



# Havarikommissionen

Accident Investigation Board Denmark

## Report 2022-150



### **Serious incident to CS-TNV (Airbus A320-214) in Copenhagen/Kastrup (EKCH) on 8-4-2022**

ISSUED FEBRUARY 2024

# INTRODUCTION

This report reflects the opinion of the Danish Accident Investigation Board regarding the circumstances of the occurrence and its causes and consequences.

In accordance with the provisions of EU Regulation 996/2010, the Danish Air Navigation Act and pursuant to Annex 13 of the International Civil Aviation Convention, the safety investigation is of an exclusively technical and operational nature, and its objective is not the assignment of blame or liability.

The safety investigation was carried out without having necessarily used legal evidence procedures and with no other basic aim than preventing future accidents and serious incidents.

Consequently, any use of this report for purposes other than preventing future accidents and serious incidents may lead to erroneous or misleading interpretations.

A reprint with source reference may be published without specific permission.

# CONTENTS

<b>GENERAL .....</b>	<b>7</b>
<b>SYNOPSIS .....</b>	<b>8</b>
<b>1 FACTUAL INFORMATION.....</b>	<b>9</b>
1.1 History of flight.....	9
1.2 Injuries to persons .....	10
1.3 Damage to aircraft.....	11
1.4 Other damage .....	11
1.5 Personnel information.....	11
1.5.1 The commander.....	11
1.5.1.1 License and medical certificate.....	11
1.5.1.2 Flying experience.....	11
1.5.1.3 Flying experience at the operator.....	11
1.5.1.4 Operator training.....	11
1.5.1.5 Flight and duty time.....	11
1.5.2 The first officer .....	12
1.5.2.1 License and medical certificate.....	12
1.5.2.2 Flying experience.....	12
1.5.2.3 Flying experience at the operator.....	12
1.5.2.4 Operator training.....	12
1.5.2.5 Flight and duty time.....	12
1.6 Aircraft information .....	12
1.6.1 General information .....	12
1.6.2 Mass and balance .....	13
1.6.3 Aircraft type certification.....	13
1.6.4 CFM56 engine.....	13
1.6.5 Thrust reverser system .....	13
1.6.5.1 Thrust lever control.....	13
1.6.5.2 Thrust reverser halves.....	15
1.6.5.3 Engine Control Unit (ECU).....	16
1.6.5.4 Hydraulic Control Unit (HCU).....	18
1.6.5.5 Independent locking system.....	18
1.6.6 Primary Flight Display (PFD) sideslip index.....	19
1.6.7 Procedures for use of reverse thrust .....	20
1.6.7.1 Flight Crew Operating Manual (FCOM).....	20

1.6.7.2	Flight Crew Technique Manual (FCTM).....	21
1.6.7.3	Operator safety bulletin .....	21
1.6.8	Landing performance calculation.....	21
1.7	Meteorological information .....	22
1.7.1	Terminal Aerodrome Forecast (TAF) .....	22
1.7.2	Aviation Routine Weather Report (METAR) .....	22
1.7.3	Aftercast valid for EKCH at 10:05 hrs.....	22
1.7.4	Automatic Terminal Information Service (ATIS).....	23
1.8	Aids to navigation .....	24
1.9	Communication.....	24
1.10	Aerodrome information .....	24
1.10.1	General information .....	24
1.10.1.1	Runway 30 .....	24
1.10.1.2	Runway 22L.....	24
1.10.2	Aerodrome chart for EKCH .....	24
1.10.3	Notice to Airmen (NOTAM) .....	24
1.11	Flight recordings .....	24
1.11.1	SSFDR data.....	25
1.11.2	SSCVR data .....	25
1.11.3	DAR data.....	25
1.11.4	Data from aircraft systems .....	25
1.11.5	ECU memory .....	25
1.11.6	Surface movement radar .....	26
1.11.7	EKCH Surveillance camera (CCTV) recordings .....	26
1.11.8	Ground plot .....	28
1.11.9	Sequence of events.....	29
1.12	Wreckage and impact information.....	29
1.13	Medical and pathological information .....	30
1.14	Fire .....	30
1.15	Survival aspects .....	30
1.16	Tests and research.....	30
1.16.1	Aircraft inspection and testing .....	30
1.16.2	Off wing inspections of engine #1 thrust reverser and associated hardware .....	31
1.16.2.1	Detailed inspections and testing of HCU, PDLs and actuators .....	31
1.16.2.2	Actuators load capability testing.....	33
1.16.2.3	TRSOV test.....	34
1.16.2.4	Filter housing test .....	34
1.16.3	Investigation of ECU software and thrust reverser operating logic .....	35

1.17	Organisation and management.....	37
1.17.1	The operator .....	37
1.17.2	Flight crew procedure and system knowledge .....	37
1.17.2.1	Previous occurrence.....	37
1.17.2.2	Crew interviews after the serious incident.....	38
1.18	Additional information.....	38
1.18.1	Consultation of the regulating and certifying airworthiness authority (EASA).....	38
1.18.1.1	Regulatory requirements for the design and certification of thrust reverser systems .....	38
1.18.1.2	Safety concerns associated to the A320 family thrust reverser logic embedded in the CFM56 ECU software .....	40
1.18.2	The aircraft manufacturer design and operational review of the thrust reverser system .....	40
1.19	Useful or effective investigation techniques .....	41
<b>2</b>	<b>ANALYSIS.....</b>	<b>42</b>
2.1	General.....	42
2.2	Approach.....	42
2.3	Go-around and flight procedures .....	42
2.4	Engine #1 thrust reverser not stowing.....	43
2.5	Technical investigation of the engine #1 thrust reverser hardware.....	44
2.6	Technical investigation of the ECU software logic and system design .....	44
2.7	The aircraft manufacturer design and operational review of the thrust reverser system .....	45
2.8	Safety actions.....	45
2.9	Certification requirements for the design of thrust reverser systems.....	46
<b>3</b>	<b>CONCLUSIONS.....</b>	<b>47</b>
3.1	Findings .....	47
3.1.1	General.....	47
3.2	Factors.....	48
3.3	Summary .....	48
<b>4</b>	<b>SAFETY RECOMMENDATIONS .....</b>	<b>50</b>
4.1	Preventative safety actions.....	50
4.2	Safety recommendations.....	50
4.2.1	CFM56 ECU software modification .....	50
4.2.1.1	Motivation.....	50
4.2.1.2	Safety recommendation no. DK.SIA-2024-0001 .....	50
4.2.2	EASA Certification Specifications for Large Aeroplanes (CS-25).....	51
4.2.2.1	Motivation.....	51

4.2.2.2	Safety recommendation no. DK.SIA-2024-002 .....	51
4.3	Additional proposed safety actions .....	51
4.3.1	Design review of thrust reverser systems on other aircraft types.....	51
4.3.2	Training of and adherence to SOPs.....	52
4.3.3	Use of FDM to monitor adherence to SOPs.....	52
<b>5</b>	<b>APPENDICES .....</b>	<b>53</b>
5.1	Final loadsheet .....	54
5.2	FCOM landing SOP extract .....	55
5.3	FCTM extract.....	57
5.4	Operator safety bulletin extract.....	58
5.5	Stevns reflectivity weather radar image.....	59
5.6	AIP Denmark aerodrome chart - EKCH .....	60
5.7	Operator airport facility chart - EKCH .....	61
5.8	SSFDR plot .....	62
5.9	DAR data plot .....	63
5.10	List of ECU thrust reverser fault codes.....	64
5.11	Ground plot .....	65
5.12	HCU CMM test results .....	66
5.13	PDLs CMM test results.....	67
5.14	Actuators CMM test results .....	68
5.15	Actuators load capability test results .....	69
5.16	TRSOV CMM test results.....	70
5.17	Filter housing test results .....	71
5.18	Revised FCOM landing SOP extract .....	72

**GENERAL**

State file number:	2022-150
UTC date:	8-4-2022
UTC time:	10:05
Occurrence class:	Serious incident
Location:	Copenhagen/Kastrup (EKCH)
Injury level:	None
Aircraft registration:	CS-TNV
Aircraft make/model:	Airbus A320-214
Current flight rules:	Instrument Flight Rules (IFR)
Operation type:	Scheduled
Flight phase:	Landing
Aircraft category:	Fixed wing
Last departure point:	Lisbon (LPPT)
Planned destination:	Copenhagen/Kastrup (EKCH)
Aircraft damage:	None
Engine make/model:	2 x CFMI CFM56-5B4/3

## SYNOPSIS

### Notification

All time references in this report are Coordinated Universal Time (UTC).

The Aviation Unit of the Danish Accident Investigation Board (AIB) was notified of the serious incident by the Portuguese Gabinete de Prevenção e Investigação de Acidentes com Aeronaves e de Acidentes Ferroviários (GPIAAF) on 8-4-2022 at 11:44 hours (hrs) and by Copenhagen Area Control Centre on 8-4-2022 at 12:27 hrs.

The AIB notified the Danish Civil Aviation and Railway Authority (DCARA), the French Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA), the Portuguese GPIAFF, the European Aviation Safety Agency (EASA), the International Civil Aviation Organization (ICAO) and the Directorate-General for Mobility and Transport (DG MOVE) on 8-4-2022 at 15:47 hrs.

The AIB notified the United States (US) National Transportation Safety Board (NTSB) on 20-4-2022 at 09:57 hrs, and the United Kingdom (UK) Air Accident Investigation Branch (AAIB) on 8-6-2022 at 12:56 hrs.

All safety investigation authorities appointed accredited representatives to the AIB safety investigation.

The accredited representatives appointed technical advisers (the operator, the aircraft manufacturer, the engine manufacturer and the thrust reverser hardware manufacturers) to the AIB safety investigation.

The US Federal Aviation Administration (FAA) requested participation in the AIB safety investigation. The AIB accepted the request, and the FAA acted as a technical adviser to the NTSB.

### Summary

During landing in gusty wind conditions, the commander felt uncomfortable with the aircraft attitude and decided, after thrust reversers had been selected, to abort the landing. The commander moved the thrust levers fully forward (selected Take-Off and Go-Around (TOGA) thrust) which deviated from the procedure in the Flight Crew Operating Manual (FCOM) stipulating that once thrust reversers had been selected, the landing had to be completed.

Engine #2 thrust reverser stowed, and engine #2 accelerated. Engine #1 thrust reverser did not stow, and Engine Control Unit (ECU) #1 commanded engine #1 to autoidle. The commander experienced difficulties in controlling and achieving the maximum capabilities of the aircraft but managed to regain control. The aircraft continued climbing and the flight crew shut down engine #1 to regain better control of the aircraft. The aircraft subsequently landed without any further occurrences.

The AIB safety investigation identified that engine #1 thrust reverser did not stow since ECU #1 did not receive a ground signal at the same time, as thrust lever #1 position signal changed from reverse to forward thrust.

Based on the findings during the safety investigation, the aircraft manufacturer implemented several safety actions, and the AIB issued two safety recommendations.

The serious incident occurred in daylight and under Visual Meteorological Conditions (VMC).



## 1 FACTUAL INFORMATION

### 1.1 History of flight

The serious incident occurred during a scheduled IFR flight from Lisbon (LPPT) to Copenhagen, Kastrup (EKCH).

The flight was uneventful until landing at EKCH. At the time of the serious incident, the commander was Pilot Flying (PF) and the first officer was Pilot Monitoring (PM).

Due to prevailing strong westerly winds, runway 30 was the sole runway in use for both take-offs and landings in EKCH.

Before the approach and by using their Electronic Flight Bags (EFB), the flight crew performed three landing performance calculations for runway 30 planning for minimum runway occupancy. The flight crew decided to land in configuration 3 (CONF3) (flaps 20°) and with autobrakes set to medium.

Copenhagen Approach issued a clearance for an Instrument Landing System (ILS) approach to runway 30.

Throughout the approach, the aircraft encountered turbulence and intermittent rain showers.

Established on the ILS approach to runway 30, the flight crew contacted Kastrup Tower.

Kastrup Tower requested the flight crew to vacate runway 30 via taxiway D after landing (1,530 meters (m) from the threshold).

The commander commented that “ATC was asking too much” and informed the first officer that it required full reverse for a CONF3 landing and a final approach speed of “140 knots (kt) - five kt more”.

The aircraft was configured for landing, and the first officer completed the final approach checklist.

At a radio height of approximately 1,400 feet (ft), the commander disengaged the autopilot. The flight crew got visual contact with the runway which was wet.

The Calibrated Air Speed (CAS) from 1,000 ft radio height down to 50 ft radio height varied between approximately 169 kt CAS and 146 kt CAS. Throughout the approach, the aircraft remained stabilised on both localiser and glidepath.

When the aircraft passed approximately 200 ft radio height, Kastrup Tower cleared the aircraft to land and reported the wind conditions to be 250° 21 kt gusting to 31 kt.

Approaching touchdown, the following automatic cockpit callouts sounded: “50, 40, 30, 20, RETARD, RETARD, RETARD, RETARD”.

During the flare, at approximately 10 ft radio height and with a CAS of 144 kt, the commander retarded both thrust levers to idle.

While aligning for landing, the aircraft drifted slightly right of the runway centreline. The aircraft banked briefly to the left (7.4°). Left Hand (LH) main wheel spin up occurred. The commander unlatched and pulled the thrust levers fully rearward to select maximum reverse thrust (REV MAX) on both engines.

Shortly after, both MLG shock absorbers compressed (Weight On Wheels (WOW)/squat/ground signal), and the thrust reversers started deploying on both engines.

Factual information

The aircraft bounced, and the LH MLG shock absorber extended which removed the WOW signal. During the same period of time, the commander felt uncomfortable with the aircraft attitude, moved the thrust levers forward and selected TOGA thrust to abort the landing.

Engine #2 (Right Hand (RH)) thrust reverser stowed, and engine #2 started accelerating to TOGA thrust. Engine #1 (LH) thrust reverser did not stow, and engine #1 remained at idle.

The commander called for a go-around flap setting (CONF2, flaps 15°) which was selected by the first officer.

The commander experienced unanticipated difficulties controlling the aircraft, and the aircraft started drifting left of the runway centreline. The commander applied a maximum of 55% of full right rudder input during the initial part of the go-around and climb-out.

The aircraft became airborne with a pitch of approximately 8.8° nose-up and passed the LH runway edge with a few feet of ground clearance. The Primary Flight Display (PFD) sideslip indication (Beta target) changed to a flag indication (SI).

The unusual aircraft behaviour and lack of expected performance surprised the flight crew.

At a position approximately 1,600 m past the runway threshold, approximately 65 m left of the runway centreline, at 11 ft radio height, with a CAS of 140 kt, and with a low rate of climb, the commander called, and the first officer selected, the landing gear lever to the up position.

The first officer reported “Go-around” to Kastrup Tower.

The first officer observed an ENG1 REVERSE UNLOCKED alert on the Electronic Centralized Aircraft Monitor (ECAM) display, and the flight crew now realised the cause of the unusual aircraft behaviour and performance.

The first officer confirmed that engine #1 thrust was at idle.

Shortly after the landing gear was retracted, the aircraft pitch was increased to approximately 12.5° nose-up, and the vertical speed reached approximately 1,000 ft/minute (min).

At an altitude of approximately 300 ft radio height, the commander declared an emergency (MAYDAY) to Kastrup Tower and requested clearance to climb straight ahead to 3,000 ft. Kastrup Tower acknowledged the emergency and approved the request.

The flight crew performed applicable ENG1 REVERSE UNLOCKED ECAM actions, including, when passing approximately 1,200 ft radio height, a shutdown of engine #1.

Subsequently, the flight crew performed a single engine approach and landing to runway 22L and taxied to parking.

On the aircraft stand, engine #1 thrust reverser blocker doors were confirmed to be out of stowed position.

**1.2 Injuries to persons**

<i>Injuries</i>	<i>Crew</i>	<i>Passengers</i>	<i>Others</i>
Fatal			
Serious			
None	7	102	

**1.3 Damage to aircraft**

During the sequence of events, the aircraft sustained no damages.

**1.4 Other damage**

None

**1.5 Personnel information**

**1.5.1 The commander**

**1.5.1.1 License and medical certificate**

The commander - male, 40 years - was the holder of a valid European Union Airline Transport Pilot License (Airplane) (ATPL (A)) issued by the Portuguese Civil Aviation Administration.

The ratings A320 and Instrument Rating/Performance Based Navigation (Multi Engine) (IR/PBN (ME)) were valid until 28-2-2023.

The medical certificate (class 1) was valid until 29-8-2022.

**1.5.1.2 Flying experience**

	Last 24 hours	Last 90 days	Total
All types	4	86	10,000
This type	4	86	5,000
Landings this type	1	30	-

**1.5.1.3 Flying experience at the operator**

	Total
All types	8,705
This type	3,348

**1.5.1.4 Operator training**

- On 29-1-2022, the commander performed his latest A320 License Proficiency Check/Operator Proficiency Check (LPC/OPC).
- On 21-3-2022, the commander performed his latest line check.
- The AIB obtained the commander training records (LPC/OPC/Line Check) for the previous three years. The records did not reveal deviations from Standard Operating Procedures (SOP).

**1.5.1.5 Flight and duty time**

	Last 24 hours	Last seven days
Flight Duty Period (FDP) hours:	4:58	4:58
Operator Duty Period (DP) hours:	5:28	5:28

## 1.5.2 The first officer

## 1.5.2.1 License and medical certificate

The first officer - male, 34 years - was the holder of a valid European Union Commercial Pilot License (Airplane) (CPL (A)) issued by the Portuguese Civil Aviation Administration.

The ratings A320 and IR/PBN (ME) were valid until 31-3-2023.

The medical certificate (class 1) was valid until 14-4-2023.

## 1.5.2.2 Flying experience

	Last 24 hours	Last 90 days	Total
All types	4	57	3,160
This type	4	57	2,000
Landings this type	1	23	800

## 1.5.2.3 Flying experience at the operator

	Total
All types	989
This type	989

## 1.5.2.4 Operator training

- On 14-3-2022, the first officer performed his latest A320 LPC/OPC.
- On 16-9-2021, the first officer performed his latest line check.
- The AIB obtained the first officer training records (LPC/OPC/Line Check) for the previous three years. The records did not reveal deviations from SOP.

## 1.5.2.5 Flight and duty time

	Last 24 hours	Last seven days
FDP hours:	4:58	12:35
DP hours:	5:28	14:05

**1.6 Aircraft information**

## 1.6.1 General information

Manufacturer:	Airbus
Type:	A320-214
Serial number:	04145
Airworthiness review certificate:	Valid until 29-7-2022
Engine manufacturer:	CFM International (CFMI)
Engine type:	2 x CFM56-5B4/3
Maximum take-off mass (MTOM):	77,000 kg
Maximum landing mass (MLM):	64,500 kg
Fuel on board (Take off):	11,000 kg
Aircraft total flight hours:	44,163
Aircraft total flight cycles:	17,552

## 1.6.2 Mass and balance

The operator forwarded the final loadsheet to the AIB. See [appendix 5.1](#).

## 1.6.3 Aircraft type certification

The French Civil Aviation Authority (CAA) Direction Generale de l'Aviation Civile (DGAC) certified the Airbus A320-211 on 8-11-1988. The aircraft was further developed into different variants, and the subject aircraft type A320-214 was type certified on 10-3-1995. In 2005, EASA became the type certifying authority for the A320.

The A320 family aircraft were initially certified with two engine options, namely the CFM56 and the IAE V2500 series (Classic Engine Option, CEO). The thrust reverser system for the two engine options were different in design. The CFM56 was fitted with a blocker door system, and the V2500 with a translating sleeve system.

By 2015, two new engine options were certified and became available for the A320 NEO (New Engine Option), namely the CFM Leap and the PW1100G. Each engine was fitted with a redesigned thrust reverser system.

## 1.6.4 CFM56 engine

The CFM56-5B4/3 engine, fitted on the subject aircraft, was a two shaft high bypass turbofan engine. The CFM56-5B4/3 was an evolution of the earlier CFM56 engine series. The CFM56 engine in other configurations powered other aircraft (Airbus A340 and Boeing 737).

Based on the control inputs from the thrust levers in combination with sensor readings, an ECU electronically controlled the engine. The ECU also incorporated some aircraft functions specified by the airframe manufacturer such as thrust reverser command logic. This is described in more detail in [section 1.6.5.3](#).

## 1.6.5 Thrust reverser system

### 1.6.5.1 Thrust lever control

On the subject aircraft, both engines were fitted with a pivoting blocker door type thrust reverser system.

The flight crew controlled the thrust reverser system by use of the two independent thrust levers. When the thrust levers were moved aft through the detents, they would hit a mechanical stop at idle position. To overcome the stop, a reverse latching lever on each thrust lever could be moved up. This allowed the thrust levers to move further aft, which would command deployment of the thrust reversers and modulate the amount of reverse thrust.

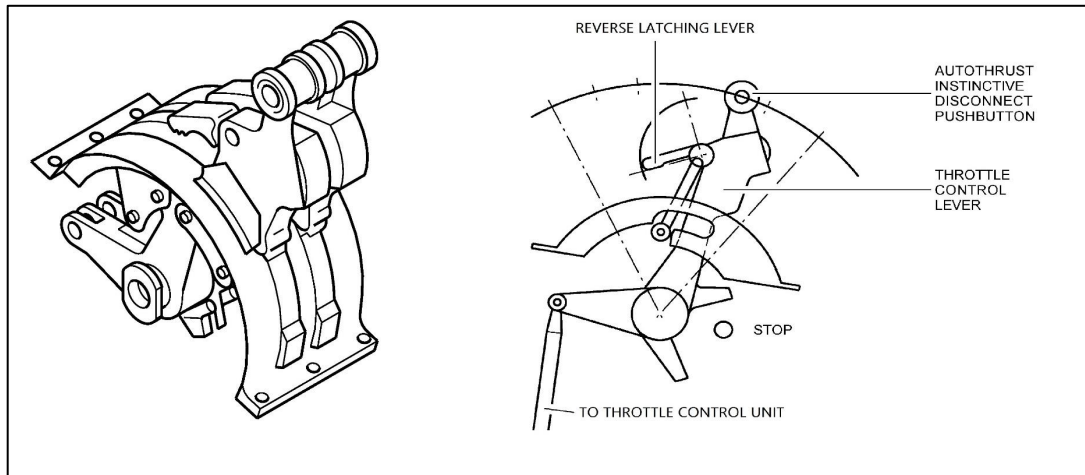


Figure 1. Throttle (thrust lever) quadrant

The thrust levers could be moved through the entire range with the aircraft on ground or in the air. The position of each thrust lever was sent to the respective ECU which controlled the thrust reverser on that respective side. Each engine thrust reverser operated independently of the opposite engine thrust reverser.

When the engine thrust reverser deployed, four blocker doors entered the engine fan air stream (but not core engine air stream) to change the direction of the engine fan air and assisted in braking the aircraft.

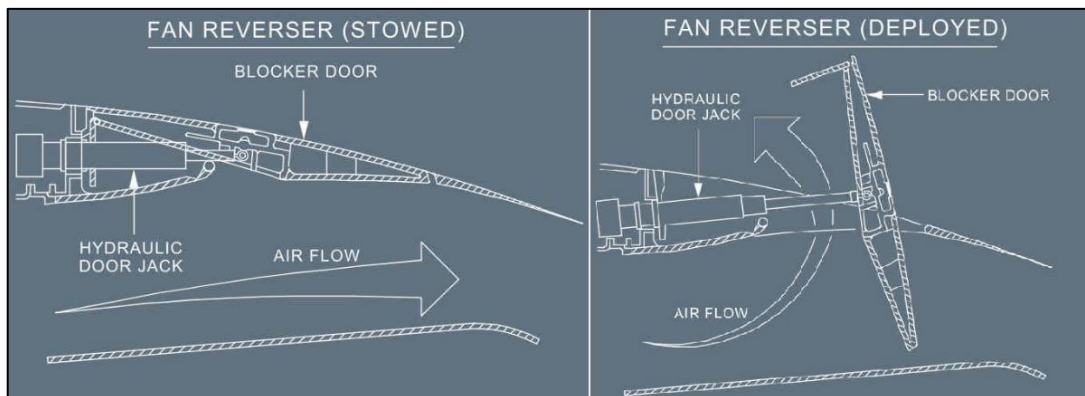


Figure 2. Thrust reverser air flow

Factual information

1.6.5.2 Thrust reverser halves

The thrust reverser was part of the engine exhaust system and fitted around the aft portion of the engine. To allow access to the engine, the thrust reverser consisted of two halves (called D-ducts) hinged at the top and latched at the bottom.

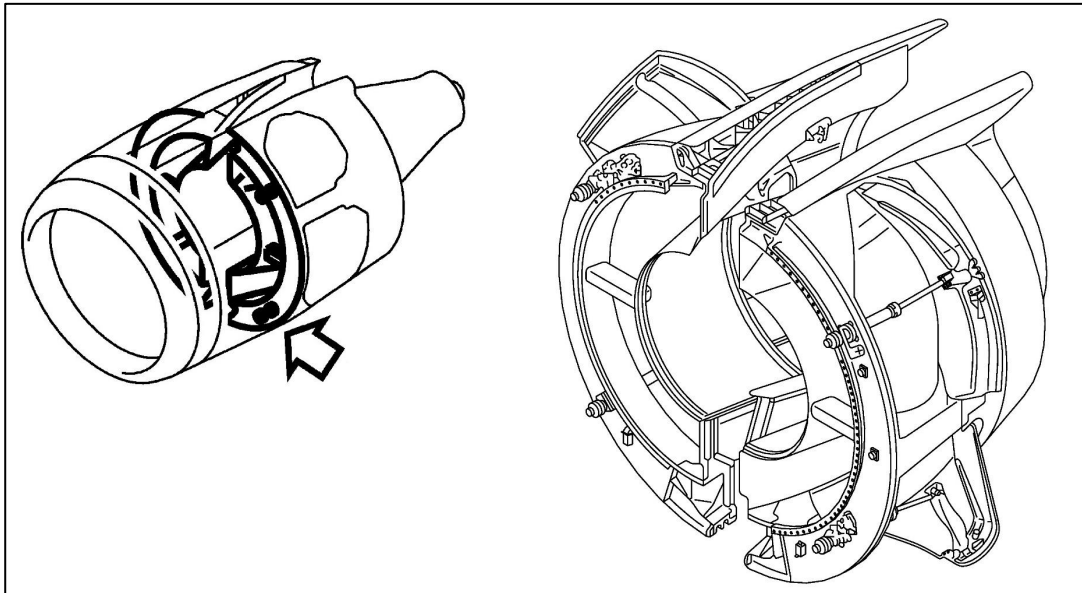


Figure 3. Engine thrust reverser D-ducts

On each D-duct, two blocker doors were fitted each with an associated Primary Door Latch (PDL), actuator and two switches. One switch activated when the door was fully open (deployed), the second when the door was fully closed (stowed). The signal was sent to the ECU and used for control and indication.

The hydro-mechanical PDLs operated as locks to keep the reverser blocker doors in the stowed position. The PDLs were hydraulically unlocked before blocker doors were deployed. A blocker door moved the respective PDL back to mechanical locked position when stowed.

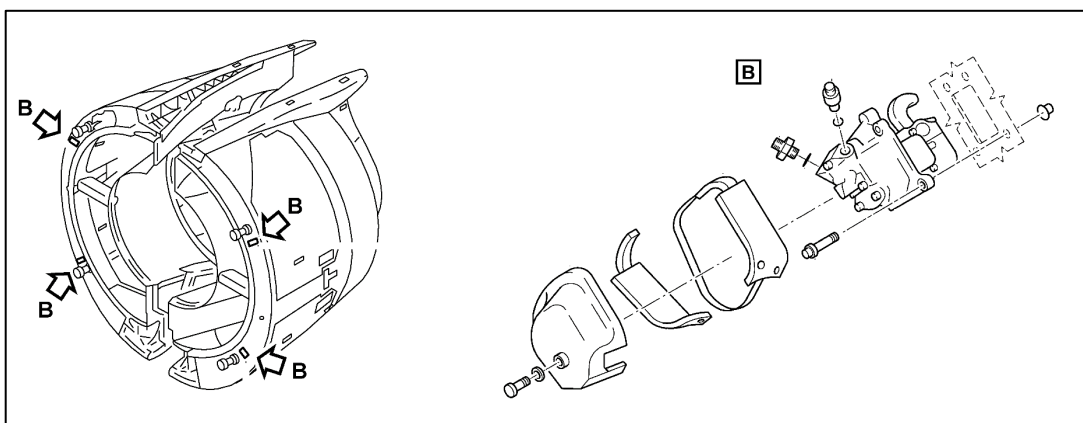


Figure 4. PDL

The four hydraulic actuators moved the blocker doors to deploy and stow positions.

A secondary locking device (tine) was fitted inside each actuator to keep the door close to stow position in case of a PDL failure. The locking device unlocked when hydraulic pressure was applied to the deploy side of the actuator, then allowing the actuator to extend and move to the deploy position. A mechanical manual override of the locking device was also fitted to the actuator.

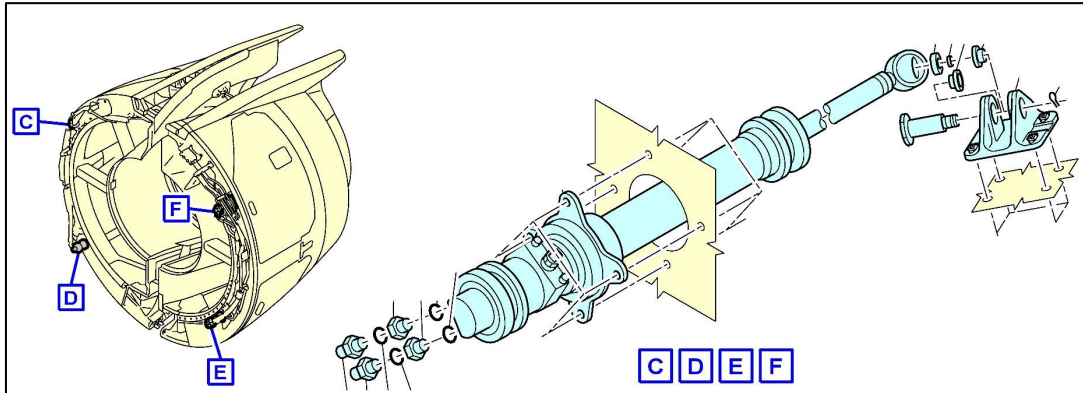


Figure 5. Blocker door actuator

### 1.6.5.3 Engine Control Unit (ECU)

Each engine was fitted with an ECU. The electronic ECU was part of a Full Authority Digital Engine Control (FADEC) system. The ECU controlled the engine and thrust reverser based on input signals. No manual override was possible.

The software of the ECU contained a logic for deployment and stowing of the engine thrust reverser. To operate the thrust reversers, the ECU received the following signals from the respective side (ECU #1 received signals from #1 units):

1. A Thrust Lever Angle (TLA) signal from the Throttle Control Unit (TCU).
2. A stow signal from four stow switches, one for each blocker door.
3. A deploy signal from four deploy switches, one for each blocker door.
4. An inhibit signal from the Multipurpose Control and Display Unit (MCDU) when the thrust reversers had been deactivated by maintenance personnel. The signal would be sent through the Engine Interface Unit (EIU).
5. A ground/air signal (both Main Landing Gears (MLG) compressed, WOW) from the Landing Gear Control and Interface Unit (LGCIU). The signal was sent through the EIU.

Based on the signals the ECU sent deploy/stow operating/command signals to the Hydraulic Control Unit (HCU). The HCU sent a signal to the ECU when pressurised.

The ECU logic for deployment of the thrust reverser included:

1. Aircraft on ground (both MLG WOW switches activated).
2. TLA at or below  $-4.2^\circ$  (thrust lever at or aft of reverse idle).

The ECU logic for stowing of the thrust reverser included:

1. Aircraft on ground (both MLG WOW switches activated).
2. TLA above  $-4.2^\circ$  (thrust lever at forward thrust).



Factual information

If a thrust lever was moved above -4.2° (TLA) while WOW signal was present, the ECU would maintain (latch) the stow signal for 8 seconds or until activation of all four stow switches regardless of a change in WOW signal (bounce).

In case the ECU received the “TLA above -4.2°” signal while WOW was not received, the ECU would start the stow sequence, as soon as WOW was received, but would not latch the stow signal. As soon as WOW was no longer received, the stow sequence would then be interrupted.

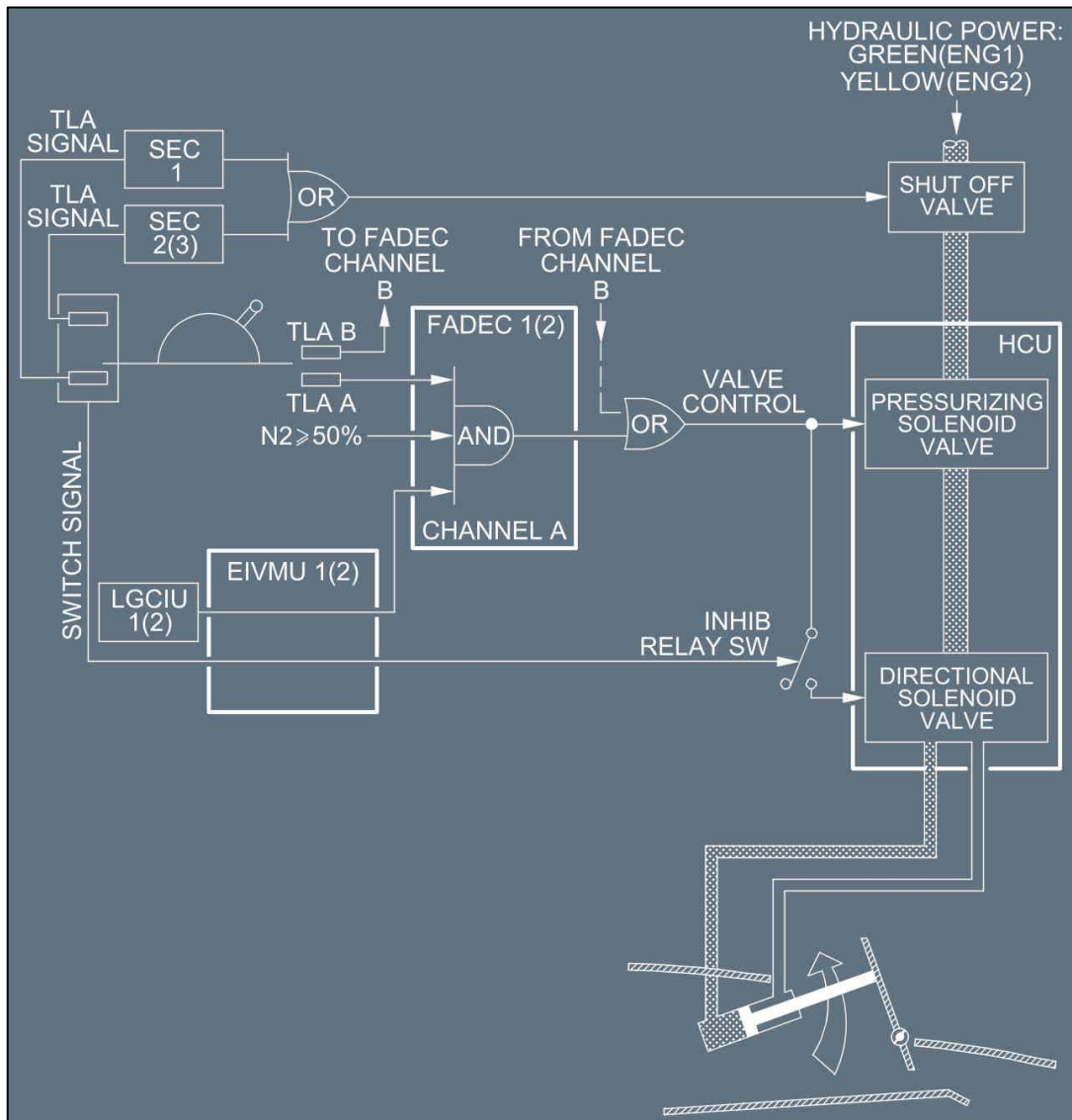


Figure 6. Thrust reverser control system

The ECU was capable of logging fault codes in a Non-Volatile Memory (NVM). This is described in more details in [section 1.11.5](#).

#### 1.6.5.4 Hydraulic Control Unit (HCU)

Each engine thrust reverser system was fitted with a HCU on the upper RH D-duct front face. The HCU controlled the hydraulic pressure to the four blocker door PDLs and actuators.

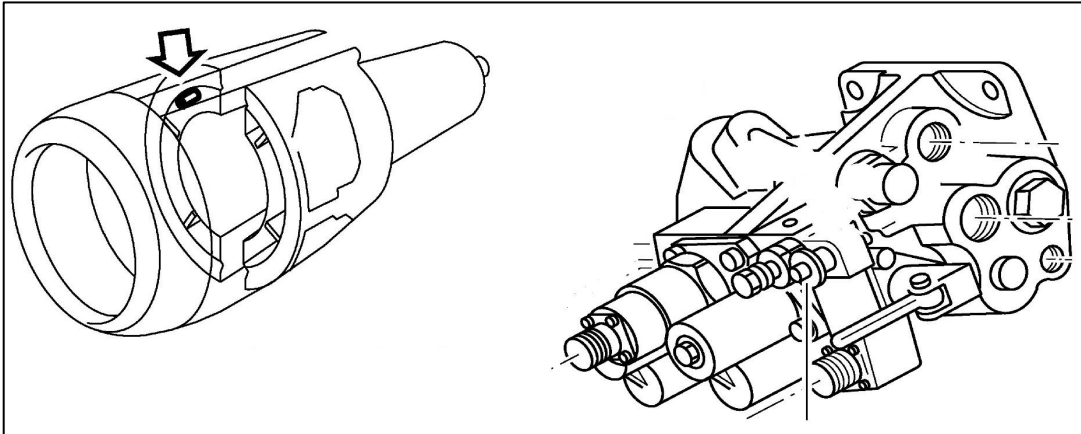


Figure 7. Hydraulic Control Unit (HCU)

The ECU controlled the HCU electrically through two solenoid valves. A pressurising valve solenoid and a directional valve solenoid.

When opened, the pressurising valve allowed hydraulic pressurisation of the stow side of the actuators, which moved the actuators and blocker doors approximately 0.5” towards closed (overstow) to unload the PDL hooks before deployment.

To deploy the thrust reverser, the ECU energised the directional valve solenoid while the pressurising valve solenoid was energised. The hydraulic pressure was then first directed to the PDLs. The PDLs unlocked in sequence one after another (Lower RH, upper RH, upper LH, lower LH) before allowing hydraulic pressure from the PDLs to move the directional valve in the HCU.

When opened, the directional valve simultaneously allowed hydraulic pressure to the deploy side of the four actuators. With the same hydraulic pressure acting on the actuators stow and deploy side, the difference in area of the actuator piston head and rod end, resulted in the actuators moving towards deploy.

To stow the blocker doors, the ECU de-energised the directional valve solenoid. This resulted in the directional valve moving back, and the pressure from the deploy side of the actuators being directed towards hydraulic return. The hydraulic pressure on the actuator stow side would then move the doors to stow, until the ECU de-energised the pressurising valve solenoid.

#### 1.6.5.5 Independent locking system

Driven by regulation changes, in consequence of the accident to OE-LAV (Boeing 767-300ER) on 26-5-1991 which involved a mid-air uncommanded engine thrust reverser deployment, an independent locking system had been designed and incorporated onto the A320 family aircraft.

To prevent inadvertent thrust reverser deployment when airborne, a Thrust Reverser Shut Off Valve (TRSOV) was fitted for each engine thrust reverser in the engine pylon. When

closed, the TRSOV prevented the hydraulic pressure from the aircraft system to the thrust reverser HCU.

The TRSOV was a solenoid operated normally closed electrohydraulic valve. The signal for opening of the TRSOV was sent by two Spoiler Elevator Computers (SEC) in parallel with either SEC capable of opening the valve. SEC #1 and #2 controlled TRSOV #1 and SEC #1 and #3 controlled the TRSOV #2.

The condition for opening of the TRSOV was the following:

1. Radio height below 6 feet, or wheel speed above 72 kt (ground signal).
2. Opposite TLA below (aft of) 30°.

If the ground signal was lost, or the opposite TLA was moved above 30°, the SECs would maintain the TRSOV open signal for 15 seconds before commanding it to close. This allowed the thrust reverser to complete the stow sequence.

To protect the TRSOV from contamination, a 15 micron filter and associated housing was installed upstream of the TRSOV. The filter housing incorporated a shut off valve, which closed when the filter was removed, to prevent draining and contamination of the system, and a pop-out filter Differential Pressure Indicator (DPI).

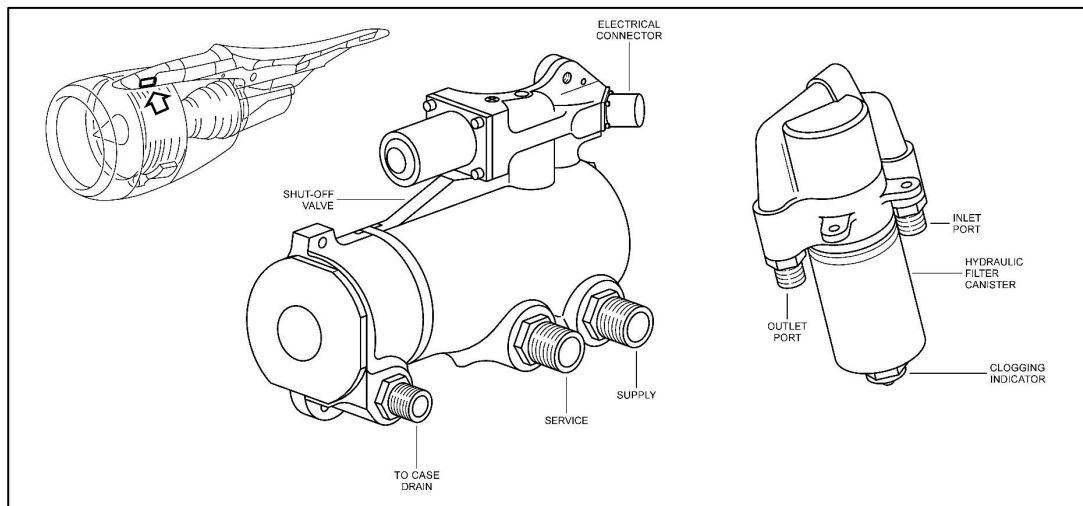


Figure 8. TRSOV and filter housing

### 1.6.6 Primary Flight Display (PFD) sideslip index

The below extract is from the operator’s Operations Manual Part B (OM-B) FCOM A319/A320/A321 (revision 24 issued on 18-8-2021):

#### (6) Sideslip Index (yellow)

This trapezoidal index moves beneath the roll index. On ground, it represents the lateral acceleration of the aircraft. In flight, it shows sideslip (as computed by the [Flight Augmentation Computer] FAC). One centimetre of displacement indicates 0.2 g. The sideslip index is against its stop at 0.3 g.

In case of engine failure at take-off or go around, the sideslip index changes from yellow to blue.

*Note: The sideslip target is blue, if:*

- CONF 1, 2, or 3 is selected, and
- Any ENG NI > 80 % or one Thrust Lever > MCT ( $\geq$  FLX if FLX or DERATED TO), and
- The difference between the ENG NI 's exceeds 35 %.

*In this case, the sideslip index is called  $\beta$  target.*

When this index is centered with the roll index, the sideslip equals the sideslip target for optimum aircraft performance.

When flagged, the text "SI" in red capital letters replaced the blue sideslip/beta target indication.

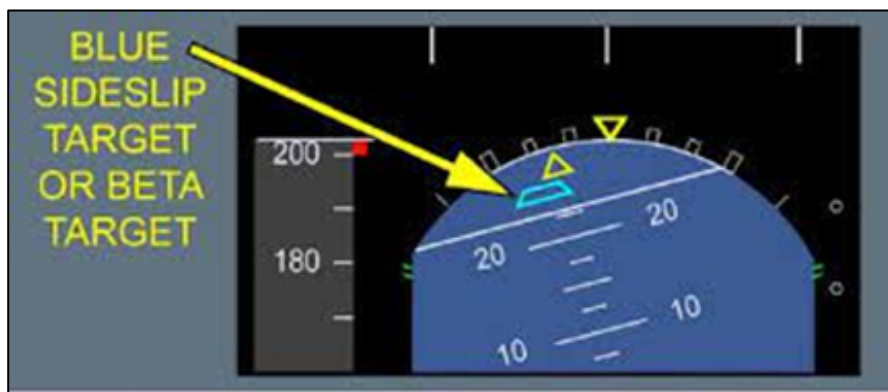


Figure 9. PFD blue sideslip index.

1.6.7 Procedures for use of reverse thrust

1.6.7.1 Flight Crew Operating Manual (FCOM)

The below extract is from the operator's OM-B FCOM A319/A320/A321 (revision 24 issued on 18-8-2021):

**AT TOUCHDOWN**

DEROTATION..... INITIATE

- Lower the nosewheel without undue delay.
- The PM continues to monitor the attitude.

ALL THRUST LEVERS..... REV MAX or REV IDLE

*The flight crew must select reverse thrust immediately after landing gear touchdown.*

*The flight crew must immediately select REV MAX, if any of the following occurs at any time during the landing:*

- An emergency
- The deceleration is not as expected
- A failure affects the landing performance
- A long flare or a long touchdown
- An unexpected tailwind.

*A small pitch up may occur during thrust reversers deployment before nose landing gear touchdown. However, the flight crew can easily control this pitch up. As soon as the flight crew selects reverse thrust, they must perform a full-stop landing.*

For full procedure refer to [appendix 5.2](#).

#### 1.6.7.2 Flight Crew Technique Manual (FCTM)

The below extract is from the operator's OM-B FCTM A319/A320/A321 (revision 38 issued on 18-8-2021):

##### **GO-AROUND NEAR THE GROUND**

The PF must not initiate a go-around after the selection of the thrust reversers. If the PF initiates a go-around, the flight crew must complete the go-around manoeuvre.

For full procedure refer to [appendix 5.3](#).

#### 1.6.7.3 Operator safety bulletin

On 4-4-2022, the operator issued Safety bulletin no. 6/2022 "A focus on the Landing Flare" to all operator Airbus pilots, based on the aircraft manufacturer safety magazine; Safety first - September 2020.

In the bulletin paragraph "Be go-around minded", the below extract was highlighted in larger font next to the paragraph:

The PF can abort the landing and go-around at any time until the thrust reversers are selected. However, when the reversers are selected, the landing must be continued.

For bulletin extract refer to [appendix 5.4](#).

#### 1.6.8 Landing performance calculation

Before the approach, the flight crew performed three landing performance calculations based on a number of factors with selectable values. The flight crew expected Air Traffic Control (ATC) to request vacating of runway via an intermediate taxiway. Such a request was not a mandatory restriction, and only to be complied with if operationally viable.

Below are listed (in extract) factors which remained fixed in all three calculations:

Landing distance available (LDA):	2,095 m
Runway surface condition:	Wet
Reversers:	All inoperative
Estimated landing mass:	55,943 kg
Wind data:	270°/24 kt
Landing technique:	Manual landing, Auto-throttle on

The flight crew selected different values for factors relating to the aircraft approach and landing configuration (flap and slat position) and the autobrake mode setting:

Approach/Landing configuration:	CONF2, CONF3 or CONFFULL
Autobrake mode:	LOW or MED

Below is listed the selected combinations of used varied factor values, with a list (in extract) of the resulting calculation output:

Input:			Output:		
Approach configuration	Landing configuration	Autobrake mode	Required runway length (m)	Vapp (kt)	Vref (kt)
CONF2	CONF3	LOW	2,063	137	N/A
CONF3	CONFFULL	LOW	1,930	133	126
CONF3	CONFFULL	MED	1,409	133	126

The flight crew decided to land in configuration 3 (CONF3) (flaps 20°) and with autobrake mode set to medium, a combination which was not included in the three calculations above. On AIB request, the operator performed an additional landing performance calculation based on the actual aircraft configuration conditions:

Input:			Output:		
Approach configuration	Landing configuration	Autobrake mode	Required runway length (m)	Vapp (kt)	Vref (kt)
CONF2	CONF3	MED	1,540	137	N/A

**1.7 Meteorological information**

**1.7.1 Terminal Aerodrome Forecast (TAF)**

TAF EKCH 072321Z 0800/0824 28020KT 9999 BKN025 TEMPO 0800/0804 29022G35KT BKN012 TEMPO 0804/0810 27020G32KT FM081000 26022G36KT 9999 SCT025 TEMPO 0810/0818 4000 SHRASN BKN012 SCT020CB BECMG 0816/0819 26015KT=  
 TAF EKCH 080507Z 0806/0906 26018KT 9999 SCT025 TEMPO 0806/0809 28020G32KT TEMPO 0809/0813 25022G36KT 4000 SHRASN BKN012 BKN020CB TEMPO 0813/0818 27018G28KT SCT020CB=

**1.7.2 Aviation Routine Weather Report (METAR)**

METAR EKCH 080920Z AUTO 26022G32KT 9999 BKN036/// 06/M02 Q0985 TEMPO SCT020CB=  
 METAR EKCH 080950Z 26016KT 8000 -RA BKN012 FEW020CB 02/01 Q0986 BECMG 9999 SCT020=  
 METAR EKCH 081020Z 25021KT 8000 -RA BKN012 FEW020CB 04/01 Q0985 BECMG 9999 SCT020=

**1.7.3 Aftercast valid for EKCH at 10:05 hrs**

Issued by the Danish Meteorological Institute (DMI).

Weather: Showers of rain/snow-mixture formed a shower line from Malmö via Køge to Skælskør. The shower line was moving towards east, and gave a shower at EKCH in the 09:50 hrs METAR and it was at 10:05 hrs located over the southern part of Amager and over Øresund south of Amager. For weather radar image see [appendix 5.5](#).

Visibility:	Outside of showers more than 10 km, probably 30-50 km. In showers visibility down to approximately 2000-3000 m near ground level where the precipitation fell mainly as showers of rain/showers of rain and snow, but at altitudes above a few hundred feet visibility in showers was probably down to approximately 500 m due to the precipitation falling as snow above these altitudes.
Clouds:	In the shower line occasional/frequent Cumulonimbus (CB), base 1200-2500 ft, top Flight Level (FL) 200-250. Outside the shower line scattered (SCT)/broken (BKN) Cumulus (CU)/Stratocumulus (SC) base 2000-3500ft.
Surface wind (10 m Above Ground Level (AGL)):	<p>Westerly or west-south-westerly. Over land mean wind 15-25 kt, generally gusting 30-35 kt, over Øresund mean wind 25-35 kt. Beside the general gusts, the showers in the shower line were associated with particularly strong gusts: The auto-SYNOP station at Drogden Fyr (located in Øresund, approximately 5 nm SSE of EKCH) measured gusts up to 50 kt at 10:00-10:10 hrs, exactly coinciding with the passage of the shower line.</p> <p>This strong gusting coinciding with the precipitation echo in the radar image suggested the presence of a significant downdraft just below the shower/CB.</p>
Turbulence/windshear:	In general light to moderate low level turbulence due to the windy conditions and the unstable air mass. In and below the shower line/CBs moderate or maybe locally severe turbulence in connection with the downdraft.

1.7.4 Automatic Terminal Information Service (ATIS)

This is Copenhagen Arrival Information Zulu at 09:50. Expect ILS approach. Runway in use for landing 30. Runway 30 wet. Transition level 70. Wind for landing 250 degrees 16 knots. Visibility eight kilometres. Light rain. Broken 1,200 feet. Few CB 2,000 feet. Temperature two, dew point one. QNH 986. Risk turbulence below 300 feet on final runway 22 left. Becoming visibility 10 kilometres, scattered 2,000 feet. This was Copenhagen Arrival Information Zulu.

This is Copenhagen Arrival Information Charlie at 09:56. Expect ILS approach. Runway in use for landing 22 left. Runway 22 left wet. Transition level 70. Reduced separation procedures applied on final. After landing expedite vacating runway. Wind for landing 250 degrees 24 knots, maximum 29 kt, minimum 11 kt. Visibility eight kilometres. Light rain. Broken 1,200 feet. Few Cumulonimbus 2,000 feet. Temperature two, dew point minus zero. QNH 986. Risk turbulence below 300 feet on final runway 22 left. Becoming

visibility 10 kilometres, scattered 2,000 feet. This was Copenhagen Arrival Information Charlie.

## 1.8 Aids to navigation

There were no reports of deficiencies to the aids to navigation at EKCH.

## 1.9 Communication

At the time of the serious incident, the flight crew were in radio contact with Copenhagen Approach (119.805 Megahertz (MHz)) and Kastrup Tower (118.100 MHz).

The AIB obtained a copy of the ATC audio recordings. The recordings were of good quality and useful to the AIB safety investigation.

## 1.10 Aerodrome information

### 1.10.1 General information

Aerodrome Reference Point:	55 37 04.50N 012 39 21.50E
Elevation:	17 feet
Runway directions:	04L/22R, 04R/22L, 12/30
Runway surface:	Asphalt

#### 1.10.1.1 Runway 30

Runway code:	4E
Runway dimensions:	2,365 m x 45 m
Strip dimensions:	2,920 m x 300 m
LDA:	2,095 m (excluding 300 m stopway)

#### 1.10.1.2 Runway 22L

Runway code:	4E
Runway dimensions:	3,300 m x 45 m
Strip dimensions:	3,422 m x 300 m
LDA:	3,300 m

### 1.10.2 Aerodrome chart for EKCH

Extract from the Aeronautical Information Publication (AIP) Denmark. See [appendix 5.6](#).

Extract from the operator's Airport Facility Chart. See [appendix 5.7](#).

### 1.10.3 Notice to Airmen (NOTAM)

A0255/22 NOTAMN  
 Q) EKDK/QMDCH/IV/NBO/A /000/999/5537N01239E005  
 A) EKCH  
 B) 2201290813  
 C) PERM  
 E) RWY 30: LDA REDUCED TO 2095M. RMK 300M SWY AVBL.

## 1.11 Flight recordings

The aircraft was equipped with one Solid State Flight Data Recorder (SSFDR), one Solid State Cockpit Voice Recorder (SSCVR) and one Quick Access Recorder (QAR).



	<u>SSFDR</u>	<u>SSCVR</u>	<u>QAR</u>
Manufacturer:	Honeywell	Honeywell	Teledyne
Part number:	980-4700-042	980-6022-001	2243800-73
Serial number:	SSFDR-16773	CVR120-09935	01074

The AIB supervised the removal of the SSFDR and SSCVR in EKCH, and shipped the recorders to Portugal. The GPIAAF downloaded and decoded the data which were of good quality and useful to the AIB safety investigation.

The QAR was configured as a Digital Access Recorder (DAR). DAR data was automatically and wirelessly transferred to the operator. The AIB received a copy of the raw and decoded data which were of good quality and useful to the AIB safety investigation.

Based on DAR data, the operator created a computerised simulation of the aircraft behaviour during the sequence of events. The AIB received a copy of the simulation. The simulation was of good quality and useful to the AIB safety investigation.

#### 1.11.1 SSFDR data

The SSFDR was capable of storing 25 hours of data recorded at a rate of 256 Words Per Second (WPS), and data were recorded in Harvard Biphasic dataframe format as a string of data. The word position in the string of data indicated when that specific parameter was sampled and recorded.

SSFDR plot. See [appendix 5.8](#).

#### 1.11.2 SSCVR data

The SSCVR contained 2 hours of audio recording on four channels.

The GPIAAF produced a transcript in English of the relevant parts of the SSCVR recording.

#### 1.11.3 DAR data

DAR data were recorded at a rate of 512 WPS. The DAR recorded many of the same parameters as the SSFDR, moreover with optional additional parameters as selected by the operator. One major difference between the DAR and the SSFDR was the recording method. The DAR data was sampled and recorded as snapshots at a sampling rate of 8 hertz (Hz). This meant that 64 words were sampled and recorded at the same time, and that the word position was irrelevant for the timestamp of the data unlike with SSFDR data.

DAR data plot. See [appendix 5.9](#).

#### 1.11.4 Data from aircraft systems

After landing, the aircraft generated a maintenance post flight report. The report contained three warning messages:

- ENG 1 reverse unlocked (two times at 10:05 and 10:24).
- ENG 1 shut down (at 10:07).

#### 1.11.5 ECU memory

The ECUs were capable of logging 130 different fault codes. 14 of these fault codes were associated to the thrust reverser system.

For a list of fault codes associated to the thrust reverser system and relevant descriptions - see [appendix 5.10](#).

After the serious incident, both ECUs were interrogated and downloaded. Neither ECU had logged any fault codes in the NVM.

#### 1.11.6 Surface movement radar

The aerodrome was equipped with an Advanced Surface Movement Guidance and Control System (A-SMGCS). The AIB received a copy of the A-SMGCS recording. The recording was of good quality and useful to the AIB safety investigation.

#### 1.11.7 EKCH Surveillance camera (CCTV) recordings

Multiple surveillance cameras were installed within the aerodrome area. Cameras at various locations recorded parts of the serious incident. The AIB obtained a copy of the recordings. The recordings were of good quality and useful to the AIB safety investigation.

Note: The AIB removed the operator logo from the following images.



Figure 10. Aircraft touchdown on runway 30 after taxiway N1

Factual information



Figure 11. Aircraft bounce during crossing of runway 04R/22L



Figure 12. Engine #2 accelerating while aircraft passes taxiway B



Figure 13. Aircraft veering off runway 30 just before taxiway D



Figure 14. The aircraft flying past the glideslope antenna for runway 12 just after taxiway A

1.11.8 Ground plot

Based on the available data, the AIB created a ground plot. See [appendix 5.11](#).

## 1.11.9 Sequence of events

Based on the available data, the AIB created a list of relevant events with approximated timestamps.

<b>Time (UTC)</b>	<b>Event</b>
10:01:55	Landing gear selected down.
10:02:20	Flap lever moved from position 2 (15°) to position 3 (20°).
10:03:20	1,420 ft radio height. Autopilot disengaged.
10:05:05	ATC issued clearance to land on runway 30.
10:05:16	Aircraft started call-outs: “50-40-30-20-10-Retard-Retard-Retard-Retard”. Flare and decrab initiated at approximately 30 ft radio height.
10:05:21	Approximately 10 ft radio height. Thrust levers moved to idle.
10:05:24	Outer LH wheel started to spin (wheel speed). De-rotation initiated. Thrust levers moved to maximum reverse. Spoilers started to deploy.
10:05:25	WOW on both MLG.
10:05:26	Briefly no WOW on LH MLG. Thrust levers moved to TOGA. Both thrust reversers unlocked.
10:05:28	No WOW on LH MLG followed by no WOW on RH MLG approximately one second later (bounce). Engine #2 thrust reverser locked (stowed). Engine #1 thrust reverser remained unlocked.
10:05:29	Flap lever moved to position 2 (15°). Engine #2 started accelerating. Engine #1 remained at autoidle.
10:05:32	LH MLG WOW for approximately two seconds (bounce).
10:05:36	LH MLG WOW for approximately 0.5 second (bounce). Aircraft passed LH runway edge with few feet ground clearance. Beta target was flagged.
10:05:40	Approximately 10 ft radio height. Positive rate of climb. Landing gear selected up.
10:06:06	300 ft radio height. Engine #1 thrust lever moved to idle. MAYDAY declared to ATC.
10:07:24	1,200 ft radio height. Engine #1 shut down. Beta target reappeared on PFD.
10:07:55	Autopilot engaged.
10:09:21	2,850 ft radio height. Flap lever moved to position 1 (10°).
10:10:11	2,900 ft radio height. Flaps 0 selected.
10:23:54	Touchdown (WOW) EKCH runway 22L.

## 1.12 Wreckage and impact information

Not applicable.

**1.13 Medical and pathological information**

Not applicable.

**1.14 Fire**

There was no fire.

**1.15 Survival aspects**

Not applicable.

**1.16 Tests and research****1.16.1 Aircraft inspection and testing**

Shortly after the serious incident, engine #1 thrust reverser system was inspected and tested in EKCH under supervision of the AIB. The operator and the aircraft manufacturer were involved in the troubleshooting of the serious incident.

The post flight report, generated by the aircraft, contained three warning messages. See [section 1.11.4](#).

The initial inspection on the aircraft stand revealed that engine #1 LH upper blocker door PDL was unlocked, but the actuator secondary lock remained locked i.e. the LH upper blocker door could not be moved to full deployment. The remaining three blocker doors were all fully deployed.

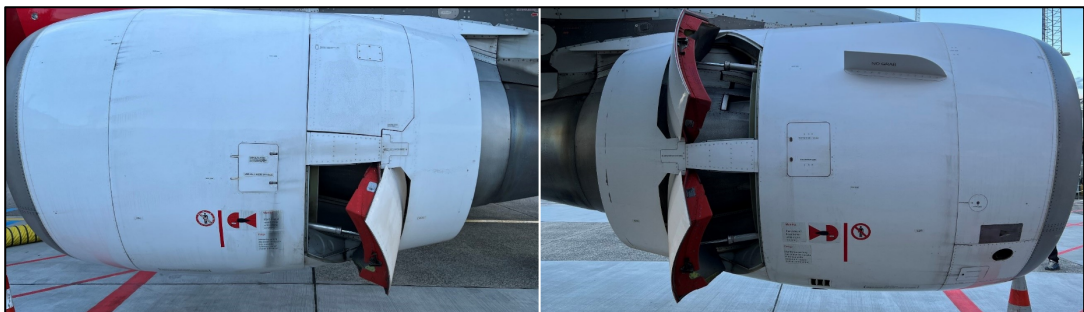


Figure 15. Engine #1 seen from the LH and RH side

Visual inspections revealed only one small defect on the LH upper door latch roller which was seized. Functional tests of the thrust reverser system with and without engine running showed normal behaviour and no faults.

After inspections to verify structural integrity, engine #1 thrust reverser was inhibited and secured and the aircraft was positioned to LPPT for further troubleshooting.

In LPPT, further testing and inspections were conducted under the supervision of GPIAAF. The analysis of the flight data revealed that neither #1 nor #2 thrust reverser had been fully deployed before they were commanded to stow by the forward movement of the thrust levers.

Therefore, tests were conducted to replicate this scenario. None of these tests were able to replicate the fault. The thrust reversers behaved normally during all tests.

The ECU memory on both engines were downloaded. No fault codes were stored in any of the ECUs.

Engine #1 thrust reverser halves (D-ducts) and associated hardware such as HCU, actuators and PDLs were removed together with the TRSOV and the filter housing. The filter housing DPI showed no indication of blockage. The parts were shipped to the Original Equipment Manufacturers (OEMs) for further inspections and tests.

#### 1.16.2 Off wing inspections of engine #1 thrust reverser and associated hardware

Under supervision of the AIB, the BEA, the operator and the aircraft manufacturer, the OEM inspected engine #1 thrust reverser D-ducts at an OEM maintenance facility in France. The inspections revealed only minor defects. The conclusion was that none of these defects could have contributed to the thrust reverser not stowing.



Figure 16. Engine #1 thrust reverser LH D-duct

Friction in the blocker door hinges was checked without the actuators installed. Friction was found to be very low. All four blocker doors moved freely.

The HCU and the four actuators and PDLs were removed and shipped to the OEM's facility in the UK for detailed inspections and testing.

A sample of the hydraulic fluid (Hyjet IV) in the system was collected. The BEA arranged an analysis of the hydraulic fluid at a laboratory. The chemical values were all within Aircraft Maintenance Manual (AMM) limits. No relevant debris was found.

##### 1.16.2.1 Detailed inspections and testing of HCU, PDLs and actuators

Under the supervision of the AIB, the BEA and the aircraft manufacturer, the OEM inspected and tested the HCU, PDLs and actuators at the OEM's facility in the UK.

The detailed inspection of the HCU, PDLs and actuators revealed only minor defects, and the OEM concluded that none of the defects could have contributed to a degradation of performance of the thrust reverser system resulting in an inability to stow.

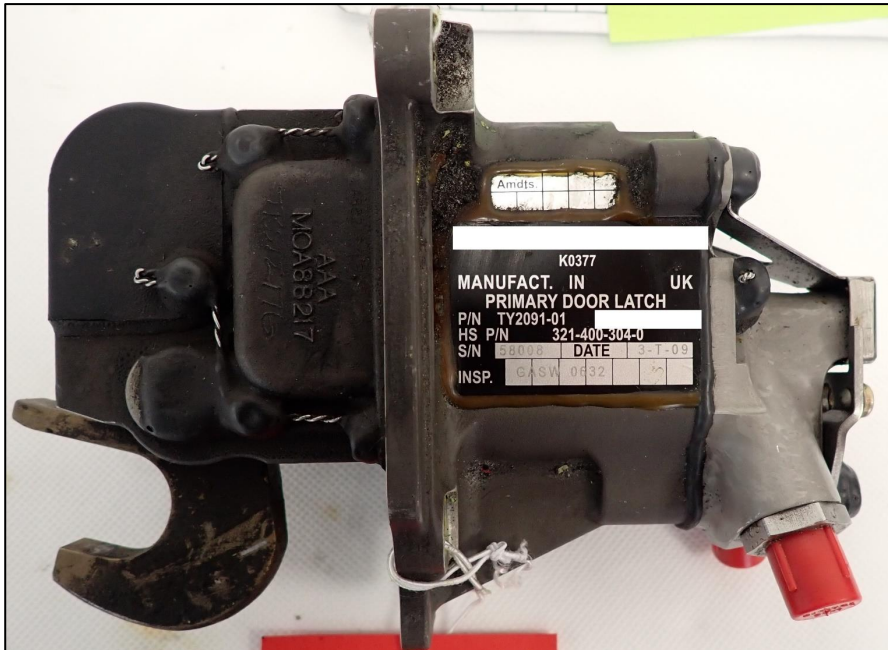


Figure 17. A PDL in as received condition

In accordance with the respective Component Maintenance Manuals (CMMs), the OEM tested the parts. All parts passed the tests in the CMMs. The test results are presented in the following appendixes:

HCU CMM test result. See [appendix 5.12](#).

PDLs CMM test result. See [appendix 5.13](#).

Actuators CMM test result. See [appendix 5.14](#).

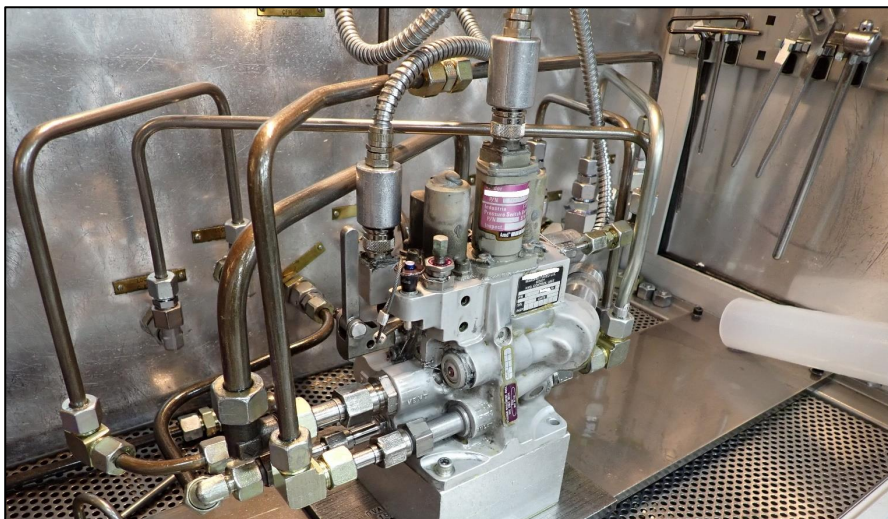


Figure 18. HCU in test rig



To verify that no damage existed on the pressurising valve and the directional valve in the HCU (as this could potentially have resulted in the valves to go periodically stuck), both valves and associated guides and parts were removed and inspected. No defects were found on any of the parts.



Figure 19. Isolation valve and associated parts shown left, and directional valve shown on the right

#### 1.16.2.2 Actuators load capability testing

To reduce the consequences of an event of a thrust reverser deployment when airborne, the thrust reverser system was designed to be able to stow the blocker doors at a higher aerodynamic load (airspeed and engine nacelle pressure) than prevailing during the TOGA application.

The actuator CMM tests did not include a verification of the actuator's load capability (maximum amount of force an actuator could produce). The functional test in the CMM (section 4F) did however include a verification of the time to retract (stow) under a specified load of approximately 25 % of the expected maximum load capability.

To verify the actuators actual capability to retract/stow under the (higher) event load, the OEM prepared a load capability test.

The event parameters recorded by the SSFDR (engine at idle, CAS 140 kt) were calculated to result in a specific load requirement on each actuator.

To test the actual load capability, each actuator was tested to retract under different loads to find the maximum capability using the nominal recorded hydraulic pressure of the aircraft system (178 bar) at the time of the serious incident. Whether the actuator was able to retract and lock (internally/secondary) and the time taken to retract was recorded.

For comparison, the OEM performed a CMM and load capability test on an actuator with very few cycles accumulated (almost new condition).



Figure 20. Actuator

During the tests, all actuators behaved very similar and produced very similar results:

- The maximum load capability of all five actuators was very similar.
- Subjected to the calculated load from the serious incident, all actuators retracted and locked within two seconds.

The test results are presented in [appendix 5.15](#).

All tests confirmed that the actuators were able to stow when subjected to the event load with approximately 50 % additional load capability.

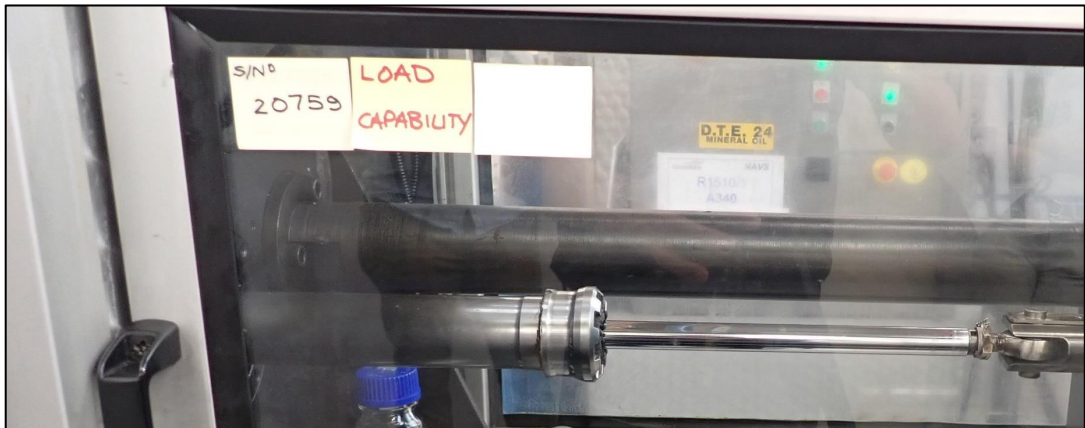


Figure 21. Actuator load capability testing

#### 1.16.2.3 TRSOV test

The TRSOV was shipped to the OEM based in the USA.

CMM testing of the component was conducted under the supervision of the NTSB and the FAA. The TRSOV passed all CMM tests.

The test results are presented in [appendix 5.16](#).

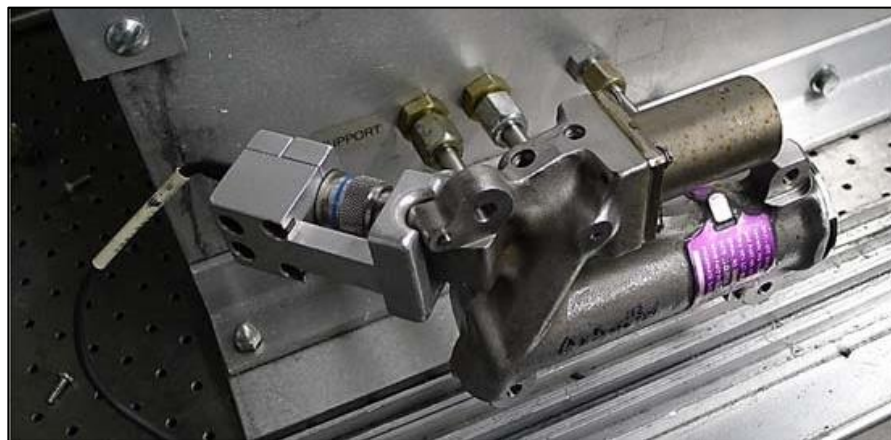


Figure 22. TRSOV in test rig

#### 1.16.2.4 Filter housing test

Under supervision of the GPIAAF, the filter housing with the installed filter was tested at the operator's maintenance facility.

The filter housing flow differential pressure test was slightly out of limit, and the shut off valve leak check failed. The operator informed that it had been a challenge in the past to test other filter housings within the CMM limit for the flow differential pressure test.

To obtain a valid test result, the filter housing with filter was shipped to the OEM based in the UK. Under supervision of the AIB, the AAIB and the thrust reverser OEM, the filter housing and filter was tested at the filter housing OEM. The OEM concluded that the filter flow was close (approximately 1 psi) to that of a new filter housing which was tested for comparison. The conclusion was that no excessive restrictions were present in the filter housing, and that the filter and housing had no influence on engine #1 thrust reverser's inability to stow.

The leakage of the shut off valve also had no influence on engine #1 thrust reverser's inability to stow.

The test results are presented in [appendix 5.17](#).

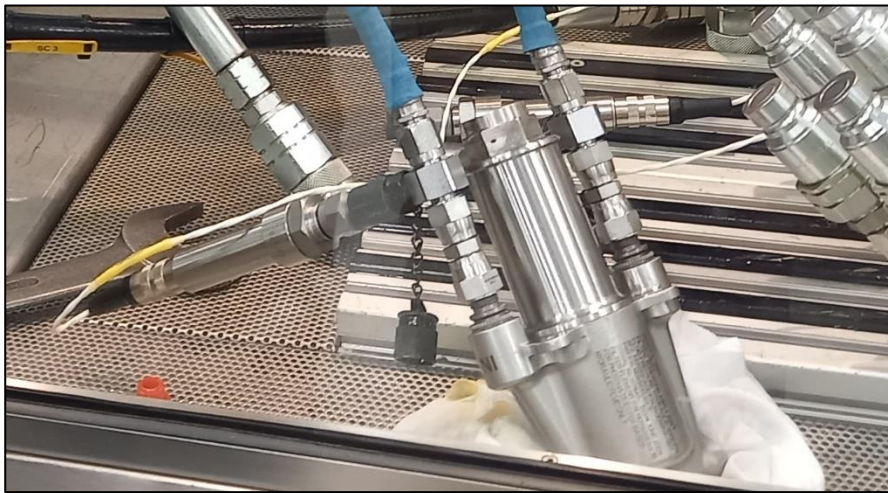


Figure 23. Filter housing test at the operator

### 1.16.3 Investigation of ECU software and thrust reverser operating logic

During the AIB safety investigation, the aircraft manufacturer presented a hypothesis that the designed software logic of the ECU did not maintain a thrust reverser stow command on engine #1. This was only the case if the thrust lever was moved forward from reverse while the ECU received an air signal (aircraft not on ground, no WOW on both MLGs).

The FDR data and DAR data confirmed that the thrust levers were moved forward during the same period of time, as the aircraft slightly bounced, and the WOW signal changed from ground to flight on the LH MLG (10:05:26.000). The recording resolution of the TLA was 1 Hz and the recording resolution of the WOW signal was 4 Hz. The recording resolution was not sufficiently high to firmly confirm the exact overlap of timing, and only the WOW signal from LGCIU #1 was recorded.

Factual information

Time (UTC)	LH MLG WOW #1	NLG WOW #1	RH MLG WOW #1	TLA #1	TLA #2
10:05:25.000	0	0	0		
10:05:25.125				-22.5	
10:05:25.250	0	0	1		
10:05:25.375					-22.5
10:05:25.500	1	0	1		
10:05:25.625					
10:05:25.750	1	0	1		
10:05:25.875					
10:05:26.000	0	0	1		
10:05:26.125				45	
10:05:26.250	1	0	1		
10:05:26.375					42.188
10:05:26.500	1	0	1		

Figure 24. DAR data extract. Transition from ground to flight status on the LH MLG highlighted. The minimum Thrust Lever Angle (TLA) value is -22.5° (full reverse), reverse idle is -4.2°, idle 0° and full forward thrust 45°

Testing the ECU software on a test ECU in a test setup, with manipulation of inputs and reading of output signals, confirmed that moving the thrust lever forward, while the ECU at the same time received an air signal, resulted in the ECU not latching the thrust reverser stow command.

When the WOW signal was received after the TLA above reverse idle signal, the ECU commanded the thrust reverser to stow. However, the stow sequence was not latched and was interrupted once the WOW signal was removed.

The actual sequence of the WOW signals during the serious incident confirmed that the stow sequence would have been interrupted before the thrust reverser had time to stow due to the insufficient amount of WOW signal time.

The potential difference in WOW and TLA signal processing and output to each ECU was analysed by the aircraft manufacturer.

The WOW signal on each side was sensed by a proximity sensor on each MLG. The signal was picked up and processed by the LGCIU, which transmitted it to the EIU before being sent to the ECU. At the same time the TLA was sensed by the TCU before being transmitted to the ECU. All these steps each required processing time.

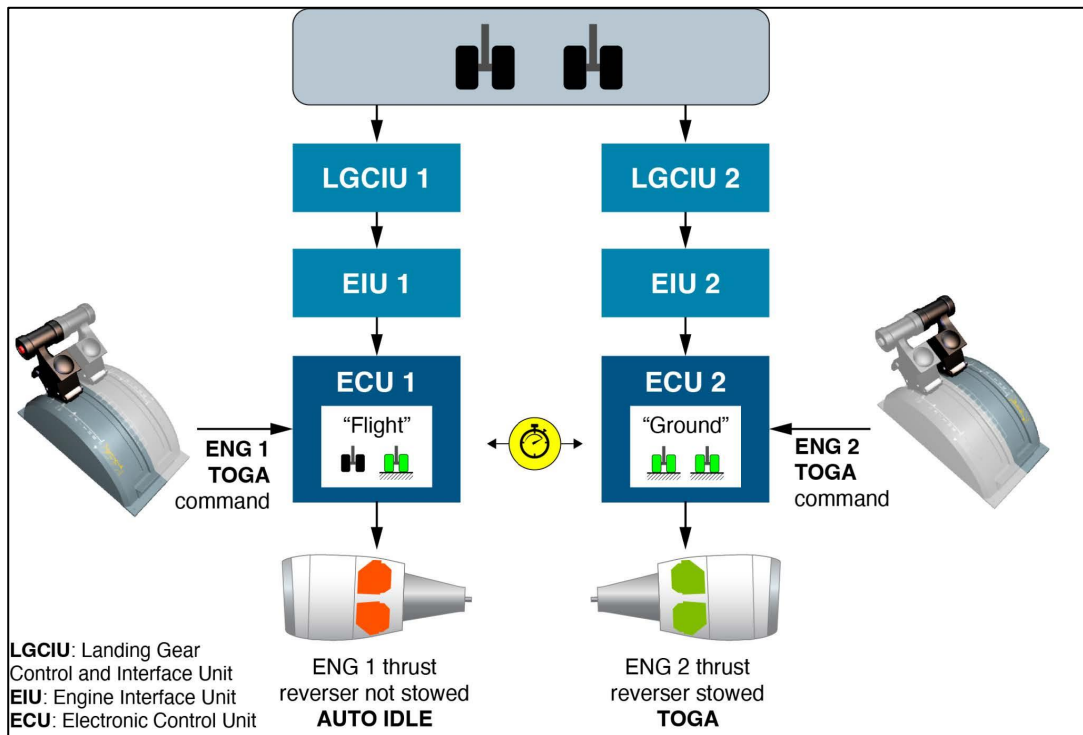


Figure 25. Illustration developed by the aircraft manufacturer to explain the difference in signals to the ECUs

The aircraft manufacturer concluded that due to the input scan and output update frequency combined with the processing time of each computer, ECU #1 received an air signal from the #1 set of computers while sensing the TLA stow signal. At the same time, ECU #2 received a ground signal by the independent #2 set of computers while sensing the TLA forward thrust signal. The opposite scenario was just as likely to have occurred.

A slightly asymmetric position between thrust levers #1 and #2 during motion from REV to TOGA detent was also considered as source of asynchronism that could explain the different behaviour between the thrust reversers on engine #1 and engine #2.

Based on the examinations, tests and analysis, the aircraft manufacturer concluded that the technical reason for engine #1 thrust reverser not stowing during the aborted landing was due to ECU #1 not latching the stow command as a result of receiving no WOW signal when the LH thrust lever was moved forward.

**1.17 Organisation and management**

- 1.17.1 The operator
- 1.17.2 Flight crew procedure and system knowledge
  - 1.17.2.1 Previous occurrence

The commander had previously experienced an aborted landing after thrust reverser selection followed by an ENG 1 REVERSE UNLOCKED alert on ECAM.

During an occurrence in 2019 at Funchal (LPMA), the commander also selected reverse thrust prior to TOGA selection. Both engine thrust reversers initially stowed, followed by one thrust reverser blocker door unlatching (opening slightly but locked by the actuator) on engine #1 at a radio height of approximately 100 feet. The unlocking of the blocker door did not result in an actual reverse thrust scenario.

The flight crew subsequently shut down engine #1 and diverted safely to Porto Santo (LPPS).

Data from the DAR and post flight report indicated that the ECU completed the stow sequence on both engines during the aborted landing. The ECU detected one PDL not latched and logged a maintenance message in conjunction with the ENG 1 REVERSE UNLOCKED alert.

The subject PDL was replaced. A workshop inspected the PDL and found it in dirty condition with only a small amount of remaining grease. The PDL passed the CMM test.

Due to the low severity level of the occurrence, no authority safety investigation was conducted. No technical conclusion was determined for the PDL unlocking.

#### 1.17.2.2 Crew interviews after the serious incident

Both the commander and the first officer were aware that following a selection of reverse thrust, they were committed to land, as per operator OM-B and Safety Bulletin SOP referenced in [section 1.6.7](#). But they were both convinced that selection of TOGA thrust would result in stowage of the thrust reversers.

According to the commander, he “did not like the attitude of the aircraft during the flare” just before touchdown, and decided to abort the landing and perform a go-around.

Immediately after the serious incident, the commander could neither recall whether the selection of TOGA was performed before or after touchdown, nor whether reverse thrust had been selected before the application of TOGA. However, in the mindset of the commander, he initiated the go-around before the aircraft touched down.

The first officer recalled that he focused his attention on the central cockpit screens in preparation for SOP callouts regarding ground spoiler deployment, thrust reverser deployment and autobrake operation. He did not recall observing the thrust levers aft of the flight idle position, nor observing any indication of thrust reverser deployment, prior to the commander called for a go-around and a go-around flaps setting. The first officer then reacted instinctively, selected the flap/slats handle to the go-around position, and changed his focus to monitor the flight parameters.

### 1.18 Additional information

#### 1.18.1 Consultation of the regulating and certifying airworthiness authority (EASA)

During the AIB safety investigation, at the time when the ECU software hypothesis was confirmed as the likely reason for the engine #1 thrust reverser not stowing, the AIB started consulting EASA on the safety concerns associated to the specific event and ECU software and on the general requirements for design of thrust reverser systems.

##### 1.18.1.1 Regulatory requirements for the design and certification of thrust reverser systems

EASA informed the AIB that at the time of the certification of the A320, there was no certification requirement for a design review of the aborted landing after thrust reverser selection scenario. A requirement for design review of the aborted landing after thrust reverser selection scenario was later implemented in Canada.

On 11-2-1978, C-FPWC (B737-200) crashed after an aborted landing at Cranbrook, Canada. The safety investigation identified that the aircraft aborted the landing (due to a snow sweeper on the runway) after thrust reversers had been selected and deployed. The

aircraft became airborne with the LH thrust reverser still deployed due to interruption of the stow sequence when the aircraft become airborne.

Based on the learnings from the safety investigation, Transport Canada (TC) published guidance material to meet certification requirements of aircraft and thrust reverser systems in the form of Airworthiness Manual Advisory (AMA) 525 (1986) which was later superseded by Advisory Circular (AC) 525-005.

According to AC 525-005 in order to comply with the Canadian certification legislation, an aircraft had to be able to perform the following manoeuvring sequence:

1. Normal landing touchdown;
2. Deployment of thrust reversers;
3. Engine speed increase and development of reverse thrust;
4. Decision to go-around;
5. Stow thrust reversers;
6. Rapid application of full forward thrust;
7. Configuration changes as required; and
8. Take-off; or
9. Stop, if a take-off is clearly not achievable.

The requirements from TC AC 525-005 were not mirrored in the certification requirements from neither FAA nor EASA. However, according to EASA, any aircraft type would have to comply with AC 525-005 to allow for operation in Canada (TC would need to approve the certification documentation from any other certifying authorities and would then take AC 525-005 into consideration).

According to the FAA website on lessons learnt from the Cranbrook accident, FAA thrust reverser certification requirements were changed by amendment 25-72 to 14 CFR 25.933 on 20-08-1990. The change required both of the following capabilities to be demonstrated:

For turbojet reversing systems-

- (1) Each system intended for ground operation only must be designed so that during any reversal in flight the engine will produce no more than flight idle thrust. In addition, it must be shown by analysis or test, or both that-
  - (i) Each operable reverser can be restored in the forward thrust position; and
  - (ii) The airplane is capable of continued safe flight and landing under any possible position of the thrust reverser;

Prior to amendment 25-72, it was sufficient to demonstrate just one of the two capabilities.

The AC 525-005 manoeuvring sequence could be interpreted as a firm and stable landing. It was considered by the aircraft manufacturer and EASA that the serious incident scenario was not identical to the AC 525-005 scenario. The A320 CFM56 ECU software would have stowed the thrust reverser in the AC 525-005 scenario, when reverser thrust was selected with a ground signal present (as performed by ECU #2 during the serious incident).

At the time of the serious incident, EASA had no certification requirement for a design review of an aborted landing after thrust reverser selection scenario.

#### 1.18.1.2 Safety concerns associated to the A320 family thrust reverser logic embedded in the CFM56 ECU software

On the basis of the safety investigation, the aircraft manufacturer informed EASA that the aircraft manufacturer would conduct a design review of the thrust reverser system, present it to EASA and decide whether a modification of the thrust reverser system was required.

EASA considered the following aspects:

- Accumulated time in service of the aircraft type without similar problems (The A320 family CFM56 fleet had accumulated more than 95 million flight cycles (landings) at the time of the serious incident).
- The scenario required deviation from a SOP.
- The possibility of the scenario re-occurring to be remote.
- The complexity and amount of work required to perform the design review.
- The risk of introducing a safety issue by modifying the thrust reverser system.

Based on the above, EASA allowed the aircraft manufacturer sufficient time to conduct a thorough design review of the thrust reverser system.

#### 1.18.2 The aircraft manufacturer design and operational review of the thrust reverser system

The aborted landing scenario after thrust reverser selection (as described by AC 525-005) was considered during the initial design review performed during certification of the A320, even though this was not a certification requirement at the time.

However, based on the findings and data from the AIB safety investigation, the aircraft manufacturer conducted a new design and an operational review on the A320 family thrust reverser systems.

Since the issue was not necessarily specific to the A320, the same review was also conducted on all the thrust reverser/ECU software designs on other aircraft designed by the aircraft manufacturer. Apart from the CFM56-5 engine (fitted on A320 and A340), no other ECU software on any of the aircraft manufacturer aircraft designs were affected.

A review of the aircraft manufacturer occurrence database indicated that this serious incident was the first event of a thrust reverser not commanded to stow by the ECU during an aborted landing.

The aircraft manufacturer had access to a database containing flight data from 3.4 million flights from 31 operators. The database was used to assess the level of adherence to the recommendations related to the use of reversers included in the SOP for landing at the scale of the A320 family fleet. The database was similar to a Flight Data Monitoring (FDM) database, which was a regulatory requirement for operators operating aircraft with a MTOM of more than 27,000 kg.

A study into the available flight data indicated that an aborted landing/go-around after thrust reverser selection and ground contact had occurred on approximately one out of one million flights ( $10^{-6}$ ) on the entire A320 family (with four different engine configurations). Transposing this figure into the entire fleet and utilisation of A320 family aircraft in service indicated that such an event occurred on average once per month with the thrust reverser fully stowed.



The aircraft manufacturer stated that adherence to the recommendations related to the use of reversers included in the SOP for landing was an important mean to keep reliable and predictable thrust reverser responses during aborted landings.

Based on the design, operational and A320 CFM fleet review, the aircraft manufacturer planned and implemented safety actions including a modification of the CFM56-5B ECU software. Only relatively few other CFM56-5 (-5A and -5C) engines were in operation and these were considered to be retired from operation in a foreseeable future.

All safety actions are described in [section 4.1](#).

**1.19 Useful or effective investigation techniques**

Not applicable.

## 2 ANALYSIS

### 2.1 General

To the AIB, the following revealed findings had no negative influence on the sequence of events:

1. Licenses, qualifications and total/recent A320 flying experience held by the flight crew.
2. Flight and duty times (with no indications of neither accumulated nor acute fatigue).
3. The operational approval of the operator.
4. The technical status of the aircraft.
5. The aircraft mass and balance.
6. SOP regarding selection of reverse thrust cf. operator OM-B (FCOM), FCTM and Safety bulletin 06/2022.

The forecasted weather conditions at EKCH were generally consistent with the actual weather reports, and the weather observations perceived by the flight crew.

### 2.2 Approach

Before descent, the flight crew performed three landing performance calculations for runway 30. None of these calculations represented the actual aircraft landing configuration, but all three calculations indicated a required runway length shorter than the LDA. The AIB calculation, representing the actual aircraft landing configuration, resulted in a required landing distance of 1,540 m.

ATC requested the flight crew to vacate runway 30 via taxiway D (landing distance 1,530 m).

The commander decided that with an intended landing speed of 140 kt and a wet runway, the use of reverse thrust was necessary to comply with the ATC request.

The remaining runway length from taxiway D to the runway end was 555 m supplemented by an additional 300 m of stopway. To the AIB, there was no flight safety issue associated to the available stopping distance. It was only an operational consideration from the flight crew.

According to the stabilised approach concept, the aircraft was stabilised throughout the final approach and the flare just until touchdown, with only minor deviations in airspeed, seemingly caused by the gusting wind conditions.

Upon thrust reduction to idle and below 10 ft radio height, the aircraft drifted right, and touched down right of the centreline just after the runway aiming markings.

### 2.3 Go-around and flight procedures

According to the recorded data, the commander selected idle thrust at approximately 10 ft radio height and then maximum reverse thrust approximately three seconds later. Around the time of selection of maximum reverse thrust, the LH MLG left wheel had started to spin up indicating slight ground contact, and de-rotation had been initiated. But the shock absorbers had not yet compressed (no WOW).

Within two seconds after the selection of maximum reverse thrust, the aircraft/ECUs received a WOW signal and both thrust reversers started to deploy.

The first officer did not register neither ground spoiler nor reverser deployment indication and made no callouts confirming a touchdown.

The wind conditions likely affected aircraft stability during landing. The commander felt uncomfortable with the aircraft attitude and, neither being aware of the aircraft touchdown nor the selection of reverse thrust, the commander decided to abort the landing and selected TOGA thrust.

The commander handling thus deviated from the operator OM-B SOP (FCOM) and the FCTM.

The subject was also highlighted in the operator Safety bulletin 06/2022 stating that once reverse thrust was selected the landing had to be completed.

The AIB recognises that in a dynamic landing environment, it might be difficult for flight crews to distinguish between aircraft flight and landing mode based primarily upon external cues like visual impression and motion sensing (g-load).

Given the flight crew knowledge regarding the obligation to land after thrust reverser selection, the AIB finds it likely that the commander decision to abort the landing was a mistake and not an intentional violation of the SOP.

The incorrect decision-making (mistake) was likely based upon incomplete information/incorrect perception and a lack of awareness of the importance of complying with the landing SOP to keep a reliable and predictable engine/thrust reverser response during an aborted landing.

Lessons learnt from this serious incident and from the study into available flight data (deviation from SOP) suggested that flight crews might not be fully aware of the rationale behind the landing SOP.

It must be emphasised that adhering to SOPs (safety barriers) may prevent multiple unwanted flight scenarios not fully considered or evaluated during the design of the aircraft.

To the AIB, FDM can be a strong and helpful tool for operators when monitoring flight crew SOP adherence.

#### **2.4 Engine #1 thrust reverser not stowing**

After initial touchdown, the aircraft bounced slightly.

At the same time, the commander moved the thrust levers from the full aft position (maximum reverse) to the full forward position (TOGA) to abort the landing.

Due to various computing factors, ECU #1 received an air signal while ECU #2 received a ground (WOW) signal. Therefore, ECU #2 latched the stow command on engine #2 thrust reverser while ECU #1 did not latch the stow command. The result was an interruption of the stow sequence on thrust reverser #1 once the aircraft was off ground and WOW signal was no longer present. The subject is further analysed in [section 2.6](#).

The ECU autoidle function ensured that the engine #1 did not accelerate and generate excessive reverse thrust and prevented the serious incident from escalating. Thereby, the engine autoidle function was an effective safety barrier in reducing the consequences of the inability to stow thrust reverser #1.

With three blocker doors deployed on engine #1, the commander experienced difficulties in maintaining control of the aircraft. Rudder pedal inputs were not sufficient to counteract

the aircraft deviation towards the LH runway edge and the LH roll excursions induced by the asymmetrical thrust and drag configuration. The aircraft drifted left off the runway into the runway safety area (runway strip) at a very low height (approximately 10 ft radio height) and nearly collided with obstacles on the ground.

Once the landing gear was retracted, the commander increased the pitch close to  $12.5^\circ$ , corresponding to the target for go-around with one engine inoperative, and the vertical speed reached approximately 1,000 ft/min.

The initial climb performance was degraded by the absence of the Beta target display on the PFD. This resulted in insufficient rudder pedal inputs which did not sufficiently reduce the aircraft sideslip. The Beta target was displayed on the PFD once engine #1 was shut down at approximately 1,200 ft radio height.

## 2.5 Technical investigation of the engine #1 thrust reverser hardware

After the serious incident, the thrust reverser system was thoroughly tested on the aircraft. No relevant faults were evident. The relevant thrust reverser hardware was removed from the aircraft for further inspections and tests.

After all hardware inspections and tests had been performed, the conclusion was that all thrust reverser hardware were in good condition and performed as per design requirements.

## 2.6 Technical investigation of the ECU software logic and system design

The aircraft manufacturer investigation of the serious incident, resulted in a hypothesis. The hypothesis suggested that ECU #1 did not receive a ground signal (WOW) while the thrust lever was moved forward (from reverse to forward thrust position).

ECU #1 likely received the WOW signal after sensing thrust lever #1 had been moved forward to forward thrust. This resulted in ECU #1 not latching and maintain the stow command and therefore interrupting the #1 thrust reverser stow sequence (depressurising HCU #1) due to the aircraft bouncing (when the WOW signal was no longer present).

If the ECU received the WOW signal at the same time as the thrust lever was sensed moving forward (TLA from less to more than  $-4.2^\circ$ ), the ECU stow command (to the HCU) would latch and be maintained for up to eight seconds, or until the thrust reverser was fully stowed (blocker doors stow switches activated). This was the case for ECU #2 which stowed engine #2 thrust reverser.

The aircraft manufacturer testing of an ECU with the same part number and software version as involved in this serious incident, confirmed the above functioning of the ECU.

No fault codes were recorded in ECU #1 memory indicating that the thrust reverser system performed as designed during the serious incident. This supported the hypothesis.

The data from the aircraft were thoroughly analysed. The resolution and recording speed of the data were insufficient to firmly confirm the hypothesis. Furthermore, only the WOW signal from LGCIU #1 was recorded. However, the data indicated that the scenario was very likely, as the overlap between WOW signal changes and thrust lever movement was confirmed.

To further investigate the hypothesis, and to understand why engine #2 thrust reverser stowed when #1 did not, the aircraft manufacturer analysed the signal route of the thrust lever and WOW signals to the ECUs. The analysis confirmed that the input scan and output update frequency in combination with processing time of the computers made the

hypothesis plausible. Potential asymmetric position between the thrust levers during forward movement would have further contributed to the difference in signals received by the ECUs.

The aircraft manufacturer concluded that the ECU software logic was the only likely explanation for thrust reverser #1 not stowing, even though thrust reverser #2 succeeded in stowing during the sequence of events. Based on safety investigation data, the AIB agrees with this conclusion.

## 2.7 **The aircraft manufacturer design and operational review of the thrust reverser system**

Based on the findings during the AIB safety investigation, the aircraft manufacturer performed a design review of the A320 family CFM56 thrust reverser system.

The design review findings included:

- The CFM56 ECU was unable to stow the thrust reverser when operated outside its intended use (defined by the landing SOP) during an aborted landing under specific conditions.
- The serious incident was the first case of this type reported on any of the aircraft manufacturer aircraft types.
- The A320 aircraft fitted with CFM56 engines entered into service in 1988 and had accumulated more than 95 million flight cycles at the time of the serious incident.
- The level of adherence to SOP, enabling flight crew to operate the thrust reversers within the intended use considered during the design, was assessed using big data representative of the A320 family aircraft operation (FDM). It indicated that the level of SOP adherence was lower than expected and represented a significant exposure.
- The vast majority of the CFM56 fleet that will remain operated in the coming years is fitted with CFM56-5B engine models.

Based in these findings, the aircraft manufacturer developed a mitigation plan to enhance both:

- Flight crew adherence to recommendations linked to the use of thrust reversers included in SOP for landing.
- Thrust reverser stow logic in the CFM56-5B ECU software.

The aborted landing scenario and non-SOP adherence rate was not considered to be specific to the A320 family aircraft. The aircraft manufacturer conducted a design review on all of the aircraft types under their responsibility. Only the CFM56 ECU software on A320 and A340 was found to be affected by the serious incident scenario.

## 2.8 **Safety actions**

Based on the design review, and to mitigate the likelihood of another event of thrust reverser(s) not stowing during an aborted landing, the aircraft manufacturer implemented safety actions. These are described in [section 4.1](#).

Despite the safety actions implemented, aborted landings after thrust reverser selection are likely to occur in the future which can potentially result in one or more thrust reversers not stowing.

The AIB considers a modification of the CFM56 ECU software to be the most effective safety barrier against thrust reverser(s) not stowing during aborted landings. The AIB

recommends aviation authorities to mandate the embodiment once the modified ECU software is available.

The AIB considers the aborted landing scenario and non-SOP adherence not necessarily to be specific to any aircraft type. The AIB therefore promotes further safety actions by encouraging design reviews on other aircraft types fitted with thrust reversers.

## 2.9 Certification requirements for the design of thrust reverser systems

During the AIB safety investigation, the AIB informed and consulted the A320 type certifying authority (EASA). EASA informed that at the time of type certification of the A320 family, evaluation of the aborted landing scenario was not a certification requirement.

However, the aborted landing scenario and aircraft controllability in case of an inadvertent thrust reverser deployment was considered during the design of the A320.

The guidance material in relation to evaluation of an aborted landing after thrust reverser selection scenario was largely based on the Cranbrook accident on 1-2-1978. The Cranbrook accident involved firm ground contact during TOGA selection unlike this serious incident.

EASA informed that certification requirements involving design review of the aborted landing scenario after thrust reverser selection had later been implemented after the certification A320 and were present at the time of the serious incident. These certification requirements included the Canadian AC525-005 describing the scenario from the accident involving C-FPWC (B737-200) at Cranbrook on 1-2-1978.

These certification requirements did not stipulate the consideration for bounces during the aborted landing. The A320 CFM56 ECU software was able to perform the scenario from AC525-005 (as ECU #2 successfully did during the serious incident). For that reason, the AIB does not consider the current certification requirements as an effective safety barrier for preventing thrust reversers from not stowing during an aborted landing.

The certification requirements for the design of thrust reverser systems requires revising to make sure lessons learned from this serious incident are carried into future aircraft thrust reverser designs. The AIB issues a safety recommendation to EASA to revise the certification requirements for large aeroplanes (CS-25).

### 3 CONCLUSIONS

#### 3.1 Findings

##### 3.1.1 General

1. The flight crew licenses, qualifications, and total/recent Airbus A320 flying experience were all in compliance and had no negative influence on the sequence of events.
2. Flight and duty times, with no indications of neither accumulated nor acute flight crew fatigue, had no negative influence on the sequence of events.
3. The operational approval of the operator was compliant and had no negative influence on the sequence of events.
4. The aircraft was airworthy and the technical status of the aircraft had no negative influence on the sequence of events.
5. The aircraft mass and balance was within the aircraft certification limitations.
6. The landing configuration selected by the flight crew resulted in a calculated landing distance of 1,540 m.
7. The ATC request to vacate runway 30 at taxiway D required a landing distance of 1,530 m.
8. Runway 30 had a total LDA of 2,095 m excluding additional stopway of 300 m.
9. The commander pulled the thrust levers to reverse just as the aircraft wheels touched the ground, but before the aircraft was firmly on the ground.
10. Based on the attitude of the aircraft during landing, the commander decided to abort the landing and moved the thrust levers fully forward (TOGA) to initiate a go-around.
11. The first officer did not observe and did not call out the thrust reversers in transit.
12. The commander was not aware of selecting thrust reversers to deploy before selecting TOGA.
13. Aborting the landing after the selection of thrust reversers was a deviation from the landing SOP described in the FCOM and FCTM.
14. Engine #1 thrust reverser did not stow when the commander moved the thrust levers from max reverse (fully aft) to TOGA position (fully forward).
15. The autoidle function on ECU #1 prevented engine #1 from accelerating.
16. The sideslip index/beta target flagged during the aborted landing.
17. The missing sideslip index/beta target on the PFD reduced the ability of the commander to achieve the optimum missed approach climb performance.
18. The commander experienced difficulties in controlling and using the maximum capabilities of the aircraft with engine #1 thrust reverser not stowed.
19. After landing, three blocker doors were in the fully deployed position. The LH upper blocker door was held in place by the actuator (secondary) lock.
20. The thrust reverser system was inspected and tested on the aircraft revealing no relevant faults.
21. The relevant engine #1 thrust reverser hardware was removed from the aircraft, and the OEM performed a detailed inspection and testing revealing no relevant faults.
22. Hydraulic fluid from engine #1 thrust reverser system was in compliance with the requirements from the AMM.
23. The aircraft manufacturer identified that the CFM56 ECU software design would not latch the thrust reverser stow command in case the ECU received an air signal at the same time as the thrust lever was moved forward.

24. The lack of ECU fault codes after the serious incident suggested that all hardware performed as designed, and that the ECU performed as per its software design.
25. The recording resolution of the available flight data (SSFDR and DAR) did not allow to firmly conclude that ECU #1 received an air signal at the same time, as the commander moved the thrust levers forward.
26. Flight data indicated that the commander moved the thrust levers forward around the same time as the WOW signal changed from ground to air.
27. Flight data recording sources did not allow a comparison between the WOW signals on the two sides (LGCIU #1 vs LGCIU #2).
28. The aircraft manufacturer's analysis of the WOW and TLA signal route to ECU confirmed that a difference in received signals between ECU#1 and #2 was plausible.
29. Potential asymmetric position between the thrust levers during forward movement could have further contributed to a difference in signals received by the ECUs.
30. A difference in ground/air signals received by the ECUs while thrust levers were moved to TOGA would result in one thrust reverser not stowing, while the opposite thrust reverser stowed.
31. The ECU software not being designed to latch a thrust reverser stow command, if a ground signal was not received at the same time as thrust levers were moved forward from reverse thrust region was the only likely technical explanation why engine #1 thrust reverser did not stow.
32. At the time of certification of the aircraft, no requirements existed at the certifying authority to evaluate the aborted landing scenario.
33. The aborted landing scenario (with firm ground contact) was considered by the aircraft manufacturer during the design of the A320.
34. The safety investigation identified that the CFM56 stow logic did not ensure thrust reverser stowing during an aborted landing under all specific conditions.
35. At the time of the serious incident, certification requirements required evaluation of an aborted landing scenario.
36. At the time of the serious incident, no certification requirements were in place at the certifying authorities to evaluate an aborted landing scenario involving a bounced landing, and with selection of TOGA thrust while aircraft was not on the ground.

### 3.2 Factors

1. Based on the attitude of the aircraft during landing, the commander decided to abort the landing and moved the thrust levers fully forward (TOGA) to initiate a go-around.
2. Aborting the landing after the selection of thrust reversers was a deviation from the procedures described in the FCOM and FCTM.
3. The aircraft manufacturer identified that the CFM56 ECU software design would not latch the thrust reverser stow command in case the ECU received an air signal at the same time as the thrust lever was moved forward.
4. At the time of certification of the aircraft, no requirements existed at the certifying authorities to evaluate an aborted landing during a bounced landing scenario.

### 3.3 Summary

During landing in gusty wind conditions, the commander felt uncomfortable with the aircraft attitude and decided, after thrust reversers had been selected, to abort the landing. The commander moved the thrust levers fully forward (selected TOGA thrust) which



deviated from the procedure in the FCOM stipulating that once thrust reversers had been selected, the landing had to be completed.

Engine #2 thrust reverser stowed, and engine #2 accelerated. Engine #1 thrust reverser did not stow, and ECU #1 commanded engine #1 to autoidle. The commander experienced difficulties in controlling and achieving the maximum capabilities of the aircraft but managed to regain control. The aircraft continued climbing and the flight crew shut down engine #1 to regain better control of the aircraft. The aircraft subsequently landed without any further occurrences.

The AIB safety investigation identified that engine #1 thrust reverser did not stow since ECU #1 did not receive a ground signal at the same time, as thrust lever #1 position signal changed from reverse to forward thrust.

## 4 SAFETY RECOMMENDATIONS

### 4.1 Preventative safety actions

As a result of the serious incident and the AIB safety investigation, the aircraft manufacturer conducted a design review of the A320 CFM56 engine thrust reverser system.

Based on the design review, the aircraft manufacturer planned and performed the following safety actions:

- In March 2023 on a safety conference, the aircraft manufacturer informed A320 family aircraft operators about the serious incident and encouraged all operators to conduct FDM analysis of aborted landings after thrust reverser selection.
- In May 2023, the aircraft manufacturer revised the FCOM to increase awareness that a full stop landing must be performed after selection of thrust reversers. See [appendix 5.18](#).
- In June 2023, the aircraft manufacturer published a flight operations transmission letter and a Safety First magazine article (Thrust reverser selection is a decision to stop) to all operators. Key subjects included adherence to SOP, avoiding premature arming of reverse thrust before touchdown and commitment to stop once reverse thrust had been selected.
- In October 2023, the aircraft manufacturer's operational and training department published a video to increase flight crew awareness about recommendations related to thrust reverser use during landing/go-around/aborted landing.
- The aircraft manufacturer launched the development of a modification of the ECU software on the CFM56-5B engine. The aircraft manufacturer estimated the ECU software modification to be ready in 2025.
- The aircraft manufacturer scheduled a modification of the EIS software for 2026 to prevent flagging of the sideslip index/beta target, when one or more thrust reversers were deployed.

### 4.2 Safety recommendations

#### 4.2.1 CFM56 ECU software modification

##### 4.2.1.1 Motivation

Despite the implementation of preventative safety actions to enhance adherence to SOP for landing, aborted landings after thrust reverser selection are still likely to occur in the future. A runway incursion for instance, might force the flight crew to make the decision to abort a landing, even though thrust reversers have been selected.

The AIB considers an ECU software modification as an important safety barrier against one or more thrust reversers not stowing during an aborted landing.

##### 4.2.1.2 Safety recommendation no. DK.SIA-2024-0001

**To prevent engine thrust reverser(s) not stowing on an A320 family aircraft during an aborted landing after ground contact, the AIB recommends EASA to ensure that the aircraft and engine manufacturer modifies the CFM56-5B ECU software, and that the software modification is mandated and embodied on the entire CFM56-5B fleet when ready for entry into service estimated in 2025.**

## 4.2.2 EASA Certification Specifications for Large Aeroplanes (CS-25)

### 4.2.2.1 Motivation

An aborted landing scenario was considered during design, and the A320 CFM56 ECU software was able to comply with the requirement of AC 525-005 where the aborted landing scenario could be interpreted to involve firm and stable ground contact during thrust reverser selection and de-selection.

Neither EASA, FAA nor TC certification requirements considered a more aggravated scenario with interrupted ground signals (bounces) such as this serious incident.

The AIB considers that having the serious incident scenario (in its most aggravated form) evaluated as part of certification requirements with at least one of these certifying authorities, can reduce the risk of thrust reversers not stowing during aborted landings.

Addressing the safety recommendation to EASA should ensure that an aircraft certified anywhere in the world will have to comply with the updated certification requirements to allow the aircraft type to fly in Europe. This should affect almost any new commercial air transport aircraft worldwide.

### 4.2.2.2 Safety recommendation no. DK.SIA-2024-002

**To prevent future aircraft designs from incorporating an engine thrust reverser design that will not stow during an aborted landing, the AIB recommends EASA to revise the certification requirement (CS-25/AMC) to include evaluation of the serious incident aborted landing after thrust reverser selection during a bounced landing scenario (in its most aggravated form).**

## 4.3 Additional proposed safety actions

### 4.3.1 Design review of thrust reverser systems on other aircraft types

Following the serious incident, the aircraft manufacturer conducted a design review on all of their aircraft/thrust reverser designs. Only the CFM56 ECU software was found to be affected.

The aborted landing after thrust reverser selection scenario was also analysed and was found to be more frequent than anticipated. The analysis indicated that an aborted landing after thrust reverser selection occurred approximately once per month on the A320 family (all engine types). Despite differences in aircraft and thrust reverser designs, it cannot be ruled out that this rate (once per one million flights) is similar or higher on other aircraft types.

Other aircraft with thrust reverser systems might also potentially be affected by the described scenario.

The safety recommendation associated to revision of CS-25 only affects new aircraft being certified (initial airworthiness) and does not affect aircraft already in service (continued airworthiness).

The AIB encourages all certifying authorities responsible for the continued airworthiness of aircraft with thrust reverser systems to ensure that the aircraft manufacturers conduct a thrust reverser system design review to determine whether their thrust reverser design(s) might be affected by the serious incident scenario (in its most aggravated form).

#### 4.3.2 Training of and adherence to SOPs

An aircraft is designed to be operated within a set of specific scenarios. The SOPs form the basis of these scenarios. Operating an aircraft in accordance with the SOPs ensures reliable and predictable aircraft and engine responses during for instance an aborted landing. The SOPs are an important safety barrier in any aircraft design.

However, aircraft SOPs only remains an effective safety barrier if they are strictly adhered to by the flight crews. The design and operational review performed by the aircraft manufacturer during this safety investigation revealed that the SOP “after thrust reversers have been selected a full stop landing must be performed” was not always adhered to.

The specific SOP “after thrust reversers have been selected a full stop landing must be performed” is common on any aircraft fitted with a thrust reverser system. It is possible that other aircraft designs might be subject to non-adherence on thrust reverser SOPs.

Specific training (initial and recurrent) in addition to dissipation of safety briefings are possible methods which an operator may apply to raise awareness of a specific SOP.

The AIB encourages all operators of aircraft with thrust reverser systems to raise awareness and conduct specific training on SOPs associated to thrust reverser operation and encourages oversight authorities to ensure that this safety action is performed by the operators.

#### 4.3.3 Use of FDM to monitor adherence to SOPs

The aircraft manufacturers design review included analysis of 3.4 million flights in a flight database (FDM).

Any aircraft operator operating aircraft of more than 27,000 kg is required to analyse their safety performance by using a FDM system.

The FDM system allows operators to build a set of algorithms and trace specific safety events (unstable approaches etc.).

The AIB encourages all operators of aircraft with thrust reverser systems to trace adherence to SOPs associated to thrust reverser operation and encourages oversight authorities to ensure that this safety action is performed by the operators.

**5 APPENDICES**

- 5.1 Final loadsheet
- 5.2 FCOM landing SOP extract
- 5.3 FCTM extract
- 5.4 Operator safety bulletin extract
- 5.5 Stevns reflectivity weather radar image
- 5.6 AIP Denmark aerodrome chart - EKCH
- 5.7 Operator airport facility chart - EKCH
- 5.8 SSFDR plot
- 5.9 DAR data plot
- 5.10 List of ECU thrust reverser fault codes
- 5.11 Ground plot
- 5.12 HCU CMM test results
- 5.13 PDLs CMM test results
- 5.14 Actuators CMM test results
- 5.15 Actuators load capability test results
- 5.16 TRSOV CMM test results
- 5.17 Filter housing test results
- 5.18 FCOM revised landing SOP extract


**5.1 Final loadsheet**Return to [mass and balance](#) [Mass and balance](#)

AN CS-TNV/FI █████/MA 004A  
 - LOADSHEET FINAL 0732 EDNO2  
 █████/08 08APR22  
 LIS CPH CS-TNV 2/4  
 ZFW 52619 MAX 61000 L  
 TOF 10796  
 TOW 63415 MAX 77000  
 TIF 7728  
 LAW 55687 MAX 64500  
 UNDL 8381  
 PAX/8/94 TTL 102  
 PAX 102 PLUS 0  
     FWD-LMT ACTL AFT-LMT  
 ZFMAC 19.32 30.64 39.41  
 TOMAC 19.09 28.52 38.84  
 WINGS+CTR 11000  
 A34 B34 C34  
 SEATROW TRIM  
 SI DOW 43037  
 DOI 50.1  
 SERVICE WEIGHT ADJUSTMENT WEIGHT/INDEX  
 ADD  
 CPH POTABLE WATER  
 200 0.7-  
 DEDUCTIONS  
 NIL  
 PANTRY CODE 6A  
 █████  
 PAX WEIGHTS USED M88 F70 C35 I0  
 CHECKED BAGGAGE PIECES CPH 1/Y/45  
 CPH 3/P/7/Y/6 5/W/1  
 PREPARED BY █████ 4 34095  
 SALEABLE CONFIGURATION 12C/156Y  
 NOTOC: NO  
 AVERAGE BAGS WEIGHTS USED: ACTUAL 15  
 LOAD IN CPTS 0/0 1/818 3/647 4/0 5/75  
 CPH C 0 M 363 B 59/ 885  
 O 0 T 0  
 LAST MINUTE CHANGES  
 DEST SPEC CL/CPT WEIGHT/IND  
 END OF LOADSHEET

Note: The AIB removed the flight number, the name of the commander and the name of the dispatcher.


5.2 FCOM landing SOP extract

Return to [Flight Crew Operating Manual \(FCOM\)](#).

 <b>A319/A320/A321</b> FLIGHT CREW OPERATING MANUAL	<b>PROCEDURES</b> <b>NORMAL PROCEDURES</b> STANDARD OPERATING PROCEDURES - LANDING
<b>MANUAL LANDING</b>	
Applicable to: ALL Ident.: PRO-NOR-SOP-19-A-00010351.0011001 / 25 APR 17	
<p><b>FLARE</b></p> <p>The cockpit cut-off angle is 20 °.</p> <ul style="list-style-type: none"> <li>● <b>In stabilized approach conditions, the flare height is approximately 30 ft:</b></li> </ul> <p>FLARE..... PERFORM</p> <p><i>Avoid flaring high. Refer to Ground Clearance Diagram.</i></p> <p>ATTITUDE..... MONITOR</p> <p>THRUST levers..... IDLE</p> <p><i>If autothrust is engaged, it automatically disconnects when the pilot sets both thrust levers to the IDLE detent.</i></p> <p><i>In manual landing conditions, the "RETARD" callout is triggered at 20 ft radio height, in order to remind the pilot to retard the thrust levers.</i></p> <p><i>Note: The ground spoilers extension is inhibited if:</i></p> <ul style="list-style-type: none"> <li>- Both thrust levers remain above the idle detent, or</li> <li>- One thrust lever is above idle and one thrust lever is at idle detent.</li> </ul> <p>Ident.: PRO-NOR-SOP-19-A-00010352.0001001 / 04 NOV 20</p>	
<p><b>AT TOUCHDOWN</b></p> <p>DEROTATION..... INITIATE</p> <ul style="list-style-type: none"> <li>- Lower the nosewheel without undue delay.</li> <li>- The PM continues to monitor the attitude.</li> </ul> <p>ALL THRUST LEVERS..... REV MAX or REV IDLE</p> <p><i>The flight crew must select reverse thrust immediately after main landing gear touchdown.</i></p> <p><i>The flight crew must immediately select REV MAX, if any of the following occurs at any time during the landing:</i></p> <ul style="list-style-type: none"> <li>- An emergency</li> <li>- The deceleration is not as expected</li> <li>- A failure affects the landing performance</li> <li>- A long flare or a long touchdown</li> <li>- An unexpected tailwind.</li> </ul> <p><i>A small pitch up may occur during thrust reversers deployment before nose landing gear touchdown. However, the flight crew can easily control this pitch up.</i></p> <p><i>As soon as the flight crew selects reverse thrust, they must perform a full-stop landing.</i></p>	
A319/A320/A321 FLEET FCOM	PRO-NOR-SOP-19 P 1/6 18 NOV 20

Procedure extract page 1 of 2

Note: The AIB removed the name of operator.

 <b>A319/A320/A321</b> FLIGHT CREW OPERATING MANUAL	<b>PROCEDURES</b> <b>NORMAL PROCEDURES</b> STANDARD OPERATING PROCEDURES - LANDING
---	--

**GROUND SPOILERS..... CHECK/ANNOUNCE**

*Check that the WHEEL SD page displays the ground spoilers extended after touchdown.*

*If no ground spoilers are extended:*

- Verify and confirm that both thrust levers are set to IDLE or REV detent.
- Set both thrust reverser levers to REV MAX, and fully press the brake pedals.

*Note: If ground spoilers are not armed, ground spoilers extend at reverser thrust selection.*

**REVERSERS..... CHECK/ANNOUNCE**

- Check that the ECAM E/WD displays that the reverse deployment is as expected (REV green).
- If reverser(s) do not deploy as expected, one of the main deceleration means is lost. The flight crew should consider adapting the available deceleration means to stop the aircraft.

**DIRECTIONAL CONTROL.....MONITOR/ENSURE**

- Monitor directional control, if the rollout is automatic.
- Ensure directional control, if rollout is manual. Use rudder pedals for directional control.
- Do not use the nosewheel steering control handle before reaching taxi speed.
- During rollout, the flight crew should avoid sidestick inputs (either lateral or longitudinal).
- If directional control problems are encountered, the flight crew should reduce thrust to reverse idle until directional control is satisfactory.

**BRAKES..... AS RQRD**

- Monitor the autobrake, if it is ON. When required, brake with the pedals
- Although the green hydraulic system supplies the braking system, if pedals are pressed rapidly, a brake pressure indication appears briefly on the BRAKE PRESS indicator.
- Braking may begin before the nosewheel has touched down, if required for performance reasons. However, when comfort is the priority, the flight crew should delay braking until the nosewheel has touched down.

*Note: If no ground spoilers are extended, the autobrake is not activated.*

**DECELERATION..... CHECK/ANNOUNCE**

*The deceleration is felt by the flight crew, and confirmed by the speed trend on the PFD.*


Ident.: PRO-NOR-SOP-19-A-00010353.0001001 / 17 JUL 13

**AT 70 KT**

**SEVENTY KNOTS..... ANNOUNCE**

**BOTH THRUST LEVERS..... REV IDLE**

*It is better to reduce thrust when passing 70 kt. However, high levels of reverse thrust may be used in order to control aircraft speed in the case of an emergency.*

 A319/A320/A321 FLEET

PRO-NOR-SOP-19 P 2/6

FCOM

← A →

18 NOV 20


Procedure extract page 2 of 2.

Note: The AIB removed the name of operator.



**5.3 FCTM extract**

Return to [Flight Crew Technique Manual \(FCTM\)](#).

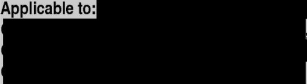
 <b>A319/A320/A321</b> FLIGHT CREW TECHNIQUES MANUAL	<b>PROCEDURES</b> <b>NORMAL PROCEDURES</b> STANDARD OPERATING PROCEDURES - GO-AROUND
--	--

If the flight crew performs a go-around near the ground, they should take into account the following:

- The PF should avoid excessive rotation rate, in order to prevent a tailstrike. For more information *Refer to PR-NP-SOP-250 Tail Strike Avoidance*
- A temporary landing gear contact with the runway is acceptable.

Only when the aircraft is safely established in the go-around, the flight crew retracts flaps one step and the landing gear.

*Note: If the aircraft is on the runway when the PF applies TOGA thrust, CONFIG ECAM red warning(s) may transiently trigger. The flight crew should disregard these alerts.*

Ident.: PR-NP-SOP-260-A-00019215.0001001 / 05 MAR 19  
 Criteria: 27-1284, P20427, SA  
 Applicable to:  CS-TNV,

**GO-AROUND NEAR THE GROUND**

The PF must not initiate a go-around after the selection of the thrust reversers. If the PF initiates a go-around, the flight crew must complete the go-around maneuver.


If the flight crew performs a go-around near the ground, they should take into account the following:

- The PF should avoid excessive rotation rate, in order to prevent a tailstrike. For more information *Refer to PR-NP-SOP-250 Tail Strike Avoidance*
- A temporary landing gear contact with the runway is acceptable.

Only when the aircraft is safely established in the go-around, the flight crew retracts flaps one step and the landing gear.

*Note: If the aircraft is on the runway when the PF applies TOGA thrust, CONFIG ECAM red warning(s) may transiently trigger. The flight crew should disregard these alerts.*

---

 A319/A320/A321 FLEET	← B	PR-NP-SOP-260 P 2/6
FCTM		18 AUG 21

Note: The AIB removed the name of the operator.

5.4 Operator safety bulletin extract

Return to [operator safety bulletin](#).

The FCTM recommends to maintain the pitch attitude and initiate a go-around in the case of a high bounce . Maintaining the pitch attitude, and counteracting any pitch-up tendency due to the thrust increase, enables the flight crew to avoid a tail strike and ensure a softer secondary touchdown should this occur.

High Bounce: **Maintain pitch**, apply **go-around thrust** and **counteract any pitch-up tendency** due to thrust increase to avoid tailstrike until safely established in the go-around.



(fig.6) Management of a high bounce

**Be go-around minded**

The PF must perform a go-around if any parameter deviation becomes excessive, or if the aircraft is destabilized just prior to the flare.

If the aircraft floats above the runway, the flight crew must initiate a go-around instead of attempting to recover the situation.

The PF can abort the landing and go-around at any time until the thrust reversers are selected. However, when the reversers are selected, the landing must be continued.

**Avoid excessive rotation rate in a go-around close to the ground**

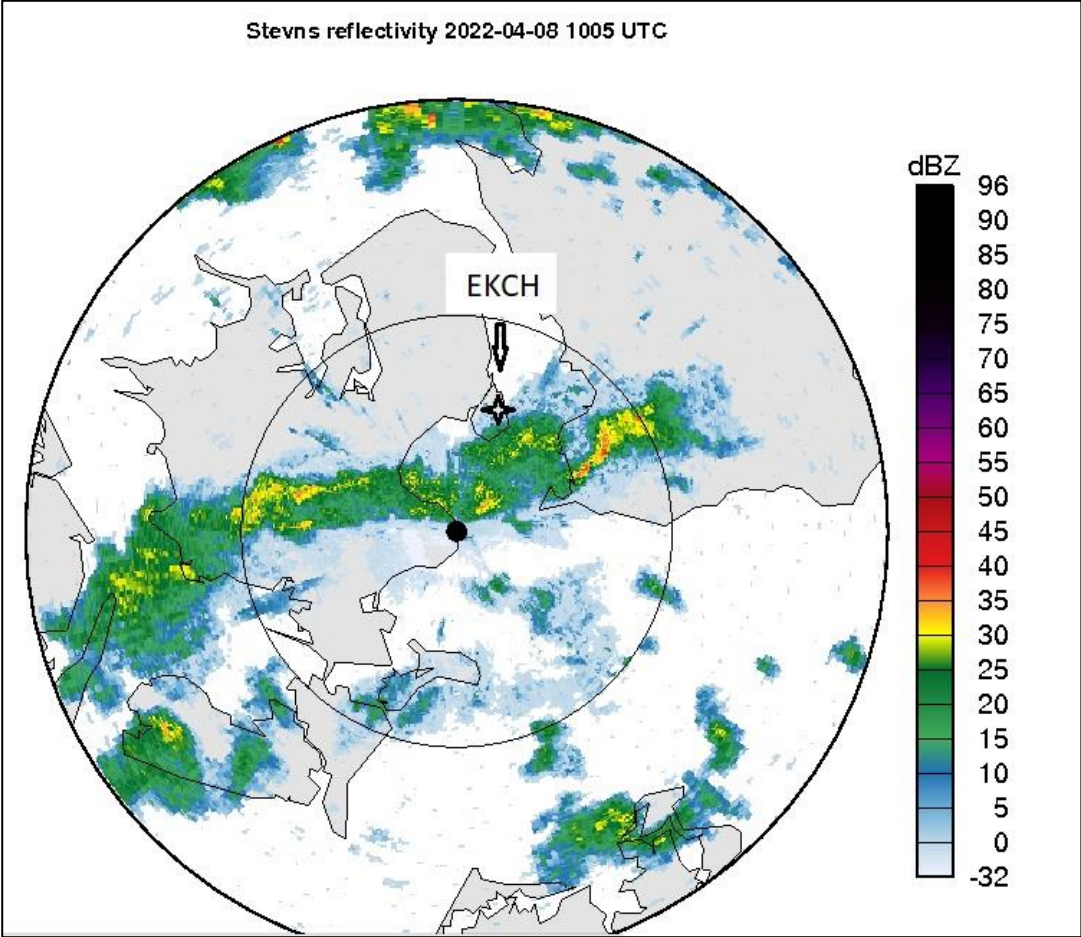
When the flight crew initiates a go-around close to the ground, they must avoid an excessive rotation rate to limit the risk of tail strike.

The flight crew must wait until the aircraft is safely established in the go-around before retracting the flaps by one step and the landing gear. ■

“The PF can abort the landing and go-around at any time until the thrust reversers are selected. However, when the reversers are selected, the landing must be continued.”

5.5 Stevns reflectivity weather radar image

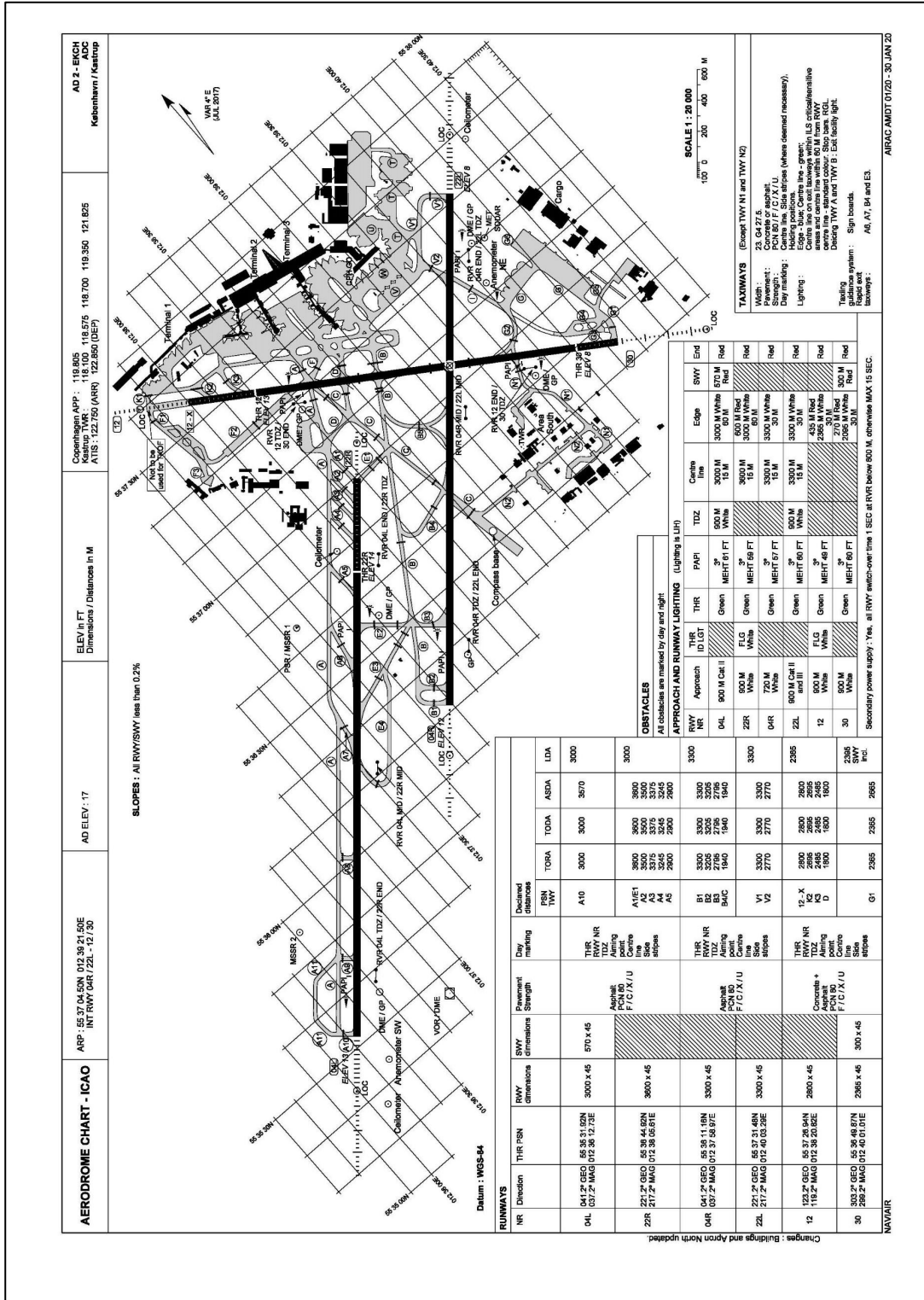
Return to [aftercast valid for EKCH at 10:05](#)



Appendices

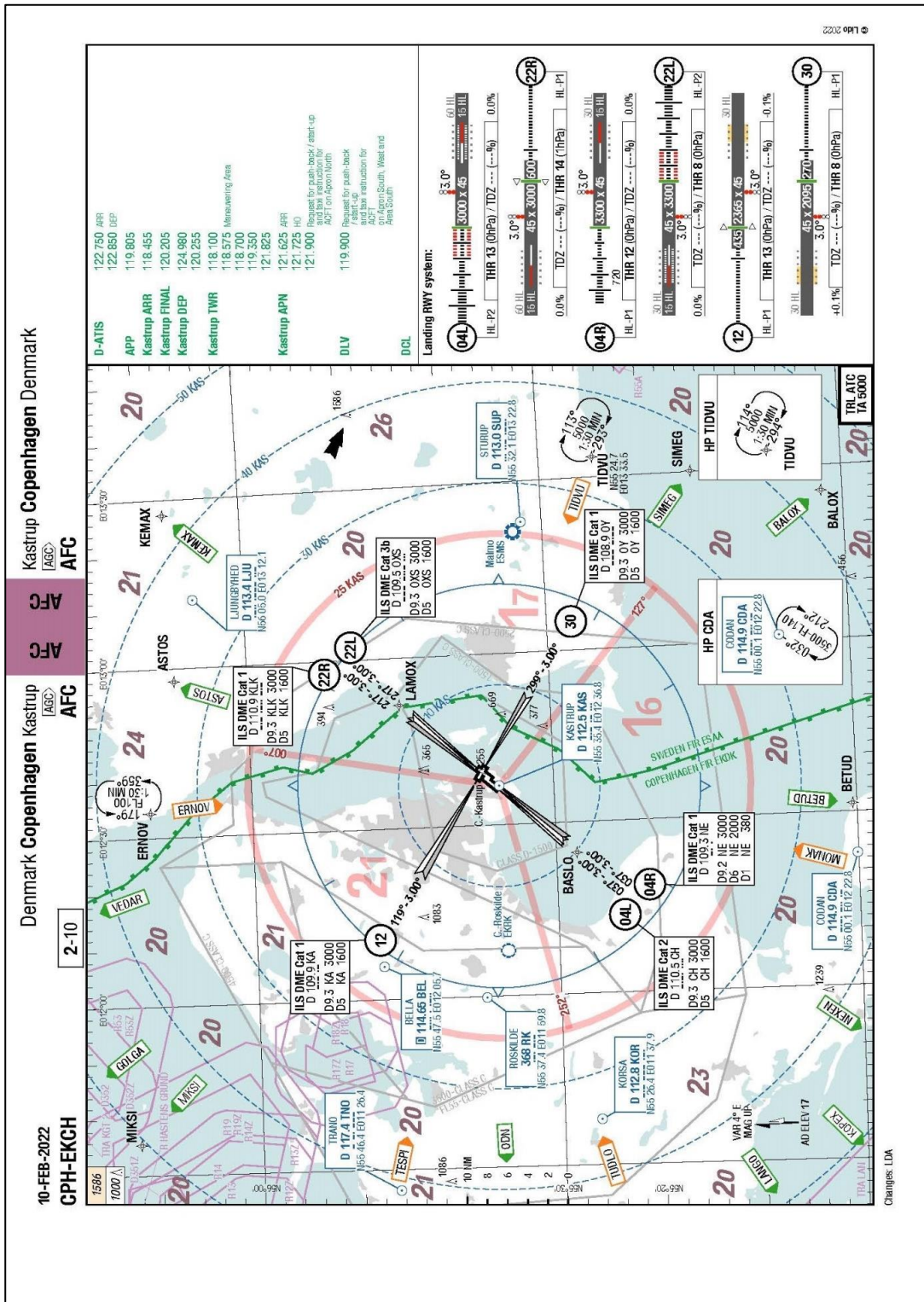
5.6 AIP Denmark aerodrome chart - EKCH

Return to [aerodrome chart for EKCH](#)



5.7 Operator airport facility chart - EKCH

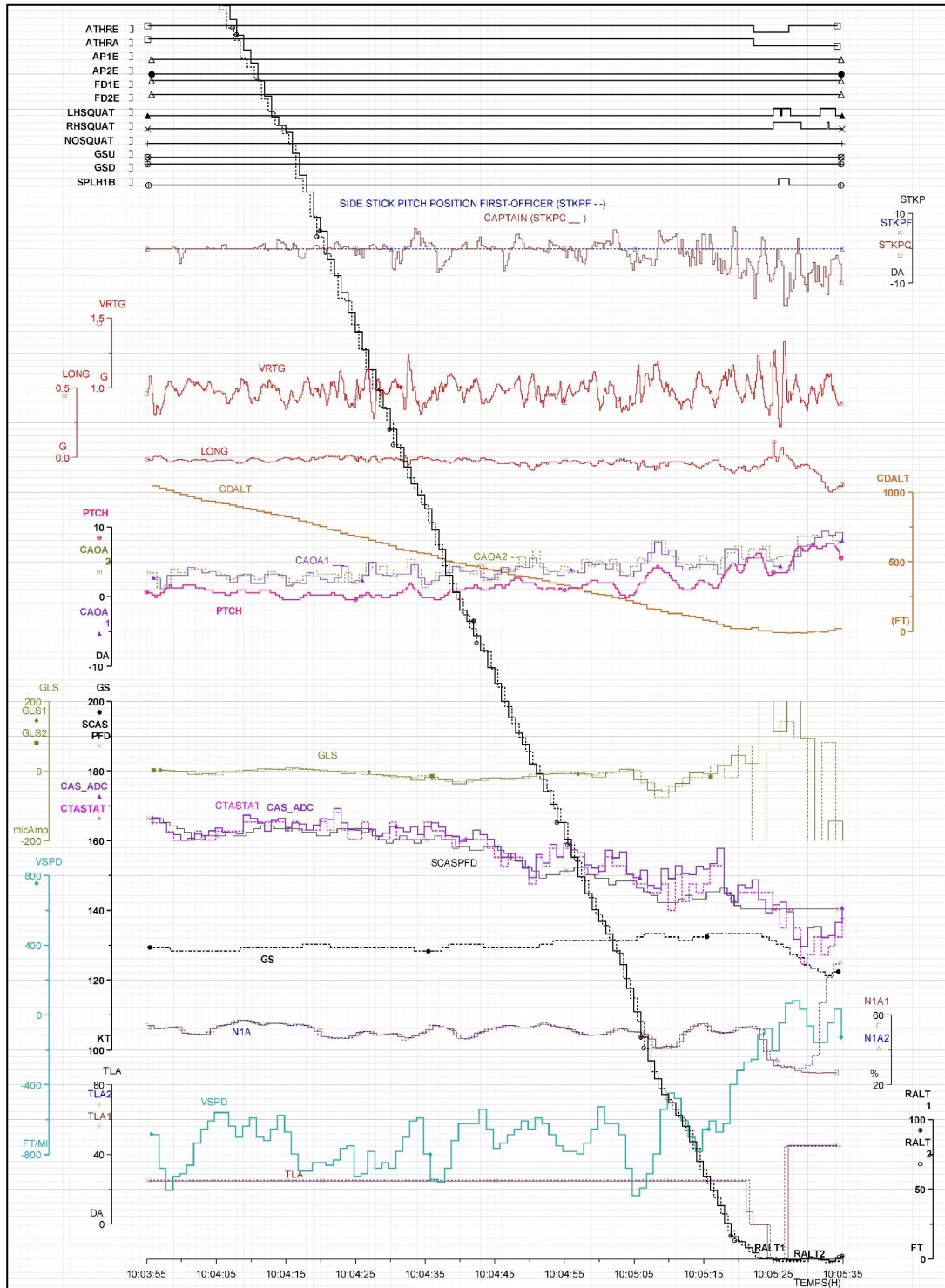
Return to [aerodrome chart for EKCH](#)



Note: The AIB removed the name of operator.

### 5.8 SSFDR plot

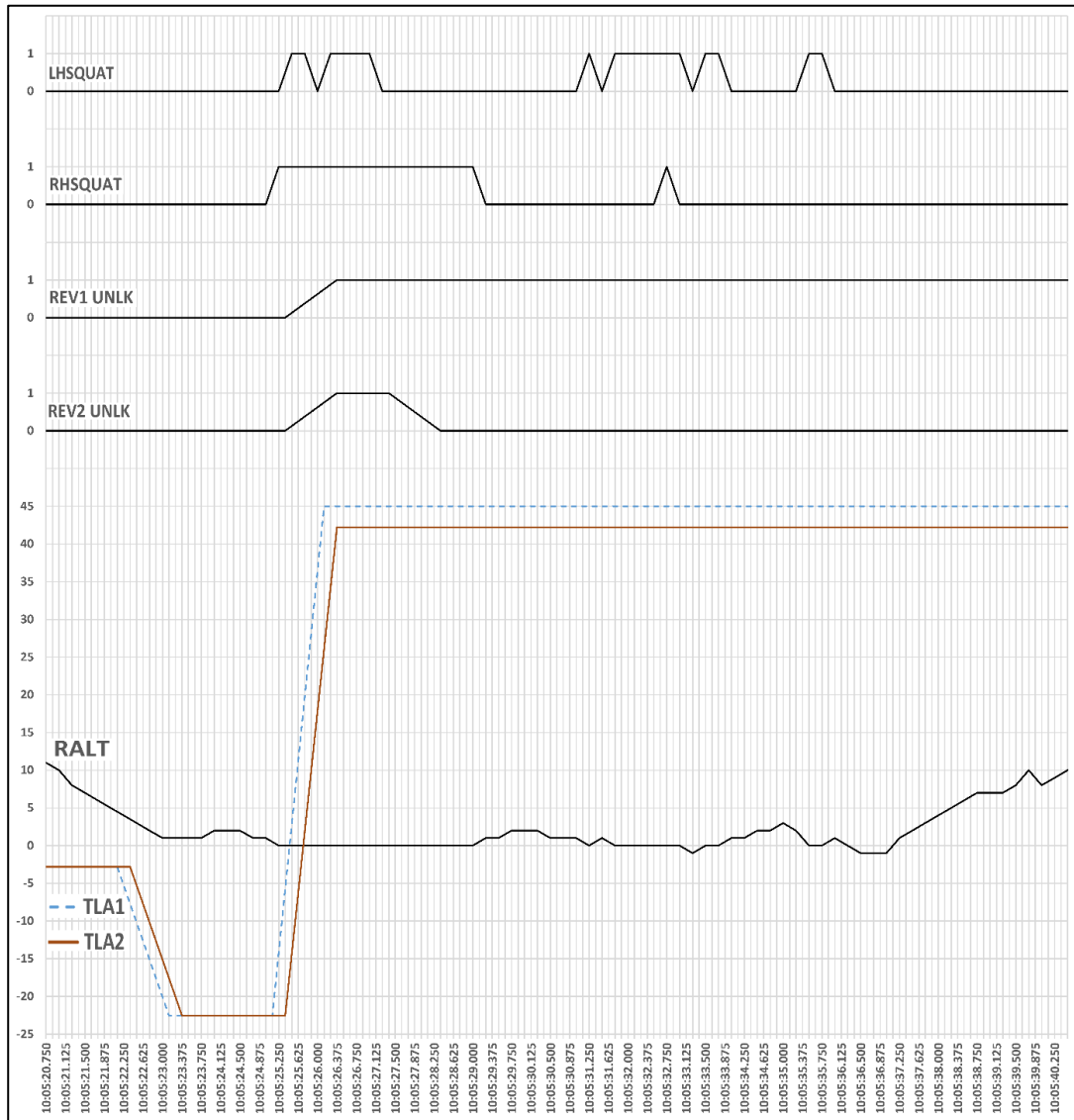
Return to [SSFDR data](#)



Appendices

### 5.9 DAR data plot

Return to [DAR data](#)



Appendices

**5.10 List of ECU thrust reverser fault codes**

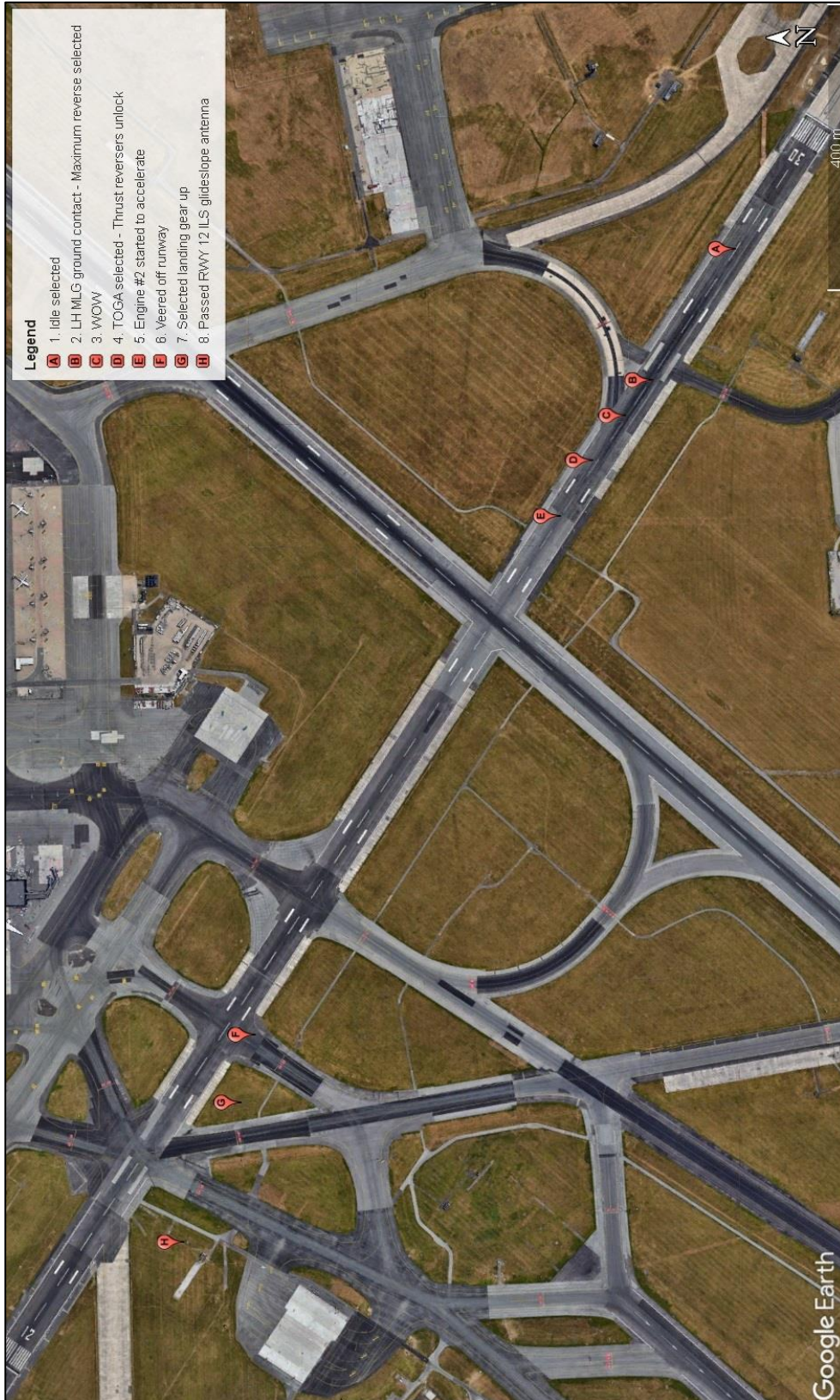
Return to [ECU memory](#)

ECU fault code	Extract of description from aircraft Troubleshooting Manual (TSM)
TR DEPLOY/STOW SW SIGNAL	Loss of the Signal of the Thrust-Reverser Blocker-Door Deploy/Stow Switches
TR DOOR(S) UNSTOWED	The fault is generated if at least one blocker door is detected unstowed by the FADEC
TR PRESS SWITCH SIGNAL	This fault message is generated if there is a disagreement between channel A and channel B on the HCU pressure switch output signal.
TR PRESS SW FAILED OPEN	This fault message is generated if there is an HCU pressure switch failed in the open position
TR DEPLOY SWITCH SIGNAL	This fault message is generated if there is a disagreement between channel A and channel B on the thrust-reverser blocker-door deploy switches signal.
TR STOW SWITCH SIGNAL	This fault message is generated if there is a disagreement between channel A and channel B on the stow switch signal of the thrust reverser blocker doors.
TR STOW TIME TOO LONG	The fault message HCU is generated if the thrust reverser stow time is greater than 8 seconds between the setting of the throttle from reverse to forward idle and the locking of the reverser blocker doors.
TR PRES SOLENOID CURRENT	The fault message is generated when the ECU detects an open circuit or a short to ground on the solenoid of the HCU pressurizing valve or on associated electrical wiring.
TR DIR SOLENOID CURRENT	The fault message is generated when the ECU detects an open circuit or a short to ground on the solenoid of the HCU directional valve or on associated electrical wiring.
TR PRES VLV ACTUATION	This fault message is generated if the ECU detects no pressurization of the thrust reverser HCU after a deploy command of the thrust reverser.
TR:PV,ISOL V,HYD FAILURE	This fault message is generated if the ECU detects no pressurization of the thrust reverser HCU after a deploy command of the thrust reverser.
TR PRES VLV FAILED OPEN	The fault message is generated if a position fault is detected on the HCU pressurizing valve (valve detected open when reverse stowage is commanded)
TR DID NOT DEPLOY	No or partial deployment of the thrust reverser when commanded to deploy
TR ISOLATION VLV OPEN	The fault message is generated if the ECU detects a pressurization of the thrust reverser HCU during the thrust reverser isolation valve monitoring test after the engine start. The message indicates that the thrust reverser isolation valve has failed in the open position or is leaking internally.



### 5.11 Ground plot

Return to [ground plot](#)



5.12 HCU CMM test results

Return to [detailed inspection and testing of HCU, PDLs and actuators](#)

CMM Page Number	Test Description	Test Requirement Tolerance	Test Result
p709 4A	Resistance of the Solenoid Valve Assemblies	Proprietary Information	
	Electrical connector 170		
	Pins 2 & 3		Passed
	Pins 4 & 5		Passed
	Electrical connector 190		
	Pins 2 & 3		Passed
	Pins 4 & 5		Passed
			Passed
p709 4B	Insulation Resistance		
p711 4C	Electrical Bonding		
	Pin 1 Connector A		Passed
	Pin 1 Connector B		Passed
	Body of connector A		Passed
	Body of connector B		Passed
	Pin 1 of pressure switch		Passed
	Body of pressure switch		Passed
p711 4C	Continuity Test		
			Passed
p106 4B	Pressure Test 5 minutes		
			Passed
p107 4C	Pressure switch operation		
	Pressure switch light extinguished		Passed
	Pressure switch light illuminated		Passed
p107 4D	Isolation Valve Assembly Operation		
	Response time: flow 35-41 litres/min	Passed	
	Response time: Stow = Output pressure	Passed	
p109 4E	Inhibiting Lever Assembly Operation		
	Stow drain leakage rate	Passed	
	Return of inhibiting lever to Deploy pos.	Passed	
p110 4F	Isolation Valve Assembly Leakage		
	Output drain leakage – solenoid not energ.	Passed	
	Output drain leakage – solenoid energized	Passed	
p111 4G	Valve & Guide Assembly Operation		
	Lock-in connection pressure	Passed	
	Flow rate	Passed	
	Pressure difference – input / stow	Passed	
	Pressure difference – Stow / deploy	Passed	
	Output drain leakage rate	Passed	
	Lock in pressure – Deploy flow ceases	Passed	
p112 4H	Solenoid Valve Assembly Operation		
	Isol. sol. energized - flow rate lock out	Passed	
	Deploy sol. energized - flow rate lock out	Passed	
p113 4I	Presence of flow at all time at output		
		Passed	
p114 4J	Isol. solenoid valve minimum voltage test		
	Coil A Voltage	Passed	
	Coil A Current	Passed	
	Zero stow pressure with polarity reversed	Passed	
	Coil B Voltage	Passed	
	Coil B Current	Passed	
	Zero stow pressure with polarity reversed	Passed	
p115 4K	Depl. solenoid valve minimum voltage test		
	Coil A Voltage	Passed	
	Coil A Current	Passed	
	Zero lock-out press. with polarity reversed	Passed	
	Coil B Voltage	Passed	
	Coil B Current	Passed	
	Zero lock-out press. with polarity reversed	Passed	
p116 4L	Flow restr. & check vlv restr. Flow test		
	Press. diff. depl/output - flow rate 38 l/min	Passed	
	Flow rate – 0-30 bar diff press - depl/output	Passed	
	Flow rate – 160 bar diff press - depl/output	Passed	
	Flow rate – Check vlv restr. drain vlv	Passed	

5.13 PDLs CMM test results

Return to [detailed inspection and testing of HCU, PDLs and actuators](#)

CMM Page Number	Test Description	Test Requirement Tolerance	PDL SN 26422	PDL SN 57984	PDL SN 57986	PDL SN 58008
Page 105 4A	Pressure Test	Proprietary information	Satisfactory	Satisfactory	Satisfactory	Satisfactory
Page 105 4B	Hydraulic Lock, High Load Integrity Test		Satisfactory	Satisfactory	Satisfactory	Satisfactory
Page 106 4C	Hydraulic Lock - Loaded		Passed	Passed	Passed	Passed
Page 106 4D	Hydraulic Unlock - No Load					
	20 Bar held for 5 minutes		Satisfactory	Satisfactory	Satisfactory	Satisfactory
	Increase pressure until unit unlocks		Passed	Passed	Passed	Passed
Page 107 4E	Piston Valve Operation Return Flow		Passed	Passed	Passed	Passed
Page 107 3F	Internal Leakage		Passed	Passed	Passed	Passed
Page 107-3G	Piston Valve Operation Normal Flow		Satisfactory	Satisfactory	Satisfactory	Satisfactory
Page 108 3H	Mechanical Unlock – No Load		Passed	Passed	Passed	Passed
Page 108 3J	Re lock Inspection		Passed	Passed	Passed	Passed
Page 108 3K	Mechanical Unlock - Loaded		Passed	Passed	Passed	Passed

5.14 Actuators CMM test results

Return to [detailed inspection and testing of HCU, PDLs and actuators](#)

CMM Page Number	Test Description	Test Requirement Tolerance	LA20745 RH Lower	LA20759 RH Upper	LA20686 LH Lower	LA20751 LH Upper	LA16383 Reference unit
p105 4A	Eye End Setting	Proprietary information	Passed	Passed	Passed	Passed	Passed
p105 4B	Swivel Joint Measurement		Passed	Passed	Passed	Passed	Passed
	Horizontal		Passed	Passed	Passed	Passed	Passed
	Vertical		Passed	Passed	Passed	Passed	Passed
p105 4C	Running In and External Leakage		Passed	Passed	Passed	Passed	Passed
p105 4D	Proof Pressure Test		Passed	Passed	Passed	Passed	Passed
(1-6)	D1 Deploy 300 bar		Passed	Passed	Passed	Passed	Passed
(7)	Leakage from stow connection		Passed	Passed	Passed	Passed	Passed
(8-9)	Deploy pressurised to 20 bar 5 mins		Passed	Passed	Passed	Passed	Passed
(12) & (4-6)	D1 Stow 300 bar		Passed	Passed	Passed	Passed	Passed
(12) & (7)	Leakage from Deploy connection		Passed	Passed	Passed	Passed	Passed
(12) & (8-9)	Stow pressurised to 20 bar 2 mins		Passed	Passed	Passed	Passed	Passed
p107 4E	Output Travel and Overtravel		Passed	Passed	Passed	Passed	Passed
	Record overtravel dimension A		Passed	Passed	Passed	Passed	Passed
	Stroke length		Passed	Passed	Passed	Passed	Passed
	Extended length		Passed	Passed	Passed	Passed	Passed
	Functioning Tests		Passed	Passed	Passed	Passed	Passed
p107 4F	Time 0-95%		Passed	Passed	Passed	Passed	Passed
	Time 0-100%		Passed	Passed	Passed	Passed	Passed
	Stroke at onset snubbing		Passed	Passed	Passed	Passed	Passed
	End stop impact speed	Passed	Passed	Passed	Passed	Passed	
	Oil Temp	Passed	Passed	Passed	Passed	Passed	
	Time 100-10%	Passed	Passed	Passed	Passed	Passed	
	Oil Temp	Passed	Passed	Passed	Passed	Passed	
p110 4G	Lock Test	Passed	Passed	Passed	Passed	Passed	
(1-6)	Pressure to unlock	Passed	Passed	Passed	Passed	Passed	
(7-10)	Unit stowed against 15-16 bar	Passed	Passed	Passed	Passed	Passed	
(11-15)	Unit stowed against 15-16 bar with 47-48 bar stow pressure	Passed	Passed	Passed	Passed	Passed	
(16-18)	Manual unlock torque	Passed	Passed	Passed	Passed	Passed	
(19-22)	Lock integrity 1615-1785 daN for 2 mins	Passed	Passed	Passed	Passed	Passed	

**5.15 Actuators load capability test results**

Return to [actuator load capability testing](#)

ED/1447/263 ME Section Number	Test Description	Test Requirement	LA20745 RH Lower	LA20759 RH Upper	LA20686 LH Lower	LA20751 LH Upper	LA16383 Reference Unit	
4.1.2.1 f)	Friction Test	Record retract pressure	4.7 bar	4.5 bar	4.5 bar	4.5 bar	4 bar	
4.1.2.2 g)	Load Capability Test at XXXX decaNewton (daN)	Does unit retract?	No	No	No	No	No	
4.1.2.2 h)	Load Capability Test at XXXX daN (highest value)	Record retract time	N/A	N/A	N/A	N/A	N/A	
		Record load	Proprietary information					
		Does actuator lock?	No	No	No	No	No	
		Record retract pressure	178 bar	178 bar	178 bar	178 bar	178 bar	
		Record retract time	N/A	N/A	N/A	N/A	N/A	
		Record load	Proprietary information					
		Does actuator lock?	No	No	No	No	No	
		Record retract pressure	178 bar	178 bar	178 bar	178 bar	178 bar	
		Record retract time	5.5 sec	5.8 sec	5.6 sec	5 sec	5 sec	
		Record load	Proprietary information					
4.1.2.2 h)	Load Capability Test at XXXX daN	Does actuator lock?	Yes	Yes	Yes	Yes	Yes	
		Record retract pressure	178 bar	178 bar	178 bar	178 bar	178 bar	
		Record retract time	3.75 sec	4.5 sec	3.7 sec	3.5 sec	4.4 sec	
4.1.2.2 h)	Load Capability Test at XXXX daN (Event load)	Record load	Proprietary information					
		Record retract time	1.5 sec	1.3 sec	1.5 sec	1.4 sec	1.7 sec	

**5.16 TRSOV CMM test results**

Return to [TRSOV test](#)

CMM Page Number	Test Description	Test Requirement Tolerance	Test Result
p103	Electrical test	Proprietary information	
B	Insulation Resistance (500 Volt for 2 mins)		Passed
C	Bonding test		Passed
p103 A	Proof pressure supply port (4500 psi, 5 mins)		Passed
p104 B	Proof pressure control port (4500 psi, 5mins)		Passed
p106 C	Proof pressure return port (4500 psi, 5mins)		Passed
p106 D	Pull-in voltage		Passed
	Drop-out voltage		Passed
p107 E	Cycle 15 times		Passed
	Leak check control port, solenoid deenergized		Passed
p107 F	Leak check return port, solenoid deenergized		Passed
p108 G	Leak check return port, solenoid energized		Passed
p109 H	No flow at 730 psi (spool valve closed)		Passed
	Supply pressure to open spool valve		Passed
p109 I	Differential pressure test		
	Solenoid energized. Supply to control port	Passed	
	Solenoid deenergized. Control to return port	Passed	



**5.17 Filter housing test results**

Return to [filter housing test](#)

CMM test results:

CMM Page Number	Test Description	Test Requirement Tolerance	Test Result
p1005 A	Low pressure leakage (XX psig)	No leakage or deformation	OK
p1005 B	High pressure leakage (XXXX psig)	No leakage or deformation	OK
p1005 C	Flow differential pressure (XXXX litres/min)	≤80 psid (5.5 bar)	90 psid
p1006 D	Differential pressure indicator actuation test	Proprietary information	Passed
			Passed
			Passed
	Post assembly testing		
p1006 A	Element ejection / shut off valve operation	No leak	Small leak

Comparison test results:

	Test rig	Stock filter housing		Returned filter housing	
Flow	Tare pressure	Filter housing pressure	Calculated differential pressure	Filter housing pressure	Calculated differential pressure
l/min	(psid)	(psid)	(psid)	(psid)	(psid)
Proprietary information	6.8	8.7	1.9	9.7	2.9
	22.7	27.9	5.2	27.9	5.2
	46.7	56.8	10.1	57	10.3
	71	106.7	35.7	107.2	36.2
	116.5	172	55.5	173.1	56.6
	175	255.5	80.5	255.6	80.6
	243	355.5	112.5	356	113

5.18 Revised FCOM landing SOP extract


Return to [safety actions](#)

<div style="background-color: black; width: 40px; height: 20px; margin: 0 auto;"></div> <p><b>A318/A319/A320/A321</b> FLIGHT CREW OPERATING MANUAL</p>	<p><b>PROCEDURES</b> <b>NORMAL PROCEDURES</b></p> <p>STANDARD OPERATING PROCEDURES - LANDING</p>
<p><b>MANUAL LANDING</b></p>	
<p>Ident.: PRO-NOR-SOP-19-A-00025032.0001001 / 09 NOV 21 Applicable to: ALL</p>	
<p><b>FOR MANUAL LANDING</b></p> <p>AP..... OFF   PF</p>	
<p>Ident.: PRO-NOR-SOP-19-A-00010351.0011001 / 05 MAY 22 Applicable to: ALL</p>	
<p><b>FLARE</b></p> <p>● <b>AROUND 30 ft RA:</b> In stabilized approach, the flare height is approximately 30 ft.</p> <p>FLARE..... PERFORM   PF ATTITUDE..... MONITOR   PM THRUST LEVERS..... IDLE   PF</p> <p>[L2] <i>Move the thrust levers to idle, and begin a gentle progressive flare to enable the aircraft to touch down without a prolonged float. If autothrust is engaged, it automatically disconnects when the flight crew sets both thrust levers to the IDLE detent. At 20 ft, an automatic "RETARD" callout will trigger, as a reminder.</i></p> <p>[L1] <i>Note: Ground spoilers extension is inhibited if one or more thrust levers remain above the IDLE detent.</i></p>	
<p>Ident.: PRO-NOR-SOP-19-A-00010352.0008001 / 03 MAY 23 Applicable to: MSN 02792-04742, 08593-08666, 08773, 08923-08946, 09055, 09120-09308, 10033-11813</p>	
<p><b>AT TOUCHDOWN</b></p> <p>● <b>As soon as the main landing gear touches down:</b> DEROTATION..... INITIATE   PF ALL THRUST LEVERS..... REV MAX or REV IDLE   PF</p> <p>[L2] <i>The flight crew must select reverse thrust immediately after main landing gear touchdown.</i></p> <p>[L1] <i>Note: As soon as the flight crew selects reverse thrust, they must perform a full-stop landing. The flight crew must immediately select REV MAX, if any of the following occurs at any time during the landing:</i></p> <ul style="list-style-type: none"> <li>- An emergency</li> <li>- The deceleration is not as expected</li> <li>- A failure affects the landing performance</li> </ul>	
<p>■ A318/A319/A320/A321 FLEET FCOM</p>	<p>PRO-NOR-SOP-19 P 1/10 A → 16 MAY 23</p>

Procedure extract page 1 of 2

Note: The AIB removed the name of operator.



 <b>A318/A319/A320/A321</b> FLIGHT CREW OPERATING MANUAL	<b>PROCEDURES</b> <b>NORMAL PROCEDURES</b> STANDARD OPERATING PROCEDURES - LANDING
--	--

- A long flare or a long touchdown
- An unexpected tailwind.

A small pitch up may occur during thrust reversers deployment before nose landing gear touchdown. However, the flight crew can easily control this pitch up.

GND SPLRS.....CHECK/ANNOUNCE | PM

**L2** Check that the **WHEEL SD** page displays the ground spoilers extended after touchdown.

If no ground spoilers are extended:

- Check that all thrust levers are set to IDLE detent
- Set both thrust reverser levers to MAX REV, and fully press the brake pedals.

**L1** **Note:** If ground spoilers are not armed, ground spoilers extend at reverse thrust selection.

REVERSERS.....CHECK/ANNOUNCE | PM

**L2** - Check that the E/WD displays the expected reverser deployment (i.e. **REV**)  
 - If reverser(s) do not deploy as expected, one of the main deceleration means is lost. The flight crew should consider adapting the available deceleration means to stop the aircraft.

**L1** DIRECTIONAL CONTROL..... MONITOR/ENSURE | PF

**L2** - Ensure directional control. Use the rudder pedals for directional control  
 - During rollout, avoid sidestick inputs (either lateral or longitudinal)  
 - If the flight crew encounters directional control problems, they should reduce the thrust to REV IDLE until directional control is satisfactory.

**L1** **Note:** Do not use the nosewheel steering control handle before reaching taxi speed.

● **If autobrake is selected:**

AUTO BRK.....CHECK/ANNOUNCE | PM

**L2** Check and announce **BRK LO** or **BRK MED** on the FMA.  
 If no ground spoilers are extended, the autobrake will not activate.

**L1** AUTOBRAKE.....MONITOR | PM

**L2** During all the rollout, the PM monitors that the FMA displays **BRK LO** or **BRK MED**, and calls out if the autobrake mode disengages.

Procedure extract page 2 of 2.

Text below is an extract from FCOM general information:

- L1: “Need to know”. Layer 1 presents information that is necessary in the cockpit.
- L2: “Nice to know”. Layer 2 presents information that is used as a reference, in order to fully understand the logic of the aircraft and pilot interfaces.