# The Use of Directional Sound to Aid Aircraft Evacuation

Professor Deborah Withington,
School of Biomedical Sciences, University of Leeds, LS2 9NQ, U.K.
& Sound Alert Technology plc.

The ability to safely evacuate passengers is an essential requirement in the event of an emergency. It is surprising that this vital act relies, primarily, on one sensory modality, namely vision. If the evacuation is required as a result of a fire, which is likely to generate smoke or fumes, the sense that is first affected is sight, rendering the exit lights above the doors and the aisle strip lighting invisible. Is there an alternative? The answer is a very definite yes. Joint research with Universities of Strathclyde and Greenwich into evacuation from buildings and ships in smoke filled conditions, has demonstrated that using directional sound can cut evacuation times by a third or more.

It can't, however, be just any type of sound. The brain is designed to pinpoint sound very accurately, as a basic survival pre-requisite. We hear sounds over a huge frequency range of about 20Hz to 20,000Hz, although this range diminishes as we age. It has long been recognised that identifying the direction of a sound source (or localizing it) requires a vast amount of neural processing.

For accurate localization we require the neural computation, in our brain, of a variety of cues. When a sound comes from one side of us, say the right, it arrives first at the right ear and is also louder in that ear. At low frequencies, the brain processes differences in the time of arrival of the sound at each ear. At higher frequencies, the important clue is the difference in loudness perceived by each ear. The final main piece of information is the way that our ears modify sounds – amplifying some frequencies and diminishing others – as they pass over the convolutions of the pinna (the outer ear). This is called the head-related transfer function (HRTF) and the HRTF of any one person is unique to that individual. The role of the HRTF is particularly important when we are trying to determine whether a sound comes from directly behind or in front of us. In such a case, the differences in timing and loudness at each ear are negligible and there is consequently very little information on which we can base a decision.

Each type of sound localization cue operates over a different and relatively narrow frequency range. Information from all cues is combined by our brains to provide us with a sense of where a sound is coming from. Only certain types of sound are easy to localize and the crucial component is that they contain a large spectrum of frequencies – i.e. broadband noise. Broadband noise can most easily be described as the sound of a rushing river or the rustling of leaves. With broadband noise, the brain has the maximum number of cues available to process. Pure tones, simple tone combinations or narrowband noise cannot be as easily or as accurately localized.

In separate research at Leeds University we have shown that the narrowband sound of conventional emergency vehicle sirens is particularly difficult to localize. In laboratory tests using a driving simulator, involving 200 drivers, participants were unable to tell whether the sound of an approaching emergency vehicle was directly behind or in front of them 56% of the time. A potentially dangerous situation if they were at the wheel of a real car! The solution, a new siren incorporating broadband noise, is now in use by many of the UK emergency services.

### Directional sound in aircraft

So, what are the advantages of combining a light source and directional sound for aircraft evacuation? Firstly, the part of our brain that is activated in the event of an emergency, and is responsible for the initial "start to move", is best activated by a combination of light and directional sound. The cells in this part of the brain respond, at one level, to light alone and to sound alone. When the two sensory stimuli are combined the same cells respond up to 500x more effectively – a great "kick start" for any evacuation.

Secondly, the layout of aircraft, with fixed forward facing seats, results in a "go forward" mentality. The last visual memory a passenger has is of the exit sign in front of him/her. They may have an exit one or two rows behind and much nearer than the one visually cued ahead of them. Additionally, the typical response of people in a panic situation is to exit by the route they are most familiar with, on aircraft this is the way they boarded. The use of combined light/sound exit markers would ensure that the passengers' attention is drawn to the nearest exit (as it would sound louder) allowing more structured evacuation using all viable exit routes. Sounders could be deactivated on non-usable exit routes. It could also stop the typical response of people in a panic situation, which is to attempt to leave by the route they have used previously to enter.

Finally, in the event of a fire, in which the smoke or fumes will render vision useless, the sounders will be the only lifeline to locate exits.

The concept of directional sound evacuation beacons combined with visual exit signs has been well received in the building industry, resulting in installations around the country. Recently, the concept was tested very successfully in the marine environment when evacuation from smoke-filled ships was enhanced dramatically when sound bacons were utilised. As a result of these sea trials, observed by the UK Government's Marine & Coastguard Agency, it is hoped that the IMO (International Maritime Organisation) will in due course mandate the use of directional sound on all passenger ships.

There is always the question of how will people know what the sound means? Aircraft with the pre-flight safety briefing provide an ideal environment in which the public can be informed of the role of the sound and its benefits for evacuation. The great advantage of the broadband sound is that it is language independent and will be as effective for British, Japanese, Russian or any nationality on board the aircraft. The trials of directional sound on ships, however, showed no influence of briefing/not briefing passengers on the evacuation times. Therefore, if the passengers are not attentive during the pre-flight briefing they will still benefit from the use of directional sound.

### Aircraft Trials

Recently, we had the opportunity to test the use of directional sound on aircraft. The trials were jointly undertaken with Universities of Cranfield & Greenwich together with the co-operation of an aircraft manufacturer and a prominent airline.

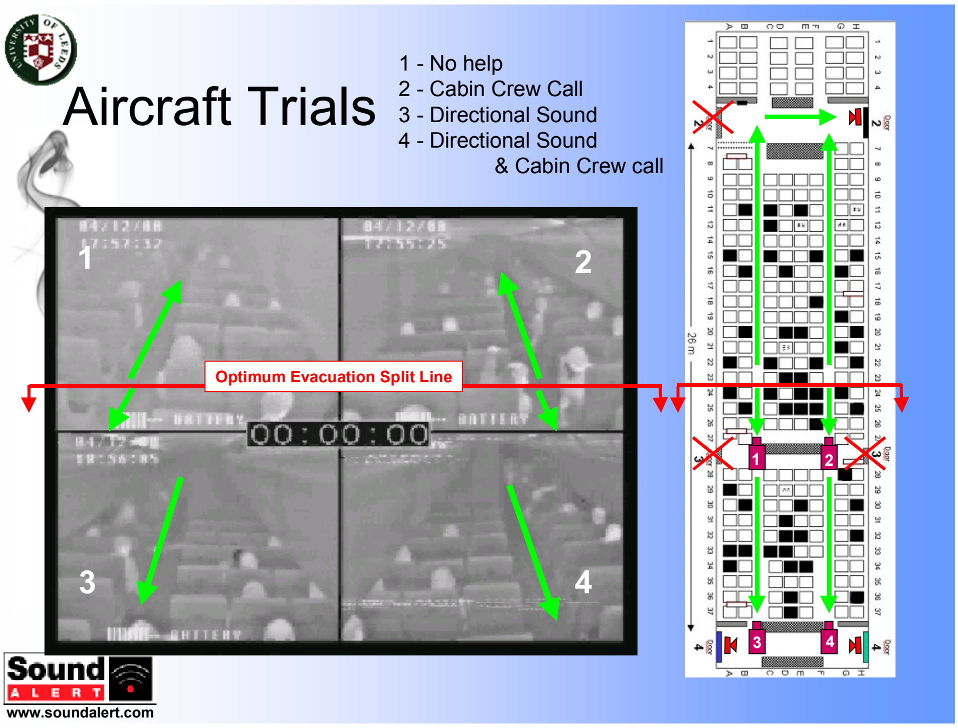


Figure 1. Left, the view from each of four thermal imaging cameras, all facing forward. Cameras 1 & 2 covering the area of the cabin forward of the monument; 3 & 4 the cabin area to the rear of the monument. Right, a schematic layout of the plane with the location of participants indicated by the black squares. The green arrows represent the expected direction of travel of the participants if they used the nearest exit. The red line indicates the idealised split line that would ensure all exits are used optimally.

The trials took place on a twin aisle aircraft and the participants were recruited over an age range from 20 – 65 years. The trials were undertaken in the evenings to ensure that participants were likely to have similar demographic and occupational profiles to normal aircraft passengers. For each trial approximately fifty passengers were used and each was issued with a boarding card to ensure a random distribution of people throughout the body of the aircraft (the first class area was not used). The passengers were given a normal safety briefing by the onboard cabin crew (Airline supplied) prior to "take off". When directional noise was used additional briefing material was incorporated into the pre-flight briefing: *" for your safety this airline has installed directional sounders to help you find the emergency exits. In the event of an evacuation the sound beacons will identify available exits. Please listen to the sound".* The sound was then played simultaneously from all the exits, ensuring the participants had no prior knowledge of which exits would be available when the evacuation commenced. Shortly into the "flight" the passengers were notified over the PA that there was a problem but that they should remain in their seats. At this point smoke started to fill the cabin. After approximately 5 minutes the evacuation was started, the emergency lighting was activated. For the purposes of the experiment only 3 exits were made available. One forward exit on the right and both left and right exits at the rear of the aircraft (all type A exits). (See Figure 1).

Four combinations were used in the trials:-

1) no cabin crew assistance and no directional noise
2) cabin crew assistance and no directional noise
3) no cabin crew assistance and directional noise
4) cabin crew assistance and directional noise.

The movement of the participants was monitored by thermal imaging cameras (normal cameras are not suitable for filming in smoke). Each passenger was wearing a numbered bib that enabled the analysis to follow evacuation of individuals as well as the group as a whole.

**Results**

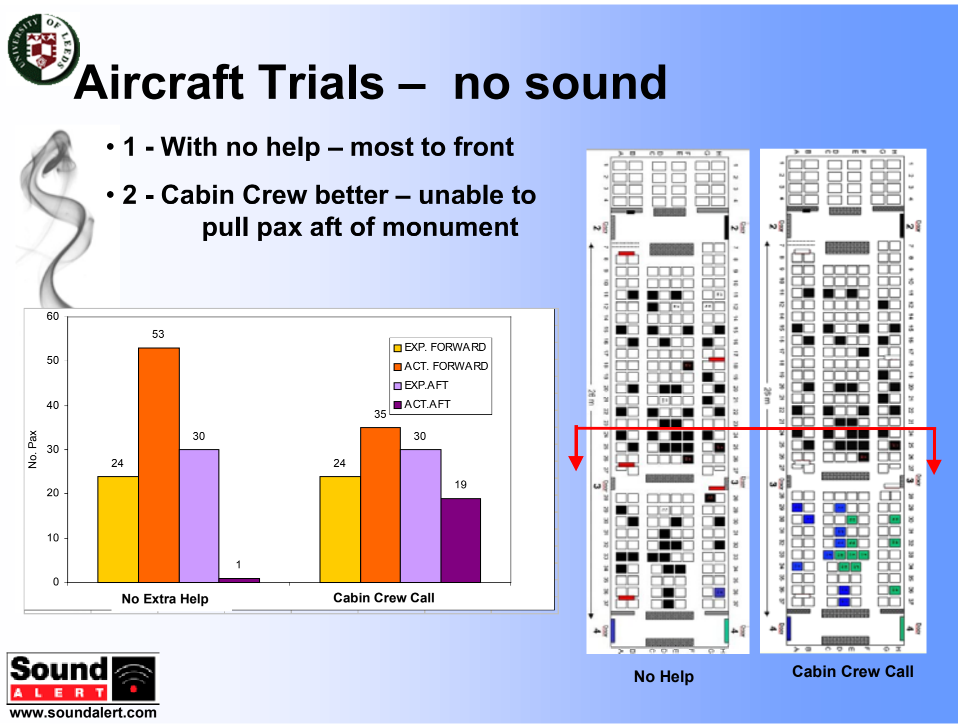


Figure 2. Data from the trials where directional sound was not used. The bar graph on the left shows the expected (exp.) and actual (act.) door usage. The schematic drawings on the right show the actual exits used by each passenger. The exits are colour coded. Black = front right exit; blue = rear left exit and green = rear right exit. Note the only passenger to use a rear exit in trials 1 used the left door rather than the nearer right!

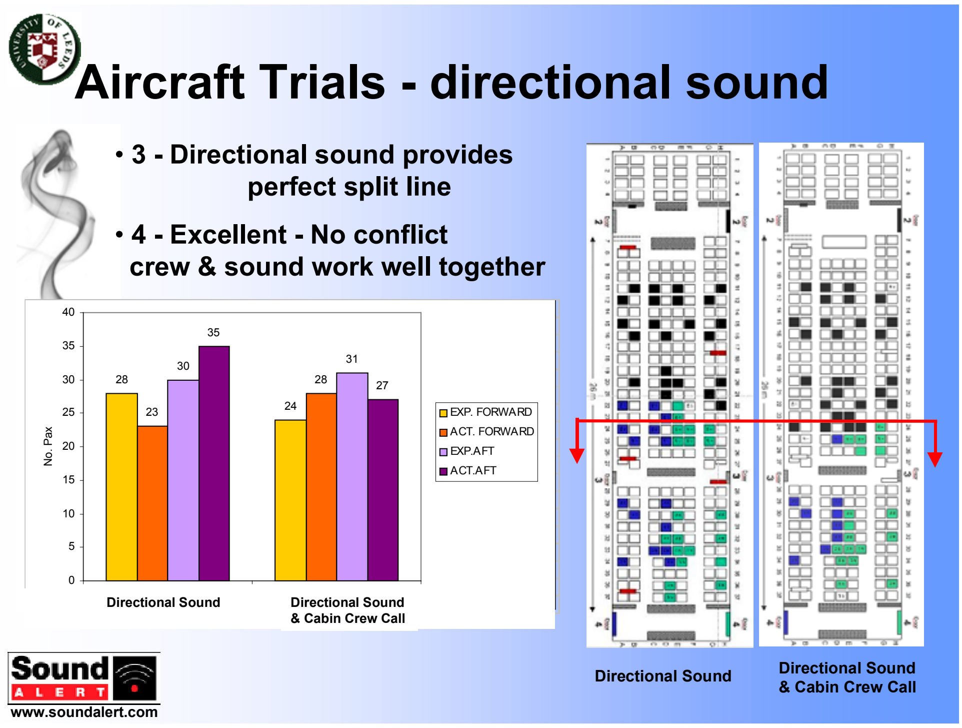


Figure 3. Data from the trials where directional sound was used. Bar graph and colour coding of schematic layouts as in figure 2.

After the trials the participants and cabin crew were asked to complete questionnaires which asked a range of questions covering the evacuation. 90% of the participants reported that the sound had aided them to a safe exit. 100% of the cabin crew said that the sound had not hindered their actions to evacuate the participants.

## Conclusions

The most striking feature of these data is the improvement in door usage when using directional sound. In particular the ability to direct passenger from forward of the monument to the correct (rear) exits which the cabin crew alone are unable to do. These data are an important first step in showing the efficacy of directional sound to aid in aircraft evacuation. It is clear from the results that the use of cabin crew and directional sound provided the best results in terms of exit usage. The results from using directional sound alone, however, were very similar to those from the combination of cabin crew and sound. This would be vital in an emergency where, for one reason or another, the cabin crew were incapacitated (may be through smoke inhalation) and unable to give verbal commands. The data were collected in a smoke-filled environment, a worst-case situation (similar to the disaster at Manchester airport). Nevertheless, the ability to direct passengers to viable exits, whether there is or isn't smoke, should be seen as a major advance in aircraft life safety.