FINAL REPORT

AIRBUS A380, REGISTRATION 9V-SKE DIVERSION TO BAKU, AZERBAIJAN

5 JANUARY 2014

AIB/AAI/CAS.101

Transport Safety Investigation Bureau
Ministry of Transport
Singapore

18 April 2017

The Air Accident Investigation Bureau of Singapore

The Transport Safety Investigation Bureau (TSIB) is the air and marine accidents and incidents investigation authority in Singapore responsible to the Ministry of Transport. Its mission is to promote aviation and maritime safety through the conduct of independent and objective investigations into air and marine accidents and incidents.

The TSIB conducts air safety investigations in accordance with the Singapore Air Navigation (Investigation of Accidents and Incidents) Order 2003 and Annex 13 to the Convention on International Civil Aviation, which governs how member States of the International Civil Aviation Organization (ICAO) conduct aircraft accident investigations internationally.

In carrying out the investigations, the TSIB will adhere to ICAO's stated objective, which is as follows:

> *"The sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents. It is not the purpose of this activity to apportion blame or liability."*

Accordingly, it is inappropriate that TSIB reports should be used to assign fault or blame or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

CONTENTS

GLOSSARY OF ABBREVIATION

ACARS	: Aircraft Communications Addressing and Reporting System
ADD	: Aircraft Deferred Defect
ALAR	: Approach and Landing Accident Reduction
ATCO	: Air Traffic Control Officer
CP	: Coverplate
CCRC	: Cabin Crew Rest Compartment
DA	: Decompression Alternate
ECAM	: Electronic Centralised Aircraft Monitoring
EDTO	: Extended Diversion Time Operations
ERA	: En-route Alternate Aerodrome
FO	: First Officer
ICAO	: International Civil Aviation Organisation
IFS	: In-flight Supervisor
PA	: Public Address
PF	: Pilot Flying
PSU	: Passenger Service Unit
RFFS	: Rescue and Firefighting Service
SEM	: Scanning Electronic Microscope

SYNOPSIS

On 4 January 2014, an Airbus A380-800 aircraft flying from Singapore to London experienced a loud noise coming from the third left door on the main deck. After the aircraft arrived in London, the defect was reported to the maintenance personnel who then visually inspected the door. The inspection did not reveal any anomaly other than a slightly-worn seal which had already been noted previously.

The aircraft was dispatched for flight back to Singapore on 5 January 2014. After taking off, the loud noise was again heard at the same door. A flight crew member checked the door but did not notice anything unusual other than the noise. The flight crew decided to proceed with the flight and monitor the aircraft's pressurisation system.

About five hours into the flight, the flight crew noticed that the cabin altitude started to climb slowly from the normal cabin altitude of 6,000 feet, suggesting a gradual loss of cabin pressure. The flight crew initiated an emergency descent as the cabin altitude was approaching 10,000 feet. After the emergency descent, the flight crew made a decision to divert to Baku, Azerbaijan. The aircraft landed in Baku without further incident. There is no injury to any person.

The accident investigation authority of Azerbaijan delegated the investigation of the occurrence to the Air Accident investigation Bureau of Singapore (AAIB)[1]. The AAIB classified this occurrence as a serious incident.

AIRCRAFT DETAILS

Aircraft type:	Airbus A380-800
Operator:	Singapore Airlines
Aircraft registration:	9V-SKE
Numbers and type of engines:	4 Rolls Royce Trent 900
Date and time of occurrence:	5 January 2014, 18:18 hours (UTC), about five hours after departure from London
Location of occurrence:	Turkmenistan Airspace
Phase of flight:	Cruising
Type of flight:	Scheduled passenger flight
Persons on board:	494

[1] The AAIB was restructured to form the Transport Safety Investigation Bureau (TSIB) on 1 August 2016.

1 FACTUAL INFORMATION

All times used in this report are Singapore times. Singapore time is eight hours ahead of Coordinated Universal Time (UTC).

1.1 History of the flight

1.1.1 On 4 January 2014, the day before the flight diversion incident, the aircraft operated a scheduled flight from Singapore to London. After take-off from Singapore, a cabin crew member noticed a loud noise coming from the third left door on the main deck (Door 3L). A flight crew member subsequently went to the cabin to check on the door and did not notice anything unusual, other than the loud noise.

1.1.2 Maintenance personnel had earlier visually inspected the door on 23 December 2013 because of a reported noise. No anomaly was found except for a slightly worn seal on the door's upper edge. An entry was made in the Aircraft Deferred Defect (ADD)[2] log for this issue to be monitored. The ADD system allowed this defect to be rectified within 120 days.

1.1.3 After the aircraft arrived in London, the defect was reported to the maintenance personnel who then visually inspected the door. The areas inspected included door seal, seal guides, rollers, stops, coverplate (CP)[3] (**Figure 1**) and the condition of the exterior door skin. No anomaly was found, other than the slightly-worn seal noted previously. The defect remained on the ADD log.

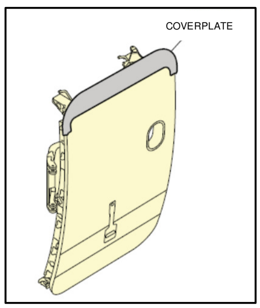

Figure 1: Door coverplate

1.1.4 On the aircraft's return flight to Singapore on 5 January 2014, the noise was heard again at Door 3L after take-off. The cabin crew member seated at Door 3L felt around the door but did not detect any air leak or vibration on the door.

[2] Aircraft Deferred Defect is an aircraft defect which has been assessed as being within technical limits or as not affecting the airworthiness of the aircraft, and has had rectification deferred within a specified limit.

[3] The main deck door on the A380 is a plug type door. When the door is closed, it serves as a plug from inside the fuselage and seals the door cutout when the aircraft is pressurised. However, there will be a small gap between the top edge of the door and the fuselage structure. The CP is mounted to the upper edge of the door skin to cover the gap to prevent water from being trapped and icing up in the gap during flight. In the door closed position, the CP is pressing against the fuselage to function as a fairing to smoothen airflow for aerodynamic performance and reduces airflow noise.

1.1.5 After the take-off and once the seatbelt sign was switched off, the cabin crew member immediately informed her cabin zone leader who in turn informed the In-flight Supervisor (IFS). The IFS went to check on the door and detected no air leak or vibration on the door. He informed the flight crew when the aircraft reached the cruise altitude of 37,000 feet. The cabin pressurisation was normal with the cabin altitude at 6,000 feet[4]. A flight crew member subsequently inspected the door and did not notice anything unusual other than the noise. On return to the flight deck, the pilot transmitted an Aircraft Communications Addressing and Reporting System (ACARS)[5] message to Singapore informing of the noise at Door 3L and requested that the problem be fixed before the next flight.

1.1.6 The extent of the noise was such that passengers and cabin crew members in the area around Door 3L could not hear clearly the announcements over the Public Address (PA) system[6]. The flight crew was aware of the PA situation, but decided to proceed with the flight and monitored the aircraft's pressurisation system, having considered that the issue of a worn seal had already been captured in the ADD, that the pressurisation of the aircraft was normal, that the aircraft had operated normally from Singapore to London, that the noise condition was known and that maintenance personnel had checked the door and certified the aircraft fit for flight.

1.1.7 About five hours into the flight, a cabin altitude advisory appeared on the Electronic Centralised Aircraft Monitoring (ECAM) system which alerted the flight crew to the increasing cabin altitude of the aircraft. This advisory subsequently disappeared. The flight crew by this time was closely monitoring the pressurisation of the aircraft. About 30 minutes later, the flight crew noticed that the cabin altitude started to climb slowly. This resulted eventually in an ECAM warning of excess cabin altitude.

1.1.8 The flight crew executed an emergency descent as the cabin altitude was approaching 10,000 feet. The flight crew declared MAYDAY to Kabul Air Traffic Control (ATC) during the descent but did not get a response. Another aircraft which was flying in the vicinity heard their MAYDAY call and relayed the message to Kabul ATC.

1.1.9 The flight crew then made a decision to back-track and divert to Ashgabat in Turkmenistan, which was the nearest Decompression Alternate (DA)[7] among those identified in the list of DAs in the operator's A380 Supplementary Procedures. The flight crew informed Kabul ATC of their decision to divert to Ashgabat.

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[4] The pressure of the air inside an aircraft's cabin is typically maintained at a level corresponding to an atmospheric pressure at an altitude of 6,000 feet even though the aircraft's altitude is much higher than 6,000 feet. This cabin pressure is higher than the air pressure outside the aircraft since, in the atmosphere, air pressure decreases as altitude increases.

[5] ACARS is a digital datalink system for transmission of short messages between aircraft and ground stations via air-band radio or satellite.

[6] Cabin crew had to call other stations through interphone to find out what the PA was about and had difficulty passing on the information to the passengers.

[7] A Decompression Alternate (DA) is a term used by the operator to denote an identified aerodrome used for diversion after an aircraft has experienced a decompression when flying over high terrain.

1.1.10 The flight crew carried out actions according to the emergency descent checklist. Although not required by the checklist, but as a precaution, the flight crew deployed the passenger oxygen masks[8].

1.1.11 On the way to Ashgabat, the flight crew was informed by the Turkmenabat Area Air Traffic Control (TAATC) that Ashgabat is not suitable for A380 aircraft[9]. After consulting the operator's headquarter via satellite communication, the flight crew decided to divert to Baku in Azerbaijan which was the next nearest airport. The aircraft landed in Baku without further incident. (see **Figure 2**)

Figure 2: Flight route

1.2 Injuries to persons

1.2.1 There was no injury to any person.

1.3 Damage to aircraft

1.3.1 The skin of Door 3L was found torn and bent outwards at the top left hand corner of the door (**Figures 3** and **4**). As a result, the aircraft was unable to maintain pressurisation. The Door 3L window shade was found collapsed. (**Figure 5**).

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[8] The passenger oxygen masks are designed to be deployed automatically when the cabin altitude reaches 13,800 feet. The flight crew can deploy the oxygen masks from the cockpit manually by pressing a pushbutton.

[9] There is a difference between the account provided by the flight crew and that provided by the Turkmenabat Area Air Traffic Control (TAATC). The flight crew said that they were told by the TAATC that Ashgabat was not A380-ready and could not accept A380 while the TAATC said that, after being informed of the flight crew's intention to divert to Ashgabat, its air traffic controllers provided the flight crew with information regarding the aerodrome and weather, and was planning to cancel another aircraft's clearance to land at the aerodrome in anticipation of the A380's diversion. The investigation team requested for a transcript of the TAATC communications with the incident flight but was informed that the TAATC did not keep record of the communications.

Figure 3: Door 3L (View from top)

Figure 4: Door 3L

Figure 5: Door 3L window shade

1.3.2 According to the manufacturer, there was no other record of such door skin failure since the start of A380 operation.

1.4 Personnel information

	Pilot-in-command	First Office	Captain No.2 (Standby crew)	First Officer No. 2 (Standby crew)
Gender	Male			
Age	56	37	49	40
Nationality	Singaporean			
Licence	Airline Transport Pilot Licence issued by the Civil Aviation Authority of Singapore			
Valid till	31 October 2014	31 December 2014	30 November 2014	31 October 2014
Aircraft rating	B744, A310, A340, A380	B777, A380	B747, B744, B777, A340, A380	B777, A380
Medical certificate	Class 1 Medical Certification. Required to wear lenses corrected for distant and near vision	Class 1 Nil limitation	Class 1 Medical certificate. Required to wear lenses corrected for near vision	Class 1 Medical certificate Nil limitation
Last base Check	13 August 2013	16 August 2013	21 November 2013	25 October 2013
Last line Check	29 September 2013	5 May 2013	10 August 2013	3 July 2013
Total flying experience	16815.7 hours	6261.20 hours	15041.93 hours	2608.4 hours
Total on type	4465.3 hours	1903.5 hours	1100 hours	392.3
Flying in last 24 hours	Nil	Nil	Nil	Nil
Flying in last 7 days	13.46 hours	13.46 hours	28.24 hours	27.07 hours
Flying in last 90 days	140.46 hours	125.35 hours	143.0 hours	130.06 hours

1.5 Flight Recorders

1.5.1 The aircraft's digital flight data recorder was removed intact by the operator and data were downloaded. The data was useful for the investigation.

1.5.2 No useful information could be extracted from the cockpit voice recorder as the relevant portion of the recording had been overwritten.

1.6 Aircraft information

1.6.1 Types of coverplate (CP) for Door 3L

1.6.1.1 There are three types of CP for Door 3L:

(a) Batch 1 CP is made of glass-fibre reinforced plastic (GFRP) laminate. The incident aircraft was delivered to the operator on 28 June 2008 with a Batch 1 CP.

(b) Batch 2 CP is also made of GFRP laminate and is practically the same as Batch 1 CP. The difference lies in the manufacturing process. No Batch 2 CP was installed on the incident aircraft.

(c) Batch 3 CP has a steel insert embedded within the GFRP laminate to improve its stiffness. The Batch 1 CP in the incident aircraft was replaced with a Batch 3 CP on 9 August 2012.

1.6.2 History of Door 3L coverplate noise

1.6.2.1 The incident aircraft had originally a Batch 1 CP. A foreign object was found at the top of Door 3L on 20 August 2008. Following the removal of the object, the door was visually inspected and no damage was found. The aircraft was then returned to service. Subsequently, noise was reported on 29 August 2008 and the CP was replaced with another Batch 1 CP on 31 August 2008.

1.6.2.2 The Batch 1 CP was replaced with a Batch 3 CP on 9 August 2012. Between 31 August 2008 and the replacement with a Batch 3 CP, there were a number of noise reports concerning the Door 3L area. Sources of the noise included: airflow over the CP; air leaks through door seals; and vibration of a portable water compressor that was installed near Door 3L. Maintenance response to such reports included: applying aluminum tapes to the fuselage area under the CP to reduce any gap between the CP and the fuselage; lubricating the door seal; and replacing the CP.

1.6.2.3 The CP replacement work on 9 August 2012 was carried out in daytime. The engineer who supervised the replacement of the CP could not recall the full details of the work as he had replaced many CPs since, but he indicated the following:

(a) The work would usually be carried out by three technicians.

(b) The CP removal process would involve removing the door inner trim to access and loosen the row of fasteners that were holding the CP and seal retainer. After removing the CP, the remaining sealant underneath the CP would be removed using a Teflon scraper followed by cleaning with a solvent.

(c) A visual inspection of the door area is required after cleaning to ascertain no anomaly before installing a Batch 3 CP. The inspection was carried out without any optical aid such as a magnifying glass or light source as the work was carried out in daylight condition. A layer of sealant was applied between the mating surfaces of the CP and the door before installing the CP fasteners.

(d) Due to insufficient ground time to re-paint the door area, an ADD was raised. The door area was subsequently painted on 28 August 2012. The door area was painted again when the entire aircraft was repainted in November 2012 during a heavy maintenance.

1.6.2.4 There were no noise reports after the CP replacement on 12 August 2012 until December 2013. As mentioned in paragraph 1.1.2, Door 3L was visually inspected on 23 December 2013 arising from a noise report but no anomaly was found except for a slightly worn seal on the door's upper edge, and an entry was made in the ADD log. Subsequently, according to the cabin crew who flew on the aircraft, the noisy condition apparently worsened before the incident on 5 January 2014.

1.7 Test and research

1.7.1 Laboratory examination of the damaged door

1.7.1.1 The damaged door of the incident aircraft was sent to the aircraft manufacturer's facility for laboratory examination, which included the following:

1. Material property check
2. Visual inspection
3. Ultrasonic test
4. Fracture analysis and striation counting using scanning electronic microscope (SEM)
5. Analysis of residue found on cracked surfaces

1.7.1.2 The material properties and chemical composition of the door skin and rivets were in accordance with design specifications.

1.7.1.3 The torque values of the CP screws were measured and no anomaly was observed. The CP was examined and no significant disbonding between the composite laminate and metal insert was detected.

1.7.1.4 **Figure 5** shows the damage at the upper left corner of Door 3L in more detail.

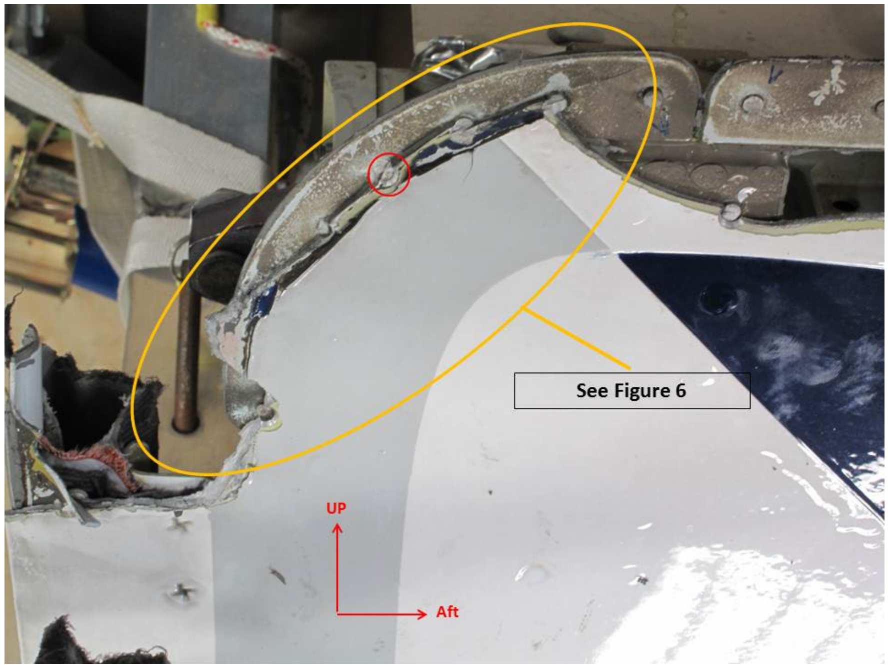

Figure 5: Damage at Door 3L upper left corner

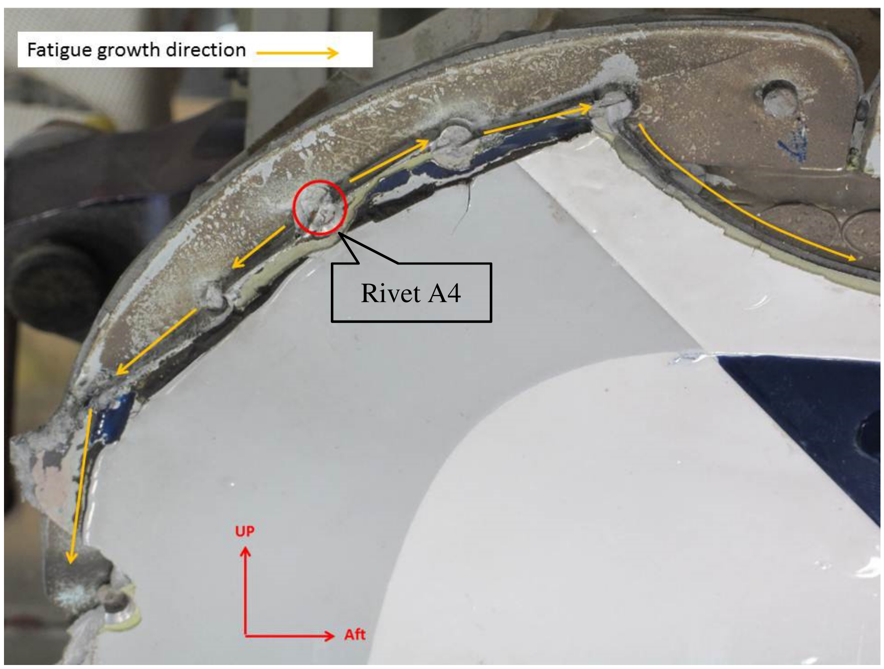

Figure 6: Crack growth direction indicated by arrows initiated from rivet highlighted in red

1.7.1.5 SEM examination of the cracked surface revealed predominantly fatigue induced fractures originating from some rivet holes (Figure 7). The crack is likely to have started at Rivet A4 and propagated away from Rivet A4 as shown in Figure 6. An analysis of the crack by the aircraft manufacturer suggests that the fractures were due to high cycle[10] fatigue failure under varying amplitude loading.

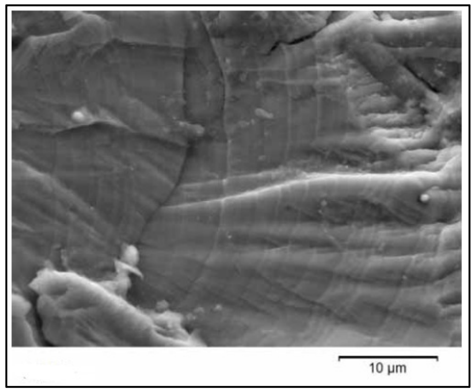

Figure 7: SEM image of fracture surface showing striation lines indicating fatigue failure

1.7.1.6 The row of affected rivets is located just below the bottom edge of the CP (**Figure 8**).

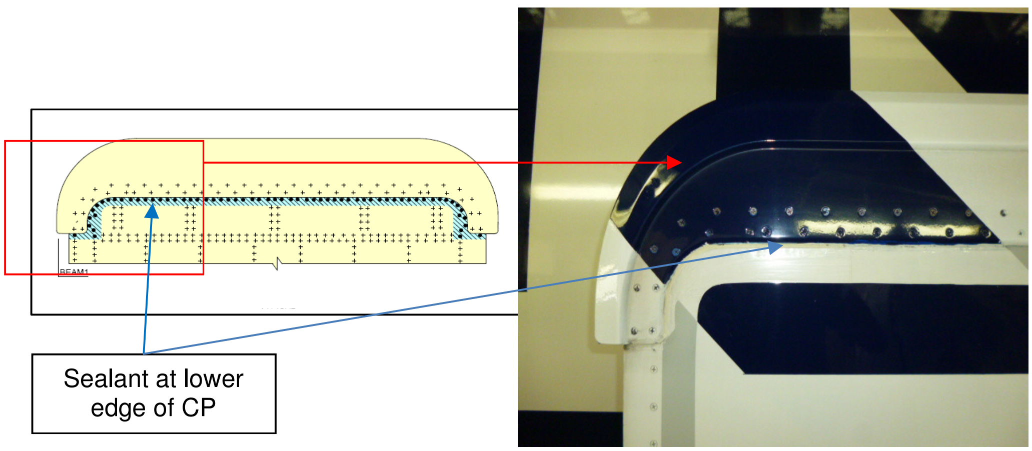

Figure 8: Location of affected row of rivets

1.7.1.7 Some paint and sealant had seeped into the door skin cracks (**Figure 9**).

[10] The striation count of the fractured surface showed that the number of loading cycles was higher than the number of flight cycles.

Figure 9: Paint seen under the door skin after seeping through existing door skin cracks

1.7.1.8 In addition, there were three missing rivet heads at the cracked area with paint and sealant found on two of the missing rivet heads' countersunk surface (**Figure 10**). Analysis of the paint revealed that the paint was PPG CA8000 (a top coat paint approved by the aircraft manufacturer).

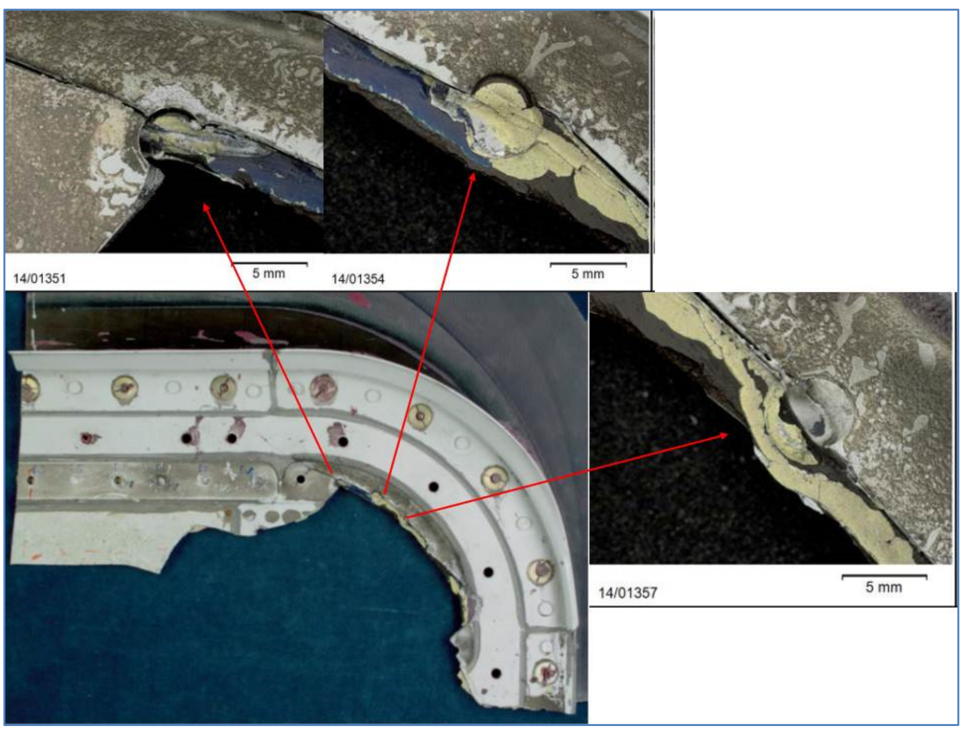

Figure 10: Paint and sealant on countersunk surface of missing rivet holes

1.7.1.9 Aeroelastic simulation of door crack propagation in the case of a pristine door fitted with Batch 3 CP arrives at damage results that are similar to the damage found in this incident.

1.7.2 Noise recording provided by a passenger

1.7.2.1 A passenger recorded the noise with his iPad and provided the recording to the investigation team. The recording was analysed. The noise spectrum does not suggest any vibration (rattling) and is consistent with that of a noise produced by airflow over the CP. The loudness of the noise cannot be estimated owing to a lack of reference sound for comparison.

1.8 Additional Information

1.8.1 Since the incident the aircraft manufacturer has:

- issued an Alert Operators Transmissions (AOT) to all A380 operators on 22 January 2014 to require ultrasonic inspection of noisy main deck doors to detect presence of crack at the upper row of rivets on the door skin. The AOT was subsequently revised to provide more guidance to the inspection and repair criteria and to introduce a smartphone noise recording procedure for flight crew;

- issued Service Bulletins A380-52-8079 to 8094 in October 2014 to introduce door structure reinforcement to provide additional margin against vibrations;

- issued Service Bulletins A380-52-8133 to 8148 in November 2014 to require repetitive ultrasonic inspection pending the incorporation of the door structure reinforcement, which became the subject of EASA Airworthiness Directive No. 2014-0253 issued in November 2014; and

- encouraged the retrofitting of Batch 1 or Batch 2 CP with Batch 3 CP, and started to monitor the retrofit status of all in-service A380 aircraft.

1.8.2 As a precaution, the operator of the incident aircraft carried out ultrasonic inspections on all passenger doors for all its A380 aircraft, regardless of whether there was any noise report. The inspections found cracks on Door 3L (fitted with Batch 3 CP) of two other aircraft. Laboratory examination of the skin of these doors found similar damage initiation and propagation as for the incident aircraft.

1.8.3 Oxygen flow

1.8.3.1 Oxygen masks will drop from the Passenger Service Units (PSUs) above each row of passenger seats and each bunk in the cabin crew rest compartment (CCRC) when the oxygen system is activated automatically in a decompression situation or manually by the flight crew.

1.8.3.2 **Figure 11**, shows a typical arrangement for oxygen to flow to the oxygen mask[11]:

(a) Oxygen will flow from the PSU through a tube to an oxygen bag and then to the oxygen mask.

(b) The tube has a flow indicator that will indicate a green band when the oxygen flow is 0.5 litre per minute or more.

(c) A lanyard is latched to the oxygen mask. Pulling on the oxygen mask will cause the lanyard to release a pin in the oxygen dispenser mechanism, thereby opening a valve to allow oxygen to flow into the tube.

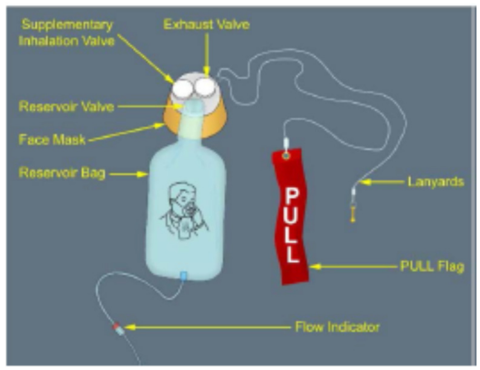

Figure 11 – Oxygen mask arrangement

(d) When a person inhales through the oxygen mask, air in the aircraft cabin will also be drawn into the mask through an inhalation check valve (**Figure 12**). Therefore, what a person is breathing in is actually a mixture of oxygen from the aircraft's oxygen supply system and air from the aircraft cabin. The resultant composition of the air mixture depends on the oxygen flow rate (which depends on the cabin altitude).

Figure 12 – Oxygen mask construction

[11] The oxygen supply on the aircraft is distributed through a series of pipelines from the oxygen bottles to the PSUs, which typically house two or three oxygen masks each.

1.8.3.3 The flight crew activated the passenger oxygen system as a precaution during the emergency descent. There was feedback from passengers and cabin crew members that five PSUs in the aircraft cabin and 13 PSUs in the CCRC did not appear to be dispensing oxygen as they could not feel any airflow after donning the mask. The investigation team found the following:

(a) The flow indicators of all the oxygen masks at the five PSUs in the aircraft cabin exhibit the green band, indicating that there was oxygen flow, even though the users felt otherwise. These PSUs were also removed for test and found to be functioning as designed.

(b) The lanyard pins of seven of the 13 PSUs in the CCRC were not released and there was therefore no oxygen flow. The others were found with green band indicating that the oxygen flow was activated.

1.8.4 Cabin crew action

1.8.4.1 The cabin crew informed the passengers seated in the area of Door 3L that the flight crew was aware of the noise situation. As the flight was quite full, only two passengers at row 44ABC were relocated to Business Class. The cabin crew provided noise cancelling headsets to help alleviate the passengers' discomfort as well as additional blankets to some of the passengers who were feeling cold.

1.8.4.2 The cabin crew was instructed by the flight crew to take their seats when the aircraft commenced the emergency descent. The oxygen masks were deployed and an announcement was made to advise the passengers to continue donning the oxygen mask as the aircraft was still descending. After about 20 minutes, when instructed by the flight crew, the cabin crew carried out the post decompression drill, going around the cabin to check and reassuring anxious passengers as well as administering oxygen from portable oxygen bottles to passengers who needed it. The flight crew subsequently announced that the flight would be diverting to Azerbaijan.

1.8.5 Rescue and firefighting

1.8.5.1 *<u>Objective of rescue and firefighting service</u>*

1.8.5.1.2 The principal objective[12] of a rescue and firefighting service (RFFS) is to save lives in the event of an aircraft accident or incident occurring at, or in the immediate vicinity of, an aerodrome. The RFFS is provided to create and maintain survivable conditions, to provide egress routes for occupants and to initiate the rescue of those occupants unable to make their escape without direct aid.

1.8.5.1.3 The prime mission[13] of the RFFS is to control the fire in the critical area to be protected in any post-accident fire situation with a view to permitting the evacuation of the aircraft occupants.

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[12] See Introductory Note in paragraph 9.2 of ICAO Annex 14 Volume 1
[13] See paragraph 12.2.1 of Part 1 of ICAO Airport Services manual (Doc 9137)

1.8.5.1.4 The RFFS must assume at all times[14] the possibility of and need for extinguishing a fire which may:

(a) exist at the time an aircraft is landing, taking off, taxiing, parked, etc.;
(b) occur immediately following an aircraft accident or incident; or
(c) occur at any time during rescue operations.

1.8.5.2 *Aeroplane RFFS category*

1.8.5.2.1 Aeroplanes have an aeroplane RFFS category number. An aeroplane's RFFS category is based on the aeroplane's dimension and determined in accordance with paragraphs 9.2.5 and 9.2.6 of ICAO Annex 14 Volume 1 (see **Appendix A**).

1.8.5.2.2 The A380 is of aeroplane RFFS Category 10, the highest category.

1.8.5.3 *Aerodrome RFFS category*

1.8.5.3.1 Aerodromes have an aerodrome RFFS category number. An aerodrome's RFFS category is based on the dimension of the longest aeroplanes normally using the aerodrome and determined in accordance with paragraph 9.2.5 of ICAO Annex 14 Volume 1 (see **Appendix A**).

1.8.5.3.2 The aerodrome RFFS category dictates the firefighting resources and capabilities, including extinguishing agents and firefighting vehicles, which the aerodrome concerned must put in place. These resources and capabilities are described in Chapter 2 of the ICAO Airport Services Manual (Doc 9137).

1.8.5.3.3 The determination of the aerodrome RFFS category takes into account the longest aeroplanes normally using the aerodrome and not the longest aeroplane using the aerodrome. ICAO recognises the impracticality of requiring an aerodrome to cater, RFFS-wise, to the longest aeroplane type using the aerodrome when the frequency of such aircraft using the aerodrome is relatively low. Thus, if the frequency is below a certain value, the aerodrome's RFFS category can be one category below the category number as determined by paragraph 9.2.5 of ICAO Annex 14 Volume 1.

1.8.5.3.4 The frequency criterion for this "category-reduction" rule is whether the number of movements (either a take-off or a landing) of the aeroplanes in the highest aeroplane RFFS category normally using the aerodrome is less than 700 in the busiest consecutive three months.

1.8.5.4 *ICAO Airport Services Manual (Doc 9137)*

1.8.5.4.1 The ICAO Airport Services Manual (ASM) addresses the factors bearing on the effective handling of a post-accident aircraft fire. These factors include personnel, equipment, vehicles, extinguishing agents, airport layout (e.g. location of fire station(s), water supply system, access

[14] See paragraph 1.1.2 of Part 1 of ICAO Airport Services manual (Doc 9137)

roads), training and procedures (e.g. emergency planning, response time, operational tactics and manoeuvres, command and communications).

1.8.5.4.2 Two types of resource are quantitatively defined in the ASM in relation to the aerodrome RFFS category. They are the RFFS vehicles and extinguishing agents.

1.8.5.4.3 The minimum number of RFFS vehicles is to be as follows:

Aerodrome RFFS category	RFFS vehicle(s)
1 - 5	1
6 - 7	2
8 - 10	3

1.8.5.4.4 As for the amount of extinguishing agent that an aerodrome needs to be able to provide for firefighting purposes, Chapter 2 of Part 1 of the ASM contains elaborate formulae for its determination. These formulae are based on the operational concept of seeking to control only the area of fire adjacent to the fuselage (the critical area[15]) for the rescue of the aeroplane occupants with the objective of safeguarding the integrity of the fuselage and maintain tolerable conditions for the occupants. Factors involved in the formulae include, among others, discharge rate, need to obtain a one-minute control time[16] on the critical area, maintenance of control and/or extinguishment of the remaining fire.

1.8.5.4.5 Chapter 2 shows the following amounts of water[17] that are required for making firefighting foam of performance level A[18] in respect of the largest aeroplane in the RFFS category[19]:

Aerodrome RFFS category	Amount of water (litres)
1	689
2	1,166
3	2,175
4	4,353
5	9,112
6	14,924
7	21,482
8	31,099
9	41,483
10	54,242

Thus for A380:

(a) the amount of water required of a Category 10 RFFS aerodrome is 54,242 litres; and

[15] See paragraph 2.4.1 of Part 1 of ICAO Airport Services manual (Doc 9137)
[16] Control time is the time required to reduce the initial intensity of the fire by 90%.
[17] See paragraph 2.3.8 and Table 2-4 of Part 1 of ICAO Airport Services manual (Doc 9137)
[18] The amounts of water in respect of the more effective performance level B and C foams may be computed in a similar way.
[19] A380 is the largest Category 10 aeroplane.

(b) the amount of water required of a Category 9 RFFS aerodrome (which may allow A380 operations under the category-reduction rule indicated in paragraph 1.8.5.3.3) is 41,483 litres. This is 76.5% of the amount required of a Category 10 aerodrome.

1.8.5.5 *Flight planning*

1.8.5.5.1 Paragraph 4.1.4 of Annex 6 Part 1 says that “An operator is required to assess the level of RFFS protection available at any aerodrome intended to be specified in the operational flight plan in order to ensure that an acceptable level of protection is available for the aeroplane intended to be used.”

1.8.5.5.2 Flight planning involves, as indicated in paragraph 3.1.1 of Attachment J of Annex 6 Part I (**Appendix B**), ensuring that the aerodrome RFFS category for each of the aerodromes used for a given flight should be equal to or better than the aeroplane RFFS category[20].

1.8.5.5.3 This paragraph 3.1.1 also spells out that “if the aeroplane RFFS category is not available at one or more of the aerodromes required to be specified in the operational flight plan, an operator should ensure that the aerodrome has the minimum level of RFFS which is deemed acceptable for the intended use in accordance with the instructions contained in the operations manual.” It adds that, when establishing acceptable levels of minimum RFFS for these situations, the operator may use the criteria in Table J-1 in Attachment J of Annex 6 Part I which is reproduced as **Table 1** below for easy reference:

[20] It has to be noted that paragraph 3.2.1 of Attachment J of Annex 6 Part I provides that “in flight, the pilot-in-command may decide to land at an aerodrome regardless of the RFFS category if, in his judgment after due consideration of all prevailing circumstances, to do so would be safer than to divert.”

Aerodromes (Required to be specified in the operational flight plan) (1)	Minimum acceptable aerodrome RFFS category (Based on published aerodrome RFFS category)
Departure and destination aerodrome	RFFS category for each aerodrome should be equal to or better than the aeroplane RFFS category. **One** category (2) below the aeroplane RFFS category may be accepted where provided as a remission in accordance with Annex 14, Volume I, 9.2, but not lower than Category 4 for aeroplanes with maximum certificated take-off mass of over 27 000 kg and not lower than Category 1 for other aeroplanes.
Departure and destination aerodrome in case of temporary downgrade and Take-off alternate, destination alternate and en-route alternate aerodromes	**Two** categories below the aeroplane RFFS category, but not lower than Category 4 for aeroplanes with maximum certificated take-off mass of over 27 000 kg and not lower than Category 1 for other aeroplanes.
EDTO en-route alternate aerodrome	RFFS Category 4 for aeroplanes with maximum certificated take-off mass of over 27 000 kg or not lower than Category 1 for all other aeroplanes, under the condition that at least 30 minutes' notice will be given to the aerodrome operator prior to the arrival of the aeroplane.

Notes.—

(1) If an individual aerodrome serves more than one purpose, the highest required category corresponding to that purpose at the time of expected use applies.

(2) Annex 14, Volume I, determines the aerodrome category for rescue and fire fighting according to 9.2.5 and 9.2.6 except that, where the number of movements of the aeroplanes in the highest category normally using the aerodrome is less than 700 in the busiest consecutive three months, the category provided may be one lower than the determined category.

Table 1. Minimum acceptable aerodrome category for rescue and firefighting

1.8.5.5.4 It is noted from Table 1 that:

(a) For an en-route alternate aerodrome (ERA), the minimum acceptable aerodrome RFFS category is two categories below the aeroplane RFFS category, but not lower than Category 4, for aeroplanes with maximum certificated take-off mass of over 27,000 kg (which is the case of A380). Thus, for A380, the ERA should be of at least Category 8; and

(b) Furthermore, for an en-route alternate aerodrome that is planned for extended diversion time operations (ERA-EDTO)[21], the minimum acceptable aerodrome RFFS category is Category 4 for aeroplanes with maximum certificated take-off mass of over 27,000 kg (which is the case of A380), under the condition that at least 30 minutes' notice will be given to the aerodrome operator prior to the arrival of the aeroplane[22]. Thus, for A380, the ERA-EDTO should be of at least Category 4.

1.8.5.5.5 To guide Singapore operators in making safety risk assessment of aerodrome RFFS, the Civil Aviation Authority of Singapore (CAAS) had issued Advisory Circular AC AOC-31(0) dated 5 October 2012 on *Safety Risk Assessment of Aerodrome Rescue and Firefighting Service by Air*

[21] EDTO is any operation by an aeroplane with two or more turbine engines where the diversion time to an en-route alternate aerodrome is greater than the threshold time established by the State of the Operator.

[22] ICAO has clarified to the investigation team that the criterion for ERA-EDTO in paragraph 1.8.5.5.4(b) applies only to the EDTO segments of a route but not for the entire route. For the non-EDTO segment, the criterion for ERA in paragraph 1.8.5.5.4(a) applies.

Transport Operators (**Appendix C**). CAAS' requirements in the AC are in line with ICAO's requirements.

1.8.5.5.6 For establishing the minimum acceptable aerodrome RFFS category, AC AOC-31(0) allowed airline operators of Singapore to use the criteria in paragraphs 1.8.5.5.4. Further reduction in aerodrome category may be considered by CAAS if this can be justified by the operators using an acceptable methodology in their safety management system that provides an acceptable level of safety[23].

1.8.5.5.7 The operators will need to seek CAAS' acceptance of its detailed risk assessment programme for any deviation from the guidance given in Table 1 above. CAAS required that the risk assessment programme should at least contain elements such as prevention and mitigation of in-flight fire and cabin crew training to ensure expeditious evacuation of passengers[24]. The CAAS would evaluate the following:

(a) Whether the operator has an operation philosophy and training which are geared towards preventing and suppressing in-flight fire or any conditions that leads to such fire

(b) Whether the cabin has been designed with consideration toward unimpeded passenger flow during emergency evacuation

(c) Whether the operator trains its crew to be proficient in evacuation procedures as well as post evacuation management of passengers

(d) Whether the operator has a policy on minimum crew complement and crew experience

(e) Whether the operator has a Minimum Equipment list (MEL) dispatch policy on aeroplane's exits and evacuation slides

(f) Whether the operator has an awareness programme on hazards such as runway incursion and excursion during aerodrome surface movements, especially under conditions of restrictive visibility

1.8.5.6 <u>*Category 4 RFFS aerodromes for planning of en-route alternates*</u>

1.8.5.6.1 The A380 is of aeroplane RFFS Category 10. The criterion in paragraph 1.8.5.5.4(a) would allow the operator to use Category 8 aerodromes (i.e. two categories below A380's Category 10) as en-route alternates (ERAs). The operator considered that it should be possible to use Category 4 aerodromes instead of Category 8 aerodromes on the ground that it believed the probability of an in-flight diversion to an ERA is no higher than that of an in-flight diversion to an ERA-EDTO, for which the minimum acceptable aerodrome RFFS is Category 4 as per AC AOC-31(0). It therefore applied to CAAS to seek approval for using Category

[23] Paragraph 10 in AC AOC-31(0)
[24] Paragraph 13 in AC AOC-31(0)

4 aerodromes for flight planning of ERAs for its A380[25]. The application was approved by CAAS.

1.8.5.7 *Operator's qualitative safety risk assessment*

1.8.5.7.1 The operator's submission to CAAS to seek approval for using Category 4 aerodromes was based on a qualitative safety risk assessment (QRSA) addressing the elements identified by CAAS in AC AOC-31(0) (see paragraph 1.8.5.5.7). In the submission, the operator identified the hazards as well as the projected consequences as follows:

Hazard	Projected consequence
Fire events (in-flight or on-ground) leading to an evacuation of passengers and crew upon a landing or take-off	If not prevented or contained, a fire may result in the need for an evacuation after landing or take-off Injury to persons
Runway/taxiway incursion and excursion that may lead to aircraft damage/fire	An evacuation for passengers and crew Injury to persons
Inability to evacuate all passengers and crew in accordance with certification standards	Injury to persons
No external support rendered to assist passengers/crew post-evacuation	Passengers may injure themselves whilst unsupervised/unattended to on the ground Injury to persons

1.8.5.7.2 For each of these hazards, the operator identified qualitatively the existing defences or mitigation actions (**Table 2** below) and concluded that the existing mitigation actions are considered sufficient to maintain the level of risk at an acceptable level.

Hazard	Defences or mitigation actions
Fire events (in-flight or on-ground) leading to an evacuation of passengers and crew upon a landing or take-off	Prevention of fire: • All flights are non-smoking. Announcement to reinforce the rule is made every flight • Operator has procedure to handle dangerous goods (DG) rules which include proper inspection of limits and packaging of DG before uplifting into the cargo holds • All flight crew and the relevant ground staff handling DG are required to undergo recurrent training and evaluation on the subject • Cabin crew members are required to perform regular in-flight inspection of lavatories • Restriction on items carried in passengers' check-in and carry-on bags (e.g. Li batteries) Containment of fire: • Fire detector are installed in engines, APU and wheel wells and smoke detectors in cargo holds, avionics compartments, lavatories and crew rest areas. Fire extinguishing systems are installed for the engines, APU, cargo holds. Automatic fire extinguisher is installed for the waste bins in the lavatory. Warning is presented in the cockpit should fire or smoke be detected. Flight

[25] In the same submission the operator also requested for deviation to aerodrome RFFS category 4 for its A330, A340 and B777 aircraft.

	crew are trained and tested on immediate corrective action as per applicable non-normal procedures • More than the minimum required number of portable fire extinguishers and protective personal equipment (PPEs) are carried on board • All flight and cabin crew members are required to undergo a comprehensive initial firefighting course and recurrent training once every two years and every year respectively • Cabin crew members are trained to handle different types of fire with recurrent training programme covering fire and smoke/ fumes scenarios, and they are tested on the procedures every year
Runway/taxiway incursion and excursion that may lead to aircraft damage/ fire	• All pilots have undergone training in runway safety including performance and signage information during initial and recurrent training. This will reduce the possibility of runway incursion/ excursion that may require an evacuation. Pilots are checked for proficiency in the execution and management of landing/take-off and/or passenger evacuation during recurrent and base checks • Standard operating procedure (SOP) requires the use of ALAR[26] tool in the approach briefing. This procedure aims to increase the pilots' awareness and reduce the possibility of a runway excursion upon landing • SOP requires pilots to independently use the onboard performance tool for aircraft performance calculations and to cross-check the results
Inability to evacuate all passengers and crew in accordance with certification standards	• The A380 is certified for evacuation of its maximum certified occupants using one half of its exits in 90 seconds, which is shorter than the required RFFS response time of 2 to 3 minutes. The A380 is configured to carry far fewer passengers than certified for and the operator has more cabin crew members than the minimum number required. The cabin crew members in excess of the minimum requirements are trained for secondary duties in assisting the primary crew in an evacuation. Apart from the required Crew-in-Charge (CIC), cabin crew complement requires other experienced crew members (senior cabin crew). Thus, the crew experience levels are an added advantage in this mitigation action • The A380 cabin is configured with clear lines and cross aisles and equipped with an emergency escape path marking system and onboard provisions for rapid evacuation, allowing expeditious and unimpeded egress of passengers. There are procedures to ensure that escape paths are clear prior to take-off and landing • The A380 Minimum Equipment List (MEL) is in compliance with the Master MEL to provide guidance for dispatch with inoperative exit/slide, fire protection system components, safety equipment, etc. • Crew members are trained, tested and assessed on their knowledge and capabilities on evacuation procedure on an annual basis
No external support rendered to assist passengers/crew post evacuation	• Cabin crew members are trained to evacuate with support equipment from the aircraft. They are trained in the theory of controlling and mustering evacuated passengers away from areas of danger • Cabin crews are trained in first aid and can offer basic support to injured passengers in the post-evacuation phase

Table 2. Defences/mitigation actions identified by the operator

1.8.5.7.3 According to the operator, it had the following mitigation measures in place for the A380:

[26] Approach and Landing Accident Reduction

- The cabin layout and configuration should allow for rapid evacuation and unimpeded egress of passengers.
- The aircraft carried far fewer passengers than it was certificated to carry.
- The operator deployed more than the required number of cabin crew members and the excess cabin crew members were trained to assist the primary crew members in an evacuation.

1.8.5.7.4 The operator also indicated it had the following measures in place to cater to occupants that may be unable to make their escape from an aircraft without direct aid:

- A "safety assistant" will be deployed on a flight to assist each passenger with reduced mobility/disability to expeditiously move to an exit in the event of an evacuation.
- A "buddy system" of seating able bodied passengers next to invalids, children and aged passengers in a pre-planned evacuation.
- When the flow of passengers ceases and it appears that no more passenger is moving towards the exit during an evacuation, the primary and assisting cabin crew members will move into the cabin to render assistance to any injured or confused passengers until the area concerned is clear or untenable.

1.8.5.7.5 During the certification of the A380 aircraft, the ability to evacuate the passengers within 90 seconds has been demonstrated by the aircraft manufacturer. As its A380 carried fewer passengers than that was certificated and as it rostered more than the minimum complement of trained cabin crew members (see paragraph 1.8.5.7.3), the operator assessed that, should there be a need to divert to an ERA with a lower RFFS category, it would be able to conduct an evacuation of all the passengers within the required 90 seconds before the arrival of the RFFS (which would normally take 2 to 3 minutes to arrive on scene). Thus, the operator considered that its capability of evacuating all its passengers was independent of the RFFS capability of such an aerodrome and that the risk of using such an aerodrome was moderate.

2 ANALYSIS

2.1 Cause of Door 3L failure

2.1.1 The root cause of the Door 3L failure was traced to a crack passing through a number of rivet holes on the door skin. The crack was probably induced by high cycle fatigue under varying amplitude loading caused by fluttering of the Batch 1 coverplate (CP) that was initially installed on the aircraft. The replacement of the Batch 1 CP by a stiffer Batch 3 CP could not prevent further propagation of the crack.

2.1.2 The discussion below focuses on the following aspects:

- Crack detection
- Noise from Door 3L
- Oxygen flow
- Use of Category 4 aerodromes for planning of en-route alternates
- ICAO documentation

2.2 Crack detection

2.2.1 Traces of sealant and paint were found on the crack surfaces as well as on the countersunk surfaces of two of the rivet holes with missing rivet heads. This means the crack was already present in August 2012 during the CP replacement and subsequent painting work. The rivet heads could also have been missing by then.

2.2.2 When the CP is in place, the lower edge of the CP would almost cover the row of rivets in question (see Figure 8) and, as mentioned in paragraph 1.7.1.6, a fillet of sealant is applied to seal the lower edge of the CP. The sealant application job does not include an inspection of the row of rivets. Anyway, it is doubtful if maintenance personnel focusing on the sealant application job would notice any such missing rivet heads, especially if the cavity left by the missing rivet heads had been filled with sealant.

2.2.3 When the CP was removed during maintenance work, one might get to inspect the condition of the row of rivets. However, if the cavity left by the rivet heads had been filled by sealant before, it might not have been possible for maintenance personnel to notice the missing rivet heads. After the CP replacement in August 2012, there was no further work done in that area and thus no opportunity to inspect the condition of the row of rivets in the area.

2.3 Noise from Door 3L

2.3.1 As mentioned in paragraph 1.1.6, the flight crew judged that the flight could proceed despite the noise problem. It is unknown if the flight crew appreciated the extent to which the noise had caused discomfort to the passengers. The operator did not have guidelines for its flight crews on such noise occurrences and the flight crews would have to make decisions on their own.

2.3.2 However, to the extent that the door noise was apparently loud enough to prevent passengers from hearing clearly the announcements over the PA system, there is then this concern that, in the case of an emergency, the instructions of the flight or cabin crew might not be transmitted quickly and effectively to the passengers through the PA system. If the operator expects the crew members to use the megaphones to overcome such door noise problem, it has to ensure that the instructions broadcast through the megaphones can be heard clearly over the door noise.

2.4 **Oxygen flow**

2.4.1 As regards the feedback from passengers that the PSUs above their seats did not appear to be dispensing oxygen, post-examination of these PSUs shows that the PSUs were in working conditions and the green band on the tubes connecting the oxygen mask to the PSUs suggests that oxygen did flow in the tubes. Given that the cabin altitude was below 12,000 feet when the oxygen system was activated, the oxygen flow rate was likely to be minimal, and users of oxygen masks would have to inhale fairly deeply to draw in the oxygen supplied through the tube. However, the air pressure in the cabin was such that the cabin air drawn into an oxygen mask through the inhalation check valve would have allowed adequate breathing.

2.4.2 As for the PSUs for the bunks in the CCRC, it is to be noted that, in a lying position, the user of an oxygen mask would have to consciously pull on the mask in order to release the lanyard pin and activate the oxygen flow, in view of the user's close proximity to the PSU and the way the user would reach for the mask (see **Figure 13**).

Figure 13 - Crew rest bunk PSU

2.5 Category 4 aerodromes for planning of en-route alternates

2.5.1 The table in paragraph 1.8.5.4.5 shows the amounts of water that are required for making firefighting foam of performance level A in respect of the largest aeroplane in each of the RFFS category. The table below has an added column showing the amounts of water in terms of percentage of the amount for RFFS Category 10:

Aerodrome RFFS category	Amount of water	
	Litres	% of the amount for Category 10
1	689	1.3
2	1,166	2.1
3	2,175	4.0
4	4,353	8.0
5	9,112	16.8
6	14,924	27.5
7	21,482	38.6
8	31,099	57.3
9	41,483	76.5
10	54,242	100.0

The percentage figures are in respect of performance level A foams. The percentage figures in respect of performance level B or C foams can be expected to be of a similar order of magnitude.

2.5.2 When an aeroplane lands at an aerodrome with a RFFS category not matching the aeroplane's RFFS category, the desired RFFS protection level will be compromised in some aspects (e.g. firefighting vehicles, equipment, amounts of water or foam, ability to achieve control of the critical area, time to achieve control of fire, ability to maintain the control and/or extinguishment of remaining fire).

2.5.3 ICAO standards allow a Category 9 aerodrome to accept a Category 10 aeroplane under the category-reduction rule. For an A380, a Category 9 aerodrome would have only about 70-80% of the required amount of water as for a Category 10 aerodrome. Presumably ICAO has done a thorough risk evaluation to come to the conclusion that the correspondingly lowered level of fire protection remains acceptable, with or without any additional measures to be put in place. However, the ICAO guidance material that the investigation team has perused does not seem to contain any details of such risk evaluation.

2.5.4 Similarly, if an A380 uses a Category 8 or Category 4 aerodrome, the aerodrome would have only about 50-60% or 10%, respectively, of the required amount of water as for a Category 10 aerodrome. Again, the investigation team has been unable to find in the ICAO guidance material information pertaining to risk evaluation as regards the use of Category 8 or Category 4 aerodrome for a Category 10 aeroplane like the A380.

2.5.5 Put another way, if a flight crew needs to choose between landing at a Category X aerodrome and a Category X-1 aerodrome, would the crew know what the difference in fire protection levels offered by these aerodromes? For example, would choosing the Category X aerodrome mean an extra one, two, three, or more minutes of fire protection, which could make a difference between a successful and unsuccessful evacuation?

2.5.6 The operator did a qualitative safety risk assessment (QRSA) when evaluating the acceptability of using Category 4 aerodromes for its A380s. The QSRA was accepted by CAAS. The investigation team is concerned that a Category 4 aerodrome with only 10% of the amount of water required by a Category 10 aircraft was being considered for use as an ERA for A380 operations.

2.5.7 On the basis of the demonstrated evacuation capability during the certification of the A380 aircraft, the operator assessed that it would be able to conduct an evacuation of all the passengers within the required 90 seconds before the arrival of the RFFS, and considered that its capability of evacuating all its passengers was independent of the RFFS capability. The investigation team is of the view that the operator's risk assessment may not have covered possible scenarios like the following:

(a) It cannot be assumed that an aircraft would land and come to rest with fuselage largely intact in a normal attitude.

(b) The accident circumstance is such that the evacuation is not of a pre-planned type.

(c) It cannot be assumed that no persons will not be trapped in the fuselage for whatever reason and will not need more than 90 seconds to be extricated.

One must remember that the need for rescue and firefighting may:

- exist at the time an aircraft is landing, taking off, taxiing, parked, etc.;
- occur immediately following an aircraft accident or incident; or
- occur at any time during rescue operations.

2.6 ICAO documentation

2.6.1 As mentioned in paragraph 1.8.5.3.3, an aerodrome's RFFS category is determined in accordance with paragraph 9.2.5 of ICAO Annex 14 Volume 1 but may be lowered by one category. This is stated in paragraph 9.2.3 of Annex 14 Volume 1:

> "The level of protection provided at an aerodrome for rescue and firefighting shall be appropriate to the aerodrome category determined using the principles in 9.2.5 and 9.2.6, except that, where the number of movements of the aeroplanes in the highest category normally using the aerodrome is less than 700 in the busiest consecutive three months, the level of protection provided shall be not less than one category below the determined category."

2.6.2 This category-reduction rule is also mentioned in Note (2) in Table J-1 of Attachment J of ICAO's Annex 6 Part I, albeit in a slightly differently worded way:

> "Annex 14, Volume I, determines the aerodrome category for rescue and firefighting according to 9.2.5 and 9.2.6 except that, where the number of movements of the aeroplanes in the highest category normally using the aerodrome is less than 700 in the busiest consecutive three months, the category provided may be one lower than the determined category."

2.6.3 The formulation "may be one lower than" is clear. For those who already know the rule, the formulation "shall be not less than one category below" could appear just as clear. However, as discovered by the investigation team, a person reading this formulation for the first time, especially at the first glance, could read the rule as:

> "… shall be *not less than one category* (i.e. minimum of two categories) below the determined category" (the focus being the question "how many categories below?"),

instead of:

> "… shall be not less than *one category below the determined category*" (the focus being the question "not less than what category level?").

2.6.4 The formulation "shall be not less than one category below" should be avoided. It is noted that the French version of paragraph 9.2.3 of Annex 14 Volume 1 says clearly that the minimum category level is the determined category minus one[27] and the Chinese version of the same paragraph uses the formulation "not lower than one category below the determined category"[28].

[27] Le niveau de protection assuré à un aérodrome en ce qui concerne le sauvetage et la lutte contre l'incendie correspondra à la catégorie d'aérodrome déterminée selon les principes énoncés aux § 9.2.5 et 9.2.6; toutefois, lorsque le nombre de mouvements des avions de la catégorie la plus élevée qui utilisent normalement l'aérodrome est inférieur à 700 pendant les trois mois consécutifs les plus actifs, le niveau de protection assuré sera au minimum, celui qui correspond à la catégorie déterminée, moins une.

[28] 对机场救援与消防所提供的保障水平，必须与采用9.2.5 和9.2.6 中的原则所确定的机场类别相适应，只有在正常使用该机场的最高类别的飞机的起降架次在最繁忙的连续三个月内少于700 架次时，所提供的保障水平才可不低于比所确定的类别低一级的类别.

3 CONCLUSIONS

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 The Door 3L failure was traced to a crack passing through a number of rivet holes on the door skin. The crack was probably caused by high cycle fatigue under varying amplitude loading due to the fluttering of the Batch 1 CP that was initially installed on the aircraft. Once the crack was initiated, the stiffer Batch 3 CP could not prevent further propagation of the crack.

3.2 There were traces of sealant and paint in the crack surfaces as well as on the countersunk surfaces of two rivet holes, meaning that the crack was present when CP was replaced in August 2012.

3.3 As regards the PSUs in the bunks in the CCRC, some cabin crew members did not seem to be aware that a conscious effort is needed to pull on the mask, when lying down, in order to release the lanyard pin to allow oxygen to flow to the mask.

3.4 The amount of water required to be make available at an aerodrome of Category X can be significantly different from that required of a Category X-1 aerodrome. The smaller amount of water available at the Category X-1 aerodrome could compromise the desired RFFS protection level. ICAO guidance material does not seem to offer a methodology for airline operators to evaluate the extent of the compromise in fire protection level when an aerodrome of a lower category than the aeroplane category is used.

4 SAFETY ACTION

During the course of the investigation and through discussions with the investigation team, the following safety actions were initiated by the regulatory authority, aerodrome operator, ground service provider and the airline operator.

4.1 In addition to the action mentioned in paragraph 1.8.1, the aircraft manufacturer issued a Flight Operations Transmission to all A380 operators on 23 January 2014 to remind operators of the existence of the Vibration/Noise Reporting Sheet and to highlight the importance of having adequate procedures between Flight Operations and Maintenance/Engineering, so as to ensure noise problems are reported quickly and action to locate the noise source taken early.

4.2 Since the incident, the operator has published a Cabin Crew Circular to educate its crew on the aircraft passenger oxygen system and on the proper donning of oxygen masks, to highlight that the lanyard pin has to be pulled to activate oxygen flow. The operator has also included the information in the cabin crew safety training briefing.

4.3 Following the occurrence, the operator has carried out a fleet-wide inspection to verify the passenger doors were free from crack initiations.

4.4 The operator has also changed all the door CPs of its A380 to the Batch 3 type.

4.5 The operator is in the process of carrying out the door structure reinforcement programme recommended by the aircraft manufacturer in Service Bulletins A380-52-8079 to 8094. To date, the airline operator has completed the door reinforcement work on five of its fleet of 19 A380 aircraft. For the remaining 14 aircraft, the airline operator will continue to perform the necessary inspection until the Service Bulletins are incorporated.

4.6 It was recommended [AAIB Recommendation R-2015-008] in the Interim Report dated 21 September 2015 by the investigation team that "the operator assess the effectiveness of the use of megaphones as a means for its crews to give instructions to passengers in an emergency when the noise level in the cabin is such as to prevent passengers from hearing clearly the instructions through the aircraft's public address system." In response, the operator has updated its Cabin Safety Instructions (CSI) to include the use of megaphone as an alternate means for unforeseen situations where the cabin noise level prevents cabin announcements from being audible to cabin crew and/or passengers. Under such situations, crew will try to maintain effective communications within the cabin by using alternative means such as:

- power megaphone;
- individual briefing; or

- passing of written instructions on a notepad or paper to affected passengers and/or cabin crew.

5 SAFETY RECOMMENDATIONS

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

It is recommended that:

5.1 The operator review its potential use of en-route aerodromes with a lower RFFS category than that reflected in ICAO guidance material. [TSIB RA-2017-008]

5.2 CAAS review the operator's potential use of en-route aerodromes with a lower RFFS category than that reflected in ICAO guidance material. [TSIB RA-2017-009]

5.3 ICAO consider providing guidance material on assessment of risks when an aircraft has to land at an aerodrome of a lower RFFS category than a desired one. [TSIB RA-2017-010]

5.4 ICAO consider amending paragraph 9.2.3 of Annex 14 Volume 1 as follows:

> "The level of protection provided at an aerodrome for rescue and firefighting shall be appropriate to the aerodrome category determined using the principles in 9.2.5 and 9.2.6, except that, where the number of movements of the aeroplanes in the highest category normally using the aerodrome is less than 700 in the busiest consecutive three months, the level of protection provided shall be not ~~less~~ lower than one category below the determined category."
> [TSIB RA-2017-011]

Extract from ICAO Annex 14 Volume 1
pertaining to Aerodrome RFFS Category

Paragraph 9.2.3 - The level of protection provided at an aerodrome for rescue and firefighting shall be appropriate to the aerodrome category determined using the principles in 9.2.5 and 9.2.6, except that, where the number of movements of the aeroplanes in the highest category normally using the aerodrome is less than 700 in the busiest consecutive three months, the level of protection provided shall be not less than one category below the determined category."

Paragraph 9.2.5 - The aerodrome category shall be determined from Table 9-1 and shall be based on the longest aeroplanes normally using the aerodrome and their fuselage width.

Aerodrome category (1)	Aeroplane overall length (2)	Maximum fuselage width (3)
1	0 m up to but not including 9 m	2 m
2	9 m up to but not including 12 m	2 m
3	12 m up to but not including 18 m	3 m
4	18 m up to but not including 24 m	4 m
5	24 m up to but not including 28 m	4 m
6	28 m up to but not including 39 m	5 m
7	39 m up to but not including 49 m	5 m
8	49 m up to but not including 61 m	7 m
9	61 m up to but not including 76 m	7 m
10	76 m up to but not including 90 m	8 m

Table 9-1. Aerodrome category for rescue and firefighting

Paragraph 9.2.6 - If, after selecting the category appropriate to the longest aeroplane's overall length, that aeroplane's fuselage width is greater than the maximum width in Table 9-1, column 3, for that category, then the category for that aeroplane shall actually be one category higher.

Attachment J of ICAO Annex 6 Part I

ATTACHMENT J. RESCUE AND FIRE FIGHTING SERVICES (RFFS) LEVELS

Supplementary to Chapter 4, 4.1.4

1. Purpose and scope

1.1 Introduction

The purpose of this Attachment is to provide guidance for assessing the level of RFFS deemed acceptable by aeroplane operators using aerodromes for different purposes.

1.2 Basic concepts

1.2.1 While all aeroplane operators should aim to have the level of RFFS protection required by Annex 14, Volume I, Chapter 9, 9.2, some of the aerodromes currently used do not meet these requirements. Furthermore, Annex 14, Volume I provisions relate to the level of aerodrome RFFS to be provided for aeroplanes normally using an aerodrome.

1.2.2 If an aerodrome is exposed to a temporary reduction of its RFFS capability, Annex 14, Volume I, 2.11.3, requires that: "Changes in the level of protection normally available at an aerodrome for rescue and fire fighting shall be notified to the appropriate air traffic services units and aeronautical information services units to enable those units to provide the necessary information to arriving and departing aircraft. When such a change has been corrected, the above units shall be advised accordingly."

1.2.3 The following guidance is intended to assist operators in making the assessment required by Chapter 4, 4.1.4. It is not intended that this guidance limit or regulate the operation of an aerodrome.

2. Glossary of terms

Aerodrome RFFS category. The RFFS category for a given aerodrome, as published in the appropriate Aeronautical Information Publication (AIP).

Aeroplane RFFS category. The category derived from Annex 14, Volume I, Table 9-1 for a given aeroplane type.

RFFS category. Rescue and fire fighting services category as defined in Annex 14, Volume I, Chapter 9.

Temporary downgrade. RFFS category as notified, including by NOTAM, and resulting from the downgrade of the level of RFFS protection available at an aerodrome, for a period of time not exceeding 72 hours.

3. Minimum acceptable aerodrome RFFS category

3.1 Planning

3.1.1 In principle, the published RFFS category for each of the aerodromes used for a given flight should be equal to or better than the aeroplane RFFS category. However, if the aeroplane RFFS category is not available at one or more of the aerodromes required to be specified in the operational flight plan, an operator should ensure that the aerodrome has the minimum level of RFFS which is deemed acceptable for the intended use in accordance with the instructions contained in the operations manual. When establishing acceptable levels of minimum RFFS for these situations, the operator may use the criteria in Table J-1.

3.1.1.1 Intended operations to aerodromes with RFFS categories below the levels specified in Annex 14, Volume I, Chapter 9, 9.2, should be coordinated between the aeroplane operator and the aerodrome operator.

Table J-1. Minimum acceptable aerodrome category for rescue and fire fighting

Aerodromes (Required to be specified in the operational flight plan) (1)	**Minimum acceptable aerodrome RFFS category** (Based on published aerodrome RFFS category)
Departure and destination aerodrome	RFFS category for each aerodrome should be equal to or better than the aeroplane RFFS category. **One** category (2) below the aeroplane RFFS category may be accepted where provided as a remission in accordance with Annex 14, Volume I, 9.2, but not lower than Category 4 for aeroplanes with maximum certificated take-off mass of over 27 000 kg and not lower than Category 1 for other aeroplanes.
Departure and destination aerodrome in case of temporary downgrade and Take-off alternate, destination alternate and en-route alternate aerodromes	**Two** categories below the aeroplane RFFS category, but not lower than Category 4 for aeroplanes with maximum certificated take-off mass of over 27 000 kg and not lower than Category 1 for other aeroplanes.
EDTO en-route alternate aerodrome	RFFS Category 4 for aeroplanes with maximum certificated take-off mass of over 27 000 kg or not lower than Category 1 for all other aeroplanes, under the condition that at least 30 minutes' notice will be given to the aerodrome operator prior to the arrival of the aeroplane.

Notes.—

(1) If an individual aerodrome serves more than one purpose, the highest required category corresponding to that purpose at the time of expected use applies.

(2) Annex 14, Volume I, determines the aerodrome category for rescue and fire fighting according to 9.2.5 and 9.2.6 except that, where the number of movements of the aeroplanes in the highest category normally using the aerodrome is less than 700 in the busiest consecutive three months, the category provided may be one lower than the determined category.

3.1.2 For all-cargo operations, further reductions might be acceptable provided that the RFFS capability is adequate to arrest fire around the flight deck area long enough for the persons on board to safely evacuate the aeroplane.

3.2 In flight

3.2.1 In flight, the pilot-in-command may decide to land at an aerodrome regardless of the RFFS category if, in the pilot's judgement after due consideration of all prevailing circumstances, to do so would be safer than to divert.

AC AOC-31(0)
5 October 2012

CAAS
Civil Aviation Authority of Singapore

Advisory Circular

SAFETY RISK ASSESSMENT OF AERODROME RESCUE AND FIRE FIGHTING SERVICE BY AIR TRANSPORT OPERATORS

1. **GENERAL.** Pursuant to paragraph 88B of the Air Navigation Order, the Director General of the Civil Aviation Authority of Singapore (DGCA) may, from time to time, issue advisory circulars (ACs) on any aspect of safety in civil aviation. This AC contains information about standards, practices and procedures acceptable to CAAS. The revision number of the AC is indicated in parenthesis in the suffix of the AC number.

2. **PURPOSE.** This AC provides guidance to Singapore air operators in making safety risk assessment of Aerodrome Rescue and Fire Fighting Services as provided under Singapore Air Operator Certificate Requirement (AOCR) chapter 5, paragraph 10.7.

3. **APPLICABILITY.** This AC applies to all Singapore Air Operator Certificate (AOC) Holders.

4. **CANCELLATION.** This is the first AC issued on this subject.

5. **EFFECTIVE DATE.** This AC is effective on 5 October 2012.

6. **REFERENCES.**
   - Air Navigation Order (ANO)
   - Singapore Air Operator Certificate Requirements (AOCR)
   - ICAO Annex 6 Part I
   - ICAO Annex 14 Volume 1
   - ICAO Doc 9137-AN/898 Part I

7. **DEFINITIONS.** For the purpose of this Circular, the following definitions shall apply:-

   Aerodrome RFFS category means the RFFS category for a given aerodrome, as published in the appropriate Aeronautical Information Publication (AIP);

   Aeroplane RFFS category means the category derived from ICAO Annex 14, Volume I, Table 9-1 for a given aeroplane type;

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RFFS category means rescue and fire fighting services category as defined in ICAO Annex 14, Volume 1, Chapter 9; and

Temporary downgrade means RFFS category as notified, including by NOTAM, and resulting from the downgrade of the level of RFFS protection available at an aerodrome, for a period of time not exceeding 72 hours.

8. INTRODUCTION.

8.1 In 1969, ICAO Air Navigation Commission established the Rescue and Fighting Panel to develop the critical area concept that was eventually adopted by ICAO in Annex 14 in 1976. Until then the method of assessing aerodrome RFFS was related to the aeroplane fuel load and passenger capacity.

8.2 The critical area is a concept for the rescue of the aeroplane occupants by seeking to control only the area of fire adjacent to the fuselage with the objective to safeguard the integrity of the fuselage and maintain tolerable conditions for its occupants.

8.3 From experiments, it has been established that the theoretical critical area of an aeroplane with fuselage length of 20m or greater and in 8 to 10 kts cross-wind component extends 24m upwind and 6m downwind. For smaller aeroplane with fuselage length less than 20m, it needs only 6m on either side. The table below depicts the aerodrome category in relation to the aeroplane fuselage length and width, as defined in Annex 14 Volume I chapter 9 Table 9-1, and the associated theoretical critical area:

Table 1: Aerodrome category and theoretical critical area

Annex 14 Volume 1 Chapter 9 Table 9-1			Theoretical Critical Area	
Aerodrome Category	Aeroplane's overall length	Maximum fuselage width	Overall length of Aeroplane	Critical Area
1	0 m up to but not include 9 m	2m		L x (12m + W)
2	9 m up to but not include 12 m	2m	L< 12m	L x (12m + W)
3	12 m up to but not include 18 m	3m	12m ≤ L > 18m	L x (14m + W)
4	18 m up to but not include 24 m	4m	18m ≤ L > 24m	L x (17m + W)
5	24 m up to but not include 28 m	4m	L > 24m	L x (30m + W)
6	28 m up to but not include 39 m	5m		L x (30m + W)
7	39 m up to but not include 49 m	5m		L x (30m + W)
8	49 m up to but not include 61 m	7m		L x (30m + W)
9	61 m up to but not include 76 m	7m		L x (30m + W)
10	76 m up to but not include 90 m	8m		L x (30m + W)
Note: If, for that aeroplane's overall length, that aeroplane's fuselage width is greater than the maximum width in column 3, for that category, then the category for that aeroplane shall actually be one category higher.			L = Overall length of aeroplane W = the width of the fuselage	

8.4 For airworthiness certification, an aeroplane is required to demonstrate its ability to evacuate its maximum certified occupants using one half of its exits in 90 seconds. Whereas for the RFFS, the operational objective "should be to achieve response times of two minutes and not exceeding three minutes to the end of each runway, as well as to any other part of the movement area, in optimum conditions of visibility and surface conditions. Response is considered to be the time between the initial call to the RFFS and the time when the first responding vehicle(s) is(are) in position to apply foam at a rate of at least 50% of the promulgated discharge rate".

8.5 In view of the time-lapse between passenger evacuation time limit of 90 seconds, and the expected time of 120 seconds for the arrival of first RFFS vehicle(s) at the scene, time taken for ATC to notify the RFFS excluded, it is obvious that the aeroplane passenger cabin layout and crew proficiency play crucial roles in safely evacuating the passengers and managing the passengers at post-evacuation prior to the arrival of the RFFS. It is arguable that, in theory, all passengers and crew could be out of the aeroplane 30 seconds before the RFFS vehicles arrive at the scene and discharge fire-fighting agents at one half of its promulgated rate.

9. AOCR REQUIREMENTS.

9.1 AOCR requires that the operator, as part of its safety management system, shall assess the level of rescue and fire fighting service (RFFS) protection available at aerodrome(s) specified in its operational flight plan to ensure that an acceptable level of protection is available for the aeroplane that is intended to be used. Information related to the level of RFFS protection that is deemed acceptable by the operator shall be contained in the operations manual.

10. MINIMUM ACCEPTABLE AERODROME RFFS CATEGORY (PLANNING PHASE).

10.1 In principle, the published RFFS category or level of RFFS protection for the aerodrome for that flight should be equal to or better than the RFFS category of the aeroplane to be used. However, if the aeroplane RFFS category is not available at one or more of the aerodromes required to be specified in the operational flight plan, an operator should ensure that the aerodrome has the minimum level of RFFS which is deemed acceptable for the intended use in accordance with the instructions contained in the operations manual. When establishing acceptable levels of minimum RFFS for these situations, the operator may use either the criteria established in Table 2 or an acceptable methodology in its safety management system that provides an acceptable level of safety.

Table 2 - Minimum acceptable aerodrome category for rescue and fire fighting

Aerodromes (Required to be specified in the operational flight plan)[1]	**Minimum acceptable aerodrome RFFS category** (Based on published aerodrome RFFS category)
Departure and destination aerodrome	RFFS category for each aerodrome should be equal to or better than the aeroplane RFFS category. One category[2] below the aeroplane RFFS category may be accepted where provided as a remission in accordance with ICAO Annex 14, Volume I, 9.2 but not lower than Category 4 for aeroplanes with maximum certificated take-off mass of over 27 000 kg and not lower than Category 1 for other aeroplanes.
Departure and destination aerodrome in case of temporary downgrade; and Take-off alternate, destination alternate and en-route alternate aerodromes	Two categories below the aeroplane RFFS category, but not lower than Category 4 for aeroplanes with maximum certificated take-off mass of over 27 000 kg and not lower than Category 1 for other aeroplanes.
ETOPS en-route alternate aerodrome	RFFS Category 4 for aeroplanes with maximum certificated take-off mass of over 27 000 kg or not lower than Category 1 for all other aeroplanes, under the condition that at least 30 minutes notice will be given to the aerodrome operator prior to the arrival of the aeroplane.

(1) If an individual aerodrome serves more than one purpose, the highest required category corresponding to that purpose at the time of expected use applies.

(2) ICAO Annex 14, Volume I, determines the aerodrome category for rescue and fire fighting according to paragraphs 9.2.5 and 9.2.6 except that, where the number of movements of the aeroplanes in the highest category normally using the aerodrome is less than 700 in the busiest consecutive three months, the category provided may be one lower than the determined category.

10.2 For all intended operations to aerodromes with RFFS categories below the levels specified in Annex 14, Volume I, Chapter 9, the operator may elect to coordinate these operations with the aerodrome operator(s) of these aerodromes.

10.3 After establishing the above assessment and identifying any instructions for operating crew that are relevant to the respective risk mitigation processes, the operator should communicate such instructions into the operations manual.

11. MINIMUM ACCEPTABLE AERODROME RFFS CATEGORY (IN FLIGHT).

11.1 In flight, the pilot-in-command may decide to land at an aerodrome regardless of the RFFS category if, in the pilot's judgement after due consideration of all prevailing circumstances, to do so would be safer than to divert.

12. CARGO OPERATIONS.

12.1 For all cargo operations, further reductions might be acceptable provided that the RFFS capability is adequate to arrest fire around the flight deck area long enough for the persons on board to safely evacuate the aeroplane.

13. OPERATOR'S SAFETY MANAGEMENT SYSTEM.

13.1 The operator should seek CAAS' acceptance of its detailed risk assessment programme for any deviations from the guidance material contained in Table 2 above. This programme should at least contain elements such as prevention and mitigation of in-flight fire and cabin crew training to ensure expeditious evacuation of passengers. For example, any deviation from the guidance material contained in Table 2 may be acceptable to CAAS, provided the operator:

(a) has an operation philosophy and training which are geared towards preventing and suppressing in-flight fire or any conditions that leads to such fire;

(b) designed the cabin with consideration toward unimpeded passenger flow during emergency evacuation;

(c) trains its crew to be proficient in evacuation procedures as well as in post evacuation management of passengers;

(d) has a policy on minimum crew complement and crew experience;

(e) has an MEL dispatch policy on aeroplane exits and evacuation slides; and

(f) has an awareness programme on hazards such as runway incursion and excursion during aerodrome surface movements, especially under conditions of restrictive visibility.

13.2 In preparation of the risk assessment programme, the operator may find the information contained in the following publications useful:

(a) Airport Cooperative Research Program (ACRP) Web-Only Document 12: Risk Assessment of Proposed ARFF Standards

(b) Initial and Recurrent Training for ARFF Highlight of International Differences. ARFF Solution

(c) National Transportation Safety Board (NTSB) PB2000-917002 NTSB/SS-00/01 Safety Study Emergency Evacuation of Commercial Airplane

(d) Flight Safety Foundation Reducing the Risk of Runway Excursions

(e) International Federation Air Line Pilots' Associations (IFALPA) Runway Safety Manual