

# **AIRCRAFT SYSTEMS**

**B. Tech III – II semester (R15)**  
**AERONAUTICAL ENGINEERING**

**Prepared by**

**Sravanthi G**

Assistant Professor

Department of Aeronautical Engineering

**Suresh Kumar R**

Assistant Professor

Department of Aeronautical Engineering

# **UNIT - 1**

## **INTRODUCTION TO AIRCRAFT SYSTEMS AND INTEGRATION**

# SYSTEM CONCEPTS

- Is a broad field of practice that covers the behavior of systems across a wide range of subjects including
  - Organizational
  - Operational
  - Practical
  - Commercial
  - Economical
  - Human and educational systems.

- For aircraft systems: elemental building blocks are the components ,physical components like pipes ,valves ,sensors etc. that determine hardware characteristics of systems.
- Apart from this software systems human is the form of pilot ,crew technician ,passengers, or a maintainer is also vital part of the systems.

It comprises Problem definition-need of system

- **Choice of objective**-physical need and value of system
- **System synthesis**-creation of possible alternative system
- **System selection**-selection of most pro massive alternative
- **System development**-up to prototype stage
- **Current engineering**-system realization beyond the scope of prototype stage.

# SYSTEM DEFINITIONS

- The system of an aircraft must be designated to meet the design targets. Such as low mass, low power consumption ,high performance ,high accuracy ,high integrity and low cost apart from safety targets.
- System applies to various combinations of components and control units that perform a use full function in the operation of aircraft.

- The Open University has long used another definition : A system is an assembly of parts, components, processes or functions connected together in an organized way
- A complete system include all equipments related facilities materials ,software's, services and personals required for its operation and support to the degree

# Everyday Examples of Systems

The word 'system' is often used loosely in everyday speech by people to describe large amorphous 'things' or corporations. These are complex things that defy a simple description.

➤ Examples include

- Natural systems such as the eco-system or solar system
- National Health Service
- Building and construction industry



# AIRFRAME SYSTEMS

Considering the aircraft as overall main system is classified into 4 imp co systems.

- The airframe can be viewed as a system since it is a complex and integrated set of structural components that supports the mass of systems and passengers, and carries loads and stresses throughout the structure.
- The airframe is designed and constructed as a set of sub-systems that are integrated to form the whole structure

# VEHICLE SYSTEMS

- The aircraft systems are also known as General Systems or Utility Systems. Many of these systems are common to both civil and military aircraft. They are a mixture of systems with very different characteristics.
- Some are high speed, closed loop, high integrity control, such as flight controls, others are real time data gathering and processing with some process control functions, such as the fuel system and yet others are simple logical processing

Coming to individual systems of vehicle systems:

- **Propulsion system** to provide the primary source of thrust and motive power via pilot demands, electronic and hydro-mechanical fuel controls.
- A propulsion system has a source of mechanical power (some type of engine or motor), and some means of using this power to generate force.

- **Fuel system** to provide a source of energy for the propulsion system. the system consists of tanks, a quantity measuring system, pumps, valves, non-return valves and pipes to transfer fuel from tank to tank and to the engines.
- An aircraft fuel system allows the crew to pump, manage, and deliver fuel to the propulsion system of an aircraft.

- **Electrical power generation and distribution:** to generate AC and DC power from the engine connected generators and batteries, and to distribute the power to all connected equipment.
- **Hydraulic power generation and distribution** to generate hydraulic power from engine driven pumps and to distribute hydraulic power to all connected systems.

- **Secondary power system** to provide a source of electrical, hydraulic and cooling power for aircraft on the ground, and to provide a form of energy to start the engines.
- **Auxiliary or secondary systems** help the aircraft perform its main function: flying from a to b.

- **Emergency power generation** to provide energy to allow safe recovery of the aircraft in the event of a major power loss.
- **Flight control systems** to convert pilot demands or demands from guidance systems into control surface movements to control the aircraft attitude.
- **Landing gear** to ensure that the aircraft is able to land safely at all loads and on designated runway surfaces.

**Brakes/anti-skid** to provide a safe form of braking without loss of adhesion under a wide range of landing speeds and loads.

- **Steering** to provide a means of steering the aircraft under its own power.

- **Environmental control system** to provide air of an appropriate temperature and humidity to provide a safe and comfortable environment for crew, passengers and avionic equipment.



- **Ice protection** to monitor external ambient conditions to detect icing conditions and to prevent the formation of ice or to remove ice.
- **External lighting** to ensure that the aircraft is visible to other operators and to ensure runway/taxiway visibility during ground movements

Military aircraft also require the following systems:

- **Crew escape** to provide a means of assisted escape for aircrew.
- **Canopy jettison or fragmentation** to provide a means of removing the canopy from the aircraft or breaking the canopy material to provide a means of exit for escaping aircrew.
- **Biological and chemical protection** to protect the crew from the toxic effects of chemical or biological contamination

- **Arrestor mechanism** to provide a means of stopping the aircraft on a carrier deck or at the end of a runway.
- **In-flight refueling** to allow the aircraft to obtain fuel from a tanker aircraft.
- **Helicopter deck** lock to secure helicopters to a carrier deck.

Commercial aircraft and large military aircraft require the following systems specifically for their use:

- **Galley** to allow meals to be prepared and cooked for passengers
- **Passenger evacuation** to allow safe evacuation of passenger

# galley



•**Entertainment systems** to provide audio and visual entertainment for passengers

•**Telecommunications** to allow passengers to make telephone calls and send e-mail in flight

•**Gaseous oxygen** for passenger use in case of de pressurization  
In case of cabin depressurization the aircraft is equipped with oxygen masks located above each seat . If it is necessary, the mask falls automatically.

•**Cabin and emergency lighting** to provide general lighting for the cabin and galley, reading lights, exit lighting and emergency lights to provide a visual path to the exit



# Depressurization



© Nikolay Ustinov | nikk.kz

# AVIONICS SYSTEMS

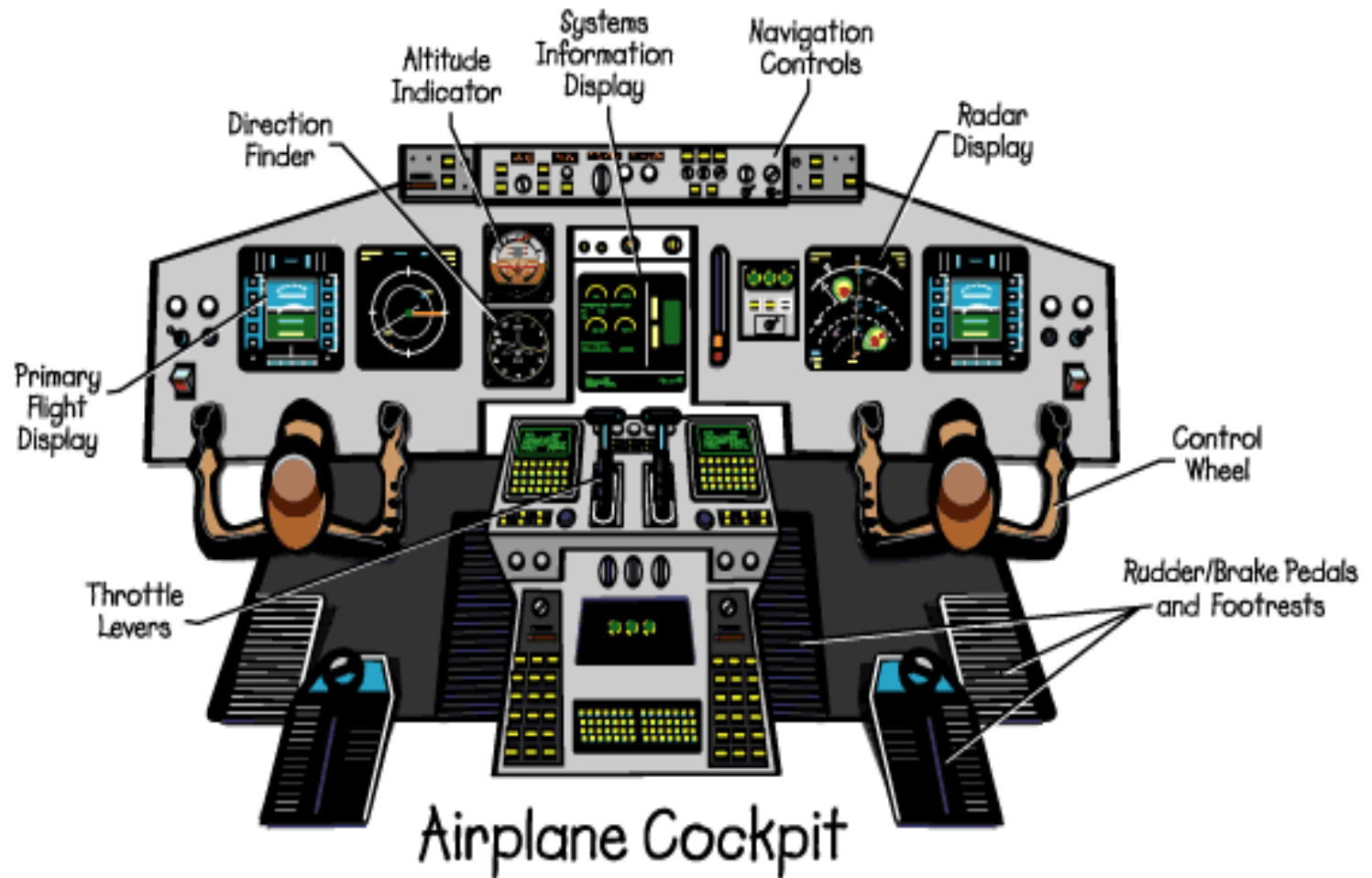
- The avionic systems are common to both civil and military aircraft. Not all aircraft types, however, will be fitted with the complete set listed below.
- The majority of the systems collect, process, transfer and respond to data.
- Any energy transfer is usually performed by a command to a vehicle system.



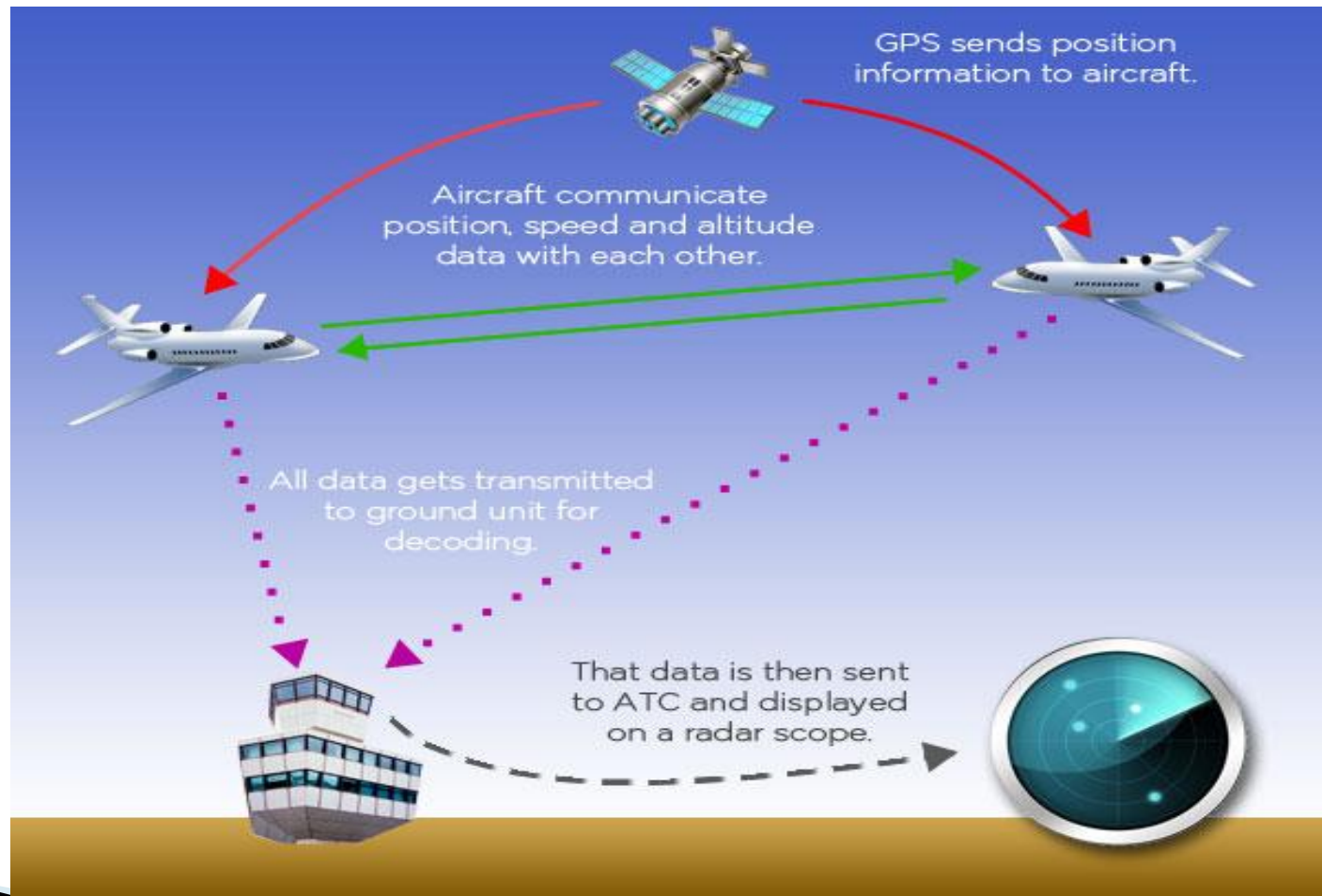
The following are the common (module) avionic systems both for civil and military aircrafts:

- **Displays and controls** to provide the crew with information and warnings with which to operate the aircraft.
- **Communications** to provide a means of communication between the aircraft and Air Traffic Control and other aircraft. Communications connect the flight deck to the ground and the flight deck to the passengers.
- **Navigation** to provide a worldwide, high accuracy navigation capability

# Display and controls



# ATC



**Flight Management System** to provide a means of entering flight plans and allowing automatic operation of the aircraft in accordance with the plans

- An FMS is a specialized computer system that automates a wide variety of in-flight tasks, reducing the workload on the flight crew to the point that modern civilian aircraft no longer carry flight engineers or navigators.

**Weather radar** to provide information on weather conditions ahead of the aircraft.

- Weather systems such as weather radar 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.

• Weather radar also called weather surveillance radar (WSR) and Doppler weather radar is a type of radar used to

- Locate Precipitation,
- Calculate its motion,
- Estimate its type (rain, snow, etc)

# WEATHER RADAR



- **IFF/SSR** to provide information on the aircraft identification and height to air traffic is a radar system used in air traffic control (ATC), that not only detects and measures the position of aircraft i.e. range and bearing, but also requests additional information from the aircraft itself such as its identity and altitude.





- Ground proximity warning system (GPWS)/Terrain avoidance warning system(TAWS) to reduce the risk of aircraft flying into the ground or into high ground.

- A ground proximity warning system (GPWS) is a system designed to alert pilots if their aircraft is in immediate danger of flying into the ground or an obstacle.

- More advanced systems introduced in 1996 are known as enhanced ground proximity warning systems (EGPWS) although sometimes called terrain awareness warning systems.

## Distance Measuring Equipment (DME)



**Distance measuring equipment (DME)** is a transponder-based radio navigation technology that measures slant range distance by timing the propagation delay of VHF or UHF radio signals.

- As the name implies DME provides information on the distance from the aircraft to the ground station.
- Used to establish position along an airway and also to establish hold points



**Distance measuring equipment (DME)**

- **Air data measurement** to provide information to other systems on altitude, air speed, outside air temperature and Mach number.
- **Accident data recorder** to continuously record specified aircraft parameters for use in analysis of serious incidents.
- **Cockpit voice recorder** to continuously record specified aircrew speech for use in analysis of serious incidents.
- **Internal lighting** to provide a balanced lighting solution on the flight deck for all panels and displays.

## Flight data recorder



Longer base

## Cockpit voice recorder



Smaller power supply unit



- A flight recorder (or aircraft's black box) is an electronic recording device placed in an aircraft for the purpose of facilitating the investigation of aviation accidents and incidents.
- Any type of aircraft in any condition of flight can be viewed in terms of its input parameters (e.g. control instructions) and output parameters (e.g. flight sensors) without any knowledge of its internal workings as a black box model.



# MISSION SYSTEMS

- Used for military aircrafts.
- The military aircraft requires a range of sensors and computing to enable the crew to prosecute designated missions.
- The mission systems gain information about the outside world from active and passive sensors and process this information to form intelligence.

The following are the major systems of a mission system:

- **Attack or surveillance** radar to provide information on hostile and friendly targets.
- **Electro-optical sensors** to provide a passive surveillance of targets.
- **Electronic support measures (ESM)** to provide emitter information, range and bearing of hostile transmitters

- In military telecommunications, the terms Electronic Support (ES) or Electronic Support Measures (ESM) describe the division of electronic warfare involving actions taken under direct control of an operational commander to detect, intercept, identify, locate, record and/or analyze sources of radiated electromagnetic energy for the purposes of immediate threat recognition (such as warning that fire control RADAR has locked on a combat vehicle, ship, or aircraft) or longer-term operational planning

# Esm



- **Magnetic anomaly detector (MAD)** to confirm the presence of large metallic objects under the sea surface (submarines) prior to attack is an instrument used to detect minute variations in the Earth's magnetic field.
- The term refers specifically to magnetometers used by military forces to detect submarines.
- Military MAD equipment is a descendent of geomagnetic survey instruments used to search for minerals by detecting their disturbance of the normal earth-field.

- **Acoustic sensors** to provide a means of detecting and tracking the passage of under water objects.
- **Mission computing** to collate the sensor information and to provide a fused data picture to the cockpit or mission crew stations.
- **Defensive aids** to provide a means of detecting missile attack and deploying countermeasures

- A defensive aids system (DAS) is a military aircraft system which defends it from attack by surface-to-air missiles, air-to-air missiles and guided anti-aircraft artillery.
- A DAS typically comprises chaff, flares, and electronic countermeasures combined with radar warning receivers to detect threats.
- On some modern aircraft, the entire system is integrated and computer-controlled, allowing an aircraft to autonomously detect, classify and act in an optimal manner against a potential threat to its safety

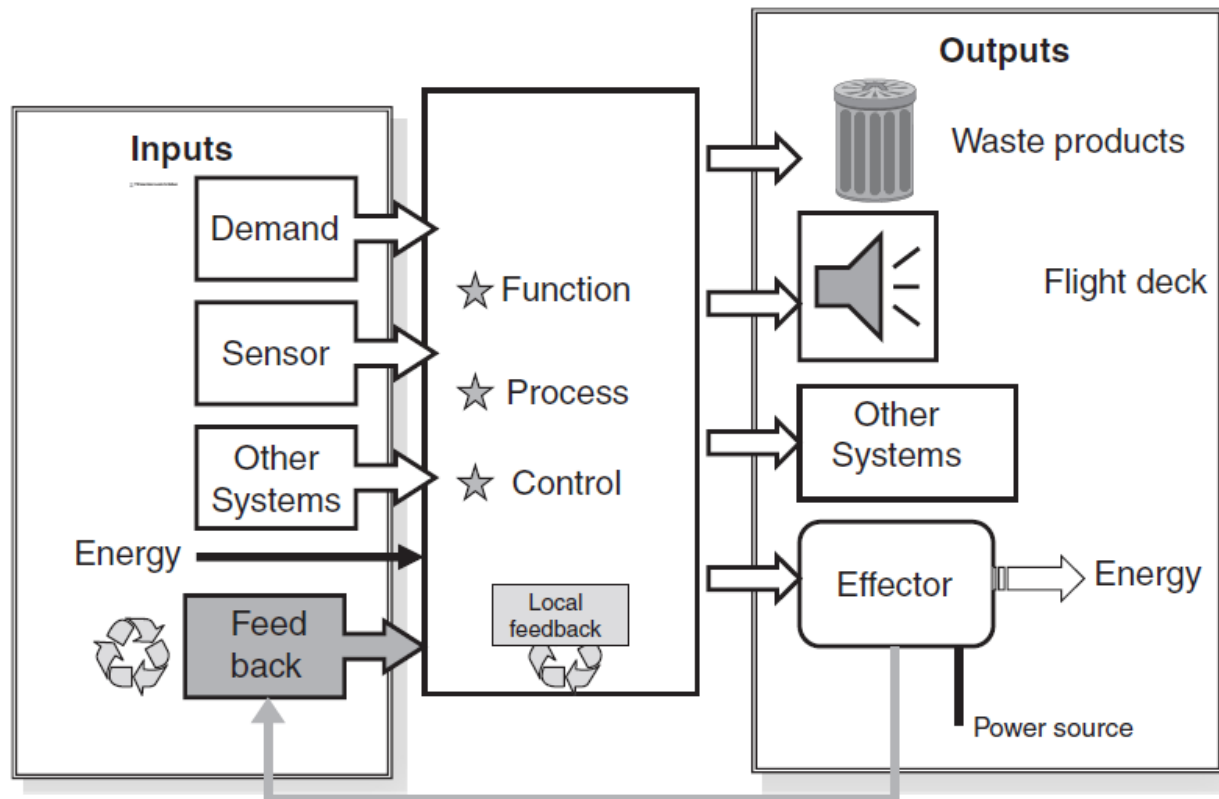
- **Helmet-mounted displays** to provide primary flight information and weapon information to the crew, whilst allowing freedom of movement of the head.
- **Data link** to provide transmission and receipt of messages under secure communications using data rather than voice



- **Data link** is the means of connecting one location to another for the purpose of transmitting and receiving digital information.
- It can also refer to a set of electronics assemblies, consisting of a transmitter and a receiver (two pieces of data terminal equipment) and the interconnecting data telecommunication circuit.
- These are governed by a link protocol enabling digital data to be transferred from a data source to a data sink.

# Generic System Definition

- An aircraft will be equipped with various combinations of these systems according to its particular role.
- Some of the systems will be integral to the aircraft, others will be carried as role equipment in pallets or wing mounted pods.
- The majority of these engineering systems are similar in their format



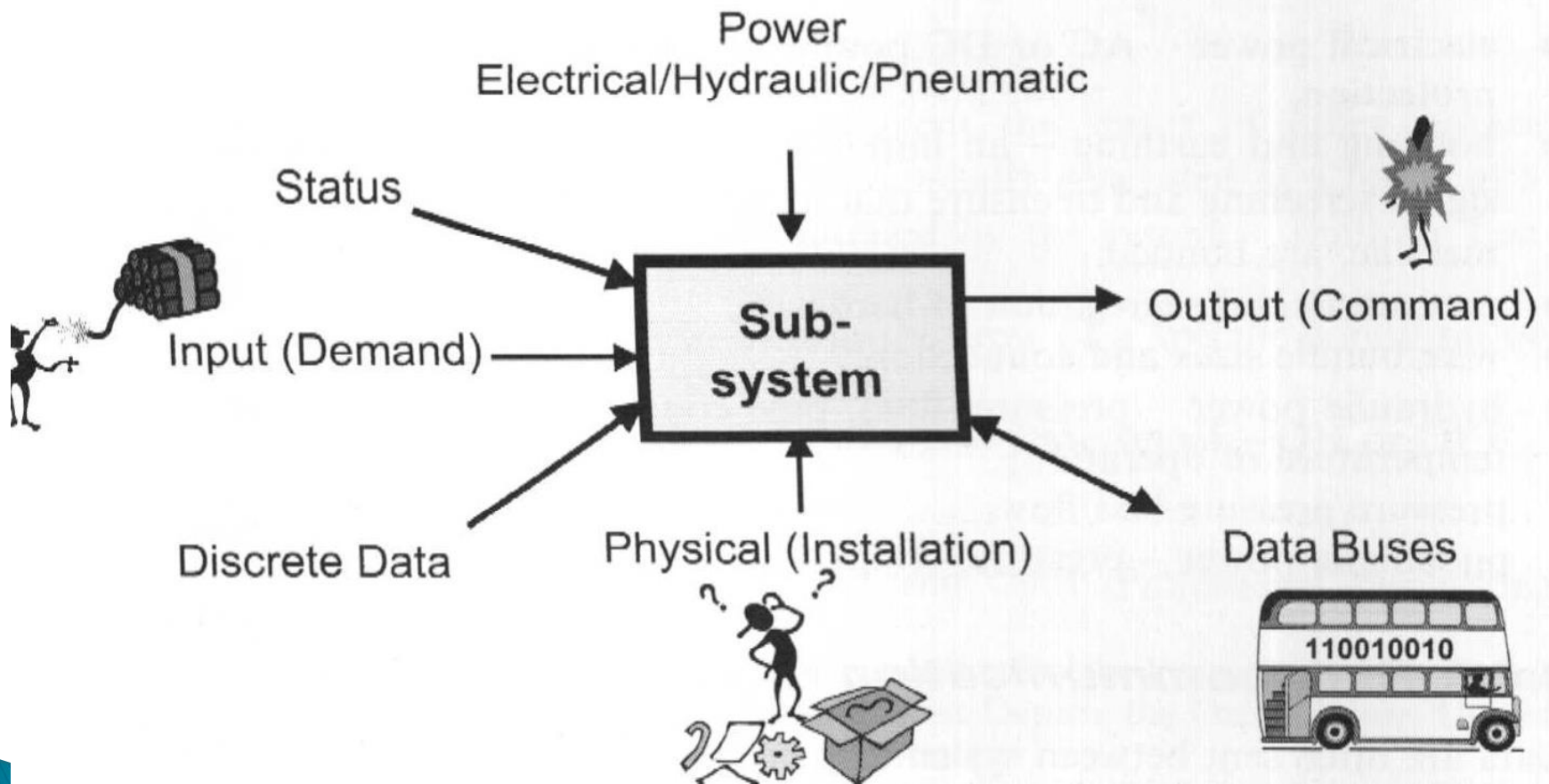
**Figure 2.9** A generic aircraft system block diagram.

# Feedback

- Feed Back is obtained from measuring devices or sensors in the output devices to allow control to be exercised for reasons of stability of the output.
- Energy is provided to enable the system to operate.
- This usually needs to be conditioned by the system to ensure that it is the correct voltage and free from transients or noise to ensure correct operation

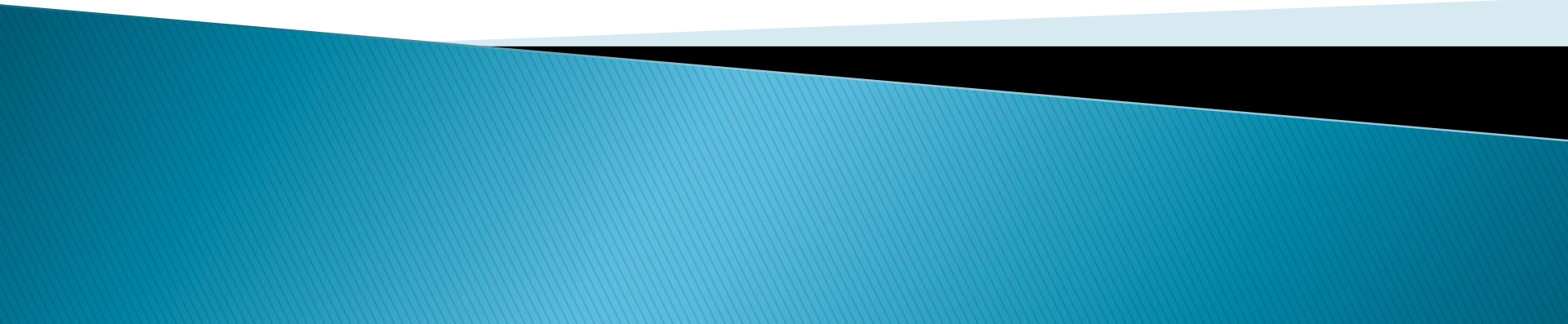
# SYSTEMS INTEGRATION

# DESIGN DRIVERS IN SUB SYSTEM ENVIRONMENT



# Unit 2

## **ELECTRICAL SYSTEMS AND FLIGHT CONTROL SYSTEMS**



# ELECTRICAL POWER SYSTEM

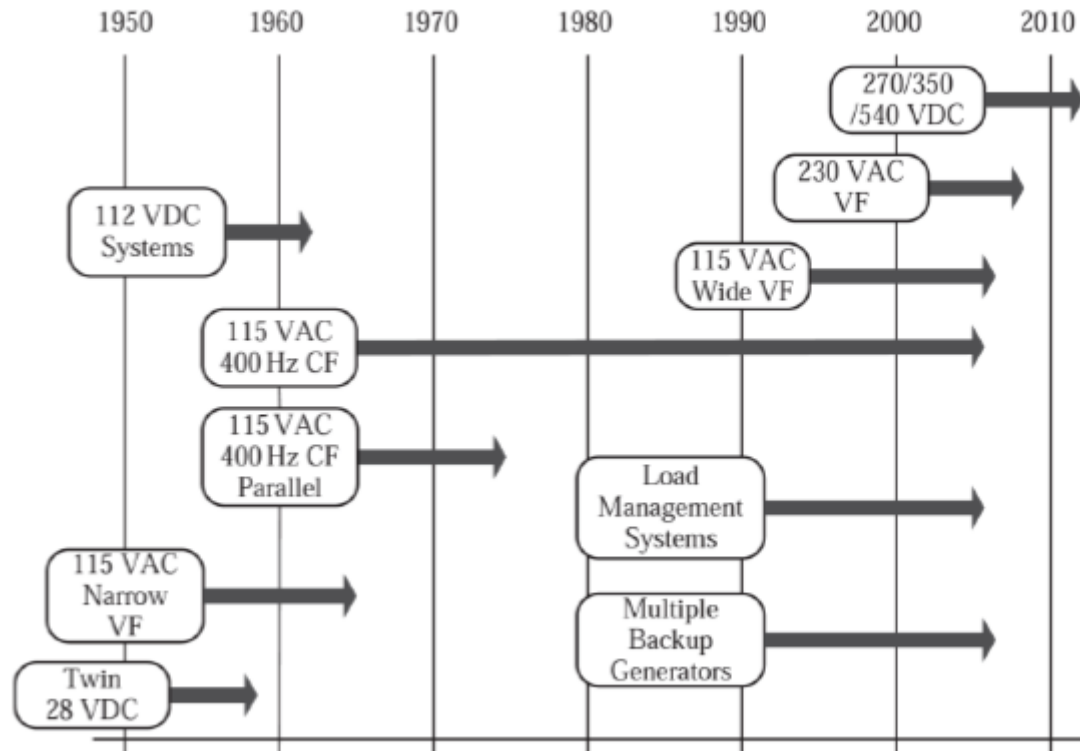
- Electrical systems have made significant advances over the years as aircraft have become more dependent upon electrically powered services.
- A typical electrical power system of the 1940s and 1950s was the twin 28 VDC system.
- This system was used a great deal on twin engined aircraft; each engine powered a 28 VDC generator which could employ load sharing with its contemporary if required.



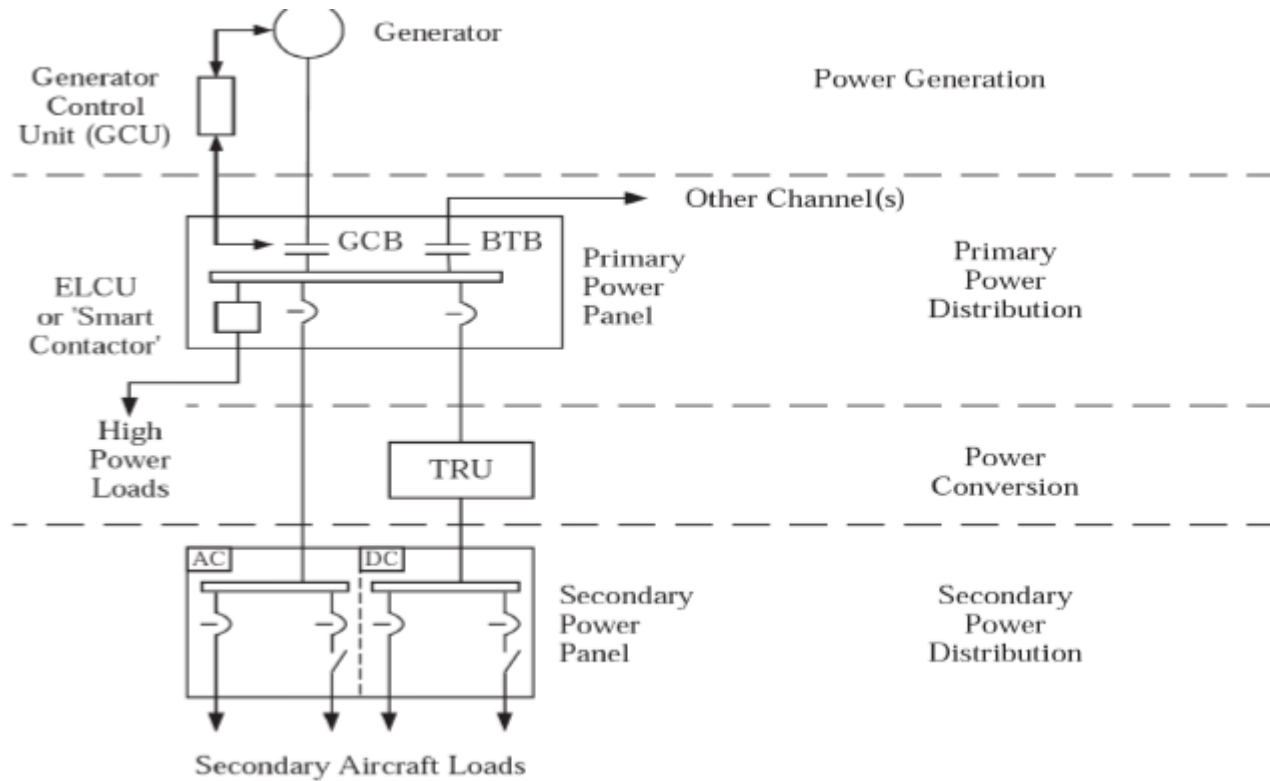
- Later aircraft were fitted with four 115 VAC generators, one being driven by each engine.
- To provide the advantages of no-break power these generators were paralleled which increased the amount of control and protection circuitry.
- 
- The generators work with the specification of 115 VAC 400 Hz.
- Recently the variable frequency generators are fitted in modern aircraft.

- The advances in high power solid state switching technology together with enhancements in the necessary control electronics have made variable speed / constant frequency (VSCF) systems a viable proposition in the last decade.
- The VSCF system removed the unreliable CSD portion; the variable frequency or frequency wild power from the AC generator being converted to 400 Hz constant frequency 115 VAC power by means of a solid state VSCF converter.

# EVOLUTION OF ELECTRICAL POWER SYSTEM



# AIRCRAFT ELECTRICAL SYSTEM



# POWER GENERATION AND CONTROL

- The primary elements of power system control are:

DC systems

- Voltage regulation
- Parallel operation
- Protection functions

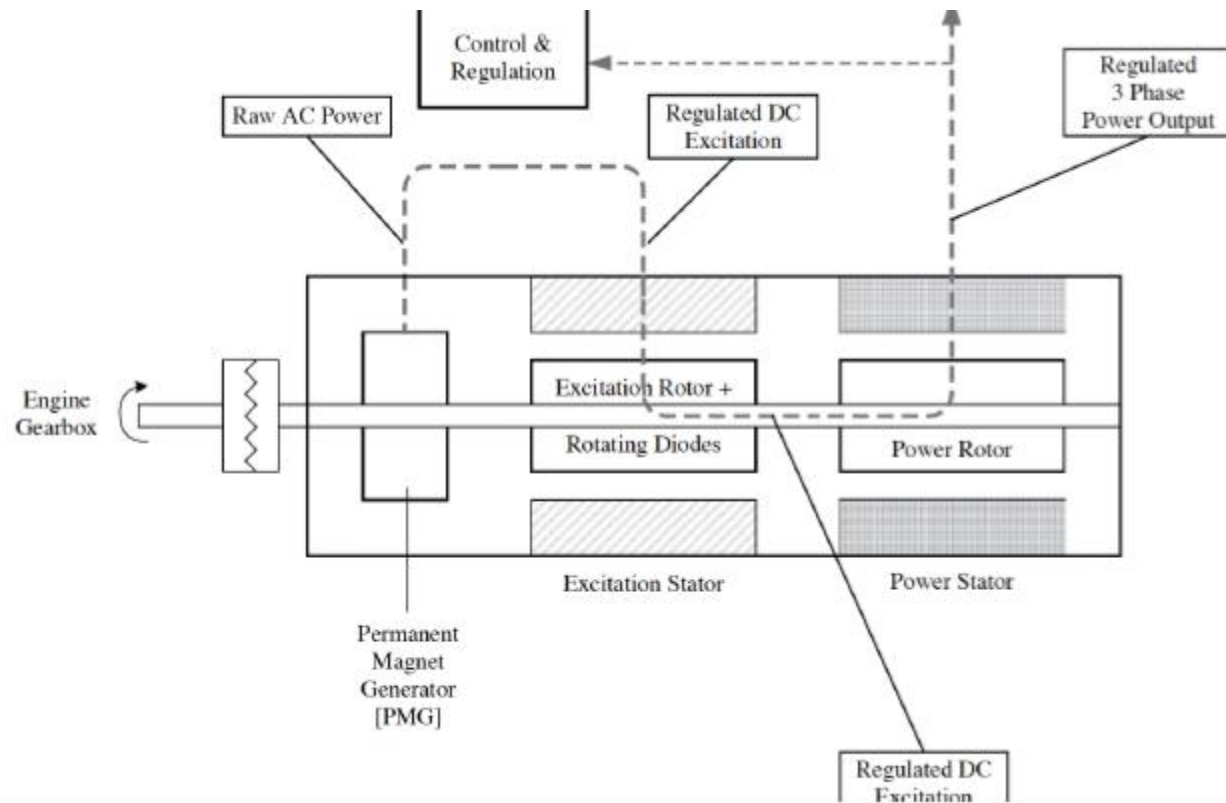
AC systems

- Voltage regulation
- Parallel operation
- Supervisory functions

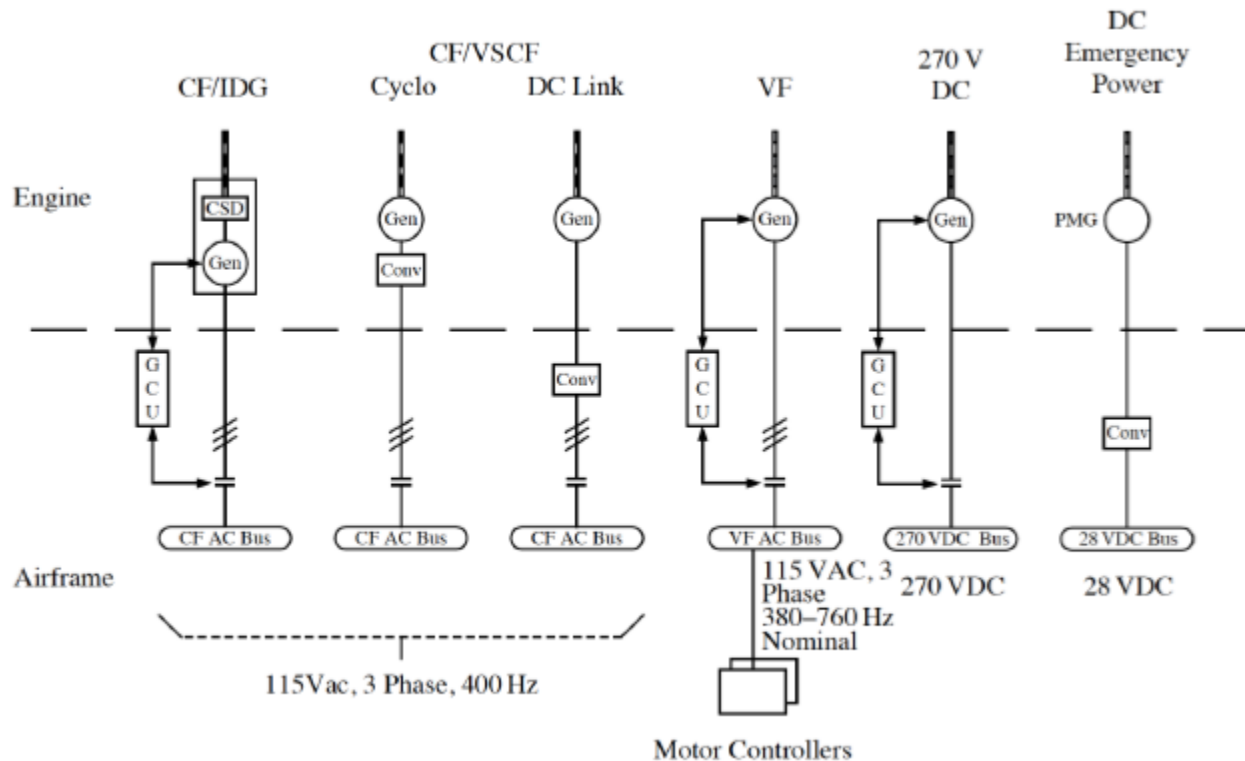
# AIRCRAFT ELECTRICAL SYSTEM

- Power generation
- Primary power distribution and protection
- Power conversion and energy storage
- Secondary power distribution and protection

# AC GENERATORS

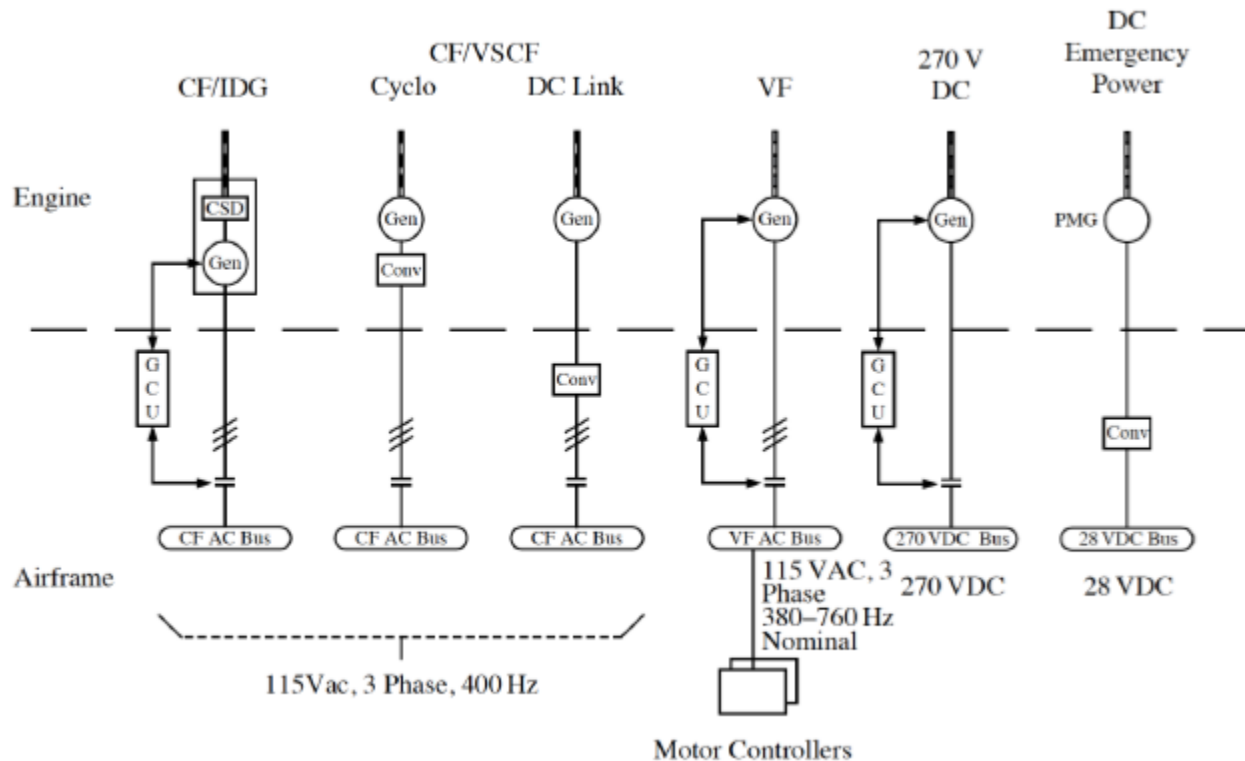


# TYPES OF GENERATION

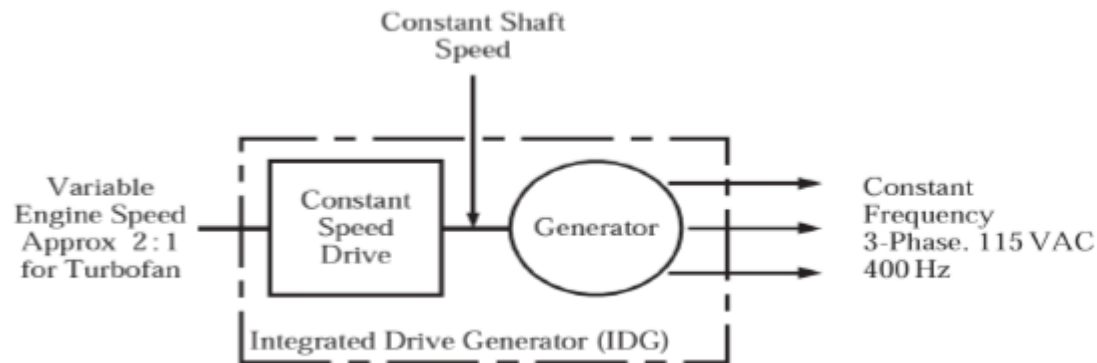




# TYPES OF GENERATION



# CONSTANT FREQUENCY SYSTEM



## Features:

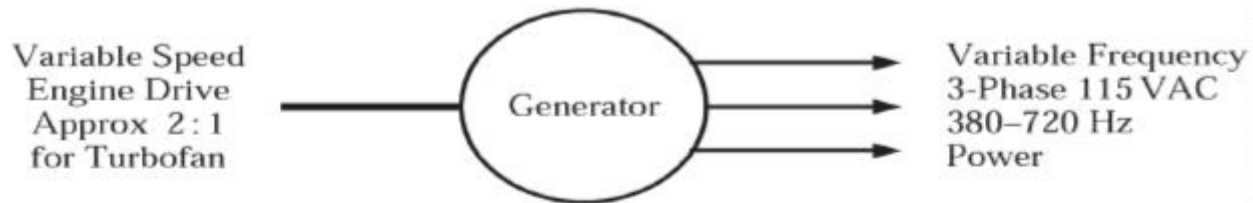
Constant frequency AC power is most commonly used on turbofan aircraft today

System is expensive to purchase & maintain; primarily due to complexity of Constant Speed Drive (CSD)

Single company monopoly on supply of CSD/IDG

Alternate methods of power generation are under consideration

# VARIABLE FREQUENCY SYSTEM



## Features:

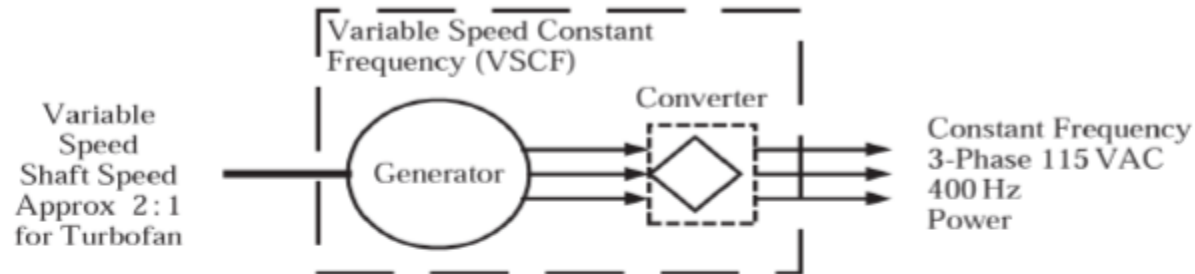
Simplest form of generating power, cheapest and most reliable

Variable frequency has impact upon other aircraft subsystems

Motor controllers may be needed for certain aircraft loads

Beginning to be adopted for new programmes: gains outweigh disadvantages

# VARIABLE SPEED CONSTANT FREQUENCY SYSTEM



## Features:

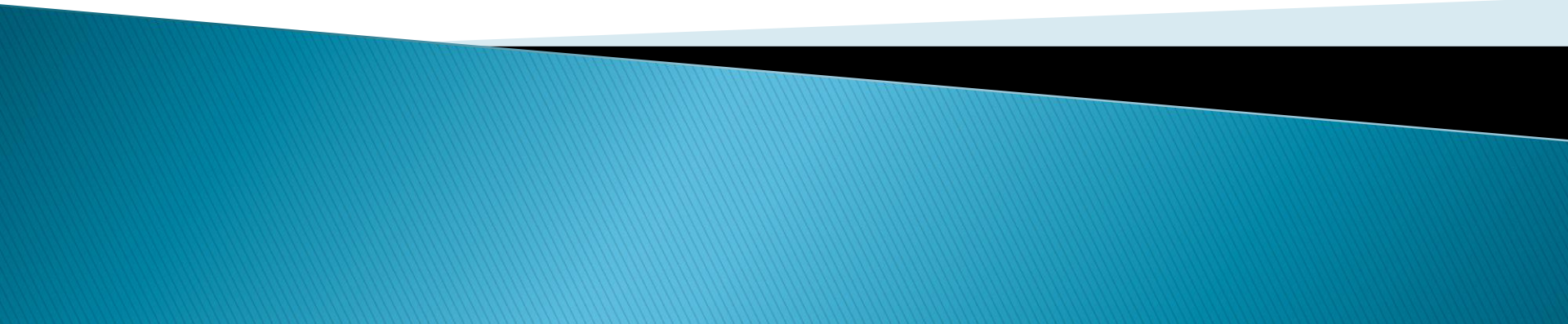
Conversion of VF electrical power to CF is accomplished by electronic controlled power switching

DC Link & Cycloconverter options available

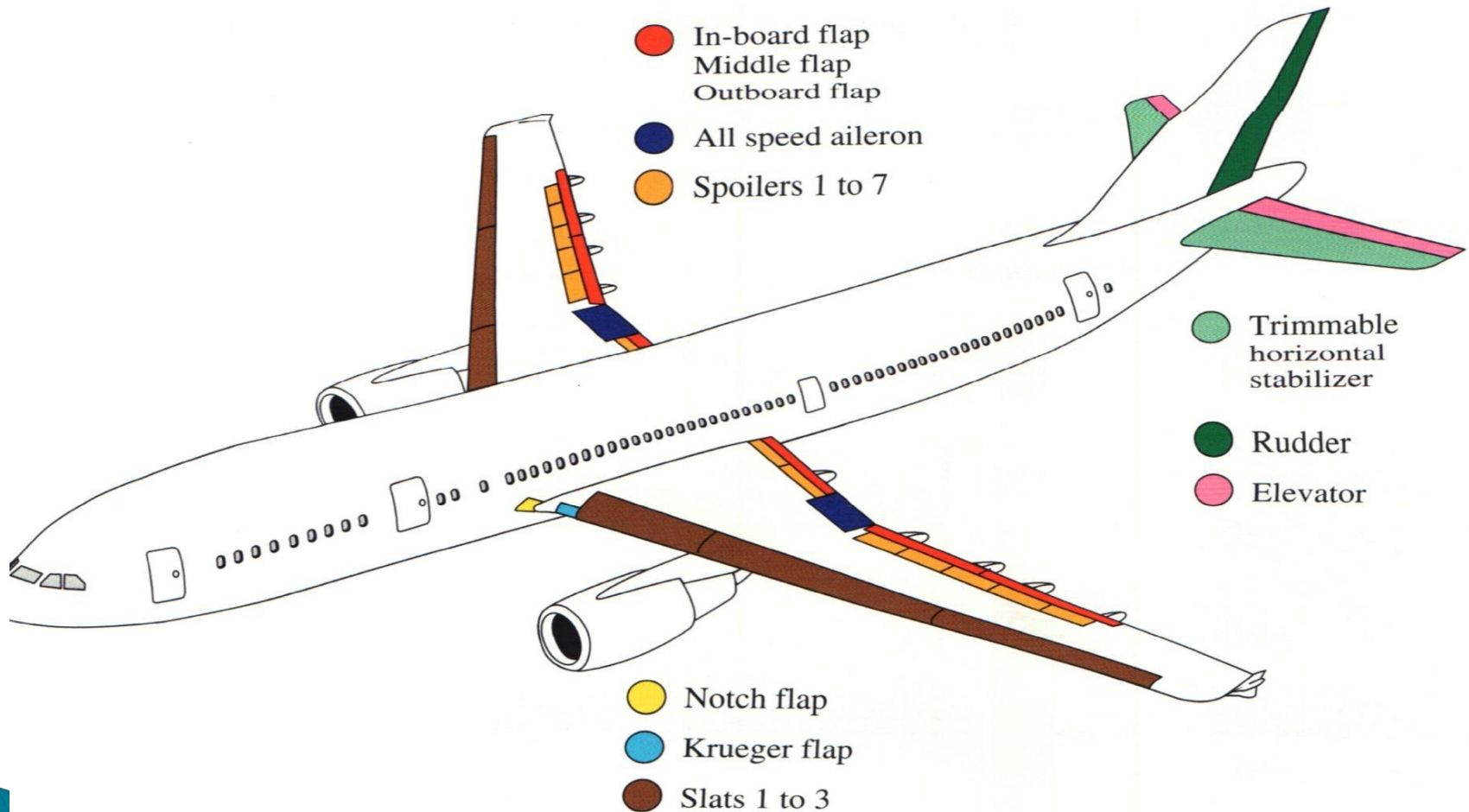
Not all implementations have proved to be robust/reliable - Cycloconverter shows most promise

Still unproven in transport market

# Flight control systems

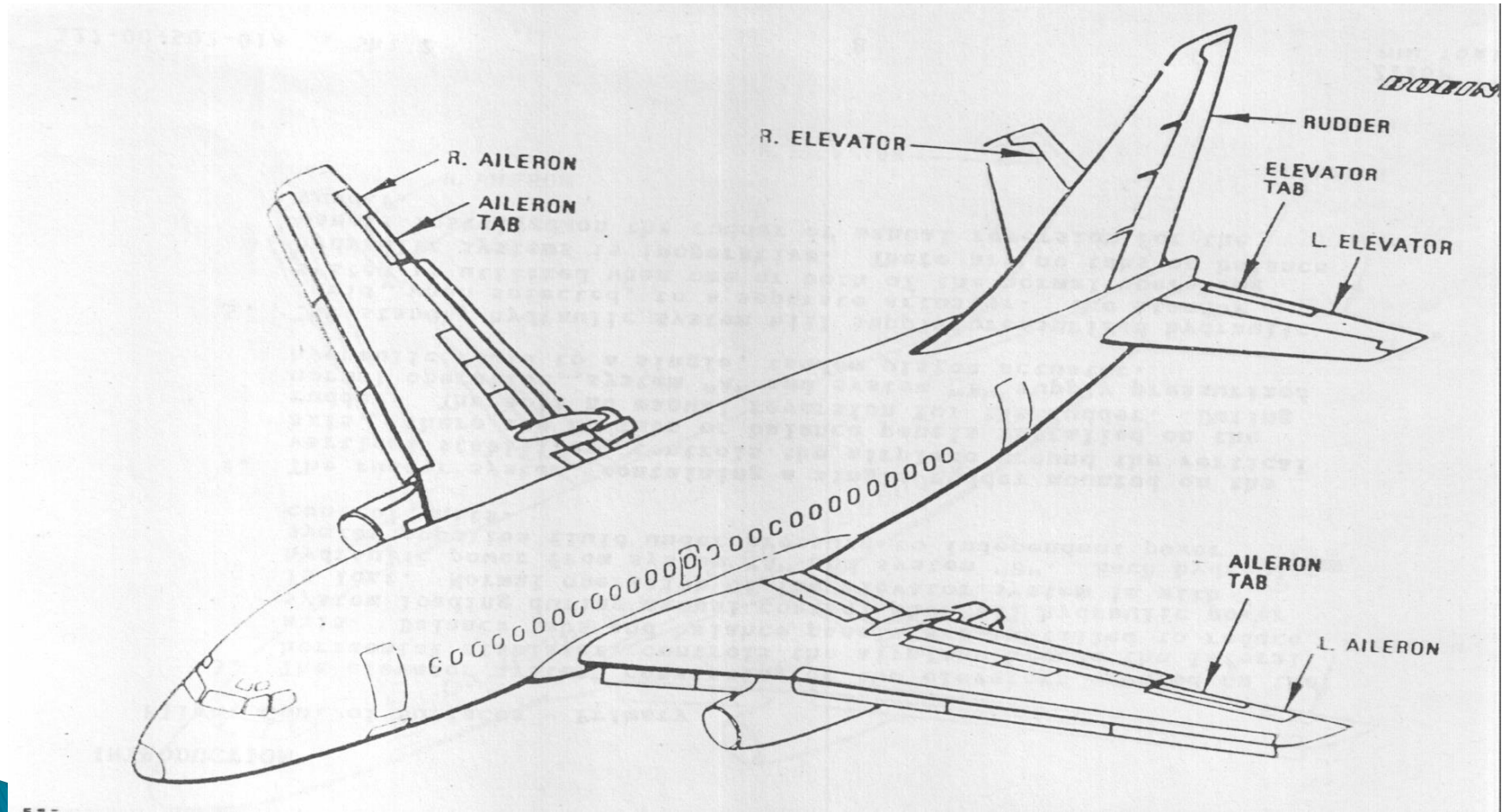


# FLIGHT CONTROLS





# PRIMARY FLIGHT CONTROLS



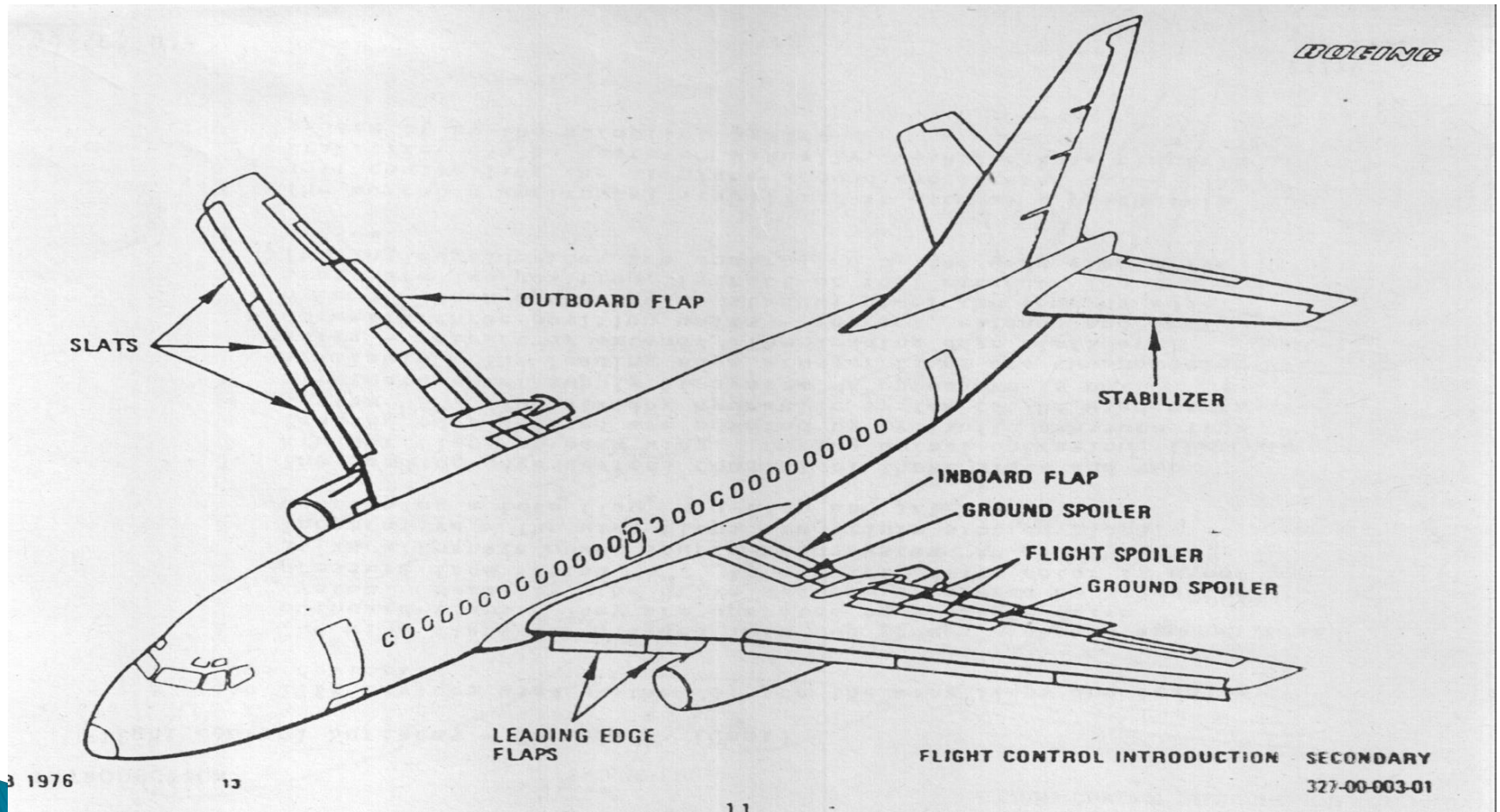
- **Pitch control** is exercised by four elevators located on the trailing edge of the tail plane (or horizontal stabilizer in US parlance).

- Each elevator section is independently powered by a dedicated flight control actuator, powered in turn by one of several aircraft hydraulic power systems.

- **Roll control** is provided by two aileron sections located on the outboard third of the trailing edge of each wing.



# SECONDARY FLIGHT CONTROLS



- **Flap control** is effected by several flap sections located on the inboard two thirds of the wing trailing edges.
- Deployment of the flaps during take-off or landing extends the flap sections rearwards and downwards to increase wing area and camber, thereby greatly increasing lift for a given speed.
- The number of flap sections may vary from type to type; typically for this size of aircraft there would be about five per wing.

- **Slat control** is provided by several leading edge slats which extend forwards and outwards from the wing leading edge.
- In a similar fashion to the flaps described above, this has the effect of increasing wing area and camber and therefore overall lift.
- A typical aircraft may have five slat sections per wing, giving a total of ten in all.

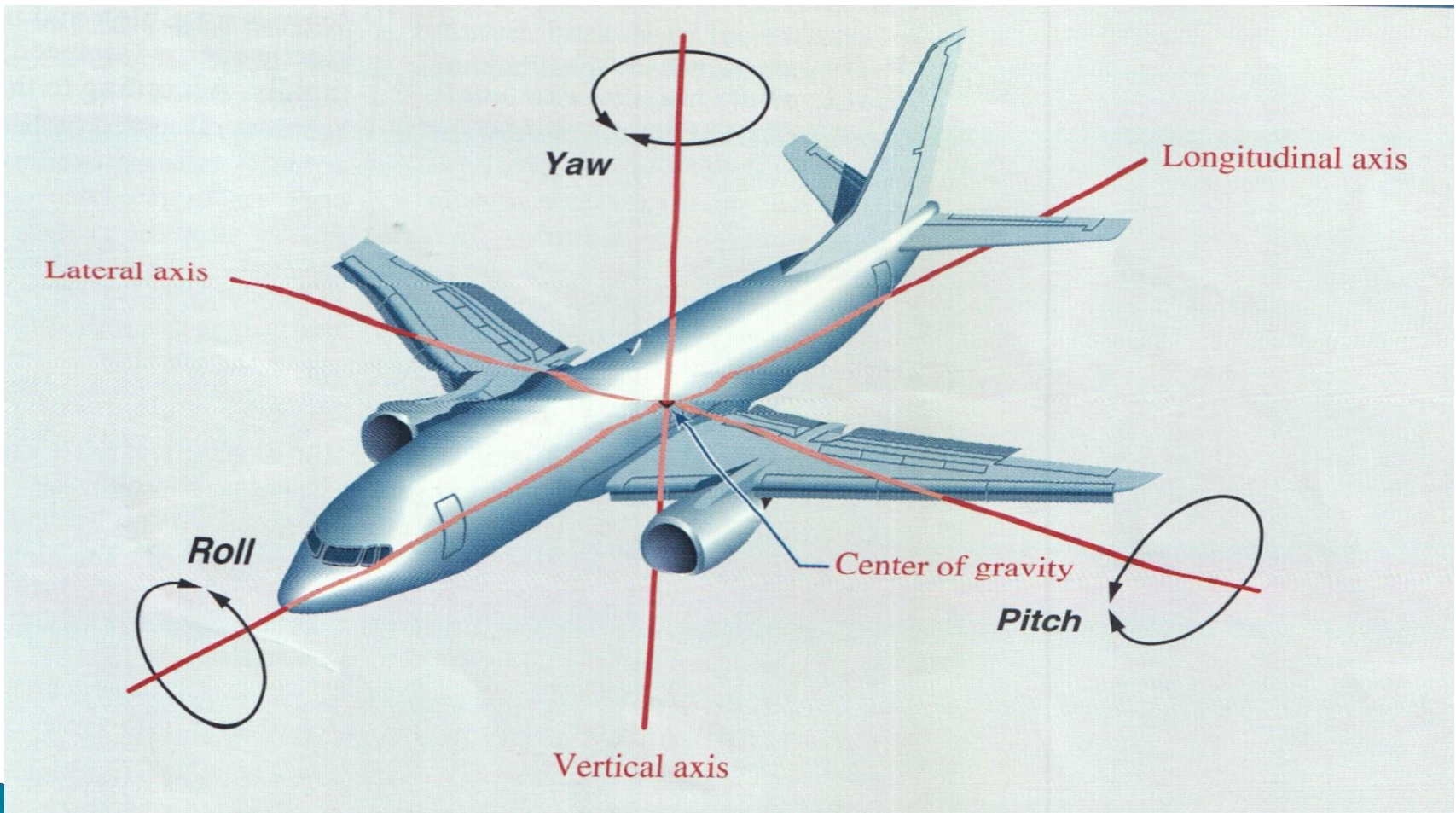
- The effect is similar to the use of air-brakes in the fighter, increasing drag so that the pilot may adjust his airspeed rapidly; most airbrakes are located on rear fuselage upper or lower sections and may have a pitch moment associated with their deployment.

In most cases compensation for this pitch moment would be automatically applied within the flight control system

- **Speed-brakes** are deployed when all of the over-wing spoilers are extended together which has the effect of reducing lift as well as increasing drag.



# THREE AXES

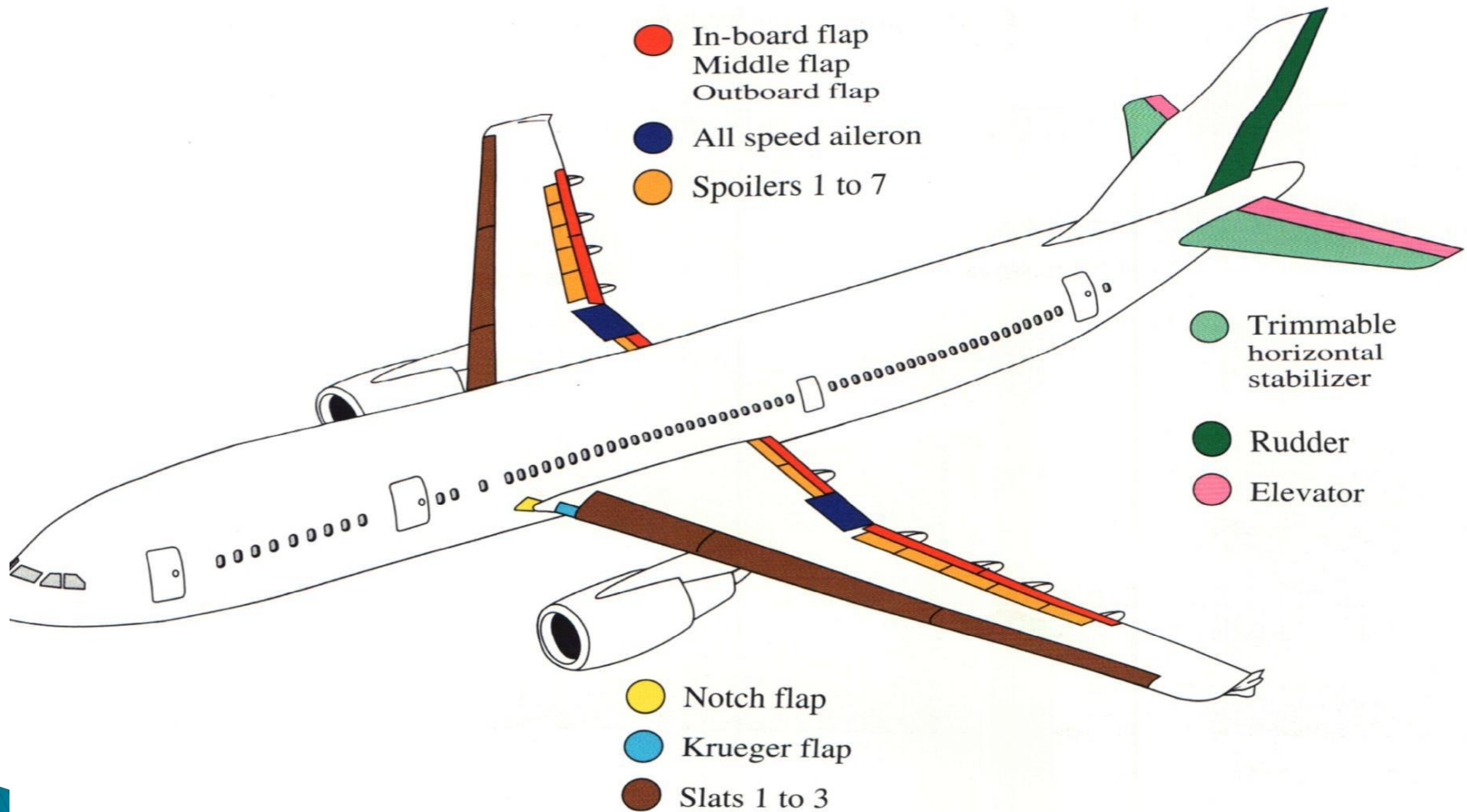


# Principles of Flight Control

- All aircraft are governed by the same basic principles of flight control, whether the vehicle is the most sophisticated high-performance fighter or the simplest model aircraft.
- The motion of an aircraft is defined in relation to translational motion and rotational motion around a fixed set of defined axes. Translational motion is that by which a vehicle travels from one point to another in space.
- For an orthodox aircraft the direction in which translational motion occurs is in the direction in which the aircraft is flying, which is also the direction in which it is pointing.

- The rotational motion relates to the motion of the aircraft around three defined axes: pitch, roll and yaw.
- In most fixed wing aircraft, if the pilot wishes to alter the aircraft heading then he will need to execute a turn to align the aircraft with the new heading.
- During a turn the aircraft wings are rotated around the roll axis ( $Oy$ ) until a certain bank is attained. In a properly balanced turn the angle of roll when maintained will result in an accompanying change of heading while the roll angle (often called the bank angle) is maintained. This change in heading is actually a rotation around the yaw axis ( $Oz$ ).

# FLIGHT CONTROLS





# FLIGHT CONTROL LINKAGE SYSTEM

The pilot's manual inputs to the flight controls are made by moving the cockpit control column or rudder pedals in accordance with the universal convention:

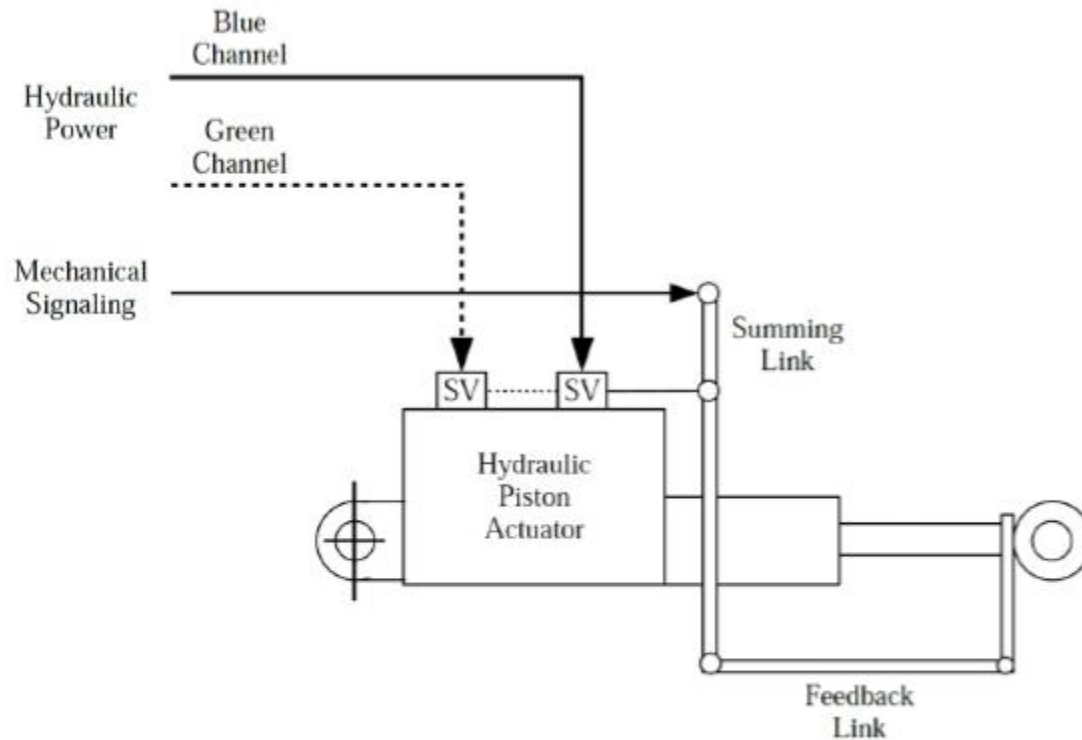
- Pitch control is exercised by moving the control column fore and aft
- Roll control is achieved by moving the control column from side to side

- Yaw is controlled by the rudder pedals; pushing the left pedal will yaw the aircraft to the left while pushing the right pedal will have the reverse effect
- There are presently two main methods of connecting the pilot's controls to the rest of the flight control system.
  - These are:
    - Push-pull control rod systems
    - Cable and pulley systems

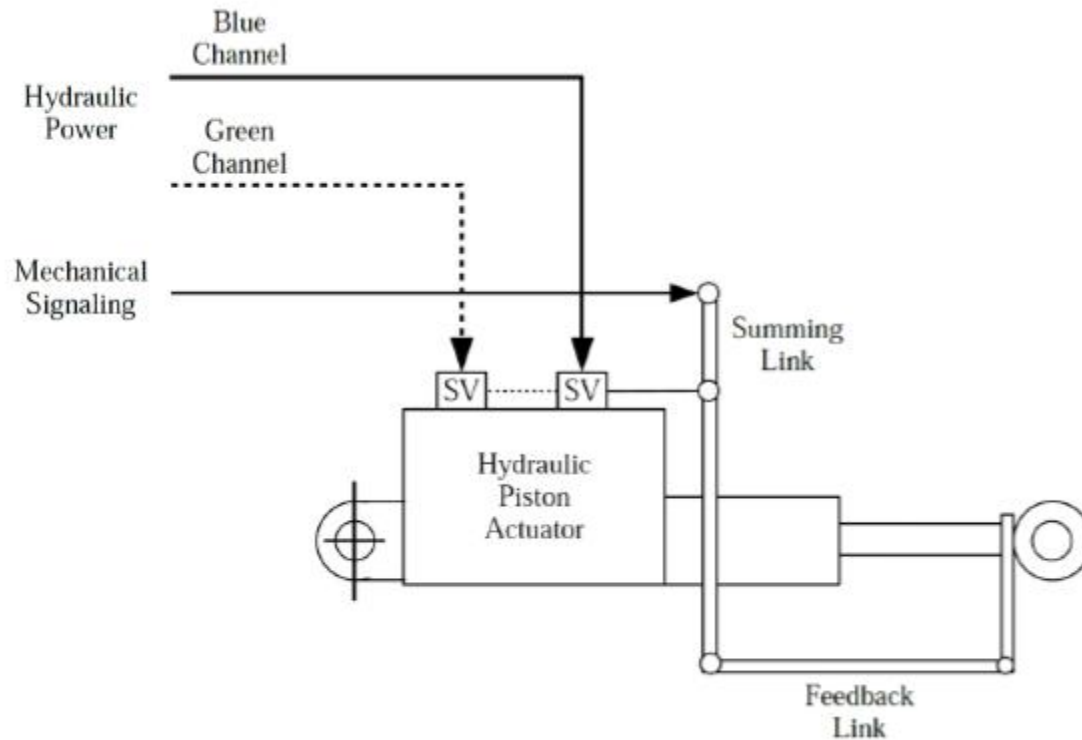
# ACTUATORS

- Addressing actuation in ascending order of complexity leads to the following categories:
- Simple mechanical actuation, hydraulically powered
- Mechanical actuation with simple electromechanical features
- Multiple redundant electromechanical actuation with analogue control inputs and feedback

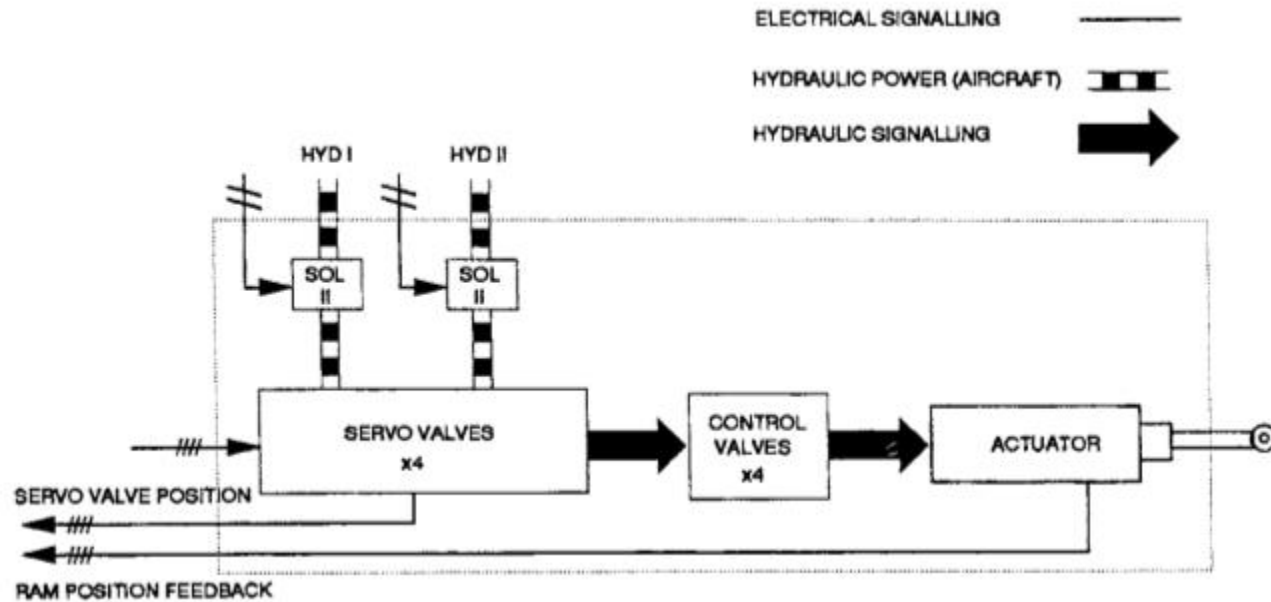
# CONVENTIONAL LINEAR ACTUATOR



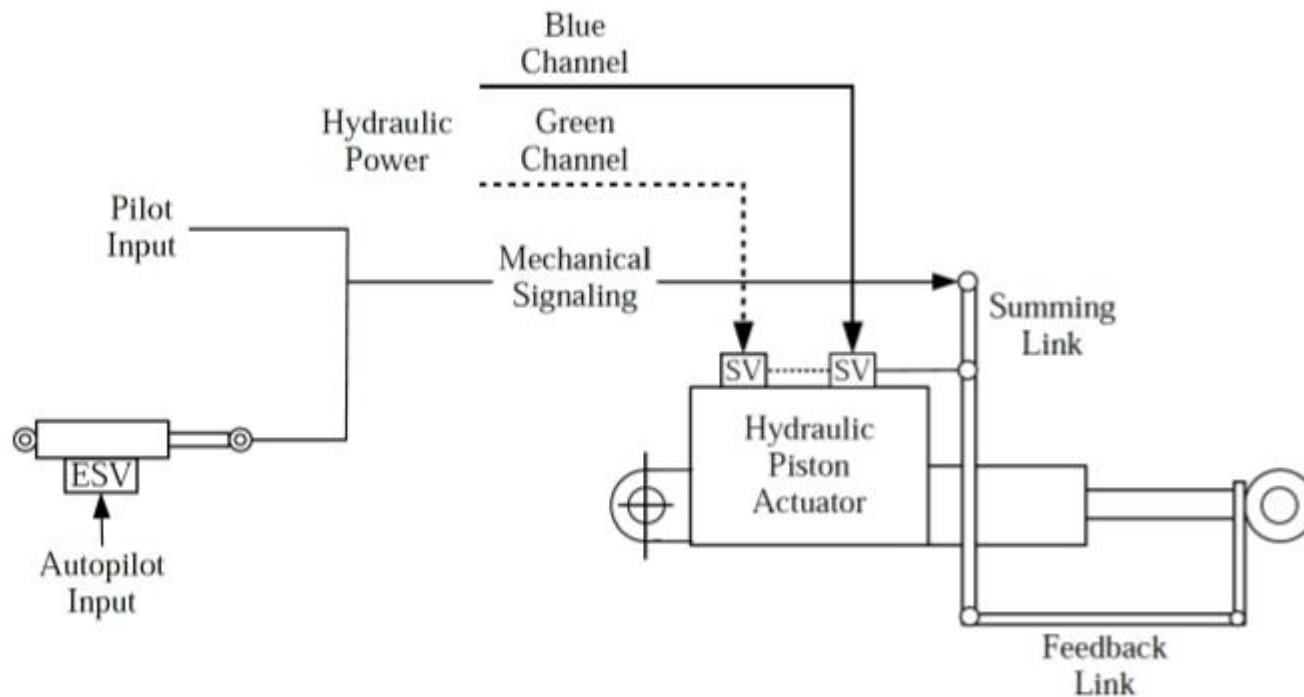
# CONVENTIONAL LINEAR ACTUATOR



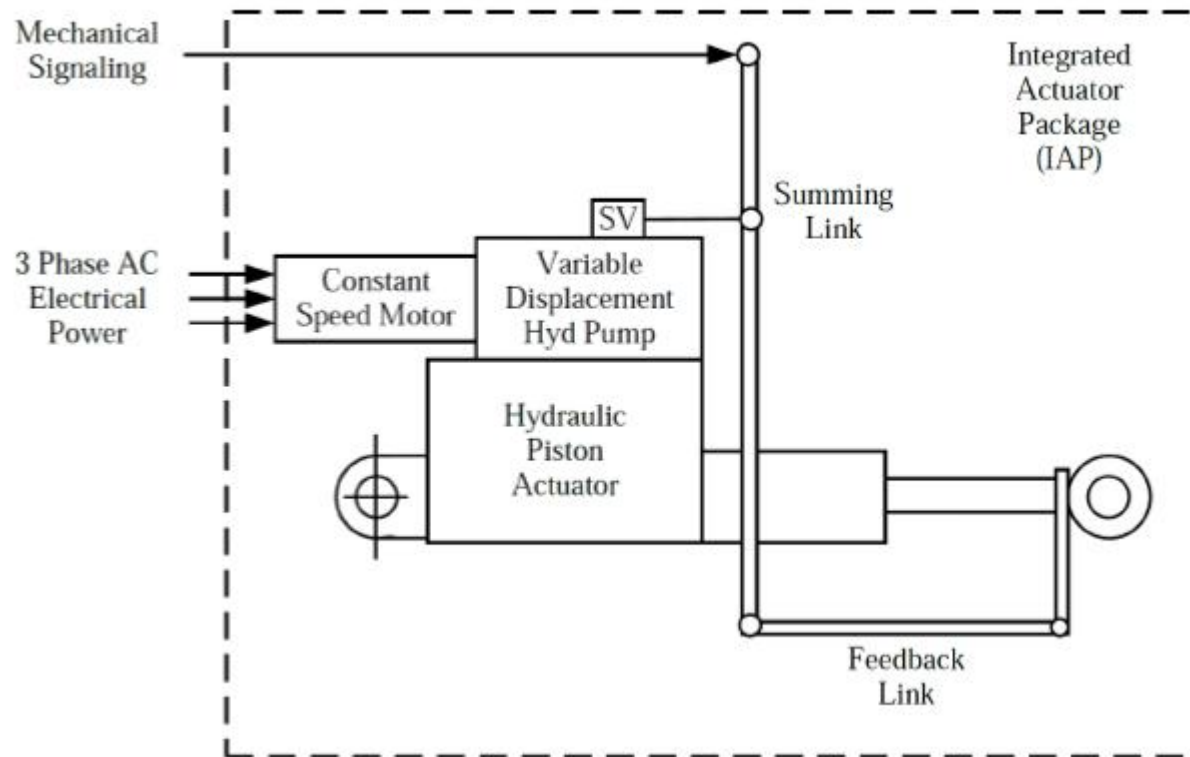
# MULTIPLE REDUNDANT ELECTRIC SIGNALLED ACTUATOR



# MECHANICAL ACTUATOR WITH ELECTRIC SIGNALLING



# INTEGRATED ACTUATOR

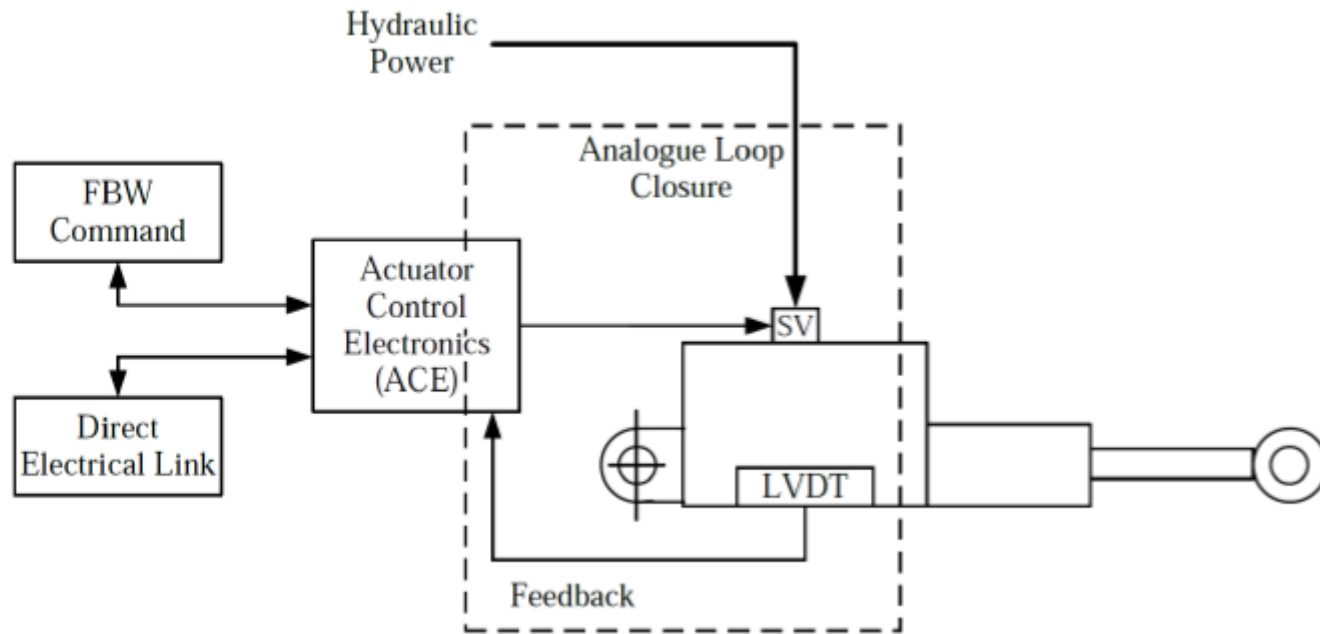




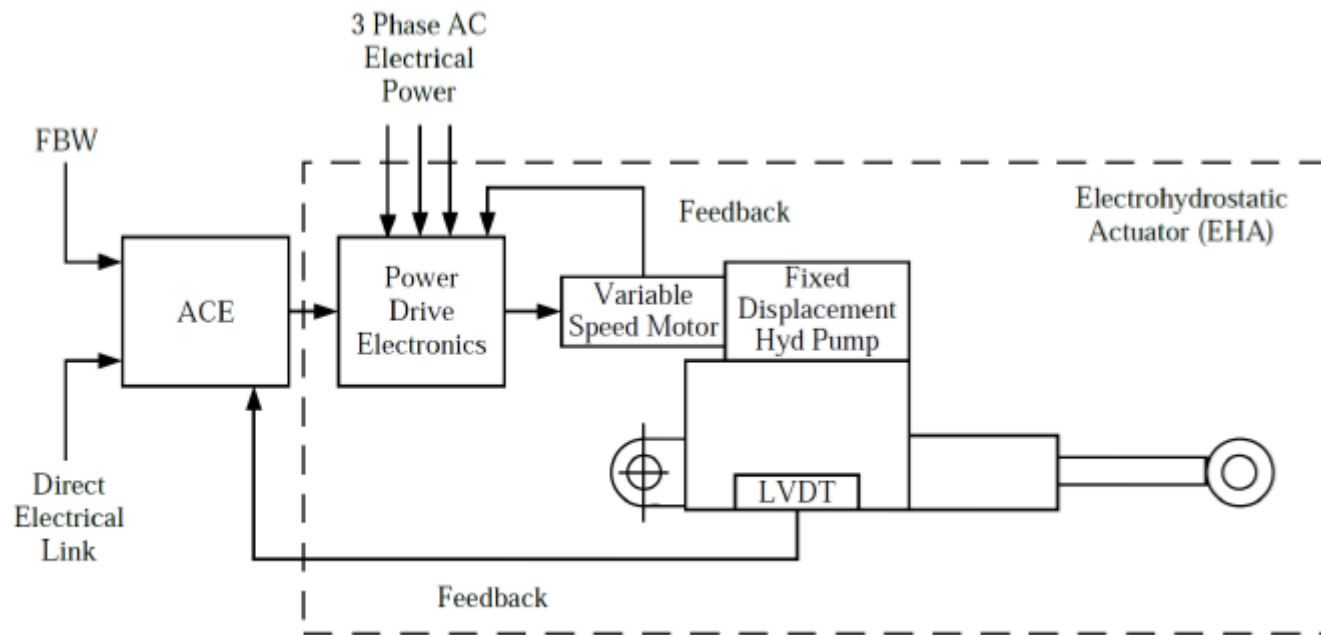
# ACTUATOR IMPLEMENTATIONS

- Direct drive actuation
- Fly-by-Wire (FBW) actuation
- Electro-Hydrostatic Actuator (EHA)
- Electro-Mechanical Actuator (EMA)

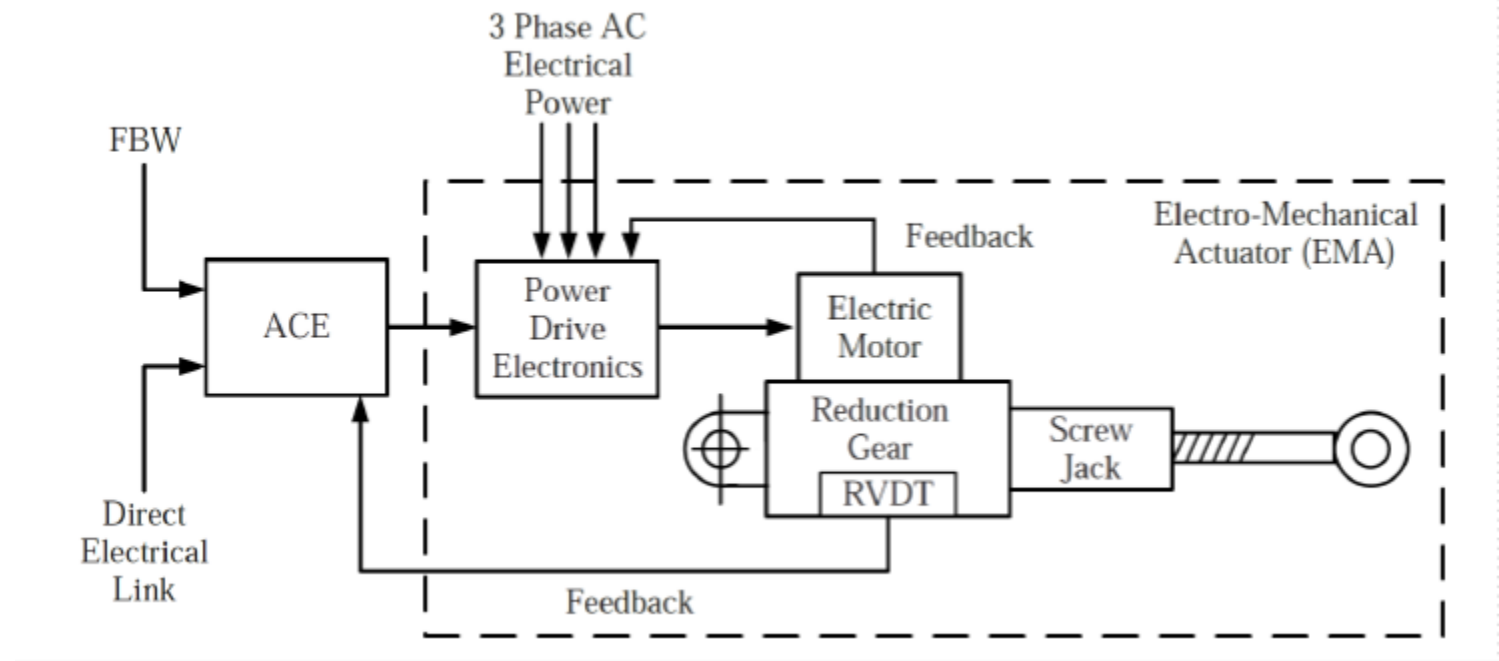
# FLY BY WIRE ACTUATOR



# ELECTRO HYDROSTATIC ACTUATOR



# ELECTROMECHANICAL ACTUATOR



# **UNIT - 3**

## **HYDRAULIC SYSTEMS**

# HYDRAULICS INTRODUCTION

- Hydraulics is a method of transmitting power through pipes and control devices, using liquid as the operating medium.
- For certain applications hydraulic systems are used in preference to mechanical or electrical systems

- Hydraulic systems made their appearance on aircraft in the early 1930s when the retractable undercarriage was introduced.
- Since that time, an increasing number of tasks have been performed by the application of hydraulic power and the power demand has consequently increased greatly.
- Hydraulic power was seen as an efficient means of transferring power from small low energy movements in the cockpit to high energy demands in the aircraft.

- Hydraulic systems now have an important role to play in all modern aircraft, both military and civil.
- The introduction of powered flying controls was an obvious application for hydraulic power by which the pilot was able to move the control surfaces with every increasing speeds and demands for maneuverability.
- This application brought hydraulics in the area of safety critical systems in which single failures could not be allowed to hazard the aircraft.



- The system developed to take account of this using multiple pumps, accumulators to store energy and methods of isolating leaks.
- The hydraulic system today remains a most effective source of power for both primary and secondary flying controls, and for undercarriage, braking and anti-skid systems.
- However, now a days, more-electric systems are being considered to replace hydraulically powered systems in some areas.

# HYDRAULICS APPLICATIONS

## ☐ Primary Flight Controls:

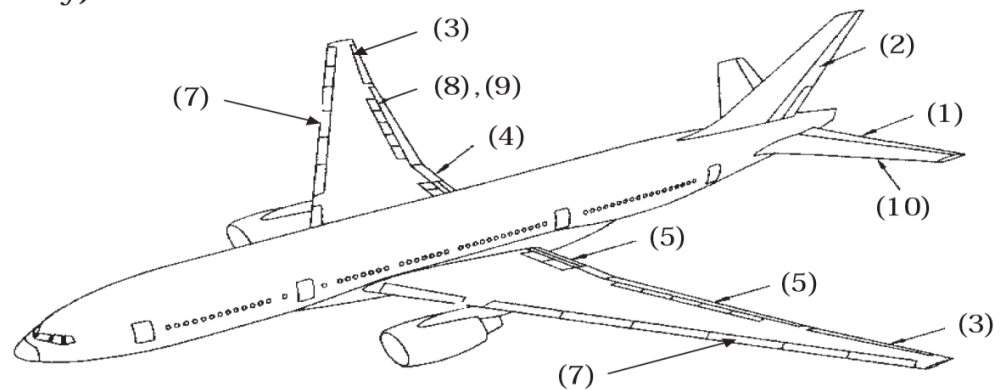
- -Elevators – (1)
- -All-moving tail surfaces (military)
- -Rudders – (2)
- -Ailerons – (3)
- -Flaperons – (4)
- -Canards

## ☐ Secondary Flight Controls

- -Flaps – (5)
- -Slats – (7)
- -Spoilers – (8)
- -Airbrakes – (9)
- -Stabilizer trim – (10)

## ☐ Utilities

- -Landing gear
- -Brakes
- -Gear steering
- -Aerial refueling probes (military)
- -Cargo doors
- -Loading ramp (military)
- -Passenger stairs



## Primary flight controls:

- Elevators
- Rudders
- Ailerons

## Secondary flight controls:

- Flaps
- Slats
- Spoilers
- Airbrakes

## Utility systems:

- Undercarriage – gear and doors
- Wheel brakes and anti-skid
- Parking brake
- Nose wheel steering
- In-flight refueling probe
- Cargo doors
- Loading ramp
- Passenger stairs
- Gun purging scoop
- Canopy Actuation

# NUMBER AND TYPE OF HYDRAULIC SYSTEMS

A source of energy – engine, auxiliary power unit or ram air turbine

- A reservoir
- A filter to maintain clean hydraulic fluid
- A multiple redundant distribution system – pipes, valves
- Pressure and temperature sensors
- A mechanism for hydraulic oil cooling
- A means of exercising demand – actuators, motors, pumps
- A means of storing energy such as an accumulator
- A means of exercising demand – actuators, motors pumps
- A means of storing energy such as an accumulator

# ADVANTAGES OF HYDRAULICS

- Ease of application of force
- Ability to increase the applied force as necessary
- Ease of routing of pipelines and
- Elimination of backlash between components.
- Incompressibility, enables movement to be transmitted through pipelines, over great distances, without loss of time or motion.

# HYDRAULICS

- Friction increases with any increases in viscosity or velocity of the liquid, results in power into heat, and in a reduction in pressure throughout the pipelines.
- Any restriction in a pipeline will increase liquid velocity and reduced pressure.
- A restrictor is used to limit the rate of liquid flow, and thus the rate of movement of components such as the landing gear or flaps.

# HYDRAULIC FLUIDS

Almost any sort of liquid could be used in a hydraulic system, but the special requirements of aircraft systems have resulted in the use of

- Vegetable oil,
- mineral oil and
- synthetic-based oil



# HYDRAULIC FLUID PROPERTIES

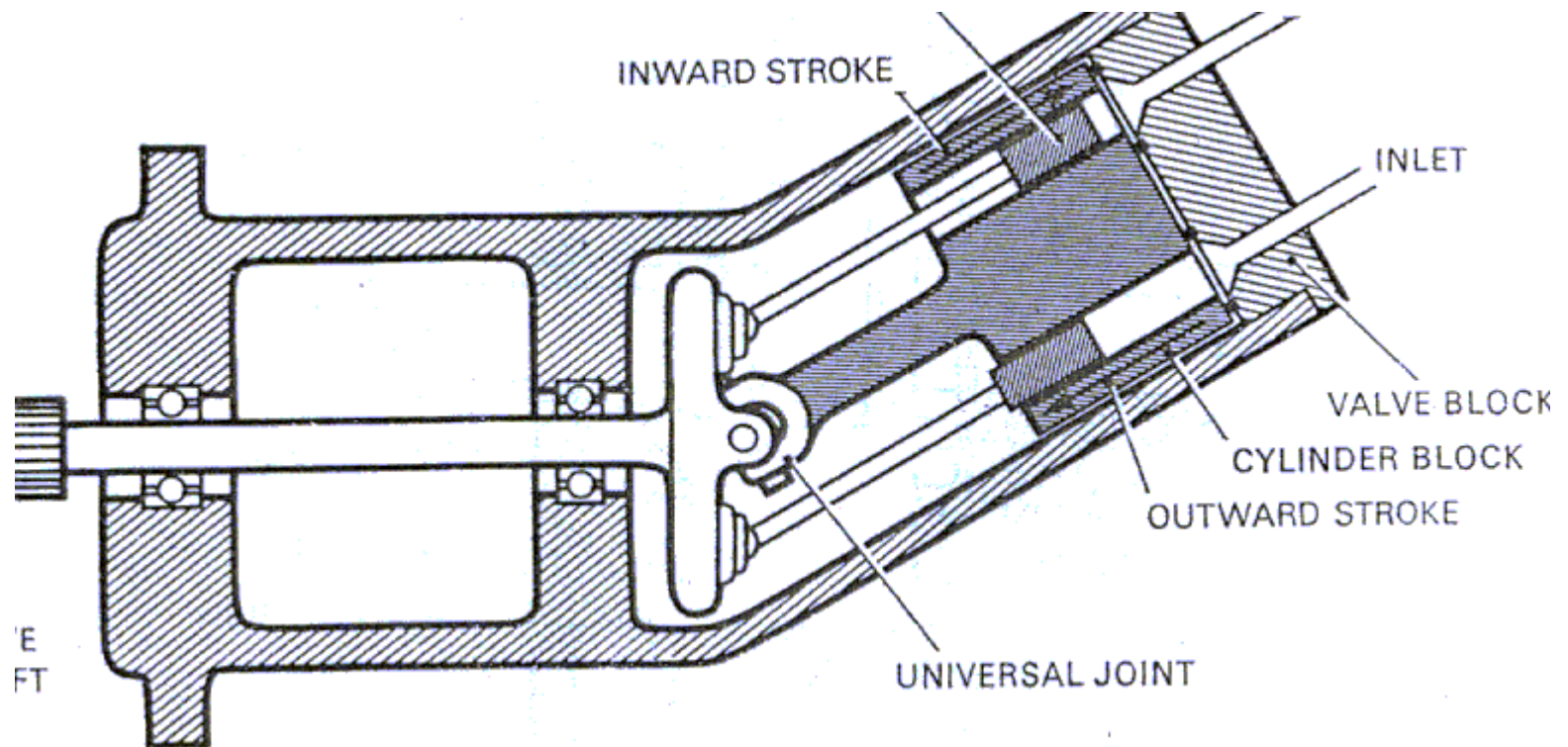
- Good lubrication of components.
- Viscosity is low enough to minimize friction , but high enough to prevent leakage from components.
- Prevents internal corrosion in the system.
- Wide operating-temperature range.

# PUMPS

- Fixed volume or variable volume, multi-piston type hydraulic pumps, driven from the engines.
- Gear or vane positive displacement pumps, are generally used for powering emergency systems.
- Hand pumps, where fitted, are often of the double-acting type.

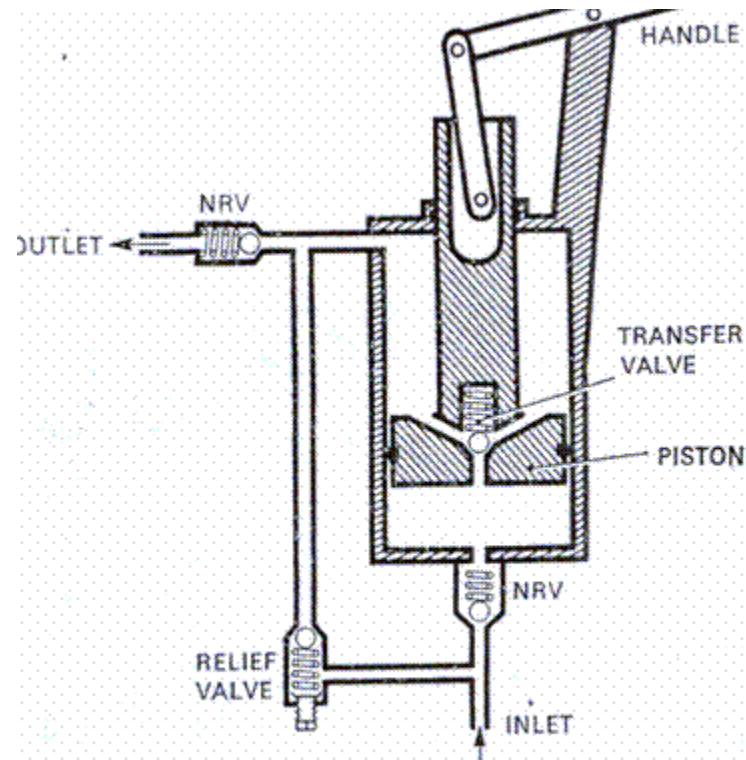
# FIXED VOLUME PUMPS

- Deliver a fixed quantity of fluid into the system at a particular speed of rotation, regardless of system requirements,
- Diverting pump output when it is not required in the system.



# HAND PUMPS

- Used for emergency use & ground servicing operations.
- DOUBLE-ACTING HAND PUMP Delivers fluid on each stroke.



DOUBLE-ACTING HAND PUMP

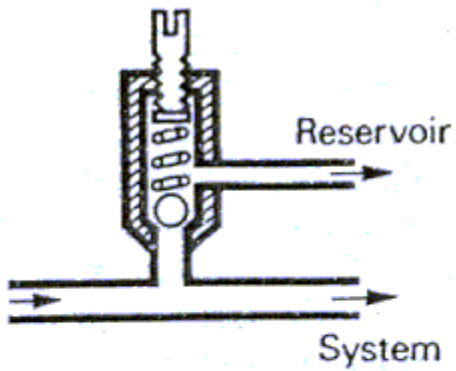
# PRESSURE CONTROL

Maximum system pressure is often controlled by adjustment of the main engine-driven pump, but a number of other components are used to maintain or limit fluid pressures in various parts of a hydraulic system, and these sometimes have additional functions.

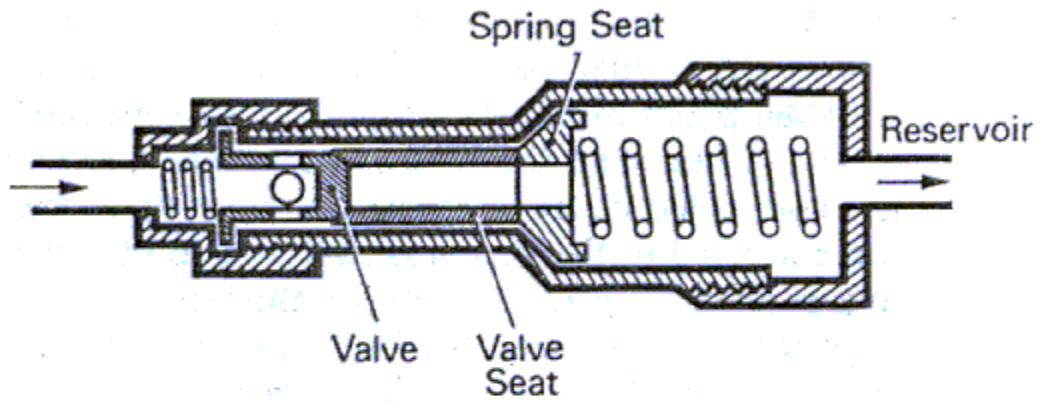
# RELIEF VALVES

- Simplest form of pressure limiting device.
- Used as a safety device, e.g. a thermal relief valve, in which case it is adjusted to blow-off at a pressure slightly higher than normal system pressure, relieves a small quantity of fluid.
- In a full-flow relief valve to by-pass full pump output to the reservoir in the event of failure of the cut-out valve, or of blockage elsewhere in the system.





BALL-TYPE RELIEF VALVE



FULL-FLOW RELIEF VALVE

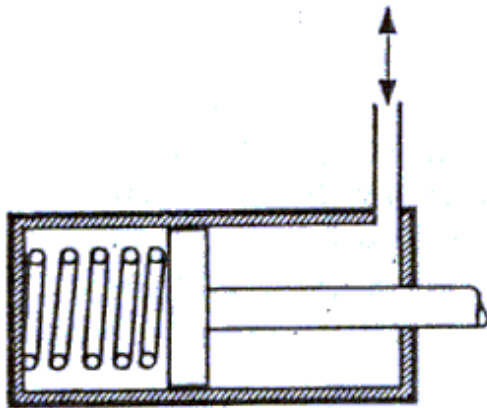
## RELIEF VALVES

# ACCUMULATORS

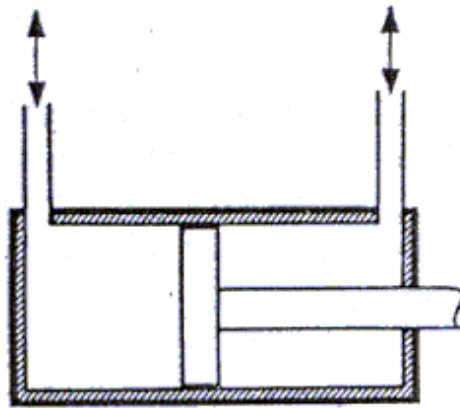
- To store hydraulic fluid under pressure, to dampen pressure fluctuations, to allow for thermal expansion, and to provide an emergency supply of fluid to the system in the event of pump failure.
- A non-return valve fitted upstream of an accumulator, prevents fluid from being discharged back to the reservoir.

# RESERVOIRS

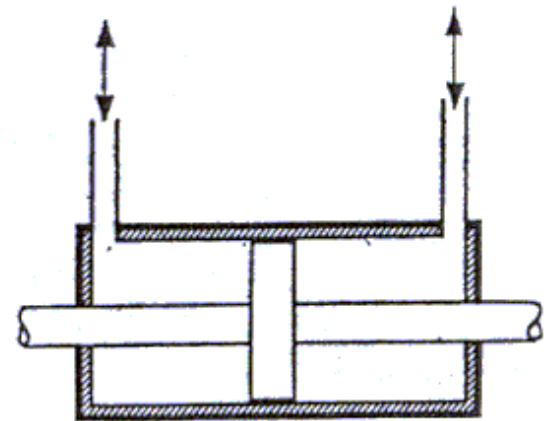
- Provides both storage space for the system fluid, and sufficient air space to allow for any variations in the volume of fluid.
- Most reservoirs are pressurized, to provide a positive fluid pressure at the pump inlet, and to prevent air bubbles from forming in the fluid at high altitude.
- On modern jet aircraft, air pressure is normally supplied from the compressor section of an engine, but it may be supplied from the cabin pressurization system.



SINGLE-ACTING



DOUBLE-ACTING



BALANCED

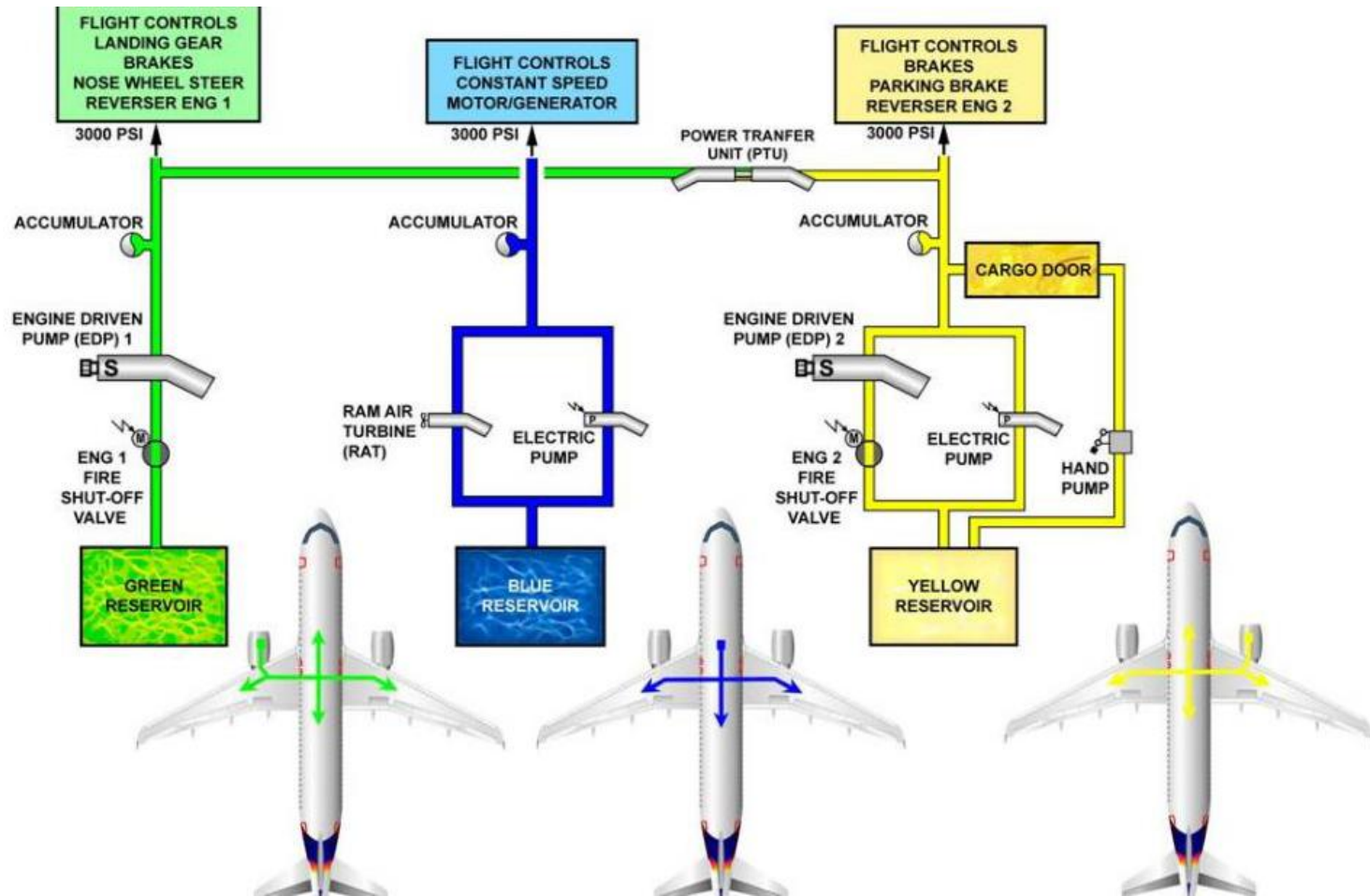
## ACTUATORS

# HYDRAULICS

- The primary source of power on an aircraft is the engine, and the hydraulic pump is connected to the engine gearbox.
- The pump causes a flow of fluid at a certain pressure, through stainless steel pipes to various actuating devices.
- A reservoir ensures that sufficient fluid is available under all conditions of demand.
- This simple system is unlikely to satisfy the condition stated above, and in practice most aircraft contain multiple pumps and connections of pipes to ensure that single failures and leaks do not deplete the whole system of power.

- The working fluid will be considered as a physical medium for transmitting power, and the conditions under which it is expected to work, for example maximum temperature and maximum flow rate are described.
- Safety regulations bring about some differences between military and civil aircraft fluids.

# A 320 HYDRAULIC SYSTEM



# LANDING GEAR

- The landing gear is the structure that supports an aircraft on the ground and allows it to taxi, take-off, and land .
- The landing gear usually includes wheels, but some aircraft are equipped with skids for snow or float for water .
- In the case of a vertical take-off and landing aircraft such as a helicopter, wheels may be replaced with skids



The primary functions of a landing gear are as follows:

- 1. To keep the aircraft stable on the ground and during loading, unloading, and taxi .
- 2. To allow the aircraft to freely move and maneuver during taxing .
- 3. To provide a safe distance between other aircraft components such as wing and fuselage while the aircraft is on the ground position to prevent any damage by the ground contact .

# Landing Gear Configuration

In general, there are ten configurations for a landing gear as follows:

- Bicycle
- Tail-gear
- Tricycle or nose-gear
- Quadricycle
- Multi-bogey
- Releasable rail
- Skid
- Seaplane landing device
- Single main
- Human leg

## Single Main

- The simplest configuration of landing gear is the single main .
- It includes one large main gear that carries a large portion of the aircraft weight and load; plus a very small gear under the nose. In terms of size, the main gear is much larger (both strut and wheel)

## Bicycle

- Bicycle landing gear, as the name implies, has two main gears one aft and one forward of aircraft cg; and both wheels have a similar size .
- The main advantages of this configuration are the design simplicity and the low weight.

## Tail-gear

- Tail-gear landing gear has two main wheels forward of the aircraft cg and a small wheel under the tail.
- The wheels in front of the aircraft cg is very close to it (compared with aft wheel) and carries much of the aircraft weight and load

# Tricycle

- Tricycle is the most widely used landing gear configuration. The wheels aft of the aircraft cg is very close to it (compared with forward gear) and carries much of the aircraft weight and load; thus is referred to as the main wheel.
- Two main gears are in the same distance from the thus both are carrying the same load.
- The forward gear is far from cg (compared with main gear); hence it carries much smaller load

# Quadricycle

- As the name implies a quadricycle landing gear utilizes four gears; similar to a car conventional wheel system. Two wheels at each side where two wheels are in front of aircraft cg and other two aft of cg.
- The load on each gear depends on its distance to cg. If aft and forward wheels have the same distance to cg, they will have to carry the same load.
- In this case, it is very hard to rotate the aircraft during take-off and landing; so the aircraft will perform a flat take-off and landing.

## Multi-bogey

- As the aircraft gets heavier, number of gears needs to be increased.
- A landing gear configuration with multiple gears of more than four wheels also improves take-off and landing safety. When multiple wheels are employed in tandem, they are attached to a structural component referred to as “bogey” that is connected to the end of the strut.



# Landing Gear Attachment

- Main gear is attached to the wing, but the nose gear is attached to the fuselage
- Main gears are attached to the wing, but the tail gear is attached to the fuselage
- All struts/wheels are attached to the fuselage
- Main gears are attached to the nacelle, but nose gear is attached to the fuselage (in a nose-wheel configuration).

# Fixed and Retractable Landing Gear

- Many small, single engine light aircraft have fixed landing gear, as do a few light twins.
- This means the gear is attached to the airframe and remains exposed to the slipstream as the aircraft is flown.
- Classification of aircraft landing gear can be made into two categories: fixed and retractable.

- Retractable landing gear stow in fuselage or wing compartments while in flight.
- Once in these wheel wells, gear are out of the slipstream and do not cause parasite drag.
- Most retractable gear have a close fitting panel attached to them that fairs with the aircraft skin when the gear is fully retracted. Other aircraft have separate doors that open, allowing the gear to enter or leave and then close again.

# LANDING GEAR APPLICATION

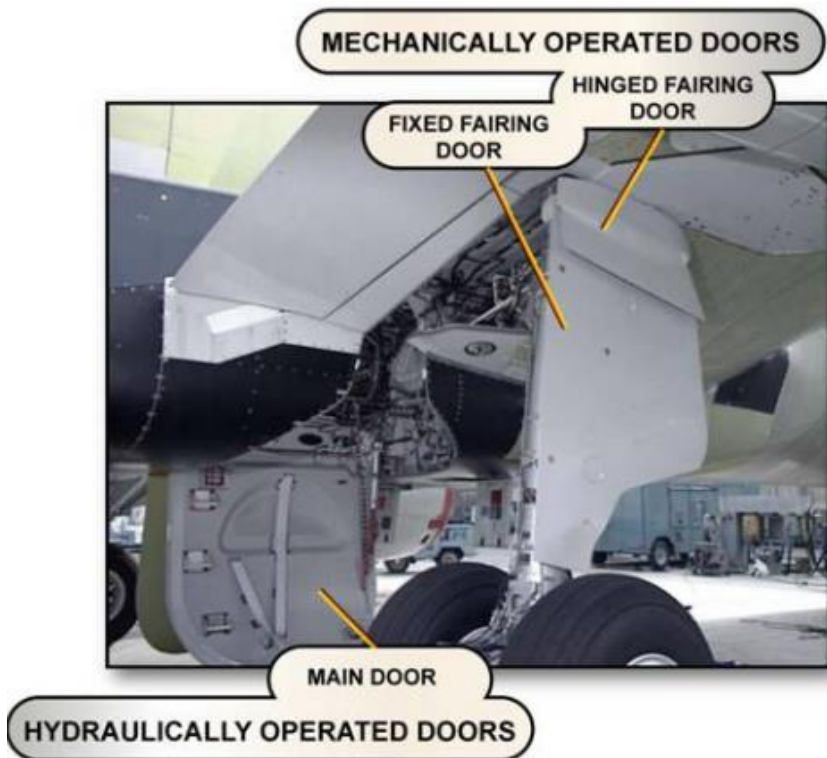




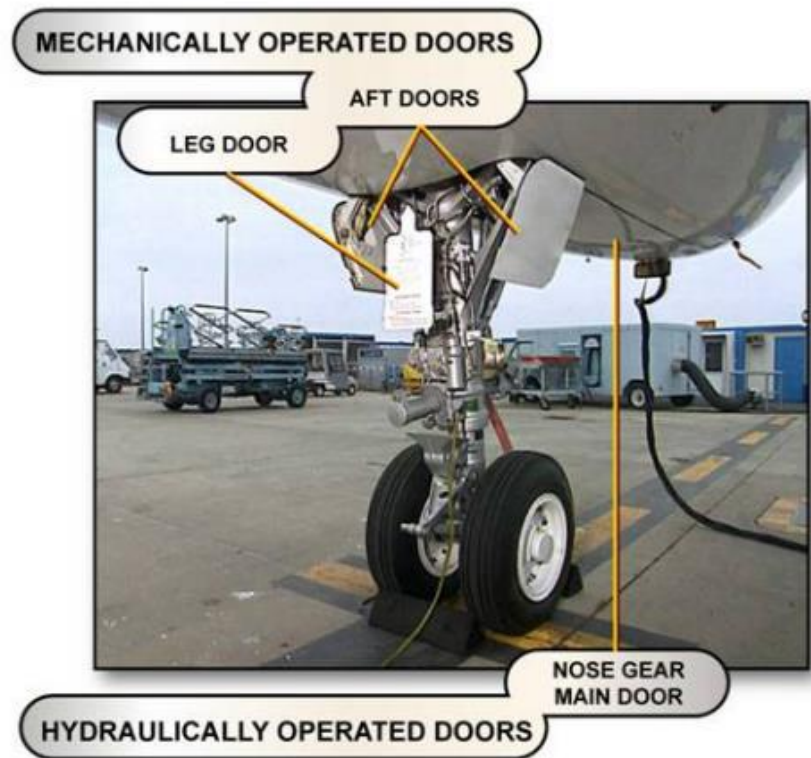
**Figure 13-105.** *Antiskid switches in the cockpit.*

# Landing Gear

- Each main landing gear has bogie beam (L and R) with four wheels or without bogie beam with two wheels.
- Landing gear supports the aircraft on ground and absorbs landing, T.O. and taxing loads.
- Each main wheel has a tubeless tyre and a brake unit.



**Main Landing Gear (MLG)**



**Nose Landing Gear (NLG)**



# **UNIT – 4**

## **PNEUMATIC AND ENVIRONMENTAL CONTROL SYSTEMS**



# PNEUMATICS

- The modern turbofan engine is effectively a very effective gas generator and this has led to the use of engine bleed air for a number of aircraft systems, either for reasons of heating, provision of motive power or as a source of air for cabin conditioning and pressurization systems.
- Bleed air is extracted from the engine compressor and after cooling and pressure reduction / regulation it is used for a variety of functions.

- A proportion of bleed air is fed into air conditioning packs which cools the air dumping excess heat overboard; this cool air is mixed with the remaining warm air by the cabin temperature control system such that the passengers are kept in a comfortable environment.
- On the aircraft, bleed air tapped from the engine is used to provide air to pressurise the cabin and provide the source of air to the cabin conditioning environmental control system.
- Bleed air is also used to provide main wing anti-ice protection.

- The pneumatic system is controlled and monitored by 2 Bleed Monitoring Computers (BMC).
- There is one BMC for each engine bleed system.
- Both BMC are interconnected and if one fails, the other takes over most of its functions.

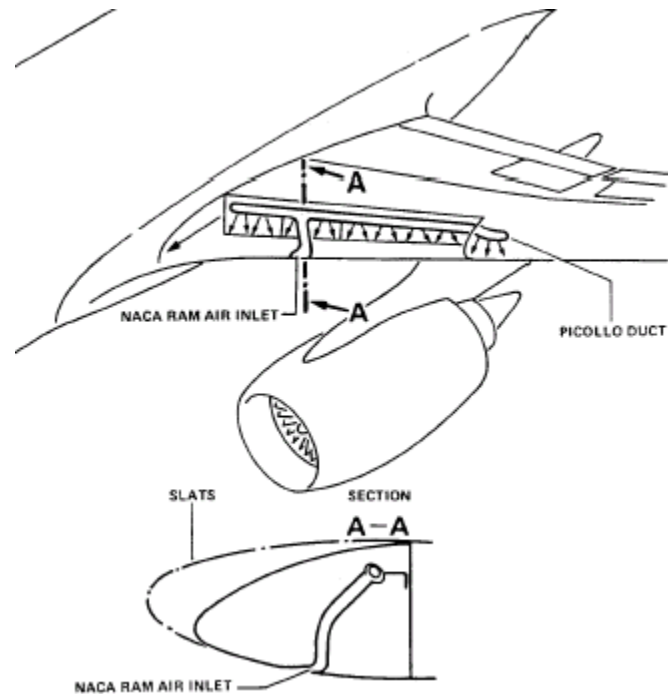
# ENVIRONMENTAL PROTECTION SYSTEM

- The environment protection system is divided into:
- Ventilation of the wing leading edge
- Protection of the wing leading edge
- Protection of the pylon
- Protection of the nacelles

# WING LEADING EDGE VENTILATION

- Ensures that the flammable fuel vapor is removed and the hot components are cooled.
- Air enters the wing leading edge through gaps around the slat tracks and goes out through drainage/ escape holes in the lower surface of the wing leading edge.

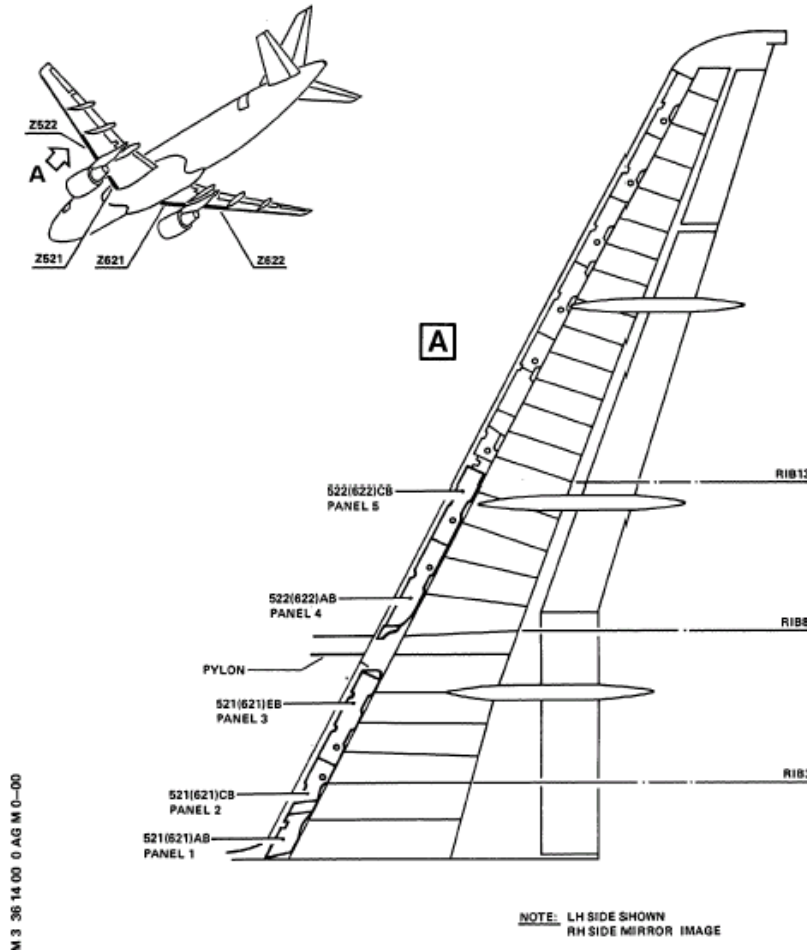
# WING LEADING EDGE VENTILATION



# Protection of the Wing Leading Edge, the Pylon and the Nacelles

- Operate if a pneumatic duct or a wing anti-ice duct bursts or has a large leak.
- Prevents damage to the structure and the systems installed. Keep the pressure in these areas to a limit.

# PROTECTION OF THE WING LEADING EDGE





# ENVIRONMENTAL CONTROL SYSTEMS

- Throughout the operation of an aircraft, whether on the ground or in the air, the crew and passengers must be kept in comfortable conditions.
- They must be neither too hot nor too cold, they must have air to breathe and they must be kept in comfortable atmospheric pressure conditions.

- The environmental control system must cope with widely differing temperature conditions, must extract moisture and provide air with optimum humidity, and must ensure that the air in the aircraft always contains a sufficient concentration of oxygen and that it is safe to breathe.

- Modern systems do this and more, for the term ‘environmental control’ also includes the provision of suitable conditions for the avionic, fuel and hydraulic systems by allowing heat loads to be transferred from one medium to another.

# PRESSURISATION CONTROL

- Controls the pressure in the fuselage.
- Operates fully automatically and has a manual backup.
- Pressure change rate is controlled to give satisfactory pressure values of safety and comfort for the passengers and crew.

# AIR COOLING SYSTEM

- Decreases the temperature of the hot bleed air from the pneumatic system.
- Also reduces the quantity of water in the hot bleed air.
- Emergency ram air is supplied if there is a failure in the two air conditioning packs.

# Ice and Rain Protection System

- The ice and rain protection system lets the aircraft operate normally in ice conditions or heavy rain.
- Ice protection is given by the use of hot air, or electrical power, to make the necessary areas of the aircraft hot. The areas that hot air supplies are:
  - the leading edge of the slats 3, 4 and 5 on each wing
  - Wing anti icing
  - the engine air intakes.
  - Nacelle anti icing
- The engine bleed air system supplies the hot air to the anti-ice system.

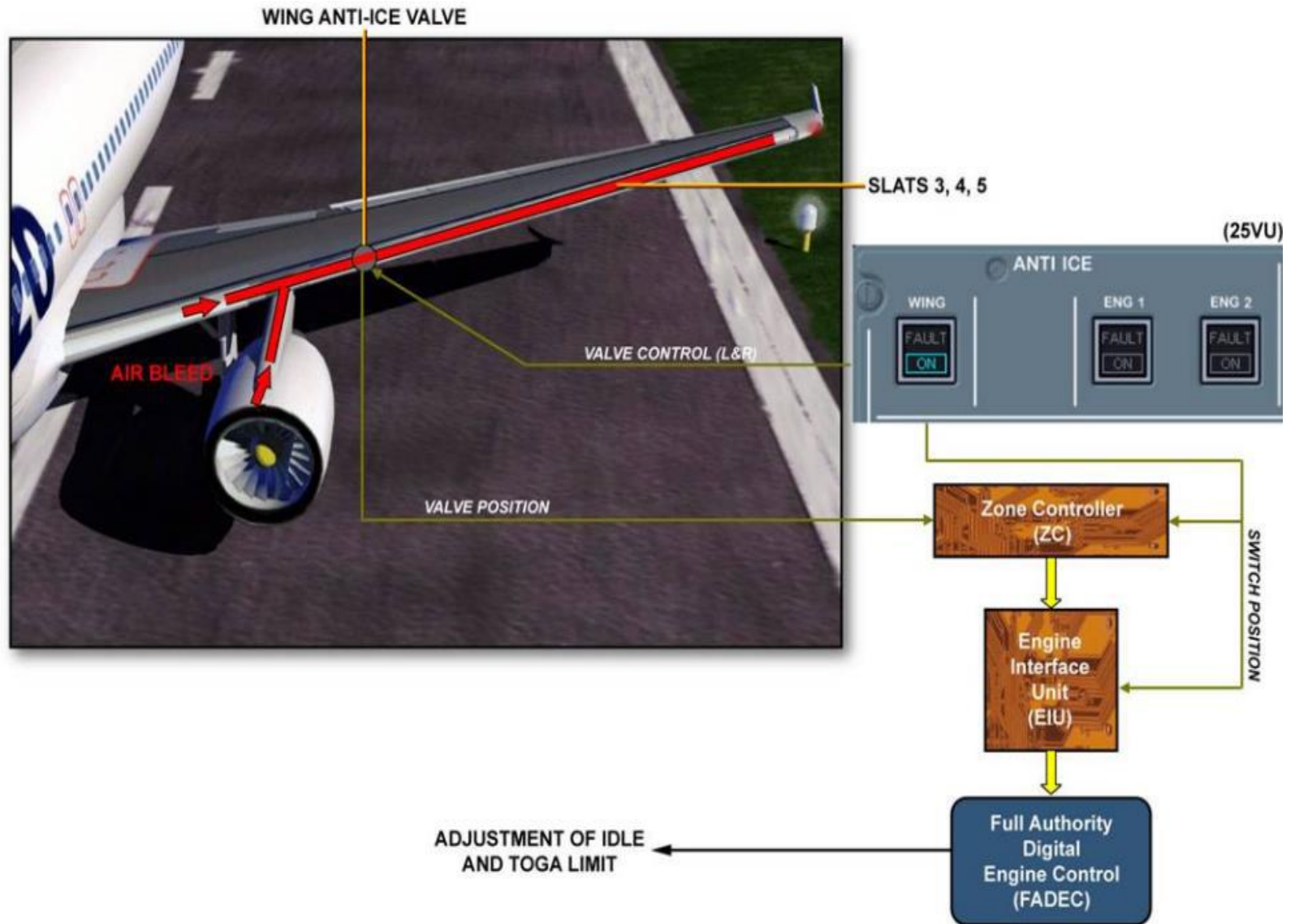
# ICE AND RAIN PROTECTION

The items with electrical heaters are:

- cockpit windshield and side windows
- Total Air Temperature (TAT) probes
- Angle of Attack (alpha) probes
- Pitot and Static probes of the Air Data System (ADS)
- waste-water drain-masts.
- Rain is removed from the windshield with windshield wipers.

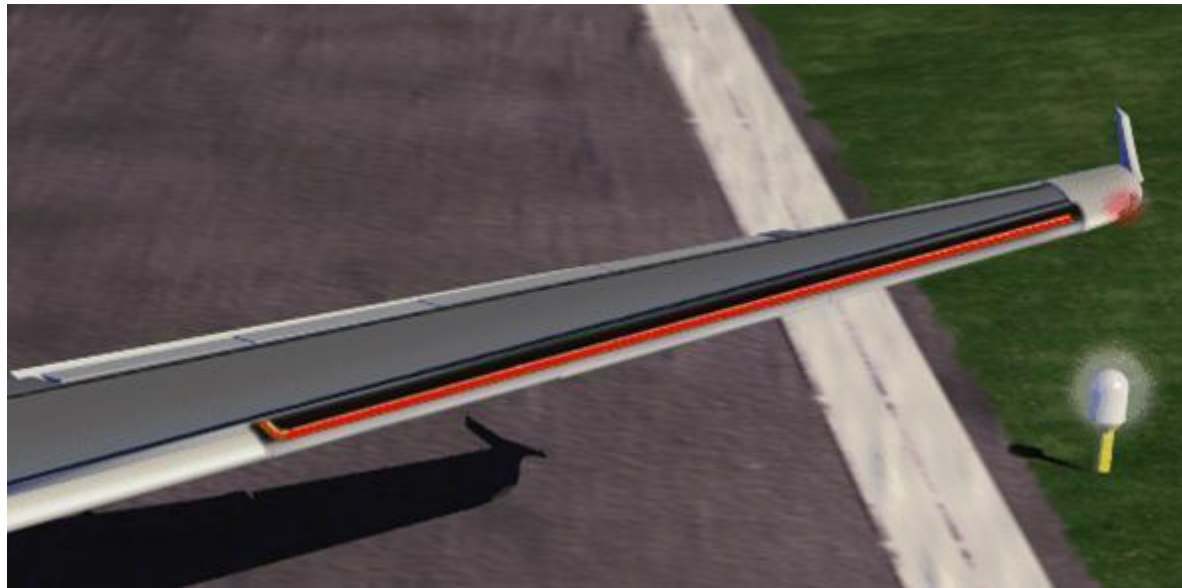
# Wing Ice protection system

- Prevents ice on leading edge of slats 3,4 and 5
- Same in LH and RH wing
- Uses hot air from pneumatic system
- Available in all flight conditions
- Both engines supply bleed
- If one engine fails cross bleed valve should be open
- Operated continuously
- When a/c is in flight
- Test possible only on ground
- Limited period (30 sec)





# Wing Ice protection system



# Control and Indications

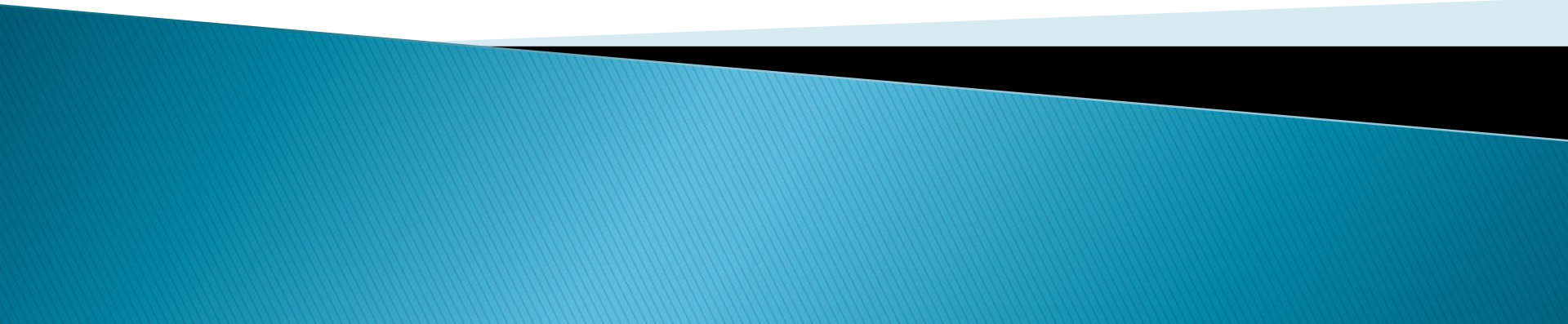
- ANTI ICE indication
- In white when p/b is pressed arrow
- Not displayed when corres valve is closed
- Green – normal opn
- Amber
- Valve open and press is low or high
- Valve open on gnd for more than 10 sec

# Engine Air intake ice protection

- Protects leading edge of air intake cowls
- Normally selected only in icing conditions
- Air bleed is from fifth stage of HP compressor

# **UNIT – 5**

## **ENGINE CONTROL AND FUEL SYSTEMS**



# Engine/Airframe Interfaces

- The engine is a major, high value item in any aircraft procurement programme. Often an engine is especially designed for a new aircraft
- this is particularly true of military projects where a demanding set of requirements forces technology forward in propulsion and airframe areas.
- There is, however, a trend to make use of existing power plant types or variant of types in an effort to reduce the development costs of a new project.

# The Control Problem

- The basic control action is to control a flow of fuel and air to the engine to allow it to operate at its optimum efficiency over a wide range of forward speeds, altitudes and temperatures while allowing the pilot to handle the engine without fear of malfunction.
- The degree of control required depends to a large extent upon the type of engine and the type of aircraft in which it is installed.
- The military aircraft is usually specified to operate in worldwide conditions, and is expected to experience a wide range of operating temperatures.

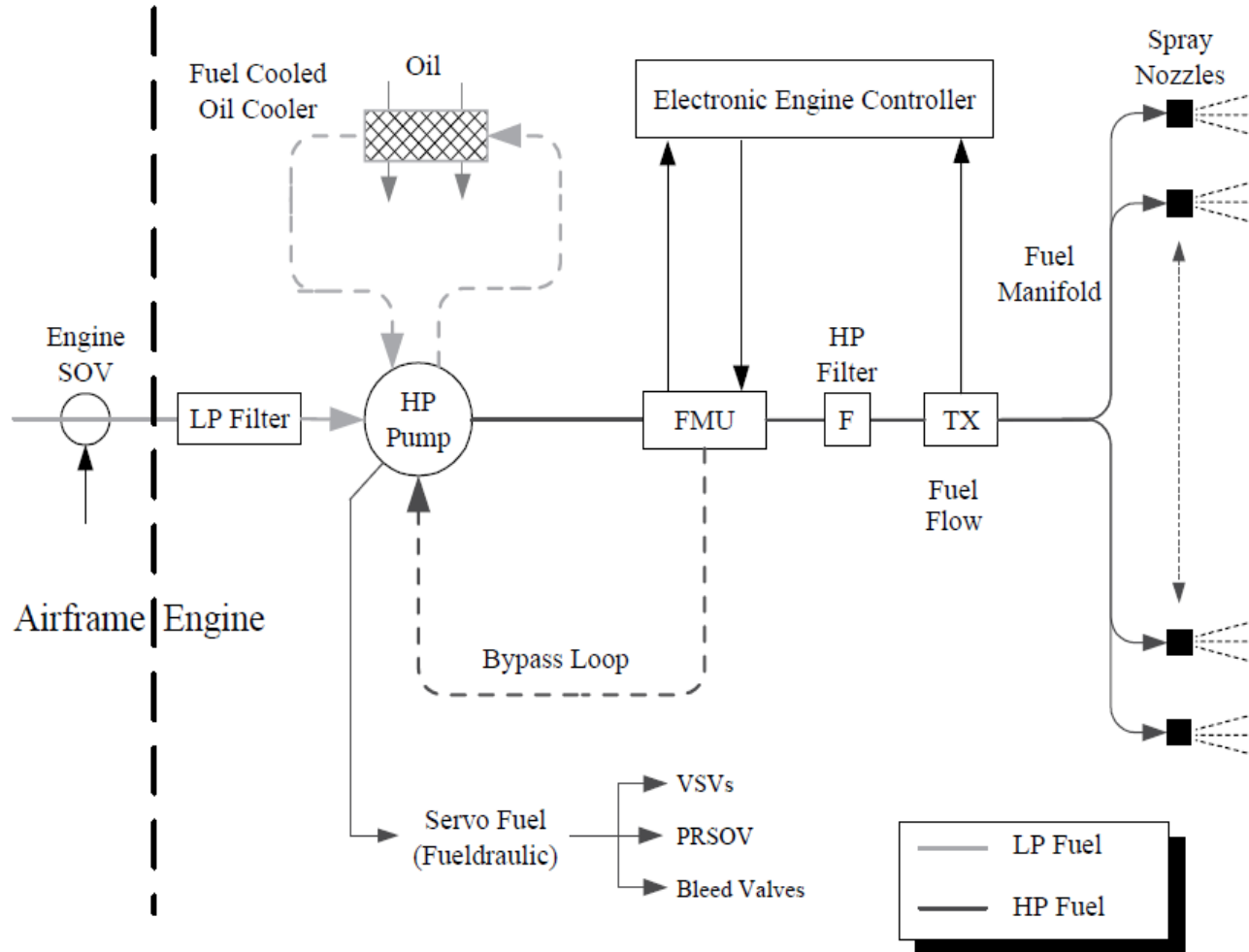
To obtain these objectives, control can be exercised over the following aspects of engine control:

- **Fuel flow** – to allow varying engine speeds to be demanded and to allow the engine to be handled without damage by limiting rotating assembly speeds, rates of acceleration and temperatures
- **Air flow** – to allow the engine to be operated efficiently throughout the aircraft flight envelope and with adequate safety margins
- **Exhaust gas flow** – by burning the exhaust gases and varying the nozzle area to provide additional thrust Electronic control

# Fuel Flow Control

- Control of power or thrust is achieved by regulating the fuel flow into the combustor.
- On turbo jet or turbo fan engines thrust can be controlled by setting an engine pressure ratio or, in the case of the larger commercial fan engines, by controlling fan speed, while on shaft power engines the speed of the gas generator is a measure of the power delivered to the propeller or to the rotor.
- When changing the thrust or power setting the fuel control system must limit the rate of acceleration and deceleration of the engine rotating assemblies in order to prevent compressor surge or flame out

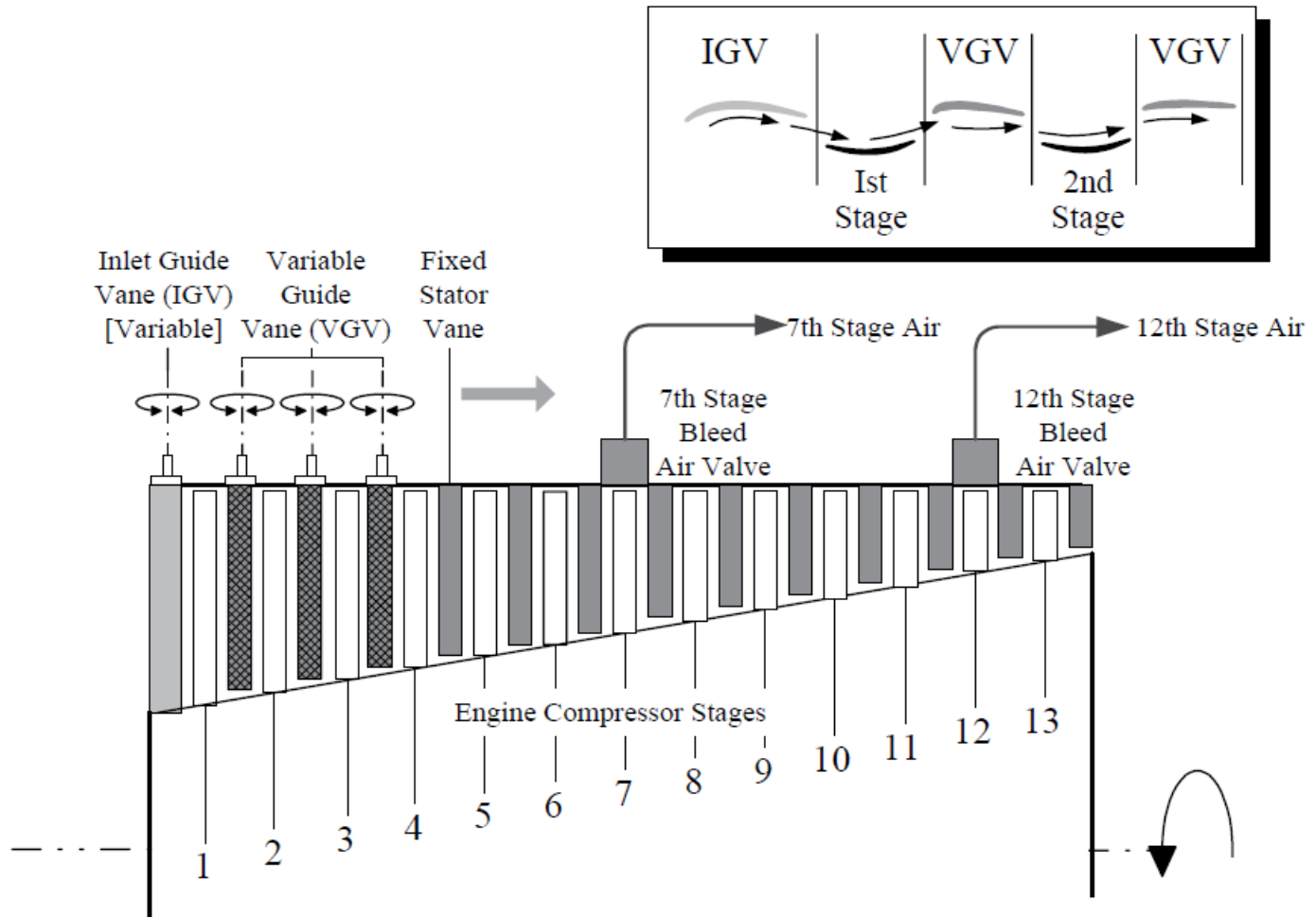




**Figure 2.2** Fuel control system

# Air Flow Control

- It is sometimes necessary to control the flow of air through to the engine to ensure efficient operation over a wide range of environmental and usage conditions to maintain a safe margin from the engine surge line.
- Most modern commercial engines have variable compressor vanes and/or bleed valves to provide optimum acceleration without surge though it is not a feature usually associated with military applications



**Figure 2.3** Engine air management

# Control Systems

- The number of variables that affect engine performance is high and the nature of the variables is dynamic, so that the pilot cannot be expected constantly to adjust the throttle lever to compensate for changes, particularly in multiengine aircraft.
- In the first gas turbine engined aircraft, however, the pilot was expected to do just that.
- A throttle movement causes a change in the fuel flow to the combustion chamber spray nozzles.

# Input Signals:

- **Throttle position** – A transducer connected to the pilot's throttle lever allows thrust demand to be determined. The transducer may be connected directly to the throttle lever with electrical signalling to the control unit, or connected to the end of control rods to maintain mechanical operation as far as possible.
- **Air data** – Airspeed and altitude can be obtained as electrical signals representing the pressure signals derived from airframe mounted capsule units.

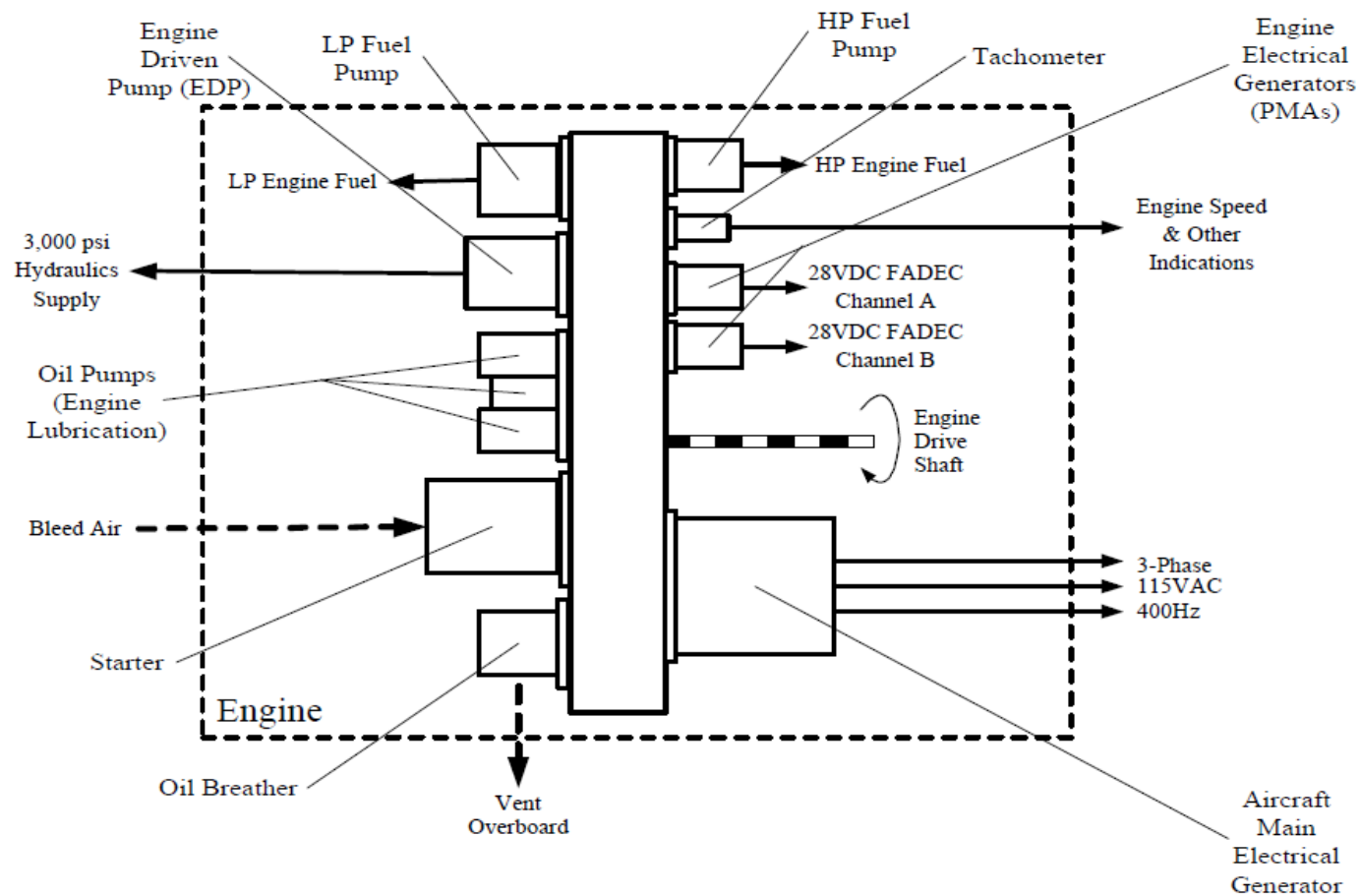
- **Total temperature** – A total temperature probe mounted at the engine face provides the ideal signal. Temperature probes mounted on the airframe are usually provided, either in the intakes or on the aircraft structure
- **Engine speed** – The speed of rotation of the shafts of the engine is usually sensed by pulse probes located in such a way as to have their magnetic field interrupted by moving metallic parts of the engine or gearbox.

- **Air flow control** – The control of air flow at different stages of the engine can be applied by the use of guide vanes at the engine inlet, or by the use of bleed valves between engine stages.
- **Fuel flow control** – The fuel supply to the engine can be varied in a number of ways depending on the type of fuel control unit used. Each device has its own particular failure modes and its own adherents

# Engine Offtakes

- The engine is the prime mover for the majority of sources of power on the aircraft.
- An accessory gearbox enables accessories to be connected to the engine HP shaft and allows a starter connection so that the engine can be started from an external supply or from the Auxiliary Power Unit (APU).





**Figure 2.28** Engine power offtakes – typical

Typical services include:

- Electrical power from generators
- Hydraulic power from hydraulic pumps
- Cabin and equipment conditioning system air from engine bleed
- Pneumatic power
- Anti and/or de-icing system air

# Reverse Thrust

Input of bleed air from a suitable air source to start the engine. This can be a ground power cart, the APU or air from the other engine if that has already been started

- Aircraft
- Main
- Electrical
- Generator
- Engine