Chapter 4

Automated Flight Control

Introduction

This chapter introduces automated flight control in the advanced avionics cockpit. You will learn to use an autopilot system that can significantly reduce workload during critical phases of flight. The two-axis autopilot system installed in most general aviation aircraft controls the pitch and roll of the aircraft. The autopilot can operate independently, controlling heading and altitude, or it can be coupled to a navigation system and fly a programmed course or an approach with glideslope. In addition to learning how to use the autopilot, you must also learn when to use it and when not to use it.

You will learn how the autopilot and the flight management system (FMS)/area navigation (RNAV) unit combine to create a fairly automated form of flight that places you in a managerial role. While the autopilot relieves you from manually manipulating the flight controls, you must maintain vigilance over the system to ensure that it performs the intended functions and the aircraft remains within acceptable parameters of altitudes, airspeeds, and airspace limits.

Autopilot Concepts

An autopilot can be capable of many very time intensive tasks, helping the pilot focus on the overall status of the aircraft and flight. Good use of an autopilot helps automate the process of guiding and controlling the aircraft. Autopilots can automate tasks, such as maintaining an altitude, climbing or descending to an assigned altitude, turning to and maintaining an assigned heading, intercepting a course, guiding the aircraft between waypoints that make up a route programmed into an FMS, and flying a precision or nonprecision approach. You must accurately determine the installed options, type of installation, and basic and optional functions available in your specific aircraft.

Many advanced avionics installations really include two different, but integrated, systems. One is the autopilot system, which is the set of servo actuators that actually do the control movement and the control circuits to make the servo actuators move the correct amount for the selected task. The second is the flight director (FD) component. The FD is the brain of the autopilot system. Most autopilots can fly straight and level. When there are additional tasks of finding a selected course (intercepting), changing altitudes, and tracking navigation sources with cross winds, higher level calculations are required.

The FD is designed with the computational power to accomplish these tasks and usually displays the indications to the pilot for guidance as well. Most flight directors accept data input from the air data computer (ADC), Attitude Heading Reference System (AHRS), navigation sources, the pilot's control panel, and the autopilot servo feedback, to name some examples. The downside is that you must program the FD to display what you are to do. If you do not preprogram the FD in time, or correctly, FD guidance may be inaccurate.

The programming of the FD increases the workload for the pilot. If that increased workload is offset by allowing the autopilot to control the aircraft, then the overall workload is decreased. However, if you elect to use the FD display, but manually fly the aircraft, then your workload is greatly increased.

In every instance, you must be absolutely sure what modes the FD/autopilot is in and include that indicator or annunciator in the crosscheck. You must know what that particular mode in that specific FD/autopilot system is programmed to accomplish, and what actions will cancel those modes. Due to numerous available options, two otherwise identical aircraft can have very different avionics and autopilot functional capabilities.

How To Use an Autopilot Function

The following steps are required to use an autopilot function:

1. Specify desired track as defined by heading, course, series of waypoints, altitude, airspeed, and/or vertical speed.
2. Engage the desired autopilot function(s) and verify that, in fact, the selected modes are engaged by monitoring the annunciator panel.
3. Verify that desired track is being followed by the aircraft.
4. Verify that the correct navigation source is selected to guide the autopilot's track.
5. Be ready to fly the aircraft manually to ensure proper course/clearance tracking in case of autopilot failure or misprogramming.
6. Allow the FD/autopilot to accomplish the modes selected and programmed without interference, or disengage the unit. Do not attempt to "help" the autopilot perform a task. In some instances this has caused the autopilot to falsely sense adverse conditions and trim to the limit to accomplish its tasking. In more than a few events, this has resulted in a total loss of control and a crash.

Specification of Track and Altitude

A track is a specific goal, such as a heading or course. A goal can also be a level altitude, a selected airspeed, or a selected vertical speed to be achieved with the power at some setting. Every autopilot uses knobs, buttons, dials, or other controls that allow the pilot to specify goals. *Figure 4-1* shows an autopilot combined with conventional navigation instruments. Most autopilots have indicators for the amount of servo travel or trim being used. These can be early indicators of adverse conditions, such as icing or power loss. Rarely will a trim indicator ever indicate full travel in normal operation. Consistently full or nearly full travel of the trim servos may be a sign of a trim servo failure, a shift in weight resulting in a balance problem, or airfoil problems such as icing or inadvertent control activation.

Figure 4-1. *A simple autopilot.*

Primary flight displays (PFDs) often integrate all controls that allow modes to be entered for the autopilot. The PFD shown in *Figure 4-2* offers knobs that allow you to enter modes without turning attention away from the primary flight instruments. Modes entered using the controls on a PFD are transferred to the autopilot.

Engagement of Autopilot Function

Every autopilot offers a collection of buttons that allow you to choose and engage autopilot modes and functions. Buttons used to engage autopilot modes appear along the bottom of the autopilot shown in *Figure 4-1*. The system shown in *Figure 4-3* does not use a separate device for autopilot controls; it integrates the autopilot function buttons into another cockpit display.

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

Figure 4-2. *Entering goals on a primary flight display.*

Figure 4-3. *An integrated avionics system with an autopilot.*

profile. Every autopilot displays which autopilot modes are currently engaged, and most indicate an armed mode that activates when certain parameters are met, such as localizer interception. The autopilot shown in *Figure 4-1* displays the active modes on the front of the unit, just above the controls. The integrated autopilot shown in *Figure 4-4* displays the currently engaged autopilot mode along the top of the PFD.

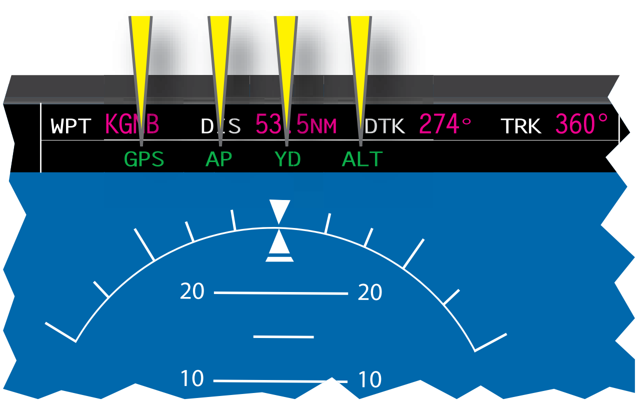

Figure 4-4. *Engaged autopilot modes shown at the top of a PFD.*

How Autopilot Functions Work

Once an autopilot mode has been engaged, the autopilot:

1. Determines which control movements are required to follow the flight profile entered by the pilot, and
2. Moves the controls to affect tracking of the flight profile.

Determination of Control Movements Required To Achieve Goals

Suppose you wish to use the autopilot/FD to turn to an assigned heading of 270°. The heading knob is used to select the new heading. Before any control movements are made, the autopilot/FD must first determine which control movements are necessary (e.g., left or right turn). To do so, the FD/autopilot must first determine the aircraft's current heading and bank angle, determine amount and direction of the turn, and then choose an appropriate bank angle, usually up to 30° or less. To make these determinations, the FD gathers and processes information from the aircraft's ADC (airspeed and altitude), magnetic heading reference instrument, and navigation systems.

Carrying Out Control Movements

Once the FD/autopilot has determined which control movements are necessary to achieve the flight change, the autopilot has the task of carrying out those control movements. Every autopilot system features a collection of electromechanical devices, called servos, that actuate the aircraft control surfaces. These servos translate electrical commands into motion, the "muscle" that actually moves the control surfaces.

Flight Director

Flight Director Functions

An FD is an extremely useful aid that displays cues to guide pilot or autopilot control inputs along a selected and computed flightpath. *[Figure 4-5]* The flight director usually receives input from an ADC and a flight data computer. The ADC supplies altitude, airspeed and temperature data, heading data from magnetic sources such as flux valves, heading selected on the HSI (or PFD/multi-function display (MFD)/ electronic horizontal situation indicator (EHSI)), navigation data from FMS, very high frequency omnidirectional range (VOR)/distance measuring equipment (DME), and RNAV sources. The flight data computer integrates all of the data such as speed, position, closure, drift, track, desired course, and altitude into a command signal.

The command signal is displayed on the attitude indicator in the form of command bars, which show the pitch and roll

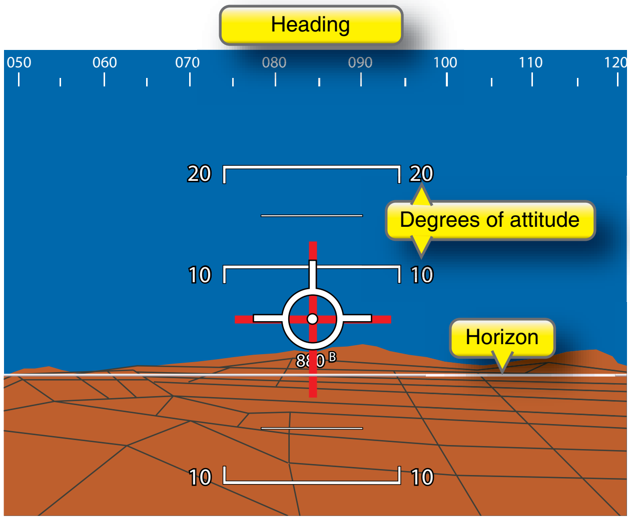

Figure 4-5. *A flight director.*

inputs necessary to achieve the selected targets. To use the flight director command bars, which are usually shaped as inverted chevrons, or V-shaped symbols, the pilot simply flies to the bars. Some older models use crossed bars, leading the pilot to the selected point. In both types, you simply keep the aircraft symbol on the attitude indicator aligned with the command bars, or allow the autopilot to make the actual control movements to fly the selected track and altitude.

Using the Flight Director (FD)

Flight Director Without Autopilot

The FD and autopilot systems are designed to work together, but it is possible to use the flight director without engaging the autopilot, or the autopilot without the FD, depending on the installation. Without autopilot engagement, the FD presents all processed information to the pilot in the form of command bar cues, but you must manually fly the airplane to follow these cues to fly the selected flightpath. In effect, you "tell" the FD what needs to happen and the FD command bars "tell" you what to do. This adds to your workload, since you must program the FD for each procedure or maneuver to be accomplished, while actually flying the aircraft. In many cases, you will have a decreased workload if you simply disable the FD and fly using only the flight instruments.

Flight Director With Autopilot

When the aircraft includes both a flight director and an autopilot, you may elect to use flight director cues without engaging the autopilot. It may or may not be possible to use the autopilot without also engaging the flight director. You need to be familiar with the system installed. When you engage the autopilot, it simply follows the cues generated by the flight director to control the airplane along the selected lateral and vertical paths.

Common Error: Blindly Following Flight Director Cues

The convenience of flight director cues can invite fixation or overreliance on the part of the pilot. As with all automated systems, you must remain aware of the overall situation. Never assume that flight director cues are following a route or course that is free from error. Rather, be sure to include navigation instruments and sources in your scan. Remember, the equipment will usually perform exactly as programmed. Always compare the displays to ensure that all indications agree. If in doubt, fly the aircraft to remain on cleared track and altitude, and reduce automation to as minimal as possible during the problem processing period. The first priority for a pilot always is to fly the aircraft.

Common Error: Confusion About Autopilot Engagement

Pilots sometimes become confused about whether or not flight director cues are being automatically carried out by the autopilot, or left to be followed manually by the pilot. Verification of the autopilot mode and engagement status of the autopilot is a necessary technique for maintaining awareness of who is flying the aircraft.

Follow Route

The FD/autopilot's navigation function can be used to guide the aircraft along the course selected on the navigation indicator. Since the navigation display in most advanced avionics cockpits can present indications from a variety of navigation systems, you can use the autopilot's navigation function to follow a route programmed into the FMS using VOR, global positioning system (GPS), inertial navigation system (INS), or other navigation data sources.

Following a Route Programmed in the FMS

Figure 4-6 demonstrates how to use the navigation function to follow a route programmed into the FMS. With the navigation function engaged, the FD/auto-pilot steers the aircraft along the desired course to the active waypoint. Deviations from the desired course to the new active waypoint are displayed on the navigation indicator. When the aircraft reaches the active waypoint, the FMS computer automatically sequences to the next waypoint in the route, unless waypoint sequencing is suspended.

It is important to note that the normal navigation function provides only lateral guidance. It does not attempt to control the vertical path of the aircraft at any time. You must always ensure the correct altitude or vertical speed is maintained.

Figure 4-6. *Using the navigation function to follow the programmed flight route.*

When combined, use of the FMS and the FD/autopilot's navigation function result in an automated form of flight that was formerly limited to very complex and expensive aircraft. This same level of avionics can now be found in single-engine training airplanes. While it is easy to be complacent and let down your guard, you must continuously monitor and stay aware of automated systems status and function and the track of the aircraft in relation to the flight plan and air traffic control (ATC) clearance.

GPS Steering (GPSS) Function

Many autopilots offer a global positioning system steering (GPSS) function. GPSS does all of the same actions as the navigation function, but achieves a higher degree of precision by accepting inputs directly from the GPS receiver. Consequently, the GPSS function follows the desired track to the active waypoint more aggressively, permitting only small excursions from the desired course. On some installations, pressing the autopilot NAV button twice engages the GPSS function.

Following a VOR Radial

The FD/autopilot's navigation function can also be used to directly track VOR radials. The navigation display must be configured to show indications from one of the aircraft's VOR receivers. Once you have tuned and identified a VOR station and selected the desired radial, you can select the navigation mode to track the selected radial. *Figure 4-7* demonstrates how to use the navigation mode to follow a VOR radial.

When the navigation mode is used to follow a route defined by VOR radials, you must still tune and identify each new VOR facility manually and select the appropriate radials along the way. The autopilot's navigation function cannot automatically manipulate the VOR receiver. However, some highly automated FMS units tune and identify VORs along a defined route, such as Victor or Jet routes. You should check the FMS documentation and installed options.

Figure 4-7. *Using the navigation mode to follow a VOR radial.*

Depending on the FMS, the highly automated flight that results when the navigation mode is used to follow a published route from the database uses a different skill set from using the navigation mode to track discreetly tuned VOR radials. Learning how to select preprogrammed routes from the database of airways can be challenging. Programming or tuning discreet VORs en route in turbulent conditions presents different challenges. Either skill set can result in a greater sharing of duties between pilot and technology and an increase in safety.

Fly Heading

The heading mode is used to steer the aircraft automatically along a pilot selected heading. Using the FD/autopilot to fly a heading is a simple matter of selecting the assigned heading and then engaging the heading function or, more commonly, accomplished by first engaging the heading mode and gently turning the heading selection knob to the new heading. Gently turning the knob with the mode already engaged allows you to make a smooth change from level to turning flight. Many autopilots make an abrupt bank if engaged when there is a big change to be made in heading or track. The heading function is illustrated in *Figure 4-8.*

You should note that, when using the heading mode, the FD/autopilot ignores the pilot-programmed route in the FMS or any VOR radials you set. When in heading mode, the FD/autopilot will fly the selected heading until fuel starvation.

Maintain Altitude

The autopilot's altitude mode maintains an assigned barometric altitude. When the altitude mode is engaged, the autopilot seeks to maintain the same barometric pressure (altitude) that the aircraft was flying at the time that the altitude mode was engaged. *Figure 4-9* shows how to engage the altitude mode for one manufacturer's autopilot.

In addition to determining and carrying out the pitch commands necessary to maintain the flight's assigned altitude, most autopilots are also able to trim the aircraft.

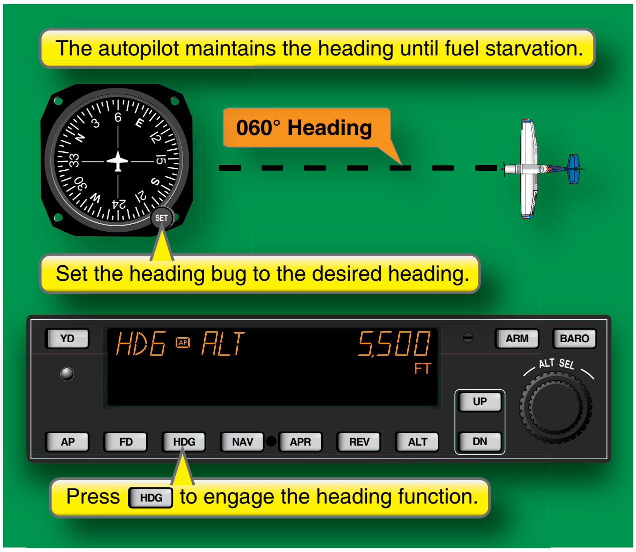

Figure 4-8. *Flying an assigned heading using the heading mode.*

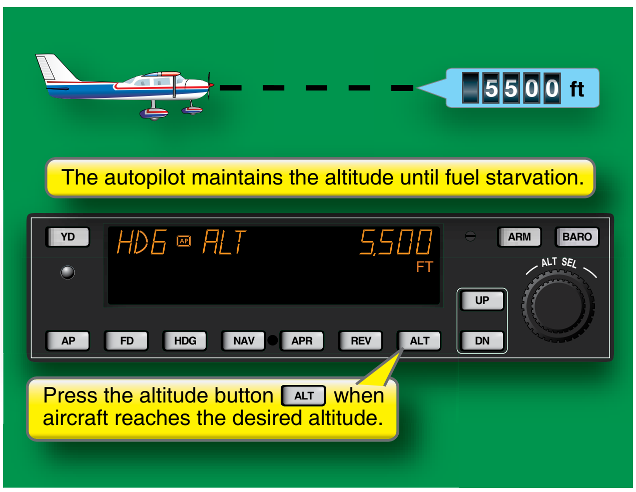

Figure 4-9. *Maintaining an altitude using the altitude hold mode.*

An autotrim system is capable of automatically making any needed adjustments to the pitch trim to maintain the aircraft at the desired altitude and in a properly trimmed condition. Pitch control pressure applied with the altitude hold mode engaged will cause the autopilot to trim against you.

Climbs and Descents

Vertical Speed

The autopilot's vertical speed mode allows you to perform constant-rate climbs and descents. *Figure 4-10* illustrates the use of the vertical speed mode for one autopilot that is integrated with a PFD.

When you engage the vertical speed mode, the FD/autopilot will attempt to maintain the specified vertical speed until you choose a different setting in autopilot, the aircraft reaches an assigned altitude set into the assigned altitude selector/alerter, or the autopilot is disconnected. If an altitude selector is not installed or functioning, the pilot has the task of leveling off at the assigned altitude, which requires monitoring progress and manually engaging the autopilot's altitude hold function once the aircraft reaches the desired altitude. You must be very careful to specify an appropriate vertical speed, as the aircraft will fly itself into a stall if you command the autopilot to climb at a rate greater than the aircraft's powerplant(s) is/are capable of supporting. You also need to monitor descent airspeeds diligently to ensure compliance with V_{NE}/V_{MO} and V_A or turbulence penetration speeds if there is doubt about smooth air conditions. As discussed in the previous chapter, you should be cognizant of the powerplant temperatures reciprocating powered aircraft and bleed air requirements for turbine-powered aircraft.

Vertical Speed With Altitude Capture

Some FD/autopilots have an altitude select/capture feature. The altitude select/capture feature is illustrated in *Figure 4-11*. The altitude select/capture feature combines use of the activated vertical speed mode and an armed altitude hold mode. To use this feature, the vertical speed function is initially engaged. The altitude hold mode usually arms automatically when a different altitude is selected for capture and vertical speed is activated. With an altitude select/capture option or feature, the altitude hold mode disengages the vertical speed mode upon capture of the selected altitude once the vertical speed function completes the necessary climb or descent. Once the aircraft reaches the assigned altitude, the vertical speed function automatically disengages, and the altitude mode changes from armed to engaged. The change from vertical speed mode to altitude hold mode is the capture mode, or transition mode. Any changes made by the pilot during this short phase usually result in a cancellation of the capture action, allowing the aircraft to continue the climb or descent past the selected altitude. Again, be familiar with the aircraft's equipment. Let the system complete programmed tasks, and understand what it will do if interrupted.

Many FD/autopilot altitude selectors include an altitude alert feature, an auditory alert that sounds or chimes as the aircraft approaches or departs the selected altitude.

Catching Errors: Armed Modes Help Prevent Forgotten Mode Changes

You have already seen how remembering to make a needed mode change in the future can be an error-prone process. Not canceling the armed function allows the altitude select mode to relieve the pilot from needing to remember to engage the function manually once the aircraft has reached the selected altitude. Do not interrupt the altitude armed or capture mode, unless prepared to manually control the process.

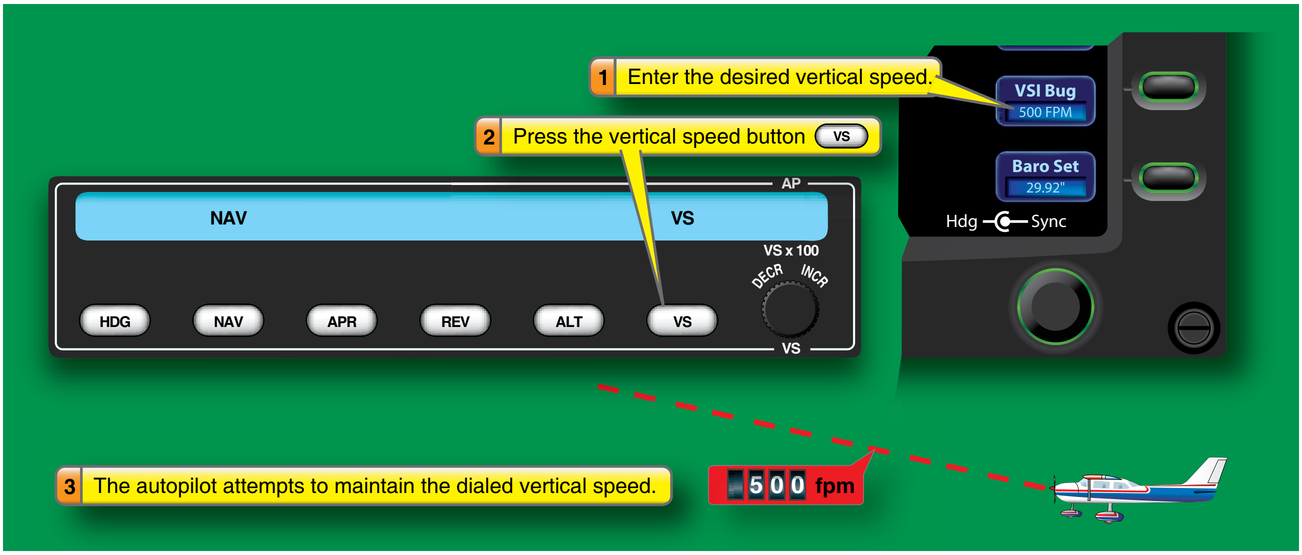

Figure 4-10. *Performing a constant-rate climb or descent using the vertical speed function.*

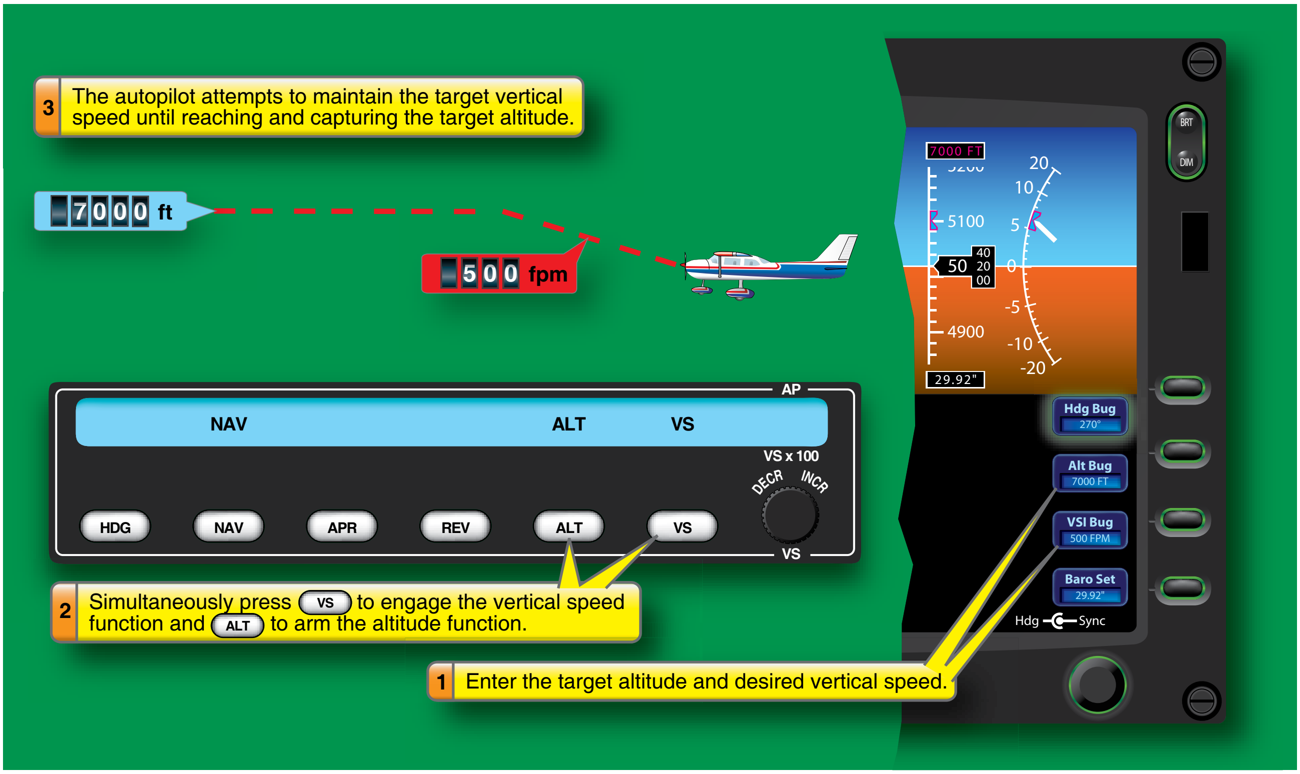

Figure 4-11. *Climbs and descents to capture using the altitude select/capture feature.*

The indications on the autopilot in *Figure 4-11* do not distinguish between functions that are armed or engaged.

The more sophisticated annunciator shown in *Figure 4-12* uses color coding to distinguish between armed and engaged autopilot functions.

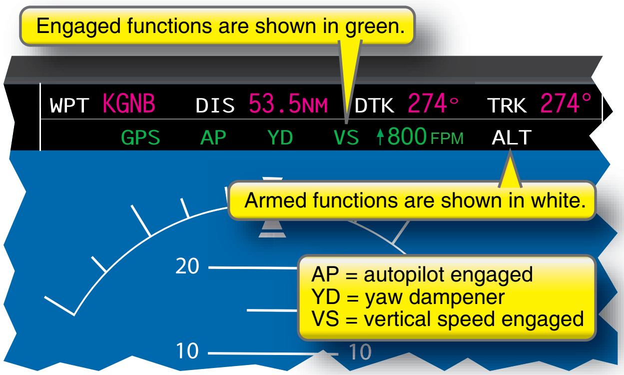

Figure 4-12. *A mode annunciator showing armed and engaged autopilot modes.*

Common Error: Failure To Arm the Altitude Mode

The most common error made by pilots during climbs and descents is failure to arm the altitude mode to capture the assigned altitude. In many instances, this happens when the crew does not correctly adjust the altitude selector or alerter. Sometimes, this malfunction occurs when the altitude is adjusted at the same time the system is attempting to go into the capture mode. This situation typically results in the aircraft climbing or descending beyond the assigned altitude, which may result in an altitude deviation. Altitude deviations are among the most common mishaps reported by pilots to NASA's Aviation Safety and Reporting System (ASRS). In any event, always monitor the actions of the FD/autopilot system and be prepared to fly the aircraft manually.

Awareness: Altitude Alerting Systems

Altitude alerting systems were mandated for commercial jet transports in the early 1970s in response to a growing number of altitude deviations in airline operations. Although they helped reduce the total number of altitude deviations, altitude alerting systems also made possible a new kind of error. Altitude deviation reports submitted to the Aviation Safety and Reporting System (ASRS) indicate that pilots sometimes rely too much on the altitude alerting system, using it as a substitute for maintaining altitude awareness. Instead of monitoring altitude, pilots sometimes simply listen for the alert. This phenomenon is one instance of what human factors experts call primary-secondary task inversion—when an alert or alarm designed as a secondary backup becomes the primary source of information. In the case of the altitude alerting system, when the alerting system is missed, or you are distracted, nothing is left to prevent an altitude deviation. You must remember that the altitude alerting system is designed as a backup, and be careful not to let the alerting system become the primary means of monitoring altitude. Most airline operators have a standard operating procedure that requires pilots to call out approaching target altitudes before the altitude alerting system gives the alert. Common errors occur when setting 10,000 feet versus 11,000 feet. Too many ones and zeros can confuse a fatigued, busy pilot, resulting in setting an incorrect altitude.

Awareness: Automatic Mode Changes

Distinguishing between "armed" and "engaged" adds complexity to the process of maintaining mode awareness. In addition to autopilot functions that are engaged by the pilot, some autopilot functions engage and disengage automatically. Automatic mode changes add to the challenge of keeping track of which autopilot functions are currently engaged and which functions are set to become engaged. You can minimize confusion by always verifying the status annunciations on the FMs, PFD/MFD, and the autopilot mode annunciator after any change of heading, altitude, or vertical speed. The verification process forces you to carefully consider the configuration of the FMS and FD/autopilot. Determine if engaging the autopilot cancels certain FD modes. Some units interact, and when the autopilot is engaged, some FD modes are automatically canceled, notably altitude hold or selection.

Learning: The Importance of Understanding

One way to learn the steps required to use an autopilot is simply to memorize them. This approach focuses solely on the button and control manipulations required to perform each procedure. Although this approach to learning may appear to be the quickest, studies have shown that pilots who take the time to develop a deeper understanding of how a system works give themselves three important advantages. These pilots are better able to:

1. Work through situations that differ from the ones they learned and practiced during training,
2. Transition from one manufacturer's system to another, and
3. Recall procedures after not having practiced them for some time.

Investing time to understand FD/autopilot functions pays off. For example, in many systems, once the aircraft reaches the selected altitude and levels off as indicated by the altitude mode annunciator, the pilot can select the next altitude in the window. Then, upon receiving the clearance to climb or descend, the pilot must select only the vertical mode. In many systems, the vertical speed mode is indicated and the altitude mode is indicated as "armed" and ready to capture the selected altitude. Only the power requires pilot manual control.

Power Management

Unless the aircraft has an autothrottle system, you must adjust the power to an appropriate setting when performing any climb, descent, or level-off. You cannot allow the aircraft to exceed any applicable speed limitations during a descent. During a climb at a vertical speed that the aircraft cannot sustain, the FD/autopilot may command a pitch that results in a stall.

Essential Skills

1. Use the FD/autopilot to climb or descend to and automatically capture an assigned altitude.
2. Determine the indications of the armed or capture mode, and what pilot actions will cancel those modes.
3. Determine if the system allows resetting of the armed or capture mode, or if manual control is the only option after cancellation of these modes.
4. Determine the available methods of activating the altitude armed or capture mode.
5. Determine the average power necessary for normal climbs and descents. Practice changing the power to these settings in coordination with making the FD/autopilot mode changes.
6. Determine and record maximum climb vertical speeds and power settings for temperatures and altitudes. Ensure the values are in agreement with values in AFM/POH for conditions. Make note of highest practical pitch attitude values, conditions, and loading. Remember powerplant factors (e.g., minimum powerplant temperature, bleed air requirements) and airframe limitations (e.g., VA in setting power).

Course Intercepts

Flying an Assigned Heading To Intercept a Course or VOR Radial

You can use the navigation mode in combination with the heading function to fly an assigned heading to intercept a course. The procedure illustrated in *Figure 4-13* takes advantage of the ability to arm the navigation mode while the heading mode is engaged.

Figure 4-13 illustrates selecting the assigned heading, setting up your FD/FMS autopilot for the assigned course, engaging the heading mode, and arming the navigation function. Once the aircraft reaches the course, the autopilot automatically disengages the heading function and engages the navigation mode.

On most FD/autopilots, courses can be intercepted by first using the heading "bug" to select an intercept course and then engaging the heading function. Alternatively, engaging the navigation function in some units causes the FD/autopilot to select an intercept heading, engage the heading function, and arm the navigation function. This can be a cause for conflict if ATC assigns an intercept heading, but the FD is programmed to use one angle. In those instances, you need to set the heading into the FD/autopilot, fly, and control the intercept until the aircraft is close enough to complete the intercept and capture without deviating from the ATC instructions. At that point you can select and arm the navigation mode, which completes the intercept and begins tracking the selected course.

Essential Skills

1. Use the FD/autopilot to fly an assigned heading to capture and track a VOR and/or RNAV course.
2. Determine if the FD/autopilot uses preprogrammed intercepts or set headings for navigation course interceptions.
3. Determine the indications of navigation mode armed conditions.
4. Determine parameters of preprogrammed intercept modes, if applicable.
5. Determine minimum and maximum intercept angle limitations, if any.

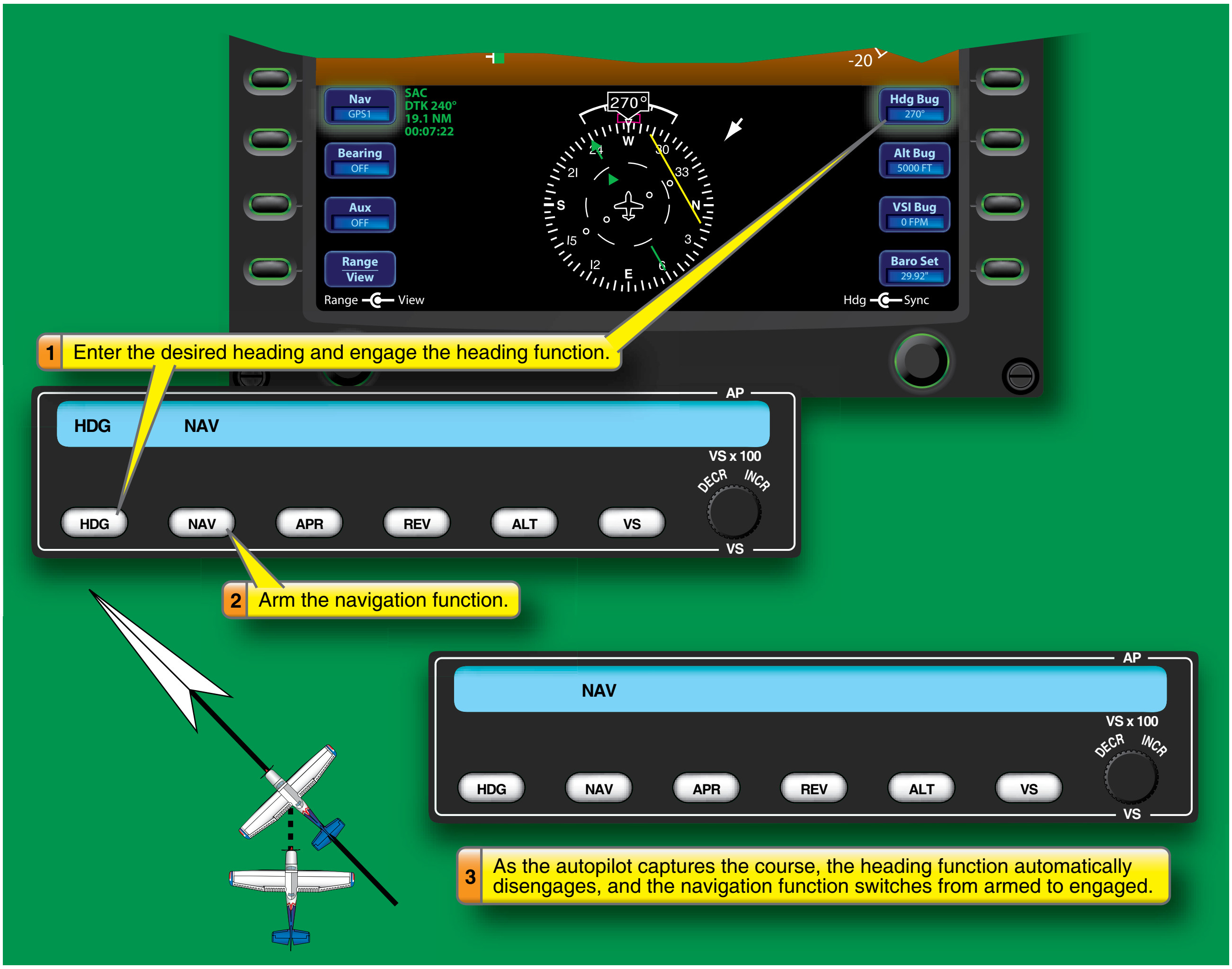

Figure 4-13. *Flying an assigned heading to intercept a course.*

Coupled Approaches

The approach function is similar to the navigation mode, but flies the selected course with the higher degree of precision necessary for instrument approaches and allows glideslope tracking in the vertical dimension. Most autopilots feature a separate button that allows you to engage the approach function, as shown in *Figure 4-14.* (NOTE: Usually, this mode is not used with most GPS receivers. The GPS approach RNP (required navigation performance) of 0.3 induces the necessary flight tracking precision. This mode is used only if specifically stated as a command in the avionics handbook for that equipment in that aircraft).

Like the navigation function, the approach mode can be used to execute precision and nonprecision approaches that rely on types of ground-based navigation facilities (e.g., VOR, VOR/DME, and localizer approaches).

ILS Approaches

Coupled ILS approaches make use of the autopilot's glideslope function. *Figure 4-15* shows the procedure for one type of autopilot.

Note that you cannot directly arm or engage the glideslope function. The autopilot must usually be engaged first in the approach and altitude modes. When the FD/autopilot begins to sense the glideslope, the glideslope function will automatically arm. When the aircraft intercepts the glideslope, the glideslope function engages automatically, and uses the aircraft's pitch control to remain on the glideslope. It is important to note that, generally, the glideslope function can capture the glideslope only from below or on glideslope.

RNAV Approaches With Vertical Guidance

Coupled RNAV approaches with vertical guidance work in the same way as coupled ILS approaches. Lateral and vertical guidance commands are generated by the FMS/NAV and sent to the FD/autopilot. The same approach and glideslope

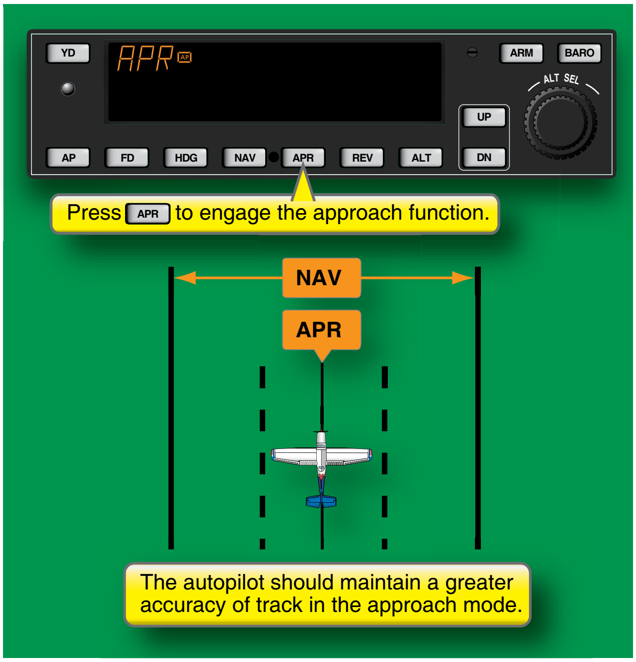

Figure 4-14. *Flying a coupled nonprecision approach.*

functions of the autopilot are used in the same way to carry out the lateral and vertical guidance and control of the aircraft. This process is transparent to the pilot. Most "VNAV" functions do not qualify as approach vertical functions and many FMS/GPS units inhibit that function during approaches.

Power Management

Since most autopilots are not capable of manipulating power settings, you must manage the throttle to control airspeed throughout all phases of the approach. The power changes needed during altitude changes must supply the necessary thrust to overcome the drag. The pilot must coordinate the powerplant settings with the commands given to the FD/autopilot. Remember, the FD/autopilot can control the aircraft's pitch attitude only for altitude or airspeed, but not both. The FD/autopilot attempts to perform as programmed by you, the pilot. If the climbing vertical speed selection is too great, the aircraft increases the pitch attitude until it achieves that vertical speed, or the wing stalls. Selection of an airspeed or descent rate that is too great for the power selected can result in speeds beyond the airframe limitations. Leveling off from a descent, without restoring a cruise power setting results in a stall as the FD/autopilot attempts to hold the altitude selected.

Essential Skills

1. Use the FD/autopilot to couple to a precision approach.
2. Use the FD/autopilot to couple to a nonprecision approach.

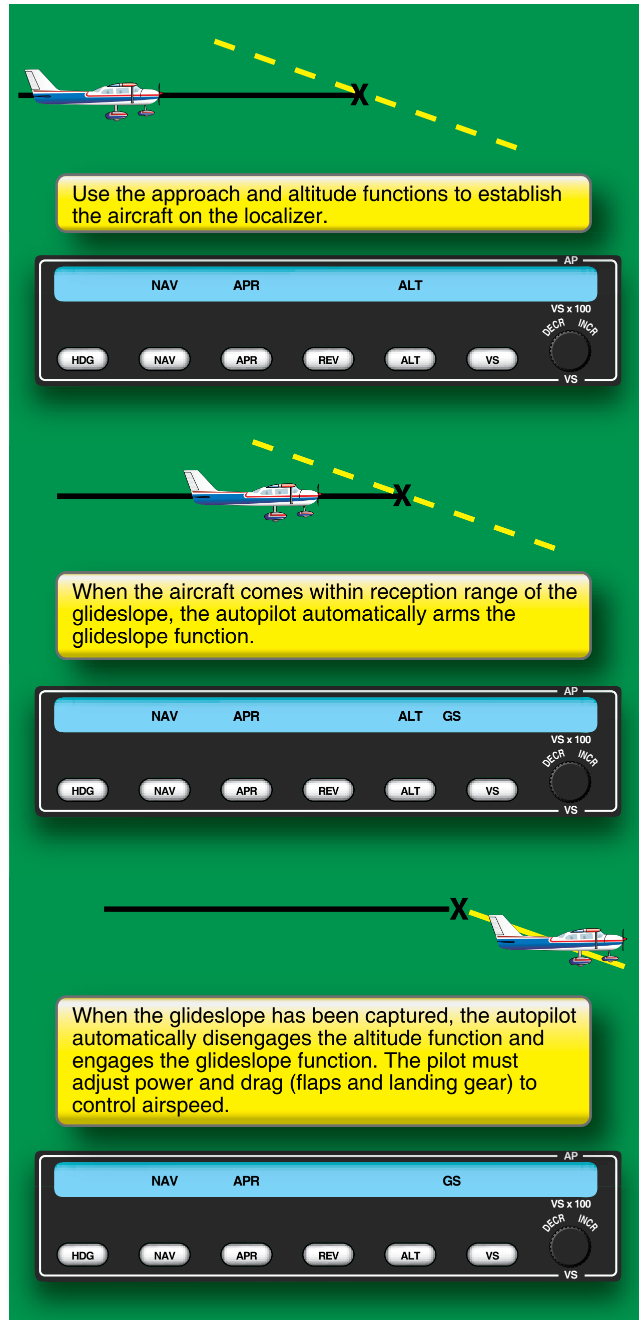

Figure 4-15. *Flying a coupled precision approach.*

3. Use the FD/autopilot to couple to an RNAV approach.
4. Determine the power setting required to fly the approaches.
5. Determine the power settings necessary for leveloff during nonprecision approaches and go-around power settings for both precision and nonprecision approaches.

6. Determine the speeds available for the minimum recommended powerplant settings. It is useful to determine if an ATC clearance can be accepted for climbs, altitudes, and descents.

Deciding When To Use the FD/Autopilot

In addition to learning how to use the FD/autopilot, you must also learn when to use it. Since there are no definitive rules about when an FD/autopilot should or should not be used, you must learn to consider the benefits and disadvantages of using the FD/autopilot in any given situation.

One of the most valuable benefits of using the FD/autopilot is delegating the constant task of manipulating the aircraft's controls to the equipment, which do nothing other than comply with the pilot's programming. This allows you more time to manage and observe the entire flight situation. Managing the flight versus actually moving the controls allows more time for:

1. Programming. Especially when flying under IFR, changes to a route are inevitable. Even when the pilot is proficient in using FMS/RNAV, this task requires focusing some attention on the programming task. The FD/autopilot keeps the aircraft on the programmed heading or course and altitude while the pilot makes the necessary changes to the flight plan. If programmed correctly, the aircraft maintains the correct track and altitude.
2. Distracting tasks/workload. Similarly, the FD/autopilot is used to control basic aircraft movement while the pilot focuses attention on tasks such as reviewing charts, briefing and configuring for an instrument approach, updating weather information, etc. The FD/autopilot can also be a great help in other high workload situations, such as flying in a busy terminal area or executing a missed approach in adverse weather conditions.
3. Maintaining autopilot skills. The FD/autopilot's ability to help manage pilot workload depends heavily on the pilot's proficiency in using it. Regular practice with the various autopilot functions (especially the approach functions) is essential to develop and maintain the knowledge and skills necessary to maximize its utilization.
4. Emergencies. The FD/autopilot can be extremely useful during an emergency. It can reduce pilot workload and facilitate efforts to troubleshoot the emergency.

Disadvantages of using the FD/autopilot include the following:

1. Forgetting to maintain manual flying skills. It is important to practice flying without the FD/autopilot often enough to maintain proficiency in basic flying skills and the instrument cross-check and scan. One common pitfall of advanced avionics is the pilot's tendency to forget to maintain hard-earned skills for instrument flight. All equipment will fail at some time. The competent pilot is ready and prepared to make a transition to aircraft piloting at any time.
2. Turbulence. The pilot's operating handbook (POH) and FD/autopilot flight manual supplements for many aircraft discourage or prohibit use of the autopilot's altitude hold function during moderate or severe turbulence. Some FD/autopilot systems may default or disengage if certain trim or control limits are encountered during turbulent conditions. You should consult the flight manual to ensure the aircraft is not operated outside specified limits. The aircraft's flightpath and mode indications should always be monitored to ensure what modes are active.
3. Minimum altitude. Autopilots are certified for use above a specified minimum altitude above ground level (AGL). Some higher performance and higher service ceiling aircraft require autopilot control above certain airspeeds and altitudes. The flight manual and operations manual (if any) should be consulted to ensure that the pilot does not operate the aircraft outside specified limits. For higher safety standards, commercial operators must observe restrictions in Title 14 of the Code of Federal Regulations (14 CFR) sections 121.579, 125.328, and 135.93, according to their regulatory classification. Adoption of these limits by private operators would add a safety margin to flights conducted under 14 CFR part 91 regulations in many cases.
4. Possible malfunction. If at any time the pilot observes unexpected or uncommanded behavior from the autopilot, he or she should disengage the autopilot until determination of the cause and its resolution. Most autopilot systems have multiple methods of disengagement; you should be immediately aware of all of them. Also be aware of the methods to cancel the FD display to avoid confusing information.

Miscellaneous Autopilot Topics

Autopilot Mode Awareness

In addition to performing the basic aircraft control and navigation function described previously, some autopilots are capable of automatically switching from one function to another. These automatic mode changes can complicate the task of maintaining mode awareness, but every autopilot has some form of flight mode annunciator that shows which autopilot functions are currently engaged. The autopilot shown in *Figure 4-4* displays the name of any autopilot mode that is currently engaged just above the button used to engage the function. It is important to develop two habits:

1. Checking the flight mode annunciator after entering a command to ensure that the selected function is indeed armed or engaged, as appropriate.
2. Including the flight mode annunciator in the scan to maintain continuous awareness of what mode is active and what is armed to activate next.

Positive Exchange of Controls

When control of the aircraft is transferred between two pilots, it is important to acknowledge this exchange verbally. The pilot relinquishing control of the aircraft should state, "You have the flight controls." The pilot assuming control of the aircraft should state, "I have the flight controls," and then the pilot relinquishing control should restate, "You have the flight controls." Following these procedures reduces the possibility of confusion about who is flying the aircraft at any given time.

Using an FD/autopilot system can present an opportunity for confusion. When engaging the autopilot, it is a good idea to announce that the autopilot is being engaged, what autopilot mode is being used, and then to confirm the settings using the flight mode annunciator. It has been general practice for many years in many aircraft to first engage the FD to determine what instructions it was going to transmit to the autopilot. This is determined by reading the FD's command bars. If the commands shown agree with your perception of the control motions to be made, then engage the autopilot to fly the entered course and vertical mode. A caution at this point: some FDs cancel the altitude hold mode when the autopilot is engaged. Always ensure that, after autopilot engagement, the desired modes are still active.

Preflighting the Autopilot

The POH or aircraft flight manual (AFM) supplement for each FD/autopilot system contains a preflight check procedure that must be performed before departure. As with other preflight inspection items, this check allows you to ensure that the autopilot is operating correctly, before depending on it in the air.

Autopilot and Electric Trim System Failures

It is vital that you become immediately familiar with the procedures required to disconnect or disable the electric trim and autopilot systems. Electric trim and autopilot failures can occur in the form of failure indications; unusual, unexpected, or missing actions; or, in the extreme case, a runaway servo actuator in the autopilot or trim system.

The first and closest method of disconnecting a malfunctioning autopilot is the autopilot disconnect switch, typically mounted on the control yoke. This switch is usually a red button, often mistaken by new pilots for the radio transmit button. You need to know which buttons activate which functions.

Most systems may be disconnected by the mode buttons on the autopilot control panel. However, there are some failures (shorted relays, wires, etc.) that remove control of the servo actuator from the control unit itself. In those rare instances, the pilot must find and pull the circuit breakers that interrupt power to both the trim and autopilot systems. Some trim systems have separate circuit breakers for trim motors that operate different control surfaces (roll, pitch, yaw). Many pilots have installed small plastic collars on the autopilot to facilitate finding and pulling the correct autopilot circuit breaker to kill the power to that circuit. Ensure that you understand all functions and equipment are lost if those (and in fact, any circuit breaker) are disabled. In too many cases, a circuit breaker installed in an aircraft supplies power to more functions than the label implies. To be absolutely sure, check the wiring diagrams, and do not pull circuit breakers unless the POH/AFM directs that specific action.

Another method of maintaining flight control when faced with a failed trim or autopilot system is the control yoke. Most autopilot and trim systems use a simple clutch mechanism that allows you to overpower the system by forcing the control yoke in the desired direction. This is usually checked during the afterstart/pretakeoff/ runup check.

Essential Skills

1. Demonstrate the proper preflight and ground check of the FD/autopilot system.
2. Demonstrate all methods used to disengage and disconnect an autopilot.
3. Demonstrate how to select the different modes and explain what each mode is designed to do and when it will become active.
4. Explain the flight director (FD) indications and autopilot annunciators, and how the dimming function is controlled.

Chapter Summary

Automated flight control can make a long flight easy for you by relieving you of the tedious second-by-second manipulation and control of the aircraft. Overdependence on automated flight controls can cost you hard-earned aircraft handling skills, and allow you to lose the situational awareness important to safe flight. You must practice your skills and cross-check.

Automated flight controls require you to study and learn the system's programming and mode selection actions. You must also learn what actions disconnect the autopilot, whether commanded or not. In preflight planning you must determine the limitations on the autopilot and what the installation in that aircraft permits.

It is important for you to be aware of what functions are automated and what activates those functions, and the actions or conditions that cancel or inhibit those functions. Remember that, in most aircraft, you must set the power and manage the powerplant(s). Even in very expensive aircraft equipped with autothrottle, you must monitor the powerplant(s) and be ready to intervene to ensure operation within safe parameters.