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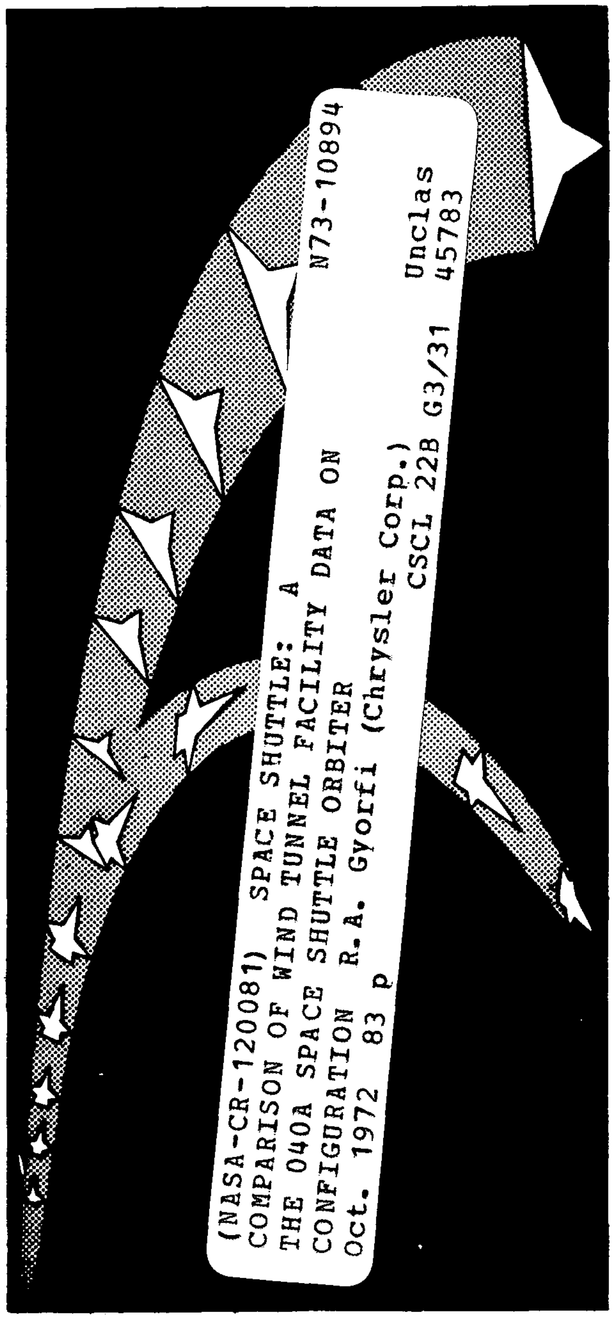

—SPACE SHUTTLE—

A COMPARISON OF WIND TUNNEL FACILITY DATA ON THE 040A SPACE SHUTTLE ORBITER CONFIGURATION

by

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MARSHALL
SPACE FLIGHT CENTER

NASA

SADSAC SPACE SHUTTLE
AEROTHERMODYNAMIC
DATA MANAGEMENT SYSTEM

CONTRACT NAS8-4016
MARSHALL SPACE FLIGHT CENTER

SPACE DIVISION CHRYSLER CORPORATION

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SADSAC/SPACE SHUTTLE

WIND TUNNEL TEST DATA REPORT

CONFIGURATION:	040 Space Shuttle Orbiter
PURPOSE:	Comparison of Aerodynamic Data Obtained from Four Different Wind Tunnel Facilities on the 040A Space Shuttle Orbiter Configuration
FACILITIES:	MSFC 14" x 14" Trisonic Wind Tunnel
	ARC 6 x 6 ft Supersonic Wind Tunnel
	JPL 20" x 20" Supersonic Wind Tunnel
	LaRC 3 x 7 ft Low Turbulence Pressure Tunnel
REPORT AGENCY:	Northrop Services, Inc.
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CONTRACT NAS 8-4016 AMENDMENT 174 DRL 297 - 84a

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SUMMARY

This report documents a series of comparisons made on the longitudinal and lateral-directional stability and control characteristics of the baseline 040A Space Shuttle Orbiter configuration. The data used for the comparisons were obtained from five wind tunnel tests conducted in four different wind tunnel facilities. The media for comparison were the aerodynamic slope values plotted as a function of Mach number for the different facilities. The slopes were computed using the SADSAC system and have been reduced relative to a common reference system. All slope data are presented in the body-axis system with the exception of $C_{L_{\delta_e}}$ which is presented in the stability axis system.

Data used for the comparison were selected based on a common baseline configuration. Identical configurations were available in all cases except MSFC 551 where an off-baseline vertical tail was tested. This is discussed later in the Configurations Investigated section. Some of the factors considered in comparing the various data were balance operating ranges and sensitivities, Reynolds number differences, scaling effects and control deflection accuracies. With these factors under consideration the overall comparison is excellent with the exception of $C_{Y_{\delta_a}}$ and $C_{n_{\delta_a}}$ where Ames 6 x 6 ft and MSFC-14 in. data differ substantially. It is believed that this could be the result of model component inaccuracies since one of the slopes, $C_{\ell_{\delta_a}}$, is apparently not affected. This theory is discussed later in the report.

The tests and test dates used in this comparison were:

- MSFC 510 - 22 October - 1 November, 1971
- MSFC 551 - 24-25 July, 1972
- JPL 20-681 - 29 November - 10 December, 1971
- ARC 66-605 - 29 November - 17 December, 1971
- LaRC LTPT 85 - 29 November - 10 December, 1971

NOMENCLATURE

(General)

SYMBOL	SADSAC SYMBOL	DEFINITION
α	ALPHA	Angle of attack, angle between the projection of the wind X_W-axis on the body X-Z plane and body X-axis, degrees
β	BETA	Sideslip angle, angle between the wind X_W axis and the projection of this on the body X-Z plane, degrees
M	MACH	Mach number, speed of vehicle relative to surrounding atmosphere divided by local speed of sound
q	Q(PSI) Q(PSF)	dynamic pressure, $\rho V^2/2$ psi psf
ρ		Air density, kg/m^3, $slugs/ft^3$
V		Speed of vehicle relative to surrounding atmosphere, m/sec, ft/sec
RN/L	RN/L	Reynolds number per unit length, million/ft
F		Force, F, lbs
M		Moment, M, in-lbs
δr_L	LRUDDR	Left split rudder surface deflection angle, degrees, positive deflection, trailing edge to the left
δr_R	RRUDDR	Right split rudder surface deflection angle, degrees, positive defection, trailing edge to the left
δ_r	RUDDER	Asymmetrical split rudder deflection for directional control $(\delta r_L + \delta r_R)/2$, degrees
δe_L	ELVN-L	Left elevon, surface deflection angle, positive deflection, trailing edge down, degrees
δe_R	ELVN-R	Right elevon, surface deflection angle, positive deflection, trailing edge down, degrees
δ_a	AILERN	Total aileron deflection angle in degrees, $(\delta e_L - \delta e_R)/2$
δ_e	ELEVTR	Total elevator deflection angle in degrees, $(\delta e_L + \delta e_R)/2$

NOMENCLATURE

(Reference and C.G. Definition)

SYMBOL	SADSAC SYMBOL	DEFINITION
S_{ref}	SREF	Reference area, m^2, ft^2
ℓ_{ref}	LREF	Reference length, m, ft, in.
b_{ref}	BREF	Wing span for reference span, m, ft, in.
c.g.		Center of gravity
MRP	MRP	Abbreviation for moment reference point
	XMRP	Abbreviation for moment reference point on X-axis
	YMRP	Abbreviation for moment reference point on Y-axis
	ZMRP	Abbreviation for moment reference point on Z-axis

NOMENCLATURE

(Body and Stability Axis System)

SYMBOL	SADSAC SYMBOL	DEFINITION
		(Common to Both Axis Systems)
C_m	CLM	Pitching moment coefficient, $M_Y/qS\ell ref$
C_Y	CY	Side force coefficient, F_Y/qS
		Stability Axis System
C_L	CL	Lift force coefficient F_L/qS
C_D	CD	Drag force coefficient, F_D/qS
C_n	CLN	Yawing moment coefficient, M_Z,s/qSb_{ref}
C_ℓ	CSL	Rolling moment coefficient, M_X, s/qSb_{ref}
		Derivatives
C_{m_α}	D(CLM)	Derivative of pitching moment coefficient with respect to alpha (alpha = 0 to 5^o), per degree
C_{n_β}	DCYNDB	Derivative of yawing moment coefficient with respect to beta (beta = $\pm 5^o$) per degree, body axis system.
C_{ℓ_β}	DCBLDB	Derivative of rolling moment coefficient with respect to beta (beta = ± 5) per degree, body axis system.
C_{Y_β}	DCY/DB	Derivative of side force coefficient with respect to beta (beta = $\pm 5^o$) per degree, body axis system
$C_{n_{\delta_r}}$	DCYNDA	Incremental yawing moment due to rudder deflection. Algebraic sum of the yawing moment coefficients of two runs divided by the algebraic sum of the rudder deflection, body axis system, per degree
$C_{\ell_{\delta_r}}$	DCBL	Incremental rolling moment due to rudder deflection. Algebraic sum of the yawing moment coefficients of two runs divided by the algebraic sum of rudder deflection, body axis system, per degree.

$C_{Y_{\delta_r}}$	DCY/DR	Incremental side force due to rudder deflection. Algebraic sum of the side force coefficients of two runs divided by the algebraic sum of the rudder deflection, body axis system, per degree.
$C_{n_{\delta_a}}$	DCYNDA	Incremental yawing moment due to aileron deflection. Algebraic sum of the yawing moment coefficient of two runs divided by the algebraic sum of the aileron deflection, stability axis system, per degree.
$C_{\ell_{\delta_a}}$	DCBLDA	Incremental rolling moment due to aileron deflection. Algebraic sum of the rolling moment coefficients of two runs divided by the algebraic sum of the aileron deflection, stability axis system, per degree.
$C_{Y_{\delta_a}}$	DCY/DA	Side force due to aileron deflection. Algebraic sum of the side force coefficients of two runs divided by the algebraic sum of the aileron deflection angle of the runs, per degree.
$C_{L_{\delta_e}}$	DCL/DE	Incremental lift force due to elevon deflection. Algebraic sum of the lift force coefficients of two runs divided by the algebraic sum of the elevon deflection angle of the runs, stability axis system, per degree.
$C_{m_{\delta_e}}$	DCLMDE	Incremental pitching moment due to elevon deflection. Algebraic sum of the pitching moment coefficients of two runs divided by the algebraic sum of the elevon deflection angle of the runs, body axis system, per degree.
C_{N_α}	D(CN)	Derivative of normal force coefficient with respect to alpha (alpha = 0 to 5°), per degree.

INTRODUCTION

The Phase-B Space Shuttle Study has offered a unique opportunity for aerodynamicists involved in configuration development. Similar models of various scale sizes were tested in different wind tunnels and the data stored for retrieval and analysis in a common data management system. These circumstances allowed engineers to consider the relative merits of various testing techniques in configuration development. In particular, Marshall Space Flight Center has evaluated the feasibility of testing relatively small scaled models of various Space Shuttle orbiter and booster configurations in the MSFC 14-inch TWT over large angle of attack ranges. This report compares data obtained on the 040A orbiter in the 14-inch TWT with that obtained at three other facilities. A similar comparison was made with data on the Grumman H-33 orbiter where a sufficient amount of data was available to conclude that comparisons between vastly different facilities were excellent (Ref. 8). Similar results were obtained for the 040A and further demonstrates the feasibility of using various model sizes and wind tunnel facilities to accomplish configuration development in an economical fashion. In order to gain an appreciation for the data comparison accuracies, the configuration is discussed, data reduction details presented, balance operating ranges and nominal loads tabulated and Reynolds number comparisons are made.

CONFIGURATION INVESTIGATED

All of the data used for this comparison were taken from identical configurations with the exception of that from MSFC 551 where the V_9 vertical tail was used instead of the baseline V_1. The V_1 tail on the .006-scale model tested at MSFC 14 x 14" TWT was reduced from a 12% airfoil to an 8% airfoil during MSFC 528 and redesignated V_9. Therefore a V_1 tail was not available for MSFC 551 and the test was conducted employing V_9. It is felt that this reduction in airfoil size has minimal effect on the characteristics studied in this comparison and therefore not considered a factor in any apparent discrepancies.

The components making up the 040A configuration are as follows.

- B_1 - Basic fuselage of the 040A SSV orbiter configuration
- C_1 - Basic canopy
- D_1 - Manipulator arm dorsal housing
- M_1 - Basic orbital maneuvering system (OMS) pod - one on each side of the aft body at F.S. 1308.5
- P_1 - Basic attitude control propulsion system (ACPS) pods - one on the vertical tail and one on each wing tip
- V_1 - Basic vertical fin of the 040A configuration
- V_9 - Same as V_1 but with 12% airfoil reduced to 8%
- W_1 - Basic 040A delta wing.

A complete description of each of these components may be found in the Model Component Description Sheets.

None of the tests employed fixed transition to promote boundary layer tripping. MSFC 510 employed transition strips for two data runs and found that the resulting axial force increment was not large enough to account for an increase in viscous drag due to transition to turbulent flow so further use of fixed transition became unnecessary (Ref. 4).

DATA REDUCTION

With the exception of $C_{L_{\delta_e}}$ all data used in the comparison were reduced along and about a set of body axes originating at the moment reference center located at F.S. 1067.9, W.L. 400 and B.L. 0 (full-scale location). The data were reduced to coefficient form using the following full-scale reference dimensions:

S_{ref} = 3155 sq. ft.
ℓ_{ref} = 609.6 in.
b_{ref} = 882.0 in.
$C.G._{loc}$ = 867.9 in. measured from the nose of the orbiter

The following table lists the five tests, the balances used and the above constants in model scale.

TEST	BALANCE	MODEL SCALE	S_{ref} (in.^{2})	ℓ_{ref} (in.)	b_{ref} (in.)	C. G. LOCATION (in. from nose)
MSFC 510	MSFC #232	.006	16.370	3.657	5.292	5.2074
MSFC 551	MSFC #200	.006	16.370	3.657	5.292	5.2074
JPL 20-681	JPL SGB6-3	.0075	25.556	4.572	6.615	6.50925
ARC 6x6 605	AMES Task MK II	.0015	102.222	9.144	13.230	13.0185
LaRC LTPT 85	LaRC #832C	.0019	164.0099	11.5824	16.758	16.4901

BALANCE INFORMATION

Representative model loads and balance capacities for each test are presented in Table I. The representative load is the maximum absolute value the balance recorded for each force or moment during any run used in the comparisons over the angle-of-attack range 0 to 15 degrees and angle-of-sideslip range -4 to +4 degrees. As the data presented in Table I indicates, the maximum measured loads and moments for some tests represent a small percentage of balance capacity. The bulk of the data used in these comparisons were obtained at less than maximum balance capability and could explain some minor differences encountered in various parameters.

Table I. BALANCE INFORMATION

		REPRESENTATIVE LOAD AT COMPARISON CONDITIONS/BALANCE CAPACITY					
TEST	BALANCE	NF (lbs)	SF (lbs)	AF (lbs)	PM (in. lbs)	YM (in. lbs)	RM (in. lbs)
MSFC 510	MSFC #232	165/300	120/150	20/50	60/392	10/196	9/100
MSFC 551	MSFC #200	100/175	2/150	18/100	75/185	3.5/160	25/50
JPL 20-681	JPL SGB6-3	70/200	7/100	11.5/30	32.5/300	2/125	2.2/20
LaRC LTPT 85	LaRC #832C	205/1000	*	*	55/2000	*	*
ARC 6x6 605	AMES Task MK II (1.5" dia.)	FORCE TYPE BALANCE - LOADS DATA NOT AVAILABLE AT THIS TIME					

**Not Applicable; data not used in any comparisons.*

SCALED REYNOLDS NUMBER COMPARISONS

Presented in Figure 2 are the Reynolds numbers based on model length. There is a relatively large Reynolds number difference between ARC 6x6 605 and the two Marshall tests, MSFC 510 and 551 at subsonic Mach numbers. Previous Phase B Reynolds number studies at ARC and LaRC have shown the importance of matching Reynolds number. (Refs. 4 and 6). Although the major effect of Reynolds number occurs in drag, stability can be effected when separated flow occurs.

DATA COMPARISON DISCUSSION

The longitudinal and lateral directional stability and control characteristics are compared mainly among three different facilities. These were MSFC 14-inch TWT, ARC 6x6 ft SWT and JPL 20-inch SWT. Longitudinal stability was also compared at a fourth facility, LaRC LTPT, but because of a lack of usable data and its low operational Mach number no other direct comparisons were available. A sufficient data base existed on the 040A to allow a good comparison of longitudinal and lateral directional stability and control characteristics. However, the control characteristics were limited in that no comparable rudder deflection data was available.

In general, the comparison among the facilities is very good. Longitudinal directional stability (Fig. 3) and the elevon deflection derivatives (Fig. 6) show excellent agreement and are well within the limits of experimental accuracy. This takes into account balance sensitivities, balance operating ranges, Reynolds number variations and model design, construction and control surface deflection accuracies. The lateral directional stability derivatives (Fig. 4) reflect excellent subsonic agreement but show some scatter in the higher Mach range; particularly in the low transonic region. There appears to be a near-constant shift in the values of the derivatives from the three facilities relative to each other while their general trends remain nearly identical. This is especially prominent in the side force derivative where the relative shifts are on the order of $\pm 10\%$ of the values obtained from the MSFC 14-inch TWT. In order to make an attempt to explain this phenomenon more data would have to be obtained from the other two facilities in overlapping Mach ranges, smaller Mach intervals and particularly in the region of critical activity around Mach 1.2.

The aileron deflection derivatives presented in Figure 5 compare the least-favorably of any in this study. It should be noted, however, that this applies only to the comparison of transonic data from ARC 66-605 with that from MSFC 551. The comparison of data at Mach 2.0 and above taken from JPL 20-681 and MSFC 551 is excellent. The discrepancies in the aileron deflection derivatives are primarily limited to $C_{y_{\delta_a}}$ and $C_{n_{\delta_a}}$. $C_{\ell_{\delta_a}}$ compares much more favorably which suggests that the cause of these discrepancies could perhaps be due to a difference in induced drag on the OMS and ACPS pods. Small differences in the induced drag on the ACPS pods located on the wing tips could produce a sizable difference in C_n and consequently $C_{n_{\delta_a}}$ due to the length of the moment arm. These differences could result from minor construction errors, surface roughness or, in the case of the OMS pods, different locations of the impinging shock in subsonic and low transonic flow. This latter theory appears to be supported by the fact that much of the data compares much more closely once the flow goes completely supersonic and the shock flattens to a more stable swept position or is blown off altogether. In any case, $C_{\ell_{\delta_a}}$ is the significant control derivative of the three and since its comparison appears quite good at all Mach numbers the overall comparison is felt to be well within the limits of experimental accuracy.

Table II. SUMMARY DATA PLOT INDEX

TITLE	PLOTTED COEFFICIENTS SCHEDULE	CONDITIONS VARYING	PLOT PAGES
Longitudinal Stability	A	Mach	17
Lateral Directional Stability - $\alpha = 0°$	B	Mach	19
Aileron Power Derivatives - $\alpha = 0°$	C	Mach	21
Aileron Power Derivatives - $\alpha = 10°$	C	Mach	22
Aileron Power Derivatives - $\alpha = 20°$	C	Mach	23
Elevon Power Derivatives - $\alpha = 0°$	D	Mach	24
Elevon Power Derivatives - $\alpha = 10°$	D	Mach	25
Elevon Power Derivatives - $\alpha = 20°$	D	Mach	26

PLOTTED COEFFICIENTS SCHEDULE:

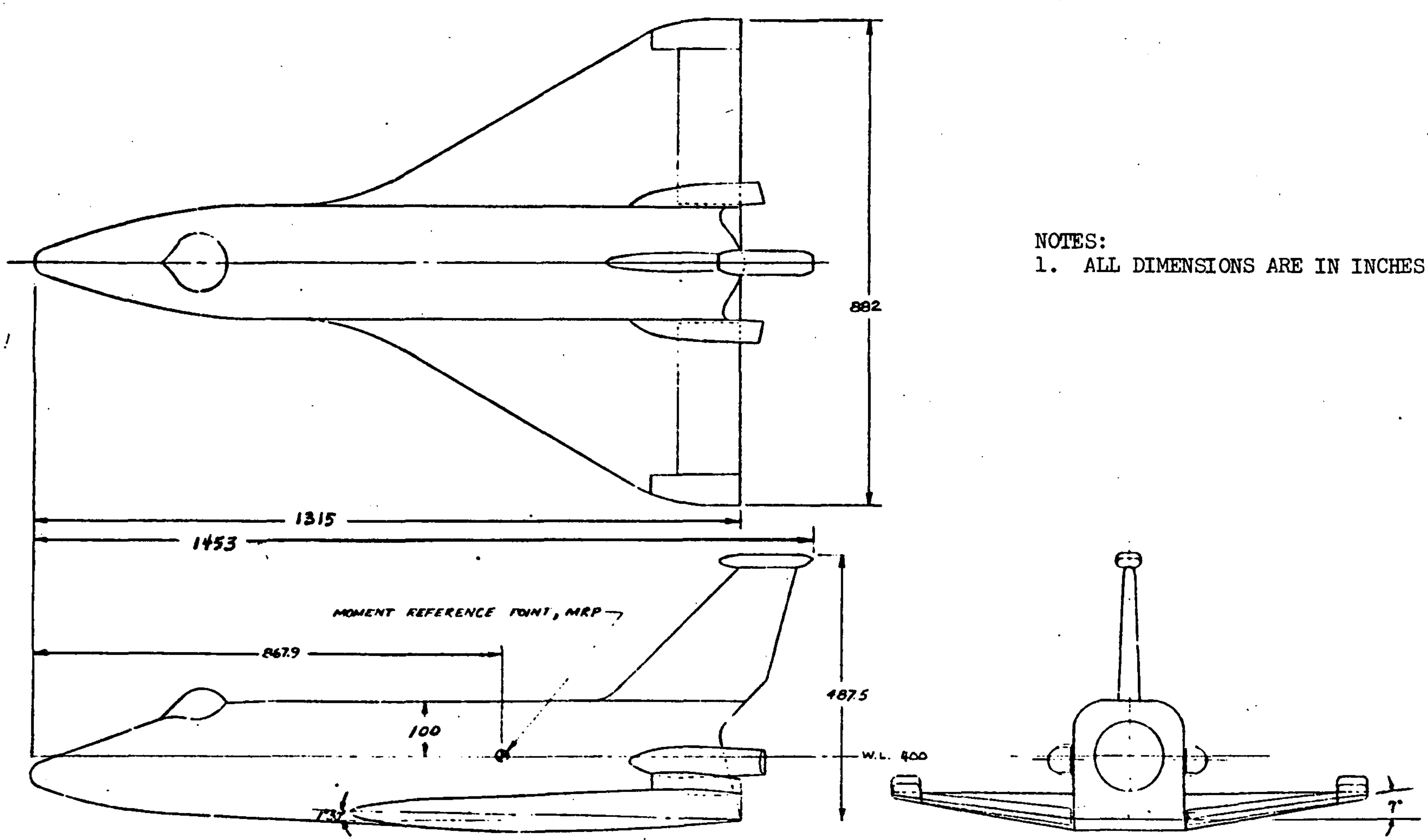
(A) D(CLM), D(CN) Vs. Mach

(B) DCYNDB, DCBLDB DCY/DB Vs. Mach

(C) DCBLDA, DCYNDA, DCY/DA Vs. Mach

(D) DCLMDE, DCL/DE Vs. Mach

Figure 1. GENERAL ARRANGEMENT, 040A ORBITER



NOTES:
1. ALL DIMENSIONS ARE IN INCHES

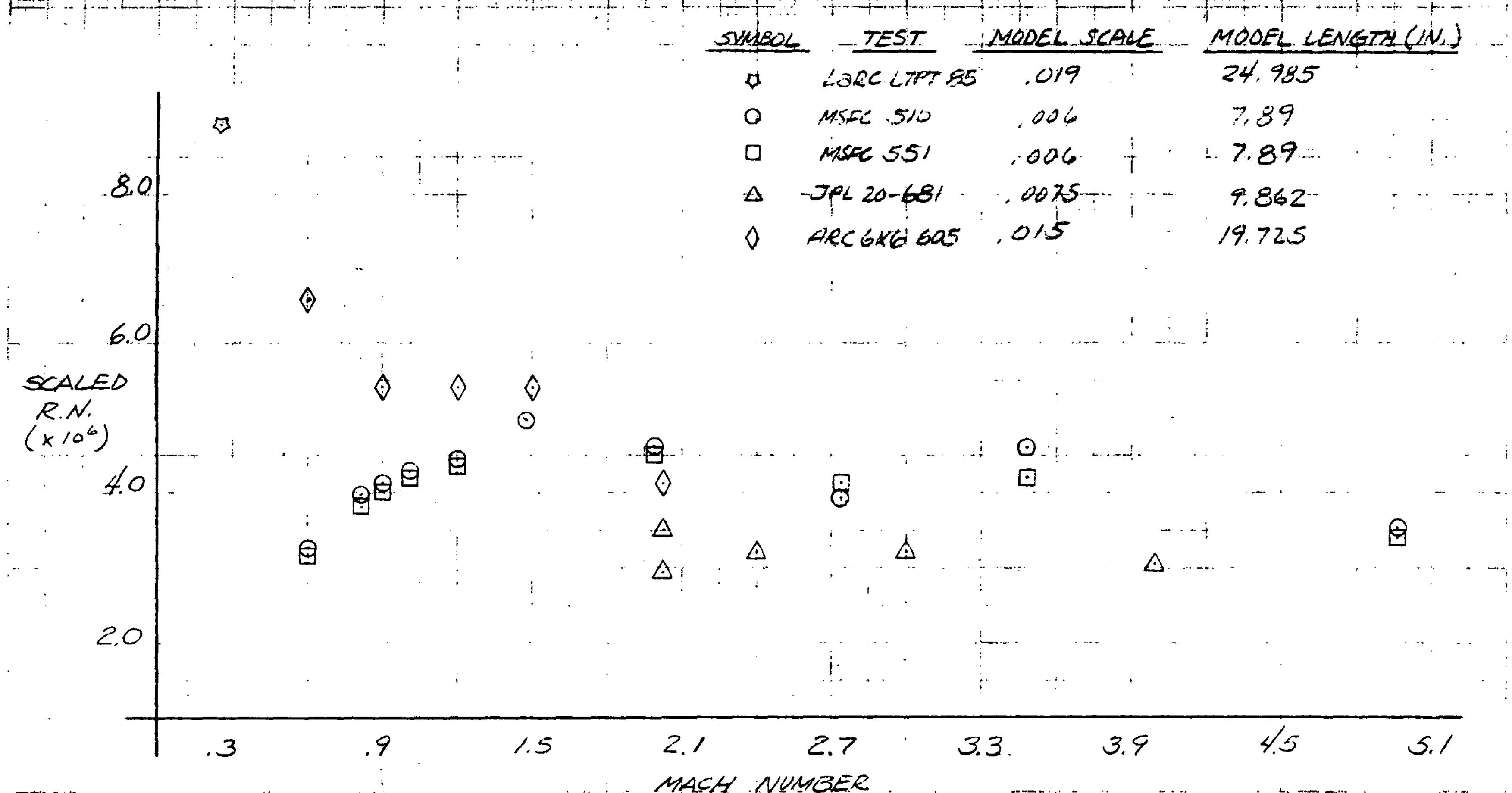
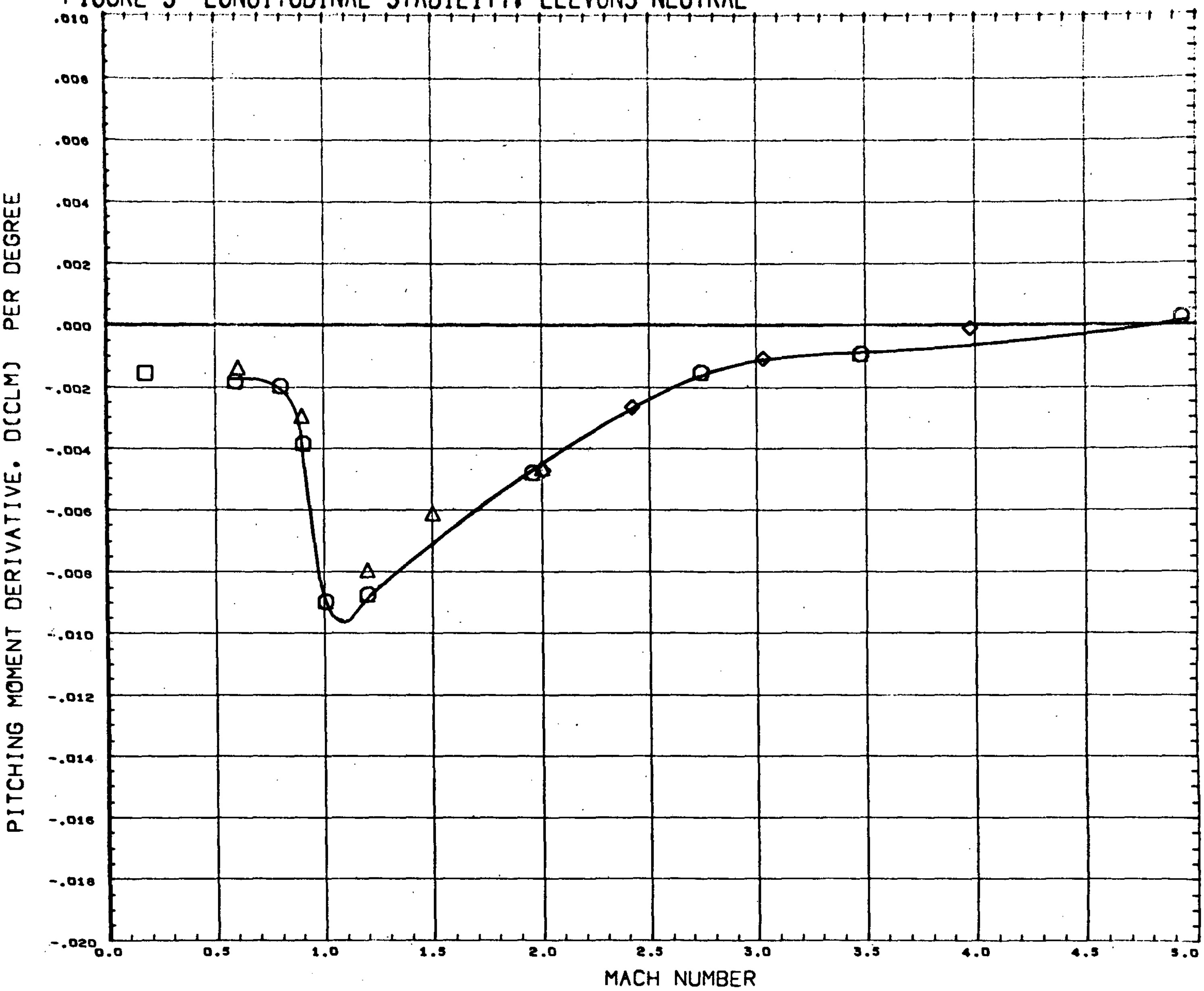


FIGURE 2. SCALED REYNOLDS NUMBER VS MACH NUMBER FOR THE 040A ORBITER

(REYNOLDS NUMBER BASED ON MODEL LENGTH)

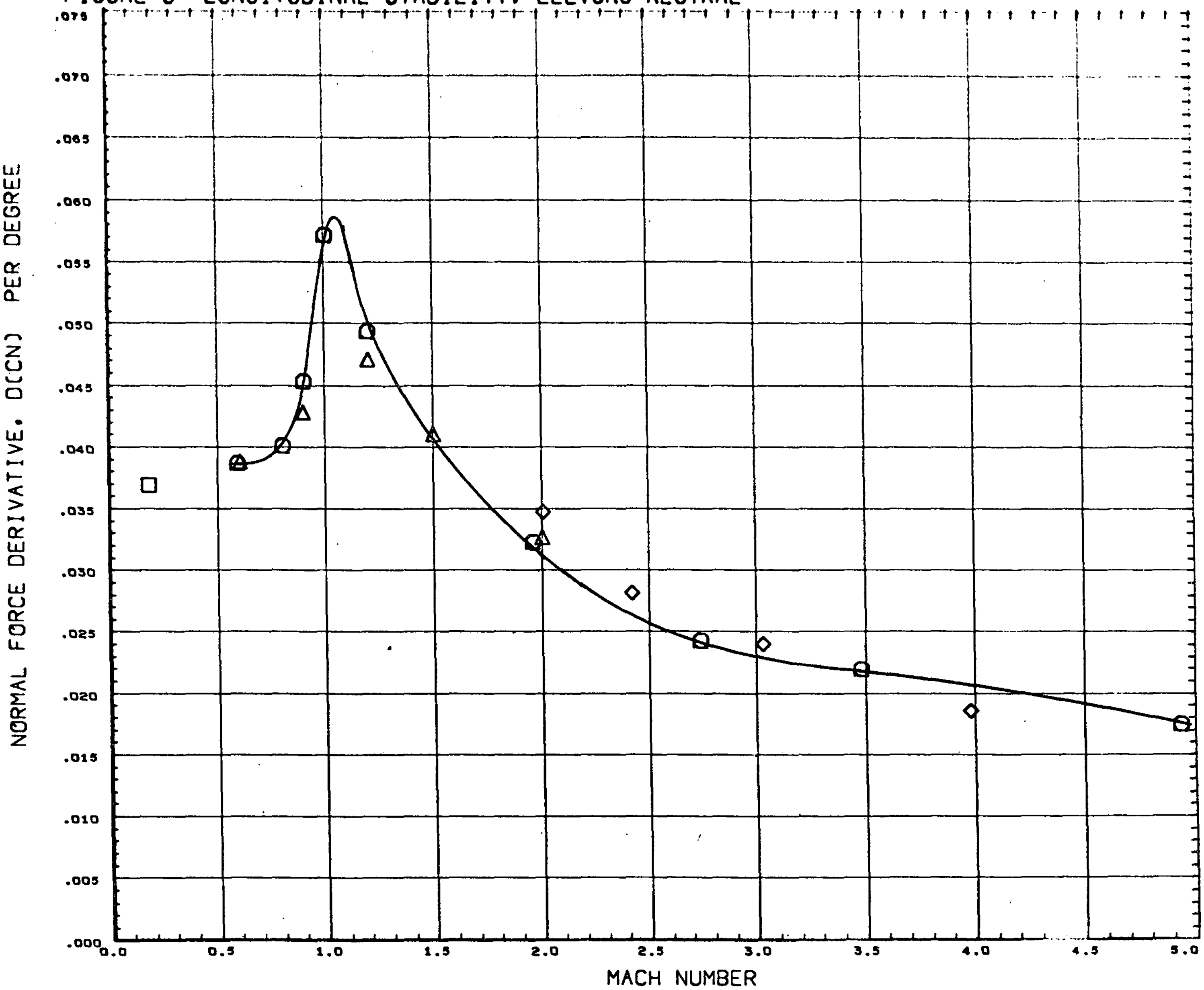
FIGURE 3 LONGITUDINAL STABILITY, ELEVONS NEUTRAL



DATA SET	SYMBOL	CONFIGURATION DESCRIPTION	RUDDER
(A74001)	○	MSFC TWT 551, 040A ORBITER, B1C1D1M1P1V9W1	0.000
(RBE001)	△	AMES 66-605, 040-A ORBITER,B1C1D1M1P1V1W1	0.000
(RGB011)	◇	JPL WT 20-681 MSC 040A B1W1V1M1P1D1C1	0.000
(AO1001)	□	LRC/LTPT 85,MDC 040A ORBITER B1C1D1W1V1M1P1	0.000

SEE THE ASSOCIATED DATA DOCUMENT FOR REFERENCE CHARACTERISTICS

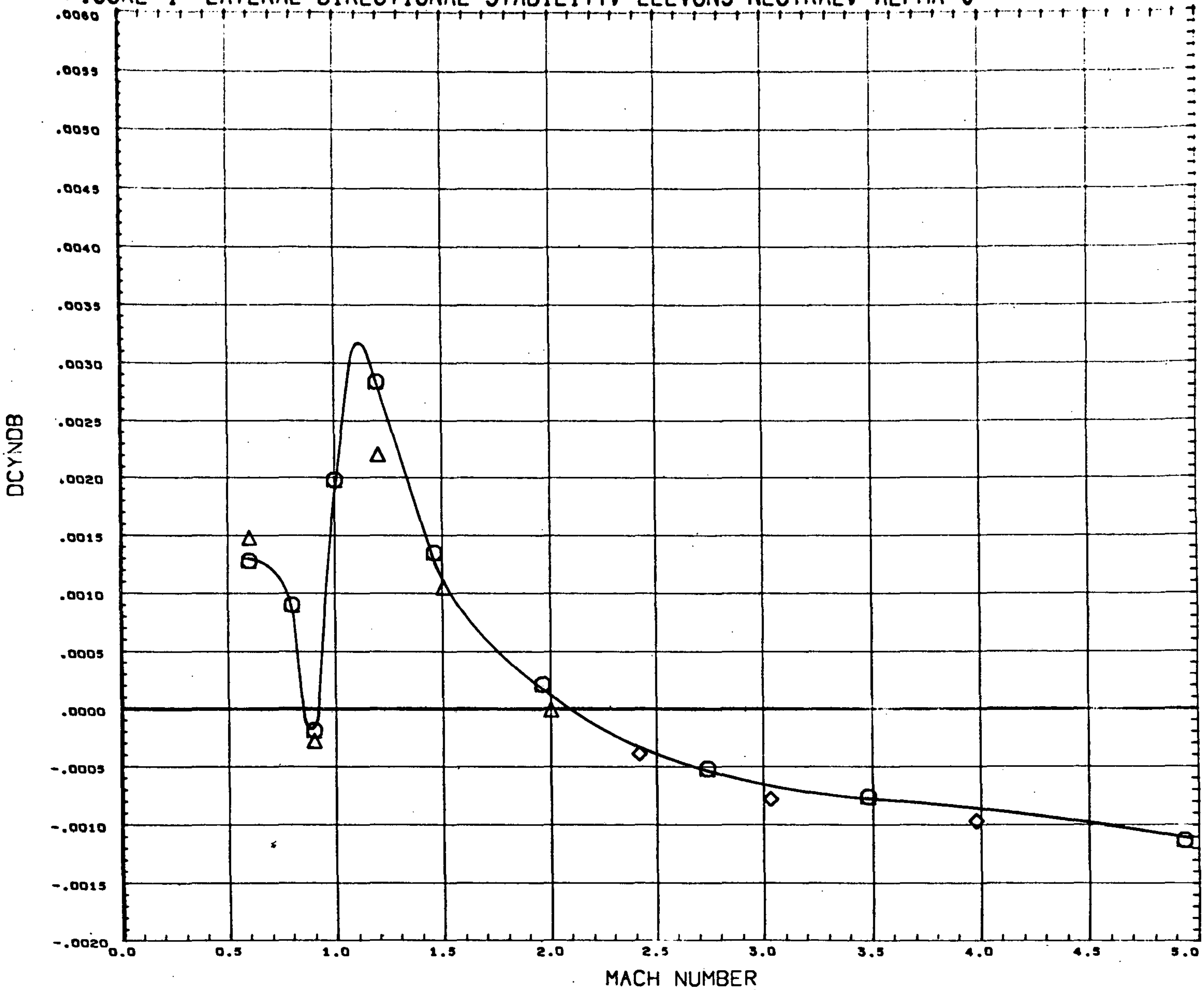
FIGURE 3 LONGITUDINAL STABILITY, ELEVONS NEUTRAL



DATA SET	SYMBOL	CONFIGURATION DESCRIPTION	RUDDER
(A74001)	○	MSFC TWT 551, 040A ORBITER, B1C1D1M1P1V9W1	0.000
(RBE001)	△	AMES 66-605, 040-A ORBITER,B1C1D1M1P1V1W1	0.000
(RGB011)	◇	JPL WT 20-681 MSC 040A B1W1V1M1P1D1C1	0.000
(A01001)	□	LRC/LTPT 85,MDC 040A ORBITER B1C1D1W1V1M1P1	0.000

SEE THE ASSOCIATED DATA DOCUMENT FOR REFERENCE CHARACTERISTICS

FIGURE 4 LATERAL-DIRECTIONAL STABILITY, ELEVONS NEUTRAL, ALPHA=0



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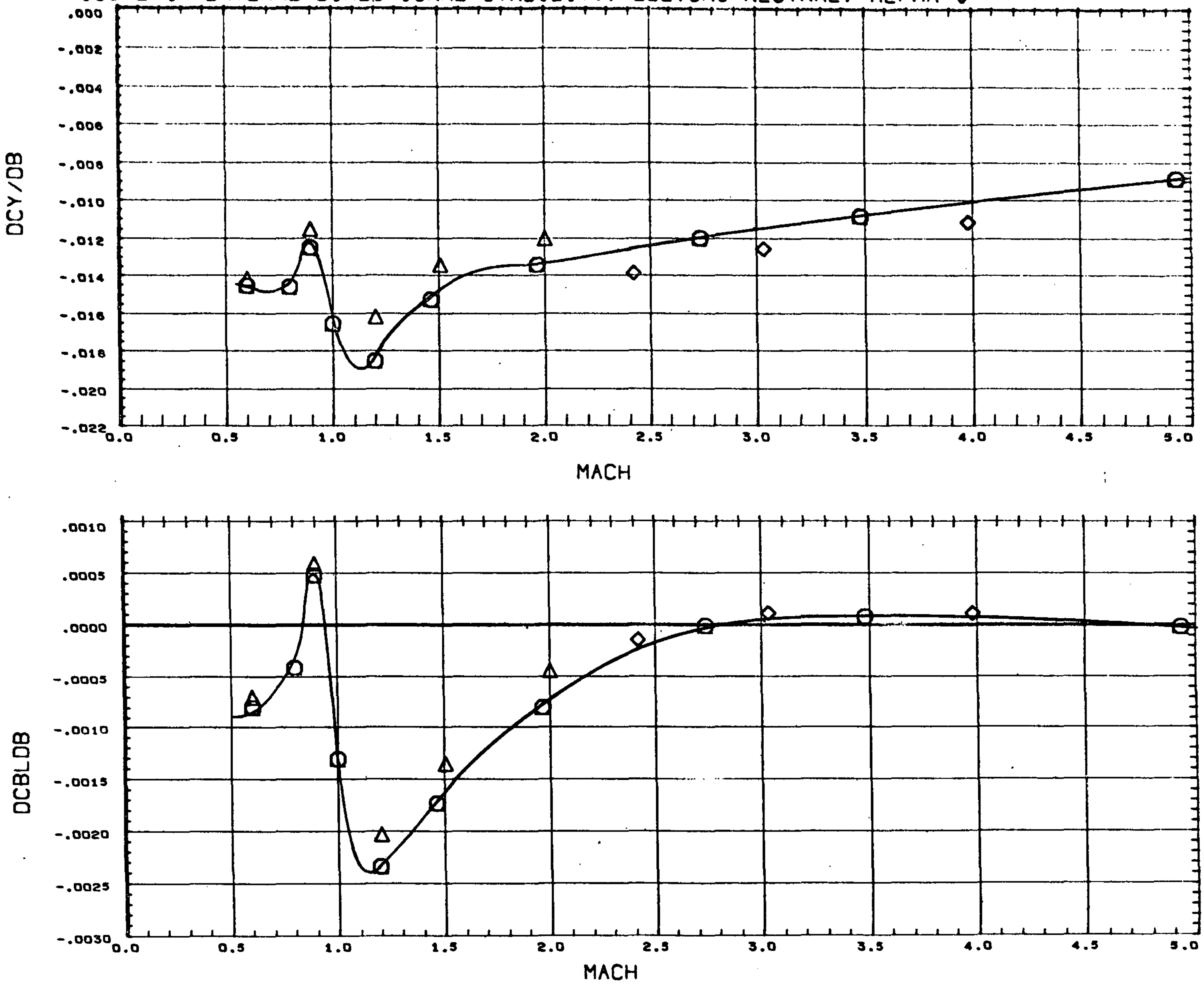
(A52015)	○	MSFC TWT 510, 040-A ORBITER,B1W1V1P1M1	0.000
(RBE031)	△	AMES 66-605, 040-A ORBITER,B1C1M1P1V1W1	0.000
(RGB151)	◇	JPL WT 20-681 MSC 040A B1W1V1M1P1C1	0.000

SEE THE ASSOCIATED DATA DOCUMENT FOR REFERENCE CHARACTERISTICS

FIGURE 4 LATERAL-DIRECTIONAL STABILITY, ELEVONS NEUTRAL, ALPHA=0



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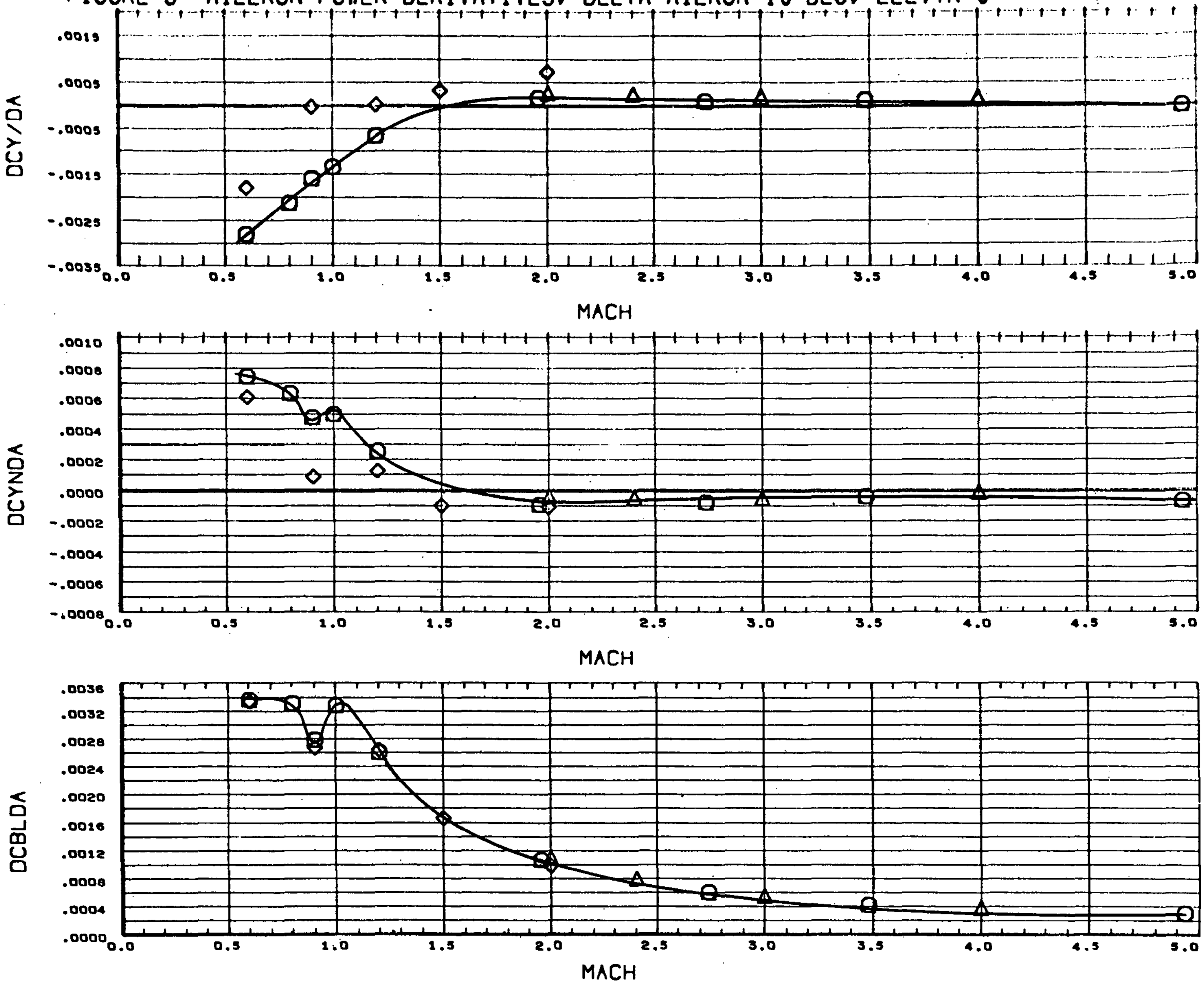
(A52015)	○	MSFC TWT 510, 040-A ORBITER,B1W1V1P1M1	0.000
(RBE031)	△	AMES 66-605, 040-A ORBITER,B1C1M1P1V1W1	0.000
(RGB151)	◇	JPL WT 20-681 MSC 040A B1W1V1M1P1C1	0.000

SEE THE ASSOCIATED DATA DOCUMENT FOR REFERENCE CHARACTERISTICS

FIGURE 5 AILERON POWER DERIVATIVES, DELTA AILRON=10 DEG, ELEVTR=0



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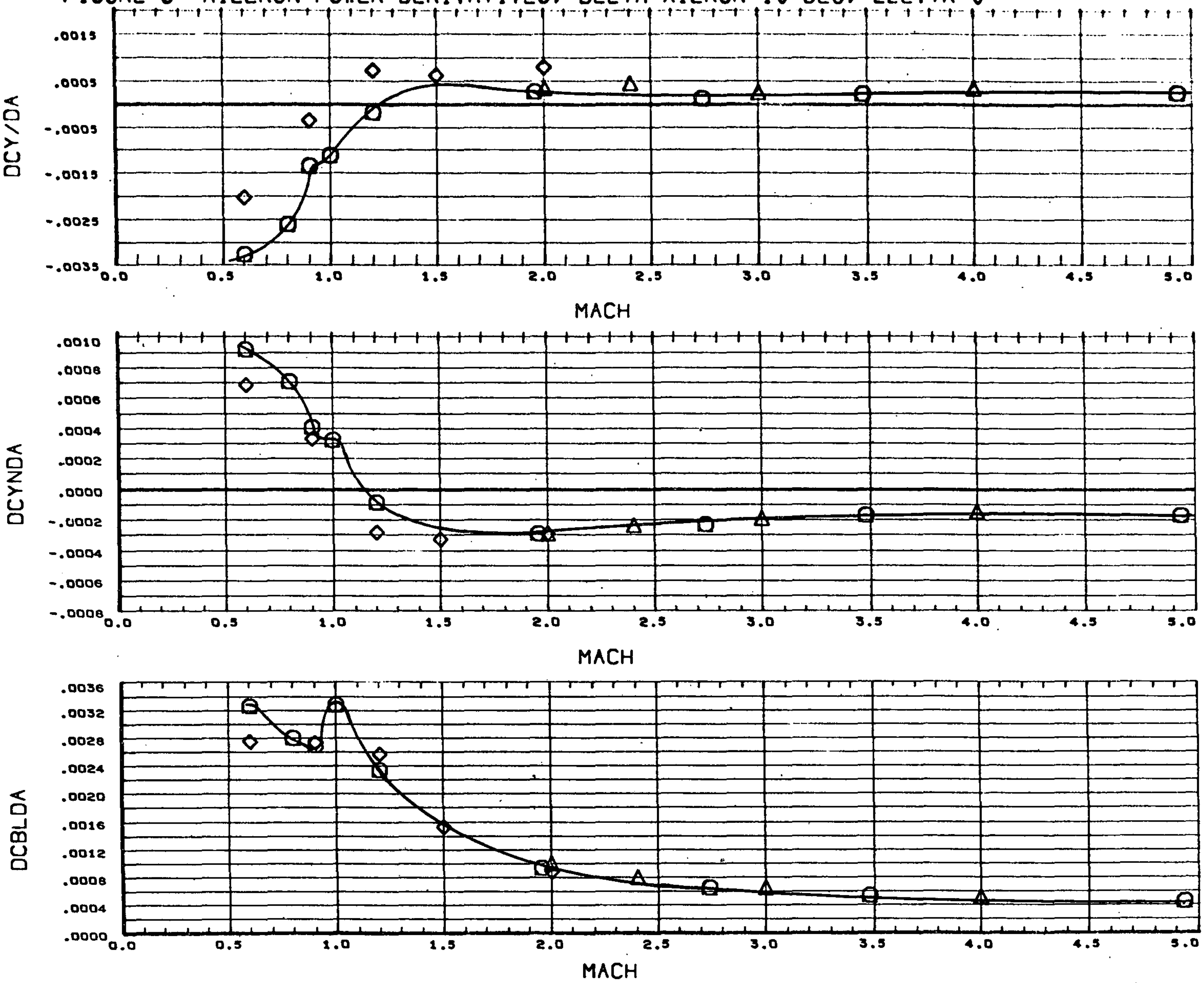
(C74002)	○	MSFC TWT 551, 040A ORBITER, B1C1D1M1P1V9W1	0.000
(CGB081)	△	JPL WT 20-681 MSC 040A B1W1V1M1P1D1C1	0.000
(BBE046)	◇	AMES 66-605, 040-A ORBITER,B1C1D1M1P1V1W1	0.000

SEE THE ASSOCIATED DATA DOCUMENT FOR REFERENCE CHARACTERISTICS

ALPHA .00

FIGURE 5 AILERON POWER DERIVATIVES, DELTA AILRON=10 DEG, ELEVTR=0

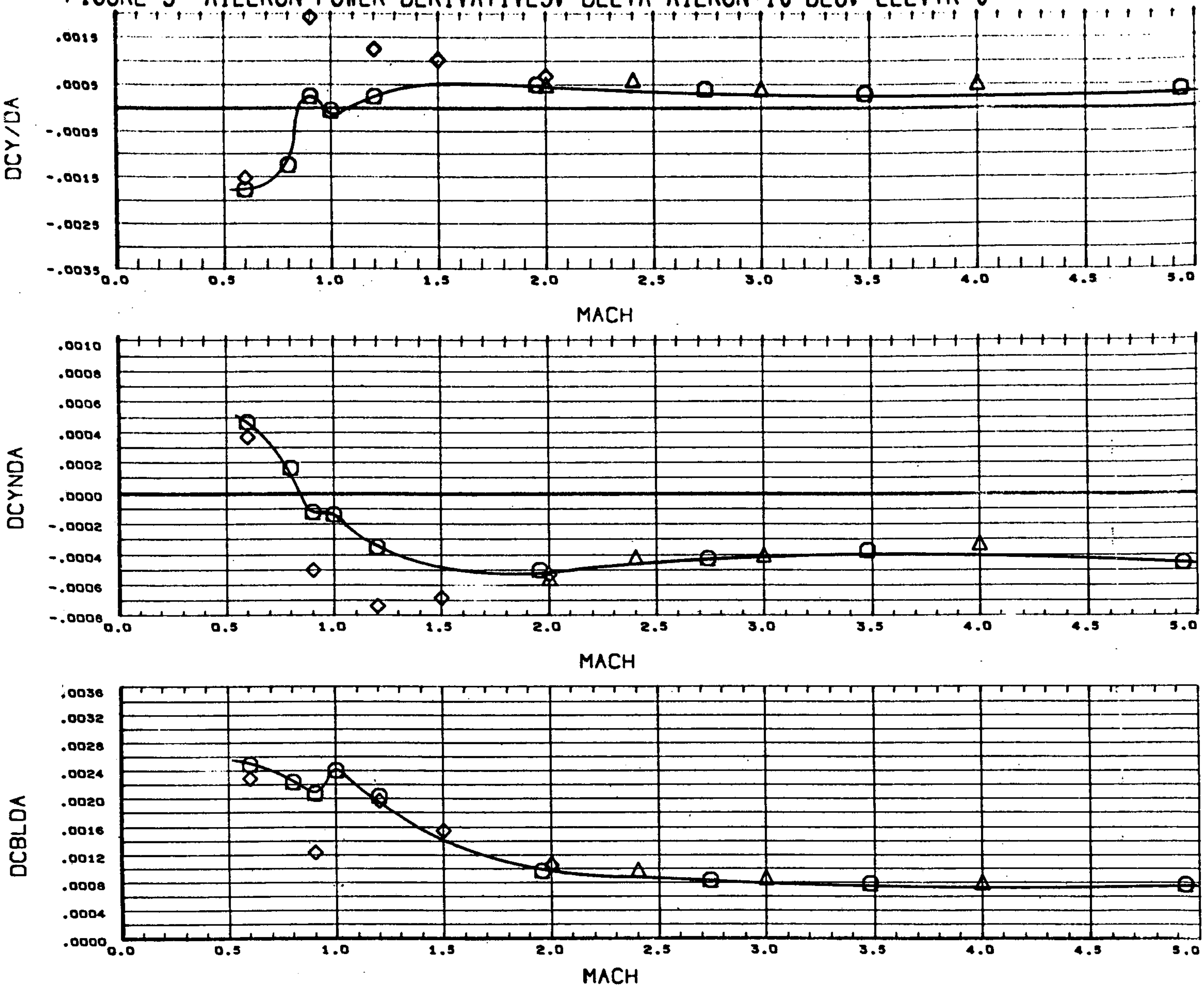


DATA SET	SYMBOL	CONFIGURATION DESCRIPTION	RUDDER
(C74002)	○	MSFC TWT 551, 040A ORBITER, B1C1D1M1P1V9W1	0.000
(CG8081)	△	JPL WT 20-681 MSC 040A B1W1V1M1P1D1C1	0.000
(BBE046)	◇	AMES 66-605, 040-A ORBITER,B1C1D1M1P1V1W1	0.000

SEE THE ASSOCIATED DATA DOCUMENT FOR REFERENCE CHARACTERISTICS

ALPHA 10.00

FIGURE 5 AILERON POWER DERIVATIVES, DELTA AILRON=10 DEG, ELEVTR=0

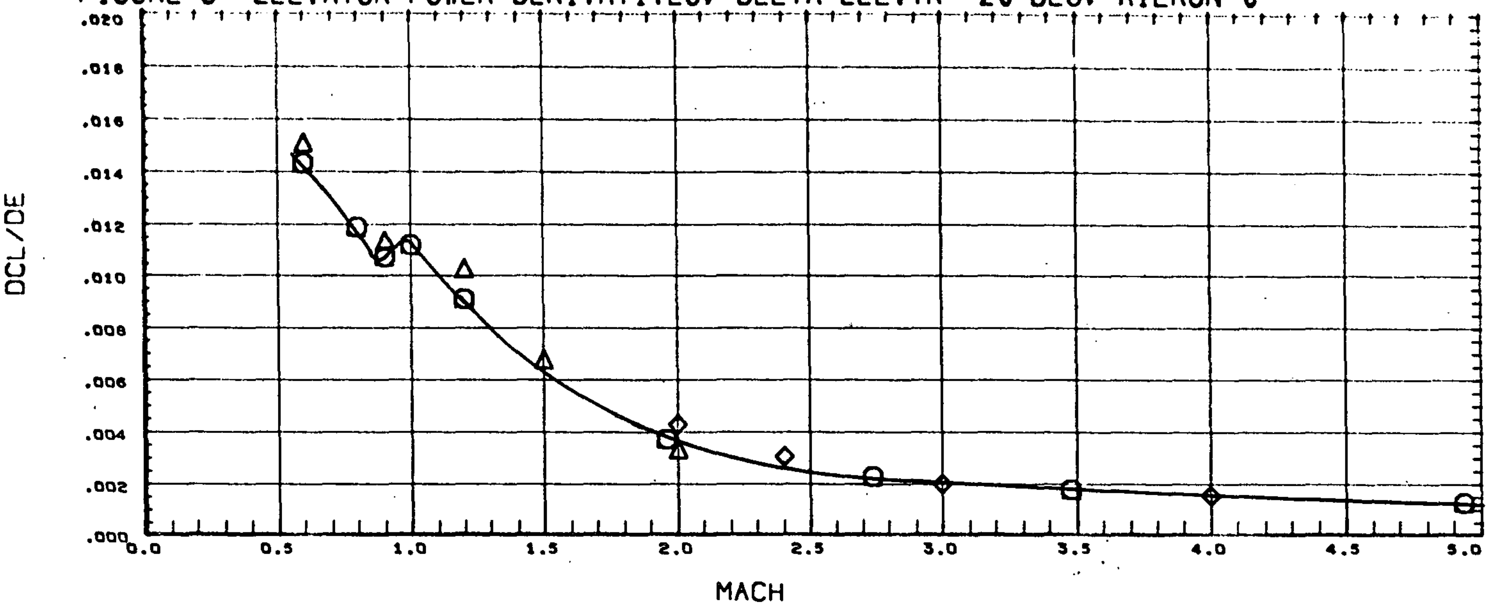


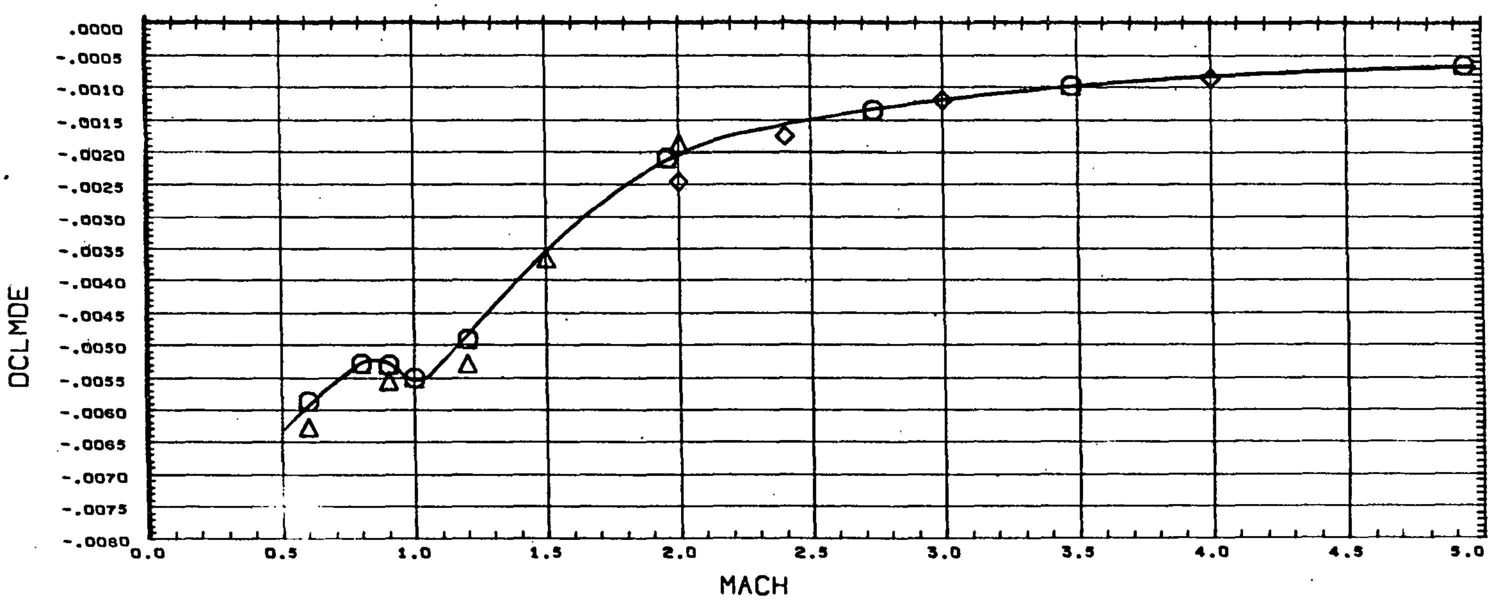
DATA SET	SYMBOL	CONFIGURATION DESCRIPTION	RUDDER
(C74002)	○	MSFC TWT 551, 040A ORBITER, B1C1D1M1P1V9W1	0.000
(CGB081)	△	JPL WT 20-681 MSC 040A B1W1V1M1P1D1C1	0.000
(BBE046)	◇	AMES 66-605, 040-A ORBITER,B1C1D1M1P1V1W1	0.000

SEE THE ASSOCIATED DATA DOCUMENT FOR REFERENCE CHARACTERISTICS

ALPHA 20.00

FIGURE 6 ELEVATOR POWER DERIVATIVES, DELTA ELEVTR=-20 DEG, AILRON=0



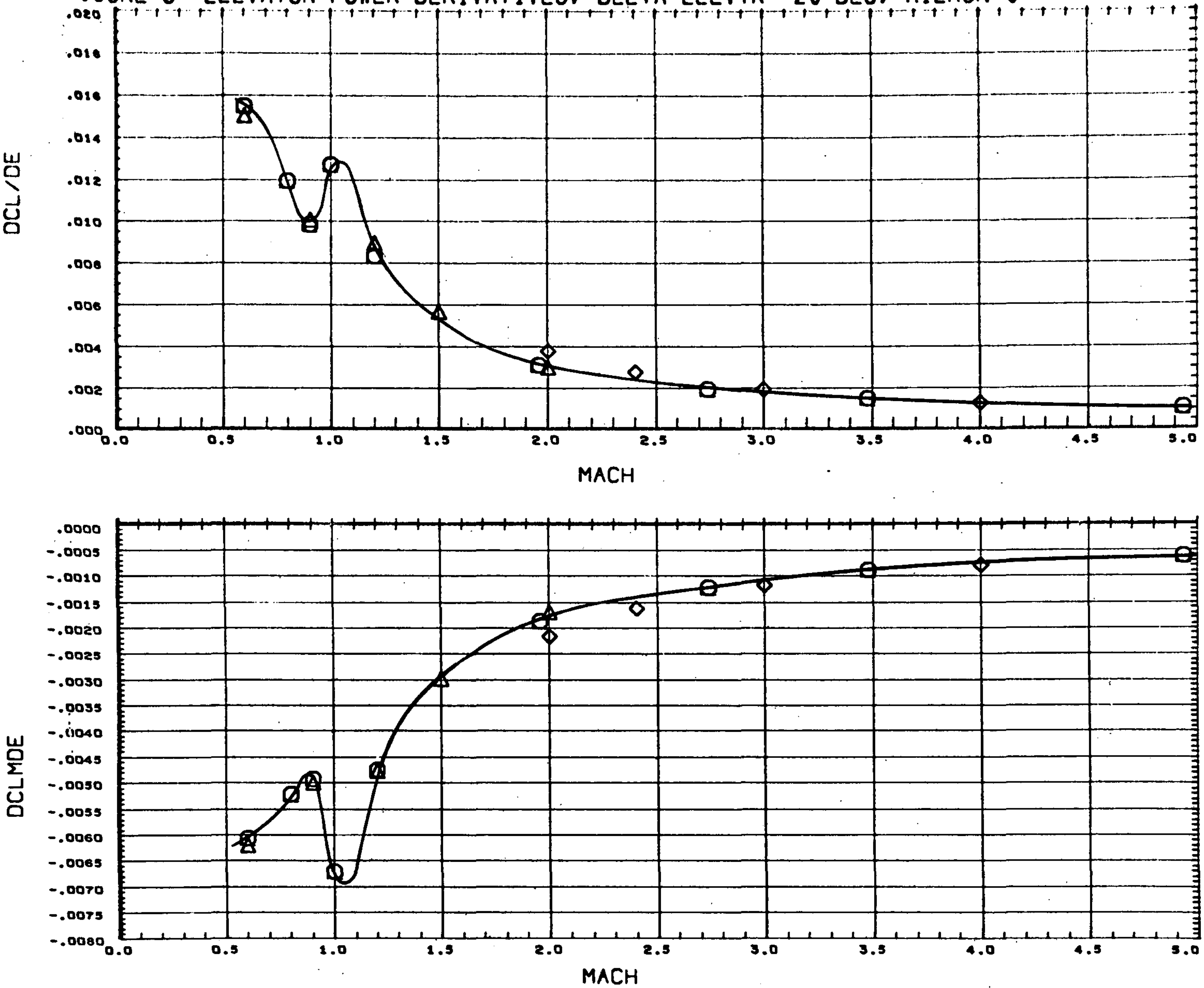


DATA SET	SYMBOL	CONFIGURATION DESCRIPTION	RUDDER
(C74003)	○	MSFC TWT 551, 040A ORBITER, B1C1D1M1P1V9W1	0.000
(CBE001)	△	AMES 66-605, 040-A ORBITER, B1C1D1M1P1V1W1	0.000
(CGB011)	◇	JPL WT 20-681 MSC 040A B1W1V1M1P1D1C1	0.000

SEE THE ASSOCIATED DATA DOCUMENT FOR REFERENCE CHARACTERISTICS

ALPHA .00

FIGURE 6 ELEVATOR POWER DERIVATIVES, DELTA ELEVTR=-20 DEG, AILRON=0

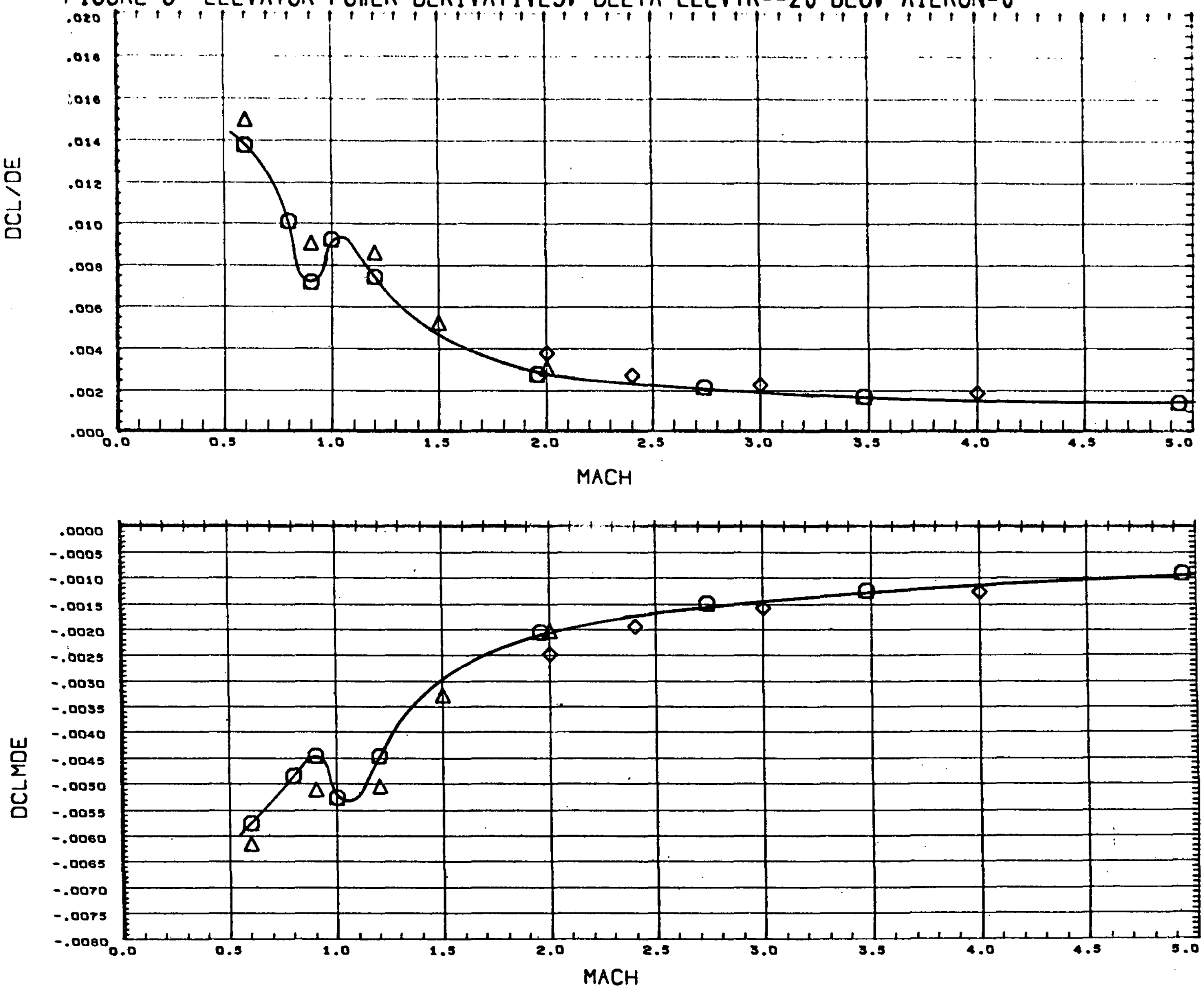


DATA SET	SYMBOL	CONFIGURATION DESCRIPTION	RUDDER
(C74003)	○	MSFC TWT 551, 040A ORBITER, B1C1D1M1P1V9W1	0.000
(CBE001)	△	AMES 66-605, 040-A ORBITER,B1C1D1M1P1V1W1	0.000
(CGB011)	◇	JPL WT 20-681 MSC 040A B1W1V1M1P1D1C1	0.000

SEE THE ASSOCIATED DATA DOCUMENT FOR REFERENCE CHARACTERISTICS

ALPHA 10.00

FIGURE 6 ELEVATOR POWER DERIVATIVES, DELTA ELEVTR=-20 DEG, AILRON=0



DATA SET	SYMBOL	CONFIGURATION DESCRIPTION	RUDDER
(C74003)	○	MSFC TWT 551, 040A ORBITER, B1C1D1M1P1V9W1	0.000
(CBE001)	△	AMES 66-605, 040-A ORBITER,B1C1D1M1P1V1W1	0.000
(CGB011)	◇	JPL WT 20-681 MSC 040A B1W1V1M1P1D1C1	0.000

SEE THE ASSOCIATED DATA DOCUMENT FOR REFERENCE CHARACTERISTICS

ALPHA 20.00

Notes:
1. Positive directions of force coefficients moment coefficients, and angles are indicated by arrows.
2. For clarity, origins of wind and stability axes have been displaced from the center of gravity.

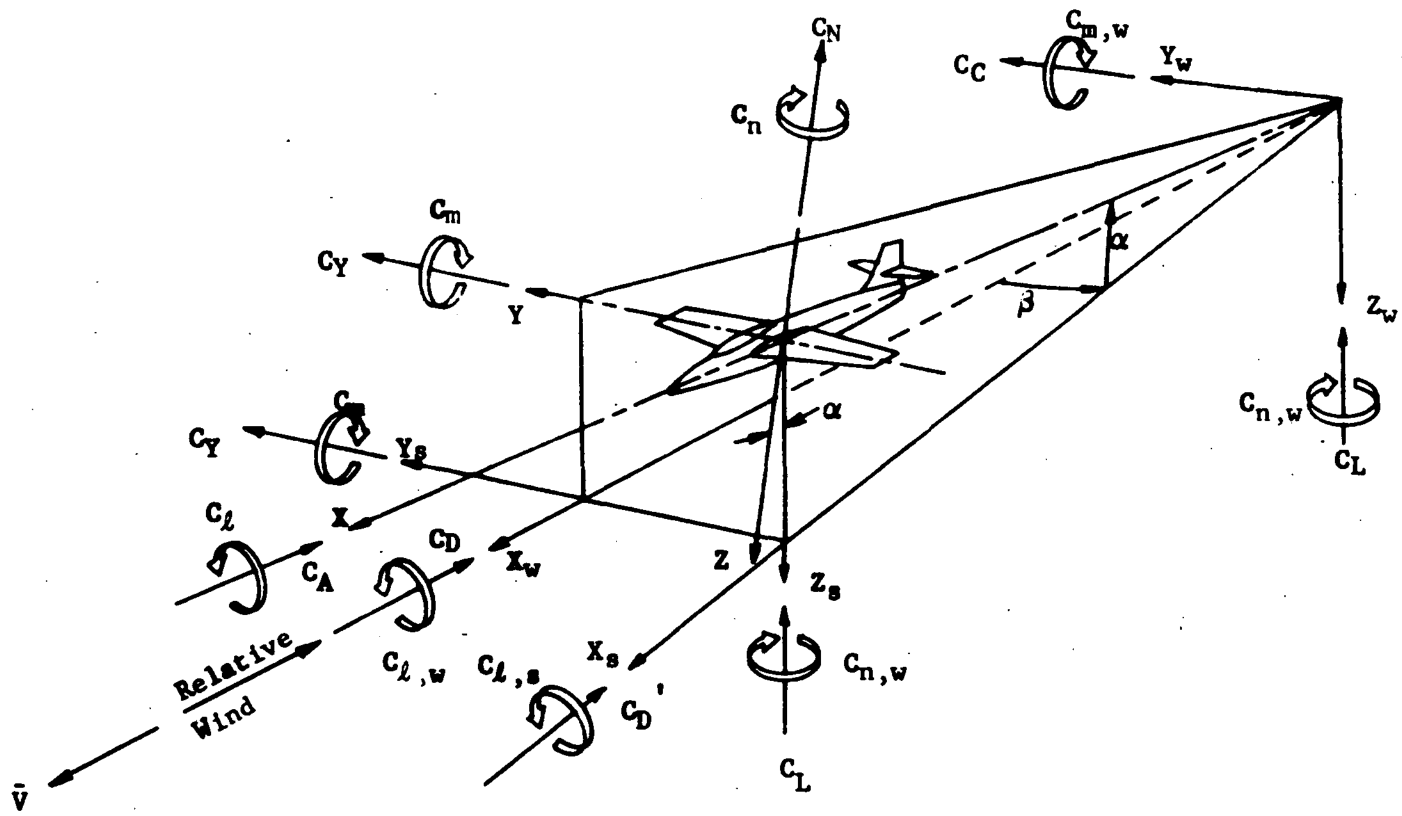


Figure 7. Axis systems, showing direction and sense of force and moment coefficients, angle of attack, and sideslip angle

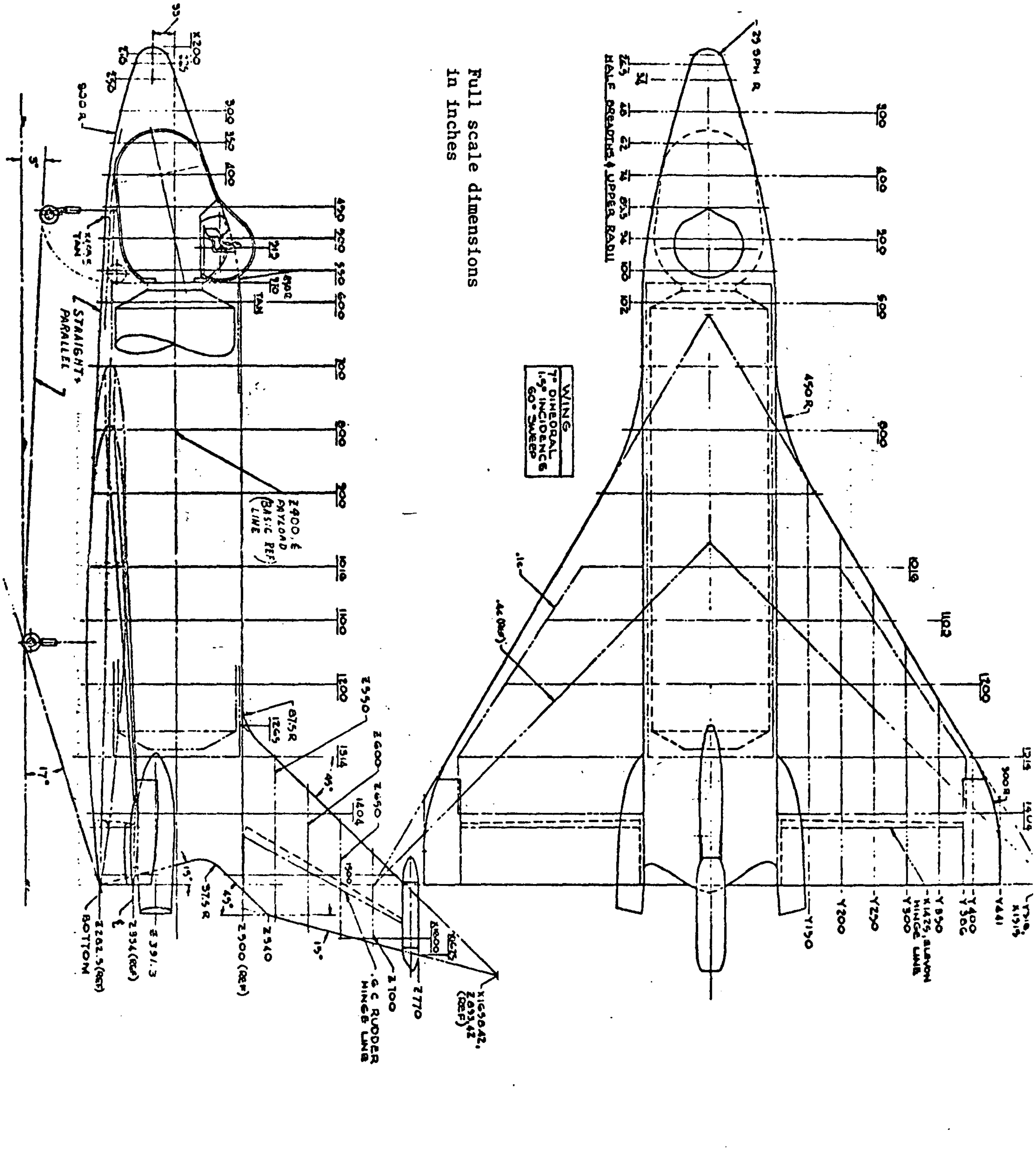


Figure 8. SIDE AND TOP VIEWS OF 040A CONFIGURATION

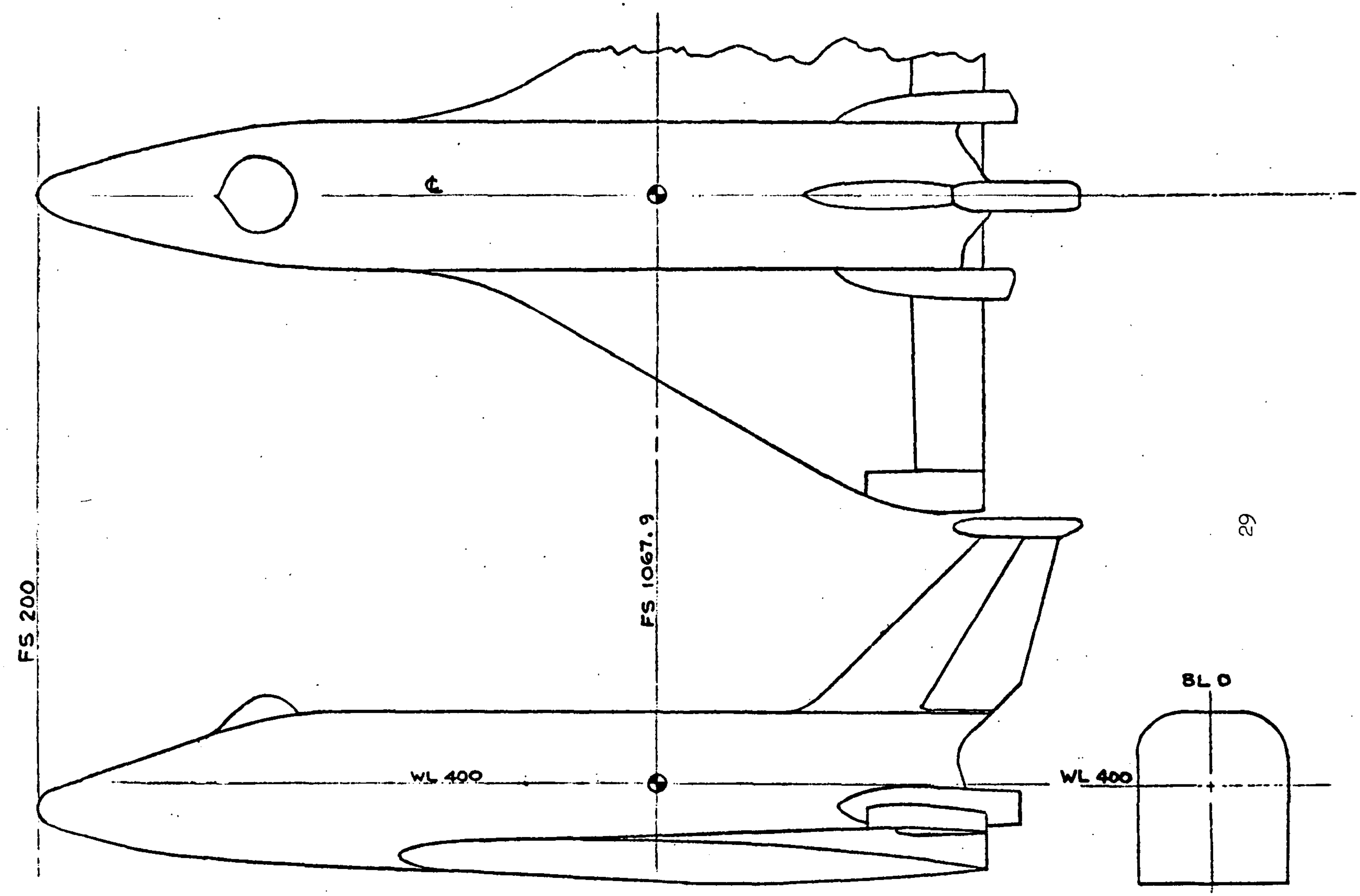


Figure 9. 040A

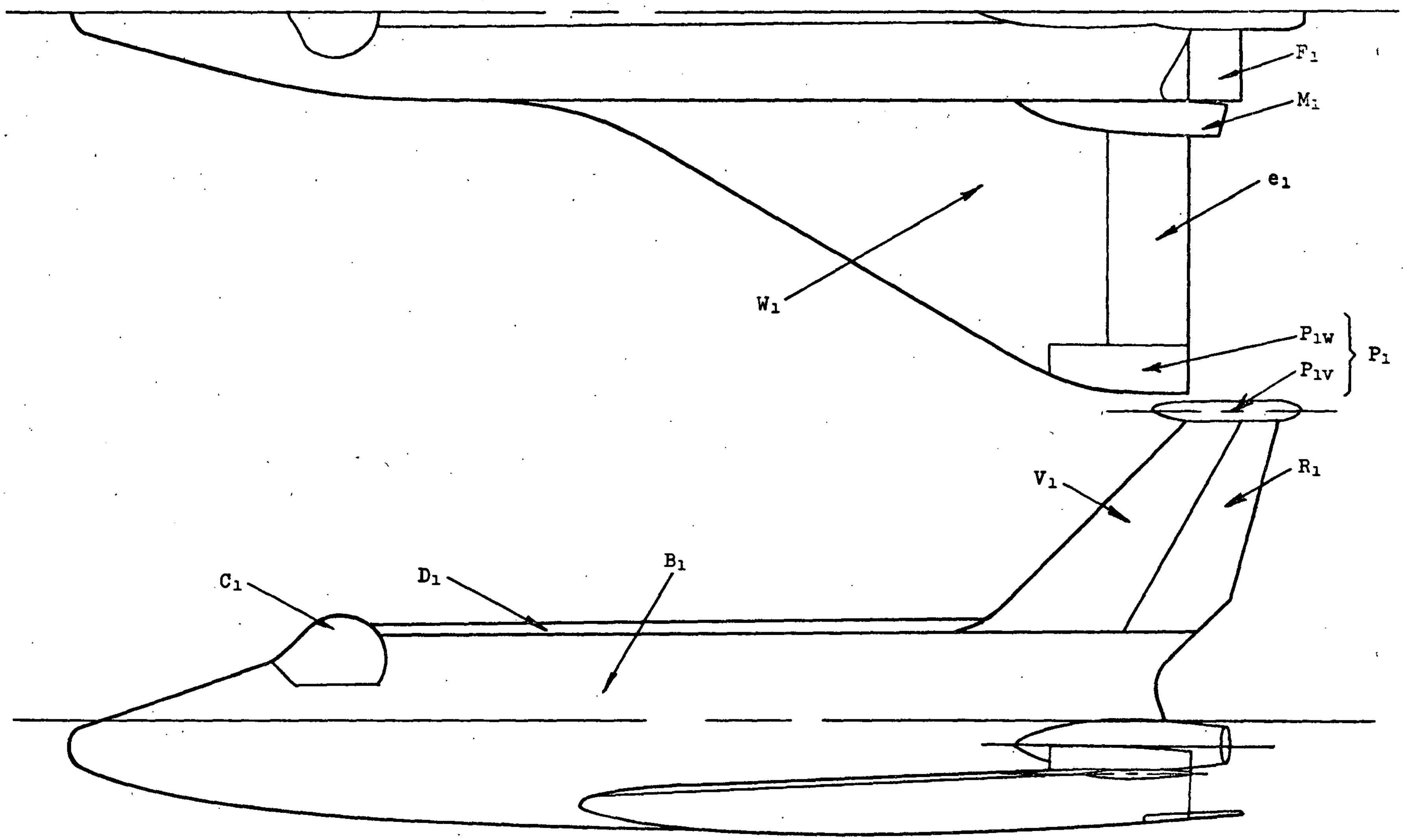


Figure 10. MODEL COMPONENT IDENTIFICATION

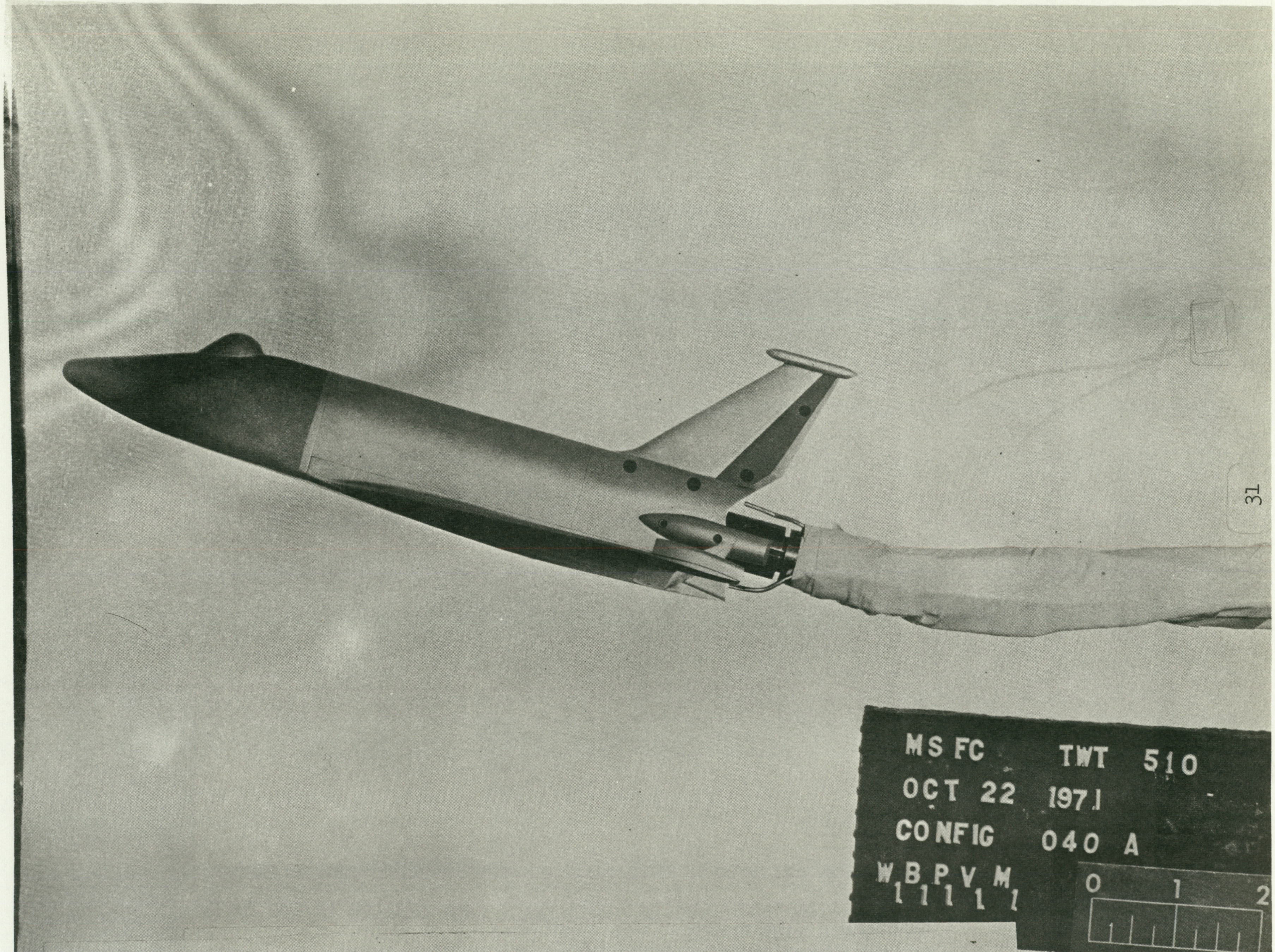


Figure 11. .006-SCALE 040A ORBITER MODEL INSTALLED IN MSFC 14 x 14 INCH WIND TUNNEL

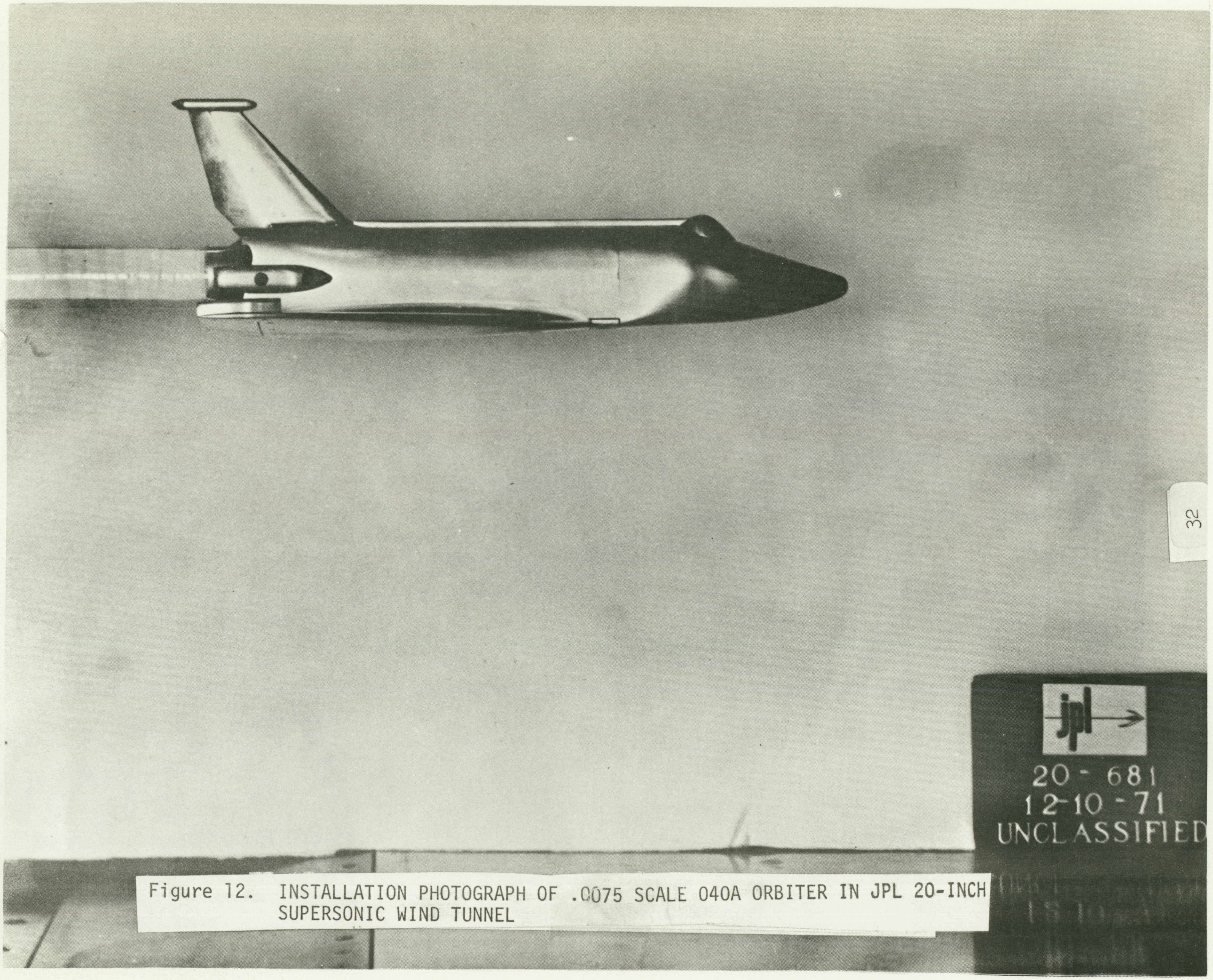


Figure 12. INSTALLATION PHOTOGRAPH OF .0075 SCALE 040A ORBITER IN JPL 20-INCH SUPERSONIC WIND TUNNEL

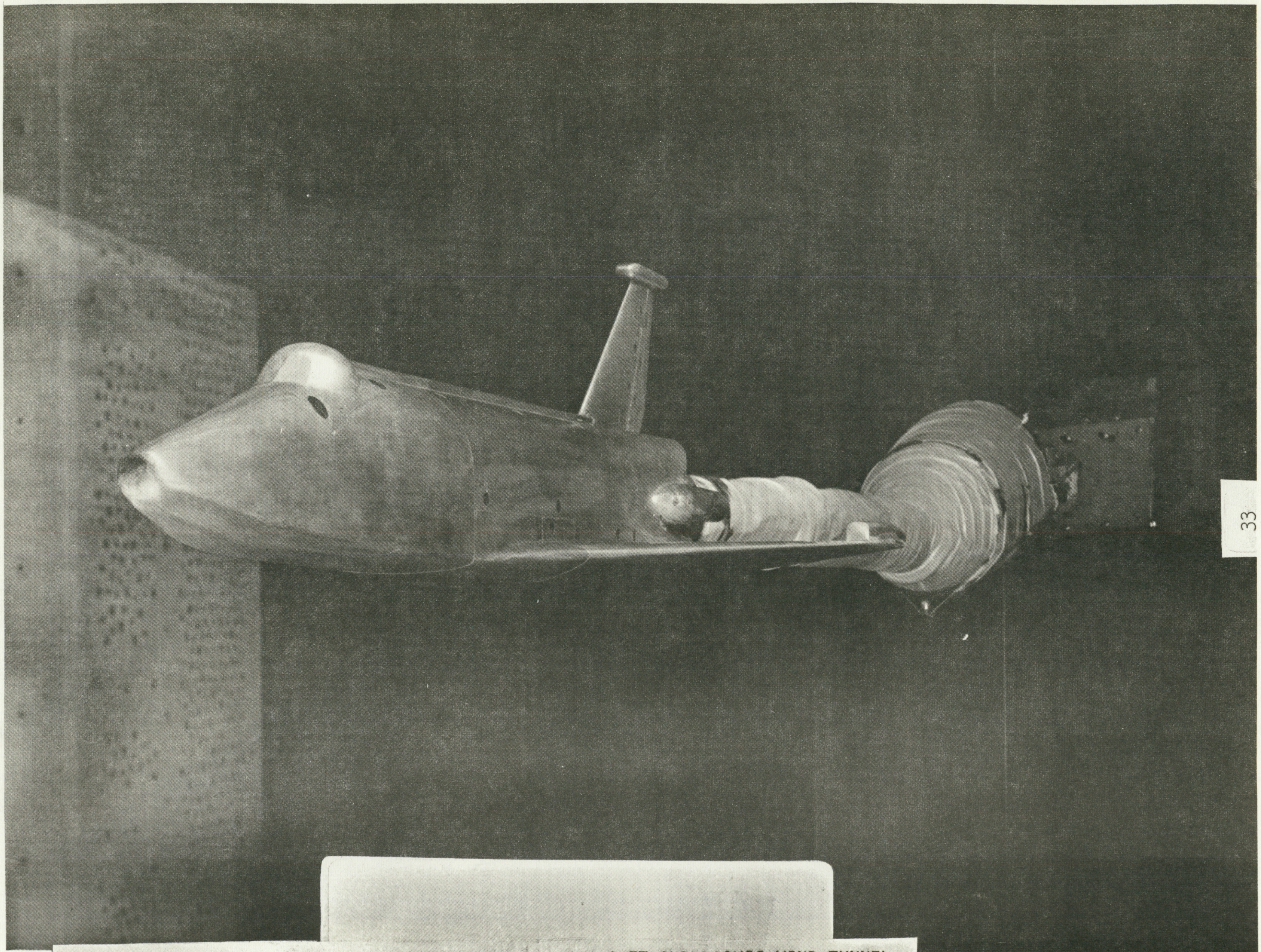
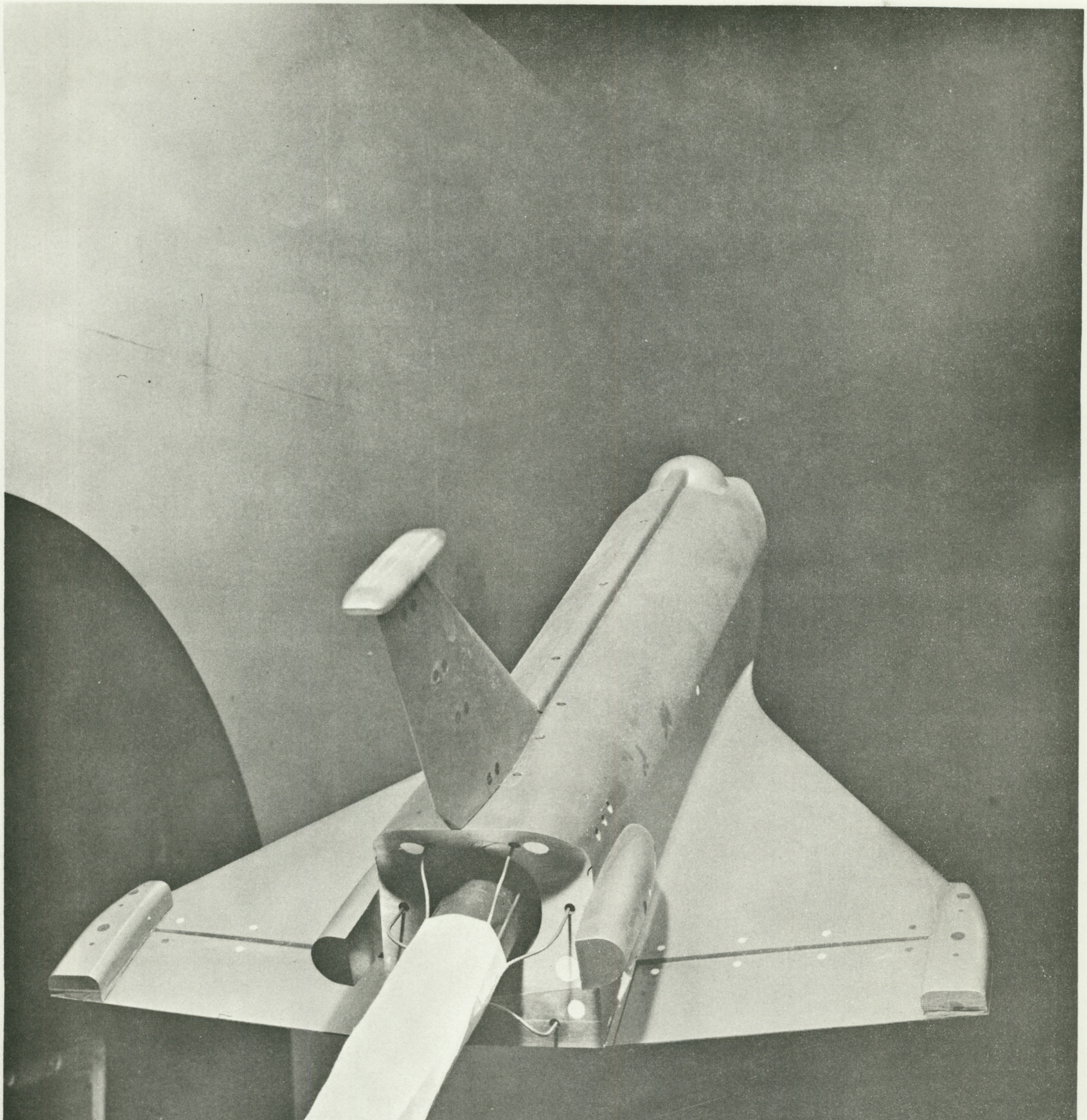
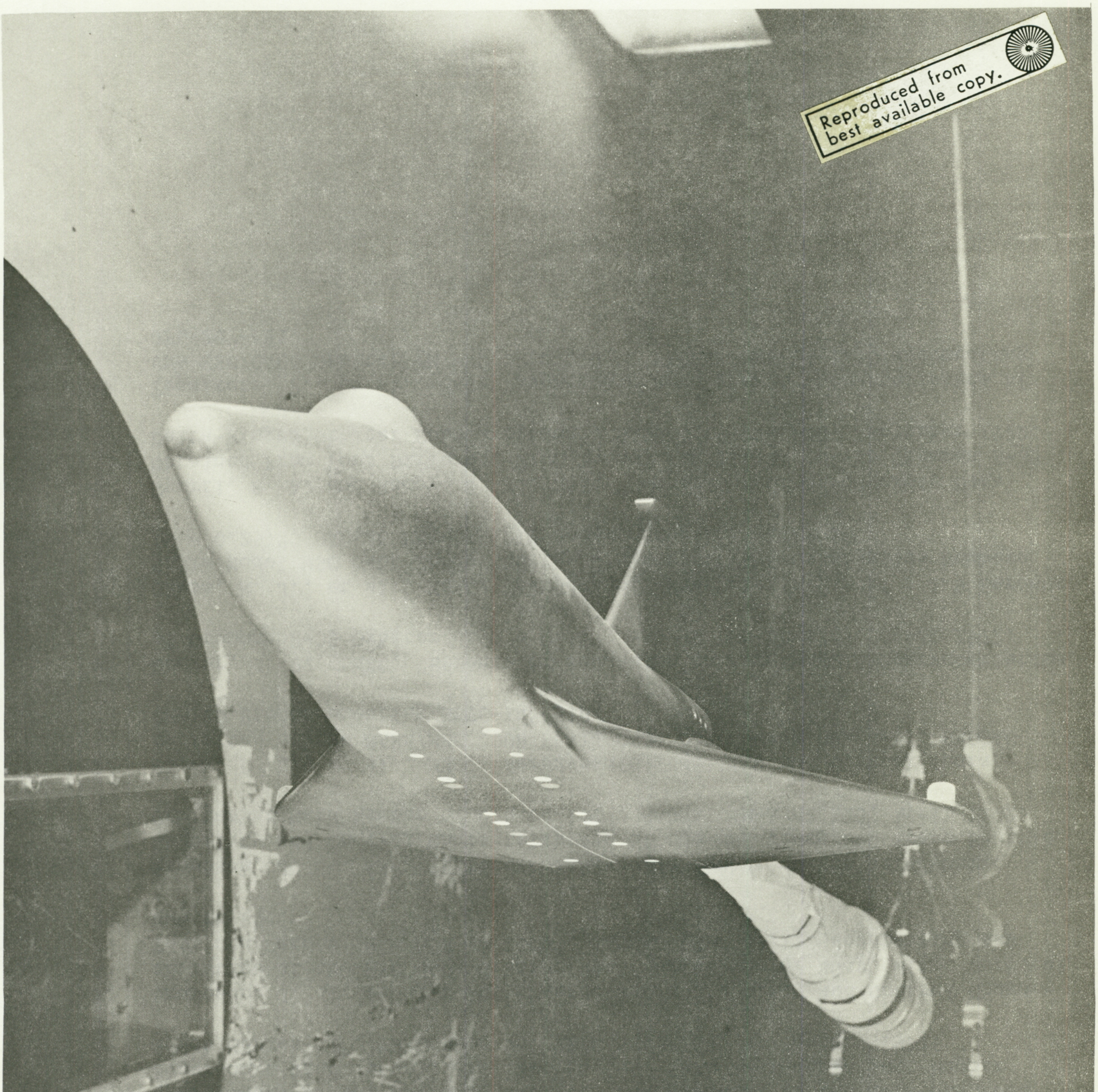


Figure 13. .015-SCALE 040A ORBITER MODEL IN ARC 6 x 6 FT SUPERSONIC WIND TUNNEL



NASA
L-71-9649

Figure 14. CONFIGURATION $B_1C_1D_1W_1V_1P_1M_1$ INSTALLED IN NASA/LaRC LOW TURBULENCE PRESSURE TUNNEL (REAR VIEW) (.019-SCALE)



NASA
L-71-9652

Figure 15. CONFIGURATION $B_1C_1D_1W_1V_1P_1M_1$ INSTALLED IN NASA/LaRC LOW TURBULENCE PRESSURE TUNNEL (FRONT VIEW) (.019-SCALE)

REFERENCES

1. Anderson, E. H., et al., MDAC, "Analysis of Data Obtained on an .0075 Scale Model of the MSC 040A Orbiter Configuration in the JPL 20 In. Supersonic Wind Tunnel, SWT Test 20-681, NASA Designated Test No. S-055", MDAC Memo No. SSPO-E241-712, 10 February 1972.

2. Bleedorn, T. G., et al., MDAC, "Analysis of Data Obtained on an .015 Scale Model of the MSC 040A Orbiter Configuration in the Ames 6x6 Foot Supersonic Wind Tunnel, ARC Test 66-605, NASA Designated Test Number S-054 Series II", MDAC Memo No. SSPO-E241-705, 31 January 1972.

3. Brownson, J. J., et al., ARC, "Aerodynamic Stability and Control Characteristics of the MSC 040A Orbiter With Variations of Body, Wing, Vertical Tail and Canopy (M = 0.6 to 2.0)", SADSAC TM-X 62,112 documenting ARC 6x6 ft-605.

4. Brownson, J. J., ARC, "Effects of Reynolds Number on the Aerodynamic Stability and Control Characteristics of the MSC Class 040 Space Shuttle Orbiter at Mach Number of 0.6 to 1.2", SADSAC TM-X 62,120, April 1972.

5. Click, P. L., et al., MMC, "Aerodynamic Stability and Control Characteristics of the NASA/MSC .006 Scale 040A Delta Wing Orbiter", SADSAC CR-120,015 documenting MSFC-14"-510.

6. Decker, J. P., LaRC, "Effects of Roughness on Aerodynamic Characteristics of Grumman H-33 Orbiter at M = 0.25", SADSAC DMS-DR-1239, April 1972.

7. Glass, K. J., et al., MDAC, "Aerodynamic Characteristics of a 1.9 Percent Scale Model MSC 040A Space Shuttle Orbiter at Various Reynolds Numbers (M = 0.25)", SADSAC DMS-DR-1215 documenting LaRC LTPT 85.

8. Gyorfi, R. A. and Rampy, J. M., NSI, "Comparison of Aerodynamic Data Obtained From Four Different Wind Tunnel Facilities on the Grumman H-33 Delta-Winged Orbiter Configuration", SADSAC CR-120,080, September 1972.

9. Tessitore, F., et al., GAC, "Supersonic Aerodynamic Characteristics of the MSC 040A Orbiter (M = 2.0 to 4.0)", SADSAC DMS-DR-1215 documenting JPL-20"-681.

APPENDIX

Table III.

MODEL COMPONENT DESCRIPTION SHEETS

Table III. MSFC 510

MODEL COMPONENT: BODY - B_1 with canopy, C_1; B_{1A} without canopy

GENERAL DESCRIPTION: 040A Orbiter Body

DRAWING NUMBER JLP SDD 9-24-71

DIMENSION:	FULL SCALE	.6% MODEL SCALE
Length, inch	1315.	7.89
Max Width, inch	204.	1.224
Max Depth, inch	238.	1.427
Fineness Ratio	7.07	7.07
Area, inch		
Max Cross-Sectional	306.2 ft^2	1.590 $in.^2$
Planform	1676. ft^2	8.68 $in.^2$
Wetted	6530. ft^2	33.8 $in.^2$
Base	298. ft^2	1.546 $in.^2$

MODEL COMPONENT: BODY - OMS ENGINE POD, M1

GENERAL DESCRIPTION: Pods mounted on both sides of aft end of fuselage.

DRAWING NUMBER JLP SDD 9-24-71

DIMENSION:	FULL SCALE	.6% MODEL SCALE
Length, inch	251.	1.509
Max Width, inch	42.8	.257
Max Depth, inch	59.0	.354
Fineness Ratio	--	--
Area, in.^{2}		
Max Cross-Sectional	1828.	.0658
Planform	9880.	.356
Wetted	25,400.	.915
Base	1807.	.0651

Table III. (Continued) MSFC 510

MODEL COMPONENT: BODY - ACPS ENGINE POD, P1

GENERAL DESCRIPTION: Blunt pod mounted on both wing tips.

DRAWING NUMBER JLP SDD 9-24-71

DIMENSION:	FULL SCALE	.6% MODEL SCALE
Length, inch	165.	.990
Max Width, inch	55.	.330
Max Depth, inch	28.	.168
Fineness Ratio	--	--
Area, in.^{2}		
Max Cross-Sectional	1540.	.0555
Planform	8280.	.298
Wetted	15,800	.568
Base	1540.	.0555

Table III. (Continued) MSFC 510

MODEL COMPONENT: VERTICAL FIN, V1 and V1A;

GENERAL DESCRIPTION: 040A Orbiter Vertical Fin. Both leading and trailing edges are swept. V1A same as V1 except less ACPS Engine Pod.

DRAWING NUMBER: JLP SDD 9-24-71

DIMENSIONS:	FULL-SCALE	.6% MODEL SCALE
TOTAL DATA, INCLUDES RUDDER, EXCLUDES TIP POD		
Area		
Planform	342. ft^2	1.772 $in.^2$
Wetted	684. ft^2	3.55 $in.^2$
Span (equivalent)	246.2	1.480
Aspect Ratio	1.228	1.228
Rate of Taper	--	--
Taper Ratio	.374	.374
Diehedral Angle, degrees	--	--
Incidence Angle, degrees	0	0
Aerodynamic Twist, degrees	0	0
Toe-In Angle	--	--
Cant Angle	--	--
Sweep Back Angles, degrees		
Leading Edge	45.	45.
Trailing Edge	15.	15.
0.25 Element Line	40.75	40.75
Chords: INCH		
Root (~~Wing Sta. 0.0~~) (Z 500)	291.6	1.750
Tip, (equivalent) (Z 746.2)	109.0	.654
MAC	214.0	1.284
Fus. Sta. of .25 MAC	X 1422.7	--
W.P. of .25 MAC	Z 604.2	--
B.L. of .25 MAC	0	--
Airfoil Section		
Root	NACA 0012-64	NACA 0012-64
Tip	" " "	" " "
EXPOSED DATA (SAME AS ABOVE)		
Area		
Span, (equivalent)		
Aspect Ratio		
Taper Ratio		
Chords		
Root		
Tip		
MAC		
Fus. Sta. of .25 MAC		
W.P. of .25 MAC		
B.L. of .25 MAC		

Table III. (Continued) MSFC 510

MODEL COMPONENT: RUDDER

GENERAL DESCRIPTION:

DRAWING NUMBER: JLP SDD 9-24-71

DIMENSIONS:	FULL-SCALE	.6% MODEL SCALE
Area	135.6 ft^2	.702 $in.^2$
Span (equivalent), INCH	246.3	1.475
Inb'd equivalent chord, INCH	115.	.690
Outb'd equivalent chord, INCH	43.8	.263
Ratio movable surface chord/ total surface chord		
At Inb'd equiv. chord	.40	.40
At Outb'd equiv. chord	.40	.40
Sweep Back Angles, degrees		
Leading Edge	29.1	29.1
Tailing Edge	15.0	15.0
Hingeline	29.1	29.1
Area Moment (Normal to hinge line)	448. ft^3	.145 $in.^3$

Table III. (Continued) MSFC 510

MODEL COMPONENT: WING, W1

GENERAL DESCRIPTION: 040A Orbiter clipped delta wing

DRAWING NUMBER: JLP SDD 9-24-71

DIMENSIONS:		FULL-SCALE	.6% MODEL SCALE
TOTAL DATA			
Area			
Planform		3155.3 ft^2	16.37 in.^{2}
Wetted		5360. ft^2	27.8 in.^{2}
Span (equivalent), inch		882.	5.292
Aspect Ratio		1.712	1.712
Rate of Taper		--	--
Taper Ratio		.1486	.1486
Dihedral Angle, degrees		7.0	7.0
Incidence Angle, degrees		1.5	1.5
Aerodynamic Twist, degrees		0	0
Toe-In Angle		--	--
Cant Angle		--	--
Sweep Back Angles, degrees			
Leading Edge		60.	60.
Trailing Edge		0	0
0.25 Element Line		52.4	52.4
Chords: inch			
Root (Wing Sta. 0.0)		897.	5.38
Tip, (equivalent) (Y = 441)		133.3	.800
MAC		609.5	3.657
Fus. Sta. of .25 MAC	X	1057.5	6.36
W.P. of .25 MAC	Z	302.3	1.812
B.L. of .25 MAC	Y	165.7	.996
Airfoil Section			
Root		NACA 0008-64	NACA 0008-64
Tip		NACA 0008-64	NACA 0008-64
EXPOSED DATA, INCLUDES ELEVONS			
Area		2010. ft^2	14.45 in.^{2}
Span, (equivalent), inch		678.	4.07
Aspect Ratio		1.590	1.590
Taper Ratio		.1850	.1850
Chords			
Root (Y102)		720.	4.32
Tip (Y441)		133.3	.800
MAC		494.	2.97
Fus. Sta. of .25 MAC	X	1145.5	6.87
W.P. of .25 MAC	Z	308.1	1.87
B.L. of .25 MAC	Y	232.8	1.397

Table III. (Continued) MSFC 510

MODEL COMPONENT: ELEVONS

GENERAL DESCRIPTION:

DRAWING NUMBER: JLP SDD 9-24-71

DIMENSIONS:	FULL-SCALE	.6% MODEL SCALE
Area	456. ft^2	2.36 $in.^2$
Span (equivalent), INCH	556.	3.33
Inb'd equivalent chord, INCH	118.	.708
Outb'd equivalent chord, INCH	118.	.708
Ratio movable surface chord/ total surface chord		
At Inb'd equiv. chord	.1662	.1662
At Outb'd equiv. chord	.517	.517
Sweep Back Angles, degrees		
Leading Edge	0	0
Tailing Edge	0	0
Hingeline	0	0
Area Moment (Normal to hinge line)	2240. ft^3	.835 $in.^2$

MODEL COMPONENT: Boundary Layer Transition Strip - Z

GENERAL DESCRIPTION: Strip of carborundum grit located on model to initiate boundary layer transition from laminar to turbulent flow.

	.6% Model Scale
Grit Size, No.	100
Strip Width, in.	.125
Location:	
Wing, % Chord (both Surfaces)	10
Vertical Tail, % Chord (both Surfaces)	10
Fuselage, in aft of nose	.50

MODEL COMPONENT: BODY - B_1

GENERAL DESCRIPTION:

DRAWING NUMBER MSC 040A 9/24/71, 518 MOD 1401, 1405

DIMENSION:	FULL SCALE INCHES	.75% MODEL SCALE
Length	1,315.0	9.862
Max Width	204.0	1.530
Max Depth	238.0	1.785
Fineness Ratio		
Area		
Max Cross-Sectional	44,086.551	2.480
Planform		
Wetted		
Base (PROJECTED)	42824.5	2.409

Table III. (Continued) JPL 20-681

MODEL COMPONENT: VERTICAL TAIL - VI

GENERAL DESCRIPTION: CENTERLINE STABILIZER

DRAWING NUMBER: MSC 040A 9/24/71, 518 MOD 1407

DIMENSIONS:	FULL-SCALE INCHES	.75% MODEL SCALE
TOTAL DATA		
Area		
Planform		
Wetted		
Span (equivalent)		
Aspect Ratio		
Rate of Taper		
Taper Ratio		
Diehedral Angle, degrees		
Incidence Angle, degrees		
Aerodynamic Twist, degrees		
Toe-In Angle		
Cant Angle		
Sweep Back Angles, degrees		
Leading Edge	45°	45°
Trailing Edge	15°	15°
0.25 Element Line, 0.5 Element line	39.23°, 32.35°	39.23°, 32.35°
Chords:		
Root (Wing Sta. 0.0)		
Tip, (equivalent)		
MAC, inches		
Fus. Sta. of .25 MAC		
W.P. of .25 MAC		
Airfoil Section		
Root	NACA 0012-64	NACA 0012-64
Tip	NACA 0012-64	NACA 0012-64
EXPOSED DATA		
Area	51,030.051	2.870
Span, (equivalent)	270.0	2.025
Aspect Ratio	1.42857	1.429
Taper Ratio	0.31250	.3125
Chords		
Root	288.0	2.160
Tip	90.0	.6750
MAC	206.285	1.547
Fus. Sta. of .25 MAC	1,428.0	10.710
W.P. of .25 MAC	111.426	.8357

MODEL COMPONENT: V1 - RUDDER

GENERAL DESCRIPTION:

DRAWING NUMBER: MSC 040A 9/24/71, 518 MOD 1407

DIMENSIONS:	FULL-SCALE INCHES	.75% MODEL SCALE
Area	19,300.4	1.086
Span (equivalent)	244.0	1.830
Inb'd equivalent chord	114.9	.8617
Outb'd equivalent chord	43.3	.3247
Ratio movable surface chord/ total surface chord		
At Inb'd equiv. chord	0.4	0.4
At Outb'd equiv. chord	0.4	0.4
Sweep Back Angles, degrees		
Leading Edge		
Tailing Edge	15°	15°
Hingeline	33°	33°
Area Moment (Normal to hinge line)		

Table III. (Continued) JPL 20-681

MODEL COMPONENT: WING - W_1

GENERAL DESCRIPTION:

DRAWING NUMBER: MSC 040A 9/24/71, 518 MOD 1403

DIMENSIONS:	FULL-SCALE INCHES	.75% MODEL SCALE
TOTAL DATA		
Area		
Planform	454,363.012	25.558
Wetted		
Span (equivalent)	882.0	6.615
Aspect Ratio	1.71212	1.712
Rate of Taper		
Taper Ratio	0.14860	.1486
Dihedral Angle, degrees	7°	7°
Incidence Angle, degrees	1.5°	1.5°
Aerodynamic Twist, degrees	0°	0°
Toe-In Angle		
Cant Angle		
Sweep Back Angles, degrees		
Leading Edge	60°	60°
Trailing Edge	0°	0°
0.25 Element Line, 0.5 Element Line	52.42°, 40.9°	52.42°, 40.9°
Chords:		
Root (Wing Sta. 0.0)	897.0	6.727
Tip, (equivalent)	133.3	.9997
MAC	609.5	4.571
Fus. Sta. of .25 MAC	857.928	6.434
W.P. of .25 MAC		
B.L. of .25 MAC	166.0	1.245
Airfoil Section		
Root	NACA 0008-64	NACA 0008-64
Tip	NACA 0008-64	NACA 0008-64
EXPOSED DATA		
Area	289,440.743	16.281
Span, (equivalent)	678.0	5.085
Aspect Ratio	1.58818	1.588
Taper Ratio	0.18501	.1850
Chords		
Root	720.50	5.404
Tip	133.3	.9997
MAC	494.201	3.706
Fus. Sta. of .25 MAC	1,144.335	8.582
W.P. of .25 MAC		
B.L. of .25 MAC	232.640	1.745

Table III. (Continued) JPL 20-681

MODEL COMPONENT: W_1 - Elevon

GENERAL DESCRIPTION:

NOTE: The following dimensions are representative of each of the two elevons.

DRAWING NUMBER: MSC 040A 9/24/71, 518 MOD 1403

DIMENSIONS:	FULL-SCALE INCHES	.75% MODEL SCALE
Area	32,784.0	1.844
Span (equivalent)	278.0	2.085
Inb'd equivalent chord	118.0	.8850
Outb'd equivalent chord	118.0	.8850
Ratio movable surface chord/ total surface chord		
At Inb'd equiv. chord	.166	.166
At Outb'd equiv. chord	.516	.516
Sweep Back Angles, degrees		
Leading Edge		
Tailing Edge	0°	0°
Hingeline	0°	0°
Area Moment (Normal to hinge line)		

MODEL COMPONENT: BODY - B_1

GENERAL DESCRIPTION: Basic 040A Delta Wing Orbiter fuselage contour.

DRAWING NUMBER

DIMENSION:	FULL SCALE	1.5% MODEL SCALE
Length, in.	1315.0	19.725
Max Width, in.	204.0	3.060
Max Depth, in.	238.0	3.570
Fineness Ratio		
Area		
Max Cross-Sectional, ft^2	306.157	0.06889
Planform		
Wetted		
Base, ft^2 (Projected)	297.39	0.067913

Table III. (Continued) ARC 605

MODEL COMPONENT: BODY - Canopy C_1

GENERAL DESCRIPTION: Bubble type MSC 040A Observation Canopy

DRAWING NUMBER

DIMENSION:	FULL SCALE	1.5% MODEL SCALE
Length	120	1.20
Max Width	106	1.59
Max Depth	WL 524	WL 7.86
Fineness Ratio		
Area		
Additional Frontal Area	10.44 ft^2	0.3382 in^2
Additional Side Area	18.37 ft^2	0.5952 in^2

Table III. (Continued) ARC 605

MODEL COMPONENT: **Manipulator Arm Dorsal Housing, D_1**

GENERAL DESCRIPTION:

DRAWING NUMBER

DIMENSION:	FULL SCALE	1.5% MODEL SCALE
Length, in	721	10.815
Max Width, in	26	0.390
Max Depth, in at ℄	14	0.210
Fineness Ratio		
Area		
Max Cross-Sectional		
Planform		
Wetted		
Base		

Table III. (Continued) ARC 605

MODEL COMPONENT: ORBITAL MANEUVERING SYSTEM (OMS) M_1

GENERAL DESCRIPTION:

DRAWING NUMBER

DIMENSION:	FULL SCALE	1.5% MODEL SCALE
Length, in.	251.5	3.773
Max Width, in.	58.0	0.870
Max Depth		
Fineness Ratio		
Area		
Max Cross-Sectional		
Planform		
Wetted		
Base		

MODEL COMPONENT: Attitude Control Propulsion System (ACPS) P_1

GENERAL DESCRIPTION: P_V - If on vertical fin

P_W - If on the wing tips

DRAWING NUMBER

DIMENSION:	FULL SCALE		1.5% MODEL SCALE	
	Vertical	Wing	Vertical	Wing
Length, in.	183	165	2.745	2.475
Max Width, in.	43.8	55	0.657	0.825
Max Depth, in.	23.8	28	0.357	0.420
Fineness Ratio				
Area				
Max Cross-Sectional				
Planform				
Wetted				
Base				

Table III. (Continued) ARC 605

MODEL COMPONENT: Vertical Fin, V1

GENERAL DESCRIPTION: Basic 040A Delta Wing Orbiter centerline vertical tail.
Airfoil section = 0012-64.

DRAWING NUMBER:

DIMENSIONS:	**FULL-SCALE**	1.5% **MODEL SCALE**
TOTAL DATA		
Area		
Planform		
Wetted		
Span (equivalent)		
Aspect Ratio		
Rate of Taper		
Taper Ratio		
Diehedral Angle, degrees		
Incidence Angle, degrees		
Aerodynamic Twist, degrees		
Toe-In Angle		
Cant Angle		
Sweep Back Angles, degrees		
Leading Edge	45	45
Trailing Edge	15	15
0.25 Element Line, .5 Line	39.23,32.35	39.23,32.35
Chords:		
Root (Wing Sta. 0.0)		
Tip, (equivalent)		
MAC		
Fus. Sta. of .25 MAC		
W.P. of .25 MAC		
B.L. of .25 MAC		
Airfoil Section		
Root	0012-64	0012-64
Tip	0012-64	0012-64
EXPOSED DATA		
Area, ft^2	354.375	0.0797
Span, (equivalent)	270.0	4.050
Aspect Ratio	1.42857	1.42857
Taper Ratio	0.31250	0.31250
Chords		
Root	288.0	4.320
Tip	90.0	1.350
MAC	206.285	3.094
Fus. Sta. of .25 MAC	1228.0	18.420
W.P. of .25 MAC	111.426	1.671
B.L. of .25 MAC	0	0

MODEL COMPONENT: RUDDER, R1

GENERAL DESCRIPTION: Rudder for basic 040A Vertical Fin V1

DRAWING NUMBER:

DIMENSIONS:	**FULL-SCALE**	1.5% **MODEL SCALE**
Area, ft^2	134.03	0.03017
Span (equivalent), in	244.0	3.660
Inb'd equivalent chord, in	114.9	1.724
Outb'd equivalent chord, in	43.3	0.650
Ratio movable surface chord/ total surface chord		
At Inb'd equiv. chord		
At Outb'd equiv. chord		
Sweep Back Angles, degrees		
Leading Edge		
Tailing Edge	15°	15°
Hingeline	33°	33°
Area Moment (Normal to hinge line)		

Table III. (Continued) ARC 605

MODEL COMPONENT: Wing W1

GENERAL DESCRIPTION: Basic 040A Delta Wing. Trailing edge dihedral = 7°, root chord incidence = 1.5°, twist = 0°.

DRAWING NUMBER:

DIMENSIONS:	FULL-SCALE	1.5% MODEL SCALE
TOTAL DATA		
Area, ft2		
Planform	3155.299	0.7099
Wetted		
Span (equivalent), in	882.000	13.2300
Aspect Ratio	1.71212	1.71212
Rate of Taper		
Taper Ratio	0.14860	0.14860
Diehedral Angle, degrees	7.0	7.0
Incidence Angle, degrees	1.5	1.5
Aerodynamic Twist, degrees	0.0	0.0
Toe-In Angle		
Cant Angle		
Sweep Back Angles, degrees		
Leading Edge	60.0	60.0
Trailing Edge	0.0	0.0
0.25 Element Line, .5 Line	52.42,40.9	52.42,40.9
Chords:		
Root (Wing Sta. 0.0)	897.0	13.455
Tip, (equivalent)	133.3	2.000
MAC	609.5	9.143
Fus. Sta. of .25 MAC	1057.928	15.869
W.P. of .25 MAC		
B.L. of .25 MAC	166.0	2.490
Airfoil Section		
Root	0008-64	0008-64
Tip	0008-64	0008-64
EXPOSED DATA		
Area	2010.005	0.4523
Span, (equivalent)	678.0	10.170
Aspect Ratio	1.58818	1.58818
Taper Ratio	0.18501	0.18501
Chords		
Root	720.50	10.808
Tip	133.3	2.000
MAC	494.201	7.413
Fus. Sta. of .25 MAC	1144.335	17.165
W.P. of .25 MAC		
B.L. of .25 MAC	232.640	3.490

MODEL COMPONENT: ELEVON, e_1

GENERAL DESCRIPTION: Constant chord elevon located on basic 040A Wing W_1.

Note: The following dimensions are representative of each of the two elevons.

DRAWING NUMBER: ____________

DIMENSIONS:	**FULL-SCALE**	1.5% **MODEL SCALE**
Area, ft^2	227.67	0.05122
Span (equivalent), in.	278.0	4.170
Inb'd equivalent chord, in	118.0	1.770
Outb'd equivalent chord, in	118.0	1.770
Ratio movable surface chord/ total surface chord		
At Inb'd equiv. chord		
At Outb'd equiv. chord		
Sweep Back Angles, degrees		
Leading Edge		
Tailing Edge	0	0
Hingeline	0	0
Area Moment (Normal to hinge line)		

Table III. (Continued) LTPT 85

MODEL COMPONENT: BODY - B1, B2

GENERAL DESCRIPTION:

DRAWING NUMBER: MSC 040A 9/24/71

DIMENSIONS:	FULL-SCALE INCHES	1.9% MODEL SCALE Inches
Length	1,315.0	24.985
Max. Width	204.0	3.876
Max. Depth	238.0	4.522
Fineness Ratio		
Area		
Max. Cross-Sectional	44,086.551	15.915
Planform		
Wetted		
Base (PROJECTED)	42,603.878	15.38

MODEL COMPONENT: WING - W1

GENERAL DESCRIPTION:

DRAWING NUMBER: MSC 040A 9/24/71

DIMENSIONS:	FULL-SCALE INCHES	1.9% MODEL SCALE Inches
TOTAL DATA		
Area		
Planform	454,363.012	164.025
Wetted		
Span (equivalent)	882.0	16.758
Aspect Ratio	1.71212	1.71212
Rate of Taper		
Taper Ratio	0.14860	0.14860
Diehedral Angle, degrees	7°	7°
Incidence Angle, degrees	1.5°	1.5°
Aerodynamic Twist, degrees	0°	0°
Toe-In Angle		
Cant Angle		
Sweep Back Angles, degrees		
Leading Edge	60°	60°
Trailing Edge	0°	0°
0.25 Element Line, 0.5 Element line	52.42°, 40.9°	52.42°, 40.9°
Chords:		
Root (Wing Sta. 0.0)	897.0	17.043
Tip, (equivalent)	133.3	2.5327
MAC	609.5	11.5805
Fus. Sta. of .25 MAC	1057.928	20.1006
W.P. of .25 MAC		
B.L. of .25 MAC	166.0	3.154
Airfoil Section		
Root	NACA 0008-64	0008-64
Tip	NACA 0008-64	0008-64
EXPOSED DATA		
Area	289,440.743	104.488
Span, (equivalent)	678.0	12.882
Aspect Ratio	1.58818	1.58818
Taper Ratio	0.18501	0.18501
Chords		
Root	720.50	13.6895
Tip	133.3	2.5333
MAC	494.201	9.3898
Fus. Sta. of .25 MAC	1,144.335	21.7424
W.P. of .25 MAC		
B.L. of .25 MAC	232.640	4.4202

Table III. (Continued) LTPT 85

MODEL COMPONENT: W1 - Elevon

GENERAL DESCRIPTION:

NOTE: The following dimensions are representative of each of the two elevons.

DRAWING NUMBER: MSC 040A 9/24/71

DIMENSIONS:	FULL-SCALE INCHES	1.9% MODEL SCALE Inches
Area	32,784.0	11.835
Span (equivalent)	278.0	5.282
Inb'd equivalent chord	118.0	2.242
Outb'd equivalent chord	118.0	2.242
Ratio movable surface chord/ total surface chord		
At Inb'd equiv. chord	.166	.166
At Outb'd equiv. chord	.516	.516
Sweep Back Angles, degrees		
Leading Edge		
Tailing Edge	0°	0°
Hingeline	0°	0°
Area Moment (Normal to hinge line)		

Table III. (Continued) LTPT 85

MODEL COMPONENT: VERTICAL TAIL - V1

GENERAL DESCRIPTION: Centerline Stabilizer

DRAWING NUMBER: MSC 040A 9/24/71

DIMENSIONS:	FULL-SCALE INCHES	1.9% MODEL SCALE Inches
TOTAL DATA		
Area		
Planform		
Wetted		
Span (equivalent)		
Aspect Ratio		
Rate of Taper		
Taper Ratio		
Diehedral Angle, degrees		
Incidence Angle, degrees		
Aerodynamic Twist, degrees		
Toe-In Angle		
Cant Angle		
Sweep Back Angles, degrees		
Leading Edge	45°	45°
Trailing Edge	15°	15°
0.25 Element Line, 0.5 Element Line	39.23°, 32.35°	39.23°, 32.35°
Chords:		
Root (Wing Sta. 0.0)		
Tip, (equivalent)		
MAC		
Fus. Sta. of .25 MAC		
W.P. of .25 MAC		
B.L. of .25 MAC		
Airfoil Section		
Root	NACA 0012-64	0012-64
Tip	NACA 0012-64	0012-64
EXPOSED DATA		
Area	51,030.051	18.422
Span, (equivalent)	270.0	5.130
Aspect Ratio	1.42857	1.42857
Taper Ratio	0.31250	0.31250
Chords		
Root	288.0	5.472
Tip	90.0	1.710
MAC	206.285	3.919
Fus. Sta. of .25 MAC	1,428.0	27.132
W.P. of .25 MAC	611.426	11.6171
B.L. of .25 MAC		

Table III. (Continued) LaRC LTPT 85

MODEL COMPONENT: V1 - RUDDER

GENERAL DESCRIPTION:

DRAWING NUMBER: MSC 040A 9/24/71

DIMENSIONS:	FULL-SCALE INCHES	1.9% MODEL SCALE Inches
Area	19,300.4	366.708
Span (equivalent)	244.0	4.636
Inb'd equivalent chord (WL ≅ 500)	114.9	2.183
Outb'd equivalent chord (WL ≅ 745)	43.3	0.823
Ratio movable surface chord/ total surface chord		
At Inb'd equiv. chord	0.4	0.4
At Outb'd equiv. chord	0.4	0.4
Sweep Back Angles, degrees		
Leading Edge		
Tailing Edge	15°	15°
Hingeline	33°	33°
Area Moment (Normal to hinge line)		

TEST FACILITY DESCRIPTIONS

NASA/MSFC 14-IN. TRISONIC WIND TUNNEL

The Marshall Space Flight Center 14" x 14" Trisonic Wind Tunnel is an intermittent blowdown tunnel which operates by high pressure air flowing from storage to either vacuum or atmospheric conditions. A Mach number range from .2 to 5.85 is covered by utilizing two interchangeable test sections. The transonic section permits testing at Mach 0.20 through 2.50, and the supersonic section permits testing at Mach 2.74 through 5.85. Mach numbers between .2 and .9 are obtained by using a controllable diffuser. The range from .95 to 1.3 is achieved through the use of plenum suction and perforated walls. Mach numbers of 1.44, 1.93 and 2.50 are produced by interchangeable sets of fixed contour nozzle blocks. Above Mach 2.50 a set of fixed contour nozzle blocks are tilted and translated automatically to produce any desired Mach number in .25 increments.

Air is supplied to a 6000 cubic foot storage tank at approximately $-40^{\circ}F$ dew point and 500 psi. The compressor is a three-stage reciprocating unit driven by a 1500 hp motor.

The tunnel flow is established and controlled with a servo actuated gate valve. The controlled air flows through the valve diffuser into the stilling chamber and heat exchanger where the air temperature can be controlled from ambient to approximately $180^{\circ}F$. The air then passes through the test section which contains the nozzle blocks and test region.

Downstream of the test section is a hydraulically controlled pitch sector that provides a total angle of attack range of 20° ($\pm 10^{\circ}$). Sting offsets are available for obtaining various maximum angles of attack up to 90°.

JPL 20-IN. SUPERSONIC WIND TUNNEL

The 20 inch supersonic wind tunnel at the Jet Propulsion Laboratory in Pasadena, California, is of the continuous-flow, variable density type. The Mach number range can be varied from 1.3 to 5.0 with corresponding earth pressure altitude simulation from 15,000 to 180,000 feet.

The geometric test section is nominally 20 inches high by 18 inches wide. A model can be pitched or rolled remotely with sector travel limited to 40°. Sideslip data can be obtained using the pitch-roll capability. Types of tests which can be run in this tunnel include internal strain gage balance, free flight, pressure (up to 120 ports), temperature (up to 150 thermocouples) and various types of flow visualization (including Schlieren) tests.

Data reduction is off-line with on-line monitoring of the raw data. Final coefficient data as well as plots can be obtained normally within several days.

NASA/AMES 6x6 FT. SUPERSONIC WIND TUNNEL

The NASA-Ames Research Center 6- by 6-Foot Supersonic Wind Tunnel is located at Moffett Field, California; it is a closed-circuit, variable pressure facility. The test section has a slotted floor and ceiling, allowing for continuous operation from Mach number 0.25 to 2.30 at stagnation pressures from 0.3 to 1.0 atmosphere for stagnation temperature of $560^{o}R$. These conditions allow Reynolds number variation from 1 - 5 x 10^6/foot and a dynamic pressure range from 200-1000 lbs/ft^2.

NASA/LaRC LOW TURBULENCE PRESSURE TUNNEL

The NASA Langley Research Center Low Turbulence Pressure Tunnel (LTPT) is a variable-pressure, single return facility with a closed test section 3.5 feet wide and 7 feet high. This facility can be operated at a Reynolds number of 1.0×10^6 to 15.0×10^6 per foot and a Mach number to about 0.4.

Table IV.

TEST CONDITIONS

TEST CONDITIONS

TEST MSFC TWT 510

MACH NUMBER	REYNOLDS NUMBER per unit length	DYNAMIC PRESSURE (pounds/sq. inch)	STAGNATION TEMPERATURE (degrees Fahrenheit)
.6	5.0 & 8.9 x 10^6	4.4 & 7.5	89 - 101
.8	6.0	6.5	98 - 102
.9	6.3	7.4	98 - 102
1.0	6.5	8.1	98 - 102
1.2	6.8	9.2	95 - 99
1.46	7.5	10.8	96 - 100
1.96	7.1	10.3	99 - 103
2.74	6.0	7.5	98 - 104
3.48	7.0	6.9	98 - 104
4.96	5.4	3.1	98 - 104

BALANCE UTILIZED: MSFC # 232

	CAPACITY:	ACCURACY:	COEFFICIENT TOLERANCE:
NF	150 lb	± .3%	
SF	50 lb	± .3%	
AF	50 lb	± .3%	
PM	--	± .3%	
YM	--	± .3%	
RM	100 lb	± .3%	

COMMENTS:

Table IV. (Continued)

TEST CONDITIONS

TEST MSFC TWT 551

MACH NUMBER	REYNOLDS NUMBER per unit length (feet)	DYNAMIC PRESSURE (pounds/sq. inch)	STAGNATION TEMPERATURE (degrees Fahrenheit)
.6	4.85×10^6	4.286	100
.8	5.8	6.465	100
.9	6.15	7.399	100
1.0	6.4	8.168	100
1.2	6.6	9.139	100
1.96	7.0	10.993	135
2.74	6.3	8.511	140
3.48	6.4	6.870	140
4.96	5.2	3.243	140

BALANCE UTILIZED: MSFC #200

CAPACITY:		ACCURACY:	COEFFICIENT TOLERANCE:
NF	175 lbs	± .5%	
SF	150 lbs	± .5%	
AF	100 lbs	± .5%	
PM	185 in. lb.	± .5%	
YM	160 in. lb.	± .5%	
RM	50 in. lb.	± .5%	

COMMENTS:

Table IV. (Continued)

TEST CONDITIONS

TEST JPL WT 20-681

MACH NUMBER	REYNOLDS NUMBER per unit length	DYNAMIC PRESSURE (pounds/sq. inch)	STAGNATION TEMPERATURE (degrees Fahrenheit)
RUNS 2 - 7			
2.01	.358 x 10^6/in.	6.30	92
REST OF RUNS			
2.01	.303	5.83	92
2.42	.326	5.23	90
3.03	.326	4.32	85
3.98	.313	3.03	100

BALANCE UTILIZED: JPL SGB6-3

	CAPACITY:	ACCURACY:	COEFFICIENT TOLERANCE:
NF	200 lbs.	0.25%	
SF	100 lbs.	"	
AF	30 lbs.	"	
PM	300 in-lbs.	"	
YM	125 in-lbs.	"	
RM	20 in-lbs.	"	

COMMENTS:

Table IV. (Continued)

TEST CONDITIONS

TEST ARC 66-605

MACH NUMBER	REYNOLDS NUMBER per unit length	DYNAMIC PRESSURE (pounds/sq. inch)	STAGNATION TEMPERATURE (degrees Fahrenheit)
0.6	4.0×10^6/ft	3.54	≈ 80°
0.9	3.3×10^6/ft	3.96	↓
1.2	3.3×10^6/ft	4.50	↓
1.5	3.3×10^6/ft	4.86	↓
2.0	2.5×10^6/ft	3.54	↓

BALANCE UTILIZED: AMES TASK MK II - 1.5" DIA.

CAPACITY:		ACCURACY:	COEFFICIENT TOLERANCE:
NF	500 lb.	0.5% Full Load	
SF	500 lb.	↓	
AF	300 lb.	↓	
PM	250 lb.	↓	
YM	250 lb.	↓	
RM	800 in. lb.	↓	

COMMENTS:

Table IV. (Continued)

TEST CONDITIONS

TEST LRC LTPT TEST 85

MACH NUMBER	REYNOLDS NUMBER per unit length	DYNAMIC PRESSURE (pounds/sq. inch)	STAGNATION TEMPERATURE (degrees Fahrenheit)
0.18	2.1×10^6	81 (PSF)	50
0.25	4.3	221	58
0.24	5.5	278	63
0.26	6.5	353	67
0.25	8.3	437	73
0.25	10.4	547	75
0.24	11.4	592	78
0.24	11.9	630	85
0.22	13.9	670	84

BALANCE UTILIZED: LaRC # 832C

CAPACITY:		ACCURACY:	COEFFICIENT TOLERANCE:
NF	1000 lb.		
SF	250 lb.		
AF	85 lb.		
PM	2000 in-lb.		
YM	1000 in-lb.		
RM	500 in-lb.		

COMMENTS:

Table V. TABLE OF SOURCE DATA

DERIVATIVE	TEST NUMBER	RUN NUMBER
C_{m_α}, C_{N_α}	LaRC LTPT 85	3
	MSFC 551	1, 2, 3, 12, 13, 14, 15, 16, 17
	JPL 20-681	2, 46, 90, 108
	ARC 6 x 6 605	1, 2, 3, 4, 5
C_{n_β}, C_{ℓ_β}, C_{Y_β} at $\alpha = 0°$	MSFC 510	61, 62, 63, 64, 65, 92, 102, 147, 148, 149
	JPL 20-681	143, 306, 331
	ARC 6 x 6 605	149, 150, 151, 152, 153
$C_{m_{\delta_e}}$, $C_{L_{\delta_e}}$ at $\alpha = 0°$, 10° & 20° ($\Delta\delta_e = -20°$)	MSFC 551	13 & 23, 14 & 24, 15 & 25, 17 & 27, 16 & 26, 12 & 10, 3 & 9, 2 & 8, 1 & 7
	JPL 20-681	2 & 15, 46 & 54, 90 & 82, 108 & 116
	ARC 6 x 6 605	1 & 174, 2 & 175, 3 & 176, 4 & 177, 5 & 178
$C_{n_{\delta_a}}$, $C_{\ell_{\delta_a}}$, $C_{Y_{\delta_a}}$ $\alpha = 0°$, 10°, & 20° ($\Delta\delta_a = 10°$)	MSFC 551	13 & 22, 14 & 21, 15 & 20, 17 & 18, 16 & 19, 12 & 11, 3 & 4, 2 & 5, 1 & 6
	JPL 20-681	2 & 25, 46 & 69, 90 & 72, 108 & 131
	ARC 6 x 6 605	1 & 254, 2 & 255, 3 & 256, 4 & 257, 5 & 258