Bundesstelle für
Flugunfalluntersuchung

German Federal Bureau of
Aircraft Accident Investigation

Interim Report

Identification

Type of Occurrence:	Serious incident
Date:	5 November 2014
Location:	12 NM north-west of Pamplona, Spain
Aircraft:	Airplane
Manufacturer / Model:	Airbus Industrie / A321-231
Injuries to Persons:	None
Damage:	None
Other Damage:	None
Information Source:	Investigation by BFU
State File Number:	BFU 6X014-14
Published:	17 March 2015

Factual Information

During climb and shortly before reaching Flight Level (FL) 310 the co-pilot noticed an irregularity in the speed characteristics displayed on the airspeed scale and disengaged the autopilot. The airplane began to descend. After about one minute the crew was able to stop the descent in approximately FL 270. After about two hours of flight time the airplane landed safely at the destination airport.

On 11 November 2014 the Spanish safety investigation authority Comisión de Investigación de Accidentes e Incidentes de Aviación Civil (CIAIAC) transferred the investigation to the German Federal Bureau of Aircraft Accident Investigation.

History of the Flight

The following description of the course of events is based on the preliminary analysis of the Flight Data Recorder (FDR) read-out, the Cockpit Voice Recorder (CVR) read-out, the aircraft and maintenance documentation, and various witness' statements.

The evening before, the airplane landed in Bilbao, Spain. It took off for scheduled services at 0748 hrs[1] with 109 persons on board. The co-pilot was Pilot Flying (PF) and the commander monitored the conduct of the flight. It rained during take-off. The airplane climbed through the cloud tops at approximately FL 200. From 0756 hrs on, the FDR recorded a constant angle of attack value (AOAcor) of 4.2° for the AOA sensor #1 (See Chapter: Aircraft Information). From 0757 hrs on, the recorded value for sensor #2 remained constant (4.6°) also. At 0803 hrs the crew received the clearance to fly directly to way point LATEK and the airplane turned to the new heading. The commander stated he noticed the indications of the Alpha Protection Band in the Primary Flight Display increasing unusually rapidly. The autopilot was in climb mode. The co-pilot stated he then reduced the rate of climb from about 800 ft/min to 500 ft/min using the Vertical Speed button of the autopilot giving the airplane a chance to accelerate. Shortly afterwards the co-pilot disengaged the autopilot and gave a short sidestick control input in order to reduce the pitch angle of the airplane. The nose of the airplane dropped further and the co-pilot counteracted this movement with the sidestick. The co-pilot stated the airplane did not respond as expected and continued to descend. Approximately 45 seconds after the autopilot was disengaged the co-pilot verbalised the airplane's limited reaction to his control inputs and therefore the commander took over the controls. At that time it had a rate of descent of about 4,000 ft/min and a pitch angle of -3.5°. The commander gave maximum backward sidestick input (pull) and the airplane's nose began to rise, the rate of descent decreased, and the airplane entered horizontal flight attitude once more.

The flight was continued in FL 270. The commander gave continuously backward sidestick input (pull) of more than 50% of the possible input; altitude and attitude remained constant. The autopilots could not be engaged again and the trim was limited

1 All times local, unless otherwise stated.

in nose up movements. The crew stated they made sure that the indicated airspeed was correct by checking the given values for pitch and power in the Quick Reference Handbook (QRH). Searching the QRH revealed that no procedure was described which would suit this situation. The Flight Augmentation Computers (FAC) 1 and 2 were reset by the crew one after the other. The FDR showed that this did not change the situation.

At 0811:12 hrs the Aircraft Communications Addressing and Reporting System (ACARS) sent an automatically generated message to the technicians of the operator's maintenance organisation. This message included the AOA values for the three Air Data Inertial Reference Units (ADIRUs).

At 0824 hrs the crew sent a telex to the technicians with a short description of the situation and the question whether an in-flight simultaneous reset of the FACs was possible. Three minutes later this was answered in the affirmative with the note that then the airplane would be in Alternate Law. At 0831 hrs the crew wrote that a constant pull on the sidestick was necessary, that the trim was not available and that the AlphaProt Band moved very rapidly. In addition, the Centralised Fault Display System (CFDS) showed the failure message "PH6 AOA3". The technicians suggested in a reply telex to retrieve the angle of attack values via the Multifunctional Control and Display Unit (MCDU) and, if necessary, to turn off the Air Data Reference unit (ADR) 3.

At 0836 hrs the crew turned off ADR 3. This did not change the situation and therefore the unit was turned on again. At 0852 hrs the crew received the following message: "…NACH SICHTUNG DER AOA WERTE, KOENNTE ES SEIN, DASS AOA1 UND AOA2 EINGEFRORENEN SIND UND EINEN ZU HOHEN ANSTROEMWINKEL MELDEN (After reviewing the AOA values it is possible that AOA1 and AOA2 are frozen and report a too high angle of attack). FALLS DAS PROBLEM WEITERHIN BESTEHT, ADR 1 UND ADR 2 AUSSCHALTEN, WAS ABER ZU ALTENATE LAW FUEHRT" (If the problem continues turn off ADR 1 and ADR 2 but that leads to alternate law). And at 0857 hrs: "…VIELLEICHT REICHT ES AUCH NUR DEN ADR 2 AUSZUSCHALTEN (Maybe it suffices to just turn off ADR 2). […]"

At 0859 hrs the crew turned off ADR 2. The flight control system changed to Alternate Law. The continuous sidestick input was no longer necessary in order to keep the airplane in horizontal flight attitude. Autotrim and autopilot functioned again.

The crew stated they decided to fly to the destination aerodrome and use the remaining flight time of about one hour to become familiar with the systems' functions and prepare the landing. At 0949 hrs the airplane landed safely at the destination aerodrome.

Personnel Information

Commander

The 52-year-old commander was a German citizen and held an Airline Transport Pilot's License (ATPL(A)) issued by the Luftfahrt-Bundesamt (German civil aviation authority, LBA) in accordance with JAR-FCL. Initially, the license was issued in Germany on 4 May 1988. The type rating Pilot in Command (PIC) for A318/319/320/321 and the instrument rating entered in the license were valid until 30 April 2015. His total flying experience was 16,438 hours, of which 12,414 hours were on the type in question. The commander held a Class 1 Medical Certificate issued in accordance with Part-MED valid until 20 August 2015. He had the restriction to wear glasses (VDL).

Co-pilot

The 35-year-old co-pilot was a German citizen and held an Airline Transport Pilot's License (ATPL(A)) issued by the LBA in accordance with JAR-FCL. Initially, the license (CPL(A)) was issued in Germany on 15 November 2006. The type rating COP for A318/319/320/321 and the instrument rating entered in the license were valid until 18 February 2015. His total flying experience was 6,473 hours, of which 5,179 hours were on the type in question. The co-pilot held a Class 1 Medical Certificate issued in accordance with Part-MED valid until 15 July 2015.

Aircraft Information

According to the authority of registry, the Airbus A321-231 is a twin-engine transport aircraft with a maximum take-off mass of 85,000 kg. The airplane was powered by two IAE V2533-A5 jet engines.

The airplane in question was manufactured in 2012 and had the manufacturer's serial number 5049.

The last Airworthiness Review Certificate was issued on 11 February 2014 valid until 27 February 2015. The last release to service was issued on 4 November 2014 at 1035 hrs in Munich.

The airplane was equipped with three AOA sensors with the P/N 0861ED manufactured at UTC Aerospace Systems.

Flight Control System

The following information is based on the statement of the aircraft manufacturer in his role as type certificate holder:

The A321 flight control system is a Fly By Wire system. Among other things, this consists of seven flight control computers: two Elevator Aileron Computers (ELAC), three Spoiler Elevator Computers (SEC) and two Flight Augmentation Computers (FAC) which control the airplane's control surfaces. All flight control surfaces are electrically controlled and hydraulically operated. The Control Laws describe the method as to how the flight control system processes the movement of the control surfaces. Basically the distinction is: Normal Law, Alternate Law and Direct Law.

Different protections are installed in the flight control computers which will prevent exceedance of the safe flight envelope. These include, for example, high angle-of-attack protection or limitation of the load factor.

If the system operates in Normal Law all these protections are available. In Alternate Law only some of these protections are still available; in Direct Law all protections are unavailable.

Measurement of the Angle of Attack

The aircraft is equipped with three AOA sensors. They measure the local angle of attack. The sensors consist of heatable and movable vanes which are subjected to the air current. A rotary encoder converts the rotational movement of the vanes in electrical signals.

Each AOA sensor is connected with an Air Data Reference (ADR). The ADR calculates the angle of attack for the airplane (AOAcor) using the local AOA values provided by the AOA sensor.

High angle-of-attack Protection

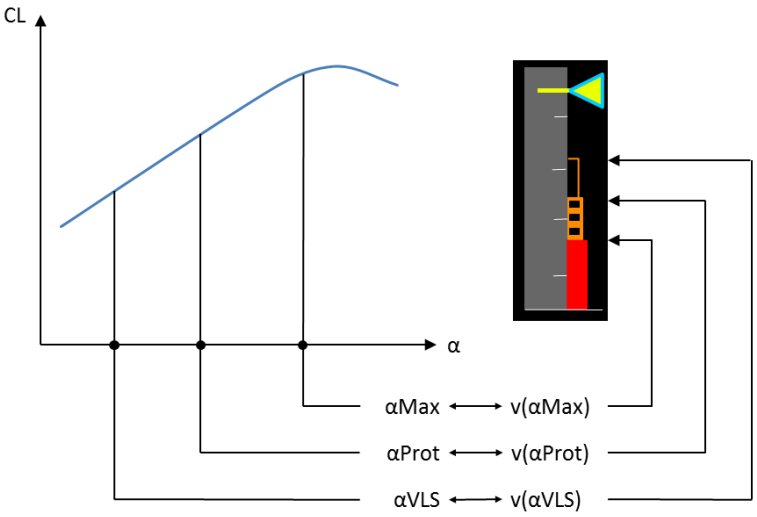
The A321 is equipped with a high angle-of-attack protection. This function will prevent angle of attacks leading to a wing stalling resulting in uncontrolled flight move-

ments. If the autopilots are disengaged, this function is activated once a certain angle of attack (AlphaProt) is reached.

If the autopilot is engaged, it automatically disengages if the angle of attack reaches AlphaProt +1° and subsequently the AOA protection activates immediately. If the AOA protection is activated the sidestick input corresponds with a certain AOA demand. The maximum angle of attack which can be demanded in Normal Law is AlphaMax. AlphaMax can only be reached if the pilot gives maximum manual backward sidestick input (pull). If the sidestick is released the flight control computers command an elevator deflection until the measured angle of attack (Alpha) targets the AlphaProt value.

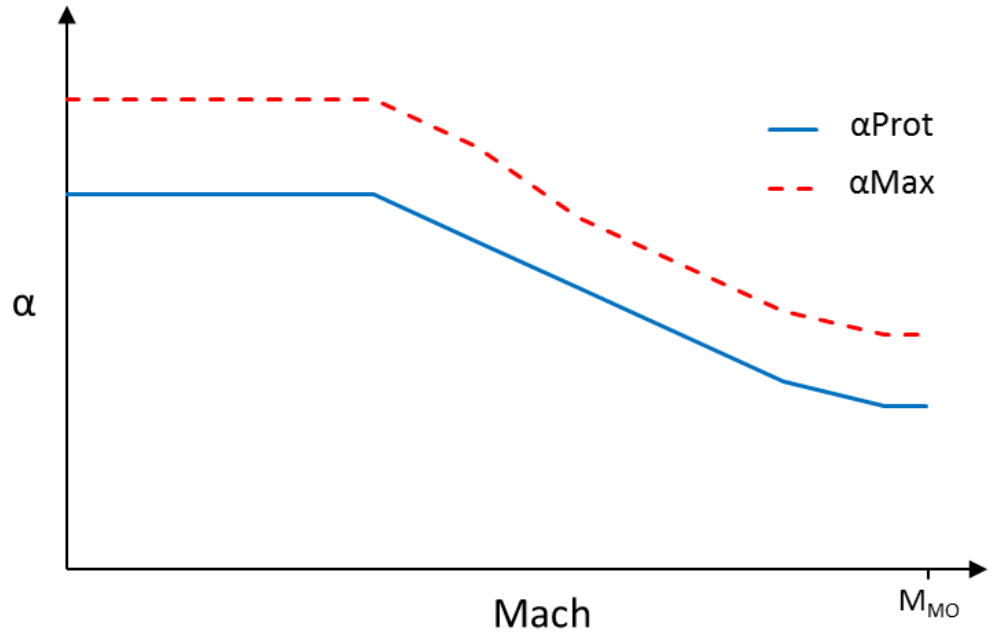
When the AOA protection is activated the trim position is stored. As long as the AOA protection is active this position is the upper trim limit in nose-up direction.

The Primary Flight Display (PFD) indicates the speeds, which are defined by AlphaProt and AlphaMax, in the speed band.



Graph: BFU

AlphaProt and AlphaMax depend on the Mach number of the aircraft, among other factors. When the Mach number increases AlphaProt and AlphaMax decrease.



Dependence of AlphaMax and AlphaProt from the Mach number Graph: BFU

Meteorological Information

At the time of the occurrence the following aviation routine weather reports (METAR) were valid for the aerodrome of departure Bilbao:

METAR LEBB 050630Z 27004KT 210V300 7000 -TSRA SCT025 FEW030CB BKN035 10/08 Q1008 TEMPO 3000 TSRA=

METAR LEBB 050700Z 30008KT 260V340 5000 TS -RA BR SCT020 FEW030CB BKN050 10/08 Q1008 TEMPO 3000 TSRA=

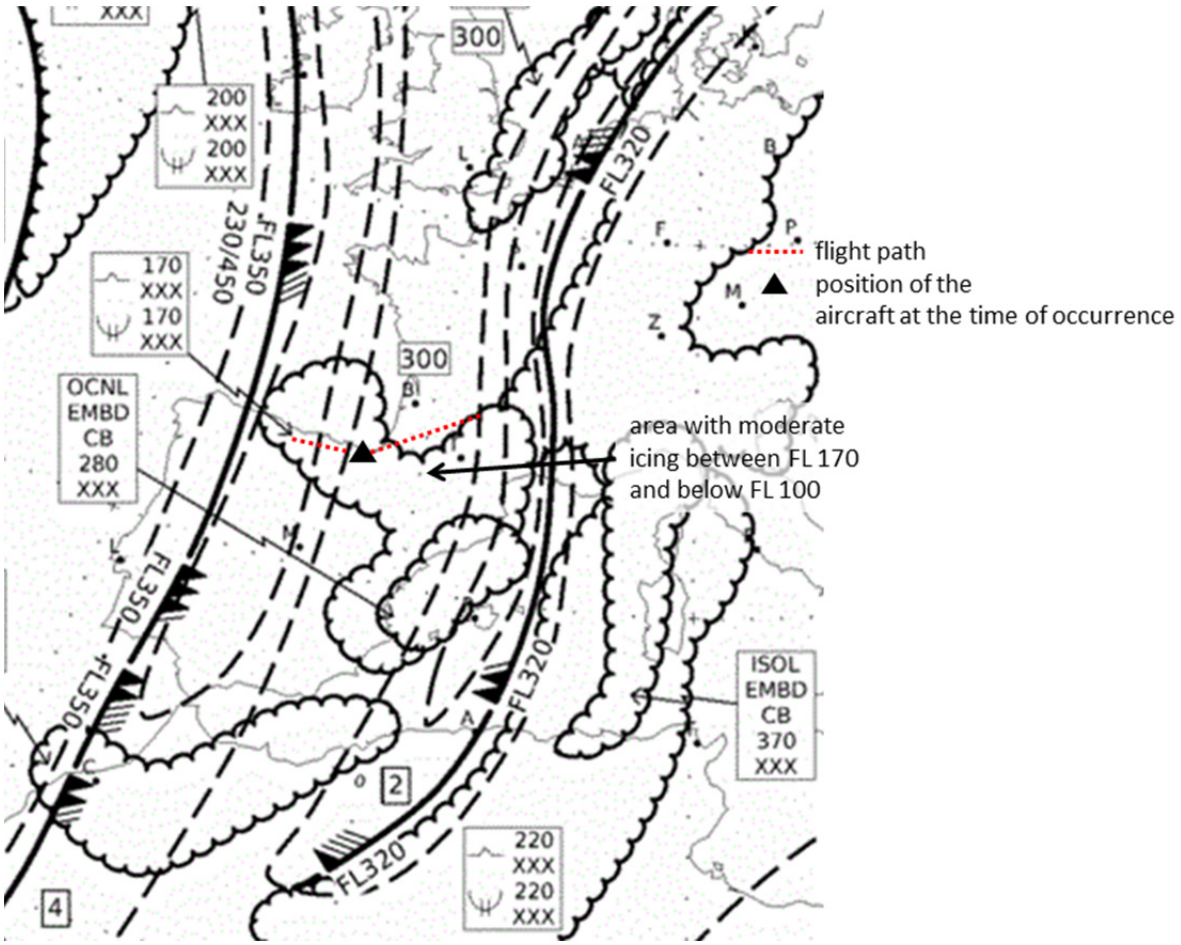
In plain language:

Station Bilbao reported on the 5. day of the month at 0630 UTC (0730 hrs local time), wind from 270° with 4 kt, wind direction variable between 210° and 300°, visibility 7,000 m, thunderstorms with slight rain, scattered clouds in 2,500 ft, few Cumulonimbus in 3,000 ft, and broken clouds in 3,500 ft above the aerodrome reference point, temperature 10°C, dewpoint 8°C, QNH (air pressure reduced to mean sea level) 1,008 hPa, temporary drop in visibility to 3,000 m and thunder showers.

At 0700 UTC the following values were reported: Wind from 300° with 8 kt, wind direction variable between 260° and 340°, visibility 5,000 m, thunderstorms with slight

rain, mist, scattered clouds in 2,000 ft, few Cumulonimbus in 3,000 ft, and broken clouds in 5,000 ft above the aerodrome reference point, temperature 10°C, dewpoint 8°C, QNH 1,008 hPa, temporary drop in visibility to 3,000 m and thunder showers.

Sunrise in Bilbao was at 0752 hrs. At the time of the incident it was daylight.



En route weather Source: German Meteorological Service

Radio Communications

At the time of the occurrence the airplane had been in radio contact with Madrid Radar. A transcript of the radio communications was provided to the BFU. Relevant passages are part of chapter History of the Flight.

During the flight different text messages, either automatically generated or manually entered, were sent and received via the Aircraft Communications Addressing and

Reporting System (ACARS). Relevant information is part of chapter History of the Flight.

Flight Recorders

The memories of the Cockpit Voice Recorder (CVR) and the Flight Data Recorder (FDR) were read out at the BFU in Braunschweig.

CVR

Manufacturer:	L-3COM
Model:	FA 2100
P/N:	2100-1026-02
S/N	744615
Medium:	Solid State
State of the Recorder:	No damages (visual inspection)

Read-out Equipment:	Portable Interface PI, OEM for Fairchild Model FA2100
Analysis Equipment:	PC, Software "Phase 88" and "VEGAS"

Recording Configuration:	120 minutes, 2 stereo channels
Recording Quality:	Good

CVR Transcript

The CVR recordings relevant for the investigation were incorporated into the report.

FDR

Manufacturer:	L-3COM
Model:	FA 2100
P/N:	2100-4045-00
S/N:	749757
Medium:	Solid State
State of the Recorder:	No damages (visual inspection)

Read-out Equipment:	HHMPI
Analysis Equipment:	PC, Software: Insight

Recording Quality:	Good, low error rate
Recording Length:	261 hours flight data
Parameter List:	823 parameters

Findings on the Aircraft

Examination of the Angle of Attack Sensors at the Manufacturer

In the presence of the BFU, all three angle of attack sensors were examined at the manufacturer in the United States of America. No indications of contamination, damage or defects, which would explain blockage, were found either in or on the sensors.

Additional Information

Analysis of the Manufacturer

The aircraft manufacturer in his role as type certificate holder analysed the available data of the occurrence. This analysis included the following results:

All three AOA sensors functioned normally at take-off of the airplane. Eight minutes after take-off, while reaching FL 195, at an outside air temperature of -35°C (SAT), freezing of the AOA sensors 1 and 2 led to AOAcor recorded at 4.5°. This value remained unchanged for the next approximately 1 hour and 32 minutes until the descent.

The ELAC receives the values for all three AOA sensors through the respective ADR. In normal operation the 3 AOA values are permanently monitored in the ELAC. If one of the AOA values deviates from a certain threshold of the mean AOA value (calculated from all three AOA values) the respective ADR is rejected by the ELACs. As long as ADR 1 and 2 are available in the ELAC (not rejected by this monitoring), only the values of the AOA from ADR 1 and 2 are considered for the subsequent calculations in the ELAC.

At 0803:19 hrs a left-hand turn with a bank angle of 15° was initiated. At 0803:52 hrs the crew disengaged the autopilot. At that time the Mach number was at 0.675, the corresponding value of the AlphaProt was at 4.2° and the one for the AlphaMax at 5.8°. Since the angle of attack the system had calculated was 0.3° higher than AlphaProt the high angle-of-attack protection was active as soon as the autopilot was disengaged and the system ordered a nose down movement. Progressively and for 15 seconds the co-pilot gave backward sidestick inputs up to 3/4 of the way to coun-

teract this movement. The pitch changed from 4.5° to -3.5 and the rate of descent increased to 4,000 ft/min. At 0804:54 hrs the ELAC rejected ADR 3 as the AOA 3 value deviated from the other two by more than the monitoring threshold. From 0805:20 hrs on the airplane once again flew stabilised with Mach 0.79 in FL 270 with 2/3 continuous backward sidestick input (pull).

Turning off ADR 2 resulted in the flight control system switching into Alternate Law and subsequently the high angle-of-attack protection had also switched off because ADR 3 had already been rejected.

After the FAC had been reset, the values of the AOA sensors no longer deviated so strongly that the limits for rejection of one ADR were reached. After ADR 2 had been turned off the FAC had two ADRs available. Once the high angle-of-attack protection had deactivated the autopilot could be engaged again.

AOA Sensor Reliability

During the investigation the BFU received data analysis results from various sources which air operators had collected as part of the Flight Operation Data Analysis. These analyses should show how often in the past individual sensors provided inappropriate constant values during a flight. The algorithms and context of these analyses differ and the BFU has no comprehensive knowledge of them.

Based on these values it is part of the further investigation to determine the probability of occurrence of a similar serious incident.

Safety Recommendations

Safety Recommendations of the BFU

During the investigation by the BFU the aircraft manufacturer and EASA have proposed the actions described below.

Due to these suggestions the BFU has, for the time being, abstained from issuing a safety recommendation.

Actions of the Aircraft Manufacturer

On 8 December 2014 the aircraft manufacturer in his role as type certificate holder issued a Flight Operations Transmission (FOT) to all A318/A319/A320/A321 operators. This FOT refers to the Operations Engineering Bulletin OEB48 Issue 1 "Abnormal V Alpha Prot" issued at the same time. The FOT explained that 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 results in continuous nose down pitch rate that may not be stopped with backward sidestick inputs, even in the full backward position. It was recommended to turn off two of the three ADRs to put the flight control system in Alternate Law and therefore deactivate the high angle-of-attack protection.

The OEB included descriptive amendments for the Flight Crew Operations Manual (FCOM), a preliminary revision for the Aircraft Flight Manual (AFM) and an amendment for the Quick Reference Handbook (QRH).

The FOT also explained that the implemented procedure is provisional and the manufacturer is working on a final solution for the described problem.

For the aircraft types A330/A340 similar FOT and OEB were issued.

Actions of the European Aviation Safety Agency

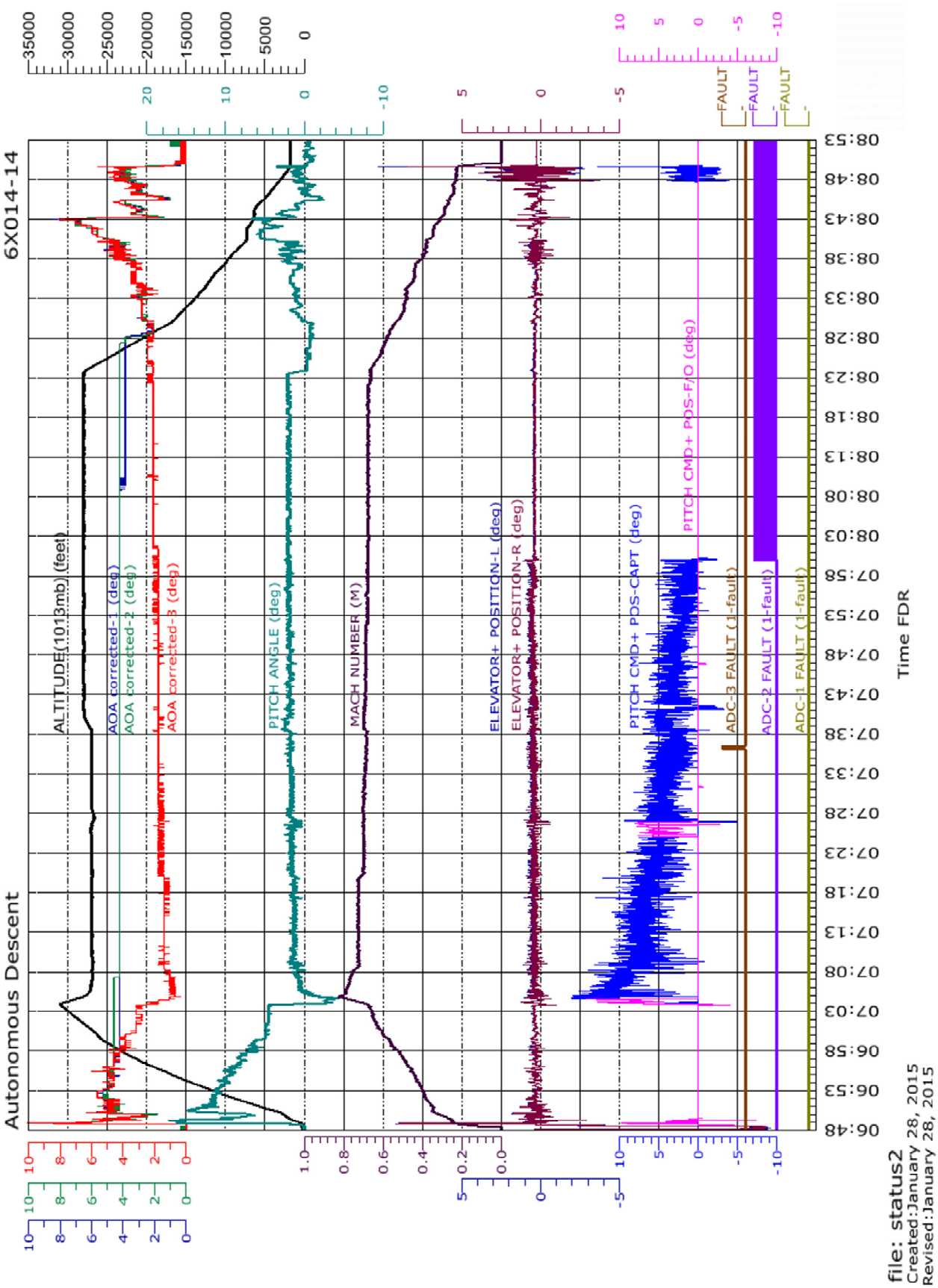
On 9 December 2014 the European Aviation Safety Agency (EASA) issued the Airworthiness Directive No 2014-0266-E Airplane Flight Manual – Undue Activation of Alpha Protection – Emergency Procedure. This Airworthiness Directive made mandatory the Aircraft Flight Manual amended by the procedure the manufacturer had described in the FOT and the OEB and a subsequent information of flight crews prior to the next flight.

EASA issued a similar Airworthiness Directive for the aircraft types A330/340.

Investigator in charge: Kostrzewa

Appendices

FDR Excerpt


6X014-14
Autonomous Descent
ALTITUDE(1013mb) (feet)
AOA corrected-1 (deg)
AOA corrected-2 (deg)
AOA corrected-3 (deg)
PITCH ANGLE (deg)
MACH NUMBER (M)
ELEVATOR+ POSITION-L (deg)
ELEVATOR+ POSITION-R (deg)
PITCH CMD+ PDS-CAPT (deg)
PITCH CMD+ PDS-F/O (deg)
ADC-3 FAULT (1-fault)
ADC-2 FAULT (1-fault)
ADC-1 FAULT (1-fault)
FAULT
Time FDR
file: status2
Created:January 28, 2015
Revised:January 28, 2015

This investigation is 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.

Published by:

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