Simulating the interaction of cabin crew with passengers during aircraft evacuation scenarios

By

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Contents

- Introduction
    - The EXODUS software
    - EXODUS validation.
- Cabin Crew Pax interaction
    - Data Sources
    - 3 Essential Types of Scenarios
    - Model Basic Principles
- Crew Base Model – certification cases
- Crew Model – emergency cases
- Conclusions

THE EXODUS SOFTWARE

- **EXODUS:** *software tools used to simulate behaviour and movement in large complex spaces*.
- R&D on EXODUS began around 1989.
- EXODUS is currently used in over 29 countries.
- Four versions currently available :
  - **airEXODUS** : aircraft applications
  - **buildingEXODUS** : built environment
  - **maritimeEXODUS** : marine applications
  - **vrEXODUS** : VR animation tool

•The airEXODUS software has been used for aircraft design applications and for examining compliance with FAR/JAR evacuation certification requirements.

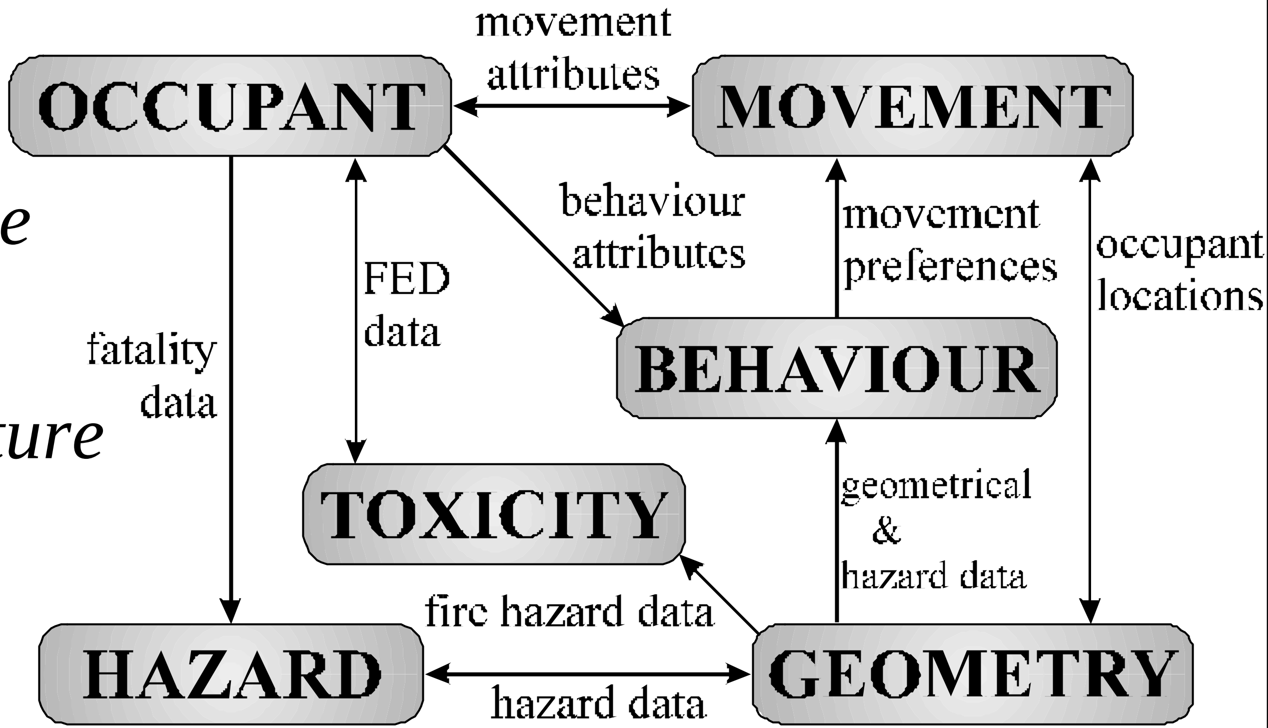
EXODUS Model

Considers

People-People

People-Fire

People-Structure

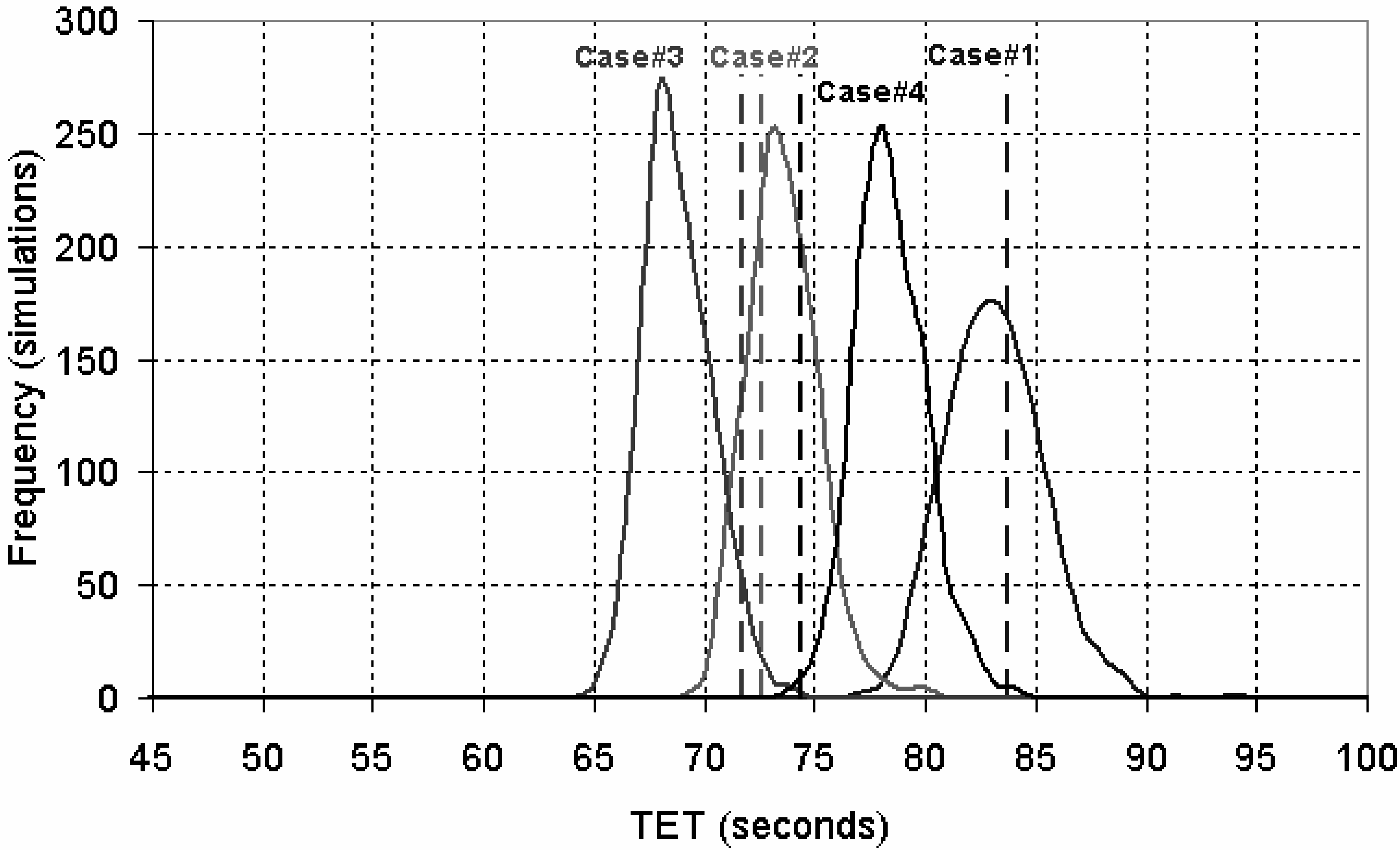


•Behaviour model is Rule Based and Adaptive.

airEXODUS Validation

- airEXODUS has undergone a range of validation trials.
- In the latest study, as part of a CAA funded project, airEXODUS predictions were systematically compared with a range of past certification trials.
- These included wide and narrow body aircraft.
- Here we present a summary of the results from 4 wide-body trials.
- airEXODUS run in certification mode
- For each case, airEXODUS run 1000 times without changing model parameters.

airEXODUS Frequency Distribution



Cabin Crew

- Cabin crew can exert a powerful influence on the outcome of an evacuation. In particular in directing or re-directing paxs towards or away from exits.
- In early versions of the airEXODUS software this was represented ***IMPLICITLY*** by the setting of model parameters e.g. assuming that an optimal cabin split was achieved.
  - While useful, it did not allow the direct representation of crew, crew performance was inferred from the model results.
  - Furthermore, while useful in exploring general objectives of crew procedures, it was not appropriate for fully exercising and experimenting with crew procedures.
- Require ***EXPLICIT*** representation of crew and their procedures.
- This is now possible with the latest version of airEXODUS.

Explicit Model of Crew Behaviour

- Model is intended to represent crew behaviour in passenger re-direction activities.
- Model must also include pax response to crew instructions and an ability for paxs to make their own decisions.
- Model should be sufficiently flexible to accommodate:
  - Different aircraft geometries such as narrow body, wide body and future concepts such as BWB aircraft.
  - Different evacuation scenarios varying from certification style to serious accident.
- Require access to reliable information regarding crew/pax interactive behaviours.
- Information to base model development derived from range of sources:
  - Discussion with cabin crew.
  - Certification video data and reports
  - Accident reports (AASK database)

Sources of Information

- All sources of information useful but video footage and certification reports information rich.

- Reviewed 22 video tapes and studied 22 reports of certification trials, both wide and narrow body aircraft:
  - **Q:** Can you explain how you decided where you were going to redirect people to go?
  - **Crew:** I knew that the slide to the back would accommodate more people than ours…
  - **Q:** But door 2 also is a Type A door and has more capability, but you decided not to send people toward Door 2.
  - **Crew:** Well, yeah, but door 2 also had a large line as well…"

- Studied over 20 accidents reports within AASK for which there was sufficient detailed information regarding crew and crew-pax interaction.

Three Regimes of Behaviour

- Suggest three regimes of behaviour need to be accommodated.
  - **Certification behaviour.**
    - Paxs compliant, crew in control, very good visual access
  - **Emergency situations not involving direct exposure to fire**
    - Paxs generally compliant, crew generally in control, good visual access
  - **Emergency situations involving direct exposure to fire**.
    - While generally compliant, paxs more likely to take control of own fate, visual access can be poor.

- Behavioural response varies on a continuum, rather than discretely, with each phase sharing a number of similarities.
- A situation can evolve from one behavioural regime to another.
- Approach Adopted: Develop basic model based on certification behaviour (ideal) and evolve the other behavioural capabilities

Crew-Pax re-direction basic Model: The Principles

- Crew primarily concerned with reducing overall evacuation time, not evacuation time of individuals ? redirect decisions are intended to be globally optimal, not locally optimal.
- Crew assess likely finish times for the exits in their vicinity and then attempt to correct any apparent imbalance by redirecting paxs to underutilised exit.
- Requires good knowledge of hardware, good visual access, good communications (crew-pax) and compliant paxs.

Knowledge/Information

- Information central to crew judgements.
- Two types of information Static and Dynamic.
  - Static: location of exits, exits of primary responsibility, number of paxs, flow rate capabilities of exits, etc.
  - Dynamic: location of paxs, current exit status, current exit flow conditions, current flow conditions within the aisles, etc,.
- Dynamic information currently collected visually, but could in future be assisted through devices such as headsets.
- For Computer Model: Very important to represent both static knowledge levels and dynamic information gathering ? important to represent visual access.

Communications

- Video footage of certification trials suggests that crew use a mixture of verbal commands (shouting, speech, etc), gestures (pointing, waving arms) or physical contact (pushing). In interviews crew stated:
  - **" …[I] started grabbing people and shouting at them and pushing them towards the exit."**
  - **"… All the passengers would have exited the aft hatch had I not physically grabbed them and pushed them through between the seats to the forward hatch…"**
  - **"I had to turn around and tell everyone to, 'turn around! Go that way!' a couple of times, and everyone seemed to be following directions pretty well. … everyone was very cooperative, obeyed commands, …"**

- Crew interviews suggest crew generally perceived physical communication to be a more effective means of asserting their will than vocal communication. This was substantiated through examination of video footage.

- Two principle modes of crew communication are important:
  - **Verbal/gesture**
  - **Physical contact.**

- Important to represent difference in communication ability and passenger receptiveness to commands.

Postulated Decision Making Process

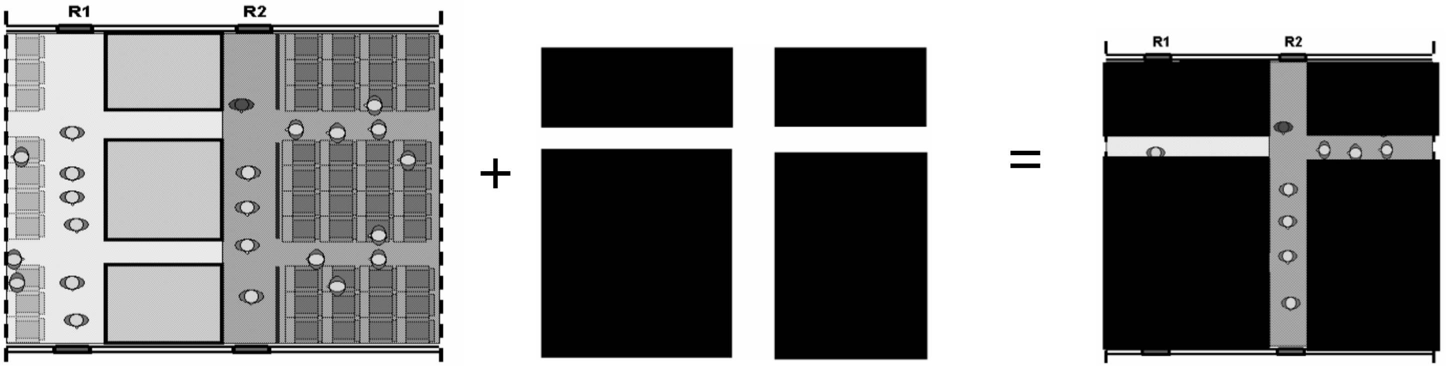
- Crew:
  - continually assess conditions at primary and secondary exit, is one exit likely to finish before another i.e. has spare capacity.
- If so, then a redirection may be beneficial.
- Crew:
  - assess whether redirection of benefit.
  - if considered beneficial, issues instruction to pax.
- Pax:
  - responds, and in certification type incidents is complainant and follows instruction.

The Model

- Model must include representation of:
  - **Visual Access**
  - **Communication**
  - **Decision making process**
    - **Is redirection needed?**
    - **Selecting a pax to redirect**
    - **Primary exit preference**
    - **Crew fallibility**
  - **Pax response.**

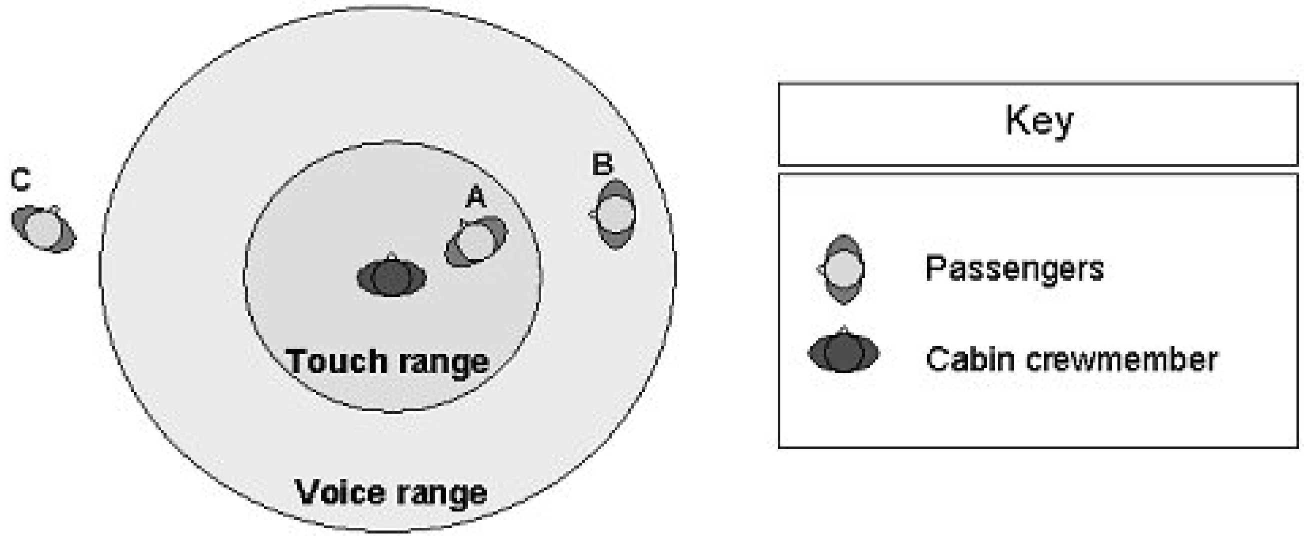
Modelling Visual Access

- Providing the crew with ability to visually assess situation is central to the model.
- Two Visual Access models implemented:
  - (i) Total Dynamic Information Set (TDIS): represents ideal situational knowledge, gives crew complete information regarding the location of paxs at all times.
  - (ii) Line Of Sight Information Set (LOSIS), limits the knowledge of the crew according to their line of sight.



Representing Communication

- Communication is categorized as being either *verbal* or *physical.*
- Define communication distance, one for each form of communication.
- Only paxs within range may be influenced.

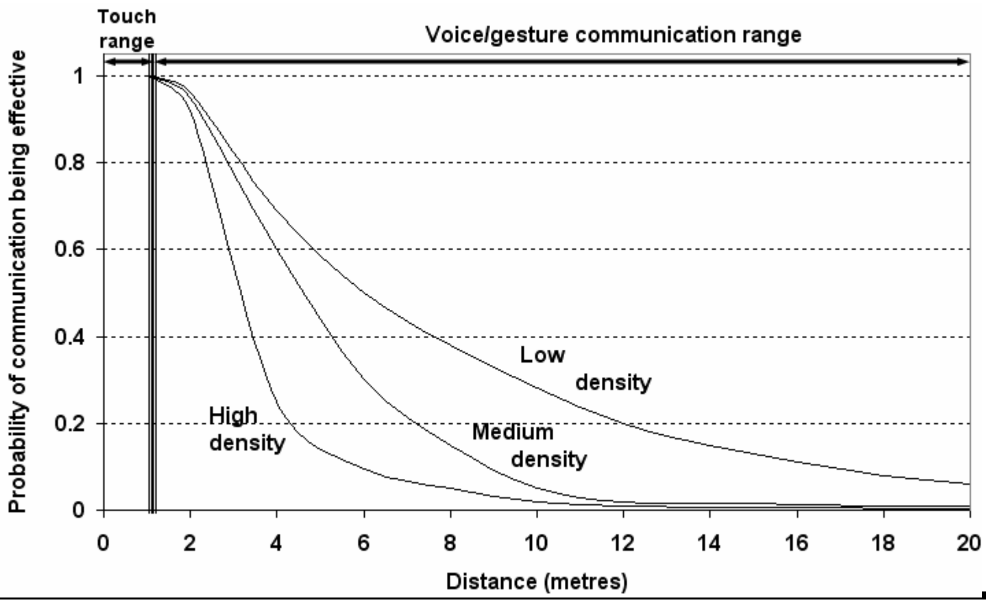


Voice Communications

- Cert Trial video footage demonstrates crew can communicate with paxs located at other end of cabin section.
  - Though less frequent during the early portion of evacuations when the cabin is densely packed.
- During the early portion of evacuations crew tend to communicate with paxs in close proximity.
  - Crew attempt to communicate to more distant passengers as cabin empties.
- During the final stages of evacuation crew are frequently witnessed shouting at individual passengers over relatively large distances (~ 10 metres).

Modelling Voice Communications

- General physical trend for sound attenuation is a quick initial decay followed by a slow decline over greater distances
- Propose functional relationship linking sound attenuation properties to pax density to produce a probability of crew communicative effectiveness.
- Vocal communication is less effective with higher pax densities and effectiveness drops off quickly with distance.



Decision Process: Is a re-direction needed?

- Crew use a simple flow calculation to determine rough est of exit finish times (***number of paxs / exit flow rate***)
- Crew attributed with reasonable knowledge of exit flow capabilities.
- Number of pax likely to use exit is based on visibility model used. (based on predefined catchment area)
- If a sufficiently large imbalance is suggested redirection may be beneficial.
- Crew constantly monitor their assigned exits.

PAX response

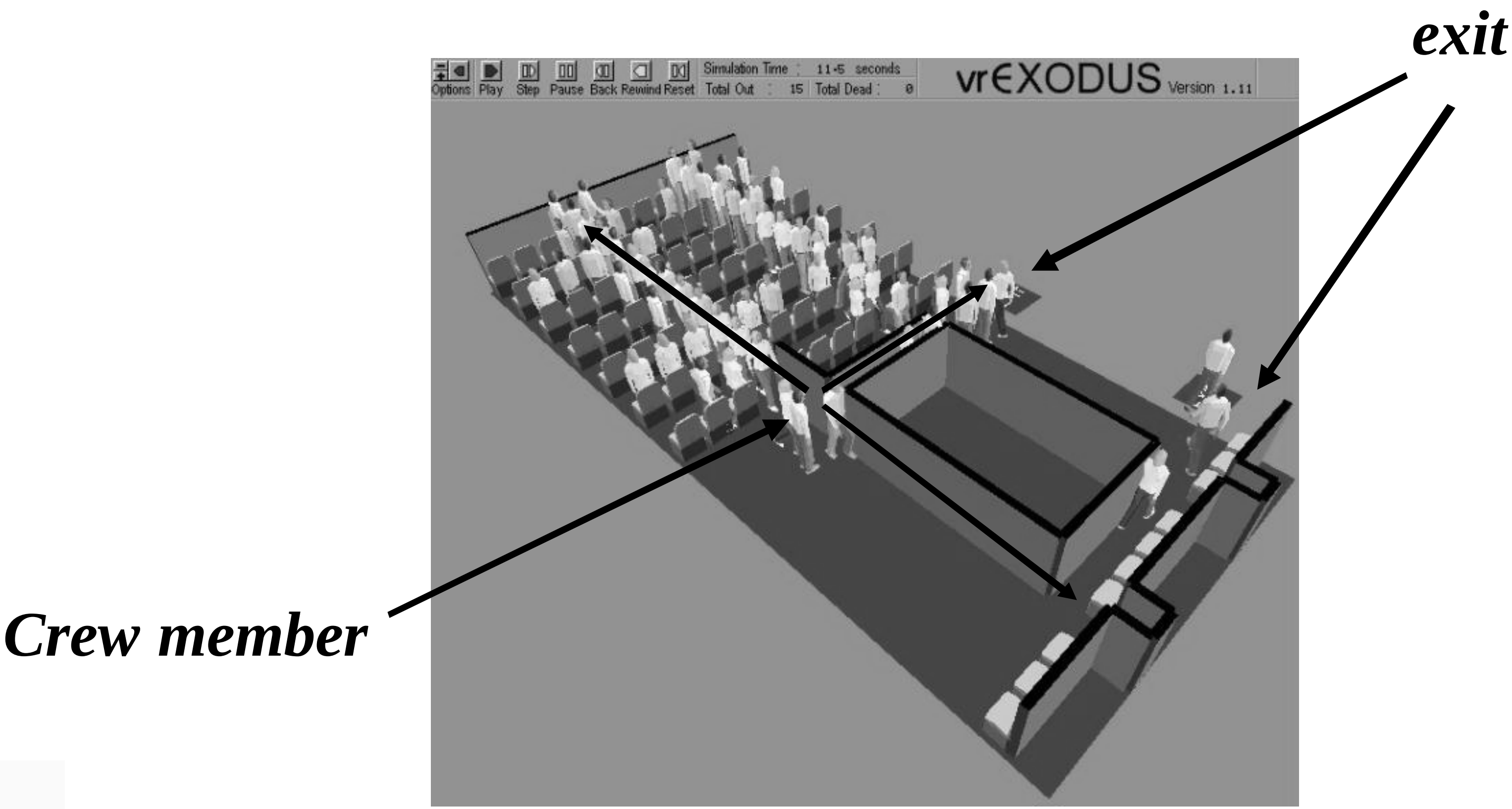
- Will pax obey or disregard the command of the crew?
- Complex issue dependent on many factors:
  - does command concur with pax decision,
  - are other paxs obeying,
  - does pax perceive new route to be dangerous,
  - does pax have physical ability to comply,
  - assertiveness of crew,
  - nature of situation.
- Simplified response model implemented.
  - A*ssertiveness* attribute is assigned to crew, used to represent the forcefulness of the crew when communicating.
  - *Drive* attribute assigned to pax.
  - Both are dynamic variables which change as scenario evolves.
  - If Crew Assertiveness > Pax Drive, pax obeys command.
- When simulating cert trials crew communication assertiveness set to max levels. In this behavioural regime *ALL* paxs obey.
- Pax also given time penalty when responding to a verbal command.

Additional Considerations: Crew Fallibility

- To represent individual variations in performance a level of 'fuzziness' can be introduced into the redirection assessment.
  - Crew can only est: pax speeds, length of evacuation route and exit flow rates.
  - Error factor can be applied to each crew members abilities to est these parameters.
  - Crew can also be programmed to miss a random percentage of redirection opportunities.

Redirection Example

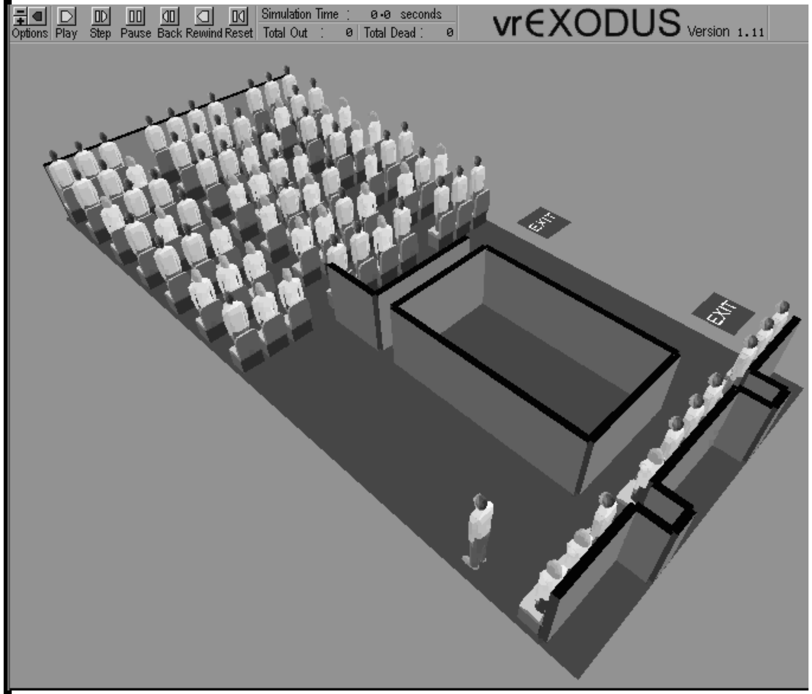
- Crewmember redirecting paxs to two exits, only one of which is in line of sight.
- Decisions based on what she can see.

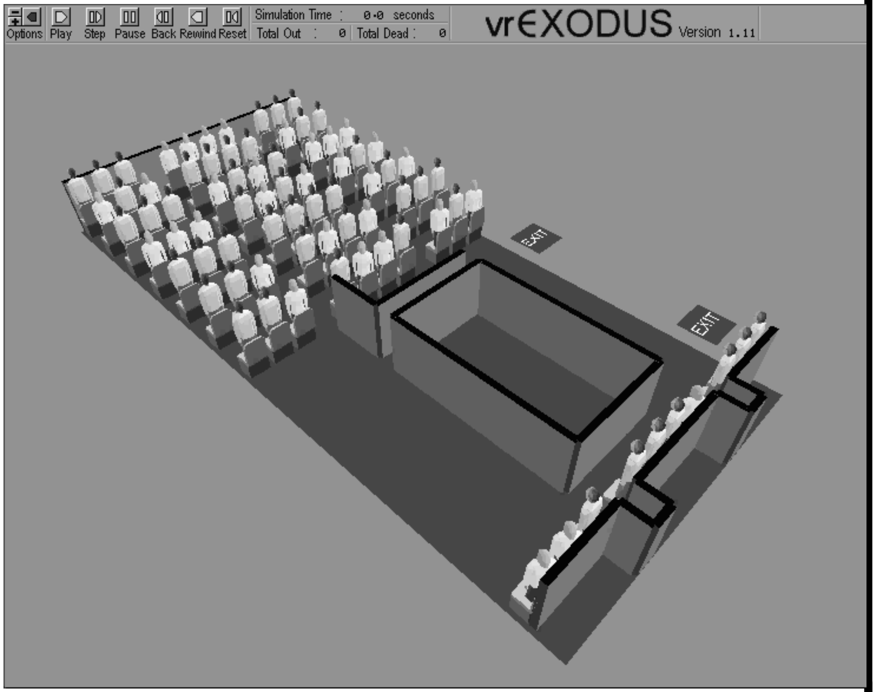


Redirection example

With Crew:
21 pax redirect,
45.1 sec

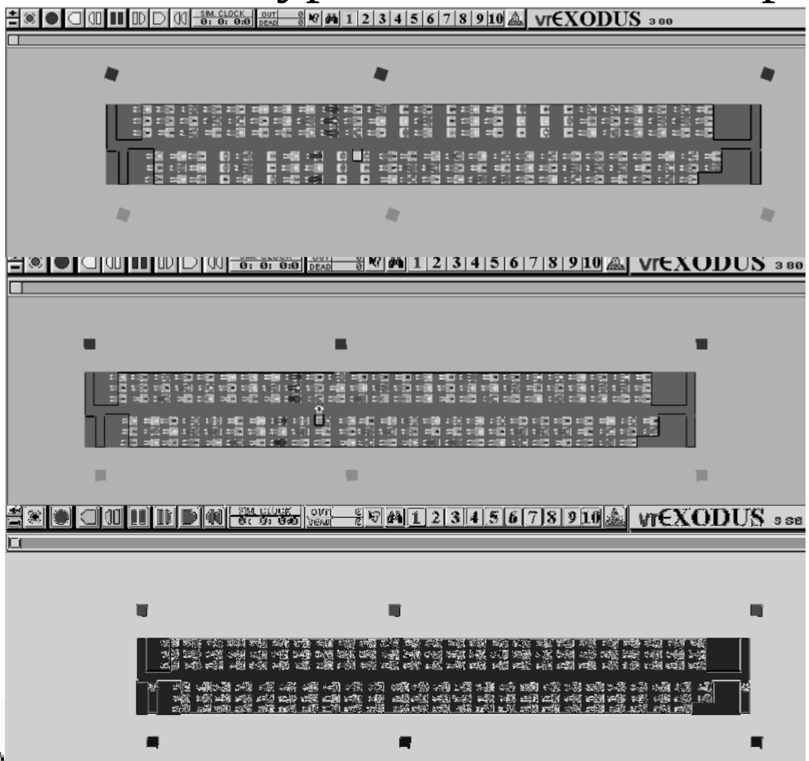
Without Crew:
18 pax redirect,
47.3 sec





Redirection example

- In this example, we consider pax behaviour near TIII exit.
- In one example we allow the paxs to determine their exit usage without intervention from crew.
- In the second example we place a crew member at the location of the Type III exit to direct paxs.



With pax redirect only,
evac time: 75-80 sec,
36-42 pax use TIII.

With Crew @ TIII,
evac time: 57-63 sec,
29-30 pax use the TIII.

With 2 Crew,
evac time: 61-67 sec,
33-34 pax use the TIII.

Real Emergency Evacuation Situations

- Basic model must be expanded to include conditions and behaviours associated with real emergency situations.

- Significant differences:
  - Cert trials are essentially co-operative. In real emergency situations, when conditions begin to deteriorate behaviour becomes more self centred.
  - Pax more likely to rely on own decision making with regards to routes in severe conditions.
  - Visual access will be affected by the smoke, heat and toxic fire products.
  - Communications will be affected by the presence of smoke.

- Other factors such as incapacitation and reduction in travel speeds already taken into account by airEXODUS

PAX Centred Exit Choice

- Data from AASK suggests pax select exit that appear to offer them most rapid evacuation.
- Pax use their knowledge of exit locations and the nature of the evolving evacuation scenario to determine which exit is best for them.
- In essence pax are performing their own flow rate calculation based on their (limited) understanding of exit capabilities and number of potential competitors for each exit.
- Differs from crew analysis in that:
  - pax calc is based on incomplete knowledge and often incorrect information.
  - Pax interested in minimising personal evacuation time.

PAX EXIT CHOICE MODEL

- Crude est of how long it will take to exit using each viable exit.
- Select exit which offers the shortest time.

PAX and CREW working together

- Pax allowed to form their own decisions.
- However once instructed by crew the Drive/Subservience look-up table is interrogated to determine whether pax obeys crew command.
- Pax Drive and Crew Assertiveness vary as situation evolves.

Impact of smoke on communication and vision

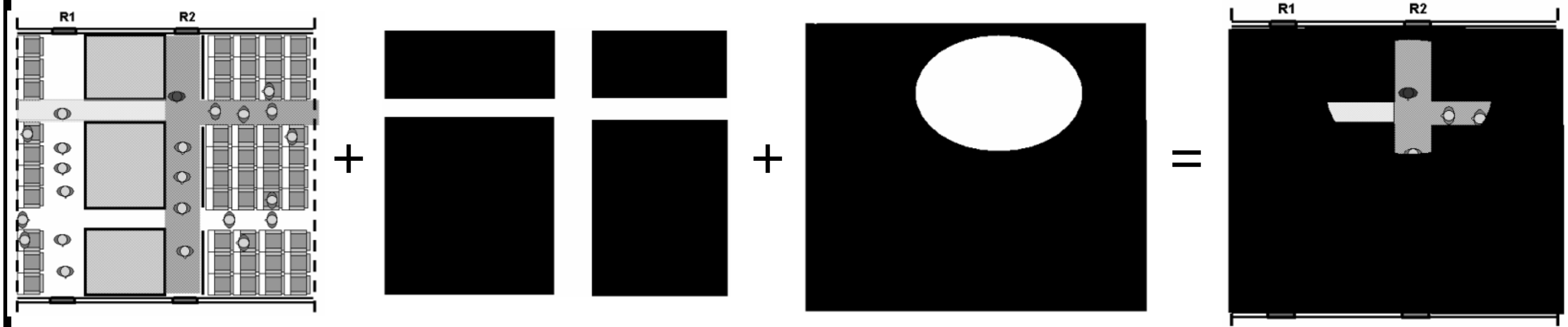
- Vocal communication distance is simply and arbitrarily reduced with the severity of situation (fire).

- Visibility distance modifications more complex:

  - airEXODUS can accept fire data from SMARTFIRE CFD fire simulation software.
  - SMARTFIRE calculates the smoke extinction coefficient, e, and passes it onto airEXODUS.
  - As e ?, smoke density ?, and visibility ?
  - e at each point in space and at each time step are stored within airEXODUS.
  - e along the line of sight are analysed to determine the extent of the visibility.

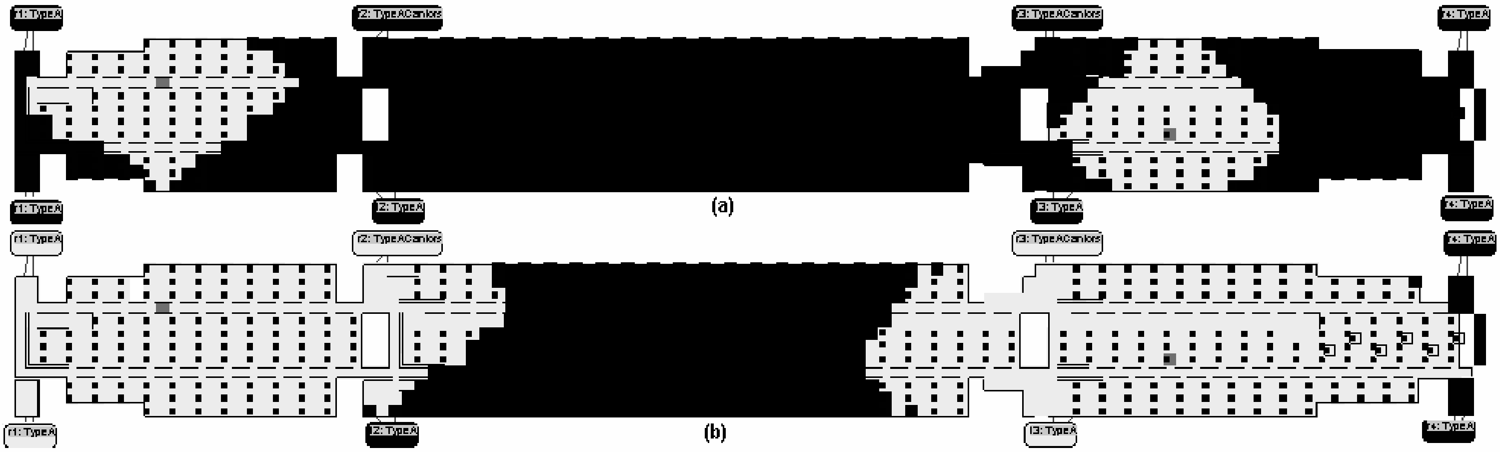
Impact of smoke on vision

- Visible region of both crew and paxs are reduced according to calculated smoke visibility.
- ? applying an additional stencil that limits visibility according to e.
- Limits both crew and pax ability to est number of paxs using each exit and confluences en route to exit.
- Paxs and crew may only redirect to visible exits.
- If pax cannot see an exit they continue with their original exit choice.
- If crew cannot see an exit they redirection paxs to their nearest exit.



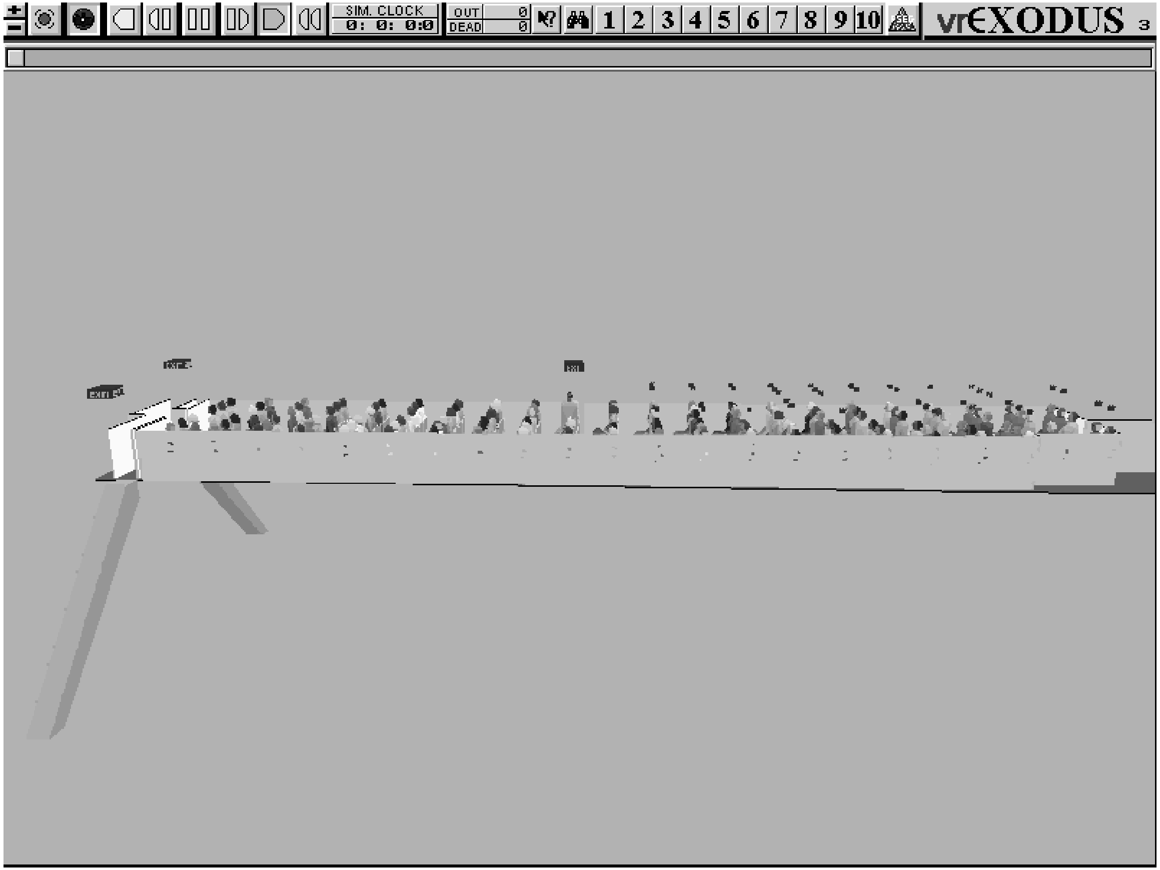
Visibility of Signs

- Method takes into account visibility of illuminated objects such as signs.
- **Example:**
  - standing level visibility in smoke for two paxs during the evacuation (a) when viewing other paxs and (b) when viewing exit signs



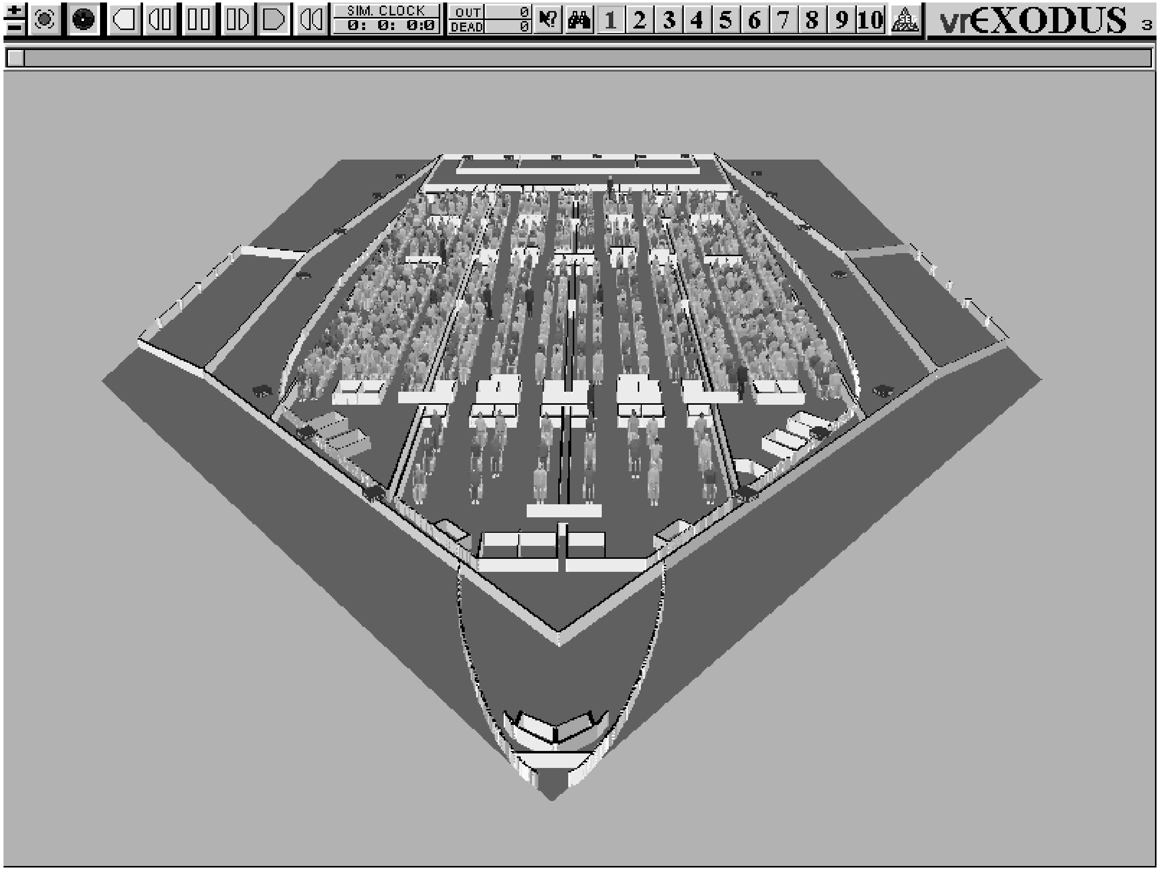
Manchester recreation

Model predicts 57-66 fatalities with average of 61.
Actual incident 55 fatalities



Blended Wing Body

Crew redirection to under utilised exits



Concluding Comments

•**Computer simulation models in conjunction with Reliable and Representative data can be used to:**

address design and certification issues associated with not only conventional aircraft, but also non-conventional designs and scenarios.