AUTOPILOTS

THE LEGACY OF MECHANICAL MIKE

Easing the flight

BY MARK M. LACAGNINA

During a recent visit with a leading manufacturer of general aviation autopilots, I spotted a simple, fixed-gear single in the company's hangar. At first, I was somewhat surprised to learn that the airplane was undergoing flight-test certification for a sophisticated, three-axis autopilot.

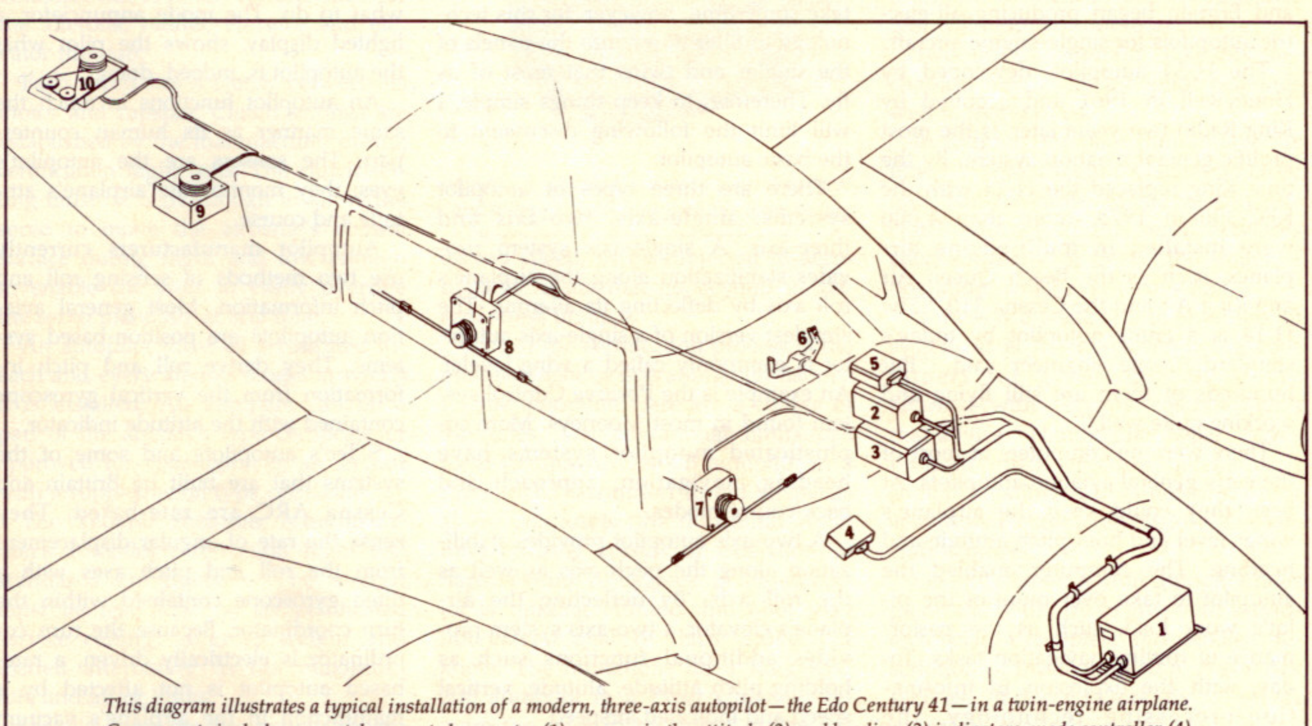
A grass-roots airplane with altitude hold is not all that surprising, though. It is portentous. It says a lot about how even the most humble models in the general aviation fleet are being flown. It also says a lot about the increasing recognition by pilots of the autopilot's capability of handling the grunt work of flying during long trips in weather and of flying through today's demanding ATC system. For a growing number of pilots, an autopilot that is functioning properly is an important consideration in making go/no-go decisions.

The evolutionary roots of the general aviation autopilot can be traced back to Wiley Post, *Winnie Mae* and "Mechanical Mike." Post and master navigator Harold Gatty achieved considerable notoriety when they flew *Winnie Mae*, a Lockheed Vega, around the world in 1931. The historic flight left Post chafing at the bit to do it again, by himself.

Recognizing that he would need some assistance to make the solo flight, Post approached the Sperry Gyroscope Company, which was experimenting with an automatic wing-leveling system. Post must have been incredibly persuasive, because he talked Sperry into installing the prototype autopilot in *Winnie Mae*. He dubbed his oil-filled, metal copilot Mechanical Mike.

Post accomplished his solo, transglobal flight in 1933. Although he was delayed several times by the necessity of having to repair hydraulic leaks in Mechanical Mike, Post trimmed 21 hours off of the record he had set two years earlier with Harold Gatty.

After the flight, Post and *Winnie Mae* went on to explore the frontiers of high-altitude flying. Mechanical Mike went back to the engineering rooms at Sperry and reemerged as the A-3 autopilot for the workhorse Douglas DC-3 transport. Autopilot technology advanced rapidly during World War II, when Sperry and Honeywell became intensively involved in efforts to develop autopilot systems for military bombers. During this time, designer William Lear patented a very expensive autopilot for Cessna's light twin, the T50 "Bamboo Bomber." *continued overleaf*



This diagram illustrates a typical installation of a modern, three-axis autopilot—the Edo Century 41—in a twin-engine airplane. Components include: a remotely mounted computer (1); sensors in the attitude (2) and heading (3) indicators; mode controller (4) and annunciator (5); trim, pitch and disconnect switches (6); and roll (7), pitch (8), yaw damper (9) and pitch-trim (10) servos.

COURTESY EDO-AVIONICS

With sensors for eyes, a computer for brains and servos for muscle, an autopilot tackles the routine tasks of flying the airplane.

One of the first autopilots designed for light, general aviation aircraft was the Sperry Zero-Reader. Introduced around 1950, the autopilot advanced the state of the art with the use of miniaturized vacuum tubes. The Zero-Reader weighed only about 40 pounds—a real featherweight compared to the 150-pound systems carried aboard the military bombers.

Vacuum tubes soon were supplanted by solid-state electronics, and Mitchell and Brittain began producing all-electric autopilots for single-engine aircraft.

The H-14 autopilot, developed by Honeywell in 1961 and acquired by King Radio two years later, is the most prolific general aviation system. By the time King replaced the H-14 with the KFC-300 in 1973, more than 4,000 were installed in multi-engine airplanes, such as the Beech Queen Air and King Air and the Cessna 310. "The H-14 is a crude autopilot by today's standards," one engineer said. "But hundreds of them are still flying and working quite well."

There were no computers in most of the early general aviation autopilots. At best, they could keep the airplane's wings level and hold pitch attitude and heading. The computer enabled the autopilot to take over more of the pilot's work load, such as the performance of routine navigation tasks. Today, with the explosion in information-processing technology, the autopilot is in danger of losing its identity as it increasingly becomes swallowed up in integrated flight-control and flight-management systems. It will take some time, however, for this technology to filter down into the panels of the singles and twins that most of us fly. Therefore, to keep things simple, I will limit the following discussion to the basic autopilot.

There are three types of autopilot systems: single-axis, two-axis and three-axis. A single-axis system provides stabilization along the airplane's roll axis by deflecting its ailerons. The simplest version of a single-axis autopilot is commonly called a wing-leveler. An example is the Positive Control system found in most Mooneys. More sophisticated autopilot systems have heading, navigation, approach and back-course modes.

A two-axis autopilot provides stabilization along the pitch axis as well as the roll axis. By deflecting the airplane's elevator, a two-axis system provides additional functions such as holding pitch attitude, altitude, vertical speed and indicated airspeed.

A three-axis autopilot incorporates a yaw damper. In most general aviation installations, this is a separate system that activates the rudder to dampen the airplane's tendency for Dutch-roll oscillations in turbulence.

The basic components of an autopilot are a mode controller and annunciator, sensors, a computer/amplifier and servo actuators. The mode controller and annunciator provide an interface between the pilot and the autopilot. The pilot pushes buttons on the mode controller to tell the autopilot what to do. The mode annunciator, a lighted display, shows the pilot what the autopilot is, indeed, doing.

An autopilot functions in much the same manner as its human counterpart. The sensors are the autopilot's eyes; they monitor the airplane's attitude and course.

Autopilot manufacturers currently use two methods of sensing roll and pitch information. Most general aviation autopilots are position-based systems. They derive roll and pitch information from the vertical gyroscope contained with the attitude indicator.

S-Tec's autopilots and some of the systems that are built by Brittain and Cessna ARC are rate-based. They sense the rate of angular displacement from the roll and pitch axes with a tilted gyroscope contained within the turn coordinator. Because the turn coordinator is electrically driven, a rate-based autopilot is not affected by a malfunction in the airplane's vacuum system. However, rate-based autopilot systems react more slowly to gust upsets than do position-based systems.

Heading and course information are derived from the horizontal gyroscope within the direction indicator and the course deviation indicator or, together, from the horizontal situation indicator. Altitude is sensed either by a potentiometer attached to the bellows within the altimeter or by a piezoelectric transducer (oscillating cylinder) hooked up to the airplane's pitot-static system.

Information on yaw attitude is derived from an accelerometer or from sensors in both the attitude and heading indicators.

Just as the eyes send neural impulses to the brain, an autopilot's sensors send electrical signals to the computer/amplifier. The signals are called error signals. For instance, when the pilot moves the heading bug, the sensors tell the computer the difference between the current and the selected headings with an electronic signal composed of a certain number of millivolts per degree of displacement.

The computer processes and amplifies the signal, and sends an electronic command to the autopilot's muscles, the servo actuators.

The servo actuator is a small, electromechanical motor that turns a grooved shaft called a capstan. A bridle cable is wrapped around the capstan, and the tips of the bridle cable are clamped to the primary control cable. A three-axis autopilot has four servos; one each for the ailerons, rudder, elevator and elevator trim tab.

Each servo has a clutch between its motor and capstan. Clutch settings are established by the manufacturer during certification flight tests. The clutch setting must be high enough to allow the servo to move the airplane's control surface during flight and low enough to enable the pilot to easily override the servo manually at any time.

An autopilot must be certificated for each and every aircraft model in which it is installed. An autopilot can be a part of the aircraft's type certificate or approved for installation in an aircraft with a supplemental type certificate.

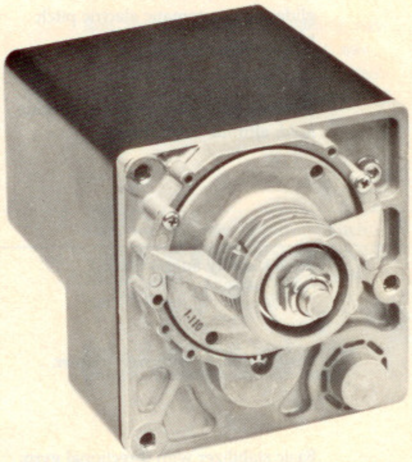
The Federal Aviation Administration's autopilot certification flight test standards are rigorous. The aircraft must be test flown at its certificated service ceiling, at gross weight and loaded alternately to the maximum fore and aft cg limits.

Usually, there are two people aboard the aircraft during the tests. Without any warning, one person uses a control box rigged to the aircraft's electrical system to induce hard runaways in the servo actuators—separately at first, then all together.

The FAA has determined that it takes an average pilot about three seconds to recognize and respond to a malfunction. Therefore, the test pilot must wait three seconds (he uses a stopwatch for this) after the onset of a servo runaway before he starts to do something to resolve it. The other person, meanwhile, takes notes.

To meet the certification standards, the pilot must not have to exert more than 50 pounds of force on the elevator, 30 pounds on the ailerons or 150 pounds on the rudder to manually overpower the runaway servo actuators. (Researchers say a normal human being can exert 150 pounds of force on the elevator, 80 pounds on the ailerons and 300 on the rudders.)

During recovery, the aircraft cannot exceed 60 degrees of bank or its never-exceed speed, or be subjected to aerodynamic loads that go beyond its design stress limits.



A servo is adjusted to move a control surface and to lose a tug of war with the pilot easily.

Part of the certification process is the establishment of operational limitations for the autopilot. Here are a couple of examples. The operational limitations for a Cessna ARC 400B autopilot in a Pressurized Centurion forbid airspeeds above 165 knots (the maximum structural cruising speed) or extension of flaps beyond 10 degrees. If the autopilot is holding altitude, the pilot may not extend gear or flaps above 115 knots. The limitations for a King KFC 200 autopilot in a Piper Chieftain require the pilot to be sitting in the left seat and have his seat belt fastened. The limitations also prescribe a minimum, as well as a maximum, airspeed for the Chieftain with the autopilot in operation.

As you can see, the operating envelope for an aircraft can be considerably tighter when the autopilot is engaged. The pilot has no excuse for not knowing the operating limitations of his autopilot: They are published in the supplements section of the aircraft operating handbook.

Beyond knowing the limitations, the pilot should make an effort to get to know how his autopilot works. If this advice sounds supercilious to you, consider the following comments by a leading autopilot engineer: "An autopilot is designed so that a pilot cannot hurt himself if he just starts pushing buttons. You would be surprised at how many pilots do just that. They don't understand their autopilots or appreciate what they can do. They make a substantial investment and blow it all by not reading the book."

When I asked engineers at three leading autopilot manufacturing companies for their advice on how a pilot can keep his autopilot happy, they were unanimous on two things. One, don't smoke. The vacuum systems in most light aircraft take in air from the cabin. If there are smoke particles in the air, they will find their way into the gyros. The result is a gummy mess that cannot be cleaned up. Installing finer-screen filters in the vacuum system will help, but not much.

Two, use the autopilot. Like any mechanical device, an autopilot responds well to frequent use.

In addition, the pilot should have the filters in the vacuum system replaced and control-cable tensions and the clutch settings in the servo actuators checked yearly or every 200 hours of operation, whichever comes first.

If there is a weak link in an autopilot system, it is the gyros. Shipping containers for gyroscopes often are adorned with brightly colored labels that advise, "Handle Like Eggs." Gyros without quick erection mechanisms should be allowed to either spin up or spin down completely before the aircraft is moved.

One final note: If your autopilot does go on the blink, try to give your service technician a complete and detailed description of the malfunction. A squawk such as, "It doesn't work; fix it," serves to make the repairman's job much more difficult and the resulting bill much longer than necessary. □

AUTOPILOTS DIRECTORY overleaf

AUTOPILOTS DIRECTORY

COMPILED BY BEVERLY P. MOWERY

Manufacturer	Models	Modes and Functions	Price, uninstalled
Astronautics Corp. of America Autopilot Div. 2416 Amsler St. Torrance, Calif. 90505 213/326-8921	Pathfinder P-1	Roll/yaw stabilization, heading.	$1,695 Includes: turn coordinator, roll amplifier, servo actuator, installation kit.
	Pathfinder P-2	Roll/yaw stabilization, heading, VOR/LOC track.	$1,935 Includes: controller, turn coordinator, aileron servo amplifier, servo actuator, installation kit.
	Pathfinder P-2A	Roll/yaw stabilization, heading, automatic VOR/LOC intercept and track.	$3,350 Includes: controller, turn coordinator, aileron servo amplifier, servo actuator, directional gyro, installation kit.
	Pathfinder P-3A	Roll/yaw stabilization, heading, automatic VOR/LOC intercept and track, altitude hold/alert.	$7,300 Includes: controller, turn coordinator, aileron servo amplifier, directional gyro, pitch and altitude sensor, elevator servo amplifier, servo actuators, attitude indicator, installation kit.
	Pathfinder P-3B	Roll/yaw stabilization, heading, automatic VOR/LOC intercept and track, altitude hold/alert, automatic glideslope, automatic electric pitch trim.	$8,700 Includes: controller, turn coordinator, aileron servo amplifier, directional gyro, pitch and altitude sensor, elevator servo amplifier, servo actuators, attitude indicator, trim servo and switch, glideslope tracking module, installation kit.
	Helicopter	Heading hold, nav coupling, attitude hold, altitude hold, hover.	$40,000 Includes: autopilot computer, control panel, altitude hold sensor, vertical gyro, yaw rate gyro, heading gyro with heading select, cyclic pitch servo actuator, cyclic roll servo actuator, yaw servo, accelerometer actuator, installation kit.
Brittain Industries, Inc. P.O. Box 51370 Tulsa Int'l Airport Hangar 12 Tulsa, Okla. 74151 918/836-7701	LevelMatic	Basic stability augmentation (wing leveler).	$1,380 Includes: redundant turn coordinator gyro, servos and mounting hardware.
	AccuTrak II	Basic stabilizer with nav coupler.	$1,860 Includes: turn coordinator gyro and electronics for coupler, brackets, servos, hardware.
	AccuFlite II	Basic stabilizer with directional gyro, heading.	$2,885 Includes: turn coordinator gyro, 3⅛-in vertical card directional gyro, all electronics, hardware.
	NavFlite II	Heading, capture track and localizer, command turn, self-contained magnetic-heading reference, all horizontal couplings.	$3,550 Includes: turn coordinator gyro, power supply, magnetic-heading sensor, controller/amplifier, hardware.
	NavFlite IV	Heading, capture track and localizer, command turn, directional gyro, all horizontal couplings.	$4,100 Includes: turn coordinator, directional gyro, controller/amplifier, power supply, hardware.
	NavFlite III	Heading, capture track and localizer, command turn, magnetic-heading reference, directional gyro, all horizontal couplings.	$5,350 Includes: turn coordinator gyro, power supply, magnetic heading sensor, controller/amplifier, directional gyro, hardware.
	B5	Heading, capture track and localizer, command turn, pitch stabilization, altitude hold, all horizontal couplings.	$5,676 Includes: turn coordinator gyro, power supply, magnetic heading sensor, controller/amplifier, servos, pitch stabilization and altitude sensor, hardware.
	B5C	Heading, capture track and localizer, command turn, self-contained pitch and altitude hold, directional gyro, all horizontal couplings.	$6,210 Includes: turn coordinator, directional gyro, controller/amplifier, power supply, pitch and altitude sensor, hardware.

Manufacturer	Models	Modes and Functions	Price, uninstalled
Brittain continued	B5B	Heading, capture track and localizer, command turn, self-contained magnetic-heading reference, pitch stabilization and altitude hold and horizontal couplings. **Note:** NavFlite II, III, IV, B5, B5B, B5C and AccuFlite can be coupled with Arinc HSI inputs.	$7,050 Includes: turn coordinator gyro, power supply, magnetic-heading sensor, controller/amplifier, servos, pitch stabilization, altitude sensor, hardware.
Cessna Aircraft Co. ARC Avionics Div. P.O. Box 150 Boonton, N.J. 07005 201/334-1800	200A	Wing leveler, direction hold, VOR intercept and track, back course, high and low sensitivity, nav select, roll stabilization, turn command, localizer intercept and track.	$2,125 Includes: turn coordinator, computer amplifier/controller, actuator, connector kit (brackets not included; gyro optional).
	300A	Heading, turn command, nav intercept and track, high and low sensitivity, back course, roll stabilization, VOR intercept and track.	$4,310 Includes: directional gyro, turn coordinator, panel-mounted computer amplifier/controller, actuator and connector kit, (brackets not included; HSI optional).
	400B	Autopilot, turn command, roll and pitch attitude control, heading, nav intercept and track, localizer coupled approach, basic pitch command, altitude hold, glideslope approach, automatic pitch trim, back course.	$11,645 to $12,095 Includes: computer amplifier, computer mount, panel mount control unit, pitch actuator and mount, roll actuator and mount, attitude gyro, trim actuator and mount, altitude sensor, airspeed switch, connector kit (brackets not included).
	1000	Roll, pitch, altitude and heading, nav 45° or variable angle intercept, nav arm and engage function, LOC, pitch sync, glideslope capture, altitude hold.	$31,910 to $32,460 Includes: computer amplifier, control unit, pitch, roll and trim actuators and mounts. Air-data computer and mount, 4-inch attitude gyro or 4-inch HSI yaw damper, yaw actuator, HSI dynaverter for integrated flight-control systems, adapter for pitch actuator, connector kit (brackets not included).
Collins Avionics Div. of Rockwell Int'l 400 Collins Rd., N.E. Cedar Rapids, Iowa 52406 319/395-1000	APS-65	Roll, heading, nav, approach, pitch, altitude, IAS and vertical speed hold, altitude select, climb, descent, soft ride, ½ bank, go-around.	$21,778 Includes: autopilot computer, air-data sensor, flight control panel, autopilot panel, servos.
	APS-106	Roll and pitch hold, heading, nav, approach, altitude hold, IAS hold.	$26,266 Includes: computer amplifier, pitch/turn control, servos, turn/slip indicator, programmer, airspeed sensor, altitude controller.
	APS-80	Heading, VOR/LOC, approach and all vertical modes with appropriate air-data systems.	$40,108 Includes: servos, autopilot, amplifier, computer and panel, yaw-damper computer, flight-guidance computer and panel.
	APS-841 (helicopter)	Roll and pitch hold, heading, nav, approach, altitude hold, IAS hold.	$41,091 Includes: computer control, servos attitude monitor, vertical gyro, altitude controller, airspeed sensor.
King Radio Corporation 400 North Rogers Rd. Olathe, Kan. 66062 913/782-0400	KAP-100	Heading hold, nav, approach, back course, wing leveler.	$4,620 Includes: installation kit (brackets not included).
	KAP-150	Heading hold, altitude hold, nav, approach, back course, glideslope coupling, wing leveler, pitch/attitude hold, altitude slew or pitch/attitude slew.	$8,635 Includes: installation kit (brackets not included).
	KFC-150	Heading, altitude hold, nav, approach, back course, glideslope coupling, pitch/attitude slew or wing leveler, altitude slew, flight director.	$13,720 Includes: V-bar flight command indicator, slaved electric HSI, installation kit (brackets not included).
	KAP-200	Heading hold, altitude hold, nav, approach, back course, glideslope coupling, wing leveler, pitch/attitude slew or altitude slew.	$14,085 Includes: slaved electric HSI, installation kit (brackets not included; yaw axis optional in some aircraft, altitude preselect optional).

continued

AUTOPILOTS DIRECTORY

Manufacturer	Models	Modes and Functions	Price, uninstalled
King continued	KFC-200	Heading, altitude hold, nav, approach, back course, glideslope coupling, pitch/attitude slew, altitude slew, wing leveler, flight director.	$14,770 Includes: V-bar flight command indicator, slaved electric HSI, installation kit (brackets not included; yaw axis optional in some aircraft, altitude preselect optional).
	KFC 250	Heading, altitude hold, nav, approach, back course, glideslope coupling, pitch/attitude slew, altitude slew, wing leveler, flight director, airspeed monitoring, yaw and altitude preselect.	$28,560 to $41,435 Includes: V-bar flight command indicator, slaved electric HSI, yaw axis, 3- or 4-inch indicator, installation kit (brackets not included).
	KFC 300	Heading, altitude hold, nav, approach, back course, glideslope coupling, pitch/attitude slew or altitude slew, wing leveler, flight director, airspeed scheduling, yaw and altitude preselect.	$68,100 Includes: V-bar flight command indicator, slaved electric HSI, yaw axis, 4-inch indicator.
EDO Corp. Avionics Div. P.O. Box 610 Mineral Wells, Texas 76067 817/325-2517	Century I	Roll and heading stabilization, radio tracker.	$2,595 Includes: radio tracker, installation kit and hardware, pre-manufactured custom cable harness.
	Century II	Roll stabilization, heading select.	$3,649 Includes: installation kit and hardware, pre-manufactured custom cable harness (radio coupler optional).
	Century 21	Heading select, radio coupler, back course, nav, roll stabilization.	$4,995 Includes: radio coupler, installation kit, pre-manufactured custom cable harness (slaved HSI, glideslope coupler optional).
	Century III	Roll stabilization, heading, pitch and altitude hold.	$7,955 Includes: installation kit and hardware, pre-manufactured custom cable harness (slaved HSI, glideslope coupler, radio coupler optional).
	Century 31	Heading, pitch/altitude hold, roll stabilization, radio coupler and glideslope, back course, nav.	$8,717 Includes: radio coupler, glideslope coupler, installation kit and hardware, pre-manufactured custom cable harness (HSI optional).
	Century 41	Heading, roll stabilization, pitch/altitude hold, radio coupler and glideslope coupler, back course, nav.	$11,717 Includes: radio coupler, glideslope coupler, installation kit and hardware, pre-manufactured custom cable harness (HSI optional).
	Century IV	Roll stabilization, pitch/altitude hold, heading, radio coupler, glideslope coupler, back course, nav.	$16,950 Includes: radio coupler, glideslope coupler, slaved HSI, installation kit and hardware.
S-Tec Corp. Wolters Industrial Complex Rt. 3, Bldg. 946 Mineral Wells, Texas 76067 817/325-9406	Yaw Damper	Yaw damper.	$1,095 Includes: panel mounted On/Off switch, trim control, remote mounted sensory amplifier, installation kit and most hardware.
	System 60 (Pitch stabilization system)	Altitude hold, glideslope coupling, vertical speed command.	$3,675 Includes: installation kit and hardware.
	ST60-1	Heading, VOR/LOC coupling.	$3,850 Includes: unlighted gyro, installation kit and hardware.
	ST60-2	Roll and pitch autopilot, VOR/LOC coupling, glideslope coupling, altitude hold, vertical speed command.	$6,950 Includes: unlighted gyro, installation kit and hardware (automatic electric trim, altitude vertical speed preselect, flight director steering horizon, slaved HSI optional).
	ST70	Roll and pitch autopilot, VOR/LOC and glideslope coupling, indicated airspeed hold, altitude hold, automatic pitch trim.	$8,995 Includes: unlighted gyro, installation kit and hardware.

All information obtained from manufacturers. For information on STC applications, contact manufacturers.