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Swiss Transportation Safety Investigation Board STSB

Aviation Division

Final Report No. 2285
by the Swiss Transportation Safety Investigation Board STSB

concerning the serious incident involving the A319-132 Airbus aircraft, registration YU-APA,

on 17 October 2014

5.5 km north-west of Zurich Airport (LSZH)

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Ursachen

Der schwere Vorfall ist darauf zurückzuführen, dass die Flugbesatzung überhastet und ohne vorausgehende Situationsanalyse einen risikobehafteten Landeanflug einleitete, nachdem sie aufgrund eines Lecks im luftgekühlten Ölkühler kurz nach dem Start das rechte Triebwerk abgestellt hatte.

Die folgenden Faktoren haben zum schweren Vorfall beigetragen:

- Mangelnde Zusammenarbeit (*crew resource management*) der Flugbesatzung;
- Nicht-Befolgen von systemtechnischen und betrieblichen Vorgaben;
- Geringe Erfahrung der Flugbesatzung auf dem Vorfallmuster.

Die Untersuchung hat folgende Faktoren ermittelt, welche die Entstehung und den Verlauf des schweren Vorfalls zwar nicht beeinflusst haben, die aber dennoch ein Sicherheitsrisiko (*factors to risk*) darstellen:

- Nicht sofortiges Abstellen des Triebwerks nach erfolgter Warnmeldung (*master warning*);
- Die Flugbesatzung landete das Flugzeug ohne eine Landefreigabe erhalten oder verlangt zu haben.

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 annexe 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, the sole purpose of an aircraft accident or serious incident investigation is to prevent further accidents or serious incidents from occurring. The legal assessment of accident and serious incidents causes and circumstances is expressly no concern of the investigation. It is therefore not the purpose of this investigation to determine blame or clarify questions of 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.

All information, unless otherwise indicated, 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 the region of Switzerland, Central European Summer Time (CEST) was the local time (LT) at the time of the serious incident. The relationship between LT, CEST and UTC is: LT = CEST = UTC + 2 h

Contents

Final Report

Synopsis

Owner	CIT Aerospace International, Dublin, Ireland
Operator	Air Serbia a.d. Belgrade, Republic of Serbia
Manufacturer	Airbus, Toulouse, France
Aircraft type	Airbus A319-132
Country of registration	Serbia
Registration	YU-APA
IATA flight number	JU 371
ICAO flight number	ASL 371
Radio call sign	Air Serbia three seven one
Location	5.5 km north-west of Zurich Airport (LSZH)
Date and time	17 October 2014, 08:40 UTC

Investigation

The serious incident occurred on 17 October 2014 at 08:40 UTC. The then Swiss Accident Investigation Board received the notification at 11:34 UTC on the same day. As the preliminary enquiries showed that the flight was subject to operational risks after one engine had been switched off, the Board therefore opened an investigation on 13 November 2014 at 09:00 UTC and informed the following states of the serious incident via the usual channels of communication: the Republic of Serbia (CDA Serbia), France (BEA France) and the United States of America (NTSB). All three countries each appointed an authorised representative, who contributed to the investigation.

The present final report is published by the Swiss Transportation Safety Investigation Board (STSB).

Summary

The Airbus A319-132 aircraft, registered as YU-APA, took off on 17 October 2014 at 08:39 UTC with ICAO flight number ASL 371 for a scheduled flight from Zurich (LSZH) to Belgrade (LYBE). The copilot was at the controls of the aircraft on this flight.

As a result of a leak in the air-cooled oil cooler (ACOC) of the right engine (ENG 2), oil was lost and the oil pressure decreased rapidly. The corresponding warning message was generated one minute after take-off. The commander immediately requested a return to Zurich and ENG 2 was subsequently switched off.

On request, ASL 371 received heading information to the east and subsequently received clearance for a visual approach to runway 28. Until turning in to the runway axis, the aircraft was flying at an altitude of 7000 ft QNH with a steady indicated airspeed (IAS) of 250 kt. When turning in to the runway axis, ASL 371 crossed the axis, reaching a bank angle of 37 degrees.

Following an unstabilized approach, the remaining engine was idle during the entire final approach until landing. The aircraft touched down 320 m beyond the runway threshold. The ground spoilers, which were not armed, deployed automatically seven seconds later when reverse thrust was activated. The aircraft came to a standstill about 60 m beyond the point where runway 28 crosses with runway 16 and subsequently taxied under its own power to the parking position. The crew and passengers were able to exit the aircraft normally.

Causes

The serious incident is attributable to the fact that, shortly after take-off, the flight crew, in an overhasty manner and without prior analysis of the situation, initiated a risky landing approach, after having switched off the right engine as a result of a leak in the air-cooled oil cooler.

The following factors contributed to the serious incident:

- Poor crew resource management within the flight crew;
- Non-compliance with systems and operational requirements;
- The flight crew's limited experience on the aircraft type.

The investigation established that the following factors, which although they did not influence the development and course of the serious incident, nevertheless still represent factors to risk:

- Engine was not switched off immediately after the master warning message had appeared;
- The flight crew landed the aircraft without having received or requested landing clearance.

Safety recommendations

No safety recommendation was issued in the context of this investigation.

1 Factual information

1.1 Prehistory and history of the flight

1.1.1 General

The recordings of the radio communication, radar data and the two flight recorders as well as statements from crew members and air traffic controllers were used for the following description of the prehistory and the history of the flight.

It was a scheduled flight under instrument flight rules (IFR) from Zurich (LSZH) to Belgrade (LYBE). During the entire flight, the copilot acted as the pilot flying (PF) and the commander as the pilot monitoring (PM), also referred to as the pilot not flying (PNF) in the relevant documents.

1.1.2 Prehistory

The crew took off with the Airbus A319 aircraft, registered as YU-APA, on the morning of 17 October 2014 at 06:27 UTC in Belgrade (LYBE) for a scheduled flight to Zurich (LSZH). After an uneventful flight, the aircraft landed in Zurich at 07:18 UTC and was in the parking position five minutes later.

The flight crew subsequently prepared the aircraft for the return flight to Belgrade. After refuelling, 8030 kg of fuel was on board. Loading of the aircraft took place as normal and at 08:04:02 UTC, the flight crew requested clearance for the flight to Belgrade, which was granted as follows: *"Air Serbia three seven one Delivery hello, runway three two, cleared to Belgrade via DEGES two Lima departure, squawk three zero one seven."* The standard instrument departure (SID) DEGES 2L route follows the runway axis for 2 NM and then, turning slightly to the right, follows the 330-degree track for up to 4 NM and, turning left, leads back across the airfield (see annex 1). The crew confirmed this clearance and following a corresponding query from the air traffic control officer (ATCO), the flight crew said that they would be ready for engine start-up in five minutes. Six minutes later, the ATCO asked the flight crew when they would be ready. They answered as follows: *"Air Serbia, we have a small technical problem and call you in a minute."* According to the flight crew, the external power supply had been interrupted.

At 08:15:31 UTC, the flight crew reported that they were ready to start the engines. They were instructed to contact Zurich Apron for engine start-up and pushback. The pushback began at 08:25 UTC.

After the engines had been started and after taxiing on the southern section of the airport, the flight crew contacted the ATCO from Zurich Ground at 08:33:33 UTC, to receive permission to cross runway 28.

After crossing runway 28 and reporting to the ATCO from Zurich Tower, the flight crew received clearance at 08:37:16 UTC to line up on runway 32.

1.1.3 History of the flight

The flight crew of the Airbus A319 aircraft, registered as YU-APA, with flight number ASL 371 and radio call sign "*Air Serbia three seven one*", received clearance on 17 October 2014 at 08:38:45 UTC for take-off from runway 32. There were 2 pilots, 4 cabin crew members and 119 passengers on board.

At 08:38:57 UTC, the copilot moved the thrust lever to the take-off position; take-off power was reached 15 seconds later. During this phase, the recordings show an increase of oil pressure in the left engine (ENG 1) to 308 PSI and 289 PSI in the right engine (ENG 2); at the same time, the oil quantity for ENG 1 decreased to 16.5 quarts (QTS) and 15.75 QTS for ENG 2; the latter subsequently rapidly decreased further.

At 08:39:42 UTC, the aircraft took off. Three seconds later, the copilot requested retraction of the landing gear and the autopilot 2 system was activated another 12 seconds later. At take-off, the recordings show an ENG 2 oil quantity of 4.25 QTS and at 08:40:05 UTC, a quantity of 0 QTS. Shortly afterwards, at 08:40:21 UTC, the copilot moved the thrust lever to the position climb (CL), and 3 seconds later, the ENG 2 oil pressure began to decrease rapidly from 170 PSI to 65 PSI while ENG 1's oil pressure remained steady at 230 PSI. In the intervening period, the crew had switched the frequency to Zurich Departure.

At 08:40:40 UTC, the ENG 2 OIL LO PR master warning message was generated in the cockpit and appeared on the engine and warning display (E/WD)[1], combined with a continuous repetitive chime (CRC). At that time, the oil pressure showed a value of 59 PSI and decreasing further. The aircraft was then climbing at an altitude of 3900 ft QNH.

The commander commented on this ECAM warning message without delay. The copilot acknowledged this and at the same time said: *"I have control."* Only a few seconds later at 08:40:56 UTC, without having previously consulted the copilot, the commander requested the following clearance from air traffic control: *"Air Serbia uh three seven one, request immediately return to the airport please."* The ATCO immediately granted clearance for a right turn on a heading (HDG) of 50 degrees. The commander acknowledged this message at 08:41:10 UTC as follows: *"Right heading zero five zero, Air Serbia three seven one, request radar vectoring, we have a problem with engine two and please priority landing."* Subsequently, the ATCO issued the flight crew with the following instruction at 08:41:26 UTC: *"Air Serbia three seven one roger, then expect vectors ILS runway two eight, I say again runway two eight, about twenty-five track miles. Make it a right turn heading zero niner zero."* This was acknowledged by the pilot.

At 08:41:34 UTC, at a flying altitude of 5400 ft QNH, the flaps and the slats were retracted. The spoilers, which had been armed for the eventuality of an aborted take-off, remained armed.

At 08:41:37 UTC, the commander asked the copilot whether he should initiate the ECAM procedure (see chapter 1.17.1.4). The copilot answered in the affirmative with the comment that he would finish the climb.

At 08:41:44 UTC, the commander initiated the ECAM procedure. At 08:41:53 UTC, 1 minute and 13 seconds after the ENG 2 OIL LO PR ECAM warning message had appeared, and in consultation with the copilot, the right thrust lever was returned to idle and at the same time, the ATCO informed the flight crew as follows: *"*[incomprehensible] *Air Serbia three seven one you can stop climb now at six thousand feet, whatever it's fine for you."* The ATCO gave the following instruction ten seconds later: *"Air Serbia three seven one stop climb at seven thousand feet,"* which he repeated five seconds later. The flight crew did not acknowledge this instruction. The recordings show that the commander commented on the 'ENG MASTER OFF' ECAM instruction at 08:42:03 UTC. He repeated this instruction and after having consulted the copilot, the ENG 2 master switch was moved to the OFF position at 08:42:15 UTC, 1 minute and 35 seconds after the master warning message had appeared on the E/WD. At that time, the aircraft was climbing at a flying altitude of 6440 ft QNH with an IAS of 214 kt and a ground speed of 260 kt. During this phase, the single chime sounded and the master caution message was

[1] This screen is part of the electronic centralised aircraft monitoring (ECAM) (see chapter 1.6.2)

activated[2] five times and the warning message AUTO FLT A/THR LIMITED remained displayed on the E/WD. The voice recordings show that the commander was busy with the 'engine shut down' procedure (see chapter 1.17.1.4, ENG 2 SHUT DOWN). At 08:42:26 UTC, the thrust lever of ENG 1 was moved to the maximum continuous thrust (MCT) position.

At 08:42:38 UTC, the ATCO contacted the flight crew as follows: *"Air Serbia three seven one expect a line-up end at twelve miles, twenty-five miles from touchdown, are you ready for approach ILS two eight?"* The flight crew responded at 08:42:51 UTC as follows: *"Uh yes we are ready and uh...please radar vectoring for runway two eight, uh maybe we will prefer from this position visual approach for two eight."* The ATCO complied with this request and gave the flight crew the instruction, in this case, to turn right on a heading of 130 degrees. This was immediately acknowledged by the flight crew.

At 08:43:29 UTC, the ATCO granted the flight crew clearance to descend to 5000 ft QNH, which was immediately acknowledged. According to the flight data recordings, the flight crew did not enter this altitude into the flight control unit (FCU). At that time, the aircraft was at an altitude of 7000 ft QNH with an IAS of 238 kt and a GS of 286 kt, and about 7 NM north-northeast of the runway 28 threshold (see annex 2).

At 08:44:09 UTC, the copilot requested execution of the 'after take-off/climb' checklist (see chapter 1.17.1.5), which was immediately initiated by the flight crew. The commander subsequently mentioned an approach briefing and commented to the copilot that from their position, it would be best to perform a visual approach to runway 28. The copilot did not intervene. However, he later made a statement that, whenever possible, he personally favoured an instrument approach because this could be flown in a more precise and calmer way. The commander later stated that he purposely wanted to remain in visual meteorological conditions (VMC), in order to be able to land in gliding flight at any time, should the second engine also fail. He also said that he had not wanted to fly a holding pattern to keep the windmilling time of the switched-off engine to a minimum because of the risk of fire.

In response to the ATCO's question as to whether the flight crew had visual contact with runway 28, they answered as follows at 08:44:25 UTC: *"Yes, we are ready for visually two eight, because we have one engine out and I think it's the best thing to do visual approach from this position."* After that, the ATCO issued the instruction to turn to the right on a HDG of 250 for a visual approach, which the flight crew acknowledged. The recordings show that the master switch of the auxiliary power unit (APU) was moved to the ON[3] position at 08:44:40 UTC.

At 08:44:48 UTC, the ATCO granted the following clearance: *"Air Serbia three seven one, you are cleared for visual approach runway two eight, you are number one, there is one aircraft at three miles but that is doing a go-around."* A few seconds later, the ATCO informed the flight crew that the fire service would be on standby. The ATCOs involved later stated that even in the absence of an urgency (PAN PAN) or distress (MAYDAY) message, they were aware that the situation had to be an emergency because of the report of engine failure and request for an immediate return to the airport. They had therefore organised all other air traffic in

[2] When the ECAM appears continuously, the single chime and the master caution message are both activated every five seconds, as long as the respective thrust lever remains below the maximum continuous thrust (MCT) in single-engine operation.

[3] When the master switch is actuated, the APU page automatically appears on the system display (SD) (see chapter 1.6.2). This disappears again when the START pushbutton is pressed and the APU reaches 95% of the nominal speed for more than 10 seconds or when the master switch is moved to the OFF position.

such a way that runway 28 was kept clear for flight ASL 371. This resulted in several go-arounds, frequency changes and instructions to change flight paths.

The recordings show that at 08:44:57 UTC, a HDG of 250 degrees and at the same time, an altitude of 3000 ft QNH were selected in the FCU. The aircraft was at an altitude of 7000 ft QNH with an IAS of 252 kt and its autopilot was still engaged.

The voice recordings show that at 08:45:11 UTC, the conversation was akin to an approach briefing. The language switched between English and Serbian and it was confirmed that the seat belt sign was switched on. Up until this point, no information had been provided to either the cabin crew or the passengers.

At 08:45:27 UTC and in the right turn towards the final approach, the autopilot was disengaged at an altitude of 6500 ft QNH and an IAS of 250 kt. The flight crew subsequently discussed the use of the speed brakes. They pointed out the high speed and established that they were a little high for the approach. During this right turn, the bank angle of 30° was exceeded at 08:45:35 UTC; the PM did not make a respective callout. At 08:45:42 UTC, the aircraft crossed the approach axis of runway 28 with an IAS of 250 kt at an altitude of 6150 ft QNH and therefore about 1750 ft above the nominal ILS/PAPI[4] glideslope of 3.3°. The distance to the runway threshold was 8.8 NM. A further three seconds later, the aircraft's bank angle reached the maximum value of 37.27°.

With a bank angle of 34.5°, the speed brakes were also deployed at 08:45:59 UTC, which simultaneously led to the disarming of the ground spoilers, which had still been armed. At that time, the aircraft was about half a nautical mile south of the runway axis at a flying altitude of 5820 ft QNH with an IAS of 241 kt. The maximum sink rate increased to up to 2880 ft/min. The bank angle of over 30 degrees was maintained until 08:46:05 UTC.

Only four seconds later at 08:46:09 UTC, the landing gear[5] was lowered at a flying altitude of 5424 ft QNH and an IAS of 242 kt. The glideslope display of the instrument landing system to runway 28 was in full scale deflection (see annexe 4). The aircraft was still about 1700 ft above the nominal glideslope of 3.3°. The commander later stated that they had been aware that they were above the glideslope. However, he had considered that to be good because the engine was producing little yaw moment in idle position and in addition, it would have been easy to land had the remaining engine also failed.

At 08:46:26 UTC, the ATCO asked the flight crew: *"Air Serbia three seven one, you are six miles from touchdown, can you make it a straight in? You're a bit high*." The flight crew answered with: *"Roger, we are ready,"* and 5 seconds later, the flaps were deployed to position 1[6]. The flying altitude was 4568 ft QNH and was therefore about 1100 ft above the nominal glideslope. The IAS was 224 kt. The ATCO instructed the flight crew at 08:46:37 UTC to switch to the aerodrome frequency. The flight crew acknowledged this. They did, however, not report to the Aerodrome Controller (ADC) until after landing.

In response to the commander's question as to whether the speed could be adhered to, the copilot answered in the affirmative and mentioned that the speed brakes were still deployed. In response to the commander's further question as to whether he intended to land with the flaps in position 3 or full, the copilot answered

[4] PAPI: precision approach path indicator (PAPI)

[5] The maximum speed for lowering the landing gear is 250 kt, according to the aircraft manufacturer.

[6] The maximum speed for deploying the flaps to position 1 is 230 kt, according to the aircraft manufacturer.

with 3. At 08:46:40 UTC, the LO[7] position was selected – using the corresponding pushbutton – for the autobraking effect after landing.

The aircraft was aligned to the runway axis when the flaps were deployed to position 2[8] at 08:47:18 UTC. At this time, the aircraft was at a flying altitude of 2676 ft QNH, the IAS was 195 kt and the sink rate was 1320 ft/min. The radio altimeter (RA) displayed a radio height (RH) of 1116 ft. Passing 1000 ft RH was not pointed out by the flight crew.

Only a few seconds later at 08:47:32 UTC, the flaps were deployed to position 3[9]. The RH was 878 ft, the IAS was 176 kt and the sink rate was 1022 ft/min. Six seconds later, at an RH of about 720 ft, a single chime rang out and the notification 'SPD BRK NOT RETRACTED' appeared. The copilot responded immediately with: *"Flight controls, speed brakes still out."* The speed brakes were retracted at 08:47:44 UTC. The ground spoilers were subsequently not armed for the landing. A short discussion about the upcoming landing took place and at 08:47:47 UTC, the copilot requested the execution of the landing checklist, which the commander initiated immediately (see chapter 1.17.1.5).

At 08:47:50 UTC, the automatic callout *"one hundred above"* rang out and was followed 7 seconds later by the callout *"minimum"*. At this time, the recordings show an RH of 600 ft.

A few seconds later, the commander called out the last action line of the landing checklist, *"ECAM memo"*, whereupon the copilot answered with *"landing imbalance monitor checked"* and not with *"landing no blue"*, as is specified in the procedures. Immediately afterwards, at 08:48:02 UTC, the automatic callout *"five hundred"* can be heard in the recording. However, the flight crew's corresponding callouts cannot be heard (see Figure 12). The aircraft was then at an RH of 500 ft, had a sink rate of 1115 ft/min and an IAS of 149 kt. This was therefore 9 kt above the correct approach speed (V_{APP}[10]). According to the glideslope display, the aircraft was 1.7 dot above the glideslope.

Only two seconds later at 08:48:04 UTC, a single chime rang out[11] and the copilot immediately responded with *"APU start".* The commander complied with this request by activating the START pushbutton shortly before the aircraft touched down.

The cabin crew were not notified (see chapter 1.17.1.4).

According to the flight data recordings, the aircraft was at an RH of 198 ft with an IAS of 144 kt at 08:48:20 UTC. The decreasing sink rate was at 1147 ft/min when the copilot mentioned that they were now on the glideslope. At 08:48:26 UTC, the

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7 Three braking levels are available for the braking effect: low (LO), medium (MED) and maximum (MAX); the MAX level cannot be armed in flight. The system takes effect after landing when the ground spoilers deploy (see chapter 1.6.3.1).

8 According to the aircraft manufacturer, the maximum speed for deploying the flaps to position 2 is 200 kt.

9 According to the aircraft manufacturer, the maximum speed for deploying the flaps to position 3 is 185 kt.

10 V_{APP} according to QRH, chapter 'IN FLIGHT PERFORMANCE', subchapter 'V_{APP} determination without failure'. The term 'failure' refers to the following two cases: reverser unlock with buffet or engine shut down with engine fire pushbutton pushed and ice accretion. Neither applied in the present case. The speed is therefore calculated as follows: VAPP = VLS + APPR COR. VAPP at VLS CONF 3 is 135 kt and the APPR COR is 5 kt (5 kt in case of A/THR-ON), resulting in a VAPP of 140 kt.

11 According to the aircraft manufacturer, this chime was most likely activated in combination with the F/CTL GND SPLR NOT ARMED master caution, which appears when passing the RH at 500 ft with disarmed ground spoilers. As no corresponding recordings are available and no response from the flight crew can be heard on the cockpit voice recorder (CVR), the investigation cannot attribute this chime to a definite warning message.

automatic callout *"one hundred"* rang out and 8 seconds later, the radio height callouts *"fifty, forty, thirty, twenty"* followed by *"retard, retard"*. During the entire final approach to touchdown, the power output of the remaining engine remained in approach idle.

At 08:48:38 UTC, the aircraft touched down 320 m beyond the runway threshold with an IAS of 136 kt, first with its left-hand side, and two seconds later with its right-hand side main landing gear. The brake pedals were then immediately applied, and when the reverse thrust was activated 7 seconds later at 08:48:47 UTC, at an IAS of 114 kt, the ground spoilers deployed (see chapter 1.6.3.1). There are no recordings of callouts from the flight crew during roll-out after touchdown. The aircraft came to a standstill about 60 m beyond the point where runway 28 crosses with runway 16.

The wheel page, which automatically appears at touchdown and also shows whether the ground spoilers are deployed, was not able to display because –contingent on the APU start, which was initiated shortly beforehand – the APU page remained on display (see footnote 3 on page 10).

At 08:49:10 UTC, the flight crew contacted the Aerodrome controller (ADC) for the first time and notified him with regards to leaving runway 28. The ADC issued the following instruction at 08:49:22 UTC: *"Air Serbia three seven one, vacate via runway one six,"* and expanded upon this instruction at 08:49:50 UTC with: *"*(...) *vacate left via Echo seven."* The copilot subsequently pointed out to the commander that the passengers had not been informed. The commander answered that this did not matter.

At 08:50:40 UTC, the ADC instructed the flight crew to switch to the Zurich Apron frequency, which the flight crew immediately acknowledged and actioned. The question, subsequently asked and repeated, as to whether the flight crew required support, was answered in the negative by them.

At 08:54:08 UTC, upon reaching parking position, the commander requested execution of the 'after landing checklist'. The copilot confirmed this request, a further response is not discernible.

At 08:56:06 UTC, the parking brakes were applied on the allocated parking position and the left engine was subsequently switched off. The passengers and the crew were able to exit the aircraft normally.

1.1.4 Location and time of the serious incident

Location	5.5 km north-west of Zurich Airport (LSZH)
Date and time	17 October 2014, 08:40 UTC
Light conditions	Daytime
Coordinates	681 183 / 261 955 (Swiss grid 1903) N 47° 30' 12'' / E 008° 30' 58'' (WGS 84)
Altitude	about 4000 ft QNH

1.2 Injuries to persons

1.2.1 Injured persons

Injuries	Crew members	Passengers	Total no. of occupants	Third parties
Fatal	0	0	0	0
Serious	0	0	0	0
Minor	0	0	0	0
None	6	119	125	N/a
Total	6	119	125	0

1.2.2 Nationalities of the aircraft's occupants

The crew consisted of six Serbian nationals.

The 119 passengers were of different nationalities.

1.3 Damage to aircraft

The aircraft itself remained undamaged. The air-cooled oil cooler (ACOC) of the right-hand side engine showed a leak, which was responsible for the oil loss (see chapter 1.16).

1.4 Other damage

None

1.5 Personnel Information

1.5.1 Flight crew

1.5.1.1 Commander

1.5.1.1.1 General

Person	Serbian citizen, born 1968	
Licence	Airline transport pilot licence aeroplane (ATPL (A)) in accordance with European Aviation Safety Agency (EASA)	
Flying experience	Total	5184:00 h
	Of which as commander	1570:00 h
	On type	233:48 h
	Of which as commander	233:48 h
	During the last 90 days	162:59 h
	Of which on type	162:59 h
	Number of landings on A32F[12]	41

All available information indicate that the commander reported for duty well-rested and healthy. There is no indication that fatigue was a factor at the time of the serious incident.

[12] A32F: stands for the Airbus A320 family, meaning the A318, A319, A320 and A321 types.

1.5.1.1.2 Additional information

The commander had completed his training on the A320-200 aircraft type at the 'Air Berlin Training Organisation'. On 3 February 2014, he obtained confirmation that he had successfully completed his training. The instructors attested a normal learning process during training and on several occasions his CRM[13] was rated good. Occasionally, the criticism was made that callouts and the standard operating procedures (SOP) must be improved. In terms of training, he had a total training time of 40 hours certified; 20 hours as PF and 20 hours as PNF.

1.5.1.2 Copilot

1.5.1.2.1 General

Person	Serbian citizen, born 1967	
Licence	ATPL(A) in accordance with EASA	
Flying experience	Total	6962:35 h
	On type	163:40 h
	During the last 90 days	153:38 h
	Of which on type	153:38 h
	Number of landings on A32F	53

All available information indicate that the copilot reported for duty well-rested and healthy. There is no indication that fatigue was a factor at the time of the serious incident.

1.5.1.2.2 Additional information

The copilot had completed his training on the A318-321 aircraft type at the 'Air Berlin Training Organisation'. According to instructors, his learning progress was average to above-average, without any weak points. He obtained confirmation that he had passed the skill test on 20 March 2014.

1.5.2 Air traffic control personnel

1.5.2.1 Air traffic control officer ADC

Function	Aerodrome Control (ADC)
Person	Swiss citizen, born 1986
Licence	Air traffic controller licence (ATCL) based on EC directive 2006/23, issued by the Federal Office of Civil Aviation (FOCA)

1.5.2.2 Air traffic control officer DEP

Function	Zurich Departure (DEP)
Person	Swiss citizen, born 1985
Licence	ATCL in accordance with FOCA

[13] CRM: crew resource management. Based on the experience gained from numerous accidents during which inadequate collaboration in the cockpit was a causal factor, CRM was developed for flight crew training. CRM aims to increase awareness that, aside from the technical understanding on board the aircraft, the interpersonal skills are essential for a safe flight.

1.6 Aircraft information

1.6.1 General information

Registration	YU-APA	
Aircraft type	A319-132	
Characteristics	Twin-engined short- and medium-range aircraft with turbofan engines	
Manufacturer	Airbus S.A.S., Toulouse, France	
Owner	CIT Aerospace International, Dublin, Ireland	
Operator	Air Serbia a.d. Belgrade, Republic of Serbia	
Engine	Type: IAE V2524-A5	engine serial number (ESN)
	Left engine:	ESN V11724
	Right engine:	ESN V11721
Max. permitted mass	Take-off	75 500 kg
	Landing	62 500 kg
Mass and centre of gravity	The mass of the aircraft at take-off was 60 980 kg. Both mass and centre of gravity were within the permissible limits of the aircraft manual (AFM).	

1.6.2 Displays in the cockpit

The general cockpit design is as follows:

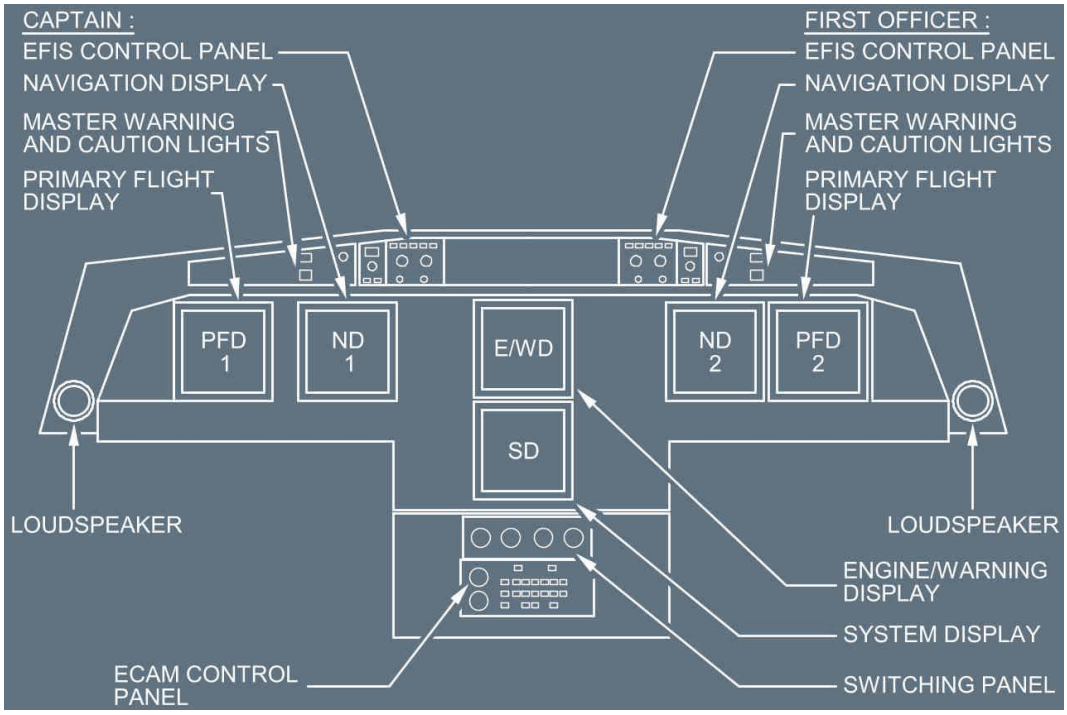

Figure 1: Cockpit design (copied from the flight crew operating manual (FCOM))

The six screens (PFD 1+2, ND 1+2, E/WD, SD) serve primarily as the following displays:

PFD These two screens, the primary flight displays (PFD), are the primary air data display units for both pilots. The primary function of the PFDs is to show flight attitude, flight altitude, airspeed and heading.

ND Both of these screens serve, among other things, as the navigation display (ND). They show maps and flight plan information. In addition, a wide range of other information can be displayed, for example, air traffic displays, weather, terrain, approach charts and waypoint information.

E/WD Engine primary indications, the flap/slat position as well as warning & caution messages are primarily provided on the engine/warning display (E/WD).

This screen is part of the electronic centralised aircraft monitoring (ECAM) system.

SD This screen serves as the system display (SD), showing simplified synoptic diagrams of the aircraft systems. The various system displays can be selected on the ECAM control panel (ECP). In addition, this display lists the aircraft status of various systems.

The electronic instrument system (EIS) can be divided into two subsystems:

- the electronic flight instrument system (EFIS)
- the electronic centralised aircraft monitoring (ECAM) system

The EFIS includes both the PFD and the ND screens.

The ECAM system includes two monitors arranged on top of each other. Engine data and warning messages are displayed on the upper engine/warning display (E/WD). System pages, which provide the pilots with an overview of the various systems and their switching state positions, are shown on the system display (SD) underneath. The system to be displayed can be selected on the ECAM control panel. In the event of a fault, the EIS automatically generates the appropriate system page.

1.6.3 System description

In the following section, only those systems relevant to the serious incident are briefly described. This concerns the function of the spoilers and engine components.

1.6.3.1 The spoilers

The spoilers have three functions. They support the ailerons controlling movement around the aircraft's longitudinal axis by deploying asymmetrically (roll spoilers). They can be used as speed brakes when deployed symmetrically. During landing and an aborted take-off, they are fully deployed (ground spoilers) to decrease lift of the wings and thereby putting maximum load from the weight of the aircraft on the landing gear wheels to increase the braking effect.

When landing, the ground spoilers are deployed either when both sets of the main landing gear have been compressed, the ground spoilers have been armed and both thrust levers are idle; or when both sets of the main landing gear have been compressed, the ground spoilers have not been armed, but reverse thrust has been selected on at least one of the two thrust levers.

The ground spoilers are partially deployed (10°) during landing, when reverse thrust has been selected on at least one of the thrust levers and one set of the main landing gear has been compressed. This partial deployment of the ground spoilers facilitates compression of the second set of the main landing gear, subsequently resulting in full deployment of the ground spoilers.

1.6.3.2 Engine components

1.6.3.2.1 General information on the oil cooling system

The relevant engine components of the V2500-A5 engine are lubricated by the oil system represented schematically in figure 2. The oil itself is first cooled by a so-called air/oil heat exchanger, i.e. an air-cooled oil cooler (ACOC), and subsequently by a fuel/oil heat exchanger, i.e. a fuel-cooled oil cooler (FCOC).

Should adverse conditions with the oil filter, oil temperature, oil pressure or oil quantity arise in the oil system, these conditions will be displayed in the cockpit on the electronic centralised aircraft monitoring (ECAM) system.

A detailed technical investigation was performed on the ACOC (see chapter 1.16).

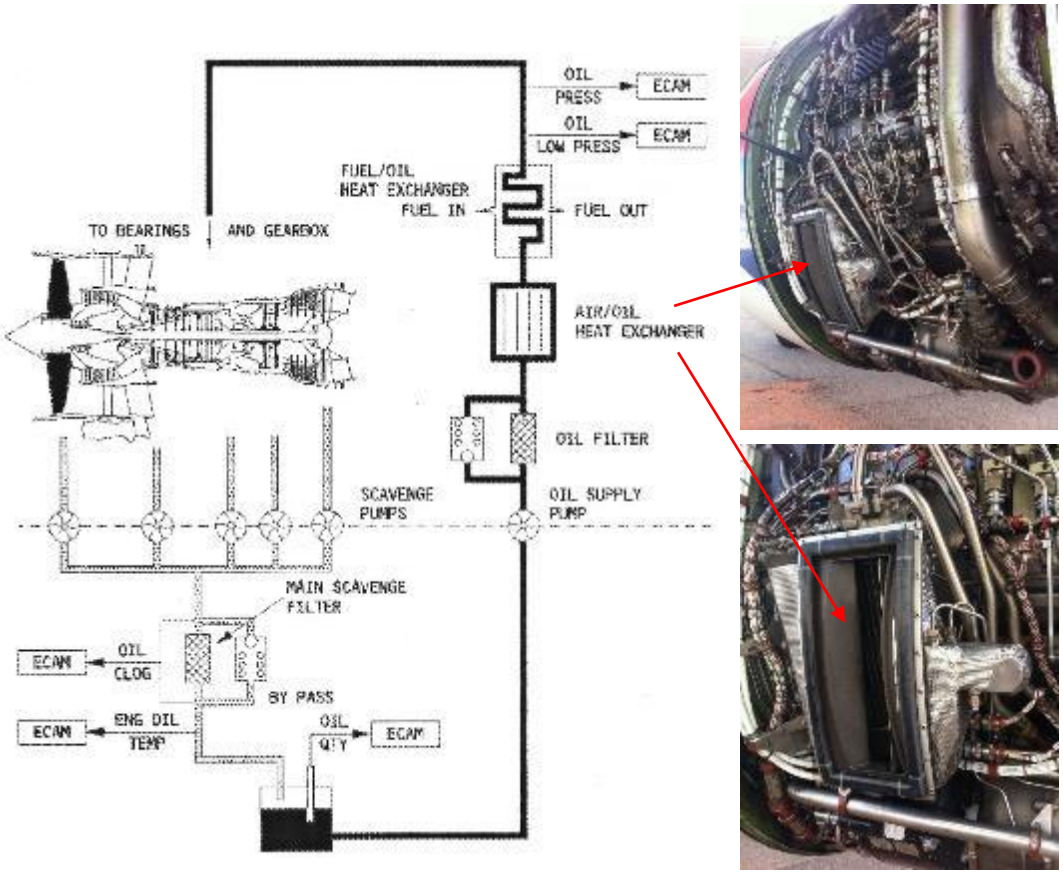

Figure 2: The engine's oil circuit (copied from the FCOM), right: engine of the YU-APA photographed after the serious incident

1.6.3.2.2 Background

The inspection of the engine, carried out after landing, showed a leak in the ACOC. The defective ACOC with part number (p/n) 50026001-1 and serial number (s/n) 0008 was removed and replaced with the ACOC with s/n 2335.

However, according to the aviation company's files, the defective ACOC should have been identified as s/n 3427, and not s/n 0008. The operator stated that they had not replaced the ACOC since they had been operating the aircraft, since 10 April 2014.

The aircraft owner stated that he did not know whether the ACOC had ever been replaced prior to 10 April 2014 and that according to their files, the defective ACOC should have s/n 3427.

Further investigations showed that for the subject engine, on the Authorised Release Certificate EASA Form 1 (form tracking number 201124388), dated 30 May 2011, and on the EASA Form 1 (form tracking number 201102936), dated 30 December 2011, s/n 3427 was recorded for the fitted ACOC. Since that time, no documents exist documenting a replacement of the ACOC.

It should be noted that adhesive residue is visible on the defective ACOC at the position where the data plate should be installed and the corresponding numbers had been printed directly on the outer surface of the ACOC (see figure 3).

Figure 3: Photo of the defective ACOC (picture taken on 10 February 2014)

The manufacturer of the ACOC, the *Sumitomo Precision Products Co. Lt.* (OEM) company, confirmed in writing that the defective ACOC was not produced by them, and was therefore not an OEM[14] component. Inquiries revealed that in 2006 the ACOC was sent by SAS as serial number 3427 under repair order 2PIE5605306 to the company Triumph Accessory Services (TAS). The ACOC was repaired in accordance with the component maintenance manual and a new Triumph-designed core assembly, serial number of 0008, was installed. TAS stated that the core assembly is not an OEM part; however, it is manufactured by an approved vendor under the FAA's Designated Engineering Representative authority. Therefore the installed ACOC was a PMA[15] part and not a suspected unapproved part (SUP).

The defective ACOC was sent to TAS for investigation. TAS writes:

„*The oil cooler had not been back to a Triumph repair facility until it arrived in March 2015 for the investigation. When the ACOC arrived at Triumph, the data plate was missing. The ACOC was marked with the OEM assembly PN, Triumph assembly PN, the Triumph core PN, and the core SN (SN 0008). It is suspected that the core SN was used in lieu the ACOC assembly PN because the data plate with the assembly SN was missing. It could not be determine when the data plate went missing and who stamped the PNs and SNs."*

The 'Maintenance Hannover GmbH' (MUT) company in Germany confirms that on the occasion of maintenance works in 2011 the ACOC with S/N 3427 was installed. Further investigations remained unsuccessful. They were made additionally difficult by the fact that since 2011 the aircraft YU-APA was operated by two other aviation companies before Air Serbia took over in 2014.

[14] OEM: original equipment manufacturer. An OEM component is an original component, which is manufactured by the aircraft manufacturer themselves or by one of their suppliers.

[15] PMA: parts manufacturer approval. A PMA component is a (replacement) component, which is not manufactured by the manufacturer themselves or one of their suppliers, but rather from a certified third-party supplier.

1.7 Meteorological information

1.7.1 General weather conditions

An undulating frontal zone ranged from the Bay of Biscay across the north side of the Alps to the High Tatras. The air mass boundary slowly shifted from the High Rhine to the Alpine Ridge throughout the morning.

At 06:00 UTC, the jet stream axis was just north of Zurich in a west-southwesterly to an east-northeasterly direction. During the morning, the jet stream axis shifted south over the Alpine Ridge and crossed Milan at 12:00 UTC in a similar direction as in the morning.

1.7.2 Weather at the time and location of the serious incident

The frontal zone – oriented almost parallel to the lines of latitude – led to a powerful westerly wind during the morning. The strongest gust of wind recorded at the SwissMetNet station in Kloten was 38 kt between 05:00 and 05:10 UTC. The 10-minute average was 22 kt. The wind speed increased between 04:00 and 05:00 UTC. At the same time, relative humidity decreased as the temperature was slightly increasing. This indicates that a superficial inversion layer lasted into the early morning despite the strong high-altitude wind. The inversion base was between 7000 and 9000 ft QNH mid-morning.

Between 06:00 and 09:00 UTC, the maximum 1-second gust wind speed reached 28 kt. The maximum 10-minute average was 16 kt within the same time interval.

At the time YU-APA landed in Zurich, the period with the strongest gusts on the ground had passed. The average wind speed was between 5 and 10 kt with gust wind speeds of up to 15 kt.

Below 8000 ft, the temperature was slightly above International Standard Atmosphere (ISA). Between 7000 and 8000 ft QNH, there was a zone with distinct wind shear. An aircraft that took off in an easterly direction recorded wind shear to be 9 kt/1000 ft between 6000 and 7000 ft QNH at 08:47 UTC, and an aircraft that took off in a westerly direction recorded wind shear to be 14 kt/1000 ft at 08:56 UTC. Maximum values around 08:52 UTC reached 24 kt/1000 ft.

The effect of wind shear and the turbulence resulting from it depend, among other things, on the size and mass of the aircraft as well as its speed. According to the Federal Aviation Administration (FAA), shears of more than 10 kt/1000 ft lead to severe turbulence for commercial aircraft. Moderate turbulence is to be expected from the interval of 6-9 kt/1000 ft.

The following webcam pictures show a flattening of horizontal convective rolls (HCR). They indicate a decrease in turbulence in the ground-level atmosphere during late morning.

Figure 4: Picture of the dock midfield at Zurich airport (LSZH) in the direction of the departure flight path, taken at 08:30 UTC

Figure 5: Picture of the Uetliberg in a north-easterly direction, taken at 08:50 UTC

Figure 6: Picture of Zurich's town hall, in a north-easterly direction, taken at 08:50 UTC

1.7.3 Astronomical information

Position of the sun	Azimuth: 139°	Elevation: 24°
Light conditions	Daylight	

1.7.4 Aerodrome meteorological reports

At 08:50 UTC, the following meteorological aviation routine weather report (METAR) applied at Zurich Airport (LSZH):

METAR LSZH 170850Z VRB27008KT 9999 SCT018 BKN055 16/13 Q1018 NOSIG=

In plain text, this means:

On 17 October 2014, the following weather conditions were observed shortly before the 08:50 UTC Zurich Airport weather report was dispatched:

Wind	From 270 degrees at 8 kt
Meteorological visibility	10 km or more
Precipitation	None
Clouds	1/8 - 2/8 at 1,800 ft AAE[16] 5/8 - 7/8 at 5,500 ft AAE
Temperature	16 °C

[16] AAE: above aerodrome elevation

Dew point	13 °C
Atmospheric pressure (QNH)	1,018 hPa, pressure reduced to sea level, calculated with the values of the ICAO standard atmosphere
Landing weather forecast	In the two hours following the weather observation, no significant changes are to be expected.

1.8 Aids to navigation

At the time of the serious incident, no restrictions relevant for flight ASL 371 were published for Zurich Airport.

1.9 Communications

Radio communication between the flight crew and the ATCOs involved was in English and proceeded without any difficulties.

1.10 Aerodrome information

1.10.1 General

Zurich Airport is in the north-east of Switzerland. In 2013, the airport served 24.86 million passengers and approximately 262 000 air traffic movements.

The reference elevation of the airport is 1416 ft AMSL[17], the reference temperature is defined as 24.0 °C.

1.10.2 Runway equipment

Zurich Airport features a system of three runways. Runways 16 and 14 are equipped with a category III instrument landing system (ILS) and runway 34 with a category I ILS. Runway 28 is equipped with an uncategorised ILS, which features increased weather minima compared to category I. The reason for non-classification is the glideslope angle of 3.3 degrees, which is above the ICAO[18]-recommended value of 3 degrees. In addition, runway 28 has a PAPI approach angle of 3.3°.

The runways at Zurich Airport have the following dimensions:

Runway name	Dimensions	Altitude of the runway threshold
16/34	3700 x 60 m	1390/1388 ft AMSL
14/32	3300 x 60 m	1402/1402 ft AMSL
10/28	2500 x 60 m	1391/1416 ft AMSL

At the time of the serious incident, all three runways in their entire lengths were available for landings.

1.10.3 Rescue and fire-fighting services

Zurich Airport was equipped with category 10 fire-fighting equipment. The airport's fire service was permanently on-call during flight operations.

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[17] AMSL: above mean sea level

[18] ICAO: International Civil Aviation Organisation. Annexe 10: 'Aeronautical Telecommunications', chapter 3.1.5.1.2.1 "***Recommendation.—*** The ILS glide path angle should be 3 degrees. ILS glide path angles in excess of 3 degrees should not be used except where alternative means of satisfying obstruction clearance requirements are impracticable."

1.11 Flight recorders

1.11.1 Flight data recorder

Type	FA 2100
Manufacturer	L3 communications
Number of parameters	1016
Recording medium	Solid state memory
Duration of recording	100 hours

The data from the flight data recorder was recorded uninterrupted and could be read.

1.11.2 Cockpit voice recorder

Type	FA 2100
Manufacturer	L3 communications
Number of channels	4
Recording medium	Solid state memory
Duration of recording	2 hours

It was possible to examine all four channels of the cockpit voice recorder (CVR) and they were made available to the investigation.

1.12 Wreckage and impact information

Not applicable

1.13 Medical and pathological information

There is no evidence of health problems or fatigue in relation to the pilots.

1.14 Fire

Not applicable

1.15 Survival aspects

Not applicable

1.16 Tests and research

The defective ACOC was thoroughly investigated by a company that specialises in critical thermal fluid management with heat exchangers. The leak could be found and it was possible to limit the search for the cause by cutting across the entire length of the ACOC.

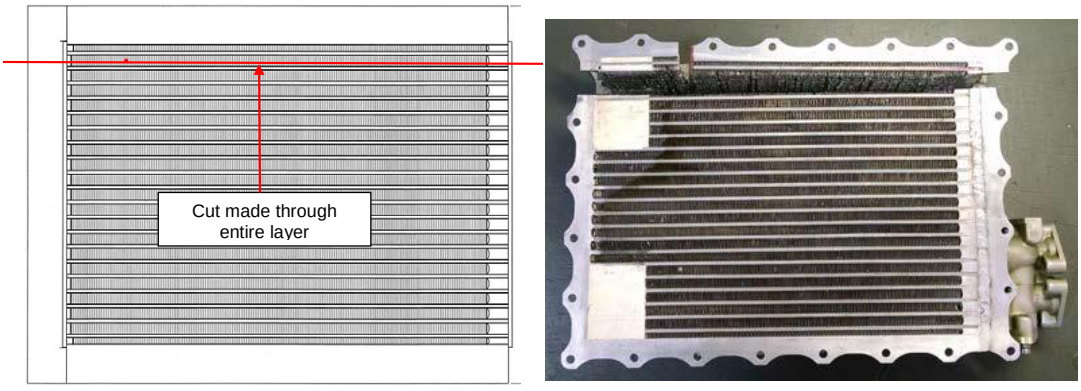


Figure 7: Copied from the respective engineering report (project 5366)

Further investigation of the cause of the leak led to the conclusion that material fatigue of the cooling tubes, caused by movements as a result of broken soldering joints, was the most likely cause. Among other things, the respective report records the following:

"This braze joint, between nosepiece and tubesheet held, had allowed a crack to form and grow through cycling, in the tubesheet itself. The failure is therefore most likely caused by fatigue of the tubesheet, which in turn allowed a crack to form, and ultimately produced a leak in the oil circuit."

1.17 Organizational and management information

1.17.1 Aviation company

1.17.1.1 General

In 2013, the aviation company Etihad Airways acquired 49% of the *Jugoslovenski Aerotransport* (JAT) airline, and the company was renamed Air Serbia in the same year. All Boeing 737-300 aircraft were taken out of service and replaced by A319-100 aircraft. On 13 October 2013, the former JAT Airways, now called Air Serbia, carried out its first flight.

The aviation company Air Serbia recorded the operating procedures for crews in various operations manuals (OM). These include OM A and OM B. Whilst OM A contains general procedural requirements, the aircraft-specific procedures are published in OM B. Air Serbia entitled OM B 'OM Part-B A319/320' and 'OM Part-B A319' respectively. Among other things, it is stated in OM B's introductory section that the procedures contained within it correspond to those of the aircraft manufacturer, Airbus, and that the manufacturer's flight crew operating manual (FCOM) should be used on the aircraft.

Furthermore, the aircraft manufacturer's so-called quick reference handbook (QRH) is used for the daily work of flight crews. This QRH is a handbook that is available to the crew on the aircraft as a hard copy, and along with standard procedures complementing ECAM procedures also contains important procedures for abnormal and emergency situations.

The aircraft manufacturer's flight crew training manual (FCTM), which also contains procedural requirements, also serves as a supplement and is used for training purposes. In its introductory section, the FCTM states that it is primarily meant to give the flight crews practical information for operating the Airbus A318/A319/A320/A321 aircraft type. In addition, it states that the FCOM takes precedence over the FCTM in cases of conflict.

The following only addresses those sections within the above operations manuals that are relevant to the present serious incident under investigation.

1.17.1.2 General procedural requirements

Among other things, OM A states the following as regards crew composition in chapter 4 'crew composition' under 4.1.3 'crewing of inexperienced flight crew members':

"1. It is considered that a flight crew member is inexperienced, following completion of a type rating or command course, and the associated line flying under supervision, until he has achieved on the Type either:

- *100 flying hours and flown 10 sectors within a consolidation period of 120 consecutive days; or*
- *150 flying hours and flown 20 sectors (no time limit).*

[...]

Inexperienced pilots shall not be scheduled to operate together.

[...]"

Both pilots had completed their training on the A320 aircraft type in February 2014 and March 2014 respectively. They had fulfilled the aviation company's conditions mentioned above, were therefore no longer considered 'inexperienced' and were permitted to be placed together as flight crew.

Regarding aircraft operations, the introductory section of OM A states the following under 'general operating procedures' in chapter 8.0.2 'CRM principles':

"Application CRM principles shall be mandatory by crew members in day-to-day operations, as published in the CRM checklist and thought during CRM classes and during initial and recurrent training. This includes following as a minimum:

- *Team Work*
- *Risk Assessment before every flight according CRM checklist*
- *Appropriate use of Automation*
- *Good Communication*
- *Mandatory Briefings for critical phases of flight*
- *Positive Task Distribution*
- *Cross-checking other pilots actions*
- *Situational Awareness*
- *Use of Standard Callouts*
- *Mandatory usage of Check-list*
- *Critical Actions Confirmation*
- *Threat and Error Management*
- *Assertiveness*
- *Conflict Resolution*
- *System Learning"*

The following is stated in chapter 8.3.0.6 'stabilised approach':

"Every flight shall satisfy criteria of stabilized approach by 1000 ft AGL[19] *in instrument conditions, 500 ft AGL in visual conditions and by 300 ft AGL during circling. For criteria for stabilized approach for each aircraft type, check Part B/SOP.*

For each flight, flight crew shall manoeuvre the aircraft so as to touchdown within the touchdown zone of the active runway. If above conditions are not met, a Go-around is mandatory."

Callouts when deviating from the criteria of a stabilised approach can also be found in the QRH (see annexe 5).

1.17.1.3 Aircraft-specific procedural requirements in OM B

OM B, called OM Part-B by the aviation company, consists of 769 pages and contains many chapters identical to those in the aircraft manufacturer's FCOM, which has 5390 pages. It also contains additional procedural requirements defined by the

[19] AGL: above ground level

aviation company that are not explicitly published in the FCOM. Neither OM Part-B nor the FCOM states which procedure is valid when two identical procedures are published in different ways.

The 'B02 NORMAL PROCEDURES' chapter of OM Part-B states, among other things, what the different briefings must contain, and what the corresponding division of tasks between PF and PM looks like. Following take-off, the following applies according to OM Part-B [bold in the original]:

"AFTER TAKEOFF CHECKLIST DOWN TO THE LINE

"AFTER TAKEOFF/CLIMB CHECKLIST".....ORDER ***PF***

AFTER TAKEOFF/CLIMB CHECKLIST.....COMPLETE ***PF & PM***

When called by the PF, PM will read the appropriate checklist

"DOWN TO THE LINE".....ANNOUNCE ***PM"***

The following is stated for the approach briefing:

APPROACH BRIEFING (PF & PM)

Applicable to: ALL

APPROACH BRIEFING . PERFORM **PF**

- *Refer to QRH/JU-SUPPL02 – Approach Briefing for a guide to completing the approach briefing.*
- *ONE ENGINE TAXI must always be considered in accordance with FCOM-PRO-SUP-90*
- *If Low Visibility Procedures are in effect an additional briefing must be completed. Refer to QRH/JU-SUPPL02 – Low Visibility Approach Briefing for a guide to completing this second briefing.*

Figure 8: Procedure for approach briefing (copied from OM Part-B)

With regards to the approach, the OM Part-B 'B02 NORMAL PROCEDURES' chapter states, among other things, the following procedural requirements relevant for the serious incident:

FINAL APPROACH

Applicable to: ALL

- The speed trend arrow and FPV help the flight crew make timely and correct thrust settings (if in manual thrust), and approach path corrections.
- Avoid descending through the correct approach path with idle thrust. (Late recognition of this situation without a prompt thrust increase may lead to considerable speed decay and altitude loss).
- Ensure that the aircraft is stabilized on the final descent path at VAPP (or ground speed mini) in the landing configuration with the thrust stabilized (usually above idle) at 500 ft above airfield elevation or as restricted by Operator policy/regulations.
- If the aircraft is not stabilized, the flight crew must initiate a go-around, unless they think that only small corrections are necessary to rectify minor deviations from stabilized conditions due, amongst others, to external perturbations.
- Avoid any tendency to "duck under" in the late stages of the approach.
- Avoid destabilizing the approach in the last 100 ft, in order to have the best likelihood of performing a good touchdown at the desired position.

Figure 9: Information for final approach (copied from OM Part-B)

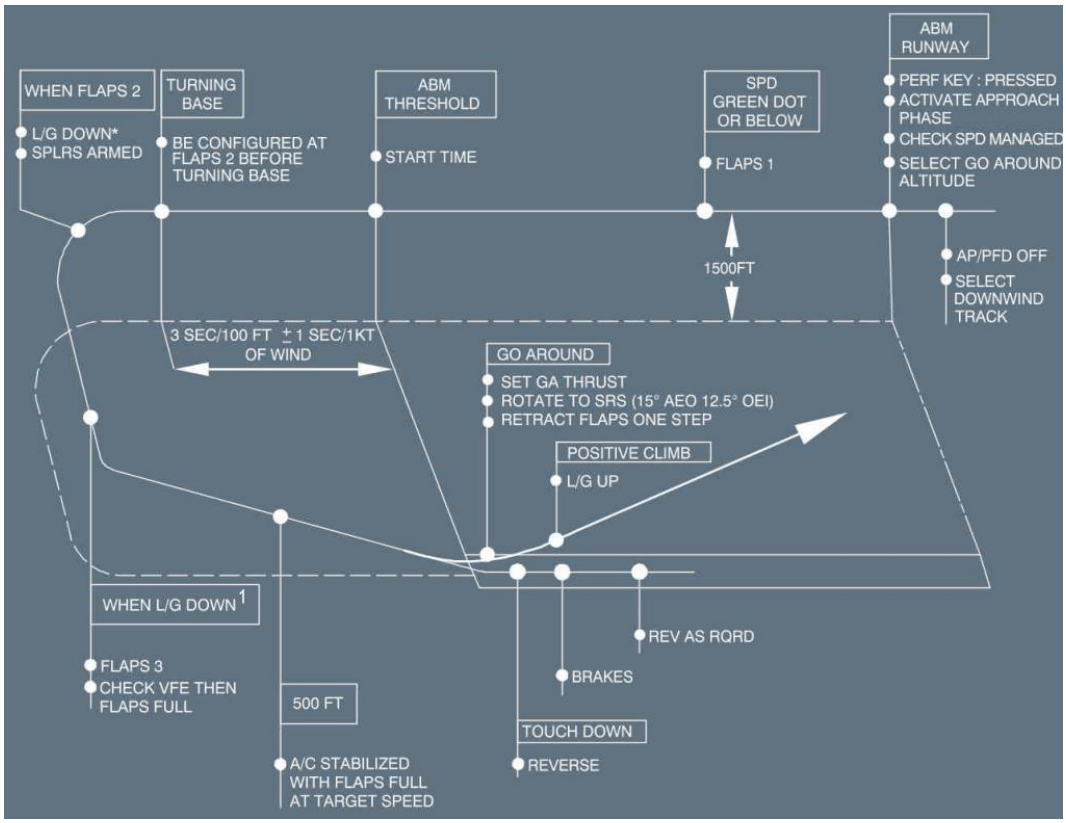
The crew had decided on a visual approach. OM Part-B states the following concerning this:

VISUAL APPROACH (1 OR 2 ENGINES) PATTERN

Applicable to: ALL

This pattern assumes the use of minimum ground speed (MANAGED SPEED guidance). If managed speed is not used, manually select the following speeds based on the FLAPS configuration selected:

- Select S speed after FLAPS 1 selection
- Select F speed after FLAPS 2 selection
- Select VAPP after FLAPS FULL selection



[1]**WHEN L/G DOWN:** For single engine approaches on high altitude airports, with high landing weight, delay selection of Gear Down and Landing Flaps/Slats configuration, until FINAL APPROACH.

Figure 10: Procedures for visual approach (copied from OM Part-B)

With reference to the serious incident under investigation, the diagram of the flight path – published in chapter 3.8.3 'engine failure after V1' ('NON-NORMAL PROCEDURES B03', page 30) of OM Part-B, labelled as 'immediate landing following ENG failure after take-off' – also applies.

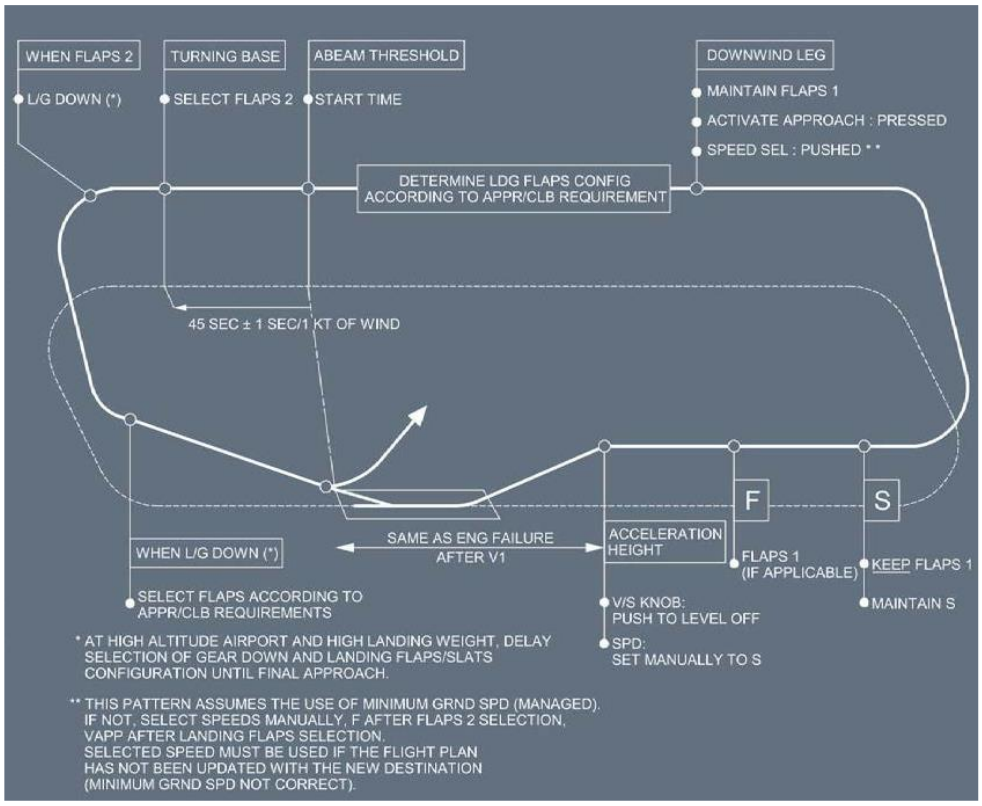


Figure 11: Procedure for engine failure after take-off (copied from FCOM)

Regarding callouts during final approach, the following is stated in the chapter 'standard operating procedures – standard callouts' on page 14:

APPROACH AND LANDING		
EVENT	**PF**	**PM**
1000 ft RA	"ON PROFILE" *(3)* or "GO AROUND - FLAPS"	"ONE THOUSAND" *(1)* "___ MILES TO TOUCHDOWN" *(2)*
500 ft AAL	"CHECKED"	"FIVE HUNDRED" *(1)* "STABLE" or "GO AROUND"
100 ft above MDA/DH	"CHECKED"	"ONE HUNDRED ABOVE" *(1)*
MDA/DH **visual reference**	"CONTINUE"	"MINIMUM" *(1)*
no visual reference	"GO AROUND - FLAPS"	
		"ONE HUNDRED" *(1)* "FIFTY" *(1)*
After touchdown **GND SPLRS extended**		"SPOILERS" *(4)*
REV green on E/WD		"REVERSE GREEN" *(5)*
Deceleration		"DECEL" *(6)*
At 70 kt	"CHECKED"	"SEVENTY KNOTS"

(1) PM monitors pin-programmed auto callout, or announces if inoperative
(2) PM should use the best available distance information from MCDU, ND or Raw Data as appropriate
(3) 1000 ft RA must occur 2 to 4 nm to touchdown
(4) If the spoilers are not extended, call "NO SPOILERS"
(5) In case of no reverse deployment, call "NO REVERSE ENGINE ____" or "NO REVERSE"
(6) In case of failure or no positive deceleration, call "NO DECEL"

Figure 12: Callouts for approach and landing (copied from OM Part-B)

In addition to the procedural requirements for standard operation, the procedural requirements for abnormal operation are of interest in the following section with regards to the serious incident. These are stated as follows in OM Part-B A319 under the main title 'NON-NORMAL PROCEDURES' in pages 1-4 of chapter B03 [bold in the original]:

"3. NON-NORMAL PROCEDURES

3.0 Operational Recommendations

Abnormal and Emergency procedures involve actions that the flight crew must perform in order to ensure adequate safety, and help to make the remainder of the flight easier.

Abnormal and Emergency procedures are actions that the flight crew performs:

- *After failures, that the ECAM detects, or*
- *After failures or situation, that the flight crew detects or encounters (e.g. CKPT WINDOW CRACKED, OVERWEIGHT LANDING), or*
- *After an aural alert (e.g. OBSTACLE AHEAD, PULL UP).*

When the flight crew performs procedures, the flight crew uses the 'READ' and 'DO' principle (oral reading).

TASKSHARING

The general tasksharing shown below applies to all procedures. The pilot's flying remains the pilot flying throughout the procedure.

The Pilot Flying (PF), is responsible for the:

- *Thrust levers*
- *Control of flight path and airspeed*
- *Aircraft configuration (request configuration change)*
- *Navigation*
- *Communications.*

The Pilot Not Flying (PNF), is responsible for:

- *Monitoring and reading aloud the ECAM and checklists*
- *Performing required actions, or actions requested by the PF, if applicable*
- *Using the engine master switches, cockpit C/Bs, IR and guarded switches, with PF's confirmation (except on ground).*

[...]

INITIATION OF PROCEDURES

Procedures are initiated on the Pilot Flying's command.

approach, or go-around.

No action is taken (apart from cancelling audio warnings, through the MASTER WARN light) until:

- *The appropriate flight path is established, and*
- *The aircraft is at least 400 ft above the runway, if a failure occurs during takeoff, approach or go-around.*

A height of 400 ft is recommended, because it is a good compromise between the necessary time for stabilization and excessive delay in procedure initiation.

In some emergency cases, provided that the appropriate flight path is established, the Pilot Flying may initiate actions before this height.

If an emergency causes LAND ASAP[20] to appear in red on the ECAM, the flight crew must land as soon as possible at the nearest suitable airport at which a safe approach and landing can be made.

If an abnormal procedure causes LAND ASAP to appear in amber on the ECAM, the flight crew should consider landing at the nearest suitable airport.

LANDING DISTANCE

Any increased landing distance, resulting from an emergency or abnormality, must be determined using QRH FPE-IFL.

[...]

CREW COORDINATION

When carrying out a procedure displayed on ECAM, both pilots must be aware of the present display. Before any 'CLEAR' action, the pilots should crosscheck to confirm that there remains no blue message (except in case of no action feedback) that they can eliminate by a direct action.

NO CLEAR ACTION BEFORE CROSS-CONFIRMATION

Example of crew coordination and cross confirmation:

WARNING DISPLAY (Example, not for operational use)	PILOT FLYING	PILOT NOT FLYING
HYD B RSVR OVHT BLUE ELEC PUMP.....OFF	READ FAILURE TAKE ATC RADIO CTL - REQUEST ECAM ACTION (1)	READ FAILURE - READ ACTION (full line) - PERFORM ECAM ACTION OR REQUEST EXECUTION BY THE PF (thrust levers)
HYD B RSVR OVHT *F/CTL B SYS LO PR	- CHECK ECAM ACTION COMPLETED - CONFIRM CLEAR	- REQUEST CLEAR
SEAT BELTS *F/CTL	- CONFIRM CLEAR	- REVIEW ALL AFFECTED EQUIPMENT SHOWN IN AMBER ON F/CTL PAGE - REQUEST CLEAR
STATUS APPR PROC HYD LO PR INOP SYS IF BLUE OVHT OUT: CAT 3 BLUE ELEC PUMP .... ON BLUE HYD SPLR 3 CAT 2 ONLY SLATS SLOW	- CONFIRM REMOVE STATUS	- READ STATUS LINE BY LINE - REQUEST REMOVE STATUS

(1) Although it is the responsibility of the pilot flying to request ECAM actions, this does not preclude the captain from either taking control of the aircraft or ordering ECAM actions he (she) considers to be necessary

20 LAND ASAP: land as soon as possible

Note: *ECAM procedures and STATUS, supplemented by a PFD/ND check suffice for handling the fault. However, before applying the ECAM procedures, the fault should be confirmed on the system display.*

When ECAM actions have been performed, and ECAM STATUS has been reviewed, the flight crew may refer to FCOM procedure (FCOM/PRO/ABN) for supplementary information, if time permits.

[...]

APPROACH PREPARATION

As always, the approach preparation begins by the review of the STATUS page.

Then, the APPROACH, LANDING and GO AROUND sections of the summary should be used to prepare and conduct the approach briefing, cross-checking, as usual, the associated FMS pages.

When appropriate, these sections include, among others, the LANDING WITH SLATS or FLAPS JAMMED procedure and the L/G GRAVITY EXTENSION procedure.

APPROACH

The APPR PROC actions given by the STATUS page should be performed by reading the APPROACH section of the summary (PNF), avoiding then to refer to other paper procedures.

Once the aircraft is in final configuration, the LANDING and the GO AROUND sections may be shortly commented, as a reminder (braking, NWS, reversers and L/G retraction in case of go-around).

Before the final approach, the PNF should review the STATUS page and check that all the APPR PROC actions have been completed."

If a serious technical problem arises, such as an engine failure, the following criteria should be followed (chapter B03, page 143 to 145) □bold in the original□:

"3.10 GUIDANCE FOR DIVERSION IN CASE OF SERIOUS TECHNICAL FAILURE

Situations which lead to diversion are mentioned in QRH. Accordingly, landing at the Nearest Suitable Airport must be made in following cases:

Any inflight fire, extinguished or not Engine failure Only one AC source remaining (engine or APU generator) One hydraulic system remaining (out of three) Structural Damage Confirmed bomb threat (red) Any other case with adverse effect on safety

3.10.1 EVALUATE SITUATION (TARD)

After completing checklist down to deferred items, gather as much information as possible from inside and outside of the a/c in time available. Request assistance/suggestions according H model (aircraft library, copilot, other pilots, ATC[21]*, purser, O.C.*[22]*, Trouble Shooting, pax...)*

21 ATC: air traffic control

22 O.C.: operation centre

Time Available

Asses Time Available - Some problems require that Non-normal management should be reduced to minimum due to limited time available:

Fire that cannot be confirmed extinguished Multiple bird strike On Battery power only Loss of thrust on both engines

Timed bomb threat

Estimate Time required to solve non-normal (do not rush through checklist if there is no benefit of an early landing).

Is delay required for pax briefing or/and deployment of ground emergency services

Analyze the Situation

Technical Assessment checklist requirements, MEL[23]/DDG[24] (advisory) Impact of the fail system on aircraft handling and performance Fuel remaining, gross weight

Operational Assessment

Weather (visibility, base, wind, temp.), NOTAMs [25], distance, PAX status, crew experience and condition, runway length and condition, terrain clearance requirements, route and airfield facilities

Requirement to modify procedures for different phases of flight (approach, landing, go-around, diversion)

Commercial Assessment (when permitted) Repair Facilities PAX handling facilities Company representation

Risk Management

What are the safety risks What is the Risk Level (see 1.8) What can be done to reduce risk What may be the cause of the problem and what further problem may that produce. Time available to make decision Back-up plan

Decide next course of action

According to above analysis decide whether to land as soon as possible or fly further for better conditions. Decide whether to inform purser and PAX and if cabin emergency announcement/preparation is required.

3.10.2 ANNOUNCE DECISION

Once the decision had been made, it should be passed-on to all interested parties inform other pilot(s) and ask for a feedback

23 MEL: minimum equipment list

24 DDG: dispatch deviations procedures guide

25 NOTAM: notice to airmen

Declare your status to ATC, inform intentions and request assistance. ATC can reduce cockpit workload by providing vectors, weather, NAVAID frequency and courses...

Inform Purser. Use NITS (Nature, Intentions, Time Available, Specials) when required.

If time is available inform O.C. directly or through ATC, with decision and request assistance if required.

Asses need to and inform pax according speech manual.

3.10.3 RISK LEVEL Minor Non-normal

No direct impact on safety, only flight comfort

Flight can be continued to destination without hazard. Purser may be informed

Moderate Non-normal

There is impact on continuance of the flight En-route diversion or return to destination may be required with normal landing Purser is to be informed. PAX are informed if diverting

Urgency Non-normal with precautionary landing (PAN-PAN)

Has a minor effect on flight safety

Precaution during landing on 3 wheels, without runway overrun expected and no need to evacuate.

Purser is briefed and PAX informed.

Distress non-normal with Emergency landing (MAYDAY)

Has impact on flight safety Safe landing cannot be guaranteed or evacuation required

Purser briefed/ cabin prepared for emergency landing and (perhaps or definitely) evacuation. PAX informed.

Any other diversion decision is up to the commander."

1.17.1.4 Aircraft-specific procedural requirements in the FCOM

Among other things, the FCOM contains Standard Operating Procedures (SOP) and Abnormal and Emergency procedures. The following procedures are SOP related to aircraft configuration during the intermediate/final approach. They match the checklists, which are published in the QRH in a different form (see chapter 1.17.1.5). This relates in particular to the following procedures for positioning the flaps and lowering the landing gear, which are recorded in the FCOM's 'PRO-NOR-SOP' ('procedures, normal procedures, standard operating procedures') chapter, 'precision approach' subchapter as follows:

"FLAPS 1" ..... ORDER **PF**
FLAPS 1 should be selected more than 3 NM before the Final Descent Point.

"SPEED CHECKED" ..... ANNOUNCE **PM**
Check the speed is below VFE NEXT and decelerating towards S speed, before making this callout.

FLAPS 1 ..... SELECT **PM**
"FLAPS 1" ..... ANNOUNCE **PM**
Check the blue number on the ECAM flaps indicator, and confirm the correct selection has been made, before making this callout.

Note: The ECAM automatically displays the STATUS page, if it is applicable, and if the flight crew has not already selected a system page manually.

Applicable to: ALL

TCAS MODE selector ..... TA or TA/RA **PM**
Select TA Mode:
- *In case of known nearby traffic, which is in visual contact*
- *At particular airports, and during particular procedures, identified by an Operator as having a significant potential for unwanted or inappropriate resolution advisories (closely-spaced parallel runways, converging runway, low terrain along the final approach, etc.)*

"FLAPS 2" ..... ORDER **PF**

"SPEED CHECKED" ..... ANNOUNCE **PM**
Check the speed is below VFE NEXT and decelerating towards F speed, before making this callout.

FLAPS 2 ..... SELECT **PM**
"FLAPS 2" ..... ANNOUNCE **PM**
Check the blue number on the ECAM flaps indicator, and confirm the correct selection has been made, before making this callout.

Applicable to: ALL

WHEN FLAPS ARE AT 2

"GEAR DOWN" ..... ORDER **PF**

L/G lever ..... SELECT **PM**
"GEAR DOWN" ..... ANNOUNCE **PM**
Check the red lights on LDG GEAR indicator to confirm gear operation, before making this callout.

AUTO BRK ..... CONFIRM **PF & PM**
If the runway conditions have changed from the approach briefing, consider using a different braking mode.

GROUND SPOILERS ..... ARM **PM**
NOSE light sw ..... ON **PM**
RWY TURN OFF light sw ..... ON **PM**

Applicable to: ALL

WHEN LANDING GEAR IS DOWN

IF LANDING WITH FLAPS 3:

"FLAPS 3" ..... ORDER **PF**

"SPEED CHECKED" ..... ANNOUNCE **PM**

Check the speed is below VFE NEXT and decelerating towards VAPP, before making this callout.

FLAPS 3 ..... SELECT **PM**

"FLAPS 3" ..... ANNOUNCE **PM**

Check the blue number on the ECAM flaps indicator, and confirm the correct selection has been made, before making this callout.

Applicable to: ALL

WHEN FLAPS AT LANDING POSITION

"CABIN CREW, TAKE YOUR SEATS FOR LANDING" .....
..... PA COMPLETE **PM**

A/THR ..... CHECK IN SPEED MODE or OFF **PF**

WING ANTI ICE pb-sw ..... OFF **PM**

Only switch the WING ANTI ICE to ON, in severe icing conditions.

Applicable to: ALL

SLIDING TABLE ..... STOW **PF & PM**

Applicable to: ALL

LDG MEMO ..... CHECK NO BLUE LINE **PF & PM**

Applicable to: ALL

LANDING CHECKLIST

"LANDING CHECKLIST" ..... ORDER **PF**

LANDING CHECKLIST ..... PERFORM **PF & PM**

"LANDING CHECKLIST COMPLETE" ..... ANNOUNCE **PM**

Figure 13: Division of tasks and callouts for configuration changes (copied from the FCOM)

Various action lines are to be completed after a successful landing; they are stated under 'normal procedures, standard operating procedures'. Tasks are divided between the pilot in the left seat (crew member 1 – CM1) and the pilot in the right seat (crew member – CM2). The procedures stated in the aircraft manufacturer's OM B is identical. In the serious incident under investigation, CM1 means the commander and CM2 means the copilot. The 'after landing checklist' is explicitly mentioned as follows:

Applicable to: ALL

AFTER LANDING CHECKLIST

"AFTER LANDING CHECKLIST" ORDER CM1

AFTER LANDING CHECKLIST COMPLETE..... CM1 & CM2

Once the aircraft has cleared the runway and when called by the CM1, CM2 will read the appropriate checklist.

"AFTER LANDING CHECKLIST COMPLETE"..... ANNOUNCE CM2

Figure 14: After landing checklist (copied from the FCOM)

Regarding collaboration in the cockpit in abnormal situations, the information in the FCOM is identical to that published in OM Part-B (see chapter 1.17.1.3).

As described in chapter 1.1.3 on the history of the flight, the ENG 2 OIL LO PR master warning message was generated at 08:40:40 UTC and appeared on the E/WD in the cockpit. At that time, the oil pressure showed a decreasing value of 59 PSI. The procedure to be followed according to the ECAM system is published in the FCOM as follows – the red colour marking, according to 'FCOM PROCEDURE LAYOUT', means that it is an emergency procedure. It also states that all actions and information, which appear on the ECAM system, are displayed in capital letters:

ENG 1(2) OIL LO PR

Ident.: PRO-ABN-70-00012075,0002001 / 14 SEP 12
Applicable to: ALL

L2 ● **If oil pressure is between 60 and 80 PSI:**

Only the ECAM amber caution title is displayed.

L1 ● **IF OIL PR < 60 PSI:**

L2 Check oil pressure indication on ENG SD page.

L1 THR LEVER (OF AFFECTED ENGINE)..... IDLE
ENG MASTER (OF AFFECTED ENGINE)..... OFF

L12

ASSOCIATED PROCEDURES

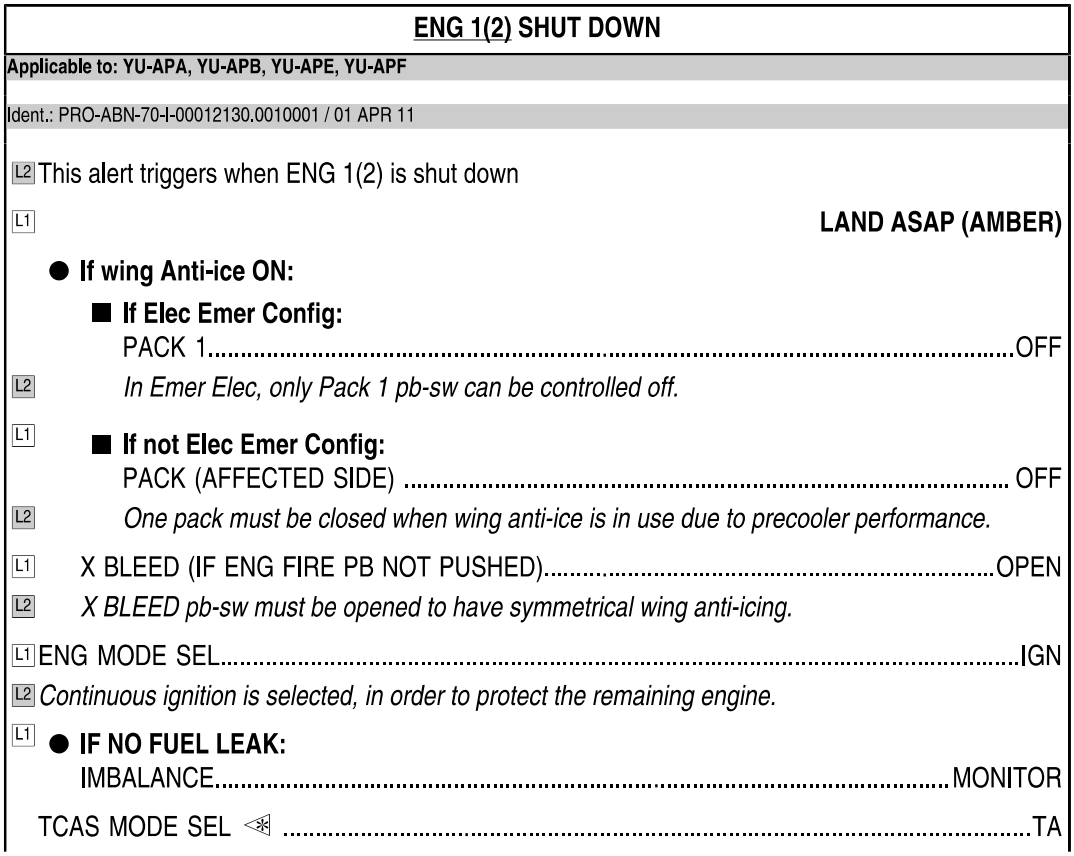
ENG 1(2) SHUT DOWN

Apply the ENG SHUT DOWN procedure (Refer to PRO-ABN-70-I ENG 1(2) SHUT DOWN).

Note: If oil pressure is low (< 60 PSI) is indicated only on ENG SD page (red indication) without the ENG OIL LO PR red warning, it can be assumed, that the oil pressure transducer is faulty. Flight crew may continue engine operation while monitoring other engine parameters.

Figure 15: Procedure for low engine oil pressure (copied from the FCOM)

After engine ENG 2 had been switched off, an ECAM procedure corresponding to the following FCOM procedure was displayed on the E/WD:



ENG 1(2) SHUT DOWN

Applicable to: YU-APA, YU-APB, YU-APE, YU-APF

Ident.: PRO-ABN-70-I-00012130.0010001 / 01 APR 11

L2 This alert triggers when ENG 1(2) is shut down

L1 **LAND ASAP (AMBER)**

● **If wing Anti-ice ON:**

■ **If Elec Emer Config:**

PACK 1.....OFF

L2 *In Emer Elec, only Pack 1 pb-sw can be controlled off.*

L1 ■ **If not Elec Emer Config:**

PACK (AFFECTED SIDE) ..... OFF

L2 *One pack must be closed when wing anti-ice is in use due to precooler performance.*

L1 X BLEED (IF ENG FIRE PB NOT PUSHED).....OPEN

L2 *X BLEED pb-sw must be opened to have symmetrical wing anti-icing.*

L1 ENG MODE SEL.....IGN

L2 *Continuous ignition is selected, in order to protect the remaining engine.*

L1 ● **IF NO FUEL LEAK:**

IMBALANCE.....MONITOR

TCAS MODE SEL ..... TA

Figure 16: Procedure for switching off the engine (copied from the FCOM)

For the flight crew, the amber prompt LAND ASAP means: consider landing at the nearest suitable airport (see chapter 1.17.1.3).

1.17.1.5 Procedural requirements in the QRH

The quick reference handbook (QRH) states the following in its introductory section:

"The QRH contains some specific procedures which are not displayed on the ECAM.

As a general rule, the procedures displayed on the ECAM are not provided in the QRH (refer to FCOM PRO/ABN)."

Generally, the procedures in the QRH are published in the form of a checklist with tasks listed separately for the PF and the PNF. The checklists therefore supplement the procedures for the individual flight phases as stated in OM B. They can be found in the QRH under 'NORMAL PROCEDURES' in annexe 5.

Furthermore, the various checklists that must be actioned during a standard flight are published on the outer back cover of the QRH. With regards to the serious incident under investigation, the following checklists that are also mentioned in OM B (see chapter 1.17.1.3) are concerned; they are listed in chronological order.

APPROACH	
BRIEFING	CONFIRMED
ECAM STATUS	CHECKED
SEAT BELTS	ON
BARO REF	SET (BOTH)
MINIMUM	SET (BOTH)
ENG MODE SEL	AS RQRD

LANDING	
CABIN CREW	ADVISED
A/THR	SPEED/OFF
AUTOBRAKE	AS RQRD
ECAM MEMO	LDG NO BLUE
- *LDG GEAR DN*	
- *SIGNS ON*	
- *CABIN READY ( )*	
- *SPLRS ARM*	
- *FLAPS SET*	

AFTER TAKEOFF / CLIMB	
LDG GEAR	UP
FLAPS	RETRACTED
PACKS	ON
BARO REF	SET (BOTH)

Figure 17: Checklists on the outer back cover of the QRH (copied from the QRH)

1.17.1.6 Procedural requirements in the training manual

With regards to division of tasks and the use of the ECAM system in abnormal situations, the FCTM lists, among other things, the following additional advice [bold in the original] in its 'OPERATIONAL PHILOSOPHY' chapter:

"TASK SHARING RULES

When the ECAM displays a warning or a caution, the first priority is to ensure that a safe flight path is maintained. The successful outcome of any ECAM procedure depends on: Correct reading and application of the procedure, effective task sharing, and conscious monitoring and crosschecking.

It is important to remember that, after ECAM ACTIONS announcement by the PF:

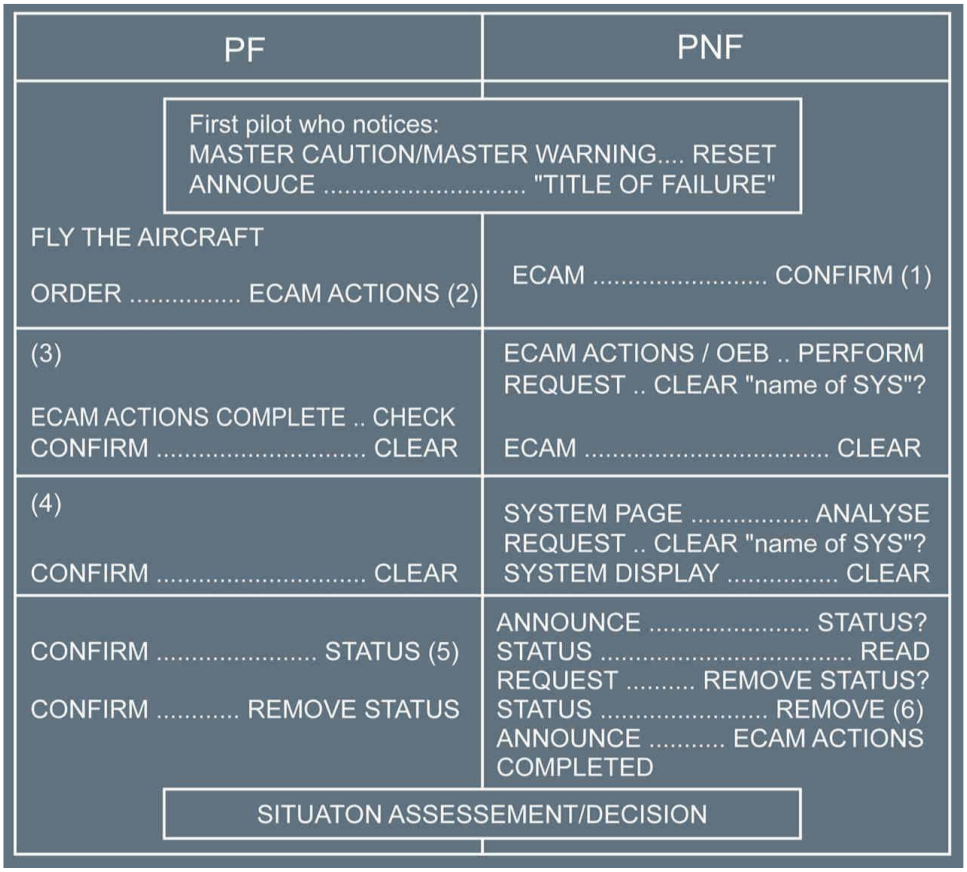
- *The PF's task is to fly the aircraft, navigate, and communicate.*
- *The PNF's task is to manage the failure, on PF command.*

The PF usually remains the PF for the entire flight, unless the Captain decides to take control. The PF will then control the aircraft's flight path, speed, configuration, and engines. The PF will also manage navigation and communication, and initiate the ECAM actions to be performed by the PNF, and check that the actions are completed correctly.

The PNF has a considerable workload: Managing ECAM actions and assisting the PF on request. The PNF reads the ECAM and checklist, performs ECAM actions on PF command, requests PF confirmation to clear actions, and performs actions required by the PF. The PNF never touches the thrust levers, even if requested by the ECAM.

Some selectors or pushbuttons (including the ENG MASTER switch, FIRE pushbutton, […] *and, in general, all guarded switches) must be crosschecked by both the PF and PNF (except on ground), before they are moved or selected, to prevent the flight crew from inadvertently performing irreversible actions.* […].

Crew Coordination



[…]"

1.18 Additional information

1.18.1 Landings without clearance

The flight crew acknowledged the Approach ATCO's instruction to switch to the aerodrome frequency. However, the Aerodrome controller (ADC) was not contacted until after landing, and the flight crew landed without the relevant clearance. The ATCOs involved stated that they were aware that the situation had to be an emergency because of the report of engine failure with request for an immediate return to the airport, even if the flight crew had not explicitly declared an emergency situation. Therefore, the ATCOs had organised all other air traffic accordingly and runway 28 was kept clear for flight ASL 371. In this context, the clearance for landing was of secondary importance to the ATCOs involved.

Landings without clearance are rare incidents and for the most part conclude without hazardous consequences or traffic conflicts. Nevertheless, they present a certain safety hazard. Close examination of 37 reports sent to NASA's[26] Aviation Safety Reporting System (ASRS) resulted, among other things, in the following observations when the contributory factors were analysed:

- Frequency change: in most cases, switching to the tower frequency failed to happen; the approach frequency was selected in more than half of the cases.
- Workload: more than half of the reports claimed a high workload during the final approach.

[26] NASA: National Aeronautics and Space Administration

Furthermore, options for reducing the hazards of landings without clearance were highlighted such as turning on the lights after receiving clearance to land, using the position of the switch as a visual reminder, or consistently switching to the tower frequency after having actioned the landing checklist.

1.19 Useful or effective investigation techniques

None

2 Analysis

2.1 Technical aspects

According to in-depth investigations, material fatigue of the cooling tubes was most likely the cause of the leak in the air-cooled oil cooler (ACOC) (see chapter 1.16); this defect was the trigger for the serious incident investigated here.

It is unsatisfactory that it was no longer possible to establish with certainty what sort of component the defective ACOC was. According to the manufacturer it is only certain that it was not an OEM[27] part. According to the aviation company's technical bookkeeping and the information provided by the former aircraft owner, the component should have had s/n 3427. This has also been confirmed by the documents available to the investigation (see chapter 1.6.2.2.2). The adhesive traces on the defective component could allow the conclusion to be drawn that the defective component had a different s/n other than 0008; however, the corresponding inscription label, for whatever reason, had come loose and got lost.

2.2 Human and operational aspects

2.2.1 General

A technical fault that leads to an engine being switched off does not generally mean that it is a serious incident. As the evaluation of the history of the flight demonstrated operational hazards, however, the situation was rated as a serious incident and subsequently investigated.

2.2.2 Flight crew

According to the voice recordings in the cockpit, the commander commented on the ENG 2 OIL LO PR master warning message without delay. This conduct was appropriate: he made the copilot aware of the situation, relevant as the autopilot had not yet been engaged at that time, and the copilot as PF was predominately focused on controlling the aircraft. Immediately after that, the commander requested an *"immediate return to the airport".* He made this decision without having consulted the copilot and under no time pressure. This contradicts the principles of crew resource management (CRM) in a two-person cockpit and contradicts the good CRM rating that the commander had been attested on several occasions during training (see chapter 1.5.1.1.2).

The flight crew's further action was influenced by this rapid decision from the commander. The rush caused by the decision is a common theme that continued throughout the rest of the flight. Furthermore, the commander unnecessarily burdened himself with radio communications from the outset after his decision, which received optimum support from air traffic control. As a result, all other relevant factors for carrying out the upcoming approach safely were given too little attention. The following points support this conclusion.

The ENG 2 OIL LO PR master warning message is a red warning message that, as a highest-priority warning, demands an immediate response from the flight crew. Performing the first two action points of the ECAM procedure, i.e. positioning the thrust lever of the respective engine to idle and moving the corresponding master switch to the OFF position, would therefore have had the highest priority (see chapter 1.17.1.4, figure 14).

[27] OEM: original equipment manufacturer. An OEM component is an original component, which is manufactured by the aircraft manufacturer themselves or by one of their suppliers.

As a result of communicating with the ATC, more than one minute passed after the master warning message had been triggered, until the thrust lever was moved to the idle position. The master switch had to be mentioned twice and was not moved to the OFF position until 1 minute and 35 seconds after the master warning message had appeared.

The first two ECAM procedures were also not followed as set out in OM B (see chapter 1.17.1.3 'crew coordination'), because a clear separation of the requested and completed actions of the PF and PM is not discernible on the voice recordings (see chapter 1.17.1.3, 'task-sharing'). This also applies to the other procedures.

After the copilot had requested execution of the 'after take-off/climb checklist' and this had been actioned by the flight crew, the commander briefly mentioned the approach briefing. Without the copilot being able to comment on such, a discussion ensued regarding the advantage of a visual approach from the present positon; this discussion was dominated by the commander. In this process, the aircraft's altitude and speed as well as the tailwind of almost 50 kt were without doubt not given the necessary consideration (see annexe 2 and 3).

The decision to immediately return to the airport was made without a situation analysis, as is stated by the aviation company in OM B chapter '3.10.1 evaluate situation (TARD)' (see chapter 1.17.1.3). This should have been carried out after the checklist had been actioned. In the serious incident under investigation, no such situation analysis was carried out prior to the decision to return immediately.

Due to the ENG 2 OIL LO PR master warning message, a situation analysis would have first of all required execution of the checklist (at least the first two action points of the ECAM procedure) before communication with the ATC could have begun. During this time, the flight crew would have remained close to the airport at all times, along the standard instrument departure (SID) route as per DEGES 2L clearance (see annexe 1), and radar vectoring for an approach to one of the three runways would have been possible at any time.

A situation analysis would have also shown that there was no reason for an immediate return. By definition, the LAND ASAP prompt, which was displayed in amber on the ECAM system (see chapter 1.17.1.4, figure 16), did also not call for this (see chapters 1.17.1.3 and 1.17.1.4).

The option of an instrument approach to one of the runways 34/16 or 14, which are 1 km longer, with a standard glideslope angle of 3°, was not considered. The commander's appraisal not to fly a holding pattern because of windmilling time and to stay in VMC and above the glideslope, in the event of failure of the remaining engine, is not convincing. In such case, it is crucial to cut off the fuel supply as quickly as possible. The windmilling time is not important; it might indeed be of interest for maintenance, but carrying out a safe flight is the pilot's primary concern. The fact that planning considerations for the approach included the eventuality of failure of the remaining engine appears to be insufficiently practice-orientated in view of the exceptionally low probability of occurrence applicable for the present case. Against the backdrop of the resulting unstabilised approach, this aspect was given too high a priority.

With the commander's justification above, the incident should have been rated at least as 'moderate non-normal' according to OM B chapter 3.10.3 'risk level' (see chapter 1.17.1.3), which would at least have required sending an urgency message (PAN PAN) and informing the cabin crew and passengers; however neither occurred. As a result, it was not possible for the cabin crew to mentally prepare for the upcoming landing and potential subsequent actions.

The rush mentioned earlier continued into the visual approach, which was shorter than an ILS approach. Due to its position, altitude and speed, it was ultimately not possible to conduct a stabilised final approach on the flight path selected by the flight crew (see annexe 4).

Many resources were subsequently used unnecessarily by the flight crew for controlling the aircraft. An approach briefing was therefore only partially carried out. Exceeding the bank angle of 30° to 37.27° was, in aeronautical terms, a logical consequence of the excessive speed when turning into the final approach. In his supervisory role, the commander did however not mention the high bank angle. Even if there is no respective company procedure defined, the STSB regards it as reasonable to address an exceedance of 30° bank. Similarly, the landing gear and flaps in the final approach were subsequently deployed, whilst the aircraft was nearly exceeding the maximum permissible corresponding speed.

It was however not possible to reduce the excessive speed, because the aircraft was still 1,700 ft above the nominal glideslope when lowering the landing gear. When attempting to aim for a glideslope of about 3° even for the visual approach, the sink rate increased to a maximum value of 2,880 ft/min. During the entire final approach to touchdown, the remaining engine stayed in idle. Among other things, this factor carries the risk that due to the spool-up delay, the flight crew would not immediately be able to assume the positive nose-up attitude, which is required for a safe go-around. The lower yaw moment in idle, brought into the equation by the commander, is also not convincing because this would have been unproblematic even for a stabilised final approach.

The criteria for callouts for configuration changes and during the final approach, as defined in the corresponding handbooks, were not observed (see chapter 1.17.1.2, OM A chapter 8.3.0.6 ‘stabilised approach’; chapter 1.17.1.3, OM B figure 8 and chapter B03 ‘approach’; chapter 1.17.1.4, figure 12 and chapter 1.17.1.6, figure 15). OM B also states (see chapter 1.17.1.3, figure 10) what the PF and PM respectively must call out during an approach from 1,000 ft radio height above ground. None of these callouts can be heard on the voice recordings. It seems clear that the flight crew were under a lot of pressure during the final approach.

Furthermore, there is also no evidence in the form of callouts from the voice recordings, as stated in chapter 1.17.1.6, that the entire ECAM procedure ‘ENG 2 SHUT DOWN’ was completed.

Rather, it can be assumed that after setting the TCAS MODE selector to TA (see Figure 16), the ECAM procedure was not followed any further, the instruction ‘IMBALANCE...MONITOR’ therefore remained displayed on the E/WD and was also read by the copilot as such. This suggests that, as a result, the LDG memo on the E/WD was not displayed to the flight crew. Furthermore, when actioning the landing checklist, the flight crew overlooked the fact that the ground spoilers had not been armed.

A further indication of the flight crew’s capacity overload is the fact that they most probably switched to the aerodrome frequency but did not report on this frequency, and the landing took place without clearance.

After touchdown also, none of the required callouts (see chapter 1.17.1.3, figure 10) can be heard on the voice recordings. It must be assumed that the flight crew did not realise that the ground spoilers had not deployed at touchdown already, but only when reverse thrust was activated. Insofar, that is not surprising as – because of the APU’s late initiation shortly before touchdown – the automatic display of the wheel page was not possible, and consequently, deployment of the ground spoilers could not be checked. In the present case, the wheel page would have had to be manually selected.

By using the wheel brakes immediately after touchdown, this fact did not greatly influence the landing distance.

Insufficient collaboration within the cockpit continued through to the end. The commander did not request execution of the ‘after landing checklist’ until arriving at the parking position, and the copilot did not provide confirmation whether this checklist had been actioned or not.

Even if the two pilots were, according to the company's requirements, no longer classified as 'inexperienced' (cf. chapter 1.17.1.2) and therefore released for crew pairing, the STSB is convinced that in the whole interaction of flight procedures, flight path selection and technical problems, the two pilot's limited experience on Airbus aircraft type played a role.

2.2.3 Aviation company

The procedural requirements set out in OM A and OM B, the FCOM, FCTM and QRH handbooks by the aviation company for the flight crews are generally complete and correspond to the aircraft manufacturer’s specifications. It cannot be ignored, however, that these documents are very substantial and it is not easy for flight crews to find summarised information necessary for safe flight operation. A few examples are listed in the following:

In OM A, which contains general, non-aircraft-specific procedural requirements, CRM principles are listed, as is best practice (see chapter 1.17.1.2). There are, however, no notes on the basic items that an approach briefing, for example, must include. Although the approach briefing is mentioned in OM B (see chapter 1.17.1.3) and also in the QRH (see chapter 1.1.7.1.6), what it should contain as essential pillars for a successful approach is nowhere to be found.

OM B contains additional procedures that are not listed in the aircraft manufacturer’s FCOM. These procedures help the flight crew and therefore represent a sensible addition to the aircraft manufacturer’s procedural requirements. However, the aviation company’s OM B does not just contain the additional procedural requirements; it also contains many procedures and instructions that are quoted verbatim from the FCOM. Any such duplication makes the overview difficult for flight crews and is therefore insufficiently pilot-friendly. It is also difficult to understand why the congruent procedures which are listed under ‘abnormal and emergency procedures’ in the FCOM have the revised title of ‘non-normal procedures’ in OM B. The number of pages of both handbooks alone, i.e. 769 pages for OM B and 5,390 pages for the FCOM, show that an overview is barely possible, and it is doubtful whether procedural revisions in these handbooks can be detected, let alone be processed by the flight crews.

2.2.4 Air traffic control

Air traffic control supported the flight crew in an optimal way from the beginning. They acted in a safety-conscious way by immediately recognising an emergency situation, even in the absence of an urgency (PAN PAN) or distress (MAYDAY) message, and keeping runway 28 clear for flight ASL 371 and rearranging all other air traffic. They monitored the flight path and, 6 NM before the runway threshold, made the flight crew aware that they were too high for a direct approach. This message was appropriate for the situation and forward-thinking.

3 Conclusions

3.1 Findings

3.1.1 Technical aspects

- The aircraft was licensed for instrument flight rules (IFR) traffic.
- At the time of the serious incident, both mass and centre of gravity of the aircraft were within the permissible limits of the AFM.
- It is most likely that material fatigue of the cooling tubes led to a leak in the air-cooled oil cooler (ACOC).
- The defective air-cooled oil cooler (ACOC) was not an OEM component.
- Apart from that, the investigation did not find any indication of pre-existing technical defects which could have caused or influenced the serious incident.

3.1.2 Crew

- The flight crew were in possession of the required licences for the flight.
- There is no indication of impairment to the flight crew's health during the serious incident.

3.1.3 Course of the serious incident

- At 08:39:42 UTC the aircraft took off. The recordings show an ENG 2 oil quantity of 4.25 QTS (right engine) at this point, which decreased to a value of 0 over the next 23 seconds.
- At 08:40:40 UTC, the ENG 2 OIL LO PR master warning message was generated in the cockpit and appeared on the electronic centralised aircraft monitoring (ECAM) system, combined with an acoustic warning chime.
- Without having consulted the copilot, the commander requested a radar vectoring approach from the air traffic control officer (ATCO) for an immediate return to the airport.
- At 08:41:44 UTC, the commander initiated the ECAM procedure and 31 seconds later, or 1 minute and 35 seconds after the master warning message had appeared on the ECAM system, the ENG 2 master switch was moved to the OFF position.
- After the copilot had requested execution of the 'after take-off/climb checklist' at 08:44:09 UTC, the commander mentioned that it would be best to perform a visual approach to runway 28. The copilot did not intervene.
- Definite execution of the 'after take-off/climb checklist' is not discernible from the recordings.
- At 08:44:25 UTC, the flight crew requested a visual approach. The ATCO complied with this request and gave the flight crew the instruction to turn onto a westerly heading.
- The recordings show that the flight crew selected this heading at 08:44:57 UTC. By this time, the aircraft was just under 3 miles north of runway 28's runway axis. The aircraft was at an altitude of 7000 ft QNH and the indicated air speed was 252 kt.
- A few seconds later, the conversation in the cockpit was akin to an approach briefing. They pointed out the high speed and established that the aircraft was a little high for the approach.

- At 08:45:42 UTC, the aircraft crossed the approach axis of runway 28 with an IAS of 250 kt at an altitude of 6150 ft QNH and therefore about 1750 ft above the nominal glideslope of 3.3°. The distance to the runway threshold was 8.8 NM, and 3 seconds later, the aircraft's bank angle reached the maximum value of 37.27°.
- At 08:45:59 UTC, the speed brakes were deployed following mutual agreement.
- The flaps and the landing gear were subsequently deployed, only just staying within the maximum permissible speed for the gear and slats/flaps operation. During this phase, the sink rate was consistently in excess of 1000 ft/min, reaching a maximum value of over 3000 ft/min.
- At a radio height (RH) of 1000 ft, the sink rate was 1320 ft/min and the indicated air speed (IAS) was 195 kt. Immediately afterwards, the speed brakes were retracted.
- At a radio height of 500 ft, the sink rate was 1115 ft/min and the IAS was 149 kt. It was therefore 9 kt above the correct approach speed of 140 kt. The remaining engine remained idle during the final approach until after landing.
- When the flight crew actioned the landing checklist, the LDG memo was not available to them as not all of the 'ENG 2 SHUT DOWN' ECAM procedures had been carried out at this point in time.
- The landing checklist had not been entirely actioned, as the ground spoilers had not been armed.
- At 08:48:38 UTC, the aircraft touched down 320 m beyond the runway threshold with an IAS of 136 kt, first with the left-hand side, and two seconds later with the right-hand side main landing gear.
- The brake pedals were then immediately applied. The ground spoilers did not deploy, which the flight crew were not aware of.
- Seven seconds later, when the flight crew activated reverse thrust, the ground spoilers were automatically deployed.
- The aircraft came to a standstill about 60 m beyond the point where runway 28 crosses with runway 16.
- The aircraft taxied under its own power to the allotted parking position. The crew and passengers, who had not been notified by the flight crew of what had been going on during the flight, were able to exit the aircraft normally.

3.1.4 General conditions

- The weather had no negative influence on the development of the serious incident.

3.2 Causes

The serious incident is attributable to the fact that, shortly after take-off, the flight crew, in an overhasty manner and without prior analysis of the situation, initiated a risky landing approach, after having switched off the right engine as a result of a leak in the air-cooled oil cooler.

The following factors contributed to the serious incident:

- Poor crew resource management within the flight crew;
- Non-compliance with systems and operational requirements;
- The flight crew's limited experience on the aircraft type.

The investigation established that the following factors, which although they did not influence the development and course of the serious incident, nevertheless still represent factors to risk:

- Engine was not switched off immediately after the master warning message had appeared;
- The flight crew landed the aircraft without having received or requested landing clearance.

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

4.1 Safety recommendations

None

4.2 Safety advices

None

4.3 Measures taken since the serious incident

The aviation company carried out its own investigation of the serious incident and recorded the results in a corresponding internal report. The aviation company published the following safety recommendations as learnings from the serious incident:

- *"Flight crew remedial training emphasizing procedural discipline, situational awareness, standard ATC & cabin communication as well as decision making skills*
- *Safety bulletin info to be published for all pilots*
- *Present ZRH incident on next Safety Seminar*
- *Check maintenance logs/historical data for similar failures and consult Airbus*
- *Review ERP*[28] *procedures NOC*[29] *duties"*

Payerne, 14 November 2016 Investigation Bureau of the STSB

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).

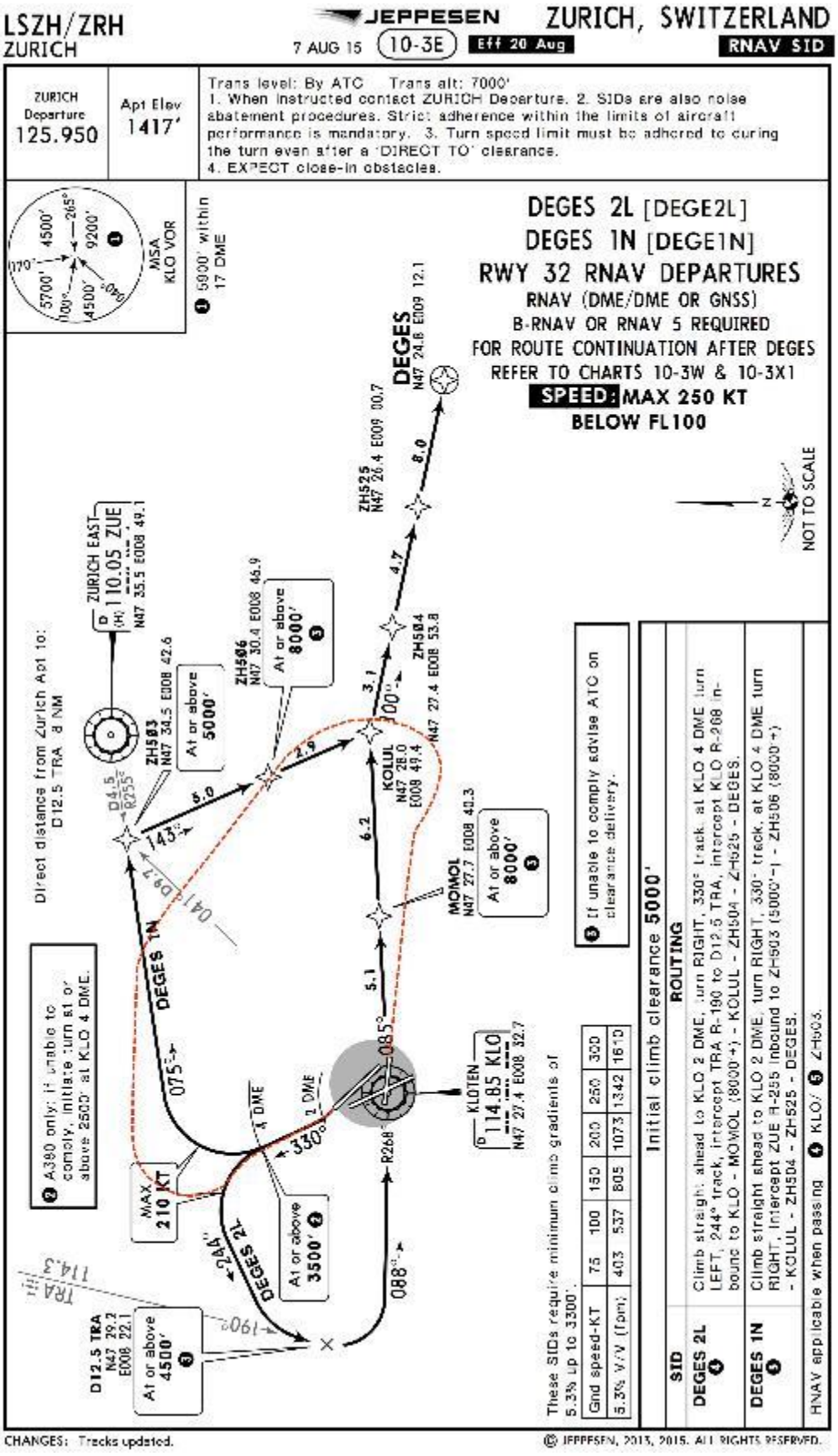
Berne, 3 November 2016

28 ERP: emergency refresher program

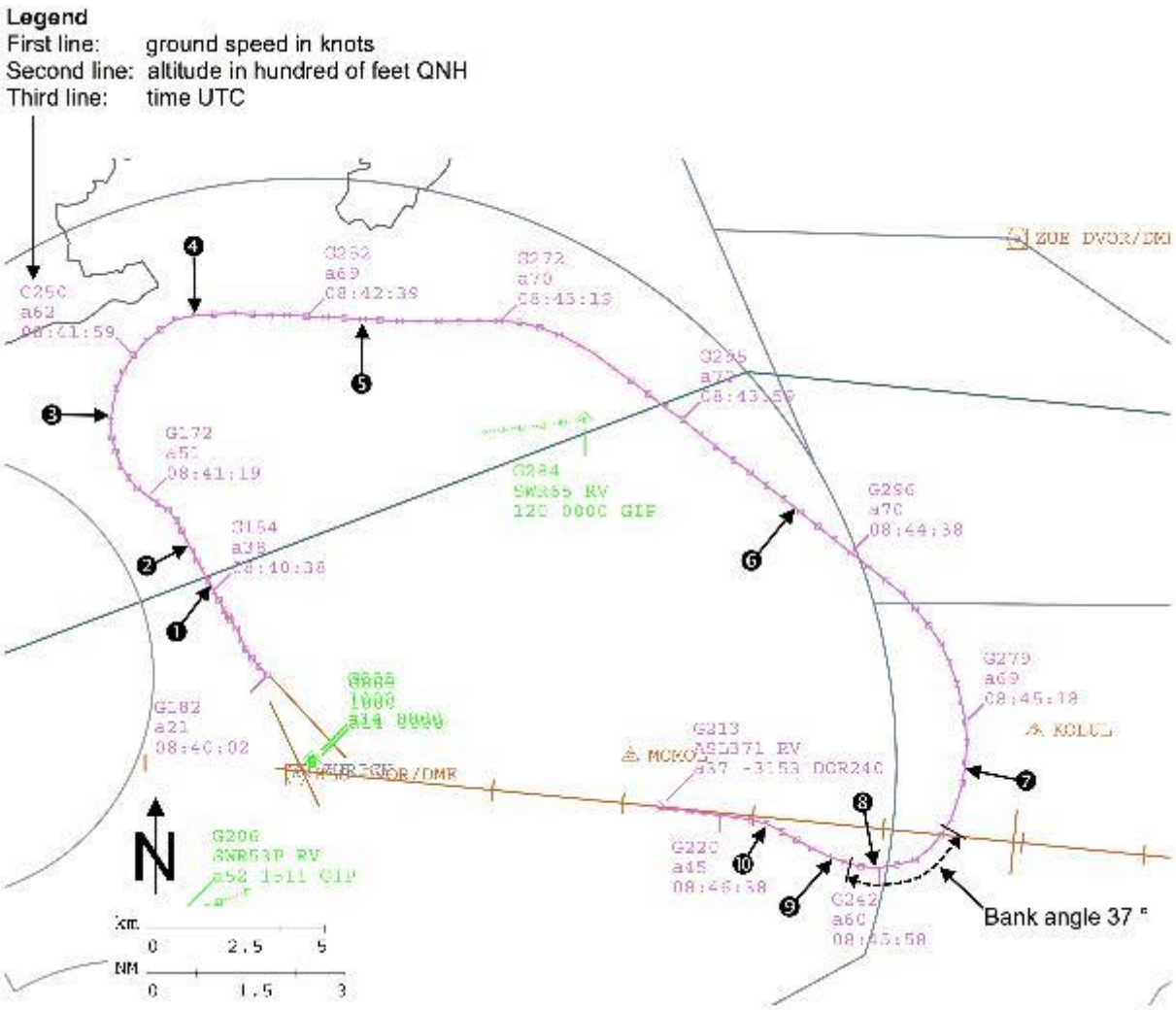
29 NOC: network operations centre

Annexes

Annex 1: Standard instrument departure (SID) DEGES 2L

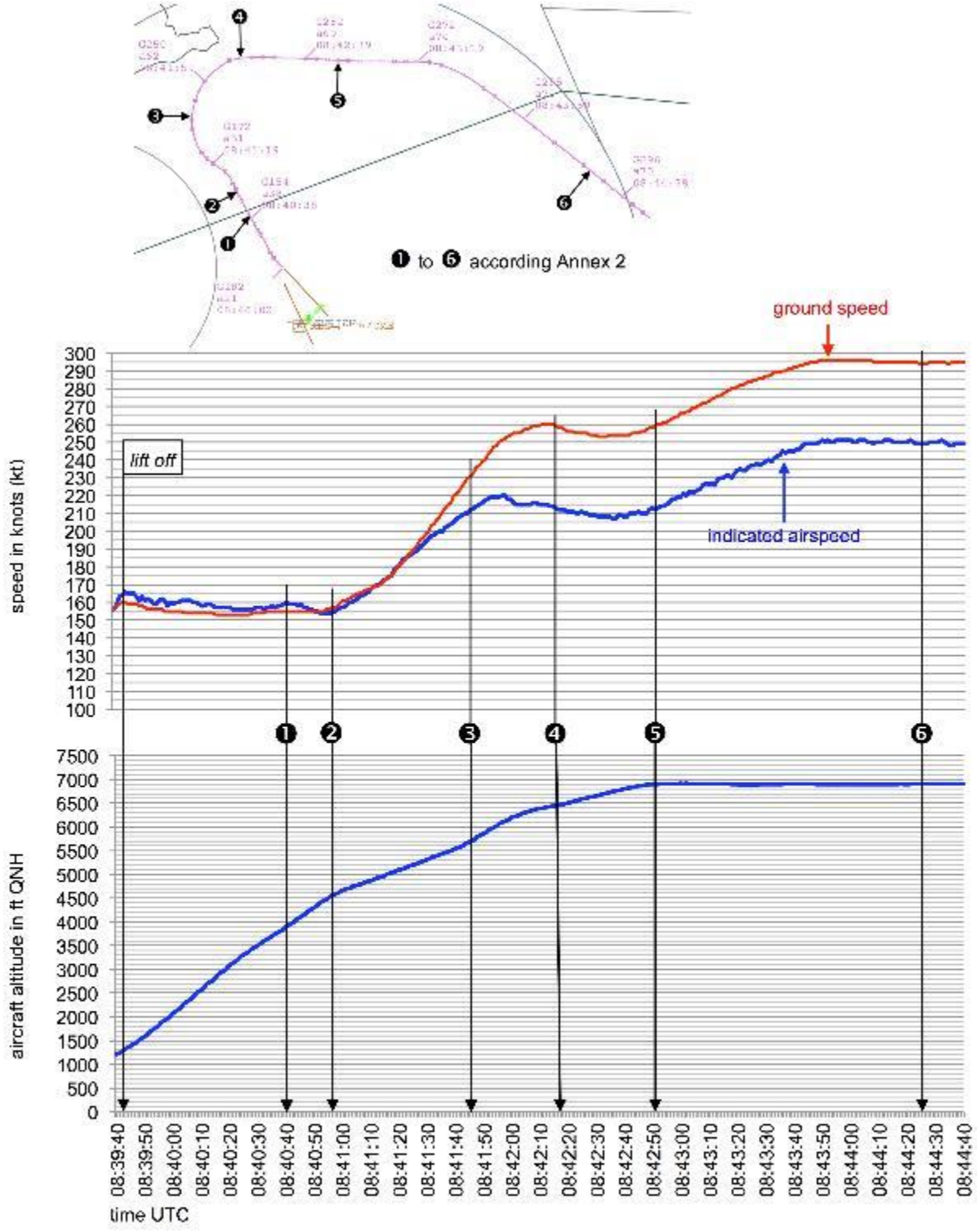


Annex 2: YU-APA's flight path and history of the flight



❶	**08:40:40 UTC**	Master warning ENG2 OIL LO PR is triggered
❷	**08:40:56 UTC**	The commander reports: *„Air Air Serbia uh three seven one, request immediately return to the airport please."*
❸	**08:41:44 UTC**	The commander starts to execute the ECAM procedure
❹	**08:42:15 UTC**	The right engine master switch is set to OFF
❺	**08:42:51 UTC**	The flight crew confirms: *„Uh yes we are ready and uh..please radar vectoring for runway two eight, uh maybe we will prefer from this position visual approach for two eight."*
❻	**08:44:25 UTC**	The flight crew confirms that they have visual contact to runway 28
❼	**08:45:27 UTC**	The autopilot (AP) is switched OFF
❽	**08:45:59 UTC**	The speed brakes get fully extended
❾	**08:46:09 UTC**	The gear gets extended
❿	**08:46:26 UTC**	The ATCO asks the crew whether they will make it because they were slightly high

Annex 3: History of the flight after take-off



❶	**08:40:40 UTC**	Master warning ENG2 OIL LO PR is triggered
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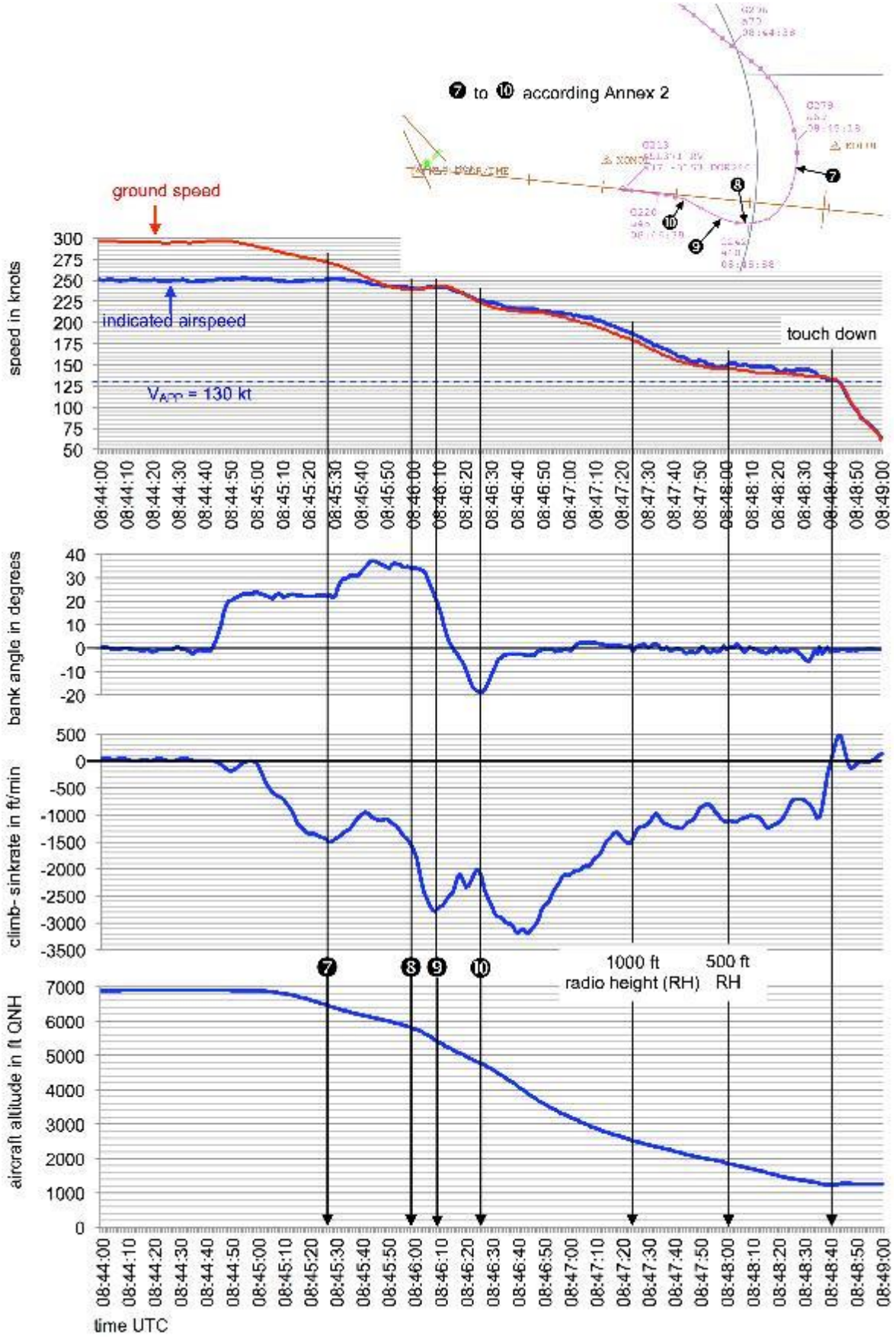
❸	**08:41:44 UTC**	The commander starts to execute the ECAM procedure
❹	**08:42:15 UTC**	The right engine master switch is set to OFF
❺	**08:42:51 UTC**	The flight crew confirms: *„Uh yes we are ready and uh..please radar vectoring for runway two eight, uh maybe we will prefer from this position visual approach for two eight."*
❻	**08:44:25 UTC**	The flight crew confirms that they have visual contact to runway 28

Annex 4: History of the flight when turning in and flying the final approach



Annex 5: Procedure according to the QRH

AFTER TAKEOFF

PF	PNF
	APU BLEED pb-sw.....AS RQRD
	APU MASTER SW.....AS RQRD
	ENG MODE selector.....AS RQRD
	TCAS Mode selector .....TA/RA
	ANTI ICE pb-sw.....AS RQRD
AFTER TAKEOFF/CLIMB C/L down to the line.....COMPLETE	AFTER TAKEOFF/CLIMB C/L down to the line.....COMPLETE

CLIMB

PF	PNF
MCDU.....PERF CLB	MCDU.....F-PLN
FCU/FMGS.....SET IF AP ON	FCU/FMGS.....SET IF AP OFF
•At transition altitude:	
BAROMETRIC REFERENCE.....SET STD/CROSSCHECK	BAROMETRIC REFERENCE.....SET STD/CROSSCHECK
AFTER TAKEOFF/CLIMB C/L below the line.....COMPLETE	AFTER TAKEOFF/CLIMB C/L below the line.....COMPLETE
RADAR.....ADJUST AS APPROPRIATE	ENG ANTI ICE.....AS RQRD
•At 10 000 ft:	
	LAND LIGHTS selector.....RETRACT
	SEAT BELTS sw.....AS RQRD
EFIS OPTION.....AS RQRD	EFIS OPTION.....AS RQRD
	ECAM MEMO.....REVIEW
	NAVAIDS.....CLEAR
	SEC F-PLN.....AS RQRD
	OPT/MAX ALT.....CHECK

DESCENT PREPARATION

PF	PNF
	WEATHER AND LANDING INFORMATION.....OBTAIN
LANDING PERFORMANCE.....CONFIRM	LANDING PERFORMANCE.....CHECK
FMS.....PREPARE	FMS PREPARATION.....CHECK
	GPWS LDG FLAP 3.....AS RQRD
LDG ELEV.....CHECK	
AUTO BRK.....AS RQRD	
APPR BRIEFING.....PERFORM	
TERR ON ND .....AS RQRD	TERR ON ND .....AS RQRD
RADAR.....ADJUST AS APPROPRIATE	
	ENG ANTI ICE pb-sw.....AS RQRD
	WING ANTI ICE pb-sw.....AS RQRD
	DESCENT CLEARANCE.....OBTAIN
CLEARED ALTITUDE ON FCU.....SET	

DESCENT

PF	PNF
DESCENT.....INITIATE	
MCDU..... PROG/PERF DESCENT	MCDU.....F-PLN
DESCENT.....MONITOR/ADJUST	
•When the aircraft approaches the transition level, and when cleared for an altitude:	
BAROMETRIC REFERENCE..... SET/CROSSCHECK	BAROMETRIC REFERENCE..... SET/CROSSCHECK
	ECAM STATUS..... CHECK
•At 10 000 ft:	
	LAND LIGHTS selector.....SET
	SEAT BELTS sw..... ON
EFIS option pb.....CSTR	EFIS option pb.....CSTR
LS pb ..... AS RQRD	LS pb..... AS RQRD
	RADIO NAV.....SELECT/IDENT
	ENG MODE selector..... AS RQRD
•If GPS PRIMARY not available:	
NAV ACCY..... CHECK	
APPROACH C/L.....COMPLETE	APPROACH C/L.....COMPLETE

AIRCRAFT CONFIGURATION FOR APPROACH

PF	PNF
INITIAL APPROACH:	
F-PLN SEQUENCING.....ADJUST	
•Approx 15 nm from touchdown:	
APPR PHASE ..... ACTIVATE or set green dot (1)	
MANAGED SPEED..... CHECK	
FLIGHT PATH.....MONITOR	NAV ACCURACY..... MONITOR
SPEED BRAKES lever.....AS RQRD	
RADAR..... ADJUST AS APPROPRIATE	
INTERMEDIATE/FINAL APPROACH:	
•At green dot:	
FLAPS 1.....ORDER	FLAPS 1.....SELECT
S SPEED..... CHECK OR SET (1)	
	TCAS ..... TA or TA/RA
•At 2 000 ft AGL:	
FLAPS 2.....ORDER	FLAPS 2.....SELECT
F SPEED..... CHECK OR SET (1)	
•When FLAPS 2:	
L/G DOWN..... ORDER	L/G..... SELECT DOWN
	AUTO BRAKE.....CONFIRM
	GRND SPLRS..... ARM
	EXTERIOR LIGHTS..... SET
•When L/G down:	
FLAPS 3.....ORDER	FLAPS 3.....SELECT
	ECAM WHEEL PAGE.....CHECK

Continued from the previous page

PF	PNF
•When FLAPS 3:	
FLAPS FULL..... ORDER	FLAPS FULL..... SELECT
	VAPP..... CHECK OR SET (1)
	A/THR..... CHECK SPD or OFF
	WING A. ICE (if not required)..... OFF
SLIDING TABLE ..... STOW	SLIDING TABLE ..... STOW
	LDG MEMO..... CHECK NO BLUE
CABIN REPORT..... RECEIVE	CABIN REPORT..... RECEIVE
	CABIN CREW..... ADVISE
LDG C/L..... COMPLETE	LDG C/L..... COMPLETE
ANNOUNCE ANY FMA MODIFICATION	FLT PARAMETERS..... MONITOR
	Announce any deviation in excess of: • V/S: 1 000 ft/min • IAS: speed target +10 kt; VAPP -5 kt • PITCH: 2.5 ° nose down; 10 ° nose up • BANK: 7 °

(1) PF if AP is ON, PNF if AP is OFF. The PF may request that this action is performed by the PNF depending on the situation.