Chapter 2

Electronic Flight Instruments

Introduction

This chapter introduces the electronic flight instrument systems available with advanced avionics. You will see how electronic flight instrument systems integrate many individual instruments into a single presentation called a primary flight display (PFD). Since all flight instruments are combined in one integrated electronic flight instrument system, a number of enhancements to conventional flight instruments are now possible. In addition to learning to interpret the primary flight and navigation instruments, you must learn to recognize failures of the underlying instrument systems based on the indications you see in the cockpit. You must also maintain proficiency in using the backup/standby instruments that are still part of every advanced cockpit.

Primary Flight Display (PFD)

A PFD presents information about primary flight instruments, navigation instruments, and the status of the flight in one integrated display. Some systems include powerplant information and other systems information in the same display. A typical primary flight display is shown in *Figure 2-1*.

Primary Flight Instruments

Flight instrument presentations on a PFD differ from conventional instrumentation not only in format, but sometimes in location as well. For example, the attitude indicator on the PFD in *Figure 2-1* is larger than conventional round-dial presentations of an artificial horizon. Airspeed and altitude indications are presented on vertical **tape displays** that appear on the left and right sides of the primary flight display. The vertical speed indicator is depicted using conventional analog presentation. Turn coordination is shown using a segmented triangle near the top of the attitude indicator. The rate-of-turn indicator appears as a curved line display at the top of the heading/navigation instrument in the lower half of the PFD.

Cross-Checking the Primary Flight Instruments

The PFD is not intended to change the fundamental way in which you scan your instruments during attitude instrument flying. The PFD supports the same familiar control and performance, or primary and supporting methods you use with conventional flight instruments. For example, when using the primary and supporting method to maintain level flight, the altimeter is still the primary instrument for pitch, while the attitude indicator is a direct indicator and the vertical speed indicator provides supporting information. However, you need to train your eyes to find and interpret these instruments in their new formats and locations.

Common Errors: Altitude Excursions and Fixation

Pilots experienced in the use of conventional flight instruments tend to deviate from assigned altitudes during their initial experience with the PFD, while they adjust to the tape display presentation of altitude information. Another common error is the tendency to fixate and correct deviations as small as one to two feet at the expense of significant deviations on other parameters.

Figure 2-1. *A typical primary flight display (PFD).*

Enhancements to the Primary Flight Instruments

Some PFDs offer enhancements to the primary flight instruments. *Figure 2-2* shows an airspeed indicator that displays reference speeds (V-speeds) and operating ranges for the aircraft. Operating ranges are depicted using familiar color coding on the airspeed indicator. One negative human factor concerning this type of presentation should be remembered: while most of the displays are intuitive in that a high indication (such as climb pitch or vertical speed) is corrected by lowering the nose of the aircraft, the situation with the usual airspeed vertical tape is the opposite. In most current displays, the lower speeds are at the lower side of the airspeed indicator, while the upper or higher speeds are in the top portion of the airspeed display area. Therefore, if a low airspeed is indicated, you must lower the nose of the aircraft to increase, which is counterintuitive to the other indications.

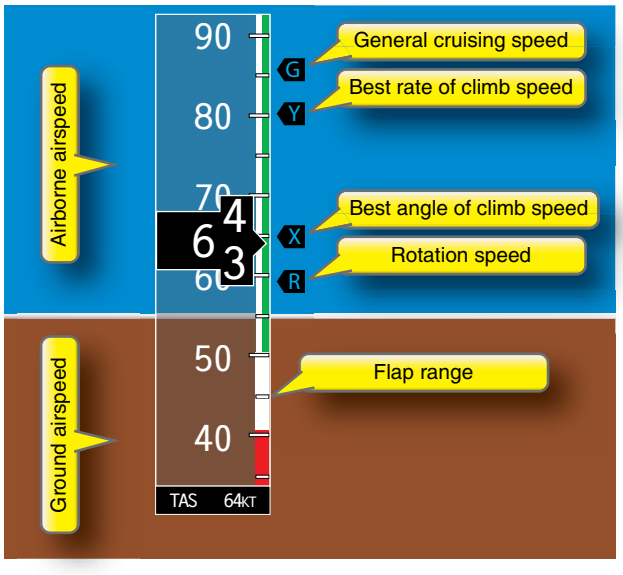

Figure 2-2. *Vertical airspeed (tape type) indicator.*

Figure 2-3 shows an attitude indicator that presents red symbols to assist in recovery from unusual attitudes. The symbols on the display recommend a lower pitch attitude.

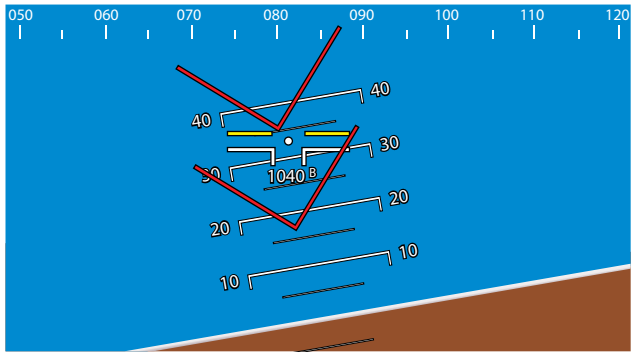

Figure 2-3. *Attitude indicator with symbols to assist in recovery from unusual attitude.*

Other valuable enhancements include trend indicators, which process data to predict and display future performance. For example, some systems generate "trend vectors" that predict the aircraft's airspeed, altitude, and bank angle up to several seconds into the future.

Primary Flight Instrument Systems

The primary flight instruments that appear on a PFD are driven by instrument sensor systems that are more sophisticated than conventional instrument systems. The attitude of the aircraft may be measured using microelectronic sensors that are more sensitive and reliable than traditional gyroscopic instruments. These sensors measure pitch, roll, and yaw movements away from a known reference attitude. Aircraft heading may be determined using a magnetic direction-sensing device such as a magnetometer or a magnetic flux valve.

Attitude and heading systems are typically bundled together as an attitude heading reference system (AHRS), which contains not only the sensors used to measure attitude and heading, but also a computer that accepts sensor inputs and performs calculations. Some AHRSs must be initialized on the ground prior to departure. The initialization procedure allows the system to establish a reference attitude used as a benchmark for all future attitude changes. As in any navigation system, attitude heading reference systems accumulate error over time. For this reason, AHRSs continually correct themselves, using periods of stable flight to make small corrections to the reference attitude. The system's ability to correct itself can be diminished during prolonged periods of turbulence. Some AHRSs can be reinitialized in flight, while others cannot. The pilot must become familiar with the operating procedures and capabilities of a particular system.

Information on altitude and airspeed is provided by sensors that measure static and ram air pressure. An air data computer (ADC) combines those air pressure and temperature sensors with a computer processor that is capable of calculating pressure altitude, indicated airspeed, vertical speed, and true airspeed. An air data attitude heading reference system (ADAHRS) combines all of the systems previously described into one integrated unit.

Navigation Instruments

PFDs and multi-function displays (MFDs) typically combine several navigation instruments into a single presentation. The instrument appearing at the bottom of the PFD in Figure 2-1 contains two navigation indicators: a course deviation indicator and a bearing pointer. These instruments can be displayed in a variety of views, and can be coupled to many of the navigation receivers (e.g., instrument landing system (ILS), global positioning system (GPS), very high frequency (VHF) omnidirectional range (VOR)) available

in the aircraft. The pilot must, therefore, be sure to maintain an awareness of which navigation receivers are coupled to each navigation indicator.

MFDs may provide the same type of display as installed in the PFD position, but are usually programmed to display just the navigation information with traffic, systems data, radar Stormscope®/ Strikefinder®. However, in many systems, the MFD can be selected to repeat the information presented on the PFD, thereby becoming the standby PFD. The pilot should be absolutely certain of and proficient with the standby modes of operation.

More sophisticated PFDs present three-dimensional (3D) course indications. The primary flight display in *Figure 2-4* shows a 3D course indication, called a highway-in-the-sky (HITS) display. This display provides both lateral and vertical guidance along the planned flight path, while simultaneously presenting a 3D picture of the surrounding terrain. Keeping the symbolic aircraft within the green boxes on the display ensures that the flight remains within the selected GPS route and altitude. Consult the AFM and avionics manual for required navigational configuration for this function to be available.

Other Flight Status Information

An important feature of the PFD is its ability to gather information from other aircraft systems and present it to the pilot in the integrated display. For example, the PFD in *Figure 2-5* presents many useful items about the status of the flight. The top bar shows the next waypoint in the planned flight route, the distance and bearing to the waypoint, and the current ground track. The outside air temperature (OAT) is shown in the lower left corner of the display. The transponder code and status are shown with the current time in the lower right corner. This PFD also allows the pilot to tune and identify communication and navigation radio frequencies at the top of the display.

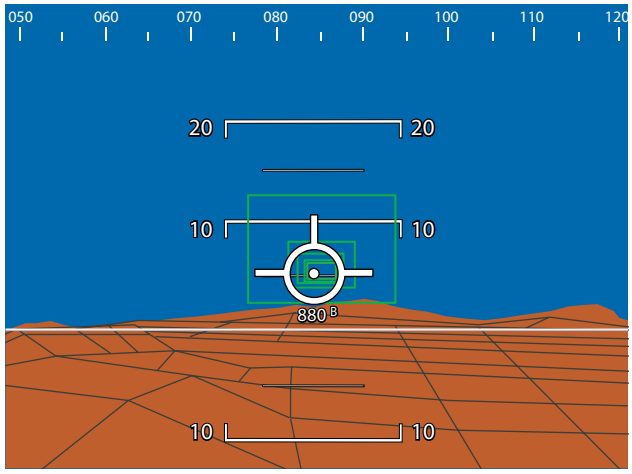

Figure 2-4. *An attitude indicator with HITS display symbology.*

Making Entries on the PFD

PFDs have evolved and have become more than flight displays in many cases. The amount of data available for display can overwhelm the pilot with data. Therefore, many manufacturers have integrated data control and display controls into the display unit itself, usually around the perimeter of the unit. These data and display controls provide different ways of selecting necessary information, such as altimeter settings, radials, and courses. *Figure 2-6* illustrates two different kinds of controls for making entries on primary flight displays. Some PFDs utilize a single knob and button-selectable windows to determine which entry is to be made. Other PFDs offer dedicated knobs for making entries; quantities are sometimes entered in one location and displayed in another. Still other units retain all controls on a separate control panel in the console or on the instrument panel.

Failures and the Primary Flight Display

Instrument System Failure

The competent pilot is familiar with the behavior of each instrument system when failures occur, and is able to recognize failure indications when they appear on the primary flight display. Manufacturers typically use a bold red "X" over, or in place of, the inoperative instruments and provide annunciator messages about failed systems. It is the pilot's job to interpret how this information impacts the flight.

The inoperative airspeed, altitude, and vertical speed indicators on the PFD in *Figure 2-7* indicate the failure of the air data computer. As do all electronic flight displays, navigation units (area navigation (RNAV)/flight management systems (FMS)) and instrumentation sensors rely on steady, uninterrupted power sources of 24 VDC or 12 VDC power. Any interruptions in the power supplies, such as alternator/ regulator failure, drive belt failure, lightning strikes, wiring harness problems, or other electrical failures, can completely disrupt the systems, leading to erratic indications or completely inoperative units. Especially in standard category aircraft not designed or built with the redundancy inherent in transport category aircraft, a proficient and prudent pilot plans for failures and has alternate plans and procedures readily available.

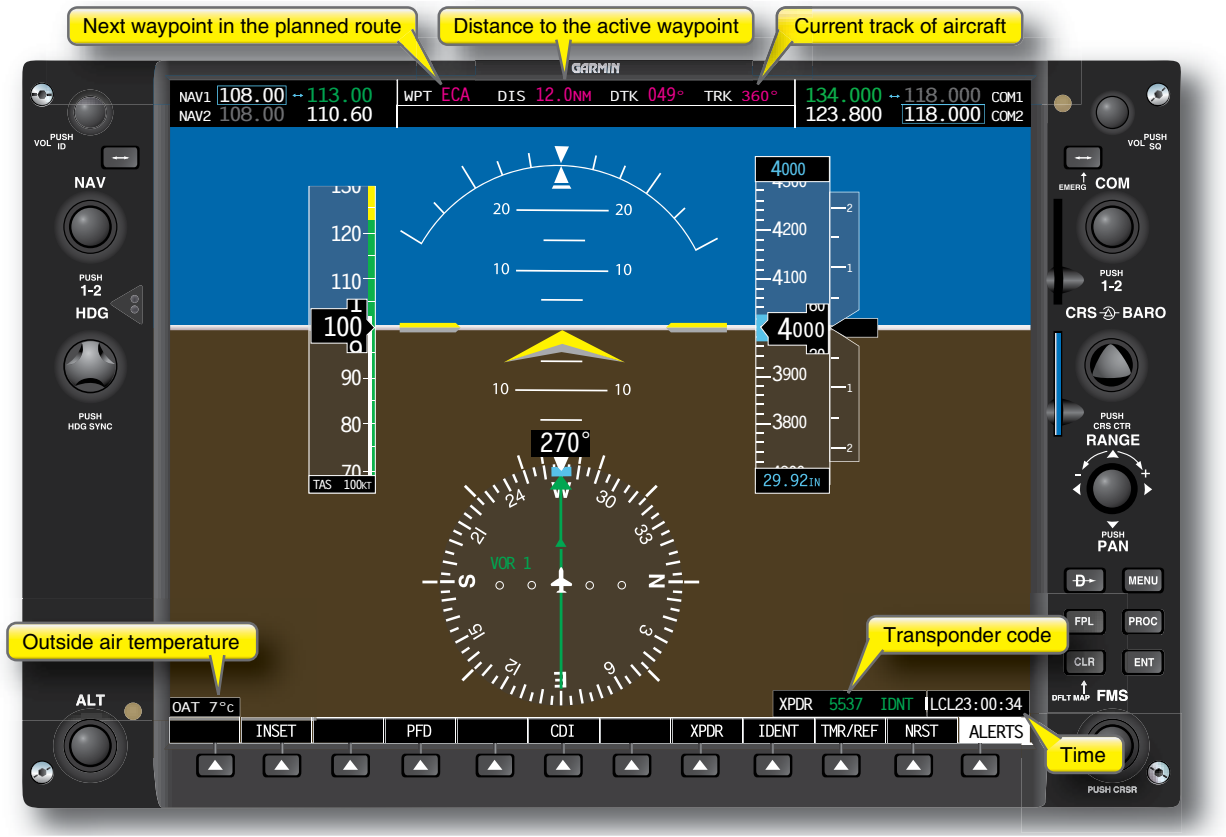

Figure 2-5. *PFD flight status items.*

Figure 2-6. *Making entries on a PFD.*