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Factors influencing passenger evacuation from smaller transport aircraft including the operation of the Type III exit

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Factors influencing passenger evacuation from smaller transport aircraft including the operation of the Type III exit

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Abstract

Accident reports and experimental research have documented difficulties when operating and evacuating through overwing emergency exits. The factors influencing exit operation and evacuation from smaller regional transport aircraft are less understood as previous studies have focussed solely on large single aisle aircraft.

Experiment One examined the influence of a smaller interior configuration and the seating configuration close to the exit on evacuation rates. The results indicated no effect for interior configuration or vertical projection. Experiment Two investigated the influence of interior configuration, a modification to the exit operating handle and the exit operator's briefing on exit operation time. The results showed the exit was operated significantly faster when an in-depth briefing was delivered. No significant differences were attributable to the operating handle mechanism or the interior configuration. Experiment Three investigated a major modification to the overwing exit mechanism on exit operation time. The results showed the exit was operated faster when an automatically opening hatch was installed compared to the traditional plug exit. Experiment Four examined the effect of the placement of the disposed traditional exit hatch on evacuation. The results showed the evacuation rate was significantly slower when the hatch was placed inside the cabin.

The experiments have contributed to knowledge regarding exit operation and evacuation from smaller transport aircraft. The benefits of an automatically disposed hatch exit mechanism on a smaller transport aircraft and an in-depth exit operator's briefing in both large and small aircraft interior configurations have been shown. The work has highlighted that the interior configuration of the smaller transport aircraft, in particular the restricted headroom, is perceived as a hindrance. Finally the work has quantified the negative impact of an inappropriately placed exit hatch inside a smaller transport aircraft cabin. Recommendations for further research in evacuation and exit operation from smaller transport aircraft are suggested.

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Contents

Index of figures

Index of tables

1.0. Introduction

1.1. Introduction to thesis

The aim of the research was to explore factors influencing passenger evacuation from smaller transport aircraft including the operation of the overwing passenger operated Type III exit. Although extensive research has been conducted on passenger evacuation and the operation of the Type III exit, the majority has concerned large single aisle cabins. Many smaller transport aircraft are configured with passenger operated Type III exits. These exits are located in the wing area of the aircraft, and on smaller transport aircraft, depending on the aircraft design are located either above or below the wings. Relatively little research is publicly available on evacuation from smaller transport aircraft (for example cabins with two seats either side of the main aisle). As a result of this imbalance, it is not known if research findings from trials conducted in large single aisle cabins will generalise to smaller transport aircraft. The issue of evacuation from smaller transport aircraft is of relevance as these aircraft have a narrower fuselage, and therefore less cabin width (and number of seats either side of the aisle) and lower headroom. In addition, regulatory full scale evacuation demonstrations are not required by the current regulations for aircraft with fewer than 44 seats, therefore there is limited knowledge of the pertinent factors influencing evacuation from these types of aircraft. The literature review will now explore issues surrounding aviation accidents, emergency evacuations and experimental research into factors influencing passenger evacuation.

1.2. Air travel

The development and advancement in aviation over the last century has been extensive. The first powered aircraft flew in 1903 and by 1909 two aircraft had been designed specifically for passenger travel (Edwards and Edwards, 1990). The “modern” airliner was developed in the United States in the 1930s, with the launch of three aircraft - the Boeing 247 which carried 12 passengers, the Douglas DC-2 with 14 passenger seats and the Lockheed L-10 Electra with 10 passenger seats (Edwards and Edwards, 1990). Developments in aircraft cabin design have also continued over the years which have resulted in a large range of aircraft with different passenger capacities and cabin designs (Edwards and Edwards, 1990).

On the 6th December 2007, the UK Department for Transport (DfT) released the latest edition of its publication Transport Trends, which provides data on usage of different modes of transport (DfT, 2007). Although the greatest increase in travel overall had been by car and van, when these data are excluded, the highest increase in distance travelled was by air, with the distance travelled increasing three fold between 1980 and 2006 (DfT, 2007).

The Federal Aviation Administration (FAA) using data from the International Civil Aviation Organisation (ICAO) reported that throughout the world, 2.2 billion passengers were carried 3.7 trillion passenger kilometres by air during 2005 (FAA, 2007a). In August 2007, ICAO predicted an average growth in scheduled air travel (measured in the number of passenger kilometres flown) of 4.6% per year until 2025 (ICAO, 2007).

Although advances in aircraft and cabin design have taken place over the years, aviation accidents do still occur.

1.3. Aviation accidents

The International Civil Aviation Organisation (ICAO) defines an aviation accident as

> *'an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, in which:*
>
> *a) a person is fatally or seriously injured as a result of: being in the aircraft, or direct contact with any part of the aircraft, including parts which have become detached from the aircraft, or direct exposure to jet blast, (except when the injuries are from natural causes, self-inflicted or inflicted by other persons, or when the injuries are to stowaways hiding outside the areas normally available to the passengers and crew; or*
>
> *b) the aircraft sustains damage or structural failure which: adversely affects the structural strength, performance or flight characteristics of the aircraft, and would normally require major repair or replacement of the affected component, (except for engine failure or damage, when the damage is limited to the engine, its cowlings or accessories; or for damage limited to propellers, wing tips,*

antennas, tires, brakes, fairings, small dents or puncture holes in the aircraft skin;)

Or c) the aircraft is missing or is completely inaccessible' (ICAO, 2001, p. 1-1).

This is in comparison to an incident, which is defined as *'an occurrence, other than an accident, associated with the operation of an aircraft which affects or could affect the safety of operation'* (ICAO, 2001, p. 1-1).

1.3.1 Accident statistics

Recent statistics published by the UK DfT (2007) show that air travel is the safest form of transport in terms of the number of fatalities per passenger kilometre when compared with travel by car, van, bus/coach or rail. It is noted that fatality rates for water travel were similar to those of air (DfT, 2007). Research conducted by the Flight Safety Foundation and Boeing Commercial Airplane Group reviewed accidents that occurred on large jet aircraft between 1987 and 1996 and divided them into the different phases of flight (Mathews, 1997). The review identified that the highest percentage of accidents occurred during final approach and landing (accounting for 22.9% and 21.7% respectively), with takeoff accounting for the second largest percentage at 14% (Mathews, 1997).

Over a 25 year period (1959-1996), Mathews (1997) identified that hull loss aviation accidents (defined as those accidents that result in the aircraft being destroyed) have fallen from 27 accidents per million departures to 1.5 per million departures. Most of this decline occurred within the 1960s with the accident rate remaining fairly stable since 1970.

Although the accident rate has remained stable over this period, Mathews (1997) and the National Transportation Safety Board (NTSB; 2001) highlight that if the number of flights dramatically increase over the next 12 to 15 years as predicted, the actual number of accidents will rise. This information is important as often it is the frequency of accidents that members of the public reflect on (as opposed to the accident rate) which may lead to public uncertainty regarding the safety of air travel (Mathews, 1997; Muir, 2000).

If an aircraft sustains an impact, a number of factors will determine if the accident is survivable. These factors include the forces associated with the impact, the extent of the impact on the cabin fuselage and the restraints used by the occupants (Johnson, 1984; NTSB, 2001). Even if the impact is deemed survivable, occupant survival is not guaranteed and will depend on the environmental conditions following the impact which may require occupants to rapidly evacuate the aircraft. The most critical threat to occupant survivability following an accident or incident is the threat from a post-crash fire. The European Transport Safety Council (ETSC) in 1996 stated that 'statistical trends clearly show that fire substantially decreases the chance of surviving an aircraft accident' (p. 8). Due to the threat from fire, extensive research and development is undertaken in three main areas of activity – in the first instance to prevent the fire from developing, secondly to contain the fire and thirdly, if a fire has developed, to evacuate all occupants (CAA, 1991).

1.3.2. Types of accident

Aircraft accidents are typically classified into one of three categories: fatal/non survivable, non-fatal/survivable and technically/partially survivable.

A fatal or non-survivable accident is one in which none of the occupants (passengers or crew) survives. An example of this category was the on board explosion and subsequent loss of the aircraft fuselage of the Pan American World Airways Boeing 747 over Lockerbie, Scotland. This accident in December 1988 resulted in the loss of all 243 passengers and 16 crew on board and 11 individuals on the ground (AAIB, 1990). An example of a fatal or non-survivable accident involving a smaller transport aircraft was the accident during final approach of a DHC-6-300 in 2001 at Saint Barthélémy in the Leeward Islands in the Caribbean. A fire erupted as the aircraft made contact with the ground, with the degree of impact resulting in no survivors amongst the three crew and 17 passengers. The aircraft was destroyed by the impact and the fire (BEA, 2001).

A non-fatal or survivable accident is one in which all of the occupants (passengers and crew) survive. A recent example of this type of accident was the Air France Airbus 340 that overran the runway and came to a standstill 1090 feet beyond the end of the runway in Toronto, Canada in August 2005. All 297 passengers and 12 crew members evacuated the aircraft in under two minutes prior to a post crash fire destroying most of the fuselage (TSB, 2005). A second example is the accident as a result of a problem with deploying the landing gear on board a Jetstream 41 in June 2005 (South African CAA, 2005). There were three crew and only 13 passengers on board, and fortunately as the flight crew knew they had an abnormal state with the aircraft both the flight and cabin crew briefed passengers in advance of the landing. There were no injuries to any of the occupants (South African CAA, 2005).

A technically survivable or partially survivable accident is one in which some (at least one) of the occupants (passengers and crew) survive**.** An example of this category of accident occurred at Los Angeles airport in the United States in February 1991. A Boeing 737 that was landing at the airport collided with a Fairchild Metroliner that was waiting for take off clearance from the same runway. Both aircraft were destroyed as a result of the impact and the post crash fire. All 10 passengers and two crew on board the Metroliner died in the accident, along with 20 passengers and two crew from the Boeing 737 (NTSB, 1991).

An example of a technically survivable accident involving a smaller transport aircraft is the Comair operated Bombardier CL-600-2B19 aircraft that encountered difficulties at Lexington in Kentucky in August 2006 (NTSB, 2006). Whilst manoeuvring onto the runway to proceed with take off, the aircraft travelled onto the incorrect runway from that instructed. The error was not detected and the aircraft ran out of runway prior to taking off, impacting with a number of trees. On board the aircraft there were 50 occupants with all but one passenger, who sustained serious injuries, perishing in the accident. The impact, which resulted in a separation of the fuselage, and the post crash fire destroyed the aircraft (NTSB, 2006).

Of importance to the current study on cabin safety was the finding from the Lexington accident that seven passengers died due to thermal injuries and 10 occupants (including the cabin crew member) died as a result of inhaling smoke or soot, with thermal/inhalation injuries also a combination factor in the death of a further eight occupants (NTSB, 2006). As the accident report highlights, this suggests that a number of the occupants survived the initial impact, but were not able to evacuate the cabin prior to being overcome by the products of the post crash fire, although the NTSB (2006) notes that it is not known how long the cabin environment remained survivable.

1.4. Cabin safety research

A range of strategies is employed to reduce and eliminate air travel related fatalities. These include the introduction of measures and procedures to avoid the accident or incident occurring and then to protect occupants if such an event does arise (NTSB, 2001). Areas of aviation safety focused on protecting occupants in the event of an accident include work into impact protection, fire protection and evacuation. It is acknowledged that some accidents, although preventable, are not survivable, so the aim of cabin safety research is to protect occupants in the event of a survivable accident and to put measures in place to ensure that occupants can evacuate the aircraft in a rapid and efficient manner. The NTSB (2001, p. 19) following a review of accident survivability concluded that 'the large number of people who survive even the most serious accidents emphasises the importance of work aimed at ensuring that crash survivors can safely remove themselves from the accident aircraft'. Although no two accidents are identical, information and knowledge from one event allows cabin safety researchers to construct a picture of the contributing and influencing factors by drawing on the similarities and differences from each event.

The ETSC in 1996 estimated that approximately 90% of aircraft accidents are survivable or technically survivable. Cherry (2007, p. 8) highlights that even though extensive research and development have led to safety improvements within aviation 'the growth in air traffic has resulted in the number of fatalities in "survivable and fire caused" accidents remaining at an almost constant level.' Cherry (2007) states that research and development into safety improvements must continue, and although attributed to a number of causes, there are approximately 350 to 400 lives lost each year in "survivable and fire caused" accidents.

The importance of ensuring that the aircraft cabin can be evacuated quickly was also emphasised by Trimble in 1996, who conducted a review of 74 survivable accidents that occurred during 1966 and 1985 where fire was a factor in the accident. Of the accidents studied, 31% of the occupants died, with 65% - 82% of those fatalities due to the effects of fire (Spietal and Hill (1988) in Trimble, 1996).

This is a critical area for cabin safety as it is tragic for an occupant to have survived an impact or technical failure with the aircraft, only to perish as they were not able to evacuate the aircraft quickly and effectively. This outcome has occurred during a number of accidents including during a collision between a Beechcraft 1900C and a King Air at Quincy airport in Illinois in 1996. All 12 occupants on board the Beechcraft and the two pilots of the King Air survived the initial impact but were overcome by smoke from the post crash fire. The difficulty experienced by the Beechcraft pilots in opening the airstair door and the delay in fighting the fire were highlighted by the accident investigators as 'contribut[ing] to the severity of the accident and the loss of life' (NTSB, 1997, p54).

Although extensive research has been conducted in cabin safety, even as recently as October 2007, at the International Fire and Cabin Safety conference the importance of engaging in research within the area of fire and cabin safety was raised. Courtney (2007) emphasised during the conference that the aviation world is not static, with continual developments and changes and as a result research and analysis of the relevant issues should continue. Engaging in research to assist the regulatory process and the need for ongoing exploration was also emphasised in the opening address by Morin (2007, p. 8) who stressed the importance of engaging in research, stating that 'solid research is the basis of sound regulations – regulations must be data driven...' Morin (2007) also emphasised that the 'outcome' of the accident and evacuation involving the Airbus 340 at Toronto in 2005 was not a 'miracle' '…but regulations based on solid research is what made it possible' (p. 22). Cherry (2007, p. 2) further emphasised this point through an analysis of worldwide aviation accidents as although 'the accident record has improved markedly over recent years…now is not the time to take our foot off the pedal'.

1.5. Aircraft evacuation

An emergency evacuation is an event where it is deemed that there is a need for the occupants of the aircraft to leave the aircraft in a rapid manner, due to a potential threat to survival. Evacuations are typically defined as planned or unplanned. If crew are aware of the need to evacuate the cabin in advance and have sufficient time (although this may only be a period of a few minutes) to review the standard emergency procedures and inform passengers of the actions they must take on landing, the evacuation is defined as planned (NTSB, 2000). During this time the crew are likely to provide passengers with information on the brace position they must adopt, they may reseat passengers in the vicinity of the exits and place cabin crew near the overwing exits (if there are more than the minimum number of crew on board). The crew will also ensure that passengers have their seatbelts fastened and that they are aware of the location and operation of the emergency exits. Unplanned evacuations differ from planned, as in these circumstances neither the crew nor the passengers have much time to prepare for the evacuation (NTSB, 2000). During an unplanned evacuation, passengers are reliant on the instructions of the crew, the information from the pre-departure safety briefing, their previous knowledge and their behavioural responses at the time.

1.5.1. Evacuation certification

Federal Aviation Regulations Part 25 (CFR FAR 25) and the European Aviation Safety Agency (EASA) regulations (CS-25) relate to all transport category aircraft. Transport category aircraft are defined by the FAA as ‘jets with 10 or more seats or a maximum takeoff weight of greater than 12,500lb or propeller-driven airplanes with greater than 19 seats or a maximum take off weight greater than 19,000lb’ (FAA, 2007b, p. 1).

For aircraft with a seating capacity of more than 44 passengers, regulation 25.803 requires all new aircraft designs to conduct and pass an emergency evacuation demonstration. However a demonstration of the evacuation capability of smaller transport aircraft with fewer than 44 passenger seats is not required by the regulators. The criteria and procedures for the emergency demonstrated are stipulated in CS-25

(EASA); FAR 25 (CFR); CAR 525 (Transport Canada) Appendix J and are summarised below.

The number of passengers for the certified maximum seating capacity must be present on board, with a representative sample of different passenger ages and sex. The number of cabin crew on board is determined by the operating rules under which the certification application relates. All exits must be set to the take off and landing position, with each member of cabin crew located in their assigned crew seat prior to the start of the demonstration. The cabin and the surrounding area must be in "dark of night" conditions, with illumination provided only by the emergency lighting installed on the aircraft. Prior to the demonstration commencing, carry-on baggage, blankets and other passenger belongings totalling approximately half the actual capacity for the aircraft must be placed at a number of sites in the cabin aisles and exit access as a form of minor obstructions (CS-25 (EASA), FAR 25 (CFR); CAR 525 (Transport Canada) Appendix J).

During the demonstration, only 50% of the available exits on the aircraft may be used, with the used exits representative of all emergency exits on the aircraft. Usually one exit in each pair is used. The evacuation is deemed complete once all passengers and crew have left the aircraft. To pass the evacuation demonstration, all crew and passengers need to evacuate to the ground within 90 seconds (FAR 25 CFR /CS-25 EASA, Appendix J).

With regards to the evacuation demonstration, the NTSB (2000) argued that 'in the interest of providing one level of safety, all passenger-carrying commercial airplanes and air carriers should be required to demonstrate emergency evacuation capabilities' (p. 77). The NTSB felt strongly about this issue which led them to recommend to the FAA that they should 'require all newly certificated commercial airplanes to meet the evacuation demonstration requirements prescribed in Title 14 Code of Federal Regulations Part 25, regardless of the number of passenger seats in the airplane' (2000, p. 80). To date, no change has been made to the requirement for evacuation certification demonstrations for newly designed aircraft irrespective of the seating capacity.

Therefore there is no current requirement for the evacuation capability of a smaller transport aircraft with fewer than 44 passenger seats to be demonstrated.

In 2000, the NTSB published a review of 46 aircraft evacuations that took place within the United States. During the course of their 16 month study (between September 1997 and June 1999), the NTSB reported that 'on average, an evacuation for the study cases occurred every 11 days' (NTSB, 2000, p. 15). Although an evacuation occurrence once every 11 days in the United States may sound a high figure, in comparison, the NTSB state that in 1998 Part 121 scheduled aircraft made 'an average of 336,328 departures […] every 11 days' (NTSB, 2000, p. 15). In addition many of these evacuations are likely to be precautionary, rather than imminently life threatening.

1.5.2. Actual evacuations

The evacuations in the NTSB review involved 2,651 passengers and 195 crew who were on board 18 different aircraft types operating under Part 121 regulations. Of the 46 evacuations, 31 were categorised as unplanned, 14 occurred after crew planning, with an unknown level of crew planning prior to one evacuation (NTSB, 2000). The NTSB analysis highlights the high number of unplanned evacuations which emphasises the importance of appropriate cabin and equipment design and passengers knowing what to do in advance of the evacuation.

Of the occupants involved in the evacuations 92% of the occupants were uninjured, 6% suffered minor injuries and 2% suffered serious injuries. Injuries as a result of the accident or the evacuation were sustained in 18 of the 46 accidents reviewed. In the 18 cases 208 passengers and 13 crew sustained injuries, and 10 passengers and one crew member were killed. The NTSB note that 65 of the minor injuries, 45 of the serious injures and all 11 of the fatalities occurred in the accident that occurred at Little Rock, Arkansas. Two of the fatalities at Little Rock were linked to the evacuation, with one fatality due to smoke inhalation and another due to thermal assault whilst evacuating. Six of the serious injuries at Little Rock were attributed to passengers leaving the aircraft wing, either via the slide or dropping down to the ground when the slide was not in place.

Fortunately the rate of serious accidents each year is low, however evacuations whether precautionary or not occur more frequently, so scientific investigation must continue to ensure all occupants are able to evacuate in a rapid and orderly manner. Information gained from emergency evacuations, including those that are deemed precautionary, is crucial to enhancing our understanding of such events. This information can then be used to determine areas of further investigation and research, as well as providing data to support regulatory change.

1.6. Behavioural responses to emergencies

There is a great deal of variability in individual responses in the event of an evacuation, with responses influenced by the individuals' prior experience and the environment. Muir, Bottomley and Marrison (1996) and Galea (2003) propose that there is no one behavioural response and evidence has been provided for a range of behaviour responses. These behavioural responses range from the completion of the required actions in a timely and effective manner, through to behavioural inaction, or even aggressive behaviour towards other occupants (Galea, 2003).

1.6.1. Panic

Panic is considered to be an irrational and counterproductive response. Quarantelli (1954, p. 267) defines panic 'as an acute fear reaction marked by a loss of self-control which is followed by non social and non rational flight'. Quarantelli further suggests that panic occurs when an individual feels trapped and 'powerless', the view of panic occurring when routes towards exits are impeded is also suggested by Edwards and Edwards (1990).

However Muir et al (1996) and Galea (2003) argue that the term panic has been used incorrectly within some commentary of passenger behaviour in aviation accidents as any behaviour that is 'ostensibly irrational and uncontrollable' has been defined as panic (Muir et al, 1996, p. 58). It is suggested that "true" panic occurs very rarely during such events as the behaviour exhibited by passengers in a life threatening situation may actually be rational in the situation that is perceived and experienced (Muir et al, 1996 and Galea, 2003).

1.6.2. Behavioural inaction

Behavioural inaction is displayed when the individual does not respond to the unfolding situation - in essence there is no behavioural response (Johnson, 1984). Behavioural inaction has been highlighted as a behavioural response during aviation emergencies by a number of authors within the field (Becker, 1973; Johnson, 1984; Galea, 2003 and Leach 2004).

Johnson (1984) during an interview with an elderly couple (the Ables), who were onboard the B747 taxing at Tenerife in 1977 when it was hit by another B747 that had commenced take off, encountered an example of behavioural inaction. Due to a childhood experience of being involved in a building fire, Mr Able always made himself aware of the exit locations and familiar with the safety information on board the aircraft. After the impact he began to make his way towards an exit, telling his wife to follow him. It was reported that at first she made no effort to move, until he spoke to her again. Mrs Able reported that as they made their way towards the exit, they observed a number of passengers just sitting in their seats. Johnson (1984, p. 34) concluded that ‘the Ables said that many more people could have survived this accident had they simply moved from their seats and gone to the exits’.

Leach (2004, p. 540) through an analysis of 11 marine and aviation accidents puts forward the idea that passenger behavioural responses can be separated into one of three groups. The first group are those who calmly respond to the event and are able to make ‘relatively unimpaired’ decisions and carry them out (approximately 10-15% of individuals). The second and largest group, comprising of approximately 75% of individuals, are ‘stunned and bewildered’ by the events around them, and the final group of approximately 10-15% of individuals will display a ‘high degree of counterproductive behaviour’, which may include confusion or anxiety. This analysis leads Leach to conclude a high prevalence of behavioural inaction is reported in emergency situations by survivors or bystanders.

Behavioural inaction is important to address due to the detrimental effect on survivability, with Johnson (1971, p. 43) suggesting that it is one of ‘the most maladaptive of behaviours in situations which require a series of quick, correct, avoidance responses to assure survival'. Having knowledge about what to do, prior training or being directed by a knowledgeable member of crew may reduce the maladaptive behaviour of behavioural inaction (Johnson, 1971). The importance of addressing behavioural inaction through training, practice and equipment usability is further highlighted by Leach (2004) who suggests that the 'systems for escape, evacuation and rescue are designed on the assumption that people will be proactive in the face of danger' (p. 539).

1.6.3. Flight or fight response

The flight or fight behavioural response as proposed by Lazarus (1966, cited in Muir et al (1996)) is evident when an individual perceives a threat to their survival and takes action to fight or remove themselves from the situation. This behavioural response has been reported in relation to passenger behaviour in emergency situations (Johnson, 1984; Leach, 2004), with Galea (2003) commenting that reports have shown that in such situations passengers have been observed undoing their seatbelts and 'fleeing' the area. The immediate situation and the individual's perception will influence the extent to which this behaviour is displayed (Muir et al, 1996).

1.6.4. Affliative behaviour

Affliative behaviour is a concept proposed by Sime (1985) and is characterised by individuals moving towards the familiar in situations where a threat is perceived. The notion of movement during an evacuation towards a familiar exit (i.e. the boarding door) was developed from Sime's analysis of occupant behaviour during evacuation from the built environment, although was transferred by some to the aviation domain. Some evidence for this behaviour was presented by Schaeffer (1994) whose analysis of exit usage during aircraft evacuation suggested that exits towards the front of the aircraft were used more often and this 'may stem from a general tendency to proceed through the door through which they boarded' (Schaefers, 1994, p. 80). However, this notion of moving towards the boarding door has since been challenged by Galea (2003) as a 'myth' following an extensive study of passenger exiting behaviours during aircraft evacuations. Galea argues that Schaefers' analysis did not consider where the participant was seated prior to the evacuation and it may have been that the forward exits were the nearest available exits during the evacuation.

Galea (2003) suggests that although exit bypass (that is passing a useable exit to use an alternative exit) has been observed during evacuations, it must not be assumed that this is because occupants are heading towards the boarding door, as there may be other factors that have led to the bypassing of the exit. Galea (2003) suggests that affliative behaviour has been observed on board but more in instances of passengers gathering their personal belonging from the overhead lockers and from under the seats prior to moving towards the exits in an evacuation.

1.6.5. Anxiety

Another behavioural response reported in the literature during emergency situations (including aircraft evacuation) is passengers reporting signs of anxiety. Egressing from an aircraft in the event of an emergency requires the passenger to complete a number of tasks, with authors commenting that the performance in completing these tasks is related to the level of anxiety or stress the individual is experiencing (Johnson, 1984; Galea, 2003). This relationship between levels of stress and anxiety and performance is curvilinear and known as the Yerkes-Dodson law. This law postulates that when low levels of stress are present, learning is not facilitated, which Johnson suggests may be why many passengers do not attend to the safety briefing. As levels of stress increase to moderate, performance is improved, however, when stress levels are high, individuals' performance on both simple and complex tasks is reduced. Johnson (1984, p. 24) argues that 'the optimal level [of stress] lies somewhere in between'.

During an analysis of passenger behaviour the simple task of undoing the seatbelt is highlighted by Galea (2003) as one task that degrades when high levels of anxiety are experienced. The relationship between anxiety and performance highlights the importance of giving passengers detailed information about what they are required to do in advance of an emergency situation. High stress levels may be present at the time of the emergency and if new information is delivered as the emergency situation is developing, passengers may experience difficulties in comprehending the information.

1.6.6. Non-adaptive group behaviour

Mintz (1951) argues that non-adaptive group behaviour has been demonstrated during situations where there is an 'unstable reward structure' (p. 151) such as emergency situations. The research involved a simulated laboratory experiment whereby a number of cones were placed in a bottle with a narrow opening and groups of individuals were required to each remove a cone from the one bottle at the same time. In order to add a degree of pressure on the individuals they were told the task should be completed within a time limit, with financial incentives used to motivate the volunteers. From the results of the experiment Mintz suggests that when all occupants work together and cooperate 'there is no conflict between the needs of the individual and those of the group' (1951, p. 151). However when a small number of individuals no longer cooperate with the group (as may be the case when access to exits is limited) 'a conflict between the needs of the group and the selfish needs of the individual then arises' (Mintz, 1951, p. 151).

The influence of competitive and collaborative behaviour has been demonstrated during simulated emergency evacuations by Muir, Marrison and Evans (1989). Muir et al developed a new technique to manipulate the motivation to escape of the individual participants during simulated evacuations from an aircraft cabin. Groups of participants were recruited to participate in either competitive or collaborative evacuations. Those participants recruited to a collaborative evacuation were each paid a standard attendance fee for participating in the trials and were instructed to evacuate as quickly as possible. However, those participants who were recruited to attend a competitive evacuation were informed that in addition to the standard attendance payment of £10, they would be offered a bonus payment of £5 for each one of the four trials in the session if they were within the first 50% of participants to evacuate the cabin (Muir et al 1989). Muir et al (1996) suggest that this is an important behaviour to acknowledge as the behaviour of competing individuals may conflict with the objectives of the overall group.

1.6.7. Other reported behavioural responses

Other behavioural responses reported by cabin safety specialists include disorientation, both physiological – due to the environmental conditions within the cabin (such as the presence of smoke, fire and gases) and situational - where the occupant is disoriented in the first instance by the events around them and takes some time to orientate themselves (Galea, 2003). Depersonalisation has been proposed by Noyes and Kletti (1977) as an 'adaptive mechanism' exhibited by some individuals in the event of experiencing a life threatening event, which is defined by 'alterations in the experience of time, emotion, sensation, volition, reality, memory, attachment, and space' (p. 383). Individuals report that they become detached from the events around them and feel as though they are onlookers to the events, rather than being actively involved. Galea (2003, p. 133) has also reported evidence for 'social bonding behaviours' where companions will seek each other out prior to evacuating the cabin and altruistic or unselfish behaviour where passengers may come to the aid of other passengers, even if this help puts them at risk.

In summary a range of behaviours has been reported by passengers in an emergency. Galea (2003) states that research and analysis has shown that 'the passenger has a very good chance of surviving' and by behaving in a 'reasonable and thought-out manner' '…can help increase his or her chance of survival' (p. 128).

1.7. Factors influencing survival

In 1972 Edwards (cited in Edwards and Edwards (1990)) proposed the human factors SHEL model as a means of explaining the different components of a system and the interactions between these components within the aviation domain. The model has then been used as a means of identifying the factors that may influence passenger survival in the event of an emergency. The model highlights four main components – software, hardware, environment and liveware, however consideration should not just be given to the components in isolation but also in combination, as interactions in the components will occur. Edwards and Edwards propose that the "system" will contain some form of hardware, be that a piece of equipment or a structure - in this case the hardware is the aircraft cabin or elements within it such as the exits. Edwards and Edwards identify that in order for the system to operate effectively operating procedures and protocols will be required, along with any overriding regulations. These elements are the software which allows the hardware to operate. In the case of the Type III exit, the software will include the regulations regarding the size and shape of the exit and aperture and the information that must be required by the passenger in terms of exit operation. The hardware and software is then all activated, controlled, managed or maintained by individuals who interact with the system whom Edwards and Edwards refer to as the liveware. The liveware – i.e. in this case the passengers and crew must also interact effectively together, as well as with the other elements of the system. Finally, the liveware must interact with the hardware and software with the constraints of the environment (the final component in the model). This may be the area the aircraft or the exit operates in, but also the social operating context. All the elements of the system must work together to ensure safe operation, with human factors research focussing on the interaction of the liveware with the other elements of the system and each other (Edwards and Edwards, 1990).

The seminal work of Snow, Carroll and Allgood (1970) identified a number of factors that influence occupant survival during an emergency evacuation of an aircraft. The categories proposed by Snow et al can be interpreted in light of SHEL model as proposed by Edwards (1972). Snow et al placed the factors into one of four categories – configurational (***H****ardware*), procedural (***S****oftware*), environmental (***E****nvironment*) and biobehavioural (***L****iveware*) as shown in Table 1 (Snow et al, 1970, p. 1).

The model proposed by Snow et al (1970) has been extended by Muir (2004). In addition to the interior configurational factors, procedural factors, biobehavioural passenger factors and the environmental conditions, Muir suggests that crashworthiness and fire protection and evacuation aids also influence passenger survival in aviation accidents. Crashworthiness and fire protection factors include developments in the strength of the occupant seats and fire resistant materials as examples. There has also been extensive development in evacuation aids such as exit signs and floor proximity lighting (Muir, 2004).

Table 1: Factors influencing survival adapted from (Snow et al, 1970, p.1).

Category	Description
Configurational	Configurational factors are the 'standard features of [the] occupant environment controlling access to exits and evacuation flow rates' Examples include the aisle width and the number, type and location of the exits.
Procedural	Procedural factors are the 'regulatory and training practices of crew and other non-passenger rescue personnel which influence evacuation procedures.' Examples include the cabin crew training and the standard operating/emergency procedures of the airline.
Environmental	Environmental factors are the 'features of the occupant space and outside the aircraft which control survivability and evacuation time.' Examples include the presence of fire and smoke, the level of lighting and the weather outside the aircraft.
Biobehavioural	Biobehavioural factors are the 'biological, psychological and cultural attributes of individual passengers which influence agility and behaviour.' Examples include the sex, age and fitness level of the passengers.

1.8. Aircraft exits

Aircraft exits for obvious reasons 'are among the most important systems on board the aircraft' (Schaefers, 1994, p. 72). There are a number of different exit types on commercial aircraft which vary in size and location. The largest exit is a floor level Type A which must be at least 42" in width and 72" in height and the smallest is a Type IV exit which is a non-floor level exit usually located in the centre of the cabin and must be at least 19" in width and 26" in height (CS-25.807 (EASA); FAR 25.807 (CFR); CAR 525.807 (Transport Canada)).

1.8.1. The Type III exit

The Type III exit is another non-floor level rectangular-shaped exit that is also located in the centre of the cabin either above or below the wings depending on the type of aircraft. Type III exits are installed on smaller transport aircraft or large single aisle aircraft with a maximum seating capacity of up to 299 seats (CS-25.807) The minimum dimensions of a Type III must be 20” in width and 36” in height, with the corner radii no greater than 7”. The step up to the exit inside the aircraft must be no greater than 20” and if positioned over the wing the step down outside the exit must be not greater than 27” (CS-25.807 (EASA), FAR 25.807 (CFR) and CAR 525.807 (Transport Canada). Due to their location on the aircraft Type III and Type IV exits are often referred to as overwing exits.

Traditional Type III exits differ in their mode of operation to floor level exits in that once they are released, the hatch plug is not attached to the fuselage and will fall into the cabin. The passenger is required to check the status of the area outside the aircraft and if deemed safe open the exit. The operating process first requires them to release the hatch by pulling down on the release handle which is located at the top of the hatch. The hatch plug then has to be brought inside the cabin, manoeuvred and rotated in the space adjacent to the exit and disposed of into a location whereby it does not impede egress. This location differs across operators and regulatory authorities. In the UK the Civil Aviation Authority (CAA) guidance is for the hatch to be placed outside the aircraft, whereas the FAA permits operators to opt for the exit to be disposed of outside or inside the aircraft.

The usage of Type III exits by passengers during aircraft evacuations was analysed by Galea (2003). Using data contained within the Aircraft Accident Statistics and Knowledge (AASK) database, Galea (2003) reviewed the passenger usage from the exits located in different areas of the aircraft cabin. The analysis used evacuation data from aircraft with three pairs of exits – forward, mid cabin and aft, where at least one exit in each pair was available for evacuation. Galea (2003) concluded that a trend towards passengers using the central mid cabin exits was apparent, as this was the nearest available exit for many passengers, suggesting that ‘this is a disturbing trend as the mid exits are the smaller Type-III passenger operated hatch exits’ (p. 148).

The prevalence of passenger usage of the Type III exit was also reported by Schaefers in 1994, who following a review of exit usage from 73 accidents between 1961 – 1992 concluded that overwing exits were used in approximately every five or six accidents out of 10 and by 30% of the occupants from wing engined aircraft in the dataset and 50% of the occupants from tail engined aircraft.

Although much smaller than floor level exits and ‘certified for a relatively small number of passengers’ accident reports and analyses have shown that the overwing exits can be used as a key egress route, with usage by a high number of passengers during some evacuations (CAA, 2004, GR No. 3, Appendix 1, p. 3). This underlines the importance of passengers being able to evacuate through them effectively.

1.8.2. Exit operator

Regulations require that a member of cabin crew is situated at each floor level exit (CS-25.785 (EASA); FAR 25.785 (CFR); CAR 525.785 (Transport Canada)) as these are viewed as the primary egress routes in the event of an emergency. During the majority of flights a member of the travelling public will be seated adjacent to an overwing exit. Some airlines with additional crew on board will allocate a member of cabin crew to control the evacuation at the Type III exit(s). However as the cabin crew are strapped in during take off and landing in other areas of the cabin, it is likely that the passenger will attempt to operate the exit prior to the crew arriving in the vicinity. It is also possible that the crew member will experience difficulty in moving to the centre of the cabin and may disrupt the evacuation flow due to the presence of other passengers. These difficulties were highlighted in the accident involving a Boeing 737 at Los Angeles in 1991. One member of cabin crew reported that after the impact ‘she attempted to make her way to the overwing exits in accordance with company procedure. Because of the number of passengers moving aft, she was only able to advance forward to the seats at rows 19 and 20 on the left’ (NTSB, 1991, p. 38). During this accident the cabin crew member was only able to move a maximum of four rows forward, which was still a considerable distance from the Type III exit row, so may not have been able to offer as much assistance as desired to the exit operators.

Cabin crew are highly trained and professional individuals, whose initial and recurrent training syllabus is governed by regulation. With regards to exit operation, crew have to undergo initial and recurrent training in the preparation and operation of the type of emergency exits on the aircraft they are certified to fly on. The regulations state that this training must occur every three years, although anecdotal evidence from some airlines suggests that due to the importance of exit operation during an emergency situation, some organisations conduct cabin crew recurrent training in exit operation every year. However, passengers who are seated next to the overwing exits are unlikely to have ever experienced operating an emergency exit prior to being required to do so in the event of an emergency. Passengers seated in the exit row are not required to undergo any training and are given only a visual screening by the airline staff and the cabin crew regarding their ability to open the exit. Passengers are provided with some information on exit operation within the safety information, however the form of this information differs from airline to airline.

1.8.3. Evacuations involving the Type III exit

Perhaps the most cited accident in cabin safety literature involving the Type III exit is the evacuation that occurred following an uncontained engine fire onboard a British Airtours Boeing 737 at Manchester Airport in the UK in 1985 (AAIB, 1988).

1.8.3.1. Summary of the accident

On the early morning charter flight to Corfu there were 131 passengers and six members of crew (including two on the flight deck). During takeoff, the left engine suffered an uncontained engine failure, which punctured a fuel tank access panel on the wing. This allowed fuel to leak which subsequently ignited. The flight crew heard a ‘thud’ and aborted the take off. The flight crew informed the cabin crew via the cabin address system that an emergency evacuation may be required via the exits on the right hand side of the aircraft (AAIB, 1988). As the pilots turned the aircraft off the runway a wind of seven knots transferred the fire onto the fuselage. The fire took hold on the fuselage, penetrating the cabin swiftly, allowing smoke to enter the cabin prior the aircraft coming to a stop. The aircraft was destroyed by the fire, with 55 occupants (53 passengers and two members of cabin crew) losing their lives (AAIB, 1988). The accident report states that ‘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 a door malfunction and restricted access to the exits’ (AAIB, 1988 p. 2).

The findings of the investigation stated that the Manchester accident should have been a survivable accident. There were no impact forces or occupant injuries from the initial aborted take off and the aircraft was still at a well-equipped airport, with rescue personnel arriving within 30 seconds of the aircraft stopping (AAIB, 1988).

1.8.3.2. Survival aspects

The internal conditions were so severe that some passengers left their seats prior to the start of the evacuation. When the aircraft had come to a stop the purser attempted to open the right hand exit at the front of the cabin, but the slide pack caught on the exit frame. The purser then went across the galley to the exit on the left hand side of the cabin and opened this exit and inflated the slide without incident. This exit was made available 25 seconds after the aircraft had come to a halt. The purser, recognising the need to make available as many exits as possible, returned to the R1 door and was able to make the exit available for egress one minute and 10 seconds after the aircraft had stopped (AAIB, 1988).

The environmental conditions inside the aircraft at Manchester were severe, with the cabin filling with thick, black smoke ‘which induced panic amongst passengers’ (AAIB, 1988, p. 48) and passengers moving into the aisle prior to the aircraft stopping and the exits being opened. Conditions in the cabin were so extreme that passengers who had made it into the aisle were struggling to move towards the exits, with some passengers collapsing in the aisle (AAIB, 1988).

1.8.3.3. The use of the Type III exit

The female passenger sitting next to the right Type III (overwing) exit, at the instigation of other passengers, attempted to open the exit by pulling on the armrest located on the lower half of the exit hatch. The individual sat in the centre seat of the row, stood up and pulled the handle at the top of the hatch allowing the hatch to fall into the cabin. The hatch, weighing 48lbs, trapped the female passenger in her seat, which required the male passenger in the seat row behind to remove the hatch and place it onto an empty seat in his row. The exit was made available 45 seconds after the aircraft had come to a stop. The accident investigation team reported that the passenger adjacent to the Type III exit 'was not familiar with the door opening procedure and unaware if the door was hinged at the top, bottom, left or right, or if it would come straight off' (AAIB, 1988, p. 50).

Due to the fire, the overwing exit at the left hand side of the cabin was not opened and neither exit at the rear of the aircraft was available for evacuation, leaving only three of the six exits in use. Of the 78 passengers who were able to evacuate the aircraft, 17 left via the forward left hand exit, 34 via the forward right hand exit and 27 through the Type III exit including an infant and a child in arms (AAIB, 1988). Although the Type III exit has historically been considered an egress route for a minimal number of passengers, during the evacuation at Manchester, the Type III exit was the nearest available exit for 76 passengers. Information from accidents has shown that in some evacuations the central overwing exits may in fact be the nearest available exit for most passengers.

1.8.3.4. Blockages at the Type III

At Manchester the Type III exit and the area inside the cabin adjacent to the exit experienced blockages throughout the evacuation. The area around the Type III 'became a mass of bodies pushing forward to the exit' (AAIB, 1988, p. 51), with a passenger sitting in the exit seat row reporting that the available space between the seats in the exit row was not sufficient for evacuation. The limited space at the exit was also reported by another passenger who was originally sitting towards the rear of the aircraft (AAIB, 1988). The overwing exit was blocked during the evacuation with 'people's bodies lying half-in and half-out of the aircraft' (AAIB, 1988. p. 51). The importance of ensuring passengers can evacuate through the exit quickly was emphasised at Manchester when passengers who were, at the start of the accident, located in the area of the cabin where the environmental conditions were extreme were able to move towards the centre of the cabin only to be overcome by the smoke (AAIB, 1988).

Following on from the Manchester accident, one of the key questions was why were all the occupants unable to evacuate the aircraft prior to being overcome by the environmental conditions (AAIB, 1988). The Boeing 737 successfully completed its regulatory full scale certification trial in 1970 with 130 passengers and five crew evacuating via the exits on the left hand side of the aircraft in 75 seconds (AAIB, 1988), however when a rapid evacuation was required at Manchester difficulties in the evacuation process occurred.

1.9. Research involving access to the Type III exit

Since the evacuation at Manchester, one area of focus of aircraft evacuation research has been the Type III overwing exit. The majority of the experimental research has been conducted at Cranfield University in the United Kingdom or at the FAA Civil Aerospace Medical Institute (CAMI) in Oklahoma City in the United States.

The regulations regarding access to the Type III exit at the time of the Manchester accident (described in section 1.8.3.1) only required the seatback to be clear of the projected exit opening and therefore it was acceptable for a passenger seat to be located adjacent to the exit (as was the case on the Manchester aircraft). In addition, the right hand armrest was mounted on the hatch, but would move with the hatch out of the egress path. To move through the aperture, passengers would climb onto the seats in the exit row. This seating configuration was widely used within industry with ‘testing show[ing] that this did not slow down the evacuation’ (CAA, 1991, p. 11). Following Manchester the investigation team concluded that the limited space available at the exit resulted in difficulty with exit operation and egress, which lead the UK CAA to issue Airworthiness Notice 79 issue 1 (CAA, 1986) which required operators to alter the seating configuration adjacent to the Type III exit. Operators were given two options. Option one was to reconfigure the seats to increase the space available for egress through the exit. The seat adjacent to the exit could not be positioned further forward than the projected centre line of the exit with a vertical projection of at least 10” [that is ‘the minimum vertically projected distance between seat rows or between a seat and any fixed structure forward of the seat (Quigley, Southall, Freer, Moody and Porter, 2001, pi)]. Option two was to remove the outboard seat in the exit row which created two passageways to the exit. The movement of the seatbacks adjacent to the exit were also restricted to prevent obstructions along the passageway leading to the exit (CAA, 1991). Concurrently the CAA also commissioned a programme of research at Cranfield University to investigate access to the Type III exit. Figure 1 shows the measurement of vertical projection, with a vertical projection of 10” shown in the figure.

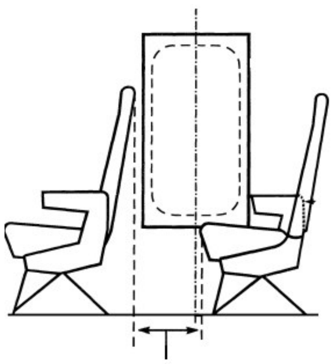

Figure 1: A 10” vertically projected passageway leading to the Type III exit (adapted from CAA (2004), GR No 3, Appendix 1, p. 3).

1.9.1 Cranfield University research

A research programme conducted by Muir et al (1989) was initiated by the UK CAA to investigate passenger behaviour in aircraft evacuations. The experimental programme had two main objectives, firstly, to investigate the influence of passageway width at the bulkhead leading to Type I floor level exits on evacuation times, and secondly (and more important to the current context), to investigate the width (in terms of vertical projection between the seat rows) and the space available in the access row to the Type III overwing exit. These objectives were formed as a result of information gathered from the Manchester accident investigation.

Seven different seating configurations at the overwing exit were tested, with trials conducted in both collaborative and competitive conditions. As previously discussed in Section 1.5, this motivational protocol involved offering incentive bonus payments to a percentage of the first passengers out of the cabin during competitive trials to encourage them to move rapidly towards the exits. In the Muir et al series of trials, bonus payments were offered to the first 50% of occupants to evacuate the cabin. The tested seating configurations were: (A) a vertical projection of 3” between the seat rows at the exit, with minimal recline and forward motion of the outboard seat. This configuration was the minimal distance allowable by CAA and FAA regulation at the time of the Manchester accident, (B) the same 3” vertical projection as in condition (A), but with no movement of the seatbacks in the exit row. Condition C involved two routes to the exit due to the removal of the outboard seat. The vertical projection at each seat row to the exit was 6”. This was one of the conditions allowable within AN79 (issue 1). During conditions D, E and F, the vertical projection between the seats was increased to 13” (an AN79 configuration), 18” and 25” respectively. For the final tested configuration (condition G) a full row of seats was removed resulting in a vertical projection of 34”.

Groups of 60 passengers were recruited to participate in a series of evacuation trials from a Hawker-Siddeley Trident (3B) aircraft that was located on the Cranfield University airfield. Each condition was tested eight times utilising the competitive methodology (where bonus payments were given to the first 50% of participants to evacuate on each trial), with the exception of condition B which included four competitive trials and four collaborative trials (where a flat rate attendance payment was given to all participant irrespective of the order in which they evacuated the cabin). To remove the individual variance of the hatch operator on participants’ evacuation times, one of two trained researchers operated the hatch during all trials.

Due to the bonus scheme in operation, only the data from the first 30 participants to evacuate through the exit were included in the analyses, as it was felt that participants in the second half of the competitive trial may have stopped competing towards the exit. Muir et al (1989) concluded that there was a significant effect attributable to seating configuration on the mean evacuation times for the 30th participant to evacuate the cabin in both competitive and collaborative conditions. When detailed analyses across each condition were conducted the time taken to evacuate was slower in the 3” vertical projection than any other seating configuration. During the competitive evacuations as the vertical projection between the exit seat rows was increased from 3” to 25”, the time taken for the first 30 passengers to evacuate was reduced, along with the number of blockages (Muir et al, 1989). However when a full row of seats were removed increasing the vertical projection from 25” to 34”, participants were slower in evacuating as the increased distance allowed more participants into the exit row at the same time which subsequently resulted in exiting delays (Muir et al, 1989).

When the data from the competitive and collaborative conditions were combined, the two exit row configurations regulated by AN79 were shown to significantly improve the speed at which the occupants could egress through the Type III exit when compared to the configuration permissible prior to AN 79 (Muir et al, 1989). Although the rates at which the participants evacuated through the overwing exit when the seat rows were configured at 13”, 18” or 25” were not significantly different from each other, Muir et al (1989, p. 20) concluded that a vertical projection at the passageway of 18” ‘would appear to be the optimum’.

Following on from the Muir et al study, the CAA commissioned a further study to investigation the influence of the passageway configuration at the Type III exit on evacuation in conditions of poor visibility simulated via the introduction of non-toxic smoke (Muir, Marrison and Evans, 1990). Four passageway configurations were tested at the overwing exit, with groups of 30 participants evacuating in only a collaborative manner (due to ethical and participant safety issues linked to evacuation in conditions of non-toxic smoke). Each group of participants completed two evacuations, one through the Type I and one trial through the Type III exit, with data available from a total of 254 participants. The trial procedure was similar to that of Muir et al 1989 to allow comparison of the data.

The information from the Type III aspect of the study is of relevance here, with four seating configurations tested, each on two occasions. The seatbacks in the exit row were restricted during all trials. The test conditions were (A) an AN79 configuration with the outboard seat removed and two 6” vertically projected passageways; (B) an AN79 configuration with a single vertically projected passageway width of 13” (the AN79 minimum was 10”); (C) a vertically projected passageway width of 18” and (D) a vertically projected passageway width of 34”.

Mean times for the thirtieth participant to evacuate on each trial showed some variation, however no statistically significant differences between the four seating configurations were reported, although the report authors questioned whether this was due to the limited number of evacuations in each condition (Muir et al, 1990).

In conclusion, Muir et al (1990) recommended increasing the sample size to allow statistical testing of the findings and based on the current knowledge a vertically projected distance between the seat rows to the Type III exit of between 13” and 25” would provide the optimum evacuation rate.

Based on the recommendations of Muir et al (1990), Muir, Bottomley and Hall (1992) were commissioned to undertake a further evacuation study to investigate the influence of reduced visibility and cabin configuration adjacent to the exit (with identical seating configurations to Muir et al, 1990) on evacuation. During this series of trials, participants were motivated through the introduction of financial incentives to the first 75% of participants to encourage competitive behaviour.

The results suggested that the 6” vertically projected passageways with the outboard seat removed (OSR) resulted in the slowest evacuation, with the 13” vertically projected passageway condition leading to the fastest times (although the report authors do note the relatively high standard deviation for this condition suggesting a degree of variability in the times from each trial). Inferential analysis (with the outliers removed) suggested a statistically significant difference between the seating configurations for the first 30 participants to evacuate the cabin. The reanalysis suggested that evacuations via the dual 6” passageways were significantly slower than the other configurations tested and for the most part, a larger vertical projection was associated with faster evacuation rates (Muir et al, 1992).

1.9.2 Civil Aero Medical Institute research

On release of AN79 in the UK, the Northwest Mountain Region of the FAA in the United States commissioned CAMI to undertake a study to assess the configurational changes in AN79 at the Type III exit in relation to the current minimum requirements as documented within the FARs.

The study conducted by Rasmussen and Chittum (1989) investigated the influence of four different seating configurations at the Type III exit on flow rates through the exit and exit preparation. The seating configurations were (A) a 6” vertically projected passageway, which was the minimum distance allowable by the FARs at the time. The seat in the exit row was as far forward as possible and the seat forward of the exit was as far aft as possible, without either seat infringing on the exit opening. Condition B included a 10” vertically projected passageway width, which was the CAA minimum under AN79 with the seat in front of the exit not impeding the aperture and the exit row seat no further forward than the centre of the exit. In condition C the distance between the seat rows at the exit was increased to 20”, with a 5” seat encroachment of the aft seat into the exit opening. The final tested condition placed the exit seat row centrally to the exit, with the OSR (Rasmussen and Chittum, 1989).

Using mean times per subject to exit as the dependent variable (exit operation times were removed from the analysed data), a significant difference between seating configurations was shown. Further analyses revealed egress was quicker when there was a 20” vertical projection or the outboard seat was removed compared to the 6” vertically projected passageway. There was also a significant difference between the 10” vertical projection and the OSR conditions (Rasmussen and Chittum, 1989).

Based on the findings of Rasmussen and Chittum (1989) and the accident at Los Angeles in 1991 involving a collision between a Boeing 737 and a Metroliner, a notice of proposed rulemaking (NPRM) was released by the FAA. The notice informed air carriers that regulations would be altered to require the passageway width at the overwing exit to be increased from the current 6” to 20”, with the aft seat encroachment distance of the exit opening of no more than 5” (NTSB, 2000). On receiving this proposed change, industry questioned the degree to which the increase in space was required. As a result of this consultation, a further study was commissioned (McLean, Chittum, Funkhouser, Fairlie and Folk, 1992) to further explore the pathway width and seating configuration at the Type III exit.

Four groups of 39 participants evacuated in four seating configurations in a counterbalanced repeated measures design to account for experience, motivation and fatigue. The four seating configurations were each tested four times: condition A involved the cushion of the aft exit seat infringing the exit opening by 5” and the seatback on the forward exit seat positioned 5” forward of the exit opening. This resulted in a 20” vertically projected exit passageway width. Condition B was comparable to condition A; however the seat forward of the exit was moved aft so that the seatback was level with the exit opening and broken forward by 15 degrees. The aft seat row was located 5” forward of the exit opening, creating a 10” vertically projected exit passageway. For condition C – a 10” vertically projected passageway was configured (as in configuration B), however the cabin was configured as a 3 x 2 seating configuration, with the double seating units on the side of the cabin where the exit was situated. Finally two Type III exits were installed for condition D, with the centre lines of the exits 29” apart. 3 x 3 seating units were installed throughout the cabin, except adjacent to the exit where seating doubles were positioned, with the outboard seat removed. This created three 6” passageways to the exits (McLean et al, 1992).

Due to the different approaches to exit operation adopted by different exit operators, McLean et al (1992) felt that total group egress time was not a suitable measure to assess the impact of the seating configurations at the exit. Data were extracted on exit operation time (the time from the start of the evacuation until the operator entered the exit aperture) and the time taken for the third participant to egress through the exit until the 37th participant passed through the aperture as it was felt that this would provide data on a continuous evacuation flow (McLean et al, 1992).

The 20” passageway with a single exit (configuration A) resulted in the quickest egress time, exit removal time and flow rates whereas configuration B with a 10” passageway resulted in the slowest egress time. Egress times in configuration C (with two seats adjacent to the exit) were lower than those in configuration B. It was concluded that evacuation time through the overwing exit was ‘highly dependent on the ergonomic restrictions encountered around the exit hatch opening’ (McLean et al, 1992, p. 5). McLean et al (1992) concluded that the findings were consistent with those of Rasmussen and Chittum (1989) and added further information to our knowledge of the influence of seating configuration on evacuation. The results from the descriptive statistics presented by McLean et al (1992) highlighted the importance of providing a wider exit row passageway, although the authors do stress that difficulties may still be experienced if the ‘available space exceeds individual passenger needs’ (McLean et al, 1992, p. i).

Even though only descriptive analyses were conducted on the data, as opposed to inferential statistics (a fact also highlighted by the NTSB in 2000), a regulatory change was issued by the FAA in 1992 which required operators to increase the distance between the seats at the overwing exit to 20”. After this ruling the Air Transport Association and a number of air carriers appealed the regulation as they felt a passageway width somewhere between 6” and 20” may provide an equivalent level of safety performance (NTSB, 2000). As a result of this appeal another series of trials were commissioned by the FAA and conducted by McLean, George, Chittum and Funkhouser (1995). The research programme investigated two independent variables - the influence of exit row passageway widths (6”, 10”, 13”, 15” and 20” vertically projected) and the seat encroachment distance (5”, 10” and 15”) on egress through a Type III overwing exit.

Participants were split into two groups of 37 based on their age (participants in group one were aged 18 to 40 and those in group two were between 40 and 62 years) and evacuated the simulator on each occasion in these groups. A repeated measures design was employed with each group of participants evacuating the simulator in each condition, which resulted in 30 evacuations.

In order to minimise participant experience with evacuating through an aircraft emergency exit and practice effects, the research team allowed participants to practice egressing through the Type III exit on two occasions with no seat assembly in place prior to the actual test evacuation. Competitive cooperation between participants was encouraged, along with optimum performance across all trials, by offering a bonus to the quickest three participants across all trials, with professional cabin crew in place to encourage a rapid evacuation (McLean et al, 1995). One member of crew was located in the outboard seat in the row in front of the exit and on the call to evacuate the crew member stood up, turned to face the exit and encouraged passengers through the exit (McLean et al, 1995). Although this procedure was done to encourage efficient evacuation, the majority of airlines do not place a member of crew in the vicinity of the overwing exit at the start of the evacuation as regulations only require crew at floor level exits.

The authors did note that some trials had to be removed from the analysis (although it is not clear which conditions the trials were in) due to changes in the cabin crew commands, which resulted in these trials becoming an evaluation of seat stepping performance rather than seat placement (McLean et al, 1995).

Using the group evacuation time for the first 35 participants to evacuate (the data from the last two participants were excluded as their location at the back of the queue may have influence their behaviour), a significant effect was reported for passageway width, seat encroachment distance and participant group (McLean et al, 1995). Participants were slower to evacuate when the vertical projection between the seats was at 6" or 10" compared to when the seats were positioned with a vertically projected distance of 13", 15" or 20" McLean et al, 1995). In addition, a significant difference was reported for the maximum seat encroachment distance but no significant difference was found for the mid and minimum seat encroachment distances. Finally, the "older" participant group were significantly slower in evacuating than the younger group. The authors concluded that the 'narrow passageways and/or large encroachments of the seat into the area of the exit opening delay[ed] egress significantly' (McLean et al, 1995, p. i). With regards to the passageway configuration, McLean et al recommended a 13" passageway with a 10" seat encroachment distance (the mid distance tested) 'would be the most restrictive configuration allowable to obtain evacuation performance essentially equivalent to that obtained with the 20-inch passageway offset 5-inches' (McLean et al, 1995, p. 9).

The findings of the McLean et al (1995) study resulted in the FAA issuing an exemption to the 20" rule and a further NPRM in January 1995. This amendment allowed the carriers to install a 13" passageway width at the overwing exit (NTSB, 2000). This rulemaking by the FAA has though been questioned by the NTSB due to some design and procedural elements of the research. This led the NTSB to recommend further experimental work, which the FAA initiated CAMI to complete.

This subsequent study was reported in 2002 by McLean, Corbett, Larcher, McDown, Palmerton, Porter and Shaffstall is the most recent published work on access to the Type III exit. The extensive research programme was commissioned by the FAA in an attempt to finally resolve the issues linked to access to Type III exits.

Four independent variables were tested in a factorial design. The crucial variable (both for the McLean investigation and the present study) was passageway configuration at the Type III exit, which was tested at four conditions – a 20" vertical projection, with 5" aft seat encroachment, a 13" vertical projection, with 10" aft seat encroachment, a 10" vertical projection, with 14" aft seat encroachment and dual 6" passageways with the outboard seat removed.

The other independent variables included the location of the disposed Type III hatch. This was tested in two conditions. Exit operators either received safety information showing the hatch disposed of inside the aircraft on the exit row seat or outside the aircraft (McLean et al, 2002). Other tested variables were participant motivation which was tested in two conditions. After boarding the simulator all participants were briefed according to the motivation condition during the trial. Participants in the low motivation (co-operative) trials were informed that there had been an accident and the aircraft was on fire and they had to get out of the cabin as quickly as possible. During other trials, a high passenger motivation (competitive) was introduced. Participants were provided with the same information as the low motivation group but in addition were informed that double pay would be provided to the first 25% of the participants to exit the cabin across all the trials in the session. The motivational payments were made across all the trials in the session in an attempt to maintain the competition between individuals throughout the session. The final independent variable was participant group density. This was tested at three levels – low (30 participants), medium (50 participants) and high (70 participants).

The authors reported that the variables were selected for inclusion as previous studies have highlighted their effects on evacuation and specifically their influence on passageway configuration, which was the key variable of interest. The experimental design was quite complex involving 2,544 participants across 48 experimental groups with 'motivational level […] nested within subject group density, which was distributed uniformly across passageway configuration nested within hatch disposal location' (McLean et al, 2002, p. 2). In order to address both participant naivety, as would be the case in an emergency situation, and differences in individual performance, analyses were conducted on the first trial only (naïve participants) and all trials conducted in a session in a repeated measures design.

Due to the differences in group numbers (one of the independent variables), evacuation time data from the first trial (48 in total) for the first 30 passengers were analysed, with no significant differences attributable to the independent variables, which included vertical projection at the exit. A multiple regression analysis using the independent variables and individual participant characteristics (height, waist size, gender and age) was conducted on the individual participant evacuation times (defined as the time from one participant exiting through the aperture until the time the next participant was through the exit). The multiple regression revealed that participant waist size accounted for the most variance, followed by gender and then age. Neither participant height nor any of the independent variables added further to the regression model. McLean et al concluded that this was an important finding as it 'was the first evidence that the individual subject characteristics were significantly more important to the evacuation outcomes than were the independent variables', accounting for 32% of the variance (2002, p. 16). Although an important finding, it is argued that industry, cabin safety researchers and human factors specialists have no control over the individual human characteristics on board the aircraft and therefore cannot regulate in the area. Therefore it is still of utmost importance that research is conducted into factors influencing evacuation over which the industry have some control.

An analysis of covariance reported a significant interaction between passageway configuration and hatch disposal location. The interaction suggested that increased evacuation times were evident with the 13” passageway width at the exit row when the hatch was disposed of inside the cabin, whereas when the hatch was disposed of outside, increased evacuation times were evident when there was a 10” passageway width (McLean et al, 2002). Further analysis of the video footage assisted in adding explanation to this finding and this was due to the exit hatch being dislodged from the intended position inside the cabin during some of the trials when the vertical projection was at 13”.

As during the McLean et al (2002) study, the authors were focused on the effect of passageway configuration and the results from these two trials were due to a ‘partial obstruction of the exit caused by improper hatch disposal’ the evacuation times were adjusted to remove the influence of the obstruction. By adjusting the results from these trials the results were aligned with those obtained from the other trials in the 13” seating configuration. The significant effect of the 13” vertical projection and significant interactions between the passageway configuration and both hatch disposal and group density were no longer apparent, leaving ‘only the egress times from the 10” passageway configuration with outside hatch disposal location as being significantly different from the rest’ (McLean et al, 2002, p. 23).

McLean et al (2002, p. 32) conclude that the ‘effects showed clearly that, of the single passageway configurations employed, only the 10” passageway configuration produced ergonomic restrictions significant with respect to egress performance, specifically for older, wider, and taller subjects’. These results ‘attest again to the inability of the 10” passageway configuration to provide an egress route that is as effective or as efficient as the other configurations for a significant portion of the flying population’ (McLean et al, 2002, p. 32). Although the results from this study have been presented as reported by McLean et al (2002), some of the analyses are questionable as individual egress times were used as the dependent variable measures which were not independent from each other. This infringes one of the assumptions of parametric statistical tests. That said, the McLean et al (2002) study suggested that in a larger single aisle cabin configuration, a 10” vertically projected passageway leading to the Type III exit results in delays to passenger evacuation. However as the study was only required to address evacuation from larger cabins, it is not known if these findings relating to vertical projection at the exit row generalise to smaller transport aircraft and specifically cabins with two seats either side of the main aisle and less headroom.

1.10. Current regulatory position on access to Type III exits

Following the experimental testing at Cranfield University into the effects of the exit row configuration on evacuation, the UK CAA issued version 3 of AN79 in March 1989 (CAA, 1989) (issue 2 was released by the CAA in 1987 to include Type IV with the airworthiness notice). Issue 3 of AN79 is still the current issue and has since been incorporated into Generic Requirement 3 within CAP 747 ‘Mandatory Requirements for Airworthiness’ (2004). CAP 747 is applicable to all UK registered aircraft with a passenger capacity of 20 or more.

In order to comply with the UK regulations, operators can opt for one of two seating configurations at the Type III exit. If a single passageway to the exit is present, the exit seat row must be configured so that no part of the seat is further forward than the centre line on the exit, with the forward seat row positioned to allow a passageway configuration of either 10” vertically projected or at least as wide as half the width of the exit hatch (whichever is greater). An alternative configuration with two passageways to the exit can be used, with space equivalent to the removal of the outboard seat next to the exit and a minimum distance between the seat rows of both passageways of at least 6” vertical projected. All movement in the seatbacks along the passageway must be prevented (CAA, 2004).

United States and Canadian regulations on access to the Type III exit are applicable to aircraft with a passenger capacity of at least 60 seats (FAR 25.813 (CFR), CAR 525.813 (Transport Canada)). Where there are seating doubles on the side of the aircraft where the Type III exit is located, regulations require a vertically projected passageway width of at least 10” and where there are triple seat assemblies in place, a vertical projection of 20” is required. The FARs also stipulate that ‘the centerline of the required passageway width must not be displaced more than 5 inches horizontally from that of the exit’ (CFR 14, 25.813, (c)(i)). A second option is available to the operator if preferred, through the creation of two passageways to the exit that have a vertically projected width of at least 6” and an unobstructed space next to the exit which is the width of a passenger seat and encompasses the exit opening (outboard seat removed) (CFR 14, 25.813).

FARs also regulate that for aircraft with at least 20 passenger seats, the projected exit opening must be clear of obstructions, with no interference from other aspects of the cabin furniture (CFR 14, 25.813). For aircraft with fewer than 20 passenger seats ‘minor obstructions in this region’ are permissible ‘if there are compensating factors to maintain the effectiveness of the exit’ (CFR 14, 25814, (2)(ii)).

In 1999, the Cabin Safety Harmonisation Working Group (CSHWG) were assigned by the FAA Aviation Rulemaking Advisory Committee to address issues surrounding access to Type III and IV exits. It was intended that members of the group (which comprised of experts from the United States, Canada and Europe) would provide guidance that would assist the FAA with rulemaking activities (FAA, 1999). During their initial assignment, the group investigated access to the Type III exit.
Based on the current FAA regulations, the then JAA rules (the JAA has now become EASA) and the research findings available at the time, the CSHWG proposed that on aircraft with a seating capacity of 20 seats or more, where there were two seats abreast of the aisle the vertical projection at the exit row should be a minimum of 10”. Where there are three seats either side of the main aisle, either a single passageway to the exit with a vertical projection of 13”, with at least 10” of the passageway within the exit aperture area was proposed or a dual passageway configuration with the outboard seat removed and two 6” vertical projected passageways (FAA, 2002). To date there has not been a change in the EASA and FAA regulations on access to the Type III exit, although some exemptions have been awarded to US airlines allowing a 13” vertical projection (FAA, 2002). Although recommendations were made by the CSHWG, the specific research studies that were used to inform the recommendations are not clear in

the information that is in the public domain. Specifically, publicly available data are limited on evacuation from smaller transport aircraft, including cabins with two seats either side of the main aisle.

1.11. Aim of the thesis – evacuation from smaller transport aircraft

As stated in Section 1.1 the main aim of the overall thesis was to explore evacuation from smaller transport aircraft. The issue of evacuation from smaller transport aircraft is of relevance as these aircraft have a narrower fuselage, and therefore less cabin width and lower headroom. Throughout this review of the literature, there has been limited reference to smaller transport aircraft and the link between the area of study and the literature may be questioned, however there is a simple reason for this. That is, there is limited cabin safety and evacuation research into evacuation from smaller transport aircraft. The majority of the publicly available research on evacuation, and specifically on Type III exits to date, has been conducted in cabins with a larger interior configuration, where there are three seats either side of the main aisle. As a result of this imbalance in the research, relatively little is known about whether research findings from trials conducted in a larger interior configuration will generalise to aircraft with a smaller interior configuration. This programme of research was undertaken with a view to gaining knowledge and informing regulatory activity on evacuation from smaller transport aircraft and to provide further data when considering if regulations for large transport aircraft are also applicable to small transport aircraft.

In addition, full scale evacuation demonstrations are not required by current regulations for aircraft with fewer than 44 seats as set out by many regulators including EASA, the FAA and Transport Canada. This research also responds to an issue raised by the NTSB in 2000 who felt that the evacuation demonstration should apply to 'all newly certificated commercial airplanes… regardless of the number of passenger seats in the airplane' (2000, p. 80). To date, no change has been made to the requirement for evacuation certification trials for newly designed aircraft. This view was reiterated by R.G.W. Cherry and Associates who conducted a study into the factors influencing evacuation from smaller transport aircraft in 2006a. As previously highlighted and confirmed by R.G.W. Cherry and Associates 'the majority of evacuation research has been directed toward larger transport airplanes', coupled with the fact that evacuation certification trials are not required for passenger carrying aircraft with fewer than 44 seats, mean that 'the significant factors in evacuation from smaller transport airplanes are less generally understood' (2006a, p. 7)

This thesis contains four experiments that investigate passenger evacuation and the operation of the Type III exit from smaller transport aircraft. The first experiment investigated passenger evacuation through the Type III exit and the potential influence of the interior configuration and the space available at the exit on the rate at which passengers evacuate through the exit. Due to the limited research it was not known if the interior configurational features associated with smaller transport aircraft (i.e. a narrower fuselage which results in less cabin width and less headroom) would influence evacuation through the Type III exit. In addition, the amount of space available at the Type III exit has been shown to be of important to evacuation speed in large single aisle aircraft and it was not known if the width of the passageway configuration at the exit would also be of importance in smaller transport aircraft.

Experiments Two and Three then focussed on the individual exit operator and potential improvements to Type III exit operation as accidents and experimental research have shown difficulties can be experienced by operators. Difficulties in operation of the Type III exit have been shown in large single aisle aircraft and it was not known if the same difficulties would also be experienced in smaller transport aircraft. Experiment Two investigated the influence of the interior configuration, a modification to the exit operating handle mechanism and the exit operator's briefing on the time taken to operate the exit. The modification to the exit operating handle was selected as this was amenable to a retrofitting programme and operator briefings are relatively simple to alter within an airline.

Experiment Three then investigated a major modification to the Type III exit mechanism on exit operation time. The modification, which was the installation of an automatically disposed hatch, had been shown to be of benefit in reducing the time taken to make the exit available in a large single aisle aircraft and it was not known if the benefits would also be seen in exit operation from smaller transport aircraft.

Finally Experiment Four examines the effect of the placement location of the disposed hatch from a traditional Type III exit on passenger evacuation. As this was an initial experiment into the issue, evacuation trials were only conducted in a smaller transport aircraft. It was felt that due to the restricted space available in an aircraft of this type, the influence of the placement of the hatch may have more of an impact than on larger aircraft.

This section has outlined the progression of the four experiments in the thesis, with the focus throughout exploring evacuation issues associated with smaller transport aircraft. The next section provides the objectives of Experiment One including the rationale for the inclusion of the variables.

1.12. Objectives of Experiment One

Based on the requirements for data on evacuation from smaller transport aircraft, one of the objectives of Experiment One was to investigate the effect of the interior configuration on evacuation. In order to compare the data obtained, tests were also conducted in a large single aisle interior configuration, with three passenger seats either side of the main aisle.

One area of extensive research in large single aisle cabins has been the influence of the passageway width and access to the Type III exit on evacuation. Vertical projection at the Type III exit is known to influence passenger evacuation through the overwing exits on larger transport aircraft (Muir et al, 1989; 1990; 1992; Rasmussen and Chittum, 1989; McLean et al 1992; 1995). In addition, the recommendations made by the Cabin Safety Harmonisation Working Group to the FAA suggested that on aircraft with two seats either side of the main aisle and at least 20 passenger seats, the access to the Type III exit should be at least 10” vertically projected and where there are three seats either side of the main aisle, either a single passageway to the exit with a vertical projection of 13” or dual passageways with two 6” vertical projected passageways and the outboard seat removed (FAA, 2002). However, as previously highlighted, it is not clear where the data used to form these recommendations came from. As a result it was decided to also investigate passageway width within this study in order to determine if the issue was also of relevance to smaller transport aircraft.

Although other research programmes have investigated vertical projection in large single aisle cabins, only two studies have included vertical projections of 10" and 13" within the same experiment. One of these was the McLean et al (2002) study which also investigated three other variables in addition to vertical projection. The results had also not been published when Experiment One was designed. In addition neither of the previous studies with these vertical projections were conducted within the Cranfield University evacuation simulator, which was the test facility for the current experiment. As a result of the considerations, evacuation trials in both large single aisle and smaller interior configurations were conducted as it was not felt appropriate comparisons could be made with existing data.

In summary, the specific objectives of Experiment One were to investigate the influence of the interior configuration (either a small or large single aisle interior configuration) and passageway width at the Type III exit (either a 10" or 13" vertical projection) on evacuation and passenger perception of the evacuation.

2.0. Method: Experiment One

2.1. Methodological considerations

2.1.1. Cabin simulator

With any aircraft evacuation trials an appropriate balance between participant safety (both physically and psychologically) and the realism of the experimental scenario has to be reached. By conducting the trials in a controlled environment it allows the researcher to manipulate the variables of interest, whilst still maintaining control of the experiment to minimise the risks. To enhance the realism of the experiment, the cabin simulator and experimental procedure (i.e. the inclusion of a pre-flight safety briefing demonstration and safety card) were made as realistic as possible. In addition participants were not briefed about the specific evacuation scenario in advance, as would be the case during an unplanned real evacuation.

The objectives of the experiment were to explore issues surrounding evacuation from smaller transport aircraft and, as a result, evacuation trials were conducted with the cabin simulator configured as either a small transport aircraft or a large single aisle aircraft. The issue of evacuation from smaller transport aircraft is of relevance as these aircraft have a narrower fuselage and therefore less cabin width (which is linked to the number of seats abreast that can be installed), and lower headroom.

When the test facility was configured as a large single aisle interior configuration, seating triples were placed either side of the main aisle and the bases of the overhead lockers were 64.5” from the ground to represent typical aircraft interiors of this type. For some of the evacuations the facility was modified to represent some of the key internal features of a smaller transport aircraft. The overall width of the fuselage was narrowed and the seating triples were replaced by seating doubles to represent an internal configuration with two seats either side of the main aisle. In addition the bases of the overhead lockers were lowered to 54.5” from the floor. It is acknowledged that in making these modifications from a large single aisle aircraft to a small transport aircraft, essentially two variables were manipulated – the seating configuration and the headroom available. However in order to enhance the ecological validity of the experiment and the representativeness of the test facility in relation to current aircraft types, a methodological comprise was made as both changes were made in combination and not in isolation.

2.1.2. Sampling

A non-probability convenience sampling method was used to recruit participants. It is acknowledged that this method of sampling may have introduced some bias as participants self-selected to volunteer for the evacuation trials.

2.1.3. Co-operative (collaborative) methodology

Two types of motivational methodology developed by Muir et al (1989) have been used with aircraft evacuation research – the co-operative approach or the competitive approach (these approaches have been described in Section 1.6.6). Both methodologies have been used successfully within a number of research programmes. Where a competitive methodology has been used, passenger behaviours have been akin to those reported during life threatening emergencies, whereas behaviours witnessed during simulated co-operative trials have been similar to those recorded during aircraft certification trials and precautionary evacuations.

The co-operative approach, which has been used widely in evacuation research, was selected for this experiment in line with the sponsor's requirements. When undertaking any aircraft evacuation research, participant safety has to be the primary consideration. As experimental trials had previously not been conducted in a small interior configuration, there was limited knowledge on the behaviours that might be observed, so a collaborative methodology was used in the first instance. There is also the risk that an evacuation trial may have to be stopped by a member of the research team due to concerns for participant safety and a result no data are collected. This may be more likely when a competitive methodology is used. Although only a secondary consideration in this experiment, due to the limited number of trials in each condition, the risk of this happening was minimised through the use of a co-operative approach. As a result of these considerations a co-operative approach was selected. .

It is acknowledged that with a co-operate methodology participants may not be as motivated to evacuate as quickly as possible, so a number of strategies were put in place to enhance the urgency to evacuate. Previous research studies have used two alternatives when employing a co-operative methodology. Studies have either offered all participants a flat rate attendance fee or offered all participants a flat rate attendance fee and in addition a group bonus, payable to all members of the group, if all group members evacuate within a time limit. The time limit is not specified to the participants. By providing the added bonus to the group to evacuate as quickly as possible, it is hoped the degree of urgency will be increased. The attendance fee plus the additional group bonus was offered in this experiment. In addition, the cabin crew were trained to behave in an assertive manner when issuing commands and directions. This is in line with the findings and Muir and Cobbett (1996) who reported that simulated evacuations with assertive cabin crew were significantly faster than those with no assertive cabin crew. Finally, anecdotal evidence from previous experimental programmes has also shown that participants can be motivated to evacuate as quickly as possible via the researcher’s briefing in advance of the trials. This additional motivational strategy was used in the experiment.

It was hoped that by using a group bonus co-operative methodology and the additional motivational strategies, participants would be encouraged to evacuate as quickly as possible, whilst minimising the risks to participant safety.

2.2. Ethical and safety considerations

The experiment was conducted in accordance with the code of conduct and ethical guidelines of the British Psychological Society (BPS, 2006). An ethics proposal was submitted to, and approved by the Human Factors Department Ethics Committee prior to the experimental trials taking place. Participant safety was a primary consideration throughout the research programme. Participants were advised of the appropriate clothing to wear for the test session (which were trousers, a long sleeved top and trainers or flat pumps and socks). All participants were recruited with regard to medical criteria, which had been approved by the ethics committee.

2.3. Research design

Experimental trials were conducted to investigate the influence of the interior configuration and vertical projection at the Type III exit on evacuation and exit operation. This resulted in a 2 x 2 factorial design. To remove practise and learning effects, it was decided to use independent measures, with each group of participants recruited to participate in only one evacuation trial.

2.3.1. Independent variables

There were two independent variables in the experiment. The first was the interior configuration, which was tested either in a small interior configuration or in a large single aisle interior configuration. The second independent variable was the passageway width at the Type III exit. This was tested at either 10” or 13” vertically projected at the exit row.

2.3.2. Dependent variables

The rate at which participants evacuated the cabin was the dependent variable from the evacuation trial. Evacuation performance timings were extracted from the time coded video footage of the trials, measured to one tenth of a second. The time taken to evacuate was taken from the Captain’s command to evacuate which was “Undo your seatbelts and get out!” until the last participant had both feet on the wing.

Participant rating scales were also collected from a post evacuation questionnaire designed specifically for evacuations through the Type III exit. A copy of the questionnaire can be found in Appendix A. The questionnaire asked participants to rate various aspects of their evacuation experience using a seven point Likert type scale and these responses were then used as dependent variables. The other questions on the questionnaire asked participants to provide qualitative comments about their experience.

2.3.3. Experimental schedule

The experimental schedule, showing how the 24 evacuation trials were run in the four test conditions, is given in Table 2.

Table 2: Experimental schedule

	Interior configuration	
Passageway width	**Large interior configuration**	**Small interior configuration**
10” vertical projection	Six groups	Six groups
13” vertical projection	Six groups	Six groups

2.4. Participants

Twenty four independent groups of up to 20 members of the public (plus reserves) were recruited as participants. Volunteers who had previous experience of operating a Type III exit were excluded from taking part. Each group was required to take part in a single evacuation, and participants were permitted to take part in one session only.

Participants were recruited via local and regional advertising. A sample of a recruiting advertisement is provided in Appendix B. Participation was restricted to people who were aged between 20 and 50, and who weighed no more than around 15 stones/95.25 kg. Participants were advised that they should be normally fit and healthy, and not excessively overweight. For safety reasons participants with any of the following medical conditions were restricted from taking part: heart disease, high blood pressure, fainting or blackouts, diabetes, epilepsy or fits, deafness, chronic back pain, ankle swelling, depression, anxiety, other nervous/psychiatric illnesses, fear of enclosed spaces, fear of heights, fear of flying, brittle bones, asthma, bronchitis, breathlessness, chest trouble, allergy, lumbago sciatica, or any other serious illness.

Participants were sent a confirmation letter outlining their booking. A sample copy of a confirmation letter is provided in Appendix C.

2.5. Equipment/materials

2.5.1. Test Facility

The test facility for the experiments was the Boeing 737 cabin simulator located within the School of Engineering, Cranfield University in the United Kingdom. The facility was fitted with four functioning exits. In the starboard side of the fuselage there were two Type I exits (one at the front and one at the rear) and a fully functional Type III exit in the centre of the cabin. In the port side of the fuselage there was one service door at the rear of the cabin. The Type III exit was used for all evacuations.

A control station was located at the front of the cabin simulator. The control station was fitted with a personal computer used to operate the lighting system, a video monitor which displayed an image of the interior of the cabin and an audio system which was used to play the audio tracks. Three infra-red cameras were located in the test facility. One camera was outside the Type III exit, one camera was positioned internally directed at the Type III exit and one was positioned along the main aisle.

Some evacuation trials were conducted in a large interior configuration, with three seats either side of the main aisle, to represent a larger single aisle transport aircraft (i.e. Boeing 737/Airbus 319). For other trials, the facility was modified to represent a small transport aircraft with two seats either side of the main aisle (i.e. the Bombardier CRJ series and the ATR-42 aircraft as examples). For tests in the larger interior configuration, seating triples were set at a seat pitch of 29”, equivalent to a vertical projection of between 3 – 4”. The bases of the overhead lockers were 64.5” above the cabin floor.

For the small interior configuration tests, the fuselage was narrowed by installation of a false wall down the port side. The overhead lockers were fitted with false bases to lower the ceiling and reduce the headroom available. The bases of the overhead lockers were 54.5” above the cabin floor. Seating doubles from an Embraer 120 regional jet were modified to fit floor mounted seat track, rather than the side of the fuselage wall. The existing seat track was relocated so that the Embraer doubles could be secured. These seats were placed at a vertical projection of 3.5”, to be equivalent to tests conducted in the larger interior configuration.

The other modification to the test facility during the experiment was the width of the passageway at the Type III exit, which was tested at either a 10” or a 13” vertical projection at the exit passageway.

Photographs of the cabin in both the large and small interior configurations are provided in Appendix D. All trials were conducted in “simulated” daylight down one side of the cabin.

2.5.2. Materials

Participants were provided with a clipboard that contained all the paperwork for the trials. The trials materials included a volunteer information sheet (a copy is provided in Appendix E), which contained details of the health and safety provisions, confidentiality and anonymity, insurance cover, and payment. A volunteer consent and medical clearance form was also provided. This form asked participants about any pre-existing psychological or physical conditions and also asked them to provided informed consent for participating in the evacuation trials. A copy of this form is provided in Appendix F.

A demographic questionnaire was also used to gather background information on the participant (a copy can be found in Appendix G), along with a post evacuation questionnaire (as shown in Appendix A). It is noted that only some of the questions on the demographic questionnaire were of relevance to the current experiment and the remainder were included at the request of the sponsor. Those that were specifically of interest to the current experiment were those that gathered data on the characteristics of the sample. The post evacuation questionnaire asked participants about their experience of the evacuation and included information on the difficulty of moving down the aisle to reach the exit row, the difficulty of moving between the seats at the exit row, and the difficulty of moving through the exit and out of the aircraft. Participants were asked to provide a difficulty rating for each of these elements on a seven point scale where 1 was very easy and 7 was very difficult. The post evacuation questionnaire also asked participants about any physical features within the cabin that had helped or hindered their evacuation. Participants were asked to provide open responses to these questions where applicable. Other questions were included on the post evacuation questionnaire at the request of the sponsor, however these were not of relevance to the current experiment and have not been analysed.

2.6. Procedure

2.6.1. Pre-trial procedure

On arrival, members of the research team greeted all participants. Each participant was issued with a bib detailing their volunteer number, and provided with a clipboard containing the trial materials.

Participants were asked to read and complete the trials paperwork and have their height and weight measured by the research team. Each participant was asked to complete the medical questionnaire (see Appendix F), and was interviewed by an occupational health nurse or first aider in order to receive clearance to take part in the trials.

The test facility was checked by the nurse/first aider prior to each trial. Participants were asked to remove loose jewellery before boarding the cabin simulator. During the trials there were always four members of the research team on the simulator platform. At least two members of the research team were inside the cabin (one acting as cabin crew), with another researcher and the nurse/first aider located directly outside the operational exit. The researcher on the wing was instructed to move the Type III exit hatch out of the path of the participants (for safety reasons), and marshal them to a place of safety. The nurse/first aider and all members of the research team were equipped with emergency alarms, and instructed to sound them if any participant was believed to be at risk of injury.

On completion of the check-in procedure, the lead researcher briefed participants. This briefing contained details of the background of the research, information relating to the conduct of the trial, and a demonstration of the emergency stop alarm. A transcript of the briefing is provided in Appendix H.

2.6.2. Trial procedure

2.6.2.1. Seating

On completion of the pre-trial briefing, the cabin crew boarded participants in the cabin simulator. Participants were assigned to seats within the cabin as they arrived at the testing session. The participant in the seat adjacent to the Type III exit was always male (seat 3a in the small interior configuration and seat 7a in the large interior configuration), although all other seat allocations were random.

2.6.2.2. Safety briefings

Once seated, the member of cabin crew provided a safety briefing which included the location of the exits, and demonstrations of the use of seatbelts and oxygen masks. In addition, the participant seated next to the Type III exit received an individual minimal briefing on their emergency duties. This briefing highlighted that the participant was sitting next to an emergency exit, that they may be required to open the exit in the event of an emergency and where they could find additional safety information on the exit operation procedure. Transcripts of both of these briefings are provided in Appendix I.

2.6.2.3. The call to evacuate

When the safety briefings were complete, the cabin crew completed a check of the cabin and ensured that all participants had their safety belts fastened. The trials were to simulate an emergency evacuation on take off. Shortly after the cabin crew had checked the cabin a pre-recorded evacuation scenario was played. This included a period of engine noise (lasting approximately 30 seconds), followed by an announcement from the Captain to “Undo your seat belts and get out!” A transcript of the evacuation scenario is contained in Appendix J.

2.6.2.4. Cabin crew actions

At the end of the Captain’s announcement the cabin crew member, who was located at the front of the cabin, commanded passengers to open and move towards the Type III exit. Passengers were urged to move quickly throughout the evacuation. The cabin crew member used assertive, concise, positive commands, in accordance with the findings of Muir and Cobbett (1996). The evacuation was deemed complete when all passengers had evacuated the cabin.

2.6.3. Post-trial procedure

On completion of the post-evacuation questionnaire, participants were thanked, debriefed and paid. Finally, participants were provided with a thank you letter containing contact details for the research team. A copy of this letter is provided in Appendix K.

2.7. Analysis

The video footage was edited and a time code was added. Data were then extracted from the video footage to allow the calculation of the dependent variable. All performance evacuation data, along with the quantitative responses from the post evacuation questionnaires were entered into SPSS version 14 for quantitative analysis.

Qualitative comments provided in response to the open questions on the post evacuation questionnaire were collated on a question-by-question basis and have been used to add depth to the quantitative results.

3.0. Results: Experiment One

3.1. Sample

A total of 439 participants took part in the testing programme, 274 were male (62.4%), 162 were female (36.9%), with three participants not answering the question. Four hundred thirty five participants (99.1% of the sample) provided their age at the time of the testing session. Participants' ages ranged from 20 to 54 years, with a mean age of 28.9 years, and a standard deviation of 7.8 years. Forty-two participants were left handed (9.6%), 381 were right handed (86.8%), 13 were ambidextrous (3%), with three participants (0.7%) of the sample not answering the question. Most participants had flown previously on a commercial flight (425 participants, or 96.8%), and one participant reported having made a previous emergency evacuation.

3.2. Completed evacuations

All planned evacuations were successfully completed, with no reported injuries. A number of participants failed to attend the session, resulting in fewer than 20 participants in some evacuations.

3.3. Descriptive results

Table 3 details the summary descriptive data for each group during each trial. Data are provided on the experimental condition, the number of participants within the group, the evacuation latency period, the overall evacuation time and the calculated evacuation rate. All mean times and mean participant ratings have been rounded up to one decimal place.

Table 3: Summary evacuation data for each group

Group	Cabin Configuration	Vertical Projection	Number of participants	Evacuation latency (seconds)[1]	Overall evacuation time (seconds)[2]	Evacuation rate (pax per minute)[3]
Gp1	Large	13”	19	10.2	29.3	56.5
Gp 2	Large	13”	16	11.8	31.2	46.4
Gp 3	Large	13”	18	7.2	26.3	53.4
Gp 4	Large	10”	18	8.2	28.5	50.2
Gp 5	Large	10”	18	13.7	37.5	42.9
Gp 6	Large	10”	20	9.4	30.6	53.8
Gp 7	Small	13”	17	10.6	28.7	53.0
Gp 8	Small	13”	20	10.0	27.4	65.5
Gp 9	Small	13”	17	9.8	29.3	49.2
Gp 10	Small	13”	15	8.8	23.5	57.1
Gp 11	Small	13”	15	10.4	26.8	51.2

[1] The latency time was taken from the call to evacuate to the second foot of the first participant was placed on the simulator wing.
[2] The overall evacuation time was taken from the call to evacuate to the second foot of the last participant was placed on the simulator wing.
[3] Calculated using the formula n-1/t, where n is the number of participants and t is the time between the second foot of the first participant was placed on the simulator wing and the second foot of the last participant placed on the simulator wing.

Group	Cabin Configuration	Vertical Projection	Number of participants	Evacuation latency (seconds)	Overall evacuation time (seconds)	Evacuation rate (pax per minute)
Gp 12	Small	13”	15	8.9	24.0	55.6
Gp 13	Small	10”	20	7.9	32.8	45.8
Gp 14	Small	10”	17	7.0	28.8	44.0
Gp 15	Small	10”	20	9.6	31.7	51.6
Gp 16	Small	10”	19	10.9	32.2	50.7
Gp 17	Small	10”	20	9.2	28.6	58.8
Gp 18	Small	10”	20	12.2	34.9	50.2
Gp 19	Large	10”	18	11.9	32.2	50.2
Gp 20	Large	10”	19	14.3	33.4	56.5
Gp 21	Large	10”	19	8.8	27.6	57.4
Gp 22	Large	13”	19	13.1	36.5	46.2
Gp 23	Large	13”	18	10.8	31.1	50.2
Gp 24	Large	13”	20	7.8	30.7	49.8

3.4. Participant evacuation rates

Mean evacuation rates for the participants to evacuate through the Type III exit in each condition are given in Table 4.

Table 4: Mean evacuation rates (passengers per minute) for participants to egress through the Type III exit in each condition.

	Interior configuration		Total
Passageway width	**Large**	**Small**	
10” vertical projection	51.8 (sd 5.3)	50.2 (sd 5.2)	**51.0 (sd 5.1)**
13” vertical projection	50.4 (sd 4.0)	55.3 (sd 5.8)	**52.8 (sd 5.4)**
Total	**51.1 (sd 4.6)**	**52.7 (sd 5.7)**	

As can be seen in Table 4, there is some variation in the evacuation rates due to the test condition. A factorial analysis of variance (ANOVA) was conducted on the data which revealed no statistically significant differences attributable to the interior configuration $F(1,20) = 0.59$, $p=0.43$ or vertical projection $F(1,20) = 0.77$, $p=0.39$ on evacuation rates. There was also no significant interaction between the interior configuration and vertical projection on evacuation rates $F(1,20) = 2.43$, $p=0.14$.

3.5. Perceived difficulty of the evacuation

In order to investigate passengers’ perceived difficulty of the evacuation procedure, data obtained from a selection of questions on the post-evacuation questionnaires were also analysed. One question on the post evacuation questionnaires related to the difficulty of moving down the aisle to reach the exit row. The mean ratings provided in response to this question are given in Table 5.

Table 5: Mean participant difficulty ratings (where 1 was very easy and 7 was very difficult) for moving down the aisle to reach the exit row in each condition.

	Interior configuration		**Total**
Passageway width	**Large**	**Small**	
10” vertical projection	2.7 (sd 1.5)	2.6 (sd 1.3)	**2.7 (sd 1.4)**
13” vertical projection	2.4 (sd 1.3)	2.3 (sd 1.3)	**2.3 (sd 1.3)**
Total	**2.6 (sd 1.4)**	**2.5 (sd 1.3)**	

Data were entered into a factorial ANOVA. The results which revealed a significant effect for vertical projection $F(1,415) = 7.34$, p=0.01. Participants evacuating in the 10” vertically projected passageway conditions reported that it was significantly more difficult to move down the aisle to reach the exit row, compared to those evacuating in the 13” vertically projected passageway as is evidenced by their higher difficulty scores in Table 5. There was no statistically significant difference attributable to the interior configuration $F(1,415) = 0.50$, p=0.49 or any significant interaction between the interior configuration and vertical projection $F(1,415) = 0.00$, p=0.97.

Participants were asked on the post-evacuation questionnaire the difficulty of moving between the seats at the exit row. The mean ratings provided in response to this question are given in Table 6.

Table 6: Mean participant difficulty ratings (where 1 was very easy and 7 was very difficult) for moving between the seats at the exit row in each condition.

	Interior configuration		**Total**
Passageway width	**Large**	**Small**	
10” vertical projection	3.6 (sd 1.7)	3.0 (sd 1.4)	**3.3 (sd 1.6)**
13” vertical projection	2.6 (sd 1.5)	2.5 (sd 1.4)	**2.6 (sd 1.4)**
Total	**3.1 (sd 1.7)**	**2.8 (sd 1.4)**	

The data were entered into a factorial ANOVA which revealed a significant effect for the interior configuration, $F(1,427) = 5.89$, p=0.02, and a significant effect for vertical projection, $F(1,427) = 23.09$, p=0.00. Participants evacuating in the large interior configuration reported that it was significantly more difficult to move between seats in the exit row than those who evacuated in the small interior configuration. In relation to vertical projection, participants evacuating in the 10” passageway condition reported that it was significantly more difficult to move between seats in the exit row than in the 13” passageway condition. There was no statistically significant interaction between the interior configuration and vertical projection $F(1,427) = 3.46$, $p=0.63$.

The post-evacuation questionnaire asked participants to rate the difficulty of moving through the exit and out of the aircraft. The mean ratings provided in response to this question are given in Table 7.

Table 7: Mean participant difficulty ratings (where 1 was very easy and 7 was very difficult) for moving through the exit and out of the aircraft in each condition.

	Interior configuration		**Total**
Passageway width	**Large**	**Small**	
10” vertical projection	3.6 (sd 1.6)	3.0 (sd 1.4)	**3.3 (sd 1.5)**
13” vertical projection	3.1 (sd 1.4)	3.1 (sd 1.5)	**3.1 (sd 1.4)**
Total	**3.3 (sd 1.5)**	**3.0 (sd 1.5)**	

The data were entered into a factorial ANOVA which revealed a significant effect for the interior configuration $F(1,429) = 4.01$, $p=0.46$ and a statistically significant interaction between the two variables $F(1,429) = 4.49$, $p=0.04$. Participants evacuating in the large interior configuration reported that it was significantly more difficult to move through the exit and out of the aircraft than in the small interior configuration as evidenced by their higher difficulty scores. A significant interaction was also reported with participants perceiving it as easier to evacuate with the 10” passageway when the interior configuration was smaller than when the interior configuration was larger. Figure 2 shows the significant interaction between the interior configuration and vertical projection on mean difficulty ratings of moving between the seats in the exit row.

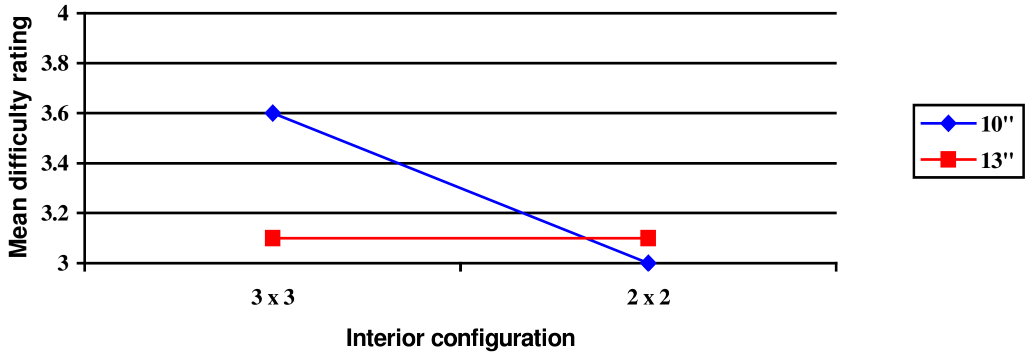

Figure 2: The interaction between interior configuration and vertical projection on the perceived difficulty rating for moving between the seats in the exit row.

As Figure 2 suggests where the passageway to the exit is narrow, the shorter it is, the easier participants perceive the evacuation to be. There was no statistically significant difference in perceived difficulty of moving through the exit and out of the aircraft due to vertical projection at the Type III exit, $F(1,429) = 3.01$, p=0.08.

3.6. Headroom in the cabin

In addition to the rating scales, participants were asked about any factors that had hindered their evacuation. Of particular interest to the current experiment was the number of comments related to the headroom in the cabin. Only four comments in the large interior configuration related to this:

"The overhead cabin being too low over the exit" (Participant 312, large interior configuration with 13" passageway)

"The overheads were quite low and I had to watch my head as I went over the seat" (Participant 2218, large interior configuration, with 13" passageway)

"I knocked my head on the overhead compartment as in the panic I forgot it was there" (Participant 615, large interior configuration with 10" passageway)

"Hit head of the overhead bag store" (Participant 619, large interior configuration, with 10" passageway)

However, in the small interior configuration, there were many more participant comments about the overhead lockers and the limited headroom hindering their evacuation. A selection is provided here:

"The ceiling was too low over the passenger seats" (Participant 710, small interior configuration with 13" passageway)

"Height of the ceiling under the storage bins" (Participant 1006, small interior configuration with 13" passageway)

"Overhead bins were very low and I had to duck quite a lot" (Participant 1015, small interior configuration with 13" passageway)

"The height above my seat - headroom was very small even though I am short, and so I could not jump up and move as quickly as I would have liked - now was there room to climb over the seat" (Participant 1502, small interior configuration with 10" passageway)

"Guy at the door was too tall to stand and this made door removal difficult" (Participant 1707, small interior configuration with 10" passageway)

"The luggage cabinets were too low!" (Participant 1720, small interior configuration with 10" passageway).

Although not reflected in the rate at which participants evacuated the cabin, the qualitative responses suggest that participants perceived the restrictive headroom in the cabin to hinder them during their evacuation.

4.0. Discussion – Experiment One

4.1. Interior configuration and vertical projection on evacuation rates

The results of the experimental trials indicated no effect for interior configuration or vertical projection on evacuation rates through the Type III exit. Although in these trials the interior configuration and vertical projection at the exit seating row did not influence the overall evacuation rate, this may be due to the limited number of passengers on board, as any blockages could be quickly resolved. In addition, participants were not competing to egress through the exit as there was no perceived threat to survival as is possible during a real evacuation or an incentive payment for being one of the first participants to evacuate. As there are no other studies that have specifically investigated the influence of the interior configuration it is difficult to place these results into the wider context.

It is noted that only vertical projections of 10” and 13” at the Type III exit row were tested within the current experiment and it is acknowledged that there is not a great degree of difference between these widths which may help explain the lack of significant differences in evacuation rates. However these vertical projections were selected by the sponsor to provide some empirical testing of the proposed regulations for passageway access to Type III exits (as recommended by the CSHWG) in a smaller transport aircraft interior configuration. It may be that differences in the effectiveness of egress through different passageway widths could be established with an investigation into other vertical projections. Although there were no differences in evacuations rates between 10” and 13”, this does not mean that either of these configurations are the most appropriate to include on small or large single aisle aircraft. Overall the previous research has suggested that a wider passageway width resulted in the fastest evacuation rates. However more recently McLean et al (2002) concluded that the effects of the passageway configuration upon evacuation are minimal, but that the 10” passageway did impede egress due to the restriction it placed on evacuation. Further work should explore evacuation in a smaller transport aircraft (and large single aisle) with other distances between the exit row seats in an attempt to determine the optimum passageway configuration.

4.2. Perceived difficulties during the evacuation

Although there were no significant differences in evacuation rates attributable to the independent variables, some differences were reported by participants on the post evacuation questionnaire. A significant difference was perceived by participants in moving down the aisle to reach the exit and in moving between the seats in the exit row. Participants perceived it to be more difficult when the vertical projection in the exit row was configured at 10” compared to when it was at 13”. This suggests that the restrictive space of the 10” vertically projected passageway was perceived by participants as causing them difficulties as they moved through the exit passageway With regards to moving along the aisle, as the passageway width was narrower in the 10” condition, it may be that participants were held up in the aisle waiting to move towards the exit and perceived this as causing them difficulty.

A significant difference was perceived in moving between the seats in the exit row and moving through the exit and out of the aircraft which was attributable to the interior configuration. Participants perceived it to be more difficult in the large aircraft interior configuration compared to the interior configuration of the small transport aircraft. As the larger interior configuration included three seats either side of the main aisle as opposed to the smaller interior configuration where there were only two seats, it may be moving between the seats was more difficult in the large configuration due to the additional length of the passageway. It is unknown why participants perceived moving through the exit as more difficult in the large interior configuration, as there was more headroom in the larger interior configuration and the exit aperture itself was unchanged across the experimental conditions. It may be that as there was more headroom in the large aircraft interior configuration, participants had a greater distance to stoop to egress through the exit aperture. Participants in the small interior configuration would have already been stooped for some of the distance required due to the presence of the overhead lockers which impeded their mobility immediately upon entering the exit row from the main aisle. As highlighted in Section 2.1.1 consideration was given to ecological validity. As the headroom and the number of seats were only tested in combination and not in isolation it is not known if this perceived difficulty was due to the number of seats either side of the aisle or the lowered height of the overhead lockers.

Finally, when participants were asked to rate the perceived difficulty of moving through the exit and out of the aircraft, there was a significant interaction. The results suggest that when moving through a narrow passageway (i.e. 10” vertically projected) to use the exit and leave the aircraft, it was perceived as more difficult when the seats were three abreast of the main aisle and there was more headroom than when they were two abreast of the main aisle, with limited headroom. This suggests that when the passageway to the Type III exit is narrow, the shorter it is, the easier it is perceived to be.

4.3. Interior configuration

As discussed in the previous chapter the headroom available in the cabin was reported by participants as influencing evacuation efficiency. Interestingly, the quantitative rating scales suggested that the large interior configuration was perceived as hindering participants moving between the seats in the exit row and out of the exit, whereas in the qualitative comments there were numerous comments about the restrictive headroom in the smaller interior configuration. In the small aircraft interior configuration, when participants were asked about any factors in the cabin that had hindered them a number of comments were made regarding the low headroom. These included participants banging their heads on the overhead lockers, having to stoop in the exit row and being unable to climb over seats due to the overhead lockers. It is noted that only four comments related to the headroom at the Type III exit from participants in the large aircraft interior configuration where there was more headroom available, whereas there were numerous comments relating to the headroom at the exit from participants evacuating in the small aircraft interior configuration. Although it may be the combined influence of the headroom available and the number of seats either side of the main aisle, the qualitative comments have highlighted that participants perceived it to be more difficult to evacuate when the headroom is more restrictive.

4.4. Summary of Experiment One

The objectives of the experiment were to investigate the effects of interior configuration and vertical projection at the exit row on evacuation rates through the Type III exit in both a small transport aircraft interior configuration and large single aisle interior configuration. In this experiment, neither of the variables were found to influence evacuation rates, however the more restrictive condition of 10" vertically projected at the exit row was found to influence the perceived ease of the evacuation. With regards to the interior configuration the quantitative rating scales showed that participants perceived moving between the seats in the exit row and out of the aircraft as more difficult in the larger interior configuration. It is suggested that this may be due to the longer seat assembly and that participants would have to stoop further to exit through the aperture in the larger interior configuration. In contrast the height of the overhead lockers in the small interior configuration was consistently reported in the qualitative comments as a hindrance to the evacuation. It is recommended that further research should investigate the interior changes of headroom and seating configuration in isolation (i.e. evacuations with either three seats or two seats either side of the main aisle and lowered overhead lockers and three seats or two seats with higher overhead lockers) to assist in identifying if either variable is more influential during the evacuation. It is acknowledged that any effects found in the experiment attributable to the interior configuration, the findings cannot be attributed to either the headroom or the number of seats abreast alone, but to the combined differences of a typical interior configuration of a smaller transport aircraft when compared to a typical large single aisle interior configuration. This must be borne in mind when conclusions are drawn.

The next stage of the research programme was designed to investigate the operation of the Type III exit in a smaller transport aircraft. Although experimental research has explored Type III exit operation in a large single aisle aircraft, there were limited data on exit operation in smaller transport aircraft. In addition, a high number of qualitative comments were made by passengers in Experiment One which referred to the difficulties experienced in evacuating due to the restrictive headroom associated with the smaller cabin interior configuration. It was also not known if the smaller interior would influence operation of the Type III exit. As a result of these factors it was decided to look at one specific aspect of evacuation from smaller transport aircraft – the operation of the Type III exit.

5.0. Introduction – Type III exit operation

5.1. Introduction to Experiment Two

Problems have been reported both during evacuation trials and experimental research concerning the operation of the Type III exit, the manoeuvrability of exit hatch and disposal of the Type III hatch. From these findings, it is proposed that there are two main ways to enhance the performance of the task, which involve either adapting the operator to the task or adapting the task to the operator (Grandjean, 1988). In response to the reported difficulties with Type III exit operation, one area of current regulatory activity is the Type III exit.

As a result of the difficulties experienced during evacuations through Type III exits, an alternative automatic Type III hatch design has been certificated on some next generation aircraft. Current regulatory activity is focussed on ensuring appropriate access to the Type III exit. The installation of a ‘non-disposable Type III exit design’ ensures that the placement of the hatch does not influence access to the exit (FAA, 2002, p. 6). The current regulatory view is to regulate the installation of an automatically disposed Type III exit hatch on ‘new type certified aircraft’ with at least 41 passenger seats to ensure the access to the exit is not impeded (FAA, 2002, p. 6). With an automatically disposed hatch (ADH) Type III exit mechanism, when released the hatch is automatically disposed of, as opposed to the exit operator having to dispose of the hatch. As the exit hatch remains attached to the fuselage it is disposed of into a location where it does not create a potential obstruction to egress both in the passageway to the exit and along the main aisle.

The Cabin Safety Harmonization Working Group who made the above recommendations further explain that current thinking regarding the scope of the regulations is due; ‘primarily on the estimate that smaller aircraft would involve a large design and cost penalty for incorporating such a feature’ (FAA, 2002, p. 6). That said, the working group ‘recognized that smaller aircraft could benefit significantly and more work would be required to make a final decision’ (FAA, 2002, p. 6).

As current regulatory activity is leaning towards legislation of the installation of non-disposable Type III exits on new type certificated aircraft, it was felt that consideration should be given to modifications that could potentially be made to the current flying fleet of Type III exits, including smaller transport aircraft (i.e. seating configurations with two seats either side of the main aisle).

5.2. The operation of the Type III exit

The operation of the Type III exit is unlike the operating procedure for other commonly used exits in other environments and even differs from the operation of other exits on board the aircraft. To operate the Type III exit, firstly the passenger is required to assess the external conditions to ensure that there are no immediate dangers outside the exit such as fire or debris.

As discussed in Section 1.7.1, once released by the passenger the traditional Type III plug hatch is not attached to the fuselage and will fall into the cabin. The large and heavy hatch plug then has to be manoeuvred and rotated inside the cabin in the space adjacent to the exit and disposed of into a location whereby it does not impede egress. The location of the disposed hatch firstly must not impede egress for the exit operator and then for the other passengers who opt to use the exit. Within the UK the most appropriate location for the disposed hatch is deemed to be outside the aircraft, whereas other regulators allow the operator to determine if the hatch should be placed inside or outside the cabin.

The idea of releasing the hatch from the fuselage, bringing it inside the cabin and then manoeuvring it in a limited amount of space to allow it to be ejected outside the cabin or placed inside the cabin is unlikely to be intuitive to the passenger. As highlighted in Section 1.7.2 the majority of passengers who will be seated next to a Type III exit will not have experienced opening an exit such as this before and are likely to have only been given minimal verbal and graphical instruction on the process of exit operation. However, in the event of an evacuation, if it is determined it is safe to do so the untrained passenger will be required to make the exit available for egress in a rapid manner in what may be a disorientating and highly stressful environment. Although passengers may receive instruction from a member of cabin crew of the need to open this exit, due to the likely location of the trained members of crew, passengers may need to make an evaluation of the unfolding situation and react appropriately.

The importance of passengers being able to operate the Type III exit efficiently was highlighted during the evacuation of a Boeing 737 in 1984 at Calgary airport in Canada. Four exits were used during the evacuations, including one overwing exit that was operated by a passenger and used by approximately 40 passengers. The accident report concludes that ‘it is also possible to assume that other, less familiar passengers would not have opened the overwing exit without supervision or command of a flight attendant’ (CASB, 1987, p. 25). It was concluded by the accident investigators that the availability of the Type III exit was crucial during the evacuation, as without this exit the time taken for all passengers to evacuate is likely to have increased, which may have had a dramatic effect on survivability, as the last passengers left the aircraft ‘at about the last possible moment’ (CASB, 1987, p. 28).

In summary, the Type III exit has been shown to be an important egress path during some evacuations. However, the operation of the Type III exit places both physical and comprehension demands on the individual. These demands are likely to be present for many exit operators but especially those operators whose physical and behavioural responses may have been impaired or influenced by the situation and/or environment that is unfolding. The operation of the Type III exit has the potential to be physically demanding due to the size and weight of the hatch and the available space in which to complete the task. The task may also require a degree of understanding as a result of the non-intuitive nature of exit operation and the decision making process both when opening the exit and then determining where to dispose of the hatch. Due to the demanding aspects of the task, aviation authorities have introduced regulations defining the seating policy for passengers in both floor and non-floor exit row seats.

5.3. Regulations relating to the Type III exit

5.3.1. Exit seating allocation

As mentioned in Section 1.7.2, regulations have been introduced by many authorities that limit some passengers from occupying seats in the exit rows. The rationale behind this is that during an evacuation these passengers may be required to assist the cabin crew or in the case of a Type III exit row, operate the exit. Restrictions on passenger seating includes incapacitated passengers, passengers with an impairment that may effect their ability to open the exit, minors under 15 years of age, individuals who would not be able to complete the tasks without the supervision of another person, individuals in custody or family groups with young children (FAR 121.585 (CFR); JAR-OPS 1.280 (JAA)). Other regulators are less specific with their seating allocation regulations. For example stating that seats in exit rows may not be allocated to passengers 'whose presence in those seats could adversely affect the safety of passengers or crew members during an emergency evacuation' (CAR 705.40 (1)(d) Transport Canada).

The FAA regulations provide further detail on the restricted passengers stating that the individual must not have a cognitive, visual, aural or communication impairment which would prevent them from reading and understanding the instructions, hearing or interpreting instructions, operating the exit, or communicating with other passengers. In addition individuals must not be allocated an exit row seat if they have limited physical movement or strength in any of their limbs. The FAA stipulates that the individual must also be able to reach in all directions, to lift, push, pull and manoeuvre the exit, to move quickly to the exit and 'maneuver over the seatbacks to the next row objects the size and weight of over-wing window exit doors; to remove obstructions similar in size and weight to over-wing exit doors' (FAR 121.585 (b)(iv) CFR).

To ensure a suitable individual is placed in the exit row seats, operators are required to 'screen' passengers to establish if they fulfil the regulatory criteria. These checks are usually made visually and through conversation with the passenger both at check-in and the boarding of the aircraft. Prior to boarding the cabin crew will also check with the passenger to ensure they themselves feel they can meet the criteria. If airline staff or the passenger feels that they do not meet the criteria, the passenger must be relocated and a suitable individual placed in the vacant seat (FAR 121.585 (CFR); JAR-OPS 1.280 (JAA); CAR 705.40 (Transport Canada)).

The decision to allow a passenger to sit in the exit row is made only by a visual observation or brief interaction with the passenger by airline employees. Even though there are regulatory restrictions on the passengers that can be placed in seats adjacent to the exit, there are still no assurances that these exits will be operated efficiently and effectively. The restrictions do not ensure that the hatch operator understands or engages with the task they may be required to do (NTSB, 2000) or is physically able to complete the tasks that may be required of them. The individual's ability to complete the tasks is not tested until the point at which an evacuation is required.

The consequences in relation to occupant survivability of a delay in the opening of a passenger operated exit were highlighted during the evacuation at Los Angeles in 1991 following a collision with another aircraft on the runway. Four of the six exits on the Boeing 737 were opened, including both overwing exits. The location of the fire meant that only two passengers were able to egress through the left hand overwing exit before the exit became unavailable, with approximately 37 passengers leaving via the right overwing exit (NTSB, 1991). The evacuation through the overwing exit was hindered by the passenger seated next to the exit who reportedly "froze" prior to opening the exit, this suggests that the passenger displayed some form of behavioural inaction. A male passenger seated in the seat row behind the exit climbed over the seats, opened the exit and assisted the passenger through the aperture. The evacuation through this exit was also hindered by two passengers who were involved in an argument at the exit which delayed the evacuation (NTSB, 1991). The NTSB felt that these two factors 'significantly hampered the evacuation to the extent that additional passengers who may have been able to escape did not' (NTSB, 1991, p. 65). The post accident investigation of the cabin located the bodies of a member of cabin crew and ten passengers who were in the aisle approximately five feet from the overwing exits, concluding that it is likely that they were overcome by the toxic smoke and fumes whilst queuing for the exit (NTSB, 1991).

5.3.2. Briefing of passengers seated adjacent to Type III exits

In addition to the restriction on exit row seating, regulators require operators to inform passengers sat adjacent to passenger operated exits of the task requirements both through a verbal briefing and in written form on the safety card and seatback placard.

5.3.2.1. Pre-flight briefings

Aviation authorities regulate that during the pre-flight briefing the cabin crew must draw passengers' attention to safety related procedures and on board equipment, this includes the emergency exits (FAR 121.571 (CFR); JAR-OPS 1.285 (JAA); CAR 705.43 (Transport Canada)). The crew should inform passengers of the location and operation of emergency exits and any additional relevant information about the use of such exits. Passengers seated in exit rows should also be provided with an individual briefing on their responsibilities for exit operation, however not all regulators are specific about the information that should be included in this individual briefing. An example of this can be found in the Canadian Aviation Regulations which state that during the pre-flight briefing operators are required to 'ensure that each passenger who is seated next to a window emergency exit is informed by a crew member that the window is an emergency exit and is made aware of how to operate that exit' (Transport Canada, CAR 705.43 (5)). As noted in the above quote, there is no suggestion of the specific information concerning exit operation that should be included.

5.3.2.2. Safety card and seatback placard

In addition to the pre-flight briefing, regulators require aircraft operators to provide passengers with a safety card that displays graphically the location and operation of all types of exits on board the aircraft, including the steps that would be required to open a passenger operated exit. This information is also required to be present on seatback placards in the exit row (FAR 121.571 (CFR); JAR-OPS 1.285 (JAA); CAR, 725.44 (Transport Canada)).

The UK CAA further state that the diagrams on the safety card and seatback placard should show the operation of the exit, including the movement of the handles, egress paths from the exits and if a traditional Type III exit is in situ, to clearly show that the hatch has to be removed by the passenger from the fuselage and the location the passenger should place the hatch after removal (CAA, 2006). The FAA regulations on exit row seating also provide further detail of the information that should be provided to passengers allocated to exit row seats. The FAA state that the safety card should inform passengers that they may be required to complete the following tasks:

> *'locate the emergency exit; recognize the emergency exit opening mechanism; comprehend the instructions for operating the emergency exit; operate the emergency exit; assess whether opening the emergency exit will increase the hazards to which passengers may be exposed; follow oral directions and hand signals given by a crewmember; stow or secure the emergency exit door so that it will not impede use of the exit; assess the condition of an escape slide, activate the slide, and stabilize the slide after deployment to assist others in getting off the slide; pass expeditiously through the emergency exit; and assess, select, and follow a safe path away from the emergency exit'* (FAR 121.585 (CFR)).

Although this is detailed in some areas, the level of depth of information required on the actual operation of the exit is not specified.

5.3.2.3. Emergency briefings

The CAA (2006) states that in the event of a premeditated emergency the passengers seated at the Type III exits should be provided with a verbal briefing and informed of the location of the pictorial diagrams regarding exit operation on the safety card and seatback placard. Guidance information is also provided on the elements of the verbal briefing which should include the:

> *'location of the exit; instructions as to when, or if, the exit should be opened; instructions for operation of the exits; description of the exit as a removable hatch or a hinged exit; guidance as to the weight of the exit hatch and the necessity for it to be removed from a seated or standing position; instructions for disposal of the exit hatch; necessity to follow any further commands given by the cabin crew and; verification that passengers have understood the briefing'* (CAA, 2006, Chapter 33, p. 1).

The guidance material refers to the verbal briefing procedures in advance of a planned emergency and not during the standard pre-flight briefing, even though many evacuations are as a result of unplanned emergencies. During the evacuation review conducted by the NTSB in 2000, unplanned evacuations were reported as occurring more often than planned evacuation and were more likely to occur following a problem on take off or landing. The majority of evacuations within the NTSB review were unplanned (31 events), with 14 planned and the prior knowledge of the passengers and crew was unknown in one case. This highlights the importance of informing passengers about the specific tasks, in particular exit operation, they would be required to complete in the event of an evacuation during or shortly after take off. In addition, as the information provided in the Civil Aviation Publication is defined as 'of long-term interest and essential or useful guidance material' (CAA, 2006, p. 1), it is not mandatory for operators to include the information.

In summary, although the regulations require operators to provide information on exit operation both graphically in the form of a safety card and seatback placard and verbally to the passengers seated adjacent to the exit, the specific level of detail on exit operation is not regulated.

5.4. Difficulties with Type III exit operation

Accident investigators and cabin safety commentators have reported numerous occasions where passengers have experienced difficulties with the operation of the traditional Type III exit mechanism. These difficulties have impeded passenger access to the exits and led to delays in making the exits available and the subsequent evacuation. In some cases these difficulties and delays have had serious and fatal consequences for passenger survivability such as the evacuations at Manchester in 1985 (discussed in Section 1.8.3) and at Los Angles in 1991 (as highlighted in Section 1.8.2).

Prior to discussing difficulties experienced by exit operators, it is of interest to highlight some of the difficulties reported with other safety critical tasks. Fennell and Muir (1992), during a study to investigate the influence of different types of safety briefings on participants' ability to complete safety related tasks, observed participants experiencing a range of difficulties when asked to don a lifejacket. These observations led Fennell and Muir to argue that ‘novel items of safety equipment which are intended to be used by passengers should be designed to ensure that the correct method of operation is obvious’ (1992, p. 39). Although Fennell and Muir were not referring directly to exit operation, it is argued that this item of safety equipment is also novel and therefore needs to be designed in such a way that it is intuitive and simple to operate.

Difficulties with the operation of the Type III exit have been widely documented. Exit operator difficulties can be broadly divided into those linked to the physical operation of the exit and those difficulties relating to understanding the task requirements and are discussed in the following sub-sections.

5.4.1. Physical difficulties

Physical difficulties with operating the Type III exit may be a result of the physical parameters (i.e. size and weight) of the hatch, the available space in the exit row (i.e. the space available between the seats and the headroom) and the need to fully remove the hatch from the fuselage and dispose of it in a safe location.

5.4.1.1. Physical difficulties with exit operation from accidents

Passengers’ ability to operate Type III exits was discussed by the NTSB in 2000 during a review of emergency evacuations within their jurisdiction. Thirteen of the 46 events involved the use of the Type III exits, with a total of 36 Type III exits operated. During the safety study the NTSB were able to access detailed evacuation information on six cases involving Type III exits. Fortunately in two cases, one involving an Airbus 320 in Ohio, and another from a Boeing 737 at Nebraska the cabin crew operated the overwing exits and reported no difficulties in exit operation. During a third case on board a Boeing at Illinois in the United States, it was reported by two passengers involved in Type III exit operation that they had not experienced any difficulties. However, in the other three evacuations where detailed information was available to the NTSB, problems with the Type III exit were reported (NTSB, 2000).

During an evacuation of a Boeing 737 at Atlanta, reports suggested that a female passenger had not been able to successfully operate the hatch, which resulted in another passenger having to complete the task (NTSB, 2000). An exit operator also reported difficulties when operating the overwing exit on a Boeing during an evacuation at Chicago in the United States. It was reported that physical difficulties were experienced with manoeuvring the exit and disposing of the hatch outside the cabin (NTSB, 2000).

Physical difficulties with exit operation were also reported by two passengers who were sat next to the overwing exits on the MD-82 aircraft that was involved in an accident at Little Rock, Arkansas. The passengers reported that they tried to open the exit hatch but were unsuccessful, although these hatches were subsequently operated successfully by other passengers.

These examples have highlighted some of the physical difficulties experienced by passengers when attempting to operate the Type III exit. In addition, passenger difficulties with the comprehension aspects of exit operation have also been reported during incidents and accidents and are discussed in the following section.

5.4.2. Comprehension difficulties

Comprehension difficulties have included passengers not realising that they are responsible for exit operation, deciding when to open the exit, understanding how to actually operate the exit, and finally, knowing where to dispose of the hatch following operation.

5.4.2.1. Comprehension difficulties with exit operation from accidents

During a review of evacuations from large passenger aircraft registered in Canada, the Transportation Safety Board of Canada (TSB) reviewed a total of 21 evacuations; eight of which were as a result of fire (TSB, 1995). The 21 evacuations included 2,305 passengers and 39 crew and resulted in 91 occupant fatalities and 78 serious injuries. Of the 91 fatalities, 36 were linked by the TSB to the evacuation (TSB, 1995).

Of interest to the current study are the comments made by the TSB relating to the operation of the Type III exit. In two of the evacuations, difficulties were reported with the operation of this type of exit due to a lack of understanding of the task requirements. It seems that in these cases the passenger seated next to the exit was unaware of their responsibility for the operation of the exit and had a lack of comprehension of the exit operating instructions.

During one evacuation at Regina, Saskatchewan, the TSB were told by another passenger that the 'exit operator' did not open the overwing exit when they were instructed to do so by other passengers and a second passenger who then went to open the exit asked another passenger 'how do you open it?' (TSB, 1995, p. 14). It was reported by the observer that after opening the exit, the passenger left the hatch in the exit aperture and did not initially move through the exit.

A second example of a lack of understanding about the exit operation task was reported at the evacuation at Kelowna in British Columbia. It was reported by the TSB that the passenger seated next to the left overwing exit did not try to operate the exit, either before or after instructed to do so by a member of cabin crew. The passenger next to the exit operator moved to release the hatch, but could not dispose of the hatch outside the cabin due to the limited space as a result of the passenger sat in the seat next to the exit. The hatch was left inside the cabin on the seat row assembly but moved onto the floor, 'creating an obstruction to egress' (TSB, 1995, p. 14). Fortunately in this incident a member of cabin crew was able to move to the central exit, remove the hatch and manage the evacuation through the exit (TSB, 1995). In conclusion the TSB felt that although they could not explicitly state that passengers who were seated adjacent to these exit were not capable of completing the task, these examples have highlighted that not all passengers operate exits in an efficient and timely manner which can 'result in delays in evacuations' (TSB, 1995, p. 14).

A lack of understanding about the exit operation process was also reported by the NTSB (2000). The NTSB as part of a safety study of large aircraft gathered information via self-completion questionnaires from passengers who were seated in the exit rows during six evacuations within the United States. Some passengers reported that in the first instance they experienced difficulties when making a decision as to whether the overwing exit should be opened or not (NTSB, 2000). In one case the auxiliary power unit (APU) torched and although the crew informed passengers to remain seated, the overwing exit was opened by a passenger. In a second evacuation, the crew ordered an evacuation through only the forward exits, however the Type III exit was still operated by passengers trying to evacuate (NTSB, 2000). These problems in decision making may be due to inattention of the safety briefing and may be resolved by providing a personal briefing to exit operators (NTSB, 2000).

In addition to the physical difficulties experienced by some passengers during the accident at Little Rock in 1999, another passenger reported that they tried to open a third Type III exit ‘by pushing the hatch out of the airplane after pulling the release handle’ however this was ineffective (NTSB, 2000, p. 39). The design of the exit mechanism on board the MD-82 was a traditional Type III design which required the hatch to be taken into the cabin before being manoeuvred and disposed of into a safe location. This account suggests that the passenger did not fully understand the operation of the exit.

Although difficulties in exit operation were reported by occupants in the evacuations studied by the NTSB, the exits in all cases were eventually operated as required (NTSB, 2000). In three of the four cases where there were problems with exit operation which led to evacuation delays, the NTSB did believe that ‘while these delays did not appear to result directly in any additional injuries, there exists the potential that future difficulties could result in injuries’ (NTSB, 2000, p. 39). A delay in making the Type III exit available occurred at Manchester in 1985, with the investigating authority concluding that a delay in operating the Type III exits resulted in injuries and fatalities to the occupants (AAIB, 1988).

The importance of providing clear comprehensible exit operating instruction and ensuring that passengers understand the task requirements was highlighted in an accident involving a smaller transport aircraft in 1982. The aircraft landed on a frozen lake, with a post crash fire breaking out. Smoke entered the cabin, resulting in reduced visibility during the evacuation. After the evacuation the passengers were asked about the safety briefing, with responses including that it was ‘garbled’, the ‘instructions were not clear’, one passenger ‘recalled hearing the briefing but could not recall the specific instructions’, the information was ‘vaguely recalled’ by another passenger, while another passenger stated that they were not able to recall any information (NTSB, 1982, p. 8). With regards to exit operation, one passenger reported that ‘he intended to open the right rear emergency exit, but did not because there was no time to read the exit operating instructions’ (NTSB, 1982, p. 9). A male passenger seated next to an emergency exit, said he did not use it ‘because he thought it was a window and he thought he would not fit through its opening. He said that he would have used it immediately if he had known it was an emergency exit’ (NTSB, 1982, p. 9).

A lack of passenger knowledge about the safety information was reported during an instrument landing systems approach in June 2003 at Brest Guipavas aerodrome in France. A CRJ-100 aircraft deviated from normal approach and landed approximately 2000 meters from the runway. The aircraft collided with objects on the ground and a post crash fire occurred (BEA, 2003). The fire subsequently destroyed the aircraft, with the effects of the smoke impeding passengers during their evacuation. The Captain was killed in the accident, with all the other occupants (three crew and 21 passengers) successfully evacuating the aircraft (BEA, 2003).

During the accident, some of the oxygen masks were released within the cabin. It was reported that a passenger had stayed in their seat and put on their oxygen mask until they were instructed by another passenger to leave the aircraft. It was also reported that two passengers moved towards the rear of the cabin until instructed to move forward by other passengers, even though the safety information stated that there were no exits at the rear of the aircraft (BEA, 2003).

With regards to exit operation, the passenger seated next to the left overwing emergency exit was a regular flyer, who opened the emergency exit prior to checking the conditions outside. The passenger observed the fire outside the exit and let go of the hatch and moved towards the front of the aircraft. The opening of this exit allowed the fire to enter the cabin (BEA, 2003). The accident report stated that ‘the fact that one passenger opened an overwing exit, without previously checking that this could be done without danger, resulted in the fire violently penetrating the centre of the cabin, thereby immediately worsening the evacuation conditions’ (BEA, 2003, p. 99). The report concluded that this action did not dramatically influence the outcome due to the reduced number of passengers in the rear of the cabin, but the circumstances could have been different. This highlights a lack of understanding about the procedures in the event of an emergency situation.

Although the actions of the passenger adjacent to the exit may have been due to the situation evolving around them, the accident report suggests that it may have been due to ‘the fact that few passengers follow the safety demonstrations attentively or read the safety instructions’ (BEA, 2003, p. 99). One of the recommendations from the investigation was to look into ways of informing passengers through the various media of safety information of the checks they must make prior to operating an emergency exit (BEA, 2003).

In conclusion, the examples from incidents and accidents have highlighted that passengers experience difficulties with understanding the task and physically operating the exit, which in turn may increase the time taken to make the exit available and delay passenger evacuation. Further work is needed to ensure that passengers are provided with the information required to complete the safety critical tasks in the event of an evacuation. Work also needs to be done to promote passenger engagement with the safety information.

5.5. Improving the Type III exit operation task

As a result of difficulties experienced by passengers the operation of the Type III exit has been the subject of scientific research trials. Research has been directed towards identifying factors that influence exit operation and identifying modifications to the task or those aimed at adapting the operator to reduce the difficulties experienced.

5.5.1. Research into the physical difficulties with exit operation

During the initial evacuation studies through the Type III exit at Cranfield University (Muir et al, 1989), the exit was operated by a trained researcher during all trials to remove any influence of exit operation on evacuation through the exit. Even though the researchers who operated the exit had undergone training, Muir et al (1989) reported that the hatch operators still found that the access to the exit and the space around the exit influenced their ability to open the exit. This highlights the complex and difficult nature of the physical aspects of the task. It is argued that if trained exit operators find operation of the Type III exit difficult, then it must be questioned how effectively untrained members of the public will be able to complete the task.

A number of evacuation studies have been conducted into potential improvements to the physical aspect of the task in an attempt to adapt the task to the operator and reduce the physical difficulties associated with exit operation. These include Fennell and Muir (1993) who investigated the influence of exit hatch weight and the seating configuration adjacent to the exit on exit operation. The results suggested that when the weight of the hatch was reduced to 12.5kg (approximately half the weight of a standard Type III hatch) and the distance between the seats in the exit row was tested at 3" and at 13" (to simulate configurations allowed pre and post the introduction of AN79), hatch operation time was decreased. This finding was consistent whether or not there was an incapacitated passenger (simulated by a 50^{th} percentile male dummy) adjacent to the exit. These adjustments to the hatch and the available space around the exit were shown to be of more benefit to the female hatch operators than the male operators. The study authors concluded that both factors 'are necessary for significant improvements in the times taken by passengers to operate the Type III exit' (Fennell and Muir, 1993, p. iii).

Rasmussen and Chittum (1989) also conducted an investigation into influence of the seating configuration in the exit row on passenger operation of the exit. The tested seating configurations included three single passageway configurations which were 6", 10" and 20" vertically projected and a dual passageway configuration with the outboard seat removed The participant sat in the seat adjacent to the exit, unless the outboard seat was removed in which case the operator sat in the outboard seats in the seat row aft of the exit. A number of ‘passive’ participants (with regards to the operation of the exit) sat in the other seats adjacent to the exit (Rasmussen and Chittum, 1989). Using exit operation time as the dependent variable (this was defined as when the top of the door started to move until the hatch was disposed of and the exit was available for egress), Rasmussen and Chittum reported no significant differences due to the seating configuration adjacent to the exit, although some differences were reported for hatch release time.

Following the results of Rasmussen and Chittum (1989), McLean et al (1992) continued the investigation into the effect of seating configuration on exit operation. McLean et al tested vertical projections in the exit passageway of 10” (either with a three seat assembly or a two seat assembly adjacent to the exit), 20”, or three passageways each with a vertical projection of 6” leading to a pair of Type III exits and the outboard seats removed. McLean et al (1992) noted that the differences in exit operation were small between the three configurations with a single exit.

During the large research programme involving an investigation into passageway configuration, group density, participant motivation and hatch disposal location on evacuation, McLean et al (2002) also reported on Type III hatch operation. Hatch operators (one for each trial in the session) were randomly selected from the group and separated from the rest of the participants. Although the rationale for this was justified by McLean et al (2002) to ensure that the operators did not discuss hatch operation or emergency evacuation with any other participants, it does remove some of the realism from the experimental procedure, which was cited as an important factor in the research study. Once separated from the other participants, hatch operators were given a visual graphical briefing on hatch operation, which included the hatch disposal location – inside or outside the cabin (which was dependent on the hatch disposal location condition under test).

There was a significant interaction between hatch location and passageway configuration, with exit availability taking longer when the hatch operator ejected the hatch outside the cabin in the 10” cabin configuration due to the limited space available in the exit row (McLean et al, 2002). Surprisingly, there were no significant effects for seating configuration, motivation or group density on exit operation (McLean et al, 2002).

McLean et al (2002) also conducted analyses to investigate the effects of the independent variables on the time taken for the first participant to evacuate. This measure was used as in some seating configurations it was not the hatch operator who left the cabin first, specifically when there were multiple passageways leading to the exit. This was done in an attempt to remove the hatch disposal delays that were observed during some evacuations.

A significant effect was reported for hatch location, with operation times quicker when the hatch was placed inside compared to when it was disposed of outside. There was also a significant interaction between hatch location and passageway width (similar to the exit availability results (McLean et al, 2002).

The authors note that the results from the first participant out times were comparable to those from exit ready to use, suggesting 'that the time required for removal and disposal of the hatch was the primary variable in launching the evacuation flow' (McLean et al, 2002, p. 10). This highlights the importance of the Type III exit being opened without delay.

McLean et al (2002) also analysed the time taken for the hatch operator to egress completely through the aperture onto the winglet. When this performance timing was analysed, the effect of the disposal location of the hatch and the interaction between hatch location and passageway configuration were no longer found to be significant. That said, a significant effect of passageway configuration was reported. The effect showed that the narrower the passageway, the longer it took the exit operator to move through the aperture. It was reported that the time again increased in the dual passageway configuration due to the space between the hatch operator's seat and the exit, the location of the hatch and the passengers using the other passageway (McLean et al, 2002).

In summary, McLean et al (2002, p. 13) reported that participants were competent at completing the hatch operation task. However it was noted that 'the techniques they used for removing the hatch were often inefficient'. Incorrect techniques included using the incorrect hand to release the operating handle which resulted in the participant experiencing difficulty with manoeuvring the hatch and having to turn counter-clockwise to be in a position to place the hatch on the exit row seating (McLean et al, 2002). These examples indicate that the task of exit operation may not be intuitive.

McLean et al (2002) argue that hatch operators are able to follow the instructions provided to them on the safety card and are prepared to act on them. However, accident reports and experimental studies have highlighted operators do not always complete the actions as required, so consideration must be given to the information provided.

In summary, research has investigated physical changes to the hatch (i.e. the weight) and to the space adjacent to the exit (i.e. passageway configuration) in an attempt to improve Type III exit operation. No other published studies were found that have investigated other minor modifications to the exit hatch.

5.5.2. Research into the comprehension difficulties with exit operation

As a result of their study into hatch operation and the potential improvements that could be achieved through increasing the space available in the exit row and reducing the weight of the Type III hatch, Fennell and Muir (1993) were able to observe the behaviours displayed by hatch operators. Fennell and Muir (1993) noted that participants displayed a lack of comprehension into correct hatch operation and disposal and as a result proposed that further work should be conducted on providing instruction to exit operators.

The recommendations from Fennell and Muir were addressed as part of a research project undertaken by Cobbett, Liston and Muir (2001). Cobbett et al investigated the possible benefits of providing additional information to exit operators during a pre-flight briefing on their subsequent ability to operate the Type III exit. Operators were allocated to one of four briefing conditions. Participants were either provided with no specific briefing regarding exit operation, a minimal briefing or a detailed briefing. The detailed briefing was either delivered verbally or in a written format dependent on the condition under test. The minimal briefing informed the operator that they were sat next to the exit, that they were responsible for exit operation and where to find further information about the task on the safety information card and seatback placard. The detailed briefing involved providing the exit operator with a detailed briefing on exit operation. This briefing included all the information in the minimal briefing along with in-depth instructions about exit operation. Participants were recruited in groups of three, with 56 independent groups involved in the study. In each group were two participants of one sex and one participant of the other sex, with the minority sex participant always seated in the exit operator's seat.

Cobbett et al (2001) concluded that providing exit operators with detailed information about the operation of the exit assisted them with the task. Increasing the level of detail in the briefing also resulted in less hesitation from participants when they were instructed to evacuate. Interestingly, Cobbett et al found no effect of the level of briefing on the time taken to actually operate the exit - defined as the time from when the participant placed their hand on the operating handle until the exit was available for use. That said, Cobbett et al reported a significant difference attributable to the level of briefing in the overall time to operate the exit, in that the more detail provided in the briefing, the quicker the exit was made available for evacuation. Cobbett et al concluded that was 'primarily due to the fact that the more detailed briefings reduced the hesitation time taken by participants to start to operate the exit' (2001, p. 17).

In addition to reducing the time taken to operate the exit, when the detailed briefings were delivered (either verbally or in writing), there were more instances of correct hatch disposal – that is, outside the cabin. Participants also reported that the exit briefing and operating diagrams were perceived as clearer when the detailed briefing was provided compared to the minimal briefing. Furthermore, participants rated the verbal briefing as clearer than the written briefing.

Cobbett et al (2001) suggested that the briefing alerted participants to the fact that they were responsible for the operation of the exit in the event of an evacuation and encouraged the operator to review the pictorial instructions located on the safety card and seatback placard. Interestingly, in the study only 10% of participants self reported that they did not review the safety card diagrams on exit operation. All of these participants were in the group that did not receive a briefing about exit operation (Cobbett et al, 2001). Although a self report measure, which can be subject to participants reporting socially acceptable answers, this finding adds further evidence on the benefits of additional detailed briefings on exit operation.

In conclusion, providing passengers sat adjacent to the Type III exit with detailed information on the process of exit operation, resulted in the exit being made available in less time (this was largely attributable to the reduction in hesitation time), increased the likelihood and them correctly disposing of the exit hatch (Cobbett et al, 2001).

Cobbett et al (2001) acknowledged that the briefing task took longer when the verbal briefing was delivered, with a mean delivery time of 67 seconds (standard deviation 3 seconds) compared to the mean delivery time for the minimum briefing of 19.5 seconds (standard deviation 3.7 seconds). The time required to complete the individual briefing would dramatically increase on aircraft with a pair of Type III exits on either side of the fuselage (Cobbett et al, 2001). Examples of aircraft with this exit configuration include the Boeing-400, Airbus 320 and Beechcraft 1900. Even though the detailed briefing took longer to deliver, the benefits of a reduction in exit operation time far outweigh the additional time required, an observation also made by Thomas (2003).

The importance of passengers engaging with and comprehending the safety information were highlighted in the McLean et al (2002) trials, who reported that exit operation and correct hatch disposal were improved by encouraging passengers of the need to attend to the safety card in advance of operation the exit. McLean et al (2002) noted that some of the actions adopted by the exit operators were not always the most appropriate given the situation. Some operators were observed using the wrong hand on the operating handle which then meant they experienced some difficulty with the size and weight of the hatch or difficulty in placing the hatch on the exit row seats (McLean et al, 2002). However, McLean et al (2002) suggest that when the exit operators were fully informed about what they were required to do ‘they were quite willing to perform as instructed’, with the report authors concluding that ‘this circumstance bodes well with regard to what can be expected of typical airline passengers who are fully informed about their responsibilities when seated adjacent to the Type III overwing exit’ (McLean et al, 2002, p. 15). McLean et al suggest that although some work has already been undertaken, further work on educating passengers on emergency procedures is essential.

McLean et al (2002) further argue that the findings from their extensive study into the factors that influence evacuation through Type III exits emphasise a lack of passenger understanding in completing the tasks required during an evacuation. McLean et al (2002) further state that research should now be conducted to ‘search for better information and more effective passenger education and training techniques that will lead to safer and more productive emergency evacuations/survival’ (McLean et al, 2002, p. 34).

The importance of exit operators knowing what they are required to do was further emphasised by McLean and Corbett (2004) who suggested that research trial participants were able to follow exit operation and hatch disposal instructions when they were able to comprehend the task requirements. One way to improve passenger comprehension of the task in hand may be to provide them with an in-depth briefing about exit operation. McLean and Corbett argue that the results of their trials show the importance of passengers being aware of the procedures to follow in the event of an emergency, concluding that ‘as passengers become more knowledgeable about the emergency environment and what to do when faced with it, less reliance on design parameters should be needed to achieve successful evacuation/survival outcome’ (McLean and Corbett, 2004, p. 19).

The importance of providing passengers with in-depth information about the actions they should do in an emergency has also been highlighted in a number of accidents. One example includes providing passengers with in-depth information in advance of an evacuation of an Airbus 320 following a problem with the nose gear. The crew were aware of the need to evacuate in advance which allowed them to brief passengers on the brace position to adopt and the location of the emergency exits. The passengers were located near the overwing emergency exits, with cabin crew placed next to the overwing exits ‘to ensure that the exits would be opened quickly’ (NTSB, 2000, p. 54). Following the evacuation ‘one passenger indicated “the amount of information and the timing of the information was outstanding – no one panicked too much” (NTSB, 2000, p. 54).

The importance of providing a detailed briefing to exit operators prior to take off was also highlighted during the evacuation of a Boeing 737 as a result of a runway collision with a Fairchild Metroliner at Los Angeles airport in 1991 (NTSB, 1991). During interviews with the accident investigators, the passengers in the exit row mentioned the briefing that the cabin crew provided before take off. The crew provided this briefing as there was a younger looking passenger in the aisle seat in the exit row, with the crew wanting to check the passenger was aware of his responsibilities of being seated in an exit row. The passenger was actually 17 years old, but as a precautionary measure the crew delivered a specific briefing to the passengers seated around the exit row. The passengers reported that the information contained in this briefing helped them during the evacuation (NTSB, 1991). The NTSB concluded that the exit row briefing delivered by the cabin crew ‘probably resulted in more passengers escaping through the overwing exits than otherwise would have’ (NTSB, 1991, p. 69) as the briefing ‘increased the preparedness of passengers for the evacuation’ (NTSB, 1991, p. 75).

Although research and accident reports have shown the benefits of providing additional information to exit operators, further research is required as detailed information is not mandatory or delivered by all operators in pre-flight safety information.

5.6. Rationale for Experiment Two

Research and accident reports have highlighted the difficulty in understanding the requirements of the Type III exit task and the benefits of providing detailed information to the exit operator. However, the depth of information contained within an individual pre-departure briefing is not currently regulated and therefore detailed information may not be provided to the exit operator. As highlighted by the NTSB in 2000 'most passengers seated in exit rows do not read the safety information provided to assist them in understanding the task they may need to perform in the event of an emergency evacuation' (p. 77). This stresses the importance of research to further explore whether providing further information on correct operation of the overwing exit verbally to passengers assists them during exit operation. Although Cobbett et al (2001) have shown the benefits of providing detailed information, further evidence was required to assist the regulatory process. In the current experiment the detailed briefing was only provided in a verbal form (as opposed to written form) as a result of the findings of Cobbett et al (2001).

Secondly, a number of research programmes have investigated a range of modifications in an attempt to improve passengers' ability to operate the hatch efficiently (i.e. seating configuration and hatch weight), however to date no published studies have been conducted on a modification to the exit operating handle. During the operation of the exit, the passenger needs to support and manoeuvre the hatch in the available space before disposing of it into an appropriate location. The hatch has an operating handle at the top which is initially used to unlatch the hatch and is then used during hatch manoeuvring. It also has a recess at the bottom which is used to support the hatch. It was proposed to conduct an investigation into whether a minor retrofit modification to the operating handle at the top of a traditional Type III exit hatch would afford significant time savings to the exit operator. The modification meant that once the handle was used as the exit was unlatched, it would remain fixed in the open position and function as a fixed and rigid handle. As with any industry there was some resistance to major changes to current aircraft features due to the cost and operational implications of retrofitting. It was felt that this modification, if beneficial, was relatively minor and could be part of a retrofit programme. As part of a retrofit programme the modification could potentially be installed on smaller transport aircraft, where the costs of an automatically disposed hatch installation are considered to be significantly higher.

It was deemed important to collect data on the benefits of the modification to the operating handle and the impact of the exit operators briefing on exit operation from both a large single aisle and small aircraft interior configuration. This would determine if there were any potential improvements in exit operation as a result of the modification and the level of detail in the briefing, within smaller transport aircraft as well as larger single aisle cabins, allowing direct comparisons to be made across the interior configurations.

5.7. Objectives of Experiment Two

The objectives of Experiment Two were to investigate the effects of a minor modification to the Type III operating handle mechanism and the level of detail contained with the exit operator's briefing on exit operation. In addition, to provide data on the extent to which regulations concerning the Type III exit would apply equally to large single aisle aircraft and small transport aircraft, tests were conducted in small and large interior cabins (as in Experiment One). As the focus was on providing data on Type III exit operation, individual operator trials were conducted.

In summary, the specific objectives of Experiment Two were to investigate the influence of a minor modification to the exit operating handle mechanism (either a retracted or a fixed handle), the interior configuration (either a small or large interior configuration) and the briefing given to the exit operator (either a minimal or in-depth briefing) on the time taken to operate the exit and the operator's perception of the task.

6.0. Method: Experiment Two

6.1. Methodological considerations

The methodological considerations relating to the cabin simulator and the sampling strategy were identical to those in Experiment One, as detailed in Section 2.1. However in this experiment, individual participants were recruited to complete the task as opposed to groups of participants.

Individual participants were used as the focus of this experiment was on improvements to the Type III operation task. By using individuals rather than groups the potential influence of the variables on the individual exit operator could be measured without the assistance other passengers may provide in task completion.

As the experiment involved individual participants it was not appropriate to use a bonus payment system. For this experiment all participants were paid a flat rate attendance fee. To add a degree of urgency, during the pre-trial briefing participants were motivated to complete the task as quickly as possible.

6.2. Ethical and safety considerations

As with Experiment One, the experiment was conducted in accordance with ethical guidelines and an ethics proposal was submitted to, and approved by the Human Factors Department Ethics Committee prior to the research trials taking place. Participant safety considerations were reviewed prior to the trials in accordance with Experiment One. Ethical and safety procedures as documented in Section 2.2 were followed with two exceptions due to the nature of the trials with individual participants. Firstly, as the trials involved only individual participants it was deemed that medical provision in the form of a first aider would be acceptable rather than an occupational health nurse. Secondly, there were only three members of the research team (including the first aider) on the simulator platform during the trials. There was one member of the research team inside the cabin (acting as cabin crew), with another researcher and the first aider located directly outside the operational exit. The actions taken by the research team outside were the same as those reported for Experiment One.

6.3. Research design

Experimental trials were conducted to investigate the influence of the exit operating handle mechanism, the interior configuration and the Type III exit operator's briefing on Type III exit operation. This resulted in a 3 x 2 factorial design.

6.3.1. Independent variables

There were three independent variables in the experiment. The first was the exit operating handle mechanism on the Type III exit. In one condition, the operating handle was not fixed, and therefore the handle retracted into its aperture after exit operation. In the second condition, the operating handle was modified, so that it became fixed after exit operation. The second independent variable was the interior configuration, which was tested in either a large interior configuration or a small interior configuration as in Experiment One.

The third independent variable was the briefing delivered to the Type III exit operator. In one condition a minimal briefing was delivered which informed the operator that that they were sat next to an emergency exit, that they may be required to open the exit in the event of an emergency, not to open the exit unless instructed to do so by the cabin crew and where they could find additional safety information on exit operation. In the other condition operators were provided with an in-depth briefing, which provided specific instructions on the physical actions required to open the exit. The briefing also included the instruction that the participant was not to open the exit unless a member of cabin crew instructed them to do so.

Photographs showing the two conditions of the exit operating handle are shown in figures 3 and 4.

Figure 3: The Type III hatch with the retracted (conventional) handle mechanism

Figure 4: The Type III hatch with the fixed (modified) handle mechanism

6.3.2. Dependent variables

The time taken to operate the exit was the main dependent variable of interest. Exit operation timings were extracted from the time coded video footage of the trials, measured to one tenth of a second. For Type III exit operation, two timings were extracted in line with those reported in cabin safety literature. The first was reaction time, which was the time from the call to evacuate (which was “Undo your seatbelts and get out!”) until the moment the Type III exit operator had placed their hand on the operating handle. The second was operation time, which was the time taken from the moment the exit operator had placed their hand on the operating handle, until the hatch had been disposed of and the exit was available for egress. The reaction and operation times were summated into the exit availability time which was also used as a dependent variable.

Participant rating scales from a post evacuation questionnaire were also collected. A copy of the questionnaire can be found in Appendix L. The questionnaire asked participants to rate various aspects of their evacuation experience using a seven point Likert type scale. The other questions on the questionnaire asked participants to provide qualitative comments about their experience.

6.3.3. Experimental schedule

All participants completed two evacuation trials. Each participant completed an evacuation trial in each handle condition (fixed and modified), but only in one internal configuration (large or small) and in one briefing condition (minimal or in-depth). This therefore led to a mixed design, with two independent group variables (interior configuration and operator's briefing) and one repeated measures variable (operating handle mechanism). The order in which participants completed the trials was counterbalanced to avoid practise and learning effects. The experimental schedule, showing how the 160 evacuation trials were run in the four test conditions, is given in Table 8.

Table 8: Experimental schedule

	Type III exit operator's briefing			
Interior configuration	**Minimal**		**In-depth**	
	Operating handle mechanism			
	Retracted (conventional)	**Fixed (modified)**	**Retracted (conventional)**	**Fixed (modified)**
Large	20 trials	20 trials	20 trials	20 trials
Small	20 trials	20 trials	20 trials	20 trials

6.4. Participants

Eighty individuals were recruited as participants, with each participant individually tested. Participants were recruited in line with the guidelines as set out in Experiment One. Volunteers who had previous experience of operating a Type III exit were excluded from taking part and all participants were permitted to take part in one session only.

6.5. Equipment/materials

6.5.1. Test facility

As with Experiment One, the test facility for the trials was the Boeing 737 cabin simulator. The Type III exit was used for all evacuations in this experiment. The camera positions were as Experiment One.

During this testing programme, the traditional Type III exit hatch handle was operated under the two conditions described within Section 6.3.1. In addition to the operating handle conditions, the interior configuration was also manipulated. Trials were conducted in either the large interior configuration or in the small interior configuration as documented during Experiment One. During all trials "simulated" daylight was present down one side of the cabin as in Experiment One.

Photographs of the cabin in both the small and large interior configurations are provided in Appendix D, along with the Type III exit and the Type III operating handle in both the retracted and fixed conditions in Appendix M

6.5.2. Materials

As per Experiment One, each participant was provided with a clipboard that contained all the paperwork for the trials. The trials materials included a volunteer information sheet which was similar to that provided in Experiment One, with specific details regarding the number of trials and payment changed for this experiment (a copy from Experiment One is provided in Appendix E). A volunteer consent and medical clearance form was also provided as per Experiment One (as shown in Appendix F).

The demographic questionnaire used in Experiment One was again used to collect background information (a copy can be found in Appendix G). As the focus of this experiment was on exit operation, the post evacuation questionnaire used reflected this (as shown in Appendix L). An identical post evacuation questionnaire was used after trials one and two. The questionnaire asked participants about the extent to which they listened to the personal safety briefing and the clarity of the exit operating instructions. The questionnaire also asked about their experience of using the Type III exit hatch, including unlatching the exit hatch, using the operating handle, opening the exit hatch and moving the hatch out of the way. Other aspects of the evacuation process were also covered on the questionnaire including the level of difficulty in moving between the seats in the exit row and moving through the exit and out of the aircraft. Participants were asked to provide a rating for each of these elements on a seven point scale where 1 was very easy/very clear and 7 was very difficult/very unclear. The post evacuation questionnaire also asked participants about any aspects of the personal briefing that had helped or hindered their evacuation and to suggest any improvements to the personal briefing. Finally participants were asked about any physical features within the cabin that had helped or hindered their evacuation. Participants were asked to provide open responses to these questions where applicable. Other questions were included on the post evacuation questionnaire at the request of the sponsor, however these were not of relevance to the current experiment.

6.6. Procedure

6.6.1. Pre-trial procedure

On arrival, members of the research team greeted and checked in each participant. Participants were then provided with a volunteer number and a clipboard containing the paperwork for the trials. The pre-trial procedure was similar to Experiment One, with the exception that there was only one participant in each session.

6.6.2. Trial procedure

6.6.2.1. Seating

On completion of the pre-trial briefing, the cabin crew member accompanied the participant to the cabin simulator. Each participant was assigned to the seat adjacent to the Type III exit for each trial.

6.6.2.2. Safety briefings

Once seated, the member of cabin crew provided a safety briefing, as described in Experiment One. In addition, the participant received an individual briefing on their emergency duties. The content of the briefing was dependent on the experimental condition under test as documented in section 6.3.1. Transcripts of both of these briefings are provided in Appendix N.

6.6.2.3. The call to evacuate

Once the safety briefings were complete, the cabin crew checked the cabin and ensured that the participant had their safety belt fastened. Shortly after the cabin check a pre-recorded evacuation scenario was played to simulate an evacuation on take off; one scenario was played during trial one and a different scenario was played during trial two. Both evacuation scenarios included a period of engine noise (approximately one minute and 40 seconds during trial one and 20 seconds during trial two), followed by an announcement from the Captain to "Undo your seat belts and get out!" The transcript of the evacuation scenarios are contained in Appendix O.

6.6.2.4. Cabin crew actions

At the end of the Captain's announcement the cabin crew member, who was located at the front of the cabin, commanded the passenger to open the Type III exit and evacuate the aircraft. The cabin crew member using assertive, concise, positive commands, in accordance with the findings of Muir and Cobbett (1996) urged participants to move quickly throughout the evacuation. The evacuation was deemed complete when the passenger had evacuated the cabin.

6.6.3. Post-evacuation questionnaires

After evacuating, participants were asked to complete a post-evacuation questionnaire. This questionnaire had been designed specifically for evacuations through the Type III exit. A copy of the questionnaire is provided in Appendix P. Whilst the participant completed the post-evacuation questionnaire, the Type III hatch was altered for the second trial. On completion of the questionnaire, participants re-boarded the cabin simulator and the procedure was completed for the second trial

6.6.4. Post-trial procedure

On completion of the second evacuation trial and post-evacuation questionnaire, each participant was thanked, debriefed and paid. Finally, each participant was provided with a thank you letter containing contact details for the research team (as provided in Experiment One and shown in Appendix K).

6.7. Analysis

The video footage was edited and a time code was added. The exit operation times were extracted from this footage. All performance exit operation data, along with the quantitative responses from the post evacuation questionnaires were entered into SPSS version 14 for quantitative analysis.

Qualitative comments provided in response to the open questions on the post evacuation questionnaire were collated on a question-by-question basis and have been used to add depth to the quantitative results.

7.0. Results: Experiment Two

7.1. Sample

A total of 80 participants took part in both phases of the testing programme. Fifty participants were male (62.5%) and 30 participants were female (37.5%). Participants provided their age at the time of the testing session. Participants' ages ranged from 21 to 49 years, with a mean age of 30.1 years, and a standard deviation of 7.8 years. Eleven participants were left handed (13.8%), 67 were right handed (83.8%) and one participant was ambidextrous (2.5%). Most participants had flown previously on a commercial flight (78 participants, or 97.5%), and one participant reported being involved in an actual emergency evacuation (1.3%).

7.2. Completed evacuations

In total, all 160 planned evacuations were conducted. There were no reported injuries or participant withdrawals.

7.3. Inferential statistics

In all inferential statistical tests, interior configuration, operating handle mechanism and Type III operator's briefing were entered as independent variables, and either the evacuation performance measure or the questionnaire ratings were entered as the dependent variable. All mean times and mean participant ratings have been rounded up to one decimal place.

7.4. Time taken to make the Type III exit available

The mean reaction times for participants are provided in Table 9.

Table 9: Mean Type III exit reaction time (in seconds) in each condition.

	Type III exit operator's briefing and **Operating handle mechanism**				
	In-depth briefing		**Minimal briefing**		
Interior	Retracted	Fixed	Retracted	Fixed	**Interior**
Large	2.5 (sd 0.6)	2.9 (sd 1.4)	4.4 (sd 1.0)	4.6 (sd 1.5)	**3.6 (sd 1.5)**
Small	3.2 (sd 1.1)	3.5 (sd 1.0)	5.0 (sd 2.0)	4.8 (sd 1.4)	**4.1 (sd 1.6)**
Briefing	**3.0 (sd 1.1)**		**4.8 (sd 1.6)**		
	Total retracted mechanism		**Total fixed mechanism**		
	3.8 (sd 1.6)		**4.0 (sd 1.6)**		

As can be seen in Table 9, there is some variation in the reaction times due to the test condition. The data were entered into a mixed model ANOVA which revealed a significant effect of interior configuration on reaction times $F(1,76) = 4.53$, p=0.04. Participants reacted quicker in the large interior configuration than when in the small interior configuration as shown in Table 9. In addition, there was also a significant main effect on reaction times due to the Type III exit operator's briefing, $F(1,76) = 46.37$, p=0.00. Participants reacted quicker when the in-depth personal briefing was delivered than when the minimal personal briefing was delivered.

There was no significant effect for operating handle on reaction times $F(1,76) = 0.87$, p=0.35, and no significant interactions between any of the variables.

The second Type III exit performance measure extracted was exit operation time. The mean exit operation times for participants are provided in Table 10.

Table 10: Mean Type III exit operation time (in seconds) in each condition.

	Type III exit operator's briefing and **Operating handle mechanism**				
	In-depth briefing		**Minimal briefing**		
Interior	Retracted	Fixed	Retracted	Fixed	**Interior**
Large	8.1 (sd 3.8)	7.6 (sd 3.1)	12.2 (sd 5.5)	11.3 (sd 5.3)	**9.8 (sd 4.9)**
Small	8.7 (sd 3.1)	10.9 (sd 6.2)	11.9 (sd 9.3)	11.3 (sd 6.7)	**10.7 (sd 6.2)**
Briefing	**8.8 (sd 4.4)**		**11.7 (sd 6.8)**		
	Total retracted mechanism		**Total fixed mechanism**		
	10.2 (sd 6.1)		**10.3 (sd 5.6)**		

As can be seen in Table 10, there is some variation in exit operation times due to test condition. The data were entered into a mixed model ANOVA which showed a significant effect for Type III exit operator's briefing on exit operation times $F(1,76) = 7.95$, p=0.01. Participants operated the exit quicker when the in-depth personal briefing was delivered than when the minimal personal briefing was delivered as shown in Table 10. There were no significant effects for interior configuration $F(1,76) = 0.81$, p=0.37 or operating handle mechanism $F(1,76) = 0.00$, p=0.95 on exit operation times, and no significant interactions between the variables.

The final Type III exit performance measure used was the overall time to make the exit available. The overall exit availability times are provided in Table 11.

Table 11: Mean Type III exit availability time (in seconds) in each condition.

	Type III exit operator's briefing and **Operating handle mechanism**				
	In-depth briefing		**Minimal briefing**		
Interior	Retracted	Fixed	Retracted	Fixed	**Interior**
Large	10.6 (sd 3.9)	10.5 (sd 3.3)	16.6 (sd 6.1)	15.9 (sd 6.3)	**13.4 (sd 5.8)**
Small	12.0 (sd 3.0)	14.4 (sd 6.1)	16.9 (sd 10.2)	16.1 (sd 7.4)	**14.8 (sd 7.3)**
Briefing	**11.9 (sd 4.5)**		**16.4 (sd 7.2)**		
	Total retracted mechanism		**Total fixed mechanism**		
	14.0 (sd 6.9)		**14.2 (sd 6.3)**		

As can be seen in Table 11, there is some variation in exit availability times due to test condition. The data were entered into a mixed model ANOVA which revealed a significant effect attributable to the Type III exit operator's briefing on exit availability times $F(1,76) = 16.45$, p=0.01. Participants made the exit available quicker when the in-depth personal briefing was delivered than when the minimal personal briefing was delivered as shown in Table 11. There were no significant effects for interior configuration $F(1,76) = 1.64$, p=0.20 or operating handle mechanism $F(1,76) = 0.59$, p=0.81 on exit availability times, and no significant interactions between the variables.

7.5. Perceived difficulty of the Type III exit

In order to investigate passengers' perceived difficulty of the task, data obtained from a selection of questions on the post-evacuation questionnaires were also analysed. One question on the post evacuation questionnaire related to the extent to which participants listened to the personal briefing provided by the cabin crew. The mean difficulty ratings are provided in Table 12.

Table 12: Mean participant attention ratings (where 1 was no attention and 7 was full attention) for listening to the personal briefing in each condition.

	Type III exit operator's briefing and **Operating handle mechanism**				
	In-depth briefing		**Minimal briefing**		
Interior	Retracted	Fixed	Retracted	Fixed	**Interior**
Large	7.0 (sd 0.0)	6.8 (sd 0.4)	6.8 (sd 0.4)	6.7 (sd 0.7)	**6.8 (sd 0.4)**
Small	6.7 (sd 0.6)	6.7 (sd 0.6)	6.2 (sd 1.3)	6.5 (sd 1.0)	**6.5 (sd 0.9)**
Briefing	**6.6 (sd 0.9)**		**6.8 (sd 0.5)**		
	Total retracted mechanism		**Total fixed mechanism**		
	6.7 (sd 0.8)		**6.7 (sd 0.7)**		

The data were entered into a mixed model ANOVA which revealed a significant effect for interior configuration on perceived attention ratings of listening to the personal briefing $F(1,74) = 4.59$, p=0.04. Participants reported paying more attention to the safety briefing in the large interior configuration than in the small interior configuration as shown in Table 12.

There were no significant effects for operating mechanism $F(1,74) = 0.01$, p=0.92 or Type III exit operator's briefing $F(1,74) = 3.41$, p=0.07 on perceived attention ratings for listening to the personal briefing, and no significant interactions between any of the variables.

Participants were asked to rate the clarity of the exit operating instructions during the personal briefing. The mean clarity ratings are provided in Table 13.

Table 13: Mean participant clarity ratings (where 1 was very clear and 7 was very unclear) for the clarity of exit operating instructions during the personal briefing in each condition.

	Type III exit operator's briefing and **Operating handle mechanism**				
	In-depth briefing		**Minimal briefing**		
Interior	Retracted	Fixed	Retracted	Fixed	**Interior**
Large	1.8 (sd 0.9)	1.7 (sd 0.6)	2.5 (sd 1.7)	2.7 (sd 1.8)	**2.1 (sd 1.4)**
Small	1.9 (sd 1.3)	2.3 (sd 1.8)	2.5 (sd 1.6)	2.4 (sd 1.6)	**2.3 (sd 1.6)**
Briefing	**1.9 (sd 1.2)**		**2.5 (sd 1.6)**		
	Total retracted mechanism		**Total fixed mechanism**		
	2.2 (sd 1.4)		**2.2 (sd 1.5)**		

The data were entered into a mixed model ANOVA which revealed a significant effect of Type III exit operator's briefing for perceived clarity ratings of the exit operating instructions provided during the personal briefing, $F(1,76) = 5.20$, p=0.03. Participants reported that the exit operating instructions were clearer in the in-depth briefing than those provided during the minimal briefing as shown in Table 13.

There were no significant effects for operating mechanism $F(1,76) = 0.23$, p=0.63 or interior configuration $F(1,76) = 0.18$, p=0.68 and no significant interactions between any of the variables.

The difficulty of unlatching the exit hatch was addressed on the post evacuation questionnaire. The mean difficulty ratings are provided in Table 14.

Table 14: Mean participant difficulty ratings (where 1 was very easy and 7 was very difficult) for unlatching the exit hatch in each condition.

	Type III exit operator's briefing and **Operating handle mechanism**				
	In-depth briefing		**Minimal briefing**		
Interior	Retracted	Fixed	Retracted	Fixed	**Interior**
Large	2.0 (sd 1.1)	2.0 (sd 1.1)	2.5 (sd 1.5)	2.3 (sd 1.3)	**2.2 (sd 1.3)**
Small	2.1 (sd 1.4)	1.9 (sd 1.0)	2.9 (sd 1.7)	2.8 (sd 1.8)	**2.4 (sd 1.5)**
Briefing	**2.0 (sd 1.1)**		**2.6 (sd 1.6)**		
	Total retracted mechanism		**Total fixed mechanism**		
	2.4 (sd 1.5)		**2.2 (sd 1.3)**		

The data were entered into a mixed model ANOVA which revealed a significant effect of Type III exit operator's briefing on perceived difficulty ratings for unlatching the exit hatch $F(1,76) = 4.70$, p=0.03. When the minimal briefing was delivered, participants perceived unlatching the hatch as more difficult compared to when the in-depth briefing was delivered as shown in Table 14.

There were no significant effects for operating mechanism $F(1,76) = 1.20$, p=0.28 or interior configuration $F(1,76) = 0.66$, p=0.42 and no significant interactions between any of the variables.

Participants were asked to rate the difficulty of using the exit operating handle during exit operation. The mean difficulty ratings are provided in Table 15. A mixed design ANOVA conducted on these data revealed no statistically significant effects attributable to operating mechanism $F(1,75) = 2.66$, p=0.11, interior configuration $F(1,75) = 0.02$, p=0.88 or Type III exit operator's briefing $F(1,75) = 1.78$, p=0.19 on difficulty ratings. In addition, there were no significant interactions between any of the variables.

Table 15: Mean participant difficulty ratings (where 1 was very easy and 7 was very difficult) for using the exit operating handle in each condition.

	Type III exit operator's briefing and **Operating handle mechanism**				
	In-depth briefing		**Minimal briefing**		
Interior	Retracted	Fixed	Retracted	Fixed	**Interior**
Large	2.1 (sd 1.2)	2.1 (sd 1.0)	2.2 (sd 1.0)	2.4 (sd 1.4)	**2.2 (sd 1.1)**
Small	1.8 (sd 1.1)	2.2 (sd 1.4)	2.2 (sd 1.2)	2.7 (sd 1.7)	**2.2 (sd 1.4)**
Briefing	**2.0 (sd 1.2)**		**2.4 (sd 1.3)**		
	Total retracted mechanism		**Total fixed mechanism**		
	2.1 (sd 1.1)		**2.3 (sd 1.4)**		

Participants were asked to about the difficulty of opening the exit hatch. The mean difficulty ratings are provided in Table 16. A mixed model ANOVA conducted on these data revealed no statistically significant effects attributable to operating mechanism $F(1,76) = 0.63$, p=0.43, interior configuration $F(1,76) = 1.77$, p=0.19 or Type III exit operator's briefing $F(1,76) = 1.17$, p=0.28 on difficulty ratings. In addition, there were no significant interactions between any of the variables.

Table 16: Mean participant difficulty ratings (where 1 was very easy and 7 was very difficult) for opening the exit hatch in each condition.

	Type III exit operator's briefing and **Operating handle mechanism**				
	In-depth briefing		**Minimal briefing**		
Interior	Retracted	Fixed	Retracted	Fixed	**Interior**
Large	2.9 (sd 1.4)	2.9 (sd 1.6)	2.8 (sd 1.2)	2.9 (sd 1.4)	**2.9 (sd 1.4)**
Small	3.1 (sd 1.9)	2.8 (sd 1.6)	3.3 (sd 1.2)	4.0 (sd 1.7)	**3.3 (sd 1.6)**
Briefing	**2.9 (sd 1.6)**		**3.2 (sd 1.6)**		
	Total retracted mechanism		**Total fixed mechanism**		
	3.0 (sd 1.5)		**3.1 (sd 1.6)**		

The difficulty of moving the hatch out of the way was also included on the questionnaire. The mean difficulty ratings are provided in Table 17.

Table 17: Mean participant difficulty ratings (where 1 was very easy and 7 was very difficult) of moving the hatch out of the way in each condition.

	Type III exit operator's briefing and **Operating handle mechanism**				
	In-depth briefing		**Minimal briefing**		
Interior	Retracted	Fixed	Retracted	Fixed	**Interior**
Large	4.8 (sd 1.6)	5.3 (sd 1.5)	5.0 (sd 1.5)	4.8 (sd 1.6)	**5.0 (sd 1.5)**
Small	5.2 (sd 2.0)	4.8 (sd 2.1)	5.2 (sd 1.5)	5.3 (sd 1.6)	**5.1 (sd 1.8)**
Briefing	**5.0 (sd 1.8.)**		**5.0 (sd 1.5)**		
	Total retracted mechanism		**Total fixed mechanism**		
	5.0 (sd 1.6)		**5.0 (sd 1.7)**		

The data were entered into a mixed model ANOVA which revealed a significant interaction in difficulty ratings for moving the hatch out of the way between interior configuration, handle mechanism and Type III exit operator's briefing $F(1,76)$ =4.89, p=0.03.

There were no significant effects for operating mechanism $F(1,76) = 0.07$, p=0.79, interior configuration $F(1,76) = 0.16$, p=0.70 or Type III operator's briefing $F(1,76) = 0.01$, p=0.92. In addition there were no other significant interactions between the variables.

7.6. Perceived difficulty of the evacuation

Participants were asked to rate the difficulty of moving between the seats in the exit row. The mean difficulty ratings are provided in Table 18.

Table 18: Mean participant difficulty ratings (where 1 was very easy and 7 was very difficult) for moving between the seats in the exit row in each condition.

	Type III exit operator's briefing and **Operating handle mechanism**				
	In-depth briefing		**Minimal briefing**		
Interior	Retracted	Fixed	Retracted	Fixed	**Interior**
Large	1.9 (sd 1.3)	1.7 (sd 0.9)	2.0 (sd 1.1)	1.8 (sd 0.8)	**1.8 (sd 1.0)**
Small	3.0 (sd 1.9)	2.7 (sd 1.6)	3.0 (sd 1.6)	2.8 (sd 1.6)	**2.9 (sd 1.7)**
Briefing	**2.5 (sd 1.7)**		**2.4 (sd 1.4)**		
	Total retracted mechanism		**Total fixed mechanism**		
	2.5 (sd 1.6)		**2.2 (sd 1.4)**		

The data were entered into a mixed model ANOVA which revealed a significant main effect of interior configuration on perceived difficulty of moving between the seats in the exit row $F(1,75) = 13.44$, p=0.00. Participants perceived that moving between the seats in the exit row was more difficult in a small interior configuration than in a large interior configuration as shown in Table 18.

There were no significant effects for operating handle mechanism $F(1,75) = 2.31$, p=0.13 or Type III exit operator's briefing $F(1,75) = 0.05$, p=0.83 on perceived difficulty ratings of moving between the seats in the exit row. In addition, there were no significant interactions between any of the variables.

Finally participants were asked to rate the difficulty of moving through the exit and out of the aircraft. The mean difficulty ratings are provided in Table 19.

Table 19: Mean participant difficulty ratings (where 1 was very easy and 7 was very difficult) for moving through the exit and out of the aircraft in each condition.

	Type III exit operator's briefing and **Operating handle mechanism**				
	In-depth briefing		**Minimal briefing**		
Interior	Retracted	Fixed	Retracted	Fixed	**Interior**
Large	2.9 (sd 1.4)	2.8 (sd 1.5)	3.0 (sd 1.2)	2.8 (sd 1.1)	**2.9 (sd 1.3)**
Small	3.6 (sd 1.7)	3.4 (sd 1.6)	3.3 (sd 1.7)	4.2 (sd 1.1)	**3.6 (sd 1.7)**
Briefing	**3.2 (sd 1.6)**		**3.3 (sd 1.5)**		
	Total retracted mechanism		**Total fixed mechanism**		
	3.2 (sd 1.5)		**3.3 (sd 1.5)**		

The data were entered into a mixed model ANOVA which revealed a significant main effect of interior configuration on perceived difficulty of moving through the exit and out of the aircraft $F(1,75) = 7.04$, p=0.01. Participants perceived that moving through the exit and out of the aircraft was more difficult in a small interior configuration than in a large interior configuration as shown in Table 19.

There were no significant effects for operating handle mechanism $F(1,75) = 0.65$, p=0.42 or Type III exit operator's briefing $F(1,75) = 0.25$, p=0.62 on perceived difficulty ratings of moving through the exit and out of the aircraft. In addition, there were no significant interactions between any of the variables.

7.7. Headroom at the Type III exit

In addition to rating scales participants were asked if there was anything in the cabin that had hindered them during their evacuation. As with Experiment One, of particular note was the number of comments related to the headroom at the Type III exit. Only two comments in the large configuration (both comments made by the same participant), specifically mentioned the available headroom and/or overhead lockers. The majority of the responses to this question by participants who evacuated in the large interior configuration related to the space between the seat(s) in which to manoeuvre the exit hatch.

"Seats in front too close and overhead lockers and curved side restricting headroom" (Participant 14, large interior configuration, in-depth Type III operator's briefing, with retracted (conventional) operating handle mechanism, trial 1)

"Curved sides and overhead lockers" (Participant 14, large interior configuration, in-depth Type III operator's briefing, with fixed (modified) operating handle mechanism, trial 2)

However, in the small interior configuration, numerous comments were made about the overhead lockers and limited headroom hindering evacuation. It is noted that due to the nature of the experimental design, the same participant may have made a comment relating to headroom after each trial. A selection of the comments is provided here:

"The boxes above me which hindered my ability to open the door and take it away (outside the cabin)" (Participant 41, small interior configuration in-depth Type III exit operator's briefing, with retracted (conventional) handle mechanism, trial 1)

"Low overhead lockers. Seat position" (Participant 34, small interior configuration, in-depth Type III exit operator's briefing, with retracted (conventional) handle mechanism, trial 2)

"Overhead lockers" (Participant 32, small interior configuration, in-depth Type III exit operator's briefing, with fixed (modified) handle mechanism, trial 1)

"The ceiling is too low and the seat where I was seated is too close to the exit door (problem with legs)" (Participant 35, small interior configuration, in-depth Type III exit operator's briefing, with fixed (modified) handle mechanism, trial 2)

"The overhead cabins were very low and, therefore, restricted my movement" (Participant 84, small interior configuration, minimal Type III exit operator's briefing, with retracted (conventional) handle mechanism, trial 1)

"The height of the overhead lockers means I had to bend down, I could not stand upright" (Participant 71, small interior configuration, minimal Type III exit operator's briefing, with retracted (conventional) handle mechanism, trial 2)

"Baggage hold was very low and did not allow much movement" (Participant 79, small interior configuration, minimal Type III exit operator's briefing, with fixed (modified) handle mechanism, trial 1)

"The height of door and height of panel fixed the door with cushion for which I had to put the door first on the floor and then pick it up again" (Participant 73, small interior configuration, minimal Type III exit operator's briefing, with fixed (modified) handle mechanism, trial 2)

7.8. Type III exit operator's briefing

The Type III exit operator's briefing delivered was shown to significantly influence the time taken to operate the Type III exit, with participants completing the task faster when the in-depth briefing was delivered. Participants were also asked about the personal Type III exit operator's briefing that was delivered. The questionnaire asked if participants had found the briefing helpful or unhelpful and why this was the case.

Positive comments to the in-depth briefing included reference to the full explanation of the exit operating procedure, explaining what participants were expected to do and highlighting the individual's responsibility for exit operation. Participants also reported that the information on the specific attributes of the exit, including that once the hatch was released it was not attached to the aperture and an indication of the weight of the hatch had helped them.

"Explaining how the door works and what was expected from me" (Participant 30, small interior configuration, in-depth Type III operator's briefing, with retracted (conventional) handle mechanism, trial 1)

"Indication of evacuation instruction and how to open door" (Participant 14, large interior configuration, in-depth Type III operator's briefing, with retracted (conventional) handle mechanism, trial 2)

"Clearly stated door operation, fall inwards, weight, no hinges" (Participant 13, large interior configuration, in-depth Type III operator's briefing, with fixed (modified) handle mechanism, trial 1)

"I know that I had to remove the door out of the cabin" (Participant 35, small interior configuration, in-depth Type III operator's briefing, with fixed (modified) handle mechanism, trial 2).

Some participants received a minimal Type III exit operator's briefing, which only highlighted to them that they were sitting next to an exit and that they may be required to open the exit in the event of an emergency. Comments suggested that the personal briefing had highlighted what to do in an emergency, the individual's responsibility for exit operation, basic exit operation, where to find further instructions about exit operation and that attention should be given to the safety information. It is noted that some participants documented that the personal briefing had provided full instructions about exit operation, however it must be remembered that these participants were not aware of the in-depth Type III operator's briefing provided in the other trials. A sample of comments in response to this question included:

"Made me aware of my responsibility to open the exit, so I made sure I had read the instructions" Participant 52, large interior configuration, minimal Type III operator's briefing, with fixed (modified) handle mechanism, trial 1)

"Help[ed] me to pay attention to any notice, and think about the evacuation method in advance" (Participant 57, large interior configuration, minimal Type III operator's briefing, with fixed (modified) handle mechanism, trial 2)

"I knew I had to pay more attention on how to open the exit as it could be my responsibility to open the exit for an evacuation" (Participant 83, small interior configuration, minimal Type III operator's briefing, with retracted (conventional) handle mechanism, trial 1)

"It provided information on the exit and where to find information on how to use it" (Participant 74, small interior configuration, minimal Type III operator's briefing, with retracted (conventional) handle mechanism, trial 2)

As with the safety briefing, if participants felt that the personal briefing had not assisted their evacuation, they were asked to explain what aspects were not helpful. Only one comment was provided by a participant in the in-depth briefing condition who stated that they *"already knew the content" (Participant 19, large interior configuration, in-depth Type III operator's briefing, with retracted (conventional) handle mechanism, trial 2).* Six participants who received the minimal Type III operator's briefing made a comment in response to this question. The majority of the comments were related to not being given or shown specific information on exit operation including *"different thing between being told and being shown" (Participant 59, large interior configuration, minimal Type III operator's briefing, with retracted (conventional) handle mechanism, trial 1)* and *"no verbal instruction on how to handle the hatch" (Participant 67, small interior configuration, minimal Type III operator's briefing, with retracted (conventional) handle mechanism, trial 2).*

Only a minimal number of respondents documented that the minimal Type III exit operator's briefing had not helped their evacuation. It must be remembered that participants were not aware of the additional information provided in the in-depth Type

III operator's briefing and so were unable to compare the effect of the two briefings on exit operation. In order to gain further information from participants about the Type III operator's briefing, all participants were asked if any improvements could be made to the personal briefing such that they would enhance their actions in the event of an emergency evacuation.

As the Type III operator's personal briefing was manipulated across the research, participants' responses have been reviewed in light of the briefing they received. Respondents who received the in-depth Type III exit operator's briefing commented on a range of issues, with suggestions for improvement including providing a visual demonstration of exit operation (i.e. via video or hand signals) and a demonstration of hand placement, providing clear information on the weight of the exit and presenting the briefing in different languages depending on the native language of the operator.

"If the operations were demonstrated with hand signals (not actually opening the door) or maybe a video clip of an actual removal and evacuation from the door" (Participant 14, large interior configuration, in-depth Type III operator's briefing, with retracted (conventional) handle mechanism, trial 1)

"Demonstrate hand placement" (Participant 6, large interior configuration, in-depth Type III operator's briefing, with retracted (conventional) handle mechanism, trial 1)

"The weight of the emergency exit should be clearly stated on the safety document and if possible I should be allowed to carry a weight equivalent to the door of the exit" (Participant 18, large interior configuration, in-depth Type III operator's briefing, with fixed (modified) handle mechanism, trial 1)

"Some travellers are not English native speakers. Therefore the personal briefing must be clear for people who do not have good English" (Participant 25, small interior configuration, in-depth Type III operator's briefing, with retracted (conventional) handle mechanism, trial 1)

Those participants who received the minimal briefing proposed a number of improvements to the personal briefing, these included specific information on the way the door works, specific instructions on how to operate the door, what to expect from exit operation (i.e. that the hatch is not attached to the exit aperture, how to pull the exit handles), a demonstration on how the overwing exit works and where to place the hatch after operation.

“’Demonstrate’ how the emergency exit work[s], or show a video about it” (Participant 59, large interior configuration, minimal Type III operator’s briefing, with retracted (conventional) handle mechanism, trial 1)

“I expected that the hatch would still be attached to the fuselage after opening (and was not going to fall down on my toes)” (Participant 47, large interior configuration, minimal Type III operator’s briefing, with fixed (modified) handle mechanism, trial 1)

“Really emphasize on the heavy metal door that need to be taken out/opened, so that passenger gets mentally prepared on the ‘hard heavy’ job of pulling the door out in panic situation” (Participant 58, large interior configuration, minimal Type III operator’s briefing, with fixed (modified) handle mechanism, trial 1)
“What to do with the door after it had been released. Reinforce that it should be placed outside the aircraft, on the wing” (Participant 71, small interior configuration, minimal Type III operator’s briefing, with retracted (conventional) handle mechanism, trial 2)

“A physical demonstration (without actually opening the exit) i.e. which hand to hold where; what to expect from the hatch door i.e. it will open towards you; which direction to turn etc…” (Participant 68, small interior configuration, minimal Type III operator’s briefing, with retracted (conventional) handle mechanism, trial 1)

“If she could specify the complete procedure [for] opening the emergency exit instead of pointing [to] the card for [it]” (Participant 73, small interior configuration, minimal Type III operator’s briefing, with fixed (modified) handle mechanism, trial 2)

Three comments of interest to the current experiment were made by participants on the post-evacuation questionnaire when asked if there were any additional comments that they wanted to make about the evacuation trial. The comments were all made by participants who received the minimal Type III exit operator’s briefing and are linked to the exit operators briefing and the information provided to participants.

“Unclear instruction on how to remove the door was more of a problem than the weight […] of the emergency hatch” (Participant 47, large interior configuration, minimal Type III operator’s briefing, with retracted (conventional) handle mechanism, trial 2).

“Maybe a step by step instruction (more clear than on the instruction placard) on how to move the door when opening. For example: pull the handle, lift the door, turn and throw out of the aircraft. Now it takes to[o] much time to find it out yourself. On the instruction placard (card) it looks much simpler” (Participant 77, small interior configuration, minimal Type III operator’s briefing, with retracted (conventional) handle mechanism, trial 2).

“I now strongly believe more overt instructions regarding where to take the hatch and where to store it before an emergency takes place would save time and, therefore,

potential injury…" (Participant 67, small interior configuration, minimal Type III operator's briefing, with fixed (modified) handle mechanism, trial 1).

8.0. Discussion – Experiment Two

8.1. Exit operator's briefing on operation time

The results indicated that exit operator's briefing had a statistically significant effect on Type III exit operation. Participants reacted to the call to evacuate, operated the exit and made the Type III exit available for evacuation significantly faster when the in-depth exit operator's briefing was delivered, compared with when the minimal exit operator's briefing was provided. The difference in reaction times attributable to the briefing adds further support to the provision of a detailed briefing and supports the findings of Cobbett et al (2001). Cobbett et al reported that the more information provided, the less the operator hesitated when told to evacuate. Interestingly, this experiment contradicts the findings of Cobbett et al who found no significant differences in exit operation time (the current experiment found a difference). However these results are in line with the Cobbett et al findings that the more information provided, the less time taken by operators to make the exit available. The overall conclusion from the Cobbett et al study and this experiment is the benefit of providing an individual briefing to the exit operator which provides clear and detailed instruction prior them being asked to complete a complex task such as Type III exit operation.

The findings from this experiment also support those of McLean et al (2002) who suggested that when exit operators are encouraged to engage with the safety material and are fully informed of the task they are willing to comply with the task requirements. The current experiment suggests that by providing exit operators with an in-depth briefing on exit operation, provided them with detailed and specific knowledge about the task they would be required to complete.

8.2. Interior configuration on operation time

There was also a significant main effect of interior configuration on reaction times, in that participants reacted quicker to the call to evacuate when seated in the large interior configuration than when seated in the small interior configuration. It is however suggested that this may be a statistical artefact as the interior configuration should not have influenced the time taken to react to the call to evacuate. There were no significant effects attributable to interior configuration on exit operation time or exit availability time. However as with the findings of Experiment One, participants reported that the limited headroom available in the smaller interior configuration influenced exit operation and evacuation efficiency. As there are no other specific studies that have investigated the influence of interior configuration on exit operation, it is not possible to place these results in a wider context.

8.3. Operating handle mechanism on operation time

The results indicated no significant effect on reaction time, exit operation time and exit availability time attributable to handle operating mechanism. It seems that the modification made to the operating handle (which meant the operating handle was fixed and could function as a second handle or handhold) had no effect on the time taken to operate the Type III exit with either a minimal or in-depth exit operator's briefing.

No other studies were found that explored the operating handle mechanism or any similar minor modification to the Type III exit, therefore placing these results in a wider context is difficult. However it is suggested that the modification may have been too minor to reduce any of the difficulties associated with the task. As a result it was suggested that further research needs to consider the other aspects of the Type III task in relation to evacuation efficiency. These may include improving the understanding of the task requirements (i.e. how to perform the task, the disposal of the hatch and the non intuitive nature of the task) and the physical operation of the exit (i.e. due to the physical parameters of the hatch, the available space in which to complete the task and the need to fully remove the hatch from the fuselage and dispose of it into an appropriate location before exiting).

8.4. Perceived difficulty of the exit operation task

Overall, when asked to rate the level of difficulty of a number of tasks during the operation of the exit, participants did not perceive any significant differences in difficulty attributable to the variables of interest. No significant differences in the level of difficulty due to operating handle mechanism, interior configuration, Type III exit operator's briefing or an interaction between the variables were reported for using the operating handle, opening the hatch, the weight of the hatch or the size of the hatch. A significant difference was reported for unlatching the hatch due to Type III exit operator's briefing, in that participants reported it as more difficult when the minimal briefing was delivered than when the in-depth briefing was delivered. During the in-depth briefing participants were informed that they were required to pull down the operating handle to unlatch the exit and therefore may have been more prepared for the task. There were no significant effects for unlatching the hatch attributable to interior configuration, operating handle mechanism or any significant interaction.

8.5. Perceived difficulty of evacuating

The results revealed that when participants were asked to rate the perceived difficulty of moving between the seats in the exit row, there was a significant difference in difficulty ratings due to the interior configuration. Participants rated it as more difficult in the small configuration than in the large configuration. This result is likely to be due to the restricted amount of headroom within the smaller interior configuration. It was noted that there were no statistically significant differences in the difficulty ratings due to Type III exit operator's briefing, operating handle mechanism, or any interaction between the variables. Finally when questioned about the difficulty of moving through the exit and out of the aircraft, participants rated the task as more difficult when in the small interior configuration than when in the large interior configuration. There were no significant differences in difficulty ratings attributed to Type III exit operator's briefing, operating handle mechanism or any interaction between the variables. It may be that the reduced headroom available in a smaller interior configuration led to participants' perceiving the task of moving between the seats in the exit row and through the exit and out of the aircraft as more difficult. This supports the perceptions of evacuees during Experiment One, who perceived the limited headroom associated with smaller transport aircraft to hinder their evacuation.

8.6. Perceptions of the Type III exit operator's briefing

When questioned on the clarity of the exit operating instructions, there was a significant effect for Type III exit operator's briefing. Participants reported that the exit operating instructions were clearer when the in-depth operator’s briefing was delivered than when the minimal operator’s briefing was delivered. This result is not surprising as the in-depth exit operator’s briefing contained explicit details about the Type III exit operation task. These findings are in line with those reported by Cobbett et al (2001) who found that the more detail that was provided in the briefing the clearer the participant reported the briefing to be.

When asked about the in-depth personal briefing, positive comments included reference to the full explanation of the exit operating procedure, information on the specific attributes of the exit and information on what the participant was expected to do throughout the process. Participants also suggested a number of improvements to the personal briefing that included providing a visual demonstration of exit operation (i.e. via video), a demonstration of hand placement actually on the hatch and presenting the briefing in multiple languages. When asked about the minimal personal briefing, participants highlighted that the briefing provided information on what to do in an emergency, the individual’s responsibility for exit operation and where to find further instructions about exit operation. Although some participants in the minimal briefing documented that the briefing provided the information they required for exit operation, it must be remembered that these participants were not aware of the content of the in-depth briefing.

Participants who experienced the minimal personal briefing also proposed a number of improvements to the personal briefing. Improvements included information on specific details on the way the exit works and instructions on exactly how to operate the exit, what to expect from exit operation (i.e. that the hatch is not attached to the exit aperture, how to pull the exit handles), a demonstration on how the overwing exit works and where to place the hatch after operation. It is noted that all these elements were included in the in-depth personal briefing. Importantly, the results relating to the benefits of the in-depth briefing as perceived by participants were aligned with the performance data on the benefits of the briefing on Type III exit operation times.

One potential disadvantage of the in-depth briefing is the time taken to deliver the briefing and, as a result, whether operators would support the change. The length of the briefing was highlighted by one participant *"It is a little bit to[o] long, especially for the foreign people which have to stay concentrated. It should be better to summarise and point out the important points" (Participant 18, large interior configuration, in-depth Type III exit operator's briefing, with fixed (modified) handle mechanism, trial 1).* It is acknowledged that the in-depth briefing takes longer to deliver than the minimal briefing. This point was also made by Cobbett et al (2001) who found it took significantly longer for the detailed briefing to be delivered compared to the minimal briefing. However as argued by Thomas (2003) and in the current experiment, the additional time is justified due to the benefits in exit operation as a result of the in-depth briefing. Further work could address if all information in the in-depth briefing is required to improve operation time to ensure that the additional time is well spent.

8.7. Perceived difficulties of the interior configuration

When asked on the post evacuation questionnaire about the personal briefing that was provided, there was a significant effect for interior configuration, such that participants reported paying more attention to the personal briefing in the large interior configuration than in the small interior configuration, although it is not clear why this may have been the case and it is suggested that this is a spurious statistical result.

In the small interior configuration, a number of comments were made regarding the low headroom, whereas only two comments regarding the headroom at the Type III exit were made by participants in the large interior configuration. Participants also noted that the limited space between the seats had hindered them during the evacuation and again align with the findings of Experiment One.

8.8. Perceptions of the operating handle mechanism

It is noted that some participants referred to the presence, location, grips or colour of the exit hatch handles when asked about factors that helped their evacuation, although no comments specifically mentioned the latching/retracting mechanism of the operating handle. Other comments provided by participants related to the ease of operation when using the hatch. A handful of participants also mentioned the exit hatch handles when asked to comment on any factors related to the exit hatch that had hindered their evacuation, although none of the comments related to the operating mechanism of the top handle. The majority of comments related to the physical dimensions of the exit hatch (i.e. size, shape and weight), the space in which to manoeuvre the hatch (i.e. position of seat and the amount of space in the exit row), the procedure for opening and disposing of the hatch and the dimensions of the exit aperture. It may be that a more major modification to the exit is required to remove the difficulties associated with exit operation.

8.9. Summary of Experiment Two

The objectives of Experiment Two were to investigate the effects of a minor modification to the Type III operating handle mechanism and the level of detail provided in the personal briefing provided to the exit operator on Type III exit operation. In addition the experiment wanted to provide data on the extent to which regulations concerning the Type III exit would apply equally to larger single aisle transport aircraft and smaller transport aircraft. Therefore tests were conducted in cabins with small and large interior configurations. The results from the experiment highlights a number of benefits of providing an in-depth exit operator's briefing in relation to exit operation and passenger perception of the evacuation. Overall the influence of the modification to the operating handle mechanism and interior configuration did not significantly influence exit operation, however the restrictive headroom associated with a smaller interior aircraft cabin was perceived by participants as hindering them during the evacuation.

9.0 Introduction – The Type III exit mechanism

9.1. Introduction to Experiment Three

Preceding chapters have highlighted a range of difficulties experienced by Type III exit operators with the traditional Type III exit design. These difficulties have been linked to the physical and the comprehension demands of the task that may be placed on the exit operator. The benefits of including ADHs have been addressed within the literature, however this has only been in relation to larger aircraft (although to date no regulation has been made that requires manufacturers to install an ADH as opposed to a traditional 'plug' Type III exit mechanism). It is not known if the benefits of such a design would equally apply to smaller transport aircraft.

9.2. An automatically disposed hatch mechanism

In order to improve passenger operation of the Type III exit and to ensure that once opened the exit hatch does not impede passenger access to the exits or the exit aperture the NTSB recommended that the FAA should 'require Type III overwing exits on newly manufactured aircraft to be easy and intuitive to open and have automatic hatch stowage out of the egress path' (2000, p. 80). One area of focus for regulatory activity is the Type III exit. Specifically, the issue is on the provision of an exit that once opened does not impede passenger access to the exits or the exit aperture on new type certificated aircraft (FAA, 1999).

The design and operation of the traditional Type III exit has been questioned by a number of cabin safety commentators. The NTSB in 2000 commented that with the traditional exit hatch mechanism it 'is not intuitively obvious that after pulling the latch, the hatch is to be turned and either placed on the exit row seats or thrown out the opening. The opening and manoeuvring of this exit is also difficult to display graphically' (NTSB, 2000, p. 40). The UK regulator also states that passenger operated exits 'need to be made more effective and is seeking international adoption of radical improvements in access to and ease of opening of such exits' (CAA, 2004, GR No 3, Appendix 1, p. 1).

As discussed in Section 5.1 an alternative to the traditional Type III exit mechanism is an automatically disposed hatch mechanism. As the name suggests with an ADH design when the operating handle is released, the operator is not required to dispose of the hatch as this process is built into the exit mechanism. The exit hatch is disposed of in such a way so that it does not create a potential obstruction to egress, as it remains attached to the fuselage.

Fennell and Muir (1993) and Cobbett, Jones and Muir (1997) reported that allowing participants to open the traditional Type III exit on a number of occasions – and essentially practicing the task, reduced the time taken to operate the exit. In addition, participants were able to 'learn and develop the necessary technique to enable them to open the hatch and manoeuvre it in the limited space available' which included the understanding that the hatch should be disposed of outside the cabin (Fennel and Muir, 1993, p. iii). These findings suggest that the specific procedures involved in correctly operating and disposing of the hatch are not intuitive to all passengers when they first encounter the exit. Although practice improved the operation of the exit, during an evacuation it is highly unlikely that the passenger will have previously operated the exit and in a time-critical situation there is no time for delay.

Following a recent review of factors influencing evacuation from smaller transport aircraft, R.G.W. Cherry and Associates suggested that with larger and heavier exits (Type II and above), 'it may be preferable that the opening of these exits does not necessitate the passenger/flight attendant to lift the hatch and throw it outside' (2006a, p. 27). It is noted that this issue may not only be relevant to exits of the size/weight of a Type II exit, as previous chapters have shown passengers experience difficulties with exit operation of the Type III exit. Although it is acknowledged that the hatch may not be as heavy on a smaller transport regional aircraft, the restrictive space in the cabin and the limited headroom may impede passengers in the event of an emergency evacuation. The weight and size of the hatch is not regulated, however the Type III exit aperture across all aircraft must be at least 20" x 30", therefore research has to consider the worst case scenario.

R.G.W. Cherry and Associates also went on to recommend that ‘when space is very limited, or the hatch is relatively heavy or large, it might be helpful to have emergency exits that are easy to open and do not require much space during opening, such as hatches that fall out after the handle is pulled’ (2006a, p. 28). It is therefore proposed that the potential benefits of an ADH mechanism should be explored on a smaller transport aircraft. Research has already been conducted on the installation of an ADH on larger aircraft; however the issue of an ADH on smaller transport aircraft has not been widely addressed within the public domain.

9.3. Research into Type III exit mechanisms

In 1994, the UK CAA commissioned Cranfield University to conduct a programme of research into means of improving the operation of the Type III exit and in turn reducing the time taken to make the exit available for egress (Cobbett et al, 1997). The specific focus of the research programme was on a change to the physical mechanism of the Type III exit.

The project involved the generation of different exit mechanism concepts which had to comply with a range of criteria. The criteria included that the newly designed exit mechanism would support the Type III hatch and that a passenger would be able to open the exit and move the hatch out of the way rapidly in the event of an evacuation. The mechanism had to comply with current airworthiness regulation, not result in a loss of passenger seats and had to maintain the cabin pressure and structural integrity of the aircraft. Specific criteria were also included relating to operation of the exit. These criteria included that the hatch must remain attached to the fuselage after operation, that it must be amenable to retrofitting onto current aircraft and ‘must be simple and obvious to operate with a minimum of effort’ (Cobbett et al, 1997, p. 4). One prototype concept was deemed to meet all the criteria and was referred to in the study as the ‘upwards sliding hatch’, which although results in some reduction in the amount of overhead locker space, met all the other criteria and was similar in design to exits that were found at the time on a number of aircraft including the Boeing 767, the Hawker Siddeley Trident, the McDonnell-Douglas DC19 and MD11 series aircraft (Cobbett et al, 1997).

The alternative exit mechanism differed to the traditional Type III exit design. On release of the exit operating handle, the hatch moved slightly inwards into the cabin (as the hatch was still required to be a plug style exit), but remained attached to the fuselage. The passenger was then required to push the hatch upwards where it moved on tracks into the overhead locker area towards the top of the fuselage. As the hatch remained attached to the fuselage, it removed the need for the operator to physically manoeuvre the hatch and resulted in a clear aperture for egress (Cobbett et al, 1997). It was hoped that the modified exit mechanism would reduce or remove many of the difficulties associated with the operation of the traditional Type III exit. A prototype of the upwards sliding hatch concept was then manufactured and tested during simulated operation trials, with baseline trials also conducted within the traditional Type III exit mechanism.

In addition to the change to the exit mechanism, Cobbett et al (1997) also manipulated the seating configuration adjacent to the exit to determine its effect on exit operation. Two seating configurations within the scope of AN79 were tested. These were a 13" vertical projection between the exit seat rows and two 6" vertical projected passageways with the outboard seat removed (OSR). During half of the trials with a 13" vertical projection, an incapacitated passenger (simulated by a mannequin) was placed in the seat adjacent to the exit, with the participant then occupying the central seat in the seating assembly. Ninety-six volunteers participated in the research programme with each participant individually completing three trials (Cobbett et al, 1997).

Using exit operation time as the dependent variable (which was defined as the time taken from when the participant placed their hand on the operating handle until they had placed one foot on the wing), a statistically significant difference attributable to the exit mechanism was reported, irrespective of the seating configuration (Cobbett et al, 1997). Participants operated the exit quicker with the modified upwards sliding ADH mechanism compared to when the traditional Type III mechanism was used. Placing an incapacitated passenger next to the exit increased the time taken to operate the exit across both exit mechanisms (Cobbett et al, 1997).

Although only the Cobbett et al study specifically investigated a change to the exit mechanism, there is support within the cabin safety industry as to the benefits of the installation of ADHs. During the McLean et al (2002) study previously reported, a number of exit operators disposed of the hatch in an inappropriate location. McLean et al argue that solutions could be put in place to diminish such events, which would include exit mechanism designs that 'are automatically stowed outside the evacuation path upon opening or an operational principle that requires the hatch to be discarded outside the airplane when cabin interior configurations more easily promote potential exit obstructions (p. 32).

9.4. Boeing's Next-Generation automatic overwing exit

The Boeing Company have responded to the need to address the difficulties associated with the operation of the traditional Type III exit through the design and development of the Next-Generation overwing hatch. This exit mechanism was designed to 'enhance the emergency egress capability' of the aircraft (Graeber and Mumaw, 1999, p. 15. The Boeing Next-Generation exit has utilised a different type of design in that 'the door remains attached to the aircraft…it moves in [due to the plug style exit] and down, then it releases out and swings up out of the way' (Graeber and Mumaw, 1999, p. 15). During this process the hatch is still attached to the fuselage by means of top hinges. The design of the hatch is such that it 'opens outwards as passengers would intuitively expect' (NTSB, 2000, p. 40). The Boeing Next-Generation automatic overwing exit is shown in Figure 5.

Figure 5: The Boeing Next-Generation automatic overwing exit Photograph courtesy of Graeber and Mumaw, 1999 in Harris, 1999, p. 15)

As highlighted by Graeber and Mumaw this new design removes both the physical elements of the exit operator having to support and manoeuvre the hatch and as the hatch remains attached to the fuselage, it removes the other main physical element of hatch disposal. It is also argued that as on release of the operating handle the exit swings out, the new mechanism removes the understanding about the process of exit operation. Graeber and Mumaw cite that during usability trials with naïve operators, operating instructions were not required in order for the passenger to understand how the exit operated (although as per good practice and regulation, operating instructions are provided adjacent to the exit).

The NTSB concluded that the design of the Boeing Next-Generation exit 'in short…eliminates any guesswork about how the exit operates or what to do with the exit hatch once it is opened. The Safety Board believes the FAA should require Type III overwing exits on newly manufactured aircraft to be easy and intuitive to open and have automatic hatch stowage out of the egress path' (NTSB, 2000, p. 40).

9.5. Rationale for Experiment Three

Following their remit by the FAA to investigate the issue, the Cabin Safety Harmonization Working Group submitted a report to support the introduction of newly designed exit mechanisms that 'shall be designed such that, when opened, the hatch/door cannot reduce the size of the exit opening and/or adjacent passageways below the required minimum dimensions, nor shall it obstruct the required exit access to or from the exit in any way' (FAA, 2002, p. 6). A number of arguments were put forward as rationale by the CSHWG for this proposed change. These included the acknowledgement that the traditional Type III exit mechanism could result in operation and disposal difficulties, that there was the potential for internal placement of the hatch to result in evacuation difficulties and that as one such exit design was already certified for use on some aircraft (i.e. the Boeing Next-Generation Type III exit) it was reasonable for non-disposal hatches to be required on all newly certified aircraft (FAA, 2002).

The CSHWG proposed the introduction of non disposing hatches on aircraft with a seating capacity of 41 seats and above as they were of the opinion that a more substantial design would be needed for installation on smaller transport aircraft and this may incur a higher cost penalty. However it is considered naïve to restrict thinking due to further design considerations and development, without establishing any potential improvements an ADH might bring to exit operation on a smaller transport aircraft. It is interesting to note that the working group themselves concluded that 'it was also recognised that smaller transport aircraft could benefit significantly [from non-disposable hatch designs] and more work would be required to make a final decision' (FAA, 2002, p. 6).

Based on the regulatory view that additional work was required regarding non-disposable hatches on smaller transport aircraft, and the consideration of the potential benefits that one automatically disposed hatch design could bring, it was decided to investigate the influence of an ADH exit design on passenger exit operation from a smaller transport aircraft. It is noted that previous work (Cobbett et al, 1997) investigated the ADH design on exit operation, however trials were only conducted from a large single aisle interior configuration. As the Cobbett et al (1997) was an extensive study into the benefits of one ADH mechanism in a large single aisle interior configuration and resources were limited in the current experiment, it was decided to focus on the benefits of an ADH mechanism in a smaller interior configuration only. With a narrower fuselage and lower headroom at the Type III exit, it was considered important to investigate Type III operation and evacuation in a smaller interior configuration. This was necessary in order to investigate the extent to which regulations concerning the Type III exit and the scope of regulations relating to automatically disposed hatches would apply to both types of aircraft.

9.6. Objective of Experiment Three

The objective of Experiment Three was to investigate the effect of one type of ADH the 'upwards sliding' mechanism (as used by Cobbett et al, 1997), referred to in the current study as the 'up and over' ADH exit mechanism, compared to the traditional 'plug' exit mechanism in the small interior cabin configuration. Data were to be provided on the time taken to operate the exit and the operator's perception of the task.

10.0 Method: Experiment Three

10.1. Methodological considerations

The methodological considerations relating to the realism of the cabin simulator and the sampling strategy were identical to those in Experiment One, as detailed in Section 2.1. However in this experiment, as in Experiment Two, individual participants were recruited to complete the task as opposed to groups of participants.

After Experiment Two, there was some concern that there was not enough pressure on participants to operate the exit and evacuate as quickly as possible. In order to add a degree of pressure on the participant to operate the exit and evacuate as quickly as possible in this experiment, three ‘stooge’ passengers were also seated in the cabin during the evacuations. Unknown to the participant, the ‘stooge’ passengers were confederates of the researcher. The ‘stooge’ passengers were seated in seats adjacent to the participant, and on the call to evacuate released their seatbelts and moved towards the exit. It was anticipated that this would encourage the participant to operate the exit as quickly as possible. The other ‘passengers’ did not assist in exit operation.

10.2. Ethical and safety considerations

Ethical and safety considerations in line with those reported in Experiments One and Two were followed. Ethical approval for the experiment was granted.

10.3. Research design

Experimental trials were conducted to investigate the influence of the Type III exit mechanism on exit operation and evacuation. This resulted in a two groups post test design.

10.3.1. Independent variables

There was one independent variable in the research study, the Type III exit mechanism. Trials were either conducted with the Type III exit configured as a traditional “plug” style exit mechanism or as a modified “up-and-over” automatically disposed hatch exit mechanism.

10.3.2. Dependent variables

As during Experiment Two, exit operation timings and questionnaire data were collected during the experiment. Exit operation timings were extracted from the time coded video footage of the trials, measured to one tenth of a second. All performance timings were taken from the Captain's command to evacuate which was "Undo your seatbelts and get out!" For Type III exit operation, several timings were taken. The first was hatch release time, which was the time from the call to evacuate (which was "Undo your seatbelts and get out!") until the point at which the exit hatch was released from the exit aperture and moved inwards as the operating handle was released. The second was operation time, which was the time taken from the point at which the exit hatch was released, until the hatch had been disposed of and the exit was available for egress. The final timing was exit availability time which was the sum of the release and operation times.

Participant rating scales from a post evacuation questionnaire were also collected. A copy of the questionnaire can be found in Appendix P. The questionnaire asked participants to rate various aspects of their evacuation experience using a seven point Likert type scale. The other questions on the questionnaire asked participants to provide qualitative comments about their experience.

10.3.3. Experimental schedule

Independent measures were used to remove practice and learning effects, it was decided to use independent measures, with each participant operating the Type III exit in only one condition. The experimental schedule, showing how the eighty evacuation trials were run in the two test conditions, is given in Table 20.

Table 20: Experimental schedule

Type III exit mechanism	
Traditional "plug" exit mechanism	**Modified "up and over" ADH mechanism**
Participants 1-40	Participants 41-80

10.4. Participants

Eighty individuals were recruited as participants, with each participant completing the evacuation individually. Each participant was recruited in accordance with the criteria specified in Experiment One. In addition as detailed in Section 10.1 there were three 'stooge' passengers in the cabin during the evacuations.

10.5. Equipment/materials

10.5.1. Test facility

As with the other experiments, the test facility for the trials was the Boeing 737 cabin simulator. The traditional Type III exit mechanism was used for half the trials and the modified ADH exit mechanism was used for the remaining trials. The modification involved converting the traditional Type III exit mechanism to an "up-and-over" style automatically disposed hatch mechanism, as used in previous research (e.g. Cobbett et al, 1997). The "up-and-over" hatch slid into the overhead lockers with the aid of a spring mechanism, rather than flipping outside against the fuselage. The Type III exit in either the traditional or modified exit mechanism was used during all evacuations in this programme.

For all tests, the facility was modified into a small interior configuration, as documented in Experiment One. The camera positions were as Experiment One. During the trials "simulated" daylight was present down one side of the cabin as in Experiment One. Photographs of the cabin with both exit mechanisms are provided in Appendix Q.

10.5.2. Materials

As per Experiments One and Two, each participant was provided with a clipboard that contained all the paperwork for the trials. The trials materials included a volunteer information sheet similar to that provided in Experiment One with the exception the information about the number of trials and the payment details (a copy from Experiment One is provided in Appendix E). A volunteer consent and medical clearance form as per Experiment One was also provided (as shown in Appendix F).

The demographic questionnaire used in Experiment One was again used to collect background information (a copy can be found in Appendix G). As the focus of this experiment was on exit operation, the post evacuation questionnaire used reflected this (as shown in Appendix P). The questionnaire asked participants about their experience of using the Type III exit hatch, including findings the operating handle, unlatching the exit hatch, using the operating handle, the clarity of the instructions for disposal of the hatch, the opening the exit hatch and moving the hatch out of the way. Other aspects of the evacuation process were also covered on the questionnaire including the level of difficulty in moving between the seats in the exit row and moving through the exit and out of the aircraft. Participants were asked to provide a rating for each of these elements on a seven point scale where 1 was very easy/very clear and 7 was very difficult/very unclear. Finally participants were asked about any physical features within the cabin or the exit that had helped or hindered their evacuation. Participants were asked to provide open responses to these questions where applicable. Other questions were included on the post evacuation questionnaire at the request of the sponsor, however these were not of relevance to the current experiment and have not been analysed.

10.6. Procedure

On arrival, members of the research team greeted and checked in each participant. Participants were then provided with a volunteer number and a clipboard containing the paperwork for the trials. The pre-trial procedure was the same as Experiment Two.

10.6.1. Pre-trial procedure

On completion of the pre-trial briefing, the cabin crew member accompanied the participant to the cabin simulator.

10.6.2. Trial procedure

10.6.2.1. Seating

Each participant was assigned to the seat adjacent to the Type III exit. The three ‘stooge’ passengers were each assigned a seat in the vicinity of the exit operator. The assigned seats were the seat directly next to the Type III operator, the seat directly in front of the Type III exit operator and the aisle seat in the Type III exit row on the port side of the cabin. Each ‘stooge’ passenger occupied the seat they were assigned for each trial.

10.6.2.2. Safety briefings

Once seated, a member of cabin crew provided a safety briefing which included the location of the exits, and demonstrations of the use of seatbelts and oxygen masks. In addition, the participant received a minimal individual briefing on their emergency duties, which only highlighted to them that they were sat next to an emergency exit, that they may be required to open the exit in the event of an emergency and where they could find additional safety information on exit operation. The briefings were identical to those provided in Experiment One and can be found in Appendix I.

10.6.2.3. The call to evacuate

When the safety briefings were complete, the cabin crew checked the cabin. As the trials were to simulate an emergency evacuation on take off, shortly after the cabin check a pre-recorded evacuation scenario was played. This included a period of engine noise (approximately 30 seconds), followed by an announcement from the Captain to “Undo your seat belts and get out!” The scenario was identical to that played during Experiment One. A transcript of the evacuation scenario is contained in Appendix J.

10.6.2.4. Cabin crew actions

At this point, the cabin crew member, who was located at the front of the cabin, commanded the passenger to open the Type III exit and move quickly throughout the evacuation process. The commands were as those documented in Experiment One. The ‘stooge’ passengers were instructed to react to the call to evacuate, undo their seatbelts and move towards the Type III exit.

As in previous experiments, members of the research team were located outside the exit and marshalled the participant to a place of safety. The evacuation was deemed complete when the passenger had evacuated the cabin.

10.6.3. Post-trial procedure

After evacuating, the participant was asked to complete a post-evacuation questionnaire. A copy of the questionnaire is provided in Appendix P. On completion of the post-evacuation questionnaire, the participant was thanked, debriefed and paid. Finally, the participant was provided with a thank you letter (as per Experiment One) containing contact details for the research team. A copy of this letter is provided in Appendix K.

10.7. Analysis

The video footage was edited and a time code was added. The exit operation times were extracted from this footage. All performance exit operation data, along with the quantitative responses from the post evacuation questionnaires were entered into SPSS version 14 for quantitative analysis.

Qualitative comments provided in response to the open questions on the post evacuation questionnaire were collated on a question-by-question basis and have been used to add depth to the quantitative results.

11.0. Results: Experiment Three

11.1. Sample

A total of 75 participants took part in the testing programme (80 experimental trials were scheduled, but several participants failed to attend). Fifty-three participants were male (70.7%) and 22 were female (29.3%). It is noted that one participant did not answer the demographic questionnaire. Participants provided their age at the time of the testing session. Participants' ages ranged from 21 to 46 years, with a mean age of 27.5 years, and a standard deviation of 5.6 years. Six participants were left handed (8.0%) and 68 were right handed (90.7%). Most participants had flown previously on a commercial flight (72 participants, or 96.0%), and no participants reported having to make an emergency evacuation. Participants were screened at the recruiting stage to ensure that they had no previous experience of operating a Type III exit.

11.2. Completed evacuations

Thirty-seven trials were conducted in the traditional "plug" exit configuration, and 38 trials were conducted in the modified "up and over" ADH exit configuration. There were no reported injuries.

11.3. Inferential statistics

In all inferential statistical tests Type III exit mechanism was entered as an independent variable and either the exit operation performance measure or the questionnaire ratings were entered as the dependent variable.

11.4. Time taken to make the Type III exit available

The mean hatch release times are provided in Table 21. All mean times and mean participant ratings have been rounded up to one decimal place. A t-test conducted on these data revealed no statistically significant difference attributable to hatch type $t(64.77) = 1.76$, $p=0.08$. As Levene's test for equality of variances was significant, equal variances were not assumed and adjusted values have been presented.

Table 21: Mean hatch release time (in seconds) in each condition

Type III exit mechanism	
Traditional "plug" mechanism	**"Up and over" ADH mechanism**
3.8 (sd 1.0)	3.3 (sd 1.4)

The mean exit operation times are provided in Table 22.

Table 22: Mean exit operation time (in seconds) in each condition

Type III exit mechanism	
Traditional "plug" mechanism	**"Up and over" ADH mechanism**
8.5 (sd 3.7)	2.5 (sd 1.2)

As can be seen in Table 22, the time taken to operate the exit varied by test condition. An independent t-test was conducted on the data which revealed a statistically significant difference in the time taken to operate the Type III exit between exit types $t(42.90) = 9.25$, $p=0.00$. As Levene's test for equality of variances was significant, equal variances were not assumed and adjusted values have been presented. Participants operated the exit significantly faster in the "up and over" automatically disposed hatch condition than they did in evacuations with the traditional "plug" exit mechanism as shown in Table 22.

The mean exit availability times are provided in Table 23.

Table 23: Mean exit availability time (in seconds) in each condition

Type III exit mechanism	
Traditional "plug" mechanism	**"Up and over" ADH mechanism**
12.2 (sd 4.3)	5.8 (sd 2.1)

As can be seen in Table 23, the time taken to make the exit available for evacuation varies by test condition. An independent t-test was conducted on the data which revealed a statistically significant difference in the time taken for participants to make the exit available for evacuation, due to exit type $t(59.11) = 8.24$, $p=0.00$. As Levene's test for equality of variances was significant, equal variances were not assumed and adjusted values have been presented. Participants were able to make the exit available faster during evacuations where the hatch had an automatic disposal "up and over" mechanism than when it was a traditional "plug" style mechanism as shown in Table 23.

11.5. Perceived difficulty of the Type III exit

In addition to the video timings on exit hatch release, operation and availability times, data from the post-evacuation questionnaires were also analysed. Specific questions were designed that concerned the Type III exit. These related to finding the exit operating handle, unlatching the exit hatch, using the exit operating handle, opening the exit hatch, the weight of the hatch, the size of the hatch, moving the hatch out of the way, and any factors related to the exit hatch that helped or hindered the participant during their evacuation.

Participants were asked about the level of difficult in finding the exit operating handle. The mean difficulty ratings are provided in Table 24. An independent t-test conducted on these data revealed no statistically significant differences attributable to exit type $t(72) = 1.06$, $p=0.30$.

Table 24: Mean Type III exit operator difficulty ratings (where 1 was very easy and 7 was very difficult) for finding the exit operating handle in each condition.

Type III exit mechanism	
Traditional "plug" mechanism	**"Up and over" ADH mechanism**
1.6 (sd 1.0)	1.3 (sd 0.9)

The perceived level of difficulty in unlatching the hatch was also addressed on the post evacuation questionnaire. The mean difficulty ratings are provided in Table 25.

Table 25: Mean participant difficulty ratings (where 1 was very easy and 7 was very difficult) for unlatching the exit hatch in each condition.

Type III exit mechanism	
Traditional "plug" mechanism	**"Up and over" ADH mechanism**
2.2 (sd 1.3)	1.5 (sd 1.0)

As can be seen in Table 25, the difficulty ratings for unlatching the exit hatch varied between the test conditions. The data were entered into an independent t-test which revealed a statistically significant difference in the difficulty ratings between exit type conditions $t(66.76) = 2.80$, $p=0.01$. Participants using the traditional "plug" exit, reported that it was significantly more difficult to unlatch the exit hatch than those using the "up and over" ADH, as evidenced by the higher difficulty rating scores as shown in Table 25.

The post evacuation questionnaire asked participants to rate the level of difficulty in using the exit operating handle. The mean difficulty ratings are provided in Table 26.

Table 26: Mean participant difficulty ratings (where 1 was very easy and 7 was very difficult) for using the exit operating handle in each condition.

Type III exit mechanism	
Traditional "plug" mechanism	**"Up and over" ADH mechanism**
2.0 (sd 0.9)	1.4 (sd 0.8)

As can be seen in Table 26, there is some variation in the mean difficulty ratings between each test condition. The data were entered into an independent t-test which revealed a statistically significant difference in the difficulty ratings between exit type conditions $t(71) = 2.93$, p=0.01. Participants perceived using the exit operating handle as significantly more difficult with the traditional "plug" exit mechanism than with the "up and over" automatically disposed hatch as shown in Table 26.

Participants were asked about the level of difficulty opening the exit hatch. The mean difficulty ratings are provided in Table 27.

Table 27: Mean participant difficulty ratings (where 1 was very easy and 7 was very difficult) for opening the exit hatch in each condition.

Type III exit mechanism	
Traditional "plug" mechanism	**"Up and over" ADH mechanism**
3.0 (sd 1.5)	1.7 (sd 1.1)

As can be seen in Table 27, the mean difficulty ratings of opening the exit hatch varied between the test conditions. The data were entered into an independent t-test which revealed a statistically significant difference in the difficulty ratings between exit type conditions $t(71) = 4.36$, p=0.01. Participants using the traditional "plug" exit, reported that it was significantly more difficult to open the exit hatch than the participants using the "up and over", as evidenced by the higher difficulty rating scores in Table 27.

The post evacuation questionnaire asked participants to rate the clarity of the instructions for disposing of the door. The mean clarity ratings are provided in Table 28. An independent t-test conducted on these data revealed no statistically significant differences attributable to exit type $t(66) = 1.20$, p=0.23.

Table 28: Mean participant clarity ratings (where 1 was very clear and 7 was very unclear) for the instructions for disposing of the door in each condition.

Type III exit mechanism	
Traditional "plug" mechanism	**"Up and over" ADH mechanism**
3.9 (sd 2.1)	3.3 (sd 2.1)

The final question analysed from the post evacuation questionnaire related to the difficulty of moving the hatch out of the way. The mean difficulty ratings are provided in Table 29.

Table 29: Mean participant difficulty ratings (where 1 was very easy and 7 was very difficult) for moving the hatch out of the way in each condition.

Type III exit mechanism	
Traditional "plug" mechanism	**"Up and over" ADH mechanism**
4.9 (sd 1.4)	2.3 (sd 1.7)

As can be seen in Table 29, the mean difficulty ratings for moving the hatch out of the way varies by test condition. The data were entered into an independent t-test which revealed a statistically significant difference in the difficulty ratings between exit type conditions $t(68) = 6.98$, p=0.01. Participants using the traditional "plug" exit, reported that it was significantly more difficult to move the hatch out of the way than the participants using the "up and over" ADH, as evidenced by the higher difficulty rating scores in Table 29.

11.6. Perceived difficulty of the evacuation

In order to investigate perceived difficulty of the evacuations, data from a selection of questions on the post-evacuation questionnaires were also analysed.

The participants were asked about the difficulty of moving between the seats at the exit row on the post evacuation questionnaire. The mean ratings provided in response to this question are given in Table 30. An independent t-test conducted on these data revealed no statistically significant differences attributable to exit type $t(66) = 1.40$, p=0.17.

Table 30: Mean participant difficulty ratings (where 1 was very easy and 7 was very difficult) for moving between the seats at the exit row in each condition.

Type III exit mechanism	
Traditional "plug" mechanism	**"Up and over" ADH mechanism**
2.7 (sd 1.6)	2.2 (sd 1.3)

The post-evacuation questionnaires asked participants to rate the difficulty of moving through the exit and out of the aircraft. The mean ratings provided in response to this question are given in Table 31.

Table 31: Mean participant difficulty ratings (where 1 was very easy and 7 was very difficult) for moving through the exit and out of the aircraft in each condition.

Type III exit mechanism	
Traditional "plug" mechanism	**"Up and over" ADH mechanism**
3.0 (sd 1.6)	2.1 (sd 1.3)

The data were entered into an independent t-test which revealed a statistically significant difference in the difficulty ratings between exit type conditions $t(71) = 2.61$, $p=0.01$. Participants perceived moving through the exit and out of the aircraft as significantly more difficult with the traditional "plug" exit mechanism than with the "up and over" automatically disposed hatch condition as shown in Table 31.

11.7. Type III exit factors that helped and hindered evacuation

In addition to the rating scales, the participants were asked to state what (if anything) related to the Type III exit hatch that had helped or hindered their evacuation. In response to any factors related to the exit hatch that helped the evacuation, a number of the comments from participants within the traditional "plug" Type III exit mechanism condition related to the exit operating handle. Participants reported that it was clear that they needed to pull the handle to operate the exit and the location of both handles on the hatch assisted them. Whereas a number of participants within the "up and over" automatically disposed hatch condition reported that it was the exit hatch mechanism itself that helped their evacuation.

Traditional "plug" exit mechanism

"It looked logical to pull the red handle" (Participant 2, traditional "plug" exit mechanism).

"The clarity of the lever to pull down to open" (Participant 5, traditional "plug" exit mechanism).

"Red handle, intuitive colour for emergencies" (Participant 33, traditional "plug" exit mechanism).

"Two handles were quite helpful" (Participant 3, traditional "plug" exit mechanism).

"Where the handles were placed on the exit door" (Participant 11, traditional "plug" exit mechanism).

"Up and over" automatically disposed exit mechanism

"Very easy to open, just slid up" (Participant 42, "up and over" ADH).

"Not heavy and slides up. There was no obstruction. And easy to use even for ladies" (Participant 57, "up and over" ADH).

"This system is a tremendous improvement on the old disposable exit" (Participant 69, "up and over" ADH).

"It was very easy to open the door and the exit operating handle was at the right position: neither too high or too low" (Participant 78, "up and over" ADH).

Participants were also asked if any factors related to the exit hatch hindered their evacuation. A number of participants who evacuated with the traditional "plug" Type III exit mechanism commented on the difficulties they experienced related to the weight, size, shape and manoeuvrability of the exit hatch. Whereas in the "up and over" automatically disposed exit condition, there were only half as many comments relating to exit hatch factors that participants reported hindered them. Participants in this condition reported that the step up required to evacuate through the exit had caused some difficulties, along with the exit mechanism itself.

Traditional "plug" exit mechanism

"The size, the weight and the room I had to manoeuvre in" (Participant 6, traditional "plug" exit mechanism).

"The weight hindered its removal" (Participant 8, traditional "plug" exit mechanism).

"Exit too big to manipulate in the space available" (Participant 14, traditional "plug" exit mechanism).

“Up and over” automatically disposed exit mechanism

“High step” (Participant 58, “up and over” ADH).

“The hatch failed to open properly” (Participant 69, “up and over” ADH).

“Hand blocked between fuselage and door, hatch too light” (Participant 62, “up and over” ADH).

“Did not know which way door would move. Tried pushing outwards nothing happened” (Participant 76, “up and over” ADH).

In addition, the participants were asked to state if any physical features within the cabin hindered their evacuation. Participants in both the traditional “plug” exit mechanism condition and in the “up and over” automatically disposed hatch condition reported that limited headroom at the Type III exit and limited space around the exit and exit row had hindered them.

Traditional “plug” exit mechanism

“The height of the overhead baggage compartments. The room between the rows. The size of the exit. (Participant 6, traditional “plug” exit mechanism).

“The lack of headroom” (Participant 8, traditional “plug” exit mechanism).

“The space between the front seat and my seat when I take out the emergency door” (Participant 20, traditional “plug” exit mechanism).

“Up and over” automatically disposed exit mechanism

“Low ceiling” (Participant 58, “up and over” ADH).

“The space too small” (Participant 60, “up and over” ADH).

“Low overhead cabins” (Participant 64, “up and over” ADH).

“Too small, you have to slightly bend to get out” (Participant 80, “up and over” ADH).

12.0. Discussion – Experiment Three

12.1. Type III exit mechanism

The results indicated that there was a statistically significant difference in the time taken to operate the Type III exit attributed to the type of exit mechanism. Participants operated the Type III exit quicker in the ADH "up and over" hatch condition than in the traditional "plug" exit condition. However, there was no statistically significant difference in exit release time due to exit type mechanism. The current research investigating an ADH exit mechanism in a smaller interior configuration replicates and supports the findings of Cobbett et al (1997). Cobbett et al found in a larger single aisle cabin participants operated the exit significantly faster with the modified "up and over" ADH exit than with the traditional "plug" exit, replicating the findings from this experiment.

There were also significant differences in the exit operators' perceptions of task difficulty. Participants perceived it as significantly more difficult to unlatch the exit hatch, use the exit operating handle and open the exit when the exit hatch mechanism was configured as the traditional "plug" exit, as oppose to when the exit was in the ADH "up and over" mechanism. This is in line with the findings of Cobbett et al (1997) who reported that more participants who operated the traditional exit mechanism reported difficulties compared to the number of participants who reported difficulties with the ADH mechanism. However, there were no significant differences due to exit type in participant's perceptions of the clarity of exit operation instructions on the safety card or during the personal briefing given by the cabin crew or the instructions for disposing of the exit. The previous experiment had shown the complex nature of Type III exit operation and the benefits of providing detailed information on the tasks involved in operation of the Type III exit. As operation of the ADH exit was simpler and more intuitive, it is surprising that the instructions given on the safety card for the ADH mechanism were not perceived as clearer by exit operators.

It was noted that in the current research programme, the cabin was configured to represent a smaller internal configuration, but the diameter of the actual fuselage was not reduced. The Cobbett et al (1997) study did highlight potential difficulties with fitting the mechanism onto smaller diameter fuselages. However the exit mechanism tested during this experiment was just a prototype to evaluate the concept of an ADH exit mechanism within a smaller transport aircraft. Other ADH designs, such as the Boeing Next-Generation outward opening design, would not have the same issues with the reduced diameter fuselage associated with smaller transport aircraft.

The findings from this experiment have provided further support to the recommendation of a number of cabin safety commentators (including Cobbett et al (1997); the NTSB (2000) McLean et al (2002); the CSHWG (2002) and R.G.W. Cherry and Associates (2006)) who have proposed the installation of ADH in place of traditional Type III exits on some aircraft types. The findings from this experiment have also provided further support to the NTSB recommendations that Type III exits with ‘automatic hatch stowage out of the egress path’ should be installed on all ‘newly manufactured aircraft’ (2000, p. 80). The experiment adds data on the issue of ADHs on board smaller transport aircraft as requested by the CSHWG in 2002. The findings from this experiment support one of the comments made by the CSHWG who felt that ‘smaller transport aircraft could benefit significantly [from non-disposable hatch designs] (FAA, 2002, p. 6).

12.2. Summary of Experiment Three

The objective of Experiment Three was to investigate the effect of one type of ADH the ‘upwards sliding’/ ‘up and over’ mechanism, compared to the traditional Type III ‘plug’ exit mechanism on exit operation in a smaller interior configuration. The results from the experiment have highlighted that the time taken to operate the exit and make it available for egress and participants’ perceptions of the operation task can be improved through the installation of an ADH on a smaller transport aircraft.

13.0 Introduction – Exit hatch placement

13.1. Introduction to Experiment Four

A review of simulated evacuation research studies, simulated trials and aircraft accidents has highlighted that Type III hatches were not always disposed of outside the aircraft and had been reported in a number of locations inside the cabin. These locations have included on the exit row seats, in the passageway leading to the exit and in the main aisle. It is likely that inappropriate placement of the Type III hatch may result in a blockage to the egress route and be a potential impediment to the remaining passengers who need to evacuate through the exit aperture.

The effect of the placement of the exit hatch is unknown as there is limited publicly available literature on the issue. Although the hatch may be an impediment to all aircraft cabins irrespective of size, it was felt that potential impediments caused by inappropriate hatch disposal may be more pronounced in smaller transport aircraft. The reasons for this are related to the physical parameters of the smaller transport cabin. These cabins are likely to have only one or two seats either side of the main aisle and if the exit hatch is placed internally, due to the reduced length of the seat assembly, it may create a greater obstruction in this area. In addition, the reduced length of the seats may result in the disposed hatch impeding passenger egress along the main aisle to the floor level exits, as well as access to the overwing exits. Finally if the hatch is left in such a location inside the cabin whereby it impedes movement towards the exit, due to the limited headroom associated with a smaller transport aircraft, passengers will have restrictive space in which to traverse over the hatch and out through the aperture.

13.2. Regulations on exit hatch disposal location

After operation of a traditional Type III exit, the exit hatch is no longer attached to the aircraft fuselage. The exit operator is required to dispose of the hatch into an appropriate location where it does not impede egress. As previously highlighted in Section 5.4 the operation of and disposal of the exit hatch may place physical and comprehension demands on the exit operator. The disposal location should not impede firstly the egress through the exit row and aperture of the exit operator and subsequently the other passengers who opt to use the exit. The exit operator has two options when considering the disposal location – outside or inside the cabin. Inside the cabin the hatch may be left on the seats either in the exit row or adjacent seat rows, on the floor in the exit row, adjacent to the fuselage if the cabin if configured with the outboard seat removed or the hatch may be placed into the main aircraft aisle.

Following the accident at Manchester in 1985 and the egress difficulties experienced at the Type III exit, the AAIB recommended that the exit hatch should be disposed of outside the aircraft ‘to avoid the hatch becoming a further obstacle to evacuating passengers’ (AAIB, 1988, p. 136). Current UK CAA guidance to operators is that Type III exit hatches should be located outside the aircraft cabin after operation. Following Manchester, the CAA concluded that ‘the exit hatch is potentially a more significant hazard inside the aircraft and could, in some circumstances, become an obstruction’ (Barthelmess, 1989, p. 7).

Although exterior placement is recommended by the UK regulator, this is not the case with other authorities who suggest that it is acceptable for the hatch to be disposed of outside or inside the aircraft cabin. Within the Advisory Circular on passenger safety cards (AC 121-24C), the FAA advise operators to display any manual tasks that passengers may be required to complete. One of the tasks is the placement of the Type III hatch. The advisory circular states that the card should show the ‘recommended placement of the hatch on the seat or outside the aircraft’ (FAA, 2003, p. 7) which implies that either placement is considered acceptable by the FAA.

13.3. Industry guidance

The Flight Safety Foundation (FSF) in 2001 explored the issue of Type III hatch placement. The FSF found that the recommended exit hatch placement location varied between manufacturers and aircraft types. Airbus informed the FSF during a telephone interview that they usually suggest where a slide is deployed the exit hatch should be disposed of inside the aircraft. Whereas when an evacuation slide is not used, the hatch should be disposed of outside the aircraft. In this study the focus is on smaller transport aircraft and the possible implications of an external hatch coming into contact with a slide are not relevant due to the absence of Type III exit slides on such aircraft. Although in conclusion Airbus were reported as stating that "the ultimate decision is left to the airline to determine" (FSF, 2001, p. 2).

This final point made by Airbus is similar to that of Boeing, who informed the FSF that it was for the manufacturer to provide the equipment, including the operating instructions, but for the individual airlines to determine the disposal location of the exit hatch. Boeing went on to explain that they can suggest a number of options to the airlines which include external or internal disposal. However in conclusion, the Boeing representative stated that "the decision depends on the evacuation situation and ultimately is the operator's responsibility based on their own criteria and conclusions" (FSF, 2001, p. 2).

From these comments it seems that the hatch disposal guidance may be inside or outside depending on the presence of an evacuation slide or the airline's operating procedures. However, if the hatch is left in an inappropriate location inside the cabin, it has the potential to impede egress and may prevent passengers from using the exit.

13.4. Type III hatch disposal in accidents

An accident analysis into Type III hatch disposal was conducted in response to regulatory activity on automatically disposed hatches (ADHs) and automatically operating exits (AOEs) by R.G.W Cherry and Associates (2006b). The project reviewed a number of aviation accidents to determine the number of Type III exits opened, and the occurrence of hatch disposal inside the aircraft cabin.

The accidents used in the analysis were selected from either the Cabin Safety Research Technical Group (CSRTG) accident database v27 or from a library of accident reports. From these accidents, a subset were selected for analysis if they involved passengers on the aircraft, a fire, an emergency evacuation and that detailed information on the accident had been provided by the accident investigation team.

Based on these criteria, 87 accidents that occurred between 1967 and 2002 were reviewed within the study. Of the 87 accidents, 57 accidents included aircraft with Type III exits. Of the 57 aircraft, 65 Type III hatches were operated, although the study authors found that, unfortunately, the location of the disposed Type III exit hatch could only be determined for 17 of the exits. Based on the cases where hatch location could be determined, the study concluded that 'approximately 80% were disposed of inside the cabin' (2006b, p. 4).

In three of the cases extracted by R.G.W. Cherry and Associates (2006b) from the accident database the hatch disposal location was reported as a hindrance to the evacuation (a point noted by the report authors). The reports were during the evacuation of the McDonnell Douglas DC-8 accident at Bangor, Maine in 1973 where it was reported that the hatch was left on the floor in the seat row and caused an impediment. The placement of the Type III hatch was also mentioned during the evacuation of the Boeing 737 following an engine fire at Calgary, Alberta, in 1984. The exit plug was reportedly disposed of on the exit row seats but the positioning resulted in a blockage along the exit row passageway. Finally in the accident and subsequent evacuation from the McDonnell Douglas MD-82 aircraft at Little Rock, Arkansas, in 1999 hatch placement was mentioned. However the report was contradictory in places. A passenger reported that the hatch caused an obstruction at the exit and someone from the outside of the aircraft removed the plug to help the evacuation, but also that the passenger progress through the exit was "smooth" (R.G.W. Cherry and Associates, 2006b).

The authors did highlight that of the 57 accidents, 35 involved the use of the Type III exits, but in only 12 cases was the disposal of, or placement of the Type III hatch detailed within the investigatory report. It was reported that it was not known if the absent information on exit hatch placement meant that the hatch did not impede the evacuation or that the hatch was disposed of correctly. The authors concluded that the data on the placement of Type III hatches is limited and the effect of hatch placement on the evacuation is indeterminate (R.G.W Cherry and Associates Ltd, 2006b).

It must be noted that during their analysis R.G.W Cherry and Associates Ltd reviewed the evacuation commentaries within the selection of accident reports to highlight any incidents where exit hatch disposal was cited as not impeding the evacuation and found two examples These were the evacuation of an aircraft at London (Heathrow) in 1992 and one in the Virgin Islands in 1976. There were no other accidents where they felt the accident report gave an unambiguous comment of the influence of an internally disposed hatch on egress.

The study authors concluded that ‘there is limited information in accident reports to suggest that disposal of Type III hatches internal to the aircraft are a frequent cause of evacuation impediment’ (R.G.W Cherry and Associates Ltd, 2006b, p. 15). If this statement was taken alone, the importance of the area may be questioned, however the report authors go on to state that ‘furthermore, the degree to which internal hatch disposal is an impediment to evacuation is unknown’ (p. 15). Although limited examples of the influence of hatch placement on evacuation were highlighted by this study, the review highlights the need for further work in the area to be conducted.

13.5. Type III hatch disposal in experimental research

During their study on passageway configuration at the Type III exit in 1989, Rasmussen and Chittum acknowledged that the disposal location of the Type III exit during the exit operation trials was not controlled, with observations from the trials suggesting ‘an indiscriminately discarded door may well be more detrimental to safe and rapid egress than many other controllable factors’ (Rasmussen and Chittum, 1989, p. 14). The study authors go on further to suggest that the placement of the Type III hatch may be dependent on the seating configuration adjacent to the exit, as it may not be as much of a hindrance with a 20” vertically projected passageway between the seats, as when a more restrictive passageway is present (Rasmussen and Chittum, 1989). Although not specifically addressed by Rasmussen and Chittum, the area adjacent to the Type III exit may be more restrictive on smaller transport aircraft as well as larger aircraft with a narrower exit row passageway.

The placement of the Type III hatch was also commented on by McLean et al (1992) during their study on the seating configuration adjacent to the exit. When the outboard seat was removed, the hatch was left in the clear area in a vertical position either leaning against the fuselage or the seat row in front of the exit on a number of occasions. Although the hatch was left it this location, it was acknowledged by the study authors that the placement of the hatch was not considered to impede egress (McLean et al, 1992).

During the McLean et al (1992) trials the hatch was also discarded by the hatch operator on the exit operator's seat and on the floor of the exit row, with a higher incident of this behaviour when the access to the exit was at a minimum configuration. McLean et al (1992) state that 'both of these placements can adversely affect the egress rate but the floor placement will generally be the most detrimental, [as] this placement may require those attempting to use the exit to step up into the seat to get past the door and/or move through the exit from a standing position on the outboard seat' (McLean et al, 1992, p. 14). In line with the findings of Rasmussen and Chittum, McLean et al concluded that the seating configuration may influence the hatch disposal location, 'at least in the absence of specific instructions' (McLean et al, 1992, p. 14).

Fennel and Muir (1993) during their research into exit row seating configurations and Type III hatch weights (as discussed in Section 5.5.1) commented on the location of the disposed hatch within the different experimental configurations. Table 32 below shows the placement of the hatch by participants.

Table 32: Placement of hatch by participants. Taken from Fennell and Muir (1993, p. 17)

Hatch placement location	**Percentage of participants**			
	Pre AN79 (3" VP) Trial 1	**AN79 (13"VP) Trial 1**	**AN79 (13"VP) Trial 2**	**AN79 (13"VP) Trial 3**
Outside on the wing	63.5%	37.5%	69.8%	80.2%
On floor in exit row	2.1%	53.1%	25.0%	16.7%
On seat in exit row	10.4%	7.3%	4.2%	2.1%
On the aisle	4.2%	-	-	-
On seat in row in front of exit	2.1%	-	-	-
Failed to complete task	17.7%	2.1%	1.0%	1.0%

As can be seen from Table 32, although the majority of operators disposed of the hatch outside the cabin, a number of operators placed the hatch inside the cabin, typically on the floor in the exit row or on the exit row seats. Interestingly a higher number of participants left the exit hatch on the floor where it was more likely to impede egress than on the seat assembly.

It was noted by Fennell and Muir (1993) that approximately 85% of participants during their first trial with a 13" vertically projected passageway disposed of the hatch into a location (either inside or outside the cabin) which may have caused an obstruction to passengers either in the exit row or once through the exit aperture. However this result must be placed into context as the trials involved individual participants in the cabin and the results may have been different if other passengers had also been in the cabin (Fennell and Muir, 1993).

Fennell and Muir highlighted that more passengers left the hatch inside the cabin during their first trial in the 13" vertically projected passageway when there was more space in the access row, although the number of participants who placed the hatch outside the cabin did increase as participants became more practiced in the task (Fennell and Muir, 1993).

The placement of the exit hatch was also reported in the Cobbett et al study (1997). When reviewing the data from the first trial only, Cobbett et al reported that only approximately 40% of participants correctly disposed of the traditional Type III hatch outside the cabin. Cobbett et al (1997) provided details on the hatch placement positions of the participants who operated the traditional Type III exit hatch and these are shown in Table 33 below.

Table 33: Hatch placement locations of participants operating the traditional Type III hatch (adapted from Cobbett et al, 1997).

Hatch placement location	**Percentage of participants**		
	Trial 1	**Trial 2**	**Trial 3**
On the floor in exit row	16.7%	6.3%	4.2%
On seat in exit row	10.4%	8.3%	8.3%
Across dummy's lap	10.4%	8.3%	6.3%
Where the outboard seat had been removed from	16.7%	10.4%	4.2%
On the floor behind the exit row (in OSR condition)	6.3%	8.3%	6.3%
Correct disposal onto wing	39.6%	58.3%	70.8%

* As the data have been converted into percentages in this table for ease of comparison across placement locations, due to rounding of decimal places to one decimal place, trial one and trial three totals equal 100.1%

As can be seen in Table 33, although many participants disposed of the hatch in the correct location outside the cabin by trial three, a high number of exit hatches were left inside the cabin during the first trial. Locations included on the floor in the exit area and on the exit row seat assembly.

Exit hatch placement was also discussed during the Cobbett et al (2001) investigation into the influence of Type III exit operator's briefings on exit operation as previously discussed in Section 5.5.2. Twenty-five per cent of participants left the exit inside the cabin, even though the exit operating instructions and briefing informed operators to leave the hatch outside. When the hatch was left inside it was left either on or between the seats in the exit row. Cobbett et al reported a significant effect attributable to level of exit operator's briefing on correct disposal of hatch (deemed to be outside the cabin).

Significantly more operators who received a detailed briefing (either in verbal or written form) disposed of the hatch correctly compared to those operators who did not receive a briefing or were in the minimal briefing group. Cobbett et al remarked that although disposing of the hatch inside the cabin resulted in 'an increase in the exit availability speed, it also meant that the hatch became a potential hindrance, obstructing passage through the exit' (2001, p. 10).

McLean et al's (2002) evacuation study previously discussed in Section 1.9.2 relating to passageway configuration at the Type III exit was the first study to manipulate the placement of the Type III hatch on exit operation and passenger evacuation. Depending on the configuration under test, participants allocated to the task of exit operator were either given a safety card showing the hatch, after operation, disposed of outside the aircraft or inside the aircraft. The internal hatch placement safety information informed operators to place the hatch horizontally on the seats in the exit row leaning against the seatbacks.

During the study it was noted by McLean et al (2002) that when the safety card showed hatch disposal outside the cabin, the operators complied with the instructions. When operators were informed to leave the hatch inside the cabin, the majority of operators placed the hatch in the location specified on the safety card, however a number of occurrences of incorrect placement were observed. Although McLean et al were not specifically looking at the effect of this incorrect placement on evacuation; this highlights the potential for the incorrect placement of the Type III hatch inside the cabin, the impact of which on evacuation is unknown.

A significant effect was shown for naïve participants for hatch location on "exit ready to use time" (this was defined as the time taken from the start of the evacuation until the first participant started to egress through the exit), with times quicker when the hatch was disposed of inside the cabin compared to outside the exit (McLean et al, 2002). McLean et al also investigated the influence of the independent variables on the time for the first person to egress through the aperture (this performance timing was taken from the end of the exit ready to use time, until the first participant had moved through the aperture). As with the exit ready to use measure, a significant effect was reported for hatch disposal location, with times quicker when the hatch was disposed of inside the cabin. McLean et al (2002, p. 10) concluded that 'the time required for removal and disposal of the hatch was the primary variable in launching the evacuation flow.' However, disposing of the hatch inside the cabin may speed up the initial part of the evacuation, but if the internally placed hatch becomes an obstruction, it is likely to have a negative effect on the overall evacuation time or the rate at which participants can evacuate through the exit. It is the overall evacuation rate that is of interest within the current experiment.

Interestingly when looking at the overall evacuation during their repeated measures analysis, McLean and Corbett (2004) removed a number of individual evacuation times that were considered outliers as they were three standard deviations from the mean. This was possible due to the large sample size and resulted in the removal of 131 of the 10,176 individual egress times. Of importance to the current discussion is the rationale given for the removal of these data, which was due to 'errant individual subject behaviour, the exit being jammed with subjects, or the hatch becoming an impediment' (McLean and Corbett, 2004, p. 7). Although McLean and Corbett were not specifically addressing the potential influence of hatch placement, and the placement of the hatch did not result in any trial being stopped, their study has highlighted the impediment that may result from an incorrectly disposed of Type III exit hatch throughout the whole evacuation.

During the McLean et al (2002) study, there was also a discussion about the placement of the Type III exit hatch and the ability of exit operators to follow the safety information given to them. When the hatch was not placed in the location shown in on the safety card, the authors classified it as an 'incorrect' placement. Although the number of incorrect placements was small and all during the internal hatch disposal conditions, the locations of the incorrectly disposed hatches were provided and are of importance to the current study. All of the incorrect exit hatch placements were when the exit operator had been informed to leave the hatch inside the cabin. During three trials the hatch was placed on the floor of the exit row in a vertical position leaning against the seat in front and once was moved during the evacuation from the seat to the floor. On three occasions the hatch was placed on the seats in the row behind the exit and on one occasion the hatch was placed on the other side of the cabin. On one final occasion the hatch was placed in between the seats in the exit row and the aircraft fuselage, although McLean et al reported that this location did not influence the evacuation.

Although in conclusion, when looking at the overall influence of the hatch disposal location on operation and evacuation, McLean et al felt that 'either hatch disposal location could be justifiably chosen for airline operations, as long as aft seat encroachment is limited to the centreline of the exit' (2002, p. 15). In most cases where internal hatch placement was shown, the hatch was placed on the exit seat row assembly and did not impede egress. However, if the hatch were to be placed on the floor or knocked from the seat assembly either into its face or the floor it may impede the access to the exit. In addition the evacuation trials within this study were from a larger transport aircraft where there is likely to be more room for the passengers to manoeuvre within. The available space both due to the narrower fuselage and restrictive headroom is likely to be less in a smaller transport aircraft.

13.6. Rationale for Experiment Four

There seems to be a lack of publicly available information on the impact of the positioning of the exit hatch on evacuation. McLean et al (1992) recommended the need for 'additional tests […] to quantify the specific effects of various door disposal locations' (p. 15). This was reiterated by R.G.W. Cherry and Associates who concluded that 'the degree to which internal hatch disposal is an impediment to evacuation is unknown' (2006b, p. 15).

As smaller transport aircraft have a narrower fuselage it was felt that potential impediments caused by inappropriate disposal may be more pronounced, therefore as an initial study simulated evacuations were only conducted in a smaller transport aircraft, with two seats either side of the main aisle.

As previously discussed in Section 5.1, regulatory thinking in 2002 was that automatically disposed hatches (where the hatch, once operated is still attached to the fuselage) should be required on newly certificated aircraft with at least 41 passenger seats. However it was also acknowledged by the Cabin Safety Harmonization Working Group that 'research trials have not always included full evaluation of the situations that could arise with respect to the hatch' and that further work was required in this area (FAA, 1999, p. 6). To date there is no regulatory requirement for the installation of ADHs on Type III exits. It was anticipated that conducting an experiment into the potential influence of inappropriate hatch placement on evacuation from a smaller cabin will provide the regulatory authorities and the aviation safety community with more information on evacuation from smaller transport aircraft when considering the passenger seating threshold for mandatory ADHs.

In order to address these issues a final study into the influence of exit hatch placement on evacuation was undertaken. Data were only collected in a smaller interior cabin due to the need for more data to explore evacuations from these smaller aircraft types. Anecdotal evidence also suggested that regulatory thinking was still to require an ADH exit mechanism on aircraft with at least 41 passenger seats. As the available resources were limited, it was considered more important, in the first instance, to explore the influence of the internal placement of the hatch within a smaller transport aircraft. It was felt that any potential obstruction caused by the placement of the hatch may be more of an issue in a smaller interior cabin due to the limited space as a result of the narrower fuselage and restrictive headroom.

13.7. Objective of Experiment Four

The objective of Experiment Four was to investigate the effect of Type III hatch placement either outside the cabin or placed internally in the cabin either vertically or horizontally on passenger evacuation from a smaller transport aircraft cabin. Data were to be provided on both evacuation rates and passenger perception of the evacuation.

14.0. Method: Experiment Four

14.1. Methodological considerations

The methodological considerations relating to the realism of the cabin simulator and the sampling strategy were identical to those in Experiment One, as detailed in Section 2.1. As with Experiment One, this experiment involved groups of participants evacuating the cabin. As with Experiment One, a co-operative methodology was used. In order to add a degree of urgency to the evacuation, a group bonus was offered to all participants in the group, if all group members evacuated within an unspecified time limit.

There was one addition challenge with the design for this experiment and that was the balance between ecological validity and experimental control. The issue revolved around the independent variable – the location of the Type III hatch. As the location of the hatch was the independent variable, it was crucial that the hatch was placed in the same location for each trial in the testing condition.

14.2. Ethical and safety considerations

As with Experiment One, the experiment was conducted in accordance with ethical guidelines and an ethics proposal was submitted to, and approved by the Human Factors Department Ethics Committee prior to the research trials taking place. Prior to the experiment, participant safety considerations were reviewed, with provisions in line with Experiment One put in place. Ethical and safety procedures as documented in Section 2.2 were followed with two exceptions. Both exceptions were due to participant safety concerns. Firstly an additional first aider was present outside the operational exit and secondly two additional members of the research team were present on the simulator during the trials. One additional member was located outside the operational exit to assist participants as they evacuated through the exit aperture. The second additional researcher was located inside the cabin and was seated in the vacant seat row opposite the Type III exit. These changes were made to ensure the safety of participants as they negotiated the Type III hatch when it had been placed inside the cabin and as they evacuated onto the wing.

The inclusion of a research confederate inside the cabin simulator to monitor participant safety was also used during the large evacuation programme reported by McLean et al (2002). In these trials the 'safety monitor' was located in the outboard seat of the seat row forward of the Type III exit. The monitor was instructed to be as inconspicuous as possible unless they were required to stop the evacuation if it was felt that there was the potential for injuries to participants (Corbett, McLean and Whinnery, 2003).

14.3. Research design

Experimental trials were conducted to investigate the influence of Type III hatch placement inside the cabin on evacuation. This resulted in a three groups post test design.

14.3.1. Independent variables

There was one independent variable in the research study – the location of the Type III hatch. Three different locations were tested – no hatch inside the cabin (i.e. to simulate hatch disposal outside the aircraft), the hatch placed vertically in the exit seat row, leaning against the seats and the hatch placed horizontally on the floor in the exit row, protruding into the main aisle. In order to ensure that the hatch was in the same location for each trial in the condition, a replica hatch was manufactured and fastened in the desired location in advance of the trial.

14.3.2. Dependent variables

The rate at which participants evacuated the cabin was the dependent variable from the evacuation trial. Evacuation performance timings were extracted from the time coded video footage of the trials, measured to one tenth of a second. All performance timings were taken from the Captain's command to evacuate which was "Undo your seatbelts and get out!" until the last participant had their first foot on the wing[4].

[4] It is noted that during experiment one, the time taken to egress was measured from the call to evacuate until the point at which the last participant had both feet on the wing. However due to the egress path participants took as they exited the simulator, the time for the second foot was sometimes difficult to obtain, therefore to enhance the reliability of the data, it was decided to use the time at which the first foot was placed on the wing

Participant rating scales were also collected from a post evacuation questionnaire designed specifically for evacuations through the Type III exit. A copy of the questionnaire can be found in Appendix R. The questionnaire asked participants to rate various aspects of their evacuation experience using a seven point Likert type scale and these responses were then used as dependent variables. The other questions on the questionnaire asked participants to select from a range of response options or provide qualitative comments about their experience.

14.3.3. Experimental schedule

The experimental schedule, showing the hatch conditions for each trial are shown in Table 34.

Table 34: Experimental schedule for trials

Group No	Hatch placement	Group No	Hatch placement
Group 1	No hatch	Group 13	No hatch
Group 2	Vertical	Group 14	Vertical
Group 3	Horizontal	Group 15	Horizontal
Group 4	No hatch	Group 16	No hatch
Group 5	Vertical	Group 17	Vertical
Group 6	Horizontal	Group 18	Horizontal
Group 7	No hatch	Group 19	No hatch
Group 8	Vertical	Group 20	Vertical
Group 9	Horizontal	Group 21	Horizontal
Group 10	No hatch	Group 22	No hatch
Group 11	Vertical	Group 23	Vertical
Group 12	Horizontal	Group 24	Horizontal

14.4. Participants

Twenty-four groups of up to 18 volunteers were recruited as participants, with each group participating in one session. Participants were recruited via local advertising using the criteria as reported in Experiment One.

14.5. Equipment/materials

14.5.1. Test facility

The test facility as in the previous experiments was the Boeing 737 cabin simulator located at Cranfield University. The Type III exit was the available exit during all trials. A replica Type III hatch was constructed from wood and secured in the required location in advance of participants boarding the simulator. The hatch was constructed in line with the dimensions of a "typical" Type III hatch. As a result of the manufactured hatch the actual exit hatch for the Type III was not in place during the trials. Instead all exits were screened (using plastic sheeting) prior to participants boarding the simulator. On the call to evacuate the cover on the Type III exit was removed and participants evacuated via the Type III exit aperture.

During all trials the facility was modified into the smaller interior configuration to represent a number of key features associated with smaller transport regional aircraft. All trials were conducted in low level lighting. The camera positions were as Experiment One, with an additional camera positioned towards the exit seating row where the hatch was located during the internal conditions.

Photographs of the modified smaller cabin interior can be found in Appendix D. Photographs of the manufactured hatch and the internal hatch locations are provided in Appendix S.

14.5.2. Materials

As per Experiment One, participants were provided with a clipboard that contained all the paperwork for the trials. The trials materials included a volunteer information sheet similar to the one provided in Experiment One with specific trial details changed for this experiment (a copy is provided in Appendix E). A volunteer consent and medical clearance form as per Experiment One was also provided (as shown in Appendix F).

The demographic questionnaire used in Experiment One was again used to collect background information (a copy can be found in Appendix G), along with a post evacuation questionnaire (as shown in Appendix R). The post evacuation questionnaire asked participants about their experience of the evacuation and included information on the difficulty of moving down the aisle to reach the exit row, the difficulty of entering the exit row, the difficulty of moving between the seats at the exit row, and the difficulty of moving through the exit and out of the aircraft. Participants were asked to provide a difficulty rating for each of these elements on a seven point scale where 1 was very easy and 7 was very difficult. The post evacuation questionnaire also asked participants about any physical features within the cabin that had helped or hindered their evacuation. Participants were asked to provide open responses to these questions where applicable. Other questions were included on the post evacuation questionnaire at the request of the sponsor, however these were not of relevance to the current experiment and have not been analysed.

14.6. Procedure

14.6.1. Pre-trial procedure

On arrival, members of the research team greeted each participant and provided them with the relevant trial details as reported in Experiment One.

14.6.2. Trial procedure

14.6.2.1. Seating

Participants were assigned seats within the cabin as they arrived at the testing session. The allocation of participant seating was conducted via random allocation. Boarding was completed in two phases: participants allocated seats in rows 1, 2 and 3 boarded via the front Type I door and participants allocated seats in rows 5 and 6 boarded via the rear service door. This was done to prevent participants physically manoeuvring around the Type III hatch (when it was placed inside the cabin) prior to the call to evacuate.

14.6.2.2. Safety briefings

Once seated, a member of cabin crew provided a safety briefing which included the location of the exits, demonstrations of the use of seatbelts and oxygen masks and the location of the safety card. This briefing was as that delivered in Experiment One, with the exception that the operator's briefing was not delivered (as there was no operator present). A transcript of this briefing can be found in Appendix I.

14.6.2.3. The call to evacuate

When the safety briefing was complete, the cabin crew checked the cabin and that participants had their seatbelts fastened. The trials were to simulate an emergency evacuation on take off, so shortly after the cabin check a pre-recorded evacuation scenario was played. This scenario was identical to that used in Experiment One and is shown in Appendix J. The evacuation scenario included a period of engine noise (lasting approximately 30 seconds) followed by an announcement from the Captain to "Undo your seat belts and get out!" The lighting within the cabin was also changed on the call to evacuate, from take off lighting to emergency lighting.

14.6.2.4. Cabin crew actions

On the call to evacuate, the cabin crew member, who was located at the front of the cabin, commanded passengers to evacuate the aircraft and directed them towards the Type III exit. Passengers were urged to move quickly throughout the evacuation. The cabin crew member used assertive, concise, positive commands, in accordance with the findings of Muir and Cobbett (1996). The evacuation was deemed complete when all passengers had evacuated the cabin. Members of the research team were located outside the exit and were instructed to marshal participants to a place of safety.

14.6.3. Post-trial procedure

After evacuating, participants were asked to complete a post-evacuation questionnaire. This questionnaire had been designed specifically for evacuations through the Type III exit. A copy of the questionnaire is provided in Appendix R. On completion of the post-evacuation questionnaire, participants were thanked, debriefed and paid. Finally, participants were provided with a thank you letter as per Experiment One, containing contact details for the research team. A copy of this letter is provided in Appendix K.

14.7. Analysis

The video footage was edited and a time code was added. Data were then extracted from the video footage to allow the calculation of the dependent variable. All performance evacuation data, along with the quantitative responses from the post evacuation questionnaires were entered into SPSS version 14 for quantitative analysis.

Qualitative comments provided in response to the open questions on the post evacuation questionnaire were collated on a question-by-question basis and have been used to add depth to the quantitative results.

15.0. Results: Experiment Four

15.1. Sample

A total of 397 participants took part in the testing programme. Two hundred and forty-three participants were male (61.2%) and 153 were female (38.5%), with data not provided by one participant. Participants provided their age at the time of the testing session. Participants' ages ranged from 20 to 50 years, with a mean age of 31.4 years, and a standard deviation of 8.9 years. 32 participants were left handed (8.1%), 354 were right handed (89.2%) and eight passengers were ambidextrous (2%), with three participants not providing any data. Most participants had flown previously on a commercial flight (376 participants, or 94.7%), with one participant also reporting that they had been involved in a previous actual emergency evacuation, evacuating via a full door onto an evacuation slide.

15.2. Completed evacuations

In total, all planned evacuations were conducted across 24 trials, with eight trials in each condition. There were no reported injuries and no participant withdrawals.

15.3. Participant evacuation data

15.3.1. Summary descriptive results

Table 35 details the summary descriptive data for each group. Data are provided on the hatch condition, the number of participants within the group (18 were recruited for each group, however several participants failed to attend the session), the evacuation latency period, the overall evacuation time and the calculated evacuation rate. All mean times and mean participant ratings have been rounded up to one decimal place.

Table 35: Summary data for each group.

Group	Hatch condition	Number of participants	Evacuation latency (seconds)[5]	Overall evacuation time (seconds)[6]	Evacuation rate (pax per minute)[7]
Group 1	No hatch	17	4.9	23.0	53.0
Group 2	Vertical	18	6.4	37.2	33.1
Group 3	Horizontal	17	6.1	27.0	45.9
Group 4	No hatch	17	3.6	23.2	49.0
Group 5	Vertical	16	3.7	28.3	36.6
Group 6	Horizontal	15	4.4	26.1	38.7
Group 7	No hatch	16	4.4	22.0	51.1
Group 8	Vertical	16	4.3	28.4	37.3
Group 9	Horizontal	16	5.5	26.9	42.1
Group 10	No hatch	16	4.6	22.6	50.0
Group 11	Vertical	17	4.9	31.4	36.2
Group 12	Horizontal	15	4.1	23.9	42.4
Group 13	No hatch	17	MD[8]	24.8	MD
Group 14	Vertical	16	4.9	31.2	34.2
Group 15	Horizontal	16	4.0	26.0	40.8
Group 16	No hatch	17	3.5	25.7	43.2
Group 17	Vertical	16	5.9	31.9	34.8

[5] The latency time was taken from the call to evacuate to the first foot of the first participant was placed on the simulator wing.
[6] The overall evacuation time was taken from the call to evacuate to the first foot of the last participant was placed on the simulator wing.
[7] Calculated using the formula n-1/t, where n is the number of participants and t is the time between the first foot of the first participant was placed on the simulator wing and the first foot of the last participant placed on the simulator wing.
[8] Due to a technical fault, the external camera did not record during the evacuation and not all evacuation times were available, therefore the trial was recorded as missing data.

Group 18	Horizontal	16	6.3	28.2	40.8
Group 19	No hatch	18	3.4	24.1	49.2
Group 20	Vertical	18	5.8	35.8	34.2
Group 21	Horizontal	17	4.9	26.3	45.0
Group 22	No hatch	17	5.3	29.3	40.2
Group 23	Vertical	15	5.8	30.3	34.2
Group 24	Horizontal	18	6.4	30.4	42.6

The descriptive statistics in Table 35, demonstrate some variation in the evacuation rate, in number of passengers per minute who evacuated through the Type III exit aperture, across the different hatch placement conditions.

15.3.2. Evacuation rates

Mean evacuation rates for participants to evacuate in each condition are given in Table 36, it is noted that data were available from 23 trials, due to the missing data from group 13.

Table 36: Mean evacuation rates for passengers per minute (ppm) to egress through the Type III exit in each condition.

Hatch placement			**Total**
No hatch in cabin	**Horizontal placement**	**Vertical placement**	
48.0 (sd 4.6)	42.8 (sd 2.3)	35.1 (sd 1.5)	41.5 (sd 6.0)

As can be seen in Table 36, there is some variation in egress rates due to test condition. The data were entered into a one-way ANOVA which produced a significant main effect on evacuation rates (passengers per minute) $F(2,22) = 35.3$, p=0.01 due to hatch placement. In order to further explore the differences in the evacuation rates, Tukey's post hoc tests were performed on the available data. The post hoc tests demonstrated a significant difference in evacuation rates between participants in the no hatch in the cabin condition and those in both the horizontal hatch placement condition and the vertical hatch placement condition. There was also a significant difference between rates in those evacuating in the vertical hatch condition and the horizontal hatch condition. Evacuation rates were higher when there was no hatch in the cabin than when the hatch was placed either horizontally or vertically in the cabin. In addition, evacuation rates were significantly higher when evacuating with the hatch placed horizontally compared to when it was placed vertically as shown in Table 36.

15.4. Perceived difficulty of the evacuation

In order to investigate passengers' perception of the evacuation procedure, data obtained from a selection of questions on the post-evacuation questionnaires were also analysed. One question on the post evacuation questionnaires related to the difficulty experience in moving down the aisle. The mean difficulty ratings are provided in Table 37. A one way ANOVA conducted on these data revealed no statistically significant differences attributable to hatch placement $F(2,389) = 2.87$, p=0.06.

Table 37: Mean participant ratings (where 1 was very easy and 7 was very difficult) for difficulty of moving down the aisle in each condition.

	Hatch placement			**Total**
	No hatch in cabin	**Horizontal placement**	**Vertical placement**	
Difficulty of moving down the aisle	3.0 (sd 1.6)	2.8 (sd 1.4)	2.5 (sd 1.5)	2.7 (sd 1.5)

Participants were also asked about the difficulty of entering the exit row. The mean difficulty ratings are provided in Table 38. A one way ANOVA conducted on these data revealed no statistically significant differences attributable to hatch placement $F(2,390) = 2.20$, p=0.11.

Table 38: Mean participant ratings (where 1 was very easy and 7 was very difficult) for difficulty of entering the exit row in each condition.

	Hatch placement			Total
	No hatch in cabin	**Horizontal placement**	**Vertical placement**	
Difficulty of entering the exit row	3.1 (sd 1.5)	3.4 (sd 1.7)	3.5 (sd 1.8)	3.3 (sd 1.7)

The post evacuation questionnaire asked participants to rate the difficulty of moving between the seats at the exit row. The mean difficulty ratings are provided in Table 39.

Table 39: Mean participant ratings (where 1 was very easy and 7 was very difficult) for difficulty of moving between the seats at the exit row in each condition.

	Hatch placement			Total
	No hatch in cabin	**Horizontal placement**	**Vertical Placement**	
Difficulty of moving between the seats at the exit row	2.9 (sd 1.6)	3.2 (sd 1.5)	3.7 (sd 1.7)	3.3 (sd 1.6)

The data were entered into a one-way ANOVA which revealed a significant effect of hatch placement on perceived difficulty ratings of moving between the seats in the exit row $F(2,390) = 8.99$, $p=0.01$. In order to identify where the significant differences were, Tukey's post hoc tests were performed. The post hoc tests demonstrated a significant difference in difficulty ratings between participants in the no hatch in the cabin condition and those in the vertically placed hatch condition. Participants reported that moving between the seats at the exit row was more difficult in the vertically placed hatch position than when there was no hatch in the cabin, as shown in Table 39. The difference between the participant difficulty ratings in the vertically placed hatch condition and the horizontally placed hatch condition did not quite reach statistical significance at the 0.05 level. However the results demonstrated a trend, in that participants rated it as more difficult when the hatch was placed vertically compared to when it was placed horizontally. There were no significant differences in participant difficulty ratings between the no hatch in the cabin condition and the horizontally placed hatch condition.

Finally, participants were asked to rate the difficulty of moving through the exit. The mean difficulty ratings are provided in Table 40.

Table 40: Mean participant ratings (where 1 was very easy and 7 was very difficult) for difficulty of moving through the exit in each condition.

	Hatch placement			**Total**
	No hatch in cabin	**Horizontal placement**	**Vertical Placement**	
Difficulty of moving through the exit	3.3 (sd 1.5)	3.1 (sd 1.5)	3.5 (sd 1.4)	3.3 (sd 1.5)

The data were entered into a one-way ANOVA which revealed a significant effect of hatch placement on perceived difficulty ratings of moving through the exit $F(2,390) = 3.16$, $p=0.04$. In order to identify where the significant differences were, Tukey's post hoc tests were performed. The post hoc tests demonstrated a significant difference in difficulty ratings between participants who evacuated with the hatch located vertically in the exit row compared to those participants who evacuated with the hatch located horizontally in the exit row. Participants reported that moving through the exit was more difficult in the vertical placed hatch position as shown in Table 40. There were no significant differences in perceived ratings between the no hatch in the cabin condition and the horizontally and vertically placed hatch conditions.

15.5. The placement of the exit hatch

In addition to the rating scales, the post evacuation questionnaire asked participants in an open response format if there were any factors that had hindered them during their evacuation. Of particular interest to the current experiment are the responses relating to the placement of the exit hatch and the influence the presence of the hatch had on their perception of the evacuation. A summary of the responses provided are presented below.

Participants who evacuated without a hatch inside the cabin reported that they were hindered by other passengers, the limited headroom available due to the overhead lockers and the available space/seats in the exit row. A selection of the comments is provided here:

"Passengers hinder the path, so I have to wait in line." (Participant 711, no hatch condition, group 7).

"People not listening to instruction: i.e. going wrong way – not towards nominated exit." (Participant 1910, no hatch condition, group 19).

"Low head height." (Participant 1007, no hatch condition, group 10).

"Low ceiling – overhead storage…" (Participant 1311, no hatch condition, group 13).

"Narrow gap between seats in exit row – I banged my shin trying to get out quickly." (Participant 1013, no hatch condition, group 10).

In response to the same question, the most reported hindrance by participants who evacuated with the hatch in the vertical position was the item or blockage that was placed in the exit row. The blockage was reported by 69 participants, this was 67.6% of the total number of participants in the vertical condition who responded to this question (n = 102). Other factors that were reported as hindering participants included the seats/available space in the exit row (it is noted that this may be related to the exit hatch located within the exit row vertically), the overhead lockers, the other passengers in the cabin and the size of the exit aperture. A sample of the comments provided in response to this question is provided.

"Obstruction on floor by seat next to exit – had to climb over." (Participant 504, vertical hatch condition, group 5).

"The emergency exit door sitting in the exit row - had to climb over/around it." (Participant 1310, vertical hatch condition, group 13).

"The seats in the exit row." (Participant 1107, vertical hatch condition, group 11).

"Headroom over seats very low. Door blocking exit row." (Participant 213, vertical hatch condition, group 2).

"Other people in the exit row, small exit door way." (Participant 2304, vertical hatch condition, group 23).

"Speed of exit of other passengers. Obstruction in exit aisle." (Participant 1403, vertical hatch condition, group 14).

Finally, respondents who experienced the hatch located horizontally within the exit row, reported that they were hindered by a number of factors. As with the vertically placed hatch trials the most frequent response was the blockage on the floor in the exit row (47/85 respondents), this was 55.3% of the total number of participants in this condition who responded to this question. Other factors that were reported as hindrances were the overhead lockers/available headroom and the other passengers evacuating the cabin. A sample of the responses is provided.

"The exit door was in the aisle in the way making it very narrow." (Participant 608, horizontal hatch condition, group 6).

"The emergency door lying on the floor." (Participant 1810, horizontal hatch condition, group 18).

"The height of the luggage hatch is too low." (Participant 913, horizontal hatch condition, group 17).

"The limited headroom made it more difficult." (Participant 1807, horizontal hatch condition, group 18).

"Other passengers". (Participant 611, horizontal hatch condition, group 6).

"Passengers in aisle - not moving quick enough." (Participant 2109, horizontal hatch condition, group 21).

Other issues reported as hindering during the evacuation across all conditions (although by a smaller number of participants) included the lighting available and other configurational aspects of the cabin (i.e. the aircraft seats and the seatbelts), along with some miscellaneous comments.

16.0. Discussion – Experiment Four

16.1. The influence of hatch placement on evacuation rates

The results from the experiment indicated that Type III hatch placement had a statistically significant effect on passenger evacuation rates from a smaller transport aircraft. The rate at which participants evacuated the cabin was significantly higher when there was no hatch in the cabin, compared to when the hatch was placed either vertically or horizontally in the cabin. In addition, the evacuation rate was significantly higher when the hatch was placed horizontally in the cabin compared to when it was placed vertically in the cabin.

It is not surprising that the rate at which participants evacuated was slower when hatch was placed horizontally or vertically, compared to when there was no hatch in the cabin, as the hatch lead to an obstruction in the area surrounding the exit. When the hatch was placed vertically in the cabin there was a total obstruction of the exit row and when the hatch was placed horizontally in the cabin there was a partial obstruction in both the exit row and the main aisle. The results add support to the accounts from some accidents where the placement of the Type III hatch inside the cabin has been described as an impediment to evacuation (e.g. the accidents at Calgary and Little Rock). Although no other experimental studies have explicitly investigated the influence of hatch placement on evacuation, hatch placement has been raised as an issue within other evacuation experiments. The findings from the current experiment are in agreement with Rasmussen and Chittum (1989) who concluded that an incorrectly placed hatch could have a negative effect on passenger evacuation. The findings also support McLean et al (1992 and 2002) who reported that some internal hatch placements could have a 'detrimental' effect on evacuation.

These results highlight the importance of ensuring that hatch operators understand what is required of them and are able to dispose of the hatch into an appropriate location so that it does not impede egress. One way to ensure that the Type III hatch could not be placed in an inappropriate location would be to have an automatically disposed hatch. With such a design the hatch once operated is still attached to the aircraft fuselage and does not need to be disposed of into a safe location. The benefits of such a design have been shown in Experiment Three on a smaller transport aircraft and by Cobbett et al (1997) on a larger single aisle aircraft.

16.2. The influence of hatch placement on participants' perceived difficulty of the evacuation

Participant's perceptions of the evacuation trials when moving between the seats at the exit row and moving through the exit and out of the aircraft also revealed significant differences attributable to hatch placement. Importantly, the results from the post evacuation questionnaires were aligned with the performance evacuation data. The rate of egress was slower when the hatch was placed inside the cabin compared to when there was no hatch present, with participants also perceiving aspects of the evacuation to be more difficult when the hatch was disposed of internally in the cabin.

When moving between the seats at the exit row, a significant difference in difficulty ratings was shown. Participants reported more difficulty in moving between the exit row seats when the hatch was placed vertically inside the cabin compared to when there was no hatch within the cabin. This result is not surprising as the placement of the hatch caused an obstruction in the exit row. The difference in difficulty ratings between the trials with the hatch placed vertically in the cabin and those when the hatch was placed horizontally in the cabin did not quite reach statistical significance, however the results demonstrated a trend in that participants rated it as more difficult when the hatch was placed vertically compared to when it was placed horizontally. There was no statistically significant difference in perception ratings when there was no hatch in the cabin compared to when the hatch was placed horizontally in the cabin.

When looking at the data on participant's perception of moving through the exit and out of the aircraft, again a significant difference was reported. On this aspect of their experience participants reported moving through the exit and out of the aircraft as more difficult in the trials with the hatch placed vertically than when the hatch was placed horizontally. This result is not surprising as the placement of the hatch in the vertical position caused a complete obstruction in the exit row, with the majority of participants having to climb up onto the seats to get over the hatch and then back into the exit row prior to leaving through the exit. No significant differences were found between the other hatch placement conditions.

Surprisingly, there was no significant difference between hatch placement conditions on participant's perceptions of entering the exit row. It was thought that due to the placement of the hatch, participants may have perceived it significantly more difficult to enter the exit row when the hatch was located in this area. The placement of the Type III hatch inside the cabin was shown to significantly influence the rate at which participants could evacuate the aircraft cabin and influence participants' perceptions of aspects of the evacuation. In addition, the qualitative responses on the post evacuation questionnaires suggested that hatch placement inside the cabin was perceived as a hindrance during the evacuation.

When asked to comment on any factors within the cabin that had hindered their evacuation, the majority of participants who evacuated with the hatch placed horizontally or vertically in the cabin reported that the blockage had hindered them. In addition, other passengers, the exit aperture and aspects of the smaller transport aircraft environment including the reduced headroom due to the overhead lockers were reported by participants across all three hatch placement conditions as hindering their evacuation.

16.3. Methodological considerations

As acknowledged in the method section for this experiment, the greatest challenge in this study was achieving an appropriate balance between ecological validity, experimental control and participant safety with regards to the placement of the Type III hatch. As the hatch disposal location was the independent variable under test, it was imperative that the hatch was placed in the same location for each trial in the condition. Also it was essential that participant safety was considered at all times and any risks to participants from the placement of the hatch were minimised. This meant the hatch had to be fastened in the desired location in advance of the trial. It is recognised that this has reduced the ecological validity of the scenario, however as participant safety and experimental control were maintained, confidence can be placed in the results obtained.

16.4. Summary of Experiment Four

The objective of Experiment Four was to investigate the effect of exit hatch placement inside the cabin on passenger evacuation through a Type III from a smaller transport aircraft (smaller interior configuration). The results from the experiment have highlighted that the placement of the exit hatch inside the cabin can have a detrimental effect on evacuation rates.

17.0. Discussion and Conclusions – Overall research programme

17.1. Summary of results

The Type III exit has been shown to be an important egress route during some evacuations. Accident reports as highlighted in Section 5.4 have highlighted some of the physical and comprehension difficulties experienced by exit operators when required to operate the exit and the difficulties experienced by passengers in evacuating through the exit aperture. Research into the difficulties experienced by operators and potential modifications to improve the exit operation task and egress through the exit are critical as Type III exits are installed on a number of aircraft types in current operation.

The aim of this series of experiments was to explore factors influencing passenger evacuation through the Type III exit from smaller transport aircraft including the operation of the Type III exit. It was felt that the area was less understood as previous evacuation studies have focussed on large single aisle aircraft or very large transportation aircraft. It was not known if the findings would generalise to smaller transport aircraft. Overall the series of experiments have found that many of the issues in relation to Type III evacuation and especially exit operation from larger single aisle aircraft are also applicable to cabin interiors typical of those of smaller transport aircraft. The findings from the individual experiments are discussed below, with the overall contribution to knowledge discussed at the end of the section.

Experiment One found that the interior configuration associated with a smaller transport aircraft (number of seats abreast of the aisle and available headroom) and the vertical projection distances test at the Type III exit row did not significantly influence evacuation rates. However from the qualitative comments received the headroom available in the smaller transport interior configuration was perceived by passengers as hindering them during the evacuation, but this did not significantly influence the overall evacuation rates.

Experiments Two and Three then explored the operation of the Type III exit. The results revealed that a major modification to the exit mechanism, in that the exit hatch was automatically disposed of, was required to improve the time taken to operate the exit. In comparison, a minor modification to the operating handle mechanism on a traditional Type III exit did not improve exit operation. The major modification made the exit operation task simple and intuitive to the untrained exit operator and removed many of the physical difficulties associated with operation of the traditional Type III exit and the disposal of the hatch. This resulted in a reduction to the time taken to make the exit available for evacuation. It is suggested that the minor modification to the operating handle mechanism did not assist operators as it did not remove the inherent difficulties of the size and weight of the hatch, the need to manoeuvre it in the limited space and dispose of it into an appropriate location. Experiment Three has shown the benefits of installing an ADH in smaller transport aircraft as well as larger single aisle aircraft as previously shown by Cobbett et al (1997). The findings suggest that ADHs should be installed on smaller transport aircraft as well as larger cabins.

It is appreciated that the number of aircraft currently flying with traditional Type III exits is likely to be considerable and a retrofit programme may be resisted by industry. Although an ADH is the preferred solution, Experiment Two has also shown that the benefits of providing an in-depth briefing to exit operators in advance of asking them to operate the exit can improve the time taken to operate the exit. In addition the detailed information was shown to improve participants' perceptions of the exit operation task. The findings from Cobbett et al (2001) had shown the benefits of providing detailed information in a larger single aisle cabin, with further support provided by this experiment and also that the findings are generalisable to smaller transport aircraft cabins.

The final experiment (Experiment Four) explored the influence of hatch placement on evacuation through the exit from an interior configuration typical to that of a smaller transport aircraft. The experiment was only run in this interior configuration as it was felt that although a misplaced hatch may impede evacuation from all cabins irrespective of size, with the configuration of a typical smaller transport aircraft (i.e. reduced fuselage width and available headroom) the effects may be more pronounced. The experiment found that when the hatch was placed internally, the rate at which passengers could evacuate was decreased compared to when the hatch was disposed of outside the cabin. When the hatch caused a total blockage to the exit row, the effect was greater than when only a partial blockage was present. This experiment has suggested that the benefits of an ADH exit mechanism are not only in exit operation, but as the disposed hatch remains attached to the fuselage it does not have the potential to impede passenger egress.

The aim and overriding contribution to knowledge of the series of experiments was to explore a number of issues linked to evacuation and Type III exit operation in smaller transport aircraft, as prior to this work there were only limited data on evacuation from smaller transport aircraft. The impact of the smaller interior configuration did not appear to influence the rate at which passengers could evacuate through the Type III exit and operate the exit, however the lower headroom associated with the smaller interior configuration was perceived by passengers as hindering them during the tasks. As with large single aisle aircraft, passengers encountered difficulties with the operation of the Type III exit on a smaller transport aircraft. These experiments have added to knowledge concerning the benefits of an automatically disposed hatch exit mechanism on a smaller transport aircraft and demonstrating the benefits of providing an in-depth detailed briefings (in both large and small aircraft interior configurations) on improving the time taken to operate the Type III exit and on operators' perception of the task. The final contribution to knowledge was demonstrated in Experiment Four. Prior to this experiment the impact of a Type III hatch placed inside the cabin on evacuation rate had not been quantified. This experiment has shown the negative effect it has on evacuation rate from a smaller transport aircraft. In summary, the series of experiments have raised some important issues regarding evacuation through the Type III exit and operation of Type III exits from smaller transport aircraft.

17.2. Evaluation of the test methodology

17.2.1 Co-operative (collaborative) methodology: Experiments One and Four

As this was an initial investigation into evacuation from a smaller transport aircraft cabin, the group evacuation trials were conducted under a co-operative methodology. Urgency was added by informing participants that they would all receive a bonus at the end of the session, if, as a group, they evacuated within a time limit on each trial. It is however noted that participants were not informed of the time limit nor were they informed how quickly they had evacuated after each evacuation. This strategy led to participants behaving in a collaborative manner. Previous research has shown that a collaborative motivational technique produces behaviours akin to those which might be in evidence in a full scale emergency demonstration, or a non-life threatening accident (Muir et al, 1989). In a life-threatening emergency situation, further evacuation problems due to the independent variables under examination may become more apparent. Hence, these results may not generalise readily to an actual life-threatening emergency situation. Nevertheless, with Experiment Four, the results suggest that even with the collaborative trials, the placement of the hatch appeared to impede egress and hinder participants. It may be that this effect is heightened in competitive trials, or a life-threatening emergency, although research would be required to confirm this.

17.2.2 Individual participants: Experiments Two and Three

It is noted that the evacuation trials reported within Experiments Two and Three were conducted with a single participant as opposed to a group of participants. The rationale for this was linked to the objectives of the experiment, which were to investigate Type III exit operation. As there was only a single participant there was no competition or assistance provided by additional participants, as may be the case in an actual emergency evacuation. It should also be noted that the evacuation was not time dependent (i.e. as in the case of a fire) as participants were not provided with a time limit in which to operate the exit and evacuate the cabin. During the second experiment with individual participants (Experiment Three), three research confederates were present in the cabin to add a degree of pressure on the participant to operate the exit and evacuate as quickly as possible. However the ‘stooge’ passengers did not assist the participant with exit operation as may be the case in group or real life evacuations. Hence, future research should investigate factors influencing the operation of the exit during group evacuations when more than one passenger may be involved in exit operation.

17.3. Smaller transport aircraft interior configurations

All of the experiments have investigated factors influencing evacuation and Type III exit operation from smaller transport aircraft in a 2 x 2 seating configuration. It is acknowledged that a 2 x 2 configuration is not the only seating arrangement found on smaller transport aircraft. Some commuter or regional jets are configured with one seat each side of the main aisle (i.e. Embraer Bandeirante and Fairchild Metro) or two seats on one side of the aisle, with only one seat on the other side of the aisle (i.e. Jetstream 31/41 and Embraer Brasilia.). This should be borne in mind when drawing conclusions from the research programme as the findings may not be generalisable to other regional aircraft seating configurations. It is recommended that seating configurations found in other smaller transport aircraft is an issue which merits further research into emergency evacuation and the operation of the Type III exit.

17.4. Limitations

As participants were aware they were taking part in a simulated evacuation trial they may have been more aware of the evacuation procedures and safety information than they would be on a routine flight. However difficulties in exit operation and evacuation were still experienced and these difficulties may be more pronounced during a real evacuation. It could be argued that especially with the individual participant trials, participants were aware that they would be required to operate the Type III exit, however the video footage demonstrated that some participants on the call to evacuate initially moved away from the exit or looked to the cabin crew for further guidance before operating the exit. This behaviour was also witnessed in the group evacuations in Experiment Four where some participants on the call to evacuate initially moved to the other exits located at the front and rear of the cabin. From this behaviour it is suggested that not all passengers assumed they were evacuating through the Type III exit, even though they may have been more aware of the evacuation procedures as it was a simulated trial.

It is acknowledged that trials were only conducted with participants who were aged between 20 and 50 years of age and were relatively fit and healthy and this must be borne in mind where drawing conclusions from the study. However it is felt that if difficulties in exit operation and evacuation were experienced during these trials, they would only be exacerbated in real aircraft emergency evacuations.

18.0. Recommendations for Future Research

The series of experiments reported within this thesis have raised some important issues regarding operation of Type III exit and evacuation through the exit from smaller transport aircraft cabins. As this was an initial investigation into evacuation and exit operation from smaller transport aircraft, a number of recommendations for further research are proposed.

In order to enhance the ecological validity when the interior configuration of the smaller transport aircraft was addressed both the number of seats either side of the main aisle and the available headroom were investigated in combination and not in isolation. Based on the qualitative findings it is recommended that further experiments should investigate these variables in isolation to determine if either variable is more influential on evacuation rates, the time taken to operate the exit and passenger perception of the difficulty of the task.

As highlighted in Experiment One, further work is recommended on access to the Type III exit in smaller transport aircraft, with experiments to address different vertical projections at the exit passageway on evacuation. Based on the findings from Experiment Two recommendations for future study include further investigation into Type III exit operator's briefings, perhaps with consideration of some of the improvements suggested by participants. The influence of different briefings and different forms of delivery could then be investigated in relation to exit operation and passenger perception, possibly involving more participants in the cabin or different emergency scenarios.

Experiment Three highlighted the benefits of installing an ADH on the time taken to operate the exit and operator perception. As the exit mechanism used in this experiment was a prototype to examine the concept, recommendations for future work include the design and development of other ADH mechanisms, with operational testing with naïve participants. Finally, Experiment Four has highlighted the impediment caused by an inappropriately placed Type III exit hatch inside the cabin. Due to the comprise between participant safety, experimental control and ecological validity that had to be reached during the experiment, further work could explore means of configuring the hatch and cabin simulator to allow the hatch to be in the aperture at the start of the evacuation and placed in the desired location by an exit operator as the evacuation commences. In addition only two internal placements were investigated within Experiment Four, further work should investigate the effects of hatch placement in different locations inside the cabin and directly outside the exit aperture. Finally further work should investigate internal hatch placement in narrower cabins (i.e. 1 x 2 seating configurations) as the placement of the hatch in relation to the other internal features (e.g. the main aisle) is likely to be different

As previously discussed, the exit operation trials were conducted with individual participants. It is recommended that the influence of exit operating mechanism, briefings and interior configurations on exit operation are explored with other passengers in the cabin, as would be the case in a real emergency. In addition, as the group evacuation trials were conducted with a co-operative methodology, it is recommended that further exploration of the issues associated with exit operation and evacuation from smaller transport aircraft should be conducted utilising a competitive methodology. It is anticipated that this investigation will provide data on the difficulties experienced when evacuating when there is a high motivation to evacuate quickly. The final recommendation from the series of experiments is that further investigation of other internal cabin configurations (e.g. cabin widths with 1 x 2 seats abreast) are conducted to determine if the reported findings are replicated.

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20.0. Appendices

Appendix A: Post-evacuation questionnaire – Experiment One

Volunteer Number: ________________________

The information we ask for in this questionnaire relates to the evacuation you have just completed. Please be honest, and complete as many questions as possible. Your answers may help us to improve the safety of air travel.

1. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty in undoing your seatbelt. Please circle **one** number only.

1	2	3	4	5	6	7
Very easy						**Very difficult**

2. On a scale of 1 to 7, where 1 is paying no attention, and seven is paying full attention, to what extent would you say you listened to the safety briefing provided by the Flight Attendants? Please circle **one** number only.

1	2	3	4	5	6	7
No attention						**Full attention**

3. For what reasons did you ***not*** give the safety briefing your full attention? Please circle **all** that apply.

   a. Not applicable – I gave the briefing my full attention (please go to question 4)
   b. I had seen the briefing before
   c. It's basic knowledge
   d. My view was obstructed
   e. I was distracted by someone else
   f. It went on for too long
   g. I didn't think I needed to
   h. Other (Please specify)

   ____
   ____

4. Did you read the safety card that was in the seat pocket in front of you? Please circle **one** option only.

   a. Yes
   b. No

5. How do you think the cabin crew aided your evacuation? Please circle **all** that apply.

   a. Directed me to the exit
   b. Shouted helpful instructions
   c. Shouted encouragement
   d. Pushed passengers through the exit
   e. Other (Please specify)

6. How do you think the cabin crew hindered your evacuation? Please circle **all** that apply.

   a. Shouted too much
   b. Shouted too loud
   c. Added to the confusion of the situation
   d. Pushed passengers through the exit
   e. Did not help passengers who needed help
   f. Occupied space or got in the way
   g. Distracted me from more important things
   h. Other (Please specify)

7. In what ways could the cabin crew have improved your evacuation?

8. In what ways did your fellow passengers help your evacuation?

9. In what ways did your fellow passengers hinder your evacuation?

10. In what ways could your fellow passengers have improved your evacuation?

____
____
____

11. What strategies did you use when evacuating? Please circle **all** that apply

a. Climbed over seats
b. Waited in line
c. Pushed past other passengers
d. Pushed other passengers towards the exit
e. Allowed passengers to get in front of me
f. Tried to get out my seat and move as far as possible down the aisle before others could
g. None
h. Other (Please specify)

____
____
____

12. Do you think that the strategies you used: (Please circle **one** option only)

a. Helped your evacuation
b. Hindered your evacuation
c. Did not make any difference

13. Did any physical features within the cabin help your evacuation? Please circle **one** option only

a. No
b. Yes (Please specify what helped you, and how)

____
____
____

14. Did any physical features within the cabin hinder your evacuation? Please circle **one** option only

a. No
b. Yes (Please specify what hindered you, and how)

____
____
____

15. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty of **moving down the main aisle to reach the exit row**. Please circle **one** option only.

1	2	3	4	5	6	7
Very Easy						**Very Difficult**

16. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty of **moving between the seats at the exit row**. Please circle **one** option only.

1	2	3	4	5	6	7
Very Easy						**Very Difficult**

17. Were you the person (or one of the people) who opened the exit in the trial you just completed? (Please circle **one** option only).

    a. Yes – Please continue answering the following questions
    b. No – Please go to question 24

18. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty you experienced in **unlatching the exit hatch**. Please circle **one** number only.

1	2	3	4	5	6	7
Very easy						**Very difficult**

19. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty you experienced in **opening the exit hatch**. Please circle **one** number only.

1	2	3	4	5	6	7
Very easy						**Very difficult**

20. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty you experienced in **moving the exit hatch out of the way**. Please circle **one** number only.

1	2	3	4	5	6	7
Very easy						**Very difficult**

21. Where did you leave the exit hatch **first** when you moved it out of the way? Please circle **one** option only.

a. Outside the cabin
b. Inside the cabin, against the wall below the exit
c. Inside the cabin, on the floor in the passageway leading to the exit
d. Inside the cabin, on my seat
e. Inside the cabin, on one of the seats in the exit row
f. Inside the cabin, on the seats in the row in front of the exit row
g. Inside the cabin, on one of the seats in the row behind the exit row
h. Inside the cabin, on the floor in the main aisle
i. I can't remember
j. Other (please specify)

____

____

22. What, if anything, do you think was difficult about operating this type of exit? Please circle **all** that apply.

a. Not applicable – the hatch was not difficult to operate (move to question 23)
b. The handles on the hatch were difficult to grip
c. The handles on the hatch were in the wrong place
d. The hatch was too big
e. The hatch was too heavy
f. I did not expect to have to bear the weight of the hatch
g. I did not expect the hatch to have to come back in to the cabin
h. I did not expect to have to turn the hatch
i. The hatch does not operate the same as a normal door
j. Other (please specify)

____

23. If you were flying on a commercial aeroplane, based on your experience today, would you be:- (Please circle **one** option only)

a. More willing to sit by this exit than before
b. Less willing to sit by this exit than before
c. As willing to sit by this exit as you were before

24. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty you experienced in **moving through the exit and out of the aircraft**. Please circle **one** number only.

1	2	3	4	5	6	7
Very easy						**Very difficult**

25. If there are any comments that you would like to make about the trial you have just completed, please do so here.

____

____

Appendix B: Sample recruiting advertisement

Cranfield UNIVERSITY

✈Earn up to £15 in an hour! ✈

Aircraft Cabin Evacuation Trials

The Human Factors Group at Cranfield University are recruiting volunteers to take part in evacuations from a cabin simulator. Please do not volunteer if you have previously taken part in trials using the small (Boeing 737) cabin simulator.

Volunteers will be required on one occasion, for approximately 1-1½ hours, and will undertake a single evacuation. Some of the evacuations may take place in low level lighting and you may be required you to lift a weight equivalent to that of a heavy suitcase. You will not be required to use emergency chutes on this occasion.

An attendance payment of £12.50 will be given to all those who participate, and there will also be the opportunity to earn a £2.50 bonus. Volunteers must be aged 20 - 50. Volunteers must also be fit, as the trials could be physically demanding.

There are several sessions available [add dates and times]. For further information, please contact [……] on telephone 01234 […..] If [……] is unavailable, please leave a message, including a daytime telephone number and we will call you back.

Appendix C: Sample booking confirmation letter

Cranfield University
Cranfield
Bedfordshire
MK43 0AL
England
Fax +44 (0) 1234 [……]
Tel + 44 (0) 1234 [……]

Dear Volunteer

Thank you for volunteering to take part in the cabin evacuation trial which is to take place on: [insert date].To ensure that the trials runs smoothly, it is essential that you arrive at the revolving-door entrance to Hangar 3 (Building 83, School of Engineering) at [insert time].You will be met by a member of the research team.

All volunteers must be between the ages of 20 and 50, and be normally fit and healthy. Volunteers should weigh no more than around 15 stones/95.25 kg, and should not be excessively overweight. The trials may be physically demanding, so please do not take part if you have any history of the following illnesses: heart disease, high blood pressure, fainting or blackouts, diabetes, epilepsy or fits, deafness, chronic back pain, ankle swelling, depression, anxiety, other nervous/psychiatric illnesses, fear of enclosed spaces, fear of heights, fear of flying, brittle bones, asthma, bronchitis, breathlessness, chest trouble, allergy, lumbago sciatica, or any other serious illness or recent surgery. Additionally, women who are pregnant, or who think they may be pregnant, should not take part. On arrival at the session, you will be asked to complete a medical questionnaire. This form will be checked by a first aider for health and safety and insurance purposes.

We will require you to take part in a single evacuation and to complete several questionnaires. You will be required for approximately 1-1½ hours. Some evacuations may take place in low level lighting. You will not be required to use the emergency chutes on this occasion, although you may be required to lift a weight equivalent to a heavy suitcase. All volunteers will be paid £12.50 for attending the session. In addition, there will be the opportunity to earn a £2.50 bonus if everybody in your group evacuates the cabin within a time limit. Please note these trials are **collaborative** and not competitive.

Your safety is of the utmost importance. Please ensure that you **wear trousers, long sleeve tops and trainers or flat pumps and socks.** Please do not wear earrings which may come loose, or which may get caught on clothing. It is not advisable to wear spectacles during the actual evacuation. Coats and bags will not be allowed on the aircraft, although we will provide a secure, supervised area in which they may be left.

Please ensure that you have read and completely understand this information, as you will be asked to sign a form to confirm your agreement to participate in the trials. Please do not hesitate to contact us if you have any queries about the information that has been supplied. Also, **we would be grateful if you could let us know if you are no longer able to participate**.

Again, thank you for volunteering. We look forward to seeing you on [insert date].

Human Factors Group

Appendix D: Photographs to accompany Experiment One

Photograph D1: The test facility in the large interior configuration.

Photograph D2: The test facility in the small interior configuration.

Appendix E: Volunteer information sheet

It is essential that you read this document carefully, and fully understand its contents before completing the Volunteer Consent and Medical Clearance form. If you feel after reading this document that you do not wish to take part, then please do not feel obliged to do so.

1) Health and Medical

a) For insurance purposes, all volunteers must be aged between 20 and 50.

b) Volunteers must have no history of the following: Heart disease, high blood pressure, fainting or blackouts, diabetes, epilepsy or fits, deafness, chronic back pain, ankle swelling, depression, anxiety, other nervous/psychiatric illnesses, fear of enclosed spaces, fear of heights, fear of flying, brittle bones, asthma, bronchitis, breathlessness, chest trouble, allergy, lumbago sciatica, or any other serious illness.

c) All volunteers who are undergoing any medical treatment or who have recently undergone surgery should consult with the medical officer before agreeing to participate.

d) Women who are pregnant, or who think they may be pregnant, should not take part.

2) Safety

To ensure the safety of all volunteers, a number of precautions have been taken:

a) If an evacuation of the aircraft is necessary, you should make your way to the exits that the Cabin Crew say are available. Various fixtures and fittings within the cabin have been padded to reduce the risk of injury in the event of an accident.

b) You may be required to open and/or move through the passenger operated over wing exit. Again, fixtures and fittings around this exit have been padded to reduce the risk of injury in the event of an accident. If you are seated next to this exit, you will be briefed by cabin crew on the location of the instructions, in case you are required to open this exit. Please note that the exit weighs about the equivalent of a heavy suitcase. You should not attempt to open this exit unless a member of Cabin Crew instructs you to do so.

c) When moving through aircraft exits, please mind your head. If you are required to evacuate using the passenger operated exit, ensure that you lift your feet and legs clear of the sill. Research staff will be available outside the exits being used, to assist you in moving away from the doors.

d) At least two members of the Cranfield research team will be present on the aircraft at all times; these individuals will make themselves known to you. Researchers on the aircraft carry alarms, as do personnel located outside the exits. If you hear an alarm, then this is a signal to HALT. This indicates that a problem has occurred, and that the trial has therefore been stopped. If a trial is stopped, you must stop immediately and await instruction from the research team.

e) A first aider is on hand. If you feel the need to consult the first aider, please do not hesitate to do so.

3) Payment
Today we will require you to take part in a single evacuation. All volunteers will be paid £12.50 for attending. In addition, there will be a bonus of £2.50 paid to every member of your group if everyone in the group evacuates the cabin within a time limit. It is important that you exit the aircraft as quickly as possible.

4) Insurance
You are advised that the test is undertaken at your own risk. The University has arranged personal accident insurance which provides benefit in the event of you sustaining accidental bodily harm. No further claims are admissible, nor shall the University be held liable in the event of any accidental injury or damage outside these benefits.

Scope of Insurance Cover: Accidental Bodily Injury

Temporary Total Disablement, per week	£150
Temporary Total Disablement, where not otherwise gainfully employed, per week (Maximum 104 weeks)	£25
Permanent Total Disablement (Other than loss of sight of one or both eyes or loss of one or more limbs)	£100,000
Loss of one or more limbs	£100,000
Permanent Total Loss of Sight of One or Two Eyes	£100,000
Death	£100,000

5) Personal Information

a) All personal information that you provide will be treated with the strictest confidence. You have been provided with a volunteer number to ensure that all information you provide remains anonymous. This means that although the information you provide will be used by Cranfield University for research purposes, you will not be personally identifiable by name, age or other personal characteristic.

b) These trials will be video recorded by Cranfield University. The video footage will be used in research to investigate the factors which influence survival in the event of an aircraft emergency. Some of this footage may also be used for promotional purposes. If you take part in these trials, you consent to your image being used in this manner, although any other personal details you provide will of course remain confidential.

c) You are free to withdraw from these trials at any stage during the session. If you wish to do so, then simply inform a member of the research team or the first aider.

After reading this document carefully, you should also complete the Volunteer Consent and Medical Clearance form. This will be checked and signed by the first aider.

Appendix F: Volunteer consent and medical clearance form

Volunteer number: ______________
Age: ______________
Sex: ______________

Part A: To be completed by the Cranfield Research Team

Volunteer height: ___________ Volunteer Weight: ___________

Part B: Your Medical History
It is essential that you answer these questions truthfully and completely. The answers you provide to these questions will be treated with the strictest confidence, although they will be checked by the evacuation nurse.

1. Have you ever experienced any of the following:	**Please tick:** **No**	**Yes**
a. Heart disease		
b. High blood pressure		
c. Fainting or blackouts		
d. Diabetes		
e. Epilepsy or fits		
f. Deafness		
g. Chronic back pain		
h. Ankle swelling		
i. Depression		
j. Anxiety		
k. Nervous/psychiatric illness		
l. Fear of enclosed spaces		
m. Fear of heights		

Have you ever experienced any of the following (cont.)

	Please tick: No	Yes
n. Fear of flying		
o. Brittle bones		
p. Asthma		
q. Bronchitis		
r. Breathlessness		
s. Chest trouble		
t. Allergy		
u. Lumbago sciatica		
v. Any other serious illness		
2. Are you currently receiving medical treatment?		
3. Have you undergone surgery within the last 6 months?		
4. Is there any possibility that you may be pregnant?		

Part C: Volunteer Consent Declaration

I, ____ (please print your name) confirm that I have read and completely and fully understand the "Volunteer Information" provided. I have completed my Medical History details fully and truthfully. I believe my health and fitness are good enough for me to cope with the work involved in the aircraft safety trial which is to take place today. I therefore give my consent to taking part in this research.

Signature____ Date_________________

Part D: Medical Clearance

First aider: _________________________ Date__________________

Appendix G: Demographic questionnaire

Volunteer Number:_________

1. Please tell us your age: ______ (years)

2. Sex: (circle one)

   a. Male
   b. Female

3. Are you: (circle one)

   a. Left Handed
   b. Right Handed
   c. Ambidextrous

4. What is your highest level educational qualification? (circle one)

   a. None
   b. GCSE Grade D or below / CSE Grade 2 or below
   c. GCSE or O Level Grade C or above or equivalent
   d. 'A' Levels or equivalent
   e. Higher National Certificate or Diploma, or equivalent
   f. Bachelor degree
   g. Post-graduate degree

5. Have you previously participated in an evacuation test?

   a. Yes If **Yes**, how long ago?_________(months)
   b. No If **No**, please skip to question 7.

6. If you previously participated in an evacuation test, did it involve going through: (circle all that apply)

   a. A full door (floor-level exit) onto a slide (chute).
   b. A full door (floor-level exit) onto a platform or ramp.
   c. Smaller exit in the cabin (over-wing exit).
   d. I do not remember.

7. Have you ever flown in a commercial airplane?

   a. Yes
   b. No (if **No**, please skip to question 10)

8. If you have flown in a commercial airplane, have you ever had to make an emergency evacuation from the aircraft?

   a. Yes
   b. No (if **No**, please skip to question 10)

9. If you have had to make an emergency evacuation from a commercial airplane, did you go through: (circle all that apply)

   a. A full door (floor-level exit) and use a slide or chute for the evacuation.
   b. A smaller exit (over-wing exit) in the cabin.
   c. I do not remember.

10. Do you get dizzy or tend to lose your balance when you look down from a height?

    a. Yes
    b. No

11. Do you have a tendency to get dizzy or feel like you are about to lose your balance when walking?

    a. Yes
    b. No

12. Do you sometimes feel as though you are falling or going to fall or jump when you are near the edge of a high platform?

    a. Yes
    b. No

13. On the following scale, circle the number that represents the degree of lack of ease or fear you have of heights.

1	2	3	4	5
None never	Rarely	Occasionally	Often	Extreme always

14. On the following scale, circle the number that represents the degree of lack of ease or fear you have when you are in very small rooms, elevators, or other close, cramped, spaces.

1	2	3	4	5
None never	Rarely	Occasionally	Often	Extreme always

15. On the following scale, circle the number that represents how good you think your reflexes are.

1	2	3	4	5
Very slow	Slow	Average	Fast	Very fast

16. On the following scale, circle the number that represents your ability to move with quick and easy grace. (That is, how physically agile and nimble you think you are).

1	2	3	4	5
Very poor	Not very agile	About average	Better than average	Very agile

17. On the following scale, circle the number that represents your ability to be mentally quick and resourceful. (That is, how mentally agile and nimble you think you are.)

1	2	3	4	5
Very poor	Not very agile	About average	Better than Average	Very agile

18. Do you have any limitations in the use of your arms, hands, legs, feet, hips, etc.? (circle one)

a. Yes (please explain)____
b. No

19. Which of the following general types of shoes are you going to wear during this evacuation test? (circle one)

a. Loafers/moccasins/slip-on shoes
b. Shoes with laces that tie
c. Boots (lace or slip-on styles)
d. Sandals

Please check that you have answered **all** questions that apply to you.

Appendix H: Researcher's briefing

Welcome and thank you all for coming this afternoon. I am going to tell you a little bit about what we are all doing here. Firstly, I'll give you a little bit of background about the trials and the cabin safety work that we do, and secondly I'll tell you a little bit about what to expect when we take you up and board you on our aeroplane.

Helen Muir has been doing cabin safety work here at Cranfield now for well over ten years, and one of the things we look at is passenger behaviour in the event of an emergency. Lots of things can have an influence on how quickly passengers can get out in the event of an aircraft accident.

Now, we know that accidents are fortunately very rare, but one of the problems is that when they do occur there is often a fire within the cabin, and if there is a fire there are usually toxic smoke and fumes, and conditions within the cabin can become non survivable within around two minutes. So, obviously it is very important if there is an accident that we can get people out in less time, because it is truly awful, as you can imagine, to actually survive the impact of the crash, and then not be able to make your escape from the aeroplane.

So, a lot of the work that Professor Muir has done is looking at how physical things within the cabin, maybe the lighting, the seating arrangements, where the exits or the exit signs are, where the cabin crew stand, or how the cabin crew behave, all of these things can have an influence on how quickly we can get passengers out in the event of an emergency. So it is quite important work, and as a result of the research that has being done here a number of regulations have been changed. So it is work that has helped to made air travel safer for everybody.

What we are doing today, essentially we have asked you to come along to do one evacuation trial for us this afternoon, so thank you all very much for coming. I hope you are not too worried about what is going to happen, but hopefully I can put you at ease a little bit. What we are going to do is pay you £12.50 for coming along this afternoon and taking part. We are going to do one evacuation, and what I will say to you is that if everybody within the group gets out of that cabin within a given period of time, we will pay everyone a £2.50 bonus as well, so you have the chance to earn up to £15 today. What we don't do unfortunately is tell you what the time limit is, that is the catch! So what you actually have to do is to make sure you get out of that aircraft as quickly as you can.

What we will do is walk you up to the aircraft and board you, our cabin crew here will place you into your seats and then you will have a pre-flight safety briefing. This will be typical of the kind of briefing you would receive if you were going on a real flight somewhere, and then you will here the sound of the engines starting up and you will hear a few things going on just like the real thing, but without the duty-free drinks I am afraid! Then you will hear a few sounds and you will hear the captain say eventually 'Undo your seatbelts and get out' and that is your cue that an emergency has happened. Then, you have to make your way out of the aircraft. Now there will be cabin crew there as I have said, and it is very important that you listen to the cabin crew's instructions and that you do what the cabin crew ask you to do. O.K? Is everybody clear on that?

When the evacuation has finished, there will be stewards outside the exit, who will be able to tell you where to move to and where to stand, to make sure you are safe. When you have actually evacuated the aeroplane we will bring you back down here and ask you to fill in the pink questionnaire which is on your clipboard.

I know there is quite a lot of questionnaire information that we are asking for, but as well as finding out how quickly people can get out of the aeroplane, it is very important to know what kind of things can help, so do taller people get out more quickly, do older people get out more quickly, and it is only when we know what is going on that we can help to make things better. So I appreciate that we do ask for a lot of information, but all of it is very important to the research and what we are trying to do.

I should mention that when you are in the aircraft you may actually be asked to use an emergency doorway that is located over the wing. The overwing exit would actually be operated by a passenger, and it is important if you are asked to use that exit, that you only use that exit when you are told to by cabin crew and that you read the instructions carefully for using that exit.

In the event that anything does go wrong up there, touch wood it is quite safe as we are not actually taking off, what we do have is a procedure for stopping an evacuation if we are not happy with it, or if we think somebody is going to get hurt. Although we ask you to move very quickly, we obviously don't want you to trample all over each other, and if that does happen what we will do is stop the evacuation. The way we do that is using one of these alarms. If you just want to cover your ears, as it is quite loud… [*sounds rape alarm*] … and if you hear that while you are up there, you know you should just stop whatever you are doing and wait for instructions from the cabin crew.

Any questions so far on what I've told you? No, OK. Well, shortly we will go up and board the cabin. I just want to ask you beforehand, if you've got any long earrings or necklaces or anything dangly, any watches with expensive straps or anything that you don't want to take on the aeroplane, we would rather that you left those kind of things here. We will be locking the door, so you are quite safe leaving those things here when we go up to the aeroplane.

Any questions at all before we go up? All right, lets go.

Appendix I: Safety briefings

Passenger pre-flight safety briefing

On boarding:
Ladies and Gentlemen, welcome on board. For your personal safety, any light articles which you have brought on board the aircraft should be placed in the overhead bins, or under the seat in front of you. Please ensure that hand luggage does not obstruct the aisles or any emergency exit. Passengers are reminded that this is a non-smoking flight. Portable telephones must not be used at any time. Electronic equipment such as computers tape recorders etc may only be used when the seat belt signs are off.

Safety demonstration:
As the safety equipment on this aircraft may differ from that on other aircraft, it is in your own best interests to pay attention to this safety briefing.

In the seat pocket in front of you there is a safety card, which the Captain would like you to read carefully before takeoff. This contains details of the demonstration.

The emergency exits are clearly marked and are being pointed out to you. These are the two doors at the rear of the cabin and the emergency over-wing exit located in the centre of the cabin.

For those of you unfamiliar with the operation of the seat belt, it is fastened and adjusted as demonstrated…. and unfastened like this.

We would also like to advise you of the emergency oxygen supply on board. Should additional oxygen be required throughout the cabin the panel above your head will open automatically and masks like these will drop down. Remain seated, pull the mask towards you, place over nose and mouth, and breathe normally. Adults should fit their own masks before assisting children.

Please now ensure that your seat table is folded away your seat back is upright with the armrest down and you seatbelt is tightly fastened.

Thank you for your attention. We would like to wish you a pleasant flight.

Briefing provided to the passenger seated adjacent to the Type III exit

Good afternoon/evening sir/madam. I'd just like to point out that you are seated next to an emergency exit. In the event of an emergency, you may be required to open that exit. The exit weighs the equivalent of a heavy suitcase. Are you happy that you could open that exit in the event that you were required to do so? *(If not, change seats with another passenger)*

Instructions for opening the exit are on the placard on the seat back in front of you, and also on the safety card in the seat pocket in front of you (*point to both*).

Please note that you must not open that exit unless a member of cabin crew instructs you to do so. There could be a fire outside.

Appendix J: Evacuation scenario – Experiment One

The scenario described below was used for each evacuation.

“Ladies and gentlemen. This is your captain speaking. We are currently in a queue of aircraft and should be airborne in a few minutes).

Approximately 30 seconds of engine noise, followed by “Undo your seatbelts and get out!”

Appendix K: Thank you letter

Cranfield University
Cranfield
Bedfordshire
MK43 0AL
England

Fax: 01234 [……]
Tel: 01234 [……]

Thank you for taking part in these evacuation trials. Should you experience any problems following these trials, and would like to talk to someone, please do not hesitate to contact the Human Factors Group at the above address.

Appendix L: Post-evacuation questionnaire – Experiment Two

Volunteer Number: ___________

The information we ask for in this questionnaire relates to the evacuation you have just completed. Please be honest, and complete as many questions as possible. Your answers may help us to improve the safety of air travel.

1. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the **difficulty in undoing your seatbelt**. Please circle **one** number only.

1	2	3	4	5	6	7
Very easy						**Very difficult**

2. On a scale of 1 to 7, where 1 is paying no attention, and 7 is paying full attention, to what extent would you say you **listened to the safety briefing** provided by the flight attendant? Please circle **one** number only.

1	2	3	4	5	6	7
No attention						**Full attention**

3. For what reasons did you ***not*** give the safety briefing your full attention? Please circle **all** that apply.

   a. Not applicable – I gave the briefing my full attention
   b. I had seen the briefing before
   c. It's basic knowledge
   d. My view was obstructed
   e. I was distracted
   f. It went on for too long
   g. I didn't think I needed to
   h. Other (Please specify)
   ____

4. If you listened to the safety briefing, did it **help** your evacuation? Please circle **one** option only.

   a. **Yes** – please specify how it helped your evacuation
   ____
   ____

   b. **No** – please specify how it did not help your evacuation
   ____
   ____

5. On a scale of 1 to 7, where 1 is paying no attention, and 7 is paying full attention, to what extent would you say you listened to the **personal briefing** provided by the flight attendant indicating you were seated next to the overwing exit and might therefore be required to operate it in an emergency? Please circle **one** number only.

1	2	3	4	5	6	7
No attention						**Full attention**

6. For what reasons did you ***not*** give the personal briefing your full attention? Please circle **all** that apply.

   a. Not applicable – I gave the briefing my full attention
   b. I had seen the briefing before
   c. It's basic knowledge
   d. My view was obstructed
   e. I was distracted
   f. It went on for too long
   g. I didn't think I needed to
   h. Other (Please specify) ____

7. If you listened to the personal briefing, did it **help** your evacuation? Please circle **one** option only.

   a. **Yes** – please specify how it helped your evacuation
   ____
   ____

   b. **No** – please specify how it did not help your evacuation
   ____
   ____

8. Did you read the safety card in the seat pocket in front of you? Please circle **one** option only.

   a. **Yes**
   b. **No**

9. If you read the safety card, did it **help** your evacuation? Please circle **one** option only.

   a. **Yes –** please specify how it helped your evacuation
   ____
   ____

   b. **No** – please specify how it did not help your evacuation
   ____
   ____

10. Did the diagrams on the safety card correspond to the briefing given by the flight attendant? Please circle **one** option only.

    a. **Yes** – please specify in what way the diagrams corresponded to the briefing?

    ____
    ____

    b. **No** – please specify in what way the diagrams did not correspond to the briefing?

    ____
    ____

11. On a scale of 1 to 7, where 1 is very clear and 7 is very unclear, please indicate the clarity of the **exit operation instructions** given in the safety card and seatback placards. Please circle **one** number only.

1	2	3	4	5	6	7
Very clear						**Very unclear**

12. On a scale of 1 to 7, where 1 is very clear and 7 is very unclear, please indicate the clarity of the **exit operation instructions** given to you **personally by the flight attendant**. Please circle **one** number only.

1	2	3	4	5	6	7
Very clear						**Very unclear**

13. What **improvements could be made to the personal briefing**, such that they would enhance your actions in the event of an emergency evacuation?

    ____
    ____
    ____
    ____

14. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty you experienced in **finding the exit's operating handle.** Please circle **one** number only.

1	2	3	4	5	6	7
Very easy						**Very difficult**

15. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty you experienced in **unlatching the exit hatch**. Please circle **one** number only.

1	2	3	4	5	6	7
Very easy						**Very difficult**

16. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty you experienced in **using the exit operating handle**. Please circle **one** number only.

1	2	3	4	5	6	7
Very easy						**Very difficult**

17. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty you experienced in **opening the exit hatch**. Please circle **one** number only.

1	2	3	4	5	6	7
Very easy						**Very difficult**

18. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty you experienced due to **the weight of the hatch**. Please circle **one** number only.

1	2	3	4	5	6	7
Very easy						**Very difficult**

19. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty you experienced due to **the size of the hatch**. Please circle **one** number only.

1	2	3	4	5	6	7
Very easy						**Very difficult**

20. On a scale of 1 to 7, where 1 is very clear and 7 is very unclear, please indicate the clarity of the **instructions for disposing of the door.** Please circle **one** number only.

1	2	3	4	5	6	7
Very clear						**Very unclear**

21. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty you experienced in **moving the exit hatch out of the way**. Please circle **one** number only.

1	2	3	4	5	6	7
Very easy						**Very difficult**

22. Where did you leave the exit hatch **first** when you moved it out of the way? Please circle **one** option only.
    a. Outside the cabin
    b. Inside the cabin, against the wall below the exit
    c. Inside the cabin, on the floor in the passageway leading to the exit
    d. Inside the cabin, on my seat
    e. Inside the cabin, on one of the seats in the exit row
    f. Inside the cabin, on the seats in the row in front of the exit row
    g. Inside the cabin, on one of the seats in the row behind the exit row
    h. Inside the cabin, on the floor in the main aisle
    i. I can't remember
    j. Other (please specify)
    ____

23. Did anything relating to the exit hatch **help** your evacuation? Please circle **one** option only.

    a. **No**
    b. **Yes** (Please specify what helped you, and how)
    ____
    ____
    ____

24. Did anything relating to the exit hatch **hinder** your evacuation? Please circle **one** option only.

    a. **No**
    b. **Yes** (Please specify what hindered you, and how)
    ____
    ____
    ____

25. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty of **moving between the seats at the exit row**. Please circle **one** option only.

1	2	3	4	5	6	7
Very Easy						**Very Difficult**

26. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty you experienced in **moving through the exit and out of the aircraft**. Please circle **one** number only.

1	2	3	4	5	6	7
Very easy						**Very difficult**

27. Did any physical features within the cabin **help** your evacuation? Please circle **one** option only.

a. **No**
b. **Yes** (Please specify what helped you, and how)

28. Did any physical features within the cabin **hinder** your evacuation? Please circle **one** option only.

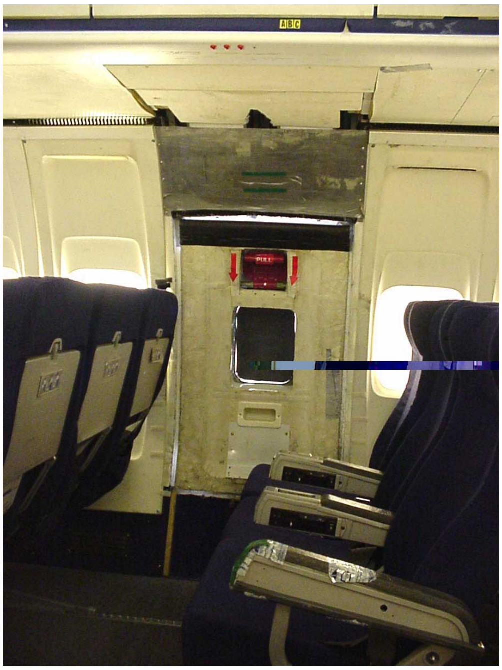
a. **No**
b. **Yes** (Please specify what hindered you, and how)

30. If you were flying on a commercial aeroplane, based on your experience today, would you be: - (Please circle **one** option only)

a. More willing to sit by this exit than before
b. Less willing to sit by this exit than before
c. As willing to sit by this exit as you were before

31. If there are any comments that you would like to make about the trial you have just completed, please do so here.

Appendix M: Additional photographs to accompany Experiment Two



Photograph M1: The Type III exit in the large interior configuration.

Photograph M2: The Type III exit in the small interior configuration.


Photograph M3: The Type III exit hatch with the retracted (conventional) handle mechanism.

Photograph M4: The Type III hatch with the fixed (modified) handle mechanism.

Appendix N: Type III exit operator's briefings – Experiment Two

Minimal briefing provided to the passenger seated adjacent to the Type III exit

Good afternoon/evening sir/madam. I'd just like to point out that you are seated next to an emergency exit. In the event of an emergency, you may be required to open that exit. The exit weighs the equivalent of a heavy suitcase. Are you happy that you could open that exit in the event that you were required to do so?

Instructions for opening the exit are on the placard on the seat back in front of you, and also on the safety card in the seat pocket in front of you (*point to both*).

Please note that you must not open that exit unless a member of cabin crew instructs you to do so. There could be a fire outside.

In-depth briefing provided to the passenger seated adjacent to the Type III exit

You are seated at an emergency exit. You may be required to operate this exit (point) in the event of an evacuation. Listen carefully to the instructions.

You must take no action unless you hear the command 'Undo your seatbelts and get out!' Look outside for a hazard such as fire (point to window). If a fire is present do not open the exit.

To support the exit place your hand in the recess (point).To open the exit, pull down the operating handle (point) as far as it will go. The exit will fall inwards at the top. The exit is not hinged and will come towards you, away from the opening. The exit is very heavy and will need effort to remove fully from the opening.

Once removed, throw the exit out of the aircraft. This will require considerable effort. Exit the aircraft onto the wing. Move away from the aircraft.

Do you understand the instructions I have given you? Do you have any questions?

Please take the safety card from your seat pocket in front of you and study the instructions for exit operation. These instructions are also found on the seat back on front of you (point).

Appendix O: Evacuation scenarios – Experiment Two

Two evacuation scenarios were used during each test session. Scenario one was used for the first trial and scenario two for the second trial.

Scenario one involved a period of engine noise lasting approximately 1 minute and 40 seconds, followed by “This is your captain speaking, we have an emergency, undo your seatbelts and get out!”

Scenario two involved a period of engine noise lasting approximately 20 seconds, followed by “Undo your seatbelts and get out!”

Appendix P: Post-evacuation questionnaire – Experiment Three

Volunteer Number: ________________________

The information we ask for in this questionnaire relates to the evacuation you have just completed. Please be honest, and complete as many questions as possible. Your answers may help us to improve the safety of air travel.

1. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the **difficulty in undoing your seatbelt**. Please circle **one** number only.

1	2	3	4	5	6	7
Very easy						**Very difficult**

2. On a scale of 1 to 7, where 1 is paying no attention, and 7 is paying full attention, to what extent would you say you **listened to the safety briefing** provided by the flight attendant? Please circle **one** number only.

1	2	3	4	5	6	7
No attention						**Full attention**

3. For what reasons did you **not** give the safety briefing your full attention? Please circle **all** that apply.

   a. Not applicable – I gave the briefing my full attention
   b. I had seen the briefing before
   c. It's basic knowledge
   d. My view was obstructed
   e. I was distracted
   f. It went on for too long
   g. I didn't think I needed to
   h. Other (Please specify) ____

4. If you listened to the safety briefing, did it **help** your evacuation? Please circle **one** option only.

   a. Yes – please specify how it helped your evacuation
   ____
   ____
   b. No – please specify how it did not help your evacuation
   ____
   ____

5. On a scale of 1 to 7, where 1 is paying no attention, and 7 is paying full attention, to what extent would you say you listened to the **personal briefing** provided by the flight attendant indicating you were seated next to the overwing exit and might therefore be required to operate it in an emergency? Please circle **one** number only.

1	2	3	4	5	6	7
No attention						**Full attention**

6. For what reasons did you **not** give the personal briefing your full attention? Please circle **all** that apply.

   a. Not applicable – I gave the briefing my full attention
   b. I had seen the briefing before
   c. It's basic knowledge
   d. My view was obstructed
   e. I was distracted
   f. It went on for too long
   g. I didn't think I needed to
   h. Other (Please specify)

   ____

7. If you listened to the personal briefing, did it **help** your evacuation? Please circle **one** option only.

   a. Yes **– please specify how it helped your evacuation**

   ____

   ____

   b. **No** – please specify how it did not help your evacuation

   ____

   ____

8. Did you **read the safety card** in the seat pocket in front of you? Please circle **one** option only.

   a. Yes
   b. No

9. If you read the safety card, did it **help** your evacuation? Please circle **one** option only.

   a. **Yes** – please specify how it helped your evacuation

   ____

   ____

   b. **No** – please specify how it did not help your evacuation

   ____

   ____

10. Did the diagrams on the safety card correspond to the briefing given by the flight attendant? Please circle **one** option only.

   a. Yes – please specify in what way the diagrams corresponded to the briefing?
   ____
   ____

   b. No – please specify in what way the diagrams did not correspond to the briefing?
   ____
   ____

11. On a scale of 1 to 7, where 1 is very clear and 7 is very unclear, please indicate the clarity of the **exit operating instructions** given in the safety card and seatback placards. Please circle **one** number only.

1	2	3	4	5	6	7
Very clear						**Very unclear**

12. On a scale of 1 to 7, where 1 is very clear and 7 is very unclear, please indicate the clarity of the **exit operating instructions** given to you **personally by the flight attendant**. Please circle **one** number only.

1	2	3	4	5	6	7
Very clear						**Very unclear**

13. What **improvements could be made to the personal briefing**, such that they would enhance your actions in the event of an emergency evacuation?
____
____
____

14. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty you experienced in **finding the exit operating handle.** Please circle **one** number only.

1	2	3	4	5	6	7
Very easy						**Very difficult**

15. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty you experienced in **unlatching the exit hatch**. Please circle **one** number only.

1	2	3	4	5	6	7
Very easy						**Very difficult**

16. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty you experienced in **using the exit operating handle**. Please circle **one** number only.

1	2	3	4	5	6	7
Very easy						**Very difficult**

17. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty you experienced in **opening the exit hatch**. Please circle **one** number only.

1	2	3	4	5	6	7
Very easy						**Very difficult**

18. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty you experienced due to **the weight of the hatch**. Please circle **one** number only.

1	2	3	4	5	6	7
Very easy						**Very difficult**

19. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty you experienced due to **the size of the hatch**. Please circle **one** number only.

1	2	3	4	5	6	7
Very easy						**Very difficult**

20. On a scale of 1 to 7, where 1 is very clear and 7 is very unclear, please indicate the clarity of the **instructions for disposing of the door.** Please circle **one** number only.

1	2	3	4	5	6	7
Very clear						**Very unclear**

21. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty you experienced in **moving the exit hatch out of the way**. Please circle **one** number only.

1	2	3	4	5	6	7
Very easy						**Very difficult**

22. Where did you leave the exit hatch **first when you moved it out of the way?** Please circle one option only.
    a. Outside the cabin
    b. Inside the cabin, against the wall below the exit
    c. Inside the cabin, on the floor in the passageway leading to the exit
    d. Inside the cabin, on my seat
    e. Inside the cabin, on one of the seats in the exit row
    f. Inside the cabin, on the seats in the row in front of the exit row
    g. Inside the cabin, on one of the seats in the row behind the exit row
    h. Inside the cabin, on the floor in the main aisle
    i. I can't remember
    j. Other (please specify) ______________________________

23. Did anything relating to the exit hatch **help** your evacuation? Please circle **one** option only.

    a. **No**
    b. **Yes** (Please specify what helped you, and how)

    ____
    ____
    ____

24. Did anything relating to the exit hatch **hinder** your evacuation? Please circle **one** option only.

    a. **No**
    b. **Yes** (Please specify what hindered you, and how)

    ____
    ____
    ____

25. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty of **moving between the seats at the exit row**. Please circle **one** option only.

1	2	3	4	5	6	7
Very Easy						**Very Difficult**

26. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty you experienced in **moving through the exit and out of the aircraft**. Please circle **one** number only.

1	2	3	4	5	6	7
Very easy						**Very difficult**

27. Did any physical features within the cabin **help** your evacuation? Please circle **one** option only.

    a. **No**
    b. **Yes** (Please specify what helped you, and how)

____
____
____
____

28. Did any physical features within the cabin **hinder** your evacuation? Please circle **one** option only.

    a. **No**
    b. **Yes** (Please specify what hindered you, and how)

____
____
____
____

29. If you were flying on a commercial aeroplane, based on your experience today, would you be: - (Please circle **one** option only)

    a. More willing to sit by this exit than before
    b. Less willing to sit by this exit than before
    c. As willing to sit by this exit as you were before

30. If there are any comments that you would like to make about the trial you have just completed, please do so here.

____
____
____
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____
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____
____
____
____
____

Appendix Q: Additional photographs to accompany Experiment Three

Photograph Q1: The Type III hatch in the small interior configuration with traditional “plug” exit mechanism.

Photograph Q2: The disposed traditional “plug” hatch on aircraft wing.

Photograph Q3: The Type III hatch in the small interior configuration with “up and over” ADH exit mechanism.

Photograph Q4: The Type III hatch with “up and over” ADH exit mechanism in motion.

Photograph Q5: The disposed ADH hatch up in the fuselage.

Appendix R: Post-evacuation questionnaire – Experiment Four

Volunteer Number: ________________________

The information we ask for in this questionnaire relates to the evacuation you have just completed. Please be honest, and complete as many questions as possible. Your answers may help us to improve the safety of air travel.

1. On a scale of 1 to 7, where 1 is paying full attention, and 7 is paying no attention, to what extent would you say you **listened to the safety briefing** provided?
   Please circle **one** number only.

1	2	3	4	5	6	7
Full attention						**No attention**

2. For what reasons did you ***not*** give the safety briefing your full attention? Please circle **all** that apply.

   a. Not applicable – I gave the briefing my full attention (please go to question 3)
   b. I had seen the briefing before
   c. It's basic knowledge
   d. My view was obstructed
   e. I was distracted by someone else
   f. It went on for too long
   g. I didn't think I needed to
   h. Other (Please specify)
   ____

3. On a scale of 1 to 7, where 1 is very helpful, and 7 is not at all helpful, please indicate the extent to which you think the **safety briefing** assisted you in this evacuation?
   Please circle **one** number only.

1	2	3	4	5	6	7
Very helpful						**Not at all helpful**

4. The cabin crew provided a **safety briefing and demonstration** prior to this evacuation. With hindsight, what information do you think could have been included to improve your evacuation?

   ____
   ____

5. Did you read the **safety card** that was in the seat pocket in front of you? Please circle **one** option only.

   a. Yes
   b. No

6. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty in **undoing your seatbelt**. Please circle **one** number only.

1	2	3	4	5	6	7
Very easy						**Very difficult**

7. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty of **moving out of your seat** to reach the main aisle. Please circle **one** number only.

1	2	3	4	5	6	7
Very Easy						**Very Difficult**

8. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty of **moving down the main aisle to reach the exit row**. Please circle **one** number only.

1	2	3	4	5	6	7
Very Easy						**Very Difficult**

9. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty of **entering the exit row**. Please circle **one** number only.

1	2	3	4	5	6	7
Very Easy						**Very Difficult**

10. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty of **moving between the seats at the exit row**. Please circle **one** number only.

1	2	3	4	5	6	7
Very Easy						**Very Difficult**

11. On a scale of 1 to 7, where 1 is very easy and 7 is very difficult, please indicate the difficulty you experienced in **moving through the exit and out of the aircraft**. Please circle **one** number only.

1	2	3	4	5	6	7
Very easy						**Very difficult**

12. On a scale of 1 to 7, where 1 is very helpful and 7 is not at all helpful, please indicate the extent to which **cabin crew instructions** assisted you in this evacuation. Please circle **one** option only.

1	2	3	4	5	6	7
Very helpful						**Not at all helpful**

13. If there are any comments you would like to make about **cabin crew instructions** in this evacuation, please provide them here.

____

____

14. Did anything within the cabin **help** your evacuation? Please circle **one** option only

    a. No
    b. Yes (Please specify what helped you, and how)

    ____

    ____

15. Did anything within the cabin **hinder** your evacuation? Please circle **one** option only

    a. No
    b. Yes (Please specify what hindered you, and how)

    ____

    ____

16. What **strategies** did you use when evacuating? Please circle **all** that apply

    a. Climbed over seats
    b. Waited in line
    c. Pushed past other passengers
    d. Pushed other passengers towards the exit
    e. Allowed passengers to get in front of me
    f. Tried to get out my seat and move as far as possible down the aisle before others could
    g. None
    h. Other (please specify)

    ____

17. Do you think that the **strategies** you used: (Please circle **one** option only)

    a. Helped your evacuation
    b. Hindered your evacuation
    c. Did not make any difference

18. If there are any other comments you would like to make regarding the evacuation you have just completed, please provide them here (please continue overleaf if required).

____

____

____

____

____

____

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Please check that you have answered all relevant questions. Thank you.

Appendix S: Additional photographs to accompany Experiment Four

Photograph S1: No hatch in cabin condition (i.e. hatch disposed of outside the cabin).

Photograph S2: No hatch in cabin condition (i.e. hatch disposed of outside the cabin).

Photograph S3: Exit hatch disposed of horizontally in cabin condition.

Photograph S3: Exit hatch disposed of horizontally in cabin condition.

Photograph S5: Exit hatch disposed of vertically in cabin condition.

Photograph S6: Exit hatch disposed of vertically in cabin condition.