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THE MINIMIZATION OF PYLON-MOUNTED STORE EFFECTS ON AIR COMBAT CAPABILITY

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SUMMARY

Some effects of pylon-mounted missiles on aft-tail delta wing supersonic fighter concepts have been investigated. Whereas minimum drag penalties do occur with the addition of missiles, the effects at higher lifts, corresponding to maneuvering flight, are less severe and often favorable. Lower speeds and altitudes enhance the maneuvering capability and one-on-one air combat would probably tend to degenerate to subsonic speeds even though the combatants may be flying supersonic fighters. Higher speed (supersonic) flight might best be reserved for interceptors with long-range missiles where the weapon carriage effects at low angles of attack are of prime importance.

INTRODUCTION

Since the advent of air-to-air missiles for air combat fighters, the integration of the weapon carriage with the airplane has been a problem that must be considered. With the obvious exception of airplanes designed with an internal weapons bay (such as the F-101 and the F-106), missiles have typically been carried externally, often on pylons. The aerodynamic effects that may be associated with this type of external carriage include the effects on lift and drag, control effectiveness, longitudinal and lateral stability, and mutual interference.

Many fighters originally designed with gun systems were adapted to accept pylon-mounted missiles. With the proliferation of pylons and missiles, many newer fighters have also been required to accommodate a wide variety of existing standard pylon and store arrangements. In some cases, such adaptation can be reasonably acceptable, whereas, in other cases, some performance limitation may result. It seems probable that through judicious location of the pylon, the effects of a pylon/store combination might be minimized.

The objective of the paper will be to make some observations on the case for simplifying the fighter/missile configuration so that adverse effects are minimized and the air combat capability maximized in the Mach number range from 0.60 to about 2.0. Delta wing configurations with two pylon mounted missiles and aft tail controls were considered. The arrangements were similar to several Soviet concepts such as Fishbed, Fishpot, and Flagon, and are illustrative of an approach to point-design air combat fighters. Some examples of the potential maneuvering capability in terms of normal acceleration and turn radius for various speeds and/or altitude will be shown. Previous NASA-Langley fighter/stores summary papers are contained in references 1 and 2. Results for the delta wing fighter configuration used in the present paper are published in reference 3. Results for the delta wing interceptor configuration used are published in reference 4.

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SYMBOLS

The longitudinal results are referrred to the stability axis system and the lateral results are referred to the body axis system. The coefficients and symbols are defined as follows:

a_n	normal acceleration in g units
b	wing span
$\bar{c}$	wing mean aerodynamic chord
C_D	drag coefficient, $\frac{\text{drag}}{qS}$
$C_{D,o}$	drag coefficient at zero lift
C_l	rolling-moment coefficient, $\frac{\text{rolling moment}}{qSb}$
C_{l_β}	effective dihedral parameter, per degree
C_L	lift coefficient, $\frac{\text{lift}}{qS}$
C_m	pitching-moment coefficient, $\frac{\text{pitching moment}}{qS\bar{c}}$
$\frac{\partial C_m}{\partial \delta_h}$	horizontal tail effectiveness
$\frac{\partial C_m}{\partial C_L}$	longitudinal stability parameter
C_{n_β}	directional stability parameter, per degree
C_{Y_β}	side-force parameter, per degree
h	altitude
L/D	lift-drag ratio
M	freestream Mach number
q	freestream dynamic pressure
R	turn radius
S	reference wing area including fuselage intercept
W	weight
W/S	wing loading
α	angle of attack, degrees

β angle of sideslip, degrees

δ_h horizontal tail deflection (positive trailing edge down), degrees

DISCUSSION

Fighter

A lightweight fighter concept, similar to a MiG-21 Fishbed, with two underwing pylon-mounted missiles is shown in figure 1. Longitudinal characteristics for this concept (fig. 2) for $M = 0.60$ and 1.20 indicate a progressive reduction in the stability level as the pylon and missile are added with no change in the total lift. This characteristic of decreasing values of C_m with no change in C_L was observed over the Mach number range from 0.60 to 2.00 and is apparently caused by a redistribution of lifting pressure on the underside of the wing that occurs primarily from the presence of the pylon. The effect was more noticeable in the speed range up to $M = 1.20$ and was somewhat reduced in magnitude at higher supersonic Mach numbers.

The drag characteristics for the delta wing fighter at $M = 0.60$ and 1.20 (fig. 3) indicate an expected increase in C_D at lower lifts but a reduction in the drag-due-to-lift as the pylon and missile are added. The net result is only a small reduction in maximum L/D and essentially no effect of stores on L/D at the higher lifts that are associated with maneuvering flight.

A summary of some of the longitudinal characteristics for the delta wing fighter (fig. 4) indicate the progressive decrease in stability level and increase in $C_{D,o}$ as the pylon and missile are added, and also show that no measurable change occurred in the horizontal tail control effectiveness. Hence, despite the increased $C_{D,o}$ due to the stores, the results indicated no degradation in maneuvering capability because of the reduced stability level, the reduced drag-due-to-lift, and the unchanged lift and control effectiveness.

Lateral stability characteristics for the fighter at $M = 0.60$ and 1.20 (fig. 5) indicate an increase in the magnitude of C_{Y_β} that might be expected due to the addition of the stores. This was translated into a decrement in C_{n_β} that was fairly large in the transonic range only (about M = 0.90 to 1.20) but still permitted positive C_{n_β} to sufficiently high angles of attack for good maneuvering capability (about 16° to 18°)because of the inherently higher values of C_{n_β} that exist in the transonic range for the basic configuration. At higher supersonic Mach numbers, the adverse effect of stores on C_{n_β} disappears and may even become favorable.

Interceptor

Some of these higher Mach number effects can be better illustrated with some results from an investigation of a delta wing interceptor configuration (ref. 3). The interceptor configuration (fig. 6) is similar to the fighter configuration in general geometry but is representative of a slightly larger airplane and missile such as the Su-11 Fishpot or the Su-15 Flagon. The longitudinal characteristics for the interceptor at $M = 1.60$ (fig. 7) indicate little effect of the pylon and missile on the control effectiveness and show a slight increase in lift at higher α's and a small decrease in stability. The increase in lift shown for this Mach number probably results from the fairly large pylon inducing an increase in local dynamic pressure over a large portion of the underside of the wing. The increase in C_D and decrease in L/D at low to moderate lifts would have some detrimental effect on acceleration and cruise flight regimes. However, if maneuvering requirements should occur, the drag and L/D at angles of attack of about 16 degrees to 18 degrees are essentially unaffected by the stores because of the decrease in drag due to lift.

The lateral characteristics for the interceptor at $M = 1.60$ (fig. 8) indicate a substantial increase in C_{n_β} due to the stores which would be of special benefit if maneuvering requirements to high angles of attack should occur. The effective dihedral is reduced by the addition of the stores resulting in a favorable reduction in the roll-to-yaw ratio. The reduction in $-C_{\ell_\beta}$, as has been noted in other investigations in the supersonic speed range, is apparently caused by an interference flow field from the store installation that, in sideslip, results in a reduction of lift on the inboard section of the windward wing and an increase in lift on the inboard section of the downwind wing.

Maneuverability

Some indication of the resultant maneuvering potential is indicated by the next two figures. The normal acceleration for a wing loading of 50 lb/ft^2 and with the maximum C_L limited to 0.8 (α = 16 degrees to 18 degrees) is shown in figure 9 for $M = 0.60$, 1.20, and 1.60 at various altitudes. Sustained a_n's shown at $M = 0.60$ and 1.20 are for a hypothetical engine of about 13,000 pounds static sea-level thrust with no afterburning. These results are included to show the greater detrimental effects on sustained a_n's at supersonic speeds due to the difference in drag level from subsonic speeds. The effects of sustained maneuver can be improved, of course, through the use of higher thrust engines or through afterburning. The expected trends are apparent--the increase in a_n with decreasing altitude and with increasing speed--both due to an increase in dynamic pressure that results in lower lift required for level flight and greater excess lift available for maneuvering. It is more or less obvious that the slower flying fighter would want to descend to low altitudes in order to achieve higher values of a_n. The fighter in supersonic flight would obviously suffer while maneuvering at lower altitudes due to structural limitations, and one-on-one air-to-air combat would eventually tend to degenerate to subsonic speeds even though the combatants may be flying supersonic fighters. These effects can also be translated in terms of turn radius where the combat advantage would generally go to the airplane capable of sustaining a tighter turn. Figure 10 illustrates the effects of a_n and M on the turn radius. The obvious is readily apparent in this nomograph--that is, turn radius can be reduced by increasing a_n for a constant M or by decreasing M for a constant a_n. The illustration shows that, for $a_n = 4$, the $M = 0.6$ airplane has a turn radius about three-eighths that of the $M = 1.2$ airplane. For the $M = 1.2$ airplane to achieve an equivalent radius, it would be necessary to increase a_n to about 10. The turn radius for the $M = 1.6$ airplane would be about 4 times that of the $M = 0.6$ airplane and the equivalent a_n is completely unrealistic. Also for $a_n = 4$, the $M = 1.2$ airplane can turn well within the capability of the $M = 1.6$ airplane and the $M = 1.6$ airplane would require an a_n of about 6 to become equivalent. It appears that air-to-air combat suffers little penalty from store installation at high lift. For high speed interceptors with long-range missiles, the weapon carriage effects at low angles of attack are of prime importance. Thus, the judicious location of pylon/store arrangements is an important consideration.

CONCLUDING REMARKS

Some effects of pylon-mounted missiles on aft-tail delta wing supersonic fighter concepts have been investigated. Whereas minimum drag penalties do occur with the addition of missiles, the effects at higher lifts, corresponding to maneuvering flight, are less severe and often favorable. Lower speeds and altitudes enhance the maneuvering capability and one-on-one air combat would probably tend to degenerate to subsonic speeds even though the combatants may be flying supersonic fighters. Higher speed (supersonic) flight might best be reserved for interceptors with long-range missiles where the weapon carriage effects at low angles of attack is of prime importance.

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4. Spearman, M. Leroy; and Monta, William J.: Effects of External Stores on the Aerodynamic Characteristics of a 60° Delta-Wing Fighter Model at Mach 1.60 to 2.87. NASA TM 74090, December 1977.

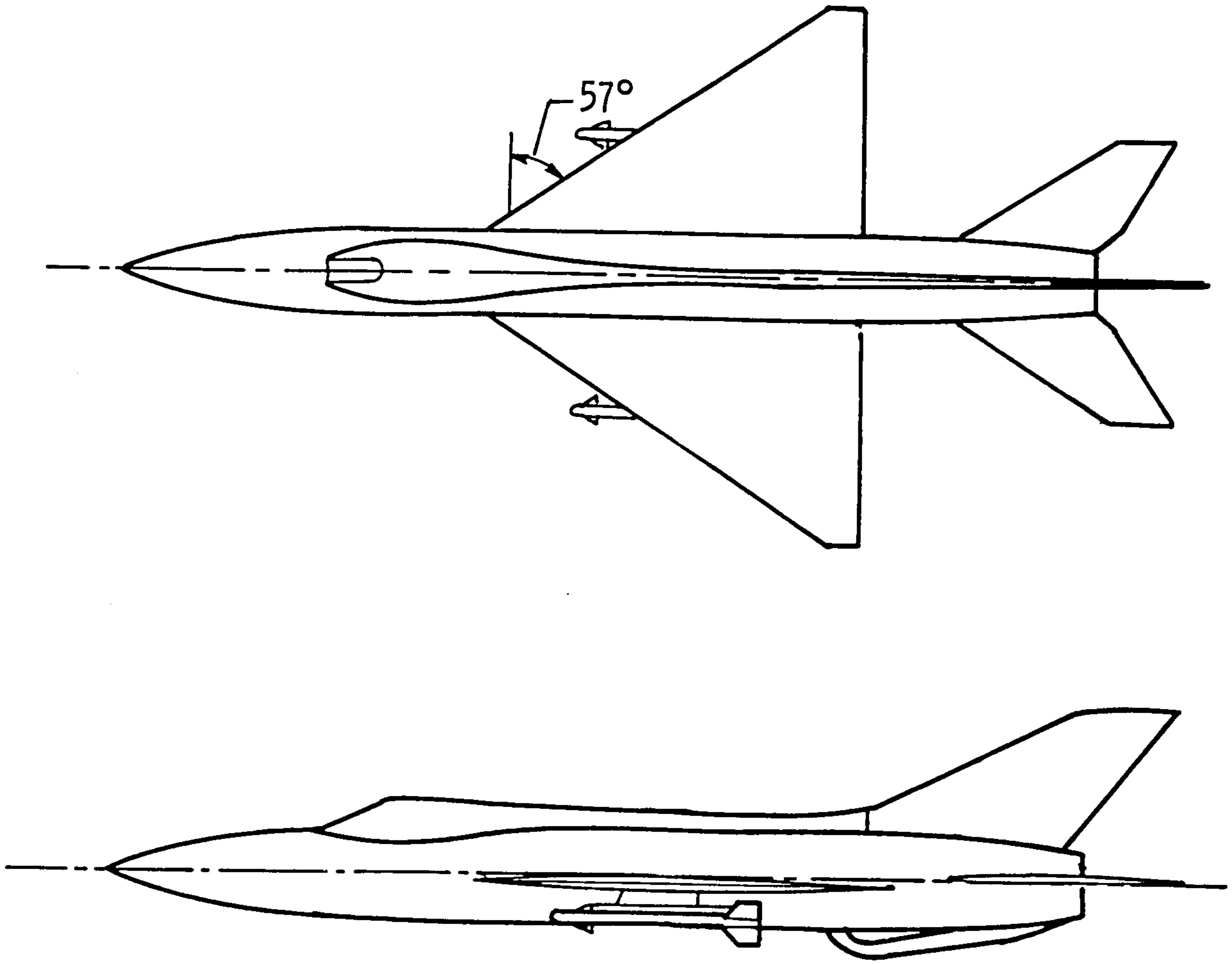


Figure 1.- Delta wing fighter configuration.

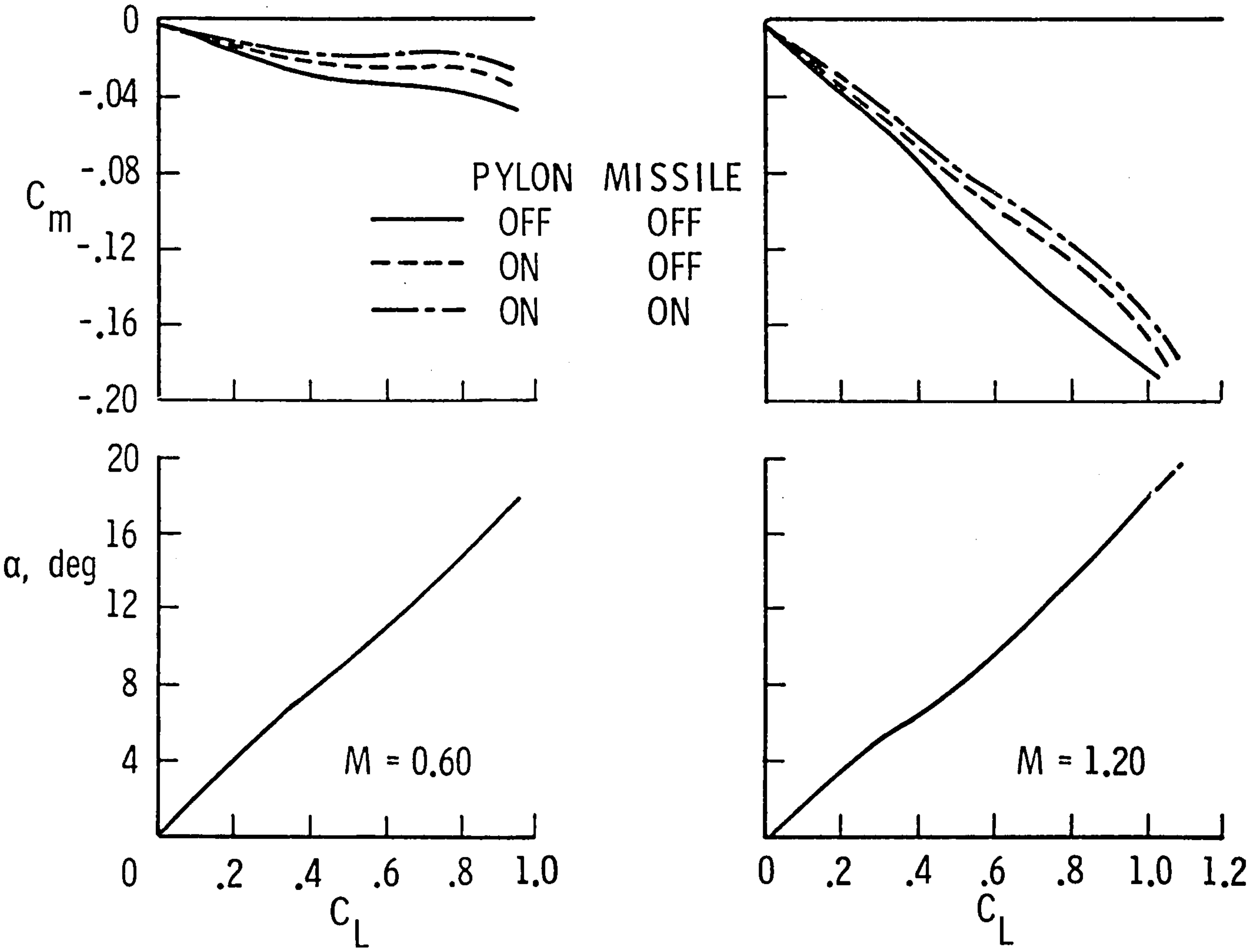


Figure 2.- Longitudinal characteristics for delta wing fighter at M = 0.60 and 1.20.

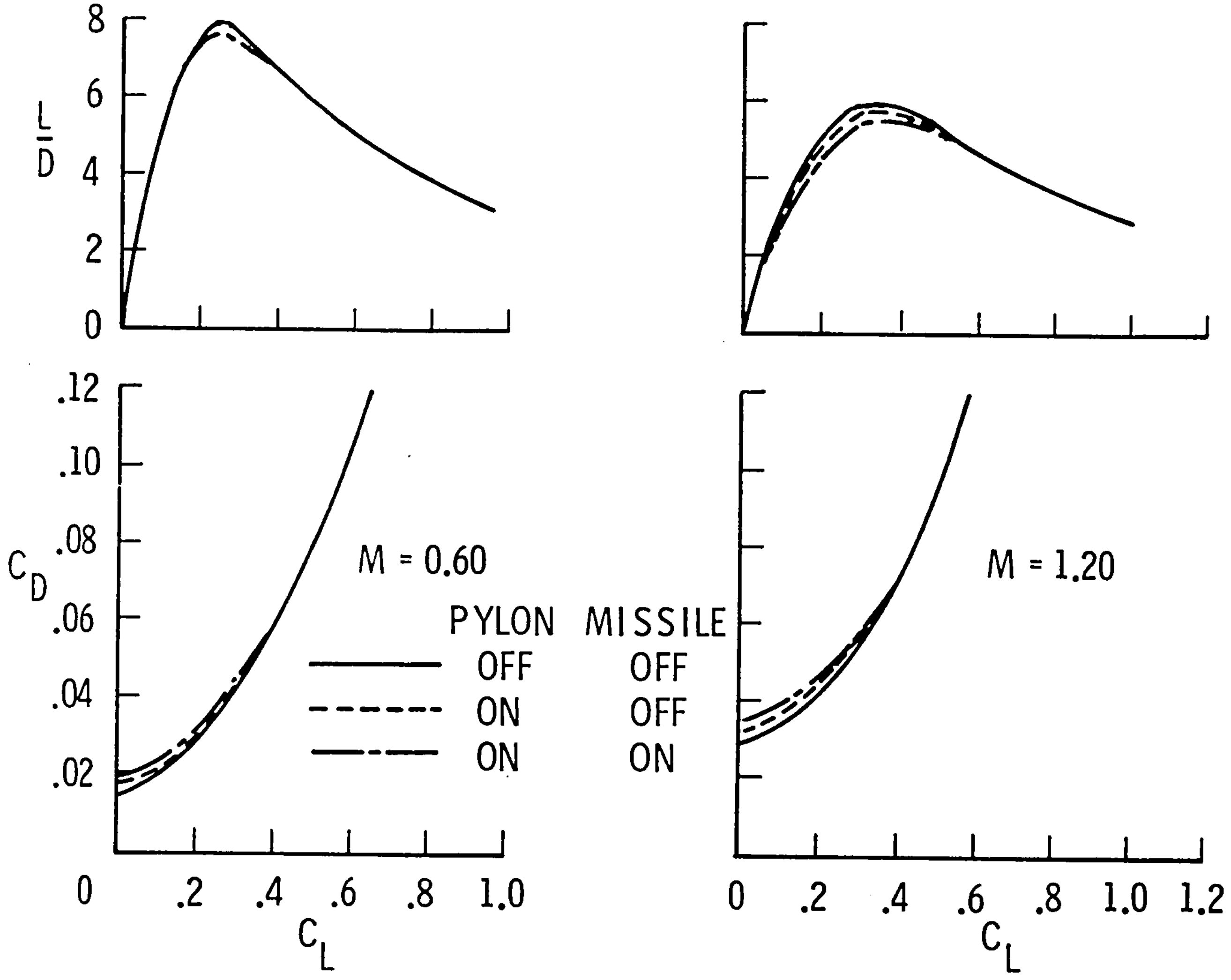


Figure 3.- Drag characteristics for delta wing fighter at M = 0.60 and 1.20.

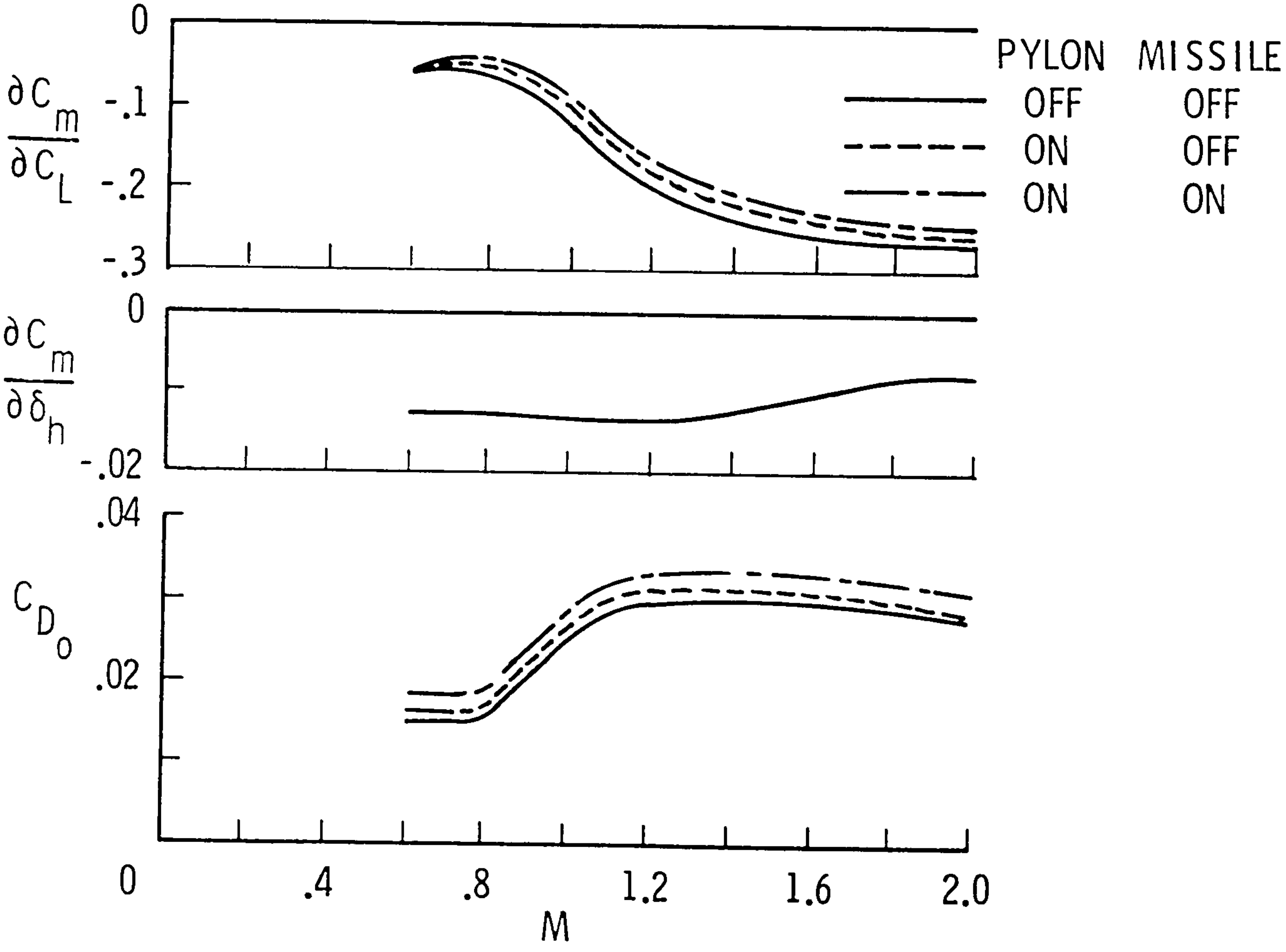


Figure 4.- Longitudinal summary for delta wing fighter.

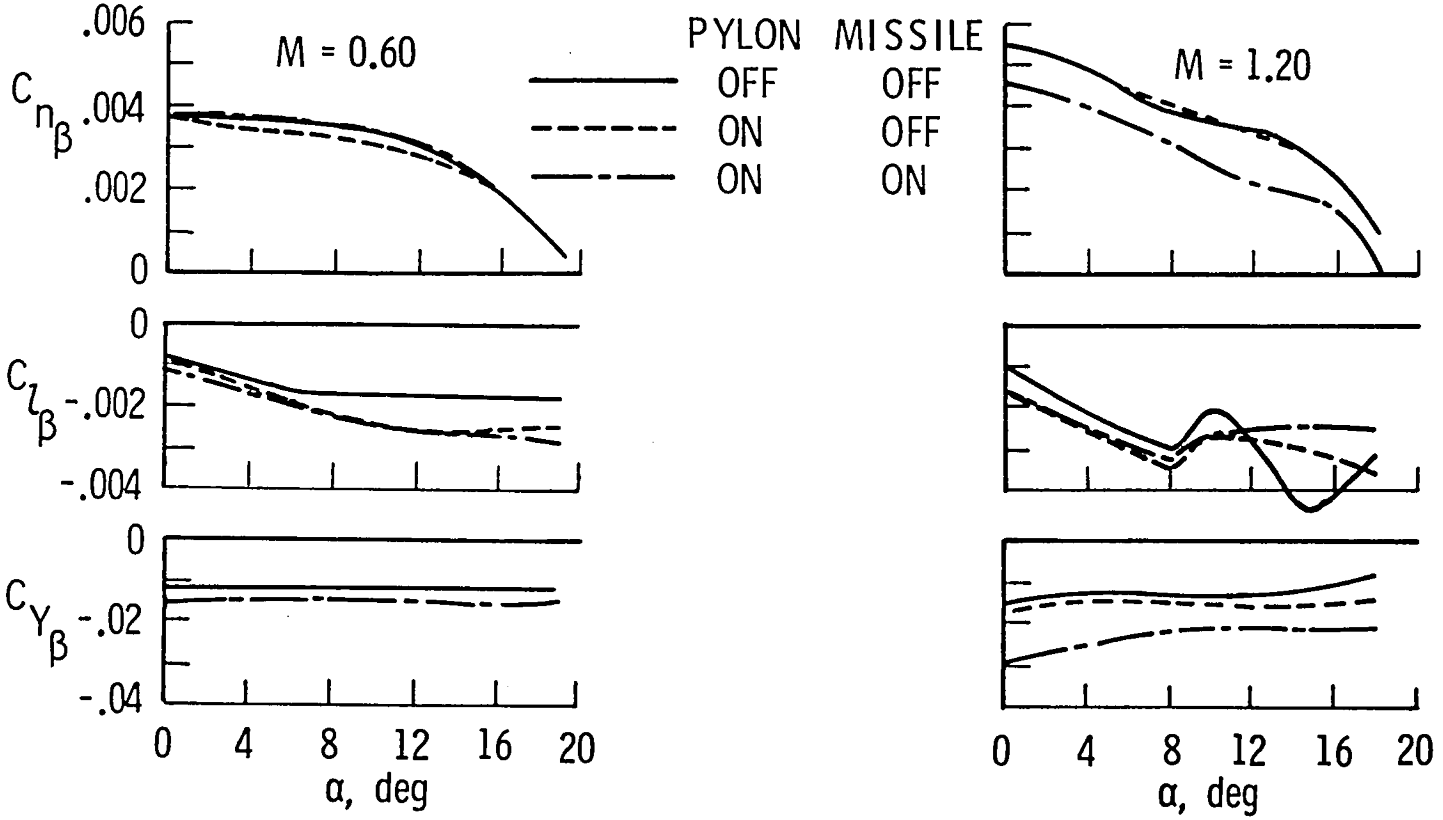


Figure 5.- Lateral characteristics for delta wing fighter at M = 0.60 and 1.20.

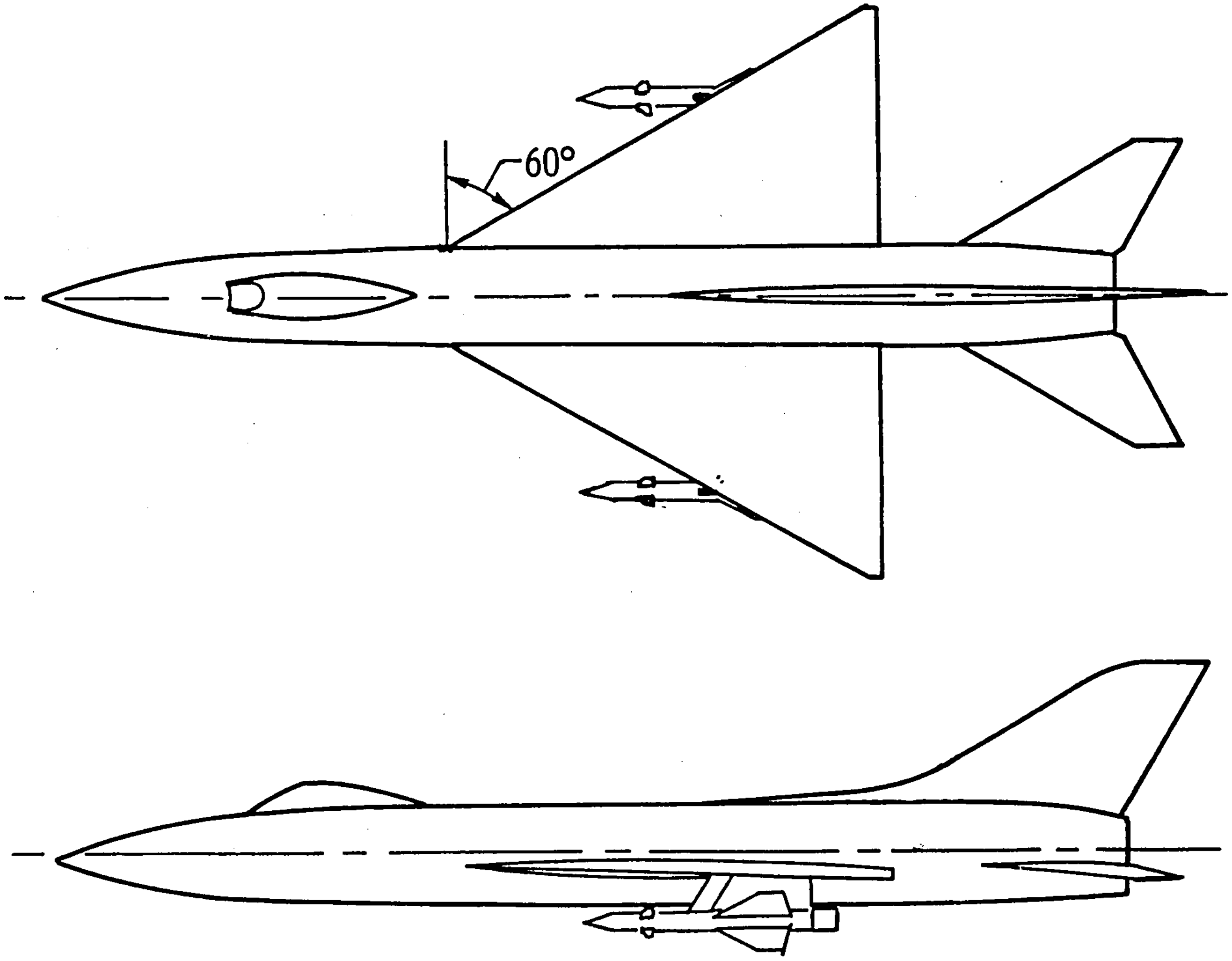


Figure 6.- Delta wing interceptor configuration.

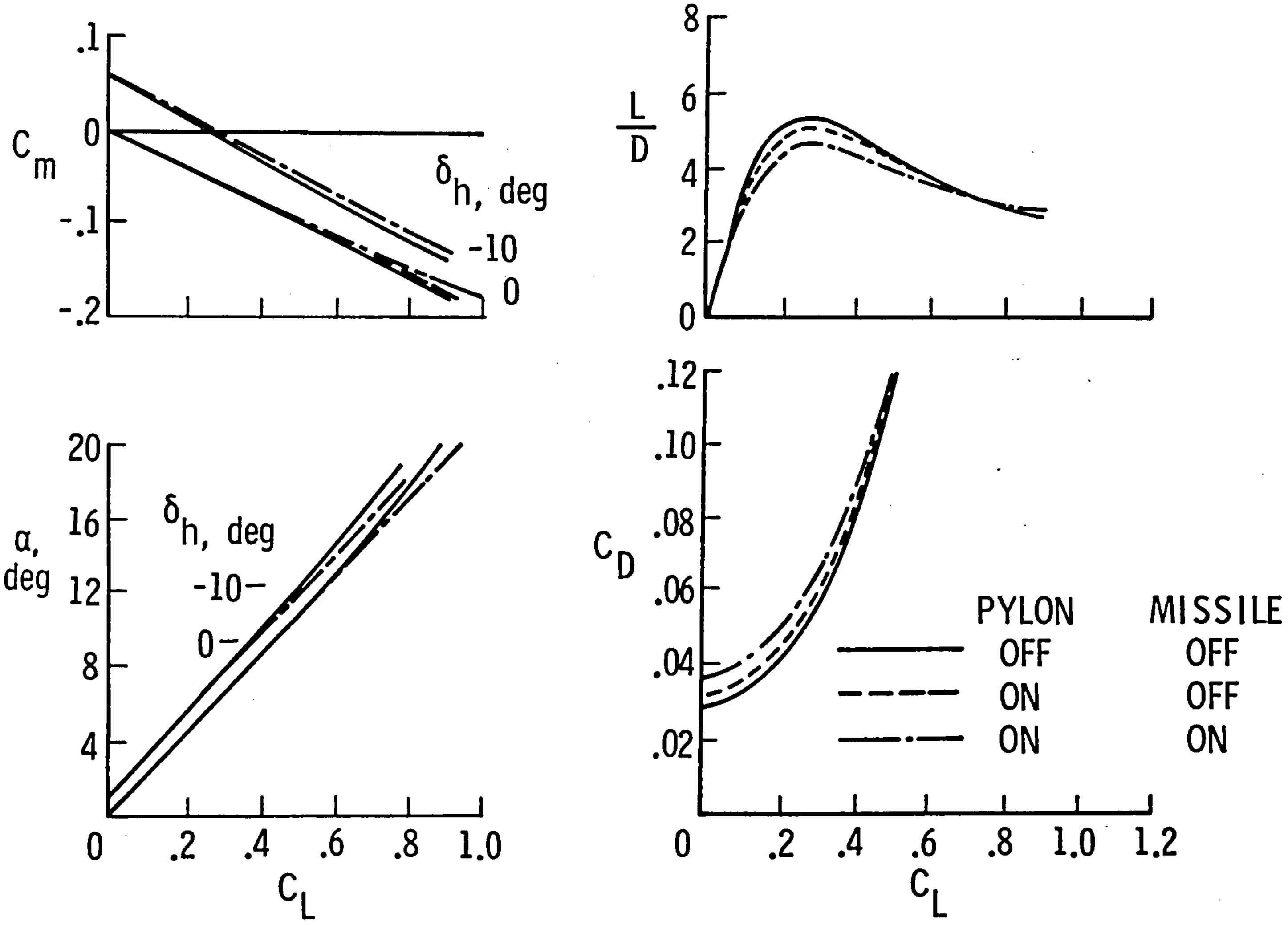


Figure 7.- Longitudinal characteristics for delta wing interceptor at M = 1.60.

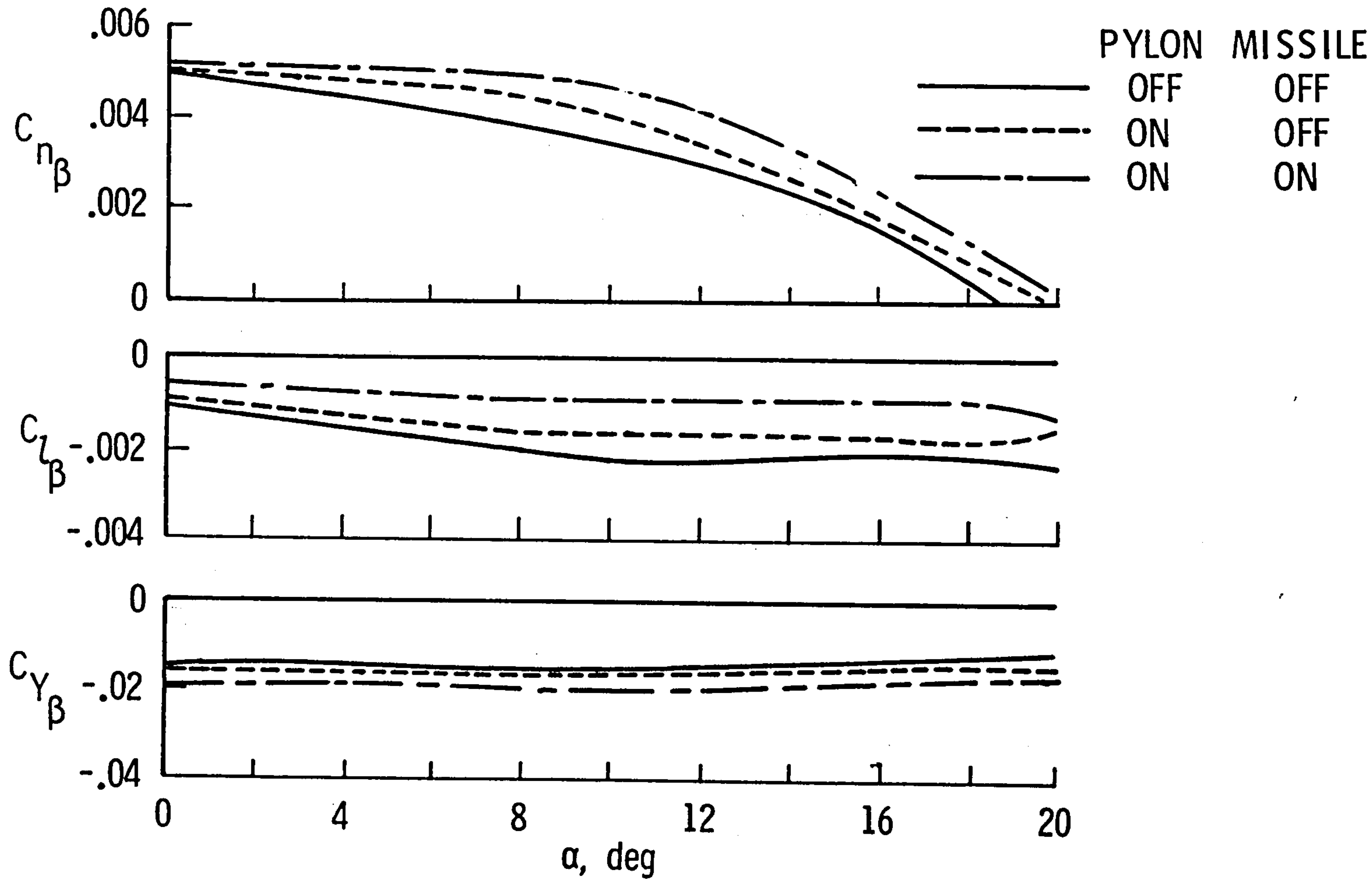
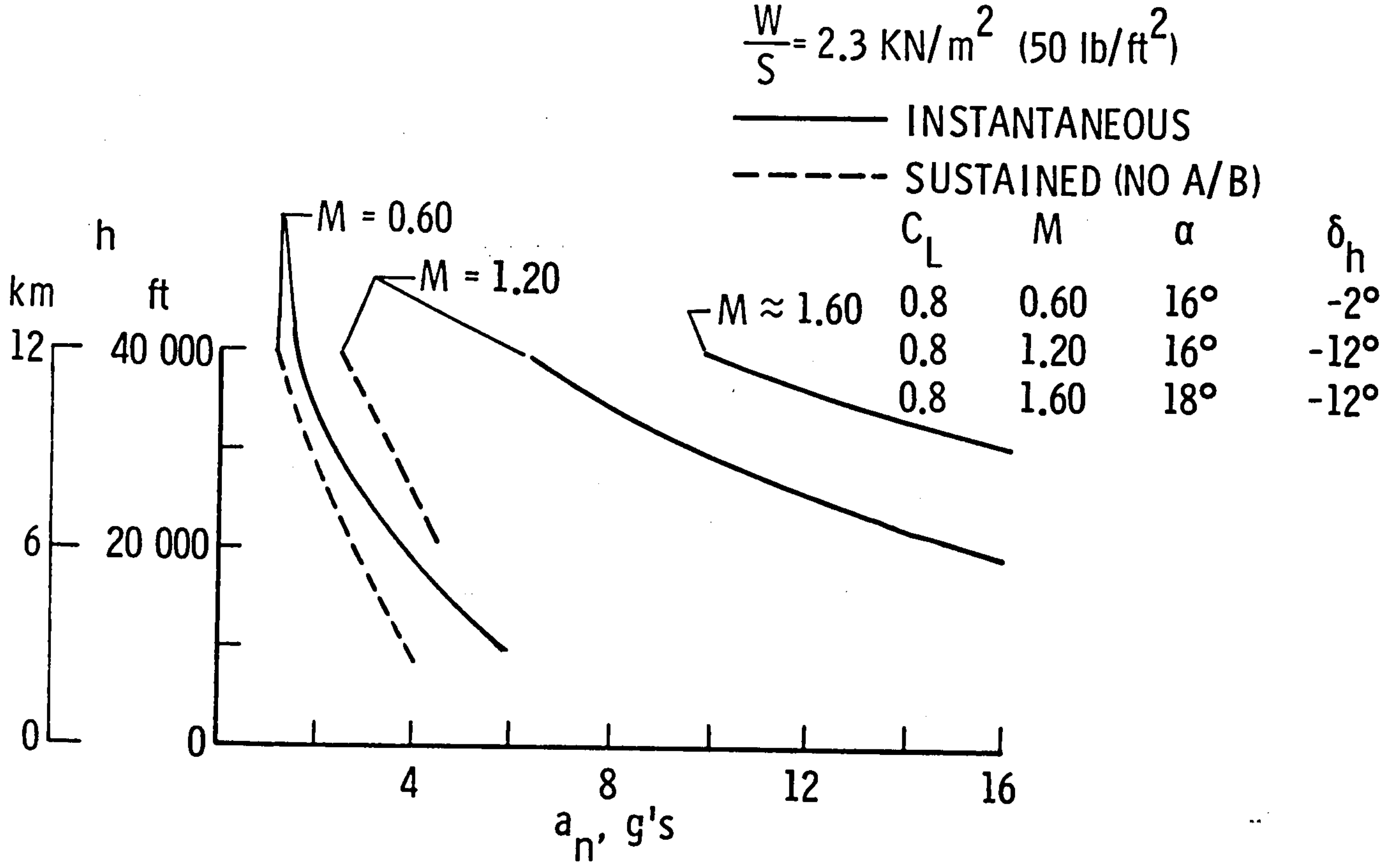


Figure 8.- Lateral characteristics for delta wing interceptor at M = 1.60.



C_L	M	α	δ_h
0.8	0.60	16°	-2°
0.8	1.20	16°	-12°
0.8	1.60	18°	-12°

Figure 9.- Normal acceleration characteristics.

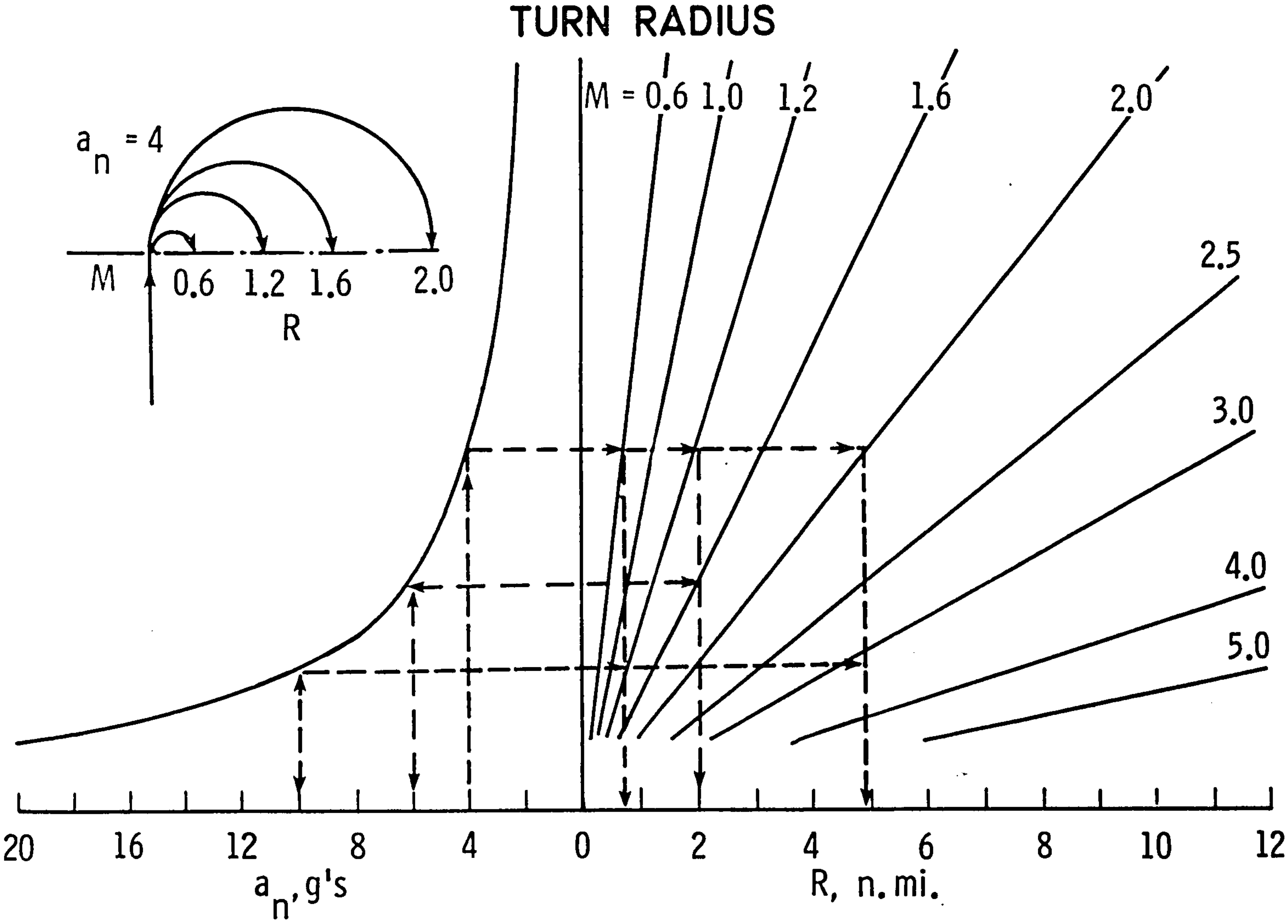


Figure 10.- Turn radius characteristics.

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16. Abstract

Delta-wing point-design fighters with two pylon mounted missiles and aft-tail controls (similar to several Soviet designs) have been investigated for a Mach number range from about 0.6 to 2.0. Whereas minimum drag penalties that are expected with the addition of external stores do occur, the effects at higher lifts, corresponding to maneuvering flight, are less severe and often favorable. The drag-due-to-lift factor is less with stores on although the lift-curve slope is unaffected. The longitudinal stability level is reduced by the addition of stores while the pitch control effectiveness is unchanged. The directional stability was generally reduced at subsonic speeds and increased at supersonic speeds by the addition of stores but sufficiently high stability levels are obtainable that are compatible with the longitudinal maneuvering capability. Measures of the maneuvering potential in terms of normal acceleration and turn radius are included.

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