NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA CR-
141508

(NASA-CR-141508) RESULTS OF FLOW-VISUALIZATION INVESTIGATIONS ON A 0.015-SCALE MODIFIED CONFIGURATION 140A/B SPACE SHUTTLE VEHICLE ORBITER (MODEL 36-0) IN THE LANGLEY RESEARCH CENTER 8-FOOT

N75-18295

Unclas
G3/18 13018

SPACE SHUTTLE

AEROTHERMODYNAMIC DATA REPORT

JOHNSON SPACE CENTER

HOUSTON, TEXAS

DATA MANagement services

SPACE DIVISION CHRYSLER CORPORATION

February, 1975

DMS-DR-2229
NASA-CR-141,508

RESULTS OF FLOW-VISUALIZATION INVESTIGATIONS ON A 0.015-SCALE MODIFIED CONFIGURATION 140A/B SPACE SHUTTLE VEHICLE ORBITER (MODEL 36-0) IN THE LANGLEY RESEARCH CENTER 8-FOOT TRANSONIC PRESSURE TUNNEL (OA102)

By

M. E. Nichols
Shuttle Aero Sciences
Rockwell International Space Division

Prepared under NASA Contract Number NAS9-13247

By

Data Management Services
Chrysler Corporation Space Division
New Orleans, La. 70189

for

Engineering Analysis Division

Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas

WIND TUNNEL TEST SPECIFICS:

Test Number: LaRC 8 TPT 687
NASA Series Number: OA102
Model Number: 36-0
Test Dates: 17 through 18 June 1974
Occupancy Hours: 18

FACILITY COORDINATOR:

Mr. David R. Stone
Mail Stop 163A
Langley Research Center
Langley Station
Hampton, Virginia 23665

Phone: (804) 827-2483

PROJECT ENGINEERS:

M. E. Nichols
Mail Code AC07
Rockwell International
Space Division
12214 Lakewood Blvd.
Downey, Ca. 90241

Phone: (213) 922-2849

G. Ware
Mail Stop 1251
Langley Research Center
Langley Station
Hampton, Va. 23665

Phone: (804) 827-3911

AERODYNAMICS ANALYSIS ENGINEER:

S. Kraus
Mail Gode AC07
Rockwell International
Space Division
12214 Lakewood Blvd.
Downey, Ca. 90241

Phone: (213) 922-4880

DATA MANAGEMENT SERVICES:

Prepared by: Liaison--D. A. Sarver,
Operations--G. G. McDonald

Reviewed by: J. L. Glynn

Approved: N. D. Kemp, Manager
Data Management Services

Concurrence: J. G. Swider, Manager
Flight Technology Branch

Chrysler Corporation Space Divison assumes no responsibility for the data other than display characteristics.

RESULTS OF FLOW-VISUALIZATION INVESTIGATIONS ON A
0.015-SCALE MODIFIED CONFIGURATION 140A/B
SPACE SHUTTLE VEHICLE ORBITER (MODEL 36-0)
IN THE LANGLEY RESEARCH CENTER
8-FOOT TRANSONIC PRESSURE TUNNEL (OA102)

By

M. E. Nichols, Rockwell International Space Division

ABSTRACT

This report details the results of a flow-visualization wind tunnel test of a 0.015-scale model of the Modified Configuration 140A/B Space Shuttle Vehicle Orbiter. The purpose of this test was to determine separation zones, flow-recirculation regions, and potential venting and contaminant-ingestion problem areas. This study was carried out by means of photographic (video tape) analysis of model-mounted tufts.

The test was conducted from 17 through 18 June 1974 during 18 test hours. It was identified as SSV Test OA102.

The model was tested at Mach numbers of 0.60, 0.90, 1.05, and 1.20, at Reynolds numbers of 3.17, 3.98, 4.16, and 4.23, respectively. Model angle-of-attack was varied from 0° to 20° at 0° sideslip-angle.

Three control-surface deflection combinations were tested. No configuration-buildup or alternate-configuration program was carried out.

(THIS PAGE INTENTIONALLY LEFT BLANK)

TABLE OF CONTENTS

INDEX OF MODEL FIGURES

NOMENCLATURE
General

SYMBOL	SADSAC SYMBOL	DEFINITION
a		speed of sound; m/sec, ft/sec
C_p	CP	pressure coefficient; $(p_l - p_\infty)/q$
M	MACH	Mach number; V/a
p		pressure; N/m^2, psf
q	Q(NSM) Q(PSF)	dynamic pressure; $1/2\rho V^2$, N/m^2, psf
RN/L	RN/L	unit Reynolds number; per m, per ft
V		velocity; m/sec, ft/sec
α	ALPHA	angle of attack, degrees
β	BETA	angle of sideslip, degrees
ψ	PSI	angle of yaw, degrees
ϕ	PHI	angle of roll, degrees
ρ		mass density; kg/m^3, $slugs/ft^3$

Reference & C.G. Definitions

SYMBOL	SADSAC SYMBOL	DEFINITION
A_b		base area; m^2, ft^2
b	BREF	wing span or reference span; m, ft
c.g.		center of gravity
ℓ_{REF} $\bar{c}$	LREF	reference length or wing mean aerodynamic chord; m, ft
S	SREF	wing area or reference area; m^2, ft^2
	MRP	moment reference point
	XMRP	moment reference point on X axis
	YMRP	moment reference point on Y axis
	ZMRP	moment reference point on Z axis

SUBSCRIPTS

b	base
l	local
s	static conditions
t	total conditions
∞	free stream

CONFIGURATIONS INVESTIGATED

The 0.015-scale Rockwell International SSV Orbiter model was built to configuration control drawings VL70-000140A and VL70-000140B as combined per model drawing BD-SS-A00130 to define the "140A/B" configuration. The OMS/RCS pods were modified to conform with proposed Vehicle 5 specifications.

The model (Model 36-0) was constructed of Armco 17-4 stainless steel to meet test safety-factors of 5 based on ultimate strength and 3 based on yield strength.

The model was mounted on a sting and sting-to-model adaptor assembly. No balance or other force or moment instrumentation was employed. Tufts were arranged at prescribed locations on the Orbiter fuselage, wings, and vertical tail, as specified below.

The elevons, bodyflap, and speedbrake/rudder assembly were capable of deflections as shown in Table II.

Component	Description
B_{26}	Orbiter fuselage per Rockwell International lines drawings VL70-000140A/B, VL70-000143, VL70-000135, VL70-000200, VL70-000205, VL70-006089, model drawing SS-A00142
C_9	Orbiter canopy per Rockwell International lines drawing VL70-000140A/B, model drawing SS-A00142
E_{26}	Orbiter full-span, unswept-hingeline, non-gapped elevons per Rockwell International lines drawings VL70-000200, VL70-006089, VL70-006092, model drawing SS-A01235
F_8	Orbiter bodyflap per Rockwell International lines drawings VL70-70-000140A, VL70-000145, model drawing SS-A01236
M_{16}	Orbiter OMS/RCS pods per Rockwell International lines study drawings VL70-008410, VL70-008410, VL70-008457 (17 May 1974).

CONFIGURATIONS INVESTIGATED (Concluded)

R_5	Orbiter rudder per Rockwell International lines drawings VL70-000146A, VL70-0000095, model drawing SS-A00143
V_8	Orbiter centerline vertical tail per Rockwell International lines drawing VL70-000146A, model drawing SS-A00143
W_{116}	Orbiter double-delta wing per Rockwell International lines drawings VL70-000200, VL70-000200, VL70-000143, model drawings SS-A00130, SS-A00143, SS-A01235

INSTRUMENTATION

No model force or moment data or pressures were obtained. Tunnel pressure data were measured for computing the usual tunnel parameters. Model angle-of-attack was also determined.

Rows of nylon tufts were attached to the model at the locations given below:

1. Tufts around the fuselage at these model stations:

Row #	Station
1	4.25
2	8.10
3	10.05
4	12.00
5	15.00
6	18.00
7	21.75

2. Tufts on top and bottom of both wings:

Row #	% Chord
8	15
9	50
10	90

3. Tufts on both sides of the vertical tail:

Row #	% Chord
11	15
12	50
13	90

4. Tufts were also mounted on a rake-post arrangement aft of the vertical tail at a distance of one inch from the trailing edge. This was identified as Row #14.

INSTRUMENTATION (Concluded)

Tufts were approximately 3/4-inch long and were spaced approximately 3/4-inch apart in their rows at the locations specified above.

TEST FACILITY DESCRIPTION

The NASA/Langley Research Center 8-Foot Transonic Pressure Tunnel is an air-medium, single-return, closed-circuit facility with the capability of continuous Mach number variation from 0.2 to 1.3. Stagnation temperature and pressure and dewpoint temperature are controlled. Reynolds number is variable from 0.3×10^6/ft to 7.0×10^6/ft, depending on Mach number.

Models are supported in the 7.1-foot-square test section by means of stings attached to the tunnel sector system. Wall mounts are also available for airfoil-type testing.

DISCUSSION OF RESULTS

The test program involved only videotape recording of tuft behavior on the Orbiter fuselage and upper and lower wing regions. The tape quality and resolution were sufficient for on-site and later off-site visual analysis, but the tapes did not lend themselves well to still-photographic reproduction for presentation here.

Extensive review of the tapes showed that the local flow directions on the aft fuselage, as affected by the late-design, shorter OMS pods, were clearly delineated by the tufts during transonic conditions. No reverse-flow, forward-traveling patterns were apparent. Concern about unusual flow from the base region forward along the fuselage (possibly even as far as the nose/canopy area) was alleviated.

Clear delineation of vortex and boundary-layer separation regions on the fuselage and wing surfaces was apparent. The transonic capabilities of tuft-analysis were affirmed. Videotape recording also allowed study of early flow-development patterns, as well as transitions during attitude change.

The videotape-form data will be retained by Rockwell International Space Division Aerodynamics personnel for future reference and study.

TABLE I.

TEST : 0A102

DATE : 18 JUNE 74

TEST CONDITIONS

MACH NUMBER	REYNOLDS NUMBER (per foot)	DYNAMIC PRESSURE (pounds/sq. inch)	STAGNATION TEMPERATURE (degrees Fahrenheit)
0.60	3.17×10^6	2.91	120
0.90	3.98×10^6	4.94	120
1.05	4.16×10^6	5.67	120
1.20	4.23×10^6	6.12	120

BALANCE UTILIZED: None

	CAPACITY:	ACCURACY:	COEFFICIENT TOLERANCE:
NF			
SF			
AF			
PM			
RM			
YM			

COMMENTS: Tuft Test:
VIDEOTAPE ONLY

TABLE II.

TEST: ØA102

DATA SET/RUN NUMBER COLLATION SUMMARY

DATE: 6-19-74

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	δ_E	δ_A	δ_{SB}	δ_R	δ_{BF}	NO. OF RUNS	MACH 0.60	MACH 0.90	MACH 1.05	MACH 1.20
001	O_x	A	0°	0	0	0	0	0	3	1	2	3	—
002	O_x	A	0°	-4	-11	63	15	16.3	3	6	5	—	4
003	O_x	A	0°	-2.5	-17.5	63	22	20	4	10	9	8	7

TEST RUN NUMBERS

1 7 13 19 25 31 37 43 49 55 61 67 75 76

α OR β SCHEDULES: $\alpha A = 0°, 5°, 10°, 15°, 20°$

COEFFICENTS IDVAR (1) IDVAR (2) NDV

$O_x = B_{26} C_9 F_8 M_{16} V_8 R_5 W_{116} E_{26}$

TABLE III. - MODEL DIMENSIONAL DATA

MODEL COMPONENT : BODY - B_{26}

GENERAL DESCRIPTION : Configuration 140A/B Orbiter Fuselage

NOTE: B_{26} is identical to B_{24} except underside of fuselage has been refaired to accept W_{116}.

MODEL SCALE: 0.015 MODEL DRAWING: SS-A00147, RELEASE 12

DRAWING NUMBER VL70-000143B, -000200, 000205, -006089, -000145, -000140A, 000140B

DIMENSIONS :	FULL SCALE	MODEL SCALE
*Length (OML: Fwd Sta. X_o=235)-In.	1293.3	19.400
*Length (IML: Fwd Sta. X_o=238)-In.	1290.3	19.350
* Max Width (@ X = 1528.3) - In.	264.0	3.960
Max Depth (@ X_o = 1464) - In.	250.0	3.750
Fineness Ratio		
Area - Ft^2		
Max. Cross-Sectional	340.88	0.077
Planform		
Wetted		
Base		

TABLE III. - MODEL DIMENSIONAL DATA - Continued.

MODEL COMPONENT : CANOPY - C_9

GENERAL DESCRIPTION : Configuration 3A, Canopy used with Fuselage B_{26}.

MODEL SCALE: 0.015 MODEL DRAWING: SS-A00147, RELEASE 12

DRAWING NUMBER VL70-000143A

DIMENSIONS :	FULL SCALE	MODEL SCALE
*Length (X_o = 434.643 to 578)	143.357	2.150
Max Width (@ X_o = 513.127)	152.412	2.286
Max Depth (@ X_o = 485.0)	25.000	0.375
Fineness Ratio		
Area		
Max. Cross-Sectional		
Planform		
Wetted		
Base		

TABLE III. - MODEL DIMENSIONAL DATA - Continued.

MODEL COMPONENT: ELEVON - E_{26}

GENERAL DESCRIPTION: Configuration 140A/B Orbiter Elevons

DATA ARE FOR ONE SIDE.

MODEL SCALE: 0.015 MODEL DRAWING: SS-A00148, RELEASE 6

DRAWING NUMBER: VL70-000200, -006089, -006092

DIMENSIONS:	FULL-SCALE	MODEL SCALE
Area Ft^2	210.0	0.0473
Span (equivalent) - In.	349.2	5.238
Inb'd equivalent chord - In.	118.004	1.770
Outb'd equivalent chord - In.	55.192	0.828
Ratio movable surface chord/ total surface chord		
At Inb'd equiv. chord	0.2096	0.2096
At Outb'd equiv. chord	0.4004	0.4004
Sweep Back Angles, degrees		
Leading Edge	0.00	0.00
Trailing Edge	-10.056	-10.056
Hingeline	0.00	0.00
* Area Moment (Product of Area & $\bar{c}$) $-Ft^3$	1587.25	0.0054
*Mean Aerodynamic Chord - In.	90.7	1.361

TABLE III. - MODEL DIMENSIONAL DATA - Continued.

MODEL COMPONENT : BODY FLAP - F_8

GENERAL DESCRIPTION : Configuration 140A/B orbiter body flap.

Hingeline located at X_o = 1528.3, Z_o = 284.3

MODEL SCALE: 0.015 MODEL DRAWING: SS-A00147, RELEASE 12

DRAWING NUMBER : VL70-000140A, VL70-000145

DIMENSIONS :	FULL SCALE	MODEL SCALE
Length (X_o=1520 to X_o=1613), In.	93.00	1.395
Max Width , In.	262.00	3.930
Max Depth (X_o = 1520), In.	23.00	0.345
Fineness Ratio		
Area - Ft^2		
Max. Cross-Sectional		
Planform	150.525	0.0339
Wetted		
Base	41.84722	0.0010

TABLE III. - MODEL DIMENSIONAL DATA - Continued.

MODEL COMPONENT : OMS POD - M_{16}

GENERAL DESCRIPTION : Configuration 140C orbiter OMS pod - short pod.

MODEL SCALE: 0.015

DRAWING NUMBER : VL70-008401, VL70-008410

DIMENSIONS :

	FULL SCALE	MODEL SCALE
Length (OMS Fwd Sta X_o=1310.5), In.	258.50	3.878
Max Width (@ X_o = 1511), In.	136.8	2.052
Max Depth (@ X_o = 1511), In.	74.70	1.121
Fineness Ratio	2.484	2.484
Area - Ft^2		
Max. Cross-Sectional	58.865	0.0132
Planform		
Wetted		
Base		

TABLE III. - MODEL DIMENSIONAL DATA - Continued.

MODEL COMPONENT: RUDDER - R_5

GENERAL DESCRIPTION: 2A, 3, 3A and 140A/B Configurations

MODEL SCALE: 0.015

DRAWING NUMBER: VL70-000146A, VL70-000095, VL70-000139.

DIMENSIONS:	FULL-SCALE	MODEL SCALE
*Area- Ft^2	100.15	0.0225
Span (equivalent) - In	201.0	3.015
Inb'd equivalent chord - In.	91.585	1.3738
Outb'd equivalent chord - In.	50.833	0.7625
Ratio movable surface chord/ total surface chord		
At Inb'd equiv. chord	0.400	0.400
At Outb'd equiv. chord	0.400	0.400
Sweep Back Angles, degrees		
Leading Edge	34.83	34.83
Trailing Edge	26.25	26.25
Hingeline	34.83	34.83
* Area Moment (Product of area & $\bar{c}$)-Ft^3	610.92	0.002
*Mean Aerodynamic Chord, In.	73.2	1.098

TABLE III. - MODEL DIMENSIONAL DATA - Continued.

MODEL COMPONENT: VERTICAL - V_8

GENERAL DESCRIPTION: Configuration 140A/B Orbiter Vertical Tail

MODEL SCALE: 0.015 MODEL DRAWING: SS-A00148, RELEASE 6

DRAWING NUMBER: VL70-000146A

DIMENSIONS:

	FULL SCALE	MODEL SCALE
TOTAL DATA		
Area (Theo) - Ft^2		
Planform	413.253	0.093
Span (Theo) - In.	315.720	4.736
Aspect Ratio	1.675	1.675
Rate of Taper	0.507	0.507
Taper Ratio	0.404	0.404
Sweep-Back Angles, Degrees.		
Leading Edge	45.000	45.000
* Trailing Edge	26.2	26.2
0.25 Element Line	41.130	41.130
Chords:		
Root (Theo) WP	268.500	4.028
Tip (Theo) WP	108.470	1.627
MAC	199.808	2.997
Fus. Sta. of .25 MAC	1463.50	21.953
W.P. of .25 MAC	635.522	9.533
B.L. of .25 MAC	0.00	0.00
Airfoil Section		
Leading Wedge Angle - Deg.	10.00	10.00
Trailing Wedge Angle - Deg.	14.920	14.920
Leading Edge Radius	2.00	0.030
Void Area	13.17	0.003
Blanketed Area	0.00	0.00

TABLE III.-MODEL DIMENSIONAL DATA--CONCLUDED.

MODEL COMPONENT: WING-W_{116}

GENERAL DESCRIPTION: Configuration 4

NOTE: Identical to W_{114} except airfoil thickness. Dihedral angle is along trailing edge of wing.

MODEL SCALE: 0.015

TEST NO.

DWG. NO. VL70-000140A, -000200

DIMENSIONS:	FULL-SCALE	MODEL SCALE
TOTAL DATA		
Area (Theo.) Ft^2		
Planform	2690.00	0.605
Span (Theo In.	936.68	14.050
Aspect Ratio	2.265	2.265
Rate of Taper	1.177	1.177
Taper Ratio	0.200	0.200
Dihedral Angle, degrees	3.500	3.500
Incidence Angle, degrees	0.500	0.500
Aerodynamic Twist, degrees	+ 3.000	+ 3.000
Sweep Back Angles, degrees		
Leading Edge	45.000	45.000
Trailing Edge	- 10.056	- 10.056
0.25 Element Line	35.209	35.209
Chords:		
Root (Theo) B.P.0.0.	689.24	10.339
Tip, (Theo) B.P.	137.85	2.068
MAC	474.81	7.122
*Fus. Sta. of .25 MAC	1136.83	17.052
* W.P. of .25 MAC	290.58	4.359
* B.L. of .25 MAC	182.13	2.732
EXPOSED DATA		
* Area (Theo) Ft^2	1751.50	0.394
* Span, (Theo) In. BP108	720.68	10.810
* Aspect Ratio	2.059	2.059
Taper Ratio	0.245	0.245
Chords		
* Root BP108	562.09	8.431
Tip 1.00 $\frac{b}{2}$	137.85	2.068
* MAC	392.83	5.892
* Fus. Sta. of .25 MAC	1185.98	17.790
* W.P. of .25 MAC	294.30	4.415
* B.L. of .25 MAC	251.77	3.777
Airfoil Section (Rockwell Mod NASA) XXXX-64		
Root $\frac{b}{2}$ =	0.113	0.113
Tip $\frac{b}{2}$ =	0.12	0.12
Data for (1) of (2) Sides		
Leading Edge Cuff		
*Planform Area Ft^2	113.18	0.025
* Leading Edge Intersects Fus M. L. @ Sta	500.0	7.50
* Leading Edge Intersects Wing @ Sta	1024.00	15.36

ORIGINAL PAGE IS OF POOR QUALITY

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

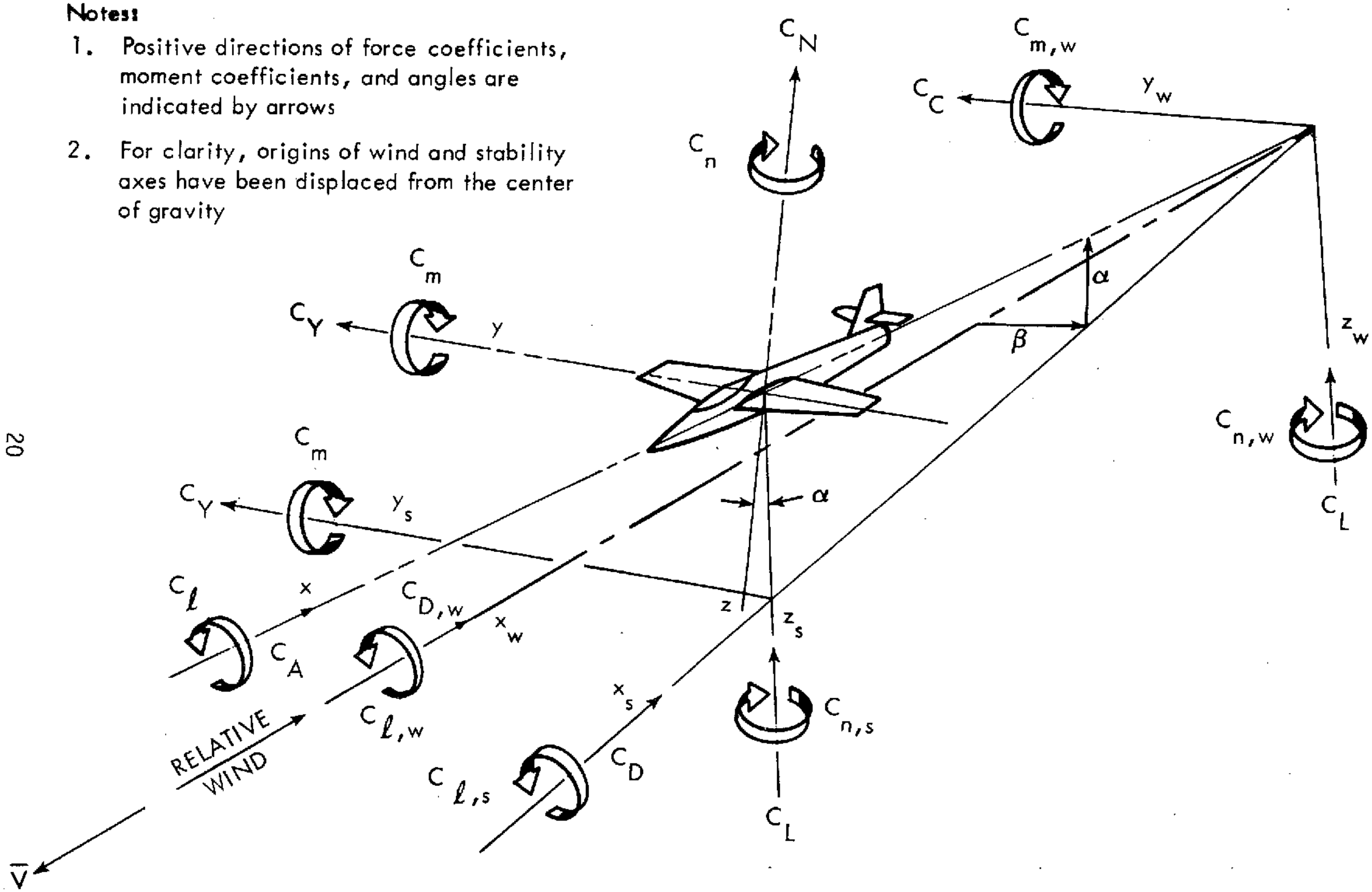

Figure 1. Axis Systems

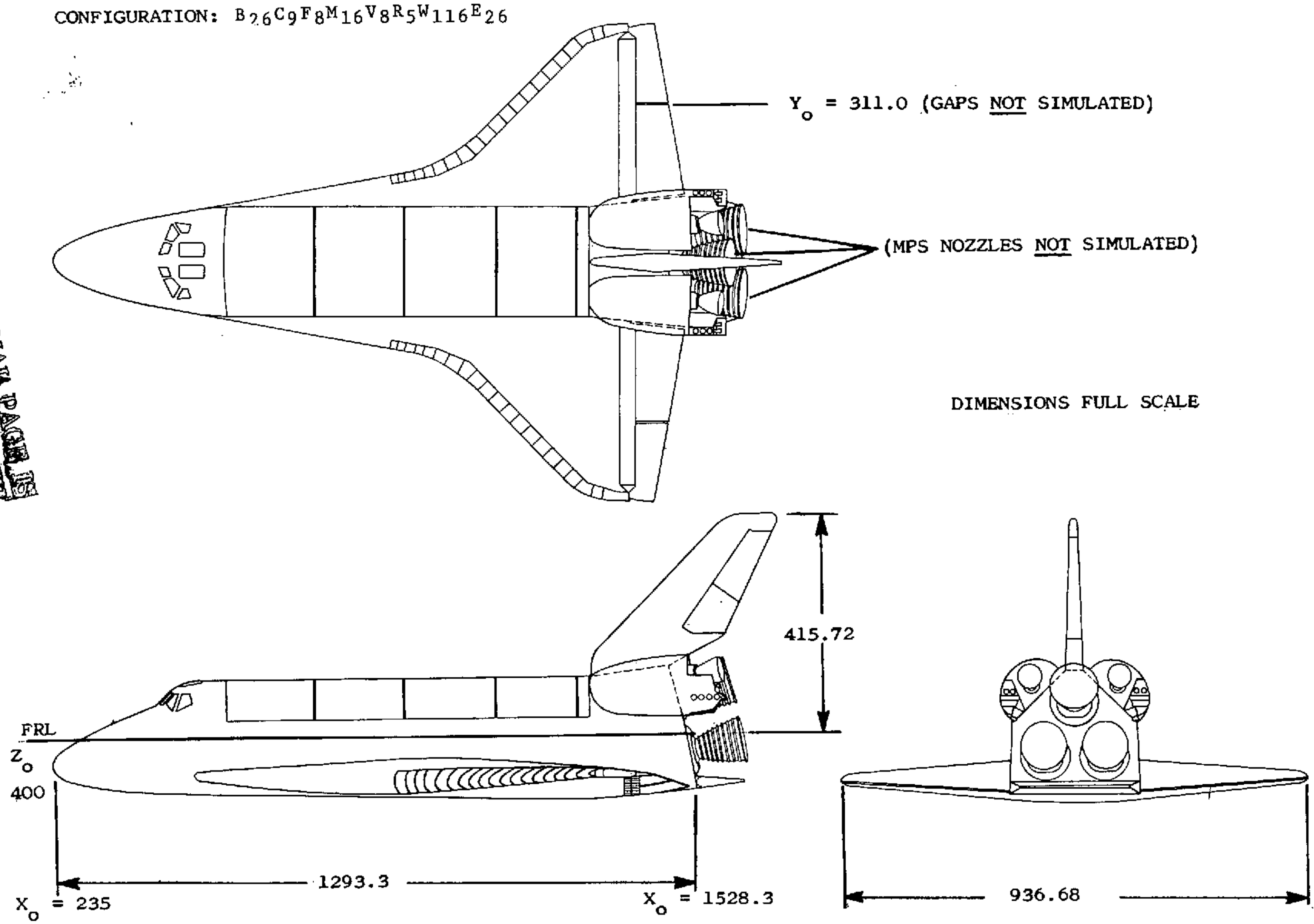

Figure 2. - General Orbiter Configuration.