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IFE and Comfort in Aircraft Cabin – State of the Art

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Abbreviations and Definitions

A/C	Aircraft
AOD	Audio On Demand
CPU	Core Processor unit
CVS	Computer Vision Syndrome
DVD	Digital Video Disc
FACE	Friendly Aircraft Cabin Environment
HCI	Human computer Interface
IFC	In Flight Cabin
IFE	In Flight Entertainment
ISP	Internet Service Provider
LAB	Labinal
LAN	Local Area Network
LCD	Liquid crystal display
MUX	Multiplexer
MPEG	Motion Picture Engineering Group
NVOD	Near Video On Demand
OIS	Onboard Information System
PAT	Purser Access Terminal
PED	Personal Electronic device
PC	Personal Computer
PCU	Personal Controller Unit
PFIS	Passenger Flight Information System
SEB	Seat Electronic Box
TAV	Thales Avionics
TIFS	Thales avionics In Flight System
USB	Universal serial bus
VCR	Video Cassette Recorder
VPN	Virtual Private Network
VOD	Video On Demand
Kinaesthetic	
lordosis	
carpal channel	
PCU	

Reference

[1] Rapport technique INRIA Rocquencourt, France - J.M. Christian BASTIEN et Dominique L. SCAPIN - «Ergonomic criteria for the evaluation of Human-Computer Interfaces»

[2] Editor: Dunod, France ISBN: 2 10 003308 5 - Jean Pierre GAILLARD - Jean Pierre GAILLARD - «Psychologie de l'homme au travail. Les relations hommes machines»

[3] OCTARES – « Traité d'ergonomie »

[4] Joint Aviation Authorities, ICE Ergonomics july 2001 – « Anthropometric study to update minimum aircraft seating standards »

[5] Editor Autrement; collection sciences en société n° 10-January 1994 ISSN1163-7765 – « Confort moderne. Une nouvelle culture du confort»

[6] Editor: PUL, 1994, France ISBN: 2-7297-0504-X - Olivier LE GOFF - «L'invention du confort»

Introduction

Passenger in a plane may suffer from stress, anxiety or even fear of flight. Passenger comfort is clearly a main factor in user's acceptance of transportation systems. An individual's reaction to a vehicle environment depends not only on the physical inputs but also on the characteristics of the individual. Surveys of airline passengers found that sex of the respondent and attitude toward flying have important influences on passenger comfort. Individual differences were also found regarding

- perceptions of environmental variables,
- the importance of factors as determinants of comfort, and
- the ease of and frequency of performing activities in flight.

The findings above clearly indicate that there are not optimal settings of the internal variables in a plane and that individual passengers will always have conflicting requirements. SEAT aims to design and manufacture smart responsive seats and interior textiles with the capability of detecting physiological and psychological changes of passenger's condition in real time. This in turn will be analysed and appropriate adjustments such as temperature control, air ventilation, seat parameters etc. put in place. Furthermore each passenger will be able to create its own retrieve with personal entertainment and office characteristics in place. The entire approach is to create an environment that responds to the individual needs and desires and not to be centrally controlled or locally adjusted by a number of manual options.

The proposed design will allow

- to increase the sense of comfort
- to ensure that potential health accidents are prevented through an early warning and
- to improve to overall psychological comfort,

through the use of smart technologies that respond intelligently to the user needs and requests.

SEAT is a Specific Targeted Research Project (STREP), within the 6th European Framework Programme: Integrating and strengthening the European Research area, Activity: Aeronautics and Space, call identifier: FP6-2005-AERO-1.

SEAT addresses high priority objectives as set in the strategic research agenda and the vision 2020 report:

- to meet society's needs for a more efficient, safer and environmentally friendly air transport,
- to win global leadership for European aeronautics, with a competitive supply chain, including small and medium enterprises.

The focus is on stress reduction during travel through introduction of responsive environment.

This report concerns the first task within work package 5 of the SEAT project. The report is about multimedia comfort requirement and onboard equipment installation, application and services.

In order to establish requirements about multimedia concerning the impact on passengers' comfort, we have first made a general overview of the situation with a state of the art of equipment, services and comfort notion and also a description of the cabin environment.

This state of this art begins with a history of aircraft cabin comfort and IFE to see how it has evolved over the past decades. Then we introduce the notion of comfort through human sciences and ergonomics considerations. Then we approach the state of the art of human factors, but also of the onboard multimedia equipment, technologies and applications.
Eventually, this report ends with an overview of the aircraft cabin environment to understand how the multimedia can be an environmental disturbance and at the same time a factor of comfort improvement.

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1. History of A/C cabin comfort and IFE

In the aeronautical world, the passenger comfort has become an important element and choice criterion for airline users. Historically, comfort was associated to the simple ownership of conveniences, but today it becomes a due. Therefore, comfort experience is now "normality" in the passenger experience and this generates other expectations.
The focus given to comfort requires companies to integrate the treatment of this notion both at the level of research and at the level of product conception. The notion of comfort is complex; the research in this domain can only be done via mixing various fields: human sciences as well as engineer sciences.
In the following chapters, we'll try to explain what the concept of comfort is in everyday life.

Today air travel is becoming increasingly more accessible to people, both through the availability of cheap flights and also because the airlines are now able to cater for individuals of all ages and disabilities. The wide bodies of many new aircraft allow the airlines to have very flexible and comfortable options like wide seats and onboard entertainment. Today these options are for airlines economic potentials.

The new generation aircraft are now integrating IFE systems in the early conception. The former Airbus L/R and S/A aircraft have been "enhanced" to integrate better possibilities for the IFE systems but the A380 really gave a spin to the trend. The next Boeing and Airbus generation A/C (787, A350, Galaxy …) will be "IFE ready" designed: airlines will be able to select IFE options like they today select the colour of their interiors. Nonetheless these new generations A/C will get more "mass produced" IFE possibilities, they will also integrate the latest technologies available on the market at the moment of their design.

Since the resurgence of the commercial airline industry in the mid-1990s, the annual profitability margins of major airlines have grown substantially. With higher profits, these airlines have had the income to invest in passengers' comfort in improving their products and services offerings. Hence, they compete by upgrading their IFE systems. The unfortunate events of September 11th, 2001 marked a slight pause in this trend but now the retrofit market is expanding significantly.

In flight entertainment (IFE) goes back in time further than many people may think. It began on air transport aircraft more than 35 years ago with film projection to the front of the passenger cabin.

Until the past decade, IFE did not change significantly, apart from the addition of new projection technologies and distributed audio entertainment. However, the distribution of video to the seat and the introduction of in-cabin commercial telephone service have boosted the industry. Currently, if an IFE system doesn't provide digital quality video and audio, it is considered as "old fashion" even though this has been accepted by many passengers for the last decades.

The term "in-flight entertainment" today encompasses more than just aircraft cabin electronic systems that "entertain," to in-seat power supply for laptop computers and other personal electronic devices (PEDs) and in-flight telecommunications. Tomorrow's IFE systems will provide access to e-mail and the Internet, as well as to entertainment content delivered via satellite in real-time through broadband networks.

Needless to say, IFE has come a long way. It continues to advance rapidly, both technologically in terms of its economic potential.

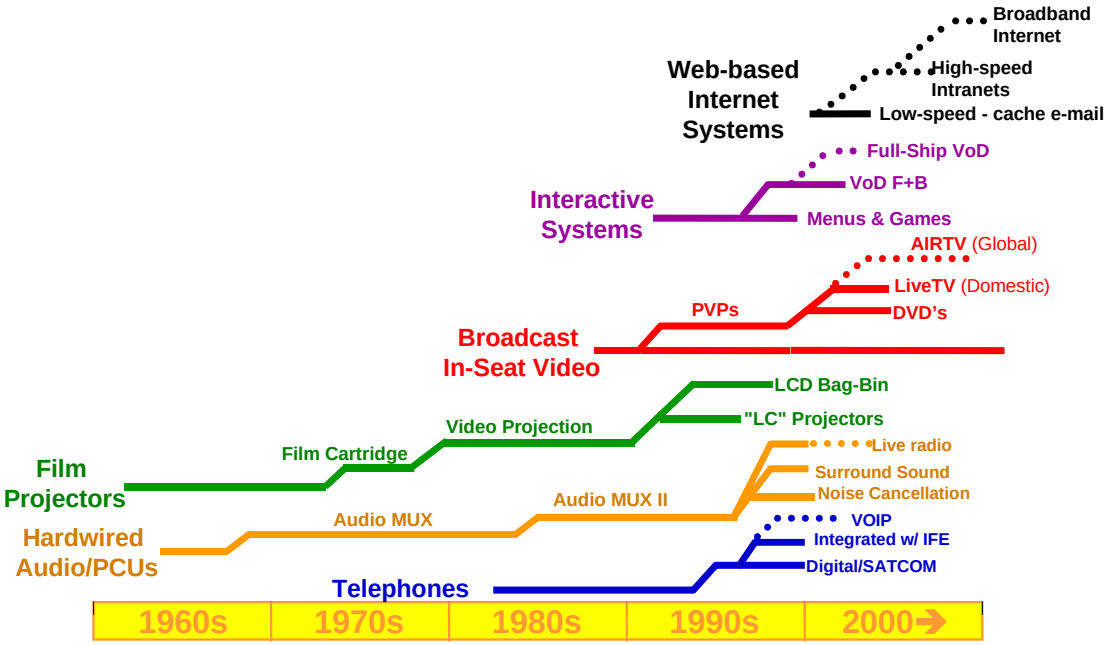


Figure 1: IFE Evolution

According to Patrick Brannelly, VP Passengers Communication & Visual Services at Emirates, "*those who do not innovate and improve will die*". The next trend in IFE system will be "applications" in order to bring to passengers on ground experience in the air. Airlines tend to offer their passengers with the same services they could have on ground: same tools hey have on their desktop PCs, "communicating everywhere" applications, etc. It is not just to be "trend" and have the latest new technologies. It is also because entertainment systems play an important role in the good progress of a flight. It brings comfort, something to do along spare time but also relax people and help them to feel secure, like "at home".

Seats have in aircraft the most important place in term of passenger comfort. They were as simple as possible in the beginning of aircraft. Since 1980, manufacturers have tried to work on electrically controlled seat. Today they develop electrical seat systems that include: electronic unit with PC power, pneumatic tilt up system, pneumatic ears, possibility to control up to 20 actuators, sliding doors … The F/C seats are tending to offer the same level of services that a traveler could get in 5 stars hotels and most of them rely upon electrical systems driven from the IFE in seat display.

We will try first, to understand the notion of comfort composed of perception of feeling and good furniture, to better improve the comfort onboard.

2. Introduction to comfort

To introduce the notion of comfort, human factor and comfort experts have to set important questions like; what is comfort? How can we understand that notion? What do tell us human sciences, and ergonomics in particular, about comfort? How and on what, can we act to improve comfort?

This chapter will try to answer these questions.

2.1. Definition

According to dictionaries, comfort is a complex notion, a mix of feeling, perception, mood and situation. It could be described as follows.
Comfort is:

- a state of being relaxed and feeling no pain,
- a feeling of freedom from worry or disappointment,
- a freedom from financial difficulty that promotes a comfortable state,
- the pleasant and satisfying feeling of being physically or mentally free from pain and suffering, or something that provides this feeling,
- assistance, relief, support,
- material well being, conveniences which make easier and more pleasant life.

These definitions introduce three common states of comfort: physical, mental and material.

- physical state of a person:
- Being relaxed, feeling no pains, pleasant and satisfying feeling of being physically, free from pain and suffering,
- mental and psychological feeling with a perception connotation:
- A state of quiet enjoyment; feeling of freedom from worry, disappointment, financial difficulty, want, or anxiety,
- material conditions of people:
- Material well being, conveniences that make life easier, more pleasant, something that provides this feeling, whatever contributes to such a condition.

These three notions will be found all along this document, as a work base to build comfort requirement.

2.2. Comfort notion developed in human sciences

Human sciences bring knowledge about comfort and the concept of comfort perception that is instructive to see, especially from the Psychology, Sociology and History point of views.

2.2.1 Psychological point of view

Human beings are made of physical, psychological, mental and spiritual bodies; the perception of comfort is also a mix of these various aspects, as follows:

- Material comfort is based on standard, hygiene and security that give a definition of minimum external condition of comfort. Nevertheless, a lot of people live far from this minimum standard without suffering any particular health condition. This is the reason why everybody has a different definition of comfort.
- Aesthetic comfort is subjective and depends on taste and personal feelings: places, shapes, fabrics, colors, lights, odors, noise (or silence)…

- Comfort of socialization answers to the need of isolating and protecting oneself, of communicating with others, in privacy or in public areas shared by all.
- Conformity comfort goes with feeling of belonging to a group, a tribe.

Each physical body tends to satisfy these four comfort categories. They are interdependent and can be complementary or conflicting.
No generic comfort can be defined for everybody. Each one has his own conception of comfort depending on his experience, history and living conditions.

2.2.2 Sociological point of view

If one has its own idea of comfort, it is conditioned by belonging to a group, a race, a family and a culture. Different socializations bring different perceptions of this comfort notion. No ethnographic study on comfort has been made, but two major classifications can be pointed out: geographical and social perception of comfort.

2.2.2.1 Geographical and ethnical perception of comfort.

There is no doubt that a large variability of comfort notions exists in different countries.
For instance, in a lot of traditional civilizations, resting postures are very different than in Europe. In East Africa, some fishermen take a rest as a wader, on one foot. In India or in Africa people seat cross-legged or on their foot soles. In Europe people prefer to seat on a chair.
When considering eating habits, comfort in western countries goes with table and chairs. On the contrary, in traditional Africa or in Japan, people eat without any furniture.
When sleeping, the comfort for African, Asian, or Oceanic people goes with the use of wooden or stone pillows whereas Europeans prefer feather pillows.

A long list of variability in comfort could be listed. It is not necessarily correlated with ethnical groups or countries but with social, cultural, educational groups.

2.2.2.2 Social perception of comfort

In upper classes of European populations, comfort is often related to luxury, pomp and ceremonial. Sometimes, this can be contradictory with immediate well being.
In European middle classes, comfort is synonym of sham. It refers to the need of showing off. People want to do and look like immediate upper class.
And in lower class, comfort is related to contraption and gadgets. It answers the need of ownership.

As seen before, defining a typology of comfort is complex because comfort perception is very variable in different population classes, depending on the life style factors.

If comfort perception is linked with social considerations, it also goes and evolves with development of techniques.

2.2.3 Comfort a modern notion, which goes with technique.

Comfort is a very old word. It appears for the first time in France, during the 11th century, in "*La chanson de Roland*". Originating from the Latin word "*confortare*" which means help, assistance, courage, and aid, the notion has evolved and it is now linked to material considerations.
The notion of material well being, in comfort is recent: in the middle of the 19th century, the industrial revolution and the availability of manufactured objects introduced this new notion in the definition of comfort. In Occident, this material comfort began to be taken into account by the population, in the first middle of the 20th century with the increase of living standard. During the 1930's, people began to bring comfort to their houses with new technologies such as telephony, TV…

We can now relate comfort as reaching an objective of material well being: a manufactured object presents comfortable (or not) characteristics which can be measured. But there is a gap between comfort level set up by the engineer and the comfort level felt by the end-user. The comfort notion is a trade off between scientific measurement from designers or engineers, and the abstract consideration of comfort perception from end-users

In one hand, measured comfort is the expression of pure technical data. On the other hand, to feel comfort, we need approval or even seduction. We are in a subjective register.

From now, when we use the notion of comfort, we will consider scientific, technical, functional aspects and in the same time visual, tactile, kinaesthetic, symbolic aspects.

Therefore, we can distinguish two big trends of comfort: comfort of pleasure and sensation is coexisting with comfort of efficiency and management. The first goes with the traditional meaning. It refers to the sensitive and body perception (e.g.: a soft lighting, a smooth sofa). The second refers to efficiency and logic (e.g.: the rational organization of a workstation, the good accessibility to the seat in A/C).

To match object and technical environment with these comforts notions, a young discipline is born in middle of the 20th century: ergonomics.

2.3. Ergonomics considerations

2.3.1 What is ergonomics?

The aim of ergonomics recommendations is to design and to build systems which match or enhance human capabilities and accommodate human limitations.

Ergonomics is the application of a set of knowledge about human abilities, human limitations and human characteristics. The aim is to the design tools, machines, systems, tasks, jobs, and environments for safe, comfortable and effective human use.
That includes, in one hand, "industrial ergonomics" concentrated on the physical aspects of a situation and human capabilities such as force, posture, and repetition. On the other hand, it includes "human factors", oriented to the psychological and social aspects of situation such as mental loading and decision

In this whole document, we use indifferently ergonomics and human factors in the same meaning.

2.3.2 What do ergonomics know about comfort?

For human factors experts, comfort doesn't have a stable definition. It is more a state to reach and to improve. It depends on each person, on each moment of the day, on each environment and on each context.

An “ergonomic object” is a commercial argument. At best, it could mean that human factors have been taken into account in the design. A given object can be comfortable or not according to different persons, situations or contexts. In such case, ergonomic is not a synonym of comfortable.

2.3.2.1 Physical comfort:

In its physical aspect, comfort is one of the goals to reach and to improve for ergonomic design by:

- reducing or delete uncomfortable postures,
- making objects, tools or workstation adjustable to people who are using them, integrating the variability of each person.
- Suppressing excessive muscular efforts, by reducing weight to carry for instance.
- Working on the environment, by reducing noise, vibrations, adapting lighting and heat.

- Integrating chrono-psychology, variation of human capacities in function of the moment of the day. We have biological rhythms, which interfere with our behavior. Night-work has to be adapted from day work to match with normal reduction of vigilance.
- Integrating different physiological, physical, psychological, states of the person like mental and physical tiredness, decrease of vigilance, hungriness, thirstiness, stress …

2.3.2.2 Comfort perception:

If physical comfort is measurable the perception of comfort depends on people feelings, which are difficult to measure. Ergonomics can bring information about perception through testimonies and surveys. This perception is very variable, depending on conditions, situations, environments and on physical, mental, emotional state of the people involved in the survey.

Perception is due to representations, analogies, experiences, and knowledge of people. It is the reason why comfort perception is so unique and linked to a particular moment.

Objects, tools, systems are comfortable for some people, in a particular physical, emotional, psychological and mental state, in a particular moment of a day, in a particular situation and context… For instance, the same small width seat could be very comfortable to watch a scary movie with a partner, a spouse or significant other, and very uncomfortable to spend eight hours in an economic class aircraft between two unknown, broad-shouldered and large weight passengers.

2.3.3 How do ergonomics improve comfort?

- To reach comfort, the first thing to do is to design and use safe and healthy objects and environment.
  Minimal standard and legal recommendations, as noise or air pollution levels, are applied to minimize injuries. Ergonomics take them into account in priority with the goal of eliminating all sources of danger.

  If it is impossible to suppress pollution, like important noise, ergonomics will recommend to protect people first and to reduce exposure time to the pollution.

- Ergonomists have knowledge to understand human functioning.
  Anthropometry is the measurement and study of human body dimensions like height, weight, lengths and field of vision. It is one of the most important data applied by ergonomists working to fit people with their physical environment. Knowledge of body dimensions allows designing things adapted to people.

  Physiological and psychological knowledge, as muscular and nervous functioning, are also used in this objective.

- Ergonomists have tools to measure physical comfort and to improve it, for people in a given situation.
  Physiological tools allow evaluation of physiological constraints of a task on the body. These methods use for instance, oxygen consumption or adaptation of cardiac rhythm.

- Ergonomists analyze real situation to take into account human variability.
  Comfort depends on variability of people, of situations and of a context. Ergonomics lean on a real situation analysis. Ergonomists usually start with an observation of a situation; then the behaviors, communications, verbalizations and results of interviews are collected and analyzed in order to make recommendations.

  For the design of new product, the situation analysis can not be done. Ergonomists use laboratory testing with mock-up if possible.

- Ergonomists make recommendations
  In collaboration with the actors, in order to ameliorate the initial situation, ergonomists make recommendations. They can follow recommendations and adjust them if necessary.

  In laboratory new tests are made to verify the well founded of the recommendations.

3. Knowledge about human factors

3.1. Comfort on long duration seating immobilization

3.1.1 Medical effects of long duration immobilization

3.1.1.1 Static effort

Long duration immobilization imposes static effort to maintain a posture. Posture, static effort and difficulties to maintain seating position are explained below.

- Posture
  Postures are functions of visual, force, precision and moving requirements for an activity. An adopted posture is the result of the adjustment of different corporal segments that allow executing the action with used tools and means. Task contents, objectives and available means to execute it form the postural constraints. Postures differently affect inter-vertebral disc pressure:

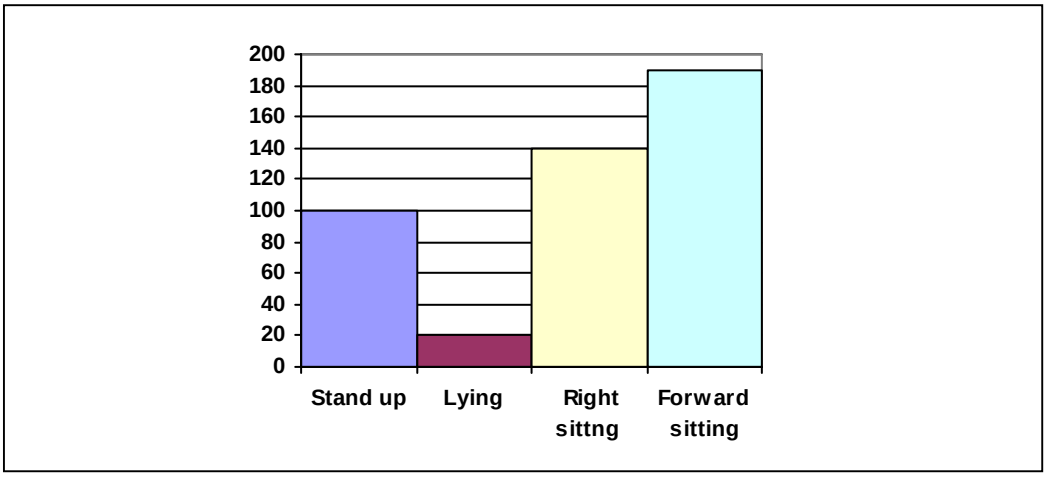


Figure 2: Pressure on L3/L4 vertebra discs in Newton according to posture Static effort

- Static effort
  Effort can be static or dynamic depending on how the muscles are used:
  - the effort is dynamic when the muscle is alternatively contracted and relaxed within a certain rhythm
  - the effort is static when the muscle remains contracted during a long period of time, without being relaxed.

  Therefore, maintaining a posture like standing or seating position results in a static effort. In such case, the blood brought to the muscle is reduced or stopped whereas the muscle claims for more oxygen (which is brought by the blood). The consequence is a lack of oxygen even for fewer intense efforts. In important static efforts like long immobilization, cardiac rhythm is accelerated and the body produces more lactic acid which is responsible for muscular pains.

- Seating posture
  People who remain seated for a long period of time suffer from lower back, neck and shoulders. Seating position can bring spinal column deviation effect and excessive solicitation of muscular groups in a static effort.

- Seating posture affects the inter-vertebral discs pressure
  Mostly back pains find their origins in vertebra disc degeneration. The disc loses its mechanical properties, collapses and perturbs normal articulation. This has an impact on tissues and nerve terminations deformations.

To have minimum solicitation on inter-vertebral disc pressure, the best posture should respect normal spinal curves of the back, with a lordosis in lower back and should avoid the person to be round-shouldered.

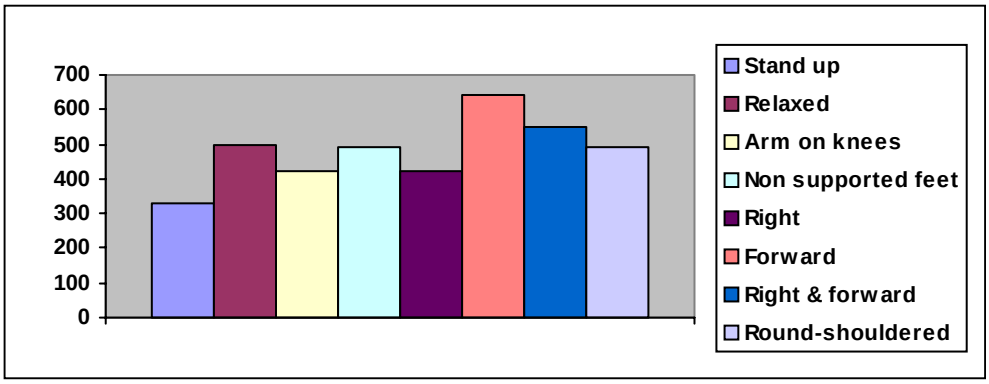


Figure 3: Pressure on vertebra discs, in Newton, according to seating

- Seating posture affects muscular activity
  To maintain seating position, a muscular contraction of skeleton is needed. Muscular tension is more important when right back than round-shouldered. Reclining the seat back strongly reduces this tension.

3.1.1.2 Seating position problems

Seating position induce constraints on the vertebra column that oblige passenger to take bad positions that create lombalgy and cervicalgy

Studies on workers that remain in seated position for a long period of time show that 57% of them suffer from back pain; 24% of these pains are located on the neck and shoulders.

Those studies show also that the following "seat functionalities" would help to reduce pain:

- seat pan height control
- back seat controlled in height (with a bulge at lumbar level)
- depth and width compatible with passenger morphology
- shoulders should be free of movement
- feet should rest on floor or footrest; often to low, it should be easily adjustable to the passenger height

Nevertheless, even the best seat, well adapted to the passenger, will eventually bring tiredness; in conclusion, the seat must allow the passenger to change its position.

Figure 4 shows the result of a study made on comfort angles for a seated position.

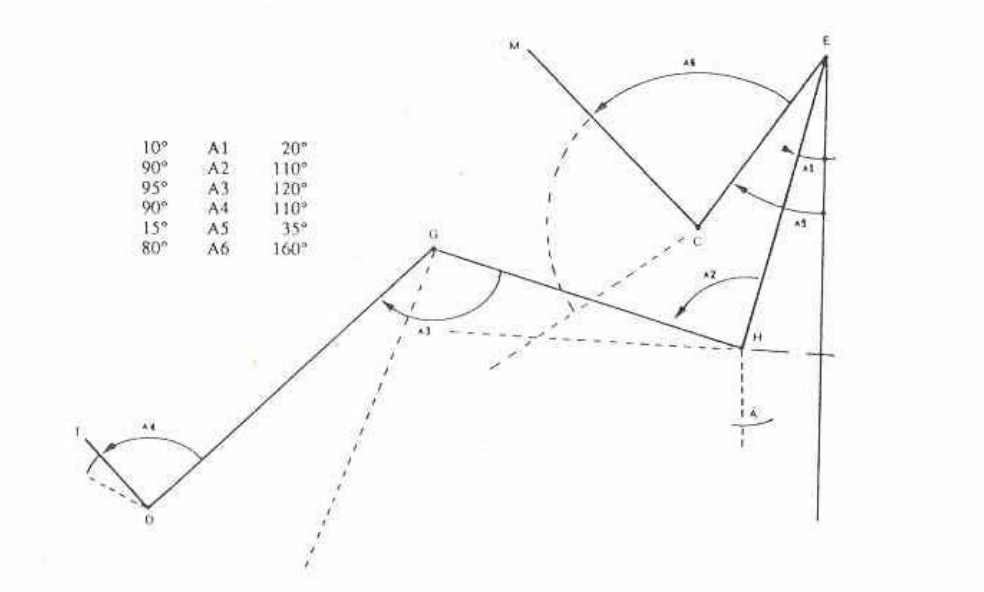


Figure 4: comfort angle scheme

To date, economical class seats are designed to match 95% passenger morphology dimensions (average of the Gaussian distribution +/- 2*standard deviation); it means 2.5% of the population get seats that are not adapted.
Ergonomics studies propose to adapt the seating position in order to relieve back pain in reading activity.
In order to reduce lombalgy, it is proposed to incline seat with an angle of 15° and table with 10° angle; this posture impose a right back and relief of the inter vertebral discs.

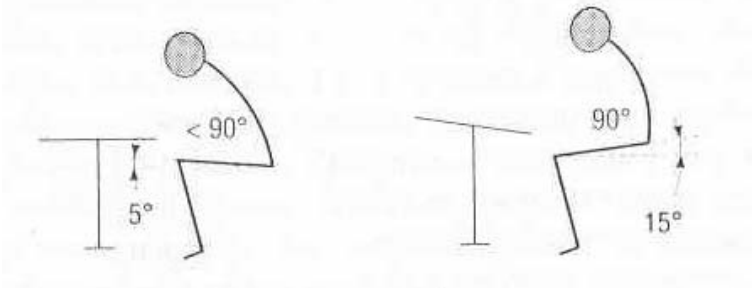


Figure 5: Typical table and seat posture vs. recommended reading adapted position

Long duration seating causes back discomfort because it:

- Restricts movement
- Strains back muscles
- Irritates sensitive nerves

3.1.2 Recommendations about seats

The ergonomic seat does not exist in absolute. The most efficient and comfortable seating position is determined after activity analysis. On a medical point of view the flat position (to lie down) induces fewer constraints on the body. The seating position is the best compromise between postural constraints and activities like eating.
Resting or working doesn't require the same constraints on the posture or the seat. Therefore, adjustment of a seat is a good answer to allow change of activities. The best way to reduce postural constraint is to allow change in various positions, from flat to a forward seated position.

Armrests allow resting back and shoulders by supporting the forearms at the condition they are set to an adequate height. If the armrest is too high, it could bind the person to shrug the shoulders and be in an uncomfortable position.

Pulse-massage seating systems target the paradoxical problem that seating requires muscular efforts, especially, long term in-flight seating which over drains supporting muscles and skeletal systems. Industrial medicine has verified that long term seating creates a state of permanent muscle tension and spinal fluid blockage. This results in discomfort, fatigue and stress, which reduces the level of satisfaction of the flight and create weary passengers. This seating induced dysfunction can be prevented only by posture control and muscle stimulation.
Massage systems selectively stimulate muscle groups with mild vibrating or pulsing massage that works surface and deep muscles on both sides of the spine and promotes critical fluid nourishment of the vertebrate. This result in decreased tension, improved comfort and more relaxed, satisfied and happy passengers.

3.2. Comfort using multimedia devices

Using multimedia device impacts user's comfort because that requires holding static postures (to watch a screen, to interact with commands …) and hearing noise.
Effects on long duration immobilization have already been approached in section 3.1. The next section focuses on what is specific to multimedia: vision, audition, posture, health, mental representation and user interface (UI) recommendations.

3.2.1 Vision

Vision is optimal in an angle of 30° below horizontal when head is in a vertical position. Outside of this range, information is on the peripheral vision zone and requires head movement to be read (refer to Figure 6).

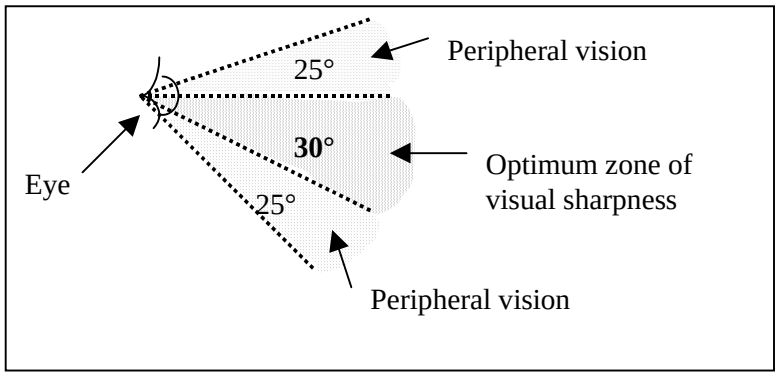


Figure 6: Vertical vision zones

When passengers are watching at a display or reading on the screen, they may experience some discomfort. It starts from minor visual tiredness, which appears after 4 hours of watching a screen, to CVS (Computer Vision Syndrome) (refer to section 3.2.4).

Visual comfort depends on the relationship between the size of observed objects and their distance from the eyes. Other parameters can also influence on performance and comfort such as contrast effects, lighting level and color effect.

Printed characters are clear because the light is coming upon them; they are stable. On the other hand, displayed characters are visible because of the light they send out. Nevertheless, they are typically less well defined than printed character and can flicker. Bad quality of the display (unclear characters, twinkle and low definition of the screen) increases this difference and causes visual tiredness.

To prevent visual diseases using screen, different elements can be adjusted: screen, illumination of the room and brightness gap between screen and environment.

- Screen

- Light intensity and contrast of the screen should be adjusted by the user depending on the room lighting.
- Sufficient size of the characters
- Color: the best is a screen with a light background and dark characters. Blue, red, purple characters and yellow or red background shall be avoided.
- Location of the screen: the top of the screen should face the top of the passenger's forehead when in seating position. The screen should be seen with minimal head and eyes movements between the screen itself and command devices.
- Rotation and tilting of the screen should be possible to avoid dazzle and to adapt its position to the user.
- 50 to 70 cm is good medium distance from eyes to the screen. It depends on the user morphology (height), size and resolution of the screen. Usually, good screen location is at arm's length: user can hardly touch screen with fingers tip.
- Cleanness: dust should be removed regularly.

- Illumination of the room
  - Screen ideal inclination is perpendicular of natural light. Windows or artificial light should not be placed behind a screen or in front of a screen to avoid dazzle.
  - 250 to 300 lux. Screen vision need twice less light than necessary to read printed characters. Lamp should not be placed above, in front of or behind screen but rather on the side. It is recommended to have a flexible individual reading light that passengers can adapt to their activity and environment (reading a book, watching/reading a screen, eating …).

- Brightness gap:
  - Backward and forward eyes motion between screen and another room area require permanent efforts to adjust to different brightness levels.
  - Dazzles and reflects can either be direct, caused by light sources, or indirect, caused by surfaces such as tables, walls… They reduce display contrast, which decrease characters readability and comfort vision. They produce pictures that superpose on displayed characters, impacting visual and nervous charge to the user. Discomfort is highest when windows are directly reflecting in the screen.
  - Avoid bright materials around screen to avoid reflects and dazzle.
  - An adjustable screen is a good solution to allow user to minimize reflects.

3.2.2 Audition

When too high, sound level, measured in Decibels (dB), can induce permanent injuries to the internal ear.

- Here are some typical acoustic level values
  - Quiet office: 30 to 40 dB
  - One meter conversation: 40 to 60 dB
  - Symphonic orchestra: 90 dB
  - Dense automobile circulation: 90 to 100 dB
  - Discotheque, human scream: 110 dB
  - Aircraft engine at 20 meters: 120 dB
  - Noisy rock group: 160 dB

- Trauma level: it depends on exposure duration, frequency and pitch of the sound.
  - A permanent auditory loss occurs with a sudden 120 dB noise.
  - 90dB is the risk limit for a short exposure.
  - 80 dB is the risk limit for an eight hours exposure.
  - Below 50 dB there is no risk on the ear.

  In working situation, ear protection is mandatory in Europe for noisy environment from 90 dB and more.

Deafness after noise exposition can not be immediate. First, the internal ear is affected; then, it is the repetition of the nuisance which causes the loss of audition.

3.2.3 Anthropometry and good posture

3.2.3.1 A good posture

A comfortable posture is when a natural position of the articulations is respected. That allows a good balance between extension and flexion of the articulations, as well between contraction and extension of the muscles implicated. To reach long duration comfort, the objective is to minimize the muscular activity, but always in relation with the activity.
Naturally, everybody is seeking to avoid sufferings and minimize efforts, especially in a “bad” or non-healthy posture.
Therefore, furniture and environment should help the person to adjust them in order to improve comfort.
A lot of surveys on workstations with computer show what could be a comfortable posture and what the optimized angles of articulations are:

- Straight vertebra column, with right neck without flexion or extension,
- Relaxed and low shoulders,
- Arms along the body,
- 90° elbow vertical angle, between forearm and arm,
- 30° interior and 60° exterior longitudinal arm angle from trunk on a table for instance,
- 0° wrist angle,
- 90° hip angle, between legs and trunk,
- 90° knee angle,
- 90° ankle angle,

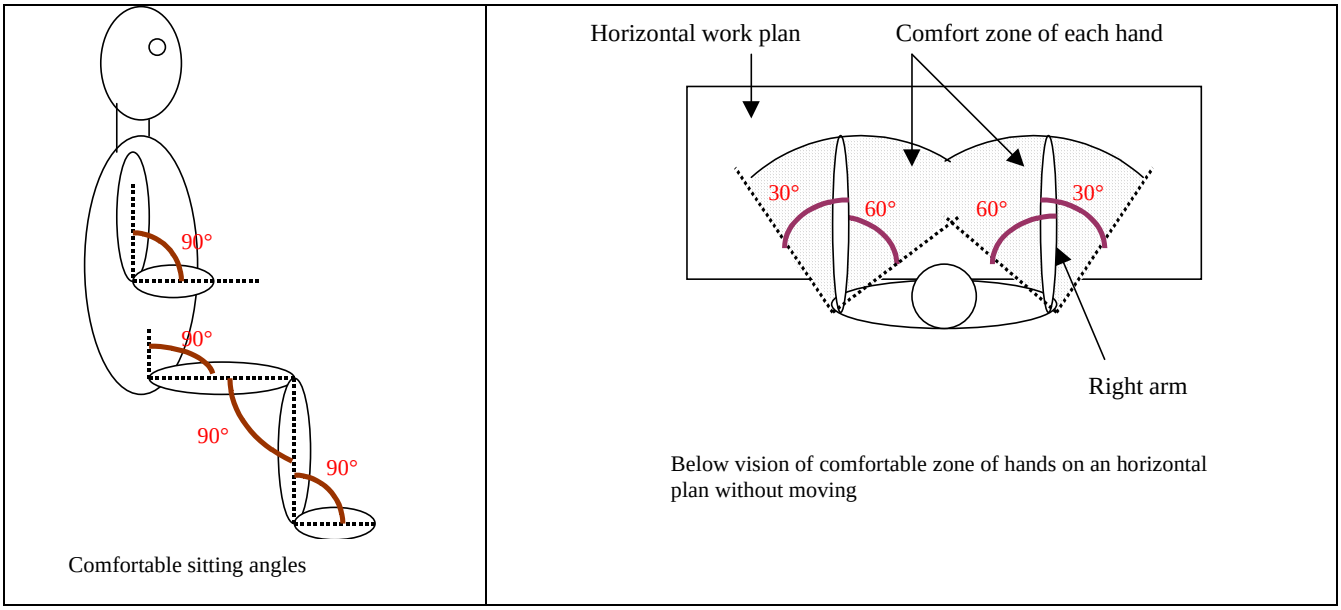


Figure 7: Comfort seating angles and comfortable manual zone

3.2.3.2 Prevention of muscular diseases

When operating computers for a long period of time, users complain of back, lower and upper limb pains. The longer the posture is maintained, the more painful are the contractions. In order to prevent this, Human Factor experts recommend:

- To avoid a too important flexion of the wrists, it is better that hands are in line with the forearm and the wrists. The best is to maintain wrist position higher than fingers. On a workstation, a good position is to have the wrists held slightly above the keyboard (or the

table) instead of lying down on the table. This can avoid the carpal channel syndrome which typically affects people who work more than 4 hours a day with a computer.

- To adjust seat position to the user size. In seating position:
  - thighs should be horizontal;
  - feet should be flat on the floor. In order to avoid being on tip toes, feet can be on a footrest;
  - the lower back should lean on the back of the seat;
  - the shoulders should be low;

  Therefore the back and the armrest should be adjustable.

- The keyboard shall be mobile and separated from the screen. Its location shall allow a 90° angle at the elbows and low and relaxed shoulders.

- To allow crossing/moving legs and changing position under the table. Therefore, there should be a gap from 20 to 26 cm between the seat plan and the keyboard/table plan.

- To pause working frequently. A change in activities and positions reduces visual stress and muscular diseases. It is also recommended to practice ocular relaxing exercises and muscular stretching.

- A mobile seat back allows trunk movements and back stretching.

3.2.3.3 Anthropometry impact on furniture choice

Dimensions of the body should guide the choice of the seat and all IFE equipment, but also their location from one to the other. To maximize comfort, mouse or PCUs should be placed where the tip of the fingers are. Passenger seat has to be large enough to allow everybody seating in it. Use of anthropometry tables (with the objective of satisfying 99% of the population) can provide useful values that will help designing seats and IFE equipment, as long as foreseeing where equipment should be adjustable for a long term usage, especially for screens, PCUs or command devices.

3.2.4 Health and use of multimedia

In western countries, since the last decades, massive use of electronic media at work or at home, by adults, teenagers or children, impacts health and behaviors.
According to numerous surveys and debates on these subjects, multimedia use can affect directly or indirectly passengers comfort.

3.2.4.1 Computer Vision Syndrome (CVS)

Any person, adult or child, who spends two hours or more per day working on a computer, may be at risk of developing Computer Vision Syndrome. Symptoms of CVS include headaches, red eyes, itchy eyes, sore or dry eyes, weary, blurred vision and neck and shoulder pain. Symptoms can escalate from persistent discomfort to chronic pain. A number of optometrists believe that computers can exacerbate conditions like near-sightedness.
Computer vision syndrome is a repetitive motion injury caused by the refocusing effort required when viewing a computer screen. A person's eyes are not suited for staring at a computer screen for hours. The words and images on a computer screen are difficult for the eye to focus on, due to their poor edge definition. The eyes tend to drift out of focus to a resting point and then work to re-focus back on the screen. This cycle can happen thousands of times a day in an effort to keep the computer image sharp and steady, stressing the eye muscles and leading to eye fatigue and discomfort.

If 70 to 75 % computers workers are complaining from eye and vision problems, this computer vision syndrome affects now children playing at video games and watching TV.

3.2.4.2 Violence on movies, games, TV and aggressiveness

A lot of public debates approach the relationship between violence, on games or on videos, and aggressiveness development. Nevertheless, no survey can demonstrate that someone looking at a violent program will be more or less aggressive.

But the Canadian Information Centre on Family Violence says that:

- a positive correlation exists between exposition to TV violence and aggressiveness;
- children who often look at violent programs, tolerate more violence from the other children without complaining;
- people who often watch TV are more easily frightened;
- TV can make people insensible to violence.

3.2.4.3 Video games, addiction and dependence

A survey made by Stephen Kline in Britain Colombia shows that young people from 11 to 17 years old have addictive behaviors to video games. They look for an experience of deep concentration, a sort of trance, a sensation of deep gratification.

In the Cyclotron Unit of Hammersmith Hospital, a survey shows that video games affect the brain chemistry. Dependence to video games can be explained by excessive liberation of dopamine. Production of dopamine is twice than normal when playing. The increase of this psychoactive hormone has the same effect than an amphetamine injection.

Video games enter in the category of compulsive games and the terms of drug and addiction are applied to them.

It is said that TV, computers and video games have significant physical and psychological consequences on our nervous system.

3.2.4.4 Media and loss of reality references

As we said before, TV can make people indifferent to violence.

Some studies show that the virtual reality of new generation games brings a loss of reality references. Games bring physical problems, related to the headset, like disorientation, vertigo and nausea.

3.2.4.5 Development of isolation

The use of numerous electronic media goes with social behavior changes. Nomadism, interactivity, remote communication, work and personalized entertainment are growing. One of the most important behavior change seems to be the isolation of people. With electronic media such as TV, video games or Internet, people can be isolated from the others at home, but also from the exterior and from members of his own family. Confrontation with others can be limited. Where is comfort, in isolation or in confrontation? No answer can be given here. Tomorrow, will this isolation with our favorite electronic devices bring an impossibility to live in proximity with others and share a common space like an aircraft cabin?

3.2.5 Mental representation

Mental representation is an ergonomic concept. It is a mental elaboration of a situation built by the operator. This elaboration is made from:

- his knowledge of a system,
- the information he can deduct from his technical and human environment,
- his psychological and physical state at the moment.

Operator's intention, task or action will influence this representation. On the other hand, this representation will not last (or will evolve) as it depends on the context. These mental representations are distinguished from knowledge because they appear in a mental activity using

only short-term memory. The long-term memory is where knowledge is stored. Representation is a subjective construction whereas knowledge has an objective and verifiable status.

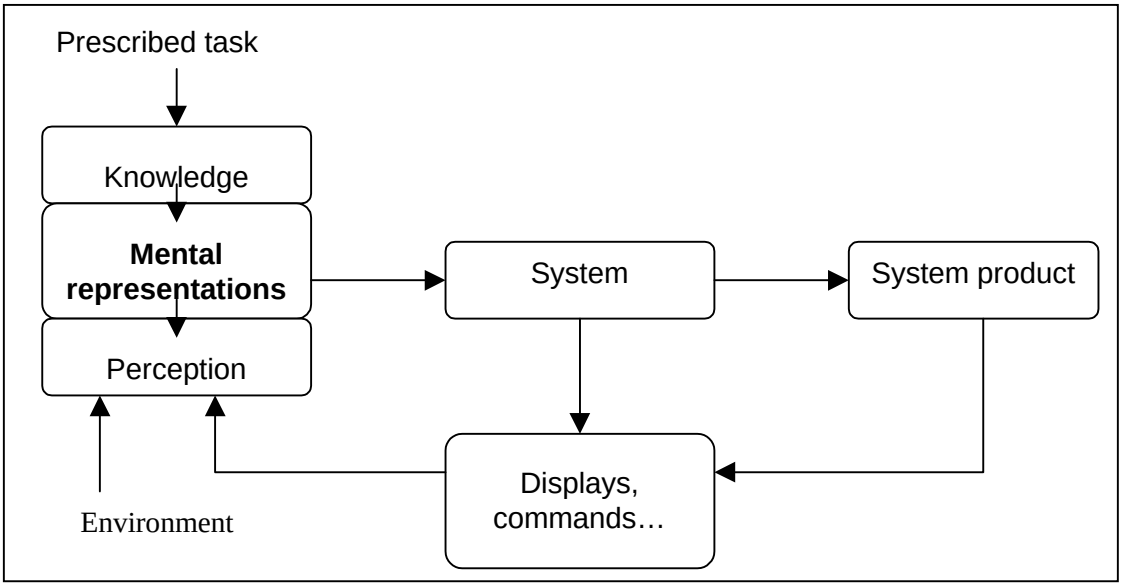


Figure 8: Representations in a Man-Machine System

These representations depend on actions to do, environment and people state. They are mental constructions made by everybody, prior to set up a task.

3.2.6 User Interfaces (UI) ergonomic recommendation

Human factor experts play an important role in helping UI designers. As well as for workstations or systems designs, they first look at potential users and the task to be done. To design general public systems, ergonomics will make user tests and analyze the situation.
As far as UI are concerned, a lot of rules and criteria already exist that can be applied for novice users and general design (e.g. first prototype).

3.2.6.1 Conception rules of UI for novice users:

- Initiatives should come from the system,
- Inputs should be short or brief,
- Input methods should be in accordance to users expectations,
- Input methods should not to require training,
- Confirmation by the user of critical input has to be required by the system,
- Messages have to be clear without ambiguity and without superfluous information,
- Number of allowed actions has to be limited,
- User has to be able to control dialogue rhythm,
- Quick and fast human help should be possible if necessary.

3.2.6.2 Ergonomic criteria for the conception of UI

With mass use of UI since the last decades, some ergonomic criteria of conception and evaluation have been developed. They help to design UI, as best adapted as possible to the cognitive and physical ability of human beings. They allow taking into account the human limitations and facilitating the users' perception, understanding and communication of/with the machine.
They can be used to design all type of computer system interfaces whatever are the input methods (mouse, touch-screen, remote control, keyboard …), output method (screen, printer, sound ..), dialogue and function of the system.

Most known criteria are:

- Compatibility
  To minimize the re-encoding of information when interacting with the interface, this criterion allows verifying compatibility between users' characteristics (memory, perception, customs, skills, age, expectations…) and the input, output and dialogue of the application. It also covers the coherence between environment and interface, for instance use the same presentation for the same information on paper and on display.

- Consistency, homogeneity
  To allow the automation in series of identical interactions on the UI and minimize the cognitive efforts, consistency is required to maintain similar design (codes, naming, formats, procedures…) in similar contexts. The same series of commands must lead to the same result. The same information categories are located at the same place in the screen from one display to another.

- Concision
  To reduce human memory effort, it is recommended to pursue concision when designing UI. An application of this criterion is, for instance, to avoid users memorizing the long and numerous information needed to execute an action on the interface.

- Flexibility and adaptability
  To allow usage by numerous and different users, the interface has to adapt to the user's experience. This can be achieved by providing different levels of entry in function of the performance.

- Feedback and guidance
  To allow users previewing the result of his actions, the interface should respond quickly, in particular to actions initiated by a human being.

- Workload
  To minimize user's workload and reduce error risk, interface has to limit the reading and input workload, the number of action steps and the response time of the system.

- Explicit control
  The system has to allow control perception of the user and execute operations only after explicit actions of the user.

- Error management
  The system has to prevent and reduce error possibility, give to the user the ability to recover them, when they occur. It also refers to error protection of the system, quality of the error message, and the error correction.

All these criteria allow designing interfaces as comfortable as possible taking into account the human capabilities and limitations.
This is the starting point of ergonomics activity, which requires an analysis of the users' situation when using the UI.

4. In Flight Entertainment & applications:

4.1. IFE equipment & technology.

A key feature of the passenger's experience is the cabin interior, particularly seat and IFE interface. All IFE equipment is delivered as an integrated part of a Cabin IFE System. A partial list of IFE equipment includes: head-end servers, in-seat electronics, Purser Access Terminals (PATs) and mobile phone micro-cell equipment. At a minimum, IFE equipment is certified to applicable IFE standards.

The IFE equipment, that have a direct impact on passenger comfort, are located near the seat and includes video display, PCU, headphone and microphone, external connectors and SEB. All this equipment will participate to passenger comfort but could also generate discomfort and trouble for example because of heat and power consumption produce by all of them.
Low power consumption is also essential for low heat dissipation in seat back.

4.1.1 Video display

The video display is the video terminal mounted in the back of the seat or in armrest. It can include a touchscreen, a privacy filter and the sizes can vary in a wide range (from 6.4" to 23") depending on airline's choice.

Touch Screen Displays

Figure 9: IFE Touch Screen displays

The latest generations of video displays have touchscreen capability that allows passenger to point the item they want to use by touching directly the screen with their fingers. This avoids the use of mouse on a PCU or navigation keys. It's a new concept of interactive application. But there is also new type of display with LCD that gives a real improvement for brightness.
The only drawback of that equipment is the heat dissipation. Some IFE suppliers require cooling systems integrated within the seats; some others (like Thales) do not.

4.1.2 PCU

The Personal Controller Unit is located in the armrest or below terminals. It allows passengers to progress into applications and navigate within the UI. It is a all-in-one equipment that can also have hard keys for game control, a credit card reader, a telephony terminal capabilities and a full keyboard. The new PCU generations have also small screens and contextual menus that are linked to the current selected application. The future generation will allow previewing a video on the small display

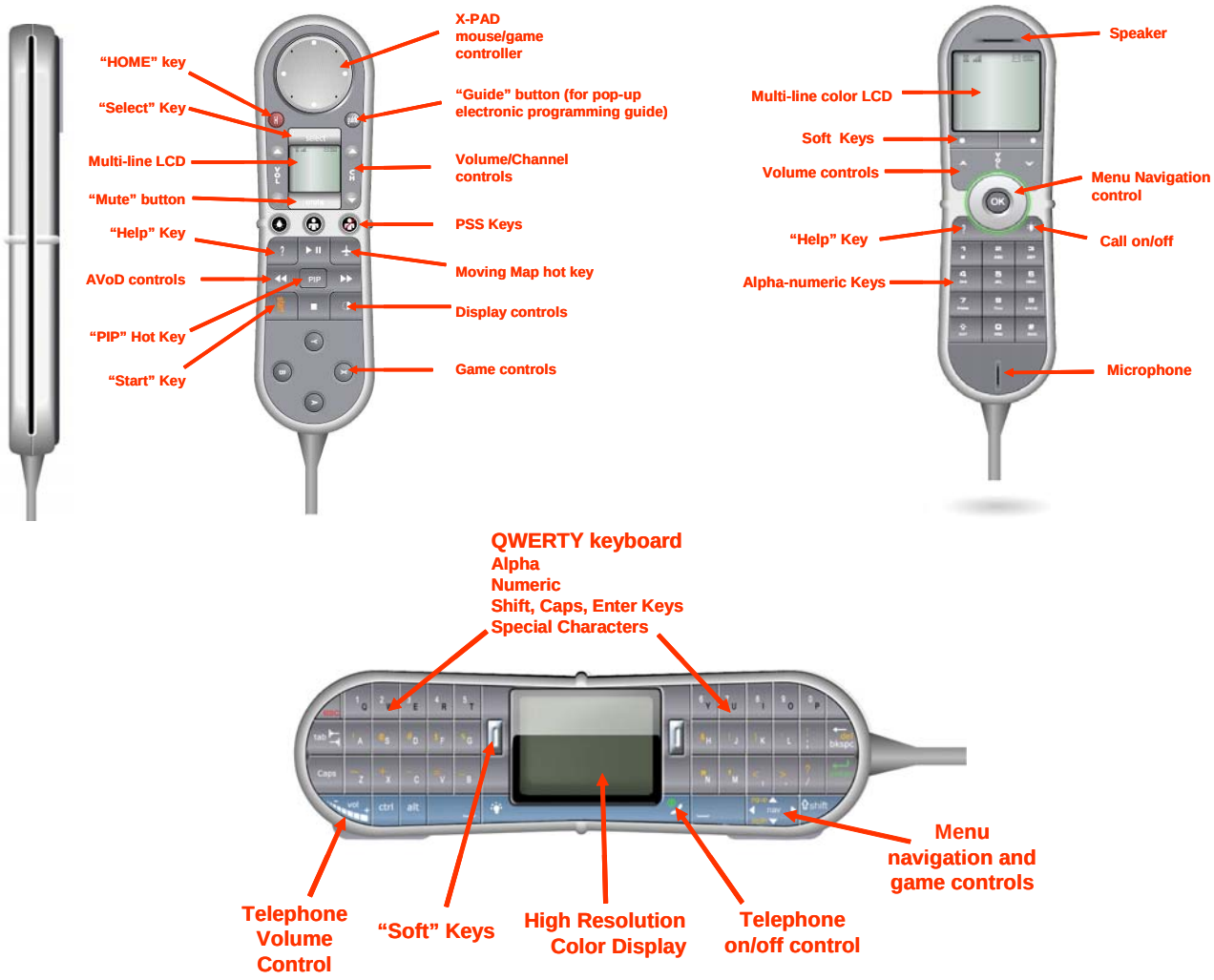


Figure 10: IFE PCU (credit card reader, telephony, keyboard)

Concerning passengers' comfort, the drawbacks are the heat dissipation (but very limited) and the movement constraints depending on the location where they are installed (back of the seat, armrest, side mounted, top mounted …). The PCU is typically attached to a cradle via a cable that can bother passengers. But, with the new generations and their intuitive contextual menus, it is a pleasant system with multiple services.

The use of screen on PCU allows customization between airlines, seating classes and geographic/cultural regions.

Wireless PCU (IR based) have been designed and work but airlines are not very willing to install them because of theft issues. Nevertheless the IR technology has a lot of constraints and other wireless techniques should be explored in order to really make a significant improvement with wireless PCU.

4.1.3 Headphone and microphone

Headphones allow passengers to listen to music at any time during a flight. It has an active noise-canceling module that intercept outside noise and sends a canceling noise signal in headphone.

Figure 11: Various IFE Head phone

The drawback is that this equipment is connected with a cable which can bother passenger's freedom of movement. Some wireless headphones do exist but for the moment they are not very popular because of two main constraints:

1. they can be stolen by passengers
2. IR or RF technologies interfere with the rest of the cabin (EMI certification issues)

The new Wi-fi technologies seem promising to deal with the EMI constraint.

The headphone exists also with microphone in order to provide telephony. Nevertheless this is a concept that most airlines have rejected in favor of the telephony integrated within the PCU (closer to real life situation). With the arrival of GSM support in the A/C, the telephony function in an IFE system is going to change significantly.
On the other hand, with the popularity of Instant Messaging Software such as Microsoft Live Messenger or Skype, it will be interesting to analyze how telephony evolves and if headsets with microphone would be a cheap solution for passengers.

4.1.4 RJ45, power and USB connectors

IFE systems provide a new level of integrated solutions for laptop connectivity (via RJ45 plugs), laptop power (domestic voltage at the seat 110V or 220V) and game pad (USB connectors). The USB and power connectors are often located in the armrest of the seat. Today, there are still cables hanging out of the USB plug to the USB device (which has movement constraints), but the future generation based on wireless technology (Bluetooth or W-USB) will improve this interactive connection.
The USB connection allows support for game pads, keyboards (when not integrated within PCU), cameras, USB stick …

4.1.5 SEB

Typical IFE systems require the installation of a Seat Electronic Box (SEB) who concentrates all the "intelligence" of the in-seat functionality. Usually this SEB is situated under the seat and reduce the passenger legroom. Today, a lot of improvements have been made:

- The video screens are becoming "smart" and within a similar thickness (and still no cooling requirements), all the digital functionalities of the SEB are transferred to the video display. The later embeds a CPU and PC based components whereas the SEB size is significantly reduce and contains only the H/W for all the analog (RF) processing and the power conversions (from 115V AC to 32 VDC for instance).
- Complete removal of the SEB occurs for systems that do not require any RF functionalities. Those IFE systems are fully digital and Thales is the first and the only one to currently offer

a system with no SEB (TopSeries™ i4500) which, of course, brings a significant improvement in comfort for the passenger legroom

- Wireless IFE systems are the next trend (especially on the B787 or the A350). In such case, the SEB (when needed) is limited to the non digital processing such as the wireless RF management and the power conversions.

4.2. Seat

At present, seat manufacturers have deployed a lot of energy helping aircraft passengers flying in safe and comfortable conditions.

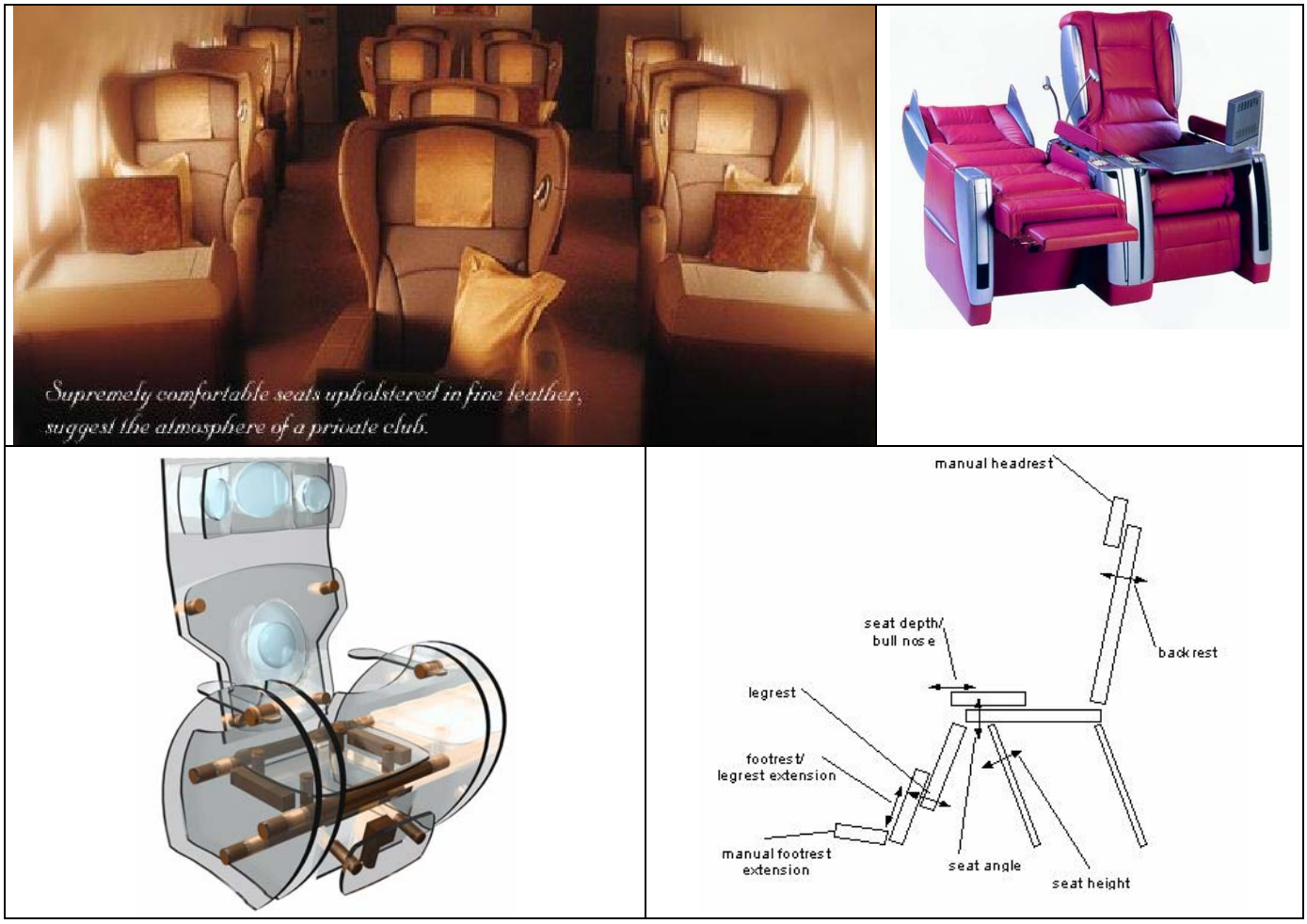


Figure 12: Images of seats

4.2.1 Possible seat settings

- Passenger can set his seat to any desired position between upright (takeoff position) and bed (180°) with:
  - Accessible button to get the emergency upright position when laid
  - Obstacle detection system when footrest is put back to upright seat position (safety)
- Recline movements: forward/backward
- Leg-rest movements: deployed/stowed
- Footrest movements: up/down
- Headrest movements: up/down, ears, tilt
- Seat pan movements: angle, up and down, extension
- Armrest movements: up/down
- Lumbar support system by mechanical or pneumatic adjustments
- Seat Tracking

- Synchronous movements performed by several actuators working simultaneously (example: when seat is moving to bed position, armrest are also moving to the same level at same time)
- Motion of elements around the seat such as: Actuated Ottoman, doors, video positioning….

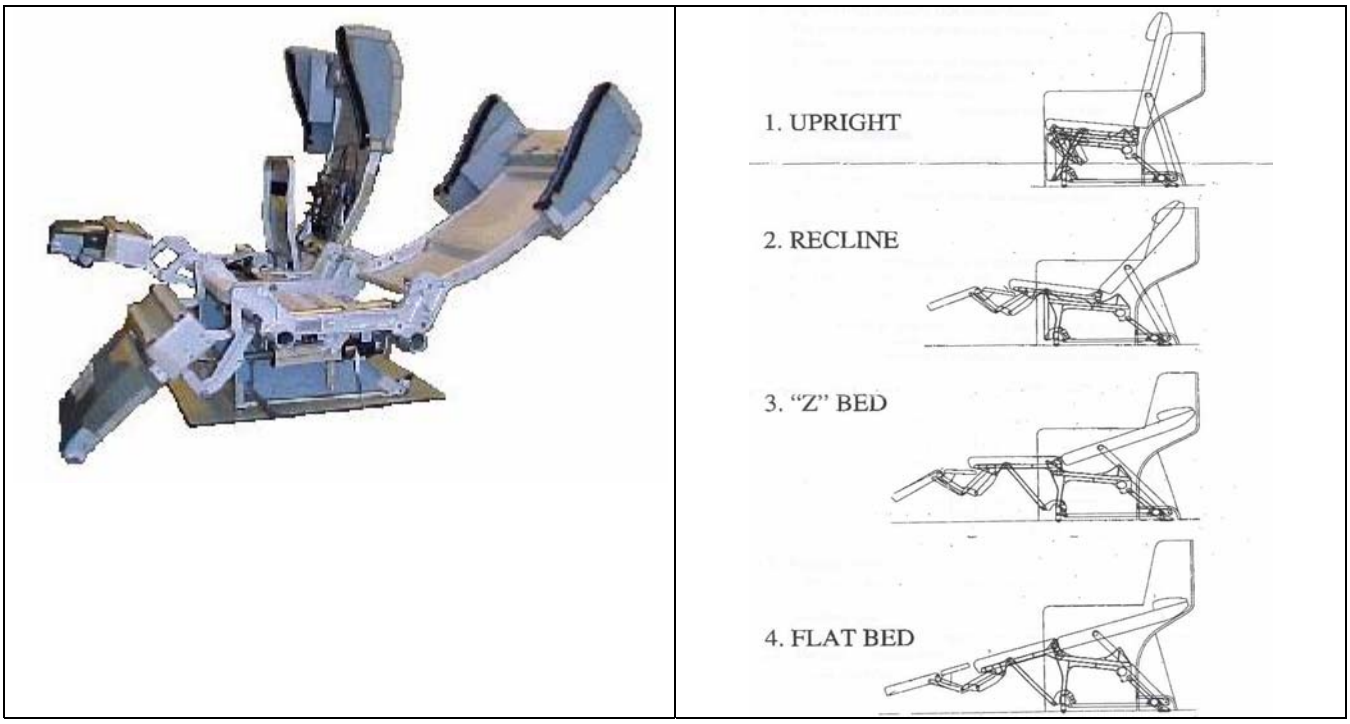


Figure 13: Possible seat positions

4.2.2 Massage and relaxation

Massage and relaxation are performed by Mechanical or Pressure systems (with several possible cycling sequences).

- Pneumatic systems:
  A pneumatic system with 4 bags device offers comfort features. These 4 bag systems are built with 2 double bags (system 1 & 2) and 2 single bags (system 3 &4). If the backrest moves into recline system 1 is vacuumed and system 2 is filled to change the backrest shape into a flat mattress. If the movement goes into the opposite direction (Take off) bag system 1 is filled and system 2 is actively vacuumed. Bag systems 3 & 4 offer massage functionality and support also the change from flat mattress to side supported of the backrest shape.

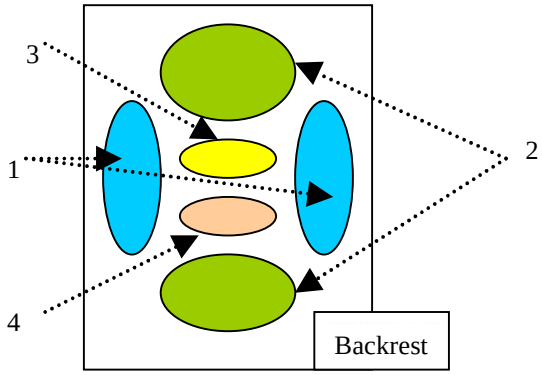


Figure 14: Pneumatic system

A pneumatic system with 4 bags device offers massage comfort. The passenger can choose in which sequence the bags will be pressurized (from bag 1 to 4 or 4 to 1); he can also choose the pressurized time between 2 bags.

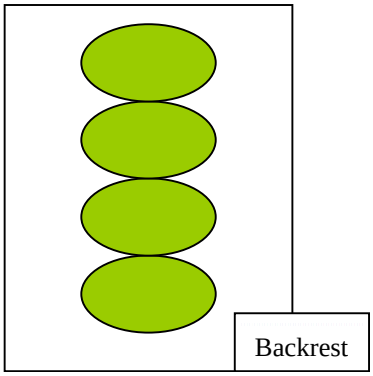


Figure 15: pneumatic system with 4 bag

A pneumatic system with 1 bag device allows the passenger to choose the maximum pressure in the bag and the time between pressurization and de-pressurization.

- Air pressure Relaxation system
  Today, more than ever before, customers are looking for superior seating comfort. Electronic massage seating components as the means of fulfilling customer's satisfaction.

Figure 16: Air pressure relaxation system

- Mechanical system:
  Some vibration motors put in different places of the seat, give relaxation.
  The passenger can choose which motors are used for the part of the body he enjoys (back, legs…)

4.2.3 Health issues

Existing Anti Thrombosis systems: The goal of these systems is to activate the foot and calf muscle pump thereby increasing the blood flow returning in the leg vein.

Figure 17 relates to a therapeutic gymnastic device for the prevention of thrombosis and which can be used on aircraft. The inventive device comprises numerous metal parts, which are fixed to the lower rear part of a seat.

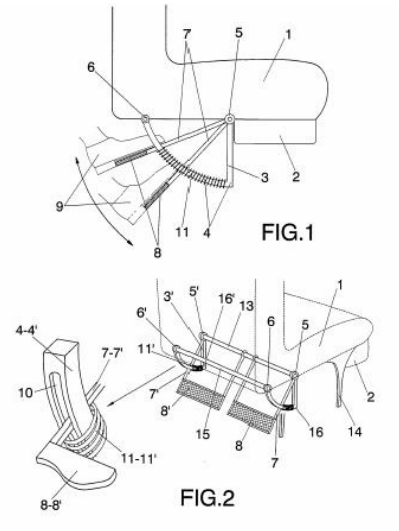


Figure 17: Health system

4.2.4 Other personal feature

- Personal adjustable Reading light: The light is completely movable, the passenger can bring it anywhere he likes.

Figure 18: Personal adjustable Reading light

- Personal deployable tray table: The height and inclination of the table can be controlled for better comfort reading and eating.

4.2.5 Economy class state of the art

- Type of up-to-date economic class seat
  Comfort Features: Adjustable headrest and footrest recline movement, individual numeric screen and cushion designed to support harmonious body pressure.

Figure 19: economy class seat

- innovating seat
  The innovation for long haul is a cushion to maximize comfort and personal seat space. By first sensing and then molding the human shape impacting it, the cushion system will facilitate the sharing of the loading force over a greater body contact area resulting in greatly reduced body pressures and a huge jump in seating comfort not available on aircraft seating up to now.
  In contrast to the conventional cushion, the cushion system senses and accommodates the body's sculptured shape whereas the conventional cushion will flatten and distort that shape which in turn restricts the natural circulation of the blood which can cause problems like Deep Vein Thrombosis (DVT).

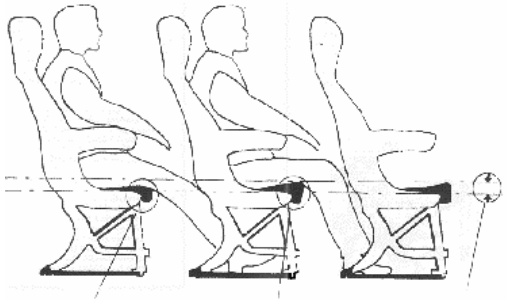


Figure 20: Cushion system

- Economy Class Seat Pitches
  The actual AN64 UK standard demands a pitch of 26 inches. According to Joint Aviation Authority document recommendations « Anthropometric study to Update Minimum Aircraft seating Standards » July 2001, a minimum of 32 inches id demanded to accommodate 95% of the passengers and 33 inches to accommodate 99% of the European passengers. These correspond to a “leg movement dimension” of 28.2 inches for 95% and 29.4 inches (747mm) for 99% of European passengers.

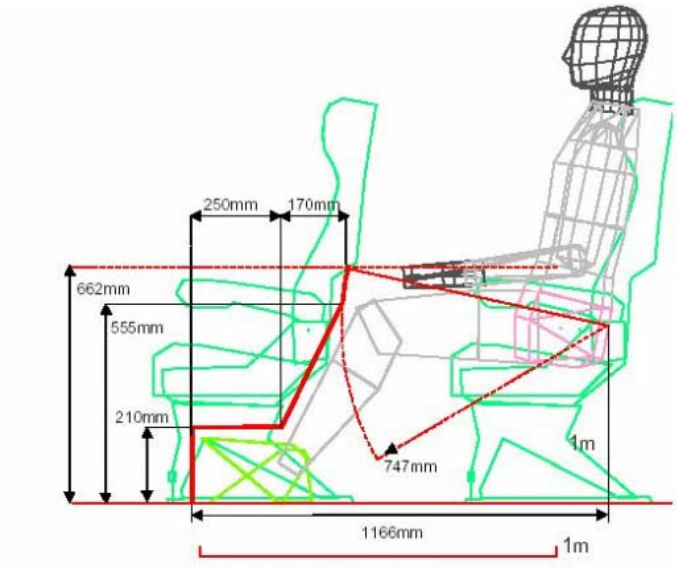


Figure 21: Leg movement space

Here is the pitch dimension for aircraft companies. (Sunday Times, The Consumer Association, Daily Mail and Daily Express)

Airline	Pitch (inches)	Airline	Pitch (inches)
Air Canada	34	SAS	32
Air China	34	Scandinavian	32
Air France	34	Singapore Airlines	32
Air New Zealand	34	United Airlines	32
American Airlines	34	Varig	32
Japan Airlines	34	British Airways	31
Lufthansa	34	Contintental	31
Malaysian	34	Delta	31
Thai Airways	34	Iceland Air	31
Air Jamaica	33	KLM	31
Alitalia	33	NW Airlines	31
Garud Indonesia	33	South African	31
Aer Lingus	32	Air 2000	30
Austrian Airlines	32	JMC	30
British Midland	32	Virgin Atlantic	30
Cathay Pacific	32	Air Tours	29
EL AL	32	Easy Jet	29
Emirate	32	Go	29
Gulf Air	32	Monarch Airlines	29
Lauda Air	32	Ryanair	29
Qantas	32	Britannia	28

4.3. Onboard multimedia services (IFE & OIS services).

The Airlines' are increasingly requiring in-flight services for the passengers that provide a entertainment or business experience similar to what could be found on ground. These IFE services are more often referred as "applications".
Nowadays, a typical In Flight Entertainment system must perform a wide range of functions (e.g. audio & video broadcast, VOD, etc.) to support high quality services. Most of the time these include for instance music, movies, features, news, shopping, games and the coming range of interactive services (Internet based services). The range of services provided depends mainly on the airline choice and policy but it will be the major differentiator factor in the coming years.
We will consider two different levels of system:

- One that can be installed all over the aircraft and rather targeted to long haul flights (High Grade). It's a high level of interactive services
- One for short haul aircraft (Low Grade), with audio, video and non interactive services

4.3.1 High Grade

Most wanted applications are:

- Video
  - Broadcast with channel selection and language selection
  - On Demand with the possibility to pause, FFWD, REWD for each passenger
  - Picture in Picture (e.g. ability to see the camera in a small window over movie)
  - From Landscape cameras
  - From Satellite TV
  - Safety videos and Duty Free products presentation
  - Pay per view movies (especially for low cost airlines)
  - Parental control

Video Synopsis / Preview


Movie with Pop-Up On- Demand Player Controls

Audio Album Select

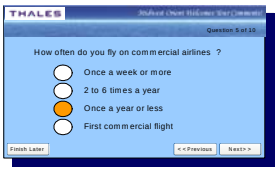

Album Play List

- Audio

  - broadcast audio with channel selection
  - On Demand Audio with the possibility to pause, select the track, FFWD, REV for each passenger
  - Playlist (select favorite audio tracks)
  - Music purchasing (MP3 download on USB sticks or Portable Music Devices)
- Flight Information
  - Broadcast Moving Map (flight position on the map)
  - Interactive Moving Map (possibility to browse the map and get data on cities)
  - Arrival/Connecting Gate Info
  - 3D and satellite maps

- Interactive applications
  - Onboard shopping cart for Duty Free
  - Status notification (non critical crew member messages on screen instead of PA)
  - Interactive meal and beverage ordering
  - Electronic books, magazine, newspaper
  - Camera Picture viewing
  - Expressing satisfaction (or lack of) via electronic surveys
  - Personalization of the IFE interface (based on Frequent flyer preferences for example)

Electronic Shopping



Pax Survey Screen

Credit Card Entry

Category Selection

Options per Title

Reader Screen

- Games and possibility network games

- Telephony and possibly Video Telephony

- Connectivity
  - on-board aircraft cached web content
  - Laptop connectivity to the Internet and possibly VPN (Virtual Private Network) to corporate LANs
  - On-board chat
  - SMS and e-mail
  - In-seat internet browsing
  - Search Engine
  - Liv e text news
  - Live TV
  - Wireless PDA connectivity


On-Board Chat Entry Keyboard and Message Display

In-seat browsing home page

- Productivity tools
  - On board office applications (Microsoft Office or Open Office type)
  - PDF viewer
  - Macromedia Flash

4.3.2 Low Grade

Based on comfort studies made, the minimal expected applications are:

- Broadcasted movies
- Broadcast video of Live events


  - Satellite TV
  - Landscape cameras
  - Safety videos and Duty Free products presentation
- Audio
  - Radio
  - Thematic audio channels
  - Live TV audio channels
- Laptop connection (business passengers don't want to stop their work)
- E-Mail and Internet

4.3.3 Video entertainment

4.3.3.1 AOD/VOD

Audio and Video On Demand allows each passenger full playback control of movie and audio programs. Video-on-Demand systems have very high requirements for hardware and software. AVOD has two sub-types:

- Near AVOD (NVOD) starts each program every few minutes, which gives to the passengers many opportunities to select a program at, or near, its beginning. NVOD does not allow the passengers to control the playback.
- Real AVOD: The service model here is similar to a DVD (Disc Versatile Decoder) allowing people to have free choice for starting, stopping, and replaying the movie. DVD functionality inherently leads to individual watching behavior. On the other hand, families or groups perhaps want to watch a movie together in a synchronous mode of operation. Therefore, an optional synchronous mode is offered.

Audio and video control: some parents may want to control the seat of their kids so they can't access certain movies/audio. High grade AVOD players shall propose this kind of feature.
Overall there is a trend to personalize the seat environment. To contribute to this, AVOD players shall offer the possibility to create playlists and favorites that a passenger can retrieve from one flight to the other.
An other home user trend is the audio and video increasing quality. Therefore AVOD has to take into account this Hi-Definition expectation. An AVOD service that requires the transfer and display of high definition digital data such as: MPEG-4, DVD files, etc.
From the passengers point of view the quality of the system is strongly related to good usability and quality of the content. The appropriate selection and quality of the content should be derived from a user poll.

4.3.3.2 Audio and Video broadcasting

Broadcast is still an expected and mandatory service.
Mandatory, because it is used to display safety rules simultaneously on all individual and overhead video screens, or to broadcast Public Announcement, safety video, duty free…
Expected, because some people want to get passive services like music channels or video channel.
It may also be a choice of the airline to save money on the IFE system configuration capacity. It is necessary to provide basic functionality like broadcast of movies, music, news, business and weather information. This can be done by conventional overhead display units, which are already set into today's aircrafts.
In some cases, it is possible to interrupt any running passenger entertainment activity. In other cases, it is a choice of the passenger.

- Choice of broadcast content:
  - pre-recorded digital content
  - live digital satellite channel or web TV
  - live analogue sources like landscape cameras, PFIS, Hi8 tapes or DVD movies

When watching live events, it is possible to freeze the picture and then either come back to the live or go on watching with a slight delay.
Standard Internet based video and audio protocols shall be supported.

- Camera system inside and outside:
  There are multiple live video inputs to the IFE system from cameras positioned throughout the aircraft, including the passenger cabin, cockpit, cargo compartment, crew rest room etc. Each video input can be made available to passengers for viewing on their seat displays as well as for the pilot for security reasons.

- Live TV:
  On short haul flights Live-TV seems to be a useful, but probably a premium feature. Especially business class passengers demand for business news and other information. On the other hand, live-TV requires high bandwidth on the external link.

4.3.4 Interactivity and connectivity

The real added value of the next IFE generation comes with Interactive applications that allow the passenger to personalize its environment, the airline to establish a more individual relation with their customers and overall to enhance the passenger comfort by making him feel like home. Connectivity solutions allow the passenger to "communicate everywhere" with their family or significant others, in the aircraft or on the ground via off aircraft communication means (e.g. satellite, 3rd party service providers …). Based on the infrastructure of a multi-media network integrated into the plane the airline can offer services and products for the passenger. Therefore, the IFE system therefore has to be customizable. A good Intranet service is either a service that is unique, or is useful, or that will shorten the time until arrival.

4.3.4.1 Connectivity

The connectivity requirements are related to personal laptop connectivity on the network. Each computer connected to the system has to have its own access to the Internet.

- Power supply is done through a unified power distribution scheme that provides a common cable plant to supply power to all in-seat equipment. Central power management permits the monitoring and controlling of power consumption to the cabin equipment for different aircraft conditions.
- Information network from the passengers' point of view simplicity of physical connection and configuration is essential.
- Laptops can be connected to RJ45 plugs and the IFE system provides an interface to allow off aircraft access via satellites. This allows the passengers to access the internet, get their emails thru webmail interfaces, check their account, e-shopping like if there were at home. For business travelers, they can access their company networks thru Virtual Private Networks.

4.3.4.2 Charging and Billing

Some services like Internet access, games or blockbuster videos may not be free. It really depends on the airline policy and the class the passenger travels.

In general the passengers expect using the same forms and security of payments as they are used to do for services and products purchased on the ground.

Therefore IFE system must provide credit card readers to slide the credit card or on screen credit card validation or "one-time" credit card number (e-credit cards) like on a e-shopping interface on the web.

As credit card are going to evolve and becoming more secure (chipsets are going to replace the magnetic tracks), next generation IFE systems will have to be able to read the chipsets.

4.3.4.3 Internet Access

In order to make the Internet available in the plane, it is necessary to provide compatibility to existing Internet technology and enable the IFE system to access Internet.

The functionality provided in the aircraft are equivalent to those of an ISP (Internet Service Provider). An ISP is responsible for the Internet-infrastructure and for local Internet services.

4.3.4.4 E-mail

On-board e-mail is one of the most expected applications today. New IFE systems are able to send & receive e-mail with or without attachment.

As heavy file attachments may be a difficulty with current communications systems (low bandwidth), some IFE systems offer the opportunity of previewing messages titles (or partial content) and selecting those worth to be downloaded on-board aircraft.

Next generation off aircraft communication (e.g. SBB) means will allow higher bandwidth and therefore higher possibilities for attachments and even internet browsing.

4.3.4.5 Games

Games require game pads because they need more interaction than video. They include a multi-player feature where people can play together or against each other. This feature is provided through open game sessions where arbitrary people play together, or through selectable groups. One of the arising problems here is that a dedicated communication channel is needed to allow communication between players.

Basic desktop PC games will continue to be required; however, the future game requirements include loading and running games at the seats that provide an experience similar to the high resolution 3D interactive games available now on PCs and home game stations (e.g. Nintendo, Play Station, etc.).

4.3.4.6 Telephony

Telephony inside and outside the aircraft is a mandatory service. At the beginning, we though that passengers were likely to use their headsets and boom-mike to talk to each other across the aircraft. Nevertheless, this trend didn't really catch up. When it comes to telephony, passengers prefer using telephone like handsets. In order to improve comfort and reduce the amount of equipment installed in the seats, telephone handsets are now integrated within the PCUs.

In addition, passengers expect the system to relay their communication to the ground with good quality. In that case they will certainly accept to pay for the service. High speed bi-directional telephony and video conferencing provides a service that can be used by both the business and tourist travelers. Video conferencing service is only viable if terrestrial performance can be maintained on the aircraft. That’s the reason why video conferencing is not available on all IFE systems.

Providing telephony services doesn’t mean that conversations are confidential. In fact all neighborhood passengers could hear one's private discussion. That could be an issue for a confidential business conversation; in such case, the passenger, most probably, would not use the telephony service. The only solution would be to have private cabin installed near door area.

Telephony integrated within the IFE can be questioned. Indeed, very soon, A/C will allow GSM based communications. People will be able to use their own cell phones, with their address book. In addition, using one's own cell phone is more comfortable because there is no cognitive effort which is the case when using the integrated telephony service of the IFE.

The business model and above all the cost of these solutions will arbitrate in favor of one solution or the other.

Maybe telephony services such as Skype or Live Messenger will be an other trend that will offer a low cost alternative to the above solutions. The benefit is that it can embed the visio conference type of communications.

4.3.4.7 Intranet

The Intranet is used for two main purposes:

- Intra & Inter seat functions:
  On board messaging, flight information, conferencing (video and text), reference materials, news, weather, and games are provided the same way than terrestrial networks support them.
  Non critical crew member announcements can also be provided via the intranet (with a notification on the screen) so the passenger can read it as he wishes. For example, when

on board duty free shopping is open, today crew member make an announcement over the cabin speakers generating noise or, sometimes, waking up passengers who were sleeping. With the status notification on the screen a message could pop up on the screen which represents less inconvenience for the passenger.

- Shopping:
  In seat shopping services have to mimic the shopping services that passengers could have when using Internet at home. Thus, IFE systems are compliant with security requirements to prevent unauthorized access to personal credit information obtained during on-board purchases.

- Interactive meal and beverage ordering
  In the same fashion than electronic shopping, IFE system can provide meal and beverage applications so passenger can either make the selection that are offered in their menu or order any drink or food they desire. The order are sent on the cabin crew terminals so the flight attendant can bring the food to the passenger.
  This can be tighted or not to a billing system. It depends on the airline policy and the travel class. For example, many of low cost airlines make profit on the food and drinks that are sold on board. Such application would improve the passenger comfort perception especially in the current trend where you can order a pizza over the internet when at home.

- Electronic books, magazine, newspaper
  Currently the trend on the ground show that newspaper and magazines are going more and more electronic. Many Press companies have adapted their business models and already offer subscription services and premium information to the subscribers like they were doing with paper newspapers.
  In addition, there is a trend to digitalize books and build electronic libraries in order to share and export literature from our culture to the other (debate recently highlighted with the Google library project).
  In an effort to reduce paper and to follow those trends, next generation IFE system will have to support electronic display of books, magazines. Those newspapers, magazines or books will have to go beyong the mere reproduction on the screen of what they offer on paper. They will have to use all the capabilities and specificities of electronic devices of the IFE systems.

- Camera Picture viewing
  Today digital pictures are well popular and have given the home users the feeling they could get instantaneously the picture they just took (compared to the many days it took in the past to reveal it on paper). To follow these expectations, IFE systems will have to support the possibility for passengers of plugging their camera devices so they can watch at the pictures they just took during their holiday, honeymoon … This is an application which is more oriented towards tourist travelers.

- Expressing satisfaction (or lack of) via electronic surveys
  People are more and more pampered and offered the possibility to express their opinions. In the same fashion, IFE systems already offer the possibility to fill out surveys that allow expression of satisfaction (or lack of) for the experience during the flight.
  In the next generation, along with the personalization of the environment, IFE systems will have to adapt the interface to the results express by these surveys, especially if the passenger expresses some in comfort when using the IFE. Moreover, if a passenger expresses some satisfaction, the passenger should remember this and try to offer it to an other passenger that would have the same criteria (e.g. gender, age …). The modelization of some comfort studies on multimedia use within the aircraft could be used for that.

4.3.4.8 In-route data show

An Interactive Passenger Flight Information System (IPFIS) is integrated within the IFE system to allow the passenger to select what is displayed at their seat. The IPFIS information displayed includes:

- Instructional videos
- High resolution maps that provide more detail as the passenger zooms in
- Up to the minute weather reports that cover all routes
- Other currently supported PFIS data
- Satellite photo or 3D view from the region

5. Understanding of A/C cabin environment

5.1. Passenger activities

Passenger comfort depends on the different activities he practices.
The same entertainment system element can be comfortable and adapted for a given activity, and on the contrary, very uncomfortable for an other.
For instance, comfortable restful armrests sustain the weight of arms. In that way, they allow a good relaxation of the back and shoulders when the passenger does not move. But when accessing and exiting the seat, the same armrests can become an obstacle, if the armrests are not foldable and you have to pass by the next seat to reach the aisle. They can oblige passenger to adopt uncomfortable postures with back torsion. They can cause injuries and handicap old or fat people. In this specific moment armrests will not be perceived as comfortable.

This is the reason why we describe different passenger's activities, which are dependent on the specific situation of the flight.

5.1.1 Different phases of the flight that impact on passenger's activities.

- Flight phase
  The different phases of the flight strongly impact on passengers' activities:

Phases	**Passenger activities**
Boarding	Get into the plane, welcomed by the crew, reach his place, install luggage, access to his seat.
Push back and Taxi (plane is running before take off)	Fasten his seat belt, listen to security instructions, and can not move from his seat.
Take off	Can not move from his seat.
Climb	Can unfasten his seat belt, get up and move in the plane.
Cruise	Can do all the activities allowed in the plane (see lower), if there is no turbulence.
Initial descent	Can still move from his seat.
Approach	Fasten seat belt.
Landing and Taxi	Can not move from his seat.
Unloading	Exit from his seat, take his luggage and leaves the plane

Turbulence and emergency are two uncomfortable moments that impact on passenger activities. It can reduce or forbid some movement and require some attention.

- Turbulence:
  Passenger has to reduce movements in the plane, reach his seat and fasten the seat belt.
  Bumps produce physiologic and psychological effects: diseases like stomach pains, stress and fears.
  So any physical and psychological comfort gain prior to the turbulence situation is lost. To improve general perception of comfort during flight, it is important to take into account this potential turbulence situation and with it, the modification of the physical, psychological and mental state of the passenger.

- Emergency:
  All normal activities are stopped. Passengers have to follow security orders, like to get on a security position, to wear an oxygen mask…
  Of course, comfort, in that case, is not a priority. Security is the most important. Of course emergency is not a very common situation, but it is critical for passengers' life.

Therefore, equipment or IFE systems designs have to take into account this eventuality. They must not hamper emergency actions. On the contrary, they have to help. For instance interrupting sound and video to display auditory and visual orders.

5.1.2 Passengers activities during flight

Physical and measurable comfort such as comfort perception depends on the different passenger's activities. Comfort criteria will take into account these activities.

- Principal activities in a long haul travel.
  Surveys regard on repartition of the different onboard activities during flight time, show for example how much time passengers spend in:

  - Sleeping 3 hrs 45 min
  - Being entertained 2 hrs 30 min
  - Reading 1 hr 40 min
  - Eating and drinking 1 hr 15 min
  - Working 50 min
  - Other 15 min Total: 10 hrs 15 min.

  These different activities need different situation or position:
  Eating, drinking, and working are easier to do in a seated position. On the contrary, resting and sleeping are better to do in a flat position. Environment disturbances, like engine noise, are better accepted when people are awake than sleepy. More concentration is needed when working than eating.
  So, physical comfort perception is also dependent on these different situations.

  Physiological activities like sleeping, eating and drinking, are the main ones and take half of the time spent onboard (5 hrs on 10 hrs 15 min flight). We know that comfort perception is depending of such activities. Equipment and IFE systems have to provide help for these activities by proposing calm and soft music to rest, for example.

  In a long haul, being entertained is the most important activity after sleeping, representing a quarter of all activities (2 hrs 30 on 10 hrs 15).
  IFE systems can be used up to 3 hrs 20 (connection to Internet included). It is less than a third of total activities, but they take a little more than a half of awaked activities (3 hrs 20 on 6 hrs 30).

- Other activities
  In the other 15 minutes (of the 10hrs15 on total), there are some activities that impact on passenger comfort and its perception
  - putting and taking things in or out the luggage compartment,
  - moving from the seat, accessing and exiting,
  - listening security announcement,
  - fastening and unfastening seat belt,
  - modifying seat position
  - modifying other parameters with a command, like personal light,
  - adjusting volume level of the sound in the headset,
  - speaking with the neighbor,
  - speaking with the crew …

  These activities are not preponderant during flight, but we have to take them into account. Firstly because in shorter flight, these other activities take, in proportion an important place. Secondly, because in longer flights, moving in/out from the seat is the most important activity for the passengers in order to relax and to go to the lavatory. It has a direct impact on comfort perception and on health. During the flight, each hour spent without moving seems more uncomfortable for passenger than the previous hour.

5.1.3 Repartition on different activities using IFE

- Concerning use of IFE, different services and programs
  The services allow communication, information, entertainment and support the use of a personal computer.

  They are:
  - In-Seat Network Surfing
  - Personal Electronics Device Network Surfing
  - E-Mail
  - FAX
  - Telephone
  - Games
  - Rebroadcast Audio
  - Rebroadcast TV/Overhead Video
  - Audio and video on demand
  - Shopping

  Comfort, using these devices, needs specific requirements:
  - A technical requirement on the IFE system: the quality of the sound for video, music and telephone.
  - Impact of the IFE system on passenger posture and on physical comfort: position of the video display and the different commands, from passenger eyes to its hands, can require people to adopt more or less comfortable posture.
  - Easiness and difficulties to use the IFE system: It concerns the usability and pertinence of it. To be perceived as comfortable, an IFE application should be simple and intuitive. For example a person may not find the same command as simple as another one that would have computer knowledge.

- Repartition of different IFE devices in the cabin:
  Most of aircraft have different classes: Economy, Business, and First. Thus, passengers will access to different services. The table below gives a realistic model to know how passengers use services.

  Passenger Service Operational Model

Passenger Service	Typical Passenger Usage			Average Usage Per Cabin
	Coach Class	Business Class	First Class	
AVOD	16%	12%	16%	14.67%
E-Mail	1%	10%	1%	4.00%
FAX	0%	1%	0%	0.33%
Games	10%	2%	10%	7.33%
In-Seat Network Surfing	5%	5%	5%	5.00%
IPFIS	5%	5%	5%	5.00%
PED Network Surfing	1%	10%	1%	4.00%
Rebroadcast Audio	6%	5%	5%	5.33%
Rebroadcast TV/Overhead Video	17%	13%	17%	15.67%
Shopping	5%	2%	5%	4.00%
Telephone	1%	1%	1%	1.00%
Video Phone	0%	1%	1%	0.67%
No IFE (reading, eating, sleeping, talking, sight seeing, etc.)	33%	33%	33%	33.00%

5.2. Physical cabin environment

Cabin environment during flight has specific physical characteristics that impact on passenger's comfort.

All flights, short and long haul, impose stress on all passengers because of lowered barometric and oxygen pressure, noise and vibration (including turbulence). There are other sources for this stress: non-smoking policy (cigarettes are banned on most airlines today), erratic temperatures, low humidity, jet lag, and cramped seating. In general, passengers with stable medical conditions usually arrive to the destination airport without any problem.

Among physical conditions of cabin environment, some of them are not felt by passengers, like ozone presence. Some of them are forgotten during cruise, like noise, when others are amplified, like lack of place. Whatever is the passenger perception level, these nuisances impose body adaptation, which consciously or not, impact on passenger comfort.

Nuisances during commercial aircraft flight are:

- Diminution of the atmospheric pressure:
  Modern aircraft are not pressurized to sea level pressure. Indeed, on most flights the cabin pressure is equivalent to the one of an altitude between 6,000 and 8,000 ft. (1828m and 2438m) even if the aircraft is flying at much higher altitudes. In other words, on most flights, it is as if you were on the top of a hill or a small mountain. This induces two types of impact on the body:
  - less oxygen,
  - expansion of gases

  In the body cavities (abdomen, middle, sinuses) gases expand about 25%. This can cause problems in the abdomen (bloating or stomach cramps), ears (a crackling sensation or ear block), and respiratory tract/sinuses.

  For more information, refer to the deliverables D1.1 and D2.1

- Noise and vibrations
  Plane engines make noise and vibrations mostly during initial and final flight phases: take off and landing.
  Noise imposes stress on internal ear and sensitive persons can suffer from it.
  Vibration imposes stress on the whole body, acting directly on the cells, changing their inner vibration level by resonance phenomenon. The aim of SEAT is to provide a mean to reduce these vibrations.
  Previous research on Active Noise Control (ANC) to enclosures has included analytical, numerical, and experimental investigations. Some of more important works are discussed briefly next. Nelson et al. [1] carried out a theoretical investigation into the feasibility of global control in arbitrary enclosures excited at a single frequency under steady state conditions. They concluded that the reduction in acoustic potential energy in an environment of high modal velocity is only possible if the control source is located within half a wave length of the primary source. Bullmore et al.[2] showed that in an acoustical environment of low modal density, global attenuation of sound with a secondary source located further than half a wavelength from the primary source is achievable provided that the secondary source is placed at an antinode of the primary field. Placing sensors in enclosures corners and minimizing the responses there has the greatest effect on reducing acoustic potential energy in an enclosure when more than one mode dominates. However, for these cases to work, the primary excitation must be at an acoustic resonance. Elliot et al.[3] attempted an experimental verification of the above studies using a simple rectangular enclosure. As predicted by the computer simulation of Bullmore et al. [2], good reductions were indeed achieved only when the enclosure was excited on resonance. Elliot et al reported very good correlations between the predicted and measured impedance transfer functions; however, correlation between the predicted and observed noise reduction were not good. They found that while the spatial distributions of the predicted and

measured controlled sound fields in the enclosure were similar the amplitude of each were different. The average amplitude of the two fields was manually set equal to allow comparison. A prediction of the achievable acoustic potential energy reduction over a narrow frequency range showed that in most cases the acoustic potential energy would be reduced, but there was a possibility chance of increasing the energy at some frequencies.

Application of ANC to a BAe 784 twin turbo-prop aircraft fuselage was reported by Bullmore et al [4]. They modelled the problem as a thin cylindrical shell and a cylindrical room (with floor). The damping of the aircraft cabin in this case was estimated by matching predicted and experimental results, and found to be approximately 30% across all modes. It is worth noting that it was not suggested that the dampening for the fuselage was 0.3, but that this was the parameter value that must be used in order to obtain reasonable agreement between experimental and theoretical results. The simulation results in [4] showed that for a control system comprised of 32 error sensors and 16 control sources, the achievable average sum of squared pressure reductions over a plane representation of the height of seated passenger was 14 dB for the first propeller blade passage frequency of 88 Hz, and 4 dB for the second harmonic. The validation of results in [4] were reported in [5,6]. Alternative configurations of control sources were tested, with improved control at the second and third harmonics obtained by concentrating the majority of the loudspeakers in the plane of the propellers. The reduction in the tone at the fundamental frequency was a maximum when a fully distributed control source arrangement throughout the cabin was used. When all three harmonics were controlled simultaneously, a less than optimal reduction was recorded at some microphones and an increase in sound level recorded at others. Another interesting aspect in [6] is the results reported from testing a two-microphone, two control source ANC system on a passenger seat. A grid was set up that enabled the sound pressure around the microphones to be measured. As one would expect, reduction down to the noise floor was achieved at the two microphones. Reasonable reduction were also recorded around the controlled microphones up to about 70mm away. This was in agreement with results in [7] where it was shown that, on average, the result of driving the pressure to zero at an error sensor will be spherical zone of quite with diameter about one tenth of the wavelength of the excitation frequency. The sound level within this zone is expected to be at least 10 dB less than the primary level at that location.

A separate study on BAe 748 was preformed by Dorling et al[8]. They predicted and verified the control of 88 Hz fundamental excitation frequency in the cabin using 72-microphones, 24-control source ANC system. Reduction of sound pressure at over 50 points in the cabin was measured and compared to reductions predicted using quadratic optimisation theory. Reasonable agreement between predicted and experimental data was achieved.

Thomas et al [9] used a cylindrical shell model of an aircraft fuselage to study the effectiveness of using structural control sources to attenuate the noise level inside the cabin. The radial component of the kinetic energy in the structure was minimised for control and produced predictions of poor global attenuation inside the cavity. Consequently, Thomas et al [9] tried to use structural forces to minimise the acoustic potential energy of the cavity instead. In [10] it was shown that good global reduction of acoustic potential energy is possible at the two harmonics of interest using relatively few structural sources. Their experience seems to suggest that better reduction of acoustic potential energy was achieved using structural force inputs than acoustic sources.

Snyder and Hassan [11] reported a theoretical study for an ANC system in enclosed spaces. The importance of optimising both the physical and electronic parts of the control system was discussed. In [11] it was shown that the mechanism by which the acoustic potential energy is reduced in an enclosure with acoustic control sources is by sources unloading, and that in optimal conditions, the sources should never cause an increase in the acoustic potential energy. In [14] the effect of control source and error sensor configurations for a simplified light aircraft fuselage was reported. The level of acoustic potential energy reduction in the aircraft structure was much more a function of the locations of the control relative to the primary source [14]. Also, a higher reduction in acoustic potential energy was achieved when the primary excitation of the structure was at an acoustic resonance.

In [15] the importance of control source locations in an ANC system placed in an aircraft fuselage was investigated. Optimal passions were calculated to reduce the total acoustic potential energy in interior cavity at a single frequency. These locations were entered into a finite element model and sound pressure level results were calculated with and without control [16,17]. The results were subsequently obtained with control sources located in random positions and compared to those obtained with the optimal source locations. Results showed that the optimal locations achieved greater global and local control than locations selected randomly. A modal coupling theory to finite element was reported in [18] and [19]; for a curved panel with simple rectangular backing cavities. More recently, Lim et al [20] reported on a finite element simulation of smart structures using an optimal output feedback controller for vibration and noise control. Varadan et al [21] developed three-dimensional finite element closed loop model to predict the effects of active passive damping on a vibrating structures.

There has also been interesting studies on modelling human body/seat system in a vibration environment [22-23]. In [24] the driving-point impedance and transmissibility techniques were used to evaluate the effects of military helicopter seat cushions on human body. The most relevant study can however be traced back to an EU project IDEA PACI project which was carried out under the Brite Euram funding. The aim of the project was to establish an aircraft passenger noise and vibration comfort index to relate subjective perception to mechanical and physical design properties. An artificial neural network was develop to simulate a virtual passenger, that is generic transfer function between external stimuli and human impressions. The main achievement of the project as summarised in [25] were as follows: a psycho-acoustic study was carried out to identify suitable descriptors and to develop a tool that allowed translating the environmental solicitation in subjective impressions. Then, experimental investigations both at ground and in flight were performed to produce a wide data-base for statistical investigations.

On the bases of the acquired results, the architecture of the ANN was defined: it was successively trained and assessed on the experimental data coming from the main test campaign, so setting the aforementioned “virtual passenger”. As the last step, artificial neural network predicted comfort levels on both experimentally and finite element data.

More details and information are available in D3.1 Deliverables: ‘State of the art review on noise and vibration control’.

[1] Nelson, et al. Journal of sounds and vibration, 117, (1987) 1-3.
[2] Bullmore,A.J. et al. Journal of sounds and vibrations, 117, 1987, 15-33
[3] Elliot,S.J. et al. Journal of sounds and vibrations, 117, 1987, 35-58
[4] Bullmore,A.J. Journal of sounds and vibrations, 140, 1990, 191-217
[5] Elliot,S.J. Journal of sounds and vibrations, 128, 1989, 355-357
[6] Elliot,S.J. et al. Journal of sounds and vibrations, 140, 1990, 219-238
[7] Elliot,S.j. et al Journal of sounds and vibrations, 120, 1988, 183-189
[8] Dorling,C.M., et al. Journal of sounds and vibrations, 128, 1989, 358-360
[9] Johansson, et al. Proc. Active 99, 1999, 741-752.
[10] Thomas, et al. Journal of sounds and vibrations, 167, 1993, 91-111
[11] Thomas, et al. Journal of sounds and vibrations, 167, 1993, 113-128.
[12] Snyder,S.D and Hansen,C.H. Journal of sounds and vibrations, 170, 1194, 433-449
[13] Snyder,S.D. and Hansen,C.H. Journal of sounds and vibrations, 170, 1994, 451-472.
[14] Zander,A.C phD , the University of Adelaide, 1994.
[15] Dai,Y. and Fuller,C. Proc. Inter Noise 95, 1995, pp 533-536.
[16] Alvelid,M. RPoc. Inter. Noise 93, 1993, 65-70.
[17] Carletti,E. et al. Proc. Inter Noise 96, 1996, 1183-1186.
[18] Cazzolato,B.S. P Journal of Acoustical Society of America, 104, 1998, 2878-2889.
[19] Unruth,J.F. Journal of Vibration, Acoustics, Stress and Reliability in Design, 110, 1988, 226-233.
[20] Lim, Y U et al. Smart Material Structures, 8, 1999, 324-337.
[21] Varadan,V.V. et al. Smart Materials and Structures, 5, 1996, 685-694.
[22] Ajovalasit, M. Proc. IMechE., part D, 219 2005, 499
[23] Rosen,J. Journal of Biomechanical Engineering, 125, 2003, 223-231.
[24] Hopcropt,R DSTO-TR-1756, DODa-AR-013-471
[25] Sorrentino,A. Acta Acustica, 2003, S11.

- Quality of air
  During flights, the half of the air comes from the out side and the other half is recycled.

  Air blown into the cabin from the outside and at high altitude is completely devoid of humidity. The result is that planes have a very low cabin humidity rate, usually ranging from 5 to 15%. There can be a drying effect on passengers, the eyes (particularly under contact lenses), and the skin.

  Chemicals in the air due to hydraulic fluids and jet engine oil, like carbon monoxide have been found. They come from the engines when the air goes through them to be heated before entering into the cabin.

  The hazards of cigarette smoking, active and passive are well known. Soon, this pollution would disappear from most part of the flights.

  For more information, refer to the deliverables D1.1 and D2.1

- Cosmic radiation and electromagnetic fields
  - Cosmic radiation: Coming from the sun and others objects of outer space, they increase as aircraft goes to higher altitude. The measurement of radiation levels remains well below the recognized health limits.

- Electromagnetic fields: Every electrical systems and radio waves generate electromagnetic fields. Aircraft presents a non negligible variety of electrical systems, and IFE systems may add some electromagnetic field. They impose at least, heating of human cells.

- Lack of space
  On most flights, regardless of aircraft type, some passengers may be seated in a small, cramped space. This can be uncomfortable and it also reduces the opportunity to get up, stretch, and walk around the cabin. Sitting for long periods is tolerable for most passengers, but for some there is the potential for ankle swelling, cramps, and other circulatory problems.

5.3. Flight risks on health

Comfort is reduced when suffering.
The exposure of aircraft cabin environment (see above) has consequences on health. Crew and passengers suffer from minor troubles to serious illness.
IFE systems can not exist without considering cabin environment. They can for example, isolate the passenger from noise with appropriate headset. They can also distract passenger's attention from pollution perception.

Nota

5.3.1 Passenger exposure

As stated above, the vast majority of travelers can fly quite safely. If a passenger has significant pre-existing illness or an unstable medical condition, a physician should be consulted before planning to travel by air. This is particularly true for those with heart or lung disease including angina pectoris, congestive heart failure, myocardial infarction (heart attack), asthma, and emphysema. Other significant illnesses would include a history of deep venous thrombosis (blood clots), seizure disorder, stroke, and diabetes.

- Contagious diseases
  Because the aircraft cabin is a confined space and flights may last a lot of hours, there is a risk of a contagious disease being passed from one passenger to another. Therefore, the risk of an illness transmission in an aircraft is no different from the transmission in any confined space including a room, office, train, or bus.
  There is no evidence that organisms pass from one person to another through the aircraft ventilation system, because of effective filtration and radial airflow of the ventilation system.

- Irritation of respiratory system
  Passengers and crew complain of symptoms that they attribute to the presence of organic substances, carbon monoxide, carbon dioxide, airborne particles and ozone in the cabin air. But studies show, no epidemiological evidences that aircraft cabin air quality is unhealthy. Introduction of ozone converters in aircraft will break down the ozone before it reaches the cabin, to reduce risks and improve comfort.

- Deep venous thrombosis
  Deep venous thrombosis, also named traveller's thrombosis, is a blood clot, usually in the leg, that can cause pain and swelling. Clots in the legs are not serious in themselves, but occasionally they break off and travel to the lungs (called pulmonary embolism) causing chest pain and shortness of breath. This is not a common occurrence, but when it does happen, it can be life threatening

  According to Dr Gouny (Angiologist Paris, France), few statistic studies demonstrate the percentage of DVT due to flight; the incidence of DVT in association with travel is between

3.2% and 17.3%. There is almost no prospective, controlled data, anecdotal and retrospective reports.

One of the causes of deep venous thrombosis is due to be prolonged immobilization, such as sitting for many hours at a time, particularly in an individual with pre-existing risk factors.

In order to minimize the risk of traveler's thrombosis, the following is recommended for all travelers:

- Do not place luggage underneath the seat in front of you because that reduces the ability to move the legs.
- Exercise the legs by flexing and extending the ankles at regular intervals while seated.
- Walk about the cabin periodically on longer duration flights and when flight conditions permit.
- Do not sleep in a cramped position and avoid the use of sleep aids.
- Drink adequate amounts of water and fruit juices to maintain good hydration. Avoid or minimize dehydrating drinks such as alcohol or cafe.
- Other preventive measures should be considered by physician. This might include compression stockings and/or anticoagulant (blood thinners) medication.

Aircraft seat redesign could theoretically reduce these risks and research should incorporate the testing of venous physiology in response to altered seat design.

For more information, refer to the deliverables D1.1 and D2.1

- Decompression sickness
  Nitrogen bubbles cause decompression sickness, forming in the blood or body fluids, when going from a high-pressure environment to a low-pressure environment. This can happen when going to altitude with an aircraft. The most common symptoms are joint and/or muscle pain (commonly known as bends). However, these bubbles can cause much more serious illness with symptoms of stroke and collapse of the cardiovascular system.

- De-synchronization of body clock
  Jet lag occurs when crossing multiple time zones. Our body clock, which controls hormone levels, is synchronized to the day/night cycle where we started. When we travel long distances in a matter of hours, we will arrive in another time zone, yet our body is still functioning as if it were in the time zone at the point of origin. This results in symptoms, such as fatigue and sleep disturbances that are well known to travelers. Crossing time zones may not only be an annoyance for well passengers, but it can also complicate the timing of medication dosages.

- Dehydration
  Dehydration can be caused by lack of humidity of the air, amplified by alcohol consumption.

- Air rage
  Some cases are mentioned in commercial flight and alcohol may interfere in it.

- Difficulties to sleep
  Multitude of causes can avoid good sleep: noise, lack of space and impossibility to change position, alcohol, stress, fear, jet lag…

- Motion sickness
  Although motion sickness is less common with jets than with propeller-driven aircraft, it may occur, particularly in susceptible individuals.

- Eye disease

Air travel conditions that affect the eye are changes in cabin pressure and dry cabin air. Because of changes in air pressure, individuals having surgery for retinal detachment, cataracts, or lens implantation should delay travel.
Turbulence during flight can cause trauma to the eye, particularly for someone who has had eye surgery recently.

- Heart disease
  Because of the pressurization of the aircraft, to a maximum of 8,000 ft., the oxygen supply in the air is decreased with a corresponding decrease in the oxygen carried in the blood. In general, reasonably healthy individuals can easily tolerate this, because the body is able to compensate by increasing the heart rate and respiratory rate.

- Ear, nose, and throat disease
  Passengers traveling by aircraft experience changes in air pressure during flight. Before takeoff, cabin pressure equals the air pressure at ground level. After takeoff and during climb to cruising altitude, the cabin pressure in commercial airliners is allowed to drop until it reaches the equivalent of the air pressure at 8,000 feet (2432 meters). Cabin pressure is maintained at this level, even if the aircraft flies at a much higher cruising altitude. When the aircraft descends, cabin pressure rises until landing when it again equals the pressure on the ground.
  As a result of these pressure changes during ascent, air must be able to flow freely from the middle ear (the space behind the eardrum) to the outside by way of the Eustachian tube and from the sinuses to the outside by way of passageways to the nose. On descent, the opposite must occur with air flowing in the reverse direction from the outside into the middle ear and sinuses. In short, this is necessary in order to equalize the air pressure in the body with that of the surrounding air. If the air pressure in the middle ear and sinuses becomes much higher or lower than the surrounding air pressure, pain, bleeding and eardrum rupture can occur.
  Problems with this important air exchange are caused by a blockage of any of the passageways. Infection, such as a bad cold, allergy, bleeding, and even a tumor can cause blockage. Although problems can occur during climb to altitude, problems tend to be much more common and severe during descent to landing.
  Flying can cause air pressure equalization problems for up to several hours after the flight. Passengers may later develop pain, ear block, and general discomfort sometimes being awakened from sleep. This is virtually always due to failure to fully equalize sinus or middle ear pressures during descent and landing.
  Another problem of air travel is related to the very low humidity in the aircraft cabin which impact on nose sensibility.

All these risks impact on passenger comfort.
In first considerations, IFE system can help passengers to forget them, and can propose advice to reduce some, as respiration and stretching program at seat.

5.3.2 Specific risks for crew members

Because they are exposed for a long time and on a long period of life, crewmembers develop specific illness linked to aircraft environment.
A lot of epidemiological and medical surveys are made on consequences of pollution exposure on crewmember health. They mention:

- Circadian rhythm rupture,
- Jet lag,
- Sleep disturbances,
- Spontaneous abortions,
- Numerous types of cancer: kidney, brain, prostate, digestive system, breast, and mouth.

The crewmembers are always in relation with passengers and confronted to theirs problems. They have to know how to react and that could be sometimes very hard. The multimedia systems are also here to help crewmembers in doing their jobs.