



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

October 2, 2018

Group Chairman's Factual Report

OPERATIONAL FACTORS

DCA17LA145

Table Of Contents

A.	ACCIDENT	4
B.	OPERATIONAL FACTORS GROUP	4
C.	SUMMARY	4
D.	DETAILS OF THE INVESTIGATION	4
E.	FACTUAL INFORMATION	5
1.0	History of Flight.....	5
2.0	Flight Crew Information	6
2.1	Captain	6
2.1.1	Captain's Pilot Certification Record	7
2.1.2	Captain's Certificates and Ratings Held at the Time of the Accident	8
2.1.3	Captain's Training and Proficiency Checks Completed	8
2.1.4	Captain's Flight Time.....	8
2.2	First Officer.....	9
2.2.1	First Officer's Pilot Certification Record.....	9
2.2.2	First Officer's Certificates and Ratings Held at the Time of the Accident	11
2.2.3	First Officer's Training and Proficiency Checks	11
2.2.4	First Officer's Flight Time	11
3.0	Airplane Information	12
3.1	Weight and Balance	12
3.2	Crosswind Limitation.....	13
4.0	Meteorological Information.....	14
5.0	Airport Information.....	14
5.1	Airport Diagram.....	15
5.2	Runway Information	15
5.3	Charts	16
6.0	Company Overview	17
7.0	Relevant Airplane Systems	18
7.1	Flaps.....	18
7.2	ECAM Audio Indicators	18
7.2.1	Dual Input.....	19
7.3	Flight Controls	20
7.4	Flight Control Laws	20
7.4.1	Normal Law.....	20

7.4.1.1	Ground Mode	21
7.4.1.2	Flight Mode	22
7.4.1.3	Flare Mode	22
7.4.1.4	Normal Law Protections.....	22
7.4.2	Alternate Law	23
7.4.2.1	Ground Mode	23
7.4.2.2	Flight Mode	23
7.4.2.3	Flare Mode	23
7.4.3	Direct Law.....	23
7.5	Pitch Limit Indicator	23
8.0	Delta Air Lines Guidance	25
8.1	Initial Operating Experience	25
8.2	Operation Experience (OE) Guide.....	26
8.2.1	Flare Maneuver	26
8.2.2	Tailstrike Avoidance	26
8.3	Stabilized Approach.....	27
8.4	Exterior Inspection – Captain or First Officer	28
8.5	Descent Checklist.....	30
8.6	Approach Briefing	30
8.6.1	Flight Crew Training Manual.....	31
8.6.2	Landing Flare Profile	33
8.7	Ground Contact Angles – Normal Landing.....	33
9.0	Airbus Guidance	35
9.1.1	Avoiding Tail Strike.....	35
9.1.2	Flight Operations Briefing Notes	37
10.0	Company Procedural Guidance	38
F.	LIST OF ATTACHMENTS	38

A. ACCIDENT

Location: Atlanta, Georgia
Date: June 23, 2017
Time: 1338 Eastern Daylight Time (EDT)
1738 Universal Time Coordinate (UTC)
Airplane: Airbus A-321-211, N315DN

B. OPERATIONAL FACTORS GROUP

Shawn Etcher - Chairman Operational Factors Division (AS-30) National Transportation Safety Board 490 L'Enfant Plaza East, SW Washington, DC 20594-2000	Patrick Hempen AVP-100 Federal Aviation Administration (FAA) 800 Independence Ave. SW Washington, DC 20591
Rai Jennings Airbus A-320 Checkairman Delta Air Lines, Inc. 1775 MH Jackson Service Road Atlanta, GA 30354	Michael Schilz Airbus A-320 Captain Air Line Pilots Association (ALPA) 535 Herndon Parkway Herndon, VA 20170

C. SUMMARY

On June 23, 2017, about 1338 eastern daylight time (EDT), Delta Air Lines flight 800, an Airbus A321-211, registration N315DN, experienced a tail strike during landing at Hartsfield-Jackson Atlanta International Airport (ATL), Atlanta, Georgia. The 192 passengers and 7 crew members¹ were uninjured. The airplane sustained substantial damage to airframe. The airplane was registered to Bank of Tokyo-Mitsubishi UFJ LTD and operated by Delta Air Lines, as "Delta 800" under the provisions of 14 *Code of Federal Regulations* Part 121. The flight departed from Boston Logan International Airport (BOS), Boston, Massachusetts, about 1057 EDT.

D. DETAILS OF THE INVESTIGATION

The National Transportation Safety Board (NTSB) investigator on the Operational Factors Group was assigned to the accident on Tuesday June 27, 2017 and did not travel to the accident scene. The group chairman was briefed by the Investigator in Charge (IIC) on the events surrounding the accident. An Operational Factors Group was formed with party members from the FAA, Delta Air Lines (Operator), and ALPA assigned.

The Operational Factors Group requested from the operator, manuals and other various items for the investigation, as well as notifying the operator that the Operational Factors Group would be interviewing the flight crew.

¹ The jumpseat pilot (also known as an Additional Crew Member - ACM) was included with the crew member count.

On Monday, July 3, 2017, the Operational Group interviewed both the event first officer and event captain, via separate conference calls.

Flight documents and company manuals were requested from Delta Air Lines, Inc.

E. FACTUAL INFORMATION

1.0 History of Flight

The flight crew reported for duty on the day of the accident at 1002 in Boston Logan International Airport (BOS), Boston, Massachusetts. The accident flight was the first flight of the day for the flight crew.

The first officer performed the walk around in BOS, prior to departure. According to the first officer, there was no damage noted to the tail section nor any other notable discrepancies during the walk around.

According to the captain, the accident flight was the third day of a four-day Operating Experience (OE)² trip, with the first officer receiving the OE training. The first officer was the pilot flying for the accident flight. He described the pushback, taxi out and takeoff as uneventful, but discussed with the first officer during the enroute portion of the flight, that the rotation rate, on takeoff, was 3.2 degrees per second and that he felt 2.6 to 3.1 degrees per second was an optimal rotation rate.

According to both pilots, the wind was out of the southwest at 12 knots with gusts of 20 knots and they landed on runway 26R. The first officer briefed the anticipated visual approach prior to the descent into ATL, the use of full flaps, and they elected to hand fly the approach without the use of the flight director and autopilot, but the auto thrust remained engaged.

According to the captain, the first officer was slightly delayed in beginning the descent; however, was able to recapture the glide slope. Both pilots reported that the airplane was stabilized during the approach and that there were no “abnormal changes” in the airspeed. The captain reported that due to the approach speed being in close proximity to the V_{LS}³ “hook” he elected to manually program the flight management computer (FMC) for an approach speed of 3 knots faster, and he informed the first officer of that action.

According to the first officer, the accident flight was her fourth landing in the A-320 series aircraft and her first in an A-321. She described the landing as “firm” and that she thought she was about a second late in getting the thrust reversers deployed. She further stated that during the landing flare the captain commanded “pull back pull back” prior to touchdown; however, both crew members reported there were no other audible warnings, and that they were looking outside, down the runway, and did not know if the pitch limit indicator was visible.

² Operating Experience (OE) is the final step in the qualification process and quite possibly an individual’s first exposure to line operations in his/her new position. Source: Delta Air Lines Flight Standards Pilot Manual pg. 75

³ Minimum speed auto thrust will maintain.

A company pilot, seated in the cockpit jumpseat, reported that it was a “completely normal flight from pushback to descent” and the captain was instructing the “many nuances” of the Airbus A-321 to the accident first officer. As the flight neared the destination there was a “brief” discussion about landing and that the descent and arrival were “uneventful up until the flare.” At which point “the F/O [First Officer] never really performed any type of flare maneuver even as the Captain repeatedly called for the F/O to perform one.”⁴

After the aircraft was parked at the gate and the cockpit door was opened, a flight attendant reported that it sounded as though a tire had burst. The first officer subsequently, looked at both main landing gear and the nose gear, but the tires were all inflated. The first officer did not perform a post-flight walk around as the airplane was scheduled out soon after they arrived and that they were not required to perform a post-flight walk around⁵.

The captain reported that about 45 minutes after they had parked at the gate, he had received a phone call from the A-320 fleet captain notifying him that the airplane appeared to have incurred a tail strike. The captain notified the first officer and they both went to verify that the airplane had incurred a tail strike.

2.0 Flight Crew Information

Documentation provided by Delta Air Lines showed that the accident flight occurred on day 3 of a 3-day crew rotation.⁶ The first day of the rotation began with a report time of 1459 and included 3 flights with a 13-hour layover. The second day (day preceding the accident flight) began with a report time of 1320 CDT⁷ with a deadhead to MSP then operated a flight to BOS, where the crew had an 11:57 layover. On the day of the accident the crew had a report time of 0957. The rotation was considered an Initial Operating Experience (IOE) rotation.

2.1 Captain

The captain was 62 years old and held an Airline Transport Pilot (ATP) certificate with a rating for airplane multiengine land with type ratings in the A-320⁸, A-330⁹, B-707¹⁰, B-720, B737¹¹. He also held a commercial pilot certificate for airplane single-engine land. He held an FAA first-class

⁴ Source: Operational Factors - Attachment 2 – Jumpseat Pilot Written Statement.

⁵ The crew is to accomplish the “Secure Procedure” checklist “*when the aircraft is to remain for two hours or more.*” Source: Delta Air Lines A319/320/321 Volume 1 pg. NP.20.64.

⁶ The captain reported it was day 3 of a 4-day trip, following the event the crew was removed from the remainder of their trip.

⁷ Central Daylight Time which is EDT minus 1 hour.

⁸ Airbus (formerly known as Groupement d’Inerte Economique Airbus Industries, France) A-318, A-319, A-320, A-321. Source: FAA Order 8900.1 Figure 5-88.

⁹ Airbus (formerly known as Groupement d’Inerte Economique Airbus Industries, France) A-330-200/300 Series, A-330-200F. Source: FAA Order 8900.1 Figure 5-88.

¹⁰ The Boeing Company, 707-100 Long Body, 707-100B Long Body, 707-100B Short Body, 707-200, 707-300, 707-300B, 707-300C, 707-400, 720 Series, 720B series and includes military designators KC-135 (all variants), C-135, C-18B, E3-A/B/C, E6-A/B, E-8C, EC-18B, EC-18D, VC-137. Source: FAA Order 8900.1, Figure 5-88.

¹¹ The Boeing Company, B-737-100, B-737-200, B737-300, B-737-400, B737-500, B737-600, B-737-700C, B-737-800, B737-900. Source: FAA Order 8900.1, Figure 5-88.

medical certificate, dated January 13, 2017 with the limitation that he must wear corrective lenses, which he reported he was wearing at the time of the accident.

At the time of the accident he was based at Detroit-Wayne Metro International Airport (DTW), Detroit, Michigan.

According to the captain's interview, he had approximately 20,000 hours of total flight experience, of which about 4,500 of those hours were in the A-320 series aircraft, and about 1,800 hours as a PIC¹² in the A-320 series. He further reported that he was originally hired by Northwest Airlines¹³ on May 4, 1996, he began flying the A-320 series in 2004, which he operated as a first officer for about 2 years, flew another aircraft type for about 7 years and then about 3 years prior to the accident became a captain on the A-320 series. He had been a check airman on the A-320 series since about January 2015.

He was conducting IOE with the accident first officer and was the pilot monitoring on the accident flight.

2.1.1 Captain's Pilot Certification Record

FAA records of the accident captain indicated the following:

Commercial Pilot – Airplane Multiengine Land Limited to Center Thrust, Instrument – Airplane certificate was issued on November 22, 1977.¹⁴

Commercial Pilot – Airplane Single-Engine Land, Airplane Multiengine Land Limited to Center Thrust, Instrument – Airplane certificate was issued on December 29, 1977.

Flight Instructor – Airplane Single-Engine certificate was issued on September 26, 1981.

Flight Instructor – Airplane Single-Engine, Instrument Airplane certificate was issued on September 30, 1982.

Commercial Pilot – Airplane Single-Engine Land, Airplane Multiengine Land; B-707, B-720, Instrument – Airplane certificate was issued on October 13, 1982.

Airline Transport Pilot – Airplane Multiengine Land; B-707, B-720, B-737, Commercial Privileges, Airplane Single-Engine Land certificate was issued on May 19, 1995.

Flight Engineer – Turbojet Power certificate was issued on June 9, 1998.
Reissued July 13, 1998.

¹² Pilot in Command

¹³ Northwest Airlines merged with Delta Air Lines and began a single operation on January 31, 2009.

¹⁴ According to FAA AC Form 8060-58 the certificate was issued based on "Military Competence."

Airline Transport Pilot – Airplane Multiengine Land; A-320, B-707, B-720, B-737, Commercial Privileges, Airplane Single-Engine Land; A-320 SIC¹⁵ Privileges Only certificate was issued on May 10, 2006.

Airline Transport Pilot – Airplane Multiengine Land; A-330, A-320, B-707, B-720, B-737, Commercial Privileges, Airplane Single-Engine Land; A-320 SIC Privileges Only certificate was issued on May 25, 2007.

Airline Transport Pilot – Airplane Multiengine Land; A-330, A-320, B-707, B-720, B-737, Commercial Privileges, Airplane Single-Engine Land; English Proficient, A-320 Circling Approach VMC¹⁶ Only certificate was issued on May 13, 2014.

2.1.2 Captain's Certificates and Ratings Held at the Time of the Accident

Airline Transport Pilot (issued May 13, 2014)

Airplane Multiengine Land

Type ratings in the A-330, A-320, B-707, B-720, and B-737

Commercial Pilot (issued October 13, 1982)

Airplane Single-Engine Land

Flight Engineer (issued July 13, 1998)

Turbojet Powered

Medical Certificate – First Class (issued January 13, 2017)

Limitations: Must wear corrective lenses for near and distant vision.

2.1.3 Captain's Training and Proficiency Checks Completed

A synopsis of the captain's recent training at Delta Air Lines is as follows¹⁷:

Captain Upgrade	March 13, 2014
QCQ – Quarterly Continuing Qualification	January 17, 2017
LC – Route/Line Check	April 23, 2017
Proficiency Check - Simulator	February 21, 2017
MV/SIM – Maneuvers Validation	February 20, 2017
LFAA – Check Airman Authorization – FAA	January 27, 2015

2.1.4 Captain's Flight Time

The Captain's flight times based on pilot's interview summary and Delta Air Lines provided documentation:

¹⁵ Second-in-Command.

¹⁶ Visual Meteorological Conditions.

¹⁷ Source: Delta Air Lines for further information see Operational Factors Group – Attachment 3 – Flight Crew Training and Recent Flight Records.

Total flying experience ¹⁸	20,000 hours
Total flying experience A-320 series	1,796 hours
Total flight experience A-321	25:06 hours
Total PIC flying experience	1,796 hours
Total flying time preceding 24 hours ¹⁹	5:31 hours
Total flying time last 7 days	17:56 hours
Total flying time last 60 days	159:30 hours
Total flying time last 90 days	184:00 hours

The captain reported that it was the third day of a 4-day pairing, and that the accident flight was the first leg in which the first officer had operated an A-321 aircraft. The accident flight was the first leg of the day.

2.2 First Officer

The FO was 29 years old. Her date of hire with Delta was October 5, 2015. Prior to Delta Air Lines, the first officer was employed by Shuttle America for about one year. The FO had been continuously employed at Delta Air Lines since her date of hire and had been an FO on the Boeing 717 aircraft prior to transitioning to the A-320 series aircraft. She had no other duties at Delta Air Lines. She estimated she had between 5,500 and 6,000 hours of total flight experience, of which approximately 2.8 hours were in the A321.

According to the FO, she had never been involved in any accidents or incidents.

The FO held an ATP certificate with type ratings for the DC-9, DHC-8 (Second in Command Only), and ERJ-170/190. She held an FAA first-class medical certificate, issued in March 2017, with no limitations.

At the time of the accident, the FO was based in DTW.

Prior to Shuttle America, the FO flew for Piedmont Airlines, and previously was a flight instructor at Purdue University.

2.2.1 First Officer's Pilot Certification Record

FAA records of the first officer indicated the following:

Private Pilot – Airplane Single-Engine Land certificate was issued January 7, 2005.

Private Pilot – Airplane Single-Engine Land; Instrument Airplane certificate was issued April 18, 2006.

¹⁸ Pilot estimated total flying experience.

¹⁹ Flight time includes the accident flight. Source: Delta Air Lines.

Notice of Disapproval – Commercial Pilot Airplane Single-Engine Land was issued on May 1, 2006. Areas for reexamination: Area of Operation IV, Tasks A&B; Area of Operation V, Task C.

Commercial Pilot – Airplane Single-Engine Land; Instrument Airplane certificate was issued on May 1, 2006.

Notice of Disapproval – Commercial Pilot Airplane Multiengine Land certificate was issued on November 10, 2006. Areas for Reexamination: Area of Operation VIII, Task C.

Commercial Pilot – Airplane Single- and Multiengine Land; Instrument Airplane certificate was issued on November 15, 2006.

Flight Instructor – Airplane Single-Engine certificate was issued on August 2, 2007.

Flight Instructor – Airplane Single-Engine; Instrument Airplane certificate was issued on May 3, 2008.

Commercial Pilot – Airplane Single & Multiengine Land; Instrument Airplane; DHC-8; Limitation: English Proficient; DHC-8²⁰ SIC Privileges Only certificate was issued on July 27, 2011.

Flight Instructor – Airplane Multiengine; Airplane Single-Engine; Instrument Airplane certificate was issued on September 26, 2011. Renewed on September 3, 2013 and September 14, 2015.

Commercial Pilot – Airplane Single & Multiengine Land; Instrument Airplane; DHC-8, ERJ-170²¹, ERJ-190; Limitation: English Proficient; DHC-8, ERJ-170, ERJ-190 SIC Privileges Only; ERJ-170, ERJ-190 Circling Approaches – VMC Only certificate was issued on June 14, 2012.

Notice of Disapproval – Airline Transport Pilot – Airplane Multiengine Land; ERJ-170 and ERJ-190 certificate issued on April 1, 2013. Areas for reexamination included: Emergency Procedures; Zero Flap Landing; Two-Engine Go-Around.

Airline Transport Pilot – Airplane Multiengine Land; DHC-8; ERJ-170; ERJ-190; Commercial Pilot Privileges; Airplane Single-Engine Land; Limitations: Engine Proficient; ATP Circling Approach VMC Only; ERJ-170, ERJ-190 Circling Approach – VMC Only; DHC-8 SIC Privileges Only certificate was issued on April 29, 2013.

Airline Transport Pilot – Airplane Multiengine Land; DC-9; DHC-8; ERJ-170; ERJ-190; Commercial Pilot Privileges; Airplane Single-Engine Land; Limitations: Engine Proficient; ATP Circling Approach VMC Only; ERJ-170, ERJ-190, DC-9 Circling Approach – VMC Only; ERJ-

²⁰ Bombardier Inc. DHC-8-100 Series, DHC-8-200 Series, DHC-8-300 Series, DHC-8-400 Series. Source: FAA Order 8900.1 Figure 5-88.

²¹ Embraer S.A. ERJ-170-100 STD, ERJ 170-100 LR, ERJ 170-100 SU, ERJ 170-100 SE, ERJ 170-200 STD, ERJ 170-200 LR, ERJ 170-200 SU, ERJ 190-100 STD, ERJ 190-100 LR, ERJ 190-100 IGW, ERJ 190-100 ECJ, ERJ 190-200 STD, ERJ 190-200 LR, ERJ 190-200 IGW. Source: FAA Order 8900.1 Figure 5-88.

170 ERJ-190 Circling Approach – VMC Only; DHC-8 SIC Privileges Only certificate was issued on December 5, 2015.

Airline Transport Pilot – Airplane Multiengine Land; A-320; DC-9; DHC-8; ERJ-170; ERJ-190; Commercial Pilot Privileges; Airplane Single-Engine Land; Limitations: Engine Proficient; ATP Circling Approach VMC Only; ERJ-170, ERJ-190, DC-9 Circling Approach – VMC Only; ERJ-170 ERJ-190 Circling Approach – VMC Only; DHC-8 SIC Privileges Only certificate was issued on June 17, 2017.

2.2.2 First Officer’s Certificates and Ratings Held at the Time of the Accident

Airline Transport Pilot (issued June 17, 2017)

Airplane Multiengine Land

Type ratings in the A-320, DC-9, DHC-8, ERJ-170, ERJ-190

Limitations: ATP/A-320, DC-9, ERJ-170, ERJ-190 circle approach in VMC only; DHC-8 SIC privileges only

Commercial Pilot (issued June 14, 2012)

Airplane Single-Engine Land

Flight Instructor (renewed September 14, 2015)

Airplane Single-Engine

Airplane Multiengine

Instrument Airplane

Medical Certificate – First Class (issued March 10, 2017)

Limitations: None

2.2.3 First Officer’s Training and Proficiency Checks

A synopsis of the FO’s recent training at Delta Air Lines is as follows²²:

INDOC – Initial Basic Indoctrination	October 5, 2015
LOE – Line Oriented Evaluation	June 17, 2017
MV – Maneuvers Validation	June 10, 2017
PV – Procedure Evaluation (Simulator)	June 3, 2017
SV -System Evaluation (Online)	May 25, 2017

2.2.4 First Officer’s Flight Time

The First Officer’s flight times based on Delta Air Lines provided documentation and pilot interview summaries:

Total flying experience ²³	5564:31 hours
---------------------------------------	---------------

²² Source: Delta Air Lines for further information see: Operational Factors Group – Attachment 3 – Flight Crew Training and Recent Flight Records.

²³ Flight time is an approximation based on the FO’s airline application of 4,572 hours of total flight experience plus 992:31 hours of flight experience at Delta Air Lines.

Total Delta Air Lines flight experience	992:31 hours
Total flying experience A-320 series	9:55 hours
Total flight experience A-321	2:49 hours
Total flying time preceding 24 hours ²⁴	5:31 hours
Total flying time last 7 days	11:44 hours
Total flying time last 60 days	11:44 hours
Total flying time last 90 days	97:55 hours

3.0 Airplane Information

The accident airplane (Registration N315DN, Serial No. 7436) was an Airbus A-321-211. The airplane was built in 2016, registered to Wells Fargo Bank Northwest, National Association, leased to Delta Air Lines, Inc. on December 6, 2016, and held a transport category airworthiness certificate dated December 7, 2016. The airplane was powered by 2 CFM56-5B3/3 engines and each were rated at 33,000 pounds of takeoff thrust. The airplane was configured with 2 pilot seats, 2 cockpit observer seats, 4 flight attendant seats, and 192 passenger seats.



Photo 1: Courtesy of JetPhotos.net website

According to the Delta Air Lines A319/320/321 Operations Manual, Chapter DF “Differences” Section 11 “A321 Differences,” the A321 was about 23 feet longer than the A320 and was *“equipped with double-slotted flaps versus single-slotted on the A320. This permits a slightly lower deck angle for takeoff and landing.”*

3.1 Weight and Balance

Delta Air Lines was authorized under their Operations Specifications (OpSpecs)²⁵ to use actual weights or a combination of actual, standard average (or segmented), or survey-derived average weights. For Domestic operations the standard weights used were 190 pounds per passenger in the

²⁴ Flight time includes the accident flight. Source: Delta Air Lines.

²⁵ Per Ops Spec A099 "Large Cabin Aircraft Passenger and Baggage Weight Program."

summer and 195 pounds per passenger in the winter. For checked baggage the weight used was 30 pounds and for "heavy" baggage the weight used was 60 pounds.

Manufacturer's Airplane weight limitations were in the Delta Air Lines A321-200 "Aircraft Loading Manual," dated February 12, 2016, pg. 3 and the Delta Air Lines "A319/320/321 Operations Manual," in the "Limitations- Operating Limitations" section pg. L.10.3, dated November 18, 2016, and are indicated in **bold** type below.

Aircraft Basic Operating Weight (BOW) ²⁶	109,840
Total Passenger Weight ²⁷	36,480
Total Cargo Weight	4,474
Maximum Zero Weight	162,701
Zero Fuel Weight	150,794
Fuel Weight	23,650
Estimated Taxi Fuel	604
Ramp Weight	175,048
Maximum Ramp Weight	197,093
Maximum Takeoff Weight (Structural)	196,211
Maximum Allowable Takeoff Weight ²⁸	184,792
Actual Takeoff Weight	174,444
Estimated Fuel Burn	15,238
Maximum Landing Weight	171,519
Estimated Landing Weight	159,206
Takeoff Center of Gravity (CG)	21.3% MAC
CG Limits (per Airplane Flight Manual)	20.9-35.6%
V _{REF} ²⁹ Flaps Full	137 knots

3.2 Crosswind Limitation

The Delta Air Lines A319/320/321 Operations Manual "Limitations – Operating Limitations," pg. L.10.2, provided the following excerpted chart wind limits:

²⁶ The Aircraft BOW was determined by the maintenance department and includes the following weights: Aircraft configures with 20 first class seats and 172 cabin class seats, 2 pilots with flight kits and bags, 4 flight attendants and bags, Galley cart and supplies, domestic level catering. Source Delta Air Lines A321-200 "Aircraft Loading Manual," dated February 12, 2016 pg. 3.

²⁷ Estimate based on a 190- pound average weight per passenger.

²⁸ This was limited by aircraft performance.

²⁹ V_{REF} was defined as 1.3 times the stalling speed in the stated landing configuration and at the prevailing aircraft weight. This is the speed required as the landing runway threshold is crossed at a height of 50 feet in landing configuration if the calculated aircraft performance is to be achieved. Source: Skybrary [https://www.skybrary.aero/index.php/Reference_Speed_\(Vref\)](https://www.skybrary.aero/index.php/Reference_Speed_(Vref))

# Delta A319/320/321 crosswind limit for takeoff or landing Note: The crosswind component may be further limited by low visibility approaches, contamination, or runway width. Note: Refer to SP.16, Guidelines for Takeoff on Contaminated Runways or Landing with Braking Action Less than Good.	38 kts (including gusts)
# Maximum Takeoff and Landing Tailwind Component	10 knots, or as permitted by the Company Pages.

Figure 1:Delta Air Lines Crosswind Limitation

4.0 Meteorological Information

Airport weather observations for ATL were obtained from the National Weather Service. Airport weather information found in the METAR³⁰ for ATL originated from an Automated Surface Observing System (ASOS). The following METARs were issued for ATL for the time period surrounding the accident:

[1252 EDT] METAR KATL 231652Z 24011G21KT 10SM SCT035 SCT100 BKN150 BKN250 29/21 A3001 RMK AO2 SLP 150 T02940211=

[1352 EDT] METAR KATL 231752Z 19012G24KT 10SM FEW040 SCT090 BKN250 29/21 A2999 RMK AO2 SLP 143 T02940206 10300 20233 58014=

5.0 Airport Information

Hartsfield- Jackson Atlanta International Airport (ATL) was the main commercial airport for the city of Atlanta, Georgia. It is located about 7 miles to the south of downtown Atlanta at 33°38.20N by 84°25.67W. The airport elevation was 1,026 feet msl³¹ and had five paved runway surfaces. The runways were all oriented in an east and west direction.

According to FAA records, the airport was owned by the City of Atlanta. The airport had an operating FAA air traffic control tower (ATCT) that operated continuously and was in operation at the time of the accident.

³⁰ Meteorological Aerodrome Report.

³¹ mean sea level.

5.1 Airport Diagram

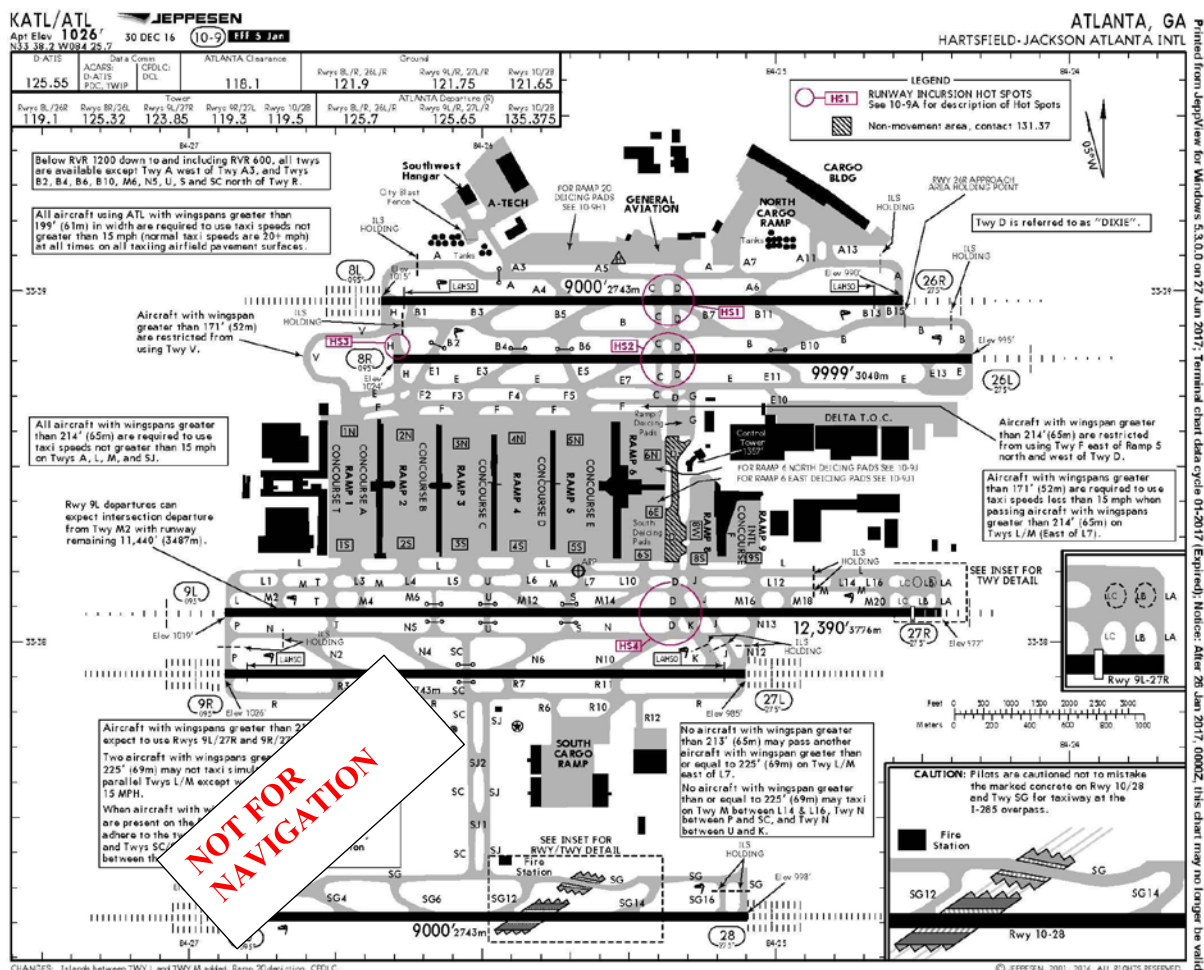


Figure 2: Jeppesen Airport Diagram of Hartsfield-Jackson Atlanta International Airport

5.2 Runway Information

Runway 8L/26R was 9,000 feet long and 150 feet wide and was grooved concrete. Runway 26R had 8,800 feet available for landing. Runway 26R was equipped with MALSR³² and had a 4-light Precision Approach Path Indicator (PAPI), with a charted 3.00° glide path, located on the left side of the runway.

According to the Aeronautical Information Manual Pilot/Controller Glossary, the precision approach path indicator (PAPI) was an airport lighting system, similar to a VASI, providing vertical approach slope guidance to aircraft during approach to landing. PAPIs consisted of a single row of either two or four lights, normally installed on the left side of the runway, and had an effective visual range of about 5 miles during the day and up to 20 miles at night. PAPIs radiated a directional pattern of high intensity red and white focused light beams which indicated that the flight is "on path" if the pilot sees an equal number of white lights and red lights, with white to the

³² Medium Approach Light System with Runway Alignment Indicator Lights.

left of the red; "above path" if the pilot sees more white than red lights; and "below path" if the pilot sees more red than white lights.

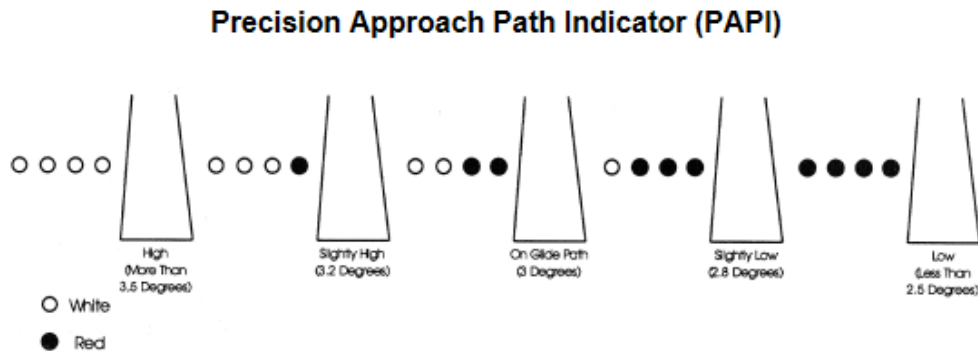


Figure 3: Precision Approach Path Indicator³³

5.3 Charts

According to crew interview statements, they used the ILS³⁴ approach to back up their visual approach clearance to runway 26R. The ILS 26R was equipped with a 3.00° glide slope and DME³⁵.

³³ Aeronautical Information Manual Chapter 2 Figure 2-1-5.

³⁴ Instrument Landing System

³⁵ Distance Measuring Equipment.

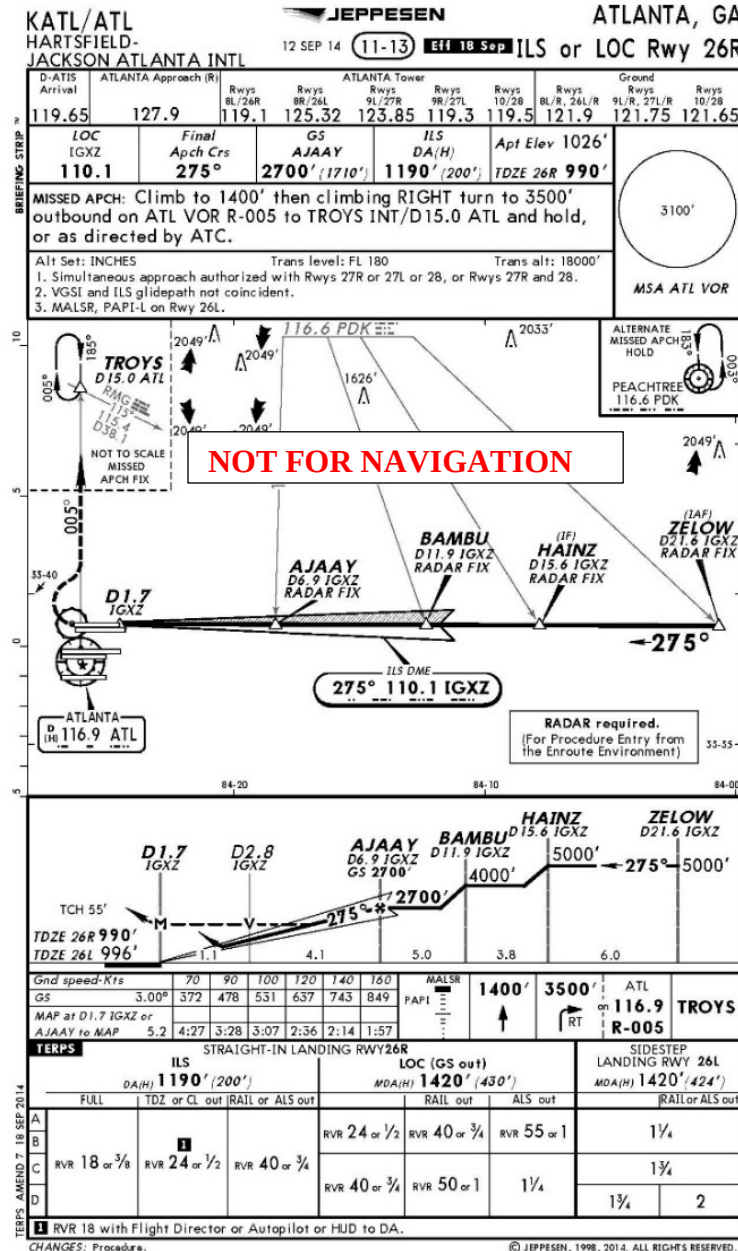


Figure 4: ILS 26R (Jeppesen)

6.0 Company Overview

Delta Air Lines, Inc. operated Delta Air Lines ("Delta") and Delta Shuttle. Delta Air Lines along with their code share agreements provided scheduled air transportation both within the United States and international markets.

According to the Delta Air Lines Operation Specification A001-1, Delta Air Lines was authorized to conduct operations in accordance with FAA-approved Operation Specification, certificate number DALA026A. Delta was authorized to conducted Domestic, Flag, Supplemental operations, and 14 CFR Part 91 flights. The following items document the operations Delta Air Lines was authorized to conduct:

- Delta Air Lines OpSpecs
- Delta Air Lines Flight Control Operations Manual
- Delta Air Lines Flight Operations Manual
- FAA-approved manuals and programs

Delta Air Lines was based in Atlanta, Georgia. Delta Air Lines began in 1924 as a crop-dusting operation and in 1929 began operating its first passenger flights from Dallas, Texas to Jackson, Mississippi, via Shreveport and Monroe, Louisiana. In 2008 Northwest Airlines merged with Delta Air Lines and began a single operation on January 31, 2009. Delta Air Lines began operating A-320 series aircraft as part of the merger.³⁶ As of July 1, 2016, Delta Air Lines had a total of 820 aircraft of which 150 were considered for “Transoceanic” use, 620 were considered for “domestic” use, and 69 of those were the A320-200 series aircraft.

Delta Air Lines pilots were each based at one of nine pilot bases, one of which was the DTW base.

7.0 Relevant Airplane Systems

7.1 Flaps

According to the Delta Air Lines A319/320/321 Operations Manual the aircraft is configured with five flap settings identified as Flaps 0, Flaps 1, Flaps 2, Flaps 3, and Flaps FULL³⁷. Certified flap settings for landing were flaps 3 and flaps FULL. The crew stated, during their respective interviews, that they landed with Flaps FULL.

7.2 ECAM³⁸ Audio Indicators

The Delta Air Lines A319/320/321 Operations Manual “Differences – A321 Differences” provided the following chart of the audio indicators provided by the ECAM for the A321:

³⁶ Source: <http://www.deltamuseum.org/exhibits/delta-history>

³⁷ Flaps FULL equals Flaps 4. Source Delta Air Lines Fleet Bulletin FB-15-03, page 5, dated March 30, 2015

³⁸ Electronic Centralized Aircraft Monitor.

Audio Indicators	Meaning	Duration	Audio Indicator Cancellation
“Go Around Windshear Ahead” (Synthetic voice)	Windshear ahead detected during the landing phase.	Permanent	Nil
“Windshear” (twice) (Synthetic voice)	Windshear detected during the takeoff phase.		
“Monitor Radar Display” (Synthetic voice)	Windshear ahead detected caution message	Permanent	Nil
Auto Call Out	Height announcement at 2500’ AGL	Permanent	Nil
“Pitch, Pitch” (Synthetic voice)	Aircraft pitch attitude is becoming excessive during the flare and landing	One Time	Nil
“Stop Rudder Input” (Synthetic voice)	Inappropriate rudder pedal inputs detected in cruise at high speed	Message repeated at least TWO TIMES	Nil

Figure 5: ECAM Audio Indicators

The section further went on to state that a pilot can cancel any audio indicator, by pressing:

- The EMER CANC pb [pushbutton] on the ECAM control
- The MASTER WARN pushbutton, except for OVERSPEED or L/G NOT DOWN warnings

Neither crewmember nor jumpseater recalled or reported audibly observing a “Pitch Pitch” alert.

7.2.1 Dual Input

A section of the Delta Air Lines A319/320/321, Volume 2, “Indicating/Recording Systems – ECAM Description” chart provided the following additional audio indicators:

Audio Indicators - DUAL INPUT

AUDIO INDICATORS	MEANING	DURATION	AUDIO INDICATOR CANCELLATION
"DUAL INPUT" (synthetic voice)	Both sidesticks are moved simultaneously	Every 5 s	One sidestick deactivated

Figure 6: Dual Input Audio Indicator

Neither crewmember nor jumpseater recalled or reported audibly observing a “Dual Input” alert.

7.3 Flight Controls³⁹

The flight control surfaces were electrically-controlled and hydraulically actuated by three independent hydraulic systems. The stabilizer and rudder could be mechanically controlled and hydraulically actuated. Pilot inputs were provided through sidesticks and rudder pedals. The sidesticks provided electrical signals to the flight control computers for pitch and roll control. The sidesticks operated independently of each other. They did not move with autopilot or opposite sidestick inputs. They had artificial feel and were spring-loaded to the neutral position. If both sidesticks were operated simultaneously both inputs were algebraically added. A takeover pushbutton enabled a pilot to deactivate the other sidestick.

There were seven flight control computers which process pilot and autopilot inputs according to normal, alternate, or direct flight control laws. In normal law the computers prevented excessive maneuvers and flight outside the safe flight envelope in pitch and roll axes. The flight crew controlled the rudder via a mechanical rudder control.

The flight control computers were: two elevator aileron computers (ELAC) for normal elevator, stabilizer and aileron control; three spoiler elevator computers (SEC) for spoiler control plus standby elevator and stabilizer control; two flight augmentation computers (FAC) for electrical rudder control. Two Flight Control Data Concentrators (FCDC) processed information from the ELACs and SECs and sent data to the Electronic Instrument System (EIS) and Centralized Fault Display System (CFDS).

7.4 Flight Control Laws⁴⁰

There were three primary flight control laws for the A320: Normal, Alternate, and Direct.

7.4.1 Normal Law

The sidesticks were used to fly the aircraft in pitch and roll (and in yaw, indirectly, through turn coordination). Normal Law was designed to provide consistent aircraft response to the same degree of sidestick input throughout the flight envelope. Computers interpret pilot input and move the flight control surfaces, as necessary, to follow these commands. However, though the sidestick input to aircraft response relationship is the same, the amount of control surface deflection used by the flight control system to achieve these results is not.

³⁹ Source: Delta Air Lines A319/320/321 Volume 2, Section 27 “Flight Controls”.

⁴⁰ Source: Delta Air Lines A319/320/321 Flight Crew Training Manual, Section 7 “Maneuvers” and Delta Air Lines A319/320/321 Volume 2, Section 27 “Flight Controls”.

Normal Law has three modes according to the phase of flight; ground, flight, and flare.

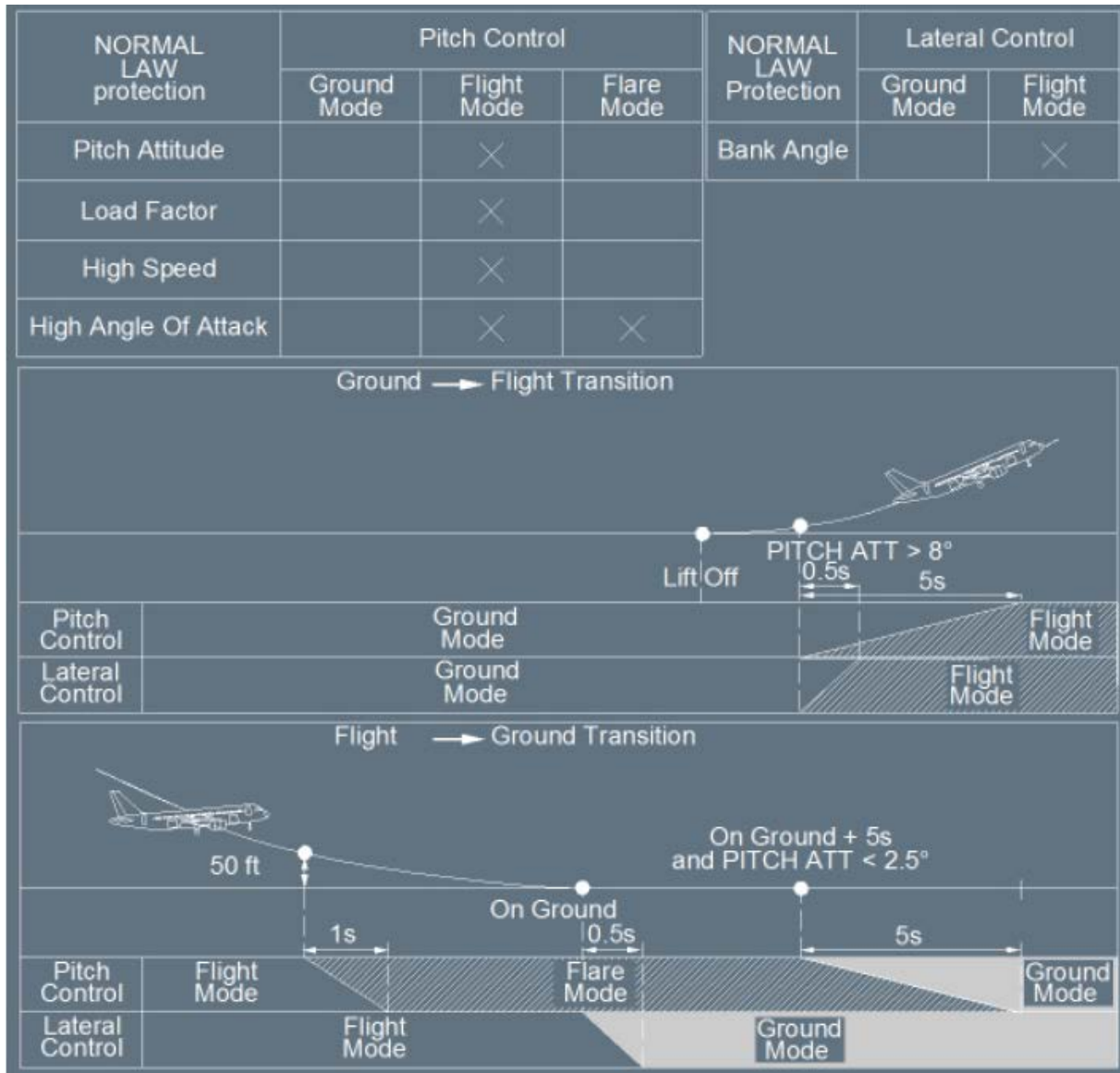


Figure 7: Normal Law Modes and Protections

7.4.1.1 Ground Mode

Ground mode was active when the aircraft was on the ground. This mode was direct relationship between sidestick deflection and elevator deflection, without auto trim. When the aircraft reaches 75 kt. during the takeoff roll, the system reduces the maximum up elevator deflection from 30° to 20°.

This mode was active until after takeoff and then active again after touchdown.

7.4.1.2 Flight Mode

Flight mode became active after takeoff and remained active until just prior to touchdown. Sidestick pitch input commanded a load factor proportional to stick deflection and independent of speed. With the sidestick at neutral, wings level, the system maintained a 1 g in pitch (corrected for pitch attitude), and there was no need for the pilot to trim by changing speed, configuration, or bank up to 33°.

Automatic pitch trim freezes in the following situations:

- The pilot enters a manual trim order.
- The radio height is below 50 ft (100 ft with autopilot engaged).
- The load factor goes below 0.5 g.
- The aircraft is under high-speed or high-Mach protection.

When angle-of-attack protection was active, the trimmable horizontal stabilizer (THS) setting was limited between the setting at the aircraft's entry into this protection and 3.5° nose down.

7.4.1.3 Flare Mode

Flare mode became active when the aircraft passes 50 ft RA⁴¹, the THS is frozen and the normal flight mode changes to flare mode as the aircraft descends to land. Flare mode is essentially a direct stick-to-elevator relationship (with some damping provided by the load factor and the pitch rate feedbacks).

The system memorizes the aircraft's attitude at 50 ft, and it becomes the initial reference for pitch attitude control.

As the aircraft descends through 30 ft, the system begins to reduce the pitch attitude to 2° nose down over a period of 8 seconds. Consequently, to flare the aircraft, a gentle nose-up action by the pilot is required.

7.4.1.4 Normal Law Protections

Normal law protected the aircraft through the flight envelope, as follows:

- Load Factor Limitation which was automatically limited to +2.5 g to -1 g for clean configuration and +2 g to 0 for other configurations.
- Pitch Attitude protection which limited pitch to 30° nose up (25° nose up in flaps FULL configuration) and 15° nose down.
- High Angle of Attack protection became active when the angle of attack exceeded alpha protection (α_{prot})⁴² which would switch elevator control from normal mode to a protection mode, in which the angle-of-attack was proportional to sidestick deflection. However, the

⁴¹ Radio/Radar Altitude

⁴² α_{prot} or Alpha Protection Speed was indicated by the top of the black and amber strip along the speed scale. It represented the speed corresponding to the angle of attack at which alpha protection becomes active. It is only displayed in normal law.

angle-of-attack will not exceed α_{MAX}^{43} , even if the pilot gently pulls the sidestick all the way back. If the pilot released the sidestick, the angle-of-attack returns to α_{prot} and stays there.

7.4.2 Alternate Law

Alternate Law provided a degraded mode of operation with some Normal Law flight characteristic and protections retrained, but it provided reduced protections compared to Normal Law.

7.4.2.1 Ground Mode

Ground mode was identical to normal law.

7.4.2.2 Flight Mode

In flight, the alternate law pitch mode follows a load-factor demand law much as the normal law pitch mode does, but it has less built-in protection (reduced protections).

7.4.2.3 Flare Mode

In pitch alternate law the flight mode changes to the flare mode when the pilot selects landing gear down. The flare mode was a direct stick-to-elevator relationship.

7.4.3 Direct Law

The pitch direct law was direct stick-to-elevator relationship (elevator deflection was proportional to stick deflection). In all configuration the maximum elevator deflection varied as a function of CG. There were no automatic trim and the pilot was required to trim manually. The PFD⁴⁴ displayed an amber message “USE MAN PITCH TRIM”. There were no protections in direct law, except for overspeed and stall warning protection.

7.5 Pitch Limit Indicator

Delta Air Lines “A320 Topics of Interest,” dated March 1, 2016, “A321 Considerations (Part 1)” provided the following guidance for “Landing Tailstrike Prevention”:

Airbus stated that most tailstrikes occur within 2-5 seconds following initial landing touchdown, either due to spoiler deployment resulting in a pitch-up or following a landing bounce. This is again in line with previous Delta experience. Both of the last two A320 tailstrikes occurred following a bounced landing (both coincidentally also happened on runway 16L at DEN). The OE Guide offers the following discussion about tailstrikes on landing (Ref. OE.3.143):

In the A320 family of aircraft most tailstrikes have occurred from one of two scenarios:

- 1. Following a bounce: Airbus indicates most tailstrikes have occurred in the subsequent touchdown following a bounce. The situation begins with the pilot perceiving a high sink rate prior to the initial touchdown. Due to this high sink rate, the pilot hesitates in retarding the thrust levers (TLs) With the TLs not in the idle range at touchdown, the spoilers don't deploy. This combined with the*

⁴³ α_{MAX} or Alpha Max was the top of the solid red strip along the speed scale. It represented the speed corresponding to a maximum angle of attack that the aircraft can obtain in normal law.

⁴⁴ Primary Flight Display

high sink rate, results in a bounce. IF the pilot then retards the TLs to IDLE, all the requirements are met for the spoilers to deploy and the aircraft sinks rapidly striking the tail first.

Ways to prevent this:

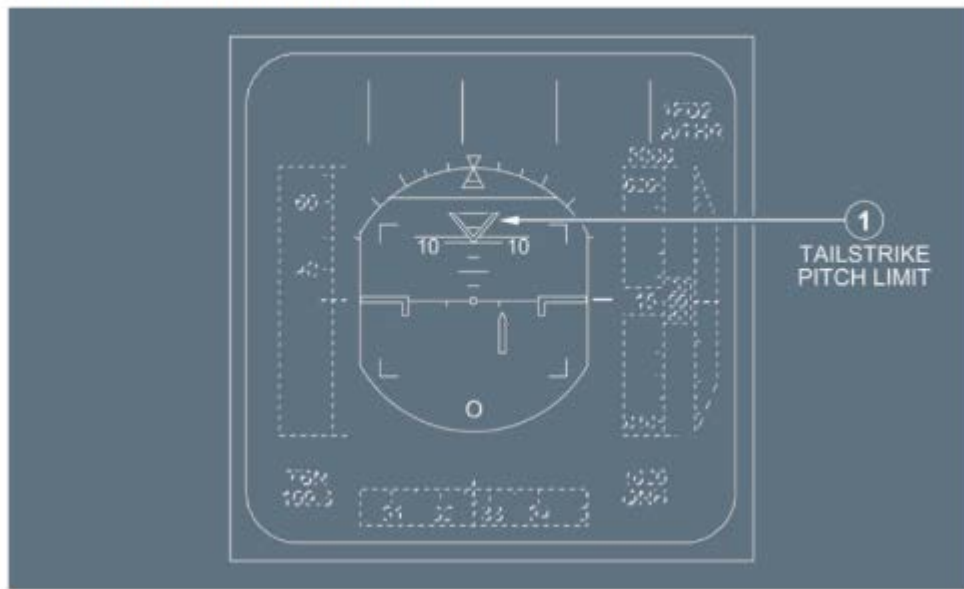
- Ensure the TLs are at IDLE at touchdown, as the spoilers will not deploy otherwise.
 - If the aircraft bounces, a pitch attitude of 5 to 6 degrees allow for an acceptable landing without too much float.
 - Pilots should avoid an excessive flare following a bounce as a tailstrike may result. A Go-around should be conducted following a high bounce.
2. The pilot attempts to prolong the flare by continuing to increase aft stick, or does not release aft stick pressure following touchdown, resulting in the aircraft exceeding its pitch limit...
- The average touchdown pitch attitude is 7.6 degrees for the A319/320 as compared to 6.6 degrees for the A321 (double slotted flaps).
 - The PM must make an awareness call when the pitch approaches 10°.
 - A321s: A pitch limit indicator is displayed on the PFD below 400 feet agl when the TLs are below the FLEX/MCT detent. Also, a “PITCH, PITCH” callout is annunciated when the pitch attitude approaches the limit and thrust is less than TOGA.
 - Pilots are cautioned that sidestick summing may prevent the PM from overriding the PF’s sidestick input. Use of the takeover pushbutton may be necessary.



Aircraft	Tail Strike Pitch Attitude (x)	Typical Pitch Attitude at Touchdown (y)	Difference [i.e., available “slop”] (x – y)
A320	13.5°	7.6°	5.9°
A321	11.2°	6.6°	4.6°

The above chart depicts tail strike pitch attitudes for the A320 and A321. It also displays the typical landing attitude at touchdown. Note that the A321’s landing pitch attitude is one degree lower than the A320’s. This is due to the A321’s double slotted flap system, which reduces the pitch attitude on final by about a degree. Other carriers that operate the A321 say a simple landing flare of around 2 degrees results in a smooth landing, well within the runway’s touchdown zone...”

Tailstrike Pitch Limit Indicator



8.0 Delta Air Lines Guidance

8.1 Initial Operating Experience

Upon completion of the initial qualification simulator phase of training for any fleet, the pilot (First Officer or Captain) will receive Initial Operational Experience (IOE) training. The objective is to qualify the pilot for line operations. The pilot is not fully certified for unsupervised line operations until completion of the IOE training. Therefore, an LCP⁴⁶ is required to conduct the training... When conducting OE, the LCP is functioning in a command position, and as such, is responsible for the safety of the aircraft. If, for instance, an abort is warranted on takeoff roll, the Captain receiving the OE should normally make the decision and initiate the abort. The LCP may, at any time, assume command of the aircraft and the decision-making process... OE is the final step in the qualification process and quite possibly an individual's first exposure to line operations in his/her new position. There is no FAR or company requirement for an OE pilot to fly each and every leg during an OE. The OE pilot should be exposed to pilot monitoring (PM) and pilot flying (PF) duties. This is especially important for First Officers. It is vital that the LCP share his/her expertise with the pilot undergoing the OE. Timely guidance is the key to productive experience. As the OE pilot is adjusting to the dynamic environment that characterizes line operations, timely input from the LCP is essential to optimizing the learning experience.

⁴⁶ Line Check Pilot

Hints and directions at appropriate points can mean the difference between the OE pilot staying up with the aircraft or falling behind.

8.2 Operation Experience (OE) Guide

The Delta Air Lines OE Guide “Stabilized Approach” pages 3.144 thru 3.152 provided guidance on various topics that were classified as “Operational Briefing Items” some of the topics were:

8.2.1 Flare Maneuver

Flight Data Recorder (FDR) information was downloaded following the event at the NTSB Recorders Laboratory. The data showed that just after weight on wheels and prior to the nose gear weight on wheel sensor registering on the ground, the pitch was recorded about 10° nose up attitude, which remained for about 1 second. The pitch attitude was preceded by a right sidestick lateral position increase.

The Delta Air Lines OE Guide and the Delta Air Lines A319/320/321 Flight Crew Training Manual provided information on the rotation rate of 2.5 to 3.0 degrees/second during takeoff. It also provided information that the maximum pitch attitude on the A-321 was 9.7° with the struts compressed. The OE Guide further provided guidance on landing which stated:

During a normal approach at Vapp, the pitch attitude is approximately 3 degrees at Flaps FULL and 4 degrees for a Flaps 3 landing. Note: The A321 is about 1 degree lower due to the double slotted flap design.

- *When the “thirty” call out is heard, raise the pitch attitude slightly (approximately 2°) to slow the rate of descent. This should be done smoothly and slowly to prevent the aircraft from inadvertently leveling off or climbing.*
- *By the “retard” callout at 20 feet, smoothly and promptly bring the thrust levers to the IDLE detent.*

Technique: *The “retard” callout is not a command, but rather a reminder. The pilot should determine when to retard the thrust.*

- *The pilot is permitted to finesse the landing with a few more degrees of pitch up command but must not allow the aircraft speed to decay appreciably or pitch attitude from increasing above approximately 8° pitch up.*
- *An Autoland is illustrative of a simple, but effective flare. The Autoland system flares the aircraft.*

8.2.2 Tailstrike Avoidance

The flight crew discussed flying the airplane in a crab and then using rudder and aileron to align the airplane straight down the runway prior to touchdown. They discussed the differences in the A-321 and the tailstrike concerns using the company provided manuals. The discussion included pictures of the “carrots” that would appear on the MFD⁴⁷ as well as the airplane would provide an audible alert of “pitch pitch” if the airplane’s computer determined that a tailstrike was possible (See Section 7.0 “Airplane Systems” for further information). The captain also provided some landing tips to the first officer, as the previous landings were “underflared” and “firm.”⁴⁸

⁴⁷ Multifunction Display

⁴⁸ Source: Operational Factors - Attachment 1 - Flight Crew Interview Summaries.

According to Delta Air Lines A319/320/321 Operating Experience Guide, “Operating Experience – Operational Briefing Items” pg. OE.3.149, “Tailstrike Avoidance” states:

Tailstrikes are twice as prevalent on landing as during takeoff. In most cases, the tailstrike has occurred 2-5 seconds following initial touchdown. Ground spoiler deployment results in a pitch up tendency. Tailstrike occurrences are more prevalent in the A321 as compared to the A319/320.

8.3 Stabilized Approach

The Delta Air Lines “A319/320/321 Operations Manual” provided the following information for stabilized approaches.

Stabilized Approach

Delta defines a stabilized approach as maintaining a stable speed, descent rate, and lateral flight path while in the landing configuration.

WARNING: At any altitude, if the following stabilized approach criteria cannot be established and maintained, initiate a go-around. Do not attempt to land from an unstable approach.

No lower than 1000 feet AFE⁴⁹:

- *Be fully configured for landing (gear and landing flaps extended).*
- *Maintain a stabilized descent rate not to exceed 1,000 fpm.*
- *Be aligned with the intended landing runway.*

No lower than 500 feet AFE:

- *Be on target airspeed.*
- *The engines are stabilized at the thrust setting required to maintain the desired airspeed and rate of descent.*

Crossing the Runway Threshold:

- *Positioned to make a normal landing in the touchdown zone.*

Planned Deviations

- *A circling maneuver and some published approaches (such as the River Visual at DCA) may require a planned deviation to the lateral stabilized approach criteria. Some published approaches require higher than standard descent rates. Verbalize all planned deviations during the approach briefing.*

⁴⁹ Above Field Elevation

Unplanned Descent Rate Exceedance

- *In the event of a momentary descent rate exceedance, crews may proceed as long as the descent rate exceedance is verbally acknowledged and corrective action is immediately initiated.*

8.4 Exterior Inspection – Captain or First Officer

The Delta Air Lines A319/320/321 Operations Manual, “Normal Procedures – amplified Procedures” provided guidance for conducting an exterior inspection of the airplane. The guidance stated, in part:

Before each flight the captain must verify the airplane is in satisfactory condition for flight. Make a complete exterior inspection, and report any discrepancies to the captain and to maintenance as soon as possible. Emphasis should be placed on tire wear, airframe or control damage, and leaking fluids.

Following the route below, complete the preflight at the point where the inspection began, ensuring a complete circuit around the aircraft.

Items at each location may be checked in any sequence.

Ensure that:

- *Surfaces and structures are clear, undamaged, not missing parts, and there are no fluid leaks;*
***Note:** Assessing the condition of the upper wing surfaces may require viewing from inside the aircraft.*
- *Hydraulic lines and electrical wires are secure and undamaged.*
- *Installed placards are readable;*
- *Gear struts are not fully compressed;*
- *Gear pins have been removed;*
- *Engine inlets and tailpipes are clear, cowlings are secured and undamaged, and the reversers are stowed;*
- *Doors and access panels that are not in use are latched;*
- *Probes, sensors, ports, vents, and drains are unobstructed, clear, and undamaged;*
- *Skin area adjacent to the pitot probes and static ports is not wrinkled;*
- *Antennas are not damaged;*
- *Light lenses are clean and not damaged;*
- *Exterior lights are illuminated in accordance with NP.12, Lights Usage*

Notify maintenance if any:

- *Tread groove is worn completely around the tire;*
- *Tires are worn beyond limits, damaged, or tread is separating;*
- *Layer of cord is showing;*

- *Questionable cut exists;*
- *Tire shows appearance of improper inflation;*
- *Wheel through-bolt or nut is missing or damaged.*

The guidance further provided the following inspection route diagram:

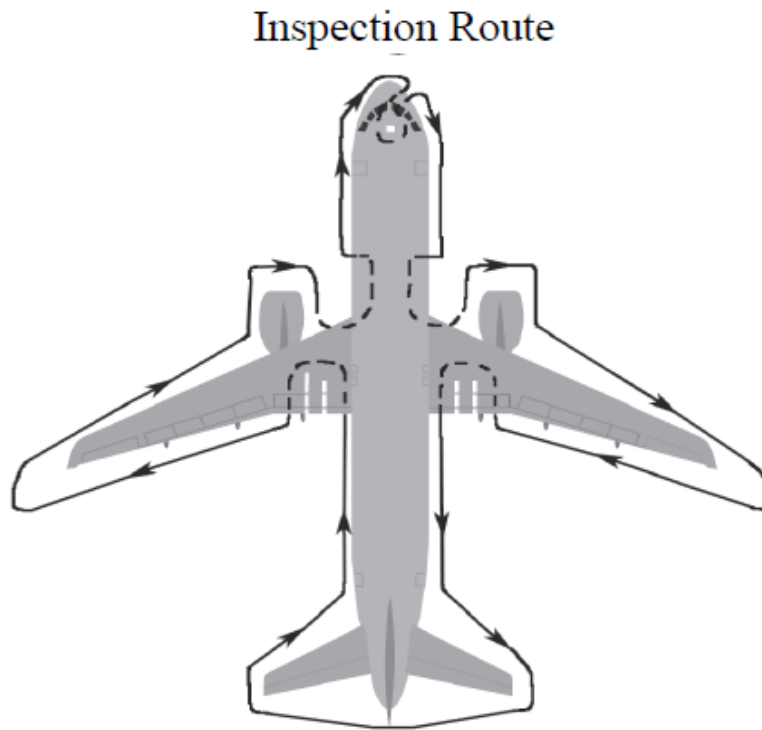


Figure 9: Inspection Route Diagram⁵⁰

The guidance further provided specific items to check during the exterior inspection. The items were categorized based on location on the airplane. The areas associated with the aft portion of the airplane provided the following specific inspection items:

⁵⁰ Source: Delta Air Lines A319/320/321 Operations Manual pg. NP.20.5.

Right Aft Fuselage

Doors and access panels (not in use)..... Latched
Probes, sensors, ports, vents, and drains (as applicable)..... Check
Outflow valve Check

Tail

Doors and access panels (not in use)..... Latched
Probes, sensors, ports, vents, and drains (as applicable)..... Check
Vertical stabilizer and rudder Check
Horizontal stabilizer and elevator Check
 The horizontal stabilizer should be set at the 0 index mark.
Static discharge wicks Check
Exterior lights Check
Lower aft fuselage surface Check
 Check for evidence of tail strike damage.

Left Aft Fuselage

Doors and access panels (not in use)..... Latched
Probes, sensors, ports, vents, and drains (as applicable)..... Check
APU fire extinguisher pressure relief red disc Check

Figure 10: Specific Exterior Inspection Items

8.5 Descent Checklist

The Delta Air Lines A319/320/321 Operations Manual provided the following guidance:

Descent Checklist

Altimeters	___, xckd	C&F
Ensure the captain, first officer, and standby altimeter/ISIS barometric settings and barometric reference (IN or HPA) are correctly set. Verbalize the altimeter setting (local or STD).		
■ Minimums	___, ___	C&F
Ensure the captain's and first officer's PFD minimums are set to the approach chart value. Verbalize "RADIO" or "BARO" and the numeric value.		
■ Landing Data	___, ___	C&F
Verbalize the displayed landing flap and VAPP speed.		
■ Approach briefing	complete	PM
Ensure the Approach Briefing has been completed by the PF.		
■ Autobrakes	as reqd	PM
Autobrakes should be used, if operable.		
Seat belts sign	ON	PM

Figure 11: Descent Checklist Guidance

8.6 Approach Briefing

Delta Air Lines Flight Operations Manual "Briefings & Cabin Crew Comm – Briefings" provided the following guidance as it pertained to an approach briefing:

The acronym "NATS" identifies each major category of the approach briefing. For all approaches, the pilot flying should consider and brief these items.

N	NOTAMS
A	Arrival/Approach Chart/Automation
T	Transition level/height/Terrain/Taxi
S	Specific Company information (Company Pages)

When conducting an approach briefing, the PF will:

- Include all pilots
- Brief the approach as soon as adequate information is available and workload is at a minimum
- Complete the briefing prior to top of descent, if able
- Verbalize the highest threats to the approach segment (e.g., weather, security, terrain, degraded aircraft systems) as well as a mitigation strategy.

If an approach is to be flown in actual instrument conditions or night VMC:

- Conduct a full approach plate briefing
- Review the relevant items of the NATS brief

If the approach is flown in day VMC, review the relevant items of the NATS brief.

If a runway change occurs and the approach briefing has been completed, re-brief the approach accordingly:

- Positive confirmation of the new runway must be established
- Re-tune navigation aids and set the inbound course
- Confirm the FMS is programmed correctly
- Altimeter bugs may need to be changed to reflect a modified approach clearance to the same runway
- If transfer of control is required due to the approach requirement (e.g., CAT II/III), accomplish in conjunction with the approach brief
- Refer to Vol. 1, NP.11 and NP.20 for additional guidance on runway change items.

Category	Briefing Items
NOTAMS	• ATIS advisories • Flight plan remarks • Chart changes notices
Arrival/Approach Chart/Automation	• Weather/wind considerations • Arrival airspeed and altitude restrictions • Designated approach/runway • Pertinent runway information (reference 10-9A page, or similar): • approach and runway lighting • usable landing distance • runway conditions affecting stopping distance (ungrooved/contaminated) • non-standard runway width • Type of approach, include level of automation to be used • Jeppesen approach chart number and date • Navigation aid(s) frequency/runway identification • Inbound course • Initial approach altitude, as required • FAP or FAF altitude • Barometric altitude at the marker, as required • Approach minima (MDA, DA, DDA, DH, AH) • Radio/barometric altimeter bug settings • Missed approach plan • go-around procedure • callouts • execution of maneuver
Transition Level/Terrain/Taxi Plan	Transition level/height other than 18,000 feet. Terrain considerations if applicable. Taxi plan: • Use the taxi chart to brief the expected taxi route • Anticipated runway exit point • Hot spots • Hold short points • Abnormalities (NOTAMs, construction, 10-8 page etc.) • Anticipated runway crossings • When visibility is less than RVR 1200, review Surface Movement Guidance & Control System (SMGCS) Low Visibility Taxi Routes Chart, if applicable
Specific Company Information	• Engine out procedures • Company Pages

Figure 12: Delta Air Lines Approach Briefing Guidance

8.6.1 Flight Crew Training Manual

Delta Air Lines A319/320/321 Flight Crew Training Manual, Chapter 6 "Landing," with a page date of April 8, 2016 provided the following guidance for the "Flare and Touchdown":

The techniques discussed here are applicable to all landings including one engine inoperative landings, crosswind landings, and landings on slippery runways. Unless an unexpected or sudden event occurs, such as windshear or collision avoidance situation, it is not appropriate to use sudden, violent, or abrupt control inputs during landing. Begin with a stabilized approach on speed, on glide path.

Note: *When a manual landing is planned from an approach with the autopilot connected, the transition to manual flight should be planned early enough to allow the pilot time to establish aircraft control before beginning the flare. The PF should consider disengaging the autopilot and*

disconnecting the autothrust no later than 1 to 2 nm before the threshold, or approximately 300 to 600 feet above field elevation.

When the threshold passes under the aircraft nose and out of sight, shift the visual sighting point to the far end of the runway. Shifting the visual sighting point assists in controlling the pitch attitude during the flare. Maintaining a constant airspeed and descent rate assists in determining the flare point.

The flight control law changes to the landing mode at 50 feet RA. Below 30 feet, the flight control system blends in a nose down command which helps the pilot to “feel” the flare. Begin the flare at approximately 30 feet AGL by gently increasing the pitch angle with back stick pressure which counteracts the tendency for the nose to drop. When the pilot hears the “thirty” callout, he should raise the pitch attitude approximately 2° to slow the rate of descent. This should be done smoothly and slowly to prevent the aircraft from inadvertently leveling off or climbing.

Conditions permitting, reduce the thrust levers to idle at about 20 feet when the pilot hears “retard”. Hold sufficient back pressure on the side stick to keep the pitch constant. Avoid the tendency to float and land long. Make small pitch attitude adjustments to maintain the desired descent rate to the runway, but do not allow the aircraft speed to decay appreciably or the pitch attitude to increase above approximately 8° nose-up. The PM should make awareness calls if the pitch attitude approaches 10°. Fly the aircraft onto the runway.

A321

A "PITCH-PITCH" synthetic voice sounds when the pitch attitude becomes excessive and a tail strike pitch limit indicator appears on the PFD to indicate the maximum pitch attitude to avoid a tail strike.

After touch down, the pilot must “fly” the nosewheel smoothly, but without delay, on to the runway, and must be ready to counteract any residual pitch up effect of the ground spoilers. However, the main part of the spoiler pitch up effect is compensated by the flight control law itself. A small nose down trim on the elevators is introduced by the control law, which compensates the pitch up tendency with ground spoiler extension.

Prolonged flare increases aircraft pitch attitude 2° to 3°. When prolonged flare is coupled with a misjudged height above the runway, a tail strike is possible. Do not prolong the flare in an attempt to achieve a perfectly smooth touchdown. A smooth touchdown is not the criterion for a safe landing.

8.6.2 Landing Flare Profile

Delta Air Lines A319/320/321 Flight Crew Training Manual, Chapter 6 “Landing”, pg. 6.13, with a page date of April 22, 2014 provided the following guidance for the “Landing Flare Profile”:

The following diagram uses these conditions:

- *3° approach glide path,*
- *flare distance is approximately 1,000 to 2,000 feet beyond the threshold,*
- *typical landing flare times range from 4 to 8 seconds and are a function of approach speed, and*
- *aircraft body attitudes are based upon typical landing weights, flaps FULL and VAPP (approach) and VLS (touchdown)*

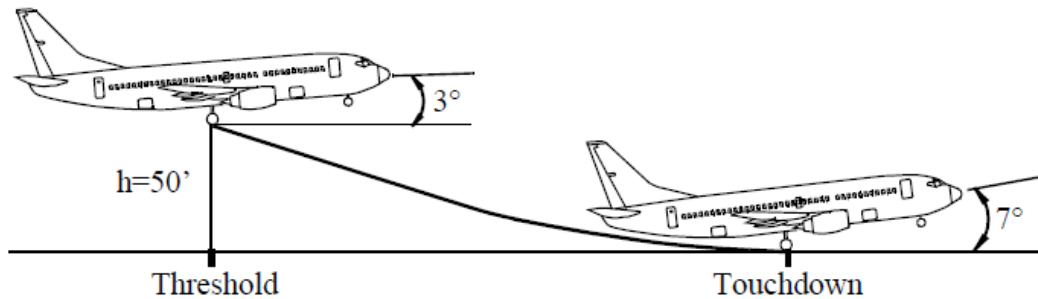


Figure 13: Landing Flare Profile

8.7 Ground Contact Angles – Normal Landing

Delta Air Lines A319/320/321 Flight Crew Training Manual, Chapter 6 “Landing”, pg. 6.16, with a page date of April 8, 2016, provided the following diagram for the “Ground Contact Angles” for the A-321 and A-320:

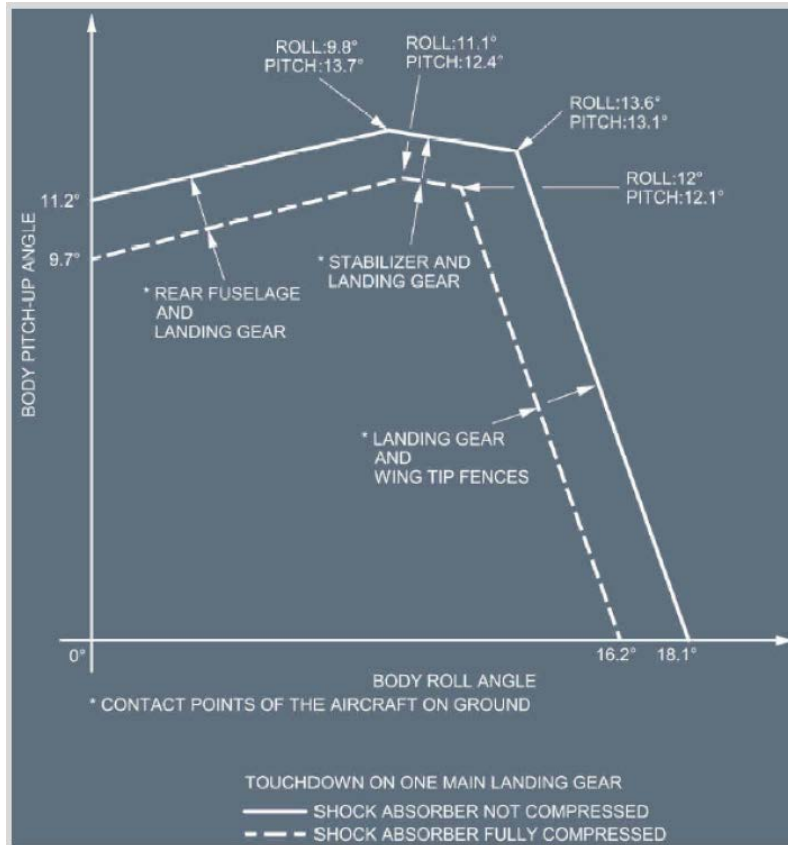


Figure 14: Airbus A-321 Ground Contact Angles

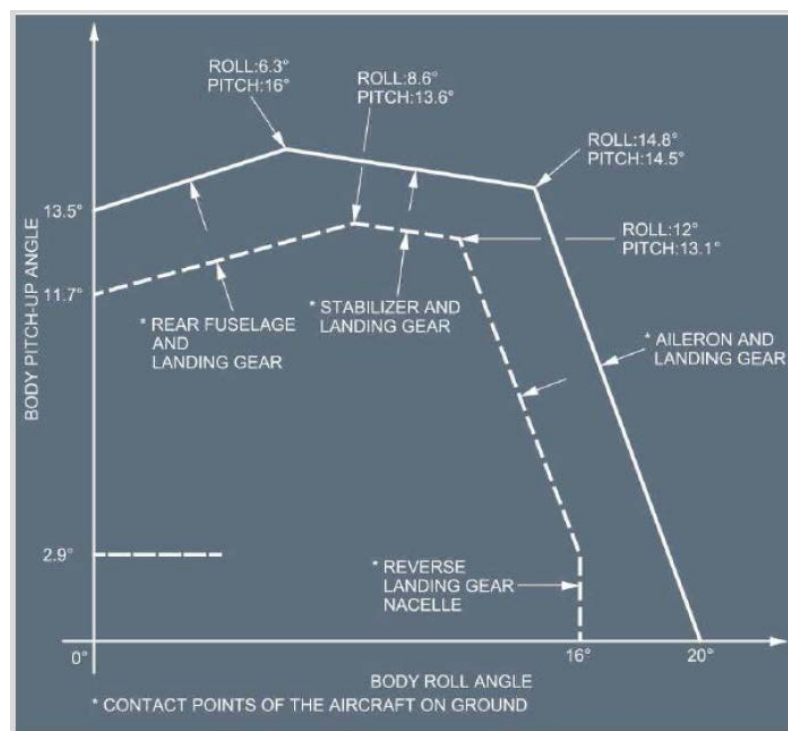


Figure 15: Airbus A-320 Ground Contact Angles

9.0 Airbus Guidance

9.1.1 Avoiding Tail Strike

Airbus guidance titled “Avoiding Tail Strike,” showed that 64% of tail strikes occurred during the landing phase of flight. A graph within the material showed that in 2001 about 13 tailstrikes per million departures occurred during the landing phase in the A-321 compared to a little over 2 per million departures in the A-320.

The guidance further provided the “most common causes” at landing in the Airbus fleet. Those causes were:

- *At landing*
 - *Unstable approach*
 - *Large thrust and pitch attitude variations*
 - *Too high sink rate close to the ground*
 - *Too low airspeed and high pitch attitude*
 - *Flare/landing technique*
 - *Improper flare initiation height*
 - *Too high, leading to significant speed drop*
 - *Too low, leading to high pitch rate*
 - *Improper anticipation of aircraft inertia*
 - *Improper thrust reduction coordination*
 - *Uncontrolled high pitch rate at touch down*
 - *High touch down vertical speed leading to bounce*
 - *Prolonged hold off during flare*
 - *Nose gear kept high after touchdown*
 - *Turbulence, wind shear/downburst*
 - *Bouncing at landing*
 - *Pitch rate not stopped after touchdown*
 - *Aft stick order not released*
 - *Pitch up effect at spoiler extension not controlled*
 - *Pitch increase, attempting to smooth the second touchdown*

Most of the time, more than one cause is involved!

The material provided factors that affected the margins and one of those factors was “Ground Clearance Geometry.” The guidance also provided the following chart showing the pitch attitude related to ground contact in the A-320 series, which included the A-319 and A-321, as well as the A-340-300 aircraft.

	Pitch attitude to ground contact			
Main gear position	A319	A320	A321	A340-300
Fully extended	15,5°	13,5°	11,2°	14,2°
Fully compressed	13,9°	11,7°	9,7°	10,1°

Figure 16: Ground Clearance Geometry

Another factor was the airspeed at touchdown and the flare technique. The material provided the chart below that showed the “Geometry limit at touchdown” for the A-320 series aircraft and the typical pitch attitude at touchdown based on the approach speed minus 8 knots.

Aircraft	Geometry limit at touchdown	Pitch attitude at touchdown (Vapp - 8) *	Clearance
A319	15.5°	7.7°	7.8°
A320	13.5°	7.6°	5.9°
A321	11.2°	6.6°	4.6°

Figure 17: Geometry Limit at Touchdown

The material went on to provide other factors that should be considered affecting the margin at landing. Those factors were:

- *High and increasing pitch rate at touch down*
- *Large lateral side stick inputs*
- *Excessive vertical speed*
- *Aircraft inertia*
- *Thrust reduction height*

The material further provided “Operational recommendations” for the various phases of flight. The following recommendations were for the landing phase:

- *Fly a stabilized approach (pitch, thrust, flight path, IAS)*
- *Do not chase the G/s close to the ground*
 - *Progressively give priority to the pitch and the sink rate*
- *Adapt the flare height to the aircraft inertia*
 - *Monitor the global energy*
 - *Co-ordinate thrust reduction with speed, vertical speed and height; touchdown with thrust at idle*
- *Zero the pitch rate prior [to] touchdown*
 - *Even attempting to avoid a firm landing*
- *Do not hold it off to make an “extra smooth” landing*

- Do not wait to fly the nose wheel to the ground
 - Initiate and control derotation just after MLG touchdown

9.1.2 Flight Operations Briefing Notes

Flight Operations Briefing Notes (FOBN) “Landing Techniques Preventing Tailstrikes at Landing”⁵¹ stated that about 65% of tailstrikes occur at landing and is often “associated with a hard landing.” The FOBN provided the following factors increase the probability of a tailstrike during landing:

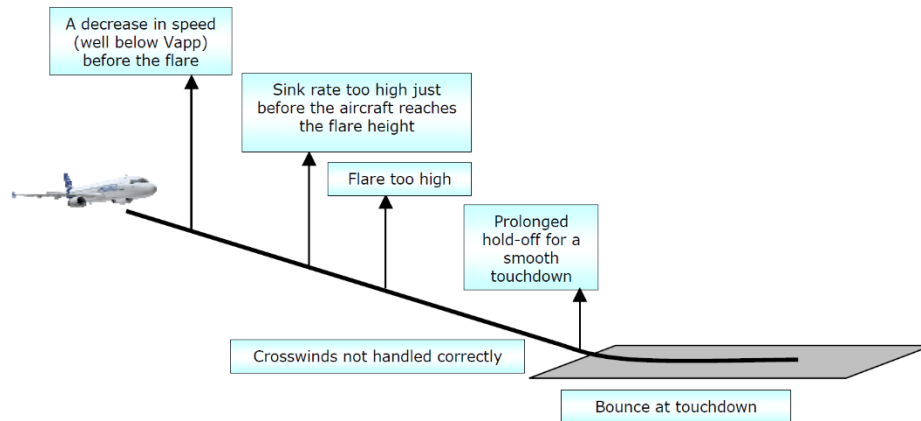


Figure 18: Operational & Human Factors Involved in Tailstrikes at Landing

Usually, no single factor will result in a tailstrike. However, the combination of several factors significantly reduce the tail clearance margin (distance between the aircraft tail and the ground).

Decrease in Speed (Well Below Vapp) Before the Flare

Flight at too low a speed results in a high Angle-of-Attack and a high pitch attitude, and therefore, reduced ground clearance. When the aircraft reaches the flare height, the flight crew must significantly increase the pitch to reduce the sink rate. This will further reduce the ground clearance.

Sink Rate Too High Just Prior to Reaching the Flare Height

If the sink rate is too high when the aircraft is close to the ground, the flight crew may attempt to avoid a firm touchdown by commanding a high pitch rate. This action will significantly increase the pitch attitude. However, if the resulting lift increase is not sufficient to significantly reduce the sink rate, a firm touchdown may occur. In addition, the high pitch rate may be difficult to control after touchdown, particularly in the case of a bounce.

Flare Too High

⁵¹ Source: <https://skybrary.aero/bookshelf/books/180.pdf>

A flare that is too high can result in a combination of decreased airspeed and a long float. Since both increase the aircraft's pitch attitude, the result is reduced tail clearance.

Prolonged Hold-Off for a Smooth Touchdown

As the pitch attitude increases, the flight crew must assess the aircraft's position in relation to the ground.

Bounce at Touchdown

In the case of a bounce at touchdown, the flight crew may decide to increase the pitch attitude, to ensure a smooth second touchdown. If the bounce results from a firm touchdown associated with a high pitch rate, it is important for the flight crew to control the pitch, so that it does not continue to increase.

Crosswinds Not Handled Correctly

When the aircraft is close to the ground, the wind velocity tends to decrease, and the wind direction tends to turn (direction in degrees decreasing in northern latitudes). The flight crew must be aware that during the approach phase, and especially during a flare, a crosswind effect could suddenly increase the pitch of the aircraft, and result in a tailstrike.

10.0 Company Procedural Guidance

Delta Air Lines procedural guidance to crewmembers were located in several manuals. The Aircraft Operations Manual (AOM), the Flight Operations Manual (FOM), the Flight Crew Training Manual (FCTM), and the OpSpecs. The AOM provided normal and non-normal procedures to be followed specifically for the A319/320/321 aircraft. The AOM was broken into 2 manuals, Volume 1 contained Limitations, Normal Procedures, Normal Operational Information, Supplementary Procedures and Differences within the A320 series. Volume 2 contained system descriptions for the A320 series aircraft at Delta Air Lines. The FOM provided policies, procedures, and information pertaining to flight operations at Delta Air Lines. The FCTM provided information and recommendations on maneuvers and techniques. The OPS SPECS were FAA issued specifications specifically for Delta Air Lines which contained guidance on the types of operations they were allowed to conduct.

Additionally, Delta Air Lines provided a Flight Standards Pilot Manual, which was to provide the Flight Standards Pilot with the direction and guidance necessary to conduct Flight Standards duties and establish responsibilities while performing flight Standards duties.

The manuals were available to crewmembers on their assigned electronic flight bag.

F. LIST OF ATTACHMENTS

Attachment 1 – Flight Crew Interview Summaries and Written Statements

Attachment 2 – Jumpseat Pilot Written Statement

Attachment 3 – Flight Crew Training and Recent Flight Experience

Attachment 4 – Operations Manual - Limitations

Attachment 5 – Operations Manual – A321 Differences
Attachment 6 – A320 Topics of Consideration – A321 Differences
Attachment 7 – Amplified Checklist
Attachment 8 – Delta Air Lines Operating Experience Guide
Attachment 9 – Approach Briefing
Attachment 10 – Flight Crew Training Manual – Flare and Touchdown
Attachment 11 – Airbus Material – Avoiding Tail Strike
Attachment 12 – Operational Factors Group Party Forms

Submitted by:

Shawn Etcher
Air Safety Investigator

THIS PAGE INTENTIONALLY BLANK