VLTA Emergency Requirements Research Evacuation Study

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Abstract

The VERRES programme was a European Commission/DG Tren funded project to examine some of the issues relevant to evacuation from next generation very large transport aircraft. The consortium included Sofréavia, CAA/SRG, JAA, Airbus, University of Greenwich, Cranfield University, Virgin Atlantic Airways and SNPNC.

The consortium identified several domains as high research priorities. These included staircase size, staircase configuration, staircase flow management, upper deck slide use, and crew co-ordination. Experiments require a high degree of control and a number of replications of each test condition, and therefore the number of variables which can be investigated in any one study is limited. However, the consortium found it difficult to define a restricted set of variables for experimental research. Given the limited number of trials available, it was therefore necessary to conduct the proposed evacuations as demonstrations rather than as scientific experimental tests.

Eight evacuation demonstrations were conducted over a period of two days, using both decks of the Large Cabin Evacuation Simulator located at Cranfield University. This facility was commissioned and funded by the United Kingdom Civil Aviation Authority in 2001. The demonstrations involved members of the public evacuating the simulator under one of three scenarios: free choice of exits between upper and lower decks, movement from the lower deck to exits on the upper deck, and moving from the upper deck to exits on the lower deck. The evacuation demonstrations were video recorded so that evacuation performance could be analysed.

Several consortium members undertook analysis of the resulting evacuation and questionnaire data. Cranfield University conducted the analysis on passenger evacuations, utilising the evacuation footage from time coded video cameras located within the facility. A summary of these results are reported within this paper. Because of limitations in the research design, these results cannot be regarded as conclusive. However, they do provide an indication of the issues relevant to passenger evacuations from future very large transport aircraft.

1. Introduction

1.1. Background

The VERRES programme was a European Commission/DG Tren funded project to examine some of the issues relevant to evacuation from next generation very large transport aircraft. The consortium members were Sofréavia, CAA/SRG, JAA, Airbus, University of Greenwich, Cranfield University, Virgin Atlantic Airways and SNPNC. The study was initiated as the development of Very Large Transport Aircraft (VLTA) is of importance in facing the forecast increase in air traffic. The VLTA represents a challenge in emergency evacuation, both for aircraft manufacturers and the certification authorities. This is because the transition to multiple aisles and double decks implies a significant rise in passenger numbers. Certification is an issue which the manufacturers need to address in a timely manner, to achieve a rapid return on the research and development investment. It is also an issue for the regulatory authorities, who may be faced with the approval of a VLTA product within a very short time scale.

The VERRES study was general in nature, and not related to any specific VLTA type. The study aimed to provide information relevant to future generation very large transport aircraft, although it was intended that some of the recommendations may have immediate applicability to aircraft of this size that are shortly to be developed. The programme of study covered three major domains: the configurational aspects of aircraft cabin design and the evacuation implications, the use of analysis supported by relevant small-scale evacuation tests and evacuation modelling software, and the human aspects such as cabin crew co-ordination and training and the mental representation layout of the aircraft for the passenger. A summary report, providing an overview of the whole programme, has been published by the Joint Aviation Authorities on behalf of the consortium (Greene & Friedrich, 2003)[1].

1.2. Research areas

The details of each of these three domains were discussed between all consortium members. This was necessary in order to select a small number of variables for experimental testing. From these discussions, a number of potential research areas were noted and were classified into two categories – either high or low priority within the specification of the VERRES project. The factors that were of interest, along with the prioritisation specified by the consortium after discussion, are shown in Table 1.

Table 1: Research areas and prioritisation according to consortium discussions

High research priority	Low research priority
Staircase size	Width of aisles
Staircase configuration	Width of bulkheads
Staircase flow management	Redirecting passengers
Upper deck slides	Visibility of exits
Crew co-ordination	

Cranfield University and the University of Greenwich used the ideas generated during this discussion to propose to the consortium an experimental design that ensured methodological rigour. The proposed design allowed for the testing of the use of the internal staircase, with and without additional dedicated cabin crew at those locations to manage passengers, and also incorporated use of the upper deck slide. Although the number of test days were limited, this experimental approach would have allowed relatively firm conclusions to be drawn from the

[1] Greene, G. & Friedrich, P. (2003) (eds) Very Large Transport Aircraft (VLTA) Emergency Requirements Research Evacuation Study (VERRES) - A Project Summary. JAA Research Paper 2003/1. Published by the Joint Aviation Authorities.

research. Confidence in the results is of primary importance where certification questions are to be resolved, because it is important that the manufacturer, the regulatory authority and the public can trust the research findings.

After further discussion, the VERRES consortium specified a larger number of potential variables of interest, and it soon became evident to Cranfield University and University of Greenwich researchers that consortium members could not limit the number of independent variables. In addition, insufficient test evacuations were available to obtain adequate replications of each test condition. As the consortium partners were unable to agree a compromise test programme, it was finally determined that the scientific method would not be adopted. Instead of an experiment, it was proposed to conduct the evacuation trials as a series of demonstration evacuations. Hence, attempts to control confounding variables or to scientifically manipulate the factors of interest were relinquished. It was accepted by all consortium members that the trials would only provide data which could then be used to explore possibilities for future research, and that the conditions under which the data were collected would not allow for quantification of effects or the testing of research hypotheses.

1.3. Design of the demonstrations

Three of the variables of interest related to the extent to which passengers might have a choice of exits between two decks on a VLTA. For example, with a free choice of exits between upper and lower decks, there may be movement from the lower deck to the upper deck, or movement from the upper deck to the lower deck. In situations where lower decks exits are not available, all lower deck passengers may be required to move up the internal staircase to the upper deck. In situations where the upper deck exits are not available, all upper deck passengers may be required to move to the lower deck to find an exit. These scenarios were included in the demonstrations. Another group of variables of interest related to the cabin crew, in that for some scenarios, additional cabin crew would be available at the staircase, while for other demonstrations, cabin crew would only be available at the exits.

The evacuation demonstrations were conducted over two test days (25 January and 1 February 2003), with four scenarios being demonstrated on each day. Because of the large number of variables being explored, and the non experimental nature of the trials, it was not possible to counterbalance the demonstrations. There was therefore no control over the effects of learning and practice on passenger or cabin crew behaviour. The only exception related to the use of the staircase. In order to obtain data from naïve volunteers, they were split into two groups, and each group was seated on either the upper or the lower deck for each trial. This was done so that University of Greenwich researchers would be able to obtain staircase data from naïve volunteers for modelling purposes. All of the demonstrations were video recorded, so that data relating to the behaviour of passengers and cabin crew could be extracted from the video footage after the demonstrations.

2. Method

2.1. Test facility

The demonstration facility was the Large Cabin Evacuation Simulator (LCES) located at Cranfield University in the UK. This facility was commissioned and funded by the Civil Aviation Authority of the United Kingdom, and was opened by HRH The Duke of Kent in July 2001. The facility is constructed over two decks in a modular fashion, so that key configurational variables can be manipulated according to specific research aims. The aisles, seats, monuments, the staircase linking the decks, and the exit size and location have all been designed and fitted such that they can be moved or relocated as required. For these demonstrations, the facility replicated the key physical features of a generic wide bodied cabin over two decks. Both decks were used in the evacuation scenarios.

The lower deck of the cabin seated up to 172 volunteers. Seats within the cabin were set at a 31″ pitch, equivalent to a vertical projection of 5 inches. Three exits were fitted on the lower deck, one forward on the port side of the cabin (Lower Left 1, or LL1). An exit pair was also located midway down the cabin at the base of the staircase, one exit on the port and one on the starboard sides. These exits were designated Lower Left 2 and Lower Right 2 (LL2 and LR2 respectively). All lower deck exits conformed to the dimensions of Type A exits, being 42″ wide by 72″ high. Platforms were available outside the three lower deck exits for volunteers to evacuate. The sill height of the lower deck platform was 5 metres above ground level.

On the upper deck, 88 seats were available, also at 31″ pitch. Two exits were fitted to the upper deck, one forward on the port side (Upper Left 1, or UL1), and one forward on the starboard side (Upper Right 1, or UR1). All upper deck exits conformed to the dimensions of Type A exits, being 42″ wide by 72″ high. UL1 had a platform outside for evacuating passengers, at 8 metres above ground level. UR1 was fitted with a dual-lane evacuation slide, again 8 metres above ground. The slide was 16 metres long and was capable of carrying upwards of 140 passengers per minute.

2.2. Demonstration volunteers

Up to 168 volunteers were recruited for each day, four demonstrations were held on each day. Volunteers were permitted to take part in a single test session only. Volunteers were members of the public who were recruited using either the database held within the Human Factors Group at Cranfield University, or local and regional advertising. The database holds contact details of people who have responded to local and regional advertising, and have thereby expressed an interest in participating in aviation safety research. To minimise the risk of injury in participating in the demonstrations, volunteers were required to be aged between 20 and 50, and relatively fit. People who had experienced any of the following conditions were excluded 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 disorders, fear of enclosed spaces, fear of heights, fear of flying, brittle bones, asthma, bronchitis, breathlessness, chest trouble, lumbago sciatica, or any other serious illness. Volunteers who were pregnant, or who thought they might be pregnant, were also excluded from participating, as were volunteers who had recently undergone surgery or who were receiving medical treatment. All volunteers were required to weigh no more than around 15 stones (95.25 kg).

In addition to the volunteers, a member of the research team took the part of a passenger as a "stooge" for each demonstration. This person - volunteer 100 - always occupied the 1J seat on the upper deck, and his task was to protect the UR1 cabin crew while they made this exit available.

2.3. Demonstration scenarios

The design of an experiment is directly related to the confidence that may be placed in the results. In any study intended to assess evacuation issues, when a robust research design is employed, the regulators may be confident that the results are purely due to the factors that were included and controlled within the study. If this is not the case, then the results may be erroneous, and may not be interpreted with confidence. This is because the experimental findings are then subject to interpretation by other factors, such as chance, learning and practise, or a confounding variable. Since the programme of VERRES evacuations did not meet these stringent requirements, it was accepted by all consortium members that the evacuations would be regarded as demonstrations only.

Given that eight demonstrations would be conducted over two days, it was decided to prioritise the scenarios that were perceived as more critical. Within the eight tests, two were free choice situations. These were demonstrations where it was anticipated that passengers would have a free choice between available exits on both decks. There were also two demonstrations of the moving upwards scenario: where passengers on the lower deck were required to move to the upper deck, where the only available exits were located. There four demonstrations of the moving downwards scenario: where passengers on the upper deck were required to move to the lower deck, where the only available exits were located.

Also of interest was the presence or absence of additional cabin crew at the staircase, but this was considered to only be relevant for conditions in which volunteers had no free choice about where they moved to available exits. Hence, one of the moving upwards tests had two additional cabin crew, and two of the moving downwards test had two additional cabin crew. Where additional crew were available at the staircase, one was located at the top of the staircase on the upper deck, and one at the bottom of the staircase on the lower deck. Because the scenarios were not conducted using the scientific experimental method, the effects of learning, practise or other confounding variables could be neither controlled nor measured. The order of the demonstrations is given in Table 2.

Table 2: Demonstrations on 25 January and 1 February 2003

Trial	**25 January 2003**	**1 February 2003**
1	<u>Free choice</u> No additional crew at staircase Available exits UR1, LL2 and LR2, Group A seated on upper deck Group B seated on lower deck	<u>Moving Downwards</u> Additional crew at staircase Available exits LL2 and LR2 Group A seated on upper deck Group B seated on lower deck
2	<u>Moving Downwards</u> No additional crew at staircase Available exits LL2 and LR2 Group A seated on lower deck Group B seated on upper deck	<u>Moving Upwards</u> No additional crew at staircase Available exits UL1 and UR1 Group A seated on upper deck Group B seated on lower deck
3	<u>Moving Upwards</u> Additional crew at staircase Available exits UL1 and UR1 Group A seated on lower deck Group B seated on upper deck	<u>Moving Downwards</u> No additional crew at staircase Available exits LL2 and LR2 Group A seated on upper deck Group B seated on lower deck
4	<u>Moving Downwards</u> Additional crew at staircase Available exits LL2 and LR2 Group A seated on upper deck Group B seated on lower deck	<u>Free Choice</u> No additional crew at staircase Available exits UR1, LL2 and LR2 Group A seated on lower deck Group B seated on upper deck

2.4. Conduct of demonstrations

On arrival at the test session, volunteers were issued with a bib detailing their volunteer number for the test session. In addition, each volunteer was provided with a clipboard of information. The height and weight of all volunteers was measured and documented by members of the research team. Volunteers were also required to complete a medical questionnaire, which was checked and signed by one of the medical team. Volunteers then were briefed with regards to the nature of the demonstrations, including instructions for the scenarios, health and safety considerations including the emergency stop procedure, and payment details.

Volunteers boarded the cabin simulator using the external staircases, to ensure they did not use the internal staircase prior to the evacuation trials. Seats were allocated according to a pre-defined seating plan on a random basis within each of the two groups. The two volunteer groups moved between decks, and no volunteer was allocated to the same seat on the same deck twice. On boarding, lights within the cabin were at take-off and landing levels. Additional lighting was used at the staircase for safety purposes; this light remained on throughout the evacuation trials.

There were ten members of cabin crew on board. Four were located at exits on the lower deck, two at the staircase (one at the top of the staircase and one at the bottom of the staircase, for scenarios where this was appropriate), and four on the upper deck, with two crew at each exit. The cabin crew on the lower deck, staircase and at UL1 were line cabin crew or cabin crew instructors supplied by Virgin Atlantic Airways. For safety purposes, the crew located at UR1 (the upper deck slide) were two members of the Cranfield University research team, trained and dressed as cabin crew. Once the volunteers were boarded and seated, the cabin crew gave volunteers a pre-flight safety briefing and safety demonstration. On completion of this, the cabin crew moved to their allocated seats, and lights within the cabin were dimmed to night levels.

The public address system was used to play one of four pre-recorded scenario messages. This was necessary so that volunteers would be unable to anticipate precisely the call to evacuate the cabin. Each pre-recorded message included a whistle signal at approximately 10 seconds after the call to evacuate, to communicate to cabin crew the estimated slide deployment time. Using such a signal meant that the stewards outside the exits would know when to signal to the crew the exit availability status. All cabin crew - with the exception of those located at Upper Right 1 (upper deck slide) - were unaware of whether their exit would be made available at the end of the estimated slide deployment time. Hence, all crew opened their exits on the call to evacuate, and managed passengers until the steward informed them of the availability status of their exit.

All commands used during the demonstrations were those in operational use by Virgin Atlantic Airways at the time of testing. This was necessary to reduce any potential confusion for the line cabin crew. The introduction of commands outside their normal procedures may have been detrimental to their later performance, should a genuine emergency situation arise on board. On the call "Emergency stations", cabin crew commanded passengers to brace, using the commands "heads down, feet back". This was shouted twice initially, and then repeated at five second intervals, until the call to evacuate. The call to evacuate was the Captain's voice shouting to passengers to "Evacuate, evacuate, evacuate". At this point, the lights within the cabin were reduced to emergency levels. Cabin crew then immediately opened their exit and stood in front of the exit for the duration of the slide deployment time. Throughout this period, they called volunteers towards them using the commands "Open seat belts and get out", "Leave everything behind" and "Come this way". On the whistle signal, cabin crew actions were then dependent on whether their exits were made available by the stewards.

On the whistle signal, cabin crew at available exits immediately stood aside in the assist space, and began calling to passengers to evacuate. This was done using commands such as “Go!” “Stay on your feet”, “Keep moving”, and “Form two lines”. Cabin crew used physical gestures and assistance as appropriate. Cabin crew at unavailable exits remained directly in front of their exit, informed passengers that the exit was blocked, and instructed them to find another exit. This was done using commands such as “Exit blocked”, and “Go that way”. Again, the cabin crew used physical gestures and assistance as appropriate.

Stewards were located immediately outside each exit, in order that evacuating passengers could be moved swiftly away. Blockages outside the exit could have slowed the evacuation rate had this not been the case. The trial was deemed complete when all passengers had evacuated the cabin. Passengers were then required to complete two post-evacuation questionnaires, one designed by Cranfield University and the other designed by Sofréavia, another consortium partner. When all volunteers had completed the questionnaires, they boarded the cabin for the next evacuation, sitting in the seat randomly allocated to them for that trial. When all four demonstrations were complete, volunteers were debriefed and paid £25 for attending the session.

3. Results

3.1. Completed demonstrations

No evacuations were halted, and data were obtained for all eight demonstrations. In total, 336 individuals volunteered to take part, although one withdrew after the first trial on 25 January 2003 (Volunteer 27). No injuries were sustained throughout the testing programme. The final sample included 336 individuals, of whom 190 were male (56.5%) and 146 were female (43.5%). The recruiting requirements specified that volunteers had to be between the ages of 20 and 50. In the event, volunteers' ages at the time of the demonstrations ranged from 19 to 68. Volunteers falling outside the specified limits were able to take part only following consultation with the medical practitioner. The average age of volunteers at the time of testing was 31 years, with a standard deviation of 9 years.

In terms of flying experience, most volunteers had travelled by air previously, since only four people (1.2%) had never previously flown. Another 47 volunteers (14.0%) had made between 1 and 3 return trips, while 52 (15.5%) had made between 4 and 7 return trips. The majority of people had made eight or more return trips (233 volunteers, 69.3% of the sample). However, only six individuals reported having undertaking a genuine emergency evacuation (1.8%). In terms of handedness, 287 volunteers (85.4%) reported themselves as being right-handed, 28 (11.3%) reported themselves as being left handed, and 10 (3.0%) claimed to be ambidextrous. There was one person who did not provide an answer to this question (0.3% of the sample). For corrected vision, 147 volunteers did not report having corrected vision (43.8%). 37 volunteers reported correcting their vision for close work (11.0%), 100 reported correcting their vision for distance tasks (29.8%), and 50 volunteers (14.9%) reported corrected vision for both close and distance work. Two people did not answer this question (0.6%) of the sample.

3.2. Data preparation

The video footage for each demonstration was dated and time-coded from the call to evacuate. The call to evacuate was the command from the captain to "Evacuate, evacuate, evacuate!" The length of this command meant that with the second, third and fourth trials of each session, volunteers were able to anticipate the command, and sometimes left their seats before the final call. However, this command is in operational use, and it was decided that it was preferable to use commands that would be familiar to the cabin crew. The evacuation time data were extracted from the time-coded footage. A person was deemed to have evacuated when they placed their first foot over the exit threshold. Hence, none of the evacuation times for the UR1 exit include the time taken to negotiate the evacuation chute. It is hoped that this strategy will have made the times obtained from different exits more comparable, although it is known that evacuation times onto platforms and slides are not directly equivalent. Data were also available from post-evacuation questionnaires, which asked volunteers to rate various aspects of the evacuation for ease and/or difficulty. A limited analysis is published here, further details are available in Greene & Friedrich, 2003.

3.3. Descriptive analysis

The first scenario was the free choice situation, and two demonstrations of this type of evacuation were conducted. The free choice scenario did not include additional cabin crew at the internal staircase. The moving upwards scenario involved lower deck passengers moving up the internal staircase to reach available exits on the upper deck. Two of these evacuations were conducted, one with additional crew at the internal staircase, and one without. The final four evacuations were conducted in the moving downwards scenario, where upper deck passengers moved to the lower deck to reach available exits. Two demonstrations were conducted with additional cabin crew at the internal staircase, and two without. It must be noted that the difference between the additional crew and no additional cabin crew scenarios may not be particularly clear in practise; cabin crew were observed on the video footage to have moved near the staircase in several demonstrations. Descriptive results for evacuation times and questionnaire results are provided for each scenario in turn.

3.3.1. Free choice demonstrations

Table 3: Summary evacuation statistics for free choice evacuations

Free choice evacuations	N	Slide deployment (seconds)*	Mean evacuation time (seconds)	Evacuation rate (passengers per minute)†	Overall exit evacuation time (seconds)§
25 January 2003 Trial 1					
UR1	33	10.7	42.4	25.4	75.6
LL2	62	10.7	31.2	56.7	64.5
LR2	74	10.7	33.4	63.3	69.2
1 February 2003 Trial 4					
UR1	36	10.7	29.9	46.4	45.3
LL2	65	10.7	22.9	92.3	41.6
LR2	68	10.7	25.3	79.4	50.6

Inferential analyses of the raw evacuation times cannot be conducted, since insufficient data are available for comparison with other demonstrations. However, there do appear to be differences in evacuation rates between the two demonstrations, with lower mean evacuation times, faster evacuation rates, and lower overall exit evacuation times evident on the last trial of the programme. This is likely to be a function of passenger learning (between the first and fourth demonstrations of each day) and cabin crew (who by the fourth demonstration on 1 February 2003 had experienced eight demonstrations).

Volunteers seated on the upper and lower decks for the free choice evacuations were also asked to choose, from several pre-defined options, the single most important factor in choosing an exit to evacuate through. The results are provided below in Table 4.

Table 4: Free choice demonstrations: the most important factor in choosing an exit

Reason for choosing the exit	Upper deck (N = 165)	Lower deck (N=165)
It was the nearest available door	33.9%	63.0%
I entered/boarded using the door	0%	0.6%
Cabin crew directed me to the door	40.6%	18.2%
It was the door with the shortest queue	12.1%	4.8%
It was the first available door I passed	3.6%	3.6%
It was the only door I could see	0.6%	2.4%
I followed the passengers in front	4.2%	3.0%
I knew about the door from the safety briefing/card	3.6%	3.0%
Other	1.2%	1.2%

* The slide deployment time was taken from the call to evacuate, to the signal to stewards that the available exits were to be opened.
† Calculated using the formula n-1/time.
§ The overall exit evacuation time was taken from the call to evacuate to the first foot of the last participant over the exit threshold.

3.3.2. Moving upwards demonstrations

Table 5: Summary statistics for moving upwards evacuations

Moving upwards evacuations	N	Slide deployment (seconds)*	Mean evacuation time (seconds)	Evacuation rate (passengers per minute)†	Overall exit evacuation time (seconds)§
1 February 2003 Trial 2 No additional crew					
UL1	112	10.7	43.9	78.9	84.4
UR1	57	10.7	47.5	38.8	86.5
25 January 2003 Trial 3 Additional crew					
UL1	119	10.7	45.3	91.1	77.7
UR1	49	10.7	45.4	36.8	78.2

Inferential analyses of the raw evacuation times cannot be conducted, since insufficient data are available for comparison with other demonstrations. However, there do appear to be marked differences in evacuation rates between UR1 and UL1, which is most likely a function of the caution exercised by cabin crew at the UR1 exit. The evacuation slide used in these trials had not been used in any previous research, and hence the cabin crew took great care to ensure volunteer safety.

As with the free choice evacuations, volunteers were asked to choose from several options the single most important factor which influenced their choice of an available exit. The results, split according to whether passengers were seated on the upper or lower deck and according to whether additional crew were available, are provided in Table 6.

Table 6: Moving upwards demonstrations: the most important factor in choosing an exit

Reason for choosing the exit	Upper deck		Lower deck	
	No additional crew (N = 84)	Additional crew (N = 83)	No additional crew (N = 82)	Additional crew (N = 80)
It was the nearest available door	56.0%	33.7%	9.8%	8.8%
I entered/boarded using the door	3.6%	1.2%	0%	0%
Cabin crew directed me to the door	13.1%	41.0%	57.3%	66.3%
It was the door with the shortest queue	11.9%	9.6%	7.3%	5.0%
It was the first available door I passed	2.4%	6.0%	8.5%	3.8%
It was the only door I could see	1.2%	3.6%	0%	1.3%
I followed the passengers in front	3.6%	2.4%	7.3%	7.5%
I knew about the door from the safety briefing/card	3.6%	2.4%	1.2%	1.3%
Other	4.8%	0%	7 (8.5%	5 (6.3%)

* The slide deployment time was taken from the call to evacuate, to the signal to stewards that the available exits were to be opened.
† Calculated using the formula n-1/t.
§ The overall exit evacuation time was taken from the call to evacuate to the first foot of the last participant over the threshold.

3.3.3. Moving downwards demonstrations

Table 7: Summary statistics for moving downwards evacuations

Moving downwards evacuations	N	Slide deployment (seconds)[*]	Mean evacuation time (seconds)	Evacuation rate (passengers per minute)[†]	Overall exit evacuation time (seconds)[§]
25 January 2003 Trial 2 No additional crew					
LL2	80	10.7	28.3	83.0	57.1
LR2	88	10.7	29.4	92.9	56.2
1 February 2003 Trial 3 No additional crew					
LL2	81	10.7	27.5	90.7	52.9
LR2	88	10.7	28.1	98.3	53.1
25 January 2003 Trial 4 Additional crew					
LL2	81	10.7	28.8	90.2	53.2
LR2	87	10.7	28.2	99.0	52.1
1 February 2003 Trial 1 Additional crew					
LL2	86	10.7	29.9	89.9	56.7
LR2	83	10.7	31.1	83.5	58.9

Inferential analyses of the raw evacuation times cannot be conducted, since insufficient data are available for comparison with other demonstrations. However, the mean evacuation times, evacuation rates and overall exit evacuation times do appear to be broadly similar over the different moving downwards demonstration evacuations.

As with the free choice and moving upwards evacuations, volunteers in the moving downwards demonstrations were asked to choose the single most important factor which influenced their choice of an available exit. The results are shown in Table 8.

[*] The slide deployment time was taken from the call to evacuate, to the signal to stewards that the available exits were to be opened.
[†] Calculated using the formula n-1/t.
[§] The overall exit evacuation time was taken from the call to evacuate to the first foot of the last participant over the threshold.

Table 8: Moving downwards demonstrations: the most important factor in choosing an exit

Reason given	**Upper deck**		**Lower deck**	
	No additional crew (N = 166)	**Additional crew (N = 164)**	**No additional crew (N = 164)**	**Additional crew (N = 165)**
It was the nearest available door	22.9%	17.7%	60.4%	61.2%
I entered/boarded using the door	0%	0.6%	0.6%	3.6%
Cabin crew directed me to the door	39.2%	61%	20.7%	19.4%
It was the door with the shortest queue	3.0%	2.4%	3.0%	1.8%
It was the first available door I passed	6.0%	3.0%	3.0%	3.0%
It was the only door I could see	2.4%	0.6%	0.6%	1.8%
I followed the passengers in front	11.4%	7.3%	5.5%	3.6%
I knew about the door from the safety briefing/card	9.0%	4.9%	3.7%	4.8%
Other	6.0%	3.0%	2.4%	0.6%

Discussion

Unfortunately, the data obtained from the evacuation demonstrations were not amenable to inferential statistical analysis. This was due to the lack of experimental control over the design of the evacuation tests. Experimental trials allow for variables of interest to be manipulated independently, while all other variables are held constant. A number of trials, all conducted under exactly the same conditions, are conducted in a carefully defined order. The order of the trials is counterbalanced so that any effects of practise, learning or fatigue can be measured and evaluated. Using this scientific method, and changing only one variable at a time, it is possible to assess the relative contribution of individual variables to evacuation outcomes in a reliable manner. In this programme, there was no control over the variables of interest, and hence the evacuations were only demonstrations, and not experimental tests. The findings are therefore only illustrative of the type of factors that influenced evacuations in these scenarios. They do not give a reliable indication of which issues were most critical, which should receive most regulatory attention, or which should receive most research investment.

Based on the data collected under these uncontrolled conditions, it is not possible to say which factors had the most impact on evacuation outcomes. However, it is possible to discuss the descriptive data and speculate on possibilities for future research. One example of a fruitful area for further work is to examine passenger exit choice behaviours. In free choice evacuation scenarios, the majority of volunteers who had been seated on the upper deck stated that the cabin crew had directed them towards the exit that they used (40.6%) and a large proportion said that they had used the nearest available door (33.9%). Passengers on the lower deck were more likely to state that they had used the nearest available exit (63.0%). For moving upwards demonstrations, some volunteers who had been seated on the lower deck reported that they had used the nearest available exit (9.8% where there were no additional crew, and 8.8% where additional crew were present). However, a far larger proportion said that the cabin crew instructions had influenced their choice of exit, 57.3% rising to 66.3% where additional crew were available. Clearly, cabin crew instructions were an important factor in directing passengers up the internal staircase. Similarly, cabin crew were also an important factor in directing upper deck passengers downstairs in the moving downwards evacuations.

Within the free choice trials, it had been planned to investigate the number of passengers on the upper deck who decided to use the internal staircase to evacuate via lower deck exits rather than the upper deck slide, as UL1 (exiting onto a platform) was not available. It was also assumed that during the free choice trials, the route taken by upper deck passengers (to exit either via UR1 or to use the internal staircase to reach the lower deck) would be a decision made by the passenger. Clearly, the results of the questionnaires suggest that the cabin crew had an important influence on passenger behaviour, and therefore it is difficult to assume that passengers decided on an exit to evacuate through without being influenced by other factors. In some cases the cabin crew gave commands related directly to staircase use to passengers; this may have influenced the actions of the passengers in selecting an exit route. In addition, the movement of other passengers would certainly have influenced the choices made by at least some of the passengers. Hence, no data is available on the number of upper deck passengers who decided, of their own accord, to move to the lower deck to evacuate.

In order to address the influence of additional crew on passenger behaviour, the scenarios included evacuations both with and without additional crew at the internal staircase. It was assumed that cabin crew stationed at exits on both the upper and lower deck would remain at their exit throughout the evacuation. However, during free choice trials, the video footage clearly shows a cabin crew member at the unavailable UL1 exit redirecting passengers, verbally and physically, towards the staircase. Once this crew member had space to move out of the assist space, s/he moved through the upper deck, redirecting passengers in the aisles and/or queuing to use the slide at UR1. The crew member felt able to leave the exit because there was a second member of crew protecting the door.

A second example of previously unanticipated cabin crew behaviour was when cabin crew moved from their assist space towards the staircase. In one evacuation demonstration, cabin crew at LL2 and LR2 were observed moving out of the assist space and positioning themselves at the base of the staircase. They were able to see passengers descending the staircase, and could manage the crowd in a manner they felt more appropriate. Although passengers were still evacuating, these crew members only left their assist space once their immediate area (i.e. the lower deck) was clear. It must be noted that the majority of cabin crew movement from the exits towards the stairs occurred when there were no additional crew present at the staircase. It is also important to note that the cabin crew may have behaved differently had the evacuations involved slides rather than platforms. However, the cabin crew movement made it difficult to investigate the effect of additional cabin crew at the staircase on passenger flow rates, as during most evacuations cabin crew played some part in passenger behaviour at the internal staircase.

These cabin crew members were following the training and procedures of the operator. They were using their judgement and initiative to evacuate the cabin of passengers in the shortest possible time. The details of why cabin crew took the actions they did may be found in the qualitative analysis conducted by Sofréavia (Greene & Friedrich, 2003). However, although this behaviour would have been appropriate in an emergency situation, it did confuse the data obtained from the demonstrations. It must be accepted that to a certain extent, this type of problem is unavoidable when using line crew in research evacuations. There are ethical issues associated with requiring operational cabin crew to use non operational commands for research purposes, since this may be detrimental to their performance in a genuine evacuation. This finding therefore serves to illustrate that researchers acting as cabin crew can sometimes add flexibility to a research evacuation protocol, since they are able to test a range of commands and actions. In this way, optimal evacuation commands, and procedures for future aircraft types, can be developed and tested most effectively.

The lack of experimental control must be regarded as a limitation of the programme. This had additional implications to those discussed above. Firstly, some consortium members requested that the cabin crew provide passengers with invalid safety information. In the safety demonstration on the upper deck, six exits were pointed out to passengers; two at the front, two at the centre, and two at the rear. In fact, only two exits were located on the upper deck, and this may have confused passengers. This was because some consortium members did not want passenger attention to be drawn to the internal staircase. In the event, the line cabin crew did command passengers to use the stairs as they were naturally keen to ensure that volunteers were evacuated as quickly as possible. The data analysis conducted by researchers at the University of Greenwich on staircase use therefore was constrained by the conditions under which the data were collected (Greene & Friedrich, 2003). However, the analysis showed that the majority of passengers used the central handrail, and this was clearly an important feature in assisting volunteers who used the staircase to move between decks.

The safety demonstration provided may also have influenced behaviour on the lower deck. There, cabin crew were instructed to point out three pairs of exits; one pair at the front, one pair in the centre, and one pair at the rear. In fact, only the exits in the centre of the lower deck, located at the bottom of the internal staircase, were used, although cabin crew were stationed at all exit locations. On some trials, volunteers moved towards the rear exits, where there were no cabin crew. In other evacuation demonstrations, the presence of observers in seat rows towards the rear inhibited volunteers from moving towards the rear. In these trials, it appears that the presence of observers informed passengers that the rear exits would not be made available, and they did not attempt to reach those exits. This would have influenced evacuation dynamics within the cabin, since the behaviour of volunteers is of course influenced by the behaviour of other "passengers".

In conclusion, the demonstrations did provide an insight into some of the issues that may be of relevance to evacuations from future very large transport aircraft. These aircraft may include configurations with multiple aisles, multiple decks and multiple cabins. Clearly, there is likely to be a degree of interaction between the configuration and various other factors, such as the actions and commands of the cabin crew, environmental factors such as signage visibility and lighting, and the behaviour of other passengers. The VERRES trials allowed for only two days of evacuation demonstrations, and therefore a limited number of factors could have been investigated in an experiment. Nevertheless, the results do raise interesting areas for future research, including passenger exit choice, cabin crew commands and procedures, and configuration factors such as staircase placement and design. The regulatory authorities will be able to take these factors into account when considering certification requirements.