Final Report

DASSAULT FALCON 7X, REGISTRATION VQ-BLP
GROUND FIRE

25 JUNE 2018

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Transport Safety Investigation Bureau
Ministry of Transport
Singapore

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The Transport Safety Investigation Bureau of Singapore

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GLOSSARY OF ABBREVIATIONS

AES	Airport Emergency Service
APU	Auxiliary Power Unit
CAS	Crew Alerting System
CVDR	Combi voice and data recorder
e-DG	easy-Dispatch Guide
FGDA	Fault Guide for Dispatch Assistant
FIM	Fault Isolation Manual
MEL	Minimum Equipment List
MPD	Maintenance Planning Document
P/B	Pushbutton
PIC	Pilot-in-Command
psi	Pound(s) per square inch (a unit of pressure)
PTFE	Polytetrafluoroethylene

SYNOPSIS

On 25 June 2018, at about 1141 local time, a Falcon 7X aircraft was preparing for departure to Seychelles when the flight crew received a backup hydraulic pump overheat caution message from the aircraft's Crew Alerting System (CAS). The cabin crew also reported to the flight crew of a burning smell in the cabin. Shortly after that, the flight crew also received a warning message from the CAS about a smoke in the baggage compartment.

The Co-pilot got out of the aircraft and went to the rear of the aircraft to check the aft baggage compartment for fire. He removed the baggage in the compartment but did not see any smoke or fire.

The passengers were disembarked and waited in the boarding room while the flight crew consulted with the operator's local maintenance service provider. The flight crew then performed troubleshooting on the backup hydraulic pump, which included several attempts to restart the backup hydraulic pump. Subsequently, a small fire occurred in the mechanic service compartment located at the tail of the aircraft. The fire was put out by the flight crew using fire extinguishers available in the cockpit. No one was injured.

The Transport Safety Investigation Bureau classified this occurrence as a serious incident.

AIRCRAFT DETAILS

Aircraft type	:	Falcon 7X
Aircraft manufacturer	:	Dassault Aviation
Operator	:	PlanAir Enterprise Limited in Bermuda
Aircraft registration	:	VQ-BLP (Bermuda-registered)
Numbers and type of engines	:	3 x Pratt & Whitney PW307A
Engine hours/cycles since new	:	2,622 hours / 717 cycles (same for all three engines)
Engine hours/cycles since last shop visit	:	Nil previous shop visit
Date and time of incident	:	25 June 2018
Location of occurrence	:	Bay 304 at Changi Airport, Singapore
Type of flight	:	Private
Persons on board	:	9

1 FACTUAL INFORMATION

All times used in this report are Singapore Local Time (LT) unless otherwise stated. Singapore Local Time is eight hours ahead of Coordinated Universal Time (UTC).

1.1 History of the flight

1.1.1 At 0915LT on 25 June 2018, a Falcon 7X aircraft departed Seletar Airport in Singapore for Changi Airport in Singapore. The purpose of the short flight was to pick up five passengers in Changi Airport for a subsequent flight to Seychelles. The flight crew comprised two captains, one flying as Pilot-in-Command (PIC) on the left seat and the other as Co-pilot on the right seat. The aircraft also carried two cabin crew. In accordance with the AFTER START checklist, the backup hydraulic pump was set to the AUTO mode (see paragraph 1.6.2) during the flight from Seletar Airport to Changi Airport.

1.1.2 The aircraft arrived at bay 304 in Changi Airport at 0946LT. The flight crew performed the AT RAMP checklist – setting the park brakes, starting the Auxiliary Power Unit (APU) to provide power to the aircraft, and shutting down the engines[1], etc.

1.1.3 When the flight crew was in the midst of performing the AT RAMP checklist, a cabin crew came to the cockpit[2] to ask for their consent to let the ground service crew come into the aircraft for aircraft servicing. The flight crew gave their consent. The cabin crew opened the aircraft door (at the front left of the aircraft) to allow the ground service crew to get into the aircraft. Later, while the flight crew were still performing the AT RAMP checklist, they were distracted by the ground service crew who asked them about the servicing they would need.

1.1.4 The flight crew ended the AT RAMP checklist without switching off the backup hydraulic pump. According to the flight crew, they missed doing so because they had been disrupted in the checklist performance by the requests of the cabin crew and the ground service crew.

1.1.5 For the departure to Seychelles, passenger boarding was completed by about 1130LT.

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[1] After the engines were shut down, the APU became the only source of power for the aircraft's operation on the ground.

[2] The aircraft was not installed with a cockpit door.

1.1.6 At about 1141LT, while preparing the aircraft for departure, the flight crew received a "BACKUP PUMP HI TEMP" caution message[3] (meaning backup hydraulic pump overheat) from the aircraft's Crew Alerting System (CAS). In response, the flight crew switched off the backup hydraulic pump and carried out the aircraft electronic checklist. The cabin crew also reported to the flight crew of a burning smell in the cabin. Shortly after that[4], the flight crew also received a "SMOKE: BAG COMP" warning message (meaning smoke in the baggage compartment) from the CAS.

1.1.7 The Co-pilot stepped out of the aircraft and went to the tail of the aircraft to check the baggage compartment. He checked the baggage compartment, with the baggage removed, but did not see any smoke.

1.1.8 At the same time, a cabin crew went to the lavatory at the aft cabin to access the baggage compartment through an access door in the lavatory. The cabin crew also did not see any smoke in the baggage compartment.

1.1.9 The flight crew then decided to disembark the passengers for them to wait at the boarding room. They used the easy-Dispatch Guide (e-DG)[5] to determine the aircraft dispatch status and then sent a snapshot of the hydraulic synoptic page and fault message to the local maintenance service provider for advice. The local maintenance service provider recommended the flight crew not to operate the backup hydraulic pump. The flight crew also contacted its company's Maintenance Control Centre who suggested that they switched off the APU power, which they did (at 1147LT). This shut down the aircraft systems (including the CAS) which were let to cool down.

1.1.10 The flight crew decided to troubleshoot the backup hydraulic pump. This involved switching on the APU and the backup hydraulic pump several times. Subsequently, a small fire occurred in the mechanic service compartment at the tail of the aircraft aft of the baggage compartment, where the backup hydraulic pump was located. The table below summarises the consequences

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[3] During the flight from Seletar Airport to Changi Airport, the backup hydraulic pump had been set in AUTO mode (see paragraph 1.6.2.2). On arrival in Changi, when the engines were shut down, the engine driven hydraulic pump for hydraulic system B stopped operating, and since the backup hydraulic pump was not switched off (see paragraph 1.1.4), the backup hydraulic pump that was in AUTO mode kicked in to power hydraulic system B. The backup hydraulic pump had been operating for about 1 hour and 50 minutes when the "BACKUP PUMP HI TEMP" message appeared (since about 0946LT when the aircraft engines were shut down after arrival at bay 304).

[4] 30 seconds later, according to data from the flight data recorder.

[5] The e-DG is in Portable Document Format (PDF) with hyperlinks to allow flight crew to navigate through different parts of the guide in response to the various fault messages, CAS messages, etc., and to help them determine the procedures to follow and whether the flight could be dispatched. The flight crew performed the e-DG process as indicated in paragraph 1.17.2

of the troubleshooting actions and the crew's observations and actions.

APU switch-on attempt	Time of switching on APU	Time of switching off APU	Remarks
1st	11:55:29LT	11:55:56 LT	• The APU was switched on about 8 minutes after the last shutdown at 1147LT). • CAS "BACKUP PUMP HI TEMP" message reappeared even though the flight crew did not switch on the backup hydraulic pump. • The flight crew immediately shut down the APU.
2nd	12:06:31LT	12:18:40LT	• The APU was switched on 11 minutes after the last shutdown. • No CAS "BACKUP PUMP HI TEMP" message or warning message appeared. • The Co-pilot stepped out of the aircraft to open the door of the mechanic service compartment to ventilate the compartment. • The flight crew switched on the backup hydraulic pump to test its functioning. There was no CAS "BACKUP PUMP HI TEMP" message but they found the hydraulic pressure very low[6]. They turned off the pump. They then

[6] Between 64 to 80 psi (according to data from the aircraft's combi voice and data recorder (CVDR)), as compared to the minimum of 2,900 psi expected from a normally operating pump.

			tried turning on the pump another five times[7] but the hydraulic pressure was found to be very low each time and they switched off the pump after each of these five tries. This confirmed to the flight crew that the backup hydraulic pump was not working. • The flight crew then shut down again the APU. • The Co-pilot disconnected the aircraft battery in the mechanic service compartment[8]. • The PIC also went to the mechanic service compartment and felt that the compartment was hot. In particular, he found the backup hydraulic pump body hot to the touch.
3rd	12:51:17LT	12:55:25LT	• The APU was switched on 32 minutes after the last shutdown. • The flight crew switched on the backup hydraulic pump at 12:53:45LT. There was no CAS "BACKUP PUMP HI TEMP" message and they noted that the hydraulic synoptic page of the CAS showed a hydraulic pressure of about 200 psi[9] only, but it dropped

[7] According to data from the CVDR

[8] The flight crew were advised by their Maintenance Control Centre to disconnect the aircraft battery. According to the operator, spurious fault messages could sometimes be cleared by disconnecting the aircraft battery (after the aircraft had been powered down totally).

[9] 198 psi, according to CVDR data

			quickly to zero psi[10]. • The flight crew made another attempt[11] to switch on the backup hydraulic pump. As the hydraulic pressure dropped to zero psi, a STBY PUMP FAIL message[12] appeared in the cockpit and the cabin crew also reported to the flight crew of the same burning smell as before. • The Co-pilot exited the aircraft again and saw fluid dripping from the mechanic service compartment and the puddle of fluid on the ground caught fire. The Co-pilot ran back to the cockpit to inform the PIC of the fire and grab a fire extinguisher. • The PIC then shut down the APU[13].

1.1.11 After grabbing a fire extinguisher from the cockpit, the Co-pilot went back to the tail of the aircraft to put out the fire on the ground (see **Figure 1**) as well as the fire in the mechanic service compartment. The PIC also came up with another fire extinguisher and discharged it into the compartment.

[10] CVDR data showed that, after the pump was switched on, the hydraulic pressure increased to 198 psi and then fluctuated. before dropping to zero psi in less than one minute.

[11] According to CVDR data

[12] The backup hydraulic pump is also referred to as a standby pump in view of its being on standby to provide power for hydraulic system B when the engine driven hydraulic pump fails.

[13] Estimated to be at 1255LT, on the basis that the APU shutdown took place at about the same time as the Co-pilot was fighting the fire, as shown in the photograph in Figure 1 of paragraph 1.1.11, which was taken by a ground staff using a mobile phone and which bore a timestamp of 1255LT.

Figure 1: Pilot putting out the fire on the ground

1.2 Injuries to persons

1.2.1 No one was injured.

1.3 Damage to aircraft

1.3.1 The damages were limited to some components and adjacent structure within the mechanic service compartment (see **Figure 2**).

1.3.2 The mechanic service compartment was inspected by the local maintenance operator's mechanic for any source of leak that could have contributed to the fire. The mechanic found hydraulic wetness on the backup hydraulic pump pressure line. There was no other leak found in the compartment.

Figure 2: Damage to mechanic service compartment

1.4 Other damage

1.4.1 Nil

1.5 Personnel information

1.5.1 Pilot-in-command

Gender	Male
Age	52

Nationality	Angola
Licence	Air Transport Pilot Licence issued by the U.S. Federal Aviation Administration Aircraft ratings - B200, FK50, F20, A310, EMB135, Falcon 7X
Licence validity	Valid till 30 July 2018
Medical certificate	Class 1 Medical Certification Limitation must wear corrective lenses
Last base check	6 Jun 2018
Last line check	2 Feb 2018
Total flying experience	8,965 hours 35 minutes
Total on type	1,252 hours 05 minutes
Flying in last 24 hours	00 hours 35 minutes
Flying in last 7 days	08 hours 25 minutes
Flying in last 90 days	71 hours 05 minutes

1.5.2 Co-pilot

Gender	Male
Age	43
Nationality	Angola
Licence	Air Transport Pilot Licence issued by the U.S. Federal Aviation Administration Aircraft rating – Falcon 7X
Licence validity	Valid till 30 Jul 2018
Medical certificate	Class 1 Medical Certification Nil limitation
Last base check	08 March 2018
Last line check	09 June 2018
Total flying experience	4,503 hours 30 minutes
Total on type	1,500 hours 00 minutes
Flying in last 24 hours	00 hours 35 minutes
Flying in last 7 days	07 hours 55 minutes
Flying last 90 days	55 hours 50 minutes

1.6 Aircraft information

1.6.1 General

1.6.1.1 The aircraft was manufactured in 2011, with serial number (S/N) 132.

Certificate of airworthiness	Issued by Bermuda Civil Aviation Authority on 28 September 2011 Expiry date - 27 October 2018
Time/Cycle since new	2,622:38 hours / 717 cycles

Last checks	B1 inspection on 16 January - 10 May 2017 12-, 24- and 36-month Inspections on 7 March - 19 April 2017

1.6.2 Backup hydraulic pump and motor assembly

1.6.2.1 The backup hydraulic pump was to provide back-up hydraulic power to hydraulic system B. The pump was mounted on and driven by an electrical motor.

1.6.2.2 Via a pushbutton (P/B) on the overhead panel in the cockpit, the backup hydraulic pump could be selected to one of the following three modes:

- AUTO mode (Normal mode when in flight) – The backup hydraulic pump will operate automatically when the engine driven hydraulic pump fails to provide power for hydraulic system B.
- ON mode – This commands the backup hydraulic pump to power hydraulic system B.
- OFF mode (Normal mode when parked) – This commands the backup hydraulic pump to stop powering hydraulic system B.

1.6.2.3 Prior to aircraft departure, after the flight crew had started the engine, the AFTER START checklist would have to be performed before aircraft taxiing. One of the steps in the checklist was to test the backup hydraulic pump by a long press on the backup hydraulic pump P/B to select ON and check that hydraulic system B had been pressurised to at least 2,900 psi. After that, the checklist would require the flight crew to press the P/B to select AUTO, i.e. the backup hydraulic pump was to be left in the AUTO mode during a flight.

1.6.2.4 At the end of a flight, the AT RAMP checklist would require the flight crew to press the backup hydraulic pump P/B to select OFF. This was to be done after the engines were shut down. Also, the engines were to be shut down before the FASTEN SEAT BELT sign was turned off.

1.6.2.5 The operational history of the backup hydraulic pump was as follows:

Installation of backup hydraulic pump	Backup hydraulic pump		Pump motor	
	Flight hours	Flight cycles	Flight hours	Flight cycles
Initially installed on Falcon 7X S/N 044	986	443	(Another motor installed)	
Then installed on	1,693	348	1,693	348

Falcon 7X S/N 090				
Then installed on occurrence aircraft (on 5 November 2014)	1,456	382	1,456	382
Total	4,135	1,173	3,149	730

1.6.2.6 The backup hydraulic pump was air cooled by an internal fan attached to the motor rotor and was designed to provide sufficient cooling at or below 15,000 feet. The aircraft manufacturer did not prescribe any calendar time nor flight cycle/flight time limits for the operation of the backup hydraulic pump, but had prescribed the following:

(a) As indicated in the AT RAMP checklist, the backup hydraulic pump was to be switched off once the engines were shut down.

(b) The backup hydraulic pump was to be replaced:
(1) following a confirmed high temperature event[14]; or
(2) as and when necessary.

1.6.2.7 The backup hydraulic pump manufacturer demonstrated, for the purpose of the pump's life qualification, that a pump could achieve cumulative cycles[15] of operation amounting to 1,528 hours with a replacement of all the motor brushes after 826 hours. The qualification test was performed in a controlled test chamber at ambient temperature from –40˚C to 75˚C (-40˚F to 167˚F) simulating cumulative cycles operation representative of the normal operation conditions of the pump during its life. The pump manufacturer also tested the pump in continuous operation for at least 40 minutes in order to be confident that the pump would be able to function as required even in a three-engines-out situation.

1.6.2.8 The backup hydraulic pump on the occurrence aircraft was installed on 5 November 2014 at aircraft flight hours of 1,166 and aircraft flight cycles of 335. The backup hydraulic pump was maintained in accordance with the aircraft

[14]The aircraft manufacturer's Fault Isolation Manual relating to the "HYD: STBY PUMP HI TEMP" message stated that any confirmed high temperature event affecting the backup hydraulic pump would entail the replacement of the hydraulic pump as the extent of the damage to the electrical motor was unquantifiable.

[15] An example of a test performed under ambient temperature of 75°C (representative of operating the unit on a 'hot' day) was to operate the pump to supply one gallon per minute for 30 seconds and 2.9 gallon per minute for 20 seconds. The unit was then turned off for nine seconds before starting the next cycle. This cycle of 50 seconds of test and nine seconds of break was repeated continuously for 49 hours. Together with other test cycles carried out at different ambient temperature, the pump was operated to accumulate a total operating time of 1,528 hours.

manufacturer's maintenance schedule[16].

1.6.2.9 There is a built-in thermal switch in the motor of the backup hydraulic pump. When the temperature of the motor reaches 180°C (356°F), the thermal switch will trigger an amber CAS message "BACKUP PUMP HI TEMP" to alert the flight crew of the overheat condition of the motor of the backup hydraulic pump. The aircraft manufacturer preferred, as the backup hydraulic pump was an emergency equipment, that the flight crew made a conscious decision to manually cut off the electrical power to the motor if they judged this as necessary after seeing the alert message.

1.6.3 Hydraulic fluid used on the aircraft

1.6.3.1 The hydraulic fluid use on this aircraft was Castrol Brayco Micronic 756 Petroleum based, low viscosity, red coloured hydraulic fluid that met the MIL-PRF-5606 standard. Its operating temperature range was from -54˚C to 135˚C and it had a flash point of 96˚C.

1.7 Meteorological information

1.7.1 Not applicable

1.8 Aids to navigation

1.8.1 Not applicable

1.9 Communications

1.9.1 Not applicable

1.10 Aerodrome information

1.10.1 Not applicable

[16] The aircraft manufacturer's Maintenance Planning Document (MPD) required a check of the length and indication of the motor brushes of the backup hydraulic pump at 7,200 flight hours or 1,800 flight cycles. The motor brushes and ball bearing assemblies were required to be replaced by 4,000 flight cycles. (Note: This backup hydraulic pump had its motor brush length and indication checked at 2,455 flight hours and 657 flight cycles and the brush was found to be within wear limit and continued in service)

1.11 Flight recorders

1.11.1 Both forward and aft combi voice and data recorders were removed and data downloaded. The voice recordings and flight data were decrypted by the investigation team with the assistance of the maintenance service provider and were useful for the investigation.

1.11.2 The maintenance service provider also downloaded the aircraft's Flight History Database and provided it to the investigation team. The Flight History Database was useful for the investigation. It provided some useful data that were not available in the data recorders.

1.12 Wreckage and impact information

1.12.1 Not applicable

1.13 Medical and pathological information

1.13.1 Not applicable

1.14 Fire

1.14.1 A small fire occurred in the mechanic service compartment located at the tail end of the aircraft. Fluid was seen dripping from the opening of the mechanic service compartment onto the tarmac and catching fire.

1.14.2 The Airport Emergency Service (AES) was informed about the fire. By the time the AES turned out at the bay, the fire had been put out by the flight crew.

1.15 Survival aspects

1.15.1 Not applicable

1.16 Tests and research

1.16.1 The backup hydraulic pump (including the motor and hydraulic lines) and a number of components[17] in the mechanic service compartment were sent to

[17] Backup pump selector valve, elevator reducing valve, thrust reverser accumulator and APU ignition exciter box

their respective manufacturers for examinations and tests. The backup hydraulic pump pressure line was found leaking. The other components did not exhibit any leakage.

1.16.2 The key findings by the backup hydraulic pump manufacturer were as follows:

(a) The fan side of the motor bearing assembly (made up of seven ball bearings) had failed (**Figure 3**). While all the seven ball bearings were accounted for, some parts of the bearing seal and cage were missing. There was no sign of grease on the ball bearing surface.

(b) The failed bearing assembly caused the motor to seize.

(c) The positive electrical terminal of the pump motor was found shorted to the casing through the armature.

(d) There were loose melted copper beads from the melted armature windings, indicating that the motor interior had experienced high temperature. The pump manufacturer opined that the high temperature was most likely a result of an electrical shorting condition[18].

(e) The motor brushes were not worn down.

[18] Typical melting point of copper wire is 1083°C. Pump manufacturer opined that the high temperature was very localized from an occurrence such as arcing, otherwise the varnish within the motor would have not been severely degraded.

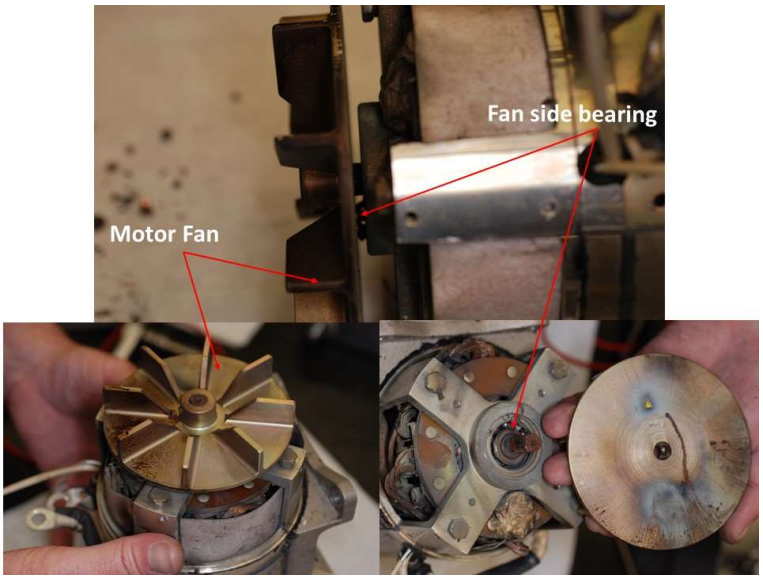

Figure 3: Fan Side Bearing

1.16.3 The ball bearings and their outer and inner ring raceways were sent to an independent test service centre for inspection. The outer and inner ring raceways were found worn with areas of electrical arcing and pitting that had been rolled over by the ball bearings. The ball bearings were found worn and showed areas of arcing similar to the raceways. The dark straw discoloration on the ball bearings and the raceways suggests that the ball bearing assembly had been exposed to temperature up to 204˚C (400˚F).

1.16.4 The hydraulic pressure line was damaged by fire. When connected to a hand pump, the hydraulic pressure line started leaking when the pressure reached 29 psi. The hydraulic pressure line leaked along its entire length but there was no leak at the end fittings. When cut open, the PTFE tube[19] inside the hydraulic pressure line was found to have melted away.

1.17 Additional information

1.17.1 Operator's sterile cockpit policy

1.17.1.1 The operator implemented a Sterile Cockpit policy in its Crew Resource Management system to prevent distraction to its flight crew during the following critical phases of flight:

(a) Departure – From aircraft engine start until the aircraft reaching 10,000 ft

[19] PTFE is an acronym of polytetrafluoroethylene. Typical melting point of PTFE is 327˚C.

above the departure aerodrome elevation or “top of climb”

(b) Arrival – From 10,000 ft above the arrival aerodrome elevation until engine shutdown after landing

(c) At any other time specified by the Pilot-in-command (e.g. in-flight emergency, security alert)

1.17.1.2 The sterile cockpit procedure precluded all extraneous communications, including entry to the cockpit by the cabin crew, non-essential interphone calls, calls from non-operational areas (e.g. company calls, use of mobile phones) or any crew conversations not related to the current phase of flight.

1.17.1.3 The operator had made sterile cockpit procedure a part of the flight briefing and cabin crew were aware of it. As this aircraft did not have a cockpit door, the seat belt sign served to indicate the sterile cockpit status.

1.17.1.4 The sterile cockpit procedure would minimise disturbance to the flight crew when they were performing a checklist. Nevertheless, should they be disturbed, the flight crew might also use the aircraft’s electronic checklist to find out at which point they had been disturbed so that they could continue with the checklist accordingly.

1.17.1.5 The aircraft’s electronic checklist had a checkbox symbol to show the flight crew where they were at in the execution of checklist items (see **Figure 4**). The symbol consisted of a white box, with a green arrow superimposed on it.

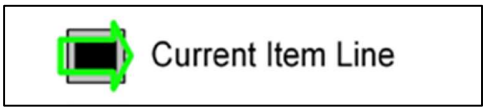

Figure 4: Types of checkbox on electronic checklist

1.17.2 Aircraft manufacturer’s dispatch guidance

1.17.2.1 According to the operator, its flight crew has been using the aircraft manufacturer’s flight operation manual, known as the Crew Operation Documentation for Dassault Easy (CODDE) operation manual together with the e-DG to make dispatch decisions.

1.17.2.2 At the time of the occurrence, the PIC had the e-DG installed on his company issued iPad and used the e-DG for troubleshooting. Starting at the e-DG home page (see **Figure 5**), a click on the “HYD” button which would bring up a list of hydraulic related messages. And clicking on the message “HYD: BACKUP

PUMP HI TEMP" would bring up a Fault Orientation Table showing the list of hydraulic related messages and the corresponding root cause and decision to be taken. The root cause indicated for the message "HYD: BACKUP PUMP HI TEMP" was "BACKUP PUMP DEGRADED" and this would result in a NO GO decision. This means that there would be no need to further troubleshoot the backup hydraulic pump. The pump would have to be replaced.

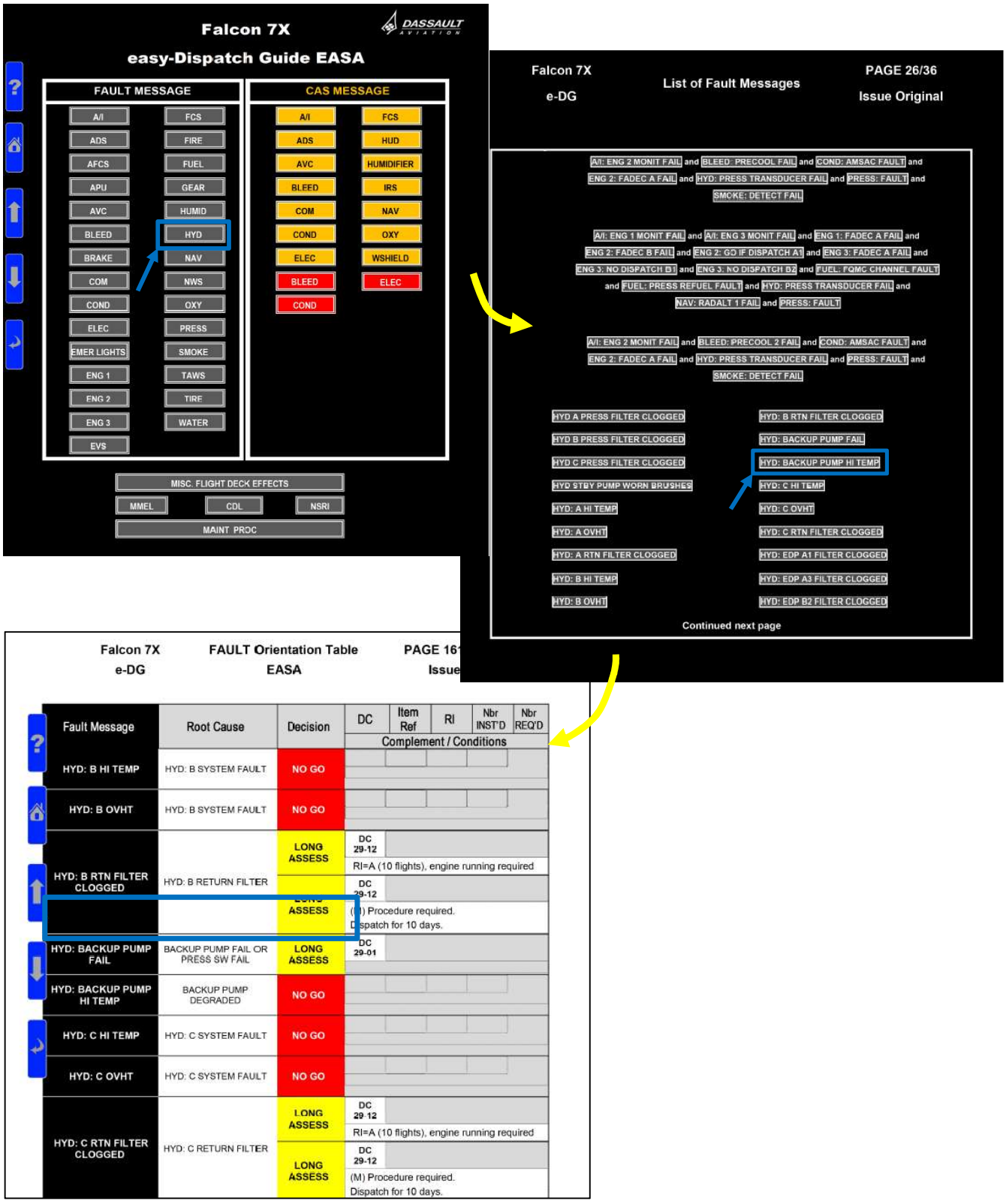

Figure 5: E-DG process

2 ANALYSIS

The investigation looked into the following:

(a) Cause of fire

(b) Aircraft manufacturer's dispatch guidance

(c) Interruption to completing of checklist

2.1 Cause of fire

2.1.1 The investigation team believe that the area around the motor of the backup hydraulic pump had become overheated and the fire was likely a result of the hydraulic fluid leaking from the pressure line and being exposed to high temperature in the area around the motor.

2.1.2 As mentioned in paragraph 1.1.10, when the flight crew made a third attempt to switch on the APU again and switching on the backup hydraulic pump to test, the hydraulic pressure initially increased to about 200 psi and then dropped sharply. This sharp drop of pressure most likely corresponded to a beginning of the hydraulic leak of the pressure line. The badly burnt pressure line did not allow the investigation team to determine whether the pressure line had been in such a badly deteriorated condition as to have allowed the leaking.

2.1.3 The investigation team believe that the area around the motor of the backup hydraulic pump had become overheated, in view of the following:

(a) A CAS message "HYD: BACKUP PUMP HI TEMP" after the motor had run continuously for 1 hour and 50 minutes. The motor was certified for only 40 minutes of continuous operation as tested by the pump manufacturer (paragraph 1.6.2.7)

(b) Seizure of the motor as a result of the bearing assembly failure and the flight crew's repeated attempt to turn on the backup hydraulic pump in such a seizure condition, which led to frictional heat.

(c) Dark straw discoloration on the ball bearings and the raceways, which suggests that the ball bearing assembly had been exposed to temperature up to 204^{o}C (400^{o}F).

(d) Short circuiting between the positive electrical terminal of the pump motor and the motor casing through the armature.

(e) Loose melted copper beads from the melted armature windings, which suggests that the motor interior had experienced high temperature.

2.2 Aircraft manufacturer's dispatch guidance

2.2.1 As far as the message "HYD: BACKUP PUMP HI TEMP" is concerned, as per the e-DG, it has to be resolved before the next flight. Based on the Root Cause information in the e-DG, the backup hydraulic pump has been degraded if there was a confirmed high temperature event affecting it. In this case, the backup hydraulic pump was hot to the touch, evident that a high temperature event had taken place. A pump replacement was unavoidable.

2.2.2 The flight crew was aware that the backup hydraulic pump was a NO GO item and aircraft could not be dispatched with a degraded backup hydraulic pump. They however, attempted to cool down the pump and restart it to confirm that it was indeed defective before cancelling the flight. They should have heeded the advice of the local maintenance service provider not to restart the backup hydraulic pump and that the Root Cause in the e-DG has stated that the backup hydraulic pump has been degraded and needed to be replaced.

2.3 Interruption to completion of checklist

2.3.1 The flight crew missed the AT RAMP checklist item of switching off the backup hydraulic pump after arriving at bay 304 in Changi Airport. Apparently they had been distracted by the intrusions into the cockpit of the cabin crew and ground service crew. This was despite the operator having a sterile cockpit policy and the aircraft having an electronic checklist that used special checkbox symbol (see paragraph 1.17.1.5) to remind the flight crew of where they were at in the execution of checklist items.

2.3.2 It appeared that both the flight crew and cabin crew might not have observed the sterile cockpit policy:

(a) On the part of the flight crew, while they were still performing the AT RAMP checklist, they should hold off entertaining the cabin crew's request about letting the ground service crew come into the aircraft.

(b) On the part of the cabin crew, they should not have approached the flight crew to seek their consent on letting the ground service crew come into the aircraft when the flight crew was going through the AT RAMP checklist and

the FASTEN SEAT BELT sign was still ON[20].

[20] According to data from the Flight History Database, parking brakes were set at about 09:46:28LT and the aircraft door was opened soon at about 0947:14LT. Parking brake setting was the first item in the AT RAMP checklist and the checklist item of turning off the FASTEN SEAT BELT sign was towards the end of the AT RAMP checklist. It would seem unlikely that the flight crew could have completed the checklist up to the FASTEN SEAT BELT sign turn-off within 46 seconds. Thus, the sign was most likely still ON.

3 CONCLUSION

From the information gathered, the following findings are made. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

3.1 During the performance of the AT RAMP checklist, the flight crew missed the checklist item of switching off the backup hydraulic pump. The pump operated for about 1 hour and 50 minutes when the pump's built-in thermal switch sensed an overheat situation and caused the CAS to generate a "BACKUP PUMP HI TEMP" caution message. This was soon followed by a CAS "SMOKE: BAG COMP" warning message.

3.2 According to the flight crew, they missed switching off the backup hydraulic pump because they had been distracted by the cabin crew and ground service crew. It appeared also that the flight crew did not make use of the aircraft's electronic checklist to help make sure they would not miss any checklist item.

3.3 The flight crew did not follow the guidance in the e-DG to have the backup hydraulic pump replaced but instead kept trying to restart the backup hydraulic pump hoping that the warning message would not reappear for the aircraft to be dispatched.

3.4 A fire in the mechanic service compartment was discovered and put out by the flight crew. The fire was likely a result of hydraulic fluid leaking from the pressure line of the backup hydraulic pump and being exposed to high heat generated by the overheated pump motor.

3.5 It appeared that both the flight crew and cabin crew might not have observed the sterile cockpit policy.

4 SAFETY RECOMMENDATION

A safety recommendation is for the purpose of preventive action and shall in no case create a presumption of blame or liability.

4.1 The investigation team would have liked to recommend to the operator the following safety recommendations:

- to require its flight crew to follow the procedures in the e-DG diligently regarding the aircraft dispatch requirements relating to the relevant fault message;
- to emphasise to its flight and cabin crews the importance of observing the sterile cockpit policy; and
- to remind the flight crew of the proper use of the electronic checklist.

However, the operator has since ceased operations.