



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

December 17, 2019

Specialist's Report

OPERATIONAL FACTORS

DCA19CA151

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A. ACCIDENT

Operator: Southwest Airlines
Location: Near Waycross, Georgia
Date: May 25, 2019
Time: 1715 Eastern Daylight Time (EDT)¹
Airplane: Boeing 737-800
Flight No.: 2842

B. AIR SAFETY INVESTIGATOR

Shawn Etcher - Investigator
Operational Factors Division (AS-30)
National Transportation Safety Board
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Washington, DC 20594-2000

C. SUMMARY

On May 25, 2019, about 1715 EDT, Southwest Airlines flight 2842, 737-8H4, N8697C, during descent into Jacksonville International Airport (JAX), Jacksonville, Florida, encountered moderate turbulence about 12,000 feet. The “D” position Flight Attendant sustained a serious injury. There were 2 Pilots, 4 Flight Attendants and 122 passengers on board. The flight was operating as a 14 *Code of Federal Regulations* part 121 flight from Chicago Midway International Airport (MDW), Chicago, Illinois, to JAX.

D. DETAILS OF THE INVESTIGATION

The National Transportation Safety Board (NTSB) Operational Factors investigator was assigned to the accident on July 11, 2019 and did not travel for this accident investigation. The group chairman was briefed by the Investigator in Charge (IIC) on the events surrounding the accident.

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

E. FACTUAL INFORMATION

1.0 History of Flight²

Southwest Airlines flight 2842 had departed MDW at 1438 Central Daylight Time (1538 EDT). The flight's planned arrival time was 1740 EDT.

¹ All times in the report will be Eastern Daylight Time except as otherwise noted. At the time of the accident Greenwich Mean Time, also known as Zulu (Z) time, was 4 hours ahead of EDT.

² Sources: Attachment 1 - “Crew Interview Summaries”

During descent into JAX, approximately 15,000 ft, while in “smooth air,” the flight was cleared direct to LIBBY³ and was subsequently given a descent to a lower altitude. The crew observed a scattered layer of clouds that they were going to encounter and decided to signal the flight attendants prior to 10,000 ft, which was the final approach signal. Descending through approximately 12,000 ft the flight encountered the cloud layer and moderate turbulence. The flight crew turned the weather radar off about 5 minutes prior to the turbulence encounter, as no weather was observed between their current position and the airport.

After encountering the turbulence the flight crew received a call from the “A” flight attendant that one flight attendant was on the floor of the aircraft with a possible leg injury. The flight crew requested, with Jacksonville approach control, to have EMTs⁴ waiting for the aircraft at their arrival gate. The captain reported that because of their proximity to the destination airport, they “determined that it wouldn’t [be] prudent to attempt a STAT MD⁵ connection” but contacted JAX operations to report the request for EMTs. The “A” flight attendant, subsequently, assisted the “D” flight attendant, who had just stood up from one of the aft jumpseats prior to the turbulence encounter.

After landing and parking at the gate the EMTs took the “D” flight attendant, to the hospital due to the ankle injury. The “B” flight attendant, who was in the aft galley, was also taken to the hospital due to her shoulder pain and tingling in her hands. The captain reported that he then contacted dispatch by telephone, reported the event, and provided a PIREP⁶ of the turbulence.

2.0 Flight Crew Information

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

2.1 Captain

The captain was 53 years old and held an Airline Transport Pilot (ATP) certificate with a rating for airplane multiengine land and type ratings on the BE-1900⁷, DC-9⁸, and B737⁹, limitations included second in command required for the BE-1900 and Second in Command privileges only in the DC-9. He held an FAA first-class medical certificate dated May 16, 2019, with a limitation of “Must wear corrective lenses.” At the time of the accident he was based at MDW.

³ LIBBY intersection was the identifier for the initial approach fix (IAF) for the instrument landing system (ILS) and area navigation (RNAV) “Y” to runway 8 at JAX. It was located southwest of the airport approximately 10.4 NM.

⁴ Emergency Medical Technicians

⁵ STAT MD provides airline consultation services for inflight emergency consultation as well as fitness to fly ground screening. Source: <http://www.stat-md.org/about/>

⁶ Pilot Report. See section 5.1.5.2 “PIREP” for the published PIREP.

⁷ Beechcraft Corporation 1900, 1900C, 1900D. Source FAA Order 8900.1, Figure 5-88, dated July 15, 2019.

⁸ The Boeing Company DC-9-11, DC-12, DC-9-13, DC-9-14, DC-9-15, DC-9-15F, DC-9-21, DC-9-31, DC-9-32, DC-9-32F, DC-9-33F, DC-9-34, DC-9-34F, DC-9-41, DC-9-51, DC-9-81, DC-9-82, DC-9-83, DC-9-87, MD-88, MD-90-30, 717-200. Source FAA Order 8900.1, Figure 5-88, dated July 15, 2019.

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.

According to information provided by Southwest Airlines, the captain had approximately 14,909 total hours of flight experience, of which 8,027 of those hours were in the B-737, and 4,992 of those hours were as pilot in command (PIC) in the B-737.

2.1.1 Captain's Training and Proficiency Checks Completed

A synopsis of the captain's recent training at Southwest Airlines was as follows¹⁰:

Date of Initial New Hire Training at Southwest	November 12, 2014
Upgrade to captain ¹¹	December 12, 2016
Most Recent Line Oriented Evaluation	December 18, 2018
Most Recent Maneuvers Observation	December 17, 2018
Most Recent Line Check	June 19, 2019
Hazardous Weather – Distance Learning 1 ¹²	March 23, 2019

2.1.2 Captain's Flight Times

The Captain's estimated flight times were based on Southwest Airlines' provided documentation:

Total pilot flight time	14,909
Total B737 flight time	8,027
Total B737 PIC flight time	4,992
Total flight time preceding 24 hours ¹³	2:06
Total flight time preceding 30 days	42:00
Total flight time last 90 days	148:00

2.2 First Officer

The First Officer (FO) was 44 years old; held an ATP certificate with type ratings on the EMB-145¹⁴, ERJ-170¹⁵, ERJ-190, and B737. He held a commercial pilot certificate for airplane

¹⁰ Source: Attachment 3 – “Flight Crew Training Records”

¹¹ Upgrade training began with initial ground school and concluded June 20, 2015 with Consolidation of Knowledge & Skills training as required under *CFR* Part 121.434.

¹² Hazardous Weather was part of “Distance Learning 1” which was quarterly training crews were required to complete within a 3-month period of time. “Distance Learning 1” was available to crews for completion during the first quarter of the year (January 1 thru March 30, 2019) and included weather avoidance and radar usage.

¹³ Flight time does **not** include the accident flight and only includes a flight on May 24, 2019 that the captain operated from Atlanta Georgia to MDW.

¹⁴ Embraer S.A. EMB-135ER, EMB-135LR, EMB-135KE, EMB-135KL, EMB-135BJ, EMB-145, EMB-145ER, EMB-145MR, EMB-145LR, EMB-145XR, EMB-145MP, EMB-145EP. 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 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.

single-engine land. He also held an FAA first-class medical certificate dated March 20, 2019, with a limitation of “Must wear corrective lenses.” At the time of the accident he was based at MDW.

According to information provided by Southwest Airlines, the first officer had accumulated about 12,538 hours of total flight experience and had about 508 hours of total flight experience in the B737.

2.2.1 First Officer’s Training and Proficiency Checks

A synopsis of the FO’s recent training at Southwest Airlines is as follows¹⁶:

Date of Initial New Hire Training at Southwest	April 10, 2018
Most Recent Line Oriented Evaluation ¹⁷	March 24, 2019
Most Recent Maneuvers Observation	March 23, 2019
Most Recent Proficiency Check	June 1, 2018
Most Recent Line Check	June 12, 2019
Hazardous Weather – Distance Learning 1 ¹⁸	February 3, 2019

2.2.2 First Officer’s Flight Times

The First Officer’s estimated flight times were based on Southwest Airlines’ provided documentation:

Total pilot flight time	12,538 hours
Total B737 flight time	508:00 hours
Total flight time preceding 24 hours ¹⁹	7:35 hours
Total flight time preceding 30 days	44:00 hours
Total flight time last 90 days	163:00 hours

¹⁶ Source: Attachment 3 – “Flight Crew Training Records”

¹⁷ The Line Oriented Evaluation included weather and windshear training among other items.

¹⁸ Hazardous Weather was part of “Distance Learning 1” which was quarterly training crews were required to complete within a 3-month period of time. “Distance Learning 1” was available to crews for completion during the first quarter of the year (January 1 thru March 30, 2019) and included weather avoidance and radar usage.

¹⁹ Flight Time includes the accident flight and 4 flights on May 24, 2019. Source: Attachment 2 - “Flight Crew Schedules”

3.0 Airplane Information



Photo 1: Accident Airplane, N8697C (Courtesy of JetPhotos.net)

The accident airplane (Registration N8697C, Serial No. 36728) was a Boeing 737-8H4. The airplane was manufactured in 2016, registered to and operated by Southwest Airlines Co., and held a transport category airworthiness certificate dated August 22, 2016. The airplane was powered by 2 General Electric CFM 56-7B E/F engines, each were rated at 27,000 pounds of thrust. The airplane was configured with 2 pilot seats, 1 cockpit observer seat, 6 flight attendant seats, and 175 passenger seats.

According to the accident flight's dispatch release there were no deferred maintenance items at the time of departure.

3.1 Weight and Balance

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

Basic Operating Weight	92,714
Total Payload	26,500
Zero Fuel Weight	119,214
Maximum Zero Fuel Weight	136,500
Fuel on Board	16,800
Taxi Fuel	300
Ramp Weight	136,014
Takeoff Weight	135,714
Maximum Takeoff Weight	174,200
Planned Fuel Burn	9,700
Planned Landing Weight ²⁰	126,314
Maximum Landing Weight	144,000

²⁰ Planned landing weight was a dispatch estimated weight based on an estimated takeoff weight.

4.0 Accident Flight Dispatch Release and Weather Packet

4.1 Dispatch Release

Southwest Airlines Domestic Dispatch Release for the accident flight was listed as “Release-1”. The dispatch release contains information for the accident flight such as, fuel required, route of flight, departure and destination airports, MEL/CDLs²¹, planned departure and arrival weights, enroute winds and temperature summary, as well as a “remarks” section. The “Remarks” section of the release contained the following information:

Dispatch Add Fuel For Possible Enroute Turbulence/Weather

The fuel section of the release showed that the dispatcher had added an addition 1,200 pounds of fuel, which equated to 15 additional minutes of fuel.

Additionally the dispatch release for the accident listed “No Items” under the MEL/CDL section of the release.

4.2 Weather Packet

The Southwest Airlines Briefing packet for the accident flight was generated on May 25, 2019 at 18:30:47Z (14:30:47 EDT). The weather packet contained the departure, enroute, and destination weather, and Weather Charts. The Weather Packet was segmented into “destination weather,” “departure weather,” “alternate weather,” “departure information,” “destination information,” and “enroute information.” PIREPs were listed under the respective “information” section. A review of the “destination information” PIREP reported only a PIREP associated with a “drone sighting.” A review of the “enroute information” PIREP reported two that were located in Indiana and reported light turbulence at FL230 and FL320 by a B-737. No other turbulence PIREPS were located in the weather packet in the proximity of the destination airport or accident location.

4.2.1 WSI Flight Plan Guidance (FPG)

The Southwest Airlines weather packet included a graphical depiction of enroute hazards on the WSI²² FPG page. The FPG provided a 12-hour forecast of enroute hazards for altitudes ranging from the surface to FL500 and were updated every 3 hours.²³ The graphical depiction in figure 1 was the FPG provided to the accident flight crew prior to departure. That graphical depiction indicated “occasional moderate” turbulence near the departure airport but did not indicate any forecasted turbulence near the arrival airport or near the accident location.

²¹ Minimum Equipment List/Configuration Deviation List

²² The Weather Company (formerly known as WSI) was a weather forecasting and information technology company that owns and operates weather.com and Weather Underground.

²³ Source: WSI Aviation Forecast Services
<https://business.weather.com/writable/documents/WSIAviationForecastServices.pdf>.

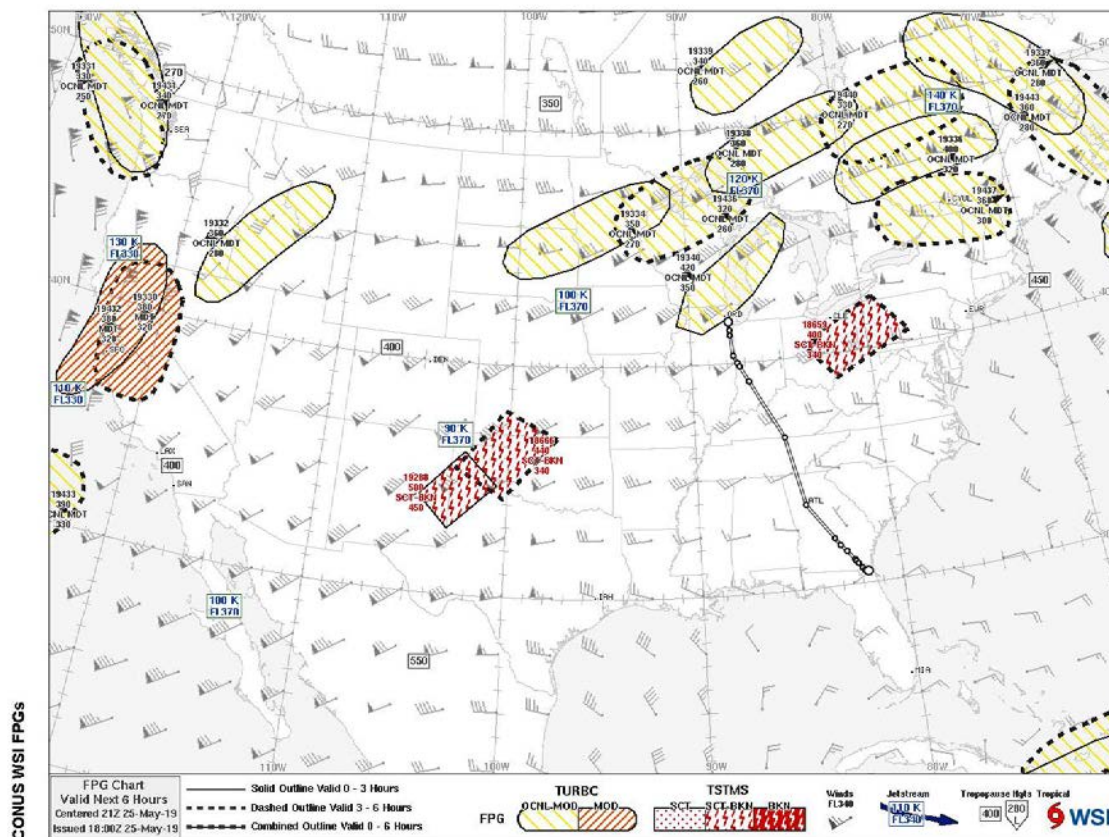


Figure 1: WSI FPG (Source: Southwest Airlines Weather Packet)

4.2.2 WSI SIGMETs

The Southwest Airlines weather packet included a graphical depiction of the WSI SIGMETs²⁴ throughout the Continental US (CONUS). The graphical depiction in figure 2 was the WSI SIGMET provided to the accident flight crew prior to departure. That graphical depiction did not indicate any SIGMETs along the entire route of flight nor around the destination airport.

²⁴ Significant Meteorological Information

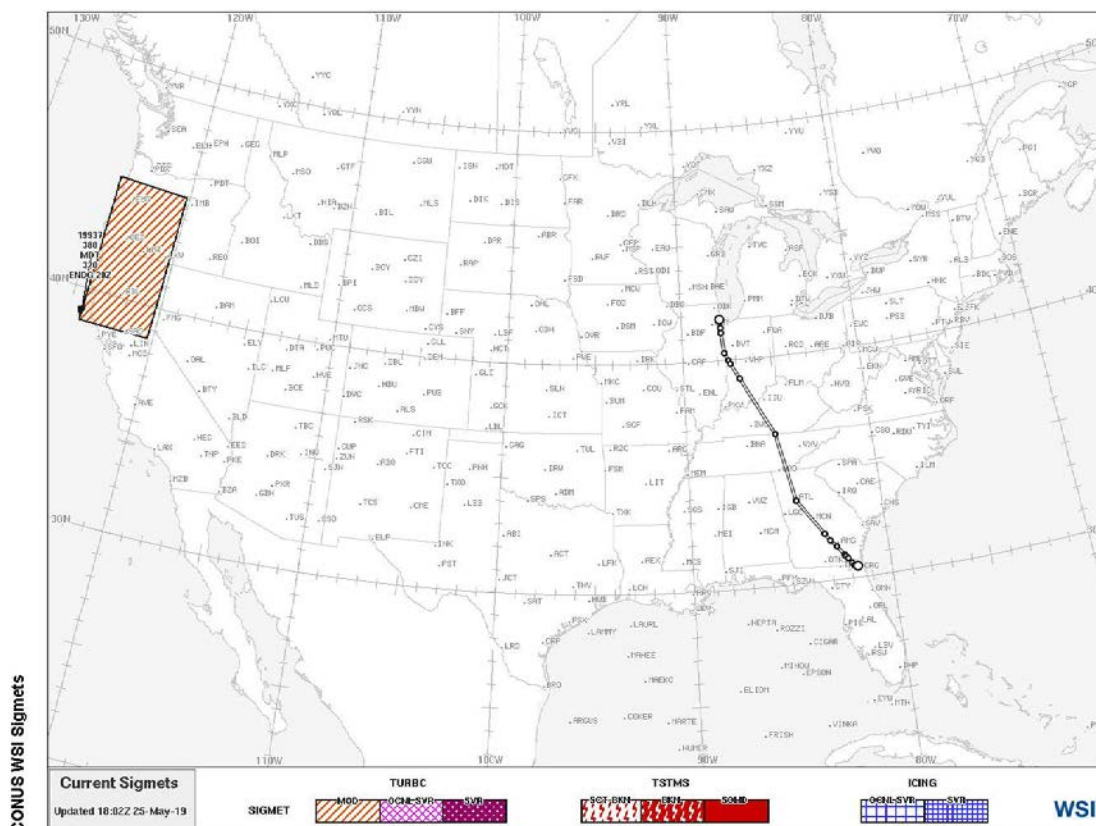


Figure 2: WSI SIGMET (Source: Southwest Airlines Weather Packet)

4.3 PIREPs

A review of archived PIREPs, throughout the national airspace system, showed that of the 389 PIREPs provided in the 2 hours prior and 2 hour after the accident flights encounter with turbulence, showed 4 reports, other than the accident flight's report, within about 300 miles of the accident location that indicated turbulence. Of those 4 reports; 2 of the reports were in the vicinity of the accident flight's route of flight. The PIREPs were as follows:

Along the route of flight:

PXE UA /OV PXE090005 /TM 2022 /FL030 /TP P28A /SK SCT060 /TB LGT /RM DURC

DBN UA /OV DBN337027/TM 2341/FL320/TP E75S/TB NEG/RM SMOOTH ZTLFD

277 miles northeast of the accident location:

*FAY UA/OV 5 EAST BBP/TM 1935/FL110/TP BE10/TB MOD-SEV/RM 110-70
TURBULENCE*

170 miles southeast of the accident location:

*COF UA /OV MLB330006 /TM 2128 /FL024 /TP P28A /SK FEW025 /TB NEG /RM
DURC*

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

Perry-Houston County Airport (PXE), Perry, Georgia routine pilot report (UA); Over a point east of PXE 5 miles; Time - 2022Z (1622 EDT); altitude of 3,000 ft; Aircraft type – Piper P28A²⁵; Sky condition - scattered at 6,000 ft; Turbulence – light; Remarks – during climb.

Dublin (DBN) VOR²⁶, Dublin, Georgia routine pilot report; over a point northwest of DBN 27 miles; Time 2341Z (1741 EDT); Flight level 320²⁷; Aircraft type – Embraer E75S²⁸; turbulence – negative; Remarks – Smooth filed by Atlanta Air Route Traffic Control Center.

Fayetteville Regional Airport (FAY), Fayetteville, North Carolina routine pilot report; over a point 5 miles east of Marlboro County Jet Port – H E Avent Field Airport (BBP), Bennettsville, South Carolina; Time 1935Z (1535 EDT); altitude of 11,000 ft; aircraft type – Beech 100²⁹; turbulence – Moderate to severe; remarks – 11,000 ft to 7,000 feet turbulence.

Patrick Air Force Base (COF), Cocoa Beach, Florida routine pilot report; over a point 5 miles northwest of Melbourne (MLB), Melbourne, Florida; Time 2128Z (1728 EDT); altitude 2,400 ft msl; Aircraft type – Piper P28A; sky condition – few clouds at 2,500 msl; turbulence – negative; Remarks – during climb.

5.0 Southwest Airlines Guidance

5.1 Turbulence

5.1.1 Turbulence Limitations and Policies

The Southwest Airlines, Flight Operations Manual, Section 15 “Adverse Weather”, Revision 19-03, dated October 3, 2018, contained the following guidance regarding “Turbulence Limitations and Policies”:

Pilots will not intentionally conduct flight operations nor will flights be dispatched in areas of known or probable severe turbulence. A combination of forecasts, PIREPs, aircraft types, times, locations, and altitudes must be considered in determining known or probable severe turbulence.

Pilots must remain on a filed mountain wave transit route. Coordinate any desired changes with Dispatch.

²⁵ Piper Cherokee was a 2 to 4 seat, metal, unpressurized, single-engine, piston-powered airplanes with low-mounted wings and tricycle landing gear.

²⁶ Very-high Omnidirectional Range

²⁷ Flight Level – A Flight Level (FL) is a standard nominal altitude of an aircraft, in hundreds of ft. This altitude is calculated from the International standard pressure datum of 1013.25-hPa (29.92 inHg), the average sea-level pressure, and therefore is not necessarily the same as the aircraft’s true altitude either above mean sea level or above ground level.

²⁸ E75S was a narrow-body short- to medium-range twin-engine jet airliner.

²⁹ Beechcraft King Air 100 – was a twin-turboprop that could carry up to 13 passengers.

Pilots must not accept an ATC reroute through active mountain wave areas that require planning mountain wave avoidance without first consulting the Dispatcher.

5.1.2 Turbulence Intensity

The Southwest Airlines, Flight Operations Manual, Section 15 “Adverse Weather”, Revision 19-03, dated October 3, 2018, contained the following guidance regarding “Turbulence Intensity”:

The following are various levels of turbulence intensity:

- *Smooth – no turbulence. There is no duration entry for smooth*
- *Light chop – slight, rapid, and somewhat rhythmic bumpiness without appreciable changes in altitude or attitude.*
- *Light turbulence – slight, erratic changes in altitude and/or attitude. Occupants may feel strain against seatbelts. Unsecured objects may be displaced slightly. Little or no difficulty walking.*
- *Moderate chop – rapid bumps or jolts without appreciable changes in aircraft altitude or attitude.*
- *Moderate turbulence – 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 strain against seatbelts. Unsecured objects are dislodged. Walking is difficult.*
- *Severe – large, abrupt changes in altitude and/or attitude. Usually causes large variations in indicated airspeed. Aircraft may be momentarily out of control. Occupants are forced violently against seatbelts. Unsecured objects are tossed about. Walking is impossible. Contact Dispatch; aircraft inspection is required.*
- *Extreme- aircraft is violently tossed about and practically impossible to control. Structural damage may result. Contact Dispatch; aircraft inspection is required.*

Southwest Airlines also provided a turbulence action table for all crew members to know what actions should be taken.

Level Turbulence Type	Description	Pilot Action	Flight Attendant Action
Light	Slightly erratic in altitude and/or attitude. Occupants may feel strain against seat belt. Unsecured objects may dislodge slightly.	Ensure FASTEN SEAT BELT sign is on. Via interphone, advise Flight Attendants of anticipated type of turbulence and expected duration. If occasional moderate or greater turbulence is anticipated or encountered, advise the Flight Attendants to be seated. Make announcement reinforcing need for Passengers to remain seated.	Continue service with caution. Flight Attendants monitor compliance by visually checking Passengers are seated with seat belts fastened.
Moderate	Changes in altitude and/or attitude occur but the aircraft remains in positive control. It usually causes variations in indicated airspeed. Occupants feel definite strain against seat belts. Walking is difficult.	Ensure FASTEN SEAT BELT sign is on. Via interphone, advise Flight Attendants of anticipated type of turbulence and expected duration. Make announcement reinforcing need for Flight Attendants and Passengers to remain seated and service to be discontinued. Communicate with Flight Attendants as required. Refer to B737NG AOM 10.5 Cruise Altitude Selection or B737MAX AOM 10.5 Cruise Altitude Selection for guidance.	Stop all service. Stow all galley equipment. Secure self in a jumpseat as soon as possible using seat belt and shoulder harness (take nearest passenger seat if necessary). "A" Flight Attendant: - Communicate with other Flight Attendants to ensure Passengers and Flight Attendants are seated. - Notify Pilots when Flight Attendants are seated. - Communicate with Pilots on cabin, as required.
Severe	Large, abrupt changes in altitude and/or attitude.	Ensure FASTEN SEAT BELT sign is on. When operationally safe to do so: - Make announcement stating, "Flight Attendants and Passengers be seated immediately and fasten seat belts." - Make announcement to inform Flight Attendants and Passengers when turbulent conditions have subsided. After conditions subside, communicate with Flight Attendants as required.	Stop all service until turbulence is reduced. Secure self in the nearest available seat. If on jumpseat, use seat belt and shoulder harness. "A" Flight Attendant notifies Pilots when cabin is secure and Flight Attendants are seated. When safe to do so: - Stow all galley equipment. "A" Flight Attendant use PA to ensure Flight Attendants and Passengers are seated. - Check for injuries or damage. "A" Flight Attendant communicates with Flight Deck Crew on cabin conditions, as required.

Figure 3: Turbulence Action Table (Source FOM 15.3)

5.1.3 Turbulence Durations

The Southwest Airlines, Flight Operations Manual, Section 15 "Adverse Weather", Revision 19-03, dated October 3, 2018, contained the following guidance regarding "Turbulence Duration":

- *Occasional – less than 1/3 of the time.*
- *Intermittent – 1/3 to 2/3 of the time.*
- *Continuous – more than 2/3 of the time.*

5.1.4 Turbulence and Hazardous Weather Guidelines

The Southwest Airlines, Flight Operations Manual, Section 15 "Adverse Weather", Revision 19-02, dated October 3, 2018, contained the following guidance regarding "Turbulence and Hazardous Weather Guidelines":

WSI SUGMETs and Flight Plan Guidance (FPGs) are distributed both in text and on a chart provided in the weather package for each flight. The format focuses on turbulence and any other type of weather-specific hazards to flight. The plotting on the WSI SIGMETs is simple, and the degree of hazard is easily discernible.

Because some encounters with light-to-moderate turbulence are unavoidable and some turbulence is unpredictable, be prepared to reassure Passengers of their safety and, in

some cases, to act quickly in preventing injuries to self and others. Pilots are expected to maintain awareness of all turbulence messages received via ACARS.

WSI SIGMET and FPG Chart Appearance and Contents

Hazardous weather phenomena are grouped into four levels of intensity:

- *Occasional Moderate (OCNL MOD/MDT) – Isolated reports of or the forecast of turbulence that causes slight, rapid, and somewhat rhythmic bumpiness without appreciable changes in altitude or attitude (FPG chart only).*
- *Moderate (MOD/MDT) – Multiple report of or the forecast of turbulence that causes intermittent, rapid, and somewhat rhythmic bumpiness without appreciable changes in altitude or attitude (SI SIGMET and FPG charts).*
- *Occasional Severe (OCNL SVR) – Isolated reports of or the short-term forecast of turbulence that causes large, abrupt changes in altitude and/or attitude and usually results in large variations in indicated airspeed. The aircraft may be momentarily out of control (WSI SIGMET chart only).*
- *Severe (SVR) – Multiple reports of or the short term forecast of turbulence that causes large, abrupt changes in altitude and/or attitude and usually results in large variations in indicated airspeed. The aircraft may be momentarily out of control (WSI SIGMET chart only)*

WSI SIGMET

WSI SIGMET data indicates the need for caution, heightened awareness, and, in some cases, action to avoid areas of known turbulent conditions. The nature of turbulence (e.g., clear air, mountain wave, convective) and the intensity/availability of new data, with the degree of change expected over a given time period, dictates the frequency that WSI SIGMET turbulence messages are issued and updated. SIGMETs, other forecast products, and actual turbulence data may be used as secondary sources to enhance situational awareness; WSI SIGMET messages prevail over NWS SIGMETs when differences exist.

The WSI SIGMET chart includes en route hazards for the following:

- *Moderate, occasional severe, and severe turbulence*
- *Scattered-broken, broken, and solid thunderstorms*
- *Occasional severe and severe icing.*

FPG

The FPG chart includes forecast en route hazards for the following:

- *FL 350 winds*
- *Jet stream*
- *Tropopause height*

- Occasional moderate and moderate turbulence
- Scattered, scattered-broken, and broken thunderstorms

5.1.5 Turbulence Communication

5.1.5.1 Turbulence Communication with Dispatch

The Southwest Airlines, Flight Operations Manual, Section 15 “Adverse Weather”, Revision 19-03, dated October 3, 2018, contained the following guidance regarding “Turbulence Communication with Dispatch”:

Flight Deck Crews and Dispatcher will communicate known or potential turbulence before, during, and after flight. Dispatchers may use the Remarks section on the Dispatch Release to advise Flight Deck Crews of known or forecast turbulence. Flight Deck Crews must send turbulence PIREPs to Dispatch via ACARS, or by radio or telephone if ACARS is unavailable. When sending turbulence PIREPs, include the duration, intensity, altitude, and location of the turbulence.

Preflight weather briefings, verbal or written, must include forecasts of turbulence and PIREPs of turbulence caused by thunderstorm activity, mountain wave activity, clear air turbulence, low altitude frontal windshear, and low altitude convective windshear.

During flight, the Pilot and Dispatcher must communicate any changes in the forecast or actual turbulence conditions via ACARS or radio to pass real-time turbulence information to other flights.

5.1.5.2 PIREP

According to a representative of Southwest Airlines, the following was entered into the WSI Fusion software by a dispatcher, when the pilot contacted them via telephone after arriving at the gate.

```
Turbulence Pirep
Reported: 25/2115z
Aircraft: B738 Large Jet
Details: JAX UA /OV KJAX300030 /TM 2115 /FL120 /TP B738 /TB MOD /RM DURD INTO KJAX
ANC-WEB:
```

5.1.5.3 Turbulence Communication with Flight Attendants

The Southwest Airlines, Flight Operations Manual, Section 15 “Adverse Weather”, Revision 19-03, dated October 3, 2018, contained the following guidance regarding “Turbulence Communication with Flight Attendants”:

If flight into forecast turbulence is unavoidable, timely notification to the Flight Attendants is crucial to their safety. Anticipated turbulence must be part of the preflight briefing to the “A” Flight Attendant.

Remember the following when dealing with turbulence:

- *Provide Flight Attendants with as much advance warning as possible before entering an area of turbulence. Discuss how much time will be required to discontinue cabin service and be seated.*
- *Ensure Flight Attendants are seated when directed. Require Flight Attendants to call as soon as seated and before getting out of their seats.*
- *Any turbulence-related communication with the Flight Attendants should use the following terminology: light, moderate, or severe. Whenever possible, show the WSI SIGMET chart to the Flight Attendants.*
- *Turbulence levels are not the same throughout the cabin. Intensity levels in forward sections may be lower than those in aft sections.*
- *Anytime Crew Members experience turbulence levels that have not been forecasted or communicated, take immediate action in response to conditions. Communicate between flight deck and cabin as soon as it is safe to do so.*

During the descent, Passengers are permitted to use large PEDs and tray tables until reaching 10,000 ft. When expecting turbulence, Pilots may direct the Flight Attendants to secure the cabin prior to 10,000 ft and be seated for their safety. Coordinate using the interphone and/or PA instead of the attend call button to allow Passengers to continue using large PEDs and tray tables until 10,000 ft.

Pilots should ensure Flight Attendants are allotted adequate time to secure galleys before entering areas of anticipated turbulence.

Pilot Responsibility	Flight Attendant Responsibility
Advise "A" Flight Attendant of expected or encountered turbulence, anticipated response time, and expected duration. Provide as much advance warning as possible so Flight Attendants can discontinue service and be seated.	Ensure other Flight Attendants are notified via interphone when turbulence is reported by Pilots. Advise Pilots if turbulence is disrupting cabin service. Flight Attendants may decide if conditions experienced in cabin are not suitable for continued service.
Turn ON FASTEN SEAT BELT sign. Make PA to ensure Passengers and Flight Attendants are seated with seatbelts fastened when level of turbulence calls for it.	If Pilots do not make seatbelt announcement, make announcement. Make PA to ensure Passengers and other Flight Attendants are seated when level of turbulence calls for it. Notify Pilots when FASTEN SEAT BELT sign is on for extended periods without turbulence or if Passengers are disregarding sign.
Direct Flight Attendants to be seated when required.	When directed by Pilots to be seated, notify Pilots when all Flight Attendants are seated.
Notify Flight Attendants when safe to move about cabin and resume service.	Report any Passenger or Crew injuries to Pilots and complete an Irregularity Report.

When actual condition in the cabin differ from the forecasted conditions, Flight Attendants must notify the Captain and take appropriate action.

5.1.6 Turbulence Consideration and Guidance

5.1.6.1 Flight Operations Manual

The Southwest Airlines, Flight Operations Manual, Section 17 “Flight Planning and Dispatch”, Revision 19-02, dated July 11, 2019, and had been revised on May 9, 2018 provided, in part, the following:

The procedures for turbulence avoidance are based on forecast and/or observed areas of turbulence, and are used both for flight planning and while en route. Due to the transient nature of turbulence, there are times when it is unavoidable. Dispatchers and Flight Deck Crews should remain vigilant and take extra precautions to ensure the safety of the flight when conditions are conducive to turbulence.

A combination of WSI SIGMETs, FPGs, Turbulence Auto PIREP System (TAPS) reports, Turbulence Advisories, and Pilot Weather Reports (including aircraft type, location, and altitude) must be used to determine whether known or probable turbulence exists. If greater-than-light turbulence is expected to impact the flight, the Dispatcher considers additional contingency fuel and, depending on the level of turbulence, selects a different altitude and/or route and advises the Flight Deck Crew. Dispatchers do not plan any flight into areas of known or probable severe turbulence.

Turbulence Data

Turbulence data indicated the need for caution, heightened awareness, and, in some cases, action to avoid areas of known turbulent conditions. the nature of turbulence (i.e., clear air, mountain wave, or convective), the intensity, the availability of new data, and the degree of change expected over a given time period dictate the frequency at which WSI SIGMET messages are issued and updated. NWS SIGMETs, AIRMETs³⁰, other forecast products, and actual turbulence data may be used as secondary sources to enhance situational awareness; WSI SIGMET messages prevail over NWS SIGMETs when differences exist.

5.1.6.2 B737NG Aircraft Operating Manual

The Southwest Airlines, B737NG Aircraft Operating Manual, Section 15 “Adverse Weather”, Revision 19-02, dated July 11, 2019, last revised January 15, 2018 provided the following guidance, in part:

Notify the Flight Attendants when approaching areas of turbulence.

In any turbulence, accomplish the following:

- *Ensure that the FASTEN SEAT BELT sign is illuminated. If possible, advise Passengers and Flight Attendants of any turbulent conditions prior to encountering them.*

³⁰ Airmen’s Meteorological Information

- *Although use of the autopilot is considered desirable in most turbulence conditions, its use is at the Captain's discretion. During flight, Boeing recommends in light to moderate turbulence, the autopilot and/or autothrottle may remain engaged unless performance is objectionable.*

In severe turbulence, accomplish the following:

- *Autothrottle – Disengage*
- *Thrust – Set (see considerations below)*
- *Autopilot (if engaged) – CWS Mode (do not use altitude Hold)*
- *Engine Start Switches – FLT*
- *Yaw Damper – Ensure ON*

The following considerations apply to flights in severe turbulence:

- *Set thrust as needed for the phase of flight and target airspeed. Change thrust setting only if needed to modify an unacceptable airspeed trend. The FMC CRZ page displays N₁ target values for level flight in turbulence.*
- *Severe turbulence causes large and often rapid variations in indicated airspeed. Do not chase the airspeed.*
- *The best airspeed and flight configuration to use in severe turbulence is that which affords ample protection from stall and high speed buffet and also provides structural integrity. Adjust the airspeed to the recommended turbulence penetration speed. Target air speed should be approximately 280 KIAS or 0.72 MACH, whichever is lower, or 250 kt below 15,000 ft.*
- *If the autopilot is engaged, use CWS (pitch and roll) mode only, adjusting attitude and heading by manual autopilot controls. If sustained trimming occurs, disengage the autopilot.*
- *If not using the autopilot, trim the aircraft for the appropriate penetration speed, and do not change the trimmed stabilizer position. Control the aircraft pitch attitude with the elevator using the attitude indicator as the primary reference instrument.*
- *In extreme up/down draft, large attitude changes may occur. Do not make sudden or large control inputs. Corrective actions should be smooth and deliberate. Altitude variations are probable in severe turbulence and should be allowed to occur if terrain clearance is adequate. Control the aircraft's attitude first, then make corrections for airspeed, altitude, and heading.*
- *Avoid any maneuver that might result in a stall or upset by maintaining a constant heading, without overcontrolling. It is impossible to maintain a constant altitude in extremely turbulent conditions'; therefore, it is important to maintain altitude with light to moderate pitch control inputs to avoid overcontrolling or overstressing the aircraft's structure.*
- *Avoid high speeds and steep turns as these impose greater structural loads on the aircraft during turbulence.*

- *The yaw damper greatly reduces the structural loads imposed on the aircraft.*
- *Flight through turbulence or hail may cause inlet airflow distortion. This distortion, along with engine icing, angle of attack changes, and high altitude engine surge margins can result in engine surge and flameout. Activate the FLT ignition as soon as severe turbulence is encountered or anticipated.*
- *Flap extension in an area of known turbulence should be delayed as long as possible because the aircraft can withstand higher gust loads with the flaps and gear retracted. Divert to another airfield if severe turbulence persists in an area.*

5.1.6.3 Flight Attendant Manual

The Southwest Airlines Flight Attendant Manual, revision 19-03, dated May 1, 2019, Section 2.2.0 “Turbulence”, provided the following guidance in regard to turbulence:

Because some encounters with light-to-moderate turbulence are unavoidable, and some turbulence is unpredictable, be prepared to reassure Passengers of their Safety and, in some cases, to act quickly in preventing injuries to yourself and others.

The manual further described in Section 2.2.1 “Communication” what information should be communicated between the Flight Attendants and Pilots regarding turbulence during the preflight briefing and during flight.

Preflight Briefing

During the preflight briefing, the Captain informs other Crew Members of any anticipated in-flight turbulence. Remember the following when dealing with turbulence:

- *Use designated turbulence levels when communicating turbulence information.*
- *Turbulence levels are not the same throughout the cabin. Intensity levels in forward sections may be lower than those in aft sections.*
- *Any time Crew Members experience turbulence levels that have not been forecasted or communicated, take immediate action in response to conditions. Communicate with the Pilots as soon as it is safe to do so.*

Pilots should ensure Flight Attendants are allotted adequate time to secure galleys before entering areas of anticipated turbulence.

During Flight

Responsibility	Communication
Pilots	Advise "A" Flight Attendant of expected or encountered turbulence, level, anticipated response time, and expected duration. Turn on FASTEN SEAT BELT sign.
Flight Attendants	If Pilots do not make seatbelt announcement, make announcement. Ensure other Flight Attendants are notified via interphone when turbulence is reported by the Pilots. Advise Pilots if turbulence is disrupting cabin service. Make PA to ensure Passengers and other Flight Attendants are seated when the level of turbulence calls for it. Flight Attendants may decide if conditions experienced in cabin are not suitable for continued service. Notify Pilots when FASTEN SEAT BELT sign is on for extended periods without turbulence or if Passengers are disregarding sign. Flight Attendants must communicate with Pilots before resuming duties. Report any Passenger or Crew injuries to flight deck and file an Irregularity Report.

WARNING: When actual cabin conditions differ from expected conditions, notify the Captain and take appropriate action.

The manual further described in Section 2.2.2 "Turbulence Levels" and provided a "Turbulence Action Chart." The section stated, in part, the following:

Turbulence is identified by three levels: light, moderate, or severe.

Light

- *Occupants may feel a slight strain against seatbelts.*
- *Unsecured objects may be displaced slight.*
- *Drinks shake, but do not splash out of cups.*

Moderate

- *Occupants feel definite strains against seatbelts.*
- *Unsecured objects are dislodged.*
- *Cabin service and walking are difficult.*
- *When possible, flight route is planned around moderate turbulence.*
- *Drinks splash out of cups with consistency.*

Severe

- *Occupants are forced violently against seatbelts.*
- *Unsecured objects are tossed about.*
- *Items fall over or lift from surfaces with consistency. Standing is impossible without holding onto a part of the aircraft.*
- *Cabin service and walking are impossible.*

- *Pilots will not intentionally fly into severe turbulence.*

Turbulence Level	Flight Deck Response	Cabin Response
Light	Ensure FASTEN SEAT BELT sign is on. Via interphone, advise Flight Attendants of turbulence level. Advise Flight Attendants of expected duration. Make announcement reinforcing need for Passengers to remain seated.	Continue service with caution. Flight Attendants will monitor compliance by walking through the cabin to verify Passengers are seated with seatbelts fastened.
Moderate	Ensure FASTEN SEAT BELT sign is on. Via interphone, advise Flight Attendants of turbulence level. Advise Flight Attendants of expected duration. Make announcement reinforcing the need for Flight Attendants and Passengers to be seated and service to be discontinued. Continue communication with Flight Attendants as required.	Stop all service. Stow all carts and galley equipment. Secure yourself in a jumpseat as soon as possible using seatbelt and shoulder harness (take nearest Passenger seat if necessary). "A" Flight Attendant: • Communicates with other Flight Attendants to ensure Passengers and Flight Attendants are seated • Notifies Pilots when all Flight Attendants are seated. • Continues communication with Pilots on cabin conditions as required.
Severe	Ensure FASTEN SEAT BELT sign is on. When operationally safe to do so: • Make announcement stating "Flight Attendants and Passengers be seated immediately and fasten seatbelts." • Make announcement to inform Flight Attendants and Passengers when turbulence conditions have subsided. After conditions subside, continue communications with Flight Attendants as required.	Stop all service until turbulence is reduced. If service cart is in use, park at an angle and set brake. Secure yourself in the nearest available seat. In a jumpseat, use seatbelt and shoulder harness. "A" Flight Attendant notifies Pilots when cabin is secure and Flight Attendants are seated. When safe to do so: • Stow all carts and galley equipment. • "A" Flight Attendant uses PA to ensure Flight Attendants and Passengers are seated. • Check for injuries or damage. "A" Flight Attendant continues communication with Flight Crew on cabin conditions as required.

Figure 4: Flight Attendant Turbulence Action Chart

6.0 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.”*³¹

6.1 FAA Turbulence Fact Sheet

The FAA provided the following guidance titled “Fact Sheet – Turbulence” on August 1, 2019 on their website:³²

What is turbulence?

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

What should passengers do to avoid injuries?

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

- *Listen to the flight attendants. Pay attention to the safety briefing at the beginning of your flight and read the safety briefing card.*

³¹ Source: https://www.faa.gov/travelers/fly_safe/turbulence/

³² Source: https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=20074

- *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?

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

<i>Year</i>	<i>Passenger</i>	<i>Crew</i>	<i>Total</i>
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.

6.2 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.

6.3 FAA Advisory Circular AC 00-30C Clear Air Turbulence Avoidance

FAA AC 00-30C “Clear Air Turbulence Avoidance,” dated March 22, 2016, section 5.1 defines Clear Air Turbulence (CAT) as “*sudden severe turbulence occurring in cloudless regions that causes violent buffeting of aircraft...includes turbulence in cirrus clouds, within and in the vicinity of standing lenticular clouds and, in some cases, in clear air in the vicinity of thunderstorms.*” The AC further went on to state “*CAT is a recognized problem that affects all aircraft operations. CAT is especially troublesome because it is often encountered unexpectedly and frequently without visual clues to warn pilots of the hazard.*” The AC, in section 7 “Modern Turbulence Reports and Forecasts” goes on to state “*Automated turbulence reporting systems are common on many commercial aircraft using the Aircraft Meteorological Data Relay (AMDAR) system. Airline pilot reports are now being relayed to others by the airline’s aircraft dispatchers and by meteorologists working at the Federal Aviation Administration’s (FAA) air route traffic control centers (ARTCC).*”

AMDAR reports turbulence in terms of Eddy Dissipation Rate (EDR) which was the International Civil Aviation Organization (ICAO) standard dimension for automated turbulence reporting. EDR was a state-of-the-atmosphere measure rather than a state-of-the-aircraft measure and thus makes it independent of aircraft type.

In-flight weather advisories such as SIGMET and AIRMET are used to disseminate important information on atmospheric turbulence, both convective and CAT. In-flight weather advisories in the contiguous United States are issued by the Aviation Weather Center (AWC) as well as 20 Center Weather Service Units (CWSUs).

7.0 Boeing AERO Magazine

Boeing AERO Magazine³³ produced the following “Turbulence Education and Training Aid”³⁴ article in Issue 04 dated October of 1998:

Turbulence Education and Training Aid

Clear-air and mountain-wave turbulence is the leading cause of injury to cabin crews and passengers in non-fatality commercial airplane incidents. The resulting rough ride also creates a negative public perception of the safety of flight. An industry team consisting of participants from U.S. operators, Douglas Products Division, and the U.S. Federal Aviation Administration (FAA) has developed a turbulence education and training aid to help reduce the number of turbulence-related incidents.

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

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

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

FAA and Operator Response

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

Implementation of Turbulence Education and Training Aid

The turbulence education and training aid is an educational resource designed to

³³Boeing AERO magazine was published quarterly by Boeing Commercial Airplanes between 1998 and 2015. Source: https://www.skybrary.aero/index.php/AERO_-_Boeing

³⁴ Source: Boeing AERO Magazine Issue 04
http://www.boeing.com/commercial/aeromagazine/aero_04/tr/tr01/index.html

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

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

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

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

More Efficient Use of Existing Technologies

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

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

Development of New Technologies

In addition to assisting with short-term solutions, government regulatory agencies can help create long-term solutions. Examples of this activity include supporting the aviation industry in the development of new systems that detect clear-air and mountain-wave

turbulence and that deliver an early warning to the flight crew. Further development of existing technologies can lead to increased communication between airplanes and the ground to provide the flight crew with continuous, real-time weather information.

Summary

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

F. LIST OF ATTACHMENTS

- Attachment 1: Crew Statements
- Attachment 2: Flight Crew Schedules
- Attachment 3: Flight Crew Training Records
- Attachment 4: Accident Flight's Dispatch Release
- Attachment 5: Accident Flight's Weather Packet
- Attachment 6: Southwest Airlines Flight Operations Manual [Excerpts]
- Attachment 7: Southwest Airlines Aircraft Operations Manual [Excerpts]
- Attachment 8: Southwest Airlines Flight Attendant Manual [Excerpts]

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