Bundesstelle für
Flugunfalluntersuchung

German Federal Bureau of
Aircraft Accident Investigation

Investigation Report

Identification

Type of Occurrence:	Serious Incident
Date:	6 November 2018
Location:	Clariden, Switzerland
Aircraft:	Transport aircraft
Manufacturer:	Airbus
Type	A340-642
Injuries to Persons:	No injuries
Damage:	None
Other Damage:	None
State File Number:	BFU18-1626-FX

This investigation was conducted in accordance with the regulation (EU) No. 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation and the Federal German Law relating to the investigation of accidents and incidents associated with the operation of civil aircraft (*Flugunfall-Untersuchungs-Gesetz - FlUUG*) of 26 August 1998.

The sole objective of the investigation is to prevent future accidents and incidents. The investigation does not seek to ascertain blame or apportion legal liability for any claims that may arise.

This document is a translation of the German Investigation Report. Although every effort was made for the translation to be accurate, in the event of any discrepancies the original German document is the authentic version.

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Content Page

Abbreviations

Glossary of Abbreviations

AD	Airworthiness Directive	Lufttüchtigkeitsanweisung
ADIRU	Air Data Inertial Reference Unit	
ADR	Air Data Reference	
AFM	Airplane Flight Manual	Flughandbuch
AFS	Auto Flight System	
AGL	Above Ground Level	über Grund
AMC	Acceptable Means of Compliance	
AMSL	Above Mean Sea Level	über dem mittleren Meeresspiegel
ANSP	Air Navigation Service Provider	Flugsicherungsorganisation
AOA	Angle of Attack	
AOC	Air Operator Certificate	Luftverkehrsbetreiberzeugnis
AOM	Airplane Operating Manual	Flugbetriebshandbuch
AP	Autopilot	automatische Flugregelungs- und Steueranlage
ARC	Airworthiness Review Certificate	Bescheinigung über die Prüfung der Lufttüchtigkeit
A/THR	Autothrust	Automatische Schubregelung
ATC	Air Traffic Control	Flugverkehrskontrolle
ATIS	Automatic Terminal Information Service	Automatische Ausstrahlung von Lande- und Startinformationen
ATPL	Airline Transport Pilot Licence	Verkehrspilotenlizenz
CAS	Calibrated Airspeed	Kalibrierte Fluggeschwindigkeit
CAST	Causal Analysis based on System Theory	
CLB	Climb (thrust setting)	
CNR-ISAC	Institute of Atmospheric Sciences and Climate des National Research Council of Italy	
COP	Co-pilot	Copilot
CPL	Commercial Pilot Licence	Berufspilotenlizenz

CRM	Crew Resource Management	
CVR	Cockpit Voice Recorder	
DME	Distance Measuring Equipment	Entfernungsmessgerät
DWD	German Meteorological Service	Deutscher Wetterdienst (German meteorological service provider)
EASA	European Union Aviation Safety Agency	Europäische Agentur für Flugsicherheit
ECAM	Electronic Centralized Aircraft Monitor	Elektronisches Flugüberwachungssystem
EPR	Engine Pressure Ratio	
FCL	Flight Crew Licensing	
FCOM	Flight Crew Operating Manual	
FCPC	Flight Control Primary Computer	
FCSC	Flight Control Secondary Computer	
FDAP	Flight Data Analysis Programm	
FCTM	Flight Crew Training Manual	
FCU	Flight Control Unit	
FDR	Flight Data Recorder	Flight Data Recorder
FL	Flight Level	Flugfläche
FMS	Flight Management System	
ft	Feet	Fuß (1 Fuß = 0,3048 m)
ft/min	Feet per minute	Fuß pro Minute
G	acceleration due to Earth's gravity (9,81 m/s²)	Beschleunigung durch die Erdanziehungskraft (9,81 m/s²)
GM	Guidance Material (EASA)	
GND	Ground	Grund
GPS	Global Positioning System	
GPWS	Ground Proximity Warning System	
GS	Ground Speed	Geschwindigkeit über Grund
HDG	Heading	Steuerkurs
HFACS	Human Factors Analysis and Classification System	
IAF	Initial Approach Fix	Anfangsanflugpunkt
IAS	Indicated Airspeed	Angezeigte Fluggeschwindigkeit

IATA	International Air Transport Association	
ICAO	International Civil Aviation Organization	
IFALPA	International Federation of Air Line Pilots' Associations	
IR	Inertial Reference	Trägheitsnavigation
KIAS	Knots Indicated Airspeed	
LOSA	Line Operations Safety Audit	
MAC	Mean Aerodynamic Chord	
MCTOM	Maximum Certified T/O Mass	Max. zugelassene Startmasse
MEP(L)	Multi Engine Piston Land	
METAR	Aviation Routine Weather Report	Routine Wettermeldung für die Luftfahrt
M_{MMO}	Maximum operating Mach number	
MTOM	Maximum T/O Mass	Maximale Startmasse
PF	Pilot Flying	Pilot, der das Flugzeug steuert
PFD	Primary Flight Display	
PIC	Pilot in Command	Pilot in Command
P/N	Part Number	Teilenummer
OEB	Operations Engineering Bulletin	
QNH	altimeter pressure setting to indicate altitude AMSL	Luftdruck in Meereshöhe
QRH	Quick Reference Handbook	
SACAA	South African Civil Aviation Authority	
SEC	Flight Control Secondary Computer	
SEP(L)	Single Engine Piston Land	
SIGMET	Information concerning en-route weather phenomena which may affect the safety of aircraft operations	Informationen bezüglich Wettererscheinungen auf der Flugstrecke, welche die Sicherheit des Flugbetriebs beeinträchtigen können

S/N	Serial Number	Seriennummer
SOP	Standard Operating Procedure	Standard-Betriebsverfahren
SUST		Schweizerischen Sicherheitsuntersuchungsstelle
TOW	Take Off Weight	tatsächliche Abflugmasse
V_{MO}	Maximum operating speed	
WAFC	World Area Forecast Centre	
ZFW	Zero Fuel Weight	Luftfahrzeugleermasse

Abstract

The aircraft was in cruise flight at Flight Level (FL) 380 in Swiss airspace, when a change of wind conditions at high altitude caused the exceedance of the maximum operating Mach. The Pilot in Command (PIC) deactivated the autopilot and steered the aircraft manually into climb. While reaching FL 400, the maximum angle of attack was reached several times and the stall warning activated. The PIC initiated the descent stabilizing the flight path again at FL 340.

On 16 November 2018, the Swiss Transportation Safety Investigation Board (STSB) delegated the investigation to the German Federal Bureau of Aircraft Accident Investigation.

The investigation determined:

- A rapidly turning wind direction during cruise flight, unpredictable for the flight crew. This caused an overspeed condition.
- The flight crew did not respond to this overspeed condition with the procedure Abnormal and Emergency Procedures / Misc / Overspeed Recovery.
- The PIC had deactivated the autopilot and in the course of the incorrect application of the OEB No. 49, he had two Air Data Reference (ADR) of the three Air Data Inertial Reference Units (ADIRU) switched off. Subsequently, the Autothrust (A/THR) was deactivated and flight idle thrust initially maintained.
- Temporarily, the aircraft was controlled in Alternate Law.
- Due to the dynamic pitch-up control inputs of the PIC, the subsequent climb and the low engine thrust in flight idle, rapid deceleration of airspeed and triggering of the stall warning occurred.
- Due to the erroneous application of the OEB No. 49, the aircraft was close to a stall at high altitude.
- The PIC’s control inputs during the active stall warning were insufficient and not energetic enough to stabilise the flight attitude in time.
- Crew cooperation during the overspeed condition and the stall recovery was erroneous in regard to the analysis of the situation and the implementation of procedures.

1. Factual Information

1.1 History of the Flight

1.1.1 Course of the Flight prior to the Occurrence

The Airbus 340-346 was on a commercial flight of an air operator from Johannesburg, South Africa, to Frankfurt/Main, Germany. On board were 259 persons. At 0526 hrs[1], the flight crew contacted Swiss Radar shortly before reaching Swiss Airspace and having just passed Milano, Italy. At the time, the aircraft was at FL 380 and flew north. Autopilot #2 (A/P 2) and A/THR were switched on. The flight crew, consisting of the PIC and two co-pilots (later: co-pilot 1 and co-pilot 2) were all in the cockpit. The PIC was programming the Flight Management System (FMS) for the approach to Frankfurt/Main Airport. Co-pilot 1 was in the right-hand seat and ate a meal. A few minutes before, he had returned from a rest period of several hours. Co-pilot 2 was in the jump seat[2] and familiarised himself with the approach charts.

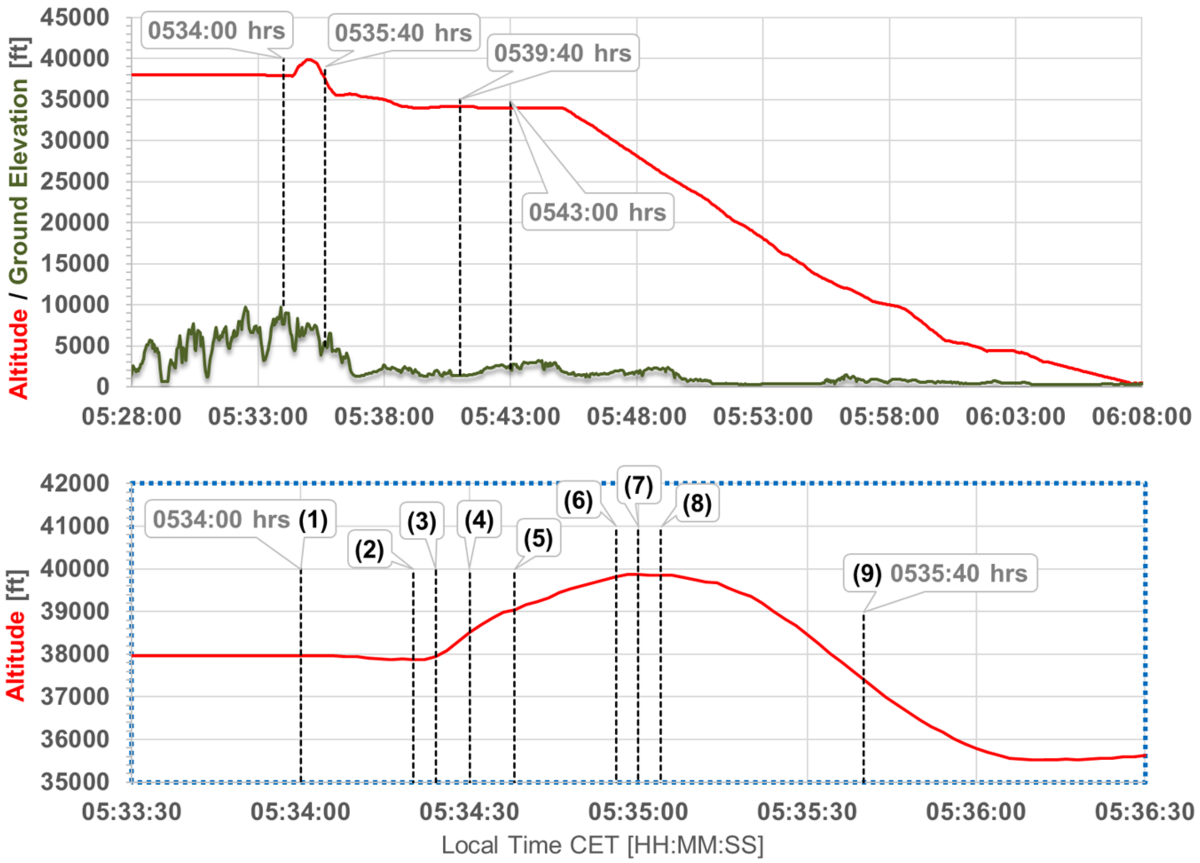
1.1.2 Course of the Flight

According to the Flight Data Recorder (FDR) recording, at FL 380 the wind came from about 205 ° with about 65 kt, while the aircraft was flying north. At about 0534 hrs, as the aircraft passed the peak Clariden[3], located north of the main Alpine Ridge, at a lateral distance of approximately 1.5 NM, the wind changed to 215° and then to 175°. Within 15 seconds windspeed decreased by 50 kt to approximately 15 kt. Based on the pilots' statements, the recordings of the FDR and the air navigation services, the chronological sequence of events depicted in Figure 1 occurred.

1 All times local, unless otherwise stated.

2 The Jump-Seat is an auxiliary seat for individuals, other than normal passengers, who are not operating the aircraft.

3 The Clariden, is a mountain of the Glarner Alps with a height of 3,267above sea level.



Nr.	Timestamp	Action
(1)	5:34:00	Wind direction change from 215° to 175°. Wind velocity reduced decreased within 15 s of 50 kt and resulted at the end with 15 kt
(2)	5:34:21	Overspeed Warning (Ma 0,88)
(3)	5:34:25	Autopilot was manually disconnected by the PF
(4)	5:34:30	Engine EPR 0,7 Units and aircraft climbed
(5)	5:34:38	VαProt increased while switching off 2 ADR´s
(6)	5:34:57	Call: “Pan Pan Pan”
(7)	5:35:00	At FL400 and CAS decreased to 203 kt (Ma 0,68)
(8)	5:35:03	Stall Warning active
(9)	5:35:40	Call: “Mayday Mayday Mayday”

Fig. 1: Vertical course of the flight, with radio communications excerpts, including legend Source: BFU

The most important events between 0533:30 hrs and 0536:30 hrs were selected (Fig. 1, blue box), numbered (1-9) and transferred to the graph. The following is a detailed description.

While the tail wind component (1) decreased, Mach increased from Ma 0.82 to Ma 0.88 and the overspeed warning (2) became active for the next 8 seconds. During this time period, Mach increased further to Ma 0.89 and then dropped again to Ma 0.86. About four seconds after the ECAM overspeed warning became active, the PIC deactivated the autopilot manually (3). Due to control inputs from the left side stick[4], the aircraft's pitch angle increased within 6 seconds from +3.5° to +11° nose up. A vertical acceleration of up to +1.6 g[5] was reached. Now the aircraft was in climb and reached a climb rate of up to +5,700 ft/min. Between 0.8 and 2.4 seconds after the autopilot had been disengaged, a Mach of Ma 0.70 was selected at the flight control unit.

Since the tailwind component had decreased, the engine pressure ratio[6] of all four engines had dropped from about 1.09 units to about 0.7 units (4).

According to all three crew members, they were surprised by the ECAM overspeed warning. Co-pilot 1 had noticed how $V\alpha_{prot}$ (5) on the Primary Flight Display (PFD) had skyrocketed shortly after the warning. Subsequently, he had told the other crew members that under the circumstances erroneous behaviour of the angle of attack[7] (AOA) protection may be present. The PIC instructed to switch off two ADRs of the three ADIRUs.

As they were passing FL 390 and 19 seconds after the autopilot was disengaged, the ADRs No. 2 and No. 3 of the three ADIRUs were switched off. Flight control law changed from Normal Law to Alternate Law and autothrust disengaged.

About three seconds later, the flight crew radioed "Pan, pan, pan [callsign]" (6).

The pitch angle decreased again and the aircraft reached FL 400. Calibrated Airspeed (CAS)[8] decreased to 203 kt and Mach to Ma 0.68 (7). Negative vertical speed and the angle of attack increased and the stall warning became active at an angle of attack of +7° and a Mach of Ma 0.70 (8). Control inputs were made at the left side stick towards nose down and the angle of attack and the pitch angle decreased again. After three seconds, the angle of attack was at +6° again and the stall warning inactive.

In the following 23 seconds, control inputs at the left side stick were made, alternately towards nose down and nose up. The pitch angle varied between +6.3° and -4.6°, the

4 Is an aircraft control column / joystick that is located on the side console of the pilot.

5 The gravitational force equivalent, or, more commonly, g-force, is a measurement of the type of force per unit mass – typically acceleration – that causes a perception of weight, with a g-force of 1 g (not gram in mass measurement) equal to the conventional value of gravitational acceleration on Earth.

6 The engine pressure ratio (EPR) is the total pressure ratio across a jet engine, measured as the ratio of the total pressure at the exit of the propelling nozzle divided by the total pressure at the entry to the compressor.

7 The Angle of Attack is the angle between a reference line on a body (often the chord line of an air foil) and the vector representing the relative motion between the body and the fluid through which it is moving.

8 Calibrated airspeed (CAS) is indicated airspeed corrected for instrument and position error.

angle of attack between +3° and +8° and the stall warning became active 3 more times for up to 4 seconds. At the time, airspeed decreased and the stall warning was triggered, i. e. the aircraft had almost reached the maximum angle of attack (buffet onset[9]).

About 14 seconds after the last stall warning, the EPR values of all four engines increased again to more than 1.0. Subsequently the PIC moved the thrust levers forward to CLB. Another four seconds later, at 0535:40 hrs, the flight crew reported via radio: "[Call sign] Mayday, Mayday, Mayday, we amend, we have no control […]" (9).

The flight crew temporarily lost control of the aircraft. At the time, the aircraft was at FL 370 and descended with a rate of descent of -6.600 ft/min. About 30 seconds later, at FL 355, rate of descent decreased briefly to about -100 ft/min. In the following 2.5 minutes, the PIC initiated the descent and stabilized the flight path again at FL340.

At 0539:40 hrs, the two ADRs were switched on again and at 0541 hrs, the flight crew reported: "[…] we managed to return to autoflight […]".

At 0543 hrs, Swiss Radar turned the aircraft over to the next air traffic control unit. At 0610 hrs, the aircraft landed at the aerodrome of destination.

Figure 2 shows the flight path on a GoogleEarth™ chart with excerpts of the radio communications.

9 The definition of the buffet onset is the following: it corresponds to a buffet in the cockpit of 0.2G (peak to peak) that appears as precursor sign of stall that will happen if the AOA continues to increase. Note: This level of buffet is the lowest one considered at detectable by the crew.

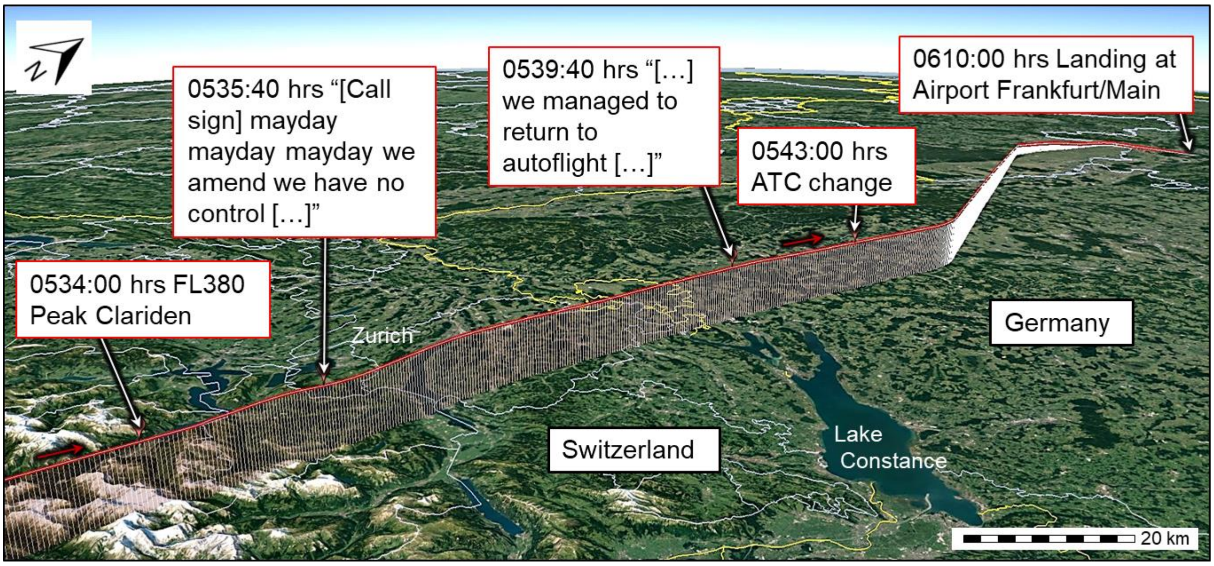


Fig. 2: Course of the flight between the occurrence and the landing at Frankfurt/Main Airport

Source: FDR, ATC, GoogleEarth™, adaptation BFU

1.2 Injuries to Persons

Injuries	Crew	Passengers	Third Parties
Fatal	0	0	0
Serious	0	0	0
Minor	0	0	0
None	15	244	0

Tab. 1: Overview injuries to persons

1.3 Damage to Aircraft

The operator's maintenance organisation inspected the aircraft after the landing. No damage was found.

1.4 Other Damage

There was no other damage.

1.5 Personnel Information

1.5.1 Pilot in Command

The 59-year-old PIC was citizen of the Republic of South Africa.

He held an Airline Transport Pilot Licence (ATPL(A)) initially issued by the South African Civil Aviation Authority (SACAA) on 19 November 1990. His licence was valid until 31 March 2019 and listed the following ratings: Multi Engine Piston Land (MEP(L)), and Single Engine Piston Land (SEP(L)) in accordance with Instrument Flight Rules (IFR).

According to his licence, the PIC held the type rating for Airbus A340-600. The rating was valid until 28 February 2019.

He also held the type ratings as PIC for Airbus A320, Boeing B737 300-900 and Douglas DC-3. In addition, he had the type ratings as co-pilot for Airbus A300, ATR-42/72, Boeing B747, and Boeing B737-100/200.

He had a total flying experience of 17,694 hours, of which 147 hours were flown on A340-600. In the 90 days prior to the occurrence, he had flown 151 hours. On 29 October 2018, he finished his Airbus A340-600 training. Since then he had flown 16:30 hours on type.

During his Secondary Recurrent Training in July 2015, the OEB No. 49 (Chapter 1.17.7.2) was discussed. On 4 December 2015, during a simulator training, he completed an Upset Recovery Training. On 29 October 2018 at the operator, he finished the so-called Operating Experience Training. On 2 November 2018, he had conducted a short-haul flight on an Airbus A340-600 as PIC. His annual recurrent CRM training was valid until 30 November 2018.

The provided simulator training documentation showed no negative assessments concerning the flying performance in the respective comments fields the flight instructors fill in.

His class 1 medical certificate, issued by the SACAA on 7 December 2017, was valid until 31 December 2018. It listed the restriction to wear corrective glasses and to carry along a hypertensive protocol and a diabetes protocol. The BFU was not provided with the current protocol.

1.5.2 Co-pilot 1

The 61-year-old co-pilot was citizen of the Republic of South Africa.

He held a Commercial Pilot License (CPL(A)). The licence was issued on 19 March 1990 by the SACAA and valid until 31 January 2019. The Instrument rating was also valid until 31 January 2019. His licence listed the ratings MEP(L) and SEP(L). The type ratings Airbus A330 and A340; Boeing B737 100/200 and B737 300-900; Boeing B747 100-300 were also listed.

He had a total flying experience of 18,534 hours. In the last 90 days prior to the occurrence, he had flown 204 hours, of which 183 hours on Airbus A340. In February 2005, he had completed this Airbus A340 type rating and since then flown 5,274 hours on type.

In January 2016, he completed the Upset Recovery Training. During the Secondary Recurrent Training in August 2016, he received the training for the OEB No. 49.

The BFU was not provided with a medical certificate of the co-pilot.

1.5.2.1 Discrepancy of the Licence

The BFU was provided with a valid CPL(A), as described above. On enquiry of the operator and review of the documentation it was determined that the operator had a valid ATPL(A). The operator had the last eight copies of his ATPL(A). As initial date of issue 19 March 2019 was listed and it was valid until 31 January 2019.

Subsequently, SACAA was contacted. They confirmed that the pilot held a valid CPL(A). According to the operator’s regulations (OM Part 1, Chapter 6.2.2) he had to have an ATPL(A).

1.5.3 Co-pilot 2

The 39-year-old co-pilot was citizen of the Republic of South Africa.

On 26 January 2005 his ATPL(A) had been initially issued by the SACAA and was valid until 31 March 2019. His licence listed the ratings SEP(L) and MEP(L). The co-pilot’s instrument rating was valid until 31 March 2019. He was rated as PIC on Airbus A320 and BE 76 (BEECH 76) and as co-pilot on Airbus A340 and JS 41 (Bae Jetstream). During cruise phase and while the PIC was absent, he was rated to occupy the left-hand seat (Relief Pilot).

He had a total flying experience of 11,453 hours. In the last 90 days prior to the occurrence, he had flown 104 hours, of which 33 hours on Airbus A340. On

17 August 2013, he had completed the Airbus A340 training. Since then he had flown 3,901 hours on type.

The BFU was provided with his class 1 medical certificate. It was valid until 28 July 2019 and did not list any restrictions.

1.5.4 Flight Duty and Rest Time

The flight crew's duty roster was made available to the BFU.

It showed that the flight crew checked in at Johannesburg Airport at 1910 hrs local. Departure was at 2027 hrs and landing at Frankfurt/Main at 0614 hrs. Flight duty time including check out was therefore 12:43 hours. The maximum permissible flight duty time for this workday was 14:30 hours.

All three flight crew members had two days off prior to this flight. During the flight, they had the option to take a rest period. Each pilot had 3:15 hours at his disposal. According to the Flight Safety Department, the PIC took 1:30 hours, co-pilot 1 about 3 hours and co-pilot 2 1:30 hours.

1.5.5 Interview of the Pilots

The BFU interviewed the pilots individually. A member of the International Federation of Air Line Pilots' Association (IFALPA) participated as neutral person.

The pilots described that up until the occurrence the atmosphere was relaxed.

According to the pilots, the atmosphere was tense and stressful during the occurrence up until the flight attitude was recovered and the autopilot engaged again. In the situation they had been aware how critical the flight status was and that they had temporarily lost control of the aircraft.

The question as to why the two ADRs as so-called memory items had been switched off could not be answered conclusively.

1.6 Aircraft

1.6.1 General Information

The Airbus A340-642 is a four-engine transport aircraft with a MTOM of 347,630 kg. It is powered by four Rolls-Royce Trent 556-61 jet engines.

As part of the Air Operator Certificate, the aircraft was certified for commercial passenger transport. In accordance with SACAA regulations, it had a certificate of registration.

The aircraft involved was manufactured in 2003, had the manufacturer’s serial number 547, and had been listed in the aircraft register of the Republic of South Africa since 28 January 2004. Until the occurrence, the aircraft had a total operating time of 65,462 hours and 7,710 flights.

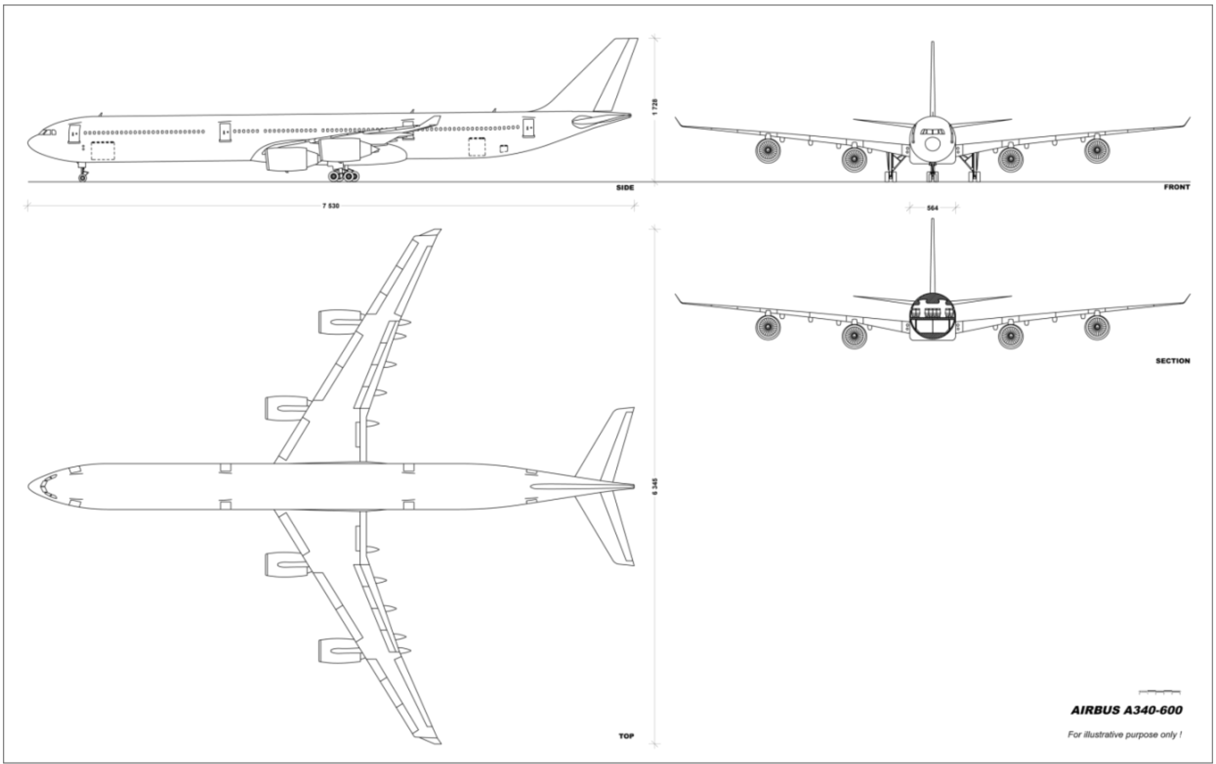


Fig. 3: Three-way view of the aircraft Source: Operator

1.6.2 Maintenance

The airworthiness certificate was valid until 31 January 2019. The last release to service was issued on 11 September 2018 in Johannesburg.

According to the maintenance documentation of the maintenance organisation, the last A-check[10] was performed on 8 September 2018 in Johannesburg. The next A-check was planned for 29 January 2019. The last C-check was performed on 11 July 2018.

The Techlogs the operator provided did not contain any entries which could have indicated a defect of the flight control system.

1.6.3 Mass and Centre of Gravity

According to the loadsheet, the TOW was 329,018 kg and the calculated landing mass 240,388 kg. The MAC for the ZFW was 25.2 % and for the TOW 24.9 %. These values were within the permissible operating limitations of the aircraft.

According to the provided documentation, at the time of the landing about 12,100 kg fuel were on board. The actual landing mass was 239,728 kg (max. permissible landing mass: 259,000 kg). At the time of the occurrence, the aircraft mass was 242,128 kg[11].

1.6.4 Flight Control System

The Airbus A340 is controlled by a fly-by-wire system. Among other things, it consists of five flight control computers: Three Flight Control Primary Computer (FCPC) and two Flight Control Secondary Computer (SEC), which control the control surfaces. The control input is transferred electronically; a hydraulic system moves the control surfaces.

The Control Laws describe the mode as to how the flight control computers process the command to move the control surfaces. Essentially, a distinction is made between Normal Law, Alternate Law and Direct Law.

Among other things, the flight control computers receive the necessary data from the ADIRU which consists of three identical ADIRUs. Each ADIRU consists of one ADR and one IR.

The ADR receives barometric height, airspeed, Mach and angle of attack, among other things. The flight control computers are programmed with different protections which

10 The maintenance concept for a transport aircraft consists of so-called letter checks (A-, B-, C- and D-checks). A-checks are performed most frequently. A B-check at an interval of six months, a C-check approximately every two years which takes several days.

11 Part of the final report of the operator.

shall protect aircraft from entering dangerous flight conditions. These include high angle of attack protection and high speed protection. Only in Normal Law are the protections fully available. In Alternate Law the protections are only partially available. In Direct Law the aircraft is no longer protected.

In which control law the aircraft is operating depends on the type and number of failed systems which influence the flight control system. In certain failure cases, flight control changes automatically from Normal Law to Alternate Law or Direct Law.

In case of failure or deactivation of two ADRs, Normal Law changes to Alternate Law and autopilot and autothrust are no longer available.

1.6.5 High Angle of Attack Protection

The A340 is equipped with a high angle of attack protection. This shall prevent that high angle of attacks occur during a flight where dynamic manoeuvres or gusts may cause stall. The protection becomes active when a certain angle of attack, α_{prot}, is reached.

The speed band at the PFD depicts the speeds $V\alpha_{prot}$ and $V\alpha_{max}$ which correspond with the aircraft speed when flying in stabilized flight conditions (α_{prot}) or at the maximum permissible angle of attack (α_{max}) (Fig. 4).

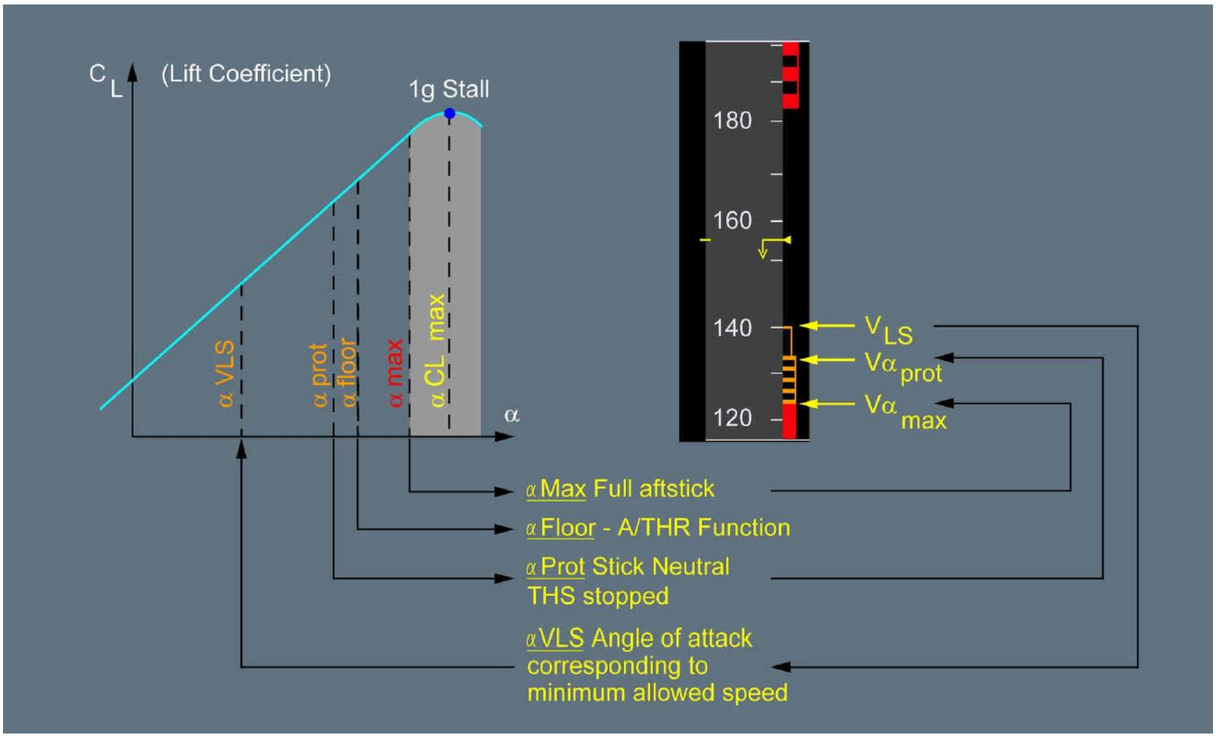


Fig. 4: Connection between a certain angle of attack and airspeed Source: FCOM

In manual flight, if the angle of attack increases to $V\alpha_{prot}$, the high angle of attack protection activates, the automatic pitch trim is stopped and the side stick input then corresponds with an angle of attack demand and no longer with a load factor demand.

In cruise, when the autopilot is engaged, if the filtered angle of attack becomes higher than $V\alpha_{prot}$ +0.7 °, the autopilot is automatically disconnected and the aircraft reverts to manual flight with the high angle of attack protection active. If the side stick is put into neutral position, the angle of attack is automatically reduced to $V\alpha_{prot}$ so that the aircraft is accelerated to $V\alpha_{prot}$.

Below a certain Mach, from an angle of attack of α_{floor}, which is between α_{prot} and α_{max}, autothrust automatically activates take-off thrust, independent of the position of the thrust levers.

If airspeed is reduced to $V\alpha_{max}$, this speed cannot be undercut by manual full deflection of the side stick. As depicted in Figure 4, α_{max} has a safety margin to the angle of attack α_{Clmax} where stall is defined as 1g. Both, α_{prot}, and α_{max}, depend on the Mach of the aircraft, among other things. With increasing Mach, α_{prot}, and α_{max} become smaller (Fig. 5).

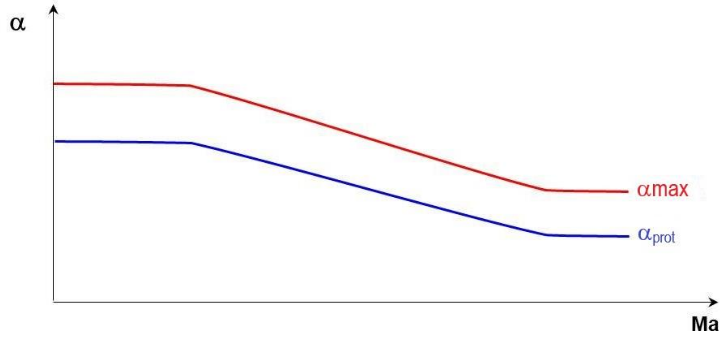


Fig. 5: Dependence of α_{prot}, and α_{max} and Mach Source: BFU

1.6.6 High Speed Protection

The Airbus 340 is equipped with a high speed protection. This function shall prevent in-flight speeds which could cause structural overload or loss of control. The high speed protection is activated either at or above the maximum operating speed, V_{MO}, or the maximum Mach, M_{MO}.

In addition, if V_{MO} +4 kt or M_{MO} +0,006 is exceeded, an ECAM overspeed warning is triggered.

In manual flight, high speed protection activates when the airspeed becomes higher than V_{MO} +6 kt or Mach higher than M_{MO} +0.01. When the autopilot is engaged, if the filtered Mach becomes higher than M_{MO} +0.01 or the filtered airspeed becomes higher than V_{MO} +6 kt, the autopilot is automatically disconnected and the aircraft reverts to manual flight with the high speed protection active.

With the aircraft involved, the autopilot is automatically disengaged at a filtered Mach of Ma 0.89 (equals M_{MO} +0,03). Filtered Mach is a mathematically smoothed and slightly delayed Mach where each abrupt change of the actual Mach is dampened. Therefore, the autopilot is more resistant to automatic shut-off if the actual Mach exceeds M_{MO}.

The Mach depicted on the PFD is the actual Mach and not the filtered one.

Figure 6 shows the filtered Mach function in combination with the FDR data of the occurrence flight. The time is marked where the PIC disconnected the autopilot.

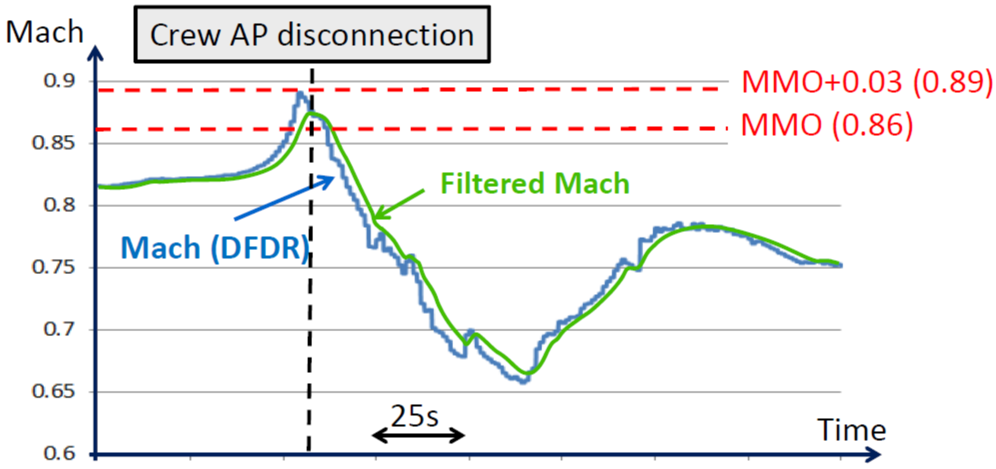


Fig. 6: Filtered Mach function in combination with the FDR data of the occurrence flight

Source: Aircraft Manufacturer

1.6.7 Flight Control Unit

The Flight Control Unit (FCU) is part of the flight management guidance and envelope system. The flight crew uses it to select or change flight parameters. It is possible to select different Flight Guidance Modes for the autopilot, the flight director and autothrust to change different targets (e.g. Mach, course, altitude).

The reduction of the Mach on the FCU to Ma 0.70 did initially not have any effect because after M_{MO} was exceeded autothrust automatically reduced engine thrust to flight idle (FCTM/Procedures/Abnormal and Emergency Procedures/MISC/Overspeed Recovery: *"[…] flight crew should keep the A/THR engaged and should check that the thrust reduces to Idle […]".*

Then A/THR was also deactivated because ADR 2 and 3 had been switched off; subsequently, the selection of Ma 0.70 on the FCU had no effect.

Even after Stall Recovery and switching ADR 2 and 3 and the A/THR back on, the selected Ma 0.70 (below V_{LS}[12]) would not have resulted in V_{LS} being undershot and another stall would not have occurred. The V_{LS} is the minimum speed with engaged A/THR and is not undercut. Even if the pilot had selected a speed below V_{LS}[13].

12 VLS is the slowest speed the AFS lets you fly in normal law
13 FCOM DSC-22-30-40

1.7 Meteorological Information

1.7.1 Light Conditions

On 6 November 2018 at 0712 hrs, in the area of the Clariden it was sunrise so it was night at 0535 hrs, the time of the occurrence.

1.7.2 Documentation

For pre-flight preparation, the operator's Flight Operation Control provided the flight crew with the following information: METAR, TAF, ICAO Area Euro SIGWX and flight path wind charts. This data was valid for the flight.

1.7.3 Significant Weather Chart

Figure 7 shows the ICAO Area Euro SIGWX for FL 100 to FL 450 between 0000 UTC to 0600 UTC. In the chart, significant weather phenomena in the European territory, e. g. icing zones, turbulence zones or weather fronts, are depicted. The World Area Forecast Centre, London, issued the weather chart.

The BFU included the flight path (Fig. 7). It shows that at the time of the occurrence, a region with moderate icing and turbulence was passed. This region was, however, in a lower flight level (up to FL 140). This weather chart was made available for the pre-flight preparation.

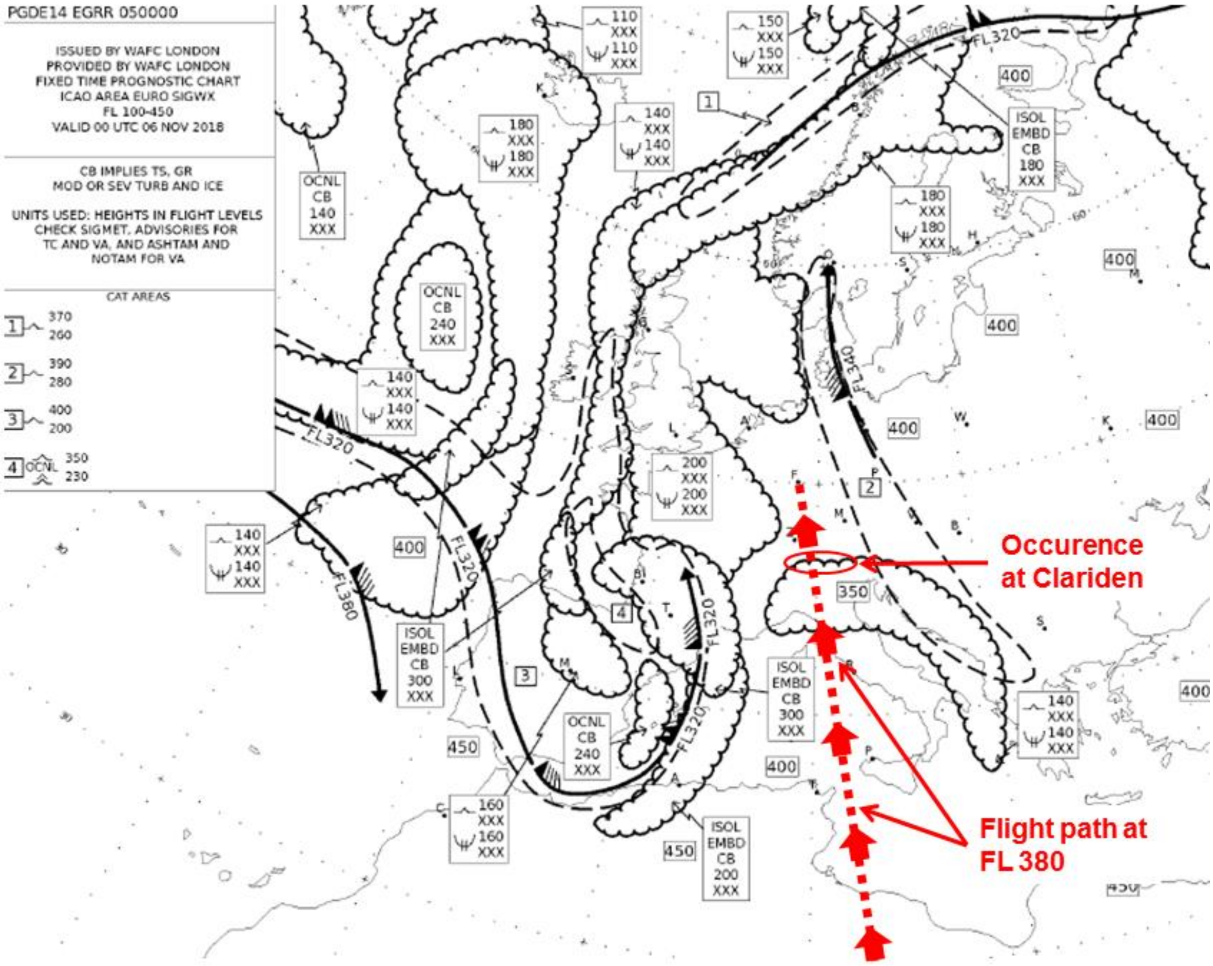


Fig. 7: ICAO AREA EURO SIGWX weather chart and flight path Source: WAFC, adaptation BFU

1.7.4 High Altitude Wind Map

Figure 8 shows an excerpt of the European territory with the flight path the BFU included and the high-altitude wind chart for the occurrence period and FL 390. The weather chart was issued by the WAFC and was valid from 0000 UTC for the following 24 hours. It depicts the approximate wind situation at the occurrence location but about 1,000 ft lower. The chart shows that at the occurrence location the wind was predicted from a south-eastern direction with 30 kt. There are no other significant weather phenomena and temperature changes depicted in the weather chart.

This weather chart was also available for pre-flight preparation.

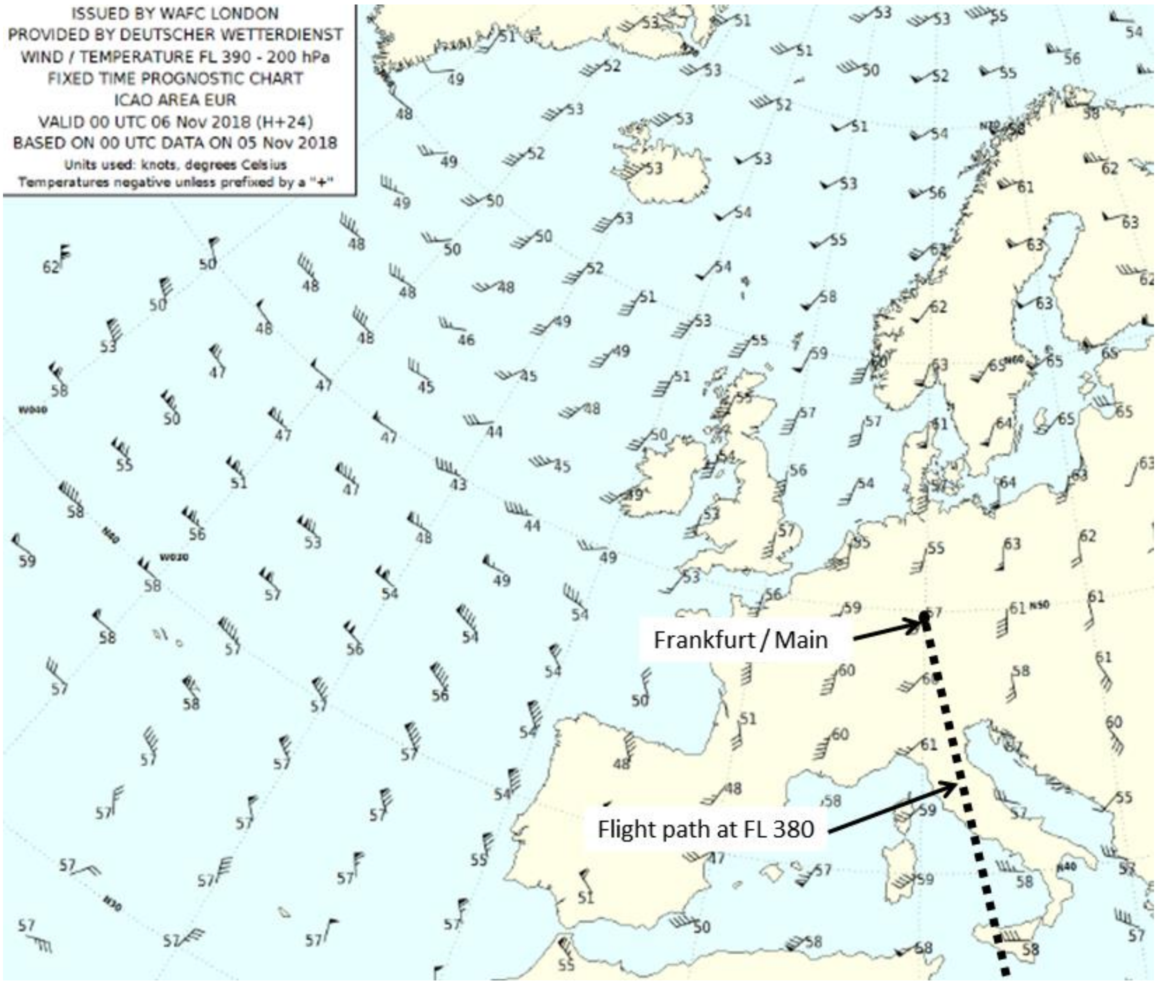


Fig. 8: Excerpt of the European territory, wind and temperature chart for FL 390 and the flight path

Source: WAFC, adaptation BFU

1.7.5 BOLAM Model

The Institute of Atmospheric Sciences and Climate of the National Research Council of Italy based its forecast on the BOLAM[14] model. It shows clearly that mountain waves were present on 6 November 2018 between 0000 hrs and 0300 hrs in the area of the occurrence (Fig. 9).

This weather chart was not available for pre-flight preparation.

14 http://www.isac.cnr.it/dinamica/projects/forecasts/bolam_short_description_2012.htm

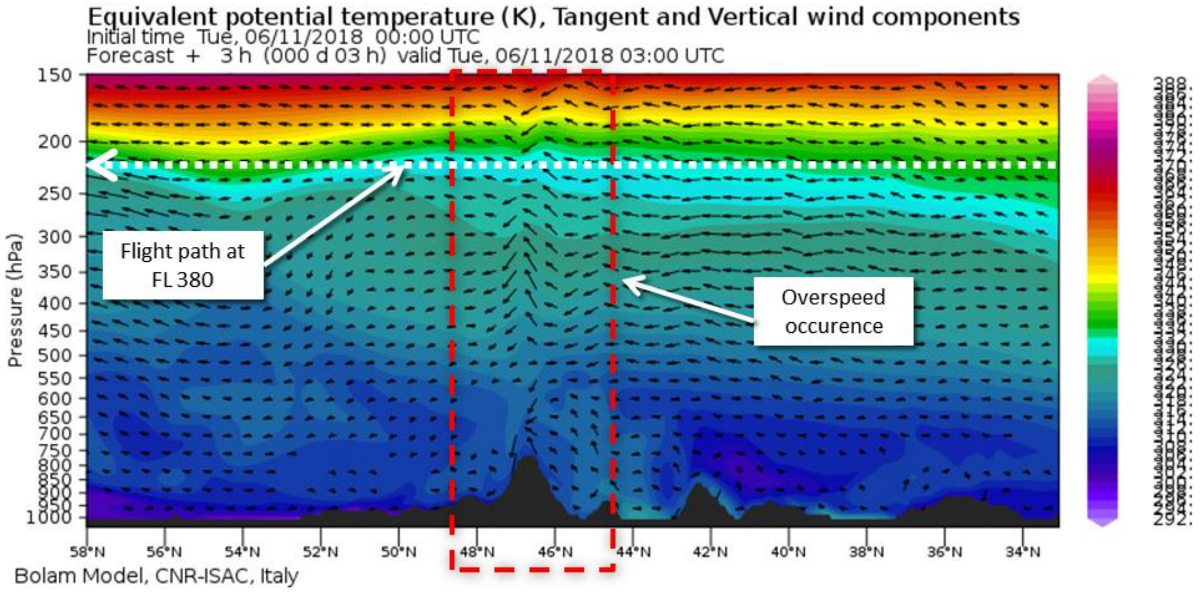


Fig. 9: BOLAM model including vertical wind components Source: BOLAM, adaptation BFU

1.7.6 Wind Gradient

The FDR parameters wind direction and wind speed at the time of the occurrence were analysed. This resulted in the following values:

Time (UTC)	Wind speed	Tailwind component
04:34:00	65 kt	65 kt
04:34:20	15 kt	15 kt
04:34:30 - 04:35:50	15 kt – 35 kt	15 kt – 35 kt

Tab. 2: Wind speed at the time of the occurrence Source: BFU

The table shows a significant decrease in wind speed between 0434:00 hrs and 0434:20 hrs. This wind activity was not linear but about 60 % of the wind speed change occurred within 4 seconds.

1.7.7 Mountain Waves

In 2018, the DWD published “Weather-related Hazards in the Area of Mountains”. Among other things, it included:

Mountain Waves and Rotors

Mountain waves are a weather phenomenon which is per definition caused by the orography and therefore is closely related to weather hazards in mountains. They have a horizontal axis and belong to the gravity waves because their propagation is dominated by gravity acceleration. Mountain waves are commonly accompanied by rotors in near-ground range.

Origin of Mountain Waves

If air overflows a mountain, mountain waves may form on the downwind side - lee. If enough moisture is present, they are often accompanied by characteristic stationary clouds which makes them easy to recognise visually. However, this is not inevitable, so that lack of such clouds is no indication that there are no mountain waves.

The following conditions aid the development of mountain waves:

- *Temperature stratification stable up to at least crest height*
- *Wind speed as high as possible, in the Alps ≥ 40 Kt*
- *Increasing wind without change of wind direction*
- *Inflow of the ridge at a right angle if possible*
- *Mountain in the vicinity of the Jetstream*

Mountain waves have a wave length of 5 to 50 km, their amplitude (strength) is determined by wind and temperature conditions. The stable stratification has a favourable effect.

1.8 Aids to Navigation

The BFU was provided with the radar recording of the Swiss air navigation service provider. The recorded data began at 0525:00 hrs and ended at 0545:59 hrs. In addition to position and altitude of the aircraft, the following parameters were recorded: ground speed, heading, and inertial vertical velocity.

1.9 Radio Communications

At the time of the occurrence, the flight crew was in radio contact with Swiss Radar on the frequency 126,050 MHz, where they had declared emergency.

The BFU was provided with the audio recordings of the radio communications between the flight crew and Swiss Radar. The recording started at 0526:10 and ended at 0543:24 hrs. Large parts of the recording could be understood well. Essential content is part of the chapter History of the Flight. Communications were conducted by everyone involved in English.

1.10 Aerodrome Information

Not applicable

1.11 Flight Recorders

The airplane was equipped with a CVR and a FDR, which were read out at the BFU laboratory.

1.11.1 Cockpit Voice Recorder

Manufacturer:	Allied Signal
Model:	SSCVR
P/N:	980-6022-001
S/N	2579
Medium:	Solid State
Recorder Condition:	Not damaged
Read-out Equipment:	RPGSE
Recording Configuration:	Two channels of 30 minutes recording time each
	Two channels of 2 hours recording time each

Four audio files (Captain, First Officer, Mixed and Area Channel) were available. The audio quality of all four channels was assessed as “good”.
After the recording was analysed, the BFU determined that the occurrence time was overwritten. The investigation determined that the maintenance organisation had not pulled the fuses and the aircraft was supplied with ground power.

1.11.2 Flight Data Recorder

Manufacturer:	L-3 Com
Model:	FA 2100
P/N:	2100-4043-02
S/N	000487015
Medium:	Solid State
Recorder Condition:	Not damaged (visual inspection)
Read-out Equipment:	HHMPI
Recording duration:	177:40:42 hours
Number of Parameters:	936

Essential parameters are part of the chapter History of the Flight. The navigation service provider provided the BFU with the recorded radar data of the flight path. These were compared with the corresponding FDR parameters. The position data, which the aircraft determined, and the position data of the radar unit are chronologically synchronous.

Appendix Chapter 5.1 shows an overview of the overspeed condition and the subsequent stall warning.

1.12 Accident Site and Findings on the Aircraft

The operator's maintenance organisation inspected the aircraft at Frankfurt/Main Airport. There were no findings.

1.13 Medical and Pathological Information

There was no evidence that physiological factors or incapacitation affected the performance of flight crew members.

1.14 Fire

There was no evidence of in-flight fire or fire during the landing.

1.15 Survival Aspects

Not applicable

1.16 Tests and Research

Not applicable

1.17 Organisational and Management Information

1.17.1 Training Program

The operator provided the BFU with the training program of the initial and cross crew qualification. The recurrent training of the operator showed that the training program for pilots did not include an overspeed condition event training during the last five years.

The operator also provided data from the Flight Data Analysis Program (FDAP). This showed that in the past three years across the operator's entire Airbus fleet 654 overspeed condition events were recorded. These included Flap Speed Exceedance during Approach. The FDAP data showed that the number of high altitude overspeed events was low compared with other overspeed condition events.

The operator had neither developed a training program nor a risk assessment strategy concerning the recorded overspeed conditions. An Evidence Based Training[15] for a simulator training in accordance with IATA requirements was not implemented

1.17.2 Overspeed Recovery Procedure

The Flight Crew Training Manual Chapter Abnormal and Emergency Procedures/Misc described the Overspeed Recovery procedure (Fig. 11), which should be applied if airspeed exceeds V_{MO} or M_{MO}. The essential items of the procedure were: autopilot remains engaged to minimise vertical loads, extend the speed brakes to maximum position to reduce speed. In case the autopilot is disengaged automatically and high speed protection becomes active, the flight crew should avoid strong control input to limit excessive vertical load factors (g-loads).

15 IATA (2013). Evidence-Based Training Implementation Guide. Reference on the IATA Website: https://www.iata.org/contentassets/632cceb91d1f41d18cec52e375f38e73/ebt-implementation-guide.pdf

A330/A340 FLIGHT CREW TECHNIQUES MANUAL	PROCEDURES ABNORMAL AND EMERGENCY PROCEDURES MISC

Ident.: PR-AEP-MISC-B-00019622.0001001 / 20 MAR 17

OVERSPEED RECOVERY

The flight crew must apply the overspeed recovery technique if the speed exceeds VMO/MMO.
The OVERSPEED warning is triggered when the speed exceeds VMO +4 kt/MMO +M 0.006, and lasts until the speed is below VMO/MMO.
The flight crew should keep the AP engaged in order to minimize the vertical load factors. In order to minimize overspeed, the flight crew should extend the speed brakes to the most appropriate lever position depending on the overspeed situation. In addition, the flight crew should keep the A/THR engaged and should check that the thrust reduces to idle.
To keep the A/THR engaged or to set the manual thrust on idle has the same effect on the overspeed recovery. Both techniques result in the same engine response in terms of thrust reduction.
If the A/THR is OFF, the flight crew must set the thrust levers to idle.
In the case of severe overspeed, the AP automatically disengages and then the High Speed Protection activates (except in direct law). As a result, the aircraft encounters an automatic pitch up. *Refer to FCOM/DSC-27-20-10-20 Protections - High Speed Protection.*

Note: *The AP does not automatically disengage as soon as the speed reaches the green bars (that represent the threshold when the High Speed Protection activates) on the PFD. The AP disengagement depends on the speed variations and the High Speed Protection logic.*

The High Speed Protection is designed to request the appropriate demand of vertical load factor. Therefore, the flight crew should smoothly adjust the pitch attitude to limit the excessive load factors.

Note: *The flight crew must disregard the Flight Director (FD) orders while the high speed protection is active. The FD orders do not take into account the High Speed Protection.*

The flight crew should keep the speed brakes because the use of the speed brakes is compatible with the High Speed Protection.

Ident.: PR-AEP-MISC-B-00020662.0001001 / 22 MAR 17

WHEN THE SPEED IS BELOW VMO/MMO

When the aircraft speed is below VMO/MMO with a sufficient speed margin, the flight crew should retract the speed brakes and should select a new speed target. If the flight crew retracts the speed brakes when the speed is close to VMO/MMO, the speed may exceed VMO/MMO again at speed brake retraction. If the A/THR is OFF, the flight crew should manually adjust thrust levers.
After severe overspeed, the flight crew should recover the flight path smoothly, and then should engage the AP in accordance with the recommended procedure for AP engagement. *Refer to AS-FG-10-1 Recommended Practice for Autopilot (AP) Engagement.*

A330/A340 FLEET PR-AEP-MISC P 13/34
FCTM ← H → 18 NOV 20

Fig. 11: Overspeed recovery procedure Source: FCTM, adaptation BFU

1.17.2.1 Aural Annunciation

The Electronic Centralized Aircraft Monitor (ECAM) Overspeed Warning (Fig. 12) with a loud continuous repetitive chime is triggered if V_{MO} +4 kt or M_{MO} +0,006 is reached and remains until V_{MO} / M_{MO} is undercut again.

A330/A340 FLIGHT CREW OPERATING MANUAL	PROCEDURES ABNORMAL AND EMERGENCY PROCEDURES OVERSPEED

OVERSPEED

Applicable to: MSN 0410-0534, 0547-0557, 0626-0630

Ident.: PRO-ABN-OVERSPEED-AS-00018522.0001001 / 20 APR 17

ANNUNCIATIONS

Triggering Conditions:

L2 This alert triggers when:

- VMO/MMO aircraft speed/mach is greater than VMO + 4 kt/MMO + 0.006, or

VMO/MMO.. 330/.86

Fig. 12: Overspeed Warning Source: FCTM

1.17.3 Turbulence during the Flight

The aircraft manufacturer had addressed the topic “Managing Severe Turbulence from the Cockpit“ in the Safety First document of November 2019[16], which was also available to the operator. The FCTM (PR-NP-SP-10-10-3 Weather Turbulence) also described the procedures. The following is an excerpt of the FCTM:

[…] *Keep autopilot ON*

Autopilot is designed to cope with turbulence and will keep the aircraft close to the intended flight path without the risk of overcorrection. The recommendation is to keep autopilot ON during a turbulence encounter. A pilot may be tempted to “fight against turbulence” when manually flying the aircraft and may overreact to sudden changes in the trajectory in some cases.

The flight crew should consider autopilot disconnection if autopilot does not perform as desired.

Keep autothrust ON

(except A300/A310) and use the QRH turbulence penetration speed if turbulence is severe.

16 https://safetyfirst.airbus.com/managing-severe-turbulence

[…]

Don’t overreact to temporary overspeed excursion

The flight crew may observe temporary overspeed situations when encountering severe turbulence due to the changes in wind intensity or direction. The flight crew must not overreact to temporary overspeed excursion since the use of V_{RA}/M_{RA} ensures sufficient margins to structural limits. The recommendation is to keep the autopilot ON and autothrust ON and accept the temporary overspeed excursion. […]

1.17.4 Stall Recovery Procedure

The FCOM chapter Abnormal and Emergency Procedures / MISC / Stall Recovery (Fig. 13) described the procedure which should be applied at first signs of in-flight stall.

There was another procedure which should be applied in case of stall warning directly after take-off, but this is not described here.

The Stall Recovery procedure is part of the Memory Items which have to be applied immediately and by memory as part of the respective checklist. It was therefore marked with [MEM].

A330/A340 FLIGHT CREW OPERATING MANUAL	PROCEDURES ABNORMAL AND EMERGENCY PROCEDURES MISC

[MEM] STALL RECOVERY

Ident.: PRO-ABN-MISC-00013664.0001001 / 17 MAR 17
Applicable to: MSN 0197-1271

As soon as any stall indication (could be aural warning, buffet...) is recognized, apply the immediate actions:

NOSE DOWN PITCH CONTROL.................................APPLY

This will reduce angle of attack

Note: In case of lack of pitch down authority, reducing thrust may be necessary.

BANK.................................WINGS LEVEL

- **When out of stall (no longer stall indications) :**

  THRUST.................................INCREASE SMOOTHLY AS NEEDED

  Note: In case of one engine inoperative, progressively compensate the thrust asymmetry with rudder.

  SPEEDBRAKES.................................CHECK RETRACTED

  FLIGHT PATH.................................RECOVER SMOOTHLY

  - **If in clean configuration and below 20 000 ft :**

    FLAP1.................................SELECT

    Note: If a risk of ground contact exists, once clearly out of stall (no longer stall indications), establish smoothly a positive climb gradient.

Fig. 13: Stall recovery procedure　　Source: FCTM

1.17.5 Upset Recovery

The upset recovery procedure was described in the FCTM under Abnormal and Emergency Procedures/MISC/Upset Recovery. Appendix 5.2 includes an excerpt of the procedure.

The ICAO document AUPRTA Rev 3.0[17], February 2017, defined an abnormal flight attitude as follows:

> *An airplane upset is an undesired airplane state characterized by unintentional divergences from parameters normally experienced during operations.*
>
> *An airplane upset may involve pitch and/or bank angle divergences as well as inappropriate airspeeds for the conditions.*
>
> *Note: undesired airplane state is defined in the Line Operations Safety Audit (LOSA) manual, ICAO Doc 9803, 1st edition.*
>
> *Deviations from the desired airplane state will become larger until action is taken to stop the divergence.*
>
> *Return to the desired airplane state can be achieved through natural airplane reaction to accelerations, auto-flight system response or pilot intervention.*

1.17.6 Comparison of Emergency Procedures

In Table 3 emergency procedures are compared. They are listed in the sequence of events. The information was taken from the FCTM checklists which were mentioned in the respective chapters. In the Upset Prevention and Recovery procedure (FCTM/PR-AEP-MISC/MISC), flight crew cooperation was explicitly mentioned:

> […] *During the maneuver, the Pilot Monitoring must monitor the airspeed and the altitude throughout the recovery. The Pilot Monitoring must also announce the flight path divergence if the recovery maneuver is not efficient.* […]

17 Https://www.icao.int/safety/loci/auprta/index.html

1	2	3	4
Weather Turbulence	**Overspeed Recovery**	**Stall Recovery**	**Upset Prevention and Recovery**
A/P On	A/P On	A/P Off	A/P Off
A/THR On	A/THR On	A/THR Off	A/THR Off

Tab. 3: Overview of the A/P and A/THR configuration during different events Source: BFU

1.17.7 Operations Engineering Bulletin

1.17.7.1 Definition

An Operations Engineering Bulletin (OEB) is generally published by an aircraft manufacturer. Aircraft operators and their pilots are informed about a temporary procedure which has to be applied under certain circumstances. Safe and efficient flight operations shall be ensured. The reason for an OEB is the deviation from the originally certified design of an aircraft in one or more systems, which effects operation significantly.

An OEB remains active until a permanent corrective measure was performed on the aircraft involved. At publication, the OEB is temporary but without a final date.

There are two types of OEB:

Red OEB: Non-compliance with such a procedure has a significant influence on the safe operation of an aircraft.

White OEB: Non-compliance with such a procedure has a significant influence on the efficient operation of an aircraft (e.g. delays or diversions).

Red OEB’s may include checklist items which have to be applied immediately and by memory. The aircraft manufacturer refers to these items as OEB with Immediate Actions and treats them like Memory Items (FCTM: Airbus Operational Philosophy/Management of Abnormal Operations/Handling of ECAM/QRH/OEB):

> […] *in some time critical situations, the flight crew has no time to refer to the ECAM / QRH / OEB procedure. Therefore, the flight crew must know, and strictly apply by memory, items referred to as MEMORY ITEMS or OEB immediate actions.* […]

In the FCOM and the QRH, OEB with Immediate Actions are like Memory Items edged with a box. The OEB also includes Preventive Entry Conditions which are listed as Read and Do Items.

1.17.7.2 Operations Engineering Bulletin No. 49

On 8 December 2014, the aircraft manufacturer, as type certificate holder, published a Red OEB, which described how pilots could deactivate the high angle of attack protection, if they suspect a malfunction. The OEB described that in continuous straight and level flight without g-factor caused for example by a turn, the indication of the $V\alpha_{prot}$ increases with increasing Mach. Subsequently, two of the three ADRs should be deactivated.

The FCOM and QRH of the aircraft involved included OEB No.°49. It was issued after an in-service event where multiple Angle of Attack (AOA) sensors were blocked during the climb phase. It described that if at least two AOA sensors are blocked during the climb phase, when Mach increases while the aircraft continues to climb, the high angle of attack protection may activate unrequested.

With increasing Mach, the α_{prot} value decreases and the speed band $V\alpha_{prot}$ rises. When in manual flight, as depicted in Figure 14, at least two of the three AOA sensors are blocked at an angle of attack of α^* which is higher than the minimum of α_{prot} and Mach increases to Ma*, the high angle of attack protection activates unrequested. If the autopilot is engaged, the following conditions result in an unrequested autopilot disconnect and a high angle of attack protection activation: two of the three AOA sensors are blocked at an AOA value above the minimum of α_{prot} +0.7°, when Mach increases to Ma*. If Mach increases to more than Ma*, the flight control computer commands a continuous nose down pitch rate.

In general, by increasing altitude (during climb) or increasing airspeed Mach increases.

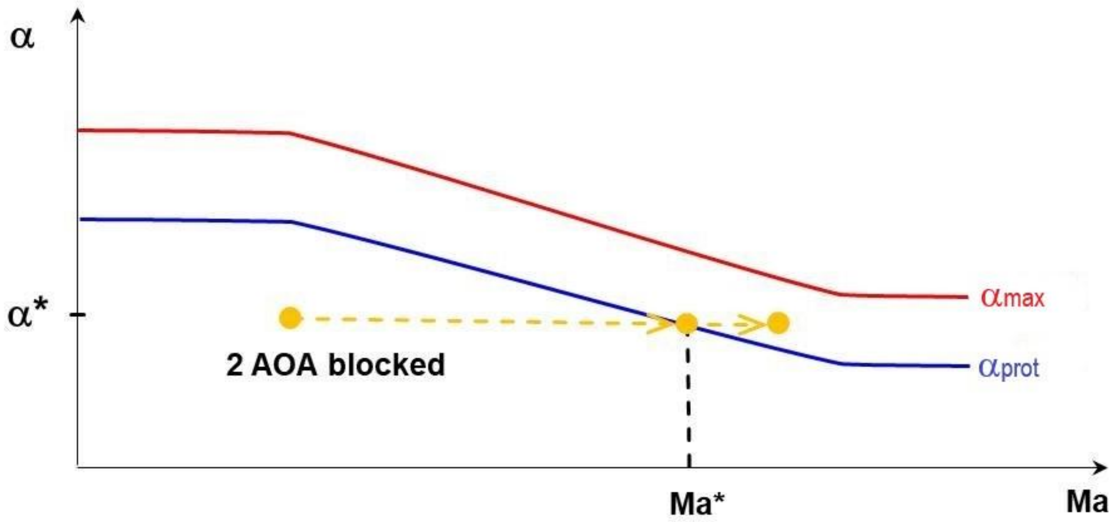


Fig. 14: Dependence of α_{prot}, α_{max} and Mach Source: BFU

The OEB No. 49 described two different scenarios where it had to be applied.

The OEB should be applied preventively if Mach increases due to increasing altitude or airspeed during stabilised straight flight without increase in g-load resulting in a rise of the $V\alpha_{prot}$ speed band (Fig. 15) so that $V\alpha_{prot}$ is above the Green Dot. This scenario is the signature of a blockage of multiple AOA sensors that could potentially lead to an unrequested high angle of attack protection activation when reaching a higher Mach. This condition is therefore the Preventive Entry Condition for OEB No.°49.

The OEB No. 49 has to be applied immediately, if at any time and at a speed above V_{LS} a continuous nose down pitch rate occurs, which cannot be stopped by pulling the sidestick back. This behaviour of the aircraft is the signature of an aircraft with high angle of attack protection unrequested active. This condition is therefore the reactive Entry Condition for the OEB No. 49.

In both cases, two ADRs had to be deactivated in order to get from Normal Law to Alternate Law so that in the first scenario this will prevent the high angle of attack protection to activate unrequested and in the second scenario, this will deactivate the unrequested active high angle of attack protection.

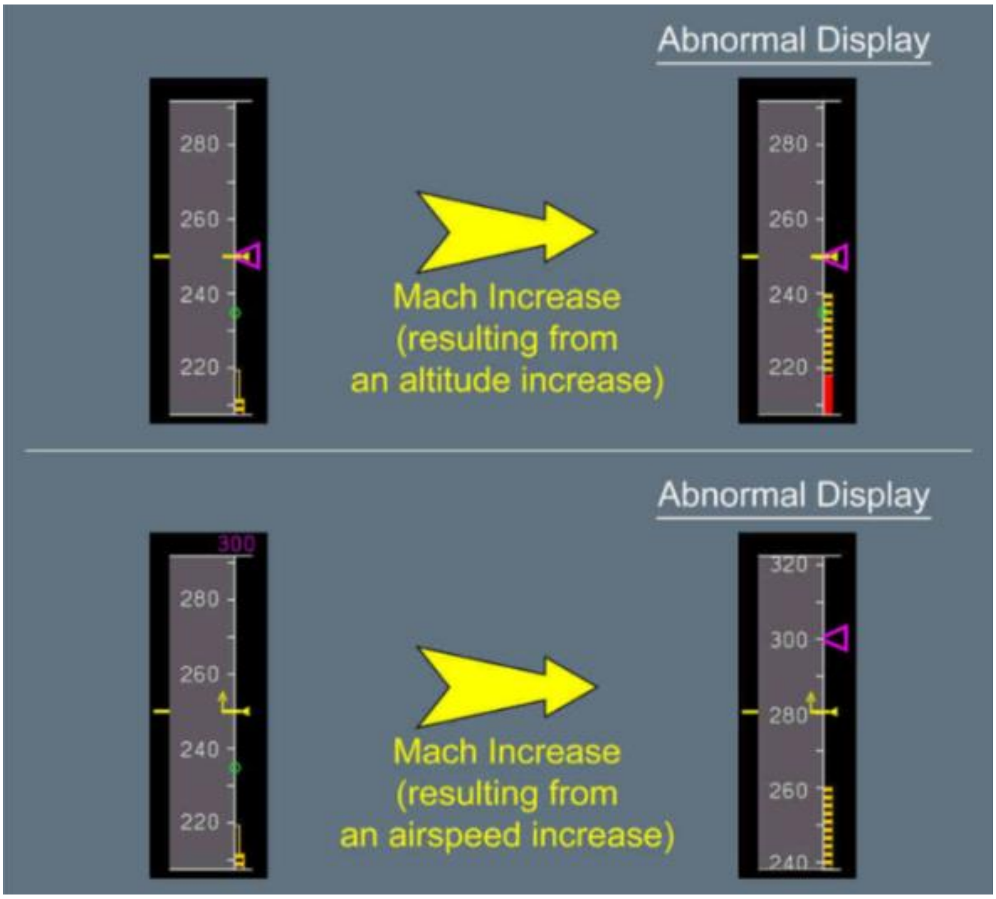
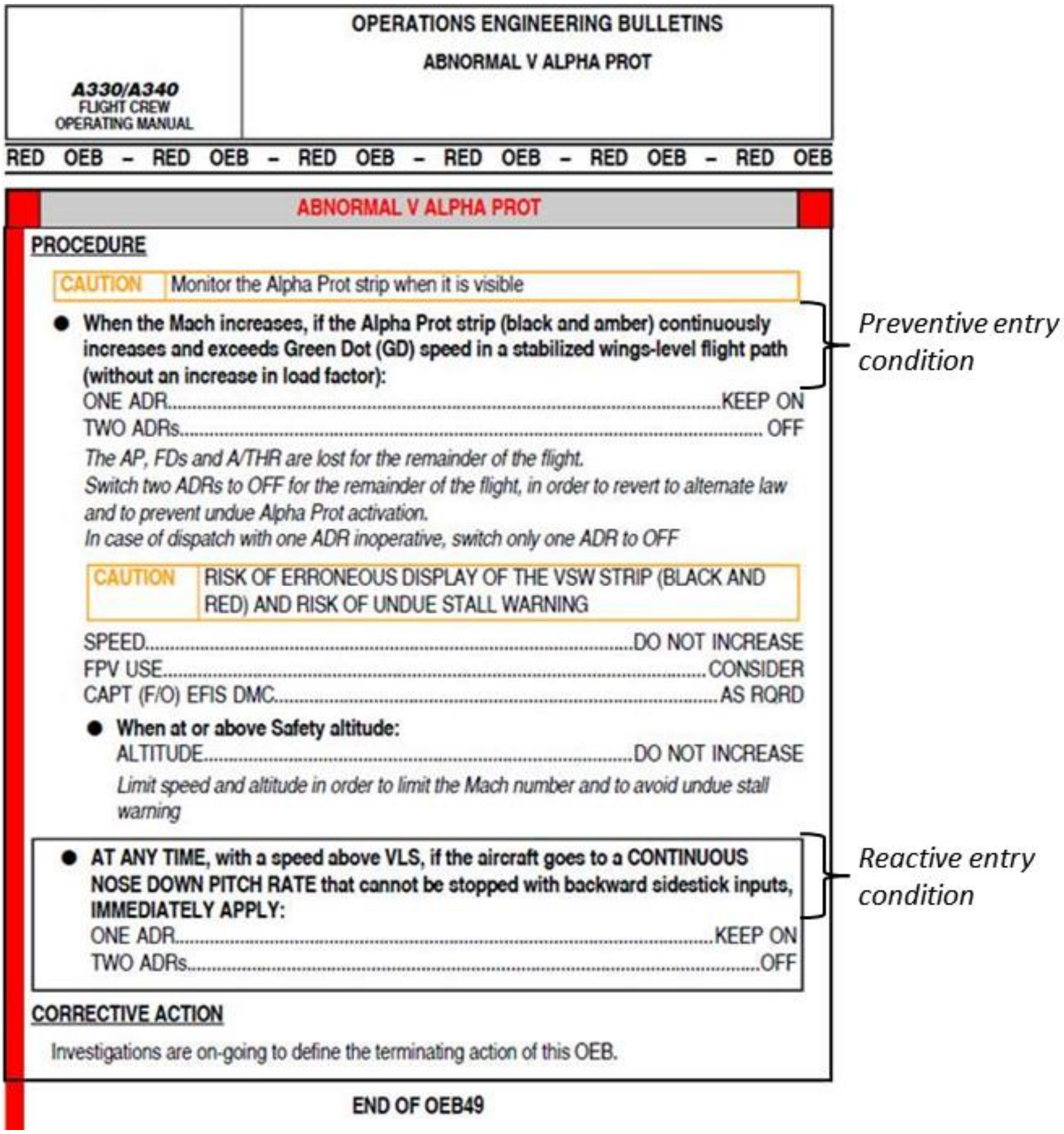


Fig. 15: Abnormal Vαprot PFD indication Source: FCOM

1.17.7.3 OEB No. 49 Procedure

The OEB No. 49 is a Red OEB with Immediate Actions.

The OEB with Immediate Actions, i.e. items which have to be treated like Memory Items, are edged with a box (Fig. 16). This part of the procedure has to be implemented during a Reactive Entry Condition.



A330/A340
FLIGHT CREW
OPERATING MANUAL

OPERATIONS ENGINEERING BULLETINS

ABNORMAL V ALPHA PROT

RED OEB – RED OEB – RED OEB – RED OEB – RED OEB – RED OEB

ABNORMAL V ALPHA PROT

PROCEDURE

CAUTION | Monitor the Alpha Prot strip when it is visible

- **When the Mach increases, if the Alpha Prot strip (black and amber) continuously increases and exceeds Green Dot (GD) speed in a stabilized wings-level flight path (without an increase in load factor):**

ONE ADR....................KEEP ON
TWO ADRs....................OFF

The AP, FDs and A/THR are lost for the remainder of the flight.
Switch two ADRs to OFF for the remainder of the flight, in order to revert to alternate law and to prevent undue Alpha Prot activation.
In case of dispatch with one ADR inoperative, switch only one ADR to OFF

CAUTION | RISK OF ERRONEOUS DISPLAY OF THE VSW STRIP (BLACK AND RED) AND RISK OF UNDUE STALL WARNING

SPEED....................DO NOT INCREASE
FPV USE....................CONSIDER
CAPT (F/O) EFIS DMC....................AS RQRD

- **When at or above Safety altitude:**

ALTITUDE....................DO NOT INCREASE

Limit speed and altitude in order to limit the Mach number and to avoid undue stall warning

- **AT ANY TIME, with a speed above VLS, if the aircraft goes to a CONTINUOUS NOSE DOWN PITCH RATE that cannot be stopped with backward sidestick inputs, IMMEDIATELY APPLY:**

ONE ADR....................KEEP ON
TWO ADRs....................OFF

CORRECTIVE ACTION

Investigations are on-going to define the terminating action of this OEB.

END OF OEB49

Fig. 16: OEB No. 49 Source: FCOM, adaptation BFU

1.17.7.4 Validity of the OEB No. 49

In April 2018, the software modification on the flight control primary computer was performed on the aircraft involved and the AOA sensors were replaced so that the OEB No. 49 could have been deleted from the documentation. At the time of the occurrence, there was no Airworthiness Directive requiring the deletion of the OEB No. 49 for this configuration. On 21 February 2019, EASA issued Airworthiness Directive 2019-0028, which required exactly that.

1.17.7.5 Timeline of Airworthiness Directives

The following is the chronological sequence of the Airworthiness Directives EASA published in regard to OEB No. 49.

Emergency AD 2014-0267-E[18] (effective 11 December 2014):

> In advance, EASA performed a risk assessment and instructed the aircraft manufacturer that operators update the Flight Manual with a copy of the AFM TR 529 “Abnormal V Alpha Prot” prior to the next flight.

AD 2015-0124[19] (effective 11 April 2015):

> EASA required modification of the flight control primary computer software within 15 months. An improved angle of attack logic was implemented to supervise malfunctions of the AOA sensors. On the aircraft involved the software modification should have been performed before 6 November 2018. The AFM TR 529 was still valid.

AD 2015-0134[20] (effective 15 July 2015):

> The AD instructed aircraft operators to replace the AOA sensors within 7 to 22 months.

AD 2019-0028[21] (effective 21 February 2019):

> The AD instructed aircraft operators to install another modified software version for the flight control primary computer within nine months. The AFM TR 529 must then be removed from the AFM.

1.17.7.6 OEB No. 49 Training

The aircraft manufacturer had performed Web conferences with A330 and A340 operators and offered training documentation on a cloud server. This included a detailed presentation of the OEB No. 49 procedure and a technical description of the system logic of the protections.

---

18 https://ad.easa.europa.eu/ad/2014-0267-E
19 https://ad.easa.europa.eu/ad/2015-0124R3
20 https://ad.easa.europa.eu/ad/2015-0134
21 https://ad.easa.europa.eu/ad/2019-0028

In addition, demo videos which show the reaction of the aircraft during a blockage of two of the three AOA sensors were offered, among other things. The operator had not used the training documentation or videos the aircraft manufacturer had provided for a fee on their cloud server.

1.17.7.7 Simulator

The operator confirmed that the used Airbus A340 simulator was technically not able to reproduce the OEB No. 49 entry conditions and the overspeed condition. The pilots' training in regard to the OEB No. 49 during the simulator training was limited to the explanations of the simulator trainer.

At the time of the occurrence, the simulator's FCPC had the Standard W6.3. This standard was implemented in September 2002. In June 2006, the aircraft manufacturer had implemented the new autopilot disconnect logic with the FCPC Version W10.

An internal investigation of the operator showed that the simulator reacted differently than the real aircraft. The autopilot in the simulator deactivated at an overspeed condition of M_{MO} +0.006 (≙ Ma 0.866). The technical report of the aircraft manufacturer described that the FCPC software in the real aircraft deactivates the autopilot at a filtered Mach of M_{MO} +0.03 (≙ Filtered Mach Ma 0.89).

1.17.8 Flight Operations Transmission

In the aircraft manufacturer's Flight Operations Transmission (FOT)[22] with ATA[23] 34 – ABNORMAL V ALPHA PROT and the respective reference 999.0148/14, Rev. 01 of 23 December 2014 described the triggering incident for the OEB No.49 as follows:

> […] *An aircraft equipped with AOA flat cover plates recently experienced an in-service event. During climb, two AOA probes remained blocked at a constant value. Further in the climb and during a turn, as the Alpha Prot strip increased quickly, the flight crew disconnected the Autopilot (AP). The Alpha Prot activated, resulting in a nose down pitch order. The flight crew stabilized the aircraft altitude by applying pitch-up orders on the sidestick. Reversion to alternate law stopped the Alpha Prot activation, and restored control of the pitch orders with the sidestick.* […]

22 Appendix chapter 5.3 Flight Operations Transmission

23 The ATA chapters refer to the numbering system and referencing standards for commercial aircraft documentation.

1.18 Additional Information

1.18.1 Fatigue on Long-Haul Flights

A NASA study examined “Crew factors in flight operations 9: Effects of planned cockpit rest on crew performance and alertness in long-haul operations”. The following is an excerpt of the study[24].

[…]

> *The rapid multiple time-zone changes, sleep disturbances, circadian disruptions, and long, irregular work schedules associated with long-haul flight operations can result in pilot fatigue. Safety and operational effectiveness during long-haul flights may be compromised because of reduced pilot performance and alertness. Pilot fatigue in long-haul flight operations is a major safety concern. Several sources lend support to this concern. Long-haul wide-body flight operations have almost a three-times higher loss ratio than combined short- and medium-range flights.*
>
> *Also, cockpit crew error, where pilot fatigue may be a contributory factor, has been related to 75% of aircraft losses since 1959. NASA's Aviation Safety Reporting System (ASRS) receives reports every month from long-haul crews describing the role of fatigue, sleep loss, and sleepiness in significant operational errors. Reported errors have included altitude deviations, improper fuel calculations, track deviations, landings without clearance, and landings on incorrect runways. These reports are not surprising, for many pilots describe anecdotally the overwhelming fatigue and sleepiness associated with all-night flying over the ocean. The flight deck environment, with constant background noise, dim lighting, and various levels of automation, can contribute to the difficulty of remaining vigilant and awake under these circumstances. As trips progress and as the number of flight legs increases, so too can the cumulative effects of sleep loss and fatigue.*
>
> *Extensive research has shown that there are at least three interrelated biological sources of the fatigue, sleep loss, and sleepiness experienced in long-haul flight operations.* […]

24 Rosekind, Mark & Graeber, Raymond & Dinges, David & Connell, Linda & Rountree, Michael & Spinweber, Cheryl & Gillen, Kelly, 1994, Crew factors in flight operations 9: Effects of planned cockpit rest on crew performance and alertness in long-haul operations.

1.18.2 Spatial Disorientation

Spatial disorientation means a pilot can no longer recognise the flight attitude, i. e. if the aircraft is rotating about its longitudinal axis, or is in climb or descent.

The effect on the human sensory perception can be illustrated with an example. A person walks from the beach into the ocean. The water rushing at him (waves) awakens the sensation of increased speed but the water slows down the body. A flight crew is also subject to such misleading perception.

The following image illustrates the effect on the human body.

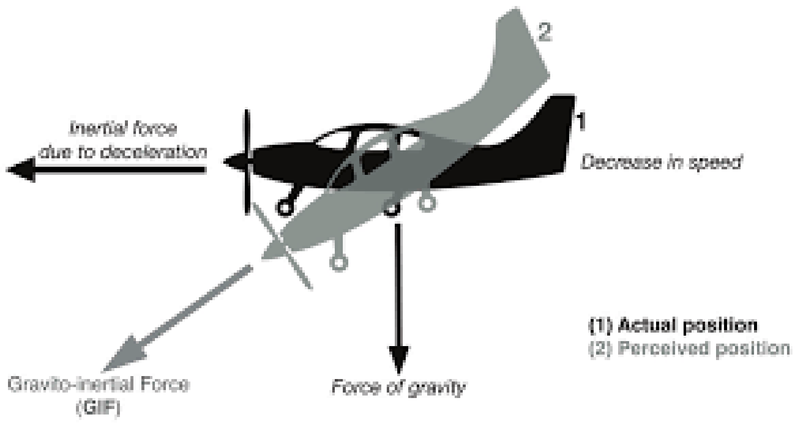


Fig. 19: Effect of spatial disorientation on the pilot

Source: Demir AE, Aydın E. Vestibular Illusions and Alterations in Aerospace Environment. Turk Arch Otorhinolaryngol 2021

The FDR data prove that the fluctuation of wind speed caused by mountain waves and their influence on the aircraft resulted in longitudinal deceleration or acceleration. Using the data of the acceleration sensors, a so-called Gravito-Intertial Force was calculated. It is a force which affects the human equilibrium organ and is experienced by pilots as pitch-up or pitch-down movement.

The following graph depicts the Gravito-Intertial Force together with the actual aircraft pitch angle and the sidestick position of the PIC (Command input - Left (max. deflection 16°)).

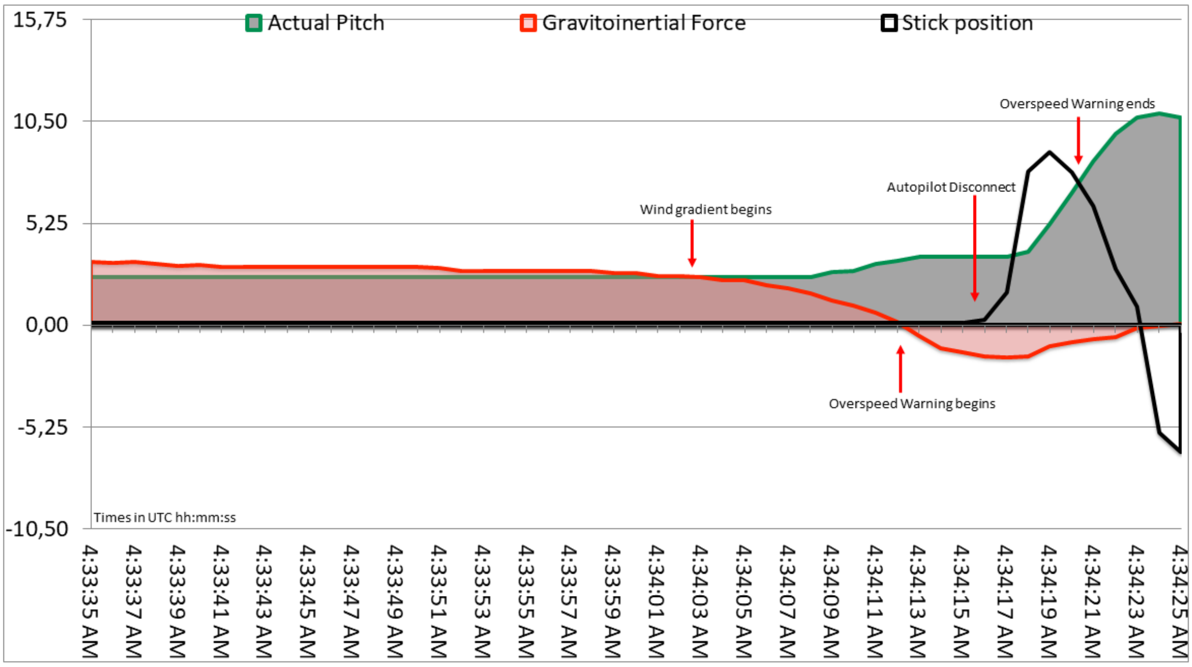


Fig. 21: Gravito-Intertial Force, the actual aircraft pitch angle and sidestick input

Source: Operator, adaptation BFU

Analysis showed that the difference between the observed pitch angel, prior to the overspeed condition, and the actual pitch angle was less than 0.5°.

The perceived pitch angle (red line) decreased and had the tendency of a nose down effect. The actual pitch angle (green line) increased towards nose up (autopilot was compensating for altitude loss in the downdraft).

1.18.3 Information by the Aircraft Manufacturer

The BFU conducted several meetings with the aircraft manufacturer. The following was discussed, among other things:

- The aircraft manufacturer described in the FCOM that during Preliminary Cockpit Preparation the respective OEBs must be looked at and a briefing conducted. The routine of a briefing may bring a negative effect especially if an OEB already exists for some time. This may result in a briefing being conducted with less detail and care. Particularly noteworthy is that knowledge as to when the conditions for application of a Red OEB are given may be lost. Thus, OEB briefings may lose relevance. To counteract this, the aircraft manufacturer had changed the Red OEB procedure in the FCTM already prior to the occurrence.

According to the FCTM, Immediate Actions of a Red OEB are treated like Memory Items (FCTM: Airbus Operational Philosophy / Management of Abnormal Operations / Handling of ECAM / QRH / OEB).

- At the time the OEB No. 49 was published, the aircraft manufacturer had developed training material, webinars and videos showing $V\alpha_{prot}$ reaction and explaining system reaction and entry conditions for application of the OEB No. 49. Operators were provided with these webinars for a fee. The aircraft manufacturer had changed this after the occurrence and now provides operators with training material and videos free of charge.
- The aircraft manufacturer considered simulator training as unnecessary and it was not intended to develop one, respectively. They viewed the published training material as sufficient to explain the situation.
- From the point of view of the aircraft manufacturer, the respective simulator operator should have adapted the simulator software. The aircraft manufacturer is not able to supervise the installation of software versions at the simulator operators. Neither can they ensure that the simulator trainings are performed correctly. Supervision whether simulator trainings are performed with obsolete simulator software for no longer valid OEB lies outside the competence of the aircraft manufacturer.
- Prior to the occurrence, the aircraft manufacturer had developed a new training to illustrate the overspeed reaction of the aircraft to flight crews.

1.19 Useful or Effective Investigation Techniques

In general, the BFU uses the ATSB-Analysis[25] for the investigation of serious incidents. Parts of the HFACS[26] method were used for analysis of the actions of the persons involved.

In addition, the BFU used the Causal Analysis based on System Theory - CAST[27]. The analysis method developed by Nancy G. Leveson (Professor of Aeronautics and Astronautics at Massachusetts Institute of Technology) supports the currently used investigation methods of the safety investigation authorities.

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25 Walker, M. B., & Bills, K. M. (2008). Analysis, Causality and Proof in Safety Investigations.
26 Shappell, Scott & Wiegmann, Douglas (2000). The Human Factors Analysis and Classification System - HFACS.
27 Leveson, Nancy G. (2019). CAST Handbook: How to Learn More from Incidents and Accidents.

2. Analysis

During the flight from Johannesburg to Frankfurt/Main a change of wind conditions caused exceedance of maximum Mach at FL 380 in Swiss airspace. The Pilot in command deactivated the Autopilot and steered the aircraft manually into climb. While reaching FL 400, the Stall Warning was activated several times for a few seconds. He initiated a descent, stabilizing the flight path again at FL 340.

The flight crew reported to have temporarily lost control of the aircraft caused by a rare but unpredictable weather phenomenon so that there was a high probability of an accident.

2.1 Persons

2.1.1 Flying Experience

The BFU rated the PIC and the co-pilots as experienced, due to their long-time aeronautical occupation and high total flying experience. The PIC's experience on type and his long-haul experience was relatively low due to the recent re-training to A340.

Both co-pilots had long-time type and long-haul experiences.

2.1.2 Licences

The PIC and co-pilot 2 held the required and valid aeronautical licences and ratings.

The investigation determined a difference in the licence of co-pilot 1. According to SACAA, he held a commercial pilot licence. Therefore, he did not meet the operator's licence requirements as co-pilot in commercial operations.

Co-pilot 1 had deceived the operator for years. The operator and SACAA have initiated consequences.

2.2 Fatigue on Long-Haul Flights

The NASA study did not supply an answer as to whether a structured sleep rhythm with enough time during a long-haul flight improves the performance of each pilot on board. It can only indicate that lack of sleep may influence human performance.

2.3 Flight Crew Actions

The PIC as PF conducted the entire flight, including the occurrence.

During cruise flight, Mach increased from Ma 0.82 to Ma 0.88 and the overspeed warning was triggered. The maximum demonstrated Mach of 0.89 was not exceeded.

The PIC deactivated the autopilot after the overspeed warning had been triggered and increased control inputs at the left sidestick to +11° nose up. The Overspeed Recovery Procedure stipulates, however, that the autopilot remains engaged. During climb, a vertical speed of +1.6 g and a rate of climb of +5,700 ft/min were reached.

The mountain waves with turning wind directions and decreasing wind speed, caused a longitudinal deceleration of the aircraft. It is very likely that the PIC perceived this as pitch down movement. This effect was possibly a contributing factor for the unnecessarily strong sidestick input which resulted in a high nose up movement.

He had assumed manual control, probably due to insufficient knowledge of the autopilot's system logic and under disregard of the FCTM Overspeed Recovery Procedure. This resulted in a relatively high g-load at great altitude and the aircraft entered a critical flight attitude.

Due to the initiated manoeuvre (g-load - wing loading), co-pilot 1 noticed that $V_{\alpha prot}$ at the PFD skyrocketed. He advised the other crew members that possibly an abnormal behaviour of the high angle of attack protection existed. The PIC instructed that two ADRs of the three ADIRUs are switched off. Flight control law changed from Normal Law to Alternate Law and autothrust disengaged.

The increasing $V_{\alpha prot}$ corresponded with the normal reaction of the system logic. Since the g-load increased to +1.6 g, $V_{\alpha prot}$ speed increased as well at this high cruise level. There was no system failure and the entry conditions for the OEB No. 49 were not given. Deactivating ADR 2 and 3 was unnecessary and wrong. In addition, important flight control protections were deactivated, e.g. the A/THR so that flight idle continued.

The dynamic pitch-up control inputs of the PIC after the overspeed condition, the subsequent climb and the low engine thrust (flight idle) resulted in the decrease in air speed to 203 kt CAS at FL 400. The aircraft descended again and pitch angle and angle of attack increased so that at an angle of attack of +7° and a Mach of Ma 0.70 the stall warning was triggered 3 times. During this flight phase, the aircraft descended to FL 340. The PIC and the co-pilot should have realised that during climb engine thrust was in flight idle and airspeed decreased. Based on the facts, the BFU concluded that the pilots neither monitored the engine values nor the airspeed. The BFU assumes that due to non-actions (e. g. Stall Recovery Procedure) crew cooperation and cockpit communication were insufficient.

Changes and deviations from a stabilised flight path, e.g. airspeed, altitude, rate of descent and engine thrust, have to be recognised and corrected by pilots. For this purpose, the FCTM procedures included the respective SOP calls-outs. Due to the missing CVR recording it could not be determined if the PIC or co-pilot 1 had applied them. The FDR data showed that during the attempt to stabilise the flight path, the sidestick inputs were not made sufficiently and vigorously enough. Thus, it has to be assumed that the SOP call-outs were not made correctly.

About five minutes elapsed between the first stall warning was triggered until a safe flight condition was reached again and the reactivation of the two ADRs. In the process, the aircraft lost about 6,000 ft altitude. The pilots' actions, to establish a controlled attitude again, did not fully comply with the Stall Recovery or the Upset Recovery Procedure, according to the FCTM - Abnormal and Emergency Procedures / MISC.

The radio communications recording with ATC and the FDR data show that the flight crew had temporarily lost control of the aircraft. The question is, whether they had been aware of the critical flight attitude at the time.

2.4 Aircraft

As part of the Air Operator Certificate, the aircraft was certified for commercial passenger transport. In accordance with SACAA regulations, it had a certificate of registration. The documentation the operator provided and the FDR data of the flight, did not contain any entries and indications which could have indicated a defect of the flight control system. No technical defects were determined which could have affected a safe flight or distracted the flight crew.

2.5 Operator

The BFU requested all required and relevant documents from the operator. At the time of the occurrence, they were up-to-date.

The operator's training department had a training program approved by the supervising authority according to their regulations for the continuous training of the pilots. According to the documentation provided, the flight crew involved was also trained in accordance with the operator's training program. The PIC received the training during his re-training for long-haul operations. Deficits during his training program and the evaluations of the operator's simulator trainers were not detected.

Up until the occurrence, the operator had conducted quite a number of international flights worldwide. Numerous flights regularly passed high mountains. The briefing package available to the pilots prior to the flight did not include weather charts for mountain waves forecast. This would be very useful, especially on long-haul flights.

2.6 Weather

At the time of the serious incident it was dark. According to the statement of the flight crew, the aircraft was free of clouds, during the occurrence.

During the interview, the pilots stated that the weather phenomenon above the Clariden had not been predicable from the weather information they had received. Therefore, it is understandable that the effect of the rapidly turning wind direction surprised the flight crew. However, due to their flight hours, they were experienced. The routes above high mountains and the subsequent weather phenomena, such as wind direction changes or turbulences, should have been nothing new. The flight crew should have been aware that such weather phenomena occur time and again, even very quickly, unheralded and unpredictable.

2.7 Cockpit Communication

Based on the flight crew's statement, a relaxed atmosphere prevailed during cruise flight. During the occurrence and until a controlled flight attitude was reached again, the atmosphere was tense. Given the safety-critical situation the aircraft was temporarily in this is understandable.

The investigation determined that the maintenance organisation did not pull the fuses of FDR and CVR and supplied the aircraft with ground power which resulted in the CVR being overwritten. Thus, the data could not be used for the investigation.

2.8 OEB No. 49

In the OEB No. 49, the two different conditions (Preventive Entry Condition and Reactive Entry Condition) were marked by a black dot and the respective procedure was displayed below. Is the first condition not relevant, one goes to the second. In this case, the Memory Items for the Reactive Entry Condition. From the layout, both cases and their respective procedures are clearly separated.

At the time of the occurrence, the textual description in the checklist, especially in regard to the Preventive Conditions as to when the OEB No. 49 had to be applied, was not clear.

2.9 EASA Airworthiness Directive

EASA had performed a risk assessment in regard to possible malfunctions of the angle of attack sensors including the effect on the flight control primary computer. The publication of the Airworthiness Directives occurred shortly after the first event in 2014 and at the respective development status of the FCPC software the aircraft manufacturer had modified. However, AD 2019-0028 was published after the occurrence of 6 November 2018. Thus, the AFM TR 529 was still active for the aircraft involved.

2.10 Training and Simulator

The Airbus A340 simulator used by the operator was technically not able to correctly produce the entry conditions for the OEB No. 49. Therefore, the simulator training of the pilots was limited to the explanations of the simulator trainers. At the time, the operator did not have any training material explaining the OEB No. 49.

The operator's investigation regarding the overspeed condition shows that an overspeed condition event in the simulator was presented as significantly weaker and experienced by pilots as considerably weaker as in the real aircraft. The data of the investigated event was presented to experienced pilots in a simulator. Never before had the pilots experienced such an intense event.

The operator neglected to update the simulator software to FCPC W10 even though in 2006 the aircraft manufacturer had published an update. The trainings department should have noticed and remedied this deficit.

The operator's Initial, Cross Crew Qualification Program and the 5-year Recurrent Training for pilots did not include training of overspeed conditions and their recovery techniques. The operator could have used the overspeed event data from the Flight Data Analysis Program and developed a respective training program. The recorded 654 overspeed events, prior to the occurrence, also included high altitude overspeed events. It would have been appropriate to use these events and explain and train them as part of a recurrent training.

A high altitude overspeed training with drastic wind speeds would have better prepared the pilots for such an event and minimised the surprise. Corresponding simulator training and explaining videos regarding the system could have minimised the probability that the PIC immediately assumes a system failure and has two of the three ADRs shut down.

2.11 Aircraft Manufacturer

An aircraft manufacturer issues a Red OEB with Immediate Actions if non-adherence negatively affects flight safety and it contains checklists items which have to be applied immediately.

The BFU is of the opinion that if flight safety can only be ensured by the publication of a Red OEB with Immediate Action by the aircraft manufacturer a simulator training has to be developed and performed.

The BFU is of the opinion that if checklists of Red OEB with Immediate Actions cannot be performed in a simulator (in this case the OEB No. 49), the aircraft manufacturer should develop demonstrations for simulators for operators. The following scenarios would have been possible with the investigated occurrence:

A) A demonstration of $V\alpha_{prot}$ increase if g-load rises, e.g. during a turn or wing-level flight, when the sidestick is pulled (change of pitch angle).

B) A demonstration that $V\alpha_{prot}$ does not change with increasing Mach, e.g. during aircraft acceleration at constant attitude or constant climb with constant airspeed.

3. Conclusions

3.1 Findings

3.1.1 Persons and their Actions

- PIC and co-pilot 2 had the required ratings in their licences to control the aircraft. Co-pilot 1 did not hold the licence required by the company - ATPL(A).
- The PIC's type experience was relatively low due to the recent re-training to A340.
- The PIC's experience on long-haul flights was very low.
- Due to their flight hours on type and on long-haul flights, co-pilot 1 and co-pilot 2 were experienced.
- The manual deactivation of the autopilot did not correspond with the overspeed recovery procedure. This action aided the later temporary loss of control.
- The flight crew did not know the airspeed at which high speed protection becomes active and the autopilot is automatically deactivated. The filtered Mach system logic was not known to them.
- The dynamic pitch up control inputs were too abrupt which caused a higher g-load which resulted in $V_{\alpha prot}$ increase.
- The decision to apply OEB No. 49 was not correct since the entry conditions were not given.
- Both pilots misinterpreted the $V_{\alpha prot}$ increase as entry condition for the OEB No. 49. The PIC followed his interpretation and instructed to switch off two ADRs.
- The A/THR was deactivated because of the shut-down of the two ADRs whereby flight idle thrust was continued.
- The completion of the OEB No. 49 checklist under consideration of the entry conditions the aircraft manufacturer had stipulated was not observed.
- For about four years, OEB No. 49 had been in the QRH. Prior to each flight, the flight crew had to brief the OEB procedure.
- The recovery of the flight attitude, after the stall warning had been active, was late, insufficient and not forceful enough.

- The pilots' situational awareness that protection systems of the aircraft had been deactivated was limited. Prior to the stall warning activation, they were not aware that speed was reducing and engine thrust was in flight idle.
- Insufficient monitoring of cockpit instruments, because the pilots neither reacted to the change in engine values nor to the airspeed and therefore did not apply the respective procedures. This resulted in a critical flight attitude.
- Insufficient cooperation and cockpit communication due to non-action (e. g. Stall Recovery Procedure) in critical flight attitudes

3.1.2 Training

- The FCPC of the training simulator had the software version W6.3, whereas the FCPC of the aircraft had version W10. One off its main emphasis was the airspeed at which the autopilot will automatically deactivate.
- Overspeed Recovery techniques were not trained during the Initial, the Cross Crew Qualification and the 5-year Recurrent trainings.
- Deficits in the flight crew training concerning the application of OEB No. 49 were determined.

3.1.3 Course of the Flight

- Prior to departure, the pilots had available all customary weather data and NOTAMS required for the conduct of the flight.
- Along the flight path, significant mountain waves activities prevailed. The flight crew did not have the information regarding the wind conditions.
- The wind condition caused a rapid overspeed condition which reached the operational and structural limitations of the aircraft.
- Co-pilot 1 did not perform his task as pilot monitoring during the stall recovery.
- During the Stall Warning, the flight crew lost situational awareness and temporarily control of the aircraft.
- The wrong application of the OEB No. 49 and the inconsistent implementation of the later necessary recovery procedures, including Standard Operating Procedures, e.g. respective call-outs, and abnormal procedures, show that they were not correctly applied.

- It is highly likely that the flight crew was overstrained with the overspeed condition.

3.1.4 Aircraft

- The aircraft was equipped for operations according to IFR.
- It had the required airworthiness certificate and was properly maintained by the maintenance organisation.
- Technical malfunctions were not determined.
- The aircraft’s V-Alpha Protection System was modified and thus met the EASA Airworthiness Directive requirement to delete the OEB N°49 from the respective manuals (FCOM, QRH and AFM). The corresponding FCPC modifications were implemented in the FCPC software standard W14.

3.2 Causes

The aircraft was in cruise flight at Flight Level (FL) 380 in Swiss airspace, when a change of wind conditions at high altitude caused the exceedance of the maximum operating Mach. The Pilot in Command deactivated the autopilot and steered the aircraft manually into climb. While reaching FL 400, the maximum angle of attack was reached several times and the stall warning activated. The PIC initiated a descent, stabilizing the flight path again at FL 340.

On 16 November 2018, the Swiss Transportation Safety Investigation Board (STSB) delegated the investigation to the German Federal Bureau of Aircraft Accident Investigation.

The investigation determined:

- A rapidly turning wind direction during cruise flight, unpredictable for the flight crew. This caused an overspeed condition.
- The flight crew did not respond to this overspeed condition with the procedure Abnormal and Emergency Procedures / Misc / Overspeed Recovery.
- The PIC had deactivated the autopilot and in the course of the incorrect application of the OEB No. 49, he had two ADRs of the three Air Data Inertial Reference Units (ADIRU) switched off. Subsequently, the A/THR was deactivated and flight idle thrust initially maintained.
- Temporarily, the aircraft was controlled in Alternate Law.
- Due to the dynamic pitch-up control inputs of the PIC, the subsequent climb and the low engine thrust in flight idle, rapid deceleration of airspeed and triggering of the stall warning occurred.
- Due to the erroneous application of the OEB No. 49, the aircraft was close to a stall at high altitude.
- The PIC’s control inputs during the active stall warning were insufficient and not energetic enough to stabilise the flight path in time.
- Crew cooperation during the overspeed condition and the stall recovery was erroneous in regard to the analysis of the situation and the implementation of procedures.

4. Safety Actions

During the investigation, the BFU had identified deficits at the operator. Due to the COVID-19 pandemic, the operator got into financial difficulties and filed for insolvency in mid-2020. The operator stopped all flight operations. Shortly afterwards a state company form was founded. The BFU abstained from issuing safety recommendations to the operator in its current form.

In 2022, the operator once again operated a fleet of long-haul aircraft types. In 2021, the operator had implemented the following:

- New processes were established to check licences. Any discrepancies regarding licences shall be monitored in cooperation with the respective civil aviation authority.
- The briefing packet for long-haul flights now contains Mountain Wave Forecasting Charts.
- The checklists of the training department and flight operations were adapted. It is to be ensured that the simulator software version and that of the real aircraft concur.
- The Upset Recovery Training is now part of the simulator training. The Evidence Based Training shall be included in the simulator training in the future. Flight operations and training department now monitor pilots’ training.

Investigator in charge:	Norman Kretschmer
Assistance:	Holm Bielfeldt, Ekkehart Schubert, Michel Buchwald, Berndt Dreyer

Braunschweig 12 June 2023

5. Appendices

5.1 Graphs of the Relevant Flight Data

For all three FDR plots the time period 0433:00 to 0443:00 UTC was considered. The times of the x-axis are in UTC.

- Figure 22: Overspeed Condition and Stall Warning
- Figure 23: Wind Direction and Speed
- Figure 24: Autopilot Mode and Angle of Attack

5.2 Upset Recovery

5.3 Flight Operations Transmission

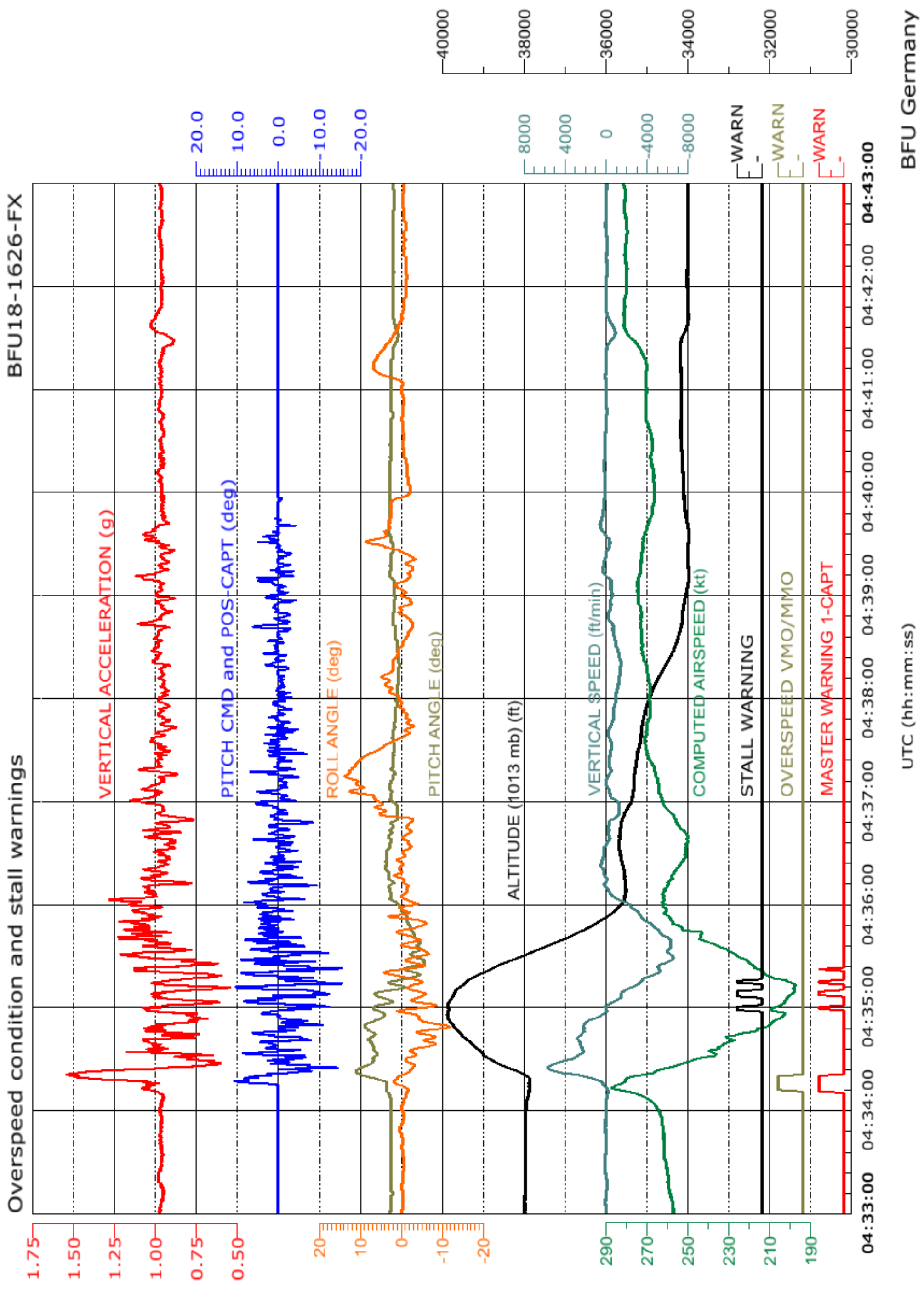

Fig. 22: Overspeed Condition and Stall Warning

Source: BFU

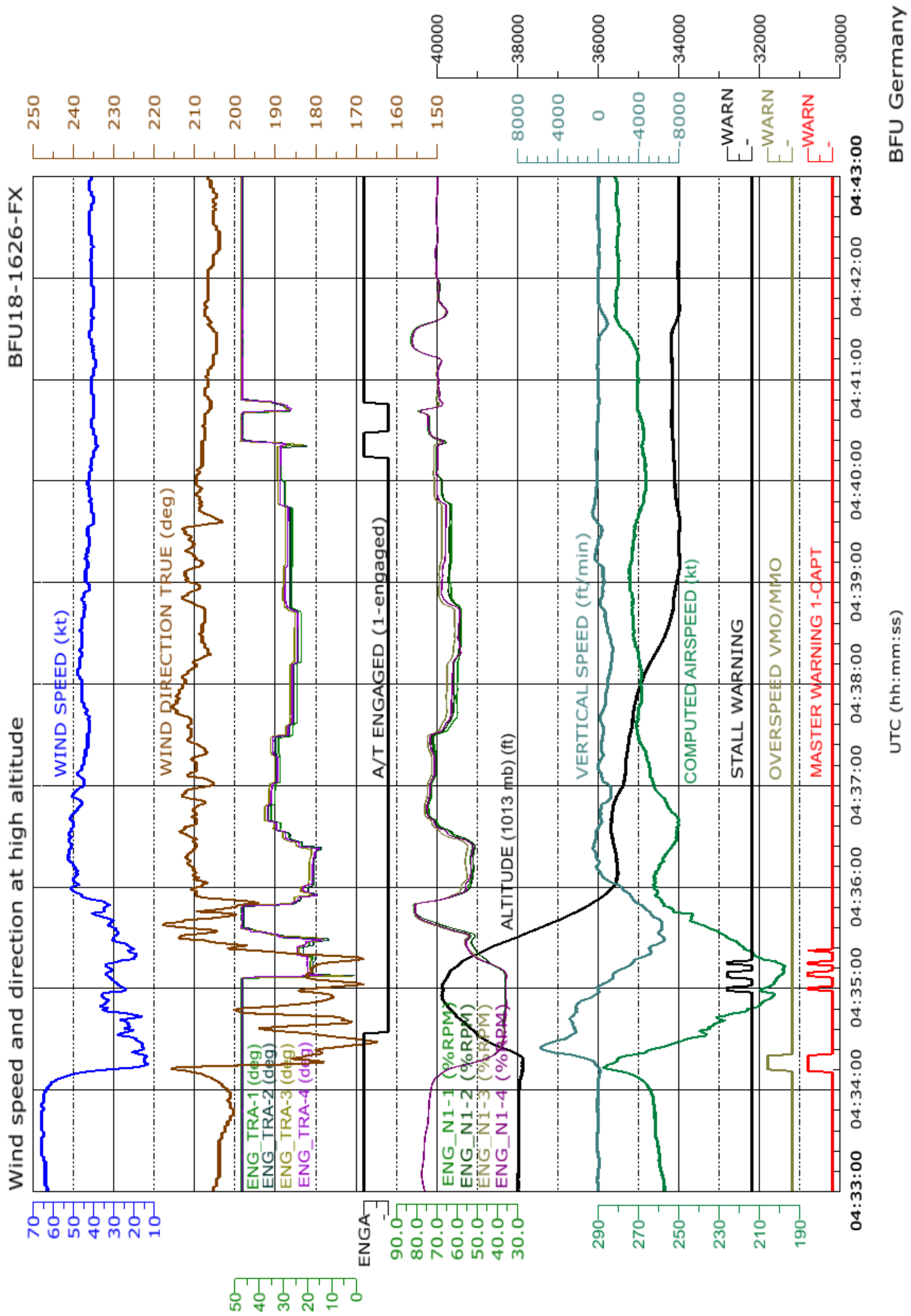

Fig. 23: Wind Direction and Speed

Source: BFU

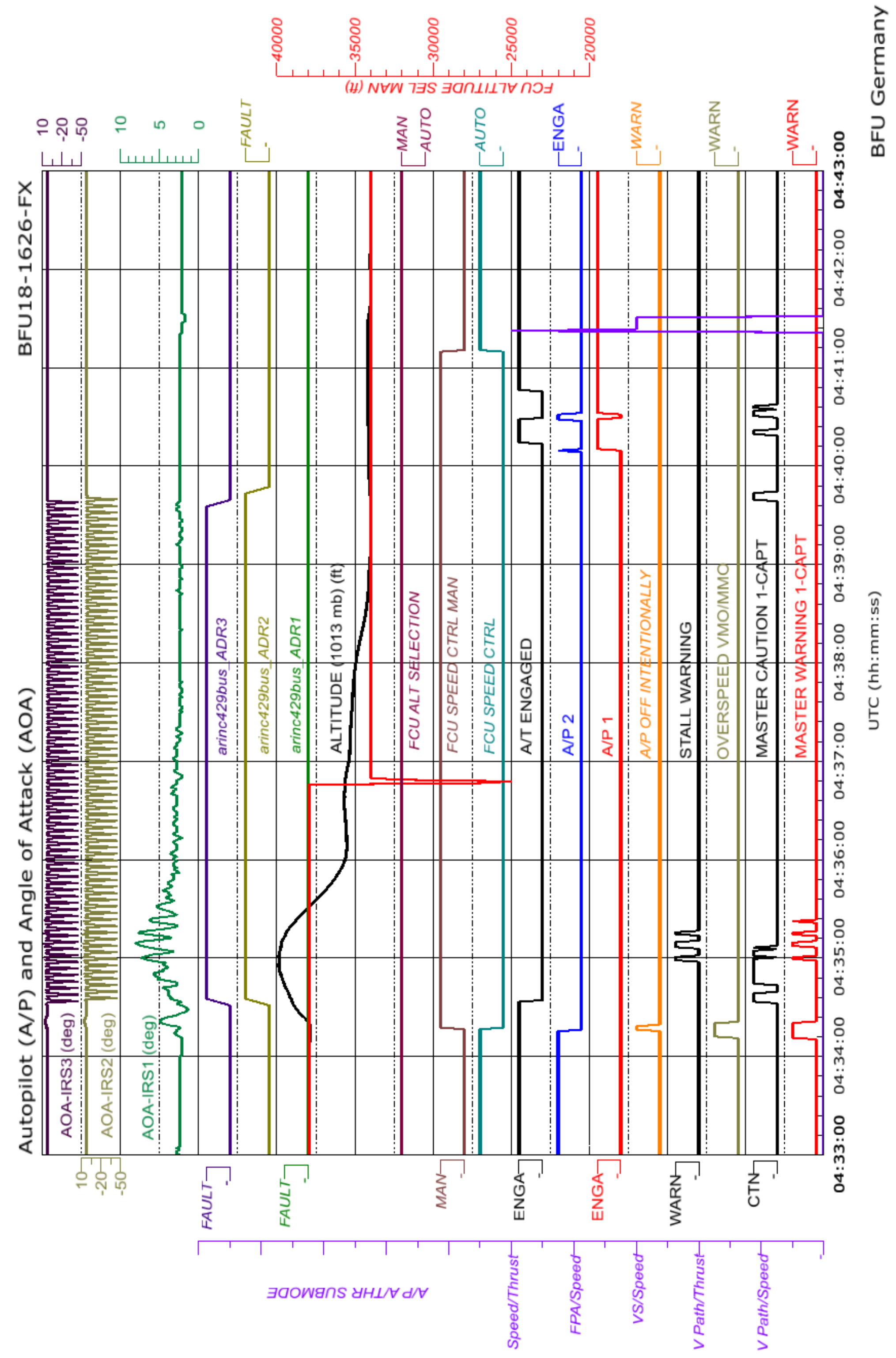

Fig. 24: Autopilot Mode and Angle of Attack Source: BFU

5.2 Upset Recovery

A330/A340 FLIGHT CREW TECHNIQUES MANUAL	PROCEDURES ABNORMAL AND EMERGENCY PROCEDURES MISC

- Assess risk and decide on a response
- Update and communicate understanding.

An efficient monitoring and effective coordination and communication are keys to prevent upset situations. As such, the flight crew should be able to assess the energy, to stop any flight path divergence, and to recover a stabilized flight path before the upset situation.

Ident.: PR-AEP-MISC-E-00020459.0001001 / 20 MAR 17

RECOVERY TECHNIQUES

The flight crew must be or become aware of the upset situation, i.e. recognize and confirm the situation before they take appropriate actions.

COMMUNICATION

Communication between crew members will assist in the recognition of upset situation and recovery actions. At the first indication of a flight path divergence, the first pilot who observes the divergence must announce it. The flight crew must use the flight instruments as primary means to analyze the upset situation.

SITUATION ANALYSIS

The situation analysis process is to:
- Assess the energy (airspeed, altitude, attitude, load factor, thrust setting, position of drag and high-lift devices and the rate of change of those conditions)
- Determine the aircraft attitude (pitch and bank angle)
- Communicate with other crew member(s)
- Confirm attitude by reference to other indicators:
  - For a nose low upset, normally the airspeed is increasing, altitude is decreasing and the Vertical Speed Indicator (VSI) indicates a descent
  - For a nose high upset, the airspeed normally is decreasing, altitude is increasing and the VSI indicates a climb.

A stalled condition can exist at any attitude and could be recognized by stall buffet and/or stall aural alert. If the aircraft is stalled, apply the stall recovery procedure. *Refer to PR-AEP-MISC Definition of the Stall*

REFERENCES FOR RECOVERY

The Primary Flight Display (PFD) is a primary reference for recovery.
Pitch attitude is determined from the PFD pitch reference scale. Even in extreme attitudes, some portion of the sky or ground indications is present to assist the pilot in analyzing the situation. The bank indicator on the PFD should be used to determine the aircraft bank.

A330/A340 FLEET PR-AEP-MISC P 31/34
FCTM ← M → 18 NOV 20

Fig. 25: Upset Recovery Procedure

Source: Operator, FCTM, PR-AEP-MISC P 30/34, 18 Nov 20

A330/A340 FLIGHT CREW TECHNIQUES MANUAL	PROCEDURES ABNORMAL AND EMERGENCY PROCEDURES MISC

Other attitude sources should be checked: Standby Attitude Indications, the pilot monitoring (PM) instruments, or references outside the cockpit when possible.

ACTIONS FOR RECOVERY

An overview of actions to take to recover from an upset would gather three basic activities:
- Assess the energy (become situationally aware)
- Stop the flight path divergence
- Recover to a stabilized flight path.

The Nose high/Nose low techniques represent a logical progression for recovering the aircraft. They are not necessarily procedural. The sequence of actions is for guidance only and represents a series of options for the pilot to consider and to use depending on the situation. The flight crew may apply these actions or part of these actions, mainly if the recovery is effective.
Depending on the situation, the PF should apply the required actions (See figures "Nose High" and "Nose Low").
During the maneuver, the PM must monitor the airspeed and the attitude throughout the recovery. The PM must also announce the flight path divergence if the recovery maneuver is not efficient.

Nose High Actions

Nose High Actions

- Recognize and confirm the situation
- Takeover and disconnect AP and A/THR (1)
- Apply nose down pitch order (2)

  Note: Excessive use of pitch trim may make the upset situation worse or may result in high structural loads.

- Adjust the thrust (3)
- Adjust the roll not to exceed 60 degrees (4)
- Recover the level flight (5)

Notes:

A330/A340 FLEET | PR-AEP-MISC P 32/34
FCTM | ← M → | 18 NOV 20

Fig. 26: Upset Recovery Procedure Source: Operator, FCTM, PR-AEP-MISC P 30/34, 18 Nov 20

A330/A340 FLIGHT CREW TECHNIQUES MANUAL	PROCEDURES ABNORMAL AND EMERGENCY PROCEDURES MISC

(1) If the AP and A/THR responses enable to stop the flight path divergence, the flight crew may keep the AP and A/THR engaged.

(2) The flight crew must apply as much nose down pitch order as required to obtain a nose down pitch rate.
In the case of lack of pitch down authority, the flight crew may use incremental inputs on the trim (nose down) to improve the effectiveness of the elevator control.

(3) Select up to maximum thrust available while ensuring adequate pitch control.
Increasing thrust may reduce the effectiveness of nose-down pitch control. It may be necessary to limit or reduce thrust to the point where control of the pitch is achieved.

(4) The bank angle must not exceed 60 degrees.
If all normal pitch control techniques are unsuccessful, the flight crew can keep the current bank or bank the aircraft to enable the nose to drop toward the horizon.
The bank angle should be the least possible to start the nose down and never exceed approximately 60 degrees. If the bank angle is already greater than 60 degrees, the flight crew should reduce it to an amount less than 60 degrees.
The flight crew must avoid entering a stall due to premature recovery at low speed or excessive g-loading at high speed.

(5) Recover to level flight at a sufficient airspeed while avoiding a stall due to premature recovery at low speed, or excessive g-loading at high speed.

Nose Low Actions

Nose Low Actions

- Recognize and confirm the situation
- Takeover and disconnect AP and A/THR (1)
- Recover from stall if required (2)

  Note: Excessive use of pitch trim may make the upset situation worse or may result in high structural loads.
- Adjust the roll in the shortest direction to wings level (3)
- Adjust the thrust and the drag (4)
- Recover the level flight (5)

A330/A340 FLEET — PR-AEP-MISC P 33/34
FCTM — ← M → — 18 NOV 20

Fig. 27: Upset Recovery Procedure Source: Operator, FCTM, PR-AEP-MISC P 30/34, 18 Nov 20

A330/A340 FLIGHT CREW TECHNIQUES MANUAL	PROCEDURES ABNORMAL AND EMERGENCY PROCEDURES MISC

Notes:

(1) If the AP and A/THR responses enable to stop the flight path divergence, the flight crew may keep the AP and A/THR engaged.

(2) Even in a nose low situation, the aircraft may be stalled and it would be necessary to recover from a stall first.

(3) In general, a nose low, high-angle-of-bank requires prompt action, because the decreasing altitude is rapidly being exchanged for an increasing airspeed.
The flight crew must avoid entering a stall due to premature recovery at low speed or excessive g-loading at high speed.

(4) The flight crew should reduce the thrust and/or use the speedbrakes to control the speed.

(5) Recover to level flight at a sufficient airspeed while avoiding a stall due to premature recovery at low speed, or excessive g-loading at high speed.

A330/A340 FLEET | PR-AEP-MISC P 34/34
FCTM | ← M | 18 NOV 20

Fig. 28: Upset Recovery Procedure Source: Operator, FCTM, PR-AEP-MISC P 30/34, 18 Nov 20

5.3 Flight Operations Transmission

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AIRBUS

FLIGHT OPERATIONS TRANSMISSION - FOT

TO: All A330,A340,A340-500,A340-600 Operators

SUBJECT: ATA 34 – ABNORMAL V ALPHA PROT

OUR REF.: 999.0148/14 Rev 01 dated 23-DEC-2014.

CLASSIFICATION: Airworthiness

APPLICABLE AIRCRAFT: This FOT is applicable to all A330 and A340 aircraft.

> Notice: This FOT provides information about a significant operational issue that is related to airworthiness or safety. It is each Operator's responsibility to distribute this FOT or to distribute the information contained in this FOT, to all of their applicable flight crews without delay. Failure to apply this FOT may have a significant impact on safe aircraft operations.

0. REASON FOR ISSUE

This FOT is re-issued to:
- Inform operators about the availability of briefing material related to OEB 49
- Provide operators with operational considerations related to OEB 49.

The revised paragraphs are indicated between ** **BEG. REV** ** and ** **END REV** **

1. PURPOSE

The purpose of this document is to inform operators about:
- Possible activation of high Angle-Of-Attack (AOA) protection (Alpha Prot) in normal law following blockage of the AOA probes
- The operational procedure to apply in order to prevent the above-mentioned effect
- The publication of a new Operational Engineering Bulletin(OEB) n°49, associated with AFM Temporary Revisions (TRs) n°528 for A330 and n°529 for A340.

2. EVENT DESCRIPTION

An Airbus aircraft equipped with AOA flat cover plates recently experienced an in-service event. During climb, two AOA probes remained blocked at a constant value. Further in the climb and during a turn, as the Alpha Prot strip increased quickly, the flight crew disconnected the AutoPilot (AP). The Alpha Prot activated, resulting in a nose down pitch order. The flight crew stabilized the aircraft altitude by applying pitch-up orders on the sidestick. Reversion to alternate law stopped the Alpha Prot activation, and restored control of the pitch orders with the sidestick.

3. INVESTIGATION STATUS

3.1 Cause

The blockage of two or three AOA probes at the same angle may cause the Alpha Prot of the normal law to activate, depending on the Mach number.

3.2 Consequences

FOT ref: 999.0148/14 Rev 01 **Page 1 of 4** **Date:** 23-DEC-2014

Fig. 29: Flight Operations Transmission, Page 1 Source: Operator

AIRBUS

FLIGHT OPERATIONS TRANSMISSION - FOT

In normal law, if two or three AOA probes are blocked at the same angle, an increase of the Mach number may activate the high angle-of-attack protection (Alpha Prot). This is due to the fact that the AOA value of the Alpha Prot decreases as the Mach number increases. When the AOA value of the Alpha Prot decreases, the Alpha Prot strip on the PFD moves upward.

In the case of Alpha Prot undue activation due to blocked AOA probes, the flight control laws order a continuous nose down pitch rate that may not be stopped with backward sidestick inputs, even in the full backward position. If the Mach number increases during a nose down order, the AOA value of the Alpha Prot will continue to decrease. As a result, the flight controls laws will continue to order a nose down pitch rate, even if the speed is above VLS.

Two or three blocked AOA probes may induce the following visible effect in the cockpit:
In a stabilized wings-level flight path (without an increase in load factor), the Alpha Prot strip (black and amber) on the speed scale of the PFD may completely and permanently hide the VLS strip (amber) and may reach the current speed.

Blocked AOA probes do not affect the current speed indication on the PFD.

In addition, in OP CLB or CLB with blocked AOA probes, the pitch order of the flight guidance may be affected by the value of the blocked AOA probes. Therefore, the aircraft may not be able to accelerate in order to reach the target speed.

4. OPERATIONAL RECOMMENDATIONS

The existing abnormal procedure, named ABNORMAL V ALPHA PROT in the ATA34 NAVIGATION section of the FCOM and QRH, was related to the effect of damaged AOA probes. The FCOM and QRH procedure is removed, and is superseded by the ABNORMAL V ALPHA PROT procedure published in OEB n°49, detailed below.

If the flight crew sees the cockpit effects described below, they must apply the following procedure to revert to the alternate law. This prevents activation of the Alpha Prot in normal law:

- If the Alpha Prot strip (black and amber) completely and permanently hides the VLS strip (amber) in a stabilized wings-level flight path (without an increase in load factor):
  ONE ADR..KEEP ON
  TWO ADRs..OFF
  The AP, FDs and ATHR are lost for the remainder of the flight.
  Switch two ADRs to OFF for the remainder of the flight in order to revert to alternate law to prevent undue Alpha Prot activation.
  In case of dispatch with one ADR inoperative, switch only one ADR to OFF.
  CAUTION: RISK OF ERRONEOUS DISPLAY OF THE VSW STRIP (BLACK AND RED) AND RISK OF UNDUE STALL WARNING
  SPEED...DO NOT INCREASE
  FPV USE..CONSIDER
  CAPT (F/O) EFIS DMC...AS RQRD
  - When at or above safety altitude:
    ALTITUDE...DO NOT INCREASE
    Limit speed and altitude in order to limit the Mach number and to avoid undue stall warning

- AT ANY TIME, with a speed above VLS, if the aircraft goes to a CONTINUOUS NOSE DOWN PITCH RATE that cannot be stopped with backward sidestick inputs, IMMEDIATELY APPLY:
  ONE ADR.. KEEP ON
  TWO ADRs..OFF

FOT ref: 999.0148/14 Rev 01 | Page 2 of 4 | Date: 23-DEC-2014

Fig. 30: Flight Operations Transmission, Page 2 Source: Operator

AIRBUS

FLIGHT OPERATIONS TRANSMISSION - FOT

5. OPERATIONAL DOCUMENTATION

Airbus published OEB N°49, named ABNORMAL V ALPHA PROT, to provide the flight crew with the procedure applicable in the case of two or three blocked AOA probes.

This OEB procedure supersedes the existing procedures in FCOM and QRH, related to damaged AOA probes. Therefore, the documentation is modified as follows:
- Update of QRH-ABN-34 ABNORMAL V ALPHA PROT procedure to refer to OEB n°49.
- Update of FCOM-ABN-34 ABNORMAL V ALPHA PROT procedure to refer to OEB n°49.

Airbus also published the AFM TRs n°528 for A330 and n°529 for A340 to introduce the operational recommendations in the AFM.

In addition, FCOM-DSC-27-20, FCOM-PRO-SUP-27-40 and FCTM-OP-020 sections provide a detailed description of the high angle-of-attack protection in Normal Law.

**** BEG. REV ****

6. OPERATIONAL CONSIDERATIONS

Further to webconferences held after the publication of OEB 49, Airbus published a set of briefing material available to all A330/A340 operators on AirbusWorld web portal.
This briefing material consists of:
- A detailed presentation of the OEB 49 procedure, including some technical descriptions of the aircraft logics and the visible effects for the flight crew
- A set of videos showing the dynamic effect of the indications on the PFD, and the aircraft behavior in case of a blockage of two or three AOA probes.

Airbus recommends operators to use this material to provide their flight crews with additional information related to OEB 49.

In addition, Airbus highlights the following considerations:

On A330/A340 aircraft, the effect of two or three blocked AOA probes will always be visible on the PFD, long before the potential undue activation of the Alpha Protection.
The early warning sign will be a continuous increase of the Alpha Prot strip, when the Mach increases (i.e. during climb and/or acceleration).
As a consequence, the Alpha Prot strip may completely and permanently hide the VLS strip, may exceed Green Dot and may reach the current speed.
In the case of a damaged AOA probe (bent AOA) these visual effects are similar, except that the Alpha Prot strip may transiently hide the VLS strip.

On A330/A340 aircraft, if the flight crew missed this visible effect on the PFD, the Alpha Protection will unduly activate when the Alpha Prot strip reaches and exceeds the current airspeed.
If the Alpha Protection unduly activates, the flight crew must **immediately apply by memory** the recovery actions. This ensures that the flight crew rapidly regains full authority on the pitch control, by reverting to Alternate law.

The flight crew must be aware of the location of the ADR pushbuttons to be able to quickly switch off two ADRs. Airbus recommends that the flight crew recalls this location during the OEB review in the Preliminary Cockpit Preparation.
The procedure does not define which ADR must be switched off, since the important step is to rapidly revert to Alternate law.

FOT ref: 999.0148/14 Rev 01 **Page 3 of 4** **Date:** 23-DEC-2014

Fig. 31: Flight Operations Transmission, Page 3 Source: Operator

FLIGHT OPERATIONS TRANSMISSION - FOT

Finally, Airbus confirms that an Abnormal V Alpha Prot does not cause unreliable speed indications.

**** END REV ****

6. FOLLOW-UP PLAN

OEB n°49 is issued as a precautionary measure until Airbus completes investigations and provides a final fix to the issue described in this FOT.

Please submit questions about the operational content of this FOT to:

A320/A330/A340 Flight Operations & Training Support - STLL
mailto: fltops.fbwstd@airbus.com

Best regards,

Capt Dominique DESCHAMPS
Vice President Flight Operations & Training Support

FOT ref: 999.0148/14 Rev 01 **Page 4 of 4** **Date:** 23-DEC-2014

Fig. 32: Flight Operations Transmission, Page 4 Source: Operator