

MODULE 05

FOR B2 CERTIFICATION

DIGITAL TECHNIQUES/ ELECTRONIC INSTRUMENT SYSTEMS

Aviation Maintenance Technician Certification Series



72413 U.S. Hwy 40
Tabernash, CO 80478-0270 USA

www.actechbooks.com

+1 970 726-5111

WELCOME

The publishers of this Aviation Maintenance Technician Certification Series welcome you to the world of aviation maintenance. As you move towards EASA certification, you are required to gain suitable knowledge and experience in your chosen area. Qualification on basic subjects for each aircraft maintenance license category or subcategory is accomplished in accordance with the following matrix. Where applicable, subjects are indicated by an "X" in the column below the license heading.

For other educational tools created to prepare candidates for licensure, contact Aircraft Technical Book Company.

We wish you good luck and success in your studies and in your aviation career!

REVISION LOG

VERSION	EFFECTIVE DATE	DESCRIPTION OF CHANGE
001	2015 01	Module Creation and Release
002	2017 02	Format Update

DIGITAL TECHNIQUES/ELECTRONIC INSTRUMENT SYSTEMS

Welcome	iii
Revision Log.....	iii
Forward.....	iv
Contents	ix

SUB-MODULE 01

ELECTRONIC INSTRUMENT SYSTEMS

Knowledge Requirements	1.1
Electronic Instrument Systems	1.2
Analog Instruments	1.2
Digital Instruments	1.2
Electronic Displays	1.3
Electronic Flight Instrument System	1.5
Engine Indication And Crew Alerting System	1.7
Electronic Instrument Computing Systems	1.9
Questions	1.13
Answers	1.14

SUB-MODULE 02

NUMBERING SYSTEMS

Knowledge Requirements	2.1
Numbering Systems	2.2
Decimal	2.2
Binary.....	2.2
Place Values.....	2.2
Binary Number System Conversion	2.3
Octal.....	2.4
Octal Place Value Chart	2.4
Octal Number System Conversion.....	2.4
Hexadecimal	2.6
Hexadecimal Place Value Chart.....	2.6
Hexadecimal Number System Conversion.....	2.6
Binary-Coded Decimals	2.7
ASCII	2.7
Questions	2.9
Answers	2.10

SUB-MODULE 03

DATA CONVERSION

Knowledge Requirements	3.1
Data Conversion.....	3.2
Analog Data.....	3.2
Digital Data	3.3
Analog To Digital Conversion	3.3
Digital To Analog Conversion	3.4

Limitations Of Conversion	3.6
Questions	3.9
Answers	3.10

SUB-MODULE 04

DATA BUSES

Knowledge Requirements	4.1
Digital Data Buses	4.2
MIL-STD-1553B	4.2
ARINC 429.....	4.5
ARINC 629.....	4.5
Aircraft Networks/Ethernet	4.6
ARINC 664 AFDX	4.6
IEEE 1394 Firewire	4.7
Questions	4.9
Answers	4.10

SUB-MODULE 05

LOGIC CIRCUITS

Knowledge Requirements	5.1
Logic Gates.....	5.2
NOT Gate	5.2
Buffer Gate.....	5.3
AND Gate	5.3
OR Gate.....	5.3
NOR Gate	5.5
Exclusive OR Gate	5.5
Exclusive NOR Gate	5.5
Negative Logic Gates	5.5
Interpretation Of Logic Diagrams.....	5.6
Adder Logic Circuits	5.6
TTL And CMOS	5.7
Aircraft Logic Circuit Applications.....	5.7
Questions	5.9
Answers	5.10

SUB-MODULE 06

BASIC COMPUTER STRUCTURE

Knowledge Requirements	6.1
Basic Computer Structure	6.2
Computer Architecture	6.2
Bits, Bytes, And Words	6.3
Software	6.4
Hardware	6.5
Central Processing Unit	6.5
Memory (RAM, ROM, PROM)	6.5
Integrated Circuits.....	6.6

CONTENTS

Microcomputers	6.7
Layout And Interface.....	6.7
Operation.....	6.7
Instruction Words	6.8
Memory Devices.....	6.9
Data Storage Systems	6.10
Aircraft Computer Systems	6.10
Questions	6.13
Answers	6.14

SUB-MODULE 07

MICROPROCESSORS

Knowledge Requirements	7.1
Microprocessors	7.2
Functions Performed	7.2
Overall Operation	7.3
Functional Components	7.3
Machine Cycle.....	7.4
Clock Timing.....	7.4
Questions	7.7
Answers	7.8

SUB-MODULE 08

INTEGRATED CIRCUITS

Knowledge Requirements	8.1
Integrated Circuits	8.2
Flip-Flops	8.3
Comparators	8.4
Encoders.....	8.5
Decoders	8.6
Scale Of Integration	8.9
Questions	8.11
Answers	8.12

SUB-MODULE 09

MULTIPLEXING

Knowledge Requirements	9.1
Multiplexing	9.2
Multiplexers	9.2
Interleaving	9.3
DeMultiplexers	9.4
Questions	9.7
Answers	9.8

SUB-MODULE 10

FIBER OPTICS

Knowledge Requirements	10.1
Fiber Optics	10.2
Advantages And Disadvantages	10.2
Fiber Optic Data Bus	10.3
Transmitters.....	10.3
Light-Emitting Diodes	10.4
Laser Diodes	10.5
Receivers	10.5
Photo-Diode Detectors	10.6
Related Terms	10.7
Terminations	10.7
Couplers And Terminals	10.8
Applications In Aircraft Systems	10.8
Questions	10.11
Answers	10.12

SUB-MODULE 11

ELECTRONIC DISPLAYS

Knowledge Requirements	11.1
Electronic Displays.....	11.2
Cathode Ray Tubes.....	11.2
Light Emitting Diodes.....	11.3
Liquid Crystal Displays	11.5
Active Matrix Liquid Crystal Display	11.6
Questions	11.7
Answers	11.8

SUB-MODULE 12

ELECTROSTATIC SENSITIVE DEVICES

Knowledge Requirements	12.1
Electrostatic Sensitive Devices.....	12.2
Risks And Possible Damage	12.2
Anti-Static Protection	12.3
Controlled Environment	12.3
Static-Safe Workstation.....	12.3
Anti-Static Wrist Straps	12.3
Grounding Test Stations	12.4
Ionizers.....	12.4
Special Handling	12.5
Questions	12.7
Answers	12.8

SUB-MODULE 13

SOFTWARE MANAGEMENT CONTROL

Knowledge Requirements	13.1
Software Management Control	13.2
Restrictions And Catastrophic Effects	13.2
Airworthiness Requirements.....	13.2
Questions	13.5
Answers	13.6

SUB-MODULE 14

ELECTROMAGNETIC ENVIRONMENT

Knowledge Requirements	14.1
Electromagnetic Environment	14.2
Electromagnetic Interference (EMI)	14.2
High-Intensity Radiated Field (HIRF).....	14.3
Lightning/Lightning Protection	14.3
Electromagnetic Compatibility (EMC)	14.4
Questions	14.7
Answers	14.8

SUB-MODULE 15

TYPICAL ELECTRONIC/DIGITAL AIRCRAFT SYSTEMS

Knowledge Requirements	15.1
Digital Aircraft Systems.....	15.2
Electronic Instrument Systems	15.4
Electronic Flight And Engine Instruments	15.4
Integrated Modular Avionics (IMA), Information Systems, And Bite	15.4
Communications, Navigation And Surveillance Systems	15.6
Aircraft Communication Addressing And Reporting System (ACARS).....	15.6
Inertial Navigation System (INS)	15.7
Ring Laser Gyros	15.7
Micro-Electro Mechanical System (MEMS)	15.8
Global Positioning System (GPS)	15.8
Wide Area Augmentation System (WAAS)	15.9
Flight Management System (FMS)	15.10
Traffic Alert And Collision Avoidance System (TCAS)	15.11
Automatic Dependent Surveillance-Broadcast (ADS-B)	15.12
Emergency Locator Transmitter (ELT)	15.15
Flight Control Systems.....	15.18
Mechanical Flight Control Systems	15.18
Automatic Digital Flight Control Systems (ADFCS)	15.19
Cabin Systems.....	15.21
Questions	15.23
Answers	15.24

Acronym Index	A.1
Index	I.1

ELECTRONIC INSTRUMENT SYSTEMS

Instruments that aid the pilot in controlling the altitude, attitude, airspeed and heading of the aircraft are known as flight instruments. Since the early days of flight there have been four basic flight instruments that have formed the well-known "T" arrangement located in the center of the instrument panel, as shown in **Figure 1-1**. These four basic instruments are 1) the airspeed indicator, located on the top left, that measures the aircraft's speed in nautical miles per hour; 2) the attitude indicator, located on top center, that shows the aircraft's attitude relative to the earth's horizon; 3) the altimeter, on the top right, that displays the barometric altitude as measured in feet; and 4) the gyro-slaved heading indicator, in the bottom center, which shows which direction the aircraft is flying.

These four basic flight instruments are typically augmented with a turn-and-bank indicator that displays the rate of turn in the roll axis and amount of bank in the yaw axis, and a vertical speed indicator that displays the rate of ascent or descent in feet per minute. Assuming that the aircraft has radio navigation aids, it will also come equipped with a Radio Magnetic Indicator (RMI) coupled to an Automatic Direction Finder (ADF), and a Course Deviation Indicator (CDI) driven by VHF

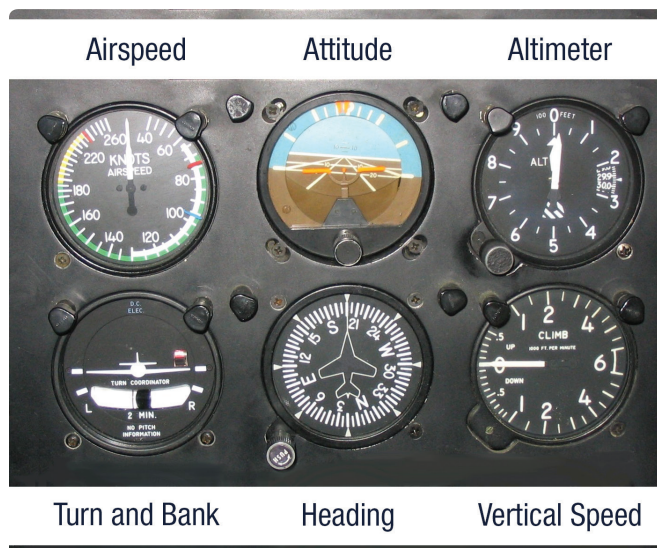


Figure 1-1. Basic analog cockpit flight instruments.

Omnidirectional Range (VOR) and Instrument Landing System (ILS) receivers. The ILS receiver drives the glideslope needle to set the glide path on an instrument approach and localizer needle provides lateral guidance to the center of the runway. A VHF Marker Beacon may be used in conjunction with the ILS to indicate position along the approach to the runway.

ANALOG INSTRUMENTS

These early flight instruments were analog meaning that they contained either mechanical or electro-mechanical rotating mechanisms to drive the pointer dials on the instruments. For example, an analog airspeed indicator receives air pressure from the pitot tube, which expands a bellows that turns the dial on the indicator. With a

digital system, the pitot air pressure enters an air data computer that converts the analog information into a digital data stream. Digital data is then sent to the airspeed indicator via an aircraft data bus where the data is converted back into analog signals to drive a pointer dial and/or is displayed digitally in numbers.

DIGITAL INSTRUMENTS

With the advent of digital electronics in the early 1970's, Electronic Instrument Systems, also known as "glass cockpits", evolved that were more much more reliable than mechanical or electro-mechanical analog instruments, and had the advantage of combining several flight and navigation functions into one display to provide the crew with greater situational awareness.

The first commercial transport aircraft to employ an Electronic Instrument System (EIS) was the McDonnell Douglas MD-80 in 1979. The EIS on the

MD-80 used Cathode Ray Tube (CRT) technology. However, during the next 10 years, Liquid Crystal Display (LCD) technology matured thereby replacing CRTs. Flat-panel LCDs are lighter than CRT displays, require less volume, and consume less electrical power, thereby generating less cockpit heat. Glass cockpit configurations vary widely between aircraft models from a single flight and navigation display in a small private aircraft to five or more LCD displays in a commercial transport aircraft. (**Figure 1-2**)



Figure 1-2. Airbus A380 EIS with 8 large LCD displays.



Figure 1-3. Equivalent Electromechanical Flight and Navigation Instruments on the left.

ELECTRONIC DISPLAYS

The early EIS displays mimicked the analog display formats for ease in pilot training as the crew transitioned from older analog displays to digital displays that were driven by aircraft data computers, known as display processors or symbol generators.

Figure 1-3 depicts an early model Boeing 737 instrument panel with an analog Attitude Direction Indicator (ADI) and analog Horizontal Situation Display (HSI)

in the left picture, and a later model B737 instrument panel with electronic ADI (EADI) and electronic HSI (EHSI) displays shown in the right picture.

The ADI or EADI is an artificial horizon with lateral bars superimposed to display computer-generated pitch, roll and bank steering commands from the Flight Director computer. The HSI or EHSI is similar to a heading indicator, except that it combines navigation commands from the VHF Omni-Range (VOR) or

Global Positioning System (GPS) receivers which are used for en-route guidance, or from the Instrument Landing System (ILS), which is used for terminal guidance. Besides heading, the HSI/EHSI also provides actual track, desired track, track angle error, drift angle, cross-track deviation, and distance to destination information from the Distance Measuring Equipment (DME) or Inertial Navigation System (INS).

(**Figure 1-4**)

The pilot and the co-pilot not only have independent EADI and EHSI displays, but they also have independent Display Processor Units, also known as Symbol Generators, to drive their displays (Figure 1-5). Display formats are produced by the Symbol Generators

that receive inputs from the crew and various on-board systems. The Flight Director Systems, Navigation Systems, Air Data Systems, and Weather Radar provide inputs to the Symbol Generators, along with commands from the each crewmember's display control panel. The Symbol Generators produce the graphics for the EADI, EHSI, and an optional Multi-Function Display (MFD) that is mounted in the center instrument panel. The MFD, which is physically identical to the EADI and EHSI, is typically used to display weather radar information; however, it can also be used to display either flight information or navigational information in the event of an EADI or EHSI failure. The following section will discuss the Boeing 777 EIS, which is a more advanced example of the one just covered.

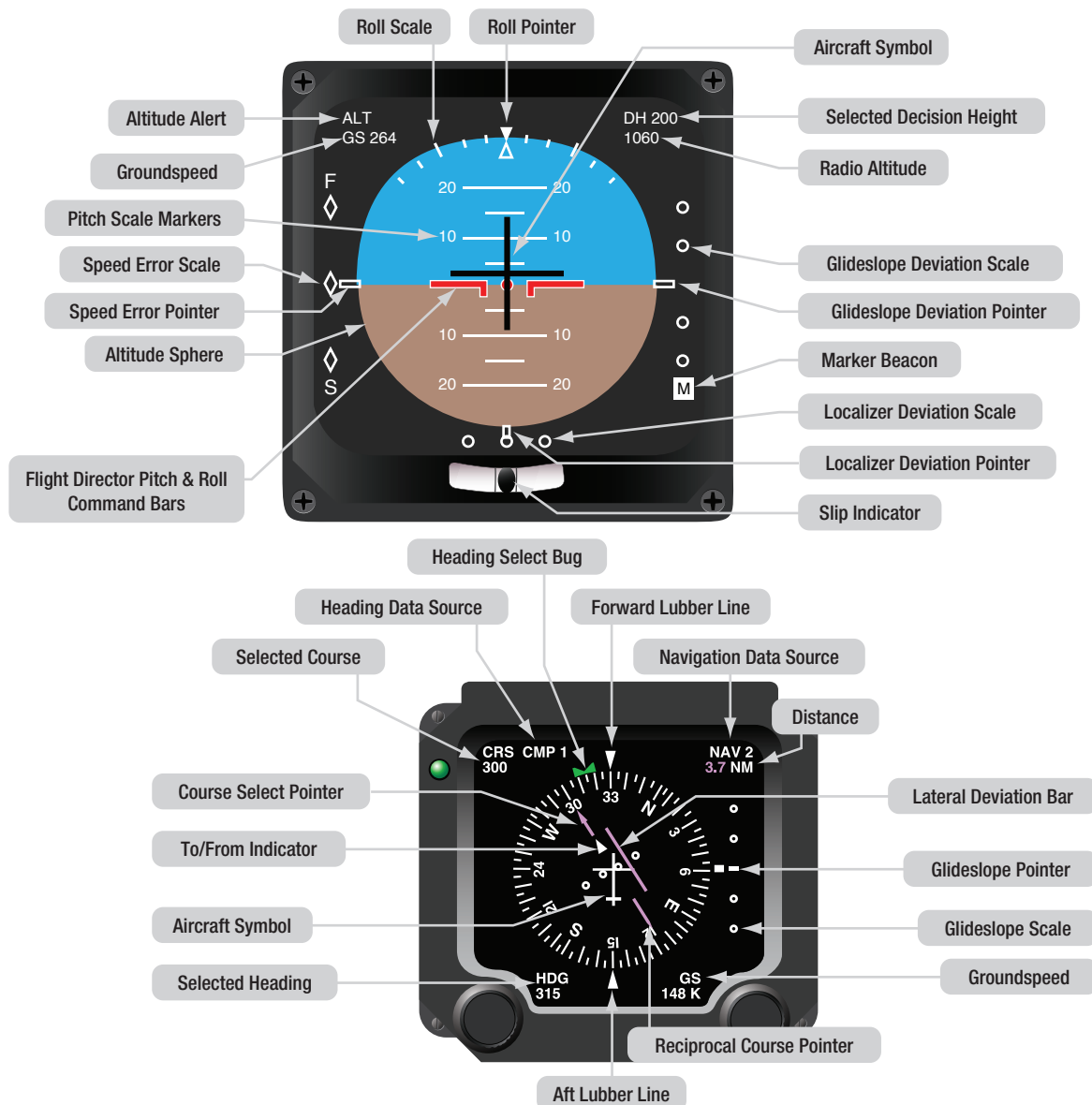


Figure 1-4. Typical EADI (top) and EHSI (bottom) Display Symbology.

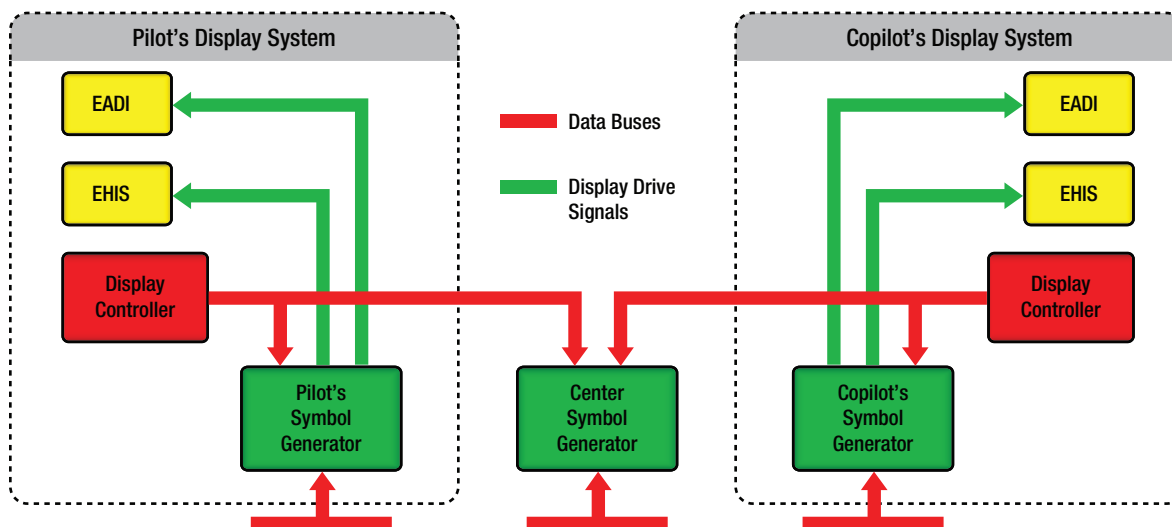


Figure 1-5. Electronic Displays are driven by Symbol Generators.

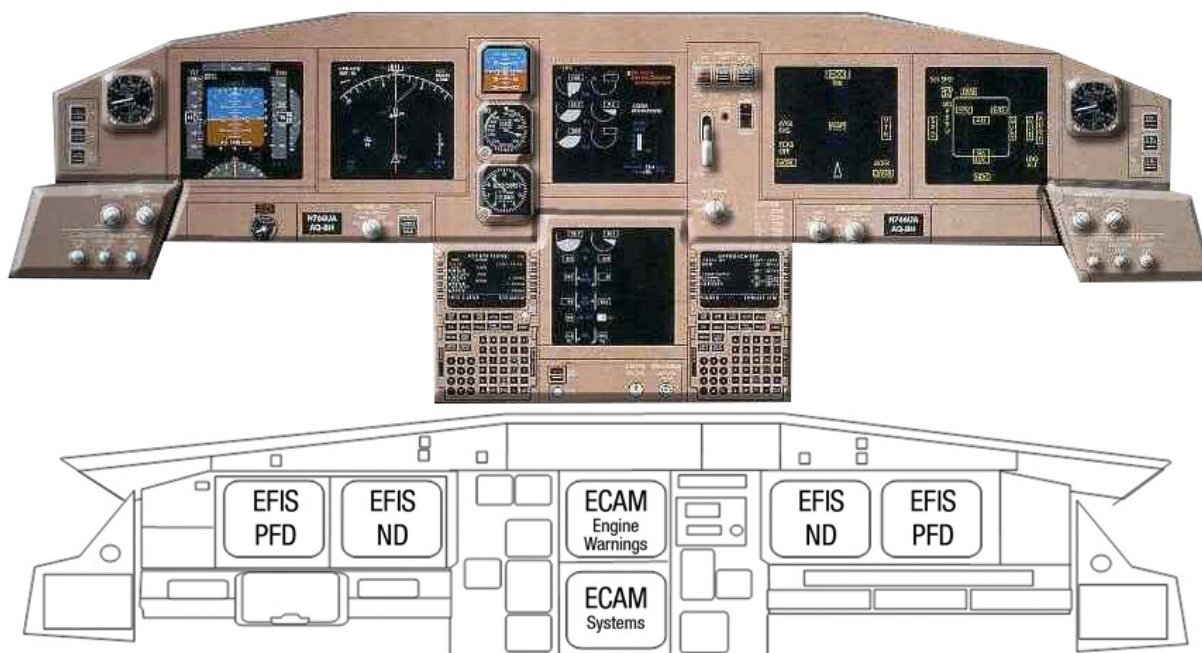


Figure 1-6. Boeing 777 Electronic Instrument System has 6 LCD Displays.

ELECTRONIC FLIGHT INSTRUMENT SYSTEM

The Boeing 777, which first entered service in 1995, has six 8' x 8" multi-color LCD displays as shown in **Figure 1-6**. The B777 EIS consists of a dual-redundant Electronic Flight Instrument Systems (EFIS) and Engine Indication and Crew Alerting System (EICAS). On the left side of the instrument panel is the Captain's EFIS, consisting of a Primary Flight Display (PFD) located outboard and a Navigation Display (ND) located inboard. The Co-Pilot's EFIS located on the right instrument panel has an identical PFD and ND, located

outboard and inboard respectively. All the displays are interchangeable to reduce the number of required spares. The information shown on each display, whether for flight or navigation, is determined by what each crew member selects on their individual display control panels.

The PFD takes the place of the EADI and displays all the information critical to flight, including attitude, airspeed, barometric altitude, vertical speed, heading, flight modes, radio altitude, ILS data, and Traffic Alert and Collision Avoidance System (TCAS) resolution advisory. The PFDs are designed to increase the

crew's situational awareness by integrating all of this information into a single composite display instead of the crew having to monitor several independent analog instruments. Also, the colors on the display change to alert the crew to potentially hazardous flight conditions, such as low airspeed, high rate of descent, etc.

Figure 1-7 is a typical Primary Flight Display format showing the artificial horizon in the center of the display, airspeed on the left side, altitude on the right side, heading on the bottom, and flight modes on the top of the display. Notice how the moving ladder format used for altitude and airspeed provide both absolute and relative information so the crew knows not only the exact numeric value, but also the rate that the altitude and airspeed is changing.

The Navigation Display, shown in **Figure 1-8**, takes the place of the EHSI display to show the requisite information to navigate the aircraft, including heading, VOR, GPS, and ILS guidance. The ND has the ability to overlay additional information on the navigation page

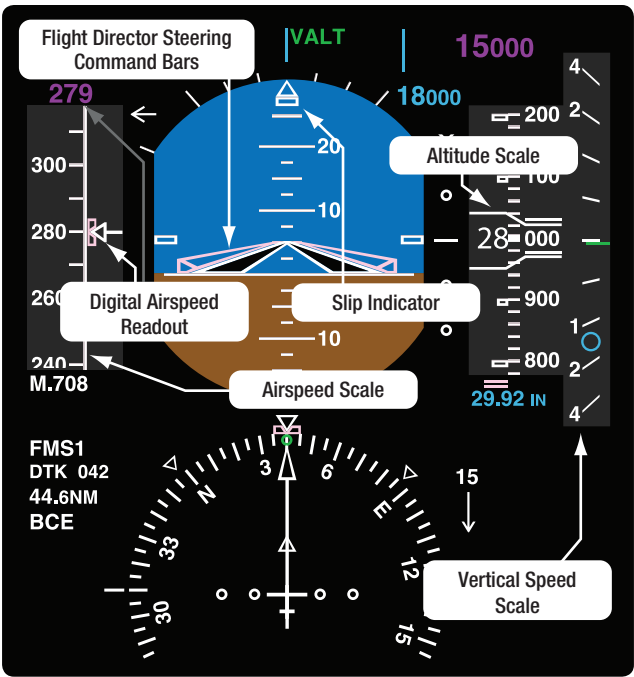


Figure 1-7. Primary flight display format.

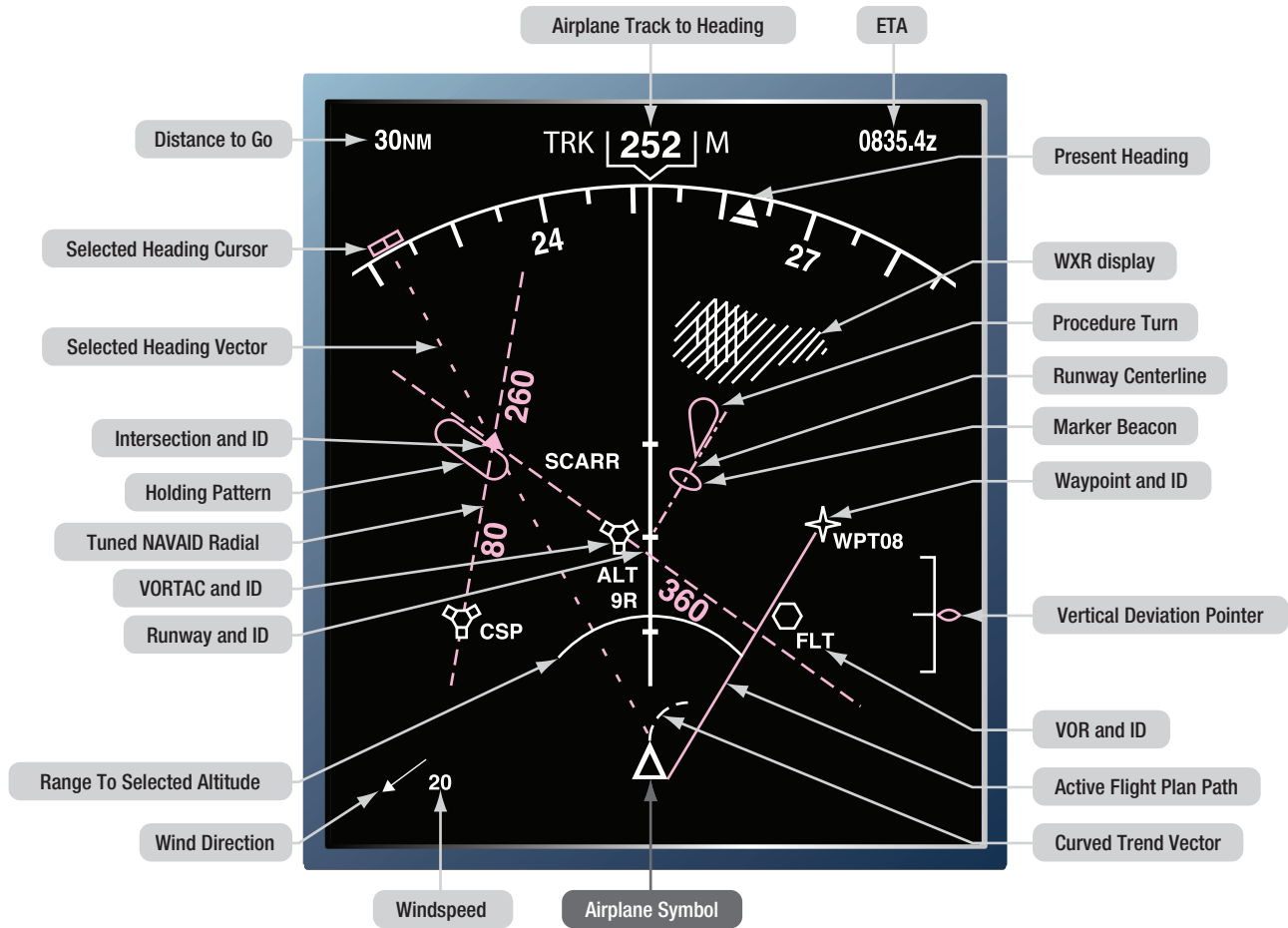


Figure 1-8. Navigation map display format.

to eliminate the need for separate dedicated displays. Some examples of information that is typically overlaid on the ND include weather information from either the onboard weather radar (WXR) or ground based sensors, and digital maps showing pre-programmed routes and waypoints from the Flight Management System.

ENGINE INDICATION AND CREW ALERTING SYSTEM

The Boeing® Engine Indication and Crew Alerting System (EICAS), also called an Electronic Centralized Aircraft Monitor (ECAM) on Airbus aircraft, performs the monitoring of aircraft systems that was previously performed by the Flight Engineer in three crew member cockpits. As previously shown in *Figure 1-6*, the two EICAS displays on the B777 are located in the center instrument panel. The upper EICAS display shows engine performance data, such as pressure ratio, N1 rotor speed, exhaust gas temperature, total air temperature, thrust mode, etc., in addition to cabin pressure, flap/slat position, landing gear position, and crew status alerts. (*Figure 1-9*)

The EICAS engine display format mimics the round analog instruments, while also providing digital readouts of the parameters. EICAS improves situational awareness by allowing the crew to see systems operation in graphical format and alerting them to any failures or impending failures. For example, if low oil pressure is detected, the EICAS will provide an aural alert and show to the oil pressure page on a lower display with a red box outlining which engine has low oil pressure.

The Airbus ECAM system provides the crew with the following levels of warning along with detailed messages as to the nature of the problem and suggested courses of action.

- **Level 3:** An overspeed, fire, or stall condition will cause a repetitive chime aural warning with a bright red flashing light.
- **Level 2:** A system failure, but not a safety of flight issue, will result in a single chime aural warning and a steady amber light.
- **Level 1:** Failure leading to system degradation results only in an amber light.
- **Mode or System Status.** If everything is normal, a green light will illuminate.



Figure 1-9. EICAS engine display format.

The lower EICAS display is called a Multi-Function Display because it provides auxiliary information to the flight crew and maintenance crew. The MFD can be used as a secondary engine display, status display, communications display, maintenance page, or electronic checklist. The MFD formats also include synoptic displays that provide system status diagrams for the fuel, electrical, hydraulic, flight control, and environmental control systems, in addition to showing door and landing gear positions. On some aircraft, the MFD is also used to display images from the ground maneuvering camera system.

Figure 1-10 is a schematic diagram of an Engine Indication and Crew Alerting System with all its associated components. The display select panel allows the crew to choose which computer is actively supplying information. It also controls the display of secondary engine information and system status displays on the lower monitor.

EICAS has a unique feature that automatically records the parameters of a failure event to be regarded afterwards by maintenance personnel. Pilots that suspect a problem may be occurring during flight can press the event record button on the display select panel. This also records the parameters for that flight period to be studied later by maintenance. Hydraulic, electrical, environmental, performance, and Auxiliary

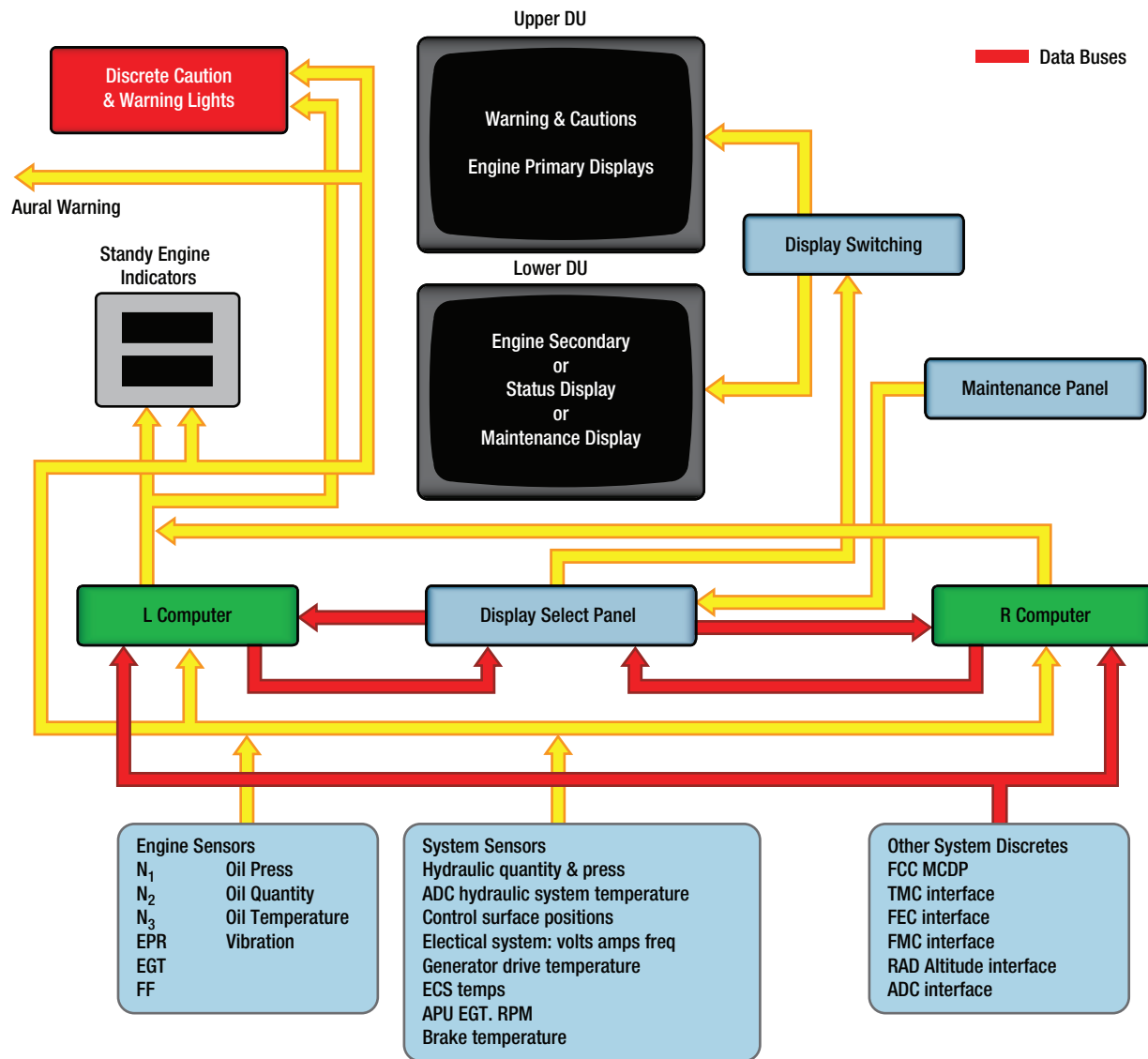


Figure 1-10. EICAS schematic diagram.

Power Unit (APU) data are examples of what may be recorded. EICAS uses Built-In-Test Equipment (BITE) for systems and components. A maintenance control panel is included for technicians. When the aircraft is on the ground, push-button switches display information pertinent to various systems for analysis. (*Figure 1-11*)

This section contained an overview of a state-of-the-art aircraft cockpit with its Electronic Instrument System. The following section will discuss how digital data streams are formed and processed by aircraft computers and then sent over digital data buses to cockpit displays to provide essential information for the flight crew and maintenance crew.