JUNE 2020

EMERGENCY EVACUATION OF COMMERCIAL PASSENGER AEROPLANES

SECOND EDITION 2020

About the Royal Aeronautical Society (RAeS)

The Royal Aeronautical Society ('the Society') is the world's only professional body and learned society dedicated to the entire aerospace community. Established in 1866 to further the art, science and engineering of aeronautics, the Society has been at the forefront of developments in aerospace ever since.

The Society seeks to; (i) promote the highest possible standards in aerospace disciplines; (ii) provide specialist information and act as a central forum for the exchange of ideas; and (iii) play a leading role in influencing opinion on aerospace matters.

The Society has a range of specialist interest groups covering all aspects of the aerospace world, from airworthiness and maintenance, unmanned aircraft systems and aerodynamics to avionics and systems, general aviation and air traffic management, to name a few. These groups consider developments in their fields and are instrumental in providing industry-leading expert opinion and evidence from their respective fields.

About the Honourable Company of Air Pilots
(Incorporating Air Navigators)

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The Company was established as a Guild in 1929 in order to ensure that pilots and navigators of the (then) fledgling aviation industry were accepted and regarded as professionals. From the beginning, the Guild was modelled on the lines of the Livery Companies of the City of London, which were originally established to protect the interests and standards of those involved in their respective trades or professions. In 1956, the Guild was formally recognised as a Livery Company. In 2014, it was granted a Royal Charter in the name of the Honourable Company of Air Pilots. The Honourable Company of Air Pilots is unique among City Livery Companies in having active regional committees in Australia, North America, Hong Kong and New Zealand.

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The majority of our members are or have been professional licence holders, both military and civil, but many are also private pilot licence holders. Air Pilots' members operate not only aircraft in airlines and all the branches of Her Majesty's armed forces but also in every area of general aviation and sporting flying.

To join the Honourable Company of Air Pilots, please contact the Clerk:

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About this paper

Any views expressed in this paper are those of the Flight Operation Group and do not necessarily represent the views of the Royal Aeronautical Society as a whole.

The Flight Operations Group (FOG) membership is made up of representatives of all areas of aviation affecting commercial aviation operations including airlines and the Royal Air Force, air traffic, airports, regulators, and in particular to enhance safety.

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A Specialist Paper prepared by the Flight Operations Group of the Royal Aeronautical Society

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Cover images: Top: The A320 after ditching on the Hudson River with passengers evacuating onto the forward slide-rafts and the wings in January 2009. (Greg Lam Pak Ng/flickr) **Middle:** Passengers having evacuated the B777-200 after an uncontained engine failure and fire during take-off at Las Vegas, USA in September 2015. (Lynn Alexander) **Bottom:** Passengers having evacuated the inferno of the SSJ-100 accident at Moscow in May 2019. (Russian Investigative Committee)

PREFACE

This is the updated Second Edition of the paper, the First Edition having been published by the Flight Operations Group (FOG) of the RAeS in April 2018.

Many accidents have identified the need for improvements in airworthiness and operational regulations resulting in changes to aeroplane manufacturing and maintenance procedures, as well as operator crew procedures and training.

While transportation by air is conducted at very high safety levels, accidents and incidents involving evacuation still occur. In the first few weeks of 2020, the accidents involving a McDonnell Douglas MD 83 at Mahshahr in Iran, a Boeing 737 at Istanbul in Turkey and a Boeing 737 at Usinsk in Russia, are stark reminders of the importance of occupant survivability and emergency evacuation.

Some accidents that happened several years ago are featured in this document as well as many that are more recent, and reflect some of the negatives as well as the many positives. The main import of this paper is to suggest areas where occupant safety and survivability might be enhanced in emergency evacuation situations. The aviation industry must never stop learning from what has gone before.

While not a new development, the ever-increasing amount of cabin baggage carried in passenger cabins can pose challenges to aeroplane crew and passengers in both evacuations and in normal operations. The significant increase in size of overhead bins in some aeroplanes, and additional costs imposed by some operators on passengers who choose to commit their baggage to aircraft holds might be seen as negative factors.

Recent emergency evacuations have highlighted the potential risks associated with passengers taking cabin baggage with them. The First Edition of this paper stated “Perhaps it is only a matter of time before an evacuation occurs when the issue of cabin baggage becomes a survival factor.” Such accidents have prompted a discussion on having overhead bins that could be locked for taxi, take-off and landing.

The increasing number of disruptive passenger incidents is a concern especially if passengers under the influence of alcohol or drugs are unable to understand or refuse to comply with crew instructions in an emergency. A diversion because of such passenger behaviour causes significant logistical problems for an operator, passengers and crew, as well as significant costs to the operator.

This Second Edition of the paper considers the potential benefits of external and internal cameras which might assist flight crew decision making in emergency situations.

The paper also questions the reality and effectiveness of current airworthiness requirements for the testing of emergency evacuation facilities and procedures, and considers if computer based mathematical modelling might be a suitable alternative.

Since the First Edition of this paper, regulatory actions have focused on several issues that might affect cabin safety and evacuation. In 2019 the US Congress required a review of the Federal Aviation Administration (FAA) aeroplane certification processes and established an independent committee formed within the structure of the Safety Oversight and Certification Advisory Group. Issues to be reviewed included passenger seated space. The FAA, under pressure from US Congress, decided to conduct testing to address the issues of passenger seated space in an emergency evacuation. The results of such testing, together with any new requirements for passenger seated space are not expected until the summer of 2020.

The European Aviation Safety Agency has identified emergency evacuation as a safety issue requiring immediate mitigation and actions are expected to be included in their European Plan for Aviation Safety 2020-2025.

This paper refers to several safety studies. In 2018 the International Civil Aviation Organisation published a manual which reflects many of the issues addressed here. Of particular importance is the information relating to passenger safety briefing material(1).

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

The authors of this paper are grateful for the comments and suggestions received from many interested parties, as well as the support and input from members of the FOG.

This paper is being published at a time when COVID-19 presents an unprecedented global threat. The aviation and aerospace industry is in uncharted territories and it will take a considerable amount of time for the situation to return to a level of normality. In the meantime, operators must ensure that aeroplane crews maintain their skills and expertise so that if an emergency evacuation is necessary it is carried out with the usual high professional standard that is expected of our aviation industry.

CONTENTS

1 ABBREVIATIONS

A	
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
AFM	Aircraft Flight Manual
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)
ASR	Air Safety Report
ATC	Air Traffic Control
B	
BAe	British Aerospace
C	
CAA	Civil Aviation Authority (United Kingdom) – UK CAA
CAMI	Civil Aerospace Medical 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 25 – 10 January 2020. (EASA)
(CS & FAR) 25.803	Certification Specifications – Emergency Evacuation (EASA and FAA)
CVR	Cockpit Voice Recorder
CRM	Crew Resource Management (Originally known as Cockpit 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

EFIS	Electronic Flight Instrument System
ELT	Emergency Locator Transmitter
EOW	Extended Over Water
EPAS	European Plan for Aviation Safety (EASA)
ESF	Equivalent Safety Finding
ETSC	European Transport Safety Council
ETOPS	Extended Range Twin Operations
EU	European Union
EXODUS	airEXODUS – Aircraft Evacuation Model (University of Greenwich – UK)

F

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

G

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

I

IAC	Interstate Aviation Committee (Russia)
IATA	International Air Transport Association
IBRACE	International Branch for Research into Aircraft Crash Events
ICAO	International Civil Aviation Organisation
IFAR	Inflatable Free Aisle Restrictor (Airbus)
IFE	In-flight Entertainment
ISASI	International Society of Air Safety Investigators

J

JAA	Joint Aviation Authorities (Predecessor to EASA)
JAR	Joint Aviation Requirement (JAA)
JOEB	Joint Operational Evaluation Board (EASA)

L

LOFT	Line Oriented Flight Training

M

MEDs	Mid Exit Doors (Boeing)
MEL	Minimum Equipment List
MFD	Multi-function Display
MPSC	Maximum Passenger Seating Capacity

N

NAA	National Aviation Authority
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
PRMs	Persons with reduced mobility (EASA)
PSUs	Passenger Service Units

Q

QRH	Quick Reference Handbook

R

RAeS	Royal Aeronautical Society
RFFS	Rescue and Fire Fighting Service
RTO	Rejected Take-off
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)
SOCAC	Safety Oversight and Certification Advisory Committee (USA)
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)
TTOL	Taxi, Take-off and Landing

U

UKTRF	United Kingdom Retail Travel Forum

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

EMERGENCY EVACUATION OF COMMERCIAL PASSENGER AEROPLANES

Date Day/Month/Year	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
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 F28-1000	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 Angles, 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 Angles, 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 Aeronuatica 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
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

EMERGENCY EVACUATION OF COMMERCIAL PASSENGER AEROPLANES

Date Day/Month/Year	**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**
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
19/10/2012	Glasgow, UK	Jet2 Flight Number: 177	Boeing 737-800	Passengers: 187 Crew:	Passengers: Nil Crew: Nil	UK AAIB	AAIB 10/2013 October 2013
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 Final Accident Report NTSB Identification: DCA15FA185 19 June 2018
27/05/2016	Tokyo, Japan	Korean Air Flight No: 2708	Boeing 777-300	Passengers: 302 Crew: 17	Passengers: Nil Crew: Nil	Japan Transport Safety Board	AA2018-5 26 July 2018
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	Accident –Final Report- AAIS AIFN/008/2016 20 January 2020
28/10/2016	Chicago, USA	American Airlines Flight No 383	Boeing 767-300	Passengers: 161 Crew: 9	Passengers: Nil Crew: Nil	US, NTSB	NTSB/AAR-18/01 30 January 2018
13/01/2018	Trabzon, Turkey	Pegasus Airlines Flight No: 8622	Boeing 737-800	Passengers: 162 Crew: 6	Passengers: Nil Crew: Nil	Directorate General of Civil Aviation - Turkey	Not identified
05/05/2019	Moscow, Russia	PJSC Aeroflot Flight Number 1492	Sukhoi Superjet 100 (RRJ-95B)	Passengers: 73 Crew: 5	Passengers: 40 Crew: 1	The Russian Interstate Aviation Committee – Air Accident Investigation Commission	Interim Accident Report RRJ-95B RA-89098

3 DEFINITIONS AND EXPLANATIONS

Accidents and incidents: Some 40 accidents and incidents are referred to in this paper and represent a cross-section of events 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. In many accidents and incidents referenced in this paper, improvements to regulatory safety standards are mentioned. In accidents and incidents where no mention is made of such, the International Civil Aviation Organisation (ICAO) Document 10062 provides such information(2).

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 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 are equally applicable to other manufacturers such as Airbus. It is not the intention of this paper to identify Boeing as having any particular issues with emergency evacuation of 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.

Baggage with integrated wheels: These are often referred to as trolley bags, wheelie bags, hard cabin suitcases with wheels, etc. For simplicity such items are referred to in this paper as 'baggage with wheels'.

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

'Combi' aeroplane: Is one where both passengers and cargo are carried on the same deck.

Crashworthiness: 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 as: "A planned event in which the flight crew knowingly makes a controlled emergency landing in water"(3).

EASA Certification Specifications CS 25 Amendment 20: This is used as the baseline for airworthiness requirements in this paper and are harmonised with the US, Canada, and Brazil. For ease of reference CS 25 (or simply 25) is used throughout this paper unless there are differences with other regulatory requirements. Although CS 25 is used in this paper some of the certification standards are historically JAR 25 (Joint Aviation Requirement) for certain aeroplanes.

Emergency exit identification: 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 non-survivable conditions throughout the cabin within a matter of seconds". Also that: "Flashfire occurs when materials in a local**is**ed 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".

Hull loss: An event resulting in damage of an aeroplane to an extent where repair is determined to be uneconomical.

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 NAAs, 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 NAAs 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 NAAs, 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 unless specified by the manufacturer and/or the NAA.

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

The 60 Foot Rule: In the late 1980s the FAA introduced a '60 foot rule' which determined that no pair of floor level emergency exits should be separated by more than 60ft. In effect this means that no passenger should be seated more than 30ft 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) some of which now been withdrawn by the CAA.

4 INTRODUCTION

This Royal Aeronautical Society specialist paper titled 'Emergency Evacuation of Commercial Passenger Aeroplanes' is produced by the Society's Flight Operations Group (FOG). 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 training. In most accidents the more rapidly an evacuation is initiated and efficiently conducted, the more likely it is that the number of occupant injuries and fatalities will be reduced. This paper addresses key factors, both positive and negative, that might influence an evacuation, including airworthiness and operational issues, as well as accident experience and research.

Improvements in occupant survivability are largely a result of actions taken by NAAs, 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 NAAs and others in implementing improvements to regulatory requirements, such as:

- Dynamic testing for seats and human injury criteria (ie 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.

Information on 'evacuation related' airworthiness and operational issues, in addition to regulatory criteria, might benefit operators in review of their operational procedures and crew training in respect of emergency evacuation.

Some airworthiness requirements have the potential to impact on flight operations. Personnel working for NAAs and for operators should have an awareness of airworthiness issues that might directly affect flight operations including aeroplane crew emergency evacuation procedures and training. Airworthiness and operational requirements might not always be compatible. They may be dealt with separately by different disciplines within NAAs, manufacturers and operators, and at different stages in the process of certification or the introduction of a new aeroplane type.

EASA Air OPS Regulations specifies technical requirements and administrative procedures for operators by mandating and regulating the use of Operational Suitability Data (OSD) by operators.

Some accidents and incidents involving evacuation require rapid disembarkation not using evacuation slides and instead the use of other facilities such as airport jetways. An accident or serious incident involving a significant threat of imminent danger to occupants may require the use of evacuation slides. Emergency evacuations using slides might include a risk of injury to occupants, particularly from twin-aisle aeroplanes and multi-deck aeroplanes as the evacuation slides are deployed from a door sill which might be a considerable height from the ground. 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 negative issues of emergency evacuations are addressed by accident investigators, the positive issues are not always identified. It is possible that important information might not be disseminated to NAAs and to industry. Therefore, NAAs, manufacturers and operators might not appreciate such factors and the potential for safety improvements could be missed. ICAO Document Number 10062 states 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”.

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 emergency evacuations are included in this paper and provide a useful review of the effectiveness of evacuation procedures and crew training, as required by EASA Air OPS Regulations.

In June 2000, the NTSB issued Safety Study: Emergency Evacuation of Commercial Airplanes, which included 20 Safety Recommendations(4). Additionally the Transportation Safety Board (TSB) of Canada issued A Safety Study of Evacuations of Large Passenger-Carrying Aircraft, in 2013(5). This FOG specialist paper takes into account issues raised in these documents and addresses other factors that might influence evacuations.

In December 2009, EASA issued a study on the CS 25 cabin safety requirements(6).The aim of this study was to consider threats to cabin safety and identify potential amendments to CS 25. Many of the issues addressed in this study are reflected in relevant parts of this paper. Further information on this study is at Section 10.5. This study was conducted by R.G.W. Cherry and Associates, 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 regulatory provisions.

5 BACKGROUND

The first recorded aviation related emergency evacuation occurred 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 limited. According to the European Transport Safety Council (ETSC) 90% of commercial transport aeroplane accidents can be categorised as survivable or technically survivable(7). Therefore, the ability of passengers to evacuate and the crew to initiate and effectively 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.

In a Safety Report issued in 2014, ICAO stated that there were 90 aeroplane accidents world-wide in 2013, with 173 fatalities arising from only nine of them(8). 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. While 2017 was one of the safest years for aviation with no fatal accidents involving large commercial passenger aeroplanes, in 2018 there were 160 accidents, 13 of which were fatal involving 534 fatalities. Tragically there were two non-survivable accidents involving the Boeing 737 MAX 8, one in October 2018 and another in March 2019. Also in May 2019 there was a fatal accident at Moscow involving a Sukhoi Superjet 100, when 41 of the 78 occupants perished in a fire on the ground after landing. However, 2019 proved to have a better safety record than 2018 with 86 accidents involving larger commercial aeroplanes, eight of which were fatal and resulted in 257 fatalities.

Note: The IAC interim Accident Report into the Moscow accident states that survival factors and emergency evacuation issues would be dealt with in the final Accident Report which was not available at the time of publication of this paper(9). A paper by the International Association for Fire Safety Science considers the circumstances of this accident(10).
See RAeS Insight Blog: www.aerosociety.com/news/the-superjet-moscow-crash-emergency-evacuation-and-survival-factors/

Aeroplane evacuation facilities have developed significantly over the years. Many improvements have been made to emergency exits including the installation of ‘power-assist’ systems to make operation in an emergency easier and faster. This is especially the case for floor level exits on larger aeroplanes, many of which are large and heavy requiring significant force to open in the non-automatic mode, and to deploy evacuation slides.

In some newer aeroplanes, Type III exits have been improved with the installation of Automatically Disposable Hatches (ADH) which is a significant improvement on earlier designs. These include the later variants of the Boeing 737, the Airbus A321 neo, the Embraer E190 E2 series and the Airbus A220 (previously the Bombardier C series).

Improvements have been made to evacuation slides, with the original non-inflatable 'hand-held' slides, sometimes referred to as 'rag-chutes', being replaced with automatically inflated slides.

Requirements for the installation of floor proximity emergency escape path lighting and associated emergency exit identifier lighting, has potentially improved passenger identification of emergency exit routes in conditions of low visibility, such as dark of night conditions or smoke. Many emergency lighting systems now have external lights that illuminate the outside areas and the surfaces onto which occupants will first step on or jump onto when evacuating the aeroplane.

Cockpit Resource Management (CRM) for flight crew 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[(11)]. In the 1980s this 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)

The secured flight deck door, mandated on larger aeroplanes after the terrorist events of September 2001, has reduced face-to-face communication between flight crew and cabin crew although in emergency situations the 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 including pre-flight and post-flight briefings between all crew members.

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 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 No 1 (left) 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 fuselage.

According to the Canadian Aviation Safety Board (CASB) Accident Report all 114 passengers, two flight crew and three flight attendants, evacuated the aeroplane, although four passengers sustained injuries[(12)].Three passengers sustained bone fractures when they jumped from the leading edge of the wing to the ground. A fourth passenger suffered fractured ribs and pelvis falling from the wing. The number and early operation of available emergency exits may have been a major factor in occupant survivability. All 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 No 1 (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 fuel onto the fuselage and 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 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" [(13)].

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 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 emergency 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 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 fuselage extends forward of the left wing whilst in the Manchester accident aeroplane, it is only present seven windows aft of the left overwing Type III exit (L2).

Wreckage of the B737-200 after an uncontained engine failure and fire during take-off at Calgary in March 1984.

Wreckage of the B737-200 after an uncontained engine failure and fire during take-off at Manchester in August 1985.

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 55 fatalities in the Manchester accident.

In both accidents there are several similarities whilst at the same time there are some significant differences, one of which is 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 in the Manchester accident were mostly holiday travellers, some of whom were with 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 FSEG (University of Greenwich, UK) in January 2017, coupled fire and evacuation simulation tools were used to analyse the Manchester accident[14]. This paper is reviewed in Section 8.17. 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. This analysis, although perhaps interpretive, suggests to the FOG that on average for every second's delay in an emergency evacuation in a catastrophic situation results in the loss of one life.

There is no reference in the AAIB Accident Report that passengers took cabin baggage with them in the Manchester accident. In recent years such actions by passengers have become more frequent as reflected in Section 9.29 and the Case Studies at Section 11. Perhaps if passengers had taken cabin baggage with them in this accident it would have had a serious adverse affect on the available time to evacuate and with the almost certain loss of more lives.

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 required cabin crew has a direct impact on the procedures for an emergency evacuation. Cabin crew are required to open emergency exits for which they are responsible in an evacuation and to ensure that such exits are not opened into hazardous conditions, such as external fire. The important operational issue of ensuring that exits are not opened in an emergency is not necessarily addressed by airworthiness criteria.

Many NAA 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 that any person who might be identified by passengers as cabin crew meets 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 is of great importance.

The policy for some NAAs 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 Type A emergency exits. CS 25.785(h)(1) requires one cabin crew seat adjacent to each Type A exit. However, for many NAAs 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 might 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 could mean that two Type A exits might 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' rule 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

In each of these accidents there were no fatalities. However, in all three 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 Section 11.)

In September 2010 the UK CAA issued FODCOM 24/2010 advising operators to consider procedures for when a cabin crew member is responsible for a pair of emergency exits in an evacuation[15]. 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. EASA Air OPS AMC1 ORO.CC.125 (d) (f) also requires training for cabin crew when responsible for a pair of floor level exits.

In October 2014, EASA issued, in draft form for public comment, Safety Information Bulletin (SIB) Number 2014-29[16]. 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[17]. EASA accepted that the wording of EASA Air OPS Regulation ORO.CC.100: Number and composition of cabin crew was potentially confusing.

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 regarding minimum cabin crew requirements[18]. Many issues in the ICAO Manual are addressed in this paper. This ICAO Manual provides useful guidance on a wide-range of cabin crew 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 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 107cm (42in wide) and 183cm (72in) high.
Type B	75 per pair of exits	Type B emergency exits are at floor level. Exit dimensions: not less than 81.3cm (32in) wide and 183cm (72in) high.
Type C	55 per pair of exits	Type C emergency exits are at floor level. Exit dimensions: not less than 76.2cm (30in) wide and 122cm (48in) high.
Type I	45 per pair of exits	Type I emergency exits are at floor level. Exit dimensions: not less than 61cm (24in) wide and 122cm (48in high.
Type II	40 per pair of exits	Type II emergency exits are either at floor level or over the wing than Exit dimensions: not less 51cm (20in) wide and 112cm (44in) 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 (20in wide) and 91.4cm 48 (36in) 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 48cm (19in) wide and 66cm (26in) high.

Type A+ emergency exits: In November 2019 EASA issued a revised Type-Certificate Data Sheet (TCDS) for the Airbus A350 in which it approved an increase in the passenger rating for Type A emergency exits, designated as Type A+ exits, from 110 passengers to 120 passengers[19]. This is a harmonised position with the FAA. Although this could potentially increase the Maximum Passenger Seating Capacity (MPSC) for other twin-aisle aeroplanes, Type A+ exits are only currently applicable to the Airbus A350 and are based on very specific design issues and operational procedures. This might not be effective for other twin-aisle aeroplanes.

The TCDS is currently only applicable to the Airbus A350-900 and the A350-1000 for various configurations of Type A+ and Type C emergency exits.

This is based on a EASA proposed Equivalent Safety Finding (ESF) published in June 2019, which determined that the increased passenger rating could be justified by enhancements to evacuation slide performance including improved signage and lighting, as well as a requirement for three cabin crew to be located adjacent to each pair of Type A+ exits[20]. This cabin crew requirement must be specified in the Aircraft Flight Manual (AFM). One of the ESF conditions is that evacuation slides at Type A+ exits should be automatically erected in 10 seconds from the time the opening means of the exit is actuated.

It is understood that in April 2018 evacuation testing of the A350-1000 was conducted by Airbus in full compliance with 25.803, using four pairs of Type A+ exits, with 480 test participants acting as passengers and 12 cabin crew. Specific evacuation procedures for the cabin crew are to be developed by Airbus and detailed in the Airbus Cabin Crew Operations Manual (CCOM).

However EASA has advised that the 25.803 criteria is only one part of the testing criteria as specified in the EASA ESF for acceptance of the Type A+ exit for the Airbus A350 and the associated MPSC. EASA states that other testing criteria is just as important, including 'comparative testing with naïve subjects' as well as evacuation in daylight conditions which was factored into the required substantiation work required of Airbus by EASA. Also that improved daylight evacuation performance due to signage and lighting was not part of the EASA rationale for acceptance of the ESF.

EASA have advised that no amendments to EASA CS 25 are planned at this time since in the case of Type A and Type A+ exits only two applicants could currently benefit from such an amendment. Normally a change to CS 25 is only made when there are sufficient ESFs to justify an amendment.

The FOG believes that the emergency evacuation procedures specifically involving the third cabin crew member must be developed and specifically reflected in cabin crew procedures and associated training for all affected operators. It is not clear as to how this might be achieved

Type III and Type IV emergency exits: These 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 for older designs remain attached to the aeroplane fuselage. For the 737 NG aeroplanes Boeing introduced a new design of overwing Type III exit hatch that operates semi-automatically and 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 are at Sections 8.9, 8.10 and 8.11. In May 2017 the FAA issued a review of such Type III exit hatches[21].

Floor level emergency exits are required by 25.809(a) 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[22]. Type III and Type IV exits have 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. Therefore passengers sat in self-help exits seat rows should be briefed by the cabin crew prior to departure on the potential external hazards and when not to open an emergency exit.

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 Development of aeroplane variants to provide increased passenger seating capacity

Manufacturers often develop variants of an initial aeroplane type as a natural progression of improving aeroplane systems, perhaps increasing the maximum passenger seating capacity without usually incurring the costs of additional 25.803 testing. Such a strategy may require the less time-consuming 'Differences Training' as opposed to full 'Type Conversion Training' and increases the number of types and variants that can be operated by cabin crew with significant benefit to operators. For example, even when an aeroplane is designated to be a new type, if emergency exits are the same, exit training will not need to be repeated as per EASA AIR OPS AMC1 ORO.CC.125.

So when should an aeroplane variant become a new aeroplane type and require a new type certificate? To answer this question, EASA uses the process of a Joint Operational Evaluation Board (JOEB) (Cabin Crew) assessment. The aeroplane is reviewed against a 'base' aeroplane, selected by the manufacturer, and any differences are determined. An aeroplane is determined to be a new type only if there is a change in the aeroplane configuration, specifically in the number of aisles or decks, or different numbers, types, location and operation of emergency exits. Additional emergency exits of the same type and operation, de-rated emergency exits and self-help emergency exits are not taken into consideration.

The Boeing 737 MAX-10 and the Boeing 737-900 ER with Mid Exit Doors (MEDs) activated provides an extra pair of floor level exits. These are located aft of the wing and are almost identical to Doors 3 on the Boeing 757 and some Boeing 767s but are a similar size, or slightly smaller than those on the Boeing 757. They are permanently armed and are operated by raising the operating handle and are hinged at the bottom opening downwards, similar to the Airbus 340-600. On the Boeing 737 MAX-10 they can be Type II exits or de-rated to Type III exits depending on the customer requirement and configuration. On Boeing 737-900 ERs with MED, they are usually Type II exits. When such exits are de-rated they do not require a cabin crew station and are considered to be passenger self-help emergency exits.

The operator in conjunction with the NAA will determine the number of types or variants that a cabin crew member may operate and this could vary from the certification definition. In this respect, an aeroplane could be considered to be a different type if it is not similar in the location and type of portable safety and emergency equipment and aeroplane type specific emergency procedures.

The Boeing 747-100 and 200 series were considered to be variants but with the extended upper deck the B747-300 series required a new initial type certificate. Correspondingly the B747-400 was considered to be a variant of the 300 series. This seems to be entirely logical for the Boeing 747-100/200 and 300/400 series.

The Boeing 737 was first certificated in the late 1960s with a maximum passenger seating capacity of 145. It had two pairs of floor level exits and one pair of overwing exits. Over the years the Boeing 737 has evolved into many variants, the most recent being the installation and repositioning of larger engines on the wings. The Boeing 737 Max-10 has a maximum passenger seating capacity of 230. It has three pairs of floor level exits and two pairs of overwing exits. But how did this aeroplane progress from its 1960s status to the present day? Boeing for more than 40 years has claimed 'grandfather rights' for certification of the B737 thereby requiring no new initial type certification. This has been accepted by the FAA and subsequently endorsed by other NAA's.

It seems that Boeing is not alone in this respect since Airbus is following similar criteria with the A321neo, which have been accepted by EASA. The same applies in respect of cabin crew exit training requirements for the Airbus A330-200/300, A340-600 and A350-1000.

The FOG has not been able to ascertain how the emergency evacuation requirements of 25.803 have been applied to the many Boeing 737 variants and how compliance has been demonstrated, possibly by analysis or partial testing, or perhaps a combination of both. This is also the case for the Airbus A321neo.

There is a desire by some operators to reduce passenger seat space in some cabins. This might be achieved by changing the types of emergency exit, exit locations and the de-rating of emergency exits as discussed in 'De-rating and removal of emergency exits'. (See section 8.8.)

Manufacturers are able to provide operators with different options as discussed below in 'Minimum space for seated passengers'. (See section 8.14.)

See Recommendation 4.

8.3 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. This can cause 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 NAA 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 NAAs may have 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.

8.4 Evacuation slides

Evacuation slides have been fitted to commercial passenger aeroplanes since the early 1950s. Early types of evacuation slides were not inflatable and had to be deployed 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. 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 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 25.810 requirements are:

- Each emergency exit that is more than 1.8m (6ft) from the ground with the aeroplane on the ground and with the landing gear extended, must have an approved assist means (ie 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 46km/hr (25kn) 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.

For some overwing exits the exit height might be above the criteria for an evacuation slide, but if the height a passenger has to deplane via the trailing edge wing flaps is less than the required criteria then no evacuation slide is required. Evacuation by this route requires that the trailing edge wing flaps be deployed by the flight crew and is dependent on the availability of hydraulic power. This might question why such exits are not required to be equipped with an evacuation slide. Also, there can be little doubt that a deployed off-wing evacuation slide will effectively guide passengers to evacuate off the trailing edge of the wing. There might also be an expectation by passengers who evacuate via overwing exits on single-aisle aeroplanes that there will be an evacuation slide available to them. (See Section 8.10.)

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 must jump down from a height of up to 1.8m (6ft) which some will find challenging and might be potentially 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.

Depending on the emergency situation, cabin crew at floor level emergency exits will need to be aware of such issues. 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 Airbus A220.

The NTSB in its 2000 Safety Study, recommended that the FAA “Review the six foot height requirement for exit assist means to determine if six 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, by requiring evacuation slides to be installed below the current criteria for an evacuation slide 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 (6ft) 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 an evacuation slide is appropriate, or if a lesser height should be applied to 25.810.

In a ditching, evacuation slides on twin-aisle aeroplanes also usually act as 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 after ditching. 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 life-rafts, 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(23). This was an important factor in the evacuation and subsequent rescue of passengers and crew in extremely cold weather conditions. (See Section 9.23 and Case Study at Section 11.)

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(24). 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. (See Case Study at Section 11.)

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.)

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 No 1 (left) engine resulting in a serious fire affecting the port wing. According to the Japan Transport Safety Board Aircraft Accident Investigation Report all of the five Type A emergency exits on the right side of the aeroplane were operated as well at exit L1. The evacuation slide at Door R5 inflated underneath the fuselage and was unusable throughout the evacuation. However, all 302 passengers, two flight crew and 17 cabin crew evacuated the aeroplane safely via the four right side available Type 'A' exits. (See Case Study at Section 11.)

Passengers taking cabin baggage with them in an evacuation is identified as a common occurrence in Section 9.29. Of concern is the potential damage from heavier items such as 'baggage with wheels' that might affect the integrity of an evacuation slide to the point when it becomes unusable.

See Recommendation 5.

8.5 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 usually not in a ditching scenario.

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.

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

The location of cabin crew seats is specified in 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 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 at 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 with no evacuation slides, do not need to comply.

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 demonstrate 'Situational Awareness' in responding to a variety of emergency situations including an emergency evacuation. This means that a cabin crew member will need to 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. 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."

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[26].

8.7 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 Accident Report into the 1985 Manchester accident which 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."*

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."

8.8 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 NAA 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 endorsed by EASA, and allows the de-rating of different types of exits.

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 25.807.

Most emergency exits that are de-rated remain the same size but often access to them is reduced. Some Type 'A' exits have been de-rated to Type 'C' exits and are allowed to have a single lane evacuation slide with an inflatable free aisle restrictor (IFAR) installed instead of a dual lane slide.

Note: An IFAR is an inflatable device which restricts the width of the exit aperture so that only one person can evacuate via the single aisle slide at a time. It is an integral part of the slide and requires no action by the cabin crew to deploy.

If approved by a NAA, emergency exit de-rating 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 remain the same, but potentially without the presence of cabin crew to operate the exit, deploy the evacuation slide and control the evacuation. If exit de-rating 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.

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 72ft 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 their Seattle Office decision and determined 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 Section 11.)

In February 1986, Boeing conducted a 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 25.803 demonstration requirements within the 90 second criteria. Partly as a result of this evacuation demonstration, British Airways decided that for the purpose of effective passenger management in an evacuation, the presence of cabin crew would be beneficial at the overwing area. British Airways opted to install 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 60ft 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.

8.9 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 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.

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. 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 first be lifted into the passenger cabin and then disposed of in some way.

CS 25 requires that the operation of exits must be simple and obvious and should 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 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"[27].

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. In January 1986 they issued UK CAA AN 79 Access to and Opening of Type III and Type IV Emergency Exits, requiring compliance by July 1986[28].

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 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"[29]. 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 Aerospace Medical 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 experimental 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[30&31].

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 NAAs.

Note: See Section 8.11-Type III emergency exit design and development.

See Recommendation 6.

8.10 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 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. 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.

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 1.8m (6ft) CS 25 criteria for evacuation slides, the usual route for passengers to evacuate is by the trailing edge of the wing. 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 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 as well as effective briefing information for passengers.

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 (UK) 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. According to Embraer, the problem with the Type III exit hatch trim was due to a manufacturing quality issue in that the correct hatch trim had not been installed on that specific aeroplane. 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 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 8ft) instead of sliding off the wing trailing edge down the extended flaps"[32]. 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 1.7m (5.6ft). Four minor injuries were sustained by passengers.

On 19 October 2012, a Boeing 737-804 operated by Jet2, (Flight Number LS177), when on take-off from Glasgow, UK, the pilots commented on a strange smell. This was followed by what appeared to be smoke in the passenger cabin which was communicated to the flight crew by the SCCM. The take-off was abandoned and the aeroplane stopped on the runway. After a visual inspection of the cabin by the commander he ordered an emergency evacuation. The AAIB in their Accident Report stated that some passengers who evacuated via the Type III emergency exits onto the wings were unable to see the wing markings showing the route to evacuate[33]. Some passengers were not aware that they should slide down the wing flaps and they expected there to be an evacuation slide. Some passengers (possibly only three) re-entered the cabin and evacuated via the Type I floor level exits. The AAIB determined that this evacuation took an 'estimated' three minutes and 38 seconds. The reasons which contributed to this extended evacuation time were determined by the AAIB to be: (1) the return to the cabin by some passengers who decided not to evacuate via the wing surface; (2) the age and infirmity of some of the passengers; and (3) passengers attempting to take belongings from overhead bins. With all four floor level exits and all four overwing exits being used in this incident, the 'estimated' evacuation time of more than three minutes raises some doubts as to the effectiveness of the evacuation procedures, since with all the exits useable the evacuation should have been completed in less than the 90 second criteria.

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 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 7.

8.11 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 14.7kg (32.4lb) on an Airbus A320, 17.5kg (38.6lb) on the Embraer 190, and up to approximately 27kg (60lb) on a Boeing 767-200.

25 813(a) now requires the manufacturer to install a placard on or adjacent to Type III exit hatches clearly showing the weight of the hatch.

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 some 27kg (60lb) does not require exceptional effort. Perhaps the wording of 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-1980s 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 14.7kg (32.4lb).
- 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 approval 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 NAAs 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. While 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 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 25.813(c)(6). As a direct result of the changes to 25.813(c)(6), Airbus A320neo, Airbus A220 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 an external position which should not obstruct evacuation.

See Recommendation 8.

8.12 Heat release requirements and the effects of toxic fumes in an evacuation

A negative factor affecting a successful evacuation is the production of toxic fumes from cabin furnishings, which might incapacitate passengers and crew before they have 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 potentially has little or no impact on a timely 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 their rapid incapacitation. This was also the cause of many of the 23 fatalities in the 1983 Cincinnati accident. (See Section 8.13.) 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 as far back as 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 1980s 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-1980s the UK CAA published AN 59 which adopted the FAA fire test standard for seat upholstery materials and required all new and existing seats to comply with this standard[(34)]. Additionally, in March 1987, the UK CAA issued AN 61 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[(35)]. Since the late 1970s 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 NAAs.

8.13 Floor proximity emergency escape path lighting

In an emergency evacuation the loss of visual reference resulting from smoke or conditions of darkness can seriously affect the orientation of passengers and crew. This may result in movement towards a useable emergency exit being delayed and in some accidents a useable emergency exit being not identified and being by-passed due to passenger or crew 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 flour 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”[(36)].

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 onwards to 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[(37)]. 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 zero 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 the1985 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 40in (101.6cm), 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 requiring that all affected UK registered aeroplanes be fitted with floor proximity path marking/lighting and low level emergency exit identifier lighting(38). The use of photoluminescent floor lighting has also been approved by most NAAs.

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.

8.14 Minimum space for seated passengers

In an emergency evacuation it is important that passengers can leave their seats and move into adjacent aisles quickly and easily in order to move towards emergency exits.

In March 1988 the UK CAA issued AN 64 which identified three dimensions that they considered important to enhance occupant survivability(39). All affected UK registered aeroplanes would need to meet the following requirements:

- *"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 26in (66cm)."*
- *"The minimum distance between a seat and the seat or other fixed structure in front shall be 7in (18cm)."*
- *"The minimum vertically projected distance between seat rows or between a seat and any fixed structure forward of the seat shall be 3in (8cm)."*

Note: "All measurements to be taken with the seats in the upright take-off and landing position."

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 of a passenger to stand up and move into the cabin aisle.

Importantly AN 64 stated "…..of particular concern is the effect that such lower seat pitches can have on the seat occupancy and the ease of egress from these seats". Some 30 years later the FOG has the same concerns.

Note: The criteria in AN 64 was transferred to UK CAA Civil Aviation Publication Number 747 'Mandatory Requirements for Airworthiness' as a Generic Requirement, but was withdrawn in November 2014.

Although the criteria in AN 64 are not included in any CS 25 requirement, EASA did include the issue of seat spacing in their 2009 CS 25 Study and suggested 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." This 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.

In the intervening years economy passenger seat space has reduced significantly. Economy seat pitch some 20 years ago was at about 32in (81cm). Now seat pitch is as low as 28in (71cm) and there is a proposal from one seat manufacturer to reduce to 27in (69cm), and even another to a comfort-defying 23in (58cm); virtually a 'standing' seat.

Since the 2009 EASA review little further action had been taken by NAA's. EASA stated in 2015: "….that the data presently at its disposal is not sufficient to justify legislative measures on seat pitch at EU level". EASA also stated that this is a: "… commercial decision taken by the airlines in a competitive market, who are free to offer different levels of services and to charge different fees for them".

The FOG disagrees with this EASA position and is of the opinion that matters of flight safety should, wherever practicable, take priority over 'commercial' factors.

In the USA in July 2018 a court of appeals circuit judge filed an 'opinion' requiring the FAA to consider developing requirements for a minimum seat space. The FAA response stated that it would not regulate airline seat space and legroom and that current seat size is not a safety issue.

The FAA made the following statements:

- *"The time it takes passengers to get out of their seats, even if those seats are relatively narrow and close together, is less than the time it takes for the emergency exits to begin functioning and for the line that forms in the aisle to clear."*
- *"The FAA has no evidence that a typical passenger, even a larger one, will take more than a couple of seconds to get out of his or her seat."*

The FOG questions the validity of these FAA statements and wonders why regulators are refusing and/or finding it so difficult to introduce minimum seat space dimensions when the UK CAA had such criteria and had implemented compliance with it for some 25 years.

In spite of the stated FAA position, in the autumn of 2018 the US Congress introduced a FAA Reauthorisation Act which stated:

"SEC. 577. MINIMUM DIMENSIONS FOR PASSENGER SEATS."

"(a) **IN GENERAL** – Not later than 1 year after the date of enactment of this Act, and after providing notice and an opportunity for comment, the Administrator of the Federal Aviation Administration shall issue regulations that establish minimum dimensions for passenger seats on aircraft operated by air carriers in interstate air transportation or intrastate air transportation, including minimums for seat pitch, width, and length, and that are necessary for the safety of passengers."

"(b) **DEFINITIONS** – The definitions contained in section 40102(a) of title 49, United States Code, apply to this section."

While most certification requirements have minimum dimensions for seat pitch at Type III emergency exits, minimum dimensions for aisle widths, and minimum dimensions for the size of emergency exits, etc, there are no minimum criteria for passenger seated space.

The International Branch for Research into Aircraft Crash Events (IBRACE) has raised concerns regarding the ability of passengers to adopt a proper brace position in a restricted passenger seat configuration. The 'Journal of International Society of Air Safety Investigators (ISASI) – October – December 2018 states: "During the discussion at the latest IBRACE meeting, members noted that it would be impossible to conduct any sled-impact testing in seats with a 28-inch pitch and using the standard Hybrid III dummy because it would not fit"(40).

Obviously brace positions for both passengers and crew vary between operators and aeroplanes and some might be easier or harder to adopt than others.

Additionally seat width has also reduced significantly over the years. Twenty years ago an economy seat was some 20 inches wide. Now it could be as little as 17 inches. This has resulted in more seats being installed in economy cabins. Almost gone are the days of the 2-4-2 or 2-5-2 seat configurations across passenger cabin interiors and for many operators it is more likely to be 3-4-3.

Seat width and the effect that very large passengers might have on persons seated immediately adjacent to them is another issue. In the UK there has been at least one case brought against an operator by a passenger for personal injury. (Posser v. British Airways – November 2018. The claim against BA was unsuccessful.)

Some operators have recognised that the size of passengers is an issue and have introduced measures to mitigate the problem by, for example, requiring such passengers to upgrade to a 'roomier' seat or purchasing an additional adjacent seat. The trend by operators to reduce the width of passenger seats will only increase this growing problem.

Smaller seat sizes might also lead to the entrapment of personal electronic devices such as mobile phones thus increasing the potential for serious damage due to the increased risk of lithium battery fires and thermal runaway, although such potential hazards might also apply to premier class seats.

The FOG considers that any further reduction of passenger seated space could seriously compromise an emergency evacuation and should take into account the following issues:

- An ageing population and the issue of persons with reduced mobility (PRMs).
- An increase in the physical size of the population.
- The potential issue of deep vein thrombosis.
- The ability of passengers to easily locate, access and don lifejackets.
- The ability of passengers to adopt an appropriate brace position.
- The increasing tendency for passengers to take cabin baggage with them in an emergency evacuation.
- The amount of personal space that a passenger might have due to a reduction in seat width when seated next to a passenger of a large size.

In September 2019 the FAA announced that evacuation testing would be conducted at their Civil Aerospace Medical Institute (CAMI) starting in November 2019 primarily to look at the issue of passenger seated space in an emergency evacuation. Results of the testing and any associated conclusions might not be available until the summer or autumn of 2020."

See Recommendation 9.

8.15 Aeroplane manufacturer's evacuation 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 25.803 demonstration then the evacuation characteristics might be significantly different. For twin-aisle aeroplanes with low density seating in premium class areas, the forward passenger cabins are likely to have a significantly faster evacuation rate.

In October 1995, UK CAA NOTACH) 7/95[41] 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 10.

8.16 25.803 – Evacuation requirements for certification of large aeroplanes

The 25.803 demonstration tests are conducted under the observation of NAAs 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 know which exits will be available in the demonstration.
- The demonstration is conducted in reduced lighting conditions.
- Cabin baggage and blankets are positioned in aisles and cross-aisles.
- All test participants must evacuate within 90 seconds under simulated emergency conditions without assistance from 'ground safety personnel'.

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

In satisfying the requirements of 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 usually 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[42].

Manufacturers develop procedures for 25.803 demonstration tests and these are used to train 'test' flight crew and cabin crew so that all participants can potentially evacuate the aeroplane within the required 90 seconds.

Additionally, if required to do so, a manufacturer must comply with the ditching criteria of 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. (See Section 9.23.)

8.17 Potential alternatives to the evacuation requirements of 25.803

For many years NAAs have required the emergency evacuation requirements of 25.803 be demonstrated by full-scale practical demonstration tests. More recently analysis or partial analysis has been accepted by NAAs for some aeroplane type certification.

However, there have been many criticisms and questions of the validity of the 25.803 criteria by interested parties, including but not limited to the following:

- Flight crew and cabin crew are trained specifically for the test and know that they have to complete the evacuation within 90 seconds. Test participants acting as passengers are usually, but not always, employees of the manufacturer and might be highly motivated to achieve this.
- Cabin crew know beforehand that only 50% of the exits will be available.
- Although the 25.803 criteria requires that only 50% of emergency exits will be available, historically test conditions have always provided that one of a pair of emergency exits are available, which is not always the case in actual emergency evacuations.
- Cabin baggage, pillows and blankets are placed in the aisles, but the baggage is very lightweight usually contains only light density materials. Again this is not representative of many emergency evacuations where passengers have taken heavier items

such as ‘baggage with wheels’ with them to emergency exits and down evacuation slides. Most baggage in test scenarios remains in the passenger cabin. FAA AC criteria require bags to be filled with clothes or newspapers but the density of such contents has sometimes been questionable.

- Children, PRMs and elderly persons are not included in testing for very valid ethical reasons.
- Test participants acting as passengers will be seated for a short amount of time prior to commencement of the test. This is not representative of a flight when passengers might have been seated for a considerable time prior to an evacuation on landing.

In some recent 25.803 evacuation tests, aeroplane manufactures have assessed test participants acting as passengers for their fitness and agility prior to the test. Manufactures’ have a duty of care to protect test participants. However, there is a potential for a resulting participant profile to affect the result of the test. NAAs should therefore have criteria to account for such a possible unrealistic passenger profile which might be unrepresentative of normal operations.

It is difficult to see how the requirements of 25.803 might be made more realistic without increasing the dangers to test participants which would be ethically unacceptable to NAAs and manufacturers.

In one such evacuation test a participant suffered life-changing injuries and as a direct result the State of California, USA, banned such testing when using evacuation slides.

Perhaps it is time to look at possible alternatives by moving away from the current requirements of 25.803 and instead maybe utilise computer based mathematical evacuation models.

Such models need to be validated, most likely by using previous 25.803 demonstration data or the results of incidents or other test evacuations. However, models can be constructed using separate data sources such as passenger movement rates generated experimentally, thus allowing the validation process to be independent of the data sources of the model.

Given that over the last 50 years a significant number of evacuation demonstrations have been conducted by manufacturers, there is an enormous amount of data on evacuation issues reflecting such variables as passenger numbers, emergency exit types and their location, as well as the number of cabin crew, their locations and their evacuation procedures.

Many industry observers would probably conclude that use of practical evacuation demonstration tests have reached the end of robust defensibility and that there is now a need for an enhanced analytical capability that such models might permit.

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 set out to determine how computer models might be reliably used for certification applications such as 25.803[43]. Applications for the use of airEXODUS include:

- Aeroplane design.
- 25.803 evacuation testing.
- Crew training.
- Crew evacuation procedures.
- Operational issues.
- Accident investigation.

The Fire Safety Engineering Group (FSEG) at the University of Greenwich has continued research on computer based mathematical modelling for many evacuation scenarios and has issued numerous papers on this subject. Additionally the FSEG has worked for many years on fire modelling for evacuation in respect of many types of transport, as well as other fire scenarios such as within buildings.

In the paper published by FSEG in January 2017, the work combined fire and evacuation simulation tools (SMARTFIRE and airEXODUS) to numerically investigate the 1985 Manchester accident involving a Boeing 737. The paper looked at many aspects of this 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 are:

- The delay and difficulty in opening the three available emergency exits (i.e. 50% of the emergency exits on this 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 16m^2.
- 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.

See Recommendation 11.

8.18 Certification of aeroplanes with 44 or fewer passenger seats installed

For aeroplanes with 44 or fewer passenger seats installed, the requirements of 25.803 are not applicable even though one cabin crew member is required when more than 19 passenger seats are installed. However, 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 25.803 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 25.803 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 such compliance is necessary for aeroplane initial type certification. These requirements include criteria for emergency exits, passenger cabin aisles, lighting systems and other related emergency evacuation provisions. According to EASA their rationale is that smaller aeroplanes are unlikely to present problems and that in-service experience has not revealed any reason to question this approach.

8.19 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 such as 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 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 25.803 demonstration were R1, R2, R3 and L4. The demonstration was conducted with 420 participants (passengers), 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 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 at the Southern California Cabin Safety Symposium(44), Boeing identified what they considered to be two significant differences between earlier 25.803 demonstrations with other aeroplane types and the first Boeing 777-200 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’ and no longer allowed in ‘test’ conditions. In some emergency evacuations flight crew might decide to use the flight deck evacuation facilities such as DV 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 25.803 demonstrations had been conducted, they were not necessarily the reason that the first Boeing 777-200 25.803 demonstration did not meet the 90 second criteria. The FAA and JAA determined that in the first Boeing 777-200 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). 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 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 these new evacuation procedures, Boeing conducted two subsequent B777-200 25.803 demonstrations in 1996, one with 400 passengers and eight cabin crew, and the other with 440 passengers and nine cabin crew. Both were successful.

8.20 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 NAAs are not always involved during the certification process. This might lead to some operational factors being overlooked and the need to develop mitigating operational 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 12.

8.21 Overhead stowage bins – bin size and the concept of lockable bins

(See associated operational considerations at Section 9.29 – Cabin Baggage.)

In the early days of commercial passenger aeroplanes, only overhead open hat racks were available for the stowage of passengers' possessions and were restricted to light items such as hats, coats and very little else. Over the years passengers began to travel with bigger and heavier items. Larger overhead stowage facilities began to be introduced by manufacturers and operators in the 1950s but most were still open and the contents unrestrained. By the mid 1970s manufacturers started to install overhead bins that included a compartment door which was latched for TTOL and other critical phases of flight. This was soon adopted by NAAs and became a regulatory requirement in the 1980s.

Cabin baggage is not weighed, so there is no verification that the weight of baggage carried in overhead bins complies with the maximum permissible weight placards. The increase in the size and associated weight of passenger baggage stowed in overhead bins may give cause for concern since there is usually no assessment by check-in staff of what is being carried. The consequence of this is that overloaded bins could fail 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 local**is**ed impact conditions exceeding the regulatory requirements.

In an impact situation the integrity of overhead bins may fail structurally, or fail to contain the contents. In the 1989 Boeing 737-400 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(45). The 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."

Some manufacturers are introducing considerably larger overhead stowage bins. For example Boeing has introduced new 'Space' bins for the B737-900 which increases the number of average sized cabin bags from some 132 to 198. Airbus has also introduced larger overhead bins on their A320 and A321 neo series. These Airbus Airspace XL overhead bins provide some 40% more storage space. On twin-aisle aeroplanes, some overhead bins and are so large that when full they are so heavy that cabin crew have difficulty closing them, especially if no power assist facility is incorporated into the design. One operator has resorted to having a third party on board to close such overhead bins prior to departure, but this does not address the in-flight issue.

It is possible that an increase in stowage capacity in the passenger cabin could result in passengers causing more congestion in the aisles when taking cabin baggage with them in an evacuation; simply because some such items that previously would be stowed in the hold, sometimes at extra cost, are now stowed in the passenger cabin. Perhaps the term 'cabin baggage' for some larger items, such as 'baggage with wheels', might be better referred to as 'hold baggage carried in the cabin'.

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 events. The JAA proposals made in 2003 in respect of overhead bin safety precautions should also be considered.

Issues discussed at Section 9.29 and the associated accidents identified where passengers took cabin baggage with them in emergency evacuations, quite clearly demonstrate that there are some serious operational problems to be addressed by industry.

One mitigating option would be for overhead bins to be centrally locked for taxi, take-off and landing. Overhead bins that contain emergency equipment that might be needed during or post evacuation should not be locked. In the first edition of this paper, published in April 2018, the FOG made several recommendations on the issue of cabin baggage and that NAA's consider the concept of lockable overhead bins.

Potential Positives for lockable overhead bins: Baggage stowed in overhead bins will remain in the passenger cabin and not be taken to exits in an emergency evacuation unless overhead bin locking devices fail or passengers succeed in forcing bins open or are unlocked by the crew.

Potential Negatives for lockable overhead bins: Passengers may delay the evacuation if they attempt to force open overhead bins. Passengers might attempt to stow larger items of cabin baggage in under seat areas and such baggage might still be taken in an evacuation. Other stowage locations such as closets used for the stowage of cabin baggage would also need to be considered.

Design considerations for lockable overhead bins: If such a concept were to be adopted the following design questions would need to be addressed:

- Should the system be linked to the on/off seatbelt sign, or activated separately at the flight crew's discretion? Linking it to the seat belt sign would also lock overhead bins in the event of decompression or turbulence.
- Should the locking system only be controlled by the flight crew thereby preventing attempts by passengers to disable the system from within the cabin?
- Should the locking system be designed, as far as is practicable, to ensure that overhead bins remain closed even after being subjected to relatively high positive-g forces on landing or impact?
- Should the system allow cabin crew to close any compartments which might be in the open position at the time of locking system activation? Or should the flight crew only activate the system when they have received the cabin secure check, although this might be after push back? Passenger would need to be advised that they must turn-off any PEDs that are stowed in overhead bins.
- With the overhead bins being locked, will the movement of passengers pushing towards exits negate the most determined of passenger attempts to force overhead bins open?
- Should the locking system incorporate some sort of 'fail safe' option so that in the event of a system failure after landing the overhead bins can be unlocked by an alternative means?
- The system would need to ensure that overhead bins containing emergency equipment or other equipment that might be needed by cabin crew in normal operations or in an emergency are not locked during taxi, take-off and landing (TTOL).

Note: It is of interest that the website containing publicity material for the Russian Irkhut MC-21 aircraft states that overhead stowage bins on this aircraft can be fitted, as an option, with remotely-controlled electromechanical locks and be visually monitored by the cabin crew.

International regulation considerations: It would be important that system(s) for lockable overhead bins be first agreed as a certification requirement by NAAs on an international basis, possibly in compliance with an ICAO standard. Many questions would have to be addressed such as its applicability to new design aeroplanes or new build aeroplanes, and retrospective installation to existing aeroplanes, as well as the application of a discriminant factor such as aeroplane weight or the number of passenger seats installed. Any proposal for introducing an international regulatory requirement for lockable overhead bins would be subject to a regulatory Cost Benefit Analysis. A lack of statistical evidence of passenger fatalities directly related to cabin baggage in emergency evacuations might have a negative effect on such a proposal.

Other operational considerations: Passenger safety briefings will need to specify that overhead bins will be locked for taxi, take-off and landing and that in the event of an evacuation the opening of overhead bins to retrieve baggage will **not** be possible. This would be of particular importance if lockable overhead bins are only to be installed on some aeroplane types and not others. There is the potential for confusion here and passengers may still attempt to retrieve cabin baggage from overhead bins without really knowing if they are travelling in an aeroplane with lockable overhead bins or not, especially if they have not listened to or taken note of safety briefings. Therefore the issue of retrospective action would be of significant importance.

See Recommendations 13 and 22.

8.22 External and internal cameras

External visibility

External cameras are invaluable in providing the flight crew with a real-time information source through which safety critical decisions can be made.

Such devices were briefly considered by the UK CAA in the aftermath of the Boeing 737 Manchester accident but this did not result in any recommendations on their future provision. More recently, external cameras have been installed on aeroplanes, linked to in-flight entertainment systems for the benefit of passengers, and to flight deck displays with Electronic Flight Instrument Systems (EFIS) which include many Multi-function Display (MFD) screens. Their use in enhancing flight crew situational awareness of external and internal conditions, and in the making of timely decisions in emergencies based on real-time information, is obvious.

Their advantages to the flight crew in situations when an emergency evacuation might be required include:

- Identifying areas of external fire and other hazards, as well as emergency exits that might be useable, and those that might not be available.
- Identification of engine fire, or conversely a less serious tailpipe fire.
- In the case of propeller aeroplanes, identifying if engines are still running.
- Identifying the configuration of wing surface/configuration for safe evacuation from overwing emergency exits.
- Identifying the location of RFFS vehicles, personnel and associated activities.

On November 2010, a Qantas Airbus A380, (Flight Number 32), was en route from Singapore to Sydney, Australia. Shortly after take-off from Singapore the A380 suffered an uncontained failure of the No 2 (left inboard) engine causing damage to the left wing and multiple system failures. On board were 440 passengers, five flight crew and 24 cabin crew. The second officer went into the cabin to assess the damage. A passenger who was a pilot pointed out to him an external view of the aeroplane on the in-flight entertainment systems from a tail-plane camera showing the fuel leak from the left wing. See Case Study at Section 11.)

Advantages to the flight crew in non-emergency situations include:

- Identifying the location and proximity of service vehicles and other equipment prior to engine start and pushback.
- Identifying any taxi issues that might present problems.
- Identifying the location and proximity of solid structures as well as other aeroplanes in the vicinity during pushback and initial taxi.
- Identifying the actions of tug and other ground operations.

External cameras in twin-aisle aeroplanes

On twin-aisle aeroplanes the following camera installations and angles should be considered:

- A belly mounted A350/380 type camera just aft of the nose gear and forward facing to observe interaction with tug crews and engineers. This is an issue with repeated Air Safety Reports (ASR) relevance, as identified by the UK Flight Safety Committee, since aeroplanes repeatedly attempt to taxi with the tug or engineers still attached. Also, the view from the flight deck on a twin-aisle aeroplane means that the first area of visible taxi way ahead is more than 20 metres away.
- The belly mounted camera also allows assessment of the nose wheel position for narrow taxi ways and runway turning to ensure that the aeroplane remains on the paved surface. A narrow runway 180° turn is an example where the nosewheel camera can be extremely useful.
- Additional external cameras could provide the flight crew with selectable views thus enhancing flight safety.
- Currently for external visibility these displays are only selectable by the flight crew. It might be a better option it they were automatically displayed by phase of flight, i.e. when an RTO is sensed they would display on an appropriate screen, but not by removing more essential information such as checklists and engine parameters. Modern electronic display screens can allow for the presentation of video imaging either on a selective or pop-up basis. Consideration would need to be given to which displays might have auto 'pop up' capability and in what circumstances.

Consideration must also be given to a means of heating to avoid formation of ice or frost obscuring the view. This can be incorporated within existing camera installations and linked to flight deck window heating systems. Likewise, consideration can be given to illuminating the areas to be covered. Again, this is incorporated in some existing camera installations with dedicated light switches for the cameras. Any lighting would have to be installed in such a way so as to not “blind” tug crews, load teams or other aeroplanes. Following careful analysis the possibility to link cameras and MFD with a specific phase of flight or with any auto-activated check list might reduce flight crew workload.

As an example, the B777-300 has cameras covering a forward view towards the nose wheel area and from the top of the tail plane, two cameras angled towards each engine tailpipe and main gear, port and starboard. The A350 and A380 have single wide-angle tail-plane cameras to observe engines and main gear and one placed aft of the nose gear looking forward.

Many of the above issues will equally or partially apply to the installation of cameras in single-aisle aeroplanes.

Internal cameras in the passenger cabin and lower lobe cargo holds

At the moment internal cameras in passenger cabins are limited and only required to be located adjacent to the flight deck security door, usually in a galley area and often next to the forward passenger toilet. More thought should be given to internal camera locations.

Additional cameras showing the passenger cabin, especially covering the emergency exits, could provide significant information to the flight crew in making evacuation decisions. The difficulties associated with communication between flight crew and cabin crew because of the requirements of a “secured” flight deck door would be reduced. Situational Awareness would be significantly enhanced and the ability to add a recording feature to the camera facility is a logical next step. Events such as passenger disruptions and/or hijack and the severity of any fire or smoke in the cabin could easily be assessed by the flight crew before the cabin crew can identify and report the situation to the flight crew.

Internal disabling action of all cameras is essential in the event of highjack with access already gained into the flight deck, so as to protect any security force action.

Infrared Cameras placed strategically in the aeroplane lower cargo holds might also help flight crew assessment of a fire or smoke situation and any associated decision making. This possibility is currently a research subject.

Summary

The above information clearly identifies the many advantages of external and internal camera installations in both emergency and non-emergency situations. The existence of EFIS and MFDs already installed on many modern aeroplanes is an important factor in recommending an extension of current installations, in order to incorporate additional cameras where possible without prejudice to time critical checklist actions.

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.

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 standard 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 both 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 emphas**is**e 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 showed significant differences in evacuation times based on the location of cabin crew seats relevant to the primary cabin crew evacuation duties[46]. CAMI stated: “Evacuations with flight attendants 24ft 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 had such an exit configuration, although in this case it is understood that the evacuation procedure was 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 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 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 other 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) should: “.....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 [47]. 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 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 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 applies 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 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 passengers are secured by an approved restraint device such a seat belt, harness or other means.
- All passenger items are safely stowed, aisles and cross-aisles are clear, and that passenger seats are in the TTOL position, tray tables and that other equipment such as footrests and 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.

9.4 Use of cabin crew assist spaces

As discussed in Section 8.6, cabin crew should make effective use of assist spaces during an evacuation in order to maintain a rapid flow of passengers. Although the Cabin Crew Operations Manuals (CCOM) of aeroplane manufactures' do specify the location of assist spaces, some operators CCOMs 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. Perhaps body-mass should be an issue for cabin crew medicals.

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."

On 10 March 1989 a Fokker F28-1000 operated by Air Ontario (Flight Number 1363), crashed some 49 seconds after take-off from Dryden, Canada, in freezing weather conditions. On board were 65 passengers, two flight crew and two flight attendants. Twenty one passengers, two flight crew and one flight attendant died in the crash. 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(48). 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 a flight attendant who was wearing shorts and a short-sleeved shirt(49). 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 criterion 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 therefore 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 of their emergency evacuation checklists were longer than necessary and included some items that were superfluous in the circumstances. In particular, the order from the flight crew to initiate an emergency evacuation was sometimes placed later in the checklist than it needed to be. In 1986 the UK CAA in Notice to AOC Holders Number 4/86 drew the attention of operators to this issue, advising them to review their checklists and to amend them if necessary(50).

FAA guidance in Advisory Circular 120-71B Standard Operating Procedures and Pilot Monitoring Duties for Flight Deck Crewmembers states: "Memory items should be avoided whenever possible. If the procedure must include memory items, they should be clearly identified, emphasized in training, less than three items, and should not contain conditional decision steps." This is based on research data and operational experience. Based on the data, if this guidance is not followed, pilots are more likely to make mistakes.

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 supply cut-off and have ceased operating or have almost done so before commanding an evacuation. (See Section 9.8 in respect of the Qantas A380 accident and the Case Study at Section 11.)

Aeroplane depressurisation: If the interior of the aeroplane retains 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 a safe 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 in the 1980s 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 those for the flight crew.

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 consider the following possibilities:

- 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 exit identifier(s) 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.
- Safety briefing(s) of passengers will need to be amended.
- Crew evacuation procedures will need to be revised and passengers will need to be re-directed way 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 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 known 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 should 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 from Singapore, suffered an uncontained failure of the No 2 (left inboard) engine, and a return to Singapore was made[51]. Numerous holes were made in the left wing by debris from the No 2 engine and multiple system failures occurred. After a successful landing at Singapore the commander faced several significant issues:

- Although the damaged No 2 (left inboard) engine and other engines were shut down after landing, the No 1 (left outboard) engine continued to run after normal shut-down procedures. It was finally shut- down some three hours after the landing by RFFS pumping foam directly into the engine inlet.
- 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 initially safer inside the aeroplane until disembarkation could be safely conducted. (See Case Study at Section 11.)

On 27 June 2016 a Boeing 777-300 operated by Singapore Airlines, (Flight Number 368) returned to Singapore after an engine oil light warning[52]. On landing at Singapore the Number 2 (left) 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 Section 11.)

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[53]. 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 Section 11.)

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 instead of making an emergency stop and initiating 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 Saudi Arabia Accident Report[54] 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 true for multi-deck aeroplanes such as the Boeing 747 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 evacuating passengers or debris. Slide speeds will also increase significantly if they become contaminated with fire-fighting agents or 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. This was true of the evacuation involving a British Airways Boeing 747-100 which on 20 November 1985 made an emergency landing at Lajes in the Azores in very bad weather. (See Case Study at Section 11.)

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 14.

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 made 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 flight crew has given the command to 'evacuate', the cabin crew will initiate the evacuation taking into account any external hazards. However, in some accidents the PA system may fail to function and therefore the means of alternative communication between flight crew, cabin crew and passengers will need to be addressed in operator's procedures and training.

If for any reason the commander is unable to give the command to evacuate, then this will be given by the next senior member of the flight crew. 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 an Asiana Boeing 777-200 accident at San Francisco, when the aeroplane descended below visual gildepath and impacted with a seawall, the NTSB stated: "The flight attendants acted appropriately when they initiated an emergency evacuation upon determining that there was a fire outside Door 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 Section 11.)

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 Aviation Safety Council of Taiwan Accident Report stated that many of the cabin crew did not hear any command to evacuate and had to make their own decisions as to the need to initiate an evacuation[(55)]. 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.

These accidents 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 into the accident 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 15.

9.10 Briefing of cabin crew by the 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. The cabin crew will pass their 'cabin secure' checks to the SCCM, who will in turn report them 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 DV 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 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 stated: "The cockpit door was found partially open by investigators. The interior of the cockpit was severely damaged"[56]. Possibly the severe damage to the flight deck delayed RFFS access to the flight crew. EASA has advised that all 'reinforced' flight deck doors should 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 an axe, can gain access to the flight deck 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)

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.

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[57]. The FAA considered that the following factors required to be addressed:

- 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.

In an emergency evacuation effective communication and coordination between flight crew and cabin crew is paramount. Usually it is the commander who has the more complete picture of both normal and emergency situations, and will contact the SCCM via the interphone system to advise the required actions to be taken. Such communication is likely to influence the outcome of the event and if the interphone system is not operative then 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 must act as a team. Valuable assistance to all cabin crew will be the shouting of evacuation commands at each emergency exit. This has the potential to alert cabin crew at other exits as to the situation in adjacent areas of the cabin, and the actions needed to evacuate passengers through the nearest exit, or redirect them to another more usable exit. When all other occupants have evacuated, the SCCM will need to establish contact with the commander and determine other necessary actions depending on injuries, the presence of RFFS personnel, and liaison with other emergency services.

An 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.

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 a jetway. On board were 277 passengers, three flight crew, nine flight attendants and two ground staff. When smoke started to fill the passenger cabin communication between the flight attendants and the flight crew could not be established. One of the flight attendants 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 flight attendants 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 jetway. The UK AAIB 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[58]. 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.)

Five months later on 28 October 2016, a Boeing 767-300 also operated by American Airlines, (Flight Number 383), during take-off from Chicago O'Hare, USA, suffered an uncontained failure of the No 2 (right) engine which resulted in a severe fire. On board were 161 passengers, two flight crew and seven flight attendants. All passengers and crew successfully evacuated the aeroplane. One passenger received a serious injury and 20 occupants received minor injuries. The aeroplane was substantially damaged by the fire.

The flight attendants initiated the evacuation whilst the No 1 (left) engine was still running which resulted in the serious injury to a passenger who had safely evacuated and was then knocked to the ground by the jet blast from the No 1 (left) engine. The NTSB in their Accident Report concluded that: "…..if the flight crew or the flight attendants had communicated after the airplane came to a stop, the flight crew could have become aware of the severity of the fire on the right side of the airplane and the need to expeditiously shut down the engines"[59]. In this accident the flight attendants were unable to operate the interphone system and communicate with the flight crew. The NTSB Accident Report concluded that: " ….American Airlines did, not adequately train flight attendants qualified on the Boeing 767 to effectively use the different interphone system models installed on the airplane during an emergency". (See Case Study at Section 11.)

In many other accidents the issue of ineffective communication between flight crew and cabin have been identified by accident investigators. The NTSB has stated that: “It is time for the FAA to emphasise the importance of ensuring that flight and cabin crew communications can facilitate safe and effective decision-making and action during situations requiring an evacuation”.

See Recommendation 16.

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 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.

Following the enforcement of the secured 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 16. (Combined with Section 9.13.)

D Passengers

9.15 Passenger safety briefing

Passenger safety briefings should ensure that essential safety information is received and understood before departure, and reinforced and repeated before arrival or whenever an in-flight situation requires it. Safety briefings have the potential to make passengers aware of their responsibilities and required actions in emergency evacuations.

Passengers who listen to and understand safety briefings are no doubt better prepared to take the correct actions in an evacuation. Under the stress of an emergency, passengers cannot always be relied upon to act rationally.

For long duration flights passengers might have to remember material on which they were briefed many hours prior to an emergency during flight or on landing.

There are many distractions that might mean passengers pay little attention to pre-flight safety briefings such as the handing out of newspapers, drinks, etc. during the boarding process, and also the now permitted use of mobile phones and other PEDs prior to departure.

Many NAAs require a specific pre-flight safety briefing of passengers seated at self-help exits but this has not been adopted internationally and is sometimes provided in a superficial way.

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

Some operators, in an attempt to capture passenger attention during pre-flight safety briefings, have produced clever and often humorous briefing routines or videos. But perhaps passengers do not adequately recognise the gravity of such briefings, or actually understand the important safety information being communicated. Operators should carefully consider safety briefing material so as to ensure that the important safety message is not overtaken by an element of comedy or other concepts which might have the potential to detract from the primary objective of providing essential safety information. It is not sufficient that safety briefings simply attract and hold the attention of passengers, but rather that, the safety content can be clearly understood and remembered when necessary.

Safety briefings should be subject to risk assessment for content and delivery rather than being accepted by in-house personnel who might be more focused on commercial issues.

Operator passenger safety briefings should include advisory information such as:

- The need for passengers to identify external hazards and not to open an emergency exit into a dangerous environment.
- Passengers not to take cabin baggage with them in an emergency evacuation.
- The nearest available emergency exit(s) might be behind them.

- The taking of photographic images during an evacuation will slow down passenger egress, and post-evacuation will interfere with RFFS operations.

Passenger safety cards should be readily understood 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 safety cards.

Although NAAs require operators to provide safety briefings there is no requirement that to ensure passengers pay attention. By default cabin crew might not be too concerned if passengers are reading, talking etc., and might not necessarily intercede.

Ideally the commander should introduce safety briefings so as to involve a level of gravitas to the information being communicated.

See Section 10.6 – ICAO Document 10086: ICAO 'Manual on Information and Instructions for Passenger Safety', which details suggested content of passenger briefing material.

See Recommendation 17.

9.16 Passenger seat allocation

Type III and Type IV are regarded as self-help emergency exits since 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 advised operators that the following categories of people are not suitable to occupy an exit seat row leading to Type III or Type IV emergency exits:

- Obese passengers.
- Children and infants.
- The elderly and infirm.
- Persons with reduced mobility.
- Prisoners in custody and deportees.

The UK CAA also determined that seats in Type III and Type IV emergency exit rows should be occupied for taxi, take-off and landing, so that in the event of an emergency evacuation, passengers 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 advised that:

- 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).

This issue is dealt with by EASA in CAT.OP.MPA.155(c) and CAT.OP.MPA.165.

In October the UK CAA 2018 published its review in CAP 1709 of operator's seat allocation which reiterated the above safety considerations, as well identifying operator's charging policy [(60)]. The review also recognised the statements made by the FOG in the First Edition of this paper and stated: "…we are currently engaging with the Royal Aeronautical Society to understand more about their recommendation and the underpinning evidence."

See Recommendation 18.

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 an impact 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 is conducted by video it is not actually required.

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

(Conclusion 49) 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[61]. 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[62].

Part of the cabin secure check 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 seat 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 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 two flight crew[63]. The 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[64].

The issue of child restraint systems (CRS) has been discussed for many years but is still unresolved in spite of numerous recommendations and initiatives.

Although most NAAs 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 19.

9.18 Passenger behaviour in emergency evacuations

Passenger behaviour in an emergency evacuation can be positive or negative. Positive behaviour can be acting calmly and following established evacuation procedures, even assisting others to evacuate. Negative behaviour results in passengers being ill-prepared to take the necessary actions to rapidly evacuate, perhaps due to inattention to safety briefings or failure to understand them. Some may become overwhelmed with fear and be ‘paralysed’ and unable to act rationally.

Passengers with reduced mobility and those under the influence of alcohol and/or drugs might not comply with crew evacuation orders. Competitive and aggressive survival instinct may have a detrimental effect on the overall evacuation as occurred in the 1984 Calgary accident, where several passengers went over seat backs to reach the exits ahead of others queuing in the aisle. This was the case in the 1985 Manchester accident and also identified in the Cranfield evacuation trials. (See Section 10.1.)

When passengers have to operate ‘self-help’ emergency exits, such as Type III exits, their actions are critical. They may fail to take the necessary actions because they are not trained to do so. Conversely, there are accidents when passengers took correct actions such as the 2009 Hudson River ditching when passengers quickly opened the Type III exits and evacuated onto the wings.

Aspects of passenger behaviour that have been experienced in evacuations:

- Panic, some overt and negative.
- A lack of appreciation of the seriousness of the situation.
- Ignoring crew commands.
- Hesitating and/or refusing to jump at emergency exits.
- Attempting to use the same exit by which they entered the aeroplane.
- Taking cabin baggage.
- Not effectively opening exit(s), if required to do so.

The increasing trend for passengers to take cabin baggage with them in an evacuation is a disturbing and a potentially fatal development. (See Section 9.29.)

Furthermore, in some recent evacuations passengers have used mobile phones and other equipment to record events both inside the passenger cabin and post-evacuation. Such actions can potentially impede the flow of passengers to emergency exits, and delay a rapid evacuation although any such evidence might be of assistance to accident investigators.

On 2 July 2017 a CRJ 700 operated by Sky West (Flight Number 5869) after landing at Denver, USA, developed a fire in the No 1 (left) engine. Several passengers having disembarked the aeroplane through the forward left emergency exit stood on the runway taking photographic images.

After evacuating an aeroplane, flight crew and cabin crew, assisted by RFFS personnel if available, should instruct passenger to move away from the aeroplane as soon as possible and make their way to areas of safety. This should be specified in Operation Manuals. This is especially important if the aeroplane is on fire since the spread of fire and/or subsequent explosions are possible. Passengers remaining in the vicinity of the aeroplane are likely to interfere with the actions of RFFS personnel in extinguishing a fire and their ability to rescue passengers who may still be inside the aeroplane. There is also the danger of passengers being hit by RFFS vehicles.

Operators might need to consider the above issues and determine if there are actions such as briefing information that might have the potential to mitigate the potential problems of such passenger behaviour.

9.19 Disruptive passenger events – the availability and consumption of alcohol and the use of drugs by passengers

In the event of an emergency, passengers under the influence of alcohol or drugs might have an adverse effect on a rapid evacuation by not understanding or not obeying crew commands. The consumption of alcohol before and during flight is identified by the UK CAA as an increasing problem. According to EASA in April 2019 the number of disruptive passenger incidents in 2018 increased by 34% compared to 2017[65]. EASA stated that in 2018, once every three hours the safety of a flight in the EU was threatened by passengers behaving in an unruly or disruptive manner. At least 70% of these incidents involved aggressive behaviour by passengers and once a month a flight was forced to make an emergency diversion when such a situation escalated.

Some operators do not require their cabin crew to monitor passenger alcohol consumption in-flight and some cabin crew have been offered incentives to sell as many drinks as possible. Duty-free shops selling ‘miniature’ bottles of spirits identical to those provided in-flight has increased the problem although some have now ceased such sales. Passengers who drink their own alcohol during flight negate cabin crew monitoring of the level of alcohol being consumed. One UK operator has introduced a ‘no alcohol’ policy on its flights before 0800. Both the International Air Transport Association (IATA) and the UK Travel Retail Forum (UKTRF) have introduced public awareness campaigns to address these issues.

There have been several cases where passengers have drunk their duty-free alcohol purchases in terminal departures areas prior to boarding and this has sometimes resulted in delays to departure due to passengers being offloaded. In at least one case an aeroplane had to return to the gate after pushback. In an in incident in 2019 an aeroplane had to return to Stansted, UK, some 45 minutes into the flight escorted by RAF Typhoons due to a concern by ATC regarding flight deck security. In this incident the passenger was sent a bill by the operators for £85,000.

In the USA duty-free alcohol purchased in terminal departure areas is available only for collection at the final departure gate. In the UK a recent move by many duty-free shops has been to place alcohol in sealed tamper-proof bags bearing a label stating “Do not open alcohol purchases until your final destination”. Although this has the potential to improve the situation on departures from the UK, unless adopted on an international basis, down-route departures will continue to be affected.

In June 2019 ICAO published Document 10117 intended to assist national governments in legislating appropriate and better harmonised measures to prevent and deal with unruly and disruptive passengers[66].

See Recommendation 20.

E Types of Evacuations

9.20 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 No 2 engine. The commander decided to make an emergency landing at Sioux Gateway Airport, Iowa. The DC-10 having lost the No 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[67]. 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.

9.21 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.

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 that other options such as external cameras might merit further research. (See Section 8.22.)

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.

9.22 Passenger initiated unnecessary evacuations

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

In July 2014 EASA issued a Report which reviewed 17 such incidents(68). 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 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 test participants acting as passengers 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 in 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.

9.23 Evacuation on water

A ditching obviously has significant differences to a land evacuation. One of the most important differences is the unavailability of emergency exits in a ditching because some might be under the waterline or close to it, and may not be designated by certification requirements as ditching 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.

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. Some aeroplanes are equipped with life-rafts which are stowed in passenger cabin overhead bins.

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 or for passengers and crew to don lifejackets or make ready for an evacuation that could be either directly into the water or onto the aeroplane wings, slide-rafts or life-rafts.

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 Canada 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. They 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 Section 11.)

Other ditching events have had less happy outcomes. 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 Maarten, Netherlands Antilles. According to the NTSB Accident Report the DC-9 ran out of fuel in bad weather and ditched near St Croix[69]. 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 Section 11.)

Another water landing occurred on 20 February 1991 when 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[70]. 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. (See Section 8.16.)

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.

9.24 Rapid disembarkation via jetways etc., as an alternative to an evacuation

An emergency evacuation is required when the commander, other flight crew, or cabin crew determine there to be an immediate life-threatening situation. Some incidents might require passengers to leave the aeroplane with some degree of urgency, but not necessarily via evacuation slides.

Rapid disembarkation might be preferable to an evacuation in circumstances where, for example, there are fumes in the passenger cabin, or there has been a large fuel spillage outside the aeroplane, or the commander has been advised that an explosive device might be on board.

Rapid disembarkation rather than the use of evacuation slides has the potential to avoid external hazards such as ground service equipment and vehicles, as well as ground personnel. In such circumstances injury to aeroplane occupants and ground personnel can be avoided.

However, rapid disembarkation can only be achieved when airstairs and/or airport terminal jetways are connected to the aeroplane, or can be rapidly repositioned at floor level emergency exits. This is also the case for aeroplanes that have integral airstairs which are usually located at the forward left emergency exit (L1).

When a jetway is used, procedures should ensure the rapid movement of passengers from the passenger cabin into a jetway and that passengers are managed so that they move quickly up the jetway and do not block passenger egress from the cabin. Aeroplanes with more than one passenger deck might require additional consideration.

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 confusion.

Operators should ensure that they have effective procedures and associated training for flight crew, cabin crew and ground personnel to deal with a rapid disembarkation and that there are effective procedures for communication between aeroplane crew and ground personnel including any outsourced agencies.

Aeroplane crew procedures and ground crew procedures should be compatible in order to achieve a positive outcome. Operators should also include procedures for the safe and rapid disembarkation of passengers when no flight crew are on board.

For the avoidance of any doubt in the minds of passengers who may have already received the pre-flight safety briefing, the commander should issue a 'Rapid Disembarkation' instruction to the SCCM only via the interphone or by a flight deck briefing and not broadcast by PA, since passengers might not understand the difference between that and an emergency evacuation. The SCCM should then pass on the 'Rapid Disembarkation' instruction to the cabin crew members discreetly avoiding any reference to 'emergency' or 'evacuation'.

Operations Manuals and crew safety training should reflect the above.

9.25 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.

9.26 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

9.27 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 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 No 1 (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 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[(71)]. This work by the AAIB showed that even a small degree of a crosswind can be significant. If as happened 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’.

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 an 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 runway width 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 evacuation.

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 No 2 (right) engine, which the flight crew shut down. ATC reported that smoke was coming from the No 2 engine and cabin crew were also aware of this. The AAIB in their Accident Bulletin stated 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”[(72)].

See Recommendation 21.

9.28 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 on 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 Section 11.)

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.

9.29 Cabin baggage

(See associated airworthiness considerations at Section 8.21 – Overhead stowage bins – bin size and the concept of lockable bins.)

Passengers taking cabin baggage with them in an evacuation is not a new occurrence. The Canadian Aviation Safety Board (CASB) Occurrence Report into the 1984 Calgary accident stated: “Many (passengers) stopped to retrieve hand baggage before they left (evacuated).”

This trend is increasing and is potentially exacerbated by a greater volume of baggage allowed by operators to be carried in passenger cabins. The use of smart phones has recently led to an increasing amount of photographic evidence showing passengers retrieving baggage and taking it with them in emergency evacuations.

In order to speed up turn round times some operators encourage more and more carry-on baggage and now charge passengers for checking ‘hold’ baggage. High charges might be imposed if cabin baggage is found to be too large during the check-in/boarding process and has to be diverted to the hold.

The value of cabin baggage contents, such as passports, legal and business documents, electronic equipment, medicines, etc is increasing, and passengers will often attempt to take cabin baggage with them in an evacuation, especially if it is all that they have with them or is where they have packed their valuable and essential items.

The number of ‘airside’ airport shops has increased dramatically in recent years and the sale of items purchased there can further contribute to cabin stowage problems.

Many operators now use ‘e-ticketing’ whereby passengers do not use airport check-in and go straight to the boarding gate. As a result, the first time the operator or their handling agent(s) have the opportunity to assess the size and amount of cabin baggage is shortly prior to or during boarding.

The determination of passengers regarding personal belongings is clearly illustrated in 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[73]. (See Case Study at Section 11.)

Other accidents where passengers evacuated with cabin baggage include:

Air France	A340-300	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
American Airlines	B767-300	Chicago, USA	28 October 2016

Some of the above accidents were clearly catastrophic involving external fire and fuselage disruption and demanded 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 their fellow passengers.

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 coming to rest in a shallow gulley. Some four minutes later, the fuselage erupted in flames. The TSB in their Accident Report stated that although all passengers managed to evacuate successfully, the evacuation was impeded because nearly 50% of passengers took their baggage in the evacuation. (See Case Study at Section 11.)

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 an emergency landing an evacuation was ordered. 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"[(75)]. The AAIB concluded that some passengers slowed down their own evacuation because of this. The AAIB Accident Report included the following statement taken from post-accident 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[(76)]. In spite of this some passengers evacuated with their baggage. The TSB Accident Report 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."

On 8 September 2015, a Boeing 777-200 operated by British Airways, (Flight Number 2276), suffered an uncontained failure of the No 1 (left) engine on take-off from Las Vegas, USA[(77&78)]. On board were 157 passengers, three flight crew and ten cabin crew. Photographic images show that some passengers evacuated the aeroplane with items including 'baggage with wheels', some the size of suitcases. The FOG is of the opinion that a significant issue in this evacuation was the number of passengers who took baggage with them. Although this did not adversely affect the evacuation, had the B777-200 been configured at its maximum passenger capacity of 440 seats installed and with that many passengers carried, the evacuation time might have been dangerously extended with potential risk to passengers.

Passengers with cabin baggage post-evacuation of a B777-200 at Las Vegas in September 2015.

On 28 October 2016, a Boeing 767-300, operated by American Airlines, (Flight Number 383) suffered an uncontained engine failure during take-off from Chicago O'Hare in the USA. Although the Boeing 767-300 has eight emergency exits, only three were available because of the post-accident fire. In the ensuing evacuation on the runway some passengers took baggage with them to the three available emergency exits. The cabin crew gave specific instructions for passengers to leave baggage behind but this was ignored by some. Physical intervention by the cabin crew had little or no affect. The NTSB in their Accident Report recommended to the FAA that research be conducted "…to (1) measure and evaluate the effects of carry-on baggage on passenger deplaning times and safety during an emergency evacuation and (2) identify effective countermeasures to reduce any detrimental risks, and implement the countermeasures (A-18-9)." The FAA have advised their intention to conduct a separate research activity to study passenger understanding and retention of cabin safety information, with the emphasis on preventing passengers from bringing their carry-on baggage to the exit in an emergency. (See Case Study at Section (11.)

It would appear that cabin crew have little control over passengers who insist on taking baggage with them in an evacuation. Even if cabin crew at an emergency exit were to succeed in removing cabin baggage from a passenger there is little or no space to place it without causing an obstruction to the evacuation.

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 baggage with them in an emergency evacuation and ignore this, they might be in breach of this legal requirement.

A survey conducted by the NTSB in 2000 found that 50% of passengers in emergency evacuations had taken cabin baggage with them because of essential items such as:

- Money, wallets and credit cards;
- Company items;
- Keys; and
- Medicines.

Many years ago a small bag was provided by operators for premium class passengers which would easily accommodate such items. Such bags should not adversely affect an emergency evacuation if taken by passengers. A return to a similar arrangement today for all passengers could make it less likely for them to attempt to retrieve their cabin baggage from overhead bins in an emergency and may indeed offer a marketing opportunity for operators. However, the best option is still for passengers to evacuate with no baggage and for essential items only to be carried in the pockets of their clothing.

In a survey of UK passengers conducted on behalf of the RAeS in 2018[79] the following statistics were obtained for an emergency evacuation involving a life-threatening situation:

- 61% of passengers said they would take nothing with them apart from what they carried in their pockets;
- 23% said that they would take valuables with them that were in easy reach; and
- 6% said that they would take all their belongings with them.

For an emergency evacuation not involving a life-threatening situation the following was identified:

- 20% said that they would take nothing with them apart from what they carried in their pockets;
- 31% said that they would take valuables with them that were in easy reach; and
- 29% said that they would take all their belongings with them.

But how do passengers identify a life-threatening situation in an emergency? Situations in an evacuation can quickly change and can be different depending on where passengers are located in the cabin. A fire in the aft of the passenger cabin may immediately be life-threatening to those passengers in that area, while at the front of the cabin passengers may not identify the seriousness of the situation and may take a less urgent approach to evacuating as quickly as possible. This potential lack of situational awareness might in some emergency evacuations include cabin crew and flight crew, especially on large aeroplane types and more especially those with two decks (Boeing 747 and Airbus A380). Even if a small minority of passengers take baggage with them in an emergency evacuation there is a potential threat to life in worst case scenarios.

In June 2011 the CAA issued Safety Notice Number SN-2011/05[80]. 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.”

In October 2015 the CAA issued Safety Notice Number SN-2015/006[81]. 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 pre-flight briefings of passengers.

See Recommendation 22.

9.30 Terrain

In the August 2005 Airbus A340 accident at Toronto, the aeroplane departed the end of the runway and came to rest in a shallow gully. At the start of the evacuation the cabin crew at emergency exits R1 and R2 assessed that they were not useable due the close proximity of a fast-flowing stream. After commencement of the evacuation the cabin crew at these exits reassessed the situation, and determined that given the increasing amount of smoke in the passenger cabin, and in order to speed up the evacuation, these exits would have to be used. (See Case Study at Section 11.)

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 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”[82]. 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

9.31 Operational demonstration of evacuation procedures, training and systems

In addition to the 25.803 demonstration that must be carried out by manufacturers during aeroplane certification. (See Sections 8.15 and 8.16). In 14 CFR 121.291 the FAA has stipulated additional evacuation testing that must be conducted by operators[83]. This test is applicable to aeroplanes with more than 44 passenger seats installed and is often referred to as a ‘partial’ or ‘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:

- 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 NAAs 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 23.

9.32 Regulatory training requirements for aeroplane evacuation

Lack of experience or realism during evacuation training has negative repercussions during actual events. Such was the case with the Ryanair accident at Stansted in February 2002, when ATC reported that smoke was coming from the No 2 (right) engine. 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 No 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 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 included Safety 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.”

However, some NAAs 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 the additional operating force required 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 in 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 NAAs 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 NAAs. Additionally, some NAAs 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.

9.33 Emergency exit and evacuation slide training devices

NAAs 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 NAA audits should include this issue.

See Recommendation 24.

9.34 Evacuation procedures and associated training

In the first 25.803 demonstration test conducted by Boeing for the B777-200, shortfalls in the cabin crew procedures were identified and to address this, Boeing developed significant procedures to improve evacuation. (See Section 8.19.) These issues were addressed in a paper presented by Boeing and British Airways at a conference in Lausanne in 1997(84) 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 passengers waiting to evacuate at 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.

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

9.35 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 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, according to the NTSB Accident Report only three of the eight floor level exits were usable throughout the evacuation[85]. (See Case Study at Section11.)

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.
- Passengers at self-help exits may fail to operate 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, or unusable due to adverse wind conditions.

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.

In the Boeing 777-300 Korean Air accident at Tokyo, Japan, in May 2016, an uncontained engine failure of the No 1 (left) engine resulted in a serious fire affecting the left wing. Six of the ten Type 'A' exits were opened by the cabin crew but only four of these exits on the right side were useable in the emergency evacuation because the evacuation slide at R5 had deployed underneath the fuselage. It is important that even when emergency exits have been opened and evacuation slides have been deployed, the conditions for a safe evacuation must first be assessed by cabin crew before commencing an evacuation. (See Case Study at Section 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)[86]. 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 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 personal 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 Section 11.)

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 Section 11.)

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.

10. RESEARCH, SAFETY STUDIES AND RELEVANT DOCUMENTS

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 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 CAA, and were intended to be initial changes prior to research being conducted on issues involving evacuation.

The 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 CAA also wanted to address the issue of evacuation though 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”(87).

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 CAA in 1985/1986 were valid, although some minor adjustments were subsequently made by the CAA to AN 79.

The following issues were addressed in 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 CAA funded a research project with Cranfield to look into the possible improvements that might be made to Type III emergency exit design(88). 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 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 and 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. Some other manufacturers have followed with similar designs.

10.3 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 some recommendations that had been made previously. Some of the recommendations address the following issues:

- New aeroplanes should meet the evacuation demonstration requirements of 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 6ft (1.8m) 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.

10.4 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 including PA systems.
- Passenger behaviour, including 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.

10.5 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.
- 'Return to seat' signs and intelligibility of public address systems in areas where the occupants are not normally seated.
- Means of external viewing including hazards.
- 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.

10.6 ICAO Manual on Information and Instructions for Passenger Safety (Doc 10086) (2018)

ICAO developed the 'Manual on Information and Instructions for Passenger Safety' in order to provide guidance on the ICAO provisions in Annex 6 Part 1, in respect of the safety related issues that an operator should make passengers familiar with. The ICAO Manual addresses in some detail many of the issues raised in this RAeS paper including:

- Passenger safety briefings and passenger safety briefing cards.
- Passenger information signs, markings and placards.
- Occupancy of emergency exit rows.
- Instructions for brace positions.
- Brace and evacuation commands.
- Cabin baggage in evacuations and other considerations.

The content of the ICAO Manual were developed by wide consensus and might therefore be considered to be a valid and fairly comprehensive document.

See Recommendation 17.

11 CASE STUDIES OF EMERGENCY EVACUATIONS

While this paper identifies many problems that have influenced emergency evacuations and new NAA requirements, 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 CRM training, associated with 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 included in 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 Maarten, Netherlands Antilles. According to the NTSB Accident Report, due to bad weather at St Maarten 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 ordered 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 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 aerodrome steps 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

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.

Christopher Ebdon/flickr

Fire damage to the L1011 TriStar which crashed shortly after take-off at New York in July 1992

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

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.

N J Butcher FRAeS

The Boeing 757-200 after departing the runway at Girona in September 1999.

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.

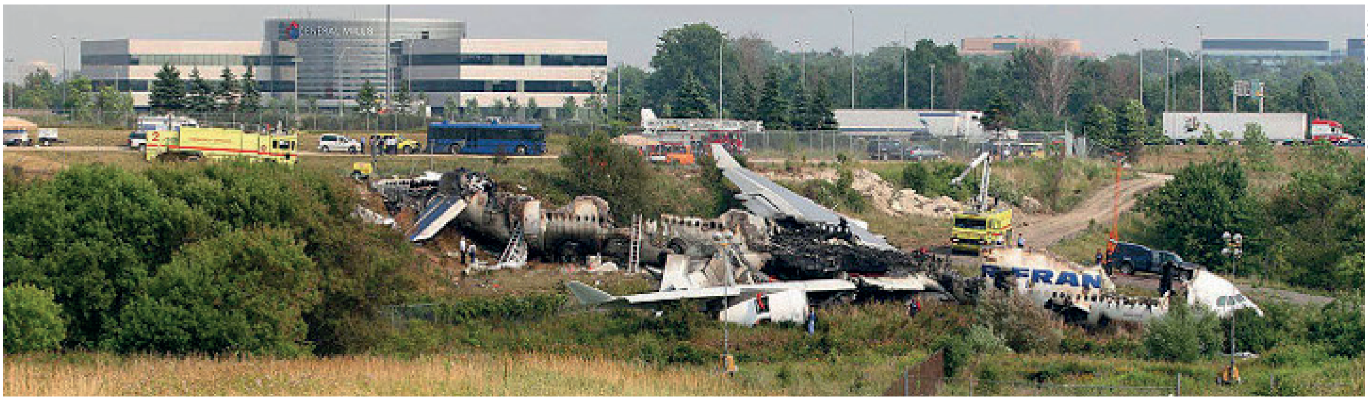
The following emergency exit and evacuation slide issues were identified in the Spanish Accident Technical Report:

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.

11.5 2 August 2005 – Air France – Airbus A340-300 – Toronto, Canada

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, two flight crew and 10 cabin crew.



Paul Cardin/RAeS

The fire-damaged wreckage of the Airbus A340-300 after departing the runaway at Toronto in August 2005.

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 these 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 270m (890ft) 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

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 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 (5ºC).

Greg Lam Pak Ng/flickr

The Airbus A320 ditched in the Hudson River, New York in January 2009.

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 4 November 2010 – Qantas – Airbus A380 – Singapore

On 4 November 2010, a Qantas Airbus A380, (Flight Number 32), was en route from Singapore to Sydney, Australia. Shortly after take-off from Singapore the A380 suffered an uncontained failure of the No 2 (left inboard) engine causing damage to the left wing and multiple systems failures. On board were 440 passengers, five flight crew and 24 cabin crew.

Passengers, who were still secured in their seats at the time, observed damage to the left wing. The SCCM saw the damage and that aviation fuel was leaking out of a number of holes in the wing. The SCCM and other cabin crew members attempted to contact the flight deck to report the damage but the flight crew did not respond, probably due to the extremely high flight deck workload in dealing with numerous issues.

From their flight deck instrumentation, the flight crew knew immediately that there was a significant problem and the second officer went into the main deck passenger cabin to assess the situation. A passenger who was also a pilot pointed out to him an external view of the aeroplane on the in-flight entertainment system from a tail-plane camera showing the fuel leak from the left wing.

The second officer moved along the cabin and observed the damage and the fuel leak coming from underneath the wing near to the No 2 (left inboard) engine. He reported his findings back to the flight crew who made several public address announcements to the cabin crew and the passengers as to the situation.

Multiple systems failures occurred as a result of the uncontained engine failure and a return to Singapore was decided to be the best option. After a successful landing the commander faced several significant issues including:

- Although the damaged No 2 (left inboard) engine and other engines were shut down after landing, the No 1 (left outboard) engine continued to run after normal shut-down procedures. It was finally shut- down some three hours after the landing by RFFS pumping water foam directly into the engine inlet.

- 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 it was safer for the passengers and crew to initially remain inside the aeroplane rather than ordering an evacuation using evacuation slides.

Knowing that the wheel brakes would probably be hot, the SCCM identified that the situation was extremely dangerous. Alarms were sounding in the passenger cabin and ‘evacuation messages’ were displayed on cabin crew information panels. Some of the cabin crew understandingly became confused but they did not panic nor did they initiate an evacuation[89].

The commander decided that disembarkation of passengers and crew could be better achieved via the right Type A emergency exit (R2) and the use of airport stairs. The other four Type A exits (R1, R3, R4 and R5) remained in the armed position and the cabin crew were briefed and ready to operate the exits and deploy the evacuation slides if it became necessary. The first passengers disembarked 50 minutes after landing. The disembarkation took approximately one hour.

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.”

11.9 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.

While 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.

11.10 6 July 2013 – Asiana Airlines – Boeing 777-200 – San Francisco, USA

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.

The wreckage of the Boeing 777-200 after crashing into the seawall at San Francisco in July 2013.

According to the NTSB Accident Report, the main landing gear impacted the seawall, and the tail plane 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. The flight attendants initiated the evacuation when they identified that there was an external fire at Door 2R. 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.

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 immediate 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.

11.11 8 September 2015 – British Airways – Boeing 777-200 – Las Vegas, USA

On 8 September 2015, a Boeing 777-200 operated by British Airways, (Flight Number 2276), suffered an uncontained failure of the No 1 (left) engine on take-off from Las Vegas, USA. On board were 157 passengers, three flight crew and ten cabin crew.

Twitter/Jordan masters

The Boeing 777-200 with the No. 1 engine on fire at Las Vegas in September 2015.

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 No 1 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 Accident Reports:

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 crew instructions to remain seated.
- Flight crew and cabin crew were quickly aware of an external fire on the left side of the aeroplane.

- Some 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.

11.12 27 May 2016 – Korean Air – Boeing 777-300 – Tokyo, Japan

On 27 May 2016, a Boeing 777-300 operated by Korean Air, (Flight Number 2708), suffered an uncontained failure of the No1 (left) engine resulting in a rejected take-off from Tokyo, Japan. On board were 302 passengers, two flight crew and 15 cabin crew. The Boeing 777-300 has five pairs of Type ‘A’ emergency exits installed (i.e. ten Type ‘A’ exits).

Tokyo Airport (Video)

The Boeing 777-300 after a rejected take-off from Tokyo in May 2016.

In the emergency evacuation five emergency exits on the right side of the aeroplane were opened as well as exit L1. The cabin crew member at L1 identified RFFS vehicles in the proximity of the tail end of the evacuation slide and determined that the slide was not useable. The evacuation slide at Door R5 inflated but deployed underneath the aeroplane fuselage and was not useable during the evacuation. The Japan Transport Safety Board Accident Report identified that there were no fatalities but that some 40 passengers sustained minor injuries.

It is estimated that the evacuation took three minutes and forty seven seconds. Subsequent investigation of the R5 evacuation slide identified a 5 cm long tear to the lower right corner of the slide outer material; no other issues were identified. Many passengers took cabin baggage with them in the evacuation despite instructions from the cabin crew not to do so. It is important that even when emergency exits have been opened and evacuation slides have been deployed, the conditions for a safe evacuation must first be assessed by cabin crew before commencing an evacuation.

11.13 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 a jetway 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.

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 a jetway. 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 a terminal jetway.
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 again reinforces the importance of CRM for all crew members and the operator has revised its procedures to reflect the difficulties encountered in this evacuation.

11.14 27 June 2016 – Singapore Airlines – Boeing 777-300 – Singapore

Brendan Grainger/Twitter

Disembarkation of the Boeing 777-300 using the forward left Type 'A' emergency exit.

On 27 June 2016, a Boeing 777-300 operated by Singapore Airlines, (Flight Number 368), returned to Singapore after the No 2 (right) engine warning light showed a low oil quantity. According to the Singapore Transport Investigation Bureau Accident Report, on landing at Singapore the No 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 taxing camera system installed at various locations on the aeroplane.
- The cabin crew who would have had a view of the right wing and No 2 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."

11.15 3 August 2016 – Emirates – Boeing 777-300 – Dubai, UAE

On 3 August 2016, a Boeing 777-300 operated by Emirates, (Flight Number 521), crash landed on the runway at Dubai, UEA, 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 No 2 (right) engine separated from the wing and there was an intense fuel in this area, as well as fire to the No 1 (left) engine.

ANI

The Boeing 777-300 after crash landing at Dubai in August 2016.

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

The Emirates GCCA Final Accident Report identified the following emergency exit and evacuation slide problems:

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. 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. Cabin crew blocked the exit.
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 the cabin crew assisted by passengers closed the exit. Passengers were re-directed to an alternative usable exit.	The off-wing ramp section of the slide failed to deploy.
L4	Exit opened.	Slide deployed but was blown by the wind against the fuselage and cabin crew blocked the exit.
R4	Exit opened. Some passengers were re-directed to another usable exit.	Slide deployed but evacuating passengers became stuck on the slide because it became filled with fire-fighting extinguishing agent. 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 preventing further use.
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. While Most of the passengers and crew evacuated in six minutes and 40 seconds, the commander and the SCCM delayed their evacuation by searching the passenger cabin for any remaining passengers. They evacuated some nine minutes after the start of the evacuation and shortly after the centre wing fuel tank exploded. They were forced into the flight deck due to smoke in the passenger cabin. Because of the reduced visibility they were unable to locate the flight deck DV window escape ropes and evacuated via L1 onto the detached and inflated evacuation slide. Four of the cabin crew sustained serious 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 Final Accident Report, stated: "The cabin crew attempted to convince passengers to leave their carry-on baggage behind, but a number of passengers evacuated with one or more pieces of carry-on baggage which prolonged the evacuation."

Rehanqureshi/Twitter

Passengers opening overhead bins to retrieve baggage in the B777-300 accident at Dubai in August 2016.

This is another occurrence where a number of passengers were using mobile phones and other devices to take photographs during emergency evacuations. It is possible that such actions might contribute to delays at a critical time.

11.16 28 October 2016 – American Airlines Boeing 767-300 – Chicago, USA

On 28 October 2016, a Boeing 767-300 operated by American Airlines, (Flight Number 383), during departure from Chicago, USA, suffered an uncontained failure of the Number 2 (right) engine which resulted in a severe fire and rejected take-off. On board were 161 passengers, two flight crew and seven flight attendants. All passengers and crew successfully evacuated the aeroplane. One passenger received a serious injury and 20 occupants received minor injuries. The aeroplane was substantially damaged by the fire. Due to communication problems the evacuation was initiated by the flight attendants using the left emergency exits with the No 1 (left) engine still running. This accident reflects several of the issues discussed in the paper.

Interphone and communication issues: The flight attendants were not able to properly operate the interphone system because they had not been effectively trained on the system installed on this specific aeroplane type and were unable to communicate with the flight crew. The NTSB Accident Report concluded that: " .…American Airlines did, not adequately train flight attendants qualified on the Boeing 767 to effectively use the different interphone system models installed on the airplane during an emergency".

The NTSB in their Accident Report concluded that: "…..if the flight crew or the flight attendants had communicated after the airplane came to a stop, the flight crew could have become aware of the severity of the fire on the right side of the airplane and the need to expeditiously shut down the engines".

The passenger who sustained the serious injury had safely evacuated but was then was knocked to the ground by the jet blast from the No 1 engine

In many other accidents the issue of ineffective communication between flight crew and cabin crew have been identified by accident investigators. The NTSB has stated that: "It is time for the FAA to emphasize the importance of ensuring that flight and cabin crew communications can facilitate safe and effective decision-making and action during situations requiring an evacuation".

Cabin baggage issues: Many passengers took cabin baggage with them in the emergency evacuation in spite of instructions by the flight attendants not to do so. The NTSB Accident Report states that one of the flight attendants at the overwing exits saw a passenger coming to the area with a large bag and was instructed to leave the bag and evacuate. The passenger did not listen and the flight attendant attempted to take the bag away from him. Realising that the struggle over the bag was causing a delay to the evacuation the passenger was allowed to evacuate with the bag. Another flight attendant stated that passengers were trying to get their bags out of overhead bins.

Exit usability issues: Of the eight emergency exits installed on this Boeing 767-300 only two floor level exits and two overwing exits were used during the evacuation. The evacuation was successfully completed in just over two minutes.

Exit	Emergency exit status	Slide status
L1	Exit opened. F/A initiated the evacuation. This exit was opened 15 second after the aeroplane came to a stop	Slide deployed
R1	Exit opened, but due to the external fire the F/A blocked the exit and redirected passengers to exit 1L	Slide deployed but not used
L2/L3	Left overwing exits. Exit L2 and L3 opened	Slide deployed
R2/R3	Right overwing exits not opened due to external fire	Slide not deployed
L4	Exit opened. Delay in starting the evacuating passengers due to evacuation slide issues. This exit was opened 40 seconds after the aeroplane came to a stop. The F/A delayed operating the exit because the No 1 engine was still running. It took 39 seconds for the first occupant to evacuate. This was one minute 25 seconds since the aeroplane came to a stop	Slide deployed but was blown aft by No 1 engine which was still running. Slide stabilised when the No 1 engine was shut down
R4	Exit not opened due to external fire	Slide not deployed

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, CRM 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 training, 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 aeroplanes without a cabin camera system and without an operational interphone system, it is unrealistic for the flight crew to be aware of specific situations in some areas of the passenger cabin, especially at the rear of the aeroplane, or on another passenger deck such as on the Boeing 747 and the Airbus A380.

There are several recurring issues that might give cause for concern. These include passengers taking their baggage with them in evacuations and the extended time it took to evacuate. In some accidents the evacuation took significantly more time than the expectations of the 90 second rule.

The Case Studies in Section 11 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 or incident and the saving of many lives.

13 RECOMMENDATIONS

Recommendation 1 – Introduction – (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 such factors did not impact on the outcome of the evacuation in a specific accident, but which might have an adverse or even positive effect in subsequent accidents.

Recommendation 2 – Minimum required cabin crew in relation to installed passenger seating – See Section 7.1.

NAAs 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 exits: number, types, classification, and location – See Section 7.2.

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

Recommendation 4 – Development of aeroplane variants to provide increased passenger seating capacity – See Section 8.2.

NAAs should consider the advisability of 'grandfather rights' relating to the Maximum Passenger Seating Capacity (MPSC) for aeroplane type certification.

Recommendation 5 – Evacuation slides – See Section 8.4.

NAAs should review the 1.8m (6ft) 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. **NAAs** should also review the height requirement for off-wing evacuation slide in respect of single-aisle aeroplanes. **NAAs** should consider a requirement for evacuation slide testing to include slide performance when large items including 'baggage with wheels' are taken by passengers when evacuating.

Recommendation 6 – Type III and Type IV emergency exits, access and ease of operation – See Section 8.9.

NAAs and aeroplane manufacturers should ensure that the operation of any emergency exit must not require exceptional effort and that this should be stated in the certification requirements. **NAAs** 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 7 – Overwing emergency exit escape routes and markings – See Sections 8.9, 8.10 and 9.15.

NAAs and aeroplane manufacturers should ensure that the design, contrast and conspicuity of any wing surface escape routes should be clear and unambiguous in both daylight and dark of night conditions. ICAO should develop a standard in **ICAO** Document 10086 for operator passenger safety briefings and safety cards to contain information on the need to reach the ground from wing surfaces as well as the **availability or non-availability of off-wing evacuation slides**. This information should be reinforced by **Operator** briefings to passengers occupying seat rows leading to overwing exits. Briefing information should also address the need for passengers to identify external hazards before opening an emergency exit.

Recommendation 8 – Type III emergency exit design and development – See Section 8.11.

For aeroplanes with 40 or more passenger seats installed, **NAAs** 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. **NAAs** 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 9 – Minimum space for seated passengers – See Section 8.14.

NAAs should develop minimum dimensions for passenger seating as a matter of urgency. The FAA testing at CAMI in late 2019 should be taken into account when developing such criteria.

Recommendation 10 – Aeroplane manufacturers' evacuation procedures – See Section 8.15.

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 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 11 – Potential alternatives to the evacuation requirements of 25.803 – See Section 8.17.

NAAs should evaluate the use of computer based mathematical modelling to facilitate different evacuation scenarios for initial aeroplane type certification. **Manufacturers, operators and cabin designers** should use such mathematical modelling in the development of cabin crew evacuation procedures and whenever the number of required cabin crew is to be reduced from the number involved in initial aeroplane type certification or where there is a significant change in the number of passenger seats installed.

Recommendation 12 – Airworthiness requirements that have the potential to impact on operational issues – See Section 8.20.

NAAs, 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 13 – Overhead stowage bins – bin size and the concept of lockable bins – See Sections 8.21 and 9.29.

NAAs should also consider the feasibility of introducing a certification requirement for taxi, take-off and landing, as well as other critical phases of flight, of a means of remotely locking from the flight deck, overhead bins in passenger cabins that do not contain emergency equipment. NTSB Recommendation A-18-9 should also be taken into account.

Recommendation 14 – The commander's decision to initiate an evacuation – See Section 9.8

Operators should ensure that their aeroplane commanders receive specific LOFT training in the assessment of emergency situations and appropriate actions including the decision to initiate, or not to initiate, an emergency evacuation.

Recommendation 15 – The command to 'evacuate' and the chain of command – See Section 9.9.

Operators should ensure that the responsibility to evacuate an aeroplane reflects the chain of command, ie. the commander, or in the event of his/her incapacity, other members of the flight crew, the SSCM or cabin crew members in successive order of authority, including any crew member if an obvious catastrophic and life-threatening event occurs.

Recommendation 16 – Communication and coordination – Crew Resource Management (CRM) – Line Oriented Flight Training (LOFT) – See Sections 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. Also 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 17 – Passenger Safety Briefings – See Sections 9.15 and 10.6

When developing passenger safety briefings and passenger safety cards, **NAAs** and **Operators** should take account of comprehensive guidelines contained in the ICAO Manual on Information and Instructions for Passenger Safety (Doc 10086).

Recommendation 18 – Passenger seat allocation – See Section 9.16.

Operators should not charge for family members to sit together. This is especially important in an emergency situation such as evacuation, decompression or air turbulence when adult assistance and supervision of children is likely to be of paramount importance.

Recommendation 19 – The 'brace' position and use of restraint systems – See Section 9.17.

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

Recommendation 20 – Disruptive passenger events – the availability and consumption of alcohol and the use of drugs by passengers – See Section 9.19.

Government agencies, airports, and operators should consider all possible steps to ensure that when passengers board an aeroplane they have not consumed an excessive amount of alcohol in airport areas. The opening hours of airport bars in departure areas and the availability of duty free prior to boarding should be subject to realistic and effective restrictions. **Operators** should ensure that their aeroplane crew are trained in how to deal with passengers under the influence of alcohol and in the serving of alcohol to passengers who may already be intoxicated.

Recommendation 21 – The effect of a crosswind on an aeroplane on fire on the ground – See Section 9.27.

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.

Recommendation 22 – Cabin baggage – See Section 9.29 and 8.21.

NAAs should conduct a review of emergency evacuations where passengers have taken cabin baggage with them and determine the potential threat to future evacuations. **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 as soon as practicable on departure and prior to landing, to confirm that all items in passenger cabins are correctly stowed and that passengers and cabin crew are secured in their seats. **Operators** should provide positive support to their commanders and cabin crew in this respect.

Recommendation 23 – Operational demonstration of evacuation procedures, training and systems – See Section 9.31.

NAAs 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. While 14 CFR 121.291 requires this for aeroplanes with more than 44 passenger seats installed. **NAAs** should also consider its applicability for aeroplanes with a lesser number of passenger seats.

Recommendation 24 – Emergency exit and evacuation slide training devices – See Section 9.33.

NAAs 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.

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