NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

September 30, 2011

GROUP CHAIRMAN'S FACTUAL REPORT

OPERATIONS/HUMAN PERFORMANCE GROUP

DCA11IA040

A. ACCIDENT

Operator:	United Airlines Inc. (UAL)
Location:	Louis Armstrong New Orleans International Airport (MSY) New Orleans, Louisiana
Date:	April 4, 2011
Time:	0725 Central Daylight Time[1] (CDT)
Aircraft:	Airbus A320-232, N409UA

B. OPERATIONS/HUMAN PERFORMANCE GROUP

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C. SUMMARY

On April 4, 2011, at about 0725 central daylight time (CDT), an Airbus 320-232 (N409UA), serial number 462, operating as United Airlines flight 497, exited the left side of runway 19 at the Louis Armstrong New Orleans International Airport (MSY) after returning due to automated warnings of smoke in an equipment bay. The airplane's nose wheel exited the side of runway 19 upon completing the landing roll and an emergency evacuation was conducted. The airplane, with 106 passengers and crew aboard, had departed MSY about 20 minutes prior. The passengers and crew exited the airplane via slides. The forward, right-hand slide reportedly failed to inflate during the emergency evacuation. There were no reported injuries, and the airplane had minor damage.

D. DETAILS OF THE INVESTIGATION

[1] All times are Central Daylight Time based on a 24-hour clock, unless otherwise noted. Actual time of accident is approximate.

The Operations/Human Performance Group was formed April 4, 2011, in Washington, D.C. Group Chairman for Operations was Roger Cox and for Human Performance, Katherine Wilson. Other group members were Michael Barnett, Bradley Peterson, and Marc Ghafouri. On May 18, 2011, Nathalie de Ziegler joined the group as technical advisor to the accredited representative from BEA.

On April 4, 2011, the group began to gather flight and company documents. Interviews with the incident crew were conducted on April 6 in Los Angeles, California. The group reconvened in Denver, Colorado, on May 18-20, 2011, to conduct further interviews with United Airlines personnel and to conduct an A320 simulator observation flight. On June 9, 2011, the group interviewed the Federal Aviation Administration (FAA) A319/320 Aircrew Program Manager (APM) for the UAL certificate in Denver.

1.0 History of the Flight

According to United Airlines (UAL) flight documents, the incident flight departed the gate at Louis Armstrong New Orleans International Airport (MSY) at 0658 CDT and took off at 0708 on April 4, 2011. The crew had reported for duty at 0600 following a layover of approximately 12 hours. The captain stated that the flight release paperwork had been placed aboard the aircraft before they arrived, and that preparation for the flight was normal. The captain stated that he added extra fuel to allow a higher than planned cruise speed because the original flight plan indicated that the flight would arrive in San Francisco 15 minutes late. The takeoff weight of 154,290 lbs was within the maximum allowable weight of 156,200 lbs for the takeoff runway. Runway 19, which was 7,001 feet in length, was used. Runway 10/28, which was 10,104 feet in length, was closed.

The First Officer (FO) stated that their only pre-departure briefing regarding an emergency return was to maintain runway heading after takeoff in the event of an engine failure. He stated that they started the engines at the gate and that he was the pilot flying for the takeoff. He stated that preflight and taxi were normal and that they made a full (TOGA)[2] power takeoff using autothrust, with flaps set to 3. According to the captain, the V2[3] for the takeoff was 147 knots[4], which was a number he later made use of while preparing for landing. The FO said they flew the runway heading with an initial clearance to 4000 feet, and after a frequency change were cleared to turn right to a 250° heading with further climb clearance to FL 180 or FL 190.[5]

The FO said that passing 4000 feet he heard a "ding"[6] and saw the ECAM[7] message "avionics smoke." The captain stated that passing 4000 feet he noticed a "yellow"[8] autothrust message on the lower ECAM screen, and saw that the FO had attempted to re-engage the autothrust.

[2] Take off go around
[3] Takeoff safety speed
[4] According to the A320 Quick Reference Checklist (QRC) the takeoff speeds for flaps 3 and 154,000 lbs were V1 and Vr 137 kts and V2 141 knots.
[5] According to an ATC recording they were cleared to 15,000 feet.
[6] A single chime
[7] Electronic centralized aircraft monitoring
[8] Caution messages are amber in color

The FO said he pushed the ATHR[9] 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"[10] ECAM message accompanied by the electrical page synoptic display and the "AVIONICS SMOKE" ECAM procedure.[11] The captain told the FO "you lost your autothrust." The FO stated that he thought the situation was serious and that he was thinking "about the everglades." The captain said he was thinking about prior in-flight fire accidents and that "he didn't want to wind up like Valujet or Swissair." He recalled that the Swissair crew had "taken too long to troubleshoot the problem," and that the red "land ASAP" was an important message in a fly by wire aircraft.

The captain directed the FO to fly the aircraft and handle ATC communication while he ran the ECAM procedures. The FO leveled the aircraft at 5000 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. However, the captain said he believed that the ECAM message was telling them that "there was smoke in the extract duct,"[12] and that the ECAM was "setting them up for emergency electrical configuration." The captain said he was trained as the pilot not flying to "run the blue ECAMS," which were the action items called for in the ECAM procedure. The captain did not recall seeing any conditional statements or a timer in the ECAM procedure[13]. He said he read the ECAM items aloud, but did not speak very loudly, and he never got to the point where he could say "ECAM complete, screen normal." He said he thought the FO was keeping up with the ECAM actions, but he did not think to use the intercom for communications.

The captain stated that he turned off the generator 2 switch first, saying to the FO, "Ron is that right?" and that his last switch movement was to turn off generator 1 using the "gen line 1" switch. The FO heard the captain say "generator switch," but did not hear him announce "avionics smoke" or see him pull out the flight manual. The FO said he was unsure what ECAM steps were being taken and felt "out of the loop." The captain said that all download of electrical power came from his moving of switches.

The FO then noticed that he had lost his flight instruments, and began flying cross cockpit, using the captain's instruments for altitude, heading and airspeed. The captain said "Ron, you have no instruments," and took control of the airplane. The captain said that at that point "the ECAM's were done" and he did not know any way to get the ECAM screen back.[14] The FO declared an emergency with Air Traffic Control (ATC) and shortly thereafter the captain reported "we have a smoke issue" to ATC. The FO stated that he thought they were in the emergency electrical configuration, but he didn't know what the ECAM steps were. He said he did not go "heads down"

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[9] autothrust

[10] As soon as possible

[11] The AVIONCS SMOKE message and associated LAND ASAP message are amber in color while the EMER ELEC CONFIG message and associated LAND ASAP message are red in color.

[12] One component of the avionics ventilation system is an extract duct.

[13] ECAM conditional statements are "if "statements displayed in white and a 5 minute countdown timer is incorporated in one conditional statement.

[14] According to the "emergency power/battery powered equipment" list the ECAM upper display is powered by either the emergency generator or batteries until on the ground and below 50 knots.

on the ECAM or follow up on the ECAM actions, and he did not use the Quick Reference Checklist (QRC) while in flight.

The FO said that once the captain had taken control of the airplane both of the FO's screens were lost and the FO's side of the radio panels was dark. He said he assumed that only communications radio 1 was working and he did not attempt to use radio 2 on his side of the panel. He said he wasn't sure how to tune the ILS or if the FMGC's[15] were working when they were in that electrical configuration. The FO decided to alert the flight attendants (FAs), 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 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[16] with no antiskid or nose wheel steering, but he did not recall telling the FO 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 he 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." He accepted a clearance to turn to a 030 degree heading and a descent to 4,000 feet. ATC advised the flight that runway 10, which had an ILS approach procedure, was closed due to men and equipment on the runway, but that airport personnel would attempt to have that runway cleared. ATC cleared the flight for a further right turn to a heading of 140 degrees and a descent to 2000 feet, and cleared them for the ILS to runway 10.

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 did not comply with the vector to runway 10, but told ATC "we've lost all our instruments, we need a PAR."[17] The captain later stated 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 stated that he did not know the minimums for the no gyro surveillance approach, but he expected to break out at 1000 feet above the ground. He said he expected to fly a 3 degree glide slope, and he knew that based on his distance to the airport that he would be able to

[15] Flight management and guidance computer
[16] Direct law is a degraded flight control status.
[17] Precision approach radar

land. He knew there was no terrain or obstacle issue in the vicinity and he did not expect to have to go around.

The captain did not advise the FO as he continued the descent through the cleared altitude of 2000 feet[18]. The FO stated that he did not recall if they were cleared to descend out of 2000 feet. According to an air traffic control (ATC) recording, the crew reported to ATC "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." According to the ATC recording, the captain told ATC "we're going to stop here at about 700 feet," and the controller replied "the airport is at one o'clock five miles. The FO stated that he did not address being high or low or make a 1000 foot call, but that they put the landing gear down crossing the shoreline[19]. According to the ATC recording, the captain said to ATC "tell us when to stop turn on final," and the controller said "you need to make a right turn; the airport is off your right side." The captain said "I've got it" and the controller replied "wind 180 at 16 gust to 20, cleared to land." The captain stated that he landed with flap configuration full and used the PAPI[20] for vertical guidance.

The captain stated that he landed on the runway 19 centerline, 1,000 to 1,500 feet down the runway, and that he used full aft stick to hold the nose up during the roll out, but that the nose dropped harder than he expected. He said he "got on the brakes," used full reverse, and used right rudder to keep the airplane in the center of the runway. He believed that a left crosswind was causing the airplane to weathervane to the left, and he stepped harder on the right brake. They were going about 10 knots when they left the runway.

The FO stated that on touchdown the cockpit door swung open. He turned to the cabin 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." Once the aircraft came to a stop, they used the QRC to conduct the evacuation. The FO said that they skipped the ATC notification step because ATC knew what was happening. They shut down the engines and the captain said "get them out." The FO could not find the "Evac" switch; the overhead was all black. The captain set off the evacuation signal and the FO then silenced it. The FO said the 1R slide did not inflate, and he yelled "go the other way." He went down the 1L slide, helped the passengers, and sent them away from the airplane. The captain came out a few minutes later, bringing a megaphone, which he used to direct the passengers away from the aircraft.

2.0 Personnel Information: Flight Crew

2.1. The Pilot in Command, Donley Kent Moffer

Year of birth: 1961

[18] The captain stated in an interview that he had continued the descent on his own authority.
[19] The captain said he put the gear down when he saw the airport.
[20] Both pilots used the term VASI (visual approach slope indicator) to refer to the PAPI (precision approach path indicator).

Date of hire with United Airlines: July 17, 1995

Pilot certificates and ratings:

Airline Transport Pilot
Airplane Multiengine Land
Type Ratings: B-737, B-747-4, B-757, B-767, B-777, BAE-125, CE-500, HS-125, A-320
Commercial Privileges
Airplane Single Engine Land
English Proficient
B-757, B-767, B747-4, A-320 Circling Approach VMC only

Airman certificate date of original issue:

Airman certificate	**Original issue date**
Private Pilot – Airplane Single Engine Land	April 16, 1987
Private Pilot – Instrument Airplane	April 14, 1988
Commercial Pilot – Airplane Single Engine Land	July 25, 1988
Commercial Pilot – Instrument Airplane	July 25, 1988
Commercial Pilot – Airplane Multiengine Land	August 17, 1988
Flight Instructor – Airplane Multiengine	April 21, 1989
Flight Instructor – Airplane Single Engine	April 22, 1989
Airline Transport Pilot – Airplane Multiengine Land	November 11, 1990
HS-125 type rating	January 23, 1993
CE-500 type rating	May 12, 1993
BAE-125 type rating	January 25, 1995
B-747-4 type rating	August 13, 1999
B-737 type rating	March 14, 2000
B-777 type rating	January 22, 2002
B-757/767 type rating	August 1, 2002
A-320 Type Rating	November 22, 2008

Medical Certificate: First Class
Date: October 20, 2010
Limitations: Glasses for near and far vision

The captain stated in an interview that he was wearing new bifocal glasses during the incident.

Flight time based on United Airlines records and crew statements:

Flight time	**Hours**
Total	15,000
Total time in type (A320)	1,487

Last 24 hours (not including incident flight)	6.5
Last 7 days	19.5
Last 30 days	46
Last 90 days	131

Most recent training and check completion dates:

Part 121 training/checks	**Date**
Recurrent proficiency check	January 22, 2011
Recurrent LOFT check	January 22, 2011
Recurrent proficiency training	April 26, 2010
Recurrent evacuation qualification	April 25, 2010

A LOFT was line oriented flight training and included an evaluation.

A check of FAA records showed that no enforcement actions had been taken against Capt. Moffer.

2.1.1. The Pilot in Command's 72-hour History

The incident flight crew was paired for a 4 day trip that started in Los Angeles International Airport (LAX). On Friday, April 1, 2011, the crew flew an overnight flight from LAX, departing at 2356 PDT[21], to Mexico City Benito Juarez International Airport (MEX), arriving at 0524 CDT on April 2. They had about a 29 hour layover in Mexico City. The captain slept about 3 hours after their arrival. He took aspirin during the layover due to the air pollution in Mexico City. On Sunday, April 3, the captain awoke about 0700 for a 1000 departure to Washington-Dulles International Airport (IAD). The crew departed MEX at 1017 CDT and arrived in IAD at 1530 EDT[22]. After clearing customs, the crew departed for MSY at 1648 EDT. The crew arrived in MSY at 1806 CDT. After arriving, he had a sandwich for dinner and went to bed about 2100. On Monday, April 4, he awoke about 0430 for a report time of 0600. He said he got about 7.5 hours of sleep which was more than his normal sleep time of 5 hours. He said he slept well. He did not eat breakfast but had coffee that morning. He expected to eat a crew meal during the flight. The incident flight was scheduled to depart about 0700.

He did not take any medications on a regular basis.

2.2. The Second in Command, Ronald Lee Young

Year of birth: 1960
Date of hire with United Airlines: April 13, 1998

Pilot certificates and ratings:

Airline Transport Pilot
Airplane Multiengine Land

[21] Pacific daylight time
[22] Eastern daylight time

Types ratings: B-757, B-767, BA-3100, A320
Commercial Privileges
Airplane Single Engine Land
English Proficient
B-757 B767- A-320 Circling approach VMC only

Airman certificate original date of issuance:

Airman certificate	Original issue date
Private Pilot – Airplane Single Engine Land	March 1, 1991
Private Pilot – Instrument Airplane	May 15, 1991
Commercial Pilot – Airplane Single Engine Land	July 29, 1991
Commercial Pilot – Instrument Airplane	July 29, 1991
Commercial Pilot – Airplane Multiengine Land	October 21, 1991
Flight Instructor – Airplane Single Engine	October 6, 1992
Airline Transport Pilot – Airplane Multiengine Land	December 29, 1995
BA-3100 type rating	December 29, 1995
SF-340 type rating	November 25, 1996
Flight Engineer – Turbojet	August 12, 1998
B-757/B-767 type rating	November 7, 2004
A-320 type rating	October 17, 2009

FO Young received two notices of disapproval on the same date, October 10, 1996, for an additional type rating on his ATP for the SF-340. Both notices cited the following maneuvers as not satisfactory: engine out ILS, engine out landing, non-precision approach, missed approach and circling approach. The first attempt also cited these maneuvers: engine failure on takeoff, rejected takeoff, and no flap visual approach. FO Young completed the SF-340 type rating on November 25, 1996.

Medical Certificate: First Class
Date: October 14, 2010
Limitations: Must wear lenses for distant vision, must have glasses for near vision

Flight time based on United Airlines records and crew statements:

Flight Time	Hours
Total	11,500
Total time in type (A320)	1,154
Last 24 hours (not including incident flight)	6.5
Last 7 days	21
Last 30 days	70-80
Last 90 days	221

Most recent training and check completion dates:

Part 121 training/checks	Date
Proficiency check	September 1, 2010
Line operations evaluation (LOFT)	September 1, 2010
Systems review and maneuvers training	August 31, 2010
Initial line operations evaluation	October 17, 2009
Initial evacuation qualification	September 25, 2009

A check of FAA records showed that no enforcement actions had been taken against FO Young.

2.2.1. The Second in Command's 72-hour History

After arriving in MEX on April 2, 2011, following the overnight flight from LAX, the FO slept about 5-6 hours. He said the environmental conditions "were not very healthy" in Mexico City and there was a lot of "smog, heat and smell" which gave him a migraine and required that he take two Aleve pills. On the layover, he went out for about 2 hours to a museum and to eat. He went to bed about 2200. On Sunday, April 3, the FO awoke about 0830 for the 1000 departure to IAD. He said they arrived in MSY about 1800 and that it was a long duty day. He did not eat dinner in New Orleans and instead had some dry cereal and drank water, but said he had eaten an extra first class meal during the flight. He went to bed about 2230-2300 and awoke about 0545 on Monday April 4. He said he only slept about 5.5 hours. Although he normally slept about 6-7 hours, he said he felt "well rested". He did not eat that morning but had coffee, because he intended to eat a crew meal during the flight. He reported for duty the morning of the incident about 0600.

He took no prescription medications.

2.3. Medical and Pathological Information

The flight crew was not tested for drugs or alcohol after the incident.

3.0 Airplane Information

According to Airbus' website, the first A320 was delivered in 1988. A total of 4,790 aircraft of the A320 family of single aisle aircraft, including the A318, A319 and A321 had been delivered as of August 31, 2011.

3.1. Weight and Balance Information:

The following information was obtained from the UAL MSY-SFO dispatch flight log, which included the flight release, load plan, takeoff performance data (TPS) and final close out figures. Limitations were obtained from the UAL A320 Operating Manual.

	Weight
Empty Operating Weight	98,654 lbs
Passenger Weight (100 adult 1 child)	19, 136 lbs

Baggage (76 x 30 lbs and 2 x 60 lbs)	2400 lbs
Zero Fuel Weight	120,190 lbs
Maximum Zero Fuel Weight*	134,400 lbs
Fuel	34,400 lbs
Ramp Weight	154,590 lbs
Maximum Allowable Ramp Weight*	170,600 lbs
Taxi Fuel Burn	300 lbs
Takeoff Weight	154,290 lbs
Maximum Allowable Takeoff Weight*	169,700 lbs
Maximum Takeoff Weight (Flt Release)	156,200 lbs
Fuel Burn (13 minutes approximate)	1900 lbs
Actual Landing Weight	152,390 lbs
Maximum Allowable Landing Weight*	142,200 lbs

***** Airplane Flight Manual Limitations

Actual landing weight was not recorded due to the loss of electrical power to the Flight Data Recorder during the latter portion of the flight. According to air traffic control recordings, the crew reported fuel on board of 32,400 lbs approximately 5 minutes before landing. A fuel burn estimate of 1900 lbs was also made during a UAL flight simulator session which approximated the conditions of the incident flight. The estimated landing weight of 152,390 lbs was 10,190 lbs above the normal maximum allowable landing weight. An overweight landing checklist was not accomplished.

The center of gravity was 26.8 % of the mean aerodynamic chord, which was within takeoff limitations.

3.2. Approach Speed and Landing Distance

According to the UAL A319/A320 Flight Manual, Landing Performance, page 8.20.8, the appropriate approach/landing corrections for failure tables shows that with an emergency electrical configuration, the aircraft should be landed with flaps 3, using a **Δ**Vref (speed additive) of 10 knots, and a landing distance multiplier factor of 2.65.[23] Guidance on page 8.20.5 stated that for a single primary failure, 1/3 the steady wind should be added to the Vref and the **Δ**Vref to arrive at Vapp, provided that **Δ**Vref is less than 20 knots.

The last wind reported by the tower prior to landing was 180 degrees at 16 gusting to 20 knots. For a landing weight of 152,000 lbs the Vref for configuration 3 was 142 knots and the Vref for configuration full was 139 knots. For a flaps 3 landing the appropriate approach speed was 142 + 10 + 5 knots = 157 knots and this would have been the appropriate speed to brief prior to landing if the crew intended to follow the normal guidance for landing in the emergency electrical configuration. However, the crew chose to land with flaps full. For a flaps full landing the appropriate approach speed was 139 + 10 + 5 knots = 154 knots. The captain stated in an interview that he set 160 knots as target airspeed and maintained between 150 and 160 knots during the approach.

[23] See attachment 7

According to Step 1 of the Landing Distance Abnormal or Irregular Configuration table on page 8.20.14 of the A319/A320 Flight Manual and using a landing distance factor of 2.65, the flaps full dry runway landing distance with maximum manual braking at a landing weight of 152,000 lbs was 8,276 feet. This calculation assumes that the airplane was at the proper approach speed of 154 knots. Step 2 of the table provides a +2% increase in landing distance for each knot of tailwind. Although credit for headwind was not allowed procedurally, applying 2% per knot of the steady headwind component of 16 knots resulted in a calculated landing distance of 5,627 feet. The aircraft departed the left side of the runway approximately 5500 feet down the 7001 foot runway 19.

During a simulator observation flight, status information pertaining to landing provided by the ECAM at the end of the avionics smoke procedure was:

"APPR PROC:

-FOR LDG….USE FLAP 3
-AT 1000 FT AGL: L/G...DN

APPR SPD: VREF + 10/140 KT
LDG DIST PROC……APPLY"

The captain stated in an interview that the ECAM was lost and he did not have time to pull out the flight manual and he did not see any list of items lost due to the electrical emergency. The captain stated that he knew he would be in direct law with no antiskid or nose wheel steering but he was confident the airplane would stop. He said the airplane pulled to the side because the wind was 30 degrees to the left. He further stated that the rudder lost effect as they slowed, that normal landing distance was 3500 to 4000', and that he used full reverse. He said the landing weight was 152,000 lbs with dry runway and full flaps, and that his approach speed was based on V2 rounded up 15-20 knots to 160. He said that this did not affect landing distance. He used full flaps rather than flaps 3 in order to reduce the landing distance.

4.0 Aircraft Systems

The following systems information is taken from the UAL A319/A320 Flight Manual.

4.1. Electrical System

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[24]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.

[24] Auxiliary power unit

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.

4.2. Circuit Breakers

Circuit breakers are installed to prevent damage to systems or components from electrical faults and can be used to isolate equipment during maintenance. They can also be used to reset computer faults not resolved after accomplishing ECAM procedure(s) or to remove power from a system that does not have a dedicated power switch (e.g., FMGC[25]).

There are two types of circuit breakers (CBs): monitored and non-monitored. Color-coding is used for identification. Green CBs are monitored by the electronic centralized and aircraft monitoring (ECAM) system. The ECAM C/B TRIPPED warning appears when a monitored circuit breaker is pulled or tripped for more than 1 minute. Black CBs, and yellow CBs (if installed)[26], are not monitored by the ECAM system. Yellow capped CBs may be pulled when flying on battery power only. Later A320s and all A319s do not have yellow circuit breakers installed; the required action is covered in the appropriate Irregular procedure.

4.3. Batteries

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. Each battery has its own battery charge limiter that monitors battery charging and controls its battery contactor. The batteries can be charged when DC power is supplied to the DC BAT bus. In addition to powering their respective HOT BAT busses, the batteries can also supply power for the following:

- APU starting
- Static inverter (used in the emergency electrical configuration)
- DC ESS bus

The batteries are automatically connected to the DC BAT bus when the APU is being started, or when the batteries are being charged, provided the BAT 1 and BAT 2 switches are on. On the ground, the batteries have an automatic cutoff logic that prevents them from being completely discharged. In flight, battery endurance is approximately 22 minutes.

[25] Flight management guidance computer
[26] Yellow capped circuit breakers were installed on the incident aircraft.

4.4. Emergency Electrical Configuration

A ram air turbine (RAT) 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 earlier A320s such as the incident aircraft, the emergency generator operates only with the landing gear retracted. On these airplanes, 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.

The following busses are powered in the emergency electrical configuration:

- During RAT extension and emergency generator coupling (approximately 8 seconds), BAT 1 powers the AC ESS bus through the static inverter. BAT 2 powers the DC ESS bus. The ESS SHED busses are not powered.

- When the RAT is extended (and nose gear retracted on earlier A320s), the emergency generator powers the AC ESS and AC ESS SHED busses, and the DC ESS and DC ESS SHED busses through the ESS TR.

- When the landing gear is extended (on earlier A320s), the emergency generator no longer powers the essential busses. BAT 1 powers the AC ESS bus through the static inverter; BAT 2 powers the DC ESS bus. The ESS SHED busses are not powered.

- When below 100 knots, the DC BAT bus connects to the batteries, providing power for APU fire detection and protection and manual pressurization.

- After landing and when below 50 knots, the AC ESS bus is no longer powered and the CRTs are lost. The DC ESS bus remains powered which provides communication capability.

According to the "Emergency Generator/Battery Powered Equipment" chart on page 14.30.21 of the UAL Flight Manual[27], 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 chart also shows both 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,

[27] See attachment 12

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.

4.5. Smoke Configuration – Electrical

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.

4.6. Avionics Ventilation

The avionics ventilation system provides cooling air for the avionics compartment, cockpit instruments, and circuit breaker panels. The system uses two electric fans to circulate cooling air. An avionics equipment ventilation computer (AEVC) controls the system. The system may be configured open (on the ground), closed (in flight and on the ground with cold temperatures), and intermediate (in flight with warm temperatures). On the ground, normal operation is open; in flight normal operation is closed. In addition to the normal operational configurations, abnormal and smoke configurations also exist. The abnormal configuration occurs when either the BLOWER or EXTRACT fan switches are selected to OVRD.

4.7. Smoke Configuration – Ventilation

The smoke configuration occurs when the BLOWER and EXTRACT switches are both selected to OVRD. The blower fan stops and the extract fan continues to run. Cooling air is provided by the air conditioning system, and all air is extracted overboard.

4.8. Ventilation Panel

The ventilation panel is located on the right side of the overhead panel. When both BLOWER and EXTRACT switches are in AUTO:

- On the ground before takeoff power applied: The ventilation system is in open circuit configuration (closed configuration when skin temperature is cold).
- On the ground after takeoff power applied, or in flight: The ventilation system is in closed circuit configuration.
- In flight, ventilation system can be in the intermediate configuration if skin temperature is warm.

When either switch is in OVRD:

- The system is in the closed circuit configuration.
- Air is supplied from the air conditioning system; there is no cargo compartment heating.

When both switches are in OVRD:

- Cooling air is provided from the air conditioning system and all air is extracted overboard.

An amber FAULT light is located in the upper half of both the BLOWER and EXTRACT push button switches

The BLOWER FAULT Light Illuminates amber when:

- Blower pressure is low.
- Duct overheat detected.
- Computer power supply fails.
- Smoke warning occurs.

The EXTRACT FAULT Light Illuminates amber when:

- Extract pressure is low.
- Computer power supply fails.
- Smoke warning occurs.

There is a CAB FANS switch located on the ventilation panel.

- ON - Activates the two cabin recirculation fans.
- OFF - Stops the two cabin recirculation fans

4.9. Smoke Detection

Smoke detectors are located in the lavatories, avionics compartment, and cargo compartments. One smoke detector is installed in the avionics compartment air extraction duct. Avionics smoke is indicated by an aural single chime (SC), the illumination of the SMOKE light on the EMER ELEC PWR panel, the BLOWER and EXTRACT FAULT lights on the VENTILATION panel and MASTER CAUT lights, and by an ECAM caution on the Engine and Warning Display (E/WD).

4.10. Communication and Navigation Systems

Two audio control panels (ACPs), one for each pilot, are located on the control pedestal. An INT/RAD switch on each ACP operates as a press-to talk switch for boom or oxygen mask interphones. A transmit button is also incorporated into each side stick control. There are three radio management panels (RMPs), two on the control pedestal and one on the aft overhead panel. A CALLS panel is located on the left side of the overhead panel. Cockpit loudspeakers are located in the cockpit overhead and their volume is controlled by knobs on the captain’s and first officer’s forward panels.

4.11. Audio Control Panels

The ACPs provide the transmission and reception of all communication, standby navigation, interphone (flight and cabin), and passenger address (PA) systems. The transmission keys also have CALL lights that illuminate with SELCAL on the VHF and HF radios. MECH and ATT lights illuminate with calls on the flight or cabin/service interphone system(s).

4.12. Cabin Intercommunication Data System (CIDS)

CIDS provides signal transmission, control, and processing for the following cabin functions:

- Cabin/service interphone
- Passenger address
- Passenger entertainment
- Other
  - Passenger lighted signs
  - Reading lights
  - Cabin illumination
  - Emergency evacuation signaling
  - Lavatory smoke indication
  - Escape slide bottle pressure monitoring (some airplanes)

4.13. Cabin Service/Interphone

The cabin/service interphone system provides communication between the cockpit and flight attendant stations, as well as communication between the cockpit and ground crew members via jacks installed at various locations (e.g., engines, avionics compartment etc.). The aural cockpit buzzer associated with cabin interphone calls (including emergency calls) is inhibited from takeoff power application to 1500 feet RA during departure and from 800 feet RA until below 80 knots after landing.

4.14. Public Address System

The PA system provides cabin announcement capability from the cockpit and flight attendant stations. Volume output is automatically increased when an engine is operating. Cockpit access to the PA system is via the ACPs, hand microphone, or the handset. The cockpit handset is dedicated to the PA system only.

4.15. Radio Management Panels

Three RMPs provide control of all VHF (and HF, if installed) communication systems. RMPs 1 and 2, located on the control pedestal, provide backup to the flight management and guidance computers (FMGC's) for navigation radio tuning. RMPs 1 and 2 are connected directly to all VHF (and HF, if installed) transceivers; RMP 3, located on the overhead panel, is connected through RMPs 1 and 2, even if RMP 1 or 2 is turned off. If two panels fail, the remaining panel can control all VHF (and HF, if installed) transceivers. In the emergency electrical configuration, only RMP 1 is functional.

4.16. Calls Panel

When the FWD/AFT Buttons are pushed individually or simultaneously:

- A red light illuminates at the respective flight attendant area call panel.
- The CAPTAIN CALL message appears on the respective flight attendant indication panel.
- A high/low chime sounds through the respective cabin loudspeaker.
-

When the EMER Switch (guarded) is selected ON:

- The white ON light flashes.
- The amber CALL light flashes.
- A red light flashes at all flight attendant area call panels.
- An EMERGENCY CALL message appears on all flight attendant indication panels.
- A high/low chime sounds three times through all cabin loudspeakers.

4.17. Emergency Evacuation Signal System

The emergency evacuation signal system alerts the flight attendants to evacuate the passenger cabin. An EVAC COMMAND switch is located in the cockpit and an EVAC CMD button is located at each flight attendant panel. The cockpit EVAC panel is located on the left side of the overhead panel. On the panel are a safety-wired EVAC COMMAND switch, a HORN SHUT OFF button, and a safety-wired CAPT & PURS/CAPT select switch, which is deactivated. Pressing the EVAC COMMAND switch activates the evacuation alert, which consists of EVAC lights which flash at the forward and aft flight attendant panels and an evacuation horn which sounds in the cabin. The EVAC light also flashes and a horn sounds in the cockpit. Pushing the EVAC COMMAND switch a second time cancels the evacuation alert. The HORN SHUT OFF button, when pushed, silences the evacuation horn in the cockpit.

4.18. Autothrust

The autothrust system, using inputs from the FMGC, controls thrust based on airplane speed, altitude, and configuration. The thrust levers do not move when the autothrust system is in use. The autothrust system is an integral part of the autoflight system. When engaged, the autothrust mode is determined by the active vertical mode of the autopilot/flight director system. Autothrust modes are indicated in the first column of the FMA[28]. The FMAs, located on the top of the PFD[29], are the only valid indication of the status of the autoflight system. The green lights on the FCU buttons only indicate that they have been selected. The FMAs display the engaged, captured and/or armed modes of the autothrust, autopilot, and flight director systems, approach capabilities, and special messages. Most FMA indications are green for an engaged mode, blue for an armed mode, white for a status indication, and amber for an advisory indication. Normally, the first line indicates engaged/captured modes, and the second line indicates armed

[28] flight mode annunciations
[29] Primary flight display

modes. When the autothrust system is in an armed mode, the FMA automatically engages when the thrust levers are placed in the engagement range.

4.19. Electronic centralized aircraft monitoring system (ECAM)

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.

4.19.1. Status page

The SD also displays a STATUS page that provides an operational summary of the airplane's system status. The STATUS page contains limitations (e.g., speed and flight level), approach procedures, landing corrections, and general information. It also lists cancelled cautions, inoperative systems, and maintenance messages. The STATUS page is displayed automatically when the pilots have cleared all of the pages corresponding to the current failure, and again when the FLAPS lever is moved out of the UP position. The STATUS page is displayed manually by pushing the STS button on the ECAM control panel. If no status messages are presented, the STATUS page appears with NORMAL annunciated in green.

4.19.2. Warning and Caution Priority Levels and Colors

4.19.2.1. Priority levels

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.

4.19.2.2. Color

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
- **Blue** Actions to be accomplished, or limitations
- **Magenta** Special messages (i.e., T.O INHIBIT and LDG INHIBIT)

4.19.2.3. Operation of ECAM during a Failure

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

- E/WD 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)
- SD 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.

4.19.3. LAND ASAP Message

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.

During interviews, three UAL A319/A320 check airmen stated that they would land as soon as possible if they received the LAND ASAP message regardless of the color of the message. However, in another interview, the FAA Aircrew Program Manager of the A319/A320 at UAL stated that regarding the relative importance of red and amber "LAND ASAP" messages, this message was an "info note" on the right side of the ECAM, and the color provided a varying degree of importance. He said it was not a mandatory action, but meant "consider this." It was just part of the overall situation, and must be put in context. The fleet had experienced some anomalous indications where sensors had given "LAND ASAP" without other indications, and this was mentioned in the flight manual. He said "don't panic" when you see it.

5.0 A320 Control Laws

The A319 and A320 incorporated a fly-by-wire flight control system. Flight control computers interpret the pilot's command and move the flight control surfaces as necessary to achieve the desired response. The flight control computers also provide protection; they do not permit flight outside of the safe envelope. All flight control surfaces are normally electrically controlled and hydraulically actuated via three independent hydraulic systems. In an emergency, the pilots can maintain airplane control using mechanical connections to the stabilizer and rudder. The flight control computers process sidestick and autopilot inputs according to flight control laws.

5.1. Normal Law

The flight control normal law provides three-axis control and the following flight envelope protections:

- Load factor limitation
- Pitch attitude protection

- High angle of attack protection
- High speed protection
- Bank angle protection

In normal law, regardless of the pilot's input, the computers prevent excessive maneuvers and exceedences of the safe envelope in pitch and roll axis. The rudder has no such protection. The pitch mode of normal law is a load factor demand law. When using the sidesticks, the elevator achieves a load factor proportional to sidestick deflection regardless of airspeed. Pitch trim is automatic with or without the autopilot engaged.

5.2. Alternate Law

The first level of flight control degradation is pitch alternate law, roll direct law and Yaw alternate law. The autopilot may be available, depending on the specific failures. The ECAM message F/CTL ALTN LAW (PROT LOST) is displayed. In pitch alternate law, all protections are lost except for load factor (aural overspeed and stall warnings are provided). The airplane can be stalled in alternate law.

5.3. Direct Law

If the flight controls degrade to alternate law for any reason other than recovery from abnormal attitude law, direct law automatically becomes active upon gear extension when no autopilots are engaged. If an autopilot is engaged, the airplane remains in alternate law until autopilot disconnection. No protections are provided in direct law; however, overspeed and stall aural warnings are furnished. The pitch direct law is a direct sidestick-to-elevator position relationship. An amber USE MAN PITCH TRIM message appears on the PFD. The roll direct law is a direct sidestick-to-aileron and spoiler position relationship. Yaw is yaw alternate or yaw mechanical, depending on malfunction. In yaw mechanical law, there is no turn coordination or yaw damping.

The captain of the incident flight stated in an interview that he did observe a USE MAN PITCH TRIM message and that he was aware that he was in direct law once the landing gear was extended.

6.0 Airport Information

6.1. Louis Armstrong New Orleans International Airport

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 its website, the airport was served by 10 domestic and 3 international airlines and had 88,564 commercial air carrier aircraft operations in 2010. 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 10 had an ILS/DME, two RNAV[30], and one VOR/DME[31] approaches. Runway

[30] Area navigation

1/19 was 7001 feet long and 150 feet wide, and was a concrete, grooved runway with an uphill slope of 0.1%. The runway had precision runway markings, a 4 light PAPI on the left side of the runway with a 3.00 degree glide slope, and a 1400 foot medium approach lighting system.

Runway 19 had two RNAV and one LOC[32] approaches. According to the Jeppesen 11-3 page, the LOC Rwy 19 approach frequency was 111.7 (identifier INOW), the inbound course was 193 degrees, and a DME[33] was incorporated but not required to be used to fly the approach. The final approach fix, JASPO intersection, was 6.1 NM from the runway approach end and the altitude required at JASPO was 2000 feet MSL. An intermediate fix, SHORE intersection, was 2.2 NM from the runway approach end, and the depicted altitude at SHORE was 700 feet MSL. The minimum descent altitude (MDA) for a straight in landing to runway 19 was 340 feet MSL with SHORE identified, but was 700 feet MSL with SHORE not identified. DME was required in order to identify SHORE. The visibility required to conduct the approach was 2 statute miles for a category C aircraft[34] without SHORE, and was ¾ statute mile or 40 RVR[35] with SHORE.

An Airport Surveillance Radar (ASR) approach to runway 19 was available and was depicted on the Jeppesen 18-1 page. The MDA for that approach was 420 feet MSL and the visibility required was 1 ¼ statute miles or RVR 60. No PAR (precision approach radar) was available.

6.2. Automatic Terminal Information Service (ATIS)

According to ACARS[36] data obtained from UAL, ATIS information prior to the incident flight was provided at 0553 CDT, 0524 CDT, and 0653 CDT.

"New Orleans ATIS information Foxtrot 1053 Zulu, wind 180 at 13 knots, visibility 8 statute miles, few clouds at one thousand six hundred feet, broken clouds at 3000 feet, temperature 24 degrees Celsius, dew point 21 degrees Celsius, altimeter two nine eight four. Arrivals expect ILS runway 10 approach, departing runway 19. Notams, runway 24 closed between runway 19 and taxiway sierra, runway 24 closed between taxiway golf and runway 28. Taxiway golf closed between taxiway alpha and taxiway G3, taxiway alpha closed between taxiway golf and runway 10, taxiway G3 closed. Airport rotating beacon out of service, bird activity vicinity of airport, advise you have information foxtrot."

"New Orleans ATIS information Golf 1124 Zulu, special, wind 180 at 14 knots gusting to 20 knots, visibility 8 statute miles, few clouds at one thousand five hundred feet, broken clouds at 2500 feet, temperature 24 degrees Celsius, dew point 21 degrees Celsius, altimeter two nine eight four. Arrivals expect localizer runway 19 approach, departing runway 19. Notams, runway 24 closed between runway 19 and taxiway sierra, runway 24 closed between taxiway golf and runway 28. Taxiway golf closed between taxiway alpha and taxiway G3, taxiway alpha closed between taxiway golf and runway 10, taxiway G3 closed. Airport rotating beacon out of service, bird activity

[31] Very high frequency omnidirectional radio range (VOR)/distance measuring equipment (DME)
[32] Localizer
[33] Distance measuring equipment
[34] The A320 is normally considered a category C aircraft
[35] Runway visual range
[36] Aircraft communications addressing and reporting system

vicinity of airport, advise you have information foxtrot."

"New Orleans ATIS information Hotel 1153 Zulu, wind 180 at 15 knots gusting to 22 knots, visibility 7 statute miles, few clouds at one thousand five hundred feet, broken clouds at 2500 feet, temperature 24 degrees Celsius, dew point 20 degrees Celsius, altimeter two nine eight four. Arrivals expect localizer runway 19 approach, departing runway 19. Notams, runway 10 and 28 closed, runway 24 closed between runway 19 and taxiway sierra, runway 24 closed between taxiway golf and runway 28. Taxiway golf closed between taxiway alpha and taxiway G3, taxiway alpha closed between taxiway golf and runway 10, taxiway G3 closed. Airport rotating beacon out of service, bird activity vicinity of airport, advise you have information hotel."

7.0 Organizational and Management Information

7.1. United Air Lines, Inc.

United Air Lines, Inc, a subsidiary of United Continental Holdings, Inc, was a major air carrier with headquarters in Chicago, Illinois and major hubs in Chicago, Cleveland, Denver, Los Angeles, San Francisco, Tokyo, and Washington, D.C. The airline's fleet of 359 aircraft included 55 A319 and 97 A320 aircraft.

7.2. A320 Flight Operations Management

The UAL A320 fleet management team was:

Fleet Captain: Captain Clarke Clodfelder
Airbus Fleet Technical Manager: Captain Brad Peterson
Fleet Technical Specialist: Russ Gray
Quality Control Manager: Captain Carol Cameron
Acting Training Manager: First Officer Christopher Neugebauer
Line Training Manager: Captain Emil Lassen

7.3. Flight Operations Policies

Operations policies for the airline are discussed in the UAL Flight Operations Manual. Relevant excerpts are presented here.

7.3.1. Managing Emergencies

The UAL Flight Operations Manual, page 5.10.1, Inflight Emergencies," stated:

"Experience reveals that during emergency situations there are C/L/R[37] techniques that result in optimal coordination with minimal confusion and errors. While it is not possible to write specific procedures that will cover every facet of every emergency or irregularity, it is possible to establish certain guidelines. When dealing with situations requiring irregular or emergency checklists and coordination with others (e.g., Dispatch, Maintenance, or flight attendants), the

[37] Command/ leadership/ resource management

following division of duties has historically resulted in the most efficient resolutions. At the Captain's discretion, the preferred technique is to designate the First Officer as both the pilot flying and the pilot responsible for routine ATC radio communications. The First Officer should use available autoflight systems and have the Captain confirm altitude and routing clearances. This allows the Captain to more effectively act as the overall event manager, accomplishing checklists and coordination with available resources. The Captain should strive to keep the First Officer informed on systems status, confirm checklists to be accomplished, obtain confirmation prior to moving flight critical switches, announce checklist completion, and solicit situational input. An available relief pilot should monitor the PF and be assigned clear duties (e.g., specific checklists, communications [radio, ACARS, SATCOM], and/or flight attendant coordination). Once checklists are complete, the situation is understood, and all relevant input has been received, the Captain should provide a systems status briefing and recovery game plan. At this point, the designation of PF may change and the PM should again become responsible for ATC communications"

Both pilots stated in interviews that the captain assigned the FO to fly the airplane and handle ATC radios while the captain ran the ECAM procedure. They stated that the FO declared the emergency, and that the captain then said on the radio "we've got a smoke issue." They also stated that once the FO lost his flight instruments the captain took control of the airplane and remained in control until the airplane landed and came to a stop. The FO stated that at the time of control transfer his side of the radio panels was dark. He assumed the #1 communications radio was working and he did not attempt to use the radios on his side of the cockpit. He also said that he did not go "heads down" on the ECAM and did not follow up on the ECAM actions. He said he believed that it was not possible to obtain ECAM information in the emergency electrical configuration. He did not recall if they had a clearance to descend from 2000 feet to 600 feet or call out being high or low at 1000 feet, He said he "just felt like they needed to get below the bases of the clouds." He heard the captain mention 147 knots plus wind additive as the approach speed but did not ask the captain how he arrived at that number. He said the status of the antiskid and nosewheel steering during the incident did not cross his mind.

The FAA APM stated in an interview that when a pilot in command (PIC) exercised his authority to deviate from a regulation in an emergency, it was a judgment call based on the situation, not a blanket authorization to do anything. The pilot must be able to justify his actions later. If a procedure called for the oxygen mask to be donned and this was not accomplished, it was "not good." There was no guidance to ignore this step. However, the avionics smoke procedure started with "if perceptible smoke," so if there was no smoke, it was okay not to don the oxygen mask. In fact, if there was no perceptible smoke, there was no reason to do any of the steps in the procedure. When asked if the crew would always be able to detect smoke from the avionics area, he was not able to say.

7.3.2. Cabin Prep/Emergency Evacuation

The UAL Flight Operations Manual, page 5.10.3, Cabin Prep/Emergency Evacuation," stated:

"Communication between the pilots and flight attendants is especially important, both to verify the situation and to ensure both groups are aware of the decision either to evacuate or not evacuate."

***"Signal to Evacuate -** Initiate evacuation with the PA command, **"Release your seat belts and get out!"** and the evacuation alarm (if installed), when called for as part of the Evacuation QRC. The PA command, in conjunction with the evacuation alarm, emphasizes to flight attendants and passengers the urgency of necessary steps to safely complete the evacuation. Pilots should rely on the flight attendants' assessment of the viability of an emergency exit, and avoid specifying which exit(s) to use (e.g., right side only."*

***"Unplanned Evacuation -** In an obvious life-threatening situation (e.g., crash, fire, bent/scraping metal, gear collapse, etc.), flight attendants initiate evacuation without awaiting orders from the Captain. This is considered a delegation of authority to prevent delays in executing an evacuation in a critical situation. In all other cases, the cockpit should be contacted to assist in the use of all resources to assess the situation before the Captain's decision is made. In a situation such as an engine fire during start, the flight attendant who observes the fire directly contacts the Captain rather than relay the information through the Purser before initiating an evacuation. If contact with the cockpit is not possible, flight attendants then make an independent decision."*

*"**Cabin to Cockpit Signal -** Flight attendants will signal the initiation of an unplanned evacuation by activating the evacuation alarm".*

***"Note:** During evacuation, silence the cockpit alarm on airplanes with evacuation alarms to facilitate execution of emergency procedures and/or necessary communications."*

The FO stated that he attempted to alert the flight attendants (FA's) after the captain took control of the airplane, but that they did not respond to an intercom call or to a pedestal handset call. He then opened the cockpit door and told the FA's that they were in an emergency and would be landing immediately. The FO said that after landing the door swung open and he shouted "remain seated, remain seated." After stopping, the captain said "get them out" and activated the evacuation alarm. The FO then positioned the switch to silence the alarm.

7.3.3. Log History

The UAL Flight Operations Manual, Maintenance Documents, page 7.90.4, "Log History," stated:

"The Log History is provided with the flight papers as a reference document that is required onboard the airplane. The Log History contains a snapshot of events at the time it was generated. It does not include MRM/FRM code-reported cabin items that are classified as nonsafety-related or AMT found-and-fixed items. The format is similar to the CURRENT MAINTENANCE STATUS section of the MRD and includes a list of the following:

- *Pilot-reported defects and aircraft refusals. The list includes the last 20 items which have been closed or all items which have been closed in the last 14 days, whichever is less.*

- *The list of Long Term Carried Forward Items, if any, is printed at the end of the Log History. The classification Long Term means that Maintenance has no plan to fix the item for at least 30 days. Some items may be listed here until the next heavy maintenance visit (which could be years away).”*

The log history for N409UA provided to the incident crew cited avionics smoke ECAM cautions on previous flights on March 28, March 29, and a cargo smoke detector fault on April 2, 2011.[38]

7.3.4. Airport Surveillance Radar

The UAL Flight Operations Manual, page 9.100.10, Airport Surveillance Radar,” stated:

“Navigational guidance is provided in azimuth and range only. The pilot is furnished headings to align the airplane with the extended centerline of the landing runway. Guidance in elevation is not possible, but the pilot is advised when to begin descent to the MDA or, if appropriate, to an intermediate stepdown fix minimum crossing altitude and subsequently to the prescribed MDA. The pilot is advised of the approach minimums, the location of the missed approach point prescribed for the procedure, and the position each mile on final from the runway, airport, or MAP, as appropriate. If requested by the pilot, recommended altitudes are issued at each mile, based on the descent gradient established for the procedure, down to the last mile that is at or above the MDA. Normally, navigational guidance is provided until the airplane reaches the MAP.

***Note:** It is United policy that these recommended altitudes be requested on all ASR approaches.*

Controllers terminate guidance and instruct the pilot to execute a missed approach unless, at the MAP, the pilot has the runway or airport in sight. At any time during the approach, if the controller considers that safe guidance for the remainder of the approach cannot be provided, the controller terminates guidance and instructs the pilot to execute a missed approach. Similarly, guidance is terminated and a missed approach executed upon pilot request. Controllers may terminate guidance when the pilot reports the runway or airport in sight, or otherwise indicates that continued guidance is not required. Radar service is automatically terminated at the completion of a radar approach.”

The captain stated that he requested a PAR[39], which is a precision radar approach, but he had not flown one in five years and did not know if a PAR was available. According to the UAL Flight Operations Manual, chapter 9, section 100, PAR is authorized as the primary approach aid only in an emergency or as a monitor when using another facility. According to an air traffic control recording, the flight was cleared initially for an ILS approach to runway 10, but later was provided a no gyro surveillance approach to runway 19.

[38] See attachment 9

[39] PAR is a ground radar guided approach which provides glide slope information.

7.4. UAL A319/A320 Operating Procedures

Operational procedures were discussed in the UAL A319/A320 Flight Manual. Relevant excerpts are presented here.

7.4.1. Standard Operating Procedures (SOPs)

The Standard Operating procedures (SOPs) section of the A319/320 Flight Manual stated on page 1.30.1, Introduction, that the A319/A320 was a highly automated airplane, and that automation can lead to complacency and lack of situational awareness unless both pilots are always aware of the airplane's status. The SOP's established how, when and where various items were accomplished during a normal flight. It stated that the captain always maintained the authority to deviate from any procedure in the interest of safety, but that during normal operations SOPs must be followed. The Introductory section went on to say on page 1.30.3 that "during all phases of flight, both pilots must be aware of the FMA's (flight mode annunciations) and verify that they reflect the intended autoflight modes."

7.4.2. Use of ECAM

According to the A319/A320 Flight Manual, Chapter 1 "Introduction", pages 1.30.9-1.30.10:

To accomplish an ECAM, pilots must complete all E/WD items, review displayed systems pages for secondary failures, review and brief the status page, and reference other available resources (i.e., Flight Manual, Dispatch, and Maintenance).

- **Complete E/WD action steps.**

– Announce the ECAM title (include the underlined system and the specific malfunction).

– Read aloud and perform the blue action items, including applicable items underneath white conditional statements.

Note: *If the associated system page displays on the SD, consider reviewing the SD before accomplishing the ECAM steps.*

Note: *Most blue action items disappear when accomplished. If a blue action item does not disappear from the ECAM, the FWC may not be able to recognize the action as accomplished (e.g., MAX SPEED . . . 320 KT) or the action may not be complete. Use available means to verify that action is complete before accomplishing the next action.*

– When all blue action items are complete, press the CLR key to remove the ECAM. Subsequent ECAMs, if any, will then move to the top to be completed next.

Note: *Normally, the CLR key is the only key needed to sequence ECAMs.*

– When the lower left E/WD area is clear of ECAM steps, the immediate actions are complete.

- **Review displayed systems pages for secondary failures.**

Other affected systems, if applicable, are displayed in amber on the lower right of the E/WD and are automatically displayed on the SD after all E/WD immediate action steps are complete. These affected systems may suggest further prudent items to accomplish (e.g., ELEC page indicating single generator operation may prompt pilots to start the APU). Workload permitting, it is recommended that both pilots review each page before the PM presses CLR to sequence to the next system. Continue until all secondary systems are removed from the lower right E/WD area and the SD displays the STATUS page.

- **Review and brief the STATUS page.**

– If the STATUS page contains additional blue action items and reference information, the PM announces each item, accomplishing appropriate blue action items until all lines have been read.

– When PF workload permits, the PM must review with the PF the status of the airplane and its systems, and implications for the remainder of the flight. When both pilots are satisfied that they have properly addressed the malfunction and understand its implications, the PM presses the CLR key one last time. When the CLR key is no longer illuminated and the E/WD and SD have returned to normal displays, the PM announces, "ECAM complete, screens normal."

- **Refer to other available resources, as necessary.**

– Irregular/Emergency Procedures chapters: Amber ECAMs are in the Irregular Procedures chapter. Red ECAM procedures are in the Emergency Procedures chapter.

– Landing Performance chapter: Provides information when landing configuration, approach speed, or landing distance are affected. If the STATUS page indicates LDG DIST PROC....APPLY, see the Approach/Landing Corrections for Failures procedure.

– Additional Procedures chapter: Provides SYSTEM FAULT RESETS that sometimes allow pilots to reset certain systems without contacting Maintenance/SAM.

– Supplementary Information chapter: Provides system anomalies information.

– Dispatch/Maintenance: May provide additional support. Report system malfunctions and other airplane discrepancies to Maintenance as soon as possible. See FOM for detailed discrepancy and defect reporting information.

In an interview, the FO stated that the captain did not announce "avionics smoke" at the beginning of the event and did not say "ECAM complete, situation normal" during the flight. He stated that he did not know what ECAM steps were being accomplished, but he believed that they went into the emergency electrical configuration. He stated that he did not follow up on ECAM actions after he gave control of the aircraft to the captain and become the PM. He stated that he believed that in the emergency electrical configuration it was not possible to obtain ECAM information.

The captain stated in an interview that "the pilot not flying runs the blue ECAM's," and that he read them off but did not speak very loudly. He said he never got to the point where he could say "ECAM complete, screens normal," but he believed that "the ECAM's were done." He said that he

knew he "would lose the electrical system" with both generators off, and that once the main electrical power was off "he did not know any way to get the ECAM back."

A UAL A320 standards captain stated in an interview that a common problem he saw regarding use of ECAM by crews in training was rushing through it, going part way through the ECAM procedure, doing the blue "to do's," and not finishing the ECAM steps. A UAL pilot instructor also stated that the biggest problem he saw regarding ECAM was that pilots would go too fast, make rapid selections (clear, clear, done) and would forget to complete the procedure all the way down to system status, which was required to complete the procedure. Another UAL A320 standards captain said in an interview that, regarding overall crew performance in training, she thought that the handling of ECAM's was a weak area. She had observed such problems with ECAM execution as skipping lines or steps, not seeing indents, having a timer line go away, failing to turn an item back on, performing steps out of order, being confused by terminology, and having trouble seeing the lines due to small print.

7.4.3. Checklists

UAL A320 checklists were divided into normal, irregular and emergency procedures.

7.4.4. Normal Checklists

The UAL Normal checklist was on a laminated card known as a Quick Reference checklist (QRC).[40] 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 Airbus, the manufacturer, did provide a QRH but he was not aware of whether other airbus operators provided their crews with a QRH or not[41]. He said UAL and airbus procedures were very similar, although there was carrier-specific information in the UAL flight manual.

The UAL A320 Flight Manual, Normals, page 10.10.2, stated:

"The Captain normally calls for the required checklists on the ground, and the PF normally calls for the required checklists in flight. While it is the Captain's responsibility to determine that each checklist is accomplished at the proper time, the First Officer must be aware of the status of the checklists and advise the Captain if a checklist is not accomplished at the proper time."

7.4.5. Irregular and Emergency SOP's

The UAL A319/A320 Flight Manual, Introduction, page 1.30.7 stated:

[40] See attachment 3

[41] A survey of A319/A320 operators revealed that 6 out of 8 operators in the U.S. used a QRH.

"There are some situations which always require a landing at the nearest suitable airport (see Emergencies/Irregulars section of FOM and FAR 121.565 for suitability criteria). These situations include, but are not limited to, operating on a degraded engine, engine failure or fire, cargo smoke, cabin smoke or fire which persists, and electrical or hydraulic faults which result in only a single critical system remaining. In any case, it is the responsibility of the Captain to assess the situation and execute sound judgment to determine the safest course of action. It should be stressed that for persistent smoke or a fire that cannot be positively confirmed to be completely extinguished, the earliest possible descent, landing, and passenger evacuation should be accomplished."

"Flight-critical items must be recognized and verbally confirmed by both pilots before the required action is accomplished. The following items are considered flight critical:

- *All red (or red-guarded) controls on the overhead panel*[42]
- *All fuel-related switches on the overhead panel*
- *IR selectors*
- *Thrust levers*
- *ENG MASTER switches"*

7.4.6. Emergency Checklist and Procedures

Emergency procedures were on the A320 EMERGENCY QRC laminated card. More detailed emergency procedures were located in the emergency procedures section of the flight manual. The UAL A319/A320 Flight Manual, Emergency Procedures, page 15.10.1-2, stated:

"Fly the airplane, Silence the Warning and Confirm the Emergency are critical steps in any emergency, and must be performed in conjunction with accomplishment of the ECAM or the QRC emergency procedures. United Airlines' policy is to use the QRC in accomplishing non-ECAM emergency procedures. The ECAM and QRC provide pilots the tools to recover the airplane from an emergency situation while minimizing errors and ensuring timeliness in accomplishing the procedure(s)."

"The ECAM and QRC cannot cover all emergency situations. Per FAR 121.557(a), "In an emergency situation that requires immediate decision and action, the pilot in command may take any action that he considers necessary under the circumstances. In such a case, he may deviate from prescribed operations, procedures and methods, weather minimums, and this chapter, to the extent required in the interest of safety."

"WARNING: *Pilots must don oxygen masks and establish communications anytime oxygen deprivation or air contamination is suspected even though an associated warning has not occurred."*

"The PM normally reads and accomplishes QRC items during flight. The PF manipulates controls directly affecting airplane control. The Evacuation QRC will be read and accomplished

[42] The EMER ELEC PWR MAN ON" switch was red-guarded.

by the First Officer, with the Captain providing backup. The Evacuation QRC should be accomplished in its entirety without interruption."

"When accomplishing REFERENCE ACTIONS, the PM, on command, reads the checklist aloud taking note of all instructions. Conditions permitting, the PF maintains an awareness of checklist progress. The PM announces when the emergency procedure is complete."

7.4.6.1. Order of Procedure Accomplishment

The UAL A320 Flight Manual, Introduction, page 1.30.7 stated:

"Certain circumstances may require accomplishing multiple irregular, emergency and/or QRC procedures. In these cases, the Captain has final authority to determine the sequence of checklists. The measure of success is based on the accomplishment of all procedures and subsequent outcome, not the order of procedure accomplishment. Captains should consider the following:

- *QRC procedures normally take precedence over ECAM emergency procedures.*
- *Emergency procedures (both QRC and ECAM) normally take precedence over irregular procedures (ECAM and non-ECAM).*
- *If a displayed ECAM procedure addresses the same condition as a QRC, it is recommended the QRC be completed, including reference actions, prior to accomplishing the ECAM."*

7.4.6.2. Avionics Smoke Procedure

The UAL A320 Flight Manual, Irregular Procedures, page 14.20.41, presented the AVIONICS SMOKE irregular procedure.[43] It was underlined and capitalized, indicating that an ECAM procedure existed. The first statement in the procedure was:

***"Condition:** Smoke is detected in the ventilation extract duct."*

The first action in the procedure was:

- ***"LAND AT THE NEAREST SUITABLE AIRPORT."***

The explanatory information stated:

"Follow this procedure to:

- *Maintain airplane control*
- *Establish a smoke configuration*
- *Attempt to isolate and turn off faulty equipment, or*
- *If unable, or if smoke continues after 5 minutes, put the electrical system in the emergency configuration*
- *Attempt to restore electrics prior to landing"*

[43] See attachment 4

A five minute countdown timer was integrated into the ECAM procedure, but the UAL A319/A320 Flight Manual did not provide a direct explanation of its location or function.[44]

The first conditional statement in the procedure was:

"IF PERCEPTIBLE SMOKE:
If smoke is confirmed, the following procedure ***must*** *be applied."*

The action steps were:

- *"Oxygen mask .....On*
  Ensure crew communication is established. Avoid the use of interphone position to minimize interference from oxygen mask breathing noise. Check oxygen diluter selector is at 100% and turn the emergency knob to remove condensation or smoke from the mask.
- *BLOWER..... OVRD*
- *EXTRACT ..... OVRD*
  Avionics ventilation is provided by air conditioning system and extracted overboard.
- *CAB FANS .....OFF*
  This prevents smoke from entering cockpit and cabin.
- *GALLEY/GALY & CAB switch.....OFF*
- *CKPT/CAB COM..... ESTABLISH*
- *Signs .....On*
- *Emergency exit lights..... ON*
  Provides minimum cabin lighting when the COMMERCIAL switch is turned OFF."

The second conditional statement pertained to the installation of a "commercial" switch, which was not installed on the aircraft.

"If COMMERCIAL switch is installed:
- *Commercial switch ..... Off"*

The next step was not a condition of having a commercial switch.

- *"Faulty equipment (if identified) ..... Off*
  Identify and turn off faulty equipment, if possible."

The third conditional step was:

"If smoke disappears within 5 minutes"

The action step following the conditional step was:

[44] See attachment 2, figure 7 for an example of the timer.

- *"NORM VENTILATION .....RESTORE"*

The fourth conditional step was:

"If smoke persists after 5 minutes:"

From this point forward, the avionics smoke procedure parallels the emergency electrical configuration procedure. The action steps following the conditional steps were:

- *EMER ELEC GEN 1 LINE ..... OFF*
  GEN 1 line contactor opens. Generator 1 supplies one fuel pump in each wing tank. Generator 2 supplies AC BUS 1 through the bus tie contactor.
- *EMER ELEC PWR .....MAN ON*
  RAT is extended and the emergency generator is connected to the airplane electrical system. Check emergency generator parameters on ECAM ELEC page (automatically displayed).

The reference action title was:

"When EMER GEN avail:"

The action steps were:

- *APU GEN ..... OFF*
- *GEN 2 ..... OFF*
  ELEC EMER CONFIG
- *MIN RAT SPEED ..... 140 KT*
  Note: *The electrical configuration is the same as for loss of both generators (except that one fuel pump in each wing tank remains supplied). See ELEC EMER CONFIG in the Emergency Procedures chapter for affected and inoperative systems.*
- *VHF 1/HF 1/ATC 1 ..... USE*
  Only VHF 1, HF 1 and ATC 1 are available in this configuration.

Note: *On A320s with yellow-capped circuit breakers[45], if normal electrical supply is not restored prior to landing gear extension, the navaids used for approach should be tuned on RMP 1 to prevent their loss at landing gear extension (FMGC is not powered in this configuration).*

The fifth conditional step was:

"If on A320s with yellow-capped circuit breakers:"

[45] The incident aircraft had yellow-capped circuit breakers.

- *APU MASTER switch (if APU not running)..... OFF*
  With APU MASTER SW selected ON, DC BAT BUS is supplied by the batteries.
- *AVOID ICING CONDITIONS*
- *FAC 1 ..... OFF THEN ON*
  Rudder trim is recovered despite no indication.

The sixth conditional step was:

"If on A320s with yellow-capped circuit breakers:"

- *LDG ELEV .....MAN ADJUST*
  Ensures proper cabin depressurization, whether normal electrical power is restored or not.

The next reference action title was:

"Before L/G Extension:"

Restore normal electrical supply for landing.

- *GEN 2..... ON*
- *EMER ELEC GEN 1 LINE..... ON*

The next reference action title was:

(PROT LOST)
Flight control normal laws and associated protections are lost. Only load factor limitation, high and low speed stability are provided.

- *MAX SPEED ..... 320 KT*
  EPR MODE FAULT N1 DEGRADED MODE ECAM message appears.

The avionics smoke procedure concluded with a summary of status information, including how to access status information on the ECAM by pressing the STS button. No reference was made in this procedure to the effect of the emergency electrical configuration on the thrust reversers. On some A320's both thrust reversers were inoperative, but in others, including the incident aircraft, the number 1 thrust reverser was operative. This information was available on the incident aircraft only by checking "status" in ECAM before landing. Airbus incorporated the thrust reverser information in its QRH by differentiating the handbook for each aircraft by manufacturer's serial number (MSN).

The following are the items shown in the conclusion to the avionics smoke procedure:

STATUS

Lower ECAM display is not available. Status page is displayed on upper ECAM if STS button is held down.

- *MIN RAT SPEED .....140 KT*
- *MAX SPEED .....320 KT*
  RUDDER WITH CARE ABV 160 KT

APPR PROC

- *MAX BRK PRESS ..... 1000 PSI*
- *FOR LDG ..... USE FLAPS 3*
- *GPWS LDG FLAP 3.....ON*
- *APPR SPD.....VREF + 10 KT*
- *LDG DIST PROC ..... APPLY*

ENG1 + 2 APPR IDLE ONLY
ENG1 + 2 N1 DEGRADED MODE
ALTN LAW: PROT LOST
WHEN L/G DN: DIRECT LAW
BOTH PFD ON SAME FAC
CTR TK FUEL UNUSABLE
INCREASED FUEL CONSUMPTION
SLATS/FLAPS SLOW

INOP SYS

F/CTL PROT
RUD TRV LIM
YAW DAMPER
RUD TRIM
AP 2
CAT 2
FAC 2
VENT BLOWER
VENT EXTRACT
AFT CRG HEAT
AFT CRG VENT[46]

CHECKLIST COMPLETE

7.4.6.3. Land ASAP (False)

The UAL A320 Flight Manual, Irregular Procedures, page 14.50.17, presented a procedure for false "land ASAP" ECAM messages. It stated:

[46] IR 2 and 3 and ADR 2 and 3 are not shown as "inop" systems, but they are shown in the emergency electrical configuration procedure.

"Condition: A transient smoke alert during preflight preparation (e.g., truck exhausts around the airplane) can cause the FWC to display the LAND ASAP memo message after takeoff without an accompanying ECAM."

"Action: If this memo is suspected to be false, the captain, after consulting with SAM, may consider cycling the circuit breakers for FWC 1 SPLY and FWC 2 SPLY in accordance with the System Fault Resets additional procedure."

7.4.6.4. Smoke/Fire/Fumes

The UAL A320 Flight Manual, Emergency Procedures, page 15.10.1 page 3 stated:

"The Smoke/Fire/Fumes procedure is a two-sided checklist.[47] *If there is cabin or cockpit smoke/fire, accomplish the QRC items, then remove the checklist from the Flight Manual and accomplish the appropriate Reference Action(s)."*

***"Note:** This checklist directs pilots to depower airplane systems and may generate ECAMs that direct re-powering of the systems. Any ECAM direction to re-power systems deliberately depowered per this checklist should not be accomplished."*

Recommended Cockpit Communication

- *The PF communicates with ATC using VHF 1.*
- *The PM continually communicates with the cabin using the cabin/service interphone.*
- *The cockpit crew communicates with each other using the flight interphone.*
- *The cockpit crew uses the cockpit speakers as needed depending on the situation."*

7.4.6.5. Emergency Electrical Configuration

The emergency electrical configuration procedure was in the UAL A319/A320 Flight Manual, Emergency Procedures, beginning on page 15.30.5.[48] Two separate procedures were presented, one for N401UA through N458UA (earlier airplanes), which included the incident airplane, and another for all other UAL A320's and all A319's (newer airplanes). Differences in the electrical system required that there be two checklists.

For the earlier A320's, including 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.

[47] See attachment 5
[48] See attachment 6

7.4.6.6. Evacuation

The evacuation procedure was presented on the QRC and in the UAL A319/A320 Flight Manual, page 15.30.20. Under crewmember responsibilities, it stated:

"Captain *- Immediately after the airplane stops, conditions permitting, accomplish cockpit shutdown, then proceed to mid cabin and exercise overall command inside the airplane. When all possible assistance has been given, leave the airplane and assume command outside.*

First Officer *- Immediately after the airplane stops, conditions permitting, accomplish cockpit shutdown, then proceed to the cabin and determine that all usable forward and overwing exits are open. When all possible assistance has been given, leave the airplane and assist in assembling passengers outside.*

All crewmembers *- Assemble the passengers a safe distance upwind from the airplane, keeping in mind the fire threat and approaching rescue vehicles. Provide first aid and comfort as necessary."*

8.0 Training

UAL operates under the Advanced Qualification Program (AQP). The UAL Flight Operations Training Document (FOTD) Vol. 1 lists three training curricula for pilots – Indoctrination, Qualification, and Continuing Qualification. Indoctrination is given to new hire pilots before they enter the fleet-specific qualification curriculum. Qualification is fleet specific and is presented to new hire pilots assigned to a fleet or existing pilots who are moving from one airplane to another. Qualification includes 10 hours of self-study and 24 days of classroom, video, FTD, operations knowledge evaluation (OKE), and FFS training followed by line check. Continuing Qualification, also fleet specific, is broken down in to two segments – Proficiency Check (PC) and Proficiency Training (PT), and each segment is on an 18 month cycle. PC includes 7.7 hours of self-study and 3 days of training focusing on systems and performance review, OKE, and FFS sessions. PT includes 10.2 hours of self-study and 2 days of training focusing on evacuation and ditching and a FFS session. UAL utilizes the classroom (ground school taught by Fleet Technical Instructors), printed materials, video, computer based training (CBT)/self study, flight training devices (FTD), full flight simulators (FFS), and the airplane for training.

8.1. Avionics Smoke

According to 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 *Electrical & Lighting* course included 1 slide that referenced the Avionics Smoke ECAM. Under the slide titled "Smoke Configuration" it states the following:

- Accomplished when the Avionics Smoke ECAM displayed
- Pilot configures airplane to the smoke configuration by placing the GEN 1 LINE switch on EMER ELEC PWR panel to OFF:
  - GEN 1 line contactor opens.

- GEN 2 powers AC busses 1 and 2.
- Main galley is shed.
- GEN 1 powers a fuel pump in each wing tank.
- Permits removing AC power from all busses during Avionics Smoke Irregular procedure without removing power from the fuel pumps.

A note to instructors states "Refer to FM page 14.20.39, Avionics Smoke checklist."

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. When smoke is detected in the avionics ventilation system, pilots are alerted by a single chime, illumination of MASTER CAUTION lights, an ECAM message on the E/WD, illumination of amber GEN 1 SMOKE light on the emergency electrical power (EMER ELEC PWR) panel, and illumination of amber BLOWER and EXTRACT fault lights on the VENTILATION panel. All faults, cautions and warnings are also displayed on the ECAM.

Pilots are also instructed that when the GEN 1 LINE switch is OFF the GEN 1 line contactor opens, a fuel pump in each wing tank remains powered by GEN 1 and GEN 2 powers both AC busses 1 and 2.

8.2. Emergency Electrical Training

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 a couple years ago, but was not currently done.

The *Electrical & Lighting* ground school presentation includes 6 slides focusing on the emergency electrical configuration. Training states that the emergency electrical configuration results from the loss of AC busses 1 and 2 and the RAT, which powers the emergency generator, will automatically extend if the airplane speed is above 100 knots. The training notes differences with "older A320s" in this configuration. Specifically, the emergency generator will not operate unless a minimum speed of 140 knots is maintained and the landing gear is retracted. It further states that if the landing gear is extended, the emergency generator will not work until the nose gear is retracted and the EMER ELEC PWR MAN ON switch is selected on. For newer models of the A319/320, the emergency generator will work with the landing gear extended until about 125 knots. When the emergency generator drops off line, the batteries will supply power to the AC and DC ESS busses and the AC and DC ESS SHED busses are shed. Schematics are shown to pilots of the emergency electrical configuration with battery power only and emergency generator power. An instructor note to trainees states "if you have any doubts as to which aircraft you are flying, look for the 'yellow collars' on the overhead circuit breaker panel. Yellow collared breakers means your airplane is equipped with the 'unenhanced RAT'."

Pilots are told that in the emergency electrical configuration, the flight controls will be in alternate law until the gear is lowered at which time the flight controls will be in direct law. Instructor notes state to inform trainees that both the FMGC 1 and MCDU 1 are lost when the gear is extended and that there will be no autoflight guidance in the event of a missed approach; all flying

will have to be done with raw data. Operational are the captain's PFD, ND, MCDU and E/WD screens, VHF 1, RMP, ACP 1 and 2 for communications, PA and interphone. The pilots are also instructed to manually tune the VOR/ILS as a back up to the ILS. The approach will need to be flown on the captain's side.

Three additional slides are presented which discuss the emergency electrical control panel. It states for newer A320s, the RAT and EMER GEN FAULT LIGHT will illuminate red with a loss of power to AC busses 1 and 2 if the emergency generator is not supplying electrical power, even with the landing gear extended. For "some A320s" the nose gear must be retracted. An instructor note states to "point out the NAV and LOGO light switch; earlier A320s display only NAV". Finally, pilots are instructed that the GEN 1 LINE SMOKE light will illuminate amber when smoke is detected in the avionics ventilation system and is used when running the Avionics Smoke ECAM.[49] GEN 1 LINE OFF opens the generator 1 line contactor, AC bus 1 is supplied from generator 2 through the tie bus and generator 1 supplies a fuel pump in each wing tank.

8.3. ECAM Training

Pilots are trained on the ECAM during A320 Qualification ground school and during Continuing Qualification PC and PT.

8.3.1. Qualification

Pilots are presented with a ground school lesson titled *ECAM* during week 1 of Qualification which familiarizes them with the ECAM system. During the *ECAM* lesson, pilots are instructed on ECAM color codes. For example, a red ECAM message "requires immediate attention", an amber message "requires awareness but not immediate action" and a magenta message is for "special messages (T.O. INHIBIT)".

The *ECAM* lesson also discusses three classes of ECAM maintenance messages. Class I has three levels of priority, are for failures indicated by ECAM that affect flight, and are listed in either amber or red. Class II messages are for failures that do not affect flight but must be cleared or deferred prior to flight. Class III messages are for failures that do not affect flight and are not displayed; they can only be accessed by maintenance.

A Class I Level 1 ECAM caution, i.e., a system failure resulting in loss of redundancy or system degradation, only requires crew monitoring, has no aural indication, and provides an amber caution message on the ECAM E/WD. It is generally not associated with any procedure. A Class I Level 2 ECAM caution, i.e., a system failure having no direct effect on flight safety[50], requires crew awareness but no immediate action, illuminates the MASTER CAUTION light amber accompanied by a single chime, and displays an amber caution message on the ECAM E/WD. A Class I Level 3 ECAM warning, i.e., system failure affecting flight safety or when the airplane is in a dangerous situation or flight limit condition, requires immediate action by the flight crew,[51] illuminates MASTER WARN light red and flashing accompanied by a continuous repetitive chime, specific sound or synthetic voice, and displays a red warning message on the ECAM E/WD. The applicable

[49] This information is also presented on one slide during the Fire Protection presentation.
[50] An example of a Class I Level 2 ECAM caution is an Avionics Smoke event.
[51] An example of a Class I Level 3 ECAM warning is the EMER ELEC configuration.

system pages will appear on the ECAM S/D for level 2 and 3 events.

The lesson provides examples of different ECAM memos and their related colors and states that a red LAND ASAP message is for a "system failure that requires immediate landing". Pilots are also instructed that magenta messages (T.O. INHIBIT and LDG INHIBIT) are crew reminders that "most failure titles and checklists are suppressed and eliminate unnecessary distractions during critical phases of flight". T.O. INHIBIT is "active from takeoff power application to 1500 feet AGL or for two minutes after takeoff".

Pilots are instructed that the ECAM STATUS page, displayed on the lower ECAM, provides crews with an operational summary of airplane system status. It is displayed automatically after a crew has cleared all pages of a current failure and when there is a status message and the flap handle is moved from 0 to 1. It can also be manually displayed by pushing the STS button located on the ECAM control panel. "NORMAL" will be annunciated in green if there are no active status messages. Pilots are also instructed that the "STATUS page may be cleared by pushing STS button a second time, or by pushing a CLR button".

Finally, the *ECAM* lesson discusses ECAM SOP in the context of an APU fire. Specifically it instructs pilots to do the following:

- Announce "ECAM."
- CAPT designates who will accomplish ECAM.
- PNF accomplishes ECAM out loud.
- PNF completes E/WD action steps.
- Review systems pages for secondary failures.
- Review and brief STATUS page.
- PNF announces "ECAM complete, screens normal."
- Refer to other available resources.

8.3.2. Continuing Qualification

Pilots are given guidance on use of the ECAM in the A319/A320 PC and PT Continuing Qualification course packets, Chapter 2 "Continuing Qualification Syllabus"[52]. The syllabus states the following:

> ***Flight Manual, Chapter 1 - Introduction, Section 30, Operational Guide*** has recently undergone significant changes. Please take the time to review these important 12 pages. Specifically, the ECAM Procedures section was modified in a recent revision, and it now breaks down the ECAM procedure into four distinct steps:
>
> - **Complete E/WD action steps.**
>
> a. If the pilot announcing "ECAM" did not already clear the MASTER CAUTION/WARNING, press to reset and/or silence before addressing ECAM steps.

[52] See A319/A320 Continuing Qualification Syllabus – PC pgs. 16-17 and A319/A320 Continuing Qualification Syllabus – PT, pgs. 16-17.

b. It is an important protocol to use the CLR button to sequence through the ECAM(s) . . . next page or off--screen items, the next underlined checklist, secondary failures, and onto the STATUS page.

c. The blue to--do items often clear themselves when accomplished; if not, after addressing, move on to the next item or checklist. The goal is not to miss any steps while working through the action items.

d. Some flight critical items must be recognized and verbally confirmed by both pilots:

- All red (or red--guarded) controls on the overhead panel
- All fuel--related switches on the overhead panel
- IR selectors
- Thrust levers
- ENG MASTER switches

– **Review displayed systems pages for secondary failures.**

a. The page may display on the SD, or the CLR button will advance you through the pages. Continue to use the CLR button while it is lit.

b. Resist the temptation to leave the ECAM to perform less essential tasks (FM/FOM) until the ECAM is complete.

– **Review and brief the STATUS page.**

a. Think “big to small” to start your brief and address any PF questions to complete the brief.

b. When the STATUS brief is complete and the CLR button is no longer illuminated, announce, “ECAM complete, screens normal.”

– **Refer to other available resources, as necessary.**

a. Consider all resources; e.g., Dispatch, SAM, FM, FOM, etc. These resources offer comprehensive considerations beyond the immediate actions just accomplished.

b. If ***LAND DIST PROC . . . . APPLY*** is displayed on the STATUS page, consider the following:

- This statement is direction to reference the ***APPROACH/LANDING CORRECTIONS FOR FAILURES*** procedure in the Flight Manual, Landing Performance chapter.
- This procedure provides/confirms landing configuration, and provides approach speed adjustments and landing distance factor for the condition. [FM: 8.20.]
- Verify landing flap handle setting, VAPP calculation (VREF is always VLS for flaps full), and required landing distance.
- The factors are different for runway condition (dry) versus braking action (good/medium) and are applied to different distances in the table.

Note: Dry runway distances do not include use of reverse thrust while good and medium distances assume use of full reverse thrust.

In addition to guidance in the course packets, ECAM procedures are emphasized on Day 1 of PC during Sim 1 Briefing and Sim 1 Maneuvers Training and on Day 2 during Systems and Performance Review. ECAM procedures are also emphasized on Day 2 of PT during Sim 1 Briefing and Sim 1 Maneuvers Training.

8.4. Flight Controls Training

Pilots receive training on Airbus flight controls during Qualification ground school. The first portion of the *Flight Controls* presentation focuses on manipulation of controls and cockpit indications. The second portion focuses on the flight control laws. Normal law provides five protections: (1) load factor limitation, (2) pitch attitude protection, (3) high angle of attack protection, (4) high speed protection, and (5) bank angle protection. In addition, normal law has three operational modes: (1) ground mode which is active only on the ground, (2) flight mode which is active from liftoff until flare mode engages, and (3) flare mode which is active during landing at 50 feet RA. The protections and modes are discussed in detail.

Training also reviews degraded laws which occur when multiple failures of redundant systems occur, including alternate law, direct law, mechanical back-up and abnormal attitude law. When alternate law is activated, pilots are trained that some protections are still provided and an "F/CTL ALTN LAW (PROT LOST)" message will appear on the ECAM. Training states direct law "occurs with specific multiple failures" and will automatically become active when the gear is extended in alternate law and the autopilot is not engaged. If the autopilot is engaged, the airplane will remain in alternate law until the autopilot is disengaged. No protections are available in direct law. Pilots will also receive an amber "USE MAN PITCH TRIM" message displayed in the third line of the vertical and lateral mode FMA columns and an amber "F/CTL DIRECT LAW (PROT LOST)" message on the ECAM. When a complete loss of electrical flight control signals or flight control computers occurs, mechanical back-up is activated. Side sticks are inoperative and pitch control is achieved by using the manual trim wheel to move the horizontal stabilizer as the elevator does not move. Lateral and roll control is achieved by using the rudder pedals which requires hydraulic power. Pilots will receive a red "MAN PITCH TRIM ONLY" alert on the FMA columns. Finally, abnormal attitude law activates in extreme attitudes or airspeeds and provides pilots with increased authority to recover to a normal attitude.

8.5. CRM/TEM Training

UAL provides crew resource management (CRM) and threat and error management (TEM) training[53] to all pilots under AQP. According to the UAL Airbus Training Manager, CRM was integrated throughout all of training, ground school and simulator sessions. In addition, pilots were evaluated for their CRM on all validations and evaluations. Pilots received a PowerPoint

[53] CRM/TEM training was previously referred to as C/L/R (command, leadership and resource management). On December 25, 2009, UAL made pilots aware of changes to the C/L/R chapter of the FOM via an *Increased Situational Awareness Briefing Sheet*. Changes to the program included additional discussion on TEM and risk management, updated flight safety model to reflect the continuous nature of TEM and language simplifying levels of automation. Pilots were encouraged to review the changes to the FOM made available through Sky Net.

presentation in Qualification and Continuing Qualification ground school. Pilots are instructed that CRM and TEM are interdependent. CRM is "how" crewmembers manage and communicate with internal and external resources. TEM is "what" crewmembers manage and communicate about operational and human errors. Training focuses on eight safe operating elements (SOEs) - Leadership Effectiveness, Situation Awareness, Systems Knowledge, Decision Making, Planning, Communication, Monitor/Cross Check, Workload Management, and Automation Management. The SOEs are considered a simplified summary of the CRM culture at United Airlines.

8.6. Fatigue Training

UAL does not present pilots with a specific fatigue training program; however, fatigue is discussed within other training curriculum. During Qualification, fatigue is discussed as a part of CRM's SOEs, namely within the workload management discussion. The top 10 sources of fatigue and the top 10 signs of fatigue are listed. Pilots are instructed to respond to fatigue and stress by not denying the signs, communicating it to the crew, practicing CRM skills, not flying when they have a sleep debt, paying attention to seat comfort/posture, avoiding quick fixes (such as too much coffee), and sleep/diet/exercise. Fatigue is also briefly discussed in Continuing Qualification. Specifically, in the A319/A320 PC Continuing Qualification course packet, fatigue is listed as a symptom of hypoxia and is also discussed as a factor that can increase one's susceptibility to hypoxia. It is explained that circadian rhythms and sleep deprivation increase this susceptibility. In the A319/A320 PT Continuing Qualification course packet, fatigue is listed as a factor that can adversely impact pilot-controller communications.

The UAL FOM, Vol. 3, Chapter 30, *Administration*, p. 1001, states UAL's fatigue policy. Specifically, the policy states:

"It is the pilot's responsibility, as a professional, to decide if he is not adequately rested for an assignment. Should a pilot feel that safety of flight may be jeopardized, call the Crew Desk to advise them of inability to continue due to fatigue, inform the Crew Desk when once again available for an assignment, and then fill out an FSAP."

The manual further outlines six factors that impact pilot alertness before a flight, including at home and on layovers, specifically - quantity and quality of sleep, exercise, nutrition, general health and fitness, consumption of alcohol and drugs, and general mental and emotional state. The manual states that pilots should determine what factors work best for them and implement them to maintain alertness during flight.

8.7. Optimized Proficiency Training

United's Optimized Proficiency Training (OPT) program addresses the proficiency issues of pilots by providing more focused, directed training during CQ.[54] In certain cases, pilots with less than satisfactory performance would transition from a 9 month interval to a 6 month interval with the 36 month CQ PC/PT cycle. A pilot would be placed in a reduced CQ interval for the following reasons: (1) the pilot failed an OPT event (see unsuccessful events defined, below), (2) the pilot chose to remain on a reduced CQ interval after becoming eligible to return to a standard

[54] United Airlines Flight Operations Training Document, Vol. 1, Tab E "Implementation and Operations Plan", Section 70 "Unsatisfactory Performance", p. E.70.1-E.70.2.

interval; (3) the pilot was assigned a reduced CQ interval through adherence to the Enhanced Pilot Proficiency Policy; this may or may not be due to failure of an OPT event, (4) fleet Management placed the pilot on a reduced-interval CQ cycle. This may or may not be due to failure of an OPT event. Unsuccessful events can be defined as: (1) Qualification: 50% more device time per Validation phase (SKV, PV, MPV, or LOFT); additional training required LOE or OKE; (2) PC: MTV, OKE or LOE additional training required; Day one holdover; (3) PT: An additional training period due to proficiency; (4) OE: 150% of fleet OE category time or legs; or (5) Line Check: Unsatisfactory.

United lists OPT rules as the following: (1) a PC always follows a Qualification Curriculum, a Requalification Curriculum where the PC has lapsed more than 12 months, or a PC with a failed LOE; (2) any unsuccessful event reduces a pilot's 9-month interval to a 6-month interval until that pilot performs a successful PC; (3) any two unsuccessful events out of three events reduce the training interval to 6 months for two complete curriculums ending with a PC. The curriculums are Qualification, CQ, or Requalification; (4) return to a 9/18 interval requires domicile Fleet Management involvement (TK Fleet Management consulted); (5) a 45-day Line Check, not to exceed 90 days, follows any failed LOE, Line Check, or OE that requires more than 150% of time or segments; and (6) a PC, to include Evacuation/Ditching training, follows a failed PC LOE in six months.

9.0 Company Communications

9.1. Avionics Smoke Warning Bulletin

On April 14, 2011, the UAL airbus fleet technical manager issued a bulletin to UAL airbus pilots which stated:

"THE AIRBUS FLEET HAS EXPERIENCED CASES OF SPURIOUS AVIONICS SMOKE WARNINGS LEADING TO AVIONICS SMOKE AND LAND ASAP ECAMS. THE SMOKE DETECTOR IS AN IONIZATION TYPE DETECTOR SENSITIVE TO AIR CONTAMINATION WITH MOISTURE, DUST AND POLLUTION. IT IS BEING UPGRADED TO AN OPTICAL DETECTOR LESS SENSITIVE TO NON SMOKE CONTAMINATES.

IF A LAND ASAP MESSAGE APPEARS ALONE, REFERENCE THE LAND ASAP (FALSE) IRREGULAR PROCEDURE AND ATTEMPT A RESET. IF THE AVIONICS SMOKE ECAM IS PRESENT, COMPLETE THE ECAM WITH THE FOLLOWING CONSIDERATIONS:

REF FM 14.20.41 – THE ECAM STEPS ONLY APPLY IF "PERCEPTIBLE SMOKE" (SEE OR SMELL) IS PRESENT, IF SMOKE IS "PERCEPTIBLE" VENTILATE THE AVIONICS BAY VIA THE ECAM STEPS. WAIT FOR 5 MINUTES. IF THE "PERCEPTIBLE SMOKE" GOES AWAY, YOU MAY RESTORE NORMAL VENTILATION, CONSIDER A DIVERT IF THE CAUSE OF THE SMOKE CANNOT BE DETERMINED.

IF AFTER 5 MINUTES THE "PERCEPTIBLE SMOKE" CONTINUES OR DOES NO DISSIPATE, CONTINUE THE ECAM AND CONFIGURE FOR EMERGENCY ELECTRICAL. IN ALL CASES THE ECAM DIRECTS A RESELECTION OF THE GENERATORS TO "ON" BEFORE LANDING GEAR EXTENSION, REFERENCE THE ECAM CHECKLIST, STATUS PAGE, AND FLIGHT

MANUAL FOR COMPLETE GUIDANCE."

10.0 Previous Avionics Smoke Warnings

10.1. NASA ASRS[55] data

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[56] and 22 appeared to be false warnings.[57]

10.2. UAL data

A UAL safety department study of company A319/A320 FOQA[58] 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.[59] 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).

E. LIST OF ATTACHMENTS

Attachment 1: Interview Summaries

Attachment 2: Flight Simulator Evaluation

Attachment 3: Quick Reference Checklist (QRC)

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[55] National Aeronautics and Space Administration Aviation Safety Reporting System
[56] Return to departure point is shown as a diversion.
[57] See attachment 10
[58] Flight operations quality assurance
[59] See attachment 11

Attachment 4: Avionics Smoke Procedure

Attachment 5: Smoke Fire Fumes Checklist

Attachment 6: Emergency Electrical Configuration Checklist

Attachment 7: Landing Performance Corrections

Attachment 8: Landing Speed Definitions

Attachment 9: Aircraft Log History in Crew Documents

Attachment 10: ASRS Avionics Smoke Reports

Attachment 11: UAL Crew Avionics Smoke Reports

Attachment 12: Emergency Generator/Battery Powered Equipment

Attachment 13: Airport Diagram and Instrument Approaches

Attachment 14: Warnings and Cautions

Attachment 15: Cockpit Preparation – Captain

Attachment 16: Auto Flight – Auto Thrust Limited