STATUS REPORT ON THE EET HORIZONTAL TAILS INVESTIGATION AND THE EET LATERAL CONTROLS INVESTIGATION

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ABSTRACT

In the late 1980's or early 1990's, jet transports will be highly fuel efficient configurations, utilizing high-aspect-ratio supercritical wings and other advanced aerodynamic concepts to reduce drag. While much preliminary work has been done in the development of practical airplane configurations, two areas of interest need to be investigated further. First, the impact of the increased nose-down pitching moments, characteristic of supercritical wings, on trim drag must be assessed. Second, the effect of the highly aft-cambered supercritical wing sections on the performance of lateral-control systems needs to be determined. These two areas are not unrelated. An aircraft employing an advanced lateral/active control system with gust and maneuver load alleviation, flutter suppression, and relaxed static stability may have a smaller horizontal tail which, in turn, may reduce the trim drag increment for the aircraft. Experimental data in these important areas were obtained in two separate wind tunnel investigations recently conducted in the Langley 8-Foot Transonic Pressure Tunnel as a part of the NASA Energy Efficient Transport Program.

In the EET Horizontal Tails Investigation, aerodynamic data were measured for five different horizontal tails on a full-span model with a wide-body fuselage. Three of the horizontal tails were low-tail configurations and two were T-tail configurations. All five tails were tested in conjunction with two wings, a current wide-body wing and a high-aspect-ratio supercritical wing. Local downwash angles and dynamic pressures in the vicinity of the tails were also measured using a yaw-head rake. The results of this investigation will provide a comparison of the aerodynamic characteristics of the two wing configurations at trimmed conditions for Mach numbers between 0.60 and 0.90.

In the EET Lateral Controls Investigation, the control effectiveness of a conventional set of lateral controls was measured over a Mach number range from 0.60 to 0.90 on a high-aspect-ratio supercritical wing semispan model. The conventional controls included a high-speed aileron, a low-speed aileron, and six spoiler segments. The wing was designed so that the last 25 percent of the chord is removable to facilitate testing of various control systems, for example, active controls.

Because these investigations have only recently been completed, data are not yet available. The current status and an indication of the data obtained in these investigations will be presented.

OBJECTIVES OF EET HORIZONTAL TAILS INVESTIGATION

The main objective of this program was to assess the trim drag of a high-aspect-ratio supercritical wing configuration relative to the trim drag of a current wide-body configuration. Included in the investigation were tests to study the effects of horizontal-tail position (low-tail versus T-tail), horizontal-tail camber, elevator effectiveness, and a survey of the flow field in the vicinity of the horizontal tails with a yaw-head rake to determine local flow angles and dynamic pressures. Figures 1 and 2 show the models used in this investigation in the Langley 8-Foot Transonic Pressure Tunnel.

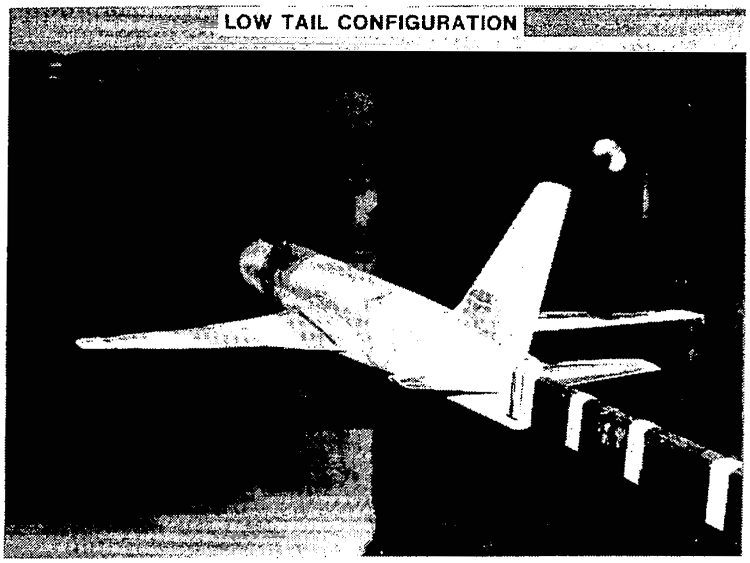

Figure 1.

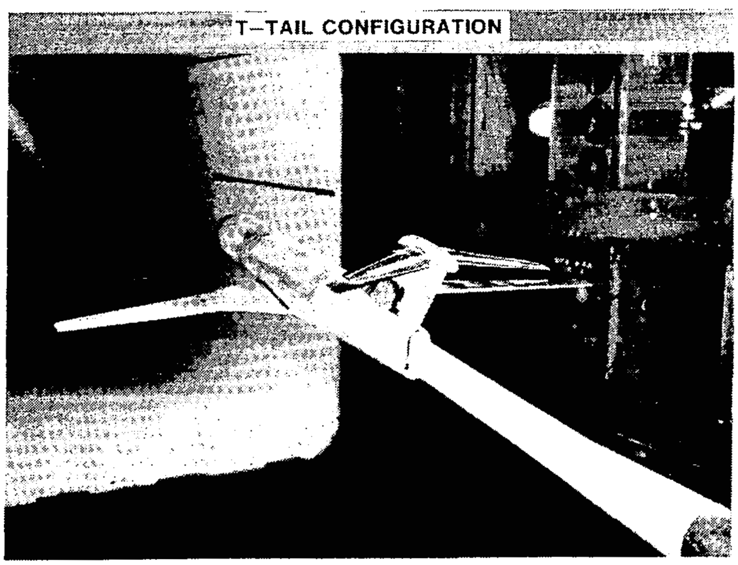

Figure 2.

LOW-TAIL WIND TUNNEL MODEL

A sketch of the model with the three low horizontal tails is shown in figure 3. H_1 and H_3, shown by the solid line, have a smaller planform area than H_2, shown by the dashed line. H_1 and H_2 have cambered supercritical airfoil sections and H_3 has a symmetrical supercritical section. The horizontal tails used incidence blocks which allowed rotation of the tail from -4° to 4° in 0.5° increments. Additionally, the cambered horizontal tails H_1 and H_2 had 30-percent-chord full-span elevators with angle brackets for deflections up to $\pm 5^\circ$. These brackets are visible in the photograph of the model in the wind tunnel (see fig. 1).

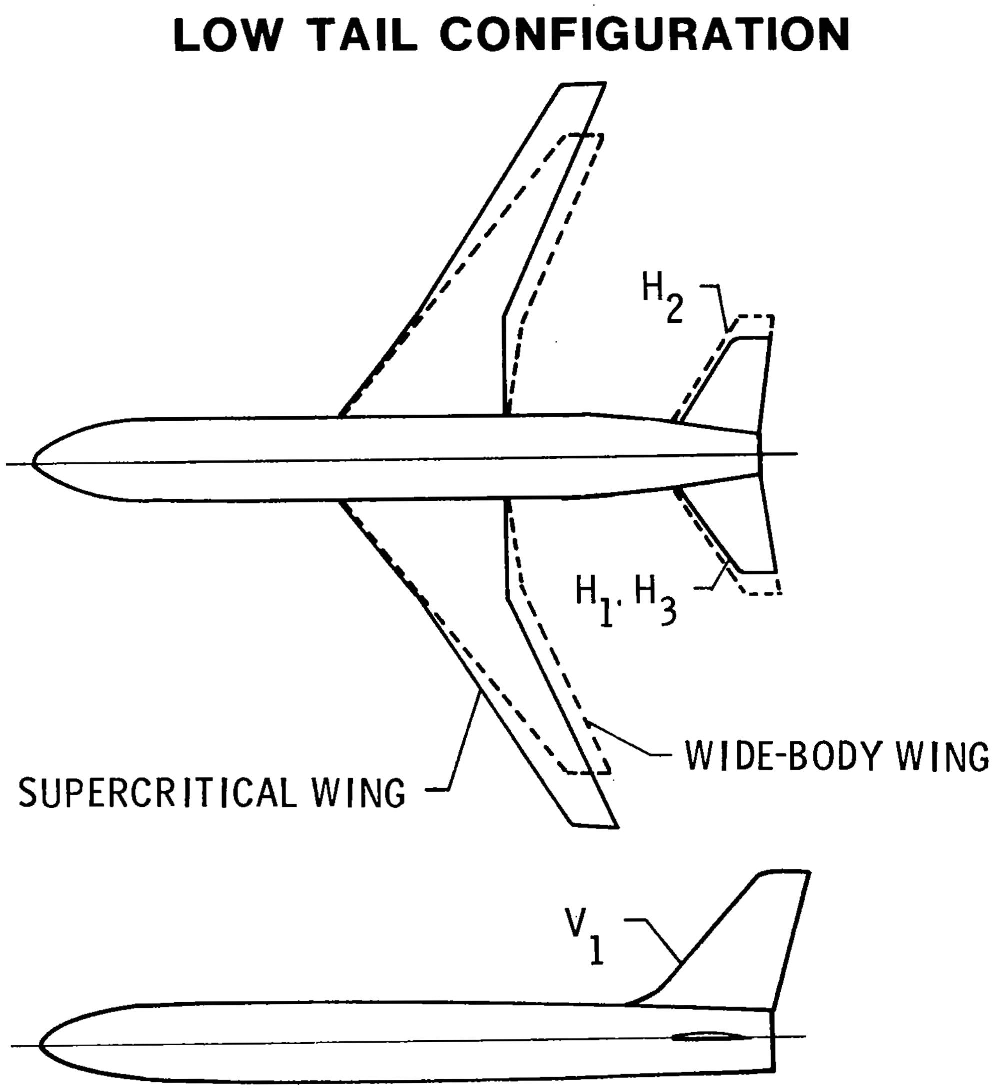

Figure 3.

T-TAIL WIND-TUNNEL MODEL

A sketch of the model in the T-tail configuration is shown in figure 4. H_4 has a cambered supercritical airfoil section and H_5 has a symmetrical section. The horizontal tails for the T-tail also had incidence blocks which allowed rotation between -4^o and 4^o in 0.5^o increments. The cambered tail, H_4, had an elevator with angle brackets similar to H_1 and H_2. A photograph of the T-tail configuration is shown in figure 2.

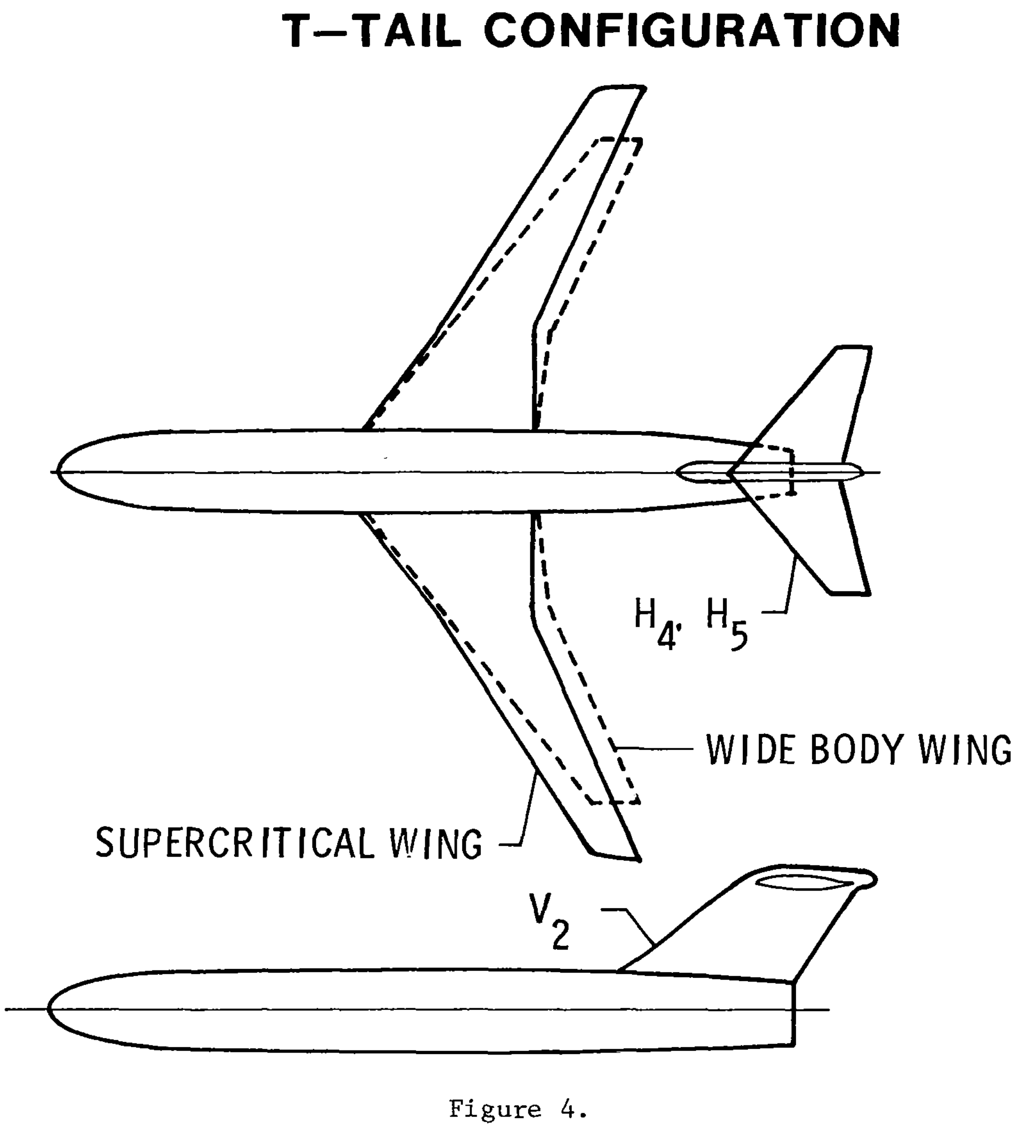

Figure 4.

HORIZONTAL- AND VERTICAL-TAIL AIRFOILS

Figure 5 shows sketches of the airfoil sections used for the horizontal and vertical tails. A 10-percent-thick cambered supercritical airfoil was used for horizontal tails H_1, H_2, and H_4. A 10-percent-thick symmetrical supercritical airfoil was used for horizontal tails H_3 and H_5 and was also used for the low-tail vertical V_1. A 12-percent-thick symmetrical supercritical airfoil was used for the T-tail vertical V_2.

HORIZONTAL AND VERTICAL TAIL AIRFOILS

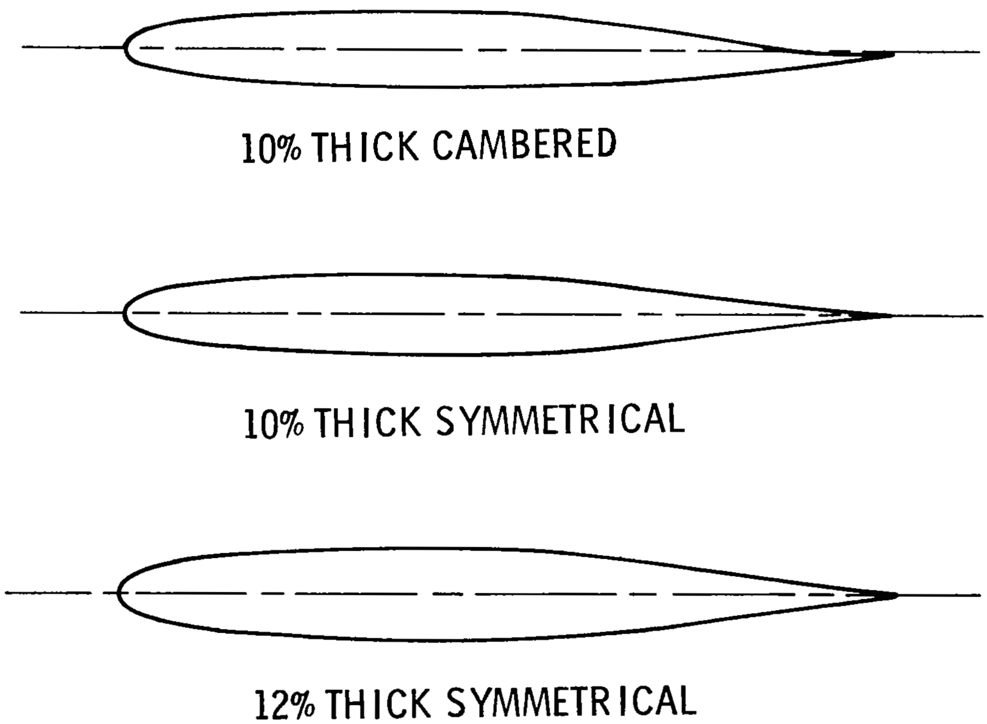

Figure 5.

TAIL CHARACTERISTICS

Several important tail parameters are presented in figure 6 for each tail. The tail area listed for the horizontal tails is the trapezoidal area extended to the fuselage center line, but for the vertical tails, the area shown is exposed area. Tail volume coefficient gives an indication of the tail contribution to overall stability level and is defined as

$$C_t = \frac{\ell_t S_t}{\bar{c}_w S_w}$$

where ℓ_t = the distance from the center of gravity to the aerodynamic center of the tail

S_t = tail planform area

$\bar{c}_w$ = mean aerodynamic chord of the wing

S_w = wing planform area

These tails were designed to have approximately the same relative size and tail volume coefficient as current technology aircraft. However, because the mean aerodynamic chord for the wide-body configuration was larger than for the supercritical wing configuration, the tail volume coefficients for the wide body are less.

Neglecting tail dihedral, horizontal tails H_1, H_3, H_4, and H_5 have the same geometry and planform area. H_2, which is slightly larger than the other horizontal tails, was designed to have the same exposed area and tail volume coefficient as the T-tail horizontal tails H_4 and H_5.

TAIL CHARACTERISTICS

	TAIL	AIRFOIL	AREA m^2 (ft)	TAIL VOLUME COEFFICIENT	
				SCW	WIDE BODY
LOW TAIL	H_1	10% THICK CAMBERED	.05 (.55)	.90	.69
	H_2	10% THICK CAMBERED	.07 (.70)	1.12	.86
	H_3	10% THICK SYMMETRICAL	.05 (.55)	.90	.69
	V_1	10% THICK SYMMETRICAL	.04 (.42)	.67	.51
T-TAIL	H_4	10% THICK CAMBERED	.05 (.56)	1.09	.84
	H_5	10% THICK SYMMETRICAL	.05 (.56)	1.09	.84
	V_2	12% THICK SYMMETRICAL	.04 (.47)	.68	.52

Figure 6.

YAW-HEAD RAKES

The two yaw-head rakes used to measure local flow angles and dynamic pressures are shown in figures 7 and 8. Data were measured at two spanwise tail locations for each set of wing panels in both the low-tail and T-tail configurations. The data from these rakes will be helpful in separating the effects of the wing downwash field and wing wake energy losses on horizontal-tail efficiency.

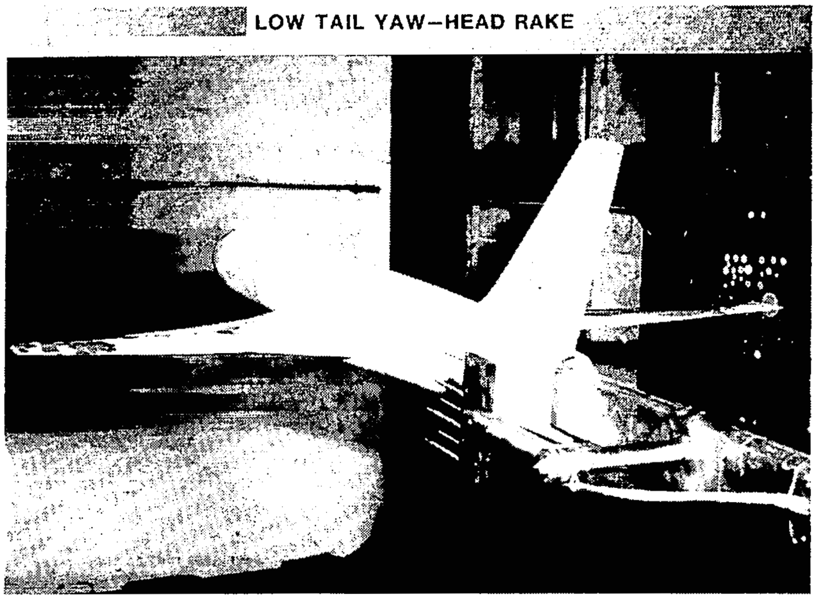

Figure 7.

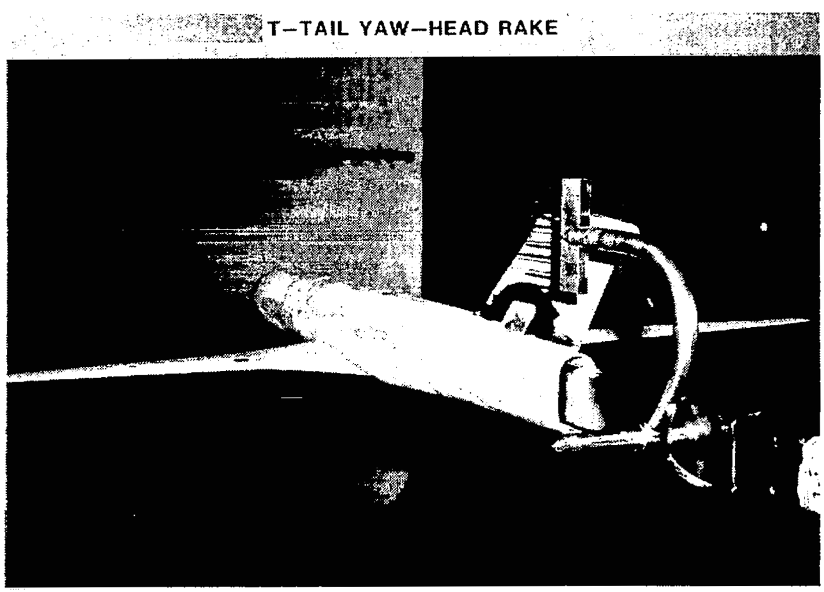

Figure 8.

SUMMARY OF DATA ACQUIRED

A summary of the data acquired in this investigation is shown in figure 9. Aerodynamic data were taken for each set of wing panels in combination with each of the five horizontal tails. Data with elevator deflected were taken for both wings with tails H_1, H_2, and H_4, as well as yaw-head rake data at two spanwise tail locations for both the low-tail and T-tail configurations. Aerodynamic data with the wing panels removed were taken to determine the lift and drag of each tail. The large amount of data from this recent investigation has not been fully analyzed and will not be presented at this time.

EET TAILS INVESTIGATION DATA ACQUIRED

WING	TAIL	ELEVATOR	YAW HEAD RAKE
SCW-4	H_1	YES	
	H_2	YES	
	H_3		
	H_4	YES	
	H_5		
			LOW-TAIL (2 POSITIONS)
			T-TAIL (2 POSITIONS)
WIDE BODY	H_1	YES	
	H_2	YES	
	H_3		
	H_4	YES	
	H_5		
			LOW TAIL (2 POSITIONS)
			T-TAIL (2 POSITIONS)
WING OFF	H_1		
	H_2		
	H_3		
	H_4		
	H_5		

Figure 9.

OBJECTIVE OF EET LATERAL CONTROLS INVESTIGATION

The objective of this investigation is to determine the lateral-control effectiveness parameters for ailerons and spoilers on a high-aspect-ratio supercritical wing configuration. Initially a conventionally sized lateral-control system with high- and low-speed ailerons and spoilers was tested. More advanced control systems (e.g., active controls) may also be tested in the future. Figure 10 shows the semispan model used in this investigation in the Langley 8-Foot Transonic Pressure Tunnel.

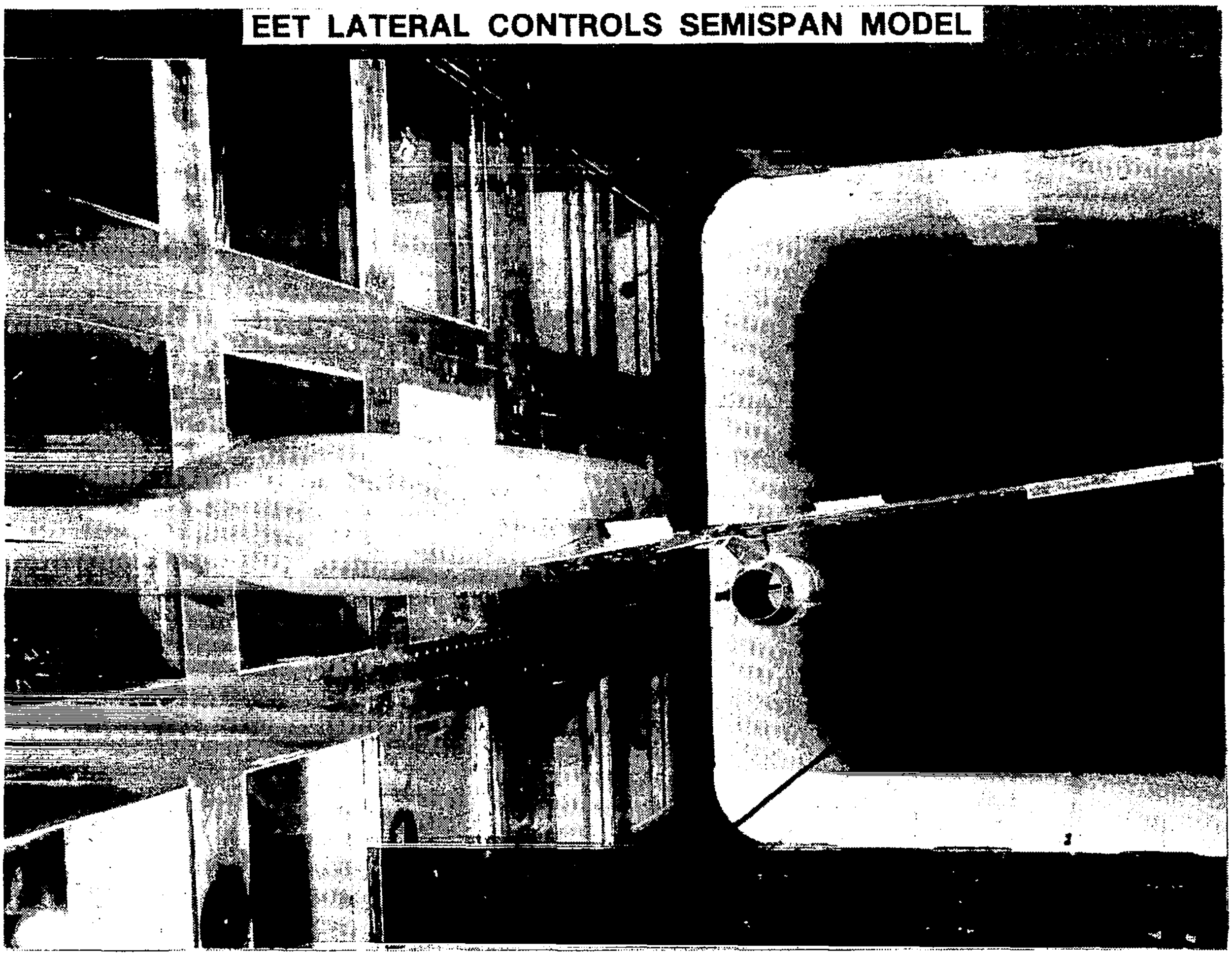

Figure 10.

WIND TUNNEL MODEL

A sketch of the high-aspect-ratio supercritical wing semispan model with a conventional set of lateral controls is shown in figure 11. The model has a high-speed and a low-speed aileron and six spoiler segments. A flow-through nacelle and pylon are located at 40 percent of the wing semispan and the model has the capability of testing winglets. The wing is instrumented with seven rows of pressure tubes and has hinge moment gauges for both ailerons. An important feature of the model is that the last 25 percent of the wing chord is removable, and therefore different control system configurations can be tested.

CONVENTIONAL LATERAL CONTROLS ON SEMISPAN MODEL

A. R. = 9.8 QUARTER-CHORD SWEEP = 30^0

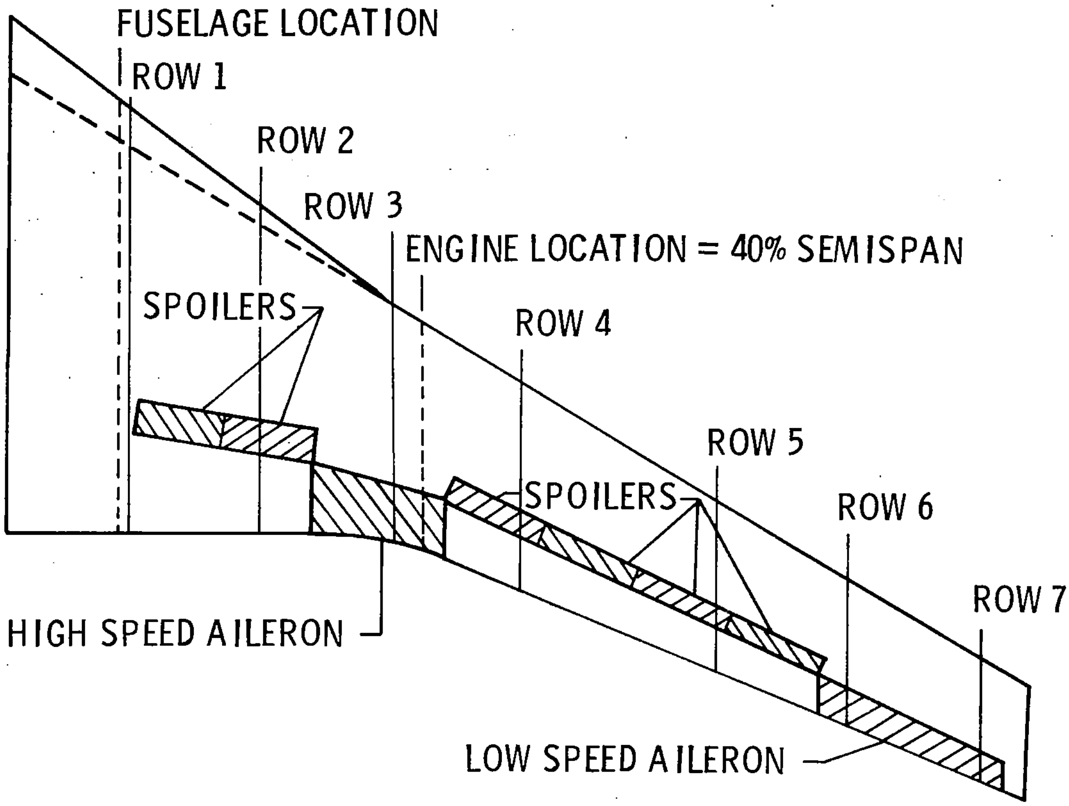

Figure 11.

MODEL CONTROL SURFACES

Detail photographs of the control surfaces are shown in figures 12 and 13. In the initial wind tunnel test of the conventional lateral-control system, data were measured for individual deflections of the high-speed aileron (-12.5° to 12.5°), the low-speed aileron (-17.5° to 17.5°), and the fourth spoiler segment (5°, 10°, 20°, 60°). Individual deflections of the remaining spoilers and combinations of controls will be tested in future wind tunnel entries. Again, because this investigation was only recently completed, data are not available and will not be presented.

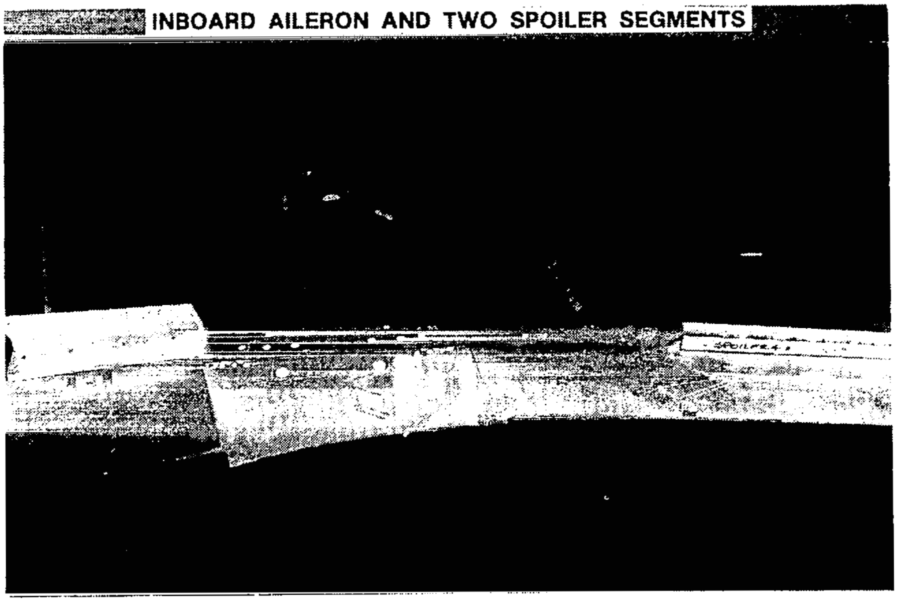

Figure 12.

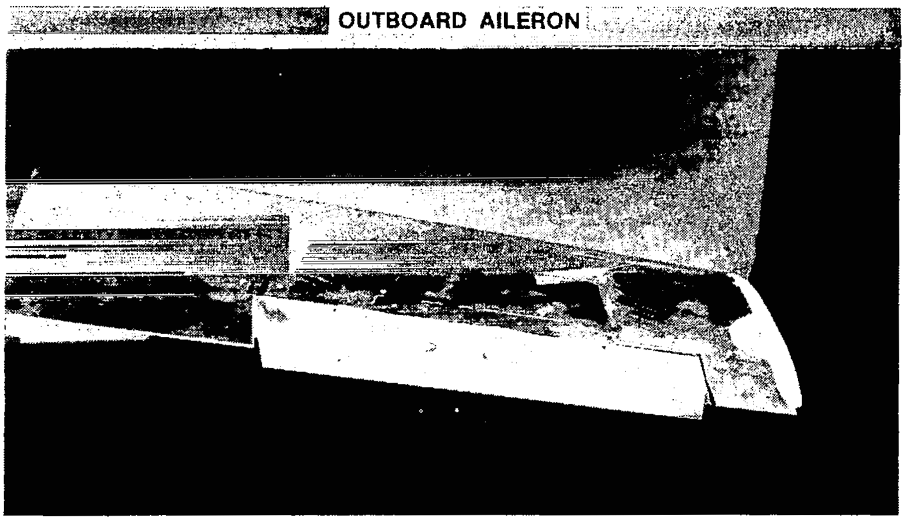

Figure 13.