



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

December 12, 2019

Specialist's Report

OPERATIONAL FACTORS

DCA19CA091

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A. ACCIDENT

Operator: Delta Air Lines
Location: Nashville, Tennessee
Date: February 17, 2019
Time: 1805 Central Standard Time (CST)¹
0005 Universal Time Coordinate (Z)
Airplane: Boeing 737-800 (N3730B)
Flight No.: 957

B. AIR SAFETY INVESTIGATOR

Shawn Etcher - Investigator
Operational Factors Division (AS-30)
National Transportation Safety Board
490 L'Enfant Plaza East, SW
Washington, DC 20594-2000

C. SUMMARY

On February 17, 2019, about 1805 CST, Delta Air Lines flight 957, B737-800, N3730B, encountered turbulence descending through approximately FL345². The flight attendants in the aft galley noted that the turbulence occurred very quickly after the PA, and they were unable to buckle their seat belts in time. As a result of the turbulence, the 2R flight attendant, who was in the aft galley, was thrown against the galley ceiling, and sustained a fractured L1 vertebra. One minor injury was reported in addition to the flight attendant's serious injury.

The flight was being operated under 14 *Code of Federal Regulations* Part 121 as a regularly scheduled passenger flight from Bozeman Yellowstone International Airport (BZN) Bozeman, Montana to Atlanta Hartsfield-Jackson International Airport (ATL), Atlanta, Georgia.

D. DETAILS OF THE INVESTIGATION

The National Transportation Safety Board (NTSB) Operational Factors investigator was assigned to the accident on July 2, 2019 and did not travel to the accident location. The Operational Factors investigator was briefed by the Investigator in Charge (IIC) on the events surrounding the accident.

¹ All times in the report will be Central Standard Time except as otherwise noted. At the time of the accident Greenwich Mean Time, also known as Zulu (Z) time, was 6 hours ahead of CST.

² Flight Level – A Flight Level (FL) is a standard nominal altitude of an aircraft, in hundreds of ft. This altitude is calculated from the International standard pressure datum of 1013.25-hPa (29.92 inHg), the average sea-level pressure, and therefore is not necessarily the same as the aircraft's true altitude either above mean sea level or above ground level.

The Operational Factors investigator requested manuals and other various items for the investigation, from the operator. Pilot certification information was obtained from the pilots, operator, and the Federal Aviation Administration (FAA).

E. FACTUAL INFORMATION

1.0 History of Flight³

Delta Air Lines flight 957 had departed BZN at 1418 Mountain Standard Time (1518 CST). The flight's planned arrival time was 1950 Eastern Standard Time (1850 CST).

During cruise flight, prior to the calculated top of descent (TOD), the flight crew was informed by air traffic control (ATC) to expect light and occasional moderate turbulence during their descent into ATL and the turbulence forecast was also displayed on their EFB⁴ Flight Weather View app.

According to flight crew statements, approximately 5 to 10 minutes prior to the calculated TOD they made a public address (PA) announcement, illuminated the fasten seatbelt sign, and instructed the flight attendants to discontinue the cabin service. Approximately 10 minutes later, the flight was cleared to descend to FL250 and assigned the CHPPR⁵ arrival by ATC. When the flight was in the vicinity of the NEWBB⁶ intersection, and while descending through FL345 the flight experienced two "rapid-bumps of light-moderate turbulence." The flight crew slowed the airplane to 280 knots and contacted the flight attendants via the cabin interphone to check on the status of the cabin. At that point they were informed by one of the flight attendants, that one of the other flight attendants, located in the aft galley, had fallen and was injured. The flight crew then slowed the aircraft down to 250 kts and increased the descent rate in order to exit the turbulence. They reported to ATC they had experienced continuous light turbulence down to FL180. The flight crew also sent an ACARS⁷ message to company dispatch following the turbulence encounter requesting that a paramedic meet the airplane at the gate upon their arrival at ATL.

According to flight attendant statements, the flight had been routine, and they had experienced some light turbulence, but "nothing too concerning at this point." They had stowed their carts, latched their carriers in the galley, and were conducting normal tasks as they were anticipating landing in about 40 minutes. Almost immediately after the captain had made the announcement over the PA to discontinue cabin service, they encountered the turbulence. The two aft galley flight attendants reported that they were thrown upwards towards the ceiling and then came "crashing back down" and landed on the galley floor.

³ Sources: Attachment 1 - "Crew Interview Summaries"

⁴ Electronic Flight Bag

⁵ The CHPPR ONE was an area navigation (RNAV) standard terminal arrival route into ATL

⁶ NEWBB was a waypoint located southeast of the Nashville (BNA) Very High Omnidirectional (VOR)

⁷ Aircraft Communications, Addressing and Reporting System which was a digital data link system for the transmission of messages between aircraft and ground stations. Source:

https://www.skybrary.aero/index.php/Aircraft_Communications_Addressing_and_Reporting_System

After landing, at 0038Z (1838 CST), and parking at the gate, at 0057Z (1857 CST), paramedics boarded the aircraft to assess the flight attendant. Once the passengers had deplaned, the injured flight attendant was placed on a back board and was taken to a local hospital.

2.0 Flight Crew Information

The accident flightcrew consisted of 2 pilots and 4 cabin crew members. The captain was the pilot flying (PF) on the accident flight and the first officer (FO) was the pilot monitoring (PM).

2.1 Captain

The captain was 63 years old and held an Airline Transport Pilot (ATP) certificate with a rating for airplane multiengine land and type ratings on the BE-200⁸, DC-9⁹, and B737¹⁰, B757¹¹, B767, limitations included “B-737 B-757 B-767 DC-9 CIRC APRC – VMC ONLY.” He held an FAA first-class medical certificate dated October 10, 2018, with a limitation of “Must wear corrective lenses and possess glasses for near and interim vision.” At the time of the accident he was based at the New York City, New York airports.

According to information provided by Delta Air Lines, the captain had approximately 16,098 total hours of flight experience, of which 6,637 of those hours were in the B-737, and 2,234 of those hours were as pilot in command (PIC) in the B-737.

2.1.1 Captain’s Training and Proficiency Checks Completed

A synopsis of the captain's recent training at Delta Air Lines was as follows¹²:

Most Recent Continuous Qualification Training ¹³	January 3, 2019
Upgrade to captain	July 7, 2016
Most Recent Simulator Evaluation	September 14, 2018
Most Recent Systems Validation Oral Event	September 14, 2018
Most Recent LOE ¹⁴	September 15, 2018
Most Recent Line Check	December 17, 2018
Most Recent Distant Learning Q218 ¹⁵	April 10, 2018

⁸ Textron Aviation Inc. 200T, 200CT, A200CT, B200C, B200T, B200CT, B200. Source FAA Order 8900.1, Figure 5-88, dated July 15, 2019.

⁹ The Boeing Company DC-9-11, DC-12, DC-9-13, DC-9-14, DC-9-15, DC-9-15F, DC-9-21, DC-9-31, DC-9-32, DC-9-32F, DC-9-33F, DC-9-34, DC-9-34F, DC-9-41, DC-9-51, DC-9-81, DC-9-82, DC-9-83, DC-9-87, MD-88, MD-90-30, 717-200. Source FAA Order 8900.1, Figure 5-88, dated July 15, 2019.

¹⁰ The Boeing Company 737-100, 737-200, 737-200C, 737-300, 737-400, 737-500, 737-600, 737-700, 737-700C, 737-800, 737-900, 737-900ER, 737-8, 737-9. Source FAA Order 8900.1, Figure 5-88, dated July 15, 2019.

¹¹ The Boeing Company 757-200 Series, 757-200PG Series, 757-200 CB Series, 757-300 Series, 767-200 Series, 767-300 Series, 767-300F Series, 767-400ER Series, 767-2C Series. Source FAA Order 8900.1, Figure 5-88, dated July 15, 2019.

¹² For additional information see Attachment 2 – Flight Crew Training Records (Excerpts) in the docket associated with this accident.

¹³ Q119 – Source: Operational Factors Attachment 2 - Flight Crew Training Records (Excerpts)

¹⁴ Line Operations Evaluation

¹⁵ Q218 Distant Learning was a training event in which weather radar basics course was accomplished. Q218 included Summer Operations and Weather Radar Basics lessons, as well as Turbulence related information.

Most Recent MV ¹⁶	February 18, 2018
Most Recent Upset Recovery Training	September 15, 2018
Most recent Weather Radar Basics course ¹⁷	April 10, 2018

2.1.2 Captain's Flight Times

The Captain's estimated flight times were based on Delta Air Lines' provided documentation:

Total pilot flight time	16,098
Total B737 flight time	6,637
Total B737 PIC flight time	2,234
Total flight time preceding 24 hours ¹⁸	5:00
Total flight time last 90 days	186

2.2 First Officer

The First Officer (FO) was 38 years old; held an ATP certificate with type ratings on the B-737, CL-65¹⁹, DC-9, and SF-340²⁰, limitations included "B-737 CL-65 DC-9 SF-340 CIRC. APRCH. – VMC ONLY." He also held an FAA first-class medical certificate dated May 22, 2018, with a limitation of "Must wear corrective lenses for distant vision and have glasses for near vision." At the time of the accident he was based at Minneapolis-St. Paul International/Wold-Chamberlain Airport (MSP), Minneapolis, Minnesota.

According to information provided by Delta Air Lines, the first officer had accumulated about 1,308 hours of total flight experience and had about 83 hours of those hours were in the B737.

He was the pilot monitoring for the accident flight.

2.2.1 First Officer's Training and Proficiency Checks

A synopsis of the FO's recent training at Delta Air Lines is as follows²¹:

Date of Initial New Hire Training at Delta	February 22, 2016
--	-------------------

¹⁶ Maneuvers Validation

¹⁷ This training was part of the Q218 Distant Learning which was within the Summer Operations and Weather Radar Basics lessons portion of the training. It also included Turbulence related information. Also in the Q417, which occurred in the 4th quarter of 2017 included a dedicated Turbulence Procedures lesson.

¹⁸ Flight time does **not** include the accident flight.

¹⁹ Bombardier Inc. CL-600-2B19, BL-600-2C10, CL-600-2D24, CL-600-2D15. Source: FAA Order 8900.1, Figure 5-88, dated July 15, 2019.

²⁰ Saab AB, Saab Aeronautics 340A (SAAB/SF340A), SAAB 340B. Source: FAA Order 8900.1, Figure 5-88, dated July 15, 2019.

²¹ Source: Attachment 2 – Flight Crew Training Records (Excerpts).

Date of Transition Training to the B737 ²²	January 7, 2019
Most Recent LOE ²³	January 7, 2019
Most Recent Line Check ²⁴	January 14, 2019
Most Recent MV ²⁵	December 31, 2018
Most Recent Upset Recovery Training	January 7, 2019
Distant Learning Q218 ²⁶	May 23, 2018

2.2.2 First Officer's Flight Times

The First Officer's estimated flight times were based on Delta Air Lines provided documentation:

Total pilot flight time	1,308 hours
Total B737 flight time	83:00 hours
Total flight time preceding 24 hours ²⁷	2:00 hours
Total flight time last 90 days	97:00 hours

3.0 Airplane Information



Photo 1: Accident Airplane, N3730B (Courtesy of JetPhotos.net)

The accident airplane (Registration N3730B, Serial No. 30538, Ship No. 3730) was a Boeing 737-832. The airplane was manufactured in 2000, registered to and operated by Delta Air Lines, and had a transport category airworthiness certificate dated September 25, 2000. The

²² The date of transition training was concluded on January 7, 2019 with a LOE; however, training began on December 4, 2018 with the start of the 739DT, which was the initial aircraft systems training (distance learning).

²³ Line Operations Evaluation – Also the First Officer's most recent simulator evaluation.

²⁴ Transition OE began on January 11, 2019 and concluded on January 14, 2019

²⁵ Maneuvers Validation

²⁶ Q218 was done while the first officer was in the MD-88 aircraft series and was the time when weather radar basics course was accomplished. Q218 included Summer Operations and Weather Radar Basics lessons, as well as Turbulence related information. During transition training to the 737 the first officer was provided weather radar modules during the training which began on December 4, 2018

²⁷ Flight time did not include the accident flight.

airplane was powered by 2 CFM56-7B26 engines, each were rated at 26,300 pounds of thrust. The airplane was configured with 2 pilot seats, 1 cockpit observer seat, 5 flight attendant seats, and 160 passenger seats.

According to the accident flight's dispatch release²⁸ there were three deferred maintenance items at the time of departure, none of which affected the performance of the weather radar or any other function associated with this accident.

3.1 Weight and Balance

The following weight and balance information was taken from the dispatch flight release. Limitations are indicated in **bold** type. All weights below are in pounds (lbs.).

Basic Operating Weight	95,720
Total Payload	31,069
Passengers ²⁹	25,809
Baggage/Cargo ³⁰	5,260
Zero Fuel Weight	126,789
Maximum Taxi Weight	174,900
Maximum Zero Fuel Weight	138,300
Planned Block Fuel ³¹	28,000
Actual Fuel Weight ³²	28,930
Taxi Fuel	247
Ramp Weight	155,719
Takeoff Weight	155,472
Maximum Takeoff Weight	174,200
Planned Fuel Burn	18,056 ³³
Estimated Weight at Time of Turbulence Encounter	138,879
Planned Landing Weight ³⁴	135,056
Maximum Landing Weight	146,300

4.0 Accident Flight Release and Weather Packet

4.1 Flight Release

Delta Air Lines Flight Release for the accident flight was listed as "RLS 1". The release contained information for the accident flight such as, fuel required, route of flight, departure, destination, and alternate airports, MELs³⁵, departure and planned arrival weights, weather which

²⁸ See Attachment 4 – Accident Flight's Flight Release for a list of the 3 deferred items.

²⁹ Passenger distribution included 16 in first class and 123 in coach class, which included 1 child in first class and 11 children in coach class.

³⁰ Cargo included 1,590 lbs. in B2, 3,570 lbs. in B3 and 100 lbs. of "Parts on Plane"

³¹ Minimum fuel for takeoff was listed as 25,991 lbs. Source: Attachment 4 – Accident Flight's Flight Release

³² Source: Attachment 3 – Accident Flight's Weight Data Record 8,600 lbs. tank 1, 8,660 lbs. tank 2, 11,670 lbs. center tank

³³ Note: The dispatch release shows a planned fuel burn of 18,055 lbs; however, the difference between the takeoff weight and planned landing weight was 18,056 lbs.

³⁴ Planned landing weight was a dispatch estimated weight based on an estimated takeoff weight.

³⁵ Minimum Equipment List

consisted of departure, enroute, destination, and alternate weather, and a “Dispatcher Remarks” section, which contained the following information:

01- Possible LT/MOD TURB FL210-300 VICINITY MCI – FAM

02-ENROUTE PENALTY OF 716 LBS APPLIED TO DRIFTDOWN AND ETP CALCULATIONS

*** DRIFTDOWN INFORMATION***

03- NO DRIFTDOWN ISSUES UP TO MPTOW 156135

The flight plan fuel section of the release showed that the dispatcher had added an addition 2,562 lbs of fuel, which equated to 33 additional minutes of fuel at 15,000 ft.

4.1.1 Route of Flight

According to a Delta Air Lines Flight Release for the accident flight showed that the route of flight was:

KBZN DCT BZN DCT CZI DCT PWE DCT MCI DCT FAM DCT BNA DCT NEWBB DCT IHAVE DCT MTHEW CHPPR1 KATL

According to a Delta Air Lines representative the filed route of flight was a National Route Program (NRP) route, which was a user preferred route allowing the airline to take the most economical route. Additionally, Delta Air Lines had 5 other possible routes they could file, all of which operated over BNA during their arrival into ATL.

4.1.2 Turbulence Related ACARS Messages

According to Delta Air Lines ACARS messages received by the accident flight, the following were messages related to turbulence reports or forecasts along the route of flight and the time it was transmitted to the flightdeck:

February 17, 2019 at 2257:20Z (1657:20 CST):

*- 41 TP SE09 172210Z
1.MS AL GA TN
2.* ADVISORY *
VOR:BWG YOCKY MCN SQS
HAZ:TURBC-OTHER
SOURCE:PIREPS
AREA:37N086W 37N083W
33N083W 34N091W
TIME:POSN AT 17/2210Z
ALTS:150-FL320 LGT/MOD
MVG FROM:27025
INFO:FAST MOVG
RAINSHWRS. MOST
TOPS AOB*

FL250..ISLD TO
FL320. CELLS MVG NE
60KTS
3.VALID 172210Z/180300Z
4.CANCEL SE08
ALONG ROUTE
ENTER 17/2357Z BNA293025
EXIT 18/0034Z KATL
;
02172257/02172257 P99999 999

February 17, 2019 at 2305:13Z (1705:13 CST):

- 41 TP SE10 172303Z
1.MS AL GA TN
2.* ADVISORY *
VOR:BWG RDU MCN SQS
HAZ:TURBC-OTHER
SOURCE:PIREPS
AREA:37N086W 37N079W
33N083W 34N091W
TIME:POSN AT 17/2302Z
ALTS:150-FL350 LGT/MOD
MVG FROM:27025
INFO:FAST MOVG
RAINSHWRS. MOST
TOPS AOB
FL250..ISLD TO
FL320. CELLS MVG NE
60KTS
3.VALID 172303Z/180300Z
4.CANCEL SE09
ALONG ROUTE
ENTER 17/2357Z BNA293025
EXIT 18/0034Z KATL
;
02172305/02172305 P99999 999

The following ACARS message was transmitted by the flight crew, reporting they encountered moderate turbulence and a flight attendant had been injured:

February 18, 2019 at 0012:11Z(1812:11 CST)

A
MOD TURB. FA INJURED.
REQUEST PARAMEDIC MEET

PLANE AT C43.
INJURED FA EMP NUM³⁶
;
02180012/02180012 P99999 999

4.1.3 Weather Briefing

The following weather information was included on the flight release for the accident flight, prior to departure from BZN:

DESTINATION FORECAST
TERMINAL FORECAST
ATL DL 171905 AMD 01 VALID 171905-182300 UTC
FM171900 10010KT 1SM -RA BR OVC002
FM172100 10010KT 3SM BR OVC004
FM180200 22006KT 4SM -RA BR OVC006
FM180600 31009KT 5SM -RA BR OVC008
FM181200 32010KT P6SM SCT012 SCT040
FM181400 32012G20KT P6SM FEW050
RMK DL TAF BY HEYING
DISCUSSION - NONE %

WEATHER AROUND DESTINATION
MGE 172000 METAR 171956Z 10009KT 3SM -DZ BR OVC006 09/08 A2991
RMK AO2A SLP124 WND DATA ESTMD ALSTG/SLP ESTMD
MGE 172000 METAR 171956Z 10009KT 3SM -DZ BR OVC006 09/08 A2991
RMK AO2A SLP124 WND DATA ESTMD ALSTG/SLP ESTMD
MGE 172000 METAR 171956Z 10009KT 3SM -DZ BR OVC006 09/08 A2991
RMK AO2A SLP124 WND DATA ESTMD ALSTG/SLP ESTMD
MGE 172000 METAR 171956Z 10009KT 3SM -DZ BR OVC006 09/08 A2991
RMK AO2A SLP124 WND DATA ESTMD ALSTG/SLP ESTMD
CSG 172000 METAR 171951Z 21007KT 10SM BKN018 BKN026 OVC065
23/17 A2986 RMK AO2 SLP107 T02280172
CHA 172000 METAR 171953Z 15003KT 1 1/2SM BR OVC005 11/09 A2984
RMK AO2 SLP106 T01060094
CHA 172018 SPECI 172016Z 16005KT 1 1/2SM -RA BR OVC004 11/09
A2983 RMK AO2 RAB1959 P0000 T01060094
BHM 172000 SPECI 171950Z 18004KT 2 1/2SM RA BR SCT007 BKN016
OVC021 17/16 A2980 RMK AO2 RAB11 P0005
BHM 172000 METAR 171953Z 20005KT 2SM -RA BR SCT007 BKN016
OVC021 17/16 A2982 RMK AO2 RAB11 SLP093 P0005
T01720161
BHM 172007 SPECI 172005Z 20004KT 3/4SM PRA BR FEW007 BKN016
OVC021 17/17 A2982 RMK AO2 P0006 T01720167 RVRNO
BHM 172019 SPECI 172017Z 00000KT 2SM RA BR FEW006 BKN016 OVC021

³⁶ Flight Attendant employee number was included in the ACARS transmission; however, was removed due to privacy considerations.

17/17 A2980 RMK AO2 PRESFR P0012 T01720167
AGS 172000 METAR 171953Z 07004KT 7SM OVC006 11/09 A2999 RMK AO2
RAB20E31 SLP154 P0000 T01060089

4.1.4 Delta Air Lines Turbulence Plots (TPs)

The following "TPS – Enroute and United States Regional Outlooks" were included on the flight release:

CN59 172100-180300
TP CN59 171744Z
1.KS OK MO IA IL IN
MI OH
2.* ADVISORY *
VOR:ICT COU BDF CRL
HAZ:TURBC-FRONT/TROP
SOURCE:FORECAST
LINE:37N097W 39N093W
41N089W 42N084W
WIDTH:120NM
TIME:POSN AT 18/0000Z
ALTS:FL370-410 LGT/MOD
FL200-300 LGT/MOD
MVG FROM:27010
3.VALID 172100Z/180300Z
4.CANCEL CN57

NE84 172100-180300
TP NE84 171948Z
1.KY TN NC VA
2.* ADVISORY *
VOR:PTW VHP BNA SWL
HAZ:TURBC-OTHER
SOURCE:FORECAST
AREA:40N076W 39N086W
35N086W 37N075W
TIME:POSN AT 18/0000Z
ALTS:FL350-400 LGT/MOD
150-FL250 LGT/MOD
MVG FROM:26030
INFO:LWR ALTS DUE TO
SHWRS/SHEAR. HIER
ALTS SPORADIC IN
CLOUDS MOSTLY LGT
3.VALID 172100Z/180300Z
4.CANCEL NE76

4.2 PIREPs³⁷

4.2.1 Delta PIREPs

The following Delta specific PIREPs were provided to the accident flight on the flight release:

DAL0928/17 SHIP 3609 POSN43277W108186,BOY,181706,400,JAC01,1827
59,JAC,M47,255030,104631C
DAL2664/17 SHIP 3033 POS MCI OVR 1736 NXT
ETA ENS ALT 350 FOB 0211 SAT 4 WND
250 10 MCH TRB LT CHOP SKY ICE RMK
DAL1193/17 SHIP 3735 POSN39172W094436,MCI,183213,370,AXC,185937
,VHP,M51,246113,1635473
DAL2816/17 SHIP 3740 POSN39171W094440,MCI,201642,370,ENL,204418
,JDUNN,M52,247136,1494FC9
DAL2891/17 SHIP 1402 POSN37218W094589,BUM02,174510,360,GLD,1841
16,DVV,M53,246171,431,81817FE
DAL2884/17 SHIP 3068 POS BUM OVR 1904 NXT
ETA ENS ALT 340 FOB 0264 SAT 4 WND
242 17 MCH TRB LT CHOP SKY ICE RMK
DAL0186/17 SHIP 7109 POSN37403W090138,FAM,173643,370,BNA,175630
,NEWBB,M55,253166,376FD69
DAL0678/17 SHIP 6714 POSN37203W090235,FAM08,174458,350,BNA,1805
01,NEWBB,M50,249155,165,80549A2
DAL0996/17 SHIP 5803 POSN36382W089267,,180327,330,VIS01,180702,
DIT02,M44,249146,231,788365E
DAL1605/17 SHIP 3852 POSN37402W090134,FAM,190806,330,BNA,192903
,NEWBB,M45,248161,16037E0
DAL2815/17 SHIP 3839 POSN38435W088401,ENL01,180837,320,IOW,1840
00,MNOSO,M44,252166,1909F9D
DAL0296/17 SHIP 7103 POSN38515W090290,STL,193105,370,BNA,195758
,NEWBB,M55,248177,3822BFC
DAL1269/17 SHIP 3724 POSN37479W086161,BWG01,192948,371,LOZ01,19
4058,KPA01,M53,255156,1476B99
REPORT INCOMPLETE

No Delta PIREP reports involving turbulence, provided to the accident flight crew on the flight release, were in the vicinity of the accident flight's turbulence encounter.

4.2.2 Archived PIREPs³⁸

A review of archived PIREPs, throughout the national airspace system, showed that of the 497 PIREPs provided in the 2 hours prior and 1 hour after the accident flight's encounter with turbulence, there were 41 PIREPs within approximately 200 miles of the accident location of those,

³⁷ Pilot Reports

³⁸ Source: Iowa State University, Iowa Environmental Mesonet
<https://mesonet.agron.iastate.edu/request/gis/pireps.php>

11 were reported as over or in the vicinity of BNA. The PIREPs in the vicinity of BNA were filed as follows:

201902172232 B737 BNA UA /OV BNA220035/TM 2232/FLDURD/TP B737/TB MOD
110 BLO 35.73054847 -87.09256071
201902172233 B737 BNA UA /OV BNA090005/TM 2233/FLDURC/TP B737/TB MOD
ABV 04036.11889 -86.59951792
201902172238 B737 BNA UA /OV BNA045030 /TM 2238 /FL040 /TP B737 /TB CONT
MOD CHOP /RM DURGC THRU FL100 NE BOUND AWC-WEB: 36.42614438 -
86.30880845
201902172238.00 B737 BNA UA /OV BNA045030 /TM 2238 /FL040 /TP B737 /TB CONT
MOD CHOP /RM DURGC THRU FL100 NE BOUND AWC-WEB 36.42614438 -
86.30880845
201902172248 B738 BNA UA /OV BNA180030/TM 2248/FL330/TP B738/TB CONT
MOD/RM ZME 35.68436669 -86.68917
201902172251 B739 BNA UA /OV BNA090025/TM 2251/FL320/TP B739/TB OCNL
MOD/RM ZME 36.11889 -86.24090961
201902172304 B738 BNA UA /OV BNA270010/TM 2304/FLDURC/TP B738/TB MOD
060 - 095 36.11889 -86.86847415
201902180010 NMRS BNA UA /OV BNA135025/TM 0010/FL370/TP NMRS/TB MOD
CHOP/RM RPTD BY NMRS ACFT. ZME 35.86284468 -86.37220204
201902180034 A319 BNA UA /OV BNA090040/TM 0034/FL370/TP A319/TB MOD/RM
ZME 36.11889 -85.97195338
201902180045 B737 BNA UA /OV BNA220035/TM 0045/FLDURD/TP B737/TB MOD
35.73054847 -87.09256071
201902180057 E145 BNA UA /OV BNA270020/TM 0057/FL070/TP E145/TB CONT
MOD 070-150/RM ZME 36.11889 -87.04777831

The PIREP reports in plain language taken from standard code and abbreviations, with altitudes in feet above mean sea level (MSL):

2019 February 17 at 2232Z (1632 CST); Aircraft – B737; Nashville VOR³⁹ BNA) Nashville, Tennessee routine pilot report (UA); Location – over a point 35 miles southwest of BNA; Time – 2232Z; During descent; Aircraft – B737; Turbulence – Moderate below 11,000 ft. 35.73054847°N/87.09256071°W.

2019 February 17 at 2233Z (1633 CST); Aircraft – B737; Nashville VOR (BNA) Nashville, Tennessee routine pilot report (UA); Location – over a point 5 miles east of BNA; Time 2233Z; During climb; Aircraft – B737; Turbulence – Moderate above 4,000 ft 36.11889°N/86.59951792°W.

2019 February 17 at 2238Z (1638 CST); Aircraft – B737; Nashville VOR (BNA) Nashville, Tennessee routine pilot report (UA); Location – over a point 30 miles north east of BNA VOR; Time 2238Z; Altitude 4,000 ft; Aircraft – B737; Turbulence – Continuous moderate chop;

³⁹ Very-high Omni-directional Range

Remarks – During climb thru 10,000 feet northeast bound; AWC website at latitude 36.42614438°N/086.30880845°W.

2019 February 17 at 2238:00Z (1638 CST); Aircraft – B737; Nashville VOR (BNA) Nashville, Tennessee routine pilot report (UA); Location – over a point 30 miles north east of BNA; Time 2238Z; Altitude 4,000 ft; Aircraft – B737; Turbulence – Continuous moderate chop; Remarks – During climb thru 10,000 feet northeast bound; AWC website at latitude 36.42614438°N/086.30880845°W.

2019 February 17 at 2248Z (1648 CST); Aircraft – B737-800; Nashville VOR (BNA); Nashville, Tennessee routine pilot report (UA); Location – over a point 30 miles south of BNA; Time – 2248Z; Altitude – FL330; Aircraft- B737-800; Turbulence – Continuous Moderate; Remarks – Memphis Air Route Traffic Control Center 35.68436669°N/86.68917°W.

2019 February 17 at 2251Z (1651 CST); Aircraft – B737-900; Nashville VOR (BNA), Nashville, Tennessee routine pilot report (UA); Location – Over a point 25 miles east of BNA; Time 2251Z; Altitude FL320; Aircraft B737-900; Turbulence Occasional Moderate; Remarks Memphis Air Route Traffic Control Center 36.11889°N/086.24090961°W.

2019 February 17 at 2304Z (1704 CST); Aircraft – B737-800; Nashville VOR (BNA), Nashville, Tennessee; routine pilot report (UA); Location – Over a point 10 miles to the west of the BNA VOR; Time 2304Z; During Climb; Aircraft – B737-800; Turbulence moderate from 6,000 ft to 9,500 ft 36.11889°N/086.86847415°W.

2019 February 18 at 0010Z (1810 CST); Aircraft – Numerous aircraft; Nashville VOR (BNA), Nashville, Tennessee; routine pilot report (UA); Location – Over a point 40 miles to the east of the BNA VOR; Time 0010; Altitude – FL370; Aircraft – numerous; Turbulence – Moderate chop; Remarks – Reported by numerous aircraft to Memphis Air Route Traffic Control Center 35.86284468°N/086.37220204°W.

2019 February 18 at 0034Z (1834 CST); Aircraft – A319; Nashville VOR (BNA), Nashville, Tennessee routine pilot report (UA); Location – over a point 40 miles to the east of the BNA VOR; Time 0034Z; Altitude – FL370; Aircraft – A319; Turbulence – Moderate; Remarks – Memphis Air Route Traffic Control Center 36.11889°N/085.97195338°W.

2019 February 18 at 0045Z (1845 CST); Aircraft – B737; Nashville VOR (BNA), Nashville, Tennessee routine pilot report (UA); Location – Over a point 35 miles to the southwest of BNA; Time – 0045Z; During descent; Aircraft – B737; Turbulence Moderate; 35.73054847°N/087.09256071°W.

2019 February 18 at 0057Z (1857 CST); Aircraft – Embraer E145; Nashville VOR (BNA), Nashville, Tennessee routine pilot report (US); Location – Over a point 20 miles west of BNA; Time – 0057Z; Altitude 7,000 ft; Turbulence – Continuous Moderate from 7,000 ft to 15,000 ft; Remarks – Memphis Air Route Traffic Control Center 36.11889°N/0-87.04777831°W.

5.0 Delta Air Lines Guidance

5.1 Delta Air Lines - Flight Operations Manual

5.1.1 Cabin Notification – Turbulence

5.1.1.1 Customers

The Delta Air Lines, Flight Operations Manual, Section 5 “Briefings & Cabin Crew Communications”, dated April 1, 2018, contained the following guidance for crews to brief the passengers:

When anticipating turbulence:

- *Illuminate the seat belt sign*
- *Make a PA (see turbulence action chart)*
- *When making a PA, use “rough air.” When speaking to flight attendants via interphone, use proper terminology (e.g., “light turbulence”).*
- *If applicable, the Language of Destination (LOD) flight attendant will make the seat belt PAs in the appropriate languages immediately following the flight deck PA*
- *Notify customers of any attempts to get out of turbulence, such as altitude changes.*

5.1.1.2 Flight Attendants

The Delta Air Lines, Flight Operations Manual, Section 5 “Briefings & Cabin Crew Communications”, dated April 1, 2018, contained the following guidance for crews to brief the flight attendants:

Cabin conditions (turbulence level) can be markedly different from what the flight deck is experiencing. Communicate with the flight leader to help assess actual cabin conditions. If flight attendants feel it is unsafe to continue service, support their decision to be seated and make the customer service PA.

Light Turbulence

For light turbulence, communicate to the flight leader/purser via interphone first and follow up with a PA as necessary (see sample PA in turbulence action chart). Communicate the following via the interphone:

- *Estimated time remaining until turbulence is encountered and*
- *Estimated duration, if known*
- *Use proper phraseology when communicating via the interphone (e.g., “light turbulence” not “rough air”)*

Moderate Turbulence

For moderate turbulence, communicate to the cabin crew via PA first (see sample PA in turbulence action chart), and then follow up via interphone with the flight

leader/purser. Use proper phraseology (e.g., “moderate turbulence” not “rough air”) on the interphone.

Note: On the A330 during Class 1 Crew Rest, direct the flight leader/purser to make the moderate turbulence PA. This is to prevent crew rest disruption due to the inability to de-select the crew rest facility from the flight deck PA system.

Severe or Greater Turbulence

Severe or greater turbulence should be avoided if at all possible. If severe turbulence cannot be avoided, communicate to the cabin crew via PA first (see sample PA in turbulence action chart), and then follow up via interphone with the flight leader/purser. Use proper phraseology (e.g., “severe turbulence” not “rough air”) on the interphone.

Descent

If moderate or greater turbulence is expected on descent to destination, notify flight attendants of the type of turbulence to expect and ask them to do their final cabin check as early as possible (e.g., We expect moderate turbulence on the descent, please do your final cabin check and be seated as early as possible.) Include the request for flight attendants being seated earlier in the descent in the top of descent PA. Refer to Customer PAs, Descent.

5.1.2 Turbulence Action Charts

The Delta Air Lines, Flight Operations Manual, Section 5 “Briefings & Cabin Crew Communications”, dated April 1, 2018, was similar guidance that was provided to cabin attendants (see Section 5.5 for cabin crew guidance) contained the following guidance for the flight crew describing aircraft indications, cabin conditions and crew actions:

Light Turbulence	
Aircraft Reaction	Slight, erratic changes in altitude and/or attitude.
Cabin Conditions	- Liquids are shaking but not splashing out of cups. - Carts can be maneuvered with little difficulty. - Passengers may feel light strain against seat belts.
Pilot Actions	- Ensure seat belt sign ON. - Via interphone advise flight leader/purser of LIGHT turbulence. - Ensure PA is made reinforcing need for passengers to be seated. - Sample PA - <i>Ladies and gentlemen, due to the rough air please return to your seats and fasten your seat belts.</i>
Flight Attendant Actions	- Continue service with caution. - Use caution serving hot food/beverages. - Visually check passenger seat belts.

Moderate Turbulence	
Aircraft Reaction	Changes in altitude and/or attitude occur but with more intensity than light turbulence. Aircraft remains in control at all times.
Cabin Conditions	- Liquids are splashing out of cups. - Difficult to walk or stand without balancing or holding onto something. - Carts are difficult to maneuver. - Passengers feel definite strain against seat belt.
Pilot Actions	- Ensure seat belt sign is ON. - Immediately make PA directing FAs and passengers to be seated and service to be discontinued. Note: On the A330 during Class 1 Crew Rest, direct the flight leader/purser to make the moderate turbulence PA. This is to prevent crew rest disruption due to the inability to de-select the crew rest facility from the flight deck PA system. - Sample PA - <i>Ladies and gentlemen, due to the rough air (that we expect in the next XX minutes), we need you to be seated and check the security of your seat belts. We are also requiring all flight attendants to discontinue their service and be seated until it is safe to continue. This is for their safety as well as yours.</i> - Via interphone advise flight leader/purser of MODERATE turbulence and expected duration. - Advise FAs when it is safe to resume their duties.
Flight Attendant Actions	WARNING: Do not wait for guidance from flight deck crew if experiencing moderate turbulence. - Discontinue service and stow all carts. - Stow galley equipment, time and conditions permitting. - FAs secure themselves in jumpseats as soon as possible using seat belt and shoulder harness and contact the flight deck to relay status of carts and flight attendants. - Visually check passenger seat belts en route to jumpseat. - Flight leader/purser continues communication with flight deck on conditions in the cabin. - Flight leader/purser calls all FA stations to ensure all passengers/crew are seated.

Severe Turbulence	
Aircraft Reaction	Large, abrupt changes in altitude and/or attitude. Usually causes large variations in indicated airspeed. Aircraft may be momentarily out of control.
Cabin Conditions	• Items are falling over. Unsecured items are tossed about. • Walking is impossible. • Passengers are forced violently against seat belts.
Pilot Actions	• Ensure seat belt sign is ON. • Immediately make PA directing FAs and passengers to be seated and service to be discontinued. • Sample PA - <i>Ladies and gentlemen, due to the rough air we need you to be seated and check the security of your seat belts. We are also requiring all flight attendants to immediately discontinue their service and be seated until it is safe to continue. This is for their safety as well as yours.</i> • Via interphone advise flight leader/purser of SEVERE turbulence and expected duration. • Advise FAs when it is safe to resume duties.
Flight Attendant Actions	WARNING: Do not wait for guidance from flight deck crew if experiencing severe turbulence. • Discontinue service immediately and leave carts with brakes engaged until turbulence is reduced. • If possible, place hot liquids on floor. • FAs secure themselves in nearest available seats. • If in jumpseat, use seat belt and shoulder harness. • If a seat is not readily available, you may need to sit on the floor and grab on to the leg of a passenger seat or sit on a passenger's lap and ask for passenger assistance. When safe to do so: • Flight leader/purser calls all FA stations to ensure all passengers/crew are seated and contacts the flight deck to relay status of carts and flight attendants. • Flight leader/purser continues communication with flight deck on conditions in the cabin. • Check for damage and injuries; notify flight deck crew of crew/passenger injuries and cabin conditions. • Stow all carts and galley equipment.

Figure 1: Delta Air Lines Turbulence Action Charts

5.1.3 Turbulence Plot (TP)

The Delta Air Lines Flight Operations Manual, Chapter 14, “Dispatch & Weather Planning,” dated October 1, 2018, provided the following guidance regarding Turbulence Plot (TP):

Avoidance measures for both planned and enroute turbulence are based primarily on Turbulence Plot (TP) messages and upper air depiction charts issued by Delta Meteorology.

These products are based on forecasts and actual pilot reports from comparable aircraft types.

TPs are issued specifically for Delta operations. The nature of the turbulence, the availability of new data, and the degree of change expected over a given period of time dictate how often they are issued.

TP messages prevail over other sources, such as SIGMETs, Flight Weather Viewer (FWV), actual turbulence data, and other forecast products. TPs may also include volcanic ash information.

Refer to Airway Manual, Weather, Weather Depiction Charts for expanded TP guidance.

5.1.4 Required PAs

The Delta Air Lines Flight Operations Manual, Chapter 11, “Customers,” Section 2 “Customer PAs” dated March 1, 2017, required the following:

PAs made on every flight:

- *Before Takeoff (required, AOM Vol. 1, Normal Procedures)*
- *Initial seat belt sign off (required, AOM Vol. 1, Normal Procedures)*
- *Descent: seat belt sign on, flight attendant prepare for arrival (required, AOM, Vol. 1, Normal Procedures).*
- *Turbulence, when encountered or anticipated*
- *After a Go-Around or Rejected Landing.*

5.2 Airway Manual

5.2.1 Airway Manual – Expanded TP Guidance

The Delta Air Lines “Airway Manual”; Chapter 6 “Weather,” section “Hazardous Weather” Avoidance, stated in part:

Delta Meteorology produces a combination of textual and graphical weather products.

The Turbulence Plot System, or TP System, is the primary method for weather hazard avoidance. The system includes four components:

- *Communication capabilities (both manual and automated/text and graphics)*
- *Avoidance policies & procedures (implemented jointly by pilots & dispatchers)*
- *TPs generated by Delta Meteorology*
- *System familiarization by pilots as well as meteorology producers and other users.*

TP messages are issued for weather conditions and reports that are potentially hazardous to aviation. These hazards include:

- *Clear air turbulence*
- *Mountain wave activity*
- *Thunderstorm activity*
- *Tropical systems*

- Windshear
- Volcanic ash
- Icing
- Significant ozone
- Space weather
- Any other weather conditions which warrant alerting flight crews TP messages and graphical weather depictions are used by dispatchers to develop a flight plan and by flight crews for preflight weather hazard awareness. Additionally, they support a pilot's enroute weather hazard monitoring...

TP Messages

Delta Meteorology issues TP messages for all possible weather related hazards. There are three types of TP messages.

- **ADVISORY:** Indicates that a hazard exists (or has the potential to develop) that is below a specified criteria for that hazard. Avoidance is not required either during pre-flight by Flight Control or enroute by crews.
- **ALERT:** Indicates that a hazard exists (or has the potential to develop) that has reached a specified criteria and avoidance or action is recommended.
- **AVOID:** Indicates that a hazard exists (or has the potential to develop) that has reached or exceeded a specified criteria and avoidance or action is required.

Audible ACARS "chimes" are only enabled for "Avoid TPs;" and are inhibited for all others.

Auto-TP Uplinks

TP messages are automatically uplinked via ACARS during certain phases of flight. Only TPs that directly intersect the aircraft's flight path are uplinked.

Pre-Flight

Auto-TP uplinks are inhibited on the ground and become active at Off + 15.

All applicable TPs will be delivered to the crew and are included in the Flight Plan Weather Briefing. Any new TPs are issued as part of the Updated Weather Briefing.

Enroute

Only TPs that directly intersect the aircraft's flight path are uplinked. TPs are sent 60 minutes prior to entry into the TP area. If a TP is issued after the Updated Weather Briefing and the aircraft is within 60 minutes of entry, the uplink will occur at Top of Climb (TOC). All TP uplinks are based upon the flight plan route (± 0 NM⁴⁰) and do not incorporate route changes, direct routing, or deviations unless the dispatcher updates the route in the flight planning system. Off course deviations require reference to the FWV to determine if any TPs are present along the intended route. If unable to reference the FWV, pilots should contact their dispatcher.

⁴⁰ Nautical Mile

Auto-TP uplinks are inhibited 20 minutes prior to the estimated On time.

5.2.2 Airway Manual – Turbulence Reporting Criteria

The Delta Air Lines “Airway Manual”; Chapter 6 “Weather - Hazardous Weather” provided the following chart for turbulence reporting criteria:

INTENSITY	AIRCRAFT REACTION	REACTION INSIDE AIRCRAFT
Light	LIGHT TURBULENCE: Turbulence that momentarily causes slight, erratic changes in altitude and/or attitude. LIGHT CHOP: Turbulence that causes slight, rapid and somewhat rhythmic bumpiness without appreciable changes in altitude or attitude.	Occupants may feel a slight strain against seat belts or shoulder straps. Unsecured objects may be displaced slightly. Food service may be conducted and little or no difficulty is encountered in walking.
Moderate	MODERATE TURBULENCE: Turbulence that causes changes in altitude and/or attitude, but with the aircraft remaining in positive control at all times. Usually causes variations in indicated airspeed. MODERATE CHOP: Turbulence that causes rapid bumps or jolts without appreciable changes in aircraft altitude or attitude.	Occupants feel definite strains against seat belts or shoulder straps. Unsecured objects are dislodged. Food service and walking are difficult.
Severe	SEVERE TURBULENCE: Turbulence that causes large, abrupt changes in altitude and/or attitude. Usually causes large variations in indicated airspeed. Aircraft may be momentarily out of control.	Occupants are forced violently against seat belts or shoulder straps. Unsecured objects are tossed about. Food service and walking are impossible.
Extreme	EXTREME TURBULENCE: Turbulence in which the aircraft is violently tossed about and is practically impossible to control. It may cause structural damage.	Occupants are forced violently against seat belts or shoulder straps. Unsecured objects are tossed about. Food service and walking are impossible.
	FREQUENCY: 1. Occasional 2. Intermittent 3. Continuous	DEFINITION: Less than 1/3 of the time Occurring 1/3 to 2/3 of the time Occurring more than 2/3 of the time

Figure 2: Turbulence Reporting Criteria (Source Delta Air Lines Airway Manual)

Note: An encounter with severe or extreme turbulence requires a logbook write up and special aircraft structural inspection. Refer to FOM, Accidents, Incidents, & Irregularities, Operational Irregularities.

5.2.3 Airway Manual – Clear Air Turbulence

The Delta Air Lines “Airway Manual”; Chapter 6 “Weather - Hazardous Weather” provided the following guidance for the various types of Clear Air Turbulence:

Clear air turbulence (CAT) is defined as turbulence that is not associated with convective clouds, and can exist during both the climb/descent phase and the enroute phase of flight. Clouds may be observed in the vicinity of CAT.

Tropopause

The tropopause marks the boundary between the troposphere and stratosphere. Over the tropics the tropopause is usually found at 50,000' to 60,000' and slope to 25,000' to 30,000' near the poles. Awareness regarding the height of the tropopause is important during any clear air turbulence encounter, no matter what the cause. When turbulence associated with tropopause does occur, it can be the result of a variety of factors, including:

- *Rapid jet stream movement*
- *Sharp ridge lines*
- *Atmospheric patterns, including strong vertical and/or directional shears, which produce waves along the tropopause boundary (sometimes manifested as transverse bands in high clouds on a satellite photo).*

In most cases, the most significant turbulence will be encountered in a layer 2000' thick, extending 1000' either side of the tropopause boundary on the warm side of the jet core.

Upper Front

The tropopause usually does not extend in an unbroken line from the tropics to the poles. Often a break or sharp dip will be found in the mid-latitudes. This break, called the upper front, is caused by an extension of a surface front into the upper troposphere. At this break, a jet stream will be found. The upper front is a boundary, sloping under the jet core, separating air masses of different characteristics. Strong vertical and horizontal windshear is present across an upper front. Moderate or greater turbulence can be expected across an upper front when the horizontal and/or vertical windshear exceeds certain values. Light/moderate turbulence can also occur across an upper front at altitudes surrounding the moderate or greater turbulence, and when horizontal and vertical windshear are above certain values.

Front/Tropopause

Turbulence can occur at two different altitudes, one due to an upper front and the other due to the tropopause. The upper front turbulence is found below the jet stream at lower altitudes. The turbulence at higher altitudes is above the jet stream and associated with the tropopause.

Trough

Not all troughs are turbulent. There are several factors which determine whether a trough will be turbulent. Any combination of the following factors can increase the risk and/or intensity of turbulence:

- *Magnitude of the wind direction change across the trough*
- *Magnitude of the vertical directional windshear across the trough*
- *Strength of wind speeds near the trough*
- *Magnitude of temperature field out of phase with wind flow*
- *Speed of lateral movement of trough*

The most intense turbulence will usually be encountered in a layer 1000' above to 4000' below the tropopause. However, the vertical extent of trough line turbulence can vary greatly. Generally, turbulence associated with a trough line is 200 NM wide, 100 NM either side of the line depicted in the TP message. In troughs where the wind pattern and the temperature pattern are out of phase, an area of moderate or greater turbulence may extend from the trough to 200 NM or more upstream. In these cases the extent of the turbulence area will be clearly stated in the TP message.

Other Turbulence

When turbulent conditions cannot be attributed to one of the three above CAT causes (tropopause, upper front, trough line), a general turbulence area TP may be issued. Other causes of CAT include anti-cyclonic curvature in a ridge, strong divergence, and thermal instability. In addition, this type of TP is used to indicate turbulence associated with wave action in areas where predetermined wave areas have not been identified (i.e. Greenland). More details regarding this are contained within the Mountain Wave section.

5.3 Delta Air Lines 737 Operations Manual Volume 1

5.3.1 Turbulence

The Delta Air Lines, 737 Operations Manual – Vol. 1, Section SP “Supplementary Procedures – Adverse Weather” dated October 29, 2018 provided the following turbulence guidance:

During flight in light to moderate turbulence, the autopilot and/or autothrottle may remain engaged unless airspeed, altitude or attitude deviations require use of manual control. Increased thrust lever activity can be expected when encountering wind, temperature changes and large pressure changes. Short-time airspeed excursions of 10 to 15 knots can be expected.

The turbulent air penetration speed provides ample protection from stall and high speed buffet, while also providing protection from exceeding the structural limit. Refer to the Limitations section for the turbulent air penetration speed.

Passenger signs ON

Advise passengers to fasten seat belts prior to entering areas of reported or anticipated turbulence. Instruct flight attendants to check that all passengers' seat belts are fastened.

Severe Turbulence

Yaw Damper switch ON
 Autothrottle..... Disconnect
 AUTOPILOTCWS

A/P status annunciators display CWS for pitch and roll.

Note: *If sustained trimming occurs, disengage the autopilot.*

ENGINE START switches FLT
 Thrust Set
Set thrust as needed for the phase of flight. Change thrust setting only if needed to modify an unacceptable speed trend.

PHASE OF FLIGHT	AIRSPPEED
CLIMB	280 knots or .76 Mach
CRUISE	Use FMC CRUISE page, TURB N1 thrust settings.
DESCENT	.76 Mach/280/250 knots. If severe turbulence is encountered at altitudes below 15,000 feet and the airplane gross weight is less than the maximum landing weight, the airplane may be slowed to 250 knots in the clean configuration.

Figure 3: Turbulence Airspeed Penetration Speed

Note: *If an approach must be made into an area of severe turbulence, delay flap extension as long as possible. The airplane can withstand higher gust loads in the clean configuration. Diversion to another airfield is the best policy if severe turbulence persists in the area.*

5.3.2 Approach Checklist

The Delta Air Lines, 737 Operations Manual, Section NP “Normal Procedures – Amplified Procedures”, dated May 11, 2018 provided the following amplified guidance for the approach checklist:

Approach Checklist

■ *Flight & nav instrumentsverified C&F*
Ensure correct arrival and approach procedures are entered.
Ensure the proper frequency and course/radial are set as appropriate.
Cabin notification complete C
Ensure that the cabin chime signal has been sounded twice.
If turbulence is anticipated on the arrival, consider an early cabin chime signal so that flight attendants can be seated.
Altimeters xckd C&F
Ensure the captain, first officer, and standby altimeter barometric settings and barometric reference (IN or HPA) are correctly set.
Verbalize the local altimeter setting.

5.3.3 Turbulence Report Due to Injury

The Delta Air Lines, 737 Operations Manual, Section SP “Supplementary Procedures – Communications”, dated February 24, 2017 provided the following guidance for ACARS turbulence reports:

ACARS Turbulence Report Due to Injury

Crews should submit an ACARS turbulence report when notified by flight attendants of a potential injury due to turbulence. DAL meteorology is an active participant in this injury mitigation effort.

Crews should complete all fields of the turbulence report during a non-critical phase of flight and must include “PINJ” in the misc text section of the report (page 3/3). This allows meteorology to collect data for analysis.

Continue to file an ASR/ASAP when any crew member reports potential injury.

5.4 Delta Air Lines 737-732/-832/-932 Operations Manual Volume 2

The Delta Air Lines 737 Operations Manual Vol. 2, Chapter 10 “Flight Instrument, Displays,” dated April 21, 2017 provided a table of ND⁴¹ Symbology. The ND had 4 mode selectors available⁴²; APP, VOR, MAP, PLN. The following excerpted table was guidance on weather radar returns when in MAP mode on the ND:

SYMBOL	NAME	MODE	REMARKS
	Weather radar returns (R, A, G, M)	MAP, MAP CTR, VOR, APP	The most intense areas are displayed in red, lesser intensity in amber, and lowest intensity green. Turbulence is displayed in magenta.

Figure 4: Weather Radar Return Symbol on the ND

5.4.1 Weather Radar

The Delta Air lines 737 Operations Manual Vol. II, Chapter 11 “Flight Management, Navigation,” dated December 15, 2017 provided, in part, the following information on the weather radar installed on the accident airplane:

The weather radar system detects and locates various types of precipitation bearing clouds along the flight path of the airplane and gives the pilot a visual indication in color of the clouds’ intensity. The radar antenna sweeps a forward arc of 180 degrees.

The radar indicates a cloud’s rainfall intensity by displaying colors contrasted against a black background. Areas of heaviest rainfall appear in red, the next level of rainfall in yellow, and the least rainfall in green.

⁴¹ Navigation Display

⁴² Source: Delta Air Lines 737 NG Systems Learning Objectives Document Revision 24, dated January 25, 2019, pg. 63.

In map mode, the radar displays surfaces in red, yellow, and green (most reflective to least reflective).

These displays enable identification of coastlines, hilly or mountainous regions, cities, or large structures. Ground mapping mode can be useful in areas where ground-based navigation aids are limited.

The radar system performs only the functions of weather detection and ground mapping. It should not be used or relied upon for proximity warning or anticollision protection.

The turbulence mode displays normal precipitation and precipitation associated with turbulence. When the radar detects a horizontal flow of precipitation with velocities of 5 or more meters per second toward or away from the radar antenna, that target display becomes magenta. This magenta area is associated with heavy turbulence. The detection of turbulence is automatically limited to a 40 nautical mile range, regardless of the selected range.

3701 – 3773

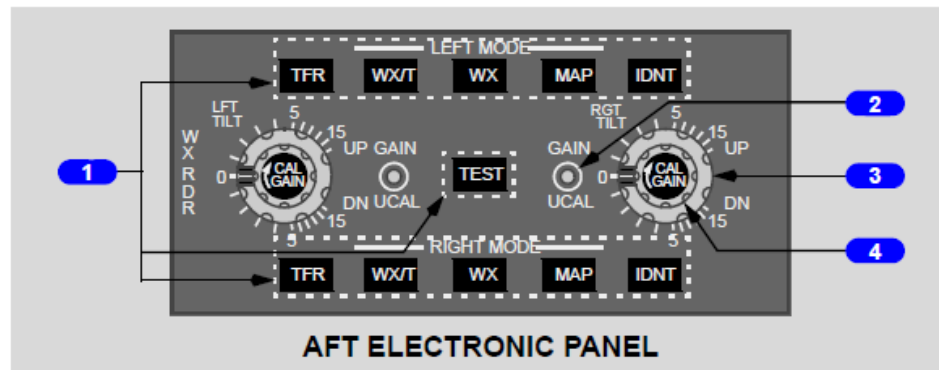
The weather radar also provides predictive windshear alerting below 1,200 feet RA. On the ground or in flight below 2,300 feet RA, radar antenna scan sweep is limited to 120 degrees with PWS enabled. Above 2,300 feet RA the radar sweep reverts to 180 degrees. (Refer to Chapter 15, Warnings.)

3701-3771

The IDNT position activates the ground clutter reduction feature. Signals that are determined to have a high probability of originating from ground returns will be automatically removed from the display. Some portions of weather targets may be removed as well. The IDNT position is provided for analysis by the pilot and is not for continuous use.

5.4.2 Weather Radar Panel

The Delta Air Lines 737 Operations Manual Vol. II, Chapter 11 “Flight Management, Navigation,” dated April 21, 2017 provided the following guidance on the weather radar panel installed on the accident airplane:



1 Weather Radar Mode Switches

Push – selects mode. Left mode switches control the Captain's radar display, right mode switches control the First Officer's radar display.

- TFR (transfer) – transfers other map display selections to related map
- WX/T (turbulence) – shows weather radar returns and turbulence. Turbulence display is available on displays of 40 nm or less.
- Note:** Turbulence detection requires presence of detectable precipitation. Clear air turbulence cannot be detected by radar.
- WX – shows weather radar returns at selected gain level
- MAP – shows ground returns at selected gain level
- IDNT – suppresses ground return in WX and WX/T modes
- TEST –
 - tests weather radar system operation without transmitting
 - shows test pattern and any fault messages on navigation display MAP, center MAP, VOR, and APP modes, with WXR selected.

Note: If the airplane is on the ground and the thrust levers are not advanced for takeoff, WXR tests the predictive windshear system (PWS) indications. These include PWS caution, PWS FAIL, and PWS warning. Deactivating WXR on the EFIS control panel will not discontinue the test and can result in automatic WXR activation on both pilot displays. The PWS test lasts approximately 15 seconds.

2 Gain Uncalibrated (GAIN UCAL) Lights

Illuminated – related gain control is in an uncalibrated position.

3 TILT Control

Rotate clockwise – radar antenna tilts up to selected degrees from horizon.

Rotate counterclockwise – radar antenna tilts down to selected degrees from horizon.

4 CAL GAIN Control

Rotate – sets gain in WX, WX/T and MAP modes.

- CAL (calibrated) gain - is selected when the CAL GAIN knob is rotated full clockwise.
- MAX gain - is selected when the CAL GAIN knob is rotated counterclockwise one click from the CAL GAIN position.
- Reduced Gain - is selected when the CAL GAIN knob is rotated counterclockwise from the MAX GAIN position.

5.5 Delta Air Lines – On-Board Manual

The Delta Air Lines On-Board Manual, Section 5.11 “Standards and Regulations” provided the following turbulence guidance to Delta Air Lines’ Cabin Crew.

5.5.1 Turbulence Guidelines

Turbulence Guidelines
Crew member guidelines:
• Discuss turbulence procedures and use designated turbulence level when communicating turbulence information during all preflight briefings and in flight. • Flight deck crew should ensure FAs are allotted adequate time to stow service and galley equipment before entering areas of anticipated turbulence. • For light turbulence, flight deck crew will communicate to Purser/FL via interphone first and follow up with PA to cabin in accordance with Turbulence Action Chart. Flight deck crew will communicate the following via interphone: - Estimated time remaining until turbulence is encountered - Estimated duration, if known - Use proper phraseology (e.g., “light turbulence” not “rough air”)
<i>NOTE:</i> On the A330, flight deck crew does not have “PA All” functionality that prevents PAs from going into crew rest facility. For this reason, flight deck crew will not make any PAs from between the initial greeting, no later than top of climb, and the “prepare the Cabin” PA, 5 minutes prior to top of descent, except as required for emergencies. During preflight briefing, the Captain will coordinate with the Purser to make the “seat belt sign on PA” associated with light turbulence so as not to disturb crew members on rest.

Crew member guidelines: (Continued)
For moderate turbulence, flight deck crew will communicate to cabin crew via PA first (see Turbulence Action Chart) and then follow up via interphone with the Purser/FL. Exception: On the A330 during crew rest, flight deck crew will direct Purser/FL to make the moderate turbulence PA. This is to prevent crew rest disruption due to inability to de-select the crew rest facility from flight deck PA system.
For severe turbulence, flight deck crew will communicate to cabin crew via PA first (see Turbulence Action Chart) and then follow up via interphone with the Purser/FL.
If conditions become turbulent (moderate or greater) in cabin, FAs should not wait for an announcement to take appropriate action to protect themselves. Follow procedures in Turbulence Action Charts, Flight Attendant Actions section.
When the flight deck announces to be seated for turbulence, all FAs must immediately adhere to the warning and protect themselves.
If passengers disregard the seat belt sign, Purser/FL should advise flight deck.
If seat belt sign has been on for long periods of time without turbulence, Purser/FL should advise flight deck.
Notify flight deck crew of the turbulence-related injury as soon as safely possible and ask that they send an ACARS Turbulence Report with location/flight level where the injury approximately occurred. Also ask them to include the code "PINJ" in the MISC TEXT section of the turbulence report. Refer to Turbulence Injury Reporting in section 8.1, Reporting Procedures for additional information.
767 Safety Seats: The last two seats in the main cabin on aircraft right are "soft blocked" for FA use in event of unanticipated turbulence while working in aft galley area. These seats will remain open if the flight is not completely full and will be the last seats ACS will assign in the main cabin. FAs should refrain from moving customers and/or jumpseat riders into these seats, if they are unoccupied.
Crew member guidelines: (Continued)
If moderate to severe turbulence is expected on descent to destination, flight deck crew will notify Purser/FL via interphone of type of turbulence to expect and the need for flight attendants to conduct final cabin checks and be seated for landing as early as possible. The pilots will include the request for flight attendants to be seated earlier in the top of descent PA. If notified of moderate or greater turbulence during descent, flight attendants will complete all Pre-Arrival procedures (Initial Descent/Top of Descent and Before Landing/10,000 Feet Double Chime) at the same time and as soon as possible following top of descent PA from flight deck crew.

Figure 5: Turbulence Guidelines (Source: Delta Air Lines On-Board Manual)

5.5.2 Turbulence Action Charts

These charts are common to the OBM and FOM. The pilot actions are taken directly from the FOM and are written for pilots. They are included here for flight attendant awareness.

Light Turbulence	
Aircraft Reaction	Slight, erratic changes in altitude and/or attitude.
Cabin Conditions	- Liquids are shaking but not splashing out of cups. - Carts can be maneuvered with little difficulty. - Passengers may feel light strain against seat belts.
Pilot Actions	- Ensure seat belt sign ON. - Via interphone advise Purser/FL of LIGHT turbulence. - Ensure PA reinforcing need for passengers to be seated is made. - Sample PA: <i>Ladies and gentlemen, due to the rough air, please return to your seats and fasten your seat belts.</i>
Flight Attendant Actions	- Continue service with caution. - Use caution serving hot food/beverages. - Visually check passengers seat belts.

Moderate Turbulence	
Aircraft Reaction	Changes in altitude and/or attitude occur but with more intensity than light turbulence. Aircraft remains in control at all times.
Cabin Conditions	- Liquids are splashing out of cups. - Difficult to walk or stand without balancing or holding onto something. - Carts are difficult to maneuver. - Passengers feel definite strain against seat belt.
Pilot Actions	- Ensure seat belt sign in ON. - Make PA directing FAs and passengers to be seated and service to be discontinued. - Sample PA: <i>Ladies and gentlemen, due to the rough air (that we expect in the next ____ minutes) we need you to be seated and check the security your seat belts. We are also requiring all flight attendants to discontinue their service and be seated until it is safe to continue. This is for their safety as well as yours.</i> - Via interphone advise Purser/FL of MODERATE turbulence and expected duration. Exception: On the A330 during crew rest, flight deck crew will direct Purser/FL to make the moderate turbulence PA. This is to prevent crew rest disruption due to inability to de-select the crew rest facility from flight deck PA system. - Advise FAs when it is safe to resume their duties.
Flight Attendant Actions	 Do not wait for guidance from flight deck crew if experiencing moderate turbulence. - Discontinue service and stow all carts. - Stow galley equipment, time and conditions permitting. - FAs secure themselves in jumpseats as soon as possible using seat belt and shoulder harness visually checking passenger seat belts en route to jumpseat. - Purser/FL calls all FA stations to ensure all passengers/ crew are seated and contacts flight deck to confirm FAs are seated and carts are stowed. - FAs resume duties once advised by flight deck crew it is safe to do so. - Purser/FL continues communication with flight deck on conditions in the cabin.

Severe Turbulence	
Aircraft Reaction	Large, abrupt changes in altitude and/or attitude. Usually causes large variations in indicated airspeed. Aircraft may be momentarily out of control
Cabin Conditions	• Items are falling over. Unsecured items are tossed about. • Walking is impossible. • Passengers are forced violently against seat belts.
Pilot Actions	• Ensure seat belt sign is ON. • Immediately make PA directing FAs and passengers to be seated and service to be discontinued. - Sample PA: <i>Ladies and gentlemen, due to the rough air, we need you to be seated and check the security of your seat belts. We are also requiring all flight attendants to immediately discontinue their service and be seated until it is safe to continue. This is for their safety as well as yours.</i> • Via interphone advise Purser/FL of SEVERE turbulence and expected duration. • Advise FAs when it is safe to resume duties.
Flight Attendant Actions	 Do not wait for guidance from flight deck crew if experiencing severe turbulence. • Discontinue service immediately and leave carts with brakes engaged until turbulence is reduced. • If possible, place hot liquids on floor. • FAs secure themselves in nearest available seats. - If in jumpseat, use seat belt and shoulder harness. - If a seat is not readily available, you may need to sit on the floor and grab on to the leg of a passenger set or sit on a passenger's lap and ask for passenger assistance. When safe to do so: • Purser/FL calls all FA stations to ensure all passengers/ crew are seated and contacts flight deck to relay status of FAs and carts. • Stow all carts and galley equipment. • FAs resume duties once advised by flight deck crew it is safe to do so. • Purser/FL continues communication with flight deck on conditions in the cabin. • Check for damage and injuries; notify flight deck crew of crew/passenger injuries and cabin conditions.

Figure 6: Turbulence Action Chart (Source: Delta Air Lines On-Board Manual)

6.0 Boeing Aero Magazine

Boeing AERO Magazine⁴³ produced the following “Turbulence Education and Training Aid”⁴⁴ article in Issue 04 dated October of 1998:

Turbulence Education and Training Aid

Clear-air and mountain-wave turbulence is the leading cause of injury to cabin crews and passengers in non-fatality commercial airplane incidents. The resulting rough ride also

⁴³Boeing AERO magazine was published quarterly by Boeing Commercial Airplanes between 1998 and 2015.
Source: https://www.skybrary.aero/index.php/AERO_-_Boeing

⁴⁴ Source: Boeing AERO Magazine Issue 04
http://www.boeing.com/commercial/aeromagazine/aero_04/tr/tr01/index.html

creates a negative public perception of the safety of flight. An industry team consisting of participants from U.S. operators, Douglas Products Division, and the U.S. Federal Aviation Administration (FAA) has developed a turbulence education and training aid to help reduce the number of turbulence-related incidents.

The turbulence created by clear-air and mountain-wave conditions presents a considerable threat of cabin crew and passenger injury and airplane damage to commercial airplane flights, and no onboard detection and warning device is currently available to alert flight crews to all impending encounters. Even though many turbulence-related incidents are minor and go unreported, data from the U.S. National Transportation Safety Board reveal that major U.S. operators have experienced more than 250 of these incidents in the past 15 years. The encounters resulted in the deaths of three passengers and serious injuries to 70 others.

The effort to reduce or even eliminate the threat of turbulence includes the following measures:

- 1. FAA and operator response.*
- 2. Implementation of turbulence education and training aid.*
- 3. More efficient use of existing technologies.*
- 4. Development of new technologies.*

FAA and Operator Response

The FAA has responded to the threat of turbulence by launching a campaign to educate the traveling public. The FAA also emphasizes the importance of wearing seat belts throughout every flight, and particularly in response to flight-crew warnings. In addition, several major U. S. operators have recently implemented a policy that requires passengers to keep seat belts fastened for the duration of their flight.

Implementation of Turbulence Education and Training Aid

The turbulence education and training aid is an educational resource designed to increase the awareness of flight crews, flight attendants, managers, dispatchers, meteorologists, and air traffic controllers to the potential for turbulence-related injuries and damage. It is also a baseline example of turbulence training that operators may use to develop their own programs. The training aid highlights the importance of operators establishing policies for avoiding turbulence and suggests that operators support in-flight avoidance actions that have the potential to delay subsequent arrival schedules. Establishing and following standard operating procedures for weather deviation and turbulence avoidance provides flight crews with the knowledge, confidence, and authority they need to act properly if they encounter turbulence.

The training aid consists of documentation and a video and is divided into four sections:

- *A management overview that describes the effects of turbulence and the benefits of using the turbulence education and training aid.*
- *An operator's guide that contains educational materials for use by flight crews, dispatchers, meteorologists, and air traffic controllers.*
- *An example training program that contains ground training, test exams, and the script for the video included in the package. The program may be used either in its existing form or customized.*
- *Background data that include a list of reference materials, a video, and a visual aid containing most of the training subject matter. The video can be used to enhance understanding of the documentation.*

An effective turbulence education program retains the key training elements of recognition and action included in the video and operator's guide. A ground-school presentation of the materials, video, and quiz can be most effective when operators customize the aid to match their existing facilities.

More Efficient Use of Existing Technologies

In addition to turbulence education and training, other means of reducing the threat in the short term include greater use of Doppler radar, turbulence plotting, flight-crew reports of turbulence, and automatic uplinks through the Aircraft Communication Addressing and Reporting System.

Government regulatory agencies throughout the world can also assist in the immediate effort by encouraging more real-time communication of weather information to flight crews and by encouraging air traffic controllers to provide additional clearances for turbulence avoidance. These agencies can also call for increased cooperation and knowledge sharing among all affected parties.

Development of New Technologies

In addition to assisting with short-term solutions, government regulatory agencies can help create long-term solutions. Examples of this activity include supporting the aviation industry in the development of new systems that detect clear-air and mountain-wave turbulence and that deliver an early warning to the flight crew. Further development of existing technologies can lead to increased communication between airplanes and the ground to provide the flight crew with continuous, real-time weather information.

Summary

The threat presented by turbulence is significant, both for passengers and for commercial airplanes themselves. Operators can now use a turbulence education and training aid, developed by several members of the aviation industry, to mitigate the effects of turbulence. This education and training of personnel can be supplemented by other short-term solutions. However, the threat posed by clear-air and mountain-wave turbulence can be eliminated only by the development of systems that detect it and provide early warning to flight crews.

7.0 FAA Guidance

The FAA defines turbulence as: “air movement that normally cannot be seen and often occurs unexpectedly. It can be created by many different conditions, including atmospheric pressure, jet streams, air around mountains, cold or warm weather fronts or thunderstorms. Turbulence can even occur when the sky appears to be clear.”⁴⁵

7.1 FAA Turbulence Fact Sheet

The FAA provided the following guidance titled “Fact Sheet – Turbulence” on August 1, 2019 on their website:⁴⁶

What is turbulence?

Clear air turbulence is air movement created by atmospheric pressure, jet streams, air around mountains, cold or warm weather fronts or thunderstorms. It can be unexpected and can happen when the sky appears to be clear.

What should passengers do to avoid injuries?

Flying is the safest way to travel. Passengers can easily prevent injuries from unexpected turbulence by keeping their seat belt buckled at all times. The FAA’s tips for staying safe:

- *Listen to the flight attendants. Pay attention to the safety briefing at the beginning of your flight and read the safety briefing card.*
- *Buckle up. Keep you and your family safe by wearing a seat belt at all times.*
- *Use an approved child safety seat or device if your child is under two.*
- *Prevent inflight injuries by adhering to your airline’s carry-on restrictions.*

What do airlines do to avoid turbulence and prevent injuries?

Working together through the Commercial Aviation Safety Team (CAST), the FAA developed guidance material to help air carriers and other operators prevent turbulence injuries. CAST develops an integrated, data-driven strategy to reduce the commercial aviation fatality risk in the United States and promotes government and industry safety initiatives throughout the world. Some of the material responds to investigative work from the National Transportation Safety Board. The focus of the material (see additional reading) is to help air carriers avoid the conditions that cause turbulence and minimize the risks when airplanes do encounter it. This impacts the operations and training of flight crews, flight attendants, dispatchers and managers.

The FAA recommends that air carriers:

- *improve dispatch procedures by keeping communication channels open full-time;*
- *include turbulence in weather briefings;*
- *promote real-time information sharing between pilot and dispatcher;*

⁴⁵ Source: https://www.faa.gov/travelers/fly_safe/turbulence/

⁴⁶ Source: https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=20074

- reinforce the air carrier's turbulence avoidance policy through dispatcher training;
- consider rerouting using automation, atmospheric modeling, and data displays; and
- use all applicable weather data as well as reporting and forecasting graphics.

The FAA also encourages air carriers to use operating procedures and training to prevent turbulence injuries, emphasize the importance of flight attendant's personal safety, promote communication and coordination, and gather data and review the air carrier's history of turbulence encounters and injuries.

How many people have been injured during turbulence?

<i>Year</i>	<i>Passenger</i>	<i>Crew</i>	<i>Total</i>
2009	74	27	101
2010	35	23	58
2011	4	25	29
2012	4	19	23
2013	2	4	6
2014	19	9	28
2015	11	16	27
2016	29	13	42
2017	9	8	17

The NTSB requires airlines to report serious injuries and fatalities. A serious injury is “any injury that (1) requires the individual to be hospitalized for more than 48 hours, commencing within seven days from the date the injury was received; (2) results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) causes severe hemorrhages, nerve, muscle, or tendon damage; (4) involves any internal organ; or (5) involves second-or third-degree burns, or any burns affecting more than five percent of the body surface.” The FAA tracks these reports, but not general incidents of turbulence.

7.2 Advisory Circular 120-88A

FAA Advisory Circular 120-88A “Preventing Injuries Caused by Turbulence” dated November 19, 2007 provided, in part, the following guidance:

Emphasize the Importance of F/A's Personal Safety. F/A injuries occur at a disproportionately high rate compared to other crewmembers and other cabin occupants because F/As spend more time in the passenger cabin unseated and, therefore, unbelted. Effective training emphasizes to F/As that:

(1) You are not invincible. The overlying objective throughout all crewmember training is to ensure that crewmembers are confident, competent, and in control while conducting their activities in the cabin. However, during a turbulence encounter, the most appropriate first response by a crewmember might be self preservation. Training courseware can make crewmembers aware of their vulnerability in moderate and extreme turbulence. Effective training can incorporate video/digital media, real world scenarios and interviews with crewmembers who have experienced moderate and severe turbulence as a way to demonstrate that “turbulence can be stronger than you are.”

(2) You have tools available to increase your safety and the safety of your passengers. Effective training shows crewmembers how to increase personal safety and passenger safety by identifying tools available to them in a turbulence encounter. Training can include the effective use of the passenger address (PA) system and other methods of communicating with passengers; the location of handholds throughout the airplane (or equipment that could be used as a handhold); and how to secure a service cart or an entire galley in minimum time.

(3) You need to recognize and avoid a denial reflex. Crewmembers can be made aware of ways in which human psychology might play into a turbulence encounter, and might actually increase their risk of injury. For example, on a short flight, with little time to complete a cabin service, crewmembers might be less conservative regarding their personal safety than on a longer flight with no time constraints. crewmembers can also increase risk and compromise their personal safety by trying to adhere to routine procedures normally accomplished on every flight, such as completing seatbelt compliance checks, rather than by responding to the nonroutine situation that a turbulence encounter presents.

It also provided the following guidance for imminent Turbulence or Turbulence Occurring:

Imminent Turbulence or Turbulence Occurring. Sudden, unexpected or imminent turbulence requiring immediate action to protect cabin crew and passengers.

(1) Captain turns on seatbelt sign and makes a PA announcement, “F/As and passengers be seated immediately. Passengers please remain seated until this area of turbulence has passed and I have cleared you to move about the cabin.”

(2) Cabin crew take first available seat and secure themselves.

(3) No compliance checks are performed and items are secured only if they present no delay in securing a person in a seat.

(4) When conditions improve, captain makes PA announcement advising the cabin crew that they may resume their duties and whether or not the passengers may move about the cabin.

F. LIST OF ATTACHMENTS

Attachment 1: Crew Statements

Attachment 2: Flight Crew Training Records

Attachment 3: Accident Flight's Weight Data Record
Attachment 4: Accident Flight's Flight Release
Attachment 5: Turbulence ACARS Message
Attachment 6: Archived PIREPs
Attachment 7: Delta Air Lines Airway Manual [Excerpts]
Attachment 8: Delta Air Lines Flight Operations Manual [Excerpts]
Attachment 9: Delta Air Lines Operations Manuals [Excerpts]
Attachment 10: Delta Air Lines On-Board Manual [Excerpt]

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