An analysis of passenger performance on stairs and upper deck slides during evacuation trials: A report from the VERRES project

By

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- **The views expressed in this paper are solely those of the authors.**

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VLTA Questions related to VERRES

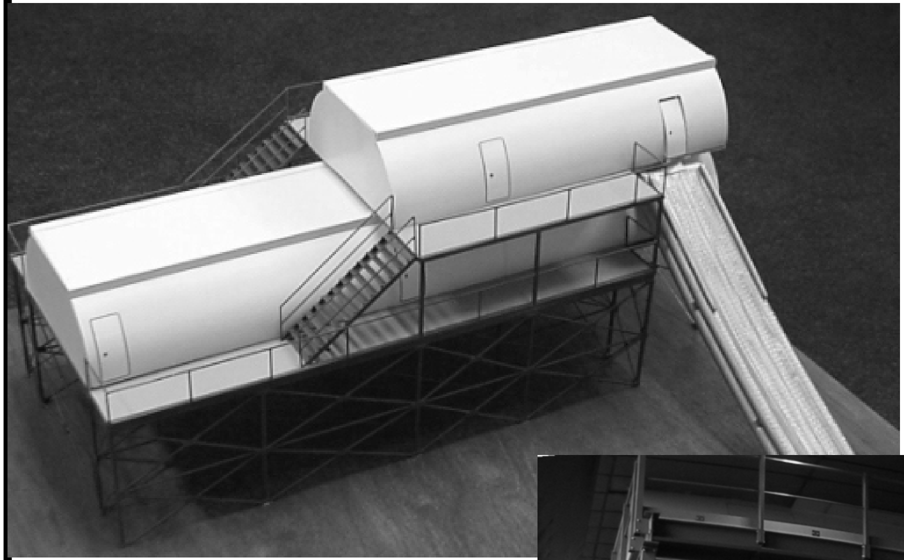
- Should passengers be allowed to travel between decks before exiting the aircraft?
- What implications does this have for crew evacuation procedures?
- What implications does this have for staircase design and location – e.g. number of staircases, number of lanes, location, riser height, location of hand rails, angle of orientation?
- How will crew communicate effectively to control such an evacuation on each deck and between decks?
- Will elevated sill heights have an impact of pax exit hesitation times?
- What impact will all these issues have on evacuation times and survivability?

Project VERRES: VLTA Evacuation Issues

- VLTA pose considerable challenges to designers, operators and certification authorities.
- The EU project VERRES was set up to examine a number of issues associated with VLTA.
- The VERRES consortium consisted of:
  - The UK CAA
  - The University of Greenwich
  - EADS Airbus
  - SOFREAVIA
  - Cranfield University
  - Virgin Atlantic
  - ETF (SNPNC) - observer
  - JAA - observer
- The aspect of VERRES that I will address in this presentation concerns:
  - Pax performance on main stairs during evacuation
  - Pax exit hesitation time at elevated sill heights.

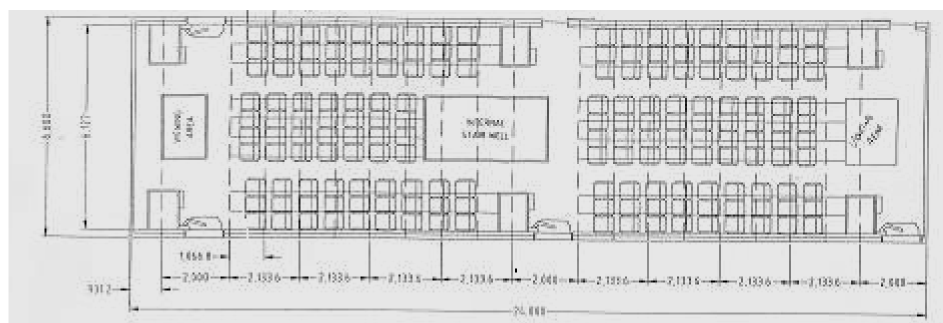
Cranfield VLES simulator

- Cranfield VLES used for all the trials.



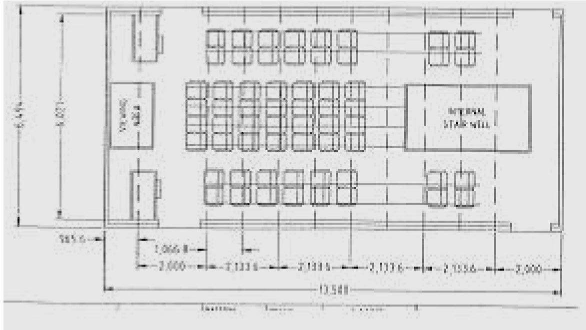
Cranfield VLES simulator

- **Lower Deck:**
  - Seats up to 172 participants, with a 31” pitch.
  - 3 exits,
    - One forward on the port side of the cabin (LL1).
    - An exit pair also located midway down the cabin at the base of the staircase, one exit on the port (LL2) and one on the starboard sides (LR2).
    - All exits were Type A, being 42” wide by 72” high.
    - Platforms available outside all lower deck exits.
    - Sill height of the lower deck platform was 5 metres above ground level.



Cranfield VLES simulator

- **Upper Deck:**
  - Seats up to 88 participants, with a 31” pitch.
  - 2 exits,
    - One forward on the port side of the cabin (UL1).
    - One forward on the starboard side of the cabin (UR1).
    - All exits were Type A, being 42” wide by 72” high.
    - UL1 fitted with platform 8 m above ground (A380, 7.9m, B747, 7.8m).
    - UR1 fitted with a dual lane slide, 16m long capable of carrying 140 pax/min.



Cranfield VLES simulator

- **Stairs:**
  - The stair consisted of two distinct pax lanes separated by a central HR.
  - Width of left lane (measured from centre of each HR) was 76.8 cms.
  - Width of right lane (measured from centre of each HR) was 75.8 cms
  - Riser height was 17.8 cms, Tread depth was 26 cms.
  - There were 16 stairs from bottom to top (excluding the floor of each deck).

Left lane	Right Lane
Tread 16	Tread 16
Tread 15	Tread 15
Tread 14	Tread 14
Tread 13	Tread 13
Tread 12	Tread 12
Tread 11	Tread 11
Tread 10	Tread 10
Tread 9	Tread 9
Tread 8	Tread 8
Tread 7	Tread 7
Tread 6	Tread 6
Tread 5	Tread 5
Tread 4	Tread 4
Tread 3	Tread 3
Tread 2	Tread 2
Tread 1	Tread 1

Cranfield VLES simulator

•**Participants:**

•Up to 168 test participants were recruited for each test day.

•Participants were members of the public subject to:

- •only allowed to take part in single test session, consisting of 4 different trials.
- •Age range of 19 - 68, with an average age of 31, all were relatively fit.
- •190 were male (56.5%) and 146 were female (43.5%).
- • 4 (1.2%) had never previously flown, 47 (14.0%) had between 1 and 3 return trips, 52 (15.5%) had made between 4 and 7 return trips and 233 (69.3%) had made eight or more return trips.
- • 6 participants reported having undertaking a genuine emergency evacuation (1.8%).
- •287 participants (85.4%) were right-handed, 28 (11.3%) were left handed, and 10 (3.0%) claimed to be ambidextrous.

•No injuries were sustained throughout the testing programme.

STAIR TRIALS

•Trials were intended to explore various aspects of aircraft evacuation in which paxs made use of the main stairs linking the upper and lower deck.

• In particular the following aspects were to be investigated:

- •Given a free choice (i.e. without direct intervention of CC), how many UD paxs would elect to use the stairs to evacuate via the exits on the lower deck.
- •Behaviour of paxs utilising the staircase.
- •Flow rates on stairs in both up and down directions.
- •Population densities on the stairs.
- •Use of HR.
- •Explore the efficiency of staircase usage with zero or two CC managing the staircase flow.

•Unfortunately, due to problems during the trials it was not possible to explore all the above, in particular, ***free choice*** and ***staircase efficiency with various crew numbers managing flow***.

PASSENGER STAIR BEHAVIOUR

- Two types of packing behaviour typically observed on stairs:
  - Staggered: occupants attempt to maintain interpersonal distance
  - Packed: occupants occupy all available space.
- Stair is sufficiently wide to allow 1 pax/tread
  - Expect to see staggered behaviour i.e. one pax every other tread.
  - The unit flow rate capacity for a standard stair as specified in the UK Building Code is 80 p/m/min or 1.33 p/m/sec.

	Number of paxs		**Density (pax/metre^2)**	
	Left lane	**Right lane**	**Left lane**	**Right lane**
1 pax per tread	11	11	6.5	6.7
1 pax every other tread	5.5	5.5	3.3	3.3
2 paxs per tread	22	22	13.1	13.3
2 paxs every other tread	11	11	6.5	6.7

Passenger Stair Behaviour: General Observations

- Paxs generally orderly behaviour on descent and ascent.
- Behaviour most frequently observed was free flowing / single file movement.
- The second most typically flow condition was close staggering.
  - This was usually coupled with higher densities on the stairs.
- In some trials it was noted:
  - UD paxs were forced to queue on stairs while LD paxs evacuated **– *stair/exit location?***
  - At the start of some trials (e.g. Day 1 Trial 4) some UD paxs disobeyed CC that was attempting to block the use of the stair use **– *number of crew required?***

Passenger Stair Behaviour

Participants queue DOWN right lane of stairs

Passenger Stair Behaviour

Two participants disobeying CC (in centre with back to camera, telling participants to go forward) during DOWN stairs movement

Passenger Stair Behaviour: General Observations

- Generally one person occupied a tread however:
  - Overtaking did occasionally occur
  - Occasional dual occupancy of a tread

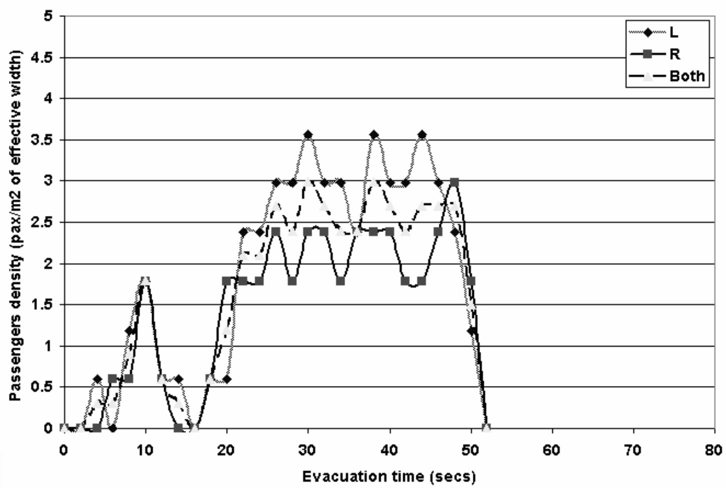
Overtaking

Dual Occupancy Downwards

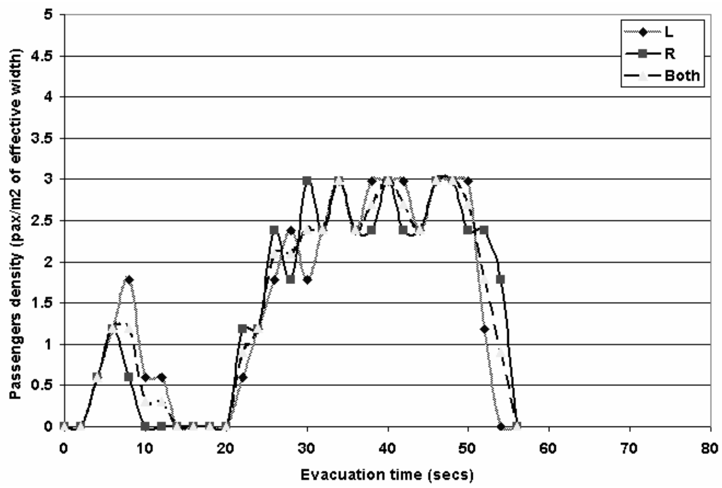
Dual Occupancy Upwards

Passenger Stair Behaviour: Packing Density

- Stair densities in UPWARD direction, generally greater than in DOWNWARD direction.
- In UPWARDS direction:
  - Highest observed density was, ~ 5 pax/m^2 (T2.2).
  - Flow condition was characterised as being dual / dual staggered.
- In DOWNWARD direction
  - Generally lower densities between 2.5 and 3.5 paxs/m^2.
  - Broadly equivalent to having 1 pax located every other tread, i.e. a single file flow.



Upwards (T2.3)



Downwards (T2.1)

Passenger Stair Behaviour

Upwards flow

Downwards flow

Passenger Stair Behaviour: Packing Density

- Possible explanations for differences in behaviour:
  - The average upward travel speed of participants may be slightly less than the average downwards travel speed.
  - This leads to a greater degree of bunching in UPWARDS direction.

OR

  - In UPWARD movement, the upper discharge from stairs consists of two pax aisles leading forward.
  - In DOWNWARDS movement, the discharge from the stairs can be fed by four aisles, (2 forwards and 2 aft).
  - In the UPWARDS case there is greater potential for a bottleneck or slower discharge resulting in the higher observed densities

Passenger Stair Behaviour: Flow Rates

- Average flow rates (AFR) – measured in paxs/min - were calculated for the total period of pax usage including 'dry-ups'.

		Flow rate (paxs/m of effective width/sec)	
		Left Lane	**Right Lane**
1.1	DOWN	1.28	1.06
1.2	DOWN	1.29	1.53
1.3	UP	1.80	1.75
1.4	DOWN	1.42	1.47
2.1	DOWN	1.37	1.42
2.2	UP	1.94	1.85
2.3	DOWN	1.55	1.51
2.4	DOWN	1.15	0.87
Mean	DOWN	1.34	1.31
Mean	UP	1.87	1.80

Passenger Stair Behaviour: Flow Rates

- DOWNWARDS flow rates are broadly equivalent to those expressed in building regulations.
- UPWARDS flow rates are 35% higher than those prescribed in building regulations (downwards direction).
- However, flow rates are less than what may be expected to be achieved in emergency situations.
- Three possible explanations:
  - As an average flow rate was calculated, periods of non-flow were included in the flow rate calculations.
  - Stair packing densities were less than what could be expected. This could be due to the level of participant urgency being low for these trials
  - Cabin layout may have contributed to slower than expected rates.

Passenger Stair Behaviour: Hand Rail

•Paxs were noted to make heavy use of the hand rail throughout the trials.

Trial	Direction	Side only	Middle only	Both	None
2.1	DOWN	10/85 (12%)	7/85 (8%)	68/85 (80%)	0/85 (0%)
2.2	DOWN	34/112 (30%)	34/112 (30%)	44/112 (39%)	0/112 (0%)
2.3	UP	12/85 (14%)	3/85 (4%)	69/85 (81%)	1/85 (1%)
2.4	DOWN	3/49 (6%)	0/49 (0%)	45/49 (92%)	1/49 (2%)

Passenger Exit Delay Times

• Passenger Exit Delay Time is term developed by FSEG in the 1990s to characterise exiting behaviour.

• The PEDT is a combination of pax exit hesitation time and pax exit negotiation time.

  • Hesitation = paxs' reluctance to quickly vacate the exit for whatever reason.

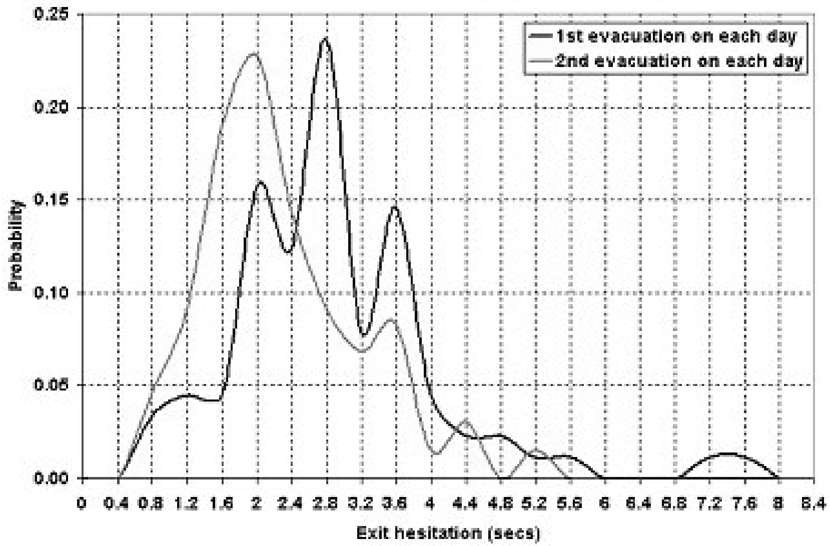
  • Negotiation = the physical act of using the exit.

•PEDT = time at which pax breaks contact with exit system
- time at which pax starts his/her last steps to the exit door sill when the exit is free to use.

• PEDT is an essential parameter for accurate modelling of evacuation.

Passenger Exit Delay Times

- PEDT from the first trial on each day was combined.
- PEDT from the second trial on each day was combined.
- Expect PEDT for second trial to be shorter due to learning experience.
- Comparing these results with generalised Type A exits:
  - Shape of PEDT curve similar to normal Type A exits
  - Means of 2nd day trials are 4X longer than assertive Type A
  - Average flow rate of 2nd day is 54pax/min, cw 120 pax/min.



Passenger Exit Delay Times

• There is insufficient data to warrant firm conclusions concerning the apparent slower nature of these exits when compared with normal Type A exits.

•However, a contributory mechanism would be the lack of assertiveness of the crew at the exit.

• This is to be expected as it was the first time the slide had been used at these heights.

• However, this is not representative of the behaviour we would expect from assertive crew.

Concluding Comments

- Pax behaviour in utilising stairs for egress is both rich and complex and warrants further investigation.

- Presence of central HR thought to aid evacuation efficiency.
- UPWARDS flow rates greater than DOWNWARDS.
- Average unit flow rate DOWNWARDS was equivalent to that specified in the UK Building Regulations.

- Clearly, stair performance can be influenced by both crew procedures and cabin layout.

- Trials support the view that for crew to consistently make appropriate or optimal redirection command decisions that include the possibility of using the stairs, they must have sufficient situational awareness.

Concluding Comments

•Trials produced inconclusive results concerning pax exit hesitation times for higher sill heights

•While measured exit flow rates are lower and pax exit delay times longer than would be expected for a normal Type-A exit, it is clear that the extreme unassertiveness of the cabin crew positioned at the exits and the lack of motivation of the paxs exerted a strong influence on the data produced.

Areas that require further fundamental research include :

- Collection of pax exit hesitation time data at high sill height exits.
- Performance of paxs on stairs, with and without HRs
- Preference for UD paxs to utilise stairs in emergency situations.
- Impact of orientation on pax stair performance.
- Number of crew required to efficiently manage between deck evacuation.
- Technological aids to assist in crew situational awareness.