REVIEW ARTICLE ON HISTORY OF EVOLUTION IN COCKPIT INSTRUMENTS & EMERGENCE OF ALL GLASS COCKPIT

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Abstract

Instrumentation is the cornerstone of a modern aircraft. It is a process of installing a set of instruments which are used in operating or monitoring a machine. In aviation it signifies the process of providing information to the pilot about flight parameters, system health, aircraft navigation, attitude and communication, for better control, decision making and flight safety. The use of electronics in aircraft began in the 1930s, and gained impetus during World War II, and a further increase in momentum from 1980 onwards, when digital technology became available in general. The aviation sector started using the modern technologies. The use of glass cockpit concept in space shuttle is also remarkable. In this article the gradual developments in the field of instrumentation and latest technologies have been discussed and evolution is emphasized.

Keywords: *Instrumentation, Avionics, HUD, Glass Cockpit, Basic-6, LCDs, Shuttle Cockpit.*

1.0 EMERGENCE & DEVELOPMENT OF COCKPIT INSTRUMENTS:

Orville Wright flew first heavier than air, man-made aircraft, the Wright Flyer-I, on December 17, 1903. The first aircraft was not as well equipped and instrumented as today's [1]. The Wright Flyer-I didn't have any instruments onboard. The pilot used a stopwatch for flight time, an anemometer to measure the wind speed and an earlier version of Tachometer to count the engine revolution [1]. The aircraft didn't have any specific cabin or display board, it was all side open.

The first completely enclosed cabin appeared in 1912 on Avro Type-F, a British single seat aircraft [2]. Soon after, Igor Sikorsky's aircraft named 'Sikorsky Russky Vityaz' had enclosed cabin [3, 4]. The control cabin was equipped with a search-light and simple machines (Tachometer, stop-watch etc.) but still there was no wind screen. This open cockpit trend continued for more than 20 years.

By the mid-1920s, basic flying instruments had found their way into cockpit. Magnetic Compass, Tachometer, Fuel Gauge, Oil pressure, Clock, Turn & Slip Indicator were gradually introduced in the cockpit. But still there were no Attitude, Airspeed, Altimeter, or Vertical Speed Indication [5]. At the beginning of 1930s first version of closed cockpit with windscreen introduced with Garville Gee-Bee series (1931), P-36 Mohawk (1935) and Waco-YKS-6 (1935) [6].

1.1 Standardization of Cockpit Instruments:

In 1937 Royal Air Force identified a set of six instruments- Altimeter, Air Speed Indicator, Directional Gyro, Artificial Horizon, Turn & Bank Indicator and Vertical Speed Indicator- as the instruments which can provide a complete 'picture' of an aircraft to the pilot while in air. These basic six instruments, Figure-1, would remain in standard flight instrument panel for next 20 years. World War II provided a significant standardization in flight instruments. Aircrafts built since about 1953 had these flight instruments located in a standardized pattern called the ***Basic-T*** or ***Basic-6*** arrangement [5].

Fig 1: Basic-6 group of Instruments. From top left clockwise: ASI, Artificial Horizon, Altimeter, VSI, Directional Gyro & TSI.

1.2 Development of CRT and Flight Displays:

World War-II made revolutionary changes in the field of aviation. Various instruments made their way in the cockpit. In accordance with Basic-6, there were numerous gauges in the aircraft which display other important data related to engine, weapon etc. [6]. All these gauges were purely mechanical and the flight information was indicated by a needle. The display was either single needle or multiple needles, quantitative or qualitative, analog or numerical as per the information. Flight attitude information is qualitative and pictorial whereas engine RPM, airspeed, fuel level etc is quantitative. Research started to make the display to digital. CRT (cathode ray tube) technology was developed for the display system instead of mechanical gauges. Aircraft of 1970s started using CRT technology. Airbus A-300 (1972), BAe Hawk Advanced Trainer (1976), Mirage-2000 (1979) had CRT based PFD (Primary Flight Display). This display was monochrome, white on black or green on black [5]. It was much like present generation multi-function-display as it was capable to display more than one data on a single screen.. A graphical pointer emulates the rotation of instrument needles to preserve the perception of information. AMLCD (Active Matrix Liquid Crystal Display) were also used in cockpit instrumentation panels [7]. Head Up Display (HUD) technology was first introduced in late 1960s as the successor to the World War II gyro gun sight [7, 9]. Aircraft in the mid-1970s had more than one hundred cockpit instruments and controls and the primary flight instruments were already crowded with indicators, crossbars, and symbols.

Fig-2: Photographs comparing a 1979, DC-80 Cockpit (left) & 2012, Boeing-787 All-Glass-Cockpit, (right) Pictures: (L) http://aluwings.blogspot.com ; (R) http:// http://airpigz.com/blog

A growing number of cockpit elements were competing for space and pilot attention. Proliferation of cockpit information must have resulted in reducing the attention span and reaction time of pilot. Hence, a need to compile multiple data on a single screen must have been felt. Thus, the idea of most advanced avionics technology "Glass Cockpit" has been introduced. Glass cockpit of an aircraft features electronic (digital) instrument displays typically large LCD screens aptly named Multi Functional Display (MFD). Although the primary sensors are still generating analog signals but these were converted to digital by onboard data computers. The digitized information along with processed data from multiple sources is multiplexed and displayed on a single screen. Earlier glass cockpits were found in the McDonnell Douglas MD-80/90 (1979), Boeing 737

Classic, 757 and 767-200/-300 and in the Airbus A-300-600 and A-310. Airbus A-380 is the latest version in which all glass cockpits has been installed [10].

2.0 PRESENT COCKPIT INSTRUMENT DISPLAYS:

The most modern airline cockpit belongs to the Boeing-787, placed into service in October 26, 2011, with All Nippon Airways [13]. Boeing allowed the pilots to retain final authority over the aircraft's flight path. In this design, the CRTs are replaced by Liquid Crystal Displays (LCD) [11]. Figure-2 compares DC-10 and Boing-787 cockpits. By the use of non-reflective glass these displays can be read in direct sunlight. The images presented can be seen at more acute angles which make them visible from the opposite side of the cockpit. LCDs are lighter and more reliable than CRTs. Along with conventional instrument displays, an integrated Engine Indication & Crew Alert System (EICAS), Flight Management System (FMS) and Multi-Function Cockpit Display Units (MCDU) are installed for reducing crew fatigue, better decision making and control of flight [14]. Electronic checklists can be brought up on the EICAS, mouse pads located below MCDUs are used to navigate through menus and communications procedures and variety of crew tasks are automated for flight management and navigation. Figure-3 shows the developmental stages in cockpit instruments since the Wright Brothers' days.

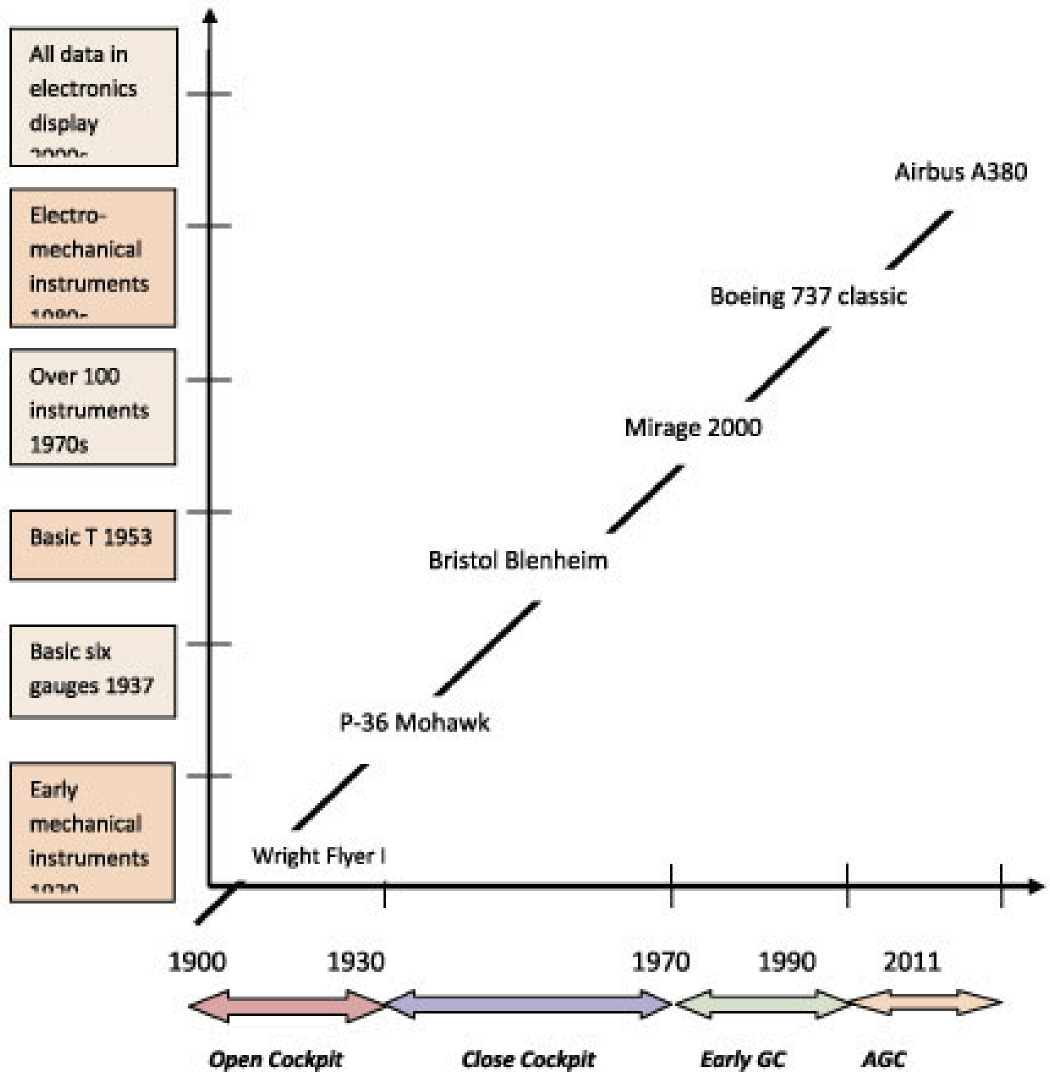

Fig 3: Developmental Stages in Aricraft Cockpits.

3.0 ADVANTAGES AND DISADVANTAGES:

Although there are some problems, the advantages heavily outweigh the disadvantages of the glass cockpit. Before glass cockpits were introduced like these days pilots played a huge role in flying of the aircraft. They had to calculate fuel consumption rate, position on the map, the right moment to turn or bank. Being a pilot and not having a glass cockpit to help him out was extremely difficult. However, nowadays with a glass cockpit, it is as simple as looking at the screen, touching the fuel statistics tab and reading off the data without giving that amount of effort. The integrated flight systems of the aircraft today will tell the pilot anything he needs to know. Ranging from the position of the aircraft to the current weather.

3.1 Advantages:

The Electronic Flight Instrument System (EFIS)

- Enhances situational awareness
- Finding unfamiliar Airports
- Locating a route around bad weather
- Pilot reaction and fatigue are reduced

The EICAS

- Making aware of the faults in Aircraft systems in an orderly manner

- Able to avoid data overload at critical times

- EICAS faults are saved and can be downloaby maintenance

- Troubleshooting became easier as mechanic's have a reference of fault history of that particular instrument.[11]

- Data bank for aircraft system health monitoring using Built-In-Tests (BIT). Data can be retrieved for analysis and preventive maintenance.

- If pilot lose situational awareness then it will take time to respond to the situation and be reoriented which is common in highly complicated systems. One of the latest versions of the FMC software (Pegasus) incorp rates a "Crew Alertness Monitor". If the FMCdoes not detect any crew activity via inputs to the flight guidance or radios within a specific period of time, the FMC start generating EICA messaes, up to and including sounding the warninbeeer [12].

3.2 Disadvantages:

With all the glass cockpit advantages, different types of problems have been created versus traditional cockpits.

- Increased training burdens of the complex-system.

- Lack of experience and knowledge on the computers for the pilots slows down the process of learning.

- FMS Aircraft has introduced additional workload at lower altitude because air traffic control often changes the programmed cleaance with little notice to the pilot.

- Overreliance on the automation is another way that automation can lead to situational awareness problems. This leads to reduction of basic piloting skills.

- Another problem of Glass Cockpit is it runs on electricity and if somehow the power of Aircraft fails, the displays that were running on electricity would not be able to function properly. Some of the components are so sensitive that if the current flow is larger than it can damage the whole system which leads to severe problem when flying [11, 12].

4.0 THE SPACE SHUTTLE COCKPIT:

The space shuttle was designed in 1970s; it used the then state-of-the-art technology to build a most complex aircraft flying. To display trajectory and system status information the original flight deck used three monochrome CRTs. Color CRTs could not be installed as the ones available were not reliable enough for space application as were not being able to withstand the vibrations and radiation of spaceflight. The basic flight instruments were electromechanical displays for attitude, airspeed/mach, vertical velocity/altitude, and a horizontal situation indicator. Over the years, these electro-mechanical instruments were becoming more difficult to maintain hence, NASA's decision to upgrade the shuttle cockpit. The LCDs are exactly the same part as in the Boeing-777, with an additional polyester sheet over the glass, to contain any glass particles in case of shattering in space. The main focus of research was to be able to read the displays during the high vibration levels experienced in launch. In space shuttle, apart from flying parameters as in a conventional aircraft an important display is of shuttle trajectory information and system monitoring. These feature work together to increase the safety margins, in particular during the ascent [11, 15].

5.0 FUTURE GLASS COCKPITS:

The new cockpit instrumentation displays add terrain, approach charts, weather, vertical displays and 3D navigation images. Trackball, thumb pad or joystick as a pilot-input device in a computer-style environment. Traditional gyroscopic flight instruments have been replaced by Attitude and Heading Reference Systems (AHRS) and Air Data Computers (ADCs), improving reliability and reducing cost and maintenance [16]. GPS receivers are frequently integrated into glass cockpits. Modern glass cockpits might include Synthetic Vision (SVS) or Enhanced Vision systems (EVS). Synthetic Vision systems display a realistic 3D depiction of the outside world (similar to a flight simulator), based on a database of terrain and geophysical features in conjunction with the attitude and position information gathered from the aircraft navigational systems. EVS add real-time information from external sensors, such as an infrared camera [16]. New airliners such as the Airbus A-380, Boeing-787 and private jets such as Bombardier. Global Express and Learjet use glass cockpits. Certain general aviation aircraft, such as the 4-seat Diamond Aircraft DA40, DA42 and DA50 and the 4-seat Cirrus Design SR20 and SR22, are available with glass cockpits. In future, with developments in field of Avionics All Optical Networks [17] and smart sensors, quality and quality of real time information and system monitoring will certainly increase. Speed, data bandwidth, reliability and better decision making will be possible with cockpit instruments and displays.

6.0 CONCLUSION:

In this article the introduction of instruments, gradual developments, transformation of system from mechanical to electro-mechanical then to electronics. Most advanced technologies, their working principle and advantages has shown. Technology is a growing process and today's most advanced technology may be considered older after 50 years. During preparation of this article we came to know about the oldest, midst and latest technologies of aircraft

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