NATIONAL TRANSPORTATION SAFETY BOARD
OFFICE OF AVIATION SAFETY
WASHINGTON, D.C. 20594

February 5, 2014

Systems Group Chairman's Factual Report of Investigation

A. ACCIDENT

Operator: UPS
Aircraft: A300-600F, MSN 841
Location: Birmingham, AL
Date: August 14, 2013
Time: 4:47 AM Local Time

B. SYSTEMS GROUP

Chairman	Steven Magladry NTSB, Washington, DC
Member	Dale Dunford FAA, Renton, WA
Member	Joe Bianco IPA, Louisville, KY
Member	Bob Kohler IBT, Louisville, KY
Member	Mike Osinski UPS, Louisville, KY
Member	Julien Ballester BEA, Paris, FR
Member	Jacques Laurent Airbus, Toulouse, FR
Member	Fabien CASES Airbus, Toulouse, FR
Member	Denis Cadoux Airbus, Toulouse, FR

Member	Jay Eller Honeywell, Phoenix, AZ
Member	Jim Mulkins Honeywell, Redmond, WA
Member	Steve C Johnson Honeywell, Redmond, WA
Member	Robert Koopman Honeywell, Phoenix, AZ

C. SUMMARY

On August, 14, 2013, at about 0447 central daylight time (CDT), United Parcel Service (UPS) flight 1354, an Airbus A300-600, N155UP, crashed short of runway 18 while on approach to Birmingham-Shuttlesworth International Airport (BHM), Birmingham, Alabama. The captain and first officer were fatally injured and the airplane was destroyed. The scheduled cargo flight was operating under the provisions of 14 Code of Federal Regulations (CFR) Part 121 and originated from Louisville International-Standiford Field Airport (SDF), Louisville, Kentucky.

Members of the systems group completed the on-scene portion of the investigation on August 19, 2013. On September, 11, 2013 members of the systems group convened at the Honeywell facility in Redmond, WA to examine the Enhanced Ground Proximity Warning System (EGPWS) computer. On September 13, 2013 Honeywell performed a download of the Flight Management Computer non-volatile memory. The following report summarizes the findings from those activities.

D. DETAILS OF THE INVESTIGATION

1.0 Enhanced Ground Proximity Warning System (EGPWS)

System Description

The Honeywell EGPWS is a Terrain Awareness and Alerting system providing terrain alerting and display functions with additional features meeting the requirements of TSO C151b Class A TAWS. The EGPWS uses aircraft inputs including geographic position, attitude, altitude, airspeed, and glideslope deviation. These are used with internal terrain, obstacles, and airport runway databases to predict a potential conflict between the aircraft flight path and terrain or an obstacle. A terrain or obstacle conflict results in the EGPWS providing a visual and audio caution or warning alert. The audio alerts are divided into categories. The performance of the following alert categories will be evaluated for this accident:

Mode 1, Excessive Decent Rate - provides alerts for excessive descent rates with respect to altitude AGL and is active for all phases of flight. This mode has outer and inner alert boundaries which can produce “Sinkrate, Sinkrate” and “Pull up” alerts respectively (Figures 1 and 2). The “Sinkrate” curve boundary is defined by the equation; Radio Altitude (FT) = -572 (FT) - 0.6035 * Altitude Rate (FPM). The outer boundary has a 0.8 second persistence condition, to reduce nuisance alerts, which means that the alert envelope must be penetrated for 0.8 seconds before an alert is initiated. The “Pull Up” curve boundary is defined by the equation: Radio Altitude (FT) = -1620 (FT) – 1.1133 * Altitude Rate (FPM), for descent rates greater than 1482 FPM and less than 1710 (FPM). There is another part of the “Pull Up” Curve for higher descent rates, but it does not apply to this accident scenario.

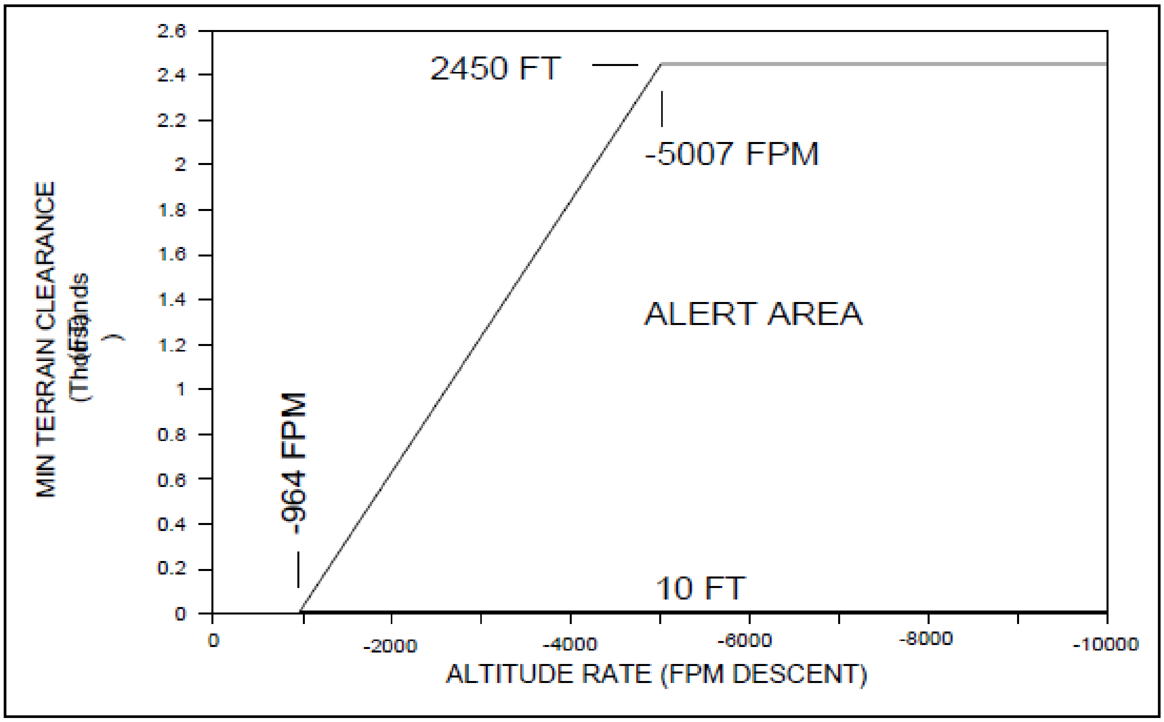

Figure 1 Sinkrate Curve Specification

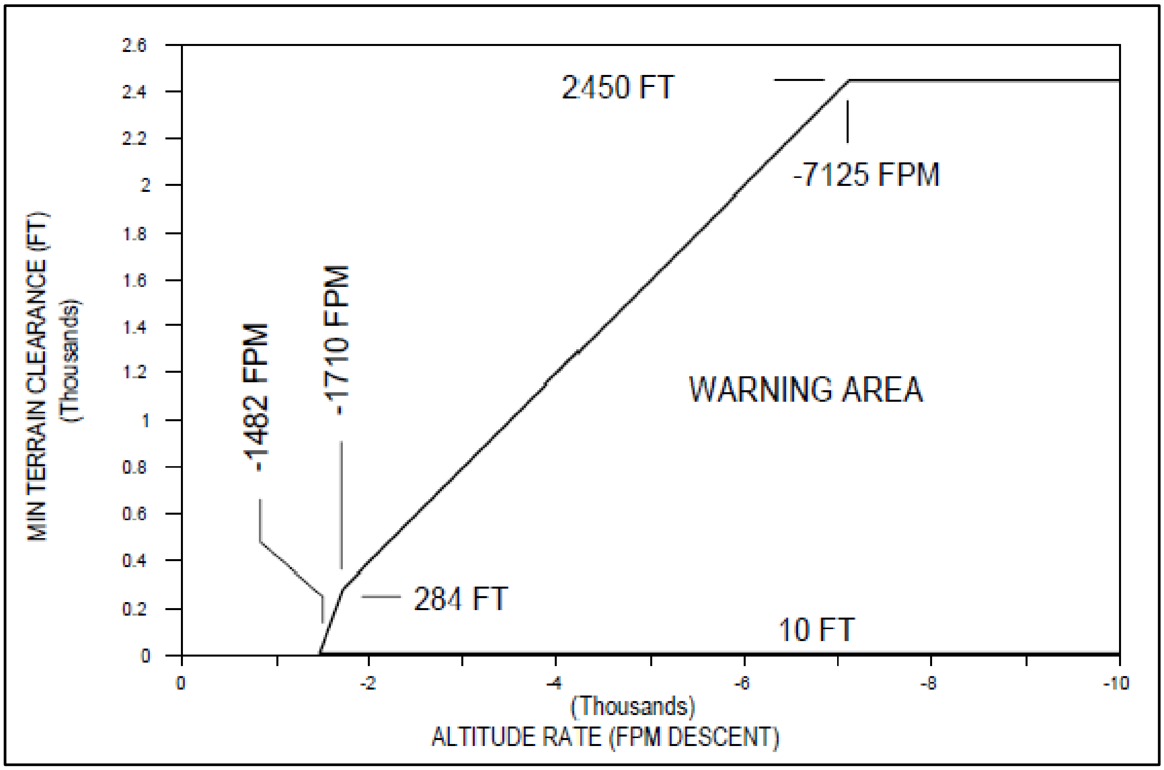

Figure 2 Pull Up Curve Specification

Mode 2, Terrain Closure Rate - provides alerts to help protect the aircraft from impacting the ground when rapidly rising terrain with respect to the aircraft is detected

Mode 3, Altitude Loss After Takeoff - provides alerts when the aircraft loses a significant amount of altitude immediately after takeoff or during a missed approach.

Mode 4, Unsafe Terrain Clearance - provides alerts for insufficient terrain clearance with respect to the phase of flight, configuration, and speed.

Mode 5, Glideslope - provides two levels of alerting for when the aircraft descends below glideslope, resulting in activation of EGPWS caution lights and aural messages.

Mode 6, Advisory Callouts - provides EGPWS advisory callouts based on the menu-selected option established at installation (set by program pin configuration). These callouts consist of predefined Radio Altitude-based voice callouts or tones and an excessive bank angle advisory. There is no visual alerting provided with these callouts.

Mode 7, Windshear - designed to provide alerts if the aircraft encounters windshear. Two alerting envelopes provide either a Windshear Caution alert or a Windshear Warning alert each with distinctive aural and visual indications to the flight crew.

Terrain Clearance Floor (TCF) – enhances the basic GPWS Modes by alerting the pilot of descent below a defined “Terrain Clearance Floor,” regardless of the aircraft configuration. The TCF alert is a function of the aircraft's Radio Altitude and distance (calculated from latitude/longitude position) relative to the center of the nearest runway in the database (all runways greater than 3500 feet in length) (Figure 3). The TCF envelope is defined for all runways and extends to infinity, or until it meets the envelope of another runway. The TCF boundary has a 1 second persistence condition, to reduce nuisance alerts, which means that the alert envelope must be penetrated for 1 second before an alert is initiated.

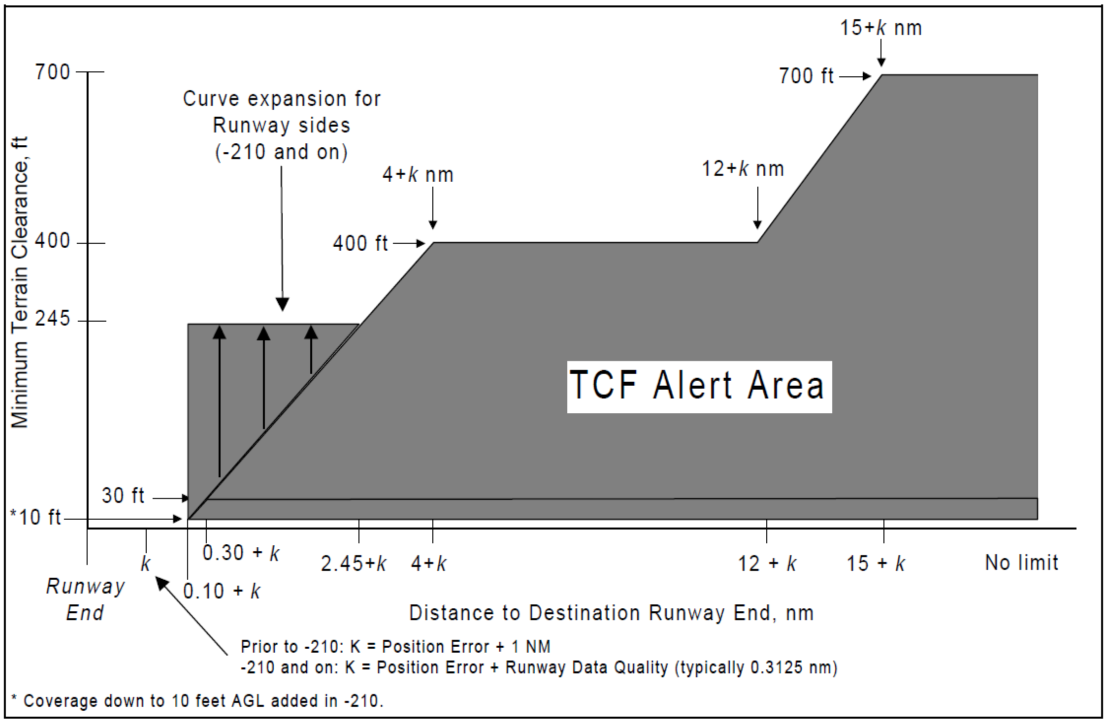

FIGURE 6.3.1.3-3: TCF ALERT CURVE

Figure 3 Terrain Clearance Floor Curve Specification

Runway Field Clearance Floor (RFCF) - similar to the TCF feature except that RFCF is based on the current aircraft position and height above the destination runway, using Geometric Altitude (in lieu of Radio Altitude). This provides improved protection at locations where the runway is significantly higher than the surrounding terrain.

Terrain Look Ahead Alerting - Provided by the internal terrain database, this feature provides the ability to look ahead of the aircraft and detect terrain or obstacle conflicts with greater alerting time. This is accomplished based on aircraft position, flight path angle, track, and speed relative to the terrain database image forward of the aircraft.

Terrain Awareness and Display (TA&D) - When a compatible Weather Radar, Electronic Flight Instrument System (EFIS), or other display is available and enabled, the EGPWS TA&D feature provides an image of the surrounding terrain represented in various colors and intensities.

Accident Airplane EGPWS

The EGPWS was located in the wreckage and retained for examination. The unit was a Honeywell MK V EGPWS, Part Number 965-0976-003-212-212, Serial Number 25312, Mod 11. The unit had a sticker which indicated the database version was 447, but according to UPS records, the loaded database version was 467, installed January 3, 2013.

According to UPS records this EGPWS, along with other related changes, was installed by Supplemental Type Certificate (STC) ST00440SE. The STC was approved for UPS A300 aircraft by the Seattle Aircraft Certification Office in February 2001, and installed on N155UP by UPS engineering orders A300-3440-12405-F (EGPWS Replacement) and A300-3440-13310-E (Peaks and Obstacles Activation) in February 2004. The FAA requires TSO-C151, Class A TAWS equipment be installed on Part 121 operations (FAR 121.354). The installed EGPWS complied with this regulation.

Examination of the EGPWS

On Sept 11-12, 2013 members of the systems group convened at the Honeywell facility in Redmond, WA to examine the EGPWS unit.

The unit was opened and the circuit cards were removed and photographed. The circuit card (A2) containing the non-volatile memory (NVM) was visually inspected with a microscope. There was no visible damage to the card, however there was a small amount of foreign debris which was removed by q-tip and water, also some other debris was removed with tweezers or compressed air. The A2 card was then installed in a known-good EGPWS unit. The unit was powered and the group queried the Present Status command and saved the information as a text file. The NVM was downloaded successfully via a PCMCIA card. The download produced the following files: Status, fault, event, counts, TANA (terrain not available), and warnings.

The Present Status showed that the unit was part number 965-0976-003-212 mod 2-212, serial number 25312, Hardware Mod 11, terrain database 467. Honeywell indicated that Database v467 was released December 2012, and v468 was released 16 May 2013. There were no faults present in the accident flight leg.

The FHW (flight warnings) command was run and reported a Mode 1 “Sinkrate” (time 23014:30:49 in hours:minutes:seconds system powered time) and Terrain Clearance Floor (TCF) “Too Low Terrain” (time 23014:30:58) alert were captured.

The warnings file contained approximately 40 parameters of data sampled at 1 Hz, recorded 20 seconds before and 10 seconds after any caution or warning. The warning file recorded the parameters 20 seconds before the “Sinkrate” alert, and 9 seconds after (when the “Too low terrain” alert activated). The data frames after the “Too low terrain” alert were labelled as invalid data. The radio altitude recorded with the same timestamp as the Sinkrate alert was 195.8 feet, the value 1 second earlier was 234.5 feet. The radio altitude was changing rapidly during this time, and it was noted initially that 195.8 feet appeared to be lower than expected.

Honeywell engineering reviewed the properties of the recorded parameters and noted the following:

1. The Radio Altitude value recorded in the EGPWS warning history has an additional 0.26 second low pass filter applied to it as compared to the radio altitude value used by Mode 1.

2. An additional 1.1 seconds of delay can occur due to the scheduling rate of the warning history recording system.

Because of this and the dynamic nature of the radio altitude signal, it can be difficult to resolve an exact value for when the Mode 1 alert occurred from this data.

The warning file showed that at the time of the alerts the airplane had the gear down and the flaps were in landing configuration. It also indicated that neither of the pilots EFIS displays was showing terrain awareness data.

Evaluation of the EGPWS Performance

The FDR, CVR and Radar data for the accident was correlated to a common time base (the Radar CDT time), as described in the Aircraft Performance Study. Because FDR parameters are sampled at different times, to combine parameters in calculations it is necessary to first interpolate them to a common time frame. This interpolation and its results are also presented in the Aircraft Performance Study. The interpolated and aligned data for Radio Altitude, Inertial Vertical Speed, Distance to runway threshold (calculated), and Local Time from the Performance Study, were used in the following evaluation to determine the expected alert times. These times could then be compared to the times that the “Sinkrate” and “Too Low Terrain” alerts were recorded on the CVR, as described in the CVR Group Chairman’s Factual Report and reflected in the Aircraft Performance Study.

The Mode 1 “Sinkrate” and “Pull Up” alert envelopes and the radio altitude of the airplane were plotted as a function of FDR time (Figure 4). The airplane entered the “Sinkrate” envelope at FDR time 253329.1, at approximately 294 feet AGL. After the 0.8 second persistence time is added, the expected alert time was 253329.9, at approximately 250 feet AGL. This FDR time corresponded to 4:47:24.4 local time. The Mode 1 “Pull Up” envelope was not penetrated.

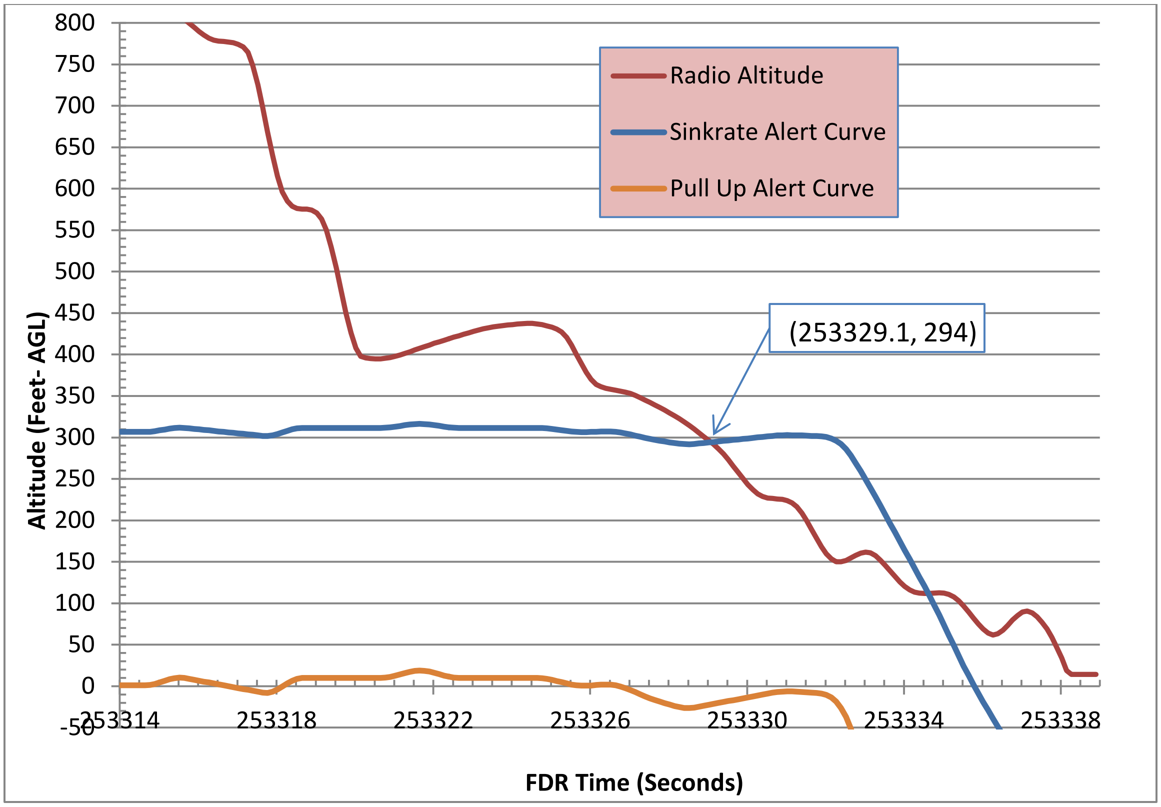

Figure 4 Mode 1 Alert Curves Using Accident Data

The Terrain Clearance Floor (TCF) alert envelope is a function of position error and runway data quality (RDQ), as indicated in the above system description (K= Position error + RDQ). There are also envelope differences depending on the EGPWS part number. One difference is the minimum K value: For units prior to -210 it is 1 nmi; for -210 through -217 it is 0.5 nmi; and for -218 and higher, it is 0.25 nmi. Another difference is the initial slope of the -218 and higher curve, which is 200 ft/nmi for the first mile (versus 100 ft/nmi for the others).

Position error was indicated in the downloaded warning file as 0.25 nmi. This position error represents a value for the accuracy of the FMS position. In the case of this installation, which had GPS as the position source, it should have been 0.13 nmi, but because of a known change in data format of the FMS Nav Mode label 270, it is incorrectly interpreted by the EGPWS part numbers earlier than the -228.

The RDQ is a function of the airport and the part number of the EGPWS. For EGPWS units earlier than the -210 the value was 1 nmi, for the -210 to -217 units the value is 0.3125 nmi. EGPWS part numbers -218 and higher can take advantage of substantially lower RDQ factors. At KBHM the RDQ for -218 and higher units is 0.0625 nmi.

Taking these numbers into account, the value of K for the accident flight was 0.5625 nmi. The value of K for a -218 through -226 unit would have been 0.3125 nmi. The value for K for -228 and higher units would be 0.25 nmi.

The -212, -218, and -228 TCF alert curves were plotted along with the actual radio altitude, shown in Figure 5. The airplane entered the -212 TCF envelope at approximately 49 feet, which correlated to approximately 4:47:32.4 local time. After the 1 second persistence time was added, the expected alert ("Too Low Terrain") time was 4:47:33.4. At that time, there was no further FDR values for radio altitude, the last recorded value was 14 feet approximately 0.6 seconds prior. The airplane would have entered the -218 TCF envelope at approximately 200 feet, and the actual alert would have occurred at approximately 150 feet, 4:47:27 local time. The airplane would have entered the -228 TCF envelope at approximately 204 feet, with the alert time being approximately the same time as the -218 (less than 0.1 s difference).

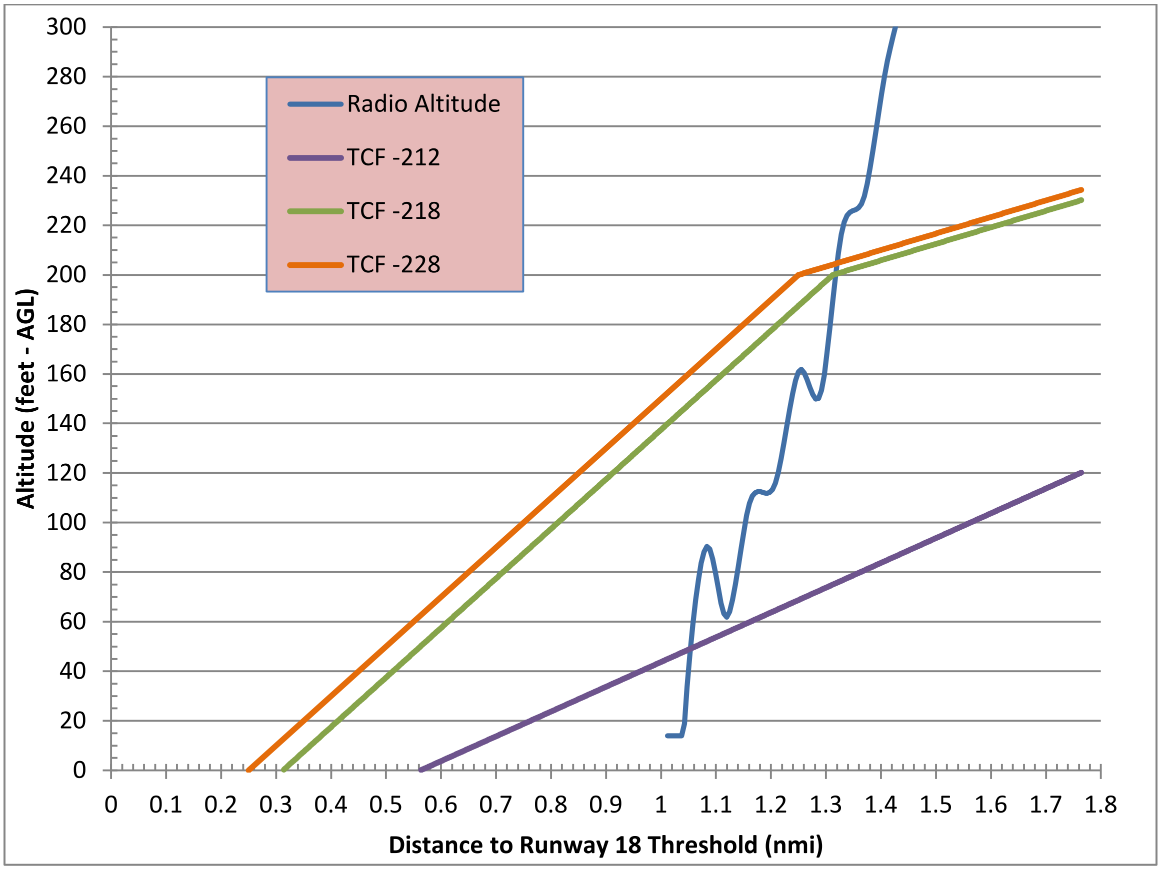

Figure 5 TCF Alert Curves Using Accident Data

Mode 2 is based on terrain clearance and closure rate. If flaps are in landing configuration, mode 2A is not operational. The Mode 2B ceiling is 789 feet radio altitude and requires closure rate in excess of 2000 feet per minute. Filtered closure rate (from analysis of EGPWS data) did not exceed 1400 fpm, so an alert would not be expected.

Mode 3 is only active in the first three minutes after takeoff or during go-around after raising gear or flaps. Since the airplane did not satisfy these conditions a mode 3 alert was not expected.

Mode 4 has three submodes 4A, B, and C. With landing gear down and flaps in a landing configuration, both 4A and 4B are deactivated. 4C is only active during takeoff or go-around, so no mode 4 alerts were expected.

Mode 5 provides alerts when the aircraft is receiving valid glideslope deviation and is more than 1.3 dots fly up. Runway 18 at KBHM does not have a glideslope signal, so no mode 5 alerts were expected.

Mode 6 provides advisory callouts when enabled by the operator, such as bank angle, altitude callouts, and minimums. UPS did not activate minimums, or the altitude callouts, but bank angle was enabled. The maximum roll angle was less than 1 degree, so no bank angle alert was expected. UPS had altitude callouts activated through the flight warning computer for radio altitudes 100, 50, 30, 20, and 10 feet AGL.
Mode 7 EGPWS windshear is not used for Airbus airplanes, so no alert is expected. On this aircraft the windshear alert function is provided through the Flight Augmentation Computer.

Runway Field Clearance Floor (RFCF) provides earlier alerts for airports that are higher than nearby terrain, which is not the case at KBHM. Runway field clearance was determined by subtracting runway field elevation from barometric altitude (MSL). The alert envelope does not begin to increase until a certain distance from the runway, which is determined from the TCF K value + an additional term for geometric altitude figure of merit. In this case, the value would be 1.562 nmi. The runway field clearance was evaluated relative to the alert envelope and no alerts were expected.

Terrain Alerting and Display maintains a background display of local terrain forward of the aircraft for optional cockpit display. In the event of terrain or obstacle caution or warning conditions, an aural alert and lamp outputs are triggered. When the airplane is less than 1.6 nmi from the runway, only terrain or obstacles more than 400 feet above runway elevation can trigger Terrain Look-Ahead alert. No terrain meets this criteria, so no alerts are expected.

2.0 Flight Management System

The Flight Management Computers (FMCs) were identified at the accident site; Part Numbers 4052510-983, Serial Numbers 0203A660, and 0219A712. Both FMCs were found in the debris field, separated from the electronic rack and considerably damaged. Most of the circuit cards were separated from the FMC housings (Figure 6) with mud and water on them. The parts were then shipped by UPS to the NTSB. Honeywell provided a description of the Mass Memory Card (MMC) which contained the data stored in Static Random-Access Memory (SRAM). The MMCs, serial numbers 61697077, and 1789290 for both FMCs were identified in the recovered parts

(Figure 7). The parts were shipped to the Honeywell Sky Harbor facility (1944 E. Sky Harbor Circle, Phoenix, AZ) where they remained locked in a bonded, secure area.

On Sept 13, 2013 NTSB representative Albert Nixon, picked the package up from the Sky Harbor facility (with both MMCs inside the package together) and hand carried it to the Honeywell, Deer Valley facility in Phoenix, AZ. Then the NTSB and Honeywell personnel convened to download the information from the MMCs. MMC SN 1789290 was cleaned of dirt and debris and inserted into a working FMC (part number 4052510-983) so that the test equipment could access the MMC data (Figure 8). The data was successfully downloaded. MMC SN 61697077 was cleaned of debris and inserted into the FMC. The test bench was able to communicate with the MMC to download the data, but the data appeared to be corrupted. However, the FMCs dual design would have assured, under normal conditions, that the flight plans were the same on both FMCs. Honeywell did confirm in the data that the FMC mode was not independent and was in fact in dual operation mode, so the one MMC card provided all the necessary data for analysis.

Figure 6 Recovered Flight Management Computer

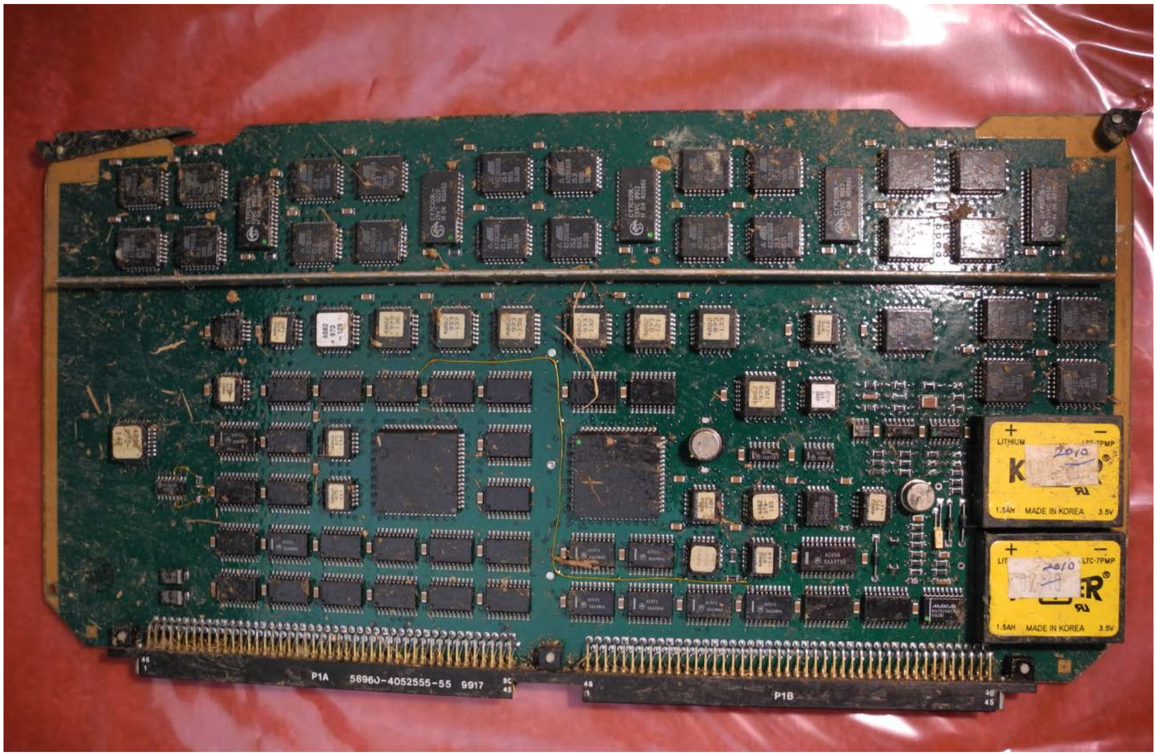

Figure 7 FMC MMC Card SN 1789290

Figure 8 Known Good FMC with Accident MMC Installed

Description of the Data Decode Process

The data recovered is from the Flight Management Computer's (FMCs) Mass Memory Card (MMC). The MMC card is used by the FMC like a backup storage device for storage of data which needs to be recovered upon FMS computer resets that might occur. An example of such would be in the event of an unexpected power loss to the FMC. The MMC does not contain the working copy of the FMS data. The MMC is updated within a couple hundred milliseconds any time any significant FMS data is changed such as a change in the flight plan. The data is stored in the native format of the low level software routines (compiled PASCAL S/W). As such, tools to automatically decode this data do not exist and a manual decoding is required. Using the compiled listing of the data definition files, a memory layout map of the MMC card, and knowledge of the compiler representations of the data, an engineer experienced in the correct vintage of FMS software was able to decode the raw hex 16 bit word data extracted from the MMC. The engineer was then able to convert this information into a "human readable" format for further analysis.

The flight plan decoding, which follows the above process, is comprised of a fixed format header and then a series of legs allocated from a fixed pool of legs. Legs, in this sense, are the primary individual components that make up the path flown over the ground. The header defines things like the origin and destination and includes an index into the pool for the first and last legs of the flight plan. Each leg contains a fix ident (in an ASCII like format), previous and next leg indexes, a via procedure ident, and many attributes necessary to define and fly the leg[1]. Those attributes include a discontinuity indication when a flight plan discontinuity exists between the current and next legs. Due to the previous and next indices, the sequence of the data is easily verified as the decode is performed. For example, when looking at the flight plan data from the accident flight, leg 5 points to leg 9 as the next leg and leg 9 points to leg 5 as the previous leg. Once the flight plan was decoded, it showed that each waypoint remaining in the flight plan after the KBHM discontinuity was from the LOC18 procedure. As a double check of the decode process for these legs, the engineer verified that the LOC18 procedure in the FMS Navigation Database contained the exact same waypoint definition of the LOC18 procedure as was decoded from the MMC data.

The vertical profile data downloaded from the FMC was obtained in a similar manner.

The following was decoded from the downloaded data:

Lateral Flight Plan

The following information details the lateral flight plan information as decoded from the FMC SRAM data.

[1] Fix ident is a fixed location identifier and has an identifier on a chart, such as the waypoint named COLIG. A via procedure ident is the name of a charted procedure, such as LOC 18 Approach

The Flight Plan ‘Header’ contained:

- Origin: KSDF
- Origin Rwy: 35R
- Dest: KBHM
- Dest Rwy: 18
- First Leg Index = 2
- Last Leg Index = 21
- Destination Leg Index =18.
- The FMS Flight Plan consisted of the following legs:
- Leg 02 Ident = T-P, via None, Next Leg Index 5, Prev Leg Index = None (TP Indicates a Direct To leg, i.e. ‘Turn Point’)
- Leg 05 Ident = KBHM, via None, Next Leg Index 9, Prev Leg Index = 2, <u>Discontinuity Exists Flag is set</u>
- Leg 09 Ident = COLIG, via LOC18, Next Leg Index 14, Prev Leg Index = 5
- Leg 14 Ident = BASKN, via LOC18, Next Leg Index 18, Prev Leg Index = 9
- Leg 18 Ident = RW18, via LOC18, Next Leg Index 19, Prev Leg Index = 14
- Leg 19 Ident = INTCPT, via None, Next Leg Index 20, Prev Leg Index = 18
- Leg 20 Ident = HANDE, via None, Next Leg Index 21, Prev Leg Index = 19
- Leg 21 Ident = HANDE, via None, Next Leg Index 00, Prev Leg Index = 20, PathTerm = Hold

The data indicated that LNAV was not engaged when the FMC lost power. The Direct To KBHM was performed at the recorded GPS position 38.21043N, 85.65584W which is about 280 nm north of KBHM.

The data also indicated that neither the Profile Mode Arm nor the Profile Mode Engage bits were set at the time power was lost. The Profile Mode status is not recorded on the FDR, but the profile mode arm and engagement status are recorded in the FMC NVM through the acquisition of FCU discrete words used by the FMC to compute its own logic.

Vertical Path

The following information details the vertical path information as decoded from the FMC SRAM data.

- The data indicated that VNAV was not engaged when the FMC lost power.
- Final Approach Segment Control State = Control_Inactive
- Final Approach Segment State = Active_FAPP (the FINAL X.X prompt had been selected)
- Final Approach Segment FPLN Change Status = Not_Lost (no flight plan change since Final X.X selection)
- Final Approach Segment Data Validity = True
- Final Approach Segment Distance to Dest = 27.68 nmi (distance along the Lateral Flight Path)

- Final Approach Segment Vertical Dev = -9424 ft (aircraft is 9424 ft low from where the FMS active leg expects the airplane to be)
- Final Approach Segment Altitude Error = 9420 ft (positive indicates below path)
- Final Approach Segment FPA = -3.252 deg
- Final Approach Segment Tangent of FPA = -0.05682373 deg
- Final Approach Segment MAP Altitude = 690 ft
- Final Approach Segment Altitude Error Rate = -6.6875 ft/sec
- Final Approach VAPP = 136.53 kts and valid
- Clearance Altitude (Altitude preselector) =3800 ft
- Minimum Decision Altitude =1200 ft
- ADC Pressure Altitude =790 ft

Miscellaneous Data Gathered from SRAM Data

- The last position for FMC AC Position: 33.5901N, 86.74729W
- The last GPS Position logged in FMC: 33.59023N, 86.74714W
- The NAVDB Cycle was cycle 2
- The stored flight phase was Approach
- The stored flight number was 1354
- The FMC BITE data indicates that no faults were recorded on the flight from KSDF to KBHM.
- The FMC serial numbers installed on flight 1354 were 0203A660 and 0210A712
- The navigation database that was loaded into the FMC was UP9-1308-001
- The FMC operational software was PS4061749-983

Display Simulation

Honeywell entered the decoded flight plan data into a working Honeywell FMC, with Control Display Units (CDUs) and simulated navigation displays. They then “Flew” a simulation aircraft from the point of the direct to KBHM (~280 nmi north of KBHM) to the point of impact (about 0.6 nmi north of KBHM). The LOC18 approach was strung 20-30 nmi from the airport. Some values in the photos may vary slightly from the actual data presented above. The following Figures 9 – 14, represent what was likely displayed on the CDU and ND pages, depending on which pages were actually selected by the crew prior to impact. Note that the ND displays are a limited desktop tool, not the actual A300 cockpit displays.

Figure 9 FMC CDU Flight Plan, Page A

Figure 10 FMC CDU Flight Plan, Page B

Figure 11 FMC CDU Progress Page

Figure 12 FMC CDU Approach Page

Figure 13 Navigation Display

Figure 14 Navigation Display

Summary

Honeywell provided the following explanation of the data:

The lateral flight plan is consistent with the crew performing a direct to KBHM and then later stringing the LOC18 approach, but never performing a direct to COLIG in order for the FMC to execute that approach. COLIG and BASKN were flown past and not sequenced out of the FMS flight plan because the active leg remained the airport KBHM. The FMS must fly past (sequence) KBHM before the subsequent leg(s) can become active. LNAV was not engaged at impact.

The vertical data indicated the crew selected the Final Approach line select (6R) on the Approach page, but VNAV (Profile) was not engaged (at impact) and the vertical path was not followed. Due to the lateral path still extending to KBHM, then followed by the LOC 18 approach, there was 27.7 nmi remaining to the destination (i.e. the distance from current aircraft position to KBHM, then KBHM back to COLIG, then COLIG back to the runway). Construction of the 3.25 degree path at 27.7 nmi from the Runway yielded a desired path 9424 ft above the airplane as the data indicated. Even if the FMS path was followed, VNAV would have disengaged at the Minimum Decision Altitude of 1200 ft as per design.

In both the lateral and vertical sense, it does not appear that the FMS was being followed.

3.0 Accident Airplane Flight Deck

Captain's Instrument Panel

PRECISION APPROACH CATEGORY STATUS INDICATOR (PIZZA WHEEL) – CAT IIIb
CAPTS ALTIMETER – 29.99
CAPTS ALTIMETER – 770'
CAPTS ALTIMETER ALTITUDE INDEX SET KNOB – 200'
CAPTS ALTIMETER FLAG – OFF
CAPTS ALTIMETER BARO SELECTOR – PULLED

STANDBY AIRSPEED – 126 KTS
STANDBY AIRSPEED INDEX – 138 VAPP
STANDBY AIRSPEED INDEX – 218 GREEN DOT

VOR RDMI HEADING – 169
VOR RDMI HEADING – FLAG
VOR RDMI 1 and 2 – FLAGS
VOR RDMI1 – 300 DEGREES
VOR RDMI 2 – 166 DEGREES
VOR RDMI SEL 1 – VOR

VOR RDMI SEL 2 – BROKEN
CAPTS CLOCKTIME MODE SWITCH - GPS

Captain's Lighting Control Panel

CAPTS INSTRUMENT LIGHT BRIGHTNESS KNOB – 9:30
CAPTS MAP LIGHT BRIGHTNESS KNOB – BRIGHT
CAPTS CONSOLE FLOOD LIGHT– BRIGHT
CAPTS SPEAKER VOLUME CONTROL KNOB – KNOB MISSING

Center Instrument Panel

STANDBY ADI – 6 DEG NOSE DOWN, WINGS LEVEL, G/S FLAG, ADI FLAG
STANDBY ALTIMETER – 110', VIBRATOR FLAG, 29.96
LANDING GEAR HANDLE – UP
CABIN LANDING ELEVATION – 680'
HIGH LANDING ELEVATION – DEPRESSED (ON)
SLAT/FLAP POSITION INDICATOR – 0/0
BRAKE FAN – DEPRESSED (ON)
BRAKE ANTISKID SWITCH – NORMAL/ON
EPR LIMIT INDEX MODE SELECTOR KNOB – DEPRESSED
ENGINE 1 – N1 RPM MAX POINTER INDEX – 117
ENGINE 1- N2 RPM MAX POINTER INDEX – 123
ENGINE 2 – N1 RPM MAX POINTER INDEX – 123
ENGINE 2 – N2 RPM MAX POINTER INDEX - 112

Center Pedestal

OIL PRESSURE/QUANTITY INDICATOR, ENG 1&2 – 0,0
CAPTAIN FMC CDU – DAMAGE
F/O FMC CDU – DAMAGE
PITCH TRIM – 5.9 UNITS NOSE UP
SPEEDBRAKE/SPOILER HANDLE – RETRACT DETENT (NOT ARMED)
ENGINE 1 THROTTLE – 30 DEGREES
ENGINE 2 THROTTLE – 55 DEGREES
ENGINE 1 & 2 REVERSERS – NOT DEPLOYED
SLATS/FLAPS LEVER – 30/40
ENGINE 1 & 2 FUEL LEVER – ON
EMERGENCY CANCEL – BREAKAWAY WIRE INTACT
RADAR WX – MODE SELECTOR- WX + T, PREDICTIVE WINDSHEAR- AUTO, ANTENNA TILT -1.5 NOSE UP
TCAS MULTI RANGE TRANSPONDER – MODE SELECTOR-TA/RA,
ALTITUDE REPORTING-POSITION 1, RANGE SELECTOR-40 MILES,
VERTICLE SELECTION-BELOW
RUDDER TRIM – 11.1 DEGREES, BUT NO LEFT OR RIGHT SYMBOL
ATC CONTROL PANEL - TA/RA

FCU/EFIS Control Panel

CAPT EFIS - PFD BRIGHTNESS KNOB – 10 o'clock
CAPT EFIS – ND BRIGHTNESS KNOB – FULL DIM
CAPT EFIS – WX RADAR/EGPWS KNOB - 3 o'clock
F/O EFIS – PFD BRIGHTNESS KNOB – 1 o'clock
F/O EFIS – ND BRIGHTNESS KNOB – 11:30 o'clock
F/O EFIS – WX RADAR/EGPWS KNOB – 8 o'clock
CAPT VOR/NAV/ILS SWITCH – ILS
F/O VOR/NAV/ILS SWITCH – ILS
CAPT ND RANGE SELECTOR – 15
CAPT ND MODE SELECTOR – MAP
F/O ND RANGE SELECTOR – 15
F/O ND MODE SELECTOR – MAP

Flight Control Unit

AUTO PILOT ENGAGEMENT LEVERS 1 and 2 – OFF

First Officer's Instrument Panel

F/O ALTIMETER – 29.96
F/O ALTIMETER – 800'
F/O ALTIMETER ALTITUDE INDEX SET KNOB – 200'
F/O ALTIMETER FLAG – OFF
F/O ALTIMETER BARO SELECTOR – PULLED

STANDBY AIRSPEED – 0 KTS
STANDBY AIRSPEED INDEX – 136 VAPP
STANDBY AIRSPEED INDEX – 240 GREEN DOT

VOR RDMI HEADING – 184
VOR RDMI HEADING – FLAG
VOR RDMI 1 and 2 – FLAGS
VOR RDMI1 – 300 DEGREES
VOR RDMI 2 – 283 DEGREES
VOR RDMI SEL 1 – VOR
VOR RDMI SEL 2 – VOR
F/O CLOCK TIME MODE SWITCH - GPS

First Officer's Lighting Control Panel

F/O INSTRUMENT LIGHT BRIGHTNESS KNOB – 12 o'clock
F/O MAP LIGHT BRIGHTNESS KNOB – 10 o'clock
F/O CONSOLE FLOOD LIGHT– OFF

F/O SPEAKER VOLUME CONTROL KNOB – OFF

Maintenance Panel

FUEL CENTER & TRIM – RANGE MODE

Overhead Panel

Note that the area of the airplane lighting controls experienced some impact damage which may explain why some of these switches are not in the normal position for the approach phase of flight.

STROBE – OFF
BEACON – OFF
EXT LT, RWY TURN OFF – L broken in OFF position
EXT LT, RWY TURN OFF – R OFF
NAV LTS – 2
NOSE TAXI LT– OFF
LAND, L - RETRACT (bent up)
LAND, R – RETRACT (broken off)
WING LTS– OFF
PITCH TRIM LEVER, 1- OFF, 2 – OFF
YAW DAMPER LEVER, 1- OFF, 2 – OFF
ATS LEVER – OFF
ENG 1 MODE – EPR (normal)
ENG 2 MODE – EPR (normal)
IGNITION SEL SWITCH – CONT RELIGHT
APU MASTER SWITCH – OFF
APU FUEL PUMP – AUTO
WIPERS, CAPT – OFF
WIPERS, F/O – OFF
FWD OUTFLOW VLV – AUTO
AFT OUTFLOW VLV – AUTO
FWD OUTFLOW VLV IND – PAST CLOSED
AFT OUTFLOW VLV IND – PAST CLOSED
MAN PRESS – AUTO
AUTO PRESS RATE LIM SEL KNOB– NORM
REG 1 – AUTO
REG 2 – AUTO
CABIN DIFF PRESS IND – 0
CABIN V/S IND– 100 FT UP
CABIN ALT IND – 1500 FT
COMPARTMENT TEMP, BULK CARGO ISOLATION VALVE – AUTO
BULK CARGO TEMP SEL– AUTO 12 o'clock
AFT CAB TEMP SEL– AUTO 12 o'clock
MID CAB TEMP SEL– AUTO 12 o'clock

FWD CAB TEMP SEL– AUTO 11:30 o'clock
COCKPIT TEMP SEL– AUTO 11 o'clock
COMPARTMENT/DUCT SELECTOR – CRT
PACK VLV, 1 – OFF
PACK VLV, 2 – AUTO
RAM AIR – OFF
ECON FLOW - ON
MAX COOL – OFF
PNEU CROSS FEED POSITION SW – pulled out of panel
CROSS FEED MODE – AUTO
ENG 1 BLEED VALVE – AUTO
ENG 1 HP VALVE – AUTO
ENG 2 BLEED VALVE – AUTO
ENG 2 HP VALVE – AUTO
APU BLEED – OFF
STBY COMPASS – OFF
ANN LT – DIM
ENG 1 ANTI-ICE – OFF
ENG 2 ANTI –ICE –OFF
WING ANTI-ICE SUPPLY – OFF
WING ANTI –ICE MODE SELECT – NORMAL
HYD QTY BLUE – UPPER SECTION OF TOP HAT (UPPER GREEN BAND)
HYD QTY GREEN – MIDDLE OF TOP HAT (UPPER GREEN BAND)
HYD QTY YELLOW – 2/3 OF TOP HAT (UPPER GREEN BAND)
ENG 1 HYD PUMP BLUE – OFF
ENG 1 HYD PUMP GREEN – ON
ENG 2 HYD PUMP GREEN – OFF
ENG 2 HYD PUMP YELLOW – ON
GREEN HYD ELECTRIC PUMPS – OFF
GREEN TO BLUE PTU – OFF
GREEN TO YELLOW PTU –OFF
BLUE SERVO CONTROL VLV – ON
GREEN SERVO CONTROL VLV – ON
YELLOW SERVO CONTROL VLV –ON
PITCH FEEL SYS 1 – ON
PITCH FEEL SYS 2 – ON
RUDDER TRAVEL 1 – ON
RUDDER TRAVEL 2 – ON
SPOILER & SPEED BRAKE PUSH BUTTONS – ON
ISDU SYS DISPLAY - OFF
ISDU DISPLAY SEL – HDG/STS
MSU 1 – NAV
MSU 2 – NAV
MSU 3 - NAV
IDG 1 & 2 DISCONNECT SWITCH COVER – BREAKAWAY WIRE INTACT
GALLEY POWER – SHED

GEN 1 - ON
GEN 2 – ON
APU GEN –ON
EXT PWR – NORMAL
OVRD SUPPLY 1 – OFF
OVRD SUPPLY 2 – OFF
BATTERY 1, 2, 3 – ON
BATTERY OVRD – OFF
STBY GEN – OFF
FIRE HANDLE ENG 1 – IN AND BREAKAWAY WIRE INTACT
ENG 1 LOOP "A" – ON
ENG 1 LOOP "B" – ON
FIRE HANDLE ENG 2 – IN AND BREAKAWAY WIRE INTACT
ENG 2 LOOP "A" – ON
ENG 2 LOOP "B" – ON
FIRE HANDLE APU – IN AND BREAKAWAY WIRE INTACT
APU LOOP "A" - ON
APU LOOP "B" – ON
EQUIP COOLING OVBD VALVE – AUTO
EQUIP COOLING EXTRACT FAN – NORMAL
MAIN DECK CARGO VLV – ON
OXYGEN LO PR SUPPLY CREW –ON
OXYGEN LO PR SUPPLY SUPERNUM – ON
OXYGEN CYL BOTTLE PRESSURE 1,2,3,4 – ZERO
OXYGEN LO SUPPLY PRESSURE CREW & SUPERNUM – END OF LOWER RED BAND
PACK 1 TEMP MODE SEL – AUTO
PACK 2 TEMP MODE SEL – AUTO
LEFT LAT, LEFT WSLD & LAT, RIGHT WSLD&LAT, RIGHT LAT – ON
CAPT, STBY, F/O PROBE HEAT –ALL ON
LWR CARGO COMP SMOKE DET FWD LOOP "A" – ON
LWR CARGO COMP SMOKE DET FWD LOOP "B" – ON
LWR CARGO COMP SMOKE DET AFT LOOP "A" – ON
LWR CARGO COMP SMOKE DET AFT LOOP "B" – ON
LWR CARGO COMP SMOKE DET AFT & BLK LOOP "A" – ON
LWR CARGO COMP SMOKE DET AFT & BLK LOOP "B" – ON
LWR CARGO COMP AGENT 1 – Guarded and breakaway wire intact
LWR CARGO COMP AGENT 2 – Guarded and breakaway wire intact
FUEL MANIFOLD CROSS FEED VALVE – CROSS LINE
FUEL ISOLATION VALVES – ALL OPEN
FUEL BOOST PUMPS – ALL ON
TRIM TANK MODE SEL – AUTO
TRIM TANK ISO VALVE – AUTO

Circuit Breakers

The following CBs were open:

Overhead Panel 21-VU

TRP Pwr Supply
Navigation F/O EFIS - ND
Radio Nav & COM – VOR 2

Panel 133 VU

LG Prox Det & Relays Sys 1 - Relays Retract & Contr (U51)
ENG 2 Rev Warn (V73)

Panel 132 VU

Waste Water - CTL FWD (J61)

Panel 131 VU

VENTILATION - EXTRACT FAN HI SPD (H62)

4.0 Flight Controls

Horizontal Stabilizer

Trimable Horizontal Stabilizer (THS) – The position of the inboard leading edge of the left THS was aligned approximately with the 7^{th} line below the zero mark of the index plate, indicating -7 degrees (nose up). The position of the THS actuator was measured. The distance from the actuator housing to the gimbal nut (x dimension) = 370mm, the distance from the gimbal nut to the end stop (y dimension) = 283mm. According to Airbus documentation these values indicate a THS position of -7 degrees (nose up).

Elevator Controls

The right elevator was undamaged. It appeared that the actuators and attach points were undamaged.

The left elevator had a portion of the surface still attached to the actuators. This area had substantial heat damage from the post-crash fire. The outboard actuator was intact with attach fittings connected. The support beam was intact. The input springrod was present with some heat damage. The middle actuator was attached but heat damaged. The support beam was melted. The input springrod was consumed by heat damage. The inboard actuator forward attachment point was intact. The aft attachment point was disconnected from the front spar of the elevator, by heat damage, but the attachment fittings were intact. The input springrod was consumed.

Rudder Controls

All three actuators were intact and attached to the end points, but experienced substantial heat damage. All three support beams were attached at the endpoints, but were melted in the middle. All three input springrods were intact. The lower springrod was detached on the forward side from heat damage, the fitting was present.

Left Wing High Lift Devices

All of the drive mechanisms for the left wing flaps detached from the wing rear spar and were located in the wreckage field. The flap drives are identified 1- 6 for each wing, with 1 being the most inboard. The drives, with the translating nut still intact, were measured to estimate the position of the flaps (X is the dimension forward of the nut, Y is aft of the nut). Using Airbus documentation the dimensions were converted to flap position:

Flap screw jack #1, X dimension 1325mm, Y dimension 25mm (full flaps 40 degrees)
Flap screw jack #3, X dimension 1235mm, Y dimension 1mm (full flaps 40 degrees).
Flap screw jack #4, X dimension 1095mm, Y dimension 22mm (full flaps 40 degrees).
Flap screw jack # 5, X dimension 1030mm. Y dimension 2mm (full flaps 40 degrees).
Flap screw jack #6, X dimension 895mm. Y dimension 21mm. (full flaps 40 degrees)

There was one complete slat screwjack identified and measured:

Slat screw jack #3, X dimension 515mm, Y dimension 20mm (30 degree slat)

Left Wing Aileron Controls

All three aileron actuators were attached at the fittings, with all three input spring rods attached. All four support beams were still attached to the aileron hinge, but the inboard two beams were mostly consumed by the post-crash fire.

Left Wing Spoiler Controls

There are seven spoiler panels, numbered inboard to outboard, on each wing. Panels 3 through 7 departed the wing and were located in the debris field, with actuators still attached.

Right Wing High Lift Devices

The right wing flaps drives stayed attached to the wing until fire consumed most of the trailing edge in the post-crash fire. The condition and position of the drives are as follows:

Right Outboard Flap: Both flap tracks (#5 and #6) are intact and attached at attachment points (Unable to access the bottom of flap to attain “X” dimension)

Right Center Flap: #4 Flap Track still attached at end points, X=1098mm, Y=20mm (full flaps 40 degrees)

Right Center Flap: #3 Flap Track Drive Screw attach point melted, X=1210mm, Y=27mm (full flaps 40 degrees)

The right wing slats were mostly intact. The position of the drives which were accessible are as follows (positions identified 1- 6, with 1 being most inboard):

Slat screw jack #1, X=478mm (30 degree slat)

Slat screw jack #2, X=449mm (30 degree slat)

Slat screw jack #3, X=503mm (30 degree slat)

Slat screw jack #4, X=505mm (30 degree slat)

Right Wing Aileron Controls

This area experienced substantial heat damage from the post-crash fire. The three aileron actuators were intact with attachment fittings connected at both ends. The three input springrods were intact. Three of the four support beams were attached at endpoints but heat damaged. The most inboard support beam end points attached, but the middle section was melted.

Right Wing Spoiler Controls

Spoiler panels and actuators 6, and 7 were intact and still attached to wing structure. Spoiler 5 actuator was intact and attached at both ends but the inboard portion of the panel was destroyed by heat damage. Spoiler panels and actuators 2 through 4 were badly heat damaged and detached from wing structure. Spoiler panel 1 was not located in the wreckage.

Electronic Equipment

The following equipment was recovered from the wreckage and retained by the NTSB for possible further examination:

Aircraft Communications Addressing and Reporting System Management Unit
Air Data Computer #1 and #2
Altimeters Captain’s, First Officers, Standby
Distance Measuring Equipment #1 and #2

Electronic Centralized Aircraft Monitoring Symbol Generator Unit #1 and #2
Enhanced Ground Proximity Warning Computer
Flight Augmentation Computer #1 and #2
Flight Control Computer #1 and #2
Feel Limitations Computer #1 and #2
Flight Management Computer #1 and #2
Flight Warning Computer #1 and #2
Global Landing Unit
Inertial Reference Unit #1, #2, and #3
Very High Frequency Receiver/Transmitter #1 and #2
VHF Omnidirectional Range
Thrust Control Computer
Flight Control Unit
System Data Analog Converter
Ground Power Control Unit

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