NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

June 24, 2020

Group Chairman's Factual Report

OPERATIONAL FACTORS/HUMAN PERFORMANCE

DCA20CA058

Table Of Contents

A. ACCIDENT

Operator: United Airlines (UAL)
Location: New Orleans, Louisiana
Date: January 10, 2020
Time: 1745 Central Standard Time[1]
Airplane: Airbus A320-232, N1902U, Serial Number 2714

B. OPERATIONAL FACTORS/HUMAN PERFORMANCE

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C. SUMMARY

On January 10, 2020, about 1745 CST, United Airlines flight 1754, an Airbus A320-232, N1902U, encountered turbulence approximately FL300[2]. A flight attendant in the forward section of the aircraft sustained injuries to her right ankle when the aircraft encountered turbulence. The flight was being operated under 14 *Code of Federal Regulations* Part 121 as a regularly scheduled passenger flight from Louis Armstrong New Orleans International Airport (MSY), Kenner, Louisiana to Newark Liberty International Airport (EWR), Newark, New Jersey.

D. DETAILS OF THE INVESTIGATION

The National Transportation Safety Board (NTSB) Operational Factors and Human Performance investigators were assigned to the accident on January 30, 2020 and did not travel to the accident location. The Operational Factors investigator requested manuals, flight crew training

[1] All times are Central Standard Time (CST) based on a 24-hour clock, unless otherwise noted. At the time of the event CST was UTC – 6 hours.
[2] A level of constant atmospheric pressure related to a reference datum of 29.92 inches of mercury, stated in three digits that represent hundreds of feet. Source Aeronautical Information Manual "Pilot/Controller Glossary." FL300 is the height above mean sea level (msl) at standard atmospheric pressure measured in hundreds of feet (i.e. FL300 is 30,000 feet msl).

records, and flight crew's recent schedules for the investigation, from the operator. Pilot certification information was obtained from the pilots, operator, and the Federal Aviation Administration (FAA).

The Operation Factors/Human Performance group convened on February 25, 2020, at the United Airlines Training Center to interview a United Airlines instructor on the weather radar and the accident flight crew.

E. FACTUAL INFORMATION

1.0 History of Flight[3]

United Airlines flight 1754 had departed MSY at 1647 and became airborne at 1655.

According to flight crew statements, the accident flight was part of OE[4] trip for the upgrading captain, who was seated in the left seat and was the pilot flying (PF). The upgrading captain briefed the flight attendants, prior to departure, that there would be "light turbulence" during the climbout and the seatbelt sign would remain on until they passed the weather.

During the climb out, both crewmembers reported the weather radar was on and they had their WSI[5] tuned to radar reports. The crew determined that although they were currently not in the clouds, the aircraft would not be able to climb above the clouds that were ahead of them. While passing FL305 for their final cruise altitude of FL370, the PF requested that the pilot monitoring (PM) request right deviation from air traffic control (ATC) in order to avoid any chop. Subsequently, ATC cleared the flight for the right deviation.

During the turn, the PM made an announcement on the public address system for the flight attendants to "take their jumpseats." Subsequently, the flight encountered "a couple bumps of light chop." At the time of the event, the LCA described the cockpit workload as "light" and the upgrading captain described it as "normal routine."

The crew stated that almost immediately, they received a call from the cabin, that the purser had fallen as she was turning to return to her assigned jump seat.

According to the injured flight attendant statement, as she was walking through the first-class cabin "unexpected turbulence" was encountered. After she fell to the floor, she heard the captain make an announcement for the flight attendants to take their jumpseats.

According to the statement of the flight attendant working in the aft cabin, she and another flight attendant were preparing the beverage cart when "unexpected severe turbulence" was encountered. Subsequently, they went to their assigned jumpseats to secure themselves and then heard the announcement from the flight crew to take their jumpseats.

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[3] Sources: Attachment 1 - "Crew Interview Summaries and Transcripts"
[4] Operating Experience
[5] The Weather Company previously known as Weather Services International.

Additionally, a United Airlines pilot that was deadheading[6] on the flight reported that prior to the turbulence encounter the "ride was relatively smooth and no more than occasional light chop." He further stated the aircraft rolled to the right which he estimated was between 10 and 15 degrees and then the airplane stabilized. He further stated the entire encounter "was short but noticeable" and that it felt like wake turbulence.

Once the flight was through the turbulence, the flight attendants made an announcement asking if there were medical personnel on board. The medical personal subsequently applied ice and a temporary splint to the purser's ankle.

The flightcrew notified their dispatcher, via ACARS,[7] and discussed the injury concerning the injured flight attendant. It was determined to continue to their destination where paramedics met the flight and the injured flight attendant was taken to the hospital.

2.0 Flight Crew Information

The accident flightcrew consisted of 2 pilots and 3 cabin crew members. The upgrading captain was the PF on the accident flight and the line check airman was the PM.

2.1 Line Check Airman

The line check airman was 60 years old and held an Airline Transport Pilot (ATP) certificate with a rating for airplane multiengine land and type ratings in the A-320[8], B-737[9], B-757[10], B-767, and SA-227[11]; limitations included "A-320 CIRC. APCH – VMC ONLY." He held an FAA first-class medical certificate dated November 25, 2019, with a restriction of "Must Wear Corrective Lenses."

2.1.1 Line Check Airman's Training and Proficiency Checks Completed

A synopsis of the line check airman's recent training at United Airlines was as follows:

Date of Hire at United Airlines	February 9, 1987
Most Recent Continuous Qualification Distance Learning	November 26, 2019
Upgrade to captain	June 21, 2002
Line Check Airman Authorization	October 16, 2015
Most Recent FAA Observation	December 6, 2018

[6] Any time that an air carrier assigns a flightcrew member to be transported by a mode of transportation, usually by air, from one location to another and that same flightcrew member is not functioning as an operating flight flightcrew member. Source: Advisory Circular (AC) 117.3 "Fitness for Duty" 11(a).

[7] Aircraft Communication Addressing and Reporting System

[8] Airbus SAS A-318 Series, A-319 Series, A-320 Series, A-321 Series includes all models on type certificate data sheet A28NM. Source: FAA Order 8900.1, Figure 5-88, dated July 15, 2019.

[9] 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.

[10] 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.

[11] M7 Aerospace LLC SA226-AT, SA226-T(B), SA226-TC, SA227-AT, SA227-CC, SA227-PC, SA227-TT. Source: FAA Order 8900.1, Figure 5-88, dated July 15, 2019.

Most Recent Recurrent Ground School	September 19, 2019
Most Recent Recurrent CRM	September 19, 2019
Most Recent Maneuvers Validation	December 5, 2018
Most Recent LOE[12]	December 6, 2018
Most Recent Line Check	March 12, 2019

2.1.2 Line Check Airman's Flight Times

The Line Check Airman's estimated flight times were based on information provided by the line check airman and documentation provided by United Airlines.

Total pilot flight time	15,918:02
Total A-320 flight time	11,678:44
Total A-320 PIC flight time	11,667:54

2.1.3 Line Check Airman's Pre-Accident Activities

The LCA was off duty prior to starting the accident trip pairing on January 8, 2020. There was nothing unusual about his off-duty time and he stated that he felt rested during the trip. On January 8, the time he woke was unknown. He went on duty at 1845 PST[13] and flew with the accident captain from San Francisco International Airport (SFO), San Francisco, California, to Portland International Airport (PDX), Portland, Oregon, departing at 1941 PST and arriving at 2135 PST. The crew was off duty at 2150. He thought he went to bed about 0100 PST. On January 9, the time he woke was unknown. The accident crew went on duty at 0852 PST and flew 3 legs; they were off duty at 2127 and overnighted in New Orleans, Louisiana. He stated he tried to stay on Pacific time and thought he went to bed about 2200 CST. On January 10, the morning of the accident, the time he woke was unknown. He and the accident captain went on duty at 1455 CST and departed MSY at 1545 CST. He did not have any difficulties sleeping nor did he take any medications that might have affected his performance in the days preceding the accident; he had never been diagnosed with a sleep disorder. He was wearing bifocal glasses during the accident flight.

2.2 Captain

The upgrading captain was 48 years old and held an Airline Transport Pilot (ATP) certificate with a rating for airplane multiengine land and type ratings on the, A-320, B-737, B-757, B-767, CL-65[14], ERJ-170[15], ERJ-190, and SJ30S[16]; limitations included "A-320 B-737 B-757 B-767 CL-

[12] Line Operations Evaluation event
[13] Pacific standard time. The crew was based in SFO.
[14] 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.
[15] Embraer S.A. ERJ 170-100 STD, ERJ 170-100 LR, ERJ 170-100 SU, ERJ 170-100 SE, ERJ 170-200 STD, ERJ 170-200 LR, ERJ 170-200 SU, ERJ 190-100 STD, ERJ 190-100 LR, ERJ 190-100 IGW, ERJ 190-100 ECJ, ERJ 190-200 STD, ERJ 190-200 LR, ERJ 190-200 IGW, ERJ 190-300. Source: FAA Order 8900.1, Figure 5-88, dated July 15, 2019.
[16] SyberJet Aircraft SJ30-2 (SIC Required), SJ30-2 (Single Pilot). Source: FAA Order 8900.1, Figure 5-88, dated

65, ERJ-170, ERJ190 CIRC APRC – VMC ONLY.” She held a FAA first-class medical certificate dated August 22, 2019, with no restrictions.

2.2.1 Captain’s Training and Proficiency Checks Completed

A synopsis of the captain's recent training at United Airlines was as follows:

Date of Hire at United Airlines	July 7, 2015
Most Recent Continuous Qualification Distance Learning	December 12, 2019
Upgrade to captain[17]	December 14, 2019
Most Recent Qualification Procedures Validation	November 30, 2019
Most Recent Maneuvers Validation	December 7, 2019
Most Recent Simulator Evaluation	December 14, 2019
Most Recent Systems Validation Oral Event	August 8, 2019
Most Recent LOE[18]	October 26, 2018
Most Recent Line Check[19]	November 9, 2018

2.2.2 Captain’s Flight Times

The Captain’s estimated flight times were based on information provided by the upgrading captain and United Airlines provided documentation:

Total pilot flight time[20]	15,000:00
Total A-320 flight time[21]	800:00
Total PIC flight time	29:46
Total A-320 PIC flight time	29:46

2.2.3 Captain’s Pre-Accident Activities

The captain’s flight and duty times were the same as the LCA. After completing training in December 2019, the captain was off duty and awaiting the start of OE. She stated there was nothing unusual about her activities during that time and she would typically wake about 0600 PST and go to bed about 2200-2230 PST. On January 8, 2020, the time she woke and went to bed were unknown. On January 9, the time she woke was unknown. She thought she went to bed about 2300 and did not recall any problems falling asleep or staying asleep. On January 10, she woke about 0900, ate breakfast, did some shopping, and had lunch before departing the hotel about 1400. She felt rested on the day of the accident. She did not take any medications that might have affected

July 15, 2019.

[17] Upgrade training began on September 13, 2019 and concluded with a Qualification Line Operations Evaluation (QLOE) event.

[18] Line Operations Evaluation event

[19] Standard procedure was a Captain Upgrade would receive a line check at the conclusion of the IOE training event.

[20] Flight time was an estimate time provided by the captain upgrade. Source: Attachment 1 – Crew Interview Summaries and Transcripts.

[21] Flight time was an estimate time provided by the captain upgrade. Source: Attachment 1 – Crew Interview Summaries and Transcripts.

her performance in the days preceding the accident and had never been diagnosed with a sleep disorder. She sometimes wore glasses and thought she wore them during the taxi-out; she had no issues with her hearing.

2.3 Crew Routing

At the time of the turbulence encounter the crew was on a 5-day trip and the event flight was the first leg of the third day.

3.0 Medical and Pathological Information

The crew was not tested for drugs or alcohol after the event.

4.0 Airplane Information

Photo 1: Accident Airplane, N1902U (Courtesy of planespotters.net)

The accident airplane (Registration N1902U, Serial No. 2714) was an Airbus A320-212. The airplane was manufactured in 2006, was registered to and operated by United Airlines 2018, and held a transport category airworthiness certificate dated September 25, 2000. The airplane was configured with 2 pilot seats, 2 cockpit observer seats, 5 flight attendant seats, and 150 passenger seats[22]. Prior to being operated by United Airlines the airplane was operated by China Southern Airlines.

According to the accident flight's dispatch release[23] there were three maintenance deferrals.

5.0 Accident Flight Release and Weather Packet

5.1 Flight Release

United Airlines 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, MELs, departure and planned arrival weights, weather which consisted of departure, enroute, destination, and alternate weather, and a "Dispatcher Remarks" section, which contained the following information:

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[22] Passengers seats were listed as 12 in first class and 138 in economy class.
[23] See Attachment 5 – Accident Flight Dispatch Release for a list of the 3 deferred items.

KEWR Ground Delay Program in Effect, CHK Latest Wheels Up Time
KEWR Demand 36 Capacity 36, Incrsd CF Gusty Winds.

The flight plan fuel section of the release showed that the dispatcher had added 1,720 lbs. of contingency fuel, 774 lbs. of "extra" fuel, and additional contingency fuel of 1,982 lbs.

5.1.1 Route of Flight

According to a United Airlines' Operational Flight Plan documentation for the accident flight, showed the route of flight was:

KMSY DCT CATLN Q22 SPA Q22 BEARI DCT FAK PHILBO3 KEWR

5.1.2 Turbulence Related ACARS Messages

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

February 10, 2020 2248Z (1748 CST)

QU HDQOPUA
.DDLXCXA 102248
AGM
FI UA1754/AN N1902U
DT DDL ATL 102248 M67A
*- /C4 MSYEWR FA [*Name Removed*]*
TWISTED ANKLE. WE HAVE
A PA EVALUATING HER. DH
*FA [*Name removed*]*
WILL BE OCCUPYING 1L
JUMPSEAT. PLEASE NOTIFY

5.1.3 Weather Briefing

The weather briefing the crew was provided prior to departure included the weather information for the departure and destination airports, winds aloft, and NOTAMS. The following weather information was included on the flight release for the accident flight, prior to departure:

FP 101657Z - TURB
VALID. 2020-01-10 18.00.00+00 UNTIL 2020-01-10 21.00.00+00
INTENSITY. OCNL MDT TYPE. CAT
LEVEL. FL300 - FL370
HORIZONTAL WIND SHEAR
AREA. 50W ODF - 15WSW MEI - 55ESE MEM - 65E BWG - 25SE VXV
ID. 28422 (WSI/SA)

FP 101648Z - CONV

VALID. 2020-01-11 06.00.00+00 UNTIL 2020-01-11 09.00.00+00
TYPE. TS
COVERAGE. SCT-BKN. LEVEL. FL260 - FL350
AREA. 30NW ROD - 35NW FAM - 15E IRK - 65NNE GIJ
ID. 29229 (WSI/AVF)

Additionally, the crew was provided with the following graphical depiction via their EFBs of the weather that was anticipated along their route of flight:

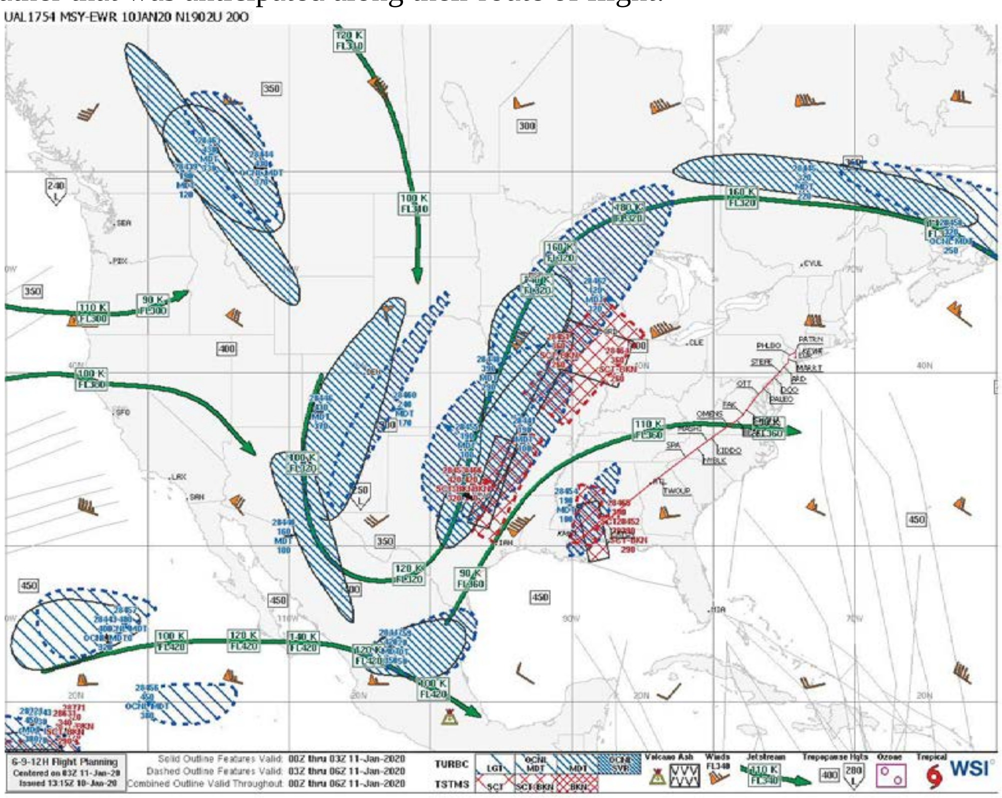


Figure 1: WSI Graphical Weather Depiction

5.2 PIREPs[24]

5.2.1 Flight Plan PIREPs

There were approximately 3 pages of PIREPs provided to the crew prior to departure. The following *italicized PIREPs* were within approximately 100 miles of where the turbulence encounter occurred. Additionally, the PIREP reports in plain language taken from standard code and abbreviations, with altitudes in feet above mean sea level (MSL) follow each PIREP:

PR 101445Z MOB UA /OV MOB325005/TM 1445/FLDURD/TP CRJ9/SK OVC012-TOPUNKN/WV 120040 AT 1200 AGL/RM LLWS +/- 10KTS ON FINAL RY15

Pilot Report January 10th at 1445Z (January 10th at 0845 CST); Mobile, Alabama Routine Pilot Report; Location – Over a point 5 nautical miles northwest of the Mobile Regional Airport, Mobile, Alabama; Time – 1445Z (0845 CST); During Descent; Aircraft Type- CRJ900 series; Sky

[24] Pilot Reports

conditions overcast at 1,200 feet cloud tops unknown; wind velocity from 120 degree at 040 knots at 1,200 feet above ground level; Remarks – Low level windshear plus or minus 10 knots on final to runway 15.

PR 101450Z BIX UA /OV KHBG /TM 1450 /FL010 /TP C560 /RM BASES FM KZHU AWC-WEB.

Pilot Report January 10 at 1450Z (January 10th at 0850 CST); Biloxi, Mississippi Routine Pilot Report; Location over the Hattiesburg Bobby L. Chain Municipal Airport, Hattiesburg, Mississippi; Time – 1450Z (0850 CST); Altitude – 1,000 feet; Type – Cessna Citation V; Remarks – Bases, from Houston Center Air Route Traffic Control Center, Center Weather Advisory – Aviation Weather Center web based entry.

PR 101520Z MOB UA /OV MOB015010/TM 1520/FL012/TP CRJ9/SK OVC012 TOPS070

Pilot Report January 10th at 1520Z (January 10th 0920 CST); Mobile Alabama Routine Pilot Report; Location over a point 10 miles to the northeast of the Mobile Regional Airport, Mobile, Alabama; Time – 1520Z (0920 CST); Altitude – 1,200 feet; Aircraft Type – CRJ-900 Series; Sky Conditions – Overcast 1,200 feet cloud tops at 7,000 feet.

PR 101546Z HSA UA /OV LSU080100 /TM 1546 /FL240 /TP PC12 /SK SKC /TB NEG /RM BTN LYRS SCT CLDS 260-280

Pilot Report January 10th at 1546Z (January 10th 0946 CST); Bay St Louis, Mississippi Routine Pilot Report; Location – Over a point 100 nautical miles east of the Fighting Tiger VORTAC, Baton Rouge, Louisiana; Time – 1546Z (0946 CST); Altitude – FL240; Aircraft – Pilatus PC12; Sky Conditions – Sky Clear; Turbulence – None; Remarks – between layers of scattered clouds at FL260 and FL280.

PR 101550Z GPT UA /OV GPT/TM 1550/FL007/TP TEX2/SK BASES 007/WX 1SM

Pilot Report January 10th at 1550Z (January 10th 0950 CST); Gulfport, Mississippi Routine Pilot Report; Location – Over Gulfport-Biloxi International Airport, Gulfport, Mississippi; Time – 1550Z (0950 CST); Altitude – 700 feet; Aircraft – Beechcraft T-6 Texan II; Sky Conditions – Cloud bases at 700 feet, in flight visibility of 1 statue mile.

PR 101610Z GPT UA /OV 2 NE BIX/TM 1610/FL010/TP CN35/SK BASES 011/WX VSBY 3 SM

Pilot Report January 10th at 1610Z (January 10th 1010 CST); Gulfport Mississippi Routine Pilot Report; Location – Over a point 2 nautical miles northeast of the Keesler TACAN, Biloxi, Mississippi; Time – 1610Z (1010 CST); Altitude – 1,000 feet; Aircraft – CASA 235; Sky Conditions – cloud bases at 1,100 feet, inflight visibility of 3 statue miles.

PR 101636Z GPT UA /OV FAP RY 14/TM 1636/FL006/TP CRJ9/SK BASES006

Pilot Report January 10th at 1636Z (January 10th 1036 CST); Gulfport Mississippi Routine Pilot Report; Location - on final approach to runway 14; Time – 1636Z (1036 CST); Altitude – 600 feet; Aircraft Type – CRJ-900 Series; Sky Conditions – cloud bases at 600 feet.

PR 101644Z HSA UA /OV 3 MILE FINAL/TM 1644/FL004/TP C130/SK BASES 004

Pilot Report January 10th at 1644Z (January 10th 1044 CST); Stennis International Airport, Bay St Louis Mississippi Routine Pilot Report; Location – on a 3 mile final; Time – 1644Z (1044 CST); Altitude – 400 feet; Aircraft Type – C130; Sky Conditions – cloud bases at 400 feet.

PR 101643Z GPT UA /OV 3 N HSA/TM 1643/FL004/TP C130/SK BASES 004

Pilot Report January 10th at 1643Z (January 10th 1043 CST); Gulfport Mississippi Routine Pilot Report; Location - over a point 3 miles to the north of the Stennis International Airport, Bay St Louis, Mississippi; Time – 1643Z (1043 CST); Altitude – 400 feet; Aircraft Type – C130 Series; Sky Conditions – cloud bases at 400 feet.

PR 101635Z GPT UA /OV 3 NW GPT/TM 1635/FL010/TP CRJ9/SK BASES 010

Pilot Report January 10th at 1635Z (January 10th 1035 CST); Gulfport Mississippi Routine Pilot Report; Location - over a point 3 miles to the northwest of the Gulfport-Biloxi International Airport, Gulfport, Mississippi; Time – 1635Z (1035 CST); Altitude – 1,000 feet; Aircraft Type – CRJ-900 Series; Sky Conditions – cloud bases at 1,000 feet.

PR 101658Z GPT UUA /OV 2 MILE FINAL RY 14 GPT/TM 1658/FL006/TP E145/WV LLWS AT 006. +/- 10 KNOTS

Pilot Report January 10th at 1658Z (January 10th 1058 CST); Gulfport Mississippi Urgent Pilot Report; Location – 2 miles final for runway 14 at Gulfport-Biloxi International Airport, Gulfport, Mississippi; Time – 1658Z (1058 CST); Altitude – 600 feet; Aircraft Type – Embraer EMB-145 Series; Wind Velocity – low level windshear at 600 feet plus or minus 10 knots of airspeed.

PR 101705Z MOB UA /OV MOB270005/TM 1705/FL014/TP UH60/SK OVC014

Pilot Report January 10th at 1705Z (January 10th 1105 CST); Mobile Alabama Routine Pilot Report; Location - over a point 5 miles to the west of the Mobile Regional Airport, Mobile, Alabama; Time – 1705Z (1105 CST); Altitude – 1,400 feet; Aircraft Type – Sikorsky UH60 Black Hawk Helicopter; Sky Conditions – overcast at 1,400 feet.

PR 101526Z GZH UA /OV KMVC /TM 1526 /FL015 /TP EC45 /SK SCT020 /WX FV08SM /RM FV08-10SM

Pilot Report January 10th at 1526Z (January 10th 0926 CST); Evergreen Alabama Routine Pilot Report; Location – over Monroe County Aeroplex Airport, Monroeville, Alabama; Time – 1526Z (0926 CST); Altitude – 1,500 feet; Aircraft Type – Airbus Helicopters EC-145; Sky Conditions –

scattered clouds at 2,000 feet, inflight visibility variable at 8 statue miles; Remarks – flight visibility variable between 8 and 10 statue miles.

PR 101659Z JKA UA /OV JKA350005/TM 1659/FL010/TP C172/SK BASES BKN012

Pilot Report January 10th at 1659Z (January 10th 1059 CST); Gulf Shores Alabama Routine Pilot Report; Location - over a point 5 miles to the north of the Jack Edward National Airport, Gulf Shores, Alabama; Time – 1659Z (1059 CST); Altitude – 1,000 feet; Aircraft Type – Cessna 172; Sky Conditions – cloud bases at 1,200 feet.

PR 101624Z GZH UA /OV KMVC045008 /TM 1624 /FL010 /TP H60 /SK OVC025 /RM OVC BASES 025-030/ SKC E

Pilot Report January 10th at 1624Z (January 10th 1024 CST); Evergreen Alabama Routine Pilot Report; Location - over a point 8 miles to the northeast of the Monroe Country Aeroplex Airport, Monroeville, Alabama; Time – 1624Z (1024 CST); Altitude – 1,000 feet; Aircraft Type – Sikorsky UH-60 Black Hawk Helicopter; Sky Conditions – overcast at 2,500 feet; Remarks – overcast bases vary from 2,500 feet to 3,000 feet, sky conditions clear to the east.

5.2.2 Archived PIREPs[25]

A review of archived PIREPs, throughout the national airspace, showed that of the 856 PIREPs provided in the approximate 2 hours prior and 1 hour after the accident flight's encounter with turbulence, there were 7 PIREPs within approximately 100 miles of the accident, 2 of which were identical and were reported by the same flight. The following *italicized PIREPs* were within approximately 100 miles of where the turbulence encountered occurred. Additionally, the PIREP reports in plain language taken from standard code and abbreviations, with altitudes in feet above mean sea level (MSL) follow each PIREP:

MOB UA /OV GCV360010 /TM 2042 /FL330 /TP A320 /TB MOD CHOP /RM FM ZHU AWC-WEB

Mobile, Alabama routine pilot report (UA); Location – over a point 10 nautical miles to the north of the Greene County VORTAC, Leakesville, Mississippi; Time – 2042Z (1442 CST); Altitude – FL330; Aircraft – A320; turbulence – Moderate Chop; Remarks – from Houston Air Route Traffic Control Center Aviation Weather Center web based entry.

MOB UA /OV MOB33003/TM 2100/FLDURD/TP CN35/SK OVC012

Mobile, Alabama routine pilot report (UA); Location – over a point 3 nautical miles to the northwest of the Mobile Regional Airport, Mobile, Alabama; Time – 2100Z (1500 CST); Altitude – during descent; Aircraft – CASA 235; Sky Conditions – overcast at 1,200 feet.

PNS UA /OV PNS35003/TM 2300/FLDURD/TP E145/SK BASES OVC005

[25] Source: Iowa State University, Iowa Environmental Mesonet https://mesonet.agron.iastate.edu/request/gis/pireps.php

Pensacola Florida routine pilot report (UA); Location – over a point 3 nautical miles to the north of the Pensacola International Airport, Pensacola, Florida; Time – 2300Z (1700 CST); Altitude – during descent; Aircraft – Embraer EMB-145 series; Sky Conditions – overcast at 500 feet.

PNS UA /OV PNS26003/TM 2300/FLDURD/TP CRJ9/SK BASES 008

Pensacola Florida routine pilot report (UA); Location – over a point 3 nautical miles to the west of the Pensacola International Airport, Pensacola, Florida; Time – 2300Z (1700 CST); Altitude – during descent; Aircraft – Bombardier CRJ 900 series; Sky Conditions – cloud bases at 800 feet.

PNS UA /OV PNS/TM 2200/FLDURC/TP P32R/SK 008OVC

Pensacola Florida routine pilot report (UA); Location – over the Pensacola International Airport, Pensacola, Florida; Time – 2200Z (1400 CST); Altitude – during climb; Aircraft – Piper PA32; Sky Conditions – overcast at 800 feet.

PNS UA /OV NSE36003/TM 2052/FL030/TP TEX2/SK OVC015 TOPS030

Pensacola Florida routine pilot report (UA); Location – over a point 3 nautical miles to the north of the Whiting TACAN, Milton, Florida; Time – 2052Z (1452 CST); Altitude – 3,000 feet; Aircraft – Beechcraft T-6 Texan II; Sky Conditions – overcast at 1,500 feet, cloud tops at 3,000 feet.

PNS UA /OV PNS26002/TM 2245/FLDURD/TP CRJ9/SK BASES OVC008

Pensacola Florida routine pilot report (UA); Location – over a point 2 nautical miles to the west of the Pensacola International Airport, Pensacola, Florida; Time – 2245Z (1645 CST); Altitude – during descent; Aircraft – Bombardier CRJ-900 series; Sky Conditions – overcast at 800 feet.

6.0 United Airlines Guidance

6.1 United Airlines - Flight Operations Manual

The following guidance was provided, in part, to all United Airlines flight crews in regard to company policies in all of the aircraft fleet.

6.1.1 Enroute Procedures

The Dispatcher shall provide the Captain with all available information that may affect the safety of the flight. This information includes meteorological conditions (including adverse weather phenomena, such as clear air turbulence, thunderstorms, and low altitude windshear), irregularities of facilities and navigation aids, and airport condition updates.

SIGNIFICANT WEATHER CHANGES

The Dispatcher must advise the Captain, before departure, of any significant change *to the information in the weather briefing. The guidance below provides examples of when dispatch may advise the pilots of changing conditions.*

Subject	Action
Alternate Weather	Advise of any change likely to cause the pilot to reconsider alternate selection.
Anticipated Non-normal Operations	Advise of any changes that affect the validity of the operating plan or that are likely to cause the pilot to reconsider agreement to the operating plan.
ATC Delay	Advise of any delay if not previously advised to expect delay. Advise of any increase in delay greater than 15 minutes.
Field Conditions	Changes in runway availability and obstructions or hazards in any operating area must be relayed to the pilot in a timely fashion. During winter storm conditions when snow, ice, or slush accumulations are constantly changing, frequent updates to the pilot are important.
NOTAMs	Advise of any change to flight-planned facilities.
Terminal Weather	Advise of change in descent or approach conditions, particularly if weather conditions are deteriorating. VFR to (or from) IFR. CAT I to (or from) CAT II. Above minimums to (or from) below minimums.
Thunderstorms, Turbulence, Shear, Icing, Freezing Precipitation	These are dynamic conditions and require frequent updating of information to keep the pilot adequately advised of any changes affecting enroute and terminal operations. Normally, reports indicating development from anticipated light intensity to moderate or severe intensity is relayed.

Figure 2: Guidance on When Flight Dispatch May Advise of Changing Conditions (Source: United Airlines FOM pg. 3.60.9)

6.1.2 Crew Briefings

The Captain is responsible for ensuring that flight planning and predeparture briefings create a clear plan of action in a working-together environment. Using the verbiage "standard operating procedure "or "SOP" is appropriate for those routine items that do not require further amplification. To enhance safety, pilots should brief with meaning and visualization, asking questions for clarity and understanding when needed.

FLIGHT ATTENDANT BRIEFING

The Captain is required to conduct a predeparture briefing with only the Purser. However, if time allows, the Captain may brief the entire crew.

The Captain should strive to conduct the briefing as early as possible to minimize disruption to other predeparture duties of the pilots and flight attendants, and minimize potential delays to our passengers. Items to be briefed include, but are not limited to the following:

- *Introductions*
- *FAM/FFDO/LEO/Jumpseat*

• Relief Pilot Items
• Flight Time/Short Taxi
• Wx/Turbulence
• Cabin Mx Items
• Channel 9 (if installed)
• Security or Unusual Circumstances
• Greater than 50 NM Offshore
• FA Coordination (T.E.S.T.[26])

*• **Introductions** Allow for an introduction of each crewmember present at the briefing. Provide the names of any pilots not present and known jumpseaters.*
*• **FAM/FFDO/LEO/Jumpseat** Notify the flight attendants of all known security resources to include FAMs, FFDOs, armed LEOs, jumpseaters etc. If FAMs are present and desire to brief the crew, have them do so.*
*• **Relief Pilot Items** If passenger seats are to be used for the relief pilots, confirm the location. Discuss any other particulars, such as estimates of when the pilot breaks will occur, etc.*
*• **Flight Time/Short Taxi** Review the planned flight time, any anticipated ground/flight delays, and any possibility of a short taxi time, as it may relate to timing of the passenger safety briefing.*
*• **Wx/Turbulence** Review the destination weather and any pertinent turbulence issues for the flight, to include approximately when the turbulence may be expected (if known). If the weather will require the flight attendants to remain seated after takeoff, provide an estimate of the duration.*
*• **Cabin Mx Items** Review any inoperative equipment that might impact the flight attendants or passengers. If the Cabin App is unavailable, provide a reminder that notification of cabin discrepancies is preferred prior to the start of the descent phase.*
*• **Channel 9 (if installed)** Advise if Channel 9 (ATC audio) will not be made available to the passengers.*
*• **Security or Unusual Circumstances** Review any known security information and any unique security measures for the flight. Discuss any unusual circumstances that may affect the flight attendants. Address any questions or open issues and ask if the flight attendants have any additional information for the pilots.*

6.1.3 Passenger Seat Belts Procedures

The seat belt signs will be turned ON before pushback, after the passengers have boarded, as a signal that aircraft movement is imminent; and will be ON for taxi, takeoff, landing, and whenever turbulence is encountered or expected.

See the PA Announcements section in this chapter for required announcements regarding the seat belt sign.

[26] Type of emergency, Evacuation, Special instructions, Time until landing.

6.1.4 Route and Altitude Selection

All flights will be dispatched and operated along the least-cost routing, with consideration to ATC constraints and hazardous weather. The least-cost route and altitude profile provides the lowest total sum of fuel, time, delay, and over-flight costs, while maximizing payload. If the route and/or altitude planned are not along the least-cost routing, the Dispatcher must state the reason for the alternative altitude or route selection in the REMARKS section of the Release.

Dispatch may add EXTRA fuel for altitude/lateral deviations, or adjust the planned altitude/routing to avoid and/or mitigate hazardous weather threats. Hazardous weather is defined as follows:

• Area of known/forecast continuous moderate or severe turbulence intensity as indicated by WSI SIGMET or Flight Plan Guidance (FPG).
• Area of broken convection (BKN) or greater coverage (SOLID) as indicated by WSI SIGMET or FPG.
• Elevated ozone concentrations (non-filtered aircraft only) as defined by WSI products or FPG.
• Areas of volcanic ash as defined by WSI SIGMET or FPG.

WSI is the FAA-approved controlling weather provider. A combination of WSI SIGMETs, Flight Plan Guidance and PIREPs (considering aircraft type, time, location and altitude) must be considered in verifying areas of continuous moderate or greater turbulence.

6.1.5 Required Dispatch Reports

For all flights the following events must be reported to Dispatch (ACARS or radio) as soon as practical (OpSpecs B043, B044, B343, and Exemption 8653):

• If actual ETA will exceed planned by more than 15 minutes, or there is an accumulated deviation of plus or minus 5 minutes from a previously reported estimate.
• If cruise altitude varies by 4000 feet or more from the flight plan.
• If a lateral deviation from the planned route exceeds 100 miles.
• Any enroute failure of a flight deck fuel quantity indicator
• If it becomes apparent that all contingency fuel will be burned (i.e., ACF, EXTRA, and HOLD) and therefore part of the reserve fuel will be burned, coordinate a plan of action with Dispatch and provide the details of what occurred (e.g., holding at destination).
• A flight encounters weather significantly different than forecast, or any time moderate or greater turbulence is encountered.
• The flight is assigned enroute or arrival holding.
• Unplanned or sustained use of deicing or anti-icing systems.
• Assigned a CDR. See Operating Information chapter>Flight Planning>Coded Departure Route.
• When an ATC-initiated callsign change occurs.

6.1.6 Turbulence Definitions

Light Turbulence *Slight bumpiness and/or momentary erratic changes in altitude/attitude:*

- *Drinks occasionally splash out of cup.*
- *Little or no difficulty in walking.*
- *Occupants may feel slight strain against seat belts.*

Light Chop *Slight, rapid and somewhat rhythmic bumpiness without appreciable changes in altitude or attitude.*

Moderate Turbulence *A harsher ride than light turbulence with changes in altitude and/or attitude, but the aircraft remains in positive control; typically causes variations in indicated airspeed:*

- *Drinks splash out of cup with consistency.*
- *Standing or walking is sometimes difficult or impossible without holding on to a part of the aircraft.*
- *Occupants feel definite strain against seat belts.*

Moderate Chop *Rapid bumps or jolts without appreciable changes in aircraft altitude and attitude.*

Severe Turbulence *Large, abrupt changes in altitude and/or attitude and the aircraft may be momentarily out of control; typically causes large variations in indicated airspeed:*

- *Unsecured items are tipped over or tossed about.*
- *Standing or walking is impossible without holding on to part of the aircraft.*
- *Occupants are forced violently against seat belts.*

Extreme Turbulence *Aircraft is violently tossed about and is practically impossible to control; it may cause structural damage.*

MODERATE OR GREATER TURBULENCE ENCOUNTERS

> ***Note:*** *Turbulence of moderate or greater intensity must be reported to Dispatch as soon as possible.*

6.1.7 Turbulence PA Commands – Forecasted or Impending

FORECASTED/IMPENDING TURBULENCE OF MODERATE OR GREATER INTENSITY		
Note: *An interphone briefing may still be accomplished, but when the flight attendants are to be seated, the command **must** be given over the PA. This allows all flight attendants to hear the PA command and informs the passengers that the flight attendants **must** be seated in their jumpseats and not completing service items.*		
Condition	**Pilot Actions**	**Flight Attendant Response**
Forecasted/Impending Turbulence Turbulence of moderate or greater is forecasted or impending.	Make PA: **"Flight attendants, take your jumpseats."**	Flight attendants will discontinue service and move the carts to a safe location outside of the aisle. Flight attendants will move to their jumpseats and fasten seatbelts/shoulder harnesses.
Turbulence Improves/Subsides Captain determines it is safe for flight attendants to resume their duties.	Make PA: **"Flight attendants, check in."**	Flight attendants are free to resume duties. After all the flight attendants have checked in with the Purser, a call from the Purser to the flight deck will be made to report cabin status. The Captain may inform Purser of any subsequent turbulence or crew actions.

Figure 3: Turbulence PA Commands – Forecast or Impending
(Source: United Airlines Flight Operations Manual pg. 7.10.2)

6.1.8 Turbulence PA Commands – Unexpected Turbulence

UNEXPECTED TURBULENCE OF MODERATE OR GREATER INTENSITY		
Note: *Anytime the Captain seats the flight attendants for turbulence, the command **must** be given over the PA. This allows all flight attendants to hear the PA command and informs the passengers that the flight attendants **must** be seated in their jumpseats and not completing service items.*		
Condition	**Pilot Actions**	**Flight Attendant Response**
Unexpected Turbulence of Moderate or Greater Sudden onset turbulence of moderate or greater intensity.	Make PA: **"Flight attendants, be seated immediately, be seated immediately."**	Flight attendants will stop the service and leave carts with brakes set. Flight attendants will either take their jumpseats, occupy the nearest available passenger seat or drop to the floor of the aircraft, whichever is closer.
Unexpected Turbulence of Moderate or Greater Improves Captain determines that flight attendants are safe to return to their jumpseats, but not safe to resume duties.	Make PA: **"Flight attendants, take your jumpseats."**	Flight attendants will discontinue service and move the carts to a safe location outside of the aisle. Flight attendants will move to their jumpseats and fasten seatbelts/shoulder harnesses.
Unexpected Turbulence of Moderate or Greater Ceases Captain determines it is safe for flight attendants to resume their duties.	Make PA: **"Flight attendants, check in."**	Flight attendants are free to resume duties. After the flight attendants have checked in with the Purser, a call from the Purser to the flight deck will be made to report cabin status. Captain may inform the Purser of any subsequent turbulence or crew actions.

Figure 4: Turbulence PA Commands - Unexpected Turbulence
(Source: United Airlines Flight Operations Manual pg. 7.10.3)

TURBULENCE ONSET TYPES

Note: *The ride experience on the flight deck may be considerably different from the ride being experienced in the cabin. Historically, the cruise and descent phases of flight are high risk for flight attendant injuries. Proper planning and coordination can significantly reduce the potential for injury.*

Unexpected

*Moderate or greater turbulence is encountered, and there is not enough time for flight attendants to safely move to their jumpseats. The pilots should ensure the seatbelt sign is on and make a PA announcement stating, "Flight attendants, be seated **immediately**, be seated **immediately**." This prompts the flight attendants to "stop, drop, and hold on" at their current locations. If necessary, make a PA announcement to inform the passengers to also be seated immediately. After making the "Flight attendants, be seated **immediately**, be seated **immediately**" PA, if the Captain does not feel that it is safe for the flight* *attendants to resume their duties, but safe enough to move to their jumpseats, then the Captain may make the, "Flight attendants, take your jumpseats" PA.*

When the Captain feels it is safe for the flight attendants to resume their duties, the "Flight attendants, check in" PA is made. This will allow the flight attendants to leave their jumpseats and return to normal duties expeditiously and simultaneously.

The Purser will assess conditions and report the status of the cabin, F/A crew, and passengers to the pilots.

Impending

There is sufficient time for the flight attendants to move to their jumpseats, but not enough time to clean up and secure their work areas. This may include reported turbulence from other aircraft, WSI forecasts, TAPS reports or possible turbulence while deviating for weather. Ensure the seatbelt sign is on and make a PA announcement stating, "Flight attendants, take your jumpseats." This triggers the flight attendants to stop service, move carts to a safe location out of the aisle, and return to their jumpseats and fasten seatbelts and shoulder harnesses. If necessary, also make a PA announcement to inform the passengers to return to their seats. An interphone briefing may still be accomplished (e.g., "There is turbulence forecasted ahead, so I'll be sitting you down in 10 minutes."), but when the flight attendants are to be seated, make the announcement over the PA.

When the Captain feels it is safe for the flight attendants to resume their duties, then the "Flight attendants, check in" PA is made. This will allow the flight attendants to leave their jumpseats and return to normal duties expeditiously and simultaneously. The Purser or designee will assess conditions and report the status of the cabin, F/A crew, and passengers to the pilots.

Forecasted/Expected

There is sufficient time for the crew coordination steps below. Allow sufficient time, depending on the size of the aircraft, for flight attendants to adjust their cabin service and secure their equipment. This also allows ample time for passengers to return to their seats.

Crew Coordination *The Captain, or designee, is responsible to inform the Purser of the following:*

- *How much time is available before the turbulence is expected.*
- *The anticipated intensity and duration of turbulence.*
- *Any special instructions (e.g., modifying or curtailing cabin service, securing galley carts).*
- *If flight attendants are to be seated in their jumpseats.*

SEVERE TURBULENCE

Do not intentionally conduct flight through areas of known severe turbulence. If a chance of severe turbulence is forecasted for the route, be alert for PIREPs and other indications of actual severity of turbulence present. If informed of the presence of severe turbulence, consider the following action:

- *In the vicinity of the departure airport, seek departure routing that avoids the turbulent area, if possible, or delay departure until conditions improve.*
- *Enroute, change altitude and/or route in order to avoid the reported area.*
- *In the vicinity of the destination airport, seek a descent and approach path to avoid the reported turbulence area. If avoidance is doubtful, consider holding until the situation improves (PIREPs, LLWAS, TDWR, etc.) or consider diversion.*
- *Contact Dispatch for help in obtaining current weather and PIREPs.*

TURBULENCE PIREPS

Turbulence of moderate or greater intensity must be reported to ATC and Dispatch as soon as possible. The preferred method of sending the Turbulence PIREP to Dispatch is to use the SUBMIT PIREP prompt in ACARS, if available. To help the situational awareness of other aircraft on frequency and to minimize follow-up questions, provide a full PIREP to ATC that includes the aircraft location, turbulence intensity and duration, whether in or near clouds, altitude, and aircraft type.

Note: *A defect report to Maintenance is required anytime severe or extreme turbulence is encountered.*

6.1.9 Automatic Turbulence Advisories

Aircraft receive auto generated turbulence advisories via ACARS, which are simultaneously sent to the flight deck and dispatch. This process automates the delivery of PIREPs, WSI Turbulence SIGMETs, WSI Convective SIGMETs, and WSI Turbulence Advisory Areas. Dispatchers are still responsible for ensuring flights are informed of all potentially hazardous turbulence information. Dispatchers will ensure the automated system is working, and that pilots are made aware of other possible turbulence hazards that don't meet the thresholds of the automated system.

Messages from the automated system include the time and location of where the flight path comes closest to the reported PIREP location or the time the flight path intersects the SIGMET or Turbulence Advisory Area.

6.1.10 TURBULENCE AUTO PIREP SYSTEM (TAPS)

TAPS is a component of the turbulence reporting program and uses aircraft accelerometers to automatically report aircraft ride quality. When an aircraft reports turbulence using the TAPS system, a Turbulence Advisory message is automatically generated by WSI for nearby aircraft and requires no pilot input. A Turbulence Advisory includes:

- *Time, location, and altitude of the reporting aircraft*
- *Time and location of where the flight path is closest to the TAPS report*
- *Turbulence Level code:*

– 0.1 to <0.2 = Light
– 0.2 to <0.3 = Moderate
– >=0.3 = Severe

Automated Turbulence Advisories

Automatic turbulence reporting messages are to increase situational awareness, and are not a substitute for vigilance. Consider turning on the seat belt sign, curtailing cabin service, and having the flight attendants seated when approaching an area that generated an automated uplink. Reference the Turbulence Action Guide in the FOM QRG to determine the appropriate response to an automated turbulence advisory.

TAPS and PIREPS Parameters

TAPS and PIREPs advisories are sent automatically via ACARS if the route of flight is within 30 minutes of entering the affected area, which is defined as 75 miles and 2000' of a:

- *TAPS report with a Turbulence Level of 0.15 or greater*
- *Turbulence PIREP of moderate or greater*

SkyPath

The SkyPath EFB application displays real-time turbulence. When the EFB is docked and calibrated, the app uses the accelerometers in the iPad to measure turbulence and converts the movements to color-coded tiles representing different turbulence severities. An algorithm filters out any movement of the EFB not associated with turbulence.

SkyPath should be used as an additional approved turbulence data source, in conjunction with other approved sources (e.g., WSI, TAPS, PIREPS) for route, speed, and altitude selection. Though SkyPath data is seen by the Dispatcher, it is not a substitution for PIREP submissions.

SIGMETs

WSI Turbulence SIGMET and WSI Convective SIGMET messages are sent when the aircraft is within 30 minutes of entering the affected area. When flights are closer than 30 minutes to the reported location or area when it is generated, an advisory is sent immediately. The message will state the time the aircraft will enter the SIGMET or Turbulence Advisory Area. If the aircraft is already in the area when the SIGMET is created, the message will state "Your aircraft is within a.. . (i.e., Turb SIGMET area)."

It is important to note that automated advisories are not issued for government-issued SIGMETs. WSI SIGMETS should be comprehensive for determining threats; however, there will be differences between the government SIGMETs announced by ATC and WSI SIGMETs.

Own Ship TAPS Reporting

When aircraft are equipped with the TAPS reporting algorithms, an ACARS message will report own ship turbulence TAPS reports for two turbulence specific metrics; Turbulence Level and Eddy Dissipation Rate (EDR). Turbulence Level is a measure of how much the aircraft is "shaking," while EDR is the "sea state" of the atmosphere. ACARS advisories are based on reported Turbulence Levels and reported with a turbulence level code.

6.1.11 Thunderstorms

WARNING: Do not attempt to penetrate a thunderstorm.

The onboard radar is the primary means of circumnavigating convective weather. WSI, in conjunction with Dispatch and ATC, may be helpful for long range routing decisions and turbulence avoidance. However, the receipt of WSI weather information may be delayed up to 15 minutes and should not be used for convective weather avoidance that is within weather radar detection range. Wi-Fi connectivity may be deferred per the MEL. The turbulence associated with thunderstorms can be minimized by adhering to the following guidance:

*• **Circumnavigating Storms** Avoid the downwind (anvil) side of the storm by at least 1 mile for every knot of wind at that flight level.*

*• **Flight Above a Thunderstorm** Should be avoided, however, if this is not practical, attempt to vertically clear the cell by at least 5000 feet. The vertically propagating convective waves associated with both building and dissipating storms present a hazard that requires careful consideration and action.*

*• **Flight Beneath a Thunderstorm** Should not be attempted for storms of moderate or severe intensity.*

*The seatbelt sign **should be on** and the flight attendants **should be seated** when operating:*

• Within 20 miles of strong radar echoes (sharply defined edges and/or contour indications of heavy precipitation).

• Within 10 miles of moderate radar echoes (less sharply defined, but still indicative of moderate thunderstorm activity).

• In airspace above thunderstorms.

6.1.12 Doppler Return Turbulence

If a Doppler return showing turbulence is associated with moderate or severe thunderstorm returns, avoid the area using the thunderstorm avoidance criteria. If a Doppler return showing turbulence is present in light precipitation, or no precipitation, avoid the area by 5 NM, if possible.

6.1.13 Enroute Storm Area Avoidance

Early detours of storms, considering distance and storm position, are good operating procedure. Plan an avoidance path as soon as possible for all weather echoes which appear beyond 100 miles. While ATC may be able to provide some assistance, controllers can only advise of precipitation areas and cannot ensure clearance from severe weather.

When serious thunderstorm conditions exist in terminal areas, prompt rerouting clearance from ATC may not be attainable. If in a terminal area and unable to obtain a clearance to deviate around a thunderstorm which in the Captain's judgment threatens *the safety of the flight, declare an emergency and advise ATC of the heading to clear the storm. The possibility of less than adequate separation from other aircraft exists and mandates early planning and immediate communication of the deviation decision to ATC.*

6.2 Flight Manual

6.2.1 Bulletin 16-02 Weather Radar Control Panels

The United Airlines A319-320 Flight Manual provided the following bulletin, dated August 7, 2019, in the 319/320 Aircraft Differences – Nose Number 48XX/49XX:

Weather Radar Control Panels
Note: *48XX/49XX aircraft may either have one of two different weather radar control panels, as shown below.*
Location: *Control Pedestal*

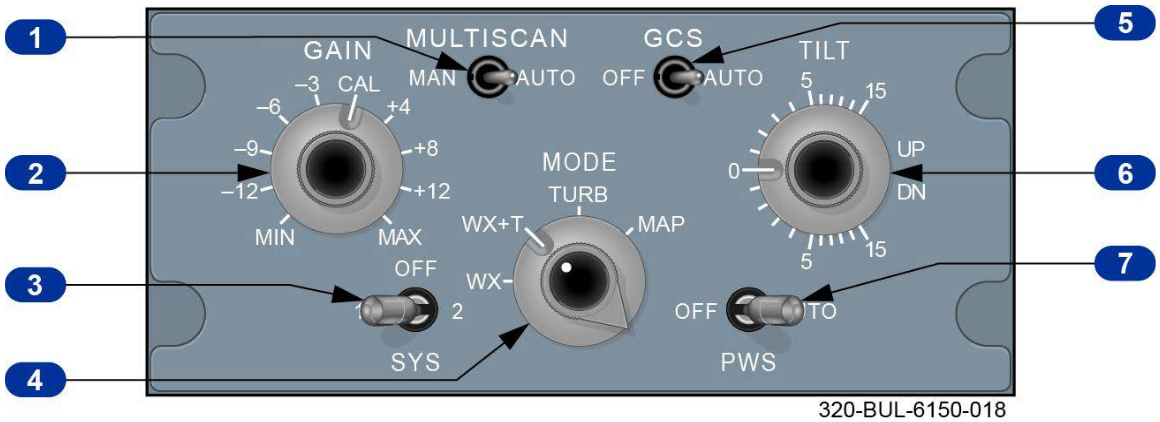
320-BUL-019

1 ***Radar Switch*** *Position 1 activates the weather radar for display on the ND in any mode except PLAN.*

Note: *Position 2 is deactivated. Inadvertently selecting this position will not turn on the radar.*

Note: *The OFF position is the middle position; therefore, exercise care to ensure the system is off after landing since the switch is positioned either full left or full right on UA-configured aircraft.*

Location: *Control Pedestal*



The normal settings are:
- *(1) MULTISCAN - AUTO*
- *(2) GAIN - CAL*
- *(3) SYS - 1*
- *(4) MODE - WX+T*
- *(5) GCS – AUTO*
- *(6) TILT – 0*
- *(7) PWS – AUTO*

1 ***MULTISCAN*** *In AUTO the radar alternatively scans at two antenna tilt settings. The weather radar image that is displayed is the result of the stored and combined information from each beam. It also removes the weather that is not on the aircraft flight path or is not a threat to the aircraft (post convective cell). In MAN the TILT setting becomes active and must be manually adjusted.*

2 ***GAIN*** *CAL provides automatic gain adjustment based on altitude, geographical area, season, and time of the day.*

3 ***SYS*** *Turns on/off weather radar system 1 or 2. The normal setting is 1 as SYS 2 may be deactivated.*

4 ***MODE*** *WX+T is the normal mode. WX operates like UA 320s, the T feature displays turbulence areas within 40 NM in magenta.*

5 ***GCS*** *Is ground clutter suppression and removes ground returns from the ND. GCS is not available when using manual modes.*

6 ***TILT*** *Zero indicates the horizon reference, as provided by the ADIRS. If MULTISCAN is set to MAN, utilize the TILT knob per normal SOP as stated in the Flight Manual.*

7 ***PWS*** *Operates like UA 320s.*

6.3 Weather Radar Operation

The United Airlines 319-320 Flight Manual, Supplementary Procedures "Adverse Weather Operations," dated September 20, 2019 provided the following guidance on the use of the weather radar:

GENERAL

While penetration of widespread areas of light stratiform rain is possible, caution should be used when flying through extended areas of moderate rain due to the possibility of embedded thunderstorms. Radar equipment is to be used as an aid ***to avoid severe weather, not as a penetration tool.***

RADAR ATTENUATION CHARACTERISTICS

In widespread ***light*** *rain, the radar displays* ***green*** *to a distance of 70 NM with the remainder of the light rain not displayed due to lower reflectivity. In widespread* ***moderate*** *rain, the radar displays* ***yellow*** *to a distance of 45 NM, then turns green for an additional 10 NM with the remainder of the moderate rain not displayed. Even though the reflectivity increases in* ***moderate*** *rain, the distance precipitation is displayed decreases due to radar attenuation.*

A storm cell 3 NM wide and 3 NM tall with heavy rain surrounded by clear air displays on radar when within 230 NM of the aircraft. The same storm cell embedded in widespread light rain displays on radar when within 160 NM of the aircraft. Embedded in widespread moderate rain, the same storm cell displays when within 80 NM of the aircraft. These distances relate to a very intense storm; storms of less intensity are not detectable until closer to the aircraft. As the cell intrudes the colored area of the radar display, it casts some shadow. Whenever flying through widespread rain, using primary tilt position and searching for shadows are very important.

> ***Note:*** *The weather radar may occasionally display red and black wedges or sharp sectors similar to a radar test pattern. This can be disregarded if these disappear in two to three radar sweeps. If the images persist, report the defect to Maintenance.*
>
> ***Note:*** *All grids for spacial [sic] comparisons only, not on actual displays.*

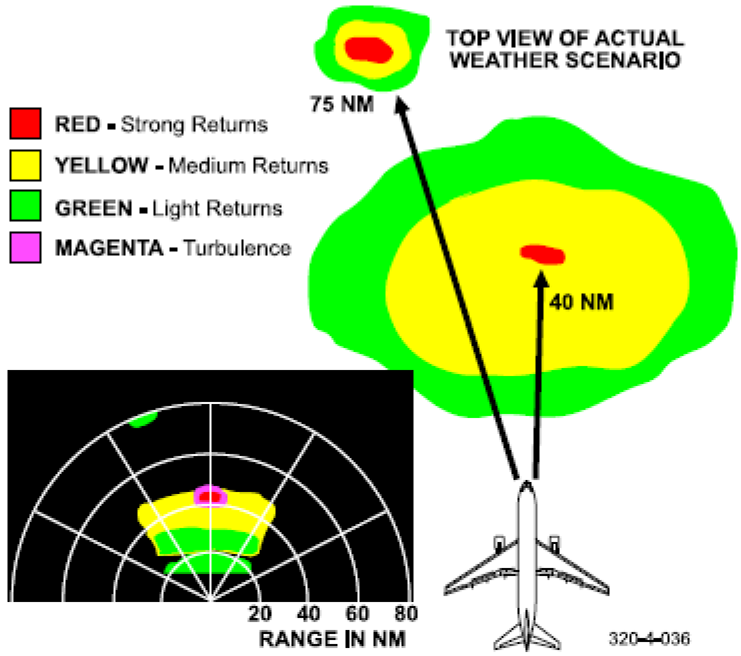


Figure 5: Radar Attenuation Characters

SYSTEM OPERATION

Weather radar mode selector . . . . Weather/turbulence

Provides normal weather radar operation plus Doppler detection of turbulence by measuring the velocity of rain droplets moving parallel to the aircraft flight path. Turbulence may be displayed in light rain or entirely outside the precipitation area. Although Doppler cannot detect clear air turbulence, it can detect turbulence in the presence of rain lighter than that displayed in the weather-only mode. Turbulence returns and Level 4 and higher storms are displayed in magenta. These areas can be ***very dangerous****. Avoid echoes in accordance with the FOM.*

ND brightness control knobs . . . . Adjust

Balance the radar returns and ND.

ND range selector . . . . As required

As weather echoes move closer to the aircraft, selecting shorter ranges yields best results. Select progressively shorter ranges during a descent. The longer ranges should be monitored periodically to detect distant storm cells. When different ranges are selected, tilt adjustment is necessary.

Tilt knob . . . . As required

See Weather Radar - Tilt Management, this section.

6.3.1 Weather Radar – Tilt Management

Range and azimuth depict the organization of the weather system, the relative position of echoes in a line, and an avoidance path. Measuring the height, gradient, reflectivity, Doppler return, and shape of cells depicts the degree of hazard. Note that shapes are often fleeting; they may appear only at certain tilt settings or disappear after a single sweep. Failure to spot a particular shape or feature does not necessarily mean the weather is nonhazardous. Also, size, intensity, and echo tops are not always clear-cut indicators of hazard.

TAKEOFF

Scan for storms in the departure path at the 10 NM range and move the tilt slowly from +15° to +4°. If the 10 NM range is clear, repeat for the 20 NM and 40 NM ranges. Look for irregular shapes and crescent-shaped storms. Normal antenna tilt position during and after takeoff is +4°.

PRIMARY TILT POSITION

While in flight, move the tilt downward until ground return is displayed.

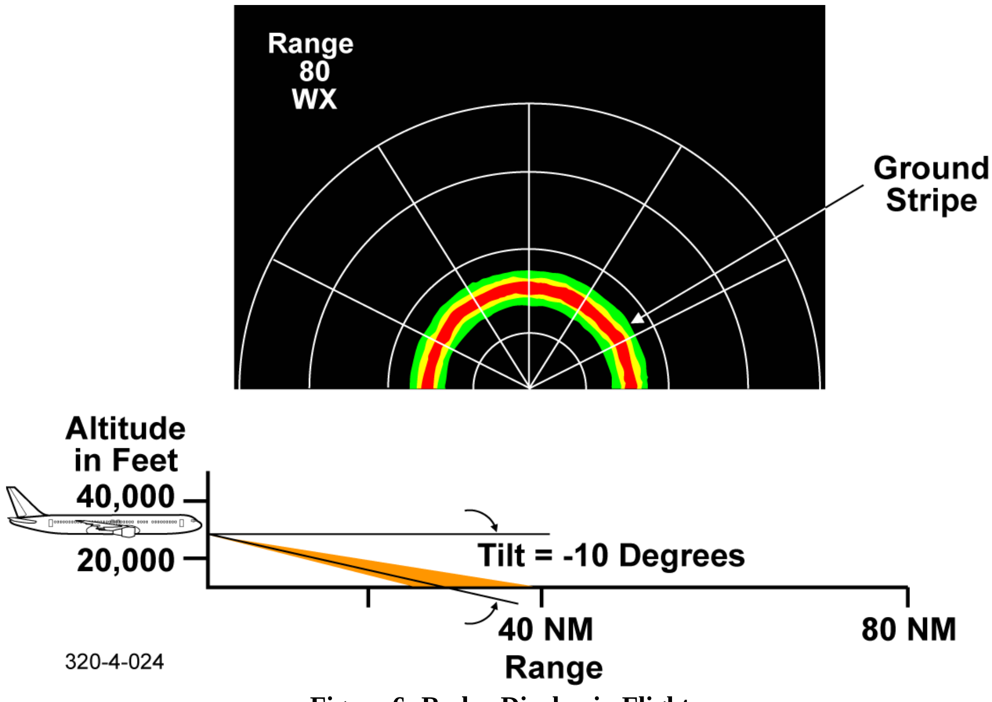
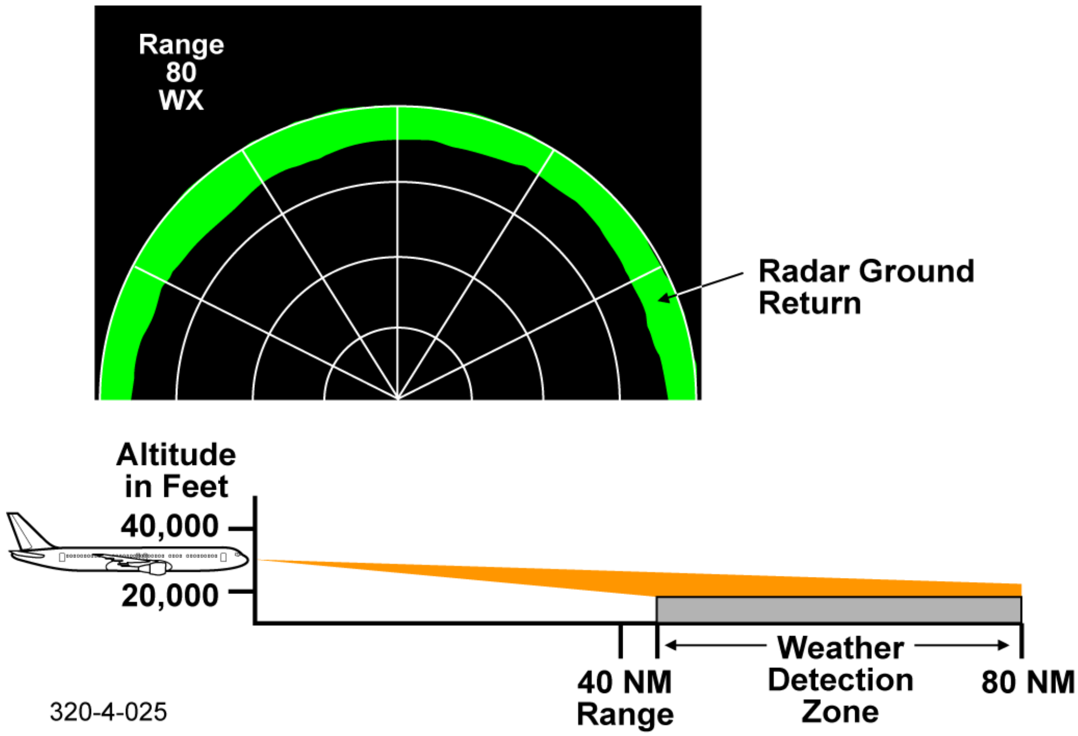
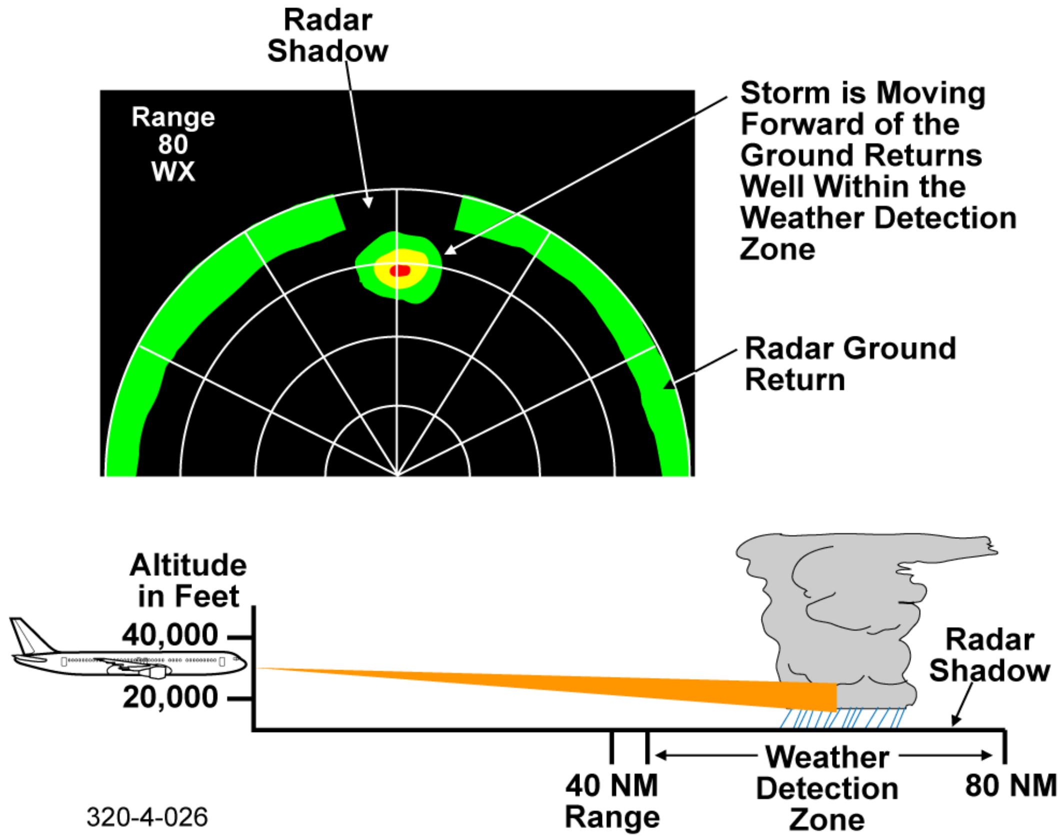


Figure 6: Radar Display in Flight
(Source: United Airlines 319-320 Flight Manual)

Raise the beam and observe the ground return moving farther out in range. A radar sweep takes about 4 seconds, so make the adjustments slowly. Stop adjusting the tilt when the ground return stripe moves to the outer edge of the indicator but can still be seen. At the higher ranges, the ground return appears as a sprinkle of ground return spots.



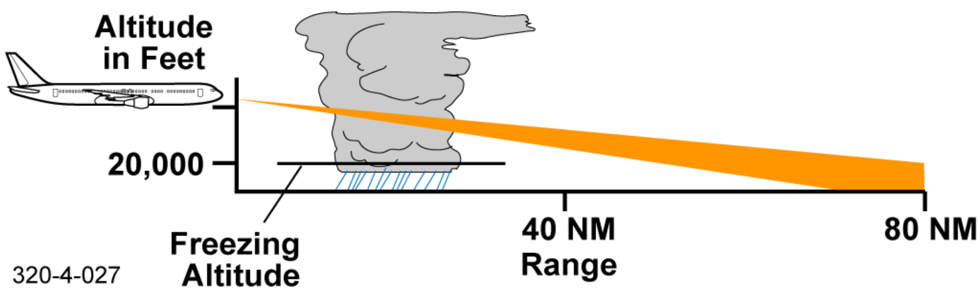
The primary tilt position creates a zone where no storm can go undetected as the radar beam is toward the most reflective section of a storm.



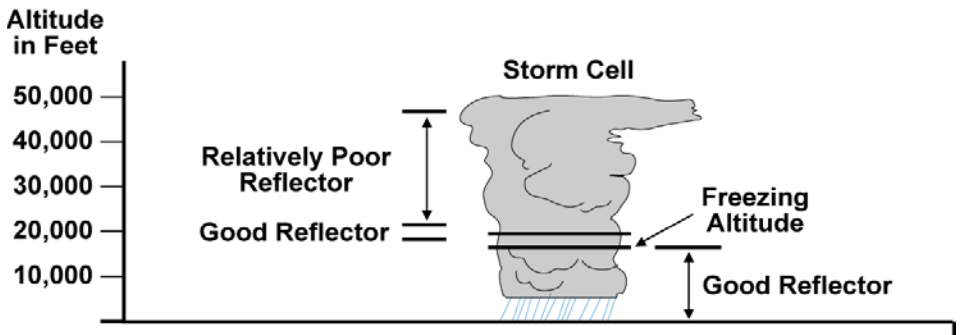
Any significant change of altitude requires a new primary tilt position; on descent, more upward tilt is needed; on climb, more downward tilt. Tilt control is independent of radar stabilization. The stabilization function maintains the antenna position parallel to the earth during aircraft maneuvering. However, tilt must be adjusted for significant altitude changes and when a different range is selected.

OVERSCANNING

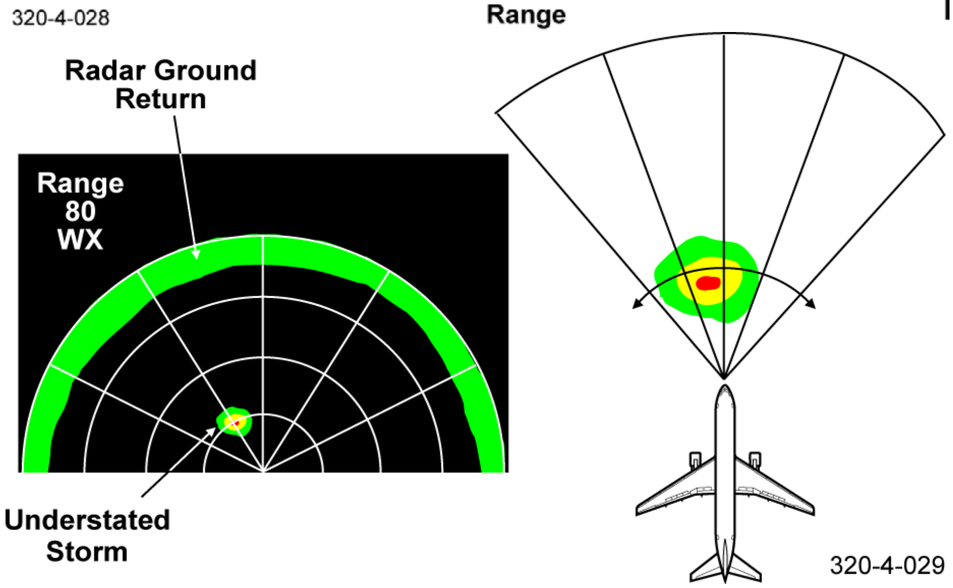
Above 25,000 feet, as the aircraft approaches storms, the storms may become dangerously understated or disappear completely from the display. This is due to overscanning the most reflective part of the storm.



320-4-027



320-4-028



320-4-029

If an echo disappears from the scope or becomes understated, due to overscanning, reduce the range and repeat the primary tilt position procedure.

Special Convective Conditions

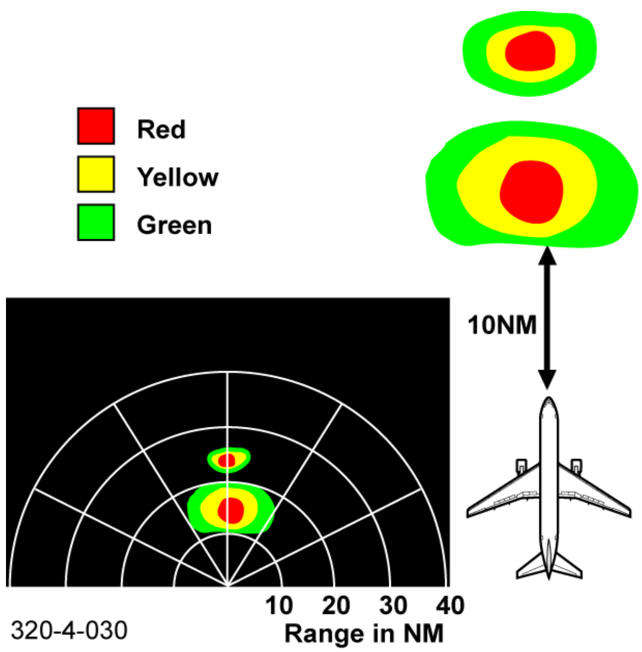
Storms in regions of unstable air (i.e., Tropics and Subtropics) may also be overscanned. To aid in detection of dry top cells:

- *Position mode selector in WX/TURB.*
- *Position GAIN selector in AUTO.*
- *Keep flight deck lights low to optimize visual detection.*
- *Use 40 NM range; keep at least one pilot on this range.*
- *Use the primary tilt position for the 40 NM range.*

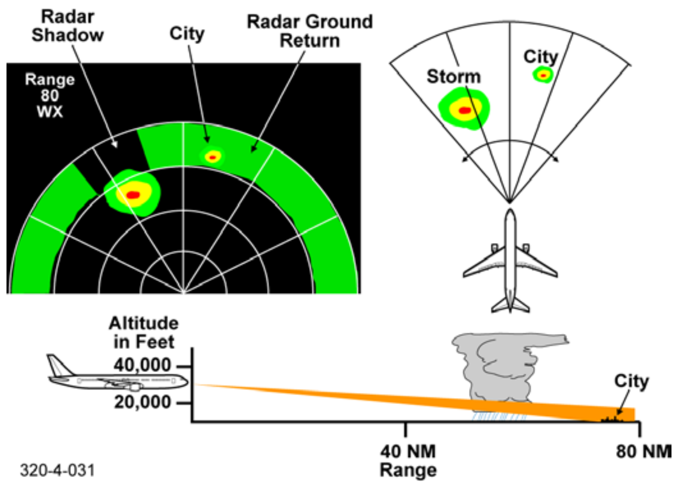
LOOKING FOR SHADOWS

Tilt the antenna down to a position that paints ground returns on the outer one-third to one-half of the display:

• If weather can be seen behind a cell, assume it is at least one level more hazardous than depicted, due to attenuation.



• If no ground return or other echoes can be seen behind a cell, a radar shadow is indicated. This shadow is an important indicator of hazardous weather; ***avoid all shadowed areas.*** *If it is an extreme storm, with only its leading edge depicted, it appears as a thin line or band of precipitation in the shape of a crescent, with the horns pointed away from the aircraft. A black area behind it (the radar shadow) is the most dangerous part of the storm. An isolated mountain echo appears as a crescent-shaped cell that casts a shadow, a city will not. Widespread areas of water (e.g., lakes, rivers) may also appear as shadows.*

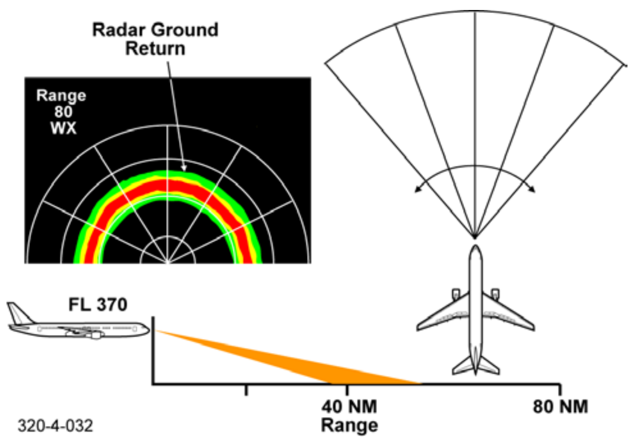


PARALLEL BEAM POSITION

This tilt position results in the bottom of the beam being parallel to the earth, and echoes depicted (weather and/or high terrain) are objects that intrude through the current altitude. It should be selected frequently, particularly when operating below 15,000 feet AGL, but for only a few sweeps. To find the parallel beam position:

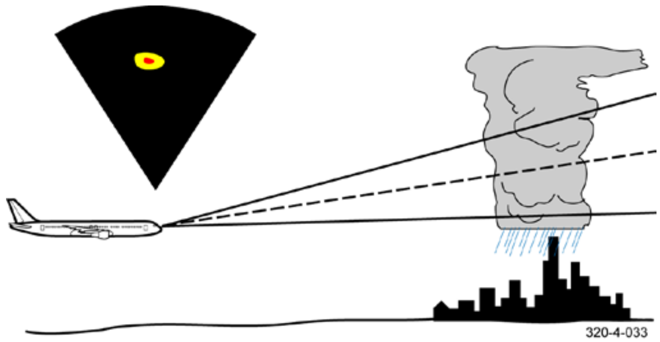
Tilt. . . . . Adjust

Adjust the tilt to paint the ground stripe at a range equal to current AGL altitude (e.g., flying at FL 370 over sea-level terrain, paint it at 37 NM; at FL 370 over Denver, paint it at approximately 32 NM):



Tilt. . . . . Increase

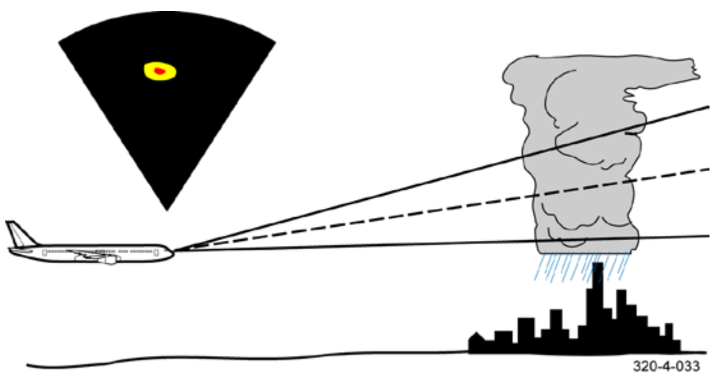
Increase the tilt 10° from the position in the previous step.



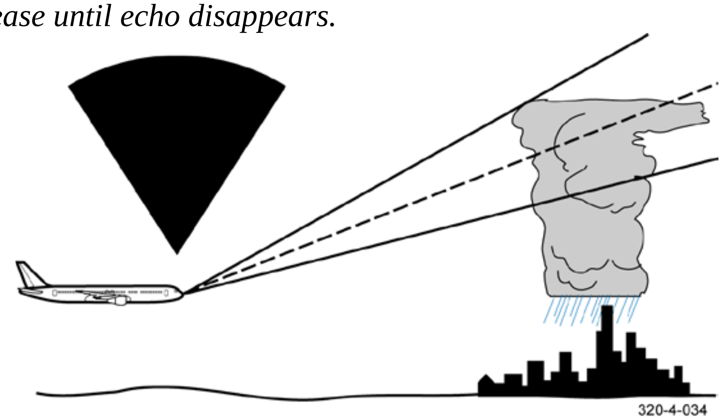
EVALUATING CELL HEIGHT

*When used for a few sweeps, this formula gives a quick estimate of radar height of the echo and may be used at any range. This is useful **only** for determining the relative severity of the storm and should not be used to attempt overflight in IMC. Radar height is **not** the storm height, due to low reflectivity in the cell tops. Assume the actual storm top is at least 20% above the measured radar top. **Severe turbulence can exist well above the actual top.***

Cell height . . . . Evaluate
Start from the parallel beam position.



Tilt. . . . . Increase
Increase until echo disappears.



Cell height evaluation. . . . . Continue

*The radar top is distance to echo x 100 x degrees of tilt change from parallel beam (e.g., an echo at 40 NM disappears with a 4° tilt increase: 40 x 100 x 4° = **radar top,** which is at least 16,000 feet above current flight level; **actual top** is 120% of 16,000 feet or at least 19,200 feet above current flight level).*

6.4 Flight Attendant Manual

The United Airlines Flight Attendant Operations Manual provided the following guidance on the flight attendant duties when turbulence was encountered rather expected or unexpected.

6.4.1 Public Address Announcements

The following public address announcements are normally made from the cockpit and the chart below the respective announcements was the flight attendant actions that should be done:

FLIGHT ATTENDANTS, TAKE YOUR JUMPSEATS.

Flight Attendant Actions
1. Discontinue service and move the carts to a safe location outside of the aisle (e.g., into galley locations, jumpseat-free cross-aisles).
2. Proceed to a jumpseat and ensure seat belts AND shoulder harnesses are securely fastened at all times.
3. Verbally advise customers to sit down and fasten seat belts. If possible, make PA announcements as necessary.
4. Remain in jumpseat until the pilots make the "Flight attendants, check in" PA announcement.

FLIGHT ATTENDANTS, BE SEATED IMMEDIATELY. BE SEATED IMMEDIATELY.

Flight Attendant Actions
WARNING: **Do not attempt to walk through the cabin.**
1. ***Stop*** Stop service (i.e., angle cart into a seat and set cart brake, leave cart within galley and set cart brake).
2. ***Drop*** Immediately secure yourself at the nearest available seat (jumpseat, if immediately adjacent; otherwise, take nearest aisle customer seat if one is available). If aisle seat is unavailable, sit on the floor and hold on to a secure stationary object (e.g., seat leg brace).
3. ***Hold On*** Remain in jumpseat, with seat belts AND shoulder harnesses securely fastened at all times, or other secure location.
4. Verbally advise customers to sit down and fasten seat belts. If possible, make PA announcements as necessary.
5. Remain in place until the pilots make either the "Flight attendants, check in" or the "Flight attendants, take your jumpseats" PA announcement.

FLIGHT ATTENDANTS, CHECK IN.

Flight Attendant Actions
1. "Flight attendants, check in" PA announcement is the indication that it is safe to resume duties.
2. Check on customers and cabin for any injuries or damages.
3. Proceed to an available jumpseat interphone and check in with the International Purser/Purser, or designee.
4. Report post turbulence findings to International Purser/Purser, or designee.
5. International Purser/Purser checks in with pilots for any further information, as soon as practical.

6.4.2 Predeparture Crew Briefings

The captain should include any information about anticipated turbulence in the briefing to the International Purser/Purser. At the captain's discretion, a review of proper communication procedures from the pilots to the light attendants may be briefed.

The International Purser/Purser is responsible for ensuring that all light attendants are provided with all of the information from the captain's briefing. If turbulence is forecasted, light attendants must use this information to manage time and service.

Flight attendants must keep the pilots advised of conditions in the cabin throughout the light.

6.4.3 Turbulence Action Guide

Turbulence intensity can be light, moderate, or severe.

The following Turbulence Action Guide defines each intensity level along with appropriate pilot and flight attendant actions.

Important: Buckle Up!
Flight attendants must use good judgment, situational awareness and secure themselves when moderate or severe turbulence is experienced regardless of whether the Fasten Seat Belt sign is on or off. Sit on the floor, in the nearest customer seat or jumpseat. Securely fasten seat belts (and shoulder harnesses, if applicable). Inform the pilots of cabin conditions as soon as advised.

6.4.3.1 Light Turbulence

Conditions During Turbulence

- *Slight bumpiness and/or erratic changes in altitude/attitude.*
- *Drinks occasionally splash out of cup.*
- *Little or no difficulty walking.*
- *Occupants may feel slight strain against seat belts.*

Pilot Actions

1. *Ensure Fasten Seat Belt signs are on.*
2. *Via interphone, advise International Purser/Purser of turbulence. Include estimated duration.*
3. *Make PA announcement reinforcing the need for customers to be seated or coordinate with the International Purser/Purser to make PA announcement.*

Flight Attendant Actions

1. *Conditions permitting; verify customer seat belts fastened, bassinets unoccupied and continue service with caution.*
2. *Secure any loose items or carts.*
3. *Monitor compliance to Fasten Seat Belt signs. Make PA announcements as necessary.*
4. *If pilots instruct flight attendants to be seated:*
    1) *Take jumpseat.*
    2) *Securely fasten seat belts AND shoulder harnesses.*
    3) *If possible, call International Purser/Purser to confirm when seated.*
    4) *Remain seated until the pilot advises that it is safe to resume duties.*
5. *International Purser/Purser updates pilots on cabin conditions as required.*

6.4.3.2 Moderate Turbulence

Conditions During Turbulence

- *Rapid bumps or jolts.*
- *Drinks splash out of cup with consistency.*
- *Standing or walking is sometimes difficult or impossible without holding on to a part of the aircraft.*
- *Occupants feel definite strain against seat belts.*

Pilot Actions

1. *Ensure Fasten Seat Belts signs are on.*
2. *Via interphone, advise International Purser/Purser of turbulence. Include estimated duration.*
3. *Make PA announcement reinforcing need for flight attendants and customers to be seated and service to be suspended.*

   PA Announcements To Flight Attendants

   If impending moderate or greater intensity:
   "Flight attendants, take your jumpseats."

   If unexpected moderate or greater intensity:
   "Flight attendants, be seated immediately. Be seated immediately."

Flight Attendant Actions

PA Announcement 1:

*If pilots make the PA announcement "**Flight attendants, take your jumpseats."***

1. *Discontinue service and move the carts to a safe location outside of the aisle ((e.g., into galley locations, jumpseat-free crossaisles).*
2. *Proceed to a jumpseat and ensure seat belts AND shoulder harnesses are securely fastened at all times.*
3. *Verbally advise customers to sit down and fasten seat belts. If possible, make PA announcements as necessary.*
4. *Remain in jumpseat until the pilots make the "Flight attendants, check in" PA announcement.*
5. *After the pilots advise that it is safe to resume cabin duties via PA announcements "Flight attendants, check in":*
    1) *Check for injuries and damage.*
    2) *Stow all carts and galley equipment.*
    3) *Verify and monitor seat belt compliance. Make PA announcements as necessary.*
    4) *International Purser/Purser updates pilots on cabin conditions as required.*

PA Announcement 2:

*If pilots make the PA announcement "**Flight attendants, be seated immediately. Be seated immediately.**"*

***WARNING:* Do not attempt to walk through the cabin.**

1. ***Stop***
   Stop service (i.e., angle cart into a seat and set cart brake, leave cart within galley and set cart brake).
2. ***Drop***
   Immediately secure yourself at the nearest available at the nearest available seat (jumpseat, if immediately adjacent; otherwise, take nearest aisle customer seat if one is available). If aisle seat is unavailable, sit on the floor and hold on to a secure stationary object (e.g., seat leg brace).
3. ***Hold On***
   Remain in jumpseat, with seat belts AND shoulder harnesses securely fastened at all times, or other secure location.
4. *Verbally advise customers to sit down and fasten seat belts. If possible, make PA announcements as necessary.*
5. *Remain in place until the pilots make either the "Flight attendants, check in" or the "Flight attendants, take your jumpseats" PA announcement.*
6. *After the pilots advise that it is safe to resume cabin duties via PA announcement "Flight attendants, check in":*
    1) *Check for injuries and damage.*
    2) *Stow all carts and galley equipment.*
    3) *Verify and monitor seat belt compliance. Make PA announcements as necessary.*

4) International Purser/Purser update pilots on cabin conditions as required.

6.4.3.3 Severe Turbulence

Conditions During Turbulence

- *Large abrupt changes in altitude/attitude.*
- *In most cases, severe turbulence will be unanticipated.*
- *Unsecured items are tipped over or tossed about.*
- *Standing or walking is impossible without holding on to part of the aircraft.*
- *Occupants are forced violently against seat belts.*

Pilot Actions

1. *Ensure Fasten Seat Belt signs are on.*
2. *Make PA announcement reinforcing need for flight attendants and customers to be seated.*

PA Announcement to Flight Attendants

If unexpected moderate or greater intensity:
"Flight attendants, be seated immediately. Be seated immediately."

Flight Attendant Actions

*If pilots make the PA announcement "**Flight attendants, be seated immediately. Be seated immediately."**:*

***WARNING:* Do not attempt to walk through the cabin.**

1. ***Stop***
   Stop service (i.e., angle cart into a seat and set cart brake, leave cart within galley and set cart brake).
2. ***Drop***
   Immediately secure yourself at the nearest available at the nearest available seat (jumpseat, if immediately adjacent; otherwise, take nearest aisle customer seat if one is available). If aisle seat is unavailable, sit on the floor and hold on to a secure stationary object (e.g., seat leg brace).
3. ***Hold On***
   Remain in jumpseat, with seat belts AND shoulder harnesses securely fastened at all times, or other secure location.
4. *Verbally advise customers to sit down and fasten seat belts. If possible, make PA announcements as necessary.*

5. *Remain in place until the pilots make either the "Flight attendants, check in" or the "Flight attendants, take your jumpseats" PA announcement.*
6. *After the pilots advise that it is safe to resume cabin duties via PA announcement "Flight attendants, check in":*
    1) *Check for injuries and damage.*
    2) *Stow all carts and galley equipment.*
    3) *Verify and monitor seat belt compliance. Make PA announcements as necessary.*
    4) *International Purser/Purser update pilots on cabin conditions as required.*

6.4.4 Expected Turbulence

The United Airlines Flight Attendant Operations Manual defined "Expected Turbulence" as "*Advance notice of turbulence has been provided."* It further provided guidance on pilot and flight attendant responsibilities:

Pilot Responsibilities

1. *Inform the International Purser/Purser.*
    - *How much time is available before the turbulence is expected.*
    - *The anticipated intensity and duration of turbulence.*
    - *Any special instructions (e.g., modifying or curtailing cabin service, securing galley carts, etc.).*
    - *If necessary, the pilots will seat the flight attendants via the PA announcement "Flight attendants, take your jumpseats".*
    - *To remind flight attendants to remain in jumpseats until notified otherwise by the pilots. This will be accomplished via the "Flight attendants, check in" PA announcement.*

NOTE:	
The International Purser/Purser must note and accurately communicate with all flight attendants the same information in order to synchronize timing and expectations.	

2. *Turn on the Fasten Seat Belt signs and make a PA announcement informing customers and crew of the anticipated turbulence.*

Flight Attendant Responsibilities

1. *Secure Service carts and stow service items prior to encountering the expected turbulence, time permitting.*
2. *When instructed by the pilots via the PA announcement "Flight attendants, take your jumpseats" or at the discretion of the International Purser/Purser (whichever occurs first), sit in a jumpseat as soon as possible with seat belts AND shoulder harnesses securely fastened.*

    - *Ensure seat belts are fastened while in crew rest area.*

3. *Remain in jumpseats and ensure seat belts AND shoulder harnesses are securely fastened at all times, until notified by the pilots via the PA announcement "Flight attendants, check in" that it is safe to move about the cabin.*

4. *Keep customers informed of interruptions or service delays due to turbulence.*

5. *Notify pilots if customers are not adhering to the fasten seat belt sign.*

6. *After the pilots advise that it is safe to resume cabin duties via PA announcement "Flight attendants, check in", perform post turbulence actions.*

6.4.5 Impending Turbulence

The United Airlines Flight Attendant Operations Manual defined "Impending Turbulence" as "*Expected moderate or greater turbulence.*" It further provided guidance on pilot and flight attendant responsibilities:

Pilot Responsibilities

1. *Make PA announcement stating:*

   "Flight attendants, take your jumpseats."

Flight Attendant Responsibilities

1. *Discontinue service and move the carts to a safe location outside of the aisle (e.g., into galley locations, jumpseat-free cross-aisles).*
2. *Proceed to a jumpseat and ensure seat belts AND shoulder harnesses are securely fastened at all times.*
3. *Verbally advise customers to sit down and fasten seat belts. If possible, make PA announcements as necessary.*
4. *Remain in jumpseat until the pilots make the "Flight attendants, check in" PA announcement.*
5. *After the pilots advise that it is safe to resume cabin duties via PA anno0uncemtn "Flight attendants, check in", perform post turbulence actions.*

6.4.6 Unexpected Turbulence

The United Airlines Flight Attendant Operations Manual defined "Unexpected Turbulence" as "*Moderate or greater turbulence is encountered unexpectedly. There may not be enough time to safely move to a jumpseat.*" It further provided guidance on pilot and flight attendant responsibilities:

Pilot Responsibilities

1. *Make PA announcement stating:*

"Flight attendants, be seated immediately. Be seated immediately."

Flight Attendant Responsibilities

***WARNING:* Do not attempt to walk through the cabin.**

1. ***Stop***
   Stop service (i.e., angle cart into a seat and set cart brake, leave cart within galley and set cart brake).
2. ***Drop***
   Immediately secure yourself at the nearest available seat (jumpseat, if immediately adjacent; otherwise, take nearest customer seat if one is available). If a seat is unavailable, sit on the floor and hold on to a secure stationary object (e.g., seat leg brace).

NOTE:	
If there is nothing secure to hold on to (i.e., in the aisle between United Polaris seats), secure yourself by bracing between the seat walls.	

3. ***Hold on***
   Remain in jumpseats with seat belts AND shoulder harnesses securely fastened at all times, or other secure location until notified by the pilots that it is safe to move about the cabin via either the "Flight attendants, take your jumpseats" or the "Flight attendants, check in" PA announcement.

NOTE:	
If a lull in turbulence is encountered and the pilots feel that there is sufficient time to allow flight attendants to move to jumpseats, a PA announcement stating, "Flight attendants, take your jumpseats," will be made. Only at that time, move to a jumpseat.	

4. *Remain in place until the pilots make the "Flight attendants, check in" PA announcement.*
5. *If the pilots do not make additional announcements to customers, verbally advise customers to sit down and fasten seat belts. If possible, make PA announcements as necessary.*
6. *After the pilots advise that it is safe to resume cabin duties via PA announcement "Flight attendants, check in", perform post turbulence actions.*

6.4.7 Post Turbulence Actions

*If the pilots make a PA announcement stating, "**Flight attendants, check in.**"*

1. *After the pilots advise that it is safe to resume cabin duties via PA announcement "Flight attendants, check in":*
   1) *Turn cabin lights to bright.*
   2) *Check for customers/crew needing attention or assistance.*
   3) *Administer first aid, as necessary.*
   4) *Calm and reassure customers.*

NOTE:	
Notify the pilots and International Purser/Purser immediately of any injuries or damage.	

2. *Proceed to an available jumpseat interphone and check in with the International Purser/Purser.*
3. *Report post turbulence findings to International Purser/Purser, or designee.*
4. *International Purser/Purser checks in with pilots for any further information, as soon as practical.*
5. *Complete appropriate forms and reports.*

6.5 Dispatch Manual

The United Airlines Dispatch Operations Manual provided the following guidance on dispatcher duties when planning and monitoring flights.

6.5.1 Turbulence Avoidance

Turbulence is the leading cause of injuries in commercial aviation. It occurs when a disturbance interrupts the normal atmospheric flow generating wind shear and atmospheric waves which may steepen and break similar to waves on a large body of water. Breaking waves result in turbulence across multiple scales of atmospheric motion (e.g. jet streams, convective anvil, low-level windshear). There are two basic sources for wave generation, ***Clear Air Turbulence (CAT)****, and* ***Convectively-Induced Turbulence (CIT)****. Dispatchers shall use the processes described below to address turbulence hazards.*

• Review upper-air depictions, enroute hazard forecasts (e.g. TWC SIGMETs and FPGs), PIREPS, and other relevant information to ascertain areas of potential turbulence when planning flights.
• Continuously monitor conditions along the routes of flights enroute for indications of turbulence. This includes but is not limited to:
- Evaluating satellite imagery for indicators of possible turbulence such as sharply-curved jet stream axes, sharply-defined darkening bands on water vapor imagery loops, and transverse banding.
- Soliciting and processing PIREPs from company flights and monitoring reports from other carriers.
- Continuously monitoring and advising the Pilot of newly issued turbulence advisories and forecasts.

Clear-Air Turbulence (CAT)

Clear Air Turbulence is defined as all turbulence in the free atmosphere that is not in or adjacent to visible convective activity, including turbulence found in cirrus clouds. CAT is generated by synoptic scale events involving rapid changes in wind direction and/or speed across a short horizontal or vertical distance (wind shear). Dispatchers are expected to be aware of and monitor the following potential causes or indicators of clear-air turbulence.

• Shear across the Tropopause (TROP) can magnify the intensity of waves generated by the jet stream or convective activity, resulting in a greater likelihood and intensity of turbulence reports. The threat is most pronounced within 5,000 FT of the boundary.
• Mountain wave turbulence typically occurs immediately along and to the lee side of a mountain range axis and gradually decreases downwind. However, under certain conditions wave/turbulence activity can propagate 100 miles or more downwind of the mountain range. Wave action and turbulence is most pronounced within 10,000 feet of the mountain tops and within 5,000 feet of the Tropopause (TROP).

Convectively-Induced Turbulence (CIT)

Convectively-Induced Turbulence is defined as turbulence in or near thunderstorm activity. CIT can occur great distances from areas of radar reflectivity, and in cloud free environments. According to NTSB statistics, CIT encounters are responsible for 75% of all turbulence-related injuries.

Dispatchers are expected to be aware of and monitor the following indicators of CIT using the latest satellite imagery:

- *Rapid vertical development of convective cells.*
- *Rapid anvil expansion.*
- *Transverse banding or striations in cirrus anvil outflow on northern periphery of an MCS.*
- *Overshooting tops and enhanced-V ("warm-wake") signatures.*

6.5.2 Thunderstorm Avoidance

Thunderstorms offer one of the greatest challenges to airline flight operations. Pinpointing the timing and location of events is difficult given the short life cycle and motion of thunderstorms. However, the science has evolved to where forecasters are able to outline areas where TS are likely to occur. Most forecasts offer information regarding location, time, echo top, coverage, and degree of confidence in occurrence.

Radar Imagery

• Base Reflectivity mode is generally used to detect and monitor falling precipitation. The radar antenna is set to 0.5 degree tilt angle above the horizon to capture reflectivity at the cloud base level.
• In Composite Reflectivity mode, the radar scans the cloud and paints the highest detected return from multiple elevation scans. It is important to note the highest return may be found in the middle or upper part of the cloud. This is especially true in newly formed or rapidly developing cells.

Enroute Deviations

It is not uncommon to receive reports of aircraft deviating in areas where radar reflectivity would not necessarily dictate the need. This often generates discussion, especially when this occurs in the terminal area and affects airport arrival and departure capacity.

Dispatchers should be mindful of the following items when evaluating potential route deviations due to convective weather:

- *Flight deviations are typically based on radar reflectivity (i.e. rainfall) gradients and FOM avoidance criteria, and in no way ensure the avoidance of lightning, hail, or turbulence in areas where deviations are occurring.*
- *Most flight deviations are related to convective activity. However, since deviations are typically based on radar returns, deviations can and do occur in areas where little or no convection is observed.*
- *When evaluating radar, echo returns are typically defaulted to base reflectivity and will not display gradients aloft. If available, evaluate a composite picture as well.*
- *The most effective way to evaluate deviations is to monitor terminal traffic via one of the company approved flight monitoring tools. Soliciting Pilot input via ACARS is also effective.*

6.5.3 PIREPs

Pilot Reports (PIREPS) provide the only direct information on actual conditions encountered inflight. Dispatchers and Pilots are responsible for actively soliciting PIREPs to validate forecast conditions and promptly advising each other of any report of hazardous conditions deemed relevant to the safety of flight (14 CFR 121.551, 121.561, 121.601). Reports of the absence of a condition, such as a "smooth ride", or "no icing" are as important as reports of stronger or more severe conditions.

6.5.3.1 PIREP PROCESSING

PIREP POLICY
PIREP entry is a key responsibility for the Dispatcher. Timely use of the Unimatic based Enhanced Airep Reporting System is required. The tool transmits Pireps to the National Weather Service. Additionally PIREPS are stored in NOC databases for quick access.

Pilots Providing PIREPs to Other Flights
Encourage pilots sending ride-report information in free-text form to other flights to use the ACARS SUBMIT-PIREP page instead. The pilot can add "CC (flight# flight# etc.)" to the remark field (by itself or AFTER any other remark they give).

The resulting PIREP will be available to all. The "CC (flight#)" entry will provide the given flight(s) an uplink message of the PIREP directly from the processor. The dispatcher for the receiving flight(s) will be notified by USM message of the PIREP sent to their flight

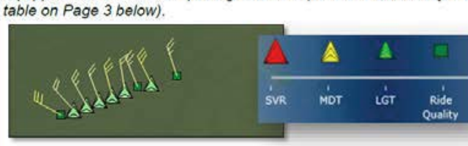
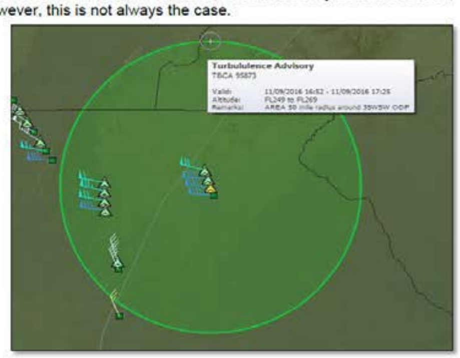
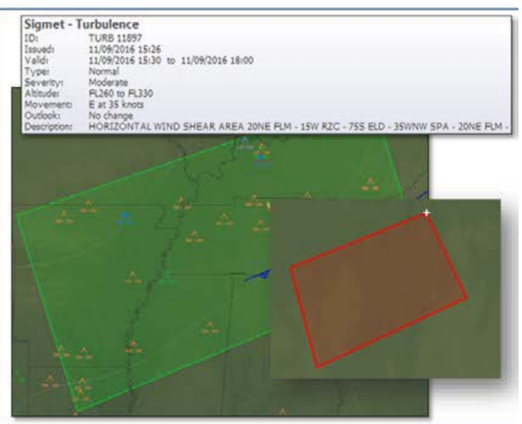
DV PIREP ENTRY TOOL
The PIREP Entry form is accessible on the DV main page via the right-click menu. Selecting PIREP Entry will open a window that pre-populates with the planned waypoint closest to the last reported position recorded in DV for the selected flight.

6.5.4 Automated Turbulence Reporting

Automated flight-specific turbulence alerts in the Dispatch View WX button queue has been implemented as part of The Weather Company's Turbulence Auto-PIREP System (TAPS). This process automatically sends tailored ACARS messages simultaneously to the flight deck and Dispatcher when a flight is projected to intersect one of five different turbulence reports and advisories.

MESSAGE TYPES

Automated alerts will be triggered based on intersection with or proximity to the following turbulence reports and advisories:

Message Type	Description
1. TAPS Event	TAPS Events are automated PIREPs generated by one of 500+ aircraft equipped with the TAPS reporting software. *(Ref. TAPS Intensity Levels table on Page 3 below).* 
2. Traditional PIREPs/AIREPs	PIREP Turb: LGT MOD SEV
3. TWC Turbulence Advisory Area	Cylindrical turbulence warning areas that are more significant than an FPG, but not yet enough to warrant a TWC SIGMET. Turbulence Advisories are generated when strong turbulence is reported and verified by TWC forecasters as an area of operational importance. If the turbulence continues or intensifies, forecasters may issue a SIGMET; however, this is not always the case. 
4. TWC Turbulence SIGMET **5. TWC Convective SIGMET**	

6.5.4.1 TAPS Intensity Levels

Intensity	Icon	Hazard Metric (rms-g)	WSI Enroute Hazard Criteria	Aircraft Reaction (AIM)	Reaction Inside Aircraft (AIM)
Smooth		< 0.075g	No SIGMET or FPG	No turbulence that causes airspeed and/or altitude variations.	No impact on crew services or passenger comfort
Ride Quality		0.075g to ≤ 0.1g	No SIGMET FPG Guidance: OCNL LGT	Turbulence that causes little or no airspeed and/or altitude variations.	Occupants feel discomfort if exposed for more than 15 minutes. Food service may be conducted and no difficulty is encountered in walking.
Light		0.1g to < 0.2g	No SIGMET FPG Guidance: LGT LGT OCNL MDT	Turbulence that momentarily causes slight, erratic changes in altitude and/or attitude.	Occupants may feel a slight strain against seatbelts or shoulder straps. Unsecured objects may be displaced slightly. Food service may be conducted and little or no difficulty is encountered in walking.
Moderate		0.2g to < 0.3g	SIGMET & FPG: MDT MDT OCNL SVR	Turbulence that is similar to light turbulence but of greater intensity. Changes in altitude and/or attitude occur but the aircraft remains in positive control at all times. It usually causes variations in indicated airspeed.	Occupants feel definite strains against seatbelts or shoulder straps. Unsecured objects are dislodged. Food service and walking are difficult.
Severe		> 0.3g	SIGMET & FPG: SVR EXTM	Turbulence that causes large, abrupt changes in altitude and/or attitude. It usually causes large variations in indicated airspeed or momentary loss of control.	Occupants are forced violently against seatbelts or shoulder straps. Unsecured objects are tossed about. Food service and walking are impossible.

6.5.4.2 Alerting Logic and Thresholds

Intersection Predictions

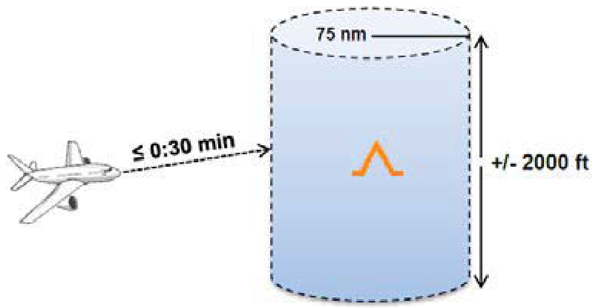
TWC's alerting engine projects a flight's present and future location based upon the best combination of the following sources of information:

• UAL-provided flight plan filings taken from the active Dispatch Release in FPM. United re-sends the FPL each time a re-release is issued.
• FAA and EuroControl ASDI data
• UAL-provided ACARS position reports
• UAL-provided FLIFO data from ODS

Alert Thresholds

A flight will be alerted when its projected path meets the following intersection and/or proximity criteria for each type of turbulence report or advisory:

Turbulence Report/Advisory	Criteria
TAPS Event **Traditional PIREP**	• PIREP ≥ **MOD** intensity from transport category aircraft *or* • TAPS Report of Turbulence Level (RMS-g) of ≥ **0.15** *(high end of LIGHT)* • Within **75nm** radius and **+/- 2000 ft** of report in ≤ **0:30** min *(see graphic below)* • Each PIREP or TAPS Event will continue to trigger alerts until the report is 30 minutes old
Turbulence Advisory	Flight intersects or is within the Advisory cylinder: • ≤ **50 nm** radius around specified NAVAID fix/radial • **+/- 1000 ft** from triggering report(s) • Valid for **30 minutes**
TWC SIGMETs **(Turbulence & Convective)**	Flight is within or projected to intersect an active SIGMET polygon (lateral/vertical coordinates, and valid period) **in the next 0:30 min.**



Note: *Flights more than 30 minutes out whose projected flight path meets the lateral/vertical intersection criteria will receive an alert upon reaching the 30 minute threshold provided the route does not change and the report or advisory is still valid.*

Filtering

Filters on alert type and intensity will be used to mitigate over-alerting, especially on days with widespread turbulence. If TWC's engine generates multiple alerts of the same type and intensity within a 10 minute period, only the first message will be sent. The process is chronological and resets after 10 minutes.

Dispatch View Alerts

Automated turbulence alerts will be displayed in the WX button in Dispatch View

- *The alerts are coded as Severity 2, which highlights the WX button and affected flight number cell (Flt# Radio#) in red, and requires acknowledgment*
- *The alerts will be stored in a new "TAPS" Sub Type category*
- *Turbulence alerts received in WX are simultaneously uplinked via ACARS to the affected flight. Dispatchers will only receive alerts in the WX button that are also sent via ACARS. Alerts inhibited by sterile cockpit rules will not appear in the WX queue.*

• Turbulence alerts will be generated for one flight at a time

• Turbulence alert uplinks are routed directly to ACARS history to avoid duplication of red alerts to the ACARS button in DV

• Closely monitor ACARS rejection messages for turbulence alerts that may not have been received in the flight deck

Flight Monitoring Considerations

The automation is intended to assist in the dissemination of information pertinent to the safety of flight by providing timely, flight-specific information for imminent (impact within 30 minutes), and/or rapidly-changing conditions, where a few seconds or minutes can mean the difference in securing the cabin and avoiding a flight attendant or passenger injury.

The intersection calculations are only as good as the accuracy of position information available to TWC. The following conditions and limitations could degrade the efficacy of the alerting:

• Flights operating in an area where they are unable to transmit position reports via ACARS

• Flights operating in non-radar environments outside of available ASDI or ADS-B feeds

• Flights operating in an area with limited ACARS communication Maintain situational awareness by recognizing when/where the automation may not function and take action to relay updated turbulence information to flights that may be subject to these limitations and/or those operating outside of the automated alerting thresholds

6.5.5 SkyPath Turbulence Tool

SkyPath is an application available on both the iPad (EFB) and PC that displays real-time turbulence. This supplemental tool provides pilots and dispatchers with an awareness of ride conditions reported by users of other SkyPath equipped EFBs. When the EFB is docked and calibrated, the app uses the accelerometers in the iPad to measure turbulence and converts the movements into color-coded tiles representing different turbulence severities. An algorithm filters out any device shaking, screen tapping or button pressing. When connected to inflight Wi-Fi, SkyPath shares the information to other users; if Wi- Fi is unavailable, the app will send the data when reconnected.

SkyPath Usage

SkyPath tiles represent turbulence data aggregated over a 10km x 10km x 2,000ft cube updated every minute and are not to be treated as a PIREP. SkyPath shall be treated as an additional data source and may be used in conjunction with (not in lieu of) other approved sources for weather evaluation.

7.0 Airbus Guidance

7.1 Safety First Magazine

An article published in the Airbus Safety First magazine[27] titled "Managing Severe Turbulence," dated September 2005, provided, in part, the following information:

> *Severe turbulence is identified as turbulence that causes large, abrupt changes in altitude and/or attitude. It usually causes also large variations in airspeed.*
>
> *Inadvertent flight into such hazardous weather environment is the leading cause of injuries to passengers and cabin crew in non-fatal airline accidents, and is so a key safety issue for any aircraft.*

This kind of events leads rarely to fatal accident but the shake-up triggered by the turbulence can cause serious injuries among non-buckled people but also generate trauma among passengers.

Some Figures

Usually only the most severe cases of turbulence are reported to the manufacturer.

Over 3 years, about 20 turbulence events have been annually reported to Airbus. These events have caused injuries for about one third of them. Generally, during such event, the main vertical longitudinal and lateral acceleration changes are concentrated within a few seconds and injuries concern generally non-buckled passengers and cabin crew when the local vertical load factor decreases under 0g before increasing again (Load factor variations generated by the turbulence are not necessarily the same at any points of the cabin).

Managing Severe Turbulence

Whenever possible, the best solution is to use all the existing means at the pilots' disposal to localize the turbulence as well and as early as possible in order to have enough time to properly avoid it or at least to secure the cabin when it is unavoidable.

But the analysis of several turbulence events has led to the conclusion that, as further developed here below, pilot awareness on the appropriate use of available means could be improved.

Turbulence detection

Optimum use of weather forecast
Firstly weather forecast information available before taking-off as well as the weather briefing have to be as complete as possible and, depending on the weather context, this

[27] Source: Operational Factors/Human Performance Attachment 12 – Airbus Managing Severe Turbulence, https://safetyfirst.airbus.com/managing-severe-turbulence/

information has to be updated in flight as often as necessary. In some severe turbulence events, analysis has shown that an appropriate update of weather information in flight would have very likely allowed the detection and consequently the avoidance of the area of turbulence.

Optimum use of the weather radar
Modern aircraft are equipped with airborne weather radars. The principle of these radars is to detect precipitation such as wet turbulence and wet hail but these radars will not detect wind, ice, fog and Clear Air Turbulence (CAT).

Despite weather radar efficiency to detect convective clouds, in-service events analysis has shown that a large part of turbulence events comes from aircraft incursions into cumulonimbus (CB) that were either not localised [sic] by the crew or not avoided with sufficient margin.

Indeed weather radar is only helpful if:

_ It is properly tuned (tilt, weather mode and range control on the Navigation Display) to present an optimum weather radar picture
_ AND the flight crew performs regularly vertical scan
_ AND the flight crew correctly interpretes [sic] the screen display.

For this a good knowledge of the radar system itself is essential and allows to optimise the use of the radar that will be tuned using all available information (pre-flight briefing, reported turbulence, updated weather forecast…).

The analysis of a large percentage of turbulence events in convective environment shows a sudden heading change demand just before encountering the turbulence that has made the radar tuning and picture interpretation questionable.

For example it is important to notice that a tilt setting in cruise too close from horizon (as presented in red in the figure here below) will only scan in a high range of altitude where humidity is in ice shape and so not reflective.

Figure 7: Radar Tilt Setting (Source: Airbus Safety first #02 September 2005)

Careful turbulence avoidance when detected

Thus, as current weather radars cannot detect dry turbulence it is essential to take adequate precautionary measures:

_ In particular, to minimise the risk of encountering severe turbulence, a cumulonimbus should be cleared by a minimum of 5000 feet vertically and 20NM laterally.
_ Furthermore, if the top of cell is at or above 25000 feet, over-flying should be also avoided due to the possibility of encountering turbulence stronger than expected.
_ In the same way flight under a thunderstorm should be avoided due to possible wind shears, microburst, severe turbulence or hail.

Secure passengers and cabin crew

Fasten equipment

A part of injuries comes from objects thrown out and coming down on buckled people. Consequently a prime task of the cabin crew is to secure trolleys and any object that can be harmful.

Passengers

Most of injuries result from non-buckled passengers or crewmembers thrown out during the turbulence. This could be prevented with seat belts fastened. Although the ideal situation would be to consider "seat belts fastened" as a full-time countermeasure, the minimum recommendation, which is normally applied, consists in requiring seat belts fastened when moderate or stronger turbulence is anticipated.

In this case fasten seat belt sign should be illuminated and cabin crew should closely check passenger seatbelts compliance. But to be efficient this measure must be used with distinction since a too long or too frequent use will make it counterproductive because not strictly followed.

In the same spirit, advise announcement requiring passengers to keep their seatbelts fastened at all times when seated is also an efficient measure to prevent non-predictive turbulence as CAT.

Flight attendants

Except if this is specifically requested by the flight crew, when the seatbelt sign is illuminated, flight attendants usually continue the cabin service.

In case of specific announcement of turbulence anticipation by the flight crew, flight attendants will secure the trolleys and ensure that all passengers are fastened before sitting down and buckling up themselves. Consequently they secure themselves quite late, which explains that injuries often concern flight attendants.

Graduation in the urgency of the flight crew warning properly perceived by the cabin crew could allow them to better adapt their actions to the situation.

Turbulence crossing

Because some turbulence are not detectable by current onboard weather radar or other cannot be detected early enough to be avoided, aircraft behaviour when crossing a severe turbulence has also to be considered and optimised.

Recommendations depend on the aircraft type.
For A300/A310/A300-600: Disconnect ATHR/Descent at or below optimum altitude / Consider Autopilot disconnection if Autopilot does not perform as desired

_ Disconnect the ATHR
_ Set the target thrust to follow the speed target (that depends on altitude) given in QRH 13.04.
_ Descent at or below the optimum altitude given in QRH 17.01. Indeed at the turbulence penetration target speed, this optimum altitude must provide sufficient margin to buffet to face severe turbulence.
_ Consider Autopilot disconnection if Autopilot does not perform as desired.

For Fly-by-wire aircraft: Keep Autopilot engaged - Keep ATHR engaged except if thrust changes become excessive

Recent severe turbulence events have clearly illustrated that potential consequences have been minimised thanks to the appropriate use of automation by the crew, mainly in keeping Autopilot engaged instead of possible instinctive reaction, which is to take over manually.

As per FCOM recommendation (section 3.04.91) when encountering a severe turbulence the following procedure has to be applied:

_ Follow the speed target (that depends on altitude) given in Section 3.04.91.
_ Maintain ATHR engaged (target speed) except if thrust changes become excessive. In this case ATHR will be disconnected and thrust will be set to give the recommended speed (See thrust table versus speed target in the same FCOM section).
_ Keep Autopilot engaged. Indeed, detailed studies regarding aircraft behaviour when crossing such external perturbations has shown that the less the aircraft reacts at short term to the turbulence, the better it is. Indeed, the dynamic of such severe turbulence is so, that any additional pitch down reaction to counter the initial up draught will accentuate in most cases the pitch down effect of the down draught usually subsequent to the up draught. This will accentuate the excursion in negative load factor and so increase the risk and number of injuries. To minimise the additional effect of such pitch down order coincident to the down draught, it is recommended to the crew not to react to the turbulence by short term side stick inputs corrections and to keep Autopilot engaged.

Software Flight Control modifications on Flyby- wire aircraft

A severe turbulence may lead to excessive high speed excursion (beyond VMO/MMO) or to excessive low speed excursion (below 'alpha prot', angle of attack threshold of alpha protection law activation). This will induce Autopilot disconnection and activation of the appropriate manual flight control law (The VMO/MMO protection or the angle of attack protection that will command respectively pitch-up and pitch down movement to reduce these excursions).

In order to keep the Autopilot engaged as long as possible, flight controls software modifications have been developed on fly-by-wire aircraft. They make the Autopilot more robust to disconnection resulting from a transient VMO/MMO or 'alpha prot' exceeding subsequent to a severe turbulence. Autopilot robustness improvement in case of transient 'alpha prot' angle of attack exceedance has been already implemented on all in-service fly-by-wire aircraft.

Autopilot robustness improvement in case of transient VMO/MMO exceedance has been introduced as shown in various flight control software.

These improvements will be also available at the entry into service of the A380.

Managing altitude burst consequent to severe turbulence

Severe turbulence can induce significant altitude excursions because of the severe turbulence itself or as a consequence of the triggering of the VMO/MMO protection or the Angle of Attack protection. Without the pilot in the loop these protections will target respectively speed and incidence decrease rather than maintaining the trajectory.

Indeed, when VMO/MMO protection or Angle of Attack protection has been activated, the Autopilot is automatically disconnected. In these conditions, it is now to the pilot to apply smooth corrections to manage the aircraft trajectory (and to avoid to apply sudden corrections fighting the turbulence). Speed will not be closely targeted. Indeed a number of altitude bursts is the consequence of pilots targeting a large speed margin after recovery from VMO/MMO. Keeping aware of the surrounding traffic, a compromise has to be found since such too large speed margins will be obtained at the detrimental of the trajectory.

Areas of improvement

Benefiting of the progress of technology, several areas of improvement are being studied at Airbus in liaison with various partners such as:

Weather forecasting improvement that will make turbulence location more reliable and precise and consequently will allow optimising the route and reducing turbulence hazards.

Enhanced weather radar that will earlier detect turbulence (depending on the aircraft speed, 2 or 3 minutes is foreseen).

Turbulence now-casting that will broadcast pilot's reports of encountered turbulence to surrounding aircraft. Information regarding turbulence (intensity, location) will be sent by an automated turbulence reporting system and displayed in other airplanes. This system will be particularly helpful to localize CAT.

Cabin safety improvement that will allow to quicker and better secure people and fasten equipment.

Clear Air Turbulence detector that will use optical technology.

Conclusion

Flights into severe turbulence are the leading cause of injuries among passengers and cabin crew and may induce also substantial aircraft damage.

Airbus has received a certain number of reports regarding severe turbulence events. All these events have been thoroughly analysed.

In response to these analyses the following can be said:

_ Use of existing detection means to avoid encountering turbulence or to allow cabin preparation could be greatly improved.
_ In this context Airbus Flight Operations Department has issued a briefing note dedicated to the Optimum Use of the Weather Radar.
_ When the turbulence is unavoidable, the consequences of turbulence could be minimised in making appropriate use of operational procedures to better handle the turbulence.
_ Airbus has also developed and implemented software flight control modifications on Fly-by wire aircraft in order to improve Autopilot robustness to severe turbulence.
_ Additional ways to mitigate the turbulence are under development. We will let you know when you get mature solutions.

7.2 Optimum use of Weather Radar

Airbus publication Safety First #22 dated July 2016 provided the following excerpted article about the use of the weather radar. The article, in its entirety is located in "Operational Factors Attachment 12 – Airbus Optimum use of the Weather Radar" which is located in the docket of this accident.

A knowledge of the radar principle is paramount in order to accurately tune this system and interpret the weather radar display correctly.

Reflectivity

Weather detection is based on the reflectivity of water droplets. The weather echo appears on the Navigation Display (ND) with a color scale that goes from red (high reflectivity) to green (low reflectivity).

The weather radar echo returns vary in intensity as a function of the droplet size, composition and quantity. For example, a water particle is five times more reflective than an ice particle of the same size.

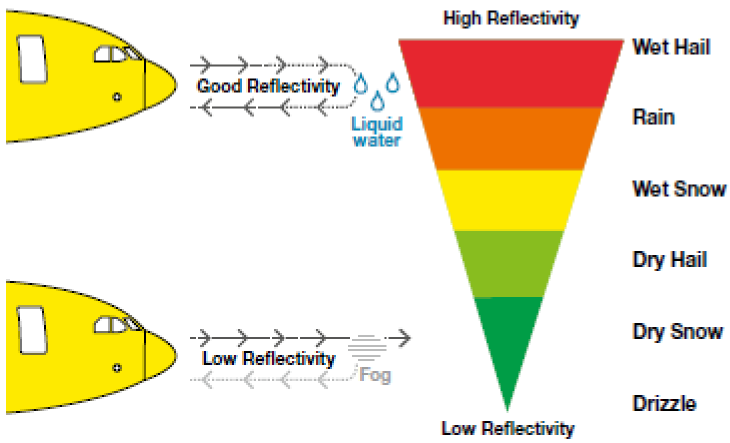


Figure 8: Airbus Weather Radar Principle
(Source: Airbus Safety First #22)

Some weather radars are fitted with a turbulence display mode. This function (the TURB function) is based on the Doppler effect and is sensitive to precipitation movement. Like the weather radar, the TURB function needs a minimum amount of precipitation to be effective. An area of light rainfall, depicted in green in normal mode, is shown in magenta when there is high turbulence activity. The TURB function is on most weather radars only active within a range of 40 NM (Doppler measurement capability) and should only be used in wet turbulence.

Weather radar limitations

Weather radar detection capability. One of the weather radar limitations is that it indicates only the presence of liquid water. The consequence is that a thunderstorm does not have the same reflectivity over its altitude range because the quantity of liquid water in the atmosphere decreases with the altitude. Yet, the convective cloud and associated threats may extend significantly above the upper detection limit of the weather radar (called 'radar top'). This means that reflectivity is not directly proportional to the level of risk that may be encountered: a convective cloud may be dangerous, even if the radar echo is weak.

This is particularly true for equatorial overland regions where converging winds produce large scale uplifts of dry air. The resulting weather cells have much less reflectivity than mid-latitude convective cells. However, turbulence in or above such clouds may have a higher intensity than indicated by the image on the weather radar display. On the other hand, air close to the sea can be very humid. In this case, thermal convection will produce *clouds that are full of water: these clouds will have a high reflectivity, but may not necessarily be a high threat.*

Consequently, limitations of weather radars must be well understood and complemented by basic meteorological knowledge of the crew and, where possible, visual observation.

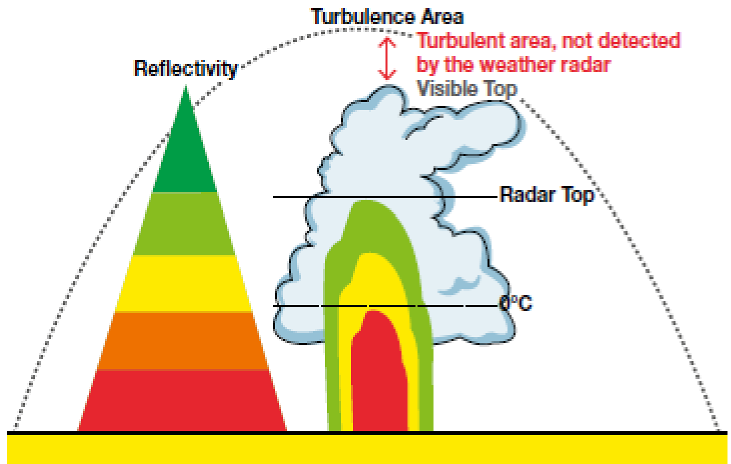


Figure 9: Reflective Imagine of a Cumulonimbus (Source: Airbus Safety First #22)

The weather radar detects:	The weather radar does not detect:
- Rainfall - Wet hail and wet turbulence - Windshear	- Ice crystals, dry hail* and snow - Clear air turbulence - Sandstorms (solid particles are almost transparent to the radar beam) - Lightning*

**the latest generations of weather radars offer hail and lightning prediction functions.*

WEATHER RADAR TECHNOLOGY: THE DIFFERENT TYPES OF WEATHER RADAR

A320 & A330 families: Multiscan radar (Rockwell Collins WXR-2100 family)

The WXR-2100 Multiscan weather radar is part of this new generation of weather radars that offers an automatic computation of tilt and gain control at all ranges, all altitudes and all times.

This weather radar is designed to work in Multiscan automatic mode. Pilots select only the desired range for the display and the radar alternatively scans at two antenna tilt settings. The image that is displayed on the ND is the result of the stored and combined information from each beam.

The radar automatically adjusts the gain and tilt based on various parameters (aircraft altitude, geographical area, season, time of the day) to obtain the best weather display in each geographic region.

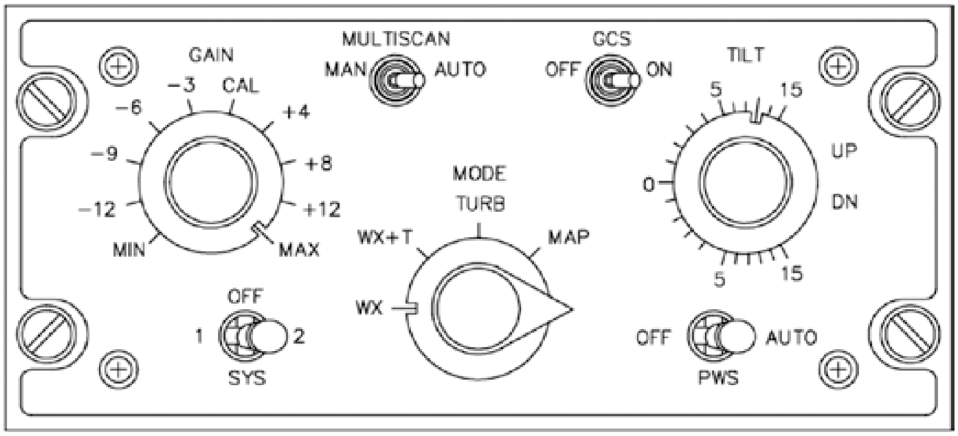


Figure 10: Rockwell Collins Multiscan (Source: Airbus Safety First #22)

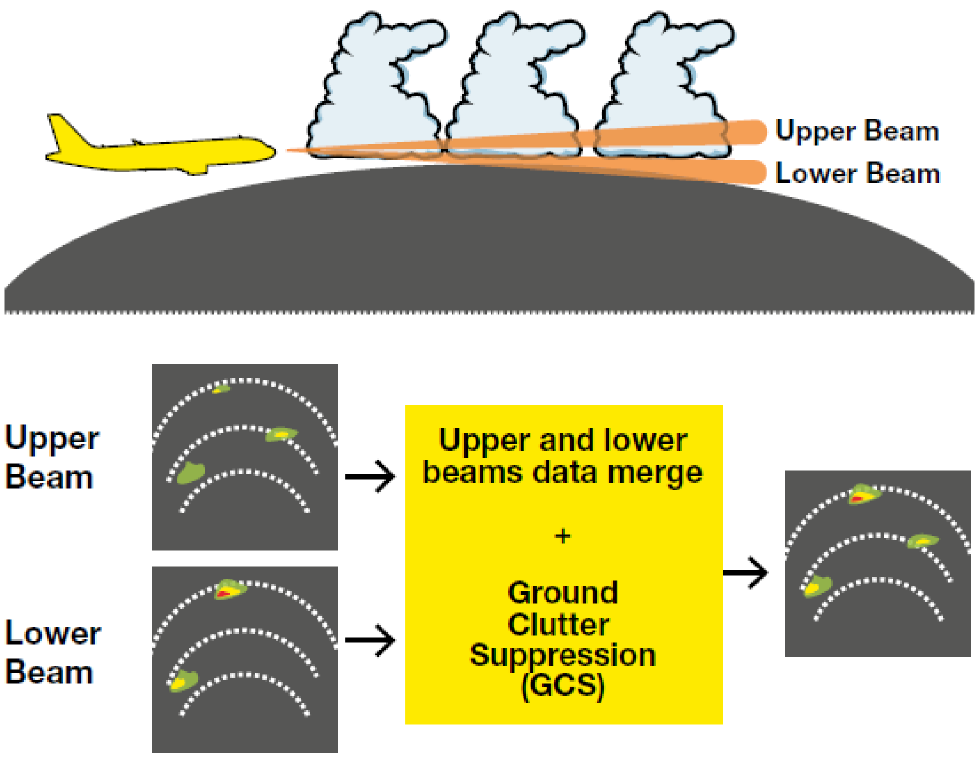


Figure 11:Rockwell Collins Multiscan Display (Source: Airbus Safety First #22)

A320 & A330 & A350 & A380 families: Honeywell RDR-4000

The Honeywell RDR-4000 model is part of the new generation of weather radars including a 3D volumetric buffer.

It can probe hundreds of miles ahead (up to 320 NM on A320 & A330 families and up to 640 NM on A350 and A380) to show the enroute weather picture, as well as automatically scan from the ground up to 60 000 feet to provide information targeted at various altitudes. The required display data are then accessed from the 3D buffer.

Figure 12: Honeywell RDR-4000 Control Panel
(Source: Airbus Safety First #22)

When it is activated in the automatic mode, the radar RDR-4000 takes into account a vertical trajectory envelope (nominally +/- 4000 ft) along the vertical flight path of the aircraft based on the flight path angle. It then defines if the weather echo is inside this envelope (relevant 'ON PATH') or not (secondary 'OFF PATH') depending on the flight profile. Weather conditions along the plane's trajectory are displayed in solid colors, while more distant vertical echoes are shown in striped pattern to help pilots determine whether weather avoidance maneuver or rerouting is necessary.

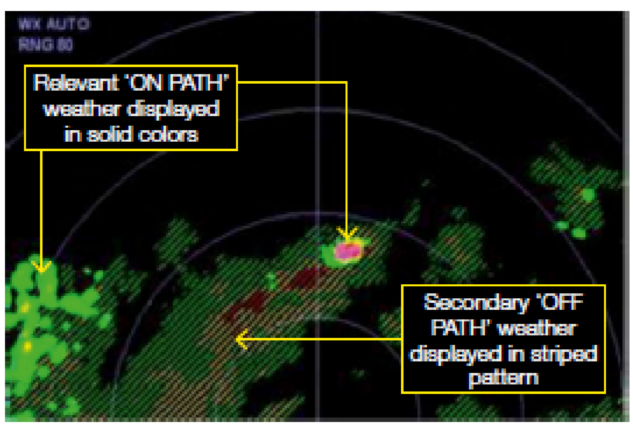


Figure 13: Honeywell RDR-4000 Display
(Source: Airbus Safety First#22)

The RDR-4000 can also be used in manual mode (elevation mode) as a tool for analyzing weather at user selected altitudes and thus, assess the vertical expansion and structure of convective clouds.

This system is available on the A380 and also on the A350 with an additional 'weather ahead' alerting function. On these aircraft, the weather displayed is a computed image on:

- *the ND, for views along the vertical flight path (in AUTO mode) or along the selected altitude (in ELEVN mode) or along the selected tilt angle (in TILT mode)*
- *as well as on the Vertical Display (VD) for views along the lateral flight path (in AUTO mode) or along the selected azimuth (in AZIM mode)*

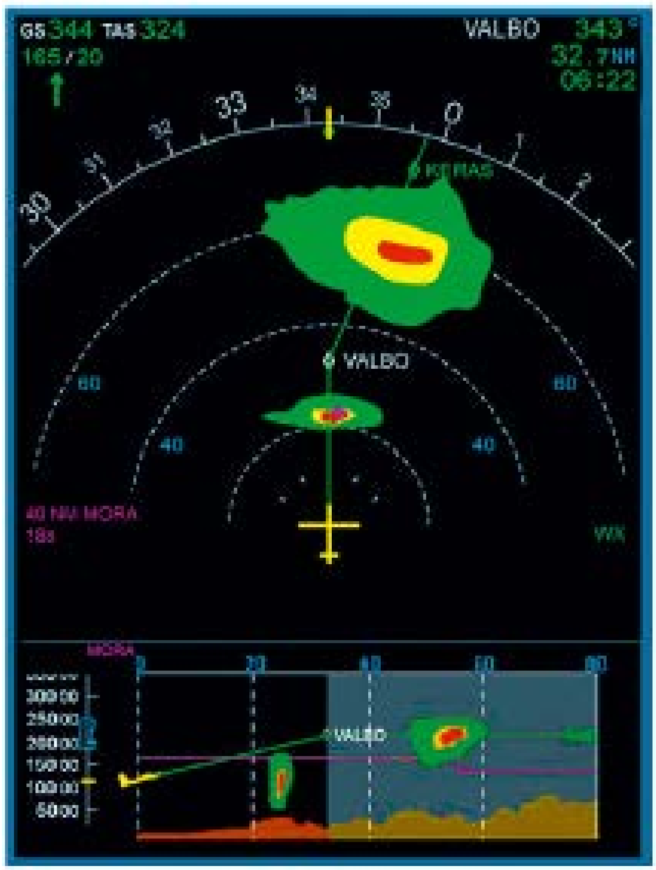


Figure 14: Vertical Display
(Source: Airbus Safety First #22)

Hail and lightning prediction: the new functions introduced by 'step 2' automatic radars

In continuity of RDR-4000 and Multiscan WXR-2100, a new step of development recently introduced:

- *Hail and lightning prediction*
- *Improved weather information.*

Honeywell RDR-4000 (V2) *includes new features to improve weather hazard assessment by automatically providing the following additional information:*

- *Weather alerting ('WEATHER AHEAD') to alert the crew when the ND is not in weather mode*
- *Hazard functions offering:*
  - *Lightning and hail prediction*

• Rain Echo Attenuation Compensation Technique (REACT): this function indicates areas where
the intensity of the radar echo has been attenuated by intervening weather.
• Extended turbulence detection (up to 60 NM instead of 40).

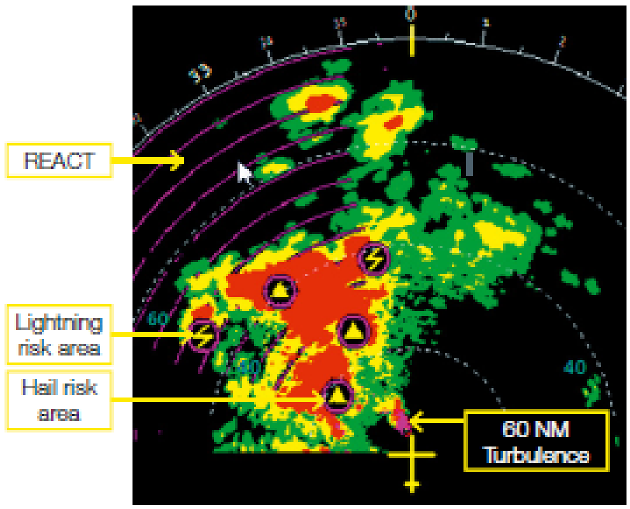


Figure 15: Honeywell RDR-4000 V2 Display
(Source: Airbus Safety First #22)

Rockwell Collins Multiscan WXR-2100 (V2) *includes an automatic weather threat assessment ("Track While Scan" function). In continuity of the Multiscan, the aim of this version is to provide not only a depiction of the reflectivity of surrounding weather cells, but also a threat assessment for each cell detected.*

Weather cells are first tracked and then, additional vertical scans are performed automatically to assess the corresponding threat based on reflectivity characteristics.

This new radar also provides hazard functions, namely:

- Lightning and hail prediction
- Predictive OverFlight (this function alerts the crew to growing cells that are potentially on the aircraft trajectory)
- Improved turbulence detection able to display an additional level of moderate turbulence.

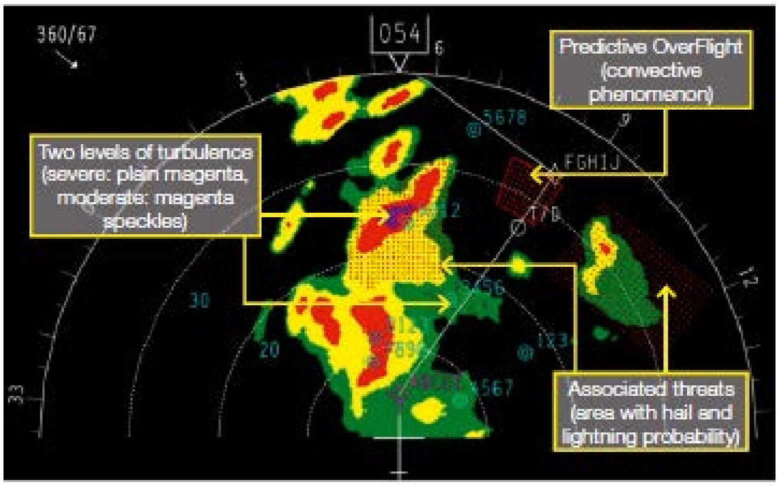


Figure 16: Rockwell Collins Multiscan V2
(Source: Airbus Safety First #22)

7.3 Airbus FAST Magazine

The following are excerpts from an article titled "Flight in Severe Turbulence A Close Encounter of the Rough Kind" published in the Airbus FAST[28] magazine Number 18, dated June 1995.

Severe turbulence encounters at altitude have been experience worldwide by all models of jet transports, sometimes resulting in injuries to passengers and cabin attendants.

The statistical data related to turbulence encounters reveal that narrowbody and widebody aircraft of all types and models are equally affected. A survey performed by the US FAA and the Flight Safety Foundation revealed that turbulence causes twice as many serious injuries to passengers and cabin attendants as does emergency evacuations.

Forecasting turbulence

The likelihood of encountering severe turbulence during a given flight can be assessed using the data contained in the standard weather briefing….

For clear Air Turbulence (CAT) due to vertical and/or horizontal wind gradient, the US National Oceanic and Atmospheric Administration (NOTA)) has analyzed wind patterns associated with jetstreams around the globe and has define a Turbulence Index which allows maps of likely areas of CAT to be established.

Some Computerized Flight Plans (CFP) provide a simple index at each wavpoint, referred to as the Shear Rate (SR), expressed in kt/1000ft, this index represents the vertical wind gradient and constitutes a dependable turbulence indicator.

[28] Source: https://www.airbus.com/aircraft/support-services/publications/fast-magazine.html and Attachment 15 - Flight in Severe Turbulence [Article]"

Moderate turbulence can be expected whenever the Shear Rate is equal to or greater than 3. Severe turbulence can be anticipated whenever the Shear Rate is equal to or greater than 5.

However, it is a fact of life that severe turbulence may be experience unexpectedly and suddenly during the course of an otherwise smooth ride, despite the sophisticated forecasting techniques available.

Computerized Flight Plan (CFP) - Shear Rate (SR)

POSN	DIST	TC	FL	WIND	TAS	ZT	B/O	....	....
MSA	DTGO	MH	SR	COMP	GS	ACTM	ACBO		
N24 14.9 E120 37.3 WATER									
WATER	025	200	31	28082	378	0004	0018	....	....
106	1753	211	06	M040	338	0012	0056	....	....

Figure 17: Example of a CFP - Shear Rate
(Source: Airbus FAST #18 Article - Flight in Severe Turbulence)

8.0 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."*[29]

8.1 FAA Turbulence Fact Sheet

The FAA provided the following guidance titled "Fact Sheet – Turbulence" on August 1, 2019 on their website:[30]

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:

[29] Source: https://www.faa.gov/travelers/fly_safe/turbulence/
[30] Source: https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=20074

- *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;*
- *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?

Year	Passenger	Crew	Total
2009	74	27	101
2010	35	23	58
2011	4	25	29
2012	4	19	23
2013	2	4	6
2014	19	9	28

Year	*Passenger*	*Crew*	*Total*
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.

8.2 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 Attendant and Deadheading Pilot Statement
Attachment 3: Flight Crew Schedule
Attachment 4: Flight Crew Training Summaries
Attachment 5: Accident Flight's Dispatch Release
Attachment 6: Accident Flight's Turbulence ACARS Message
Attachment 7: Archived PIREPs
Attachment 8: United Airlines Flight Operations Manual [Excerpts]
Attachment 9: United Airlines Airbus 319/320 Flight Manual [Excerpts]
Attachment 10: United Airlines Flight Attendant Manual [Excerpts]
Attachment 11: United Airlines Dispatch Operations Manual [Excerpt]
Attachment 12: Airbus Optimum use of Weather Radar [Article]
Attachment 13: Airbus Managing Severe Turbulence [2019 Article]
Attachment 14: Airbus Managing Severe Turbulence [2005 Article]
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Attachment 16: Operational Factors Group Party Forms

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