National Transportation Safety Board
Office of Aviation Safety
Washington, DC 20594

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OPERATIONAL FACTORS

Group Chair's Factual Report

July 15, 2024

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A. ACCIDENT

Location:	Kahului, Hawaii
Date:	December 18, 2022
Time:	1007Hawaii Standard Time (HST) 2007 coordinated universal time (UTC)
Airplane:	N393HA, A330-243, SN 1422

B. OPERATIONAL FACTORS

Group Chair	Warren Abrams NTSB Washington, DC
Group Member	Todd Gentry[1] Federal Aviation Administration (FAA) Washington, DC
Group Member	Kent Fujimoto Hawaiian Airlines Honolulu, HI
Group Member	John Crabbe Airline Pilots Association (ALPA) Honolulu, HI

C. SUMMARY

On December 18, 2022, about 1007 Hawaii standard time, Hawaiian Airlines flight 35, an Airbus A330-200, N393HA, was operating at FL400 about 65 nautical miles north-northeast of Kahului, Hawaii when the airplane encountered severe turbulence. Of the 2 flight crewmembers, 8 flight attendants, and 283 passengers including 2 off-duty Hawaiian Airlines pilots in the cockpit jumpseats and 3 lap held children) aboard the airplane, 4 occupants (1 flight attendant and 3 passengers) sustained serious injuries, and 20 occupants (3 flight attendants and 17 passengers) sustained minor injuries. The airplane sustained minor damage. The regularly scheduled domestic passenger flight was operating under the provisions of Title 14 Code of Federal Regulations Part 121

[1] FAA Inspector Eddie Miller was substituting for FAA Inspector Todd Gentry who was unable to travel to HNL at the time of the initial interviews. FAA Inspector Gentry joined the investigation on January 17, 2023.

from Phoenix Sky Harbor International Airport (PHX), Phoenix, Arizona, to Daniel K. Inouye International Airport (HNL), Honolulu, Hawaii.

D. DETAILS OF THE INVESTIGATION

December 19, 2022: The Operational Factors (Ops) Group Chairman was assigned to the investigation. The Ops group Chairman requested operational manuals from the airline to include, weight and balance information, dispatch information, ACARS[2] information, weather information and training records. A written statement was requested from the two pilots as well. A request was made to the FAA requesting pilot information for the two pilots.

An Ops group was formed with ALPA and Hawaiian Airlines as group members.

December 27, 2022 – The Ops Group Chairman and the FAA inspector were to fly to HNL and conduct interviews on January 3 & 4. A conference call with Hawaiian Airlines on December 27, indicated that pilot staffing was extremely tight over the holidays and requested the ops group postpone their interviews by one week which was agreed to.

January 8, 2023. The Ops group chairman traveled to HNL to interview the pilots and Jumpseat riders.

January 9, 2023 – The day started with the Ops Group Chairman having a discussion with four attorneys, representing the parties who will be interviewed, about the NTSB policy of recording interviews.

After the discussions, the first officer was the first to be interviewed, followed by the captain, then the jumpseat rider (JS) 1, and then JS 2, both of which were A-330 type rated. All four interviewees were explained that the NTSB policy was to record all interviews and have those recordings transcribed. All four interviewees would only agree to be interviewed but only if the interviews were not recorded. As previously advised by NTSB General Counsel, the ops group chairman ended the interaction, and the interviewees were excused. All four of the Hawaiian pilots that refused to have their interviews recorded were represents by counsel from ALPA.

April 3, 2023 – The Ops Group Chairman traveled to HNL to interview and record the captain and the first officer as well as the two A330 type rated jumpseat riders.

[2] Aircraft Communication Addressing and Reporting System.

April 4, 2023 – The Ops Group reconvened at 0800 HST and conducted recorded interviews with all parties that were in the cockpit at the time of the accident. Recorded interviews were with the first officer, the captain[3] and the two jumpseat riders[4].

E. FACTUAL INFORMATION

1.0 History of Flight

The first officer was the pilot flying and the captain was the pilot monitoring. The captain stated that they were in visual meteorological conditions (VMC) at FL400 and were above a cirrostratus cloud layer that was about 37,000 to 38,000 feet. He stated that flight conditions were smooth with clear skies above the cirrostratus layer and the on-board weather radar was on and set to "ALL" with no returns displayed on radar. A cloud shot up vertically (like a smoke plume) in front of the airplane in a matter of seconds, and there was not enough time to deviate, he indicated. He called the lead flight attendant to advise her that they may have turbulence. Within about 1 to 3 seconds, he said the airplane encountered severe turbulence. Shortly after the turbulence-related upset, the lead flight attendant informed the flight crew that there were multiple injuries in the cabin.

Post accident examination of the weather in the area revealed that there was an occluded frontal system with an associated upper-level trough moving towards the Hawaiian Islands. Satellite and weather radar imagery, and lightning data depicted strong cells in the vicinity of the flight. The U.S National Weather Service (NWS) had issued a current Significant Meteorological (SIGMET) warning for embedded thunderstorms with tops reaching FL380 over the region. There were no pilot reports of severe turbulence along the route prior to the accident.

2.0 Flight Crew Information

2.1 Captain

The accident flightcrew consisted of captain, first officer, and 2 jumpseat riders.

[3] See Attachment 1 for the pilot's interviews.
[4] See Attachment 1 for the Jumpseat Riders interviews.

The captain was 51 years old and held an Airline Transport Pilot (ATP) certificate with a rating for airplane multiengine land and type ratings on the A330,[5] B757,[6] B767, DC-9[7], and DHC-8[8]. He held a commercial pilot certificate for airplane single-engine land. He held an FAA first-class medical certificate dated September 21, 2022, with a limitation of "Must wear corrective lenses". At the time of the accident, he was based at HNL.

2.1.1 Flight Times

Based on the information provided by the airline, the captain had the following flight time:

Total Time	12,291
Total Pilot in Command (PIC)	9,224
Total Time A330	5,887
Last 90 days	214
Last 30 days	60
Last 24 hours	12

2.1.2 Captain Certification Records

FAA records of the pilot indicated the following certificate history:

Private Pilot – Airplane Single-Engine Land certificate was issued on May 4, 1992.

Private Pilot – Airplane Single and Multiengine Land certificate was issued on September 8, 1992.

Private Pilot – Airplane Single and Multiengine Land, Instrument Airplane certificate was issued on July 12, 1994.

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[5] Airbus SAS, A330-200 Series, A330-200 Freighter Series, A330-300 Series, A330-900 Series: Source: FAA Order 8900.1, Figure 5-88, dated July 15, 2019.

7 The Boeing Company, 757-200 Series, 757-200PF Series, 757-200CB 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 March 29, 2024

8 The Boeing Company, DC-9, DC-9-11, DC-9-12, 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 March 29, 2024

9 Bombardier Inc., DHC-8, DHC-9-100 Series, DHC-8-200 Series, DHC-8-300 Series, DHC-8-400 Series. Source: FAA Order 8900.1, Figure 5-88, dated March 29, 2024

Commercial Pilot – Airplane Single and Multiengine Land, Instrument Airplane certificate was issued September 15, 1994.

Airline Transport Pilot – Airplane Multi Engine Land. Commercial Privileges – Airplane Single Engine Land certificate was issued March 11, 1998

Notice of Disapproval of Application. Aircraft DHC-8, Areas of Operation IV, C – Powerplant Failure – Multiengine Airplane, VIII – Emergency Procedures was issued February 26, 2004.

Airline Transport Pilot – Airplane Multiengine Land, DHC-8, Commercial Privileges Airplane Single-Engine Land certificate was issued March 5, 2004.

Airline Transport Pilot – Airplane Multiengine Land, B757 B767 DHC-8, Commercial Privileges Airplane Single-Engine Land certificate was issued August 8, 2006.

Airline Transport Pilot – Airplane Multiengine Land, B757 B767 DC-9 DHC-8, Commercial Privileges Airplane Single-Engine Land certificate was issued November 2, 2006.

Airline Transport Pilot – Airplane Multiengine Land, A330 B757 B767 DC-9 DHC-8, Commercial Privileges Airplane Single-Engine Land certificate was issued October 28, 2014.

2.1.3 Certification and Ratings Held at the Time of the Accident

AIRLINE TRANSPORT PILOT (Issued October 28, 2014)
Airplane Multiengine Land
A330, B757, B767, DC-9, DHC-8
Commercial Privileges Airplane Single-Engine Land
Limitations: A330 Circ. Apch-VMC Only, English Proficient
MEDICAL CERTIFICATE FIRST CLASS (issued September 21, 2022)
Limitations: Must wear corrective lenses.

2.2 First Officer

The first officer was 50 years old and held an ATP certificate with a rating for airplane multiengine land and type ratings on the A330[9], ATR-42[10], ATR-72, DC-9[11]and DHC-8[12]. He held an FAA first-class medical certificate dated October 12, 2022, with a limitation of "Must have glasses available for near vision." At the time of the accident, he was based at HNL.

2.2.1 Flight Times

Based on the information provided by the airline, the first officer had the following flight time

Total Time	8,214
Total Time A330	1,031
Last 90 days	189
Last 30 days	62
Last 24 hours	12

2.2.2 First Officer Certification Records

FAA records of the first officer indicated the following certificate history:

Private Pilot Airplane Single-Engine Land certificate was issued January 26, 2003.

Private Pilot Airplane Single and Multiengine Land certificate was issued September 15, 2003.

Private Pilot Airplane Single and Multiengine Land Instrument Airplane certificate was issued December 19, 2003.

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[9] Airbus SAS, A330-200 Series, A330-200 Freighter Series, A330-300 Series, A330-900 Series: Source: FAA Order 8900.1, Figure 5-88, dated July 15, 2019

[10] ATR-GIE Avions de Transport Regional, ATR-42, ATR-72, ATR42-200, ATR42-300, ATR42-320, ATR42-500, ATR72-101, ATR72-201, ATR72-102, ATR72-202, ATR72-211, ATR72-212, ATR72-212A. Source : FAA Order 8900.1, Figure 5-88, dated July 15, 2019.

[11] The Boeing Company, DC-9, DC-9-11, DC-9-12, 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.

[12] Bombardier Inc., DHC-8, DHC-9-100 Series, DHC-8-200 Series, DHC-8-300 Series, DHC-8-400 Series. Source: FAA Order 8900.1, Figure 5-88, dated July 15, 2019.

Commercial Pilot Airplane Single and Multiengine Land Instrument Airplane certificate was issued July 30, 2004.

Airline Transport Pilot Airplane Multiengine Land Commercial Privileges Airplane Single-Engine Land Limitation: English Proficient certificate was issued September 1, 2010.

Airline Transport Pilot Airplane Multiengine Land ATR-42 ATR-72 Commercial Privileges Airplane Single-Engine Land Limitation: English Proficient certificate was issued November 14, 2012.

Airline Transport Pilot Airplane Multiengine Land DHC-8 ATR-42 ATR-72 Commercial Privileges Airplane Single-Engine Land Limitation: English Proficient certificate was issued March 17, 2017.

Airline Transport Pilot Airplane Multiengine Land DHC-8 ATR-42 ATR-72 DC-9 Commercial Privileges Airplane Single-Engine Land Limitation: English Proficient DC-9 Circ. Apch-VMC Only certificate was issued June 26, 2017.

Airline Transport Pilot Airplane Multiengine Land A330 DHC-8 ATR-42 ATR-72 DC-9 Commercial Privileges Airplane Single-Engine Land Limitation: English Proficient A330 DC-9 Circ. Apch-VMC Only certificate was issued June 26, 2017.

2.2.3 Certifications and Ratings Held at the Time of the Accident

AIRLINE TRANSPORT PILOT (Issued June 26, 2017)
Airplane Multiengine Land
A330, DHC-8, ATR-42, ATR-72, DC-9
Commercial Privileges Airplane Single-Engine Land
Limitations: A330, DC-9 Circ. Apch-VMC Only, English Proficient
MEDICAL CERTIFICATE FIRST CLASS (issued October 12, 2022)
Limitations: Must have available glasses for near vision.

3.0 Airplane Information

Figure 1: Accident Airplane, N393HA (courtesy of JetPhotos.net)

The accident airplane (Registration N393HA, Serial No. 1422) was an Airbus 330-243. The airplane was manufactured in 2013, registered to Hawaiian Airlines and held a transport category airworthiness certificate dated January 20, 2013, with an expiration date of June 30, 2029. The airplane was powered by 2 Rolls-Royce RR772B-60 engines. The airplane was configured with 2 pilot seats, 2 cockpit observer seats, 11 flight attendant seats, and 278 passenger seats.

3.1 A330 Dimensions

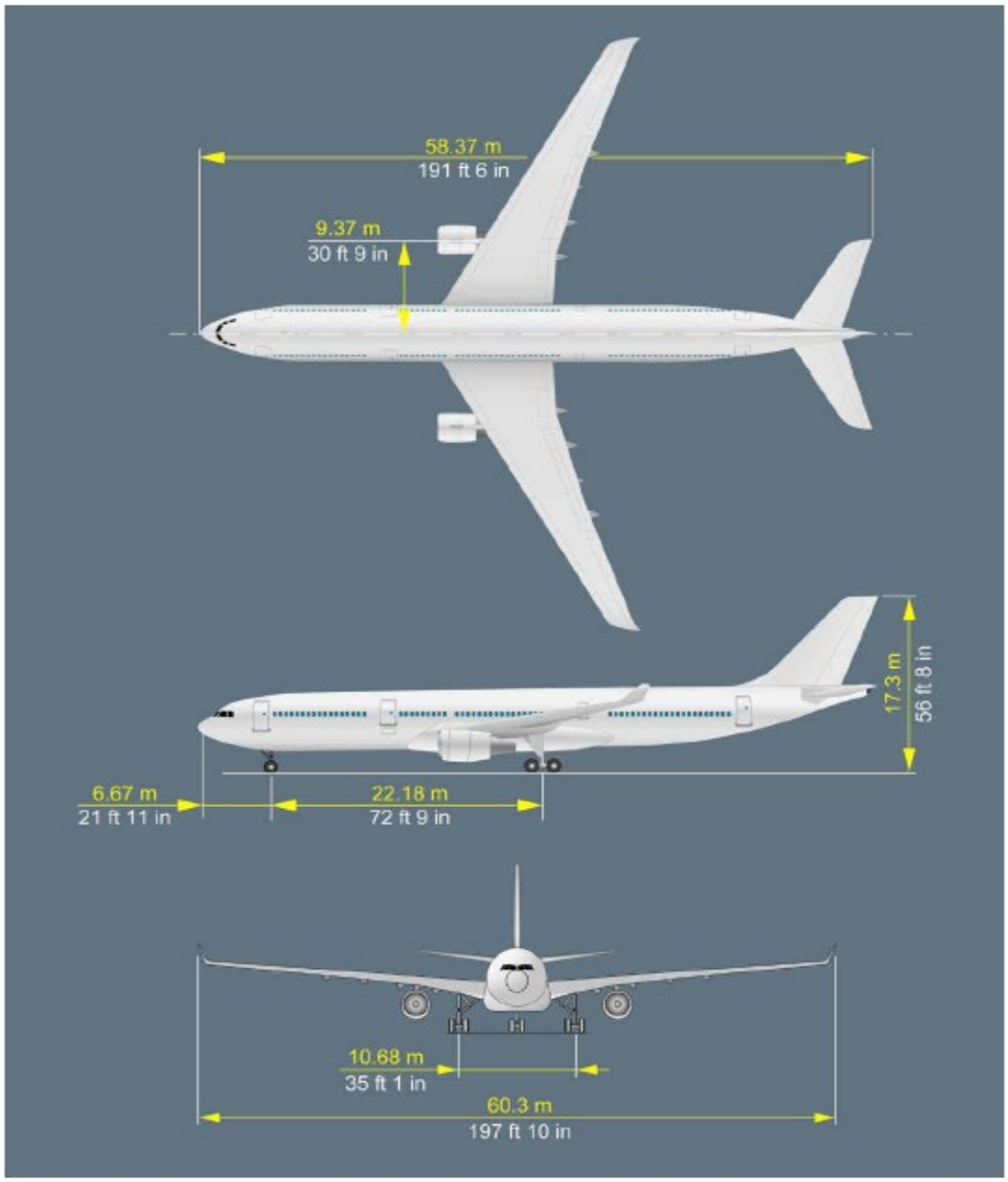

Figure 2: Aircraft Dimensions (Source: Hawaiian Airlines Flight Crew Operating Manual dated December 12, 2022.)

4.0 Hawaiian Airlines

According to the Hawaiian Airlines website[13] it was incorporated on January 30, 1929 under the name Inter-Island Airways Ltd. with the first scheduled flight being

[13] Source: History | Hawaiian Airlines

operated on November 11, 1929. The airline began operating passenger flights aboard a DC-9-10 in 1966 and then added the DC-9-50 in 1975. Hawaiian began operating scheduled service to the South Pacific in 1984 and the Transpacific flights in 1985. In 2001 Hawaiian began replacing the DC-9 with B-717 airplanes.

According to the Hawaiian Airlines general fact sheet, as of February 2024 they had 7,380 employees with an average of 225 daily flights based on the approximate average for the first quarter of 2024, to five island destinations which comprised of about 150 flights per day, 15 north American destinations and 10 international destinations. The airline has a total of 61 airplanes with 19 of those airplanes being the Boeing 717 and 42 being A330.

5.0 Flight Dispatch

5.1 Dispatch Meteorology

The Hawaiian Airlines Dispatch Procedures Manual (DPM) section 18.2, page 1 of 19, containing the following information about ensuring the dispatcher uses proper weather information and reporting methods in conducting daily flight operations.

- *The Dispatcher will not release a flight and the Pilot-in-Command (PIC) will not begin a flight unless they are thoroughly familiar with reported and forecast weather conditions on the route to be flown.*
- *HA uses approved weather sources listed in OpSpecs A010 to obtain weather reports and forecasts. Dispatch will utilize these services to control flight movement and to provide weather reporting along the HA route system.*
- *Before beginning a flight, the Dispatcher must provide the PIC with all available weather reports and forecasts of weather phenomena that may affect the safety of flight, including adverse weather phenomena, such as clear air turbulence, thunderstorms, and low altitude windshear for each route to be flown and each airport to be used.*
- *During a flight, the Dispatcher must provide the PIC any additional available information of meteorological conditions, including adverse weather phenomena, and irregularities of facilities and services that may affect the safety of the flight.*
- *No person will dispatch or release an aircraft, continue to operate an aircraft enroute, or land an aircraft when in the opinion of the PIC or the Dispatcher icing conditions are expected or met that might adversely affect the safety of the flight.*
- *No person will dispatch or release an aircraft into known or expected icing condition's unless all of the necessary deicing equipment is operable. The Dispatcher will review*

the MEL of the aircraft to prior to each flight to ensure the proper equipment is operative. If it is not, the dispatcher will advise the MOD in order to cancel or swap aircraft.

- *The PIC must notify an appropriate ground station, as soon as practicable, when the PIC encounters meteorological conditions or irregularities in ground facilities or navigation aids during flight, which the PIC considers essential to the safety of other flights.*

5.2 Weather Sources

Hawaiian Airlines provides the dispatcher with this list of approved weather sources and available weather reporting services for obtaining reports of adverse weather phenomena (such as clear air turbulence and thunderstorms) that could affect the safety of flight.

- *National Weather Service for the United States and its territories located outside of the 48 contiguous States.*
- *U.S. and North Atlantic Treaty Organization (NATO) military observing and forecasting sources.*
- *Members of the World Meteorological Organization (WMO)*
- *Active meteorological offices operated by a foreign state that subscribes to the standards and practices of the International Civil Aviation Organization (ICAO) conventions.*
- *A meteorological station or automated observation weather product authorized by an ICAO member state.*
- *For reports of adverse weather phenomena: Pilot Weather Reports (PIREP) provided by aircraft of the same, or similar, type and size.*
- *N-Flight Planning*
- *N-Tracking*
- *DTN*
- *Aviation Sentry*

5.3 Aircraft Enroute

The Hawaiian DPM provides the following guidance for the dispatcher to follow when an aircraft is enroute:

<table>
<tr><th>Step</th><th>Dispatcher</th></tr>
<tr><td>1</td><td>Monitor weather and operational conditions:
PIREPs
Forecasts
SIGMETs
Aircraft return for additional deicing or diverting around hazardous areas
Airport operations suspended</td></tr>
<tr><td>2</td><td>While flight is enroute:<table><tr><th>If....</th><th>Then....</th></tr><tr><td>Weather conditions become, in the opinion of the Dispatcher, operationally marginal or unsafe,</td><td>Determine potential routes or airports for diversion to avoid encountering unsafe icing conditions.
Establish contact with the Flight Crew to advise them of the situation and obtain aircraft fuel status.
Consult with the PIC on re-route or possible diversion.</td></tr></table></td></tr>
</table>

Figure 3: Dispatcher Enroute Requirements: Source Hawaiian Airlines

5.4 Dispatcher Requirements for Turbulence

The Hawaiian Airlines DPM has the following information for the dispatcher to follow dealing with turbulence:

Dispatchers must apply flight planning practices known to be effective against injury caused by turbulence.

- *No HA flight will be dispatched or operated through areas of known (PIREPs or OBS SEV TURB SIGMETs) severe turbulence. The Captain and the Dispatcher must agree on revised routing hat remains clear of known severe turbulence.*
- *No HA flight will be dispatched or operated through areas of forecast severe or moderate to severe turbulence (Prognosis Charts (Prog Charts) or FCST SEV TURB SIGMETs), unless in the opinion of the Captain and Dispatcher, other available information indicates the forecast turbulence is not likely to be encountered.*
- *Dispatchers will communicate with Pilots, and vice versa before, during, and after a flight, and are encouraged to do so whenever necessary. In the preflight planning phase, the Dispatcher will use the "Remarks" section of the dispatch release and an enhanced briefing if necessary to advise pilots of known or forecast turbulence. A "Please call for a brief" notation on the dispatch release may be included to indicate that the Dispatcher believes a telephone conversation with the PIC is as necessary. Communication may resume at any time during or after flight using ACARS, telephone or other HA approved communication method, and is encouraged by HA management to improve the flow of real-time information regarding turbulence.*

- *Preflight weather briefings, verbal or written, must include forecasts of turbulence and pilot reports (PIREPs) of turbulence caused by thunderstorm activity, mountain wave activity, clear air turbulence, low altitude frontal windshear and low altitude convective windshear.*
- *During a flight, the Pilot and Dispatcher must communicate any changes in the forecast or actual turbulence conditions via voice or digital communication methods in order to pass real-time turbulence information along to other flights. Dispatcher turbulence monitoring during the flight will be accomplished using NFP and N- Tracking.*

5.4.1 Turbulence Intensity / Aircraft Reaction

The Hawaiian Airlines DPM list four different levels of turbulence and aircraft reaction.

1. *LIGHT*
   - *Turbulence that momentarily causes slight, erratic changes in altitude and/or attitude (pitch, roll, yaw). Report as light turbulence.*
   - *Turbulence that causes slight, rapid, and somewhat rhythmic bumpiness without appreciable changes in altitude or attitude. Report as light chop.*
2. *MODERATE*
   A. *Changes in altitude and/or attitude occur, but the airplane remains in positive control at all times.*
   B. *Turbulence that is similar to light turbulence but of greater intensity. It usually causes variations in indicated airspeed. Report as moderate turbulence.*
   C. *Turbulence that is similar to light chop but of greater intensity. It causes rapid bumps or jolts without appreciable changes in altitude or attitude. Report as moderate chop.*
3. *SEVERE*
   A. *Turbulence that causes large, abrupt changes in altitude and/or attitude.*
   B. *It usually causes large severe variations in indicated airspeed. Airplane may be momentarily out of control. Report as severe turbulence.*
4. *EXTREME*

   A. Turbulence in which the airplane is violently tossed about and is practically impossible to control.

   NOTE

   Whenever a Pilot encounters a meteorological condition in-flight, the knowledge of which they consider to be essential to the safety of other flights, the PIC will notify an appropriate ground station (ATC or Dispatch) as soon as practical.

   B. Extreme may cause structural damage. Report as extreme turbulence.

6.0 Hawaiian Airlines Guidance

6.1 Severe Turbulence

The Hawaiian Airlines A330 Flight Crew Operating Manual, QRH, Severe Turbulence, Procedures Abnormal and Emergency Procedures, dated March 17, 2017, contained the following:

When possible, the flight crew should plan to fly above or around areas of severe turbulence. If turbulence is unavoidable, aim to keep the speed in the region of the target speed given in this section, so as to provide the best protection against the effect of gust on the aircraft structure, whilst maintaining an adequate margin above VLS.

Sufficient buffet margin exists at optimum altitude. In order to further increase the margin to buffet onset, consider descending to a lower altitude.

Severe turbulence is defined as turbulence that causes large, abrupt changes in altitude and/or attitude. It usually causes large variations in airspeed.

Occupants are forced violently against their seat belts and loose objects will move around the aircraft.
If severe turbulence occurs during flight, the flight crew must make a logbook entry in order to initiate maintenance action.

Before the aircraft enters an area where turbulence is expected:
- All loose equipment must be secured in the cockpit and in the cabin
- The flight crew must set the SEAT BELTS sw to ON.

Keep the autopilot ON.
When thrust changes are excessive: Disconnect Autothrust
For approach : Use Autothrust for managed speed.

6.2 Weather Radar

The Hawaiian Airlines, A330 Flight Crew Operating Manual, Weather Radar – General, p. PRO-NOR-SUP-NAV P3/24 contained the following:

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

The intensity of the weather echo is associated with the droplet size, composition and quantity (e.g. the reflectivity of a water particle is five times more than an ice particle of the same size). The flight crew must be aware that the weather radar does not detect weather that has small droplets (e.g. clouds or fog), or that does not have droplets (e.g. clear air turbulence).

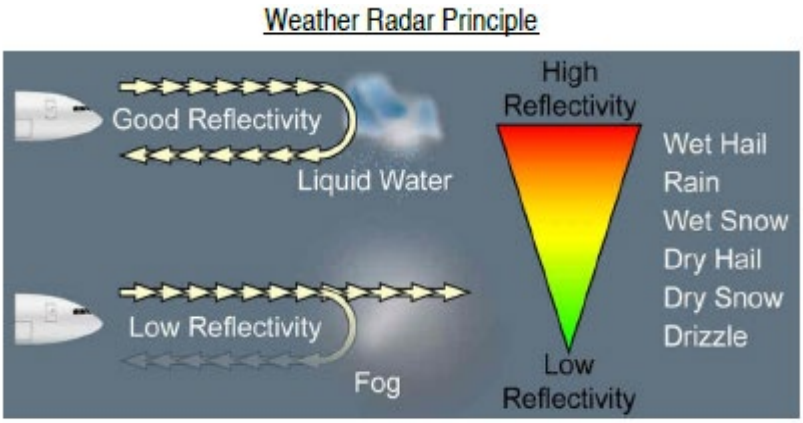

Figure 4: Reflective Weather Radar Description

The purpose of the weather radar is to help the flight crew detect and avoid storm cells (e.g. cumulonimbus). Due to its large vertical expansion, a storm cell does not have the same reflectivity depending on the altitude. The quantity of liquid water in the atmosphere decreases with the altitude. Therefore, the reflectivity of a storm cell decreases with the altitude.
The upper detection limit of the weather radar is called the radar top.
The flight crew must be aware of both of the following:

- *The radar top is not the visible top of the storm cell*
- *The storm cell and associated turbulence extend significantly above the radar top.*

6.2.1 Use of On Path and Elevation Display Modes

The Hawaiian Airlines, A330 Flight Crew Operating Manual, Weather Radar – General, p. 3/24 contained the following:

At high altitude, when the weather radar display mode is set to ON PATH (or PATH WX), any weather return (green, yellow, or red) should be considered as a potential threat.

In the case of low altitude weather, the flight crew can also use the ELEVN display mode, with an elevation setting above the low altitude weather, to identify the threatening storm cells.

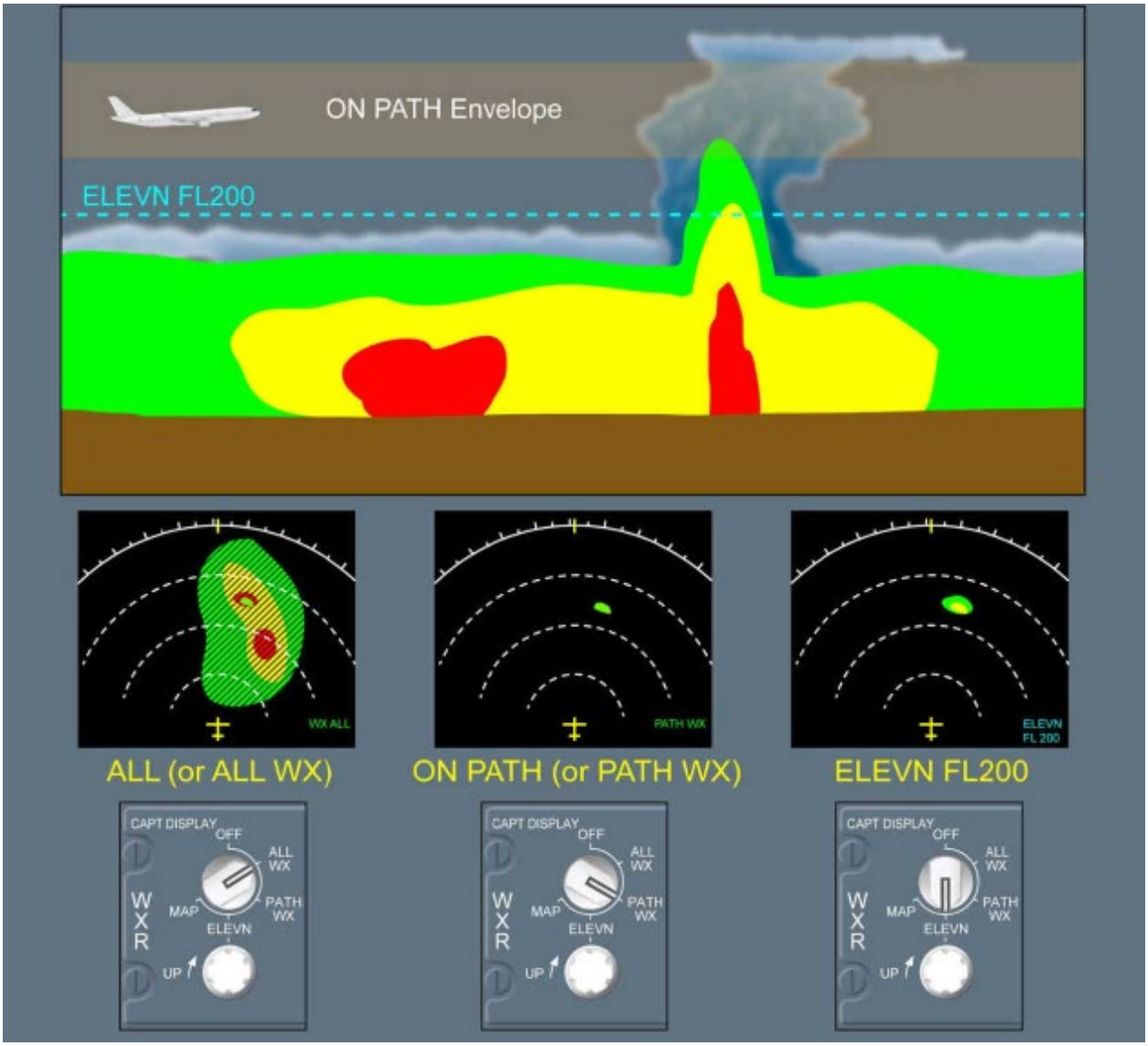

Figure 5: Depiction of All, On Path and Elevation Modes on the weather radar. (Source Hawaiian Airlines A330 Flight Crew Operating Manual)

6.3 Specific Weather Shapes

The Hawaiian Airlines, A330 Flight Crew Operating Manual, Weather Radar – General, p3/24 contained the following:

The flight crew should carefully observe shapes, more than colors, in order to detect adverse weather conditions.

Areas of different colors that are near to one another usually indicate zones of severe turbulence. Some shapes are good indicators of severe hail and signify strong vertical drafts. Shapes that change quickly, whatever form they take, also indicate high weather activity.

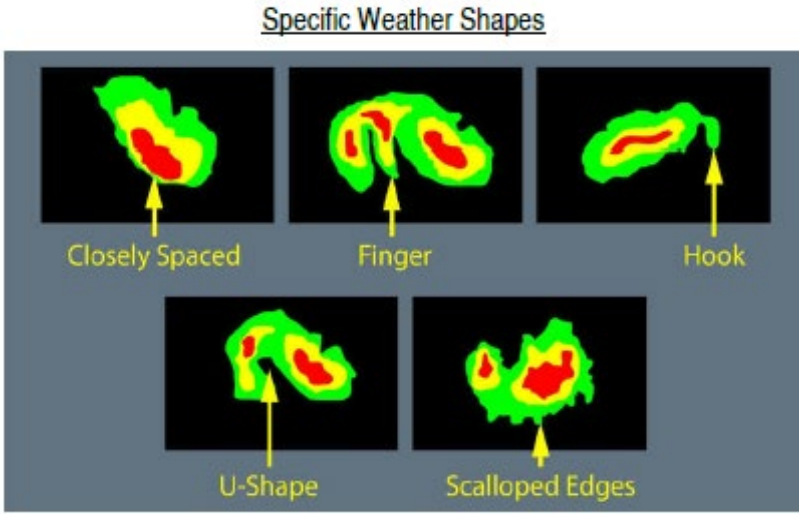

Figure 6: Specific Weather Radar Shapes (Source: Hawaiian Airlines A330 Flight Crew Operating Manual)

6.3.1 Blind Alley Effect

The flight crew should determine appropriate course changes to avoid adverse weather conditions, with the use of both high and short ND[14] ranges. This technique avoids the "blind alley effect", defined by the following: A course change that may appear safe with a short ND range, may be blocked when observed with a higher ND range.

[14] Navigational Display

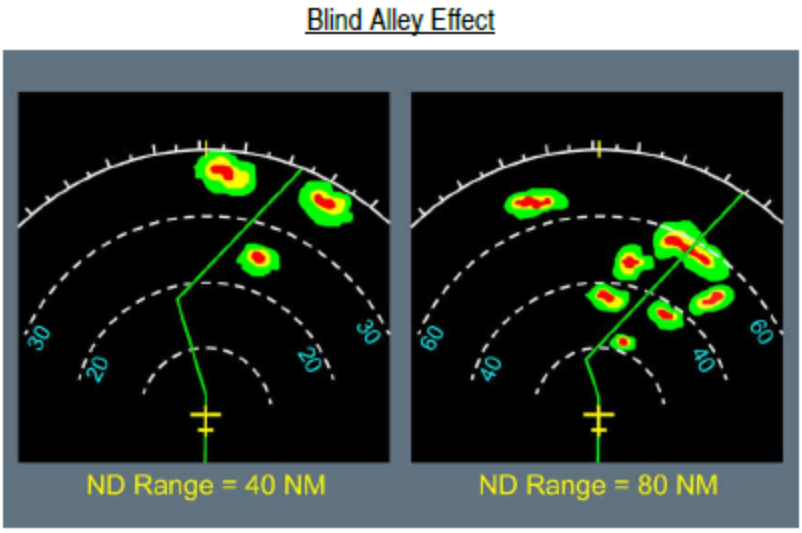

Figure 7: Weather Radar Depicting Blind Alley Effect. Source; Hawaiian Airlines A330 Flight Crew Operating Manual.

6.3.2 Attenuation Effect

The Hawaiian Airlines A330 Flight Crew Operating Manual advises the crews of the following:

In areas of heavy precipitation, an important part of the weather radar signal is reflected by the frontal part of the precipitation due to its strong reflectivity. Therefore, the area behind the precipitation returns low signals, that appears as green or black areas (storm shadows). Attenuation of long-distance weather or attenuation of ground returns can help the flight crew to identify an area of heavy precipitation that may be a very active storm cell.
Some radars provide an indication on the ND to highlight areas that may be affected by attenuation:

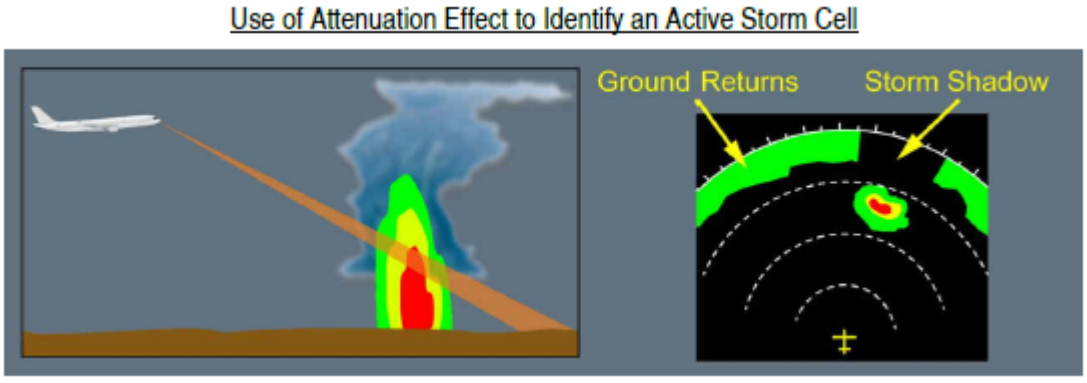

Figure 8: Photo of Attenuation Effect to Identify an Active Storm Cell (Source Hawaiian Airlines A330 Flight Crew Operating Manual.

6.3.3 Use of Manual Gain for Weather Analysis

The Hawaiian Airlines A330 Flight Crew Operating manual states the following.

To assess the general weather conditions, the flight crew can use manual gain. Manual gain adjusts the color calibration of the radar. Therefore, the weather will appear either stronger (gained increased) or weaker (gain reduced).

When operating in heavy rain, the weather radar picture can be saturated. In this case, manually reduce the gain will help the flight crew to identify the areas of heaviest rainfall, that are usually associated with active storm cells.

Note: *After a storm cell analysis, the flight crew must set the GAIN knob back to AUTO/CAL.*

Use of Reduced gain to Identify Heaviest Rainfall

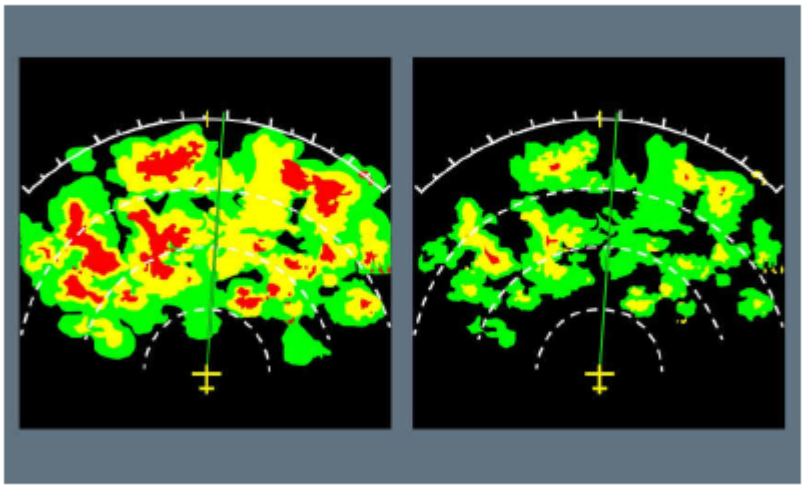

Figure 9: Photo of reduced radar Gain to Identify Heaviest Rainfall. Source: Hawaiian Airlines A330 Flight Crew Operating Manual.

6.3.4 Radar Interference

The Hawaiian A330 Flight Crew Operating manual states:

High power external radio frequency sources that operate at a frequency next to the frequency of the weather radar may create interferences. These interferences may result in a not usual return display on the ND. The radar return will appear as a single wedge that extends out along the ND toward the source of interference.
The width and color of the interference may differ on the ND, depending on the distance to the source and its strength.

This interference does not damage the radar system and will disappear as soon as the source of interference is outside the limit of the radar scan zone.

Note: *Radar interference may also be known as 'spoking' or 'alien radar'.*

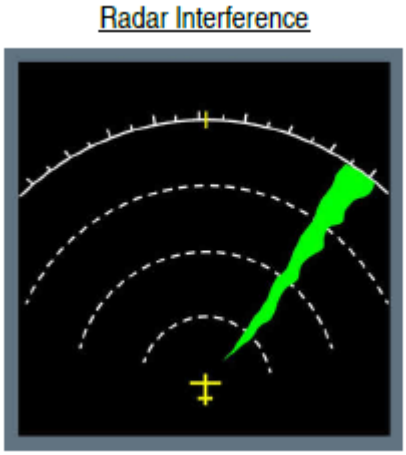

Figure 10: Photo of Radar Interference Source: Hawaiian Airlines A330 Flight Crew Operating Manual.

6.4 Weather Avoidance

The Hawaiian Airlines, A330 Flight Crew Operating Manual, Weather Radar – General, P11/24 contained the following:

GENERAL RECOMMENDATION

In the case of the detection of a significant storm cell, the flight crew should apply the following recommendations:

- *To avoid a large and active storm cell, the flight crew must make a decision at a distance of 40 NM from the storm cell*
- *The flight crew should deviate upwind instead of downwind of a storm cell (there is less probability of turbulence or hail)*
- *For storm cell avoidance planning, the flight crew should consider the height of the storm cell and apply the following:*
  - *Avoid all yellow, red, or magenta areas by at least 20 NM.*
  - *Avoid all green, yellow, red, and magenta areas of storm cells above 28 000 ft by at least 20 NM.*
  - *The flight crew should consider storm cells above 35 000 ft as highly hazardous. Therefore, the flight crew should apply an additional separation to the 20 NM already applied.*
- *If the top of the storm cell is at or above 25 000 ft, the flight crew should not overfly, because the aircraft may encounter turbulence stronger than expected*
- *The flight crew should not attempt to enter a storm cell, or overfly its top by less than 5 000 ft, because the aircraft may encounter severe turbulence*

- *In addition, the flight crew should not fly under a storm cell, because the aircraft may encounter shear, microburst, severe turbulence, or hail.*
- *The flight crew should avoid areas where attenuation is identified:*
    - *By radar attenuation effect*
    - *By the attenuation detection function of the radar*

- *For weather radars equipped with hazard prediction functions, avoidance of the detected weather always has priority over avoidance of the predicted hazards. The flight crew must apply standard storm avoidance recommendations in priority, and hazard areas should be avoided as much as possible.*

ENTRY IN TO A STORM CELL

In the case of storm penetration, the flight crew must take full advantage of the radar.

7.0 FAA Guidance

The FAA defines turbulence as *"air movement that normally cannot be seen and often occurs unexpectedly. It can be created by many different conditions, including atmospheric pressure, jet streams, air around mountains, cold or warm weather fronts or thunderstorms. Turbulence can even occur when the sky appears to be clear.*[15]

7.1 FAA Turbulence Fact Sheet

The FAA provided the following guidance titled "Fact Sheet – Turbulence" as of August 1, 2019, on their website:[16]

> ***What is turbulence?***
>
> *Clear air turbulence is air movement created by atmospheric pressure, jet streams, air around mountains, cold or warm weather fronts or thunderstorms. It can be unexpected and can happen when the sky appears to be clear.*
>
> ***What should passengers do to avoid injuries?***
>
> *Flying is the safest way to travel. Passengers can easily prevent injuries from unexpected turbulence by keeping their seat belt buckled at all times. The FAA's tips for staying safe:*
> - *Listen to the flight attendants. Pay attention to the safety briefing at the beginning of your flight and read the safety briefing card.*
> - *Buckle up. Keep you and your family safe by wearing a seat belt at all times.*

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

- *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.

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*

Year	Passenger	Crew	Total
2014	19	9	28
2015	11	16	27
2016	29	13	42
2017	9	8	17

Figure 11 showing Turbulence Injured Passengers by Year (Source FAA website)

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

7.2 Advisory Circular 120-88A

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

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

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

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

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

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

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

(1) Captain turns on seatbelt sign and makes a PA announcement, "F/As and passengers be seated immediately. Passengers, please remain seated until this area of turbulence has passed and I have cleared you to move about the cabin."
(2) Cabin crew take first available seat and secure themselves.
(3) No compliance checks are performed and items are secured only if they present no delay in securing a person in a seat.
(4) When conditions improve, captain makes PA announcement advising the cabin crew that they may resume their duties and whether or not the passengers may move about the cabin.

7.3 FAA Advisory Circular AS 00-03C Clear Air Turbulence Avoidance

FAA AC 00-30C[17] "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

[17] The FAA Advisory Circular AS 00-03C has now been cancelled effective 12-22-2022. The cancellation notice further states: All ACs dealing with weather have been consolidated into a new handbook in order to streamline access to the FAA's weather documentation for users of the National Airspace System (NAS).

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 wat 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)."

F. LIST OF ATTACHMENTS

Attachment 1: Flight Deck Crew Interview Transcripts
Attachment 2: Dispatcher Interview Transcript
Attachment 3: A330 Flight Crew Operating Manual [Excerpts]
Attachment 4: Dispatch Procedures Manual [Excerpts]

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