RESEARCH MEMORANDUM

AERODYNAMIC CHARACTERISTICS OF MISSILE CONFIGURATIONS WITH WINGS OF LOW ASPECT RATIO FOR VARIOUS COMBINATIONS OF FOREBODIES, AFTERBODIES, AND NOSE SHAPES FOR COMBINED ANGLES OF ATTACK AND SIDESLIP AT A MACH NUMBER OF 2.01

By Ross B. Robinson

Langley Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON
June 25, 1957
Declassified January 12, 1961
AERODYNAMIC CHARACTERISTICS OF MISSILE CONFIGURATIONS WITH WINGS OF LOW ASPECT RATIO FOR VARIOUS COMBINATIONS OF FOREBODIES, AFTERBODIES, AND NOSE SHAPES FOR COMBINED ANGLES OF ATTACK AND SIDESLIP AT A MACH NUMBER OF 2.01

By Ross B. Robinson

SUMMARY

An investigation has been made in the Langley 4- by \( \frac{1}{4} \)-foot supersonic pressure tunnel to determine the aerodynamic characteristics of a series of missile configurations having low-aspect-ratio wings at a Mach number of 2.01. The effects of wing plan form and size, length-diameter ratio, forebody and afterbody length, boattailed and flared afterbodies, and various nose shapes were determined. Six-component force and moment data are presented for combined angles of attack and sideslip to about 26°. No analysis of the data has been made in this report.

INTRODUCTION

A problem of increasing importance in missile design is the efficient utilization of internal stowage space in aircraft. The use of low-aspect-ratio lifting surfaces with small span-diameter ratios would result in more compact missiles occupying materially less volume than the same number of configurations with large-span lifting surfaces.

Another problem of missile design is the maneuverability required by the limited scanning angles of the missile seeking equipment. The missile should be capable of large attitude changes with minimum control deflections. A configuration with nonlinear lift and pitching-moment variations such that the values of static margin and lift-curve slope are low near zero angle of attack would satisfy this requirement.
The data are presented at the center of pressure at the leading edge of the wing. All the data are referred to the body coordinates.

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_N$</td>
<td>normal-force coefficient, $\frac{N}{qS}$</td>
</tr>
<tr>
<td>$C_x$</td>
<td>axial-force coefficient, $\frac{X}{qS}$</td>
</tr>
<tr>
<td>$C_m$</td>
<td>pitching-moment coefficient, $\frac{M_y}{qS\alpha}$</td>
</tr>
<tr>
<td>$C_r$</td>
<td>rolling-moment coefficient, $\frac{M_x}{qS\alpha}$</td>
</tr>
<tr>
<td>$C_p$</td>
<td>yawing-moment coefficient, $\frac{M_z}{qS\alpha}$</td>
</tr>
<tr>
<td>$C_Y$</td>
<td>side-force coefficient, $\frac{Y}{qS}$</td>
</tr>
<tr>
<td>$N$</td>
<td>normal force</td>
</tr>
<tr>
<td>$A$</td>
<td>axial force</td>
</tr>
</tbody>
</table>
... lengths of cylindrical

... tripod tip

... on tripod

... cylinder with hemispherical nose

... with the Fairing
Afterbodies (fig. 2(d)):
\[
\begin{align*}
A_0 & \quad \text{no afterbody} \\
A_1, A_2 & \quad \text{cylindrical afterbodies} \\
A_3, A_4, A_5 & \quad \text{boattailed afterbodies} \\
A_6, A_7, A_8 & \quad \text{flared afterbodies}
\end{align*}
\]

Wings (fig. 2(f)):
\[
\begin{align*}
W_0 & \quad \text{wing off} \\
W_1, W_2, W_3 & \quad \text{delta wings} \\
W_4, W_5, W_6 & \quad \text{rectangular wings}
\end{align*}
\]

MODEL AND APPARATUS

Sketches of a typical complete model and of the model components are shown in figure 2. The geometric characteristics of the various components and combinations of forebodies, wings, and afterbodies are given in table I. Values of $x/l$ and $l/d$ for all the bodies are also given in table I. The models used in this investigation are shown in figure 3.

The various configurations were obtained by attaching combinations of forebodies, afterbodies, and wings to a cylindrical section $W_0$ having a diameter of 3.00 inches (this diameter is hereinafter referred to as 1 caliber in calculating body lengths) housing the internal strain-gage balance (fig. 2(f)).

The basic forebodies investigated were a series of 3.5-caliber ogive-cylinders with varying lengths of cylindrical section (fig. 2(b)). In addition, a 3.5-caliber ogive with a rounded nose ($F_5$, fig. 2(c)) to which a slotted cage ($F_6$, fig. 2(c)) or a 3-inch spike could be attached ($F_4$, fig. 2(c)), and a flat-face cylinder with a tripod, with and without a wire mesh around the tripod ($F_2$ and $F_3$, fig. 2(c)) were tested. The 3-inch spike was selected as a result of tests at a Mach number of 1.61 of a similar configuration (refs. 4 and 5) which indicated this spike length to be optimum for minimum drag at small angles of attack.
The afterbodies, shown in figure 2(d), consisted of the following configurations: $A_0$, no afterbody; $A_1$, a 1-caliber cylinder; $A_2$, a 2-caliber cylinder; $A_3$, a 1-caliber 6.50° boattail; $A_4$, a 1-caliber 6.50° boattail attached to a 1-caliber cylinder; $A_5$, a 2-caliber 3.25° boattail; $A_6$, a 1-caliber 6.50° flare; $A_7$, a 1-caliber 6.50° flare attached to a 1-caliber cylinder; and $A_8$, a 2-caliber 3.25° flare.

Cruciform wings were mounted in slots in the balance housing. Three rectangular-wing and three delta-wing configurations were tested (fig. 2(f) and table 1). The wings were so designed that the exposed areas of the medium and large wings of each series were two and four times, respectively, those of the small wings. Areas of corresponding wings in each series were equal; for example, the exposed area of the large rectangular wing was equal to that of the large delta wing.

Two spoilers, one for each horizontal wing panel, were provided for the large delta wing (fig. 2(g)). Deflections of 45° and 90° were obtained by facing either the oblique or the perpendicular face of the spoiler forward. The length of each spoiler was 3.094 inches and the width of each spoiler was 0.625 inch. The height of each spoiler was 0.625 inch.

The models were mounted on a rotary sting to permit testing through ranges of combined angles of attack and sideslip. Six-component force and moment data were measured by an internal strain-gage balance. Base pressures were measured with a single tube well inside the model. A cylindrical wooden block approximately the same size as the base of the model and 1 inch long was attached to the sting about 1/8 inch behind the model base.

TESTS, CORRECTIONS AND ACCURACY

Test Conditions

The tests were made at a Mach number of 2.01, a stagnation temperature of 100°C, and a stagnation pressure of 1,440 pounds per square foot absolute. The Reynolds number, based on the maximum diameter, was $0.62 \times 10^6 (2.47 \times 10^6$ based on a length of 1 foot). Stagnation dewpoints of -25°C or below were maintained to eliminate condensation effects. The angle-of-attack range for pitch tests was from -4° to about 28° at zero sideslip, and the angle-of-sideslip range was from -4° to a maximum of about 28° at angles of attack of about 0°, 4.1°, 8.2°, 12.3°, 16.4°, 20.5°, and 24.7°.
The angles of attack and sideslip were kept constant at 0°, and the balance was cut-off at 5% chord. The mean values of the lift, drag, and moment coefficients were calculated from the data. The uncertainties in the values of the coefficients are as follows:

- \( C_l \) = 0.000 ± 0.001
- \( C_d \) = 0.000 ± 0.001
- \( C_m \) = 0.000 ± 0.001
- \( C_l \) = 0.000 ± 0.001
- \( C_m \) = 0.000 ± 0.001
- \( C_y \) = 0.000 ± 0.001

The angles of attack at zero sideslip and zero sideslip are estimated to be within 0.01° of the mean values. The angles of attack and sideslip for the analyses were corrected within 0.01° of the mean values.
The effects of delta afterbodies on the aerodynamic characteristics in pitch at high speeds with various cylindrical afterbodies are presented in figures 4 to 21. Figures 22 to 29 present tests for configurations with various prismatic and flared afterbodies with various angles of attack. The measured base pressures were not accurate and no base pressures for similar configurations were available.

CONCLUDING REMARKS

An investigation was made in the Langley 4- by 4-foot supersonic pressure tunnel to determine the aerodynamic characteristics on a configuration with various combinations of forebodies, afterbodies, nose cones, and wings with low aspect ratio. Six-component force and moment
data were obtained for combined angles of attack and sideslip to about 28°. No analysis of the data has been made in this report.

Langley Aeronautical Laboratory,  
National Advisory Committee for Aeronautics,  
Langley Field, Va., April 3, 1957.

REFERENCES


<table>
<thead>
<tr>
<th>Characteristics of Model Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wings:</td>
</tr>
<tr>
<td>Area, exposed, sq ft</td>
</tr>
<tr>
<td>0.3611</td>
</tr>
<tr>
<td>Aspect ratio, exposed panel</td>
</tr>
<tr>
<td>Taper ratio</td>
</tr>
<tr>
<td>Root chord, exposed, in.</td>
</tr>
<tr>
<td>Root chord, center line, in.</td>
</tr>
<tr>
<td>Leading-edge sweep, deg</td>
</tr>
<tr>
<td>Ratio of total span to maximum body</td>
</tr>
<tr>
<td>Ratio of exposed wing area to maximum body cross-sectional area</td>
</tr>
<tr>
<td>Balance section, ( W_9 ):</td>
</tr>
<tr>
<td>Length, in.</td>
</tr>
<tr>
<td>Maximum diameter, in.</td>
</tr>
<tr>
<td>Length-diameter ratio, ( l/d )</td>
</tr>
<tr>
<td>Maximum cross-sectional area, sq ft</td>
</tr>
<tr>
<td>Forebodies:</td>
</tr>
<tr>
<td>Length, in.</td>
</tr>
<tr>
<td>Maximum diameter, in.</td>
</tr>
<tr>
<td>Maximum cross-sectional area, sq ft</td>
</tr>
<tr>
<td>Special noses:</td>
</tr>
<tr>
<td>Length, in.</td>
</tr>
<tr>
<td>Maximum diameter, in.</td>
</tr>
<tr>
<td>Maximum cross-sectional area, sq ft</td>
</tr>
<tr>
<td>Afterbodies:</td>
</tr>
<tr>
<td>Length, in.</td>
</tr>
<tr>
<td>Ratio of length to forward diameter</td>
</tr>
<tr>
<td>Half-angle of boattail</td>
</tr>
<tr>
<td>Rear diameter, in.</td>
</tr>
</tbody>
</table>
TABLE I.- GEOMETRIC CHARACTERISTICS OF MODELS - Concluded.

(b) Body-component combinations

<table>
<thead>
<tr>
<th>Component combinations</th>
<th>Length, in.</th>
<th>Length-diameter ratio</th>
<th>Center-of-gravity location from base, calibers</th>
<th>Center-of-gravity location from nose, x/l</th>
<th>Alternate afterbodies used</th>
</tr>
</thead>
<tbody>
<tr>
<td>F₁W₀A₀</td>
<td>24.00</td>
<td>8</td>
<td>4.33</td>
<td>0.459</td>
<td>None</td>
</tr>
<tr>
<td>F₂W₀A₀</td>
<td>27.00</td>
<td>9</td>
<td>4.33</td>
<td>.519</td>
<td>None</td>
</tr>
<tr>
<td>F₁W₀A₁</td>
<td>27.00</td>
<td>9</td>
<td>5.33</td>
<td>.408</td>
<td>None</td>
</tr>
<tr>
<td>F₂W₀A₀</td>
<td>30.00</td>
<td>10</td>
<td>4.33</td>
<td>.567</td>
<td>None</td>
</tr>
<tr>
<td>F₁W₀A₁</td>
<td>30.00</td>
<td>10</td>
<td>5.33</td>
<td>.467</td>
<td>None</td>
</tr>
<tr>
<td>F₁W₀A₂</td>
<td>30.00</td>
<td>10</td>
<td>6.33</td>
<td>.367</td>
<td>A₃ or A₆</td>
</tr>
<tr>
<td>F₂W₀A₁</td>
<td>33.00</td>
<td>11</td>
<td>4.33</td>
<td>.606</td>
<td>None</td>
</tr>
<tr>
<td>F₂W₀A₁</td>
<td>33.00</td>
<td>11</td>
<td>5.33</td>
<td>.515</td>
<td>A₄, A₅, A₇, A₈</td>
</tr>
<tr>
<td>F₀W₀A₂</td>
<td>36.00</td>
<td>12</td>
<td>6.33</td>
<td>.424</td>
<td>None</td>
</tr>
<tr>
<td>F₁W₀A₂</td>
<td>36.00</td>
<td>12</td>
<td>5.33</td>
<td>.556</td>
<td>None</td>
</tr>
<tr>
<td>F₂W₀A₂</td>
<td>39.00</td>
<td>13</td>
<td>6.33</td>
<td>.473</td>
<td>None</td>
</tr>
<tr>
<td>F₃W₀A₀</td>
<td>23.36</td>
<td>7.78</td>
<td>4.33</td>
<td>.513</td>
<td>None</td>
</tr>
<tr>
<td>F₄W₀A₀</td>
<td>26.36</td>
<td>8.78</td>
<td>4.33</td>
<td>.443</td>
<td>None</td>
</tr>
<tr>
<td>F₅W₀A₀</td>
<td>26.36</td>
<td>8.78</td>
<td>4.33</td>
<td>.507</td>
<td>None</td>
</tr>
<tr>
<td>F₆W₀A₀</td>
<td>26.36</td>
<td>8.78</td>
<td>4.33</td>
<td>.507</td>
<td>None</td>
</tr>
<tr>
<td>F₇W₀A₀</td>
<td>22.12</td>
<td>7.37</td>
<td>4.33</td>
<td>.412</td>
<td>None</td>
</tr>
<tr>
<td>F₈W₀A₀</td>
<td>22.12</td>
<td>7.37</td>
<td>4.33</td>
<td>.412</td>
<td>None</td>
</tr>
</tbody>
</table>
Figure 1.- Axis systems. Arrows indicate positive directions of forces, moments, and angles.
Figure 2 - Details of models. All dimensions are in inches except as noted.
(b) Forebodies with 3.5-caliber-ogive cylinders and with constant rear diameter of 3.00 inches.

Figure 2.- Continued.
(c) Special nose shapes.

Figure 2.- Continued.
(d) Afterbodies. (All afterbodies are bodies of revolution.)

Figure 2.- Continued.
(e) Fuselage combinations. (All configurations include balance section \( \omega_0 \). See \( F_1A_1 \) and figs. 2(b) and 2(d) for details.)

Figure 2. Continued.
Delta wing series

Rectangular wing series

(f) Details of wings.

Figure 2.- Continued.
(g) Details of spoilers.

Figure 2.—Concluded.
(a) Typical delta-wing configuration.

Figure 3.—Models used in investigation.
(b) Typical rectangular-wing configuration. L-94317

Figure 3.- Continued.
(c) Ogive cylinders and 2-caliber boattailed and flared afterbodies.

Figure 3.- Continued.
Figure 3.— Concluded.
Figure 4.- Effects of delta wings on aerodynamic characteristics in pitch. No afterbody; l/d = 10.
Figure 5.- Effects of delta wings on aerodynamic characteristics in pitch. One-caliber cylindrical afterbody; l/d = 10.
Figure 6.- Effects of delta wings on aerodynamic characteristics in pitch. Two-caliber cylindrical afterbody; $l/d = 10$. 
(a) $\alpha = 0^\circ$.

Figure 7. Effects of delta wings on aerodynamic characteristics in side-slip. No afterbody; $l/d = 10$. 
(b) $\alpha \approx 4.1^\circ$.

Figure 7.- Continued.
(c) $\alpha = 8.2^\circ$.

Figure 7.- Continued.
(d) \( \alpha \approx 12.3^\circ \).

Figure 7. - Continued.
Figure 7.- Continued.

(e) $\alpha \approx 16.4^\circ$. 
Figure 7. - Continued.

(f) $\alpha \approx 20.5^\circ$.
Figure 7.- Concluded.

(g) \( \alpha = 24.7^\circ \).
Figure 8. - Effects of delta wings on aerodynamic characteristics in sideslip. One-caliber cylindrical afterbody; $l/d = 10$.

(a) $\alpha = 0^\circ$. 
(b) $\alpha = 4.1^\circ$.

Figure 8.- Continued.
(c) \( \alpha = 8.2^\circ \).

Figure 2. Continued.
Figure 8.— Continued.

(a) $\alpha \approx 12.3^\circ$. 
Figure 8.- Continued.

\( \alpha \approx 16.4^\circ \).

(e) \( \alpha \approx 16.4^\circ \).
(f) $\alpha = 20.5^\circ$.

Figure 8.- Continued.
Figure 8.- Concluded.

(e) \( \alpha = 24.7^\circ \).

Figure 8.- Concluded.
Figure 9.— Effects of delta wings on aerodynamic characteristics in sideslip. Two-caliber cylindrical afterbody; \( l/d = 10 \).
Figure 9.—Continued.

(b) \( \alpha = 4.1^\circ \).
(c) $\alpha \approx 8.2^\circ$.

Figure 9.- Continued.
Figure 9.—Continued.

(d) \( \alpha \approx 12.3^\circ \).
(e) $\alpha = 16.4^\circ$.

Figure 9.- Continued.
(f) $\alpha = 20.5^\circ$.

Figure 9. - Continued.
Figure 9.- Concluded.

(\(c\)) \( \alpha = 24.7^\circ \).

Figure 9.- Concluded.
Figure 10.- Variation of $C_m$ and $C_N$ with $\beta$ for various angles of attack. Delta-wing series; no afterbody; $l/d = 10$. (a) Body alone, $F_o W O A_0$.
(b) Large delta wing, $F_0 \beta \dot{A}_0$.

Figure 10.- Continued.
Figure 10. - Continued.

(c) Medium delta wing, $F_{o_{20}}$.
Figure 11: Variation of $C_m$ and $C_N$ with $\beta$ for various angles of attack. Delta-wing series; body alone, $\frac{c}{d} = 1$. Cylindrical afterbody, $\frac{c}{d} = 10$. 

(a) $C_m$ and $C_N$ with $\beta$ for various angles of attack.
(b) Large delta wing, $F_{1/2}A_0$.

Figure 11.-- Continued.
(c) Medium delta wing, $F/A = 1$.

Figure II. Continued.
(d) Small delta wing, $F_{\beta\beta}A_1$.

Figure 11.- Concluded.
(a) Body alone, $F_1W/A_0$.

Figure 12.- Variation of $C_m$ and $C_N$ with $\beta$ for various angles of attack. Delta-wing series; 2-caliber cylindrical afterbody; $l/d = 10$. 
(b) Large delta wing, $\frac{F_1 W_1 A_0}{\rho}$. 

Figure 12.- Continued.
Figure 12.- Continued,

(c) Medium delta wing, $F_1W_2A_2$.

Figure 12.- Continued.
Figure 15.- Effect of rectangular wings on aerodynamic characteristics in pitch. No afterbody; $l/d = 10$. 
Figure 14. - Effect of rectangular wings on aerodynamic characteristics in pitch. One-caliber cylindrical afterbody; $l/d = 10$. 
Figure 15.- Effect of rectangular wings on aerodynamic characteristics in pitch. Two-caliber cylindrical afterbody; \( l/d = 10 \).
Figure 16. - Effect of rectangular wings on aerodynamic characteristics in sideslip. No afterbody; l/d = 10.
Figure 16—Continued.

(b) $\alpha \approx 4.1^\circ$. 
(c) $\alpha \approx 8.2^\circ$.

Figure 16.- Continued.
(d) $\alpha \approx 12.3^\circ$.

Figure 16.--Continued.
Figure 16.- Continued.

(e) \( \alpha \approx 16.4^\circ \).
(f) $\alpha = 20.5^\circ$.

Figure 16. - Continued.
(g) $\alpha \approx 24.7^\circ$.

Figure 16.- Concluded.
Figure 17.- Effects of rectangular wings on aerodynamic characteristics in sideslip. One-caliber cylindrical afterbody; $l/d = 10$. 

(a) $\alpha \approx 0^\circ$. 
Figure 17.—Continued.

(b) \( \alpha = 4.1^\circ \).
(c) $\alpha \approx 8.2^\circ$.

Figure 17.- Continued.
(d) $\alpha = 12.3^\circ$.

Figure 17.- Continued.
Figure 17.- Continued.

(e) $\alpha = 16.4^\circ$. 
Figure 17.- Continued.

(f) $\alpha = 20.5^\circ$. 

Figure 17.- Continued.
Figure 17.- Concluded.
Figure 18. - Effect of rectangular wings on aerodynamic characteristics in sideslip. Two-caliber cylindrical afterbody; $l/d = 10$. 
(b) $\alpha \approx 4.1^\circ$.

Figure 18.- Continued.
(e) $\alpha = 8.2^\circ$.

Figure 18.- Continued.
(d) $\alpha = 12.5^\circ$.

Figure 18.- Continued.
Figure 18.- Continued.

(e) $\alpha \approx 16.4^\circ$. 

Figure 18.- Continued.
Figure 18.- Continued.

(f) $\alpha = 20.5^0$.

Figure 18.- Continued.
Figure 18.- Concluded.

\[ \alpha = 24.7^\circ. \]
Figure 19.- Variation of $C_m$ and $C_N$ with $\beta$ for various angles of attack. Rectangular wings; no afterbody; $l/d = 10$. 

(a) Large rectangular wing, $F_0W^4A_0$. 
(c) Small rectangular wing, F8W(Ao).

Figure 19. Concluded.
Figure 20.- Variation of $C_m$ and $C_N$ with $\beta$ for various angles of attack. Rectangular wings; 1-caliber cylindrical afterbody; $l/d = 10$. 

(a) Large rectangular wing, $F_{\gamma W A_1}$. 
(a) Medium rectangular wing, F-78-A1.

Figure 20 - Continued.
(c) Small rectangular wings, $F_{\text{c}}W_{\text{c}}A_{1}$.

Figure 20.- Concluded.
Figure 21.- Variation of $C_m$ and $C_N$ with $\beta$ for various angles of
attack. Rectangular wings; 2-caliber cylindrical afterbody; $l/d = 10$. 

(a) Large rectangular wing, $F_{1W_1A_2}$. 
(b) Medium rectangular wing, $F/W_6A_2$.

Figure 21.- Continued.
(c) Small rectangular wing, $F_{1.6}A_2$.

Figure 21.- Concluded.
Figure 22.- Effect of forebody length on aerodynamic characteristics in pitch. Large delta wing; no afterbody.
Figure 23.- Effects of forebody length on aerodynamic characteristics in pitch. Large delta wings; 1-caliber cylindrical afterbody.
Figure 24: Effects of forebody length on aerodynamic characteristics in pitch. Large delta wings; 2-caliber cylindrical afterbody.
Figure 25.- Effect of forebody length on aerodynamic characteristics in sideslip. Large delta wings; no afterbody.

(a) $\alpha = 0^\circ$. 
(b) $\alpha \approx 4.1^\circ$.

Figure 25.- Continued.
(b) Concluded.

Figure 35 - Continued.
(c) \( \alpha = 8.2^\circ \).

Figure 25. - Continued.
(d) $\alpha \approx 12.3^\circ$.

Figure 25.- Continued.
Figure 25.-- Continued.

(e) $\alpha = 16.4^\circ$. 
Figure 25.- Continued.

(f) $\alpha \approx 20.5^\circ$.

Figure 25.- Continued.
Figure 25.—Continued.

(g) \( \alpha = 24.7^\circ \).

F W A

1 0 0
1 7 0
7 7 0
9 0 0
9 1 0

\( C_n \quad 12 \)
\( 8 \)
\( 4 \)
\( 0 \)
\( -4 \)
\( -8 \)

\( C_y \)

\( -8 \)
\( -6 \)
\( -4 \)
\( -2 \)
\( 0 \)
\( 2 \)
\( 4 \)
\( 6 \)
\( 8 \)
\( 10 \)
\( 12 \)
\( 14 \)
\( 16 \)
\( 18 \)
\( 20 \)

\( \beta, \text{ deg} \)
(g) Concluded.

Figure 25.- Concluded.
Figure 26.- Effect of forebody length on aerodynamic characteristics in sideslip. Large delta wings; 1-caliber cylindrical afterbody.
(b) $\alpha = 4.1^\circ$.

Figure 26. - Continued.
(c) $\alpha \approx 8.2^\circ$.

Figure 26.- Continued.
(c) Concluded.

Figure 25. - Continued.
Figure 26.—Continued.

(d) $\alpha = 12.3^\circ$.

Figure 26.—Continued.
(e) \( \alpha \approx 16.4^\circ \).

Figure 26.- Continued.
(f) $\alpha = 20.5^\circ$.

Figure 26.- Continued.
(g) $\alpha = 24.7^\circ$.

Figure 26.—Continued.
(g) Concluded.

Figure 26.- Concluded.
Figure 27.- Effects of forebody length on aerodynamic characteristics in sideslip. Large delta wings; 2-caliber cylindrical afterbody.

(a) $\alpha \approx 0^\circ$. 
(b) $\alpha = 4.1^\circ$.

Figure 27.- Continued.
(c) \( \alpha \approx 8.2^\circ \).

Figure 27.- Continued.
Figure 27. Continued.
(d) $\alpha = 12.3^\circ$.

Figure 27.- Continued.
(e) \( \alpha \approx 16.4^\circ \).

Figure 27.- Continued.
(e) Concluded.

Figure 27.—Continued.
Figure 27. - Continued.

(f) $\alpha \approx 20.5^\circ$.
\( \alpha \approx 24.7^\circ \).

Figure 27. - Continued.
(g) Concluded.

Figure 27.- Concluded.
Figure 28.- Variation of $C_m$ and $C_N$ with $\beta$ for various angles of attack. Various forebody lengths; large delta wings; no afterbody.
Figure 28 - Continued.

(c) Body alone, Fg<0.

(Continued)
(d) Large delta wing, $F_1 W_1 A_0$.

Figure 28.- Continued.
(e) Large delta wing, $F_{\gamma W_1 A_0}$.

Figure 28.- Continued.
Figure 28.— Concluded.

(f) Large delta wing, $F_{91A0}$. Figure 28.— Concluded.
(a) Body alone, $F_1 W_0 A_1$.

Figure 29.- Variation of $C_m$ and $C_N$ with $\beta$ for various angles of attack. Various forebody lengths; large delta wings; 1-caliber cylindrical afterbody.
(b) Body alone, F83A1.

Figure 29 - Continued.
(d) Large delta wing, $F_{1W1A_1}$.

Figure 29.- Continued.
(e) Large delta wing, F8W1A1.

Figure 29.- Continued.
Large delta wing, FgW1A1.

Figure 29.- Concluded.
Figure 30.- Variation of $C_m$ and $C_N$ with $\beta$ for various angles of attack. Various forebody lengths; large delta wings; 2-caliber cylindrical afterbody.
(d) Large delta wing, $F_7W_1A_2$.

Figure 30.- Continued.
(e) Large delta wing, $F_0W_1A_2$.

Figure 30.—Continued.
(f) Large delta wing, $F_g W_1 A_2$.

Figure 30.- Concluded.
Figure 31.- Effects of 1-caliber boattail (A3) and 1-caliber flare (A6) afterbodies on aerodynamic characteristics in pitch. Large delta wings; l/d = 10.
Figure 32.—Effects of 2-caliber cylinder-boattail (A4) and 2-caliber cylinder-flare (A7) afterbodies on aerodynamic characteristics in pitch. Large delta wings; l/d = 10.
Figure 33.-- Effects of 2-diameter boattail ($A_5$) and 2-caliber flare ($A_8$) afterbodies on aerodynamic characteristics in pitch. Large delta wings; $l/d = 10$. 
Figure 34.- Effects of 1-caliber boattail (A3) and 1-caliber flare (A6) afterbodies on aerodynamic characteristics in sideslip. Large delta wings; \( l/d = 10 \).
(b) $\alpha = 4.1^\circ$.

Figure 34.- Continued.
(c) \( \alpha = 8.2^\circ \).

Figure 34.- Continued.
Figure 34.- Continued.

(d) \( \alpha \approx 12.3^\circ \).

Figure 34.- Continued.
(e) $\alpha = 16.4^\circ$.

Figure 34.—Continued.
Figure 34. - Continued.

(f) \( \alpha \approx 20.5^\circ \).
Figure 34. - Concluded.

(g) $\alpha = 24.7^\circ$.

Figure 34. - Concluded.
(a) $\alpha \approx 0^\circ$.

Figure 35.— Effects of 2-caliber cylinder-boattail ($A_4$) and 2-caliber cylinder-flare ($A_6$) afterbodies on aerodynamic characteristics in sideslip. Large delta wings; $l/d = 10$. 
Figure 35. - Continued.

(b) $\alpha = 4.1^\circ$.
(c) $\alpha \approx 8.2^\circ$.

Figure 35.- Continued.
Figure 35.- Continued.

(d) $\alpha = 12.5^\circ$.
Figure 35.- Continued.

(e) \( \alpha = 16.4^\circ \).
(f) \( \alpha = 20.5^\circ \).

Figure 35.-- Continued.
(g) $\alpha \approx 24.7^\circ$.

Figure 35. - Concluded.
Figure 36.- Effects of 2-caliber boattail ($A_5$) and 2-caliber flare ($A_6$) afterbodies on the aerodynamic characteristics in sideslip. Large delta wings; $l/D = 10$. 

(a) $\alpha \approx 0^\circ$. 
(b) $\alpha \approx 4.1^\circ$.

Figure 36.- Continued.
(c) \( \alpha = 8.2^\circ \).

Figure 36.- Continued.
(d) $\alpha \approx 12.3^\circ$.

Figure 36.- Continued.
Figure 36.- Continued.

(e) \( \alpha = 16.4^\circ \).
(f) $\alpha = 20.5^\circ$.

Figure 36.-- Continued.
Figure 36.- Concluded.

\[(g) \quad \alpha \approx 24.7^\circ.\]
Figure 37.- Variation of $C_m$ and $C_n$ with $\beta$ for various angles of attack. One-caliber boat-tail ($A_f$) and 1-caliber flare ($A_c$) afterbodies; large delta wings; $l/d = 10$. 

(a) Body alone, $F/W$. 

(b) Body with $A_f$.
(b) Body alone, $P_{\text{WcA}_6}$.

Figure 37. - Continued.
(c) Large delta wing, $F_{W0A3}$.

Figure 37. - Continued.
(d) Large delta wing, F7W1A6.

Figure 37.- Concluded.
Figure 39 - Variation of $C_m$ and $C_N$ with $\beta$ for various angles of attack. Two-caliber cylinder-boattail ($A_t$) and 2-caliber cylinder-flare ($A_t$) afterbodies; $l/d = 10$. 

(a) Body alone, $F_{l,0}$.
Figure 36. Continued.

(b) Body alone, F/L 0.7.
(c) Large delta wing, $F_{1W1A_1}$.

Figure 38.- Continued.
(d) Large delta wing, F_{1W1A7}.

Figure 38.- Concluded.
(a) Body alone, $F_1W_{0A_5}$.

Figure 39.- Variation of $C_m$ and $C_N$ with $\beta$ for various angles of attack. Two-caliber boat-tail ($A_5$) and 2-caliber flare ($A_8$) afterbodies; large delta wings; $l/d = 10$. 
(b) Body alone, FlwGA8.

Figure 39 - Continued.
Figure 39.- Continued.

(c) Large delta wing, $F_{1W1A_5}$.
(d) Large delta wing, $F_{1}W_{1}A_{8}$.

Figure 39.- Concluded.
Figure 40.- Aerodynamic characteristics in pitch of tripod nose configuration with screen (F₃) and without screen (F₂). No afterbody; large delta wings.
Figure 41.- Aerodynamic characteristics in pitch of rounded nose configuration (F₅) with spike (F₄) and with slotted-cone (F₆). No afterbody; large delta wings.
Figure 42.- Aerodynamic characteristics in sideslip of tripod nose configuration with screen (F3) and without screen (F2). No afterbody; large delta wings.
(b) \( \alpha = 4.1^\circ \).

Figure 42.- Continued.
(c) $\alpha \approx 8.2^\circ$.

Figure 42.- Continued.
Figure 42. - Continued.

(d) \( \alpha = 12.5^\circ \).

Figure 42. - Continued.
(e) $\alpha \approx 16.4^\circ$.

Figure 42. - Continued.
(f) \( \alpha = 20.5^\circ \).

Figure 42.- Continued.
(g) $\alpha = 24.7^\circ$.

Figure 42.- Concluded.
Figure 43.- Aerodynamic characteristics in sideslip of rounded-nose configuration (F₅) with spike (F₄) and with slotted cone (F₆). No afterbody; large delta wings.

(a) $\alpha \approx 0^\circ$. 
Figure 45.- Continued.

(b) $\alpha = 4.1^\circ$. 

Figure 45. - Continued.
(c) \( \alpha = 8.2^\circ \).

Figure 43.- Continued.
Figure 43. - Continued.

(d) $\alpha = 12.5^\circ$. 

Figure 43. - Continued.
Figure 43.- Continued.

(e) \( \alpha = 16.4^\circ \).
Figure 43.- Continued.

(f) $\alpha = 20.5^\circ$.
(g) $\alpha \approx 24.7^\circ$.

Figure 43.- Concluded.
Figure 44.— Variation of $C_m$ and $C_N$ with $\beta$ for various angles of attack. Tripod-nose configurations; no afterbodies; large delta wings.
Figure 44.- Concluded.

(b) Screen off, $F_2W_{1A_0}$.
Figure 45.- Variation of $C_m$ and $C_N$ with $\beta$ for various angles of attack. Rounded-ogive nose; no afterbody; large delta wings.
(b) Rounded-ogive nose with spike, $F_4 W_1 A_0$.

Figure 45.-- Continued.
(c) Rounded-ogive nose with slotted cone, $F_{oW_{A0}}$.

Figure 45.- Concluded.
(a) The variation of $C_m$, $C_A$, and $C_N$ with $\alpha$. $\beta = 0^\circ$.

Figure 46.- Effects of spoiler deflection on aerodynamic characteristics ($F_{\text{W1A1}}$). One-caliber afterbody; large delta wings; $l/d = 10$. 
(b) The variation of $C_n$, $C_l$, and $C_Y$ with $\beta$. $\alpha = 0^\circ$.

Figure 46.- Continued.
(c) The variation of $C_m$ and $C_N$ with $\beta$, $\alpha = 0^\circ$.

Figure 46.- Concluded.