SCHOOL OF AERONAUTICS (NEEMRANA)

UNIT-1 NOTES

FACULTY NAME: D.SUKUMAR. **CLASS: B.Tech AERONAUTICAL**

SUBJECT CODE: 5AN3 **SEMESTER: III**

SUBJECT NAME: AIRCRAFT SYSTEMS

AIRPLANE CONTROL SYSTEMS

Conventional Systems - Power assisted and fully powered flight controls – Power actuated systems – Engine control systems - Push pull rod system, flexible push pull rod system - Components- Modern control systems - Digital fly by wire systems - Auto pilot system active control Technology,

Introduction to Communication and Navigation systems Instrument, landing systems, VOR - CCV case studies.

CONTROL SYSTEMS

Introduction

The architecture of the flight control system, essential for all flight operations, has significantly changed throughout the years. Soon after the first flights, articulated surfaces were introduced for basic control, operated by the pilot through a system of cables and pulleys. This technique survived for decades and is now still used for small airplanes.

The introduction of larger airplanes and the increase of flight envelopes made the muscular effort of the pilot, in many conditions, not sufficient to contrast the aerodynamic hinge moments consequent to the surface deflection; the first solution to this problem was the introduction of aerodynamic balances and tabs, but further grow of the aircraft sizes and flight enveops brought to the need of powered systems to control the articulated aerodynamic surfaces.

Nowadays two great categories of flight control systems can be found: a full mechanical control on gliders and small general aviation, and a powered, or servo-assisted, control on large or combat aircraft.

One of the great additional effects after the introduction of servomechanisms is the possibility of using active control technology, working directly on the flight control actuators, for a series of benefits:

• compensation for deficiencies in the aerodynamics of the basic airframe;

• stabilisation and control of unstable airplanes, that have commonly higher performances;

• flight at high angles of attack;

• automatic stall and spinning protection;

• gust alleviation.

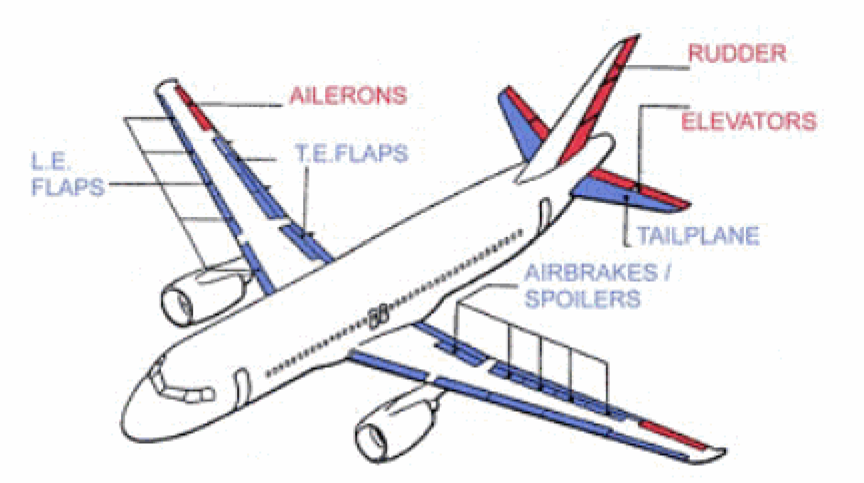


Fig. 1 – Flight control surfaces on airliner

A further evolution of the servo-assisted control is the fly-by-wire technique, based on signal processing of the pilot's demand before conversion into actuator control.

The number and type of aerodynamic surfaces to be controlled changes with aircraft category. Fig. 11 shows the classic layout for a conventional airliner. Aircraft have a number of different control surfaces:

those indicated in red form the primary flight control, i.e. pitch, roll and yaw control, basically obtained by deflection of elevators, ailerons and rudder (and combinations of them); those indicated in blue form the secondary flight control: high-lift and lift-dump devices, airbrakes, tail trimming, etc.

Modern aircraft have often particular configurations, typically as follows:

- elevons on delta wings, for pitch and roll control, if there is no horizontal tail;
- flaperons, or trailing edge flaps-ailerons extended along the entire span:
- tailerons, or stabillisers-ailerons (independently controlled);
- swing wings, with an articulation that allows sweep angle variation;
- canards, with additional pitch control and stabilization

Primary flight control capability is essential for safety, and this aspect is dramatically emphasized in the modern unstable (military) airplanes, which could be not controlled without the continued operation of the primary flight control surfaces. For this reason the actuation system in charge of primary control has a high redundancy and reliability, and is capable of operating close to full performance after one or more failures.

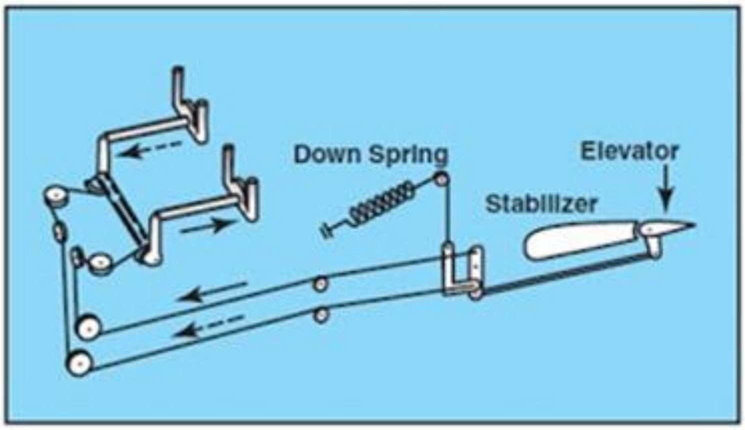
Secondary actuation system failure can only introduce flight restriction, like a flap less landing or reduction in the max angle of attack; therefore it is not necessary to ensure full operation after failures.

FULLY POWERED FLIGHT CONTROLS

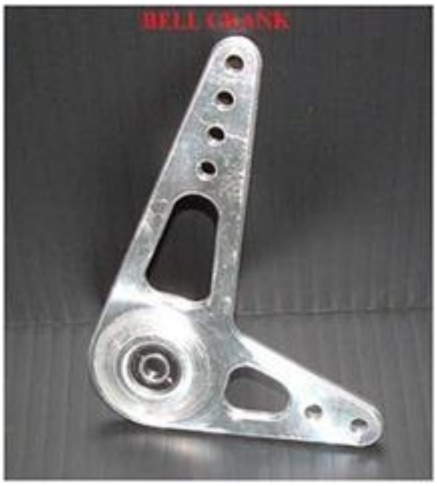
Fully powered Flight Controls

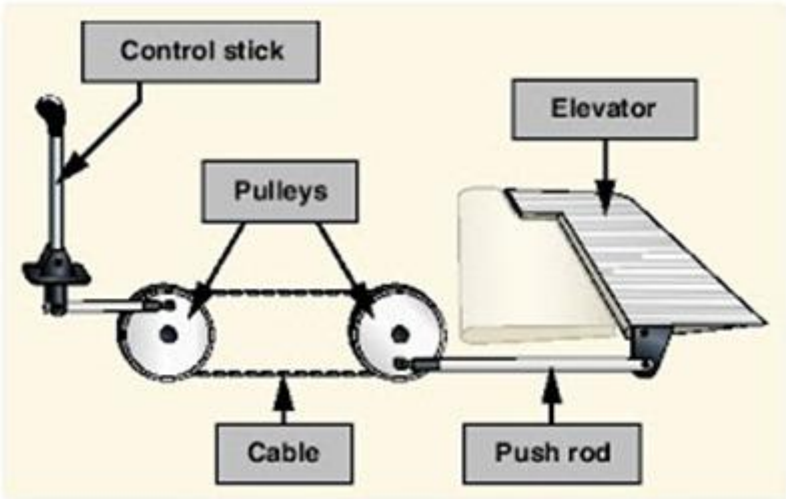
To actuate the control Surface the pilot has to give full effort. This is very tough to actuate the control surfaces through simple mechanical linkages. One can feel the equal toughness when raising the hand perpendicular to the airflow on riding a motorbike.

In this type of flight control system we will have



S.No	Item	Purpose
1	The cable	To transmit the power
2	Cable connector	To connect the cable
3	Turnbuckle	To adjust the Cable length
4	Fairlead	To guide the Cable
5	Pulley	To guide the in radial direction
6	Push pull rod	To go for and aft as per requirement
7	Control stick	To make orders for the remaining circuit





MECHANICAL FLIGHT CONTROL SYSTEM

The most basic flight control system designs are mechanical and date back to early aircraft. They operate with a collection of mechanical parts such as rods, cables, pulleys, and sometimes chains to transmit the forces of the flight deck controls to the control surfaces. Mechanical flight control systems are still used today in small general and sport category aircraft where the aerodynamic forces are not excessive. When the pilot pushes the control stick forward/backward the cable is getting tensed through the linkages and it causes the Control surface to move respectively.

Power actuated systems

Hydraulic control

When the pilot's action is not directly sufficient for a the control, the main option is a powered system that assists the pilot.

A few control surfaces on board are operated by electrical motors: as already discussed in a previous chapter, the hydraulic system has demonstrated to be a more suitable solution for actuation in terms of reliability, safety, weight per unit power and flexibility, with respect to the electrical system, then becoming the common tendency on most modern airplanes: the pilot, via the cabin components, sends a signal, or demand, to a valve that opens ports through which high pressure hydraulic fluid flows and operates one or more actuators.

The valve, that is located near the actuators, can be signalled in two different ways: mechanically or electrically; mechanical signalling is obtained by push-pull rods, or more commonly by cables and pulleys; electrical signalling is a solution of more modern and sophisticated vehicles and will be later on discussed.

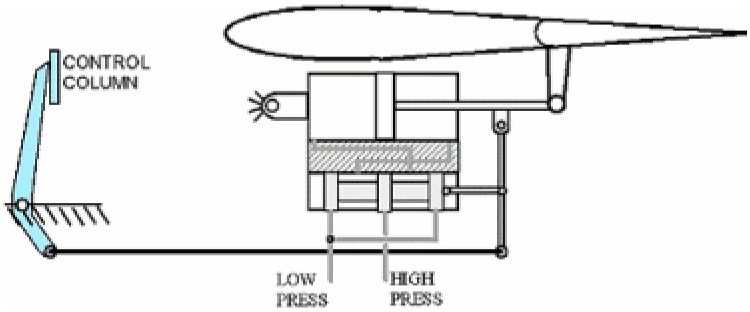
The basic principle of the hydraulic control is simple, but two aspects must be noticed when a powered control is introduced:

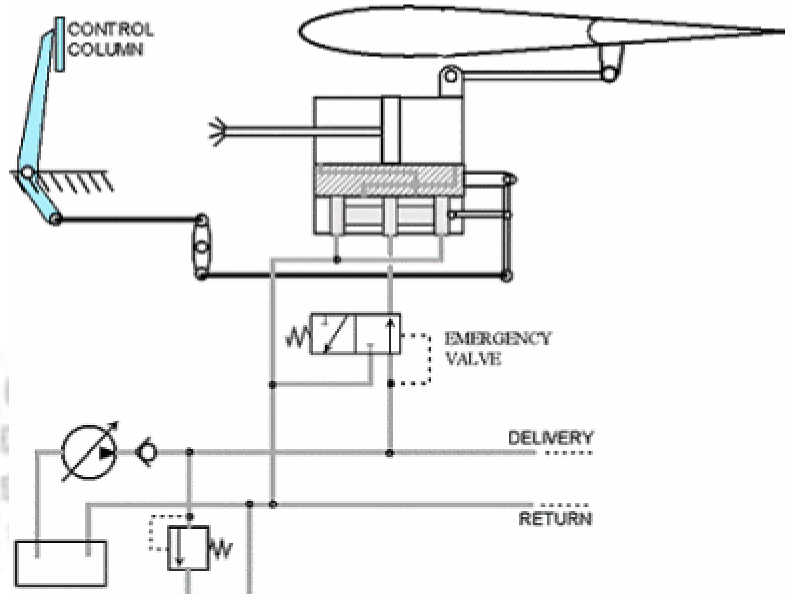
1. the system must control the surface in a proportional way, i.e. the surface response (deflection) must be function to the pilot's demand (stick deflection, for instance);

2. the pilot that with little effort acts on a control valve must have a feedback on the manoeuvre intensity.

The first problem is solved by using (hydraulic) servo-mechanisms, where the components are linked in such a way to introduce an actuator stroke proportional to the pilot's demand; many examples can be made, two of them are sketched, the second one including also the hydraulic circuit necessary for a correct operation.

In both cases the control valve housing is solid with the cylinder and the cabin column





Classic hydraulic servomechanisms

It has a mechanical linkage to drive the valve spool.

In the first case, the cylinder is hinged to the aircraft and, due to valve spool displacement and ports opening, the piston is moved in one direction or the other; the piston rod is also linked to the valve spool stick, in such a way that the piston movement brings the spool back towards its neutral position; when this is reached, the actuator stops, then obtaining a deflection that is proportional to the demand.

In the second case the piston is constrained to the aircraft; the cabin column controls the valve spool stick; this will result in a movement of the cylinder, and this brings the valve housing again towards the valve neutral position, then resulting in a stroke proportional to the pilot's demand. The hydraulic circuit also includes an emergency valve on the delivery segment to the control valve; if the delivery pressure drops, due for instance to a pump or engine failure, the emergency valve switches to the other position and links all the control valve inlets to the tank; this operation hydraulically unlocks the system, allowing the pilot for manual actuation of the cylinder.

It is clear now that the pilot, in normal hydraulic operating conditions, is requested for a very low effort, necessary to contrast the mechanical frictions of the linkage and the movement of the control valve: the pilot is then no more aware of the load condition being imposed to the aircraft.

For this reason an artificial feel is introduced in powered systems, acting directly on the cabin control stick or pedals. The simplest solution is a spring system, then responding to the pilot's demand with a force proportional to the stick deflection; this solution has of course the limit to be not sensitive to the actual flight conditions. A more sophisticated artificial feel is the so-called Q feel. This system receives data from the pitot-static probes, reading the dynamic pressure, or the difference between total (p_t) and static (p_s) pressure, that is proportional to the aircraft speed v through the air density ρ:

$$p_t - p_s = \frac{1}{2}\rho v^2 .$$

This signal is used to modulate a hydraulic cylinder that increases the stiffness in the artificial feel system, in such a way that the pilot is given a contrast force in the pedals or stick that is also proportional to the aircraft speed.

DIGITAL FLY BY WIRE SYSTEMS

Fly-By-Wire

In the 70's the fly-by-wire architecture was developed, starting as an analogue technique and later on, in most cases, transformed into digital. It was first developed for military aviation, where it is now a common solution; the supersonic Concorde can be considered a first and isolated civil aircraft equipped with a (analogue) fly-by-wire system, but in the 80's the digital technique was imported from military into civil aviation by Airbus, first with the A320, then followed by A319, A321, A330, A340, Boeing 777 and A380 (scheduled for 2005).

This architecture is based on computer signal processing and is schematically shown in fig. 6.5: the pilot's demand is first of all transduced into electrical signal in the cabin and sent to a group of independent computers (Airbus architecture substitute the cabin control column with a side stick); the computers sample also data concerning the flight conditions and servo-valves and actuators positions; the pilot's demand is then processed and sent to the actuator, properly tailored to the actual flight status.

The flight data used by the system mainly depend on the aircraft category; in general the following data are sampled and processed:

• pitch, roll, yaw rate and linear accelerations

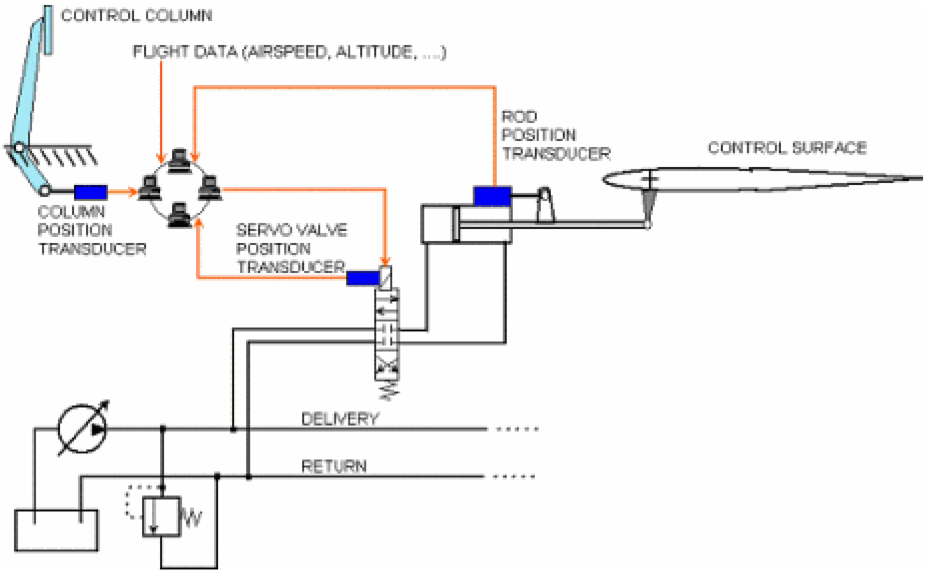
angle of attack and sideslip;

• airspeed/mach number, pressure altitude and radio altimeter indications;

• stick and pedal demands;

• other cabin commands such as landing gear condition, thrust lever position, etc.

The full system has high redundancy to restore the level of reliability of a mechanical or hydraulic system, in the form of multiple (triplex or quadruplex) parallel and independent lanes to generate and transmit the signals, and independent computers that process them; in many cases both hardware and software are different, to make the generation of a common error extremely remote, increase fault tolerance and isolation; in some cases the multiplexing of the digital computing and signal transmission is supported with an analogue or mechanical back-up system, to achieve adequate system reliability.



Fly-by-wire system

Fly-by-wire system between military and civil aircraft; some of the most important benefits are as follows:

• flight envelope protection (the computers will reject and tune pilot's demands that might exceed the airframe load factors);

• increase of stability and handling qualities across the full flight envelope, including the possibility of flying unstable vehicles;

• turbulence suppression and consequent decrease of fatigue loads and increase of passenger comfort;

• use of thrust vectoring to augment or replace lift aerodynamic control, then extending the aircraft flight envelope;

• drag reduction by an optimised trim setting;

• higher stability during release of tanks and weapons;

• easier interfacing to auto-pilot and other automatic flight control systems;

• weight reduction (mechanical linkages are substituted by wirings);

• maintenance reduction;

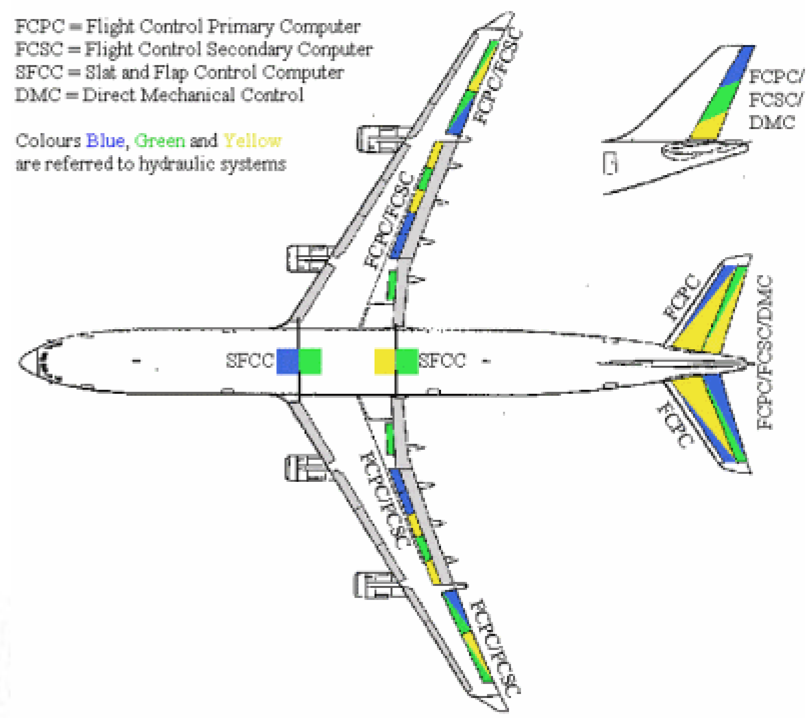
• reduction of airlines' pilot training costs (flight handling becomes very similar in an whole aircraft family).

the flight mode: ground, take-off, flight and flare. Transition between modes is smooth and the pilot is not affected in its ability to control the aircraft: in ground mode the pilot has control on the nose wheel steering as a function of speed, after lift-off the envelope protection is gradually introduced and in flight mode the aircraft is fully protected by exceeding the maximum negative and positive load factors (with and without high lift devices extracted), angle of attack, stall, airspeed/Mach number, pitch attitude, roll rate, bank angle etc; finally, when the aircraft approaches to ground the control is gradually switched to flare mode, where automatic trim is deactivated and modified flight laws are used for pitch control.

The control software is one of the most critical aspects of fly-by-wire. It is developed in accordance to very strict rules, taking into account the flight control laws, and extensive testing is performed to reduce the probability of error. The risk of aircraft loss due to flight control failure is 2×10^{-6} per flight hour for a sophisticated military airplane, that anyway has the ejection seat as ultimate solution; the risk is reduced to 10^{-9} per flight hour for a civil airplane, were occupants cannot evacuate the airplane during flight.

Figure below shows, as example, the fly-by-wire layout for the Airbus 340. Three groups of personal computers are used on board: three for primary control (FCPC), two for secondary control (FCSC) and two for high lift devices control (SFCC). The primary and secondary computers are based on different hardware; computers belonging to the same group have different software.

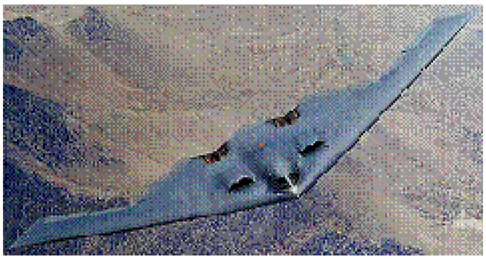
Two additional personal computers are used to store flight data.



A340 fly-by-wire layout, including hydraulic system indications

In the drawing the computer group and hydraulic system that control each surface are indicated (there are three independent hydraulic systems on the A340, commonly indicated as Blue, Yellow and Green). The leading edge flaps are linked together, and so are the trailing edge flaps, and then they are controlled by hydraulic units in the fuselage.

The drawing shows a considerable redundancy of the flight control system: the inboard and outboard ailerons, elevators and rudder are controlled by both the primary and secondary computers and operated by the three hydraulic sub-systems; the high lift devices are controlled by their specific computers and operated by the three hydraulic systems (Blue and Green for the leading edge,Yellow and Green for the trailing edge); the vertical stabiliser, having a secondary role, is controlled only by the secondary computers and operated by two hydraulic sub-systems. Thanks to this layout, first of all, in case of double hydraulic sub-system fault, the aircraft can be basically controlled with one hydraulic sub-system. Moreover, in case of total power black-out, the pilot can control the rudder and elevators by a mechanical back-up system, since the capability of this aircraft to land safely has been demonstrated with only limited pitch and yaw control.

Fly-by-wire architecture is inevitable for some aircraft categories: figure shows a typically unstable aircraft and a tilt rotor aircraft.  **Northrop B-2**	 **Bell-Boeing V-22** Fig – Need of fly-y-wire architecture for unstable (B-2) and thrust vectoring (V-22) airplanes

ENGINE CONTROL SYSTEMS

- It allow the engine to perform at maximum efficiency for a given condition
- Aids the pilot to control and monitor the operation of the aircraft's power plant
- Originally, engine control systems consisted of simple mechanical linkages controlled by the pilot then evolved and became the responsibility of the third pilot-certified crew member, the flight engineer
- By moving throttle levers directly connected to the engine, the pilot or the flight engineer could control fuel flow, power output, and many other engine parameters.
- Following mechanical means of engine control came the introduction of analog electronic engine control.
- Analog electronic control varies an electrical signal to communicate the desired engine settings
- It had its drawbacks including common electronic noise interference and reliability issues
- Full authority analogue control was used in the 1960s.
- It was introduced as a component of the Rolls Royce Olympus 593 engine of the supersonic transport aircraft Concorde. However the more critical inlet control was digital on the production aircraft.
- In the 1970s NASA and Pratt and Whitney experimented with the first experimental FADEC, first flown on an F-111 fitted with a highly modified Pratt & Whitney TF30 left engine.

Rolls Royce Olympus 593 engine

F-111C - Fighter – Bomber

Pratt & Whitney F100 – First Military Engine

Pratt & Whitney PW2000 - First Civil Engine fitted with FADEC

Pratt & Whitney PW4000 - First commercial "dual FADEC" engine.

The Harrier II Pegasus engine by Dowty & Smiths Industries Controls - The first FADEC in service.

Functions

- FADEC works by receiving multiple input variables of the current flight condition including air density, throttle lever position, engine temperatures, engine pressures, and many other parameters
- The inputs are received by the EEC and analyzed up to 70 times per second
- Engine operating parameters such as fuel flow, stator vane position, bleed valve position, and others are computed from this data and applied as appropriate.
- It controls engine starting and restarting.
- Its basic purpose is to provide optimum engine efficiency for a given flight condition.
- It also allows the manufacturer to program engine limitations and receive engine health and maintenance reports. For example, to avoid exceeding a certain engine temperature, the FADEC can be programmed to automatically take the necessary measures without pilot intervention.
- The flight crew first enters flight data such as wind conditions, runway length, or cruise altitude, into the flight management system (FMS). The FMS uses this data to calculate power settings for different phases of the flight.
- At takeoff, the flight crew advances the throttle to a predetermined setting, or opts for an auto-throttle takeoff if available.
- The FADECs now apply the calculated takeoff thrust setting by sending an electronic signal to the engines.
- There is no direct linkage to open fuel flow. This procedure can be repeated for any other phase of flight
- In flight, small changes in operation are constantly made to maintain efficiency.
- Maximum thrust is available for emergency situations if the throttle is advanced to full, but limitations can't be exceeded
- The flight crew has no means of manually overriding the FADEC.
- True full authority digital engine controls have no form of manual override available, placing full authority over the operating parameters of the engine in the hands of the computer
- If a total FADEC failure occurs, the engine fails
- If the engine is controlled digitally and electronically but allows for manual override, it is considered solely an EEC or ECU.
- An EEC, though a component of a FADEC, is not by itself FADEC. When standing alone, the EEC makes all of the decisions until the pilot wishes to intervene.

Safety

- With the operation of the engines so heavily relying on automation, safety is a great concern.
- Redundancy is provided in the form of two or more, separate identical digital channels.
- Each channel may provide all engine functions without restriction.
- FADEC also monitors a variety of analog, digital and discrete data coming from the engine subsystems and related aircraft systems, providing for fault tolerant engine control.

Applications

- FADECs are employed by almost all current generation jet engines, and increasingly in piston engines for fixed-wing aircraft and helicopters.
- The system replaces both magnetos in piston-engined aircraft, which makes costly magneto maintenance obsolete and eliminates carburetor heat, mixture controls and engine priming.
- Since, it controls each engine cylinder independently for optimum fuel injection and spark timing, the pilot no longer needs to monitor fuel mixture.
- More precise mixtures create less engine wear, which reduces operating costs and increases engine life for the average aircraft.
- Tests have also shown significant fuel savings

Advantages

- Better fuel efficiency
- Automatic engine protection against out-of-tolerance operations
- Safer as the multiple channel FADEC computer provides redundancy in case of failure
- Care-free engine handling, with guaranteed thrust settings
- Ability to use single engine type for wide thrust requirements by just reprogramming the FADECs.
- Provides semi-automatic engine starting
- Better systems integration with engine and aircraft systems
- Can provide engine long-term health monitoring and diagnostics
- Reduces the number of parameters to be monitored by flight crews
- Due to the high number of parameters monitored, the FADEC makes possible "Fault Tolerant Systems" (where a system can operate within required reliability and safety limitation with certain fault configurations)
- Can support automatic aircraft and engine emergency responses (e.g. in case of aircraft stall, engines increase thrust automatically).

Disadvantages

- No form of manual override available, placing full authority over the operating parameters of the engine in the hands of the computer.
- If a total FADEC failure occurs, the engine fails.
- In the event of a total FADEC failure, pilots have no way of manually controlling the engines for a restart, or to otherwise control the engine.
- With any single point of failure, the risk can be mitigated with redundant FADECs
- High system complexity compared to hydro mechanical, analogue or manual control systems
- High system development and validation effort due to the complexity

Auto pilot System

An autopilot is a mechanical, electrical, or hydraulic system used to guide a vehicle without assistance from a human being. An autopilot can refer specifically to aircraft, self-steering gear for boats, or auto guidance of space craft and missiles. The autopilot of an aircraft is sometimes referred to as “George”, after one of the key contributors to its development.

Today, autopilots are sophisticated systems that perform the same duties as a highly trained pilot. In fact, for some in-flight routines and procedures, autopilots are even better than a pair of human hands. They don’t just make flights smoother -they make them safer and more efficient. We'll look at how autopilots work by examining their main components, how they work together — and what happens if they fail.

Autopilots and Avionics

In the world of aircraft, the autopilot is more accurately described as the automatic flight control system (AFCS). An AFCS is part of an aircraft's avionics – the electronic systems, equipment and devices used to control key systems of the plane and its flight. In addition to flight control systems, avionics include electronics for communications, navigation, collision avoidance and weather. The original use of an AFCS was to provide pilot relief during tedious stages of flight, such as high-altitude cruising. Advanced autopilots can do much more, carrying out even highly precise maneuvers, such as landing an aircraft in conditions of zero visibility.

Although there is great diversity in autopilot systems, most can be classified according to the number of parts, or surfaces, they control. To understand this discussion, it helps to be familiar with the three basic control surfaces that affect an airplane's attitude.

Autopilots can control any or all of these surfaces. A single-axis autopilot manages just one set of controls, usually the ailerons. This simple type of autopilot is known as a "wing leveler" because, by controlling roll, it keeps the aircraft wings on an even keel.

A two-axis autopilot manages elevators and ailerons. Finally, a three-axis autopilot manages all three basic control systems: ailerons, elevators and rudder.

The invention of autopilot

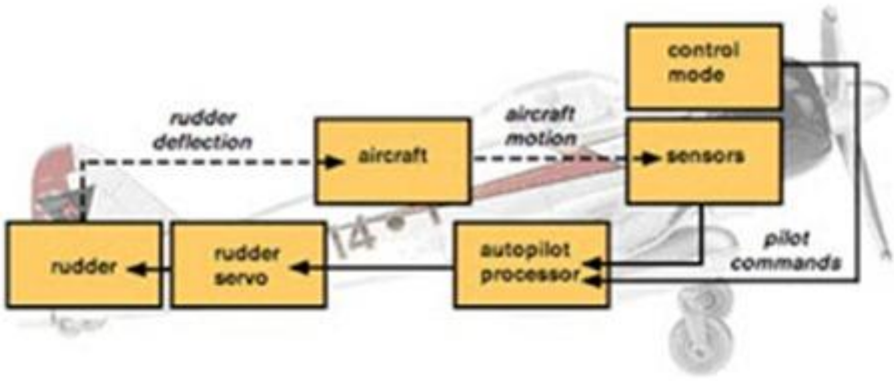
Famous inventor and engineer Elmer Sperry patented the gyrocompass in 1908, but it was his son, Lawrence Burst Sperry, who first flight-tested such a device in an aircraft. The younger Sperry's autopilot used four gyroscopes to stabilize the airplane and led to many flying firsts, including the first night flight in the history of aviation. In 1932, the Sperry Gyroscope Company developed the automatic pilot that Wiley Post would use in his first solo flight around the world.

Autopilot Parts

The heart of a modern automatic flight control system is a computer with several high-speed processors. To gather the intelligence required to control the plane, the processors communicate with sensors located on the major control surfaces. They can also collect data from other airplane systems and equipment, including gyroscopes, accelerometers, altimeters, compasses and airspeed indicators.

The processors in the AFCS then take the input data and, using complex calculations, compare it to a set of control modes. A control mode is a setting entered by the pilot that defines a specific detail of the flight. For example, there is a control mode that defines how an aircraft's altitude will be maintained. There are also control modes that maintain airspeed, heading and flight path.

These calculations determine if the plane is obeying the commands set up in the control modes. The processors then send signals to various servomechanism units. A servomechanism, or servo for short, is a device that provides mechanical control at a distance. One servo exists for each control surface included in the autopilot system. The servos take the computer's instructions and use motors or hydraulics to move the craft's control surfaces, making sure the plane maintains its proper course and attitude.



The above illustration shows how the basic elements of an autopilot system are related. For simplicity, only one control surface — the rudder — is shown, although each control surface would have a similar arrangement. Notice that the basic schematic of an autopilot looks like a loop, with sensors sending data to the autopilot computer, which processes the information and transmits signals to the servo, which moves the control surface, which changes the attitude of the plane, which creates a new data set in the sensors, which starts the whole process again. This type of feedback loop is central to the operation of autopilot systems.

Autopilot Control Systems

An autopilot is an example of a control system. Control systems apply an action based on a measurement and almost always have an impact on the value they are measuring. A classic example of a control system is the negative feedback loop that controls the thermostat in your home. Such a loop works like this:

1. Its summertime and a homeowner set his thermostat to a desired room temperature say 78°F.

2. The thermostat measures the air temperature and compares it to the preset value.

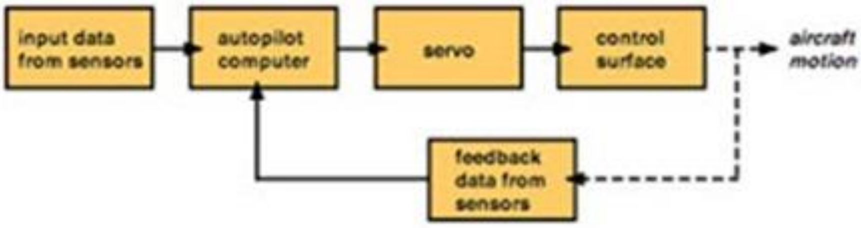
3. Over time, the hot air outside the house will elevate the temperature inside the house. When the temperature inside exceeds 78°F, the thermostat sends a signal to the air conditioning unit.

4. The air conditioning unit clicks on and cools the room.

5. When the temperature in the room returns to 78°F, another signal is sent to the air conditioner, which shuts off.

It's called a negative feedback loop because the result of a certain action (the air conditioning unit clicking on) inhibits further performance of that action. All negative feedback loops require a receptor, a control center and an effector. In the example above, the receptor is the thermometer that measures air temperature. The control center is the processor inside the thermostat. And the effector is the air conditioning unit.

Automated flight control systems work the same way. Let's consider the example of a pilot who has activated a single-axis autopilot — the so-called wing leveler we mentioned earlier.



1. The pilot sets a control mode to maintain the wings in a level position.

2. However, even in the smoothest air, a wing will eventually dip.

3. Position sensors on the wing detect this deflection and send a signal to the autopilot computer.

4. The autopilot computer processes the input data and determines that the wings are no longer level.

5. The autopilot computer sends a signal to the servos that control the aircraft's ailerons. The signal is a very specific command telling the servo to make a precise adjustment.

a) Each servo has a small electric motor fitted with a slip clutch that, through a bridle cable, grips the aileron cable. When the cable moves, the control surfaces move accordingly.

b) As the ailerons are adjusted based on the input data, the wings move back toward level.

c) The autopilot computer removes the command when the position sensor on the wing detects that the wings are once again level.

d) The servos cease to apply pressure on the aileron cables.

This loop, shown above in the block diagram, works continuously, many times a second, much more quickly and smoothly than a human pilot could. Two- and three-axis autopilots obey the same principles, employing multiple processors that control multiple surfaces. Some airplanes even have auto thrust computers to control engine thrust. Autopilot and auto thrust systems can work together to perform very complex maneuvers.

Autopilot Failure

Autopilots can and do fail. A common problem is some kind of servo failure, either because of a bad motor or a bad connection. A position sensor can also fail, resulting in a loss of input data to the autopilot computer. Fortunately, autopilots for manned aircraft are designed as a failsafe — that is, no failure in the automatic pilot can prevent effective employment of manual override. To override the autopilot, a crew member simply has to disengage the system, either by flipping a power switch or, if that doesn't work, by pulling the autopilot circuit breaker.

Some airplane crashes have been blamed on situations where pilots have failed to disengage the automatic flight control system. The pilots end up fighting the settings that the autopilot is administering; unable to figure out why the plane won't do what they're asking it to do. This is why flight instruction programs stress practicing for just such a scenario. Pilots must know how to use every feature of an AFCS, but they must also know how to turn it off and fly without it. They also have to adhere to a rigorous maintenance schedule to make sure all sensors and servos are in good working order. Any adjustments or fixes in key systems may require that the autopilot be tweaked. For example, a change made to gyro instruments will require realignment of the settings in the autopilot's computer.

Modern Autopilot Systems

Many modern autopilots can receive data from a Global Positioning System (GPS) receiver installed on the aircraft. A GPS receiver can determine airplane's position in space by calculating its distance from three or more satellites in the GPS network. Armed with such positioning information, an autopilot can do more than keep a plane straight and level — it can execute a flight plan.

Most commercial jets have had such capabilities for a while, but even smaller planes are incorporating sophisticated autopilot systems. New Cessna 182s and 206s are leaving the factory with the Garmin G1000 integrated cockpit, which includes a digital electronic autopilot combined with a flight director. The Garmin G1000 delivers essentially all the capabilities and modes of a jet avionics system, bringing true automatic flight control to a new generation of general aviation planes.Wiley Post could have only dreamed of such technology back in 1933.

Communications

Communications connect the flight deck to the ground, and the flight deck to the passengers. On board communications are provided by public address systems and aircraft intercoms.

The VHF aviation communication system works on the airband of 118.000 MHz to 136.975 MHz. Each channel is spaced from the adjacent by 8.33 kHz. amplitude modulation (AM) is used. The conversation is performed by simplex mode. Aircraft communication can also take place using HF (especially for trans-oceanic flights) or satellite communication.

Navigation

Navigation is the determination of position and direction on or above the surface of the Earth. Avionics can use satellite-based systems (such as GPS and WAAS), ground-based systems (such as VOR or LORAN), or any combination thereof. Older avionics required a pilot or navigator to plot the intersection of signals on a paper map to determine an aircraft's location; modern systems, like the Bendix/King KLN 90B, calculate the position automatically and display it to the flight crew on moving map displays.

Monitoring

Glass cockpits started to come into civilian use with the Gulfstream G-IV private jet in 1985. However, these largely stemmed from the need of military pilots to quickly deal with increasing amounts of flight data while concentrating on the task (dogfight with enemy aircraft, detection of surface targets, etc.) Display systems present sensor data that allows the aircraft to fly safely in a more flexible manner as skipping unnecessary information was not possible with the earlier mechanical (usually dial-type) instruments. Almost all new aircraft include glass cockpits. ARINC 818, titled Avionics Digital Video Bus, is a protocol used by many new glass cockpit displays in both commercial and military aircraft.

Aircraft flight control systems

Airplanes and helicopters have means of automatically controlling flight. They reduce pilot workload at important times (like during landing, or in hover), and they make these actions safer by 'removing' pilot error. The first simple auto-pilots were used to control heading and altitude and had limited authority on things like thrust and flight control surfaces. In helicopters, auto stabilization was used in a similar way. The old systems were electromechanical in nature until very recently.

The advent of fly by wire and electro actuated flight surfaces (rather than the traditional hydraulic) has increased safety. As with displays and instruments, critical devices which were electro-mechanical had a finite life. With safety critical systems, the software is very strictly tested.

Collision-avoidance systems

To supplement air traffic control, most large transport aircraft and many smaller ones use a TCAS (Traffic Alert and Collision Avoidance System), which can detect the location of nearby aircraft, and provide instructions for avoiding a midair collision. Smaller aircraft may use simpler traffic alerting systems such as TPAS, which are passive (they do not actively interrogate the transponders of other aircraft) and do not provide advisories for conflict resolution.

To help avoid collision with terrain, (CFIT) aircraft use systems such as ground-proximity warning systems (GPWS), radar altimeter being the key element in GPWS. A major weakness of (GPWS) is the lack of "look-ahead" information as it only provides altitude above terrain "look-down". To overcome this weakness, modern aircraft use the Terrain Awareness Warning System (TAWS).

Weather systems

Weather systems such as weather radar (typically Arinc 708 on commercial aircraft) and lightning detectors are important for aircraft flying at night or in Instrument meteorological conditions, where it is not possible for pilots to see the weather ahead. Heavy precipitation (as sensed by radar) or severe turbulence (as sensed by lightning activity) are both indications of strong convective activity and severe turbulence, and weather systems allow pilots to deviate around these areas.

Lightning detectors like the Storm scope or Strike finder have become inexpensive enough that they are practical for light aircraft. In addition to radar and lightning detection, observations and extended radar pictures (such as NEXRAD) are now available through satellite data connections, allowing pilots to see weather conditions far beyond the range of their own in-flight systems. Modern displays allow weather information to be integrated with moving maps, terrain, traffic, etc. onto a single screen, greatly simplifying navigation.

Aircraft management systems

There has been a progression towards centralized control of the multiple complex systems fitted to aircraft, including engine monitoring and management. Health and Usage Monitoring Systems (HUMS) are integrated with aircraft management computers to allow maintainers early warnings of parts that will need replacement.

The integrated modular avionics concept proposes an integrated architecture with application software portable across an assembly of common hardware modules. It has been used in Fourth generation jet fighters and the latests generation of airliners.

Mission or tactical avionics

Military aircraft have been designed either to deliver a weapon or to be the eyes and ears of other weapon systems. The vast array of sensors available to the military is used for whatever tactical means required. As with aircraft management, the bigger sensor platforms (like the E-3D, JSTARS, ASTOR, Nimrod MRA4, Merlin HM Mk 1) have mission management computers.

Police and EMS aircraft also carry sophisticated tactical sensors.

Military communications

While aircraft communications provide the backbone for safe flight, the tactical systems are designed to withstand the rigours of the battle field. UHF, VHF Tactical (30-88 MHz) and SatCom systems combined with ECCM methods, and cryptography secure the communications. Data links like Link 11, 16, 22 and BOWMAN, JTRS and even TETRA provide the means of transmitting data (such as images, targeting information etc.).

Radar

Airborne radar was one of the first tactical sensors. The benefit of altitude providing range has meant a significant focus on airborne radar technologies. Radars include airborne early warning (AEW), anti-submarine warfare (ASW), and even weather radar (Arinc 708) and ground tracking/proximity radar.

Besides its primary role as the main sensor for fighters, the military uses radar in fast jets to help pilots fly at low levels. Earlier models were just separate devices often mounted under the primary (e.g. air-to-air) unit and covered with the same randome; modern technologies allow the creation of multi-functional, weapon-controlling radars that additionally perform such terrain-mapping. While the civil market has had weather radar for a while, there are strict rules about using it to navigate the aircraft.

Sonar

Dipping sonar fitted to a range of military helicopters allows the helicopter to protect shipping assets from submarines or surface threats. Maritime support aircraft can drop active and passive sonar devices (Sonobuoys) and these are also used to determine the location of hostile submarines.

Electro-Optics

Electro-optic systems include Forward Looking Infrared (FLIR), and Passive Infrared Devices (PIDS). These are all used to provide imagery to crews. This imagery is used for everything from Search and Rescue through to acquiring better resolution on a target.

ESM/DAS

Electronic support measures and defensive aids are used extensively to gather information about threats or possible threats. They can be used to launch devices (in some cases automatically) to counter direct threats against the aircraft. They are also used to determine the state of a threat and identify it.

Police and air ambulance

Police and EMS aircraft (mostly helicopters) are now a significant market. Military aircraft are often now built with the capability to support response to civil disobedience. Police helicopters are almost always fitted with video/FLIR systems allowing them to track suspects. They can also be equipped with searchlights and loudspeakers.

EMS and police helicopters will be required to fly in unpleasant conditions which may require more aircraft sensors, some of which were until recently considered purely for military aircraft.

LONG RANGE NAVIGATION (LORAN).

The LORAN has been an effective alternative to Rho/Theta R-Nav systems. Hyperbolic systems require waypoint designation in terms of latitude and longitude, unlike original R-Nav (distance navigation) systems, which define waypoints in terms of distance (Rho) and angle (Theta) from established VOR or Tacan facilities. Accuracy is better than the VOR/Tacan system but LORAN is more prone to problems with precipitation static. Proper bonding of aircraft structure and the use of high-quality static wicks will not only produce improved LORAN system performance, but can also benefit the very high frequency 9/27/01 AC 43.13-1B **CHG 1** Par 12-16 Page 12-7 (VHF) navigation and communications systems. This system has an automatic test equipment (ATE).

NOTE: Aircraft must be outside of hangar for LORAN to operate. Normally self test check units, verification of position, and loading of flight plan will verify operation verification of proper flight manual supplements and operating handbooks on board, and proper software status can also be verified.

GLOBAL POSITIONING SYSTEM (GPS).

The GPS is at the forefront of present generation navigation systems. This space-based navigation system is based on a 4-satellite system and is highly accurate (within 100 meters) for establishing position. The system is unaffected by weather and provides a world-wide common grid reference system. Database updating and antenna maintenance are of primary concern to the GPS user.

NOTE: Aircraft must be outside of hangar for ground test of GPS. 12-18. AUTOPILOT SYSTEMS.

Automatic Flight Control Systems (AFCS)
are the most efficient managers of aircraft performance and control. There are three kinds of autopilot; two axes, three axes, and three axes with coupled approach capability. Attention must be given to the disconnect switch operation, aural and visual alerts of automatic and

intentional autopilot disconnects, override forces and mode annunciation, servo operation, rigging and bridle cable tension, and condition. In all cases the manufacturer's inspection and maintenance instructions must be followed.

FLIGHT DATA RECORDER.

The flight data recorder is housed in a crush-proof container located near the tail section of the aircraft. The tape unit is fire resistant, and contains a radio transmitter to help crash investigators locate the unit under water. Inspection/ Operational checks include:

a. Check special sticker on front of the flight data recorder for the date of the next tape replacement, if applicable.

b. Remove recorder magazine and inspect tape for the following:

(1) broken or torn tape,

(2) proper feed of tape, and

(3) all scribes were recording properly for approximately the last hour of flight.

c. Conditions for tape replacement (as applicable): AC 43.13-1B **CHG 1** 9/27/01 Page 12-10 Par 12-23

(1) There is less than 20 hours remaining in the magazine as read on the *tape remaining* indicator.

(2) Tape has run out.

(3) Broken tape.

(4) After hard landings and severe air turbulence have been encountered as reported by the pilots. After the same tape has been in use 1 year (12 months), it must be replaced.

(5) Ensure that a correlation test has been performed and then recorded in the aircraft records.

d. Refer to the specific equipment manufacturer's manuals and procedures.

a. **The state-of-the art Solid-State Flight Data Recorder (SSFDR)** is a highly flexible model able to support a wide variety of aeronautical radio, incorporated (ARINC) configurations. It has a Built-In Test Equipment (BITE) that establishes and monitors the mission fitness of the hardware. BITE performs verification after storage (read after write) of flight data and status condition of the memory. These recorders have an underwater acoustic beacon mounted on its front panel which must be returned to their respective manufacturer's for battery servicing. For maintenance information refer to the equipment or aircraft manufacture's maintenance instruction manual.

COCKPIT VOICE RECORDERS (CVR).

CVR's are very similar to flight data recorders. They look nearly identical and operate in almost the same way. CVR's monitors the last 30 minutes of flight deck conversations and radio communications. The flight deck conversations are recorded via the microphone monitor panel located on the flight deck. This panel is also used to test the system and erase the tape, if so desired. Before operating the erase CVR mode, consult the operational manual of the manufacturer for the CVR

. **a. Playback is possible** only after the recorder is removed from the aircraft.

b. Refer to the specific equipment manufacturer's manuals and procedures.

c. The Solid State Cockpit Voice Recorder system is composed of three essential components a solid state recorder, a control unit (remote mic amplifier), and an area microphone. Also installed on one end of the recorder is an Under water Locator Beacon (ULB). The recorder accepts four separate audio inputs: pilot, copilot, public address/ third crew member, and cockpit area microphone and where applicable, rotor speed input and flight data recorder synchronization tone input. For maintenance information refer to the equipment manufacturer’s maintenance manual.

WEATHER RADAR.

Ground performance shall include antenna rotation, tilt, indicator brilliance, scan rotation, and indication of received echoes. It must be determined that no objectionable interference from other electrical/electronic equipment appears on the radar indicator, and that the radar system does not interfere with the operation of any of the aircraft’s communications or navigation systems.

ALTIMETERS.
Aircraft conducting operations in controlled airspace under instrument flight rule (IFR) are required to have their static system(s) and each altimeter instrument inspected and tested within the previous 24 calendar months. Frequent functional checks of all altimeters and automatic pressure altitude reporting systems are recommended.

a. The tests required must be performed by:
(1) The manufacturer of the aircraft on which the tests and inspection are to be performed.
(2) A certificated repair station properly equipped to perform those functions and holding:

- **(a)** An instrument rating Class I.

- **(b)** A limited instrument rating appropriate to the make and model of appliance to be tested.

- **(c)** A certified/qualified mechanic with an airframe rating(static system tests and inspections only). Any adjustments shall be accomplished only by an instrument shop certified/ qualified person using proper test equipment and adequate reference to the manufacturer’s maintenance manuals. The altimeter correlation adjustment shall not be adjusted in the field. Changing this adjustment will nullify the correspondence between the basic test equipment calibration standards and the altimeter. It will also nullify correspondence between the encoding altimeter and its encoding digitizer or the associated blind encoder.

b. Examine the altimeter face for evidence of needle scrapes or other damage. Check smoothness of operation, with particular attention to altimeter performance during decent.
c. Contact an appropriate air traffic facility for the pressure altitude displayed to the controller from your aircraft. Correct the reported altitude as needed, and compare to the AC 43.13-1B **CHG 1** 9/27/01 Page 12-8 Par 12-20 reading on the altimeter instrument. The difference must not exceed 125 feet.

TRANSPONDERS.

There are three modes (types) of transponders that can be used on various aircraft. Mode A provides a (non altitude-reporting) four-digit coded reply; Mode C provides a code reply identical to Mode A with an altitude-reporting signal; and Mode S has the same capabilities as Mode A and Mode C and responds to traffic alert and collision avoidance system (TCAS)-

Equipped Aircraft. **a. Ground ramp equipment** must be used to demonstrate proper operation. Enough codes must be selected so that each switchposition is checked at least once. Low and high sensitivity operation must be checked. Identification operation must be checked. Altitude reporting mode must be demonstrated. Demonstrate that the transponder system does not interfere with other systems aboard the aircraft, and that other equipment does not interfere with transponder operation. Special consideration must be given to other pulse equipment, such as DME and weather radar.

b. All transponders must be tested every 24-calendar months, or during an annual inspection,
if requested by the owner. The test must be conducted by an authorized avionics repair facility.

EMERGENCY LOCATOR TRANS- MITTERS (ELT).

The ELT must be evaluated in accordance with TSO-C91a, TSO-C126 for 406 MHz ELT's, or later TSO's issued for ELT's. ELT installations must be examined for potential operational problems at least once a year (section 91.207(d)). There have been numerous instances of interaction between ELT and other VHF installations. Antenna location should be as far as possible from other antennas to prevent efficiency losses. Check ELT antenna installations in close proximity to other VHF antennas for suspected interference. Antenna patterns of previously installed VHF antennas could be measured after an ELT installation. Tests should be conducted during the first 5 minutes after any hour. If operational tests must be made outside of this time frame, they should be coordinated with the nearest FAA Control Tower or FSS. Tests should be no longer than three audible sweeps.

INSPECTION OF ELT.

An inspection of the following must be accomplished by a properly certified person or repair station within 12-calendar months after the last inspection:

a. Proper Installation.
(1) Remove all interconnections to the ELT unit and ELT antenna. Visually inspect and confirm proper seating of all connector pins. Special attention should be given to coaxial center conductor pins, which are prone to retracting into the connector housing.
(2) Remove the ELT from the mount and inspect the mounting hardware for proper installation and security.
(3) Reinstall the ELT into its mount and verify the proper direction for crash activation. Reconnect all cables. They should have some slack at each end and should be properly secured to the airplane structure for support and protection.
b. Battery Corrosion. Gain access to the ELT battery and inspect. No corrosion should be detectable. Verify the ELT battery is approved and check its expiration date.

b. **Operation of the Controls and Crash Sensor.** Activate the ELT using an applied force. Consult the ELT manufacturer's instructions before activation. The direction for mounting and force activation is indicated on 9/27/01 AC 43.13-1B **CHG 1** Par 12-22 Page 12-9 the ELT. A TSO-C91 ELT can be activated by using a quick rap with the palm. A TSO-C91a ELT can be activated by using a rapid forward (throwing) motion coupled by a rapid reversing action. Verify that the ELT can be activated using a watt meter, the airplane's VHF radio communications receiver tuned to 121.5 MHz, or other means (see NOTE 1). Insure that the “G” switch has been reset if applicable.

c. **For a Sufficient Signal Radiated From its Antenna.** Activate the ELT using the ON or ELT TEST switch. A low-quality AM broadcast radio receiver should be used to determine if energy is being transmitted from the antenna. When the antenna of the AM broadcast radio receiver (tuning dial on any setting) is held about 6 inches from the activated ELT antenna, the ELT aural tone will be heard (see NOTE 2 and 3). **Verify that All Switches are Properly Labeled and Positioned**.

f. Record the Inspection. Record the inspection in the aircraft maintenance records according to 14 CFR part 43, section 43.9. We suggest the following: I inspected the Make/Model ______________
ELT system in this aircraft according to applicable Aircraft and ELT manufacturer’s instructions and applicable FAA guidance and found that it meets the requirements of section 91.207(d).