Design Modelling Test for R80's aircraft Flight Deck with Human Digital Ergonomic Factors (HDEF)

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ABSTRACT
To ensure the human/pilots and machines work together effectively in the aviation system, the airframers and equipment supplier should be focused their attention on reducing the complexity of aircraft technology by putting forward explicitly the "aircraft design philosophy" as a primary an outline of the top-level operational and Human Factors (HF) design principles that will dictate the design of the FlightDeck / Cockpit or the modification of a system in the Flight Deck. Most of the time the aircraft's Flight Deck is equipped with Man-Machine-Interface (MMI) to operate the aircraft. The advent of touch screen type to simultaneously Control & Monitoring (C&M) has a positive implication, e.g. pilot or operator just see or watch in one certain area display. However, the repetitive eye movement along with hands to touch the display into the same display location tends to bring awkwardness. In addition, the repetition of tasks in the same location will be brought fatigue in long-term operational aircraft scenarios. To avoid the awkward & fatigue sourcing from those touch-screen control & display, it obviously needs to model the test of operational display C&M with respect to Human Digital Engineering Factor (HDEF).

Keywords: *Human Factors, FlightDeck/Cockpit, Man-Machine-Interface, Control & Monitoring, awkward, fatigue*

1. INTRODUCTION

FAA report shows the rate of accidents and incidents in both commercial and general aviation (GA) is steady from 2001 through 2005, even though it already decreased significantly in the period 1990 through 2000. For these reasons, FAA investigates to identify the causal problems by using theory namely Human Factors Analysis and Classification System (HFACS). By analyzing the underlying human causes of both commercial and general aviation (GA) accidents FAA identifies general trends of human factors issues and aircrew error that contributed to civil aviation accidents. Thereafter FAA can identify the exact nature of the human errors that significantly caused the accidents. Based on the individual human causal factors associated with the accidents, FAA generates intervention programs such as training, reviewing the cockpit operation, and making an approach to diminish the causal[1]. In general, the error category known by HFACS expanded to three basic error types such as decision, skill-based and perceptual errors. Boeing 737-8 MAX accidents flight number ET-302 in 2018 in Ethiopia and Miami Air Flight 293 slipped off the runway and crashed into the rive St. John [2] have triggered the automation evaluation in the cockpit aircraft [3]. Referring to analyzing of the automation implementation in the cockpit, it concluded that automation creates new problems when its design is too complex, poorly designed, lacks functionality, fails to perform according to the pilot's expectations, does not control the aircraft the way pilots do, not standardized, poorly integrated, or poorly documented. Trend accident in cockpit automation has already been investigated by [4] who say the primary purpose of cockpit automation is to enhance aviation safety and efficiency in aircraft operation by reducing pilot workload. Thereafter the conclusion state that cultural differences as part of crew resource management (CRM) have been found as influencing factors in cockpit operation in addition to informational resource/support as CRM is the sharing of knowledge and best practices to reduce errors and incidents. More or less the cultural differences significantly influence to the design philosophy of the aircraft design and mission.

Reflecting to the significant differences between the design philosophies of the two manufacturers, Boeing and Airbus, it is in the area of envelope protection [5]. The table below compares the Airbus VS Boeing's Flight Deck Design Philosophies.

Table 1 High Level Flight Deck Design Philosophies [5]

No.	Airbus	Boeing
1	The pilot is ultimately responsible for the safe operation of the aircraft. He has final authority with adequate information and means to exercise this authority	The pilot is the final authority for the operation of the airplane.
2	The design of a cockpit is dictated by safety, passenger comfort, and efficiency in that order of priority.	Flight crew tasks, in order of priority, are: safety, passenger comfort, and efficiency
3	The design of a cockpit accommodates for a wide range of pilot skill levels and experience acquired on previous aircraft.	Design for crew operations based on pilots' past training and operational experience.
4	The automation is considered as a complement available to the pilot, who can decide when to delegate and what level of assistance is desirable, according to the situation.	Apply automation as a tool to aid, not replace the pilot.
5	The human machine interfaces are designed considering system features, together with pilot's strengths and weaknesses.	Address fundamental human strengths, limitations, and individual differences – for both normal and non-normal operations.
6	The use of new technologies and implementation of new functionalities are dictated by: • Significant safety benefits • Obvious operational advantages • A clear response to a pilot's needs	Use new technologies and functional capabilities only when: • They result in clear and distinct operational or efficiency advantages, and • There is no adverse effect to the human machine interface.
7	State of the art human factors considerations are applied in the system design process to manage the potential pilot errors.	Design systems to be error-tolerant.
8	The overall cockpit design favors crew communication.	Both crew members are ultimately responsible for the safe conduct of the flight.
9	The cockpit design aims at simplifying the crew's task by enhancing situational and aircraft status awareness.	The hierarchy of design alternatives is: simplicity, redundancy, and automation.
10	The full authority, when required, is obtained with simple intuitive actions, while aiming at eliminating the risks of overstress or over control.	

Airbus' philosophy has led to the implementation of what has been described as "hard limits", where the pilot provide whatever control inputs he or she desires, but the airplane will not exceed the flight envelope. In contrast, Boeing has "soft limits" [6], where the pilot will meet increasing resistance to control inputs that will take the airplane beyond the normal flight envelope, but can do so if he or she chooses. In either case, it is important for the pilot to understand what the design philosophy is for the airplane being flown. Different philosophies can be effective when each is consistenly applied in design, training and operations, and if each supports flight crew members in flying their aircraft safely. To ensure this effectiveness, it is critical that the design philosophy be documented explicitly and provided to the pilots who will be operating the aircraft, the trainers and the procedure developers.

The purpose of Flight Deck Philosophy document is to provide for the designers with a referential basis for developing a new flight deck or implementing modifications. It provides guidance during the generation of design concepts and implementation principles to ensure consistent HMI – Human-Machine-Interface, HCI – Human-Computer-Interface and operations. It serves an important bridge to be applied to future modifications of existing designs to facilitate consistency with the current flight deck concept.

R80's aircraft flight deck design concept and philosophy describe below.

2. FLIGHT DECK DESIGN PHILOSOPHY

Definition Flight Deck Design Philosophy

The Flight Deck Philosophy is primarily an outline of the top level operational and Human Factor design principles that will dictate the design of the flight deck or of the modification of a system in the flight deck. As such, it should list the objectives of the design:

- in terms of the needs of the flight crew and their main tasks of aviating, navigating,
- communicating and managing aircraft systems;
- in terms of possible strategic choices of the manufacturer/provider;
- in terms of the airspace environment constraints existing and expected, that the design will have to take into account.

The overall goal is to define the design concept that will fulfill the above objectives for the flight deck layout, flight controls, automation, as well as the alerts and alarms.

Components of the Flight Deck Design Philosophy

The Top Level Operational and Human Factor related design principles should address, among others, the following essential topics:

1) Pilot or flight crew responsibility,
2) Physical Authority of the pilot,
3) Pilot or flight crew characteristics,
4) Automation,
5) Use of new technology and functionality,
6) Addressing Human error,
7) Communication,
8) Design priorities, and
9) Designing for Crew task simplification.

Design Priorities

Factors that dictate the design and/or modification of flight decks or systems to support flight crew tasks in order of priority are: safety, passenger comfort, and efficiency.

Designing for Crew Tasks Simplification

Simplification of the flight crew's task is achieved by designing for system simplicity, redundancy, or automation, in that order. The guidelines or principles are:

- Simplify panel design,
- Simplify the crew's taks by enhancing situational and aircraft status awareness,

- De-clutter and remove data not requires for crew decision-making procedures inflight,
- Provide centralized, prioritized crew alerting system.

R80 Flightdeck Design Philosophy - INITIAL

Some key factors affect Flightdeck designers for Commercial Aviation as follows:

1. Global Requirements:
   - Reduction of Aviation accident rate
   - Definition of Future Airspace Operations
   - Expectations of a Future Pilot Corps that will grown up with Computers
   - Flight Crew Workload as minimum as possible
   - Minimum time required for Training
2. Specific Requirements:
   - Pilot role and responsibilities augmented by Flight Computer
3. Observable factors in the Aviation Environment for Future Flight Deck are:
   - Pilot-centered Flight Deck Systems,
   - Expected advances in Technology that are being driven by other than Aviation Requirements,
   - Revolutionary Flight Deck configuration changes with development of humancentered
   - Flight Deck design methodologies that take full advantage of commercial and/or entertainment-driven technologies.
   -

The proposed R-80 Flight Deck Philosophy based on Crew-Centered Philosophy as follows:

1) The pilot is the final authority for the operation of the airplane.
2) Flight crew tasks, in order of priority, are: Safety, Passenger comfort and efficiency.
3) Apply automation as a tool to aid, not replace, the Pilot.
4) Address fundamental human strengths, limitations and individual differences – for both normal and non-normal operations.
5) Use new technologies and functional capabilities only when:
   a. They result in clear and distinct operational or efficiency advantages, and
   b. There is no adverse effect to the human-machine interface.
6) Design systems to be error-tolerant.
7) Both crew members are ultimately responsible for the safe conduct of the flight.
8) The hierarchy of design alternatives is: Simplicity, Redundancy and Automation.
9) Design for crew operations based on Pilot's past training and Operational
10) Experience.
11) The combined Pilot and Flight Deck System performance is met overall Flight
12) Safety and Efficiency.

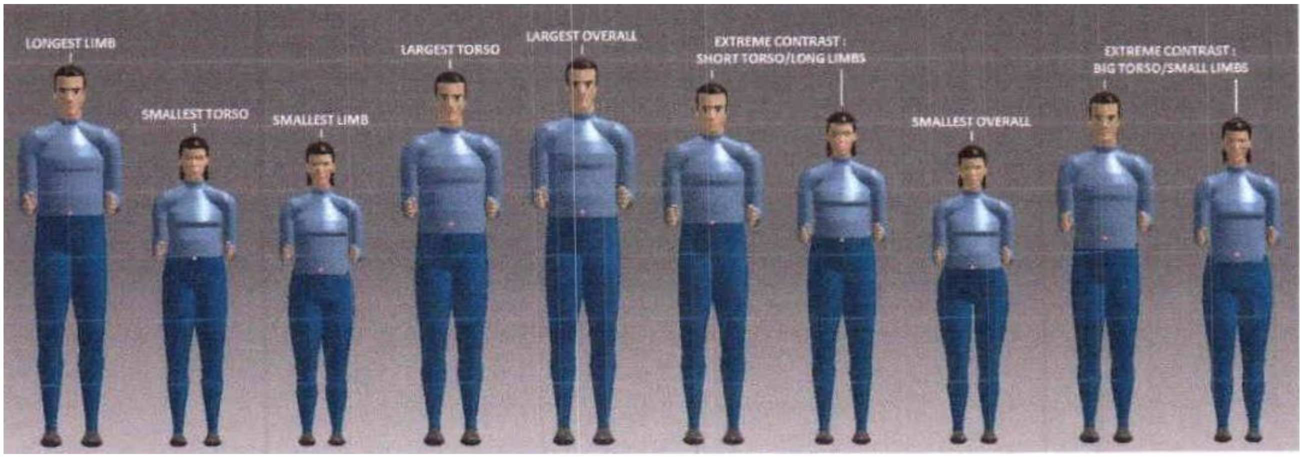


Figure 1. Boundary Models simulated in CATIA

R80 Flightdeck Boundary Model

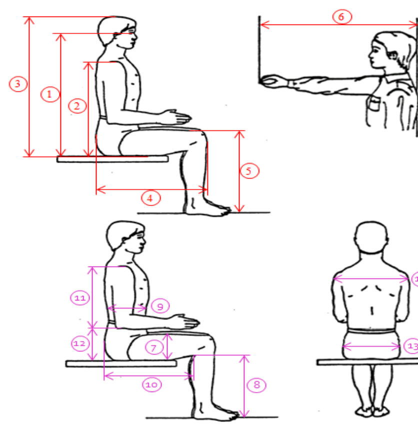
Refering to initial flightdeck design philosophy above then boundary models of flight crew is defined to ensure level of accomodation in R80's flightdeck. The source of boundary models presented in this research derived from Anthropometric Survey (ANSUR) 1988 men and women populations [7]. Percentile approach which are generally being used to ensure a desired level of accommodation in flight deck design process is not sufficient. Percentile values from one variable are unrelated to those of other variables, while within the flight deck workspace some variables are being used simultaneously. Human body dimensions are multivariate which means all dimensions has some kind of simultaneous relations with each others.

All variables should be used and analyzed as a whole. Using the Principal Component Analysis (PCA) method, the multivariate structure of sample population could be described, then reduced the large number of variables to a smaller number of Principal Components (PC) without any loss in the analytical objectives. After the reduction of variables, it becomes easier to obtain a number of boundary models representing a desired level of accommodation from the selected population. Figure 1 shows the drawing various human men-women size as boundary models.

Anthropometric Variables

Careful selection of variables for the multivariate analysis is the key to its success. The variable must characterize the application environment as well as offer relevant combination of anthropometric measures. Figure below show critical and dynamic sitting variables.

CRITICAL VARIABLES	
1	Eye Height, sitting
2	Acromial Height, sitting
3	Sitting Height
4	Buttock-Knee Length
5	Knee Height, sitting
6	Thumb Tip Reach
DYNAMIC SITTING VARIABLES	
7	Thigh Clearance
8	Poplitheal Height
9	Abdomen Depth
10	Buttock-Poplitheal Length
11	Arm Length (Shoulder to Elbow)



12	Elbow Height, sitting
13	Hip Breadth, sitting
14	Shoulder Breadth, sitting

Figure 2. Critical and Dynamic sitting variables in Workstation accommodation

Population Selection and Databases

Multivariate analysis method demands the individual data or raw data of anthropometric survey to be used as input. Free anthropometric databases from the internet only consisted of summary statistics (for example, percentile data, frequency table, mean, standard deviation, total sample, etc.). These kinds of data are not enough to represent relationships among the anthropometric variables from the sample populations. Moreover we need more than one population to get the best representing boundary cases. Besides the American populations, some of the Europeans and Asians populations representing both the largest and smallest population should also be considered in the design. Therefore this research will analysis by using ANSUR 1988 provided by Open Design Lab at Penn State University [7][8].

3. RESULTS AND DISCUSSION

Sample Calculation – Thumb Tip Reach

The following figure below show the sample calculation the critical anthropometric which is contained 90% of target population within the ellipse (red-line).

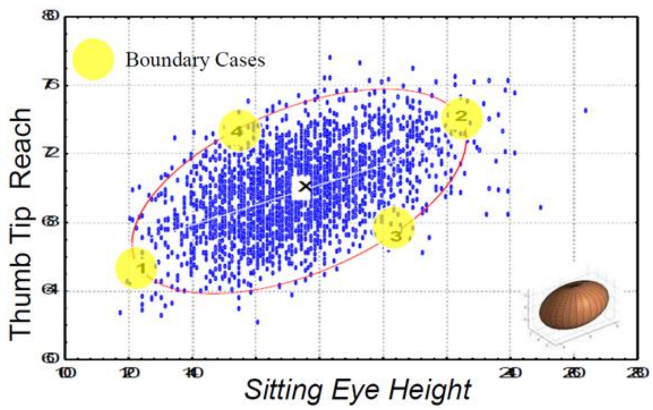


Figure 3. Relation between 2 variables: Sitting Eye Height VS Thumb Tip Reach

Other anthropometric variables are calculate to know the relations when fullfill R80 flightdeck's boundary models and not shown here. Shortly the result how the pilot seat in the cockpit shown in the figure 5 in various field-of-view. Further, the complete calculations give us the result space-volume required by the human when sitting in the cockpit-seat namely "Dynamic Sitting Variables Accommodation" such shown on table 2.

Table 2 Dynamic Sitting Variables Accommodation

The optimum view of pilot's eye can be estimated to the position of cockpit-display horizontally and vertically. Others such maximum and minimum view will provide range of view for pilot in term of sitting. The vision-cone of human-eye shown in figure below.

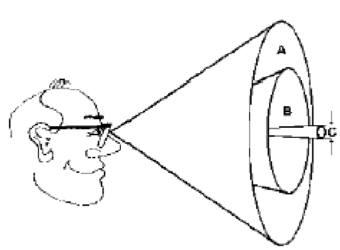
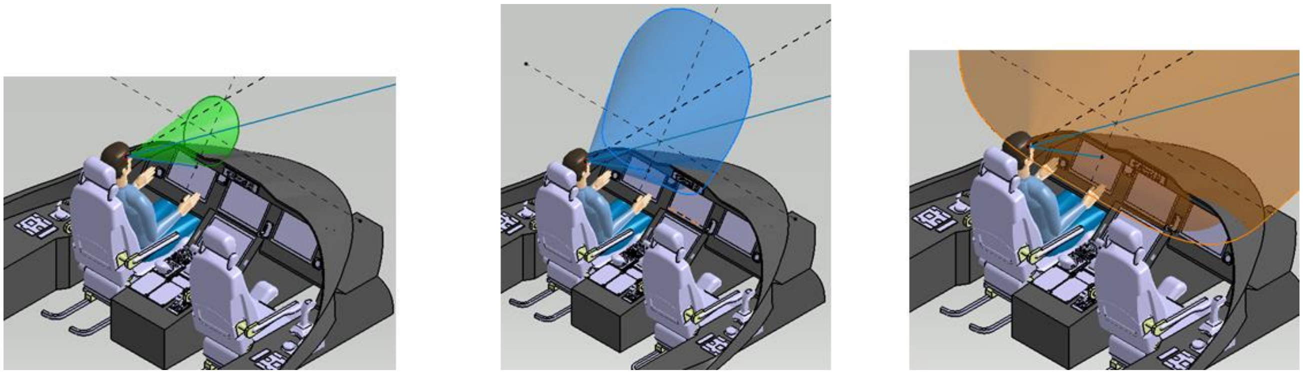


Figure 4. Vision Cone [9]



Optimum Primary Field of View | Maximum Primary Field of View | Secondary Field of View

Figure 5. Pilot/CoPilot Visibility to Cockpit Panel Display

4. CONCLUSION

Starting from anthropometric models in 3D create using CATIA and using partial ANSUR 88 data bring us to estimate the required space-volume for flightcrew (pilot & copilot) where the hardware components in the cockpit laydown and integrate. This ensure comfortable flightdeck space volume to accommodate the pilot/flightcrew populations. Further it ensures convenient operation and to prevent confusion and inadverntent operation. However anthropometry is only one part from the first phase of ergonomic design as a whole. Other ergonomics design elements should be carefully considered and calculate.

Anthropometric Variables	Accommodation Range (mm)
Thigh Clearance	140 – 190
Poplitheal Height, sitting	352 – 476
Abdomen Depth, sitting	208.9 – 313.9
Buttock-Poplitheal Length	440.35 – 546.35
Arm Length (Shoulder to Elbow)	310.95 – 402.6
Elbow Heigt, sitting	176 – 273
Hip Breadth, sitting	357.2 – 426.2
Shoulder Breadth, sitting	403.1 – 540.45

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