5/3/05

High Speed Research Program
Aerodynamic Performance Technology Workshop

High Lift Technology Element

Evaluation of Alternate Control Surface Concepts

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OUTLINE

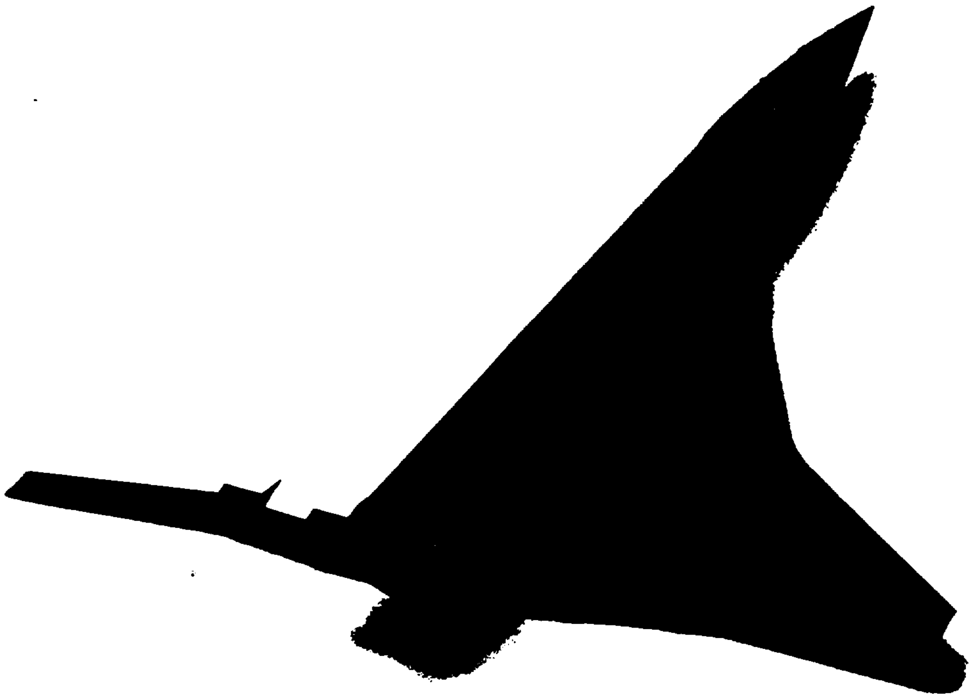
Aerodynamic effects of canard longitudinal and height placement, relative area, and aspect ratio on longitudinal aerodynamics.

Potential of asymmetric chine deflection with emphasis on varying forebody location, height, dihedral, and incidence angle.

Advantages of strategically locating wing mounted upper surface fins relative to the local surface flow.

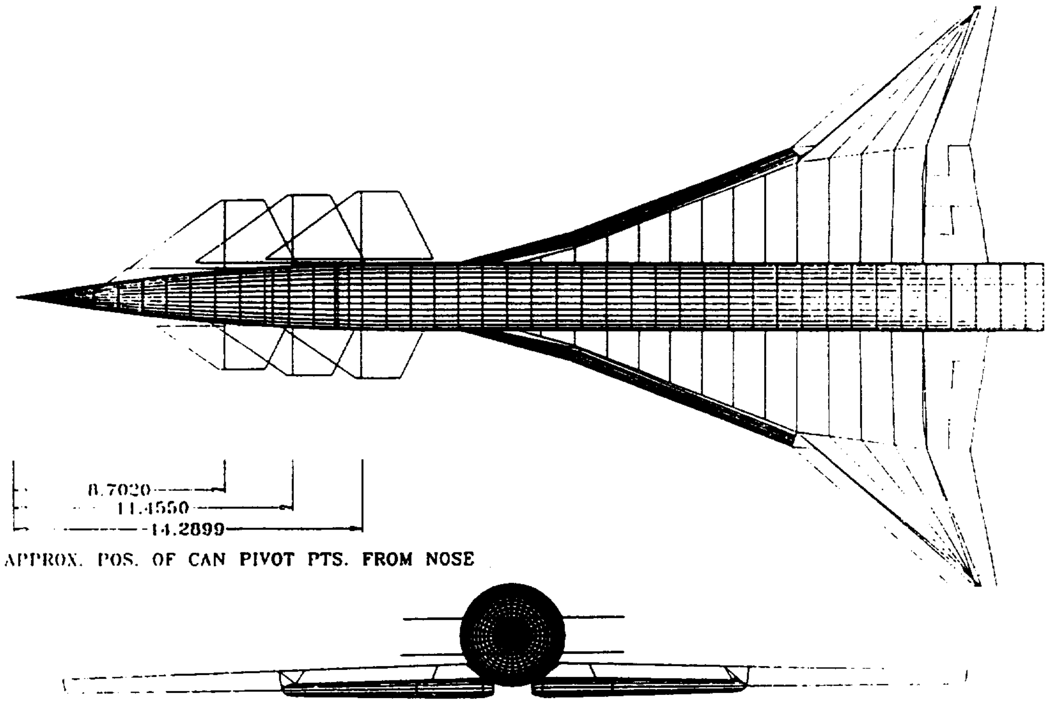
Recommendations

Although several viable concepts have been investigated during recent years, time constraints do not allow for a detailed discussion of each. Therefore, only a small segment of these concepts will be discussed during this workshop. Emphasis will be placed on canards, forebody chines and wing fins.



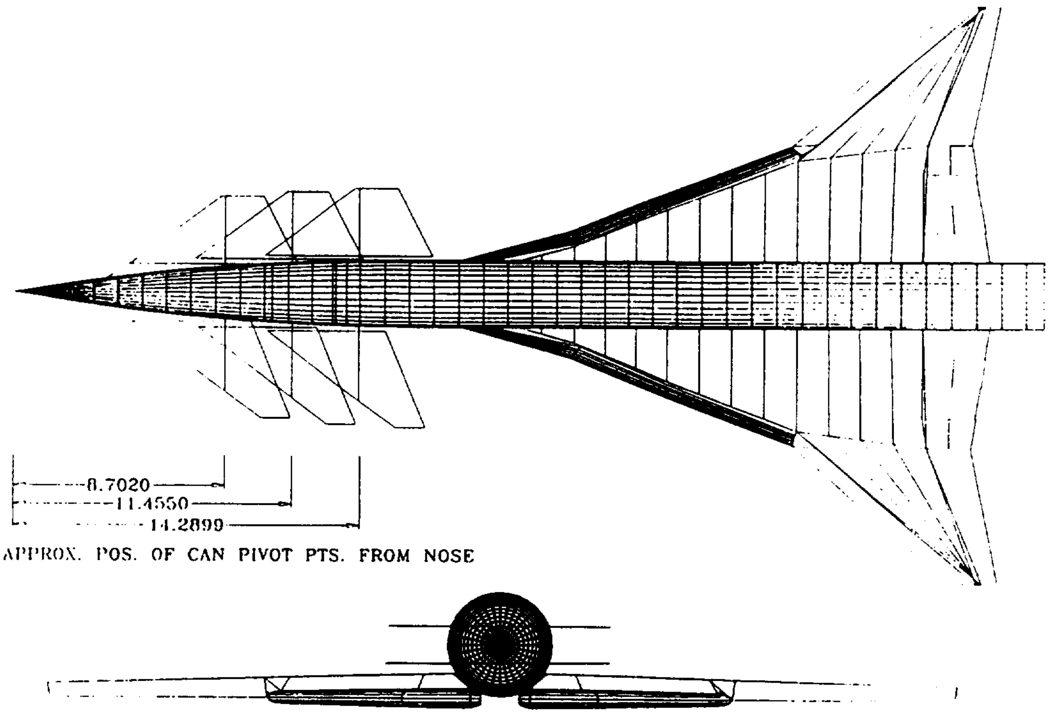
The majority of the data presented were obtained using a 0.01542 scale representation of the HSR Reference-H model. This model was similar in planform, and incorporated full-span leading-edge flaps and segmented trailing-edge flaps. Shown in the photograph is the high-lift configuration of leading-edges at 30°, and trailing-edges at 10°. The wing had no twist or camber. The forebody and fuselage were simple bodies of revolution. A detachable aft fuselage, complete with empennage, was incorporated during the chine study, and removed during the canard tests. The overall length (including aft fuselage) was approximately 58 inches; and the span was 24 inches.

Characteristics of Longitudinal Canard Placement



The canard investigation looked at the effects of canard longitudinal placement, height, surface area, and aspect ratio. This figure shows the baseline canard, sized to be similar to the Ref-H horizontal tail, compared with one half the surface area. Each canard was capable of a wide range of incidence.

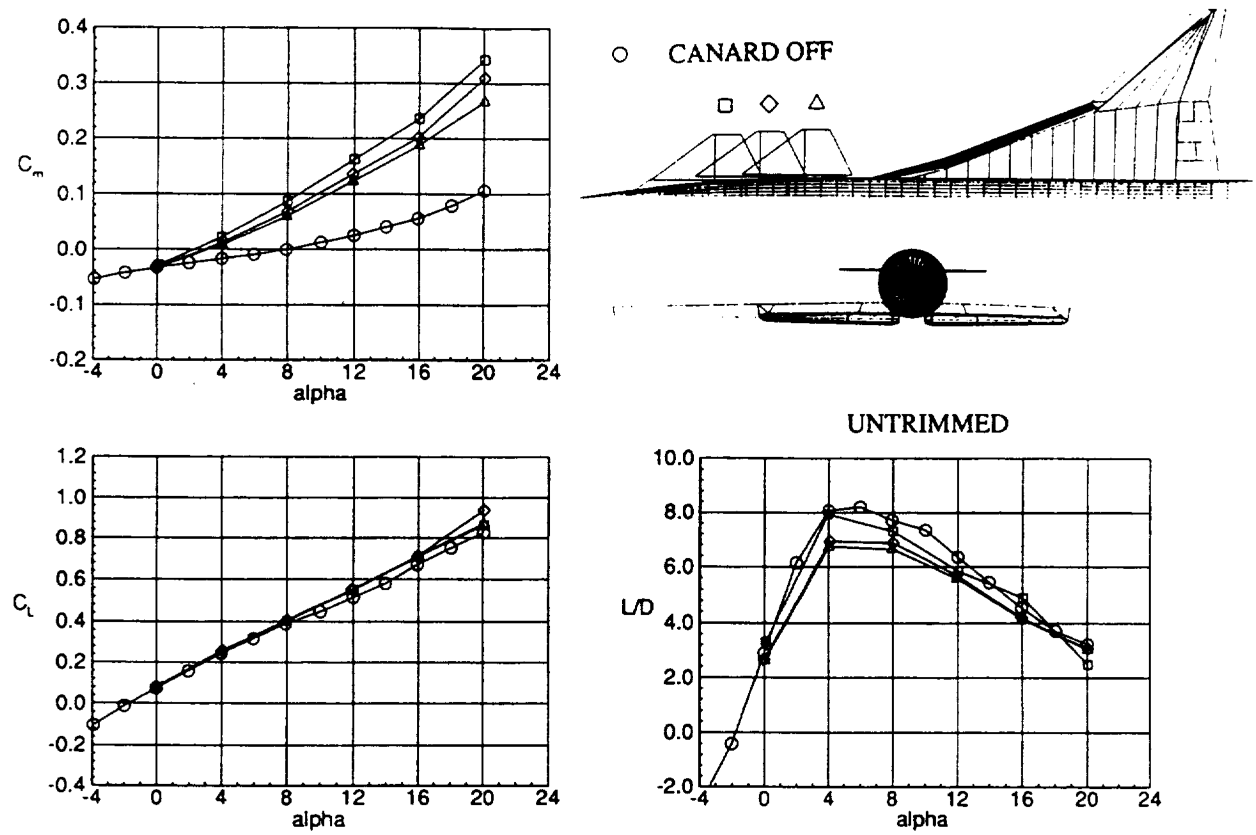
Characteristics of Longitudinal Canard Placement



The canard investigation looked at the effects of canard longitudinal placement, height, surface area, and aspect ratio. This figure shows the baseline canard, sized to be similar to the Ref-H horizontal tail, compared with one that is twice the aspect ratio. Each canard was capable of a wide range of incidence.

Aerodynamic Effects of Canard Longitudinal Placement

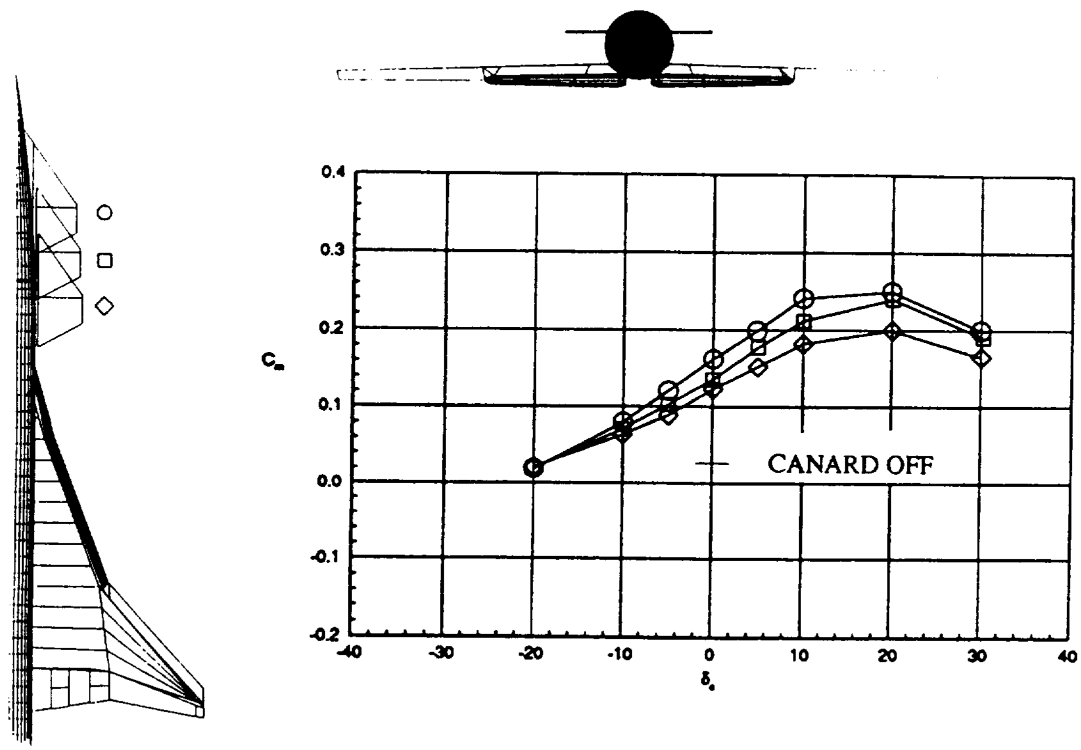
Baseline Canard, Height = upper, $\delta_c = 0^\circ$, Flaps at $30^\circ/10^\circ$, q=25 psf



Reducing the canard moment arm has the effect of similarly reducing the overall pitch of the model. Changing this location had little influence on lift; but, as seen in the L/D plot, has an influence on drag.

Control Power Effects of Canard Longitudinal Placement

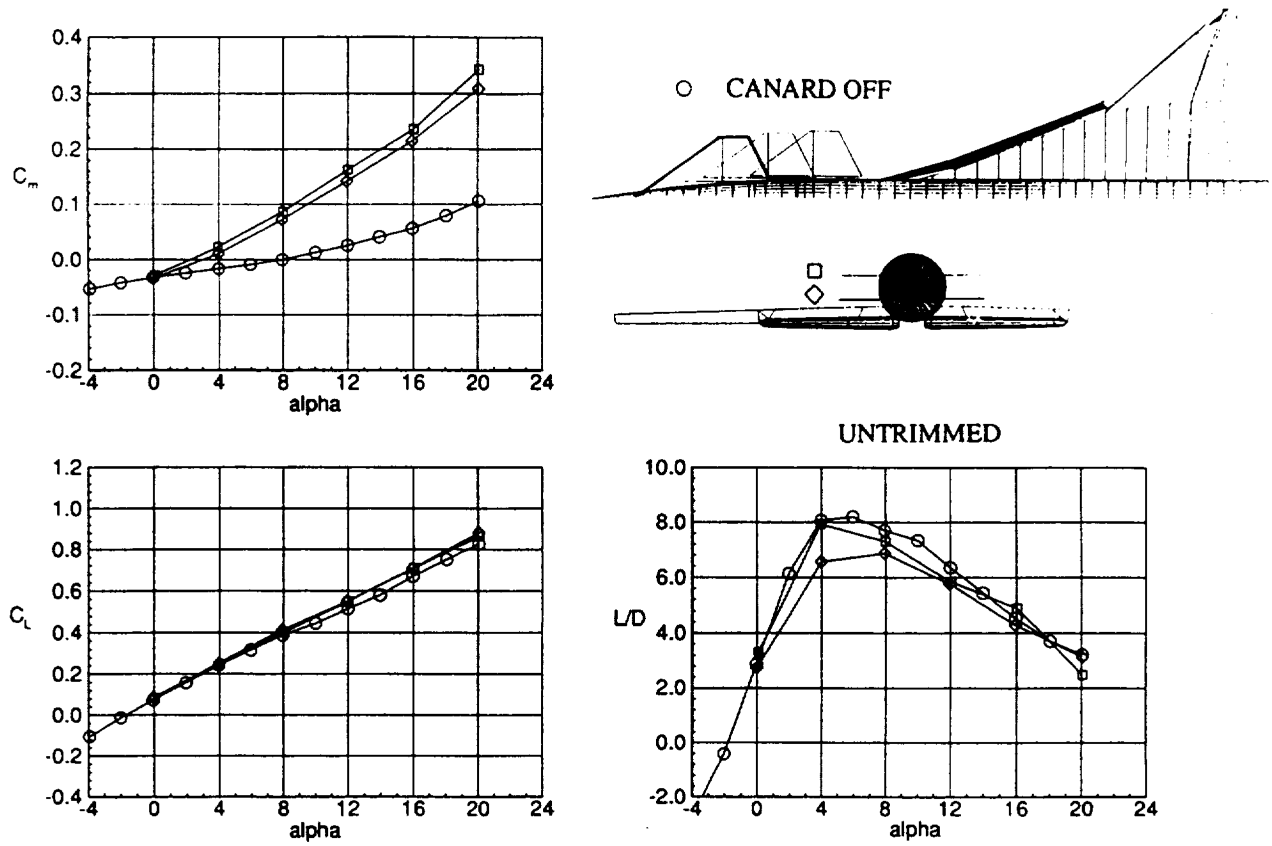
Baseline Canard, Height = upper, α=12°, Flaps at 30°/10°, q=25 psf



The magnitude of control power for each canard location is show for a range of canard incidence angles. Clearly, the more forward position provided significant improvements.

Aerodynamic Effects of Canard Height Placement

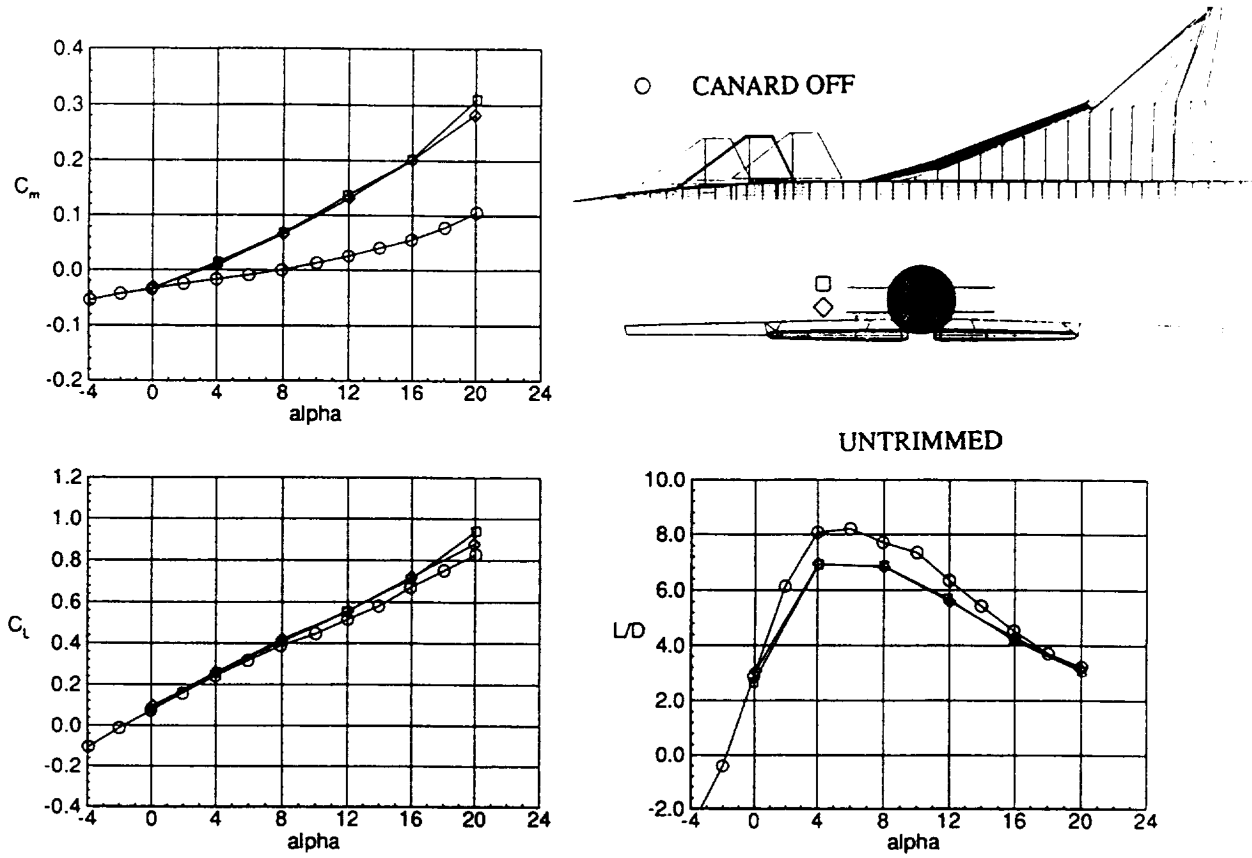
Baseline Canard, Forward Position, $\delta_c=0^o$, Flaps at 30°/10°, q=25 psf



The overall pitch up of the model is reduced by lowering the canard height on the fore-body. However, doing so adversely effects the untrimmed L/D.

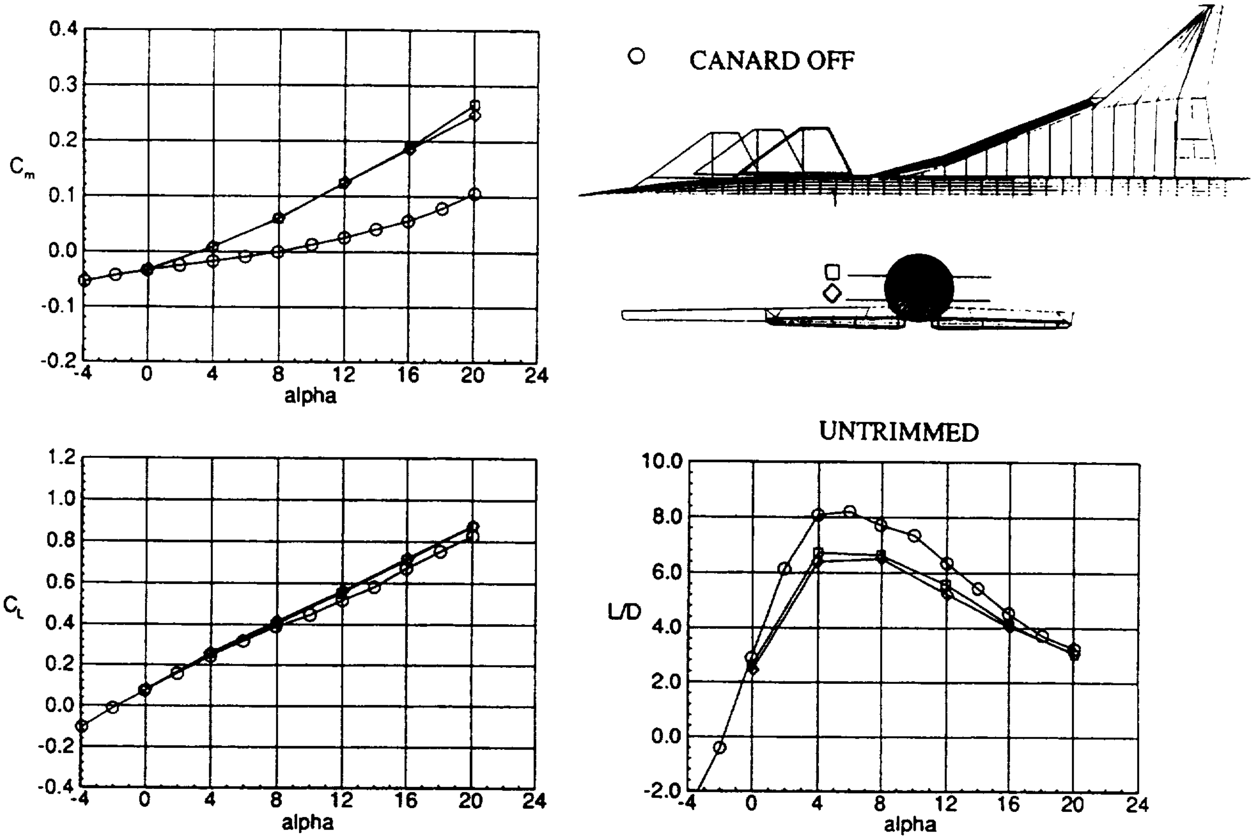
Aerodynamic Effects of Canard Height Placement

Baseline Canard, Middle Position, $\delta_c=0^o$, Flaps at $30^o/10^o$, q=25 psf



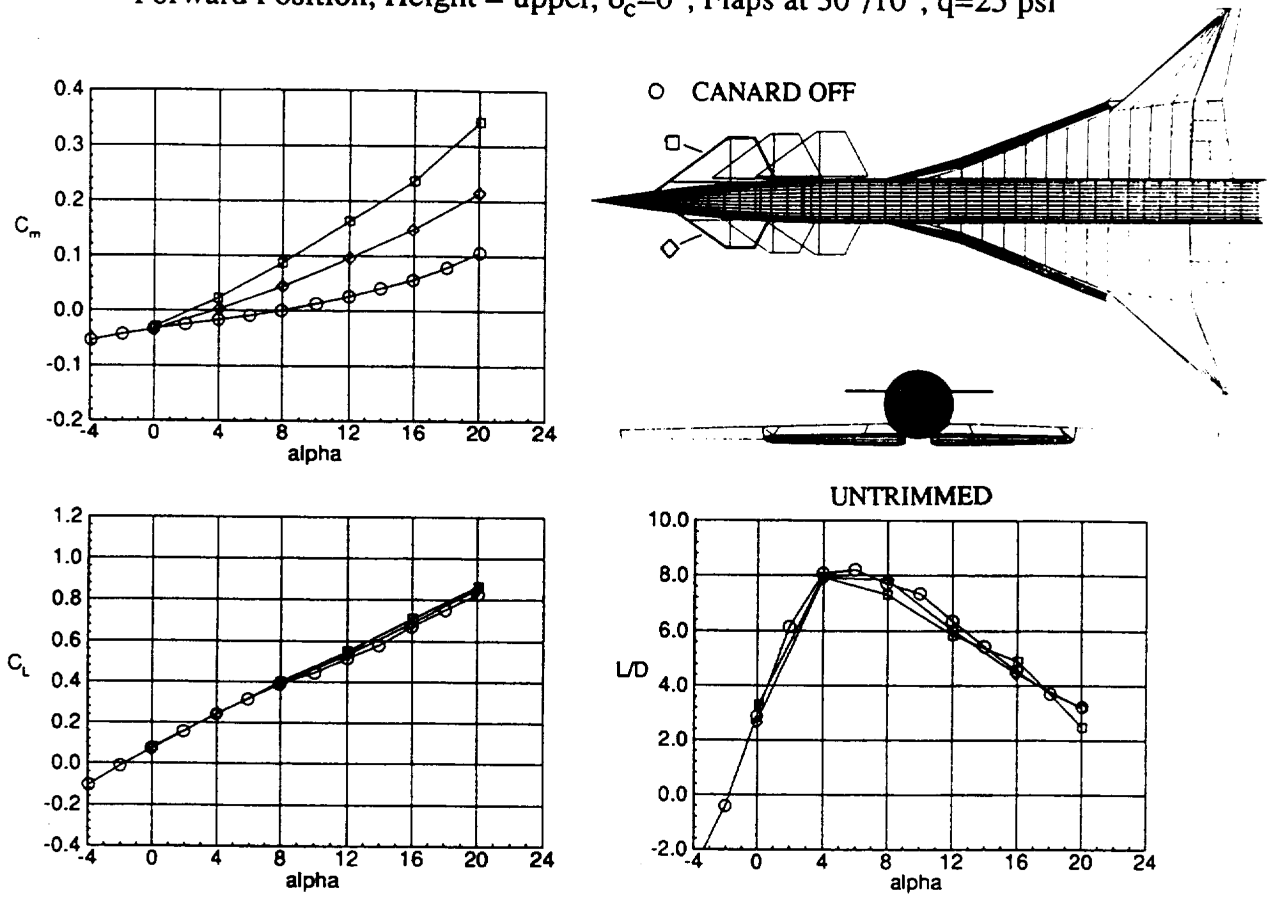
Aerodynamic Effects of Canard Height Placement

Baseline Canard, Aft Position, $\delta_c=0^o$, Flaps at $30^o/10^o$, q=25 psf



Aerodynamic Effects of Canard Surface Area

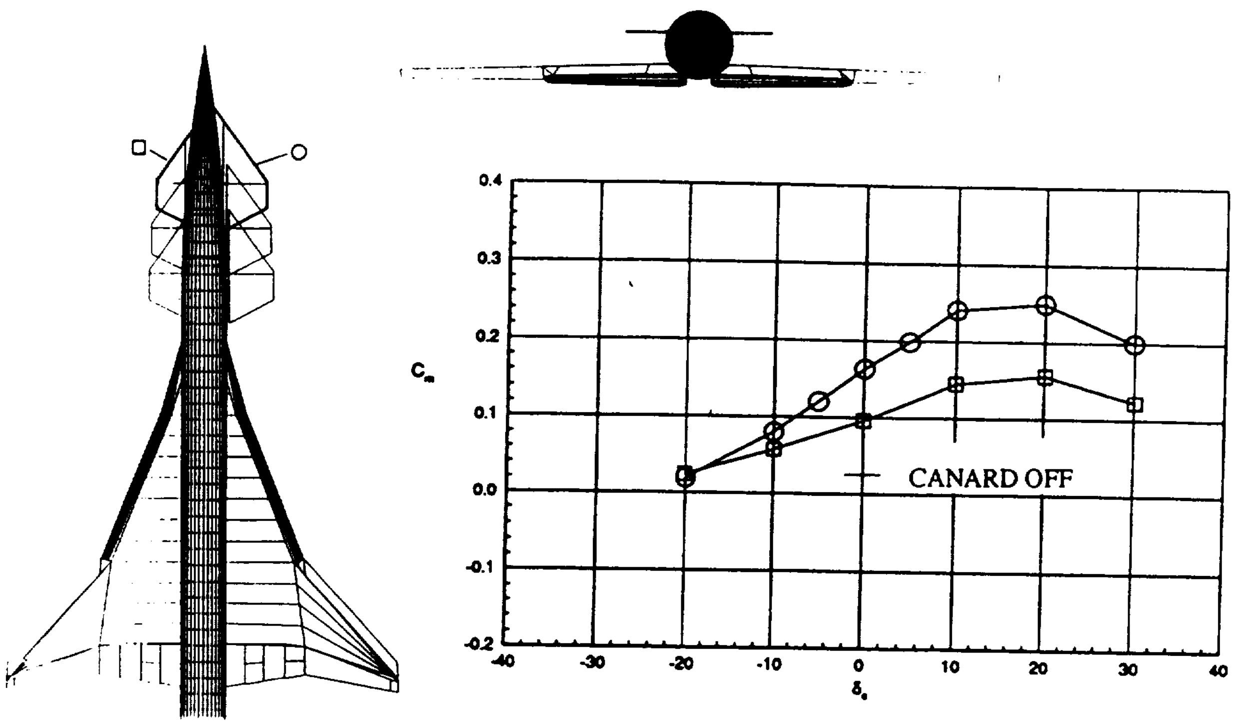
Forward Position, Height = upper, $\delta_c=0^\circ$, Flaps at $30^\circ/10^\circ$, q=25 psf



Halving the canard surface area had the effect of halving the overall model pitch up with little influence on lift. The untrimmed L/D, however, reflects an improvement.

Control Power Effects of Canard Surface Area

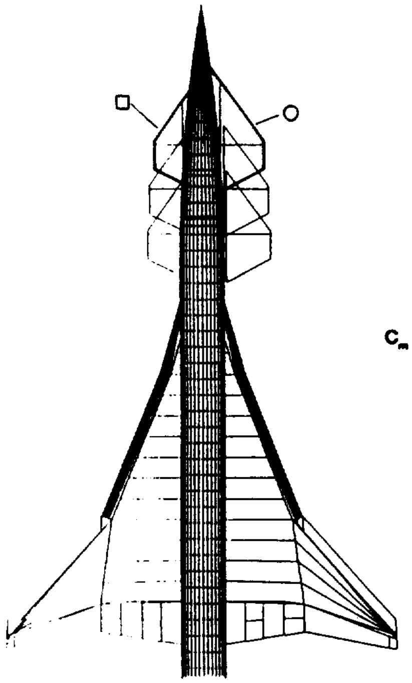
Forward Position, Height = upper, α=12°, Flaps at 30°/10°, q=25 psf

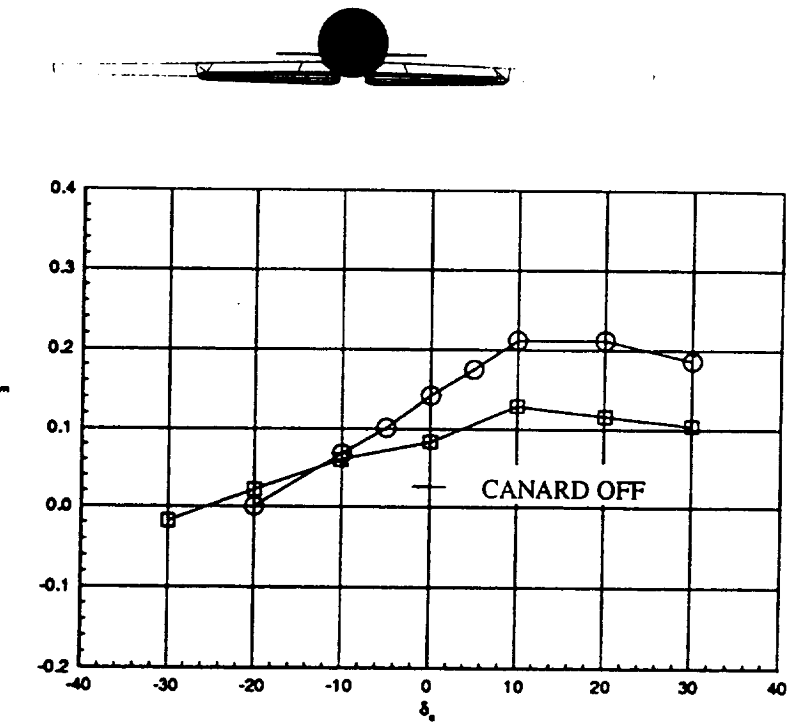


Control power seems to be linearly related to the canard surface area.

Control Power Effects of Canard Surface Area

Forward Position, Height = lower, α=12°, Flaps at 30°/10°, q=25 psf

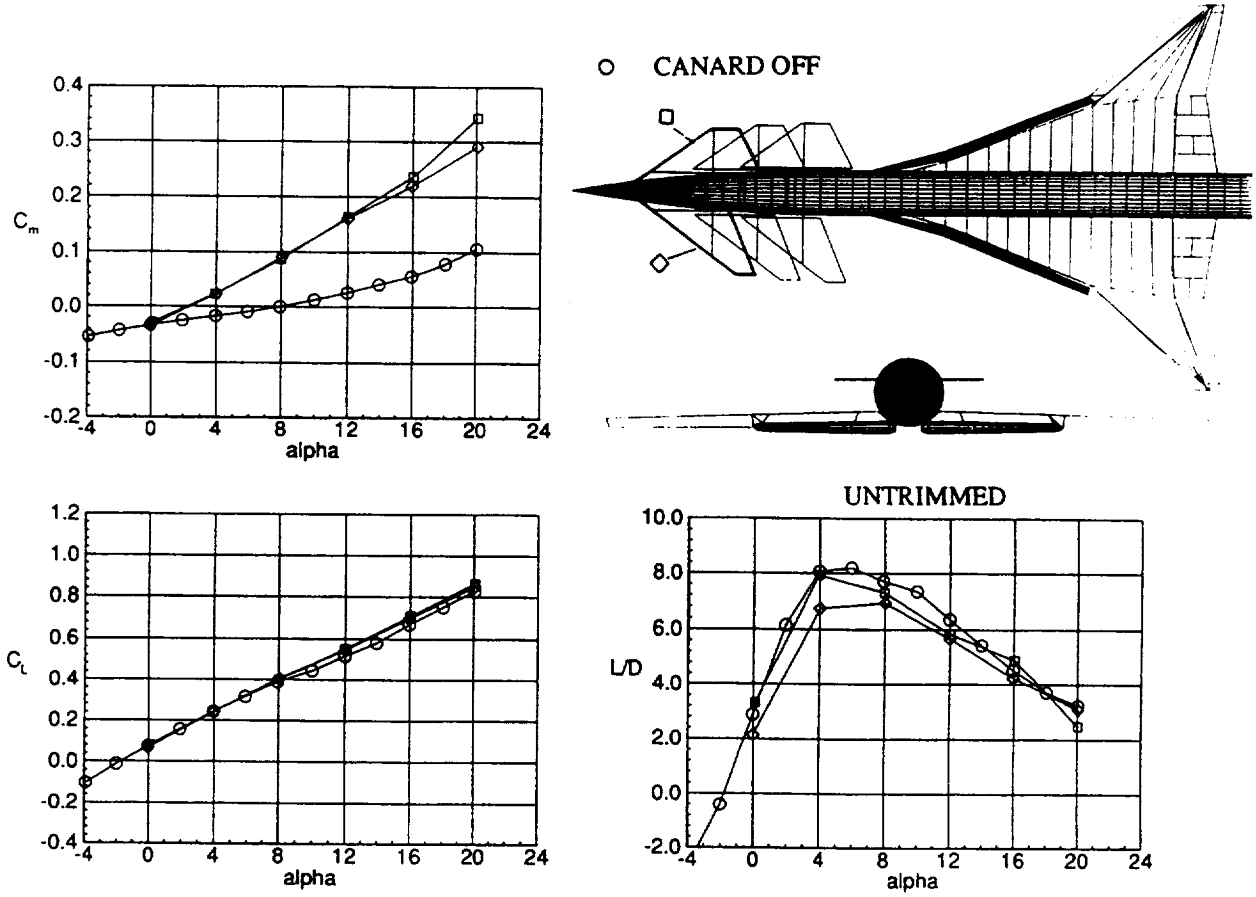




Although the linearity of canard surface area to control power is preserved for the lower height position, the overall magnitude for a given deflection angle is reduced.

Aerodynamic Effects of Canard Aspect Ratio

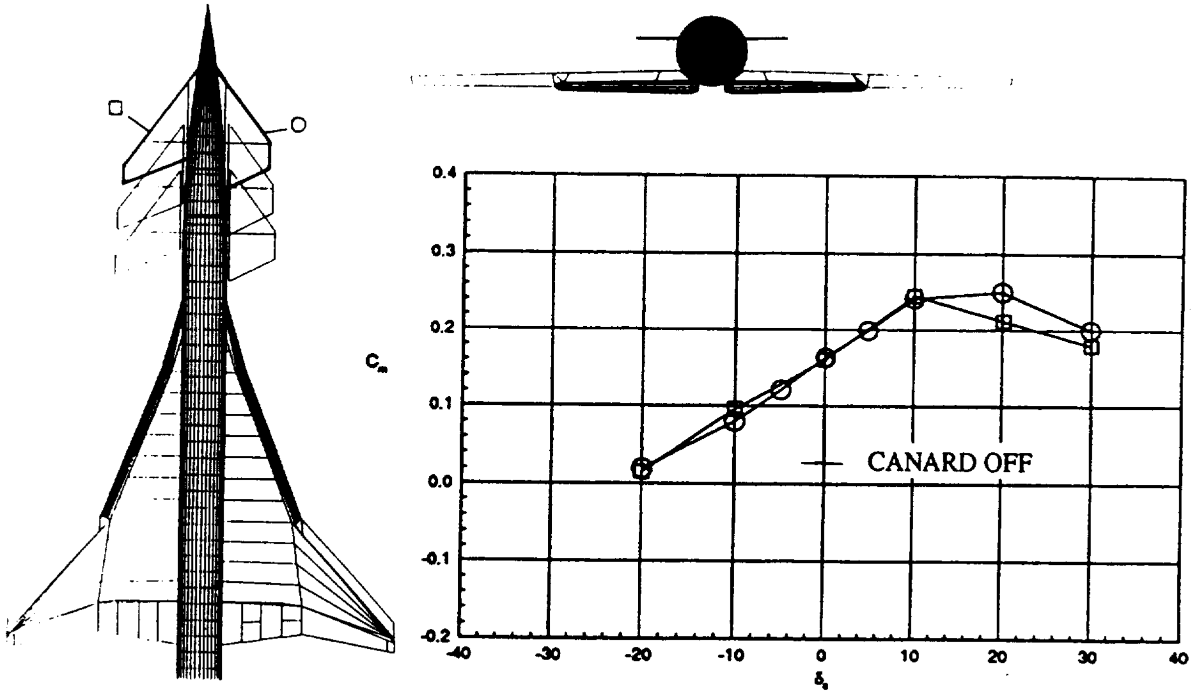
Forward Position, Height = upper, δ_c=0°, Flaps at 30°/10°, q=25 psf



The change in aspect ratio has a direct effect on model pitch at higher angles of attack. The effects on lift are relatively small. Whereas, the effects on untrimmed L/D are significant.

Control Power Effects of Canard Aspect Ratio

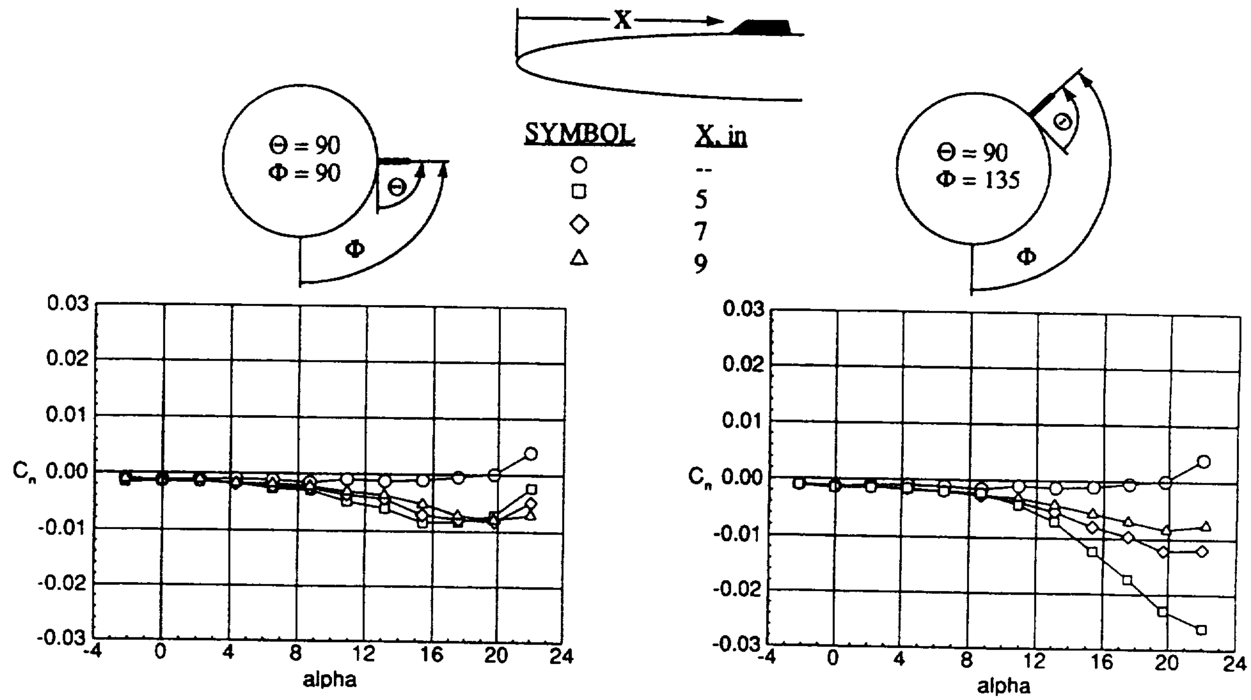
Forward Position, Height = upper, α=12°, Flaps at 30°/10°, q=25 psf



No significant effects on control power due to canard aspect ratio are observed over the linear range. The are some effects over the canard stall range.

Directional Control Effects of Longitudinal Chine Placement

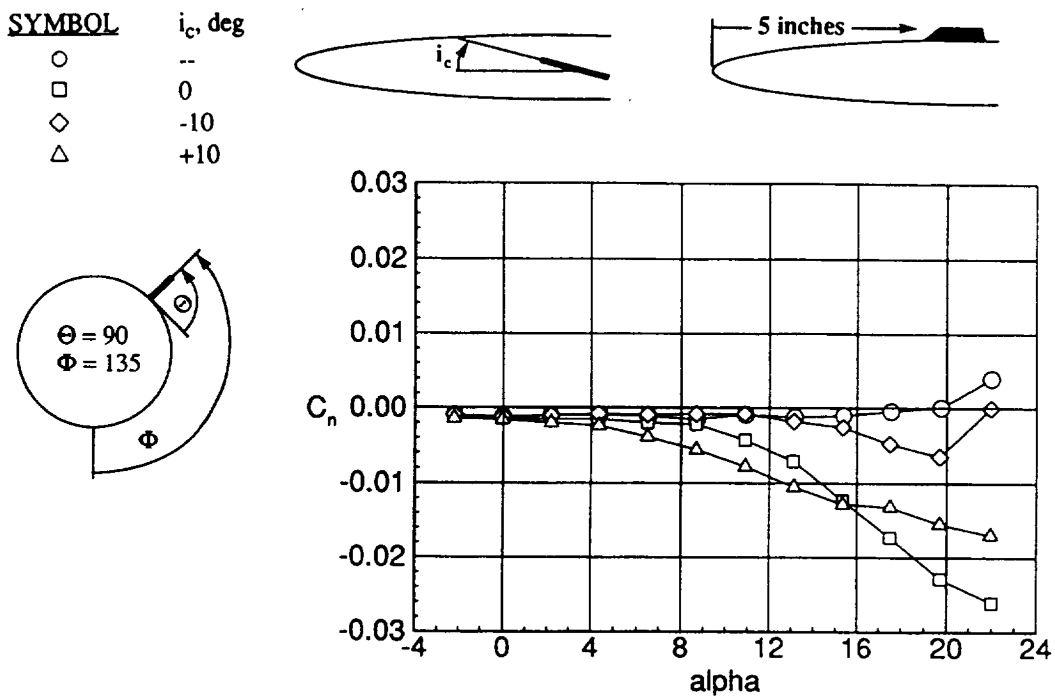
Asymmetric Chines = right side only, β=0°, Flaps at 30°/10°, q=20 psf



Moving an asymmetric chine forward on the forebody increases the directional control. Increasing the azimuthal angle further enhances these effects.

Directional Control Effects of Chine Incidence

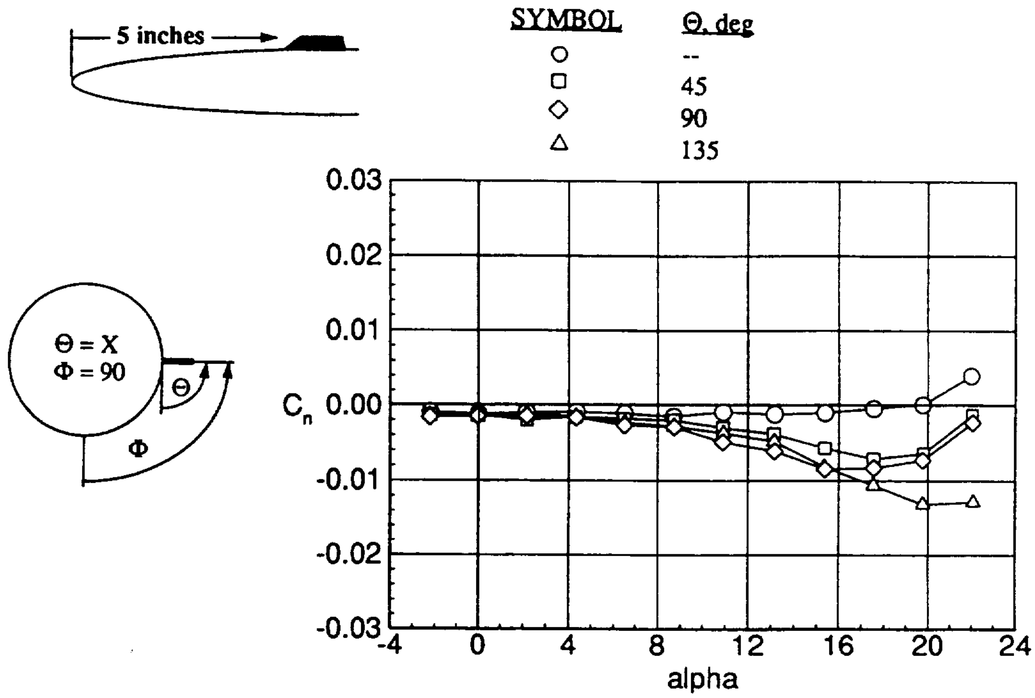
Asymmetric Chines = right side only, β=0°, Flaps at 30°/10°, q=20 psf



Increasing the relative chine incidence angle further increases directional control. At high angles of attack, the undeflected chine provides greater control. This would indicate a changing local forebody flowfield, and thus warrant a schedule for chine incidence as a function of angle of attack to supplement the vertical tail.

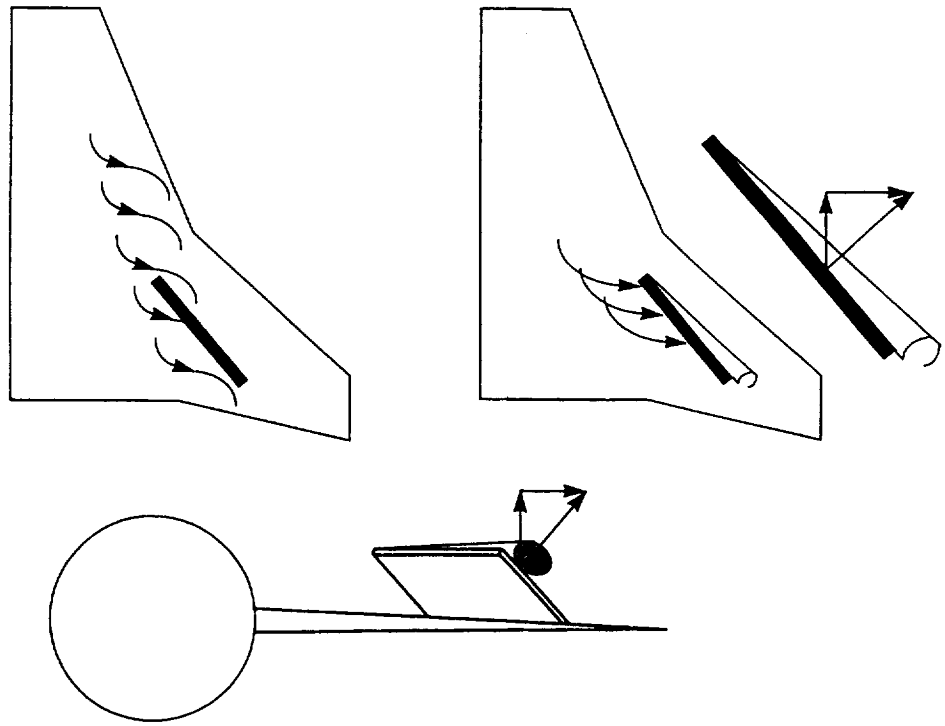
Directional Control Effects of Chine Dihedral

Asymmetric Chines = right side only, $\beta = 0^o$, Flaps at $30^o/10^o$, q=20 psf



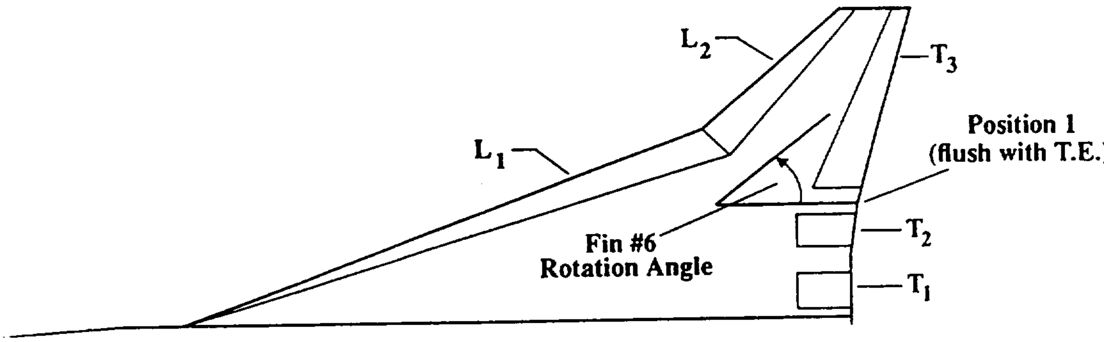
As with asymmetric chine incidence angle, the effects of chine dihedral vary with angle of attack and would benefit from a deflection schedule.

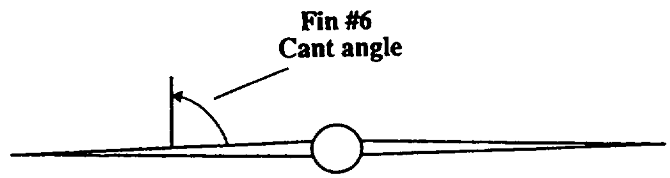
Potential Benefits from Wing-Mounted Upper Surface Fins



Potential aerodynamic improvements exist by properly aligning wing mounted upper surface fins relative to the local vortex induced spanwise flow. However, proper fin rotation and cant are essential to gain the benefits of increased lift and cleaner flow over the aileron.

71/50 HSR Model Showing Fin Concept

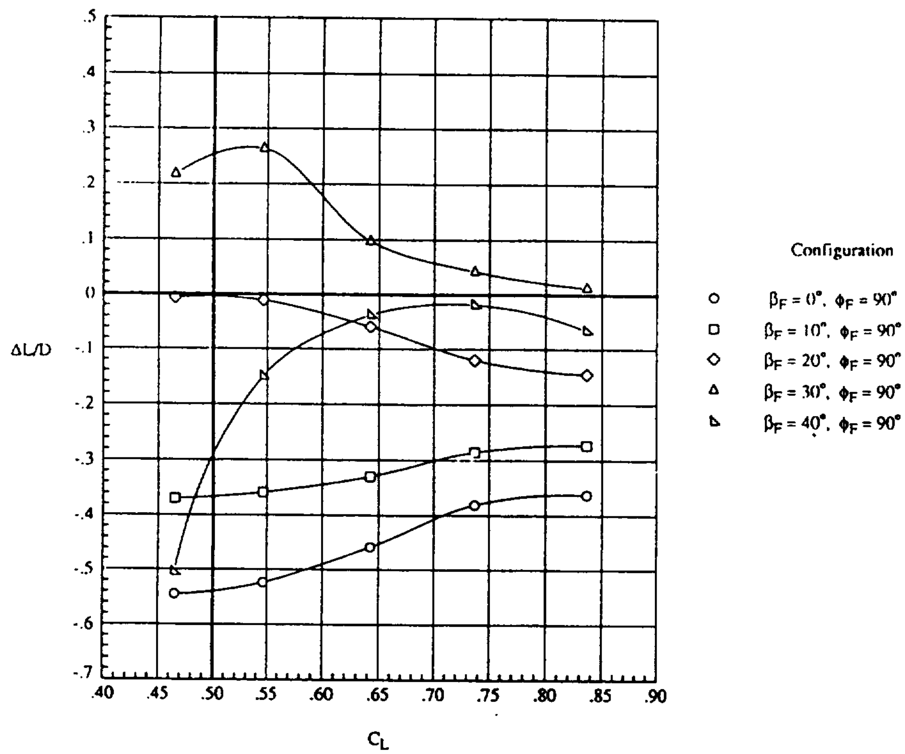




The concept of fin rotating and canting were tested on the HSR 71/50 model at the 14- by 22-Foot Subsonic Tunnel.

L/D Effects of Wing Fin Rotation with Cant at 90°

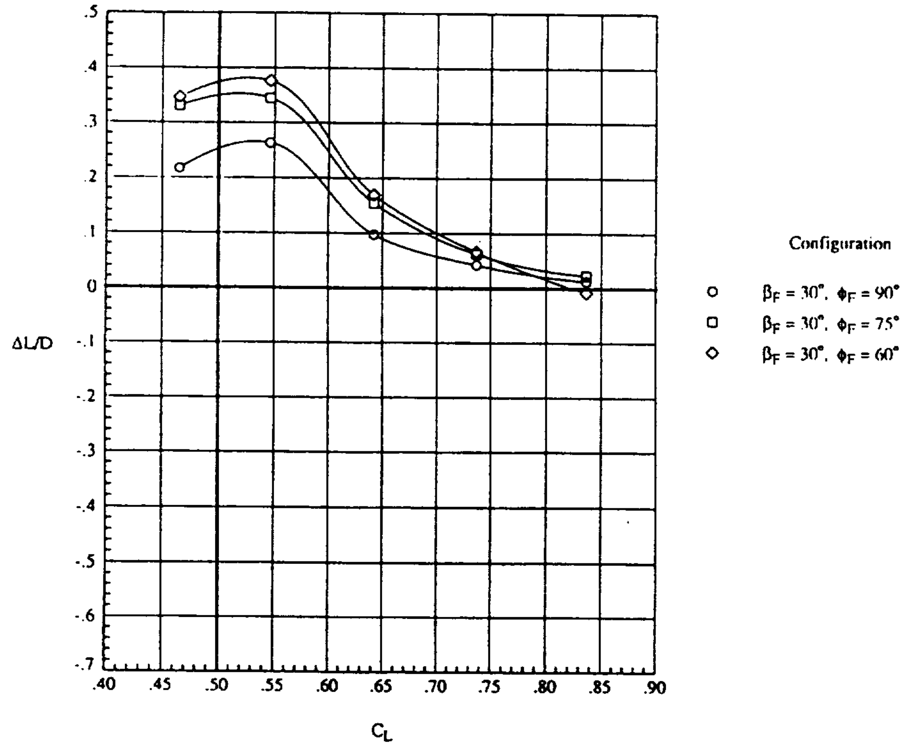
Fin L.E. Sweep=65, Fin Aspect Ratio=0.5, Flaps at 26/10/13, q=70 psf



There exists a precise angle of fin rotation for each angle of attack due to the changing location of the vortex trajectory.

L/D Effects of Wing Fin Canting with Rotation at 30°

Fin L.E. Sweep=65, Fin Aspect Ratio=0.5, Flaps at 26/10/13, q=70 psf



Significant improvements in L/D can be achieved by properly canting the rotated fin.

Recommendations

The placement of canards on the forebody must take into account not only the local airflow around the forebody, but the resulting impact of the canard wake interaction and its ability to alter the local wing upwash field as it articulates through its relative deflections.

The use of asymmetric chine deflections provide a powerful tool for increased directional control. However, the relative placement of the chine is very sensitive to the local forebody flow; thus, great care must be given to its location.

Methods such as the optimally placed wing mounted fins may be desirable to favorably utilize the local spanwise flow to increase L/D, and by the nature of their placement, decrease the spanwise flow over the aileron surfaces, thus allowing greater roll authority and the possible use of split ailerons for increased yaw control.

The placement of canards, chines, and wing fins must take into account the pattern and the dynamics of the local flow structures, not necessarily the global free stream characteristics. By following this thought process, significant aerodynamic improvements in high lift and control are possible.

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