The Very Large Airplane: Safety, Health, and Comfort Considerations

AIR TRANSPORT MEDICINE COMMITTEE,
AEROSPACE MEDICAL ASSOCIATION

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In recent years, aircraft manufacturers have been considering a very large airplane with a capacity of 600–1000 passengers. The human factors aspects of such an unprecedented enterprise demand that the aerospace medicine community take an active role early on in the design phase. Consequently, the Aerospace Medical Association formed an international task force to prepare a paper containing pertinent human factors recommendations for the manufacturers. This paper, including the recommendations herein, has been forwarded to Boeing and Airbus as well as to 50 major airlines of the world.

INTRODUCTION

As we move into the next century, it is clear that air travel will greatly increase world-wide. In order to accommodate an increasing number of passengers, more aircraft will be taking to the skies, and much larger aircraft with a passenger capacity much greater than today's 747 will go into production. The aircraft industry has been discussing a very large airplane (VLA) with a capacity of up to 1000 passengers. Undoubtedly, we will be seeing a commensurate increase in passengers who are elderly, disabled, or with preexisting illnesses. Consequently, efforts must be made to examine the issue of passenger safety, health, and comfort in the context of the VLA.

In order to provide the aircraft industry with input from the aerospace medicine community, the Aerospace Medical Association Air Transport Medicine Committee organized a task force of experts to prepare this report. In order to ensure international input, three sub-committees were formed chaired by Dr. Reizo Kikuchi (Far East), Dr. Jose Pinto-Ferreiar (Europe, Middle East, Africa), and Dr. Claude Thibeault (North America). Each subcommittee worked independently, forwarding its report to the Aerospace Medical Association Home Office where the three reports were integrated. The result of this process is this document entitled "The Very Large Airplane: Passenger Safety, Health, and Comfort Considerations." We fully recognize that there are engineering constraints that demand compromise on many of our recommendations. However, we ask you to give them due consideration as you plan for the very large airplane. The material presented herein is divided into six parts.

I. Environment and Cabin Air Quality
II. Safety and Comfort
III. Food and Water
IV. Medical Considerations
V. Emergency Evacuation
VI. Summary and Recommendations

I. ENVIRONMENT AND CABIN AIR QUALITY

Cabin air quality is of universal interest today. Cockpit and cabin crew, as well as passengers, often complain of a legion of symptoms including headache, nausea, vomiting, fatigue, dizziness, and even menstrual abnormalities that they attribute to poor cabin air quality. A number of studies have been published with others underway to determine if cabin air quality is unhealthful and the cause of the many symptoms of which crew and passengers complain. Let it suffice to say that although these studies are not yet complete, there is no evidence that cabin air is substandard or deleterious to one's health either in older aircraft that provide 100% fresh air or in newer aircraft that provide 50% fresh air. This can be stated with reasonable certitude, especially for flights in which there is a total smoking ban. Nevertheless, the many complaints cannot be simply dismissed as inconsequential or imaginary. There is certainly something inherent in flight to cause them.

At this time, the evidence points not toward unhealthful cabin air but toward other factors inherent in flight such as a lowered barometric pressure and lowered oxygen pressure, vibration, crowding, noise, and jet lag—all facts of flight. These appear to be the real culprits. Although it is an unrealistic expectation to eliminate these factors by designing them out, every effort should be made by the aeronautical engineering community to ameliorate them as far as it is technically feasible and cost effective. Consequently, we recommend the following:

1. Maintain a cabin altitude as close to sea level as

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possible. Although there is no solid evidence that there are fewer medical events or less discomfort at lower cabin altitudes, this is a very reasonable assumption since human physiology functions optimally at sea level conditions. Hence, the lower the altitude, the better we function.

2. Design oxygen drop-down masks so that they are as reliable as possible. There have been reports that drop-down masks occasionally do not deploy or do not deliver oxygen as required.
3. Ban smoking on all flights since it is known to cause discomfort, as well as adverse effects on health, due to passive smoking.
4. Provide instrumentation for the environmental monitoring of carbon monoxide, carbon dioxide, ozone, and respiratory particulates. If it could be demonstrated over a long period that levels do not exceed current standards, arguments impugning cabin air would be disarmed.
5. Install high efficiency particulate air filters (HEPA) in all aircraft and properly maintain them.
6. Ensure optimum cabin air quality by designing systems that will provide:
   A. Airflow: 19 CFM/per passenger
   B. Fresh Air Supply: 10 CFM/per passenger
   C. Relative Humidity: as close to 30% as possible
   D. Ozone: less than 0.1 ppm
   E. CO_2: less than 1000 ppm
   F. CO: less than 25 ppm
   G. Respiratory Particulates: less than 260 $\mu g \cdot M^3$

II. SAFETY AND COMFORT

Although passenger safety must have the highest priority in aircraft design, due consideration must also be given to passenger comfort. Passenger comfort, in itself, is desirable not only from the passenger's perspective, but also from a medical perspective because uncomfortable conditions, in some cases, can cause illness or exacerbate preexisting illness.

Of particular concern is crowding, which is a universal complaint of air travelers. Cramped seating with inadequate leg room, as well as poorly designed seats, is the bane of many passengers. Current seating configurations in most commercial aircraft not only cause discomfort, but also make it more difficult to stand, stretch, or even walk about the cabin. The latter is important since prolonged sitting in predisposed individuals can cause deep venous thrombosis (DVT) or blood clot in the leg and its possible sequela of pulmonary embolism (clot in the lung) both of which have been reported as consequences of air travel. (The term "Economy Class Syndrome" has been coined to describe this illness, although it has been reported in passengers travelling business and first class as well.) Consequently, it is strongly recommended that the aircraft seating configuration be designed to accommodate all passengers, tall people in particular, by increasing the distance between rows. Therefore, the minimum seat width and pitch should be determined anthropometrically. In addition, headrests and lumbar supports should be integrated into each seat to accommodate a higher percentile of passengers than is currently the case.

There are also significant psychological factors that can be induced by crowding in a small space, such as an aircraft cabin. Studies have demonstrated that crowding—particularly in individuals with a predisposition—can cause increased stress and arousal, a decreased tolerance for frustration, and a negative influence on individual cognitive ability. This can result in some loss of self-control, as well as hostility reactions and aggressiveness. As an example, it was reported that on a flight in the Middle East, the aircraft encountered considerable turbulence. This induced many passengers to panic and to run about the interior of the aircraft, upsetting its balance and causing control problems for the pilots. Although the proximate cause for this stress reaction and undesirable behavior was due to turbulence, the underlying cause was believed due to the effects of crowding. Other incidents of belligerent behavior on the part of passengers have been reported. Consequently, it is essential to relieve crowding as much as possible by improving seat width, increasing seat pitch, increasing aisle space, and improving seat density and aisles using anthropometric data.

The number of emergency exits, their size and location, will be particularly critical on a VLA because of the large number of passengers. The usual standard for aircraft emergency ground egress is 90 s and should be the same for any aircraft regardless of size. Hence, it becomes even more compelling to consider the number of exits and their location in order to meet the 90-s standard. In addition, they should be relatively easy to open and every effort should be made to avoid seating children, the disabled, or the elderly adjacent to these emergency exits.

In order to relieve crowding and encourage passengers to exercise in flight without blocking aisles, we recommend that a lounge area be provided where small numbers of passengers can stand and walk about. (Such lounges did exist in the 747 when they first began operations.) The lounge could also be designed to serve as a patient treatment area should there be a need to treat a seriously ill passenger in-flight (see Section IV, Medical Considerations).

Passengers, on occasion, develop ear or sinus blocks or general ear discomfort on ascent and descent, due to pressure equilibration between cabin pressure and pressure within the body cavities. This discomfort can be minimized to a great extent by having a maximum ascent rate of 500 $ft \cdot min^{-1}$ and a maximum descent rate of 300 $ft \cdot min^{-1}$. With slower ascent and descent rates, equilibration of air pressure would be facilitated.

It is not uncommon in today's aircraft to see a number of people in line waiting for the lavatory. This causes not only passenger discomfort but also impedes moving about the aisles. Consequently, there should be a sufficient number of lavatories located throughout the aircraft so as to avoid long lines and unreasonable waiting times. In addition, at least one of these lavatories should be able to accommodate the handicapped (wheel-chair accessible). Furthermore, for sanitation and aesthetic reasons, it might be desirable to have a toilet refuse system that would provide for a drying and incinerating process. (Such a system was considered for the SST.)

Although lap belts currently used are reasonable restraint devices for adult passengers, there still remains the problem of securing infants. There have been reported cases of infants being injured or even killed when the adult was unable to hold on to the infant due to high accelerative forces. Consequently, continued research must be conducted to determine how best to restrain infants and small children.

In addition, the carrying on board of large, heavy hand-carried luggage must be discouraged because of the potential for blocking aisles during emergency ground egress as well as injury due to accelerative forces. Most luggage should be checked, with the exception of very small, light-weight articles. If this cannot be done, storage bins must be made large enough and strong enough to accommodate all heavy articles and must be well-secured to avoid unlocking and opening during flight, as well as during high accelerative forces.

III. FOOD AND WATER

Food and water sanitation will be increasingly important as the VLA flies to all points around the globe. Fortunately, there have been very few reported food-borne illness epidemics associated with air travel, although there is always the potential. For example, it was only a few years ago that a number of passengers became acutely ill because of cholera caused by an in-flight meal. Galleys must be designed to hold a large number of meals at proper temperatures if the risk of food-borne illness in-flight is to be reduced to a minimum. Furthermore, food must be procured only from certified vendors and provisions must be made for a strict food sanitation program, including site and food handler inspection.

It is extremely important that all water on board aircraft be potable. Although this is not a problem in most countries of the world, there is the possibility of non-potability in some developing nations. Consequently, it is recommended that chlorination capability be available (possibly a portable apparatus) that could be used only for those flights on high-risk routes.

IV. MEDICAL CONSIDERATIONS

With the expected increase in air travel, it is reasonable to assume that there will be more elderly and disabled passengers, as well as those with preexisting illnesses. Consequently, there must be a capability to provide a reasonable degree of medical care in-flight. Appropriate space must be afforded to stow expanded medical kits. In addition, there is the possibility that many airlines will opt to have on-board bulky equipment such as defibrillators and ventilators. In anticipation of such an eventuality, again space must be allocated during the design phase.

When acute illness occurs in flight, such as a suspected heart attack, it is extremely difficult in today's aircraft to render treatment because of lack of space as well as privacy. Consequently, it would be desirable to designate a patient treatment area where a health-care provider could render care in a reasonable space in privacy and with medical supplies and equipment in proximity. It is recommended that the treatment area be the passenger lounge, as suggested in the above Section II. A medical kit, medical supplies, and defibrillator as well as a litter could be discreetly stored in this area and deployed if needed. The lounge could be closed to passengers, thus creating a small medical facility.

Although most airlines do have a ground consultant program in the event of in-flight illness, the development of telemedicine communications would be advantageous, particularly over areas where diversion is impossible. Miniaturized telemedicine communications equipment could be built into the passenger lounge area and deployed as required.

A major concern today is the availability of medical oxygen for passengers. As more passengers with cardiopulmonary disease take to the air, there will be an increased demand. Besides the use of carry-on oxygen cylinders, other sources could be a molecular sieve system or the aircraft ring-main oxygen supply. The molecular sieve, a device that extracts oxygen from the air, is attractive because it requires no cylinders, obviating the need to carry oxygen on board. Furthermore, it is light weight and is a very safe and efficient method for providing medical oxygen. However, because it relies on the aircraft power system, appropriate outlets must be provided throughout the aircraft once molecular sieve technology becomes easily available to passengers. Another option would be to use oxygen from the aircraft emergency (ring-main) oxygen system. Although this is not the practice of most airlines today, one major airline does allow use of ring-main oxygen for scheduled and unscheduled use. If use of ring-main oxygen for medical purposes becomes common practice, the carrying capacity of the oxygen system must be increased accordingly.

There will most likely be an increased demand for suction and ventilation capability. This would again require power points and outlets within the aircraft in order for them to operate. It is recommended that the appropriate power points and outlets be installed in the passenger lounge where this equipment could be used as required. Again, the lounge's primary purpose would be to provide a place for passengers to stand and stretch in a relatively open space but, in the event of a medical emergency, it could be placed off-limits to passengers and quickly converted into a patient treatment area.

V. EMERGENCY GROUND EVACUATION

Although emergency ground egress is a very rare event, it can cause an excessive number of injuries and deaths if precautions are not taken. Most important, there must be an adequate number of exits about the aircraft that are large enough to accommodate all passengers and are easy to operate. Furthermore, there must be adequate space between each row as well as wide aisles to accommodate the rapid movement of passengers. Illuminating lights leading to the exits should be installed to facilitate finding the exit even in a smoke-filled cabin. To facilitate operation of the doors, the elderly, very young, and disabled should not be assigned seats adjacent to these exits. Escape slides that are carefully designed to minimize the risk of injury should be installed at the exits. Furthermore, an appropriate number of life rafts for a large passenger load and adequate water survival equipment should be available.

In order to minimize casualties, the interior of the aircraft—including the carpeting, upholstery and panels—

must be made of fire-resistant materials that produce non-toxic pyrolysis products. Toxic substances unleashed because of fire and high temperatures have been the cause of many deaths due to aircraft fires. Unfortunately, this has occurred in a number of otherwise survivable accidents. Consideration should also be given to the use of smoke masks or smoke hoods as a further protective measure. If these are adopted, then appropriate storage space and ease of accessibility must be assured.

In the event of an emergency of any kind, there must be excellent communications between the cockpit crew and cabin crew and passengers. Current public announcement systems are often inaudible because they are not loud enough or there is excessive static. Therefore, public address systems within the aircraft should be extremely efficient, providing a clear, understandable and reasonably loud volume system to ensure that passengers fully comprehend the information or directions given them by the crew.

VI. SUMMARY AND RECOMMENDATIONS

The Aerospace Medical Association, in its efforts to advocate passenger safety, health and comfort, respectfully submits the following recommendations to the aircraft industry and the airlines:

1. Provide instrumentation for environmental monitoring of the aircraft cabin.
2. Ensure aircraft ventilation and cabin air quality meet published standards.
3. Maintain cabin altitude as close to sea level as is practical.
4. Ensure high reliability of drop-down oxygen masks.
5. Ban smoking on all flights.
6. Install and properly maintain high efficiency air filters (HEPA) on all aircraft.
7. Reduce crowding by proper design of aisle spacing and seat configuration (width and pitch) giving particular attention to anthropometric data. Head rests and lumbar supports should also be designed into passenger seats.
8. Give careful consideration to emergency exits including size, location, and number to allow for an evacuation time of 90 s.
9. Avoid seating children, the disabled, or elderly adjacent to emergency exits.
10. Designate an area to be used as a lounge where passengers can walk about. Provisions should also be made so that the lounge could convert into a patient treatment area if required. The lounge should have storage space for a litter and medical kit/equipment/supplies that could be deployed as required. Outlets should be provided for medical oxygen, suction and ventilation, and a defibrillator as required.
11. Adjust rate of ascent and descent to avoid barotrauma.
12. Ensure an adequate number of lavatories with at least one wheel-chair accessible for handicapped individuals.
13. Consider a toilet refuse system that provides for drying and incineration.
14. Design a restraint system for infants and small children.
15. Prohibit large, heavy carry-on luggage. Otherwise design large, well-secured storage bins.
16. Ensure galleys can maintain proper food handling temperatures.
17. Provide for a portable apparatus for in-flight water purification for use on high-risk routes.
18. Provide a telemedicine communications system.
19. Investigate feasibility of utilizing the ring-main emergency oxygen system for scheduled and unscheduled medical use.
20. Install floor illuminating lights leading to exits.
21. Design escape slides to minimize risk of injury.
22. Ensure adequate storage space for life rafts and survival equipment.
23. Use fire-resistant materials and those that produce non-toxic pyrolysis products in the aircraft interior including wall panels, bins, carpeting and upholstery.
24. Investigate feasibility of passenger smoke hoods/masks.
25. Ensure an efficient, understandable public-address system.