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# COMPUTER-AIDED SPACE SHUTTLE ORBITER WING DESIGN STUDY

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# COMPUTER-AIDED SPACE SHUTTLE ORBITER

## WING DESIGN STUDY

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### SUMMARY

An analytical and experimental investigation has been made to define a space shuttle orbiter wing configuration meeting the requirements for landing performance, stability, and hypersonic trim for a specified center-of-gravity envelope. The analytical part of the study was facilitated by the use of the Optimal Design Integration system (ODIN). Limited experimental studies were made in the Langley low-turbulence pressure tunnel and the Langley continuous-flow hypersonic tunnel to verify the aerodynamic characteristics of the orbiter configuration selected analytically.

Use of the ODIN system greatly simplified the handling of analytical data while maintaining compliance with the space shuttle general vehicle requirements and allowed the expedient selection of a desirable wing planform. The analytical aerodynamic estimates obtained by using the ODIN system were in reasonable agreement with experimental results obtained subsequently for the orbiter configuration selected. The analytical study suggested reductions in wing sweep to produce a minimum-wing-area (minimum-weight) configuration. Reductions in wing area and sweep also enhanced the high-angle-of-attack trim capability at hypersonic speeds. This trend, however, was constrained by entry heating considerations to preclude wing-leading-edge sweep angles below  $45^{\circ}$ . Hypersonic considerations of elevon size effects redirected the study toward unsweeping the wing trailing edge to provide increased trimmed angle-of-attack capability for a  $46.8^{\circ}$  swept-wing configuration which satisfied the guideline subsonic flight requirements. The analytically selected orbiter configuration required minor experimental wind-tunnel refinements to provide a viable orbiter configuration. The primary refinement

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was the addition of a small planform fillet to increase lift coefficients at landing attitudes. Significant reductions in lift-drag ratio losses due to the addition of attitude control propulsion system wing-tip pods were attained by tailoring the external shape of pods designed to house the roll-attitude control system. The use of sequentially deflected segmented elevons improved subsonic trimmed lift-drag ratios which may be beneficial to landing-approach glide-slope performance.

## INTRODUCTION

As the space shuttle program has matured, significant effort has been devoted to reductions in system weight resulting, in turn, in a smaller orbiter vehicle. The payload weight and volume requirements remained fixed, however, and the variations in potential payload centers of gravity exert an increased influence on the flight characteristics of the smaller vehicle. In addition to wide center-of-gravity excursions due to the various payloads, other interacting requirements such as a maximum allowable landing speed, acceptable unaugmented low-speed flying qualities, and stable hypersonic trim at high angles of attack present a formidable challenge to aerospace design.

Definition of a near-optimum design solution to these conflicting requirements within a reasonable time frame requires the rapid examination of a large number of configuration variables. Studies of means to automate design problems such as these have resulted in the formulation of an Optimal Design Integration system (ODIN) described in reference 1. The derived system is a unique approach to design synthesis in that it allows interactive operation of existing analysis programs representing the various problem-related technology areas. This paper presents the results of an initial utilization of this approach.

In the present study an existing orbiter design with known weight characteristics but unacceptable aerodynamic performance served as a baseline and the body, tail, and internal arrangement were held constant. The ODIN system was utilized to determine rapidly a wing configuration meeting the system requirements insofar as possible at a minimum weight. The aerodynamic characteristics of the analytically derived configuration were verified by experimental studies at subsonic and hypersonic speeds.

Also included in the subsonic experimental studies were the effects of a wing leading-edge planform fillet, wing twist, and the use of segmented elevons. The effects of wing-tip-mounted attitude-control propulsion system pods were also determined at subsonic speeds.

## SYMBOLS

Values are given in both SI and U.S. Customary Units. The measurements and calculations were made in U.S. Customary Units.

|                     |   |
|---------------------|---|
| A                   | aspect ratio  |
| $\bar{c}$           | mean aerodynamic chord, meters (ft)   |
| $C_D$               | drag coefficient, $\frac{\text{Drag}}{q_\infty S_{\text{ref}}}$                               |
| $C_L$               | lift coefficient, $\frac{\text{Lift}}{q_\infty S_{\text{ref}}}$                               |
| $C_m$               | pitching-moment coefficient, $\frac{\text{Pitching moment}}{q_\infty S_{\text{ref}} \bar{c}}$ |
| $C_{mC_L}$          | static longitudinal stability level based on $\bar{c}$ , $\frac{\partial C_m}{\partial C_L}$  |
| $C_N$               | normal-force coefficient, $\frac{\text{Normal force}}{q_\infty S_{\text{ref}}}$               |
| $i_{\text{wing}}$   | incidence angle of wing, deg  |
| L/D                 | lift-drag ratio   |
| $l$                 | length of fuselage, meters (ft)   |
| M                   | Mach number   |
| $q_\infty$          | free-stream dynamic pressure, newtons per meter <sup>2</sup> (lb/ft <sup>2</sup> )            |
| $R_l$               | free-stream Reynolds number based on $l$  |
| $S_{\text{elevon}}$ | elevon area, meters <sup>2</sup> (ft <sup>2</sup> )   |
| $S_{\text{ref}}$    | wing reference area, meters <sup>2</sup> (ft <sup>2</sup> )                                   |

|                |  |
|----------------|--|
| $V_{\min,des}$ | minimum flying speed at design conditions and $\alpha = 17^{\circ}$ , knots                |
| $x,y$          | coordinates of exposed reference wing planform (origin at exposed root chord leading edge) |
| $x_{cg}$       | center-of-gravity location from nose of vehicle  |
| $x_{wing}$     | location of exposed wing leading-edge root chord from nose of vehicle, meters (ft)         |
| <b>XSF</b>     | scale factor for x-ordinates of exposed wing planform                                      |
| <b>YSF</b>     | scale factor for y-ordinates of exposed wing planform                                      |
| $\alpha$       | angle of attack, deg   |
| $\delta_e$     | elevon deflection angle, deg   |
| $\lambda$      | taper ratio  |
| $\Lambda_{le}$ | leading-edge sweep angle, deg  |
| $\Lambda_{te}$ | trailing-edge sweep angle, deg   |

**Subscripts:**

|                 |                                     |
|-----------------|-------------------------------------|
| $e_1, e_2, e_3$ | inboard to outboard elevon segments |
| <b>des</b>      | design conditions                   |
| <b>max</b>      | maximum                             |



min            minimum

trim           trim conditions

Abbreviations:

ACPS           attitude control propulsion system

BW<sub>P</sub>V<sub>2</sub>        body-plane (untwisted) wing-large vertical tail (subsonic model)

BW<sub>T</sub>V<sub>2</sub>F        body-twisted wing-large vertical tail-fillet (subsonic model)

BW<sub>P</sub>V<sub>1</sub>        body-plane (untwisted) wing-small vertical tail (hypersonic model)

Design P/L    design payload condition (18 144 kg (40 000 lb) at payload bay centroid)

JSC            NASA Johnson Space Center

Mod            modified

ODIN          Optimal Design Integration system

P<sub>1</sub>            semifaired ACPS tip pod design

P<sub>2</sub>            fully tailored ACPS tip pod design

P/L out        payload-out condition

TPS            thermal protection system

W<sub>1</sub> to W<sub>35</sub>    wing designations

W/40K PL      with 18 144 kg (40 000 lb) payload at payload bay centroid

## METHOD OF ANALYSIS

An existing orbiter design, designated the 040A (ref. 2), of known weight characteristics with aerodynamic performance characteristics unacceptable relative to established criteria, was used as a baseline configuration. The body, vertical tail, and internal arrangement were held constant and the ODIN system was utilized to determine a wing geometry and location to meet the system requirements in the longitudinal mode. Use of the ODIN system allowed rapid perturbation of the orbiter wing geometry by directing the sequential execution and data retrieval from a selected group of analytical programs. The specific programs were chosen to provide pertinent information representing the technology areas of subsonic and hypersonic aerodynamics, stability and control, weight, balance, geometry, and graphics.

### Analysis Criteria

The guidelines established for the wing design study (see table I) were in accord with those outlined and/or implied by the general vehicle requirements of the space shuttle program. The orbiter geometry and accompanying weight statement used as a study baseline are indicated in table II and table III, respectively. The design criteria are further depicted on the design envelope of payload loadings for the orbiter shown in figure 1. The requirement of a minimum design speed of 150 knots or less is shown for an 18 144 kg (40 000 lb) payload located at the half-length station of the payload bay. This payload loading represents the maximum return payload anticipated in its most forward location in the payload bay. Minimum design speed ( $V_{\min,des}$ ) is used herein to denote the level flying speed at  $\alpha = 17^\circ$  and sea-level standard day conditions for an orbiter having the design payload loading. Additional design criteria included stable subsonic static margin and high-angle-of-attack trim capability ( $\alpha_{\max} = 50^\circ$ ) hypersonically over the center-of-gravity range dictated by the payload envelope.

Parameters descriptive of these criteria, along with descriptive weights and geometry data, were output in the ODIN summary reports for each wing design and are included herein as an appendix. Pertinent information for the wings is summarized in the appendix. These summary reports enabled the user to determine the wing having the most desirable characteristics.

TABLE I.- ANALYSIS CRITERIA

- Baseline orbiter configuration:  
 JSC-040A geometry (ref. 2)  
 040A weights (table II)
- Orbiter design criteria:  
 Subsonic:  
 (a)  $C_m/C_L$  (All payloads)  $\leq 0$   
 (b)  $V_{min,des}$  (Design payload)  $\leq 150$  knots at  $\alpha = 17^\circ$
- Hypersonic:  
 (a)  $\alpha_{max,trim}$  (Design payload) =  $50^\circ$   
 (b)  $\Lambda_{le} \geq 45^\circ$

TABLE II.- BASELINE GEOMETRY

[XSF = YSF = 1.0]

Overall configuration:

|  |        |          |
|--|--------|----------|
| Area, planform, m <sup>2</sup> (ft <sup>2</sup> ) . . . . .  | 346.0  | (3723.0) |
| Length, nose to wing leading edge at body, m (in.) . . . . . | 15.765 | (620.68) |
| Length, nose to wing $\bar{c}/4$ , m (in.) . . . . .         | 22.453 | (883.97) |
| Angle, ground plane, deg . . . . .                           | 17.00  |          |

Fuselage:

|   |        |          |
|---|--------|----------|
| Area, wetted, m <sup>2</sup> (ft <sup>2</sup> ) . . . . . | 586.2  | (6307.0) |
| Length, nose to end of body, m (in.) . . . . .            | 33.401 | (1315.0) |

Wing:

|  |              |          |
|--|--------------|----------|
| Area, reference, m <sup>2</sup> (ft <sup>2</sup> ) . . . . . | 293.3        | (3155.8) |
| Area, elevon, m <sup>2</sup> (ft <sup>2</sup> ) . . . . .    | 42.33        | (455.52) |
| Span, m (in.) . . . . .                                      | 22.403       | (882.00) |
| Chord, mean aerodynamic, m (in.) . . . . .                   | 15.485       | (609.63) |
| Chord, center-line root, m (in.) . . . . .                   | 22.787       | (897.14) |
| Chord, tip, m (in.) . . . . .                                | 3.386        | (133.32) |
| Taper ratio, theoretical . . . . .                           | 0.14860      |          |
| Aspect ratio, theoretical . . . . .                          | 1.7118       |          |
| Aspect ratio, exposed span . . . . .                         | 1.5882       |          |
| Angle, leading-edge sweep, deg . . . . .                     | 59.998       |          |
| Angle, trailing-edge sweep, deg . . . . .                    | 0.0          |          |
| Angle, dihedral, deg . . . . .                               | 7.0          |          |
| Angle, incidence, deg . . . . .                              | 1.5          |          |
| Airfoil section, root . . . . .                              | NACA 0008-64 |          |
| Airfoil section, tip . . . . .                               | NACA 0008-64 |          |
| xwing, m (in.) . . . . .                                     | 18.289       | (720.04) |

TABLE III. - BASELINE WEIGHT STATEMENT

|   |          |           |
|---|----------|-----------|
| Wing group, kg (lb) . . . . .                             | 6699.7   | (14 704)  |
| Tail group, kg (lb) . . . . .                             | 1496.9   | (3300)    |
| Body group, kg (lb) . . . . .                             | 16 391.1 | (36 136)  |
| Induced environmental protection, kg (lb) . . . . .       | 12 265.7 | (27 041)  |
| Landing, docking, recovery, kg (lb) . . . . .             | 4301.0   | (9482)    |
| Propulsion - ascent, kg (lb) . . . . .                    | 10 065.3 | (22 190)  |
| Propulsion - cruise, kg (lb) . . . . .                    | 98.4     | (217)     |
| Propulsion - auxiliary, kg (lb) . . . . .                 | 4140.9   | (9129)    |
| Prime power, kg (lb) . . . . .                            | 1583.0   | (3490)    |
| Electrical conversion and distribution, kg (lb) . . . . . | 1285.9   | (2835)    |
| Hydraulic conversion and distribution, kg (lb) . . . . .  | 440.0    | (970)     |
| Surface controls, kg (lb) . . . . .                       | 1183.9   | (2610)    |
| Avionics, kg (lb) . . . . .                               | 2501.6   | (5515)    |
| Environmental control, kg (lb) . . . . .                  | 1397.1   | (3080)    |
| Personnel provisions, kg (lb) . . . . .                   | 384.2    | (847)     |
| Growth/uncertainty, kg (lb) . . . . .                     | 5305.2   | (11 696)  |
| Dry weight, kg (lb) . . . . .                             | 69 509.9 | (153 242) |
| Personnel, kg (lb) . . . . .                              | 714.4    | (1575)    |
| Payload, kg (lb) . . . . .                                | 18 143.8 | (40 000)  |
| Residual and reserve fluids, kg (lb) . . . . .            | 1376.2   | (3034)    |
| Landing weight, kg (lb) . . . . .                         | 89 744.3 | (197 851) |
| ACPS propellant (entry), kg (lb) . . . . .                | 3724.9   | (8212)    |
| Entry weight, kg (lb) . . . . .                           | 93 469.2 | (206 063) |

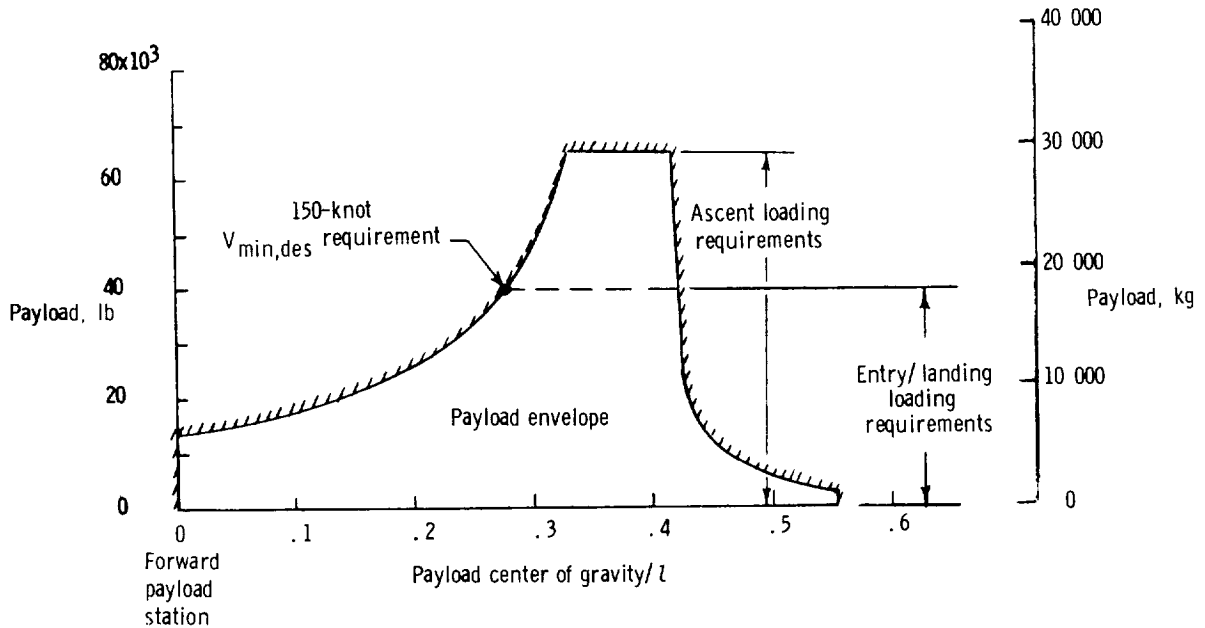
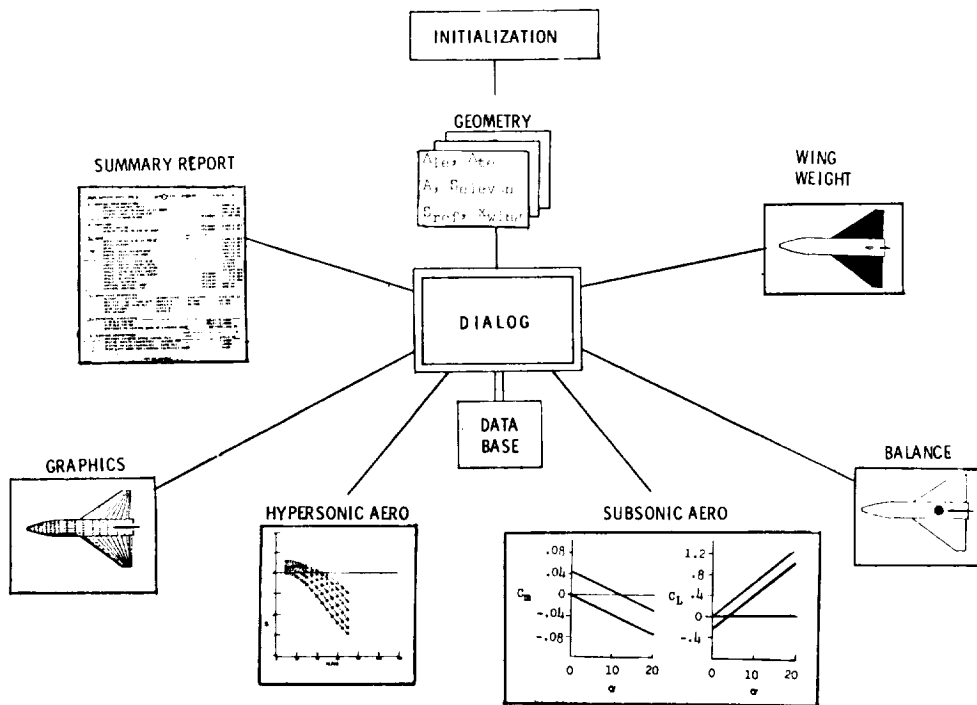


Figure 1.- Payload envelope depicting loading and flight requirements for the space shuttle orbiter.

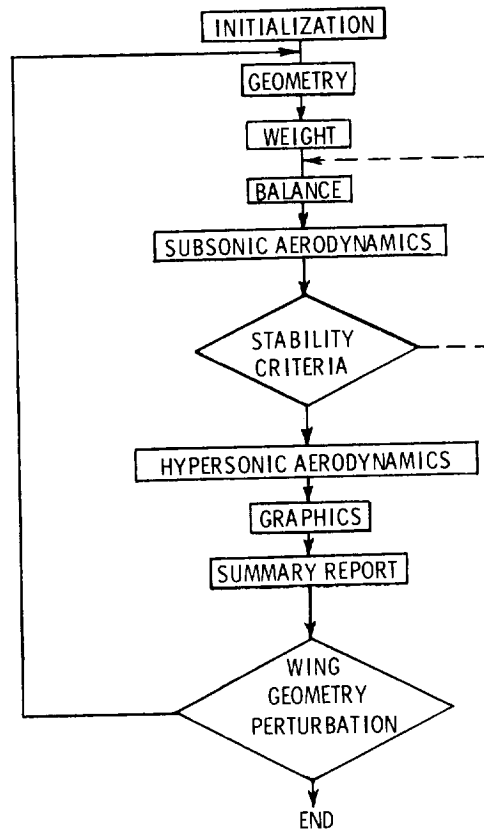
## Method

The general programming arrangement within the ODIN system is shown in figure 2(a), and the detailed programming arrangement for this problem is shown in figure 2(b). After initialization, the geometry program calculated the geometric characteristics of a matrix of wings selected as reasonable perturbations from the baseline shape. This information was stored in the data base by the executive program DIALOG. The calculations then proceeded sequentially for each wing geometry. The necessary information needed to calculate wing weight was retrieved from the data base by utilizing the DIALOG program which also input these values into the weight programs. Weights were assigned to the fuselage structure, to the fuselage-contained components, and to the vertical tail and were held constant during the study. The structural and the thermal protection system weights of the wing were calculated by the methods described in reference 3. This process was repeated through the balance program which calculated the centers of gravity of the vehicle for the payload-in and payload-out conditions. The



(a) General programming arrangement.

Figure 2.- Orbiter wing design problem formulation within the ODIN system.



(b) Programing arrangement.

Figure 2.- Concluded.

static margins and trimmed  $C_L$  were obtained from the subsonic aerodynamics program (ref. 4). Static margins were obtained for payload-out and the design-payload conditions. The payload-out static margin was weighed against a target static margin of  $0.03\bar{c} \pm 0.002$ , which assured longitudinal stability at the guideline subsonic flight conditions. If this condition was not met, the system adjusted the longitudinal position of the wing and performed an iterative looping back through the geometry, balance, and subsonic aerodynamics programs until convergence was attained. After the final subsonic static margin calculation, the hypersonic characteristics were calculated by using the methods outlined in reference 5. The graphics program was then used to depict the vehicle and plot the aerodynamic characteristics. A summary report provided the pertinent information such as wing geometry, the weight of the vehicle, the center-of-gravity locations, the minimum design speed, and the maximum hypersonic trim angle of attack and thereby completed the design calculations for a specific wing.

## Study Variables

The wing study variables were leading-edge sweep angle, aspect ratio, and exposed wing area. These parameters were varied by using x- and y-scale factors (XSF and YSF) to depict the exposed planform of a study wing which is represented by the dashed outline in figure 3 (that is, a wing planform having XSF = 0.9 and YSF = 1.3 has exposed root and tip chords equal to 0.9 times the exposed root and tip chords of the baseline wing and an exposed span equal to 1.3 times the baseline exposed wing span). The trailing-edge sweep angle was fixed ( $\Lambda_{te} = 0^\circ$ ) and the taper ratio of the exposed wing was held constant for most of the study. To meet the subsonic static margin requirement, the longitudinal wing position  $x_{wing}$  was varied. For some of the wings considered in this study,  $\Lambda_{te}$  and  $S_{elevation}$  were also varied. Twenty-five different wing planforms were considered in the initial matrix which covered a broad spectrum of possible wing designs. (See fig. 4(a).)

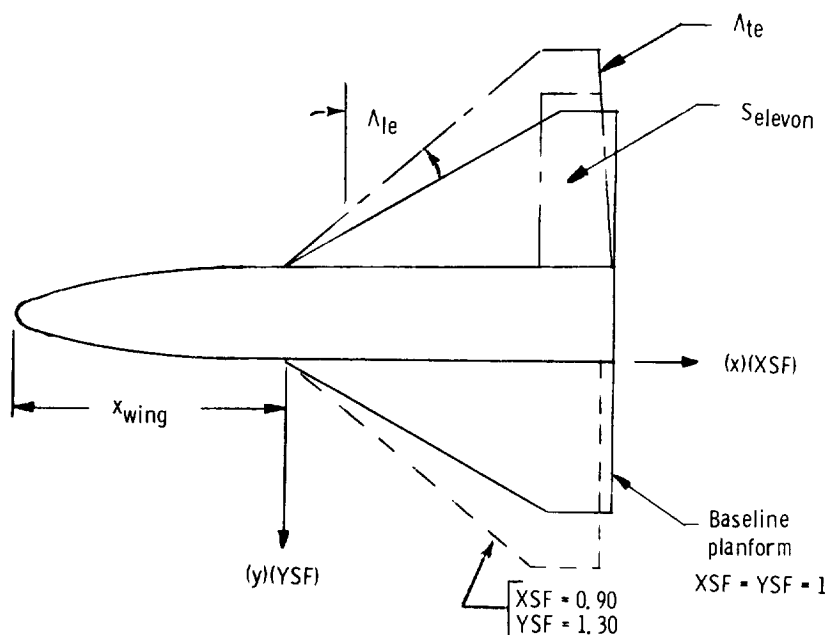
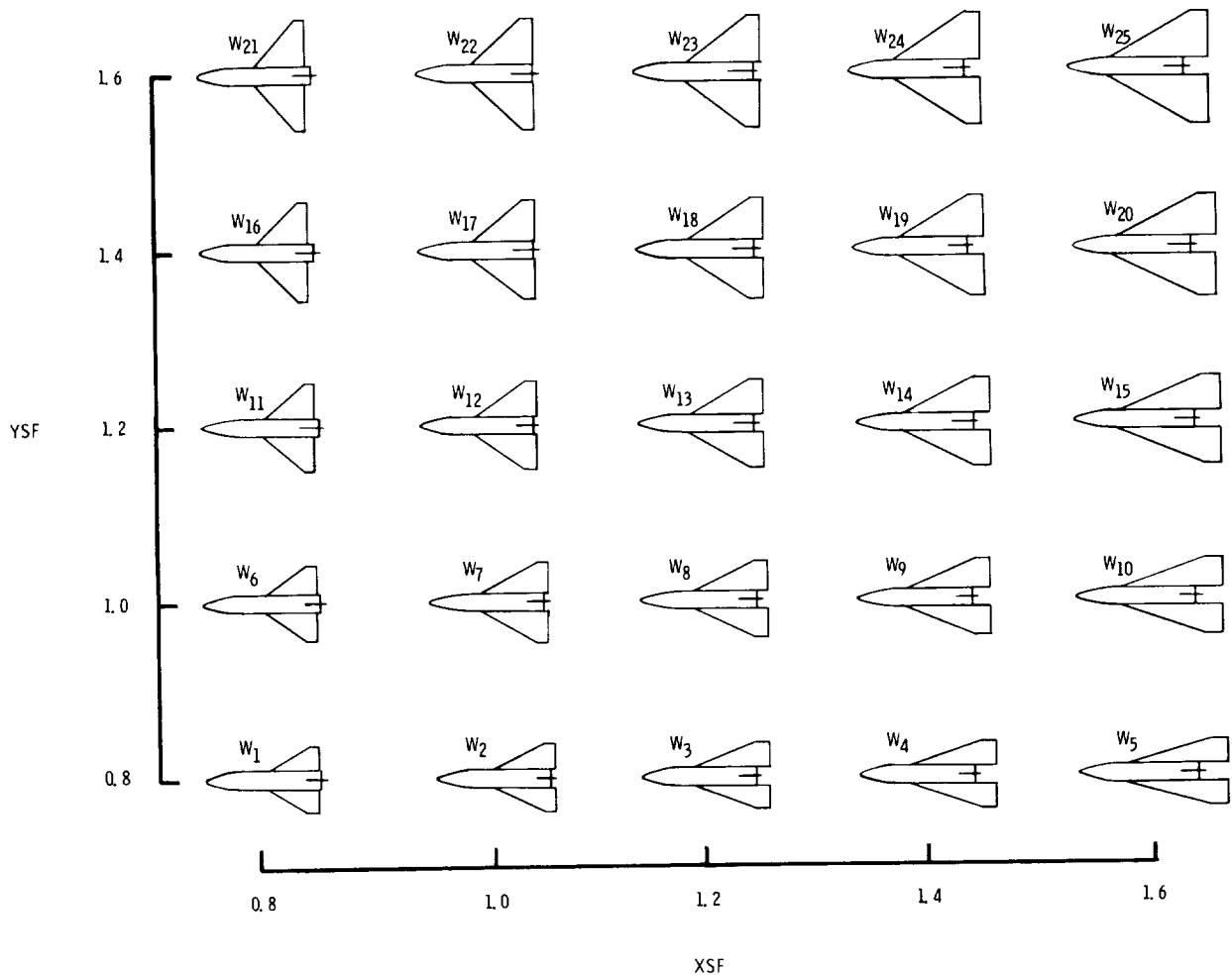


Figure 3.- Study variables.

The results of this matrix calculation were displayed in computer-generated maps of combined design and performance data (figs. 4(b) to 4(d)) which enabled rapid isolation of the effects of design variables. Based on the initial survey, 10 additional matrix points were added to indicate the desired configuration more clearly.



(a) Matrix of wings considered.

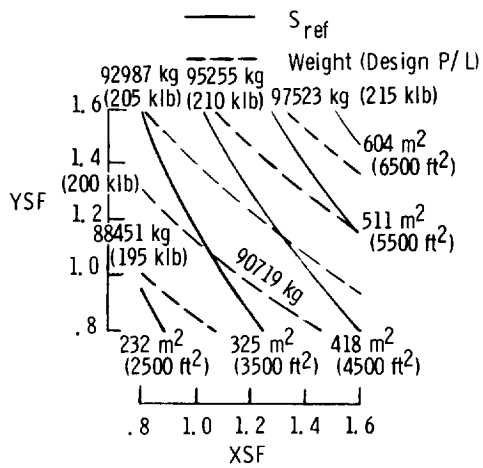
Figure 4.- Summary of geometric, weight, and aerodynamic characteristics.  
 $\Delta_{te} = 0^\circ$ .

The entire 35 wing matrix calculations required approximately 1 hour of computer time. Individual assessment by conventional means was estimated conservatively to require one-half man-year.

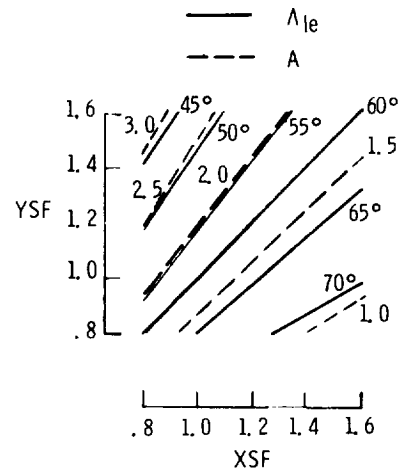
### Verification

To complete the study cycle, models were constructed of the selected configuration to verify the estimated aerodynamic characteristics at both subsonic and hypersonic speeds. These models were then used to examine minor configuration improvements for

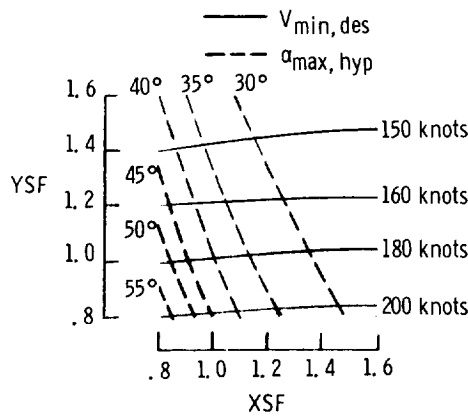




(b)  $S_{ref}$  and landed weight.



(c)  $\Lambda_{le}$  and  $A$ .



(d)  $V_{min,des}$  and  $\alpha_{max,hyp}$ .

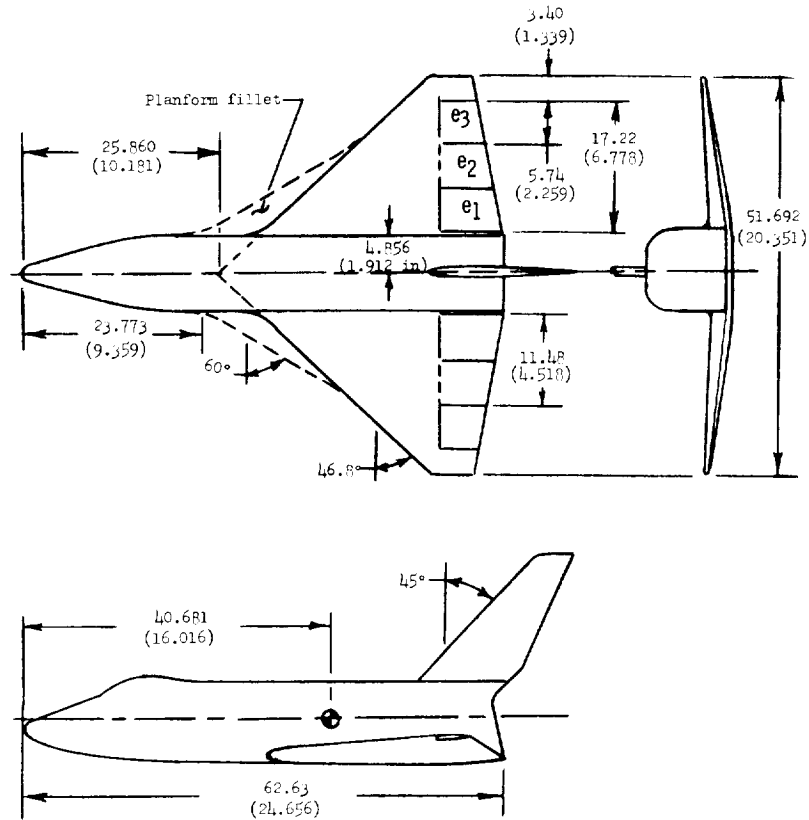
Figure 4.- Concluded.

which analytical techniques are inadequate. The following section entitled "Apparatus and Tests" is devoted to the introduction of the experimental aspects of the study.

## APPARATUS AND TESTS

### Subsonic

Model.- Details of the 0.01875-scale model used in the subsonic wind-tunnel design verification investigation are shown in figure 5(a). The model incorporated the analytically selected wing ( $W_{33}$  (Mod), table IV) mounted on a similarly scaled 040A fuselage. (See ref. 2.) The model wing had a leading-edge sweep angle of  $46.8^\circ$ , a trailing-edge sweep



(a) Subsonic model;  $BW_T V_2$  (0.01875 scale);  $S_{ref} = 0.11067 \text{ m}^2$ ;  
 $\Lambda_{le} = 46.8^\circ$ ;  $\Lambda_{te} = -11.0^\circ$ ;  $\lambda = 0.135$ .

Figure 5.- Model schematic views. All dimensions are in centimeters (inches) unless otherwise specified.

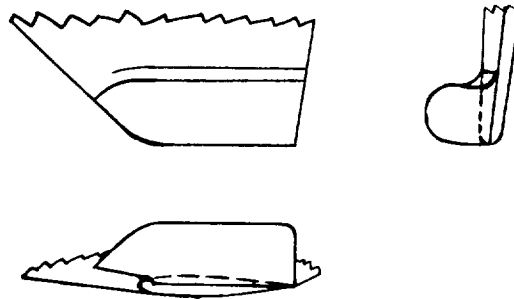
of  $-11.0^\circ$ , and an unswept elevon hingeline. The elevon tip chord was equal to 50 percent of the local wing chord. The basic (unfilleted) wing had an NACA 0008-64 airfoil section at the exposed root chord and varied linearly to an NACA 0012-64 section at the wing tip chord. Two basic wings identical in projected planform were utilized: a plane (untwisted) wing  $W_P$  with  $1.5^\circ$  incidence; and a twisted wing  $W_T$  having the same incidence at the exposed root chord and  $4.5^\circ$  washout. Trisegmented elevons were incorporated for the model wings. A  $60^\circ$  swept planform fillet could be added ahead of the wing leading edge. This fillet had a leading-edge radius of about 0.20 cm and a hand-faired section which was tangential with the basic wing section at the local maximum thickness stations. Addition of the wing fillet increased the exposed model wing area by about 8.5 percent.

TABLE IV.- SUMMARY DATA FOR SELECTED CONFIGURATION

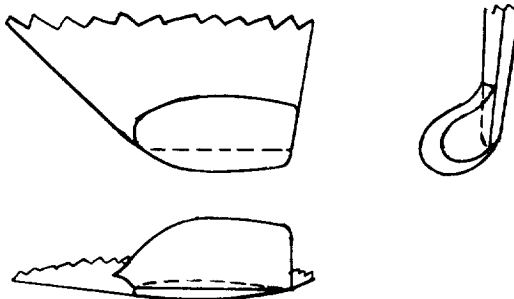
[ODIN summary data for W<sub>33</sub> (Mod)]

|   |           |            |                |              |
|---|-----------|------------|----------------|--------------|
| Overall configuration:  |           |            |                |              |
| Area, planform, m <sup>2</sup> (ft <sup>2</sup> ) . . . . .               |           |            | 378.0          | (4069.3)     |
| Length, nose to wing leading edge at body, cm (in.) . . . . .             |           |            | 1655.32        | (651.70)     |
| Length, nose to wing $\bar{c}/4$ , cm (in.) . . . . .                     |           |            | 2267.71        | (892.80)     |
| Fuselage:   |           |            |                |              |
| Area, wetted, m <sup>2</sup> (ft <sup>2</sup> ) . . . . .                 |           |            | 585.9          | (6307.0)     |
| Length, nose to end of body, cm (in.) . . . . .                           |           |            | 3340.1         | (1315.0)     |
| Wing:   |           |            |                |              |
| Area, theoretical or total, m <sup>2</sup> (ft <sup>2</sup> ) . . . . .   |           |            | 314.67         | (3387.1)     |
| Area, elevon, m <sup>2</sup> (ft <sup>2</sup> ) . . . . .                 |           |            | 63.06          | (678.75)     |
| Span, cm (in.) . . . . .  |           |            | 2756.9         | (1085.4)     |
| Chord, mean aerodynamic, cm (in.) . . . . .                               |           |            | 1362.76        | (536.52)     |
| Chord, center-line root, cm (in.) . . . . .                               |           |            | 2011.91        | (792.09)     |
| Chord, tip, cm (in.) . . . . .  |           |            | 270.92         | (106.66)     |
| Taper ratio, theoretical . . . . .  |           |            | 0.13465        |              |
| Aspect ratio, theoretical . . . . .                                       |           |            | 2.4154         |              |
| Aspect ratio, exposed span . . . . .                                      |           |            | 2.2896         |              |
| Angle, leading-edge sweep, deg . . . . .                                  |           |            | 46.825         |              |
| Angle, trailing-edge sweep, deg . . . . .                                 |           |            | -11.0          |              |
| Angle, dihedral, deg . . . . .  |           |            | 7.0            |              |
| Angle, incidence, deg . . . . .   |           |            | 1.5            |              |
| Airfoil section, root . . . . .   |           |            | NACA 0008-64   |              |
| Airfoil section, tip . . . . .  |           |            | NACA 0008-64   |              |
|   |           | Weight     | $x_{cg}$       | $x_{cg}/l$ , |
| Mass properties at flight condition:                                      | kg        | (lb)       | m (ft)         | percent      |
| Orbiter landing (Design P/L) . . . . .                                    | 90 541    | (199 609)  | 21.7 (71.181)  | 64.96        |
| Orbiter landing (P/L out) . . . . .                                       | 72 397    | (159 609)  | 22.41 (73.523) | 67.096       |
| Wing weight . . . . .   | 7473.80   | (16 476.8) |                |              |
| Thermal protection system weight . . . . .                                | 12 258.96 | (27 926.2) |                |              |
| Principal parameters:   |           |            |                |              |
| x-scale factor, XSF . . . . .   |           |            |                | 0.80000      |
| y-scale factor, YSF . . . . .   |           |            |                | 1.3000       |
| Distance to leading edge of exposed wing, $x_{wing}$ , cm (in.) . . . . . |           |            | 1655.31        | (651.70)     |
| Landing performance:  |           |            |                |              |
| Minimum landing speed (Design P/L), knots . . . . .                       |           |            |                | 150.2        |
| Static margin (subsonic) (Design P/L) . . . . .                           |           |            |                | 0.0804       |
| Static margin (subsonic) (P/L out) . . . . .                              |           |            |                | 0.0280       |
| Trim $C_L$ for landing ( $\alpha = 17^\circ$ ) . . . . .                  |           |            |                | 0.7715       |
| Hypersonic aerodynamic trim data:   |           |            |                |              |
| Trim angle of attack at elevon $-45^\circ$ , deg . . . . .                |           |            |                | 45.59        |

The vertical tail  $V_2$  (ref. 2) had NACA 0012-64 airfoil sections. Semifaired and fully tailored wing-tip-mounted ACPS pods were included as model configuration variables  $P_1$  and  $P_2$ , respectively. These pods were sized to represent the scaled volumetric requirement of the ACPS roll control. (See fig. 5(b).)



Semifaired pods,  $P_1$   
Volume (2 pods) =  $31.0 \text{ cm}^3$



Fully tailored pods,  $P_2$   
Volume (2 pods) =  $31.0 \text{ cm}^3$

(b) Wing tip roll ACPS pods (0.01875-scale model).

Figure 5.- Continued.

Tunnel.- Subsonic tests were conducted in the Langley low turbulence pressure tunnel which is a variable-pressure, single-return facility with a closed test section 0.914 meter (3.0 feet) wide and 2.29 meters (7.5 feet) high. The tunnel is a low subsonic facility ( $M \leq 0.4$ ) with the capability of Reynolds numbers per unit length up to about  $49.2 \times 10^6$  per meter ( $15.0 \times 10^6$  per foot).

Test conditions.- The investigation was conducted at a Mach number of about 0.25 and at Reynolds numbers from about  $12.6 \times 10^6$  to  $21.0 \times 10^6$ , based on the fuselage length. Test angle of attack was varied from approximately  $-3^\circ$  to  $20^\circ$  at  $0^\circ$  sideslip.

Measurements and corrections.- An internally mounted six-component strain-gage balance was used to measure aerodynamic forces and moments acting on the model. No base- or chamber-pressure corrections were applied to the data. Corrections have been applied to the angles of attack and sideslip to account for sting and balance deflections produced by aerodynamic load on the model. All pitching-moment coefficient data are presented about the moment reference point location shown in figure 5(a) unless otherwise specified. The subsonic longitudinal aerodynamic coefficients and angles of attack have been corrected for blockage and lift interference in accordance with the techniques outlined in references 6 and 7.

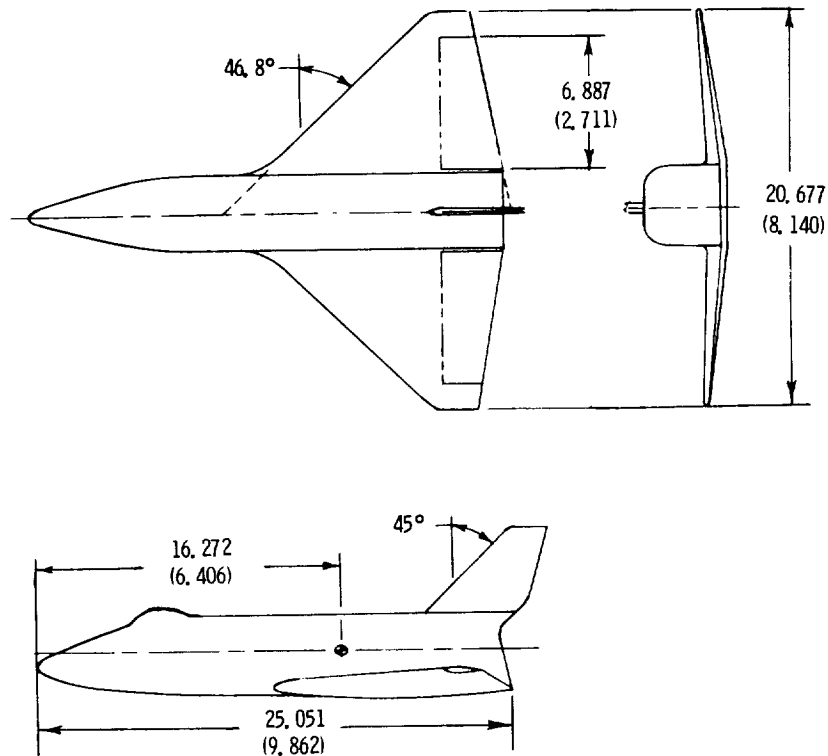
### Hypersonic

Model.- The hypersonic model was a 0.0075-scale model of the analytically selected configuration and is shown in figure 5(c). The model wing geometric features were similar to the subsonic plane (untwisted) model wing. The vertical tail  $V_1$  was geometrically similar in planform to the 040A vertical tail  $V_1$  (ref. 2) and used NACA 0012-64 airfoil sections.

Tunnel.- The hypersonic tests were made in the Langley continuous-flow hypersonic tunnel, which is designed to operate over a pressure range of 15 to 150 atmospheres (1 atmosphere =  $101\,325 \text{ N/m}^2$ ) at temperatures up to 1090 K ( $1960^\circ \text{ R}$ ). Air is heated by an electrical resistance multitube heater prior to entry into a water-cooled contoured nozzle which has a 79-cm-square (31-inch-square) test section. Continuous operation is achieved by recirculating the air flow through a series of compressors. Reynolds number varies from  $1.64 \times 10^6$  to  $8.53 \times 10^6$  per meter ( $0.5 \times 10^6$  to  $2.6 \times 10^6$  per foot).

Test conditions.- The hypersonic tests were conducted at a Mach number of about 10.3, a stagnation pressure of about 50 atmospheres, and a test Reynolds number of about  $0.8 \times 10^6$  based on the fuselage length. Data were taken at angles of attack from approximately  $15^\circ$  to  $48^\circ$  at  $0^\circ$  sideslip.

Measurements and corrections.- Aerodynamic force and moment data were measured by an internally mounted six-component strain-gage balance. The balance was strut mounted on an injection system assembly which inserted the model into the airstream.



(c) Hypersonic model;  $BW_{pV_1}$  (0.0075 scale);  $S_{ref} = 0.1771 \text{ m}^2$ ;  
 $\Lambda_{le} = 46.8^\circ$ ;  $\Lambda_{te} = -11.0^\circ$ ;  $\lambda = 0.135$ .

Figure 5.- Concluded.

Balance temperatures were continuously monitored to allow model retraction prior to overheating of the components. Angles of attack have been corrected to account for sting and balance deflections produced by aerodynamic loading. No base- or chamber-pressure corrections were applied to the data. The pitching-moment coefficient data are presented about the moment reference point location shown in figure 5(c).

## RESULTS AND DISCUSSION

### Analytical Results

Effect of wing geometry on aerodynamics, weight, and performance.- Summary results from the initial 25-wing matrix ( $\Lambda_{te} = 0^\circ$ ) are shown in figure 4 and in the appendix.

The resulting configuration geometries, curves of constant landed weight, wing reference area, aspect ratio, leading-edge sweep, minimum design speed, and maximum hypersonic trim angle of attack are presented in figure 4. In order to satisfy the guidelines of the study, a wing is required to have the geometry specified at or above and to the left of the intersection of the 150-knot  $V_{\min,des}$  curve with the curve for a hypersonic trimmed  $\alpha_{\max}$  of  $50^\circ$ . This projected intersection would occur at values of XSF and YSF of about 0.75 and 1.4, respectively, which represents an  $A > 3.0$  wing configuration having a leading-edge-sweep angle less than  $45^\circ$ . (See fig. 4(b).) Entry heating considerations, however, which were used to establish the  $45^\circ$  minimum wing sweep boundary of table I precluded the further consideration of the aerodynamically desirable wing configurations indicated in figure 4. The nearby region containing wings having leading-edge sweep angles of  $45^\circ$  or greater was then investigated since it should contain the wing configurations most nearly conforming with the established guidelines and constraints. For this purpose 10 additional wing configurations were added to the initial matrix. Summary data for these additional configurations are presented in the appendix.

Effect of elevon size and  $\Delta l_e$ .- Figure 6 shows the effect of elevon chord increases on the hypersonic trim capability of the orbiter wings included in the study matrix. These results indicate that increasing the elevon area by about 4 percent of the wing area increases the maximum hypersonic trim angle from  $6^\circ$  to  $8^\circ$  for wings having reference areas between 210 and 330  $m^2$  (2260 and 3552  $ft^2$ ). Figure 7 shows the effect of leading-edge sweep angle on the subsonic minimum design speed. The lower sweep angles allow the smaller wing areas to meet the subsonic requirement for a minimum design speed of 150 knots. In addition, reduced wing areas yield increased hypersonic trim angle-of-attack capability as indicated in figure 6.

Configuration selection.- Two configurations  $W_{27}$  and  $W_{33}$  (see appendix) were selected from the study matrix for further analysis. These configurations exhibited values of XSF and YSF indicated in figure 4 and would most likely result in wing planforms capable of meeting the subsonic-hypersonic criteria without violating the  $45^\circ$  minimum sweep constraint. The configuration  $W_{27}$  is defined in the appendix for values of XSF and YSF of 0.9 and 1.3 and configuration  $W_{33}$  by XSF and YSF values of 0.8 and 1.3. These two configurations were selected since each was considered to be marginally acceptable in satisfying the guidelines of the study regarding hypersonic trim and minimum design speed. As indicated in the index in the appendix (table V),  $V_{\min,des}$  for  $W_{27}$  and  $W_{33}$  were 151 knots and 154 knots, respectively. Also indicated are maximum

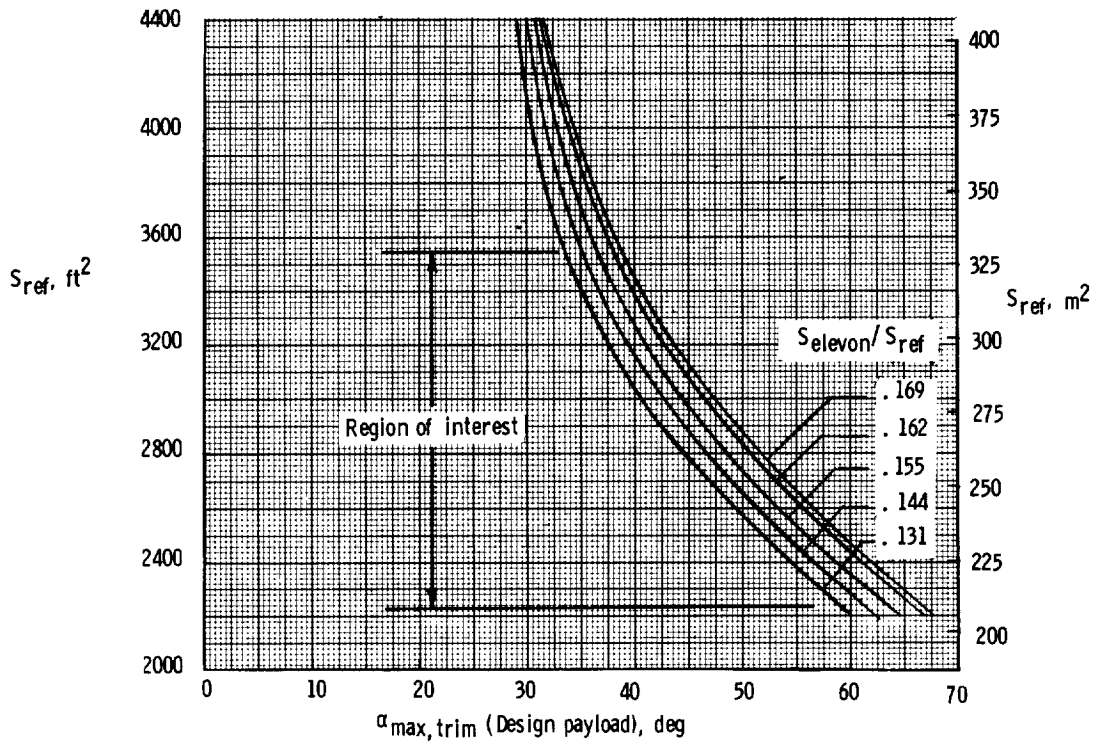


Figure 6.- Analytical effects of elevon size at hypersonic speeds for study wings.  $\Lambda_{te} = 0^\circ$ .

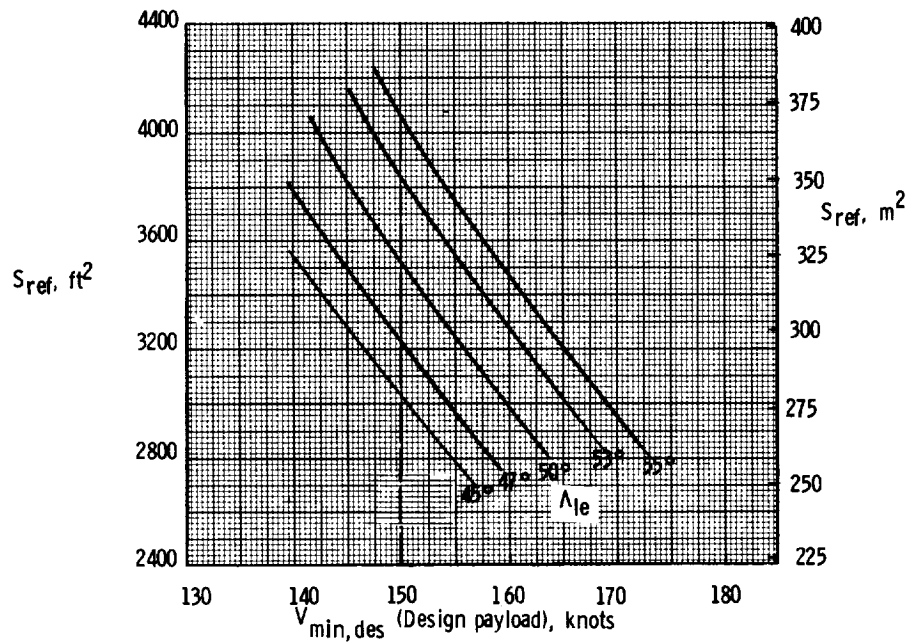


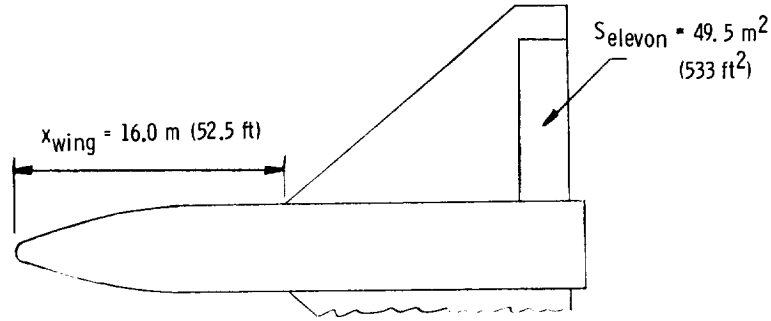
Figure 7.- Analytical effect of leading-edge sweep angle.



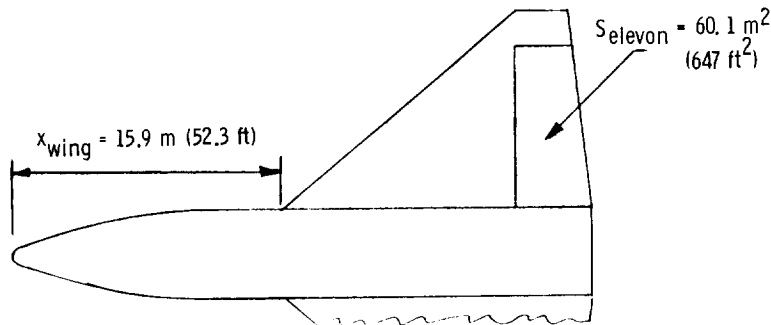
hypersonic trim angles of  $40^\circ$  and  $46^\circ$ , respectively, for the two configurations. At this point in the design cycle, improvements in the analytical aerodynamic characteristics as well as the introduction of empirical or experience factors are required to insure experimental compliance of the selected configurations with the established aerodynamic guidelines. For example, past comparisons with experiment have indicated higher analytical values of subsonic  $C_L$  and hypersonic trim capability (ref. 8) than experimental results for delta wings of moderate aspect ratio and sweep.

Reduction of  $V_{\min,des}$  to the 150-knot guideline value requires an increase in wing area for both configurations (W<sub>27</sub> and W<sub>33</sub>); hypersonic trim requirements, on the other hand, dictated a decrease in wing area or that the wing be moved forward to reduce the level of longitudinal stability. The subsonic stability criteria constrained the forward wing movement for both wings and thereby precluded meeting the hypersonic trim guidelines.

A possible solution to these conflicting requirements would be to increase the wing area slightly by using a negatively swept trailing edge and move the wing forward to comply with subsonic stability requirements and to achieve increased hypersonic trim capability. Additional benefits in hypersonic trim might also be realized by retaining the present elevon hingeline locations relative to the exposed wing to provide increased movable elevon areas. The effects of these modifications on wings W<sub>27</sub> and W<sub>33</sub> are shown in figures 8 and 9, respectively. Analytical results for the W<sub>27</sub> modification indicate that the target  $V_{\min,des}$  of 150 knots was achieved, whereas the hypersonic  $\alpha_{\max,trim}$  increased by only  $1^\circ$  to a value of  $41^\circ$ . Since the wing-forward movement was very slight, the corresponding increase in hypersonic trim angle was extremely small. (Compare fig. 8(a) with fig. 8(b).) Comparison of figure 9(a) with figure 9(b) shows that these modifications of W<sub>33</sub> produced more desirable results. The value of  $V_{\min,des}$  for the modified wing was reduced to 150 knots whereas hypersonic trim capability was extended to  $49^\circ$ . This wing configuration was selected for the experimental verification with one further modification; the elevon chords were arbitrarily reduced to improve structural integrity of the wing tips. The resulting configuration selected is shown in figure 10 and pertinent summary characteristics are shown in table IV. The analytical results indicated that the selected configuration met all the aerodynamic design requirements outlined in table I with the exception of the maximum angle-of-attack hypersonic trim. Because of the reduced elevon area, the design exhibited a maximum trimmed angle of attack  $4^\circ$  less than the required value ( $50^\circ$ ). This deficiency could be eliminated



- (a)  $\Lambda_{te} = 0^\circ$ ;  $W_{27}$ ;  $V_{min,des}$  (Design P/L) = 151 knots;  
 hypersonic  $\alpha_{max,trim}$  (Design P/L) =  $40^\circ$ ;  
 $S_{ref} = 312 \text{ m}^2$  (3357  $\text{ft}^2$ ).



- (b)  $\Lambda_{te} = -7.0^\circ$ ;  $W_{27}$  (Mod);  $V_{min,des}$  (Design P/L) = 150 knots;  
 hypersonic  $\alpha_{max,trim}$  (Design P/L) =  $41^\circ$ ;  $S_{ref} = 328 \text{ m}^2$  (3535  $\text{ft}^2$ ).

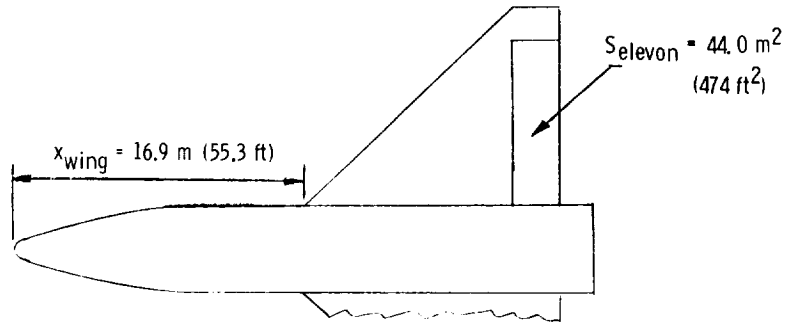
Figure 8.- Effect of trailing-edge sweep angle on wing  $W_{27}$ .  $\Lambda_{1e} = 50.2^\circ$ .

by some fuselage nose reshaping (not considered in the wing study) which has been shown to provide a positive increment in pitching moment. (See ref. 9.)

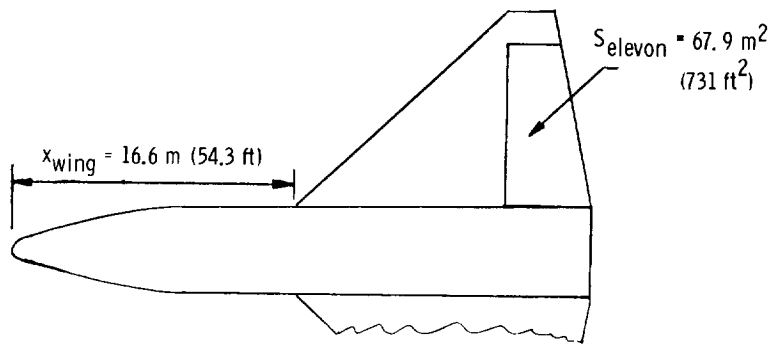
Subsequent experimental wind-tunnel studies using the selected configuration were made to validate these aerodynamic estimates and to demonstrate the aerodynamic development required to produce a satisfactory orbiter design.

### Experimental Results

The basic longitudinal aerodynamic data obtained at subsonic and hypersonic speeds for the selected configuration are presented. The subsonic data are shown in figures 11



- (a)  $\Lambda_{te} = 0^\circ$ ;  $W_{33}$ ;  $V_{min,des}$  (Design P/L) = 154 knots;  
 hypersonic  $\alpha_{max,trim}$  (Design P/L) =  $46^\circ$ ;  
 $S_{ref} = 315 \text{ m}^2$  (2983  $\text{ft}^2$ ).



- (b)  $\Lambda_{te} = -11.0^\circ$ ;  $W_{33}$  (Mod);  $V_{min,des}$  (Design P/L) = 150 knots;  
 hypersonic  $\alpha_{max,trim}$  (Design P/L) =  $49^\circ$ ;  $S_{ref} = 315 \text{ m}^2$  (3387  $\text{ft}^2$ ).

Figure 9.- Effect of trailing-edge sweep angle on wing  $W_{33}$ .  $\Lambda_{le} = 46.8^\circ$ .

to 17 with hypersonic data in figure 18. The subsonic aerodynamic characteristics of the configuration selected are summarized in figures 19 to 22. Longitudinal aerodynamic characteristics obtained at hypersonic speeds are summarized in figure 23.

Subsonic analytical and experimental comparisons.- A comparison of the analytical predictions with subsonic longitudinal aerodynamic characteristics obtained at high Reynolds number ( $R_L \approx 20 \times 10^6$ ) in the Langley low turbulence pressure tunnel is shown in figure 19. The wind-tunnel and analytical data are in good agreement at low to moderate angles of attack. The pitch-down tendency which occurs at high angles of attack in the

$$\begin{aligned} \Lambda_{le} &= 46.8^\circ \\ \Lambda_{te} &= -11.2^\circ \\ S_{ref} &= 315 \text{ m}^2 \\ &\quad (3387 \text{ ft}^2) \\ S_{elevation} &= 63.1 \text{ m}^2 \\ &\quad (679 \text{ ft}^2) \\ \lambda &= .135 \\ A &= 2.4 \\ i_{wing} &= 1.5^\circ \end{aligned}$$

Payload out:

$$\text{Landed weight} = 72398 \text{ kg (159609 lb)}$$

$$x_{cg} = 0.671l$$

$$C_{mC_L} = -0.028 \bar{c}$$

Design payload:

$$\text{Landed weight} = 90542 \text{ kg (199609 lb)}$$

$$x_{cg} = 0.650l$$

$$C_{mC_L} = -0.080 \bar{c}$$

$$V_{min,des} (\alpha = 17^\circ) = 150 \text{ knots}$$

$$\alpha_{max,trim} \text{ at hypersonic speeds} = 46^\circ$$

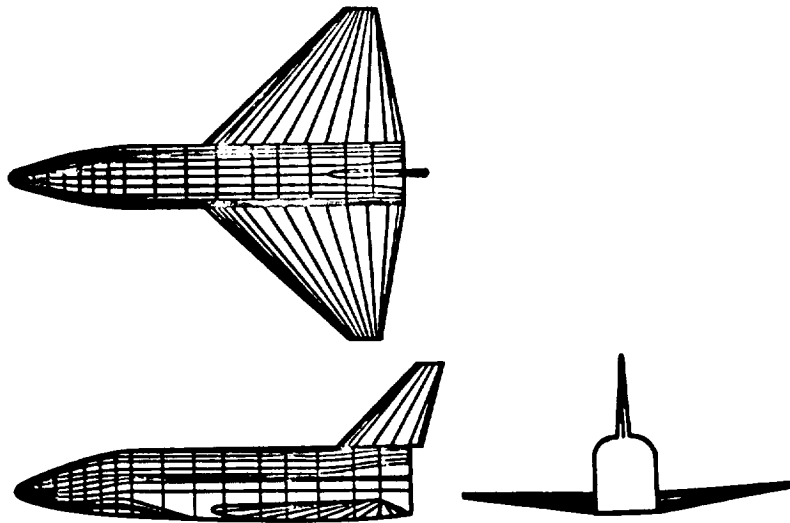


Figure 10.- Configuration selected,  $W_{33}$  (Mod).

experimental data was not predicted analytically because linear trends were assumed. This tendency reduces trimmed lift coefficient at high angles of attack below the level predicted and would result in an increase in minimum design speed of 12 knots for the design payload condition.

Effect of planform fillet on subsonic characteristics.- In an attempt to alleviate the landing lift decrement, a wing leading-edge planform fillet was added to the subsonic model (figs. 5(a) and 20). The fillet provided sufficient lift at the higher angles of attack

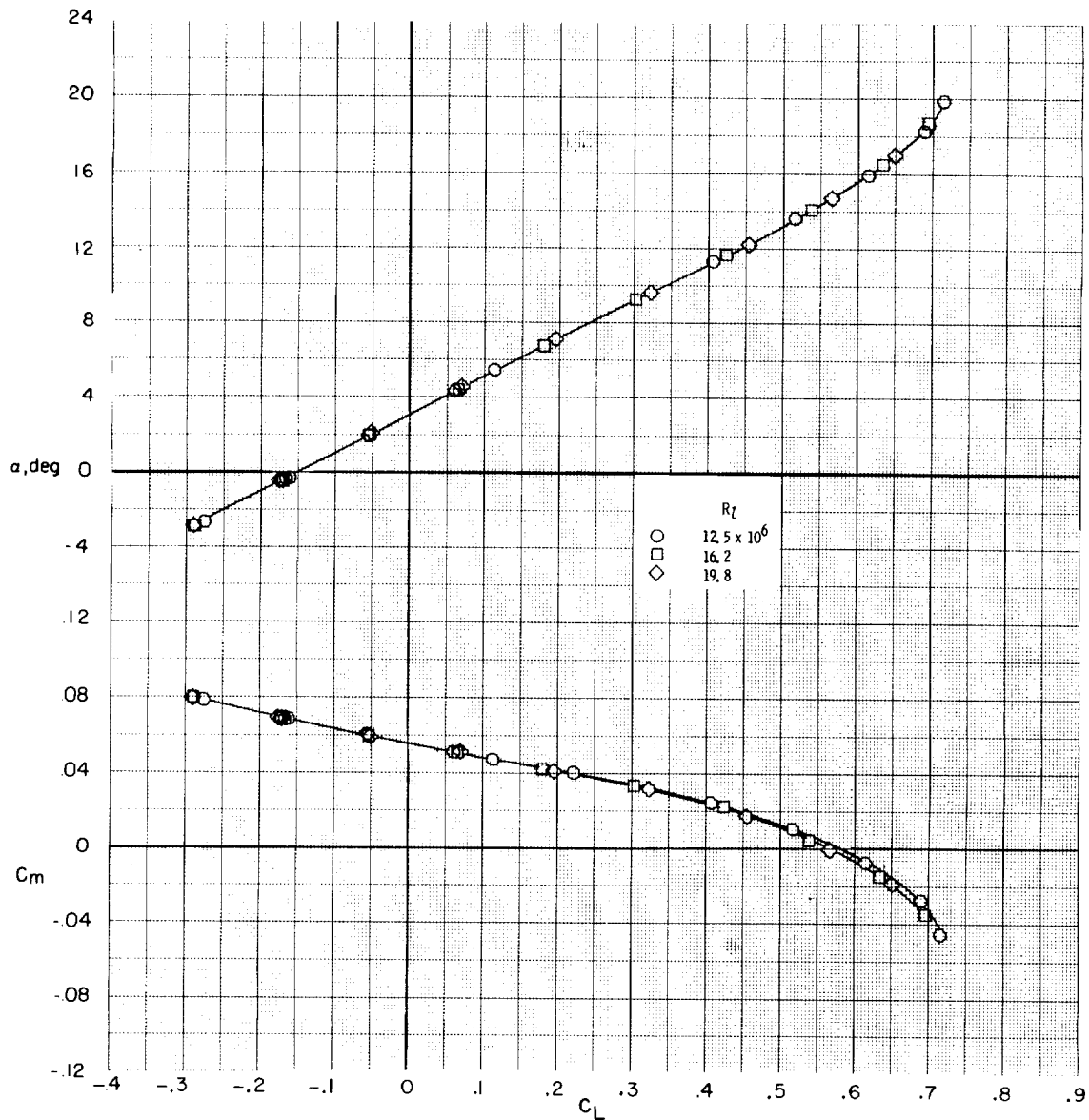


Figure 11.- Effect of Reynolds number on the longitudinal aerodynamic characteristics of the untwisted wing configuration BW<sub>P</sub>V<sub>2</sub>.  $\delta_{e_1} = \delta_{e_2} = \delta_{e_3} = -10^0$ .

to linearize the trimmed lift curve and provide a minimum design speed of about 150 knots. The addition of the fillet shifted the aerodynamic center of the configuration about  $0.05\bar{c}$  forward and required a rearward shift of the wing of about the same amount to keep the static margin of the configuration (payload out) at  $0.03\bar{c}$ .

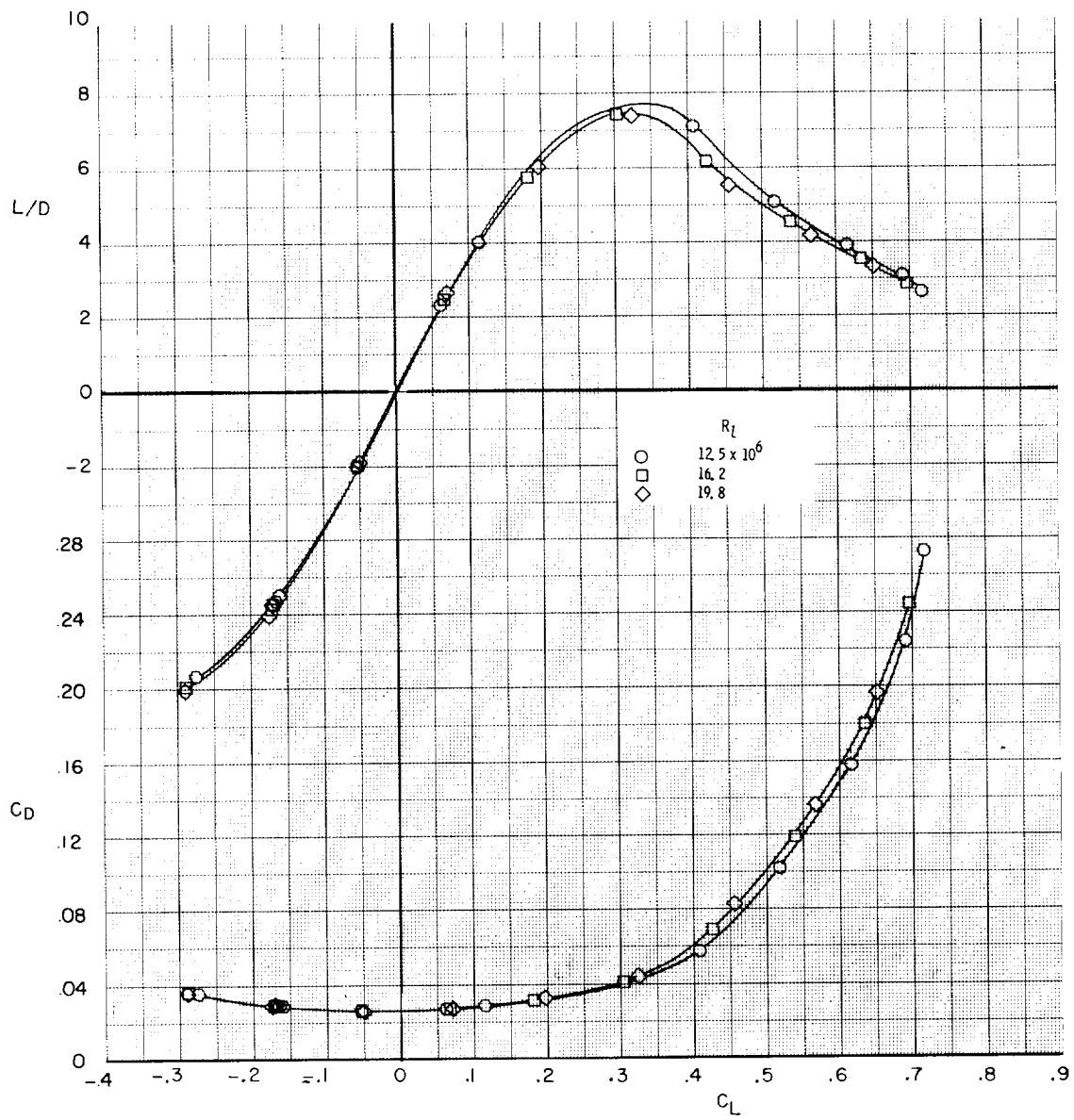


Figure 11.- Concluded.

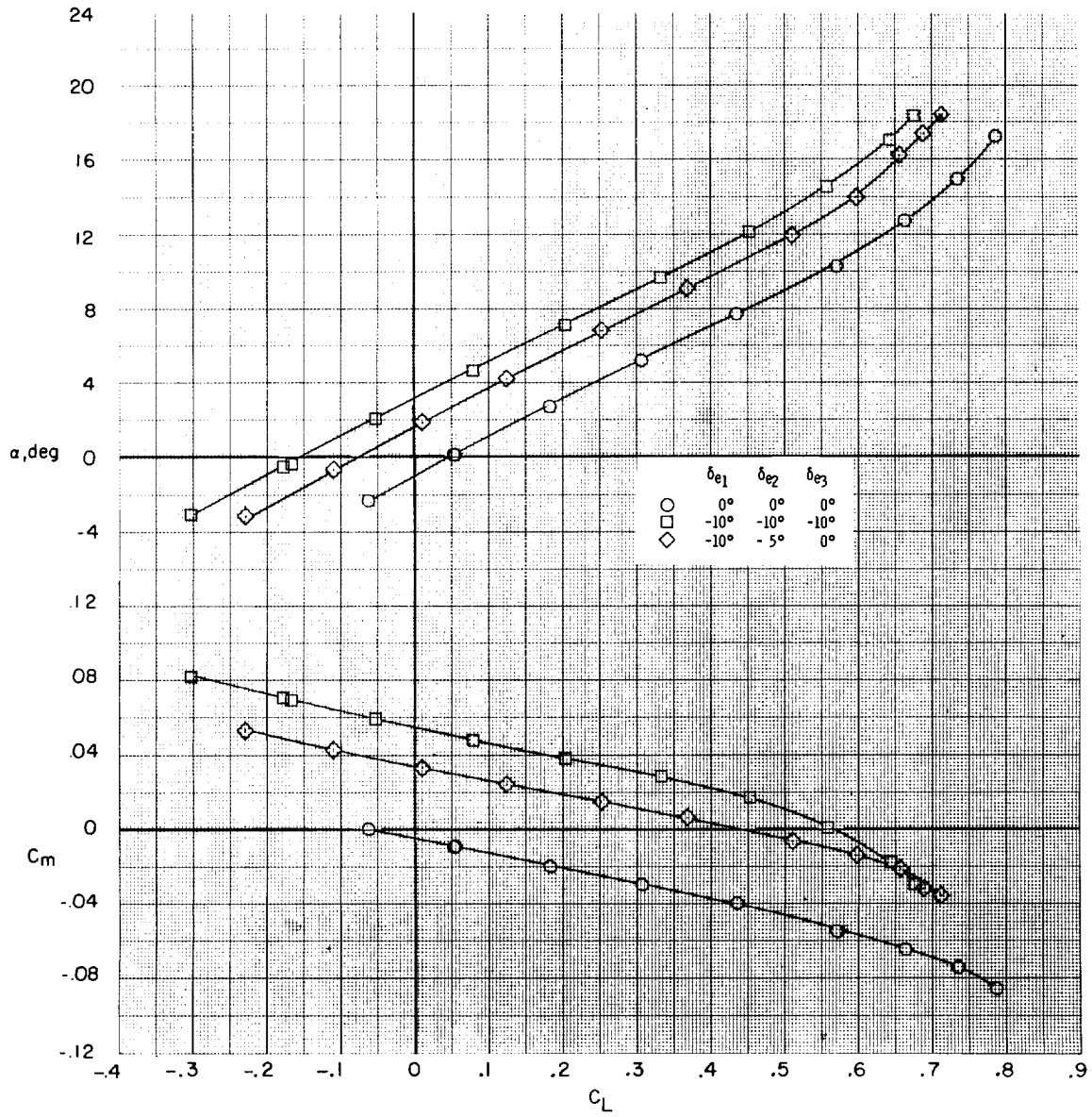


Figure 12.- Comparative longitudinal trim effects of unsegmented and segmented elevons for the untwisted wing configuration BW<sub>p</sub>V<sub>2</sub>.  $R_l \approx 20.1 \times 10^6$ .

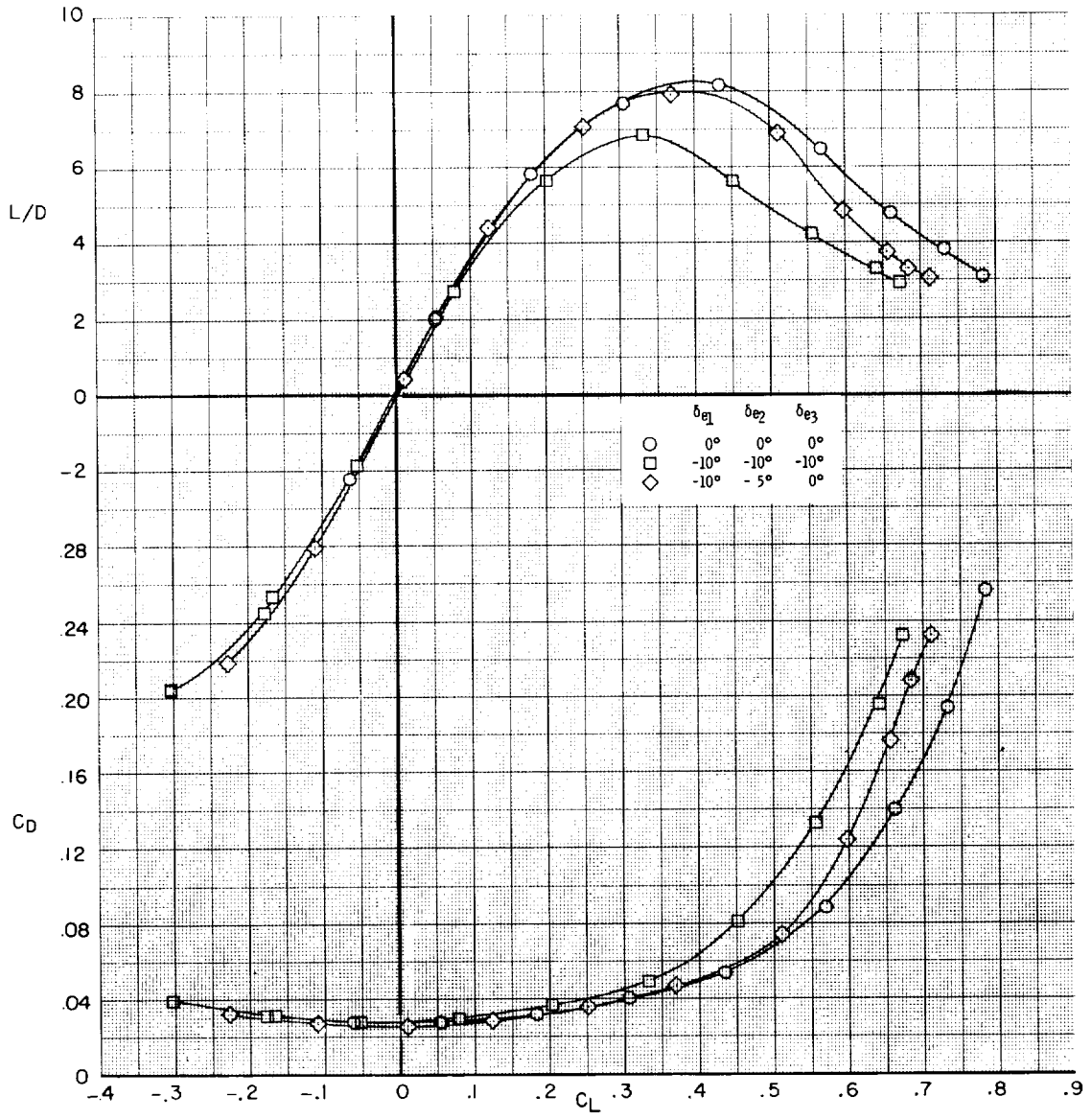


Figure 12.- Concluded.



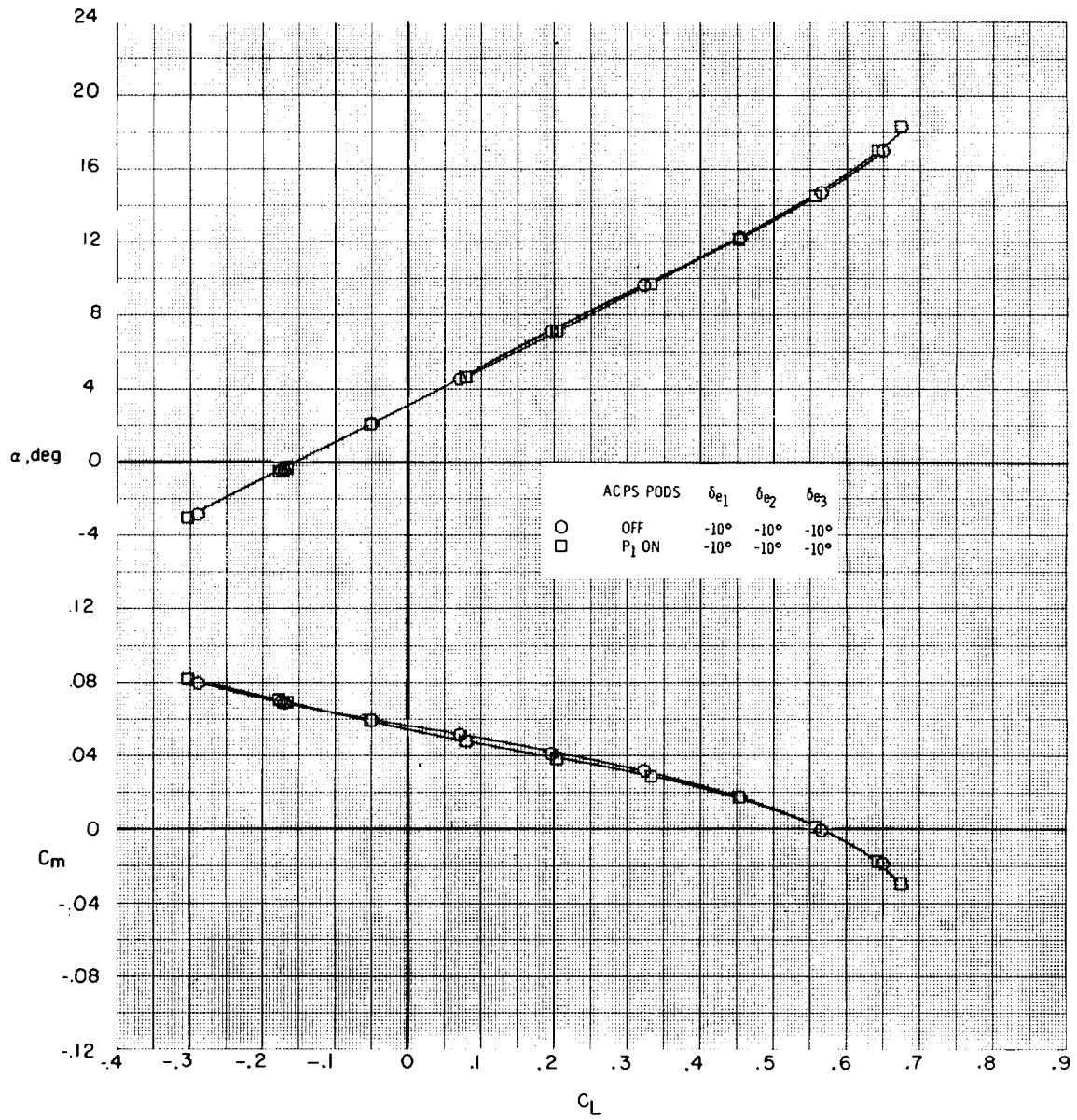


Figure 13.- Effect of adding ACPS pods P<sub>1</sub> on the aerodynamic characteristics of the untwisted wing configuration BW<sub>P</sub>V<sub>2</sub>.  $R_L \approx 20.0 \times 10^6$ .

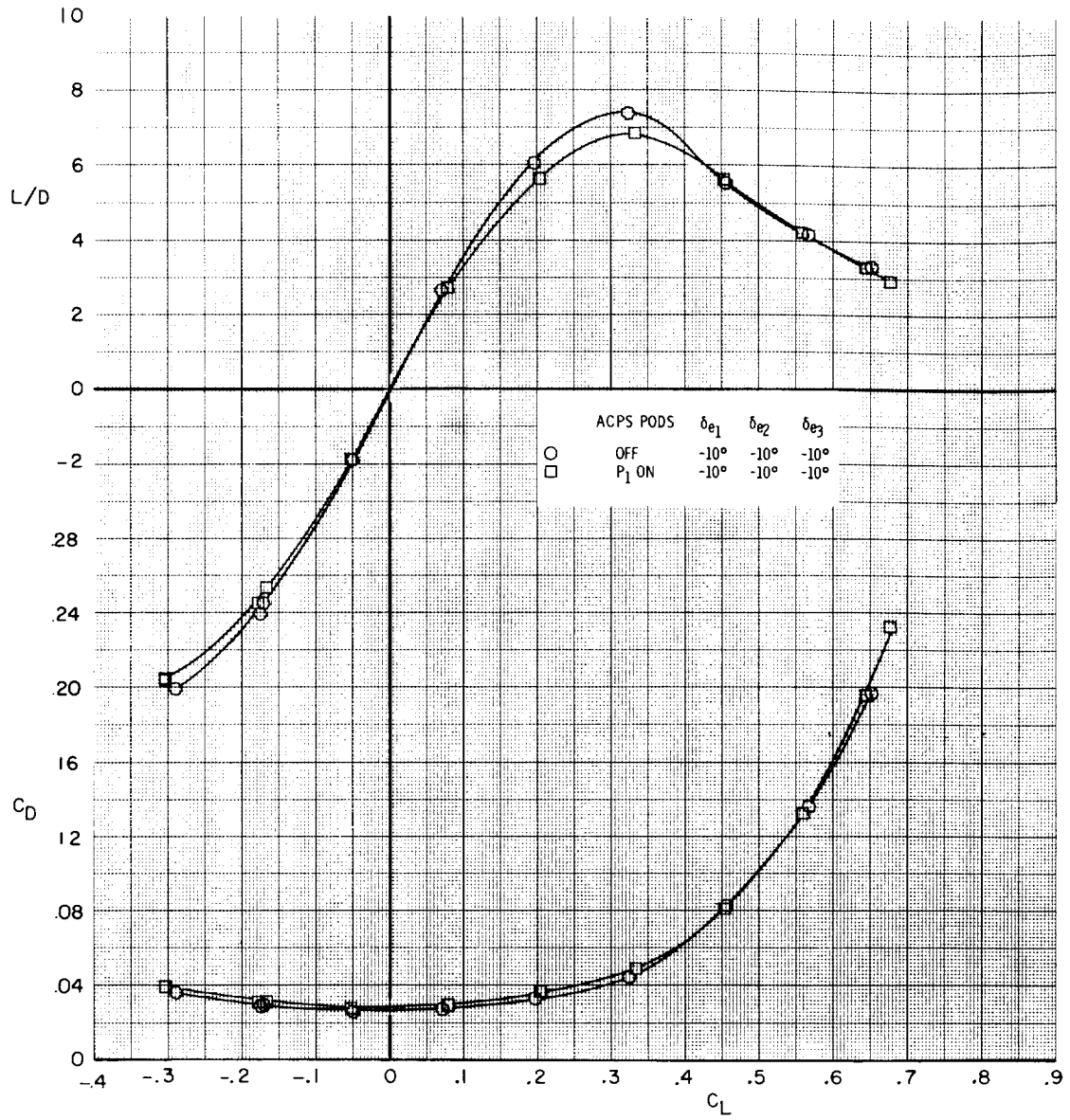


Figure 13.- Concluded.

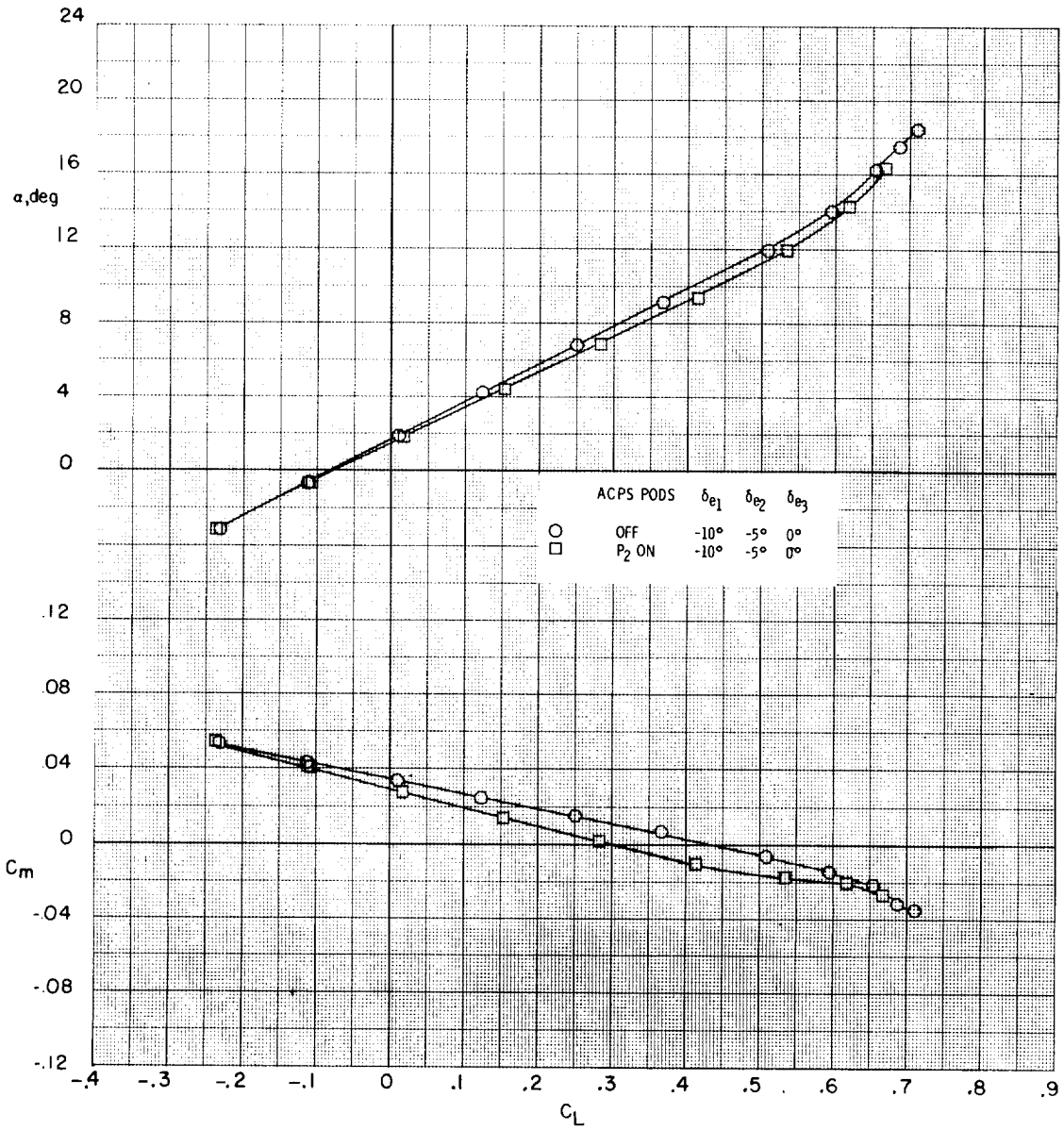


Figure 14.- Effect of adding contoured ACPS pods P<sub>2</sub> on the aerodynamic characteristics of the untwisted wing configuration BW<sub>P</sub>V<sub>2</sub>.  $R_l \approx 20.3 \times 10^6$ .

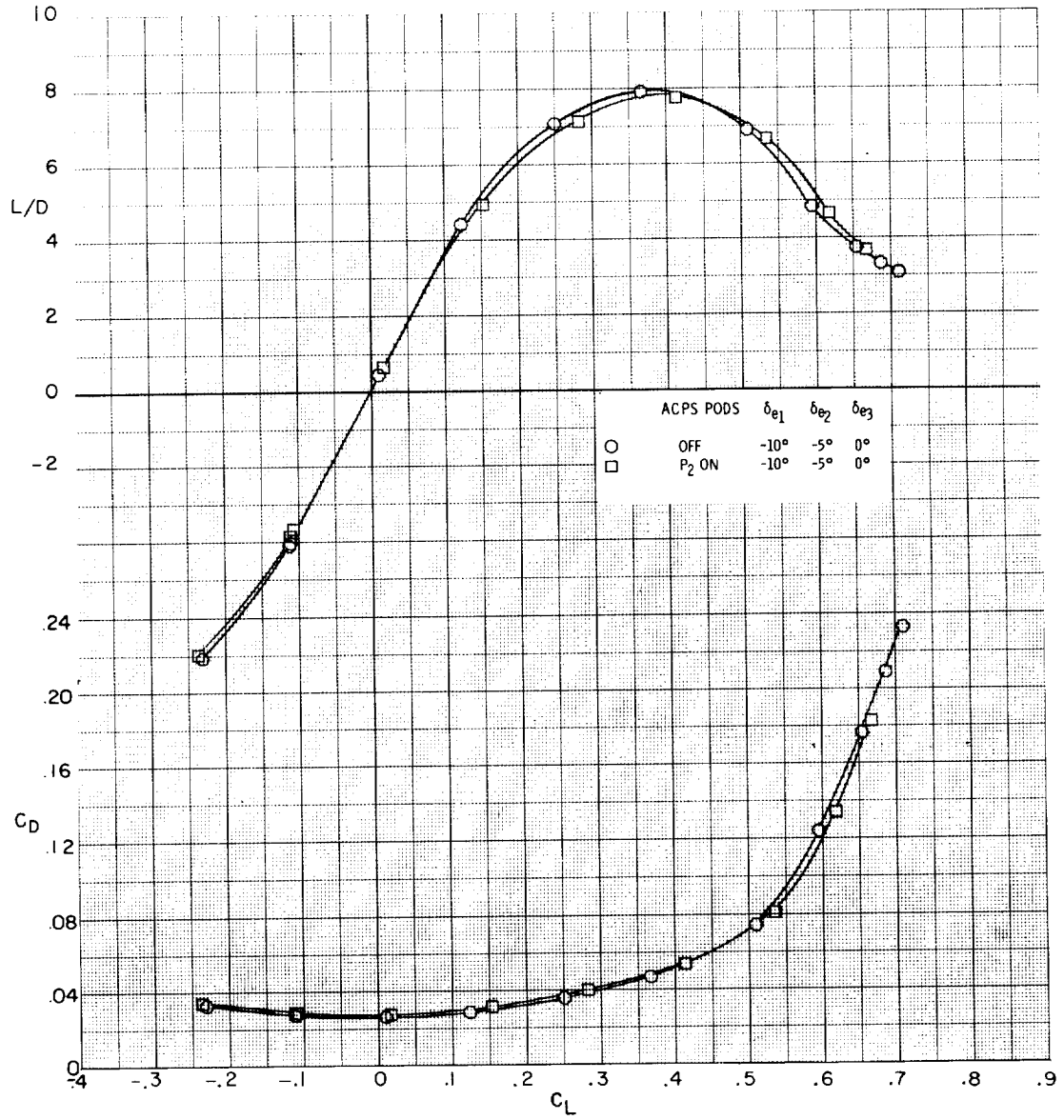


Figure 14.- Concluded.

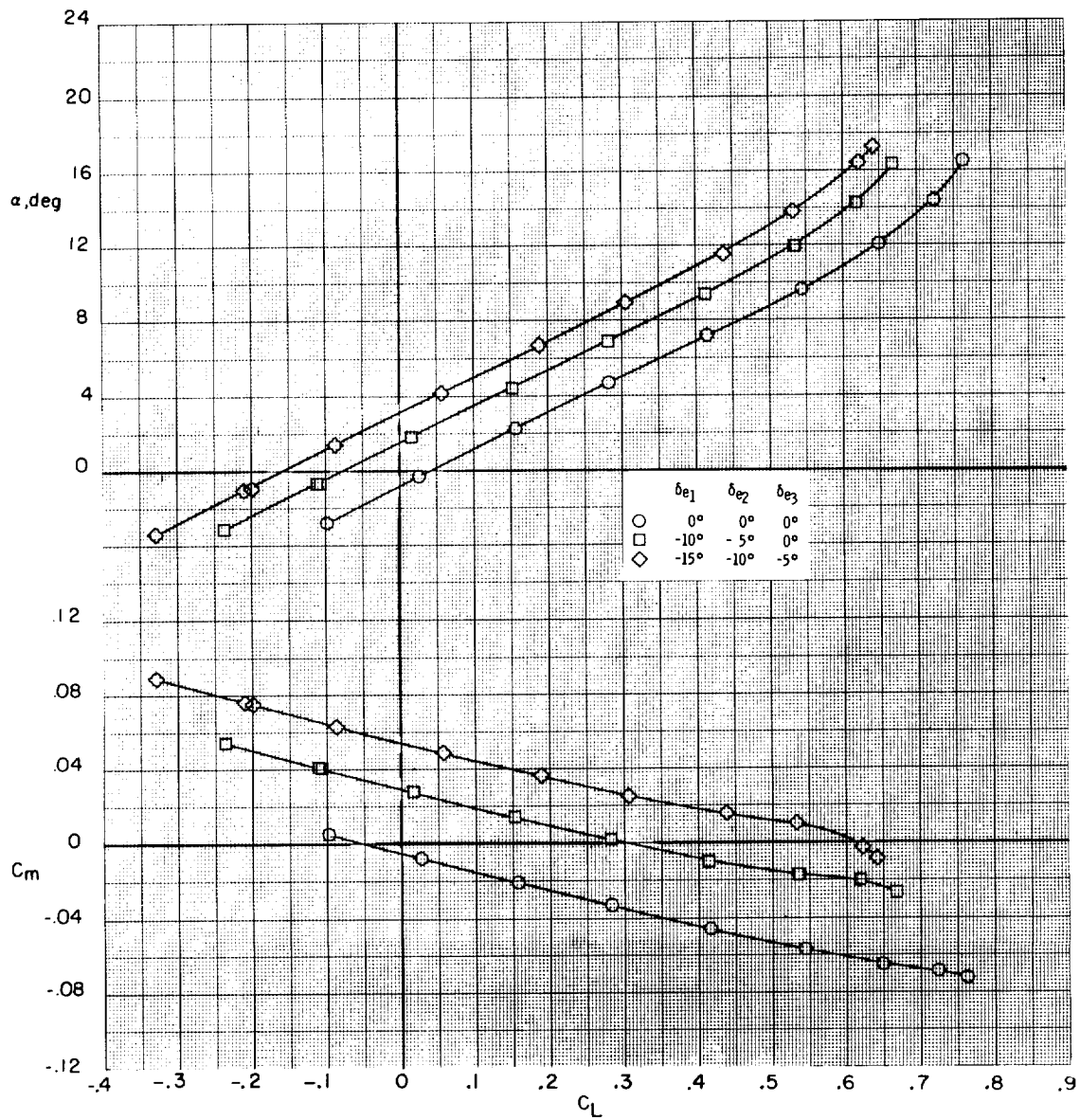


Figure 15.- Effect of segmented elevon deflections on the longitudinal aerodynamic characteristics of the untwisted wing configuration with ACPS pods  $P_2$  on.  $BW_P V_2 P_2$ ;  $R_l \approx 20.6 \times 10^6$ .

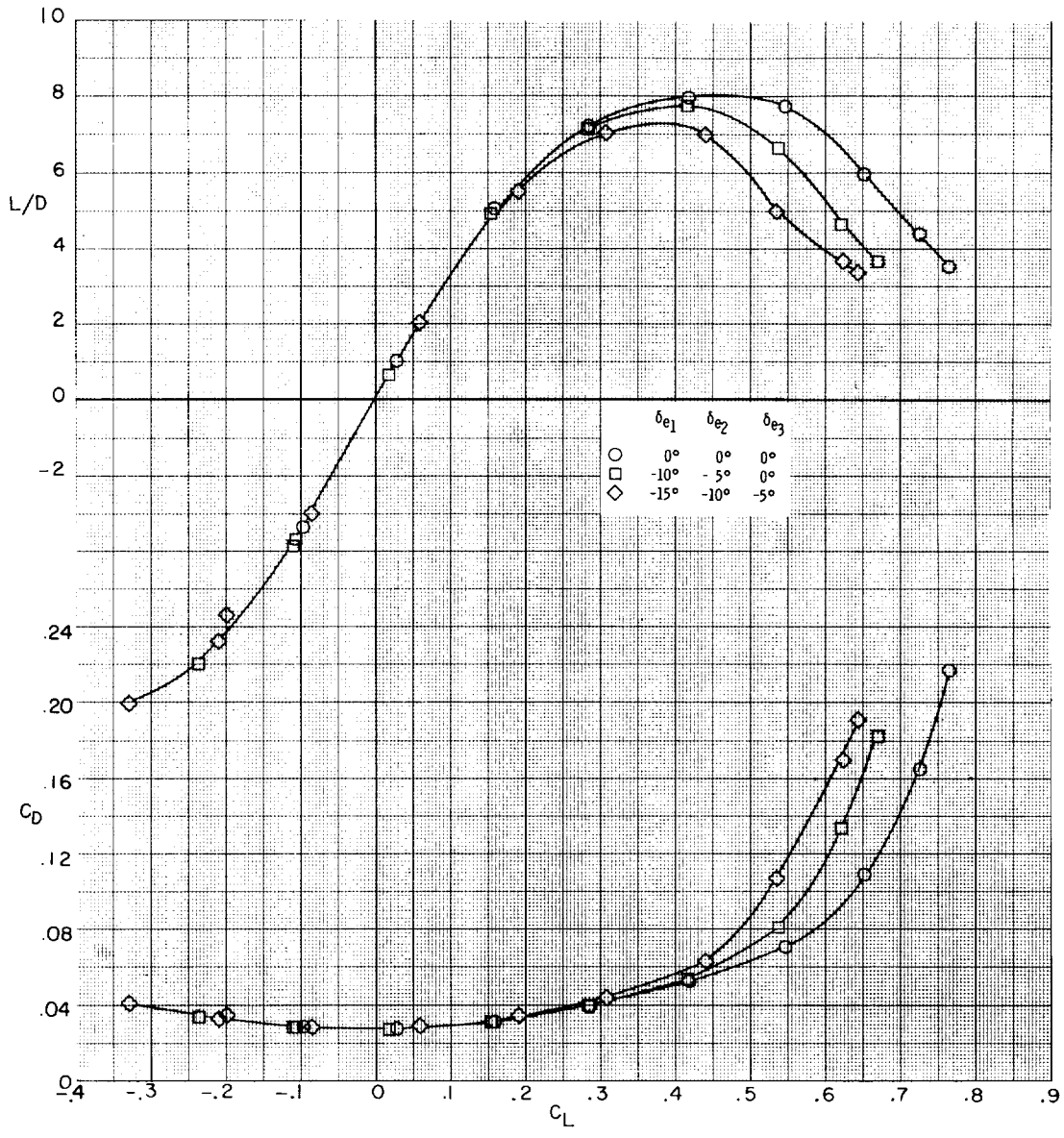


Figure 15.- Concluded.

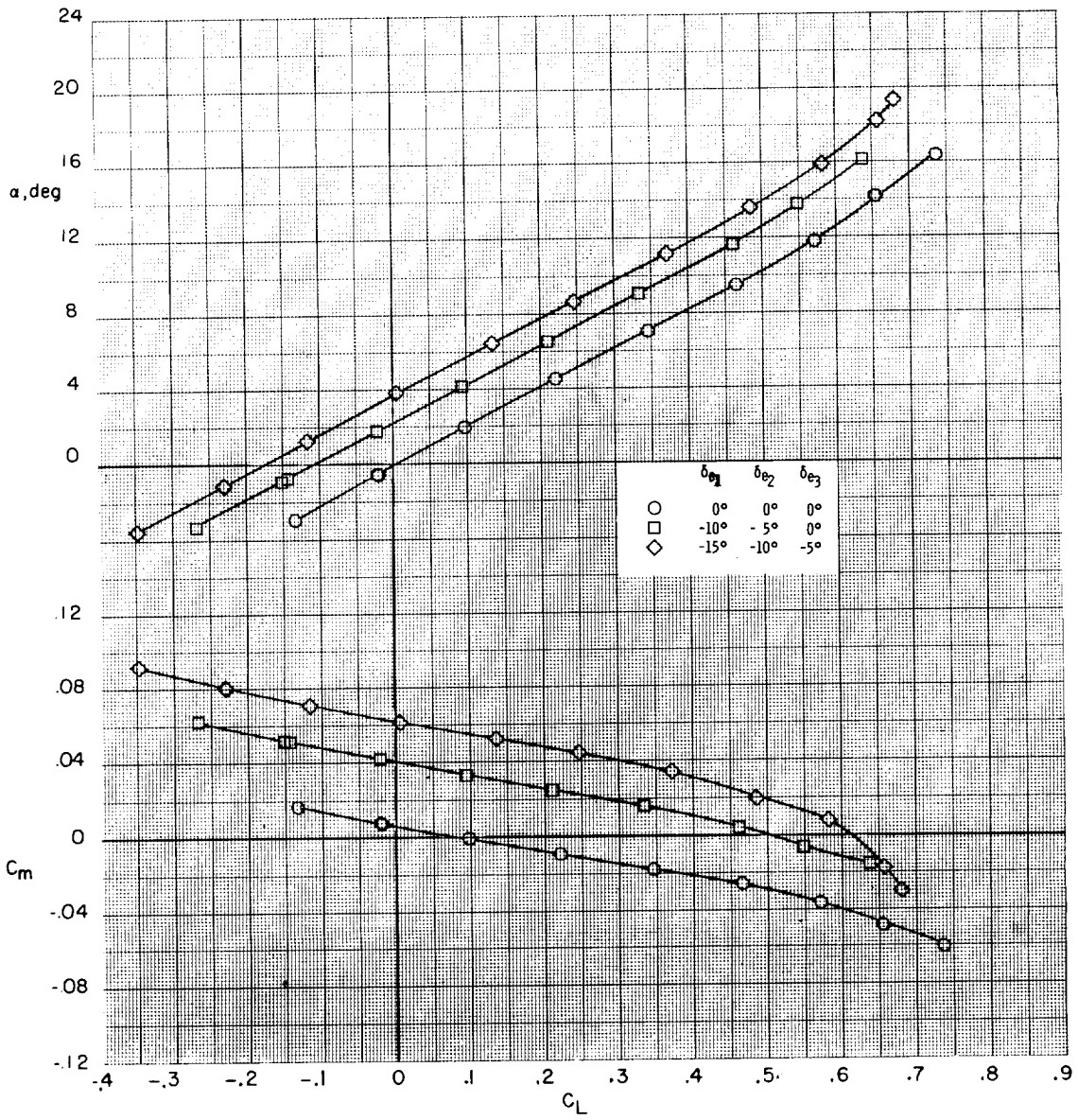


Figure 16.- Effect of segmented elevon deflections on the longitudinal aerodynamic characteristics of the twisted wing configuration  $BW_{TV2}$ .  $R_l \approx 20.1 \times 10^6$ .

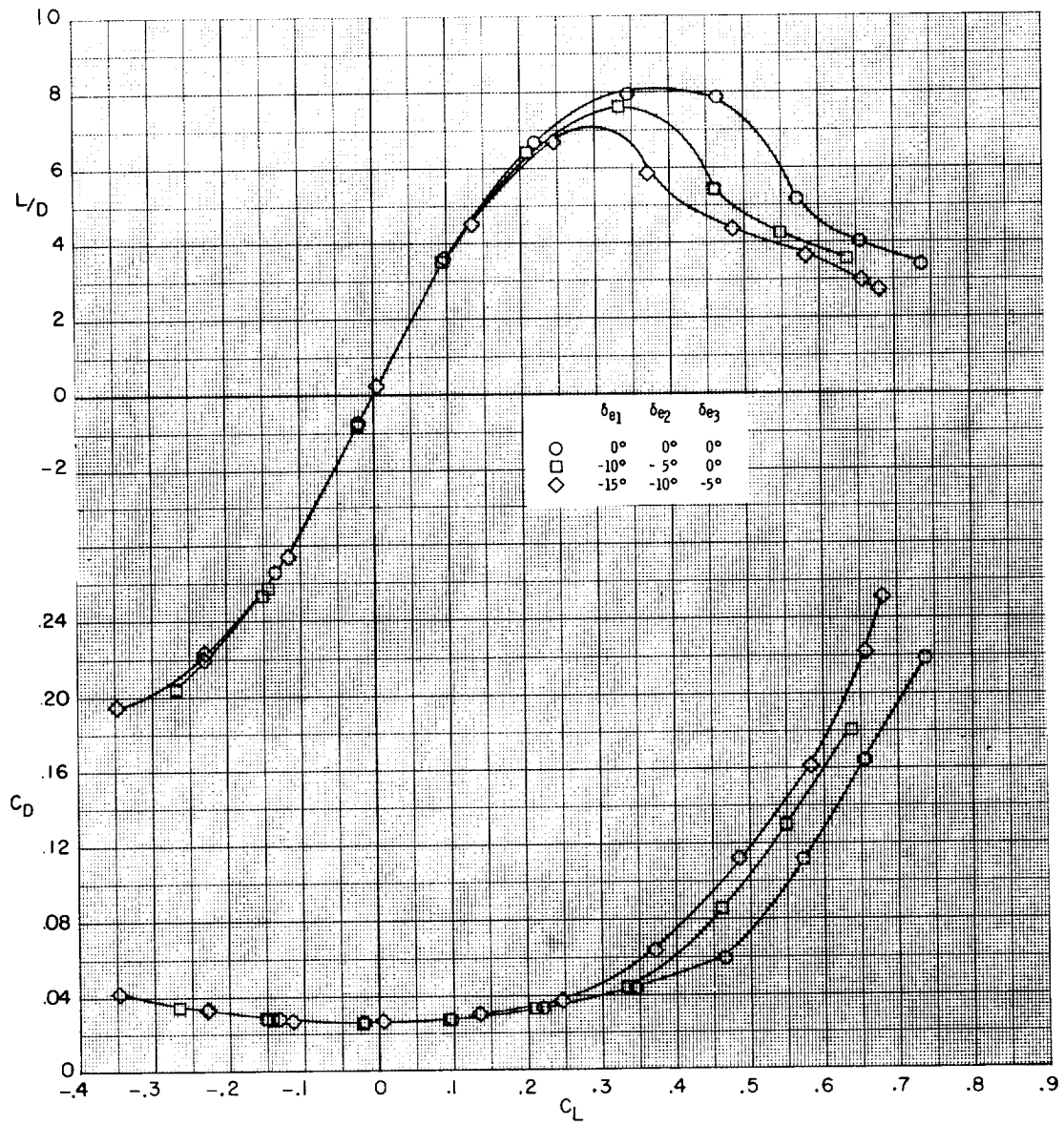


Figure 16.- Concluded.



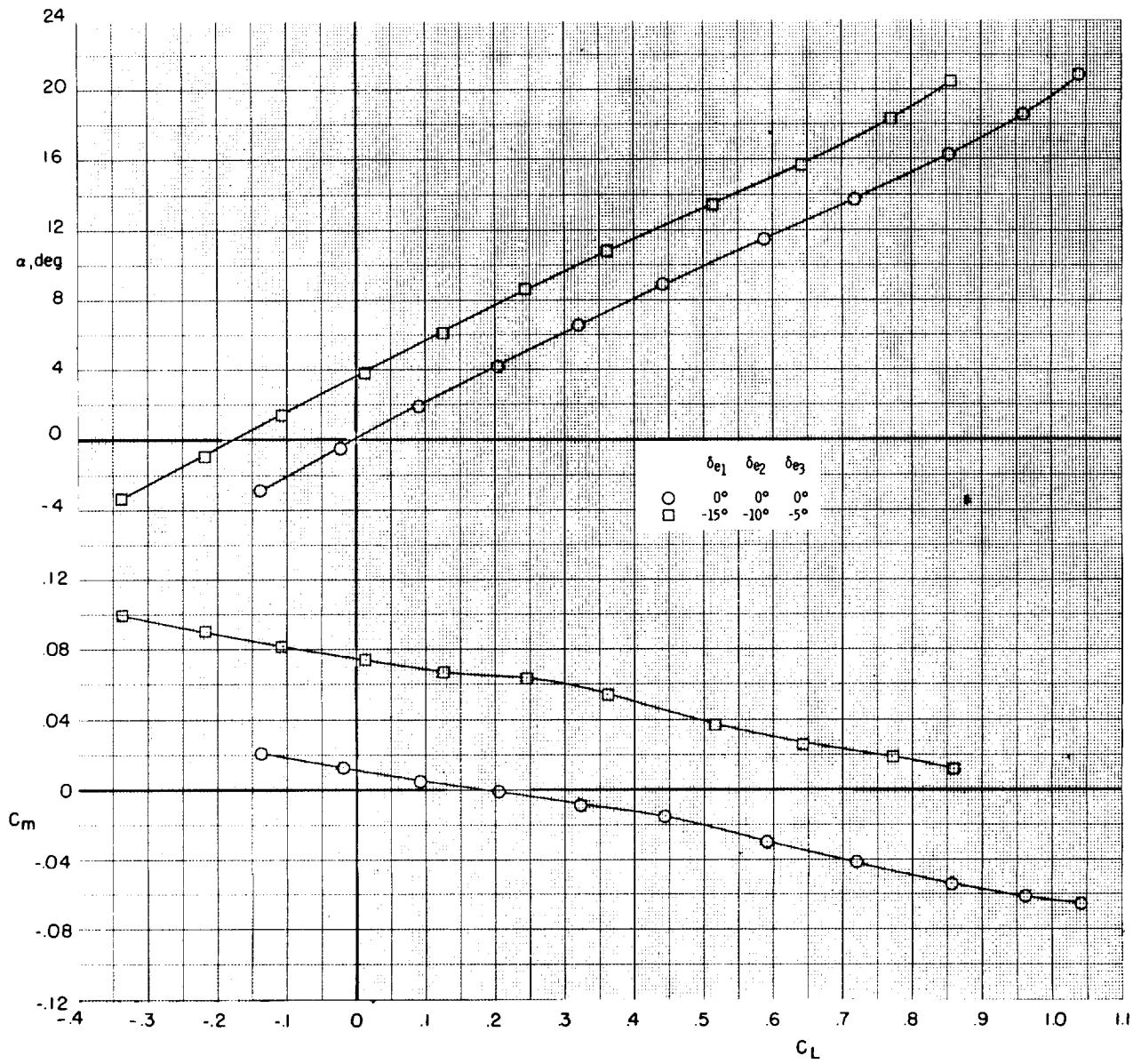


Figure 17.- Effect of segmented elevon deflections on the longitudinal aerodynamic characteristics of the twisted wing configuration with a planform fillet.  $BW_T V_2 F$ ;  $R_L \approx 13.4 \times 10^6$ .

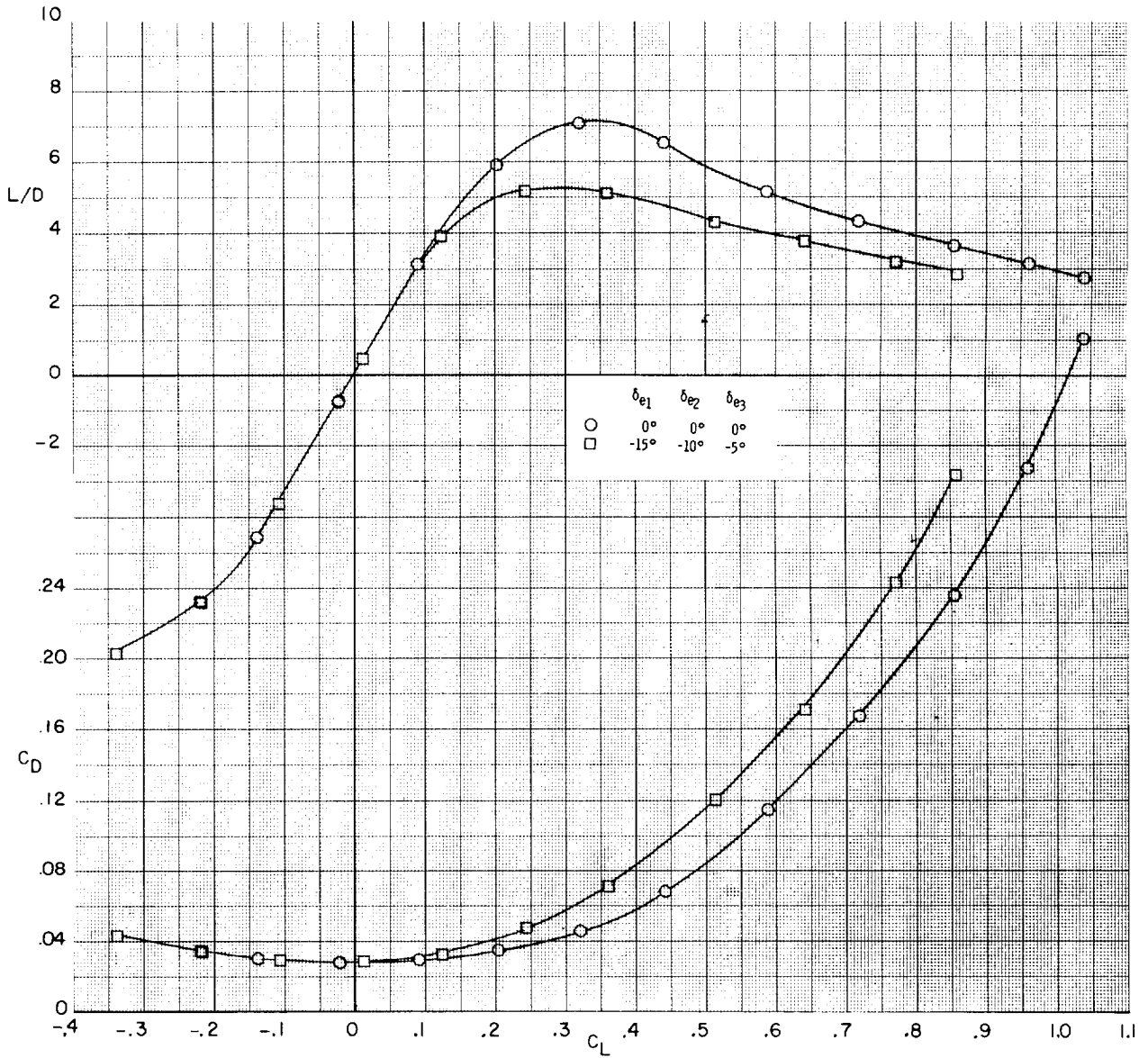


Figure 17.- Concluded.

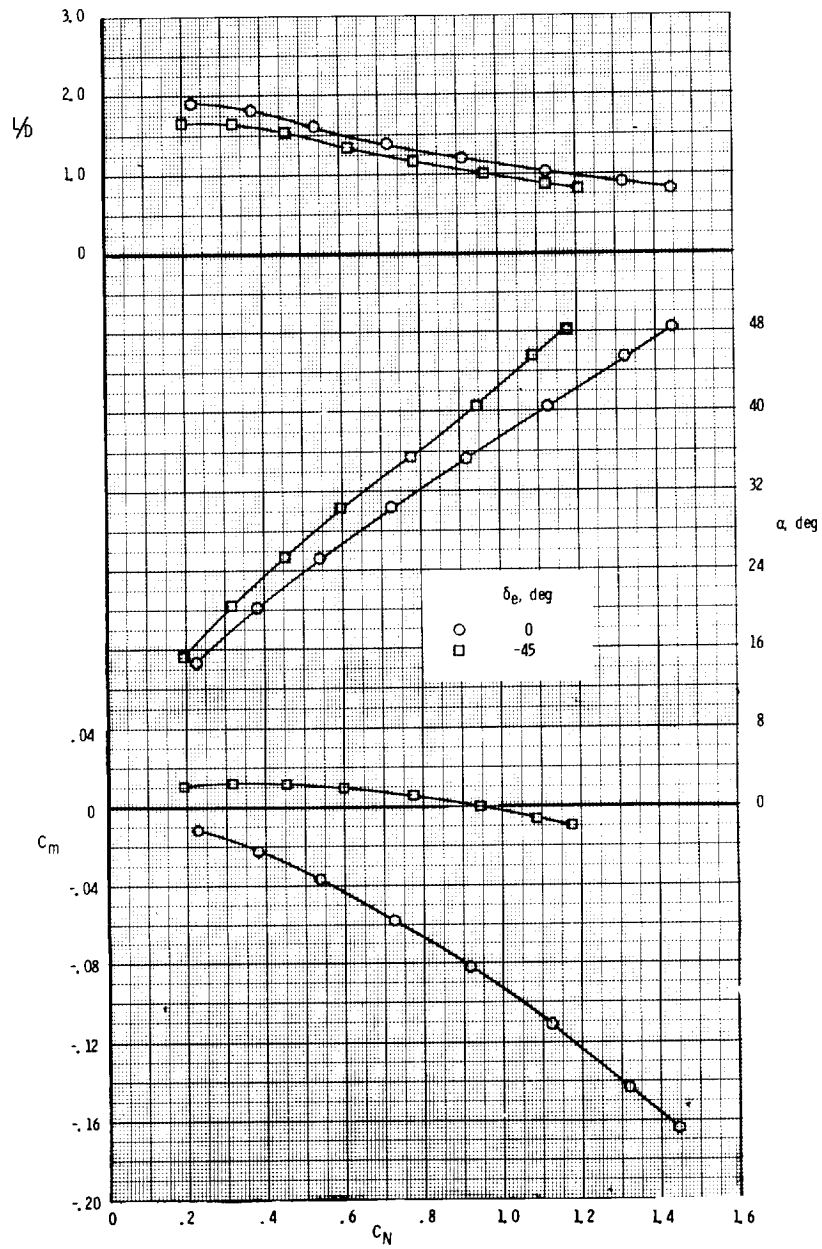


Figure 18.- Hypersonic aerodynamic characteristics for configuration BW<sub>p</sub>V<sub>1</sub>. M = 10.33.

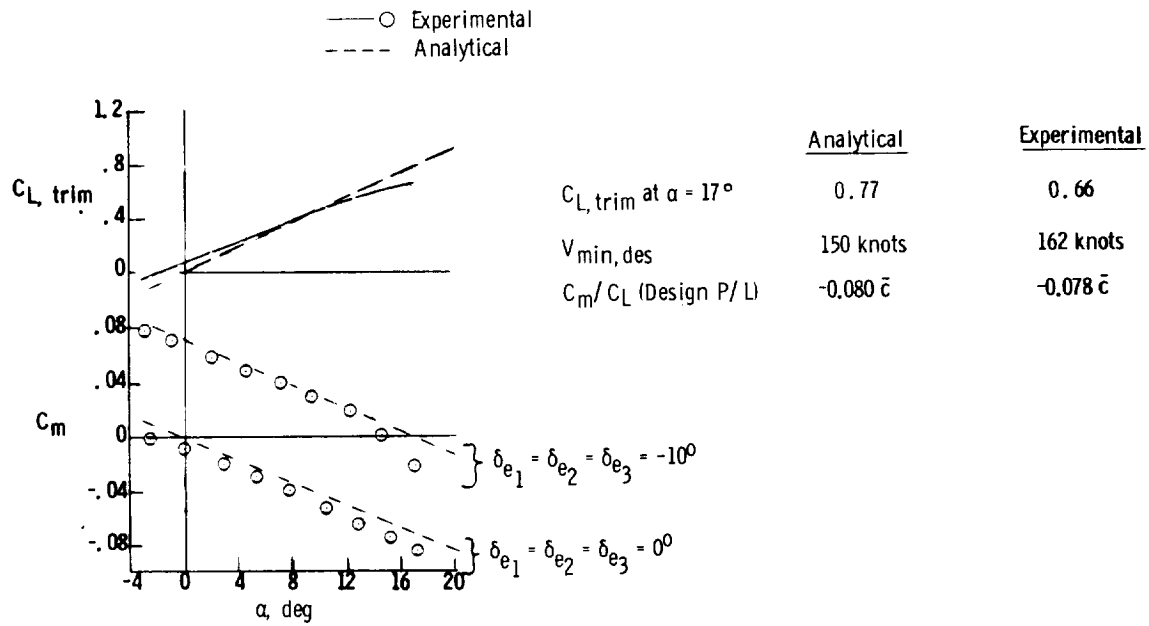


Figure 19.- Comparison of subsonic analytical aerodynamic characteristics with wind-tunnel experimental values for configuration BW<sub>p</sub>V<sub>2</sub>.

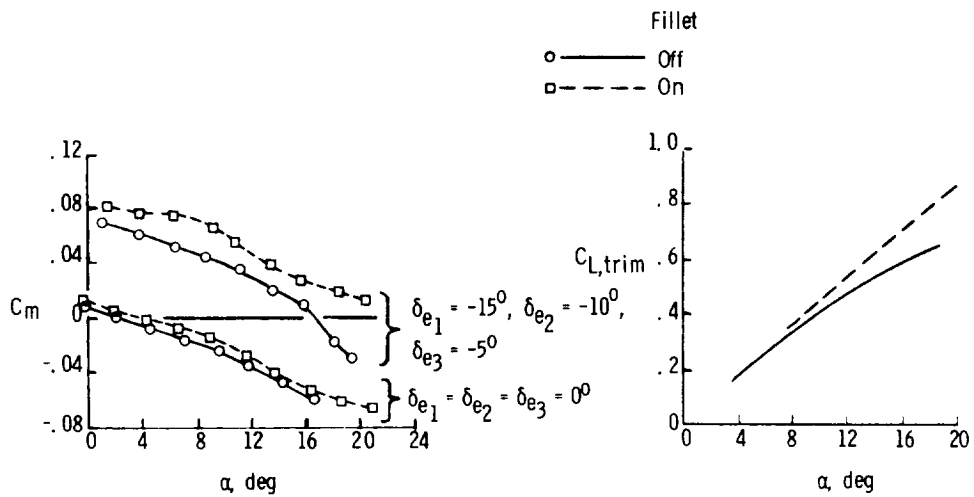


Figure 20.- Effect of the planform fillet on the subsonic aerodynamic characteristics of configuration BW<sub>T</sub>V<sub>2</sub>.

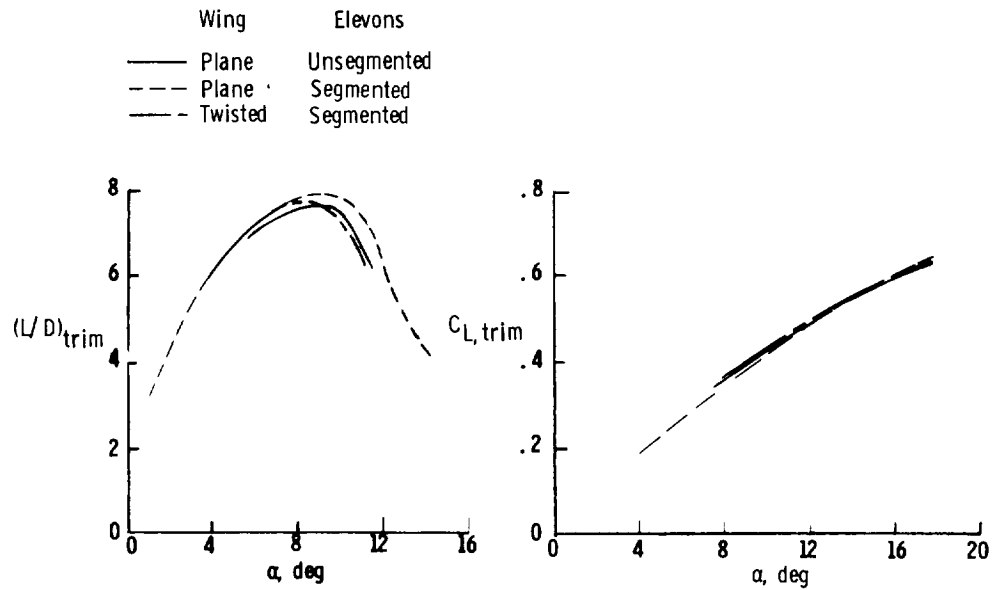


Figure 21.- Some experimental effects of segmented elevons and wing twist on the trimmed subsonic aerodynamic characteristics.

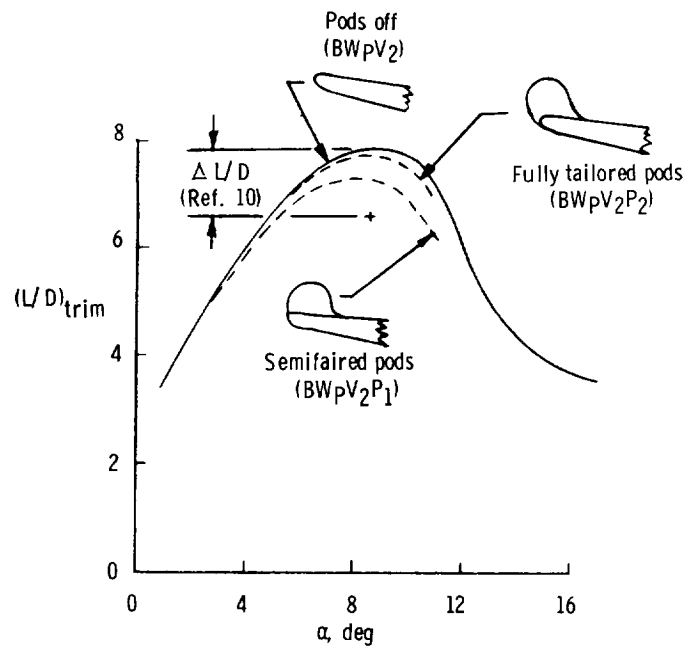


Figure 22.- Experimental subsonic effects of wing-tip-mounted ACPS pods.

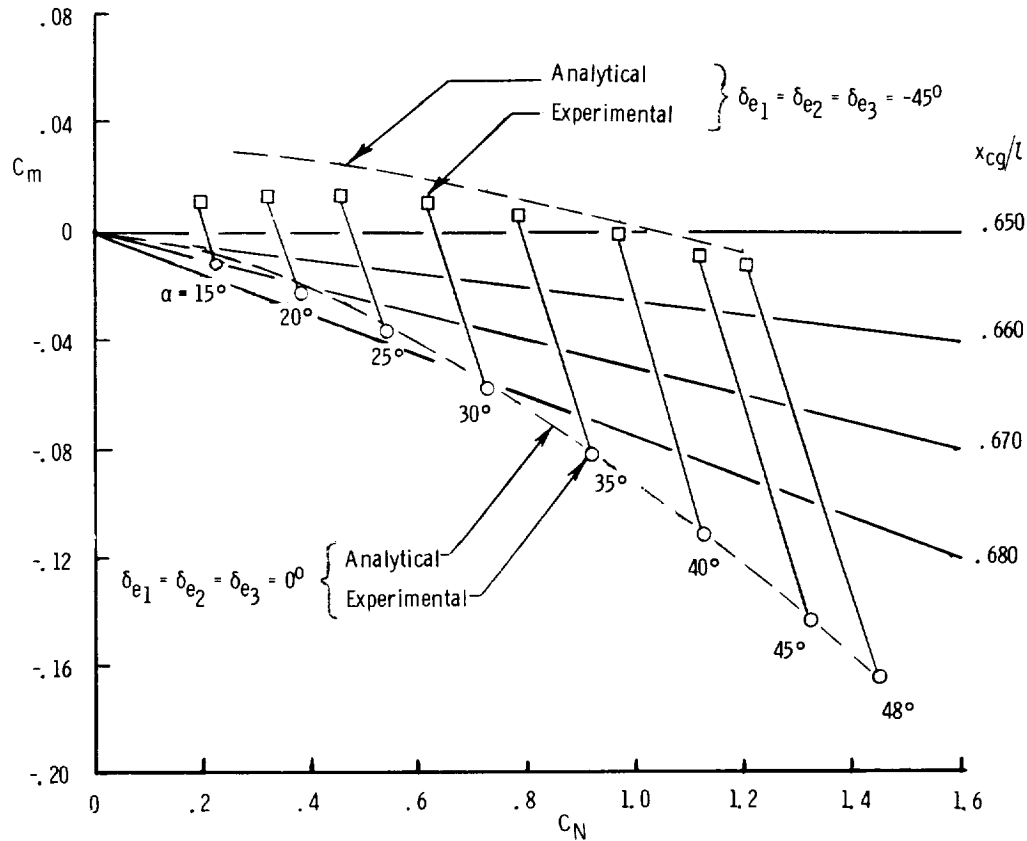


Figure 23.- Experimental hypersonic trim characteristics as compared to analytically obtained values for configuration BWpV1.

Effects of segmented elevons and wing twist.- The effect of varying spanwise deflections of trisegmented elevons (more negative for the inboard segments) and wing twist on the longitudinal trim characteristics of the configuration is shown in figure 21. Use of variations in spanwise elevon deflections produced little or no increase in trimmed lift coefficients at landing angles of attack ( $\alpha > 15^\circ$ ) for the basic plane wing configuration. However, some increase in trimmed  $(L/D)_{max}$  was noted for the configuration using variations in spanwise elevon deflection for trim. Only slight changes in trimmed lift coefficients were produced by incorporating linear wing twist ( $4.5^\circ$  washout) in the subsonic model although some reductions in  $L/D$  are attributed to the introduction of wing twist for angles of attack near and above  $(L/D)_{max}$ .

Subsonic ACPS tip pod effects.- Significant degradations in trimmed lift-drag ratios have been associated with the addition of unfaired wing-tip-mounted ACPS pods to space shuttle orbiters (ref. 10). Figure 22 shows the  $(L/D)_{max}$  decrement from reference 10

to be about 1.2 which would result in an approach glide-slope angle increase somewhat greater than  $1^\circ$ . An attempt was made to assess the effects of tailoring the ACPS pod external shape on  $L/D$  ratios. For this purpose, two wing-tip pod configurations were tested on the plane-wing configuration  $BW_PV_2$  (fig. 5(b)) which fulfilled the volumetric requirements for roll-control ACPS. The two configurations represented semifaired and fully tailored designs. Addition of the semifaired pod to configuration  $BW_PV_2$  produced a trimmed  $(L/D)_{\max}$  decrement of about 0.7 (fig. 22) whereas the fully tailored fairing of the pods resulted in a decrement of only about 0.1.

Hypersonic analytical and experimental comparisons.- The basic longitudinal aerodynamic characteristics obtained for configuration  $BW_PV_1$  at  $M = 10.33$  in the Langley continuous-flow hypersonic tunnel are shown in figure 18. A comparison of these data with the analytically predicted pitch trim characteristics is presented in figure 23. This experimental data comparison indicates a reduction of approximately  $5^\circ$  in maximum trimmed angle-of-attack capability for the configuration with  $\delta_{e_1} = \delta_{e_2} = \delta_{e_3} = -45^\circ$ ; this reduction thereby produces an  $\alpha_{\max, \text{trim}}$  of about  $40^\circ$  for the design payload condition ( $x_{cg}/l = 0.650$ ). Experimental effects of fuselage widening and of changing the fuselage nose camber (see ref. 9) indicate the necessity of only minor modifications to increase the trimmed hypersonic maximum angle of attack for the present configuration from  $40^\circ$  to  $50^\circ$ . Although no hypersonic data were obtained for configuration  $BW_PV_1F$  (incorporating the planform fillet and the aftward wing movement), estimates of stability and control indicate the possibility of some improvement in hypersonic maximum angle-of-attack trim capability for this configuration.

Summarization of vehicle performance characteristics.- During the course of the present analytical and experimental orbiter wing design study, a configuration  $BW_TV_2F$  (incorporating a  $0.03\bar{c}$  aft wing movement) was developed which would essentially satisfy the established design guidelines. Figure 24 summarizes the experimental aerodynamic performance, stability, and control characteristics for this configuration. Stable subsonic static margins were found for the configuration throughout the envelope which are in accord with the preset study guidelines as is the  $V_{\min, \text{des}}$  value of 148 knots.

Maximum hypersonic trim capability for configuration  $BW_PV_1F$  is estimated at  $\alpha_{\max, \text{trim}} \approx 40^\circ$  for the design payload condition. This value is approximately  $10^\circ$  less than the guideline value of  $50^\circ$  which might be attained with some fuselage nose reshaping and/or elevon resizing which would not adversely alter the subsonic flight characteristics.

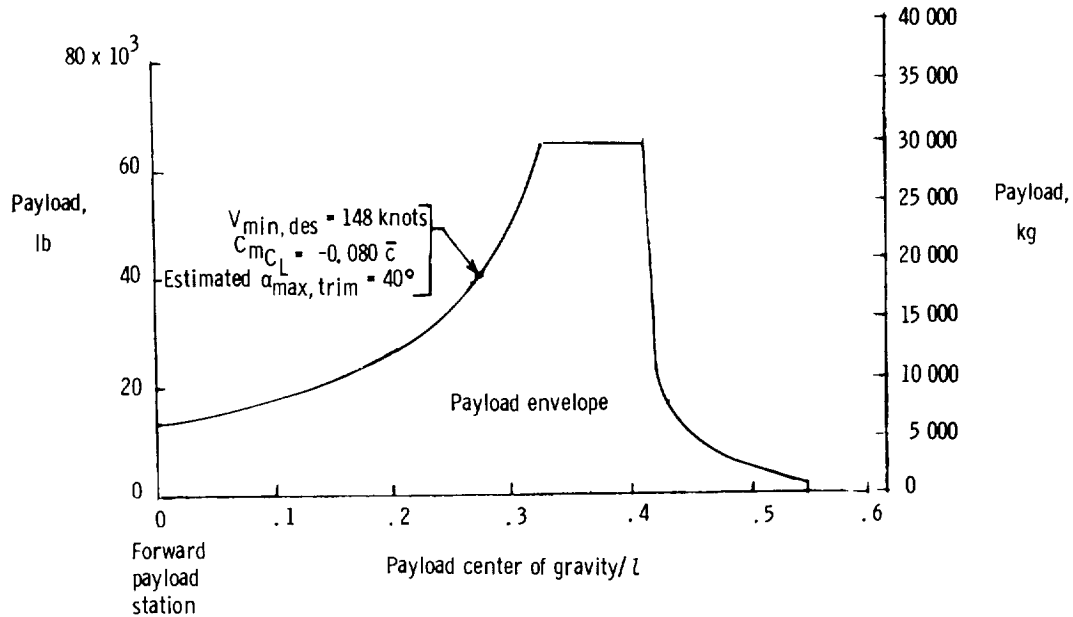


Figure 24. - Summary of experimental performance characteristics for configuration BW<sub>T</sub>V<sub>2</sub>F as applied to the various landed payload loadings of the space shuttle.

### SUMMARY OF RESULTS

An analytical and experimental investigation has been made to define a space shuttle orbiter wing configuration meeting requirements for landing performance, stability, and hypersonic trim for a specified center-of-gravity envelope. The analytical part of the study was facilitated by the use of the Optimal Design Integration system (ODIN). Limited experimental studies were made in the Langley low-turbulence pressure tunnel and the Langley continuous-flow hypersonic tunnel to verify the aerodynamic characteristics of the orbiter configuration selected analytically. Results are summarized as follows:

1. Use of the ODIN system greatly simplified the handling of analytical data while maintaining compliance with the space shuttle general vehicle requirements and allowed the expedient selection of a desirable wing planform. The analytical aerodynamic estimates obtained by using the ODIN system were in reasonable agreement with experimental results obtained subsequently for the orbiter configuration selected.

2. The analytical study suggested reductions in wing sweep to produce a minimum wing area (minimum weight) configuration. Reductions in wing area and sweep also



enhanced the high-angle-of-attack trim capability at hypersonic speeds. This trend, however, was constrained by entry heating considerations to preclude wing leading-edge sweep angles below  $45^{\circ}$ . Attempting to meet the hypersonic and subsonic guidelines directed the study toward using a negatively swept wing trailing edge to provide increased hypersonic trim capability and desirable subsonic flight characteristics.

3. The analytically selected orbiter configuration required minor experimental wind-tunnel refinements to provide a viable orbiter configuration. The primary refinement was the addition of a small planform fillet to increase lift coefficients at landing attitudes accompanied by an aft wing movement.

4. Significant reductions in lift-drag ratio losses due to the addition of attitude-control propulsion system wing-tip pods were attained by tailoring the external shape of pods designed to house the roll-attitude control system.

5. The use of sequentially deflected segmented elevons improved subsonic trimmed lift-drag ratios which may be beneficial to landing-approach glide-slope performance.

Langley Research Center,  
National Aeronautics and Space Administration,  
Hampton, Va., January 18, 1974.

## APPENDIX

### ANALYTICAL DATA

The characteristics of the wings investigated are presented in this appendix. An index of these characteristics is presented in table V.

TABLE V. - INDEX OF CHARACTERISTICS OF WINGS INVESTIGATED

| Wing                  | $x_{wing}/l$ | $S_{ref}$      |                 | $\Lambda_{le}$ ,<br>deg | $\Lambda_{te}$ ,<br>deg | A    | Subsonic $C_{mC_L}$<br>(based on $\bar{c}$ ) |         | $V_{min,des}$ ,<br>knots<br>(40K P/L) | Hypersonic<br>$\alpha_{max,trim}$ ,<br>deg<br>(40K P/L) | XSF | YSF | $\frac{S_{elevator}}{S_{ref}}$ | Page |
|-----------------------|--------------|----------------|-----------------|-------------------------|-------------------------|------|--|---------|---------------------------------------|---|-----|-----|--------------------------------|------|
|                       |              | m <sup>2</sup> | ft <sup>2</sup> |                         |                         |      | P/L out                                      | 40K P/L |                                       |   |     |     |                                |      |
|                       |              |                |                 |                         |                         |      |  |         |                                       |   |     |     |                                |      |
| W <sub>1</sub>        | 0.5404       | 207.0          | 2228            | 60.0                    | 0.0                     | 1.74 | -0.0282                                      | -0.0843 | 204                                   | 59  | 0.8 | 0.8 | 0.131                          | 47   |
| W <sub>2</sub>        | .4928        | 258.7          | 2785            | 65.2                    |                         | 1.39 | -.0282                                       | -.0759  | 203                                   | 45  | 1.0 | .8  | .131                           | 48   |
| W <sub>3</sub>        | .4517        | 310.5          | 3342            | 68.9                    |                         | 1.16 | -.0293                                       | -.0721  | 204                                   | 36  | 1.2 | .8  | .131                           | 49   |
| W <sub>4</sub>        | .4152        | 362.2          | 3899            | 71.7                    |                         | .99  | -.0310                                       | -.0708  | 206                                   | 31  | 1.4 | .8  | .131                           | 50   |
| W <sub>5</sub>        | .3805        | 414.0          | 4456            | 73.9                    |                         | .87  | -.0316                                       | -.0696  | 207                                   | 29  | 1.6 | .8  | .131                           | 51   |
| W <sub>6</sub>        | .5192        | 234.5          | 2524            | 54.2                    |                         | 2.14 | -.0290                                       | -.0870  | 179                                   | 53  | .8  | 1.0 | .144                           | 52   |
| W <sub>7</sub>        | .4718        | 293.2          | 3156            | 60.0                    |                         | 1.71 | -.0275                                       | -.0770  | 177                                   | 41  | 1.0 | 1.0 | .144                           | 53   |
| W <sub>8</sub>        | .4335        | 351.8          | 3787            | 64.3                    |                         | 1.42 | -.0318                                       | -.0764  | 178                                   | 33  | 1.2 | 1.0 | .144                           | 54   |
| W <sub>9</sub>        | .3942        | 410.4          | 4418            | 67.6                    |                         | 1.22 | -.0312                                       | -.0727  | 178                                   | 30  | 1.4 | 1.0 | .144                           | 55   |
| W <sub>10</sub>       | .3586        | 469.1          | 5049            | 70.2                    |                         | 1.07 | -.0317                                       | -.0712  | 178                                   | 28  | 1.6 | 1.0 | .144                           | 56   |
| W <sub>11</sub>       | .5074        | 262.9          | 2830            | 49.1                    |                         | 2.54 | -.0278                                       | -.0873  | 161                                   | 48  | .8  | 1.2 | .155                           | 57   |
| W <sub>12</sub>       | .4627        | 328.6          | 3537            | 55.3                    |                         | 2.03 | -.0288                                       | -.0798  | 158                                   | 37  | 1.0 | 1.2 | .155                           | 58   |
| W <sub>13</sub>       | .4243        | 394.3          | 4244            | 60.0                    |                         | 1.69 | -.0324                                       | -.0786  | 158                                   | 31  | 1.2 | 1.2 | .155                           | 59   |
| W <sub>14</sub>       | .3842        | 460.0          | 4952            | 63.7                    |                         | 1.45 | -.0312                                       | -.0741  | 157                                   | 28  | 1.4 | 1.2 | .155                           | 60   |
| W <sub>15</sub>       | .3486        | 525.7          | 5659            | 66.6                    |                         | 1.27 | -.0316                                       | -.0725  | 157                                   | 27  | 1.6 | 1.2 | .155                           | 61   |
| W <sub>16</sub>       | .5010        | 291.6          | 3139            | 44.7                    |                         | 2.94 | -.0283                                       | -.0891  | 147                                   | 44  | .8  | 1.4 | .163                           | 62   |
| W <sub>17</sub>       | .4563        | 364.6          | 3924            | 51.1                    |                         | 2.35 | -.0277                                       | -.0800  | 143                                   | 34  | 1.0 | 1.4 | .163                           | 63   |
| W <sub>18</sub>       | .4179        | 437.5          | 4709            | 56.0                    |                         | 1.96 | -.0306                                       | -.0779  | 142                                   | 30  | 1.2 | 1.4 | .163                           | 64   |
| W <sub>19</sub>       | .3796        | 510.4          | 5494            | 60.0                    |                         | 1.68 | -.0311                                       | -.0752  | 141                                   | 27  | 1.4 | 1.4 | .163                           | 65   |
| W <sub>20</sub>       | .3431        | 583.3          | 6279            | 63.2                    |                         | 1.47 | -.0314                                       | -.0735  | 141                                   | 26  | 1.6 | 1.4 | .163                           | 66   |
| W <sub>21</sub>       | .4973        | 320.7          | 3452            | 40.9                    |                         | 3.34 | -.0287                                       | -.0906  | 136                                   | 40  | .8  | 1.6 | .169                           | 67   |
| W <sub>22</sub>       | .4554        | 400.9          | 4315            | 47.3                    |                         | 2.67 | -.0287                                       | -.0821  | 132                                   | 32  | 1.0 | 1.6 | .169                           | 68   |
| W <sub>23</sub>       | .4179        | 481.0          | 5178            | 52.4                    |                         | 2.23 | -.0324                                       | -.0810  | 131                                   | 28  | 1.2 | 1.6 | .169                           | 69   |
| W <sub>24</sub>       | .3778        | 561.2          | 6041            | 56.6                    |                         | 1.91 | -.0310                                       | -.0762  | 129                                   | 27  | 1.4 | 1.6 | .169                           | 70   |
| W <sub>25</sub>       | .3422        | 641.4          | 6904            | 60.0                    |                         | 1.67 | -.0312                                       | -.0745  | 129                                   | 26  | 1.6 | 1.6 | .169                           | 71   |
| W <sub>26</sub>       | .4882        | 279.7          | 3011            | 54.8                    |                         | 2.08 | -.0278                                       | -.0817  | 168                                   | 44  | .9  | 1.1 | .150                           | 72   |
| W <sub>27</sub>       | .4791        | 311.9          | 3357            | 50.2                    |                         | 2.44 | -.0254                                       | -.0806  | 151                                   | 40  | .9  | 1.3 | .159                           | 73   |
| W <sub>28</sub>       | .4763        | 344.4          | 3707            | 46.1                    |                         | 2.79 | -.0272                                       | -.0837  | 139                                   | 37  | .9  | 1.5 | .166                           | 74   |
| W <sub>29</sub>       | .4417        | 381.2          | 4103            | 55.7                    |                         | 1.99 | -.0327                                       | -.0818  | 150                                   | 32  | 1.1 | 1.3 | .159                           | 75   |
| W <sub>30</sub>       | .4572        | 346.5          | 3730            | 53.1                    |                         | 2.19 | -.0261                                       | -.0776  | 150                                   | 36  | 1.0 | 1.3 | .159                           | 76   |
| W <sub>31</sub>       | .4846        | 295.7          | 3183            | 52.4                    |                         | 2.26 | -.0289                                       | -.0836  | 159                                   | 42  | .9  | 1.2 | .155                           | 77   |
| W <sub>32</sub>       | .4773        | 328.0          | 3531            | 48.1                    |                         | 2.62 | -.0261                                       | -.0819  | 144                                   | 38  | .9  | 1.4 | .163                           | 78   |
| W <sub>33</sub>       | .5046        | 277.1          | 2983            | 46.8                    |                         | 2.74 | -.0297                                       | -.0900  | 154                                   | 46  | .8  | 1.3 | .159                           | 79   |
| W <sub>34</sub>       | .5366        | 233.1          | 2509            | 47.8                    |                         | 2.87 | -.0286                                       | -.0940  | 171                                   | 59  | .7  | 1.1 | .150                           | 80   |
| W <sub>35</sub>       | .5320        | 214.7          | 2311            | 45.3                    |                         | 2.71 | -.0289                                       | -.0949  | 163                                   | 57  | .7  | 1.2 | .155                           | 81   |
| W <sub>27</sub> (Mod) | .4773        | 328.4          | 3535            | 50.2                    | -7.0                    | 2.31 | -.0281                                       | -.0804  | 150                                   | 41  | .9  | 1.3 | .183                           | 82   |
| W <sub>33</sub> (Mod) | .4955        | 314.7          | 3387            | 46.8                    | -11.0                   | 2.42 | -.0280                                       | -.0804  | 150                                   | 49  | .8  | 1.3 | .216                           | 83   |

APPENDIX - Continued

ODIN Wing W<sub>1</sub>

|   |             |           |                |
|---|-------------|-----------|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |                |
| AREA, PLANFORM (SFT)                      |             |           | 2999.4         |
| LENGTH, NOSE TO WING LE AT BODY           |             |           | 710.02 IN      |
| LENGTH, NOSE TO WING C/4                  |             |           | 903.27 IN      |
| ANGLE, GROUND PLANE                       | *FIXED*     |           | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |                |
| AREA, WETTED                              | *FIXED*     |           | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY               | *FIXED*     |           | 1315.0 IN      |
| 3. WING                                   |             |           |                |
| AREA, THEORETICAL OR TOTAL                |             |           | 2228.1 SFT     |
| AREA, ELEVON                              |             |           | 291.53 SFT     |
| SPAN                                      |             |           | 746.40 IN      |
| CHORD, MEAN AERODYNAMIC                   |             |           | 510.88 IN      |
| CHORD, CENTERLINE ROOT                    |             |           | 753.05 IN      |
| CHORD, TIP                                |             |           | 106.66 IN      |
| TAPER RATIO, THEORETICAL                  |             |           | .14163         |
| ASPECT RATIO, THEORETICAL                 |             |           | 1.7364         |
| ASPECT RATIO, EXPOSED SPAN                |             |           | 1.5882         |
| ANGLE, LEADING EDGE SWEEP                 |             |           | 59.998 DEG     |
| ANGLE, TRAILING EDGE SWEEP                | *FIXED*     |           | 0.0 DEG        |
| ANGLE, DIHEDRAL                           | *FIXED*     |           | 7.0 DEG        |
| ANGLE, INCIDENCE                          | *FIXED*     |           | 1.5 DEG        |
| AIRCIL SECTION, ROOT                      | *FIXED*     |           | 008-64         |
| AIRCIL SECTION, TIP                       | *FIXED*     |           | 008-64         |
| 4. O40A MASS PROPERTIES                   |             |           |                |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) | X-CG (PC L)    |
| ORBITER LNDG (W/40K PL)                   | 191590.2    | 70.881    | 64.684         |
| ORBITER LNDG (W/O PL)                     | 151590.2    | 73.268    | 66.863         |
| WING WEIGHT                               | 12493.5     |           |                |
| IPS WEIGHT                                | 22990.7     |           |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |                |
| X-SCALE FACTOR                            |             |           | SCLX= .80000   |
| Y-SCALE FACTOR                            |             |           | SCLY= .80000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           | XOF=710.023 IN |
| 6. LANDING PERFORMANCE                    |             |           |                |
| MINIMUM LANDING SPEED (W/40K PL)          |             |           | 203.5 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             |           | -.0843         |
| STATIC MARGIN (SUBSONIC) (W/O PL)         |             |           | -.0282         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |           | .6134          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           | 58.59 DEG      |

APPENDIX - Continued

ODIN Wing W<sub>2</sub>

|   |             |           |                |
|---|-------------|-----------|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |                |
| AREA, PLANFORM (SFT)                      |             |           | 3321.0         |
| LENGTH, NOSE TO WING LE AT BODY           |             |           | 648.44 IN      |
| LENGTH, NOSE TO WING C/4                  |             |           | 890.00 IN      |
| ANGLE, GROUND PLANE                       |             | *FIXED*   | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |                |
| AREA, WETTED                              |             | *FIXED*   | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY               |             | *FIXED*   | 1315.0 IN      |
| 3. WING                                   |             |           |                |
| AREA, THEORETICAL OR TOTAL                |             |           | 2785.1 SFT     |
| AREA, ELEVON                              |             |           | 364.42 SFT     |
| SPAN                                      |             |           | 746.40 IN      |
| CHORD, MEAN AERODYNAMIC                   |             |           | 638.60 IN      |
| CHORD, CENTERLINE ROOT                    |             |           | 941.31 IN      |
| CHORD, TIP                                |             |           | 133.32 IN      |
| TAPER RATIO, THEORETICAL                  |             |           | .14163         |
| ASPECT RATIO, THEORETICAL                 |             |           | 1.3891         |
| ASPECT RATIO, EXPOSED SPAN                |             |           | 1.2705         |
| ANGLE, LEADING EDGE SWEEP                 |             |           | 65.207 DEG     |
| ANGLE, TRAILING EDGE SWEEP                |             | *FIXED*   | 0.0 DEG        |
| ANGLE, DIHEDRAL                           |             | *FIXED*   | 7.0 DEG        |
| ANGLE, INCIDENCE                          |             | *FIXED*   | 1.5 DEG        |
| AIRCIL SECTION, ROOT                      |             | *FIXED*   | 008-64         |
| AIRCIL SECTION, TIP                       |             | *FIXED*   | 008-64         |
| 4. O40A MASS PROPERTIES                   |             |           |                |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) | X-CG (PC L)    |
| ORBITER LNDG (w/40K PL)                   | 194150.0    | 71.624    | 65.362         |
| ORBITER LNDG (w/O PL)                     | 154150.0    | 74.165    | 67.681         |
| WING WEIGHT                               | 12994.4     |           |                |
| TPS WEIGHT                                | 25049.5     |           |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |                |
| X-SCALE FACTOR                            |             |           | SCLX= 1.0000   |
| Y-SCALE FACTOR                            |             |           | SCLY= .80000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           | XOF=648.442 IN |
| 6. LANDING PERFORMANCE                    |             |           |                |
| MINIMUM LANDING SPEED (w/40K PL)          |             |           | 203.3 KT       |
| STATIC MARGIN (SUBSONIC) (w/40K PL)       |             |           | -.0759         |
| STATIC MARGIN (SUBSONIC) (w/O PL)         |             |           | -.0282         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |           | .4980          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           | 45.35 DEG      |

APPENDIX - Continued

ODIN Wing W3

|   |              |           |                |
|---|--------------|-----------|----------------|
| 1. OVERALL CONFIGURATION                  |              |           |                |
| AREA, PLANFORM (SFT)                      |              |           | 3642.6         |
| LENGTH, NOSE TO WING LE AT BODY           |              |           | 554.36 IN      |
| LENGTH, NOSE TO WING C/4                  |              |           | 884.23 IN      |
| ANGLE, GROUND PLANE                       | *FIXED*      |           | 17.00 DEG      |
| 2. FUSELAGE                               |              |           |                |
| AREA, WETTED                              | *FIXED*      |           | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY               | *FIXED*      |           | 1315.0 IN      |
| 3. WING                                   |              |           |                |
| AREA, THEORETICAL OR TOTAL                |              |           | 3342.1 SFT     |
| AREA, ELEVON                              |              |           | 437.30 SFT     |
| SPAN                                      |              |           | 746.40 IN      |
| CHORD, MEAN AERODYNAMIC                   |              |           | 766.32 IN      |
| CHORD, CENTERLINE ROOT                    |              |           | 1129.6 IN      |
| CHORD, TIP                                |              |           | 159.98 IN      |
| TAPER RATIO, THEORETICAL                  |              |           | .14163         |
| ASPECT RATIO, THEORETICAL                 |              |           | 1.1576         |
| ASPECT RATIO, EXPOSED SPAN                |              |           | 1.0588         |
| ANGLE, LEADING EDGE SWEEP                 |              |           | 68.947 DEG     |
| ANGLE, TRAILING EDGE SWEEP                | *FIXED*      |           | 0.0 DEG        |
| ANGLE, DIHEDRAL                           | *FIXED*      |           | 7.0 DEG        |
| ANGLE, INCIDENCE                          | *FIXED*      |           | 1.5 DEG        |
| AIRFOIL SECTION, ROOT                     | *FIXED*      |           | 008-64         |
| AIRFOIL SECTION, TIP                      | *FIXED*      |           | 008-64         |
| 4. O40A MASS PROPERTIES                   |              |           |                |
| FLIGHT CONDITION                          | WEIGHT (LBS) | X-CG (FT) | X-CG (PC I)    |
| ORBITER LNDG (W/40K PL)                   | 196729.0     | 72.551    | 66.208         |
| ORBITER LNDG (W/J PL)                     | 156729.0     | 75.286    | 68.704         |
| WING WEIGHT                               | 13508.6      |           |                |
| TPS WEIGHT                                | 27114.4      |           |                |
| 5. PRINCIPAL PARAMETERS                   |              |           |                |
| X-SCALE FACTOR                            |              |           | SCLX= 1.2000   |
| Y-SCALE FACTOR                            |              |           | SCLY= .80000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |              |           | XCF=594.360 IN |
| 6. LANDING PERFORMANCE                    |              |           |                |
| MINIMUM LANDING SPEED (W/40K PL)          |              |           | 204.1 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |              |           | -.0721         |
| STATIC MARGIN (SUBSONIC) (W/O PL)         |              |           | -.0293         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |              |           | .4172          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |              |           |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |              |           | 36.33 DEG      |

APPENDIX - Continued

ODIN Wing W<sub>4</sub>

|   |             |           |                |
|---|-------------|-----------|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |                |
| AREA, PLANFORM (SFT)                      |             |           | 3964.2         |
| LENGTH, NOSE TO WING LE AT BODY           |             |           | 546.17 IN      |
| LENGTH, NOSE TO WING C/4                  |             |           | 884.35 IN      |
| ANGLE, GROUND PLANE                       |             | *FIXED*   | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |                |
| AREA, WETTED                              |             | *FIXED*   | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY               |             | *FIXED*   | 1315.0 IN      |
| 3. WING                                   |             |           |                |
| AREA, THEORETICAL OR TOTAL                |             |           | 3899.1 SFT     |
| AREA, ELEVON                              |             |           | 510.18 SFT     |
| SPAN                                      |             |           | 746.40 IN      |
| CHORD, MEAN AERODYNAMIC                   |             |           | 894.04 IN      |
| CHORD, CENTERLINE ROOT                    |             |           | 1317.8 IN      |
| CHORD, TIP                                |             |           | 186.65 IN      |
| TAPER RATIO, THEORETICAL                  |             |           | .14163         |
| ASPECT RATIO, THEORETICAL                 |             |           | .59223         |
| ASPECT RATIO, EXPOSED SPAN                |             |           | .50753         |
| ANGLE, LEADING EDGE SWEEP                 |             |           | 71.740 DEG     |
| ANGLE, TRAILING EDGE SWEEP                |             | *FIXED*   | 0.0 DEG        |
| ANGLE, DIHEDRAL                           |             | *FIXED*   | 7.0 DEG        |
| ANGLE, INCIDENCE                          |             | *FIXED*   | 1.5 DEG        |
| AIRFOIL SECTION, ROOT                     |             | *FIXED*   | 008-64         |
| AIRFOIL SECTION, TIP                      |             | *FIXED*   | 008-64         |
| 4. U40A MASS PROPERTIES                   |             |           |                |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) | X-CG (PC L)    |
| ORBITER LNDG (W/40K PL)                   | 159310.4    | 73.656    | 67.217         |
| ORBITER LNDG (W/O PL)                     | 159310.4    | 76.625    | 69.926         |
| WING WEIGHT                               | 14021.4     |           |                |
| TPS WEIGHT                                | 29183.0     |           |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |                |
| X-SCALE FACTOR                            |             |           | SCLX= 1.4000   |
| Y-SCALE FACTOR                            |             |           | SCLY= .80000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           | XUF=546.165 IN |
| 6. LANDING PERFORMANCE                    |             |           |                |
| MINIMUM LANDING SPEED (W/40K PL)          |             |           | 205.6 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             |           | -.0708         |
| STATIC MARGIN (SUBSONIC) (W/O PL)         |             |           | -.0310         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |           | .3572          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           | 31.46 DEG      |

APPENDIX - Continued

ODIN Wing W<sub>5</sub>

|   |             |           |         |                |
|---|-------------|-----------|---------|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |         |                |
| AREA, PLANFORM (SFT)                      |             |           |         | 4285.8         |
| LENGTH, NOSE TO WING LE AT BODY           |             |           |         | 500.27 IN      |
| LENGTH, NOSE TO WING C/4                  |             |           |         | 886.77 IN      |
| ANGLE, GROUND PLANE                       |             |           | *FIXED* | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |         |                |
| AREA, WETTED                              |             |           | *FIXED* | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY               |             |           | *FIXED* | 1315.0 IN      |
| 3. WING                                   |             |           |         |                |
| AREA, THEORETICAL OF TOTAL                |             |           |         | 4456.2 SFT     |
| AREA, ELEVON                              |             |           |         | 583.07 SFT     |
| SPAN                                      |             |           |         | 746.40 IN      |
| CHORD, MEAN AERODYNAMIC                   |             |           |         | 1021.8 IN      |
| CHORD, CENTERLINE ROOT                    |             |           |         | 1506.1 IN      |
| CHORD, TIP                                |             |           |         | 213.31 IN      |
| TAPER RATIO, THEORETICAL                  |             |           |         | .14163         |
| ASPECT RATIO, THEORETICAL                 |             |           |         | .86820         |
| ASPECT RATIO, EXPOSED SPAN                |             |           |         | .75409         |
| ANGLE, LEADING EDGE SWEEP                 |             |           |         | 73.896 DEG     |
| ANGLE, TRAILING EDGE SWEEP                |             |           | *FIXED* | 0.0 DEG        |
| ANGLE, DIHEDRAL                           |             |           | *FIXED* | 7.0 DEG        |
| ANGLE, INCIDENCE                          |             |           | *FIXED* | 1.5 DEG        |
| AIRFOIL SECTION, ROOT                     |             |           | *FIXED* | 008-64         |
| AIRFOIL SECTION, TIP                      |             |           | *FIXED* | 008-64         |
| 4. O40A MASS PROPERTIES                   |             |           |         |                |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) |         | X-CG (PC L)    |
| ORBITER LNDG (W/40K PL)                   | 201884.8    | 74.906    |         | 68.358         |
| ORBITER LNDG (W/J PL)                     | 151884.8    | 78.136    |         | 71.305         |
| WING WEIGHT                               | 14524.8     |           |         |                |
| TPS WEIGHT                                | 31254.1     |           |         |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |         |                |
| X-SCALE FACTOR                            |             |           |         | SCLX= 1.6000   |
| Y-SCALE FACTOR                            |             |           |         | SCLY= .80000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           |         | XOF=500.272 IN |
| 6. LANDING PERFORMANCE                    |             |           |         |                |
| MINIMUM LANDING SPEED (W/40K PL)          |             |           |         | 206.9 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             |           |         | -.0696         |
| STATIC MARGIN (SUBSONIC) (W/C PL)         |             |           |         | -.0316         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |           |         | .3125          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |         |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           |         | 28.85 DEG      |

APPENDIX - Continued

ODIN Wing W6

|   |             |           |                |
|---|-------------|-----------|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |                |
| AREA, PLANFORM (SFT)                      |             |           | 3321.0         |
| LENGTH, NOSE TO WING LE AT BODY           |             |           | 682.59 IN      |
| LENGTH, NOSE TO WING C/4                  |             |           | 893.22 IN      |
| ANGLE, GROUND PLANE                       |             | *FIXED*   | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |                |
| AREA, WETTED                              |             | *FIXED*   | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY               |             | *FIXED*   | 1315.0 IN      |
| 3. WING                                   |             |           |                |
| AREA, THEORETICAL OR TOTAL                |             |           | 2524.7 SFT     |
| AREA, ELEVON                              |             |           | 364.42 SFT     |
| SPAN                                      |             |           | 882.00 IN      |
| CHORD, MEAN AERODYNAMIC                   |             |           | 487.70 IN      |
| CHORD, CENTERLINE ROOT                    |             |           | 717.72 IN      |
| CHORD, TIP                                |             |           | 106.66 IN      |
| TAPER RATIO, THEORETICAL                  |             |           | .14860         |
| ASPECT RATIO, THEORETICAL                 |             |           | 2.1398         |
| ASPECT RATIO, EXPOSED SPAN                |             |           | 1.9852         |
| ANGLE, LEADING EDGE SWEEP                 |             |           | 54.181 DEG     |
| ANGLE, TRAILING EDGE SWEEP                |             | *FIXED*   | 0.0 DEG        |
| ANGLE, DIHEDRAL                           |             | *FIXED*   | 7.0 DEG        |
| ANGLE, INCIDENCE                          |             | *FIXED*   | 1.5 DEG        |
| AIRFOIL SECTION, ROOT                     |             | *FIXED*   | 008-64         |
| AIRFOIL SECTION, TIP                      |             | *FIXED*   | 008-64         |
| 4. O40A MASS PROPERTIES                   |             |           |                |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) | X-CG (PC L)    |
| ORBITER LNDG (W/40K PL)                   | 154958.8    | 70.967    | 64.763         |
| ORBITER LNDG (W/O PL)                     | 154958.8    | 73.325    | 66.915         |
| WING WEIGHT                               | 14260.4     |           |                |
| TPS WEIGHT                                | 24592.4     |           |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |                |
| X-SCALE FACTOR                            |             |           | SCLX= .80000   |
| Y-SCALE FACTOR                            |             |           | SCLY= 1.0000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           | XOF=682.590 IN |
| 6. LANDING PERFORMANCE                    |             |           |                |
| MINIMUM LANDING SPEED (W/40K PL)          |             |           | 179.1 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             |           | -.0870         |
| STATIC MARGIN (SUBSONIC) (W/O PL)         |             |           | -.0290         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |           | .7111          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           | 53.21 DEG      |



APPENDIX - Continued

ODIN Wing W7

|   |             |           |                |
|---|-------------|-----------|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |                |
| AREA, PLANFORM (SFT)                      |             |           | 3723.0         |
| LENGTH, NOSE TO WING LE AT BODY           |             |           | 620.68 IN      |
| LENGTH, NOSE TO WING C/4                  |             |           | 883.97 IN      |
| ANGLE, GROUND PLANE                       |             | *FIXED*   | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |                |
| AREA, WETTED                              |             | *FIXED*   | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY               |             | *FIXED*   | 1315.0 IN      |
| 3. WING                                   |             |           |                |
| AREA, THEORETICAL OR TOTAL                |             |           | 3155.8 SFT     |
| AREA, ELEVON                              |             |           | 455.52 SFT     |
| SPAN                                      |             |           | 882.00 IN      |
| CHORD, MEAN AERODYNAMIC                   |             |           | 609.63 IN      |
| CHORD, CENTERLINE ROOT                    |             |           | 897.14 IN      |
| CHORD, TIP                                |             |           | 133.32 IN      |
| TAPER RATIO, THEORETICAL                  |             |           | .14860         |
| ASPECT RATIO, THEORETICAL                 |             |           | 1.7118         |
| ASPECT RATIO, EXPOSED SPAN                |             |           | 1.5882         |
| ANGLE, LEADING EDGE SWEEP                 |             |           | 59.998 DEG     |
| ANGLE, TRAILING EDGE SWEEP                |             | *FIXED*   | 0.0 DEG        |
| ANGLE, DIHEDRAL                           |             | *FIXED*   | 7.0 DEG        |
| ANGLE, INCIDENCE                          |             | *FIXED*   | 1.5 DEG        |
| AIRFOIL SECTION, ROOT                     |             | *FIXED*   | 008-64         |
| AIRFOIL SECTION, TIP                      |             | *FIXED*   | 008-64         |
| 4. O40A MASS PROPERTIES                   |             |           |                |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) | X-CG (PC L)    |
| ORBITER LNDG (w/40K PL)                   | 197850.1    | 71.748    | 65.475         |
| ORBITER LNDG (w/O PL)                     | 157850.1    | 74.260    | 67.768         |
| WING WEIGHT                               | 14703.5     |           |                |
| TPS WEIGHT                                | 27040.6     |           |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |                |
| X-SCALE FACTOR                            |             |           | SCLX= 1.0000   |
| Y-SCALE FACTOR                            |             |           | SCLY= 1.0000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           | XOF=620.678 IN |
| 6. LANDING PERFORMANCE                    |             |           |                |
| MINIMUM LANDING SPEED (w/40K PL)          |             |           | 176.9 KT       |
| STATIC MARGIN (SUBSONIC) (w/40K PL)       |             |           | -.0770         |
| STATIC MARGIN (SUBSONIC) (w/O PL)         |             |           | -.0275         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |           | .5917          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           | 40.83 DEG      |

APPENDIX - Continued

ODIN Wing W8

|   |             |           |                |
|---|-------------|-----------|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |                |
| AREA, PLANFORM (SFT)                      |             |           | 4125.0         |
| LENGTH, NOSE TO WING LE AT BODY           |             |           | 570.47 IN      |
| LENGTH, NOSE TO WING C/4                  |             |           | 886.42 IN      |
| ANGLE, GROUND PLANE                       |             | *FIXED*   | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |                |
| AREA, WETTED                              |             | *FIXED*   | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY               |             | *FIXED*   | 1315.0 IN      |
| 3. WING                                   |             |           |                |
| AREA, THEORETICAL OR TOTAL                |             |           | 3787.0 SFT     |
| AREA, ELEVON                              |             |           | 546.63 SFT     |
| SPAN                                      |             |           | 882.00 IN      |
| CHORD, MEAN AERODYNAMIC                   |             |           | 731.55 IN      |
| CHORD, CENTERLINE ROOT                    |             |           | 1076.6 IN      |
| CHORD, TIP                                |             |           | 159.98 IN      |
| TAPER RATIO, THEORETICAL                  |             |           | .14860         |
| ASPECT RATIO, THEORETICAL                 |             |           | 1.4265         |
| ASPECT RATIO, EXPOSED SPAN                |             |           | 1.3235         |
| ANGLE, LEADING EDGE SWEEP                 |             |           | 64.305 DEG     |
| ANGLE, TRAILING EDGE SWEEP                |             | *FIXED*   | 0.0 DEG        |
| ANGLE, DIHEDRAL                           |             | *FIXED*   | 7.0 DEG        |
| ANGLE, INCIDENCE                          |             | *FIXED*   | 1.5 DEG        |
| AIRFOIL SECTION, ROOT                     |             | *FIXED*   | 008-64         |
| AIRFOIL SECTION, TIP                      |             | *FIXED*   | 008-64         |
| 4. O40A MASS PROPERTIES                   |             |           |                |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) | X-CG (PC L)    |
| ORBITER LNDG (W/40K PL)                   | 200777.2    | 72.776    | 66.413         |
| ORBITER LNDG (W/O PL)                     | 160777.2    | 75.498    | 68.898         |
| WING WEIGHT                               | 15175.0     |           |                |
| TPS WEIGHT                                | 29456.2     |           |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |                |
| X-SCALE FACTOR                            |             |           | SCLX= 1.2000   |
| Y-SCALE FACTOR                            |             |           | SCLY= 1.0000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           | XOF=570.473 IN |
| 6. LANDING PERFORMANCE                    |             |           |                |
| MINIMUM LANDING SPEED (W/40K PL)          |             |           | 177.5 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             |           | -.0764         |
| STATIC MARGIN (SUBSONIC) (W/O PL)         |             |           | -.0318         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |           | .4969          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           | 32.97 DEG      |

APPENDIX - Continued

ODIN Wing W<sub>9</sub>

|   |             |           |                |            |
|---|-------------|-----------|----------------|------------|
| 1. OVERALL CONFIGURATION                  |             |           |                |            |
| AREA, PLANFORM (SFT)                      |             |           |                | 4527.0     |
| LENGTH, NOSE TO WING LE AT BODY           |             |           |                | 518.90 IN  |
| LENGTH, NOSE TO WING C/4                  |             |           |                | 887.50 IN  |
| ANGLE, GROUND PLANE                       |             | *FIXED*   |                | 17.00 DEG  |
| 2. FUSELAGE                               |             |           |                |            |
| AREA, WETTED                              |             |           | *FIXED*        | 6307.0 SFT |
| LENGTH, NOSE TO END OF BODY               |             |           | *FIXED*        | 1315.0 IN  |
| 3. WING                                   |             |           |                |            |
| AREA, THEORETICAL OR TOTAL                |             |           |                | 4418.1 SFT |
| AREA, ELEVON                              |             |           |                | 637.73 SFT |
| SPAN                                      |             |           |                | 882.00 IN  |
| CHORD, MEAN AERODYNAMIC                   |             |           |                | 853.48 IN  |
| CHORD, CENTERLINE ROOT                    |             |           |                | 1256.0 IN  |
| CHORD, TIP                                |             |           |                | 186.65 IN  |
| TAPER RATIO, THEORETICAL                  |             |           |                | .14860     |
| ASPECT RATIO, THEORETICAL                 |             |           |                | 1.2227     |
| ASPECT RATIO, EXPOSED SPAN                |             |           |                | 1.1344     |
| ANGLE, LEADING EDGE SWEEP                 |             |           |                | 67.588 DEG |
| ANGLE, TRAILING EDGE SWEEP                |             | *FIXED*   |                | 0.0 DEG    |
| ANGLE, DIHEDRAL                           |             | *FIXED*   |                | 7.0 DEG    |
| ANGLE, INCIDENCE                          |             | *FIXED*   |                | 1.5 DEG    |
| AIRFOIL SECTION, ROOT                     |             | *FIXED*   |                | 008-64     |
| AIRFOIL SECTION, TIP                      |             | *FIXED*   |                | 008-64     |
| 4. U40A MASS PROPERTIES                   |             |           |                |            |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) | X-CG (PC L)    |            |
| ORBITER LNDG (w/40K PL)                   | 203721.8    | 73.913    | 67.451         |            |
| ORBITER LNDG (w/J PL)                     | 163721.8    | 76.864    | 70.144         |            |
| WING WEIGHT                               | 15659.4     |           |                |            |
| TPS WEIGHT                                | 31950.4     |           |                |            |
| 5. PRINCIPAL PARAMETERS                   |             |           |                |            |
| X-SCALE FACTOR                            |             |           | SCLX= 1.4000   |            |
| Y-SCALE FACTOR                            |             |           | SCLY= 1.0000   |            |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           | XCF=518.903 IN |            |
| 6. LANDING PERFORMANCE                    |             |           |                |            |
| MINIMUM LANDING SPEED (w/40K PL)          |             |           | 177.5 KT       |            |
| STATIC MARGIN (SUBSONIC) (w/40K PL)       |             |           | -.0727         |            |
| STATIC MARGIN (SUBSONIC) (w/O PL)         |             |           | -.0312         |            |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |           | .4323          |            |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |                |            |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           | 29.60 DEG      |            |

APPENDIX – Continued

ODIN Wing W10

|   |             |           |                |
|---|-------------|-----------|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |                |
| AREA, PLANFORM (SFT)                      |             |           | 4929.0         |
| LENGTH, NOSE TO WING LE AT BODY           |             |           | 472.06 IN      |
| LENGTH, NOSE TO WING C/4                  |             |           | 893.31 IN      |
| ANGLE, GROUND PLANE                       |             | *FIXEC*   | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |                |
| AREA, WETTED                              |             | *FIXEC*   | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY               |             | *FIXEC*   | 1315.0 IN      |
| 3. WING                                   |             |           |                |
| AREA, THEORETICAL OR TOTAL                |             |           | 5049.3 SFT     |
| AREA, ELEVON                              |             |           | 728.84 SFT     |
| SPAN                                      |             |           | 882.00 IN      |
| CHORD, MEAN AERODYNAMIC                   |             |           | 975.40 IN      |
| CHORD, CENTERLINE ROOT                    |             |           | 1435.4 IN      |
| CHORD, TIP                                |             |           | 213.31 IN      |
| TAPER RATIO, THEORETICAL                  |             |           | .14860         |
| ASPECT RATIO, THEORETICAL                 |             |           | 1.0699         |
| ASPECT RATIO, EXPOSED SPAN                |             |           | .99261         |
| ANGLE, LEADING EDGE SWEEP                 |             |           | 70.157 DEG     |
| ANGLE, TRAILING EDGE SWEEP                |             | *FIXEC*   | 0.0 DEG        |
| ANGLE, DIHEDRAL                           |             | *FIXEC*   | 7.0 DEG        |
| ANGLE, INCIDENCE                          |             | *FIXEC*   | 1.5 DEG        |
| AIRCIL SECTION, ROOT                      |             | *FIXEC*   | 008-64         |
| AIRCIL SECTION, TIP                       |             | *FIXEC*   | 008-64         |
| 4. 040A MASS PROPERTIES                   |             |           |                |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) | X-CG (PC I)    |
| ORBITER LNDG (W/40K PL)                   | 206672.3    | 75.231    | 68.654         |
| ORBITER LNDG (W/O PL)                     | 166672.3    | 78.446    | 71.588         |
| WING WEIGHT                               | 16146.7     |           |                |
| TPS WEIGHT                                | 34419.6     |           |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |                |
| X-SCALE FACTOR                            |             |           | SCLX= 1.6000   |
| Y-SCALE FACTOR                            |             |           | SCLY= 1.0000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           | XOF=472.056 IN |
| 6. LANDING PERFORMANCE                    |             |           |                |
| MINIMUM LANDING SPEED (W/40K PL)          |             |           | 178.2 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             |           | -.0712         |
| STATIC MARGIN (SUBSONIC) (W/O PL)         |             |           | -.0317         |
| TRIM LIFT CLCF FOR LANDING (ALPHA=17 DEG) |             |           | .3808          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           | 27.57 DEG      |

APPENDIX - Continued

ODIN Wing W11

|   |             |           |         |                |
|---|-------------|-----------|---------|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |         |                |
| AREA, PLANFORM (SFT)                      |             |           |         | 3642.6         |
| LENGTH, NOSE TO WING LE AT BODY           |             |           |         | 667.15 IN      |
| LENGTH, NOSE TO WING C/4                  |             |           |         | 889.36 IN      |
| ANGLE, GROUND PLANE                       |             |           | *FIXED* | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |         |                |
| AREA, WETTED                              |             |           | *FIXED* | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY               |             |           | *FIXED* | 1315.0 IN      |
| 3. WING                                   |             |           |         |                |
| AREA, THEORETICAL OR TOTAL                |             |           |         | 2829.6 SFT     |
| AREA, ELEVON                              |             |           |         | 437.30 SFT     |
| SPAN                                      |             |           |         | 1017.6 IN      |
| CHORD, MEAN AERODYNAMIC                   |             |           |         | 472.27 IN      |
| CHORD, CENTERLINE ROOT                    |             |           |         | 694.16 IN      |
| CHORD, TIP                                |             |           |         | 106.66 IN      |
| TAPER RATIO, THEORETICAL                  |             |           |         | .15365         |
| ASPECT RATIO, THEORETICAL                 |             |           |         | 2.5414         |
| ASPECT RATIO, EXPOSED SPAN                |             |           |         | 2.3823         |
| ANGLE, LEADING EDGE SWEEP                 |             |           |         | 49.105 DEG     |
| ANGLE, TRAILING EDGE SWEEP                |             |           | *FIXED* | 0.0 DEG        |
| ANGLE, DIHEDRAL                           |             |           | *FIXED* | 7.0 DEG        |
| ANGLE, INCIDENCE                          |             |           | *FIXED* | 1.5 DEG        |
| AIRFOIL SECTION, ROOT                     |             |           | *FIXED* | 008-64         |
| AIRFOIL SECTION, TIP                      |             |           | *FIXED* | 008-64         |
| 4. U40A MASS PROPERTIES                   |             |           |         |                |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) |         | X-CG (PC L)    |
| ORBITER LNDG (W/40K PL)                   | 198306.2    | 71.103    |         | 64.887         |
| ORBITER LNDG (W/0 PL)                     | 158306.2    | 73.446    |         | 67.025         |
| WING WEIGHT                               | 15588.4     |           |         |                |
| TPS WEIGHT                                | 20211.5     |           |         |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |         |                |
| X-SCALE FACTOR                            |             |           |         | SCLX= .80000   |
| Y-SCALE FACTOR                            |             |           |         | SCLY= 1.2000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           |         | XOF=667.154 IN |
| 6. LANDING PERFORMANCE                    |             |           |         |                |
| MINIMUM LANDING SPEED (W/40K PL)          |             |           |         | 160.7 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             |           |         | -.0873         |
| STATIC MARGIN (SUBSONIC) (W/0 PL)         |             |           |         | -.0278         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |           |         | .8017          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |         |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           |         | 48.43 DEG      |

APPENDIX - Continued

ODIN Wing W12

|   |             |           |                |
|---|-------------|-----------|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |                |
| AREA, PLANFORM (SFT)                      |             |           | 4125.0         |
| LENGTH, NOSE TO WING LE AT BODY           |             |           | 608.36 IN      |
| LENGTH, NOSE TO WING C/4                  |             |           | 886.12 IN      |
| ANGLE, GROUND PLANE                       | *FIXED*     |           | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |                |
| AREA, WETTED                              | *FIXED*     |           | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY               | *FIXED*     |           | 1315.0 IN      |
| 3. WING                                   |             |           |                |
| AREA, THEORETICAL OR TOTAL                |             |           | 3537.0 SFT     |
| AREA, ELEVON                              |             |           | 546.63 SFT     |
| SPAN                                      |             |           | 1017.6 IN      |
| CHORD, MEAN AERODYNAMIC                   |             |           | 590.33 IN      |
| CHORD, CENTERLINE ROOT                    |             |           | 867.70 IN      |
| CHORD, TIP                                |             |           | 133.32 IN      |
| TAPER RATIO, THEORETICAL                  |             |           | .15365         |
| ASPECT RATIO, THEORETICAL                 |             |           | 2.0331         |
| ASPECT RATIO, EXPOSED SPAN                |             |           | 1.9058         |
| ANGLE, LEADING EDGE SWEEP                 |             |           | 55.283 DEG     |
| ANGLE, TRAILING EDGE SWEEP                | *FIXED*     |           | 0.0 DEG        |
| ANGLE, DIHEDRAL                           | *FIXED*     |           | 7.0 DEG        |
| ANGLE, INCIDENCE                          | *FIXED*     |           | 1.5 DEG        |
| AIRFOIL SECTION, ROOT                     | *FIXED*     |           | 008-64         |
| AIRFOIL SECTION, TIP                      | *FIXED*     |           | 008-64         |
| 4. 040A MASS PROPERTIES                   |             |           |                |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) | X-CG (PC L)    |
| ORBITER LNDG (W/40K PL)                   | 201537.7    | 71.967    | 65.675         |
| ORBITER LNDG (W/D PL)                     | 161537.7    | 74.476    | 67.565         |
| WING WEIGHT                               | 16378.3     |           |                |
| TPS WEIGHT                                | 29053.4     |           |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |                |
| X-SCALE FACTOR                            |             |           | SCLX= 1.0000   |
| Y-SCALE FACTOR                            |             |           | SCLY= 1.2000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           | XOF=608.363 IN |
| 6. LANDING PERFORMANCE                    |             |           |                |
| MINIMUM LANDING SPEED (W/40K PL)          |             |           | 158.0 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             |           | -.0798         |
| STATIC MARGIN (SUBSONIC) (W/D PL)         |             |           | -.0288         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |           | .6738          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           | 36.79 DEG      |

APPENDIX - Continued

ODIN Wing W13

|   |             |           |  |                |
|---|-------------|-----------|--|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |  |                |
| AREA, PLANFORM (SFT)                      |             |           |  | 4607.4         |
| LENGTH, NOSE TO WING LE AT BODY           |             |           |  | 557.64 IN      |
| LENGTH, NOSE TO WING C/4                  |             |           |  | 890.95 IN      |
| ANGLE, GROUND PLANE                       |             | *FIXED*   |  | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |  |                |
| AREA, WETTED                              |             | *FIXED*   |  | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY               |             | *FIXED*   |  | 1315.0 IN      |
| 3. WING                                   |             |           |  |                |
| AREA, THEORETICAL OR TOTAL                |             |           |  | 4244.4 SFT     |
| AREA, ELEVON                              |             |           |  | 655.95 SFT     |
| SPAN                                      |             |           |  | 1017.6 IN      |
| CHORD, MEAN AERODYNAMIC                   |             |           |  | 708.40 IN      |
| CHORD, CENTERLINE ROOT                    |             |           |  | 1041.2 IN      |
| CHORD, TIP                                |             |           |  | 159.98 IN      |
| TAPER RATIO, THEORETICAL                  |             |           |  | .15365         |
| ASPECT RATIO, THEORETICAL                 |             |           |  | 1.6943         |
| ASPECT RATIO, EXPOSED SPAN                |             |           |  | 1.5882         |
| ANGLE, LEADING EDGE SWEEP                 |             |           |  | 59.998 DEG     |
| ANGLE, TRAILING EDGE SWEEP                |             | *FIXED*   |  | 0.0 DEG        |
| ANGLE, DIHEDRAL                           |             | *FIXED*   |  | 7.0 DEG        |
| ANGLE, INCIDENCE                          |             | *FIXED*   |  | 1.5 DEG        |
| AIRFOIL SECTION, ROOT                     |             | *FIXED*   |  | 008-64         |
| AIRFOIL SECTION, TIP                      |             | *FIXED*   |  | 008-64         |
| 4. 040A MASS PROPERTIES                   |             |           |  |                |
| FLIGHT CONDITION                          | WEIGHT (LR) | X-CG (FT) |  | X-CG (PC L)    |
| ORBITER LNDG (W/40K PL)                   | 204814.6    | 73.055    |  | 66.668         |
| ORBITER LNDG (W/O PL)                     | 164814.6    | 75.779    |  | 69.154         |
| WING WEIGHT                               | 16804.9     |           |  |                |
| IPS WEIGHT                                | 31903.7     |           |  |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |  |                |
| X-SCALE FACTOR                            |             |           |  | SCLX= 1.2000   |
| Y-SCALE FACTOR                            |             |           |  | SCLY= 1.2000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           |  | XOF=557.644 IN |
| 6. LANDING PERFORMANCE                    |             |           |  |                |
| MINIMUM LANDING SPEED (W/40K PL)          |             |           |  | 157.7 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             |           |  | -.0786         |
| STATIC MARGIN (SUBSONIC) (W/O PL)         |             |           |  | -.0324         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |           |  | .5733          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |  |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           |  | 30.86 DEG      |

APPENDIX - Continued

ODIN Wing W<sub>14</sub>

|   |             |           |                |
|---|-------------|-----------|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |                |
| AREA, PLANFORM (SFT)                      |             |           | 5089.8         |
| LENGTH, NOSE TO WING LE AT BODY           |             |           | 505.20 IN      |
| LENGTH, NOSE TO WING C/4                  |             |           | 894.06 IN      |
| ANGLE, GROUND PLANE                       |             | *FIXED*   | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |                |
| AREA, WETTED                              |             | *FIXED*   | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY               |             | *FIXED*   | 1315.0 IN      |
| 3. WING                                   |             |           |                |
| AREA, THEORETICAL OR TOTAL                |             |           | 4951.7 SFT     |
| AREA, ELEVON                              |             |           | 765.28 SFT     |
| SPAN                                      |             |           | 1017.6 IN      |
| CHORD, MEAN AERODYNAMIC                   |             |           | 826.47 IN      |
| CHORD, CENTERLINE ROOT                    |             |           | 1214.8 IN      |
| CHORD, TIP                                |             |           | 186.65 IN      |
| TAPE RATIO, THEORETICAL                   |             |           | .15365         |
| ASPECT RATIO, THEORETICAL                 |             |           | 1.4522         |
| ASPECT RATIO, EXPOSED SPAN                |             |           | 1.3613         |
| ANGLE, LEADING EDGE SWEEP                 |             |           | 63.669 DEG     |
| ANGLE, TRAILING EDGE SWEEP                |             | *FIXED*   | 0.0 DEG        |
| ANGLE, DIHEDRAL                           |             | *FIXED*   | 7.0 DEG        |
| ANGLE, INCIDENCE                          |             | *FIXED*   | 1.5 DEG        |
| AIRFOIL SECTION, ROOT                     |             | *FIXED*   | 008-64         |
| AIRFOIL SECTION, TIP                      |             | *FIXED*   | 008-64         |
| 4. O+DA MASS PROPERTIES                   |             |           |                |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) | X-CG (PC I)    |
| ORBITER LNDG (W/40K PL)                   | 208119.6    | 74.249    | 67.758         |
| ORBITER LNDG (W/D PL)                     | 168119.6    | 77.203    | 70.454         |
| WING WEIGHT                               | 17254.2     |           |                |
| TPS WEIGHT                                | 34759.4     |           |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |                |
| X-SCALE FACTOR                            |             |           | SCLX= 1.4000   |
| Y-SCALE FACTOR                            |             |           | SCLY= 1.2000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           | XCF=505.200 IN |
| 6. LANDING PERFORMANCE                    |             |           |                |
| MINIMUM LANDING SPEED (W/40K PL)          |             |           | 157.0 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             |           | -.0741         |
| STATIC MARGIN (SUBSONIC) (W/D PL)         |             |           | -.0312         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |           | .5037          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |                |
| TRIM ANGLE OF ATTACK AT ELEVEN=-45 DEG    |             |           | 28.33 DEG      |



APPENDIX - Continued

ODIN Wing W15

|   |              |           |                |            |
|---|--------------|-----------|----------------|------------|
| 1. OVERALL CONFIGURATION                  |              |           |                |            |
| AREA, PLANFORM (SFT)                      |              |           |                | 5572.2     |
| LENGTH, NOSE TO WING LE AT BODY           |              |           |                | 457.88 IN  |
| LENGTH, NOSE TO WING C/4                  |              |           |                | 902.29 IN  |
| ANGLE, GROUND PLANE                       |              |           | *FIXED*        | 17.00 DEG  |
| 2. FUSELAGE                               |              |           |                |            |
| AREA, WETTED                              |              |           | *FIXED*        | 6307.0 SFT |
| LENGTH, NOSE TO END OF BODY               |              |           | *FIXED*        | 1315.0 IN  |
| 3. WING                                   |              |           |                |            |
| AREA, THEORETICAL OR TOTAL                |              |           |                | 5659.1 SFT |
| AREA, ELEVON                              |              |           |                | 874.60 SFT |
| SPAN                                      |              |           |                | 1017.6 IN  |
| CHORD, MEAN AERODYNAMIC                   |              |           |                | 944.53 IN  |
| CHORD, CENTERLINE ROOT                    |              |           |                | 1388.3 IN  |
| CHORD, TIP                                |              |           |                | 213.31 IN  |
| TAPER RATIO, THEORETICAL                  |              |           |                | .15365     |
| ASPECT RATIO, THEORETICAL                 |              |           |                | 1.2707     |
| ASPECT RATIO, EXPOSED SPAN                |              |           |                | 1.1911     |
| ANGLE, LEADING EDGE SWEEP                 |              |           |                | 66.585 DEG |
| ANGLE, TRAILING EDGE SWEEP                |              |           | *FIXED*        | 0.0 DEG    |
| ANGLE, DIHEDRAL                           |              |           | *FIXED*        | 7.0 DEG    |
| ANGLE, INCIDENCE                          |              |           | *FIXED*        | 1.5 DEG    |
| AIRFOIL SECTION, ROOT                     |              |           | *FIXED*        | 008-64     |
| AIRFOIL SECTION, TIP                      |              |           | *FIXED*        | 008-64     |
| 4. O40A MASS PROPERTIES                   |              |           |                |            |
| FLIGHT CONDITION                          | WEIGHT (LBS) | X-CG (FT) | X-CG (PC L)    |            |
| ORBITER LNDG (W/40K PL)                   | 211440.1     | 75.640    | 69.027         |            |
| ORBITER LNDG (W/D PL)                     | 171440.1     | 78.861    | 71.967         |            |
| WING WEIGHT                               | 17715.5      |           |                |            |
| TPS WEIGHT                                | 37618.6      |           |                |            |
| 5. PRINCIPAL PARAMETERS                   |              |           |                |            |
| X-SCALE FACTOR                            |              |           | SCLX= 1.6000   |            |
| Y-SCALE FACTOR                            |              |           | SCLY= 1.2000   |            |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |              |           | XOF=457.883 IN |            |
| 6. LANDING PERFORMANCE                    |              |           |                |            |
| MINIMUM LANDING SPEED (W/40K PL)          |              |           | 157.2 KT       |            |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |              |           | -.0725         |            |
| STATIC MARGIN (SUBSONIC) (W/D PL)         |              |           | -.0316         |            |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |              |           | .4462          |            |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |              |           |                |            |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |              |           | 26.74 DEG      |            |

APPENDIX - Continued

ODIN Wing W16

|   |             |           |                |
|---|-------------|-----------|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |                |
| AREA, PLANFORM (SFT)                      |             |           | 3964.2         |
| LENGTH, NOSE TO WING LE AT BODY           |             |           | 658.86 IN      |
| LENGTH, NOSE TO WING C/4                  |             |           | 889.32 IN      |
| ANGLE, GROUND PLANE                       |             | *FIXED*   | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |                |
| AREA, WETTED                              |             | *FIXED*   | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY               |             | *FIXED*   | 1315.0 IN      |
| 3. WING                                   |             |           |                |
| AREA, THEORETICAL OR TOTAL                |             |           | 3139.3 SFT     |
| AREA, ELEVON                              |             |           | 510.18 SFT     |
| SPAN                                      |             |           | 1153.2 IN      |
| CHORD, MEAN AERODYNAMIC                   |             |           | 461.25 IN      |
| CHORD, CENTERLINE ROOT                    |             |           | 677.33 IN      |
| CHORD, TIP                                |             |           | 106.66 IN      |
| TAPER RATIO, THEORETICAL                  |             |           | .15746         |
| ASPECT RATIO, THEORETICAL                 |             |           | 2.9419         |
| ASPECT RATIO, EXPOSED SPAN                |             |           | 2.7793         |
| ANGLE, LEADING EDGE SWEEP                 |             |           | 44.703 DEG     |
| ANGLE, TRAILING EDGE SWEEP                |             | *FIXED*   | 0.0 DEG        |
| ANGLE, DIEDRAL                            |             | *FIXED*   | 7.0 DEG        |
| ANGLE, INCIDENCE                          |             | *FIXED*   | 1.5 DEG        |
| AIRFOIL SECTION, ROOT                     |             | *FIXED*   | 008-64         |
| AIRFOIL SECTION, TIP                      |             | *FIXED*   | 008-64         |
| 4. O40A MASS PROPERTIES                   |             |           |                |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) | X-CG (PC L)    |
| ORBITER LNDG (W/40K PL)                   | 201628.5    | 71.277    | 65.046         |
| ORBITER LNDG (W/O PL)                     | 161628.5    | 73.614    | 67.179         |
| WING WEIGHT                               | 17679.7     |           |                |
| TPS WEIGHT                                | 27842.8     |           |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |                |
| X-SCALE FACTOR                            |             |           | SCLX= .80000   |
| Y-SCALE FACTOR                            |             |           | SCLY= 1.4000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           | XCF=658.861 IN |
| 6. LANDING PERFORMANCE                    |             |           |                |
| MINIMUM LANDING SPEED (W/40K PL)          |             |           | 147.0 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             |           | -.0891         |
| STATIC MARGIN (SUBSONIC) (W/O PL)         |             |           | -.0283         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |           | .8772          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           | 43.87 DEG      |

APPENDIX - Continued

ODIN Wing W<sub>17</sub>

|  |             |           |  |                |
|--|-------------|-----------|--|----------------|
| 1. OVERALL CONFIGURATION                   |             |           |  |                |
| AREA, PLANFORM (SFT)                       |             |           |  | 4527.0         |
| LENGTH, NOSE TO WING LE AT BODY            |             |           |  | 600.61 IN      |
| LENGTH, NOSE TO WING C/4                   |             |           |  | 888.69 IN      |
| ANGLE, GROUND PLANE                        |             | *FIXED*   |  | 17.00 DEG      |
| 2. FUSELAGE                                |             |           |  |                |
| AREA, WETTED                               |             | *FIXED*   |  | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY                |             | *FIXED*   |  | 1315.0 IN      |
| 3. WING                                    |             |           |  |                |
| AREA, THEORETICAL OR TOTAL                 |             |           |  | 3924.1 SFT     |
| AREA, ELEVON                               |             |           |  | 637.73 SFT     |
| SPAN                                       |             |           |  | 1153.2 IN      |
| CHORD, MEAN AERODYNAMIC                    |             |           |  | 576.57 IN      |
| CHORD, CENTERLINE ROOT                     |             |           |  | 846.67 IN      |
| CHORD, TIP                                 |             |           |  | 133.32 IN      |
| TAPER RATIO, THEORETICAL                   |             |           |  | .15746         |
| ASPECT RATIO, THEORETICAL                  |             |           |  | 2.3535         |
| ASPECT RATIO, EXPOSED SPAN                 |             |           |  | 2.2235         |
| ANGLE, LEADING EDGE SWEEP                  |             |           |  | 51.050 DEG     |
| ANGLE, TRAILING EDGE SWEEP                 |             | *FIXED*   |  | 0.0 DEG        |
| ANGLE, DIHEDRAL                            |             | *FIXED*   |  | 7.0 DEG        |
| ANGLE, INCIDENCE                           |             | *FIXED*   |  | 1.5 DEG        |
| AIRFOIL SECTION, ROOT                      |             | *FIXED*   |  | 008-64         |
| AIRFOIL SECTION, TIP                       |             | *FIXED*   |  | 008-64         |
| 4. 040A MASS PROPERTIES                    |             |           |  |                |
| FLIGHT CONDITION                           | WEIGHT (LR) | X-CG (FT) |  | X-CG (PC L)    |
| ORBITER LNDG (w/40K PL)                    | 205210.0    | 72.199    |  | 65.887         |
| ORBITER LNDG (w/O PL)                      | 165210.0    | 74.709    |  | 68.178         |
| WING WEIGHT                                | 18023.7     |           |  |                |
| TPS WEIGHT                                 | 31080.3     |           |  |                |
| 5. PRINCIPAL PARAMETERS                    |             |           |  |                |
| X-SCALE FACTOR                             |             |           |  | SCLX= 1.0000   |
| Y-SCALE FACTOR                             |             |           |  | SCLY= 1.4000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING   |             |           |  | XOF=600.614 IN |
| 6. LANDING PERFORMANCE                     |             |           |  |                |
| MINIMUM LANDING SPEED (w/40K PL)           |             |           |  | 143.2 KT       |
| STATIC MARGIN (SUBSONIC) (w/40K PL)        |             |           |  | -.0800         |
| STATIC MARGIN (SUBSONIC) (w/O PL)          |             |           |  | -.0277         |
| TRIM LIFT COEFF FOR LANDING (ALPHA=17 DEG) |             |           |  | .7534          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA        |             |           |  |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG     |             |           |  | 34.12 DEG      |

APPENDIX - Continued

ODIN Wing W18

|   |             |           |         |                |
|---|-------------|-----------|---------|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |         |                |
| AREA, PLANFORM (SFT)                      |             |           |         | 5089.8         |
| LENGTH, NOSE TO WING LE AT BODY           |             |           |         | 549.15 IN      |
| LENGTH, NOSE TO WING C/4                  |             |           |         | 854.84 IN      |
| ANGLE, GROUND PLANE                       |             |           | *FIXED* | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |         |                |
| AREA, WETTED                              |             |           | *FIXED* | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY               |             |           | *FIXED* | 1315.0 IN      |
| 3. WING                                   |             |           |         |                |
| AREA, THEORETICAL OR TOTAL                |             |           |         | 4708.9 SFT     |
| AREA, ELEVON                              |             |           |         | 765.28 SFT     |
| SPAN                                      |             |           |         | 1153.2 IN      |
| CHORD, MEAN AERODYNAMIC                   |             |           |         | 691.88 IN      |
| CHORD, CENTERLINE ROOT                    |             |           |         | 1016.0 IN      |
| CHORD, TIP                                |             |           |         | 159.98 IN      |
| TAPER RATIO, THEORETICAL                  |             |           |         | .15746         |
| ASPECT RATIO, THEORETICAL                 |             |           |         | 1.9612         |
| ASPECT RATIO, EXPOSED SPAN                |             |           |         | 1.8529         |
| ANGLE, LEADING EDGE SWEEP                 |             |           |         | 56.035 DEG     |
| ANGLE, TRAILING EDGE SWEEP                |             |           | *FIXED* | 0.0 DEG        |
| ANGLE, DIHEDRAL                           |             |           | *FIXED* | 7.0 DEG        |
| ANGLE, INCIDENCE                          |             |           | *FIXED* | 1.5 DEG        |
| AIRFOIL SECTION, ROOT                     |             |           | *FIXED* | 008-64         |
| AIRFOIL SECTION, TIP                      |             |           | *FIXED* | 008-64         |
| 4. 040A MASS PROPERTIES                   |             |           |         |                |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) |         | X-CG (PC L)    |
| ORBITER LNDG (W/40K PL)                   | 208841.9    | 73.343    |         | 66.931         |
| ORBITER LNDG (W/O PL)                     | 168841.9    | 76.069    |         | 69.419         |
| WING WEIGHT                               | 18408.3     |           |         |                |
| TPS WEIGHT                                | 34327.6     |           |         |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |         |                |
| X-SCALE FACTOR                            |             |           |         | SCLX= 1.2000   |
| Y-SCALE FACTOR                            |             |           |         | SCLY= 1.4000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           |         | XOF=549.145 IN |
| 6. LANDING PERFORMANCE                    |             |           |         |                |
| MINIMUM LANDING SPEED (W/40K PL)          |             |           |         | 142.1 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             |           |         | -.0779         |
| STATIC MARGIN (SUBSONIC) (W/O PL)         |             |           |         | -.0306         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |           |         | .6490          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |         |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           |         | 29.53 DEG      |

APPENDIX - Continued

ODIN Wing W19

|   |             |           |             |
|---|-------------|-----------|-------------|
| 1. OVERALL CONFIGURATION                  |             |           |             |
| AREA, PLANFORM (SFT)                      |             |           | 5652.6      |
| LENGTH, NOSE TO WING LE AT BODY           |             |           | 498.90 IN   |
| LENGTH, NOSE TO WING C/4                  |             |           | 902.21 IN   |
| ANGLE, GROUND PLANE                       |             | *FIXED*   | 17.00 DEG   |
| 2. FUSELAGE                               |             |           |             |
| AREA, WETTED                              |             | *FIXED*   | 6307.0 SFT  |
| LENGTH, NOSE TO END OF BODY               |             | *FIXED*   | 1315.0 IN   |
| 3. WING                                   |             |           |             |
| AREA, THEORETICAL OR TOTAL                |             |           | 5493.7 SFT  |
| AREA, ELEVON                              |             |           | 892.82 SFT  |
| SPAN                                      |             |           | 1153.2 IN   |
| CHORD, MEAN AERODYNAMIC                   |             |           | 807.19 IN   |
| CHORD, CENTERLINE ROOT                    |             |           | 1185.3 IN   |
| CHORD, TIP                                |             |           | 186.65 IN   |
| TAPER RATIO, THEORETICAL                  |             |           | .15746      |
| ASPECT RATIO, THEORETICAL                 |             |           | 1.6811      |
| ASPECT RATIO, EXPOSED SPAN                |             |           | 1.5882      |
| ANGLE, LEADING EDGE SWEEP                 |             |           | 59.998 DEG  |
| ANGLE, TRAILING EDGE SWEEP                |             | *FIXED*   | 0.0 DEG     |
| ANGLE, DIHEDRAL                           |             | *FIXED*   | 7.0 DEG     |
| ANGLE, INCIDENCE                          |             | *FIXED*   | 1.5 DEG     |
| AIRCIL SECTION, ROOT                      |             | *FIXED*   | 008-64      |
| AIRCIL SECTION, TIP                       |             | *FIXED*   | 008-64      |
| 4. O&A MASS PROPERTIES                    |             |           |             |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) | X-CG (PC L) |
| ORBITER LNDG (W/40K PL)                   | 212508.6    | 74.636    | 68.111      |
| ORBITER LNDG (W/O PL)                     | 172508.6    | 77.605    | 70.820      |
| WING WEIGHT                               | 18821.4     |           |             |
| TPS WEIGHT                                | 37581.2     |           |             |
| 5. PRINCIPAL PARAMETERS                   |             |           |             |
| X-SCALE FACTOR                            |             | SCLX=     | 1.4000      |
| Y-SCALE FACTOR                            |             | SCLY=     | 1.4000      |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             | XOF=      | 498.503 IN  |
| 6. LANDING PERFORMANCE                    |             |           |             |
| MINIMUM LANDING SPEED (W/40K PL)          |             |           | 141.4 KT    |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             |           | -.0752      |
| STATIC MARGIN (SUBSONIC) (W/O PL)         |             |           | -.0311      |
| TRIM LIFT CLEF FOR LANDING (ALPHA=17 DEG) |             |           | .5711       |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |             |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           | 27.36 DEG   |

APPENDIX - Continued

ODIN Wing W20

|   |             |           |                |
|---|-------------|-----------|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |                |
| AREA, PLANFORM (SFT)                      |             |           | 6215.4         |
| LENGTH, NOSE TO WING LE AT BODY           |             |           | 451.62 IN      |
| LENGTH, NOSE TO WING C/4                  |             |           | 912.54 IN      |
| ANGLE, GROUND PLANE                       |             | *FIXED*   | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |                |
| AREA, WETTED                              |             | *FIXED*   | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY               |             | *FIXED*   | 1315.0 IN      |
| 3. WING                                   |             |           |                |
| AREA, THEORETICAL OR TOTAL                |             |           | 6278.5 SFT     |
| AREA, ELEVON                              |             |           | 1020.4 SFT     |
| SPAN                                      |             |           | 1153.2 IN      |
| CHORD, MEAN AERODYNAMIC                   |             |           | 922.51 IN      |
| CHORD, CENTERLINE ROOT                    |             |           | 1354.7 IN      |
| CHORD, TIP                                |             |           | 213.31 IN      |
| TAPER RATIO, THEORETICAL                  |             |           | .15746         |
| ASPECT RATIO, THEORETICAL                 |             |           | 1.4709         |
| ASPECT RATIO, EXPOSED SPAN                |             |           | 1.3897         |
| ANGLE, LEADING EDGE SWEEP                 |             |           | 63.196 DEG     |
| ANGLE, TRAILING EDGE SWEEP                |             | *FIXED*   | 0.0 DEG        |
| ANGLE, DIHEDRAL                           |             | *FIXED*   | 7.0 DEG        |
| ANGLE, INCIDENCE                          |             | *FIXED*   | 1.5 DEG        |
| AIRFOIL SECTION, ROOT                     |             | *FIXED*   | 008-64         |
| AIRFOIL SECTION, TIP                      |             | *FIXED*   | 008-64         |
| 4. 040A MASS PROPERTIES                   |             |           |                |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) | X-CG (PC L)    |
| ORBITER LNDG (W/40K PL)                   | 216198.1    | 76.106    | 69.453         |
| ORBITER LNDG (W/O PL)                     | 176198.1    | 79.346    | 72.410         |
| WING WEIGHT                               | 19253.1     |           |                |
| TPS WEIGHT                                | 40839.0     |           |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |                |
| X-SCALE FACTOR                            |             |           | SCLX= 1.6000   |
| Y-SCALE FACTOR                            |             |           | SCLY= 1.4000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           | XOF=451.616 IN |
| 6. LANDING PERFORMANCE                    |             |           |                |
| MINIMUM LANDING SPEED (W/40K PL)          |             |           | 141.4 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             |           | -.0735         |
| STATIC MARGIN (SUBSONIC) (W/O PL)         |             |           | -.0314         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |           | .5086          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           | 26.10 DEG      |

APPENDIX - Continued

ODIN Wing W21

|   |             |           |                |
|---|-------------|-----------|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |                |
| AREA, PLANFORM (SFT)                      |             |           | 4285.8         |
| LENGTH, NOSE TO WING LE AT BODY           |             |           | 654.40 IN      |
| LENGTH, NOSE TO WING C/4                  |             |           | 891.05 IN      |
| ANGLE, GROUND PLANE                       | *FIXED*     |           | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |                |
| AREA, WETTED                              | *FIXED*     |           | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY               | *FIXED*     |           | 1315.0 IN      |
| 3. WING                                   |             |           |                |
| AREA, THEORETICAL OR TOTAL                |             |           | 3451.9 SFT     |
| AREA, ELEVON                              |             |           | 583.07 SFT     |
| SPAN                                      |             |           | 1288.8 IN      |
| CHORD, MEAN AERODYNAMIC                   |             |           | 453.00 IN      |
| CHORD, CENTERLINE ROOT                    |             |           | 664.72 IN      |
| CHORD, TIP                                |             |           | 106.66 IN      |
| TAPER RATIO, THEORETICAL                  |             |           | .16045         |
| ASPECT RATIO, THEORETICAL                 |             |           | 3.3416         |
| ASPECT RATIO, EXPOSED SPAN                |             |           | 3.1764         |
| ANGLE, LEADING EDGE SWEEP                 |             |           | 40.892 DEG     |
| ANGLE, TRAILING EDGE SWEEP                | *FIXED*     |           | 0.0 DEG        |
| ANGLE, DIHEDRAL                           | *FIXED*     |           | 7.0 DEG        |
| ANGLE, INCIDENCE                          | *FIXED*     |           | 1.5 DEG        |
| AIRFOIL SECTION, ROOT                     | *FIXED*     |           | 008-64         |
| AIRFOIL SECTION, TIP                      | *FIXED*     |           | 008-64         |
| 4. O40A MASS PROPERTIES                   |             |           |                |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) | X-CG (PC L)    |
| ORBITER LNDG (W/40K PL)                   | 204924.5    | 71.471    | 65.223         |
| ORBITER LNDG (W/O PL)                     | 164924.5    | 73.809    | 67.356         |
| WING WEIGHT                               | 19336.9     |           |                |
| IPS WEIGHT                                | 29481.6     |           |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |                |
| X-SCALE FACTOR                            |             |           | SCLX= .80000   |
| Y-SCALE FACTOR                            |             |           | SCLY= 1.6000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           | XCF=654.398 IN |
| 6. LANDING PERFORMANCE                    |             |           |                |
| MINIMUM LANDING SPEED (W/40K PL)          |             |           | 136.3 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             |           | -.0906         |
| STATIC MARGIN (SUBSONIC) (W/C PL)         |             |           | -.0287         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |           | .9438          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           | 39.53 DEG      |

APPENDIX - Continued

ODIN Wing W22

|   |             |           |                |
|---|-------------|-----------|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |                |
| AREA, PLANFORM (SFT)                      |             |           | 4929.0         |
| LENGTH, NOSE TO WING LE AT BODY           |             |           | 598.27 IN      |
| LENGTH, NOSE TO WING C/4                  |             |           | 894.09 IN      |
| ANGLE, GRUND PLANE                        |             | *FIXED*   | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |                |
| AREA, WETTED                              |             | *FIXED*   | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY               |             | *FIXED*   | 1315.0 IN      |
| 3. WING                                   |             |           |                |
| AREA, THEORETICAL OR TOTAL                |             |           | 4314.9 SFT     |
| AREA, ELEVON                              |             |           | 728.84 SFT     |
| SPAN                                      |             |           | 1288.8 IN      |
| CHORD, MEAN AERODYNAMIC                   |             |           | 566.25 IN      |
| CHORD, CENTERLINE ROOT                    |             |           | 830.89 IN      |
| CHORD, TIP                                |             |           | 133.32 IN      |
| TAPER RATIO, THEORETICAL                  |             |           | .16045         |
| ASPECT RATIO, THEORETICAL                 |             |           | 2.6732         |
| ASPECT RATIO, EXPOSED SPAN                |             |           | 2.5411         |
| ANGLE, LEADING EDGE SWEEP                 |             |           | 47.268 DEG     |
| ANGLE, TRAILING EDGE SWEEP                |             | *FIXED*   | 0.0 DEG        |
| ANGLE, DIHEDRAL                           |             | *FIXED*   | 7.0 DEG        |
| ANGLE, INCIDENCE                          |             | *FIXED*   | 1.5 DEG        |
| AIRCIL SECTION, ROOT                      |             | *FIXED*   | 008-64         |
| AIRCIL SECTION, TIP                       |             | *FIXED*   | 008-64         |
| 4. 040A MASS PROPERTIES                   |             |           |                |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) | X-CG (PC ( )   |
| ORBITER LNDG (W/40K PL)                   | 208864.9    | 72.478    | 66.141         |
| ORBITER LNDG (W/O PL)                     | 168864.9    | 74.999    | 68.442         |
| WING WEIGHT                               | 19642.3     |           |                |
| TPS WEIGHT                                | 33116.7     |           |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |                |
| X-SCALE FACTOR                            |             |           | SCLX= 1.0000   |
| Y-SCALE FACTOR                            |             |           | SCLY= 1.6000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           | XOF=598.269 IN |
| 6. LANDING PERFORMANCE                    |             |           |                |
| MINIMUM LANDING SPEED (W/40K PL)          |             |           | 132.0 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             |           | -.0821         |
| STATIC MARGIN (SUBSONIC) (W/O PL)         |             |           | -.0287         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |           | .8204          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           | 31.79 DEG      |



APPENDIX - Continued

ODIN Wing W23

|   |             |           |                |
|---|-------------|-----------|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |                |
| AREA, PLANFORM (SFT)                      |             |           | 5572.2         |
| LENGTH, NOSE TO WING LE AT BODY           |             |           | 549.09 IN      |
| LENGTH, NOSE TO WING C/4                  |             |           | 904.07 IN      |
| ANGLE, GROUND PLANE                       | *FIXED*     |           | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |                |
| AREA, WETTED                              | *FIXED*     |           | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY               | *FIXED*     |           | 1315.0 IN      |
| 3. WING                                   |             |           |                |
| AREA, THEORETICAL OR TOTAL                |             |           | 5177.9 SFT     |
| AREA, ELEVON                              |             |           | 874.60 SFT     |
| SPAN                                      |             |           | 1288.8 IN      |
| CHORD, MEAN AERODYNAMIC                   |             |           | 679.50 IN      |
| CHORD, CENTERLINE ROOT                    |             |           | 997.07 IN      |
| CHORD, TIP                                |             |           | 159.98 IN      |
| TAPER RATIO, THEORETICAL                  |             |           | .16045         |
| ASPECT RATIO, THEORETICAL                 |             |           | 2.2277         |
| ASPECT RATIO, EXPOSED SPAN                |             |           | 2.1176         |
| ANGLE, LEADING EDGE SWEEP                 |             |           | 52.409 DEG     |
| ANGLE, TRAILING EDGE SWEEP                | *FIXED*     |           | 0.0 DEG        |
| ANGLE, DIHEDRAL                           | *FIXED*     |           | 7.0 DEG        |
| ANGLE, INCIDENCE                          | *FIXED*     |           | 1.5 DEG        |
| AIRFOIL SECTION, ROOT                     | *FIXED*     |           | 008-64         |
| AIRFOIL SECTION, TIP                      | *FIXED*     |           | 008-64         |
| 4. O40A MASS PROPERTIES                   |             |           |                |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) | X-CG (PC L)    |
| ORBITER LNDG (W/40K PL)                   | 212858.0    | 73.723    | 67.278         |
| ORBITER LNDG (W/D PL)                     | 172858.0    | 76.475    | 69.789         |
| WING WEIGHT                               | 19989.2     |           |                |
| TPS WEIGHT                                | 36762.8     |           |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |                |
| X-SCALE FACTOR                            |             |           | SCLX= 1.2000   |
| Y-SCALE FACTOR                            |             |           | SCLY= 1.6000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           | XOF=549.090 IN |
| 6. LANDING PERFORMANCE                    |             |           |                |
| MINIMUM LANDING SPEED (W/40K PL)          |             |           | 130.6 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             |           | -.0810         |
| STATIC MARGIN (SUBSONIC) (W/D PL)         |             |           | -.0324         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |           | .7113          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           | 28.05 DEG      |

APPENDIX - Continued

ODIN Wing W24

|   |             |           |                |
|---|-------------|-----------|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |                |
| AREA, PLANFORM (SFT)                      |             |           | 6215.4         |
| LENGTH, NOSE TO WING LE AT BODY           |             |           | 497.01 IN      |
| LENGTH, NOSE TO WING C/4                  |             |           | 911.15 IN      |
| ANGLE, GROUND PLANE                       |             | *FIXED*   | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |                |
| AREA, WETTED                              |             | *FIXED*   | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY               |             | *FIXED*   | 1315.0 IN      |
| 3. WING                                   |             |           |                |
| AREA, THEORETICAL OR TOTAL                |             |           | 6040.8 SFT     |
| AREA, ELEVON                              |             |           | 1020.4 SFT     |
| SPAN                                      |             |           | 1288.8 IN      |
| CHORD, MEAN AERODYNAMIC                   |             |           | 792.75 IN      |
| CHORD, CENTERLINE ROOT                    |             |           | 1163.3 IN      |
| CHORD, TIP                                |             |           | 186.65 IN      |
| TAPER RATIO, THEORETICAL                  |             |           | .16045         |
| ASPECT RATIO, THEORETICAL                 |             |           | 1.9095         |
| ASPECT RATIO, EXPOSED SPAN                |             |           | 1.8151         |
| ANGLE, LEADING EDGE SWEEP                 |             |           | 56.580 DEG     |
| ANGLE, TRAILING EDGE SWEEP                |             | *FIXED*   | 0.0 DEG        |
| ANGLE, DIHEDRAL                           |             | *FIXED*   | 7.0 DEG        |
| ANGLE, INCIDENCE                          |             | *FIXED*   | 1.5 DEG        |
| AIRCFOIL SECTION, ROOT                    |             | *FIXED*   | 008-64         |
| AIRCFOIL SECTION, TIP                     |             | *FIXED*   | 008-64         |
| 4. O40A MASS PROPERTIES                   |             |           |                |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) | X-CG (PC 1)    |
| ORBITER LNDG (W/40K PL)                   | 216889.8    | 75.059    | 68.497         |
| ORBITER LNDG (W/O PL)                     | 176889.8    | 78.050    | 71.226         |
| WING WEIGHT                               | 20367.7     |           |                |
| TPS WEIGHT                                | 40416.0     |           |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |                |
| X-SCALE FACTOR                            |             |           | SCLX= 1.4000   |
| Y-SCALE FACTOR                            |             |           | SCLY= 1.6000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           | XCG=497.008 IN |
| 6. LANDING PERFORMANCE                    |             |           |                |
| MINIMUM LANDING SPEED (W/40K PL)          |             |           | 129.3 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             |           | -.0762         |
| STATIC MARGIN (SUBSONIC) (W/O PL)         |             |           | -.0310         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |           | .6343          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           | 26.57 DEG      |

APPENDIX - Continued

ODIN Wing W25

|   |             |           |                |
|---|-------------|-----------|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |                |
| AREA, PLANFORM (SFT)                      |             |           | 6858.6         |
| LENGTH, NOSE TO WING LE AT BODY           |             |           | 450.04 IN      |
| LENGTH, NOSE TO WING C/4                  |             |           | 923.35 IN      |
| ANGLE, GROUND PLANE                       |             | *FIXED*   | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |                |
| AREA, WETTED                              |             | *FIXED*   | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY               |             | *FIXED*   | 1315.0 IN      |
| 3. WING                                   |             |           |                |
| AREA, THEORETICAL OR TOTAL                |             |           | 6903.8 SFT     |
| AREA, ELEVON                              |             |           | 1166.1 SFT     |
| SPAN                                      |             |           | 1288.8 IN      |
| CHORD, MEAN AERODYNAMIC                   |             |           | 906.00 IN      |
| CHORD, CENTERLINE ROOT                    |             |           | 1329.4 IN      |
| CHORD, TIP                                |             |           | 213.31 IN      |
| TAPER RATIO, THEORETICAL                  |             |           | .16045         |
| ASPECT RATIO, THEORETICAL                 |             |           | 1.6708         |
| ASPECT RATIO, EXPOSED SPAN                |             |           | 1.5882         |
| ANGLE, LEADING EDGE SWEEP                 |             |           | 59.998 DEG     |
| ANGLE, TRAILING EDGE SWEEP                |             | *FIXED*   | 0.0 DEG        |
| ANGLE, DIHEDRAL                           |             | *FIXED*   | 7.0 DEG        |
| ANGLE, INCIDENCE                          |             | *FIXED*   | 1.5 DEG        |
| AIRCIL SECTION, ROOT                      |             | *FIXED*   | 008-64         |
| AIRGIL SECTION, TIP                       |             | *FIXED*   | 008-64         |
| 4. 040A MASS PROPERTIES                   |             |           |                |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) | X-CG (PC L)    |
| ORBITER LNDG (W/40K PL)                   | 220549.2    | 76.612    | 69.914         |
| ORBITER LNDG (W/O PL)                     | 180949.2    | 79.879    | 72.896         |
| WING WEIGHT                               | 20769.3     |           |                |
| TPS WEIGHT                                | 44073.9     |           |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |                |
| X-SCALE FACTOR                            |             |           | SCLX= 1.6000   |
| Y-SCALE FACTOR                            |             |           | SCLY= 1.6000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           | XOF=450.039 IN |
| 6. LANDING PERFORMANCE                    |             |           |                |
| MINIMUM LANDING SPEED (W/40K PL)          |             |           | 129.0 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             |           | -.0745         |
| STATIC MARGIN (SUBSONIC) (W/O PL)         |             |           | -.0312         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |           | .5678          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           | 25.58 DEG      |

APPENDIX - Continued

ODIN Wing W26

|  |             |           |                |
|--|-------------|-----------|----------------|
| <b>1. OVERALL CONFIGURATION</b>            |             |           |                |
| AREA, PLANFORM (SFT)                       |             |           | 3702.9         |
| LENGTH, NOSE TO WING LE AT BODY            |             |           | 642.36 IN      |
| LENGTH, NOSE TO WING C/4                   |             |           | 886.42 IN      |
| ANGLF, GROUND PLANE                        |             | *FIXED*   | 17.00 DEG      |
| <b>2. FUSELAGE</b>                         |             |           |                |
| AREA, WETTED                               |             | *FIXED*   | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY                |             | *FIXED*   | 1315.0 IN      |
| <b>3. WING</b>                             |             |           |                |
| AREA, THEORETICAL OR TOTAL                 |             |           | 3010.9 SFT     |
| AREA, ELEVON                               |             |           | 450.97 SFT     |
| SPAN                                       |             |           | 949.80 IN      |
| CHORD, MEAN AERODYNAMIC                    |             |           | 539.19 IN      |
| CHORD, CENTERLINE ROOT                     |             |           | 792.98 IN      |
| CHORD, TIP                                 |             |           | 119.99 IN      |
| TAPER RATIO, THEORETICAL                   |             |           | .15131         |
| ASPECT RATIO, THEORETICAL                  |             |           | 2.0807         |
| ASPECT RATIO, EXPOSED SPAN                 |             |           | 1.9411         |
| ANGLE, LEADING EDGE SWEEP                  |             |           | 54.790 DEG     |
| ANGLE, TRAILING EDGE SWEEP                 |             | *FIXED*   | 0.0 DEG        |
| ANGLE, DIHEDRAL                            |             | *FIXED*   | 7.0 DEG        |
| ANGLE, INCIDENCE                           |             | *FIXED*   | 1.5 DEG        |
| AIRFOIL SECTION, ROOT                      |             | *FIXED*   | 008-64         |
| AIRFOIL SECTION, TIP                       |             | *FIXED*   | 008-64         |
| <b>4. 040A MASS PROPERTIES</b>             |             |           |                |
| FLIGHT CONDITION                           | WEIGHT (LB) | X-CG (FT) | X-CG (PC L)    |
| ORBITER LNDG (W/40K PL)                    | 198158.8    | 71.412    | 65.169         |
| ORBITER LNDG (W/O PL)                      | 158158.8    | 73.835    | 67.380         |
| WING WEIGHT                                | 15331.4     |           |                |
| TPS WEIGHT                                 | 26721.3     |           |                |
| <b>5. PRINCIPAL PARAMETERS</b>             |             |           |                |
| X-SCALE FACTOR                             |             |           | SCLX= .90000   |
| Y-SCALE FACTOR                             |             |           | SCLY= 1.1000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING   |             |           | XOF=642.360 IN |
| <b>6. LANDING PERFORMANCE</b>              |             |           |                |
| MINIMUM LANDING SPEED (W/40K PL)           |             |           | 167.6 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)        |             |           | -.0817         |
| STATIC MARGIN (SUBSONIC) (W/O PL)          |             |           | -.0278         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG)  |             |           | .6916          |
| <b>7. HYPERSONIC AERODYNAMIC TRIM DATA</b> |             |           |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG     |             |           | 44.09 DEG      |

APPENDIX - Continued

ODIN Wing W27

1. OVERALL CONFIGURATION

|                                 |                   |
|---------------------------------|-------------------|
| AREA, PLANFORM (SFT)            | 4064.7            |
| LENGTH, NOSE TO WING LE AT BODY | 630.36 IN         |
| LENGTH, NOSE TO WING C/4        | 885.34 IN         |
| ANGLE, GROUND PLANE             | *FIXED* 17.00 DEG |

2. FUSELAGE

|                             |                    |
|-----------------------------|--------------------|
| AREA, WETTED                | *FIXED* 6307.0 SFT |
| LENGTH, NOSE TO END OF BODY | *FIXED* 1315.0 IN  |

3. WING

|                            |                 |
|----------------------------|-----------------|
| AREA, THEORETICAL OR TOTAL | 3356.9 SFT      |
| AREA, ELEVON               | 532.96 SFT      |
| SPAN                       | 1085.4 IN       |
| CHORD, MEAN AERODYNAMIC    | 524.63 IN       |
| CHORD, CENTERLINE ROOT     | 770.74 IN       |
| CHORD, TIP                 | 119.99 IN       |
| TAPER RATIO, THEORETICAL   | .15568          |
| ASPECT RATIO, THEORETICAL  | 2.4371          |
| ASPECT RATIO, EXPOSED SPAN | 2.2940          |
| ANGLE, LEADING EDGE SWEEP  | 50.172 DEG      |
| ANGLE, TRAILING EDGE SWEEP | *FIXED* 0.0 DEG |
| ANGLE, DIHEDRAL            | *FIXED* 7.0 DEG |
| ANGLE, INCIDENCE           | *FIXED* 1.5 DEG |
| AIRFOIL SECTION, ROOT      | *FIXED* 008-64  |
| AIRFOIL SECTION, TIP       | *FIXED* 008-64  |

4. 040A MASS PROPERTIES

| FLIGHT CONDITION        | WEIGHT (LB) | X-CG (FT) | X-CG (PC L) |
|-------------------------|-------------|-----------|-------------|
| ORBITER LNDG (W/40K PL) | 201665.9    | 71.584    | 65.326      |
| ORBITER LNDG (W/O PL)   | 161665.9    | 73.996    | 67.527      |
| WING WEIGHT             | 17015.6     |           |             |
| TPS WEIGHT              | 28544.3     |           |             |

5. PRINCIPAL PARAMETERS

|  |                |
|--|----------------|
| X-SCALE FACTOR                           | SCLX= .90000   |
| Y-SCALE FACTOR                           | SCLY= 1.3000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING | XOF=630.360 IN |

6. LANDING PERFORMANCE

|   |          |
|---|----------|
| MINIMUM LANDING SPEED (W/40K PL)          | 150.8 KT |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       | -.0806   |
| STATIC MARGIN (SUBSONIC) (W/O PL)         | -.0254   |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) | .7799    |

7. HYPERSONIC AERODYNAMIC TRIM DATA

|  |           |
|--|-----------|
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG | 40.36 DEG |
|--|-----------|

APPENDIX - Continued

ODIN Wing W<sub>28</sub>

1. OVERALL CONFIGURATION

|                                 |                   |
|---------------------------------|-------------------|
| AREA, PLANFORM (SFT)            | 4426.5            |
| LENGTH, NOSE TO WING LE AT BODY | 626.27 IN         |
| LENGTH, NOSE TO WING C/4        | 889.25 IN         |
| ANGLE, GROUND PLANE             | *FIXED* 17.00 DEG |

2. FUSELAGE

|                             |                    |
|-----------------------------|--------------------|
| AREA, WETTED                | *FIXED* 6307.0 SFT |
| LENGTH, NOSE TO END OF BODY | *FIXED* 1315.0 IN  |

3. WING

|                            |                 |
|----------------------------|-----------------|
| AREA, THEORETICAL OR TOTAL | 3707.2 SFT      |
| AREA, ELEVON               | 614.95 SFT      |
| SPAN                       | 1221.0 IN       |
| CHORD, MEAN AERODYNAMIC    | 513.96 IN       |
| CHORD, CENTERLINE ROOT     | 754.43 IN       |
| CHORD, TIP                 | 119.99 IN       |
| TAPER RATIO, THEORETICAL   | .15904          |
| ASPECT RATIO, THEORETICAL  | 2.7927          |
| ASPECT RATIO, EXPOSED SPAN | 2.6470          |
| ANGLE, LEADING EDGE SWEEP  | 46.101 DEG      |
| ANGLE, TRAILING EDGE SWEEP | *FIXED* 0.0 DEG |
| ANGLE, BIHEDRAL            | *FIXED* 7.0 DEG |
| ANGLE, INCIDENCE           | *FIXED* 1.5 DEG |
| AIRFOIL SECTION, ROOT      | *FIXED* 008-64  |
| AIRFOIL SECTION, TIP       | *FIXED* 008-64  |

4. BADA MASS PROPERTIES

| FLIGHT CONDITION        | WEIGHT (LB) | X-CG (FT) | X-CG (PC L) |
|-------------------------|-------------|-----------|-------------|
| ORBITER LNDG (w/40K PL) | 205152.2    | 71.819    | 65.540      |
| ORBITER LNDG (w/0 PL)   | 165152.2    | 74.238    | 67.747      |
| WING WEIGHT             | 18668.4     |           |             |
| TPS WEIGHT              | 30377.7     |           |             |

5. PRINCIPAL PARAMETERS

|  |                |
|--|----------------|
| X-SCALE FACTOR                           | SCLX= .90000   |
| Y-SCALE FACTOR                           | SCLY= 1.5000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING | XUF=626.268 IN |

6. LANDING PERFORMANCE

|   |          |
|---|----------|
| MINIMUM LANDING SPEED (w/40K PL)          | 138.7 KT |
| STATIC MARGIN (SUBSONIC) (w/40K PL)       | -.0837   |
| STATIC MARGIN (SUBSONIC) (w/0 PL)         | -.0272   |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) | .8492    |

7. HYPERSONIC AERODYNAMIC TRIM DATA

|  |           |
|--|-----------|
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG | 36.55 DEG |
|--|-----------|

APPENDIX - Continued

ODIN Wing W29

|   |             |           |                |
|---|-------------|-----------|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |                |
| AREA, PLANFORM (SFT)                      |             |           | 4587.3         |
| LENGTH, NOSE TO WING LE AT BODY           |             |           | 580.70 IN      |
| LENGTH, NOSE TO WING C/4                  |             |           | 892.35 IN      |
| ANGLE, GROUND PLANE                       |             | *FIXED*   | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |                |
| AREA, WETTED                              |             | *FIXED*   | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY               |             | *FIXED*   | 1315.0 IN      |
| 3. WING                                   |             |           |                |
| AREA, THEORETICAL OR TOTAL                |             |           | 4102.9 SFT     |
| AREA, ELEVON                              |             |           | 651.40 SFT     |
| SPAN                                      |             |           | 1085.4 IN      |
| CHORD, MEAN AERODYNAMIC                   |             |           | 641.21 IN      |
| CHORD, CENTERLINE ROOT                    |             |           | 942.01 IN      |
| CHORD, TIP                                |             |           | 146.65 IN      |
| TAPER RATIO, THEORETICAL                  |             |           | .15568         |
| ASPECT RATIO, THEORETICAL                 |             |           | 1.9940         |
| ASPECT RATIO, EXPOSED SPAN                |             |           | 1.8769         |
| ANGLE, LEADING EDGE SWEEP                 |             |           | 55.692 DEG     |
| ANGLE, TRAILING EDGE SWEEP                |             | *FIXED*   | 0.0 DEG        |
| ANGLE, DIHEDRAL                           |             | *FIXED*   | 7.0 DEG        |
| ANGLE, INCIDENCE                          |             | *FIXED*   | 1.5 DEG        |
| AIRFOIL SECTION, ROOT                     |             | *FIXED*   | 008-64         |
| AIRFOIL SECTION, TIP                      |             | *FIXED*   | 008-64         |
| 4. 040A MASS PROPERTIES                   |             |           |                |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) | X-CG (PC L)    |
| ORBITER LNDG (W/40K PL)                   | 205097.8    | 72.652    | 66.301         |
| ORBITER LNDG (W/O PL)                     | 165097.8    | 75.274    | 68.693         |
| WING WEIGHT                               | 17403.0     |           |                |
| TPS WEIGHT                                | 31588.8     |           |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |                |
| X-SCALE FACTOR                            |             |           | SCLX= 1.1000   |
| Y-SCALE FACTOR                            |             |           | SCLY= 1.3000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           | XOF=580.704 IN |
| 6. LANDING PERFORMANCE                    |             |           |                |
| MINIMUM LANDING SPEED (W/40K PL)          |             |           | 150.3 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             |           | -.0818         |
| STATIC MARGIN (SUBSONIC) (W/O PL)         |             |           | -.0327         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |           | .6537          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           | 31.84 DEG      |

APPENDIX - Continued

ODIN Wing W30

|   |             |           |                |
|---|-------------|-----------|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |                |
| AREA, PLANFORM (SFT)                      |             |           | 4326.0         |
| LENGTH, NOSE TO WING LE AT BODY           |             |           | 601.69 IN      |
| LENGTH, NCSE TO WING C/4                  |             |           | 885.01 IN      |
| ANGLE, GROUND PLANE                       | *FIXED*     |           | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |                |
| AREA, WETTED                              | *FIXED*     |           | 6307.0 SFT     |
| LENGTH, NCSE TO END OF BODY               | *FIXED*     |           | 1315.0 IN      |
| 3. WING                                   |             |           |                |
| AREA, THEORETICAL OR TOTAL                |             |           | 3729.9 SFT     |
| AREA, ELEVON                              |             |           | 592.18 SFT     |
| SPAN                                      |             |           | 1085.4 IN      |
| CHORD, MEAN AERCDYNAMIC                   |             |           | 582.92 IN      |
| CHCRD, CENTERLINE ROOT                    |             |           | 856.38 IN      |
| CHORD, TIP                                |             |           | 133.32 IN      |
| TAPER RATIO, THEORETICAL                  |             |           | .15568         |
| ASPECT RATIO, THEORETICAL                 |             |           | 2.1934         |
| ASPECT RATIO, EXPOSED SPAN                |             |           | 2.0646         |
| ANGLE, LEADING EDGE SWEEP                 |             |           | 53.108 DEG     |
| ANGLE, TRAILING EDGE SWEEP                | *FIXED*     |           | 0.0 DEG        |
| ANGLE, DIHECRAL                           | *FIXED*     |           | 7.0 DEG        |
| ANGLE, INCIDENCE                          | *FIXED*     |           | 1.5 DEG        |
| AIRFOIL SECTION, ROOT                     | *FIXED*     |           | 008-64         |
| AIRFOIL SECTION, TIP                      | *FIXED*     |           | 008-64         |
| 4. 040A MASS PROPERTIES                   |             |           |                |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) | X-CG (PC L)    |
| ORBITER LNDG (W/40K PL)                   | 203375.9    | 72.052    | 65.753         |
| ORBITER LNDG (W/O PL)                     | 163375.9    | 74.553    | 68.036         |
| WING WEIGHT                               | 17204.5     |           |                |
| TPS WEIGHT                                | 30065.4     |           |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |                |
| X-SCALE FACTOR                            |             |           | SCLX= 1.0000   |
| Y-SCALE FACTOR                            |             |           | SCLY= 1.3000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           | XOF=601.694 IN |
| 6. LANDING PERFORMANCE                    |             |           |                |
| MINIMUM LANDING SPEED (W/40K PL)          |             |           | 149.6 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             |           | -.0776         |
| STATIC MARGIN (SUBSONIC) (W/O PL)         |             |           | -.0261         |
| TRIM LIFT CCEF FOR LANDING (ALPHA=17 DEG) |             |           | .7195          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           | 35.82 DEG      |



APPENDIX - Continued

ODIN Wing W31

|   |             |           |                |
|---|-------------|-----------|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |                |
| AREA, PLANFORM (SFT)                      |             |           | 3883.8         |
| LENGTH, NOSE TO WING LE AT BODY           |             |           | 637.56 IN      |
| LENGTH, NOSE TO WING C/4                  |             |           | 887.54 IN      |
| ANGLE, GROUND PLANE                       | *FIXED*     |           | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |                |
| AREA, WETTED                              | *FIXED*     |           | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY               | *FIXED*     |           | 1315.0 IN      |
| 3. WING                                   |             |           |                |
| AREA, THEORETICAL OR TOTAL                |             |           | 3183.3 SFT     |
| AREA, ELEVON                              |             |           | 491.96 SFT     |
| SPAN                                      |             |           | 1017.6 IN      |
| CHORD, MEAN AERODYNAMIC                   |             |           | 531.30 IN      |
| CHORD, CENTERLINE ROOT                    |             |           | 780.93 IN      |
| CHORD, TIP                                |             |           | 119.99 IN      |
| TAPER RATIO, THEORETICAL                  |             |           | .15365         |
| ASPECT RATIO, THEORETICAL                 |             |           | 2.2590         |
| ASPECT RATIO, EXPOSED SPAN                |             |           | 2.1176         |
| ANGLE, LEADING EDGE SWEEP                 |             |           | 52.409 DEG     |
| ANGLE, TRAILING EDGE SWEEP                | *FIXED*     |           | 0.0 DEG        |
| ANGLE, DIHEDRAL                           | *FIXED*     |           | 7.0 DEG        |
| ANGLE, INCIDENCE                          | *FIXED*     |           | 1.5 DEG        |
| AIRFOIL SECTION, ROOT                     | *FIXED*     |           | 008-64         |
| AIRFOIL SECTION, TIP                      | *FIXED*     |           | 008-64         |
| 4. 040A MASS PROPERTIES                   |             |           |                |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) | X-CG (PC L)    |
| ORBITER LNDG (W/40K PL)                   | 199915.0    | 71.517    | 65.265         |
| ORBITER LNDG (W/O PL)                     | 159915.0    | 73.940    | 67.476         |
| WING WEIGHT                               | 16177.7     |           |                |
| TPS WEIGHT                                | 27631.3     |           |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |                |
| X-SCALE FACTOR                            |             |           | SCLX= .90000   |
| Y-SCALE FACTOR                            |             |           | SCLY= 1.2000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           | XDF=637.561 IN |
| 6. LANDING PERFORMANCE                    |             |           |                |
| MINIMUM LANDING SPEED (W/40K PL)          |             |           | 159.2 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             |           | -.0836         |
| STATIC MARGIN (SUBSONIC) (W/C PL)         |             |           | -.0289         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |           | .7314          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           | 41.53 DEG      |

APPENDIX - Continued

ODIN Wing W32

| ODIN SUMMARY DATA, 040 A                   |             | PITCH.TRIM | PROBLEM     | CYCLE   | 1          |
|--|-------------|------------|-------------|---------|------------|
|  |             | .90000     | 1.4000      | 52.322  | 4/27/72    |
| <b>1. OVERALL CONFIGURATION</b>            |             |            |             |         |            |
| AREA, PLANFORM (SFT)                       |             |            |             |         | 4245.6     |
| LENGTH, NOSE TO WING LE AT BODY            |             |            |             |         | 627.86 IN  |
| LENGTH, NOSE TO WING C/4                   |             |            |             |         | 887.14 IN  |
| ANGLE, GROUND PLANE                        |             |            |             | *FIXED* | 17.00 DEG  |
| <b>2. FUSELAGE</b>                         |             |            |             |         |            |
| AREA, WETTED                               |             |            |             | *FIXED* | 6307.0 SFT |
| LENGTH, NOSE TO END OF BODY                |             |            |             | *FIXED* | 1315.0 IN  |
| <b>3. WING</b>                             |             |            |             |         |            |
| AREA, THEORETICAL OR TOTAL                 |             |            |             |         | 3531.7 SFT |
| AREA, ELEVON                               |             |            |             |         | 573.96 SFT |
| SPAN                                       |             |            |             |         | 1153.2 IN  |
| CHORD, MEAN AERODYNAMIC                    |             |            |             |         | 518.91 IN  |
| CHORD, CENTERLINE ROOT                     |             |            |             |         | 762.00 IN  |
| CHORD, TIP                                 |             |            |             |         | 119.99 IN  |
| TAPER RATIO, THEORETICAL                   |             |            |             |         | .15746     |
| ASPECT RATIO, THEORETICAL                  |             |            |             |         | 2.6150     |
| ASPECT RATIO, EXPOSED SPAN                 |             |            |             |         | 2.4705     |
| ANGLE, LEADING EDGE SWEEP                  |             |            |             |         | 48.071 DEG |
| ANGLE, TRAILING EDGE SWEEP                 |             |            |             | *FIXED* | 0.0 DEG    |
| ANGLE, DIHEDRAL                            |             |            |             | *FIXED* | 7.0 DEG    |
| ANGLE, INCIDENCE                           |             |            |             | *FIXED* | 1.5 DEG    |
| AIRFOIL SECTION, ROOT                      |             |            |             | *FIXED* | 008-64     |
| AIRFOIL SECTION, TIP                       |             |            |             | *FIXED* | 008-64     |
| <b>4. 040A MASS PROPERTIES</b>             |             |            |             |         |            |
| FLIGHT CONDITION                           | WEIGHT (LB) | X-CG (FT)  | X-CG (PC L) |         |            |
| ORBITER LNDG (W/40K PL)                    | 203411.8    | 71.698     | 65.430      |         |            |
| ORBITER LNDG (W/O PL)                      | 163411.8    | 74.113     | 67.634      |         |            |
| WING WEIGHT                                | 17845.8     |            |             |         |            |
| TPS WEIGHT                                 | 29460.0     |            |             |         |            |
| <b>5. PRINCIPAL PARAMETERS</b>             |             |            |             |         |            |
| X-SCALE FACTOR                             |             |            |             | SCLX=   | .90000     |
| Y-SCALE FACTOR                             |             |            |             | SCLY=   | 1.4000     |
| DISTANCE TO LEADING EDGE OF EXPOSED WING   |             |            |             | XCF=    | 627.864 IN |
| <b>6. LANDING PERFORMANCE</b>              |             |            |             |         |            |
| MINIMUM LANDING SPEED (W/40K PL)           |             |            |             |         | 144.3 KT   |
| STATIC MARGIN (SUBSONIC) (W/40K PL)        |             |            |             |         | -.0819     |
| STATIC MARGIN (SUBSONIC) (W/O PL)          |             |            |             |         | -.0261     |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG)  |             |            |             |         | .8164      |
| <b>7. HYPERSONIC AERODYNAMIC TRIM DATA</b> |             |            |             |         |            |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG     |             |            |             |         | 38.33 DEG  |

APPENDIX - Continued

ODIN Wing W33

|  |             |           |                |
|--|-------------|-----------|----------------|
| <b>1. OVERALL CONFIGURATION</b>            |             |           |                |
| AREA, PLANFORM (SFT)                       |             |           | 3803.4         |
| LENGTH, NOSE TO WING LE AT BODY            |             |           | 663.70 IN      |
| LENGTH, NOSE TO WING C/4                   |             |           | 890.35 IN      |
| ANGLF, GROUND PLANE                        |             | *FIXED*   | 17.00 DEG      |
| <b>2. FUSELAGE</b>                         |             |           |                |
| AREA, WETTED                               |             | *FIXED*   | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY                |             | *FIXED*   | 1315.0 IN      |
| <b>3. WING</b>                             |             |           |                |
| AREA, THEORETICAL OR TOTAL                 |             |           | 2984.0 SFT     |
| AREA, ELEVON                               |             |           | 473.74 SFT     |
| SPAN                                       |             |           | 1085.4 IN      |
| CHORD, MEAN AERODYNAMIC                    |             |           | 466.34 IN      |
| CHORD, CENTERLINE ROOT                     |             |           | 685.10 IN      |
| CHORD, TIP                                 |             |           | 106.66 IN      |
| TAPER RATIO, THEORETICAL                   |             |           | .15568         |
| ASPECT RATIO, THEORETICAL                  |             |           | 2.7417         |
| ASPECT RATIO, EXPOSED SPAN                 |             |           | 2.5808         |
| ANGLE, LEADING EDGE SWEEP                  |             |           | 46.825 DEG     |
| ANGLE, TRAILING EDGE SWEEP                 |             | *FIXED*   | 0.0 DEG        |
| ANGLE, DIHEDRAL                            |             | *FIXED*   | 7.0 DEG        |
| ANGLF, INCIDENCE                           |             | *FIXED*   | 1.5 DEG        |
| AIRFOIL SECTION, ROOT                      |             | *FIXED*   | 008-64         |
| AIRFOIL SECTION, TIP                       |             | *FIXED*   | 008-64         |
| <b>4. 040A MASS PROPERTIES</b>             |             |           |                |
| FLIGHT CONDITION                           | WEIGHT (LR) | X-CG (FT) | X-CG (PC L)    |
| ORBITER LNDG (W/40K PL)                    | 199970.6    | 71.202    | 64.977         |
| ORBITER LNDG (W/O PL)                      | 159970.6    | 73.545    | 67.115         |
| WING WEIGHT                                | 16838.4     |           |                |
| TPS WEIGHT                                 | 27026.2     |           |                |
| <b>5. PRINCIPAL PARAMETERS</b>             |             |           |                |
| X-SCALE FACTOR                             |             |           | SCLX= .80000   |
| Y-SCALE FACTOR                             |             |           | SCLY= 1.3000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING   |             |           | XOF=663.696 IN |
| <b>6. LANDING PERFORMANCE</b>              |             |           |                |
| MINIMUM LANDING SPEED (W/40K PL)           |             |           | 153.8 KT       |
| STATIC MARGIN (SURSONIC) (W/40K PL)        |             |           | -.0900         |
| STATIC MARGIN (SURSONIC) (W/O PL)          |             |           | -.0297         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG)  |             |           | .8366          |
| <b>7. HYPERSONIC AERODYNAMIC TRIM DATA</b> |             |           |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG     |             |           | 45.66 DEG      |

APPENDIX - Continued

ODIN Wing W<sub>27</sub> (Modified)

|   |             |           |                |
|---|-------------|-----------|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |                |
| AREA, PLANFORM (SFT)                      |             |           | 4182.2         |
| LENGTH, NOSE TO WING LE AT BODY           |             |           | 628.13 IN      |
| LENGTH, NOSE TO WING C/4                  |             |           | 889.39 IN      |
| ANGLE, GROUND PLANE                       |             | *FIXED*   | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |                |
| AREA, WETTED                              |             | *FIXED*   | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY               |             | *FIXED*   | 1315.0 IN      |
| 3. WING                                   |             |           |                |
| AREA, THEORETICAL OR TOTAL                |             |           | 3535.1 SFT     |
| AREA, ELEVON                              |             |           | 646.66 SFT     |
| SPAN                                      |             |           | 1085.4 IN      |
| CHORD, MEAN AERODYNAMIC                   |             |           | 555.61 IN      |
| CHORD, CENTERLINE ROOT                    |             |           | 818.02 IN      |
| CHORD, TIP                                |             |           | 119.99 IN      |
| TAPER RATIO, THEORETICAL                  |             |           | .14668         |
| ASPECT RATIO, THEORETICAL                 |             |           | 2.3143         |
| ASPECT RATIO, EXPOSED SPAN                |             |           | 2.1747         |
| ANGLE, LEADING EDGE SWEEP                 |             |           | 50.172 DEG     |
| ANGLE, TRAILING EDGE SWEEP                |             |           | -7.0 DEG       |
| ANGLE, DIHEDRAL                           |             | *FIXED*   | 7.0 DEG        |
| ANGLE, INCIDENCE                          |             | *FIXED*   | 1.5 DEG        |
| AIRFOIL SECTION, ROOT                     |             | *FIXED*   | 008-64         |
| AIRFOIL SECTION, TIP                      |             | *FIXED*   | 008-64         |
| 4. O40A MASS PROPERTIES                   |             |           |                |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) | X-CG (PC L)    |
| ORBITER LNDG (W/40K PL)                   | 201478.4    | 71.606    | 65.346         |
| ORBITER LNDG (W/O PL)                     | 161478.4    | 74.027    | 67.555         |
| WING WEIGHT                               | 16828.1     |           |                |
| TPS WEIGHT                                | 28544.3     |           |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |                |
| X-SCALE FACTOR                            |             |           | SCLX= .90000   |
| Y-SCALE FACTOR                            |             |           | SCLY= 1.3000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           | XOF=628.134 IN |
| 6. LANDING PERFORMANCE                    |             |           |                |
| MINIMUM LANDING SPEED (W/40K PL)          |             |           | 150.0 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             |           | -.0804         |
| STATIC MARGIN (SUBSONIC) (W/O PL)         |             |           | -.0281         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |           | .7480          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           | 40.81 DEG      |

APPENDIX - Concluded

ODIN Wing W<sub>33</sub> (Modified)

|   |             |                    |
|---|-------------|--------------------|
| 1. OVERALL CONFIGURATION                  |             | 4069.3             |
| AREA, PLANFORM (SFT)                      |             | 651.70 IN          |
| LENGTH, NOSE TO WING LE AT BODY           |             | 892.80 IN          |
| LENGTH, NOSE TO WING C/4                  | *FIXED*     | 17.00 DEG          |
| ANGLE, GROUND PLANE                       |             |                    |
| 2. FUSELAGE                               |             | *FIXED* 6307.0 SFT |
| AREA, WETTED                              | *FIXED*     | 1315.0 IN          |
| LENGTH, NOSE TO END OF BODY               |             |                    |
| 3. WING                                   |             | 3387.1 SFT         |
| AREA, THEORETICAL OR TOTAL                |             | 731.03 SFT         |
| AREA, ELEVON                              |             | 1085.4 IN          |
| SPAN                                      |             | 536.52 IN          |
| CHORD, MEAN AERODYNAMIC                   |             | 792.09 IN          |
| CHORD, CENTERLINE ROOT                    |             | 106.66 IN          |
| CHORD, TIP                                |             | .13465             |
| TAPER RATIO, THEORETICAL                  |             | 2.4154             |
| ASPECT RATIO, THEORETICAL                 |             | 2.2896             |
| ASPECT RATIO, EXPOSED SPAN                |             | 46.825 DEG         |
| ANGLE, LEADING EDGE SWEEP                 |             | -11.0 DEG          |
| ANGLE, TRAILING EDGE SWEEP                | *FIXED*     | 7.0 DEG            |
| ANGLE, DIHEDRAL                           | *FIXED*     | 1.5 DEG            |
| ANGLE, INCIDENCE                          | *FIXED*     | 008-64             |
| AIRFOIL SECTION, ROOT                     | *FIXED*     | 008-64             |
| AIRFOIL SECTION, TIP                      |             |                    |
| 4. 040A MASS PROPERTIES                   |             |                    |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT)          |
| ORBITER LNDG (W/40K PL)                   | 199609.0    | 71.181             |
| ORBITER LNDG (W/O PL)                     | 159609.0    | 73.523             |
| WING WEIGHT                               | 16476.8     |                    |
| TPS WEIGHT                                | 27026.2     |                    |
| 5. PRINCIPAL PARAMETERS                   |             | SCLX= .80000       |
| X-SCALE FACTOR                            |             | SCLY= 1.3000       |
| Y-SCALE FACTOR                            |             | XOF=651.696 IN     |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |                    |
| 6. LANDING PERFORMANCE                    |             | 149.9 KT           |
| MINIMUM LANDING SPEED (W/40K PL)          |             | -.0804             |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             | -.0280             |
| STATIC MARGIN (SUBSONIC) (W/O PL)         |             | .7742              |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |                    |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             | 48.90 DEG          |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |                    |

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APPENDIX - Continued

ODIN Wing W33

|  |             |           |                |
|--|-------------|-----------|----------------|
| <b>1. OVERALL CONFIGURATION</b>            |             |           |                |
| AREA, PLANFORM (SFT)                       |             |           | 3803.4         |
| LENGTH, NOSE TO WING LE AT BODY            |             |           | 663.70 IN      |
| LENGTH, NOSE TO WING C/4                   |             |           | 890.35 IN      |
| ANGLF, GROUND PLANE                        |             | *FIXED*   | 17.00 DEG      |
| <b>2. FUSELAGE</b>                         |             |           |                |
| AREA, WETTED                               |             | *FIXED*   | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY                |             | *FIXED*   | 1315.0 IN      |
| <b>3. WING</b>                             |             |           |                |
| AREA, THEORETICAL OR TOTAL                 |             |           | 2984.0 SFT     |
| AREA, ELEVON                               |             |           | 473.74 SFT     |
| SPAN                                       |             |           | 1085.4 IN      |
| CHORD, MEAN AERODYNAMIC                    |             |           | 466.34 IN      |
| CHORD, CENTERLINE ROOT                     |             |           | 685.10 IN      |
| CHORD, TIP                                 |             |           | 106.66 IN      |
| TAPER RATIO, THEORETICAL                   |             |           | .15568         |
| ASPECT RATIO, THEORETICAL                  |             |           | 2.7417         |
| ASPECT RATIO, EXPOSED SPAN                 |             |           | 2.5808         |
| ANGLE, LEADING EDGE SWEEP                  |             |           | 46.825 DEG     |
| ANGLE, TRAILING EDGE SWEEP                 |             | *FIXED*   | 0.0 DEG        |
| ANGLE, DIHEDRAL                            |             | *FIXED*   | 7.0 DEG        |
| ANGLE, INCIDENCE                           |             | *FIXED*   | 1.5 DEG        |
| AIRFOIL SECTION, ROOT                      |             | *FIXED*   | 008-64         |
| AIRFOIL SECTION, TIP                       |             | *FIXED*   | 008-64         |
| <b>4. 040A MASS PROPERTIES</b>             |             |           |                |
| FLIGHT CONDITION                           | WEIGHT (LR) | X-CG (FT) | X-CG (PC L)    |
| ORBITER LNDG (W/40K PL)                    | 199970.6    | 71.202    | 64.977         |
| ORBITER LNDG (W/O PL)                      | 159970.6    | 73.545    | 67.115         |
| WING WEIGHT                                | 16838.4     |           |                |
| TPS WEIGHT                                 | 27026.2     |           |                |
| <b>5. PRINCIPAL PARAMETERS</b>             |             |           |                |
| X-SCALE FACTOR                             |             |           | SCLX= .80000   |
| Y-SCALE FACTOR                             |             |           | SCLY= 1.3000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING   |             |           | XOF=663.696 IN |
| <b>6. LANDING PERFORMANCE</b>              |             |           |                |
| MINIMUM LANDING SPEED (W/40K PL)           |             |           | 153.8 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)        |             |           | -.0900         |
| STATIC MARGIN (SUBSONIC) (W/O PL)          |             |           | -.0297         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG)  |             |           | .8366          |
| <b>7. HYPERSONIC AERODYNAMIC TRIM DATA</b> |             |           |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG     |             |           | 45.66 DEG      |

APPENDIX - Continued

ODIN Wing W<sub>34</sub>

|   |             |           |                |
|---|-------------|-----------|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |                |
| AREA, PLANFORM (SFT)                      |             |           | 3260.7         |
| LENGTH, NOSE TO WING LE AT BODY           |             |           | 706.16 IN      |
| LENGTH, NOSE TO WING C/4                  |             |           | 895.99 IN      |
| ANGLE, GROUND PLANE                       |             | *FIXED*   | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |                |
| AREA, WETTED                              |             | *FIXED*   | 6307.0 SFT     |
| LENGTH, NOSE TO END OF BODY               |             | *FIXED*   | 1315.0 IN      |
| 3. WING                                   |             |           |                |
| AREA, THEORETICAL OR TOTAL                |             |           | 2341.8 SFT     |
| AREA, ELEVON                              |             |           | 350.75 SFT     |
| SPAN                                      |             |           | 949.80 IN      |
| CHORD, MEAN AERODYNAMIC                   |             |           | 419.37 IN      |
| CHORD, CENTERLINE ROOT                    |             |           | 616.76 IN      |
| CHORD, TIP                                |             |           | 93.324 IN      |
| TAPER RATIO, THEORETICAL                  |             |           | .15131         |
| ASPECT RATIO, THEORETICAL                 |             |           | 2.6752         |
| ASPECT RATIO, EXPOSED SPAN                |             |           | 2.4957         |
| ANGLE, LEADING EDGE SWEEP                 |             |           | 47.782 DEG     |
| ANGLE, TRAILING EDGE SWEEP                |             | *FIXED*   | 0.0 DEG        |
| ANGLE, DIHEDRAL                           |             | *FIXED*   | 7.0 DEG        |
| ANGLE, INCIDENCE                          |             | *FIXED*   | 1.5 DEG        |
| AIRFOIL SECTION, ROOT                     |             | *FIXED*   | 008-64         |
| AIRFOIL SECTION, TIP                      |             | *FIXED*   | 008-64         |
| 4. C40A MASS PROPERTIES                   |             |           |                |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) | X-CG (PC L)    |
| ORBITER LNDG (W/40K PL)                   | 195128.5    | 70.687    | 64.507         |
| ORBITER LNDG (W/O PL)                     | 155128.5    | 72.970    | 66.591         |
| WING WEIGHT                               | 14939.6     |           |                |
| TPS WEIGHT                                | 24082.8     |           |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |                |
| X-SCALE FACTOR                            |             |           | SCLX= .70000   |
| Y-SCALE FACTOR                            |             |           | SCLY= 1.1000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           | XOF=706.163 IN |
| 6. LANDING PERFORMANCE                    |             |           |                |
| MINIMUM LANDING SPEED (W/40K PL)          |             |           | 171.4 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             |           | -.0940         |
| STATIC MARGIN (SUBSONIC) (W/C PL)         |             |           | -.0286         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |           | .8380          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           | 59.10 DEG      |



APPENDIX - Continued

ODIN Wing W35

|   |             |           |                |
|---|-------------|-----------|----------------|
| 1. OVERALL CONFIGURATION                  |             |           |                |
| AREA, PLANFORM (SFT)                      |             |           | 3401.4         |
| LENGTH, NOSE TO WING LE AT BCDY           |             |           | 695.20 IN      |
| LENGTH, NOSE TO WING C/4                  |             |           | 893.63 IN      |
| ANGLE, GRCOND PLANE                       |             | *FIXED*   | 17.00 DEG      |
| 2. FUSELAGE                               |             |           |                |
| AREA, WETTED                              |             | *FIXED*   | 6307.0 SFT     |
| LENGTH, NOSE TO END CF BODY               |             | *FIXED*   | 1315.0 IN      |
| 3. WING                                   |             |           |                |
| AREA, THEORETICAL CR TOTAL                |             |           | 2475.9 SFT     |
| AREA, ELEVON                              |             |           | 382.64 SFT     |
| SPAN                                      |             |           | 1017.6 IN      |
| CHORD, MEAN AERODYNAMIC                   |             |           | 413.23 IN      |
| CHORD, CENTERLINE ROOT                    |             |           | 607.39 IN      |
| CHORD, TIP                                |             |           | 93.324 IN      |
| TAPER RATIO, THEORETICAL                  |             |           | .15365         |
| ASPECT RATIO, THEORETICAL                 |             |           | 2.9044         |
| ASPECT RATIO, EXPOSED SPAN                |             |           | 2.7226         |
| ANGLE, LEADING EDGE SWEEP                 |             |           | 45.294 DEG     |
| ANGLE, TRAILING EDGE SWEEP                |             | *FIXED*   | 0.0 DEG        |
| ANGLE, DIHEDRAL                           |             | *FIXED*   | 7.0 DEG        |
| ANGLE, INCIDENCE                          |             | *FIXED*   | 1.5 DEG        |
| AIRFOIL SECTION, ROOT                     |             | *FIXED*   | 008-64         |
| AIRFOIL SECTION, TIP                      |             | *FIXED*   | 008-64         |
| 4. 040A MASS PROPERTIES                   |             |           |                |
| FLIGHT CONDITION                          | WEIGHT (LB) | X-CG (FT) | X-CG (PC L)    |
| CPBITER LNDG (W/40K PL)                   | 196714.8    | 70.746    | 64.561         |
| CPBITER LNDG (W/C PL)                     | 156714.8    | 73.021    | 66.637         |
| WING WEIGHT                               | 15812.6     |           |                |
| TPS WEIGHT                                | 24796.1     |           |                |
| 5. PRINCIPAL PARAMETERS                   |             |           |                |
| X-SCALE FACTOR                            |             |           | SCLX= .70000   |
| Y-SCALE FACTOR                            |             |           | SCLY= 1.2000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING  |             |           | XOF=699.198 IN |
| 6. LANDING PERFORMANCE                    |             |           |                |
| MINIMUM LANDING SPEED (W/40K PL)          |             |           | 163.4 KT       |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       |             |           | -.0949         |
| STATIC MARGIN (SUBSONIC) (W/C PL)         |             |           | -.0289         |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) |             |           | .8787          |
| 7. HYPERSONIC AERODYNAMIC TRIM DATA       |             |           |                |
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG    |             |           | 56.65 DEG      |

APPENDIX - Continued

ODIN Wing W27 (Modified)

1. OVERALL CONFIGURATION

|                                 |                   |
|---------------------------------|-------------------|
| AREA, PLANFORM (SFT)            | 4182.2            |
| LENGTH, NOSE TO WING LE AT BODY | 628.13 IN         |
| LENGTH, NOSE TO WING C/4        | 889.39 IN         |
| ANGLE, GROUND PLANE             | *FIXED* 17.00 DEG |

2. FUSELAGE

|                             |         |            |
|-----------------------------|---------|------------|
| AREA, WETTED                | *FIXED* | 6307.0 SFT |
| LENGTH, NOSE TO END OF BODY | *FIXED* | 1315.0 IN  |

3. WING

|                            |                 |
|----------------------------|-----------------|
| AREA, THEORETICAL OR TOTAL | 3535.1 SFT      |
| AREA, ELEVON               | 646.66 SFT      |
| SPAN                       | 1085.4 IN       |
| CHORD, MEAN AERODYNAMIC    | 555.61 IN       |
| CHORD, CENTERLINE ROOT     | 818.02 IN       |
| CHORD, TIP                 | 119.99 IN       |
| TAPER RATIO, THEORETICAL   | .14668          |
| ASPECT RATIO, THEORETICAL  | 2.3143          |
| ASPECT RATIO, EXPOSED SPAN | 2.1747          |
| ANGLE, LEADING EDGE SWEEP  | 50.172 DEG      |
| ANGLE, TRAILING EDGE SWEEP | -7.0 DEG        |
| ANGLE, DIHEDRAL            | *FIXED* 7.0 DEG |
| ANGLE, INCIDENCE           | *FIXED* 1.5 DEG |
| AIRFOIL SECTION, ROOT      | *FIXED* 008-64  |
| AIRFOIL SECTION, TIP       | *FIXED* 008-64  |

4. G40A MASS PROPERTIES

| FLIGHT CONDITION        | WEIGHT (LB) | X-CG (FT) | X-CG (PG L) |
|-------------------------|-------------|-----------|-------------|
| ORBITER LNDG (W/40K PL) | 201478.4    | 71.606    | 65.346      |
| ORBITER LNDG (W/O PL)   | 161478.4    | 74.027    | 67.555      |
| WING WEIGHT             | 16828.1     |           |             |
| TPS WEIGHT              | 28544.3     |           |             |

5. PRINCIPAL PARAMETERS

|  |                |
|--|----------------|
| X-SCALE FACTOR                           | SCLX= .90000   |
| Y-SCALE FACTOR                           | SCLY= 1.3000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING | XOF=628.134 IN |

6. LANDING PERFORMANCE

|   |          |
|---|----------|
| MINIMUM LANDING SPEED (W/40K PL)          | 150.0 KT |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       | -.0804   |
| STATIC MARGIN (SUBSONIC) (W/O PL)         | -.0281   |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) | .7480    |

7. HYPERSONIC AERODYNAMIC TRIM DATA

|  |           |
|--|-----------|
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG | 40.81 DEG |
|--|-----------|

APPENDIX - Concluded

ODIN Wing W<sub>33</sub> (Modified)

1. OVERALL CONFIGURATION

|                                 |         |           |
|---------------------------------|---------|-----------|
| AREA, PLANFORM (SFT)            |         | 4069.3    |
| LENGTH, NOSE TO WING LE AT BODY |         | 651.70 IN |
| LENGTH, NOSE TO WING C/4        |         | 892.80 IN |
| ANGLE, GROUND PLANE             | *FIXED* | 17.00 DEG |

2. FUSELAGE

|                             |         |            |
|-----------------------------|---------|------------|
| AREA, WETTED                | *FIXED* | 6307.0 SFT |
| LENGTH, NOSE TO END OF BODY | *FIXED* | 1315.0 IN  |

3. WING

|                            |         |            |
|----------------------------|---------|------------|
| AREA, THEORETICAL OR TOTAL |         | 3387.1 SFT |
| AREA, ELEVON               |         | 731.03 SFT |
| SPAN                       |         | 1085.4 IN  |
| CHORD, MEAN AERODYNAMIC    |         | 536.52 IN  |
| CHORD, CENTERLINE ROOT     |         | 792.09 IN  |
| CHORD, TIP                 |         | 106.66 IN  |
| TAPER RATIO, THEORETICAL   |         | .13465     |
| ASPECT RATIO, THEORETICAL  |         | 2.4154     |
| ASPECT RATIO, EXPOSED SPAN |         | 2.2896     |
| ANGLE, LEADING EDGE SWEEP  |         | 46.825 DEG |
| ANGLE, TRAILING EDGE SWEEP |         | -11.0 DEG  |
| ANGLE, DIHEDRAL            | *FIXED* | 7.0 DEG    |
| ANGLE, INCIDENCE           | *FIXED* | 1.5 DEG    |
| AIRFOIL SECTION, ROOT      | *FIXED* | 008-64     |
| AIRFOIL SECTION, TIP       | *FIXED* | 008-64     |

4. 040A MASS PROPERTIES

| FLIGHT CONDITION        | WEIGHT (LB) | X-CG (FT) | X-CG (PC L) |
|-------------------------|-------------|-----------|-------------|
| ORBITER LNDG (W/40K PL) | 199609.0    | 71.181    | 64.958      |
| ORBITER LNDG (W/O PL)   | 159609.0    | 73.523    | 67.096      |
| WING WEIGHT             | 16476.8     |           |             |
| TPS WEIGHT              | 27026.2     |           |             |

5. PRINCIPAL PARAMETERS

|  |                |
|--|----------------|
| X-SCALE FACTOR                           | SCLX= .80000   |
| Y-SCALE FACTOR                           | SCLY= 1.3000   |
| DISTANCE TO LEADING EDGE OF EXPOSED WING | XOF=651.696 IN |

6. LANDING PERFORMANCE

|   |          |
|---|----------|
| MINIMUM LANDING SPEED (W/40K PL)          | 149.9 KT |
| STATIC MARGIN (SUBSONIC) (W/40K PL)       | -.0804   |
| STATIC MARGIN (SUBSONIC) (W/O PL)         | -.0280   |
| TRIM LIFT COEF FOR LANDING (ALPHA=17 DEG) | .7742    |

7. HYPERSONIC AERODYNAMIC TRIM DATA

|  |           |
|--|-----------|
| TRIM ANGLE OF ATTACK AT ELEVON=-45 DEG | 48.90 DEG |
|--|-----------|

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