Various Display System

1.SHEIKH MAHMOOD AL RAFID-ID NO:201522009
2.TANIA RIFAT JAHAN-ID NO: 201522029
3.SHAKIB HASAN MISHU-ID NO: 21522041
4.SAMIA AKTER-ID NO:201522042
5.MD. SAMRAT HOSSAIN-ID NO:201522046
6.NOOR MOHAMMAD NAYEEM-ID NO: 201522047
7.KHAN MD. MAHBUBA ALAHI-ID NO:201522048
8.TANVIR HASAN –ID NO: 201522052
9.MD. KHAYRUL ISLAM-ID NO:201422031
10.REHMAN SOBHAN MUKTO-ID NO: 20142237

Abstract— Since the beginning of manned flight, it has been recognized that supplying the pilot with information about the aircraft and its operation could be useful and lead to safer flight. From that simple beginning, a wide variety of instruments and various display systems have been developed to inform flight crews of different parameters. This article contains, for which requirements, the first display system war introduced and how they are being developed day by day. This also includes the evolution of normal cockpit to glass cockpit.

INTRODUCTION

The ability to capture and convey all of the information a pilot may want, in an accurate, easily understood manner, has been a challenge throughout the history of aviation. As the range of desired information has grown, so too have the size and complexity of modern aircraft, thus expanding even further the need to inform the flight crew without sensory overload or overcluttering the cockpit. As a result, the old flat panel in the front of the cockpit with various individual instruments attached to it has evolved into a sophisticated computer-controlled digital interface with flat-panel display screens and prioritized messaging. A visual comparison between a conventional cockpit and a glass cockpit widths, line spaces, and text fonts are prescribed; please do not alter them. You may note peculiarities. For example, the head margin in this template measures proportionately more than is customary. This measurement and others are deliberate, using specifications that anticipate your paper as one part of the entire proceedings, and not as an independent document. Please do not revise any of the current designations.

Analog cockpit display sytem

This type of display represents the information by the needle which can be interpreted almost instantly. The needle can provide information on direction and rate of change which can be interpreted with little effort required. But it has a doubt of accuracy in its readings. The evolution from the Flyer took about 13 years in 1916 there was provided a degree of practicality to operating the aircraft never realizable with the original "Flyers." While the Wright's first "Flyer" models required the pilot to be prone, the later versions did at least provide seats for the pilots, who could now fly the airplane from a more comfortable sitting position

Fig 1: Analog cockpit display system

The seccond significant development was noticed as cockpits evolved, was after World War 2 around the late 1970's when the old round analog gauges (affectionately called by pilots, "Steam Gauges") began to disappear in favor of new digital or so-called "Glass Panel" instrumentation for flight crews. Another interesting evolutionary change had been in the primary control called the "stick." The "Control Stick" was used mainly in single engine aircrafts and also later larger airlines were most typically equipped with "Control Wheels" or "Yokes". The use of the glass panels (similar to computer monitors) greatly simplified the appearance of the airplane instrumentation layout. Other significant developments along the evolutionary road inside cockpit was in how the instrumentation and controls began to follow new rules for standardization. Similarly, the controls and instruments were also re-designed in favor of both comfort and safety, as the cockpits began to be laid our according the principles of ergonomic design.

BASIC SIX INSTRUMENTS

Airspeed Indicator

The **airspeed indicator** or **airspeed gauge** is an instrument used in an aircraft to display the craft's airspeed, typically in knots, to the pilot. In its simplest form, an ASI measures the difference in pressure between the air around the craft and the increased pressure caused by propulsion. The needle tracks pressure differential but the dial is marked off as airspeed. The airspeed indicator is used by the pilot during all phases of flight, from take-off, climb, cruise, descent and landing in order to maintain airspeeds specific to the aircraft type and operating conditions as specified in the Operating Manual.

Vertical Speed Indicator

The vertical speed indicator (VSI) or vertical velocity indicator indicates whether the aircraft is climbing, descending, or in level flight. The rate of climb or descent is indicated in feet per minute. If properly calibrated, this indicator will register zero in level flight.

Fig 2: Basic six instruments in analog and Airspeed indicator

Vertical Speed Indicator

Altimeter

Aircraft altimeters tell pilots how high they're flying. It's a simple and basic flight instrument, yet it is often misinterpreted by pilots - sometimes with grave consequences. Understanding how your aircraft altimeter works is necessary for safe flight. The instrument itself is simple enough, but its operation comes with a few caveats.

Altimeter

Gyro horizon

An attitude indicator (AI), also known as gyro horizon or artificial horizon or attitude director indicator (ADI, when it has a Flight Director), is an instrument used in an aircraft to inform the pilot of the orientation of the aircraft relative to Earth's horizon. It indicates pitch (fore and aft tilt) and bank (side to side tilt) and is a primary instrument for flight in instrument meteorological conditions.

Gyro horizon

Direction and heading indicator

The heading indicator (also called an HI) is a flight instrument used in an aircraft to inform the pilot of the aircraft's heading. The heading indicator works using a gyroscope, tied by an erection mechanism to the aircraft yawing plane. the pilot will typically maneuver the airplane

Turn & Bank indicator

The turn and slip indicator can be referred to as the turn and bank indicator, although the instrument does not respond directly to bank angle. Neither does the turn coordinator, but it does respond to roll rate, which enables it to respond more quickly to the start of a turn. The turn and bank indicator are essentially two aircraft flight instruments in one device. One indicates the rate of turn, or the rate of change in the aircraft's heading, the other part indicates whether the aircraft is in coordinated flight, showing the slip or skid of the turn.

INSTRUMENTS OF DIGITAL COCKPIT

Electronic Flight Instrument System (EFIS)

An electronic flight instrument system (EFIS) is a flight deck instrument display system that displays flight data electronically rather than electromechanically. An EFIS normally consists of a primary flight display (PFD), multi-function display (MFD), and an engine indicating and crew alerting system (EICAS) display.[1]Early glass cockpits, found in the Boeing 737 classic, 757 used Electronic flight instrument system (EFIS) to display attitude and navigational information only. Later glass c cockpits, found in the Boeing 737NG, 747-400, 767-400, 777 have completely replaced the mechanical gauges and warning lights in previous generations of aircraft, although they still retain some analog instruments as backups in case the EFIS displays malfunction.

Primary Flight Display(PFD)

A primary flight display is a modern aircraft instrument dedicated to flight information. Much like multifunction displays , primary flight displays are built around an Liquid crystal or CRT display device. Representations of older six pack or "steam gauge" instruments are combined on one compact display, simplifying pilot workflow and streamlining cockpit layouts.

Primary Flight Display (PFD)

Engine Indicating and Crew Alerting System (EICAS)

An engine-indicating and crew-alerting system (EICAS)[1] is an integrated system used in modern aircraft to provide aircraft crew with aircraft engines and other systems instrumentation and crew annunciations.

EICAS typically includes instrumentation of various engine parameters, including for example revolutions per minute, temperature values, fuel flow and quantity, oil pressure etc. Typical other aircraft systems monitored by EICAS are for example hydraulic, pneumatic, electrical, deicing, environmental and control surface systems. EICAS has high connectivity & provides data acquisition and routing. EICAS is a key function of a glass cockpit system, which replaces all analog gauges with software-driven electronic displays. Most of the display area is used for navigation and orientation displays, but one display or a section of a display is set aside specifically for EICAS. The crew-alerting system (CAS) is used in place of the annunciator panel on older systems. Rather than signaling a system failure by turning on a light behind a translucent button, failures are shown as a list of messages in a small window near the other EICAS indications.

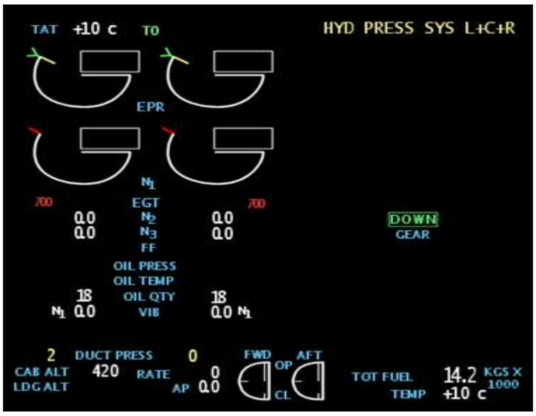

fig. Engine Indicating and Crew Alerting System (EICAS)

The electronic CAS that is part of an EICAS display is a superset of these old panels and can display a much bigger set of alerts. The specific alerts that can be shown will cover most error and failure modes the airplane systems can reasonably encounter. Cautions are yellow in color and will illuminate the master caution and sound an audible chime. Warnings are red in color and will illuminate the master warning and sound the triple chime (and the fire bell for certain conditions). There may also be advisory messages displayed in another color, e.g. cyan, on the EICAS. The messages themselves are terse and not detailed, though detail can be inferred from the pre-defined message text. Warnings and cautions that are displayed can be addressed with memory immediate action items (memorized checklists) and/or the QRH (quick reference handbook) which defines the procedures for dealing with problems in a verbose checklist flowchart. The QRH will be indexed by the messages on the CAS so they can be easily found and referenced.

Electronic Centralized Aircraft Monitor (ECAM)

ECAM is similar to another system named Engine Indicating and Crew Alerting System (EICAS), used by Boeing and Embraer, which displays data concerning aircraft systems and also failures. Airbus developed ECAM, such that it not only provided the features of EICAS, but also displayed corrective action to be taken by the pilot, as well as system limitations after the failures. Using a colour-coded scheme the pilots can instantly assess the situation and decide on the actions to be taken. It was designed to ease pilot stress in abnormal and emergency situations, by designing a paperless cockpit in which all the procedures are instantly available.

ECAM is actually a series of systems designed to work in unison to display information to the pilots in a quick and effective manner. Sensors placed throughout the aircraft, monitoring key parameters, feed their data into two System Data Acquisition Concentrator (SDACs) which in turn process the data and feed it to two Flight Warning Computers (FWCs). The FWCs check for discrepancies in the data and then display the data on the ECAM displays through the three Display Management Computers (DMCs). In the event of a fault the FWCs generate the appropriate warning messages and sounds. More vital systems are routed directly through the FWCs such that failures in them can still be detected even with the loss of both SDACs. The whole system can continue to operate even with a failure of one SDAC and one FWC.

fig. Electronic Centralized Aircraft Monitor (ECAM)

Failures are classed by importance ranging from level 1 failures to level 3 failures. In the event of simultaneous failures the most critical failure is displayed first. The warning hierarchy is as follows:

Level 3 Failures: red warnings, situations that require immediate crew action and that place the flight in danger. For example, an engine fire or loss of cabin pressure. They are enunciated with a red master warning light, a warning (red) ECAM message and a continuous repetitive chime or a specific sound or a synthetic voice. The chime can be silenced by pressing the master warning push button.

Level 2 Failures: amber cautions, failures that require crew attention but not immediate action. For example, air bleed failure or fuel fault. They have no direct consequence to flight safety and are shown to the crew through an amber master caution light, a caution (amber) ECAM message and a single chime.

Level 1 Failures: Cautions, failures and faults that lead to a loss of system redundancy, they require monitoring but present no hazard. Examples include the loss of DMC3 when not in use. Level 1 failures are enunciated by a caution (amber) ECAM message only (no aural warning).In addition to the three failure levels are following status messages:

Advisory: System parameters' monitoring. It causes an automatic call of the relevant system page on the system display (S/D). The affected parameter pulses green.

Information: Recalls normal or automatic selection of functions which are temporarily used. It causes a green, amber, or magenta message on engine warning display (E/WD).

Synthetic Vision Systems (SVS)

A synthetic vision system (SVS) is an aircraft installation that combines three-dimensional data into intuitive displays to provide improved situational awareness to flight crews. This improved situational awareness can be expected from SVS regardless of weather or time of day. In addition the system facilitates a reduced pilot workload during complex situations and operationally demanding phases of flight, e.g. on approach. SVS merges a high resolution display(s) with databases of terrain and obstacle data, aeronautical information, data feeds from other aircraft, and GPS to show pilots where they are and what is in their immediate surrounding area. SVS displays a model of the real world, presenting information to the flight crew in a way that is easy to understand and rapidly assimilated. The picture presented on the SVS display(s) replaces conventional sky and ground depiction to include a 3D representation of the external environment with details of terrain, obstacles, weather, the approach path, runway and aerodrome manoeuvring areas, and other traffic.

fig. Synthetic Vision Systems (SVS)

SVSs have been developed for improving aircrew situational awareness, particularly during the approach and landing phase of flight. They are also very effective in improving flight safety, specifically with regard to reducing the incidence of controlled flight into terrain (CFIT) events. SVS operations can also represent a flight safety challenge due to potential flight crews' overreliance on the SVS to the detriment of other references necessary for safe navigation or due to the utilization of SVSs by un-qualified crews. From a technical point of view, an SVS installed in an aircraft must meet the minimum safety performance standards documented for SVS. In the domain of flight operations, training represents the main defence for operators to prevent the misuse or non-standard use of SVSs by flight crews. A flight crew must undergo training on SVS operation as part of the rating on their aircraft type and meet any applicable currency requirement to be qualified for SVS operations. From a technical perspective, unless redundancy is built in, pilots can quickly lose situational awareness should there be a malfunction in the SVS unless they are trained to rely on other cockpit information available. Another concern is incorrect or corrupted data, and the SVS must have strict currency and validation criteria as well as reliable reception of transmitted data. As a result of the adoption of SVS primary flight displays, the operator must ensure that the phenomenon of attention tunnelling or capture is given appropriate or increased emphasis during training to make flight crews aware that they can become overly focussed on the SVS display to the exclusion of other references or information inside and outside the aircraft.

Enhanced flight vision system(EFVS)

An Enhanced flight vision system (EFVS) is a system for imaging the external world from an aircraft, and to provide an image in which objects can be better detected. In other words, an EFVS is a system to provide an image which is better than unaided human vision. An EFVS includes sensors (one or many) such as a color camera, infrared camera or radar, and typically a display for the pilot, which can be a head-up display or head-down display. An EFVS may be combined with a synthetic vision system to create a combined vision system.

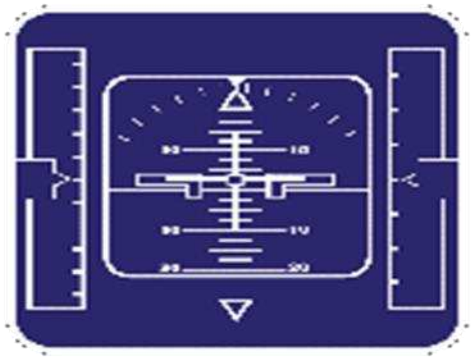

fig. Enhanced flight vision system(EFVS)

Night vision systems have been available to pilots of military aircraft for many years. More recently business jets have added similar capabilities to aircraft to enhance pilot situational awareness in poor visibility due to weather or haze, and at night. The first civil certification of an Enhanced Vision System

(EFVS) on an aircraft was pioneered by Gulfstream Aerospace using a Kollsman IR camera.

EVSs are traditionally based on a Forward looking infrared camera which gives a thermal image of the world, and shows up heat released from airport approach lights. Most airports use incandescent Parabolic aluminized reflector lights, though energy efficiency standards have caused some airports to switch to LED lighting, which as a lower thermal signature.

However, since 2007 airports are switching to the more energy efficient LED lighting, which has a lower thermal profile. The new EVS designs are multispectral, to capture both visual light from LED lights and the thermal image of previous EVS generations. Future EVS designs focus on all-weather vision, which can be accomplished by intelligently fusing images and data from cameras operating in visible light, infrared, and millimeter-wave.

Engagement of Autopilot Function

Every autopilot offers a collection of buttons that allow to choose and engage autopilot modes and functions.

Fig 2: A simple autopilot

Buttons used to engage autopilot modes appear along the bottom of the autopilot shown in above Figure. The system shown in Figure3 does not use a separate device for autopilot controls; it integrates the autopilot function buttons into another cockpit display.

Fig 3 : An integrated avionics system with autopilot

Verification of Autopilot Function Engagement

It is very important to verify that an autopilot mode has engaged, and the aircraft is tracking the intended flight.

Once an autopilot mode has been engaged, the autopilot:

Determines which control movements are required to follow the flight profile entered by the pilot, and

Moves the controls to affect tracking of the flight profile.

GPS Navigation Display

'NavDisplay' instrument has another kind of dynamic texture, along with ground-radar. It is designed to show navigation type info (route, waypoints, traffic, airports, navaids) in a customisable way, and hence be used to simulate the navigation modes of various modern cockpits.

The 'NavDisplay' code in FlightGear 2.6 is already fully generic - using XML and some clever PNGs, it should be able to approximate most moving-map type displays - Honeywell/Boeing, Airbus, a basic Garmin (maybe not a G1000), or various military displays.

Fig: Navigation Display

Pilot should be able to get the ND showing TCAS, waypoints, the route path, VORs and airports. The symbol definitions and textures are similar as Airbus A380 and Boeing 778.

Fig: GPS Navigation

The navigation display (ND) instrument provides a texture resembling the display of the navigation or map displays found in many digital cockpits and GPS units. The instrument tries to be sufficiently generic, to approximate many different real-world displays. Fortunately, most real-world displays are quite similar to each other, with some systems offering additional features that will be added later.

Since the ND system simply displays entities (AI objects, navaids, etc), in an area into a 2D display, it's hoped that it can be reused for some other kinds of cockpit display.

Fig: Nav path finder

Weather radar (WXR) and terrain (TERR /EGPWS) layers are planned as complementary textures, which would be displayed beneath the ND texture.

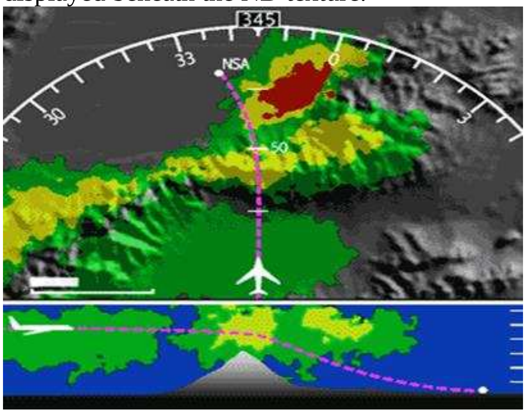

Fig: Weather information display

The ND instrument has a number of configuration properties, most of which can be changed dynamically to reflect display state changes. Importantly, the logical origin on the display can be moved to simulate ARC versus centred modes, the 'up' heading can be set to allow for PLAN vs up-is-aircraft-track vs up-is-aircraft-heading modes. Similarly the range (in nm) can be set.Certain values cannot be changed at runtime - principally the output texture size and related properties. The output texture size is intended to model the real-world device's physical resolution, i.e you can create an artificially pixelated display by choosing a low size. (The size should still be a power of two) Very large sizes may have a performance impact - to be tested.

Symbols are the main display element of the ND. Each symbol can have a textured quad, positioned and rotated on the display, with a color assignment, and optionally a text label. The main configuration task in creating a ND, is to define the symbols.

Fig: Different symbols of navigation display (Boeing 787)

At runtime, the ND code finds potential display items, and then locates the best matching symbol rule(s) to use for them. Many symbols are small - for example identifying an obstacle, VOR or waypoint. The design intentionally allows for large symbols, to achieve various effects - for example a tuned VOR might have a large symbol rotated along the selected radial.

It's also assumed that occasionally multiple symbols might be used to create the appearance for one on-screen element - eg for a TCAS element, the traffic type and vertical-speed arrow might be defined by separate rules.

GPS Navigation Display in Analog Cockpit

Civilian flight navigators (a mostly redundant aircrew position, also called 'air navigator' or 'flight navigator'), were employed on older aircraft, typically between the late-1910s and the 1970s. The crew member, occasionally two navigation crew members for some flights, was responsible for the trip navigation, including its dead reckoning and celestial navigation. This was especially essential when trips were flown over oceans or other large bodies of water, where radio navigation aids were not originally available. (GPS coverage is now provided worldwide). As sophisticated electronic and space-based GPS systems came online, the navigator's position was discontinued and its function was assumed by dual-licensed pilot-navigators, and still later by the flight's primary pilots (Captain and First Officer), resulting in a downsizing in the number of aircrew positions for commercial flights. As the installation of electronic navigation systems into the Captain's and FO's instrument panels was relatively straight forward, the navigator's position in commercial aviation (but not necessarily military aviation) became redundant. (Some countries task their air forces to fly without navigation aids during wartime, thus still requiring a navigator's position). Most civilian air navigators were retired or made redundant by the early 1980s.

GPW Display in Glass Cockpit

(Boeing 787)

The system monitors an aircraft's height above ground as determined by a radar altimeter . A computer then keeps track of these readings, calculates trends, and will warn the captain with visual and audio messages if the aircraft is in certain defined flying configurations ("modes").

The modes are:

Excessive descent rate ("SINK RATE""PULL UP")

Excessive terrain closure rate ("TERRAIN""PULL UP")

Altitude loss after take off or with a high power setting ("DON'T SINK")

Unsafe terrain clearance ("TOO LOW – TERRAIN""TOO LOW – GEAR""TOO LOW – FLAPS")

Excessive deviation below glideslope ("GLIDESLOPE"),Excessively steep bank angle ("BANK ANGLE")Windshear protection ("WINDSHEAR")

Fig: GPW Display

The traditional GPWS does have a blind spot. Since it can only gather data from directly below the aircraft, it must predict future terrain features. If there is a dramatic change in terrain, such as a steep slope, GPWS will not detect the aircraft closure rate until it is too late for evasive action.

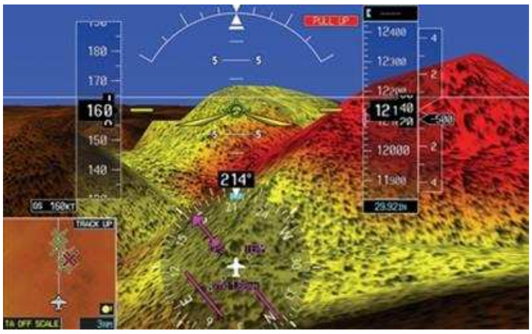

Fig: Advanced GPW Display

In the late 1990s improvements were made and the system was renamed "Enhanced Ground Proximity Warning System" (EGPWS/TAWS). The system was now combined with a worldwide digital terrain database and relies on Global Positioning System (GPS) technology. On-board computers compared its current location with a database of the Earth's terrain. The Terrain Display now gave pilots a visual orientation to high and low points nearby the aircraft.

EGPWS software improvements were focused on solving two common problems; no warning at all, and late or improper response.

GPW Display in Analog Cockpit

In the late 1960s, a series of controlled flight into terrain (CFIT) accidents took the lives of hundreds of people. A CFIT accident is one where a properly functioning airplane under the control of a fully qualified and certified crew is flown into terrain, water or obstacles with no apparent awareness on the part of the crew.

Beginning in the early 1970s, a number of studies examined the occurrence of CFIT accidents. Findings from these studies indicated that many such accidents could have been avoided if a warning device called a ground proximity warning system (GPWS) had been used. As a result of these studies and recommendations from the U.S. National Transportation Safety Board (NTSB), in 1974 the FAA required all large turbine and turbojet airplanes to install TSO-approved GPWS equipment.

The ICAO recommended the installation of GPWS in 1979.

C. Donald Bateman, a Canadian-born engineer, developed and is credited with the invention of GPWS.

In March 2000, the U.S. FAA amended operating rules to require that all U.S. registered turbine-powered airplanes with six or more passenger seats (exclusive of pilot and copilot seating) be equipped with an FAA-approved TAWS.The mandate affects aircraft manufactured after March 29, 2002.

Head-up display(HUD)

A head-up display gives pilots -access to the critical flight information needed to safely fly the aircraft while allowing them to focus their attention outside the cockpit for -potential conflicts or threats.

Fig. Head-up Display

A head-up display gives pilots -access to the critical flight information needed to safely fly the aircraft while allowing them to focus their attention outside the cockpit for -potential conflicts or threats.

A HUD projector sends critical flight, navigation and aircraft energy-management data to a glass screen, called a combiner, hanging at eye level between the pilot and the windshield. As the pilot peers through the combiner glass, he or she can view the -outside world and also see airspeed, altitude, heading, course, and flight-path guidance symbology on the screen.

The concave-shaped combiner glass is coated with a proprietary -material that reflects the color green but allows everything else, such as the scenery outside, to pass through, appearing quite naturally. The coating reflects green to illuminate the HUD’s symbology, because the human eye is most sensitive to that color.

The HUD projector attached to the ceiling above the pilot contains a backlighted liquid-crystal display as the light source to aim the flight data at the combiner screen. The LCD aims the information forward, -focusing it through a series of -multiple relay lenses aligned nonsymmetrically. As the light hits the combiner glass, the rays of light are forced to align themselves in parallel rows to an infinite point in space, a little trick that prevents the pilot from needing to -refocus his eyes as he peers through the screen. That alignment of the light is referred to as collimation.

Like aircraft, not all HUDs are created equal. One difference relates to field of view, essentially how wide left or right the flying pilot can see the outside world through the combiner glass. Because aircraft don't always fly where the nose is pointed, a wider field of view allows the HUD to accurately project data at the edges of the display in strong crosswinds. The -lateral field of view can vary from 15 degrees to as much as 21 degrees either side of the nose. Vertically, it ranges from 24 to 30 degrees.

Older HUDs use cathode ray tubes to project the operational data but are quickly being traded for LCD light sources. CRT projectors are much heavier and don't produce images nearly as sharp as those from an LCD.

Head-down display (HDD)

Flight deck display is critical to safely and efficiently operating your aircraft. It offers a full range of sizes and configurations for forward-fit or retrofit applications.

fig.Head Down Display(HDD)

It's full-color-graphics video and night vision- and sunlight-compatible displays expand the capability and utility of your flight deck. It incorporates industrial grade, commercial off-the-shelf technology components and designs to ensure your solution is not only feature rich but affordable. These highly reliable displays are flying on a majority of the world's commercial and military aircraft fleets.

COLCLUSION

The glass cockpits offer the pilot a great deal more information like no parallax error, precision, graphical weather, on screen checklist, system redundancy, traffic avoidance , passenger confidence and so on which can be presented in a way that has be designed to help increase situational awareness. So it can be said that, glass cockpits aren't perfect by any means, but they do offer some very real benefits to their usere.[8]More needs to be done to make sure that the pilots who use glass cockpits understand the systems fully before being allowed to fly off solo by teaching them the correct action to warnings and to understand why they are there.

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