Aviation Investigation Final Report

Location:	New Orleans, Louisiana	**Incident Number:**	DCA11IA040
Date & Time:	April 4, 2011, 07:25 Local	**Registration:**	N409UA
Aircraft:	Airbus A320	**Aircraft Damage:**	Minor
Defining Event:	Electrical system malf/failure	**Injuries:**	109 None
Flight Conducted Under:	Part 121: Air carrier - Scheduled		

Analysis

According to flight data recorder (FDR) data, the Avionics Smoke warning was active at the time the recording began. Since the caution was inactive at power up, it was most likely caused from contaminants detected before the airplane was powered up. Based on this, when the crew arrived at the airplane, they should have had three primary cues alerting them of an Avionics Smoke event, including: a master caution light illuminated amber; an amber AVIONICS SMOKE warning on the upper Electronic Centralized Aircraft Monitor (ECAM); and Blower and Extract fault lights and Gen 1 Line smoke light illuminated amber on the overhead panel. In addition, when they viewed the status page of the ECAM (as required per the captain's Cockpit Preparation checklist), VENT BLOWER and VENT EXTRACT would have been listed under inoperative systems. It is unlikely that airline personnel would have cleared or canceled this warning without communicating this information with the crew, and the crew stated that they did not cancel the warning. Had the warning been inadvertently cleared or cancelled, the overhead panel lights would have remained illuminated and vent blower and vent extract would have remained inoperative systems. Because the cockpit voice recorder (CVR) did not contain any discussion related to any Avionics Smoke event while on the ground, or after takeoff prior to about 1500 feet (during which time both crewmembers responded with surprise), it is unlikely that the crew had previously seen the warning but purposefully ignored the available cues. It is also possible that the crew did not see the cockpit indications since the captain did not complete at least one step of his cockpit preparation checklist–pushing the recorder ground control switch. Because of this, the CVR and FDR did not begin until the time that the APU started, when it should have started much sooner in the sequence of preflight events. So, the investigation was not able to determine whether the crew completed other checklist items that should have alerted them to the Avionics Smoke warning. Finally, investigators were unable to find any condition in which the caution could be recorded on the FDR but not displayed to the crew. Therefore, although the incident flight crew was not aware of the Avionics Smoke event prior to takeoff, investigators could not determine the reason for this.

At 7:10:08.7, the captain began the after takeoff checklist. Item 3 of that checklist is "ECAM memo…checked." When completing this step, the captain detected the Avionics Smoke event on the

upper ECAM. Primary cues available were the Avionics Smoke procedure and an amber LAND ASAP message. Although the crew were surprised when they noticed the alert message, there was no corresponding master caution aural warning during this time, which confirms that the Avionics Smoke alert had been active prior to takeoff. The captain then delegated crew duties, assigning the first officer as the pilot flying and indicated that he would complete the ECAM. At 07:10:30.8, the captain began the Avionics Smoke ECAM procedure and stated, "perceptible smoke", referring to the first conditional statement of the procedure "if perceptible smoke". Airbus stated that completion of the Avionics Smoke procedure is dependent on "direct detection by the crew [and] secondary detection by a detector which is considered as a help." Detection by crew can be by sight or smell. According to the procedure, "If perceptible smoke" is a conditional statement and if the crew did not detect smoke, they were not to continue the procedure. After the incident the first officer stated that if Avionics Smoke was detected by the sensor, then there was Avionics Smoke and he was not going to question that.

About 38 seconds after the flight crew became aware of the Avionics Smoke warning, the captain stated, "hey you lost your autopilot too." The FDR indicated that the crew received an autothrust message. CVR data suggests that the captain became very apprehensive about the situation. The flight crew concluded that the failure of the autopilot meant that their situation was deteriorating and they needed to land the airplane promptly. Likely adding to the captain's apprehension was the LAND ASAP [i.e. as soon as possible] message displayed on the ECAM. Although an amber LAND ASAP message was presented, discussions with UAL instructors and pilots indicated that, to a pilot, land ASAP means land ASAP, regardless of color. After the incident, the captain stated that during his last proficiency training session, in-flight fires were emphasized. Specifically, pilots were told that delaying landing by a few minutes could be the difference between a successful landing and loss of an aircraft, such as Swissair [flight 111, that occurred September 2, 1998] and Valujet [flight 592, that occurred May 11, 1996]. The captain said, "he did not want this to be the next Valujet."

The captain continued with the Avionics Smoke procedure but did not do so with the necessary thoughtfulness and made several missed steps. For example, the procedure states action item "EMER ELEC PWR…MAN ON" followed by the conditional statement "WHEN EMER GEN AVAIL:" and action item "GEN 2…OFF". In this instance, the captain should have turned on the emergency electrical power (i.e., deployed the RAT13), and then when emergency generator power was available turned off generator 2. Data show that the captain did not manually deploy the RAT prior to turning off generator 2. As a result, when generator 2 was turned off prematurely, there was a brief disruption in the power supply and the airplane entered the emergency electrical configuration. The EMER ELEC procedure and a red LAND ASAP message appeared on the ECAM. This configuration caused the RAT to automatically deploy which restored electrical power to the airplane after about 6 seconds. The airplane remained in the emergency electrical configuration. Therefore, the captain became apprehensive about the Avionics Smoke event and hastily performed the ECAM procedure resulting in the airplane entering the emergency electrical configuration.

At 7:12:51.5, the first officer alerted the captain that he had no instruments. Two seconds later the captain took control of the airplane and told the first officer to call the flight attendants. The flight crew did not adequately transfer control of the airplane – the first officer did not brief the captain on the status of the airplane and the captain did not brief the status of the emergency procedures. Over the next two and a half minutes the crew focused primarily on contacting the flight attendants and did not discuss completing the EMER ELEC procedure. About 30 seconds later, the flight crew lowered the landing gear without restoring power to the airplane, per the EMER ELEC procedure, and the airplane began

operating on battery power. As a result, the CVR recording ended and no further communications in the cockpit were available with the exception of ATC communications. Completion of the EMER ELEC procedure would have restored power to generators 1 and 2 prior to landing gear extension and maintained electrical power to the airplane. After the incident, the captain said when they lowered the landing gear, operating on battery power was not on his mind.

After touchdown, reverser 2 did not deploy, and the airplane veered to the left and exited the runway. The flight crew was not aware that reverser 2 was an inoperative system based on the electrical configuration of the airplane. Had the first officer checked the ECAM status per the Approach Descent Checklist, the inoperative system would have been identified. However, this was not completed likely due to the time constraints. After landing, engine status cues would have alerted the first officer that reverser 2 did not deploy and he should have informed the captain. While it is unknown if the first officer monitored engine status and made the required reverser call out after landing, staff believes it is unlikely because the captain stated in a post incident interview that the airplane departed the runway because of a crosswind. Therefore, the flight crew became distracted by the emergency and focused on landing the airplane without completing necessary checklist items, resulting in the airplane operating on battery power and partial loss of reverse thrust on landing.

It is the captain's responsibility as a leader to set the tone in the cockpit for the entire flight, and this is even more critical when a crew is faced with an abnormal situation. CVR data suggests the tone in the cockpit was very casual. For example, prior to performing the before takeoff checklist, the first officer asks the captain "ready to read em and weep?" And just before takeoff, the first officer stated, "let's get…outta here man." The captain then stated "Brakes released. You got it man. Throttles yours. Whatever you want to do." The casual tone in the cockpit during preflight activities and the taxi did not support the creation of a functional team environment conducive to the crew's subsequent attempts to resolve the abnormal situation. This was manifested in the crew's undisciplined management of the situation in that they failed to adequately assess and understand the situation they were presented with. For example, as the captain completed the after takeoff checklist, he noticed the Avionics Smoke warning on the ECAM; however he failed to announce what the warning was. Instead, he delegated the first officer to fly the airplane and stated he would complete the ECAM. There was no discussion between crewmembers about the situation they were faced with. It is not clear if the first officer was aware of what the warning on the ECAM was. Once the airplane entered the emergency electrical configuration, the captain stopped managing the emergency and the crew's coordination deteriorated further. After the captain stated they were in emergency electrical configuration, the first officer stated "yup confirm. Let's go back." Had the captain been properly managing the abnormal, and now emergency, situation, he should have made the decision to return to the airport rather than the first officer making that decision. In addition, the captain abandoned the EMER ELEC procedure and his pilot monitoring duties. He made radio calls to ATC requesting vectors back to the airport and declaring an emergency. Upon recognizing that the first officer did not have any instruments, the captain assumed control of the airplane. At no point did he delegate the first officer to complete the EMER ELEC procedure but only to inform the flight attendants of the emergency. Completing the EMER ELEC procedure would have resulted in power restoration prior to lowering the landing gear and maintained full use of reverse thrust on landing. After the incident, the first officer stated he did not feel that he had time to be aware of the captain's actions when acting as the pilot flying and said he "took for granted" that the captain completed the ECAM procedure. Finally, during the transfer of flight duties from the first officer to the captain, the first officer stated, "I got the radios", however, subsequent radio communications were made by both crewmembers. Therefore, the captain's failure to set the tone in the

cockpit and ineffective management of the emergency resulted in neither crewmember fully understanding the situation they were faced with and subsequent escalation of an abnormal situation to an emergency.

The investigation evaluated a number of criteria to determine the extent to which fatigue impacted the flight crew's performance during the incident flight including circadian factors, sleep length, acute or chronic sleep loss, and time since awakening. Based on the pilots' schedules and normal sleeping habits the incident occurred at a time when melatonin is low and body temperature is rising. Therefore, the investigation did not identify any risk of circadian factors in the incident.

Investigators also evaluated the flight crew's sleep in the few nights prior to the incident. The captain and the first officer received more than the minimum required rest periods during their trip pairing in the days before the incident, and their flight and duty times in the week and month before the incident would not have precluded them from obtaining adequate sleep. However, both crew members complained of smog, heat and smell during their 29-hour layover in Mexico City on April 2, 2011, which gave them headaches and required use of over the counter pain relief medication. They did not report any difficulties sleeping in Mexico City. The night prior to the incident, the captain obtained about 7.5 hours of sleep, although he said he normally slept about 5 hours per night. This could suggest that he had a sleep debt from previous night's rest that he was trying to overcome, however, staff has no additional information to support that the captain was experiencing a sleep debt. The first officer obtained about 5.5 hours the night before the incident. Although the first officer said he felt rested on the morning of the flight, he received about 1.5 hours less sleep than he normally obtained. Although it is possible that the first officer was experiencing a small acute sleep debt on the morning of the incident, there is no evidence to suggest that this affected his performance during the flight. CVR data indicates he was alert and performed his duties per the captain's delegation and even took an assertive role in deciding to return the flight to the airport. Furthermore, there was no discussion about being tired or yawning heard on the CVR. Neither pilot ate breakfast, but both drank coffee prior to the incident flight. At the time of the incident, the captain had been awake about 2.5 hours and the first officer had been awake about 1.5 hours at the time the Avionics Smoke event was recognized. This was ample time for the body to adjust to being awake and for the crew to maintain alertness and does not believe time since awakening was a factor. Therefore, although it is possible that the first officer was experiencing an acute sleep debt, there is no evidence to suggest that this affected his performance during the flight. His performance was more consistent with poor leadership from the captain and the establishment of a casual tone in the cockpit.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this incident to be: the captain's failure to properly recognize and manage the abnormal condition, resulting in it escalating to an in-flight emergency.

Findings

Aircraft	Central computers (e.g. EICAS) - Incorrect use/operation
Personnel issues	Identification/recognition - Pilot
Personnel issues	CRM/MRM techniques - Pilot

Factual Information

History of Flight

Initial climb	Electrical system malf/failure (Defining event)
Enroute-climb to cruise	Fire/smoke (non-impact)
Landing-landing roll	Runway excursion

HISTORY OF FLIGHT

On April 4, 2011, at about 0725 central daylight time (CDT), United Airlines flight 497, an Airbus 320-232, N409UA, departed the left side of runway 19 while conducting an emergency landing due to an avionics smoke warning at the Louis Armstrong New Orleans International Airport (MSY), New Orleans, Louisiana. An emergency evacuation was conducted. There were no injuries to the 104 passengers or five crew members and the airplane sustained only minor damage. The flight was a 14 Code of Federal Regulations part 121 regularly scheduled passenger flight and had originally departed MSY destined for San Francisco International Airport, San Francisco, California.

The first officer (FO) was the pilot flying for the flight and the captain was the pilot monitoring. According to flight crew statements and recorded data, the incident flight takeoff began at 0708. At about 0710:10, the cockpit voice recorder (CVR) recorded the captain began the after takeoff checklist and stated, "…wait a minute what do we got here." The captain then states, "okay ECAM I got the uh— uh you got the jet. I got this." The CVR then records the captain beginning the Avionics Smoke ECAM checklist procedure.

The FO stated that about that time he became aware of an "avionics smoke" warning electronic centralized aircraft monitoring (ECAM) message and the captain stated that he noticed a "yellow" autothrust ECAM message. The FO reported he pushed the autothrust (ATHR) button on the mode control panel (MCP), but this did not succeed in re-engaging the autothrust. The captain said the autothrust message was followed by a red "LAND ASAP" ECAM message accompanied by the electrical page synoptic display and the "AVIONICS SMOKE" ECAM procedure.

The FO leveled the aircraft at 5,000 feet in instrument meteorological conditions (IMC) and retarded the thrust levers to slow the aircraft. The captain stated that the first item on the avionics smoke ECAM procedure was to don oxygen masks, but that he and the FO agreed not to don the masks because there was no smell of smoke. The captain did not recall seeing any conditional statements or a timer in the ECAM procedure.

At about 0711:22, the captain stated "line one off" followed by "okay emergency electrical power man on when uh emergency generator available. gen two off." Concurrent with the second generator being switched off, the flight data recorder stopped recording and there was about a six second power interruption of the CVR. When the CVR resumed recording, the captain is discussing the ram air turbine (RAT) and that the airplane is in emergency electrical configuration. The FO then lost his flight instrument

displays and began using the captain's primary flight display for altitude, heading and airspeed. A short time later, the captain took control of the airplane.

The FO said that once the captain had taken control of the airplane, he stated that he thought they were in the emergency electrical configuration but he didn't know what the ECAM steps were for that configuration. He said he did not follow up on the ECAM actions, and he did not use the Quick Reference Checklist (QRC) while in flight.

The first officer then tried to alert the flight attendants (FA), but he said he "did not hear the bell" when he called and the FAs did not respond. He used the pedestal handset to call the FA's, but he got no response. He then opened the cockpit door and told the FAs that they were in an emergency and would be landing immediately.

The pilots both stated in interviews that they did not conduct an approach briefing, tune the navigation radios, enter an approach in the FMGC, check the ECAM status page, use the flight manual to determine what systems were affected or lost, conduct an approach descent checklist, conduct an overweight landing checklist, determine the applicable approach speed or landing distance from the FMGC or flight manual, or attempt to repower the electrical system. The captain later said that there was no time to do these things because of the severity of the emergency.

The captain said he knew he would be in direct law with no antiskid or nose wheel steering, but he did not recall telling the first officer this. He estimated that the approach speed should be 160 knots, based on the takeoff V2 of 147 knots, rounded up for wind additive. He said that normal landing distance was 3,500 to 4,000 feet and was confident the airplane would stop on the runway. Both pilots stated that they wanted to keep the approach speed above 140 knots in order to avoid stalling the ram air turbine (RAT).

The captain told ATC that they would need a vector back to the airport and requested "the longest runway." ATC advised that runway 10, which was 10,104 feet long, was still closed due to the equipment on the runway, but that airport personnel were attempting to clear the runway. At about 07:16:03, as the flightcrew lowered the landing gear, the CVR stopped recording.

The captain stated that he could hear the tower on the radio talking to the operations personnel working on runway 10 and he realized that they would not be able to clear that runway in time for the flight to land. The captain then told ATC "we've lost all our instruments, we need a PAR." The captain stated during his interview that he had attitude and compass information but no localizer, and that the screens started to fade during the approach. ATC told the flight that they would provide a no-gyro surveillance approach.

The captain did not advise the FO as he continued the descent through the cleared altitude of 2000 feet. The FO stated that he did not recall if they were cleared to descend out of 2000 feet. According to the ATC recording, the crew reported they "we're at 1000 feet now and we've got water contact, where are we from the airport?" The controller replied that he was at 330 degrees from the airport and said on their present heading they would be "set up for the shoreline 19." After some additional communication with ATC, the captain said "I've got it" and the controller replied "wind 180 at 16 gusts to 20, cleared to land." The captain stated that he landed with full flaps and used the PAPI for vertical guidance.

The captain stated that he landed on the centerline, approximately 1,500 feet down the runway. He also state that he "got on the brakes," used full reverse, and used right rudder to keep the airplane in the center of the runway. The FO stated that on touchdown the cockpit door swung open and that he turned and

shouted "remain seated, remain seated." He said that when the engines came out of reverse the captain went to the tiller but the aircraft pulled to the left. The captain had said "I can't control it," and "we're going to evacuate." The airplane continued to veer to the left and the captain indicated he stepped harder on the right brake pedal. The airplane departed the left side of runway 19 approximately 5000 feet from the threshold at a low speed, and the nose gear sank into the soft groundoff the side of the runway.

Once the aircraft came to a stop, the flightcrew used the QRC to conduct the evacuation. The captain set off the evacuation signal and the first officer then silenced it. The first officer said the 1R slide did not inflate and he yelled "go the other way." He went down the 1L slide and began helping the passengers get away from the airplane. The captain came out a few minutes later with a megaphone, which he used to direct the passengers away from the aircraft.

INJURIES TO PERSONS:

There were no injuries to the 104 passengers, which included 3 children and 1 infant lap child, two flight crew, or three flight attendants.

DAMAGE TO AIRCRAFT:

Post incident inspection of the airplane revealed no evidence of fire or smoke in the avionics compartment, ducts, or anywhere on the airplane. The nose landing gear bracket and weight-on-wheels switch assembly was broken and an electrical conduit in the area of the nose landing gear received minor damage.

The right main landing gear tires were found deflated. The tread of the outboard tire had two flat spots, one of which was an open hole. The inboard tire (#3) was found deflated, the beads of the tire were not mounted on the wheel halves, and heavy abrasion was found to one tread shoulder.

PERSONNEL INFORMATION:

The captain, age 50, was hired by United Airlines on July 17, 1995. He held an Airline Transport Pilot certificate, multi-engine land, with type ratings in A320, B737, B747-4, B767, B777, BAE125, CE500, and HS125. He held an FAA first class medical certificate with limitations: must have glasses for near and far vision. Company records indicate that he had 15,000 hours total time with 1,487 hours on the A320. He had no previous accidents, incidents, or violations. The incident flight was the first flight of the day for the Captain.

The first officer, age 51, was hired by United Airlines on April 13, 1998. He held an Airline Transport Pilot certificate, multi-engine land, with type ratings in the A320, B757, B767, and BA3100. He held an FAA first class medical certificate with the following limitations: must wear lenses for distant vision, must have glasses for near vision. He reported a total of 11,500 flight hours, with 1,154 hours in the A320. He had no previous accidents, incidents, or violations. The incident flight was the first flight of the day for the FO.

The three flight attendants were all current and qualified on the Airbus A320.

AIRCRAFT INFORMATION:

The incident airplane was an Airbus Industries A320-232, registration N409UA, manufacturer serial number 462, and was equipped with two IAE Aerospace V2500 turbofan engines and an Auxiliary Power International Corporation (Hamilton Sundstrand Company) Auxiliary Power Unit (APU). The airplane was purchased new by United Air Lines, Inc. from Airbus Industries on March 21, 1994. The airplane had accumulated 58,253:02 flight hours and 21,414 cycles at the time of the incident.

The electrical system generates and distributes AC and DC power to airplane systems. Three generators provide AC power, two batteries provide power for APU start and for emergency power, and an emergency generator provides AC power in the event all three main generators fail. System operation is normally automatic. An electrical control panel, located in the center part of the overhead panel, includes generator on/off push button switches for generator one, generator two, the APU generator, and for each of the two batteries. An emergency electrical power control panel, located on the left side of the overhead panel, includes GEN LINE 1, RAT & EMER GEN, and MAN ON push button switches.

Smoke detectors are located in the lavatories, avionics compartment, and cargo compartments. The avionics compartment detector is a Cerberus Model CG7GO ionic smoke detector, and is installed on the air extraction duct of the avionics ventilation system. The ionic type of smoke detector was installed in the A320 up to MSN number 1540. A320 airplanes following those line numbers and on all A318 airplanes, the ionic type of detector was no longer installed, and optical smoke detectors were installed. The A320 series airplanes cool the avionics compartment with outside air when the airplane is on the ground.

When avionics smoke is first detected, the detection is indicated by an aural single chime (SC), the illumination of the SMOKE light on the EMER ELEC PWR panel, the illumination of BLOWER and EXTRACT FAULT lights on the VENTILATION panel and MASTER CAUTION lights, and by an ECAM caution on the Engine and Warning Display (E/WD). Five minutes after smoke is detected in the avionics compartment, the caution "latches" if the detection is still active, and the caution remains in effect until the warning system is reset. If avionics smoke is detected, ECAM directs the airplane be placed in the smoke configuration. This requires placing the GEN 1 LINE switch on the EMER ELEC PWR panel to OFF. When this occurs, the GEN 1 line contactor opens, GEN 2 powers AC busses 1 and 2 (main galley bus is shed) through the tie bus, and GEN 1 powers a fuel pump in each wing tank. This permits removing AC power from all busses during the AVIONICS SMOKE ECAM procedure without removing power from the fuel pumps.

An amber SMOKE light is located in the upper half of the GEN LINE 1 switch, and illuminates when there is an avionics smoke warning. When pushed, the GEN LINE 1 switch stops the generator from supplying power to its normal buses, but continues to provide power to a fuel pump in each wing. A red FAULT light is located in the upper half of the RAT AND EMER GEN switch which illuminates red when AC busses 1 and 2 are lost and the emergency generator is not supplying power and the nose gear is retracted (some A320's). The MAN ON switch is a red guarded switch. It is normally left in the guarded AUTO position, which will cause the RAT to extend automatically with the loss of AC busses 1 and 2 and speed above 100 knots. When the guard is opened and the ON position is selected, the RAT extends and couples the emergency generator to the electrical system

The ram air turbine automatically extends if both AC busses 1 and 2 lose electrical power above 100 knots; however, a minimum airspeed of 140 knots is required to provide sufficient blue hydraulic pressure to operate the emergency generator. The RAT pressurizes the blue hydraulic system, which powers the

emergency generator via a hydraulic motor. A generator control unit (GCU) controls the generator speed, voltage, generator line contactor, and start-up. The emergency generator is automatically coupled to the electrical system after RAT extension is complete.

On the incident aircraft, the emergency generator operates only with the landing gear retracted; if the landing gear is extended and AC busses 1 and 2 lose power, the emergency generator does not operate until the nose gear is retracted and the EMER ELEC PWR MAN ON switch is selected ON. If the nose gear is extended after RAT deployment, the emergency generator drops off line and cannot be manually recoupled until the nose gear is retracted. After the emergency generator drops off line, power is transferred to the batteries. The RAT can be stowed only on the ground.

According to the "Emergency Generator/Battery Powered Equipment" contained in the UAL Flight Manual, the upper ECAM is displayed when the aircraft is on emergency generator power or on battery power, except after speed falls below 50 knots. The captain's and FO's audio control panels (ACP), the cabin intercommunication data system (CIDS), the interphone, the left cockpit loudspeaker, the captain's primary flight display (PFD), the ECAM control panel, the brake pressure indicator, and the cabin and cockpit emergency lights operate normally on either the emergency generator or battery power. The captain's Flight Management Guidance Computer (FMGC), the captain's multipurpose control display unit (MCDU), the captain's navigation display (ND) and the #1 flight augmentation computer (FAC) are powered by the emergency generator but not by battery power.

Two batteries, BAT 1 and BAT 2, are installed. They are not connected in parallel, and each is connected directly to its respective HOT BAT bus. In addition to powering their respective HOT BAT busses, the batteries can also supply power for APU starting, operation of the static inverter (used in the emergency electrical configuration), and powering the DC ESS bus. In flight, battery endurance is approximately 22 minutes. In-flight, the batteries are the only source of electrical power when the generators, including the RAT-driven emergency generator, are not available. This includes flight with the nose landing gear extended and in during the approximately 8 seconds required from initiating extension of the RAT until the emergency generator is on-line.

The ECAM system presents airplane engine and system data on two identical CRT displays located on the center instrument panel below the glareshield. The upper screen is the engine/warning display (E/WD) and the lower screen is the system display (SD). The E/WD has priority over the SD. If the upper ECAM screen fails or is selected off, the E/WD data automatically transfers to the lower screen. If this occurs, SD data can be temporarily displayed on the lower ECAM screen by pushing and holding the applicable system button on the ECAM control panel. If the lower ECAM screen fails or is turned off, SD data can be temporarily displayed on the upper ECAM screen by pushing and holding the applicable system button on the ECAM control panel

There are three priority levels defined for warnings and cautions, identified as level one, two, and three, with level three being the most serious. The flight warning computer (FWC) uses the same priority for displaying the seriousness of the problem.

To signify the importance of a failure or indication, the ECAM uses color as follows:

Red - Requires immediate action

Amber - Requires awareness but not immediate action

Green - Normal operation

White - Titles and remarks

Cyan (Blue) - Actions to be accomplished, or limitations

Magenta - Special messages (i.e., T.O INHIBIT and LDG INHIBIT)

The following items occur when a failure is detected by the ECAM:

Engine/warning display presents the warning/caution messages

MASTER CAUT or MASTER WARN lights illuminate (except for level 1 cautions)

Aural warning/caution is triggered (except for level 1 cautions)

System display presents the affected system page

CLR button illuminates on the ECAM control panel

The lower left side of the E/WD (memo action) is replaced with primary or independent failure information to include the title of the failure and the steps to be accomplished. The lower right side continues to display MEMO information and secondary failures. In addition, a system fault light directly controlled by the affected system may illuminate. After completion of the procedure, the pilots must push the CLR button until the ECAM returns to the normal configuration.

For the specific detection of avionics smoke, the ECAM directs the airplane be placed in the smoke configuration. This requires placing the GEN 1 LINE switch on the EMER ELEC PWR panel to OFF. When this occurs, the GEN 1 line contactor opens, GEN 2 powers AC busses 1 and 2 (main galley bus is shed) through the tie bus, and GEN 1 powers a fuel pump in each wing tank. This permits removing AC power from all busses during the AVIONICS SMOKE ECAM procedure without removing power from the fuel pumps.

If the avionics smoke detector is activated while in flight, the lower left portion of the upper ECAM contains the following items: (preceded in this table by the color of the message displayed on the ECAM; A-Amber, W-White, C-Cyan):

<u>ECAM Items:</u>

A AVIONICS SMOKE

W IF PERCEPTIBLE SMOKE :

C -OXY MASK/GOGGLE. . . . . ON

C -CABIN FANS .. . . . . OFF

C -BLOWER . . . .OVRD

C -EXTRACT . . . .OVRD

W ..IF SMOKE AFTER 5MNOOS:

[Confirmed 5MN00S]

C EMER ELEC GEN1 LIN… OFF

C -EMER ELEC PWR . . .MAN ON

W WHEN EMER GEN AVAIL :

C -APU GEN . . . . . OFF

C -GEN 2 . . . . . .OFF

C MIN RAT SPEED . . . . .140 KT

C FUEL GRVTY FEED

C - PROC: GRVTY FUEL FEEDING

Note the "IF SMOKE AFTER 5MN00S" line is a countdown timer. After 5 minutes have elapsed, that conditional step no longer appears on the ECAM. While this ECAM message is displayed, a "Land ASAP" amber message appears on the lower right portion of the upper ECAM. The UAL A320 Flight Manual, Irregular Procedures, page 14.20.41, also contains the AVIONICS SMOKE irregular procedure.

Execution of the avionic smoke ECAM procedures removing AC power from all busses, the aircraft is placed in EMER ELEC configuration, and the Emergency Electrical configuration procedure is displayed on upper ECAM. Additionally, the "Land ASAP" message on the lower right of upper ECAM changes to red.

A specific explanation of the ECAM "LAND ASAP" message was not provided in the UAL A319/A320 flight manual. During a simulator observation flight the Operations Group verified that the LAND ASAP message associated with the avionics smoke warning was amber and the LAND ASAP message associated with the emergency electrical configuration was red.

The emergency electrical configuration procedure is also contained in the UAL A319/A320 Flight Manual, Emergency Procedures, beginning on page 15.30.5. For the incident airplane, a note at the beginning of the emergency electrical configuration checklist stated:

"The RAT will stall below 140 knots. Therefore, the emergency generator is disconnected at landing gear extension and electrical power is supplied by the batteries only."

The emergency electrical configuration procedure was incorporated into the irregular avionics smoke procedure. However, the note regarding being on batteries only after gear extension was not shown in the avionics smoke procedure.

The UAL Normal checklist was on a laminated card known as a Quick Reference Checklist (QRC). The QRC provided summary normal procedures, emergency procedures, takeoff speeds, and landing distance information. No Quick Reference Handbook (QRH) was provided. In the event that a crew needed more detailed procedures, it was company policy for the crew to use the flight manual, which was maintained in the aircraft.

In an interview, the FAA APM stated that regarding the fact that UAL did not use a Quick Reference Handbook (QRH) in the airbus fleet, he knew that the manufacturer did provide a QRH but he was not aware of whether other airbus operators provided their crews with a QRH or not. He said UAL and airbus procedures were very similar, although there was carrier-specific information in the UAL flight manual.

According to UAL instructors interviewed, the Avionics Smoke ECAM procedure was not specifically trained in the simulator portion of training. However, Avionics Smoke was referenced during A320 Qualification ground school, specifically in the *Electrical & Lighting* and *Fire Protection* courses. The *Fire Protection* course discusses the avionics fire protection system and related panels in the cockpit. Pilots are instructed that one smoke detector is located in the avionics air extraction duct. Additionally, according to instructors, the emergency electrical configuration was covered thoroughly in A320 Qualification ground school, and electrical irregular events were presented in the fixed base simulator and in the full flight simulator. Emergency electrical configuration was a SPOT maneuver during initial qualification in the past, but was not currently done.

METEOROLOGICAL INFORMATION

The Louis Armstrong New Orleans International Airport 0653 EDT weather observation indicated 8 miles visibility, few clouds at one thousand six hundred feet, broken clouds at 3000 feet, wind from 180 degrees at 13 knots, temperature 24º C, dew point 21º C. There was no precipitation.

AERODROME INFORMATION

The Louis Armstrong New Orleans International Airport (MSY) was located approximately 10 miles west of New Orleans, Louisiana, at an elevation of 4 feet above mean sea level (MSL). According to the FAA Airport Facility Directory and the Jeppesen 10-9 page, the airport had 3 runways: 10/28, 1/19, and 6/24. Runway 10/28, the longest runway, was 10,104 feet long and 150 feet wide, and was a concrete, grooved runway. Runway 1/19 was 7001 feet long and 150 feet wide, and was a concrete, grooved runway. At the time of the incident, repairs had been initiated on runway 10/28, which was 10,104 feet in length, and was occupied with construction vehicles.

FLIGHT RECORDERS

The Digital Flight Data Recorder was a Honeywell Solid State Flight Data Recorder (SSFDR), which records airplane flight information in a digital format using solid-state flash memory as the recording medium. The recorder was not damaged and the data were extracted normally at the NTSB's Vehicle Recorder Laboratory.

The FDR system on the incident airplane is designed to operate automatically on the ground for 5 minutes after the aircraft's electrical network is energized, or with one engine running. The data indicate that the FDR began recording on the morning of April 4, 2011 at 0653:47. The avionics smoke warning parameter, which originates from the flight warning computer (FWC), had a warning indication and remained in a

warning indication continuously until the last recorded data point for the flight, which occurred about 18 minutes later at 0711:42. Neither the master warning, nor any other warnings or faults recorded by the FDR, activated during the recorded portion of the data. Master caution was not a parameter captured by the system.

The FDR stopped recording data less than 4 minutes after take-off during the event flight. In reviewing the electrical configuration for the FDR on this A320 aircraft, it receives power from the 202XP normal bus bar. This bus is located on AC Bus 2 and is powered by the number 2 generator. The FDR stops recording valid data at 0711:42 as a result of a loss of power. At this time, the aircraft was climbing through 5,224 feet, at an airspeed of 252 knots, and a heading of 251 degrees.

A review of the last 54.5 hours of recorded FDR data for N409UA, showed one other occurrence where the avionic smoke warning parameter was active. The data showed that two days before the event flight on April 2, 2011, at about 2001:39 UTC (FDR time), the FDR recorded an avionic smoke warning in between flights on the ground. The warning stayed active for about 18 minutes, until the parameters began recording invalid data which is indicative of either a power interruption in the system, or in the source providing the data to the FDR. About 96 seconds later, the avionic smoke warning parameter again began recording valid data and was no longer recording a "warn" indication. The aircraft took off shortly thereafter.

The Cockpit Voice Recorder was a Honeywell 6020 SSCVR 30, a solid-state CVR that records 30 minutes of digital cockpit audio in a four-channel format: one channel for each flight crew, one channel for the cockpit area microphone (CAM), and one channel for the interphone, public address, or additional crewmember. The CVR was not damaged and the audio information was extracted normally from the recorder at the NTSB's Vehicle Recorder Laboratory.

The CVR is powered by the AC Shed Ess bus of the electrical system. In normal operation, this bus is supplied by the integrated drive generator (IDG) 1 through the AC 1 and AC Ess bus bars. In the event of loss of power from IDG 1, the AC1 and AC Ess bus can be supplied by IDG 2. In the case of loss of power from both IDG 1 and IDG 2 in the absence of APU power, or when Emergency Electrical Power is selected "ON" by the flight crew, the ram air turbine (RAT) will deploy, powering the blue hydraulic system which drives the emergency generator by means of a hydraulic motor. In this configuration power to both main AC bus bars is lost, but the AC Ess and AC Shed Ess bus bars remain powered through the emergency generator.

The CVR lost power twice in flight. The first interruption occurred from 0711:43.5 to 0711:49.2 CDT, when the captain turned off the number two IDG. If power is lost from both IDGs before the RAT has fully deployed, electrical power is supplied to the system by the batteries, shedding the AC Shed Ess bus bar until the emergency generator has spun up to speed causing a brief power interruption to the CVR.

The CVR ended at 0716:03 while the aircraft was returning to MSY just after the captain called for landing gear extension. When the landing gear is lowered or the RAT stalls, the emergency generation network automatically transfers to the batteries and the AC Shed Ess bus bar is shed, removing power from the CVR.

TESTS AND RESEARCH

The Cerberus Model CG7GO ionic avionics smoke detector installed in the incident A320 was removed from the airplane for further testing. The functional tests were performed at the FAA Fire Research Laboratory in the Hughes Technical Center at Atlantic City, New Jersey.

The tests were conducted inside a NBS smoke chamber using a relatively low smoke output thermoplastic sample material exposed to a radiant heater. A mixing fan was installed inside the chamber to ensure a homogeneous smoke cloud existed within the chamber. A vacuum pump was attached to one side of the detector to draw the smoke filled air into the detector. The detector was installed inside the test chamber, adjacent to a vertical smoke meter light beam that measured the light transmission per foot of the test chamber.

The tests were conducted with the initial light transmission at 100% (clear air). The radiant burner was then powered on, exposing the sample material to heat and creating the smoke for the tests. The light transmission per foot was recorded at the time the unit went into warning. The tests were repeated 5 times and the part met all warning requirements.

No standard exists for smoke detector warning capabilities at various atmospheric humidity levels. Because the United Airlines airplane had generated multiple false warnings in humid environments, a humid environment was generated by placing a pot of water on a hot plate in the test chamber. The detector went into warning mode in the humid environment generated during the testing.

The 1R Emergency Evacuation Slide/Rafts was examined at Air Cruisers/Aerazur, Inc. Examination of the 1R emergency evacuation slide and pack board found the lacing cover cable with no damage. Remnants of safety wire were found at the slide release disk, as was designed to occur when the lacing cover releases from the pack board. The spacing between the lacing covers was in accordance with the OEM packing instruction. The mooring line, normally stored inside the girt was found completely out of the girt and the full length of the line was unraveled. All frangible links except for the frangible links at the toe end of the slide released.

Five of the 6 pouch snaps designed to secure the sea anchor were found unsnapped. The snap closest to the sill end of the slide was the only snap that remained snapped. The sea anchor stainless steel cable was found routed through the pouch at the sill end of the pouch and secured by the single snap that remained snapped. The sea anchor and sea anchor line had separated from its pouch and the sea anchor line (similar to the mooring line) ran beneath the slide/raft, wrapped around the inflation bottle gage lead and tube and across the bottom of the slide/raft to the aft aspirator. The sea anchor and remaining sea anchor line were ingested in the aft aspirator.

ADDITIONAL INFORMATION

A review of the NASA ASRS safety database showed that 42 reports using the term "avionics smoke" and involving A319/A320/A321 type aircraft had been submitted by flight crews between 1996 and 2011. A review of the narratives of these reports showed that of the 42 events, 3 took place on the ground, 33 took place in flight, and 6 took place first on the ground and then again in flight. 35 of the events resulted in diversions and 22 appeared to be false warnings.

A United Airlines safety department study of company A319/A320 FOQA data found that from January, 2006 to March, 2011 UAL had had 22 flights where the avionics smoke warning was on at the beginning of the recording and remained on the entire flight. Of those 22 flights, 6 returned to the field or diverted.

In addition, there were 26 flights where the avionics smoke warning was on at the beginning of the flight and went out while the flight was airborne. Of those 26 flights, 2 returned to the field or diverted.

Another UAL safety department study of de-identified pilot safety reports from 2004 to 2011 found 19 reports related to avionics smoke warnings. Only one of the 19 reports cited actual smoke, which was caused by a damaged extract fan. 15 of the 19 flights either returned to the departure airport or diverted to an enroute alternate airport.

A UAL safety department study of maintenance records on UAL A319/A320 aircraft from 2009 to 2011 found 142 occurrences of maintenance entries related to avionics smoke, including 17 on the incident airplane. 72 of the 142 entries took place at coastal airports (Cancun, New Orleans, Houston, Puerto Vallarta, and San Juan).

As a result of the past events, Airbus implemented changes to reduce the rate of false smoke detector alarms. The company developed an alternative smoke detector that utilizes an optical sensor, rather than the ionic type of sensor that was the basis of the Cerberus CG7GO detector. In July 1999, Airbus issued a Technical Follow Up message, known as TFU 26.15.15.001, applicable to all A319, A320, and A321 airplanes. A revision was issued December 2002 to change the section titled "MAINTENANCE ADVICE." According to the TFU, some operators have reported many cases of spurious avionics smoke warnings, leading to "Avionics Smoke" or "Land ASAP" ECAM messages. These warnings have mainly been reported on ground, however there have been a few cases generated in flight, shortly after take-off and gear retraction. The TFU stated:

"INVESTIGATIONS HAVE SHOWN THAT THE IONIZATION TYPE SMOKE DETECTORS SENSITIVITY IS SUBJECT TO THE AMBIENT TEMPERATURE, PRESSURE AND AIR CONTAMINATION WITH MOISTURE, DUST OR POLLUTON. THE HIGHEST SENSITIVITY TRANSLATED INTO A VOLTAGE SHIFT BEING ON THE GROUND AND DURING TAKE-OFF."

Additionally, the TFU prescribed a solution as

"PERMANENT OR FINAL SOLUTION: A NEW GENERATION OF SMOKE DETECTOR PN CGDU2000-00 USING AN OPTICAL TECHNOLOGY HAS BEEN DEVELOPED IN ORDER TO REPLACE THE 'OLD' GENERATION OF IONIZATION TYPE SMOKE DETECTOR. THIS NEW GENERATION TYPE OF SMOKE DETECTOR HAS A DIFFERENT TRIGGERING PRINCIPLE AND IS THEREFORE NOT AFFECTED BY THE TEMPERATURE AND PRESSURE CONDITIONS."

At the time of event, approximately 96% of the United Airlines fleet had been upgraded with optical detectors on an attrition basis. After the incident, the change became a scheduled event, and the entire UAL fleet was retrofitted by November 30, 2011.

The avionics smoke procedure for the A320 contains several sequential steps, and depending on conditions, there may be as many as 31 steps in the procedure. Since the ECAM screen can only display seven lines at one time, multiple items must be cleared before the procedure is completed. There are as many as six conditional steps in the procedure, each one requiring the pilot to evaluate whether or not to proceed. At the time of the incident, explanatory information was provided in the UAL avionics smoke flight manual procedure. Since the incident and merger with Continental Airlines, Inc., United Airlines

has indicated that the avionics smoke procedure will follow Continental Airlines protocol, and be contained in the QRH.

After the incident, Air Cruisers/Aerazur representatives informed the NTSB that they previously experienced the ingestion of a sea anchor during the inflation/deployment of an A320 emergency evacuation slide/raft (Part number D03664-309, Serial number 00083) during a June 19, 2010 acceptance test procedure (ATP.) Air Cruisers/Aerazur issued Service Bulletin (S.B.) A320 004-25-91 on 30 January, 2012 to recommend replacement of Airbus A318/ A319/ A320/ and A321 emergency evacuation slide/raft existing sea anchor sling with a different sea anchor pocket. The service bulletin states: "The fully enclosed pocket (62675-101) eliminates the potential for the aspirator to "ingest" the sea anchor during the deployment sequence of the emergency evacuation slide/raft."

Information

Certificate:	**Age:**
Airplane Rating(s):	**Seat Occupied:**
Other Aircraft Rating(s):	**Restraint Used:**
Instrument Rating(s):	**Second Pilot Present:**
Instructor Rating(s):	**Toxicology Performed:**
Medical Certification:	**Last FAA Medical Exam:**
Occupational Pilot:	**Last Flight Review or Equivalent:**
Flight Time:	

Aircraft and Owner/Operator Information

Aircraft Make:	Airbus	**Registration:**	N409UA
Model/Series:	A320 232	**Aircraft Category:**	Airplane
Year of Manufacture:	1994	**Amateur Built:**	
Airworthiness Certificate:	Transport	**Serial Number:**	462
Landing Gear Type:	Tricycle	**Seats:**	200
Date/Type of Last Inspection:		**Certified Max Gross Wt.:**	169756 lbs
Time Since Last Inspection:		**Engines:**	2 Turbo fan
Airframe Total Time:		**Engine Manufacturer:**	Iae
ELT:		**Engine Model/Series:**	V2500SERIES
Registered Owner:	Wells Fargo Bank Northwest Na Trustee	**Rated Power:**	9895 Horsepower
Operator:	United Airlines	**Operating Certificate(s) Held:**	Flag carrier (121)
Operator Does Business As:		**Operator Designator Code:**	UALA

Meteorological Information and Flight Plan

Conditions at Accident Site:	Instrument (IMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	KMSY,4 ft msl	**Distance from Accident Site:**	2 Nautical Miles
Observation Time:	12:53 Local	**Direction from Accident Site:**	286°
Lowest Cloud Condition:	Scattered / 1700 ft AGL	**Visibility**	6 miles
Lowest Ceiling:	Broken / 2300 ft AGL	**Visibility (RVR):**	
Wind Speed/Gusts:	16 knots / 23 knots	**Turbulence Type Forecast/Actual:**	/
Wind Direction:	180°	**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	29.84 inches Hg	**Temperature/Dew Point:**	24°C / 21°C
Precipitation and Obscuration:	Moderate - None - Haze		
Departure Point:	New Orleans, LA (MSY)	**Type of Flight Plan Filed:**	Unknown
Destination:	San Francisco, CA (SFO)	**Type of Clearance:**	IFR
Departure Time:		**Type of Airspace:**	

Airport Information

Airport:	Louis Armstrong New Orleans MSY	**Runway Surface Type:**	Concrete
Airport Elevation:	6 ft msl	**Runway Surface Condition:**	Dry
Runway Used:	19	**IFR Approach:**	None
Runway Length/Width:	7000 ft / 150 ft	**VFR Approach/Landing:**	

Wreckage and Impact Information

Crew Injuries:	5 None	**Aircraft Damage:**	Minor
Passenger Injuries:	104 None	**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	109 None	**Latitude, Longitude:**	29.989721,-90.249443

Administrative Information

Investigator In Charge (IIC):	Bower, Daniel
Additional Participating Persons:	
Original Publish Date:	April 6, 2020
Last Revision Date:	
Investigation Class:	Class
Note:	
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=78757