FLIGHT CONTROLS
AXES OF CONTROL

- Normal Axis
- Yaw
- Rudder

- Longitudinal Axis
- Roll
- Ailerons

- Lateral Axis
- Pitch
- Elevators

Centre of Gravity
CONTROL SURFACES

- Elevator
- Rudder
- Ailerons
- Trailing Edge Flaps
- Leading Edge Flaps
- Flaperons
- Spoilers
FLYING CONTROLS

• There are 4 methods of actuating flying controls. These are:
  - Manual
  - Electric
  - Pneumatic
  - Hydraulic

• In addition, the non-manual systems can be sub-classified as either Power operated or Power assisted.

• On large transport aircraft, both control surfaces and operating systems are duplicated (at least) to provide redundancy.

• Effectiveness depends on:
  - Distance from aircraft CG
  - Control surface area
  - Degree of deflection
  - Dynamic pressure (IAS)

• Controls are said to be reversible if aerodynamic loads provide feedback (feel) to the pilot; they are irreversible if no such feedback is provided. Such systems need artificial feel.
Basic Principle of Fully Manual Control System

A manual flight control system uses a collection of mechanical parts such as:
pushrods,
tension cables,
pulleys, counterweights,
sometimes chains

to transmit the forces applied to the cockpit controls directly to the control surfaces.
Fly-by-Wire Systems

A fly-by-wire (FBW) system replaces manual flight control of an aircraft with an electronic interface.

Flight control movements are converted to electronic signals transmitted by wires (fly-by-wire term), and flight control computers determine how to move the actuators at each control surface to provide the expected response.

Computer commands are also input without the pilot's knowledge to stabilize the aircraft, perform other tasks and provide flight envelop protection.

Reduces weight and pilot workload
**POWER ASSISTED & POWER OPERATED**

**Power Assisted**

Movement of the control column will move both the flying control and the pilot valve

Reversible controls

**Power Operated**

Movement of the control column only moves the pilot valve

Irreversible controls
CONTROL LOCKS

- Aircraft controls are normally locked on the ground to prevent damage caused by wind movement. In light aircraft these can be fitted either externally at the control surfaces or in the cockpit to prevent movement of the cockpit controls.

- In larger aircraft, with electro-hydraulic systems, the controls lock automatically when power is removed. Other types of locks on larger aircraft consist of mechanical, lever and cable operated bolts or pins, that are engaged from within the aircraft.

CONTROL STOPS

- Manually operated controls are fitted with stops to limit their range of movement. These are classified in 2 ways:
  - Primary stops are fitted to the control surfaces.
  - Secondary stops are fitted to the cockpit controls.
GROUND LOCKS
ARTIFICIAL FEEL (Q-FEEL)

- Artificial feel systems are designed to increase control column/rudder pedal forces to reflect increases in:
  - IAS (q) by sensing dynamic pressure
  - Control deflection
  in order to reduce the chance of overstressing the aircraft

- Normally duplicated and fitted in parallel with the control runs
TAKE-OFF CONFIGURATION WARNING SYSTEM (TOCWS)

- Gives a warning on the ground prior to take-off if the aircraft is incorrectly configured and the throttles are advanced
- Required inputs could include:
  - Control locks removed
  - All powered flying controls operative
  - Feel simulators operative
  - Flap settings correct
  - Slat settings correct
  - Trim within limits
  - ‘Aileron upset' armed but not applied
  - Speedbrakes/spoilers in
  - Doors locked

* ‘Aileron Upset' is a system that biases ailerons up in order to move the wing centre of pressure inwards and reduce wing bending stresses
CONTROL POSITION INDICATIONS

- In addition to TOCWS, most large aircraft have control position indicators. A typical, non-EFIS system is shown below:
SPEED BRAKE INDICATION

SPEED BRAKE DO NOT ARM illuminates with an amber coloured light when there is an abnormal condition.

SPEED BRAKE ARMED illuminates green when the automatic system is operating correctly.

Courtesy of the Boeing Company
SPEED BRAKE INDICATION
TRIM TABS

Purpose is to zero control column/rudder pedal loads
BALANCE TABS

• Purpose is to provide aerodynamic balance and make it easier for the pilot to move the controls. There are a number of different types.

• Simple balance tab:

As the elevator is moved this automatically moves the trim tab.
Servo Tab

Spring Tab

Control lever free to pivot against spring pressure
ANTHI-BALANCE TAB

- The anti-balance tab makes it more difficult to move the controls
VARIABLE INCIDENCE TAILPLANE

- Control is effected by normal elevators, with trimming being accomplished by changing the position of the tailplane using a trim jack

Trim jack with input from trim control

Mechanical lock prevents flutter and creep
MASS BALANCING

The purpose of mass balancing is to prevent flutter.

This is accomplished by fitting weights ahead of the control hinge line to move its centre of gravity onto or ahead of the hinge line.

Aircraft with powered, irreversible controls do not suffer from flutter.
AERODYNAMIC BALANCING

Aerodynamic forces assist the pilot in moving the controls
Aerodynamic balancing may also be assisted by use of an internal balance or balance panel (horn balances and inset hinge lines may also be utilised)
Tabs & Balancing

BAe 146

Horizontal Stabiliser
Elevator
Trim Tab
Servo Tab
Aerodynamic Balance
AILERONS

Ailerons are primary control surfaces mounted on the trailing edge of the wing, near the wing tip.

Some aircraft have a second set of 'inboard ailerons' mounted closer to the fuselage - these ailerons are used in high-speed flight instead of the normal ailerons to overcome the problems associated with wing twist due to the forces generated by the normal ailerons at the wing tip.
ADVERSE AILERON YAW

When ailerons are deflected, the **downgoing** aileron (on the **upgoing** wing) produces more drag than the upgoing aileron.

This will yaw the aircraft in the opposite direction from the roll (and intended direction of turn). This is undesirable and inefficient.

The following design features are incorporated to reduce or eliminate this **adverse aileron yaw**:

- Frise ailerons
- Differential ailerons
- Aileron/rudder coupling
- Spoilers for roll control
Frise Ailerons

Frise ailerons have an asymmetric leading edge.

The up-going aileron protrudes below the surface of the wing, causing high drag.
RUDDERVATORS

V-tail with Ruddervators
TAILERONS/ALL-MOVING TAILPLANE/STABILATOR
CANARDS
HIGH LIFT DEVICES (TRAILING-EDGE)

- All aircraft employ high-lift devices. Some typical trailing-edge devices are as follows:

  - Plain Flap
  - Split Flap
  - Zap Flap
  - Double Slotted Flap
  - Fowler Flap
TYPICAL TRAILING-EDGE FLAP CONTROL
HIGH LIFT DEVICES (LEADING-EDGE)

• Typical leading-edge high lift devices are:

Leading edge flap

Kreuger flap

• Flaps are fitted to the inboard section of the leading edge; slats with slots are fitted to the outboard sections
KREUGER FLAP
HIGH LIFT DEVICES (LEADING-EDGE)

Slat with slot

Slat retracted

Slat extended

Slot
Pitch control is provided by 2 elevators and a movable horizontal stabiliser. Roll control is provided by 2 flaperons, 2 ailerons and 14 spoilers.

In the normal mode the flaperons are used for roll control with the flaps either retracted or extended. For increased lift, they move down and aft in proportion to trailing edge flap extension.

For increased lift, the ailerons move down for flaps 5, 15, and 20, to improve takeoff performance. In the normal mode, the ailerons and spoilers 5 and 10 are locked out during high-speed flight; the flaperons and remaining spoilers provide sufficient roll control. During low speed flight, these panels augment roll control.

A single rudder provides yaw control. The lower portion of the rudder has a hinged section that deflects twice as far as the main rudder surface to provide additional yaw control authority.

Flaps and slats provide high lift for takeoff, approach, and landing.

Asymmetric spoilers assist in roll control. Symmetric spoilers are used as speedbrakes.

A 2-position Krueger flap provides a seal between the inboard slat and engine nacelle.