KLM UK Engineering

EASA PART 66
CAT B1

MODULE 5

DIGITAL TECHNIQUES/ ELECTRONIC INSTRUMENT SYSTEMS

AIRFRANCE INDUSTRIES KLM Engineering & Maintenance

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CONTENTS

14 ELECTRONIC/DIGITAL AIRCRAFT SYSTEMS

Electronic and digital processes are used in many of today's aircraft for a variety of purposes: navigation, dissemination of information, flying and controlling the aircraft. It should be borne in mind that as each manufacturer introduces such a system to the market the chances are that new names for it are added to the dictionary of terms. For instance, an Engine Indication and Crew Alerting System (EICAS) is much the same as a Multi-Function Display System (MFDS), the main difference being the manufacturer.

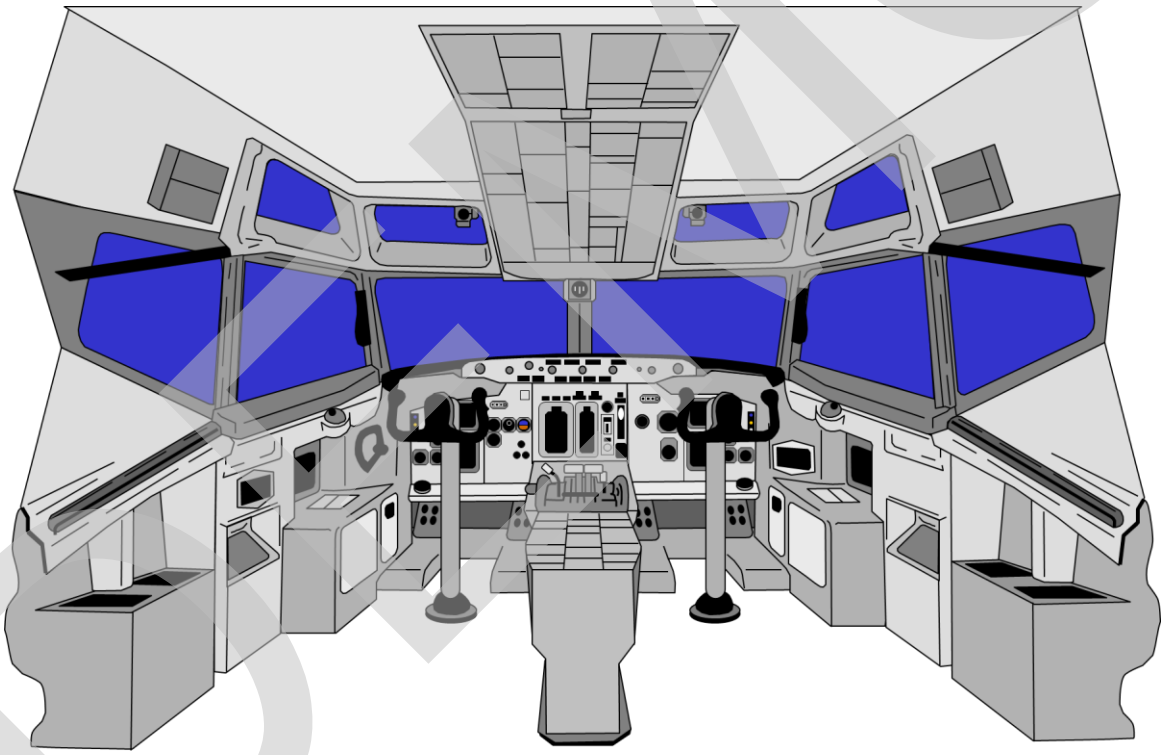
This module will deal with the following Electronic/Digital Systems:

1. EFIS – Electronic Flight Instrument System
2. EICAS – Engine Indication and Crew Alerting System
3. ECAM – Electronic Centralised Aircraft Monitoring
4. HUD – Head Up Display
5. ACARS – Aircraft Communication Addressing and Reporting System
6. FBW – Fly by Wire.
7. FMS – Flight Management System.
8. IRS – Inertial Reference System.

14.1 ELECTRONIC INSTRUMENT SYSTEMS

All instruments essential to the operation of an aircraft are located on panels, the number of which vary in accordance with the number of instruments required for the appropriate type of aircraft and its flight deck layout. The front instrument panel, positioned in the normal line of sight of the pilots, contains all instruments critical for the safe flight of the aircraft. This panel is normally sloped forward 15° from the vertical to minimize parallax errors. Other panels within the flight deck are typically positioned; Overhead, left and right side and centrally between the pilots.

Figure 1 shows the layout of a Boeing 737 flight deck.



Boeing 737 Flight Deck
Figure 1

14.2 FLIGHT INSTRUMENTS

14.2.1 The Basic Six

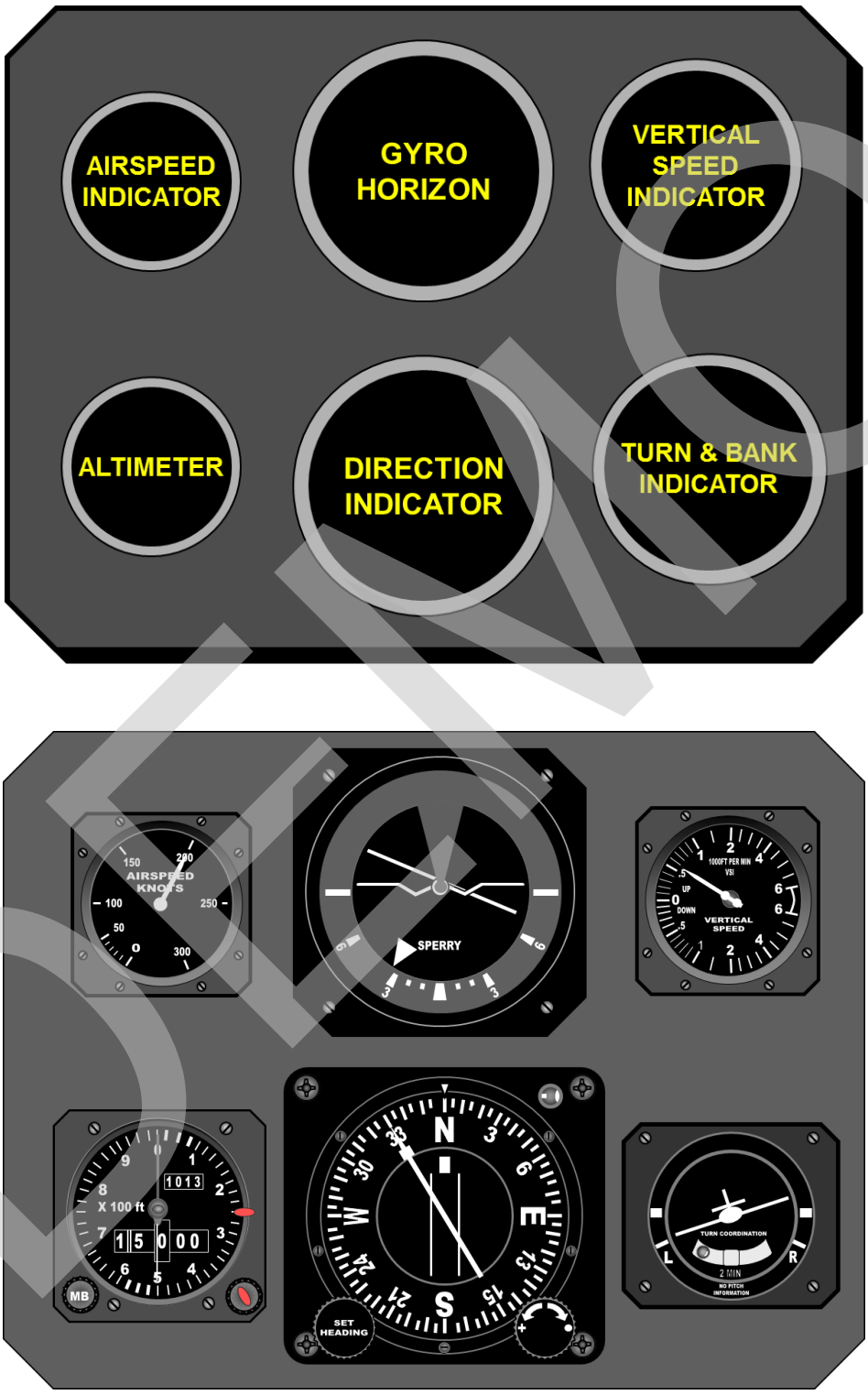
There are six flight instruments whose indications are so co-ordinated as to create a 'Picture' of an aircraft's flight condition and required control movements. These instruments are:

1. Airspeed Indicator.
2. Altimeter.
3. Gyro Horizon Unit (GHU).
4. Direction Indicator (DI)
5. Vertical Speed Indicator (VSI).
6. Turn & Bank Indicator.

The first real attempt at establishing a standard method of grouping was the 'Blind Flying Panel' or 'Basic Six'. The GHU occupies the top centre position, and as it provides positive and direct indications of the aircraft's attitude, it is utilised as the 'Master Instrument'. As control of airspeed and altitude is directly related to attitude, the Airspeed Indicator, Altimeter and VSI flank the GHU.

Changes in direction are initiated by banking the aircraft, and the degree of heading change is obtained from the DI. The DI supports the interpretation of the roll attitude and is positioned directly below the GHU. The 'Turn & Bank Indicator' serves as a secondary reference instrument for heading changes, so it also supports the interpretation of roll attitude.

Figure 2 shows the layout of the basic 6 instrument groupings.



Basic 6 instrument groupings
Figure 2

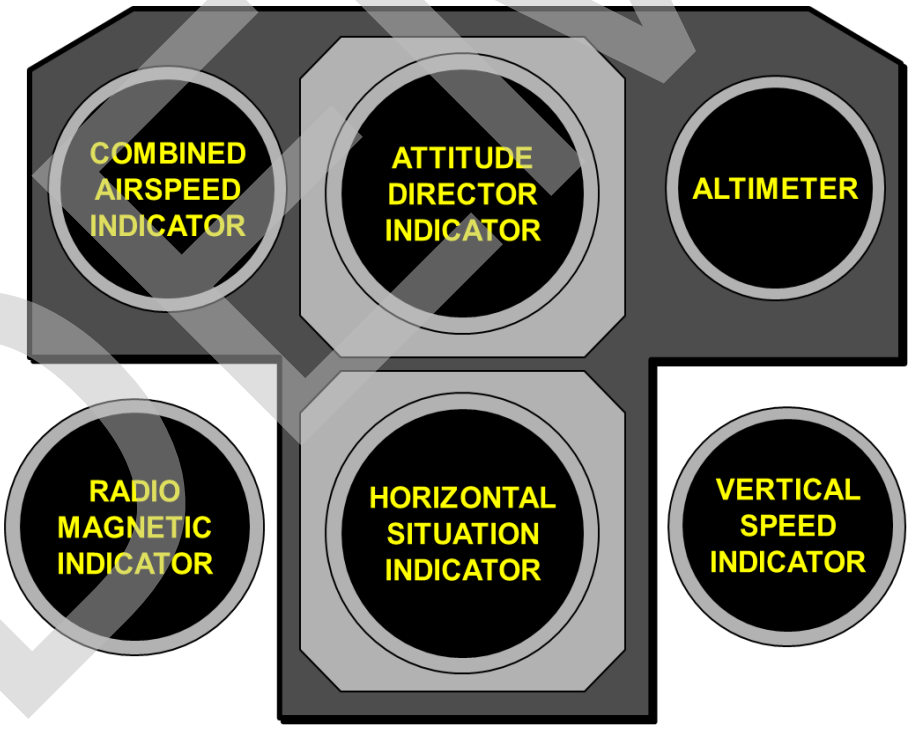
14.2.2 The Basic ‘T’

With the development and introduction of new types of aircraft with more comprehensive display presentation, afforded by the indicators of flight director systems, a review of the functions of certain instruments and their relative positions within the group resulted in the adoption of the ‘Basic T’ arrangement as the current standard.

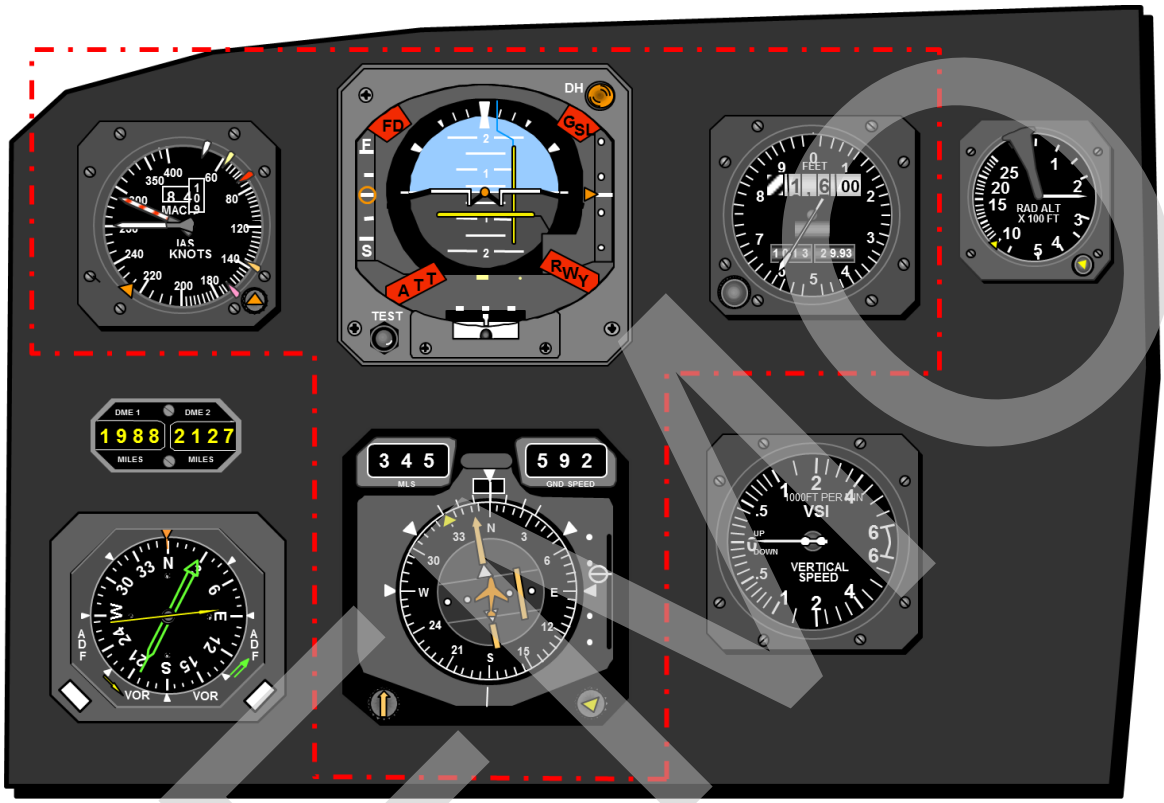
There are now four key indicators:

1. Attitude Director Indicator.
2. Horizontal Situation Indicator.
3. Combined Speed indicator.
4. Altimeter.

Figures 3 and 4 show the layout of the Basic ‘T’ instrument groupings.



Basic ‘T’ instrument groupings
Figure 3



Basic 'T' instrument groupings
Figure 4

14.3 ELECTRONIC INSTRUMENTS

Modern technology has enabled some significant changes in the layout of flight instrumentation on most aircraft currently in service. The biggest change has been the introduction of Electronic Instruments. This instrumentation has meant that many complex Electro-mechanical instruments have now been replaced by TV type colour displays. These systems also allow the exchange of images between display units in the case of display failures.

The main systems within which electronic instruments are used include:

1. Electronic Flight Instrument System (EFIS).
2. Engine Indicating & Crew Alerting System (EICAS).
3. Electronic Centralised Aircraft Monitoring (ECAM).

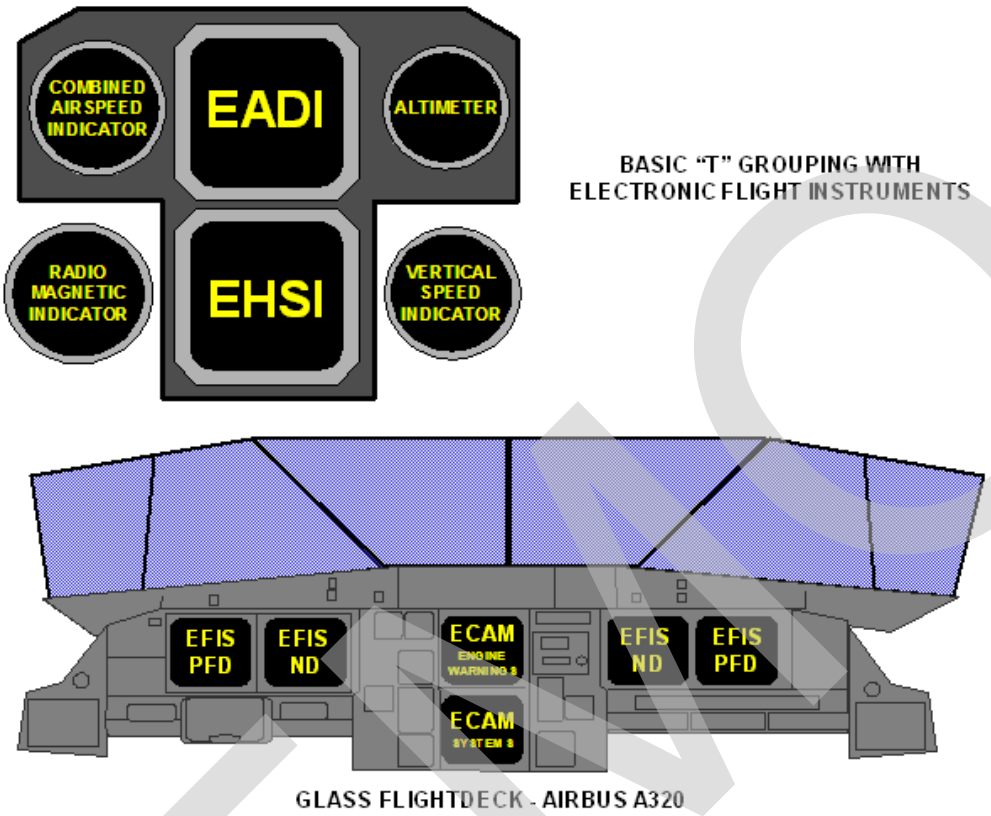
14.4 ELECTRONIC FLIGHT INSTRUMENT SYSTEM

As in the case of conventional flight instrument systems, a complete EFIS installation is made up of left (Captain) and right (First Officer) systems. Each system comprises the following flight deck items:

1. EFIS Symbol Generator (SG)
2. Electronic Attitude Director Indicator/Primary Flight Display (EADI/PFD).
3. Electronic Horizontal Situation Indicator/Navigation Display (EHSI/ND).
4. Display/EFIS Control Panel.
5. Remote Light Sensor.

The EADI and EHSI can be positioned side by side or vertically top and bottom, with the Combined Speed Indicator (CSI), Radio Magnetic Indicator (RMI), Altimeter and Vertical Speed Indicator (VSI) positioned around the displays. Normally the EADI is positioned on the top or on the on-side position. PFD and ND typically side by side with the PFD using the outboard display.

Figure 5 upper shows a flight deck layout of an ATR-72 using EADI/EHSI. The lower figure shows the layout of PFD and ND of an Airbus A320.

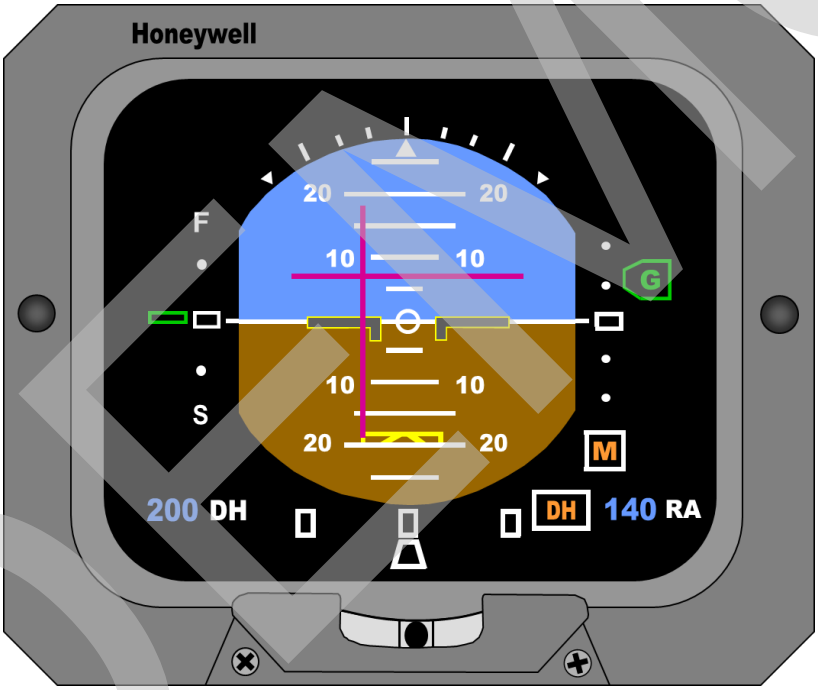


EFIS Layout
Figure 5

14.5 Electronic Attitude Director Indicator

The EADI displays traditional attitude information (Pitch & Roll) against a two-colour sphere representing the horizon (Ground/Sky) with an aircraft symbol as a reference. Attitude information is normally supplied from an Attitude Reference System (ARS).

The EADI will also display further flight information; Flight Director commands right/left to capture the flight path to Waypoints, airports and NAVAIDS and up/down to fly to set altitudes. Information related to the aircraft's position w.r.t. Localiser (LOC) and Glideslope (GS) beams transmitted by an ILS, Auto Flight Control System (AFCS) deviations and Autothrottle mode, selected airspeed (Indicated or Mach No) Groundspeed, Radio Altitude and Decision Height information. Figure 6 shows a typical EADI display

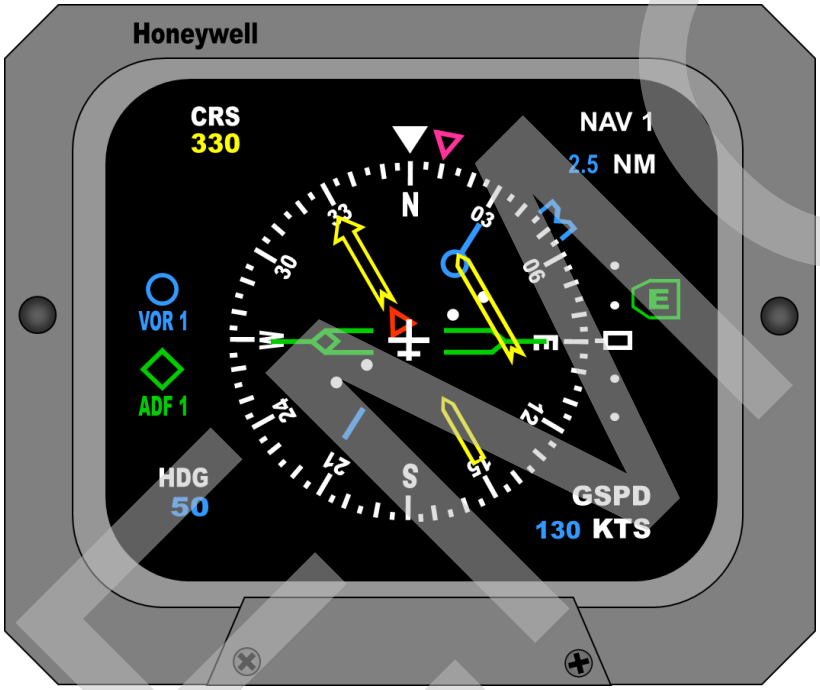


EADI display
Figure 6

14.6 ELECTRONIC HORIZONTAL SITUATION INDICATOR

The EHSI presents a selectable, dynamic colour display of flight progress with plan view orientation. The EHSI has a number of different modes of operation which can be selected by the flight crew. The number of modes is dependent on the system fitted.

Figure 7 shows an EHSI display in Rose mode.



EHSI display in Rose mode
Figure 7

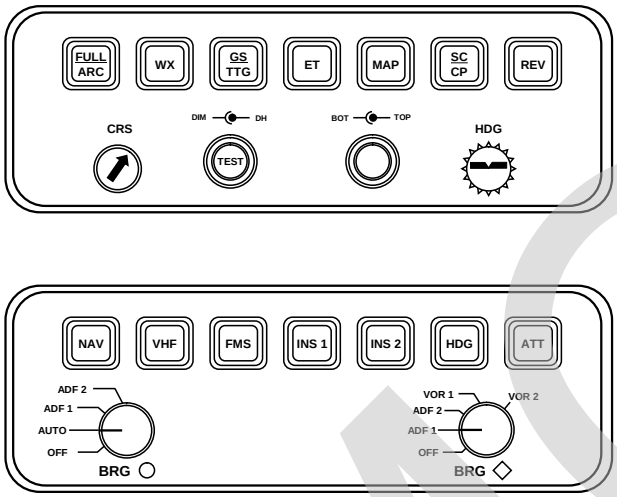
14.6.1 Control Panel

Allows the crew to select the required display configuration and what information is to be displayed. Both Captain and Co-Pilot have their own display controllers. The controllers have two main functions:

Display Controller: Selects the display format for EHSI as FULL, ARC, WX or MAP.

Source Select: Selects the system that will provide information required for display. The source information will be VOR, ADF, INS, FMS, VHF and NAV.

EFIS Display Controller and the Source Controller are shown at Figure 8.



EFIS Display and Source Controller
Figure 8

14.6.2 EFIS Symbol Generator

These provide the analog, discrete and digital signal interfaces between the aircraft's systems, the display units and the control panel. They provide symbol generation, system monitoring, power control and the main control functions of the EFIS overall.

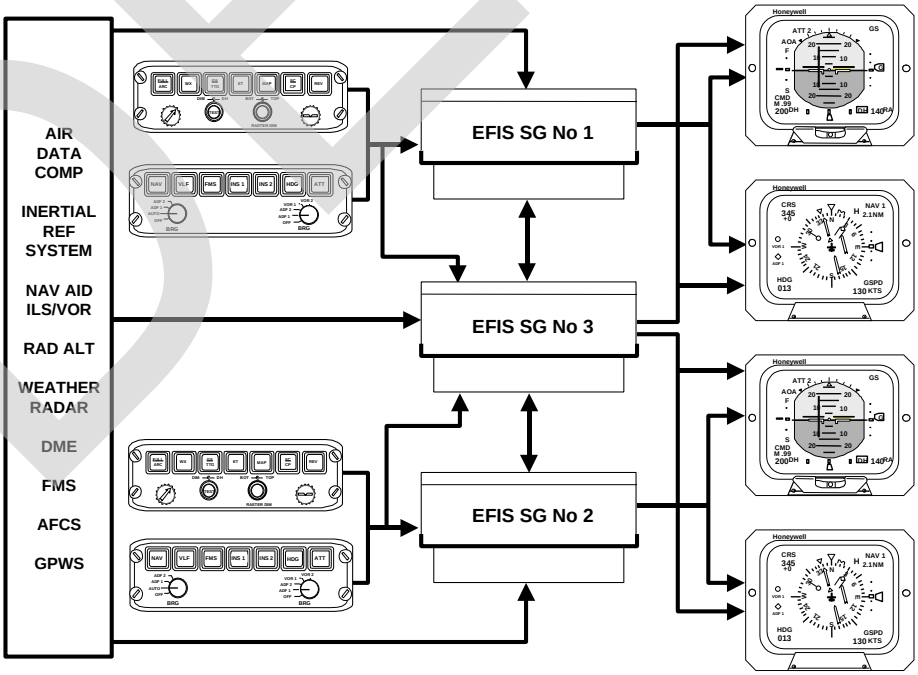


Figure 9 shows the EFIS units and signal interface in block schematic form
EFIS Block Schematic
Figure 9

14.6.3 EFIS General Test

An EFIS General Test of a Bae 146 system is controlled from the TEST button located on the EFIS Dimming Panel as shown at Figure 10. The test, if carried out using the First Officer's Dimming Panel, will have the following effect on the Captain's EADI:

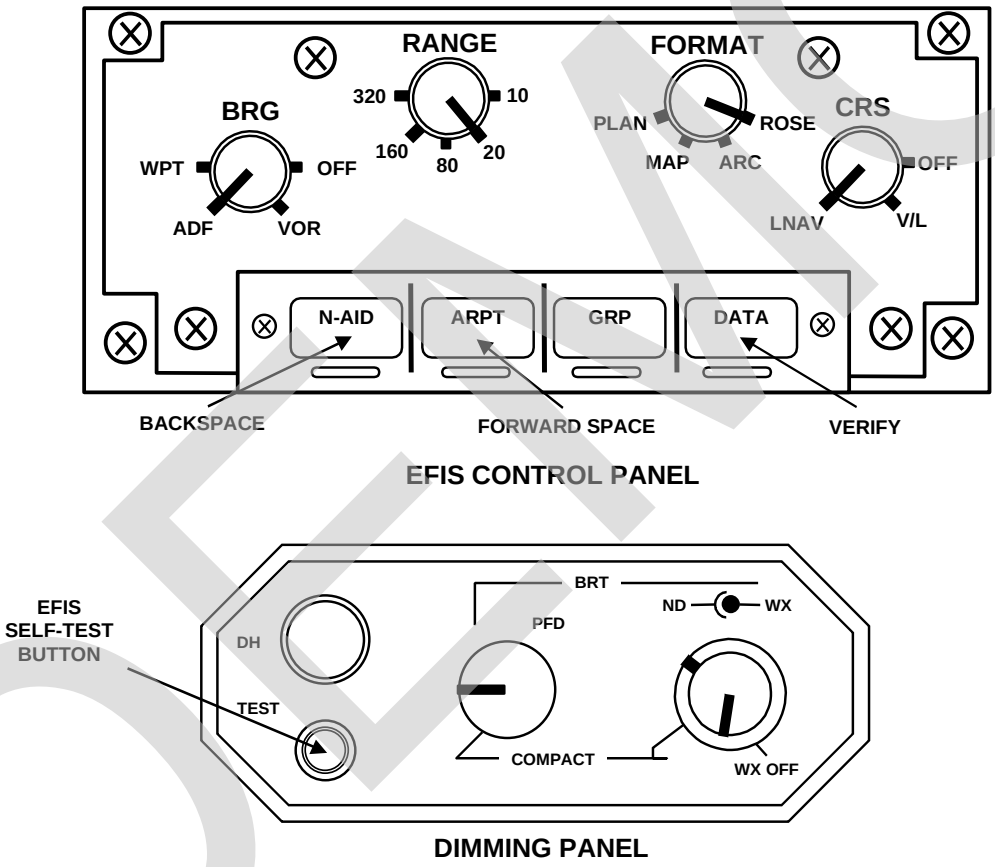
1. Runway symbol will fall.
2. Rad Alt digital display indicates 95 to 100 feet.
3. The First Officer's EADI warning will be activated:
4. Amber dashes are displayed on the Rad Alt digital display.
5. Amber dashes are displayed on the selected DH digital display.

When the TEST button is pressed on the Captain's EFIS control panel the same test sequence takes place. The test altitude value remains displayed as long as the TEST button is pressed. Releasing the knob causes actual altitude to be displayed and digits of the DH display to show the selected value at the end of the test. The test sequence can be initiated during flight except during APP (Approach).

14.7 SYMBOL GENERATOR BITE

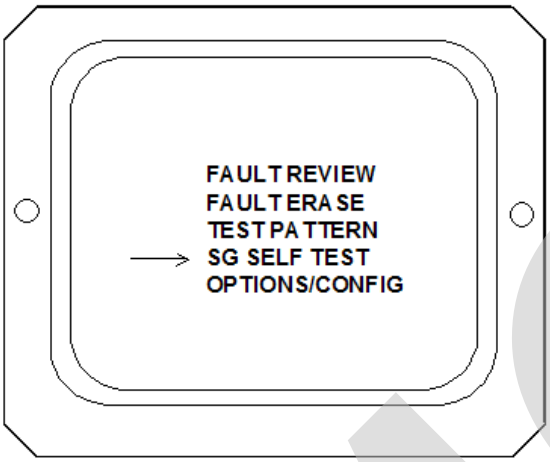
Some EFIS systems have the capability of carrying out a comprehensive Symbol Generator BITE. As an example, the BAe 146 EFIS SG BITE is described.

It is initiated by selecting SELF-TEST on the Dimming Panel and pressing the verifying (DATA), button on the EFIS Control panel. Refer to Figure 10.



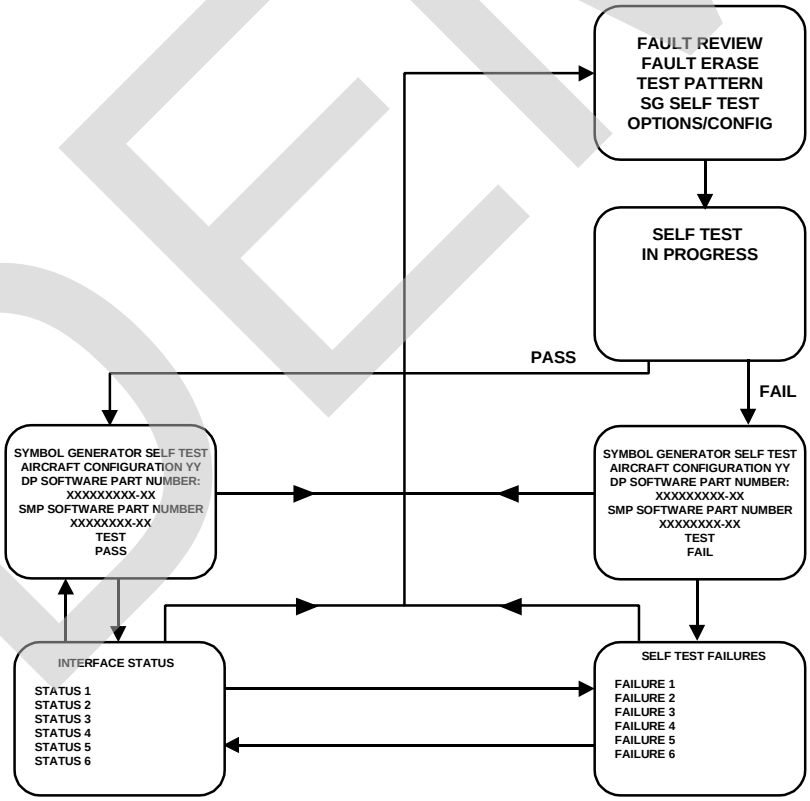
BAe 146 EFIS Control & Dimming Panels
Figure 10

The Display Unit will now display the 'Maintenance Master Menu' format as shown in Figure 11. Using the backspace – forward space controls on the EFIS Control Panel, select 'SG SELF TEST'.



Maintenance Master Menu Display
Figure 11

The Symbol Generator Self-Test sequence is automatic and the process is as shown in Figure 12.



SG Self-Test Process
Figure 12

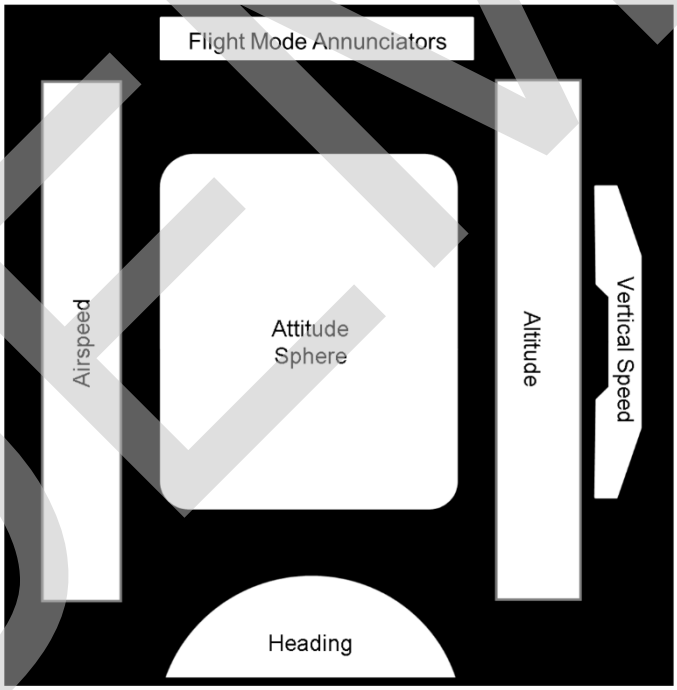
The test fail message will appear if any failures internal to EFIS are detected. Depressing the 'Forward Space' key after 'FAIL', on completion of the self-test, brings up a self-test failure page that lists the first test that failed. Depressing the 'Forward Space' key again brings up the Interface Status page.

Depressing the 'Forward Space' after 'PASS', on completion of the self-test, brings up the Interface Status page. This page lists any interfaces that are not valid.

After confirming the status of the 'Self-test Failures' and 'Interface Status', then the operator can reselect the Maintenance Format page to carry out further testing.

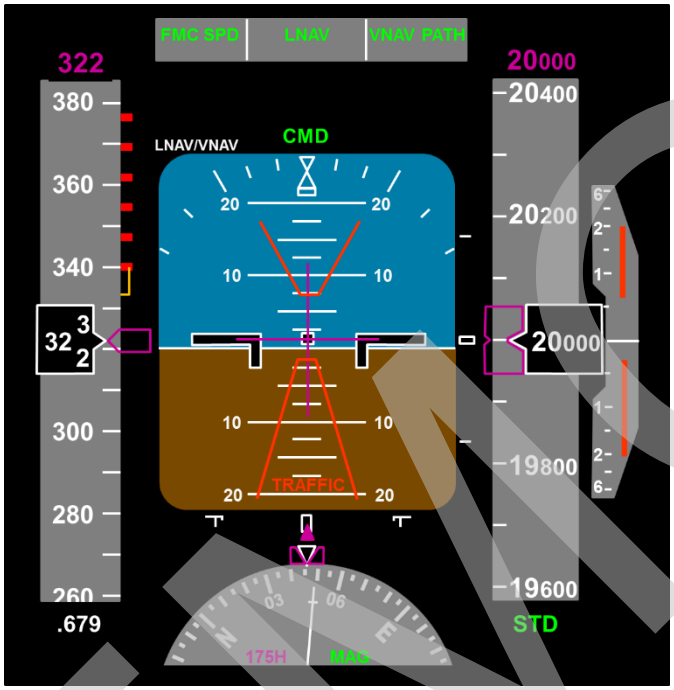
14.8 PRIMARY FLYING DISPLAY

The Primary Flying Display (PFD) provides a progression from the EADI in that it incorporates the airspeed, mach number, altitude and vertical speed. The main areas of the PFD are shown in figure 13.



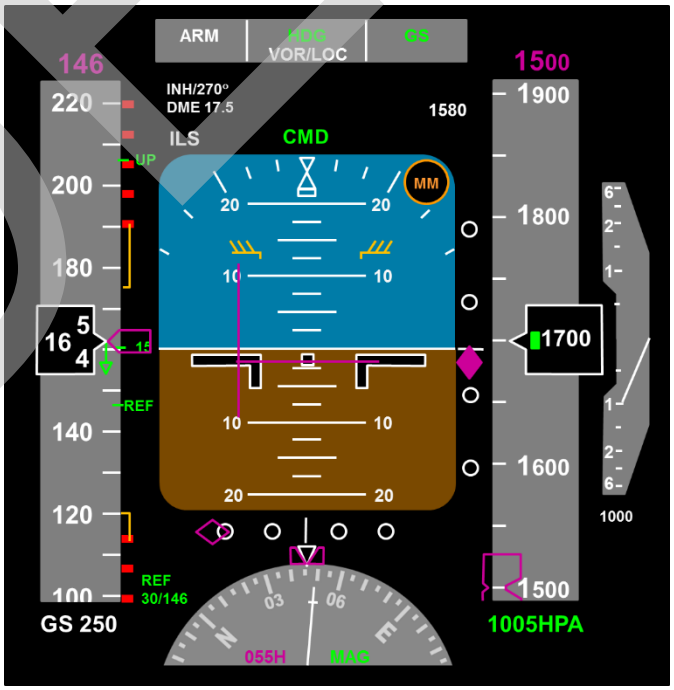
PFD Main areas
Figure 13

Figure 14 showing a typical PFD display with the aircraft at altitude with a TCAS Resolution Advisory warning



PFD with TCAS Resolution Advisory warning
Figure 14

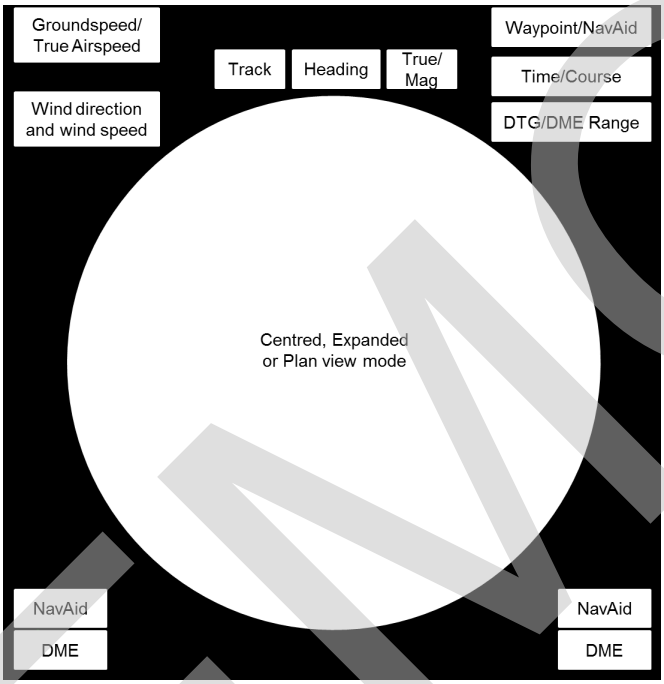
Figure 15 shows a typical PFD display during an ILS approach.



PFD display during an ILS approach
Figure 15

14.9 NAVIGATION DISPLAY

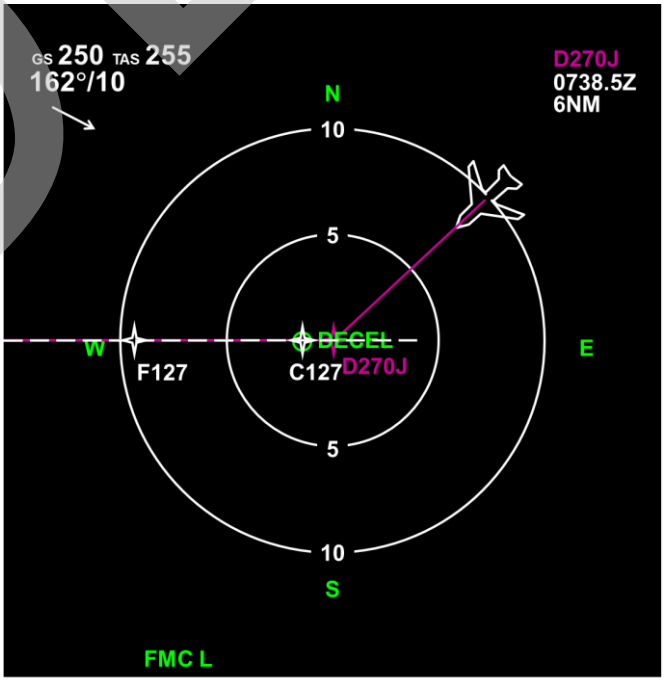
The Navigation Display (ND) again provides a progression from the earlier EHSI in that it incorporates the additional display modes. Typical information areas displayed by the ND is shown in figure 16.



Typical ND information areas
Figure 16

14.9.1 Navigation Display Modes

- Plan mode (Figure 17)



- Expanded Map mode with Weather and TCAS (Fig 18)

- Centred Map mode (Fig 19)

14.10 EFIS CONTROL PANEL

14.10.1 EFIS Control Panel controls

The EFIS control panels control the information that shows on the display units. The typical controls that are found on this panel are:

- Minimums controls
- Meters switch
- VOR/ADF switches
- Range selector 3
- Weather radar switch
- Map switches
- Flight path vector switch
- Barometric controls
- Mode controls
- Traffic switch
- Terrain switch

Figure 20 shows a typical EFIS control panel

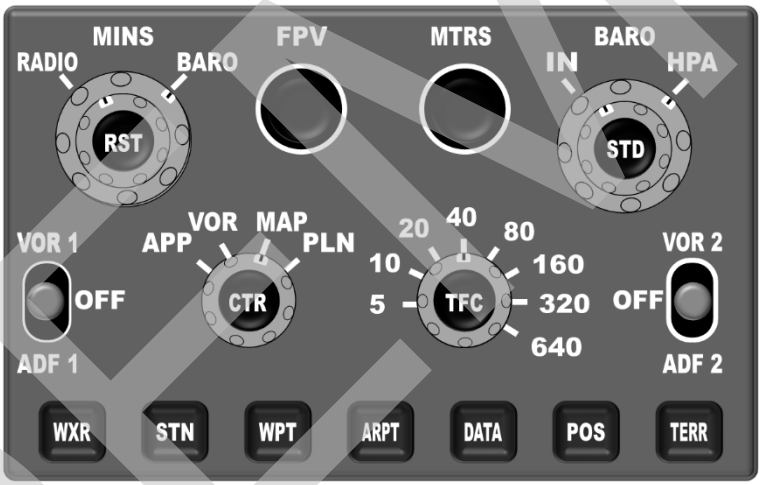
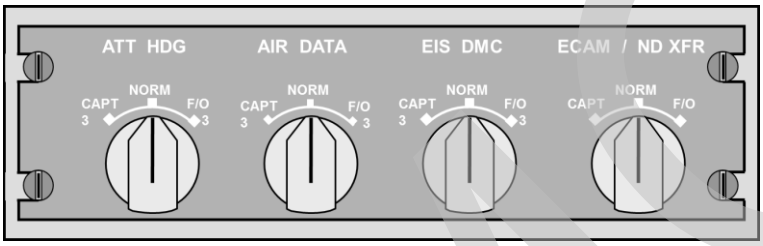


Figure 20

14.11 ELECTRONIC INSTRUMENT SYSTEM (EIS)

The Electronic Instrument System (EIS) also allows the flight crew to configure the instrument layout by allowing manual transfer of the Primary Flight Display (PFD) with the Navigation Display (ND) and the secondary Electronic Centralised Aircraft Monitoring (ECAM) display with the ND. Figure 21 shows the switching panel from Airbus A320, with Figure 22 showing the manual transfer interchanges possible.



Airbus A320 display switching panel
Figure 21

Display manual transfer
Figure 22

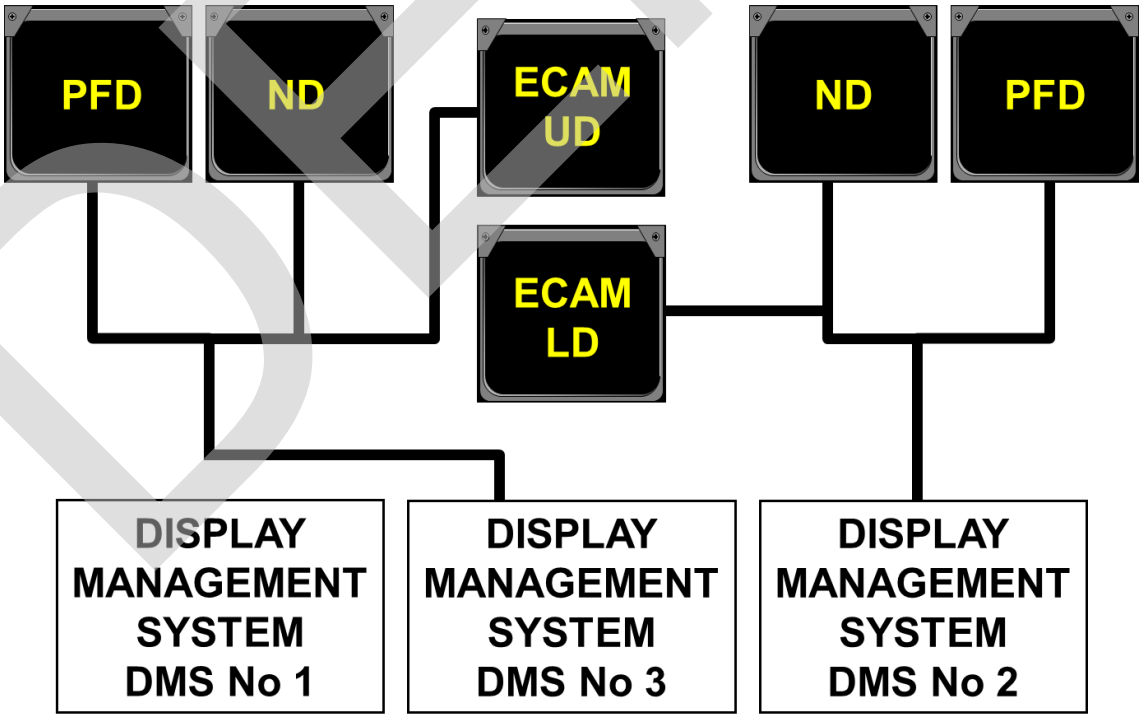
As well as a manual transfer, the system will automatically transfer displays when either the PFD or the primary ECAM display fails. The PFD is automatically transferred onto the corresponding ND, with the ECAM secondary display used for the primary ECAM display. Figure 23 shows this automatic transfer.

Display automatic transfer
Figure 23

The system will also automatically transfer the primary ECAM information onto the ND if a double failure of the ECAM display system occurs. Figure 24 shows this automatic transfer during a double display failure.

Double display transfer
Figure 24

The EIS for the Airbus 320, as with other aircraft types, typically have a Display Management System which acquire the required information from the respective aircraft systems, produce the imagery and symbology to be displayed and control the display system. The system works using a triple channel approach which provides redundancy if any of the Display Management Systems have a failure. Figure 25 shows a block schematic of the EIS for the Airbus 320.



Airbus A320 EIS
Figure 25

14.12 ELECTRONIC INSTRUMENTS (ENGINE & AIRFRAME)

The display of the parameters associated with engine performance and airframe systems control, by means of display units has, like those of flight instrument systems, become a standard feature of many types of aircraft.

The display units form part of two principal systems designated as:

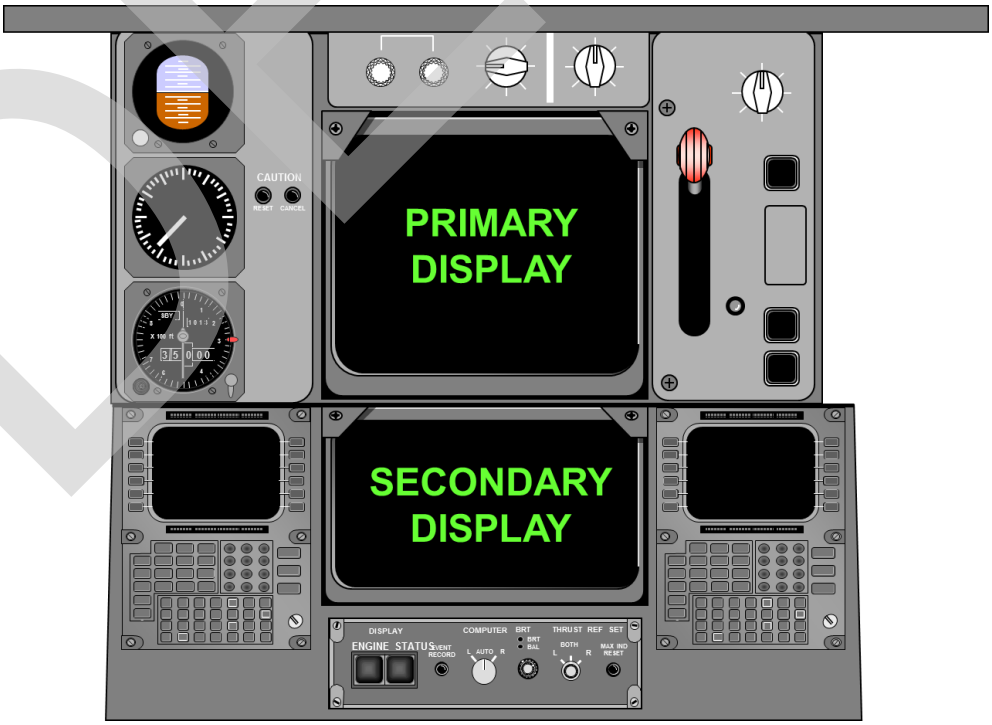
1. Engine Indicating and Crew Alerting System (EICAS).

2. Electronic Centralised Aircraft Monitoring (ECAM).

14.13 ENGINE INDICATING & CREW ALERTING SYSTEM (EICAS)

The basic system comprises two display units, a control panel and two computers supplied with analogue and digital signals from the engine and system sensors. The computers are designated ‘Left’ and ‘Right’ and only one is in control of the system at any one time, the other is held in standby. In the event of a failure, it may be switched in either manually or automatically.

Operating in conjunction with the system are discrete caution and warning lights, standby engine indicators and a remotely-located panel for selecting maintenance data display. The system provides the flight crew with information on primary engine parameters (Full-time), with secondary engine parameters and advisory/caution/warning alert messages displayed as required. Figure 26 shows layout of the EICAS Displays.



EICAS displays
Figure 26

14.13.1 Display Units

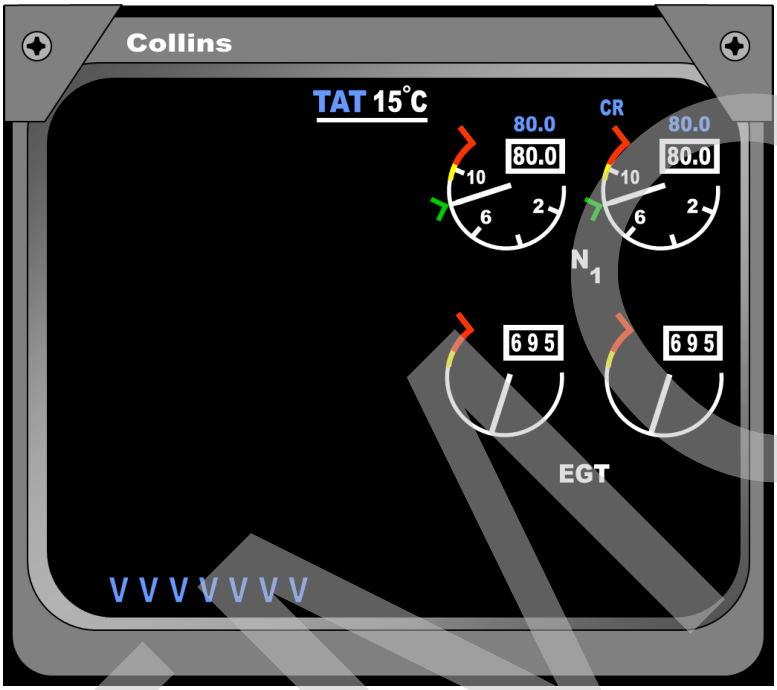
These units provide a wide variety of information relevant to engine operation, and operation of other automated systems. The operation of these displays is as for those in the EFIS as previously described.

The upper unit displays primary engine parameters, i.e. N1 speed, EGT, and warning and caution messages. The lower unit displays secondary parameters, i.e. N2 speed, fuel flow, oil quantity, pressure and temperature. In addition, the status of non-engine systems i.e. flight control surface position, hydraulic system, APU, etc., can be displayed.

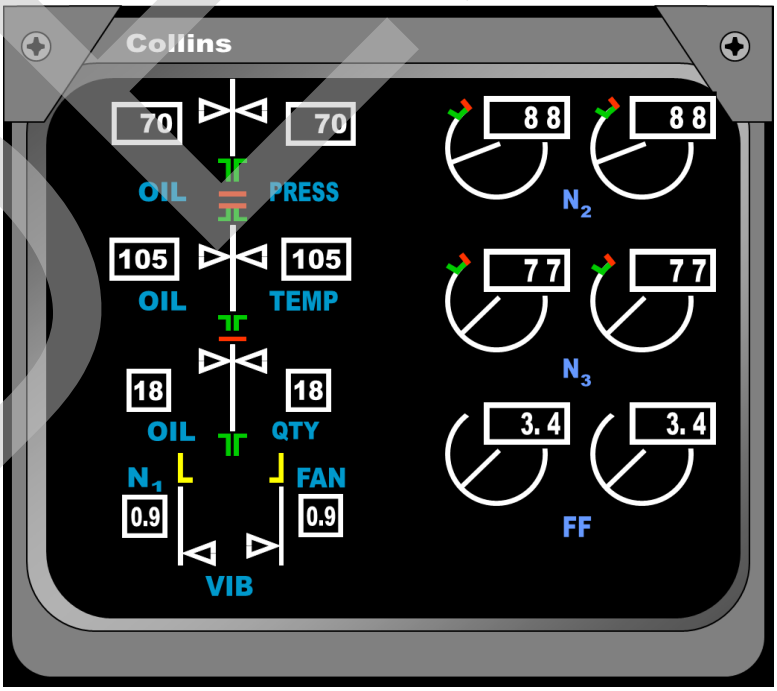
On the upper unit, a row of Vs (Blue Grass) will appear when secondary information is being displayed on the lower unit. Several colours are produced by the CRTs for displaying information. These have the following functions:

Colour	Function
White	All scales, normal operating range of pointers and digital readouts
Red	Warning messages requiring immediate crew action, Maximum operating limit marks on scales & digital readouts
Amber	Caution messages requiring immediate crew awareness
Green	Normal condition, operating within limits
Blue	Action messages that the crew are required to carry out
Magenta	Parameters and associated warnings inhibited during certain flight phases

Figure 27 and 28 show display formats for primary and secondary displays respectively.



EICAS Primary display
Figure 27



EICAS secondary display
Figure 28

14.13.2 Display Modes

EICAS is designed to categorize displays and alerts according to the function and usage. For this purpose there are three modes of displaying information:

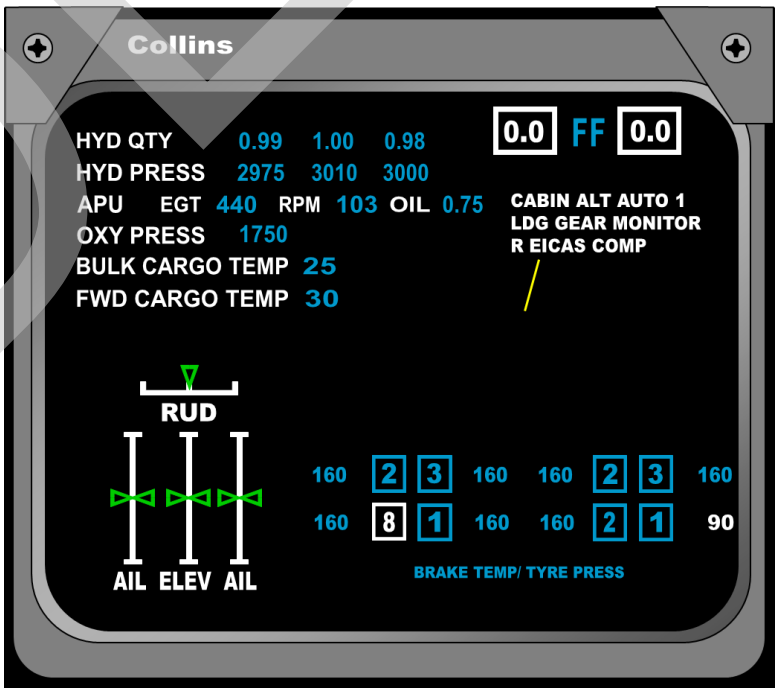
1. Operational (selected by the flight crew).
2. Status (selected by the flight crew).
3. Maintenance (ground use only and selected via the maintenance panel).

14.13.3 Operational Mode

This mode displays the engine operating information and any alerts requiring action by the crew in flight. Normally only the upper display unit presents information: the lower one remains blank and can be selected to display secondary information as and when required.

14.13.4 Status Mode

When selected this mode displays data to determine the dispatch readiness of an aircraft, and is closely associated with details contained in the aircraft's Minimum Equipment List. The display shows the positions of the flight control surfaces in the form of pointers registered against vertical scales, selected sub-system parameters, and equipment status messages on the lower display unit. Selection is normally done on the ground, either as part of the pre-flight checks of dispatch items, or prior to shutdown of electrical power to aid the flight crew in making entries in the aircraft's Technical log. Figure 29 shows an example of a status page.



EICAS Status page display
Figure 29

14.13.5 Maintenance Mode

This mode provides maintenance engineers with information in five different display formats to aid them in fault finding and verification testing of major sub-systems.

14.13.6 Display Select Panel

To control the operation of the EICAS, a control panel is situated on the centre pedestal. Figure 29 shows a typical EICAS control panel.

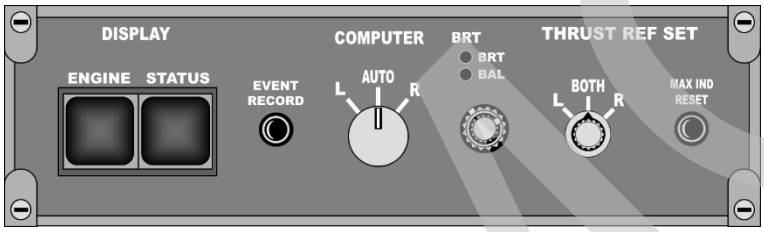


Figure 30

14.13.7 Display Select Panel Operation

Engine Display Switch: This is a push type switch for removing or presenting the display of secondary information on the lower display.

Status Display Switch: This is a push type switch for removing or presenting the status page on the lower display.

Event Record Switch: Normally, there is an auto event function and this will automatically record any malfunctions as they occur. The push switch enables manual event marking so that the crew can record a suspect malfunction for storage in a non-volatile memory. This data can be retrieved from the memory and displayed by ground engineers by operating the ground maintenance panel. The manual switch can also be used for activating the recording of fault data, either in the air or on the ground, on the Environmental Control system, Electrical Power system, Hydraulic system and APU.

Computer Select Switch: In the 'AUTO' position it selects the left, or primary computer and automatically switches to the other in the event of a failure. The other positions are for manually selecting either the right or left computers.

Display Brightness: Controlled by the inner knob for the display intensity, the outer for display brightness.

Thrust Reference Set Switch: Pulling and rotating the inner knob positions the reference cursor on the thrust indicator display (either EPR or N1) for the engines, which are selected by the outer knob.

Max Indicator Reset: If any of the measured parameters i.e. Oil Pressure, EGT etc. exceed normal operating limits, it will be automatically alerted on the display units. The purpose of the reset button is to clear the alerts from the display when the excess limits no longer exist.

14.13.8 Alert Messages

The system will continually monitor a large number of inputs (400+) from engine and airframe systems. If a malfunction is detected, then the appropriate alert message is annunciated on the upper display. Up to 11 messages can be displayed and are at the following levels:

LEVEL A - Warning: Requiring immediate corrective action and are displayed in 'RED'. Master warning lights are also activated and aural warnings (Fire Bell Type) from the Central Warning System are given.

LEVEL B - Caution: Requiring immediate crew awareness and possible action. They are displayed in 'AMBER'. An aural tone (Single Chime) is also repeated twice.

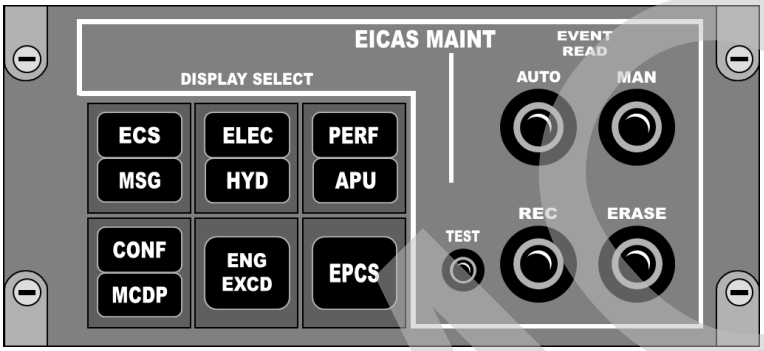
LEVEL C - Advisory: Requiring crew awareness, displayed in 'AMBER'. There are no caution lights or aural tones associated with this level.

Figure 31 shows a display with the three different types of alert messages displayed on the Upper EICAS.

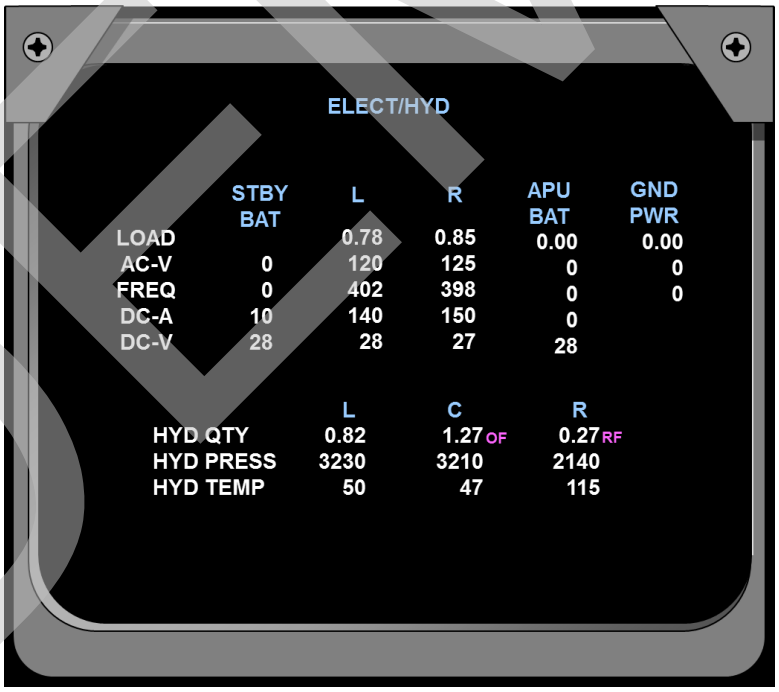
EICAS alert messages
Figure 31

14.13.9 Maintenance Control Panel

The panel is used by maintenance engineers for displaying maintenance data stored within the system's computer memories. Figure 32 shows a typical maintenance control panel with Figure 33 showing the ELEC/HYD Maint page.



Maintenance Control Panel
Figure 32



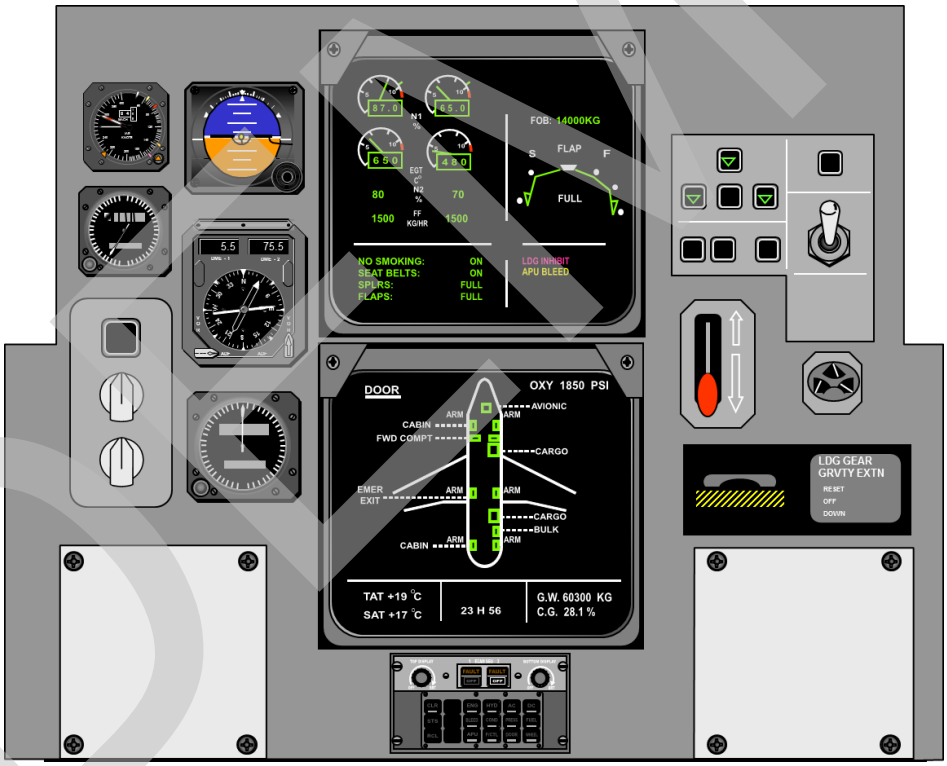
EICAS ELEC/HYD Maint page
Figure 33

14.14 ELECTRONIC CENTRALISED AIRCRAFT MONITORING (ECAM)

ECAM differs from EICAS in that the data displayed relates essentially to the primary systems of the aircraft and are displayed in checklist and pictorial or synoptic format.

14.14.1 Display Units

Mounted either side-by-side or top/bottom. The left-hand/top unit is the dedicated **Engine/Warning Display** providing information on the status of the systems and warnings and corrective actions in a sequenced checklist format. The right-hand/bottom unit is the **System Display** providing information relating to the current aircraft Flight Phase unless an Alert has occurred or a System Display Switch or the Status Switch has been pressed. Figure 34 shows the Engine/Warning Display and System Display in Top/Bottom configuration.



ECAM displays
Figure 34

14.14.2 ECAM Display Modes

There are four system display modes, three of which are automatically selected and referred to as:

Phase-Related Mode – Lower Display shows info relating to Flight Phase

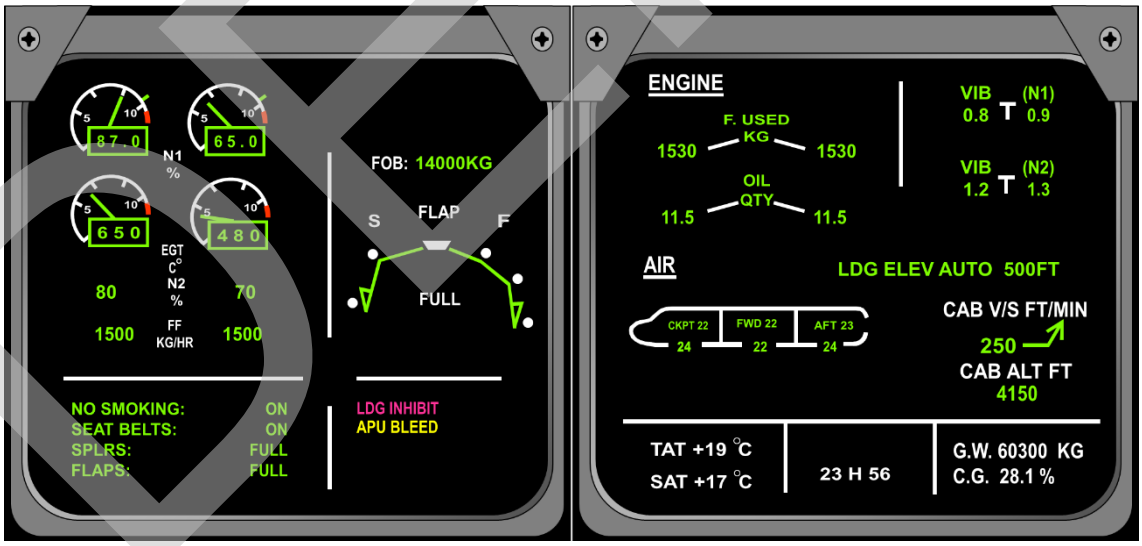
Advisory Mode – Lower Display shows System Page relating to minor problem

Failure Mode – Lower Display shows System Page relating to System Failure

The fourth mode is manual and permits the selection of diagrams related to any one of 12 of the aircraft's systems for routine checking, and also the selection of status messages, provided no warnings have been triggered for display.

14.14.3 Flight Phase Related Mode

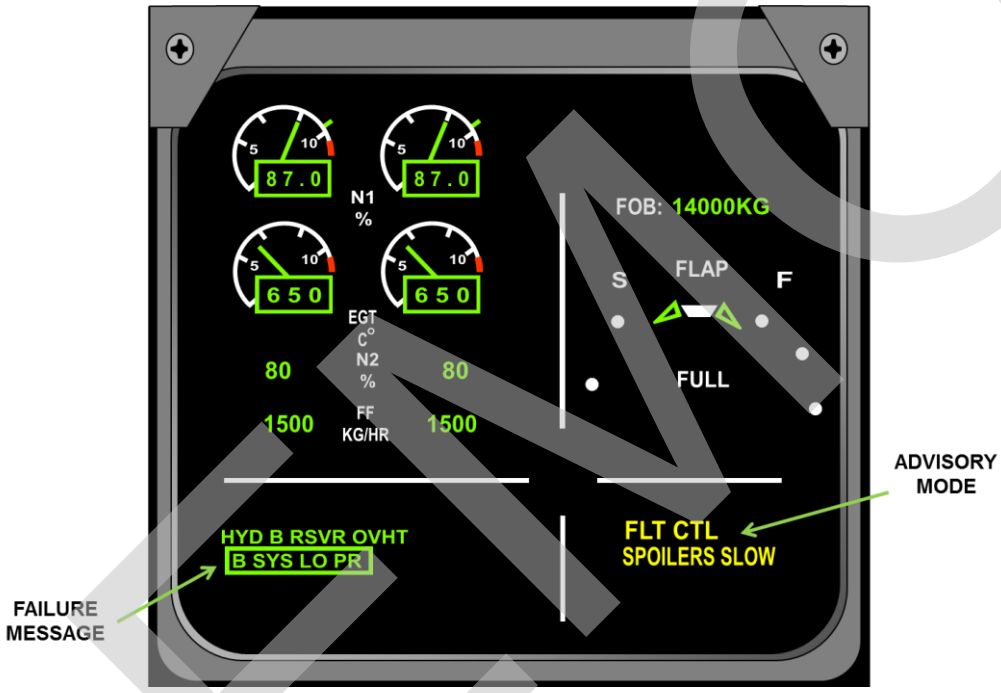
In normal operation, the automatic flight phase related mode is active. The upper display shows the Engine/Warning page and the lower display shows the page relating to the current phase of flight. There are seven flight phases, Pre-Flight, Take-Off, Climb, Cruise, Descent, Approach and Post-Landing. The Cruise page is shown for the majority of the flight. Figure 35 shows the **Engine/Warning Display** (upper display) and the **Cruise Mode** (lower display)



ECAM Display modes
Figure 35

14.14.4 Advisory Mode

Highlights the aircraft's condition following the detection of an abnormality that could possibly downgrade an affected system in the future. An example may be engine vibration that could become excessive. The Secondary Engine System Page would be shown on the Lower Display and the Engine Vibration Value would pulse, but the colour would remain Green.



ECAM Advisory message
Figure 36

14.14.5 ECAM Failure Mode

The failure mode takes precedence over the other modes and the System Page relating to the detected failure will appear automatically on the Lower Display. Failures are classified in 3 levels

Level 3: Warnings

This corresponds to an emergency configuration. This requires the flight crew to carry out corrective action immediately. This warning has an associated aural warning (fire bell type) and a visual warning (Master Warning), on the glare shield panel.

Level 2: Cautions

This corresponds to an abnormal configuration of the aircraft, where the flight crew must be made aware of the caution immediately but does not require immediate corrective action. The flight crew decide on whether action should be taken. These cautions are associated to an aural caution (single chime) and a steady (Master Caution), on the glare shield panel.

Level 1: Cautions

This gives the flight crew information on aircraft configuration that requires monitoring, mainly failures leading to a loss of redundancy or degradation of a system, i.e. Loss of 1 FUEL TANK PUMP LH or RH but not both.

The advisory mode will not trigger any aural warning or ‘attention getters’ but a message appears on the primary ECAM display.

14.14.6 Control Panel

The control panel allows selection of the display for system and status images. The layout of the control panel is shown in Figure 37.

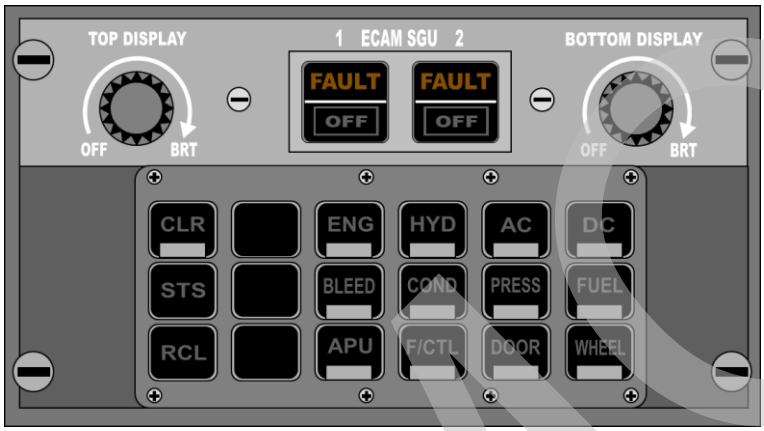


Figure 37

SGU Selector Switches: Controls the respective symbol generator units. Lights are off in normal operation of the system. 'FAULT' is illuminated amber if an SGU internal test circuit detects a failure. Releasing the switch isolates the corresponding SGU and causes the 'FAULT' caption to extinguish and the 'OFF' caption to illuminate white.

System Synoptic Display Switches: Permit individual selection of synoptic diagrams corresponding to each of the 12 systems and illuminate white when pressed. A display is automatically cancelled whenever a warning or advisory occurs.

CLR Switch: Light illuminates white whenever a warning or status message is displayed on the left-hand display unit. Press to clear messages.

STS Switch: Permits manual selection of an aircraft's status message if no warning is displayed. Illuminates white when pressed also illuminates the CLR switch. Status messages are suppressed if a warning occurs or if the CLR switch is pressed.

RCL Switch: Enables previously cleared warning messages to be recalled, provided the failure conditions which initiated the warnings still exists. Pressing this switch also illuminates the CLR switch. If a failure no longer exists, the message 'NO WARNING PRESENT' is displayed on the left-hand display unit.

Figure 38 – 42 shows the 12-system pages and status page available.

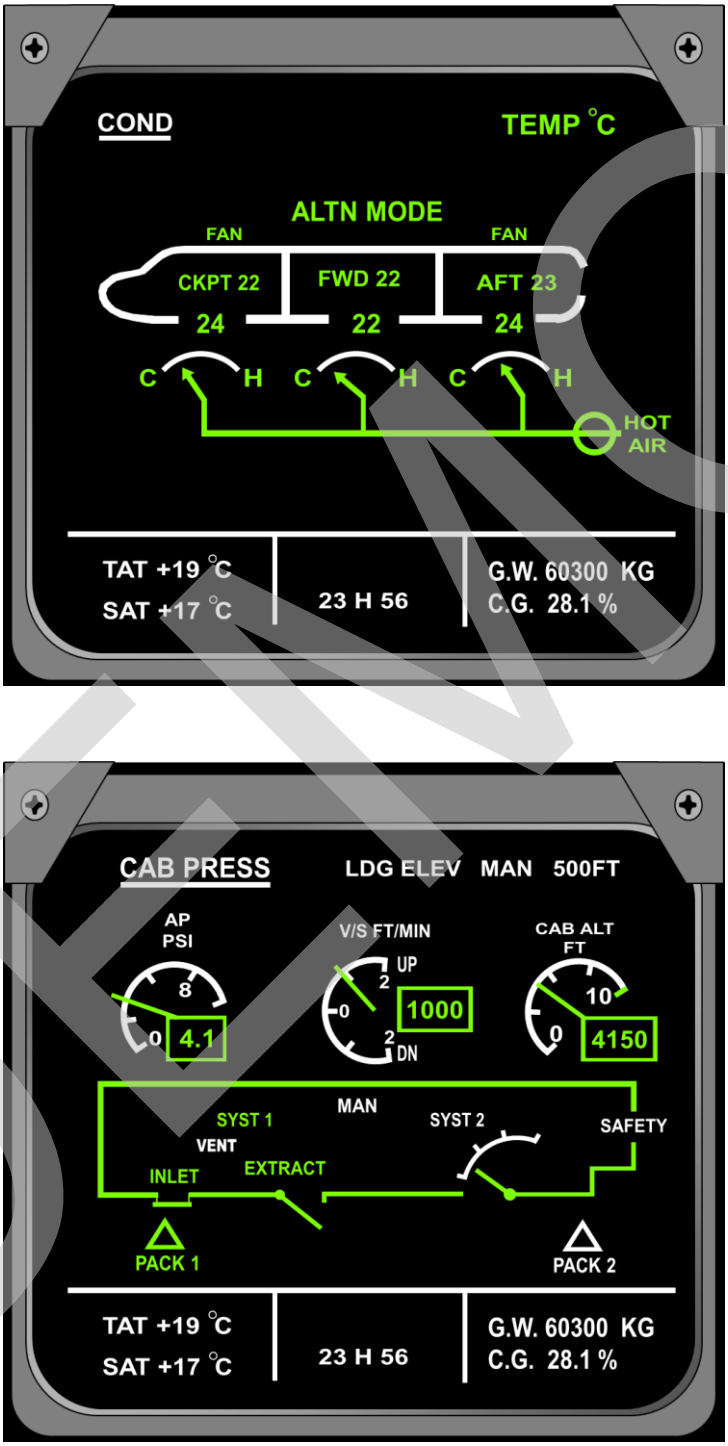


Figure 38

Note; These pages are displayed:

Automatically due to an advisory or failure related to the system.

Whenever called manually.

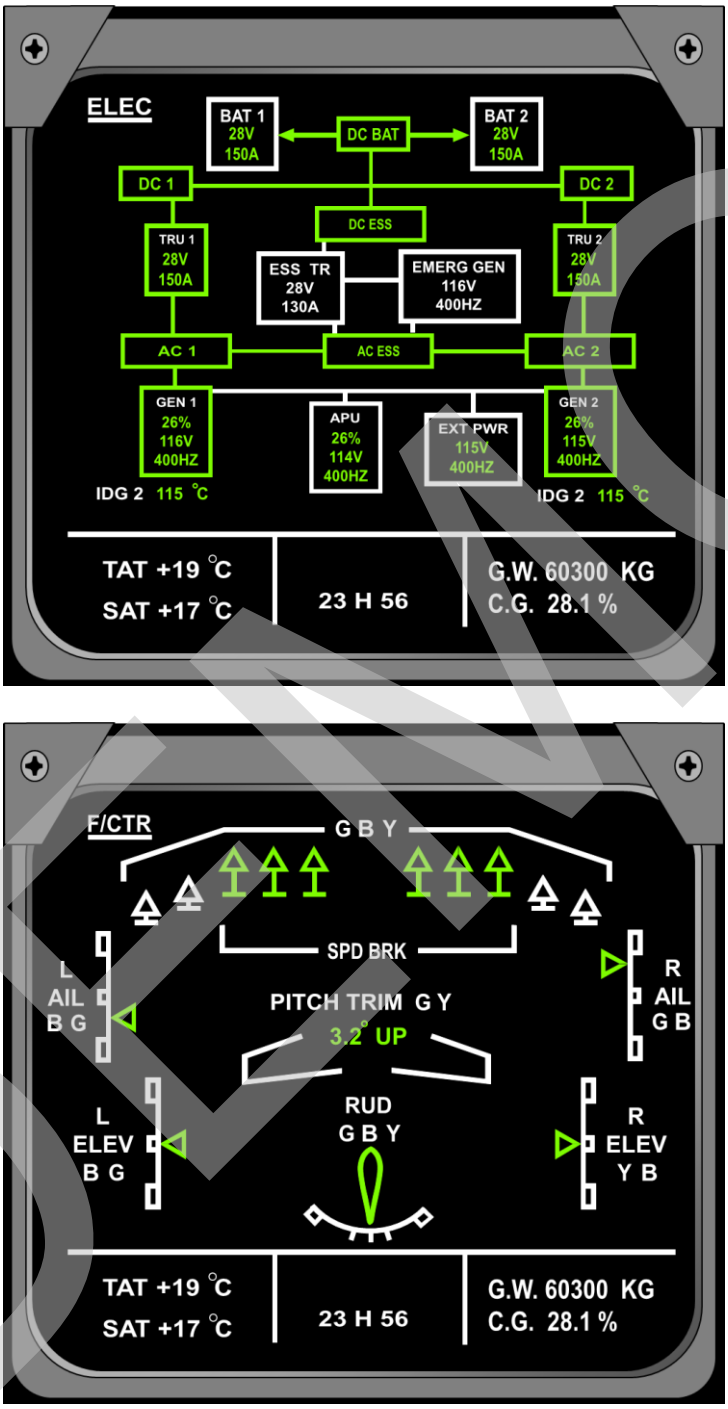


Figure 39

Note; These pages are displayed:

Automatically due to an advisory or failure related to the system.

Whenever called manually.

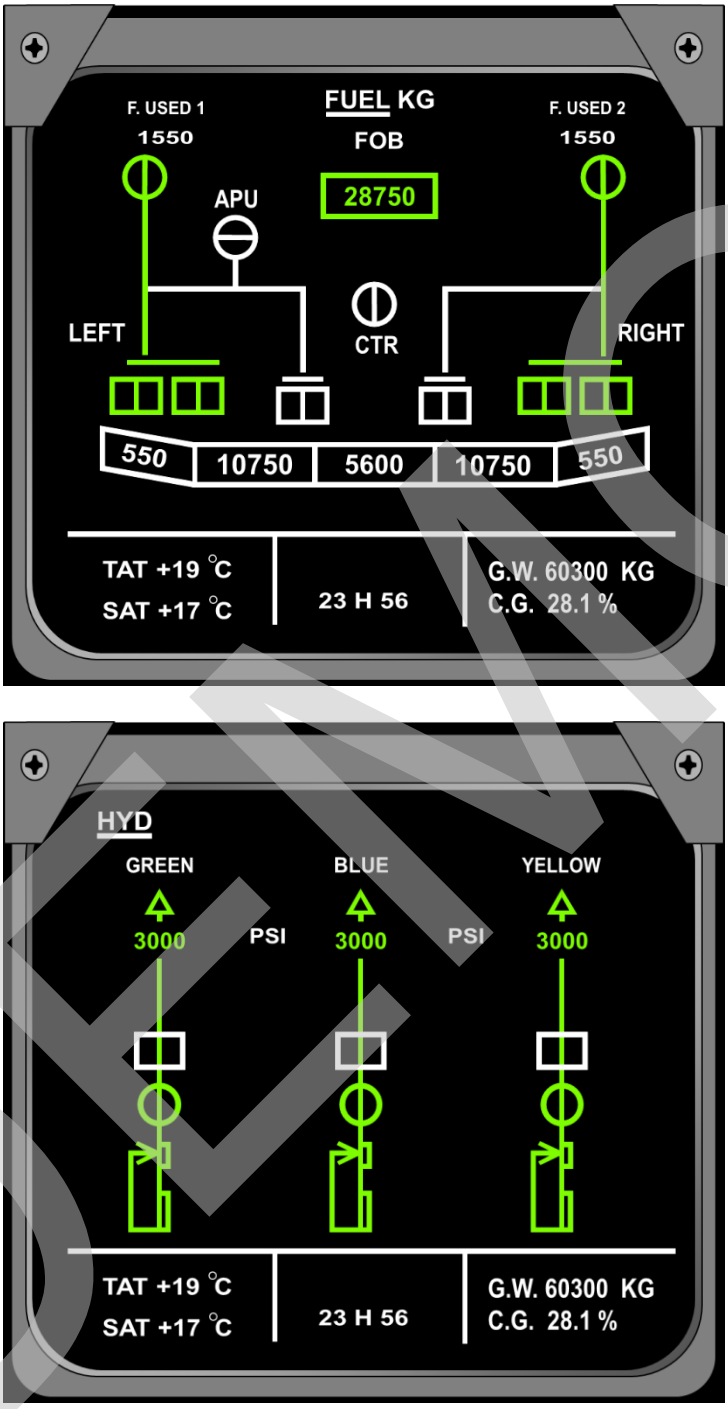


Figure 40

Note; These pages are displayed:

Automatically due to an advisory or failure related to the system.

Whenever called manually.

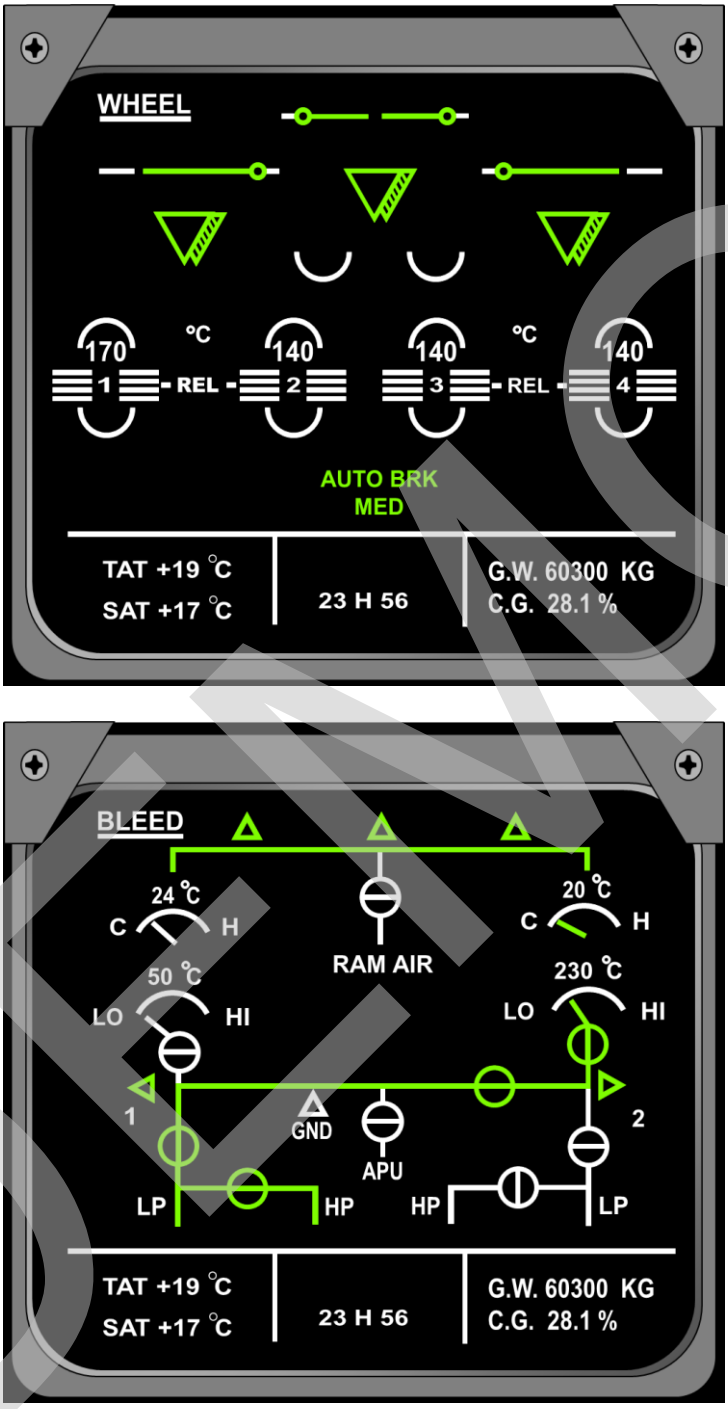


Figure 41

Note; These pages are displayed:

Automatically due to an advisory or failure related to the system.

Whenever called manually.

The Gear/Wheel page is displayed at the related flight phase.

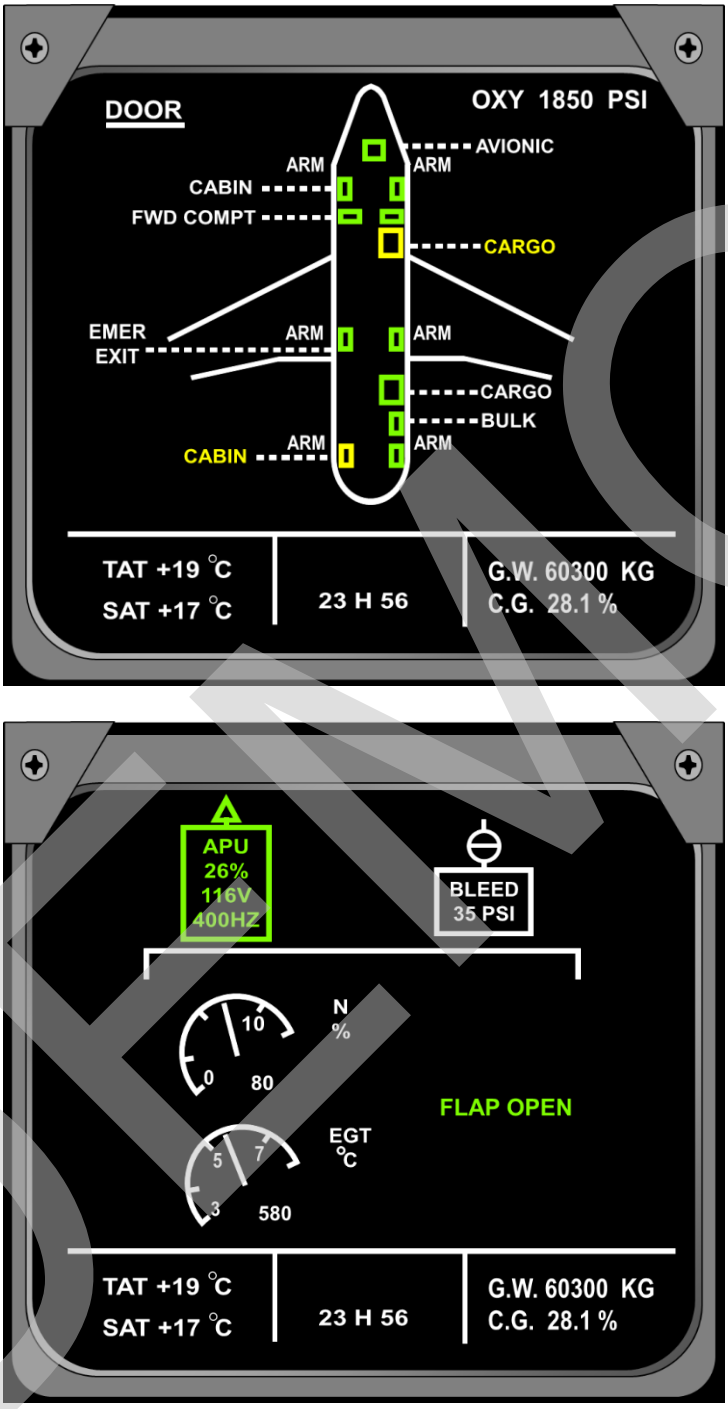


Figure 42

Note; These pages are displayed:

Automatically due to an advisory or failure related to the system.

Whenever called manually.

Related flight phase.

14.14.7 Status Display

The STATUS Page is selected and displayed on the Lower Display either:

Automatically after a warning message, as soon as all corrective actions have been performed

or

Manually by pressing the STS key on the ECAM Control Panel

The ECAM Status Page is divided into three separate sections:

On the left section of the display is an operational summary of the aircraft's condition, listing all the failures having consequences upon operational aspects, such as:

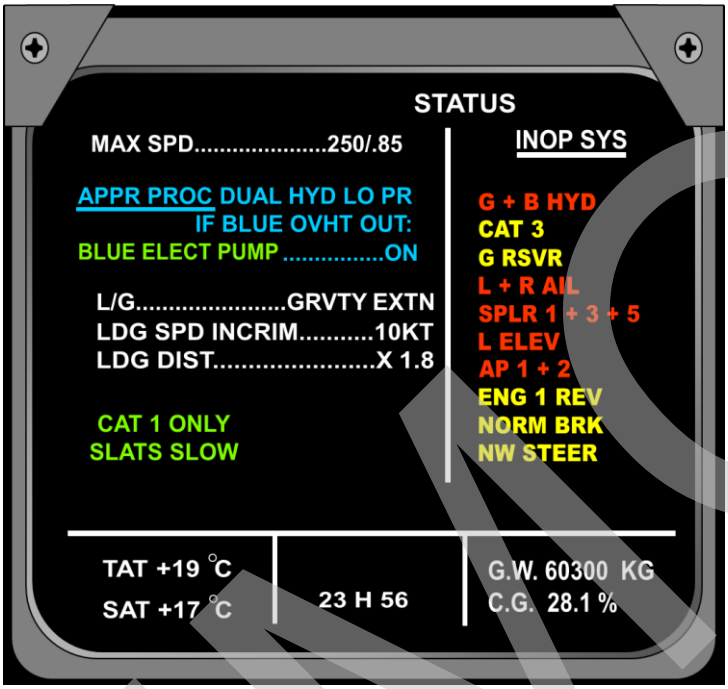
1. Emergency procedures (LAND ASAP)
2. Landing capability and procedures
3. Limitations (Speed/Altitude)
4. Procedures that may be postponed and not displayed on first page.
5. Lost systems or functions
6. Information

On the right section of the display is a list of secondary failures or systems that are inoperative

On the bottom section of the display there is a list of permanent data such as Total Air Temperature and Static Air Temperature.

There is a Fault Warning Computer (FWC) which generates the status messages.

Figure 43 shows a typical status page.

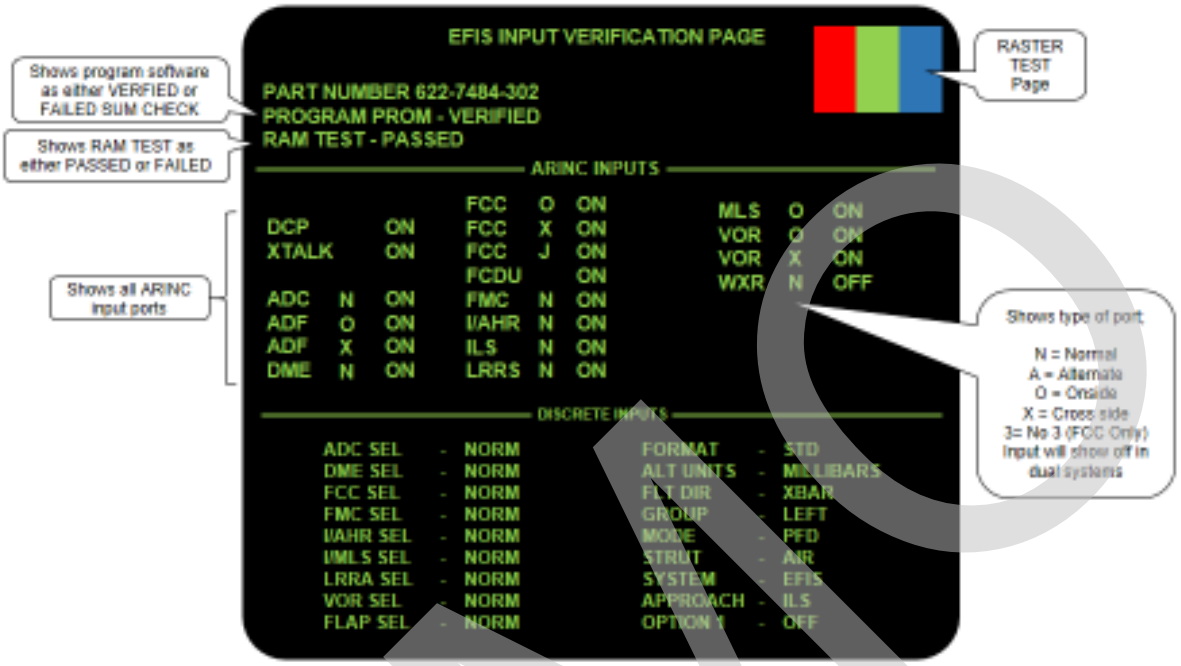


ECAM Status page
Figure 43

14.15 BIT FUNCTIONS ON EFIS

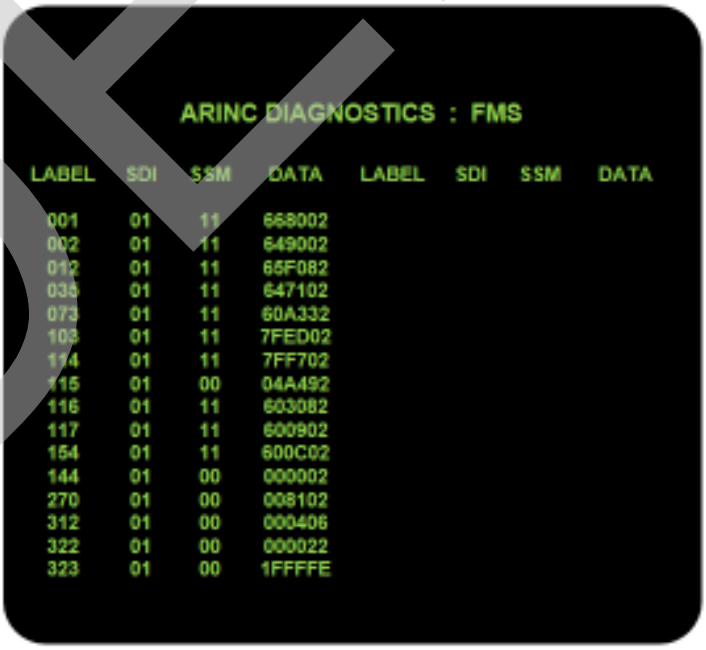
A limited BIT function is available on EFIS Systems. The EFIS PFD and ND are used to verify the test outputs of the various avionic systems supplying data to the EFIS. When, for example, the LRRA system is put into test mode, the LRRA output is set to 40ft and this is verified by the engineer by observing the LRRA output changing to this value on the PFD. In another example, the ADF test bearing is 135 degrees and, when put into test mode, the engineer verifies the ADF bearing pointer has driven to this bearing on the ND.

Additionally, the EFIS itself can be put into VERIFY mode via a guarded switch on the Maintenance and Test Panel (MTP). On selection, the EFIS displays show identical displays on both the PFD and ND. During this initial period, the EFIS system performs a self-test on its software and hardware functions and the results of the test are displayed to the engineer after a few seconds have elapsed, see Figure 44. The page indicates the results of a SUM CHECK and RAM TEST as well as showing the status of the various ARINC and DISCRETE inputs to the EFIS. Additionally, a RASTER TEST PATCH allows the engineer to confirm that the colour outputs are satisfactory.



EFIS Verification page (both PFD and ND screens)
Figure 44

An additional ARINC DIAGNOSTICS page is available showing the LABEL, SDI, SSM and DATA for each input to a selectable system, see Figure 45.

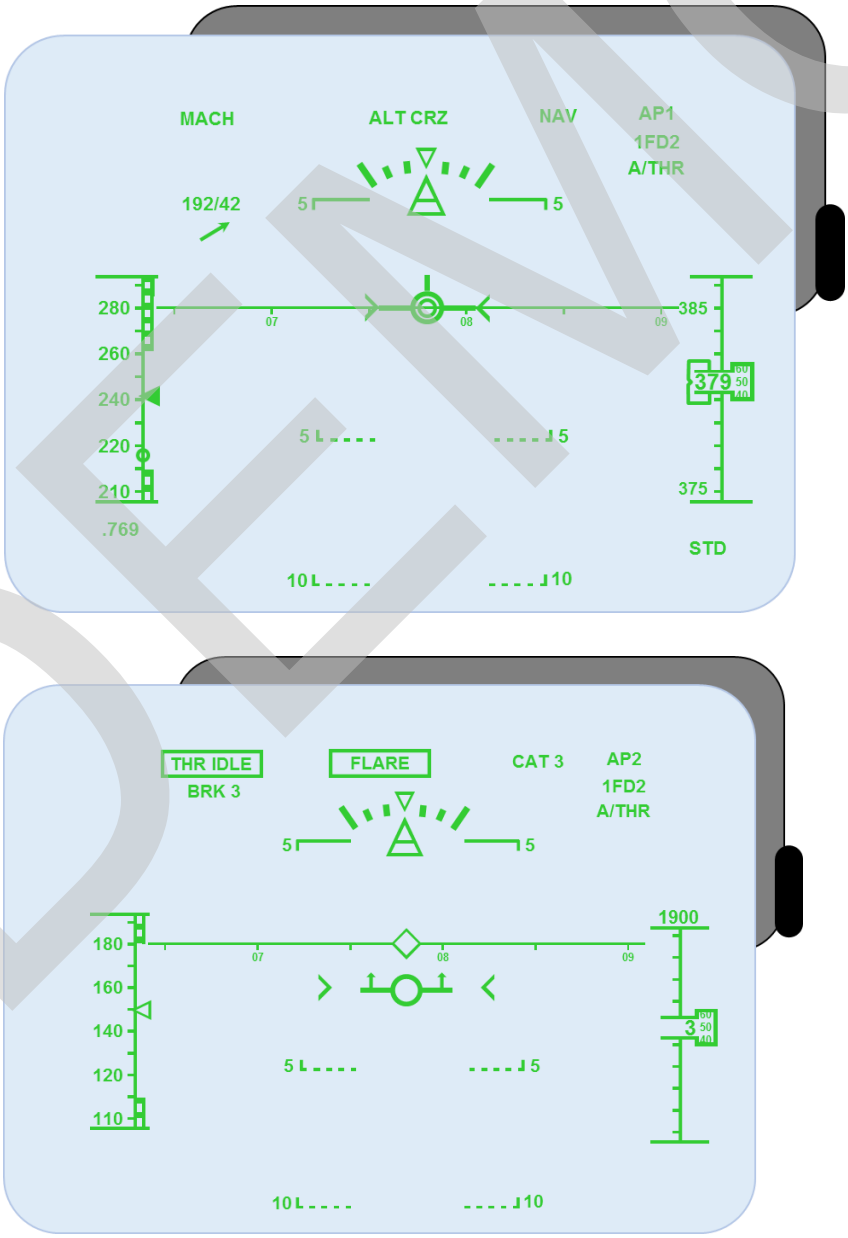


EFIS ARINC DIAGNOSTICS page (both PFD and ND screens)
Figure 45

14.16 HEAD UP DISPLAY

14.16.1 Head-Up Display System

The Head Up Display (HUD) provides pilots with an array of flight-related information, when and where they need it most. The HUD combiner glass, which folds down and locks into position in front of the pilot's eyes, displays PFD related flight data and symbology directly in the forward field of vision. On a non-precision approach at night or in poor weather, this information is of huge value, particularly when viewed in the context of past aircraft accident investigations. Figure 46 shows an A350 Head-Up Display with the aircraft at altitude and during landing phase.



Head-Up Display (HUD)
Figure 46

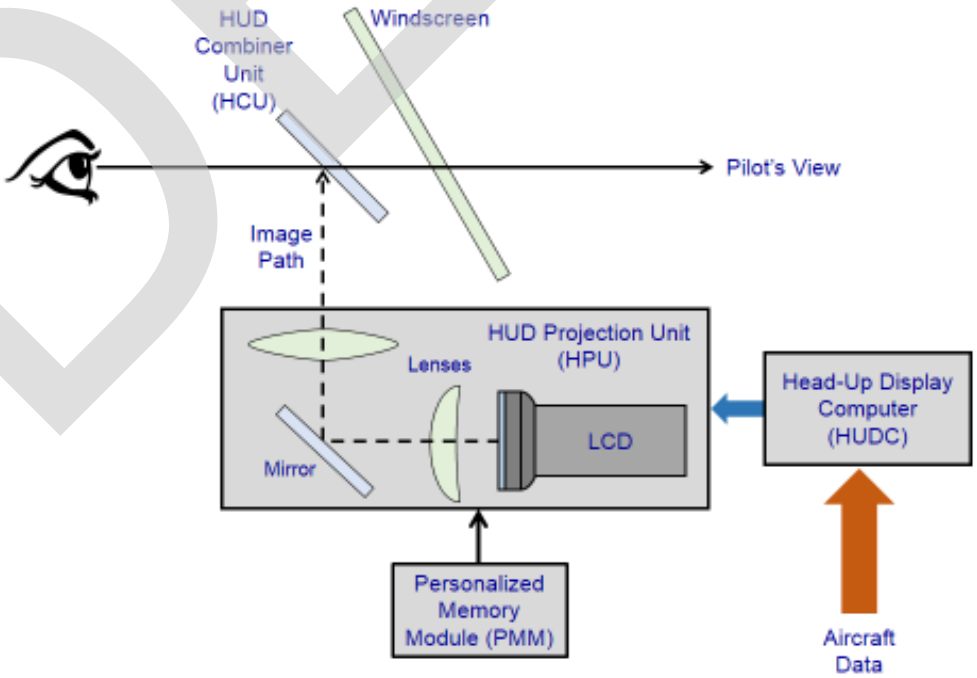
Early HUDs developed for civil aviation typically showed the same data that was available on a head-down primary flight display (PFD), namely airspeed, altitude, localiser, glideslope and so on. Today's HUDs offer a far broader menu of symbology, including a flight-path marker, path and airspeed trend vectors, angle-of-attack readout, runway depictions, landing-flare cues, runway-remaining information, tail-strike warning, unusual-attitude-recovery symbology, TCAS resolution advisories and other vital data. Add to this list the recent certification of HUD-based infrared enhanced-vision systems (EVS) and the ongoing research of database-derived synthetic-vision systems (SVS), and the potential value of HUDs as a tool for improved situational awareness is readily evident.

14.16.2 Functional Overview

The HUD system is used for a wide variety of flight guidance functions available to the flight deck crew in all phases of flight, including take-off and landing. HUD also provides a visual aid for airport surface operations. The HUD system components generally comprise the following units:

- HUD Display Computer (HUDC).
- HUD Projection Unit (HPU).
- HUD Combiner Unit (HCU).
- Personalised Memory Module (PMM).

Figure 47 shows a typical HUD layout.



HUD Schematic
Figure 47

14.16.3 Head-Up Display Computer (HUDC)

The HUDC receives data on the aircraft's flight and navigational aids from the Aircraft Information System via the ARINC 629 data bus. It processes this information and generates the display graphics and outputs video pulses to the Head-Up Projection Unit (HPU) for the required display symbology. It also incorporates Built-In Test Equipment (BITE) for system self-monitoring and fault data storage.

14.16.4 Head-Up Projection Unit (HPU)

The HPU receives video pulses from the HUDC and uses these signals to generate the required display on to a LCD screen. The use of LCD technology offers additional graphic capabilities and a good quality of legibility of the symbology. The image from the LCD is projected via a mirror and various lenses on to the Combiner Unit.

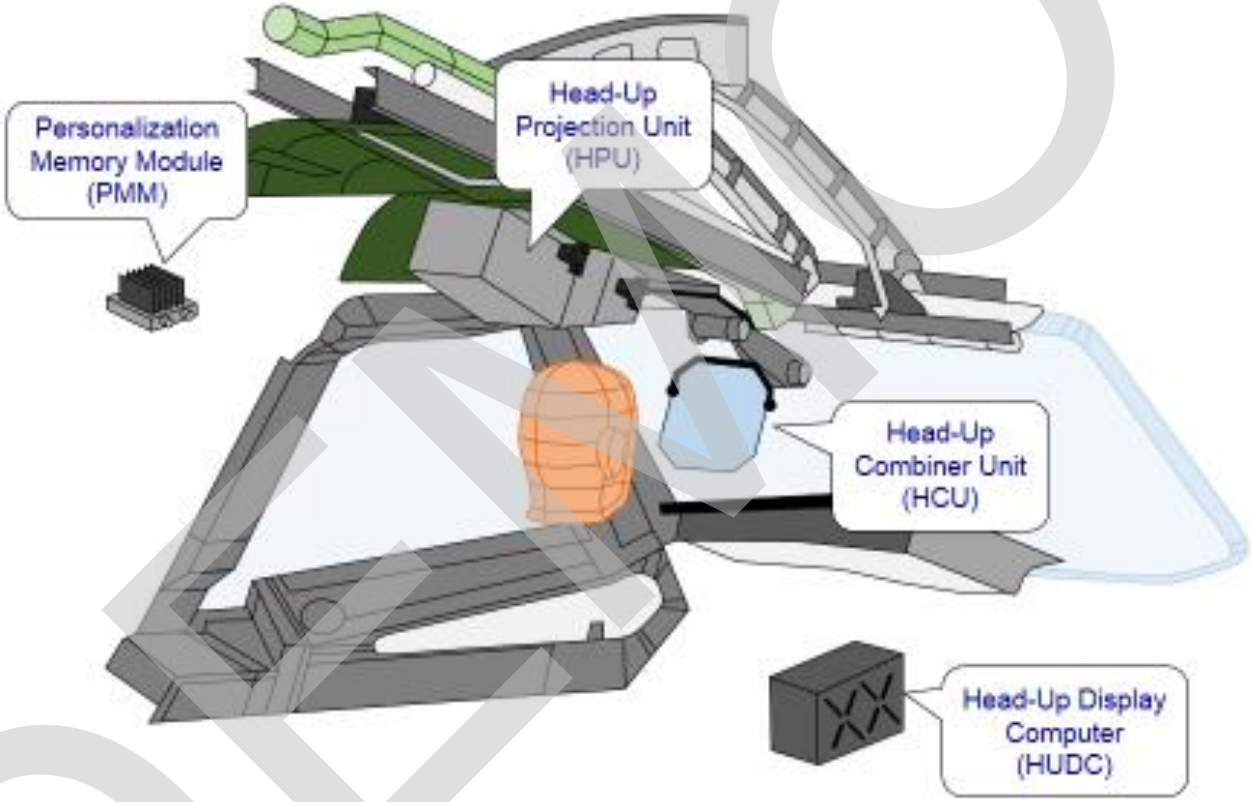
14.16.5 Head-Up Combiner Unit (HCU)

The HCU consists of an optical unit (Glass Plate) which is mounted behind the aircraft's windshield. The HCU reflects the projected image from the HPU towards the pilot. Whilst the superimposed image, which is focused to infinity, provides the flight crew with flight information, they can continue to observe external ground reference points during each phase of flight. The HCU is hinged so that when not required it can be stored away out of the pilot's field of view. Figure 48 shows a HCU

Head up Combiner Unit (HCU)
Figure 48

14.16.6 Personalisation Memory Module (PMM)

The PMM is used for storing the electronic bore sighting parameters for that particular aircraft. This involves an electronic process which aligns the optical reference of the HUD flight-deck equipment with that of the aircraft and this avoids the need to repeat the process should a HUD LRU be replaced. Figure 49 shows a schematic of an Airbus Industries Head-Up Display System.



HUD System (Airbus Industries)
Figure 49

14.16.7 HUD Symbology

The primary aim of the HUD symbology is to provide essential flight data and the information required for the safe and effective control of the aircraft. It is necessary for the symbology to accurately represent the outside (conformal) view, while not obstructing the outside view. The following items are unique to HUD symbology:

Conformal Elements – Some HUD symbols are designed to overlay the real world as seen by the pilot through the HUD Combiner Unit (HCU).

Viewing Position – The HUD is designed to be viewed from the flight-deck eye reference point and a head movement around this point called the ‘Eye Motion Box’.

Viewing into the Sun – The HUD is designed to be able to project symbology that can be seen against a very bright background (3400 Cd/m^2). The pilots can also use a dedicated Sun-Visor to reduce the intensity of the sun and can set the brightness of the symbology so that it can be seen (or use an automatic brightness feature).

The core symbology of the HUD is the Attitude/Energy Box, which is composed of;

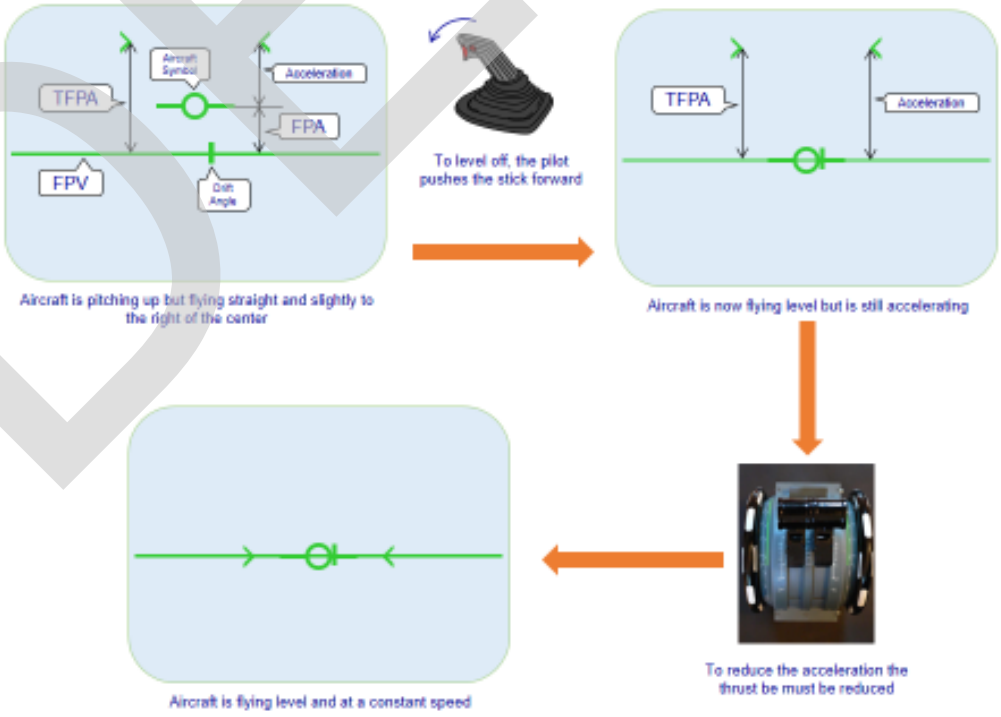
- Aircraft Attitude (Pitch, Roll, side-slip and heading).
- Flight Path Vector (FPV).
- The Total Flight Path Angle (TFPA).
- Airspeed Scale.

14.16.8 Flight Path Vector (FPV)

The FPV indicates the actual aircraft's trajectory through the aircraft's Flight Path Angle (FPA) as the longitudinal component of the aircraft's drift angle as the lateral component.

14.16.9 Total Flight Path Angle (TFPA)

The TFPA is represented on the display by two chevrons which indicate the actual total energy of the aircraft (both Potential and Kinetic). It provides indications of the aircraft's acceleration and deceleration. Along with the FPV, it assists the pilots is controlling the aircraft's airspeed and flight path stability during an approach. Figure 50 shows FPA, TFPA & FPV indications.

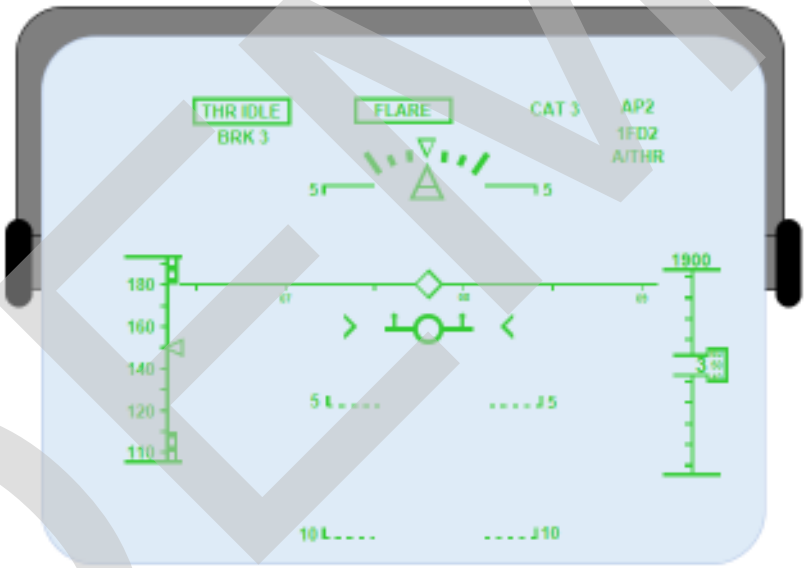


FPA, TFPA & FPV Indications
Figure 50

The HUD system improves the flight crew's situational awareness and therefore contributes to the safety of the aircraft is providing;

- Situational awareness for the manual visual approach and landing.
- Enhanced stability of a manually flown approach (Instrument and visual approach).
- Enhanced pilot situational awareness when close to the ground by showing confrontal trajectory related symbols superimposed to the symbols superimposed to the external scene.
- Situational information for the monitoring of automatic approaches with Autoland Cat II & Cat III approaches.

Figure 51 shows a HUD display for an aircraft approaching the touchdown point.



HUD Approach Display
Figure 51