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UNCONVENTIONAL MISSILE CONCEPTS FROM CONSIDERATION OF VARIED MISSION REQUIREMENTS

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SUMMARY

Some missile concepts are considered from the standpoint of volumetric efficiency, minimum carriage constraints, and aerodynamic performance to achieve some perceived mission requirements. The mission requirements considered include air-to-surface roles such as defense suppression or anti-shipping where payload and range may have priority over high-maneuver capability, and air-to-air and surface-to-air roles where attention must be given to good maneuvering capability as well. The concepts include monoplanes with highly-swept, thick delta wings, highly-swept delta wings mounted either high or low on a semicircular body, some ring-wing and semiring-wing arrangements, parasol wing, and elliptical lifting bodies. The drag and wing-loading characteristics of the highly-swept, relatively large wing-area concepts result in vehicles potentially capable of flying at maximum lift-to-drag ratio for high altitude, high speed conditions and for low altitude, lower speed conditions. Such capability is of interest for high-altitude, long-range, high-speed cruise, and low-altitude penetration missions. The use of ring and parasol wings show the flow field effects on lift and pitching moment at zero angle of attack and indicate configurations for which high values of lift-to-drag ratio can be achieved at low angles of attack.

In general, the unconventional missile configurations considered indicate some possible approaches toward resolving problems of carriage and storage while retaining good volumetric and aerodynamic efficiency. The configurations could result in the capability to accomplish a wide variety of possible missions.

INTRODUCTION

It has been fairly well established that a variety of potential threats exist that introduce some vehicle needs and requirements. To provide a creditable deterrent to counter the potential threat involves mission capabilities including strategic penetration, tactical penetration, air defense, air superiority, and antishipping. In many cases, the use of missiles is an appropriate way to meet these missions needs. Missiles, which are typically used in only one-way missions and do not have man-rated constraints, offer some advantages in penetrability, range, speed, simplicity, affordability, and volumetric efficiency. It is the purpose of this paper to examine some unconventional missile concepts with a view toward adaptability in meeting some challenging mission requirements.

SYMBOLS

C_D drag coefficient

c.g. center of gravity

C_L lift coefficient

C_m pitching-moment coefficient

C_{m_α}, $\frac{\delta C_m}{\delta C_L}$ longitudinal stability parameters

C_{n_β} directional stability parameter

C_N normal force coefficient

c.p. center of pressure

L/D lift-drag ratio

M Mach number

α angle of attack, degrees

l body length

δ_{pitch} deflection of four tail panels for pitch

Coefficients for the configurations presented herein are nondimensionalized in various ways depending primarily on configuration geometry. Reference areas, for example, may be the wing area for some cases or body cross-sectional area for other cases. Reference lengths may be body length, body diameter, or wing mean chord. However, the numerical value of the coefficients does not affect the interpretation of the results for this paper. Detailed information for each of the configurations presented may be found in the references.

DISCUSSION

Delta Wing/Bodies

Cone with and without wings.- The characteristics of a simple conical body with and without a wing have been extracted from reference 1. The concept (see fig. 1) is a slender blunted cone, having an included angle of 14.2 degrees, to which highly swept wings and small directional fins are added. The longitudinal characteristics at M = 2 (see fig. 2) indicate that a substantial increment of lift is provided by the relatively small slender wing and that positive longitudinal stability is provided at the same time. Both the lift and the pitching moment variations with angle of attack are linear to at least 26 degrees. The wing also contributes an increment of drag; however, the lift-drag ratio (when corrected for base drag to simulate jet-flow at the base) indicates an impressive maximum value of almost 5 at an angle of attack of only 6 degrees. For such a vehicle, with a body length of 2.5 feet, these results translate into a near sea-level flight load-carrying capability of about 385 pounds for a thrust of about 77 pounds. Mission capability, insofar as range and lethality are concerned, would depend on vehicle size, flight altitude, and distribution of weight components.

Thick delta wings.- A thick delta wing concept also extracted from reference 1 is shown in figure 3. The configuration has a 79-degree swept leading edge that was beveled in such a way that the forebody was fairly slender with a diamond cross-section and the afterbody translated into a relatively thick octagonal cross-section near the tip and base. Wedge-shaped vertical surfaces were attached on the aft top and bottom centerline and half-wedge fins were also attached at the wing tips. The longitudical characteristics at M = 2 are shown in figure 4 for the configuration with and without the tip fins. The addition of the tip fins transmits a flow field over the outer wing surface that results in an increase in lift and a stabilizing increment in pitching moment. Although the tip fin drag results in a loss in L/D, a maximum value of 4.5 was still achieved at $\alpha = 6^0$ (corrected for base drag). Thus, for this condition, a vehicle having a length of 2.5 feet flying near sea level at M = 2 could sustain a weight of about 714 pounds for a thrust of about 160 pounds. A weight of about 140 pounds could still be sustained at an altitude of about 42,000 feet for the same size vehicle. Further data for this configuration for Mach numbers up to 4.63 may be found in reference 2. A cursory look at these data indicate that the 2.5-foot vehicle flying at M = 4.63 could sustain a weight of about 240 pounds near an altitude of 65,000 feet.

Semiconical body with delta wings.- A semiconical body-wing configuration (see fig. 5) was also extracted from references 1 and 2. The configuration has a slender semiconical body and a relatively thin delta wing with 78-degree swept leading edges. The configuration was tested, as shown, as a low wing and also inverted as a high wing. Because of some asymmetry in the body and wing, inverting the model resulted in some geometric differences other than wing height. The longitudinal characteristics at M = 2 (see fig. 6) indicate that the inverted model (high wing) resulted in positive increments in lift and pitching moment throughout the α range when compared to the low wing version. These results are due in part to the induced flow field of the body on the wing and in part to the asymmetric forebody profile. In any event, in spite of an attendant increase in drag, the high-wing configuration displays a substantial increase in maximum L/D at a lower α and provides an L/D of about 3 at $\alpha = 0^0$. For the high wing configuration with a body length of 2.5 feet flying near sea level at M = 2, a weight of about 270 pounds could be sustained with a thrust of about 90 pounds at $\alpha = 0^0$. At only 4-degree angle of attack, the weight carrying capability increases to 930 pounds with a thrust requirement of about 145 pounds. At M = 4.63 and an altitude of about 65,000 feet, the weight sustaining capability is about 226 pounds. Increasing the vehicle length to 25 feet would increase the weight sustaining capability to 22,600 pounds.

Directional stability for delta concepts.- The static directional stability characteristics at M = 2 for the three types of delta wing-body concepts just discussed are shown in figure 7. The cone with wings and fins attached indicates a high degree of directional stability to angles of attack well beyond that for maximum L/D (about 8 degrees). The directional stability deteriorates rather rapidly above $\alpha = 12^0$ and instability is indicated above $\alpha = 18^0$.

The thick delta wing without tip fins has a low level of directional stability up to $\alpha = 26^0$; however, the addition of the tip fins provides a high level of directional stability over the test angle of attack range to 26 degrees. The positive increment in directional stability is compatible with the stabilizing longitudinal stability that is provided by the tip fins (see fig. 4).

The semiconical body with high or low wings indicates a basic directional instability for the configuration as tested. This condition could be corrected by the addition of small fins on the body or at the wing tips. The variation of directional stability with angle of attack for these concepts illustrates some interference flow field effects. It is believed that these variations result from pressure field effects of the wing on the forebody, which, in the case of the low wing would be expected to induce a decrease in sideforce over the forebody (stabilizing) and, in the case of the high wing, would induce an increase in sideforce over the forebody (destabilizing). These variations with angle of attack, being relatively small, may not be reflected in the characteristics of the configurations if tip fins were attached.

Ring/Parasol Wing-Bodies

Ring-wing-body.- Many attempts have been made over the years to exploit ring-wing-body concepts as a means of reducing wave drag through the interaction of reflected shocks from the wing with the afterbody. While some wave drag reductions have been produced, it is generally found that the bulk of the total drag is still adversely affected by the drag of the wing and the related support struts. Some results have been extracted from reference 3 in which a ring-wing-body and a half-ring-wing-body were investigated at M = 2.2. The configurations are shown in figure 8 and the longitudinal characteristics are presented in figure 9. While the results contained in reference 3 indicate a reduction of about 50 percent in wave drag with the ring wing, the reduction in total drag was only about 7 percent. The half-ring-wing was investigated in order to reduce the drag increment of the wing. The results are interesting in that the total drag was reduced and the lift-drag ratio increased. Of particular interest is the positive increment of lift at $\alpha = 0^o$ induced by the forebody shock intersecting with the half-ring-wing and resulting in a lift-drag ratio of about 2 at $\alpha = 0^o$. Thus a load-carrying capability is achievable that would permit level flight cruise at $\alpha = 0^o$.

Flat body with half-ring and swept-parasol wings.- The results of the half-ring-body investigation of reference 3 prompted other investigations of parasol-type arrangements. Reference 4 presents results for a modified-half-ring-wing and a swept-parasol-wing on a semi-flat body. These configurations are shown in figures 10 and 11. Some representative longitudinal characteristics at M = 3 are presented in figure 12. Although the two wings have the same total area, the geometric differences obviously produce different aerodynamic characteristics. The modified half-ring-wing did capitalize more on the reflected shock interference effect as indicated by the lower drag level for a constant angle of attack. However, the swept-wing planform was such that the configuration had a higher lift-curve slope, lower drag due to lift, a further aft aerodynamic center (more stable), and higher lift-to-drag ratios except at $\alpha = 0^o$ where the difference was very small. Such a vehicle, only 3 feet long, could fly at M = 3 and an altitude of 35,000 feet with a sustained load of about 740 pounds. Increasing the size of the vehicle by a factor of 10 could provide a load-carrying capability of about 7400 pounds at an altitude of 85,000 feet.

Parasol-wing-body with high/low wing.- A further modification of the parasol-swept-wing concept extended over a Mach number range from 3 to 4.63 and included various wing locations above the body (ref. 5). The concept is shown in figure 13 for a high and a low parasol wing position. Some longitudinal characteristics for this concept are shown in figure 14 for M = 3.00 and 4.63 and a summary of longitudinal parameters with Mach number is shown in figure 15. The results shown in figure 14 indicate the possibility of trimming with no control deflection at maximum L/D at a lift coefficient that corresponds to an angle of attack of about 4 degrees. The low angle of attack is again a result of the favorable interference effects with the reflected shock on the parasol wing. The summary (see fig. 15) indicates that the lower wing position becomes somewhat superior to the high wing as the Mach number is increased in that higher values of L/D are achieved. This concept flying at M = 3 for a body length of only 3 feet could sustain a weight of about 650 pounds at 40,000 feet. A vehicle 10 times larger and flying at M = 4.6 would sustain a weight of about 11,000 pounds at an altitude of 90,000 feet.

Monoplanar Missile with Circular/Elliptical Body

Monoplanar missiles with elliptical body cross-sections have been investigated fairly extensively. Such a concept is intended to provide some relief to carriage constraints and to provide enhanced maneuverability, when compared to circular bodies, by capitalizing on the lifting capability of the body. An example of one investigation will be used to illustrate some of the differences between an elliptical body monoplane concept and a circular body monoplane concept (ref. 6). The basic circular body concept had a monoplanar wing and cruiciform tail fins in 30-degree planes (see fig. 16). The elliptical body concept (see fig. 17) had the same area distribution as the circular body but was compressed to a 3:1 ellipse so that a portion of the original wing was overlaid by the body and hence the exposed wing area was decreased. The tail geometry was identical for the two concepts.

The longitudinal characteristics of the two concepts at M = 2 and 4.6 (see fig. 18) indicate a substantial increase in normal force for the elliptical concept and a reduction in the stability level. The detailed test results indicated about a 25-percent increase in lifting efficiency for the elliptical concept over the circular concept with a sizeable portion of that increase distributed over the forward portion of the body. Thus, for a given angle of attack, a higher normal force is achievable for the elliptic concept and a lower stability level is indicated. Trimmed stable flight for high angle of attack would require a forward movement of the center of gravity for the elliptical concept and a rearward movement for the circular concept.

The directional stability characteristics that accompany the longitudinal illustrations just shown indicate stable directional stability for the elliptical concept but very low stability or instability for the circular concept (see fig. 19). The difference results primarily from the difference in the body alone stability levels with the circular body being considerably more inherently unstable. The center of gravity movements that were indicated as desirable for enhanced longitudinal maneuvering capability at high angles of attack (forward for the ellipse and rearward for the circle) would further increase the directional stability for the elliptical concept and would worsen the directional stability for the circular concept.

The longitudinal and directional characteristics for these two concepts are summarized as functions of Mach number in figures 20 and 21. Figure 20 illustrates the forward variation of c.p. with M for both concepts and the further aft c.p. location for the circular concept. The reference c.g. is shown at 60 percent of the body length and suggests that the forward movement desirable for the elliptical concept should not be difficult to accomplish but that the aft movement associated with the circular concept might be more difficult to realize. This point is further illustrated in figure 21 which shows the progressive decrease in both longitudinal and directional stability with increasing M for both concepts but also shows the higher longitudinal stability level and low directional stability level for the circular concept. If the center of gravity was relocated so that the longitudinal and directional characteristics were within stable bounds throughout the Mach number range for both concepts, then it is again apparent that a high level of longitudinal stability that must be trimmed would exist for the circular concept and that the directional stability for the elliptic concept would be further enhanced.

The maximum values of lift-drag ratio for the two concepts are shown in figure 22 as a function of Mach number. The elliptical concept displays somewhat higher values because of both a higher lifting capability as well as a lower drag level. For configurations of this type, the higher lift-drag ratio could be used to provide a greater range capability for cruise or smaller turn radii for maneuvering flight.

Mission Implications

The somewhat unconventional missile concepts depicted herein offer some unique characteristics that may be adaptable to particular mission requirements. Among the many requirements that may be included are such items as good load-carrying capability, low drag, low detectability, ease of carriage and storage, low cost, and so on.

Tactical penetration.- A possible approach to the battlefield suppression of massed armor and troops might be through the use of concepts capable of high-speed, low-altitude, overflight with a downward spray of warhead fragments. The illustrative concepts presented herein indicate that with vehicle lengths of only 2.5 feet flying at low altitude ($<$ 5000 ft) and $M = 2$, a load-carrying capability of about 714 pounds at $\alpha = 6^{\circ}$ was achievable with the thick delta wing and about 930 pounds at $\alpha = 4^{\circ}$ was achievable with the semiconical body-high delta wing. These concepts, being small and slender, should be difficult to detect. The shapes are reasonably well suited to high heat absorption and high structural loads and could most likely be designed to operate to destruction.

Strategic penetration.- High-speed, high-altitude concepts with good aerodynamic efficiency for volume and range might be a possible approach to the strategic penetration problem. The parasol wing concepts offer the possibility of efficient operation under such conditions through the exploitation of interference flow fields that provide high lift capability at low angles of attack (reduced thrust). The flat-body with a swept parasol wing, for example, indicated that a vehicle about 30-foot long flying at $M = 3$ and 85,000 feet could sustain a weight of about 7500 pounds at $\alpha = 0^{\circ}$. A low-parasol-wing concept indicated the possibility of a 30-foot long vehicle flying at $M = 4.6$ and 90,000 feet with a weight-sustaining capability of about 11,000 pounds at $\alpha = 4^{\circ}$.

Maneuvering missiles.- A monoplanar missile with an elliptical body indicated the possibility of providing enhanced maneuvering capability through the exploitation of body aerodynamics. The elliptical body in comparison to a circular body not only provided higher lift but also lower drag, lower but controllable longitudinal stability, and greater directional stability. Such characteristics would be beneficial for highly maneuverable missiles for air defense or air combat missions. The higher values of lift-drag ratio for the elliptical body might also have application to improved range for air-to-surface missions.

Antishipping.- Some of the features inherent in the missiles discussed herein may have applicability in the role of antishipping. For both air-launched and surface-launched systems, the potential for load-carrying capability, speed, low detectability, and improved storage/carriage/launch are important features.

General.- These mission capabilities are general in nature and are intended only to be thought-provoking. Many other possible mission capabilities could be explored depending on such factors as vehicle size, weight distribution, propulsion system, launch platform, and so on.

CONCLUDING REMARKS

It has been the purpose of this paper to examine some unconventional missile concepts with a view toward adaptability to challenging mission requirements.

Briefly, some concluding observations are:

- O Highly-swept delta wing and delta wing-body combinations may offer the potential for good load-carrying capability at high speed and low altitude with some special application to tactical penetration and antishipping roles.
- O Parasol wing configurations, through the exploitation of shock interference, offer some potential for high lift and low drag at high speed and high altitude with some special application to strategic penetration and antishipping roles.
- O A monoplanar elliptical body configuration, through the exploitation of body forces, offers some potential for high lift, low drag, and good maneuver and stability characteristics with some special application to air defense, air combat, and air-to-surface roles.

REFERENCES

1. Foster, Gerald V.: Static Stability Characteristics of a Series of Hypersonic Boost-Glide Configurations at Mach Numbers of 1.41 and 2.01. NASA TM X-167, 1959.

2. Graves, Ernald B.; and Carmel, Melvin M.: Aerodynamic Characteristics of Several Hypersonic Boost-Glide-Type Configurations at Mach Numbers from 2.30 to 4.63. NASA TM X-1601, 1968.

3. Morris, Odell A.: Aerodynamic Characteristics in Pitch of Several Ring-Wing-Body Configurations at a Mach Number of 2.2. NASA TN D-1272, 1962.

4. Morris, Odell A.; and Lamb, Milton: Aerodynamic Characteristics in Pitch of a Modified-Half-Ring-Wing-Body Combination and a Swept-Wing-Body Combination at Mach 2.16 to 3.70. NASA TM X-1551, 1968.

5. Morris, Odell A.; and Mack, Robert J.: Aerodynamic Characteristics of a Parasol-Wing-Body Combination Utilizing Favorable Lift Interference at Mach Numbers from 3.00 to 4.63. NASA TN D-4855, 1968.

6. Graves, Ernald B.: Aerodynamic Characteristics of a Monoplanar Missile Concept with Bodies of Circular and Elliptical Cross Sections. NASA TM 74079, 1977.

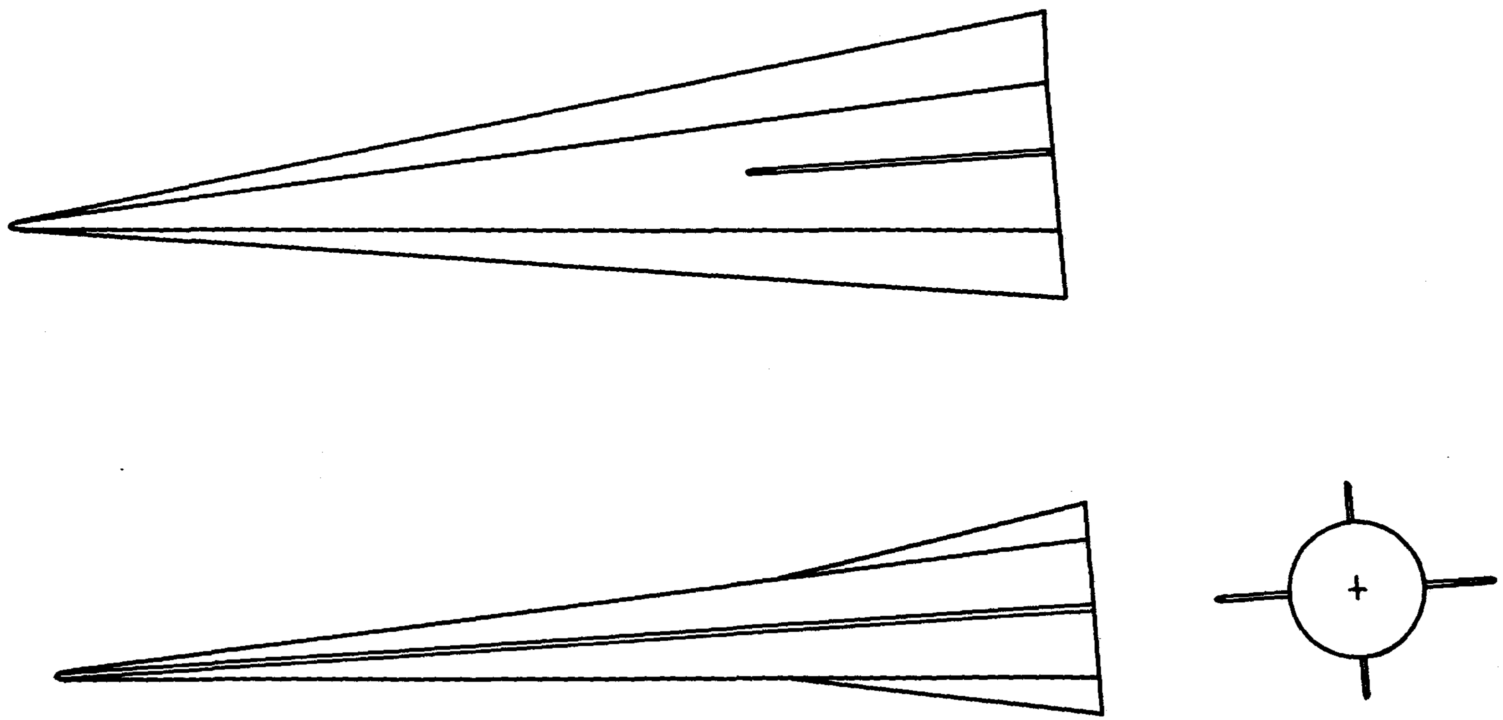

Figure 1.- Conical delta wing-body concept.

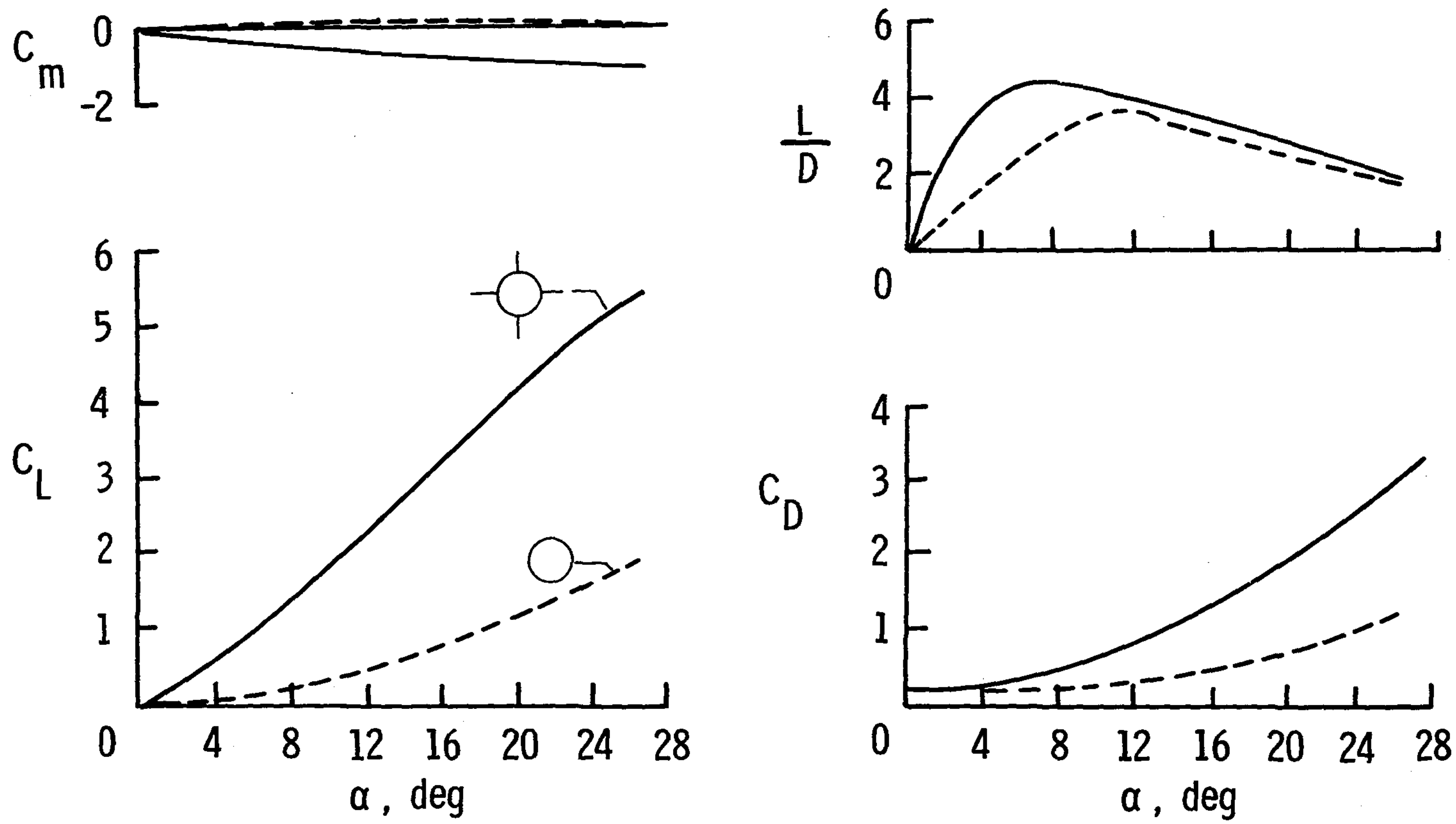

Figure 2.- Longitudinal characteristics for conical delta wing-body at M = 2, c.g. = 0.666_l.

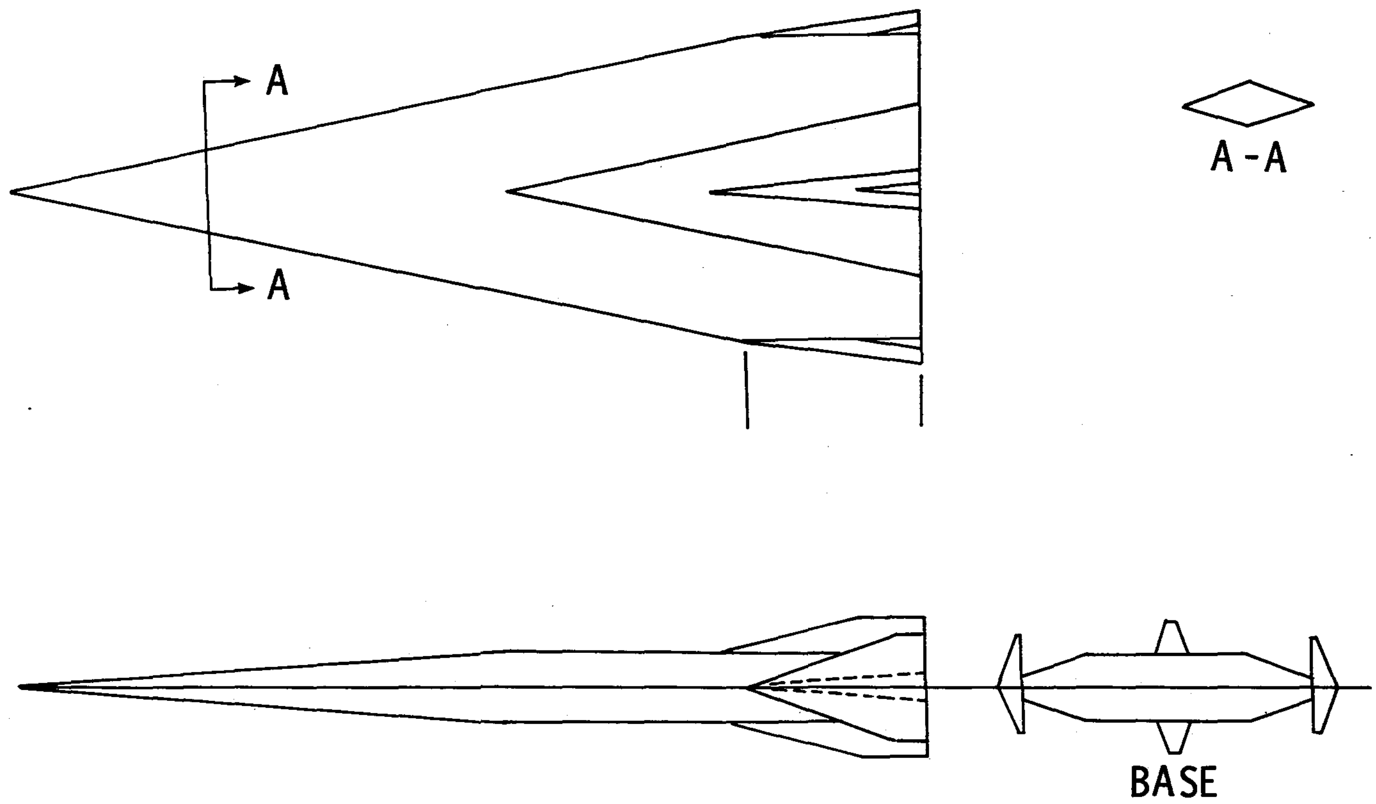

Figure 3.- Thick delta wing concept.

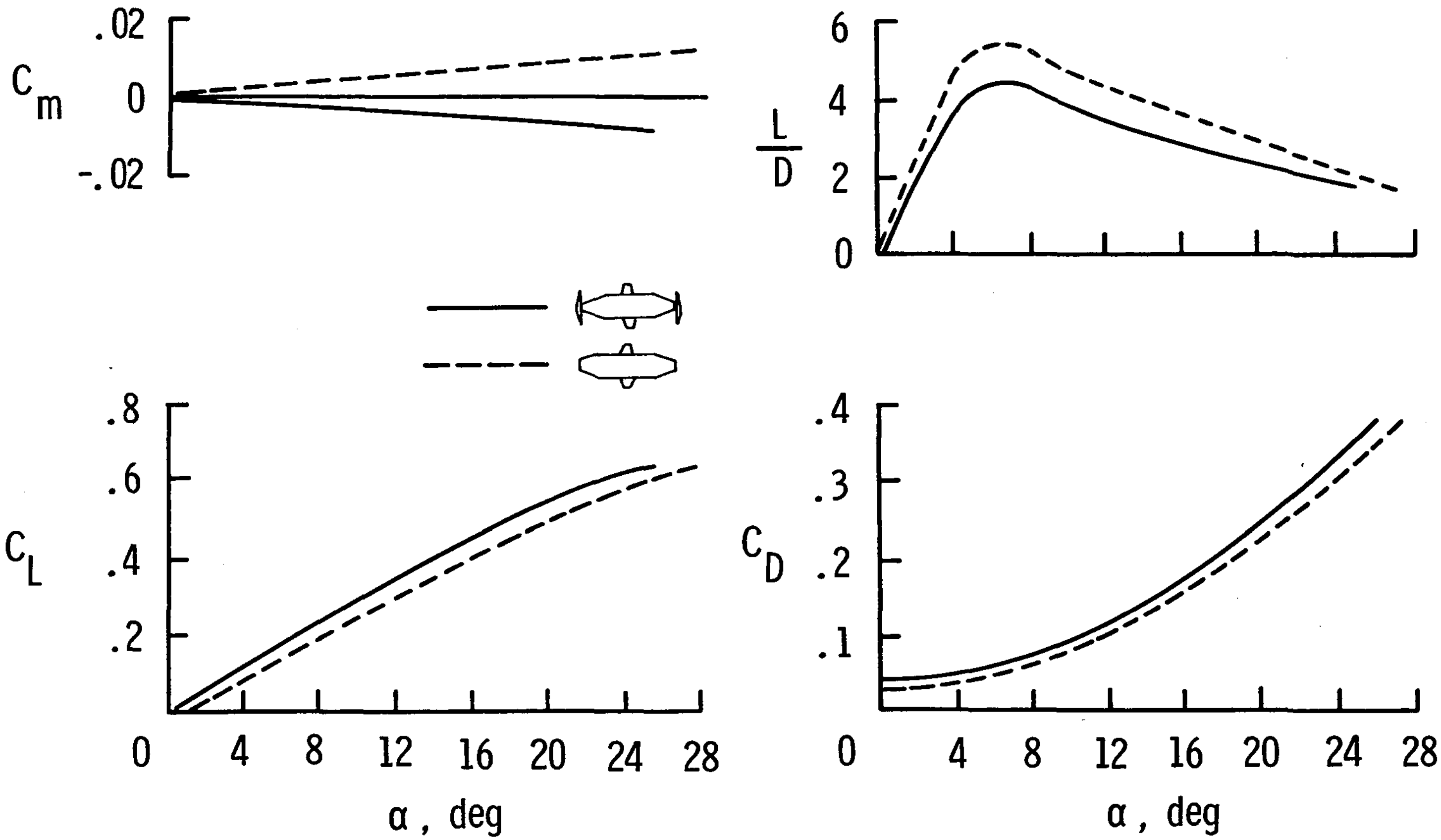

Figure 4.- Longitudinal characteristics for thick delta wing at M = 2, c.g. = 0.666l.

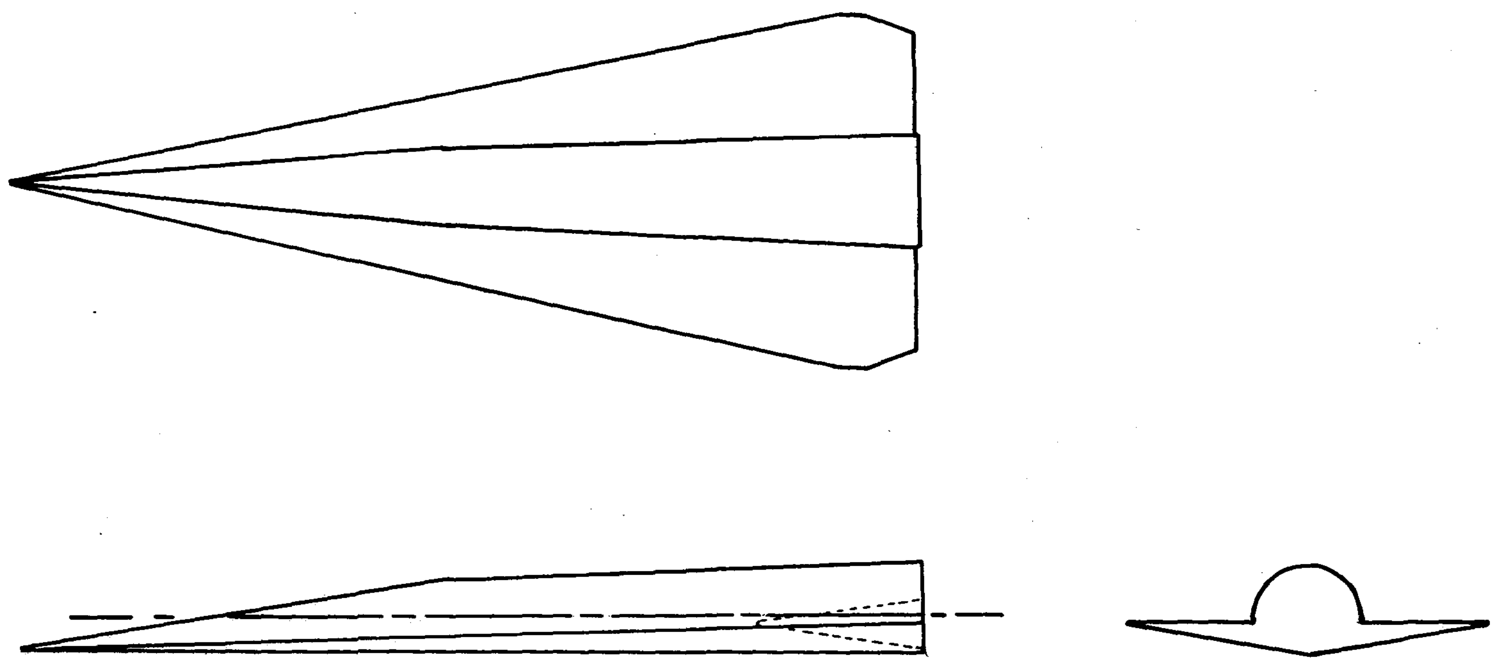

Figure 5.- Semiconical body with delta wings.

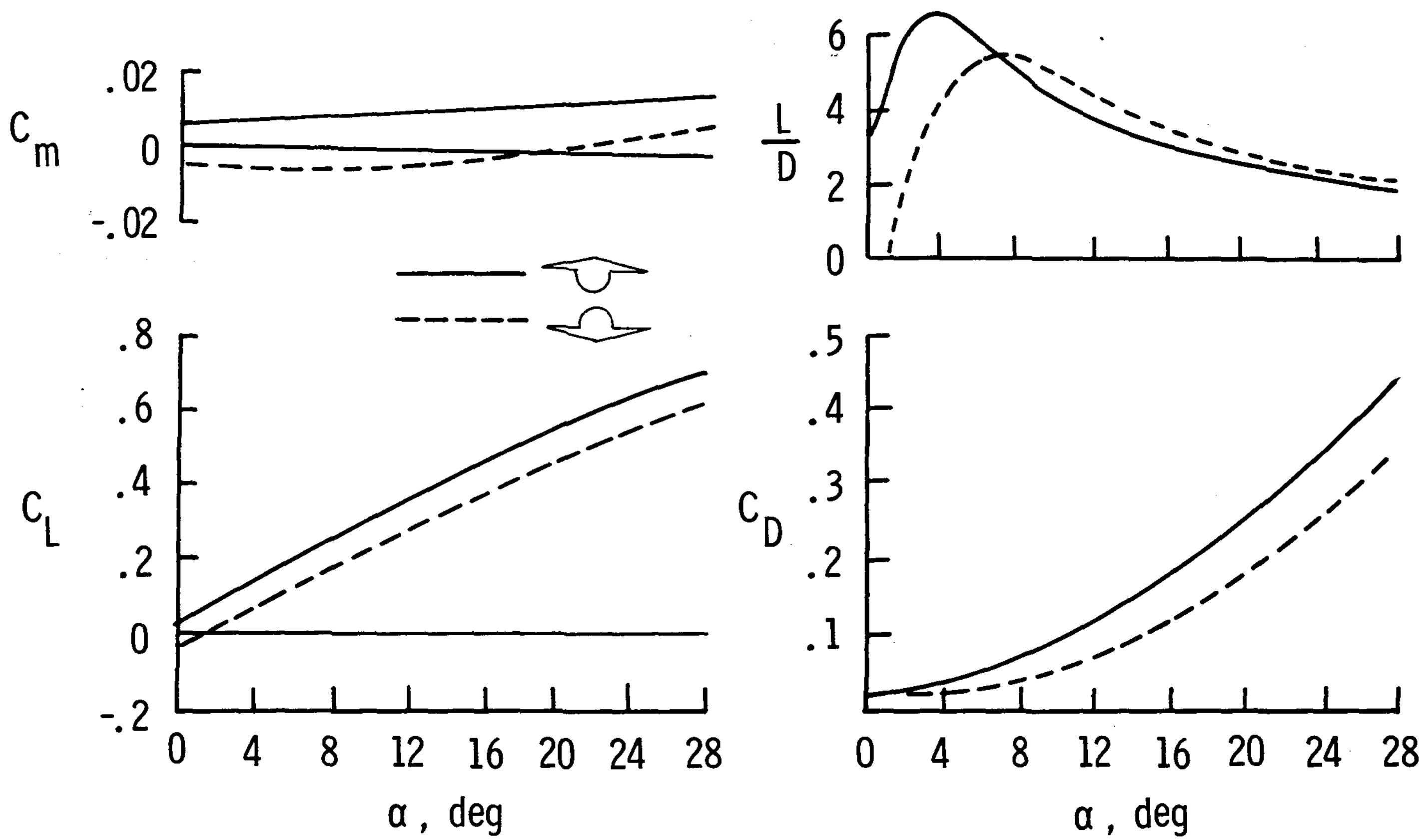

Figure 6.- Longitudinal characteristics for semiconical body with a high and a low delta wing at M = 2, c.g. = $0.666l$.

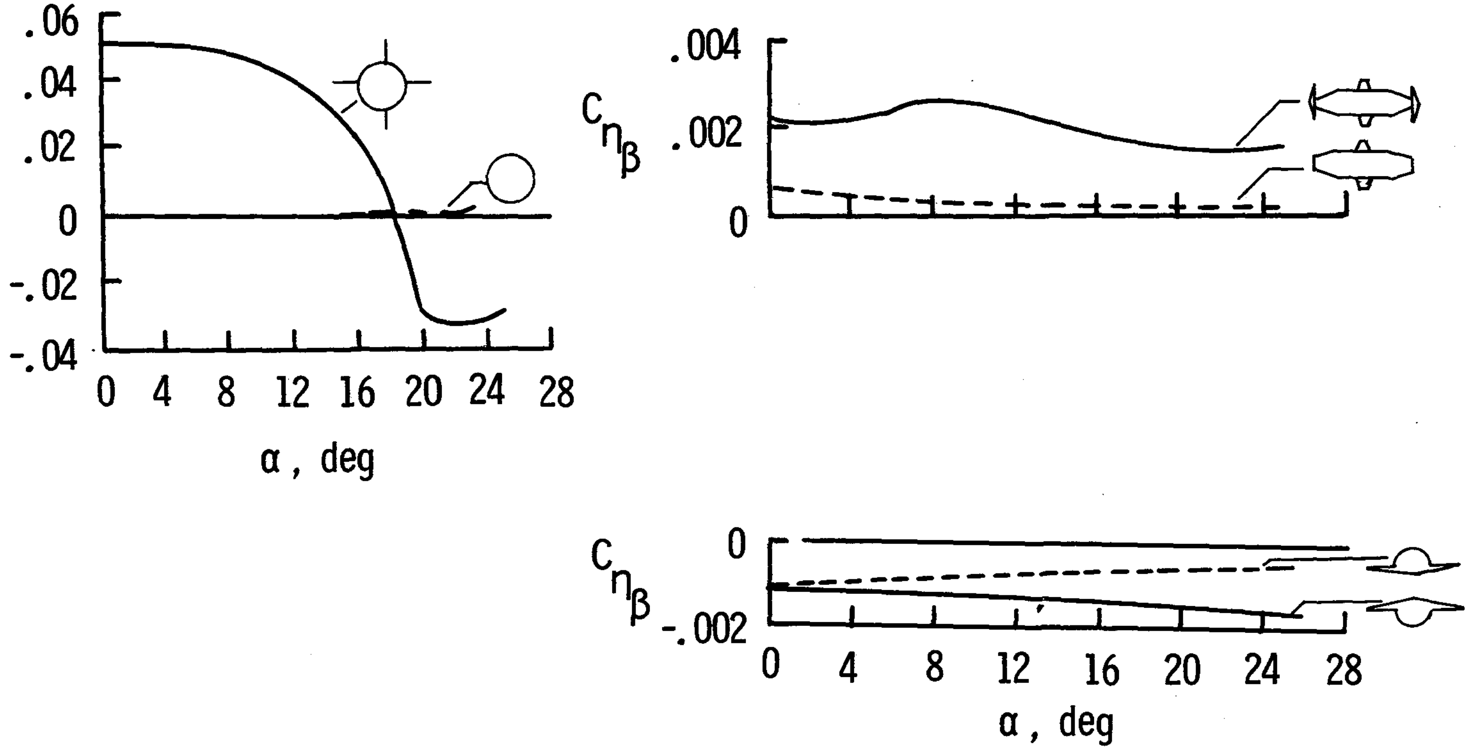

Figure 7.- Directional characteristics for delta wing concepts at M = 2, c.g. = 0.666 l.

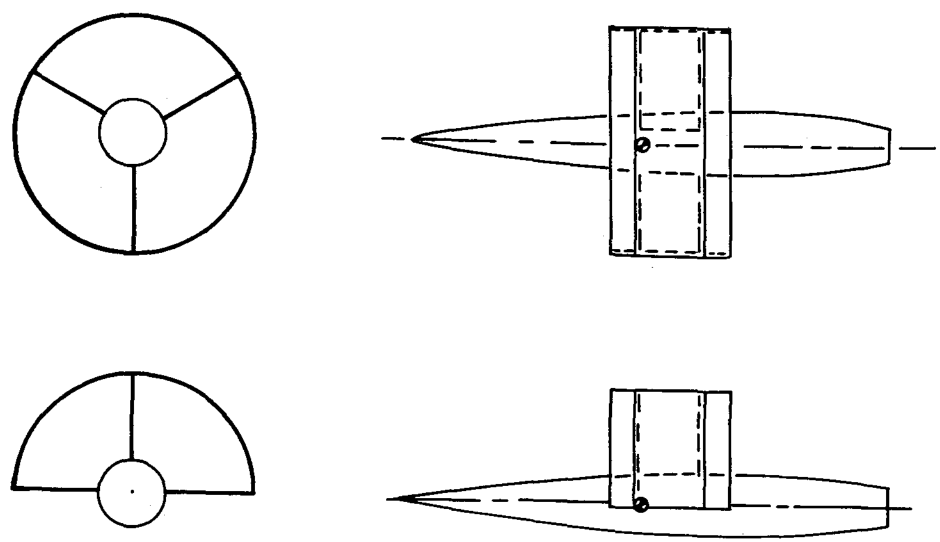

Figure 8.- Ring-wing body concepts.

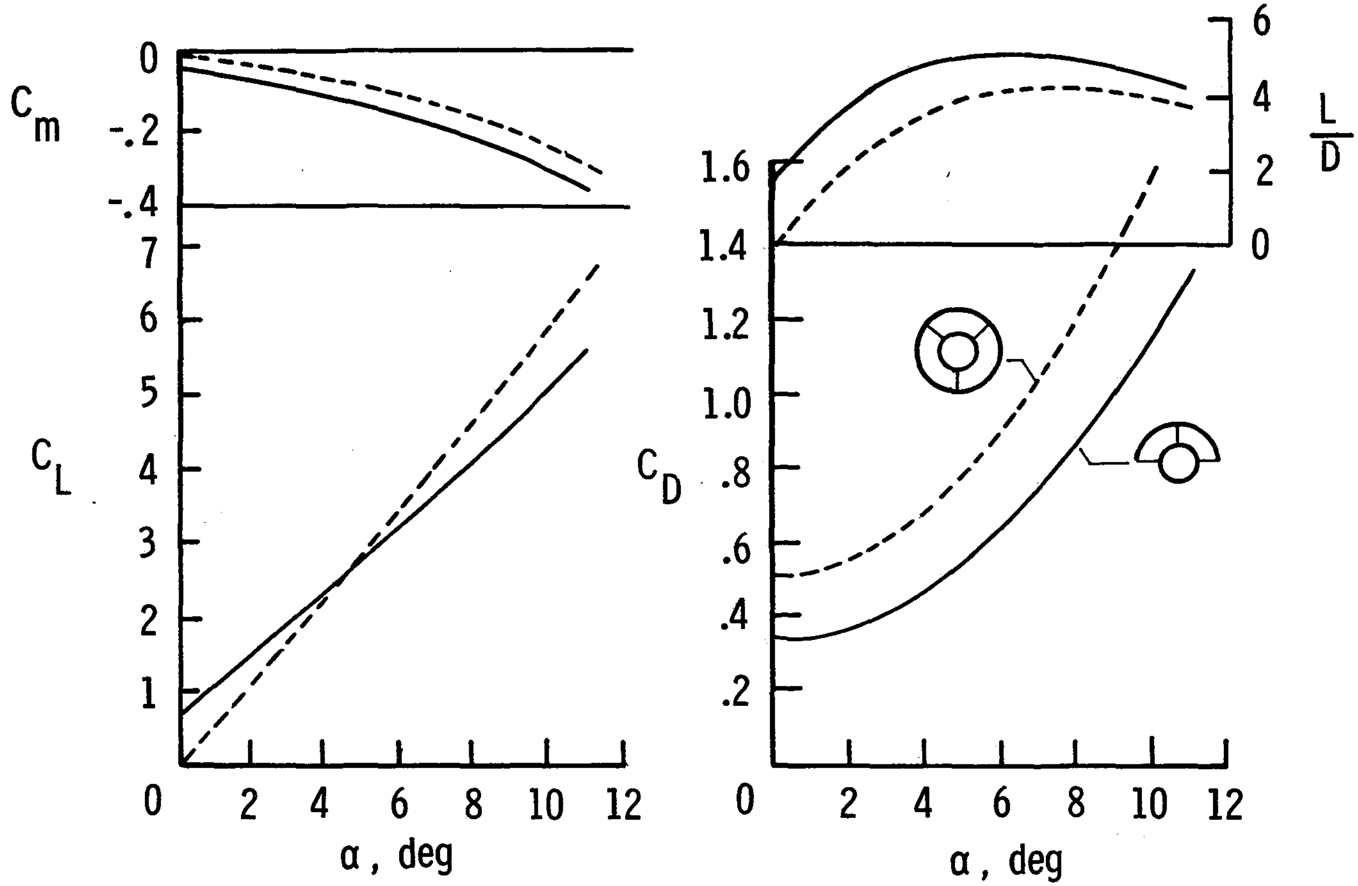

Figure 9.- Longitudinal characteristics for ring-wing-body concepts at M = 2.2, c.g. = 0.5_l.

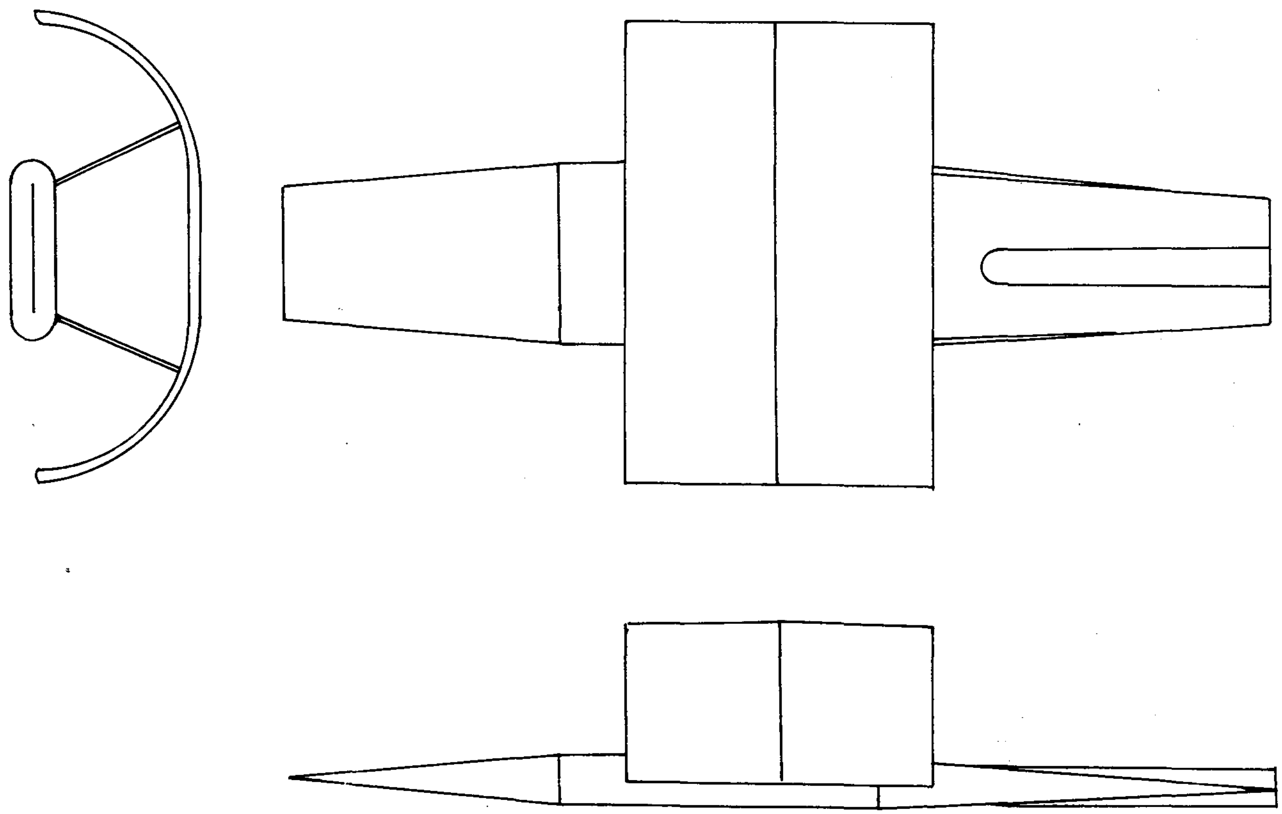

Figure 10.- Flat body with modified half-ring-wing.

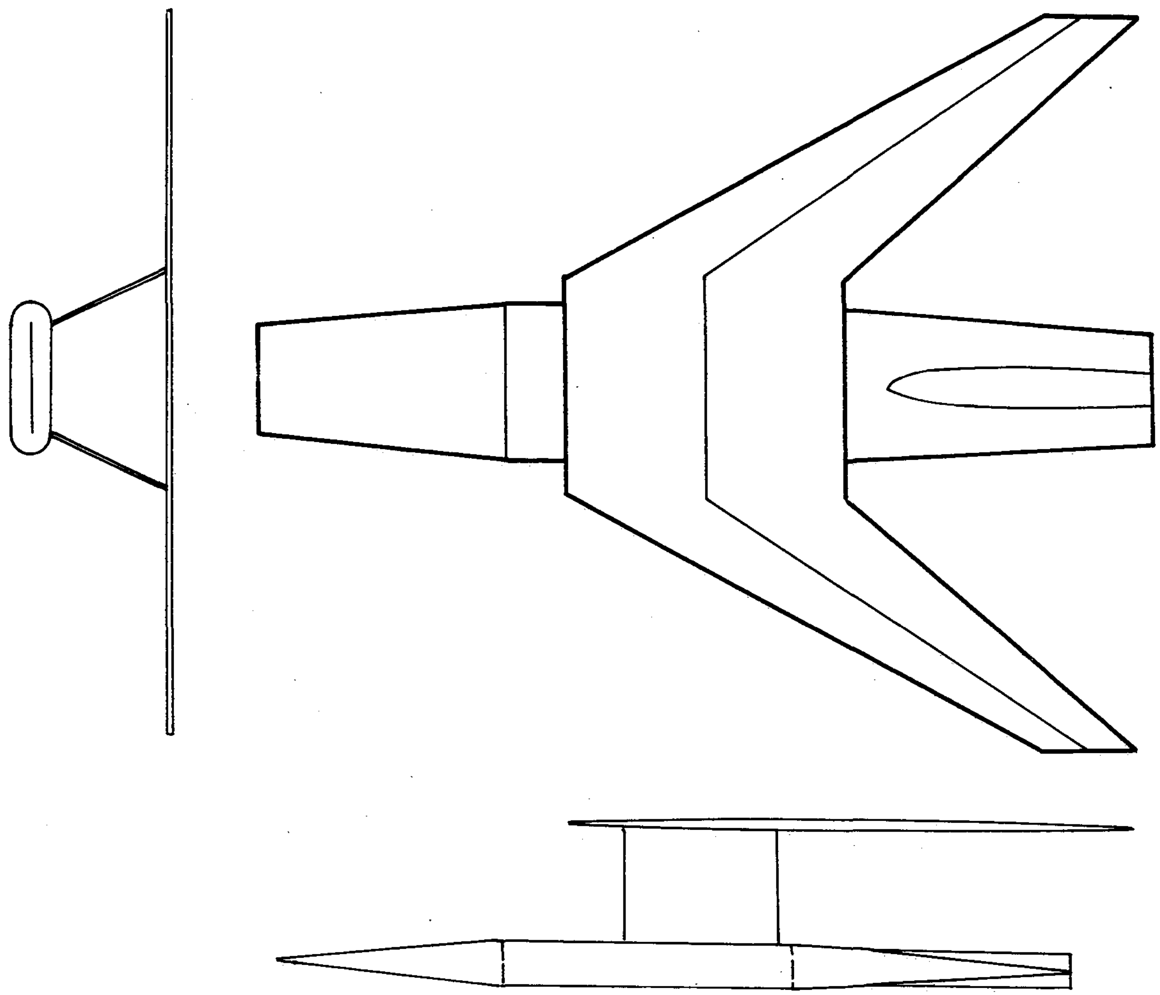

Figure 11.- Flat body with swept parasol wing.

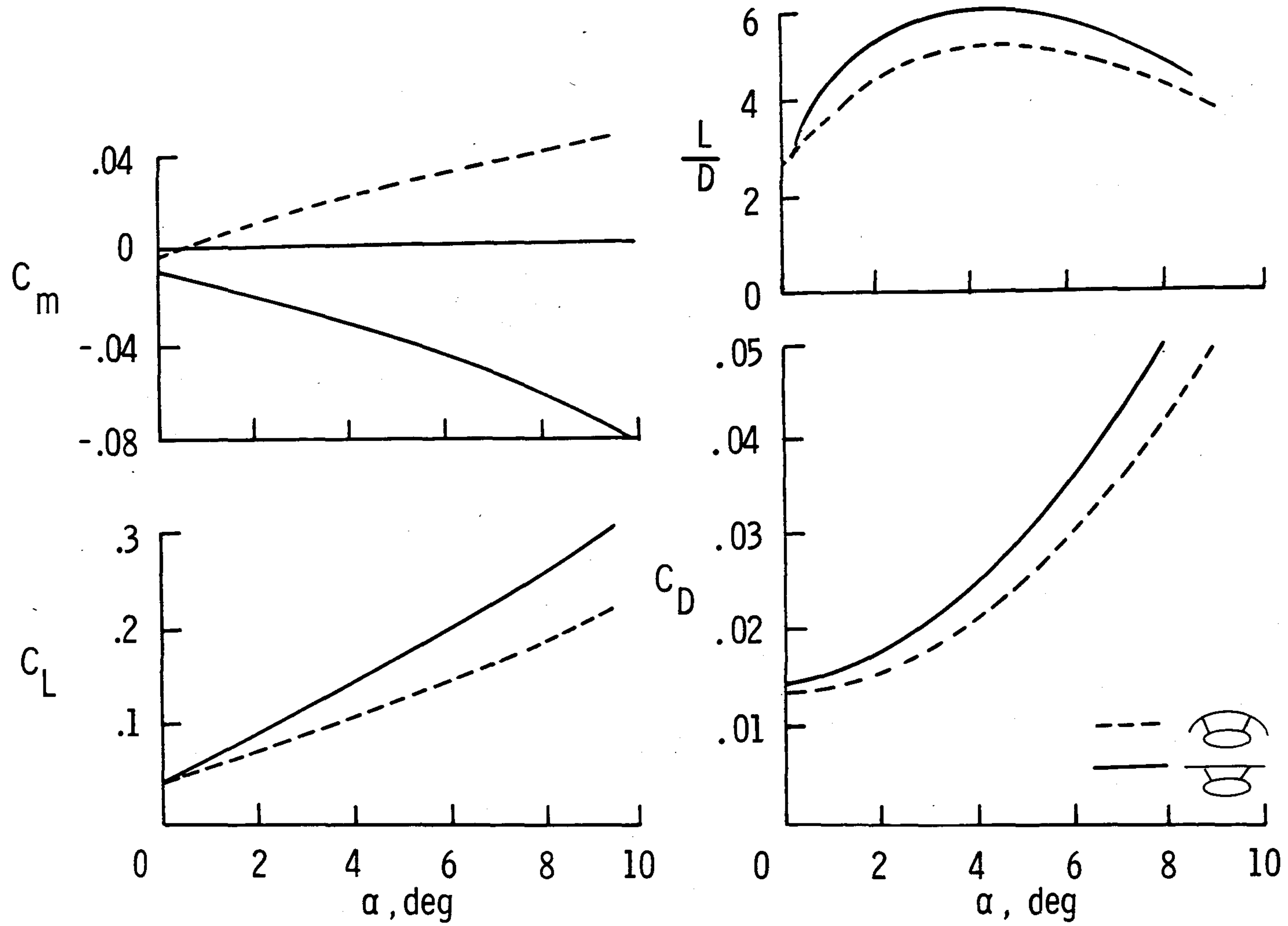

Figure 12.- Longitudinal characteristics for flat body with modified half-ring-wing and with swept parasol wing at $M = 3$, c.g. = 0.6_l.

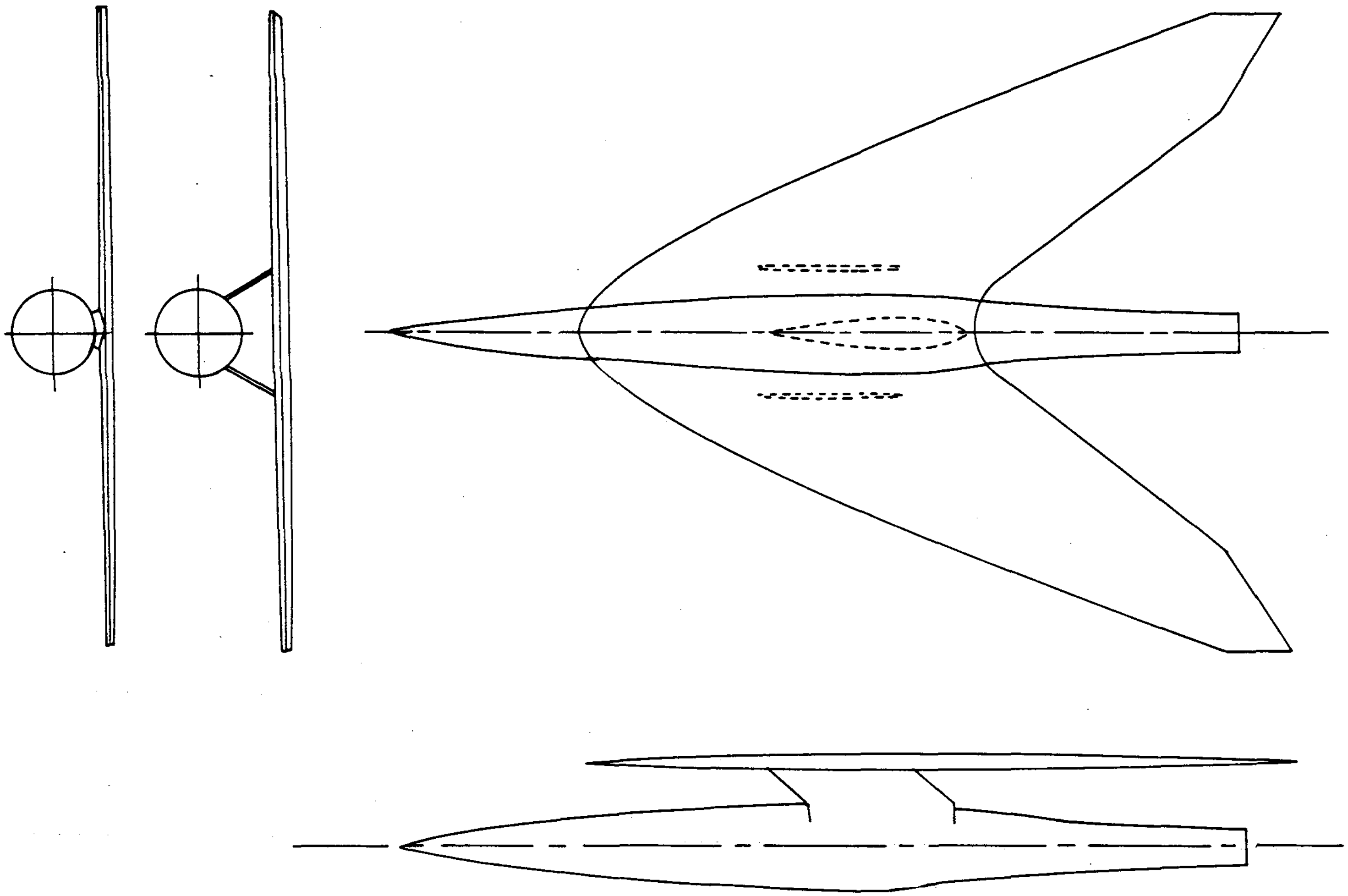

Figure 13.- Modified parasol-wing-body concept.

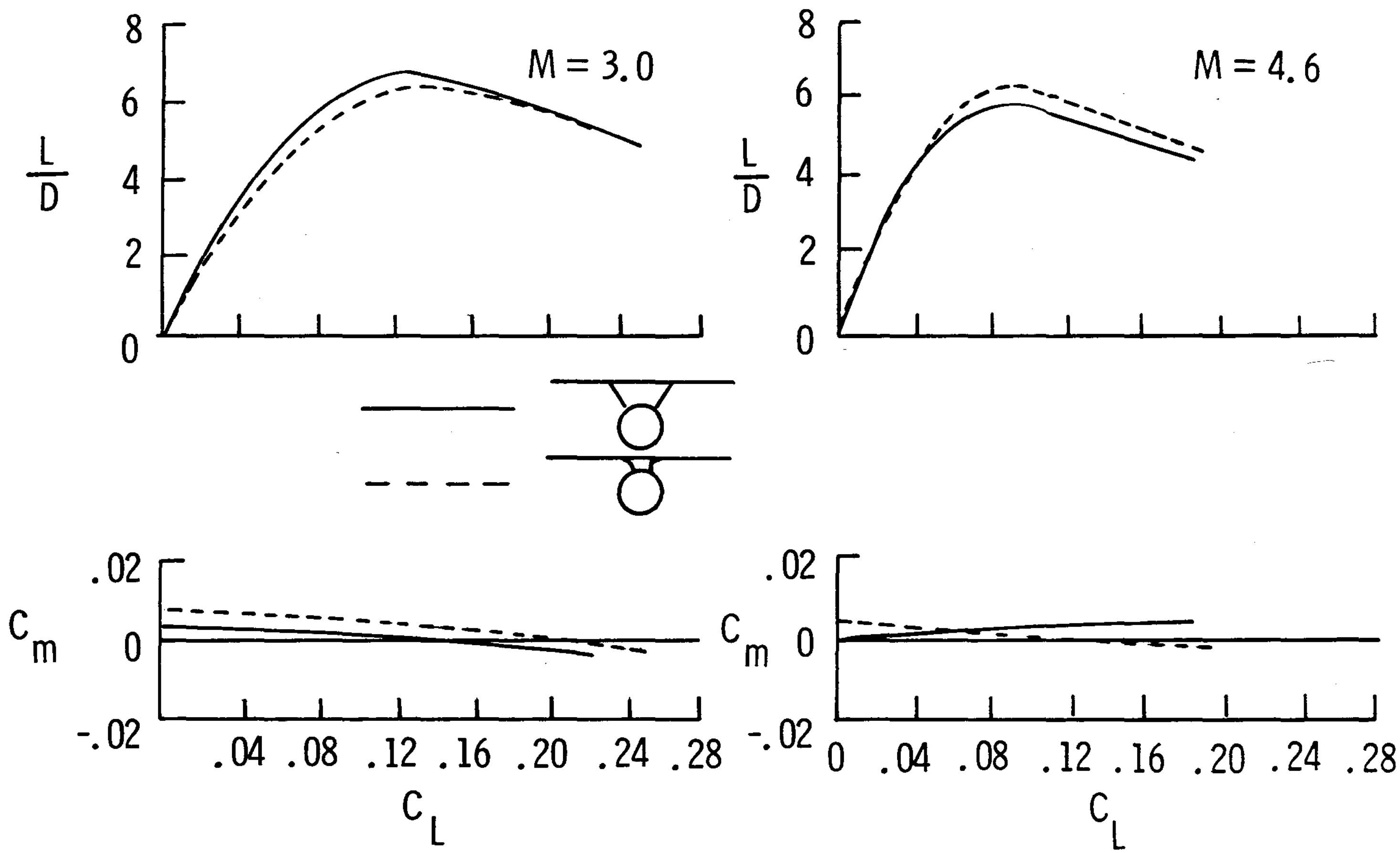

Figure 14.- Longitudinal characteristics for modified parasol-wing-body concepts at M = 3 and 4.63, c.g. = 0.6_l.

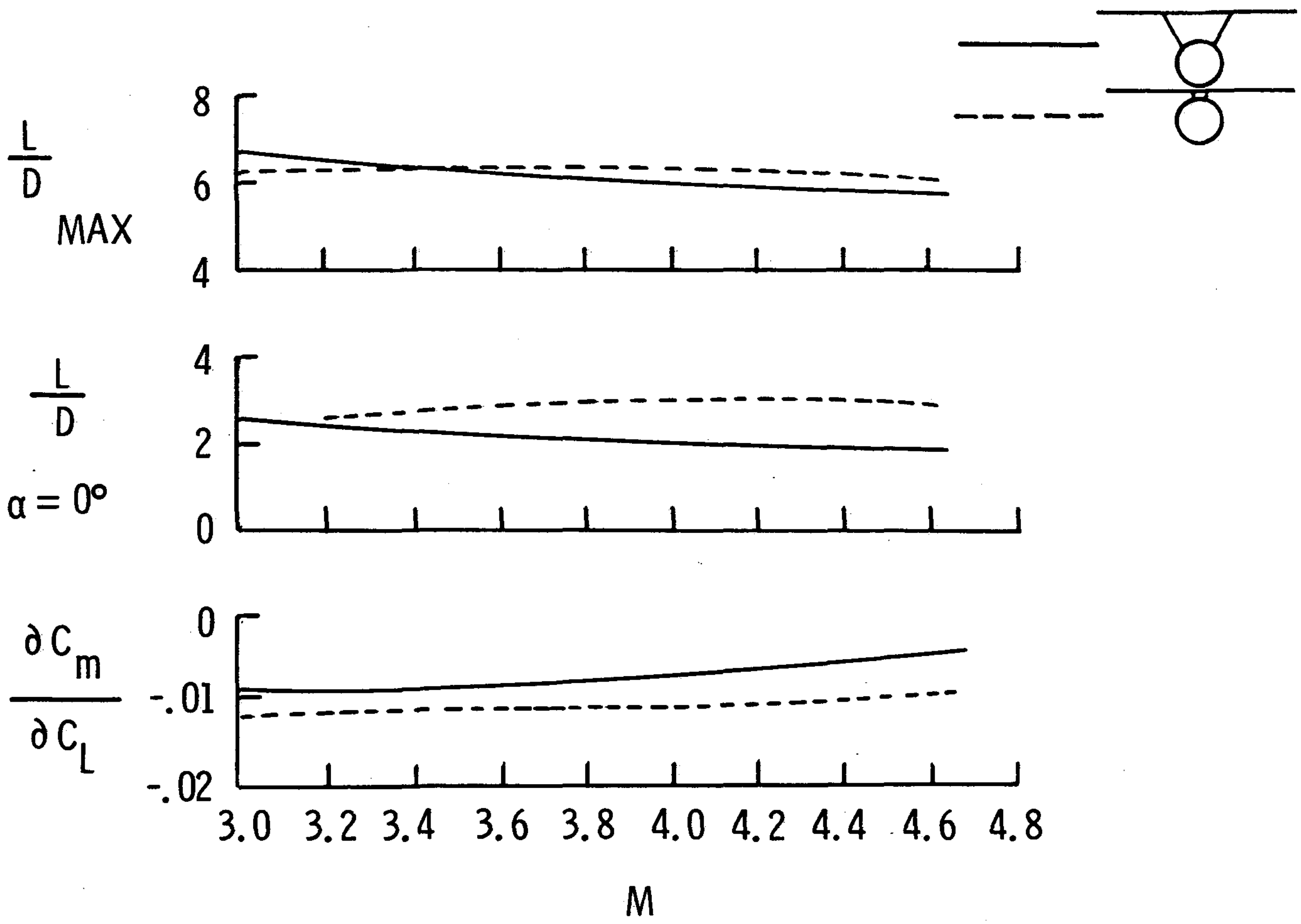

Figure 15.- Longitudinal parameters for modified parasol-wing-body concepts as a function of M, c.g. = 0.6_l.

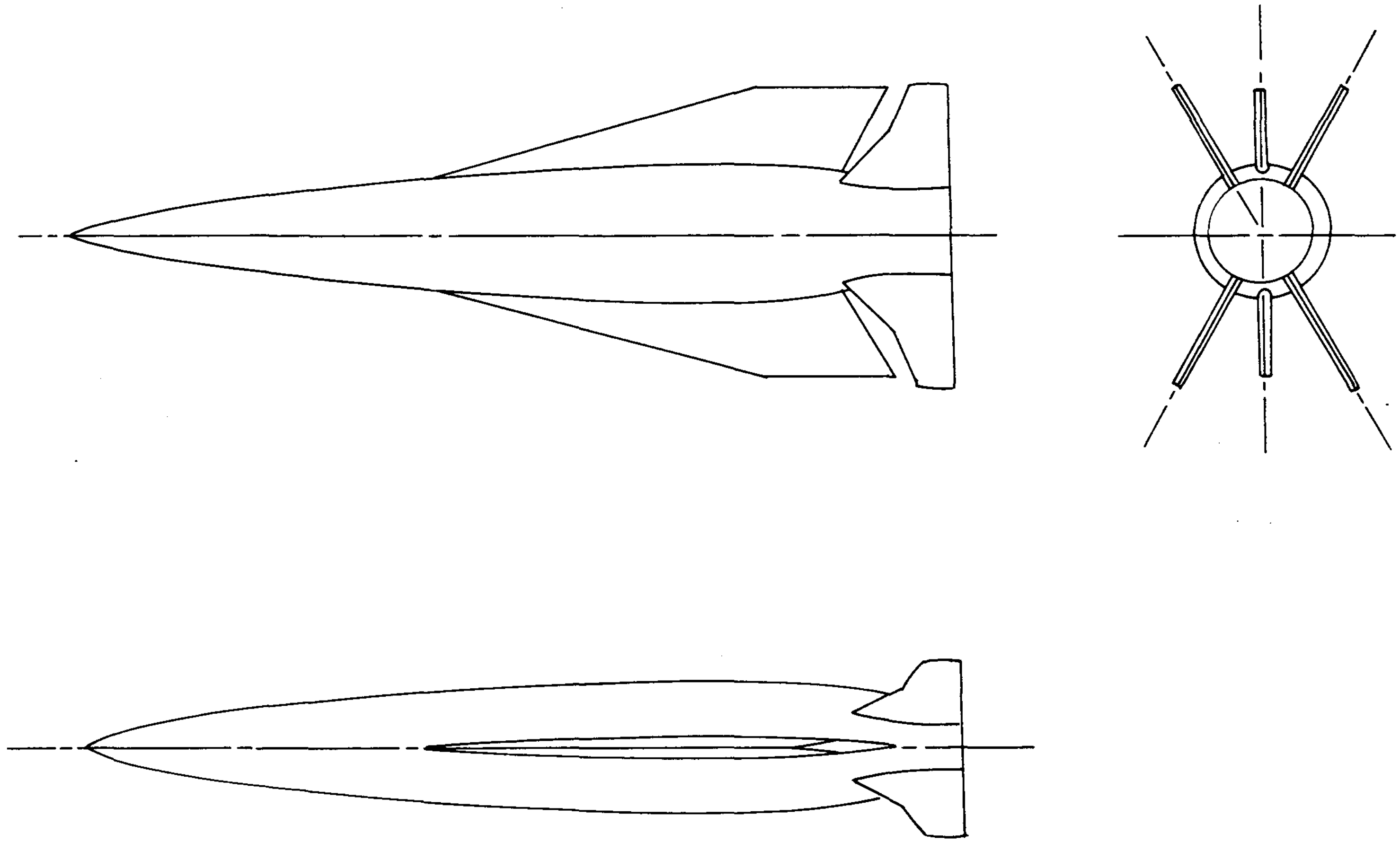

Figure 16.- Monoplanar missile with circular body.

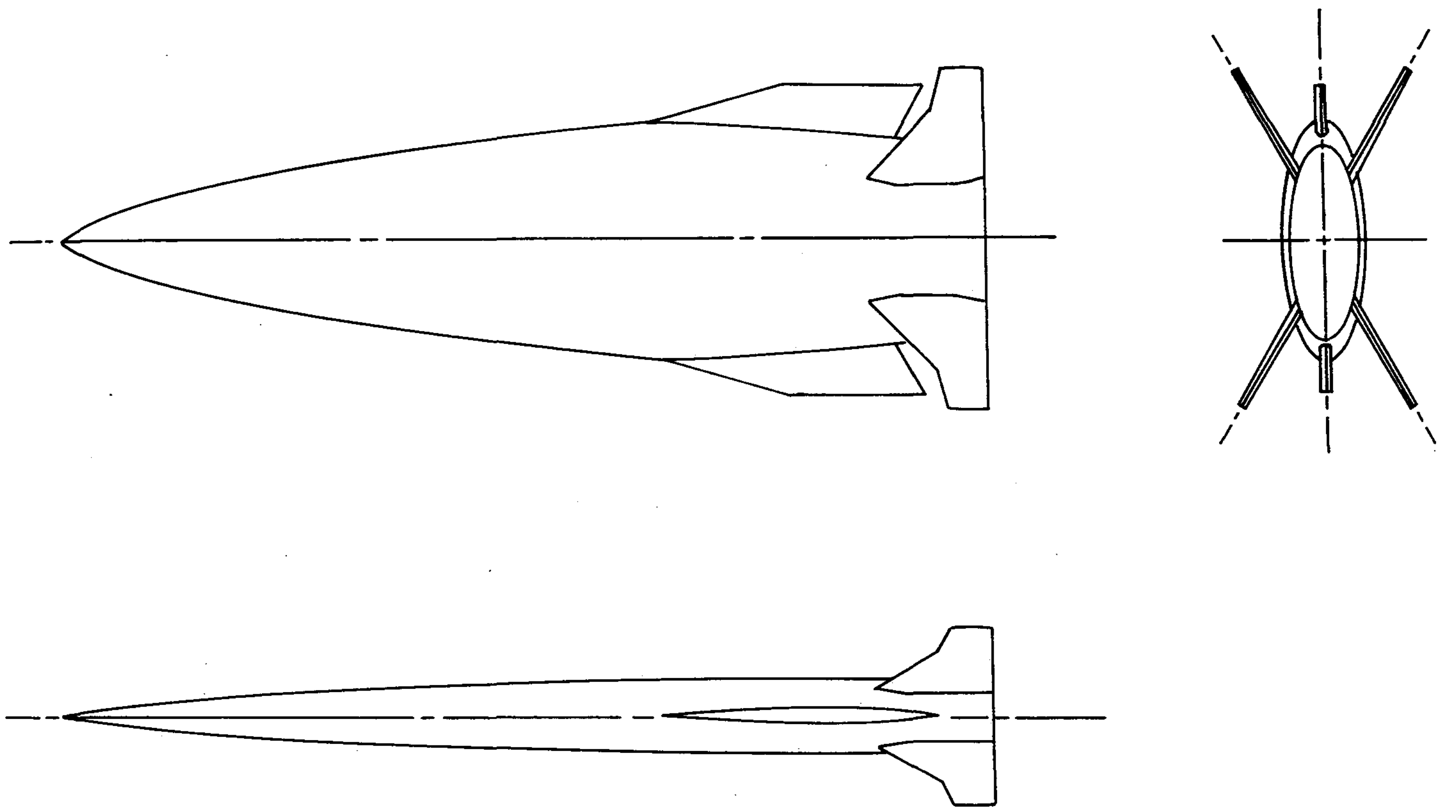

Figure 17.- Monoplanar missile with elliptical body.

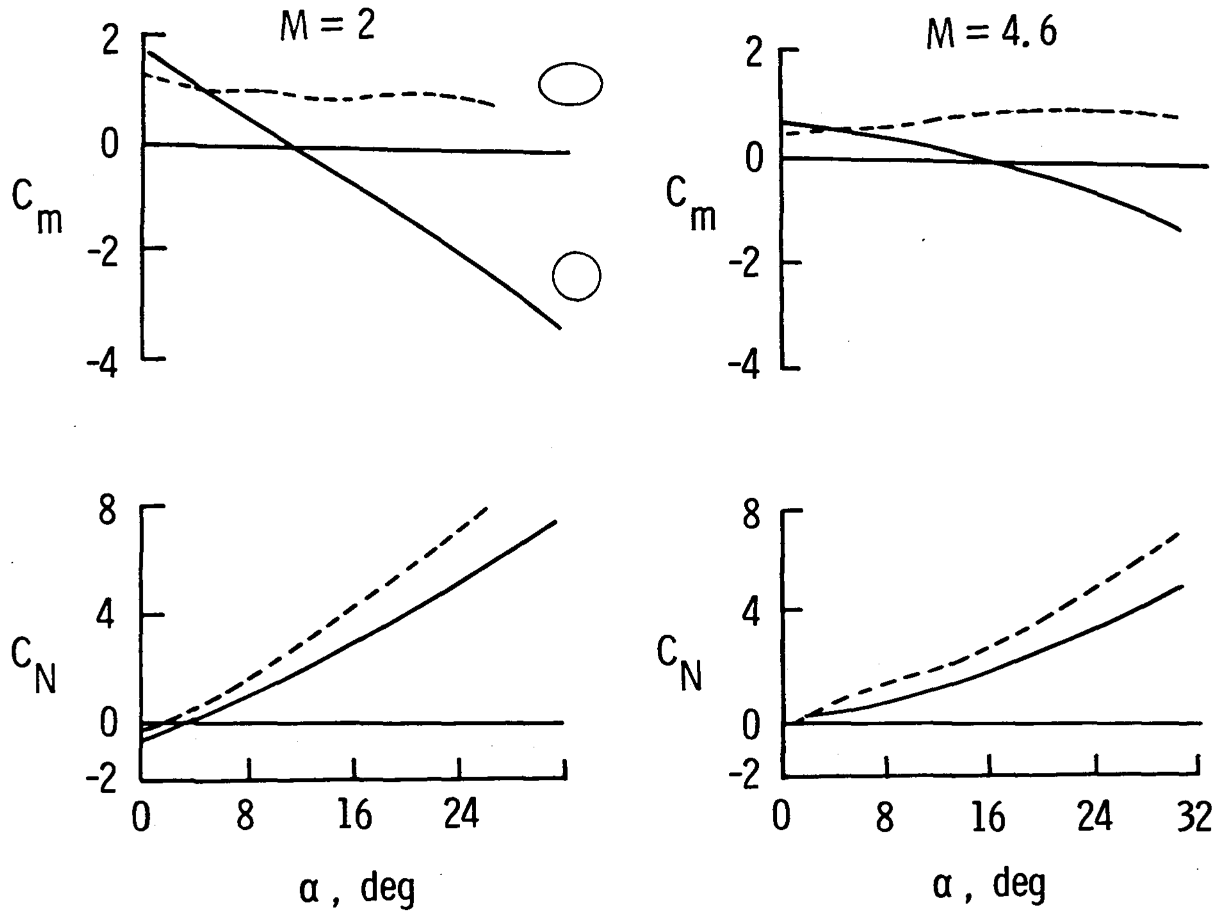

Figure 18.- Longitudinal characteristics for monoplanar missile concepts with a pitch control deflection of 10^0, M = 2 and 4.6, c.g. = 0.60_l.

FIGURE 19 MISSING FROM ORIGINAL DOCUMENT.

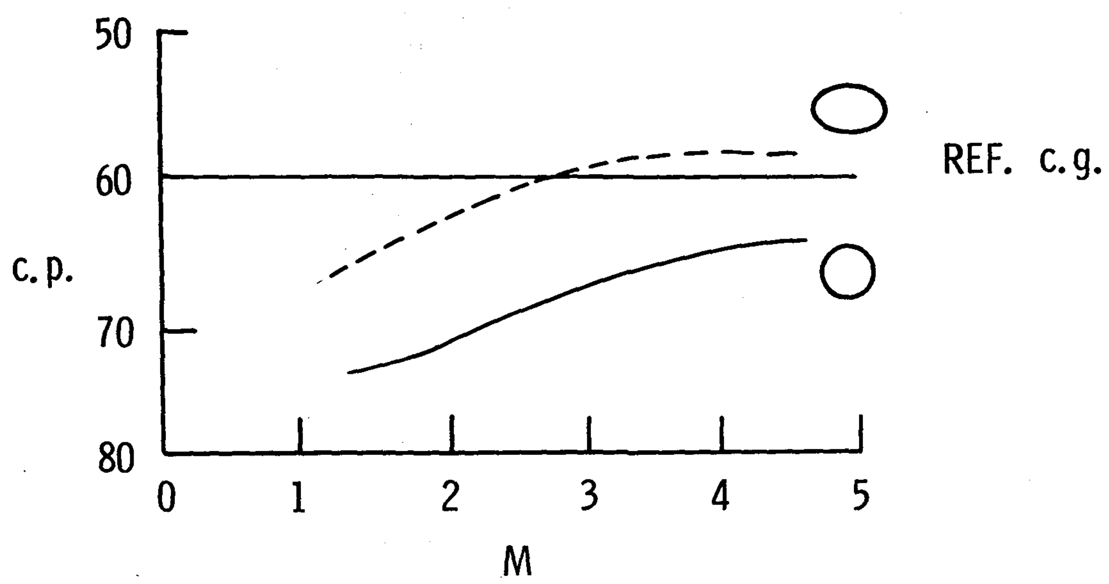

Figure 20.- Center of pressure variations with M for monoplanar missile concepts at $\alpha = 0^o$.

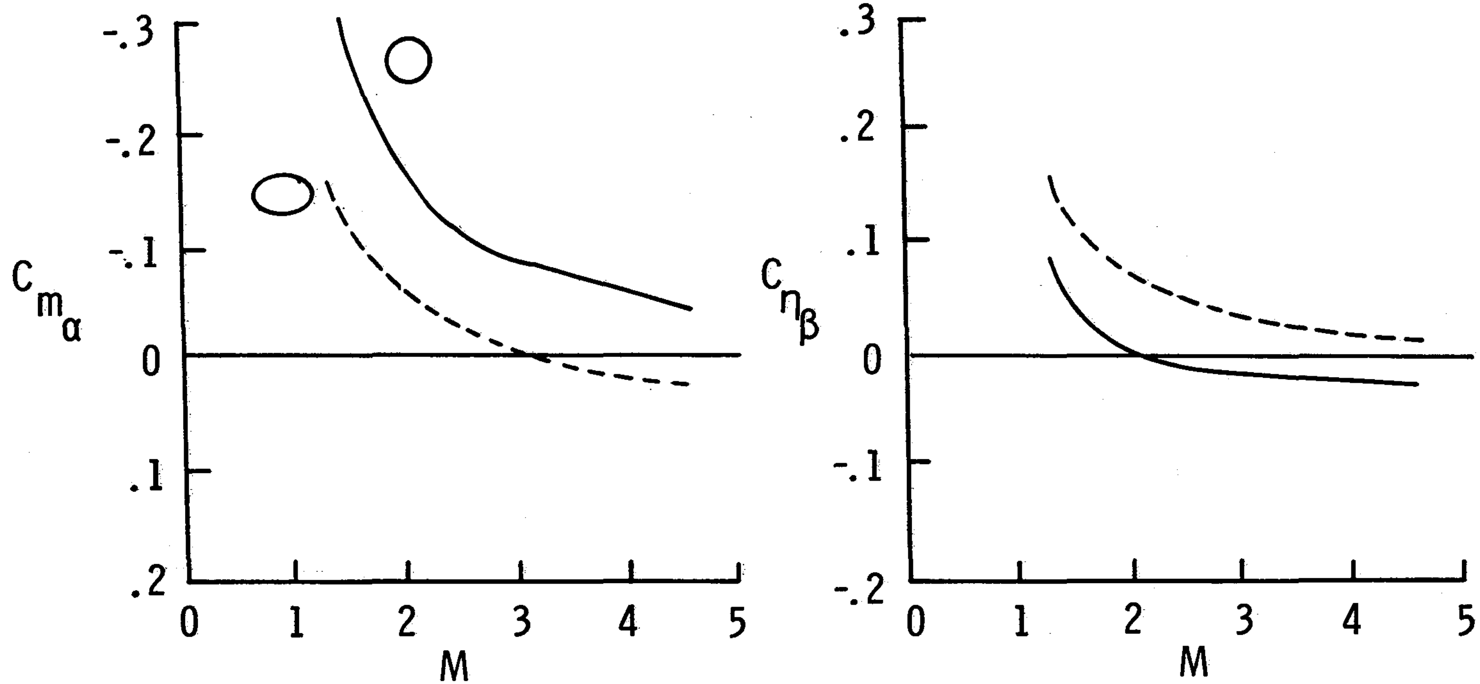

Figure 21.- Longitudinal and directional stability variations with M for monoplanar missile concepts at $\alpha = 0^{o}$ and c.g. = $0.60l$.

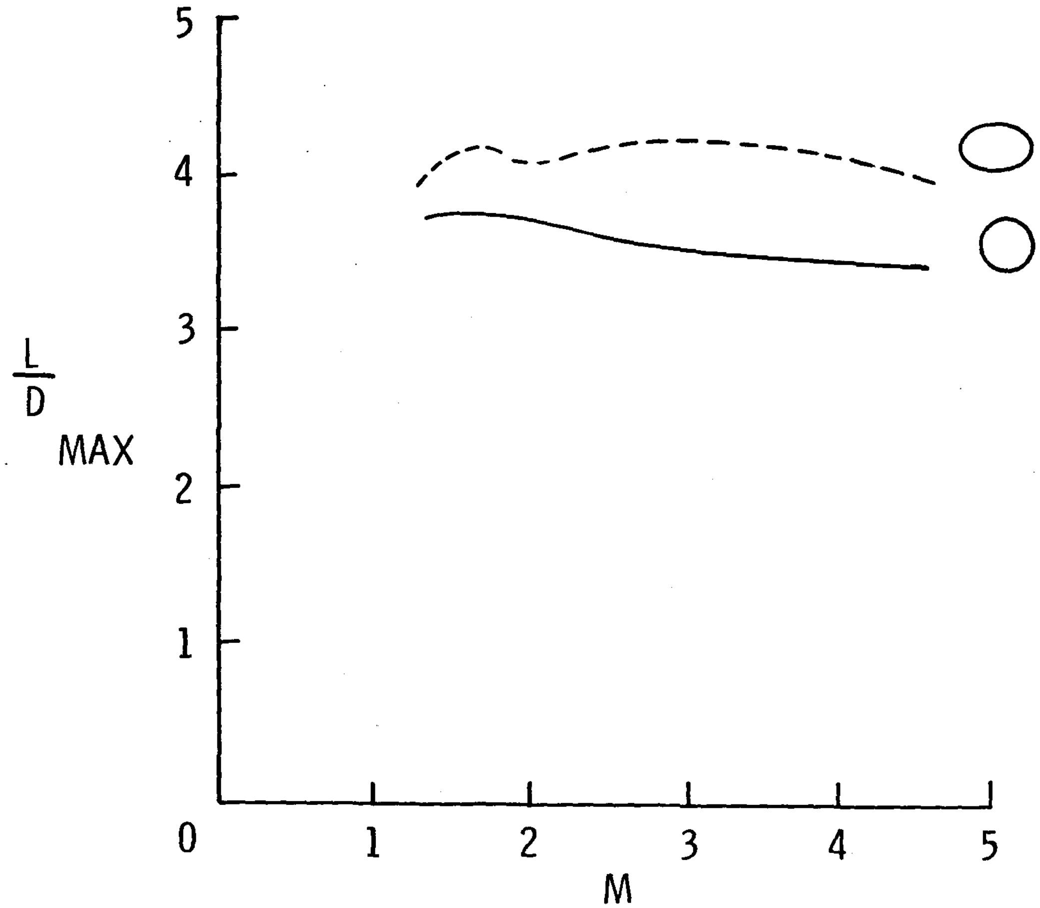

Figure 22.- Maximum lift-drag ratios for monoplanar missile concepts.

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15. Supplementary Notes

16. Abstract

Some missile concepts are considered from the standpoint of volumetric efficiency, minimum carriage constraints, and aerodynamic performance to achieve some perceived mission requirements. The mission requirements considered include air-to-surface roles such as defense suppression or anti-shipping where payload and range may have priority over high-maneuver capability, and air-to-air and surface-to-air roles where attention must be given to good maneuvering capability as well. The concepts are also intended to provide for ease of storage or carriage. The concepts include monoplanes with highly-swept, thick delta wings, highly-swept delta wings mounted either high or low on a semicircular body, some ring-wing and semiring-wing arrangements, parasol wing, and elliptical lifting bodies.

In general, the unconventional missile configurations considered indicate some possible approaches toward resolving problems of carriage and storage while retaining good volumetric and aerodynamic efficiency. The configurations could result in the capability to accomplish a wide variety of possible missions with relatively simple vehicle shapes.

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