Harrier's flight control

The sight of Hawker Siddeley's Harrier flying a demonstration V/Stol routine holds a perennial fascination for all audiences. Whether accelerating rapidly away towards wing-born flight, or manoeuvring towards a predetermined spot landing, it consistently displays a delicate precision of handling. Not many years ago, this sort of demonstration, while spectacular, would produce from the critics sceptical comment about the value of such techniques. Today's critics are noticeably quieter, however, as public pressures mount against the conventional transport's noisy approach and climb-out.

The problems of flight control from zero ground-speed, through transition, to transonic cruise are already exercising civil aircraft designers, and much of the experience gained with the Harrier may well be embodied in the Stol transports of ten or 12 years hence.

From the very outset of the HS.1127 studies, it was clear that some of the most important design problems centred around control over a very wide range never previously attempted with a fixed-wing machine. Two modes of flight control were needed, one for use in the wing-born phase of the mission and another to handle the aircraft below the normal stall. The selection of system had to be weighed very carefully in the light of an almost unprecedented weight sensitivity.

The solution that emerged contained three basic control elements, comprising conventional flying controls, vectored-thrust engine-nozzle actuation equipment and the reaction-control system.

The conventional aerodynamic controls comprise powered aileron and tailplane channels, with no manual reversion, and a manual rudder channel. The muscle for the powered channels is supplied through duplicated 3,000lb/sq in hydraulic systems driving the Fairey tandem actuator jacks which position the control surfaces. These jacks are fitted within an integral housing, or PCU (power control unit). Acting as delicate command-sensing transducers, these PCUs have pressure stabilisation feedback on their hydraulic valves and accept inputs from the limited-authority Elliott autostabiliser.

The lack of manual reversion on aileron and tailplane channels requires the provision of an emergency hydraulic system. This is a Plessey ram-air turbopump which extends into the airflow in the event of main-engine shut-down. To cut down weight, maximum use has been made of compensated cable runs to transmit input demands to the control-surface push-pull rods.

Two separate control methods are used to cope with the jet-born-flight phase, with nozzle actuation forming the primary mode.

The nozzle-actuation system is pneumatically powered, the air supply being drawn from the sixth stage of the Pegasus high-pressure compressor. This air passes through a double-skinned pipe which contains the Plessey filter and pressure-reducing valve. The hot air at a nominal 35lb/sq in is then piped to the Plessey air motor servo unit (AMSU), which controls the rotation of the forward and rear pairs of Pegasus efflux nozzles via bevel gearboxes and a geared chain and sprocket.

The AMSU comprises two air motors and their associated drives and services. Nozzle actuation can be maintained with one of the air motors failed, and the unit has been cleared for 200hr flight operation with one motor out. Control of nozzle actuation is provided from a separate selection lever, mounted alongside the main throttle and operating in the same sense. A linkage from the AMSU progressively opens the reaction-control system's master butterfly valve, thus eliminating the need for a separate control.

The reaction-control system taps air from the eighth-stage high-pressure compressor, which is then ducted to shutter valves at the nose, tail and wing tips via the master on/off butterfly valve. Operation of the master valve occurs during the first 20° rotation of the main engine nozzles. From here, the hot air is led to the pitch-control valves at the nose and tail, and to the roll valves at the wing tips. Control of the reaction shutter valves is achieved mechanically through push-pull rods connected to the ailerons, rudder and tailplane. Command inputs from the Elliott autostabilisation system, when selected, act through the conventional surface controls. Pitch control is effected by varying the downward-directed airflow through the nose and tail shutter valves, with the tail-mounted valve carrying additional lateral shutters to control yawning moments. A recent modification incorporates a Fairey electro-hydraulic actuator downstream of the manual rudder circuit, acting on the yaw-stabilisation shutters. Roll control is maintained by varying the mass flow and direction (up or down) of the air ejected from the lateral valves.

Two over-riding factors—weight and component reliability—have been uppermost during the design of the flight-control system; with these have been coupled fail-safe principles.

Much weight has been saved by choosing carefully the system or sub-system employed. For example, a pneumatic nozzle-actuation drive is lighter than a comparable hydraulic-powered unit.

Fail-safe thinking has been applied to new areas in this V/Stol design. Even where the nozzle jams at the same time as the pressure-reducing valve fails in the wide-open position, a normal vertical or short landing should be possible (depending on the angle of the jammed nozzles). Similarly, in the event of an auto-stabilisation fault, its limited control authority, 20 per cent, can be readied over-ridden by the pilot. While the computer-controlled autostabiliser is capable of operation at all speeds below 250kt, the handling characteristics in the jet-born region are such that many V/Stol transitions and landings are made without using it.

The Harrier flight-control system is accumulating considerable in-service flying experience. Specific overall and component evolution continues, as evidenced by the new yaw-control actuator. Simultaneously, Hawker Siddeley, Fairey and Plessey are each devoting effort to improving component reliability.