SHERIFFDOM OF GLASGOW AND STRATHKELVIN
AT GLASGOW

SUBMISSIONS FOR THE CROWN

in the

FATAL ACCIDENT INQUIRY

into the deaths of

GARY LOUIS ARTHUR
ANTHONY LYNDON COLLINS
JOSEPH ROBERT CUSKER
COLIN GIBSON
ROBERT JAMES JENKINS
JOHN MCGARRIGLE
SAMUEL BELL MCGHEE
KIRSTY MARY NELIS
MARK EDWARD O'PREY and
DAVID IAIN TRAILL

1. These submissions are in three parts.
   1.1. The legal framework;
   1.2. Proposed findings in fact; and
   1.3. Discussion of the Consolidated List of Issues, which participants agreed the inquiry should address.

I – Legal framework

2. The onus of proof is on the Crown (*Carmichael*, 4-25, p111). Mr Carmichael derives this from the fact that, under the legislation, the procurator fiscal has a duty to lead evidence: "other parties *may* appear at the inquiry and adduce evidence. The procurator fiscal *must*

do so" (emphasis supplied). Presumably this passage is not intended to exclude the evidential burden on participants seeking to establish any particular factual proposition (*Davidson*, 4.01, 4.05-4.08).

3. Proof is on a balance of probabilities. Carmichael adds at 4.26, p111, that, "Proof on a balance of probabilities means that in a competition between different versions of the same event, the sheriff is to accept as established that version which is, in his opinion, *the more probable*" (emphasis suppled). With respect, this passage should be read subject to the qualification that the preferred version of events must also be established as being more probable than not. It cannot be enough that it is simply more probable than its rival, in circumstances where each version is itself regarded as improbable (see The Popi M [1985] 1 WLR 948, per Lord Brandon at p955). Sometimes in an FAI, the sheriff may feel driven to the conclusion that it does not know what caused the accident (as was, for example, Sir Stephen Young, in his investigation into the fatal accident concerning the Chinook MKII ZD576, 21 March 1996).

4. In this FAI, the procedure has been adopted in which participants were required to intimate during the preliminary hearing phase precisely which aspects of the AAIB report, if any, they take issue with. In the Crown's submission, the findings and conclusions of the AAIB should be adopted by the inquiry, unless there was credible evidence that its investigation was incomplete, flawed or deficient. This would be consistent with the position described in *R (SS for Transport) v Her Majesty's Senior Coroner for Norfolk* [2016] EWHC 2279 (Admin). Although that case concerned the scope of coroners' inquests, in cases where there was an AAIB investigation or report, the comments made by Singh, J at para 49, and the Chief Justice at paras 54-57 are of general application where there are overlapping jurisdictions to investigate accidents. In particular, at para 56, the Chief Justice said this:

> "There can be little doubt but that the AAIB, as an independent state entity, has the greatest expertise in determining the cause of an aircraft crash. In the absence of credible evidence that the investigation into an accident is incomplete, flawed or deficient, a Coroner conducting an inquest into a death which occurred in an aircraft accident, should not consider it necessary to investigate again the matters covered or to be covered by the independent investigation of the AAIB."

II Proposed findings in fact

5. The Crown proposes that the court adopt all the findings, causal factors and contributory factors identified in the conclusions to the AAIB report (CP 327, e106-8).

6. In some cases, sheriffs have not considered it necessary, when providing determinations in FAIs, to go beyond what is stated by the AAIB (eg G-REDL, 2014 FAI 5, Sheriff Principal Pyle, para 3). However, in the event that it may be of assistance to the Court, the Crown proposes the following summary, which, unless otherwise indicated, is taken from the AAIB report (CP327).

The crash

7. On Friday 29 November 2013, at about 2044 hrs, the helicopter registered as G-SPAO, being a Eurocopter EC135 T2+ type aircraft, departed Glasgow City Heliport in support of Police Scotland operations. On board were the pilot and two Police Observers. After their initial task, south of Glasgow City Centre, they completed four more tasks: one in Dalkeith, and three others to the east of Glasgow, before routing back towards the heliport.

8. When the helicopter was about 2.7 nautical miles from Glasgow City Heliport, the right engine flamed out. Shortly afterwards, the left engine also flamed out. A successful autorotation and flare recovery were not achieved and at approximately 2222 hours the helicopter descended onto the roof of the Clutha Vaults, otherwise known as the Clutha Bar, Stockwell Street, Glasgow. The helicopter came to rest embedded in the single-storey building. The roof of the bar collapsed onto members of the public within the premises.

Deaths

9. A total of ten people were fatally injured (see Joint Minute 1):-
   9.1. Gary Louis Arthur, aged 48 years, formerly residing at flat 1/1, 3 Main Road, Paisley. He was formally pronounced dead on 29 November 2013 at the Clutha Vaults, Stockwell Street, Glasgow. The cause of death was head injury due to an aircraft crash.
   9.2. Anthony Lyndon Collins, aged 43 years, formerly residing at 121 Randolph Drive, Clarkston, Glasgow. He was formally pronounced dead on 30 November 2013 at the Clutha Vaults, Stockwell Street, Glasgow. The cause of death was head, neck and chest injuries due to an aircraft crash.
   9.3. Joseph Robert Cusker, aged 59 years, formerly residing at 51 Holmhills Drive, Cambuslang, Glasgow. He died on 12 December 2013 at Glasgow Royal Infirmary,

Glasgow. The cause of death was multiple organ failure due to neck and chest injuries due to an aircraft crash.

9.4. Colin Gibson, aged 33 years, formerly residing at 63 Galloway Avenue, Ayr. He was formally pronounced dead on 30 November 2013 at the Clutha Vaults, Stockwell Street, Glasgow. The cause of death was traumatic asphyxia due to an aircraft crash.

9.5. Robert James Jenkins, aged 61 years, formerly residing at 13 St Leonard's Road, East Kilbride. He was formally pronounced dead on 1 December 2013 at the Clutha Vaults, Stockwell Street, Glasgow. The cause of death was head injury due to an aircraft crash.

9.6. John McGarrigle, aged 58 years, formerly residing at 181 Hazel Road, Cumbernauld. He was formally pronounced dead on 30 November 2013 at the Clutha Vaults, Stockwell Street, Glasgow. The cause of death was chest injuries due to an aircraft crash.

9.7. Samuel Bell McGhee, aged 56 years, formerly residing at 50A Holmbyre Road, Glasgow. He was formally pronounced dead on 30 November 2013 at the Clutha Vaults, Stockwell Street, Glasgow. The cause of death was chest injuries due to an aircraft crash.

9.8. Kirsty Mary Nelis, aged 36 years, formerly residing at 33 Lairds Dyke, Inverkip. She was formally pronounced dead on 30 November 2013 at the Clutha Vaults, Stockwell Street, Glasgow. The cause of death was head, neck and chest injuries due to an aircraft crash.

9.9. Mark Edward O'Prey, aged 44 years, formerly residing at 143 Loch Striven, East Kilbride. He was formally pronounced dead on 30 November 2013 at the Clutha Vaults, Stockwell Street, Glasgow. The cause of death was head, neck and chest injuries due to an aircraft crash.

9.10. David Iain Traill, aged 51 years, formerly residing at Craig Ryan, Market Hill Holdings, Lochwinnoch. He was formally pronounced dead on 30 November 2013 at the Clutha Vaults, Stockwell Street, Glasgow. The cause of death was head, neck and chest injuries due to an aircraft crash.

Fuel starvation

10. Both aircraft engines flamed out sequentially while the helicopter was airborne, as a result of fuel starvation, due to depletion of the contents of the supply tanks.

11. Fuel in the helicopter's main tank was transferred by two transfer pumps into two supply tanks, situated side by side, aft of the main tank. Each supply tank served its respective engine. Depending on the amount of fuel in the main tank and the attitude of the helicopter, one or other transfer pump might become exposed.

12. The helicopter's Caution and Advisory Display (CAD) displayed caution and advisory messages and fuel contents indications. The dry running of a pump for more than three minutes would be accompanied by the illumination of a caution on the helicopter's CAD: F PUMP AFT or F PUMP FWD. In that event, the *Pilot's Checklist Emergency and Malfunction Procedures* (the *Pilot's Checklist*) (CP66 e45/46, CP 212 e196/199 – see also Joint Minute 3 paras. 2 and 3) instructed the pilot to check the fuel level in the main tank. The *Pilot's Checklist* could be found on flight reference cards normally stored within the pilot's door pocket. Where the main fuel tank quantity was low, the pilot was instructed to switch the relevant transfer pump OFF.

13. The fact that the aircraft flew for as long as it did indicated that one or both fuel transfer pumps had been ON during much of the flight.

14. During the post-crash examination of the helicopter, 76kg of fuel was recovered from the main fuel tank, 73kg of which was usable. However, the supply tanks were found to contain no usable fuel. From an examination of the wreckage and testing, the switches for both transfer pumps were in the OFF position and must have been so for a sustained period before the accident, rendering the usable fuel in the main fuel tank unusable.

The fuel transfer pump switches

15. After the accident the fuel transfer pump circuit breakers were found IN and the bleed air was in the OFF position. However, the fuel transfer pump switches were found in the OFF position.

16. The fuel transfer pump switches were located alongside the prime pump switches on the overhead switch panel. All four switches were toggle-type switches, intended to be operated by light finger-pressure and retained at their selected positions by light internal spring pressure. They were not guarded. While certain emergency procedures require the prime pumps to be switched ON, they would not be in use in normal flight. After engine start the prime pumps were normally selected OFF and would remain so throughout flight. After the accident at least one of the fuel prime pump switches was found in the ON position.

The fuel indication system

17. The contents of the fuel tank system were measured by means of four sensors: two in the main tank (forward and aft), and one in each of the supply tanks. The sensors were typical of aviation fuel gauge units, being capacitors in which the electrically charged “plates” took the form of concentric tubes and where the dielectric was the material occupying the space between the tubes.

18. With fuel occupying the full depth of the tank, the dielectric would be aviation fuel, whilst in an empty tank the dielectric would be air. The difference in dielectric characteristics between air and fuel would result in a different capacitance, and different frequency, when the tank was full from that when it was empty. The low frequency created with a full tank contrasted with the high frequency with an empty tank. Proportionate frequencies would be generated at intermediate fuel levels.

19. The tolerance of the sensors was +/- 1.25% of the nominal output frequency (CP1129). The tolerance of the fuel gauge on the CAD may be expressed as +/- 2% of the capacity of the tank plus +/- 4% of the actual contents of the tank (Mendick 7: 106: 12-17).

20. Water alters the dielectric of fuel, lowering the frequency generated by the capacitance sensors in the fuel tank. The measured contents of the tank are then displayed on the CAD as greater than they are in fact (Mendick 7:73:18 – 7:74:17).

21. The FUEL QTY FAIL and DGR alerts are also generated when the presence of water alters the dielectric to such an extent that the sensor emits a frequency below a certain level recognised by the software as impossible, i.e a frequency that is consistent only with the supply tank containing more fuel than it would when full to the ceiling of the headroom (Mendick, 7:49:12 – 7:49:21, 7:52:11 - 7:52:18).

22. When one or both transfer pumps are operating, the CAD will display full supply tanks (47kg in supply tank 1 and 43kg in supply tank 2) and a depleting main tank. Unless both transfer pumps are OFF, for example when the main tank is empty and they have been switched OFF, this is what will normally be displayed (for the “typical” installation, see the flight manual: CP 214, e530).

23. The “virtual tank” is the ullage or headroom above the supply tank fence. (Mendick 7:45:18 – 7:46:4) Software attributes the measured contents of the virtual tank to the main tank (Mendick 7:46:23 – 7:47:7).

Low fuel Cautions and Warnings

24. The helicopter was equipped with two independent systems for advising and warning pilots of low fuel (CP472).

25. A FUEL caution would appear on the CAD whenever the sensor-measured contents of either or both of supply tank 1 or supply tank 2 fell below certain levels (34-36kg in supply tank 1, and 30-32kg in supply tank 2 (CP66, e48).

26. The LOW FUEL warning system is independent of the fuel level indication system. LOW FUEL warnings are triggered by changes in temperature of thermistors attached at a certain height to the outside of the probes. The thermistors are accurate to +/- 3mm (CP1130, note 5; CP1131, note 6).

27. The AMM expresses the following range within which the LOW FUEL warnings appear: 26-34kg for LOW FUEL 1 and 22-30kg for LOW FUEL 2 (CP281, 28-40-00, 5-2, p502, e657). When the fuel in the supply tanks dropped below these levels, LOW FUEL warning lights illuminate, accompanied by a repetitive aural gong. The aural gong could be acknowledged using the reset button on the top of the cyclic control stick. This would silence the gong. However, the visual warning would remain illuminated on the warning unit so long as the fuel remained within the set range.

The Pilot's Checklist

28. The *Pilot's Checklist* detailed a clear procedure to be followed in the event of a LOW FUEL warning (CP66, e22; Prior 30:81:10 – 30:82:5; Dalton 31:35:22 – 31:36:9).

29. Firstly, the pilot was required to check the fuel quantity indication, and if there was a positive fuel indication in the main tank, to check that both fuel transfer pump switches were ON, and that both fuel transfer pump circuit breakers were in. If the warning remained, the pilot was instructed to switch the air conditioning OFF (if installed) and switch the bleed air OFF, if the outside air temperature was greater than 5 degrees Celsius. The procedure also required the pilot to land the helicopter within 10 minutes if the warning remained ON.

G-SPAO – LOW FUEL warnings

30. The warning unit of the helicopter contained non-volatile memory which recorded changes in the status of all visual and aural warnings, and the sequence of such changes. However, it did not record the timings of any such change in status, or the duration of any warning status.

31. Investigation of the non-volatile memory of G-SPAO for the accident flight showed that both LOW FUEL 1 and LOW FUEL 2 warnings had illuminated during the flight. "LOW FUEL 1" referred to the tank on the left-hand side, from the pilot's perspective, while "LOW FUEL 2" referred to the tank on the right-hand side. The LOW FUEL 1 warning was initially intermittent, illuminating and disappearing three times before illuminating continuously for the remainder of the flight. After the LOW FUEL 1 warning had illuminated and been extinguished twice, the LOW FUEL 2 warning illuminated. It remained illuminated continuously for the remainder of the flight. Each illumination was accompanied by an aural gong. Each gong was acknowledged and silenced by the pilot.

32. Both LOW FUEL warnings illuminated before the aircraft reached Bothwell.

33. The aircraft did not land within 10 minutes of the LOW FUEL warnings. The fuel transfer pumps were not selected ON.

Water contamination

34. Water can enter the fuel tank system by a compressor clean or wash carried out "cold", that is, with the engines cranking, as well as by condensation, contaminated source fuel, and refuelling in wet weather (Mendick 7:68:16 – 7:69:15, CP 227).

35. In the case of a compressor wash or clean, the water enters supply tank 2 via the expansion tank. It may be in a partially emulsified state (Mendick 8:98:14 – 8:101:19).

36. Generally, water can only enter the sensors in the form of a water/fuel emulsion. Microscopic droplets enter the space between the concentric tubes via the sensors' crash-protection joints, the drip holes at the bottom, or, depending on the fuel levels within the tank, the ventilation holes at the top of the sensor (Mendick 7:90:17 – 7:95:17). Free water in the tank tends to fall to the bottom, and gather in the sumps (Mendick 8:28:9 – 8:28:25).

37. It is theoretically possible, but highly unlikely, that water droplets formed as a result of condensation might drip into the sensors (Mendick 8:80:14 – 8:80:21).

38. The exchange of fuel via the transfer pumps and the overspill channel spreads the emulsified fuel/water mix around the entire fuel system. Micro-droplets of water entering the space between the concentric tubes of the sensor tend to precipitate out of emulsion, and coalesce with other droplets to former larger drops. The water drops fall to the bottom of the sensor. Their relative size and surface tension means they do not always escape through the drip hole (Vickery 5:54:9 – 5:56:21, Vickery 5:182:13 – 5:183:12, Mendick 7:91:16 – 7:95:17).

39. Water drops within and touching the sides of both concentric tubes would cause a short circuit and a FUEL QTY FAIL caption to appear on the CAD (in respect of either supply tank sensor, or both main tank sensors, and a FUEL QTY DGR caption in respect of either main tank sensor alone) (CP227, Vickery 5:29:19 – 5:31:4). However, at some point in or around 2003 (Weir 21: 59: 13-14) the probe manufacturer applied a varnish or lacquer to the base of the inner concentric tube preventing the short circuiting from taking place (Mendick, 7:60:6 – 7:61:12).

Erroneous fuel indications

40. For several years prior to the accident, operators, including the operator of G-SPAO, had been experiencing occasional unusual or erroneous fuel quantity indications on EC135 helicopters (see Mendick 9: pages 35-52, CP1324, e32). On 21 January 2013, the manufacturer issued to operators Information Notice No 2535-I-28, entitled "FUEL SYSTEM – Water contamination of the Fuel System" (CP 277). It reported that when the sensors had been returned to the manufacturer for repair, the sensors showed no sign of external damage or contamination within the two concentric metal tubes. Most of the sensors had been tested with the result "no fault found". The evidence suggested that contamination of the fuel sensor with water was the most probable root cause of the fuel indication failures.

41. Information Notice NO 2535-I-28 highlighted the potential for water entering the space between the two concentric tubes of the fuel sensor to decrease the output frequency, thereby causing a higher fuel level to be displayed on the CAD compared to the actual fuel level in the tank. In the event of a high concentration of water, the frequency could decrease

to such a level that the CAD would recognise the sensor as having failed and, as a result, display one of two associated cautions: F QTY FAIL or F QTY DEGR. "Also", the notice made clear, "there is a potential risk that the CAD shows a higher fuel quantity level compared to the actual fuel level within the fuel tank system".

Maintenance – compressor wash/clean

42. Information Notice No 2535-I-28 mentioned that water contamination of the fuel and/or the fuel tank system could occur in a number of ways, including when carrying out an engine compressor wash. At the time of the accident, the operator's fleet was generally subject to a daily "hot" wash (Price 15:37:7 – 15:37:17, CP 579). Periodically, however, maintenance would carry out a cold chemical clean.

G-SPAO – compressor wash, water contamination, and fuel indications

43. On the day of the accident, it was intended to give G-SPAO a cold chemical clean. For operational reasons, this was not implemented. Instead, G-SPAO received a cold wash (Taylor 18:74:5 – 18:74:24).

44. There was no evidence that, on the day of the accident, G-SPAO's fuel tank, fuel tank sensors, or its fuel were contaminated with water.

45. There was no evidence that the fuel contents display system was operating incorrectly in the lead up to the accident.

Double engine flameout

46. The supply tanks were divided in their lower sections by a partition and connected by the undivided volume of their upper sections. The capacity of the No 1 (left) supply tank was 49kg, whilst the No 2 (right) supply tank had a capacity of 44.5kg, 47 43 CAD unusable fuel. The difference was achieved by including an intrusion into the volume at the bottom of the No 2 supply tank.

47. The System Description Section of the Aircraft Maintenance Manual (CP 290), produced by the manufacturer to inform engineers and technicians of the features of the EC135, gave information on the reason for the difference in volume. In Chapter 28-10-00, 2 (CP290,

e317), it explained that the design feature allows for unintentional non-activation of both fuel transfer pumps, leading to a double engine flame-out.

48. The difference in volume created an interval of time within which the pilot could set the fuel transfer pumps to ON. It stated that the time interval would be 3-4 minutes. In fact, a difference in volume of 4.5kg would be capable of generating an interval of no more than 2 minutes, based on the average rate of consumption, and with just one engine operative.

49. In the case of the accident flight, the left engine flamed out approximately 32 seconds after the right engine, and about 8 seconds before the crash.

The AAIB investigation

50. The helicopter crash was the subject of an investigation by the Air Accidents Investigation Branch (AAIB) of the Department for Transport of the United Kingdom Government, carried out under the provisions of Regulation EU 996/2010 and the Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996, and with the participation, in accordance with established international arrangements, of the Bundesstelle für Flugunfalluntersuchung (BFU) of Germany, representing the State of Design and Manufacture of the helicopter, the Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA) of France, representing the State of Design and Manufacture of the engines, and the National Transportation Safety Board (NTSB) of the USA, representing the State of Design and Manufacture of the Full-Authority-Digital-Engine-Controls (FADECs) on the engines. They were supported by advisors from the helicopter manufacturer, the BEA and the engine manufacturer. The European Aviation Safety Agency (EASA), the UK Civil Aviation Authority (CAA), and the helicopter operator also assisted the AAIB. The AAIB report on the accident, Report 3/2015, was published on 23 October 2015.

III – Discussion

51. The participants agreed a list of issues for the inquiry. The Crown's submissions on each of these issues are contained in the Appendix to this Note.

SEAN SMITH QC

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Advocates Deputes

APPENDIX

1. **When and where each of the deaths occurred.**
   1.1. This is a matter of agreement, and is set out in Joint Minute No 1.

2. **When and where the aircraft crash occurred.**
   2.1. This is a matter of agreement, and is set out in Joint Minute No 1.

3. **The cause or causes of each of the deaths.**
   3.1. This is a matter of agreement, and is set out in Joint Minute No 1.

4. **The cause or causes of the helicopter crash, including:-**
   4.1. **how fuel was managed on the aircraft and in particular why both transfer pumps were switched OFF, rendering unusable the otherwise usable fuel in the main tank**;
      4.1.1. The transfer pumps are situated forward and aft of the main tank (CP1137, CP327 Fig 3 p14/e26). This ensures fuel continues to be transferred to the supply tanks at low fuel levels notwithstanding changes in pitch attitude. One or other transfer pump may become exposed depending on the fuel level and pitch attitude. If it is exposed for three minutes a transfer pump caution appears on the CAD (Vickery, 5:106:11- 107:6). In that event, the pilot is instructed to switch the relevant transfer pump OFF (CP66 e45, e46). Only when there is no fuel in the main tank should it be necessary for both transfer pumps to be switched OFF (Vickery 5:108: 3 -6, Prior 30:47:21 – 30:48:4). With 73kg of usable fuel found in the main tank of G-SPAO, there was no fuel-management reason for the transfer pumps both to have remained switched OFF in the latter stages of the flight. What is unclear is whether there was ever any fuel-management reason for either of them to have been switched OFF in the first place.
      4.1.2. The AAIB and Airbus flight trials are adequately described in 1.16.8 and 1.16.9 of the AAIB report (CP327, e70-73). In addition the inquiry heard evidence from the AAIB, the manufacturer's test pilot (Nater, 9:138:18 onwards, CP751) and Prior (day 30).
      4.1.3. AAIB's flight trial, undertaken with an EC135 similarly equipped to G-SPAO, was able to generate an AFT fuel pump caution, while flying level with indicated fuel levels of 63kg in the main tank and 39kg and 34kg in supply tanks 1 and 2, a total

of 136kg. Mr Prior's calculations concurred with the AAIB's view (CP1340, 3.2.2). Although Airbus were not able to generate such a caution during their trial, it might be concluded that it was at least possible that the AFT fuel pump caution was triggered at some point during the transit back from Dalkeith.

4.1.4. The principal focus of this aspect of the inquiry was on the FWD transfer pump. In order for the F PUMP FWD caution to have illuminated, the forward transfer pump would require to have been exposed for at least 3 minutes. Having regard to the track of G-SPAO, this could only have occurred at or around Dalkeith where the aircraft had been orbiting while carrying out a surveillance task. That task would have required a sustained nose-up attitude.

4.1.5. Neither the AAIB trials nor the Airbus trials were able to generate a FWD pump caution for 3 minutes.

4.1.6. Without setting out specifically to replicate the accident flight, Captain Trott had the opportunity, while flying G-BZRS, a police helicopter in the Babcock fleet, similar to G-SPAO, to see whether he could generate a F PUMP FWD caution at a fuel state similar to that of G-SPAO while flying over Dalkeith. Shortly after the caution illuminating, he took a photograph of the cockpit display panel (CP864). It shows fuel contents of 46/94/42, an airspeed of approximately 30 knots, and a nose-up angle of approximately 6 degrees (Trott 28:103: 9-12). 46 kg and 42kg represented full supply tanks for this particular helicopter (Trott 28:101:10-17). There was no record of the cockpit display during the previous 3 minutes. Even assuming that Captain Trott had managed to maintain that speed and angle for the required period (Trott 28:103: 6-8), he accepted that the main tank contents at the start of the 3 minute period when the forward transfer pump was first exposed would have been approximately 10kg greater (Trott 28: 101: 3-7), ie 104kg. This is considerably less than the figure estimated by the AAIB for G-SPAO at the time it arrived at Dalkeith, being 203kg overall (CP327, 1.1.2, 5/17), which corresponds to 113kg for the main tank, assuming G-SPAO's supply tanks were full at that stage. The evidence from G-BZRS is therefore inconclusive.

4.1.7. On the basis of the AAIB and Airbus evidence the court might reasonably conclude that it is unlikely that the FWD fuel pump caution illuminated. However, Mr Prior identified an absence of radar evidence for approximately 4 minutes at or around Dalkeith. He thought the Airbus trial in particular did not take account of 3 factors: 1) the centre of gravity of G-SPAO would have required, by comparison with the police helicopter used by Airbus, a greater nose-up attitude (Prior 30: 71: 5); 2) roll as well as pitch, which might have been greater trying to orbit over a fixed point, compared to the Airbus trial, where the pilot appeared to be attempting to fly the perfect circle (Prior 30: 69: 1-14, 74:20-75:1, 75:23-76:3); and 3) the attitude of the aircraft would have brought the "virtual tank" into play, such that the displayed contents of the main tank are in fact greater than the actual main tank quantities (Prior 30: 67:25-68:20).

4.1.8. It is difficult to assess in any precise way the impact of any or all of these factors on the accident flight. However, having regard to these factors, as well as the missing radar evidence, it may not be possible entirely to exclude the possibility that the FWD transfer pump caution might have come on at or around Dalkeith.

4.2. **whether the *Pilot's Checklist* was available to the pilot**;

4.2.1. The *Pilot's Checklist* was kept within a compartment on the inside of the pilot's door (Young 22:37:18 – 22:38:1). The cards recovered from the wreckage of G-SPAO and on the floor of the Clutha are those contained in CP212 (Joint Minute 3, paragraph 2; Vickery 5: 17:12 to 18:12). These included the cards relative to the FUEL caution (E-2-21, CP212, e194) and the LOW FUEL warnings (CP212, e226). E-6-1 and E-6-2 were missing (Vickery 5: see above).

4.3. **whether it was within the competence of a helicopter pilot qualified to fly G-SPAO on police duties to comply with the requirements of the *Pilot's Checklist***;

4.3.1. Yes: see Prior 30: 83: 22-84:1.

4.4. **at what stage in flight did the LOW FUEL warnings likely occur**;

4.4.1. The AAIB found that the thermistors were undamaged in the crash, and, having tested them, found that they worked correctly (CP237, 1.12.4.1, p48, e60).

4.4.2. The thermistors are each triggered at some point within an 8kg range. That range will be entered at the same time in level attitude, if the same quantity of fuel has been removed from both supply tanks. However, the configuration within the supply tanks of the probes to which the sensors are attached, together with changes in attitude, might generate an early warning or delay it (CP237, 1.6.7, pp19-20, e31-22). In addition, fuel may spill from one supply tank to another, when the fuel levels are close to the height of the fence.

4.4.3. Table 3 of the AAIB report summarised the AAIB's findings, taken from the aircraft's non-volatile memory, regarding the sequence of warnings (CP237, 1.11.4.3, p33, e45), and their acknowledgement by the pilot.

4.4.4. The average fuel consumption figure of 200kg/hour was very accurate (Trott 28:80:23 – 23:81:1; Cook 2:125.23 – 2:127:13 'a hang your hat on' figure). Applying that burn rate, it was possible to determine when, within a period of time, the LOW FUEL warnings would have been triggered. On that basis, and taking account also of fuel spillage from the supply tanks to the main tank, the AAIB calculated that both LOW FUEL warnings were triggered before the aircraft reached Bothwell (CP327, Finding 8, p94, e106; see also 1.11.6, p35, e47, and 2.1.1, p72, e84).

4.4.5. No participants have challenged any of these findings or conclusions of the AAIB report. Accordingly, the Crown invites the Court to adopt the AAIB's estimate of when the LOW FUEL warnings were illuminated.

4.5. **why, having acknowledged the LOW FUEL warnings, did the pilot not complete the actions detailed in the *Pilot's Checklist***;

4.5.1. This issue was framed under reference to that part of the AAIB report which stated, "the investigation could not establish why a pilot with over 5,500 hours flying experience in military and civil helicopters, […] with previous assessments as an above average pilot, did not complete the actions detailed in the *Pilot's Checklist* for the LOW FUEL 1 and LOW FUEL 2 warnings" (CP327, 2.1.2, e90). In fact, as their report also makes clear, the AAIB were unable to establish whether the pilot even had regard to the actions contemplated in that checklist (CP327, 2.1., e89).

4.5.2. As the AAIB acknowledged in evidence before the inquiry, this was "frustrating for everyone" (Wivell 4:52:23). The absence, in particular, of any CVFDR on board G-SPAO meant that the AAIB were unable to discover what discussions took place among the crew in response to the warnings, "of which all three crew members would have been aware" (CP327, 2.1.2, e89).

4.5.3. The same absence of evidence has hampered the police investigation, notwithstanding the considerable number of documents analysed and witness statements taken. The result is that the Crown is in no better position than were the AAIB to answer this fundamental question.

4.5.4. What can be said is that the accident was caused, in part, by a failure to ensure that the transfer pump switches were ON, and a failure to land the helicopter within 10 minutes "following continuous activation of the LOW FUEL warnings" (CP327, p95, e107).

4.5.5. Issues 4.6, 4.8 and 4.9 focus for discussion three separate hypotheses purporting to explain why the *Pilot's Checklist* was not completed. However, each hypothesis is to a greater or lesser extent a matter of speculation. In addition, as the Crown submits in what follows, there are considerable difficulties, in the light of the evidence, in accepting any of these hypotheses as even a plausible explanation for the accident.

4.6. whether the timing and/or the initially intermittent character of the LOW FUEL warnings contributed to the *Pilot's Checklist* procedure not being completed;

4.6.1. If it is accepted that the LOW FUEL warnings became continuous before the aircraft reached Bothwell (see issue 4.4), then it is difficult to see how the timing of the warnings could have contributed to the *Pilot's Checklist* procedure not being completed.

4.6.2. For similar reasons, it is difficult to see how the intermittence of the LOW FUEL 1 warning could have contributed to the procedure not being followed. In respect of each successive triggering of a LOW FUEL 1 warning, a new 10 minute period would begin (Cook 3: 50: 1-9). (Without calling into question the clarity of the procedure, one pilot indicated that he would start the clock from the first triggering of a LOW FUEL warning, and not turn it OFF if the warning cleared, but rather would monitor the situation (Mortimore, 26: 123:21 – 124:3). The fact that the LOW FUEL 1 warning was initially intermittent should have meant only that the pilot was required to restart the clock each time the warning was re-triggered. However, the LOW FUEL 2 warning, which was continuous from the moment it was triggered, was calculated to have come on before the aircraft had reached Bothwell, Accordingly, on any view of the intermittence of LOW FUEL 1, the pilot will have had more than 10 minutes within which to ground the aircraft.

4.6.3. It might be suggested that the initially intermittent character of the LOW FUEL 1 warning might have provided the pilot with a reason to regard it as spurious, particularly if coupled with other doubts he may have had about the genuineness of the warning. However, in a situation where the pilot received warnings from two independent supply tanks, then each will have reinforced the genuineness of the other. In other words, whatever doubts he may initially have had regarding LOW FUEL 1 should have been removed by the appearance, still before Bothwell, of a continuous LOW FUEL 2.

4.7. whether there have been other instances of LOW FUEL warnings not being followed;

4.7.1. There was no evidence of other LOW FUEL warnings not being followed.

4.8. whether the pilot believed the fuel transfer pumps were operating, notwithstanding the LOW FUEL warnings, because he believed he had switched the fuel transfer pumps back ON, and if so whether the design or layout of the switches contributed to such errors occurring;

4.8.1. The prime pumps would not normally be on in flight. If the prime pump switches had been found in the ON position in the immediate aftermath of the crash, this would suggest that the prime pump switches had at some point been selected in error, possibly when the pilot had been intending to switch ON the adjacent transfer pump switches.

4.8.2. However, photographs taken by the first responders appeared to show at least one of the prime pump switches in the OFF position (CP1187, photo number, e5), albeit that when examined by the AAIB both switches were in the ON position (CP327, 1.12.2, e58). Accordingly, the AAIB concluded that the "pre-impact position of the prime pump switches could not be verified beyond doubt" (CP327.2.2.7.1, e98).

4.8.3. There was no other evidence directly supporting the hypothesis that a switching error had occurred. There is some evidence counting against it. Specifically, had the prime pump switches been inadvertently switched ON, this would have been reflected on the CAD, where a PRIME PUMP caution would have appeared and the transfer pump cautions would have failed to disappear (Prior 30: 128: 11-14).

4.9. whether the pilot believed the transfer pumps were operating, notwithstanding the LOW FUEL warnings, as a result of erroneous fuel indications being displayed on the CAD;

4.9.1. According to this hypothesis, there was a considerable amount of evidence of fuel indication errors being displayed on the CAD. For example, the G-NWEM incident on 11 December 2013, less than two weeks after the crash, and, more recently, the G-POLD incident on 13 March 2018, demonstrated that the CAD is capable of presenting the supply tanks as full with the main tank contents decreasing, when the exact opposite is the case. Had such a misreading occurred during the accident flight, it may have lead the pilot to treat the LOW FUEL warnings with scepticism, since it would be consistent with one or both transfer pumps being on.

4.9.2. The pilot's initial scepticism might have been reinforced by the apparently sudden appearance of the LOW FUEL warnings, without any prior FUEL caution, and at a time when he would have known that he had not been flying long enough to have reached such a low fuel state.

4.9.3. More generally, when the operator's fleet of 22 aircraft was tested, shortly after the G-NWEM incident, 9 helicopters, including G-NWEM, were found to have a fuel supply tank indication problem (CP557). G-SPAO itself had experienced problems with fuel indications in July and October 2013 and most recently on 24 November 2013, less than one week before the crash.

4.9.4. The plausibility of the hypothesis that the pilot had been given reason to treat the LOW FUEL warnings with scepticism is perhaps reinforced by the evidence that at least one very experienced air observer, trained to challenge the pilot when it was appropriate to do so, continued with routine, administrative duties, as if unaware of anything more serious occurring in the cockpit.

4.9.5. However, in the Crown's submission, there are a number of serious difficulties with this hypothesis. These can be considered under two broad headings. Firstly, on the evidence, it is unlikely that G-SPAO's sensors were contaminated with water at the time of the crash. Secondly, even if they were, and even if they generated a fuel indication consistent with the transfer pumps being on, this would have been unlikely to have persuaded an experienced pilot to disregard the LOW FUEL warnings.

4.9.6. Firstly, consider the evidence for water contamination of the sensors. There was no evidence of water contamination from source, or from refuelling in wet weather. The other two routes discussed in evidence were water contamination following a cold compressor wash or clean, and as a result of condensation.

4.9.7. Water following a cold compressor wash or clean may affect the CAD readings in two ways. Firstly, the micro-drops of water present in a fuel/water emulsion during the accident flight might itself generate an over-reading, though tests indicated that this was unlikely to be significant (Mendick 7:104:13 - 7:105:25). Had a fuel/water emulsion been generated during the day of the accident, potentially causing the supply tank sensors to misread, this would have left a trace of water throughout the fuel tank system (Mendick 7:96:22 – 7:97:7). The fuel samples taken from G-SPAO's main tank were unadulterated, free from water contamination and within specification (CP327, paragraph 1.16.1 p53/e65; CP742).

4.9.8. Further, the AAIB thoroughly checked the inside of the fuel tanks for the presence of water and found none (Vickery 5:26: - 5:28:17, 5:141:13 – 5:143:22; see in particular the response to cross at 5: 142: 20 to 5: 143: 22: there was "nothing to collect"; this was a collective decision based on "discuss[ions] with other experts"; they "had [their] hands in there").

4.9.9. Secondly, water drops which had precipitated out of emulsion would fall to the bottom of the sensors. This could occur during the accident flight, if an emulsion was present. But even if there was no emulsion present during the accident flight, there may have been a build-up of water contamination in the bottom of the sensors from earlier emulsifying events. Although the sensors included a drain hole, this appeared to be "just the right size to trap the water" (Vickery 5: 156: 10-11).

4.9.10. However, in relation to G-SPAO, there was no evidence of pitting of the sensors such as one might expect to find had there been a build-up of contamination (CP863). Further, had there been a build-up of contamination, it might be expected that this would already have had some effect on the CAD on the day of the accident. However, as the AAIB noted (CP327, 2.2.6, e97; Finding 6, e106), "there was no evidence that the fuel system in G-SPAO was indicating incorrectly in the lead up to the accident". This finding is unchallenged insofar as it relates to events prior to the accident flight itself.

4.9.11. Moreover, there is positive evidence that the CAD was reading 400kg correctly at the start of the flight, since that would mean that the aircraft consumed 327kg of fuel (there being 73kg of usable fuel found in the tank), which is consistent with the expected fuel consumption over 98 minutes of flight at 200kg/hour or 3.33kg/minute ie 326.34kg (compare Prior, 30:24:10: - 30:26:10, paragraph 6.2.2 of CP1340; see also the AAIB's own calculations at CP327, 2.2.6, e97).

4.9.12. Contamination of the sensors as a result of condensation was described as theoretically possible, but very unlikely (Mendick, 8:80:14 - 8:80:-21). There are other difficulties with condensation as a plausible mechanism, as discussed below.

4.9.13. In summary, the court is invited to conclude that there was no evidence of water contamination of G-SPAO's fuel tank, its sensors, or its fuel during the accident flight.

4.9.14. Secondly, and if the court were to entertain the possibility that water might somehow have been present in G-SPAO during the accident flight in such a way as to give rise to an over-reading, the court should consider whether the over-reading is likely to have given rise to any erroneous belief on the part of an experienced pilot such as David Traill. This will be considered under reference to two topics: the likelihood that the pilot checked the transfer pump switches; and the anomalous fuel indications that would inevitably be associated with any over-reading that might superficially appear consistent with the transfer pumps being on.

Checking the transfer pump switches

4.9.15. In this context, there is no difficulty in acknowledging that the pilot does not slavishly or unthinkingly follow the *Pilot's Checklist.* The checklist itself instructs pilots to "analyse" the situation, and reminds them that it is impossible to provide instructions for every situation in which a pilot might find himself (CP66, e7). However, that does not mean that one dispenses with the *Checklist* altogether, and it is difficult to imagine circumstances in which a pilot, confronted with a LOW FUEL warning, would not at least check, sooner or later, that the transfer pump switches were indeed ON.

4.9.16. In the first place, at the time the LOW FUEL warnings were triggered, the aircraft would still have contained approximately 130kg of fuel. The pilot would have been aware of his fuel situation had he been carrying out the sort of cross-checks described in evidence, based on flight time and burn rate. This is likely to be the primary reason for initially treating the LOW FUEL warnings with scepticism, rather than any misreading presented on the CAD. However, it is just because the pilot is likely to be initially sceptical of the LOW FUEL warnings that he is likely to have checked whether the transfer pump switches were ON. In this connection, it is worth underlining that the *Pilot's Checklist* requires the pilot to check, not that the transfer pumps are on, but rather that the transfer pump switches are ON (CP66, e22).

4.9.17. Had the pilot made such a check he would have discovered that the transfer pump switches were OFF. Even if he had somehow mistaken the transfer pump switches for the prime pump switches, since the prime pump switches would likely have been OFF, he would have believed, correctly, that the transfer pumps were OFF – albeit, in this case, for the wrong reasons. However, the important point is not the route by which he would have reached this conclusion, but the fact that he would have reached it. This is because the fact that the transfer pump switches were OFF would have provided the pilot with the correct explanation why the LOW FUEL warnings had been triggered, notwithstanding his relatively high fuel state.

4.9.18. In addition, if the CAD were at that stage presenting him with a contrary indication, the fact that the transfer pumps switches were OFF would have given him an additional reason, independent of the LOW FUEL warnings themselves, for believing that the CAD was wrong.

Further anomalous fuel indications

4.9.19. Even if one puts the likely transfer pump check to one side, the hypothetical misreading CAD – one which appears superficially consistent with the transfer pumps being on - will quickly give rise to further anomalous fuel indications that are likely only to alert the experienced pilot that something is wrong.

4.9.20. Firstly, a pilot would only conceivably believe the transfer pumps were on if the main tank contents were reducing. Since the transfer pumps were off clearly the actual main tank contents were not reducing. Indeed, taking account of a degree of overspill from the supply tanks, the actual contents of the main tank would have increased slightly. So the picture of reducing main tank contents could only be generated by a combination of over-reading sensors in one or other or both supply tanks, on the one hand, and the phenomenon of the "virtual tank" on the other. In other words, the over-reading in one or other or both supply tanks must be such that their measured contents exceed 47kg and 43kg. The supply tanks will then read as full, and the extent of the excess is then attributed to the main tank, and will reduce as the fuel in the supply tanks gets burned.

4.9.21. However, in order for a pilot to be presented with this picture, the measured excess over the full contents of each supply tank may not exceed 25kg in each case (Mendick 7:53:13 – 7:53:21), otherwise a FUEL QTY FAIL caption will be triggered, alerting the pilot to the unreliability of the reading (Mendick 7:50:16 – 7:51:8).

4.9.22. Accordingly, and assuming that the supply tanks were full when the transfer pumps were both OFF, then the distorting effect – of showing full supply tanks and reducing main tank contents – could only have lasted for a maximum of approximately 15 minutes (based on a maximum of 50kg burned at 3.33kg/minute). In other words, the pilot would have been presented with the distorted picture on the CAD for a period of at most 15 minutes following the transfer pumps being switched off. Immediately thereafter, the supply tank contents would have reduced below their full levels, and the main tank contents would have stabilised. This would immediately have alerted the pilot to the fact that the transfer pumps were not on.

4.9.23. In addition, however, the hypothetical misreading entails that the pilot would have been presented with a total fuel contents indication substantially in excess of what his own calculations would have told him must be the case. For example, if the over-reading was 25kg in each supply tank when they were full (any more in either would have triggered a FAIL), then the CAD would have been presenting a total fuel situation of about 200kg instead of 150kg at the time the transfer pumps were switched off. An experienced pilot carrying out the sort of fuel checks that were described in evidence, would have been skeptical of such an alarming increase in the quantity of available fuel.

4.9.24. Of course, the extent of the over-reading may be less than 25kg in each supply tank. However, in that event, to the extent to which the over-reading is less than 25kg, the sooner would the virtual tank be exhausted, and the sooner would the supply tank contents start to reduce below their full amounts. In short, the sooner would the distorting picture of full supply tanks and a depleting main tank disappear.

4.9.25. A further difficulty is that it is unlikely that each supply tank will be contaminated to exactly the same extent producing an equivalent over-reading in each case. Of course, any differences are disguised while the measured contents of both exceed 47kg and 43kg. But as soon as the measured contents in either supply tank drop below the floor of the headroom, then the displayed contents of the supply tank will reduce. Since this is unlikely to occur at precisely the same time for each sensor, the pilot is unlikely, in such a scenario, to be presented with a picture where the level in supply tank 1 is precisely 4kg greater than that of supply tank 2. It may be more; it may be less; the level in supply tank 2 may even be greater than in supply tank 1. Since the difference between the levels of fuel in the supply tanks is likely to be anomalous, the pilot will be immediately alerted to the fact that something is wrong. This differential effect of water contamination on the supply tank sensors is supported by the evidence (G-POLD: Crown Notice to admit 2, paragraph 14.b.iii ; G-NWEM: CP755; see also CP425, CP377, CP385, CP387 and CP395).

4.9.26. This is a difficulty in particular for condensation as a mechanism of water contamination. In order for condensation to cause an over-reading such that both supply tank sensors read full, and the main tank is seen as reducing, then the condensation will require to occur in both supply tank sensors, as well as neither main tank sensor. This seems unlikely. While one supply tank sensor might cause an over-reading of as much as 25kg without generating a F QTY FAIL, and while this may be sufficient to show the main tank contents depleting for approximately 7 and a half minutes, unless condensation had occurred in the other supply tank sensor, it would immediately show depleting contents once the transfer pumps were switched OFF. Again, the pilot would immediately be alerted that something is wrong.

4.9.27. In summary, even assuming that there may have been misleading indications on the CAD, it is unlikely to have been something that will have led the experienced pilot to believe that the transfer pumps were on. He would in all likelihood have checked the transfer pump switches, and reached the conclusion that the LOW FUEL warnings were genuine, and the CAD incorrect. In addition, if one examines the constraints underlying the hypothetical misreading CAD, it is clear that the distorting effect – in which both supply tanks appear full, and the main tank contents reducing – is incapable of lasting for long enough to confuse an experienced pilot, and will inevitably give rise to further anomalies which would only alert the experienced pilot to the fact that something is wrong with the fuel indications on the CAD.

4.10. what the root cause or causes were of any such erroneous fuel indications and whether they were adequately investigated and acted upon prior to the accident;

4.10.1. Having adopted the AAIB's evidence that there was no evidence of any erroneous fuel indications during the accident flight, it may be that, strictly, this issue does not require to be addressed. However, in the event that the court comes to the view that there might have been erroneous fuel indications on the CAD, the Crown would make the following submissions.

4.10.2. It was not until the investigation into G-NWEM that the manufacturer and operator became aware of the precise mechanism by which water, in the form of microdroplets of water in a fuel/water emulsion, entered the sensors.

4.10.3. Holger Mendick suggested that Airbus had believed that over-readings were caused by fuel getting stuck within the sensors (9:42:12 – 9:42:24). David Price thought that water contamination would give rise to a F QTY FAIL in the supply tank sensors (15:53:1 – 15:53:9). He was surprised to learn that the sensor manufacturer had inserted lacquer or insulation at the foot of the probe, and suggested that by preventing the caution from being triggered in the event of a short circuit, the problem of over-readings caused by water contamination was being masked (15:51:9 - 15:52:9).

4.10.4. However, the problem of water entering the fuel system following a compressor wash was known to the manufacturer and operator as far back as 2003 at the latest (CP419). And by 2013 at the latest, both the manufacturer and operator were aware of the fact that water was entering the space between the two concentric metal tubes, following a compressor wash, amongst other routes, and that even a couple of drops might be sufficient to cause inaccurate fuel quantity indications even without a DGR or FAIL caution being triggered (Information Notice No 2535-I-28, CP277).

4.10.5. Had investigations been carried out in January 2013, similar to those eventually carried out in the aftermath of the G-SPAO crash and the G-NWEM incident, it is likely that the mechanism of water contamination of the sensors via the water/fuel emulsion would have been discovered. It might also be said that the various measures taken by the manufacturer in 2014 to mitigate the problem of water contamination (eg SB EC135-71-047 POWER PLANT – Drain lines: Modification of the fuel pump drain lines, CP254) would in all likelihood have been introduced earlier.

4.10.6. To reiterate there is insufficient evidence that the earlier investigation and the earlier adoption of mitigation would have prevented the accident. The routes by which water may enter the fuel system are so various and difficult to control that it may never entirely be eliminated as a risk. Indeed, the evidence suggested that the problem of water contamination of the fuel system following a cold compressor wash or clean may not even now have been adequately resolved.

4.11. whether there was a failure of any part of the CAD prior to the accident;

4.11.1. There was no evidence to support this conclusion. See above.

4.12. what steps were open to a helicopter pilot qualified to fly this helicopter after both engines flamed out;

4.12.1. The *Pilot's Checklist* gives a single instruction in the event of a double engine failure in flight: perform an autorotation (CP66, e93, E-6-2). This is a memory item.

4.13. whether the designed time-interval between engine flame-outs was compromised by the design of the fuel tank system and, in particular, the undivided volume above the supply tanks, which, depending on the attitude of the helicopter, might have allowed fuel to spill from one supply tank to another;

4.13.1. The System Description Section of the maintenance documentation (CP290) describes the purpose of the foam intrusion in supply tank 2 as reducing the usable fuel quantity in supply tank 2 by approximately 5 litres, equivalent to 4kg (28-10-00, 2 – e317). It is designed to prevent simultaneous exhaustion of the supply tanks in the event of unintentional non-activation of both fuel transfer pumps. The difference is designed to give the pilot sufficient time to switch the fuel transfer pumps to ON.

4.13.2. The System Description Section incorrectly described the remaining flight time of supply tank 1 as "3-4 minutes". It seems clear that the designed time-interval between flameouts is the time-equivalent of 4kg of fuel. This cannot provide 3-4 minutes of flying time irrespective of burn rate. The manufacturer has acknowledged that this is an error (CP327, e92) and has removed any reference to time, as distinct from the difference in fuel volumes, from subsequent issues of this document. The AAIB estimated, in consultation with the manufacturer, that 4kg of fuel in OEI would give the pilot no more than 1 minute and 30 seconds (CP327, 2.1.5, e92).

4.13.3. In this accident, the engines flamed out within 32 seconds of each other. As the AAIB suggested, this may have been due to fuel spilling from supply tank 1 to supply tank 2, when the fuel levels were close to the top of the fence (CP327, 2.1.5, p80/e92), and trials confirmed this can occur during unbalanced flight (CP327, 1.16.8.1, pp59-60-e71-2).

4.13.4. Accordingly, it does appear that the design time interval can be compromised by fuel migration or spillage from supply tank 1 to supply tank 2. As stated, the purpose of the foam intrusion is to allow the pilot to switch the transfer pumps back ON. For spillage to occur the fuel must be close to the top of the fence. It was unclear from the evidence whether the time interval would ever be completely eliminated or compromised to such an extent that a pilot would be unable to switch the transfer pumps back ON.

4.14. why autorotation, flare recovery and landing were not completed successfully;

4.14.1. In order to enter autorotation a pilot requires to maintain the rotor speed (Nr) of a helicopter. The aim is to maintain Nr as near to 100% as possible. The minimum Nr from which rotor speed can be recovered is 75%. If the rotor speed drops below 75% then the aircraft will not be able to recover (AAIB report p50 e62). It will not be able to enter autorotation. The phenomenon known as lead-lag resonance occurs at 60%-70% of Nr (AAIB report p50 e62).

4.14.2. The pilot requires to reduce the collective within a second or two of the second flameout in order to maintain the Nr (Cook 2:151:11 – 2:151:15). This is a memory item on the flight reference card (CP 66, e99). This lowers the pitch angle of the rotor blades and reduces drag.

4.14.3. In G-SPAO, the CPDS end of flight conditions were met "a few seconds" after the second engine flameout (AAIB report p75 e87 para 6). This indicated that the Nr had decayed below the range that lead-lag resonance can occur (less than 60%). The blades sustained damage caused by lead lag resonance. Although the Nr was recovered on 2 occasions (see AAIB report, Table 3 p33 e45) it was not maintained. It decayed past the point which it was recoverable (75%) within a few seconds of the second engine flaming out. The pilot would have effectively lost control (Prior 30:89:8 – 30:90:4).

4.14.4. There was no reason in principle why the helicopter could not at least enter autorotation. It did not do so, due to the decay in the Nr within a few seconds. The pilot was unable to maintain the Nr. The AAIB was unable to establish why autorotation was not achieved.

4.14.5. Regarding flare recovery and landing, the helicopter did not successfully enter autorotation. The Nr had decayed below 75%. The blades had suffered lead lag resonance (at an Nr of between 60-70%). The Nr then decayed below this range. This occurred within a few seconds of the second engine flaming out. The aircraft was in a state where flight control had effectively been lost shortly thereafter (Prior 30:90:5 – 30:90:13). Accordingly flare recovery and landing were not completed successfully.

4.15. whether the ability to carry out autorotation, flare recovery and landing was compromised by the design of the cockpit layout.

4.15.1. There was no evidence that the design of the cockpit layout compromised the ability to carry out autorotation, flare recovery and landing.

5. **The precautions, if any, which could reasonably have been taken, and which, had they been taken, might realistically have resulted in the helicopter crash being avoided, including whether the crash might realistically have been avoided**:-

5.1. by including within the fuel contents indication system a caution or warning that both transfer pumps were switched OFF;

5.1.1. If both transfer pumps are switched OFF, the supply tanks will begin to drain of fuel until the FUEL caution illuminates, followed by the LOW FUEL warnings. The FUEL caution and LOW FUEL warnings each contain instructions to check that the transfer pump switches are ON. In other words they function in such a way as to alert the pilot that both transfer pumps are switched OFF.

5.1.2. It is not reasonable to expect the manufacturer to have introduced a separate earlier caution or warning to the same effect. Nor would it realistically have avoided the crash.

5.2. **by including within the fuel contents indication system a caution or warning that a fuel pump, having been switched OFF, has since been submerged in fuel**;

5.2.1. Each transfer pump supplies fuel at a faster rate than can be consumed by both engines. Therefore having one transfer pump switched OFF will not deplete the contents of the supply tanks. The supply tanks will only begin to be depleted when both transfer pumps are switched OFF.

5.2.2. It may be that the helicopter undergoes a change in pitch attitude. Let us say that the helicopter was initially nose down, and that after three minutes during which the aft transfer pump was exposed, the AFT transfer pump caution illuminated. The pilot switches OFF the transfer pump. The helicopter then goes nose up, re-submerging the aft transfer pump but exposing the forward transfer pump. After 3 minutes the FWD fuel pump caution illuminates. It is likely that, at this point, while switching OFF the forward pump, the pilot would remember to switch the aft transfer pump switch back ON (Rooney, 25:60:2-26:61:1). Obviously the converse would be true, when transitioning from a nose up to a nose down attitude.

5.2.3. Against that background, it is not reasonable to expect the manufacturer to have introduced a separate caution or warning as proposed. Nor would it realistically have avoided the crash.

5.2.4. It is not clear that there is any need to introduce yet another caution or warning of the sort being proposed. Once again, in the event that the pilot forgets to switch both transfer pumps back ON, he will soon be reminded to do so by the FUEL caution, failing which, the LOW FUEL warnings.

5.3. by designing the fuel tank system and fuel contents indication system in such a way that the fuel transfer pumps did not require to be switched ON or OFF during flight;

5.3.1. G-SPAO was fitted with Test-Fuchs transfer pumps. They can run dry for longer than any EC135 could fly without refuelling. If all Airbus EC135s were equipped with such pumps there would be no reason on safety grounds alone to require them to be switched OFF during flight, though that might still be preferable for reasons of efficiency or maintenance.

5.3.2. However some of the Airbus EC135s are fitted with Globe fuel pumps. They have a dry running time of 20 minutes or so. There would still be a need to switch them ON and OFF in flight. Unless this product could be recalled, if need be, compulsorily, some EC135s would continue to be equipped with the Globe transfer pumps.

5.3.3. So long as some of the existing fleet carried the Globe transfer pump with the limited dry-running time, there would always be a requirement for a transfer pump caution instructing the pilot to turn the transfer pump OFF. There was no clear evidence before the court on whether it would be possible to design different avionics for aircraft with different transfer pumps. In addition, the existing transfer pump caution does not differentiate between a dry-running pump and a blocked pump, and so it might have been necessary to retain the caution in the existing fleet even if only to meet the latter situation.

5.4. **by including within the fuel contents indication system a caution or warning, in the case of anomalous or implausible combinations of outputs from the sensors**;

5.4.1. Fuel gauges are permitted a margin of tolerance. This is defined as +/- 2% of the capacity of the tank plus +/- 4% of its contents (Mendick 7:106:8 – 7:106:17). It was unclear precisely how this would be applied to the geometry of the EC135 fuel tank, but it seems likely that it will embrace significant over-readings (and under-readings).

5.4.2. By "anomalous or implausible combinations", it is presumably intended to refer not simply to an over-reading or under-reading, as such. There was no evidence that pilots had failed to notice anomalous or implausible combinations of outputs from the sensors. Specifically there was no evidence that pilots have been lead to believe, as a result of information presented on the CAD, that the transfer pumps were running when they were not. There was no evidence that the accident was caused by any anomalous or implausible combination of outputs. Nor was there evidence that the crash could realistically have been avoided by means of a caution or warning of the sort proposed.

5.5. **by designing the fuel tank system, and in particular the differential capacities of the supply tanks, in such a way as to ensure that the design objective of creating an interval of 3-4 minutes between engine flame-outs, or such other interval of time as would be represented by 4.5kg of fuel, or any other safe interval of time, was achieved;**

5.5.1. It is difficult to see how the differential volume of the supply tanks could be entirely protected without their being entirely separated from one another. The court did not hear any expert testimony on how a common area above the fence could be maintained in such a way as would prevent the migration of fuel over the fence from one supply to another when the aircraft was flown out of balance.

5.5.2. However, Holger Mendick gave evidence that the common area was an essential part of designing a small twin-engine helicopter able to meet the certification requirements for Category A operations (Mendick 7: 21: 19-23). Helicopters certified to fly such operations must achieve a degree of engine separation. In the event that one engine is inoperative, there must be at least 20 minutes of fuel available to the remaining engine. This requirement is met in the EC135 by the installation of the fence separating supply tank 1 from supply tank 2 (Mendick 7: 21:12-21). The common space above the fence was necessary in order to avoid an overly complex fuel tank system (Mendick 7: 22: 8-18). The court did not hear any contrary evidence.

5.5.3. In any event, there is no evidence that the accident would have been avoided even assuming that the time-equivalent of 4kg had been available to the pilot.

5.6. **by ensuring that power to the RADALT and steerable landing light was automatically maintained in the event of a double engine flame-out**.

5.6.1. It is unlikely that the RADALT and steerable landing light, even if automatically maintained, would have avoided the crash. In the circumstances of the accident, Nr decayed to a level below which it could not be recovered. As a result the pilot lost control over the aircraft and would have been unable to execute a landing flare or landing. In addition, a radio altimeter only provides reliable information over flat surfaces, as opposed to congested areas such as the centre of Glasgow covered with buildings and other obstacles.

6. **The defects, if any, in any system of working which contributed to the deaths or the accident, including:-**

6.1. **whether any aspect of the system of maintenance of G-SPAO, including its washing regime, contributed to the contamination of the fuel and/or the fuel tank system with water;**

6.1.1. There was no evidence that either G-SPAO's fuel tank system or the fuel contained within it were contaminated with water during the accident flight.

6.2. **whether any aspect of the pre-flight check procedures contributed to the accident occurring;**

6.2.1. There was no evidence that any aspect of the pre-flight check procedures contributed to the accident occurring.

6.2.2. The question was explored in evidence whether the water contamination check might more sensibly have been carried out after the washing/cleaning of the aircraft rather than before. However, William Taylor (18:31:20 – 18:32:21) said that the sequence of checks in which the water contamination check was carried out in the hangar before the aircraft was moved out on to the take-off pad was necessary for operational reasons. In any event, since there was no evidence that either G-SPAO's fuel tank system or the fuel contained within it were contaminated with water during the accident flight, it cannot be said that any aspect of the pre-flight check procedures contributed to the accident occurring.

6.3. **whether any aspect of the training of pilots, in particular, with regard to fueling, pre-flight checks, the pilot handover procedure, the operation of the fuel contents indication system, erroneous fuel indications, the appropriate response to fuel cautions and warnings, and the execution of an autorotation at night, contributed to the accident occurring**;

6.3.1. The Crown's submissions focus on two aspects of training: training in respect of LOW FUEL warnings, and autorotation training.

Training in respect of LOW FUEL warnings

6.3.2. The pilot received initial type rating training for the EC135 in June 2008. That included training specifically in relation to the fuel tank system and the fuel indication system. It included training in relation to cautions and warnings pertinent to the fuel system, and in particular the order of cautions and warnings that would be displayed in the event of a low fuel situation. Such training would normally have included the need to comply with the relevant flight reference cards in the *Pilots' Checklist*. There was no evidence to suggest that training was provided to Captain Traill other than in the manner in which it was normally provided.

6.3.3. Apart from formal training of this sort, there may be a question whether pilots were provided with sufficient practical training in relation to low fuel situations and specifically the procedure to be followed in response to a FUEL caution or a LOW FUEL warning. The simulator was not used to simulate low fuel situations. It was considered by the operator to be unrealistic to instigate a scenario leading to a LOW FUEL warning. As a result the pilot would not have been assessed on his actions in the event of a LOW FUEL warning (CP327, 2.1.4, e91).

6.3.4. The AAIB expanded on this in evidence, explaining that pilot testing was based on "scenarios" which are followed from start to finish (Cook 2: 140: 12-25). The scenarios chosen by the operator were based on handling the helicopter at high weights (high fuel quantities). To move from such high fuel states to a situation where a helicopter had nearly run out of fuel very quickly was unrealistic (Cook 2: 140: 20-22). However, the AAIB accepted that by the inadvertent flick of the transfer pump switches one could move from "a high fuel state … to a low fuel warning" (Cook 2: 141: 11). They also accepted that one should be testing for things that are outwith the ordinary day-to-day experience of the pilot (Cook 2: 141: 21). In summary the supposedly "unrealistic" nature of the scenario did not seem, with respect, a particularly convincing reason not to test for it.

6.3.5. This is particularly so when pilots would not ordinarily have had much experience if any with LOW FUEL warnings. There was evidence that a LOW FUEL warning might come on just before landing. But in that event the suggestion was that the pilot would simply complete the landing of the helicopter. It was not suggested that this was an occasion in which reference was required to be made to the procedure set out in the relevant Flight Reference Card. There was evidence that Captain Traill had experienced a LOW FUEL warning in flight (Graham, 6:133: 20-6:134:1) however this was as the aircraft was about to land.

6.3.6. It is therefore difficult to say whether the absence of practical training in relation to low fuel situations contributed to the accident. Perhaps it cannot be excluded, although ultimately, as the AAIB concluded, the reasons why the helicopter did not land within 10 minutes of the LOW FUEL warnings, are unknown.

Autorotation training

6.3.7. So far as autorotation is concerned, there were obvious practical constraints on carrying out training. One particular point of interest, however, is the need to maintain rotar speed above 75%, otherwise it would be irrecoverable. Captain Redfern, who is Head of Flight Operations with BAS, and, at the time of the accident, was a training captain with BAS, was unaware of the existence of such a limit (23: 30: 17). Pilots were trained to apply the collective lever in order to maintain the Nr within limits (step 1 in the relevant flight reference card for autorotation: CP66, e95). The limits are those triggering the rotor rpm warning: 97% and 106%. Pilots did not appear to have received any specific training in the limit below which Nr could not be recovered. Indeed, Captain Redfern had never seen Nr drop to below 75% in the simulator (23: 39: 7-13).

6.3.8. This raises the possibility, if pilots had never practised trying to establish autorotation at these low levels of rotor speed - or if they were not even aware of the existence of a threshold below which they should not under any circumstances allow rotor speed to fall - whether they were adequately trained in that regard.

6.3.9. The Nr recovered on two occasions (CP327, Table 3, e45). The AAIB considered that this was evidence of an attempt on the part of the pilot "to actively manage the autorotation before it got into a position of … getting below 75%" (Cook 2: 154: 6-9). Accordingly, it would be difficult to conclude that any failure in training regarding pilots' awareness of the 75% limit contributed to the accident occurring. However, it is another matter whether the absence of any simulator training, specifically in ensuring that rotor speed did not fall below that value, contributed to the accident. Perhaps it cannot be excluded, although ultimately, as the AAIB concluded, the reasons why a successful autorotation was not achieved are unknown (CP327, e108).

6.4. whether the practice of the "day-shift" pilot handing the aircraft over already fueled to the "night-shift" pilot contributed to the accident occurring.

6.4.1. The Crown is not aware of any evidence suggesting that this practice contributed to the accident.

7. any other facts which are relevant to the circumstances of the deaths, including:-

7.1. **whether, and the extent to which, the Safety Recommendations of the AAIB in their Report 3/2015 have been adopted and implemented**;

7.1.1. The extent to which the AAIB Safety Recommendations have been adopted and implemented is adequately summarised in CP1423.

7.2. **whether, and the extent to which, the operator, helicopter manufacturer and engine manufacturer have taken necessary and appropriate safety actions following the accident, including those considered by the AAIB in their Report 3/2015;**

Operator

7.2.1. Reference is made to the actions taken by the operator highlighted in the AAIB report (CP327).

7.2.2. The operator continues to operate with a final reserve fuel of 90kg (Stobo, 14:36, CP261, CP262, Operations manual).

7.2.3. The system check of the supply tank indication (CP250, 253) has now been incorporated into the maintenance regime for the aircraft. The operator was appropriately involved in the investigation into G-NWEM in December 2013 which led to the introduction of this check.

7.2.4. The compressor wash concession by the engine manufacturer to Babcock continues in operation (Babcock production 21). Accordingly, there is no requirement for a cold chemical clean. The daily wash is carried out as a hot wash. The hot water regime removes any risk of water returning through the return-to-tank line (Price, 16:4:21-16:4:21).

7.2.5. A new sector record page was introduced in July 2016 (Babcock Production 37). This now requires completion of ‘planned fuel uplift’ and ‘actual fuel uplift’ (Redfern 23:59:20 – 23:60:22).

7.2.6. The operator has installed new tactile switch covers on all its aircraft (Price 16:15:8-16:15-14, CP545 e23). The ‘double action’ switches designed by Airbus (as described by Mr. Nater 9:159:12 – 9:197:13) is considered by Babcock to be a positive factor in the design switch (Price 16:16:19 – 16:16:25).

Helicopter manufacturer

7.2.7. Reference is made to the actions taken by the manufacturer highlighted in the AAIB report (CP327).

7.2.8. The system check of the supply tank indication (CP250, 253) has now been incorporated into the maintenance regime for the aircraft. The helicopter manufacturer was appropriately involved in the investigation into G-NWEM in December 2013 which led to the introduction of this check (CP250, CP 467).

7.2.9. A modified probe was designed by Airbus employee Holger Mendick and two of his colleagues. It has been available from 16 March 2018 (CP1049). The drainage holes have been widened (see CP454, e16).

7.2.10. The System Description Section of the Aircraft Maintenance Manual has been updated to delete the erroneous 3-4 minute time given between engine flameouts. The Flight Reference card for Low Fuel Warnings has been amended by Alert Service Bulletin CP251 (although this was already clear – see Prior 30:81:18-30:81:5).

7.2.11. A modified transfer pump switch design has been developed which has a guard, a bulkier shape and requires a double-action to switch them into the OFF position (Nater. 9:195:12-9:197:13).

7.2.12. The Helionix avionics suite is available in new aircraft. It allows flight data monitoring. Once data is uploaded, it triggers an alert if fuel levels in the aircraft have gone below 90kg (Stobo 14:36). In addition, it does not require the switching OFF of the Test-Fuchs pump (Bernhardt, 11:77:4 – 11:77:18).

Engine manufacturer

7.2.13. The manufacturer issued a concession to the operator on 8 December 2014 (Babcock production 21).

7.3. **whether, and the extent to which, any recommendations should be made by this Court.**

7.3.1. S.26(1)(b) and s.26(4) of the Inquiries into Fatal Accidents and Sudden Deaths etc. (Scotland) Act 2016 gives the court power to make recommendations in relation to specific matters 'which might realistically prevent other deaths in similar circumstances'.

7.3.2. No recommendations are proposed by the Crown.