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CONSIDERATIONS IN AUTOPILOT LITIGATION*

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I. INTRODUCTION

THE AVIATION automatic pilot (autopilot) developed from a prototype gyroscopic wing leveler first installed in an airplane in 1909.[1] Sperry Gyroscope Company improved this primitive system into a two-axis autopilot that was used in World War I. By 1933, Sperry installed a three-axis autopilot into a Lockheed Vega named *Winnie Mae*, in which Wiley Post made a solo, around-the-world flight. Sperry improved this three-axis autopilot into the A-3 automatic pilot, which was used in the Boeing 247 and Douglas DC-3 transports. Sperry and Honeywell further developed the autopilot during World War II. The first reported case involving aviation autopilot litigation in the United States was *Trihey v. Transocean Air Lines, Inc.*[2] In this action, brought under the

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[1] Letter from E. Sperry, AOPA PILOT, April 1983, at 11-12; LaCagnina, *The Legacy of Mechanical Mike*, AOPA PILOT, Jan. 1983, at 37.

[2] 255 F.2d 824 (9th Cir.), *cert. denied*, 358 U.S. 838 (1958). Litigation involving autopilots has been part of marine litigation since the development of the first automatic steering device. An entire body of law dealing with autopilot accidents in marine vessels now exists. *See, e.g*, Green v. Crow, 243 F.2d 401 (5th Cir. 1957); Petition of H. & H. Wheel Ser., 219 F.2d 904 (6th Cir. 1955); Daniels v. Trawler Sea-Rambler, 294 F. Supp. 228 (E.D. Va. 1965).

Death on the High Seas Act,[3] the plaintiffs alleged that faulty maintenance of the autopilot was the cause of the loss of an aircraft in the Pacific Ocean near Wake Island in 1953.[4]

During the next twenty years, airline travel became an accepted way of life in the United States, and as aircraft design safety improved, so did the navigation instruments and autopilot systems installed in the aircraft. It therefore was a shock to the aviation industry when a Lockheed 1011 jetliner was lost in the Florida Everglades because altitude-hold mode on the autopilot had disengaged while the flight crew was diverted by a landing gear problem.[5] As a result of this accident, improved warning devices for pilots were developed regarding the engagement, disengagement, and mode of operation of the autopilot and flight director systems.[6]

The 1980's have brought tremendous developments in microprocessors and digital technology which have been applied to flight control systems for both airline and general aviation aircraft. As a result, recent autopilot litigation has become "high-tech." The purpose of this article is to provide a basic understanding of the operation of a general aviation autopilot, to review the reported cases involving autopilots, and to suggest some of the issues to be decided in future autopilot litigation.

II. JURY PERCEPTION OF AUTOPILOTS

Most jurors have no aviation experience. When they learn that they have been selected to decide a case involving an aircraft autopilot, their past experience may be of little benefit in helping them understand the significance of the testimony they will hear. Most of them are familiar with the cruise control of an automobile, but many probably envision an

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[3] 46 U.S.C. § § 761-768 (1976 & Supp. IV 1980).

[4] 255 F.2d at 827. The trial court's holding for the plaintiff was affirmed on appeal. The trial court did not invoke the doctrine of res ipsa loquitur. *Id.*

[5] *See* Gellert v. Eastern Air Lines, 370 So. 2d 802, 804 (Fla. Dist. Ct. App. 1979).

[6] *See* Garrison, *Integrated Flight-Control Systems, Automatic Navigation Systems and Frequency Management Systems*, AVIONICS NEWS, Sept. 1982, at 24; Address by Taylor, *New Developments in Avionics*, Fourteenth Annual SMU Air Law Symposium, Dallas, Texas (March 6-8, 1980).

autopilot as it was presented in the movie *Airplane*; that is, as an inflatable, cigar-smoking dummy that can be called upon in a moment of crisis to fly the airplane when the pilot and co-pilot have been overcome by food poisoning.

During the early part of a trial, the plaintiff's attorney will emphasize the control over an airplane that an autopilot exerts. He may attempt to persuade the jury that an autopilot is like a robot that sits in the co-pilot's seat and pushes and pulls on the controls of the aircraft with great authority. He may ask the jury to imagine that there is a curtain separating the pilot and the robot, so that the pilot cannot see what maneuver the robot autopilot will next execute.

The defense attorney, of course, emphasizes the pilot's control over and responsibility for the autopilot. He explains to the jury that the autopilot assists the pilot if necessary but that the pilot is at all times in command of the aircraft. The pilot can disengage or overpower the autopilot at any time and the autopilot is designed to operate as a very weak pilot. If there is any malfunction of the autopilot, the pilot is provided visual and aural warnings, and he can easily disengage the autopilot and continue the flight of the aircraft just as if it had not been equipped with an autopilot. In some cases, the attorney may need to distinguish the functions of an autopilot from those of an entire flight control system.

During the course of the trial, counsel will need to teach the jury the general theories of autopilot operation. In order to prevent the jury from becoming confused by the electronic and mechanical details of the autopilot, an attorney should use numerous simplified visual aids and should call expert witnesses who can explain the principles of autopilots and give the jury an understanding of how an autopilot works in the air. A Glossary of Terms has been provided as an appendix to this article to aid in explanation to the jury of aviation and autopilot terminology.[7]

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[7] For further explanation of aviation terms, see *In re* Aircrash Disaster at Boston, Mass., July 31, 1973, 412 F. Supp. 959 (D. Mass. 1976); J. Foye & D. Crane, Aircraft Technical Dictionary (1978).

III. THE FUNCTIONING OF AN AUTOPILOT

The first step in understanding how an autopilot works is understanding how an airplane flies. The *Pilot's Handbook of Aeronautic Knowledge*, prepared by the Federal Aviation Admistration (FAA), reviews common aeronautical terms such as lift, thrust, drag, airfoils, climb, descent, turn, pitch, roll, yaw, and explains the cockpit controls and aircraft control surfaces that determine flight.[8] Diagram "A" illustrates the components of a typical autopilot system installed in a general aviation aircraft.

The general aviation autopilot is designed to assist the pilot in flying the airplane by maintaining the aircraft heading and altitude and by relieving the pilot of the need to make continual small corrections for atmospheric disturbances, such as gusts or winds. Autopilots usually have additional capabilities, such as automatic navigation and automatic tracking. The autopilot flies like the pilot by sensing the pitch, roll, heading, and altitude information from the basic flight instruments and then feeding that information into the autopilot computer. The autopilot computer gives a signal to and actuates an electric motor (servo) that in turn moves cables attached to the aircraft control surfaces (rudder, aileron, elevator, or one of the trim tabs on those surfaces) to give the desired flight path. In addition to the basic heading and altitude-hold function, general aviation autopilots typically have full navigation and tracking capabilities, including full VOR, localizer and glide slope coupling. Other modes may include go around, back course, control wheel steering, and altitude pre-select. Autopilots are capable of performing in all three axes (pitch, roll, and yaw). Complete flight control systems including a flight director, are also available for general aviation aircraft. [9]

Diagram "B" illustrates the pitch control system, which is central to the operation of an autopilot on a typical 2-axis autopilot. This example is an electrically driven system that

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[8] FAA, PILOT'S HANDBOOK OF AERONAUTICAL KNOWLEDGE, 1-34 (1980). See the Appendix for an explanation of any unfamiliar terms.

[9] Garrison, *Integrated Flight-Control Systems, Automated Navigation Systems and Frequency-Management Systems*, AVIONICS NEWS (Sept. 1982), at 24.

operates both the elevator and elevator trim tab. Diagram "C" shows how a typical servo attachment to the elevator operates by the use of a clutch to make the necessary adjustments to the elevator. Upon a command from the autopilot computer, the servo attachment pitches the nose of the airplane up or down along the pitch axis.

A. *Primary Pitch Control*

The primary pitch control function of the autopilot regulates the position of the elevator. If, for example, the pilot commands the autopilot to climb, the autopilot computer will send a signal to the elevator servo, commanding the servo motor to run in the "elevator-up" direction. This servo must have sufficient strength or authority to perform the desired maneuver, should not have so much strength or authority that it would ever constitute a problem for flight safety. Therefore, a "slip clutch" arrangement limits the amount of torque that can be transmitted from the servo to the elevator itself. The servo motor is connected to a set of cables through this clutch arrangement, and the cables are connected to the control surface. If the servo motor, for any reason, attempts to deflect the control surface faster or with more strength or authority for which it is designed, the clutch will slip, and prevent an overactive servo from transmitting more "pull" to the control surface than is desirable.

One type of malfunction associated with the primary pitch servo is a "hard-over," which results in a maximum pitch-up or pitch-down response in the servo. As will be explained later, the autopilot system must be designed so that the maximum hard-over signal through the servo will not constitute a flight safety problem. In fact, there is "smoothing" circuitry in the autopilot computer, which directs the elevator servo to move the elevator at a gradual, controlled rate, providing a smooth and comfortable flight, and a safety factor against the "hard-over" occurrence.

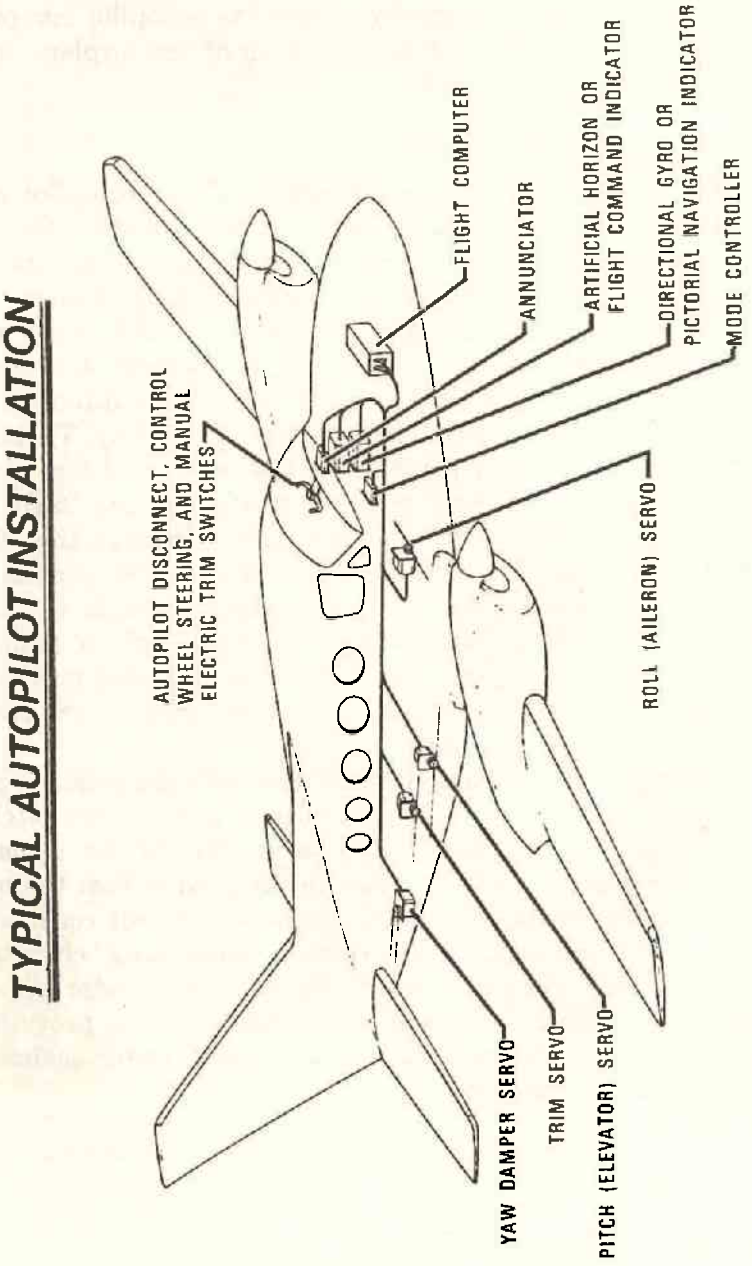

TYPICAL AUTOPILOT INSTALLATION
AUTOPILOT DISCONNECT, CONTROL WHEEL STEERING, AND MANUAL ELECTRIC TRIM SWITCHES
FLIGHT COMPUTER
ANNUNCIATOR
ARTIFICIAL HORIZON OR FLIGHT COMMAND INDICATOR
DIRECTIONAL GYRO OR PICTORIAL NAVIGATION INDICATOR
MODE CONTROLLER
ROLL (AILERON) SERVO
YAW DAMPER SERVO
TRIM SERVO
PITCH (ELEVATOR) SERVO

Diagram "A"

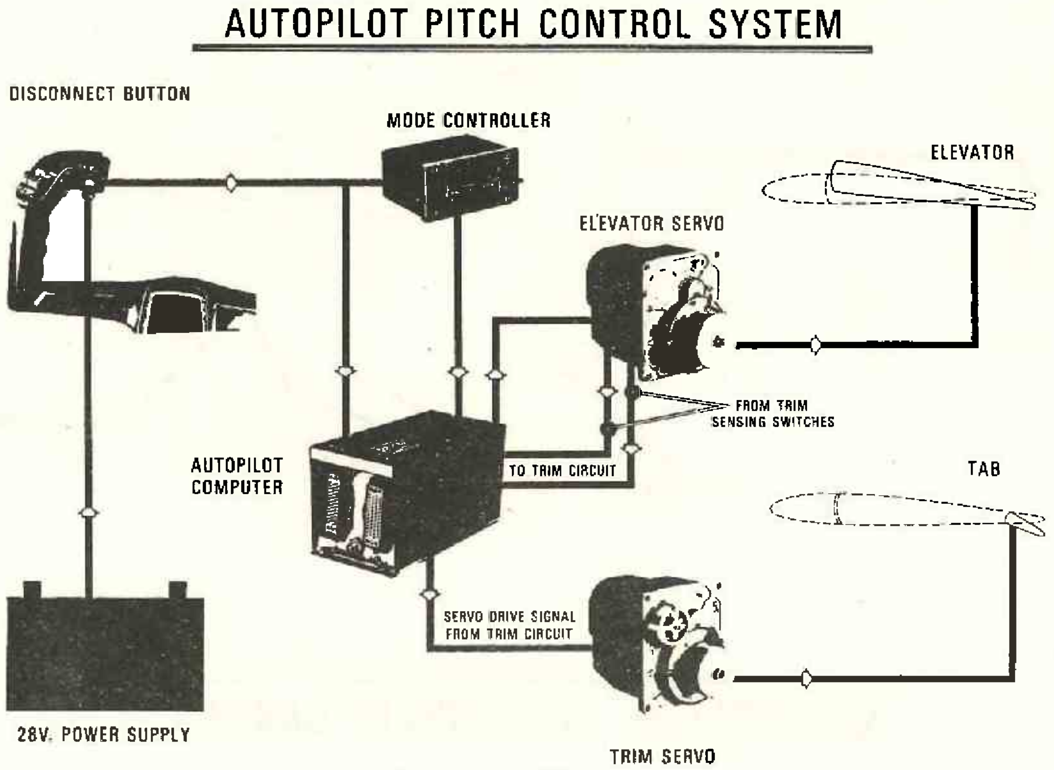
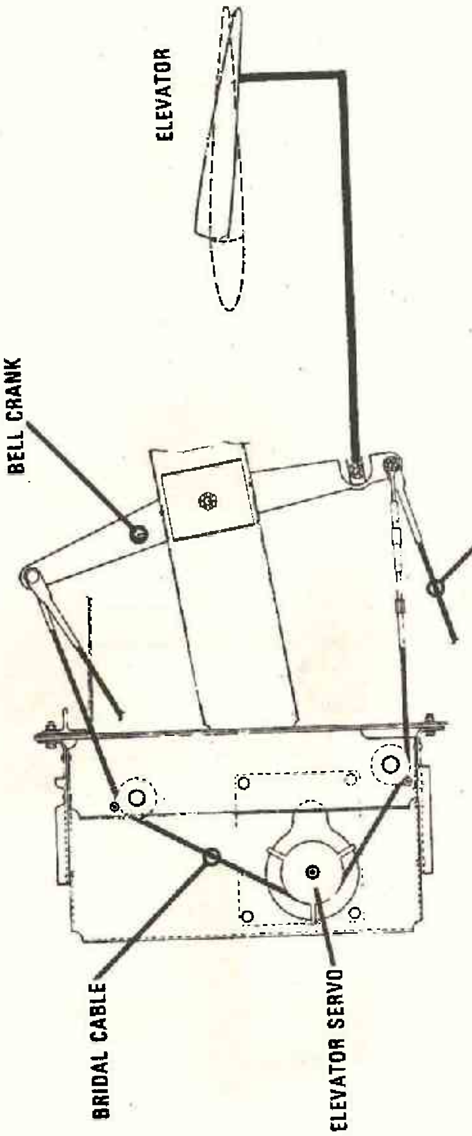

AUTOPILOT PITCH CONTROL SYSTEM
DISCONNECT BUTTON
MODE CONTROLLER
ELEVATOR
ELEVATOR SERVO
FROM TRIM SENSING SWITCHES
AUTOPILOT COMPUTER
TO TRIM CIRCUIT
TAB
SERVO DRIVE SIGNAL FROM TRIM CIRCUIT
28V. POWER SUPPLY
TRIM SERVO

Diagram "B"



SERVO ATTACHMENT TO ELEVATOR

Diagram "C"

B. *Automatic Pitch Trim*

A second servo operates the elevator trim tab, to relieve the load on the elevator servo. For example, the pilot may command a climb that will last for several minutes. Rather than having the elevator servo hold the elevator out of trim for the duration of the climb, the flight computer, after a short delay, will activate the pitch trim servo, which will run the elevator trim to relieve the load on the elevator, and the load on the elevator servo.

This "autotrim" function of the autopilot also incorporates a slip clutch. However, the major safety feature in the autotrim function is provided by a control on the rate at which the trim tab is moved. Generally, the autotrim function moves the trim tab at a very slow rate, much slower than the pilot could manually introduce trim, and usually slower than the manual electric trim, discussed below.

Several problems can occur in the trim function, including the trim running without an appropriate command (sometimes referred to as "trim run-away"), the trim failing to run upon command, or the trim running in the wrong direction. When a pilot observes one of these undesirable responses occurring, he may be incorrect in assuming that the autopilot is at fault. The autopilot is only part of an integrated system, which relies upon the power supply, other instruments providing information, and the attachments between the servos and the control surface or trim tabs. A failure of the airplane to respond to a given command by the pilot therefore can be the result of a problem existing outside of the autopilot itself.

A time delay is designed into the system so that the autotrim does not operate automatically every time the elevator is deflected for minor corrections. If the elevator servo is to deflect the elevator for only a short period of time (a matter of a few seconds), the trim will not operate. If the elevator deflection is to continue for more than a few seconds, the trim will be activated to assist the elevator servo after a short delay.

In some systems, it is possible that a run-away trim condition will be opposed by the autopilot through the elevator servo so that the pilot will not observe the defect. For example, if there is a trim run-away in the "nose-up" position, the computer may command the elevator servo to run in the nose-down direction, to counteract the effect of the trim. The elevator servo will be able to hold the elevator in its deflected position, effectively masking the trim problem (assuming that the pilot has not observed any visual or aural warnings of a trim malfunction), until the autotrim condition causes the forces on the elevator to exceed the setting of the elevator servo's slip clutch. At that point, the clutch will begin to slip, the autopilot will gradually lose its ability to mask the autotrim run-away situation, and the aircraft will begin to deviate from its commanded attitude.

If at some point the autopilot is suddenly disengaged by the pilot in an out-of-trim position, all direct control of the elevator will be released and the aircraft may enter into a sudden pitch up or down. Likewise, if the human pilot overpowers the autopilot in some systems without disengaging, his pushing or pulling on the control column will be sensed by the computer, which will attempt to maintain the attitude originally commanded in opposition to the efforts of the pilot. In this way, the pilot can actually induce the autopilot to place the aircraft in an out-of-trim position. If the pilot then suddenly releases the control column or disengages the autopilot without anticipating this out-of-trim position, he may experience a similar pitch response.

C. *Manual Electric Trim*

An aircraft may be equipped with a manual electric trim system that allows the pilot to operate a switch on the control panel which engages the pitch trim servo and moves the pitch trim tab. The manual electric trim is designed to assist the pilot during takeoff and landing and for his convenience enroute. This system is not a part of the autopilot and will operate the elevator trim tab at a rate faster than that of the autotrim function in the autopilot.

D. *Roll Axis*

An autopilot system also has roll control through servos connected to the aileron cables and aileron trim, but a separate explanation is not included here because the theory of operation of the roll axis is the same as for the pitch axis.

E. *Disengagement of the Automatic Pilot*

Any time the pilot desires, the autopilot may be completely disengaged by the use of the red disconnect button on the control wheel, the on/off switch on the mode controller, the avionics power switch, or (in some systems) the manual electric trim switch. The autopilot can also be disengaged by pulling the autopilot's electric circuit breaker. Additionally, the system may be overpowered by the pilot if necessary.

F. *Summary*

The pilot selects the autopilot function through the mode controller. The autopilot computer obtains further information from sensors (gyroscopes, altitude deviation and navigation radios). The commands are carried out by actuators (servos) that affect the aircraft control surfaces.[10]

IV. CERTIFICATION OF AUTOPILOTS BY THE FAA

The Federal Aviation Regulations (FARs) require that all aircraft manufacturers obtain a Type Certificate from the FAA which is issued upon a showing that the design of the specific aircraft meets the detailed standards for operation, air safety, material, and performance.[11] Generally, all manufacturers of autopilot systems obtain a Supplemental Type Certificate (S.T.C.) from the FAA in order to allow the installation of their autopilot system in any particular aircraft.[12] An

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[10] For an excellent explanation of the general aviation autopilot, see J. Roskam & M. See, *A Primer on General Aviation Autopilots*, 1 SAE IN AEROSPACE ENGINEERING (Sept. 1981)(based on SAE paper 810582, *The State of the Art of General Aviation Autopilots: Now and in the Future*, Univ. of Kansas) (Copies may be obtained from the Society of Automotive Engineers). For a detailed explanation of any particular autopilot, see the FAA Approved Airplane Flight Manual Supplement for the desired aircraft as well as the autopilot manufacturer's pilot guide.

[11] 14 C.F.R. § § 21.21-.41 (1982). *See also* Carsey, *Initial and Continuing Responsibilities of General Aviation Manufacturers*, 37 J. AIR L. & COM. 295 (1971).

[12] 14 C.F.R. § § 21.111-.119 (1982).

S.T.C. is issued for all major design changes to Type Certified products when the changes are too minor to require a new Type Production Certificate.[13] The S.T.C. gives FAA approval for the installation of the autopilot for each airplane model.[14]

In order to obtain the S.T.C., the autopilot system must meet the requirements of FAR No. 23.1329, *Automatic Pilot Systems*, which sets forth the airworthiness standards for approval of the installation for general aviation autopilot systems.[15] FAR 25.1329 correspondingly applies for transport

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[13] 14 C.F.R. § 21.113 (1982).

[14] *See* 14 C.F.R. § 21.119(b) (1982).

[15] 14 C.F.R. § 23.1329 (1982). This section provides:

> If an automatic pilot system is installed, it must meet the following:
>
> (a) Each system must be designed so that the automatic pilot can -
>
> (1) Be quickly and positively disengaged by the pilots to prevent it from interfering with their control of the airplane; or
>
> (2) Be sufficiently overpowered by one pilot to let him control the airplane.
>
> (b) Unless there is automatic synchronization, each system must have a means to readily indicate to the pilot the alignment of the actuating device in relation to the control system it operates.
>
> (c) Each manually operated control for the system operation must be readily accessible to the pilot. Each control must operate in the same plane and sense of motion as specified in § 23.779 for cockpit controls. The direction of motion must be plainly indicated on or near each control.
>
> (d) Each system must be designed and adjusted so that, within the range of adjustment available to the pilot, it cannot produce hazardous loads on the airplane or create hazardous deviations in the flight path, under any flight condition appropriate to its use, either during normal operation or in the event of malfunction, assuming that corrective action begins within a reasonable period of time.
>
> (e) Each system must be designed so that a single malfunction will not produce a hardover signal in more than one control axis. If the automatic pilot integrates signals from auxiliary controls or furnishes signals for operation of other equipment, positive interlocks and sequencing of engagement to prevent improper operation are required.
>
> (f) There must be protection against adverse interaction of integrated components, resulting from a malfunction.
>
> (g) If the automatic pilot system can be coupled to airbourne navigation equipment, means must be provided

category aircraft.[16]

An FAA Advisory Circular entitled *Automatic Pilot Systems Approval (non-transport)*, sets forth acceptable means by which compliance with the automatic pilot installation requirements of FAR 23.1329 could be shown.[17] This Advisory Circular was cancelled, however, in May of 1977, and has not been replaced.[18] Presently, general aviation autopilot manufacturers are operating under FAA policy letters in order to set an acceptable means of compliance with FAR 23.1329. A presently effective advisory circular, entitled *Automatic Pilot Systems Approval*,[19] applies to transport category aircraft and contains many standards similar to the *Automatic Pilot Systems Approved (non-transport)* Advisory Circular.

In order to obtain the S.T.C., an FAA Engineering Test Pilot, or a pilot approved by the FAA under the FAA's designated alteration station (D.A.S.) authority,[20] undertakes a certification flight test to confirm that the autopilot system meets the FAA certification requirements.[21] During the flight test portion of the certification, a Supplemental Type Inspection Report is filled out that covers all safety related aspects of the test flight. The FAA also approves the Airplane Flight Manual Supplement for the autopilot during this portion of the testing and that Supplement must be attached to the Airplane Flight Manual.[22]

Almost all general aviation autopilots are manufactured to meet the standards of FAR 37.119.[23] This section sets the minimum standards for a technical standard order authoriza-

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> to indicate to the flight crew the current mode of operation. Selector switch position is not acceptable as a means of indication.

Id.

[16] *Id.*

[17] FAA, Advisory Cir. No. 23.1321-1, Automatic Pilot Systems Approval (non-transport) (1965) (cancelled in 1977).

[18] *Id.*

[19] FAA, Advisory Cir. No. 25.1329-1A, Automatic Pilot Systems Approval (1968).

[20] 14 C.F.R. § 21.431 (1982).

[21] *Id.* § 21.35.

[22] *Id.* § 21.

[23] *Id.* § 37.119.

tion (T.S.O.) for an automatic pilot. Automatic pilots manufactured after September 15, 1960 are required to meet additional standards.[24]

Generally, an autopilot system will not receive FAA certification unless the manufacturer can demonstrate that under normal conditions, in the event of any malfunction, the autopilot cannot produce hazardous loads on the airplane or create hazardous deviations in the flight path, if the pilot initiates corrective action "within a reasonable period of time."[25] One of the most basic design decisions for the autopilot manufacturer is to determine how much authority the autopilot must have to fly the airplane (performance capability) while still ensuring that any conceivable malfunction of the autopilot under normal usage will not involve a problem of flight safety.

In the certification process, the manufacturer must demonstrate that its system can be quickly and positively disengaged or easily overpowered by the human pilot without interfering with control of the aircraft in the event of a malfunction. The manufacturer must also demonstrate, among many other things, that no single malfunction can produce a "hard-over" signal in more than one control axis.[26]

In the actual flight testing during the certification procedure, a number of malfunctions will be artificially introduced in the system to demonstrate compliance with FAR 23.1329. Under the guidelines set out in the advisory circulars and policy letters mentioned above,[27] a three second delay between pilot recognition of the induced autopilot malfunction and initiation of corrective action is used as the basis for approval. Generally, in the certification flight test: (1) the artificial malfunction will be induced into the system; (2) deviation will begin; (3) the pilot will recognize the deviation, either through the behavior of the aircraft, or a reliable failure warning sys-

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[24] *Id. See* SOCIETY OF AUTOMOTIVE ENGINEERS, SAE AERONAUTICAL STANDARD AS-402A AUTOMATIC PILOTS (Feb. 1959) (Copies may be obtained from the Society of Automotive Engineers).

[25] 14 C.F.R § 23.1329(d) (1982). *See supra* note 15.

[26] *Id.* § 23.1329(e).

[27] *See supra* notes 17-19 and accompanying text.

tem; (4) the pilot will wait to take any action for a period of three seconds; and (5) corrective action will be initiated. The corrective action must not result in dangerous dynamic conditions or deviations from the flight path, nor create loads in excess of one "G." The three second delay period is reduced to one second for demonstrated malfunctions on a coupled approach on the theory that the pilot is more likely to be paying closer attention to his instruments and the operation of the autopilot on approach than he would be if he were cruising at altitude.

Therefore, an autopilot that has received certification must have demonstrated that no malfunction should cause a flight safety problem. This may be of significant benefit to autopilot manufacturers in defending claims for product defect on a theory of strict liability, particularly in those states which require the plaintiff to prove not only a defect in the product, but also that the defect rendered the product "unreasonably dangerous."[28] Arguably, the purpose and result of certification of an autopilot system are to demonstrate that no malfunction of the autopilot can create an unreasonably dangerous situation for the pilot and substantially hinder adequate proof of all the elements of the plaintiff's cause of action in strict liability.

V. TREATMENT OF AUTOPILOT CASES IN THE COURTS

A. *Definition*

In *Underwriters at Lloyds, London v. Cherokee Laboratories, Inc.*,[29] the United States Court of Appeals for the Tenth Circuit, in an action by the insurance company to recover under an aircraft hull policy, stated that the aircraft "was equipped and capable of being flown with an automatic pilot, a device allowing the pilot to be relieved under routine flying conditions but subject to being overwhelmed by manual con-

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[28] *See* RESTATEMENT (SECOND) OF TORTS § 402A (1965).

[29] 288 F.2d 95 (10th Cir. 1961).

trol if necessary or desireable."[30] Similarly, the Supreme Court of Nevada defined an automatic pilot as "an instrument which, when activated, will maintain the course and altitude the pilot selects for the flight of the aircraft."[31]

B. *Negligence*

Upon the occurrence of an unexplained crash, passengers in a resulting suit will attempt to invoke the doctrine of res ipsa loquitur to shift the burden of proving the cause of the accident to the defendant airline. Evidence of the defendant airline's failure to properly maintain the autopilot would then become very damaging. This strategy was unsuccessful in *Trihey v. Transocean Air Lines, Inc.*, [32] in which the Court of Appeals for the Ninth Circuit refused to overturn a trial court's finding that the defendant airline was not liable for an unexplained crash in the ocean.[33] In this action, brought under the Death on the High Seas Act,[34] a passenger airline crashed in the Pacific without warning. The representatives of passengers attempted to invoke res ipsa loquitur and introduced evidence that the crash may have resulted from defendant's faulty maintenance of the autopilot.[35]

The trial court found for the defendant airline, but was unclear whether res ipsa loquitur had been applied. The court of appeals affirmed, finding that while res ipsa loquitur could have been applied by the trial court, it did not mandate a finding for the plaintiff when the evidence was contradictory.[36] The appellate court did not hold that the trial court's findings of fact and law were clearly erroneous.[37]

The representatives of a deceased passenger proved more successful in invoking res ipsa loquitur in *Nelson v. American*

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[30] *Id.* at 97-99.

[31] Lightenburger v. Gordon, 81 Nev. 553, 407 P.2d 728, 733 (1965). *See also* 2 J. KENNELLY, LITIGATION AND TRIAL OF AIR CRASH CASES, ch. 3, at 61 (1968).

[32] 255 F.2d 824 (9th Cir.), *cert denied*, 358 U.S. 838 (1958).

[33] *Id.* at 832-33.

[34] 46 U.S.C. § § 761-68 (1976 & Supp. IV 1980).

[35] 255 F.2d at 827.

[36] *Id.* at 826-27.

[37] *Id.* at 832.

Airlines, Inc.[38] In that case, an aircraft passenger brought suit against the airline when she was injured when thrown about the cabin by a sudden and unexpected maneuver of the airplane due to a malfunction of the automatic pilot.[39] The automatic pilot overcompensated pitch trim, causing the aircraft to nose down, rather than to stay level, when the altitude-hold feature of the automatic pilot was engaged. The co-pilot immediately disengaged the automatic pilot and assumed manual control, but some passengers were injured due to the severe movement in the rear of the plane. The amplifier computer, a component of the autopilot, had been replaced the day prior to the incident because of trouble with the altitude-hold feature. The trial court rendered judgment for the airline upon a finding that the passengers' injuries were not caused by any want of due care on the part of the airline.

The California Appellate Court reversed, however, holding that the doctrine of res ipsa loquitur mandated a finding for the plaintiff unless the defendant airline could demonstrate that there was some cause of the accident other than defendant's lack of due care or that the accident was caused by an unknown unpreventable cause.[40] The court found no evidence in the record that negligence in the installation or maintenance of the equipment did not cause the accident.[41]

While a pilot is not required to utilize the autopilot on a landing, his failure to use it may be inconsistent with good operating procedure and may be evidence of a failure of due care. In *Klein v. United States*,[42] a Piper crashed on an instrument landing after encountering the wake turbulence of a jet liner that the Piper was following at a distance of three miles. The plaintiff alleged liability on the part of the air traffic controllers for improper instructions. The court found that the pilot had not engaged his autopilot on approach, which automatically would have placed the pilot on approach on the

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[38] 263 Cal. App. 2d 742, 70 Cal. Rptr. 33 (1968).

[39] 70 Cal. Rptr. at 35.

[40] *Id.* at 36.

[41] *Id.* at 36-37. The court rejected the trial court's reliance on a pre-flight check as negating the inference of negligence. *Id.*

[42] 13 Av. Cas. 18,137 (D. Md. 1975).

centerline of the glide slope and the localizer.[43] This resulted in the pilot's approaching below the lowest limit of the glide slope corridor. The court held that the pilot's failure to utilize the autopilot and his operation of the aircraft below the glide slope corridor, along with his failure to properly set his altimeter, were the proximate cause of the wake turbulence encounter and the crash.[44]

A court may also infer negligence on the part of the pilot from evidence that suggests that the pilot switched from automatic pilot to manual in a crisis situation. In *Wells v. United States*,[45] the pilot of a Piper Turbo Arrow began a flight on Visual Flight Rules (VFR). When the pilot encountered bad weather, an air traffic controller directed him to turn to a nearer airport. The pilot was forced to fly through clouds with little visual contact with the ground, relying on his autopilot. The plane inexplicably entered into a spiral and crashed into the ground.[46]

The trial court held that the pilot, rather than the air traffic controller, was responsible for the crash.[47] The court concluded that the plane could not have gone into a spiral unless the pilot disengaged or overrode the autopilot. The court suggested that when an airplane flies into clouds spatial disorientation may result, causing the pilot to misperceive the plane's attitude.[48] This pilot in particular had also lost control on several occasions in the past while flying manually. He was, therefore, negligent in attempting to fly into clouds without the use of the autopilot.

The representatives of a pilot of a twin-engine Beechcraft were similarly unable to establish the liability of air traffic controllers when the plane crashed on an instrument approach in *Michelmore v. United States*.[49] The pilot, who was

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[43] *Id.* at 18,138.

[44] *Id.* at 18,141.

[45] 16 Av. Cas. 17,914 (W.D. Wash. 1981).

[46] *Id.* at 17,917.

[47] *Id.* at 17,918. A pilot in command is directly and solely responsible for the safe operation of his aircraft. 14 C.F.R. § 91.3 (1982).

[48] 16 Av. Cas. at 17,917.

[49] 299 F. Supp. 1116 (C.D. Cal. 1969).

not rated for instrument flying, began his flight even though he had received reports of bad weather. The weather forced the pilot to attempt an emergency instrument landing under the guidance of the air traffic controllers. The court held that the plaintiffs had produced insufficient evidence of air traffic controller negligence to meet their burden of proof.[50] The court dismissed the plaintiffs' contention that the automatic pilot had failed or that the pilot had overridden the autopilot because of spatial disorientation.[51]

An application of the doctrine of res ipsa loquitur to a set of bizarre facts occurred in *Merrill v. United Airlines*.[52] When an airliner crashed into the Rocky Mountains at 11,570 feet, the defendant airline presented evidence that the autopilot was engaged at a certain point along the route and set at an altitude of 10,000 feet.[53] Based upon evidence found at the crash site that smoke masks had been used, the defendant suggested that the pilot and co-pilot had become incapacitated, and the airliner had continued to fly with the autopilot engaged until impact with the mountain. Defendant's expert contended that the mountain wave effect pushed the airplane up 1,570 feet to the impact altitude of 11,570 feet, in spite of the action of the autopilot on altitude-hold.[54] The jury returned a verdict for the defendant airline, which was upheld on appeal, in spite of a res ipsa loquitur charge.

C. *Strict Liability*

A suit against the aircraft manufacturer in strict liability in tort may be possible upon the malfunction of the automatic pilot or the pitch control system generally, as was illustrated in *Federal Insurance Co. v. Piper Aircraft Corp.*[55] In that case, the Tenth Circuit Court of Appeals upheld a jury verdict against an aircraft manufacturer based upon breach of im-

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[50] *Id.* at 1125.

[51] *Id.* at 1119-20.

[52] 25 F.R.D. 68 (S.D.N.Y. 1960).

[53] *Id.* at 72-73.

[54] *Id.* at 73. Plaintiff's theory of the crash was that the pilots had deviated from their safer scheduled course to make up lost time. *Id.*

[55] No. 78-1444 (10th Cir., filed Mar. 7, 1980).

plied warranty and strict liability in tort. The plaintiffs had argued that a defect in the manual electric trim caused the plane to "pitch up" when the automatic pilot was disengaged. The defendant manufacturer argued that the plaintiffs had produced insufficient evidence to demonstrate proximate causation. The plaintiffs' expert witness testified that wreckage showed that the plane had been cruising at a high speed with the autopilot engaged, but that the autopilot disengaged immediately before the crash. The stabilizer trim had been unresponsive to control (in a "runaway" condition), and the fuselage had a compression bend near the tail, which had crippled the plane and was the immediate cause of the crash.[56] The expert developed a theory that the autopilot had masked a defect in the manual electric trim. When the automatic pilot was disengaged, the stabilizer and trim were abruptly released, resulting in a severe nose-up motion in the plane. This caused the compression bend in the fuselage and the subsequent crash. The court found sufficient evidence to uphold this theory of the crash and the jury verdict.[57]

D. *Expert Opinion*

In *Lightenburger v. Gordon*[58] a light twin engine aircraft flew into the Los Angeles International Airport under extremely poor conditions of ceiling and visibility, and the plane crashed after a missed approach. The aircraft was equipped with an automatic pilot and approach coupler. An investigation of the wreckage suggested that the automatic pilot was off. An expert testified that the pilot may have unwittingly pressed the disconnect button under his left thumb on the control wheel and deactivated the autopilot during the approach.[59] The estate of the passenger filed a wrongful death suit against the pilot of the aircraft. The jury found for the defendant pilot, but the Supreme Court of Nevada reversed

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[56] *Id.*

[57] *Id.*

[58] 81 Nev. 553, 407 P.2d 728 (1965).

[59] 407 P.2d at 733.

and remanded on other grounds.[60]

E. *Design/Warnings*

In *Goldsmith v. Martin Marietta Corp.*,[61] a passenger airliner inexplicably crashed into a mountain. The plaintiffs' theory of the case was that an unguarded switch on the navigational compass was inadvertently and unknowingly activated by the crew when the plane was in a bank preparing to land, causing the aircraft to be off course and crash. The caging switch for a flux gate navigational compass instrument was mounted in the same location as the automatic pilot pedestal controller. Plaintiffs suggested that the pilot had changed the compass while intending to adjust the automatic pilot. Bendix was sued for designing and manufacturing a flux gate caging without a guard.[62]

The Bendix manual for the equipment contained two warnings. It warned against the navigational hazards created by incorrect positioning of the flux gate and further warned that an incorrect positioning could result from accidental operation. The district court granted summary judgment for defendant Bendix, holding that "[t]he design of the caging switch, in fact, did include a guard . . . . It did not guard against negligent actuation of the switch; rather, it gave warning of the occurrence of such negligence."[63]

F. *Autopilot as Necessary Equipment*

In *Air Line Pilot's Assoc., Int'l v. Federal Aviation Administration*[64] the United States Court of Appeals for the District of Columbia held that an airline pilot did not have a protected right to refuse to fly in inclement weather for lack of an operable autopilot unless the autopilot is required by the aircraft minimum equipment list for the particular airplane.

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[60] *Id.* at 742.

[61] 211 F. Supp. 91 (D. Md. 1962).

[62] *Id.* at 93.

[63] *Id.* at 98.

[64] 454 F.2d 1052 (D.C. Cir. 1971).

There was no such requirement for the aircraft in question.[65] The court struggled to uphold the FAA administrative decision because pilots are given the ultimate authority and responsibility to fly or not fly[66] and may base their decision on weather factors. The court concluded, however, that a rationality standard compelled it to uphold the FAA decision.[67]

VI. PROBLEMS OF PROOF AND CAUSATION IN AUTOPILOT LITIGATION

A. *Proving Autopilot On Or Off*

Reconstruction of the flight path of an airplane may indicate whether the pilot used the autopilot at the time of the crash. Even after a skilled investigator has examined the air traffic controller/pilot communications, the FAA air traffic control computer printouts (DART, D-logs, ITAP) of the flight path, the available weather information, the pilot history, the aircraft maintenance history, and the wreckage, he may still find it virtually impossible to determine whether the autopilot was on or off at the time of the accident. Determining whether the autopilot had been used but disengaged or overpowered by the pilot prior to the accident is also difficult. Digital avionics and autopilot control switches that automatically go off with the interruption of electrical power hardly ever leave a trail of evidence in the wreckage to answer these questions.

Some experts claim, however, to be able to determine the position and mode selected by the pilot in an autopilot or flight director from post-crash examination of the light filaments in the annunciator panel.[68] Sometimes the pilot will advise air traffic control that he is operating with the autopilot

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[65] *Id.* at 1053-54. 14 C.F.R. § § 121.301-.369, 121.627(c) (1982). An autopilot is required equipment for certain Part 135 Flights if there is to be no co-pilot aboard. 14 C.F.R. § 135.105 (1982).

[66] 14 C.F.R. § 91.3 (1982).

[67] 454 F.2d at 1055.

[68] Address by Baker & Linquist, *Lamp Examination for On or Off in Traffic Accidents*, Nw. U. Traffic Inst. (1976).

engaged. Absent a survivor, the only other method to determine whether the autopilot was on at the time of the accident is the testimony of the pilot's prior custom and practice, coupled with expert opinion that may be sufficient to prove, by circumstantial evidence, whether the autopilot was on or off.[69]

B. *Problems Other Than the Autopilot*

Another difficulty is determining whether the information fed to the autopilot through the primary gyro-instruments is faulty. When a gyro fails, the autopilot loses one of its primary sensors. For example, when the dry vacuum pump in the single engine airplane fails, the artificial horizon and other air-driven instruments also fail. The autopilot gets its information from these sensors and feeds them to the computer. Information from a failed artificial horizon renders the autopilot useless even though the autopilot itself may be operating perfectly.

Furthermore, the autopilot's performance depends upon its proper installation in the aircraft. If, for example, the control cables are attached improperly or at the wrong tension, a properly operating autopilot will not be able to fly the aircraft as desired. Improper installation, therefore, may also cause poor autopilot performance.

C. *Severe Weather*

Atmospheric conditions can cause an aircraft to deviate from its intended flight path much more severely than any autopilot malfunction. Wind shear[70] and thunderstorms are the most obvious examples of this kind of turbulence. Ice, hail, wind gusts, freezing rain, and snow can also cause problems for an aircraft beyond its design capability or autopilot system. The aircraft flight manuals normally recommend disengagement of the altitude-hold mode in turbulence.

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[69] *See supra* notes 45-48, 52-57, and accompanying text.

[70] *See* Hardy, *Windshear and Clear Air Turbulence*, 42 J. AIR L. & COM 165 (1976).

D. *Human Factors*

The pilot in command is directly responsible for the safe operation of the aircraft,[71] and the autopilot is only a secondary control system. Regarding human factors, numerous studies have been done in the field of instrument flying and spatial disorientation.[72] To the knowledge of these authors, however, no studies have been published in the area of whether an autopilot malfunction can cause spatial disorientation of the pilot. Likewise, there are no studies available to support the FAA certification standard of a three second delay (en route) or a one second delay (on approach) before initiation of recovery by the pilot from an autopilot malfunction.[73] These are questions that should be answered in a scientifically controlled environment, rather than through autopilot litigation.

VII. CONCLUSION

The 1980's have already brought substantial advances in autopilot technology. The Boeing 767 uses one autopilot to monitor its other two autopilots, much like the systems used in the Space Shuttle. The autopilot system in the Boeing 767 with autoland, has the capability to land at lower landing minimums than the capabilities of most United States airports. Even more interesting is the fact that the autopilot systems in some advanced aircraft can now bring an aircraft to a decision height so low that if a go-around is necessary, the capabilities of the aircraft in a landing configuration to do a go-around from that altitude may be impossible.

For general aviation aircraft, the digital autopilot is the autopilot of the 80's. It is now replacing the older analog computer autopilots. With this new technology comes new safety provisions. The new digital autopilots have mandatory self-

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[71] 14 C.F.R. § 91.3 (1982).

[72] *See, e.g.*, Kraus, *Disorientation in Flight. An Evaluation of the Etiological Factors*, AEROSPACE MED., Sept. 1959, at 664; Zeller, Normand & Burke, *Aircraft Accidents and Aircraft Instruments*, AEROSPACE MED., Jan. 1961, at 42.

[73] FAA, ADVISORY CIR. NO. 25.1329-1A, AUTOMATIC PILOT SYSTEMS APPROVAL (NON-TRANSPORT) (1968).

test requirements that must be satisfied before the autopilot can be engaged. If the autopilot and all its circuitry are not working properly, the autopilot will not turn on and will warn the pilot. There are new servo monitors that read any hard voltage and disengage the autopilot in order to prevent any possibility of a "hard-over."

The air traffic control system of the United States will be revolutionized in the next ten years by the wonders of electronics.[74] Aircraft owners and operators can look forward to Mode "S" transponders, microwave landing systems, and computer-generated solutions to potential air conflicts. The future for automatic pilots, transportation and general aviation aircraft is a bright one. The litigation that unfortunately results from advances in technology will require extra effort on the part of lawyers and experts in order to be able to understand and explain these new systems.

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[74] Allison, *Automation in the Skies*, HIGH TECH. MAG., Nov.-Dec. 1981, at 40; Garrison, *Integrated Flight-Control Systems, Automatic Navigation Systems and Frequency-Management Systems*, AVIONICS NEWS, SEPT. 1982, AT 24; SCHEFTER, *FAA's Revolutionary Control System*, POPULAR SCI., Oct. 1982, at 80.

APPENDIX

GLOSSARY OF TERMS

ADAPTER CARD: A "card" or "circuit board" in a flight computer. This card is designed to allow the functions of a flight control system to be adapted to the specific requirements of a certain aircraft type.

AERODYNAMICS: That branch of science which deals with the production of lift by the movement of a specially shaped surface through the air.

AFT: To the rear, or toward the tail of the aircraft.

AILERON: A control surface near each wing tip. When the aileron is deflected up, the wing will move down. When the aileron is deflected down, the wing will move up. This causes roll, or rotation about the longitudinal axis.

AIR SPEED INDICATOR: An aircraft instrument which measures ram air pressure and indicates the speed of the aircraft through the air. At lower altitudes, where air pressure tends to be higher than above, the indicated air speed will be greater than indicated at higher altitudes, even though the airplane is moving at the same true air speed. At sea level, indicated air speed and true airspeed are the same.

ALTIMETER: An aircraft instrument which measures air pressure, and thus indicates the altitude at which an aircraft is flying above a particular reference point.

ALTITUDE: Vertical elevation of an aircraft above a given reference, normally expressed in terms of feet above mean sea level.

ALTITUDE HOLD CARD: One of the "cards" or "circuit boards" in a flight computer. This card governs the altitude-holding capability of the autopilot.

ATTITUDE: The angular position of an aircraft determined with relationship to the earth's horizon.

AUTOMATIC PILOT (or AUTOPILOT): An automatic flight control system which keeps an aircraft in level flight or on a set course, as may be directed by the human pilot.

AUTOTRIM: The function of the autopilot which causes automatic movement of the elevator trim tab, to compensate for forces upon the aircraft elevator without action by the human pilot.

AVIONICS: Electronic equipment on board an aircraft.

AXIS: An imaginary straight line about which a body can rotate. The lateral axis (also called the pitch axis) extends through the aircraft wings, and the aircraft moves about the lateral axis or pitch axis when the nose of the aircraft pitches up or down. The longitudinal axis (also called the roll axis) runs from the nose of the aircraft to the tail, and the aircraft rotates about the longitudinal (or roll) axis when the aircraft enters into a roll, one wing up and the other wing down. The vertical axis extends vertically through the aircraft's center of gravity. The aircraft rotates about the vertical axis (also called the yaw axis) when the nose of the airplane moves to the left or to the right.

CARD: In this case, this refers to a circuit board, or a small plastic board containing a number of electrical circuits, which is installed in the flight computer. In particular, the flight computer contains an altitude hold card, an adapter card, and a pitch card.

CENTER OF GRAVITY: Also referred to as "c.g." It is a point within an aircraft at which all the weight is considered to be concentrated.

CIRCUIT BOARD: A plastic board which contains a number of electrical circuits and which is installed in the flight computer. Also referred to as a "card".

CONTROL COLUMN: The column or shaft in the aircraft cockpit on which a control wheel is mounted. Rotating the wheel causes movement of the ailerons and in-out movement causes movement of the elevator.

CONTROL SURFACE: Normally refers to either one of the ailerons, the elevator, or the rudder.

CONTROL WHEEL: Hand operated wheel in the cockpit used to operate the elevator (by in-out movement) and ailerons (by rotating the wheel).

D-LOG: Data log or a computer printout of information secured by FAA Air Traffic Control stations relating to the flight history of aircraft in the area.

DENSITY ALTITUDE: The altitude above mean sea level under conditions of standard temperature and standard air pressure which corresponds to the same air density and performance characteristics for an aircraft which are actually experienced in nonstandard conditions at any particular altitude.

ELEVATOR: A horizontal moveable control surface on the tail of the airplane. In flight, when the elevator is deflected up, the nose of the airplane tends to move up. Likewise, when the elevator is moved or deflected down, the nose of the aircraft will tend to move down.

EMPENNAGE: The rear portion or tail section of the aircraft.

ENCODING ALTIMETER: A form of altimeter which is interconnected to the transponder, and causes the transponder to transmit different codes to indicate changes in altitude.

FAA: Federal Aviation Administration; the agency of the federal government which establishes and enforces rules and regulations relating to manufacture and operation of civil aircraft, including those used in general aviation.

FAR: Federal Aviation Regulations, which are the rules, regulations and guidelines established by the FAA for safety and operation of civil aircraft.

FIN: The vertical portion of the tail, also known as the vertical stabilizer, to which the rudder is connected.

FLIGHT COMPUTER: The flight computer is a small computer on board the aircraft which is connected to the autopilot and other systems of a flight control system.

FUSELAGE: The body of the aircraft, to which the wings, tail, and landing gear are attached.

G-UNIT: A measure of acceleration force. A force of one "g" is the force of gravity upon a body at rest. A net force of zero "g's" causes weightlessness. A force of two "g's" is twice the force of gravity upon a body at rest.

GENERAL AVIATION: That portion of the aviation industry other than military aviation or airlines.

HORIZONTAL STABILIZER: The horizontal portion of the tail which does not move and to which the elevator is attached. Sometimes referred to in two parts as left horizontal stabilizer and right horizontal stabilizer.

IFR: Instrument Flight Rules; the rules of the FAA for flight by reference to instruments rather than outside visibility. These rules apply when the ceiling and/or visibility are below certain minimums set by the FAA.

KNOT: One nautical mile per hour (approximately 1.15 statute miles per hour).

LATERAL AXIS: The axis of an aircraft which extends through the center of gravity from wingtip to wingtip. Also called the pitch axis.

LONGITUDINAL AXIS: The axis of an aircraft which extends through the fuselage from nose to tail, also called the roll axis.

MANUAL/ELECTRIC TRIM: A function of a trim system, by which a pilot moves a switch with his finger, sending an electrical signal to the pitch trim servo to cause movement of the trim tab when indicated.

MEAN SEA LEVEL: The average height of the surface of the sea for all stages of tide; used as a reference for elevations or altitudes throughout the United States.

MICROSWITCH: A small electric switch which is used to open or close a circuit with a small amount of movement. A microswitch is used on the primary pitch servo component to send an electric signal to the pitch trim servo to cause movement of the trim tab when indicated.

MODE CONTROLLER: This is a small panel containing a number of buttons and switches which the pilot can engage to use various functions of the flight control system.

NTSB: National Transportation Safety Board; the agency of the federal government which is responsible for investigating aircraft accidents involving fatalities.

NAUTICAL MILE: A measure of distance used primarily in navigation. A nautical mile equals 6,080 feet, or approximately 1.15 statute miles. Aircraft speeds are often expressed in terms of "knots," which are nautical miles per hour.

PITCH: Rotation of the aircraft about its longitudinal axis. When the aircraft pitches up, the nose of the aircraft goes up.

When the aircraft pitches down, the nose of the aircraft goes down.

PITCH CARD: One of the "cards" or "circuit boards" of the flight computer which is part of the flight control system. This card controls the pitch function of the autopilot.

PITCH TRIM SERVO: An electric motor which controls the movement of the elevator trim tab.

PRE-FLIGHT INSPECTION: Inspection of the aircraft before takeoff to determine that all systems are functioning properly for the intended flight.

PRIMARY PITCH SERVO: An electric motor which is part of an autopilot system, and when engaged, will cause movement of the aircraft elevator.

ROLL: The motion of the aircraft about the lateral axis, controlled by the ailerons. When an aircraft rolls to the right, the right wing drops and the left wing rises. When the aircraft rolls to the left, the left wing drops and the right wing rises.

RUDDER: The movable vertical control surface attached to the vertical stabilizer. Movement of the rudder causes the aircraft to rotate about its vertical axis. When the rudder is moved to the left, the nose of the airplane tends to move to the left. When the rudder is moved to the right, the nose of the aircraft tends to move to the right.

SERVO: An electric motor.

SOLENOID: A coil or wire with a movable core, which operates as an electromagnet.

STABILIZERS: The non-movable portions of the tail, referred to as the vertical stabilizer, and the left or right horizontal stabilizers.

STATUTE MILE: The distance commonly referred to as a mile, being 5,280 feet.

STOP: In aviation, often refers to a device used to limit the travel of a control surface. For example, the elevator stop limits the amount of travel of the elevator up or down.

TAIL CONE: The rearmost part of an aircraft fuselage.

TRIM TAB: A small hinged portion of a movable control surface that may be adjusted by the pilot in flight to a position which will result in a balance of control forces. For example, the elevator trim tab is located on the elevator.

TRIM WHEEL: A small wheel located in the cockpit which can be operated manually by the pilot to adjust the trim tab. This trim wheel will also move by operation of the manual/electric trim or automatic trim functions.

VA: Maneuvering speed. The maximum speed at which an airplane's control surface can be fully deflected without structural damage.

VD: Designed diving speed. The maximum speed at which an aircraft may safely execute a dive.

VNE: Never exceed speed. The speed beyond which an aircraft should never be flown, also know as red line speed.

VERTICAL SPEED INDICATOR: Also known as the rate-of-climb indicator. An aircraft instrument which measures air pressure changes and indicates the rate of altitude change in feet per minute (as either a climb or descent). For example, as an aircraft descends, the altitude air pressure tends to increase, and this instrument will show the rate of descent.

VERTICAL STABILIZER: The vertical portion of the tail which does not move, also known as the fin, to which the rudder is attached.

VFR: Visual Flight Rules, the rules of the FAA which apply to the operation of aircraft when instrument flight rules do not apply.

WIND SHEAR: The rate of change of the direction or speed of the wind over a given distance; conventionally expressed as vertical or horizontal wind shear.

YAW: Movement of the aircraft about the vertical axis. When an aircraft yaws to the left, the nose moves to the left. When an aircraft yaws to the right, the aircraft moves to the right.