NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

October 1, 2021

Attachment 1 - Simulator Evaluation

OPERATIONAL FACTORS/HUMAN PERFORMANCE

DCA18LA163

Contents

SIMULATOR EVALUATON

Location: Delta Air Lines, Atlanta, GA
Date: September 28, 2020
Time: 1430-1830 EDT
Overall Objectives:

- Document simulator fidelity
- Document procedures for engine fire warnings prior to V1, after V1 but prior to Vr, and immediately after MLG weight off wheels.
- Document aircraft performance under similar environmental conditions as the accident flight's takeoff
- Document any difference with airplane handling and indications
- Document ECAM messages and fire indications before and after a dual loop fault, fire detect fault and engine fire.

Aircraft: Airbus A330-200[1] Simulator 3 at Delta Air Lines
Airport: Hartsfield-Jackson Atlanta International Airport (ATL)
Invited Participants:

Lorenda Ward (NTSB, IIC) (attended virtually via video conference)
Shawn Etcher (NTSB, Operations)
Katherine Wilson (NTSB, Human Performance)
Taylor Smith (Delta Air Lines)
Mike Schilz (Airline Pilots Association)
Todd Gentry (FAA)
Michael Millat (P&W) (attended virtually via video conference)
Craig Hildebrandt (Airbus)

Initial Simulator Setup:

- Pilots
  - Left seat – Pilot Flying – A330 Chief Line Check Pilot (CLCP)
  - Right seat – Pilot Monitoring – A330 Fleet Captain
- Configuration:
  - Weight ~468,000 lbs.
  - Fuel 118,000 lbs.
  - CG 29.7
  - Stab N/U 2.7
  - Engine 1 - 94.7% N2, Engine 2 – 94.4 N2
    - Flex Temp 36°C
  - APU - OFF
  - Outside temp 27.2°C
  - V1 -144, VR-146, V2- 150
  - Flaps 2
  - MEL items[2]

[1] The simulator was set with the GE engine profile however, the ECAM messages were determined to be the same.
[2] Neither MEL should have a factor on the accident.

        - Performance Correction for International WIFI Radome (S53-00-01)
        - Live Animals Are only authorized to be loaded in Bulk B (S25-51-02)
- Runway 26L
    - 9,999 feet
    - .4% slope down
- Weather:
        - KATL 2152Z 24015G25 10 SM FEW250 27/07 A2992 RMK AO2 PK WND 21033/2134 SLP 124 T02720067
    - Day
- Left seat is Pilot Flying (PF); Right seat was Pilot Monitoring (PM) at takeoff, normal CRM throughout.
- Fuel freeze to be utilized during the entire simulator evaluation in order to repetitively simulate the accident flight.
- All takeoffs began in place on runway 26L, except for the first takeoff which began at the holdshort line for runway 26L.
- All runs used Flex thrust for takeoff
- All runs were conducted with motion **off** unless noted otherwise.
- All runs maximum altitude of 7,000 feet
- All runs conducted until either landing or completion of checklist.
- All EGT temperatures required manual input and did not automatically increase based on the event except for events with predeteremined rate of increase such as engine acceleration or engine hot start. A Simulated EGT Overtemp was done on engine number 1 and it was a steady trend but took about 12 seconds to the EGT over limit temp of 975 degrees.

Normal Procedures Checklist

Taxi
□ **Flaps . . . . . ___, ___, ___ C&F**
□ **Takeoff speeds . . . . . ___, ___, ___ C&F**
□ **Thrust . . . . . .TOGA / FLEX ___ C&F**
□ **Trim . . . . . ___, 0 C&F**
Flight controls . . . . . ckd C&F

Before Takeoff
□ **Runway position . . . . . ___, ___ C&F**
□ **Takeoff memo . . . . . all green C&F**
□ **Takeoff briefing . . . . . .complete C**
TCAS . . . . . .TA/RA F
Flight attendants . . . . notified & acknowledged F
Re-accomplish items for rwy / performance change

After Takeoff
Flaps . . . . . up
Landing gear . . . . . up
APU . . . . . off

Climb
Altimeters . . . . . STD, xckd C&F

Descent
Altimeters . . . . . ___, xckd C&F
□ Minimums . . . . . ___, ___ C&F
□ Approach briefing . . . . . .complete PM
□ Autobrakes . . . . . as reqd PM
Seat belts sign . . . . . .ON PM

Approach
□ Flight & nav instruments . . . . . verified C&F
Cabin notification . . . . . complete C
□ FMS flight phase . . . . . APPR/DES PM
Altimeters . . . . . ___, xckd C&F

Landing
Landing gear . . . . . down C&F
Flaps . . . . . ___, ___ C&F
Spoilers . . . . . ARMED PM

After Landing
Flaps . . . . . up
Spoilers . . . . . retracted
Radar . . . . . OFF
Re-accomplish items for rwy / performance

Engine Fire Checklist

ENG 1 (2) FIRE (In Flight)

Condition: An engine fire has been detected in flight.

LAND ASAP

1. THR LEVER (affected engine) . . . . Confirm . . IDLE

Note: If after selecting the THR LEVER to idle, all FIRE indications abate (disappear), engine shut down is not mandatory. As a precaution, if the engine is at idle, use single-engine approach/land procedures (flaps 3, etc.).

2. ENG MASTER (affected engine) . . Confirm . . OFF
3. ENG FIRE pb (affected engine) . . . Confirm .. PUSH
4. APU BLEED (if engine 1 affected) . . . . . OFF

► If the crossbleed does not close automatically:

- X BLEED. . . . . CLOSE

5. AGENT 1 AFTER 10 S . . . . . DISCH
6. ATC . . . . . NOTIFY

► IF FIRE AFTER 30 S:

- AGENT 2 . . . . . DISCH

ENG 1 (2) SHUTDOWN

7. ENG START SEL . . . . . IGN
8. FUEL IMBALANCE . . . . . MONITOR

Note: After ensuring that a fuel leak does not exist, the WING X FEED valve may be opened to prevent fuel imbalance.

9. TCAS MODE SEL . . . . . TA

▼ Continued on next page ▼

▼ ENG 1 (2) FIRE (in flight) continued ▼

AIR ABNORM BLEED CONFIG

Note: Keep the X BLEED valve closed to prevent spreading of the fire or contamination of bleed air.

10.AVOID ICING CONDITIONS

- **When** flaps & slats UP:
  > If Y ELEC PUMP is running:
    - Y ELEC PUMP (lower pb) . . . . . .OFF
- Turn off wing anti-ice and do **not** use APU BLEED air for wing ant-ice purposes.
- For approach, if ice has formed on the aircraft, use an approach speed of V_{LS} (FULL) + 10 knots and apply the landing distance procedure (refer to ODM).
- Start the APU (if available) and use the APU generator for an additional source of electrical power.
- Do **not** attempt a restart of the affected engine.

Caution! Use caution if speeds below V_{LS} (e.g., windshear) are encountered with full asymmetric power. Control authority is limited as speeds approach V_{MCA}.

▼ Continued on next page ▼

▼ ENG 1 (2) FIRE (in flight) continued ▼

STATUS

CAT III approach not authorized.

APPROACH PROCEDURES	*INOP SYS*
► IF ENG 1 SHUT DOWN and G HYD SYS lost: BEFORE S/F EXTENSION: • BLUE ELEC PUMP. . . . . OFF ► IF ENG 2 SHUT DOWN and G HYD SYS lost: BEFORE S/F EXTENSION: • YELLOW ELEC PUMP. . . OFF 1. PERF APPR . . . select CONF 3 2. FOR LDG . . . . . USE FLAPS 3 3. Monitor fuel balance. 4. LDG DIST PR . . . . . APPLY (refer to ODM) 5. If a go-around is necessary, use FLAPS 2 for the go-around. **Note:** If landing overweight, see "Overweight Landing" on page 0.27.	GEN 1 (2) PACK 1 (2) ENG 1 (2) BLEED REV 1 (2) G ENG 1 (2) PUMP PART GALLEY PART SPLRS BLUE HYD (if ENG 1) ALTN BRK (if ENG 1) YELLOW HYD (if ENG 2) YAW DAMPER 2 (if ENG 2)

■ ■ ■ ■

Engine Fire on Ground

ENG 1 (2) FIRE (On Ground)

Condition: An engine fire has been detected on the ground. If at gate, refer to the EVACUATION CHECKLIST.

1. THRUST LEVERS . . . . . IDLE

WHEN A/C IS STOPPED:

2. PARKING BRK . . . . . ON

3. ATC . . . . . NOTIFY

Note: Use VHF 1 (available on battery power).

4. CABIN CREW. . . . . ALERT

5. ENG MASTER (affected engine) . . . . . .OFF

6. ENG FIRE P/B (affected engine). . . . . PUSH

7. AGENT 1 (affected engine) . . . . . .DISCH

8. AGENT 2 (affected engine) . . . . . .DISCH

► If at least one outflow valve is controlled manually:

- DELTA P . . . . . CHECK ZERO

9. ENG MASTER (opposite engine). . . . . .OFF

10. ENG FIRE P/B (opposite engine) . . . . . PUSH

Note: If the APU is not running, the aircraft will be on battery electrical power only.

11. X BLEED (if not automatically closed) . . . .CLOSE

► IF EVAC REQUIRED:

- Perform the Evacuation procedure on QRH back cover.
- APU MASTER SW. . . . . .OFF

► IF EVAC **NOT** REQUIRED:

- CABIN CREW + PAX. . . . . NOTIFY

■ ■ ■ ■

Fire Det Fault

ENG 1 (2) FIRE DET FAULT

Condition: Both fire loops on one engine are inoperative.

Note: Fire detection on the affected engine is inoperative.

1. Monitor engine parameters more closely than normal for signs of fire and/or over temperature.

Note: Consult with Dispatch regarding ETOPS considerations.

STATUS
INOP SYS
FIRE DET 1 (2)

■ ■ ■ ■

ENG 1 (2) FIRE LOOP A (B) FAULT

Condition: Fire loop A or fire loop B is inoperative on one engine.

1. No action is required. This message is for crew information only.

STATUS
INOP SYS
ENG LOOP A (B)

■ ■ ■ ■

Run 1: Normal Takeoff

Procedure

- Normal takeoff procedures
- Allow for acclimation of normal procedures and indications

	Notes
	Aircraft indications noted Aircraft/Pilot Notes: T/O Inhibit message. (Ref Photo 1 below) Inhibit non-essential messages and inhibited until 1,500 feet for takeoff. Landing also has an inhibit switch and that is in effect from 800 feet and below

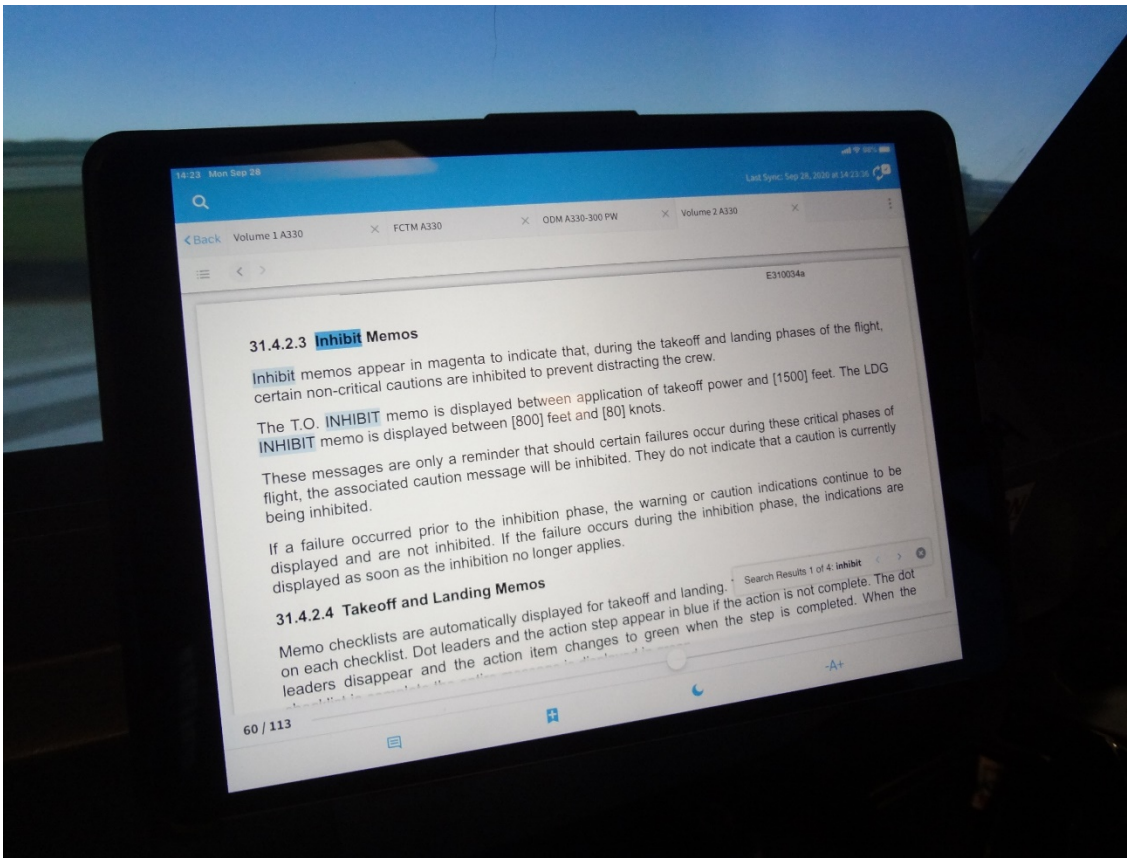

Photo 1: DAL Inhibit Message Guidance

Run 2: Normal Takeoff with Engine Fire Prior to V1 but after 80 knots

Procedure

- Normal takeoff procedures except:
- Fire indication at 135 knots (documentation of prior to V1 inhibit stage)

- Note any warning messages
- Note time elapse from fire initiation to indication and what first indication was
- Note EGT temps at fire initiation and throughout until end of simulation
- Photograph ECAM message priority
- Note and photo-document any other indication of a fire remaining after FIRE message and audibles extinguish.
- Note if Dual Loop fault message illuminates and FIRE Message extinguishes
- photo document ECAM priorities with dual loop fail

		Notes
		Normal RTO event. Fire Light on overhead panel illuminated approximately 2 seconds prior to ECAM message indication and fire audible alert[3]. It was determined to be a simulator limitation. Possibility of the Fire Warning Computer simulation delay. The firelight did illuminate at 135 knots on the overhead panel and the audible V1 was heard followed almost immediately by the fire bell.

[3] The Airbus term for the audible alert was "Continuous Repetitive Chime (CRC)".

Photo 2: T/O Inhibit Message
(Note: ENG 2 FIRE P/B on Upper Center Panel Illuminated)

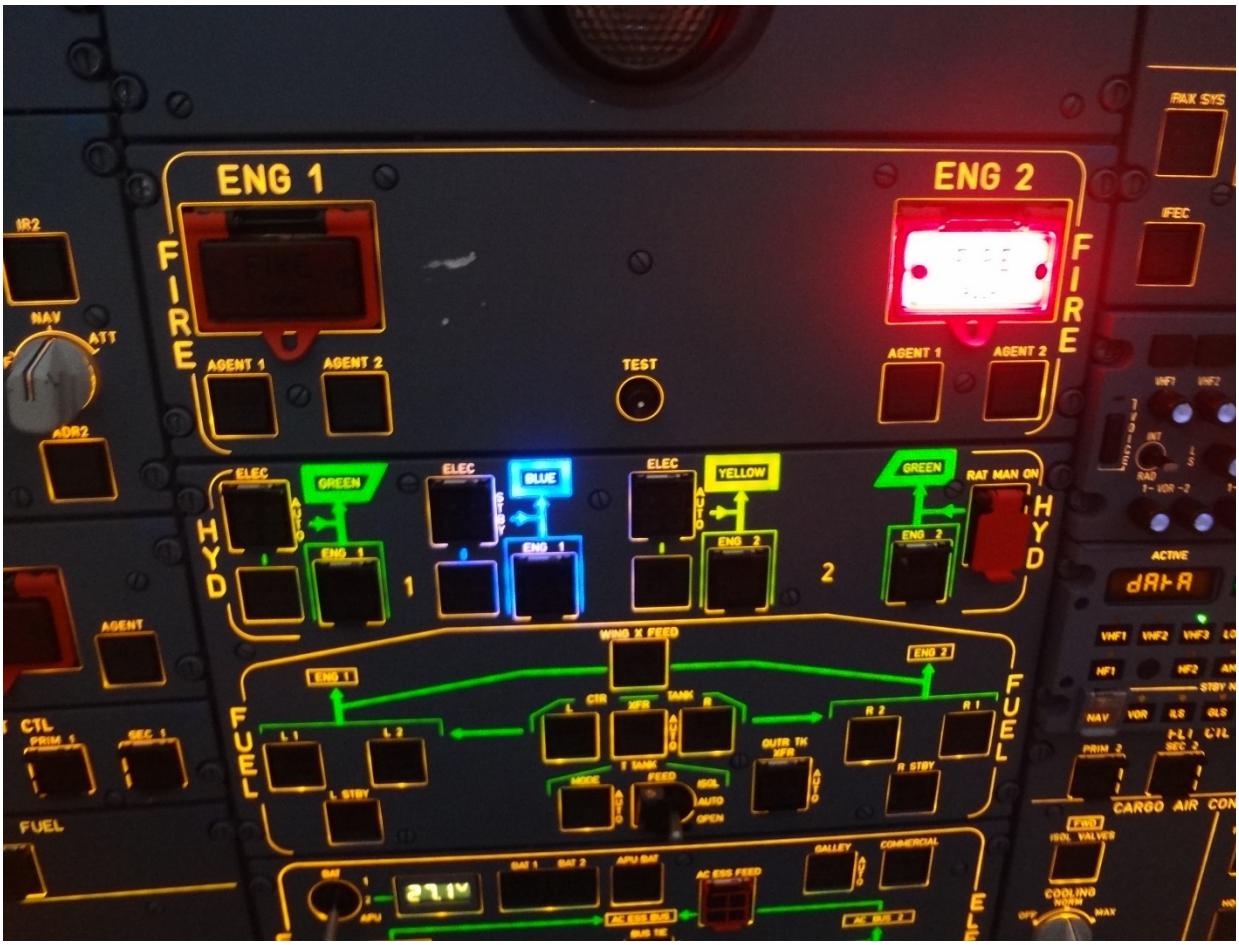

Photo 3: ENG 2 FIRE P/B Located on Upper Center Panel

Run 3: Normal Takeoff with Engine Fire at V2

Procedure

- Normal takeoff procedures <u>except</u>:
- Fire indication at V2 (150 knots)
- Note any warning messages/audibles
- Note time elapse from fire initiation to indication and what first indication was
- Note EGT temps at fire initiation and throughout until end of simulation
- Photograph ECAM message priority
- Note and photo-document any other indication of a fire remaining after FIRE message and audibles extinguish
- Note if Dual Loop fault message illuminates and FIRE Message extinguishes. Dual Loop failed per the FDR about 11m7s after liftoff.
- photo document ECAM priorities with dual loop fail

		Notes
		Engine fire was initiated at 150 knots and the indication was about 160 knots. The engine fire light on the overhead panel and on center console illuminated; however, no audible bell or Engine Fire Warning message illuminated on the ECAM until about 15 seconds after liftoff during the inhibit phase[4]. After that time expired the engine fire warning message illuminated and the audible fire bell was observed. During climbout crew ran the following checklist: ENG 2 FIRE[5] ENG 2 SHUT DOWN AIR ABNORM BLEED CONFIG (reappeared after the discharge of agent 2 on ENG 2) ELEC amber message appeared with master lever was shutoff. The following messages were indicated on the ECAM following the ENG 2 FIRE pushbutton being pressed: HYD *HYD (an * item denotes association with an item on the current open or primary checklist) F/CTL Additionally the simulator operator simulated a Dual Loop fault by simulating opening of the Eng 2 Loop A and Eng 2 Loop B fire loop circuit breaker which resulted in the Elect C/B Tripped message, which is a normal message generated by the Fire Warning Computer. However, in the simulator this message was a result of the simulator operator simulating pulling the two-circuit breaker to simulate the fault; that method was only used due to the limitation of the simulator. Additionally, ENG 2 FIRE DET FAULT caution message illuminated, and the LAND ASAP red message changed to an amber message[6], which were messages the crew should have received. Of note: The Nacelle Temp Advisory message remained after the fire indication stopped. The run ceased with the beginning of the fire checklist. The crew received vectors from simulated ATC while they accomplished the checklist items associated with the various messages. Additionally, it was noted that when only Loop B was failed the fire light on the overhead panel and the fire light at the Master

[4] The inhibit for a fire warning ceases at liftoff +15 seconds

[5] When the ENG 2 FIRE message illuminated the Nacelle Temperature Advisory appeared and was indicated by only the “ADV” white flashing message on the ECAM with a pulsing nacelle temp on the engine system page.

[6] According to a representative of Airbus when a fire detection fault occurs and the fire warning ceases, the red LAND ASAP will extinguish. The amber LAND ASAP message will illuminate due to and engine being shutdown not due to the FIRE DET FAULT.

	Lever illuminated; however, when Loop A failed and Loop B was operational only the overhead Engine Fire light illuminated. Airbus will research if that is normal in the airplane or if a simulator limitation. Additional question for Pratt and Whitney would be where in the loop the fire is detected. Additionally, powerplants may have asked that question in reference to the fire indication within the timeline.

Photo 4: T/O Inhibit Message
(ENG 2 FIRE P/B Illuminated on Upper Center Panel)

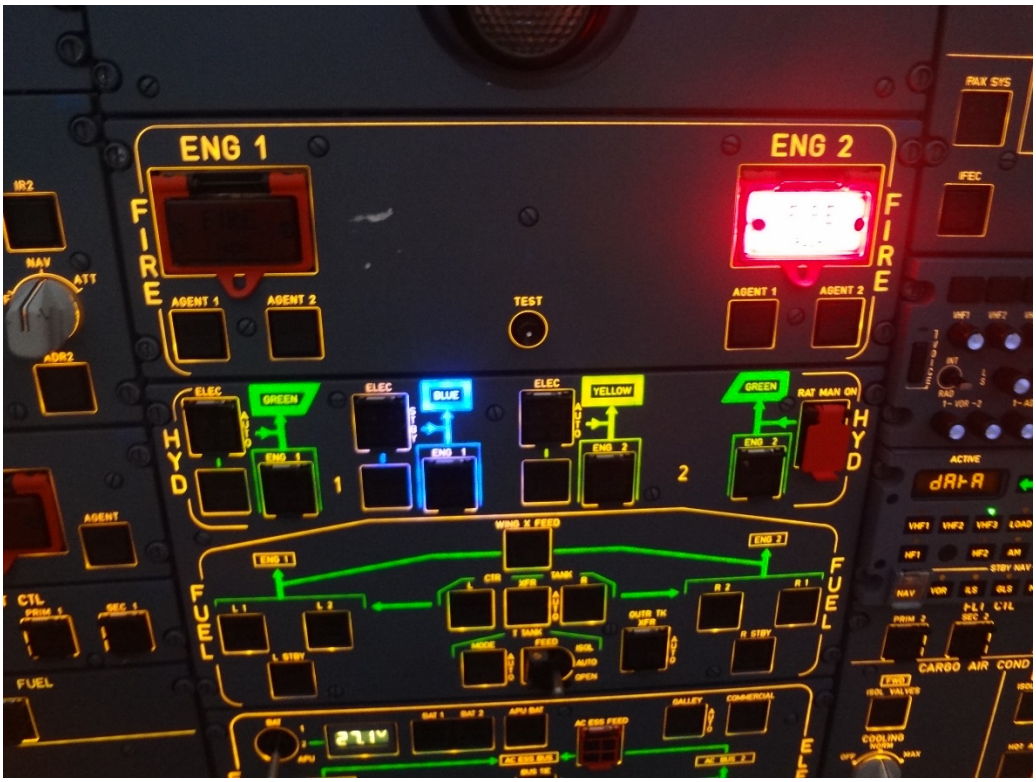

Photo 5: ENG 2 FIRE P/B Located on Upper Center Panel

Photo 6: Engine 2 Master FIRE Light Illuminated

Photo 7: Liftoff + 15 seconds ENG 2 FIRE message[7]

Photo 8: ENG 2 FIRE message and Additional Prioritized messages

[7] T/O Inhibit is still illuminated however, Liftoff + 15 seconds will illuminate specific messages, ENG FIRE was one of those messages.

Run 4: Normal Takeoff with Engine Fire and Dual Loop Failure

Procedure

- Normal takeoff procedures **except**:
- Fire indication at 160 knots (on initial climbout but less than 15 seconds since V1 knots) (**NOTE** FDR should show when the fire was even if inhibited to crew; however, shows the warning occurred at Liftoff +17 seconds[8])
- **SIM NOTE**: Select Eng 2 Fire – Unextinguishable
- Note any warning messages/audibles
- Note time elapse from fire initiation to indication and what first indication was
- Note EGT temps at fire initiation and throughout until end of simulation
- Photograph ECAM message priority
    - ~52 seconds after liftoff manually open GLC2 and BTC 1 and BTC2 closed forcing side 2 to be powered by GEN1
    - **SIM NOTE**: ~1m41s (101s) after liftoff Manual input GEN 2 FAULT and IDG 2 OIL LO PR
    - ~1m10s (70s) after liftoff ENG1 to TOGA, ENG 2 to IDLE (note HYD pressures (should be 3000 psi) and EGT should decrease steadily)
    - ~2m12s (132s) after liftoff ENG1 thrust lever to MCT notch
    - ~2m44s (164s) after liftoff ENG2 M/L OFF (HPSOV and LPSOF should close) Note HYD Pressure and EGT2 temp to see if decreasing, note ENG2 N2 speed (likely below 50% additionally note HYD pressure (Yellow dropped to 2900 on FDR)
    - ~3m (180s) after liftoff discharge bottle 1
    - **SIM NOTE**: ENG 2 FADEC A FAULT, will yield No ECAM in Sim discuss if needed
    - ~5m(300s) APU start
    - ~5m55s (355s) after liftoff ENG2 OIL TEMP advisory
    - **SIM NOTE**: Manual input ENG 2 HIGH OIL TEMP
    - ~6m5s (365s) after liftoff S/F conf 1+F selected
    - ~6m40s (400s) after liftoff Electrical reconfig (manually open BTC1 and close AGC, side 2 powered by APU Gen.)
    - **SIM NOTE**: Manual Select Eng. 2 HIGH OIL TEMP
    - ~9m53s (593s) manually input Dual Loop fault
    - **SIM NOTE**: Manual Select/Open Circuit Breakers for both Eng. 2 fire Loops
    - Note if Dual Loop fault message illuminates and FIRE Message extinguishes
        - photo document ECAM priorities with dual loop fail
    - ~10m (600s) after liftoff
    - Select - S/F conf CLEAN
    - ~10m16s (616s) ENG2 FIRE warning stop (likely manual input from sim, however, show amber LAND ASAP message if not automatic)

[8] Reference page 3 of Airbus DAL A330 MSN578 ENG2 Fire event – DFDR Timeline – with ECAM alerts pdf

- **SIM NOTE** manual input ENG 2 EGT 2 600C for over limit warning (FDR showed ~30s later).
- **SIM NOTE**: Manual input ENG2 OIL TEMPERATURE
- ~15m30s (930s) decrease HYD-Y to 0
- **SIM NOTE**: manual input, HYD Y RSVR LO PR and HYD Y SYS LO PR (should trigger ECAM warning leave active until on runway)
- 16m20s (980s) manual select PRV2 open
- **SIM NOTE**: Manual Input EGT2 Temp (FDR shows 800C) Note ECAM EGT TEMP_____C
- ~17m30s (1050s) SIM NOTE: Manual input ENG 2 EGT to 250C. Note ECAM EGT TEMP _____C
- ~18m30s (1110s) S/F Conf 1 select
- **SIM NOTE**: manual input pressure drop on HYD G and B during slat operations
- after ~22m25s (1345s) S/F Conf 2 select, Landing gear down, S/F Conf 3 in normal sequence.

	Notes
	Similar to Run 3, the length of the run was about 26 minutes[9] in length. Engine fire was initiated at 150 knots and the indication was about 160 knots. The engine fire light on the overhead panel illuminated; however, no audible bell or Engine Fire Warning message illuminated on the ECAM until about 15 seconds after liftoff during the inhibit phase. After that time expired the engine fire warning message illuminated and the audible fire bell was observed. During the run Engine 2 EGT temperatures did not display after a period of time following the engine shut down, due to the FADEC being depowered. Those engine indications were replaced with amber "X"s. The EGT over limit message did not appear on the ECAM. During climbout crew ran the following checklist: ENG 2 FIRE ENG 2 SHUT DOWN IDG LOW OIL PRESS GEN 2 FAULT[10] AIR ABNORM BLEED CONFIG (reappeared after the discharge of agent 2 on ENG 2) ELEC amber message appeared with master lever was shutoff. HYD *HYD (an * item denotes association with an item on the current open or primary checklist) F/CTL

[9] During the simulator evaluation with the other group members performing this scenario they timed the run at 27m27s.

[10] In the simulator these were cleared by the flight crew due to the action of disconnecting the IDG could not be accomplished. A likely reason was due to the reduction in oil pressure following the engine being shut down.

		NOTE: the photos from the previous run include the same messages as this run as the runs were identical to the initiation of the ENG FIRE checklist. The following photos were specific photos for this run.

Photo 9: ENG 2 FIRE checklist items displayed on the ECAM

Photo 10: ENG 2 FIRE P/B on Upper Center Panel

Photo 11: ENG 2 Master FIRE Light Illuminated on Center Pedestal Aft of the Thrust Levers.

Photo 12: ENG 2 FIRE Message and Associated Messages on ECAM

Photo 13: ENG 2 SHUT DOWN Checklist on ECAM.

Photo 14: ENG 2 FIRE P/B Pressed and Agents 1 and 2 Discharged

Photo 15: HYD Y SYS LO PR Message on ECAM and Hydraulic System Page Displayed on Lower Screen

Photo 16: Status Messages on ECAM

Photo 17: ENG 2 FIRE DET FAULT Message[11]

[11] C/B TRIPPED message was due to the simulator operator simulating opening up the circuit breaker as was the way of simulating both fire loop A and B fault messages.

Photo 18: Normal Indication of FIRE DET FAULT Message Without Opening Circuit Breaker

Photo 19: ENG 2 FIRE P/B Not Illuminated Following the FIRE DET FAULT Message.

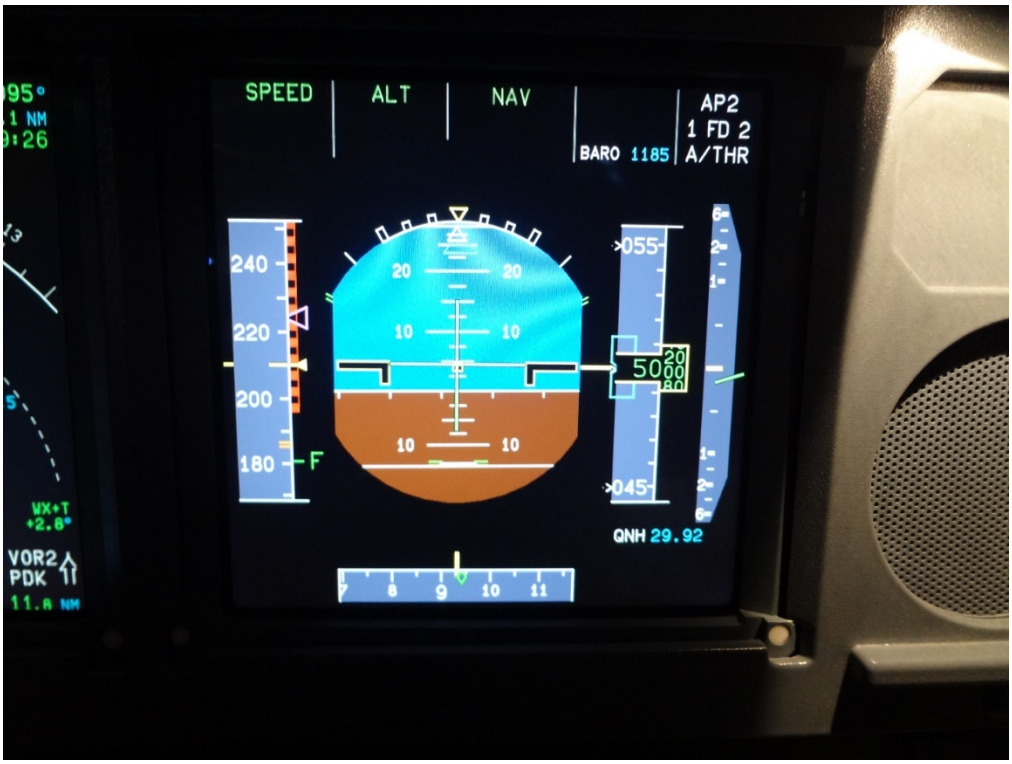

Photo 20: Overspeed Indication when Thrust Levers Not Reduced

Run 5: Normal Takeoff with Engine Fire (DAL Procedures)

Procedure

- Normal takeoff procedures except:
- Fire indication at 700 feet.
- Note any warning messages/audibles
- Note time elapse from fire initiation to indication and what first indication was
- Note EGT temps at fire initiation and throughout until end of simulation
- **SIM NOTE**: Manual Select ENG 2 FIRE – UNEXTINGUISHABLE
- **SIM NOTE**: Input GEN 2 FAULT when appropriate
- **SIM NOTE**: Open C/Bs for ENG2 Fire loops during but later in the event
- Discharge bottles as appropriate per procedures
- Photograph ECAM message priority
- Note if Dual Loop fault message illuminates and FIRE Message extinguishes (if not automatic open circuit breakers for loop system)
- photo document ECAM priorities with dual loop fail

	Notes

		The length of the run was about 11m15s[12] in length. Crew operated this run as if a real-life event and what they would have done. Of note: the crew routinely landed at ATL, they were aware that the length of the intended runway had adequate stopping distance for the flight; therefore, the crew did not run the performance numbers in the manual. Engine fire was initiated at 150 knots and the indication was about 160 knots. The engine fire light on the overhead panel illuminated; however, no audible bell or Engine Fire Warning message illuminated on the ECAM until about 15 seconds after liftoff during the inhibit phase. After that time expired the engine fire warning message illuminated and the audible fire bell was observed. During climbout crew ran the following checklist: ENG 2 FIRE ENG 2 SHUT DOWN AIR ABNORM BLEED CONFIG (reappeared after the discharge of agent 2 on ENG 2) ELEC amber message appeared with master lever was shutoff. HYD *HYD (an * item denotes association with an item on the current open or primary checklist) F/CTL During the landing flare the master caution alert for the Elect C/B Tripped message and ENG 2 FIRE DET FAULT message illuminated on the ECAM. NOTE: This run was similar to the previous run; however, it was conducted at what the pilots in the simulator considered a "normal" return to the airport following an engine fire indication.

[12] During the simulator evaluation with the other group members, during this run they timed the event as 11m1s

Airport Diagram

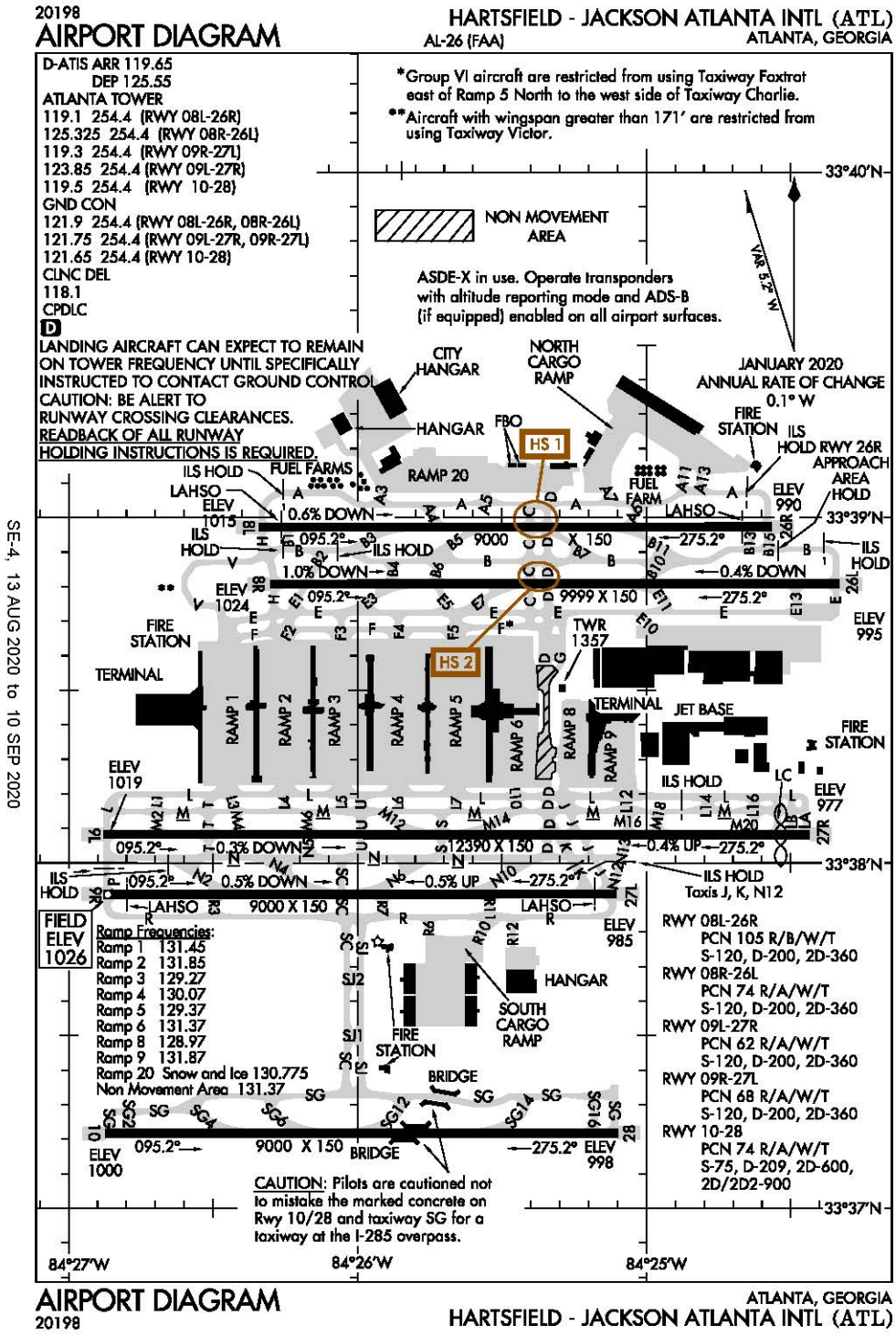

Figure 1: ATL Airport Diagram

ILS 27R

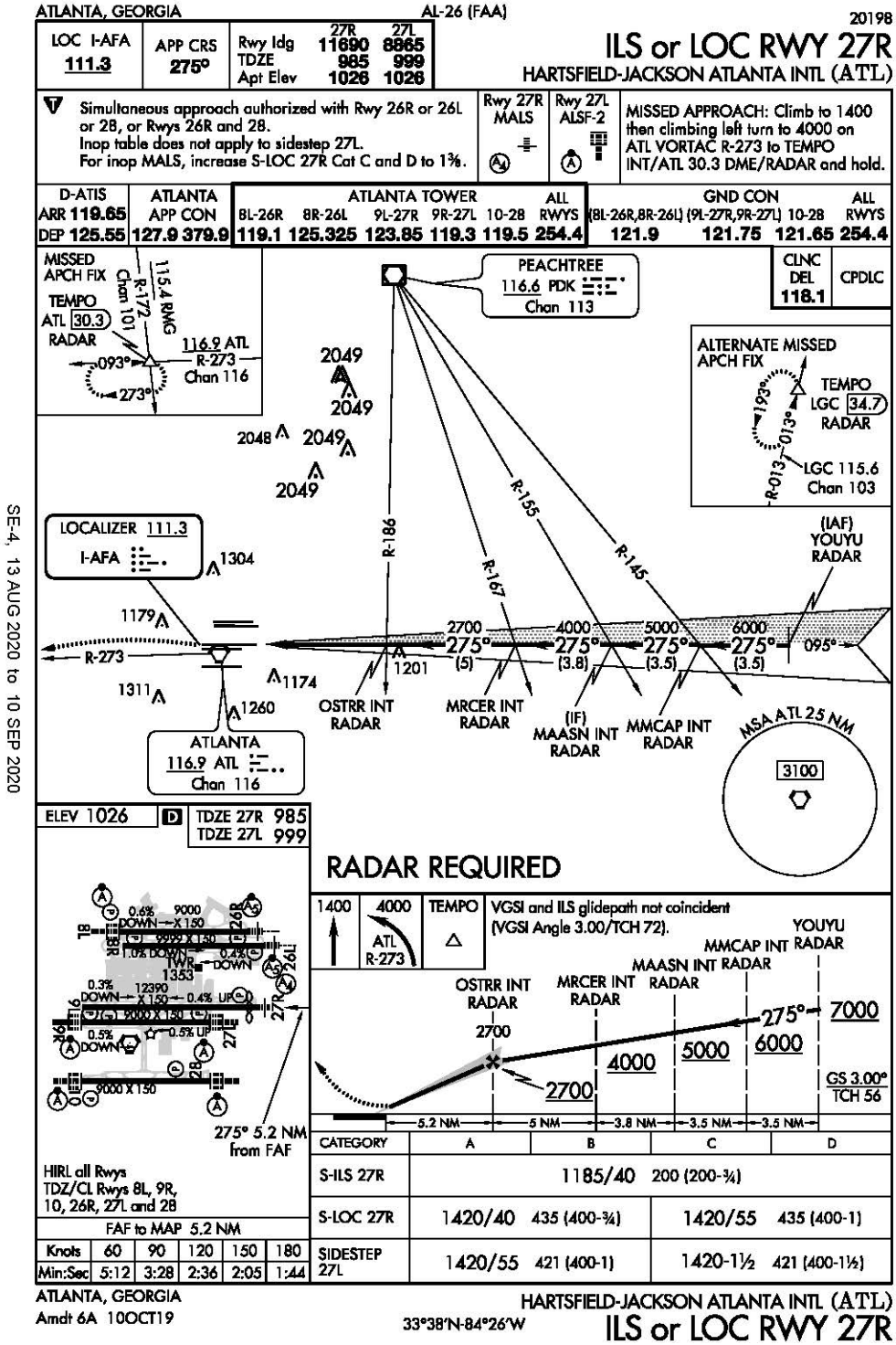

Figure 2: ATL ILS 27R Approach Chart

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APPENDIX 1

Airbus Response to Questions During Simulator Evaluation

As a result of the simulator testing, the investigative group requested that Airbus research the warnings triggered by the engine fire detection unit (see "Notes" section, page 16 of this document). The following information is an excerpt from the email received from a Bureau d'Enquêtes et d'Analyses (BEA) of France investigator, on March 17, 2021, in response:

Extract from the Airbus report (TT1 Final Airbus full report DAL A330 MSN 578 N806NW Eng2 fire):

The Engine Fire and Overheat Detection on A330 comprises thermo-sensitive sensing element also called loops, installed in the engine core compartment enabling to detect a fire or overheat condition.

When the temperature in the monitored area where the engine core compartment reaches the preset threshold, the loops trigger warnings via the Fire Detection Unit (FDU) which processes the signals generated by the responder of the detectors.

The fire detectors are installed by pair (loop A / loop B) in the core compartment:
-under the pylon box,
-at the left thrust/reverser (T/R) cowl door,
-at the right thrust/reverser (T/R) cowl door.

For the Fire detection function, the two channels normally operate together, with an AND logic. However, if one loop is inoperative, each loop can operate independently in the fire detection function. Each channel receives and analyzes continuously the signal given from its related detection loop. Three comparators are used for this analysis:
-the FIRE comparator,
-the CONTAMINATION comparator,
-the INTEGRITY comparator.

The output signals of the fire detection unit are generated via discrete signals and/or the ARINC 429 bus.

When a fire or overheat detection is confirmed by the engine fire detection unit (FDU), the following fire warnings are triggered:
-the ENG/FIRE control panel (255VU),
-the ENG MASTER control panel (125 VU),
-the MASTER WARN light,
-the Engine Warning Display (EWD),
-the System Display (SD),
-the aural warning sounds.

The monitoring circuitry analyses and monitors continuously the fire detection system. In case of failure of the system, the monitoring circuitry memorizes the fault in a non-volatile memory, isolates the faulty channel, generates the appropriate discrete signals (i.e. LOOP A(B) INOP ENG 1 (2) to the FWC 1(2)).

Per standard operating procedure during cockpit preparation, the TEST pushbutton is activated to monitor the state of the Engine fire protection system.

Per regulation (CS 25.1203(e)), each fire detection system component penetrating in the designated fire zone which corresponds to the core compartment has been demonstrating to withstand a standard fire (fire of roughly 1100°C providing a heat flux of 116 kW/m2) during at least 5 minutes corresponding to the Fire Resistant qualification. For a fire duration of more than 5 minutes, some components of the fire detection system within the zone where the fire is located can therefore fail. The consequence at the Fire detection system level, if one component in each channel fails (within a duration longer than 5 seconds) is to declare a Fire Detection Fault which is a signal appearing at the ECAM display, meaning that the system is no longer able to detect a fire.

It has to be noted that the Fire Warning remained "On" during 10min 2sec during this event with the Fire Warning popping up at 22:09:22 then stopping at 22:19:24 according to the DFDR. This is consistent with the Fire Det Fault message that appeared during the minute 22:19 according to Airman report.

<u>Extract from the NTSB Factual OPS HF report:</u>

Consequences of "Fire Detection Fault" activation on other messages:

- *Fire Warnings cease:*
  -the ENG/FIRE control panel (255VU),
  -the ENG MASTER control panel (125 VU),
  -the MASTER WARN light,
  -the Engine Warning Display (EWD),
  -the System Display (SD),
  -the aural warning sounds
- *When a fire detection fault occurs and the fire warning ceases, the red LAND ASAP will extinguish. The amber LAND ASAP message will illuminate due to an engine being shutdown, not due to the FIRE DET FAULT.*

<u>Comments:</u>

In terms of Engine Fire Warning messages as experienced during the subject event within the 5 minutes from the triggering of the first related warning, they are coherent with the applicable certification requirements.

In terms of warning system logic after that the FIRE DET FAULT message triggers, it is designed on the concept that the system is not anymore able to detect the fire. Keeping all the Fire Warnings "On" would include the case where the fire is not there anymore, and the ENG FIRE warning remains "On" just because the FIRE

DET FAULT is "On". From a system point of view (in terms of certification), the current logic complies with the certification requirements.

From a Human Factors perspective, although the flight deck indications do not reflect the actual aircraft situation in the case described above and could therefore be seen as misleading for the crew, it has to be noted that there is no more flight crew action expected nor available with regards to the fire extinguishment. Discussion is ongoing from a HF point of view on the required crew awareness: should the crew attention be kept on the fire situation or on the required LAND ASAP. These considerations need to be studied and may require a change from amber to red of the LAND ASAP message in case of FIRE DET FAULT triggering, and on the priority assigned in the list of messages to the FIRE DET FAULT itself.