

EMERGENCY EVACUATION OF COMMERCIAL PASSENGER AEROPLANES



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Emergency Evacuation of Commercial Passenger Aeroplanes

A Specialist Paper prepared by the Flight Operations
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Front cover:

Top picture: On 8 September 2015, British Airways Flight 2276 caught fire during take-off from Las Vegas-McCarran International Airport, prompting an aborted take-off and the evacuation of all 157 passengers and 13 crew. (Jordan Masters)

Bottom picture: Emirates Flight 521 from Thiruvananthapuram carrying 282 passengers and 18 crew crash-landed at the Dubai International Airport on 3 August 2016. (Courtesy of ANI)

PREFACE

This paper titled 'Emergency Evacuation of Commercial Passenger Aeroplanes' has been developed by the Royal Aeronautical Society's (RAeS) Flight Operations Group (FOG).

Over many years several accidents have identified the need for improvements to regulatory airworthiness and operational requirements, resulting in changes to aeroplane manufacturing and maintenance procedures, as well as to operators' crew procedures and training.

This paper is therefore partly historical and is a record as to why changes were made to aviation requirements. While transportation by air is conducted at very high safety levels, accidents and incidents involving emergency evacuation still occur. Some accidents that happened several years ago are featured in this document, as well as some that are more recent, and reflect some of the negatives as well as the many positives.

Recent issues such as the secured flight deck door, introduced after the terrorist

attacks of 2001, and the increasing amount of cabin baggage being allowed into passenger cabins can pose new challenges to both flight crew and cabin crew in emergency evacuations.

The intention of this paper is to provide aviation authorities, aeroplane manufacturers, operators, and air accident investigation agencies, with a wide-range of information on evacuation issues.

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The Flight Operations Group is grateful for the comments received in the development of this paper from various aviation safety agencies including aviation authorities, aeroplane manufacturers and air accident investigators.

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- 11.5 2 August 2005 - Air France - Airbus A340-300 - Toronto, Canada
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- 11.8 16 April 2012 – Virgin Atlantic – Airbus A330-300 – London Gatwick, UK
- 11.9 6 July 2013 - Asiana Airlines - Boeing 777-200 - San Francisco, USA
- 11.10 8 September 2015 - British Airways - Boeing 777-200 - Las Vegas, USA
- 11.11 27 May 2016 - Korean Air - Boeing 777-300 - Tokyo, Japan
- 11.12 26 June 2016 – American Airlines – Airbus A330-300 – London Heathrow, UK
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- 11.14 3 August 2016 - Emirates - Boeing 777-300 - Dubai, UAE

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1. ABBREVIATIONS

A:

AA	Aviation Authority
AASK	Aircraft Accident Statistics and Knowledge Database
AAIB	Air Accidents Investigation Branch (UK)
AIA	Accident Investigation Authority (ICAO)
AC	Advisory Circular (FAA)
ACOB	Air Carrier Operations Bulletin (FAA)
AD	Airworthiness Directive (Various National Aviation Authorities)
ADH	Automatically Disposable Hatch
AOC	Air Operator's Certificate
AOE	Automatically Opening Exit
AGARD	Advisory Group for Aerospace Research and Development
AMC	Acceptable Means of Compliance (EASA)
AN	Airworthiness Notice (UK CAA)
ANAC	Agencia Nacional de Aviação Civil (Brazil)
ANO	Air Navigation Order (United Kingdom)
APU	Auxiliary Power Unit
ARFF	Airport Rescue and Fire Fighting (USA)
ATP	Advanced Turbo-Prop (British Aerospace)
ARAC	Aviation Rulemaking Advisory Committee (USA)
ATC	Air Traffic Control

B:

BAe	British Aerospace
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C:

CAA	Civil Aviation Authority (United Kingdom) – UK CAA
CAMI	Civil Aeromedical Institute (FAA)
CAP	Civil Aviation Publication (UK CAA)
CARAC	Canadian Aviation Regulation Advisory Council (TCCA)
CASB	Canadian Aviation Safety Board (Predecessor to the TSB)
CCOM	Cabin Crew Operations Manual – (Generic term used in this paper)
14 CFR – Part 25	Code of Federal Regulations - Airworthiness Standards: Transport Category Airplanes (USA)
14 CFR 25.803	Code of Federal Regulations – Emergency Evacuation (USA)
CM	Certification Memorandum (EASA)
CS	Certification Specification (EASA)
CS 25	Certification Specifications and Acceptable Means of Compliance for Large Aeroplanes – Amendment 20 – 24 August 2017 (EASA)
CS 25.803	Certification Specifications – Emergency Evacuation (EASA)
CVR	Cockpit Voice Recorder

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CRM	Crew Resource Management
CRS	Child Restraint Systems

D:

DGP	Dangerous Goods Panel (ICAO)
DV	Direct View (Flight deck window)

E:

EASA	European Aviation Safety Agency
EASA Air OPS Regulation	Regulations for Commercial Transportation by Aeroplane
ELT	Emergency Locator Transmitter
EOW	Extended Over Water
ETSC	European Transport Safety Council
ETOPS	Extended Range Twin Operations
EXODUS	airEXODUS – Aircraft Evacuation Model (Greenwich University – UK)

F:

FAA	Federal Aviation Administration (USA)
FODCOM	Flight Operations Department Communication (UK CAA)
FOG	Flight Operations Group (Royal Aeronautical Society)
FSEG	Fire Safety Engineering Group (Greenwich University – UK)
FSF	Flight Safety Foundation
FTL	Flight Time Limitations

G:

GCAA	General Civil Aviation Authority (United Arab Emirates)
GR	Generic Requirement (UK CAA)

I:

ICAO	International Civil Aviation Organisation
IFE	In-flight Entertainment

J:

JAA	Joint Aviation Authorities (Predecessor to EASA)
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L:

LOFT	Line Oriented Flight Training
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M:

MEL	Minimum Equipment List
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N:

NG	Next Generation of Boeing 737 aeroplane (600 series onwards)
NPA	Notice of Proposed Amendment
NPRM	Notice of Proposed Rulemaking
NTAOCH	Notice to AOC Holders (UK CAA)
NTSB	National Transportation Safety Board (USA)

O:

OM	Operations Manual
OSD	Operational Suitability Data (EASA)

P

PA	Public Address
PBE	Protective Breathing Equipment
PED	Portable Electronic Device
PSUs	Passenger Service Units

Q:

QRH	Quick Reference Handbook
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R:

RAeS	Royal Aeronautical Society
RFFS	Rescue and Fire Fighting Service
RVR	Runway Visual Range

S:

SCCM	Senior Cabin Crew Member
SIC	Safety Information Circular (JAA)
SIB	Safety Information Bulletin (EASA)
SN	Safety Notice (UK CAA)
SOP	Standard Operating Procedure

T:

TC	Type Certificate
TCCA	Transport Canada Civil Aviation
TCDS	Type Certificate Data Sheet
TSB	Transportation Safety Board of Canada (formerly CASB)

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2 ACCIDENTS AND INCIDENTS REFERRED TO IN THIS PAPER WITH ACCIDENT REPORT REFERENCES

Date: <i>Day/Month/ Year.</i>	Location:	Operator and Flight Number:	Aeroplane:	Number of Passengers and Crew on board:	Number of Passenger and Crew fatalities:	Accident Investigation Agency:	Accident Report Number and Date:
02/05/1970.	St. Croix, US Virgin Islands.	Overseas National Airways. Flight No: 980.	McDonnell Douglas DC-9.	Passengers: 57. Crew: 6.	Passengers: 22. Crew: 1.	US, NTSB.	NTSB /AAR-71-8. 31 March 1971.
20/12/1972. *	Chicago, USA. (Ground collision.)	North Central Airlines. Flight No: 575.	McDonnell Douglas DC-9.	Passengers: 41. Crew: 7.	Passengers: 10. Crew: Nil.	US, NTSB.	NTSB-AAR-73-15. * 5 July 1973.
20/12/1972. *	Chicago, USA. (Ground collision.)	Delta Airlines. Flight No: 954.	Convair CV-880.	Passengers : 86. Crew: 7.	Passengers: Nil. Crew: Nil.	US, NTSB.	As above.*
28/12/1978.	Portland, USA.	United Airlines Flight No: 173.	McDonnell Douglas DC-8.	Passengers: 181. Crew: 8.	Passengers: 8. Crew: 2.	US, NTSB.	NTSB-AAR-79-7. 7 June 1979.
19/08/1980.	Riyadh, Saudia Arabia.	Saudia Arabia Airlines. Flight No: 163.	Lockheed L1011-200 Tristar.	Passengers: 287. Crew: 14.	Passengers: 287. Crew: 14.	Presidency of Civil Aviation - Saudi Arabia.	Aircraft Accident Report. 16 January 1982.
02/06/1983.	Cincinnati (Covington), USA.	Air Canada. Flight No: 797.	McDonnell Douglas DC-9.	Passengers: 41. Crew: 5.	Passengers: 23. Crew: Nil.	US, NTSB.	NTSB/AAR-86-02 and 84-09. 31 January 1986.
22/03/1984.	Calgary, Canada.	Pacific Western Airlines. Flight No: 501..	Boeing 737-200.	Passengers: 114. Crew: 5.	Passengers: Nil. Crew: Nil.	Canadian Aviation Safety Board.	84-H40003. 24 February 1987.
22/08/1985.	Manchester, UK.	British Airtours. Flight No: 28M.	Boeing 737-200.	Passengers: 131. Crew: 6.	Passengers: 55. Crew: 2.	UK, AAIB.	AAIB 8/1988. 15 December 1988.
20/11/1985.	Lajes, Azores.	British Airways. Flight No: 256.	Boeing 747-100.	Passengers: 333. Crew: 18.	Passengers: Nil. Crew: Nil.	No agency identified.	No report identified.
28/02/1987.	Los Angeles, USA.	British Airways. Flight No: 282.	Boeing 747-200.	Passengers: 387. Crew: 17.	Passengers: Nil. Crew: Nil.	No agency identified.	No report identified.
08/01/1989.	Kegworth, UK.	British Midland. Flight No: 92.	Boeing 737-400.	Passengers: 118. Crew: 8.	Passengers: 47. Crew: Nil.	UK, AAIB.	AAIB 4/90. 25 August 1990.
10/03/1989.	Dryden, Canada.	Air Ontario. Flight No: 1363.	Fokker F28-100.	Passengers: 65. Crew: 4.	Passengers: 21. Crew: 3.	Canadian Commission of Inquiry.	Final Report. Date not identified.
19/07/1989.	Sioux City, USA.	United Airlines. Flight No: 232.	McDonnell Douglas DC-10.	Passengers: 279. Crew: 17.	Passengers: 110. Crew: 1.	US, NTSB	NTSB/AAR-90/06 1 November 1990
01/02/1991. **	Los Angeles, USA. (Ground collision.)	USAir. Flight No: 1493.	Boeing 737-300.	Passengers: 89. Crew: 6.	Passengers: 20. Crew: 2.	US NTSB.	NTSB/AAR-91/08.** 22 October 1991.
01/02/1991. **	Los Angeles, USA. (Ground collision.)	SkyWest Airlines. Flight No: 5569.	Fairchild Metroliner.	Passengers: 10, Crew: 2.	Passengers: 10. Crew: 2.	US, NTSB.	As above. **
20/02/1991.	Puerto Williams, Chile.	Lan Chile. Flight No: 1069.	BAe 146-200.	Passengers: 66. Crew: 7.	Total: 20. Not known if this includes crew.	Direccion General de Aeronautica Civil Inspectoria General	33910225770. Date not identified.
30/07/1992.	New York, USA.	Trans World Airways. Flight No: 843.	Lockheed L1011-385 Tristar.	Passengers: 280. Crew: 12.	Passengers: Nil. Crew: Nil.	US, NTSB.	NTSB/AAR-93/04. 31 March 1993.
08/06/1995.	Atlanta, USA.	ValuJet Airlines. Flight No: 597.	McDonnell Douglas DC-9.	Passengers: 57 Crew: 5.	Passengers: Nil. Crew: Nil.	US, NTSB.	NTSB/AAR-96/03. 30 July 1996.

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Date:	Location:	Operator and Flight Number:	Aeroplane Type:	Number of Passengers and Crew on board:	Number of Passenger and Crew fatalities:	Accident Investigation Agency:	Accident Report Number and Date:
14/09/1999.	Girona, Spain.	Britannia Airways. Flight No: 226A.	Boeing 757-200.	Passengers: 236. Crew: 9.	Passengers: Nil. Crew: Nil.	Comision de Investigacion de Accidentes e Incendentes de Aviacion Civil ,and UK, AAIB	A-504/1999. Bulletin SI/2000.
31/10/2000.	Taoyuan, Taiwan.	Singapore Airlines. Flight No: 006.	Boeing 747-400.	Passengers: 159. Crew: 20.	Passengers: 79. Crew: 4.	Aviation Safety Council, Taiwan. Rep. of China.	ASC-AAR-02-04-001. Copyright 2002.
27/02/2002.	London Stansted, UK.	Ryanair. Flight No: 296.	Boeing 737-800.	Passengers: 117. Crew: 7.	Passengers: Nil. Crew: Nil.	UK, AAIB.	Bulletin 7/2004. 2004.
02/08/2005.	Toronto, Canada.	Air France Flight No: 358.	Airbus A340-300.	Passengers: 297. Crew: 12.	Passengers: Nil. Crew: Nil.	Transportation Safety Board of Canada.	A05H0002. Date not identified.
17/01/2008.	London Heathrow, UK.	British Airways. Flight No: 38.	Boeing 777-200.	Passengers: 136. Crew: 16.	Passengers: Nil. Crew: Nil.	UK, AAIB.	AAIB 1/2010. 9 February 2010.
01/08/2008.	Ronaldsway, UK.	Flybe. Flight No: Not known.	Embraer ERJ190-200LR.	Passengers: 90. Crew: 5.	Passengers: Nil. Crew: Nil.	UK, AAIB.	Bulletin No: 6/2010 EW/C2008/01. September 2010.
15/01/2009.	New York. USA.	US Airways. Flight No: 1549.	Airbus A320-200.	Passengers: 150. Crew: 5.	Passengers: Nil. Crew: Nil.	US, NTSB.	NTSB/AAR-10/03. 4 May 2010.
25/02/2009.	Amsterdam, Netherlands.	Turkish Airlines. Flight No: 1951.	Boeing 737-800.	Passengers: 128. Crew: 7.	Passengers: 5. Crew: 4.	The Dutch Safety Board.	M2009LV0225_01. May 2010.
04/11/2010.	Singapore.	Qantas. Flight No: 32.	Airbus A380.	Passengers: 440. Crew: 29.	Passengers: Nil. Crew: Nil.	Australian Transport Safety Bureau.	AO-2010-89. 27 June 2013.
16/04/2012.	London Gatwick, UK.	Virgin Atlantic. Flight No: 27.	Airbus A330-300.	Passengers: 304. Crew: 13.	Passengers: Nil. Crew: Nil.	UK.AAIB.	AAIB 1/2014. 12 February 2014.
22/12/2012.	Nunavut, Canada.	Perimeter Aviation LP. Flight No: 993.	Fairchild SA227-AC Metro III.	Passengers: 7. Crew: 2.	Passengers: 1. Crew: Nil.	Transportation Safety Board of Canada.	A12Q0216. Date not identified.
06/07/2013.	San Francisco, USA.	Asiana Airlines. Flight No: 214.	Boeing 777-200.	Passengers: 291. Crew: 16.	Passengers: 3. Crew: Nil.	US, NTSB.	NTSB/AAR-14/01. 24 June 2014.
29/03/2015.	Halifax, Canada.	Air Canada Flight Number: 624.	Airbus A320-200.	Passengers: 133. Crew: 5.	Passengers: Nil. Crew: Nil.	Transportation Safety Board of Canada.	A15H0002. Date not identified.
08/09/2015.	Las Vegas, USA.	British Airways. Flight No: 2276.	Boeing 777-200.	Passengers: 157. Crew: 13.	Passengers: Nil. Crew: Nil.	US, NTSB.	Survival Factors DCA15FA185. 28 February 2017.
27/05/2016.	Tokyo, Japan.	Korean Air. Flight No: 2708.	Boeing 777-300.	Passengers: 302. Crew: 17.	Passengers: Nil. Crew: Nil.	No agency identified. Data based on media information.	Not identified.
26/06/2016	London Heathrow, UK	American Airlines Flight No: 731	Airbus A330-300	Passengers: 277 Crew: 12	Passengers: Nil. Crew: Nil.	UK, AAIB.	Bulletin No: 12/2017 EW/C20 16/06/02
27/06/2016.	Singapore.	Singapore Airlines. Flight No: 368.	Boeing 777-300.	Passengers: 222. Crew: 19.	Passengers: Nil. Crew: Nil.	Transport Investigation Bureau. Ministry of Transport, Singapore.	AIB/AAI/CAS.122. 27 February 2017.
03/08/2016.	Dubai, United Arab Emirates.	Emirates. Flight No: 521.	Boeing 777-300.	Passengers: 282. Crew: 18.	Passengers: Nil. Crew: Nil.	Emirates General Civil Aviation Authority.	Preliminary Report AAIS AIFN/008/2016. 5 September 2016.
13/01/2018.	Trabzon, Turkey.	Pegasus Airlines. Flight No: 8622.	Boeing 737-800.	Passengers: 162 Crew: 6.	Passengers: Nil. Crew: Nil.	No agency identified. Data based on media information.	Not identified.

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3 DEFINITIONS AND EXPLANATIONS

Accidents and incidents: Some 30 accidents and incidents are referred to in this paper. They are a cross-section of scenarios that have occurred world-wide over many years. The use of the word '*catastrophic*' in airworthiness terminology usually refers to '*hull loss*' whereas operationally it usually refers to '*life-threatening*' situations. Accident Report references and related documents can be found in the Accident Table at Section 2 and in Appendix 1 Accident Report References. In many accidents and incidents referenced in this paper, enhancements to regulatory safety standards are mentioned. In accidents and incidents where no mention is made of such enhancements, the International Civil Aviation Organisation (ICAO) Document 10062 – Manual on the Investigation of Cabin Safety Aspects in Accidents and Incidents – Chapter 3 - provides such information. (Ref: 1)

Aeroplanes/aircraft/airplane terminology: The terms '*aeroplane*', '*aircraft*' and '*airplane*' are used in this paper as appropriate, and have the same meaning. This paper does not include helicopter operations.

Aeroplane crew terminology: The term '*Commander*' is used by EASA, whereas ICAO uses '*pilot-in-command*'. For consistency this paper uses the term '*Commander*' unless another term is used in quoted text. The term '*cabin crew*' is used in Europe, and in many other countries as well as by ICAO, whilst in North America the term '*flight attendant*' is normally used. This paper uses the terminology of cabin crew' and 'flight attendant' as appropriate and as reflected in accident reports referred to in this paper.

Boeing 777-200: The Boeing 777-200 is used in this paper simply as an example of several safety considerations. Such issues could equally be applied to other manufacturers including Airbus. It is not the intent of this paper to identify Boeing as having any particular issues with emergency evacuation of commercial passenger aeroplanes that are not relevant to other manufacturers.

'Burn-though': '*Burn-through*' occurs when an external fire penetrates an aeroplane fuselage and enters the passenger cabin or cargo compartment. '*Burn-through*' has the potential to immediately and significantly threaten the survivability of both passengers and crew.

Cabin crew assist space: A cabin crew assist space is a specific area in which a cabin crew member should stand during an emergency evacuation.

'Combi' aeroplane: A '*combi*' aeroplane is one where both passengers and cargo are carried on the same deck.

Crashworthiness: In terms of cabin safety, crashworthiness is the ability of an aeroplane structure to protect passengers and crew in the event of an accident impact.

Ditching: The National Transportation Safety Board (NTSB) defines a ditching in its Aviation Coding Manual (Ref: 2), as: "*A planned event in which the flight crew knowingly makes a controlled emergency landing in water.*"

EASA Certification Specifications CS 25 Amendment 20: This is used as the baseline for airworthiness requirements in this paper and are harmonized with the US, Canada, and Brazil. Therefore, for ease of reference CS 25 is used throughout this paper unless there are differences with other regulatory requirements such as 14 CFR Part 25 (USA). Although CS 25 is used in this paper, some of the certification standards are JAR 25 for certain aeroplanes.

Reference 1: ICAO Document Number 10062: Manual on the Investigation of Cabin Safety Aspects in Accidents and Incidents. July 2016
Reference 2: NTSB Coding Manual – Part II Definitions. Date of Manual: Revised December 1998.

Emergency exit identification: Different organisations have different ways of identifying the location of emergency exits. For consistency this paper refers to exits as left and right, i.e. L and R, and then by exit number from forward to aft. Therefore, the forward exits are designated as L1 and R1, i.e. the forward left exit and the forward right exit, looking towards the front of the passenger cabin. The next exits moving aft are designated as L2 and R2, and so on. Upper deck exits are designated U/D L1 and U/D R1, etc.

Fire rescue services: The terminology Rescue and Fire Fighting Service (RFFS) is used throughout this paper, although in some countries other terminology is used. For simplicity this paper uses RFFS throughout.

Flashover and Flashfire: According to Federal Aviation Administration (FAA) and the Advisory Group for Aerospace Research and Development (AGARD): “**Flashover** in an airplane cabin environment occurs when enough heat has built up along the ceiling so that the radiant flux down to the materials below the heat layer reaches a level that is high enough to cause an almost instantaneous ignition of the material. FAA research has indicated that flashover produces nonsurvivable conditions throughout the cabin within a matter of seconds”. Also that: “**Flashfire** occurs when materials in a localized area burn and emit combustible gases. The combustible gases, a result of result of incomplete combustion, accumulate until they reach a flammable limit and will, if there is a source of ignition, ignite”.

Survivable accident: According to the NTSB: “By definition, a survivable accident is one in which the forces transmitted to the occupants do not exceed the limits of human tolerance to abrupt acceleration, either positive or negative, and in which the structure in the occupant’s immediate environment remains structurally intact to the extent that an occupiable volume is provided for the occupants throughout the crash sequence.”

The ‘one-per-50 rule: The ‘one-per-50’ rule is used by EASA and the FAA, as well as many other AAs, to determine the number of cabin crew required to be carried on aeroplanes with 50 or more passenger seats installed. This is based on a requirement that one cabin crew member is required to be carried for every 50 passenger seats, or fraction of 50 passenger seats installed. Some AA’s have some additional requirements when an aeroplane is operated with a lesser number of passenger seats installed, compared to the number of passenger seats installed at the time of initial type certification. For aeroplanes with more than 19 passenger seats installed, EASA and the FAA, as well as many other AAs, require one cabin crew member to be carried irrespective of the number of passengers carried on any specific sector. For aeroplanes with 19 or fewer passenger seats installed a cabin crew member is not required to be carried.

The 90 second evacuation demonstration: This demonstration is required by CS 25.803 to be conducted on aeroplanes with more than 44 passenger seats installed for initial aeroplane type certification. The requirements for CS 25.803 are harmonised with the US, Canada and Brazil, and many other countries.

The 60 Foot Rule: In the late 1980’s the FAA introduced a ‘60 foot rule’ which determined that no pair of floor level emergency exits should be separated by more than 60 feet. In effect this means that no passenger should be seated more than 30 feet from a floor level exit.

UK CAA references: In this paper, reference is made to UK CAA Airworthiness Notices (ANs) in respect of cabin safety issues. These ANs were incorporated into UK Civil Aviation Publication (CAP) Number 747: Mandatory Requirements for Airworthiness, as Generic Requirements (GRs).

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4 INTRODUCTION

This Royal Aeronautical Society specialist paper titled 'Emergency Evacuation of Commercial Passenger Aeroplanes' is produced by the Society's Flight Operations Group. The purpose of this paper is to emphasise the importance of emergency evacuation and to show how effective crew procedures and associated training can increase the probability of a successful evacuation.

Even in clearly catastrophic circumstances such as fire or fuselage disruption, a high level of occupant survivability can be achieved. The outcome of numerous accidents and incidents over many years has identified issues with the adequacy and effectiveness of flight crew and cabin crew procedures, and associated training.

The more rapidly an evacuation is initiated and is efficiently conducted, the more likely the number of injuries and fatalities to occupants will be reduced. This paper addresses some of the key factors, both positive and negative, that might influence an evacuation, including airworthiness and operational issues and relevant research using accidents.

Improvements in occupant survivability are largely a result of actions taken by AAs, aeroplane manufacturers and operators, to address a wide-range of significant issues. Although this paper refers to some accidents that occurred many years ago, these events still have historical importance in that they directly influenced AAs and others in implementing improvements to regulatory requirements, such as:

- Dynamic testing for seats and human injury criteria (i.e. 16G seats).
- Fire retardant interior cabin materials, including seats.
- Thermal acoustic insulation with flame propagation testing.
- Low heat release and smoke density testing.
- Floor proximity emergency escape path lighting.
- Lavatory smoke detectors and automatic fire extinguishers for waste containers.
- Crew protective breathing equipment (PBE).
- Radiant heat resistant evacuation slides.
- Emergency exit design and evacuation slide qualification.
- Cargo compartment smoke detection and fire suppression systems.
- Aeroplane crew safety training including Crew Resource Management (CRM).
- Flight crew emergency evacuation checklists.
- Passenger seating restrictions at emergency exits.
- Passenger safety briefings.

New information on evacuation related airworthiness and operational issues, in addition to regulatory criteria as they become available, might benefit operators in any review of their operational procedures and crew training in respect of aeroplane evacuation.

Some airworthiness requirements have the potential to impact flight operations. Operational and airworthiness personnel working for AAs and for operators should have an awareness of airworthiness issues that might directly affect aeroplane crew emergency evacuation procedures and training. Airworthiness and operational requirements may not always be compatible, and may be dealt with separately by different disciplines within AAs, and at different stages in the process of certification or the introduction of a new aeroplane type. EASA Air OPS Regulation specifies technical requirements and administrative procedures for operators by mandating and regulating the use of Operational Suitability Data (OSD) by operators.

Accidents and incidents involving evacuation occur on a regular basis, many of which require rapid disembarkations not using evacuation slides, whilst a lesser number of evacuations occur when a significant threat of imminent danger exists to aeroplane occupants. Both scenarios include a risk of injury to passengers and crew, since getting to the ground from an emergency exit can involve jumping into an evacuation slide from a considerable height. This is especially the case for twin-aisle aeroplanes, and even more so for an evacuation from an upper-deck on multi-deck aeroplanes.

Additionally, there is a risk of injury to occupants who have to evacuate via exits that are not required to be equipped with evacuation slides.

A review of accident reports has identified that although the negative issues of emergency evacuations are addressed, the positive issues are not always identified. Therefore, it is possible that important information might not be disseminated to AAs and to industry so that positive lessons might be learned and, if appropriate, be acted upon. Therefore, regulators, manufacturers and operators might not appreciate such factors and the potential for safety improvements can be missed. In July 2016, ICAO issued Document Number 10062 'Manual on the Investigation of Cabin Safety Aspects in Accidents and Incidents. ICAO stated that *"Cabin safety aspects, including survival factors, should be addressed as part of the investigation process. However, these aspects are often overlooked. Therefore, States and industry may be missing out on the possibility for further safety enhancements"*. Additionally, not all accident investigation agencies have survival factors or cabin safety experts, and therefore such issues will need to be dealt with by others on the investigating team.

See Recommendation 1.

Case studies of both fatal and survivable aeroplane evacuations are included in this paper. They provide a useful review of the effectiveness of evacuation procedures and crew training. Flight crew and cabin crew training required by EASA Air OPS Regulation includes review of accidents and incidents as well as case studies.

In June 2000, the NTSB issued *Safety Study: Emergency Evacuation of Commercial Airplanes*, which included 20 safety recommendations. (Ref: 3) Additionally, the Transportation Safety Board (TSB) of Canada issued *A Safety Study of Evacuations of Large Passenger-Carrying Aircraft*, in 2013 (Modified). (Ref: 4) This FOG specialist paper takes into account issues raised in the NTSB and the TSB Safety Studies and addresses other factors that might influence emergency evacuations.

In December 2009, EASA issued a study on the cabin safety requirements contained in EASA CS 25 Certification Specifications. (Ref: 5) The aim of this study was to consider threats to cabin safety and identify potential amendments to EASA CS 25. Many of the issues addressed in the EASA CS 25 Study are reflected in relevant parts of this RAeS paper. Also, further information on the EASA CS 25 Study is at Section 9.6. This EASA study was conducted by an independent organisation and does not necessarily reflect the views of EASA, nor indicate a commitment to a particular course of action, and is not a substitute for current legislative and regulatory provisions.

This paper makes 17 Recommendations addressed mainly to AAs and to operators.

5 BACKGROUND

The first recorded aviation related emergency evacuation was in 1793, when Jean-Pierre Blanchard used a parachute to escape from his hot air balloon when it ruptured.

Most accidents involving commercial passenger aeroplanes are survivable, including some catastrophic accidents where occupant survivability might have been expected to be an issue. According to the European Transport Safety Council (ETSC) (Ref: 6), 90% of commercial transport aeroplane accidents can be categorised as survivable or technically survivable. Therefore, the ability of passengers to evacuate and for the aeroplane crew to initiate and manage the evacuation is critical to the outcome of the event.

In their 2000 Safety Study the NTSB stated: *"On average, an evacuation for the study cases occurred every 11 days"*. This was in the US alone involving 14 CFR Part 121 operations.

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| Reference 3: | NTSB Safety Study Emergency Evacuation of Commercial Airplanes – PB2000-917002 – NTSB/SS-00/01. |
| Reference 4: | TSB - Safety Study – SA9501 – A Safety Study of Evacuations of Large Passenger-Carrying Aircraft . |
| Reference 5: | EASA Study on CS-25 Cabin Safety Requirements – Issue 6 – (Project EASA.2008.C18) |
| Reference 6: | ETSC. Increasing the Survival Rate in Aircraft Accidents: Impact Protection, Fire survivability and evacuation. December 1996. |

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In a Safety Report issued in 2014 (Ref: 7), ICAO stated that there were 90 aeroplane accidents world-wide in 2013, with 173 fatalities arising from only nine of them. A review of ICAO accident data between 2009 and 2013 involving commercial scheduled air transport indicated that there were no fatalities in 87.7% of accidents.

Aeroplane evacuation facilities have developed significantly over the years and many improvements have been made to emergency exits including the installation of 'power-assist' systems to make exit operation easier and faster. This is especially the case for floor level exits on larger aeroplanes, many of which have large and heavy exits and some that need significant force to open and to deploy evacuation slides.

In some newer aeroplanes, fully self-supporting overwing Type III emergency exits have been installed and are a significant improvement on earlier Type III exit designs. Also, many improvements have been made to evacuation slides, with the original non-inflatable 'hand-held' slides, otherwise known as 'rag-chutes', being replaced with automatically inflated slides. Aeroplanes that have self-supporting Type III emergency exits include the Boeing 737 NG series, the Bombardier C series, and the Embraer E190 E2 series.

Additionally, the requirements for the installation of floor proximity emergency escape path lighting and associated emergency exit identifier lighting has improved passenger identification of emergency exit routes in conditions of low visibility, such as darkness or smoke. Emergency lighting systems also have external lights that illuminate the general outside areas and particularly the surface onto which the passengers or crew will first step after evacuating the aeroplane.

CRM was initially introduced by some operators after the accident on 28 December 1978 involving a McDonnell Douglas DC-8, operated by United Airlines, (Flight Number 173), at Portland, USA and was, at that time, limited to flight crew. In the 1980's the philosophy was extended to include cabin crew and in 1999 was mandated by the FAA. The terminology became Crew Resource Management. (See Section 9.13 and 9.14 for more information on CRM.) The secured flight deck door, mandated on larger aeroplanes after the terrorist events of September 2001, has reduced face-to-face communication between the flight crew and the cabin crew, although in emergency situations the aeroplane commander can override such restrictions. Although such face-to-face communication has been reduced, it importantly reinforces the need for effective CRM at all stages of a flight as well as pre-flight and post-flight briefings between flight crew and cabin crew.

The rapid growth in the operation of passenger commercial transport aeroplanes in recent years has seen a corresponding increase in emergency evacuations. Even in catastrophic accidents where fire or fuselage disruption occurs there can be a high level of occupant survivability. The potential for survivability derives from the following important factors:

- Improved regulatory airworthiness and operational requirements.
- Improvements in aeroplane design by manufacturers in respect of emergency evacuation systems and associated reliability.
- Improvements to flight crew and cabin crew procedures and training.

6 A COMPARISON OF TWO SIMILAR ACCIDENTS - Calgary and Manchester

On 22 March 1984, a Boeing 737-200 operated by Pacific Western Airlines, (Flight Number 501), suffered an uncontained engine failure during take-off at Calgary, Canada, when a compressor disc penetrated the left wing fuel tank resulting in leaking fuel being immediately ignited, causing a large external fire on the left side of the aeroplane fuselage.

Reference 7: ICAO Safety Report – 2014 Edition. A Coordinated, Risk-based Approach to Improving Global Aviation Safety.

All 114 passengers, two flight crew and three flight attendants, evacuated the aeroplane, although four passengers sustained injuries. Three passengers sustained bone fractures when they jumped from the leading edge of the wing to the ground. A fourth passenger fractured ribs and pelvis falling from the wing to the ground. In this accident the number and early operation of emergency exits may have been a major factor in occupant survivability. All of the right side exits, including the aft right floor level Type I exit were available during the evacuation (R1, R2 and R3), as well as the forward left side floor level Type I exit (L1).

On 22 August 1985, 17 months after the Calgary accident, a Boeing 737-200 operated by British Airtours, (Flight Number 28M), was departing Manchester, UK. On board were 131 passengers, two flight crew and four cabin crew. During take-off the left engine suffered an uncontained failure when a section of the combustion can was forcibly ejected from the engine and punctured a hole in a left wing fuel tank access panel, discharging burning aviation fuel onto the fuselage and onto the ground. This combined with the direction of a seven knot wind resulted in the fire rapidly burning through the fuselage and entering the passenger cabin.

In the emergency evacuation at Manchester, only three of the six emergency exits could be used due to the intensity of the external fire which mainly affected the rear of the aeroplane fuselage, the left wing, and the rear of the passenger cabin. In this accident 53 passengers and two cabin crew died. The AAIB Accident Report stated: *"The major cause of the fatalities was rapid incapacitation due to the inhalation of the dense toxic/irritant smoke atmosphere within the cabin, aggravated by evacuation delays caused by door malfunction and restricted access to the emergency exits"*.

There were other significant problems in the Manchester evacuation. These included the 25-second delay in the opening of the forward left floor level Type I emergency exit (L1), the 70-second delay in the opening of the forward right floor level Type I exit (R1), and the 45-second delay in the opening of the right overwing Type III exit (R2). Passengers had difficulties in accessing and passing through the bulkheads leading to the two forward floor level Type I exits (L1 and R1), and also evacuating via the seat row leading to right overwing Type III exit (R2).

The aft left floor level Type I emergency exit (L3) was not opened during the evacuation due to the external fire. The aft right floor level Type I exit (R3) was opened by a cabin crew member some six seconds after the aeroplane came to a full stop and the evacuation slide was deployed and inflated. However, due to the intensity of the external fire this exit was unusable.

Fuselage burn-through of the Boeing 737 at Calgary and the Boeing 737 at Manchester are remarkably similar as shown in the photographs below, although burn-through on the Calgary accident aeroplane fuselage extends forward of the left wing whilst in the Manchester accident aeroplane, burn-through of the fuselage is only present seven windows aft of the left overwing Type III emergency exit (L2) and extending aft to the area of the rear left floor level Type I exit (L3).



Photo copyright required.

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Comparison Table – Calgary and Manchester Accidents

FACTOR	CALGARY	MANCHESTER
Aeroplane	Boeing 737-200	Boeing 737- 236
Emergency exits installed:	L1, R1, L2, R2, L3 and R3.	L1, R1, L2, R2, L3 and R3.
Number of passenger seats installed:	Not known.	130.
Number of passengers carried:	114.	131 including 2 infants.
Number of crew:	2 flight crew and 3 flight attendants.	2 flight crew and 4 cabin crew.
Emergency exits available:	L1, R1, R2 and R3.	L1, R1, and R2.
Emergency exit usage:	The only recorded data is that approximately 40 passengers used the R2 emergency exit.	L1 = 17. R1 = 35. R2 = 26. Flight deck window = 2.
Number of fatalities and injuries:	Four serious injuries to passengers. Five minor or no injury to crew. No fatalities.	Passengers – 53 fatalities. Crew (cabin) – 2 fatalities. A further 15 serious injuries.

The Calgary accident resulted in no fatalities compared to the Manchester accident which had 55. In both accidents there are several similarities whilst at the same time there are some significant differences. One of the most significant differences is probably the early opening of the four emergency exits in the Calgary accident, including the right overwing Type III exit and its use by some 40 passengers (14 passengers more than Manchester). The delay in the opening and use of all three of the available exits in the Manchester accident affected the time to evacuate, and as a consequence reduced the time available before the environment in the passenger cabin became incapacitating.

The Canadian Aviation Safety Board (CASB) in its Aviation Occurrence Report into the 1984 Calgary accident stated that: *“Almost all the passengers were frequent air travellers familiar with the Boeing 737. This contributed to the success of the evacuation.”* CASB also stated: *“It is also possible to assume that other, less familiar passengers would not have opened the over-wing exit without supervision or command of a flight attendant. It is estimated that about 40 passengers exited via the over-wing exit. Had this exit not been available for use or not been available until later in the evacuation sequence, the evacuation time would have been significantly increased.”* Passengers on the Manchester accident aeroplane were mainly holiday travellers many of whom were accompanied by children.

The Manchester accident was a watershed in terms of aeroplane safety, and resulted in the UK CAA reviewing many aspects of occupant survivability. Research into airworthiness and operational regulations resulted in rule-making and implementation of new certification and operational requirements that were to significantly improve future occupant survivability. Many of these issues are dealt with in this paper.

In a paper published by the Fire Safety Engineering Group (FSEG) at the University of Greenwich in January 2017, (Ref: 8) coupled fire and evacuation simulation tools were used to analyse the Manchester accident. This paper is reviewed in Section 10.3. Of considerable interest is that the paper concludes *“...a 1-minute delay in opening the forward exits contributed to the loss of 48 lives while a 30-second delay in opening the over-wing exit contributed to the loss of 20 lives. Had all the viable exits been opened within the time achieved in evacuation certification trials, it is suggested that all passengers and crew could have safely evacuated.”* Other important issues identified in the paper were wind direction and the associated burn-through time. The numbers quoted above in the FSEG paper are not simplistic and are combined values.

Reference 8: Greenwich University. Numerical investigation of the fatal 1985 Manchester Airport B737 fire. Published by the Cambridge University Press – The Aeronautical Journal.

7 OVERVIEW OF MINIMUM REQUIRED CABIN CREW, AND EMERGENCY EXITS

7.1 Minimum required cabin crew in relation to installed passenger seating

The number and location of cabin crew on board an aeroplane does have a direct impact on the procedures for an emergency evacuation. Cabin crew are required not only to open emergency exits in an evacuation but also to ensure that exits are **not** opened into hazardous conditions, such as an external fire. This important operational issue is not necessarily addressed by airworthiness criteria.

Many AA requirements are based on the 'one-per-50' rule that requires one cabin crew member to be carried for each 50, or fraction of 50 passenger seats installed in the aeroplane, irrespective of the number of passengers carried on any particular flight. This does not necessarily take into consideration the location and number of emergency exits and the need for exits to be managed by cabin crew in an evacuation. For example, the Fokker F50 with 50 or fewer passenger seats installed has a pair of floor level exits at the front and the rear of the passenger cabin. For this aeroplane there is the potential for a pair of floor level exits not to be managed by cabin crew. EASA Air OPS Regulation ORO CC 100 primarily contains other criteria, and only ultimately resorts to the 'one-per-50' rule in the absence of information necessary to apply the primary criteria of the requirement.

For aeroplanes with 19 or fewer passenger seats installed, there is no requirement for cabin crew to be carried at all unless specifically required for demonstration of compliance with certain CS 25 requirements (e.g. width of aisles, access to emergency exits, etc). However, sometimes a person is carried to provide cabin service. If wearing a uniform, or a mode of dress that might identify them to passengers as being a crew member, then it is likely that passengers will expect such persons to provide assistance in an evacuation. EASA requires any person who might be identified by passengers as cabin crew meet all the relevant EASA Air OPS Regulation requirements. Where no cabin crew are carried, passengers may have to operate emergency exits and commence an emergency evacuation without the assistance of flight crew, so the effectiveness of passenger briefing given by the flight crew is of great importance.

The policy for some AAs is that each floor level emergency exit on twin-aisle aeroplanes should have a cabin crew member dedicated to the exit and be seated adjacent to the exit for take-off and landing in a cabin crew seat required by CS 25. The majority of twin-aisle aeroplanes are configured with only Type A emergency exits. CS 25.785(h)(1) requires one cabin crew seat adjacent to each Type A exit. However, for many AAs there is no associated operational requirement that these cabin crew seats be occupied by a cabin crew member for take-off and landing, and therefore a potential disconnect between airworthiness and operational requirements could exist.

In twin-aisle aeroplanes, certificated for 440 passenger seats with four pairs of Type A floor level emergency exits and requiring nine cabin crew, subsequent operation with first or business class cabins will inevitably reduce the total number of passenger seats. Thus there will be fewer seats than at the time of initial type certification – perhaps only 300, and by the 'one-per-50' rule only six cabin crew members would be required. This would mean that two Type A exits would not have a cabin crew member seated adjacent to them. When operators reduce the number of cabin crew and do not have cabin crew allocated to a specific floor level exit(s), they should conduct a risk assessment including an evaluation of how that decision is made, by whom and on what basis. According to EASA when a new configuration is approved, the minimum number of cabin crew will be determined by the relevant design organisation (TC holder or approved organisation). This might be lower, equal or greater than the number established by applying the 'one-per-50' principle.

The following Boeing 777-200/300 accidents in 2015 and 2016 (which are referred to later in this paper) demonstrate the effectiveness of aeroplane crew evacuation procedures despite the non-availability of Type A emergency exits due to external fire:

Operator:	Aeroplane Type:	Location:	Date:	Number of Passengers:
British Airways	B777-200	Las Vegas	8 September 2015	157
Korean Air	B777-300	Tokyo	27 May 2016	302
Emirates	B777-300	Dubai	3 August 2016	282

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In each of these accidents there were no fatalities. However, in all three of these accidents the number of passenger seats installed was significantly fewer than the number approved at the time of initial type certification. Also the number of passengers actually on board was less than the number of passenger seats installed, and the number of cabin crew on board was significantly more than required by the 'one-per-50' rule. If the maximum number of passengers had been on board, and if only the minimum number of required cabin crew had been carried, the outcome of these accidents might have been quite different with extended evacuation times. Furthermore, the outcome of these accidents benefitted from the fact that the aeroplanes were not at maximum capacity in respect of passenger seats installed. (See Case Studies at Sections 11.10, 11.11 and 11.14.)

In September 2010 the UK CAA issued FODCOM 24/2010 (Ref: 9), advising operators to consider procedures for when a cabin crew member might be responsible for a pair of emergency exits in an evacuation. The FODCOM made the following Recommendations:

- *"Operators who have a cabin crew complement where a cabin crew member is, or could be, responsible for a pair of exits should include procedures for training in their Aircraft Conversion and Recurrent training courses. This training should include practical exercises in the operation of two exits and effective crowd control techniques and commands."*
- *"Operators should ensure that their Operations Manuals and Cabin Crew Training Manuals include normal and emergency procedures to be followed when a cabin crew member is, or could be, responsible for a pair of exits."*
- *"Operators should consider including appropriate briefings for passengers seated adjacent or close to a pair of exits controlled by a single cabin crew member."*

Previously, in 1992 the NTSB recommended that flight attendants who are responsible for opening more than one floor level exit during an evacuation should demonstrate proficiency in the methods that they will use to open these emergency exits. This should include managing the flow of passengers to and through these exits. Flight attendants who do not have the opportunity to be tested in such skills may not be able to perform the appropriate procedures in an emergency evacuation.

In October 2014, EASA issued, in draft form for public comment, Safety Information Bulletin (SIB) Number 2014-29. (Ref: 10) The draft SIB included the following statements:

"Considering the distance separating two emergency exits of the same pair on a twin-aisle aeroplane, it is not realistic to expect that a single cabin crew member will be capable of:

- *simultaneously giving commands for two emergency exits, including perhaps preventing passengers opening an emergency exit unsafe to use;*
- *reaching and operating the opposite emergency exit; and*
- *keeping control of the evacuation and of the passenger flows to both emergency exits of a pair."*

"Associated risks are adverse passenger behaviour in the absence of adequate supervision of the evacuation with a potentially negative impact on the evacuation rate and, in worst cases, on passenger survivability rate." "Given the above, EASA does not find it acceptable that, on a twin-aisle aeroplane, a pair of emergency exits is supervised and operated by one cabin crew member only."

EASA SIB 2014-29 was not issued as a final document because of adverse comment received from industry. EASA decided to address one specific design issue that had been raised during discussions with industry by means of a Certification Memorandum (CM) CM-CS-08 issued in July 2017. (Ref: 11) EASA accepted that the wording of EASA Air OPS Regulation ORO.CC.100: Number and composition of cabin crew was potentially confusing.

Reference 9:	UK CAA FODCOM 24/2010: Cabin Crew Members Responsible for a Pair of Exits.
Reference 10:	EASA Safety Information Bulletin (SIB) Number 2014-29: Minimum Cabin Crew for Twin Aisle Aeroplanes.
Reference 11:	EASA CM-CS-008 Issue 01: Certification Memorandum 'Large Aeroplane Evacuation Certification Specifications – Cabin Crew Members Assumed to be On Board'.

CM-CS-08 states: “.....it has also been decided to request from now on that aeroplane design substantiation documentation involving a showing of compliance to the emergency evacuation requirements (CS 25.803) will include a clear statement regarding the assumed number and location of cabin crew members.” CM-CS-008 also states: “Furthermore, it has become clear that in some cases the optimum locations of cabin crew members within the passenger cabin during taxi, take-off and landing might not be obvious. Therefore, the assumed seating locations of the cabin crew members should also be clearly indicated.”

In order that cabin crew, flight crew, ground staff and managers can ascertain quickly and accurately the number of cabin crew to be carried in all circumstances on each type of aeroplane to be operated, the Operations Manual should state the minimum number of required cabin crew and how it is calculated.

In 2017 ICAO issued Document Number 10072. (Ref: 12) Many issues in the ICAO Manual are addressed in this paper. This ICAO Manual provides useful guidance on a wide-range of cabin crew complement issues.

See Recommendation 2.

7.2 Emergency exits: number, types, classification, and location

Each type of emergency exit has a classification based on the number of passengers that might as an optimum be expected to evacuate via the pair of emergency exits as specified in CS 25.807 ‘Emergency exits’. These are briefly described as follows:

EMERGENCY EXIT TYPE	PASSENGER SEAT RATING	ADDITIONAL INFORMATION
Type A	110 per pair of exits	Type A emergency exits are at floor level. Exit dimensions: not less than 107 centimetres (42 inches) wide and 183 centimetres (72 inches) high.
Type B	75 per pair of exits	Type B emergency exits are at floor level. Exit dimensions: not less than 81.3 centimetres (32 inches) wide and 183 centimetres (72 inches) high.
Type C	55 per pair of exits	Type C emergency exits are at floor level. Exit dimensions: not less than 76.2 centimetres (30 inches) wide and 122 centimetres (48 inches) high.
Type I	45 per pair of exits	Type I emergency exits are at floor level. Exit dimensions: not less than 61 centimetres (24 inches) wide and 122 centimetres (48 inches) high.
Type II	40 per pair of exits	Type II emergency exits are either at floor level or over the wing. Exit dimensions: not less than 51 centimetres (20 inches) wide and 112 centimetres (44 inches) high.
Type III	35 per pair of exits	Type III emergency exits are usually overwing exits and usually are not at floor level. Exit dimensions: not less than 51 centimetres (20 inches) wide and 91.4 centimetres (36 inches) high.
Type IV	9 per pair of exits	Type IV emergency exits are usually overwing or underwing exits and usually are not at floor level. Exit dimensions: not less than 48 centimetres (19 inches) wide and 66 centimetres (26 inches) high.

Type III and Type IV emergency exits are usually installed only on single-aisle aeroplanes but occasionally are found on twin-aisle aeroplanes (e.g. some variants of the Boeing 767 have Type III exits). Type III and Type IV exits are removable hatches that are usually operated by passengers, and once opened do not remain attached to the aeroplane fuselage. For the 737 NG aeroplanes Boeing

Reference 12: ICAO Document Number 10072: Manual on the Establishment of Minimum Cabin Crew Requirements (First Edition – advance – unedited).

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introduced a new design of overwing Type III exit hatch that operates semi-automatically so that the hatch remains attached externally to the aeroplane fuselage without the need for any additional actions. More information on these types of Type III exits is at Section 8.10. In May 2017 the FAA issued a review of such Type III exit hatches. (Ref: 13)

Floor level emergency exits are required by CS 25.809(a) (Ref:14) to have a viewing facility so that the aeroplane crew can see outside the passenger cabin and, if necessary, determine any external hazards before deciding to operate the emergency exit. Type III and Type IV exits have passenger cabin windows and passengers should be able to see external hazards but might not always be able to evaluate such dangers in the way that a trained crew member would.

As identified in Section 3 Definitions and Explanations, different organisations have various ways of identifying the location of emergency exits. A standard for emergency exit identification and location would be of benefit to operators, regulators, manufacturers, rescue personnel and accident investigators.

See Recommendation 3.

8 DESIGN, AIRWORTHINESS AND AEROPLANE TYPE CERTIFICATION

8.1 The aeroplane manufacturer's initial design criteria

The criteria for emergency evacuation originate in the early planning stages of the aeroplane design. The aeroplane manufacturer first determines the potential market for the aeroplane, the routes to be operated, the maximum flight duration, as well as the maximum number of passenger seats to be installed, including the potential for different classes of the passenger cabins. Among other things, this will determine:

- Number, type and location of required emergency exits, and evacuation slides.
- Minimum number of required cabin crew
- Requirements for portable emergency equipment.
- Requirements for fixed systems, such as interphone and public address.

8.2 The number of passenger seats installed

The maximum number of passenger seats installed in an aeroplane and approved at the time of initial type certification might be less than subsequently operated. The reduction in the number of passenger seats installed can cause some issues if the number of cabin crew to be carried is only dictated by the 'one-per-50' seats installed rule. According to the rule, an aeroplane such as the Boeing 777-200 with 4 pairs of Type A emergency exits might be operated in a mixed class configuration, with for example 300 passenger seats, thereby requiring only six cabin crew to be carried based on the 'one-per-50' rule. This would result in two Type A floor level emergency exits not having a cabin crew member seated immediately adjacent to the emergency exit.

ICAO Annex 6 - Part 1 requires that an operator establish to the satisfaction of the AA responsible for the operator, the minimum number of cabin crew members for each aeroplane in its fleet based on seating capacity or the number of passengers carried. Some AAs have adopted a 'one-per-50 passenger(s) carried' rule rather than a 'one-per-50 seats installed' rule. In the case of the passengers carried rule there is potential for even more floor level emergency exits to not have a cabin crew member immediately adjacent when operating at low passenger loads.

8.3 Evacuation slides

Evacuation slides have been fitted to commercial passenger aeroplanes since the early 1950's. Early types of evacuation slides were not inflatable and had to be deployed

Reference 13: DOT/FAA/AR-09/92: A review of Issues Related to the Fitment of Automatically Disposable Hatches at Type III Exits With Regard to the Number of Certificated Passenger Seats.
Reference 14: EASA - Certification Specifications and Acceptable Means of Compliance for Large Aeroplanes – CS 25. Amendment 19. 12 May 2017.

manually from the emergency exits. Passengers or aeroplane crew would have to climb down a rope or an evacuation slide and hold the base of the slide in order to make it useable. The procedures for the deployment of these non-inflatable evacuation slides were both complicated and time-consuming. Starting in the 1960s, newly manufactured aeroplanes began to be equipped with inflatable evacuation slides which were capable of being deployed much more rapidly.

The requirements for evacuation slides are specified in CS 25.810 Emergency egress assisting means and escape routes, which states: *"It must be automatically deployed and deployment must begin during the interval between the time the exit opening means is actuated from inside the aeroplane and the time the exit is fully opened. However, each passenger emergency exit which is also a passenger entrance door or a service door must be provided with means to prevent deployment of the assisting means when it is opened from either the inside or the outside under non-emergency conditions for normal use."* This means that when an emergency exit is opened in the emergency mode from inside the passenger cabin the evacuation slide must deploy. If an exit is in the emergency mode and is opened from outside, the evacuation slide must **not** deploy.

The requirements for evacuation slides differ depending on the type of emergency exit at which they are installed. In brief the EASA CS 25.810 requirements are:

- Each emergency exit that is more than 1.8 metres (six feet) from the ground with the aeroplane on the ground and with the landing gear extended, must have an approved assist means (i.e. evacuation slides) to assist passengers and crew to evacuate and to descend to the ground;
- The assist means must be automatically activated by a crew member or passenger from inside the aeroplane;
- The assist means must be fully deployed and ready for evacuation in ten seconds from the time that the opening means of the emergency exit is actuated;
- The assist means must be of such a length that when fully deployed that the toe end of the evacuation slide is self-supported on the ground and provides safe evacuation for passengers and crew with one or more of the landing gears being collapsed; and
- The assist means must have the capability to deploy in 46 kilometres/hour (25-knot) winds directed at it from the most critical angle with any engine(s) simultaneously running at ground idle, and to remain useable after full deployment to evacuate passengers and crew to the ground.

In the case of twin-aisle aeroplanes, Type A floor level exits are required to be equipped with dual lane evacuation slides to facilitate two parallel lines of evacuating passengers.

EASA in their 2009 CS 25 Study raised the issue of the unavailability of some emergency exits combined with evacuation slide problems at other emergency exits that might be adversely affected by high winds. The study came to the conclusion that it was necessary to investigate the adequacy of the requirements relating to winds and wind gusts on evacuation slides during deployment, as well as any associated actions that might be required to stabilise an evacuation slide in order to effect a safe evacuation. The EASA review also addressed the potential for improvement in evacuation slide design to minimise injuries to passengers and crew taking into consideration operational and design aspects.

For aeroplanes that are not required to be equipped with evacuation slides, passengers and crew will have to jump down from a height which some will find challenging or even injurious. Delays in an evacuation are possible if passengers decide to sit on the emergency exit sill and jump, or sit and slide at exits equipped with evacuation slides. This is more likely to be the case for elderly and infirm passengers, for children, as well as for adults with infants. The 1.8 metre maximum height limit for evacuation slides might be too high for such passengers to manage without serious injury. Depending on the emergency scenario, cabin crew at floor level emergency exits will need to be aware of such issues and their evacuation procedures and training will need to address how best to deal with them as safely as possible without slowing down an evacuation unnecessarily. Aeroplanes that do not need to be equipped with evacuation slides include, but are not limited to, the Embraer 145, the Fokker F50 and the Bombardier CRJ-200.

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The NTSB in its 2000 Safety Study, recommended that the FAA “Review the 6-foot height requirement for exit assist means to determine if 6 feet continues to be the appropriate height below which an assist means is not needed. The review should include, at a minimum, an examination of injuries sustained during evacuations. (A-00-79).” In its review of the NTSB recommendation the FAA determined that the number of injuries to passengers was minimal. Also that by requiring evacuation slides to be installed below the current assist means height criteria might result in shallow evacuation slides not being able to meet the required evacuation flow rates. The FAA did not believe that an amendment to the current criteria was justified.

In their 2009 CS 25 Study, EASA reiterated some of the above concerns and stated: “The evidence available from accidents and research studies suggests that the requirement to jump to the ground from a height of 1.8m (6 feet) during evacuation, without assist means, may potentially cause serious injury or may delay the progress of an evacuation due to hesitation or unwillingness to jump.” The EASA study recommended that further research be undertaken to establish if the current height requiring assist means is appropriate, or if a lesser height should be applied to CS 25.810.

In a ditching, evacuation slides on twin-aisle aeroplanes also usually act as life-rafts (i.e., “slide-rafts”), whereas on single-aisle aeroplanes the evacuation slides are usually only used as flotation aids, i.e., something for passengers in the water to hold onto. However for extended overwater operations some single-aisle aeroplanes are equipped with slide-rafts at floor level emergency exits. In both cases the slides are detached from the aeroplane fuselage. For the Boeing 747, the upper deck slides are not used as slide-rafts but in the case of the Airbus A380 all of the six upper deck slides are used as slide-rafts. Evacuation slides at overwing emergency exits on both single-aisle and twin-aisle aeroplanes are not used as rafts or flotation aids, since the slides are not designed to be detached from the aeroplane. Also, it is possible that evacuation slides at overwing exits may not inflate and deploy correctly due to water ingress. According to the NTSB Accident Report, in the case of the 2009 USAir Hudson river ditching, the Airbus A320 was equipped for Extended Over Water (EOW) operations and slide-rafts were installed at each of the four floor level emergency exits, even though this was not an EOW sector. This was an important factor in the evacuation and subsequent rescue of passengers and crew in extremely cold weather conditions. (See Section 9.22 and Case Study at 11.7.)

In some accidents evacuation slides have inflated inside the passenger cabin. This was the case in the accident on 6 July 2013 involving the Asiana Airlines Boeing 777-200ER, (Flight Number 214) which crashed on final approach to San Francisco, USA, with a descent below the correct glidepath resulting in an impact with a seawall. It is thought that inadvertent slide inflation into the passenger cabin was a result of catastrophic failure of the slide release mechanism during multiple impacts of the aeroplane fuselage. (See Case Study at 11.9.)

Even when fully inflated and deployed, evacuation slides might still not be useable during an emergency evacuation for a number of reasons, for example if the slides are blown by strong winds. (See accidents and incidents in Case Studies at Section 11.)

See Recommendation 4.

8.4 Airstairs

Airstairs are installed on many business aviation aeroplanes, on most regional aeroplanes such as the Embraer 145 and on some medium size aeroplanes such as the Boeing 737 and the Airbus A320. For business aviation aeroplanes, airstairs are the primary means of passenger embarkation and disembarkation, and are the primary means of emergency evacuation on land, but not necessarily in a ditching scenario. Airstairs are not normally installed on twin-aisle aeroplanes with some exceptions, such as the US Presidential Boeing 747, Air Force One.

In their Safety Study of 2013 (Modified), the TSB determined that in four incidents the commander decided to disembark the passengers via the forward airstairs since no immediate threat to life was perceived. In each case the crew were not able to deploy the airstairs and after significant delays

were forced to use the evacuation slides. The lack of an available power source was suspected to be the cause of the failure of the airstairs to deploy.

8.5 Location of cabin crew seats, cabin crew assist spaces and assist handles

The location of cabin crew seats is specified in CS 25.785 'Seats, berths, safety belts and harnesses':

*"(h) Each seat located in the passenger compartment and designated for use during take-off and landing by a cabin crew member required by the operating Rules must be –
(1) Near a required floor level emergency exit, except that another location is acceptable if the emergency egress of passengers would be enhanced with that location. A cabin crew member seat must be located adjacent to each Type A or Type B emergency exit. Other cabin crew member seats must be evenly distributed among the required floor level exits to the extent feasible."*

The location of cabin crew assist spaces is required by CS 25.813 'Emergency exit access and ease of operation':

"(b) Adequate space to allow crew member(s) to assist in the evacuation of passengers must be provided as follows: (1) Each assist space must be a rectangle on the floor, of sufficient size to enable a cabin crew member, standing erect, to effectively assist evacuees. The assist space must not reduce the unobstructed width of the passageway below that required for the exit"

Cabin crew assist spaces are intended to:

- Provide a space where a cabin crew member can safely stand without the risk of being inadvertently pushed out of the emergency exit by evacuating passengers; and
- Provide a space where a cabin crew member can stand whilst providing any necessary physical assistance in motivating passengers to evacuate and without obstructing passenger flow to and through the emergency exit.

Cabin crew assist spaces are usually only required for floor level emergency exits. On single-aisle aeroplanes with Type I floor level exits a cabin crew assist space is required on one side of the exit, whereas for twin-aisle aeroplanes with Type A exits an assist space is required both forward and aft of the exit. However, not all floor level exits are required to have an assist space. Type C, I and II exits on aeroplanes with 80 or fewer passenger seats installed, and no escape slides, do not need to have assist spaces.

Although the above appears to be quite clear in its applicability, this might sometimes be open to interpretation by those assessing the suitability of assist spaces. From an operational perspective, there might not be any specific requirement for a cabin crew member to make use of an assist space in an emergency evacuation – only that the designated assist space is available.

Cabin crew training should include the ability of cabin crew members to use 'Situational Awareness' in responding to a variety of emergency scenarios including an emergency evacuation. This means that a cabin crew member will position themselves in a location that will best respond to the specific emergency, and if necessary provide them with an element of safety by securing themselves to the aeroplane whilst carrying out their emergency procedures. CS 25.813(6) states:

"There must be a handle, or handles, at each assist space, located to enable the crew member to steady himself or herself:

- (i) While manually activating the assisting means (where applicable), and*
- (ii) While assisting passengers during an evacuation."*

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Assist handles are usually installed immediately adjacent to floor level emergency exits and provide crew members with the following safety functions:

- Opening of emergency exits, especially in the non-power assist mode;
- Protecting crew members from being inadvertently being pushed out of an emergency exit during an evacuation or when activating the evacuation slide manual inflation handle; and
- Blocking an emergency exit that has been opened, but is not safe to use in an evacuation.

Further information on cabin crew seats can be found in FAA AC 25.785 1B issued in 2010. (Ref: 15)

8.6 Cabin crew direct view

It is important that cabin crew can see into the passenger cabin during taxi, take-off and landing from a seated position in order to take necessary safety actions. The restricted amount of direct view from the forward cabin crew seats was identified as an issue by the AAIB in their report into the 1985 Manchester accident. The AAIB Accident Report stated:

- *“There were sounds of distress in the cabin and the purser leaned inboard in an attempt to improve his view and saw passengers standing up.”*
- *“The forward cabin crew seats were on the left side of the aircraft in the forward entrance vestibule, from where the view into the cabin was restricted by a galley bulkhead. This made it difficult to see what was happening in the cabin particularly on the left side, although the purser did become aware that passengers were becoming agitated.”*
- *“The forward cabin crew seats were positioned such that, when seated, the crew members had a restricted view of the passenger cabin.”*

The AAIB Accident Report recommended that the UK CAA review the cabin configuration that existed on the Manchester accident aeroplane in respect of the restricted view of the passenger cabin provided to the forward cabin crew when seated.

In their 2009 CS 25 Study, EASA identified that improvements might be needed to the monitoring of the passenger cabin by cabin crew. It was recommended that consideration be given to further research to include the following:

- *“A survey of current commercial transport aeroplanes may need to be conducted to ascertain how, if applicable, the requirement of CS 25.785(h)(2) has been complied with.”*
- *“A review of incidents associated with cabin crew’s ability to monitor cabin areas.”*
- *“A survey involving cabin crew of very large transport aeroplane.”*

CS 25.785(h) (2) states that required cabin crew seats are: “To the extent possible, without compromising proximity to a required floor level emergency exit, located to provide a direct view of the cabin area for which the cabin crew member is responsible.”

8.7 De-rating and removal of emergency exits

An operator with an aeroplane that has a lesser number of passenger seats installed than that approved at the time of initial type certification, may apply to their AA to have an emergency exit or pair of exits de-rated. Guidance on the de-rating of exits is specified in FAA AC 25-17A, which is formally endorsed by EASA, and allows the de-rating of the following exits:

- Type A exit to Type I exit;
- Type A exit to Type III exit; and
- Type I exit to Type III exit.

Note: *Relevant parts of the FAA Advisory Circular 25-17A Transport Airplane Cabin Interiors Crashworthiness Handbook, dated May 2009, are accepted by EASA as providing an acceptable means of compliance with CS 25.807.*

If approved by an AA, emergency exit de-activation might permit the access to the exit to be reduced, allowing incursion into the exit area of passenger seats or other solid structures. Potentially a cabin crew seat adjacent to a Type A or Type I exit could be removed and cabin crew assist space(s) might not be required. Although access to a Type A or Type I exit might have been marginally reduced, procedures for operation of exits and evacuation slides will remain the same, but potentially without the presence of cabin crew to operate the exit, and control the evacuation. If de-rating an exit results in the removal of cabin crew seats, this will require significant changes to cabin crew evacuation procedures and possibly the minimum number of cabin crew required.

CS 25.785(h) (1) requires: *“A cabin crew member seat must be located adjacent to each Type A or B emergency exit. Other cabin crew member seats must be evenly distributed among the required floor level emergency exits to the extent feasible.”*

In 1983, some operators of the Boeing 747-100/200, requested that Boeing determine if it was possible to remove the overwing Type A emergency exits (L3 and R3) when fewer than 440 passenger seats were installed on the main deck because of their weight and the cost of continued maintenance. Boeing submitted a case to the FAA Seattle Office and in December 1983, that office agreed that this pair of Type A exits could be removed. Some operators quickly went ahead with the removal of the overwing Type A exits on their Boeing 747-100/200 aeroplanes.

The removal of the overwing Type A emergency exits resulted in a forward to aft distance of some 72 feet between the Type A floor level exits forward and aft the wings, (i.e. between L2-L4 and R2-R4).

However, the FAA in Washington overturned the Seattle Office decision and decided that no US registered Boeing 747 would be allowed to remove the overwing Type A emergency exits. The FAA then introduced 'the 60-foot rule' regarding the maximum allowable distance between exits.

On 20 November 1985, a Boeing 747-100 operated by British Airways, (Flight Number 256), was en-route from Barbados to London Heathrow, when a flight deck warning light came on indicating a smoke or fire problem in the aft cargo compartment. This Boeing 747-100 had the overwing Type A emergency exits removed and no cabin crew seats were installed at these exits. The aeroplane commander decided that a diversion to the US Air Force base at Lajes in the Azores (Portugal) was necessary. In spite of bad weather, with heavy rain and high cross winds, the evacuation of 333 passengers, three flight crew and 15 cabin crew was successfully completed. (See Case Study at 11.2.)

In February 1986, Boeing conducted a CS 25.803 demonstration of the upper deck of a Boeing 747-300, and a concurrent main deck evacuation with the overwing Type A emergency exits deactivated. Both the upper deck and the main deck evacuations of the Boeing 747-300 met the CS 25.803 demonstration requirements within the 90 second criteria. Partly as a result of this full-scale evacuation demonstration, British Airways decided that for the purpose of effective passenger management in the event of an evacuation, the presence of cabin crew would be beneficial in the middle of the passenger cabin at the overwing area. British Airways installed two cabin crew seats in this area even though this was not required by any airworthiness or operational criteria.

More recently the FAA has acknowledged that the 60 feet criteria might have been arbitrarily selected based on a selection of aeroplane designs that existed at that time. The FAA has determined that it would be preferable in the future to have a performance standard which would not artificially constrain design options.

8.8 Type III and Type IV emergency exits, access and ease of operation

Type III and Type IV emergency exits are usually only installed on single-aisle aeroplanes, typically in the middle of the passenger cabin in overwing locations, and are not normally located adjacent to

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cabin crew seat(s). One exception to this is the twin-aisle Boeing 767 which has either one or two pairs of overwing Type III exits, depending on the number of floor level exits. Once opened these exits hatches do not remain attached to the fuselage; they can be heavy and not always easy to manoeuvre. The exit hatch must be lifted into the passenger cabin and then disposed of in some way.

Type III and Type IV emergency exits are often referred to as 'self-help' exits since they are usually expected to be operated by passengers. Such exits can be more difficult to operate than the floor level emergency exits operated by trained cabin crew. CS 25 requires that the operation of exits must be simple and obvious and may not require exceptional effort; both physical and intuitive aspects are included in the criteria. The FOG believes that the design and weight of emergency exit hatches, and the actions necessary to make the exit ready for evacuation can be problematic. Passengers are not trained to undertake the required actions and may not always understand safety briefings or the information in passenger safety cards or on exits placards. Passenger safety cards will usually specify that the exit hatch should be disposed of through the exit aperture, but operators cannot rely on untrained passengers to correctly achieve this. In some cases an exit hatch outside the aeroplane might be a trip hazard, whilst inside the passenger cabin it is likely to obstruct access to the emergency exit. In April 2008, EASA in NPA Number 2008-04 (Ref: 16) stated: *"The operation of Type III removable hatches requires levels of strength and dexterity that cannot be easily reconciled with the fact that the task will most likely fall to naive persons, i.e. passengers. In addition to the extended time taken to perform the initial opening of the exit, correct and quick disposal of a weighty hatch has been shown in many accidents and tests to be problematical."*

In the 1985 Manchester accident, access to and egress through the right overwing Type III emergency exit was a significant problem and eventually the exit became blocked when a passenger was trapped in the exit aperture. Shortly after the Manchester accident, the UK CAA determined that there was an immediate need to improve Type III and Type IV exit requirements, and in January 1986 issued UK CAA AN 79 Access to and Opening of Type III and Type IV Emergency Exits, (Ref: 17) requiring compliance by July 1986.

AN 79 required improvements in the access to, and operation of Type III and Type IV emergency exits. Movement of seat backs in such exit rows were restricted so they could not break-over forward or recline backward. Seat pan and lower back suspensions were required to be free of any gaps that might entrap a foot or a hand. Also, placards showing the operation of Type III exits were to be located at eye level for passengers seated in such exit seat rows. Additionally, there was an operational recommendation for operators to conduct a discrete briefing of passengers seated in such exit seat rows regarding the operation of the exit

On 1 February 1991, a Boeing 737-300, Operated by USAir, (Flight Number 1493), whilst landing at Los Angeles, landed on top of a Fairchild Metroliner operated by SkyWest Airlines, (Flight Number 5569), which was waiting for take-off on the same runway. After impact with the Metroliner, the Boeing 737 continued down the runway with the smaller aeroplane crushed underneath it. It was some time before the Los Angeles RFFS identified a second aeroplane underneath the Boeing 737-300. All 12 occupants of the Metroliner died in the accident. In the case of the Boeing 737 there were 23 fatalities and 30 injuries. The NTSB identified in their accident investigation that there were once again problems with the operation and access to one of the overwing Type III emergency exits.

The NTSB in their accident report into the Los Angeles accident recognised that there were similarities to the 1985 Manchester accident and stated, *".....that many passengers attempted to exit from an overwing exit [Type III] in a very limited period of time"*. The NTSB also stated that: *"The size of the Type III exit is a limiting factor during an evacuation."* As a result of recommendations in the NTSB Accident Report, the FAA initiated further tests at the FAA Civil Aeromedical Institute (CAMI) to refine and confirm their earlier findings on access to Type III exits. This further work took into account the requirements of UK CAA AN 79 as well as CAA tests conducted at Cranfield. As a result of the work at CAMI, in April 1991 the FAA issued an NPRM followed in May 1992 by a Final Rule to address such issues. (Ref: 18 and 19)

Reference 16:	EASA NPA No 2008-04: Type III Emergency Exit Access and Ease of Operation. Date of NPA: 10 April 2008.
Reference 17:	UK CAA AN Number 79: Access to and Opening of Type III and Type IV Emergency Exits. First published in January 1986 and subsequently amended.
Reference 18:	FAA NPRM 56 FR 14446: Improved Access to Type III Exits'
Reference 19:	FAA Final Rule 57 19220 'Improved Access to Type III Exits'

Note: All of the above requirements and recommendations have been subsequently adopted by EASA in CS 25, and some by the FAA in 14 CFR 25, as well as by many other AAs.

See Recommendations 5 and 6.

8.9 Overwing emergency exit escape routes and markings

Having evacuated via a Type III or Type IV emergency exit, passengers usually have to reach the ground without any supervision from the aeroplane crew. Such an evacuation would normally be achieved by use of the trailing edge of the wing. Arrow markings are required to be on the surface of the wing to indicate the evacuation route but these are not always readily identifiable to evacuating passengers, and even less identifiable in conditions of darkness.

For all aeroplanes, including those that have Type III or Type IV emergency exits installed over the wings, and do not need to meet the 1.8 metre (6 foot) CS 25 criteria for evacuation slides, the usual route for passengers to evacuate is by the trailing edge of the wing. In order to facilitate evacuation the flight crew have to retract the wing spoilers and extend the trailing edge wing flaps. Failure to do so will hinder the evacuation and may cause injury to passengers and crew. Flight crew emergency evacuation checklists usually specify such actions; for example the Boeing 737 evacuation checklist states: *“Verify that the flaps are 40 before the engine start levers are moved to CUTOFF”*. Some operators have decided that this should be a checklist ‘memory’ item.

In their 2009 Study of CS 25, EASA stated that setting the wing flaps position for emergency evacuation is highly dependent on flight crew actions together with the availability and speediness of the systems for lowering the flaps. They believed that further consideration should be given to ensuring the adequacy of CS 25.810(d) on the subject of measurement of the height of the terminal edge with the wing flaps in the take-off or landing position.

The evacuation route from the wing also depends on the location of the engines and it is important that passengers and crew are not exposed to engine inlet areas or propeller blades. So for most aeroplanes with engines mounted at the rear of the fuselage the evacuation route is off the leading edge of the wing to avoid engine inlet ingestion areas behind the trailing edge of the wing. Jumping from the leading edge of the wing, which in most cases will be higher than the trailing edge of the wing might be counter-intuitive and this reinforces the need to have conspicuous wing markings depicting the route of evacuation.

On 1 August 2008 an Embraer ERJ 190-200LR operated by Flybe was en-route from Manchester (UK) to Belfast City (UK) when both pilots sensed a sulphurous burning smell and the commander decided that a diversion to Ronaldsway on the Isle of Man was required. After landing the commander ordered an emergency evacuation. The Embraer ERJ 190-200 LR is equipped with two pairs of floor level emergency exits, forward and aft, and one pair of overwing Type III exits. Initially, passengers were unable to open the right overwing Type III exit due to the upper part of the exit hatch trim being jammed under the ceiling edge trim. The AAIB Accident Report stated: *“Having climbed out of the cabin, passengers disembarking from the left overwing exit were unsure of how to descend from the wing to the ground. A number congregated on the wing looking for a way down. Cabin crew eventually noticed the confusion and urged the passengers to get off the wing. Some passengers slid or jumped from the wing tip and leading edge (a drop of some 7 to 8 feet) instead of sliding off the wing trailing edge down the extended flaps.”* Although the trailing edge wing flaps were extended, in accordance with the flight deck evacuation checklist, there still remained a drop to the ground of approximately 5.6 feet. Four minor injuries were sustained by passengers. According to Embraer, the problem of the Type III exit hatch trim was due to a manufacturing quality issue and the correct hatch trim was not installed on that specific Embraer ERJ 190. The ERJ 190 is provided with approved placards in the passenger cabin, and markings on the wing surface providing passengers with the direction of the evacuation route via the trailing edge of the wing.

The AAIB made Safety Recommendation 2010-007 which stated: *“It is recommended that the European Aviation Safety Agency review the design, contrast and conspicuity of wing surface markings associated with emergency exits on Public Transport aircraft, with the aim of ensuring that*

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the route to be taken from wing to the ground is marked unambiguously". EASA examined the circumstances of this evacuation and also addressed this in their CS 25 Study.

In the 1984 Calgary accident, three passengers that evacuated via an overwing Type III emergency exit failed to identify the best escape route from the wing and sustained injuries when they jumped from the leading edge of the wing.

See Recommendation 6.

8.10 Type III emergency exit design and development

Some Type III emergency exits are based on designs that go back some 50 years. Type III exit hatch weights differ considerably and can weigh 14.7 kilograms (32.4 pounds) on an Airbus A320, 17.5 kilograms (38.6 pounds) on the Embraer 190, and up to approximately 27 kilograms (60 pounds) on a Boeing 767-200. CS 25 813(a) requires the manufacturer to install a placard on or adjacent to Type III exit hatches clearly showing the weight of the hatch.

CS 25.809(c) states that *"The means of opening emergency exits must be simple and obvious and may not require exceptional effort"* It is perhaps difficult to comprehend how lifting a weight of 27 kilograms (60 pounds) does not require exceptional effort. Perhaps the wording of CS 25.809 needs to be changed to *'must not'* rather than *'may not'*, or alternatively a limiting weight should be determined.

For the Airbus A320, which was developed in the mid-1980's, the JAA determined that additional design criteria for the Type III emergency exits was required for initial Type Certification. Airbus submitted the following Type III exit design enhancements, which were accepted by the JAA:

- A lightweight Type III exit hatch – approximate weight 14.7 kilograms (32.4 pounds).
- The Type III exit to be a slightly different colour to the passenger cabin interior panels.
- Instruction placards showing exit operation located adjacent to the exit operating handle.

For the B737 NG aeroplanes, Boeing requested permission to increase the number of passenger seats installed. The JAA determined that improvements to passenger evacuation were required. The Boeing response was to have a fully supported overwing Type III emergency exit hatch that would require no additional action other than operation of the exit handle to fully open the exit and with the exit hatch remaining attached to the fuselage. The JAA accepted this proposal and all Boeing 737 NG aeroplanes have this new overwing Type III exit hatch design. Section 10.2 addresses research work carried out at Cranfield University on the development of Automatically Disposable Hatches.

Several AAs and accident investigation agencies have identified evacuation issues in respect of Type III emergency exits. EASA in NPA Number 2008-04 stressed the importance of Type III exits in an evacuation and stated: *"Studies have determined that in accidents to aircraft configured with Type III exits, 50% of passengers that evacuate through exits use the overwing exits. Whilst this proportion reduces to approximately 30% in high fire intensity accidents, it illustrates the importance of Type III exits to the evacuation system."*

Also in NPA Number 2008-04 EASA defined fully supported emergency exits as either 'Automatically Disposable Hatches' (ADH) or 'Automatically Opening Exits' (AOE). An ADH is an emergency exit hatch which, although requiring action by the operator of the exit, has the advantage that its correct disposal is assured by the design and mechanisms so that after operation the exit hatch moves to a safe stowage location. An AOE emergency exit hatch is an enhancement of this approach in that it incorporates a powered source that requires a minimal amount of effort to operate the exit. According to the EASA NPA, the intent of requiring automatic disposal of a Type III hatch/door is to remove the risk of confusion to passengers once the operating handle movement has been initiated. Also, the exit hatch/door must move from its closed position to a fully open position in one simple and continuous motion.

More importantly EASA NPA 2008-04 introduced a new requirement for Type III exits. As a result CS 25.813(c)(6) now states: *“For aeroplanes with a passengers seating configuration of 41 or more, each Type III exit must be designed such that when operated to the fully open position, the hatch/door is automatically disposed so that it can neither reduce the size of the exit opening, the passageway(s) leading to the exit, nor the unobstructed space specified in sub-paragraph (c)(2)(ii) of this paragraph, to below the required minimum dimensions. In the fully open position it must also not obstruct egress from the exit via the escape route specified in CS 25.810(c).”* For such aeroplanes EASA no longer accepts the provision of a removable hatch to meet the requirements of CS 25.813(c)(6). As a direct result of the changes to CS 25.813(c)(6), Bombardier C aeroplanes and Embraer 190 aeroplanes are equipped with fully supported Type III emergency exits.

ADH and AOE exit hatches are a significant improvement since they can be rapidly operated with minimal effort and the exit hatch once opened is located in a position which should not obstruct evacuation through the exit.

See Recommendation 7.

8.11 Heat release requirements and the effect of toxic fumes in an evacuation

Another factor affecting a successful evacuation is the production of toxic fumes from cabin furnishings, which might incapacitate passengers and crew before they have the time to evacuate. According the FAA Fire Safety Branch at the Technical Centre in Atlantic City, the installation of cabin materials with a low rate of heat release as required by CFR 25 amendments 61 and 66 addresses this issue. For passenger cabins installed with heat release compliant materials, the production of toxic fumes now occurs at a later stage of fire development and might have little or no impact on evacuation.

In the 1985 Manchester accident, 48 of the 55 fatalities were caused by inhalation of dense toxic smoke in the passenger cabin resulting in rapid incapacitation. This was also the cause of many of the 23 fatalities in the 1983 Cincinnati accident (see Section 8.12). According to the NTSB, in the 1991 Los Angeles accident, 20 of the fatalities were caused by asphyxia due to smoke inhalation.

The need for fire retardant cabin furnishings is not new. The FAA first considered the issue in 1947. By 1972, the FAA had introduced flammability test requirements for interior panels, seats and carpets. Full-scale fire tests conducted by the FAA in the 1980's confirmed that the rate of fire development and the level of toxic fumes in passenger cabins were significantly influenced by seat upholstery materials, ceiling and wall panels, and other interior installations. This led to the FAA issuing new regulations in 1985 (amendments 121-189 and 25-61), for “Improved Flammability Standards for Materials Used in the Interiors of Transport Category Airplane Cabins.”

In the mid-1980's the UK CAA published AN 59 (Ref: 20) which adopted the FAA fire test standard for seat upholstery materials and required all new and existing seats to comply with this standard. Additionally, in March 1987, the UK CAA issued AN 61 (Ref: 21) requiring that all newly manufactured aeroplanes comply with enhanced standards of fire resistance for passenger cabin wall and ceiling panels as well as other interior furnishings including seats, carpets, etc. Since the late 1970's Boeing, Airbus and other manufacturers have implemented specific fire, smoke and toxicity standards applicable to all flammable materials installed in the pressurised sections of aeroplanes.

Note: *All of the above requirements and recommendations have been subsequently adopted by EASA in CS 25 (and earlier in JAR 25), and by the FAA in 14 CFR 25 as well as by many other AAs.*

8.12 Floor proximity emergency escape path lighting

In an emergency evacuation the loss of visual reference resulting from smoke or darkness can seriously affect the orientation of passengers and crew. This may result in movement towards a

Reference 20: CAA Airworthiness Notice Number 59: Seats And Berths - Resistance To Fire.
Reference 21: CAA Airworthiness Notice Number 61: Improved Flammability Test Standards For Cabin Interior Materials.

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useable emergency exit being delayed and in some accidents a useable emergency exit being bypassed due to inability to identify or locate the exit.

On 20 December 1972, a McDonnell Douglas DC-9 operated by North Central Airlines, (Flight Number 575), was taking off from O'Hare International Airport, Chicago, USA in foggy conditions. It collided with a Convair CV-880 operated by Delta Airlines, (Flight Number 954), which was taxiing across an active runway. On board the Convair CV-880, were 86 passengers, three flight crew and four flight attendants, all of whom survived the accident with just 2 minor injuries. The Commander of the Convair estimated that evacuation was completed in approximately five minutes. On board the DC-9 there were 41 passengers, two flight crew and two flight attendants. Ten passengers died and 13 passengers and two crew members sustained injuries. The evacuation of the DC-9 was difficult due to the smoke-filled cabin and some passengers had difficulty locating the exits. The bodies of two passengers were found on the flight deck. These two passengers had moved past the open forward left floor level emergency exit (L1). The NTSB Accident Report stated: *"Passengers testified that there were no lights visible in the cabin during the evacuation. They also stated that the smoke was dense, particularly in the upper portion of the cabin."*

On 2 June 1983, a McDonnell Douglas DC-9 operated by Air Canada, (Flight Number 797), experienced an in-flight fire en route from Dallas/Fort Worth to Toronto and Montreal. On board were 41 passengers, two flight crew and three flight attendants. According to the NTSB Accident Report, the flight attendants were unable to identify the exact source of the fire in the aft lavatory compartment and the flight crew diverted to Cincinnati Airport, in Covington, Kentucky. Although not specified in the emergency checklist, during the diversion the first officer shut down the air conditioning and pressurisation packs, intending to starve the fire of oxygen, but this actually accelerated the build-up of heat, smoke and combustible gases in the passenger cabin. The uncontained fire spread into the passenger cabin and by the time that the aeroplane landed, the situation had deteriorated significantly; visibility in the cabin was virtually nil at heights higher than one foot above the cabin floor. As soon as the aeroplane stopped on the runway, the flight attendants opened the forward floor level emergency exits (L1 and R1), the passengers opened three of the overwing Type III exits, and the two flight crew exited via the flight deck windows. Although the useable emergency exits were opened as soon as the aeroplane stopped, due to the dense smoke in the cabin it was difficult for some of the passengers to locate them. Survivors who had moved aft to the overwing Type III exits found them because they counted the seatbacks as they moved aft and because they could see a dim glow of light when they reached the exit area. Approximately 60 to 90 seconds after exits were opened a 'flash fire' enveloped the passenger cabin. Twenty three passengers died in this accident. The 'flash fire' was similar to that which occurred in the 1985 Manchester accident.

Research into cabin fires has shown that buoyant hot smoke initially fills a passenger cabin at higher levels and obscures overhead lighting and emergency exit signs, whilst clear air remains at or near to the passenger cabin floor for much longer. Work conducted by the FAA using lighting systems positioned at a height of 40 inches (101.6 centimetres), resulted in a 20% faster evacuation rate in a smoke-filled passenger cabin, by comparison to that achieved with exit signs in upper areas of the passenger cabin.

As a result of work conducted by the FAA and the recommendations made by the NTSB, in January 1986 the UK CAA issued AN 56 (Ref: 22), requiring that all affected UK registered aeroplanes be fitted with floor proximity path marking/lighting and low level emergency exit identifier lighting. The use of photoluminescent floor lighting has also been approved by AAs.

EASA, in their 2009 CS 25 Study, came to the conclusion that further research was needed to identify technologies that might be used by passengers to locate emergency exits, with or without the assistance of cabin crew, as well as the feasibility of such systems for evacuation in conditions of low visibility.

Reference 22: UK CAA AN Number 56: Emergency Floor Path Lighting System – Issue 4.

8.13 Passenger seat pitch

In an emergency evacuation it is important that passengers can leave their seats and move into the aisle quickly and easily in order to move towards the emergency exits. In 1988 the UK CAA addressed the issue of passenger seat pitch and identified three dimensions that they considered important to enhanced occupant survivability:

- *“The minimum distance between the back support cushion of a seat and the back of the seat or other fixed structure in front, shall be 26 inches.”*
- *“The minimum distance between a seat and the seat or other fixed structure in front shall be seven inches.”*
- *“The minimum vertically projected distance between seat rows or between a seat and any fixed structure forward of the seat shall be three inches.”*

Additionally the UK CAA determined that any new requirements needed to take into account head, torso and leg strike areas of the seat in front of passengers in crash conditions, and the ability for a passenger to stand up and move into the cabin aisle. In March of 1989 the UK CAA issued AN 64, (Ref: 23), which detailed the dimensions that all affected UK registered aeroplanes would have to meet.

Although the above are not included in any CS 25 requirement, EASA did include the issue of seat spacing in their 2009 CS 25 Study and that further research might be required to: *“.....investigate the effects of various seat spacing dimensions on evacuation, not just on the passenger’s ease of egress but also on the overall dynamics of the emergency evacuation. The investigation should take into account the projected increasing proportion of elderly people in the flying population and people from the higher body dimension percentile group.”* The EASA review also considered that there would be a need to investigate the economic aspects of any proposed changes to the CS 25 requirements with respect to passenger seat spacing.

8.14 Aeroplane manufacturers’ evacuation procedures

It is usual for an aeroplane manufacturer to develop the evacuation procedures to be used in the required CS 25.803 demonstration, and the manufacturer will train the ‘test’ crew in these procedures.

When introducing a new aeroplane type, operators will take into account the manufacturer’s recommendations for evacuation, their Standard Operating Procedures (SOPs), as well as the number of passenger seats installed, and the minimum number of required cabin crew. The number of passenger seats installed and the minimum number of required cabin crew will have a significant influence on evacuation procedures. If the number of passenger seats installed is greatly reduced from that in the CS 25.803 demonstration then the evacuation characteristics might be significantly different. For twin-aisle aeroplanes with low density seating in premium class cabins the forward passenger cabins are likely to have a significantly faster evacuation rate.

In October 1995, the UK CAA NOTACH) 7/95 (Ref: 24) which recommended that cabin crew evacuation training include the following:

- Crew co-ordination and communication.
- Passenger management areas.
- Re-direction of passengers from unusable exits.
- The problems of exit overload.
- Crew evacuation commands.
- The physical contact that may be required to assist passengers out of an exit.

See Recommendation 8.

Reference 23: UK CAA AN Number 64: Minimum Space For Seated Passengers.
Reference 24: UK CAA NOTACH Number 7/95: Flight Operations Bulletin – Cabin Safety.

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8.15 CS 25.803 - Evacuation requirements for certification of large aeroplanes

The CS 25.803 demonstration is conducted under the observation of AAs using but not limited to the following criteria:

- Only 50 percent of emergency exits are available during the demonstration.
- None of the test participants including the aeroplane crew are aware of which exits are available prior to commencement of the demonstration.
- The demonstration is conducted in reduced lighting conditions.
- Cabin baggage and blankets are positioned in aisles and cross-aisles.
- All test participants and crew must evacuate the aeroplane and be on the ground within 90 seconds under simulated emergency conditions without assistance from any 'ground safety personnel'.

A manufacturer must meet the evacuation requirements of CS 25.803 and Appendix J, (otherwise referred to as the '90 second demonstration' or the 'full-scale demonstration'). The requirements of the four principle AAs are aligned in respect of the CS 25.803 criteria and in this respect are almost identical. The manufacturer's emergency evacuation criteria will be analysed by the primary AA responsible for the certification of the aeroplane, i.e. the FAA for Boeing, EASA for Airbus, TCCA for Bombardier and ANAC for Embraer.

In satisfying the requirements of CS 25.803, a manufacturer will usually use a passenger cabin configuration that represents the highest permitted number of passenger seats based on the number and types of emergency exits, as well as the most restrictive passenger cabin configuration in accordance with certification minima. This will allow a single demonstration test that will meet all future passenger cabin configurations without the need for further testing. FAA Advisory Circular 25.803-1A provides additional conditions to extend the passenger seating configuration by means of an engineering analysis without the need for further practical testing.

Additionally, if required to do so, a manufacturer must comply with the ditching criteria of CS 25.801(d) which states: *"It must be shown that, under reasonably probable water conditions, the flotation time and trim of the aeroplane will allow the occupants to leave the aeroplane and enter the life rafts required by CS.25.1415."* Therefore, to comply with this requirement, the manufacturer must demonstrate that the flotation time for the specific aeroplane type in a ditching scenario is sufficient to allow the cabin crew to perform their ditching evacuation procedures.

8.16 EASA/FAA certification of aeroplanes with 44 or fewer passenger seats installed

For aeroplanes with 44 or fewer passenger seats installed, the requirements of CS 25.803 are not applicable even though one cabin crew member is required when more than 19 passenger seats are installed. The requirements of CS 25.803(a) remain applicable and it must be demonstrated that crew and passenger compartments have emergency means to allow rapid evacuation taking into account the possibility of the aeroplane being on fire on the ground. The difference with CS 25.803(c) is that no time limit is required for the test. For aeroplanes with 44 or fewer passenger seats installed, the manufacturer may be required to conduct an analysis to show that an emergency evacuation can be achieved by using the passenger cabin aisles and emergency exits, even though an actual evacuation test may not be required.

As a consequence of the non-applicability of CS 25.803(c) for smaller aeroplanes, the manufacturer is not specifically required to produce recommended emergency evacuation procedures for use by the crew or training personnel, although many manufacturers do provide such information to their customers. It is sometimes left to individual operators to develop their own evacuation procedures perhaps with little or no expert assistance from the manufacturer. However, some manufacturers do recommend emergency evacuation procedures to their customers and these are often specified in manufacturer manuals. The lack of data from an evacuation demonstration does not necessarily restrict the manufacturer developing emergency evacuation procedures based on best practice. Thus, there is potential for passengers carried on commercial passenger aeroplanes with 44 or fewer passenger seats installed, to be afforded a lesser level of safety in an accident requiring an

emergency evacuation, compared to an aeroplane with more than 44 passenger seats installed. However, for smaller aeroplanes an acceptable level of safety can be achieved through compliance with all other CS 25 cabin safety requirements and is necessary for aeroplane initial type certification. Such requirements include criteria for emergency exits, passenger cabin aisles, lighting systems and other related emergency evacuation provisions. EASA rationale is that smaller aeroplanes are unlikely to present problems and that in-service experience has not revealed any reason to question this approach.

8.17 The certification of the Boeing 777-200 in respect of evacuation

The Boeing 777-200 is used in this paper simply as an example of several safety considerations. Such issues could equally be applied to other manufacturers including Airbus. It is not the intent of this paper to identify Boeing as having any particular issues with emergency evacuation of commercial passenger aeroplanes that are not relevant to other manufacturers

The first CS 25.803 demonstration of the Boeing 777-200 conducted in February 1995, did not fully meet the pass criteria because not all of the participants (passengers) evacuated in the required 90 seconds. The active emergency exits in the first Boeing 777-200 CS 25.803 demonstration were R1, R2, R3 and L4. The demonstration was conducted with 420 participants (passengers), as well as the two flight crew and nine cabin crew.

The FAA allowed the issue of a Boeing 777-200 initial Type Certificate limiting the total number of passenger seats installed to 419, taking into account the number of occupants evacuated in 90 seconds. Boeing had estimated that the CS 25.803 demonstration would be successfully completed in 85 seconds or less, and in fact 419 of the 420 'passengers' did reach the ground in 85.7 seconds. The last person on the ground was a cabin crew member at 94.3 seconds.

In a paper presented in 1996, (Ref: 25) Boeing identified what they considered to be two significant differences between earlier CS 25.803 demonstrations with other aeroplane types and the first Boeing 777-200 CS 25.803 demonstration:

- *"The Flight Deck crew were required to evacuate the airplane without assisting flight attendants in passenger management during the evacuation."*
- *"Flight attendant training prior to the evacuation test was reduced in both content and duration. Some of the passenger management procedures we've always considered essential to safe and rapid evacuation were curtailed or eliminated."*

These differences resulted from FAA/JAA policy changes in which the flight deck crew being able to assist in an emergency evacuation should be considered a 'bonus'. In some emergency evacuations flight crew might decide to use the flight deck evacuation facilities such as windows or hatches. This was the case in the 1985 Manchester accident. In other accidents it might be the case that the flight crew are incapacitated to such an extent that they are not able to assist in an evacuation. Additionally, the reduced amount of cabin crew training was considered by the FAA and JAA to be consistent with the amount of training that would be received in normal operator training for cabin crew. At that time the FAA determined that the operational evacuation procedures used by the 'test' crew should be reflected in subsequent procedures and training for all Boeing 777-200 operations.

Although Boeing identified two differences in the way that previous CS 25.803 demonstrations had been conducted, they were not necessarily the reason that the first Boeing 777-200 CS 25.803 demonstration did not meet the 90 second criteria. The FAA and JAA determined that in the first Boeing 777-200 CS 25.803 demonstration, the small number of persons that evacuated via the forward floor level Type A emergency exit (R1) was an important factor. The flow of persons at this exit ceased at 53.7 seconds and for a period of 28 seconds there was no flow of persons out of this exit. Without doubt this caused an overload at the next nearest available floor level Type A exit (R2).

Reference 25: Paper entitled; 777-200 Full Scale Evacuation Demonstration, Presented at the Southern California Safety Institute Cabin Safety Symposium in January 1996, by Robert. S. Satterfield, Boeing Commercial Airplane Group.

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Had passengers arriving at the unusable L2 exit, been re-directed to the R1 exit rather than the overloaded R2 exit, it is more than likely that overall evacuation time would have been 90 seconds or less.

As a result of this CS 25.803 demonstration, Boeing determined that cabin crew passenger management in an emergency evacuation should stress the following important issues:

- The need for assertive action by cabin crew;
- Cabin crew to be familiar with the location and use of assist spaces at emergency exits;
- Cabin crew to be familiar with emergency exit operation;
- Cabin crew to understand the importance of primary and secondary evacuation duties; and
- Secondary duties to include: establishing a flow of passengers from unusable emergency exits to usable emergency exits, monitoring the progress of evacuation at active exits and adjacent zones, and direction or re-direction of passengers to all active exits.

Using the one-per-50 rule and these new evacuation procedures, Boeing conducted two subsequent B777-200 CS 25.803 demonstrations in 1996, with 400 passengers and eight cabin crew, and 440 passengers and nine cabin crew. Both were successful.

8.18 Airworthiness requirements that have the potential to impact operational issues

There are several airworthiness requirements with respect to aeroplane certification that impact operational issues. However, operational personnel from some AAs are not always involved during the certification process. This might lead to some operational factors being overlooked and the need to develop mitigating measures to overcome such issues after certification. It is recommended that in all areas that have the potential to impact on operational considerations, airworthiness and operational personnel have effective liaison on such matters.

For smaller aeroplanes the type and location of emergency equipment can be an issue when trying to ensure that aeroplanes of the same type are delivered to a consistent standard to the operator. This may result in aeroplane crew having to operate on the same type of aeroplane but with differences in the type and location of emergency equipment. This can also be complicated by individual owners of aeroplanes, who may have specific requirements that might influence passenger cabin configurations and affect the location of emergency equipment. A mitigating factor might be that some aeroplane crews are often scheduled to operate on a specific aeroplane and are therefore familiar with the passenger cabin configuration, including the provision of emergency equipment.

See Recommendation 9.

9 FLIGHT OPERATIONS

A. Cabin Crew

9.1 Cabin crew primary and secondary duties in an emergency evacuation

Cabin crew procedures in an emergency evacuation specify that their primary duty is to operate emergency exit(s) immediately adjacent to their crew seats and to manage the evacuation of passengers as quickly and as safely as possible. According to the FAA, some operators specify a second-choice emergency exit assignment for cabin crew, such as overwing Type III emergency exits. A major consideration for cabin crew in an emergency evacuation is the potential problem of moving to a second-choice exit, probably against a flow of evacuating passengers, as well as the need to evaluate their own personal risk.

CS 25.807(e) states: *“Uniformity. Exits must be distributed as uniformly as practicable, taking into account passenger seat distribution.”* In the USA 14 CFR 121.391(2)(d) states: *“....during takeoff and landing, flight attendants required by this section shall be located as near as practicable to required floor level exits and shall be uniformly distributed throughout the airplane in order to provide the most effective egress of passengers in the event of an emergency evacuation.”*

14 CFR 121 are operating rules and, as such might be published to address occupant safety enhancements that have been made to airworthiness standards. As any new airworthiness standards cannot change the basis of certification for a particular product and cannot be applied retrospectively, an operating rule might sometimes be used to address in-service aeroplanes and require compliance with an enhancement where the continued carriage of passengers is required by an operator.

The movement of cabin crew from their seats to other emergency exits in the passenger cabin was an issue in the 1985 Manchester and the 1991 Los Angeles accidents. One cabin crew member in each of these accidents attempted to reach the overwing Type III exits from their seats at floor level exits and died in the attempt.

According to the NTSB Accident Report into the 1991 Los Angeles accident, the USAir procedures, assigned flight attendants with second choice exits at overwing Type III emergency exits which are some distance from their seats. The NTSB stated that *"...air carriers that have a second choice exit assignment should emphasize in flight attendant training the need to evaluate personal risk in a decision to go to a second choice exit as opposed to choosing a closer escape path."*

FAA research conducted at CAMI (Ref: 26) showed significant differences in evacuation times based on the location of cabin crew seats relevant to the primary cabin crew evacuation duties.

CAMI stated: *"Evacuations with flight attendants 24 feet aft of their primary emergency exits proceeded significantly slower than evacuations with a flight attendant next to the exit. Delays resulting from passenger inability to open the exit or indecisiveness can be reduced if flight attendants are available to assist."*

In passenger cabin configurations such as the Fokker 100 some of the cabin crew seats are located away from any emergency exit. The Fokker 100 has one or two cabin crew seats installed at the rear of the passenger cabin where the nearest exits are the overwing Type III exits located in the middle of the passenger cabin, some nine seat rows away. It is understood that the Fokker 100 recommended cabin crew evacuation procedure is for one of the cabin crew at the rear of the passenger cabin to move to the overwing Type III exits and manage the evacuation from that location. However, with a full aeroplane once an emergency evacuation has been initiated and passengers have started to leave their seats, it is questionable whether a cabin crew member could move to that exit in a fully occupied passenger cabin without considerable difficulty. Some Bombardier aeroplanes also have such an exit configuration, although in this case it is understood that the evacuation procedure is for the aft cabin crew member to direct and command passengers at the overwing Type III exits to open them, rather than for the cabin crew member to attempt to reach the overwing area through a crowd of evacuating passengers. This may also be the case for other aeroplanes such as the Embraer 135/145.

When application was made to add the Fokker 100 onto a UK Air Operator's Certificate (AOC), the UK CAA Flight Operations Department reviewed the conduct and outcome of the CS 25.803 demonstrations for the Fokker 100 and concluded that the evacuation procedures and the locations of the cabin crew seats gave cause for concern. For the addition of the Fokker 100 onto the UK register, the UK CAA Flight Operations Department determined that there should be a cabin crew seat installed adjacent to the overwing Type III emergency exits.

The NTSB considered this in their Emergency Evacuation of Commercial Airplanes Safety Study of June 2000, and concluded that the FAA should address this issue with US operators of the Fokker 100. The NTSB was of the opinion that: *"On some Fokker airplanes, the aft flight attendant is seated too far from the overwing exits, the assigned primary exits, to provide immediate assistance to passengers who attempt to evacuate through the exits."* The NTSB made the following safety recommendation to the FAA: *"Require the aft flight attendants on Fokker 28 and Fokker 100 airplanes*

Reference 26: CAMI – Mark George and Cynthia Corbett - Effects of Cabin Crew Location and Passenger Motivation on Aircraft Evacuations . Proceedings of the November 1998 International Aircraft Fire and Cabin Safety Research Conference. Atlantic City, New Jersey, USA.

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to be seated adjacent to the overwing exits, their assigned primary exits. (A-00-78)." However this recommendation has been "Closed – No Longer Applicable", possibly due to the absence of Fokker 28 and Fokker 100 on the US register, although both aeroplanes are still operating in many countries.

The NTSB Accident Report into the 1991 Los Angeles accident recommended that the Emergency Evacuation Subcommittee of the FAA Aviation Rulemaking Advisory Committee (ARAC): *".....to examine flight attendant emergency procedures regarding the second choice exit assignments to ensure that such assignments provide for use of the nearest appropriate exit point"*.

The FAA issued Air Carrier Operations Bulletin (ACOB) Number 1-94-26. (Ref: 27) The ACOB addressed the need for operators to review their approved training programmes taking into consideration the following:

- *"For air carriers that have second choice exit assignment for flight attendants (e.g., overwing Type III exits), the need, during training, to evaluate personal risk in a decision to use a closer escape path rather than using the assigned second choice exit. For example, another door or any opening in the fuselage may be more acceptable and more appropriate."*
- *"That during a crash sequence, flight attendants must remain properly restrained and seated in their crew seats until the airplane has come to a complete stop."*

EASA in their 2009 CS 25 Study also addressed this issue. EASA concluded that accident experience had shown that cabin crew located remotely from their assigned emergency exits could have an adverse affect on emergency evacuation time and stated: *"This threat is particularly relevant to some aircraft designs, for example the Fokker 28 and Fokker 100."* EASA considered that this situation was not addressed in CS 25.785(h) (1) and concluded that amendment to CS 25 might be required and stated that further research *"....may be required to confirm the magnitude of the threat and ascertain how the threat is best mitigated."*

9.2 Cabin crew duties during the taxi phase of flight

On departure, once the aeroplane has commenced the taxi phase of flight, cabin crew procedures should be limited to safety duties, such as the briefing of passengers and the securing of the passenger cabin and galley areas. Service duties such as the handing out of newspapers, drinks and other items should not take place during the taxi phase of flight. This should also apply to after landing when cabin crew should remain secured in their cabin crew seats until the aeroplane has come to a final stop for passenger disembarkation.

9.3 Reporting of the 'cabin secure check' to the flight crew

Once the cabin crew have completed the pre-flight briefing of passengers and a 'cabin secure check', they should return to their cabin crew seats, report their check(s) to the SCCM or the commander, and secure themselves with their full harnesses for the remainder of the taxi phase of flight. The same is the case for a 'cabin secure check' prior to landing. If an incident or accident occurs when a cabin crew member is not properly restrained in their seat, it is more likely that they will receive injuries that might incapacitate them to such an extent that they will not be able to perform their emergency duties.

A cabin secure check passed to the flight crew by the cabin crew or by the SCCM prior to take-off and prior to landing confirms that the cabin and the cabin crew are properly secured as follows:

- All passenger items are safely stowed and that passenger seats are in the up-right position, tray tables and that other equipment such as video screens are safely stowed.
- All galley equipment is correctly stowed and secured.
- All overhead bins have been properly closed.
- All emergency exits and evacuation slides are in the automatic mode.
- All cabin crew are seated in their crew seats and secured with their full harnesses.

Reference 27: FAA Air Carrier Operations Bulletin No. 1-94-26: Flight Attendant Restraint During a Crash and Emergency Evacuation Second Choice Exit Determination.

9.4 Use of cabin crew assist spaces

As discussed in Section 8.5, cabin crew should make effective use of assist spaces during an evacuation in order to maintain a rapid flow of passengers. However, Cabin Crew Operating Manuals (CCOM) and associated training might not actually identify the exact location of cabin crew assist spaces for each aeroplane type to be operated.

The size of a cabin crew member may affect his or her ability to stand in an assist space without obstructing the width of the passageway below that required by the exit type. It might be the case that some cabin crew either by height or by girth might have issues with effectively fitting into assist spaces on some aeroplanes.

9.5 Suitability of cabin crew uniforms for conducting an evacuation

The requirements for cabin crew uniforms are addressed in EASA Air OPS Regulation GM1 ORO.CC.210(d) Additional conditions for assignments to duties, which states: *“The uniform to be worn by operating cabin crew should be such as not to impede the performance of their duties, as required for the safety of passengers and flight during operations, and should allow passengers to identify the operating cabin crew including in an emergency situation.”*

In 1997 TCCA issued Advisory Carrier Circular 0136. (Ref: 28) In this document two accidents were identified where crew uniforms were a safety factor. On 10 March 1989 a Fokker F28-1000 operated by Air Ontario (flight Number 1363), crashed shortly after take-off from Dryden, Canada. According to the Canadian Commission of Inquiry, one of the flight attendants clothing comprised of slip-on shoes, a light dress and a sleeveless vest. She lost one shoe in the passenger cabin and another outside in the snow. In order to better help the survivors she had to borrow a pair of shoes from one of the passengers. On 8 June 1995, a McDonnell Douglas DC-9 operated by ValueJet Airlines (Flight Number 597), suffered an uncontained engine failure on take-off from Atlanta, USA. A fire in the passenger cabin erupted. The NTSB investigation determined that the most serious injury were burns sustained by the aft flight attendant who was wearing shorts and a short-sleeved shirt. FAA advisory material for passenger attire is to wear: *“.....sensible clothing, such as clothes made of natural fabrics, and recommends long sleeves and trousers that fully cover arms and legs.”* It would seem a logical conclusion that crew uniforms should comply with this criteria and should be fire retardant and not be manufactured from thermo-plastic materials.

The female cabin crew uniforms of some operators, including those in some Asian countries, might not be compatible with emergency scenarios including an emergency evacuation, where mobility and ease of movement is needed to successfully manage an evacuation. Female cabin crew uniforms that include a ‘sarong kebaya’ might be an issue in the conduct of emergency duties. Female footwear such as high-heeled shoes, if worn by cabin crew during taxi, take-off and landing phases of flight, might be an issue if an emergency evacuation is required. A firm footing is required for the operation of emergency exits and the deployment of evacuation slides, as well as for commanding and assisting with passenger evacuation in both land and ditching scenarios. Furthermore, high-heeled shoes could puncture an evacuation slide or ditching flotation equipment and are thus, inappropriate.

B. Flight Crew

9.6 Flight crew procedures and checklists

In the aftermath of the 1985 Manchester accident, a review of flight crew procedures conducted by the UK CAA showed that some flight deck emergency evacuation checklists were longer than necessary and included some items that were superfluous under the circumstances. In particular, the order from the flight crew to initiate an emergency evacuation was sometimes placed later in the

Reference 28: TCCA Advisory Carrier Circular 0136 – Flight Attendant Attire.

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checklist than it needed to be. In 1986 the UK CAA in Notice to AOC Holders Number 4/86 (Ref: 29) drew the attention of operators to this issue, advising them to review their checklists in this respect and to amend them if necessary.

Evacuation related flight crew checklist items include the following important issues:

Engine fuel cut-off levers to cut-off: This is so that evacuation slides can deploy without being torn or collapsed by engine exhaust gases, and so that passengers can evacuate without risk of encountering propellers, ingested by operating engines or injured by any thrust still being produced. The flight crew will need to assure themselves that the engines have responded to having their fuel cut-off and have ceased operating or have almost done so before commanding an evacuation. (Also see Section 9.8 in respect of the Qantas A380 accident.)

Aeroplane depressurisation: If the interior of the aeroplane contains a higher pressure than exists outside, it may be difficult, impossible or even dangerous to attempt to open emergency exits. The flight crew will need to assure themselves that the pressure differential has reduced to a safe level before commanding an evacuation. Some aeroplanes automatically depressurise whilst others have to be manually depressurised; in such cases this should be reflected in flight crew evacuation checklists.

Position of speed brakes, slats and flaps: In most aeroplanes, extended speed brakes may comprise a hazard to anyone standing on the wings, and in some aeroplanes the (leading edge) slats and (trailing edge) flaps may need to be extended so as to assist a smooth descent from the wings. It is essential that all of these devices be in the correct position before commanding an evacuation.

Parking brake: If the parking brake is not applied after the aeroplane has come to a complete stop and it remains on a smooth surface, there is the possibility that it will move if it is on a slope or affected by a strong wind. This presents a hazard to passengers and crew evacuating down slides or moving around outside the aeroplane. The flight crew should ensure that the parking brake is applied before commanding an evacuation.

As a result of discussions between the UK CAA and aeroplane manufacturers, including Boeing, some manufacturers revised their flight crew checklists in respect of emergency evacuation and the timing of the command to evacuate.

Cabin crew do not have checklists in the same way as flight crew. Cabin crew checklists are usually specified in the CCOM and in the case of emergencies are usually 'memory items' only. However, some operators do have a 'Quick Reference Handbook' (QRH), in the form of a card located at cabin crew seats for emergency scenarios, but these are not used in the same way as flight crew checklists and there is no 'double checking' of crew member actions. Whichever system an operator has for cabin crew checklists and procedures, they should be consistent with flight crew checklists and procedures.

On 28 February 1987 a British Airways Boeing 747-200, (Flight Number 282), en-route to London Heathrow, returned to Los Angeles following a bomb scare. The 387 passengers and 17 crew evacuated the aeroplane using eight main deck emergency exits in a time of 52 seconds. Using the new order of the flight deck evacuation checklist, it is estimated that the evacuation command from the flight deck was given significantly earlier than previously.

9.7 Minimum Equipment List items relevant to evacuation

MELs in respect of any inoperative emergency exits will need to address the following scenarios:

- The interphone system between the flight deck and cabin is inoperative.
- The emergency exit is not operative.
- The evacuation slide is not operative.
- The floor proximity escape path lighting system has exit identifier(s) that are not operative.
- The illuminated emergency exit sign is not operative.
- The emergency exit interior lighting is not operative.
- The emergency exit exterior lighting is not operative (i.e. during night-time sectors).

It is essential that operators evaluate the impact of the above defects and their potential effect on a possible emergency evacuation. Such an evaluation will normally be by means of an appropriate risk assessment. If any of the above factors apply, then passenger numbers may need to be reduced in the affected cabin zone, and this should be specified in the operator's MEL.

Crew procedures will need to be reflected and amended as follows:

- All crew must be briefed as to the location of the inoperative exit and/or equipment.
- The safety briefing(s) for passengers will need to be amended.
- Crew evacuation procedures will need to be revised and passengers will need to be re-directed away from an inoperative exit.
- An inoperative exit should have any associated exit signs de-identified prior to passenger boarding.
- When passenger numbers are reduced to meet the MEL requirements, passengers should if practicable be seated in cabin areas away from the inoperative exit.

Even though an emergency exit is deemed to be inoperative, it may be the case that in some extreme circumstances it might have to be used if other emergency exits are not useable. For example if the exit is operative but the associated evacuation slide is not operative then the exit might be useable with caution, depending on the attitude of the aeroplane which might be affected by undercarriage or nose gear collapse. The crew will need to assess the situation as it develops.

9.8 The aeroplane commander's decision to initiate an evacuation

The decision by the aeroplane crew to conduct an emergency evacuation and the timing of an evacuation command is of critical importance.

The commander will usually make the decision to evacuate taking into consideration all factors that will enable passengers and crew to leave the aeroplane in a rapid and safe manner. A planned evacuation of passengers and cabin crew allows the commander to fully consider all relevant factors and to brief the cabin crew and passengers on the actions required of them once the command to evacuate has been given. In clearly catastrophic accidents and incidents such as a fire on the ground or fuselage break-up, the need to evacuate is obvious and that action is required to be taken immediately.

There will be scenarios when an immediate emergency evacuation might not be the best option. For example, on 4 November 2010, a Qantas Airbus A380, (Flight Number 32), en route to Sydney, Australia, suffered an uncontained failure of the Number 2 engine, and a return to Singapore was made. Numerous holes were made in the left wing by debris from the Number 2 engine which caused multiple system failures. On arrival at Singapore the commander faced several significant issues:

- Although the damaged Number 2 engine and other engines were shut down after landing, the Number 1 engine continued to run after normal shut-down procedures. It was finally shut-down some three hours after the landing by RFFS pumping fire fighting foam directly into the engine inlet.

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- The left main landing gear brakes had reached a temperature of 900 degrees Celsius.
- Aviation fuel was leaking from the left wing.

These factors would have made an emergency evacuation potentially hazardous and the commander determined that passengers and crew were safer inside the aeroplane rather than ordering an evacuation using the evacuation slides. The commander decided that a disembarkation of passengers and crew could be better achieved by the use of airport steps on the right side of the aeroplane and this was completed some two hours after landing. The Australian Transport Safety Bureau Accident Report stated: *“The crew’s decision to perform a precautionary disembarkation via the stairs likely provided the safest option, particularly given the low immediate safety threat and the elevated risks associated with an emergency evacuation into a potentially hazardous external environment.”*

On 27 June 2016 a Boeing 777-300 operated by Singapore Airlines, (Flight Number 368), returned to Singapore after an engine oil light warning. On landing at Singapore the number 2 engine caught fire and the right wing became engulfed in flames. On board were 222 passengers and four flight crew and 15 cabin crew. The commander decided to evacuate the passengers via airport steps at L1 rather than use the evacuation slides even though the No 2 engine and the right wing were on fire. There were no fatalities or injuries during this accident, but circumstances might have been different if the external fire had spread or the right wing tank had exploded. (See Case Study at 11.13.)

An emergency may require the commander to make an urgent decision whether to evacuate or not, possibly based on limited available information. In the 1984 Calgary accident and the 1985 Manchester accident, information from the control tower to the flight crew assisted the commander to initiate an emergency evacuation as soon as practicable. RFFS might be a good source of advice, if they arrive early at the scene of the accident. However, external assistance might not always be readily available, for example in the case of an emergency during low visibility operations, ATC might not have visual contact with the aeroplane and confirmation of the problem might not be possible. Additionally, RFFS might be slow to arrive at the accident due to limited visibility. ATC might not actually be aware that an aeroplane has had a problem on take-off, or on landing. This was the case with the accident on 14 September 1999, to a Boeing 757-200, operated by Britannia Airways, (Flight Number 226A), at Girona, Spain. In this accident the Boeing 757-200 on its second attempt to land in adverse weather conditions inadvertently departed the runway after touch-down. It was some time before the RFFS were able to locate the aeroplane and by the time they arrived at the scene most of the passengers and crew had evacuated. (See Case Study at 11.4.)

On 19 August 1980 a Lockheed L-1011-200 Tristar operated by Saudi Arabia Airlines, (Flight Number 163), was en route from Karachi, Pakistan to Jeddah, Saudi Arabia. On board were 287 passengers and 14 crew. An en-route stop was made at Riyadh, Saudi Arabia. Some seven minutes after take-off from Riyadh, the flight crew were alerted by visual and aural warnings to smoke in the aft C-3 cargo compartment, and the commander decided on an immediate return to Riyadh. After landing at Riyadh the commander taxied to the end of the runway rather than make an emergency stop and an initiate an evacuation. The flight crew were not able to find the correct evacuation checklist procedure, since there were looking in the wrong section of the QRH. The aeroplane only came to a complete stop on an adjacent taxiway some two minutes and 40 seconds after touch-down. All 301 occupants died in the internal fire which destroyed the aeroplane. The accident report found that contributing factors included:

- Failure of the commander to prepare the cabin crew for an immediate evacuation on landing.
- Failure of the commander to make an immediate stop on the runway.
- Failure of the commander to order an immediate evacuation.

In any evacuation there is always potential for injury to passengers and crew, but the risk is increased with larger aeroplane types. This is especially the case for multi-deck aeroplanes such as the B747 and Airbus A380 with evacuation slides deployed from a significant height. Greater slide height increases the arrival speed of occupants at the bottom end of the slide which exacerbates the effects of falls or impacts with other evacuees or debris. Slides speeds will also increase significantly if they become contaminated with fire-fighting agents or are subject to wet weather. Logistically there is a big difference between the emergency evacuation of a regional jet with perhaps four or less evacuation

slides and 100 passengers, and a large aeroplane such as the Airbus A380 with 16 evacuation slides and perhaps 500 or more passengers.

In a planned emergency evacuation, a commander will also need to take into account weather at the destination or diversion aerodrome. Heavy rain might result in the emergency evacuation slide deceleration pads being less effective than in dry conditions, and high cross-winds might be an issue in that the toe-end of the evacuation slides may not deploy onto the ground until the first passengers have evacuated. Cabin crew will need to be aware of external conditions after evacuations slides have inflated. In such circumstances and depending on the nature of the emergency, the commander might need to consider the use of airport steps or other means of evacuation depending on the availability of equipment and the nature of the emergency.

See Recommendation 10.

9.9 The command to 'evacuate' and the chain of command

The command to 'evacuate' to the cabin crew and to the passengers will usually be by the commander via the PA system. If time permits the commander or the SCCM will brief the passengers, and the cabin crew will prepare the passengers and the cabin for an emergency landing or ditching. Once the commander has given the command to 'evacuate' the cabin crew will initiate the evacuation taking into account any external hazards. However, in many accidents the PA system has failed to function and therefore the means of alternative communication between flight crew, cabin crew and passengers will need to be addressed in operator procedures and training.

If for any reason the commander is unable to give the command to evacuate, then this will be given by the first officer. If no evacuation command is given by the flight crew then the SCCM will attempt to make contact. If no contact can be established and the SCCM believes there to be a clearly catastrophic situation such as fuselage disruption or fire, then the SCCM should order the evacuation.

In the Spanish Technical Report into the 1999 Girona accident the following statements were made:

- *"The commander was unconscious when the aircraft first came to a halt; he recovered consciousness shortly thereafter. The FO carried out the recall actions for a passenger evacuation. His seat had been displaced as a result of cockpit floor deformation and he had some difficulty in locating the required switches in the darkness."*
- *"Apart from the direct effects of the injury, the captain's resulting temporary disablement at a potentially critical point could have adversely affected aircraft shutdown and evacuation operations."*
- *"The passenger evacuation was initiated separately in each of the three cabin sections by the cabin crew members."*

In extremely serious situations that are clearly catastrophic, any cabin crew member, irrespective of seniority or experience, should initiate an emergency evacuation. This is especially the case for very large aeroplanes where the situation in one part of the passenger cabin, or on another deck, might be very different and potentially more dangerous than the situation elsewhere in the aeroplane including the flight deck.

At a Public Hearing held on 24 June 2014, in respect of the Asiana Boeing 777-200 accident at San Francisco, the NTSB stated: *"The flight attendants acted appropriately when they initiated an emergency evacuation upon determining that there was a fire outside door 2R [R2]. Further, the delay of about 90 seconds in initiating an evacuation was likely due partly to pilot monitoring's command not to begin an immediate evacuation, as well as disorientation and confusion."* (See Case Study at 11.9.)

On 31 October 2000 a Boeing 747-400 operated by Singapore Airlines, (Flight Number 006), crashed on take-off at CKS Airport Taoyuan, Taiwan, Republic of China, when using a closed runway. The impact with heavy equipment on the closed runway destroyed much of the aeroplane fuselage and was sufficient to break the fuselage into two. The Accident Report issued by the Aviation Safety Council of Taiwan, stated that many of the cabin crew did not hear any command to evacuate and

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had to make their own decisions as to the need to initiate an evacuation. A significant fire destroyed the forward part of the fuselage. Of the 159 passengers and 20 aeroplane crew, there were 83 fatalities including four crew members.

In the Boeing 777-200 and Boeing 747-400 accidents mentioned above, the scenarios were obviously catastrophic with both external fire and significant break-up of the aeroplane fuselage. So clearly, the cabin crew had little option other than to initiate and manage the evacuation to the best of their abilities. In the Boeing 777-200 San Francisco accident the flight attendants initially deferred to the flight crew who advised not to evacuate, but when smoke was observed at about 90 seconds the flight attendants initiated the evacuation.

Cabin crew and especially SCCMs should be trained that the flight crew will not usually order an evacuation until they confirm that the engines have stopped running or are just about to do so. This is so that passengers and crew are not ingested into engine intakes and are not injured by hot gases issuing from engine tail pipes. Large engine fans have considerable inertia and can take ten seconds or more to run down to safe speeds after the fuel supply has been turned off. Cabin crew should be made aware of these potential hazards during their training, and also the need to assess the status of exits and evacuation slides after operating emergency exits.

See Recommendation 10.

9.10 Briefing of cabin crew by the aeroplane commander in the event of a planned evacuation

In a planned evacuation, with sufficient time available, the commander will brief the cabin crew whilst still in flight as to the nature of the emergency and the actions that the crew will need to take before, during and after landing or ditching. The commander will usually brief the SCCM beforehand and, if time permits this might be a face-to-face briefing on the flight deck.

Essential information to be provided by the commander to the SCCM and the cabin crew will include at least the following:

- The nature of the emergency.
- The intent to land or ditch the aeroplane.
- The amount of time available for the cabin crew to prepare the cabin and the passengers.
- Whether an evacuation is planned or is just a possibility.
- The possibility that some emergency exits might not be available for evacuation, e.g. ditching.

The SCCM and the cabin crew will take the necessary actions prior to landing or ditching and will pass the cabin secure checks to the SCCM, who will in turn report the 'cabin secure' check to the flight crew.

Note: Many operators refer to the briefing of the SCCM by the commander as the 'NITS' briefing – *Nature of the problem – Intentions – Time available – Special instructions.*

9.11 Flight crew evacuation

The commander will determine how the flight crew might best evacuate. In most evacuations the flight crew will evacuate via the forward emergency exits in the passenger cabin. However, in some accidents the flight crew might decide to evacuate using an escape rope deployed through a flight deck window. In the 1985 Manchester accident, both the flight crew evacuated using this means. The Boeing 747 and Boeing 787 are equipped with escape hatches and inertia reels, whilst many aeroplane flight decks are equipped with ropes. Whichever flight deck evacuation system is installed the flight crew will probably have had no practical experience in using such equipment in safety training, which is most likely to be addressed by touch drills and possibly a video/DVD presentation.

In the case of the flight crew electing to use the passenger cabin emergency exits it is possible that the opening of the flight deck door may affect an established flow of passengers evacuating via the

forward exits. In many scenarios, when practical, the commander may decide to check the entire passenger cabin before leaving the aeroplane.

The involvement of the flight crew in the conduct of the evacuation might be of assistance to the cabin crew either inside or outside the aeroplane, but it is possible that their presence inside the passenger cabin could have a negative effect because on many aeroplanes there is limited space available at emergency exits for additional crew to assist in passenger evacuation.

9.12 Flight crew incapacitation

In some accidents, one or more of the flight crew might be incapacitated to such an extent that they are unable to contact the cabin crew, or to evacuate. An indication of such a problem with the flight crew might be the lack of their issuing an evacuation command.

One of the cabin crew whose seat is located nearest to the flight deck should be responsible for contacting the flight crew in order to determine the situation on the flight deck. Usually this will be the responsibility of the SCCM. When no communication with the flight crew can be established it will be the decision of the SCCM regarding the initiation of an emergency evacuation. One of the cabin crew should be designated as being responsible for determining if the flight crew need assistance and there should also be a procedure for cabin crew to communicate the status of the flight crew to RFFS personnel.

On 25 February 2009, a Boeing 737-800 operated by Turkish Airlines, (Flight Number 1951), crashed on landing at Amsterdam Schiphol Airport, Netherlands. On board were 128 passengers, three flight crew and four cabin crew. Five passengers, three flight crew and one cabin crew died in this accident. Some media reports stated that it took some considerable time for the RFFS personnel to access the flight deck due to the secured/locked flight deck door. However, this was not reflected in the Dutch Safety Board Accident Report which only stated: *"The cockpit door was found partially open by investigators. The interior of the cockpit was severely damaged."* Possibly the severe damage to the flight deck delayed RFFS access to the flight crew. EASA has advised that all 'reinforced' flight deck doors unlock when the main generated electrical power is lost, which will happen after a crash landing. Also, there is a requirement for it to be demonstrated that RFFS using normally available equipment such as an axe, can gain access in a reasonable time, even with a locked or jammed flight deck door.

C. Crew Coordination

9.13 Communication and coordination – Crew Resource Management (CRM)

In an emergency evacuation effective communication and coordination between flight crew and cabin crew is essential, and is likely to influence the outcome of the event.

Initially Cockpit Resource Management (CRM) was limited to flight crew and it was only in the 1980s that the philosophy was extended to cabin crew and became Crew Resource Management. In 1988 the FAA issued a document on Cockpit and Cabin Crew Coordination (Ref: 30) The FAA considered that the following factors required addressing:

- Inadequate crew communication in emergencies.
- Confusion relating to 'sterile cockpit' procedures.
- Inadequate instruction on the duties of other crew members during training.
- Failure to properly secure the passenger compartment for take-off and landing.

Communication between flight crew and cabin crew is of paramount importance and usually it will be the commander who has the more complete picture of the situation. In most emergencies the commander will contact the SCCM via the interphone system to advise the situation, as well as the

Reference 30: FAA Report Number: DOT/FAA/FS-88/1. FAA Office of Flight Standards.

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required actions to be taken by the cabin crew. If the interphone system is not operative and time is limited, direct instructions by the commander via the PA system might be necessary.

EASA, in their 2009 CS 25 Study, addressed the issue of communication equipment and considered that “.....cabin crew communication systems should be improved to enable more effective communication especially during emergency situations.” The provision of radio headsets for cabin crew was an option that was considered to be worth looking into.

Once an emergency evacuation is initiated, the flight crew and the cabin crew will need to act as a team. Valuable assistance to all cabin crew will be the calling of evacuation commands at each emergency exit. This has the potential to alert cabin crew at nearby exits as to the situation in adjacent areas of the passenger cabin, and the necessary actions to be taken to evacuate passengers through the nearest exit, or to redirect them to a more useable exit. When all passengers and crew have been evacuated, the SCCM will need to establish contact with the commander and determine what other actions are required, depending on the level of injuries, the presence of RFFS personnel, and other emergency services that have arrived on the scene.

An emergency evacuation whilst an aeroplane is on a stand close to an airport terminal poses several problems, not least the use of evacuation slides and the possible proximity of service vehicles to emergency exits. On 26 June 2016, an Airbus A330 operated by American Airlines, (Flight Number 731), at London Heathrow, was evacuated after passengers had boarded, with the aeroplane still on the stand and connected to the terminal via an airbridge. On board were 277 passengers, three flight crew, nine cabin crew and two ground staff. When smoke started to fill the passenger cabin communication between the cabin crew and the flight crew could not be established and one of the cabin crew initiated an emergency evacuation which the commander attempted to stop by a PA announcement. Four of the aft floor level emergency exits were operated by cabin crew and passengers with one exit not in the ‘armed’ mode and therefore with no evacuation slide deployed. Some 25 passengers evacuated via the L4 and R4 exits with the remainder of the passengers and crew evacuating via exit L2 and onto the airbridge. The UK AAIB investigated this incident and issued Bulletin 12/2017 in December 2017, identifying that there was a problem with the APU and that smoke had entered the passenger cabin when an oil seal was compromised. The AAIB also identified that the lack of CRM was an important factor during the evacuation. Many of passengers had difficulty in hearing the instructions from the crew and some found these to be confusing and contradictory. (See Case Study at Section 11.12.)

Crew Resource Management is a vital element in emergency evacuations and is an essential part of flight crew and cabin crew training. The securing of the flight deck door following the terrorist events of 2001 makes effective communication and coordination between flight crew and cabin crew even more important.

See Recommendation 11.

9.14 Line Oriented Flight Training (LOFT)

LOFT offers flight crew, and sometimes cabin crew, the opportunity of training in a flight simulator by allowing the flight crew to train in a realistic environment and, at the same time, provides challenging scenarios that require good overall crew coordination, leadership skills, communication skills and effective decision making. In order to have an accurate understanding of how well a flight crew reacts to anomalies, the abnormal situations that might be encountered would not be briefed beforehand. It is therefore often used in conjunction with CRM training.

Through exposure to various real time scenarios, especially those with high work load and extreme situations, flight crew can develop the capabilities to improve decision making, intercommunication skills as well as leadership ability during flight operations.

Since the enforcement of the locked flight deck door, some operators schedule cabin crew to observe such sessions to understand the issues that flight crew need to deal with in difficult situations.

In particular it is important for cabin crew, especially SCCMs, to understand the flight deck work load during events leading up to an emergency evacuation and the command to evacuate. Cabin crew need to appreciate that at such critical moments there might be delays in communication with the flight crew.

See Recommendation 11.

D. Passengers

9.15 Passenger safety briefing

Much has been written over the years by safety agencies on the issue of passenger briefing. There is no doubt that a passenger who listens to and understands a pre-flight briefing or an emergency briefing is better prepared to take the correct actions in an evacuation. However, under the stress of an emergency, passengers cannot be relied on to always act correctly or logically.

The methods of conducting passenger briefings can vary considerably between operators whilst still meeting the mandatory AA requirements.

There are many distractions that might result in passengers paying little attention to pre-flight safety briefings, such as the handing out of newspapers, drinks, etc., and also the permitted use of mobile phones and other electronic equipment. Additionally, for long duration flights it might mean that passengers have to remember what they were briefed on many hours prior to an emergency event.

Many AAs require a specific pre-flight safety briefing of passengers seated in Type III and Type IV exit seat rows but this requirement has not been adopted internationally. For this reason aeroplane manufacturers when conducting 25.803 demonstrations have not been allowed to include such briefings. Such specific briefings have the potential to make passengers more aware of their responsibilities and required actions in emergency evacuation situations.

Passenger safety cards should be easy to understand and should be consistent with safety briefings. If placards are required to be located at Type III and Type IV emergency exits, they should be identical or at least consistent with the exit operating instructions on passenger safety cards.

Some operators, in an attempt to capture passenger attention during pre-flight safety briefings, have produced clever and often quite humorous briefing routines or videos. However, there is some question as to whether passengers adequately recognise the gravity of such briefings, or actually understand the important safety information being provided.

Safety briefings should advise passengers that the nearest available emergency exit might be behind them. Counting the number of seat rows to exits is an ideal but perhaps not always feasible or effective, since in some accidents involving impact, seats might be separated from floor mountings.

See Recommendation 6.

9.16 Passenger seat allocation

Type III and Type IV are regarded as self-help emergency exits since in most cases there is no cabin crew seat adjacent to the exit which has to be operated by passenger(s).

After the 1985 Manchester accident, the UK CAA determined that guidance to operators should be issued as to the type of passengers who should not be seated in exit rows adjacent to Type III and Type IV emergency exits. The following categories of passengers were determined by the UK CAA to be unsuitable to occupy an exit seat row leading to Type III or Type IV emergency exits:

- Obese passengers.
- Children and infants.
- The elderly and infirm.

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- Persons with reduced mobility.
- Prisoners in custody and deportees.

The UK CAA also determined that passengers should occupy seats in Type III and Type IV emergency exit rows for taxi, take-off and landing, so that in the event of an emergency evacuation they would not have to move from other seats to an exit row and then have to familiarise themselves with the exit handle location and the operation of the exit. Additionally, the UK CAA decided that the seating of family groups should be such that family members are not seated remotely from each other, since group members who are separated might seek each other out in an emergency evacuation, which might have a serious impact on passenger flow to emergency exits. The UK CAA provided the following recommendations:

- Children accompanied by adult(s) should ideally be seated in the same seat row as the adult.
- In twin-aisle aeroplanes, children and accompanying adults should not be separated by more than one aisle.
- When this is not possible, then children should not be seated more than one seat row forward or aft, from accompanying adult(s).

Note: In February 2018 the UK CAA initiated a review of operator allocated seating policies in respect of some passengers being charged to sit together. It is not clear if this review will include the safety issues identified above.

See Recommendation 12.

9.17 The 'brace' position and use of restraint systems

For passengers to successfully evacuate an aeroplane they must quickly leave their seats and move to emergency exits once the command to evacuate has been given. In a post-impact situation passengers might be injured and may have to rely on RFFS personnel to rescue them. Adopting a 'brace' position may afford some degree of protection in a crash landing. However, if passengers have not looked at the safety briefing card they may not be aware of how to adopt the 'brace' position. Although some operators may include such information if the safety briefing demonstration is conducted by video or other means it is not required to be part of the passenger safety briefing.

On 8 January 1989, a Boeing 737-400 operated by British Midland, (Flight Number 92) suffered engine problems and crashed onto a motorway embankment short of the runway at East Midlands Airport, UK. On board were 118 passengers including one infant, two flight crew, and six cabin crew. The infant was sat on its mother's lap and was secured by a supplementary loop-type belt. The AAIB accident report stated: *"Following the impact the majority of passengers were trapped due to injury, seat failure or debris from overhead. Only 14 of the passengers were able to make a significant contribution to effecting their own escape."* In this accident there were 39 fatalities with a further eight passengers who died later due to their injuries. Two flight crew, five cabin crew and 67 passengers including one infant sustained serious injury. The AAIB Accident Report stated: *"The injuries to the mother and child in seat 3F highlighted the advantages of infants being placed in child seats rather than in a loop-type supplementary belt."*

Following this accident the UK CAA commissioned a research programme to study occupant kinematics in order to assess the effectiveness of 'brace' positions, and in October 1993 issued NOTACH 8/93. (Ref: 31) More recently, TCCA have issued comprehensive guidance on brace positions in various seating configurations and direction of seating, including both seats belts and upper torso restraint devices. This information is published September 2016 in TCCA AC 700-036. (Ref: 32)

Part of the cabin secure check (see Section 9.3) should ensure that passengers are restrained by their seat belts for taxi, take-off and landing. In spite of this check by cabin crew some passengers may not comply. In the 2013 San Francisco accident, two passengers who were not wearing their

Reference 31: UK CAA NTAOCH 8/93 Passenger Brace position for impact.
Reference 32: TCCA AC 700-036 Issue 01 – Brace for Impact Positions for all Aircraft Occupants.

seats belts were ejected from the aeroplane during the impact. Had they been restrained by their seat belts it is likely that these two passengers would have remained inside the passenger cabin and would have survived. On board were 291 passengers, four flight crew and 12 cabin crew.

The issue of child restraint systems (CRS) has been discussed for many years but is still unresolved in spite of numerous recommendations and initiatives. On 22 December 2012, a Fairchild SA227-AC Metro III operated by Perimeter Aviation LP, (Flight Number 993), crashed beyond the departure end of the runway at Nunavut, Canada. The TSB Aviation Investigation Report stated that on board were seven passengers including one infant and the two flight crew. Two flight crew and the infant sustained serious injuries. According to the TSB, at the time of impact the infant was held on the mother's lap without any restraint system and was ejected from the mother's arms. The infant was found near to the commander's rudder pedals and was fatally injured.

The TSB has recommended that: *"The Department of Transport [Canada] work with industry to develop age- and size-appropriate child restraint systems for infants and young children travelling on commercial aircraft, and mandate their use to provide an equivalent level of safety compared to adults."* Additionally, in January 2015 ICAO published Document Number 10049 regarding the use of child restraint systems. (Ref: 33)

Although most AAs have for many years accepted or approved the use of automotive child car seats in aeroplanes, and some have approved aviation child seats, it seems strange that the important issue of the level of infant/child occupant safety remains at the discretion of the adult passenger accompanying the infant, rather than required by any aviation regulation.

See Recommendation 13.

9.18 Passenger behaviour in emergency evacuations

The behaviour of passengers in an emergency evacuation can be either positive or negative. On the positive side, passengers often behave calmly, quickly executing required evacuation procedures, and display quite courageous behaviour as they work to help fellow passengers get out of the aeroplane. On the negative side however, passengers might either pay little attention to safety briefings or fail to understand them, so in an unplanned evacuation, at least some passengers are ill-prepared to take the necessary actions to rapidly evacuate an aeroplane. Some may also become overwhelmed with fear and be "paralysed" and seemingly unable to act. Elderly, infirm, passengers with reduced mobility and those who are under the influence of alcohol or different types of drugs are often slower to comply with evacuation orders. As discussed further in Section 9.28, there is an increasing trend for passengers to take cabin baggage with them in emergency evacuations.

Some passengers might become quite aggressive as they attempt to reach emergency exits. Competitive behaviour occurred in the 1984 Calgary accident, where there was some pushing and several passengers went over seat backs to get the exits ahead of other passengers who were queuing in the aisle. This was also the case in the 1985 Manchester accident and similar situations occurred during some of the Cranfield evacuation tests. (See Section 10.1.)

Passenger behaviour is critical when they have to initiate action such as opening emergency exits especially where no cabin crew are seated in that location. In several accidents, passengers seated immediately next to Type III exits have failed to take the necessary action when the evacuation command has been given. It is not surprising that passengers hesitate to open exits since they are not trained to do so. Conversely, there are many accidents when passengers took correct actions. An example of this is the 2009 ditching in the Hudson River (New York) when passengers opened the overwing Type III and rapidly evacuated onto the off-wing evacuation slides.

Reference 33: ICAO Manual on the Approval and Use of Child Restraint Systems – Document Number 10049.

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Other aspects of passenger behaviour that have been experienced in evacuations include:

- Panic, some overt and negative.
- A lack of appreciation of the seriousness of the situation.
- Ignoring aeroplane crew commands.
- Refusing to jump at emergency exits.
- Determination to use the exit that they used to enter the aeroplane.
- Determination to take cabin baggage with them.
- Not effectively opening exits if required to do so.

E. Types of Evacuations

9.19 Planned and unplanned evacuations

When a commander has time to plan for an emergency landing and evacuation, the cabin crew will be briefed as to the nature of the emergency, the amount of time available to prepare the passengers and the passenger cabin, and any additional factors that the cabin crew will need to know. The commander will also communicate with air traffic control (ATC) as to the nature of the emergency and will receive advice from ATC as the best options for an emergency landing at the nearest suitable aerodrome.

On 19 July 1989, a McDonnell Douglas DC-10 operated by United Airlines, (Flight Number 232), was en-route from Stapleton International Airport, Denver, USA to Chicago, USA when it suffered an uncontained failure of the tail mounted number 2 engine. The commander decided to make an emergency landing at Sioux Gateway Airport, Iowa. The DC-10 having lost the number 2 engine did not respond to flight control inputs and the flight crew identified that the hydraulic pressure and quantity gauges indicated zero. Therefore, the flight crew had very limited control of the aeroplane during its approach to and landing at Sioux City, and the commander advised the SCCM to prepare for an emergency landing. According to the NTSB Accident Report the flight attendants concentrated on securing passengers as well as all cabin and galley equipment for the event. All passengers and cabin crew were in the 'brace' position on landing. The first contact with the ground occurred when the right wing and right landing gear impacted. The aeroplane then skidded to the right of the runway rolled to an inverted position resulting in significant fuselage disruption and fire. Despite the serious nature of the impact and the substantial post-impact fire, of the 285 passengers and 11 crew, 185 occupants survived this accident.

Unplanned evacuations will present the flight crew and the cabin crew with serious challenges. Often the crew will have little or no time to react to the situation and communication between crew members might be limited or non-existent. In such scenarios individual crew members will need to deal with the situation as it confronts them and their actions might not always follow operator SOPs.

9.20 Evacuation of passengers and cabin crew

When the evacuation command has been ordered, the cabin crew will initiate the evacuation by opening emergency exits, and if applicable deploying evacuation slides, life-rafts and/or slide-rafts, and evacuating passengers as rapidly and as safely as possible. Many of the issues addressed in this paper will play an important part in an evacuation. Both flight crew and cabin crew should evaluate their own personal safety in emergency evacuations. Many operators specify that crew should conduct a check of the entire passenger cabin before they evacuate, but in some catastrophic accident scenarios this may not be possible without placing crew members at extreme risk.

Cabin crew need to assess external conditions before operating an emergency exit and ensure that no exit is opened into hazards such as an external fire or aeroplane debris. In order to facilitate an external view of the area outside an emergency exit, most aeroplanes are equipped with a viewing means such as a small window installed in or adjacent to emergency exits. The EASA 2009 CS 25 Study addressed this issue in their Regulatory Impact Assessment and considered other options such as external cameras might merit further research.

9.21 Passenger initiated unnecessary emergency evacuations

There have been incidents where passengers have initiated unnecessary emergency evacuations.

In July 2014 EASA issued a Report (Ref: 34) which reviewed 17 incidents. Most of these incidents were whilst aeroplanes were parked or during taxi prior to take-off. There were 12 incidents involving single-aisle aeroplanes and 5 incidents involving twin-aisle aeroplanes. Many of the incidents occurred on engine or APU start up, when passengers perceived a threat of fire from engine flames or 'torching'. Many of these passenger-initiated evacuations involved single-aisle aeroplanes with Type III emergency exits where no cabin crew are seated and are unable to control passenger actions.

Once an evacuation has commenced, it might be very difficult for the crew to stop passengers evacuating from the aeroplane. This is reflected in the CS 25.803 demonstration of a British Aerospace (BAe) Advanced Turbo-Prop (ATP) in 1986 when due to a technical problem the evacuation demonstration was aborted shortly after it had commenced. The cabin crew were unable to halt the evacuation and all passengers (test participants) evacuated the aeroplane. If in a relatively controlled test environment, crew are unable to stop an evacuation in progress, then they will probably have even less chance of doing so during an operational situation. If a passenger has initiated an evacuation, cabin crew should contact the flight crew so that they can shut down the engines to reduce the risk of injury to evacuating occupants. Commands by the flight crew via the PA and shouted instructions by the cabin crew might assist in halting an unnecessary evacuation.

However, there may be circumstances where passengers may need to initiate an emergency evacuation, and for passenger seated at some exits they might have been provided with specific information on how to operate exits.

9.22 Evacuation on water/ditching

A ditching obviously has significant differences to a land evacuation. One of the most important differences is the availability of emergency exits in a ditching because some exits might be under the waterline or close to it, and may not be designated as emergency exits. For the Boeing 747-100/200/300/400, slide-rafts are only located on the main deck, so in a ditching upper deck passengers will have to move to the main deck to evacuate into the slide-rafts. For the Airbus A380 all the upper deck evacuation slides act as slide-rafts.

Other obvious differences include that passengers and crew have to don lifejackets and that an evacuation will either be directly into the water, onto the aeroplane wings, slide-rafts or life-rafts. For some aeroplanes life-rafts might need to be launched through Type III or Type IV emergency exits and such actions should be controlled by the cabin crew. Many aeroplanes are equipped with life-rafts which are often stowed in passenger cabin overhead bins.

For some smaller aeroplanes, including business jets, an additional issue is that there might be only one emergency exit that can be used in a ditching. In smaller aeroplanes such as business jets, the structural integrity is generally better and it is more likely that the fuselage will remain intact and afloat if the ditching drills are completed correctly by the flight crew. This was also the case in the Airbus A320 Hudson River accident. EASA, in their 2009 review of CS 25 requirements, recommended that further investigation be conducted to assess the extent of risk this poses and if amendment to CS 25 should be required.

On 2 May 1970, a McDonnell Douglas DC-9 operated by Overseas National Airways Inc (operating as Antilliaanse Luchtvaart), (Flight Number 980) departed New York for San Marteen, Netherlands Antilles. According to the NTSB Accident Report the DC-9 ran out of fuel in bad weather and ditched near St Croix. Of particular importance was the failure to launch any of the life-rafts carried on board. On board were 57 passengers, three flight crew and three flight attendants. Twenty two passengers and one flight attendant did not survive the accident. (See Case Study at 11.1.)

Reference 34: EASA Safety Analysis and Research Department. Short Report: Unauthorized opening of doors / exits by passengers.

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On 20 February 1991 a BAe 146-200 operated by Lan Chile, (Flight Number 1069) overshot a wet runway at Guardiamarina Zanartu Airport, Puerto Williams, Chile, and ended up in the waters of the Beagle Channel. On board were 66 passengers, two flight crew and four cabin crew. The BAe 146 ditching characteristics are that the aeroplane will float nose up with the forward floor level emergency exits being most likely to be above the waterline, and with the aft exits at or below the waterline. However in this accident the forward part of the fuselage was damaged by debris at the end of the runway. Although the aeroplane initially floated 'nose-up' it soon became 'nose-down' with the aft floor level exits being the only exits available resulting in 20 passenger fatalities.

However, there have been ditching scenarios where the flight crew has had some limited time to make a successful controlled ditching. One such event with no fatalities, occurred on 15 January 2009 involving an Airbus A320 operated by US Airways, (Flight Number 1549). Shortly after take-off from La Guardia, New York, it struck a flock of Canadian Geese which caused almost total loss of thrust in both engines. The commander quickly assessed that no available runway could be reached before the aeroplane lost height, and he elected to ditch in the Hudson River adjacent to Manhattan Island. The controlled ditching was successful and all 150 passengers, two flight crew and three flight attendants evacuated onto slide-rafts and onto the wings, and were rescued by a variety of boats that rapidly arrived at the scene of the accident. The evacuation was initiated by the cabin crew within seconds of the ditching. (See Case Study at 11.7.)

Many evacuations on water are unplanned scenarios with little or no time for the flight crew or the cabin crew to prepare for the event, sometimes with bad results for occupant survival. The NTSB Accident Report into the Airbus A320 ditching in the Hudson River identified that passengers who had no warning were unlikely to take the necessary 7 to 8 seconds (average) to retrieve their lifejackets before moving to an exit.

Note: *The certification requirements for transport category aeroplanes are currently under review by an aviation rulemaking committee of the FAA (Crashworthiness and Ditching Evaluation Working Group) with international representation from AAs and aeroplane manufacturers. Also see FAA 'Review and Assessment of Transport Category Airplane Ditching Standards and Requirements – DOT/FAA/TC-14/8.*

9.23 Rapid disembarkation as an alternative to an evacuation

Some incidents might require the commander to instruct passengers to leave the aeroplane with some degree of urgency, but not necessarily via evacuation slides. Rapid disembarkation has the potential to avoid external hazards such as ground service equipment and vehicles, as well as ground service personnel. In such circumstances injury to aeroplane occupants and ground personnel can be avoided. Rapid disembarkation can only be achieved when stairs and/or jetways are in place, or can be rapidly positioned at floor level emergency exits, or when airport terminal piers are connected to the aeroplane. This is also the case for aeroplanes that have integral airstairs which are usually located at the forward left emergency exit (L1).

Rapid disembarkation might be preferable to evacuation in circumstances where, for example, there has been a large fuel spillage outside the aeroplane, or the commander has been advised that an explosive device might be on board the aeroplane. If an operator specifies that rapid disembarkation might be used as an alternative to an evacuation, then this terminology should be used by the commander and be clearly understood by the cabin crew so as to avoid any confusion. Operations Manuals and crew safety training should reflect this.

9.24 Evacuation of aeroplanes where cabin crew are not required to be carried

For aeroplanes with 19 or fewer passenger seats installed, which would include most business jet operations, there is no regulatory requirement for cabin crew to be carried. Passengers may therefore have to operate emergency exits and evacuate without assistance from the flight crew.

For many smaller aeroplanes, where cabin crew are not required, there may be no provision for a cabin crew seat. In such operations, when cabin crew are on board, there is more discretion as to where cabin crew are seated for take-off and landing. Obviously for a planned emergency evacuation,

the cabin crew member should sit as close to the emergency exit(s) most likely to be used in the evacuation. In addition, the cabin crew should use a rearward facing seat, if available. The actions in the event of an emergency evacuation will depend on whether cabin crew are carried or not. Crowd control is vital in either case, but particularly important when cabin crew are not carried, and when passengers may have to initiate an emergency evacuation without clear direction from the flight crew. If cabin crew are carried, they should control the evacuation on receiving the evacuation command from the flight crew by operating the exit(s), controlling the evacuation inside the passenger cabin and leading passengers to a safe area outside the aeroplane. If no cabin crew are carried, the first officer should undertake the cabin crew duties specified above. The commander should secure the aeroplane and then complete a final check of passenger cabin before evacuating.

9.25 Evacuation of multi-deck aeroplanes

Multi-deck commercial passenger aeroplanes are currently limited to the Boeing 747 and the Airbus A380. In the event of a planned emergency landing or ditching, if time is available, the commander may decide, depending on seat availability, to transfer some or all passengers from the upper deck to the main deck where evacuation slides are deployed from a lower height. Operators of Boeing 747 aeroplanes might consider the planned ditching aspects whereby all passengers will need to use the main deck slide-rafts.

F. Evacuation Difficulties

9.26 The effect of a crosswind on an aeroplane on fire on the ground

In the 1985 Manchester accident, during the take-off roll the flight crew heard a 'thud' and thinking that this noise was caused by either a tyre-burst or a bird strike, immediately abandoned the take-off and turned off the runway. A wind of just seven knots carried the uncontained left engine fire onto and around the rear fuselage. According to the UK AAIB Accident Report, *"The fire which resulted developed catastrophically, primarily because of adverse orientation of the parked aircraft relative to the wind, even though the wind was light"*. The AAIB Accident Report also stated: *"Although the wind was only 5-7kt – a strength so slight that it would have been a relatively insignificant factor in terms of aircraft handling - there is a powerful body of evidence which clearly shows that the influence of wind on this accident was paramount. Not only did it drive the static fire plume against and beneath the hull, making a more rapid penetration of the aluminium alloy fuselage skins inevitable, it created an aerodynamic pressure field around the fuselage which, once door and exits had been opened on the side opposite to the fire, induced the products of the external fire into and down the length of the cabin interior. In turn, some interior materials ignited leading to development of the fire inside the cabin."*

After the 1985 Manchester accident, the UK CAA in 1986 issued NTAOCH 4/86, (Ref: 35) which was based on work conducted by the AAIB, on the effect of cross-winds and the survival factors that might be of influence when an aeroplane is on fire on the ground. This work by the AAIB showed that even a small degree of a crosswind can be significant. If, as happened with in Manchester accident, the aeroplane is brought to a stop with the fire on the upwind side of the aeroplane, the fire will be driven against the fuselage and will rapidly penetrate the aeroplane skin resulting in 'burn-through'. In some conditions fire penetration of fuselage skin can occur very quickly with times ranging from 20 to 60 seconds. However, if the aeroplane is stopped with the fire on the downwind side of the fuselage the situation will be very different and the fire will not necessarily be driven against the fuselage. As a consequence the potential for the fire to directly penetrate the fuselage is significantly reduced. If fire penetration does occur it is likely to happen at a later stage in the event. Photos of 'burn-through' in respect of the 1984 Calgary accident and the 1985 Manchester accident can be seen in Section 6.

Note: See Section 3 Definitions and Explanations for an explanation of 'burn-through'.

Reference 35: Notice to AOC Holders 4/86 – Flight Operations Bulletin.

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NTAOCH 4/86 advised operators that the permutations of circumstances providing advantages and disadvantages of aeroplane position in relation to the wind direction appear to be too numerous for a commander to consider properly in different emergency scenarios. General advice was for the flight crew to try to leave the aeroplane heading into the wind if this could be achieved within the confines of the runway or taxiway, and without causing undue delay to the initiation of the emergency evacuation. In scenarios in which the flight crew has identified an external fire, it is better to stop the aeroplane with the fire on the downwind side of the fuselage.

Depending on the size of the aeroplane, there may be little opportunity to turn on the runway so as to reduce the effect of wind on an external fire. This is especially the case for twin-aisle aeroplanes where the width of the runway might be an issue. The overriding principle is not to turn an aeroplane in such a way that the wind direction and its impact on the fire scenario could affect a successful emergency evacuation.

In their investigation into the RyanAir ground fire at Stansted in February 2002, the AAIB said that the destructive potential of crosswind on an aeroplane fire on the ground was well documented and stated: *“Had the right engine developed an uncontained fire, the relative wind would have exacerbated the situation and adversely affected the survivability of such an event.”*

The FSEG at Greenwich University in its 2017 paper also identified wind direction as a major factor and stated: *“The aircraft orientation in a fire is critically important even under a mild wind. Aircrew should be advised to position the aircraft beneficially against the wind in the event of a ground fire.”*

On 8 September 2015, a Boeing 777-200 operated by British Airways (Flight Number 2276), was taking off from Las Vegas, USA, when there was an uncontained failure of the number one engine resulting in a serious fire affecting the port wing and the area of L2 emergency exit. The commander declared a Mayday and ordered an emergency evacuation. On board were 157 passengers, three flight crew and ten cabin crew. It is understood that the aeroplane came to a stop on the runway with the number one engine upwind, which if this was the case, might have resulted with the fire being blown onto the fuselage in a similar way to the 1985 Manchester accident. This might account for the external fire breaching the pressured structure of the aeroplane. Emergency response from the Las Vegas RFFS was rapid and the fire was extinguished in approximately two and a half minutes after the start of fire-fighting operations. (See Case Study at 11.10.)

Note: *The final NTSB Las Vegas Accident Report was not available at the time of publication of this paper. The information in this paragraph is based on best information available at time of publication.*

See Recommendation 14.

9.27 Internal obstructions

Internal obstructions in an impact situation might include passenger cabin structural failure which may result in injury to passengers and crew and may impact evacuation routes. Overhead bins may fail and contents might be ejected. Incorrectly stowed cabin baggage may also impede an evacuation. Other interior structures including passenger service units, and seats might be compromised and be forced by impact damage into aisles and cross-aisles.

In the 1999 Girona accident the aeroplane left the runway and came to rest with the fuselage broken into three sections. In spite of substantial damage in the passenger cabin, all the passengers and crew evacuated the aeroplane, although there were two serious injuries and some 40 minor injuries. Damage to passenger seats involved severe sideways canting of the seats some of which significantly reduced the aisle width. Damage to passenger service units (PSUs), and video screens also made the evacuation more difficult. (See Case Study at 11.4.)

In their 2009 CS 25 Study, EASA concluded that there was a need to ensure that the 16G seat requirements are compatible with passenger cabin floor strengths. Further research on structural design of both components in order to ensure retention of 16G passenger seats on the surface of the passenger cabin floor was recommended.

9.28 Cabin baggage

The widespread ownership of smart phones has led to an increasing amount of photographic evidence showing passengers retrieving cabin baggage and taking it with them despite the potential threat to interfere with safe and expeditious evacuations. Such actions by passengers are not new. The Canadian Aviation Safety Board (CASB) Occurrence Report into the 1984 Calgary accident stated: *"Most passengers chose the closest exit for evacuation. Many stopped to retrieve hand baggage before they left."* This trend appears to be increasing and can only be exacerbated by the increasing volume of cabin baggage being permitted by some operators for commercial reasons.

Many operators are being restrictive on hold luggage, possibly in order to speed up turn-round times. Some operators now charge passengers for checking in 'hold' baggage, and impose high charges if cabin baggage is found to be too big during the check-in/boarding process and has to go in the hold. Another issue is the value of the contents of cabin baggage, such as passports, legal and business documents, laptops, mobile phones, cameras, other electronic equipment, medicines, etc. The probability is that passengers will want to take such items with them in an evacuation, the more so if cabin baggage is all that a passenger has with them for their journey.

Most operators now use 'e-ticketing' whereby passengers do not have to use check-in and can go straight to the boarding gate. Also, the number of 'airside' airport shops has increased dramatically in recent years where the sale of items, if taken into passenger cabins, can further contribute to the cabin stowage problems. As a result, the first time the operator or their handling agent has the opportunity to assess the size and amount of cabin baggage is shortly prior to boarding.

A further issue is that cabin baggage is not usually weighed, so there is little or no verification that the mass of baggage carried in overhead bins comply with the maximum permissible mass placards. The consequence of this is that overloaded bins could collapse during an accident, causing injury and impeding an evacuation. According to the FAA, given that a 60 inch long overhead bin can accommodate up to 180lbs, it is unlikely that bins are routinely overloaded. Where overhead bins have failed in an accident impact it is generally due to a design error or localized impact conditions exceeding the regulatory standards, rather than simply being under-strength.

In an impact situation the integrity of overhead bins may fail structurally or fail to contain the contents. In the 1989 Kegworth accident, almost all of the overhead bins became detached from their mountings. The AAIB Accident Report concluded that the failure of the overhead bins was not due to passenger cabin baggage exceeding the weight limits. The AAIB Accident Report stated: *"This leads to the conclusion that the design of the stowage bins installed in ME [the accident aeroplane] was not sufficiently robust to withstand the deformation of the attachment structure combined with the dynamic loading of the second impact."* The AAIB Accident Report stated: *"Although the overhead stowage bins met the appropriate Airworthiness Requirements for static loading, all but one of the 30 bins fell from their attachments, which did not withstand the dynamic loading conditions in this accident."* Additionally, the AAIB Accident Report stated: *"There was also evidence that some of the bin doors opened during the last moments of flight, before the first impact."*

The determination of passengers regarding personal belongings is clearly illustrated in the case of an accident on 17 January 2008 to a Boeing 777-200 operated by British Airways, (Flight Number 38), which crashed on final approach at London Heathrow, UK. The AAIB in their Accident Report identified that a passenger having evacuated the aeroplane re-entered the passenger cabin via an evacuation slide in order to retrieve personal belongings.

Other accidents where passengers evacuated with cabin baggage include:

• Air France	A340-3300	Toronto, Canada	2 August 2005
• Virgin Atlantic	A330-300	London Gatwick, UK	16 April 2012
• Asiana Airlines	B777-200	San Francisco, USA	6 July 2013
• Air Canada	A320-200	Halifax, Canada	29 March 2015
• British Airways	B777-200	Las Vegas, USA	8 September 2015
• Emirates	B777-300	Dubai, Emirates	3 August 2016

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Most of the above accident were catastrophic, involving external fire and in one case fuselage disruption. These accidents required a degree of urgency in the evacuation, yet passengers seemed to be more concerned with their personal possessions rather than their own safety or the safety of fellow passengers. (See Case Studies at 11.5, 11.8, 11.9, 11.10 and 11.14.

On 2 August 2005, an Airbus A340-300, operated by Air France, (Flight Number 358) touched down on runway 24L at Toronto. It departed the end of the runway and came to rest in a shallow gully with its fuselage split into several pieces. Approximately four minutes later, the A340 fuselage erupted in flames. The TSB in their Accident Report stated that although all passengers managed to evacuate, the evacuation was impeded because nearly 50% of the passengers retrieved their cabin baggage.

On 16 April 2012, an Airbus A330-300, operated by Virgin Atlantic, (Flight Number 27) returned to London Gatwick, UK, after a smoke warning in the aft cargo compartment. After a successful emergency landing an emergency evacuation was ordered. In the AAIB Accident Report stated: *"Some passengers stopped to try and bring their bags with them and had to be told to leave them behind."* The AAIB Accident Report concluded that some passengers slowed their own evacuation due to issues with cabin baggage. The AAIB Accident Report included the following statement in Passenger Questionnaires: *"A number of passengers stated that they took their hand baggage with them whereas others commented that passengers retrieving hand baggage from overhead lockers delayed the evacuation."*

On 29 March 2015 an Airbus A320-200 operated by Air Canada, (Flight Number 624), crashed in adverse weather conditions landing short of the runway at Halifax, Canada. In the TSB Accident Report it was stated that the pre-flight safety briefing had instructed passengers to leave their 'carry-on' baggage in the event of an emergency evacuation. In spite of this some passengers evacuated with their baggage. The TSB report also stated: *"If passengers retrieve or attempt to retrieve their carry-on baggage during an evacuation, they are putting themselves and other passengers at a greater risk of injury or death."*

In the 2015 Las Vegas Boeing 777 accident many passengers evacuated the aeroplane with items of cabin baggage including suitcases. The FOG is of the opinion that a significant issue in this emergency evacuation was the number of passengers who took cabin baggage with them to the emergency exits and down the evacuation slides. Although this did not appear to affect the emergency evacuation, had the B777-200 been configured at its maximum capacity of 440 seats installed and passengers carried, the evacuation time might have been dangerously extended.



Photo copyright required.

The UK Air Navigation Order (ANO) requires passengers to comply with all commands that the aeroplane commander may give for the safety of the aeroplane. The ANO requires that passengers must not interfere with crew members in the performance of their duties. It could be argued that if passengers, having been instructed that they must not take cabin baggage with them in an emergency evacuation, and ignore this instruction, they might be in breach of this regulation.

In June 2011 the CAA issued Safety Notice Number SN-2011/05. (Ref: 36) The SN stated that the CAA had received an increasing number of reports highlighting concerns regarding the quantity and size of hand baggage. A series of inspections conducted by the CAA identified the following issues:

- *“Non-compliance with procedures in an operator’s Operations Manual with regard to size and weight of hand baggage;*
- *Exits being blocked by hand baggage during boarding and, usually, refuelling;*
- *Confrontation between cabin crew and ground staff over ownership of delays, possibly leading to non-compliance with safety procedures;*
- *Confrontation between cabin crew and flight crew members, possibly leading to less effective crew resource management;*
- *Confrontation between cabin crew and passengers, possibly leading to disruptive behaviour;*
- *Hand baggage being relocated to the hold (internal or external) without being subject to questioning about content, particularly with regard to spare lithium batteries;*
- *Numerous items of hand baggage being relocated to the external hold without flight crew knowledge or the supervision of an aircraft loader, and associated mass and balance considerations;*
- *Hand baggage being relocated to the internal hold without flight crew knowledge or the supervision of an aircraft loader, and associated mass and balance considerations;*
- *Hand baggage being stowed in non-approved stowages including toilets;*
- *Aircraft taxiing whilst cabin crew were still trying to stow hand baggage;*
- *Passengers standing during taxiing due to inability to stow hand baggage; and*
- *Unrestrained hand baggage being carried on the flight deck.”*

As a result of this Safety Notice the CAA determined a series of actions that operators needed to implement to ensure compliance with the relevant requirements.

In October 2015 the CAA issued Safety Notice Number SN-2015/006. (Ref: 37) The SN stated that passengers taking hand baggage in an emergency evacuation can present a significant hindrance to egress and could cause injury to passengers and damage evacuation slides. The Notice advised operators to address such issues in the pre-flight briefing of passengers as well as in cabin crew passenger management training.

Some aeroplane manufacturers are introducing larger overhead stowage bins. For example Boeing has introduced new ‘Space’ bins for the B737-900 which increases the number of average cabin size bags from 132 to 198. It is possible that an increase in stowage capacity in the passenger cabin could result in more passengers taking cabin baggage with them in an evacuation, simply because such items that previously would have had to be in the hold can now be stowed in overhead stowage bins. One mitigating option would be for overhead bins to be centrally locked for taxi, take-off and landing, although passengers would still be able to retrieve under-seat stowage items in an evacuation. Overhead bins that contain emergency equipment that might be needed in an evacuation should not be locked.

Reference 36: CAA Safety Notice Number SN-2011/05: Passenger Hand Baggage.
Reference 37: CAA Safety Notice Number SN-2015/006: Management of Cabin Baggage in the Event of an Aircraft Evacuation.

The website for the new Russian Irkut MC-21 aeroplane states: *“The overhead stowage bins can hold more carry-on luggage of standard size. The bins can also hold bulky items including wheeled bags of 24”x18”x10” (609x457x254mm) overall dimensions and long articles.”* The website also states: *“Optionally, the bins may be equipped with remotely-controlled interlocking electromechanical locks, and be visually monitored by the cabin crew.”*

EASA in their 2009 CS 25 Study concluded that there was a need to improve the standards of overhead bins including the potential of bin detachment as well as the failure of bin latches. It was recommended that research be conducted into the feasibility of improved design standards including baggage retention for both in-flight and post-impact. The JAA proposals made in 2003 in respect of overhead bin safety precautions should also be considered.

It would appear that cabin crew have little control over passengers who insist on taking cabin baggage with them in an evacuation. Perhaps it is only a matter of time before an evacuation occurs when the issue of cabin baggage becomes a survival factor.

See Recommendation 15.

9.29 Terrain

On 13 January 2018, a Boeing 737-800 operated by Pegasus Airlines (Flight Number 8622), landed at Trabzon, Turkey, in wet weather conditions and inadvertently departed the runway coming to rest on a steep slope a very short distance from the waters of the Black Sea. The aeroplane sustained significant damage.

In spite of the adverse terrain conditions and probable collapse of the landing gear, all passengers and aeroplane crew safely evacuated. On board were 162 passengers, two flight crew and four cabin crew. Most of the passengers and crew evacuated via the overwing Type III emergency exits and the aft floor level Type I exits.

Note: *It is understood that in the past the Turkish Directorate General of Civil Aviation has been responsible for investigating air accidents occurring in Turkey (i.e. the State of Occurrence). ICAO has now advised that Turkey has established an independent Accident Investigation Authority (AIA) in accordance with ICAO Annex 13 (Ref:38) which states: “A State shall establish an accident investigation authority that is independent from State aviation authorities and other entities that could interfere with the conduct or objectivity of an investigation.” No Accident Report was available at the time of publication of this paper. The above accident information is based on best information available at time of publication of this paper.*

G. Evacuation Demonstration and Training

9.30 Operational demonstration of evacuation procedures, training and systems

In addition to the CS 25.803 demonstration that must be carried out by manufacturers during aeroplane certification (see Section 8.15 and 8.16). In 14 CFR 121.291 (Ref: 39), the FAA has stipulated additional evacuation testing that must be conducted by operators. This test is applicable to aeroplanes with more than 44 passenger seats installed and is often referred to as a ‘partial’ evacuation test, or a ‘mini’ evacuation test as it only involves flight attendants (i.e. no flight crew or passengers (test participants)). Such testing is required to be conducted by the operator in the following circumstances:

Reference 38: ICAO Annex 13 – Aircraft Accident and Investigation. 11th Edition – Amendment 15 – November 2016.
Reference 39: 14 CFR 121.291: Demonstration of emergency evacuation procedures.

- Initial introduction of a type or model of an aeroplane into commercial passenger operation;
- A change in the number, location, or evacuation duties or procedures of required flight attendants; and
- A change in the number, location, type of emergency exits, or type of emergency exit opening mechanisms for evacuation. This is required to demonstrate flight attendant proficiency and that the operator has adequate procedures, training and sufficient number of flight attendants to conduct the test.

The purpose of this test is for the operator to demonstrate to the FAA:

- Effectiveness of evacuation procedures including ditching, flight attendant training programmes and flight attendant competency; and
- Reliability and capability of emergency equipment and evacuation systems.

The test specifies that the minimum number of required flight attendants open 50% of the required floor level emergency exits and 50% of the non-required floor level emergency exits, and deploy 50% of the emergency exit evacuation slides in a usable condition for evacuation in 15 seconds.

Additionally the 14 CFR 121.397 – Emergency and evacuation duties, states:

“(a) Each certificate holder shall, for each type and model of airplane, assigned to each category of required crewmember, as appropriate, the necessary functions to be performed in an emergency or a situation requiring emergency evacuation. The certificate holder shall show those functions are realistic, can be practically accomplished, and will meet any reasonably anticipated emergency including the possible incapacitation of individual crewmembers or their inability to reach the passenger cabin because of shifting cargo in combination cargo-passenger airplanes.”

“(b) The certificate holder shall describe in its manual the functions of each category of required crewmembers under paragraph (a) of this section.”

For aeroplanes with 44 or fewer passenger seats installed many AAs have no requirement for evacuation demonstrations as part of any aeroplane certification process or operational procedure. However, TCCA has similar demonstration requirements to the FAA applicable to the operator.

See Recommendation 16.

9.31 Regulatory training requirements for aeroplane evacuation

Lack of experience or realism during evacuation training has negative repercussions during actual events. Such was the case on 27 February 2002, when a Ryanair Boeing 737-800 (Flight Number 296), upon landing at London Stansted Airport, UK, experienced a vibration in the right engine, which the flight crew shut down. ATC reported that smoke was coming from the right engine and cabin crew were also aware of this. The Stansted RFFS advised the flight crew that an emergency evacuation should be via the left side, although the flight crew did not acknowledge this advice. In the subsequent evacuation, cabin crew operated some of the right side emergency exits. The Stansted RFFS had to command six passengers who had evacuated via the right Type III overwing exit to re-enter the passenger cabin and find an alternative exit due to the Number 2 engine fire.

This accident was investigated by the AAIB and in Bulletin Number 7/2004 identified that the two forward cabin crew members had had difficulty opening floor level Type I emergency exits (R1 and R2). The AAIB Bulletin stated: *“At the time of the incident, whilst a few of the new entrant cabin crew personnel would operate the emergency exit doors in the armed mode during Conversion and Differences training, most would not. For the latter, the door opening forces which they encountered during training were considerably less than those that would be encountered in a real evacuation with an armed evacuation slide. Although their instruction was supplemented with the advice that the fully rigged door would be more resistant to opening in the real event because of the integral slide deployment, during training they would have acquired no sense of the forces they would normally encounter trying to open an armed door.”* AAIB Bulletin Number 7/2004 included Safety

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Recommendation Number 2004-53 which stated: *“It is recommended that the Irish Aviation Authority and JAA review the requirements for cabin crew initial and refresher training in respect of the operation of all normal and emergency exits, to ensure that crew members become, and remain, familiar with the different operating procedures, and opening characteristics, in both normal and emergency modes of operation.”*

Some AAs do not necessarily specify that for non-automatic slide deployment, the operating forces required to drag the evacuation slide out of the slide bustle are replicated in emergency exit training equipment and therefore a cabin crew member may not experience this additional operating force unless they have operated the exits in an actual emergency evacuation.

As a result of the 2002 Stansted accident and the Safety Recommendations made by the AAIB, the JAA amended the training requirements for exit operation. This is stipulated in EASA Air OPS Regulation AMC1 ORO.CC.125(c) which states for training on the operation of doors and exits: *“This training should be conducted in a representative training device or in the actual aircraft and should include failure of power assist systems where fitted and the actions and forces required to operate and deploy evacuation slides.”*

All AAs require that aeroplane crew complete practical training in the operation of emergency exits and many require the practical use of evacuation slides. However, the frequency of such training can differ between AAs. Additionally, some AAs do not require theoretical or practical training in passenger management and crowd control in an emergency evacuation, the shouting of evacuation commands and the physical contact which might be necessary to encourage passengers to evacuate. These issues are essential skills for cabin crew in effectively managing an evacuation.

9.32 Evacuation procedures and associated training

In the first CS 25.803 demonstration conducted by Boeing for the B777-200, shortfalls in the cabin crew procedures were reviewed and Boeing identified five significant factors that had the potential to affect an evacuation. These issues were addressed in a paper presented by Boeing and British Airways at a conference in Lausanne in 1997 (Ref: 40) and included the following:

Cabin crew assist space: If cabin crew do not stand in assist spaces then there is potential for the effective flow of passengers to be obstructed, and in the case of a dual lane exit and evacuation slide, this could result in only a single line of passengers being evacuated rather than two lines of passengers that the exit was designed and certificated to accommodate.

Assertiveness: The UK CAA had long been advocating the need for cabin crew to be assertive in an evacuation. Boeing adopted this philosophy and recommended that cabin crew should be assertive both verbally and if required physically in order to motivate and assist passengers in an evacuation.

Dried-up emergency exits: A dried-up emergency exit is one where the passenger flow has stopped due to that area of the passenger cabin being evacuated earlier than other areas. Cabin crew will need to be aware of when passenger flow to an exit has stopped and take actions to re-direct passengers to any dried-up emergency exits if necessary.

Re-direction: When an emergency exit or an evacuation slide is not usable at the start of an evacuation, or becomes unusable during the evacuation, cabin crew will need to re-direct passengers to the nearest usable emergency exit. If an emergency exit becomes overloaded, i.e. there are queues of passenger waiting to evacuate an emergency exit and where other emergency exits have either dried-up or have only a small number of passengers waiting to evacuate, it might be advisable to re-direct passengers to other emergency exits.

Reference 40: New Evacuation Techniques – Anna Damski (British Airways) and Laurie Richardson (Boeing Aircraft): Paper presented at the Civil Aviation Training Conference in Lausanne in the spring of 1997.

Exit 'by-pass': Emergency exit 'by-pass' is similar to 're-direction' and is intended to pass an overloaded exit on one side of the passenger cabin and direct passengers into another cabin area that has fewer passengers waiting to evacuate and to exits that may have already dried-up. Exit 'by-pass' is probably only an effective procedure on twin-aisle aeroplanes. This issue was identified in the first Boeing 777-200 CS 25.803 demonstration when a cabin crew member at an unavailable Type A exit only directed passengers across the aisle to the opposite available Type A exit, rather than re-direct them into a forward cabin where there was Type A exit which had dried-up and was available for evacuation.

Cabin crew procedures and training for the second and third Boeing 777-200 full-scale evacuation demonstrations reflected the above procedures, but some twenty years after the initial Type Certification it is possible that some operators of the Boeing 777-200 do not actually include the above in their cabin crew procedures and training.

9.33 Availability and use of emergency exits, evacuation slides and airstairs

In many accidents some emergency exits and evacuation slides will not be usable and it is partly for this reason that the CS 25.803 demonstration is conducted with only 50% of the exits available. While this 50% availability might be considered as a worst case scenario, there have been accidents in which fewer than 50% of exits were available. For example, in the accident that occurred on 30 July 1992, involving a Lockheed L1011 TriStar operated by Trans World Airlines, (Flight Number 843), at New York, USA, only three of the eight floor level exits were usable throughout the evacuation. (See Case Study at 11.3.)

The unavailability and/or use of emergency exits are subject to several factors. These include:

- Exits that cannot be opened because the operating system has failed.
- The flight crew have instructed that an evacuation be conducted via only certain exits.
- The cabin crew identify external hazards, such as fire or debris.
- In a ditching some exits might be close to, or under the waterline, and/or are not designated as ditching exits.
- Crew members have become incapacitated and are not able to open exits.
- Evacuation slides have deployed, but have not inflated correctly, or have been subject to damage.
- Evacuation slides have been deployed, but there is a problem with the angle of the slides due to a partial or total collapse of the landing gear.

EASA, in their 2009, CS 25 Study concluded that there was evidence of emergency exits jamming, resulting in occupant fatalities, during post-crash fires. It was determined that further research was required to establish the level of the cabin safety threat in respect of exit jamming and the extent which it might be mitigated by amendments to airworthiness requirements.

On 27 May 2016, a Boeing 777-300 operated by Korean Air, (Flight Number 2708), was taking off from Haneda Airport, Tokyo, Japan, when there was an uncontained engine failure of the number one engine resulting in a serious fire affecting the port wing. All of the five Type A emergency exits on the right side of the aeroplane were operated as well as exit L1. The evacuation slide at Door R5 inflated underneath the fuselage and was unusable throughout the evacuation. However, all 302 passengers and 17 crew evacuated the aeroplane. (See Case Study at 11.11.)

In an evacuation cabin crew will need to have a good sense of 'Situational Awareness' especially with respect to emergency exit and evacuation slide availability and usability. An exit and evacuation slide that is initially identified by cabin crew as usable, might become unusable after slide deployment. Conversely an evacuation slide when initially deployed and identified as unusable might become usable in certain circumstances. An example of this is the accident on 3 August 2016 involving a Boeing 777-300 operated by Emirates at Dubai, UAE, (Flight Number 521). In this accident mainly due to adverse wind conditions and external fire, several of the exits opened by cabin crew could not be used in the evacuation because some of the slides were blown against the aeroplane fuselage, or

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did not reach the ground due to the high winds or the aeroplane attitude. One evacuation slide was lifted off the ground by the high wind and was initially identified as unusable, but one of the RFFS personnel noticed the problem, and held the evacuation slide to the ground allowing the cabin crew to redirect passengers to this exit. (See Case Study at 11.14.) Another example of cabin crew awareness of emergency exit and evacuation slide usability and the need to assess and re-assess external conditions, is the evacuation of a Boeing 777-200 at Las Vegas in September 2015. In this accident external fire and problems with slide deployment were factors affecting safe evacuation. (See Case Study at 11.10.)

In their Safety Study of Evacuations of Large Passenger-Carrying Aircraft, the TSB identified that the use of airstairs in an emergency evacuation could be problematic. In three separate occurrences involving Boeing 737 aeroplanes, the commander decided to disembark passengers via the forward airstairs since no immediate threat to life was perceived. Following significant delays in attempting to deploy the airstairs, the evacuation slides had to be used. This was also the case for one incident involving a McDonnell Douglas DC-9 aeroplane.

9.34 Emergency exit and evacuation slide training devices

AAs require that flight crew and cabin crew receive practical training in the use of emergency exits and evacuation slides. Many operators use exit and evacuation slide training equipment rather than conduct this training on an actual aeroplane. Such equipment should be representative in terms of exit operational forces and evacuation slide heights of the aeroplane to be operated. Operators should have a maintenance schedule for such equipment, and AA audits should include this issue.

See Recommendation 17.

10 RELEVANT RESEARCH AND SAFETY STUDIES

10.1 Research at Cranfield University – Evacuation

The 1985 Manchester accident caused an increased focus on emergency evacuation. Many research projects were conducted, and associated papers were published by various agencies, including the UK CAA, the FAA and TCCA. In January 1986 the UK CAA published AN 79, which required changes to passenger seat configuration at Type III and Type IV emergency exits in order to speed up access to, operation of and egress through such exits. The requirements introduced by AN 79 were based on subjective assessments made by the UK CAA, and were intended to be initial changes prior to research being conducted on issues involving evacuation.

The UK CAA initiated a wide-range of research work at the Cranfield Institute of Technology (now Cranfield University). In addition to Type III exit evacuation trials the UK CAA also wanted to address the issue of evacuation through bulkheads leading to Type I floor level emergency exits. The need to confirm and justify the changes introduced by AN 79 was of paramount importance. Many aspects of emergency evacuation were considered and passenger behaviour was an important part of this research. In trying to replicate some of the passenger competitive behaviour that was experienced in the Manchester accident, test participants were offered a small financial reward if they were among some of the first passengers to evacuate through either overwing Type III exits or Type I floor level exits. The results of these tests showed that it took very little incentive in a controlled test environment to encourage people to aggressively compete with each other.

Such competitive behaviour also occurred in the 1984 Calgary accident when there was some pushing and several passengers went over seat backs to get to the emergency exits ahead of other passengers who were queuing in the aisle. This was also the case in the Manchester accident and was similar to that identified in the Cranfield evacuation tests. The Cranfield Test Director stated: *“In a situation where an immediate threat to life is perceived, rather than all passengers being motivated to help each other, the main objective which will govern their behaviour will be survival for themselves, and in some instances, members of their family. In this situation, people do not work collaboratively and the evacuation can become very disorganised.”* (Ref: 41)

Initial tests at Cranfield in 1987 continued for several years, and included many variations, such as competitive and non-competitive participant behaviour, as well as assertive and non-assertive cabin crew actions at Type I floor level emergency exits. The research in 1987 and 1988 regarding access to and ease of operation of Type III exits confirmed that the subjective assessments made by the UK CAA in 1985 were valid, although some minor adjustments were subsequently made to CAA AN 79.

The following issues were addressed in UK CAA-funded trials at Cranfield which also had the support, collaboration and funding from the FAA and TCCA.

- Access to and operation of Type III exits – competitive and non-competitive.
- Access past bulkheads leading to Type I floor level exits – competitive and non- competitive.
- Cabin crew assertiveness and non-assertiveness at Type I floor level exits.
- Evacuation in conditions of water spray/mist.
- The effectiveness of passenger safety briefings.

10.2 Research at Cranfield University – Type III emergency exit design

Given the problems that passengers had with the operation Type III exit hatches in the 1985 Manchester accident, the UK CAA determined that research was needed to ascertain if a self-supporting and semi-automatic exit hatch might be a feasible option. In 1993 the UK CAA funded a research project with Cranfield to look into the possible improvements that might be made to Type III

Reference 41: Flight Safety Foundation – Cabin Crew Safety – Volume 25, Number 2 March/April 1990: Helen Muir and Clare Marrison. Human Factors in Cabin Safety.

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emergency exit design (Ref: 42). After many tests, Cranfield developed a Type III exit hatch system that ran on two tracks into the upper crown area of the passenger cabin. This new design incorporated a spring mechanism to assist in lifting the exit hatch upwards along the tracks to an upper stowage position. As a result, the effort required to open the exit was minimal and a safe stowage location for the hatch was assured.

At the same time Boeing was developing the Boeing 737 NG aeroplane and developed a Type III emergency exit hatch that opened outwards on two hinges that were spring loaded and only required a single movement to operate the exit, which remained attached to the fuselage. It required no action with respect to exit hatch disposal. This new Type III exit hatch was approved by the FAA and has been installed on all Boeing 737 variants from the B737-600 onwards.

10.3 Research at Greenwich University - Mathematical and fire modelling for evacuation

The UK CAA for many years funded research projects at the University of Greenwich regarding the development of an evacuation model initially known as EXODUS and later as airEXODUS.

In April 2005 CAA Paper 2004/05, (Ref: 43) set out to determine how computer models might be reliably used for certification applications such as CS 25.803.

Applications for the use of airEXODUS include:

- Aeroplane design.
- CS 25.803 evacuation testing.
- Aeroplane crew training.
- Aeroplane crew emergency evacuation procedures.
- Operational issues.
- Accident investigation.

Greenwich University has continued research on mathematical modelling for many evacuation scenarios and has issued numerous papers on this subject. Additionally the Fire Safety Engineering Group (FSEG) at Greenwich University has worked for many years on fire modelling for evacuation in respect of many types of transport, as well other fire scenarios such as buildings. In a paper published in January 2017, this work coupled fire and evacuation simulation tools (SMARTFIRE and airEXODUS) were used to numerically investigate the Manchester accident.

The paper looked at many aspects of the 1985 Manchester accident including the emergency evacuation, the external fire, burn-through into the passenger cabin and the subsequent internal fire. The paper identified several important issues, some of which were reflected in the AAIB Accident Report. Of particular interest were:

- The delay and difficulty in opening the three available emergency exits (i.e. 50% of the emergency exits installed on the aeroplane).
- The positioning of the aeroplane and the direction of the wind.
- The size of the external fuel pool fire, which FSEG estimated to be 16 square metres.
- The speed of burn-through of the fuselage and penetration of the external fire into the passenger cabin, which the FSEG estimated to be one minute after the aeroplane came to a stop.
- The spread of the fire within the passenger cabin and the effects on occupants of inhalation of toxic fire gases and exposure to the heat of the fire.

Reference 42: CAA Paper 97006. The Design and Evaluation of an Improvement to the Type III Exit Operating Mechanism.
Reference 43: CAA Paper 2004/05. Report on the Testing and Systematic Evaluation of the airEXODUS Aircraft Evacuation Model. Date of Paper: September 1997.

10.4 NTSB Safety Study - Emergency Evacuation of Commercial Airplanes (2000)

In 2000, the NTSB issued a *Safety Study of Emergency Evacuation of Commercial Airplanes* in which they examined accidents and incidents involving US Part 121 operators and identified many of the issues that are reflected in this paper.

The NTSB Safety Study included all 42 emergency evacuations that occurred during a 16-month period (on average, one evacuation every 11 days). The Study contained 20 safety recommendations directed to the FAA and reiterated three additional recommendations that had been made previously. Some of the recommendations address the following issues:

- New aeroplanes should meet the evacuation demonstration requirements of CS 25.803, irrespective of the number of passenger seats installed.
- All commercial operators should comply with the partial evacuation requirements of 14 CFR 121.291, irrespective of the number of passenger seats installed.
- Cabin crew on the Fokker 100 (and Fokker 28) should be seated adjacent to the overwing Type III emergency exits.
- The 6 foot (1.8 metre) criteria for evacuation slides should be re-evaluated taking into consideration injuries sustained in emergency evacuations.
- Advisory material to address the issue of cabin baggage in emergency evacuations should be developed.

10.5 TSB Safety Study - Evacuations of Large Passenger-Carrying Aircraft (Modified 2013)

The TSB in their *Safety Study of Evacuations of Large Passenger-Carrying Aircraft* of 2013 (Modified) identified many of the issues that are reflected in this paper.

The Safety Study included the following evacuation issues:

- The passenger cabin environment.
- Exit operation.
- Crew communications.
- Passenger behaviour, including that of passengers seated in exit rows.
- Passenger preparedness.
- Pre-landing briefings.
- Fire, smoke and toxic fumes.
- Flammability requirements for passenger cabins.
- Emergency exit doors, overwing exits and airstairs.
- Evacuation slide failures.
- PA systems.

10.6 EASA Study on CS 25 Cabin Safety Requirements – Issue 6 (2009)

In December 2009 EASA issued a Study on CS-25 Cabin Safety Requirements. Many of the issues addressed in this EASA study are dealt with in this RAeS paper.

The aim of the EASA study was to consider threats to cabin safety and identify potential amendments to CS 25. Seven of the cabin safety threats were identified as having potential to involve amendment to CS 25, and EASA determined that they would need to be addressed by Regulatory Impact Assessment. These seven cabin safety threats were:

- Power supplies for public address, interphone, and evacuation alert systems.
- Occupant protection from post-crash fire and smoke.
- Requirements for fire protection in remote/isolated compartments not permanently occupied during flight.
- Reliability of the emergency flight deck access system.



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- 'Return to seat' signs and intelligibility of public address systems in areas where the occupants are not normally seated.
- External viewing means.
- Passenger emergency exit locator signs.

The EASA CS 25 Study also identified recommendations for further research of cabin safety threats including many issues relating to emergency evacuation:

- Evacuation alert systems.
- Cabin crew communications.
- Effects of seat spacing on the overall dynamics of an evacuation.
- Crashworthiness standards.
- Protection from lower limb injuries during impact.
- Emergency conditions during a landing on water.
- Effect of wind on evacuation slides.
- Evacuation slide design to minimise injury to occupants in an evacuation.
- Jamming of exits in an emergency evacuation.
- Location of emergency exits in low level visibility.
- Monitoring of the passenger cabin by cabin crew.
- Effectiveness of cabin crew seat location during an emergency evacuation.
- Appropriateness of current minimum sill height for requiring an assist means.
- Adequacy of the terminal edge height measurements with regard to flap positions during an emergency evacuation.
- Effect of Type emergency III exits not having a foothold.
- Evacuation issues on aeroplanes with multiple stairways between passenger decks.
- The risks related to the jamming of the only ditching exit on aeroplanes with 35 or fewer passenger seats installed.

11 CASE STUDIES OF EMERGENCY EVACUATIONS

Whilst this paper identifies many problems that have influenced emergency evacuations, there are also many examples of evacuations that have been conducted effectively and efficiently by both flight crew and cabin crew. Most accidents are survivable including some of the most life-threatening events. Even in the worst case accident scenarios a significant number of passengers and crew will survive. The flight crew and the cabin crew play an essential role in the evacuation of passengers and the saving many lives can be attributed to their actions. In this respect, cabin crew emergency procedures and training are equally important as flight crew procedures and training. Some of the following accidents were clearly catastrophic, but survivable. Although some of these evacuations occurred some time ago, there are lessons that still have relevance today.

Accident Report References are at Appendix 1.

11.1 2 May 1970 - Overseas National Airways – McDonnell Douglas DC-9 - St Croix, US Virgin Islands

On 2 May 1970, a McDonnell Douglas DC-9 operated by Overseas National Airways Inc (Flight Number 980) departed New York, USA non-stop for St Marteen, Netherlands Antilles. According to the NTSB Accident Report, due to bad weather at St Marteen a diversion to St Croix, Virgin Islands, was initiated but due to several factors including reduced visibility the DC-9 ran out of fuel and ditched into the sea.

According to the NTSB Accident Report, some ten minutes before the DC-9 ditched the commander instructed the SCCM to instruct passengers to don their lifejackets. The SCCM thought that this order was a precautionary measure and assumed that further information would be provided if a ditching was necessary. A critical issue was the inoperative flight deck microphone for the PA system and, as a result, no direct instructions from the flight crew were given to the passengers. Several passengers and one cabin crew member were still standing at the time of impact with the water, and at least five passengers did not have their seat belts fastened.

The NTSB Accident Report stated that once the DC-9 had ditched, one of the flight attendants and the flight navigator attempted to open the L1 emergency exit but found it to be jammed and inoperable. One of the flight attendants opened the R1 exit. Three of the crew then attempted to free the life-raft from the galley equipment but it inadvertently inflated blocking the galley area from the passenger cabin. At least one passenger and four crew members evacuated at the R1 exit. The commander evacuated via the flight deck window and swam to the left side overwing Type III exits and opened them. The aft right side overwing Type III exit was opened by a passenger and most of the surviving passengers evacuated via this exit.

None of the five life-rafts were successfully launched by the crew, and although the US Coast Guard dropped life-rafts, none were able to be used. Of the 57 passengers, three flight crew, and three flight attendants on board, 22 passengers and one flight attendant did not survive the accident. All survivors were rescued by US Coast Guard, US Navy and US Marine Corps helicopters.

The NTSB concluded: *“...that the probability of survival would have been increased substantially in this accident if there had been better crew coordination prior to and during the ditching.”*

11.2 20 November 1985 - British Airways - Boeing 747-100 - Lajes, Azores, Portugal

On 20 November 1985, a Boeing 747-100 operated by British Airways, (Flight Number 256), was en-route from Barbados to London Heathrow, when a flight deck warning light came on indicating a smoke or fire problem in the aft cargo compartment. This Boeing 747-100 had the overwing Type A emergency exits de-activated (L3 and R3).

The aeroplane commander decided that a diversion to the US Air Force base at Lajes in the Azores was necessary. There was adverse weather reported at the time at Lajes with heavy rain and high

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cross-winds at 25 knots steady gusting to 35 knots. By the time of landing at Lajes the weather had deteriorated with heavy rain and cross-winds at 45 knots steady and gusting to 55 knots. After landing at Lajes, the commander decided that the best option was to order an emergency evacuation due to the lack of airstairs or other equipment suitable for the safe disembarkation of passengers from a Boeing 747.

The high cross-winds initially affected the usability of the emergency evacuation slides, which when first deployed were in a horizontal attitude. The emergency evacuation of 333 passengers, three flight crew and 15 cabin crew was successfully completed in approximately one minute from the command to evacuate (two minutes and 43 seconds after touch-down).

There were some minor injuries to 12 passengers, most of which were caused by the heavy rain that created a waterfall effect on the deceleration pads of the evacuation slides, resulting in a high speed of exit from the end of the slides by passengers and crew.

Note: No Accident or Incident Report could be identified.

11.3 30 July 1992 - Trans World Airlines - Lockheed L1011 TriStar - New York, USA



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On 30 July 1992, a Lockheed L1011 TriStar, operated by Trans World Airlines (TWA), (Flight Number 843), aborted take-off immediately after lift-off from John F Kennedy International Airport at New York, USA. On board were 280 passengers, three flight crew and nine flight attendants. According to the NTSB Accident Report the aeroplane was airborne for approximately six seconds and came to rest upright and on fire about 100 metres to the left of the departure end of the runway. The aeroplane was immediately engulfed with fire and was totally destroyed.

The L1011 TriStar had 8 Type A floor level exits but because of the post-crash external ground fire the only available exits in this accident were the forward exits at L1, R1 & L2. The flight attendant at L2 had difficulty in identifying the external conditions via the emergency exit window.

Given the lack of available emergency exits and in spite of the potential difficulties of passenger management, the evacuation was successfully completed in approximately two minutes. Five 'dead-heading' flight attendants assisted in the evacuation. The NTSB Accident Report stated that *"The Safety Board believes that if there had not been an extra flight attendant near the L2 exit, that exit might not have been opened and the evacuation might have been delayed. In addition, the timeliness of the evacuation was augmented by the fact that the extra flight attendants were in areas of the cabin other than exit doors, where they assisted in keeping passengers moving to and through available exits."*

Additionally the NTSB Accident Report stated that the speed in evacuating 280 passengers was complemented by the TWA requirement for nine flight attendants rather than the FAA minimum requirement of six flight attendants. It is the opinion of the FOG that had only six flight attendants been carried resulting in two Type A floor level emergency exits not being managed by a crew member, then the evacuation time might have been extended with potentially serious consequences. There were no fatalities to passengers or crew although one passenger sustained serious injuries.

11.4 14 September 1999 - Britannia Airways - Boeing 757-200 - Girona, Spain



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On 14 September 1999, a Boeing 757-200, operated by Britannia Airways, (Flight Number 226A), was on its second attempt to land in adverse weather conditions at Girona, Spain, when it suffered a main landing gear failure on touch-down. On board were 236 passengers, two flight crew and seven cabin crew. The aeroplane left the runway and travelled some 350 metres before hitting a mound, becoming semi-airborne and then hitting a number of small trees and a boundary fence. The Boeing 757 came to rest in a field off the airport.

It was some time before Girona ATC became aware of the accident and a search by RFFS was initiated. It was some 18 minutes before the aeroplane was located and a further 14 minutes before RFFS gained access to the crash site.

The damage to the airframe was substantial and the fuselage was fractured in two places. The situation was obviously critical. The evacuation was conducted in total darkness, torrential rain and with no assistance from the Girona RFFS.

Due to the undercarriage failure, the aeroplane was resting on its belly and some of the slides failed to inflate. The slides that did inflate were only deployed at a very shallow angle and quickly filled with rainwater. There was no fire and this was obviously a relevant factor in the survivability of this accident.

The following emergency exit and evacuation slide issues were identified in the Spanish Accident Technical Report:

Exit:	Exit status:	Evacuation slide status:
L1	Exit found to be fully open.	Slide dropped 0.6m to the ground but did not inflate.
R1	Exit found cracked open.	Slide found armed but not deployed.
L2	Exit found fully open.	Slide found inflated.
R2	Exit found fully open.	Slide found inflated.
L3	Exit found closed.	Slide armed but not inflated.
R3	Exit found fully open	Slide inflated.
L4	Exit found fully open.	Slide dropped 0.6m to the ground but did not inflate.
R4	Exit found cracked open.	Slide armed but not deployed.

According to the Spanish Accident Technical Report, passengers rapidly evacuated the aeroplane via the available emergency exits. By the time the flight crew had completed their evacuation drills most of the passengers had evacuated.

There were no fatalities to passengers or crew, although one passenger died after the accident, possibly due to a pre-existing medical condition.

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11.5

2 August 2005 - Air France - Airbus A340-300 - Toronto, Canada



Paul Cardin.

On 2 August 2005, an Airbus A340-300, operated by Air France, (Flight Number 358) touched down on runway 24L at Toronto, Canada, but according to the TSB Accident Report further along the runway than usual, and was unable to stop. It departed the end of the runway and came to rest in a shallow gully with its fuselage split into several pieces. Approximately four minutes later, the A340 fuselage erupted in flames. On board were 297 passengers and 12 crew.

The weather at the time of the accident was a crucial factor, with severe winds, heavy rain, localised thunderstorms and lightning in the immediate vicinity of the airport.

When the aeroplane came to a stop the SCCM quickly became aware of the external fire. When the commander was advised of this and the need to initiate an evacuation the commander pushed the EVAC ON pushbutton to activate the evacuation alert system which then failed to respond. The cabin crew then commanded the evacuation at four of the eight emergency floor level emergency exits.

There were several issues with emergency exit availability and usability. R1 and R2 emergency exits were initially assessed as unusable due to their proximity to a water-filled creek. However, as the evacuation progressed the cabin crew reassessed the situation and decided that the emergency exits would have to be used in order to expedite the evacuation given the increasing level of smoke in the passenger cabin.

The following emergency exit and evacuation slide issues were identified in the TSB Accident Report:

Exit:	Exit and evacuation slide status and use:
L1	Exit opened - slide partially inflated - punctured and deflated - used by some passengers.
R1	Exit initially assessed as unusable – slide deployed at a shallow angle – subsequently used by some passengers.
L2	Became open during impact – slide not deployed – assessed as unusable – unattended part of the time during the evacuation – used by 16 passengers – two seriously injured.
R2	Exit initially assessed as unusable – slide deployed - subsequently used – slide deployed – used by some passengers.
L3	Exit not opened due to proximity of external fire – exit blocked by cabin crew and passengers re-directed.
R3	Exit opened – slide deployed then deflated and assessed as unusable. Two passengers evacuated – exit closed and passengers re-directed.
L4	Exit not opened due to proximity of external fire.
R4	Exit opened with difficulty – slide deployed – exit used by two-thirds of passengers.

All passengers were rapidly evacuated but due to the problems with some of the emergency exits and evacuation slides, there were some 50 injuries. There were no fatalities to passengers or crew.

11.6

17 January 2008 - British Airways - Boeing 777-200 - London Heathrow, UK

On 17 January 2008, a Boeing 777-200 operated by British Airways, (Flight Number 38), crash landed some 270 metres (890 feet) short of Runway 27L at London Heathrow, UK. On board were 136 passengers, three flight crew and 13 cabin crew. The AAIB Accident Report determined that the

cause of this accident was ice crystals that had formed in the fuel during the flight and blocked the engine fuel filters causing the engines to flame out.

There was not enough time for the commander to brief the cabin crew on the emergency landing or issue a 'brace' command. Initially the commander ordered the evacuation over the VHF radio but this was then repeated over the cabin interphone system. The commander activated the evacuation alarm system but this was not heard clearly by the cabin crew who initiated the evacuation. Cabin crew opened all of the eight floor level Type A emergency exits and deployed the evacuation slides. At the L2 exit the cabin crew identified that there was debris at the bottom of the evacuation slide and decided to block the exit and redirect passengers to L1 and R2. The lack of fire and any significant damage in the passenger cabin resulted in an efficient and speedy evacuation and with the cabin crew providing clear instructions to evacuating passengers.

Some of the passengers took cabin baggage with them in the evacuation and one passenger re-entered the passenger cabin via the evacuation slide at exit L4 after having successfully evacuated, to retrieve their personal belongings.

Of the 152 occupants on board, 46 sustained injuries one of which was serious. There were no fatalities.

11.7 15 January 2009 - US Airways - Airbus A320-200 - Hudson River, New York, USA



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On 15 January 2009, an Airbus A320-200, operated by US Airways, (Flight Number 1549), departing La Guardia Airport at New York, struck a flock of Canada Geese on initial climbout. According to the NTSB Accident Report, the aeroplane suffered an immediate and almost complete loss of thrust in both engines. On board were 150 passengers, two flight crew and three flight attendants. Air temperature at the time of the accident was approximately 19°F (-7.22°C) with a wind chill factor of 2°F (-16.7°C).

The commander decided that there was no possibility of safely reaching any alternative runway and that he had no option than to ditch in the Hudson River. The commander turned the A320 south, gliding down the Hudson River and successfully ditched the aeroplane.

The A320 floated nose up with the aft emergency exits at or below the waterline.

The L1 Type I floor level emergency exit was opened by the flight attendant but the slide/raft did not inflate until she pulled the manual inflation handle. The R1 Type I floor level exit was opened by the other forward flight attendant but the exit did not engage the 'gust' lock so she assigned an 'able-bodied' passenger to keep the exit door off the evacuation slide. The flight attendants evacuated the passengers via these floor level exits onto the slide/rafts.

In the middle of the passenger cabin the left overwing Type III exits were opened by passengers just 15 seconds after impact and the right exits were opened shortly afterwards. Passengers evacuated onto both wing surfaces which quickly became crowded and near to standing capacity. Many of the

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passengers who evacuated onto the wings were exposed to water up to waist level within two minutes.

The aft floor level Type I emergency exits were not usable due to the water level and the aft passenger cabin quickly filled with water up to the passenger seat pan level. The aft flight attendant reported that she found the aft left Type I floor level exit was “cracked” open but it was not clear who might have done this. The NTSB Accident Report stated: *“Flight attendant B reported that a passenger came into the aft galley and lifted the handle of door 2L, ‘cracking’ the door open; however, several passengers reported that the door was ‘cracked’ open before they arrived in the aft galley.”* In the aft passenger cabin passengers were queuing in the aisle to reach the overwing Type III exits. The aft flight attendant improvised the evacuation commands by shouting “go over the seats”. Several of these passengers by-passed the crowded overwing Type III exits and evacuated via the forward Type I floor level exits.

At the time of the accident US Airways were operating a fleet of 75 Airbus A320s, 20 of which were equipped for Extended Over Water (EOW) operations. The NTSB Accident Report stated: *“Although the airplane was not required by Federal Aviation Administration regulations to be equipped for extended overwater operations to conduct the accident flight, the fact that the airplane was so equipped, including the availability of forward slide/rafts, contributed to the lack of fatalities and the low number of serious cold-water immersion-related injuries because about 64 occupants used the forward slide/rafts after the ditching.”*

According to the NTSB Accident Report, in addition to approximately 64 occupants that were rescued from the two forward slide/rafts, about 87 occupants were rescued from the wings. The NTSB Accident Report stated: *“The flight attendants initiated the evacuation promptly, and, although they encountered difficulties at their exits, they still managed an effective and timely evacuation.”*

Several boats in the vicinity immediately went to the aeroplane to rescue the survivors. The first arrived at the aeroplane four minutes after the ditching. If the rescue boats had arrived later at the ditched aeroplane it is likely that some of the passengers would have drowned due to shock or inability to swim in the cold water. The water temperature was approximately 41°F (5°C).

There were no fatalities to passengers or crew. Other factors associated with this event's successful outcome include that it occurred during daylight hours with good visibility and relatively benign winter weather conditions, apart from the very low temperatures, and with several boats nearby.

11.8 16 April 2012 – Virgin Atlantic – Airbus A330-300 – London Gatwick, UK

On 16 April 2012, an Airbus A330-300, operated by Virgin Atlantic, (Flight Number 27) returned to London Gatwick, UK, after a smoke warning in the aft cargo compartment. After a successful emergency landing an emergency evacuation was ordered by the commander.

All emergency exits were operated by the cabin crew and opened simultaneously. All the evacuation slides inflated and deployed, apart from the slide at R4 which inflated but did not deploy correctly due to an unbroken secondary restraint. Passengers at this exit were redirected to evacuate via L4. The AAIB Accident Report states: *“From the first sign of a door opening until the first exited the aircraft took approximately 12 seconds.”* Most of the passengers evacuated within one minute with all passengers and crew evacuating 109 seconds after the emergency exits were opened. Cabin crew stated that the evacuation was conducted in accordance with Virgin Atlantic SOPs, although some commented on the speed of passenger descent down the evacuation slide and one stated that it was *“more violent than in training”*.

Cabin crew were surprised that passengers were generally quiet during the evacuation but that some stopped to try and bring cabin baggage with them. Several passengers did not jump into the evacuation slides and sat on the exit sill before entering the slides. Some passengers slowed their evacuation because they were carrying cabin baggage. The AAIB Accident Report states *“A number of passengers stated they took their hand baggage with them whereas others commented that passengers retrieving hand baggage from overhead lockers delayed the evacuation.”*

Gatwick RFFS manned the bottom of the evacuation slides and reported that some passengers coming off the evacuation slides appeared to be in pain. The AAIB Accident Report states: *“A number of passengers landed awkwardly at the bottom of the slides and many toppled forward onto the concrete suffering minor injuries. Passengers on the slides were very close to each other and many did not have the time to clear the area at the bottom of the slide before being hit by the following passenger.”* At one emergency exit the RFFS asked the cabin crew to slow down the evacuation rate due to the number of passengers blocking the toe end of the evacuation slide.

Whilst it was not possible to identify the number of passengers using each exit it was estimated that 15 occupants evacuated via R1, 30 occupants via R2 and 25 occupants via R3. Some 244 occupants evacuated via L1, L2, L3 and L4.

The AAIB made two Safety Recommendations to EASA: one in respect of passenger briefing and the need to emphasise that passengers leave cabin baggage behind in an evacuation, and one in respect of advice to passengers, including those with young children, on the use of evacuation slides.

11.9 6 July 2013 - Asiana Airlines - Boeing 777-200 - San Francisco, USA



Alexander Nevarro.

On 6 July 2013, a Boeing 777-200 operated by Asiana Airlines, (Flight Number 214), crashed on final approach to San Francisco, USA, with a descent below the glidepath resulting in an impact with a seawall. On board were 291 passengers, four flight crew and 12 flight attendants.

According to the NTSB Accident Report, the main landing gear impacted the seawall, and the tailplane separated from the fuselage at the aft pressure bulkhead. The impact forces exceeded certification limits. This resulted in two of the slide-rafts inflating inside the passenger cabin and initially trapping two of the flight attendants in their seats.

Four of the flight attendants seated in the aft galley area were ejected from the aeroplane during the impact when the tail plane separated from the fuselage and were restrained by their crew harnesses. Two passengers who were not wearing their seats belts were also ejected from the aeroplane during the impact and were killed. It is likely that these two passengers, if they had been restrained by their seat belts, would have remained inside the passenger cabin and would have survived.

When the SCCM came to the flight deck to ask for information about initiating an emergency evacuation she was instructed to ‘standby’ and then told ‘No, please wait’. The SCCM then made a PA telling passengers to remain seated. Immediately after this PA from the SCCM, the command to evacuate was given by the flight crew over the PA. It seems that the first emergency exits (L1 and L2) were opened 1 minute and 33 seconds after the aeroplane came to a final stop, and approximately 10 seconds later passengers started to evacuate. Most of the passengers evacuated via the forward exits. Two of the flight attendants were trapped in their seats because of deployment of evacuation slides inside the passenger cabin at Doors R1 and R2. They were released from their seats with some difficulty by crew and passengers.

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The following difficulties affected the emergency evacuation:

- Significant impact forces.
- Separation of the tailplane from the fuselage.
- External and internal fire.
- Deployment of two evacuation slides inside the passenger cabin that blocked an emergency exit and trapped two flight attendants.
- No evacuation command was given by the flight crew.
- Injuries to flight attendants – only one flight attendant at the back of the passenger cabin was able to assist in the evacuation.

Despite of the difficulties encountered, there were only three fatalities all involving passengers, including the two who were not wearing their seat belts at the time of impact and were ejected outside of the aeroplane. There were 49 serious injuries and 138 minor injuries to passengers and aeroplane crew. A substantial number of occupants received no injuries. Despite clearly catastrophic circumstances, some passengers still decided to evacuate with their cabin baggage.

11.10 8 September 2015 - British Airways – Boeing 777-200 - Las Vegas, USA



Jordan Masters.

On 8 September 2015, a Boeing 777-200 operated by British Airways, (Flight Number 2276), suffered an uncontained failure of the number 1 engine on take-off from Las Vegas, USA. On board were 157 passengers, three flight crew and ten cabin crew.

The commander aborted the take-off and sent one of the First Officers into the passenger cabin to assess the situation. It is understood that the First Officer had difficulty getting to L2 because passengers were standing in the aisle. A significant fire was identified in the Number One engine at the area of L2 and the commander ordered the evacuation.

The following emergency exit and evacuation slide issues were identified in the NTSB Survival Factors Report.

Exit:	Exit and evacuation slide status and use:
L1	Exit opened and slide inflated – after five passengers had evacuated flames were evident and passengers were re-directed to R1.
R1	Exit opened and slide inflated – the cabin crew member reported being pushed by a passenger and had to grab the assist handle. Passengers evacuated.
L2	Exit not opened due to external fire. Passengers re-directed to R1.
R2	Exit not opened due to external fire. Passengers re-directed to R1.
L3	Exit not opened due to external fire. Passengers re-directed to R3, L4 and R4.
R3	Exit opened and slide inflated but did not deploy in a usable attitude. Passengers re-directed to 4L.
L4	Exit opened and slide inflated. Passengers evacuated.
R4	Exit opened and slide inflated but did not deploy in a usable attitude – it was twisted and being blown by the wind. Passengers re-directed to L4.

The NTSB Survival Factors Report mentioned the following:

- Passengers were quickly out of their seats in spite of P/As to remain seated.
- Flight crew and cabin crew were quickly aware of an external fire on the left side of the aeroplane.
- Many passengers took cabin baggage with them in the evacuation.
- In the area of L3 an elderly woman fell in the aisle and other passengers “walked over her”.
- The evacuation was completed in approximately 2 minutes and 32 seconds.
- Some 55 passengers evacuated via R1 and some 105 passengers evacuated via L4.
- Five cabin crew and three flight crew evacuated via R1. Five cabin crew evacuated via L4.

There were no fatalities to passengers or crew. One cabin crew member sustained a serious injury and 19 passengers sustained minor injuries.

11.11 27 May 2016 - Korean Air - Boeing 777-300 - Tokyo, Japan



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On 27 May 2016, a Boeing 777-300 operated by Korean Air, (Flight Number 2708), suffered an uncontained failure of the number 1 engine on take-off from Tokyo, Japan. On board were 302 passengers and 17 crew. In the emergency evacuation five emergency exits on the right side of the aeroplane were operated as well as exit L1. The evacuation slide at Door R5 inflated but deployed underneath the aeroplane fuselage and was not useable during the evacuation. It has been reported that there were no fatalities and some 12 non-fatal injuries.

Note: No Accident Report was available at the time of publication of this paper. The above information is based on best information available at time of publication of this paper.

11.12 26 June 2016 – American Airlines – Airbus A330-300 – London Heathrow, UK

On 26 June 2016, an Airbus A330 operated by American Airlines, (Flight Number 731) was evacuated at London Heathrow. UK when the passenger cabin filled with smoke after passengers had boarded. The aeroplane was still on stand and connected to the terminal via an airbridge at emergency exit L2. On board were 277 passengers, three flight crew, nine cabin crew and two ground staff. When smoke started to fill the passenger cabin the cabin crew attempted to contact the flight crew but without success, and one of the cabin crew initiated an emergency evacuation believing the situation to be life-threatening.

The UK AAIB investigated this incident and issued Bulletin 12/2017 in December 2017, in which they identified that there was a problem with the APU and that smoke entered the passenger cabin when an APU load compressor oil seal was compromised.

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Several cabin crew members had attempted to call the cockpit, but used the normal interphone call function. The flight crew, who were dealing with unrelated system defects along with other ground staff in the cockpit, did not notice the interphone call possibly because alarms had started sounding. Some of the cabin crew mistook the lavatory smoke alarm(s) with the emergency evacuation signal.

The cabin crew commenced an emergency evacuation, in accordance with their SOPs in circumstances when the flight crew could not be contacted. The commander attempted to halt the evacuation by making a PA announcement, thinking that he had already dealt with the source of the smoke by switching off the APU bleed. A major factor in this evacuation was the lack of communication between the flight crew and the cabin crew and vice versa. Many passengers had difficulty in hearing the instructions from the crew and some found these to be conflicting, confusing and contradictory. The AAIB concluded that this resulted in some confusion among the passengers.

Some 25 passengers evacuated via the aft two L4 and R4 exits. The L3 and R3 exits were opened by passengers with no cabin crew in the vicinity, but were not used in the evacuation. The exits at L1, R1 and R2 were not opened and the majority of passengers and crew evacuated via exit L2 which was connected to the airbridge. Although these actions might have been the most appropriate in this situation, it was not a procedure that the flight crew and the cabin crew were familiar with. It was concluded that better crew coordination and training was necessary.

The AAIB Bulletin identified the following emergency exit issues:

Exit(s):	Exit and evacuation slide status and use:
L1, R1 and R2	Exits not opened.
L2	Exit attached to the terminal airbridge.
L3	Exit opened by a passenger in the 'disarmed' mode. The evacuation slide did not deploy and fortunately no passengers attempted to evacuate via this exit.
R3	Exit 'armed' and opened by a passenger. Evacuation slide deployed but no passengers evacuated via this exit.
L4 and R4	Exit 'armed' and opened by cabin crew.

The AAIB issue several Safety Recommendations including one to EASA stating: *"It is recommended that the European Aviation Safety Agency require cabin crew on aircraft that are parked and with passengers on-board to be evenly distributed throughout the cabin and in the vicinity of floor-level exits, in order to provide the most effective assistance in the event of an emergency."*

This incident demonstrates the importance of CRM for all crew members and the operator has revised its procedures to reflect the difficulties encountered in this evacuation.

11.13 27 June 2016 - Singapore Airlines - Boeing 777-300 - Singapore



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On 27 June 2016, a Boeing 777-300 operated by Singapore Airlines, (Flight Number 368), returned to Singapore after the number 2 engine warning light showed a low oil quantity. According to the Singapore Transport Investigation Bureau Accident Report, on landing at Singapore the number 2 engine caught fire and the right wing became engulfed in flames. On board were 222 passengers, four flight crew and 15 cabin crew.

The Accident Report stated that there was no indication of the fire on the flight deck fire detection system. The Singapore RFFS Fire Commander advised the flight crew that they were trying to contain a large fire and advised disembarkation on the left side of the aeroplane. The flight crew placed a large degree of their decision making at this time on the information from the RFFS Fire Commander. Other resources of information that were not used by the flight crew included:

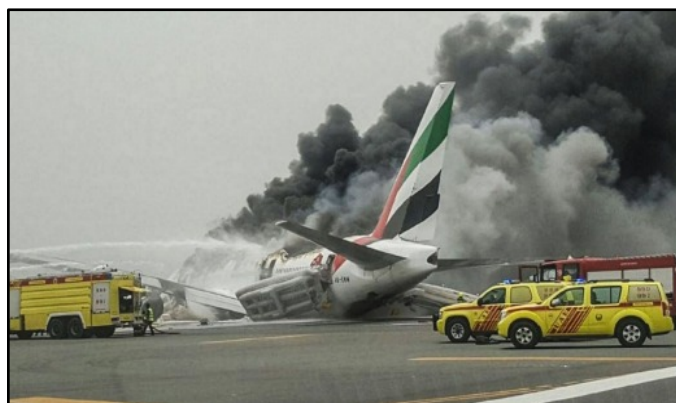
- The taxiing camera system installed at various locations on the aeroplane.
- The cabin crew who would have had a view of the right wing and engine area via the passenger cabin windows.

Additionally, the Accident Report stated: *“The flight crew could have opened the cockpit escape window on the right side to find out the situation outside. Extending the upper body out of the right escape window would allow a person to obtain a view of the fire situation at the right wing and engine area.”*

The commander decided to evacuate the passengers via mobile stairs which were positioned by ground staff at L1, rather than use the evacuation slides. Passenger disembarkation commenced approximately 20 minutes after the aeroplane came to a stop and it took another 21 minutes for the passengers and crew to disembark. There were no fatalities or injuries but circumstances could have been different if the external fire had spread or the right wing tank had exploded.

The Accident Report concluded that: *“The flight crew depended on the fire commander as their sole information source when deciding whether an evacuation was needed. Several other resources which could have aided them in making their decision were not utilised.”*

11.14 3 August 2016 – Emirates - Boeing 777-300 - Dubai, UAE



ANI.

On 3 August 2016, a Boeing 777-300 operated by Emirates, (Flight Number 521), crash landed on the runway at Dubai, UAE, after an attempted 'go-around'. On board were 282 passengers, two flight crew and 16 cabin crew. As the aeroplane slid along the runway, the Number 2 engine separated from the wing and an intense fuel fire was observed in this area, as well as fire to the underside of Number 1 engine.

After the aeroplane came to a stop the commander ordered the evacuation, but because of the high winds and the external fire there were issues with the evacuation.

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In the Emirates GCCA Air Accident Investigation Preliminary Report, the following emergency exit and evacuation slide problems were identified:

Exit:	Emergency exit status:	Slide status:
L1	Exit opened. It required two cabin crew to operate the exit and deploy the evacuation slide.	Slide deployed but detached from the aeroplane making the exit unusable.
R1	Exit opened,	Slide deployed but was blown by the wind against the fuselage and blocked the exit. Not usable for much of the evacuation but later on the slide settled to the ground and was used by some passengers.
L2	Exit opened. This exit should have been opened by one cabin crew member, but it required two cabin crew to operate the exit and deploy the evacuation slide.	Slide did not touch the ground. The slide was then blown by the wind against the fuselage making the slide unusable.
R2	Exit opened. Due to smoke in this area, evacuation of passengers and crew only took place later when the smoke cleared.	Slide deployed.
L3	Exit not opened due to external smoke.	N/A.
R3	Exit opened but due to external fire and smoke, passengers were re-directed to an alternative usable exit.	Not known.
L4	Exit opened.	Slide deployed but was blown by the wind against the fuselage and blocked the exit.
R4	Exit opened. Subsequent evacuation passengers were re-directed to another usable exit.	Slide deployed but evacuating passengers became stuck on the slide due to it becoming filled with fire-fighting water. Passengers re-directed to R5.
L5	Exit opened.	Slide deployed. Passengers initially evacuated via this exit but towards the end of the evacuation the slide was blown against the fuselage and blocked the exit.
R5	Exit opened.	Slide deployed. The slide was lifted off the ground by the wind and was not used until RFFS personal noticed the problem and held the slide down onto the ground.

In spite of the above problems, 282 passengers and 18 crew evacuated the Boeing 777-300 with only 24 injuries, one of which was serious. Dubai RFFS experienced the worst proportion of casualties during response to this accident with one fatality and eight injuries.

This was another accident in which passengers evacuated with cabin baggage. Images taken by passengers on mobile phones show overhead bins being open to retrieve baggage even though the evacuation had already commenced and a degree of urgency was obvious due to smoke in the cabin and the external fire. The Emirates General Civil Aviation Authority Preliminary Accident Report, stated: *"The cabin crew members followed the Operator's safety instructions that prohibit passengers taking their carry-on baggage during an evacuation, and they instructed the passengers to leave their bags behind. However, several passengers evacuated the Aircraft carrying their baggage."*



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Another recent occurrence is the number of passengers using mobile phones and other devices to take photograph during emergency evacuations. It is possible that such actions might contribute to delays at a critical time.

12 SUMMARY OF FACTORS INFLUENCING A SUCCESSFUL EMERGENCY EVACUATION

The accidents listed above demonstrate that no matter how bad the situation or substantial damage to the aeroplane, a very high level of occupant survivability can be achieved. Effective crew procedures, training and actions can play an important role in effecting a safe and rapid evacuation.

The procedures and training of flight crew and cabin crew in evacuation, ***appropriate to each specific type of aeroplane and variant that they operate***, is an essential element that should be reflected in both theoretical and practical training. Procedures and training should include the problems of inoperative or unavailable exits and necessary alternative procedures. Cabin crew identification of external hazards should be included in training, both for ground evacuation and ditching.

The importance of the selection and training of SCCM and their leadership qualities should not be underestimated. This is also the case for operations with a single cabin crew member.

The 'chain-of-command' is equally important, especially if larger aeroplane types are to be operated such as the Airbus A380, where more than the minimum required cabin crew will be on board in order to provide an adequate level of cabin service.

That said, smaller aeroplanes with fewer than 50 passenger seats installed, and only one cabin crew member is required, also presents important operational challenges with respect to emergency situations including evacuations.

All the above issues are reliant on several aspects of effective flight safety and most importantly crew coordination and communication.

In the event of a catastrophic accident, cabin crew will initially rely on the flight crew to provide them with essential information that might affect the evacuation. However, in circumstances where there is no information or evacuation command from the flight deck, the SCCM and other cabin crew members may have to initiate an evacuation. On very large aeroplane types, it is unrealistic for the flight crew to be aware of the specific situation(s) in the passenger cabins at the back of the passenger cabin or on another passenger deck.

The above accidents clearly demonstrate that flight crew and cabin crew procedures and training, together with leadership qualities and crew coordination are essential elements to the successful outcome of an aeroplane accident and the saving of many lives.

13 RECOMMENDATIONS

Recommendation 1 - Accident investigation - See Section 4.

Accident Investigation Agencies should identify all factors that might have an effect on an emergency evacuation in their accident reports, even if they did not impact on the outcome of the evacuation in that accident, but which might have an adverse or even positive effect in subsequent accidents.

Recommendation 2 - The number of required cabin crew - See Section 7.1

AAs should ensure that all commercial passenger aeroplanes comply with the applicable requirements with respect to the minimum number of required cabin crew, and that any person identifiable to passengers as cabin crew through their wearing a uniform is trained on the specific aeroplane type to be operated. The optimum criteria for twin-aisle passenger cabins is that one cabin crew member be seated for take-off and landing at each floor level emergency exit.

Recommendation 3 - Emergency Exit Location Identification - See Section 7.2

ICAO, or another appropriate agency, should develop terminology for emergency exit location identification so that, operators, fire rescue services, **AAs**, manufacturers and accident investigation agencies work to a consistent standard.

Recommendation 4 - Evacuation slides - See Section 8.3.

AAs should review the 1.8 metre maximum height criteria for evacuation slides, so as to minimise the risk of injury to crew and passengers especially to the elderly, the infirm and children, who would otherwise have to jump from such a height.

Recommendation 5 - Type III emergency exits - See Section 8.8.

AAs should consider a requirement for locating cabin crew seats at Type III emergency exits on larger aeroplane types in the following circumstances:

- When cabin crew primary procedures in an emergency evacuation require them to move from their cabin crew seats at either end of the passenger cabin to Type III exits to manage an evacuation;
- For ETOPS aeroplanes operating overwater and requiring life-raft(s) to be launched through Type III exits.

Recommendation 6 - Operation of emergency exits and passenger briefing - See Sections 8.8, 8.9 and 9.15.

AAs and aeroplane manufacturers should ensure that the operation of any emergency exit **must not** require exceptional effort and that this should be stated in certification requirements. The design, contrast and conspicuity of any wing surface escape routes should be clear and unambiguous in both daylight and dark conditions. **Operators'** safety briefings and safety cards should include information on all evacuation routes to be taken by passengers, including floor proximity lighting systems and overwing exits, and the need to reach the ground from the wing surface. This information should be reinforced by briefings of passengers in seat rows leading to Type III and Type IV exits and it is recommended that **ICAO** also consider this issue.

Recommendation 7 - New design of Type III and Type IV emergency exits - See Section 8.10

For aeroplanes with 40 or less passenger seats installed, **AAs** should encourage **aeroplane manufacturers** to consider the use of semi-automatic Type III and Type IV exits that open outwards, and stay attached to the fuselage, after having been operated. **AAs** should take into consideration Type III and Type IV exit hatch weight and establish a weight discriminate which, if exceeded, would require the installation of semi-automatic exit hatches.

Recommendation 8 - Evacuation procedures - See Section 8.14.

Irrespective of the number of passenger seats installed for initial type certification, **aeroplane manufacturers** should develop specific emergency evacuation procedures to assist operators in developing their own procedures for each type and configuration of aeroplane to be operated. This should take into account individual passenger cabin configurations where the number of passenger

seats installed in certain parts of the cabin might differ from those demonstrated in CS 25.803. Such procedures should also reflect any changes to emergency exit status such as exit de-rating or deactivation as well as any changes affecting cabin crew direct view.

Recommendation 9 - Airworthiness and operational liaison - See Section 8.18.

AAs, manufacturers and operators should ensure that there is effective liaison between their airworthiness departments and operational departments to address airworthiness issues that have a direct impact on operational procedures. Such issues include, but are not limited to:

- The location of cabin crew seats, assist spaces and direct view;
- The de-rating and de-activation of emergency exits;
- Crew rest areas and other areas for crew or passenger use in passenger cabins, or in lower lobe or upper crown areas, which will need specific operational procedures.

Additionally, **Operators** should conduct an appropriate risk assessment for emergency evacuation of each aeroplane passenger cabin configuration to be operated and this should include any changes that are introduced subsequent to the initial type certification of the aeroplane.

Recommendation 10 - The decision to evacuate and the evacuation command - See Sections 9.8 and 9.9.

Operators should ensure that the responsibility for the decision to evacuate the aeroplane rests with the commander or, in the event of his/her incapacity, with the next senior flight crew member or cabin crew members in successive order of authority, or any crew member if an obvious catastrophic and life-threatening event occurs. **Operators** should ensure that their aeroplane commanders receive specific LOFT training in the assessment of emergency situations and appropriate actions.

Recommendation 11 - CRM training - See Section 9.13 and 9.14.

Operators should ensure that communication and coordination between all aeroplane crew members in respect of emergency evacuation is addressed during combined flight crew and cabin crew CRM training on a continuous basis, and that SCCMs are included in appropriate LOFT sessions when practicable and this should also be included in single cabin crew member training if practicable. Training should include coordination between flight crew and ATC, between flight crew and cabin crew and with RFFS personnel as appropriate.

Recommendation 12 - Passenger seat allocation - See Section 9.16.

Operators should not charge for family members to sit together. This is especially important when adults and their children need to be seated near to each other if an emergency situation occurs, such as an evacuation, decompression or air turbulence, when the assistance and supervision of an adult is likely to be of paramount importance.

Recommendation 13 - Child Restraint Systems - See Section 9.17.

AAs should initiate a united approach to resolve the long outstanding and complex issues of child restraint systems.

Recommendation 14 - Wind direction in the event of a fire on the ground - See Section 9.26

Operators should emphasise in flight crew procedures and training the primary importance of expediting an evacuation through all available emergency exits in the event of a fire on the ground. If possible, flight crew should consider the effects of an external fire and wind direction that might compromise the integrity of an aeroplane fuselage and the availability of emergency exits in an evacuation. **Operators** should establish best practice for commanders with respect to aeroplane type-specific procedures to deal with ground fire situations. **Operators** should also ensure that cabin crew procedures address the suitability of usable emergency exits and different emergency scenarios when emergency exits might not be available because of external fires.

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Recommendation 15 - Cabin baggage - See Section 9.28.

Operators should ensure that cabin baggage allowed into passenger cabins is placed only in stowages designed to prevent movement (approved areas), and that effective checks are conducted during the check-in and boarding process to ensure this. Checks should take into account the size and weight of such items. The safe stowage and restraint of cabin baggage and other items in passenger cabins is the responsibility of both operators and aeroplane commanders. This should be enforced by a positive 'cabin secure check' being passed from the SCCM to the commander prior to push-back on departure and prior to landing, to confirm that all items in passenger cabins are correctly stowed. **Operators** should provide positive support to their commanders and cabin crew in this respect. **AAs** should consider the feasibility of introducing a certification requirement for a means of remotely locking, from the flight deck, overhead bins in passenger cabins that do not contain emergency equipment, for taxi, take-off and landing.

Recommendation 16 - Operational demonstration of evacuation procedures, training and systems - See Section 9.30

AA's should consider introducing an evacuation demonstration requirement similar to 14 CFR 121.291. This would require each operator to demonstrate the effectiveness of cabin crew evacuation procedures, training and evacuation systems. Whilst 14 CFR 121.291 requires this for aeroplanes with more than 44 passenger seats installed, **AAs** should also consider its applicability for aeroplanes with a lesser number of passenger seats.

Recommendation 17 - Training equipment - See Section 9.34.

AAs should ensure that their auditing of operators includes the use of emergency exit and slide training equipment, that it is representative of that on the aeroplane type(s) that are operated, and that operators have an effective maintenance programme for such equipment.

APPENDIX 1 ACCIDENT AND INCIDENT REPORT REFERENCES

AAIB. Accident Report Number: 8/1988: British Airtours, Boeing 737-236, G-BGJL, Manchester International Airport, 22 August 1985.
Date of Accident Report: 15 December 1988.

AAIB. Aircraft Accident Report 4/90. Report on the accident to Boeing 737-400 G-OBME near Kegworth, Leicestershire on 8 January 1989.
Date of Accident Report: 25 August 1990.

AAIB. Bulletin No: 7/2004 – EW/C2002/02/07: Ryanair Boeing 737-8AS, EI-CSA, London Stansted Airport, UK, 27 February 2002.
Date of Bulletin: 2004.

AAIB. Accident Report 1/2010: Report on the accident to Boeing 777-236ER, GYMMM, at London Heathrow Airport on 17 January 2008.
Date of Accident Report: 9 February 2010.

AAIB. Bulletin Number 6/2010 – EW/C2008/01: Serious Incident:
Embraer ERJ 190-200LR, Ronladsway, Isle of Man, UK, 1 August 2008.
Date of Bulletin: September 2010.

AAIB. Accident Report Number: 1/2014: Report on the accident to Airbus A330-343, G-VSXY, London Gatwick Airport, 16 April 2012.
Date of Accident Report: 12 February 2012.

AAIB. Bulletin Number 12/2017 – EW/C2016/06/02: Serious Incident:
Airbus A330-323, London Heathrow, UK, 26 June 2016.
Date of Bulletin: December 2017.

Australian Transport Safety Bureau. In-flight uncontained engine failure, Airbus A380-842, VH-OQA, Overhead Batam Island, Indonesia, 4 November 2010 – Aviation Occurrence Investigation AO-2010-89 – Final.
Date of Accident Report: 27 June 2013.

Aviation Safety Council of Taiwan. Aircraft Accident Report ASC-AAR-02-04-001. Crashed on a partially closed runway during takeoff, Singapore Airlines Flight 006, Boeing 747-400, 9V-SPK, CKS Airport, Taoyuan, Taiwan, 31 October 2000.
Date of Accident Report: Copyright 2002.

Canadian Aviation Safety Board (CASB). Civil Aviation Occurrence Report Number 84-H40003: Pacific Western Airlines, Boeing 737-200, C-GQPW, Calgary International Airport, Calgary, Alberta, 22 March 1984.
Date of Accident Report: 24 February 1987.

Comision de Investigacion de Accidentes e Incidentes de Aviacion Civil. Technical Report Number A-504/1999: Accident to Boeing 757-200, G-BYAG, Girona, Spain, 14 September 1999. Report date not identified. Also, AAIB Special Bulletin Number S1/2000.

Direccion General de Aeronautica Civil Inspectoria General. Investigacion de Accidente de Aviacion Investigation Number 33910225770: Lan Chile Flight 1069 – British Aerospace BAe 146 200, Guardiamarina Zanartu Airport, Puerto Williams, Chile, 20 February 1991.
Report date not identified.

NTSB. Accident Report Number NTSB/AAR-71-8: Overseas National Airways, Douglas DC-9, N935F, Flight 980, Near St. Croix, Virgin Islands, 2 May 1970.
Date of Accident Report: 31 March 1971.

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NTSB. Aircraft Accident Report Number NTSB-AAR-73-15: North Central Airlines, McDonnell Douglas DC-9-31, N954H, and Delta Airlines, Convair CV-880, O'Hare International Airport, Chicago, Illinois, 20 December 1972.

Date of Accident Report: 5 July 1973.

NTSB. Aircraft Accident Report Number NTSB-AAR-79-7. United Airlines, McDonnell-Douglas, DC-8-61, N808NU, Portland, Oregon, 28 December 1978.

Date of Accident Report: 7 June 1979.

NTSB. Aircraft Accident Report. Number NTSB/AAR-86/02. Air Canada, Flight 797 DC-9-32, C-FTLL, Greater Cincinnati International Airport, Covington, Kentucky, 2 June 1983.

Date of Accident Report: 31 January 1986. Supersedes NTSB/AAR-84/09.

NTSB. Aircraft Accident Report Number NTSB/AAR-90/06: United Airlines Flight 232, McDonnell Douglas DC-10-10, Sioux Gateway Airport, Sioux City, Iowa, 19 July 1989.

Date of Accident Report: November 1990.

NTSB. Accident Report Number NTSB/AAR-91/08: Runway Collision of USAir Flight 1493, Boeing 737 and SkyWest Airlines Flight 5569, Fairchild Metroliner, Los Angeles International Airport, Los Angeles, California, 1 February 1991.

Date of Accident Report: 22 October 1991.

NTSB. Aircraft Accident Report NTSB/AAR-93/04: Aborted Take-off Shortly After Liftoff, Trans World Airlines, Flight 843, Lockheed L-1011, N1002, John F Kennedy International Airport, Jamaica, New York, 30 July 1992.

Date of Accident Report: 31 March 1993.

NTSB. Aircraft Accident Report Number NTSB/AAR-96/03: Uncontained Engine Failure/Fire, ValuJet Airlines Flight 597, Douglas DC-9-32, N908VJ, Atlanta, Georgia, June 8, 1995.

Date of Accident Report: 30 July 1996.

NTSB. Accident Report Number NTSB/AAR-10/03: Loss of Thrust in Both Engines After Encountering a Flock of Birds and Subsequent Ditching on the Hudson River, US Airways Flight 1549, Airbus A320-214, N106US, Weehawken, New Jersey, 15 January 2009.

Date of Accident Report: May 2010.

NTSB. Accident Report Number NTSB/AAR-14/01: Descent Below Visual Glidepath and Impact With Seawall, Asiana Airlines, Flight 214, Boeing 777-200ER, HL7742, San Francisco, California, 6 July 2013.

Date of Accident Report: 24 June 2014.

NTSB. Docket - Survival Factors – Specialist's Factual Report: DCA15FA185. British Airways, Boeing 777-200, Las Vegas, USA, 8 September 2015.

Date of Accident Report: 28 February 2017.

Presidency of Civil Aviation – Jeddah – Saudi Arabia – Aircraft Accident Report: Saudi Arabia Airlines, Lockheed L-1011, HZ-AHK, Riyadh, Saudi Arabia – 19 August 1980.

Date of Accident Report: 16 January 1982.

The Dutch Safety Board. Accident Report Project Number M2009LV0225-01: Crashed during approach, Boeing 737-800, near Amsterdam Schiphol Airport, 25 February 2009.

Date of Accident Report: May 2010.

Emirates General Civil Aviation Authority. Air Accident Investigation Sector – Preliminary Report AAIS Case No. AIFN/0008/2016: Runway Impact During Attempted Go-Around - Emirates Boeing 777-31H – Dubai International Airport, The United Arab Emirates, 3 August 2016.

Date of Accident Report: 5 September 2016.

Transport Investigation Bureau – Ministry of Transport Singapore. AAIB/AAI/CAS.122:

Singapore Airlines, B777-300ER, Registration 9V-SWB. Engine Fire. 27 June 2016.

Date of Accident Report: 27 February 2017.

TSB (Canada). Aviation Investigation Report Number A05H0002: Runway Overrun and Fire, Air France, Airbus A340-313, F-GLZQ, Toronto/Lester B. Pearson International Airport, Ontario, 2 August 2005.

Report date not identified.

TSB (Canada). Aviation Investigation Report A12Q0216. Low Energy rejected landing and collision with terrain. Perimeter Aviation LP, Fairchild SA227-AC Metro III, C-GFWX, Sanikiluaq, Nunavut, 22 December 2012.)

Report date not identified.

TSB (Canada). Aviation Investigation Report: A15H0002.: Collision with Terrain, Airbus Industrie A320-211, C-FTJP, Halifax/Stanfield International Airport, Halifax, Nova Scotia, 29 March 2015.

Report date not identified.

APPENDIX 2 SOME ADDITIONAL RELATED REFERENCES

Airbus. Flight Operations Briefing Notes – Cabin Operations – Unplanned Ground Evacuation. (November 2006.)

Airbus. Flight Operations Briefing Notes – Cabin Operations – Planned Ground Evacuation. (March 2007.)

Butcher (N J) UK CAA. United Kingdom Civil Aviation Policy on Cabin Safety, Presented at the Fifth International Aircraft Cabin Safety Symposium at Oakland, California. (February 1988.)

Butcher (N J) UK CAA. Paper: Operational Cabin Safety Issues, Presented at the Very Large Transport Aeroplane Conference at Noordwijkerhout, Netherlands. (October 1998.)

Butcher (N J) RAeS. Article: Out of the FOG – The Importance of Cabin Safety in Respect of Survivable Accidents. The Aerospace Professional. (February 2012.)

CAA. Paper 2001/7: The development of a behavioural rating tool for use in passenger evacuation research. (2001.)

CAA. Paper 97006: The Design and Evaluation of an Improvement to the Type III Exit Operating Mechanism. (September 1997.)

CAA. Paper 93008: Aircraft Evacuations - The effect of a cabin water spray system on evacuation rates and behaviour. (March 1993.)

CAA. Paper 93009: Cabin Water Sprays for Fire Suppression: An experimental evaluation. (March 1992.)

CAA. Paper 90013: Aircraft Evacuations - Preliminary investigation of the effect of non-toxic smoke and cabin configuration adjacent to the exit. (September 1990.)

CAA. Paper 92005: Aircraft Evacuations - Competitive evacuations in conditions of non-toxic smoke. (March 1992.)

CAA. Paper 93010: Cabin Water Sprays for Fire Suppression - Design consideration and safety benefit analysis based on past accidents. (August 1993.)

CAA. Paper 2002/04: A benefit analysis for cabin water spray systems and enhanced fuselage burnthrough protection. (April 2003.)

CAA. Paper 2002/01: A benefit analysis for enhanced protection from fires in hidden areas on transport aircraft. (September 2002.)

CAA. Paper 89019: Aircraft Evacuations: The effect of passenger motivation and cabin configuration adjacent to the exit. (November 1989.)

CAA. Paper 93015: The Influence of Hatch Weight and Seating Configuration on the Operation of a Type III Hatch. (August 1993.)

CAA. Paper 92015: Passenger attitudes towards airline safety information and comprehension of safety briefings and cards. (December 1992.)

CAA. Civil Aviation Publication 747: Mandatory Requirements for Airworthiness. (2014.)

CAA. Civil Aviation Publication 789: Requirements and Guidance Material for Operators – Chapter 30, Paragraph 9. (February 2011.)

Cranfield University Innovation and Technology Assessment Unit. Paper: Probabilistic Risk Assessment Modelling of Passenger Aircraft Fire Safety.

EASA. NPA 2015-18 (C): Draft Implementing Rules and Draft AMC/GM on passenger seating and briefing.

FAA. Paper: The influence of adjacent seating configurations on egress through a Type III emergency exit. DOT/FAA/AM-89/14.

FAA. Paper: Access to egress: A meta-analysis of the factors that control emergency evacuation through the transport airplane Type III overwing exit. DOT/FAA/AM-01/2.

FAA. Paper: Access-to-Egress: Interactive effects of factors that control the emergency evacuation of naïve passengers through the transport airplane Type III overwing exit. DOT/FAA/AM-02/16.

FAA. Paper: Access-to-Egress II: Subject management and injuries in a study of emergency evacuation through the Type-III exit. DOT/FAA/AM-03/15.

FAA. Paper: Access-To-Egress III: Repeated Measurement of Factors That Control the Emergency Evacuation of Passengers Through the Transport Airplane Type-III Overwing Exit. DOT/FAA/AM-04/2.

FAA. Paper: Effects of Seating Configuration and Number of Type III Exits on Emergency Aircraft Evacuation. DOT/FAA/AM-92-27.

FAA. Paper: Effects of Seat Placement at the Exit. DOT/FAA/AM-95-22.

FAA. Paper: Aircraft Evacuations Through Type III Exits II: Effects of Individual Subject Differences. DOT/FAA/AM-95-25.

FAA. 14 CFR 121.310(m).

FAA. Transport Water Impact and Ditching Performance – Final Report – DOT/FAA/AR-95/54. (March 1996.)

FAA. 14 CFR Part 25 – Airworthiness standards: Transport category airplanes.

FAA. Advisory Circular 25-17A Transport Airplane Cabin Interiors Crashworthiness Handbook. (May 2009.)

FAA. Order 8900.1. Paragraph 3-1802 of Volume 3, Chapter 23, Section 4.

Grant, R L; and Muir, H C. Paper: Design Considerations for Enhanced Passenger Aircraft Evacuation. In Encyclopaedia of Aerospace Engineering. Volume 8. Ed. by Blockley, R and Shyy, W West Sussex: John Wiley and Sons Ltd. (2010.)

Greene, G; Friedrich, P; Muir, H C; Wilson, R L; and Thomas, L J. (2003) Very Large Transport Aircraft (VLTA) Emergency Requirements Research Evacuation Study (VERRES) - A Project Summary. JAA Research Paper 2003/1. Published on behalf of the VERRES Consortium.

ICAO. Annex 6 to the Convention of International Civil Aviation: Operation of Aircraft, Part 1 – International Commercial Air Transport – Aeroplanes.

JAA. Safety Information Circular (SIC) No 5: Cabin Crew Responsible for a Pair of Exits. (May 2006.)

Muir, H C; Thomas, L J; and Wilson, R L. (2004). Paper: Passenger safety in future very large transport aircraft. Human Factors and Aerospace Safety 4 (3), 259-27.

EMERGENCY EVACUATION OF COMMERCIAL PASSENGER AEROPLANES



Muir, H C; Thomas, L J; and Wilson, R. (2003). Paper: Passenger safety in future very large transport aircraft. Proceedings of the Sixth International Australia Aviation Psychology Symposium, Sixth International Australia Aviation Psychology Symposium. Held 01-05 Dec 2003 in Sydney, Australia.

Muir, H C; and Cobbett A. Paper: The effect on aircraft evacuations of changes to the vertical projections between the seat rows adjacent to the overwing exit. Prepared for the JAA Type III Exit Ad Hoc Working Group. College of Aeronautics, Cranfield University, UK. Report Number 9408. (May 1996.)

Rasmussen, P G; and Chittum, C B. Paper: The influence of Adjacent Seating Configurations on Egress Through a Type III Emergency Exit. Office of Aviation Medicine Report, DOT/FAA/AM-89-14, Washington DC. (1989.)

R G W. Cherry and Associates. Paper: A Study Analyzing the Trends in Accidents and Fatalities in Large Transport Airplanes. (October 2013)

R G W. Cherry and Associates. Paper: A Research Study into the More Pertinent Features of Small Commercial Aeroplanes Affecting Emergency Evacuation. (July 2012)

Wilson, R L; and Muir, H C. (2010). Paper: The effect of overwing hatch placement on evacuation from smaller transport aircraft. *Ergonomics* 53 (2), 286-293.