

# **The use of computer simulation for aircraft evacuation certification: A report from the VERRES project**

By

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



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# Evacuation Modelling and the Regulatory

## Environment

- One of the primary drivers for the development of aircraft evacuation models is to augment and eventually replace – where appropriate – the current certification process.
- As a first step in this process, it is suggested that evacuation modelling be adopted as part of the certification process and used to replicate the live certification trial to address some of the shortcomings of the current certification process.



# CURRENT REGULATORY ENVIRONMENT

- Regulators attempt to maintain safety standards through a set of essentially prescriptive rules that have evolved over time.
- In Europe they are known as Joint Aviation Requirements (JAR) while in the USA the rules are known as the Federal Aviation Regulations (FAR), e.g:
  - The so-called “60-foot” rule, FAR (i.e. 25.803 (f) (4));
  - *“For an airplane that is required to have more than one passenger emergency exit for each side of the fuselage, no passenger emergency exit shall be more than 60 feet from any adjacent passenger emergency exit on the same side of the same deck of the fuselage, as measured parallel to the airplane’s longitudinal axis between the nearest exit edges.”*



# CURRENT REGULATORY ENVIRONMENT

- In addition there is a performance requirement commonly known as the '*90 second certification test*'.
- Compliance with this rule is demonstrated by performing a full-scale evacuation demonstration.
  - performed with a representative cross-section of the travelling public
  - in darkness
  - utilising only half of the normally available exits
  - Crew and passengers do not know before hand which exits will be made available.
  - The test involves evacuating all passengers and crew to the ground within 90 seconds if the aircraft is to pass the performance test.
- The common perception – which is not discouraged by the industry - is that success at the 90 sec test conveys a measure of safety on the aircraft.
- 90 second test is only intended to provide a measure of the performance of the aircraft under an artificial benchmark evacuation scenario.
- It is not intended to predict the performance of the aircraft under a realistic accident scenario.
- It simply allows the performance of different aircraft to be compared under a set of identical – if somewhat artificial – scenario conditions.

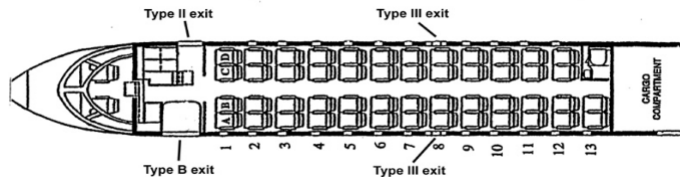
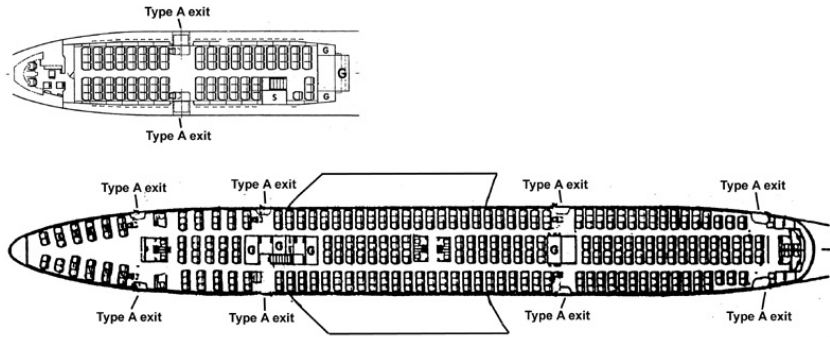


# CURRENT REGULATORY ENVIRONMENT

- Difficulties with this process include:
  - A number of the prescriptive rules are arbitrary.
  - Threat of injury to trial participants. Between 1972 and 1991, 378 volunteers (6% of participants) injured.
  - Lack of realism inherent in the scenario – co-operative behaviour.
  - Groups are excluded.
  - Available exits are far from realistic or meaningful.
  - Only a single trial, so impossible to gauge likely performance.
  - Full-scale trial can be extremely expensive ~\$US2 million.
  - Does one size fit all? Why 90 seconds?
- Process provides little useful information regarding the suitability of cabin layout or crew procedures in real situations.



# One Size Fits All?



- Does it make sense to have the same prescribed scenario for these two very different aircraft?





# KEY PREMISE

- Introducing computer models for aircraft certification should improve the certification process, not simply make it more efficient.
- Introducing computer simulation should provide the aviation community and the paxs that use the aircraft something more than the simple one-off testing provides.



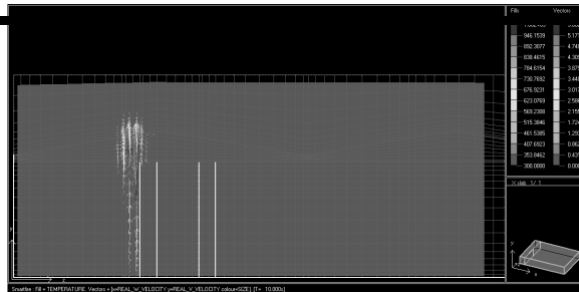
# EVACUATION MODELLING

- In the design and modification of buildings, ships and aircraft, evacuation and fire safety related issues have traditionally been dealt with through **PRESCRIPTIVE CODES**.
  - Regulations established over time based on experience of past fires, usually incorporate many “*magic numbers*”.
- New paradigm in the building and maritime industries is the **PERFORMANCE CODE**
  - These specify objectives and performance levels rather than pre-determined solutions.
  - **Mathematical Models**, together with **reliable data**, provide a means of determining and examining the proposed designs.
  - These allow the engineer to select the most efficient design that meets the set objectives and delivers the required performance.

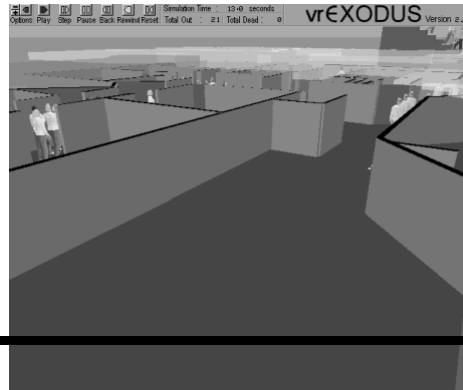
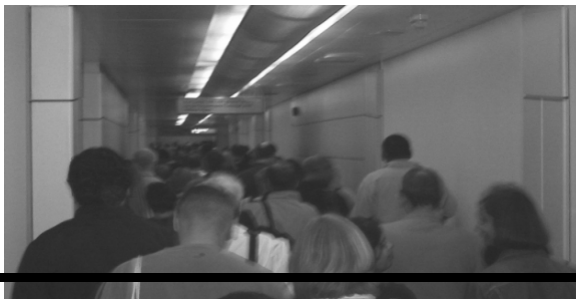


# Goal of Fire Engineering

**ASET** – Driven by fire development – determined by fire model



**Objective: ASET > RSET**



**RSET** – Driven by human behaviour – determined by evacuation model



# THE IMO APPROACH

- The maritime community through IMO have adopted a half way house approach, (IMO/MSC 1033).
- Maintained the prescriptive performance codes and performance criteria, but have adopted evacuation modelling to demonstrate compliance with these requirements.
- The IMO requirements set out how the model should be used and how the results should be interpreted.
- In doing so they have addressed most of the shortcomings associated with the current aviation protocols and provide a model for the way forward.



# PROPOSED METHODOLOGY FOR AVIATION

- Essential that a protocol be developed for acceptable use of computer simulation for aircraft certification applications.
  - Not intended to replace entire cert process i.e. slide inflation testing, door opening etc would still be required.
  - Protocol should be considered an addition to the current certification process.
  - Modelling in isolation, without use of fundamental data is not considered viable.
- Protocol should address the following five key issues:
  - **(1) Model validation and demonstration requirements**
  - **(2) Supporting Documentation.**
  - **(3) Simulation protocols**
  - **(4) The Scenarios to be Investigated**
  - **(5) The Acceptance Criteria**



# **(1) Model validation and demonstration requirements**

- Prior to accepting a model for certification applications, it must be demonstrated that the model is capable of simulating the certification test with a specified degree of reliability and accuracy.
- A set of test cases should be developed which are fully specified according to the requirements of the protocol.
- Successful simulation of the test cases would need to be demonstrated to the regulators.
- This would in essence be part of the certification process for the modelling tool.
- The cases examined in the validation of airEXODUS could form the basis of such validation/demonstration cases



## **(2) SUPPORTING DOCUMENTATION**

- This documentation is intended to demonstrate both the credibility and appropriateness of the modelling approach adopted and furthermore allow easy verification and reproduction of the submitted results.
- Requirements should include:
  - A detailed user guide/manual specifying the nature of the model and its assumptions and guidelines for the correct use of the model and interpretation of results.
- And the specification of:
  - Model in-put parameters (geometry, passengers, crew, equipment).
  - Full listing of all data used within the model.
  - In-put files used to generate the model predictions, allowing reproduction of simulations.



## .... SUPPORTING DOCUMENTATION

- When dealing with truly ‘new’ aircraft features, sufficient data may not exist and so may be necessary to combine model simulations with component testing, e.g:
  - A new type of exit,
  - An existing exit type with a significantly higher sill height.
- Component testing is intended to generate the ‘missing’ data.
- In such cases, the data collection methodology must also be documented.





### **(3) SIMULATION PROTOCOLS**

- The manner in which the simulations are to be run and the results presented must be specified.
- To a certain extent this will be dictated by the nature of the scenarios to be investigated.
  - How many repeat simulations are required?
  - What results are to be presented e.g. time out of the aircraft, time on ground, evacuation curves for each exit, evacuation curves for entire aircraft, distribution of total evacuation times, window of evacuation curves, average level of congestion experienced by paxs, exit flow rates achieved, etc.
  - How many different populations are to be used?
  - Number of different seat allocations for each population?
  - What exit opening times are to be used? Should they be the same for each repeat simulation?
  - If component testing is required to augment the modelling, the nature of the required testing should be specified.



## **(4) THE SCENARIOS TO BE INVESTIGATED**

- What scenario(s) should be considered?
- Computer simulation offers the potential to investigate a range of scenarios. These can include:
  - The standard 90 second scenario as a base case.
  - Additional scenarios drawn from accident analysis, suggesting likely number and location of available exits.
  - Likely failure modes could be considered through the introduction of “what if” scenarios - likely to be aircraft specific.
- Whether concerned with; real accident, computer simulation or exp trial, an aircraft evacuation scenario is defined by 6 key components.



# What Defines a Scenario?

- ***Aircraft configuration spec:*** cabin layout, exit configuration and availability.
- ***Aircraft environmental spec:*** orientation of aircraft, nature of cabin atmosphere (heat, smoke toxic gases) and lighting levels.
- ***Crew behaviour:*** number and role of available crew, level of assertiveness, and the exit ready times.
- ***Pax pop distribution:*** nature of pax pop; age, gender, disability level, seating allocation, affiliation.
- ***Pax behaviour:*** non-competitive behaviour or accident specific competitive behaviour (e.g. seat jumping, etc).
- ***Pax exit selection:*** which exits the paxs attempt to utilise, can be categorised into one of three basic types, optimal exit, nearest exit, or case specific sub-optimal exit selection.
- Changing the selection of any of these parameters is equivalent to changing the nature of the question posed.



## Current Certification Scenario

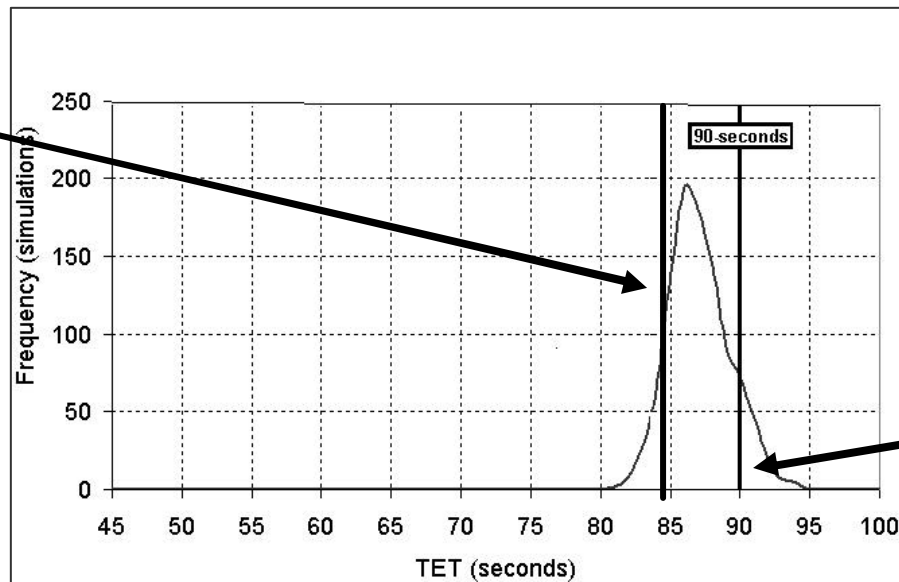
- Current 90 second certification scenarios would typically consist of the following settings:
  - *Aircraft configuration spec*: cabin layout and exit specification given by aircraft drawings, half # exit's on one side are available.
  - *Aircraft environmental spec*: normal orientation, darkness/emergency lighting and no fire products.
  - *Crew behaviour*: assertive crew and generalised exit ready times.
  - *Pax pop distribution*: standard 90 sec pop distribution.
  - *Pax behaviour*: non-competitive behaviour.
  - *Pax exit selection*: optimal exit selection.



## (5) THE ACCEPTANCE CRITERIA

- How do we determine that an aircraft has met the pass/fail criteria or the “deemed to satisfy” requirement?
- Consider scenarios equivalent to the 90-sec cert criteria.
- Current practice is to require a *SINGLE* full-scale test which is deemed to be representative of the distribution of aircraft performance for this scenario.

*One-off trial  
performance  
84 s  
Aircraft  
deemed  
acceptable*



*5% of trials  
over 90 s*



## ....THE ACCEPTANCE CRITERIA

- Unlike full-scale testing, models allow many repeat simulations for any particular scenario to be performed, producing a range of results for given scenario.
- For a particular scenario what should the requirement be:
  - Should *every* simulation be sub-90 seconds?
  - Should the distribution mean be sub-90 seconds?
  - Should the 95 percentile result be sub-90 seconds?
- IMO have selected the 95 percentile acceptance level for pax ship evacuation analysis.



# SUGGESTED USE OF COMPUTER SIMULATION FOR CERTIFICATION

## Proposed Step 1:

- Apply the outlined protocol and use computer simulation to replace the full-scale certification test.
  - Applies to derivative aircraft for which sufficient data, experience and confidence exists.
  - For aircraft involving truly ‘new’ features – in which data is not available - component testing of the new feature will also be necessary.
- All other prescriptive rules and requirements would still apply.



# SUGGESTED USE OF COMPUTER SIMULATION FOR CERTIFICATION

## Proposed Step 2:

- As confidence in the technique develops, additional, more representative and demanding scenarios could be added to the certification process.





# **SUGGESTED USE OF COMPUTER SIMULATION FOR CERTIFICATION**

- **Advantages:**

- A safer alternative to full-scale evacuation trials,
- Provide improved insight into the actual capabilities of the aircraft by generating a performance probability distribution or performance envelope rather than a single datum, and
- Offers a less expensive route to certification.

- **Disadvantages:**

- Too radical for some sectors of aviation industry.
- May be interpreted by some as offering no safe guards



# **SUGGESTED USE OF COMPUTER SIMULATION FOR CERTIFICATION**

## **Alternative Approach:**

- Gradually phase in the use of modelling.
- Use models to address recognised failings of the cert process.

## **Step 1:**

- Continue with conventional one-off full-scale certification test.
- In addition, perform repeated simulations of cert trial using evacuation model and the identified protocol, to produce probability distribution of likely evacuation performance.
- Trial data point should fall on the probability distribution produced by computer simulation.
  - Provides further validation of the modelling process
  - Provides insight into performance of the aircraft under repeated trials.
  - Pass-fail based on both actual trial result and model predictions.
  - Delivers improved confidence in cert results.



# **SUGGESTED USE OF COMPUTER SIMULATION FOR CERTIFICATION**

## **Step 2:**

- Full reliance on modelling:
  - After sufficient experience and confidence in the use of computer models had been developed.
  - In circumstances where there was sufficient data on which to be confident in the modelling approach.

## **Step 3:**

- The nature of the evacuation scenarios investigated as part of the cert process could be made more realistic, with the introduction of more credible accident scenarios.



# Concluding Comments

- Evacuation models have the potential to enhance the current 90 second certification practice.
- However, before models can be adopted within the regulatory framework a protocol for their use must be developed. Such a protocol has been presented in this paper.
- Until such protocols are in place, it is unlikely that the aviation industry will adopt the use of computer simulation for evacuation certification analysis.



# Concluding Comments

- Along with the suggested protocol, a phased introduction of computer models to certification has been suggested which:
  - Delivers improved confidence in cert results.
  - Provides improved insight into aircraft performance.
  - Provides further validation of the modelling process.
  - Can easily be extended to include additional realistic scenarios.
- These capabilities will provide regulators, manufacturers, unions, airlines, crew and passengers significantly more than the current simple one-off testing procedure provides.
- By adopting this approach we may achieve our goal of producing safer aircraft which the industry say they want and the travelling public deserve.

