Airbus flight control system

- The organisation of the Airbus A330/340 flight control system

"Fly by wire" control

- Conventional aircraft control systems rely on mechanical and hydraulic links between the aircraft's controls and the flight surfaces on the wings and tail. The controls and flight surfaces are directly connected. Mechanical links are also used for the engine control.

- In fly-by-wire systems, the cockpit controls generate electronic signals that are interpreted by a computer system and are then converted into outputs that drive the hydraulic system connected to the flight surfaces. Engine control is also mediated by the FCS computers.

Advantages of 'fly-by-wire'

- Pilot workload reduction
  - The fly-by-wire system provides a more usable interface and takes over some computations that previously would have to be carried out by the pilots.

- Airframe safety
  - By mediating the control commands, the system can ensure that the pilot cannot put the aircraft into a state that stresses the airframe or stalls the aircraft.

- Weight reduction
  - By reducing the mechanical linkages, a significant amount of weight (and hence fuel) is saved.

Fault tolerance

- Fly-by-wire systems must be fault tolerant as there is no 'fail-safe' state when the aircraft is in operation.

- In the Airbus, this is achieved by replicating sensors, computers and actuators and providing 'graceful degradation' in the event of a system failure. In a degraded state, essential facilities remain available allowing the pilot to fly and land the plane.
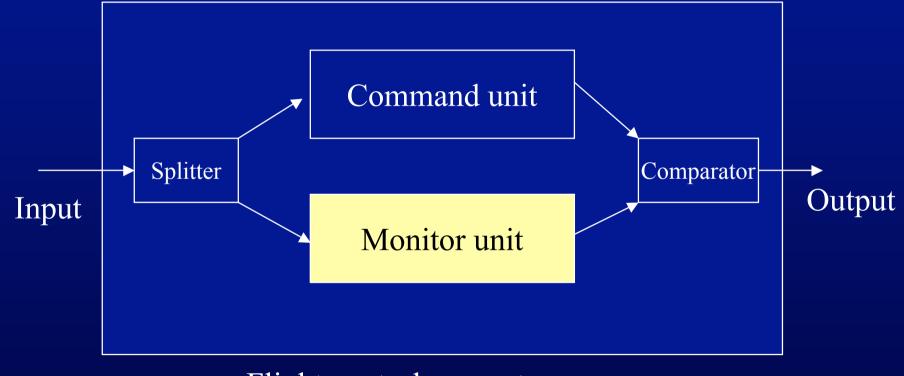
Hardware organisation

- Three primary flight control computers
  - Responsible for calculations concerned with aircraft control and with sending signals to the actuators associated with the control surfaces and engines.
- Two secondary flight control computers
  - Backup systems for the flight control computers.
  - Control switches automatically to these systems if the primary computers are unavailable.
- Only one computer is required for flight control.
  - Therefore, quintuple redundancy is supported. All operational computers operate in parallel so there is no switching delay.
- Two data concentrator computers
  - Gather information from the flight control system and pass this to warning and display systems, flight data recorders and maintenance systems.

Hardware diversity

- The primary and secondary flight control computers use different processors.

- The primary and secondary flight control computers are designed and supplied by different companies.

- The processor chips for the different computers are supplied by different manufacturers.

- All of this reduces the probability of common errors in the hardware causing system failure.

Computer organisation

Flight control computer

Computer organisation

- The command unit and the monitor unit are separate channels within a single computer.

- Each channel has separate hardware and different software.

- If the results of the channels disagree (as checked by the comparator) or are not produced at the same time then an error is assumed and control switches to another machine.

Software diversity

- The software for the different channels in each computer has been developed by different teams using different programming languages.

- The software for the primary and secondary flight control computers has been developed by different teams.

- For the secondary computers, different languages are again used for the different channels in each machine.

Dynamic reconfiguration

- The FCS may be reconfigured dynamically to cope with a loss of system resources.

- Dynamic reconfiguration involves switching to alternative control software while maintaining system availability.

- Three operational modes are supported

  - Normal - control plus reduction of workload;

  - Alternate - minimal computer-mediated control;

  - Direct - no computer-mediation of pilot commands.

- At least 2 failures must occur before normal operation is lost.

Control diversity

- The linkages between the flight control computers and the flight surfaces are arranged so that each surface is controlled by multiple independent actuators.

- Each actuator is controlled by different computers so loss of a single actuator or computer will not mean loss of control of that surface.

- The hydraulic system is 3-way replicated and these take different routes through the plane.

Airbus FCS problems

- There have been a number of Airbus accidents that may be related to problems with the FCS.

- One accident (Warsaw runway overrun) has been clearly identified as a problem with the specification and not with the system itself.

- There is no evidence of any failures of the FCS hardware or software.

- However, the pilots may misinterpret how the system operates and hence make errors that it can't cope with. Most likely when the system was newly introduced.