required of Rafale cannot be achieved by a plain delta, however. The solution is a double delta, which combines the basic planform’s low supersonic drag with the lower manoeuvre drag of a longer-span, moderate-sweep wing. Rafale’s wing is also larger, 47m² against 41m² for the Mirage 2000, with a greater aspect ratio (2.5 against 1.97). Wingtip-mounted missiles increase effective span still further.

Dassault’s experience with the delta-canard configuration is also long standing. It began with a moustachioed Milan in 1969, in an attempt to overcome the landing-speed drawbacks of the traditional delta. The retractable-foreplane Milan was followed in 1979 by the Mirage 4000, and in 1982 by the “new generation” Mirage IIID—both with close-coupled foreplanes added to destabilise the fly-by-wire aircraft for manoeuvrability. The Mirage 4000, with its variable-incidence foreplane, had perhaps the greatest relevance to the Rafale design.

In addition to improving overall aerodynamic efficiency, Rafale’s all-moving foreplane is positioned to improve wing efficiency at high angles of attack, says Dassault. The company also argues that the shoulder location of the foreplane avoids obstruction of the pilot’s downwards view. Ensuring high manoeuvrability throughout the flight envelope requires mastery of the longitudinal balance of forces, Dassault notes, and the foreplane and elevons work together to maximise lift-to-drag ratio at all times.

Rafale owes its distinctive appearance to its unique semi-ventral intakes. Gone are Dassault’s familiar semicircular side intakes with their moving half-cone centrebodies (nicknamed souris, or mice), chosen for their good pressure recovery at Mach 2. In fact, Rafale’s intakes are an evolution of this traditional design, moved downwards to a position where the forward fuselage deflects airflow into the inlets at high angles of attack. Early Rafale impressions show the intakes complete with souris, but these are now gone, leaving a simple inlet with no moving parts and no boundary-layer bleed, yet still capable of Mach 2 operation.

According to Dassault the intakes were the last element of the Rafale design to be finalised. One requirement was for entirely separate inlets, to prevent the failure of one engine affecting airflow into the other. This segregation also leaves room on the centreline for a long underfuselage store. Because of its intake design Rafale sits much lower on the ground than British Aerospace’s EAP fighter technology demonstrator, with its chin intake.

The rationale behind the design of the entire front fuselage, including inlets and foreplanes, is to provide clean air to the engines at greater angles of attack than are possible with the Mirage 2000, Dassault says without being specific (the Mirage 4000 is capable of angles of attack up to 25°).

Manoeuvrability is a function of thrust-to-weight ratio, so the desire to reduce aircraft weight is driven not only by cost, but also by performance. About 35% of Rafale’s structure weight is advanced materials—carbonfibre and Kevlar composites, aluminium-lithium, and superplastic-formed/diffusion-bonded (SPF/DB) titanium. Again Dassault points to its previous experience, particularly to the all-composite fin tank on the Mirage 4000 and the all-composite wing for the Falcon V10F business jet.

About 25% of Rafale’s structure weight is composites—mainly carbonfibre with some Kevlar. Carbonfibre components include the forward fuselage, centre fuel tank, wing, fin, foreplane, landing gear and engine-bay doors, and other panels. Kevlar parts include the radome, tail fairing, and wing/fuselage fillets. The all-composite wing design is based on technology developed for the V10F wing, with a new high-strength material (Hercules IM6 fibre in Narmco 5245C resin) allowing even greater weight savings, says Dassault.

Although it has the potential to replace 60% of the aluminium used in the airframe—for a 10% per cent weight saving—lighter, stiffer aluminium-lithium (Al-Li) is used only to a limited extent on Rafale A, for fuselage skins which double as fuel tank walls and for wing and fin attachment fittings. At the time manufacture started, large billets of Al-Li suitable for fuselage frames were not available, although such major components are now being manufactured.

Dassault first used SPF/DB titanium for the deceptively complex intake strakes on the Mirage 2000. On Rafale the process allowed the six leading-edge-slat sections to be produced to accurate shapes and dimensions. Each self-stiffened slat was formed in a single operation from titanium sheet, saving weight and, in volume production, cost.

The Rafale flight control system is a development of that used in the Mirage 2000, and is all-digital where the earlier system is a hybrid with analogue control law computation and digital monitoring. Where the Mirage 2000 has seven control surfaces at its disposal, Rafale has 17—six elevons, six slats, two foreplanes, two airbrakes, and a rudder. Computer power and speed is increased accordingly.

Dassault declines to describe the Rafale control system in detail, saying only that it is much more elaborate than that in the Mirage 2000. As in the earlier aircraft, computing redundancy is quadruplex, with a fifth, entirely independent electrical channel providing get-home capability. In Rafale this backup channel is more sophisticated than on the Mirage 2000, and with three elevons per side, plus all-moving foreplanes, Rafale has greater scope for surviving actuator failure or control-surface damage, says Dassault.

A closer look at the Mirage 2000 fly-by-wire may provide clues to the nature of the Rafale system. The four computers are grouped in two boxes, one responsible for the outer pair of elevons, the other for the...