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Design Review of Aircraft Cockpit for Aesthetic and Ergonomic Considerations

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Abstract: ***This review presents the design of aircraft cockpit for aesthetic and ergonomic consideration. With projections indicating an increase in mobility over the next few decades and annual flight departures expected to rise to over 16 billion by 2050, there is a demand for the aviation industry and associated stakeholders to consider new forms of aircraft and technology. Customer requirements are recognized as a key driver in business and hence aesthetic and ergonomic factors play a key role. The goal of this design review is to express the role of aesthetic and ergonomic in aircraft design.***

Keywords: Aircraft, Design, Cockpit, Aesthetic, Ergonomic, Solar Impulse

1. Introduction

Although industrial and product designers are keenly aware of the importance of design aesthetics, they make aesthetic design decisions largely on the basis of their intuitive judgments and _educated guesses'. Whilst ergonomics and human factors researchers have made great contributions to the safety, productivity, ease-of-use, and comfort of human-machine-environment systems, aesthetics is largely ignored as a topic of systematic scientific research in human factors and ergonomics. Decision making in design is crucial to arriving at viable and worthwhile cabin formats. Too little innovation will result in an aircraft manufacturer and airlines using its products falling behind its competitors, possibly with already antiquated technologies at the point of release. Too much may result in an over-extension, for example the use of immature technologies that do not have the necessary reliability for a safety critical industry. In a fast paced technology sector, adaptability to projected new technologies is important.

Now a days lot of importance is given for human comfort and the way of living. From design and associated decision making perspectives, optimization tends to preclude strategies that deliver high quality results in consumer scenarios whereas win-win solutions may present challenges in complex technical environments. The motto of customer satisfaction is viral in today's world and hence this design review is necessary.

2. General terms and definitions

Cockpit: Aircraft cockpit is the area where an aircraft pilot controls the airplane. Usually this area is located in front of the plane. From the cockpit, the aircraft is controlled on the ground and in the air. Most modern cockpits are enclosed, except on some small aircraft, and cockpits on large airlines that are physically separated from the cabin. Term cockpit appeared for the first time in 1914. The cockpit of an aircraft contains flight instruments on an instrument panel, and the control, which enable the pilot to fly the aircraft. In nowadays the airlines cockpit are reinforced against bullets, and are fortified against access of hijackers.

Aesthetics
The term 'aesthetics' concerns our senses and our responses to an object. If something is aesthetically pleasing to you, it is 'pleasurable' and you like it. If it is aesthetically displeasing to you, it is 'displeasurable' and you don't like it. Aesthetics involves all of your senses - vision, hearing, touch, taste, and smell - and your emotions. It is concerned with how things look. The appearance of an object is the feature that people notice first [1].

Ergonomics
Ergonomics is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance**.** Ergonomics is a design factor which is of critical importance. It is the understanding of interactions among humans and other elements of a system[1].

3. Aesthetic consideration in design

There are four different 'pleasure types' to consider:

Physio-pleasure - pleasure derived from the senses from touch, smell, sensual pleasure etc. For example the smoothness of a curve in a hand-held product or the smell of a new car[2]

Socio-pleasure - pleasure gained from interaction with others. This may be a 'talking point' product like a special ornament or painting, or the product may be the focus of a social.
gathering such as a vending machine or coffee machine. This pleasure can also come from a product that represents a social grouping, for example, a particular style of clothing that gives you a social identity.

Psycho-pleasure - pleasure from the satisfaction felt when a task is successfully completed. Pleasure also comes from the

extent to which the product makes the task more pleasurable, such as the interface of an ATM cash machine that is quick and simple to use. It is closely related to product usability.

Ideo-pleasure - pleasure derived from entities such as books, art and music. This is the most abstract pleasure. In terms of products, it is the values that a product embodies, such as a product that is made of eco-friendly materials, and processes that convey a sense of environmental responsibility to the user.

Each of these pleasures should be considered in turn - their importance to the product you are designing, and how each aspect might show itself in that product[2]

Each product is to be designed to perform a specific function or a set of functions to the satisfaction of customers.

The parameters that are normally considered by the customer while selecting the product are:

1) Functional Performance
2) Durability
3) Initial and Running Costs
4) Ability to Withstand Adverse Conditions
5) Service Support Available
6) Comfort to User
7) Appearance

In a present days of buyer's market, with a number of products available in the market are having most of the parameters identical, the **appearance of product** is often a major factor in attracting the customer. This is particularly true for consumer durables like: automobiles, domestic refrigerators, television sets, music systems, etc.

Appearance *is an outward expression of quality of the product and is the first communication of the product with the user.*

At any stage in the product life, the aesthetic quality cannot be separated from the product quality.

The growing importance of the aesthetic considerations in product design has given rise to a separate discipline, known as ‗industrial design'. The job of an industrial designer is to create new shapes and forms for the product which are aesthetically appealing.

3.1 Guidelines in Aesthetic Design

For any product, there exists a relationship between the functional requirement and the appearance of a product.
The aesthetic quality contributes to the performance of the product, though the extent of contribution varies from the product to product.

For example, the chromium plating of the automobile components improves the corrosion resistance along with the appearance. Similarly, the aerodynamic shape of the car improves the performance as well as gives the pleasing appearance.

The following guidelines may be used in aesthetic design (design for appearance):

1) The appearance should contribute to the performance of the product. For example, the aerodynamic shape of the car will have a lesser air resistance, resulting in the a lesser fuel consumption.
2) The appearance should reflect the function of the product. For example, the aerodynamic shape of the car indicates the speed.
3) The appearance should reflect the quality of the product. For example, the robust and heavy appearance of the hydraulic press reflects its strength and rigidity.
4) The appearance should not be at too much of extra cost unless it is a prime requirement.
5) The appearance should be achieved by the effective and economical use of materials.
6) The appearance should be suitable to the environment in which the product is used.

3.2 Aspects of Aesthetic Design

The various aspects of the aesthetic design, which are discussed below, are also related to: functional requirements, ergonomic considerations, manufacturing considerations, assembly considerations and cost, in addition to the aesthetic considerations

1) Form (Shape)
2) Contrast
3) Symmetry and Balance
4) Color
5) Impression and Purpose
6) Style
7) Material and Surface Finish
8) Noise

3.3 Elements of Aesthetics

There are many different things that contribute to your overall perception of a product, and to your opinion as to whether it is aesthetically pleasing to you.

- Vision
- Hearing
- Touch
- Taste
- Smell

Opinion about a product may also be influenced by certain associations that are important to you, such as: • how fashionable it is • whether it is a novelty, or an old favorite • whether it is a symbol of wealth or love • how much danger or risk is involved • if it provides a link with your past. You might also take into account whether it is safe and reliable and fit for its purpose. Consistency with a particular aesthetic concept may be a significant factor in creating a product's appeal too, for example, the current appreciation of 'retro' designs. However, such trends are often cultural and almost certainly always short-lived, so their popularity can't be guaranteed.

4. Aesthetics in Cockpit Design

Figure 1: Cockpit

The first airplane with an enclosed cabin appeared in 1913 on Igor Sikorsky's airplane The Grand. However, during the 1920s there were many passenger aircraft in which the crew was open to the air while the passengers sat in a cabin. Military biplanes and the first single engines fighters and attack aircraft also had open cockpits into the Second World War. The very early generation of flying was based solely on see (visual) and feel was a relatively physical task.

4.1 Dashboard

The dashboard design was very basic with very few instruments to provide the pilot with information on aircraft and engine performance. But, during the war, pilot had to fly without visual clues, such as at night or in cloud. So it became necessary to increase the instruments in aircraft and also improve the design. A study performed by Gannon in 2005 tested the impact of the visual appeal of different primary flight display "skins" in a series of simulated instrument on 24 pilots. Gannon identified a linkage between aesthetics and pilots workload according to which there was significantly lower overall workload associated with the most attractive one, and vice versa. Gannon's test did not find any linkage between aesthetics and performance.

4.2 Cabin lights and Ambience

Airliner cockpit lights are mainly bright white lights. However, during night flights we keep the lights turned off and use only the instrument back lights to keep an eye on them. Once on ground we turn the lights back on. To allow pilots to read check lists each one of them have their own reading light together with a map view light. The intensity of these two lights can be adjusted from very dim to very bright. The electronic instrument displays[3]are also fully adjustable in terms of their brightness. White light does affect your night vision but as most airliners fly IFR, a visual view of the things outside the aircraft is not a necessity for maneuvering. We fly completely relying on instruments right up until we turn to the finals. Then what you see is of course a brightly lit runway. Airliners also have storm lights which floods the cockpit instruments in case you are flying in a thunderstorm where a sudden burst of lightening could blind you for a while. In GA aircraft red cockpit lights are quite important though. With their limited instrument capability and flights which are mostly VFR, a constant white light could easily make it difficult for a pilot to keep an eye on what is happening in the outside environment. These lights make perfect working environment for pilot[4]

Figure 2: Dashboard in 1990's

Figure 3: Dashboard in 2016

5. Ergonomic Consideration in Design

In engineering, design is a component of the engineering process. Many overlapping methods and processes can be seen when comparing Product design, Industrial design and Engineering. Ergonomics is employed to fulfill the two goals of health and productivity. It is relevant in the design of such things as safe furniture and easy-to-use interfaces to machines. Proper ergonomic design is necessary to prevent repetitive strain injuries, which can develop over time and can lead to long-term disability. Ergonomics is concerned with the _fit' between people and their technological tools and environments. It takes account of the user's capabilities and limitations in seeking to ensure that tasks, equipment, information and the environment suit each user.

According to the International Ergonomics Association:

- Physical ergonomics: is concerned with human anatomical, and some of the anthropometric, physiological and bio mechanical characteristics as they relate to physical activity;
- Cognitive ergonomics: is concerned with mental processes,

such as perception, memory, reasoning, and motor response, as they affect interactions among humans and other elements of a system. Relevant topics include mental workload, decision-making, skilled performance, human computer interaction, human reliability, work stress and training as these may relate to human system and Human-Computer Interaction design;

- Organizational ergonomics: is concerned with the optimization of socio technical systems, including their organizational structures, policies, and processes. Relevant topics include communication, crew resource management, work design, design of working times, teamwork, participatory design quality management[5]

5.1 Areas Covered Under Ergonomics

The different area covered under the ergonomics are:

1) Communication Between Man (User) and Machine;
2) Working Environment;
3) Human Anatomy and Posture While Using the Machine; and
4) Energy Expenditure in Hand and Foot Operations.

5.2 Communication between Man (User) and Machine

- Figure 4 shows the man-machine closed loop system. The machine has a display unit and a control unit.
- A man (user) receives the information from the machine display through the sense organs.
- He (or she) then takes the corrective action on the machine controls using the hands or feet.
- This man-machine closed loop system in influenced by the working environmental factors such as: lighting, noise, temperature, humidity, air circulation, etc.

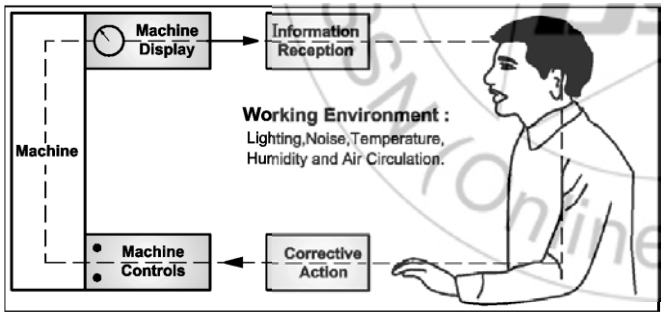

Figure 4: Man-Machine closed loop system

6. Ergonomics in Cockpit Design

The layout of the cockpit, especially in the military fast jet, has undergone standardization, both within and between aircraft different manufacturers and even different nations. 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.

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 size of the pilots that could fit into them. 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 themselves 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". 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

The layout of control panels in modern airliners has become largely unified across the industry. The majority of the systems-related controls (such as electrical, fuel, hydraulics and pressurization) for example, are usually located in the ceiling on an overhead panel. Radios are generally placed on a panel between the pilot's seats known as the pedestal. Automatic flight controls such as the autopilot are usually placed just below the windscreen and above the main instrument panel on the glare shield. Most modern cockpit will also include some kind of integrated warning system.

6.1 Display

Displays *are the devices through which the man (user) receives the information from the machine.* A good display device is one which allows the proper combination of speed, accuracy and sensitivity of display.

Figure 5: Dashboard Displays

The basic objective in the design of the displays is to minimize the fatigue to the user. The ergonomic considerations in the design of the displays are as follows:

1) The scale should be clear and legible.
2) The size of the numbers or letters on the scale should be taken such that,

$$\text{Height of the number or letter} \geq \frac{\text{Reading distance}}{200}$$

6.2 Controls

Controls *are the devices through which the man (user) conveys his instructions to the machine.*

All the controls should be in human reach. The information on display should be large enough for easy view from the rest position of pilot. Controls which are required repeatedly should be placed near and vice versa[6]

Selection of control devices :
The type and size of the control device selected for a given application depends upon the following factors :
1) The required speed of operation;
2) The required accuracy of the control;
3) The required range of the control;
4) The required direction of the control;
5) The convenience of the user..

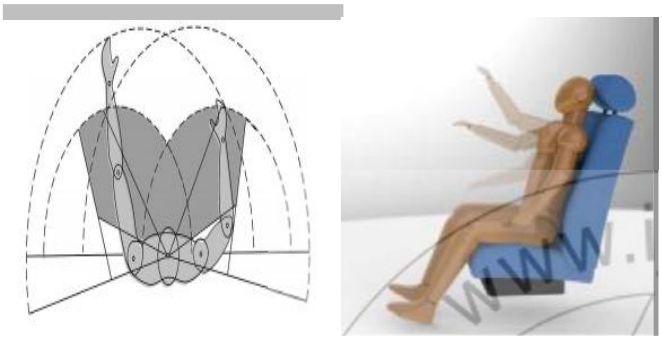

Figure 6: Human Reach

In most cockpits the pilot's control column or joystick is located centrally (centre stick), although in some military fast jets and in some commercial airliners the pilot uses a side-stick (usually located on the outboard side and/or at the left) windows

Figure 7: Joystick

The ergonomic considerations in the design of the controls are as follows:
1) The control devices should be logically positioned and easily accessible.
2) The control operation should involve minimum and smooth moments.
3) The control operation should consume minimum energy.
4) The portion of the control device which comes in contact with user's hand should be in conformity with the anatomy of human hands.
5) The proper colours should be used for control devices and backgrounds so as to give the required psychological effect.
6) The shape and size of the control device should be such that the user is encouraged to handle it in such a way as to exert the required force, but not excessive force.

6.3 Working Environment

The working environment affect significantly the man-machine relationship. It affects the efficiency and possibly the health of the operator. The major working environmental factors are:
1) Lighting,
2) Noise,
3) Temperature,
4) Humidity and Air Circulation.

6.3.1 Lighting

The amount of light that is required to enable a task to be performed effectively depends upon the nature of the task, the cycle time, the reflective characteristics of the equipment involved and the vision of the operator. Codes of practice are available that recommend the amount of light necessary for a certain task. The intensity of light in the surrounding area should be less than that at the task area. This makes the task area the focus of attention.

Operators will become less tired if the lighting and colour schemes are arranged so that there is a gradual change in brightness and colour from the task area to the surroundings. The task area should be located such that the operator can occasionally relax by looking away from the task area towards a distinct object or surface. The distinct object or surface should not be so bright that the operator's eyes take time to adjust to the change when he or she again looks at the task. Glare often causes discomfort and also reduces visibility, and hence it should be minimised or if possible eliminated by careful design of the lighting sources and their positions [7]

6.3.2 Noise

The noise at the work place cause annoyance, damage to hearing and reduction of work efficiency. The high pitched noises are more annoying than the low pitched noises .Noise caused by equipment that a person is using is less annoying than that caused by the equipment, being used by another person, because the person has the option of stopping the noise caused by his own equipment, at least intermittently. The industrial safety rules specify the acceptable noise levels for different work places. If the noise level is too high, it should be reduced at the source by maintenance, by the use of silencers and by placing vibrating equipment on isolating mounts.

Further protection can be obtained by placing the sound-insulating walls around the equipment. If required, ear plugs should be provided to the operators to reduce the effect of noise. Noise caused by equipment that a person is using is less annoying than that caused by the equipment, being used by another person, because the person has the option of stopping the noise caused by his own equipment, at least intermittently. The industrial safety rules specify the acceptable noise levels for different work places. If the noise level is too high, it should be reduced at the source by maintenance, by the use of silencers and by placing vibrating equipment on isolating mounts. Further protection can be obtained by placing the sound-insulating walls around the

equipment. If required, ear plugs should be provided to the operators to reduce the effect of noise.

6.3.3 Temperature

For an operator to perform the task efficiently, he should neither feel hot nor cold. When the heavy work is done, the temperature should be relatively lower and when the light work is done, the temperature should be relatively higher. The optimum required temperature is decided by the nature of the work. The deviation of the temperature from the optimum required reduces the efficiency of the operator.
Due to weight restriction the cockpit is not pressurized, so there is complete oxygen and backup system to allow pilots to breathe above 3000m. In order to protect the pilot from extreme cold temperature at maximum altitude, the cockpit shell is made of high density thermal insulation developed by Bayer material science. At 8500m above sea level, the air temperature can be as low as -40 degrees and with this insulation the cockpit temperature should not drop below -20 degree. The pilot still needs specific clothing to protect him at these temperature.

6.3.4 Humidity and Air Circulation

Humidity has little effect on the efficiency of the operator at ordinary temperatures. However, at high temperatures, it affects significantly the efficiency of the operator.

At high temperatures, the low humidity may cause discomfort due to drying of throat and nose and high humidity may cause discomfort due to sensation of stuffiness and over sweating in a ill-ventilated or crowded room. The proper air circulation is necessary to minimize the effect of high temperature and humidity [7]

6.4 Pilot Seats

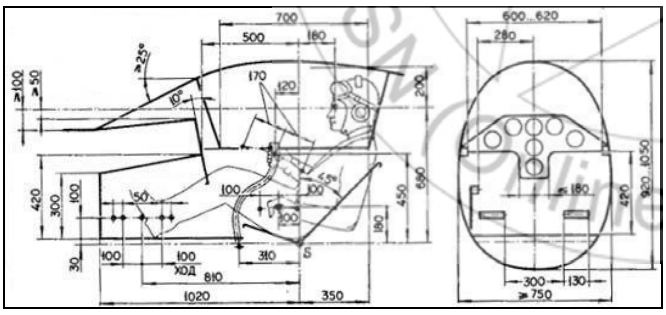

Figure 8: Standard Measurements

The cockpit is easy to use because its designed in a ergonomic matter everything is within reach it offers him the possibility to be in the flight position and have access to all of the controls and it also offers him the flexibility to return into a resting position and be comfortable within the cockpit. The pilot can take any position from the flight position which 90 degree and allows him to control of the airplane and recline the seat all the way down to 180 degree[8]Where he can take the resting position and he can also take any position in between if he wants to relax monitor the controls and the many position allow him to do flight, relax or to do exercise resting and access to more difficult to reach areas within the cockpit.

The pilot seat was developed by lantal textiles including both ergonomic function such as an adjustable cushion to give the pilot back support and safety function including a built in parachute and life raft. Below the seat is a toilet that consists of removable bags giving the pilot, some level of relief during the long stages of flight[9]During the flight when your seating for 5 days and 5 nights, you lose muscle atrophy, you lose strength, you lose blood circulation, joints get stiff and yoga become an absolute life saver to keep them completely active as one person is in walking and going around doing things. Yoga just in that confined space, we have enough to move every muscle every part of the body and keeping them in good shape.

Pilot stays in contact with the mission control centre using the swisscom.sat.com system. The team there monitor the pilots vital signs such as his heart rate and use alertness tests to check that he is coping with the mental fatigue from flying for so long.

Rest breaks are possible due to solar impulse‘s monitoring [10]and alerting system an innovation from partner Altran that keeps the aircraft on a constant heading. While the pilot takes 20 min periods of sleep. If pilot needs to tend to the controls, he is awoken using vibrating cuffs built into the arms of his flying suit. Cockpit windows may be equipped with a sun shield. 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 may be equipped with a transparent aircraft canopy.

Future Scope

DSI has pushed its NASA SATS research in several dirctions Mostly as part of its Assured Aviation Web Services product, one of the key components in creating the airborne internet.

The company partnered with Microsoft Corporation to create the Connected Cockpit of the Future, which has the potential to make flying an aircraft as safe, easy, affordable, and connected as driving a car, but without all of the headaches and traffic problems found on today‘s highways. The Connected Cockpit of the Future is built on a Microsoft platform, allowing it to extend and embrace third-party applications through a new, aviation-grade communication standard that allows multiple applications to collaborate and share information.

Thales Avionics 2020 it‘s the future of aircrafts, with feature as finger print access, bullet proof glass, 4d trajectories, multi touch LED display.

Conclusion

Cockpit design and layout started from very basic which advanced to an overcrowded cockpit. It results in high stress levels and high error rate. As a results of the research carried out, cockpit were designed to better suit the human operator. Therefore the use of glass cockpit and display will reduce the number of instruments.

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