3.0 Conclusions

3.1 Findings as to Causes and Contributing Factors

1. The replacement engine was received in an unexpected pre-SB configuration to which the operator had not previously been exposed.
2. Neither the engine-receipt nor the engine-change planning process identified the differences in configuration between the engine being removed and the engine being installed, leaving complete reliance for detecting the differences upon the technicians doing the engine change.
3. The lead technician relied on verbal advice during the engine change procedure rather than acquiring access to the relevant SB, which was necessary to properly complete the installation of the post-mod hydraulic pump.
4. The installation of the post-mod hydraulic pump and the post-mod fuel tube with the pre-mod hydraulic tube assembly resulted in a mismatch between the fuel and hydraulic tubes.
5. The mismatched installation of the pre-mod hydraulic tube and the post-mod fuel tube resulted in the tubes coming into contact with each other, which resulted in the fracture of the fuel tube and the fuel leak, the initiating event that led to fuel exhaustion.
6. Although the existence of the optional Rolls-Royce SB RB.211-29-C625 became known during the engine change, the SB was not reviewed during or following the installation of the hydraulic pump, which negated a safety defence that should have prevented the mismatched installation.
7. Although a clearance between the fuel tube and hydraulic tube was achieved during installation by applying some force, the pressurization of the hydraulic line forced the hydraulic tube back to its natural position and eliminated the clearance.
8. The flight crew did not detect that a fuel problem existed until the Fuel ADV advisory was displayed and the fuel imbalance was noted on the Fuel ECAM page.
9. The crew did not correctly evaluate the situation before taking action.
10. The flight crew did not recognize that a fuel leak situation existed and carried out the fuel imbalance procedure from memory, which resulted in the fuel from the left tanks being fed to the leak in the right engine.
11. Conducting the FUEL IMBALANCE procedure by memory negated the defence of the Caution note in the FUEL IMBALANCE checklist that may have caused the crew to consider timely actioning of the FUEL LEAK procedure.
12. Although there were a number of other indications that a significant fuel loss was occurring, the crew did not conclude that a fuel leak situation existed – not actioning the FUEL LEAK procedure was the key factor that led to the fuel exhaustion.

3.2 *Findings as to Risk*

1. The carry-forward items list that accompanied the replacement engine listed a post-modification hydraulic pump model, whereas the fuel and hydraulic tubes installed on the engine were pre-mod.
2. Time pressures, difficulties in accessing the SB and the apparent knowledge of the engine specialist influenced the lead technician to curtail his search for the SB and to rely on verbal advice.
3. The post-installation quality control checks following the engine change did not specifically require checking the installation of the hydraulic pump, hydraulic tube and the fuel tube.
4. In the absence of a requirement to conduct a pre-installation, configuration (SB) parity check, and of a commonly accepted method of carrying out this check, there is a risk that incompatible components may be installed on aircraft and not be detected by existing maintenance planning processes.
5. Not being able to understand and resolve the unusual oil readings in the right engine contributed to the crew's uncertainty.
6. The final forward transfer of the 3.2 tons of fuel in the trim tank resulted in this fuel feeding the leak in the right engine and delaying the annunciation of the fuel Advisory by 15 minutes.
7. There was not a clear, unambiguous indication or warning that a critical fuel leak existed.
8. The seriousness of a fuel imbalance situation caused by a fuel leak is undermined by the facts that such a situation only results in an advisory notice not requiring immediate action by the pilot that reference to a fuel leak only appears in a Caution note in the FUEL IMBALANCE procedure.
9. Following the crew actions to crossfeed the fuel, cockpit activities became so high that the crew had little time and limited mental capacity to re-examine its mental model of the situation, specifically to reassess actions already taken, or to re-evaluate other indications to conclude that a fuel leak existed.
10. The flight crew members had never experienced a fuel leak situation during operations or training, which contributed to their not being able to conclude that a fuel leak existed and that actioning the FUEL LEAK procedure was required.
11. The lack of training in the symptoms of fuel leak situations resulted in this crew not being adequately prepared for the situation encountered on the occurrence flight.
12. The Captain's skill in conducting the engines-out glide to a successful landing averted a catastrophic accident and saved the lives of the passengers and crew.
13. The First Officer provided full and effective support to the Captain during the engines-out glide and successful landing.
14. The CD on the company's network containing the Rolls-Royce EIPC for the Trent 772B and related SB's could not be accessed due to a company computer system fault.

15. The overwriting of 90 minutes of the CVR recording deprived the investigation of data that could have resulted in a clearer understanding of the underlying factors to this occurrence.
16. There was no documentation readily available to the crew regarding the deactivation of the flight recorders; consequently, only two of the three recorder circuit breakers were pulled, which allowed the inadvertent overwriting of the CVR recording.
17. Jamming of the L3 emergency exit somewhat hampered the evacuation of the aircraft.
18. Having three Portuguese-speaking flight attendants enhanced passengers' understanding of the safety briefings being given in preparation for the anticipated emergency ditching and actual land evacuation

3.3 Other Findings

1. The unusual oil parameters on the right engine were the result of the high fuel-flow rate through the fuel/oil heat exchanger after the leak commenced.
2. There is not a readily available, effective, commonly accepted method to compare the SB (configuration) status of engines, placing reliance on other processes to detect configuration differences.
3. The logbook entry detailing the installation of the fuel line from the replaced engine was not recorded.
4. The risk associated with the application of force while installing mixed-construction lines is not well known in the maintenance community, and is not covered in the training of maintenance technicians.
5. Failure of the oxygen container doors to open resulted in the contained oxygen masks to not be available for use by the passengers.
6. The failure to remove the maintenance installation retaining pin from the oxygen regulator at position R3 resulted in the contained masks to be unavailable for use by the flight attendant seated at this position.
7. The installation and quality-control process used to ensure that only one type of life jacket is installed on an aircraft did not preclude the installation of some two-strap life jackets on an aircraft that should have been equipped with only the single-strap lifejackets.