ADVANCES IN ERGONOMIC AIRCRAFT DESIGN WITH SPECIAL REFERENCE TO INDIAN AIRCRAFT INDUSTRIES

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Abstract

The objective of the paper was to study the utilization and applicability of 'Applied Cognitive Ergonomics Design (ACED)' principles for aircraft from 'the design of cockpit to cabin' keeping in view the comfort of crew, passengers and pilots. Hence, ergonomics and human factors concerns are important in the design of modern Aircraft. The cabin pressure and it's control, cabin lay-out, design of the seats in the cabin, window design, cockpit design and function of cockpit displays, and controls as per ergonomic considerations, safety and comfort have been analysed in this paper. The current ergonomic design of cockpit with multifunctional displays is being designed to accommodate from the 1st percentile female physical size and the 99th percentile male size at Indian Aircraft Industries. The analysis is carried out by studying the existing literature and the trends adopted by various aircraft manufacturers in the world, compared with IAI's current programmes of Next Generation aircraft manufacture. Literature has been reviewed to the extent of relevant design principles together with analysis of their applicability to the Indian aircraft domain.

Key Words: Ergonomic Design, Cabin Design, Seat Design, Cabin comfort, Anthropometry, Glass Cockpit/ Multi Function Displays, Aircraft Instruments, Ergonomic Mat, Cabin & Cockpit Windows,

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1. Preamble

Aircrafts, Helicopters, Space Shuttles and all flying machines need special design with reference to human comfort and safety. Aerospace companies all over the world are striving for more dynamic developments with the utilization of technology advancement. Advanced new aircraft with ergonomic changes are bringing in revolutionary changes in the aircraft industry both in Civil and Military versions. These ergonomic aircraft designs are offering greater augmentation to pilot, crew and passenger comfort, especially on long transnational hops along with benefits from a 'fuel efficiency boost' apart from improving safety.

Indian Aircraft Industry (IAI) is catering to the needs of Civil and Defence sector in India with its multi role model aircraft manufacturing, service and acquisitions. IAI is putting its efforts to simplify and make cost-effective design process of variety of airplanes especially used for defence. With new and safe technology with 'in-house' expertise and international collaborations and contracts, IAI has shown the way that industries can do the best with respect to Human Comfort and safety, with simple expenditure on the research and development, which can result in modernizing the product offerings, to increase its competitiveness in the international markets. IAI has brought in the right technical solutions through Ergonomic Design of Aircraft, so that it can produce world-class Aircraft, including the fixed wing small passenger aircraft – 'Doriner-228' to many more other new variants in line with major Aircraft manufacturers in the world. IAI has especially proved its competence in meeting the needs of the 'Indian Defence Aerospace Industry' by introducing new ergonomic products and ensuring safer workplaces for their employees with its concentration on Ergonomics, and aircraft safety.

2. Literature Review

Literature related to the design of cabin, cockpit, multi-function displays, seats, instruments, windows and other issues associated with ergonomics, human safety, was collected from a variety of printed books, journals and internet sources for review. Existing design guideline documents with IAI related to seat design, pilot and co-pilot seat design, Multi Function Display design and cabin design, fuselage design have been studied. 'Design Guidelines for User-System Interface Software (Smith & Mosier, 1984)'; 'Handbook of Human-Computer Interaction (Helander, Landauer, & Prabhu, 1997)'; 'Designing the User Interface (Shneiderman, 1992)';

'Human-Computer Interface Guidelines (Goddard Space Flight Center, 1992)'; 'Advanced Human-System Interface Design Review Guideline (U.S. Nuclear Regulatory Commission, 1985)', FAA, JAA & CEMILAC Standards, recommended procedures &practices, and standard practice documents have been consulted.

Text Books and print material on Ergonomics in the Automotive Design Process Vivek D Bhise, Tailor& Francis group – CRC Press, 2011; 'Introduction to Human factors and Ergonomics for Engineers' – Mark Letho, Steven J Landry, CRC press; 'Ergonomic Design for People at Work' by Suzanne H Rodgers - Van Nostrand Reinhold of Kodak Ergonomics Group publication; 'Pilot-System Integration (Aerospace Recommended Practice, 1988)'; 'Transport Category Airplane Electronic Display Systems (FAA Advisory Circular, 1987)'; 'Human Engineering Design Criteria for Controls and Displays in Aircrew Stations' (NATO Standardization Agreement, 1992); 'Operations Concepts for Cockpit Display of Traffic Information Applications (RTCA Special Committee Report, 1998)'; 'Human factors and ergonomic handbooks' also were examined. The additional sources that are consulted are- 'Handbook of Human Factors and Ergonomics (Salvendy, 1997)'; 'Human Factors Design Handbook (Woodson, Tillman, & Tillman, 1992)'; 'Engineering Data Compendium: Human Perception and Performance (Boff & Lincoln, 1988a-i)' which were given deep knowhow about Ergonomic Considerations.

Several scientific journals were examined, including: Human Factors, International Journal of Aviation Psychology, Ergonomics, 'Human Factors and Ergonomics Society', International Conference on Human-Computer Interaction in Aeronautics, Digital Avionics System Conference, SAE/AIAA World Aviation Congress, Silicon Valley Ergonomics Conference etc. Other sources perused are 'Aviation human factors and general design; Human Factors in Aviation (Wiener & Nagel, 1988); Human Factors in Flight (Hawkins, 1987); Aviation Automation (Billings, 1997); Design for Success: A Human-Centered Approach to Designing Successful Products and Systems (Rouse, 1991); To Engineer is Human, The Role of Failure in Successful Design (Petroski, 1985), The Design of Everyday Things (Norman, 1990)'.

Several national and international seminal references were also perused for study, Viz., 'Analysis of human factors data for electronic flight display systems (Semple, Heapy, Conway & Burnett, 1971); Design criteria for airborne map displays (Carel, McGrath, Hershberger, and Herman, 1974) & Design and use of computer-generated electronic area navigation map displays (Streeter, Weber, and McGrath, 1973)'. In addition to these published works, conversations & interviews were held with aviation research scientists, officials at IAI, chief test pilots, commercial pilots, fuselage and cabin designers, interior designers, officials at Pilkington Aerospace (manufacturers of various aircraft wind screens internationally), cockpit designers, and vehicle interiors designers, to better understand design modalities and issues. After a comprehensive review of the existing information, the present review is an attempt at a total insight into the design parameters, and it is hoped that this study will be helpful for additional ergonomic improvements in the aircraft sector and will also pave the way for further research.

3. Ergonomics in a nutshell

'Ergonomics is the scientific discipline concerned with the understanding of interactions among human-beings and other elements of a system, and the profession that applies theory, principles, practices, data and methods to design, in order to optimize human well-being and overall system performance'. Ergonomics has two main goals viz., health and productivity. Proper ergonomic design is necessary to prevent Repetitive Strain Injuries (RSI), discomfort, and uneasiness, which can develop over time and may lead to long-term disability.

Ergonomics is a multi disciplinary science involving fields that have 'information about people and their psychology, anthropometry, biomechanics, anatomy, physiology and psychophysics'. It also involves studying human characteristics, physical features, capabilities and limitations, and applying this information to design the equipment and systems that people use.

The general dimensions of ergonomic discipline include, design theory and practice, Management, technology, and environment along with social needs with the aim of comfort and safety as detailed in figure 1.

'Ergonomics is about designing for people, wherever they interact with products, systems or processes. The emphasis in ergonomics is to ensure that designs complement the strengths and abilities of people working in the system and minimise the effects of their limitations, rather than forcing them to adapt'. In achieving this aim, it is necessary to understand and design for the variability represented in the population, spanning such attributes as age, size, strength, cognitive ability, prior experience, cultural expectations and goals.

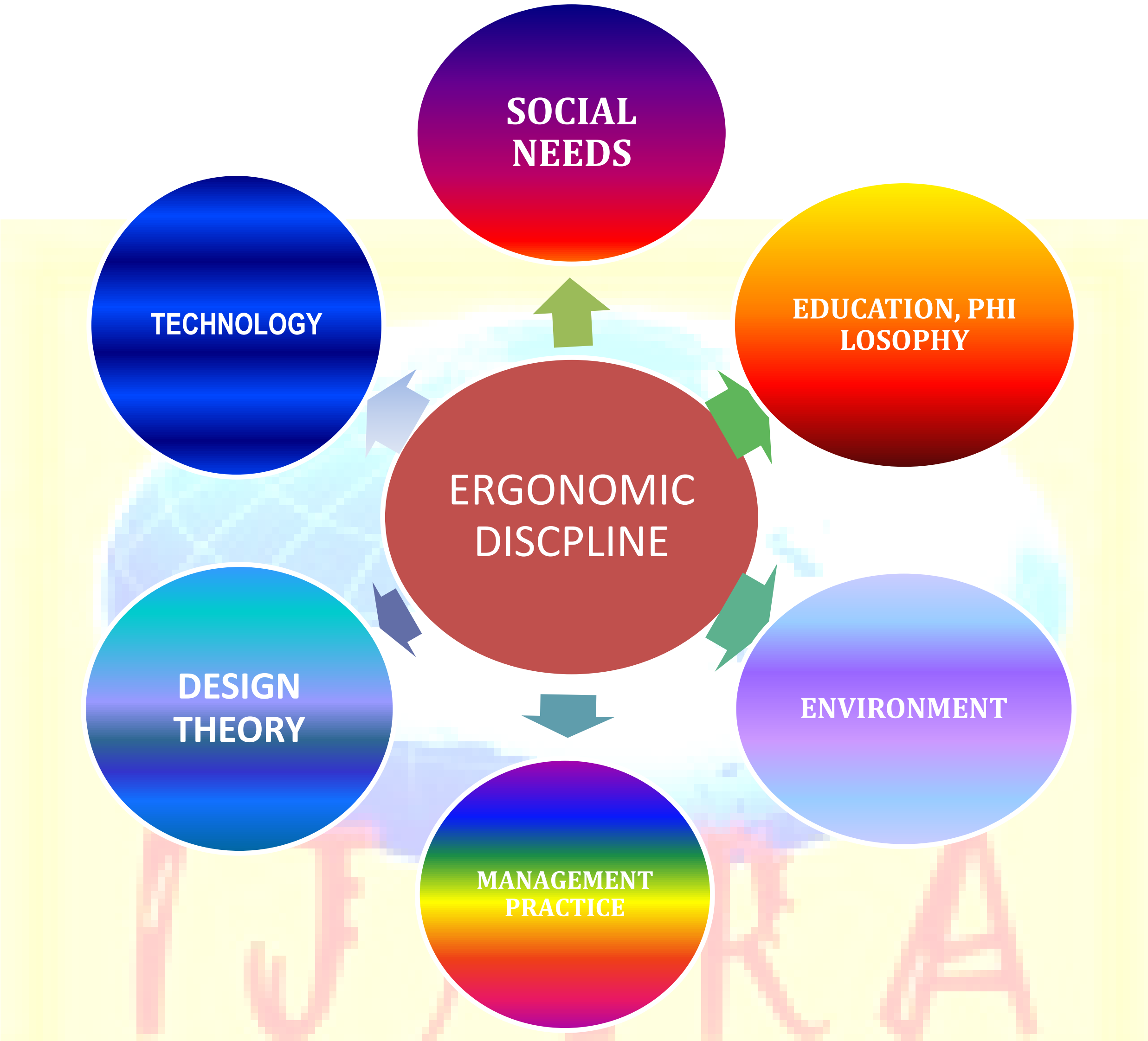


Figure 1: General Dimensions of Ergonomic Discipline

Researchers study the biomechanical, physiological and cognitive effects of work on people, or users' understanding of processes, or the efficiency of systems. Practitioners study how people interact with products, processes and environments on a day to day basis in order to improve them, to make them more comfortable, safer, more 'user friendly', and more efficient. But, as practising researchers, we have taken cues from both sides into account and have applied relevant research to help with this study and to suggest recommendations. Applying good ergonomics will make a product easy to use and it will help to increase the efficiency of the manufacturing process.

This study of human characteristics and interaction of human beings with the equipment, machinery, methods, products or even workplaces may either take the reactive or proactive approach when applying ergonomics into practice.

Reactive ergonomics is when something needs to be fixed, and corrective action is taken. Proactive ergonomics is the process of seeking areas that could be improved and fixing the issues before they become problems. Problems may be fixed through equipment design, methods re-designing, task design, or environmental design.

At IAI, the Aircraft design in the recent past followed the route of Proactive Ergonomic Process. The Dornier-228 New Generation Aircraft (Figure- 2) is the right example for such special design.

Figure 2: Dornier -228 Aircraft

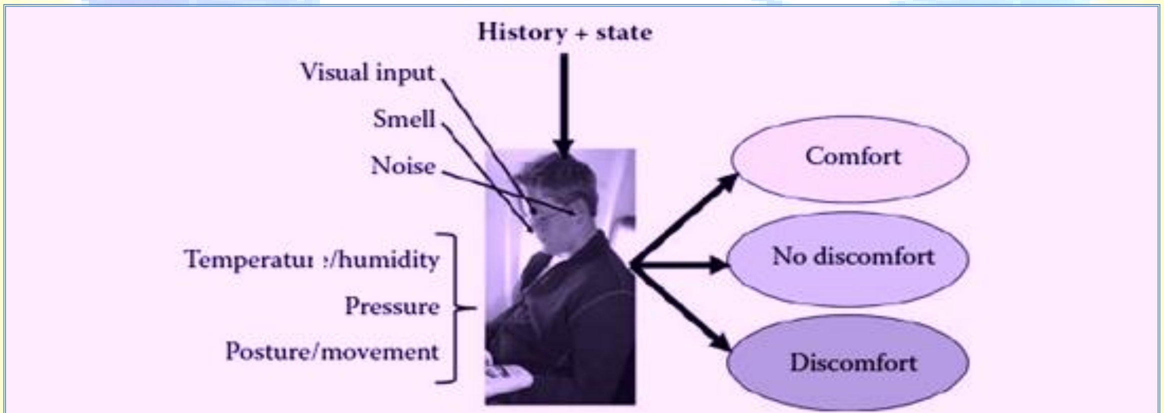
4. State of Mind

The state of mind influences whether the experience is comfort or discomfort. The comfort schema describing the inputs leading to the output (dis)comfort is visualized in Figure- 3.

On the right side in the figure, is 'output: comfort, no discomfort, and discomfort'. This output, the experience of discomfort or comfort, is partly due to our own selves, depending on our history of comfort experiences, and our current state, which could be excited or relaxed. The experience of comfort and discomfort is also caused by external stimuli (input). The inputs are shown on the left side in the figure.

For example – 'Our sensors receive the pressure. After this input, the selection and weighing processes begin. Our state of arousal and past experiences influence these weighing processes, and based on these processes, the product causes comfort, discomfort, or nothing'.

By applying proactive Ergonomic design keeping in mind the state of mind of the crew and passengers boarding the aircraft, the comfort level automatically gets improved as the ergonomic design will take care of the look and feel of the environment, apart from design considerations including Cabin Pressure and Anthropometry.



The comfort input/output schema. The feeling of (dis)comfort is determined by the input recorded by sensors and the information processing that is influenced by the history and state of the participant.

Figure 3: Comfort & Discomfort

5. Design Considerations for the Modern Aircraft

5.1 Anthropometry

'Anthropometry, which literally translates to 'measure of man', is the science of measuring human individuals' (Aghazadeh, 1994). Anthropometry is the study of body sizes and other associated characteristics. Measurements can be in the form of_

- Static measurements: Attributable measurements when the body is static position or still position. (e.g. Passenger/ Pilot sitting height)
- Dynamic measurements: Attributable measurements when the body is moving (e.g. a pilot's reach envelope for the overhead panels)
- Contour measurements: Main Measurements of the body (e.g. head circumference or waist size)

Anthropometry is an integral part of ergonomic design and for aircraft designers, anthropometry is not limited to the measurements alone but also entices the targeted users and operators (Table 1). The ergonomic designer must be familiar with the human body movements and Therbligs, especially when designing workspaces. It is not feasible to design the aircraft – fuselage, cabins, interiors and cockpit for the comfort of every individual in the world. 'Simply a normal distribution is used where an aircraft is designed for the 5th to 95th percentile of the intended population (NASA, 1978). (95% acceptance level)'.(Figure -4).

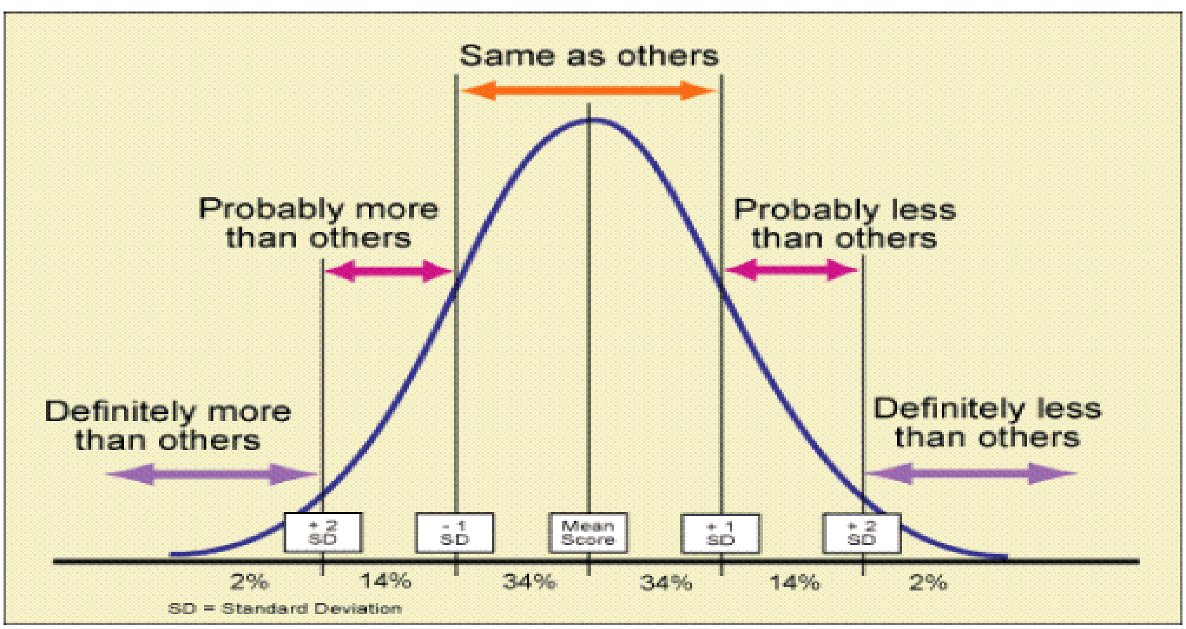


Figure 4: Distribution of the 5th-95th percentile

Table1: Anthropometry considerations in aviation

Body dimensions	Clothing (including gloves, shoes, blazer/coat, suit)
Hand size	Size, location and layout of button, switches, levers and small controls. Access to maintenance engineers
Length of arms and legs	Reach envelope for control locations
Sitting eye height	Seat adjustment to establish correct eye datum
Sitting height, sitting knee height and thigh thickness	Control column yoke clearance, desk and console design
Standing height	Ceiling and door height limitations, overhead panel reach
Sitting elbow rest height/ length	Armrest location
Body width and thickness	Fuselage, passageway, door and hatch size limitations
Thigh length	Seat length
Foot size	Foot location, space and controls (rudder and brakes)
Muscle strength	Control feedback forces (real or artificial). Service and maintenance requirements. Portable equipment weights

5.2 Total Cabin Comfort

The atmospheric pressure decreases as the altitude rises. This has been carefully measured and the following curve represents the pressure evolution according to the altitude. Accordingly a particular pressure corresponds to a specific altitude.

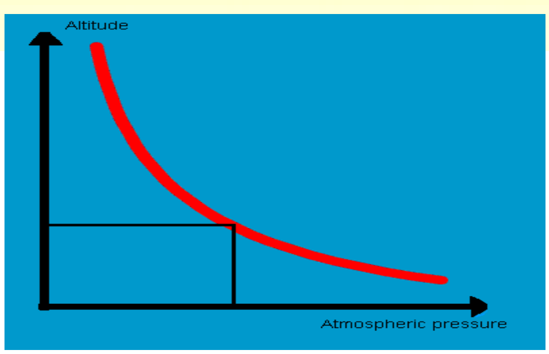


Figure 5: Altitude – Atmospheric pressure.

Human body needs a minimum air pressure level. Moreover to feel comfortable the air pressure needs to remain at the minimum value even at the height of 8000 Feet (2438 meters) which is the general altitude of modern aircraft flight path.

An aircraft cabin is similar to a closed volume container. The cooling air required for passenger's comfort and breathing, is injected inside this closed volume. Accordingly, it is necessary to control and maintain the inside pressure at the required level.

This is done through a kind of tap which is carefully opened or closed by an automatic system, known as the cabin pressure control system**.** Human comfort mainly depends on this cabin pressure.

‘The purpose of the pressurization control system is to fully automatically control the pressure in the fuselage. The pressure level and change rate are controlled to provide satisfactory pressure values for comfort and safety for all the passengers and crew’.

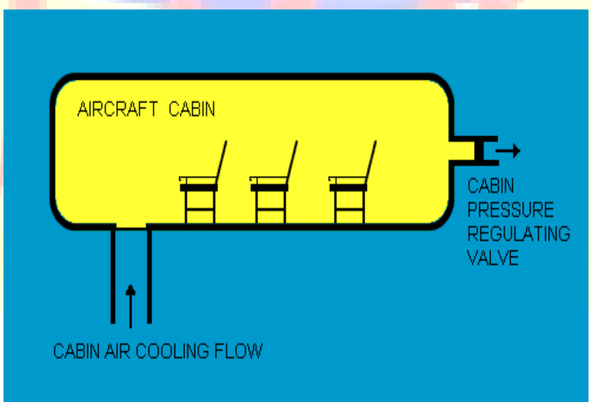


Figure 6: Aircraft Cabin -Air flow

This is made by the control of the quantity of air that flows out of the fuselage through one or several outflow valves installed on the fuselage surface or on the aft bulkhead as indicated figure 3.

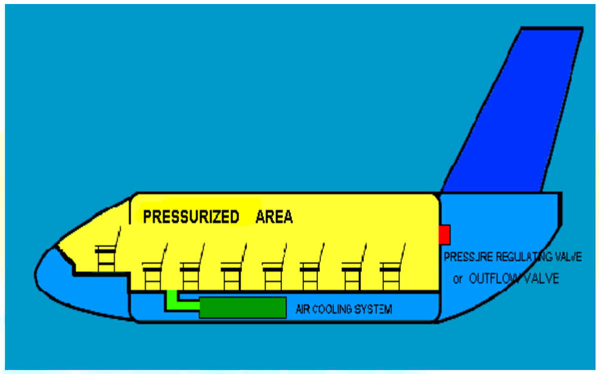


Figure 7: Fuselage – Pressurized Area

These outflow valves are operated by computerized controls by measuring various parameters of human comfort including air velocity, humidity and temperature. 'The specific computers measure the outside pressure (at the altitude where the aircraft flies), the current pressure inside the fuselage and then drive the opening or closing of the outflow valves according to programmed parametric to get the proper pressure inside the fuselage'. This parametric takes into account the flight phase viz., take-off, climb, cruise, and descent, landing and taxiing.

The general system behaviour is as per the following schematic-

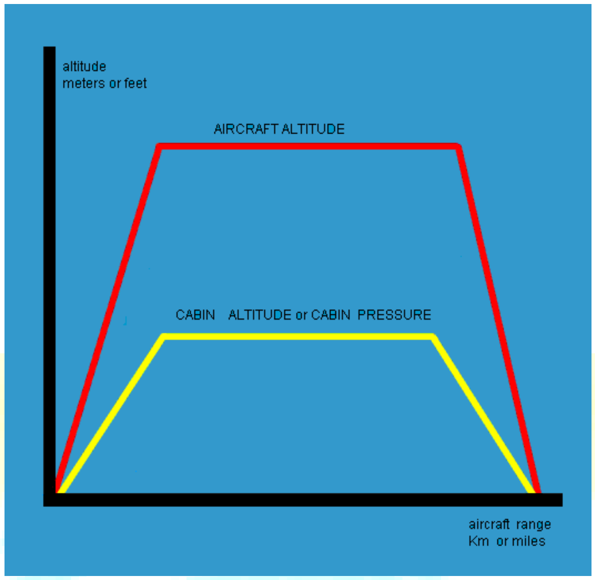


Figure 8: Cabin Pressure

As the aircraft climbs, the pressure inside the cabin generally decreases at a lower speed than outside. The important point to be noted during this phase is the ‘pressure rate of change’.

This can be controlled in reasonable limits for the passenger's comfort by the pressurization system which mainly takes account of the aircraft vertical speed. If a too large deviation from the required pressure rate of change occurs in the cabin, this may have an important and direct possible consequence as ear-ache along with inconvenience.

The human physiology dictates that the pressure rate of change must not exceed 18 mbar per minute during a climb phase. This speed allows air to flow inside human head (nose, throat, internal ear), causing same pressure on each side of the ear drum causing nausea and ear-ache.

Therefore in Ergonomic design of the cabin and cockpit, the ‘pressure rate of change’ is controlled to provide comfort and safety.

Various indicators and controlling devices are installed in the aircraft to ensure proper corrective actions by the pilots to have comfort for all the passengers and crew.

Figure 9: Modified Seat

5.2.1 IAI's modifications – redefining comfort

IAI's latest modifications on various aircraft – redefines passenger experience, passenger comfort, environmental performance, reduced operating cost and better economic concert.

The wings, tail, nose and flight deck windows have all been engineered for the maximum aerodynamic efficiency reducing fuel consumption. 'The composite fuselage and smooth wing design is much more efficient than earlier airplanes in the similar size and group'.

The substantial breakthrough in its fuel consumption and maintenance cost will help airlines save money while providing flexibility to expand into new markets. The spacious architecture, stowage space, cleaner and healthier air, lower cabin altitude, dimmable-windows ensure a smoother and more comfortable passenger experience. IAI's plans for their aircraft in civil and defence versions include-

1. The spacious entryway, the decorative ceiling with a spectacular entry arch welcomes the passenger into the aircraft. A soothing cabin atmosphere with dynamic LED cabin lighting scheme immediately creates a comfortable ambience, helping transition through time zones.
2. The large windows provide openness and natural light for every passenger and crew. The windows are electronically dimmable where passengers can select the perfect level of light at the push of a button, from lightest to darkest shade taking only few seconds. These controls are also centralized and can be operated by flight attendants to ensure appropriate cabin light for all phases of flight.
3. The state-of-the-art In-Flight Entertainment system in flights, provides AVOD (Audio Video On Demand). The system is built upon the latest generation industry standards for network architecture and technology to provide passengers with audio, video, games, entertainment and communications features better than the latest in-home capabilities.
4. The IFE system is controlled by 'Tethered' Passenger Control Units with gaming capacity. Besides, a USB port is provided, capable of connecting Passenger Electronic Devices e.g. Digital Camera, Keyboard, MP3 Player, Mobile phone charging. Also, an overhead video Broadcast is provided with LCD monitors throughout the cabin.
5. Testing shows that passengers experience fewer headaches and less fatigue at 6,000 feet/1800 meter than at higher altitudes. The cabin environment allows more oxygen to be absorbed into the blood reducing headaches and dizziness.
6. The IAI's new Generation aircraft system includes a High Efficiency Particulate Air (HEPA) filter to remove bacteria, viruses and fungi. An additional new gaseous filtration system also removes odours, irritants and gaseous contaminants. This creates a cabin environment with fewer complaints of headaches, dizziness, or throat and eye irritation due to dryness.

7. The airplane is equipped with a system that senses turbulence and commands wing control surfaces to counter it, greatly smoothing out the ride. Passengers will enjoy a more comfortable, smooth flight and smoother ride.

5.2.1.1 Innovative Windows

The innovative windows were one of its most pioneering elements. More than 30% bigger than those on a normal aircraft, the gel-filled windows let in lots of light, and could be dimmed at the touch of a button to simulate the sun rising and setting.

Figure 10: Innovative windows

Comfortable blue (Figure 10) leather seats are lit by colour-changing mood lighting, and feature a small amount of sought-after extra legroom. Most relaxing of all is the fact that the windows let in plenty of light and require no shutter to shade the view, instead the gel-filled glass darkens at the touch of a button in the seat – simulating sunset and sunrise to help the passenger or crew to adjust to changing time zones.

5.2.1.2 Interior Design Modifications

User friendly web-site for ticket booking, easy check-in systems, seat choice on-line, positive attention of crew during check-in, 'First sight' good looking interiors, spacious seating place, personal gift, seat feels good, no obstacles, no pressure, no stress on the body are some of the issues which are important apart from designing the comfort in the Aircraft Cabins, cockpits and Systems. Flight selection depends on these parameters in general especially for passengers of long haul, in particular.

Flight selection behaviour of passengers is becoming important in generating revenues in civil aircraft and perfect target triumph by the defence individuals as either pilot or co-pilot. Most of the passengers first select the most convenient route and departure time at the best price in general. In those cases in which the passenger is indifferent between equally convenient flights at a similar price, other aspects break the tie. These other aspects include comfort, service, the airline's reputation for on-time performance, and marketing programs, such as frequent flyer programmes etc., Even in defence Aircraft, the new variants and new models with ergonomic features are better accepted by the officials and hence seniority and other antecedents have been considered for handling such aircraft for the specific purpose. For short distances, on-time performance is more important and, for long-haul flights, the comfort and service aspects play the most important role.

5.2.1.3 Design eye position/ Eye Datum

The design eye position, also known as 'eye datum or design eye reference point' (DERP) is one of the key aspects of window design of the cabin, design of 'Audio Visual Accessories'. This design eye position is also most important for cockpit design. 'A pilot should be able to view all the main cockpit instruments while maintaining a reasonable view of the outside world with minimal head movement (FAA, 1993)'. 'The instruments should be located high enough for easy viewing but low enough so that it does not obstruct the view of the runway ahead during take-off and landing'.

Similarly the cabin windows also should be of optimum size for crew and passenger's comfortable view. 'In IAI the basic aircraft designing starts from designing eye position and from there build the fuselage, cabin and also build the cockpit around the instruments and other equipment, factoring in the reach envelope to position the controls, switches and dials to cater for the 5th to 95th percentile'. In order to operate the aircraft as intended it can be seen that all pilots must use the same reference datum. 'This is normally achieved by adjusting the seating position in both vertical and fore/aft axis. At IAI the aircraft will also have adjustable rudder pedals and/or control yoke/joy stick to ensure that the pilot's view is in alignment with the design eye position'.

5.2.1.4 Ergonomic Design with Aesthetics

The increasing trend in ergonomics with all of the new ergonomic concepts, the Indian Aircraft Industry (IAI) had innovating to create new ergonomic console designs that are not only functionally superior but also aesthetically pleasing in form. At Indian Aircraft Industry, the systems are first tested under simulated conditions particularly with respect to Human Comfort and Ergonomic abundance in terms of _

- Greater Safety for the crew and the passengers
- A perfect analysis of posture, vision, motion and effort
- Easier execution of service, maintenance and repair work
- Easier working with every type of airplanes/ Helicopters or even space shuttles
- Compliance with standards of certification agencies and the ensuring of ergonomic quality, like the best accessibility, and the usability of all the controls
- Comfortable Cockpit and passenger compartment design
- Comfortable and acceptable seat design and development in terms of ergonomic specification and validation.
- Ergonomic appraisal of passenger catering services
- Analysis of special passenger's discomforts & flight attendant injuries.
- Ergonomic workplace assessment of baggage handlers

Nausea, pain in hands and neck, had also been experienced by both crew and passengers while travelling in several aircrafts. The reasons for such include vibrations, turbulence and sound. It is also been found that a positive correlation exists between hygiene and comfort in Aircraft. If the aircraft has clean seats and windows, with a bright, new-looking interior, crew and passengers were more likely to experience a comfortable flight. Passengers as well as crew also found flying on newer planes to be more comfortable due to enhanced comfort frills. The comfortable seat, orderliness in equipment with ergonomic design has improved morale in defence sectors too in the new defence aircrafts.

The Ergonomic Design of aircraft and interior furnishings have brought in revolutionary changes in IAI that have resulted in significantly higher passenger ratings for newer aircraft compared with older versions that are in service either in Defence or in Civil aviation. Aircraft utilization has been driven to a greater degree by comfort and safety, as a result of improved comfort and safety provisions which gave an opportunity to attract more passengers. The main ergonomic design is concentrated on-

- Comfort at first sight
- Passenger expectations
- Short-term comfort
- Long-term comfort

"In each phase, the input to the pilots, crew and passengers' senses can be optimized, which leads to new opportunities for comfort improvement. It is important to recognize that not only hardware can improve comfort, but recent research has shown that good ergonomic design, passenger expectations and crew professionalism play a major role in comfort improvement".

Contemporary aircraft manufacturing enterprises aim to deliver better aircraft with special modifications (MODs) and systems through friendly and satisfying working environment. Human-centered design factors, which strongly affect manufacturing process, as well as the potential end-users' are also crucial.

The development of new Aircraft, with special fuselage and tail-fin arrangements, cockpit design and multi-role modifications (MODs) besides addition of special instruments like Windows Glow Control, Dimmable windows, Moving Map, Entertainment with new technologies, safety systems like – 'An-ARC systems', 'Travel Collision Avoidance Systems' is attributed to the advancement of Human Factors as a formal discipline.

5.3 IAI'S Dornier Aircraft

"Dornier Aircraft (Figure 11) stands for a long and successful history in the airplane manufacturing in Indian Aircraft Industries. More than 20 years of experience and continuous technical improvements made Dornier 228 Aircraft as one of the largely proven multipurpose aircraft in operation for both defence and civilian functions."

The existence of high demand for this small Aircraft, especially suitable for Indian environmental and geographical conditions, Indian Aircraft Industries (IAI) has now revitalized its production of Dornier-228, combining with proven Ergonomic and state-of-the-art technology, such as a glass cockpit, 5-blade propeller and digital avionics, in the range of small aircraft. Dornier- 228 is a flexible, reliable and cost-effective airplane applicable to a wide range of special mission and commuter operations in addition to the passenger travel to remote and hilly areas.

Figure 11: Dornier -228 Next Generation Aircraft

Figure 12a: Wind Shield Assembly for Dornier-228 Aircraft

Defence officials, crew and Passengers likes the Dornier 228-212 New Generation aircraft, because of its comfort and spaciousness which is second-to-none compared with aircrafts of similar size, utility and usability. The Doriner-228 can be deployed in passenger and cargo transportation, as an air taxi, for corporate purposes, for aircrew training, maritime surveillance, search and rescue, border patrolling and medical evacuation missions. The seating arrangement inside the aircraft is so flexible, that the aircraft is translatable to suit various operations.

The Doriner-228 NG was built by integrating modern technologies such as a new five bladed composite propeller, advanced Honeywell TPE 331-10 engines, retractable landing gear, dimmable windows, unique TNT wing unit, reduced weight, glass cockpit, digital avionics and displays. IAI carries out aircraft final assembly, payload integration, production compliance inspection and deliveries as per international standards. The important features are-

- wide, light and roomy cabin
- more room for head and shoulders
- low interior noise

Pilots like the Dornier 228-212 New Generation with its coherent and clearly arranged cockpit. Its logical layout of controls and instruments, its modern digital displays make it a pleasure flying. It is designed for both single and dual pilots operations

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Figure 12b: The Seating Arrangement in Dornier 228 Aircraft.

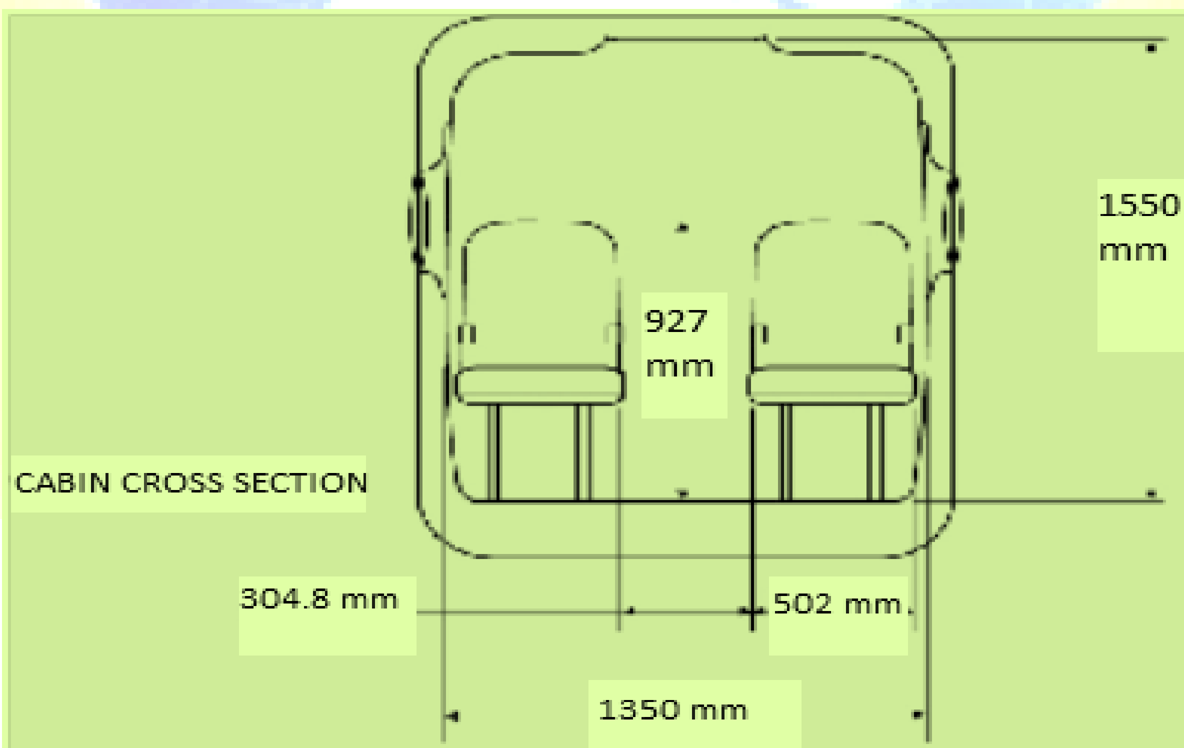

Figure 14: Cabin Cross section for simple seating.

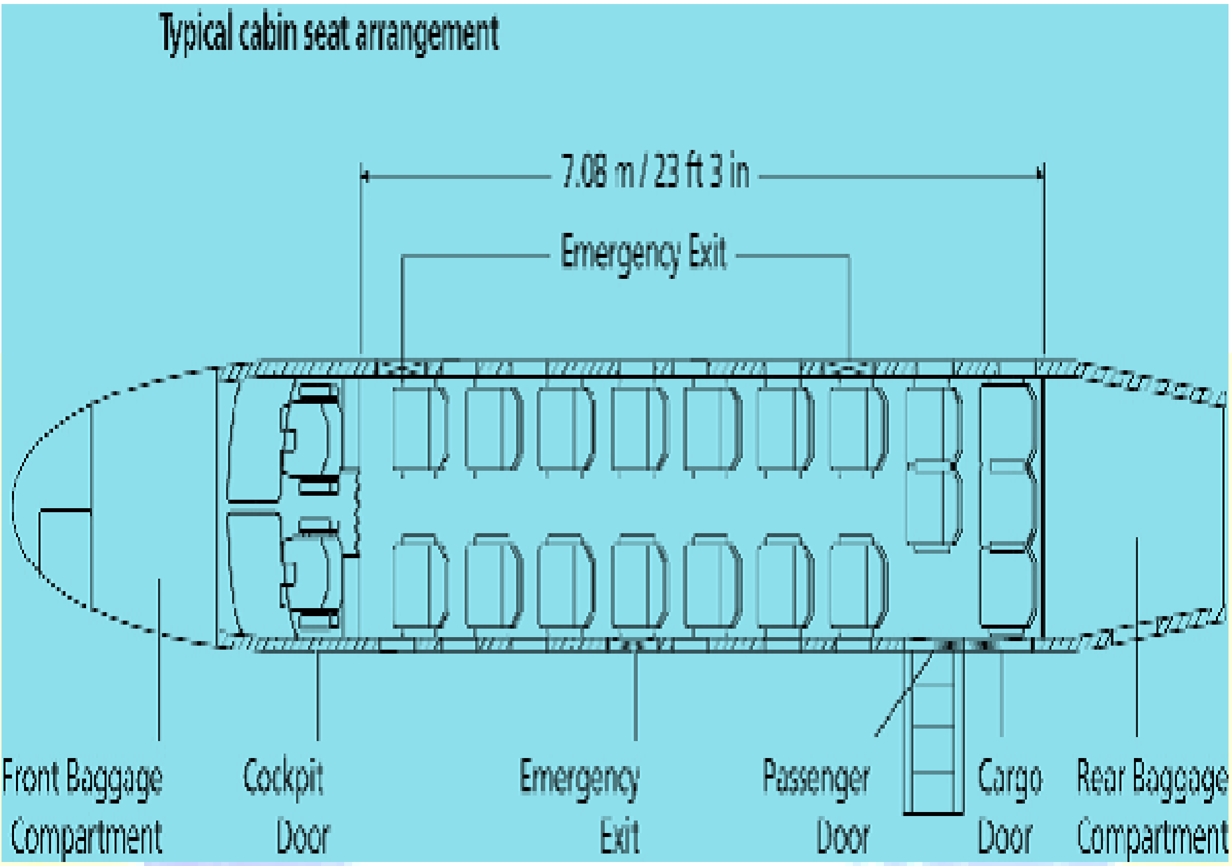

Figure 15: Typical Cabin and Pilot seat arrangements in Dornier-228 Aircraft.

Figure 16: Dornier 228 Aircraft Cockpit arrangement

Figure 17: Arrangement of Cockpit – T Design.

Figure 18: Aerodynamic and Ergonomic body design of Dornier-228 Aircraft

Figure 19: Arrangement of Cockpit – T Design Illuminated

5.4 Comparison with Early Day Aircraft – Fuselage, Tail and Cockpit

“The early generation of flying was based solely on see (visual) and feel (tactile) and was a relatively physical task. Control of the aircraft was solely ‘stick’ and ‘rudder’ and was a manual operation. Therefore Cockpit design was very basic with very few instruments to provide the pilot with information on aircraft and engine performance, cockpits normally consisted of three or four major instruments and controls were provided only for basic flight. Aircraft cabins, interiors and cockpit ergonomic layouts are a typical man-machine interaction in a small space in this small aircraft”. Layouts are designed and evaluated, not only based on the physical relation between the cabin facilities, passenger amenities with-in the aircraft and cockpit facilities, but also from the different types of uncertain linguistic evaluation information.

For these reasons, an evaluation system for the aircraft and its users is a key factor for selecting the optimal ‘layout case’, namely, the most effective, reasonable, and comfortable aircraft layout. The cockpit of an aircraft contains flight instruments on an instrument panel, and the controls, which enable the pilot to fly the aircraft. New Generation aircraft cockpits are reinforced against bullets, and are fortified against access of hijackers.

5.5 Ergonomic Seat Design

The most important part of the Aircraft to ensure human comfort and safety is the seat for passenger and pilot. The current designed seats offer more flexibility than traditional 'pockets,'. Using the concept of the bungee cord the storage area is now comfortably able to carry water bottles, jackets and even kids' toys. The innovative tablet holder also enables the passengers to create their own personal in-flight entertainment system."

5.5.1 Seating Arrangements

Aircraft seating arrangements and interiors with ergonomic design are also a good criteria in present aircraft ensuring comfort. Much focus has gone recently on changing the seat layout. Instead of row upon row all facing forwards, some aircraft now been modified with orientation of seats in a zigzag pattern, or alternate the seats with front/back facing, to give the passengers more leg room.

5.5.2 Flexible seats (Figure 21)

At IAI, designers are exploring even more futuristic concepts for economy class seats. IAI has designed an all-fabric economy seat, with a mechanism that can adjust to the width and shape of individual passengers in real time with licensing agreement with International Seat Manufacturers.

Figure 20: Seating Arrangements

Figure 21: Design for new seating that could change the way seats move back and forward

This flexible conceptual seat is designed by replacing the three traditional foam pads on the seats with a stretched fabric. Underneath are a frame, and a series of moveable formers that allow the seat's shape to change. The fabric is clamped down by the armrests and the upper dividers to form three individual hammock seats.

"Taller passengers have also been accommodated in the new design and all the reclining is done within the space of the seat by stretching the base forwards. The seat back does not move into the knees of the person behind. The ability to position the formers anywhere means a family of three can make one slimmer seat for the child and wider seats for the adults or a couple travelling together can eliminate the middle seat all together". Specific Dornier-228 Aircraft with such changes has been used for transporting various spares along with mechanics and operators in one direction to reach the repair centre and has been used with best seat arrangements for the higher officials travel in other direction.

5.5.3 Pilot Seat

"Aircraft pilots remain seated for an extended period of time, long haul routes are often in excess of sixteen hours. While the importance of seat comfort itself is explanatory, there is also big emphasis on designing a seat that offers sufficient back support (Roskam, 2002)".

The pilot seat design is very important ergonomically and to say that safety of the passengers depends on the said pilot seat design is not very farfetched. 'The best way to reduce pressure in the back is to be in a standing position. However, there are times when one needs to sit. When sitting, the main part of the body weight is transferred to the seat. Some weight is also transferred to the floor, back rest, and armrests. Where the weight is transferred is the key to a good seat design'. When specific areas are not supported, sitting in a seat all day can put unwanted pressure on the back causing pain. 'The seat must be adjustable, because the pilot has to have the best position to look at the instrument panel and also outside on the window. The view should not be blocked'.

5.5.4 Leg Room and Seat Adjustments

The most important area in Aircraft for human comfort is the 'Leg Room', especially on longer flights. Many of the passengers and crew experienced discomfort in the back of legs, which is only amplified when one can't stretch legs because there is simply not enough room. Increased back-pain problems have also been experienced by many of the passengers. Less legroom generally results in higher discomfort ratings.

5.6 Ergonomic Cockpit Design

Ergonomics and human factors concerns are important in the design of modern cockpits. The layout and function of cockpit displays controls are designed to increase pilot situation awareness without causing information overload. In the past, many cockpits, especially in fighter aircraft, limited the leg room for the pilots. Now, cockpits are being designed to accommodate from the 1st percentile female physical size and the 99th percentile male size. In the design of the cockpit in a military fast jet, the traditional "knobs and dials" associated with the cockpit are mainly absent. Instrument panels are now almost wholly replaced by electronic displays which are often re-configurable to save space. While some hard-wired dedicated switches must still be used for reasons of integrity and safety, many traditional controls are replaced by multi-function re-configurable controls or so-called "soft keys" in all the aircraft in IAI, especially in Dornier-228 NG version. Controls are incorporated onto the stick and throttle to enable the pilot to maintain a head-up and eyes-out position – the so called Hands on Throttle and Stick or HOTAS concept.

Cockpit windows are of gel-filled sun shield type. Most cockpits have windows which can be opened when the aircraft is on the ground. Nearly all glass windows in large aircraft have an Anti-reflective coating, and an internal heating element to melt ice. Smaller aircraft are equipped with a transparent aircraft canopy in IAI. The layout of the cockpit, especially in the military fast jet, has undergone standardization, both within and between different aircraft manufacturers and collaborators/ licensing agencies. One of the most important developments was the “Basic Six” pattern, later the “Basic T”, developed from 1937 onwards by the Royal Air Force, designed to optimize pilot instrument scanning and is adopted by IAI with simple modifications.

5.6.1 Pilot Comfort

Humidity and illumination can also affect pilot comfort. Most large aircraft cockpits have a separate environmental control panel for pilots to regulate the ambient temperature. The difference in isolation due to the large windscreens often means that the cockpit will require a different setting than the rear cabin. The illumination on the left and right side of the instrument panel should have the ability to be adjusted independently to suit the individual pilot.

5.6.2 Safety Harness

The main function of the safety harness is to reduce the momentum of the pilot (Jarrett, 2005). The harnesses secure the pilot during turbulence or in emergency situations such as rapid descend or explosive decompression (eg: windscreen failure). For this reason the safety harness must be worn at all times during flight. There are four main types of safety harness (Table-2):

‘Table 2: Safety Harnesses

Lap	Single belt that is wrapped across the waist. This is not an acceptable form of cockpit safety harness as it provides little to no protection across the various planes of motion
Three point harness/ sash	Most commonly found in automobiles, although the three point harness provides good protection along the fore/aft plane. It does not provide adequate protection for lateral and vertical movements the aircrafts are subject to
Four point harness	This is the ideal harness and almost universally used in all modern airliners
Five/six/seven point harness	Similar to the four point harness but with additional straps. This is used extensively in aerobatic aircraft but too cumbersome for airline use

Source: aviationknowledge.wikidot.com'

Most harnesses utilise an inertia reel which consist of a centrifugally operated internal mechanism that allows slow (intentional) movements but locks under quick travel. Most inertia wheels are designed to lock at 1 'g' deceleration and can sustain a short burst of 20 'g' deceleration without breaking (Coombs, 2005).

5.6.3 Display

The display is the presentation of information and can come in the form of visual, aural or tactile. While visual is the main form of display in the cockpit, aural and tactile have their uses too. Aural warnings from the likes of ground proximity warning system (GPWS) or traffic collision avoidance system (TCAS) and tactile warnings such as the stick shaker are powerful aids for the aircraft to communicate and alert the pilot.

5.6.4 Display light and colour

Illumination and colour plays a vital role in instrument displays. Instruments and controls can be lit internally, externally or both. Aircraft designers need to ensure lighting does not create glare or shadows and produce the correct brilliance for day and night operations.

There should then be a way for pilots to fine tune the luminosity to accommodate each individual's light sensitivity. Modern day LCD screens on glass cockpits have a narrower field of vision, however as long as the pilot is seated aligned with the design eye position the display should not interfere with everyday operations (Nagabhushana & Sudha, 2011). The correct use of colour schemes can aid in alerting the pilot if something needs to be bought to attention.

Using too many different colours however may clutter the screen and cause confusion. The main colours used for system monitoring are green (normal), amber (caution) and red (alert or emergency). On the Horizontal Situational Indicator (HSI), the following colours (Table-3) are typically used.

Table 3: Horizontal Situational Indicator – Colour Code

Green	Active or selected mode and/or dynamic conditions
White	Present status situation and scales
Magenta	Command information, pointers, symbols and fly to tracks. Magenta is also used on the weather radar to indicate areas of strong return (ie: possible turbulence/wind shear)
Cyan	Non active and background information
Red	Warnings
Yellow/Amber	Cautions, flags and faults
Black	Blank areas or system off

5.6.5 Ergonomic Instruments & Avionics

The entire suite of displays, autopilot, communication, navigation, surveillance, maintenance, emergency indicator and data management systems are now being ergonomically designed by various manufacturers like Rockwell Collins using advanced technology while maximizing commonality.

Rockwell Collins WXR-2100 Multi Scan Hazard Detection System is the first and only radar system that analyzes and determines actual weather hazards, and just not simply atmospheric moisture content. It is a fully automatic, hands-free airborne radar system with more than four years of proven operational integrity and is one of the most important equipment on Dornier-228 aircraft. This is a safety device incorporated for the total safety of the Aircraft as well as designed with ergonomic considerations for the comfort of the pilots.

The WXR-2100 reduces pilot workload and enhances safety and passenger comfort by minimizing unexpected turbulence encounters, while providing optimal clutter-free weather detection from the nose of the airplane up to a distance of 320 nautical miles ahead, (593 kilometres).

The display system, featuring Rockwell Collins DU-7001 LCD displays, has also now been upgraded to include many of the advanced features, such as an electronic checklist with cursor control panel, navigation performance scales and vertical situation displays. The autopilot and navigation systems have also been enhanced with GPS aided Landing System functionality, providing additional safety to the passengers and crew.

All communication systems including Communication Management Unit, Satellite Communications System, VHF and HF transceivers, VHF Omni directional Radio, Distance Measuring Equipment, Automatic Direction Finder, Multi Mode Receiver, Mode S Transponder, Cockpit Voice Recorder, Flight Data Recorder, Emergency Locator Transmitter, Flight Deck Printer and the Data Management Unit are designed ergonomically for simplicity of operation. Flight instruments are cockpit instruments of an aircraft that provide information for the pilot, such as altitude, speed, wind speed and direction.

5.7 Glass Cockpit

The term "glass cockpit" is synonymous with multi-function displays (MFDs). 'A typical glass cockpit configuration includes up to 6 electronic display units, backup flight instruments (liquid crystal displays or electromechanical instruments) and a few critical systems indicators on the main instrument panel (Billings, 1997)'. "Aircraft systems controls are located on the overhead systems panel. A mode control panel, also called a flight control unit, is located centrally on the glare shield below the windscreens. Other flight management system control units and communications controls are located on the pedestal between the pilots, together with power and configuration controls” (Billings, 1997).

‘A traditional cockpit relies on numerous mechanical gauges to display information, whereas a glass cockpit uses several displays driven by flight management systems that can be adjusted to display flight information as needed and designed with total ergonomic considerations’. This simplifies aircraft operation and navigation and allows pilots to focus only on the most pertinent information. The glass cockpit (MFDs) is pilot friendly and ergonomically far superior to older versions.

5.8 Instruments on Dornier-228

The main instruments on Dornier-228 are Radar altimeter, engine indication and crew alert system, integrated standby instrument system, an enhanced ground proximity warning system, traffic collision and avoidance system and mode-S-transponder. The avionics suite installed in the Dornier-228 includes VHF communication, flight data recorder, cockpit voice recorder, terrain awareness warning system, automatic direction finder, distance measuring equipment, dual horizontal situational indicators, vertical speed indicator and dual altimeters.

Other avionics encompass a Spectrolab SX-16P searchlight, Primus 500 colour weather radar, GEC Marconi's electro optics multi-sensor turret system, Sextant's Totem-3000 internal navigation / global positioning system, the IFF 400AM system and an annotating camera.

5.9 Warning System

Aircraft warnings and alerts serve one or more of the four following functions-

- Alert the crew of a problem
- Describe the nature of the problem
- Direct the appropriate actions
- Provide feedback (is the problem fixed or does it still exist)

'Failures will either be a warning (red) or a caution (amber). A warning indicates that immediate crew action is required or there will be direct consequences to flight safety. A caution is to alert the crew of a failure although no immediate action is required (Nagabhushana & Sudha, 2011)'. Warnings can be presented in visual, aural or tactile form as detailed in display systems. While warnings should draw the attention of the crew immediately, it should not distract the crew from the current main function.

'Modern aircraft systems are integrals of many separate systems which may again be part of another subsystem (Pallett, 1992)'. Although any part of the system has the potential to fail, the workspace constraints make it impractical to situate all the different warnings in prominent view to the pilot. Typically, a master warning and a master caution light is positioned somewhere directly in front of the pilot. Should the master warning or master caution light up, the pilot will have to determine the source of the problem by referring to annunciator panel located elsewhere or on a more modern aircraft opening the relevant pages in the Electronic Flight Instrument System (EFIS).

'The most important aspect of any warning system is that it needs to be reliable and only report genuine problems or malfunctions. The crew must be able to trust the information presented to them, even in situations where it may appear to be contradictory to what is perceived to be happening. False warnings can be detrimental to flight safety. For example, a false engine fire warning may result in an unnecessary in flight engine shut down, creating additional workload on the other engine. This is why with some systems such as the GPWS, it is mandatory by law to report any false alerts which are known as nuisance warnings. The idea of compiling this information is to enhance the reliability of such crucial equipment (Spitzer, 2006)'. Therefore the design of the warning system is crucial for the Human Comfort and safety of crew and passengers in the aircraft.

6. Human Factors influence on cockpit design and Layouts

'The complexity in instruments displaying aircraft systems and performance resulted in high stress levels and error rates. Examples of this were missed signals, misinterpreted information and limited detection and recognition of a number of instruments by the flight crew (Weiner and Nagel, 1988)'.

'Data shows that there was an increasing trend in the number of displays (Instruments & gauges) up until the 1980's where there was a sharp decrease (Wiener & Nagel, 1988)'. 'The reduction of the number of instruments in cockpit designs coincided with the perception and human information processing focus that dominated the Human Factors era in aviation around that same time (Salas and Maurino, 2010)'. It also coincided with the introduction of next generation aircraft such as the Boeing 757/767/777/787, A310/ A320/A380 and small aircraft Dornier 228, 328 and NG. 'In modern next generation cockpits the results of these studies related to Human Factors topics are reflected in design. There is not only a significant reduction in the number of instruments but the display of information in the form of glass cockpits reflects the improved understanding of the human cognitive process and the application to this in design of the systems'. IAI has preferred the Glass Cockpit design for its small aircraft also due to its convenience and acceptance

6.1 Direction

'The direction of controls and levers should operate in the natural sense and also flow with the checks and procedures. It is natural for example, to turn a dial clockwise to increase something and anticlockwise to decrease. In an emergency situation where the pilot is overloaded with information, switches and controls will be operated in an instinctive manner which may be opposite to what the pilot intends to do if it is not designed to operate in the normal sense'.

'IAI's philosophy on switch direction is the 'sweep on' concept, (Figure-22) where all switches on the cockpit sweep/switch on with the arm rising up no matter where the switch is located. Although this is very different compared to the other international majors, single push ON/OFF button operation, the commonality between the two design philosophies is that it is put in place to reduce the chance of inadvertent operation'.

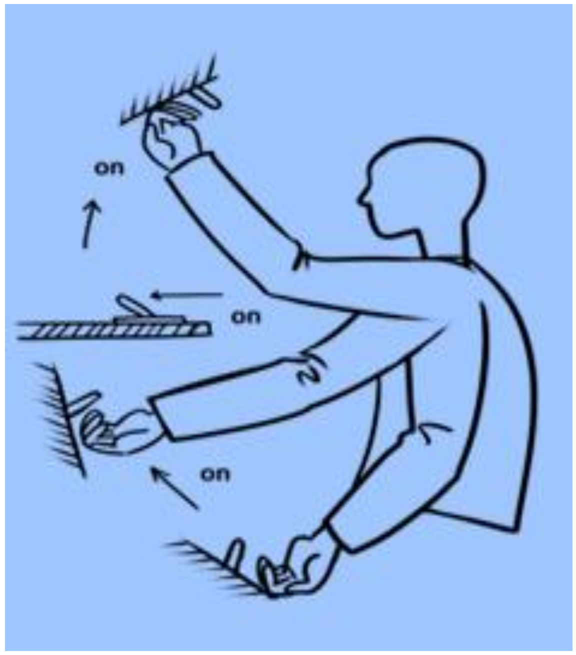

Figure 22: Common Switching Direction

‘The modern, light twin training aircraft has three identical levers for the park brake, cabin heat and cabin defroster situated together forward of the main throttle quadrant. The aft position of lever is to turn the cabin heat and cabin defroster unit OFF but park brakes ON’.

‘There are cases where aircraft have landed with park brakes on (in some cases resulting to a forward flip), the natural tendency for the pilot to line up all the levers would have contributed to the cause of the accidents’. That ergonomic positive design would avoid such problems has been recognized by IAI and hence the ‘Sweep on’ method introduced.

6.2 Standardisation

‘Standardisation is important to avoid unnecessary confusion (Roskam, 2002)’. Although different aircraft manufacturers have their slight differences, generally the layout of controls and gauges are set in the natural sense. ‘Good aircraft type knowledge may not always prevent inadvertent actions but standardised layouts reduce the chances of such errors’. At IAI maximum commonality is ensured with standardised instruments and parts.

6.3 Control Loading

'Control loading is the amount of forced feedback the pilot receives when manipulating the primary flight control. The force feedback must not be too strong such that an average strength pilot will have difficulty in moving the controls, nor too light which will create over controlling problems. The force should be linear and equal between different axes. The force should be strong but sensitive enough for the pilot to appreciate what is happening and provide control responses matching to what is required (Enol, 2012)'.

'On large aircraft with hydraulic systems this can be achieved by manipulating the control feedback motor torque, on aircraft with direct linkage between control and control surfaces, this is achieved by the use of aerodynamic devices such as trim tabs, anti trim tabs and horn balance which manipulate the aerodynamic force exerted on the control surface'.

6.4 Ergonomic Aircraft Work Matting

Ergonomic Aircraft Work Matting (Figure 23) is designed for the mechanics and inspection team, who are to sit or kneel down on hard or unpleasant surfaces for long periods of time. Much thought has gone into making these mats ideal for application in the maintenance and inspection programme of the Aerospace Industry.

Figure 23: Ergonomic Aircraft Work Matting

The IAI's work matting has got following features-

- Built-in Handle
- Hangs up easy to store
- Will not absorb liquids
- Will not compression set-in
- Protects sensitive surfaces and equipment
- Non-conductive surface
- Conforms to irregular surfaces
- Does not disintegrate
- Non-skid surface
- Durable

7. Multiple Attribute Evaluation System of Cockpit Ergonomic Layout

The IAIs cockpit ergonomic layout method has a characteristic of multiple attributes Viz., Pilot, Autopilot, instruments and ejection seat are the main elements, and each has many primary attributes, like body posture, view, muscle strength of pilot, instrumentation and display's principle and display, usage principle of ejection seat, and luminous environment of cockpit visibility, where different main primary attributes also have common primary attributes. The attributes of aircraft and cockpit layout conforming to ergonomic factors are given below-

'Table 4: Evaluation system facing to aircraft & cockpit ergonomic layout.

Main element	**Primary attribute**	**Secondary attribute**
Pilot / Co-pilot	View	Best view performance, comfort, fatigue resistance, efficiency, and so forth.
	Body posture	Comfort, support, regulatory, naturalness, and so forth.

	Body action	Amplitude, strength, speed, beat regulatory, shortest moment vector, simple, and so forth.
	Muscle strength	Intensity suitability, fatigability, comfort, convenience, and so forth.
Passenger	View	Best view performance, comfort.
	Body posture	Comfort, support, regulatory, naturalness, and so forth.
	Body action	Amplitude, strength, speed and so forth
	Muscle strength	Intensity suitability, fatigability, comforts, convenience, and so forth.
Instrumentation and display	Display format	Character, text, image, table, display rate, parameter form, and so forth.
	Display principle	Visibility, clarity, manipulation, functional allocation, control consistency, identification, logic standardization, and so forth.
	Fault emergency and alarm	Obvious, alarm classification, visual presentation, voice alarm, auditory alarm, alarm reminding, and so forth.
Manipulator	Control mechanism	Throttle lever, joystick central control stick, side stick, pedal controller, common used controller, and so forth.
	Control principle	Comfort, convenience, display-control consistency, efficiency, order identification, coordination, and so forth.
Ejection seat	Seat mechanism	Ejection mechanism, support pad, slide rails,

		and so forth.
	Usage principle	Convenience, comfort (dynamic and static), supportive, stationary, and so forth.
Cockpit environment	Luminous environment	Emergency lighting, portable lighting, antiglare, adjustable brightness, color, light distribution, uniformity, standardization, and so forth.
	Colour coating	Patch size, consistency, clarity, plain, indicative, standardization, and so forth.
	Thermal environment	Temperature, humidity, thermal, radiation, suitability, and so forth.
	Active space	Workspace suitability, meeting the demand of dynamic activities, and so forth.
Flight safety	Integrated design	Relationship evaluation of the overall and detail, and so forth.

‘

8. Ergonomic Engines on Dornier-228 NG aircraft

The Dornier-228 is powered by two Garrett TPE-331-5-252D turboprop engines rated at 710hp (533kW) each. The engine is designed and built by Honeywell Aerospace. Less noise and low turbulence are the main ergonomic requirements giving right thrust for flying with reliability. It is equipped with a three-stage axial flow turbine, a reverse annular combustor, dual-stage centrifugal compressor and a four-bladed constant speed ‘Hartzell’ propeller. The engine is 1.1meters long and its diameter is only 0.53meters. The dry weight is only 153kg and is the specific design for Dornier-228 aircraft. The time between overhaul of the engine is 2,000 hours.

The twin engines of 710 HP each are ergonomically selected and are helpful in smooth functioning during ‘taxiing’ and also ‘in flight’ mode. Now the new version, the NG version has the newer Honeywell TPE331-10 engines in the current Indian model, which are 25 percent more powerful than the Honeywell Garrett TPE-331-5-252D engines, as also a modern glass cockpit and five blade composite propellers. The new propellers are lighter and smaller in diameter, thereby reducing noise and adding to the safety factors.

The NG aircraft is a twin turbo-prop aircraft with advanced technologies in design and production which is highly fuel-efficient, rugged, reliable, and has been developed specifically to meet the manifold requirement of various roles for military, paramilitary and civil operators.

Functional versatility with low operating cost makes Dornier-228 of IAI adaptable for a wide variety of roles including Commuter, Utility, Corporate, Aircrew Training, Maritime Surveillance, Search & Rescue and for Observation & Communication duties.

8.1 Performance

The Dornier-228 can climb at the rate of 9.5m/s. The never-exceed and maximum speeds of the aircraft are 470km/h and 433km/h respectively. The cruise speed is 315km/h. The stall speed is 148km/h. The range and service ceiling of the aircraft are 1,037km and 8,534m respectively. These parameters are well with-in comfortable ranges in line with Human Factor’s Engineering.

The propeller has a ‘wooden core and a surface consisting of multiple fibre composite layers’. IAI expects this to allow the engine to start quicker and the narrow diameter blades to reduce vibration and noise. The company also says the aircraft’s fuel consumption of 5.41 litres is good for 100 passenger kilometres. “One very simple thing,” the IAI expert says “With the five-bladed propeller, the diameter’s less, so ... have more freedom with the floor in terms of ground clearance. The ground clearance is better, its better for take-off or landing on gravel, and also on unpaved runways.” Unfortunately, to borrow another cliché, the dream frequently turned into a nightmare as years of manufacturing delays, teething issues, and those pesky unexplainable battery fires took a toll. These problems, along with others, contributed to an entry into service with the new technologies four years behind schedule. A few modern airlines suffered from such a long and troubled gestation period. However, the ergonomic design has seen the light of the day.

It is pertinent to mention that formerly aircraft manufacturers had to travel the world to locate various suppliers to shop for seats, lavatories, galleys, IFE (in-flight-entertainment systems), carpeting, etc. For the first time, IAI has achieved ergonomic standardization through knowledge sharing and all these options are now made available under 'one roof' through Supply Chain Management integration.

9. Conclusion

Aircraft Cabin and Cockpit design with engines, instruments and other equipment have been analysed in detail with the aim of passenger safety and security, along with human comfort. 'The basic layout had an overcrowded cockpit, due to the introduction of many instruments and gauges for the purpose of providing information to the pilot regarding the performance of the aircraft. This however also resulted in high stress levels and a high error rate due to the lack of the human capability to process all this information simultaneously'.

'Advanced ergonomic studies relating to the human cognitive process and attention and memory limitations, culminated in special research world-wide, resulting in new systems, methods and designs. Cabins, seats and cockpits were designed to better suit the crew and passengers. Increased window sizes, window arrangements, dimmable windows, cabin pressure adjustment, airflow- adjustments, and reduced number of instruments in the cockpit, the use of the Glass Cockpit and the display of information on these screens are amongst many other things that have been introduced in the recent years with a lot of innovation by IAI'.

It is inevitable that aircraft layout and design will change, but it is important that this change should be concurrent with Human Factors research which best suits the human operators and their limitations and capabilities. The future aircrafts design will have an advanced glass cockpit with greater ergonomic emphasis than the current design. At IAI every day is for innovation, and the new innovative, ergonomic friendly designs will have better visibility, inside and outside, and they will be more comfortable for every person either operating or using the aircraft.

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