Lecture 3 - Control Surfaces

Dr Tom Richardson & Professor Mark Lowenberg
Department of Aerospace Engineering
University of Bristol
thomas.richardson@bristol.ac.uk

February 4, 2019

Conventional Control Surfaces

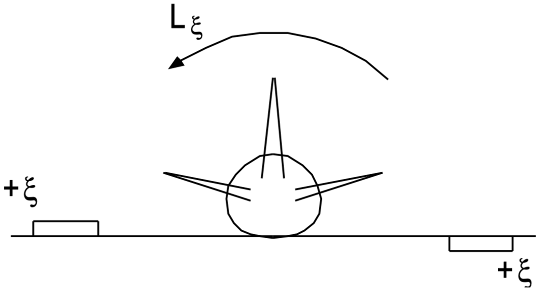
Conventional Control Surfaces - Ailerons

- Conventional control surfaces are built as moveable parts of the lifting surfaces, connected through a hinge that is nominally parallel with the "span" of the surface.

Ailerons

- Generally, a small spanwise portion of the trailing edge.
- Relatively far out from the aircraft centre-line to give a good moment arm for roll control.
- Some aircraft have split ailerons.
- The deflection angle is ξ [ksi], positive when the starboard trailing-edge is down (and the port t.e. is up) - *checks!*

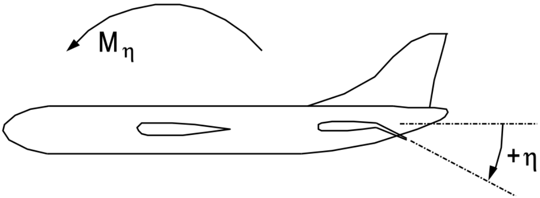
Conventional Control Surfaces - Ailerons



- View is from aft.
- A positive aileron deflection is shown which causes a negative rolling moment following the sign convention which we use.
- Note: full span ailerons are sometimes used for aerobatic aircraft.

Conventional Control Surfaces - Elevator

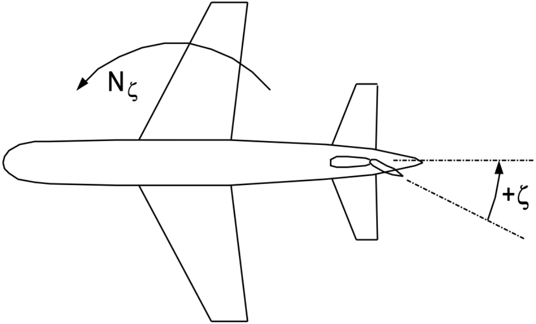
- This can occupy the whole of the spanwise extent of the trailing-edge of the horizontal tail plane, but is usually smaller.
- The tip area is often used for "balance".
- The deflection angle is η [eta], positive for trailing edge down.



- the moment shown is due to positive elevator but is negative, following the sign convention for pitching moment.

Conventional Control Surfaces - Rudder

- Generally, this will be a large portion of the fin trailing-edge.
- The deflection angle is ζ [zeta], positive when the t.e. is to port.



- the moment shown is due to positive rudder but is negative, following the sign convention for yawing moment.

Primary Control Actions

- Note: that all of these controls are essentially designed to provide strong moments about the flight axes while providing relatively small direct forces.
- Note: *each positive control surface rotation follows the right-hand rule about its own nominal axis.*

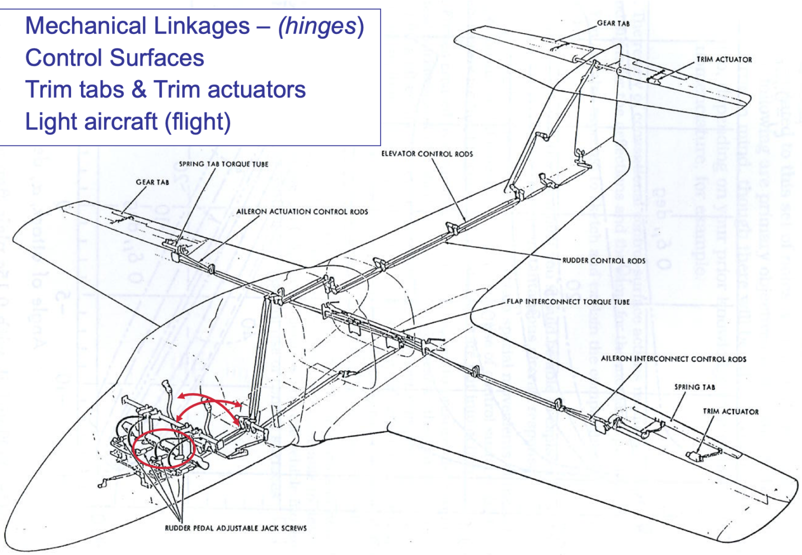
Control Surfaces

Note: *Each positive control surface rotation follows the right-hand rule about its own nominal axis.*

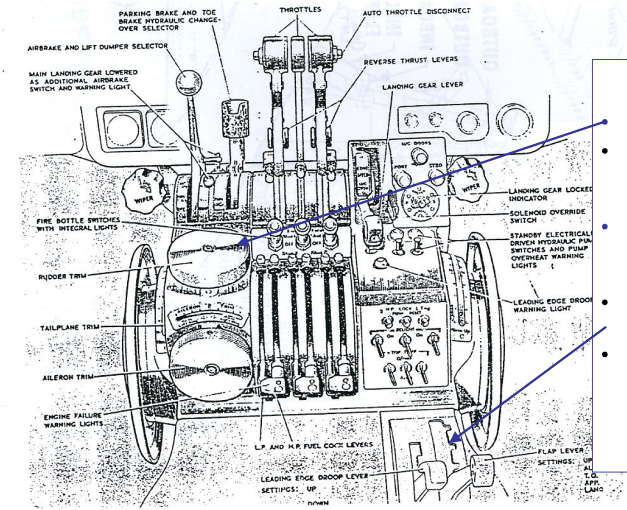
- positive ξ [ksi] produces negative L (rolling moment)
- positive η [eta] produces negative M (pitching moment)
- positive ζ [zeta] produces negative N (yawing moment)

Note: *Alternative terminology may define positive notation which results in a positive moment.*

- Mechanical Linkages – *(hinges)*
- Control Surfaces
- Trim tabs & Trim actuators
- Light aircraft (flight)



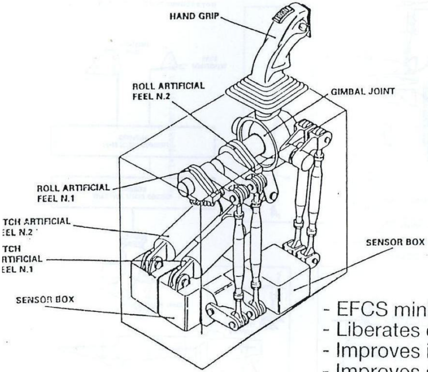
Classical Design - Trident Cockpit

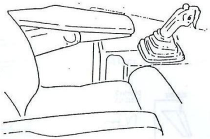


Note

- Trim Wheels
- Rotate in the direction in which they have an effect
- Tactile recognition – different shapes and sizes
- Limited number of Flap settings
- Auto-throttle disconnects quickly

A320 Side stick controller





The side stick controller is constructed as shown and can be regarded as a "plug in L.R.U."

It is installed in the side console and the associated arm-rest is mounted on the pilots seat

- EFCS minimises forces so large controller not needed.
- Liberates cockpit design.
- Improves instrument panel design and view.
- Improves seat access
- Makes a work table possible.

- Alternative Control Inceptor

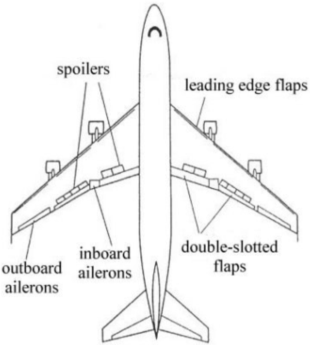
A330 Flight Deck

Additional Control Surfaces

Additional Control Surfaces - Spoilers

- Normally hinged to the upper surface of the wings at a point that is further forward than the hinge-line for conventional trailing-edge devices.
- (i.e. hinged at about $x/c = 0.6\text{-}0.7^{+}$).
- The Boeing-747 figure on the following slide shows the lateral distribution of spoilers and also shows their hinge-lines well forward of the flap hinges.

Additional Control Surfaces - Spoilers



Boeing 747

Images from http://people.clarkson.edu/~pmarzocc/AE430/AE-430-5.pdf, accessed 30/10/2012

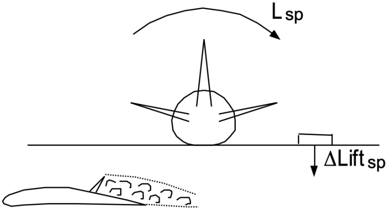
Airbus A319

Boeing 777

Additional Control Surfaces - Spoilers

- These can be operated on only one side at a time, in flight, to augment the ailerons for roll control, but obviously this produces a loss of overall lift at the same time.
- Used simultaneously on the ground, these are referred to as "lift-dumpers" and, when deployed, will ensure that the aircraft weight is rapidly transferred to the wheels for effective braking; they also serve as "air brakes" because they produce a lot of drag.

Additional Control Surfaces - Spoilers



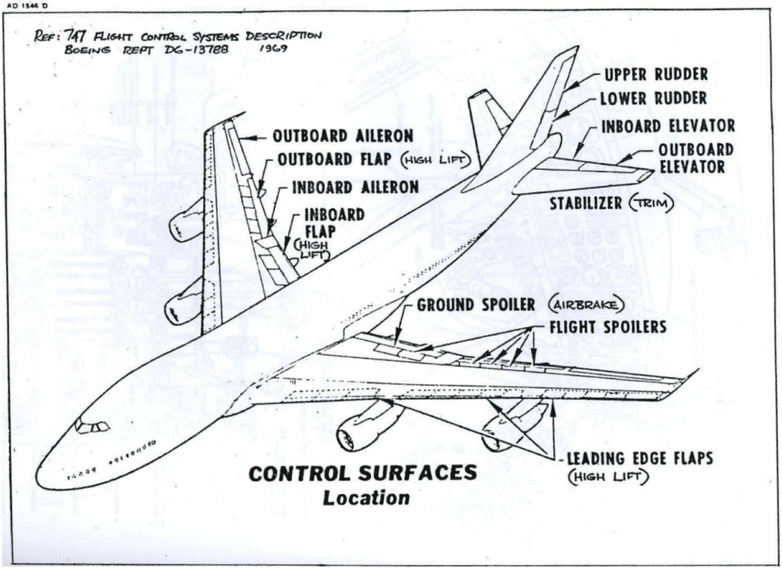
view is from aft

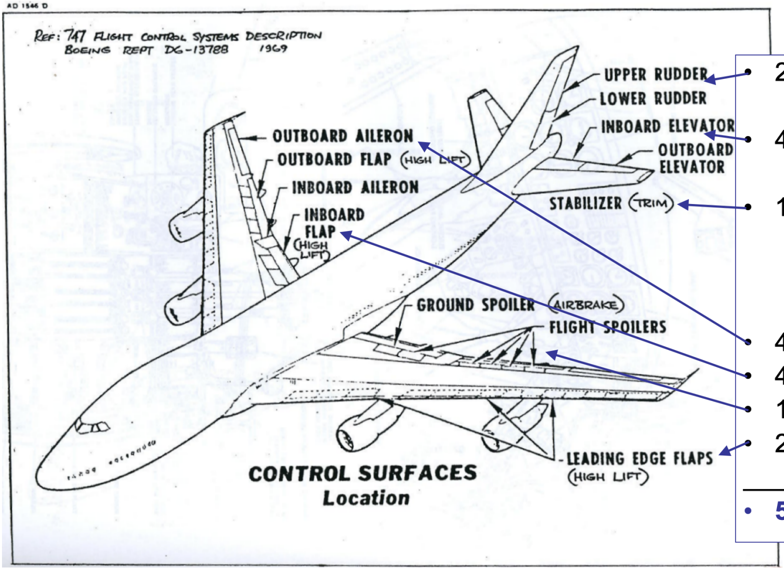
- sketch shows positive spoiler deflected on only one side

Stopping a Large Passenger Aircraft!?

- Cut throttle
- Apply spoilers – after firm contact with the ground
- Reverse thrust
- Brakes - relatively small contribution

How many Control Surfaces are there on a 747?


AD 1546 D
REF: 747 FLIGHT CONTROL SYSTEMS DESCRIPTION
BOEING REPT D6-13788 1969
UPPER RUDDER
LOWER RUDDER
INBOARD ELEVATOR
OUTBOARD ELEVATOR
OUTBOARD AILERON
OUTBOARD FLAP (HIGH LIFT)
INBOARD AILERON
INBOARD FLAP (HIGH LIFT)
STABILIZER (TRIM)
GROUND SPOILER (AIRBRAKE)
FLIGHT SPOILERS
LEADING EDGE FLAPS (HIGH LIFT)
CONTROL SURFACES
Location



- 2
- 4
- 1
- 4
- 4
- 12
- 26

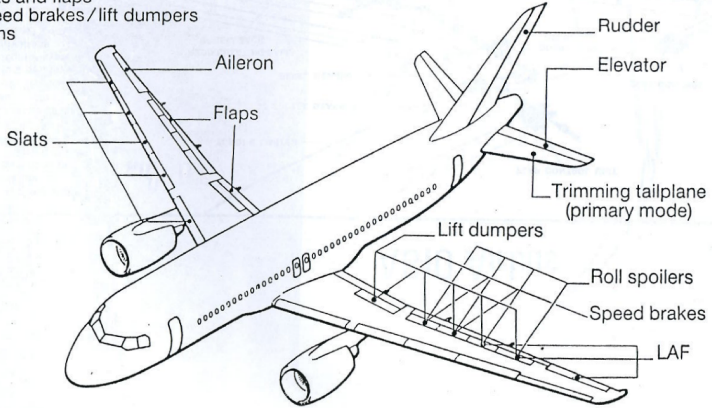
- **53**

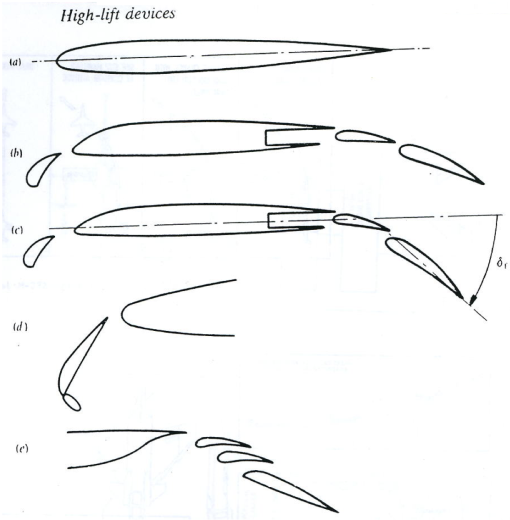
A320 Flight control surfaces

- Hydraulic actuation of all surfaces

- Electrical control
  - Elevators
  - Ailerons
  - Roll spoilers
  - Tailplane trim
  - Slats and flaps
  - Speed brakes / lift dumpers
  - Trims

- Mechanical control
  - Rudder
  - Tailplane trim (Reversionary mode)





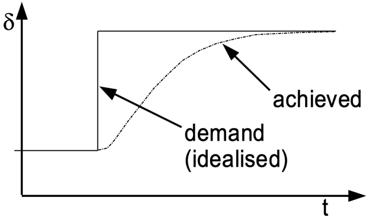
High-lift devices
(a)
(b)
(c)
δ_f
(d)
(e)

Boeing 747

Note the large deflection of trailing-edge flaps.

Response to a Pilot Input

- In modern systems the response time of a control surface to a pilot demand (e.g. *aileron or rudder*) is relatively fast, with typical response times in the region of a fraction of a second.



- The first-order time-constant would be of order 0.1s, but the demand issued by a pilot would not normally be as sharp as the step shown here; it is more likely to be a ramp input over 0.5s or more.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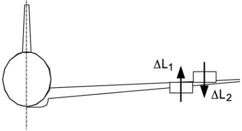
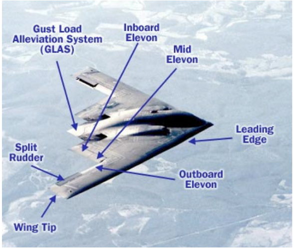
Unconventional Control Motivators

Other Methods for Developing Control Forces

- Several other possible means of creating aerodynamic or thrust-control deserve some attention, some of these being simply unconventional uses of conventional surfaces, e.g. :
  - symmetric aileron deflection, which will alter wing lift directly without producing a rolling moment.
  - split-ailerons (each side has two parts: one deflected up while the goes down) generate drag without generating additional lift or rolling moment. See also ‘split rudder’ on B2 ⇨





B2 control surfaces
http://people.clarkson.edu/~pmarzocc/AE430/AE-430-5.pdf, accessed 30/10/2012

  - anti-symmetric deflection of the two sides of an all-moving tailplane, which will augment normal aileron action for roll-control

Thrust Vectoring - e.g. Harrier

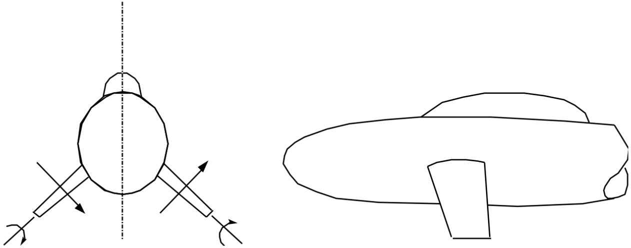
Thrust Vectoring - e.g. Harrier

F-15B ACTIVE with Thrust Vectoring

- The aircraft is highly modified and is not representative of production F-15 aircraft. It was selected to serve as the research testbed for the ACTIVE program because of the flexibility of its unique quad-redundant, digital-fly-by-wire, flight and propulsion control system.
- The twin-engine F-15 is equipped with Pratt & Whitney nozzles that can turn up to 20 degrees in any direction, giving the aircraft thrust control in the pitch (up and down) and yaw (left and right) directions.
- NASA flight testing started in 1996, using thrust-vectoring to improve aircraft performance and control.
- The F-15 ACTIVE in flight over the Mojave desert.

F-15B ACTIVE with Thrust Vectoring

Other Methods for Developing Control Forces



- Canards which are intended only for control purposes (not a significant augmenting of lift) are often not horizontal and thus a differential (or anti-symmetric) deflection can produce a rolling moment and a side-force.

Other Methods for Developing Control Forces

Long-coupled canards ⇨

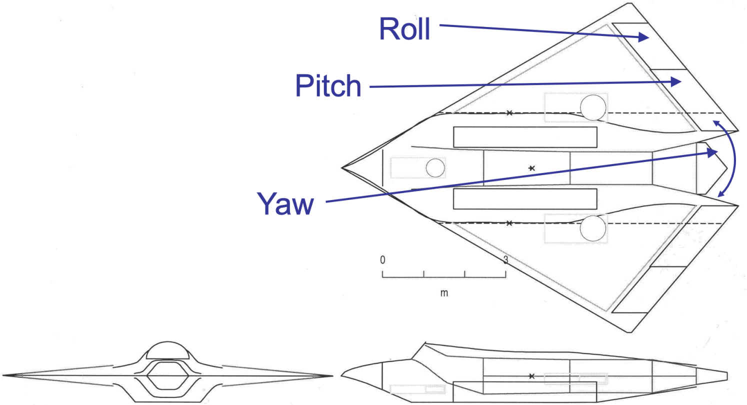
Short-coupled canards ⬂

Rockwell B-70 Valkyrie

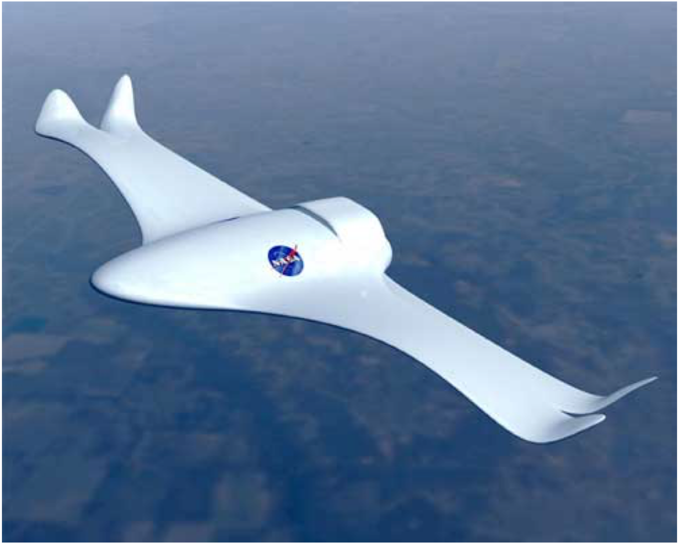
http://people.clarkson.edu/~pmarzocc/AE430/AE-430-5.pdf, accessed 30/10/2012

Saab Gripen

Eurofighter Typhoon


Roll
Pitch
Yaw
0
3
m


NASA
805

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© SWNS


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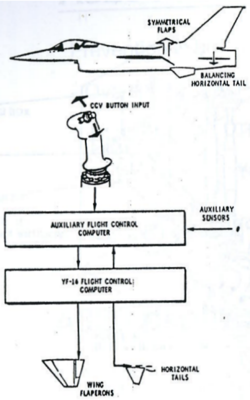
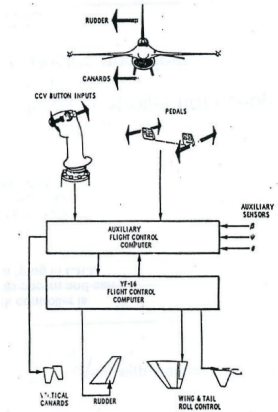
'Control Configured Vehicle'

CCV: Control-configured Vehicles - (ML - TSR)

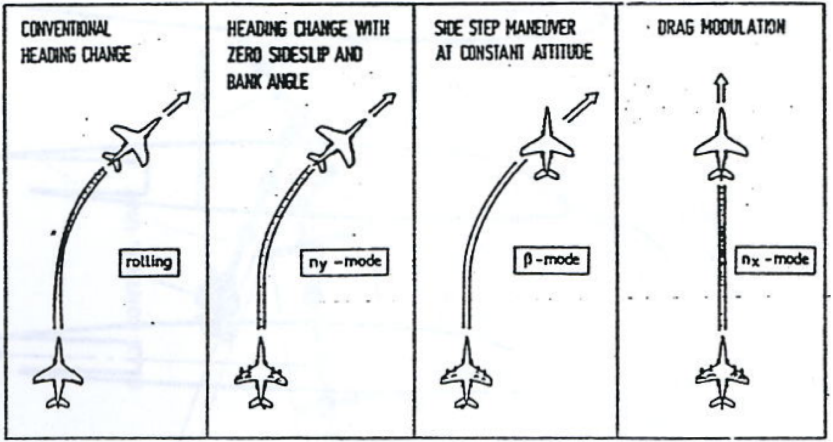


Direct Lift Implementation

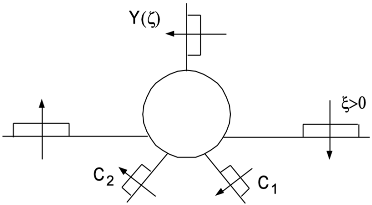


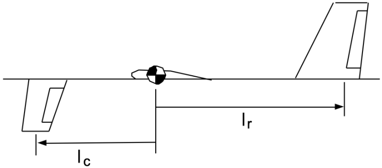
Direct Sideforce Implementation

CCV: Control-configured Vehicles



Other Methods for Developing Control Forces





Exercise: Consider how this configuration might be used to create:

- Pure Lateral Motion
- Pure Vertical Motion

whilst balancing Forces and Moments

QinetiQ VAAC Harrier

Next Lecture

Strip Theory