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Swiss Transportation Safety Investigation Board STSB

Final Report No. 2355 by the Swiss Transportation Safety Investigation Board STSB

concerning the serious incident involving the A220-300 aircraft, HB-JCC,

on 15 July 2018

at Porto Airport (LPPR), Portugal

Swiss Transportation Safety Investigation Board STSB
3003 Bern
Tel. +41 58 466 33 00, Fax +41 58 466 33 01
info@sust.admin.ch
www.sust.admin.ch

General information on this report

This report contains the Swiss Transportation Safety Investigation Board's (STSB) conclusions on the circumstances around and causes of the serious incident under investigation.

In accordance with Article 3.1 of the 10th edition of Annex 13, effective from 18 November 2010, to the Convention on International Civil Aviation of 7 December 1944 and Article 24 of the Federal Aviation Act (CAA, SR 748.0) of 21 December 1948, Status as of 1 January 2019), the sole purpose of an investigation into an aircraft accident or serious incident is to prevent further accidents or serious incidents from occurring. Legal assessment of the circumstances around and causes of aircraft accidents and serious incidents is expressly excluded from the safety investigation. It is therefore not the purpose of this report to establish blame or to determine liability.

Should this report be used for purposes other than those of accident prevention, this statement should be given due consideration.

The German version of this report constitutes the original and is therefore definitive.

Unless otherwise indicated, all information relates to the time of the serious incident.

All of the times mentioned in this report, unless otherwise indicated, are given in coordinated universal time (UTC). For Portugal, Western European Summer Time (WEST) was the local time (LT) at the time of the serious incident. The relationship between LT, WEST and UTC is:
LT = WEST = UTC + 1 hour

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Final report

Synopsis

Owner	LHAMI Leasing Limited, Dragonara Road, MT-3140 St Julian’s STJ, Malta
Operator	Swiss International Air Lines Ltd, Malzgasse 15, 4052 Basel
Manufacturer	C-Series Aircraft Limited Partnership (CSALP), Mirabel (Québec), Canada
Aircraft type	A220-300
Country of registration	Switzerland
Registration	HB-JCC
Location	Porto Airport (LPPR)
Date and time	15 July 2018, 02:01 UTC
Type of operation	Scheduled line flight
Flight rules	Instrument flight rules (IFR)
Point of departure	Porto Airport (LPPR)
Destination	Geneva Airport (LSGG)
Flight phase	Takeoff and climb
Type of serious incident	Non-compliance with the standard operating procedures

Investigation

The serious incident took place at 02:01 UTC on 15 July 2018. The Swiss Transportation Safety Investigation Board (STSB) did not receive notification of the incident until 24 July 2018. The STSB opened the investigation on 25 July 2018 and informed the investigation authority of Portugal about the serious incident. They delegated the investigation to the STSB and appointed an authorised representative, who was working with the investigation.

The following principles were available for the investigation:

- Data from the flight recorder;
- Information disclosed by the flight crew and Porto’s air traffic control.

This final report is published by the STSB.

Summary

On 15 July 2018, the scheduled flight (flight number LX 2077) from Porto (LPPR) to Geneva (LSGG) was carried out on the A220-300 commercial aircraft, registered as HB-JCC. Two pilots, three cabin crew members and 41 passengers were on board.

After being given clearance by the aerodrome control tower at 01:59:36 UTC, HB-JCC taxied to runway 35, lining up from intersection C. In the process, the commander (CMD) acting as the pilot flying (PF) armed[1] the autothrottle (AT).

[1] This puts a system into a mode from which it automatically activates when certain parameters are met.

The flight crew performed a rolling takeoff. Once the aircraft was aligned to the runway axis, the PF advanced the thrust levers, assuming that the AT would now be engaged and would set the takeoff power to the required level. As the PF had advanced the thrust levers to a thrust lever angle (TLA) of only 20.6°, the AT remained armed without becoming engaged. This went unnoticed by the flight crew. For activation, a TLA of 23° would have been required.

After exceeding an indicated airspeed of 60 kt, the spoilers extended as they are designed to do; this was not indicated to the flight crew.

As per the standard operating procedures, one of the things that the flight crew must check is that the required takeoff power is set when exceeding a speed of 80 kt. Neither of the pilots could remember whether they had executed this check. The engine power being too low went unnoticed.

Due to slow acceleration and the remaining length of the runway, the PF realised that the power had been set too low. By then, the aircraft had reached a speed of between 90 and 100 kt. He pushed the throttles forward and, when the TLA passed 23°[2], the spoilers retracted as they are designed to do. In addition, the warning CONFIG SPOILER was displayed in red letters.

The aircraft took off approximately 1000 metres before the end of the runway, at a distance that was 1.5 times the length of the calculated takeoff distance, continued to climb and landed in Geneva without any further incidents.

Causes

The serious incident, in which a commercial aircraft took off with insufficient engine power, can be attributed to the fact that the flight crew was too late to notice that the engine power required for takeoff was not set.

The following factors contributed to the serious incident:

- Non-compliance with the aviation company’s standard operating procedures (SOP);
- Inappropriate prioritisation by the flight crew during the takeoff roll.

Although they did not influence the development and course of the serious incident, the following risk factors were identified during the investigation:

- The design of the spoiler deployment;
- The design of the autothrottle (AT), whereby the AT switches to HOLD mode during the takeoff roll, even if the required takeoff power (target N1) has not yet been reached.

Safety recommendations and safety advice

One safety recommendation and one piece of safety advice are made in this final report.

[2] According to the National Aircraft Certification (TCCA) this value is 22.5° (GLD reset logic). Since the value of 23° is continously published in the Manufacturer’s Flight Crew Operational Manual (FCOM), it will also consequently be mentioned in this report.

1 Factual information

1.1 Preflight history and history of the flight

1.1.1 Preflight history

On 13 July 2018, the flight crew flew from Zurich (LSZH) to Budapest (LHBP) and back, followed by a flight to Geneva (LSGG), together. Their duty ended at 22:05 UTC after 7 hours and 35 minutes.

On 14 July 2018, the flight crew started their duty at 18:25 UTC for flight LX2076 to Porto (LPPR). They landed in Porto at 21:46 UTC. The scheduled return flight to Geneva was planned for 01:50 UTC.

The commander was the pilot flying (PF) and the copilot was the pilot monitoring (PM) throughout this flight.

It was a scheduled flight carried out under instrument flight rules (IFR).

1.1.2 History of the serious incident

The flight crew calculated the engine power required for takeoff from intersection C of runway 35 using data from the loadsheet. Based on the length of the runway and the environmental conditions at Porto, the flight crew decided on a so-called TO-3 takeoff with the flaps in position 2. TO-3 is a takeoff with derated takeoff thrust and corresponds to the maximum-possible reduction in engine thrust rating.

The calculations for TO-3 resulted in a takeoff power equivalent to an N1[3] of 80.7 %. The following speeds have also been determined as vital for takeoff: V_1[4] = 117 kt, V_R[5] = 122 kt and V_2[6] = 129 kt. At TO-3 engine performance, the accelerate stop distance (ASD[7]) was calculated to be 1749 metres.

At 01:35:03 UTC, the flight crew received clearance for their flight to Geneva. Following that, the flight crew entered the standard instrument departure (SID) route they had been given, BELDU 8E, into the flight management system (FMS). Subsequently, the crew saw that contrary to expectations the flight plan displayed a discontinuity. In their takeoff briefing, the PF therefore stated that the PM was to keep a close eye on the FMS during the takeoff roll.

At 01:59:36 UTC, the flight crew received clearance to line up and take off. When lining up, the commander (CMD) armed the autothrottle (AT). The flight crew performed a rolling takeoff. Aligned to the runway, the CMD advanced the throttles at 02:00:31 UTC, assuming that the AT would then set the takeoff thrust required to an N1 of 80.7 % (see chapter 1.6.3.2). The data shows that the throttle lever angle (TLA) was 20.6° after the throttles had been advanced. For AT activation, the TLA would have needed to be more than 23°; the AT therefore remained armed without being engaged. This went unnoticed by the flight crew.

The data also shows that, after the wheel speed (WS) had exceeded 60 kt during the takeoff roll (see chapter 1.6.3.2), the spoilers automatically extended without alerting the flight crew in the form of a warning (see annexes 1 and 2).

[3] N1: Rotational speed of the low-pressure part in a multi-shaft turbo jet engine as a percentage of the nominal speed.

[4] V_1 stands for decision speed. If an engine fails at this speed, the aircraft is able either to continue the takeoff with a safe climb or to abort the takeoff and come to a standstill on the runway.

[5] V_R stands for rotation speed. At this speed, a rotation around the pitch axis is initiated to lift off.

[6] V_2 stands for takeoff safety speed. This speed ensures a safe climb if an engine fails at V_1.

[7] ASD stands for accelerate stop distance. This is the sum of the distance required to accelerate to the V_1 speed and the distance required to bring the aircraft to a standstill using the wheel brakes after an aborted takeoff at V_1.

As per the standard operating procedures, the flight crew has to carry out the so-called ‘80-kt check’ at an indicated airspeed (KIAS) of 80 kt (see figure 9). That is to say, both pilots have to verify that the speeds displayed on their screens are identical and that the N1 rpm is equivalent to the takeoff power required. The data shows that, by this time, the power output of N1 was set at 65.3 % instead of the required 80.7 %. Both pilots stated that they could not say for certain whether they had executed the 80-KIAS check including the associated monitoring of the power output.

According to the CMD, acceleration seemed slower than usual at a speed of between 90 and 100 KIAS; however, he sensed a degree of uncertainty as takeoff was carried out at derated thrust. At that moment, the copilot notified the CMD that the FMS was working again and that the flight plan no longer displayed a discontinuity.

Due to the slow acceleration, the CMD checked the set takeoff power. He then realised that it was too low and pushed the throttles forward. The data shows that the speed was 109 KIAS at this time and that the throttles had been set at a TLA of 28.5°, equivalent to an N1 power output of 76.6 %. According to the flight crew’s statement, they became aware almost simultaneously of the CONFIG SPOILER warning, which illuminated for four seconds. The copilot responded to this warning at once, voicing that the spoiler lever was in the retracted (RET) position. The CMD briefly considered aborting takeoff. However, as he had exceeded speed V_1 (117 kt) in the meantime, he decided to continue the takeoff roll. The aircraft took off 52 seconds after takeoff was initiated, at a distance that was 1.5 times the length of the calculated takeoff distance, and approximately 1000 metres before the end of the runway.

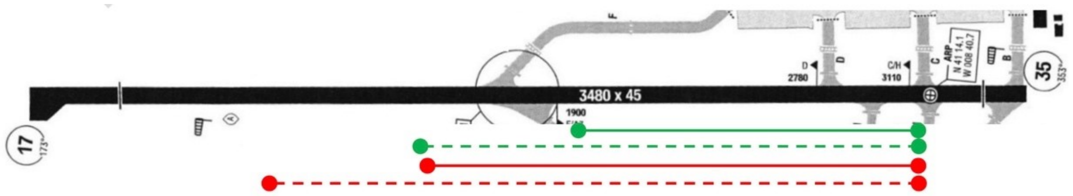

Figure 1: Distance from start of takeoff roll until lift-off with the correct power setting (green line); with a power setting as it was in the serious incident (red line). Additionally: the respective accelerate stop distance (ASD) (dotted line).

The remainder of the flight was uneventful. The aircraft landed in Geneva at 04:02:29 UTC.

1.1.3 Location and time of the serious incident

Date and time	15 July 2018, 02:01 UTC
Light conditions	Night
Coordinates	N 41° 14’ 53’’ / W 008° 40’ 53’’ (WGS[8] 84)
Elevation	69 m AMSL, equivalent to 227 ft AMSL[9]

[8] WGS: World geodetic system. The WGS 84 standard was adapted in aviation by a resolution issued by the International Civil Aviation Organization (ICAO) in 1989.

[9] AMSL: Above mean sea level

1.2 Injuries to persons

1.2.1 Injured persons

Injuries	Crew members	Passengers	Total number of occupants	Other
Fatal	0	0	0	0
Serious	0	0	0	0
Minor	0	0	0	0
None	5	41	46	Not applicable
Total	5	41	46	0

1.3 Damage to aircraft

There was no damage to the aircraft.

1.4 Other damage

None

1.5 Personnel information

1.5.1 Flight crew

1.5.1.1 Commander

Person	Swiss citizen, born 1959	
Licence	EASA (European Aviation Safety Agency) airline transport pilot licence aeroplane (ATPL (A)), issued by the Swiss Federal Office of Civil Aviation (FOCA)	
Flying experience	Total	14 766:42 h
	On the incident type	301:35 h
	During the last 90 days	108:09 h
	On the incident type	108:09 h

All of the evidence available suggests that the commander started his duty in good health. However, in his report he does not rule out a certain element of fatigue.

1.5.1.2 Copilot

Person	Swiss citizen, born 1984	
Licence	EASA ATPL (A), issued by FOCA	
Flying experience	Total	1783:45 h
	On the incident type	397:39 h
	During the last 90 days	138:40 h
	On the incident type	138:40 h

All of the evidence available suggests that the copilot started his duty in good health. That a certain element of fatigue played a role cannot completely be excluded because he wrote a respective report.

1.6 Aircraft information

1.6.1 General

Registration	HB-JCC
Aircraft type	A220-300
Characteristics	Twin-jet short and medium range passenger aircraft
Manufacturer	C-Series Aircraft Limited Partnership (CSALP), Mirabel (Québec), Canada
Year of manufacture	2017
Serial number	55012
Owner	LHAMI Leasing Limited, Dragonara Road, MT-3140 St Julian's STJ
Operator	Swiss International Air Lines Ltd, Malzgasse 15, 4052 Basel
Engines	Pratt&Whitney, PW1524G-3
Technical restrictions	Takeoff: 65 000 kg Landing: 58 740 kg
Mass and centre of gravity	At the time of takeoff, the centre of gravity as well as the mass of 48 413 kg were within the limits according to the aircraft flight manual (AFM).

1.6.2 Cockpit layout

The layout of the display units (DUs) in the cockpit is as follows:

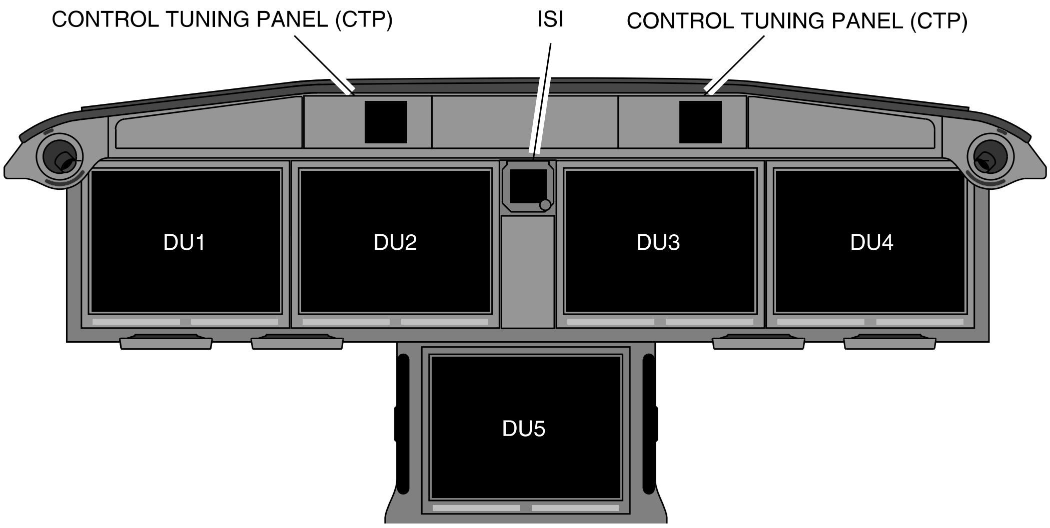

Figure 2: Copied (detail) from FCOM[10] 1, (figure 08-02-1)

The displays on the 5 DUs show the flight crew all of the relevant data for flying. Furthermore, they are used to monitor the engine data as well as different systems. Schematically the DUs show primarly the following:

[10] FCOM: Flight crew operating manual

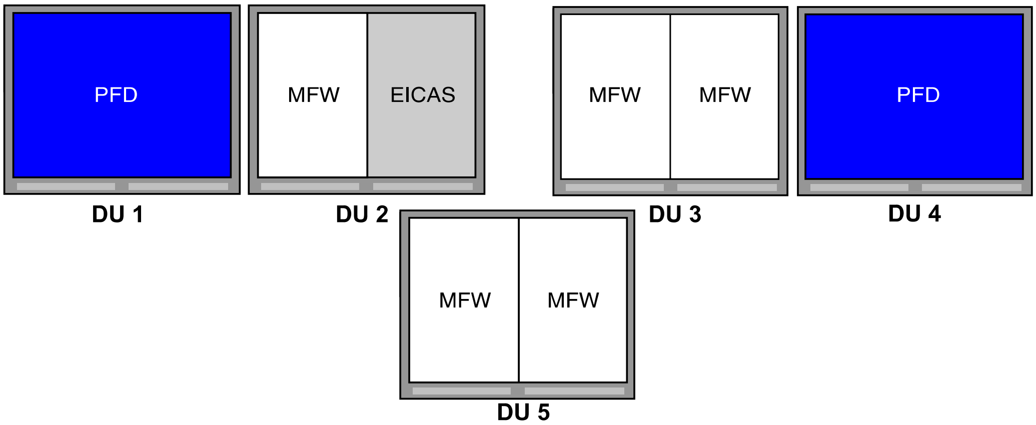

Figure 3: Normal display (copied from FCOM 1, figure 08-02-6)

DU 1 and DU 4	Primary flight display (PFD) – this screen shows primary flight and navigation data such as attitude, altitude, speed and heading.
DU 2	The multifunction window (MFW) on the left half of the screen can be configured to show the flight crew the following: FMS, route and map displays, synoptic pages, tuning windows, charts, documents, video or electronic checklist (ECL). The engine indication and crew alerting system (EICAS) on the right half of the screen can display the status of different systems on one side and messages, faults and warnings on the other side.
DU 3	MFW on the left and right half of the screen
DU 5	MFW on the left and right half of the screen

If the pilot in the right-hand seat is the PF, the displays can be changed so that DU2 will show two MFWs and DU3 will show the EICAS page (left half) and a MFW (right half).

The operator determined the following MFW setting as being standard for takeoff:

DU 2	MFW: map display EICAS (see figure 3)
DU 3	Map display for both MFWs, therefore showing a larger map compared to DU2. If necessary, the left MFW for instance shows the checklist (CHKL page) that has to be executed by the flight crew. If the EICAS shows a warning that requires crew action, this page, when selected, shows automatically the possibly dedicated checklist.
DU 5	The MFW on the left shows the performance page (PERF), displaying the most important engine data for takeoff and initial climb out. The MFW on the right shows the entered flight plan (route). Typically, the PF chooses the PERF page on his side and the PM the route page.

The engine data on the EICAS is displayed on the upper left half as follows:

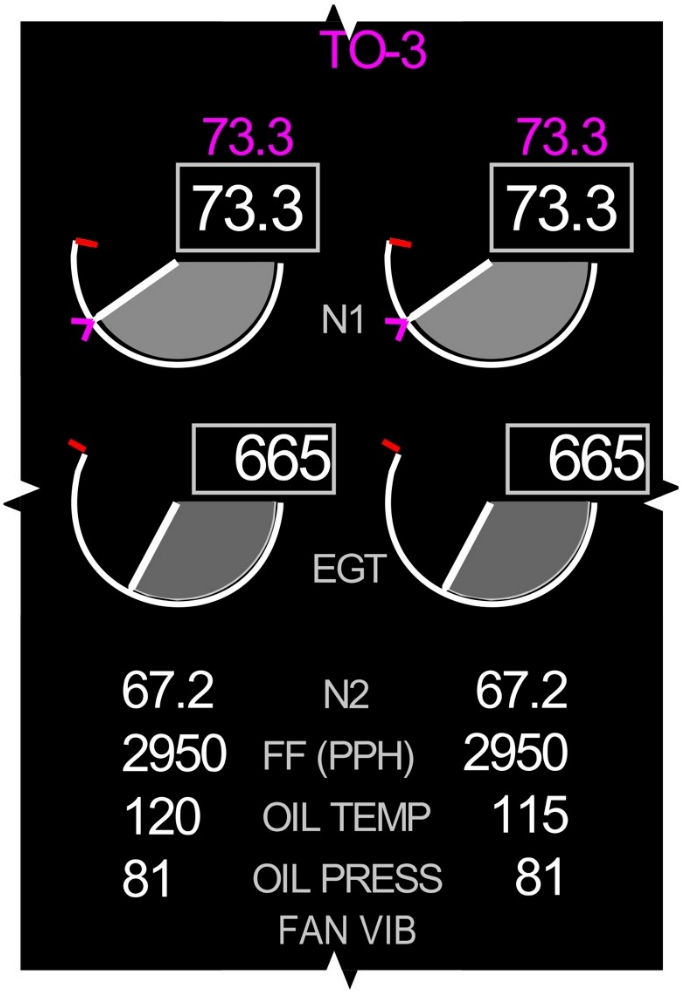

Figure 4: Detail from the EICAS with engine data (based on figure 18-09-14, FCOM 1)

The example in figure 4 shows a calculated power setting with an N1 of 73.3 % (magenta) for a TO-3 takeoff (derated takeoff thrust). The actual N1 power output is shown in white with a grey sector area – in this example also correctly set at 73.3 %.

1.6.3 Selected systems and equipment on the aircraft

1.6.3.1 General

The following sections only briefly describe systems that bear any significance with regards to this serious incident.

1.6.3.2 Autothrottle

The aircraft HB-JCC is equipped with an autothrottle (AT) system that automatically manages the engine thrust. When the AT is engaged and not in AT HOLD mode, the AT servomotors in the throttle quadrant assembly (TQA) automatically position the thrust levers during the complete flight profile. The AT also ensures engine synchronisation.

The autothrottle system is engaged/disengaged by the following components:

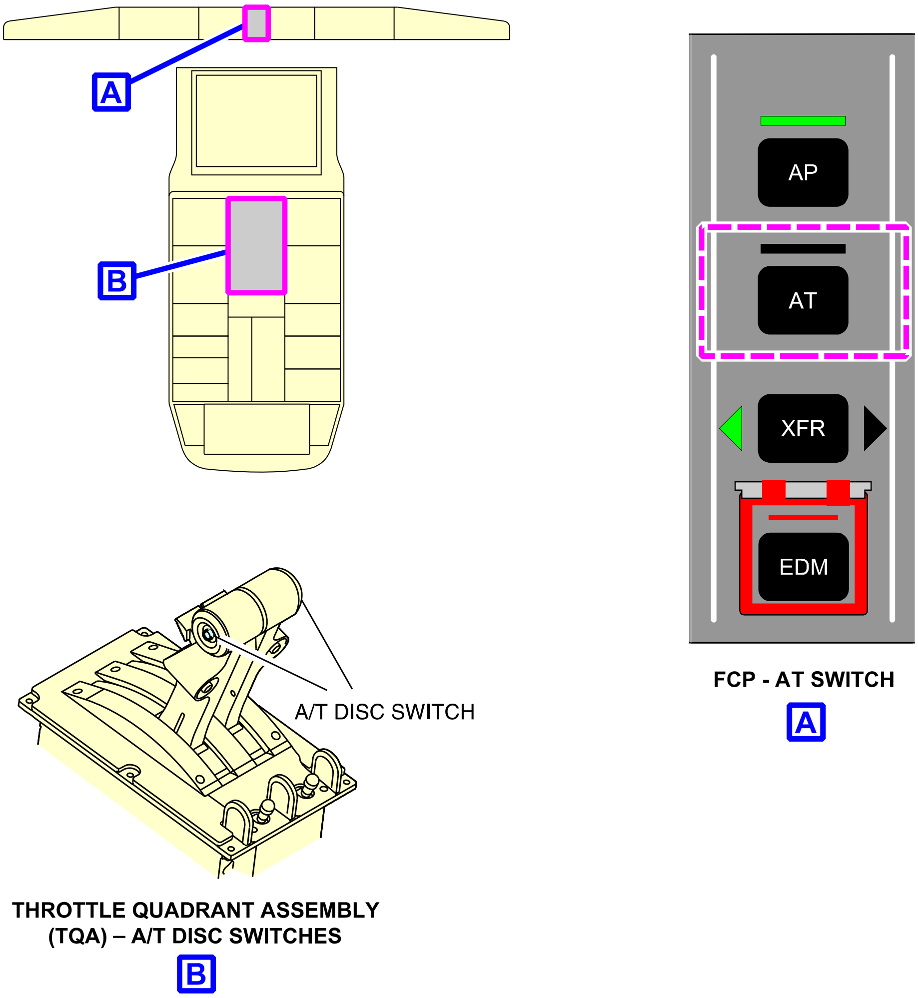

Figure 5: AT system controls (copied from FCOM 1, figure 03-05-1)

The AT is normally engaged manually and can be disengaged at any time. The AT is highly integrated with the automatic flight control system (AFCS) and the flight management system (FMS).

The AT also provides speed and thrust envelope limiting. The AT system status is displayed on the flight mode annunciator (FMA) and fault messages are displayed on the EICAS page.

Before takeoff, the AT is armed by pressing the push button (p/b) on the flight control panel (FCP). The dark line above the AT p/b illuminates in green and the FMA shows AT (white) (see figure 6). The white arrow indicates that the AT uses navigation sources and altimeter settings of the left side.

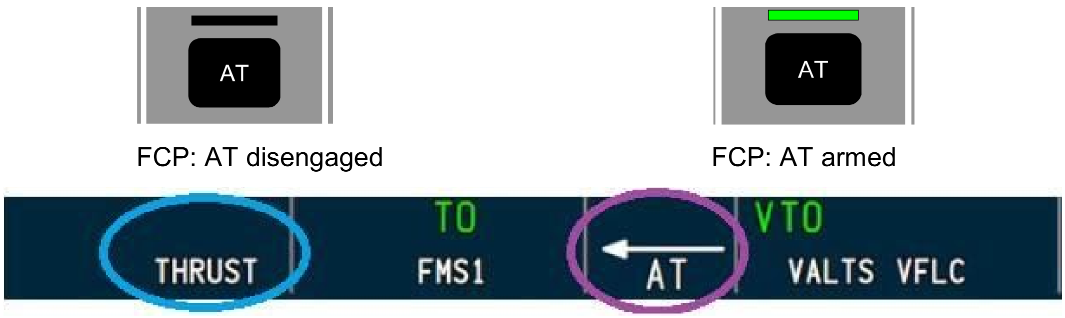

Figure 6: Two different FCP displays and FMA display with AT armed

At takeoff, the thrust levers are advanced to approximately N1 of 50 %. Once the engines are stabilized the thrust levers are moved further forward. If the throttles are further advanced through the 23-degree Thrust Lever Angle (TLA) position (approximately 60 % N1), the AT activates and takes over thrust lever control, and the thrust levers automatically travel into the takeoff thrust position. THRUST and AT are now displayed in green and SPD (speed) is shown in white (armed). Furthermore it has to be mentioned that the TLA value is not visible to the flight crew.

Figure 7: TLA > 23°, AT engaged in THRUST mode, speed < 60 KIAS

When the airspeed increases above 60 KIAS, the THRUST HOLD mode activates. In HOLD mode, all autothrottle commands are suspended and power is removed from the thrust levers. This means that the thrust levers and N1 speed remain at this approximate position. Normally, this position corresponds to the takeoff N1 selected through the FMS.

Figure 8: TLA > 23°, AT in THRUST HOLD mode, speed > 60 KIAS

Since the TLA in the present case was still less than 23°, the AT remained armed and switched directly to HOLD mode when the speed exceeded 60 KIAS.

The THRUST HOLD mode remains active until the aircraft reaches an altitude of 400 ft above ground level.

Figure 9: AT switches to THRUST mode when the aircraft is 400 ft above ground level

Regardless of the AT mode, the AT is disengaged by the actions that follow:

- Pressing the AT DISC p/b (cf. figure 5, figure B);
- Moving the thrust levers[11];
- Pressing the AT p/b on the FCP if engaged, or
- AT system failure is detected.

If the AT disconnects, be this manually or automatically, a flashing AT (in amber) displays on the FMA with an aural AUTOTHROTTLE alert.

If the AT disconnects due to a detected system failure, the advisory message AT FAIL is displayed in blue at the same time.

If the throttles are advanced to the forward mechanical stop, maximum takeoff thrust is selected in any case.

[11] The National Aviation Certification (NAC) of the Transport Canada Civil Aviation (TCCA) added that this is not true if the AT switches direct from ARM mode in HOLD mode during takeoff. In such a case the AT can only become active 400 ft above ground level.

1.6.3.3 Spoilers

The secondary flight controls consist of the multifunction spoilers (MFSs), ground spoilers (GSs) and the horizontal stabiliser (HSTAB).

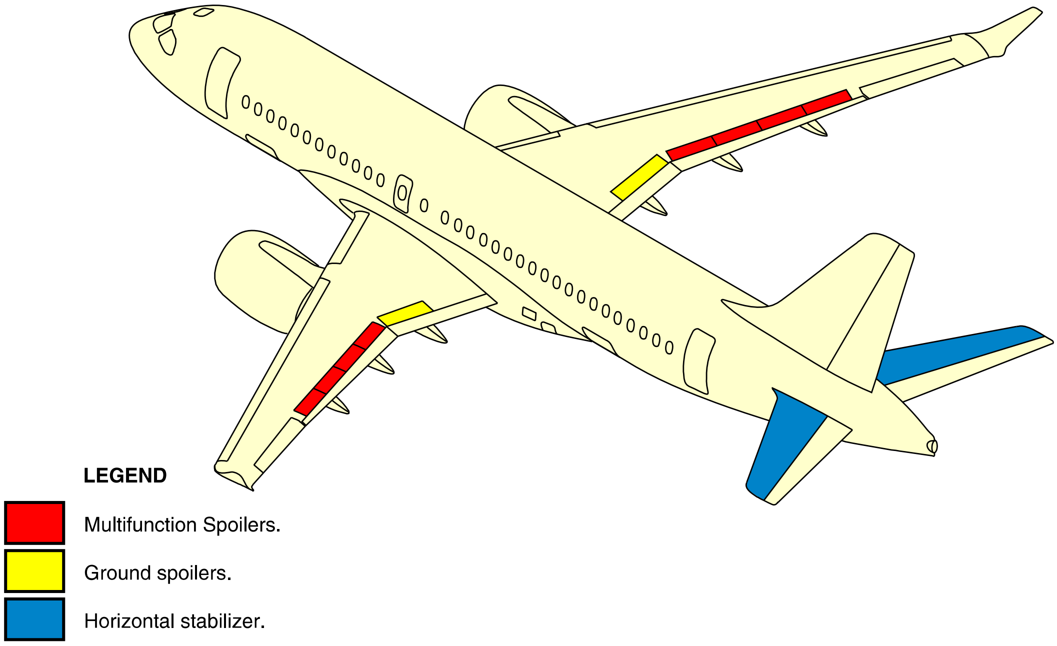

Figure 10: Secondary flight controls (copied from FCOM 1, figure 10-04-1)

The MFSs deploy automatically on one wing at a time to assist roll control. They are also used as speed brakes during flight. When used as speed brakes, the MFSs are manually deployed (symmetrically on both wings) by moving the flight SPOILER lever. In addition, the MFSs – together with the ground spoilers (GSs) – provide ground lift dumping (GLD). In the normal mode, when the aircraft lands, all the MFSs are automatically extended to full deflection. This function is automatic and requires no pilot input.

The ground spoilers operate symmetrically to provide lift dumping at touchdown. Automatic deployment of the ground spoilers is computed through the primary flight control computers (PFCC). Amongst other things, the deployment logic is based on a wheel speed (WS) of 60 kt and on the weight-on-wheels. Furthermore, the thrust lever angle (TLA) must be less than 23 degrees. The lift dump function is automatic and does not need to be armed by the pilot.

Conversely, if the TLA of both throttle levers is less than 23 degrees during aircraft acceleration, the spoilers will deploy automatically if the wheel speed is above 60 kt.

A respective note can be found in the checklist "*touch and go landing procedure*" (FCOM Operational Guidance, chapter 08.02.02 page 7). The first note reads:

"Ground lift dumping (GLD) are automatically deployed with weight-on-wheels, and retract when the thrust levers are advanced beyond a 23-degree lever angle (approximately vertical)."

The spoiler position can be seen on the FLT CTRL synoptic page. The spoiler status for both the MFSs and GSs is indicated by the colour displayed: green for normal, and amber for failure. Furthermore, the following information is given to flight crews in the chapter *"secondary flight controls – spoiler indication"* (bold and font colour as in original):

"When thrust is set for takeoff with any spoiler not stowed, the ***CONFIG SPOILER*** *EICAS warning message displays and the 'CONFIG SPOILER' aural alert sounds repeatedly."*

1.7 Meteorological information

1.7.1 General weather conditions

An area of low pressure with its centre off the coast of Portugal determined the weather.

1.7.2 Weather at the time and location of the serious incident

The sky was slightly overcast; there was light wind. Visibility was at least 10 kilometres.

Cloud	1/8–2/8 at 4,000 ft AAE[12]
Visibility	10 km or more
Wind	140°, 3 kt
Temperature / dew point	16°C / 15°C
Atmospheric pressure (QNH)	1017 hPa, pressure reduced to sea level, calculated using the values of the ICAO[13] standard atmosphere
Risks	None

1.7.3 Astronomical information

Position of the sun	Azimuth: --	Elevation: --
Light conditions	Night	

1.8 Aids to navigation

Not applicable

1.9 Communications

Up until the serious incident took place, radio communication between the flight crew and air traffic control in Porto was duly undertaken in English and proceeded without any difficulties.

1.10 Aerodrome information

1.10.1 General

Porto Airport is roughly at sea level, 11 kilometres north of the city centre. It is the second-largest commercial airport in Portugal, after Lisbon. The runway system comprises a single runway (17/35) with a length of 3480 metres, running parallel to the Atlantic coast.

1.10.2 Runway

Runway	Dimensions	Threshold elevation
17/35	3480 x 45 m	55.1 / 69.2 m AMSL

12 AAE: Above aerodrome elevation

13 ICAO: International Civil Aviation Organization

The entire length of runway 35 was available for takeoff. The flight crew started their takeoff run from intersection C, meaning they had a runway length of 3120 metres available.

1.11 Flight recorders

1.11.1 General information

As the data from the cockpit voice recorder (CVR) had already been overwritten when the investigation was opened, this data was no longer available for the investigation. However, the data from the digital flight data recorder (DFDR) was available.

1.11.2 DFDR findings

It was possible to reconstruct the individual sequences of the takeoff roll in detail (see annexes 1 and 2).

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

Not applicable

1.17 Organizational and management information

1.17.1 History

The Bombardier C-series was originally developed by Bombardier Inc. of Canada as a single aisle, twin engine, medium range jetliner and dates back to 2005. Bombardier received a type certificate from Transport Canada on 18 December 2008. On 11 March 2009, the German airline Lufthansa ordered 30 aircraft for use by Swiss. Swiss were the world's first airline to use a CS100 for commercial operation, the first flight having taken place on 15 July 2016.

In June 2016, 'C-Series Aircraft Limited Partnership' (CSALP) was formed. Bombardier Aerospace had a share of 50.5 % and the Province of Quebec owned 49.5 %. On 1 July 2018, Airbus acquired a 50.01 % interest in CSALP. Following this acquisition by Airbus, the C-series has been marketed as the Airbus A220[14] since 10 July 2018, the CS100 now being an A220-100 and the CS300 being an A220-300.

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[14] The aviation company will rename their aircraft in the respective register on 27 October 2019

1.17.2 Procedures

1.17.2.1 General

The various procedures are recorded in the respective operations manuals of the aviation company. The general procedures are in operating manual (OM) A and the aircraft-specific procedures in OM B. According to information from the aviation company, the corresponding details in OM A are consistent with the content of the aircraft manufacturer's flight crew operating manual (FCOM). The following sections will only address those items that are relevant for this serious incident.

1.17.2.2 General procedures

As a general guideline for collaboration in the cockpit regarding CRM[15], chapter 8.3.112 in the OMA includes amongst others the following:

"All Swiss flight operations are based on the optimum use of crew resource management. The principle of continuous mutual briefing and assistance shall be applied at all times. In normal cockpit work the CMD shall endeavor to establish open communication between crew members in the cockpit and in the cabin as well as with ground personnel and air traffic services.

All aircraft equipment shall be used with care and to the best of its capability.

Checklists and standard operating procedures shall be used at all times in normal operations.

Consideration should be given to distractions (e.g., runway change during taxi out, ATC call during approach) which, despite being a normal feature of the daily operational environment, disrupt the normal flow of procedures. Such distractions (including operationally non-relevant distractions, especially during a sterile cockpit phase of flight) present a considerable hazard because they call for a response and may lead to the momentary (or lengthier) interruption of an ongoing activity. Pilots are expected to exercise caution in order to protect the timely and accurate accomplishment of checklists and SOPs. This implies conscious recognition of each distraction and a deliberate prioritization among the activity being interrupted and the task demand arising from the interruption. Multitasking, trying to do more than one tasks at the same time, without this awareness and prioritization is known to divert and often tunnel attention and lead to inadvertent omissions of procedural steps and checklist items. It is the responsibility of the flight crew to avoid multitasking, or at least mitigate it by using CRM principles for communicating decisions about handling multiple task demands, deferring activities, specific plans for resuming suspended tasks, etc., and for monitoring each other in order to ensure the integrity of performance of SOPs."

With regards to collaboration, 'closed loop' communication is pointed out in particular. This is described in detail in chapter 8.3.131. Essentially, all of the actions carried out by the pilot flying (PF) have to be checked and acknowledged by the pilot monitoring (PM).

[15] CRM: Crew resource management. Based on experience of numerous accidents in which insufficient coordination between individual crew members was a causal factor, a training tool for crews, called CRM, was developed. CRM shall raise awareness of the fact that, in addition to technical knowledge on board an aircraft, human relations are also a decisive factor for flying safely.

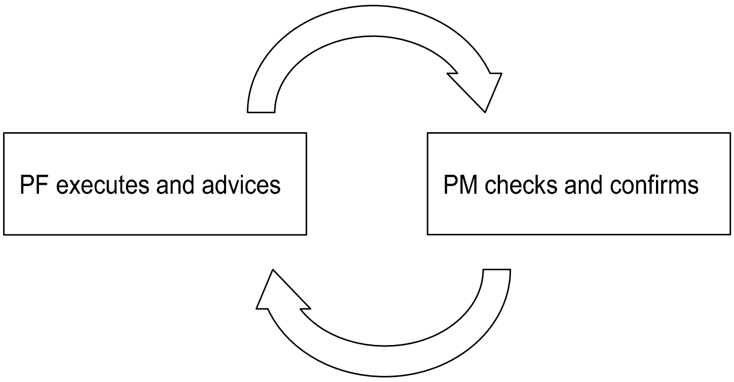


Figure 11: Simplified closed loop (copied from OM A)

With regards to the use of the aircraft's autothrottle, OM A states the following (bold type as in the original):

*"**8.3.333 Use of autothrottle***

If technically available, the autothrottle should be engaged in the appropriate mode at all times. Deviations/exceptions are regulated in the OM B."

Furthermore, chapter 8.3.532.10 in OM A includes amongst others the following with regards to an aborted takeoff (bold type as in the original):

*"**Policy***

- *If an engine failure occurs before V_1, a rejected takeoff must be performed.*
- *A rejected takeoff should be performed at the PIC's[16] discretion, whenever deemed necessary. The takeoff rejection shall be executed by the PIC.*

For the SOP including task sharing, standard call outs refer to the OM B.

The decision to reject a takeoff should be based on all relevant factors as:

- *type of malfunction;*
- *speed at the time of the failure;*
- *aircraft mass;*
- *runway condition.*

Note: In some conditions an engine failure may be difficult to recognise. For instance, a partial power loss in crosswind conditions may not cause much yaw; or a seizure may be so abrupt as to be mistaken for a structural failure of the aircraft.

8.3.532.20 Continued takeoff

Continued takeoff addresses:

- *any failure/situation during takeoff which has occurred at or after V_1; or*

any failure/situation during takeoff before V_1 which does not necessarily require a takeoff rejection."

1.17.2.3 Aircraft procedures

The specific operating procedures correspond exactly to those given by the aircraft manufacturer (see chapter 1.17.2.1).

The "*Takeoff procedures*" chapter states the following regarding autothrottle:

[16] PIC: Pilot in command

"If the use of autothrottle is desired, it is recommended the autothrottle is selected on the runway before takeoff."

With regards to this instruction, it should be noted that, according to the guidelines set out in OM A, the autothrottle should essentially always be armed (see chapter 1.17.2.1).

Before every takeoff, the following checklist must be completed:

BEFORE TAKEOFF

When approaching the runway and the cabin **READY** message has been received (or via intercom confirmation), the PF will request the BEFORE TAKEOFF checklist.

When entering the active runway, the PF will select the STROBE lights ON, and the PM advises the cabin crew of imminent takeoff.

When takeoff clearance is received, the PF will select all LDG LTS and TAXI WIDE lights ON.

(1) FMS...Set
Confirm the FMS includes last minute changes. Refer to FMS Operating Guide.

(2) Trims...Set
Check rudder trim is centered (green) and stab trim is set for takeoff.
(a) Stabilizer trim...Set
Check correct takeoff CG value in the green range on the EICAS status page.

(3) Cabin...Ready
If applicable, on EICAS page, check CABIN tile is **READY**.

(4) FLAP...Set
Confirm correct flap selection.

(5) ANTI-ICE...Set
Confirm correct setting for takeoff.

(6) AUTOBRAKE...As required

(7) EICAS and INFO...Checked
Check and acknowledge messages, if required.

(8) Thrust...Checked
Verify that the target N1 values correspond to the thrust setting data generated from the C-OPT (±1.0%).

(9) Runway...() confirmed
Ensure correct runway.

- COMPLETE -

Figure 12: Copied from FCOM 2, section 03.01.02, "*Normal Procedures – before takeoff*", page 23

Furthermore, the FCOM provides advice on four different types of takeoff under "*Takeoff procedures*". The fourth type, restricted takeoff, is not relevant for this serious incident. The other three require the completion of the following checklist, voicing the corresponding call-outs:

STANDING, ROLLING OR EXPEDITE TAKEOFF

[...]

- <u>When aligned on the active runway:</u>

  (1) Brakes................................ .... As required

  Note: *Published performance for standing takeoff is based on holding the brakes until the thrust levers are advanced to the takeoff setting. When not holding the brakes, the rolling or expedite takeoff performance data must be used. Advancing the thrust levers while the aircraft is moving, expedite takeoff performance data must be used. For restricted takeoff, release brakes after setting 50% N1.*

  (2) Heading... Verify

  Make sure that the airplane heading agrees with the assigned runway.

  (3) Autothrottle......................... ....Select, if required

  (4) Thrust levers............................ .... Advance

  (a) Advance to approximately 50% N1 on both engines.

  (b) Check that N1 for both engines is stabilized.

  (c) Advance to takeoff setting.

  Caution: *Failure to achieve takeoff setting promptly can cause a CONFIG SPOILER warning message.*

  When thrust levers are advanced towards the takeoff setting and the autothrottle is selected, the autothrottle engages and sets target takeoff N1 (as selected in the FMS and as limited by the Thrust Limitation at Low Speed (TLLS)).

  (5) Flight and engine instruments... Monitor

- <u>At 80 KIAS:</u>

  (6) Airspeed................................ .... Check

  (7) Engines......................... ....Confirm thrust set

  Both PFD speed indicators must agree and target takeoff N1 is set.

- <u>At V_R:</u>

  (8) Rotate towards PTM. [pitch target markers]

  (a) Rotate 3 to 5 degrees per second towards PTM pitch attitude and transition to the FD when available.

[...]

Mode Selection and Callouts – Takeoff			
Condition	**Mode Selection**	**PF**	**PM**
At 80 KIAS and thrust at required N1 value	–	–	**"80 knots, thrust set"**
	–	**"Checked"**	–
At V_1	–	–	*"V_1"*
At V_R	–	–	**"Rotate"**
When positive rate of climb is confirmed	–	–	**"Positive rate"**
	–	**"Gear up"**	–

Figure 13: Copied (detail) from FCOM 2, section 03.01.02, "*Normal Procedures – takeoff procedures*", pages 28 and 29.

A corresponding diagram (*takeoff profile*) can also be found in the same section:

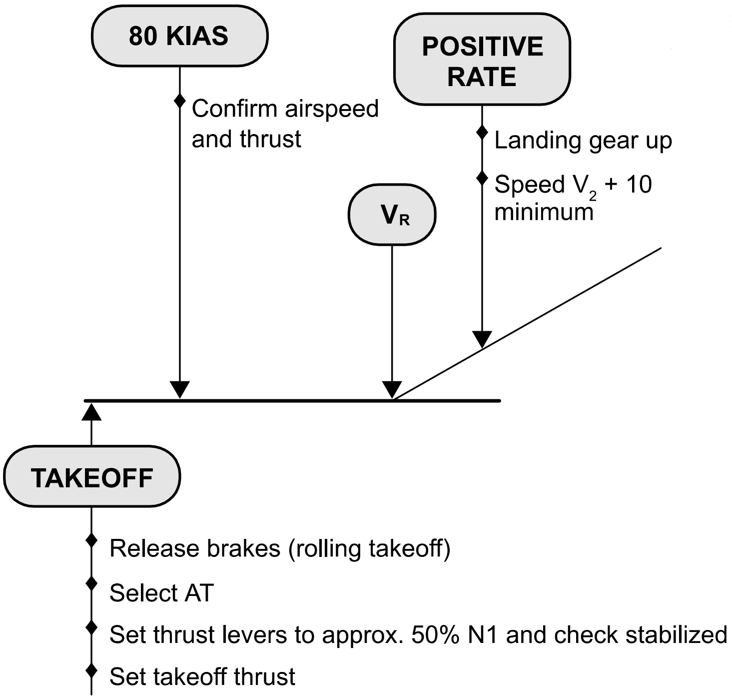


Figure 14: Copied (detail) from FCOM 2, section 03.01.02, "*Normal Procedures – takeoff profile*", page 30

1.18 Additional information

1.18.1 Similar incidents

According to information from the aviation company, between 14 February 2018 and 30 July 2018 the same aircraft type was involved in five takeoffs in which the engines' takeoff power (N1) was not set properly. The inactivated autothrottle was the cause in every one of these instances. In four of the five cases, this went unnoticed by the flight crew. It is not clear from the flight crews' statements whether the 80-KIAS check (see chapter 1.17.2.2) was carried out with the required consistency.

The fifth instance, involving the aircraft HB-JCF, was almost identical to this investigated serious incident. The PF advanced the AT to a TLA of just under 23° and, when 60 kt was exceeded, the spoilers extended without alerting the flight crew in the form of a warning. When the PF advanced the thrust levers to a TLA of 28.8° 5 seconds later, the CONFIG SPOILER warning appeared and the spoilers retracted. At the same time, the AT automatically disconnected, the relevant aural and visual warnings were generated, and the flight crew aborted takeoff at a speed of around 90 KIAS.

1.18.2 Findings from the simulator

During the investigation, the scenario of this serious incident was recreated in a simulator. The systems behaved as they are designed to do, and in a way that matched the data in the DFDR. It was noteworthy however, that the AT, which was in HOLD mode, disconnected automatically when the throttles were advanced in four of five cases. In addition to footnote 10 the NAC added that multiple tests in the simulator would not be representative since the engines must be shutdown and restarted before every takeoff in order to reset the logic. Consequently, the AT should not have disconnected automatically only during the first takeoff in the simulator tests but it did during the fourth takeoff.

A further test was to show how the aircraft behaves if the flight crew does not notice that the takeoff power is set too low and the power subsequently fails to increase. The data from the investigated flight was used to initiate a takeoff that matched the initial scenario: a TLA of 20.6°, equivalent to an N1 takeoff power of 65.3 %. As expected, the spoilers extended at 60 kt and remained deployed. The V_1 takeoff decision speed of 117 KIAS was reached at virtually the same time as in this investigated incident, but it took 6 seconds longer until the rotation speed of 122 KIAS was reached. Due to the slow speed increase the subsequent rotation was also performed slow. The aircraft nose lifted, but the circumstances resulted in a tailstrike 7 seconds later and the aircraft was unable to take off properly. The entire process from reaching V_R until the tailstrike took up around 900 metres of the runway length. Had the takeoff been aborted at this moment, it would not have been possible to bring the aircraft to a stop on the runway.

1.19 Useful or effective investigation techniques

Not applicable

2 Analysis

2.1 Technical aspects

There is no indication of pre-existing technical defects that could have affected the serious incident.

The fact that the spoilers extended during the takeoff roll was due to their design by the manufacturer. Prerequisites for spoiler deployment are amongst others a wheel speed (WS) of more than 60 kt and a throttle lever angle (TLA) of less than 23° (see chapter 1.6.3.2). Both conditions are met during a landing, a touch and go and an aborted takeoff because the throttles are in the idle position at this moment.

During this serious incident, these conditions were also met because the TLA was just 20.6° at the start of the takeoff roll. The spoilers therefore extended when the WS of 60 kt was exceeded. This change in configuration is only shown on the flight control (FLT CTRL) synoptic page and therefore cannot be seen by a flight crew as this page is not preset on any multifunction window (MFW) during the takeoff roll (see chapter 1.6.2). These windows furthermore display the deflections of the spoilers in green, which relates to a normal condition, and this therefore does not necessarily signal a warning.

A spoiler deployment design that does not consider the acceleration vector only meets the criteria as given for an aborted takeoff, a landing and a touch and go. Therefore, information about the operation of the spoilers can only be found in the FCOM in relation to these aforementioned flight phases. The fact that the spoilers also extend without the flight crew intending or noticing during a takeoff roll, in which the critical TLA of 23° is not exceeded, is not stated anywhere. In addition, a TLA equivalent N1 of approximately 60 % is specified in the section that describes the AT (FCOM page 03-05-12), but an N1 of 68 % is specified in the TAKE-OFF CONFIGURATION WARNING section (FCOM page 08-05-40).

The above facts lead to the conclusion that this scenario – which was not an isolated incident (see chapter 1.18.1) – was not considered when the spoiler deployment was designed. Yet, the fact that the spoilers can deploy during the acceleration phase of the takeoff roll without intervention from the flight crew carries great safety risks. A safety recommendation was therefore issued (see chapter 4.1.1).

Only once the CMD had pushed the throttles forward at a later time did the TLA change to above 23° and the spoilers retracted within 2 seconds, 23 seconds after having extended (see annex 1). As observed by the flight crew, the SPOILER CONFIG warning displayed on the EICAS for 4 seconds whilst the spoilers were retracting.

The AT remained armed and switched directly to HOLD mode, when 60 KIAS was exceeded. The power set at that time remains the same until the AT switches to THRUST mode at an altitude of 400 ft above ground. Any power not matching the required takeoff power (target N1) represents a high safety risk if there is no intervention from the flight crew (see chapter 1.18.2).

When the PF pushed the throttles forward to a TLA that exceeded the critical 23° at a speed of 109 KIAS, the AT should have disconnected automatically, and the crew should have been informed about this by an aural AUTOTHROTTLE alert (see chapter 1.6.3.2). Why the AT did not disconnect explained the Transport Canada Civil Aviation (TCCA) National Aircraft Certification (NAC) by the fact that the AT switched directly from the ARM to the HOLD mode and therefore could only get active after passing 400 ft above ground level (cf. footnote 10). However, this is in contrast to the incident of HB-JCF mentioned in chapter 1.18.1 and the statement in the All Operator Message (AOM) dated 21 December 2018 and published by the manufacturer (cf. chapter 4.3.2).

2.2 Human and operational aspects

2.2.1 Human aspects

When lining up on runway 35, the PF armed the AT. It can be assumed that the AT was armed following the closed-loop procedure described in OM A and that the PM checked the action taken by the PF.

After the flight crew had received clearance to line up and takeoff, the PF advanced the throttles. The data shows that the throttles stopped at a TLA of 20.6°. The TLA of 23° required to engage the AT was consequently not exceeded. As a result, the AT was not engaged and the white THRUST indicator on the FMA did not change its colour to green. During this phase, closed-loop communication obviously did not take place as intended, as the flight crew did not notice that the AT only remained armed and had not been engaged.

The fact that the deployment of the spoilers went unnoticed by the flight crew can be explained by the prescribed choice of displays during takeoff (see chapter 1.6.2). This would only have been visible on the appropriate synoptic page, however the indicator for extended spoilers would have been displayed in green, which generally does not imply that they are in a wrong position.

In line with the operating procedures, the flight crew had to check the speed and engine data for takeoff at a speed of 80 KIAS (see chapter 1.17.2.3). Both pilots stated that they could not remember whether they had performed this check. This cannot be explained by anything other than that the check – if it took place – was not performed with the required level of attention. Both the FMA indicator as well as the N1 engine data – set at only 65.3 % instead of 80.7 % – did not correspond with expectations.

At a speed of between 90 and 100 KIAS, the PF became aware of the unusually low level of acceleration, noticed that the power output did not meet the required takeoff power, and advanced the throttles further. The data shows that a TLA of 28.5° was thereby reached, which is only equivalent to an N1 rpm of 76.6 % and was still below the calculated takeoff power. The fact that this lack of required power continued until the AT automatically changed modes at an altitude of 400 ft above ground suggests that the flight crew was unaware of the power actually set.

In light of the remaining length of the runway and the required obstacle clearance along the takeoff path, in particular in the event of engine failure, it is advisable in a situation such as this that the thrust levers are pushed forward to the mechanical stop. This would cause the AT to disconnect and the appropriate warnings to be triggered, which would however result in maximum possible takeoff thrust being initiated (see chapter 1.6.3.2). This is particularly relevant during a takeoff with derated takeoff thrust.

When the CONFIG SPOILER warning was displayed, the PM immediately checked that the spoiler lever was in the retracted position and confirmed this to the PF. This reaction is understandable, as the flight crew had – as is reasonable – not anticipated the spoilers to deploy automatically during a takeoff roll. The PF briefly considered aborting takeoff but dismissed this thought as the decision speed V_1 (117 kt) had already been exceeded in the meantime. According to the data, the CONFIG SPOILER warning displayed one second after the throttles had been advanced and disappeared four seconds later. The decision not to abort the takeoff was appropriate for the situation because, when aborting a takeoff after V_1, it can never be said with any certainty whether an aircraft can be brought to a stop on the remaining length of the runway.

2.2.2 Operational aspects

When programming the FMS for the return flight, the flight crew identified a discontinuity upon entering the standard instrument departure route into the flight plan. They were not able to eliminate this discontinuity and therefore decided that the PM should pay particular attention to the FMS during takeoff. This in turn made it more difficult for him to monitor takeoff procedures with the required level of attention. In this important phase of the flight, this prioritisation was inappropriate.

Following the flight, neither of the pilots could say with certainty whether they had vigilantly monitored the power output at 80 KIAS. This indicates that they were not sufficiently aware of the importance of this check. This assessment is corroborated by other events such as the AT not being activated for takeoff going unnoticed and generally expressed doubts as to whether the 80-KIAS check was performed at all (see chapter 1.18.1). If the engines are not outputting the calculated takeoff power by this time at the latest, it is not always possible to ensure the safe continuation of takeoff or the takeoff path respectively, but it is possible to abort takeoff in the low speed regime without increased risk.

It is therefore essential that the set takeoff power is always monitored immediately after the throttles have been advanced. The setting of the power output is described in detail in points 4a to 4c in the appropriate checklist (see figure 13). The subsequent monitoring of the set power output, e.g. as point 4 d), is probably therefore no longer explicitly mentioned.

After setting the takeoff power, point 5 on the checklist stipulates that the flight and engine displays have to be monitored even before the 80-kt check; this also includes monitoring of the set power output.

If the set power output is only checked for the first time at 80 KIAS, it is generally harder for the PM on uneven surfaces to read the values than at lower speeds. Furthermore, as the AT switches to HOLD mode when the aircraft exceeds 60 KIAS (see figure 8), the AT disconnects if the PF corrects the power by advancing the throttles appropriately.

As a result of the reasons given above, one piece of safety advice has been issued (see chapter 4.2.1.2).

Both pilots stated that they had felt an element of fatigue. It cannot be ruled out whether this factor had an influence on the development and course of the serious incident.

3 Conclusions

3.1 Findings

3.1.1 Technical aspects

- The aircraft had the required permissions for operation under instrument flight rules (IFR).
- Both the mass and centre of gravity of the aircraft were within the permissible limits of the aircraft flight manual (AFM) at the time of the serious incident.
- The investigation did not find any indication of pre-existing technical defects which could have influenced the serious incident.
- The aircraft technical systems relevant to the serious incident were functioning as they are designed to. As per the spoiler deployment logic, the spoilers automatically extended when the wheel speed (WS) exceeded 60 kt during the takeoff roll because the throttle lever angle (TLA) was less than 23°.
- As per the autothrottle (AT) design, the AT switches to HOLD mode at 60 KIAS, even if the required takeoff power (target N1) has not yet been reached.

3.1.2 Flight crew

- The pilots possessed the necessary licences for the flights.
- There is no indication that the pilots experienced any health problems during the serious incident.
- A certain fatigue of the flight crew cannot be excluded.

3.1.3 History of the serious incident

- At 01:59:36 UTC on 15 July 2018, the A220-300 commercial aircraft, registered as HB-JCC, taxied to runway 35 at Porto Airport (LPPR), lining up from intersection C for its return flight to Geneva (LSGG).
- During the line-up, the commander (CMD) acting as the pilot flying (PF) armed the autothrottle (AT).
- Whilst initiating the takeoff roll, the PF advanced the throttles, assuming that the AT would then engage and would set the takeoff power to the required level.
- The throttles were set to a TLA of 20.6°. The TLA of more than 23° required for activation was not met.
- When 60 KIAS was exceeded, the AT switched to HOLD mode and the spoilers extended as they were designed to do, without it being possible for the flight crew to notice this due to the prescribed choice of displays.
- As per the standard operating procedures, one of the things that the flight crew had to check was that the required takeoff power (N1 rpm) was met when exceeding 80 KIAS. The fact that the takeoff power was too low went unnoticed.
- Due to discontinuity of the flight plan in the FMS, the pilot monitoring (PM) kept a close eye on the FMS during the takeoff roll.
- When the aircraft had reached a speed of between 90 and 100 KIAS, the PF realised – because of slow acceleration and the remaining length of the runway – that the power had been set too low.

- The PF then pushed the throttles forward. The TLA reached 28.5°, which was equivalent to an N1 of 76.6 %.
- The required takeoff power (target N1) of 80.7 % was never reached during takeoff. This remained unnoticed by the flight crew.
- Once the TLA had exceeded 23°, the spoilers retracted within 2 seconds, 23 seconds after having extended. The CONFIG SPOILER warning displayed for 4 seconds (see annex 1).
- The aircraft took off approximately 1000 metres before the end of the runway, at a distance that was 1.5 times the length of the calculated takeoff distance, continued to climb and landed in Geneva at 04:02:29 UTC without any further incidents.

3.1.4 General conditions

- On 14 July 2018, the flight crew started their duty at 18:25 UTC for their flight to Porto (LPPR). They landed in Porto at 21:46 UTC.
- The return flight to Geneva was at 02 UTC.
- The weather had no influence on the serious incident.

3.2 Causes

The serious incident, in which a commercial aircraft took off with insufficient engine power, can be attributed to the fact that the flight crew was too late to notice that the engine power required for takeoff was not set.

The following factors contributed to the serious incident:

- Non-compliance with the aviation company’s standard operating procedures (SOP);
- Inappropriate prioritisation by the flight crew during the takeoff roll.

Although they did not influence the development and course of the serious incident, the following risk factors were identified during the investigation:

- The design of the spoiler deployment;
- The design of the autothrottle (AT), whereby the AT switches to HOLD mode during the takeoff roll, even if the required takeoff power (target N1) has not yet been reached.

4 Safety recommendations, safety advice and measures taken since the serious incident

4.1 Safety recommendations

In accordance with the provisions of Annex 13 of the International Civil Aviation Organization (ICAO) and Article 17 of Regulation (EU) 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 and repealing Directive 94/56/EC, all safety recommendations listed in this report are intended for the supervisory authority of the competent state, which must decide on the extent to which these recommendations are to be implemented. Nonetheless, any agency, any establishment and any individual is invited to strive to improve aviation safety in the spirit of the safety recommendations expressed.

Swiss legislation provides for the following regulation regarding implementation in the Ordinance on the Safety Investigation of Transport Incidents (OSITI):

"Art. 48 Safety recommendations

1 The STSB shall submit the safety recommendations to the competent federal office and notify the competent department of the recommendations. In the case of urgent safety issues, it shall notify the competent department immediately. It may send comments to the competent department on the implementation reports issued by the federal office.

2 The federal offices shall report to the STSB and the competent department periodically on the implementation of the recommendations or on the reasons why they have decided not to take measures.

3 The competent department may apply to the competent federal office to implement recommendations."

The STSB shall publish the answers of the relevant federal office or foreign supervisory authorities at www.stsb.admin.ch to provide an overview of the current implementation status of the relevant safety recommendation.

4.1.1 Spoiler deployment

4.1.1.1 Safety deficit

When initiating takeoff, the pilot flying (PF) advanced the thrust levers, assuming that the autothrottle (AT) – which had already been armed – would now engage and would set the takeoff power to the required level (N1 rpm). As the thrust levers were only advanced to a thrust lever angle (TLA) of 20.6°, the AT remained armed without becoming engaged.

After exceeding a wheel speed (WS) of 60 kt, the spoilers deployed by design.

At an indicated airspeed of between 90 and 100 kt, the flight crew noticed that the power had been set too low. After advancing the throttles past the critical TLA of 23°, the spoilers retracted by design. During this time, the CONFIG SPOILER warning was displayed for four seconds.

The aircraft took off approximately 1000 metres before the end of the runway, at a distance which was 1.5 times the length of the takeoff distance calculated, continued to climb and landed in Geneva without any further incidents.

4.1.1.2 Safety recommendation no. 552

Together with the manufacturer, the National Aircraft Certification at Transport Canada (TC) should ensure that the spoilers are not automatically deployed when taking off with insufficient takeoff power.

4.2 Safety advice

The STSB may publish safety advice in response to any safety deficit identified during the investigation. Safety advice shall be formulated if a safety recommendation in accordance with Regulation (EU) No. 996/2010 does not appear to be appropriate, is not formally possible, or if the less prescriptive form of safety advice is likely to have a greater effect. The legal basis for STSB safety advice can be found in article 56 of the OSITI:

"Art. 56 Information on accident prevention

The STSB may prepare and publish general information on accident prevention."

4.2.1 Checking of takeoff thrust

4.2.1.1 Safety deficit

When initiating takeoff, the pilot flying (PF) advanced the thrust levers, assuming that the autothrottle (AT) – which had already been armed – would now engage and would set the takeoff power to the required level (N1 rpm). However, as the PF advanced the thrust levers to a thrust lever angle (TLA) of only 20.6°, the AT remained armed without becoming engaged. The AT switched directly in the HOLD-mode after exceeding an indicated airspeed of 60 kt.

According to standard operating procedures (SOPs), the flight crew must monitor the flight and engine data after setting the takeoff power. In addition, upon exceeding an indicated airspeed of 80 kt, they must explicitly check, amongst other things, whether the required takeoff power (N1) is set.

At an indicated airspeed of between 90 and 100 kt, the PF noticed that the power had been set too low and pushed the throttles forward. The aircraft took off approximately 1000 metres before the end of the runway, at a distance that was 1.5 times the length of the calculated takeoff distance.

The investigation found that the design of the AT allowing a switch to HOLD mode, even though the required takeoff power (target N1) has not yet been achieved, is a risk factor. If the PF corrects the power output by advancing the throttles appropriately whilst the AT is in HOLD mode, the AT disconnects and the corresponding visual and aural warnings are triggered.

If the power setting is only checked for the first time at 80 KIAS, it is too late and it is generally harder on uneven surfaces to read the values than at lower speeds. If the engines are not outputting the calculated takeoff power by this time at the latest, it is not possible to ensure the safe continuation of takeoff or the takeoff path respectively. The later the lack of takeoff power is noticed, the greater the level of risk involved in a subsequent aborted takeoff.

4.2.1.2 Safety advice no. 26

Target group: Flight crews

The aviation company should use suitable measures to ensure that the required takeoff power is immediately checked and confirmed by the flight crew after it has been set.

4.3 Measures taken since the serious incident

The measures taken, which are known to the STSB, are mentioned below without further comment.

4.3.1 By the Transport Canada Civil Aviation

The Transport Canada Civil Aviation (TCCA) made together with their National Aviation Certification (NCA) amongst others the following statements in their written comment:

„The HOLD mode function of the AT may not be fully understood and, as previously described, there may be weaknesses in the Flight Mode Annunciator (FMA) annunciations. On takeoff using AT, HOLD mode will be entered at 60 kt and will post in green on the FMA. During this time, the Engage Enable discrete to the Throttle Quadrant Assembly (TQA) servo from the Flight Control Panel (FCP) is de-energized. If the AT hasn't transitioned to an active mode (i.e., THRUST) by 60 kt, it will not activate until 400 ft Above Aerodrome Elevation (AAE). It is suspected that in the case where the AT did not automatically disengage, it may not have been engaged in an active mode in the first place. It is acknowledged that the AT HOLD being annunciated on the FMA in green is misleading. Documentation describing HOLD as an "active mode" may also be misleading. As previously mentioned, TC may recommend that the Original Equipment Manufacturer (OEM) investigate means to improve the AT Engagement and Active mode awareness, as well as potentially improved documentation."

„This incident investigation has brought to light that the FMA AT annunciations could be misleading during the takeoff flight phase. Transport Canada (TC), will recommend the OEM investigate the AT mode annunciation design."

„In addition to recommending that the manufacturer investigate possible improvements to the automatic Ground Lift Dumping (GLD) function robustness, TC acknowledges that a better description of the spoiler's auto deployment conditions and criteria during takeoff could be useful, and this will be investigated with the manufacturer."

4.3.2 By the manufacturer

In a so called „All Operator Message" (AOM), dated 21 December 2018, the manufacturer informed all „CS100/CS300" operators about the following purpose:

„This AOM is issued to advise all Operators of a Ground Lift Dumping (GLD) deployment during takeoff incident involving an A220 (formally C Series) aircraft."

After a brief description of the history of the serious incident, the manufacturer asked all operators to inform their flight crews as follows:

„The investigation will determine the cause of the incident and CSALP[17] will share the final report with A220 Customers when the report is published by the authorities.

However, CSALP would like to ensure that the following key messages are communicated to all Operators' Flight Operations crews:

- *Ensure Autothrottle is engaged when taking off with Autothrottle (Autothrottle engages at 23 degrees TLA or 68 % N1 equivalent);*
- *Ensure proper Takeoff engine thrust is set;*

[17] CSALP: C Series Aircraft Limited Partnership

- *Thrust settings are checked at 80 kt in accordance with the FCOM Vol. 2 page 03-02-27.*
- *If this procedure is not followed, once ground speed is above 60 kt and TLA is less than 23 degrees or 68 % N1 equivalent, the following will occur:*
  - *The Ground Lift Dump (GLD) will fully activate;*
  - *There will be no EICAS message to indicate the status of the GLD;*
  - *Autothrottle will switch to HOLD and can disconnect if manipulated lightly. On HOLD mode, the thrust levers are always free for thrust adjustment and maintain a new selected position.*
  - *All Operators are requested to communicate this information to their respective flight operations and quality departments to raise awareness of the criticality of correct TLA setting for Take Off relative to Autothrottle operation and the Takeoff Configuration warning trigger.*
  - *All Operators are requested to communicate any similar events that may have been reported within your organization to the contact person listed below."*

4.3.3 By the aviation company

Based on the serious incident, the operator has adapted the takeoff procedure by adding two new call-outs. It was relayed to the flight crews on 27 July 2018 in what they call a Flight Operation Bulletin as follows:

"Dear colleagues,

Due to an incident on our fleet, the takeoff procedure will be adapted with immediate effect. More detailed background information about the incident and the technical systems will be provided in a coming OPS Flash.

In order to avoid an undesired state of flight, we have to implement two mandatory FMA Callouts during the initial part of the takeoff, to make sure that the A/T system is armed and activated correctly and subsequently the configuration warning and spoiler systems are set for the takeoff phase.

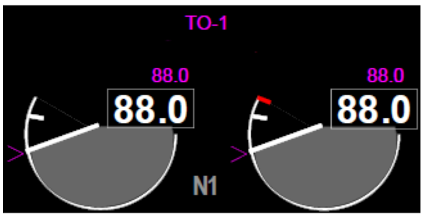
New Callouts for all Takeoff Methods

As soon as the AT is selected by the LP and before commencing the takeoff, the LP calls out "THRUST ARMED" and the RP confirms the correctly armed mode with "CHECKED".

The thrust levers have to be advanced to 50 % N1 on both engines. Check that N1 for both engines is stabilized. Then the thrust levers are further advanced.

After the thrust levers have been advanced to takeoff setting and the AT system has taken over and a clear movement of the thrust levers by the system is noticeable, the PF checks the activation of the thrust mode on the FMA and calls out "THRUST" while the PM confirms the correct mode with "CHECKED".

Reminder: "80 kt – Thrust set"



At 80 KIAS the PM has to check the thrust at required N1 value as per current procedures. It has to be clearly confirmed that the actual thrust setting matches the magenta required N1 value. As the N1 value increases during the takeoff roll this check is of utmost importance."

Furthermore, the operator relayed the following additional information to the flight crews in what they call an OPS Flash, dated 30 July 2018 [translated from German]:

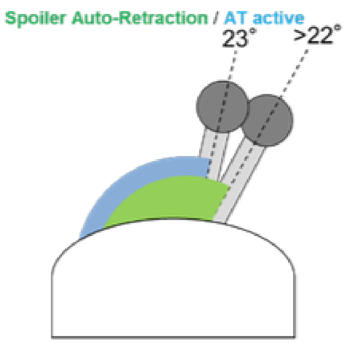
“Technical additional information

In order to be able to correctly classify the course of these events and the importance of their consequences, it is imperative that we consider the functions of the systems relevant to this event listed below in detail.

Automatic ground lift dumping function

From our books (FCOM1) it is known that the C-series’ FBW system provides a ground lift dumping (GLD) function. As the name suggests, the purpose of this function is to decrease the lift generated by the wings after the aircraft has landed in order to allow the aircraft to effectively slow down. Other technical documents, which are not available for all FCMs, show that the design of this function has additional parameters such as the wheel speed. More precisely, the GLD is armed as soon as the wheel speed exceeds 60 knots: if the aircraft is on the ground, the spoilers are then deployed automatically. So that this does not happen during takeoff, the function is disabled as soon as one of the thrust lever angles (TLAs) is >22° (see ‘Spoiler auto-retraction function’ below).

Spoiler auto-retraction function



A further function of the FBW system, which played a central role in the context of this incident, is the so-called spoiler auto-retraction function. Depending on the flight phase and other parameters, such as AOA sensors, the spoilers are automatically retracted.

This occurs in a balked landing or a go-around, for example. In this case, the spoilers are automatically retracted subject to the TLA being greater than 22° (FCOM1).

Autothrottle/config warning

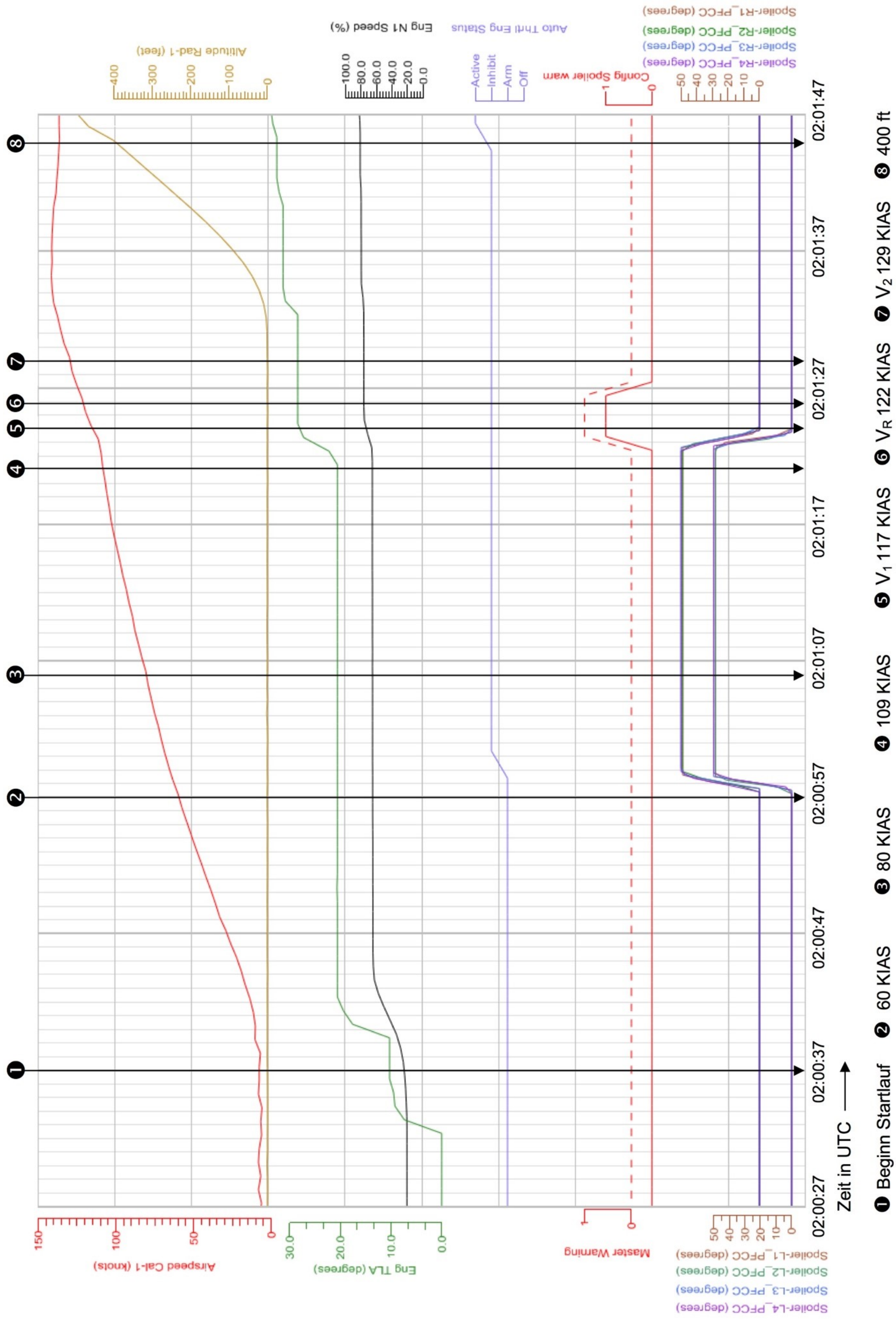
Another function that is controlled and/or engaged by the positioning of the thrust levers (TLs) is the well known autothrottle (AT). If the AT is armed (THRUST), the TLA must be advanced past at least 23° in order to engage the AT (THRUST).

Something that is not as widely known is that all config warnings are also only active once a TLA of more than 23° (takeoff mode) has been achieved. This fact had extensive consequences in this case.”

This final report was approved by the Board of the Swiss Transportation Safety Investigation Board STSB (Art. 10 lit. h of the Ordinance on the Safety Investigation of Transportation Incidents of 17 December 2014.

Bern, 25 February 2020 Swiss Transportation Safety Investigation Board

Annex 1: Records during takeoff roll of HB-JCC



Annex 2: Events during the takeoff roll on runway 35 in Porto