Aircraft	Normal Gross Weight lb	Wing Area ft²	Takeoff Power hp	Maximum Speed mph
Spitfire IX	7900	242	1580	408 @22 500 ft
P-51B	9800	233·19	1380	440 @25 000 ft
P-51D	10 100	235·75	1490	437 @25 000 ft
Fw190A-8	9660	196·98	1700	402 @18 045 ft
Fw190D-9	9480	196·98	1776	426 @21 650 ft

Table 1
Nominal aircraft specifications

The Spitfire wing is famous for having an elliptic planform. Indeed, the chord distribution is elliptical. An examination of the resulting circulation distribution for a trimmed condition mentioned above, shows that the loading distribution is not elliptical, though it is probably the most optimum of the three aircraft from the induced drag standpoint. The reason for deviation from elliptical is the 2° of washout added to the elliptical planform, which shifts the loading inboard. The elliptical wing planform appears to have been chosen primarily to provide greater wing depth in the inboard portion of the wing, while keeping the aerofoil thickness-to-chord ratios low[7]. This depth was necessary to house the outward retracting landing gear and wing gun ammunition boxes.

WETTED AREA COMPARISON

Previously, wetted areas have been computed based upon rules of thumb, but they can now be calculated with great accuracy, based upon the panel model representation. The wetted areas of the aircraft considered here, excluding the ducts for the cooling system, are presented in Table 2. Notable is that the Mustang has the largest wetted area of this group of aircraft. With the same version of the Rolls-Royce Merlin and propeller installed, the Mustang X was measured to be 23 mph faster than the Spitfire IX[8]. The Mustang X was an Allison powered Mustang re-engined by Rolls-Royce. The P-51B, with an improved cooling system configuration is even faster than the Spitfire IX. The difference in performance between the Mustang and the Spitfire is attributed to several factors. These include the superior configuration of the Mustang's cooling system and the Spitfire's relatively high level of excrescence drag, generated by open wheel wells, a non-retractable tail wheel and other design details[9–11]. The Spitfire IX and Fw190A are credited with about equal performance up to 22 000 ft[12]. It is estimated that the Fw190A has slightly more power available at this altitude than the Spitfire IX. This three-way comparison implies that the Mustang has the lowest value of drag per unit of wetted area ($C_{D_{swet}}$, a measure of "aerodynamic cleanliness").

Table 2
Calculated wetted areas

Spitfire IX	831·2 ft²
P-51B Mustang	869·8 ft²
P-51D Mustang	878·0 ft²
Fw190A-8	727·1 ft²
Fw190D-9	760·6 ft²

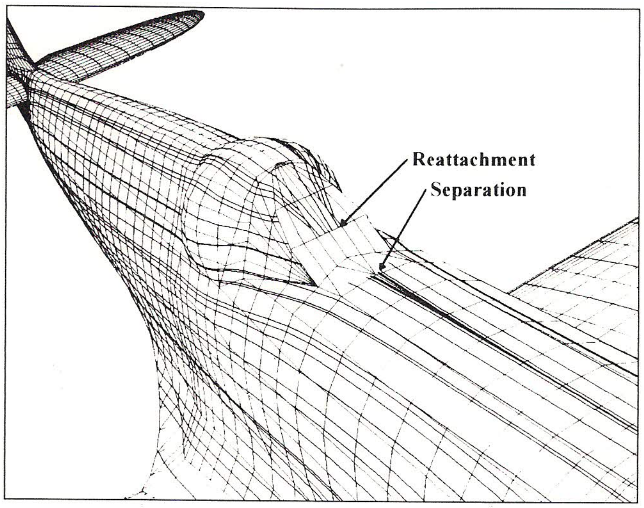

Figure 8. Calculated Spitfire windscreen separation.

SPITFIRE ANALYSIS HIGHLIGHTS

Many interesting features were noted in the results of the analysis of each aircraft using VSAERO. For the sake of brevity, only two major points of interest will be discussed for each aircraft. A full discussion of the results obtained for the P-51 Mustang can be found in Ref. 6.

One of the first things to come to light in the VSAERO analysis of the Spitfire is a region of separated flow at the base of the windscreen. The computation indicates that the boundary layer separates approximately 6 in ahead of the windscreen, due to the adverse pressure gradient (Fig. 8). The boundary layer traces which stop at separation have been restarted on the windshield at the point where the static pressure is the same as that at separation. Such a separation is not present on either of the other two aircraft reviewed here. However, this is a feature quite common on automobiles and is related to the slope of the windscreen[13]. The Spitfire's windscreen is at a 35° angle to the forward deck, while the Fw190's is at a 22° angle and the P-51's is at a 31° angle. Evidently, the Spitfire's windscreen is too steep. An experimental windscreen, rounded and of shallower slope, was fitted to a Spitfire IX in 1943 and produced a speed increase of 12 mph at $M = 0{\cdot}79$[7]. A similar windscreen introduced on the Seafire XVII, is credited with a speed gain of 7 mph, at 400 mph[14].

Supermarine is often regarded as being one of the first companies to make use of the breakthroughs made by Meredith at RAE Farnborough in the design of ducts for cooling systems[15]. In fact, the Spitfire's radiator ducts were designed using these guidelines. The VSAERO calculation indicates the boundary layer on the lower surface of the wing is ingested by the cooling system inlet. Running into the severe adverse pressure gradient ahead of the radiator, the boundary layer separates shortly after entering the duct, resulting in a large drag penalty (Fig. 9). Experimentally, it

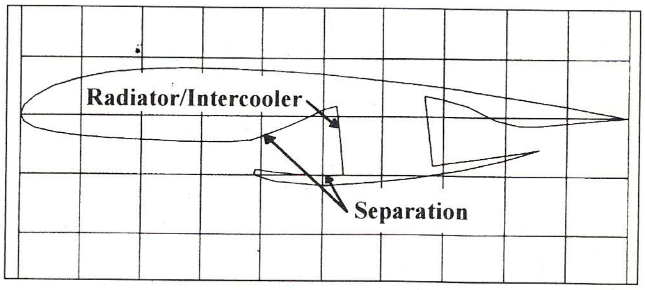

Figure 9. Calculated separation locations in the Spitfire cooling system.