Published: July 2019

INVESTIGATION REPORT

Serious incident to the AIRBUS A340-313E
registered **F-GLZU**
and operated by **AIR FRANCE**
on 11 March 2017
at Bogotà (Colombia)

BEA
Bureau d'Enquêtes et d'Analyses
pour la sécurité de l'aviation civile
Ministère de la Transition Écologique et Solidaire

Safety investigations

The BEA is the French Civil Aviation Safety Investigation Authority. Its investigations are conducted with the sole objective of improving aviation safety and are not intended to apportion blame or liabilities.

BEA investigations are independent, separate and conducted without prejudice to any judicial or administrative action that may be taken to determine blame or liability.

SPECIAL FOREWORD TO ENGLISH EDITION

This is a courtesy translation by the BEA of the Final Report on the Safety Investigation published in July 2019. As accurate as the translation may be, the original text in French is the work of reference.

Contents

Glossary

AC	Advisory Circular
AD	Airworthiness Directive
ADV	Analyse des Vols (Flight analysis)
AEO	All Engines Operative
AF	Air France
AFM	Airplane Flight Manual
APU	Auxiliary Power Unit
ASD	Acceleration Stop Distance
ASDA	Acceleration Stop Distance Available
ASR	Air Safety Report
ATC	Air Traffic Control
ATP	Acceptance Test Procedure
ATPL	Airline Transport Pilot Licence
BEA	Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation civile (French civil aviation safety investigation authority)
BFU	Bundesstelle für Flugunfalluntersuchung (German Federal Bureau of Aircraft Accident Investigation)
CCQ	Cross Crew Qualification
CG	Center of Gravity
CIAIAC	Comisión de Investigación de Accidentes e Incidentes de Aviación Civil (Spanish Civil Aviation Accident and Incident Investigation Commission)
CVR	Cockpit Voice Recorder
CWY	ClearWaY
DAR	Direct Access Recorder
DFDR	Digital Flight Data Recorder
DGAC	Direction Générale de l'Aviation Civile (French civil aviation authority)
DSAC	Direction de la Sécurité de l'Aviation Civile (French civil aviation safety directorate)
EASA	European Aviation Safety Agency
ECAM	Electronic Centralized Aircraft Monitor
ECP	Entraînements et Contrôles Périodiques (Recurrent training and checking)

ECR	European Central Repository
EFB	Electronic Flight Bag
EGT	Exhaust Gas Temperature
ENAC	École Nationale de l'Aviation Civile (National School of Civil Aviation)
EOFDM	European Operator Flight Data Monitoring
FAA	Federal Aviation Administration
FCOM	Flight Crew Operating Manual
FCPC	Flight Control Primary Computer
FCTM	Flight Crew Training Manual
FD	Flight Director
FDM	Flight Data Monitoring
FDR	Flight Data Recorder
FMGEC	Flight Management Guidance and Envelop Computer
FO	First Officer
FOBN	Flight Operation Briefing Note
FSO	Flight Safety Officer
Ft	Feet
FWC	Flight Warning Computer
GRIAA	GRupo de Investigación de Accidentes Aéreos (Colombian accident investigation authority)
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
JAA	Joint Aviation Authorities
JAR	Joint Aviation Requirements
Kt	Knots
LDA	Landing Distance Available
LIFUS	Line Flying Under Supervision
LOC	LOCalizer
MCT	Manuel de Contrôle Technique (Technical Inspection Manual)
METAR	Aerodrome routine meteorological report
MTOW	Maximum Take-Off Weight
OCV	Organisme du Contrôle en Vol (Flight control organization)

OEI	One Engine Inoperative
PEPN	Pôle Expertises Personnels Navigants (Flight crew expertise centre)
PF	Pilot Flying
PFD	Primary Flight Display
PFR	Post Flight Report
PLI	Pitch Limit Indicator
PM	Pilot Monitoring
QAR	Quick Access Recorder
QFU	Magnetic orientation of runway (in tens of degrees)
QNH	Altimeter setting to obtain aerodrome elevation when on the ground
RA	Radio Altimeter
SB	Service Bulletin
SRS	Speed Reference System
SWY	StopWaY
TEM	Threat and Error Management
THS	Trimmable Horizontal Stabilizer
TOD	Take-Off Distance
TODA	Take-Off Distance Available
TOGA	Take-Off Go Around
TOR	Take-Off Run
TORA	Take-Off Run Available
TOW	Take-Off Weight
TR	Type Rating
TRI	Type Rating Instructor
V_{ef}	Speed at which the critical engine is assumed to fail during take-off
V_{LOF}	Lift off speed
V_R	Rotation speed
V_1	Decision speed
V_2	Take-off safety speed

Synopsis

Time	23:55[1]
Operator	Air France
Type of flight	Commercial air transport
Persons on board	Captain (PF); first officer (PM); relief pilot; 10 cabin crew; 268 passengers
Consequences and damage	None

[1]Except where otherwise indicated, the times in this report are in Universal Time Coordinated (UTC).

Abnormally long take-off

On 11 March 2017, the Airbus A340 registered F-GLZU and operated by Air France carried out flight AF423 (a commercial passenger flight) from Bogotá Eldorado airport (Colombia) to Paris Charles de Gaulle airport (France). Two hundred and sixty eight passengers and 13 crew members were on board. The captain was the Pilot Flying (PF) for this leg.

The take-off was performed at night from runway 13R which is 3,800 m long with a clearway (CWY) of 300 m. At 23:54 UTC, the crew applied 50 % thrust on brakes and then took off with full thrust (TOGA).

The captain initiated the rotation when the calibrated airspeed had reached the rotation speed (VR). The aeroplane was at 2,760 m from the 13R threshold. The rotation rate of the aeroplane was slow. The three crew members said that they heard the audio warning "*PITCH PITCH*". The main landing gears left the ground when the aeroplane was at 140 m from the opposite runway threshold.

The aeroplane flew over the opposite runway threshold at 6 ft, detected by the Radio Altimeter (RA). The end of the CWY was crossed at a height of 20 ft RA. The speed was V2 + 9 kt. The aeroplane flew over the ILS antennas (first obstacle) at a vertical distance of 12 ft.

The climb then continued without any other particularity and the regulatory margins for obstacle clearance on the climb path of the second segment were complied with.

The investigation showed that the serious incident was the result of insufficient nose-up inputs from the PF which increased the take-off distance by 424 m with respect to the certified theoretical take-off distance plus regulatory safety margins, in the operational conditions of the day. As a consequence of this, the risk of a runway overrun or collision with obstacles was significantly increased.

In the conditions of the serious incident, the initial nose-up input then held at the typical value recommended by the FCTM (2/3 of the backward deflection) was not sufficient to reach the rotation rate of 3°/s which is the rotation rate retained in the certified performance model, also mentioned in the FCTM.

Before this event, the difference between the rotation rates obtained in operations and that taken into account in the performance calculations had not been identified by the operators of the Airbus A340-400 due to the absence of air safety reports and monitoring of take-off performance during flight analyses.

During the investigation, the operators, Air France and Lufthansa, the manufacturer, Airbus and the certification authority, the European Aviation Safety Agency (EASA) adopted safety measures which were communicated to the BEA.

On the basis of the safety investigation and taking into account these safety measures, the BEA has addressed seven safety recommendations to EASA. These recommendations concern:

- the certification of take-off performance;
- the management of risks related to long take-offs;
- the flight analysis programme.

ORGANISATION OF THE INVESTIGATION

After the serious incident of 11 March 2017, the crew wrote an Air Safety Report (ASR) on 14 March and requested the analysis of the flight data. The ASR indicated that the take-off was very long and that the aircraft flew over the threshold of the opposite runway at a radio altimeter height of a few feet.

From 21 to 23 March, the Air France internal investigation team carried out several investigations with various Air France departments in order to collect information and characterize the event. The flight data was thus analysed by the flight analysis department. The procedure to detect long take-offs was not yet in existence and the preliminary results of the flight analysis indicated that the opposite threshold was flown over at a height of 4 ft. Verifications were also made with the freight, dispatch and aircraft performance departments. The preliminary results did not reveal a data entry error by the crew, a technical problem or a weight and balance problem. Air France then decided to open an internal investigation and, in accordance with the protocol signed by Air France and the BEA(2), informed the latter of this on 24 March 2017.

(2)This protocol specifies the conditions in which Air France and the BEA implement, in the interest of aviation safety, the means and procedures required for the transmission of safety data regarding events to be notified.

The data and preliminary results from the flight analysis supplied by Air France led the BEA to classify this event as a serious incident.

In accordance with the standards and recommended practices in Annex 13 to the Convention on International Civil Aviation (ICAO), the BEA informed the GRIAA, its Colombian counterpart, Colombia being the State of Occurrence of this serious incident. The BEA also requested that the GRIAA delegate the investigation to them. This delegation proposal was accepted by the GRIAA on 5 April 2017 who then designated an accredited representative (Accrep).

The BEA involved its following foreign counterparts in the investigation, who designated accredited representatives:

- The BFU (Germany), as Lufthansa also operates Airbus A340s, some of them being of the same version as F-GLZU, at Bogotá. This meant that the investigation was able to benefit from the help of Lufthansa technical advisers.
- The CIAIAC (Spain), as Iberia also operates Airbus A340s, but of a different version to F-GLZU, at Bogotá.

The BEA also associated technical advisers from EASA, the French civil aviation authority (DGAC), Airbus and Air France.

The safety investigation was organized into three working groups in the following fields: Aircraft, Aeroplane systems and Operations. The accredited representatives and technical advisers were split between these three groups.

1 - FACTUAL INFORMATION

1.1 History of the flight

On 11 March 2017, the Airbus A340 registered F-GLZU and operated by Air France carried out flight AF423 (a scheduled commercial passenger flight) from Bogotá Eldorado airport (Colombia) to Paris Charles de Gaulle airport (France). Two hundred and sixty eight passengers and 13 crew members were on board. The flight crew was composed of a captain (PF on this leg), a FO and a relief pilot[(3)]. The FO, in the right seat, was line flying under supervision on the A340. The crew members said that they had not felt excessively tired during the layover and had consulted the flight file on their tablets (EFB) before arriving at the airport. The flight planning was carried out in the cockpit. The crew said that they were not disturbed by an excessive number of interruptions to their tasks.

Take-off was planned for 23:30. Runway 13R was in use; the runway was wet at the time of the event. The QNH was 1026 hPa, the temperature 13°C and the wind 310° for 4 kt.

The crew said that, in the flight planning, they did several take-off performance calculations on the EFB, for runway 13R and had anticipated a wet runway. In the conditions of the day, the EFB supplied the following calculation results to the crew:

- V1 = 128 kt, VR = 142 kt, V2 = 149 kt;
- maximum take-off weight due to performance limitation MTOW(perf) = 237 t, for a take-off weight of 236.3 t;
- the take-off performance was limited by the distance of the take-off run with one engine inoperative (TOR_{N-1}[(4)]);
- in the event of an acceleration-stop, the margin was 57 m.

The crew specified that this final calculation showed a positive margin of a few hundred kilos with respect to the day's maximum take-off weight with the hypotheses adopted. The Threat and Error Management (TEM) strategy used by the crew was that recommended by the operator: application of 50 % TOGA thrust on brakes and packs switched to the APU. The crew also mentioned the line-up with the runway threshold at 90°. The pilots specified that they paid specific attention to the safety altitudes, wind and the possible contamination of the runway due to the rain.

At 23:54:06, the controller cleared the crew to take-off from runway 13R and informed them of a wind from 300° at 4 kt. This value complied with that entered in the EFB.

At the end of the line-up, the aeroplane was 45 m from the runway 13R threshold. The brakes were released when the engine thrust (N1) reached 50 % at 23:54:20

At 23:55:20, the PF initiated the rotation at VR i.e. 142 kt. The aeroplane was at 2,760 m from the 13R threshold. The sidestick deflection was recorded at 9° nose up, two seconds after the initiation of the rotation (which corresponds to a deflection of around 57 %, the maximum deflection being 16°). The nose-up input then oscillated between 5° to 11° for the duration of the rotation.

At 23:55:30, i.e. 11 seconds after the rotation was initiated, the main landing gears were recorded as decompressed when the aeroplane was at 140 m from the opposite runway threshold. The aeroplane pitch attitude was 8.5°.

(3) Flight duty periods which exceed the flight time limitations fixed by regulations are carried out by augmented or double crews. In the case of a flight between Bogotá and Paris, the crew is augmented by a first officer.

(4) Cf. section 1.16.2.

One second later, the aeroplane crossed the opposite threshold at a height of 6 ft RA and a calibrated airspeed of 155 kt i.e. V2+6 kt.

At 23:55:33, the aeroplane reached mid-distance between wheel lift-off and a height of 35 feet which corresponds to a take-off run distance from the threshold of runway 13R of 4,005 m.

The crew indicated that they heard the "*PITCH PITCH*" audio warning start when the pitch attitude was at 10° and the aeroplane still on the ground.

The aeroplane crossed the end of the clearway (CWY) at a height of 20 ft RA and a speed of 158 kt i.e. V2+9 kt.

The aeroplane flew over the first obstacle, the LOC antenna, at a height of 32 ft RA, i.e. 12 ft RA above the obstacle at a speed of 159 kt i.e. V2+10 kt. The attitude was 12.3° and the vertical speed close to 0. The time between the first nose-up input initiated at VR and the moment when the aeroplane reached its target attitude of 12.5° was 15 seconds.

The aeroplane reached a height of 35 ft RA at 4,350 m from the runway 13R threshold. The Take-Off Distance (TOD) was 4,305 m.

The take-off continued and the aeroplane flew over the obstacles of the second segment with margins greater than the regulatory minimums.

The crew was aware of the erosion of the take-off margins. The relief pilot then asked the captain whether there was a possibility that they had struck the antennas. The crew checked the WHEEL page where no anomaly was displayed.

The flight then continued to destination without any other particularity. The crew wrote an ASR to advise of the long take-off and flight over the opposite threshold at an estimated RA height of 4 ft.

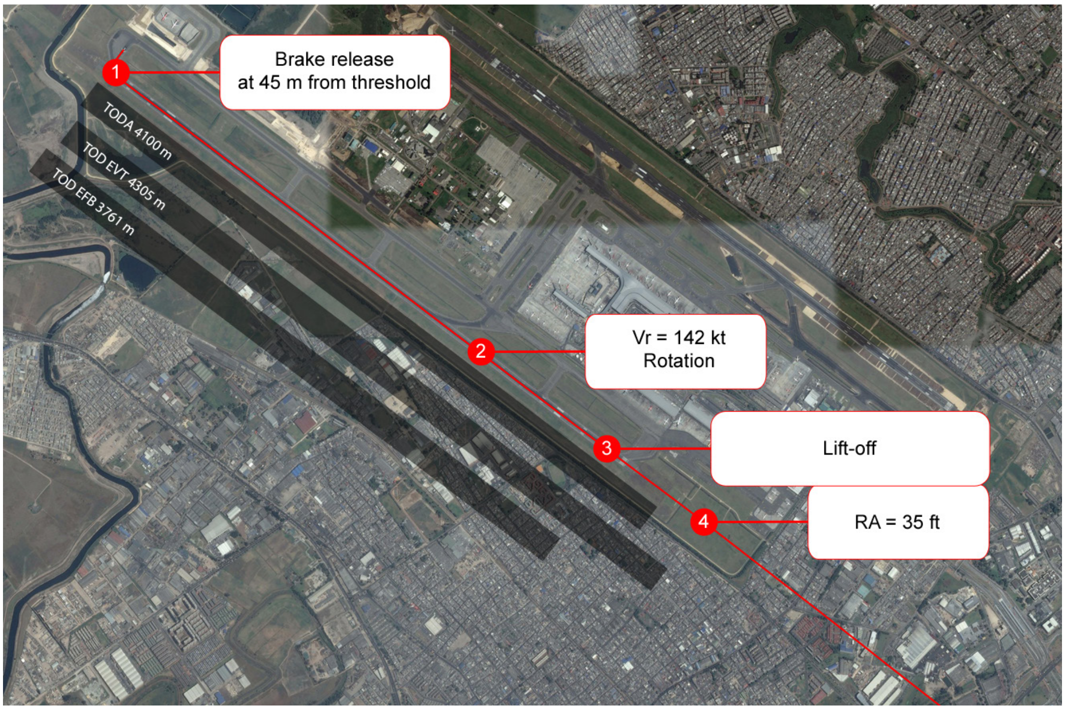


Figure 1: Take-off distances

1.2 Injuries to persons

	Injuries		
	Fatal	**Serious**	**Minor/None**
Crew	**-**	**-**	**13**
Passengers	**-**	**-**	**268**

1.3 Damage to aircraft

None.

1.4 Other damage

None.

1.5 Personnel information

1.5.1 Flight crew

1.5.1.1 Captain

Male, aged 47, French national.

Licence, rating
Airline Transport Pilot Licence (ATPL) issued on 14 February 2009.
First Type Rating (TR) on A330/A340 in 2013.
A340 TR valid until 30 September 2017.
A330 TR valid until 31 March 2017.
A340 Type Rating Instructor (TRI) qualification issued on 6 October 2016.
Class 1 medical check-up valid until 31 January 2018.

Experience
Total experience: 14,050 flight hours, including 8,003 as captain.
On A320: 8,158 flight hours, including 5,580 as captain.
On B747: 2,896 flight hours as FO.
On A340: 815 flight hours as captain.
On A330: 1,608 flight hours as captain.
In the previous three months: 155 flight hours.
In the previous seven days: 40 flight hours.
In the previous 72 hours: flight time of 13 hours 20 minutes.

Bogotá experience: One rotation on 2 December 2016

Aviation career
Trained as airline transport pilot at the French National School of Civil Aviation (ENAC) and then recruited by Air France.
Employed as FO on A320 for five years.
Employed as FO on B747 for seven years.
Employed as captain on A320 and then A330/A340 from 2013.

1.5.1.2 First officer

Male, aged 50, French national.

Licence, rating, training and checks
ATPL issued on 28 December 2003.
A340 TR valid until 31 December 2017.
A330 TR valid until 30 June 2017.
Class 1 medical check-up valid until 1 September 2017.

Experience
Total experience: 11,312 flight hours.
Air force: 6,832 hours (Transall), of which 4,772 hours as captain.
Air France: 4,480 flight hours as FO.
On A320: 3,900 flight hours.
On A340: 117 flight hours.
On A330: 441 flight hours.
In the previous three months: 114 flight hours.
In the previous 30 days: 48 flight hours.
In the previous 72 hours: flight time of 13 hours 20 minutes.

Bogotá experience: first rotation the day of the serious incident.

Aviation career
Military sector then recruited by Air France. Employed as FO on A320 in 2007.
Started long-haul flights (A330) in 2016.

1.5.1.3 Relief pilot

Male, aged 34, French national.

Licence, rating, training and checks
ATPL issued on 13 February 2014.
A340 TR valid until 28 February 2018.
A330 TR valid until 30 September 2017.
Class 1 medical check-up valid until 28 February 2018.

Experience
Total: 6,494 flight hours as FO.
On A320: 4,197 flight hours.
On A340: 1,021 flight hours.
On A330: 1,035 flight hours.
In the previous three months: 203 flight hours.
In the previous 30 days: 60 flight hours.
In the previous 72 h: flight time of 13 hours 20 minutes.

Bogotá experience: eight rotations before the flight of the serious incident.

Aviation career
Trained as airline transport pilot at the ENAC and then recruited by Air France.
Employed as FO on A320 in 2006.
Assigned to long-haul flights (A330/A330) in 2013.

1.6 Aircraft information

1.6.1 Airframe

Manufacturer	Airbus
Type	A340-313E
Serial Number	377
Registration	F-GLZU
Entry into service	3 December 2000
Airworthiness review certificate	15 January 2017 valid until 30 January 2018
Operation as on 11 March 2017	72,451 flight hours and 9,740 cycles

1.6.2 Engines

Manufacturer: CFMI
Type: 4 x CFM56-5C4

	Engine No 1	Engine No 2
Serial number	741894	741686
Installation date	23 May 2013	30 June 2015
Total operating time	70,441 hours and 9,351 cycles	79,058 hours and 10,715 cycles
Operating time since last maintenance	15,317 hours and 2,186 cycles	6,687 hours and 949 cycles

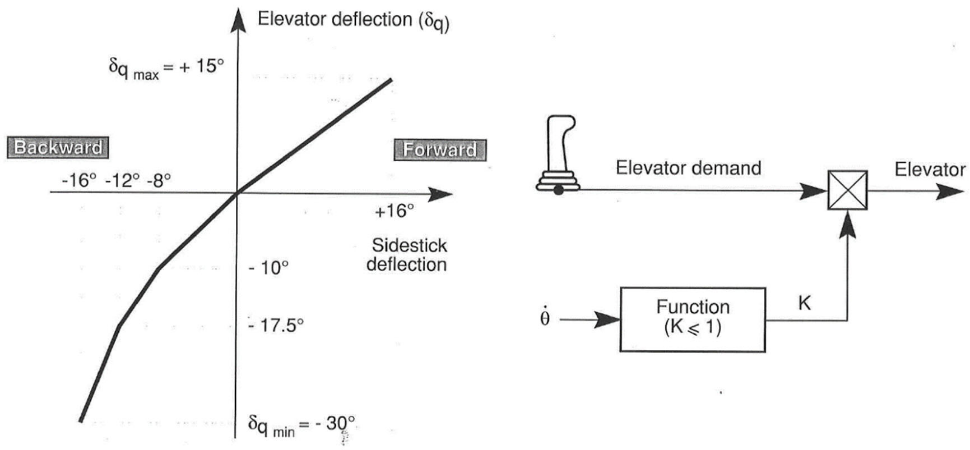
	Engine No 3	Engine No 4
Serial number	741896	740326
Installation date	21 January 2014	19 February 2016
Total operating time	69,701 hours and 9,149 cycles	87,619 hours and 11,841 cycles
Operating time since last maintenance	12,233 hours and 1,760 cycles	4,223 hours and 581 cycles

1.6.3 Rotation control laws

1.6.3.1 Pitch control law

On the A340-300, on the ground, the pitch control law is direct. Except for the pitch damper function discussed below, there is a direct relation between the sidestick pitch position and the position of the aeroplane elevator. There is no automatic trim in this law. On the ground, the Trimmable Horizontal Stabilizer (THS) is automatically positioned at 5° nose-up. After engine starting, the crew must modify this position for take-off according to the Centre of Gravity (CG) value.

This flight control law includes a pitch damper which dampens rotation inputs which are too strong in order to limit the risks of a tailstrike. This pitch damper reduces the position of the elevator by up to 40 % for rotation rates above 5°/s.



Source: Airbus

Figure 2: Diagram of direct law and pitch damper law

Once the systems consider that the aeroplane is in flight, the control law progressively changes to the pitch normal law. Piloting is then carried out according to the load factor demand.

Changes to pitch control law

On 13 June 2008, Airbus published Service Bulletin No. A340-27-4148 recommending the modification of the Flight Control Primary Computer (FCPC). This modification (Standard L19) introduced, among other things, the following two functions to reduce the risk of tailstrike:

- a feedforward order (anticipator) which reduces the response time between the initial input made with the sidestick and the start of rotation of the aeroplane. This function modifies the position of the elevator by less than 10 %.
- An Electronic Tail Bumper which adds a nose-down input (maximum 2/3 of input given by the direct law) when the tailstrike margin has dropped below a certain threshold (based on the radio altimeter and pitch).

In 2010, EASA integrated the Airbus SB into Airworthiness Directive No 2010-0081R1[5]: *Flight Controls – Elevator Servo Control Solenoid Valve O-ring Seals – Replacement & Airplane Flight Manual/Master MEL – Temporary Revision & Elevator Servo Controls – Modification & Primary and Secondary Computers – Modification* which made mandatory, the replacement of devices included in the elevator controls which led to the update of the documentation and the replacement of the computers concerned by the Airbus SB.

The SB, AD and Flight Crew Operating Manual (FCOM) do not mention the protections against the risk of tailstrike provided by these new functions.

[5] https://ad.easa.europa.eu/ad/2010-0081R1

1.6.4 In-flight and technical checks of A340-313E registered F-GLZU following serious incident

The A340-313E registered F-GLZU was withdrawn from operation between 19 and 27 April in order to undergo the following technical checks:

- weight: check for conformity between the aeroplane gross weight and that entered in the performance calculation software;
- test and measurement of the thrust of the four engines;
- visual inspection of the slats and flaps to detect any possible damage likely to explain the degraded performance;
- check flight in coordination with Airbus.

The check flight and the verifications showed that all the data checked complied with the reference values given by the manufacturer. The aeroplane was returned to service on 27 April 2017.

1.6.5 Airbus documentation

1.6.5.1 General

The operational reference documents for the crews are made up of:

- **Flight Crew Operating Manual (FCOM)**

The FCOM is a document intended for the flight crew, which must set out the technical information in the AFM in an operationally usable form.

The FCOM is designed to:

- Supply all the limitations, procedures, performance and information about the systems, required by the flight crew, so that they can operate the aeroplane in a safe and effective way in normal, abnormal and emergency situations.
- Be used as it is or as a basis for operators to develop their own operating manuals, in accordance with the applicable regulatory requirements.
- Act as a reference guide during initial and continuous training of the flight crews.

- **Flight Crew Techniques Manual (FCTM)**

The FCTM is published as a supplement to the FCOM. It is intended to provide pilots with practical information on the way of using the aeroplane. It should be read in conjunction with the FCOM. In case of disagreement, the FCOM prevails.

The FCOM and the FCTM are not documents approved by the certification authorities.

1.6.5.2 Operational documents regarding rotation technique

The Airbus A340 rotation technique is described in the FCOM and FCTM. The FCOM states that at VR, the pilot must initiate the rotation with a positive sidestick input to achieve a continuous rotation rate of about 3°/s, towards a pitch attitude of 12.5°, and then follow the SRS pitch command bars on the PFD once in flight.

The FCOM also provides recommendations in the event of a tailstrike in a boxed paragraph (see below).

Ident.: PRO-NOR-SOP-12-A-00012078.0002001 / 19 JAN 11
Applicable to: MSN 0078-0399

AT VR

ROTATION...ORDER
ROTATION...PERFORM

- *At VR, initiate the rotation with a positive sidestick input to achieve a continuous rotation rate of about 3 °/s, towards a pitch attitude of 12.5 °.*
- *Minimize lateral inputs on ground and during the rotation, to avoid spoiler extension. In strong crosswind conditions, small lateral stick inputs may be used, if necessary, to aim at maintaining wings level.*
- *After lift-off, follow the SRS pitch command bar.*

CAUTION	If a tailstrike occurs, avoid flying at an altitude requiring a pressurized cabin, and return to the originating airport for damage assessment.

Figure 3: Excerpt from FCOM - Standard Operating Procedure - Take-off

In addition, the FCTM recommends that the rotation is initiated with a "*smooth positive backward sidestick input (typically 2/3 backstick)*" and exposes the effect of the aeroplane's inertia on its take-off performance.

It recommends avoiding "*aggressive and sharp inputs.*" It adds that rotation rates which are too low (significantly below 2°) should be avoided (reduction of take-off performance). It states that the pilot must avoid rapid and large corrections, particularly at the time of lift-off, as this significantly increases the possibility of tailstrike.

AIRFRANCE ***A330/A340*** **FLIGHT CREW TECHNIQUES MANUAL**	**PROCEDURES** **NORMAL PROCEDURES** STANDARD OPERATING PROCEDURES - TAKEOFF

ROTATION TECHNIQUE

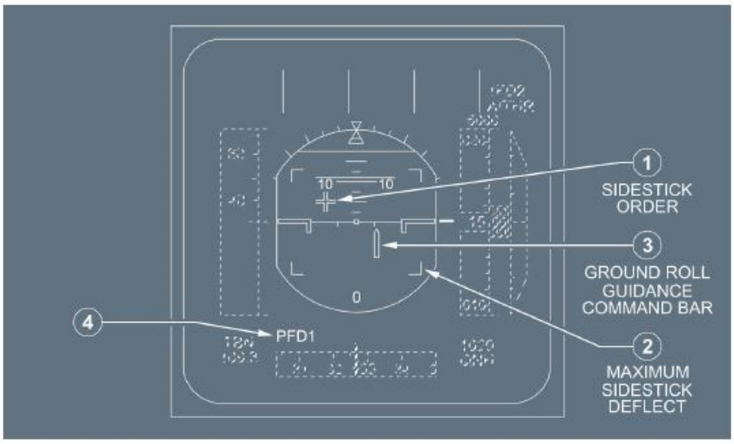
Rotation is conventional. During the takeoff roll and the rotation, the pilot flying scans rapidly the outside visual reference and the PFD . Until airborne, or at least until visual cues are lost, this scanning depends on visibility conditions (the better the visibility, the higher the priority given to outside visual references). Once airborne, the PF then controls the pitch attitude on the PFD using FD bars in SRS mode which is then valid.
The higher the inertia of the aircraft is, the more it is important to initiate the rotation with a smooth positive backward sidestick input (typically 2/3 backstick). Avoid aggressive and sharp inputs.
The initial rotation rate takes time to establish. For a given sidestick input, once it has developed, it remains relatively constant. It is typically about 3 °/s. Avoid low rotation rates as this will have an impact on takeoff performance by increasing the takeoff ground run. Rotation rates between 2 °/s and 3 °/s will have a minimal impact on takeoff run but rates significantly below 2 °/s should be avoided. The time for rotation (from start of rotation input to lift off) is typically around 5 s to 7 s.
If the established pitch rate is not satisfactory, the pilot must make smooth corrections on the stick. He must avoid rapid and large corrections, which cause sharp reaction in pitch from the aircraft. If, to increase the rotation rate, a further and late aft sidestick input is made around the time of lift-off, the possibility of tailstrike increases significantly.
During rotation, the crew must not chase the FD pitch bar, since it does not give any pitch rate order, and might lead to overreaction.
Once airborne only, the crew must refine the aircraft pitch attitude using the FD , which is then representative of the SRS orders. The fly-by-wire control laws change into flight normal law, with automatic pitch trim active.

Figure 4: Excerpt from FCTM - Standard Operating Procedure - Take-off

For training purposes, the FCTM recommends practising during taxiing, by moving the sidestick 2/3 of its maximum deflection using the white cross (2/3 of reference square).

SPECIFIC GROUND INDICATIONS

Ident.: DSC-31-40-00000604.0001001 / 13 JAN 14
Applicable to: ALL



(1) Sidestick order indication (white)
This is displayed, as soon as one engine is started.
It indicates the total of the pilot's and copilot's sidestick orders (shown here as left wing down, pitch up).

(2) Max Sidestick Deflection (white)
This is displayed, as soon as one engine is started.

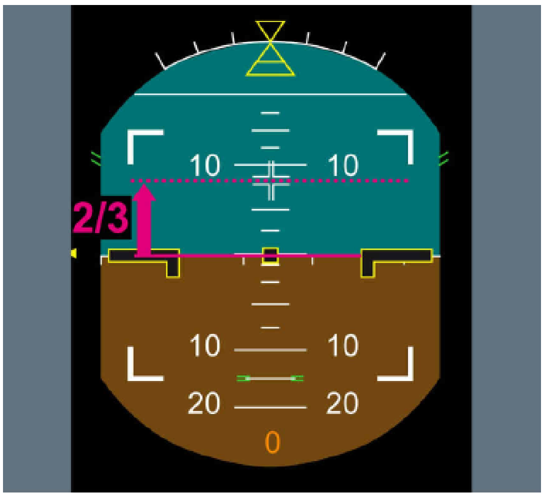
ROTATION

Ident.: PR-NP-SOP-120-00019529.0001001 / 20 MAR 17
Applicable to: ALL

INITIAL STICK INPUT CALIBRATION IN TRAINING

In training, during taxi, the crew may calibrate the appropriate effort and displacement for the initial stick input for rotation (2/3 back-stick), by pulling aft on the stick and observing the position of the stick cross symbol on the PFD, compared to the stick position reference square.

Side Stick Input Calibration During Taxi



Note: *the cross is not to be used by PF during the takeoff, whereas the PM can check the validity of the PF initial stick input.*

Figure 5: Excerpt from FCTM - Standard Operating Procedure – Take-off

The FCTM details the risks of tailstrike and the main contributing factors:

- starting rotation before VR;
- rotation technique;

ROTATION TECHNIQUE

The recommendation given in the ROTATION TECHNIQUE paragraph should be applied.
A fast rotation rate increases the risk of tailstrike, but a slow rate increases take-off distance.
The recommended rate is between 2 and 3 °/s , which reflects the average rates achieved during flight test, and is also the reference rate for performance calculations.

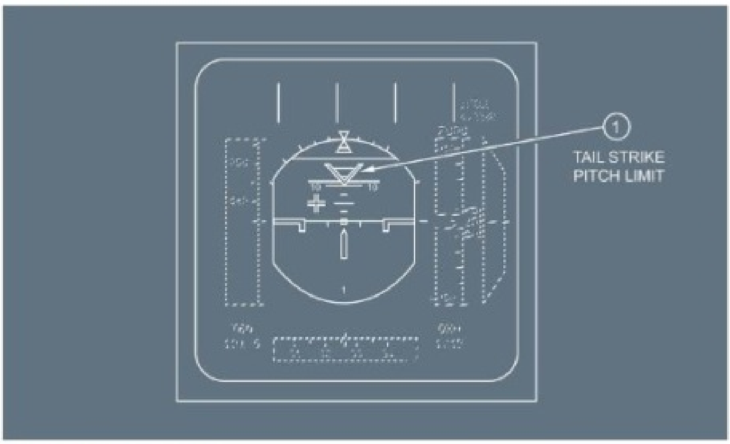
- configurations;
- trim settings;
- taking off with crosswind;
- shock-absorber pressure.

The manufacturer has also developed a system to reduce the risks of tailstrike:

- the "*tailstrike pitch limit indicator*" displayed on the PFD when the aeroplane is on the ground and which disappears after take-off when there is no longer a risk of tailstrike;
- the audio call-out "*PITCH PITCH*" (synthetic voice) when the pitch attitude is excessive (only available during the flare and landing phases).

TAIL STRIKE PITCH LIMIT INDICATOR

Ident.: DSC-31-40-00017879.0006001 / 21 MAR 16
Applicable to: ALL



(1) Tail Strike Pitch Limit
The pitch limit indicates the maximum pitch attitude to avoid the tail strike risk at takeoff and landing. During takeoff, the indication progresses from the pitch limit value with main landing gear compressed, to the pitch limit value with main landing gear extended. The indication is removed when the tail strike risk disappears.
During landing, the indication is a fixed value corresponding to the main landing gear compressed. The indication appears at 400 ft radio height.

Figure 6a: Description of Tail Strike Pitch Limit Indicator

The aeroplane reaches VR and the PF calls out "ROTATE" at T0.

The PF initiates the rotation with a nose-up input of more than 2/3 of the deflection in less then one second, T0+1s.

The pitch indicator quickly moves vertically towards the TAILSTRIKE PITCH LIMIT chevron, at T0 + 5 s and touches the chevron.

The chevron then moves away from the pitch indicator which is the sign of the start of lift-off (decompression of landing gears) at T0 + 6 s and then disappears.

1.7 Meteorological information

The Colombian authorities provided the BEA with the following weather information:

METARS for 23:30 and 00:00 UTC:

- METAR SKBO 112300Z 35006KT 9000 VCSH SCT015CB SCT070 13/10 A3025 RETSRA RMK CB/VCSH/LTNG/NW/=
- METAR SKBO 120000Z 31004KT 9000 VCSH SCT015CB SCT070 13/10 A3029 RMK CB/VCSH/LTNG/NW/=

1.8 Aids to navigation

Not applicable.

1.9 Communications

Not applicable.

1.10 Aerodrome information

The Bogotá El Dorado international airport (SKBO) is located in the north-west of the city at an altitude of 8,360 ft in a mountain environment. It is open to commercial air transport and has two parallel runways, 13L/31R and 13R/31L.

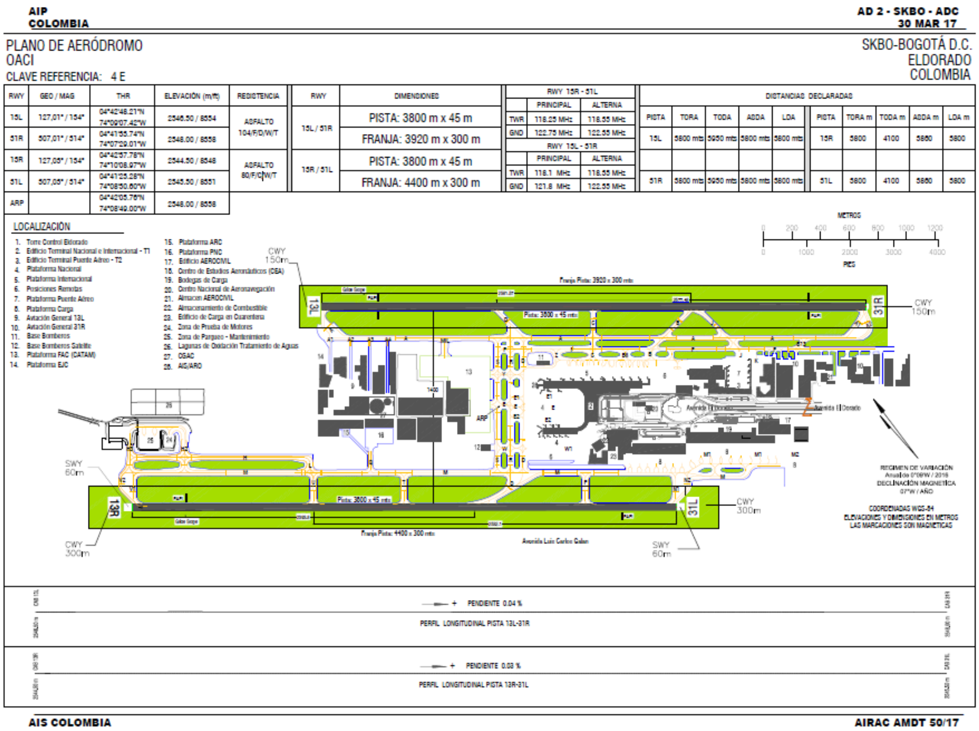


Figure 8 : AIP Colombia aerodrome chart

Characteristics of runway in use on day of serious incident:

Runway	Dimensions (m)	LDA	TODA	TORA	ASDA	SWY (m)	CWY (m)
13R	3,800 x 45	3,800	4,100	3,800	3,860	60	300

1.11 Flight recorders

1.11.1 General

The aeroplane was equipped with two flight recorders (FDR and CVR) in accordance with the regulations in force[6] and a DAR recorder designed to systematically analyse the flights. Certain data recorded by this equipment supplements the FDR data.

[6]On certification of this aeroplane in March 1995, JAR25 (Change 13) was applicable. It imposed on-board recorders meeting the EUROCAE ED55 (FDR) and ED56 (CVR) specifications.

The BEA was notified on 24 March 2017, i.e. 13 days after the event. The aeroplane continued flying during this lapse of time which meant that it was not possible to read and analyse the flight data of the event, provided by the regulatory recorders. In accordance with regulations, the recorders which equip this aeroplane have a data storage period of 25 hours for the FDR and two hours for the CVR.

The BEA received the DAR data on 28 March 2017. This data only contained the event flight.

1.11.2 Read out and analysis of DAR data

The data curves are available in Appendix I. The essential points for understanding the history of the serious incident are given in Section 1.1 History of the flight.

1.11.3 Difficulties encountered with read out and analysis of DAR data

It was observed that the read out of the DAR data by Air France, Airbus and the BEA gave different results for the description of the take-off phase. This could be explained by both the choice of data to be read out and their sampling frequency.

The work required to analyse this flight data and define the associated metrics was long and complex as some DAR data was raw and other data was already interpreted by the various systems of the aeroplane. This data did not all have the same time references or the same refresh rate. These characteristics thus introduced biases and made the following calculations difficult:

- accurate determination of wheel lift off;
- accurate determination of rotation rate during rotation time;
- accurate determination of tailstrike margin.

These difficulties had already been observed in the scope of the working group, European Operator Flight Data Monitoring (EOFDM) set up by EASA. This working group had considered that the monitoring of rotation rates by means of flight analysis is still difficult to implement in practice and depends on the level of technology available. This monitoring requires specific data and analysis techniques which must be developed and tested.

Nevertheless, a good practices guide was provided back in March 2014 indicating that relatively "*simple*" indicators could be set up to detect unusual take-offs in terms of take-off distance or rotation time, such as:

- distance between wheel lift-off and opposite runway threshold;
- time between initial nose-up input and wheel lift-off.

Detailed information in this respect is available in Appendix 2.

1.11.4 Post Flight Report (PFR)

The PFR did not reveal any malfunction which could explain the serious incident.

1.12 Wreckage and impact information

Not applicable.

1.13 Medical and pathological information

Not applicable.

1.14 Fire

Not applicable.

1.15 Survival aspects

Not applicable.

1.16 Tests and research

1.16.1 Take-off performance

1.16.1.1 Certification of take-off performance

Certification basis

The certification requirements for the Airbus A340 were contained in the JAR-25 (*Joint Aviation Requirements for Large Airplanes*) change 13, the reference document at European level for the certification of transport aeroplanes. This document contains the requirements for the take-off distances and speeds which must be shown in the certification[7].

[7]Cf. section 1.16.1.2, Runway limitations

In addition to this document, the FAA Advisory Circular 25-7 "*FLIGHT TEST GUIDE FOR CERTIFICATION OF TRANSPORT CATEGORY AIRPLANES*" contains the acceptable methods and procedures for showing conformity with these requirements during the certification flight tests.

Certification of A340-300 take-off performance

The A340 take-off performance was initially certified for the 311 version. After this version, two variants were certified:

- version 313 with different engines (CFM56-5C4 instead of CFM56-5C2);
- version 313E with greater weights, reinforced landing gears and optimization of the wings for cruise flight. This is the F-GLZU version.

During the certification, the test campaigns substantiated the take-off performance modelling of these two versions.

During the certification of the 311 version, the rotation rate was the subject of:

- thirty four tests with All Engines Operative (AEO);
- forty five tests with One Engine Inoperative (OEI);

at the Toulouse-Blagnac, Istres-Le Tubé and Abha (Saudi Arabia, altitude 6,600 ft) aerodromes. The tests were carried out with a forward centre of gravity, in the three slat and flap configurations (CONF 1+F, CONF 2 and CONF 3), with a wide range of aeroplane weights, thrust and V2 to cover the operating envelope.

Documents produced

The data from these tests was compiled into several documents:

- Certification Cards produced for each test which give the test conditions, the recorded data curves, an airworthiness assessment and the approval of the certification authorities (JAA).
- The Performance Certification Flight Test Report which compiles the results from all the performance tests and presents for each one, a summary of the results along with a description of the test technique and methods which were used to arrive at the AFM performance data. For the rotation rates, it contains the standard values taken for all engines operative (3.1°/s) and one engine inoperative (2.6°/s). This document specifies that these standard values were obtained using a conventional rotation technique and had not required any specific training or skill for them to be repeatedly obtained by the JAA test pilots involved in these tests.
- The Data Basis for AFM which details how the rotation rates shown in the AFM were calculated and the numerical values used.

The JAR 25 in force when the A340-300 was certified states that the take-offs performed to determine aircraft performance must not require the use of exceptional piloting techniques or vigilance. The AC 25-7 specifies that it must be possible for the procedures applied during these flight tests "*to be consistently executed in service by crews of average skill,* [that the procedures must] *use methods or devices that are safe and reliable, and include allowances for any time delays in the execution of the procedures that may reasonably be expected in service. These requirements prohibit the use of exceptional piloting techniques, such as higher control force inputs or higher pitch rates than would occur in operational service, from being used to generate unrealistic take-off distances. The intent of these requirements is to establish take-off performance representative of that which can reasonably be expected to be achieved in operational service.*"[8]

Asked by the BEA about the existence of definitions for a conventional rotation technique and exceptional piloting technique, the certification authority (EASA) stated that there is no specific criteria to define a conventional rotation technique in the regulations and that the JAR 25 paragraph quoted above means that the pilots must be able to repeat without difficulty, the procedures drawn up by the manufacturer.

[8]*"In accordance with § 25.101(f), testing for determining the accelerate-stop distances, takeoff flight paths, and takeoff distances should be accomplished using procedures established by the applicant for operation in service. In accordance with §25.101(h), these procedures must be able to be consistently executed in service by crews of average skill, use methods or devices that are safe and reliable, and include allowances for any time delays in the execution of the procedures that may reasonably be expected in service. These requirements prohibit the use of exceptional piloting techniques, such as higher control force inputs or higher pitch rates than would occur in operational service, from being used to generate unrealistic takeoff distances. The intent of these requirements is to establish takeoff performance representative of that which can reasonably be expected to be achieved in operational service."*

Reference rotation rate

The Data Basis gives the typical pitch attitude profile during rotation:

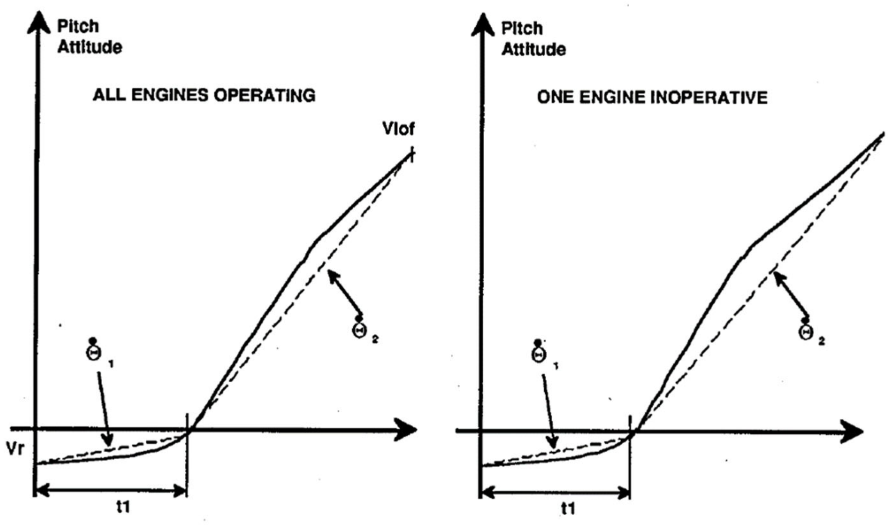


Figure 9: Excerpt from Data Basis certification document. Rotation rate

This profile was broken down into two parts:

- part 1 corresponding to the initial reaction of the aeroplane to the pilot's input with the stick;
- part 2 corresponding to the consecutive increase in pitch attitude, up to wheel lift-off - the definition of the "*continuous rotation rate*" is based on part 2.

Based on the 34 tests with AEO and 45 tests with OEI, the average value for the duration of part 1, the rotation rate in this part and the rate in part 2 were calculated.

Rotation rate (°/s)			
Part 1		Part 2 corresponding to "continuous rotation rate"	
Time	Rate	One Engine Inoperative (OEI)	All Engines Operative (AEO)
1.7 s	1°/s	2.6 °/s	3.1 °/s

These values were then used to build the aeromechanical model used to calculate the certified take-off distances and speeds. It was this model that was used to establish the AFM take-off performance data and also used for each calculation carried out by the crew using the EFB.

Stick input

The pitch profiles from the various AEO tests are shown below, superimposed on the event profile, along with the corresponding stick inputs.

The pitch profile shown in blue (curve 1 below) corresponds to the average test values shown in the AFM. Test V0102-06 is the closest (shown in orange). It corresponds to an initial stick input of 15° (i.e. 94 % of maximum deflection) applied in approximately 0.5 s and then held at around 12° (75 % of maximum deflection).

The brown curve (curve 2 below) corresponds, in the test conditions, to an initial stick input of 11° (which corresponds to the 2/3 typical initial stick deflection indicated in the FCTM) applied in around 0.5 s and then held at around this value. This test corresponds to the lower pitch profiles and to a rotation rate below that of the AFM used to calculate the take-off performance.

The green curve corresponds, in the test conditions, to an initial full backstick input (-16°) applied in 0.5 s then held for around 0.7 s before being moved to between 9 and 12°. This test corresponds to the upper pitch profiles and to a rotation rate above that of the AFM used to calculate the take-off performance.

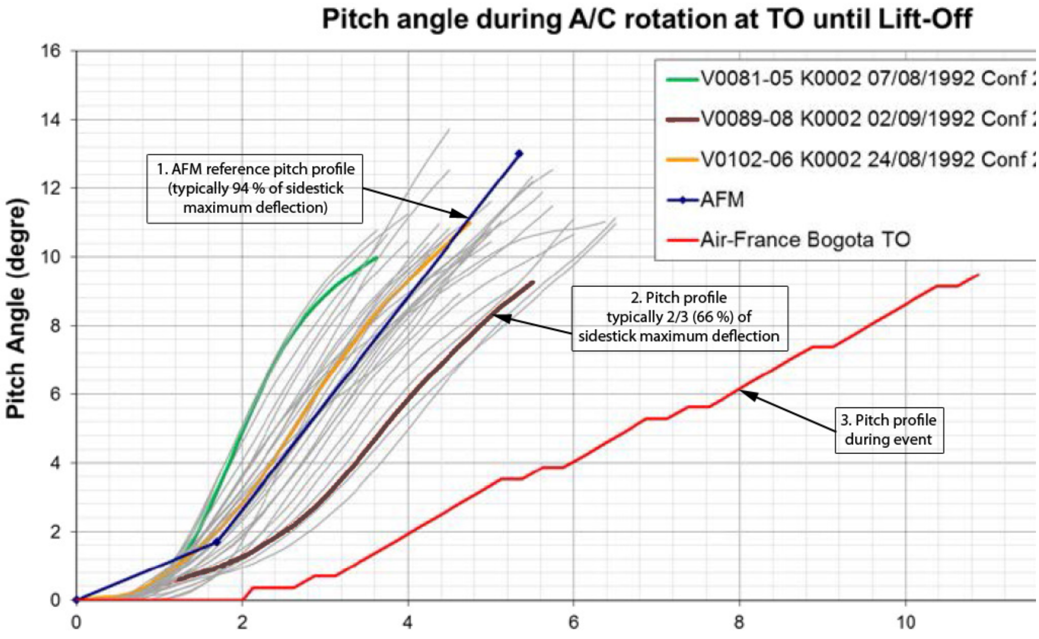
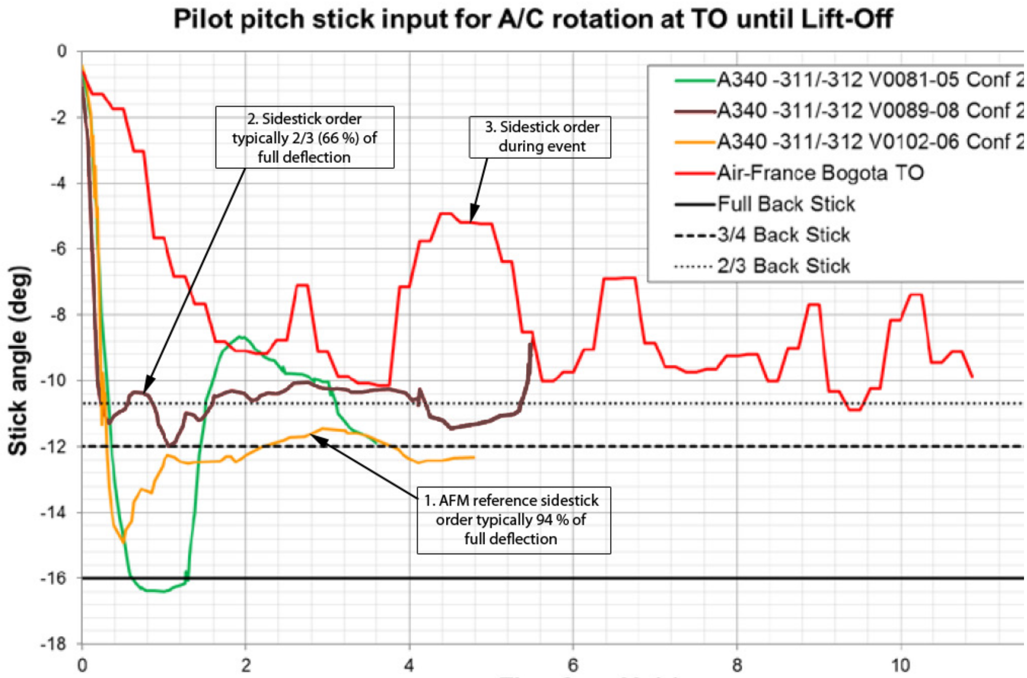


Figure 10: Pitch profiles

1. Curve 1 (orange): pitch profile close to AFM model. In the test conditions, it corresponds to a flight for which the initial sidestick input was around 94 % of the maximum stick deflection. Blue curve: pitch profile model retained in the AFM performance model, i.e. an established rotation rate of 3°/s.

2. Curve 2 (brown): pitch profile corresponding, in the test conditions, to an initial stick input close to the typical initial stick input described in the FCTM (around 2/3 - 66 % - of the sidestick's maximum deflection) and held at 2/3 of the deflection.

3. Curve 3 (red): pitch profile reached in serious incident of 11 March.



Source: Airbus

Figure 11: Sidestick inputs

1. Orange curve: sidestick input during test flight closest to the profile retained for the AFM.

2. Brown curve: sidestick input close to that described in the FCTM (around 2/3 (66 %) of the sidestick's maximum deflection).

3. Red curve: sidestick input applied in serious incident of 11 March 2017.

1.16.1.2 Calculation of operational performance at take-off

When carrying out the flight planning, the crew must, among other tasks, calculate the aeroplane performance at take-off. This is done, for the chosen runway and aeroplane configuration, and in the day's external conditions, to:

- ❒ determine the maximum weight at which the aeroplane can take-off while complying with all the regulatory margins (take-off distance, acceleration-stop distance, obstacle clearance margins, minimum climb gradient, etc.);
- ❒ calculate the take-off speeds V1, Vr and V2.

To do this, the crew use the performance calculation software provided by Airbus via an interface called EFB[10].

On the day of the event, the aeroplane was "limited by the runway" which means that the maximum weight was limited by the aeroplane take-off distance. These operational limitations are detailed below.

[10]The EFB is described in more detail in the Electronic Flight Bag section.

Runway limitations

To determine the runway limitations, the certification specifications for transport aeroplanes[11] define the following three distances to be calculated during the flight planning:

[11] CS 25.

- Take-Off Distance (TOD);
- Take-Off Run (TOR);
- Acceleration-Stop Distance (ASD).

a) TOD

On a dry runway, the TODdry is the greater of the two values below:

- 1.15*$TOD_{N,dry}$: 115 % of the distance covered between brakes off and the moment when the aeroplane is 35 ft above the take-off surface, all engines operative;
- $TOD_{N-1,dry}$: distance covered between brakes off and the moment when the aeroplane is 35 ft above the take-off surface, assuming a critical engine failure identified by the crew at V1.

On a wet runway, the TOD is the greater of the two values below:

- TOD_{dry};
- $TOD_{N-1,wet}$: distance covered between brakes off and the moment when the aeroplane is 15 ft above the take-off surface, assuming a critical engine failure identified by the crew at V1.

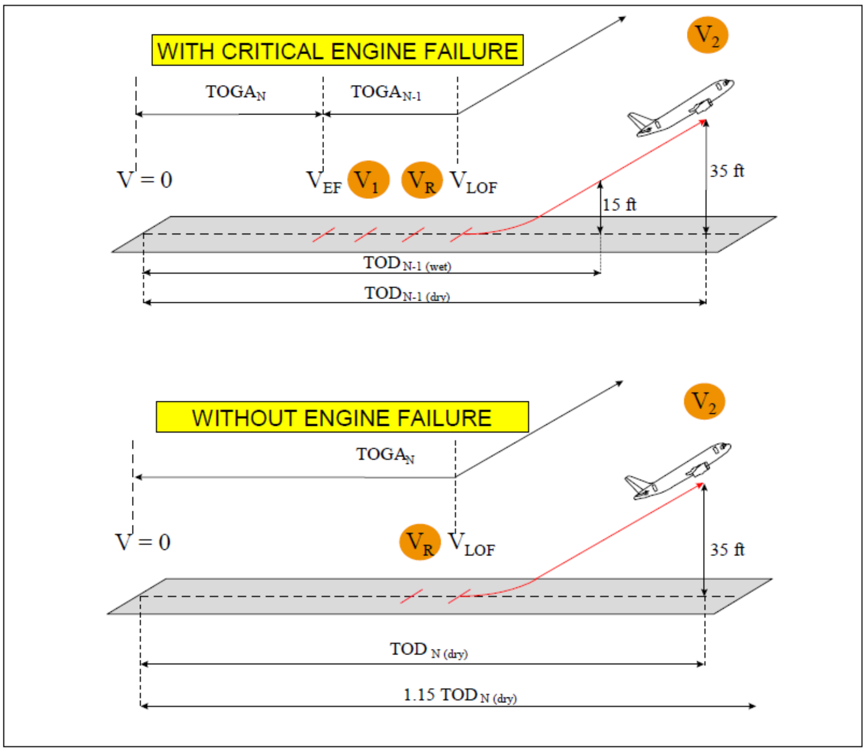


Figure C5: Takeoff Distance (TOD)

Source: Airbus

Figure 12: Excerpt from Getting [to] grips with aircraft performance

b) TOR
On a dry runway, the TOR_{dry} is the greater of the two values below:

- ❒ $1.15*TOR_{N,dry}$: 115 % of the distance covered between brakes off and the point midway between lift-off and when the aeroplane is at 35 ft, all engines operative;
- ❒ $TOR_{N-1,dry}$: distance covered between brakes off and the point midway between lift-off and when the aeroplane is at 35 ft, assuming a critical engine failure identified by the crew at V1.

On a wet runway, the TOR_{wet} is the greater of the two values below:

- ❒ $1.15*TOR_{N,wet}$: 115 % of the distance covered between brakes off and the point midway between lift-off and when the aeroplane is at 35 ft, all engines operative;
- ❒ $TOR_{N-1,wet}$: distance covered between brakes off and the moment when the aeroplane is 15 ft above the take-off surface, assuming a critical engine failure identified by the crew at V1. It is equal to $TOD_{N-1,wet}$.

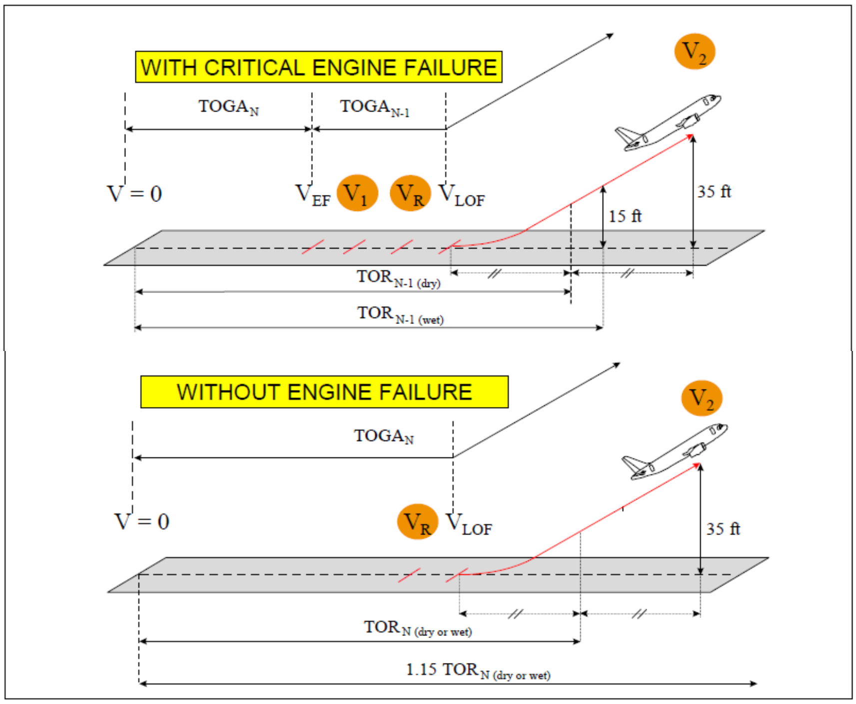


Figure C6: Takeoff Run (TOR) with a Clearway

Source: Airbus

Figure 13: Excerpt from Getting [to] grips with aircraft performance

c) ASD
On a dry runway, the ASD is the greater of the two values below:

- ❒ ASD_{N-dry} which is the sum of:
  - ■ the distance required to accelerate the aeroplane up to V1;
  - ■ the distance required to stop the aeroplane, assuming that the crew abort the take-off at V1, all engines operative;
  - ■ an additional distance margin corresponding to two seconds at speed V1[12].

[12]This definition applies to the A340, it may differ for aeroplane types certified at a later date.

- ASD$_{N-1,dry}$ which is the sum of:
  - the distance required to accelerate the aeroplane up to V_{EF}, speed at which the engine failure occurs, all engines operative;
  - the distance required to accelerate from V_{EF} to V1 assuming a critical engine failure at V_{EF} and that the crew react at V1;
  - the distance required to bring the aeroplane to a standstill;
  - an additional distance margin corresponding to two seconds at speed V1.

The definitions are identical on a wet runway and the ASDwet is the greater of all the distances calculated.

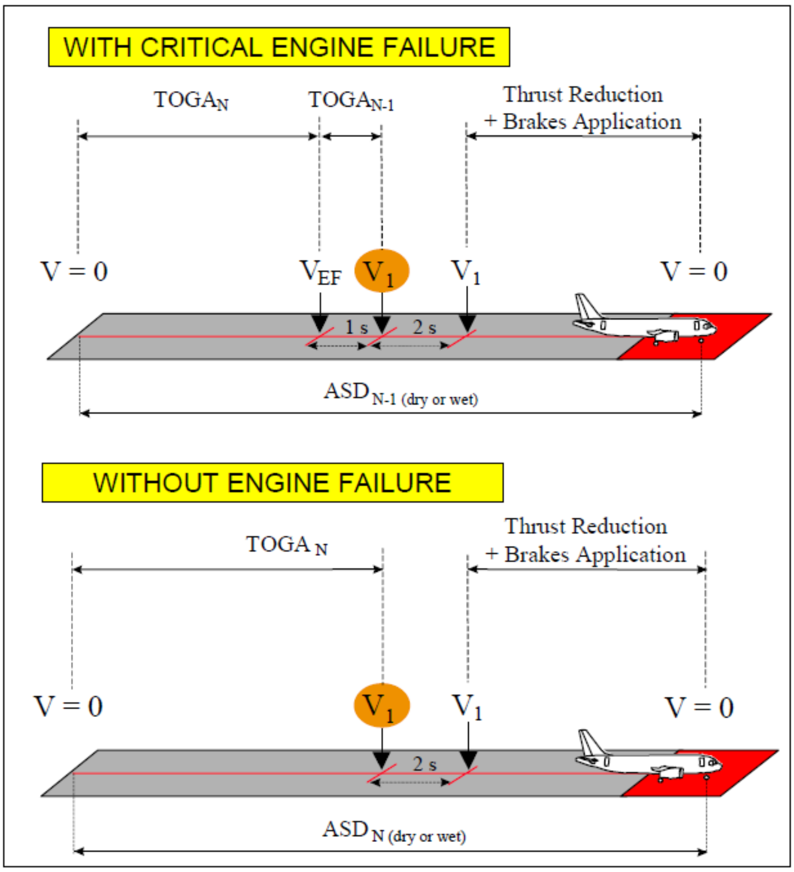


Figure C7: Accelerate Stop Distance (ASD)

Source: Airbus

Figure 14: Excerpt from Getting [to] grips with aircraft performance

Declared distances

Each of these distances (TOR, TOD, ASD) is compared with the declared distances for the corresponding runway in use, the definition of which is given in the diagram below.

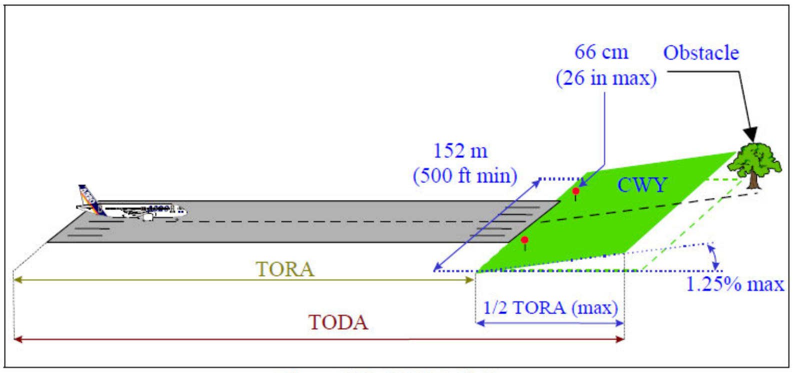


Figure C10: TODA Definition

Source: Airbus

Figure 15: Excerpt from Getting [to] grips with aircraft performance

The requirement to be complied with therefore, is that TOD<TODA, TOR<TORA, ASD<ASDA.

In addition to the runway limitations described above, the take-off performance calculation must also guarantee, with an engine failure occurring at V_{EF} processed by the crew at V1, that the take-off path will:

- clear obstacles with a sufficient margin;
- obtain a minimum climb gradient in each segment of the climb phase.

Limitations also exist with respect to the take-off speeds V1, VR, VLOF and V2, in order to guarantee that the aeroplane remains controllable on the ground and in flight in the event of an engine failure, and that the tires and brakes are not damaged.

Electronic Flight Bag (EFB)

This tool, designed by Airbus and programmed by Air France for its activity, is used by crews to calculate take-off performance. The take-off distance and speed calculations are based on the certified aeroplane model contained in the AFM, the regulatory margins defined by the certification and the operational regulations[13].

[13] Cf. previous section 1.16.1.1.

As well as being on the pilots' tablets used for the flight planning, the EFB is available on a lateral screen in the cockpit.

To carry out a calculation, the pilot enters the following information:

- aeroplane type and registration;
- runway in use for take-off;
- wind, temperature and atmospheric pressure (QNH) and runway condition (dry, wet, contaminated by water, etc.);
- centre of gravity and slat/flap configuration;
- use or not of the anti-icing systems and the air conditioning system during take-off;
- aeroplane Take-Off Weight (TOW) as specified on the weight and balance sheet.

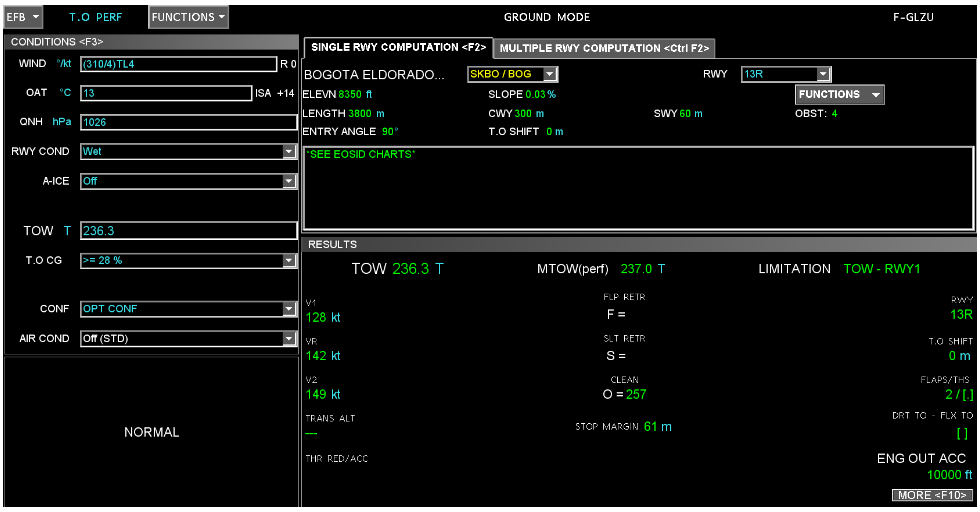


Figure 16: Entering of data in EFB

Based on this input data, the EFB calculates the distances, speeds and take-off path in the vertical plane. It then determines the maximum take-off weight in the conditions of the day which ensures that all the limitations described above are complied with. This weight is called the Maximum Take-Off Weight due to performance limitations (MTOW(perf)).

The data supplied to the crew is comprised of, notably:

- take-off speeds V1, VR and V2;
- MTOW(perf);
- remaining distance in the event of an acceleration-stop initiated at V1, the "stop margin".

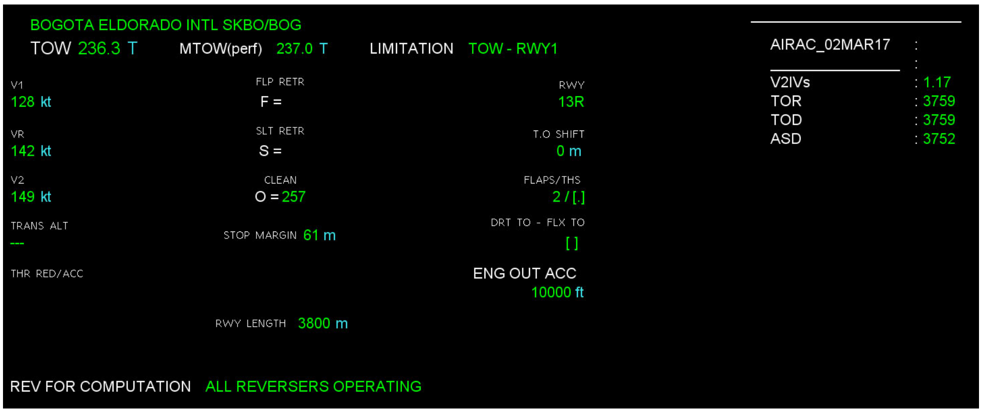


Figure 17: Calculation result

There can be two possibilities:

- if the TOW is below the MTOW(perf), the aeroplane can take-off;
- if the TOW is above the MTOW(perf), the aeroplane cannot take-off. The weight must be reduced and the crew must therefore refuse either freight, luggage or passengers.

The "OPT CONF" option can be chosen by the crew to calculate performance. In a case such as Bogotá (i.e. with performance limitation), the EFB will determine the configuration, generally CONF 2 or CONF 3 in order to have the optimum (highest) TOW in the conditions of the day.

1.16.2 Calculation of performance for event flight

There was no error in the data entered in the EFB by the crew and Airbus established that the EFB calculations complied with the certified performance model.

In the conditions of the day, the EFB supplied the crew with the following results:

- V1 = 128 kt, VR = 142 kt, V2 = 149 kt;
- MTOW(perf) = 237 t, for a take-off weight of 236.3 t;
- the centre of gravity position is 32 %;
- Stop margin = 57 m;
- limitation code TOW-RWY1[14].

The alignment distance defined by Air France in its performance calculation tool for the A340-300 was 22 m with respect to the runway threshold (this value can be modified by the operators according to their operating conditions). In the incident, 45 m was used for the alignment, i.e. an additional 23 m.

The aeroplane certified performance model (AFM) gave, in the conditions of the day:

- ***a run distance with all engines operative until wheel lift-off of 2,989 m i.e. a theoretical wheel lift-off 789 m before the opposite threshold;***
- ***a take-off distance (aeroplane at 35 ft) with all engines operative of 3,318 metres i.e. 760 metres before the end of the clearway.***

To comply with regulations, the aeroplane must pass the height of 35 ft at speed V2 at the latest, at the end of the clearway. The theoretical calculations of the aeroplane's certified performance model are supplemented by the regulatory margins which add an additional 15 % to the take-off distance (in the conditions of the day) and 150 % with respect to the tail wind value. These regulatory margins are designed to cover operational uncertainties and contingencies (e.g. uncertainties about weather conditions and the condition of the runway on take-off, aeroplane loads, individual variations in the aeroplane performance or pilot inputs).

The aeroplane's regulatory take-off performance, integrating these margins, is then:

- ***a run distance with all engines operative until wheel lift-off, of 3,498 m i.e. a regulatory margin of 509 m and a wheel lift-off at 280 m from the opposite runway threshold;***
- ***a take-off distance (aeroplane at 35 ft) with all engines operative of 3,881 metres i.e. a regulatory margin of 563 m and the aeroplane passing 35 ft, 197 m before the end of the clearway.***

[14] The limitation code "*TOR-RWY1*" means that the maximum take-off weight on the day of the incident was determined by the take-off run distance with one engine inoperative TORN-1 i.e. 3,761 m.

The tables below provide:

- the theoretical take-off distances provided by the performance model determined during the certification (AFM);
- the regulatory maximum take-off distances (AFM distances plus the margins defined by the regulations[(15)];
- the take-off distances calculated by Airbus with the hypotheses of an initial sidestick input applied at VR of 2/3 of the deflection in one second and then held at this value;
- the actual take-off distances covered the day of the serious incident.

[(15)]Regulations impose a margin of 150 % with respect to the tail wind (6 kt) and 115 % with respect to the distance previously calculated.

Distances:	TOR (TORA=3,800 m)	TOD (TODA= 4,100 m)
AFM	3,154 m	3,318 m
AFM + regulatory margins	3,690 m	3,881 m
Initial held input of 2/3 deflection	3,436 m	3,696 m
Serious incident	3,960 m	4,305 m

Lengthening of calculated distances between serious incident and:	TOR	TOD
AFM	+806 m	+987 m
AFM + regulatory margins	+270 m	+424 m
Percentage of regulatory margins used	150 %	175 %

The day of the serious incident, an initial input of 2/3 of the sidestick deflection with the stick then held at this value would not have permitted the take-off performance expected by the AFM to be reached. With such an input in the conditions of the serious incident, the regulatory margin applied to the distance from brakes off to the aeroplane passing 35 ft would have been reduced by 67 %.

Lengthening of calculated distances between a held 2/3 nose-up input and:	TOR	TOD
AFM	+282 m	+378 m
AFM + regulatory margins	-254 m	-185 m
Percentage of regulatory margins used	53 %	67 %

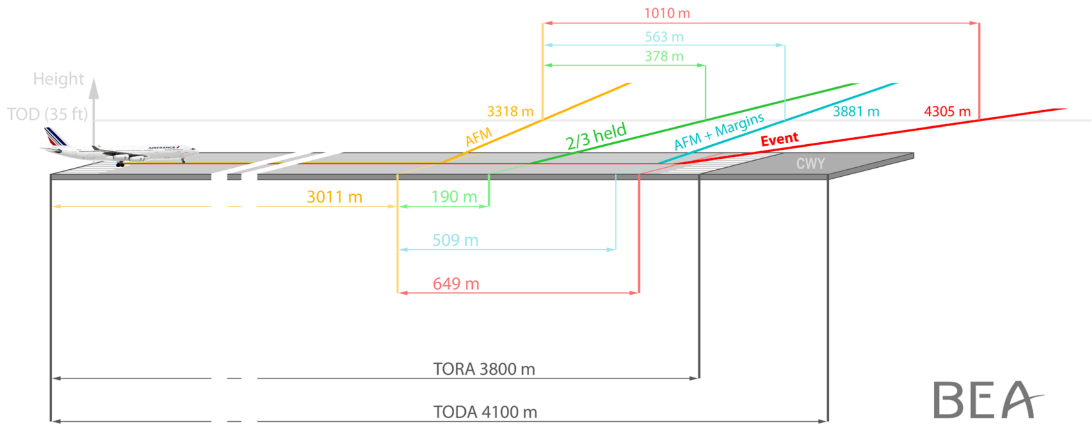


Figure 18 : Take-off distances including alignment distances

On observing these differences, performance calculations were carried out by Airbus with the following objectives:

- determine if the behaviour of the aeroplane was nominal;
- determine the causes of the lengthening of the distances;
- determine the stick inputs required to obtain the AFM performance.

The results of the calculations and simulations carried out by Airbus showed that:

- *The weight and balance of the aeroplane complied with what was calculated before take-off.*
- *The average value of the tail wind complied with that given by the ATC (4 kt) and that the aeroplane had been subject to a tail wind gradient of approximately +3 kt during the rotation to reach a maximum tail wind of 7.5 kt without significant consequences on the aeroplane's performance. Compared to a constant tail wind of 4 kt, this gradient of +3 kt contributed to increasing the distance between brakes off and lift-off by ten metres and the distance between lift-off and the height of 35 ft by seven metres.*
- *The behaviour of the aeroplane was nominal in terms of acceleration on a wet runway and response to sidestick inputs made by the PF.*

The calculations and simulations carried out by Airbus showed that the main cause for the lengthening of the distances resulted from a rotation rate significantly lower than that used to determine the take-off distances (AFM performance model).

Simulation scenario in conditions of event	Sidestick input	Consequence of rotation rate on increasing distance of wheel lift-off (m)
Serious incident	9° in 2 s	+ 540
2/3 of deflection	10.5° in 1 s	+ 190
Input required to obtain the AFM model performance (> 80% of deflection)	13.5° in 0.5 s	0

Airbus determined that, in the conditions of the serious incident, the initial nose-up sidestick input to be applied at VR in order to obtain the theoretical take-off performance (AFM) is an initial nose-up input close to 80 % of maximum deflection (between -13° and -14° of deflection) of half a second which is then held at around 12° (75 % of maximum deflection).

1.16.3 Additional tests and research

1.16.3.1 PITCH PITCH call-out

The three members of the crew said that they heard the "*PITCH PITCH*" call-out during the take-off. This call-out is normally inhibited during this flight phase[16].

The investigation showed that this witness account was not isolated. The Lufthansa flight analysis department said that it had received the witness account from one of its pilots mentioning a "*PITCH PITCH*" call-out during a take-off.

The "*PITCH PITCH*" call-out warns the crew when the aeroplane's pitch attitude becomes excessive. Its purpose is to anticipate a risk of tailstrike on landing.

It is installed as a standard system on all A340-500/600 and is optional on the A330 and A340-200/300. The Air France and Lufthansa A340-300 fleets are equipped with this option.

This call-out is made in the following conditions:

1. the autopilot is not engaged;
2. at least 1 radio altimeter is functional;
3. the (RA) height of the aeroplane remains less than 27 ft for 150 ms or is less than 25 ft;
4. the estimated pitch attitude at 1 second remains greater than 9° for 150 ms;
5. the aeroplane is not in a take-off or cruise phase.

[16] It is however, described by error in the section, STANDARD OPERATING PROCEDURES –TAKEOFF (PR-NP-SOP-120) of the FCTM used by the crew. The documentation wwas corrected in June 2017.

Examination of FMGEC and FWC computers

The examinations carried out on the computers which participate in generating this warning did not make it possible to confirm this call-out was made during the event take-off.

The ATP tests did not reveal any computer faults except for a problem with reading a serial number which is not related to this call-out.

Airbus calculations and simulations

The calculations carried out by Airbus showed that, during the rotation in the conditions of the day of the serious incident, the first four conditions for the call-out were present.

Flight phase

Airbus stated that in certain conditions, it is possible that during take-off (phase 4) the systems detect phase 8 (landing), the latter being a phase in which this call-out is not inhibited. This anomaly is possible when the take-off conditions are not detected by the systems.

These conditions are:

- thrust levers beyond the MCT detent;
- at least one engine operative.

These conditions were present during the event flight.

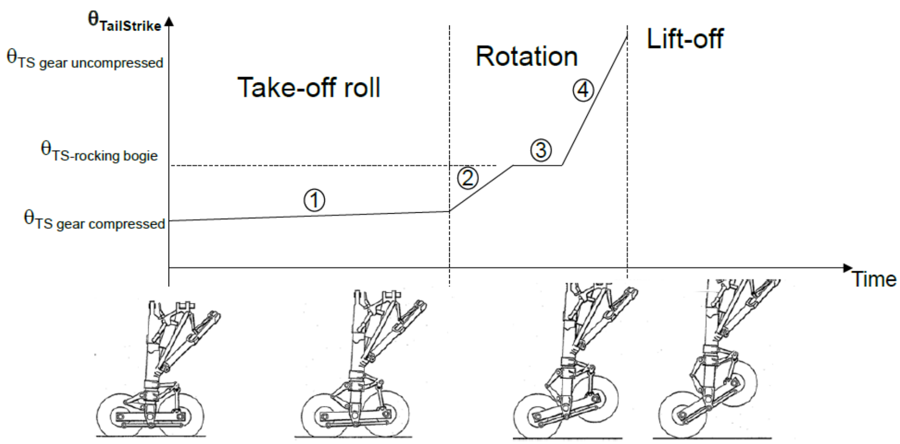
No additional analysis was carried out as the warning would have been activated late in the rotation sequence[17] (Cf. Airbus PITCH PITCH theoretical activation curves) and would not, therefore, have been a contributory factor in explaining the low rotation rate observed during the rotation.

[17]The activation at the end of the rotation sequence is confirmed by the crew witness accounts.

1.16.3.2 Tailstrike risk

General

The A340 is equipped with rocking boogie main landing gears. The rotation movement between the beam and the shock absorber moves the axis of rotation of the aeroplane from the landing gear leg to the rear axle of the boogie. This permits the tailstike margin to be mechanically increased for a given pitch attitude.



Source: Airbus

Figure 19: Kinematics of rocking boogie

This rocking boogie system operates both on take-off and landing. Airbus simulations showed that it obtained a tailstrike margin of 60 cm in take-offs complying with AFM performance.

The specific kinematics of the rocking boogie are such that the tailstrike margin is minimal just before wheel lift-off whereas this margin is generally minimal after wheel lift-off on aeroplanes equipped with conventional landing gears.

This specificity constitutes an additional reason for avoiding large-deflection and sharp nose-up inputs just before wheel lift-off.

Tailstrike at take-off statistics and associated documentation

Airbus has identified 11 cases of tailstrikes at take-off on the A340-200/300 fleet up to 2014.

The main contributory causes and factors are the following:

- sustained nose-up input at maximum deflection;
- anticipated rotation;
- wind gradient;
- dual input;
- roll correction with spoiler extension;
- low shock absorber pressure.

	<2005	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
A330	2	0	0	0	0	0	0	0	0	1	0
A340-200/300	7	2	1	0	0	0	1	0	0	0	0
A340-500/600	0	0	1	0	0	1	0	0	0	1	0
TOTAL	9	2	2	0	0	1	1	0	0	2	0

Source: Airbus

Figure 20: Number of tailstrikes during take-off on A330/340

1.6.3.3 Manufacturer documents and presentations regarding tailstrike risk

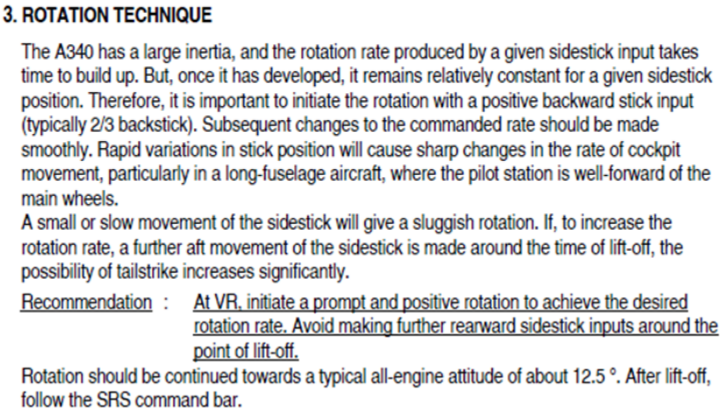
The tailstrike risk is mentioned in both operational documents, the FCOM and FCTM [18].

The tailstrike risk was also the subject of dedicated publications:

- **Flight Crew Bulletins "*Avoiding tail strikes*";**
- **Flight Operation Briefing Note (FOBN) "*Take off and departure operations – Preventing Tailstrike at takeoff*";**
- **A330/A340 e-briefing – Tailstrike Avoidance**.

In the Flight Crew Bulletins, "*Avoiding tailstrikes*", it was recommended to initiate a "*prompt and positive*" rotation at VR which differs from the FCTM which says to make a "*smooth positive backward sidestick input*" (typically 2/3 backstick).

[18] Cf. section 1.6.4.2 Operational documents regarding rotation technique



3. ROTATION TECHNIQUE

The A340 has a large inertia, and the rotation rate produced by a given sidestick input takes time to build up. But, once it has developed, it remains relatively constant for a given sidestick position. Therefore, it is important to initiate the rotation with a positive backward stick input (typically 2/3 backstick). Subsequent changes to the commanded rate should be made smoothly. Rapid variations in stick position will cause sharp changes in the rate of cockpit movement, particularly in a long-fuselage aircraft, where the pilot station is well-forward of the main wheels.
A small or slow movement of the sidestick will give a sluggish rotation. If, to increase the rotation rate, a further aft movement of the sidestick is made around the time of lift-off, the possibility of tailstrike increases significantly.

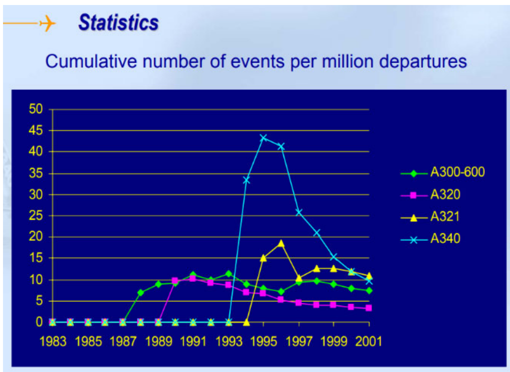
Recommendation : At VR, initiate a prompt and positive rotation to achieve the desired rotation rate. Avoid making further rearward sidestick inputs around the point of lift-off.

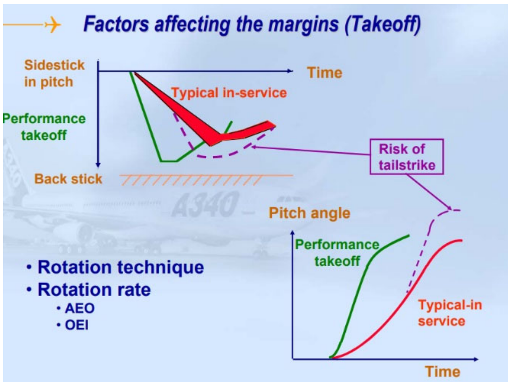
Rotation should be continued towards a typical all-engine attitude of about 12.5 °. After lift-off, follow the SRS command bar.

Figure 21: Excerpt from Flight Crew Bulletins "*Avoiding tail strikes*"

The FOBN, "*Take off and departure operations – Preventing tailstrike at takeoff*", says that on a long-fuselage aeroplane such as the A340, the accelerations felt by a crew during the rotation are different to those felt on a shorter-fuselage aeroplane such as the A320. It informs crews that the sensations felt may lead them to over-react and make sidestick inputs resulting in high pitch oscillations. This document and the A330/340 e-briefing repeat the FCTM recommendations and advise making a "*smooth positive backward sidestick input*" and to avoid "*aggressive and sharp inputs.*"

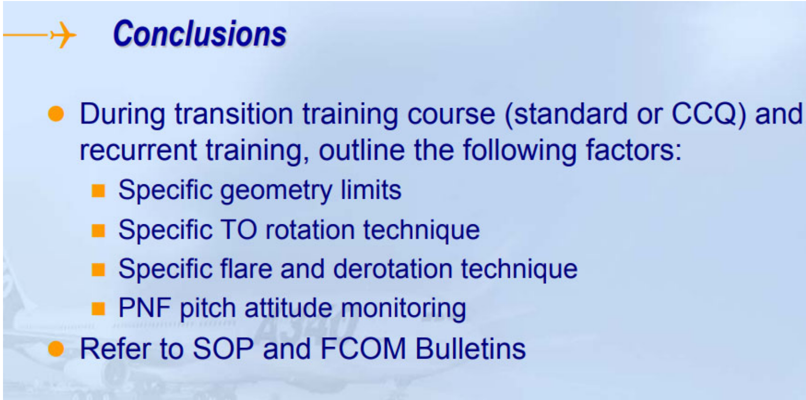
The manufacturer also organized conferences with operators and gave specific presentations about the tailstrike risk. In 2002 and 2004 as part of the "*Operational Liaison Meeting FBW aircraft*". In 2003 as part of the Performance & Operations Conference. The excerpts below show the key elements given during these conferences:





In 1995, i.e. two years after the entry into service of the A340, statistics indicate that the tailstrike rate on this type of aeroplane was situated between 40 and 45 per million take-offs. In 2017, the cumulated tailstrike rate per million A340 departures was a little less than five.

This presentation also shows that back in 2003, Airbus knew about the difference between the sidestick deflections made in operations and those expected to reach the aeroplane's certified performance. The difference between the rotation rate used to calculate the theoretical performance and the average rotation rate reached in operations also appears.



Figures 21 and 22: Excerpts from AIRBUS presentation "*Performance & Operations Conference*"

The manufacturer also recommends raising crew awareness during their initial and recurrent training and reiterates that the objective of a continuous rotation rate at 3°/s is the best adapted to take-off performance while avoiding tailstrike risks.

1.17 Organizational and management information

1.17.1 Air France

1.17.1.1 A340 fleet operated by Air France

In its long-haul aircraft fleet, Air France operates nine A340-300 which fly to Africa, South America, North America, the Caribbean and the Middle-East.

Five airports are considered as being limitative in terms of take-off performance:

- Bogotá (Colombia);
- Antananarivo (Madagascar);
- Montreal (Canada);
- Niamey (Niger);
- Saint-Martin.

1.17.1.2 Pilot training in rotation technique on A340

A study of the training documents given to crews during their initial training and recurrent training found that the rotation technique was not the subject of specific attention:

- Initial training: CCQ A330/A340
  The instructor booklet, CCQ A330/A340, gives no specificities about the take-off technique.

❒ Recurrent training (ECP)
The instructor booklets for the last three years of ECP do not include any take-off exercise focusing on the amplitude of inputs and their consistency with the FCTM (2/3 sidestick deflection). Neither is any specific attention paid to the average rotation rate reached.

Likewise, the rotation technique is not the subject of specific attention in flight proficiency checks.

The study of the training documents of the F-GLZU crew the day of the serious incident did not reveal any comments about the take-off rotation technique of these pilots during checks and training.

1.17.1.3 Paris CDG-Bogotá route

The company stated that the specificities of the take-off limitations were not the subject of specific attention during the analysis of the route. The pilots have access to an E-learning video to familiarize themselves with the airport. The video gives numerous specificities about the Bogotá airport: safety altitudes, ground speeds, need for an anticipated stabilization, ATC, tailwind, and describes the key arrival points.

For the take-off, the e-learning notably advises that it is performed “with limits”, of the possibility of a tailwind, the risk of EGT Overlimit, the possible impact of tolerances accepted on departure from Roissy-CDG, on the performance at take-off from Bogotá and the difficulty of obtaining the QFU 31 (three hour wait).

No mention is made of the influence of the rotation rate on take-off performance nor of the difficulties in arbitrating between the rotation rate and the risk of tailstrike.

Figure 23: Excerpt from Air France e-learning page about take-offs

1.17.1.4 Air Safety Report (ASR)

The Paris CDG-Bogotá route has been the subject of 13 air safety reports since 2007. These ASRs mention the difficulties in obtaining reliable weather information at the airport, payload difficulties or questions about the instructions to use the flaps in CONF 2.

Up to the report concerning the serious incident of 11 March 2017, submitted by the crew on 14 March, no ASR had mentioned concerns about take-off performance or a long take-off.

1.17.1.5 Air France flight analysis

The Air France flight analysis department explained that the problem of long take-offs was not monitored on the Airbus A340 fleet before the event of 11 March 2017. Air France had not set up indicators to detect long take-offs such as those recommended by the EOFDM group back in 2014. However, developments were in progress before this serious incident with the aim of supplying factual elements regarding take-offs in the first quarter of 2017.

Monitoring and analysis algorithms specific to the rotation had thus been created or improved in order to provide the databases with:

- calculations of the rotation time and distance;
- calculations of the remaining distance before the opposite runway threshold at wheel lift-off;
- calculation of the radio-altimeter height when passing the opposite threshold;
- pitch at wheel lift-off;
- comparison between the distance from application of thrust to height of 35 ft * 1.15 (this represents the Take-Off Distance (TOD) increased by the regulatory margin of 15 %) with the available distance (TODA).

This new procedure was being assessed at the end of February 2017 on the various fleets operated by Air France and was applied to the analysis of the event notified by the crew's ASR. After the serious incident, Air France consolidated this new procedure and was thus able to detect another long take-off on 6 April 2017[19]. This procedure was also applied to conserved flight data and meant that around 2,400 take-offs prior to March 2017 were analysed.

An analysis carried out initially on all A340-300 take-offs from Bogotá and then generalized to all of the Air France network revealed that a considerable proportion of take-offs with the A340-300 had a rotation rate below that modelled in the tool (EFB) and used to calculate the take-off performance (AFM performance model). The average rotation rate (blue curve in the diagram below) reached on take-offs with the A340-300 was in fact less than 2°/s whereas the performance tool used a theoretical rotation rate of 1°/s for 1.7 s and then 3.1°/s (green curve).

[19] This long take-off is also the subject of an investigation opened by the BEA. The analysis of the DAR data showed that the characteristic take-off distances were the following:
• distance from brakes off to wheel lift-off = 3,700 m (TORA 3,800 m);
• distance from brakes off to height of 35 ft = 4,095 m (TODA 4,100 m);
• rotation time = 10 s;
• estimated rate = 1.4°/s.
This case is similar to the serious incident dealt with in this investigation report. The main cause for these lengthened take-off distances results from the rotation technique leading to a rotation rate which is lower than that retained in the certified take-off performance model.

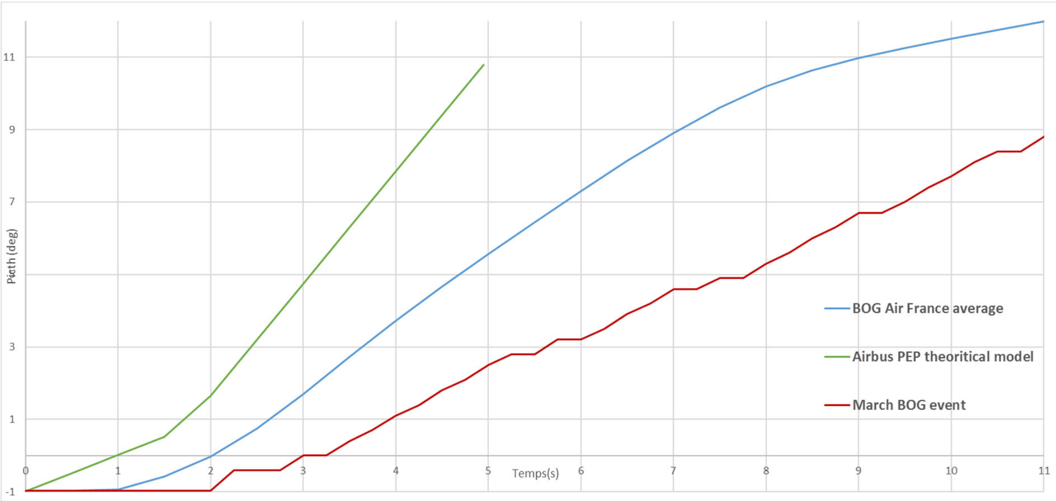


Figure 24: Air France curves

This analysis was also used to model the average stick input made by Air France crews on the A340-300 during take-offs from Bogotá (blue curve) and to superimpose it on a held 2/3 stick deflection input (green curve) and the stick input made during the serious incident (red curve).

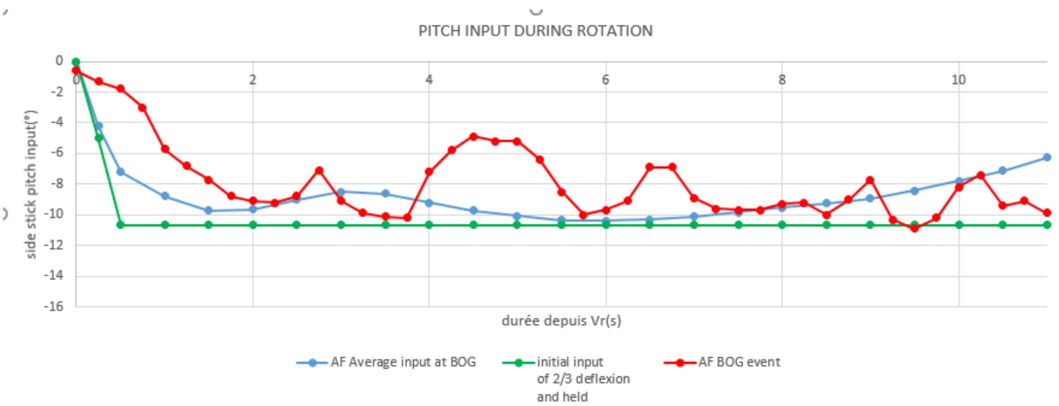


Figure 25: Air France curves

Moreover, the BEA asked Air France to provide them with the average rotation rate value obtained by the PF of the serious incident. On the Airbus A340 and at other airports, the average rotation rate obtained by this pilot is very slightly below the average rate obtained by all the pilots of the A340 fleet.

1.17.1.6 Lufthansa flight analysis

As part of the investigation, the BEA contacted other States who have operators likely to be exposed to similar events, notably Germany whose operator, Lufthansa, flies the A340-300 to Bogotá.

The Lufthansa flight analysis department had started analysing the rotation technique following an incident which occurred at the take-off of an A340-300 at Johannesburg (South Africa) in 2004 and cases of long take-offs in 2007, 2011 and 2012. A comparison was made between the certified take-off performance model and the actual performance reached in operations by the Lufthansa crews.

The results showed that:

- ❒ there was no significant difference between the performance model and the performance in operations in the initial phase from brakes off to VR;
- ❒ the average continuous rotation rate reached in operations was around 1.9°/s whereas the performance model required 3.1°/s.

The Lufthansa flight analysis department also showed that this difference was greater on the A340-300 than on the A340-600 and the A330-300.

Performance Model (Airbus)	**A340-300**	**A330-300**	**A340-600**
Performance Model Reaction Time	0,0 s	0,0 s	0,7 s
Performance Model Initial Rotation	1,7 s @ 1,0°/s	1,8 s @ 0,8°/s	2,5 s @ 1,3°/s
Performance Model Rotation Rate	3,1°/s	3,2°/s	2,3°/s
Lufthansa FDM data (2017 - 2018)	**A340-300**	**A330-300**	**A340-600**
Avg. Rotation Rate (1,7° pitch change - liftoff)	1,9°/s	2,4°/s	1,8°/s
Initial pitch command	66 %	57 %	69 %
Avg. pitch command (1,7° pitch change - liftoff)	57 %	44 %	59 %

Figure 26: Summary of performance by Lufthansa

The flight analysis department also studied the average rotation rate obtained according to the amplitude of the average nose-up input applied by the pilots.

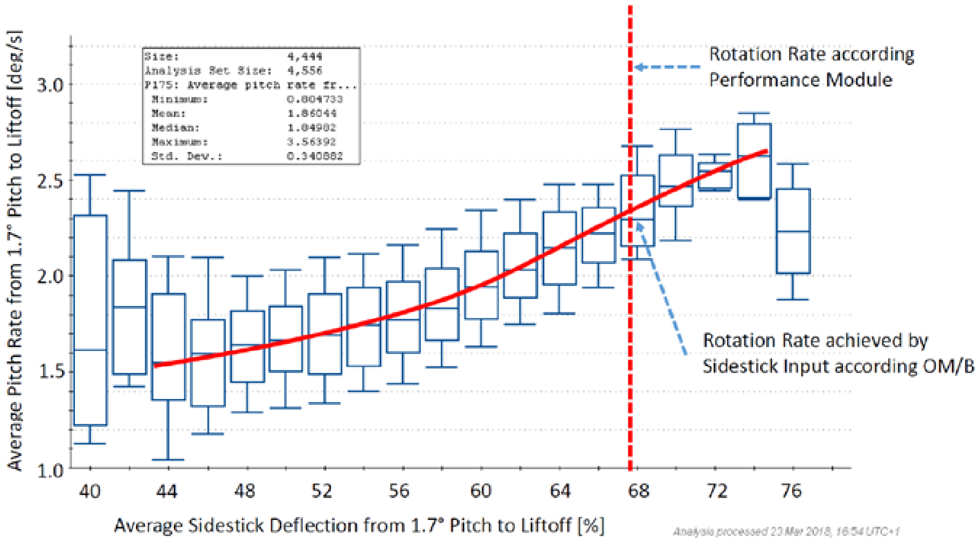


Figure 27: Summary of rotation rates obtained according to sidestick inputs when pitch reached 1.7°

1.17.1.7 Air France/Lufthansa joint flight analysis

Air France and Lufthansa coordinated with each other to jointly develop rotation algorithms in order to compare their flight data (Bogotá take-offs) i.e. 1,900 take-offs for Air France and 400 take-offs for Lufthansa.

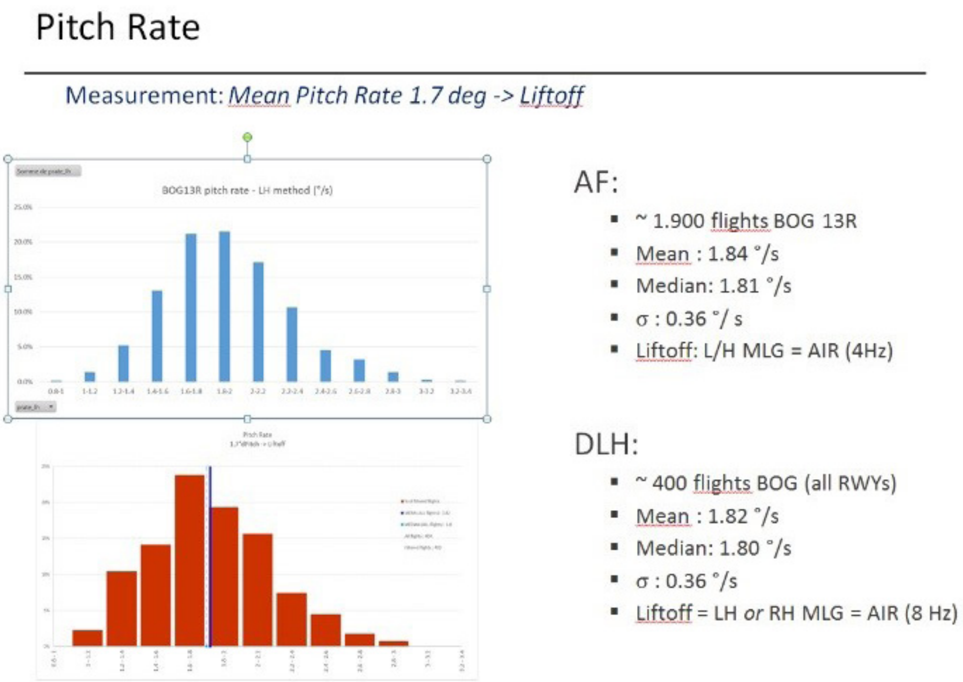


Figure 28: Air France-Lufthansa statistics

The two operators have average continuous rotation rate values, rotation time values and a dispersion of average continuous rotation rate values which are very similar, i.e.

- ***an average continuous rotation rate of around 1.8°/s;***
- ***an average rotation time of around seven seconds;***
- ***a dispersion defined by a standard deviation of 0.36°/s, nearly 1 % of the take-offs are carried out with a continuous rotation rate of between 1 and 1.2°/s (minimum value) and 1 % of the take-offs are carried out with a continuous rotation rate of between 2.8 and 3°/s .***

These differences between the theoretical performance (AFM) and the performance in operation increase the take-off run distance by an average of around 200 metres.

1.17.2 Civil aviation safety directorate

The French civil aviation safety directorate (DSAC) is part of the French civil aviation authority (DGAC) and has national authority. Under ARO.GEN.300 of the AIR OPS European regulations[20], the DSAC checks continued compliance with the applicable requirements, of organisations it has certified, specialised operations it has authorised and organisations from whom it received a declaration. As such, the DSAC is responsible for the oversight of Air France.

This oversight covers all operational aspects but does not replace actions by the operator as part of their internal oversight. The operator thus remains responsible for the regulatory conformity of its operations.

Each DSAC oversight action can cover one or more topics, amongst which:

- flight organisation and safety;
- training of crew members;
- flight planning;
- stopover or base (opening of route, etc.) ;
- flight (proficiency check).

The DSAC informed EASA of the event on 24 April 2017, as soon as it was advised of Air France's classification of the criticality of the event.

The DSAC indicated to the BEA that it had not detected during its oversight actions, any points regarding degraded performance during take-offs on the A340 fleet. No PEPN and/or OCV check had been carried out on Bogotá in particular.

Only one finding on the topic of take-off rotation rates had been notified in 2015 following a proficiency check on an A320 in which it was noted that the rotation rate was low. This finding remained limited to the scope of the A320 fleet.

As part of the processing of this finding, Air France carried out a study based on the analysis of flights using a procedure which measured the average rotation rate reached in operations on the A318/A319/A320/A321. This study analysed 6,400 flights in 2015. The results of this study showed that the average rotation rates reached by the crews corresponded to the FCOM recommendations, i.e. 3°/s in compliance with FCTM recommendations, with sidestick deflections of 1/3 to 1/2. Moreover there was a very small standard deviation in these average values which is characteristic of a homogeneous sample around the average value.

Following this analysis, it was considered that there was no systemic problem with respect to the rotation rates on the A320 family fleet. Nevertheless, Air France set up a campaign to raise crew awareness about complying with the rotation rate of 3°/s until the SRS was usable. This raising of awareness message was also passed on by the A320 instructors.

This rotation rate study was not applied to the A340 fleet before 11 March 2017, date of the serious incident.

[20]Commission Regulation (EU) No 965/2012 of 5 October 2012 laying down technical requirements and administrative procedures related to air operations pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council. The Air OPS requirements common to all types of operation and applicable to the authorities are described in Part-ARO, which is Appendix II of the Regulation.

The DSAC also indicated to the BEA that it had not detected during its oversight actions of Air France, the absence of take-off performance indicators set up by the operator for its A340 fleet.

1.17.3 EASA

European Central Repository of air safety reports

EASA has set up an European Central Repository (ECR) grouping all the reports on safety-related events written by civil aviation stakeholders and sent by member states.

EASA informed the BEA that a search for similar cases had been made in the ECR database with the following criteria:

- search started from January 2014;
- for all four-engine aeroplanes (A340, A380 and B747);
- occurrence containing the keywords: degraded performance, long take-off.

EASA identified five cases concerning the A340-300 at the Frankfurt and Bogotá airports, which included the long take-off of the serious incident flight of 11 March and that of 6 April 2017. Another report concerned a long take-off on an A380 at Johannesburg where the crew stated that the PF had intentionally performed a "slow" rotation. The two other cases identified do not mention a link with a rotation technique.

1.17.4 AIRBUS

Certification aspects

Airbus indicated that for the A330 and A340, the operational recommendation (FCTM) of an initial sidestick input at VR, of 2/3 of maximum defection is not representative of the inputs applied during the certification campaign[21]. Airbus specified that in the 1990s, the rotation technique during take-off performance certification tests was not specifically formalized for aeroplanes under direct law on take-off.

Airbus said that it was not in a position to find the origin of these practices.

Airbus added that for more recent aeroplanes (e.g. A380), the rotation techniques used by the test pilots during the certification process had become more consistent with the FCTM operational recommendation.

Impact of average rotation techniques in operations, on take-off distances

Using the data from the Air France flight analysis, Airbus calculated the lengthening of the take-off distances resulting from the average pitch profile achieved by crews in operations[22].

The results were the following:

- an additional 200 m for lift-off;
- an additional 300 m to reach height of 35 ft (TOD).

[21] Cf. section 1.16.1.1 Certification of take-off performance.

[22] Cf. section 1.17.1 Flight analysis.

This average additional distance of 300 m to reach the height of 35 ft represents approximately half of the 15 % margin defined by the regulations in the conditions of the event.

1.18 Additional information

1.18.1 Witness statements

1.18.1.1 Captain's witness account

The captain advised that he was aware that Bogotá was a complicated airport and that it was generally impossible to take all of the load. So he had anticipated the flight planning on his tablet.

As the briefing took place in the cockpit, he had paid particular attention to interruptions to the tasks. Conservative parameters were chosen (WET runway forecast), optimum configuration - flap configuration 2. The margin with respect to the MTOW on 13R was around 500 kg.

During the take-off run, he said that he identified the red and white lights at the end of the runway.

He specified that the nose-up input at the time of the rotation was "more or less as usual" but it seemed to him that the rotation rate was lower.

He could not remember his first nose-up input. However, on his second input, he remembered hearing "*PITCH PITCH*", looked at the PFD and read the value 7.5°.

The take-off that day seemed to him to be really unusual hence his ASR.

The captain said that the three factors which could explain the long take-off were wind variations, the runway condition and uncertainties about the gauges.

He did not identify the rotation rate as a possible cause of the event.

1.18.1.2 First officer's (pilot monitoring) witness account

As the FO was line flying under supervision, he said that he had studied the destination with particular attention (LIDO charts, e-learning, FCOM).

He was aware that Bogotá was a complicated airport, probably the most difficult one in the network. He had anticipated the flight planning on his tablet. He said the main problem at Bogotá was the payload.

He indicated that the crew had been conservative in the choice of parameters (WET runway, tailwind value slightly increased). The pre-departure briefing principally covered performance, the terrain and the packs switched to the APU.

He said that he was aware that take-offs with four-engine aeroplanes were generally long. Nevertheless, he had always taken off in an area situated in around the last 600 metres.

He explained in the ASR that at the time of the rotation, the nose seemed heavy and the rate too slow. After reaching V1, he added that he was aware that the end of the runway was coming up. In TOGA thrust, there was no more thrust margin. He decided to announce the VR at 2 to 3 kt before the VR so that the PF pulled exactly at VR. At VR he said that the aeroplane "had not moved". He remembered hearing the "*PITCH PITCH*" warning. When he heard the noise of the landing gear decompressing, he looked at the radio altimeter display and read zero ft.

1.18.1.3 Relief pilot's witness account

He said that in flight planning, they did several calculations for a take-off from 13R and had anticipated a WET runway. The planned take-off was in the "optimum" configuration (conf 2).

The TEM strategy of the day was 50 % thrust on brakes, TOGA, alignment at 90° and specific attention to safety altitudes.

As a general rule, he explained that the pre-take-off briefings mention that the aeroplane is heavy, the runway limitative, the run is longer and the rotation smooth.

During the take-off run, he specified that his attention was focused on the N1 data in order to be the first to announce any anomaly. He did not identify the EGT as being too high.

He remembered hearing the "*PITCH PITCH*" call-out when the pitch attitude was at 10° and the aeroplane still on the ground. He said that the nose of the aeroplane seemed high to him but that he had the impression of sinking.

After take-off, he asked the other pilots it they could have struck a beacon. They consulted the WHEEL page and continued the flight.

1.18.2 Perception of movement at take-off

The execution of the rotation can be considered as a perceptual-motor task in which the pilot is going to detect the information required to control his action. The action is going to generate a flow of information and in return, the perception permits control of the force field that is required to produce the movement. This is called action-perception coupling.

The information comes from an integration process of sensory information from various sensors: the eye, vestibular apparatus[(23)], somesthetic receivers[(24)] and audition. Some of the different signals perceived may be redundant, the two most important modalities generally being the vision and vestibular system.

As regards the visual perception, the movement of the visual scene, configuration changes resulting from the movement generate an optical flow in which the useful information to control the action resides. The speed discrimination thresholds are relatively low and increase with speed. The thresholds are thought to be less than 0.2°/s for a speed of 2°/s. However, these results are only the results of experimental studies; they show the maximum perception abilities of the eye.

[(23)]The vestibular system situated in the internal ear is composed of otoliths and semicircular canals. The former are sensitive to linear accelerations and the position of the head to the vertical and the latter, to angular accelerations.

[(24)]The somesthetic receptors correspond to receptors sensitive to stimulations (mechanical, temperature) of the body tissues. They provoke sensations of touch and pressure, pain, joint and member positioning, hot and cold.

As regards the vestibular cues, the accelerations due to movement (inertia) and the accelerations due to gravity are physically different but indistinguishable. The otoliths alone cannot distinguish between a linear acceleration and the head's tilted position in relation to gravity.

The tilt of the head initially causes an angular acceleration leading to a response from the semicircular canals. For an angular acceleration to be perceived, the product of its amplitude multiplied by its duration must reach a certain threshold. One of the consequences of this law of perception is that there is a lag in perception according to the strength of the angular acceleration.

In the central nervous system, the evaluation of the speed comes from the integration of visual and vestibular information, with priority being given to visual information. The richness of the visual scene affects the time required for the interpretation. As the vestibular information is based on the accelerations, it leads the visual information. The circular canals are sensitive to the angular acceleration but the sensation is integrated and it is the rotation speed which is perceived.

The elements which have a direct influence on the pilot's perception and control are not clearly defined. In particular, the take-off phase has been little documented in literature (compared to the approach phase).

During take-off, the pilot's senses are stimulated in three distinct phases in time:

1. Longitudinal acceleration during the acceleration phase on the runway;
2. Pitch angular acceleration during rotation;
3. High pitch attitude and associated forces in first segment of climb.

The possible sensory information for each of these phases is given below:

	Longitudinal acceleration during the acceleration phase on the runway	**Pitch angular acceleration during rotation**	**High pitch attitude and associated forces in first segment of climb.**
Crew actions	Thrust, brakes off	Actions on sidestick (deflection). The pilot must smoothly pull the sidestick in order to obtain 3°/s with a target pitch attitude of 12.5°. If the **continuous** rotation rate is not satisfactory, make smooth corrections.	Actions on sidestick. Follow the flight director SRS bars (reference: FCTM).
Aircraft/flight controls	Engine thrust	Relationship between sidestick inputs and movement of elevator[25].	

[25] Cf. section 1.6.3 Rotation control laws.

Aircraft/ dynamics	Acceleration	Angular acceleration –› Pitch attitude. The initial rotation rate takes **time** to become established. The rotation time between the initial nose-up input and wheel lift-off is typically 4 to 5°/s according to the amended version of the FCTM.	Wheel lift-off.
Visual information	Motion (optic flow). Alternation between monitoring parameters given by the instruments and outside references.	Until wheel lift-off or at least until the visual information is lost, scanning depends on the visibility conditions (**the better the visibility, the greater the priority to be given to visual references**). Sources: Rotation speed of nose/ horizon (optic flow until a certain moment/runway or runway lights)/PFD (speed of motion of artificial horizon and PLI chevron). Possible loss of visual references before lift-off.	Use of FD bars to reach pitch (SRS).
Vestibular information	Stimulation of otoliths due to linear acceleration	Limited perception of rotation by otoliths as they have been previously stimulated during the linear acceleration. Perception of rotation by semicircular canals.	Perception of wheel lift-off unlikely due to the distance between the cockpit and the centre of gravity of the aeroplane.

The speed discrimination thresholds suggest that it is theoretically possible for a pilot to distinguish a 2°/s speed from a 3°/s speed by means of the visual information. However, there can be a moment before wheel lift-off in which the pilot no longer has sufficient external visual references.

The vestibular information supplements this assessment, notably with information from the rotation of the pilot's head. The ability to discriminate the rotation speed decreases, however, with the speed, in other words, the greater the rotation speed, the less the pilot is able to detect a difference. The first moments of the rotation are therefore decisive and the time available to make an adjustment is limited: the time given by the manufacturer between the initialization of the rotation and wheel lift-off is in the region of four to five seconds.

Moreover, there is a lag of several seconds between the initial nose-up input and the initialization of the rotation due to the inertia of the aeroplane. The pilot therefore does not have an immediate response to the actions that he has made.

It is therefore difficult to determine if a pilot can, in the first seconds of the start of the rotation, reliably distinguish a 2°/s rotation rate from a 3°/s rate in real take-off conditions.

What is more, the perceptual interpretation depends on the weight of each sensory modality and the history of the simulation conditions, i.e. this interpretation is going to depend on the pilot' s learning and experience.

In their learning period, the pilots detect and use different informational variables until they find those which allow them to correctly carry out a required task. The acquisition of a perceptual-motor skill and thus the rotation technique, can be facilitated if the attention of the trainee pilot is directed towards the most useful informational variables for controlling the action. The learning period is going to consist of discovering and optimizing specific relationships between the informational variables present in the perceptive flow, and kinetic variables and then refining this perceptual-motor dialogue by exploring all the possible solutions. For the visually controlled piloting tasks, the optical flows have to be supplemented, in particular, by the pilot's cognitive representation of the aircraft's dynamics.

2 - ANALYSIS

2.1 Scenario

The aeroplane was correctly maintained and all the systems were functioning nominally. The weight and balance sheet was correctly completed and within the limits defined by the manufacturer.

In the operational conditions of the day, the expected take-off performance of the aeroplane allowed take-off from runway 13R in compliance with the regulatory distances associated with the take-off.

During the flight planning, the crew entered, without error, the data concerning the conditions of the day, in the performance calculation software (which complied with the aircraft's certified performance model).

The day of the serious incident, wheel lift-off occurred 140 m before the threshold of the opposite runway. The aeroplane reached a height of 35 ft, 250 m after the end of the CWY and flew over the localizer antennas with a height of 12 ft. This take-off distance represents an additional 987 m with respect to the take-off distance defined by the certified performance model and 424 m with respect to the take-off distance taking into account the regulatory margins, thus exposing the aeroplane to an increased risk of runway excursion or collision with an obstacle.

The simulations carried out by the manufacturer showed that the rotation rate the day of the event was significantly lower than the hypothetical rotation rate retained for the certified performance and that it was the main contributory factor to the lengthening of the take-off distance.

This slow rotation rate is the exclusive result of the rotation technique applied by the PF who made nose-up inputs of an amplitude and duration below those which would have been required to reach a rate of 3°/s.

The analysis of the operator's flights identified a significant difference between the rotation technique used during the flight of the event and the rotation technique commonly practised in operation as well as between the rotation technique commonly practised in operation and the rotation rate expected by the certified performance.

2.2 Take-off performance of A340-300

Determining performance during certification

The take-off performance of the A340-300 was established during certification by flight tests. The flight data collected was used to produce the analytical and aeromechanical model of the aeroplane (AFM performance model).

The certified take-off performance model is used by operators to calculate aircraft performance during take-off. Safety margins of an additional length of 15 % to the take-off distance with all engines operative and a tailwind value of 150 %, as required by the certification and operational regulations, are applied.

The rotation rates of 3.1°/s (AEO) and 2.6°/s (OEI) used in the model were defined by calculating the average rotation rates obtained during the take-offs performed during the performance flight test campaign.

The flight test which had the closest rotation rate to the certified performance model was obtained with an initial stick input of 15° (i.e. 94 % of maximum deflection) applied in approximately 0.5 s and then held at around 12° (75 % of maximum deflection).

The simulations carried out by Airbus showed that in the operational conditions on the day of the serious incident, the pilot should have applied at VR, an initial nose-up input corresponding to a deflection of more than 80 % of the maximum deflection for around 0.5 s in order for the rotation rate and take-off distances to be consistent with the certified performance model of the aircraft.

Manufacturer's procedures and documentation regarding rotation technique

The JAR 25 regulation in force when the A340-300 was certified states that the take-offs performed to determine aircraft performance must not require the use of exceptional piloting techniques or vigilance.

EASA, the certification authority, specifies that there is no specific criteria to define a conventional rotation technique in the regulations and that the paragraph in the JAR 25 regulation quoted above means that the pilots must be able to repeat without difficulty, the procedures drawn up by the manufacturer.

The manufacturer wrote two operational documents for operators:

- The FCOM which states that the pilot must reach a continuous rotation rate of around 3°/s until reaching a pitch attitude of 12.5°.
- The FCTM which clarifies the procedure that the pilot must apply to reach the objective given by the FCOM. It specifies that it is important to initiate the rotation with a smooth nose-up input of around 2/3 of the maximum deflection. It also recommends avoiding "*aggressive and sharp*" inputs as well as quick and large-amplitude corrections. In particular, it mentions that the risk of a tailstrike is significantly increased if there is such a large-amplitude input close to lift-off. It also states that slow rotation rates (below 2°/s) must be avoided as this will have an impact on take-off performance by increasing the take-off run distance.

During the certification flight test campaign, a take-off was performed with an initial nose-up input of 2/3 of the deflection. The rotation rate reached by the aeroplane was lower than that retained in the AFM performance model and corresponded to the lower limit of all the rotation rates reached during the performance flight tests.

The manufacturer simulated an initial nose-up input of 2/3 of the deflection in one second which was then held at this value, in the operational conditions on the day of the serious incident. The rotation rate induced was lower than the reference rotation rate used in the certified performance model. The result of this was the lengthening of the TOD by around 378 m with respect to the specified theoretical distance. Applying this rotation technique would have consumed 67 % of the regulatory margin.

The investigation showed that the application of a nose-up input of 2/3 of the deflection in at least two different weight and balance conditions (certification test flights and flight of serious incident) did not permit the performance expected in the AFM to be reached. Conversely, the BEA has no knowledge of operating conditions in the thousands of flights analysed by Air France and Lufthansa in which the application of a nose-up input held at 2/3 of the deflection permitted the certified performance to be obtained.

What is more, the flight conditions of the event (no external visual reference) made it difficult to immediately estimate the initial rotation rate obtained with a "typical" nose-up initial input of 2/3 of the sidestick deflection (FCTM) and its deviation from a continuous rotation rate of 3°/s also recommended by the FCTM. No information about the instantaneous rotation rate is provided by the systems with a view to reaching 3°/s. Conversely, the PLI displayed on the PFD during the rotation only shows a maximum pitch value not to be exceeded to prevent the risk of a tailstrike.

Even if this deviation had been detected, it seems unrealistic to think that a pilot would continue the rotation with the application of a greater nose-up input in order to reach 3°/s for the following reasons:

- the initial inputs required to reach a rotation rate of 3°/s during the certification flights and serious incident flight were significantly greater than 2/3 of the deflection and were very far from common practices;
- the FCTM states that the pilot must avoid corrections, in particular nose-up corrections, which are too quick or large, particularly at the time of lift-off, as this significantly increases the possibility of a tailstrike.

Moreover, the typical initial nose-up input recommended by the A340 FCTM is also different from that recommended by the A320 FCTM (aeroplane on which a majority of Air France pilots have acquired experience, as is the case for numerous other operators of A340s). On this family of aeroplane, the application of an initial nose-up input of 1/3 to 1/2 of the deflection (A320 FCTM) obtains the rotation rate of 3°/s retained in the certification. The analysis of take-off performance carried out by Air France on A320 flights did not reveal that the pilots in operation had any particular difficulty with applying a rotation technique which complies with the indications in the FCTM and of reaching the certified performance.

The flight analyses carried out by Lufthansa on the Airbus A330 and A340-600 also show that the application of the typical initial input mentioned by the FCTM obtains a higher average rotation rate in operations on these aeroplanes than on the A340-300.

2.3 Take-off performance in operation below certified performance

Two European operators (Air France and Lufthansa) coordinated together to define and analyse the FDM data in order to identify the average rotation rates of their crews. They studied the flight data recorded for around 1,900 Airbus A340-300 take-offs from Bogotá airport and 750 take-offs from all the airports that they serve.

These two operators, with similar average rotation rates, observed a significant difference between the theoretical take-off performance and that obtained in operation at all the airports.

This difference was principally the result of an operational rotation technique bringing about an average rotation rate in operation which was notably lower than that retained in the certified performance calculation model of the aeroplane.

They also observed that the crews' rotation technique in operation corresponded, on average, to an initial sidestick input slightly below 2/3 of the backward deflection, reached in one and a half seconds, i.e. an initial sidestick input close to the "typical" input described in the manufacturer's operational documents (FCTM). The corresponding average rotation rate is established at 1.9°/s. The PF during the event had an average which was slightly below the average of other pilots.

The analysis carried out after the event made it possible to estimate that nearly 30 % of the take-offs from Bogotá thus occurred in the last 500 metres of the runway. Moreover, the variability in the pilots' rotation techniques in operations has led to extreme cases where wheel lift-off occurred in the last 200 metres of the runway.

On limitative runways such as those at Bogotá, the risk, during take-off on an A340, that wheel lift-off does not occur before the end of the runway is therefore significant and the operators have identified this risk as major given its frequency and the potential seriousness of its consequences.

2.4 Difference between rotation techniques applied in operations and those taken into account in certified performance model

A combination of several factors can explain the difference observed between the rotation technique required to reach the rotation rate retained in the certified performance model and the average rotation technique applied in operation.

In the first few years of operation of the aeroplane, several tailstrikes occurred and the manufacturer reacted by amending its operational documents in order to raise the pilots' awareness of this risk. The latter is mentioned in the two operational documents (FCOM and FCTM) and is the subject of dedicated publications (Flight Crew Bulletins "*Avoiding tailstrikes*" and Flight Operation Briefing Note "*Avoiding tailstrikes*"). These documents state that the nose-up inputs must be smooth and that quick and large-amplitude inputs must be avoided just before wheel lift-off, the moment when the tailstike margin is minimal.

The manufacturer also organized conferences with operators and gave specific presentations about this risk. This raising awareness campaign and the various updates of the operational documents highlighted the tailstrike risk to the detriment of the risk of lengthening the take-off distances and its consequences. This could have influenced the pilots in their rotation technique, even though the amplitude of the nose-up input to be applied on the A340 to reach the certified performance is particularly large, with respect to other aeroplanes such as the A320 or A330.

Furthermore, scientific studies also show the limitations of human perception in distinguishing between the rotation rates of 2°/s and 3°/s, in particular at the very beginning of the rotation. Besides the ability to distinguish between rates, additional factors such as the time to detect the deviation, to determine the corrective input to be applied, to apply it and for the aeroplane to react[26] could explain the difference between the rotation technique applied in operations and that required to reach the certified performance.

[26] It is mentioned in the FCTM that the A340-300 has high inertia and the rotation induced by a nose-up input requires a certain amount of time before starting.

2.5 Difference between rotation techniques published in manufacturer's documentation and those taken into account in certified performance model

The investigation showed that to obtain a continuous rotation rate of 3.1°/s taken into account in the performance calculation model required, in the operational conditions studied as in the certification flights to which the BEA had access, a nose-up input during the rotation of around 75 to 80 % of the deflection, thus more aggressive than that described in the manufacturer's operational documents (2/3 of the deflection).

The AC 25-7 which is the reference document for carrying out flight tests for performance certification states that it must be possible for the procedures applied during these flight tests "*to be consistently executed in service by crews of average skill,* [that the procedures must] *use methods or devices that are safe and reliable, and include allowances for any time delays in the execution of the procedures that may reasonably be expected in service.*" The difference between the piloting techniques and the rotation performance observed in service on the one hand, and those retained when establishing the certified performance of the A340 on the other hand, seems to indicate that this objective has not been met.

Furthermore, the AC 25-7 prohibits *"the use of exceptional piloting techniques, such as higher control force inputs or higher pitch rates than would occur in operational service, from being used to generate unrealistic take-off distances."* When looking at the profiles of the sidestick inputs applied during the flights retained for establishing the certified performance, and the significant variability in these profiles, even though applied by test pilots[27], it seems that specific piloting techniques are required to obtain the rotation rate retained by the certified performance model and raises the question of the possibility of applying these techniques in operation in a consistent and safe manner by crews of average skill.

[27] Cf. Figures 10 and 11, section 1.16.1.1.

2.6 Taking into account risks associated with long take-offs

By Air France safety management system

Unidentified, the risk linked to a slow rotation rate during take-off from a limitative runway was not taken into consideration in the risk analysis carried out by the operator on opening the air route to Bogotá, and more generally, on limitative runways.

This risk was not, therefore, the subject of an awareness campaign or specific information given to crews, in neither the operator's operational documents nor the pre-take-off briefing (TEM).

Before the event of 11 March 2017, the operator's air safety report database and those of the authorities did not include any mention of long take-offs. Paradoxically, informal crew statements made after the serious incident indicated in the majority, that they were aware that take-offs from Bogotá with the A340-300 were particularly long. It is possible that crews interpreted this situation as being linked to the take-off performance of the A340 at Bogotá, notably the aeroplane's inertia mentioned in the FCTM, and not to their rotation technique. This could explain the absence of ASR from the pilots.

Before 2017, the operator's Flight Data Monitoring (FDM) programme did not include the metrics related to long take-offs with the A340. It was therefore impossible for it to identify the risks inherent in long take-offs. However, the operator was in the final phase of the development of a procedure for monitoring this risk. This procedure was in the test and validation phase on the operator's various fleets with the exception of the Airbus A340 fleet.

In the absence of air safety reports and a flight analysis programme associated with long take-offs, the operator was not in a position to take this risk into consideration before the serious incident of 11 March 2017.

By EOFDM working group on improvement of flight data analysis

Back in 2012, EASA set up the working group, EOFDM, whose goal was to facilitate the implementation of flight data monitoring by operators. This group recommended, in particular, the monitoring of simple data to detect long take-offs (distance of lift-off point from opposite runway threshold).
While this type of data cannot be used to identify the cause of long take-offs and consequently is insufficient for a precise analysis, it nevertheless has the advantage of alerting the operator who must then report it to its competent authority, in accordance with regulations.

The absence of long take-off reports from all the European operators of the A340 seems to indicate that not one of them had set up this type of indicator in its flight analysis.

The EOFDM group then published a document in May 2014, grouping the studies regarding potential precursors that could lead to runway excursion risks during take-off or landing. It was recommended, in particular, that indicators were developed to detect slow rotations. This document provided no precise information about the type of parameters or the method to be followed to develop these indicators.

In April 2017, the EOFDM group published a document giving more precise details as to how to develop these indicators. It recommended monitoring the rotation time and the take-off distances while explaining that the monitoring of these parameters had not yet reached a sufficient degree of maturity to be reliable.

The production of this working group (publications, presentations, study results and recommendations) has no regulatory value and thus remains good practice recommendations.

By Airbus follow-up of A340-300 fleet operation

The investigation showed that the manufacturer had knowledge of the fact that the average rotation rate in operations was lower than the reference rotation rate used in the performance software to calculate the take-off distances. The manufacturer had in fact communicated about the risks of tailstrikes and long take-offs in documents and presentations made in the early 2000s in which the average rotation rates performed by operators were shown. These documents mention identical average rotation rates to those observed by the operators, Air France and Lufthansa, in their flight analysis work associated with the investigation. However, these documents do not underline the impact of these deviations in the rotation rate on take-off performance.

In successive updates of the manufacturer's operational documents, information regarding the tailstrike risk has been emphasised to the detriment of that regarding the long take-off risk.

The manufacturer explained to the investigators that the tailstrike risk has significantly decreased following the introduction of new rotation laws. It did not communicate to operators about these new flight control laws.

2.7 Rotation technique training and checks

During the initial training to obtain the type rating, the trainee pilot is trained to comply with the procedures described in particular, in the FCTM.

The purpose of the recurrent training, simulator checks and flight checks is to ensure that this technique has been acquired and is repeatedly implemented.

The investigation showed that the initial stick inputs applied on average, in operations, by the Air France and Lufthansa A340 pilots were slightly lower than those recommended in the FCTM and that their dispersion led to take-off situations with an average continuous rotation rate of 1.8°/s, the extreme values being 1°/s and 3°/s.

In the absence of the awareness of and monitoring of the long take-off risks, the training and checks did not identify that the application of this rotation technique did not permit the rotation rate of 3°/s required by the AFM to be reached.

3 - CONCLUSIONS

3.1 Findings

- The F-GLZU had a valid airworthiness certificate.
- The maintenance documentation did not show any system failures incompatible with the planned flight.
- The examination of the flight data recorded in the QAR did not reveal any failure or anomaly likely to have contributed to the serious incident.
- The weight and balance were within the limits defined by the manufacturer.
- In the conditions of the day, the certified take-off performance of F-GLZU allowed take-off from runway 13R in compliance with the regulatory distances.
- The crew held the necessary licences and ratings to carry out the flight.
- The aeroplane was aligned on the runway using 45 m, i.e. 23 m more than the alignment distance defined by Air France in its performance calculation tool for the Airbus A340-300.
- Wheel lift-off occurred 140 m before the threshold of the opposite runway.
- The Take-Off Distance (TOD) was 4,305 m from brake release, i.e. 987 m more than the theoretical TOD determined by the certified performance model and 424 m more than the theoretical TOD plus regulatory safety margins.
- The localizer antenna at the end of the runway was flown over with a height of 12 ft.
- The main contributory factor to these lengthened distances resides in the rotation technique applied, significantly different to that recommended by the Airbus procedures.
- The rotation technique used by the Pilot Flying (PF) on the day of the serious incident was also different (smaller nose-up input amplitudes) from the average rotation technique used in operation by this pilot as by all the pilots.
- In the conditions of the event, the sidestick inputs required to obtain a TOD similar to that of the certified model (which requires a rotation of 3°/s) correspond to initial stick inputs with an amplitude and application time significantly different to the technique taught since the entry into service of the aeroplane which is based on the "typical" initial input of 2/3 mentioned in the FCTM, as an initial deflection of nearly 80 % in 0.5 s would have been required.
- The application of an initial deflection limited to 2/3, in the conditions of the event, would have led to the TOD being lengthened by 378 m with respect to the certified model, i.e. a reduction of around 67 % of the regulatory margin required in operations in the conditions of the day.
- The investigation showed that the application of the "typical" initial inputs mentioned in the A318/A319/A320/A321, A330, A340-600 and A380 FCTMs made it possible to reach or come close to rotation rates in operation similar to those retained in the certified performance models of these aeroplanes.
- Unlike the A330, A380 and A320 family, the average rotation rate reached in operations on the A340-300 is below that retained in the certified performance model. This leads to the TODs being lengthened on average by around 300 m.
- The Air France analysis department had not set up take-off performance indicators for the A340 fleet before the event.

- The recorded flight data available to operators is not suitable for the operators to carry out a systematic analysis and determine with precision, the take-off performance, notably the rotation rate calculation, in order to compare it with the aircraft's certified performance.
- The Air France and Lufthansa flight analyses of the 2,300 take-offs from Bogotá showed that the rotation technique of crews in operations leads to average continuous rotation rates which are similar and insufficient to reach the aeroplane's certified performance.

3.2 Causes of serious incident

The serious incident is the result of inadequate nose-up inputs from the PF which increased the TOD by 424 m with respect to the certified theoretical TOD plus regulatory safety margins, in the operational conditions of the day. As a consequence of this, the risk of a runway overrun or collision with obstacles was significantly increased.

The investigation showed that the nose-up input from the PF during the rotation of the event was situated in the lower limit of the values observed in operations, in several companies operating the A340-300. It was lower than the nose-up input recommended in the FCTM in force at the time of the event.

In the conditions of the serious incident, the application of an initial nose-up input of a typical amplitude of 2/3 deflection as mentioned by the FCTM, which is then held at this deflection value, does not permit reaching the rotation rate of 3°/s mentioned in the same document and retained in the certified performance model established on completion of the certification flight test phase.

No flight data processing process was aimed at monitoring long take-offs at the time of the event and no notification of an insufficient take-off performance had been made by European crews on the A340-300 at the date of the event.

4 - SAFETY ACTIONS TAKEN SINCE SERIOUS INCIDENT OF 11 MARCH 2017

4.1 Air France actions

After the serious incident, Air France set up various precautionary measures.

❒ 11 April 2017: withdrawal of F-GLZU from the Roissy-CDG - Bogotá route then withdrawal of F-GLZU for in-flight and technical checks of elements which could affect its performance, notably with respect to engine operation. The results of these checks were compliant with the manufacturer's recommendations.

❒ 14 April 2017: setting up of the following take-off procedure at Bogotá:
- 50 % thrust on brakes;
- take-off with full TOGA thrust;
- fictitious reduction of the runway length by 200 m to determine the take-off parameters and limitations.

This fictitious reduction of the runway by 200 metres was calculated to take into account the most critical case identified (serious incident of 11 March) and to ensure that the regulatory margins are complied with on taking off in these conditions. This reduction was then increased to 380 m in order to take into account the occurrence of an engine failure.

❒ 1 July 2017: update of the precautionary measure and application at all airports served by the A340 of:
- 50 % thrust on brakes followed by full TOGA thrust;
- additional 30 m to all the alignment distances;
- increase in margin from 15 % to 20 % on the TOR N engine distance and creation of a 15 % margin for the TOR (N-1) engine distance, for all A340 take-offs from all aerodromes;
- request to crews to take into account the most disadvantageous wind value of the two thresholds, no later than at alignment, for the take-off performance calculations.

In terms of operation, this precautionary measure leads to a reduction in the allowable load (on average around 6.5 t).

During the process to determine the reduction in runway length, Air France contacted Airbus, the DSAC and then EASA respectively.

Airbus validated the calculations but did not wish to give an opinion on the need for these operational measures based on the most critical case.

The DSAC and EASA told Air France that the validation of the precautionary measures was not part of their prerogatives[28].

❒ Air France also set up specific training in the rotation technique on A340.
This training is designed to:

- raise crew awareness of the good practices set out in the FCTM ("typical" initial nose-up deflection of 2/3 of sidestick);
- improve the overall rotation rate of the pilots;
- reduce the variability in rotation rates;
- reinforce knowledge of the risks linked to a non-standard rotation technique (tailstrike or deficit in performance).

[28] An operator is required to process the safety risks by means of its identification of dangers and risk management processes. In the case of the setting up of a risk mitigation measure in the area of take-off performance (CAT.POL.A.205), the prior approval from the competent authority (DSAC) is not required.
The operator informs the authority of the measure by submitting the corresponding amendment to its operations manual, part B, in accordance with the approved procedure for "*All changes not requiring prior approval*" [(ORO.GEN.130 (c)).
The competent authority (DSAC) assesses the information supplied in the notification [(ARO.GEN.330 (c))] and checks for compliance with the applicable performance requirements.
No EASA validation is required as it is not the operator's competent authority.

The DSAC validated the crew training process and asked Air France to systematically follow-up the results observed in operations.

By October 2017, all the Air France A340 crews had attended the rotation technique training course. The first flight analysis results (around 600 flights) showed that the crews had modified their rotation technique resulting in an increase in the average rotation rate (from 1.8°/s to 2.2°/s) and a decrease in the rotation time.

The introduction of the precautionary measures and the training course have reduced the average take-off distances which nevertheless remain greater than those of the theoretical model (AFM).

Briefing

The briefing reiterates notably, the elements of the TEM, revises knowledge, details the initiation of the rotation, the piloting of the rotation rate and finishes with the following key points:

- ❒ at VR, sharp and sustained input to 2/3 of nose-up deflection in accordance with the FCTM version in force at the date of the serious incident;
- ❒ the external references must be used as a priority during the initial phase;
- ❒ no acceleration of rotation rate close to wheel lift-off;
- ❒ suitable, smooth sidestick corrections, the sidestick lateral inputs must remain close to neutral.

The simulator session lasts around one hour and allows each trainee to perform two take-offs.

Debriefing

The simulators do not record specific information for take-offs as they do for landings. As part of the setting up of the rotation technique training, Air France therefore developed a representation of the different useful parameters. As the curves cannot be kept or printed, the instructors freeze the simulator and take photos of the curves displayed in order to use them during the debriefing. The instructor thus has an image which comprises: ground speed, radio altitude (RA), F/O pitch control, captain pitch control, pitch rate and pitch attitude. The scale of these curves cannot be modified and does not permit a close analysis to be carried out. An on-the-spot debriefing is carried out after each take-off.

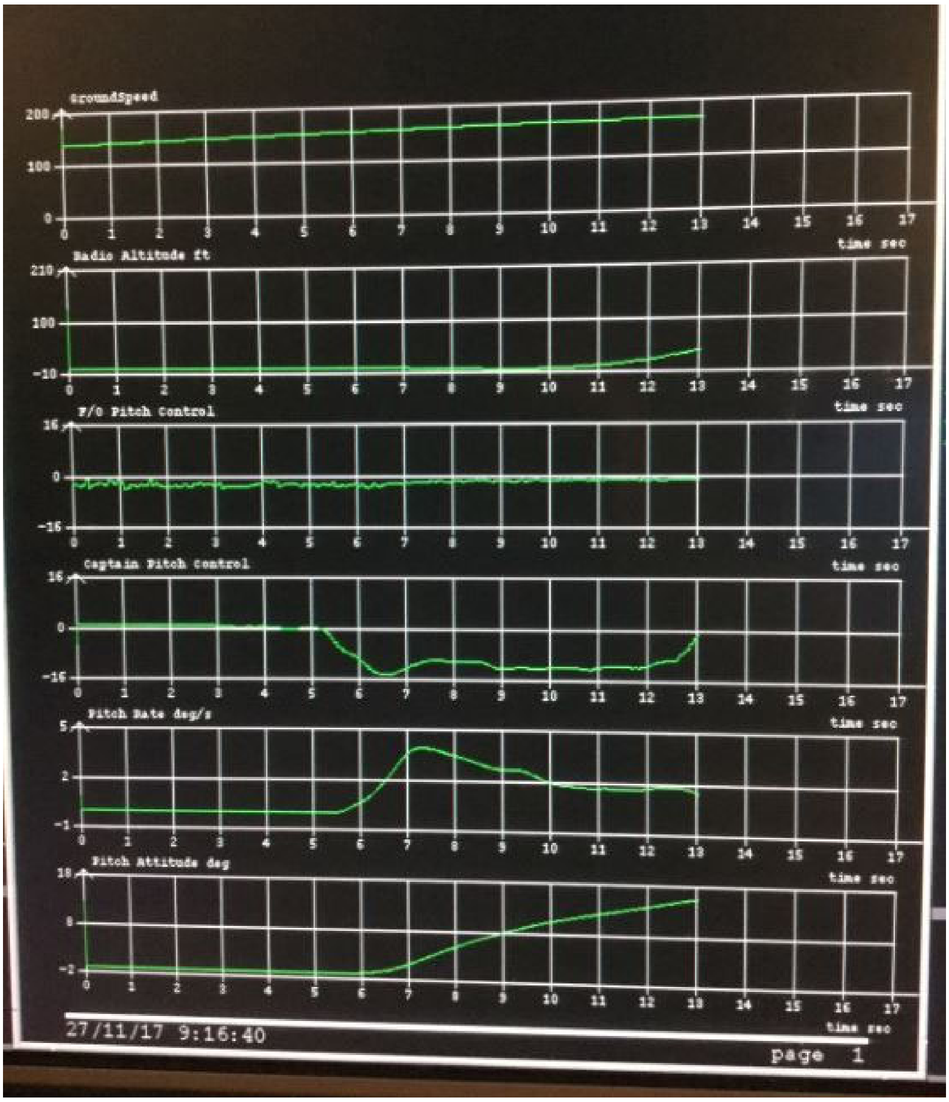


Figure 29: Photo of curves available on simulator

In order to have the possibility of providing pilots who wish it, with specific information about their rotation techniques when back from a flight, Air France has set up a simplified process allowing the flight analysis department to rapidly supply the same information on a pilot requesting this in their pilot report.

Air France has also set up and improved its flight analysis procedure which henceforth includes around ten specific metrics to identify and assess the long take-off risk.

4.2 Lufthansa actions

Lufthansa has also set up a precautionary measure which consists in introducing a fictitious reduction in the length of available runway by 280 m for the performance calculations of all A340-300 take-offs from Bogotá.

For several years, Lufthansa has paid specific attention to the training of its crews in the rotation technique on the A340. Lufthansa did not wish, however, to carry out a training action to modify the take-off technique of pilots in operation in order not to be exposed to an increased tailstrike risk.

4.3 EASA actions

On 27 November 2017, EASA published[29] a Safety Information Bulletin[30].

This document advises operators, the manufacturer, training organizations (ATOs) and the authorities of the serious incident of 11 March 2017 and of the associated risk with a long take-off on four-engine aeroplanes. The incident is disidentified and does not specify the aeroplane type.

It states that the "*main contributing factor*" to the lengthening of the take-off distance was the "*slow aeroplane rotation rate*." EASA reiterates that the "*application of the manufacturer take-off technique is fundamental to ensure that the required take-off performance is achieved [...]*." In this document, EASA does not deal with the possibility that the procedures recommended by the manufacturer cannot be safely performed in an easily repeatable way in normal operations or do not permit the performance established in the certification to be reached.

EASA then recommends that operators of four-engine aeroplanes identify, assess and take the necessary measures to limit this risk.

EASA also requests that the relevant competent authorities ensure that the operators which they oversee take this risk into consideration. Should an operator be confronted with this risk, EASA recommends setting up training in rotation techniques based on the manufacturer's operational documentation. EASA added that the operator must also consider the "*unintended introduction of additional risks (e.g. tailstrikes) [...] when analysing possible mitigating measures*."

[29] https://ad.easa.europa.eu/ad/2017-2

[30] SIB No 2017-20 "*Slow Rotation Take-off*", Cf. Appendix 3.

4.4 Airbus actions

4.4. 1 Update of operational documentation

On 13 December 2017, Airbus issued a bulletin[31] for the attention of operators and ATOs.

This OTT is applicable to the Airbus A340 and issues the recommendations that Airbus would provide in the "*Rotation Technique*" chapter of the amended FCTM. This OTT was also written to encourage instructors to monitor and, if applicable, correct the rotation technique of pilots during initial and recurrent training (TR or CCQ).

On 11 March 2018, Airbus informed the BEA of the update of the FCTM operational documentation. The instruction to apply a "typical" initial nose-up input of 2/3 sidestick deflection is withdrawn from the recommendations provided in the "*Rotation Technique*" chapter and crews are informed of the consequences of a slow rotation rate.

[31] Operations Training Transmission OTT Ref. 999.0109/17 A340 ROTATION TECHNIQUE , Cf. Appendix 4.

The document contains no figures regarding the sidestick input value to be applied and no qualitative indication with respect to the amplitude of the nose-up input to be applied on the A340. The documentation now indicates that the typical time between the initiation of the rotation and wheel lift-off (which occurs with a pitch attitude of around 10°) must be four to five seconds.

Airbus also updated in the same way, all the FCTMs of the other aircraft types (A320 and A380 family). These FCTM revisions came into force in March 2018.

Airbus explained to the investigators that as for all aeroplanes under direct law on take-off, a unique sidestick input to obtain a rotation rate objective, whatever the operational conditions, does not exist. The sidestick input must, therefore, inevitably be adapted to the conditions of the day. Airbus added that the lesson learnt from the analysis of this serious incident showed that the fact of indicating a "typical" value for the initial sidestick input had the effect of changing the objective of the technique in the pilot's mind. The objective was considered to be a calibrated sidestick input which overshadowed the real objective of this technique, namely a rotation rate (piloted according to the conditions of the day).

Based on these two observations, it appeared preferable for Airbus to no longer give an indication as regards the initial sidestick input to be applied but to supply an indication solely characterizing the continuous rotation rate and rotation time.

AIRBUS A330/A340 FLIGHT CREW TECHNIQUES MANUAL	PROCEDURES NORMAL PROCEDURES STANDARD OPERATING PROCEDURES - TAKEOFF

ROTATION

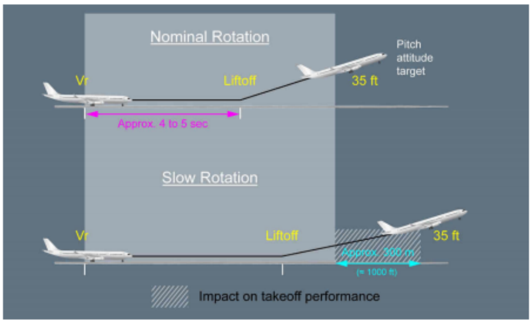
Ident.: PR-NP-SOP-120-00019529.0001001 / 22 FEB 18 - CREATED
Criteria: (LR)

ROTATION TECHNIQUE

The rotation technique is similar on all fly-by-wire aircraft.
To initiate the rotation, the flight crew performs a positive backward stick input. When the rotation is initiated, the flight crew achieves a rotation rate of approximately 3 °/s resulting in a continuous pitch increase.
During the rotation, the aircraft liftoff occurs at approximately 10 ° of pitch, typically around 4 to 5 s after the initiation of the rotation. After the liftoff, the PF targets the required pitch attitude.
To monitor the rotation, the PF uses the outside visual references. Once airborne, the PF controls the pitch attitude target on the PFD.

A slow rotation rate or an under rotation (below takeoff pitch target) has an impact on takeoff performance (refer to below graphic):
- The takeoff run and the takeoff distance increase,
- The obstacle clearance after takeoff decreases.

Performance impacts for a rotation rate of approximately 2 °/s



AIB FCTM — C — PR-NP-SOP-120 P 3/12 — 22 FEB 18

Source: Airbus

Figure 30: Excerpt from updated FCTM

Airbus did not provide additional information on changes to the tailstrike risk if operators concentrated on standardizing initial sidestick inputs to reach the rotation rate of 3°/s.

5 - SAFETY RECOMMENDATIONS

Note: in accordance with the provisions of Article 17.3 of Regulation No. 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation, a safety recommendation in no case creates a presumption of fault or liability in an accident, serious incident or incident. The recipients of safety recommendations report to the authority in charge of safety investigations that have issued them, on the measures taken or being studied for their implementation, as provided for in Article 18 of the aforementioned regulation.

5.1 Certification of Airbus A340-300 take-off performance

The certification regulations in force when the take-off performance of the Airbus A340-300 was determined, indicated that this performance should be obtained without requiring the use of exceptional piloting techniques or vigilance. The principle of these requirements was and continues to be, to establish a performance which is representative of what can be reasonably reached in service by crews of average skill.

It must also be possible for the procedures to be consistently executed in service and include allowances for any time delays in their execution. With respect to the take-off performance, these requirements prohibit, in particular, higher control force inputs or higher pitch rates than would occur in operational service from being used and which could generate unrealistic take-off distances.

The flight analyses of the two major European operators indicate that the average continuous rotation rate reached in operations on the A340-300 is around 2°/s, significantly lower than the rotation rate of 3°/s used in the certified take-off performance calculations. This results in greater average TODs than the TODs established during the certification. The result of this situation is a risk of runway overrun or collision with obstacles during the climb-out phase.

The fundamental principle of "*performance representative of that which can reasonably be expected to be achieved in operational service*" can therefore be called into question in the precise case of the A340-300 take-off performance. In the test flights carried out during the certification campaign and in the results of the calculations carried out in retrospect in the conditions of the event, a nose-up input with an unusually high deflection was in fact required to obtain the certified performance.

This nose-up input was significantly different from the "typical" technique mentioned in the A340 Flight Crew Techniques Manual (FCTM) at the time of the event although the application of the "typical" techniques mentioned in the FCTMs of other aeroplanes of the Airbus family allowed the certified performance to be reached.

In March 2018, Airbus modified the A340 FCTM and then those of other aircraft types. This revision mentions the rotation rate to be obtained to comply with the certified performance (3°/s) and recommends that crews comply with a four to five second interval between the initial nose-up input and lift-off. Information about the piloting technique to reach the certified performance in a safe and repeatable way is no longer provided. In particular, no information is provided about the "typical" initial input to be applied to reach the expected rotation rate although the investigation has shown that the nose-up input to be applied is of an unusually high amplitude with respect to other aircraft. Consequently, it is up to operators to set up the necessary training actions to reach this objective. The effect of a variability of 2 to 3°/s has also been requantified: what was initially a minimal impact is now assessed as a lengthening of the take-off distance by 300 m. This infers an increased appreciation of the inevitable variability in the rotation technique in operations which had not been taken into account at the time of the certification.

With respect to this variability in service, Air France and Lufthansa, the two operators associated with the investigation chose not to require their crews to strictly comply with a rotation rate of 3°/s due to the amplitude of the deflection required which could lead to a greater tailstrike risk and to a difficulty in consistently executing the required action, whatever the flight conditions. This decision by the two operators who have extensive experience in the operation of the A340-400 and the observed variability in the profiles of the sidestick inputs applied during the flights retained for establishing the certified performance, even though applied by test pilots, suggests that specific piloting techniques are required to obtain the rotation rate retained by the certified performance model and raises the question of the possibility of applying these techniques in operation in a consistent and safe manner by crews of average skill.

Airbus argues that the additional protections (Feedforward Order and Electronic Tail Bumper) introduced in 2008 limit this risk and facilitate the "systematic" execution of a take-off reaching the certified performance.

The differences observed between the certified take-off performance and that reached in operations require clear communication about the type of change to be made if a piloting technique different to the current common practice was to be selected.

Consequently, the BEA recommends that EASA, in coordination with Airbus:

- **Re-examine the validity of the initial certification hypotheses of the A340-300 take-off performance.**
  - **[Recommendation FRAN2019-020]**
- **Take the necessary measures to re-establish consistency between the take-off performance in operations and that established during certification on the Airbus A340-300.**
  - **[Recommendation FRAN2019-021]**
- **With the other primary certification authorities, examine whether other CS-25 type aircraft are affected by this type of difference in performance and take the corrective measures that may be necessary.**
  - **[Recommendation FRAN2019-022]**

5.2 Management of risks related to long take-offs: diminution in the variability of the crews' rotation technique and adoption of restrictive measures

The Safety Information Bulletin (SIB) published by EASA in November 2017, sets out the need for each operator to identify, assess and take the appropriate measures to limit the risk associated with a long take-off. In particular, operators and training organisations are recommended to implement specific training about the rotation technique while taking into account the introduction of additional risks such as the tailstrike.

Air France has set up specific training designed to inform pilots of the risks linked to a slow rotation rate and to train them to apply an initial input of at least 2/3 of the deflection. This measure has resulted in a reduction in the observed variability in the pilots' rotation technique and permits an average continuous rotation rate in operation of around 2.2°/s to be reached.

Additional safety measures taken by Air France and Lufthansa - in particular, the fictitious reduction of runway lengths - have restored sufficient take-off distance margins, to the detriment, however, of the payload, in order to take into account a continuous rotation rate objective in operations which is different to that retained during the A340-300 certification. These measures have proven their effectiveness when they aim to systematize a crew practice.

However, not all Airbus A340-300 operators have necessarily measured the impact of the variability in their crews' rotation technique on their risk management of long take-offs.

Consequently, the BEA recommends that pending measures taken to re-establish consistency between the performance reached in operations and those established by the certification, EASA, in coordination with the national oversight authorities:

- **Require operators operating the A340-300 to set up safety measures to reduce the observed variability in the pilots' rotation technique.**
  - **[Recommendation FRAN2019-023]**
- **Require operators operating the A340-300 to set up safety measures to restore sufficient take-off distance margins by comparing the possible difference between the take-off performance reached in operations and that established during certification.**
  - **[Recommendation FRAN2019-024]**

5.3 Use of flight analysis data by authorities ensuring continuing airworthiness

The significant number of years which have elapsed between the entry into service of the A340-300 and the identification of the difference between the certified take-off performance and that reached in operational situations, shows that operators and the manufacturer were not fully aware of the impact of this difference on operation safety before the serious incident of 11 March 2017. Yet the EOFDM working group had recommended from 2012 that operators set up monitoring of simple parameters to detect long take-offs.

The investigation showed the importance for an authority to have flight data information available based on the shared analysis of a significant number of flights performed by several operators.

Consequently, the BEA recommends that EASA in coordination with the national oversight authorities:

- **Ensure that European operators introduce in their flight analysis programmes, the indicators required to monitor take-off performance and at the very least, long take-offs.**
  - **[Recommendation FRAN2019-025]**
- **Collect and analyse the results of this monitoring in order to produce a report on the actual situation in operations.**
  - **[Recommendation FRAN2019-026]**

APPENDICES

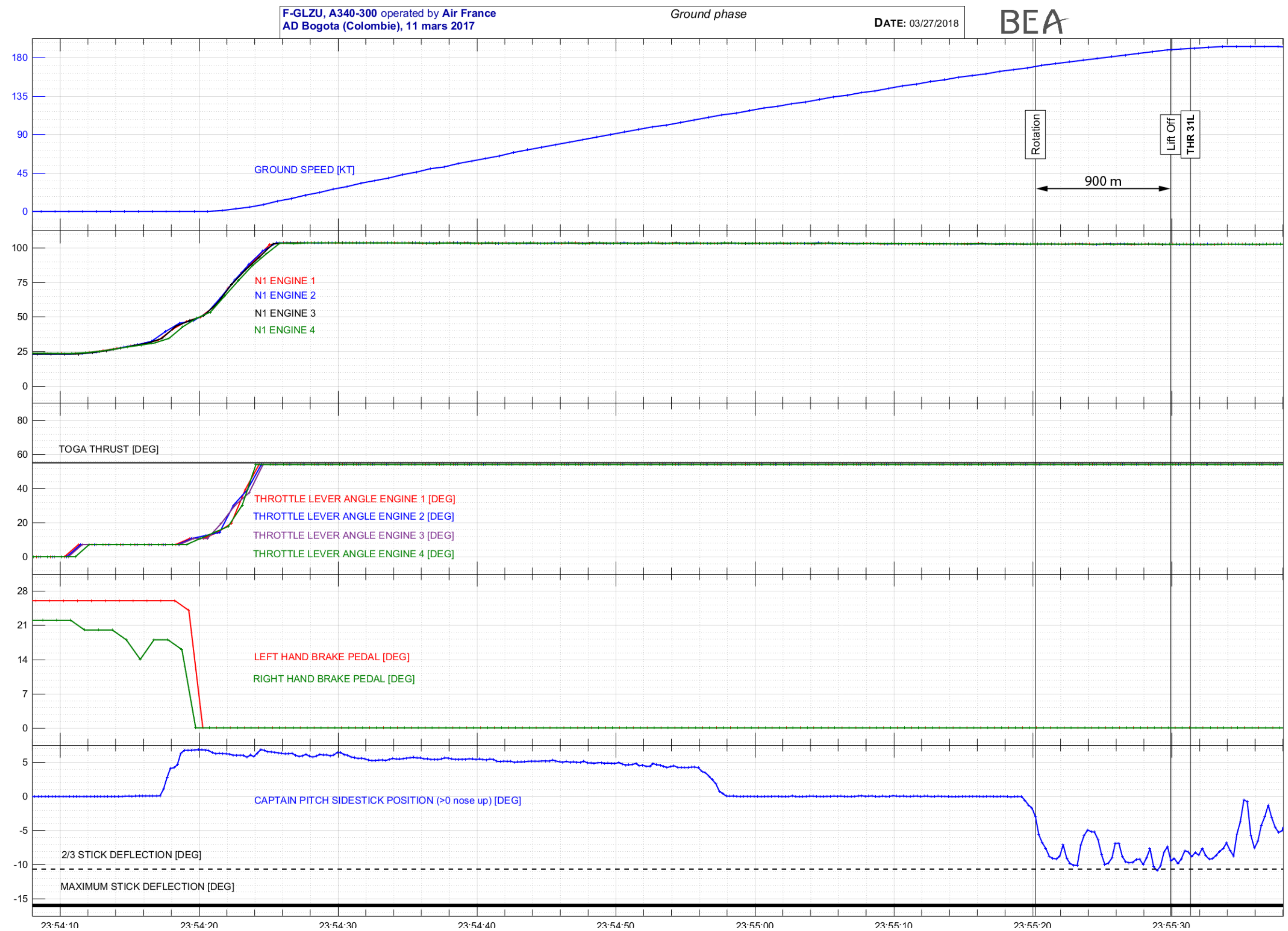
Appendix 1
Flight data curves from read out and analysis of DAR

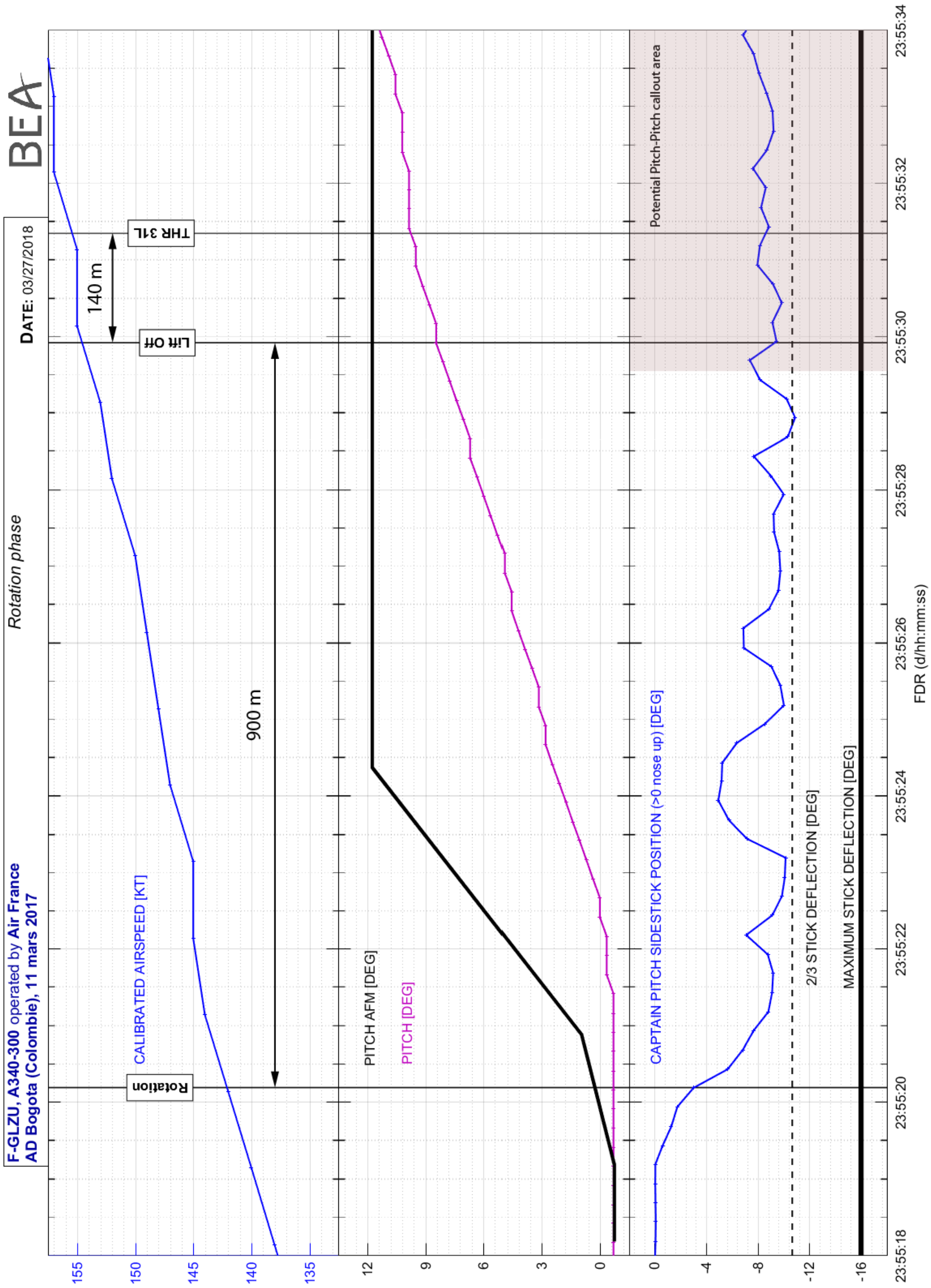
Appendix 2
Difficulties encountered in the read out and analysis of DAR data

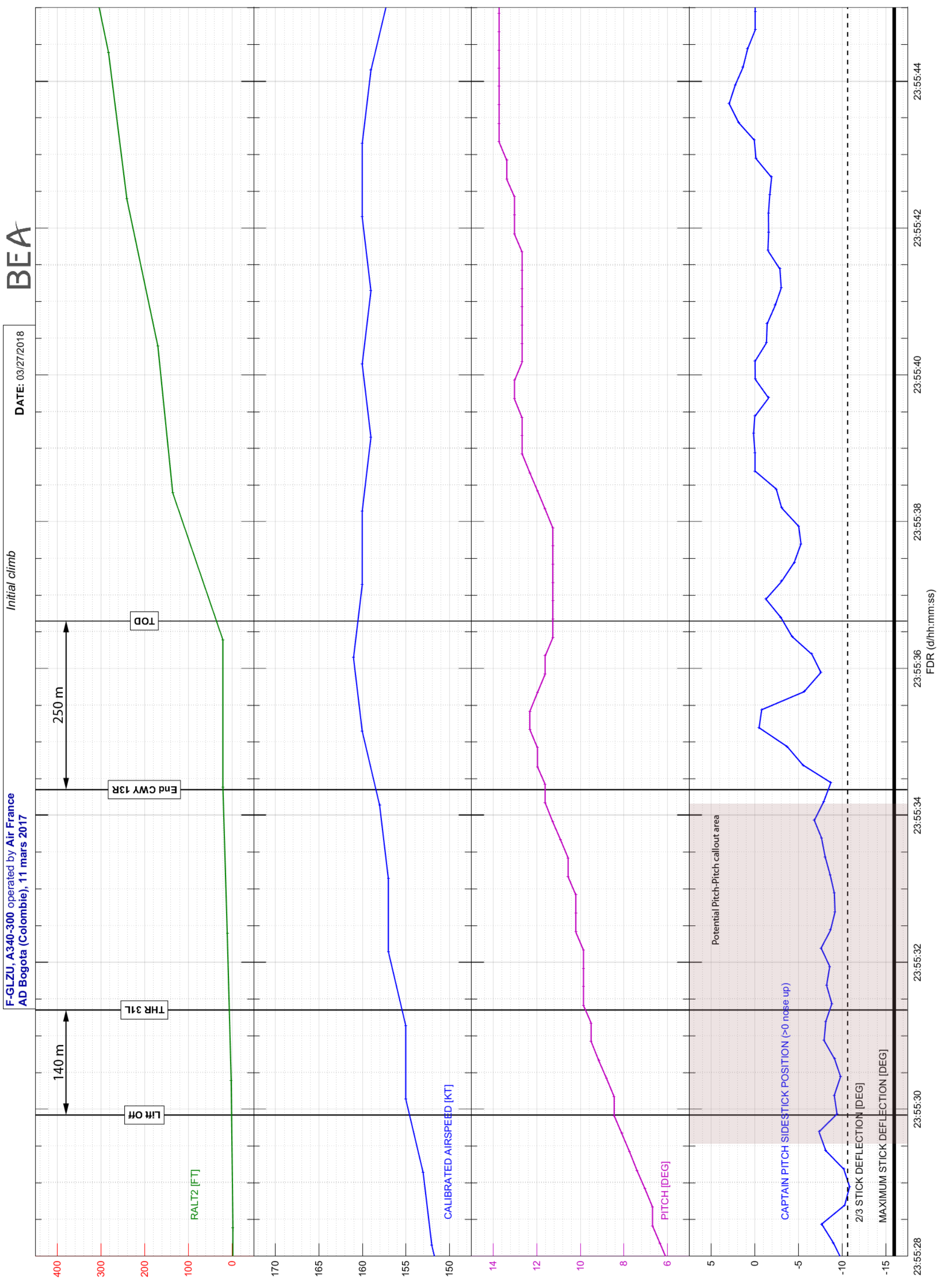
Appendix 3
Safety Information Bulletin No. 2017-20 published 27 November 2017

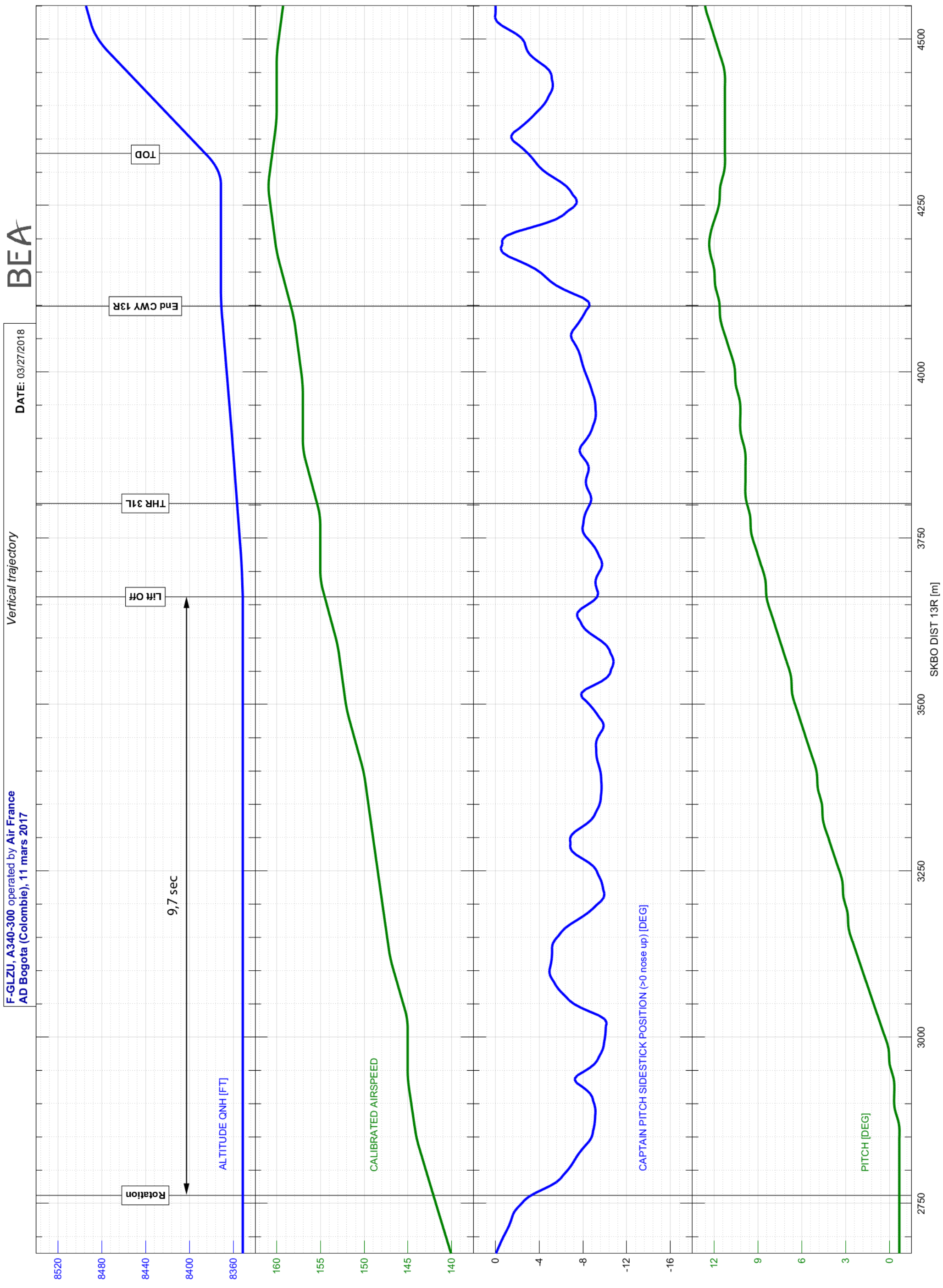
Appendix 4
Safety Information Bulletin No. 2017-20 published 27 November 2017

Appendix 1
Flight data curves from read out and analysis of DAR




F-GLZU, A340-300 operated by Air France
AD Bogota (Colombie), 11 mars 2017
Rotation phase
DATE: 03/27/2018
BEA
CALIBRATED AIRSPEED [KT]
PITCH AFM [DEG]
PITCH [DEG]
CAPTAIN PITCH SIDESTICK POSITION (>0 nose up) [DEG]
2/3 STICK DEFLECTION [DEG]
MAXIMUM STICK DEFLECTION [DEG]
Potential Pitch-Pitch callout area
Rotation
Lift Off
THR 31L
900 m
140 m
FDR (d/hh:mm:ss)
23:55:18
23:55:20
23:55:22
23:55:24
23:55:26
23:55:28
23:55:30
23:55:32
23:55:34


F-GLZU, A340-300 operated by Air France
AD Bogota (Colombie), 11 mars 2017
Initial climb
DATE: 03/27/2018
BEA
Lift off
THR 31L
End CWY 13R
TOD
140 m
250 m
RALT2 [FT]
CALIBRATED AIRSPEED [KT]
PITCH [DEG]
CAPTAIN PITCH SIDESTICK POSITION (>0 nose up)
2/3 STICK DEFLECTION [DEG]
MAXIMUM STICK DEFLECTION [DEG]
Potential Pitch-Pitch callout area
23:55:28
23:55:30
23:55:32
23:55:34
23:55:36
23:55:38
23:55:40
23:55:42
23:55:44
FDR (d/hh:mm:ss)


F-GLZU, A340-300 operated by Air France
AD Bogota (Colombie), 11 mars 2017
Vertical trajectory
DATE: 03/27/2018
BEA
Rotation
Lift Off
THR 31L
End CWY 13R
TOD
9,7 sec
ALTITUDE QNH [FT]
CALIBRATED AIRSPEED
CAPTAIN PITCH SIDESTICK POSITION (>0 nose up) [DEG]
PITCH [DEG]
SKBO DIST 13R [m]

Appendix 2
Difficulties encountered in the read out and analysis of DAR data

Landing gear compression parameters

The DAR records seven parameters concerning landing gear compression. These parameters come from two different computers, the BSCU and the FWC.
During the take-off of the event, a difference of more than 8 seconds was observed between the decompression of the right main landing gear recorded by the BSCU and that recorded by the FWC which Airbus was not able to explain.

	BSCU	FWC
Train avant	1 Hz	4 Hz
Train principal droit	1 Hz	1 Hz
Train principal gauche	1 Hz	4 Hz
Train central		1 Hz

Pitch attitude

The pitch attitude parameter is sampled at 4 Hz with a resolution of around 0.35° (take-off attitude varies between 0° and approximately 8°). This resolution means that it is not possible to accurately calculate an instantaneous rotation rate.
During the summer of 2017, Air France asked Airbus to analyse the two events on the A340-300 linked to a tailstrike risk.
These events followed an inappropriate input by the pilots flying, during the rotation. In both cases, they made a significant nose-up input just before wheel lift-off (Cf. section 1.16.3.2 Tailstrike risk).
The manufacturer calculated that the tailstrike margins were between 0.8 m and 0.9 m for the first event and between 0.8 m and 1.3 m for the second, i.e. uncertainties respectively of 10 cm and 50 cm.
Airbus states that given the binary character of the landing gear compression parameter, it is difficult to calculate a precise margin:

Note 3: Depending on gear compressed / uncompressed status, tail strike margin varies a lot.
It is therefore difficult to compute an accurate trail strike margin. In the following, 2 values are provided;
first one with gear fully compressed, second one with gear fully extended.
Real tail strike margin should be within these 2 extreme values.

At mid-distance between the main landing gears and the rear tip of the aeroplane, the resolution of 0.35° for the pitch attitude parameter introduces a 10 cm error with respect to the tailstrike margin.
The biases introduced by the recorded parameters make monitoring of the flight data linked to this risk impossible.

EOFDM

In 2012, EASA set up a working group, EOFDM, with the goal of:

- ❒ facilitating the implementation of FDM by operators;
- ❒ helping operators draw the maximum safety benefits from a FDM programme.

This working group was divided into three sub-groups which had the following main goals.

Working group A - Monitoring operational safety issues:

- define common risks, safety defences and related operational issues to be monitored by FDM programmes;
- develop the basis for detailed FDM related implementations to be performed by working group B.

Working group B - Programming and equipment related aspects:

- define and test FDM events needed for monitoring operational issues;
- identify useful techniques to investigate flight data, either for automatic analysis or for manual analysis;
- define parameters and their characteristics (sampling rate, recording resolution, accuracy, etc.) needed to: define FDM events, conduct data analysis and make flight measurements;
- investigate aircraft DAR/QAR related issues (data format, parameter sampling rate, data frame layout documentation, aircraft related hardware and software issues);
- look for ways to improve the interoperability between equipment available on the market, including ground FDM replay and airborne equipment;
- provide and update the overview of technical solutions (hardware and software) and of their comparative performance.

Working group C - Integration of the FDM programme into operator's processes:

- compile best practice intelligence and develop guidance material for the integration of flight-data monitoring into an operator's SMS;
- provide guidance that will help an operator to improve management;
- identify best practices with regards to data handling.

The sub-group A published a document in May 2014, "*REVIEW OF ACCIDENT PRECURSOR FOR RUNWAY EXCURSIONS*"[32] grouping the studies regarding potential precursors that could result in runway excursions while the aircraft is either taking-off or landing. In particular, it was recommended to develop indicators to detect the following situations:

[32] https://www.easa.europa.eu/sites/default/files/dfu/214908_EOFDM_WGA_Runway_Excursions-R1.pdf

Late rotation: A late rotation caused either by slow acceleration (excessive time to Vr) or by delayed action by the crew could increase the distance required for takeoff and reduce the safety margin against an overrun.	**RE07 Late rotation**: Develop means to detect rotations conducted after Vr or beyond the expected distance (or time) after the start of the takeoff roll.
Slow rotation: an excessively slow rotation may be the consequence of other problems (incorrect loading, pilot technique, poor elevator authority, etc) and could delay the liftoff reducing the safety margin against an overrun. This could also prompt the crew to reject the takeoff at speeds above V1 which could also lead to an overrun.	**RE08 - Slow rotation**: Develop means to detect slow rotations.
No liftoff: If after rotation the aircraft does not become airborne, the crew could decide to do a high speed rejected takeoff which could lead to an overrun. This situation may be coupled with tail strikes, where the increased drag further delays acceleration to a sufficiently high airspeed to enable liftoff.	**RE09 - No liftoff**: Develop means to measure detect late liftoff (in time and/or distance) after rotation or start of takeoff roll.
Reduced runway remaining at liftoff: Abnormal situations like a slow or late rotation or delayed liftoff (with or without tail strike) could result in a takeoff run distance greater than TORA	**RE15 Runway remaining at liftoff:** Develop means to estimate runway remaining ahead of the aircraft at the moment of liftoff and detect abnormal values

Excerpts from "*REVIEW OF ACCIDENT PRECURSOR FOR RUNWAY EXCURSIONS*"

However, this document provided no precise information about the type of parameters or the method to be followed to develop these indicators.

In April 2017, the sub-group B published a document "*EUROPEAN OPERATORS FLIGHT DATA MONITORING WORKING GROUP B - GUIDANCE FOR THE IMPLEMENTATION OF FDM PRECURSORS*" giving more precise information about how to develop these indicators. It was thus recommended to monitor the rotation time and the take-off distances.

RE07 – Late Rotation

Summary

Develop means to detect rotations conducted after Vr or beyond the expected distance (or time) after the start of the takeoff roll.

Rationale

This precursor evaluates the time it takes from the point where rotation should start, i.e., when the Indicated Airspeed assumes the value of the rotation Speed (Vr) and the point of liftoff from the Main Landing Gear.

Aircraft Parameters

Parameter	Type
Indicated Airspeed (Note 1)	Analog
Vr (Note 2)	Analog

Note 1: During Takeoff IAS may be unstable and better results may come up from the use of the "Ground Speed" instead of IAS.
Note 2: In case the Rotation Speed (Vr) is not recorded, other means are valid to access this speed (See RE01, Future Developments)

Measurements and Events

Search Window	Measurements	Event	Event Threshold
Takeoff	Trot2 = Rotation Time 2 (Since IAS=Vr to Liftoff) (Note 2)	"Late Rotation"	Raise event if Trot2 > Threshold (Note 1)

Note 1: The value of threshold can increase to control the number of false positives.

Maturity Level

Level 1

RE08 – Slow Rotation

Summary

Develop means to detect slow rotations

Rationale

Under this recommendation the time within the first Elevator input and Lift-Off. This corresponds to the rotation time and will be referenced in the document as *Trot*.

Special care should be taken on the determination of the first elevator input. The instant may not be evident to determine from the control column or side-stick pitch control. Other methods can be used such as:

- Extract the reference value from a pool of significant flights
- Use the pitch rate parameter
- This extraction may be facilitated, if the SOP indicates that the side-stick should be pushed forward during the take-off roll.

Aircraft Parameters

Parameter	Type
Pitch Command	Analog
Pitch Rate	Analog

Measurements and Events

Search Window	Measurements	Event	Event Threshold
Takeoff	***Trot1*** = Rotation Time 1 (Since the application of the first Elevator input to Liftoff)	"High Time During Liftoff"	Raise event if ***Trot1*** > Threshold (Note 1)
Takeoff	***NA***	"Low Pitch rate During Liftoff"	Raise event if ***Pitchrate*** < Threshold (Note 1)

Note 1: The value of threshold can increase to control the number of false positives.

Maturity Level

Level 1

RE09 – No Liftoff

Summary

Develop means to detect late Lift-Off (in time and/or distance) after rotation or start of Takeoff roll.

Rationale

This precursor evaluates the distances run by the aircraft since the application of Takeoff power till each of the performance speeds V1 and V2 are attained. These distances will be named in this document as DV1 and DV2 respectively.

It is proposed a check from each of these distances against the performance distances, ASDA and TODA in a way that:

- DV1 is compared with ASDA
- DV2 is compared with TODA

For this solution to be implemented, external source of information concerning the Runway Database is necessary (see RE01, Future Developments).

Aircraft Parameters

Parameter	Type
Ground Speed (Note 1)	Analog
Indicated Airspeed (Note 2)	Analog
V1 (Note 3)	Analog
V2 (Note 3)	Analog

Note 1: To be used to perform the distance calculation by its integration over time. The position (LAT/LONG) and also be used to determine the distance.
Note 2: During Takeoff IAS may be unstable and better results may come up from the use of the "Ground Speed" instead of IAS.
Note 3: In case the performance speeds (V1 and V2) are not recorded, other means are valid to access these speeds (See RE01, Future Developments).

Measurements and Events

Search Window	Measurements	Event	Event Threshold
Takeoff	***DV1*** = Distance from the application of Takeoff Power till the speed attains V1	ASDA short limit	Raise event if ***DV1*** > Threshold
Takeoff	***DV2*** = Distance from the application of Takeoff Power till the speed attains V2	TODA short limit	Raise event if ***DV2*** > Thersold

Maturity Level

Level 1

RE15 – Runway Remaining At Liftoff

Summary

Develop means to estimate runway remaining ahead of the aircraft at the moment of liftoff and detect abnormal values

Rationale

Each time a Liftoff is detected, a measurement of the distance from where it happen till the end of the Runway is performed. This distance will be designated in this document as ***Dlift*** (remaining Liftoff distance).

For this solution to be implemented, the calculation of ***Dlift*** will rely on the availability of information about the End of Runway coordinates. This requires that the Runway Database is providing this input to the FDM System (see RE01, Future Developments). Both the coordinates of the point where Liftoff was detected and the End of Runway are the used to determine the remaining distance.

Aircraft Parameters

Parameter	Type
Latitude	Analog
Longitude	Analog

Measurements and Events

Search Window	Measurements	Event	Event Threshold
Takeoff	***Dlift*** = Distance from the Liftoff detection point to the End of the Runway	"Short Remaining Distance after Liftoff"	Raise event if ***Dlift*** < Threshold

Maturity Level

Level 1

Excerpts from "*EUROPEAN OPERATORS FLIGHT DATA MONITORING WORKING GROUP B - GUIDANCE FOR THE IMPLEMENTATION OF FDM PRECURSORS*"

The maturity level indicated, with respect to the monitoring of rotation rates, means that the proposed solution is only conceptual and depends on the level of technology available. This solution requires specific data and analysis techniques which must be developed and tested.

Maturity Levels

The Maturity Level is the evaluation of implementation of precursors throughout Working Group members. The initial goal for all precursors is to escalate to Level 2 according to the definition table below.

Level	Description
2	The proposed solution (or similar) is already implemented in the industry for at least one aircraft type but has not been subject to the formal Quality Assurance test as specified by WGB (As of today, this methodology has not yet been developed but it will likely consist of a number of checks that will result in either a "pass" or a "fail" classification for the solution).
1	The proposed solution is only conceptual and depends on unavailable technology, special types of data or analysis techniques yet to be developed or tested.
0	WGB was unable to address WGA recommendation either because of lack of time, could not find a way to solve the problem or has to get some inputs from other areas (meteorology, aircraft systems, etc). In either case, this is a way to let the industry know that there is a safety concern which needs further work and/or an innovative idea.

Moreover, the production of these working group (publications, presentations, study results, recommendations, etc.) has no regulatory value and is thus purely for information purposes.

Appendix 3
Safety Information Bulletin No. 2017-20 published 27 November 2017

EASA European Aviation Safety Agency

Safety Information Bulletin
Operations

SIB No.: 2017-20

Issued: 27 November 2017

Subject: **Slow Rotation Take-off**

Ref. Publications:
None.

Applicability:
Operators of 4-engine wide-body aeroplanes, approved training organisations (ATOs) providing relevant flight training, and their competent authorities.

Description:
The intent of this SIB is to raise awareness about a safety issue identified during an on-going investigation of a serious incident involving a 4-engine wide-body aeroplane. In this event, the aeroplane took-off from a limitative runway, near its maximum performance weight. The aeroplane needed a very long take-off run and, when passing the opposite runway threshold, was still below the minimum required height. The analysis of preliminary information gathered by the investigating authority, in cooperation with the affected operator and manufacturer, showed that slow aeroplane rotation rate was a main contributing factor to the event.

The preliminary findings of the investigation also highlighted that similar events had occurred at the same airport, involving another 4-engine wide-body aeroplane operator, and that slow rotation rates were applied in a significant number of take-offs.

Furthermore, the Agency identified one more event that occurred at another airport with a limitative runway, affecting a different type 4-engine wide-body aeroplane. As a consequence, pending the outcome of the full investigation, the Agency deems it appropriate to promptly address the issue of slow rotation rate on take-off in the abovementioned operational context.

Certification Aspects: Take-off performance for large transport aeroplanes is certified against CS-25 standards, which include various requirements regarding the parameters affecting take-off. During certification, take-off distances are established carrying out the manufacturer's recommended take-off procedure, which is described in the operational documentation. The application of the manufacturer take-off technique is fundamental to ensure that the required take-off performance is achieved (e.g. a take-off path with adequate clearance from obstacles).

Recommendation(s):
The Agency recommends operators of 4-engine wide-body aeroplanes, and ATOs providing relevant flight training, to assess whether their operating procedures may be affected by the identified safety issue. If so, they should apply their hazard identification and risk management processes, as follows:

- identify whether slow rotation rate on take-off is a hazard in their operation (e.g. through the analysis of FDM, occurrence reports, training & checking activities);
- if a hazard is identified, assess the associated risks, in particular on airports with limitative runways; and
- if these risks are assessed as not acceptable, establish controls to mitigate the risks to an acceptable level. These controls may include the provision of ad-hoc training on rotation techniques based on aeroplane manufacturer's operational documentation. The unintended introduction of additional risks (e.g. tail strikes) should also be considered when analysing possible mitigating measures; the involvement of the manufacturer may be useful in determining such measures.

The Agency also recommends the relevant competent authorities to consider this SIB as part of the continuing oversight of applicable operators and ATOs.

The Agency will consider the need for additional actions that may be triggered from any further lesson learnt in the course of the investigation or the thorough analysis of the safety issue.

At this time, the safety concern described in this SIB does not warrant the issuance of an operational directive under Regulation (EU) 965/2012, Annex II, ARO.GEN.135(c).

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Appendix 4

Safety Information Bulletin No. 2017-20 published 27 November 2017

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AIRBUS

OPERATIONS TRAINING TRANSMISSION - OTT

TO: All A340 Operators

SUBJECT: ATA 00 – A340 ROTATION TECHNIQUE

OUR REF.: 999.0109/17 Rev 00 dated 13-DEC-2017

APPLICABLE AIRCRAFT: This OTT is applicable to A340-200, A340-300, A340-500, and A340-600 aircraft.

Notice: This OTT provides Operators with recommendations on training techniques or training programs. These training recommendations aim to enhance the efficiency or safety of operations. It is each Operator's responsibility to distribute the information contained in this OTT to ensure application of the training recommendations in the Operator's own training department or any training organization where their crews are trained.

1. PURPOSE

This OTT provides training recommendations to Operators and Approved Training Organizations (ATOs) on the rotation technique to be used during A340 type rating and recurrent training.

This document provides guidance to emphasize the following:

- The proper way to perform the rotation,
- The proper way to monitor the rotation using all cues that are available to the flight crew: sidestick handling, external visual references, aircraft behaviour.

2. DESCRIPTION

On A340 aircraft, some cases of inappropriate rotation rate during takeoff occurred in service. During these events, the inappropriate rotation performed by the flight crew led to a significant increase of the takeoff run and take off distance.

Data analysis of the events revealed that, on A340, the flight crew have a tendency to achieve a slow rotation rate combined with a tendency to release the sidestick during the rotation.

3. ROTATION TECHNIQUE

An appropriate rotation technique ensures that:

- The takeoff performance (takeoff run and take off distance) is fulfilled,
- The tailstrike margin is ensured.

This paragraph emphasizes the correct rotation technique:

- To initiate the rotation, the PF applies a positive backward sidestick input.

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When the aircraft rotates, the PF should achieve an aircraft rotation rate of approximately 3° per second, resulting in a continuous pitch increase toward a pitch attitude of 12.5°.

During the rotation, the aircraft will lift off approximately at 10° of pitch attitude, typically 4 or 5 seconds after the initiation of the rotation.
After the lift off, the PF should target a pitch of 12.5°.

- To monitor the rotation, the PF uses the outside visual references. Then, once airborne, the PF controls the pitch attitude target on the PFD.

4. OPERATIONAL DOCUMENTATION AMENDMENT

The FCTM PR-NP-SOP will be amended to further emphasize the recommended rotation technique.

The amended FCTM content will be published with the associated FCTM Main Change, by the first quarter of 2018.

The FCTM amendment is applicable to all Airbus aircraft. However, this OTT is sent to A340 Operators only, in order to emphasize the rotation technique following several reported events.

5. TRAINING

We recommend that during Type Rating training, Cross Crew Qualification (CCQ) or Recurrent training, the instructors assess the flight crew for the correct rotation technique as per the technique described in above chapter 3 and amended FCTM.

For any questions about the operational content of this OTT, please use TechRequest Flight Operations Domain on AirbusWorld.

Best regards,

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