N69-31783

NASA CR-96008

AIRCRAFT STABILITY AND CONTROL DATA

By Gary L. Teper

April 1969

Prepared under Contract No. NAS 2-4478 by

Systems Technology, Inc.
Hawthorne, California

for

Ames Research Center
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FOREWORD

This report was prepared under Contract NAS2-4478 between Systems Technology, Inc., Hawthorne, California and the National Aeronautics and Space Administration. The NASA project monitor was L. W. Taylor. The STI project engineer was Gary L. Teper.

The author gratefully acknowledges the aid of the STI staff in collecting, interpreting, and organizing the data. The author also wishes to acknowledge the fine work of the STI publications department in the preparation of this report.

Preceding page blank

ABSTRACT

Data of interest to handling qualities investigators is presented for various current aircraft. Included are those required to obtain transfer functions for the aircraft's response to control inputs. Where possible, an analytical description of the aircraft's stability augmentor is given, and also the complete flight envelope of each aircraft is covered for its most common configuration and loading. Computed transfer functions for various flight conditions are included.

CONTENTS

		Page
I.	INTRODUCTION	1
II.	A-7A	3
III.	A-4D	27
IV.	F-106B	49
V.	T-38	57
VI.	F-5A	65
VII.	F-104	73
VIII.	F-105B	81
IX.	B-58	91
X.	NAVION	99
XI.	DC-8	105
APPENDIX A.	AXIS SYSTEMS, SYMBOLS, AND DERIVATIVE DEFINITIONS	A-1
APPENDIX B.	TRANSFORMATION OF NON-DIMENSIONAL STABILITY AXIS DERIVATIVES TO BODY AXIS	B-1
APPENDIX C.	EQUATIONS OF MOTION, TRANSFER FUNCTIONS, AND COUPLING NUMERATORS	C-1

SECTION I

INTRODUCTION

The purpose of this document is to provide handling qualities investigators with readily usable data on various current aircraft. Included are those data required to obtain transfer functions relating the aircraft's response to control inputs. An analytical description of the aircraft's stability augmentor is also given.

For those aircraft for which complete information was available, the following summarizes the contents and presentation:

1. A general description is given, including:
    a. Three-view drawing and reference geometry.
    b. Flight envelope.
    c. Nominal configuration (weight, inertias, and c.g. location).
    d. References.
    e. Basic data sources.
2. A block diagram of the augmentor showing feedbacks, gains, and scheduling.
3. Trim angle-of-attack and elevator versus Mach number and altitude.
4. Longitudinal and lateral nondimensional stability derivatives* versus Mach number and altitude for the trimmed nominal configuration.
5. Geometrical parameters, longitudinal and lateral dimensional derivatives, and longitudinal and lateral transfer functions for the nominal configuration at various flight conditions. These data are usually given for body-fixed centerline axes (body axes).

For the remaining aircraft, some portion of the above is presented as dictated by the limits of the available data.

*These are given for the axis system of the data source.

The intention has been to make this report completely self-consistent insofar as symbols, nomenclature, definitions, etc. The system used is described in three appendices. Appendix A covers axis systems, symbols and notation, and definitions of nondimensional and dimensional stability derivatives. Appendix B gives the axis system transformations for the derivatives. Appendix C includes the aircraft equations of motion and transfer functions used herein.

While complete coverage of each aircraft including only the "latest" and "best" data would be desirable, the major criterion used was that the data be immediately accessible to the author. This is why only isolated flight conditions are given for some aircraft, and also why, as those people more intimately familiar with each particular aircraft will recognize, the data presented may represent an early estimate in the design process and perhaps the "nominal configuration" is one which never left the drawing board. The data have been reviewed and, although not all those presented indicate unquestionable trends, those data known to be based on only early "guesstimates" or showing unreasonable trends have been deleted. As to how well the data can be expected to match the flying aircraft, it is assumed that those for whom this document is intended know well the difficulties of obtaining derivatives from flight test data. Every attempt has been made to insure reliable translation, interpretation, and transcription of the data from their source documents.

The manufacturers of the aircraft described herein can not be held accountable for the information presented, nor would they be bound to concur in any conclusions with respect to their aircraft which might be derived from its use.

SECTION II

A-7A

Figure II-1

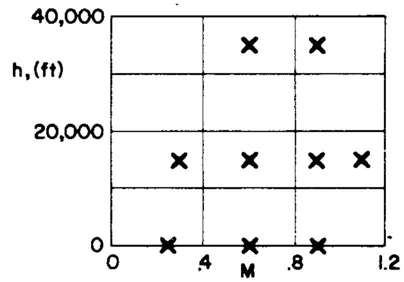
A-7A

NOMINAL CRUISE CONFIGURATION

Clean Airplane
60% Fuel
W = 21,889 lbs
C G at 30% MGC

I_x = 13,635 Slug ft^2	Body Ref. Axes	
I_y = 58,966 Slug ft^2		
I_z = 67,560 Slug ft^2		
I_{xz} = 2,933 Slug ft^2		

FLIGHT ENVELOPE



× *Transfer functions given for these flight conditions*

REFERENCE GEOMETRY

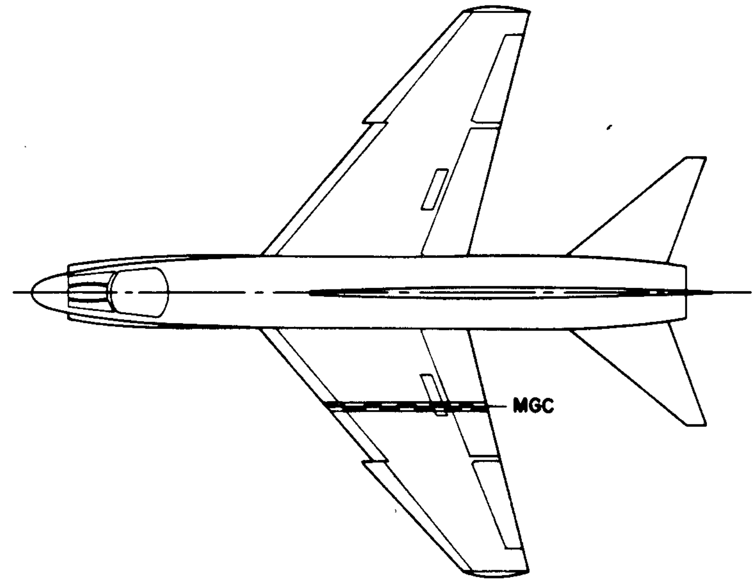
S = 375 ft^2
c = 10.8 ft
b = 38.7 ft

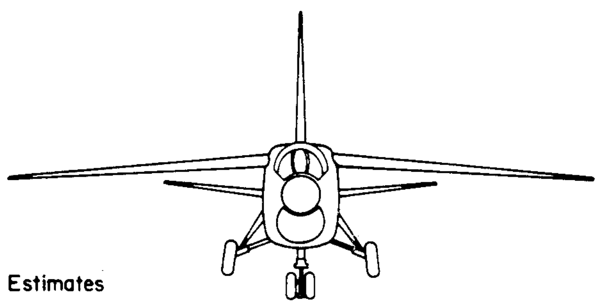
REFERENCES

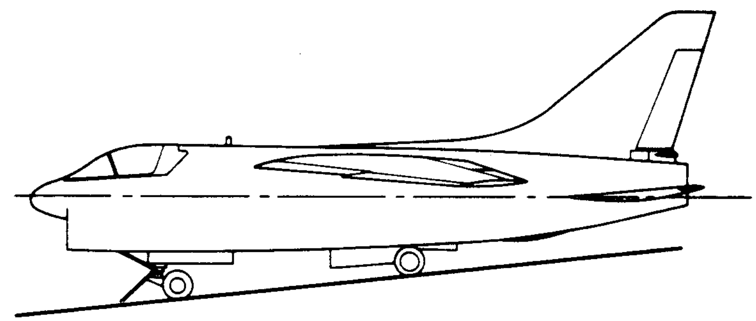
1) LTV Vought Aeronautics Div. Rept. No. 2-53310/5R-1981, "A-7A Aerodynamics Data Report", 21 May 1965 (U)

2) LTV Vought Aeronautics Div. Rept. No. 2-53310/5R-5121, Rev. I, "A-7A Estimated Flying Qualities", 20 August 1965 (C)

3) LTV Vought Aeronautics Div., "Updated A-7A Aircraft Lateral-Directional Cruise Device Configuration Data, 25 Augut 1967







BASIC DATA SOURCES

Wind Tunnel Test and Estimates
Some Lateral-Directional Derivatives
Adjusted After Flight Test

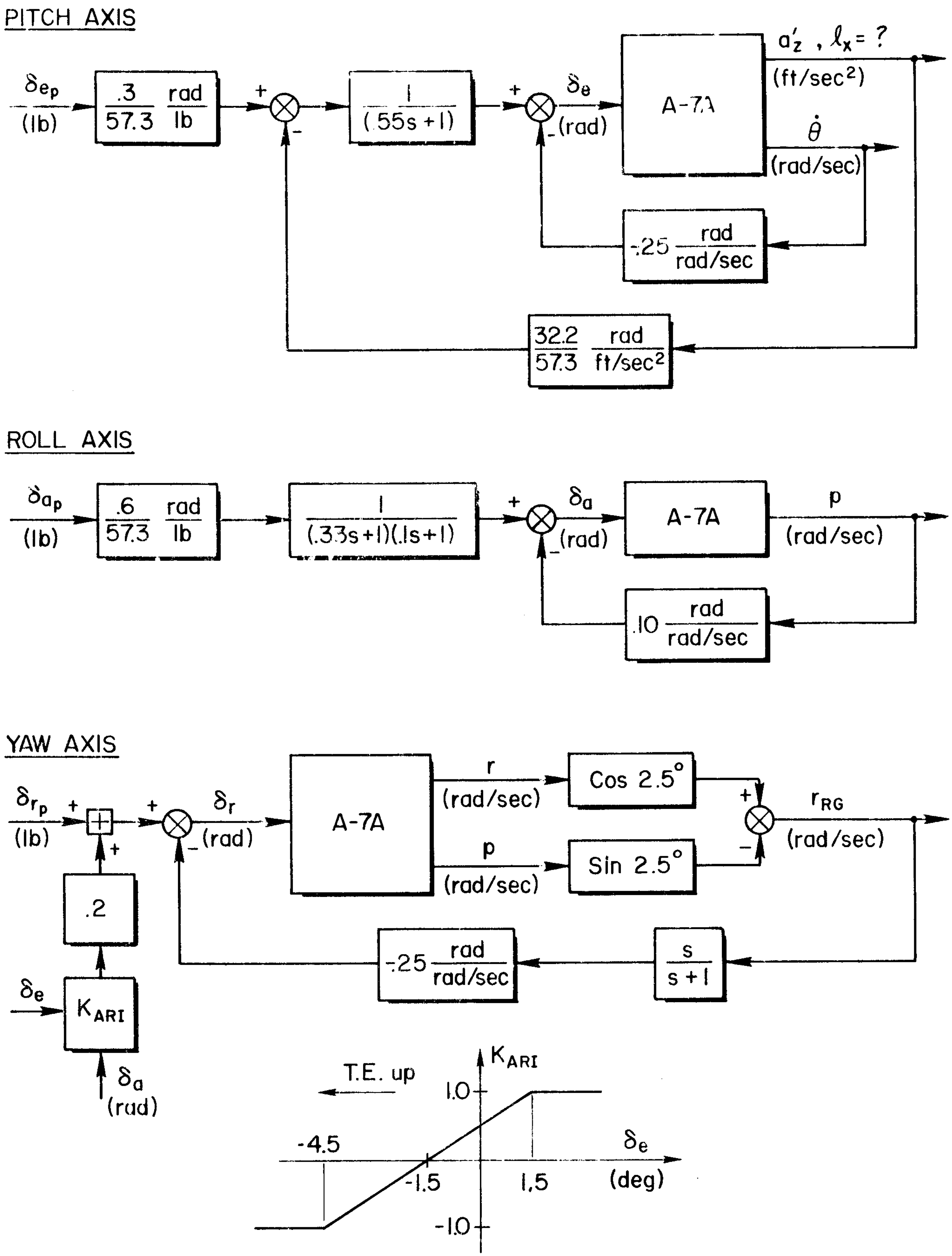
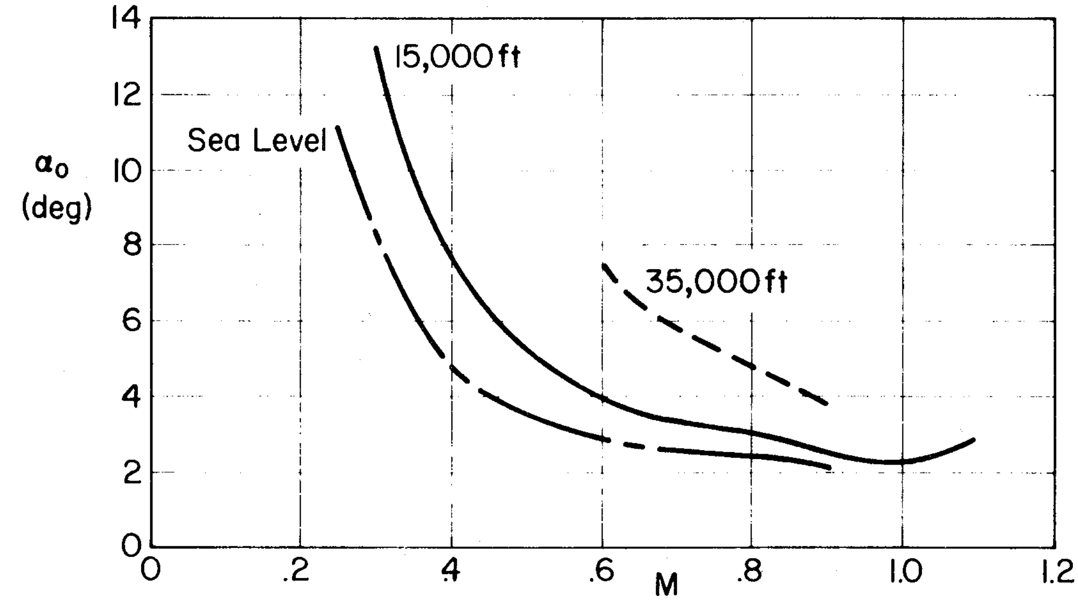
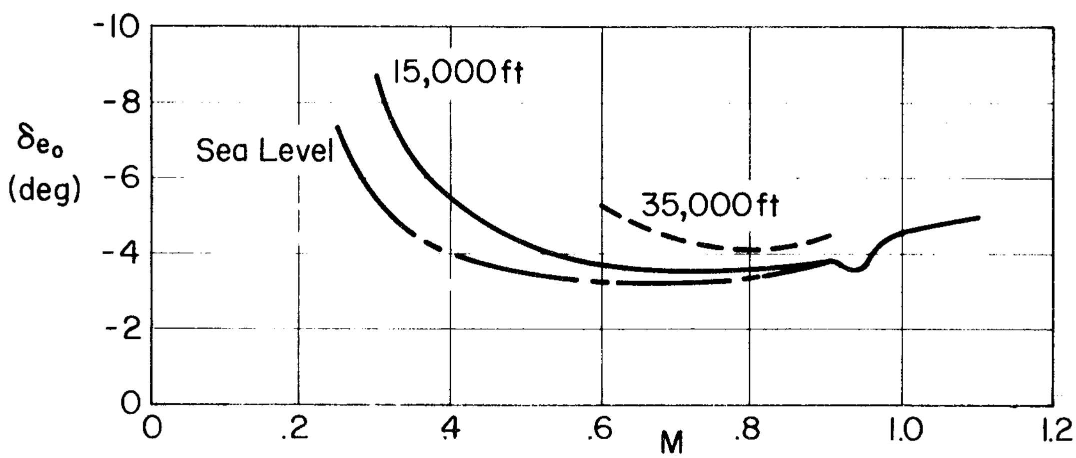
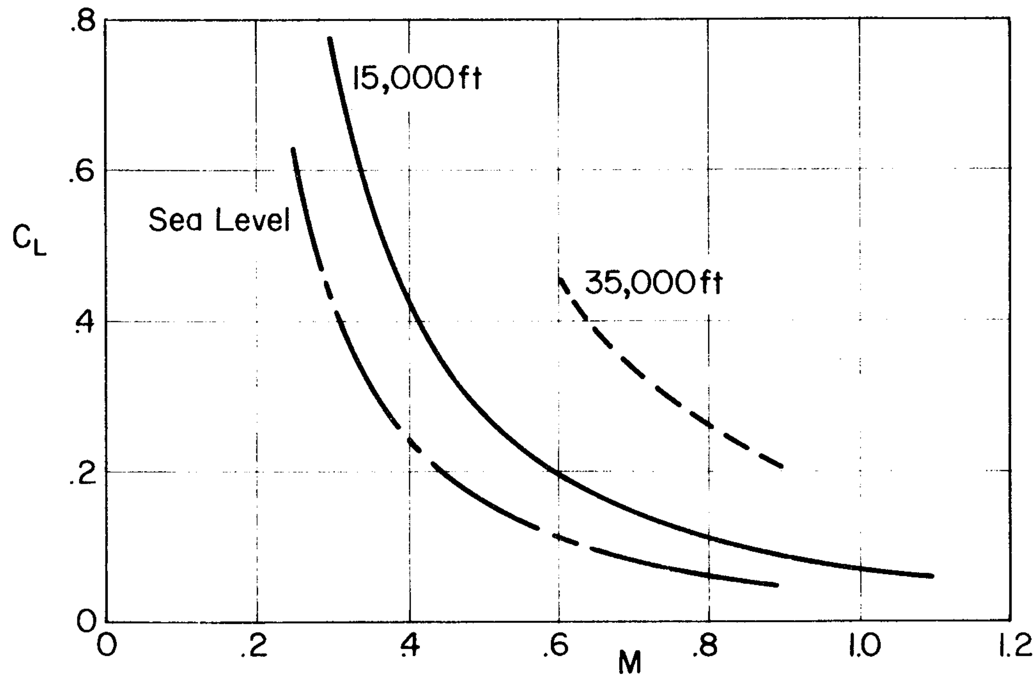


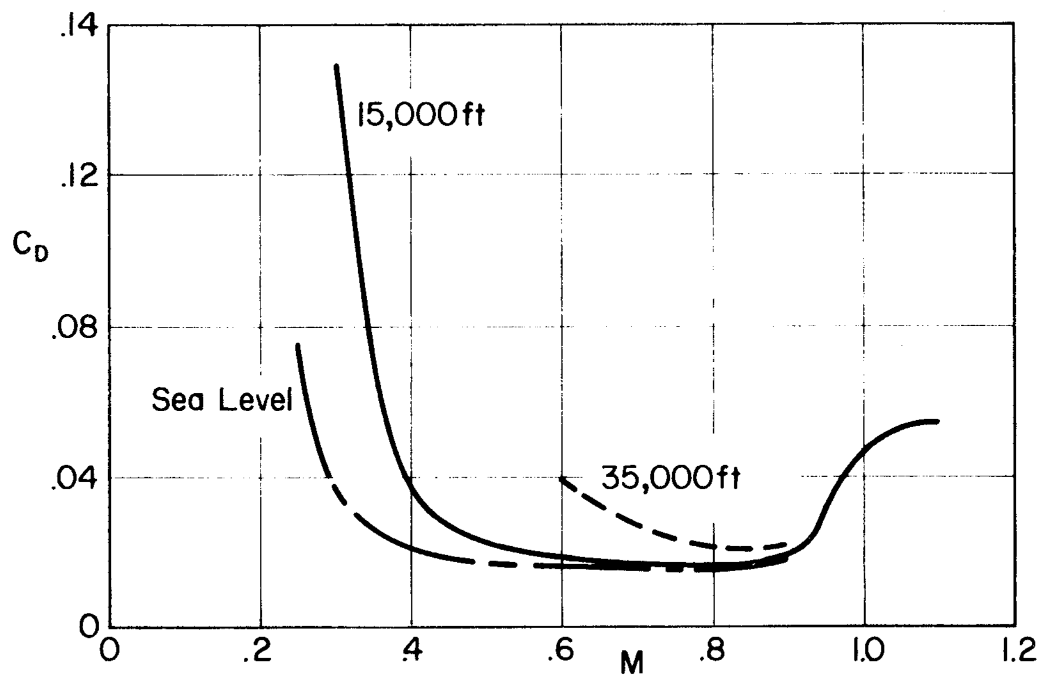
Figure II-2. A-7A Stability Augmentation System


14
12
10
8
6
4
2
0
α_o (deg)
15,000 ft
Sea Level
35,000 ft
0
.2
.4
.6
M
.8
1.0
1.2

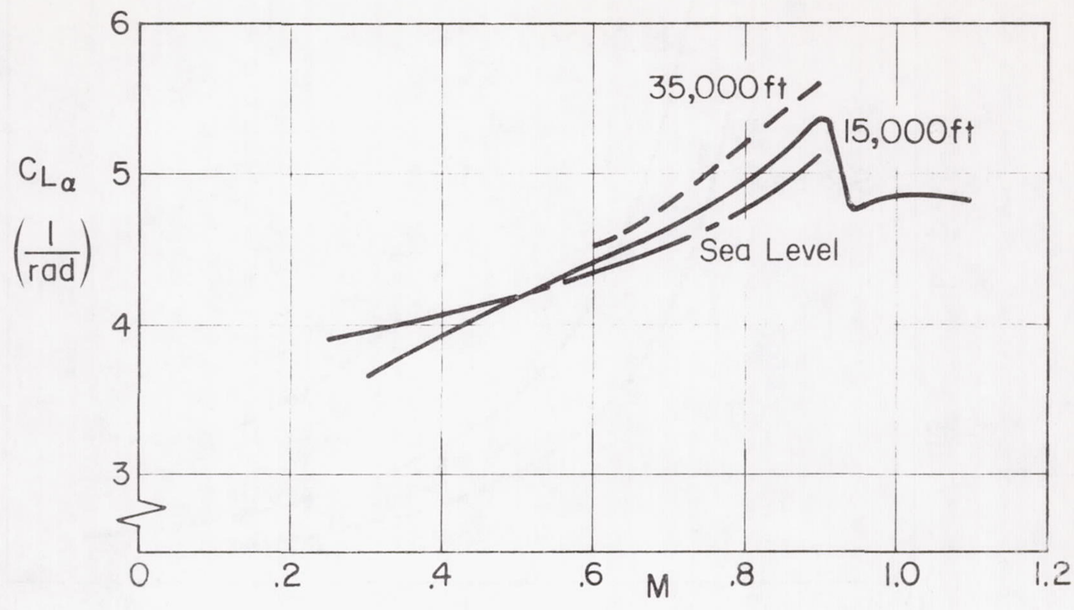

-10
-8
-6
-4
-2
0
δ_{e_o} (deg)
15,000 ft
Sea Level
35,000 ft
0
.2
.4
.6
M
.8
1.0
1.2

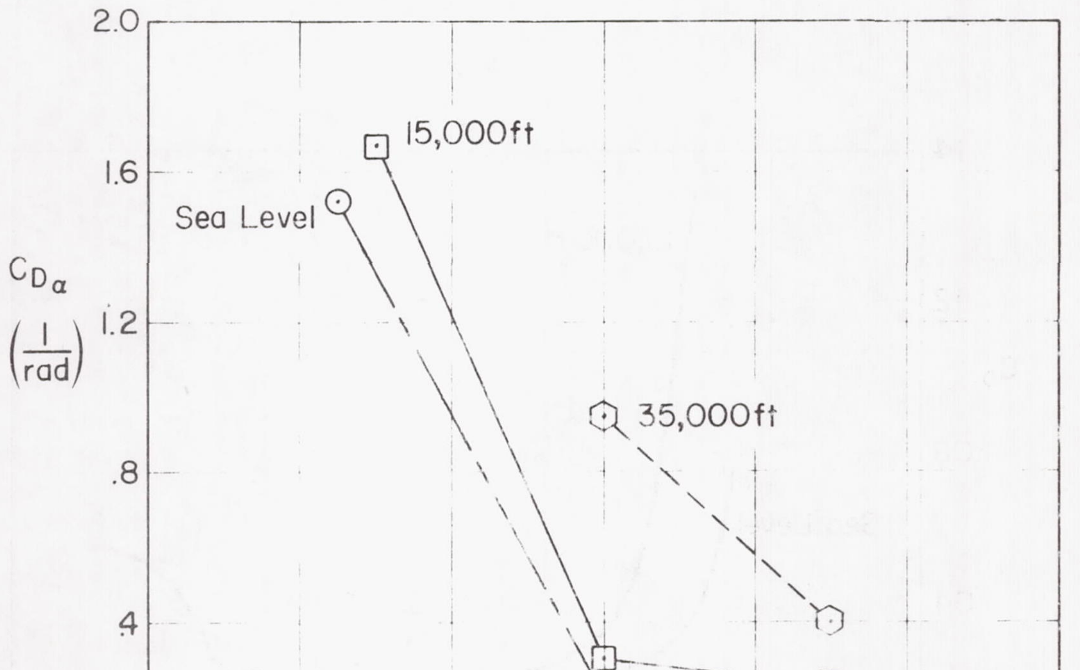


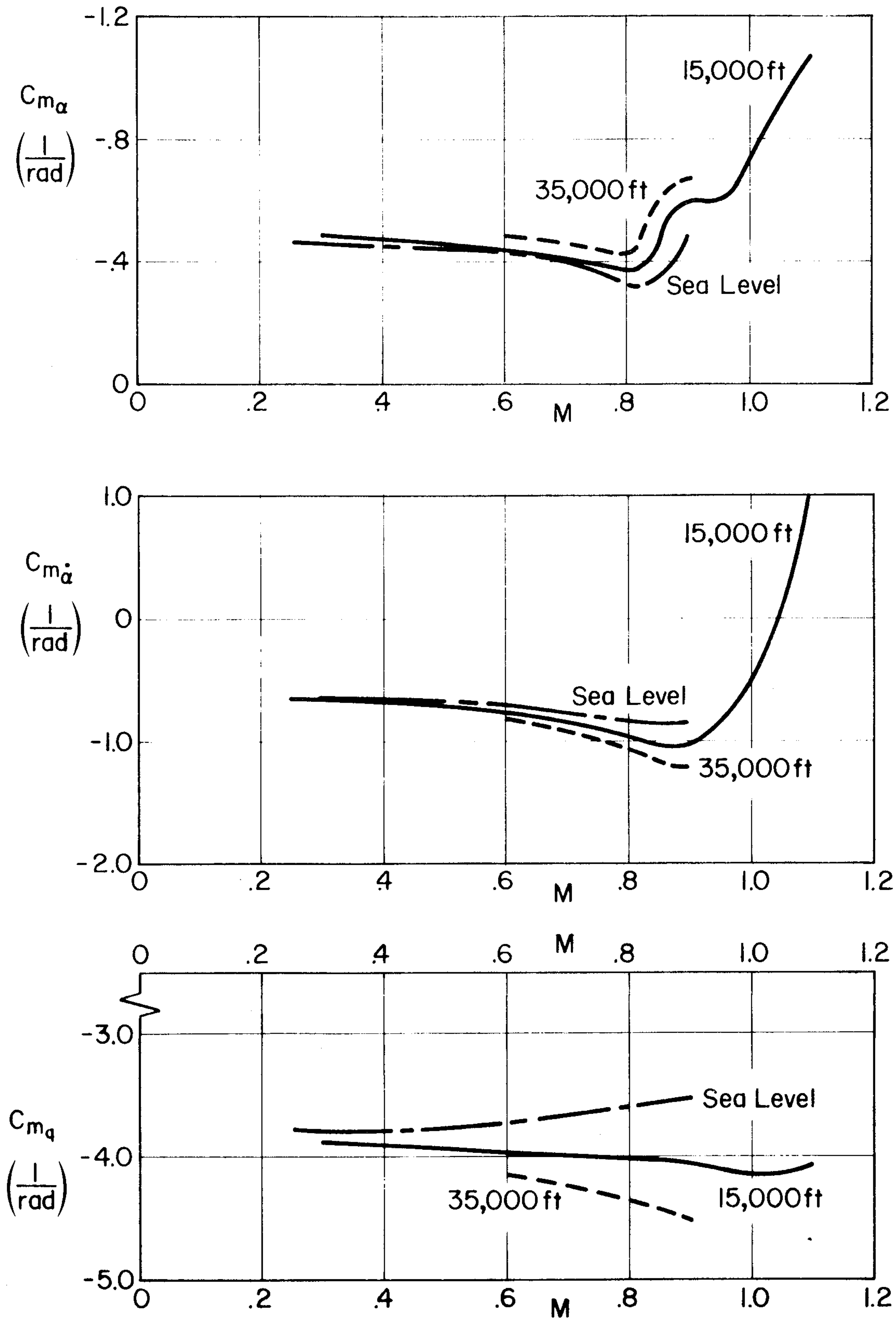
.8
.6
.4
.2
0
C_L
15,000 ft
Sea Level
35,000 ft
0
.2
.4
.6
.8
1.0
1.2
M



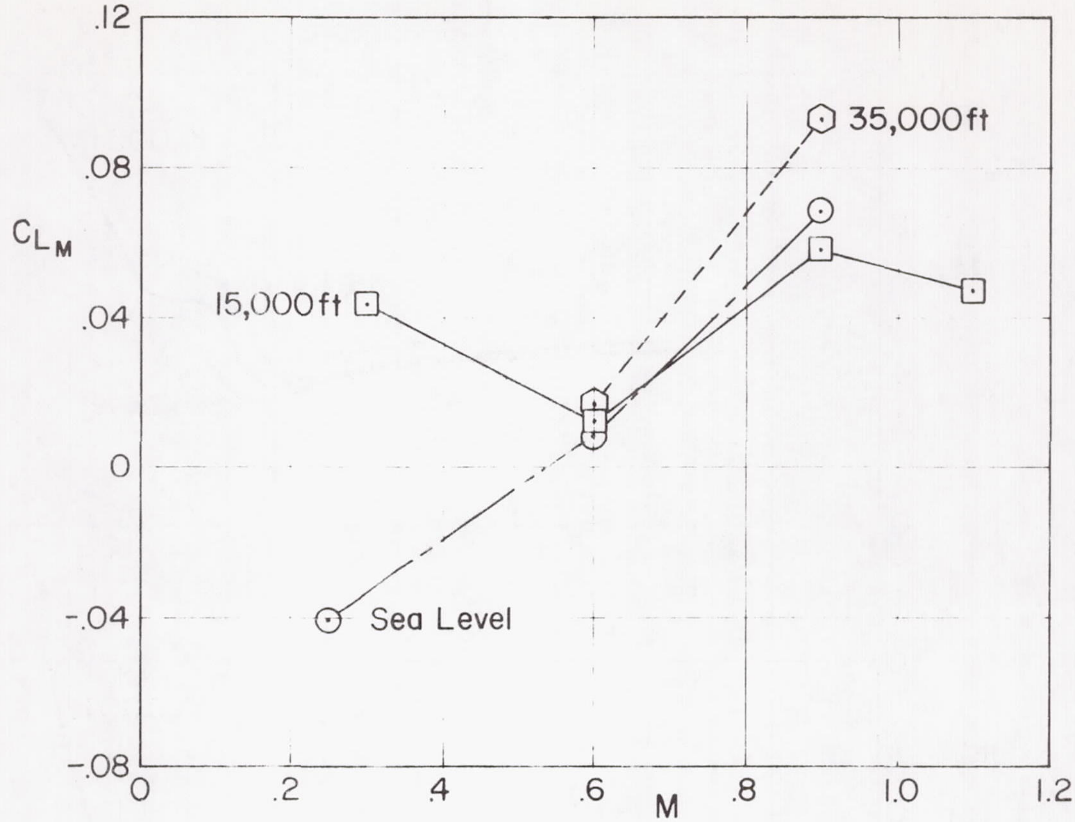
.14
.12
.08
.04
0
C_D
15,000 ft
Sea Level
35,000 ft
0
.2
.4
.6
.8
1.0
1.2
M

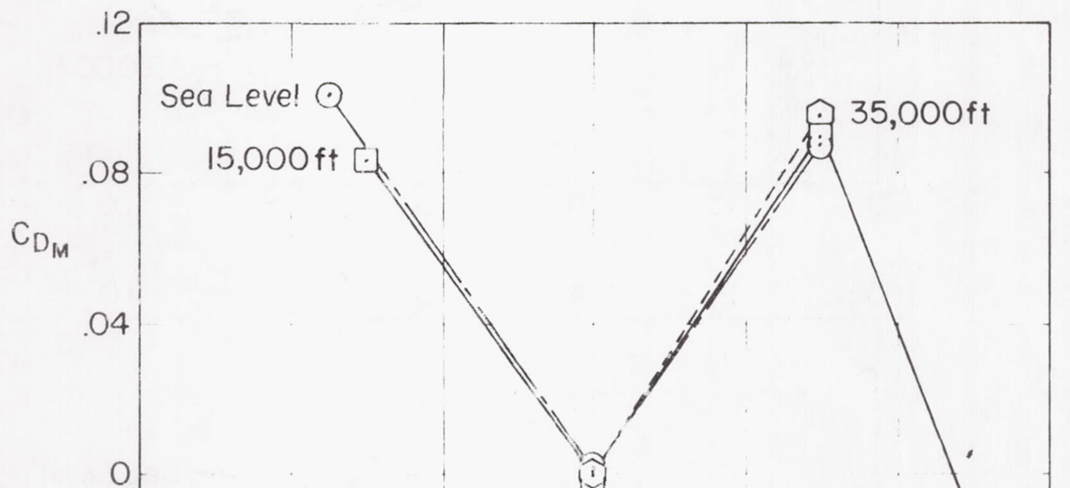

6
5
4
3
C_{L_α}
$\left(\frac{1}{rad}\right)$
35,000 ft
15,000 ft
Sea Level
0
.2
.4
.6
.8
1.0
1.2
M

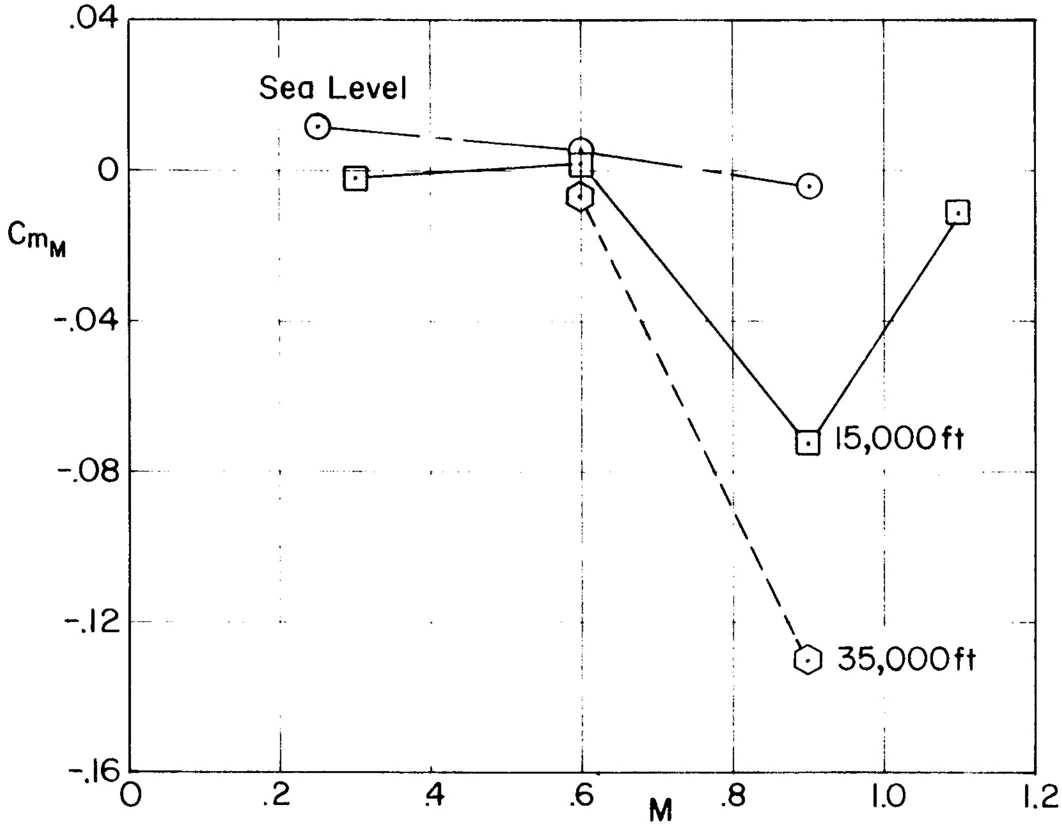

2.0
1.6
1.2
.8
.4
0
C_{D_α}
$\left(\frac{1}{rad}\right)$
15,000 ft
Sea Level
35,000 ft
0
.2
.4
.6
.8
1.0
1.2
M

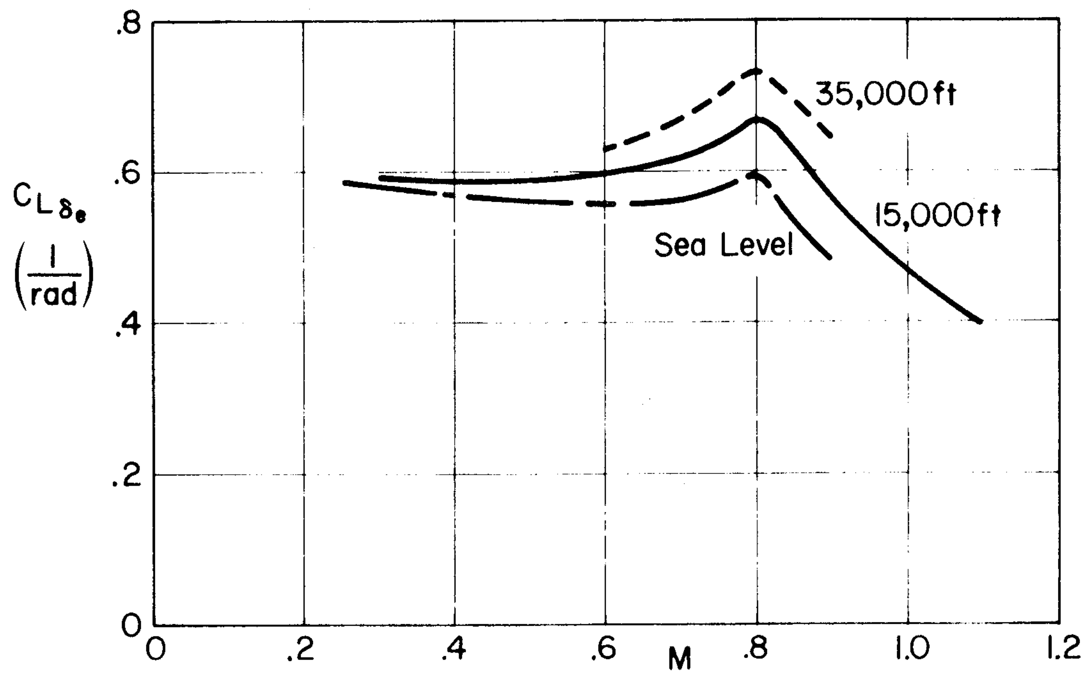


C_{m_α} $\left(\frac{1}{rad}\right)$
-1.2
-.8
-.4
0
15,000 ft
35,000 ft
Sea Level
0 .2 .4 .6 .8 1.0 1.2
M
$C_{m_{\dot\alpha}}$ $\left(\frac{1}{rad}\right)$
1.0
0
-1.0
-2.0
15,000 ft
Sea Level
35,000 ft
0 .2 .4 .6 .8 1.0 1.2
M
M
0 .2 .4 .6 .8 1.0 1.2
C_{m_q} $\left(\frac{1}{rad}\right)$
-3.0
-4.0
-5.0
Sea Level
35,000 ft
15,000 ft
0 .2 .4 .6 .8 1.0 1.2
M

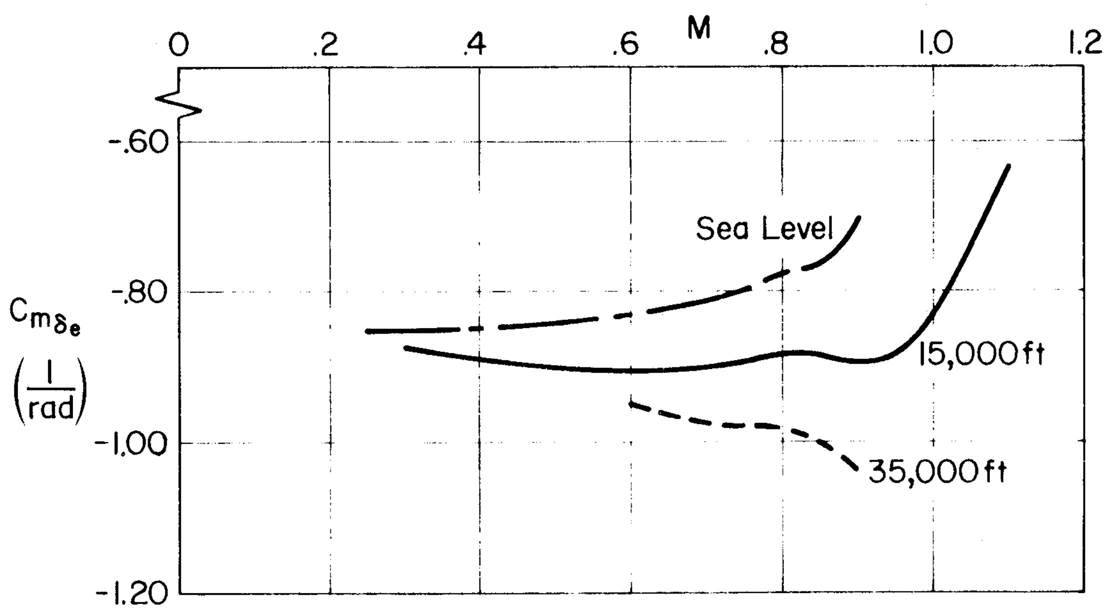

.12
.08
.04
0
-.04
-.08
C_{L_M}
35,000 ft
15,000 ft
Sea Level
0
.2
.4
.6
.8
1.0
1.2
M


.12
.08
.04
0
-.04
C_{D_M}
Sea Level
15,000 ft
35,000 ft
0
.2
.4
.6
.8
1.0
1.2
M

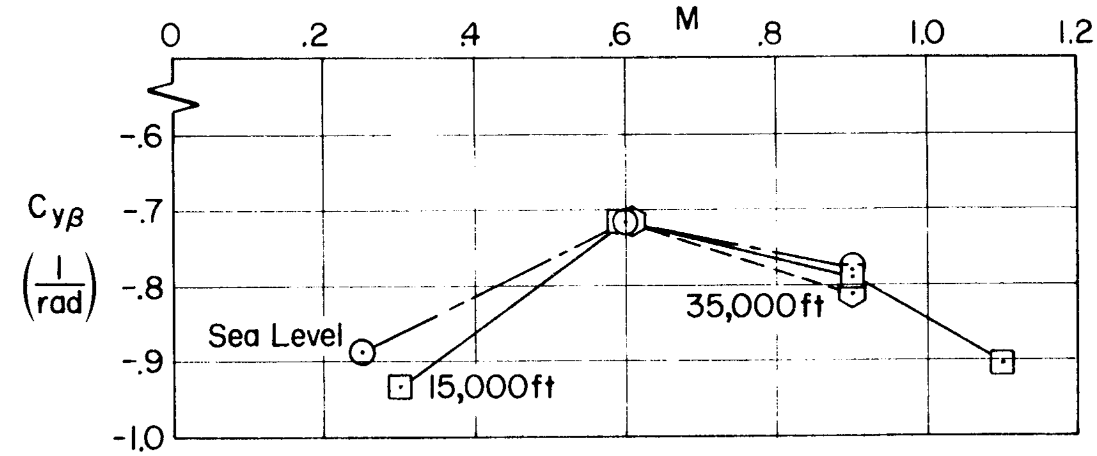

.04
Sea Level
0
Cm_M
-.04
-.08
-.12
-.16
15,000 ft
35,000 ft
0
.2
.4
.6
M
.8
1.0
1.2

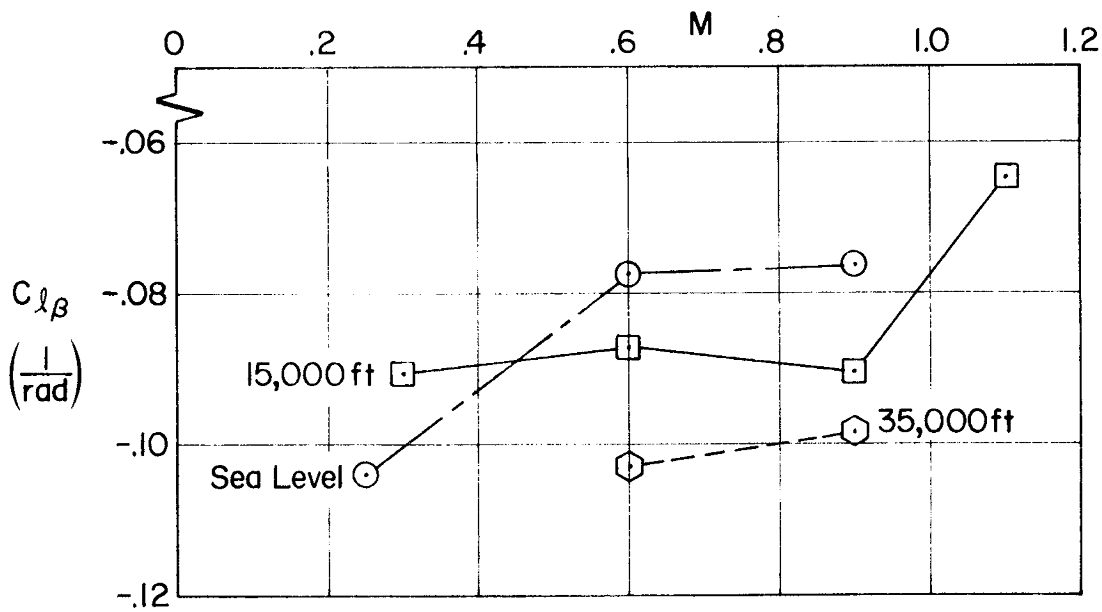


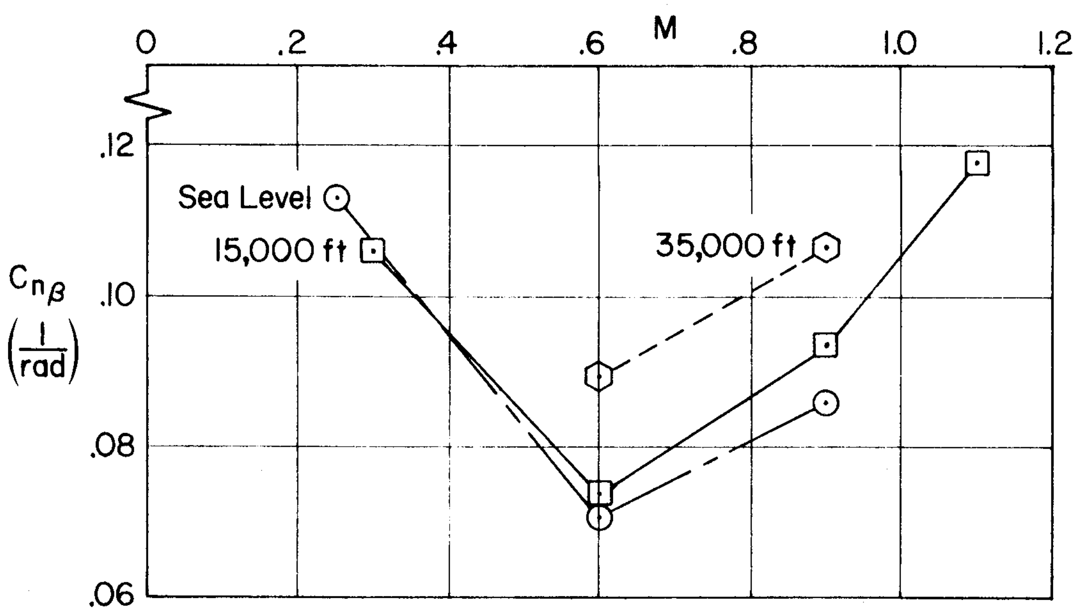
.8
.6
.4
.2
0
$C_{L\delta_e}$
$\left(\frac{1}{rad}\right)$
0
.2
.4
.6
M
.8
1.0
1.2
35,000 ft
15,000 ft
Sea Level

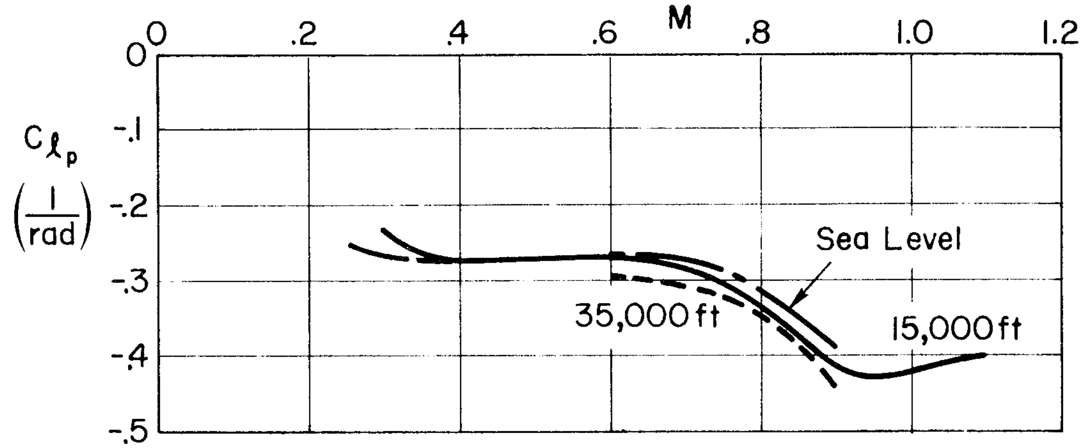


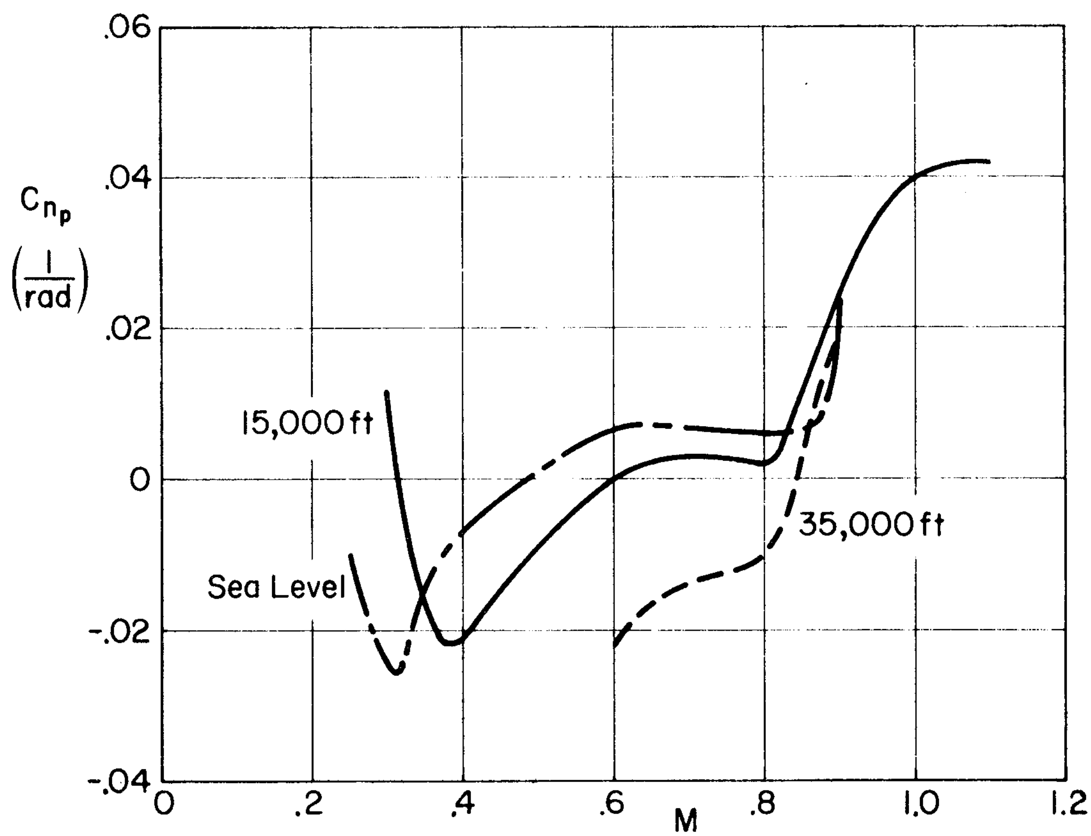
0
.2
.4
.6
M
.8
1.0
1.2
-.60
-.80
-1.00
-1.20
$C_{m\delta_e}$
$\left(\frac{1}{rad}\right)$
Sea Level
15,000 ft
35,000 ft

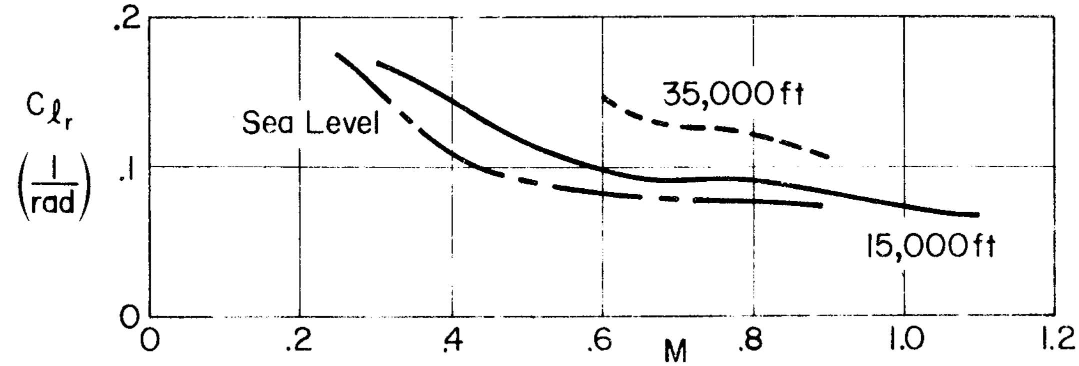

M
0
.2
.4
.6
.8
1.0
1.2
-.6
-.7
-.8
-.9
-1.0
$C_{y\beta}$
$\left(\frac{1}{rad}\right)$
Sea Level
15,000ft
35,000ft


M
0
.2
.4
.6
.8
1.0
1.2
-.06
-.08
-.10
-.12
$C_{\ell\beta}$
$\left(\frac{1}{rad}\right)$
15,000ft
35,000ft
Sea Level

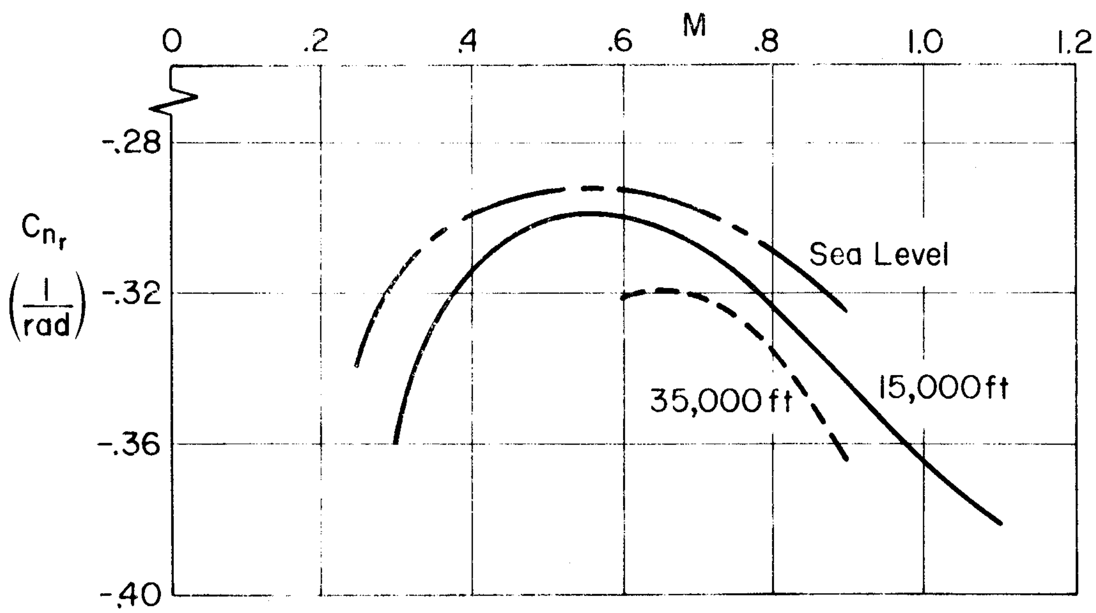

M
0
.2
.4
.6
.8
1.0
1.2
.12
.10
.08
.06
C_{n_β}
$\left(\frac{1}{rad}\right)$
Sea Level
15,000 ft
35,000 ft


M
0
.2
.4
.6
.8
1.0
1.2
0
-.1
-.2
-.3
-.4
-.5
C_{ℓ_p}
$\left(\frac{1}{rad}\right)$
Sea Level
35,000 ft
15,000 ft

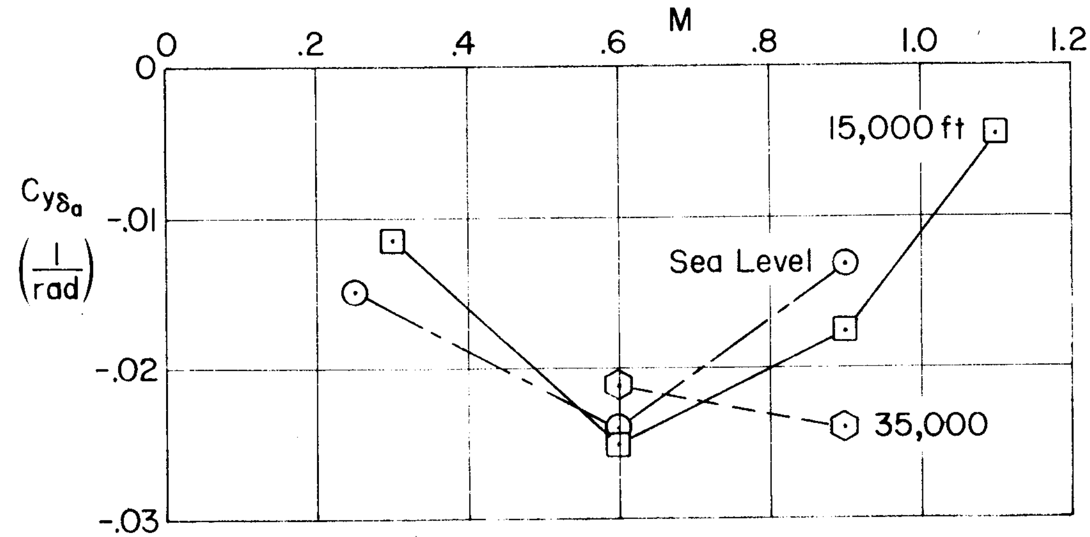

.06
.04
.02
0
-.02
-.04
C_{n_p}
$\left(\frac{1}{rad}\right)$
15,000 ft
Sea Level
35,000 ft
0
.2
.4
.6
.8
1.0
1.2
M



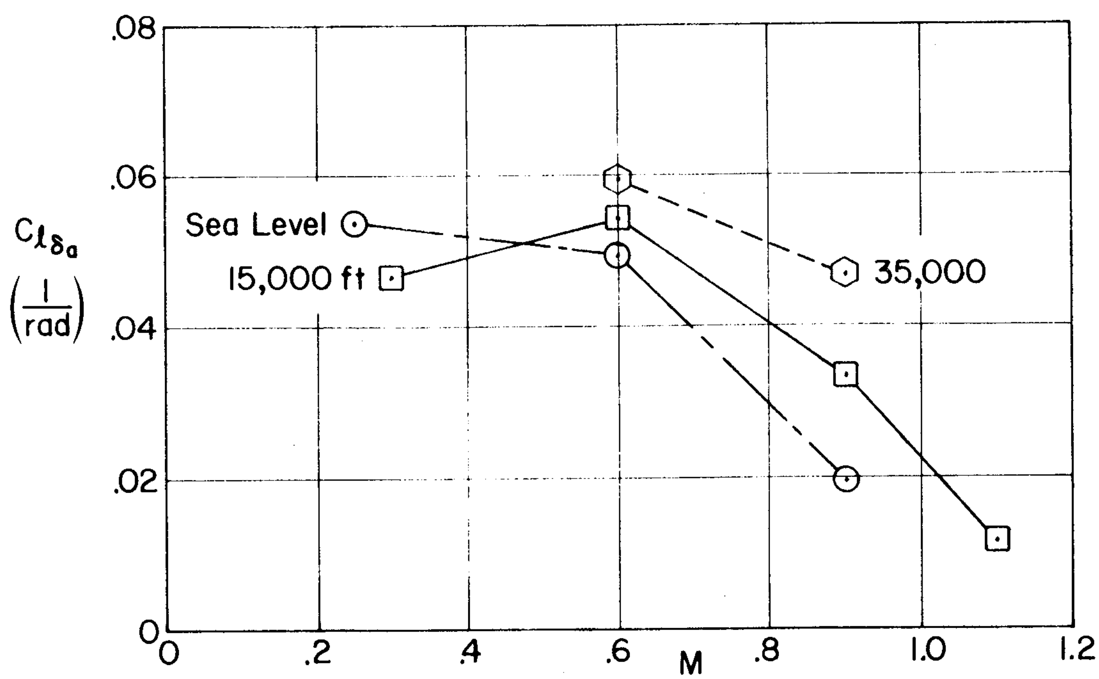
C_{ℓ_r}
$\left(\frac{1}{rad}\right)$
.2
.1
0
0
.2
.4
.6
M
.8
1.0
1.2
Sea Level
35,000 ft
15,000 ft

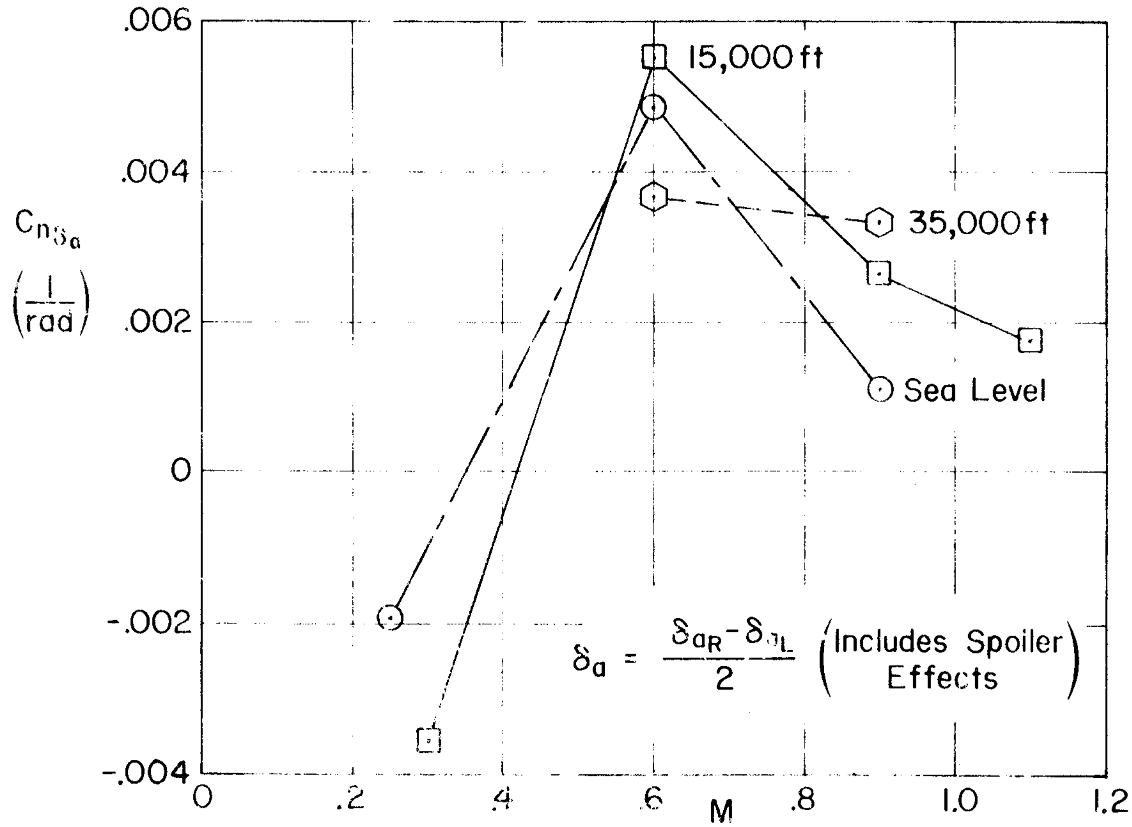


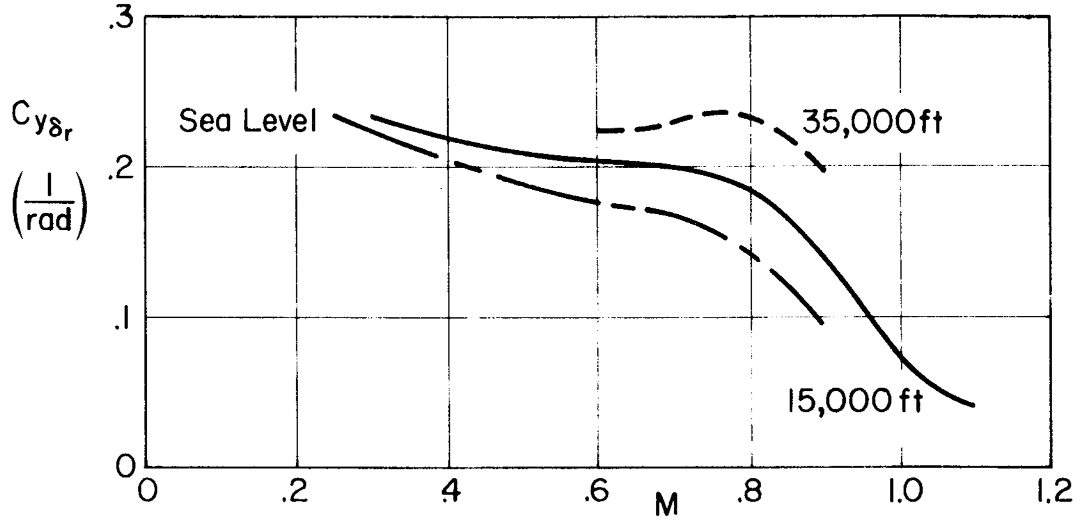
M
0
.2
.4
.6
.8
1.0
1.2
C_{n_r}
$\left(\frac{1}{rad}\right)$
-.28
-.32
-.36
-.40
Sea Level
35,000 ft
15,000 ft



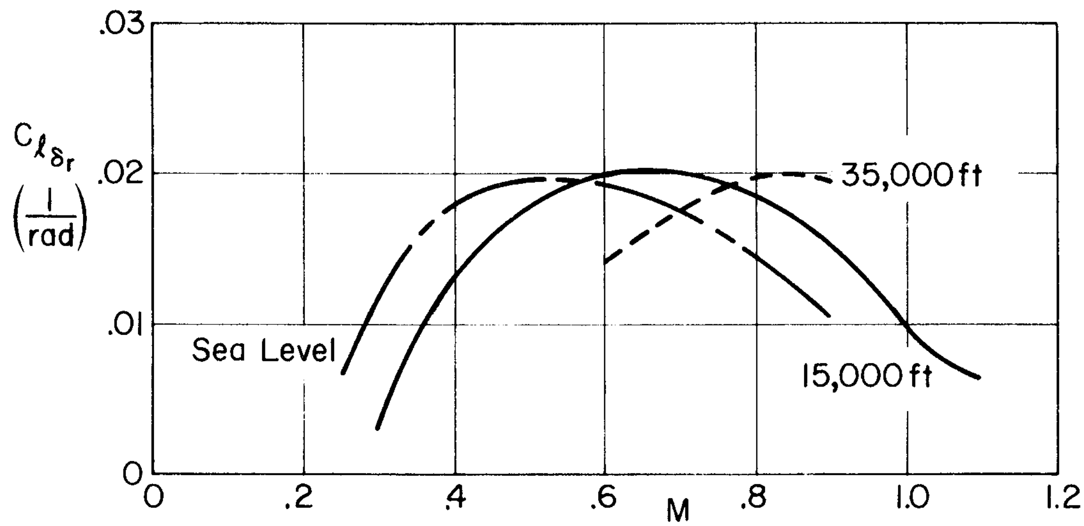
$$\delta_a = \frac{\delta_{a_R} - \delta_{a_L}}{2}$$ (Includes Spoiler Effects)




.006
.004
.002
0
-.002
-.004
$C_{n_{\delta_a}}$
$\left(\frac{1}{rad}\right)$
15,000 ft
35,000 ft
Sea Level
$\delta_a = \frac{\delta_{a_R} - \delta_{a_L}}{2}$ (Includes Spoiler Effects)
0
.2
.4
.6
.8
1.0
1.2
M



$C_{y_{\delta_r}}$
$\left(\frac{1}{rad}\right)$
.3
.2
.1
0
0
.2
.4
.6
M
.8
1.0
1.2
Sea Level
35,000 ft
15,000 ft



$C_{\ell_{\delta_r}}$
$\left(\frac{1}{rad}\right)$
.03
.02
.01
0
0
.2
.4
.6
M
.8
1.0
1.2
Sea Level
35,000 ft
15,000 ft

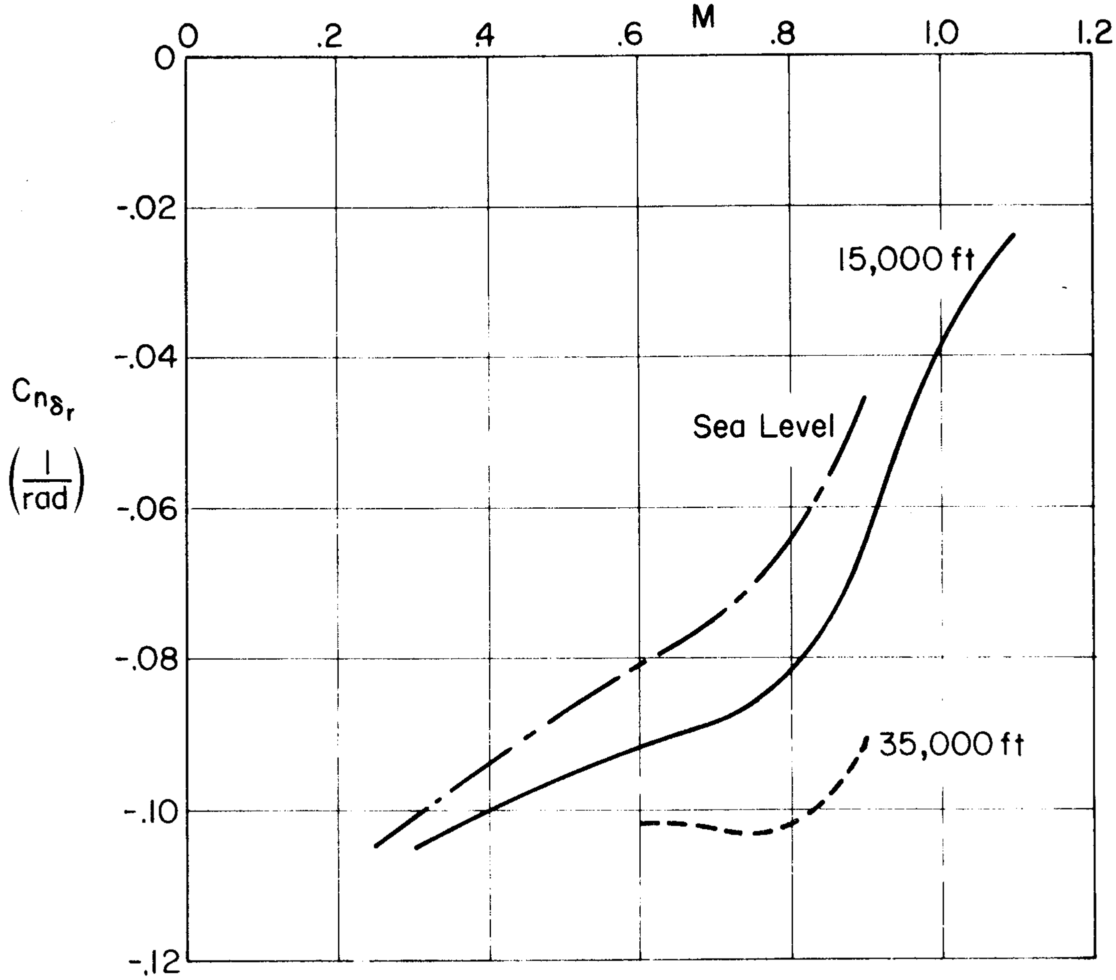

M
0
.2
.4
.6
.8
1.0
1.2
0
-.02
-.04
-.06
-.08
-.10
-.12
$C_{n_{\delta_r}}$
$\left(\frac{1}{rad}\right)$
15,000 ft
Sea Level
35,000 ft

TABLE II-A

GEOMETRICAL PARAMETERS FOR THE A-7A

Note: Data for body-fixed centerline axis, clean flexible airplane

$S = 375\ ft^2$, $b = 38.7$ ft, $c = 10.8$ ft

$W = 21{,}889$ lb, $m = 680$ slugs, c.g. at 30 percent MGC

$I_x = 13{,}635\ slug\text{-}ft^2$, $I_y = 58{,}966\ slug\text{-}ft^2$, $I_z = 67{,}560\ slug\text{-}ft^2$, $I_{xz} = 2{,}933\ slug\text{-}ft^2$

	FLIGHT CONDITION								
	1	2	3	4	5	6	7	8	9
h (ft)	0	0	0	15,000	15,000	15,000	15,000	35,000	35,000
M (–)	0.25	0.6	0.9	0.3	0.6	0.9	1.1	0.6	0.9
a (ft/sec)	1,117	1,117	1,117	1,058	1,058	1,058	1,058	973.3	973.3
ρ (slugs/ft^3)	0.002378	0.002378	0.002378	0.001496	0.001496	0.001496	0.001496	0.000736	0.000736
V_{T_o} (ft/sec)	279	670	1,005	317	635	952	1,164	584	876
$\overline{q} = \rho V_{T_o}^2/2$ (lb/ft^2)	91.5	534	1,200	75.3	301	677	1,010	126	283
α_o (deg)	11.2	2.9	2.1	13.3	4.0	2.5	2.9	7.5	3.8
U_o (ft/sec)	274	669	1,004	309	633	951	1,163	579	874
W_o (ft/sec)	54.2	33.9	36.8	72.9	44.3	41.5	58.9	76.2	58.1
δ_{e_o} (deg)	−7.4	−3.35	−3.8	−8.8	−3.8	−3.85	−4.95	−5.4	−4.4
γ_o (deg)	0	0	0	0	0	0	0	0	0

TABLE II-B

LONGITUDINAL DIMENSIONAL DERIVATIVES FOR THE A-7A

Note: Data are for body-fixed centerline axis, clean flexible airplane

	FLIGHT CONDITION								
	1	2	3	4	5	6	7	8	9
h	0	0	0	15,000	15,000	15,000	15,000	35,000	35,000
M	0.25	0.6	0.9	0.3	0.6	0.9	1.1	0.6	0.9
X_w	−0.0145	−0.0568	−0.0284	0.00464	0.0537	0.0339	0.0386	0.0146	0.0316
X_u	0.0162	−0.0123	−0.0732	0.00501	−0.00620	−0.0440	−0.0431	0.00337	−0.0193
X_{δ_e}	5.75	8.34	11.6	5.63	6.96	9.13	11.2	5.70	6.61
Z_w	−0.779	−1.92	−3.40	−0.545	−1.16	−2.12	−2.34	−0.554	−1.01
Z_u	−0.0814	−0.00244	0.0184	−0.0857	−0.0244	0.00279	0.0353	−0.0392	−0.0223
Z_{δ_e}	−29.0	−165	−318	−23.8	−99.6	−209	−220	−43.2	−99.4
M_w	−0.00982	−0.0232	−0.0402	−0.00777	−0.0143	−0.0292	−0.0639	−0.00711	−0.0150
$M_{\dot{w}}$	−0.000286	−0.000308	−0.000370	−0.000178	−0.000210	−0.000280	+0.000332	−0.000111	−0.000163
M_q	−0.466	−1.11	−1.57	−0.340	−0.696	−1.07	−1.31	−0.330	−0.539
M_u	0.00201	0.00137	0.00118	0.00183	0.00104	−0.00194	0.00245	0.000873	−0.00160
M_{δ_e}	−5.44	−30.6	−58.6	−4.52	−18.9	−41.7	−44.2	−8.19	−20.2

TABLE II-C

LATERAL DIMENSIONAL DERIVATIVES FOR THE A-7A

Note: Data are for body-fixed centerline axes, clean flexible airplane

	FLIGHT CONDITION								
	1	2	3	4	5	6	7	8	9
h	0	0	0	15,000	15,000	15,000	15,000	35,000	35,000
M	0.25	0.6	0.9	0.3	0.6	0.9	1.1	0.6	0.9
Y_v	−0.162	−0.314	−0.514	−0.122	−0.187	−0.310	−0.435	−0.0847	−0.145
$Y^*_{\delta_a}$	−0.00274	−0.0105	−0.00857	−0.00150	−0.00655	−0.00691	−0.00216	−0.00267	−0.00427
$Y^*_{\delta_r}$	0.0430	0.0769	0.0626	0.0307	0.0537	0.0550	0.0192	0.0267	0.0347
L'_β	−11.9	−44.8	−98.0	−8.79	−29.2	−66.0	−71.2	−14.9	−30.6
L'_p	−2.00	−4.46	−9.75	−1.38	−2.73	−6.19	−7.31	−1.40	−3.00
L'_r	1.18	1.15	1.38	0.857	0.868	0.843	0.859	0.599	0.563
L'_{δ_a}	5.34	28.4	25.2	3.75	17.6	24.1	12.5	7.96	14.2
L'_{δ_r}	2.22	11.4	13.2	1.82	7.27	11.2	7.27	3.09	6.55
N'_β	1.28	5.74	17.2	0.948	3.12	10.2	21.9	1.38	4.72
N'_p	−0.0870	−0.168	−0.319	−0.0310	−0.116	−0.207	−0.169	−0.0799	−0.112
N'_r	−0.369	−0.905	−1.54	−0.271	−0.541	−0.975	−1.33	−0.247	−0.455
N'_{δ_a}	0.402	2.08	1.56	0.280	1.37	1.64	1.04	0.652	1.01
N'_{δ_r}	−1.93	−8.61	−11.1	−1.56	−5.54	−8.80	−4.83	−2.54	−5.11

TABLE II-D

ELEVATOR LONGITUDINAL TRANSFER FUNCTION FACTORS FOR THE A-7A

Note: Data for body-fixed centerline axes, clean flexible airplane

		FLIGHT CONDITION								
		1	2	3	4	5	6	7	8	9
	h	0	0	0	15,000	15,000	15,000	15,000	35,000	35,000
	M	0.25	0.6	0.9	0.3	0.6	0.9	1.1	0.6	0.9
Δ	ζ_{sp}	0.367	0.383	0.395	0.277	0.316	0.316	0.185	0.225	0.230
	ω_{sp}	1.76	4.21	6.76	1.63	3.15	5.48	8.81	2.08	3.68
	ζ_p $(1/T_{p_1})$	0.0594	0.100	0.790	0.118	0.0620	(0.0888)	0.589	0.0449	(0.0616)
	ω_p $(1/T_{p_2})$	0.156	0.0698	0.0472	0.140	0.0710	(−0.0513)	0.0372	0.0751	(−0.0501)
$N^{\theta}_{\delta_e}$	A_θ	−5.43	−30.6	−58.4	−45.1	−18.8	−41.6	−44.3	−8.18	−20.2
	$1/T_{\theta_1}$	−0.0214	0.0122	0.0728	−0.00823	0.00716	0.0443	0.0422	−0.00316	0.0202
	$1/T_{\theta_2}$	0.731	1.79	3.19	0.506	1.09	1.97	2.02	0.516	0.933
$N^{u}_{\delta_e}$	A_u	5.75	8.34	11.6	5.63	6.96	9.13	11.2	5.70	6.61
	$1/T_{u_1}$	51.1	125	186	8.5	120	190	234	109	177
	ζ_u $(1/T_{u_2})$	(0.411)	0.665	(1.22)	(0.369)	0.627	0.854	(0.899)	0.925	0.753
	ω_u $(1/T_{u_3})$	(1.03)	1.30	(2.28)	(0.587)	0.890	1.24	(1.23)	0.466	0.719
$N^{w}_{\delta_e}$	A_w	−29.0	−165	−318	−23.8	−99.6	−209	−220	−43.2	−99.4
	$1/T_{w_1}$	51.7	126	187	58.9	121	191	234	110	178
	ζ_w $(1/T_{w_2})$	−0.110	0.239	(−0.00603)	−0.0444	0.0567	(−0.00939)	(−0.0131)	−0.0553	0.419
	ω_w $(1/T_{w_3})$	0.105	0.0210	(0.0773)	0.0990	0.0386	(0.0518)	(0.0530)	0.0494	0.0219
$N^{\dot{h}}_{\delta_e}$	A_h	29.6	165	318	24.5	99.8	209	221	43.6	99.7
	$1/T_{h_1}$	−0.0624	0.00956	0.0719	−0.0549	0.00225	0.0431	0.0412	−0.0154	0.0173
	$1/T_{h_2}$	6.21	15.6	25.3	5.41	11.8	20.0	22.2	7.64	13.2
	$1/T_{h_3}$	−5.57	−14.3	−23.3	−4.92	−11.0	−18.7	−21.2	−7.22	−12.5
$N^{a_z}_{\delta_e}$ CG	A_{a_z}	−29.0	−165	−318	−23.8	−99.6	−209	−220	−43.2	−99.4
	$1/T_{a_{z1}}$	−0.00998	−0.00248	−0.00117	−0.00417	−0.00405	−0.00147	−0.00139	−0.00170	−0.00250
	$1/T_{a_{z2}}$	−0.0506	0.0120	0.0729	−0.0497	0.00627	0.0445	0.0425	−0.0136	0.0197
	$1/T_{a_{z3}}$	6.33	15.6	25.3	5.55	11.8	20.0	22.2	7.69	13.2
	$1/T_{a_{z4}}$	−5.73	−14.3	−23.3	−5.08	−11.0	−18.7	−21.3	−7.28	−12.5

TABLE II-E

AILERON LATERAL TRANSFER FUNCTION FACTORS FOR THE A-7A

Note: Data for body-fixed centerline axes, clean flexible airplane

		FLIGHT CONDITION								
		1	2	3	4	5	6	7	8	9
	h	0	0	0	15,000	15,000	15,000	15,000	35,000	35,000
	M	0.25	0.6	0.9	0.3	0.6	0.9	1.1	0.6	0.9
Δ	$1/T_s$	0.0462	0.0411	0.0180	0.0449	0.0435	0.0214	0.0102	0.0319	0.0191
	$1/T_R$	1.62	4.46	9.75	0.968	2.71	6.17	7.15	1.28	2.92
	ζ_d	0.237	0.202	0.218	0.231	0.156	0.175	0.189	0.114	0.128
	ω_d	1.81	2.91	4.68	1.65	2.29	3.66	5.03	1.81	2.58
$N^p_{\delta_a}$	A_p	5.34	28.4	25.2	3.75	17.6	24.1	12.5	7.96	14.2
	$1/T_{p_1}$	−0.0219	−0.00234	−0.00113	−0.0232	−0.00347	−0.00144	−0.00137	−0.00718	−0.00241
	ζ_p	0.217	0.217	0.222	0.191	0.173	0.176	0.173	0.122	0.124
	ω_p	1.49	3.05	4.91	1.27	2.34	3.87	5.33	1.62	2.64
$N^\varphi_{\delta_a}$	A_φ	5.42	28.5	25.2	3.81	17.7	24.1	12.6	8.04	14.3
	ζ_φ	0.210	0.217	0.222	0.183	0.173	0.177	0.175	0.119	0.124
	ω_φ	1.51	3.05	4.91	1.29	2.34	3.87	5.32	1.62	2.64
$N^r_{\delta_a}$	A_r	0.402	2.08	1.56	0.280	1.37	1.64	1.04	0.652	1.01
	$1/T_{r_1}$	0.596	1.12	1.13	0.445	0.777	0.944	0.581	0.420	0.593
	ζ_r	0.0852	0.287	0.597	0.146	0.151	0.446	0.638	0.0198	0.193
	ω_r	2.35	2.29	3.26	2.18	2.13	2.78	3.98	2.03	2.45
$N^\beta_{\delta_a}$	A_β	−0.00274	−0.0105	−0.00857	−0.00150	−0.00655	−0.00691	−0.00216	−0.00267	−0.00427
	$1/T_{\beta_1}$ (ζ_β)	(0.885)	3.26	7.76	(0.726)	2.21	5.77	10.7	0.793	(0.872)
	$1/T_{\beta_2}$ (ω_β)	(0.667)	−0.627	−0.254	(0.471)	−1.63	−0.245	−0.113	0.422	(10.6)
	$1/T_{\beta_3}$	−233	63.1	78.2	−391	23.2	86.8	188	−147	−0.545
$N^{a_y}_{\delta_a}$ CG	A_{a_y}	−0.766	−7.06	−8.61	−0.477	−4.16	−6.58	−2.51	−1.56	−0.0374
	$1/T_{a_{y_1}}$ ($\zeta_{a_{y_2}}$)	(0.943)	2.29	−1.16	(0.758)	1.32	−0.596	−0.146	0.290	(0.801)
	$1/T_{a_{y_2}}$ ($\omega_{a_{y_2}}$)	(0.648)	5.92	−1.84	(0.461)	3.12	−2.66	−7.93	0.961	(2.34)
	ζ_{a_y} ($1/T_{a_{y_3}}$)	0.0896	−0.810	(3.65)	0.0673	−0.294	(3.79)	0.897	0.0499	−0.113
	ω_{a_y} ($1/T_{a_{y_4}}$)	6.37	1.76	(10.7)	7.10	1.99	(−6.63)	9.31	3.92	1.30

TABLE II-F

RUDDER LATERAL TRANSFER FUNCTION FACTORS FOR THE A-7A

Note: Data for body-fixed centerline axes, clean flexible airplane

		FLIGHT CONDITION								
		1	2	3	4	5	6	7	8	9
	h	0	0	0	15,000	15,000	15,000	15,000	35,000	35,000
	M	0.25	0.6	0.9	0.3	0.6	0.9	1.1	0.6	0.9
Δ	$1/T_s$	0.0462	0.0411	0.0180	0.04[illegible]9	0.0435	0.0214	0.0102	0.0319	0.0191
	$1/T_R$	1.62	4.46	9.75	0.968	2.71	6.17	7.15	1.28	2.92
	ζ_d	0.237	0.202	0.218	0.231	0.156	0.175	0.189	0.114	0.128
	ω_d	1.81	2.91	4.68	1.65	2.29	3.66	5.03	1.81	2.58
$N^p_{\delta_r}$	A_p	2.22	11.4	13.2	18.2	7.27	11.2	7.27	3.09	6.55
	$1/T_{p_1}$	−0.0224	−0.00242	−0.00117	−0.0237	−0.00352	−0.00147	−0.00141	−0.00723	−0.00243
	$1/T_{p_2}$	2.68	5.35	8.31	2.33	4.31	6.63	5.56	3.16	4.39
	$1/T_{p_3}$	−3.38	−5.31	−7.88	−2.79	−4.45	−6.33	−4.55	−3.44	−4.38
$N^\varphi_{\delta_r}$	A_φ	1.84	10.9	12.8	1.45	6.89	10.8	7.03	2.75	6.21
	$1/T_{\varphi_1}$	2.78	5.37	8.29	2.48	4.35	6.64	5.53	3.27	4.43
	$1/T_{\varphi_2}$	−4.11	−5.53	−8.18	−3.48	−4.68	−6.57	−4.76	−3.79	−4.61
$N^r_{\delta_r}$	A_r	−1.93	−8.61	−11.1	−1.56	−5.54	−8.80	−4.83	−2.54	−5.11
	$1/T_{r_1}$	1.13	4.33	9.87	0.553	2.35	6.12	7.31	0.578	2.64
	ζ_r	0.538	0.475	0.674	0.414	0.473	0.535	0.790	0.440	0.526
	ω_r	1.02	0.642	0.502	1.17	0.735	0.541	0.381	1.12	0.585
$N^\beta_{\delta_r}$	A_β	0.0430	0.0769	0.0626	0.0307	0.0537	0.0550	0.0192	0.0267	0.0347
	$1/T_{\beta_1}$	−0.0624	−0.00199	0.000266	−0.0603	−0.00616	0.000578	0.00271	−0.0178	−0.00216
	$1/T_{\beta_2}$	1.73	4.45	9.76	1.14	2.70	6.17	7.11	1.32	2.94
	$1/T_{\beta_3}$	54.7	120	186	63.6	113	170	272	110	160
$N^{a_y}_{\delta_r}$ CG	A_{a_y}	12.0	51.5	62.9	9.74	34.1	52.3	22.4	15.6	30.4
	$1/T_{a_{y_1}}$	−0.123	−0.0145	−0.00502	−0.108	−0.0227	−0.00654	0.000648	−0.0436	−0.0107
	$1/T_{a_{y_2}}$	1.87	4.43	9.57	1.27	2.69	6.16	7.06	1.36	2.97
	$1/T_{a_{y_3}}$	−2.00	−4.97	−7.84	−1.96	−3.69	−5.78	−8.91	−2.28	−3.81
	$1/T_{a_{y_4}}$	2.60	5.92	9.57	2.45	4.30	6.80	10.5	2.61	4.30

SECTION III

A-4D

Figure III-1

A-4D

NOMINAL CRUISE CONFIGURATION

Clean Airplane

W = 17,578 lbs

C G at 25% MGC

I_x = 8090 slug-ft^2
I_y = 25,900 slug-ft^2
I_z = 29,200 slug-ft^2
I_{xz} = 1300 slug-ft^2
} Body Ref. Axes

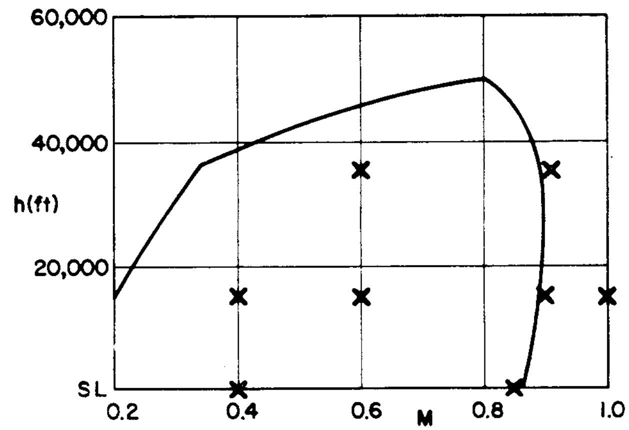
REFERENCE GEOMETRY

S = 260 ft^2

c = 10.8 ft

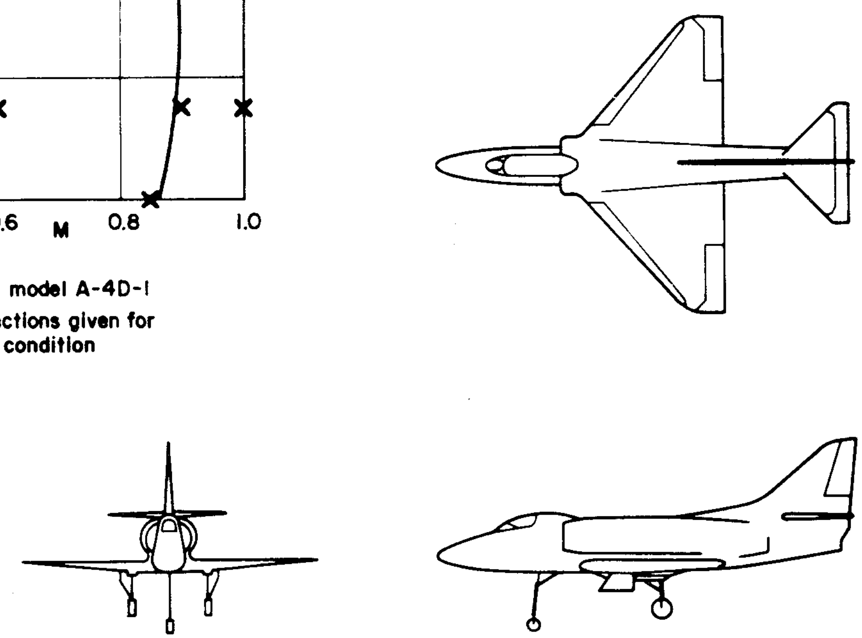
b = 27.5 ft

FLIGHT ENVELOPE



—— Envelope for model A-4D-1

✕ Transfer functions given for these flight condition



REFERENCES

1) Abzug, M.J. and R.L. Faith, Aerodynamic Data for Model A4D-1 Operational Flight Trainer, Douglas Aircraft Co. Report ES-26104, November 1, 1955

2) Johnston, D.E. and D.H. Weir, Study of Pilot-Vehicle-Controller Integration for A Minimum Complexity AFCS, Systems Technology, Inc. Technical Report No. 127-1, July 1964

BASIC DATA SOURCES

Wind Tunnel Test

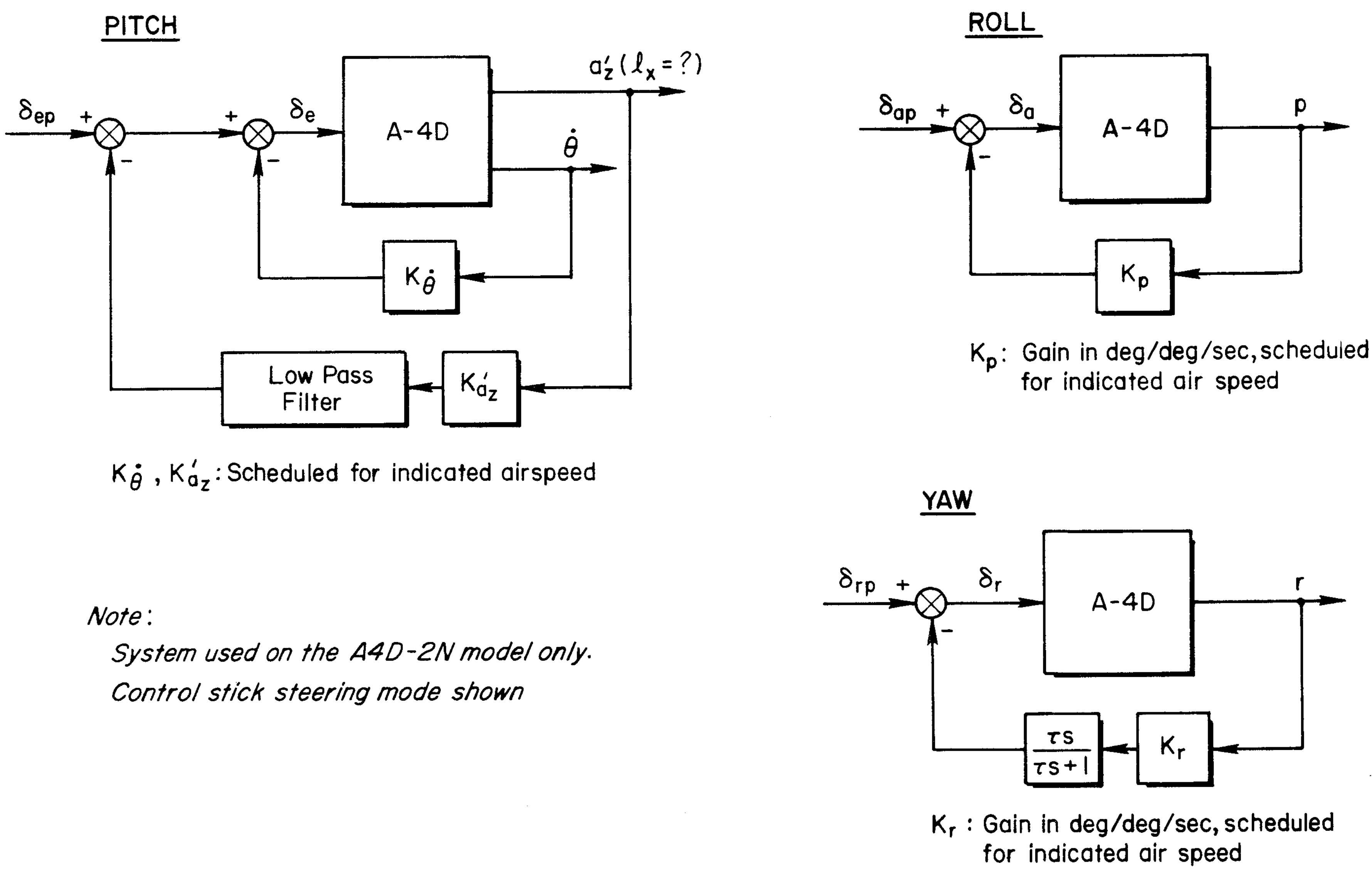
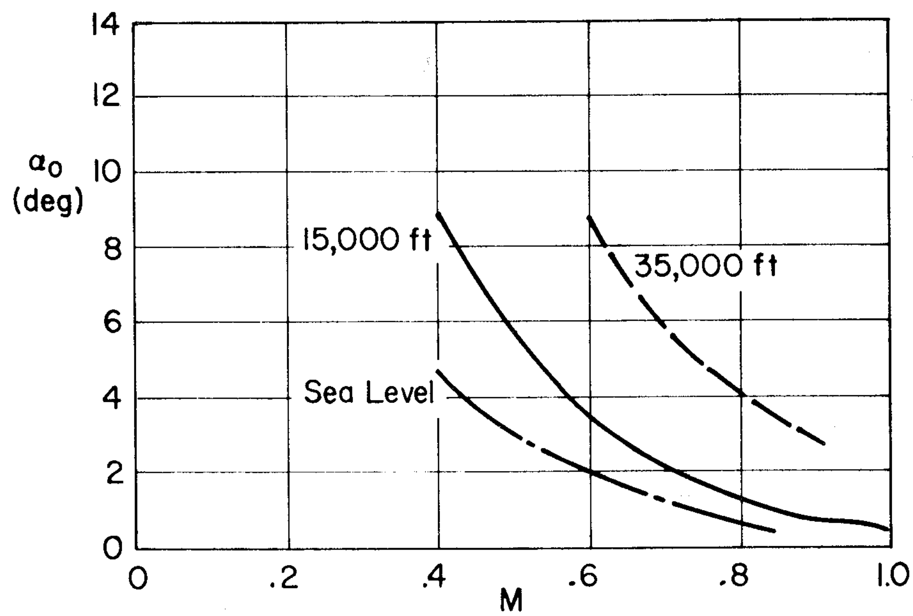
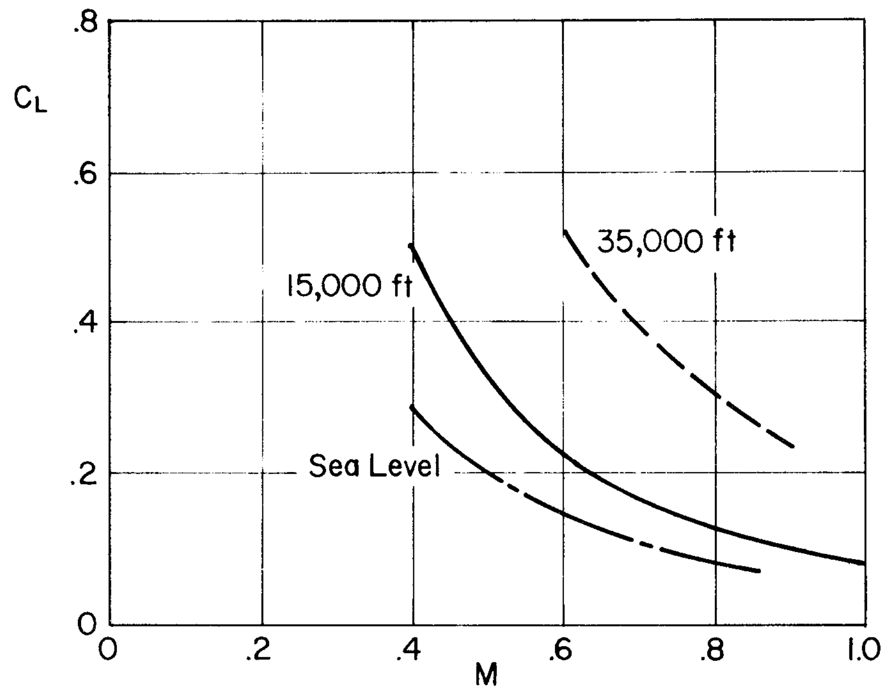
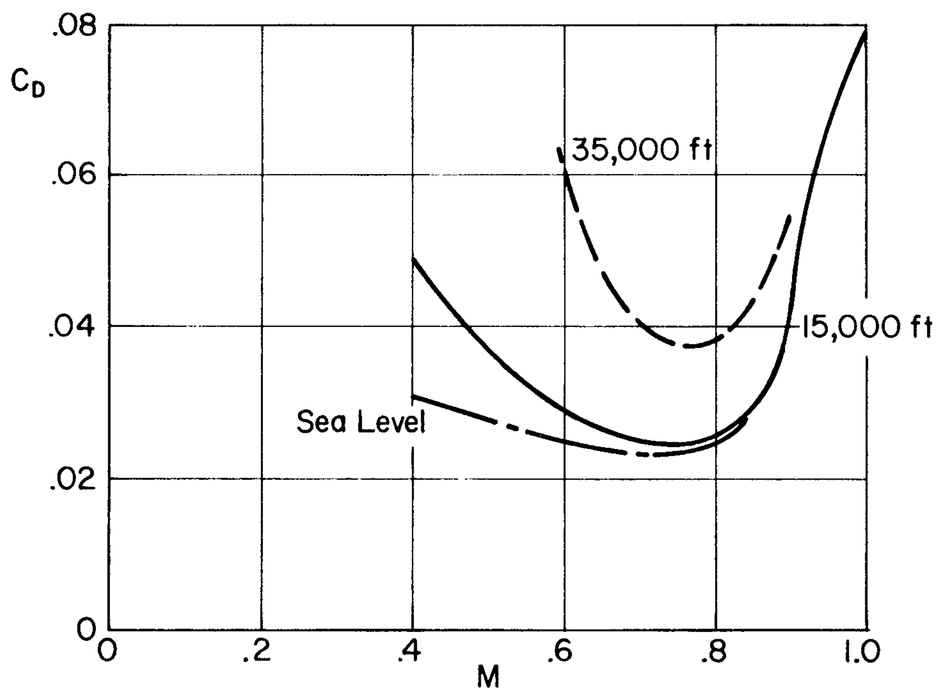


Figure III-2. A-4D — Stability Augmentation System

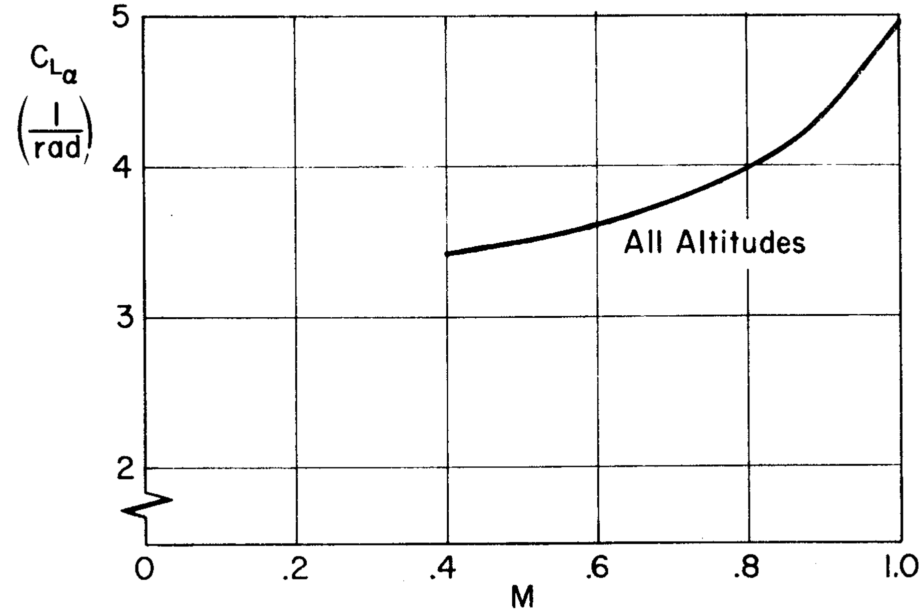

14
12
10
8
6
4
2
0
α_0
(deg)
15,000 ft
35,000 ft
Sea Level
0
.2
.4
.6
.8
1.0
M



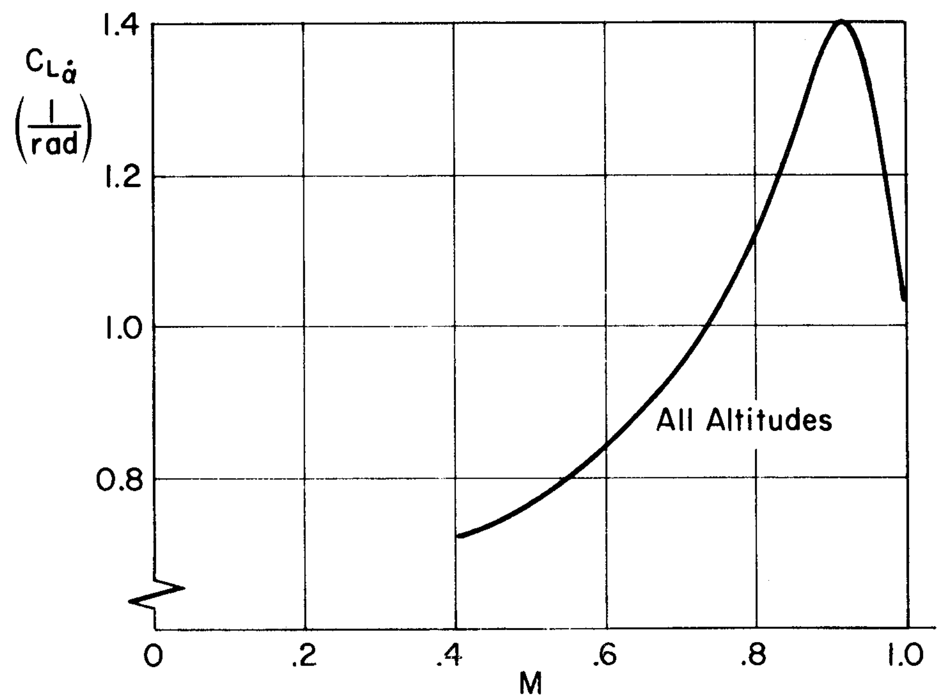
.8
.6
.4
.2
0
C_L
35,000 ft
15,000 ft
Sea Level
0
.2
.4
.6
.8
1.0
M



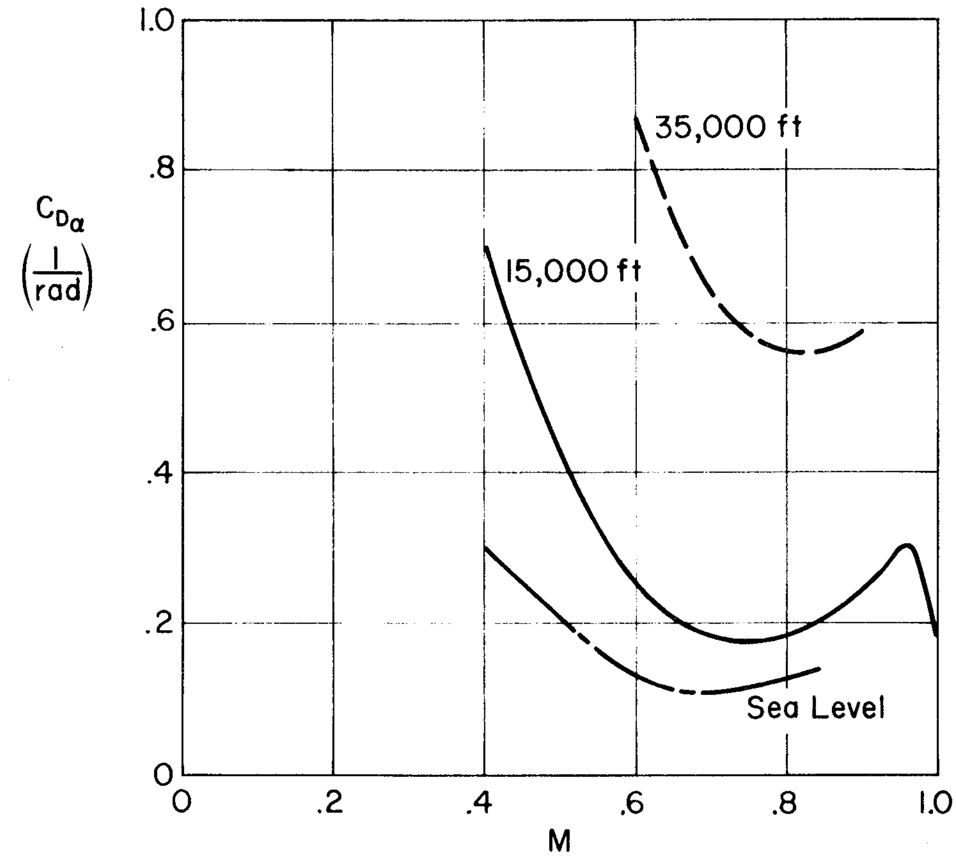
.08
.06
.04
.02
0
C_D
35,000 ft
15,000 ft
Sea Level
0
.2
.4
.6
.8
1.0
M

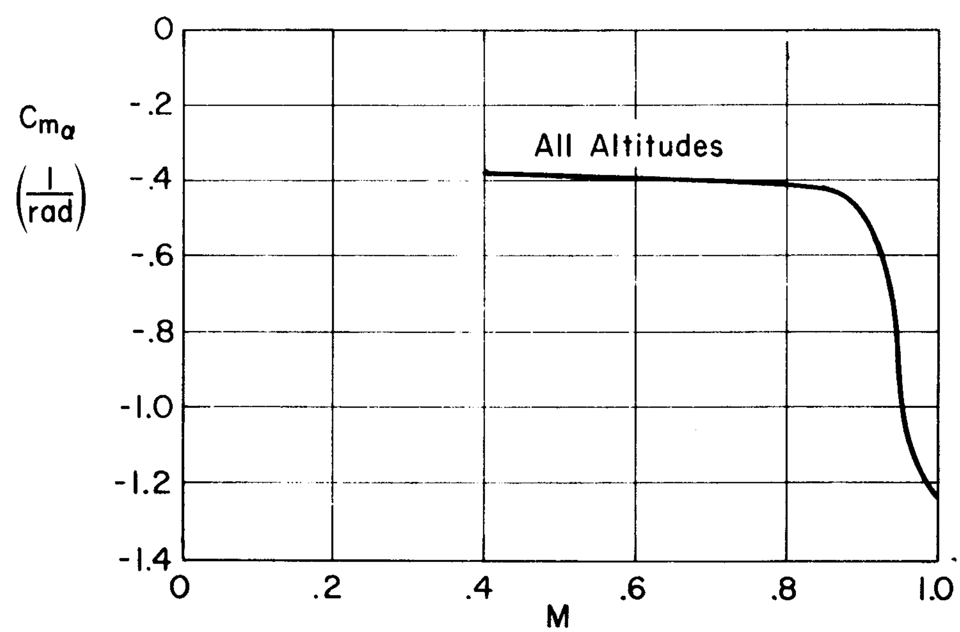


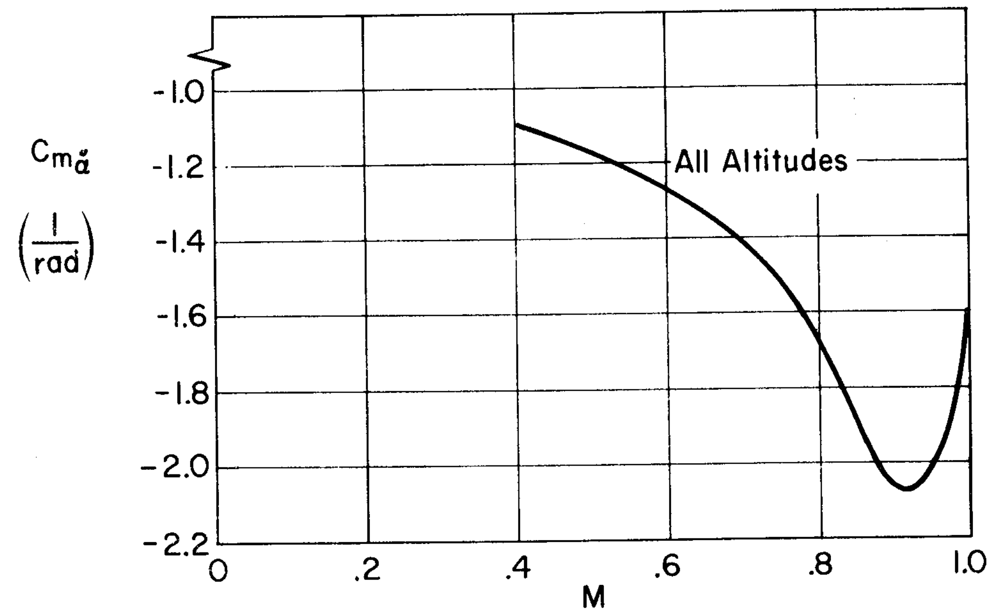
C_{L_α}
$\left(\frac{1}{rad}\right)$
5
4
3
2
All Altitudes
0
.2
.4
.6
.8
1.0
M

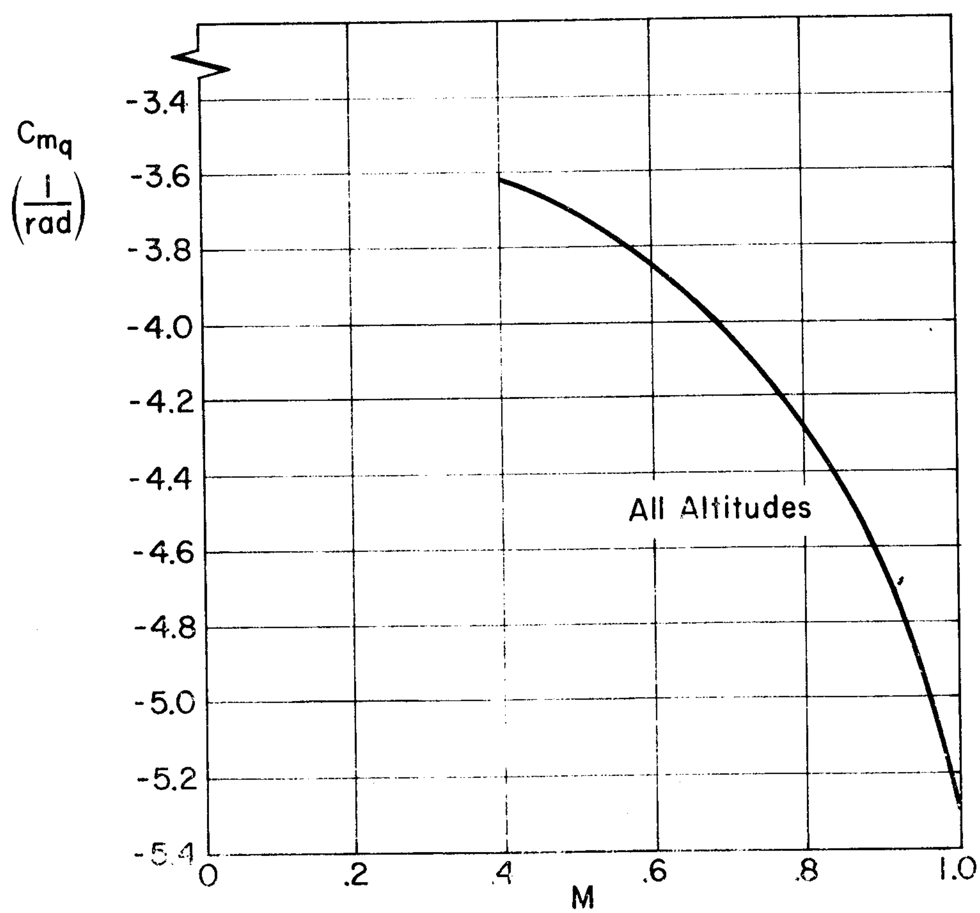


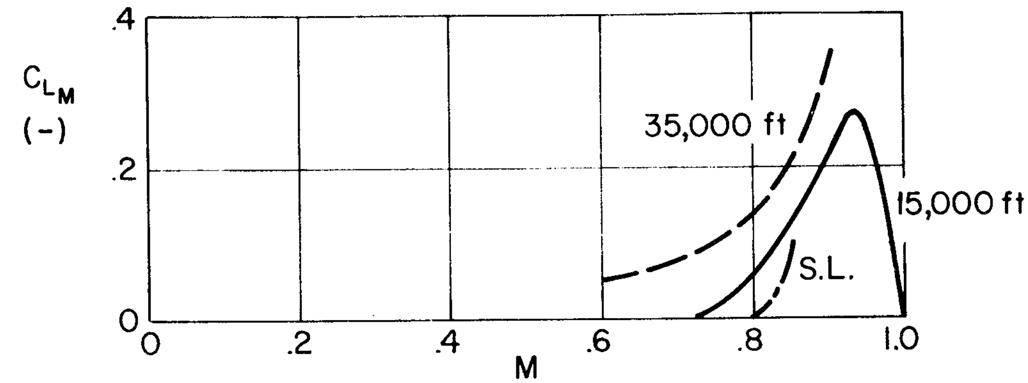
$C_{L_{\dot{\alpha}}}$
$\left(\frac{1}{rad}\right)$
1.4
1.2
1.0
0.8
All Altitudes
0
.2
.4
.6
.8
1.0
M


1.0
.8
.6
.4
.2
0
C_{D_α}
$\left(\frac{1}{rad}\right)$
35,000 ft
15,000 ft
Sea Level
0
.2
.4
.6
.8
1.0
M

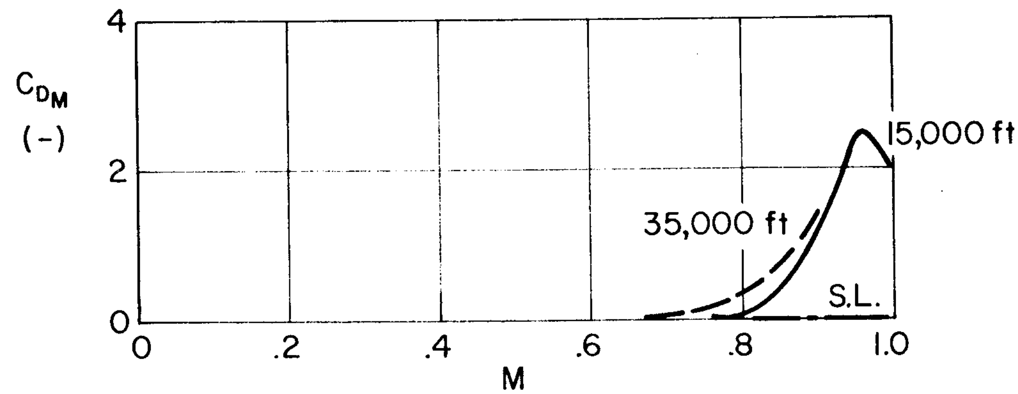

0
-.2
-.4
-.6
-.8
-1.0
-1.2
-1.4
C_{m_α}
$\left(\frac{1}{rad}\right)$
All Altitudes
0
.2
.4
.6
.8
1.0
M


$C_{m_{\dot{\alpha}}}$
$\left(\frac{1}{rad}\right)$
-1.0
-1.2
-1.4
-1.6
-1.8
-2.0
-2.2
0
.2
.4
.6
.8
1.0
M
All Altitudes

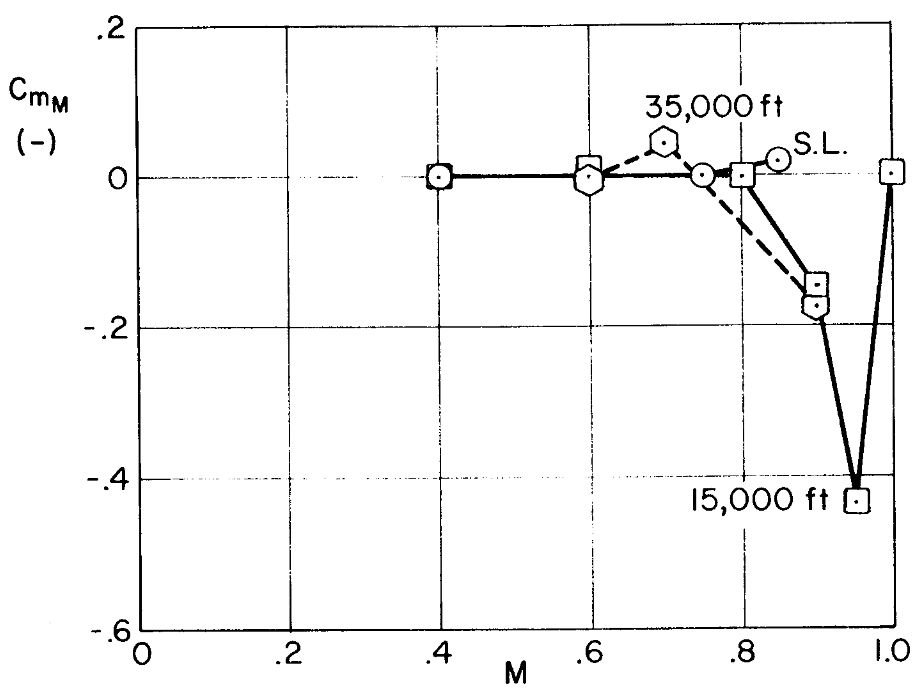

C_{m_q}
$\left(\frac{1}{rad}\right)$
-3.4
-3.6
-3.8
-4.0
-4.2
-4.4
-4.6
-4.8
-5.0
-5.2
-5.4
0
.2
.4
.6
.8
1.0
M
All Altitudes



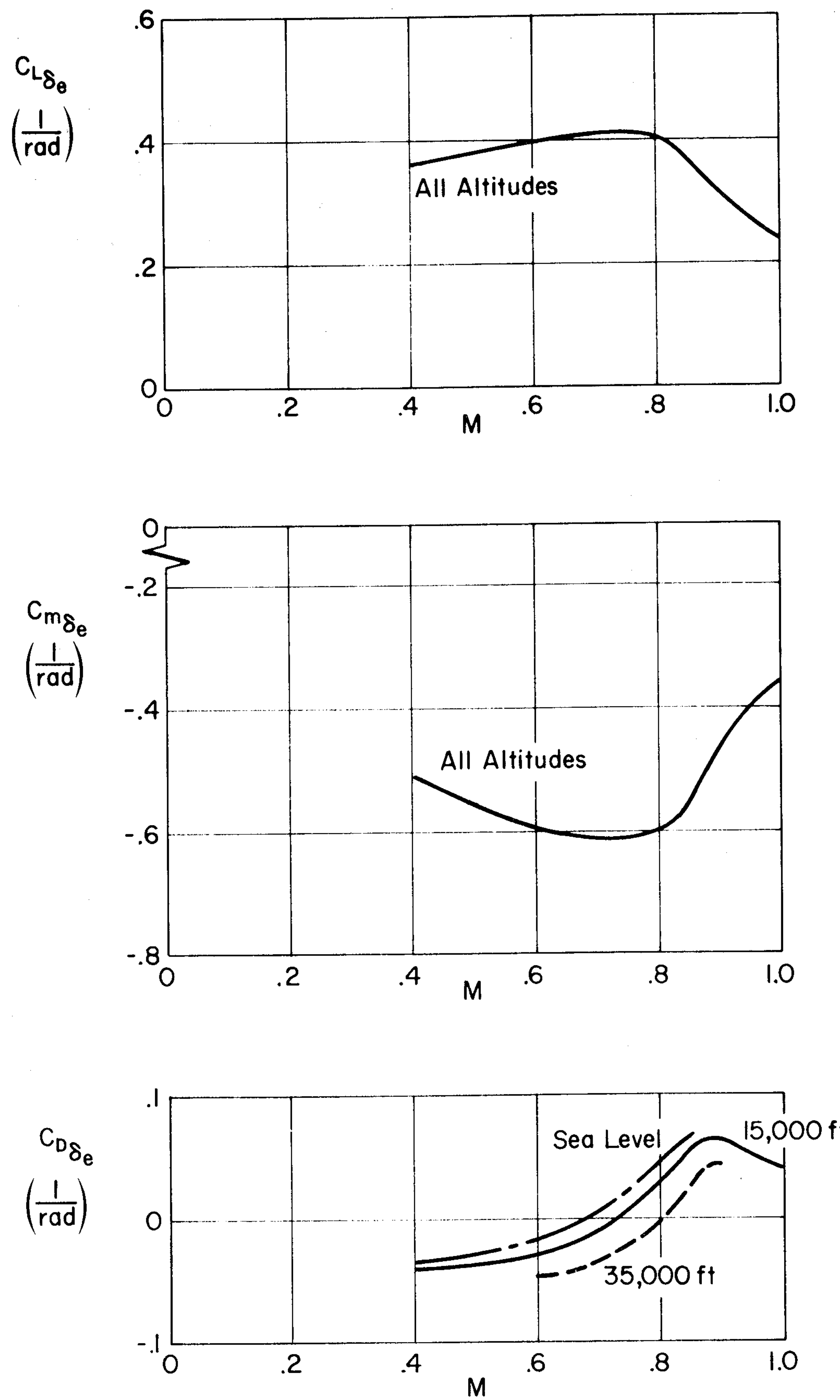
C_{L_M}
(-)
35,000 ft
15,000 ft
S.L.
M



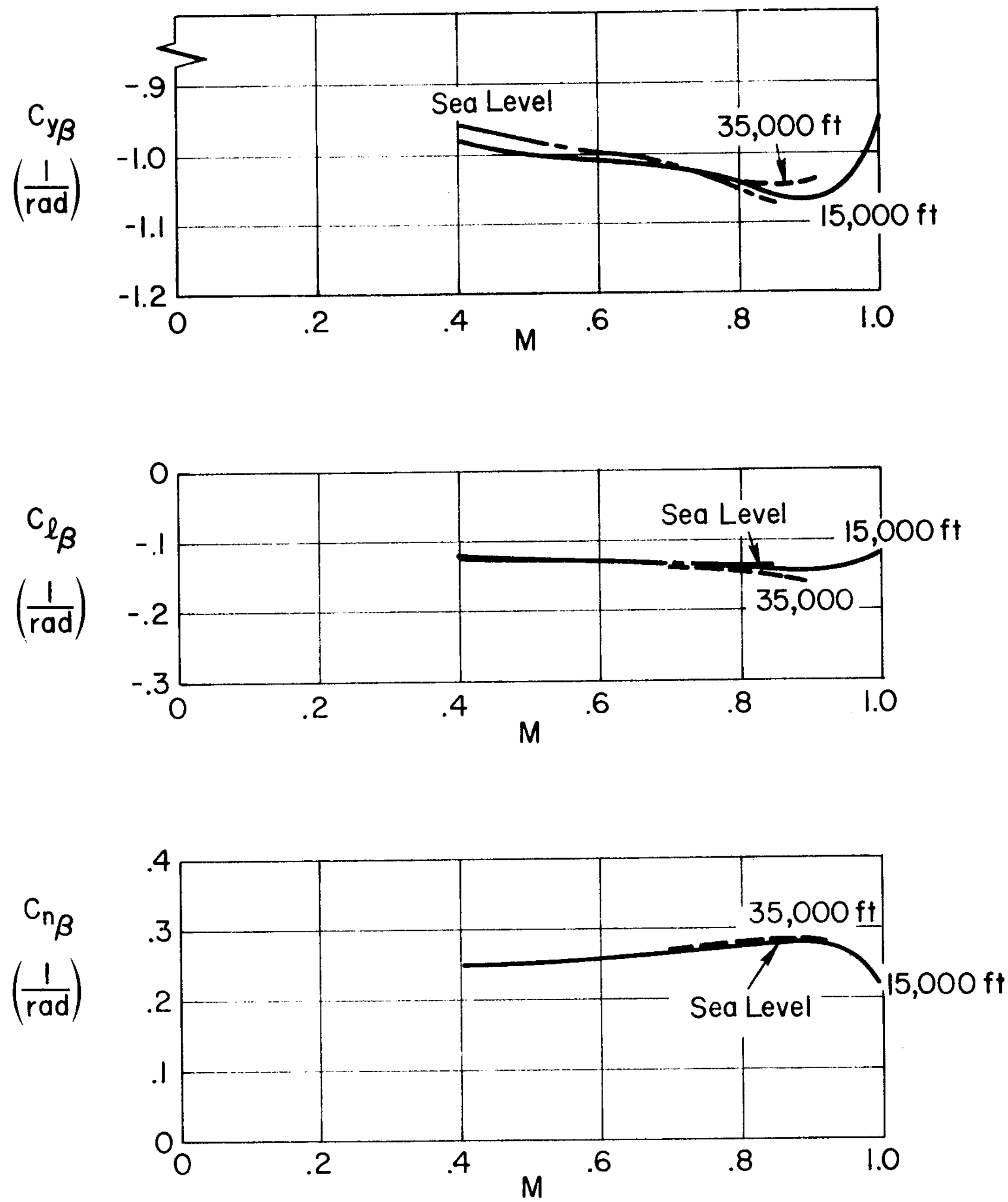
C_{D_M}
(-)
15,000 ft
35,000 ft
S.L.
M



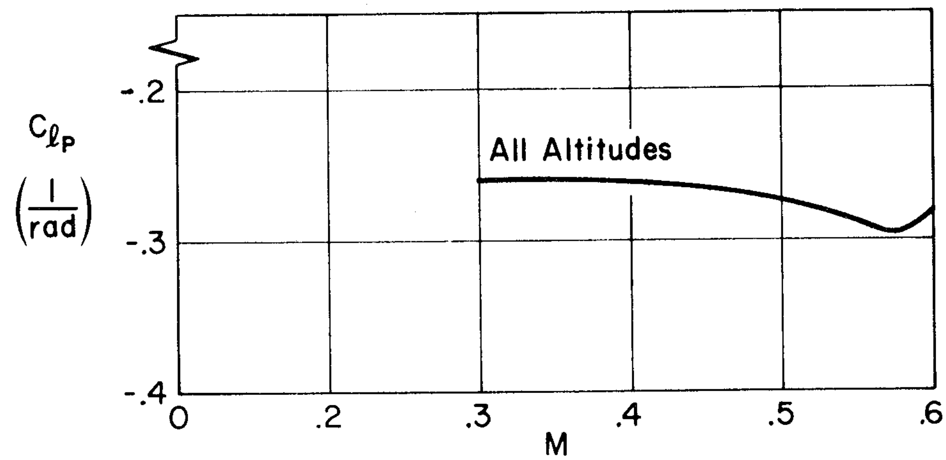
C_{m_M}
(-)
35,000 ft
S.L.
15,000 ft
M



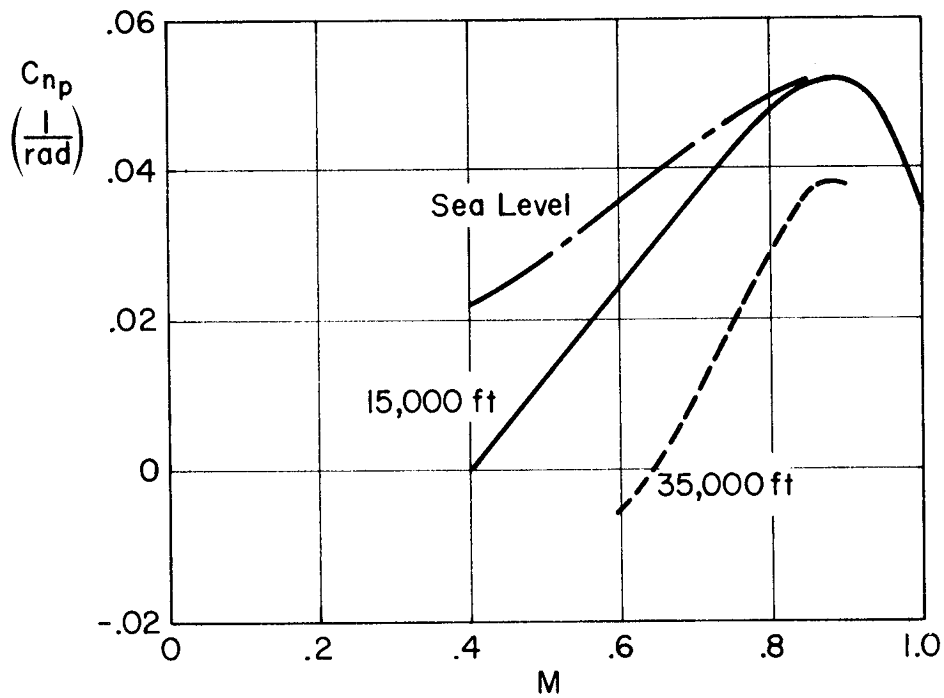
$C_{L_{\delta_e}}$
$\left(\frac{1}{rad}\right)$
.6
.4
.2
0
All Altitudes
0
.2
.4
.6
.8
1.0
M
$C_{m_{\delta_e}}$
$\left(\frac{1}{rad}\right)$
0
-.2
-.4
-.6
-.8
All Altitudes
0
.2
.4
.6
.8
1.0
M
$C_{D_{\delta_e}}$
$\left(\frac{1}{rad}\right)$
.1
0
-.1
Sea Level
15,000 ft
35,000 ft
0
.2
.4
.6
.8
1.0
M



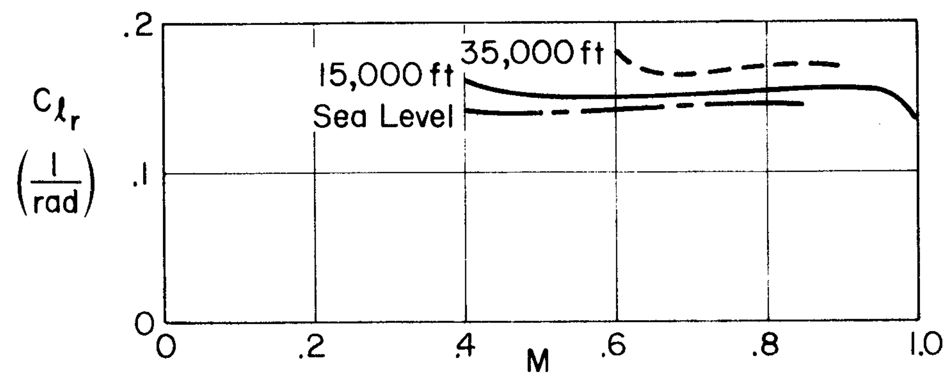
C_{y_β}
$\left(\frac{1}{rad}\right)$
-.9
-1.0
-1.1
-1.2
Sea Level
35,000 ft
15,000 ft
0
.2
.4
.6
.8
1.0
M
C_{ℓ_β}
$\left(\frac{1}{rad}\right)$
0
-.1
-.2
-.3
Sea Level
15,000 ft
35,000
M
C_{n_β}
$\left(\frac{1}{rad}\right)$
.4
.3
.2
.1
0
35,000 ft
Sea Level
15,000 ft
M

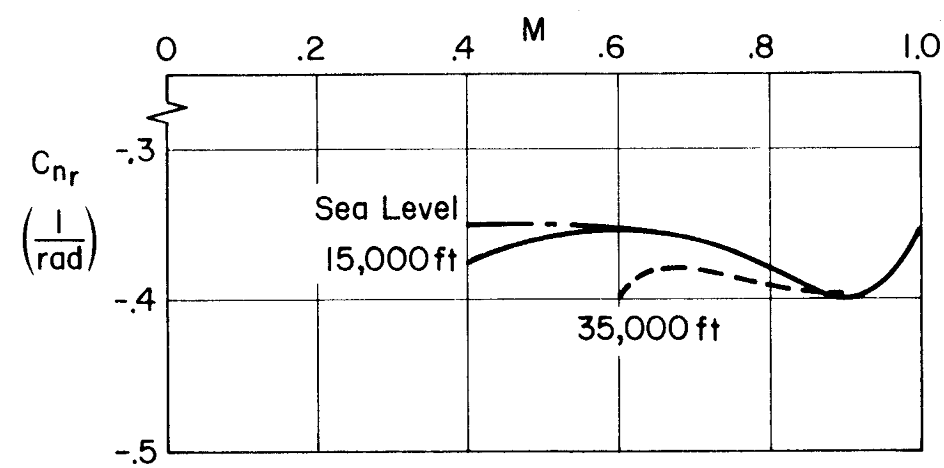


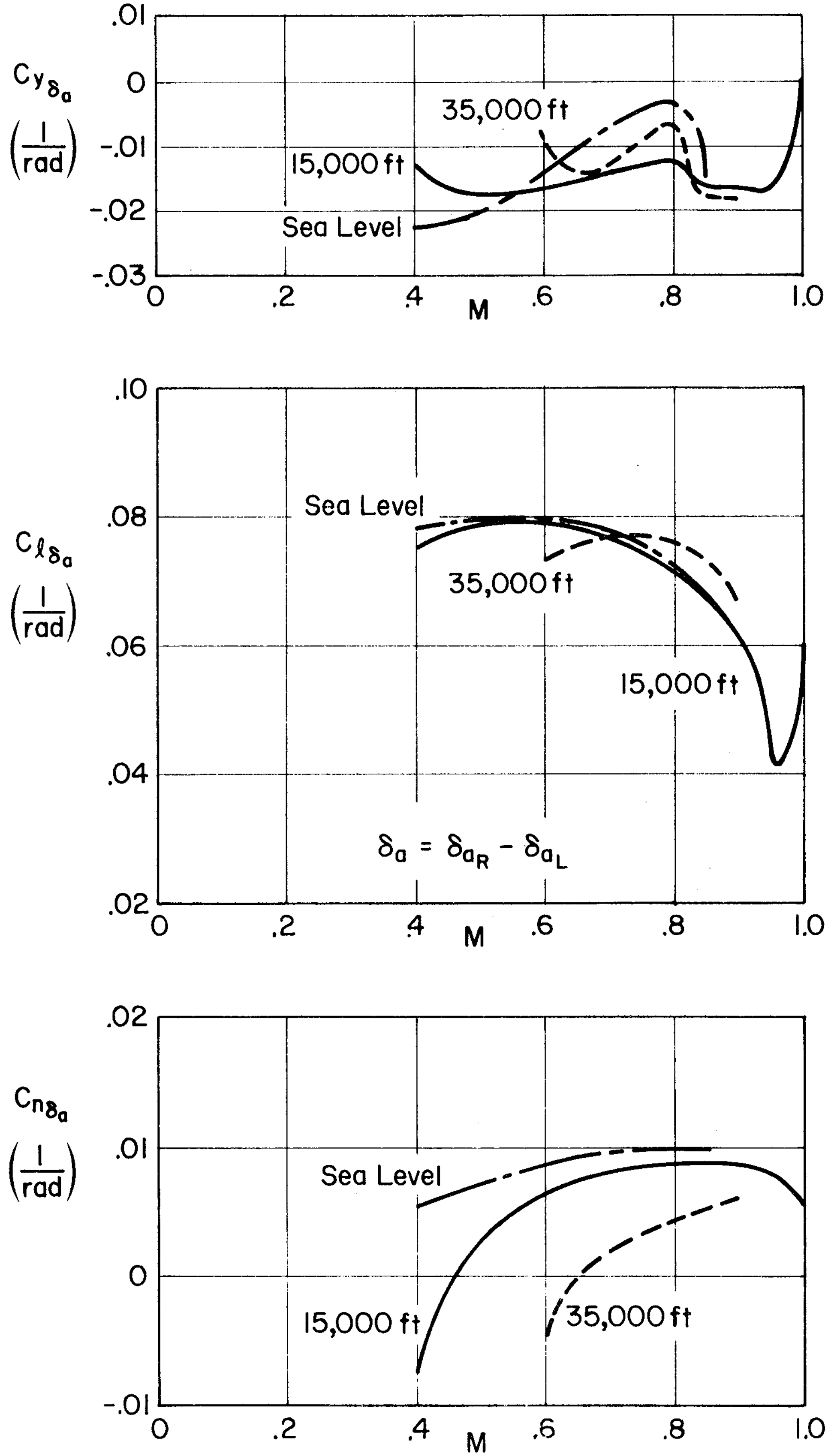
C_{ℓ_p}
$\left(\frac{1}{rad}\right)$
-.2
-.3
-.4
0
.2
.3
.4
.5
.6
M
All Altitudes



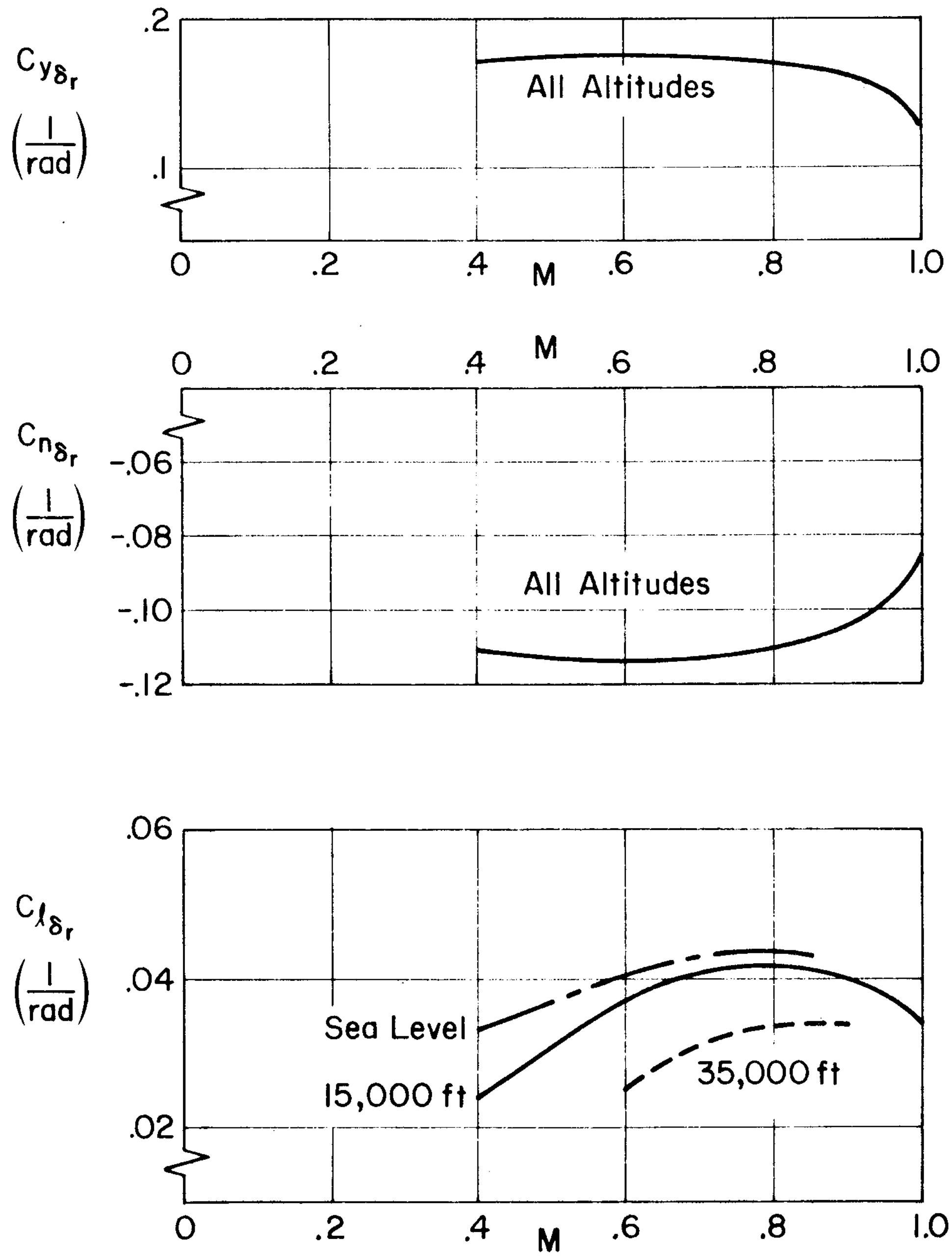
C_{n_p}
$\left(\frac{1}{rad}\right)$
.06
.04
.02
0
-.02
0
.2
.4
.6
.8
1.0
M
Sea Level
15,000 ft
35,000 ft


.2
.1
0
C_{l_r}
(1/rad)
35,000 ft
15,000 ft
Sea Level
0
.2
.4
.6
.8
1.0
M


M
0
.2
.4
.6
.8
1.0
C_{n_r}
(1/rad)
-.3
-.4
-.5
Sea Level
15,000 ft
35,000 ft



$C_{y_{\delta_a}}$
$\left(\frac{1}{rad}\right)$
.01
0
-.01
-.02
-.03
35,000 ft
15,000 ft
Sea Level
0
.2
.4
M
.6
.8
1.0
$C_{\ell_{\delta_a}}$
$\left(\frac{1}{rad}\right)$
.10
.08
.06
.04
.02
Sea Level
35,000 ft
15,000 ft
$\delta_a = \delta_{a_R} - \delta_{a_L}$
0
.2
.4
M
.6
.8
1.0
$C_{n_{\delta_a}}$
$\left(\frac{1}{rad}\right)$
.02
.01
0
-.01
Sea Level
15,000 ft
35,000 ft
0
.2
.4
M
.6
.8
1.0



$C_{y_{\delta_r}}$ $\left(\frac{1}{rad}\right)$
.2
.1
All Altitudes
0
.2
.4
M
.6
.8
1.0
$C_{n_{\delta_r}}$ $\left(\frac{1}{rad}\right)$
-.06
-.08
-.10
-.12
All Altitudes
$C_{l_{\delta_r}}$ $\left(\frac{1}{rad}\right)$
.06
.04
.02
Sea Level
15,000 ft
35,000 ft

TABLE III-A

GEOMETRICAL PARAMETERS FOR THE A-4D

Note: Data are for body-fixed centerline axis, cruise configuration.

$S = 260\ ft^2$, $b = 27.5$ ft, $c = 10.8$ ft

W = 17,578 lbs, m = 546 slugs, c.g. at 25% MAC

$I_x = 8,780\ slug\text{-}ft^2$, $I_y = 25,900\ slug\text{-}ft^2$, $I_z = 28,500\ slug\text{-}ft^2$, $I_{xz} = -4,070\ slug\text{-}ft^2$

	FLIGHT CONDITION							
	1	2	3	4	5	6	7	8
h (ft)	0	0	15,000	15,000	15,000	15,000	35,000	35,000
M (–)	0.4	0.85	0.4	0.6	0.9	1.0	0.6	0.9
a (ft/sec)	1117	1117	1058	1058	1058	1058	973.3	973.3
ρ (slugs/ft^3)	0.002378	0.002378	0.001496	0.001496	0.001496	0.001496	0.000736	0.000736
V_{T_o} (ft/sec)	447	950	423	635	952	1058	584	876
$\bar{q} = \rho V_{T_o}^2/2$ (lb/ft^2)	237	945	134	301	677	836	126	283
α_o (deg)	4.7	0.4	8.9	3.4	0.70	0.40	8.8	2.9
U_o (ft/sec)	446	950	418	634	952	1058	577	875
W_o (ft/sec)	36.6	6.6	65.4	37.7	11.6	7.4	89.3	44.3
γ_o (deg)	0	0	0	0	0	0	0	0

TABLE III-B

LONGITUDINAL DIMENSIONAL DERIVATIVES FOR THE A-4D

Note: Data are for body-fixed centerline axes, clean flexible airplane.

	FLIGHT CONDITION							
	1	2	3	4	5	6	7	8
h	0	0	15,000	15,000	15,000	15,000	35,000	35,000
M	0.4	0.85	0.4	0.6	0.9	1.0	0.6	0.9
X_w	0.0687	−0.0215	0.052	0.0422	−0.0303	−0.0251	0.0227	−0.0212
X_u	−0.00934	−0.0298	0.000877	−0.00938	−0.0615	−0.1343	0.000806	−0.0282
X_{δ_e}	7.612	−33.944	6.068	7.396	−19.723	−15.289	6.288	−3.873
Z_w	−0.899	−2.23	−0.535	−0.822	−1.478	−1.892	−0.3874	−0.677
Z_u	−0.0765	−0.0982	−0.0704	−0.0533	−0.1174	−0.0487	−0.0525	−0.0869
Z_{δ_e}	−42.08	−188.28	−22.273	−56.68	−103.23	−94.606	−23.037	−43.149
M_w	−0.0228	−0.0502	−0.0131	−0.0204	−0.0379	−0.1072	−0.00908	−0.01735
$M_{\dot{w}}$	−0.000763	−0.00131	−0.000476	−0.000555	−0.000902	−0.000683	−0.000270	−0.000443
M_q	−1.151	−2.936	−0.670	−1.071	−1.934	−2.455	−0.484	−0.876
M_u	0.00232	0.00340	0.00253	0.00162	−0.00906	0.00263	0.001824	−0.00412
M_{δ_e}	−13.728	−63.987	−7.400	−19.456	−33.809	−31.773	−8.096	−14.084

TABLE III-C

LATERAL DIMENSIONAL DERIVATIVES FOR THE A-4D

Note: Data are for body-fixed centerline axes, clean flexible airplane.

	FLIGHT CONDITION							
	1	2	3	4	5	6	7	8
h	0	0	15,000	15,000	15,000	15,000	35,000	35,000
M	0.4	0.85	0.4	0.6	0.9	1.0	0.6	0.9
Y_v	−0.2484	−0.5755	−0.1476	−0.228	−0.3628	−0.358	−0.1034	−0.1596
$Y_{\delta_a}^*$	−0.00582	−0.00807	−0.00188	−0.0038	−0.00556	0.00207	−0.000819	−0.002763
$Y_{\delta_r}^*$	0.044	0.0898	0.02561	0.03958	0.0549	0.049	0.01791	0.02487
L'_β	−29.71	−118.1	−17.52	−35.95	−82.086	−82.02	−17.557	−40.7
L'_p	−1.813	−3.844	−1.111	−1.566	−2.503	−2.708	−0.761	−1.167
L'_r	0.8731	1.776	0.613	0.812	1.208	1.113	0.475	0.6227
L'_{δ_a}	17.2	64.359	8.99	21.203	39.282	44.89	8.1704	16.85
L'_{δ_r}	8.217	37.214	4.309	10.398	22.103	22.943	4.1675	8.717
N'_β	13.203	67.279	6.706	16.629	42.527	39.85	6.352	17.31
N'_p	−0.029	0.02953	−0.0348	−0.02173	0.01647	−0.0260	−0.02513	−0.00539
N'_r	−0.5761	−1.4	−0.3432	−0.5144	−0.899	−0.88	−0.2468	−0.3893
N'_{δ_a}	1.4875	5.484	0.538	1.769	17.43	3.212	0.5703	1.399
N'_{δ_r}	−6.1953	−26.642	−3.280	−7.78	−16.36	−16.562	−3.16	−6.744

TABLE III-D

ELEVATOR LONGITUDINAL TRANSFER FUNCTION FACTORS FOR THE A-4D

Note: Data are for body-fixed centerline axes, clean flexible airplane.

		FLIGHT CONDITION							
		1	2	3	4	5	6	7	8
h		0	0	15,000	15,000	15,000	15,000	35,000	35,000
M		0.4	0.85	0.4	0.6	0.9	1.0	0.6	0.9
Δ	ζ_{sp}	0.352	0.435	0.2838	0.301	0.3435	0.233	0.214	0.2478
	ω_{sp}	3.39	7.348	2.445	3.718	6.232	10.857	2.358	3.951
	$\zeta_p(1/T_{p_1})$	0.0735	0.195	0.682	0.086	(−0.06835)	(0.02574)	0.0859	(−0.050)
	$\omega_p(1/T_{p_2})$	0.1035	0.08615	0.1105	0.0747	(0.1101)	(0.1019)	0.0822	(0.0563)
$N^{\theta}_{\delta_e}$	A_θ	−13.726	−63.98	−7.4	−19.456	−33.805	−33.771	−8.096	−14.083
	$1/T_{\theta_1}$	0.0141	0.0319	0.00353	0.0112	0.0526	0.1284	−0.000615	0.02184
	$1/T_{\theta_2}$	0.8234	2.079	0.489	0.76	1.362	1.572	0.3591	0.6259
$N^{u}_{\delta_e}$	A_u	7.628	−34.074	6.076	7.408	−19.776	−15.32	6.293	−3.878
	$1/T_{u_1}$	66.931	−12.608	80.193	99.8	−20.49	−13.172	115.28	−160.9
	$\zeta_u(1/T_{u_2})$	0.584	(2.615)	0.725	0.638	(0.98)	0.49	0.8554	(0.3383)
	$\omega_u(1/T_{u_3})$	0.8481	(3.813)	0.4926	0.8042	(3.733)	2.824	0.3595	(1.337)
$N^{w}_{\delta_e}$	A_w	−42.08	−188.28	−22.274	−56.68	−103.23	−94.606	−23.034	−43.149
	$1/T_{w_1}$	149.77	325.77	139.54	218.67	313.69	357.77	203.34	286.42
	$\zeta_w(1/T_{w_2})$	0.0614	0.2653	−0.0172	0.0835	0.4915	(0.01471)	−0.0238	0.249
	$\omega_w(1/T_{w_3})$	0.0761	0.0602	0.0771	0.0538	0.0546	(0.1127)	0.0565	0.0516
$N^{h}_{\delta_e}$	A_h	42.565	188.04	22.946	57.02	102.98	94.496	23.728	42.898
	$1/T_{h_1}$	0.00122	0.0299	−0.0208	0.00436	0.050	0.1270	−0.01842	0.01593
	$1/T_{h_2}$	11.623	27.426	8.454	13.376	21.62	24.916	8.5806	13.782
	$1/T_{h_3}$	−10.415	−24.502	−7.712	−12.282	−19.671	−22.453	−8.048	−12.892
$N^{a_z}_{\delta_e}$	A_{a_z}	−42.08	−188.28	−22.274	−56.68	−103.23	−94.606	−23.037	−43.149
	$1/T_{a_{z_1}}$	−0.0085	−0.00025	−0.0228	−0.00404	−0.000431	−0.000214	−0.0181	−0.00227
	$1/T_{a_{z_2}}$	0.00962	0.0301	0.00187	0.00835	0.05043	0.127	−0.000296	0.01805
	$1/T_{a_{z_3}}$	11.668	27.412	8.56	13.405	21.597	24.903	8.7174	13.762
	$1/T_{a_{z_4}}$	−10.471	−24.484	−7.84	−12.321	−19.645	−22.437	−8.203	−12.868

TABLE III-E

AILERON LATERAL TRANSFER FUNCTION FACTORS FOR THE A-4D

Note: Data for body-fixed centerline axes, clean flexible airplane.

		FLIGHT CONDITION							
		1	2	3	4	5	6	7	8
h		0	0	15,000	15,000	15,000	15,000	35,000	35,000
M		0.4	0.85	0.4	0.6	0.9	1.0	0.6	0.9
Δ	$1/T_s$	0.00914	0.00568	0.00508	0.00595	0.00658	0.00726	0.00432	0.0067
	$1/T_R$	1.744	3.81	1.0152	1.5346	2.48	2.772	0.7013	1.137
	ζ_d	0.112	0.1207	0.0949	0.0885	0.0966	0.09123	0.0676	0.065
	ω_d	3.955	8.293	3.058	4.342	6.618	6.392	2.996	4.403
$N^p_{\delta_a}$	A_p	17.199	64.36	8.988	21.203	39.282	44.89	8.17	16.85
	$1/T_{p_1}$	−0.00572	−0.000233	−0.01182	−0.003	−0.00041	−0.000211	−0.0085	−0.00185
	ζ_p	0.1149	0.121	0.0977	0.0923	0.1015	0.0968	0.0717	0.0669
	ω_p	3.986	8.845	2.779	4.442	8.914	6.787	2.742	4.553
$N^\varphi_{\delta_a}$	A_φ	17.321	64.398	9.073	21.308	39.495	44.91	8.259	16.921
	ζ_φ	0.1149	0.121	0.0951	0.0924	0.1021	0.0968	0.070	0.067
	ω_φ	3.985	8.843	2.798	4.439	8.891	6.785	2.76	4.55
$N^r_{\delta_a}$	A_r	1.4875	5.484	0.5376	1.769	17.427	3.212	0.5703	1.39
	$1/T_r$	0.9025	4.364	0.4868	0.873	2.601	3.054	0.3565	0.739
	ζ_r	0.1024	0.0571	0.0185	0.0847	0.0946	−0.0646	0.017	0.0695
	ω_r	3.767	2.655	4.475	3.694	1.521	2.523	4.073	3.519
$N^\beta_{\delta_a}$	A_β	−0.00582	−0.00807	−0.001883	−0.0038	−0.00556	0.00207	−0.000819	−0.00276
	$1/T_{\beta_1}(\zeta_\beta)$	−2.178	−0.1615	(0.9834)	−0.723	−0.0447	−0.2036	(0.974)	−0.369
	$1/T_{\beta_2}(\omega_\beta)$	3.287	4.156	(0.5504)	1.704	2.537	2.2264	(0.4294)	1.368
	$1/T_{\beta_3}$	19.185	625.29	−456	134.95	3048.0	−1396.8	−838.16	197.67
$N^{a_y}_{\delta_a}$ CG	A_{a_y}	−2.66	−7.665	−0.7967	−2.413	−5.294	2.193	−0.4781	−2.42
	$1/T_{a_{y_1}}(\zeta_{a_{y_2}})$	(0.7012)	−0.1975	0.3891	(−0.8875)	−0.0468	−0.1843	0.3626	−0.903
	$1/T_{a_{y_2}}(\omega_{a_{y_2}})$	(1.923)	4.248	0.6872	(2.2183)	2.54	2.266	0.4622	1.651
	$\zeta_{a_{y_3}}(1/T_{a_{y_3}})$	−0.0505	(−16.43)	0.0215	(1.869)	(−32.14)	0.0324	0.00935	(−2.903)
	$\omega_{a_{y_4}}(1/T_{a_{y_4}})$	3.049	(17.628)	8.743	(4.149)	(33.046)	23.254	9.772	(3.712)

TABLE III-F

RUDDER LATERAL TRANSFER FUNCTION FACTORS FOR THE A-4D

Note: Data for body-fixed centerline axes, clean flexible airplane.

		FLIGHT CONDITION							
		1	2	3	4	5	6	7	8
h		0	0	15,000	15,000	15,000	15,000	35,000	35,000
M		0.4	0.85	0.4	0.6	0.9	1.0	0.6	0.9
Δ	$1/T_s$	0.00914	0.00568	0.00508	0.00595	0.00658	0.00726	0.00432	0.0067
	$1/T_R$	1.744	3.81	1.0152	1.5346	2.48	2.772	0.7013	1.137
	ζ_d	0.112	0.1207	0.0949	0.0885	0.0966	0.09123	0.0676	0.065
	ω_d	3.955	8.293	3.058	4.342	6.618	6.392	2.996	4.403
$N^p_{\delta_r}$	A_p	8.217	37.214	4.309	10.398	22.103	22.944	4.167	8.717
	$1/T_{p_1}$	−0.00576	−0.000236	−0.0119	−0.003	−0.000412	−0.000212	−0.00851	−0.00186
	$1/T_{p_2}$	3.0425	4.375	2.532	3.208	4.359	4.534	2.587	3.743
	$1/T_{p_3}$	−3.029	−3.957	−2.6	−3.207	−4.196	−4.275	−2.664	−3.79
$N^\varphi_{\delta_r}$	A_φ	7.708	37.028	3.795	9.936	21.9	22.83	3.678	8.375
	$1/T_{\varphi_1}$	3.086	4.376	2.642	3.248	4.378	4.539	2.725	3.797
	$1/T_{\varphi_2}$	−3.211	−3.98	−2.902	−3.33	−4.227	−4.293	−2.936	−3.90
$N^r_{\delta_r}$	A_r	−6.195	−26.642	−3.28	−7.78	−16.362	−16.562	−3.159	−6.744
	$1/T_r$	1.5484	3.815	0.615	1.348	2.495	2.786	0.393	0.930
	ζ_r	0.3075	0.363	0.308	0.272	0.1783	0.1828	0.207	0.20
	ω_r	0.7438	0.463	1.032	0.718	0.578	0.5411	1.128	0.850
$N^\beta_{\delta_r}$	A_β	0.044	0.09	0.0256	0.0396	0.0549	0.049	0.0179	0.0249
	$1/T_{\beta_1}$	−0.00945	0.00133	−0.0209	−0.0067	−0.000324	0.000941	−0.0175	−0.00539
	$1/T_{\beta_2}$	1.7532	3.812	1.0312	1.537	2.485	2.76	0.711	1.145
	$1/T_{\beta_3}$	156.02	300.91	153.0	212.32	303.67	342.14	210.23	289.01
$N^{a_y}_{\delta_r}$ CG	A_{a_y}	20.1	85.33	10.835	25.134	52.296	51.83	10.459	21.784
	$1/T_{a_{y_1}}$	−0.0219	−0.00154	−0.039	−0.0147	−0.00486	−0.00224	−0.0326	−0.0141
	$1/T_{a_{y_2}}$	1.760	3.814	1.043	1.54	2.489	2.752	0.717	1.150
	$1/T_{a_{y_3}}$	5.14	10.957	3.864	5.73	8.618	9.465	3.733	5.385
	$1/T_{a_{y_4}}$	−4.49	−9.526	−3.415	−5.174	−7.7	−8.63	−3.411	−4.964

SECTION IV

F-106B

Figure IV-1

F-106B

NOMINAL CRUISE CONFIGURATION

Clean Airplane

W = 29,776

CG at 30.5% MGC

I_x = 18,634 slug-ft^2
I_y = 177,858 slug-ft^2
I_z = 191,236 slug-ft^2
I_{xz} = 5,539 slug-ft^2
} Body Ref. Axes

REFERENCE GEOMETRY

S = 695 ft^2

c = 23.755 f

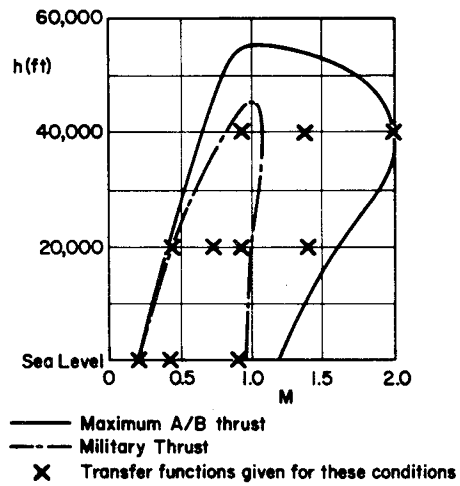
b = 38.13 ft

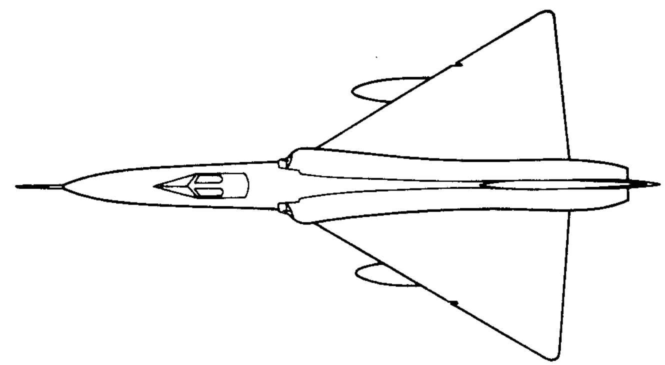
REFERENCES:

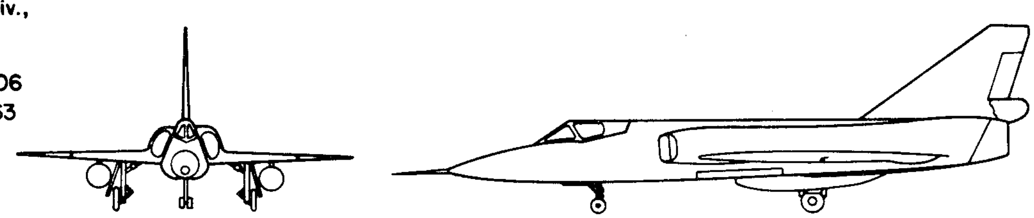
Weyel, A.E., A.H. Terp, C.A. Lunder, Description of F-106B Aircraft to Be Used as a Variable Stability Trainer, Service Engineering Div., Kelly AFB, Exhibit SANE-86, 9 Dec. 1963

Collette, J.G.R., General Dynamics, Convair, A Compilation of F-106 Data From Various Convair Reports Contained in Letter, 14 May 1963

FLIGHT ENVELOPE







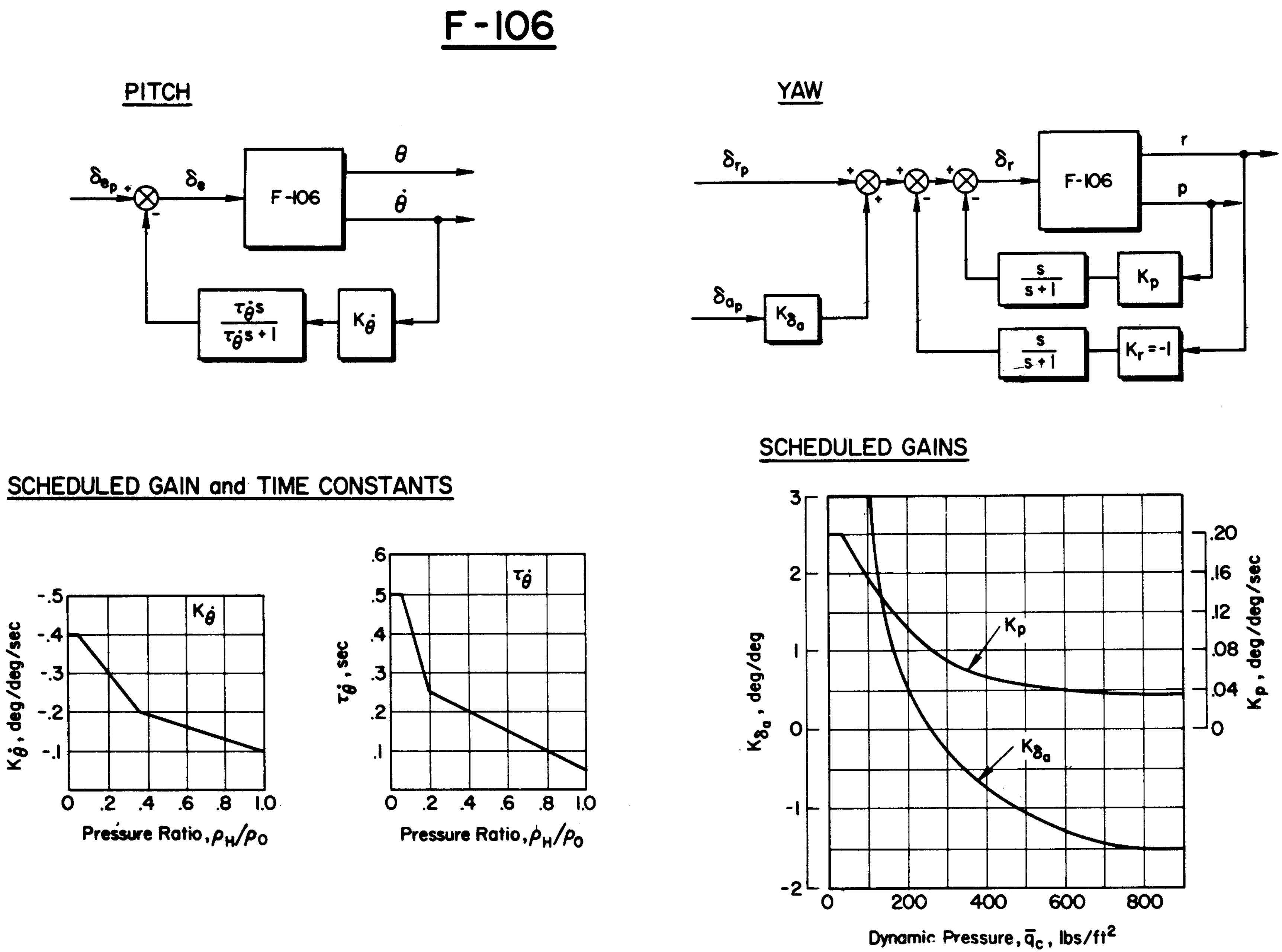


Figure IV-2. F-106 — Stability Augmentation System

TABLE IV-A

GEOMETRICAL PARAMETERS FOR THE F-106B

Note: Data are for body-fixed centerline axes

$S = 695$, $b = 38.13$, $c = 23.755$, cockpit location: $l_x = 17.5$, $l_z = -3.35$

	FLIGHT CONDITION											
	1	2*	3	4	5	6	7	8	9	10	11	12
h (ft)	20,000	20,000	20,000	S.L.	S.L.	20,000	S.L.	20,000	40,000	20,000	40,000	40,000
M (—)	0.755	0.755	0.755	0.2	0.4	0.4	0.9	0.9	0.9	1.4	1.4	2.0
a (ft/sec)	1,037	1,037	1,037	1,116	1,116	1,037	1,116	1,037	968	1,037	968	968
ρ (slugs/ft^3)	0.001267	0.001267	0.001267	0.002377	0.002377	0.001267	0.002377	0.001267	0.000587	0.001267	0.000587	0.000587
V_{T_0} (ft/sec)	785	785	785	223.2	446.4	414	1004.4	933	871	1,450	1,355	1,936
$\bar{q} = \rho V_{T_0}^2/2$ (lb/ft^2)	392	392	392	59.3	237.2	108.6	1,199	551	223	1,332	549	1,100
W (lb)	35,000	30,000	28,000	25,500	29,776	29,776	29,776	29,776	29,776	29,776	29,776	29,776
Mass (slugs)	1,090	931	870	791.9	924.7	924.7	924.7	924.7	924.7	924.7	924.7	924.7
I_x (slug-ft^2)	25,490	18,744	15,809	15,800	18,634	18,634	18,634	18,634	18,634	18,634	18,634	18,634
I_y (slug-ft^2)	195,156	185,300	177,645	160,783	177,858	177,858	177,858	177,858	177,858	177,858	177,858	177,858
I_z (slug-ft^2)	215,262	198,707	187,115	170,301	191,236	191,236	191,236	191,236	191,236	191,236	191,236	191,236
I_{xz} (slug-ft^2)	4947.1	5310.9	6015.4	5,727	5,539	5,539	5,539	5,539	5,539	5,539	5,539	5,539
x_{CG}/c	0.29	0.305	0.26	0.305	0.305	0.305	0.305	0.305	0.305	0.305	0.305	0.305
α_0 (deg)	4.42	4.04	3.88	18.0	4.9	11.0	2.0	2.7	5.4	1.2	2.70	1.2
γ_0 (deg)	0	0	0	0	0	0	0	0	0	0	0	0
θ_0 (deg)	4.42	4.04	3.88	18.0	4.9	11.0	2.0	2.7	5.4	1.2	2.7	1.2
U_0 (ft/sec)	784	784	784	212	445	406	1,004	933	868	1,450	1,355	1,936
W_0 (ft/sec)	60.6	55.4	53.1	73	40	80	36	44	82	30	64	40

*Optimum design condition

TABLE IV-B

LATERAL DIMENSIONAL DERIVATIVES FOR THE F-106B

Note: Data are for body-fixed centerline axes
Static aeroelastic corrections are included

	FLIGHT CONDITION											
	1	2	3	4	5	6	7	8	9	10	11	12
h	20,000	20,000	20,000	S.L.	S.L.	20,000	S.L.	20,000	40,000	20,000	40,000	40,000
M	0.755	0.755	0.755	0.2	0.4	0.4	0.9	0.9	0.9	1.4	1.4	2.0
Y_v	-0.207	-0.239	-0.259	-0.126	-0.237	-0.109	-0.561	-0.277	-0.112	-0.423	-0.182	-0.217
$Y^*_{\delta_a}$	0.0799	0.0926	0.100	0.0492	0.0865	0.0443	0.175	0.108	0.0523	0.0470	0.0287	0.0128
$Y^*_{\delta_r}$	0.0347	0.0402	0.0435	0.0280	0.0438	0.0225	0.0669	0.0392	0.0185	0.0235	0.00898	0.00940
L'_β	-6.61	-8.78	-10.1	-20.0	-22.3	-19.2	-51.2	-27.6	-18.9	-116	-55.1	-60.5
L'_p	-1.69	-2.30	-2.74	-1.22	-2.35	-1.08	-5.14	-1.89	-1.23	-4.25	-2.05	-2.69
L'_r	1.22	1.64	1.91	3.51	2.86	2.12	4.56	2.59	1.60	2.63	1.36	2.65
L'_{δ_r}	7.06	9.51	11.1	2.08	6.17	2.97	19.5	11.1	5.07	7.31	4.18	5.23
L'_{δ_a}	-44.7	-61.1	-73.0	-13.3	-39.1	-19.5	-105	-71.2	-34.7	-36.4	-26.2	-26.1
N'_β	5.07	5.42	5.68	-0.192	2.17	0.506	16.0	7.50	2.79	18.9	7.78	11.1
N'_p	-0.0307	-0.0527	-0.0787	-0.0351	-0.0582	-0.0261	-0.135	-0.0442	-0.0301	-0.113	-0.0512	-0.0684
N'_r	-0.472	-0.498	-0.513	-0.199	-0.472	-0.218	-1.27	-0.627	-0.263	-0.823	-0.364	-0.376
N'_{δ_r}	-2.55	-2.68	-2.75	-0.505	-1.63	-0.792	-6.16	-3.28	-1.44	-2.90	-1.45	-1.91
N'_{δ_a}	-5.09	-6.03	-7.01	-1.12	-3.51	-1.69	-15.4	-9.34	-3.85	-7.54	-4.59	-3.64

TABLE IV-C

AILERON LATERAL TRANSFER FUNCTION FACTORS FOR BASIC F-106B

		Flight Condition											
		1	2	3	4	5	6	7	8	9	10	11	12
Mach No., M		0.755	0.755	0.755	0.2	0.4	0.4	0.9	0.9	0.9	1.4	1.4	2.0
Altitude, h		20,000	20,000	20,000	S.L.	S.L.	20,000	S.L.	20,000	40,000	20,000	40,000	40,000
C G		29	30.5	26	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5
Weight		35,000	30,000	28,000	25,500	29,776	29,776	29,776	29,776	29,776	29,776	29,776	29,776
α_c, deg		4.42	4.04	3.88	18.0	4.9	11.0	2.0	2.7	5.4	1.2	2.7	1.2
Δ_{lat}	$1/T_s$	-0.0170	-0.0166	-0.0164	0.169	0.032	0.080	-0.004	-0.006	0.001	0.010	0.010	-0.003
	$1/T_R$	1.60	2.19	2.62	0.592	2.09	0.678	5.03	1.84	1.05	4.39	1.97	2.76
	ω_D	2.37	2.47	2.54	2.42	2.01	2.00	4.34	3.01	2.12	4.73	3.22	3.57
	ζ_D	0.164	0.175	0.178	0.162	0.233	0.162	0.224	0.159	0.129	0.116	0.095	0.074
p/δ_a	A_{p_a}	-44.7	-61.1	-73.0	-13.3	-39.1	-19.5	-105	-71.2	-34.7	-36.4	-26.2	-26.1
	$1/T_{p_a}$	-0.00310	-0.00282	-0.00270	-0.041	-0.006	-0.014	-0.001	-0.002	-0.003	-0.0005	-0.001	-0.0003
	ω_{p_a}	2.44	2.53	2.61	1.24	2.08	1.48	4.96	3.37	2.22	6.59	4.19	4.43
	ζ_{p_a}	0.171	0.181	0.186	0.298	0.245	0.192	0.260	0.191	0.132	0.147	0.101	0.112
φ/δ_a	A_{φ_a}	-45.1	-61.5	-73.5	-13.6	-39.4	-19.8	-106	-71.7	-35.0	-36.6	-26.4	-26.2
	ω_{φ_a}	2.43	2.53	2.61	1.27	2.08	1.49	4.95	3.37	2.22	6.58	4.18	4.43
	ζ_{φ_a}	0.172	0.182	0.188	0.277	0.245	0.188	0.262	0.191	0.132	0.148	0.102	0.112
r/δ_a	A_{r_a}	-5.09	-6.03	-7.01	-1.12	-3.51	-1.69	-15.4	-9.34	-3.85	-7.54	-4.59	-3.64
	$1/T_{r_a}$	0.591	0.672	0.716	0.430	0.949	0.406	2.64	0.837	0.411	2.68	0.569	1.26
	ω_{r_a}	1.88	1.97	1.99	2.32	1.87	2.15	1.40	1.87	1.98	1.31	2.04	1.36
	ζ_{r_a}	0.254	0.318	0.348	0.110	0.250	0.109	0.700	0.242	0.157	0.506	0.324	0.410
β/δ_a	A_{β_a}	0.0799	0.0926	0.100	0.049	0.086	0.044	0.175	0.108	0.052	0.047	0.029	0.013
	$1/T_{\beta_{a1}}$	-0.295	-0.281	-0.271	-61.7	-1.57	-45.4	-0.116	-0.231	-0.445	-0.042	-0.006	-0.045
	$1/T_{\beta_{a2}} (\omega_{\beta_a})$	2.35	3.56	3.83	(0.543)	(3.91)	(0.548)	4.78	1.70	2.26	3.88	2.05	2.35
	$1/T_{\beta_{a3}} (\zeta_{\beta_a})$	20.6	18.0	20.3	(0.898)	(0.580)	(0.759)	67.9	56.3	10.8	145	117	243
a_y/δ_a (CG)	A_{a_a}	62.9	72.9	78.9	11.6	38.8	18.7	176	101	45.8	68.3	39.0	24.8
	$1/T_{a_{a1}} (\omega_{a_a})_1$	(1.79)	(2.19)	(2.40)	(3.68)	(1.59)	(2.97)	-0.243	-0.729	(1.64)	-0.079	-0.115	-0.061
	$1/T_{a_{a2}} (\zeta_{a_a})_1$	(0.792)	(0.819)	(0.881)	(0.073)	(0.828)	(0.0837)	6.07	1.52	(0.184)	3.38	2.19	2.17
	$1/T_{a_{a3}} (\omega_{a_a})_2$	(0.935)	(0.925)	(0.950)	(0.461)	(1.54)	(0.440)	-3.47	-1.63	(0.677)	-5.62	-3.07	-5.93
	$1/T_{a_{a4}} (\zeta_{a_a})_2$	(-0.358)	(-0.427)	(-0.511)	(0.959)	(0.0622)	(0.910)	4.05	3.35	(0.657)	7.39	3.41	6.88
a'_y/δ_a (cockpit)	A'_{a_a}	-176	-237	-288	-52.5	-154	-76.1	-446	-301	-138	-186	-129	-126
	$1/T'_{a_{a1}}$	-0.324	-0.336	-0.337	-1.12	-0.589	-0.719	-0.197	-0.275	-0.291	-0.071	-0.083	-0.055
	$1/T'_{a_{a2}}$	0.481	0.551	0.584	0.334	0.574	0.289	1.51	0.567	0.277	1.28	0.536	0.859
	$\omega'_{a_{a2}}$	2.53	2.61	2.69	1.30	2.11	1.42	5.25	3.60	2.25	6.66	4.22	4.75
	$\zeta'_{a_{a2}}$	0.110	0.109	0.108	0.541	0.219	0.326	0.093	0.115	0.114	0.078	0.067	0.050

TABLE IV-D

RUDDER LATERAL TRANSFER FUNCTION FACTORS FOR BASIC F-106B

		Flight Condition											
		1	2	3	4	5	6	7	8	9	10	11	12
Mach No., M		0.755	0.755	0.755	0.2	0.4	0.4	0.9	0.9	0.9	1.4	1.4	2.0
Altitude, h		20,000	20,000	20,000	S.L.	S.L.	20,000	S.L.	20,000	20,000	20,000	40,000	40,000
C G		29	30.5	26	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5
Weight		35,000	30,000	20,000	25,500	29,776	29,776	29,776	29,776	29,776	29,776	29,776	29,776
q, lb/ft^2		392	392	392	59	237	109	1,199	551	223	1,332	549	1,100
Δ_{lat}	$1/T_s$	-0.0170	-0.0166	-0.0164	0.169	0.032	0.080	-0.004	-0.006	0.001	0.010	0.010	-0.003
	$1/T_R$	1.60	2.19	2.62	0.592	2.09	0.678	5.03	1.84	1.05	4.39	1.97	2.76
	ω_D	2.37	2.47	2.54	2.42	2.01	2.00	4.34	3.01	2.12	4.73	3.22	3.57
	ζ_D	0.164	0.175	0.178	0.162	0.233	0.162	0.224	0.159	0.129	0.116	0.095	0.074
p/δ_r	A_{p_r}	7.06	9.51	11.1	2.08	6.17	2.97	19.5	11.1	5.07	7.31	4.18	5.23
	$1/T_{p_{r1}}$	-0.00314	-0.00286	-0.00275	-0.043	-0.006	-0.015	-0.351	-0.782	-0.003	-0.0005	-0.001	-0.0003
	$1/T_{p_{r2}}(\omega_{p_r})$	(1.64)	(1.72)	(1.79)	1.88	1.85	1.97	-0.001	-0.002	1.54	5.13	3.35	3.10
	$1/T_{p_{r3}}(\zeta_{p_r})$	(0.0633)	(0.0701)	(0.0736)	-2.64	-2.05	-2.34	0.565	0.829	-1.69	-5.29	-3.40	-3.58
φ/δ_r	A_{φ_r}	6.86	9.32	10.9	1.92	6.03	2.81	19.3	11.0	4.94	7.25	4.11	5.19
	$1/T_{\varphi_{r1}}(\omega_{\varphi_r})$	(1.67)	(1.74)	(1.81)	-2.98	-2.12	-2.49	-0.406	-0.808	-1.74	-5.34	-3.45	-3.61
	$1/T_{\varphi_{r2}}(\zeta_{\varphi_r})$	(0.0468)	(0.0545)	(0.0582)	1.99	1.85	2.02	0.555	0.823	1.55	5.13	3.37	3.10
r/δ_r	A_{r_r}	-2.55	-2.68	-2.75	-0.505	-1.63	-0.792	-6.16	-3.28	-1.44	-2.90	-1.45	-1.91
	$1/T_{r_{r1}}$	-0.436	-0.431	-0.427	0.442	2.18	0.430	5.57	2.00	0.735	4.28	1.43	2.71
	$\omega_{r_r}(1/T_{r_{r2}})$	(0.349)	(0.365)	(0.375)	2.48	0.680	1.74	(0.383)	0.190	0.674	0.592	.736	0.430
	$\zeta_{r_r}(1/T_{r_{r3}})$	(2.00)	(2.71)	(3.28	0.214	0.415	0.243	(0.0062)	0.582	0.502	0.435	.610	0.384
β/δ_r	A_{β_r}	0.0347	0.0402	0.0435	0.028	0.0438	0.023	0.067	0.039	0.019	0.024	0.009	0.009
	$1/T_{\beta_{r1}}$	-0.00111	-0.000727	-0.000530	-0.259	-0.033	-0.086	-0.004	-0.009	-0.021	-0.003	-0.004	-0.010
	$1/T_{\beta_{r2}}$	1.56	2.11	2.53	0.690	2.07	0.780	5.08	1.85	1.07	4.36	1.98	2.74
	$1/T_{\beta_{r3}}$	89.5	83.8	81.1	41.3	50.4	60.0	104	97.8	103	130	184	215
a_y/δ_r (C G)	A_{a_r}	27.3	31.6	34.2	6.57	19.6	9.52	67.2	36.6	16.2	34.1	12.2	18.2
	$1/T_{a_{r1}}(\omega_{a_r})_1$	0.00614	0.00656	0.00679	(1.02)	-0.067	-0.333	-0.004	-0.010	-0.034	-0.012	-0.011	-0.012
	$1/T_{a_{r2}}(\zeta_{a_r})_1$	1.53	2.04	2.44	(0.986)	2.05	0.904	6.89	1.85	1.08	4.29	1.99	2.74
	$1/T_{a_{r3}}(\omega_{a_r})_2$	-3.30	-3.41	-3.49	(1.21)	-2.42	-1.16	-5.65	-3.92	-2.44	-5.37	-4.59	-5.65
	$1/T_{a_{r4}}(\zeta_{a_r})_2$	3.92	4.16	4.29	-(0.243)	3.25	1.88	5.17	4.59	2.88	6.16	5.02	5.99
a'_y/δ_r (cockpit)	$A_{a'_r}$	6.40	16.6	23.3	4.71	11.8	5.60	24.9	16.5	8.03	7.89	0.784	2.32
	$1/T_{a'_{r1}}$	0.0646	0.00670	0.00693	-0.300	-0.061	-0.135	-0.004	-0.010	-0.031	-0.012	-0.010	-0.012
	$1/T_{a'_{r2}}$	-8.81	-6.05	-5.56	0.402	-6.36	0.428	-16.1	2.69	0.844	3.35	1.33	2.50
	$(\omega_{a'_{r1}})1/T_{a'_{r3}}$	(3.05)	(2.99)	(3.08)	-5.38	(2.17)	-5.47	(5.81)	-8.13	-5.89	-21.5	-51.0	-34.4
	$(\zeta_{a'_{r1}})1/T_{a'_{r4}}$	(0.890)	(0.730)	(0.663)	-3.26	(0.949)	3.55	(0.703)	3.39	3.35	8.69	10.9	8.54

SECTION V

T-38

Figure V-1

T-38

NOMINAL CRUISE CONFIGURATION

Clean Airplane

W = 9000 lbs

CG at 23% MGC

I_x = 1438 slug-ft^2
I_y = 25,874 slug-ft^2
I_z = 26,779 slug-ft^2
I_{xz} = 0 (assumed)
} Body Ref. Axes

REFERENCE GEOMETRY

S = 170 ft^2

c = 7.73 ft

b = 25.25 ft

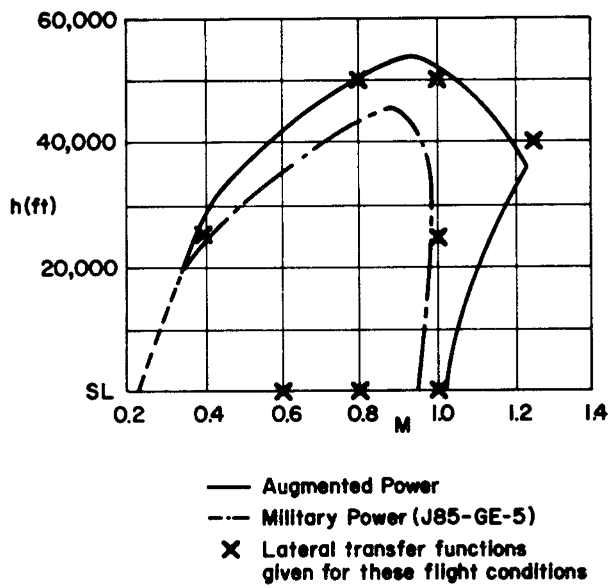
REFERENCES

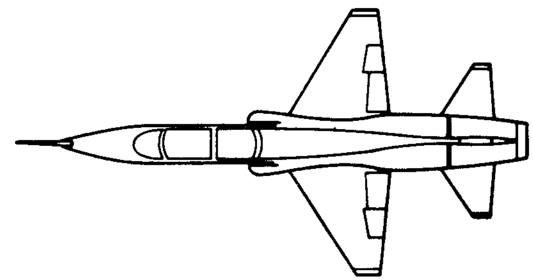
1) T-38 Dynamic Stability, Norair Report NAI 58-704, April 1959

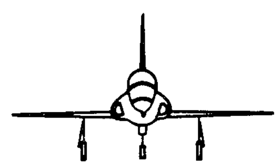
BASIC DATA SOURCES

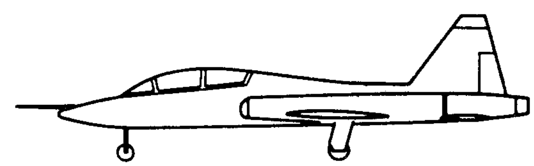
Wind Tunnel Tests

FLIGHT ENVELOPE









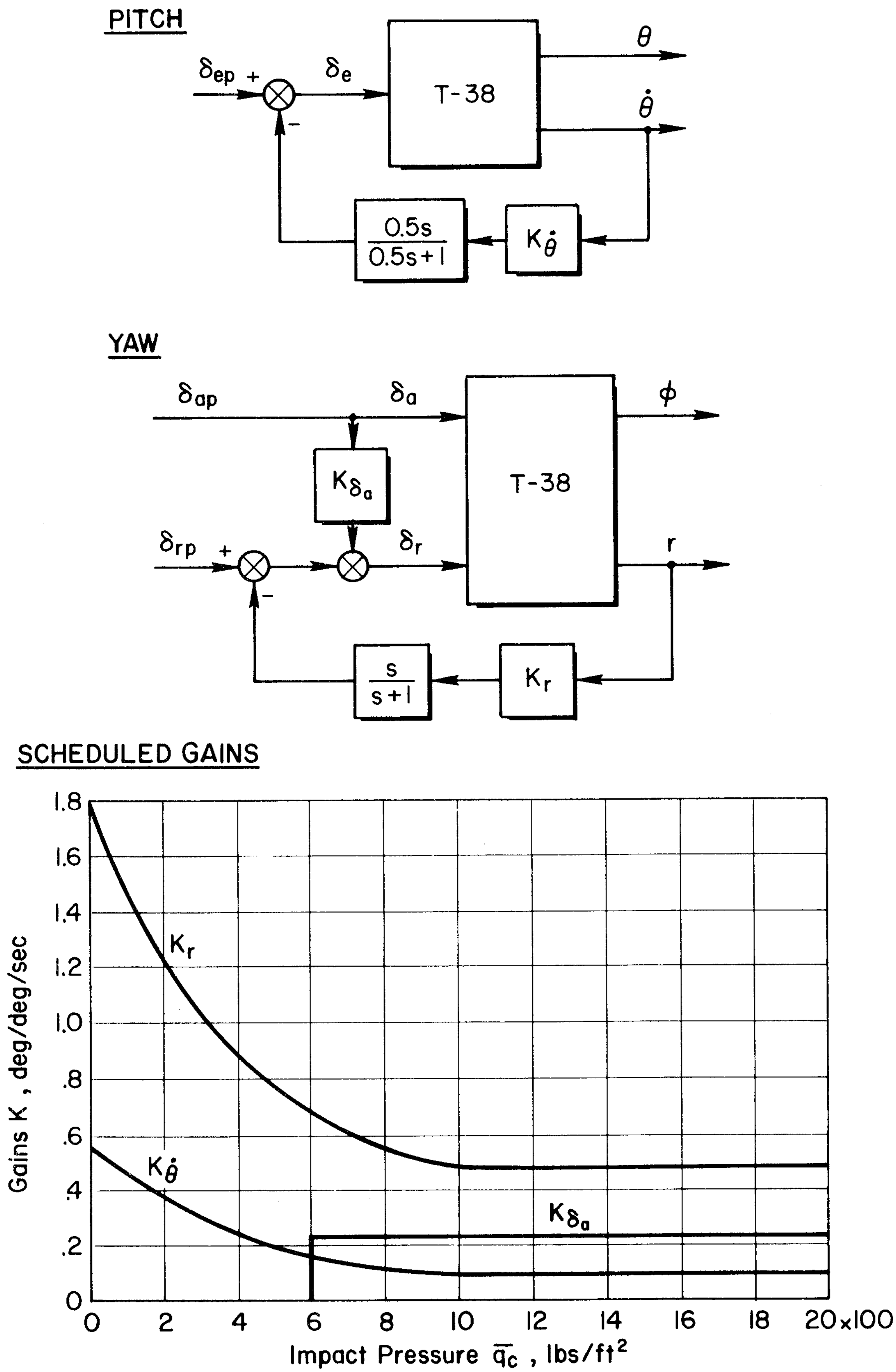


Figure V-2. T-38 — Stability Augmentation System

TABLE V-A

GEOMETRICAL PARAMETERS FOR THE T-38

Note: Data for body-fixed centerline axes, cruise configuration

$S = 170\ ft^2$, $b = 25.25$ ft, $c = 7.73$ ft

$W = 10,000$ lbs, m - 311.0 slugs, c.g. at 23% MAC

$I_x = 4,400\ slug\text{-}ft^2$, $I_y = 30,000\ slug\text{-}ft^2$, $I_z = 34,000\ slug\text{-}ft^2$, $I_{xz} = 0$

	FLIGHT CONDITION							
	1	2	3	4	5	6	7	8
h (ft)	0	0	0	25,000	25,000	50,000	50,000	40,000
M (—)	0.6	0.8	1.0	0.4	1.0	0.8	1.0	1.25
a (ft/sec)	1117	1117	1117	1016	1016	968.5	968.5	968.5
ρ (slug/ft^3)	0.002378	0.002378	0.002378	0.001065	0.001065	0.000367	0.000367	0.000585
V_{T_o} (ft/sec)	670	893	1117	406	1016	774	968.5	1210
$\bar{q} = \rho V_{T_o}^2/2$ (lb/ft^2)	535	950	1482	88	550	109	170	424
α_o (deg)	1.1	0.8	0.6	8.7	1.5	5.0	3.1	1.2
γ_o (deg)	0	0	0	0	0	0	0	0
U_o (ft/sec)	669.8	892.8	1116.8	401.2	1015.7	771.3	965	1209.7
W_o (ft/sec)	12.7	12.5	11.7	61.3	26.6	67.4	52.3	25.3

TABLE V-B

LATERAL NONDIMENSIONAL STABILITY DERIVATIVES FOR THE T-38

Note: Data are for body fixed centerline axes, cruise configuration

	FLIGHT CONDITION							
	1	2	3	4	5	6	7	8
h (ft)	0	0	0	25,000	25,000	50,000	50,000	40,000
M (–)	0.6	0.8	1.0	0.4	1.0	0.8	1.0	1.25
V_{T_o} (ft/sec)	670	893	1117	406	1017	774	968	1210
C_{y_β}	–0.715	–1.27	–1.35	–1.26	–1.35	–1.26	–1.41	–1.20
$C_{y_{\delta_a}}$	0	0	0	0	0	0	0	0
$C_{y_{\delta_r}}$	0.155	0.172	0.103	0.160	0.132	0.183	0.126	0.097
C_{ℓ_β}	–0.057	–0.063	–0.085	–0.097	–0.086	–0.086	–0.080	–0.052
C_{ℓ_p}	–0.320	–0.330	–0.275	–0.270	–0.365	–0.335	–0.390	–0.295
C_{ℓ_r}	0.080	0.095	0.110	0.155	0.115	0.140	0.135	0.130
$C_{\ell_{\delta_a}}$	0.037	0.030	0.0069	0.040	0.026	0.053	0.032	0.019
$C_{\ell_{\delta_r}}$	0.016	0.018	0.012	0.017	0.015	0.021	0.016	0.0103
C_{n_β}	0.262	0.315	0.332	0.240	0.335	0.286	0.340	0.310
C_{n_p}	0.076	0.078	0.084	0.085	0.078	0.052	0.070	0.076
C_{n_r}	–0.470	–0.435	–0.490	–0.340	–0.490	–0.380	–0.500	–0.53
$C_{n_{\delta_a}}$	0.013	0.0143	0.0126	0.0069	0.0126	0.0149	0.0137	0.0149
$C_{n_{\delta_r}}$	–0.092	–0.092	–0.063	–0.103	–0.086	–0.106	–0.086	–0.060

TABLE V-C

LATERAL DIMENSIONAL DERIVATIVES FOR THE T-38

Note: Data are for body-fixed centerline axes, cruise configuration

	FLIGHT CONDITION							
	1	2	3	4	5	6	7	8
h (ft)	0	0	0	25,000	25,000	50,000	50,000	40,000
M (–)	0.6	0.8	1.0	0.4	1.0	0.8	1.0	1.25
Y_v	–0.311	–0.737	–0.98	–0.151	–0.4	–0.0982	–0.137	–0.232
$Y^*_{\delta_a}$	0	0	0	0	0	0	0	0
$Y^*_{\delta_r}$	0.0675	0.1	0.075	0.191	0.0391	0.0143	0.0122	0.0188
L'_β	–29.69	–58.29	–123.03	–8.491	–46.24	–9.293	–13.46	–21.73
L'_p	–3.14	–4.316	–4.5	–0.727	–2.435	–0.588	–0.8544	–1.286
L'_r	0.785	1.242	1.8	0.417	0.767	0.246	0.296	0.567
L'_{δ_a}	19.27	27.75	9.987	3.503	13.98	5.727	5.383	7.941
L'_{δ_r}	8.334	16.65	17.37	1.489	8.065	2.269	2.691	4.305
N'_β	17.65	37.71	62.18	2.72	23.31	4.0	7.402	16.77
N'_p	0.0965	0.132	0.178	0.296	0.0673	0.0118	0.0198	0.0429
N'_r	–0.597	–0.736	–1.037	–0.1185	–0.423	–0.086	–0.142	–0.30
N'_{δ_a}	0.876	1.712	2.36	0.0782	0.877	0.2084	0.298	0.806
N'_{δ_r}	–6.2	–11.01	–11.8	–1.167	–5.984	–1.482	–1.872	–3.245

TABLE V-D

AILERON LATERAL TRANSFER FUNCTION FACTORS FOR THE T-38

Note: Data for body-fixed centerline axes, cruise configuration

		FLIGHT CONDITION							
		1	2	3	4	5	6	7	8
h		0	0	0	25,000	25,000	50,000	50,000	40,000
M		0.6	0.8	1.0	0.4	1.0	0.8	1.0	1.25
Δ	$1/T_s$	0.0025	–0.0014	0.00141	–0.013	0.00016	–0.00594	–0.0031	–0.0043
	$1/T_R$	3.0197	4.145	4.185	0.605	2.275	0.548	0.803	1.236
	ζ_d	0.121	0.133	0.146	0.102	0.1	0.0527	0.0585	0.0705
	ω_d	4.251	6.2	7.97	1.98	4.94	2.187	2.847	4.151
$N^p_{\delta_a}$	A_p	19.273	27.75	10.0	3.50	13.98	5.727	5.383	7.941
	$1/T_{p_1}$	–0.00091	–0.0005	–0.0003	–0.012	–0.00082	–0.00362	–0.0018	–0.000554
	ζ_p	0.108	0.12	0.127	0.0852	0.085	0.0473	0.052	0.0675
	ω_p	4.382	6.473	9.628	1.703	5.137	2.081	2.856	4.365
$N^\varphi_{\delta_a}$	A_φ	19.29	27.78	10.01	3.515	14.0	5.745	5.4	7.96
	$1/T_{\varphi_1}$ (ζ_φ)	(0.108)	(0.12)	(0.127)	(0.0829)	(0.0853)	(0.047)	(0.0522)	(0.068)
	$1/T_{\varphi_2}$ (ω_φ)	(4.381)	(6.471)	(9.617)	(1.719)	(5.135)	(2.086)	(2.856)	(4.361)
$N^r_{\delta_a}$	A_r	0.876	1.712	2.36	0.782	0.877	0.2084	0.298	0.806
	$1/T_r$	4.439	5.405	4.80	0.535	1.52	0.484	0.638	1.401
	ζ_r	0.267	0.423	0.47	0.192	0.405	0.0827	0.129	0.143
	ω_r	2.127	2.113	1.523	4.345	2.95	3.19	2.765	1.884
$N^\beta_{\delta_a}$	A_β	–0.511	–1.323	–2.255	0.446	–0.511	0.289	–0.0074	–0.64
	$1/T_{\beta_1}$ (ζ_β)	–0.167	–0.0832	–0.0353	(0.706)	–0.0843	(0.58)	–0.21	–0.066
	$1/T_{\beta_2}$ (ω_β)	6.926	7.439	5.334	(0.287)	4.90	(0.283)	18.624	1.795
	$1/T_{\beta_3}$	—	—	—	—	—	—	—	—

TABLE V-E

RUDDER LATERAL TRANSFER FUNCTION FACTORS FOR THE T-38

Note: Data are for body-fixed centerline axes, cruise configuration.

		FLIGHT CONDITION							
		1	2	3	4	5	6	7	8
h		0	0	0	25,000	25,000	50,000	50,000	40,000
M		0.6	0.8	1.0	0.4	1.0	0.8	1.0	1.25
Δ	$1/T_s$	0.0025	−0.0014	0.00141	−0.013	0.00016	−0.00594	−0.0031	−0.0043
	$1/T_R$	3.0197	4.145	4.185	0.605	2.275	0.548	0.803	1.236
	ζ_d	0.121	0.133	0.146	0.102	0.1	0.527	0.585	0.0705
	ω_d	4.251	6.2	7.97	1.98	4.94	2.187	2.847	4.151
$N^p_{\delta_r}$	A_p	8.33	16.65	17.37	1.49	8.065	2.27	2.691	4.305
	$1/T_{p_1}$	−0.00092	−0.0005	−0.0003	−0.0119	−0.00082	−0.00361	−0.0018	−0.000583
	$1/T_{p_2}$ (ζ_p)	−2.07	−0.797	−4.522	−2.06	−3.311	−1.454	−1.395	(0.0081)
	$1/T_{p_3}$ (ω_p)	2.154	1.10	4.79	1.905	3.341	1.423	1.408	(0.605)
$N^\varphi_{\delta_r}$	A_φ	8.215	16.5	17.245	1.31	7.91	2.14	2.59	4.237
	$1/T_{\varphi_1}$ (ζ_φ)	−2.11	−0.827	−4.557	−2.293	−3.372	−1.526	−1.443	(−0.0103)
	$1/T_{\varphi_2}$ (ω_φ)	2.15	1.09	4.79	1.994	3.350	1.451	1.42	(0.608)
$N^r_{\delta_r}$	A_r	−6.2	−11.01	−11.8	−1.167	−5.984	−1.482	−1.872	−3.245
	$1/T_{r_1}$	3.0	4.114	4.196	0.561	2.252	0.519	0.78	−0.0571
	ζ_r ($1/T_{r_2}$)	0.206	(0.0302)	0.674	0.14	0.373	0.11	0.196	(0.193)
	ω_r ($1/T_{r_3}$)	0.309	(0.367)	0.465	0.833	0.456	0.502	0.346	(1.23)
$N^\beta_{\delta_r}$	A_β	0.067	0.0998	0.0748	0.0191	0.0391	0.0143	0.0122	0.188
	$1/T_{\beta_1}$	−0.00063	−0.0016	−0.00212	−0.0372	−0.0034	−0.0107	−0.0052	−0.0041
	$1/T_{\beta_2}$	2.994	4.075	4.205	0.655	2.302	0.558	0.810	1.23
	$1/T_{\beta_3}$	94.93	113.63	161.56	72.21	159.0	117.48	164.64	178.02
$N^{a_y}_{\delta_r}$ CG	A_{a_y}	45.24	89.16	83.53	7.852	39.77	11.08	11.88	22.72
	$1/T_{a_{y_1}}$	−0.0057	−0.0018	−0.00447	−0.0496	−0.00561	−0.014	−0.0063	−0.00398
	$1/T_{a_{y_2}}$	3.89	3.795	4.223	0.683	2.322	0.565	0.813	1.226
	$1/T_{a_{y_3}}$	−3.027	−6.248	−9.098	−2.525	−5.987	−2.536	−3.709	−4.732
	$1/T_{a_{y_4}}$	2.882	7.327	10.416	2.736	6.529	2.66	3.90	5.096

SECTION VI

F-5A

Figure VI-1

F-5A

CONFIGURATIONS

GAR-8 - GAR-8 on wing tips

I - Centerline Tank
150 gal. tanks at W.S. 85
750 lb. stores at W.S. 114.5
50 gal. tip tanks

I-A - as I with 50% fuel

II - 2000 lb centerline store
1000 lb stores at W.S. 85
750 lb stores at W.S. 114.5
50 gal. tip tanks

REFERENCE GEOMETRY

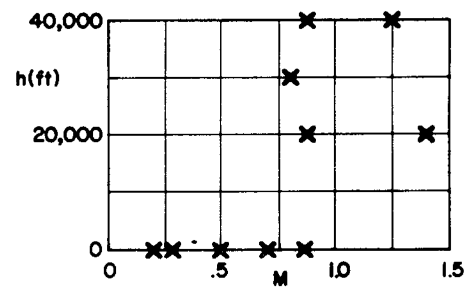
$S = 170\ ft^2$
$b = 25.25\ ft$
$c = 7.75\ ft$

REFERENCE

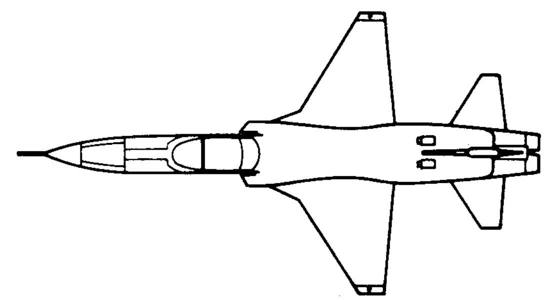
1) Jex, H.R. and J. Nakagawa, Typical F-5A Longitudinal Aerodynamic Data and Transfer Functions for 14 Conditions, Systems Technology, Inc., Technical Memorandum No. 239-4, March 1964

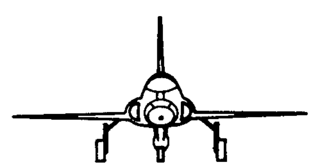
BASIC DATA SOURCES

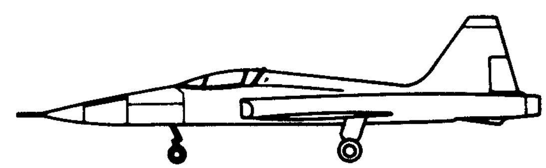
Wind tunnel tests with corrections made per flight test.



✕ Longitudinal data given at these flight conditions, see Table E.5a for configuration, $\overline{n_z}$, and γ_o







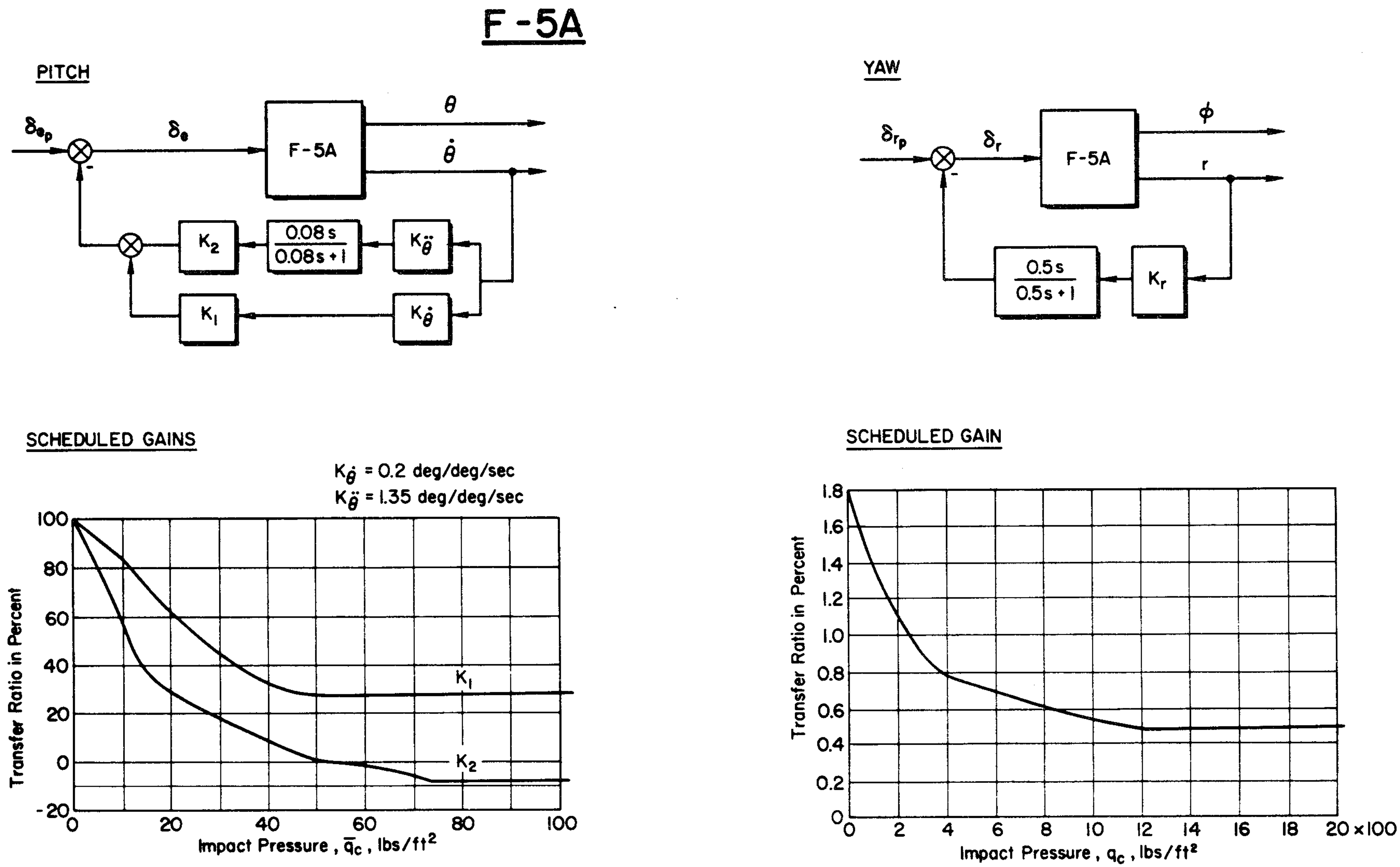


Figure VI-2. F-5A — Stability Augmentation System

TABLE VI-A

GEOMETRICAL PARAMETERS FOR THE F-5A

Note: $S = 170\ ft^2$, $b = 25.25$ ft, $c = 7.73$ ft, $\xi_o = 0.5$ deg

Data are for body-fixed stability axes.

	FLIGHT CONDITION													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Configurations	GAR-8	GAR-8	GAR-8	GAR-8 + Dive Brake	GAR-8 Flaps + Slats	I + Flaps	I	I-A + Dive Brake	MK 84 ℄ + TT Empty	TT Empty	I-A	I-A	II 50% Fuel	II 50% Fuel
h (ft)	40,000	40,000	0	20,000	0	0	30,000	20,000	0	0	0	0	0	0
M	0.875	1.25	0.875	1.40	0.204	0.286	0.8	0.875	0.875	0.875	0.70	0.70	0.50	0.50
γ_o (deg)	0	0	0	-60	0	0	0	-60	0	0	0	0	0	0
$n_z = L/W \cos \gamma_o$	1.0	1.0	1.0	0.5	1.0	1.0	1.0	0.5	1.0	4.0	1.0	4.0	1.0	2.0
α_o (deg)	3.2	1.0	0.8	0	12	12	9.0	2.8	1.2	2.8	2.8	7.0	4.4	8.0
V_{T_o} (ft/sec)	850	1210	980	1450	228	320	796	910	980	980	784	784	560	560
$\bar{q}$ (lb/ft^2)	210	428	1130	1340	61.9	122	282	521	1,130	1,130	725	725	370	370
W (lbs)	10,000	10,000	10,000	10,000	10,000	19,000	17,000	14,000	14,000	12,000	14,000	14,000	17,000	17,000
$x_{c.g.}/\bar{c}$	0.22	0.22	0.22	0.22	0.22	0.14	0.12	0.15	.03	0.17	0.15	0.15	0.13	0.13
m (slugs)	311	311	311	311	311	590	528	435	435	373	435	435	528	528
δ_{e_o} (deg)	−1.15	−1.80	−0.45	1.02	−4.28	−6.26	−2.57	0.52	−1.55	−2.62	−1.13	−4.62	−2.86	−5.77
I_y (slug-ft^2)	30,000	30,000	30,000	30,000	31,000	34,600	34,600	37,900	38,700	37,100	37,900	37,900	34,400	34,400
l_x (Pilot)	12.0	12.0	12.0	12.0	12.0	11.4	11.2	11.4	10.5	11.6	11.4	11.4	11.3	11.3

TABLE VI-B

LONGITUDINAL NONDIMENSIONAL DERIVATIVES FOR THE F-5A

Note: Data are for body-fixed stability axes

	FLIGHT CONDITION													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
CONFIGURATION	GAR-8	GAR-8	GAR-8	GAR-8 + Dive Brake	GAR-8 Flaps + Slats	I + Flaps	I	I-A + Dive Brake	MK 84 ℄ + TT Empty	TT Empty	I-A 50% Fuel	I-A	II 50% Fuel	II 50% Fuel
h (ft)	40,000	40,000	0	20,000	0	0	30,000	20,000	0	0	0	0	0	0
M	0.875	1.25	0.875	1.40	0.204	0.286	0.8	0.875	0.875	0.875	0.70	0.70	0.50	0.50
γ_o (deg)	0	0	0	−60	0	0	0	−60	0	0	0	0	0	0
C_L	0.280	0.132	0.052	0.022	0.95	0.92	0.355	0.079	0.072	0.248	0.113	0.452	0.27	0.54
C_D	0.0279	0.0451	0.0178	0.0540	0.180	0.180	0.0422	0.0272	0.0191	0.0234	0.0232	0.0411	0.0347	0.0588
α_o (deg)	3.2	1.0	0.8	0	12	12	9.0	2.8	1.2	2.8	2.8	7.0	4.4	8.0
δ_{e_o} (deg)	−1.15	−1.80	−0.45	1.02	−4.28	−6.26	−2.57	0.52	−1.55	−2.62	−1.13	−4.62	−2.86	−5.77
C_{L_α} (1/rad)	5.38	5.38	5.38	4.35	3.32	3.84	4.58	4.81	4.06	4.18	4.75	4.41	4.75	3.84
C_{L_q} (1/rad)	7.8	5.5	7.8	3.8	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
C_{L_M}	0.40	−0.70	0.40	−0.6	0	0	−0.25	0.40	0	−0.50	0	0	0	0
$C_{L_{\delta_e}}$ (1/rad)*	1.03	0.745	0.888	0.602	0.745	0.802	0.888	0.888	0.916	0.916	0.831	0.831	0.831	0.831
C_{D_α} (1/rad)	0.339	1.97	0.0362	−0.0195	1.37	1.20	0.352	0.0268	0.0232	0.196	0.0640	0.406	0.264	0.472
C_{D_q} (1/rad)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C_{D_M}	0.0450	0	0.030	0	0	0	0.100	0.030	0.030	0.045	0	0	0	0.050
$C_{D_{\delta_e}}$ (1/rad)	0	0	0	0	0.172	0.172	0	0	0	0	0	0	0	0
C_{m_o}	0.000902	0.00146	0.000575	0.001745	0.00582	0.0214	0.001695	0.00651	0.001235	0.0001756	0.00225	0.00398	0.0525	0.00890
C_{m_α} (1/rad)**	−0.367	−1.46	−0.367	−1.47	−0.745	−0.974	−0.691	−0.481	−1.03	−0.618	−0.539	−0.630	−0.686	−0.670
$C_{m_{\dot\alpha}}$ (1/rad)	−1.2	3	−0.7	2.30	−0.005	−0.005	−0.50	−1.0	−0.7	−0.7	−0.10	−0.10	−0.10	−0.10
C_{m_q} (1/rad)*	−10.2	−9	−9.7	−6.9	−6.8	−6.8	−9.5	−11.5	−9.7	−9.7	−7.8	−7.8	−6.8	−6.8
C_{m_M}	−0.050	−0.100	0	−0.010	0	0	0.020	−0.270	−0.300	0.16	0	0	0	0
$C_{m_{\delta_e}}$ (1/rad)*	−1.55	−1.29	−1.46	−1.08	−1.26	−1.20	−1.39	−1.44	−1.54	−1.54	−1.24	−1.24	−1.20	−1.20
$\partial T/\partial M$ (lbs)	600	3500	−2000	1250	−1470	−950	1400	0	−2000	−2000	−1150	−550	−2000	−950

*Derivatives take into account the elastic mode at 0.25c.

**Corrected for c.g. shift.

TABLE VI-C

LONGITUDINAL DIMENSIONAL DERIVATIVES FOR THE F-5A

Note: Data are for body-fixed stability axes, quasi-steady aeroelastic corrections included.

	FLIGHT CONDITION													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Configurations	GAR-8	GAR-8	GAR-8	GAR-8 + Dive Brake	GAR-8 Flaps +Slats	I + Flaps	I	I-A + Dive Brake	MK 84 ℄ + TT Empty	TT Empty	I-A	I-A	II 50% Fuel	II 50% Fuel
h (ft)	40,000	40,000	0	20,000	0	0	30,000	20,000	0	0	0	0	0	0
M	0.875	1.25	.875	1.40	0.204	0.286	0.8	0.875	0.875	0.875	0.70	0.70	0.50	0.50
X_w (1/sec)	-0.00803	-0.0126	0.0101	0.0209	-0.0609	-0.0301	0.000338	0.0117	0.0222	0.0276	0.0178	0.0167	0.00128	0.0144
X_u^* (1/sec)	-0.0109	-0.00589	-0.0452	-0.0505	0.0564	-0.0401	-0.0158	-0.0362	-0.0335	-0.0505	-0.0192	-0.0309	-0.0182	-0.0319
Z_w (1/sec)	-0.734	-1.05	-3.44	-2.22	-0.508	-0.431	-0.521	-1.10	-1.86	-2.23	-1.74	-1.61	-1.02	-0.828
Z_u^* (1/sec)	-0.124	0.118	-0.289	0.401	-0.276	-0.197	-0.0575	-0.114	-0.0656	-0.0310	-0.0822	-0.327	-0.115	-0.229
Z_{δ_e} (ft/sec²/rad)	-119	-175	-555	-439	-24.1	-26.9	-78.6	-181	-409	-475	-236	-235	-99.1	-97.7
M_w (1/sec-ft)	-0.00399	-0.0227	-0.0187	-0.0593	-0.00838	-0.0138	-0.00852	-0.00961	-0.0408	-0.0253	-0.0174	-0.0202	-0.0174	-0.0169
$M_{\dot{w}}$ (1/ft)	-0.0000595	0.000149	-0.000141	0.000247	0	0	-0.0000327	-0.0000851	-0.000109	-0.000114	-0.0000159	-0.0000159	-0.0000176	-0.0000176
M_q (1/sec)	-0.429	-0.540	-1.92	-1.08	-0.296	-0.372	-0.488	-0.888	-1.48	-1.55	-0.973	-0.969	-0.667	-0.662
M_u^* (1/sec-ft)	-0.000462	-0.00193	0.0000737	-0.000534	0.000142	0.000626	0.000325	-0.00499	-0.0103	0.00585	0.000166	0.000266	0.000327	0.000477
M_{δ_e} (1/sec²/rad)	-14.3	-24.2	-73.1	-63.2	-3.16	-5.31	-14.5	-26.1	-59.8	-62.1	-31.3	-31.0	-17.0	-16.7

Note: The transfer functions given in Table E.5c) are based on the above derivatives and the equations of Appendix C with additional corrections made for Inertial Bending as follows:

$$(\omega_{sp}^2)_{IB} = \frac{(\omega_{sp}^2)_R + U_o K_{a_z}(Z_\delta M_w - Z_w M_\delta)}{1 - K_{a_z} Z_\delta}$$

$$(\text{First coefficient})_{IB} = \frac{1}{(1 - K_{a_z} Z_\delta)} \cdot (\text{first coefficient})_R \qquad K_{a_z} = -0.000162 \text{ rad/ft/sec}^2$$

$$(\text{DC gain})_{IB} = \frac{(\omega_{sp}^2)_R}{(\omega_{sp}^2)_{IB}} \cdot \frac{1}{(1 - K_{a_z} Z_\delta)} \cdot (\text{DC gain})_R$$

where subscript IB ≡ corrected value

R ≡ rigid-body + quasi-steady aeroelastic corrections

TABLE VI-D

LONGITUDINAL TRANSFER FUNCTIONS FOR THE F-5A

Note: Data are for body-fixed stability axes; corrections have been made for Inertial Bending

		FLIGHT CONDITION													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	h (ft)	40,000	40,000	0	20,000	0	0	30,000	20,000	0	0	0	0	0	0
	M	0.875	1.25	0.875	1.40	0.204	0.286	0.8	0.875	0.875	0.875	0.70	0.70	0.50	0.50
	$\bar{n}_z/\gamma_o$ (deg)	1.0/0	1.0/0	1.0/0	0.5/-60	1.0/0	1.0/0	1.0/0	0.5/-60	1.0/0	4.0/0	1.0/0	4.0/0	1.0/0	2.0/0
	Wt.	10,000	10,000	10,000	10,000	10,000	19,000	17,000	14,000	14,000	12,000	14,000	14,000	17,000	17,000
	C.G	0.22	0.22	0.22	0.22	0.22	0.14	0.12	0.15	0.03	0.17	0.15	0.15	0.13	0.13
Δ	ω_{sp}	2.29	5.84	5.65	11.4	1.43	2.14	2.82	3.78	8.05	7.39	4.81	4.95	3.50	3.36
	ζ_{sp}	0.266	0.121	0.325	0.128	0.286	0.188	0.182	0.270	0.215	0.262	0.283	0.262	0.243	0.223
	ω_p $(1/T_{p_1})$	0.0367	(-0.0721)	0.0856	(-0.0346)	0.197	0.147	0.0553	(-0.0530)	(-0.0964)	0.126	0.0601	0.115	0.0852	0.118
	ζ_p $(1/T_{p_2})$	0.0761	(0.0750)	0.257	(0.104)	0.108	0.142	0.153	(0.116)	(0.128)	0.197	0.157	0.129	0.106	0.132
$N^{\theta}_{\delta_e}$	A_{θ_e}	-14.6	-25.0	-80.4	-68.3	-3.16	-5.31	-14.6	-26.9	-64.0	-67.0	-32.6	-32.2	-17.3	-17.0
	$1/T_{\theta_{e_1}}$	0.0955	0.00778	0.0461	0.0457	0.0170	0.0223	0.0159	0.0371	0.0334	0.0516	0.0202	0.0348	0.0184	0.0367
	$1/T_{\theta_{e_2}}$	0.703	0.885	3.30	1.81	0.484	0.379	0.474	1.03	1.58	2.04	1.60	1.46	0.921	0.724
$N^{u}_{\delta_e}$	A_{u_e}	0.970	2.26	-6.15	-9.91	1.47	0.810	-0.0269	-2.19	-9.74	-14.1	-4.38	-4.06	-0.130	-1.44
	$1/T_{u_{e_1}}$	0.580	0.602	4.72	-1.95	0.312	0.280	0.478	2.91	4.68	9.53	2.79	2.42	0.942	0.969
	$1/T_{u_{e_2}}$	586	523	-294	100	98.6	273	-17,450	-68.6	-71.4	-32.6	-137	-154	-4210	-288
$N^{w}_{\delta_e}$	A_{w_e}	-121	-180	-610	-474	-24.1	-26.9	-79.5	-186	-438	-513	-246	-244	-101	-99.7
	$1/T_{w_{e_1}}$	103	168	131	210	29.5	62.1	146	131	145	129	105	104	96.3	95.6
	ω_{w_e} $(1/T_{w_{e_2}})$	0.0673	(-0.0563)	0.0969	(-0.0338)	0.199	0.143	0.0492	0.0501	(-0.00410)	0.0496	0.0583	0.116	0.0820	0.116
	ζ_{w_e} $(1/T_{w_{e_3}})$	0.0809	(0.0622)	0.233	(0.103)	0.139	0.139	0.161	0.666	(0.0376)	0.509	0.165	0.132	0.111	0.137
$N^{\dot{h}}_{\delta_e}$	A_{h_e}	121	180	610	238	24.1	26.9	79.5	93.4	438	513	246	244	101	99.7
	$1/T_{h_{e_1}}$	0.00309	0.0117	0.0432	0.0680	-0.0718	-0.337	0.0108	0.0661	0.0335	0.0503	0.0180	0.0253	0.0110	0.0180
	$1/T_{h_{e_2}}$	-8.23	-12.0	-19.6	-18.8	-3.39	-4.50	-8.04	-11.0	-14.3	-15.3	-12.4	-11.9	-9.05	-7.98
	$1/T_{h_{e_3}}$	8.72	12.4	21.7	19.6	3.81	4.95	8.56	12.0	15.9	17.0	13.4	12.8	9.73	8.67
$N^{a_z'}_{\delta_e}$ (Pilot)	A'_{z_e}	54.0	120	353	346	13.8	33.6	84.8	119	233	264	125	124	94.6	93.2
	$1/T'_{z_{e_1}}$ $(\omega'_{z_{e_1}})$	0	0	0	0.0177	0	0	0	(0.0338)	0	0	0	0	0	0
	$1/T'_{z_{e_2}}$ $(\zeta'_{z_{e_1}})$	0.00309	0.0117	0.0432	0.0499	-0.0714	-0.0336	0.0108	(0.984)	0.0335	0.0503	0.0180	0.0254	0.0110	0.0180
	ω'_{z_e}	12.8	15.0	27.1	22.7	4.76	4.23	8.03	14.5	20.6	22.5	18.1	17.2	9.70	8.60
	ζ'_{z_e}	0.0476	0.0559	0.101	0.0720	0.0871	0.0505	0.0276	0.0381	0.0379	0.0618	0.0781	0.0699	0.0613	0.0468

SECTION VII

F-104

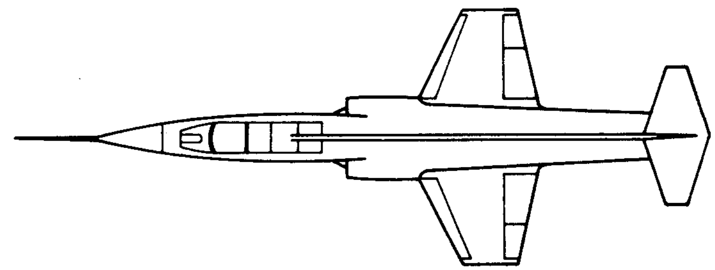
Figure VII-1

F-104

FLIGHT CONDITIONS

		1	2	3	4	5
		Takeoff	Start Cruise	End Cruise	V_{MAX}	V_{MAX} Sea Level
	h(ft)	Sea Level	30,000	30,000	30,000	Sea Level
	M	.273	.84	1.0	1.9	1.36
	W(lb)	24,000	23,310	14,960	15,000	15,000
	x_{CG}/c	.046	.040	.18	.18	.18
External Tanks	Tip	On	On	Clean	Clean	Clean
	Pylon	On	On	Clean	Clean	Clean
Flaps	Leading Edge	-15°	-3°	-3°	-3°	-3°
	Trailing Edge	15°	15°	0°	0°	0°

***Note**: Lateral data not available*

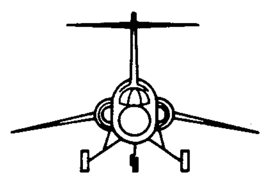


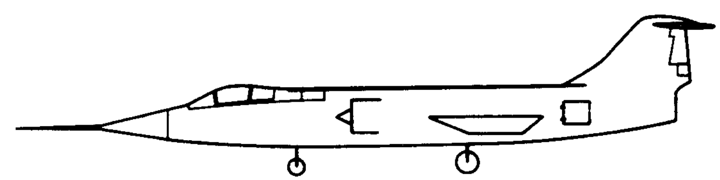
REFERENCE GEOMETRY

$S = 196\ ft^2$

$b = 21.9\ ft$

$c = 9.53\ ft$

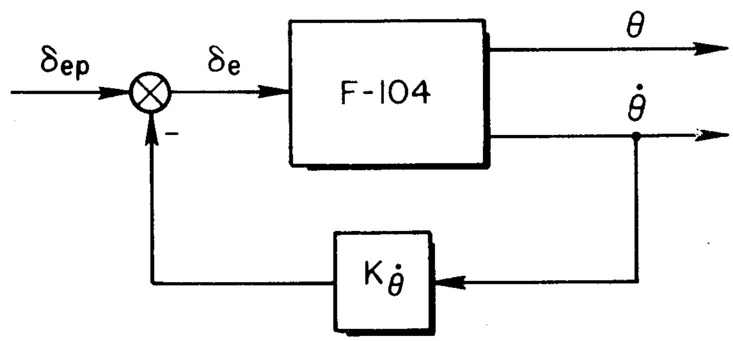




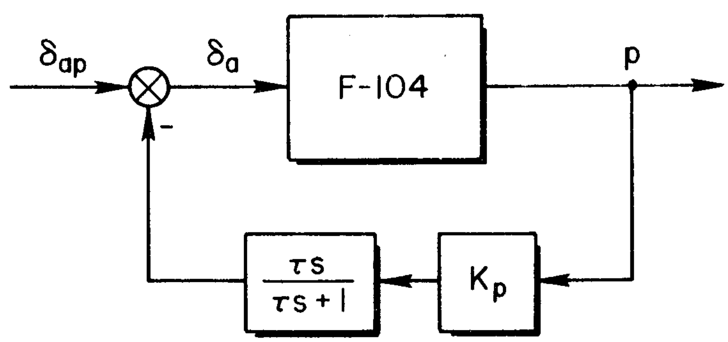
REFERENCES

Unpublished Data

PITCH:



ROLL:



YAW:

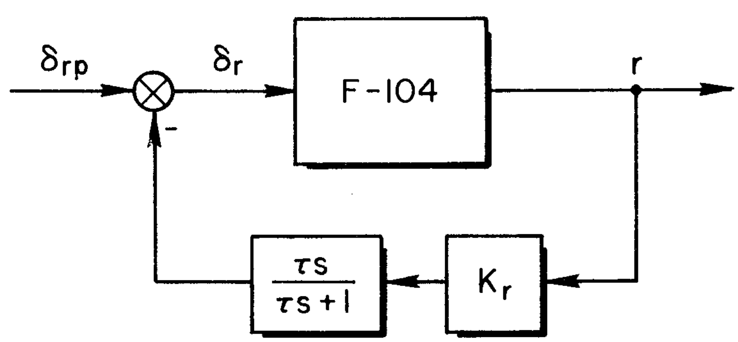


Figure VII-2. F-104 — Stability Augmentation System

TABLE VII-A

GEOMETRICAL AND INERTIAL PARAMETERS FOR THE F-104

Note: Data are for body-fixed stability axes

$S = 196.1\ ft^2$, $c = 9.53$ ft , $b = 21.9$ ft

	FLIGHT CONDITION				
	1 TAKEOFF	2 START CRUISE	3 END CRUISE	4 V_{max}	5 V_{max} SEA LEVEL
h (ft)	Sea Level	30,000	30,000	30,000	Sea Level
M (–)	0.273	0.84	1.0	1.9	1.36
a (ft/sec)	1117	995	995	995	1117
ρ (slugs/ft^3)	0.00238	0.000889	0.000889	0.000889	0.00238
V_{T_o} (ft/sec)	305	836	995	1892	1519
$\bar{q} = \rho V^2/2$ (lb/ft^2)	110.5	310	440	1590	2740
W (lb)	24,000	23,310	14,960	15,000	15,000
m (slugs)	746	724.5	465	466	466
I_y (slug-ft^2)	65,000	64,500	56,650	56,650	56,650
$x_{c.g.}/\bar{c}$	0.046	0.040	0.18	0.18	0.18
α_o (deg)	19.6	4.0	2.0	1.4	1.1
γ_o (deg)	10	0	0	0	0
θ_o (deg)	29.6	4.0	2.0	1.4	1.1

TABLE VII-B

LONGITUDINAL NONDIMENSIONAL DERIVATIVES FOR THE F-104

Note: Data are for body-fixed stability axes.

	FLIGHT CONDITION				
	1	2	3	4	5
h (ft)	0	30,000	30,000	30,000	0
M (–)	0.237	0.84	1.0	1.9	1.36
C_L	1.125	0.342	0.1375	0.0383	0.0278
C_D	0.185	0.0365	0.04	0.041	0.045
C_{L_α}	4.44	4.97	5.10	2.92	4.18
$C_{L_{\dot{\alpha}}}$	0	0	0	0	0
C_{L_M}	0	0	0	0	0
$C_{L_{\delta_e}}$	0.762	1.015	1.071	0.6925	0.8035
C_{D_α}	0	0.1094	0.0255	0	0
C_{D_M}	0	0.038	0.040	0.042	0.045
$C_{D_{\delta_e}}$	0	0	0	0	0
C_{m_α}	–1.496	–1.319	–1.564	–1.255	–1.80
$C_{m_{\dot{\alpha}}}$	–3.44	–3.90	–4.99	–3.04	–2.005
C_{m_M}	0	0	0	0	0
C_{m_q}	–5.615	–8.03	–8.60	–4.59	–6.825

TABLE VII-C

LONGITUDINAL DIMENSIONAL DERIVATIVES FOR THE F-104

Note: Data are for body-fixed stability axes.

	FLIGHT CONDITION				
	1 TAKEOFF	2 START CRUISE	3 END CRUISE	4 V_{max}	5 V_{max} SEA LEVEL
h (ft)	Sea Level	30,000	30,000	30,000	Sea Level
M (–)	0.273	0.84	1.0	1.9	1.36
X_u (1/sec)	–0.0352	–0.0106	–0.0224	–0.0573	–0.115
X_w (1/sec)	0.107	0.0234	0.0209	0.0136	0.0211
X_{δ_e} [(ft/sec^2)/rad]	0	0	0	0	0
Z_u (1/sec)	–0.214	–0.0688	–0.0513	–0.0271	–0.0422
$Z_{\dot{w}}$ (–)	0	0	0	0	0
Z_w (1/sec)	–0.440	–0.504	–0.959	–1.05	–3.21
Z_{δ_e} [(ft/sec^2)/rad]	–22.1	–85.3	–199	–464	–927
M_u (1/sec-ft)	0	0	0	0	0
$M_{\dot{w}}$ (1/ft)	–0.00056	–0.000239	–0.000349	–0.000212	–0.000375
M_w (1/sec-ft)	–0.0156	–0.0142	–0.0228	–0.0348	–0.107
M_q (1/sec)	–0.279	–0.412	–0.598	–0.607	–1.94
M_{δ_e} (1/sec^2)	–4.67	–17.8	–30.8	–57.2	–140

TABLE VII-D

ELEVATOR LONGITUDINAL TRANSFER FUNCTION FACTORS FOR THE F-104

Note: Data are for body-fixed stability axes

		FLIGHT CONDITION				
		1 TAKEOFF	2 START CRUISE	3 END CRUISE	4 V_{max}	5 V_{max} SEA LEVEL
Mach No., M (—)		0.273	0.84	1.0	1.9	1.36
Altitude, h (ft)		Sea Level	30,000	30,000	30,000	Sea Level
CG (% c)		4.6	4.0	18	18	18
Weight, W (lb)		24,000	23,310	14,960	15,000	15,000
Δ_{long}	ζ_{sp}	0.206	0.161	0.197	0.126	0.220
	ω_{sp}	2.21	3.48	4.83	8.16	13.0
	ζ_p $(1/T_{p_1})$	0.0532	0.102	0.277	(0.00959)	(0.00808)
	ω_p $(1/T_{p_2})$	0.145	0.051	0.0402	(0.0477)	(0.107)
$N^{\theta}_{\delta_e}$	A_θ	−4.66	−17.8	−30.7	−57.1	−140
	$1/T_{\theta_1}$	0.133	0.0144	0.0237	0.0578	0.115
	$1/T_{\theta_2}$	0.269	0.432	0.812	0.767	2.51
$N^{u}_{\delta_e}$	A_u	−2.37	−2.00	−4.15	−6.29	−19.6
	$1/T_{u_1}$	−0.0391	1.11	2.26	3.61	24.8
	$1/T_{u_2}$	6.17	−113	−85.7	−62.2	−23.2
$N^{w}_{\delta_e}$	A_w	−22.1	−85.3	−199	−464	−927
	$1/T_{w_1}$	64.7	175	155	234	231
	ζ_w $(1/T_{w_2})$	0.0566	0.102	0.275	(0.00967)	(0.00833)
	ω_w $(1/T_{w_3})$	0.147	0.0514	0.0407	(0.0476)	(0.107)
$N^{\dot{h}}_{\delta_e}$	$A_{\dot{h}}$	21.8	85.3	199	464	927
	$1/T_{\dot{h}_1}$	0.0185	0.00816	0.0217	0.0571	0.115
	$1/T_{\dot{h}_2}$	5.21	9.03	11.7	13.9	25.2
	$1/T_{\dot{h}_3}$	−4.76	−8.41	−10.7	−12.9	−22.7

SECTION VIII

F-105B

Preceding page blank

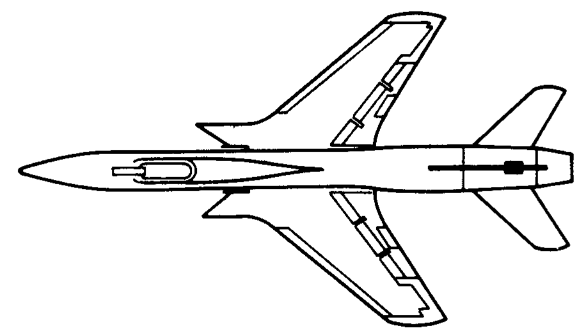
Figure VIII-1

F-105B

FLIGHT CONDITIONS

		1*	2*	3	4	5
		Takeoff	Start Cruise	End Cruise	Power Approach	V_{MAX}
	h (ft)	Sea Level	35,000	35,000	Sea Level	40,000
	M	.261	.9	.9	.241	2.1
	W(lb)	41,230	41,230	35,370	30,000	35,370
	x_{CG}/c	.295	.295	.308	.308	.308
External Tanks	Centerline	1-650gal.	1-650gal.	Clean	Clean	Clean
	Wing Pylon	2-450gal.	2-450gal.	Clean	Clean	Clean
Flaps	Leading Edge	20°	0	0	20°	0
	Trailing Edge	46°	0	0	46°	0

** Lateral data not available at these conditions*

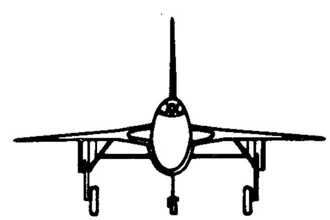


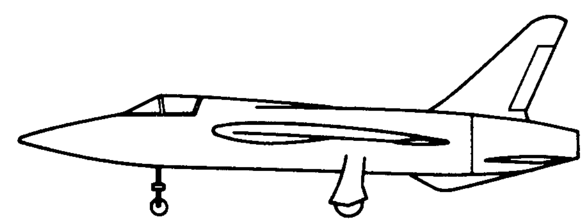
REFERENCE GEOMETRY

$S = 385\ ft^2$

$b = 34.9\ ft$

$c = 11.5\ ft$





REFERENCES

Unpublished Data

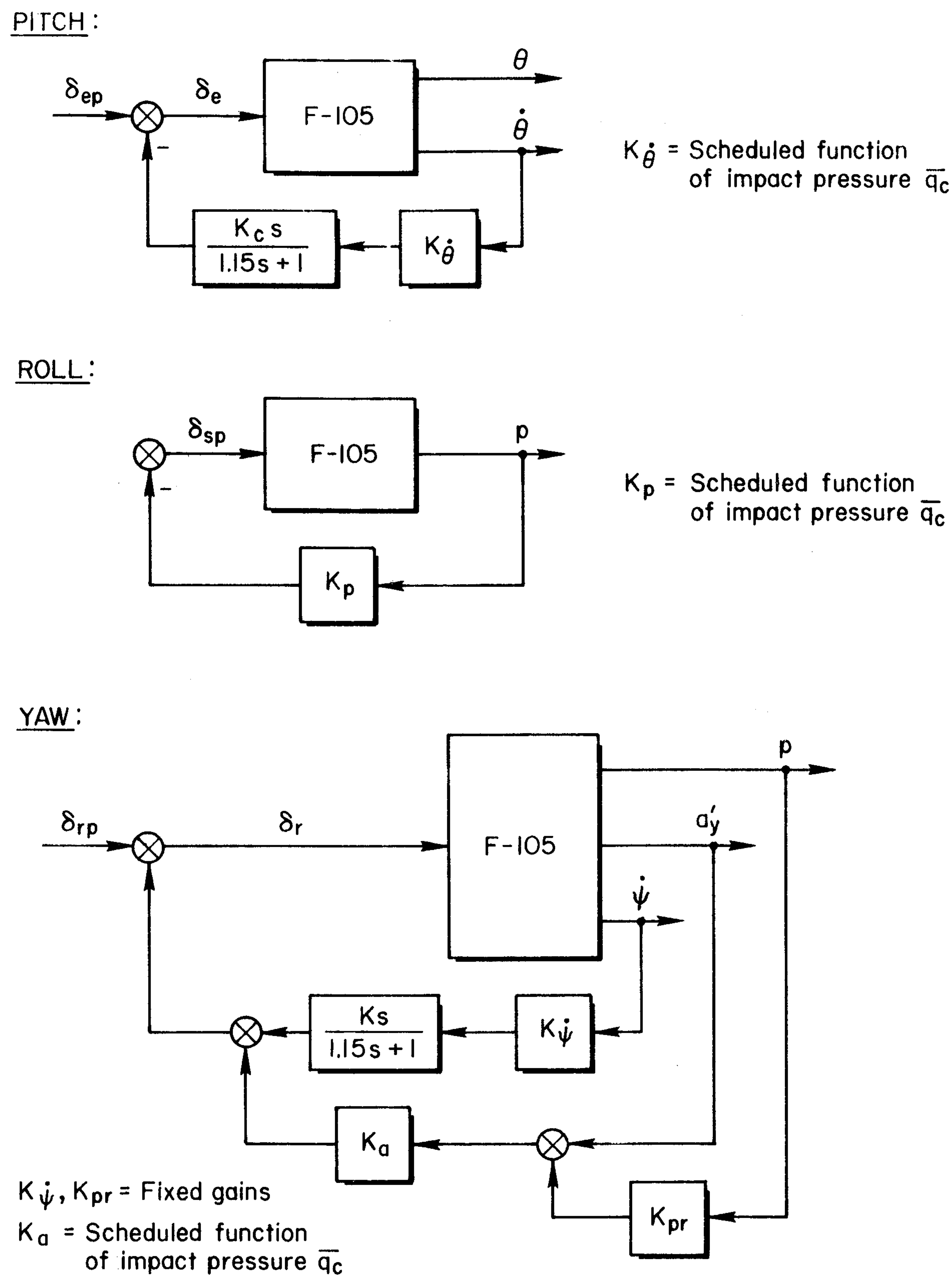


Figure VIII-2. F-105 — Stability Augmentation System

TABLE VIII-A

GEOMETRICAL AND INERTIAL PARAMETERS FOR THE F-105B

Note: Inertia data are for principal axes.

$S = 385\ ft^2$, $b = 34.9$ ft, $C = 11.5$ ft

	FLIGHT CONDITION				
	1 TAKEOFF	2 START CRUISE	3 END CRUISE CLEAN	4 POWER APPROACH CLEAN	5 V_{max} CLEAN
h (ft)	Sea Level	35,000	35,000	Sea Level	40,000
M (–)	0.261	0.9	0.9	0.241	2.1
a (ft/sec)	1117	973.3	973.3	1117	968.5
ρ (slugs/ft^3)	0.00237	0.000738	0.000738	0.00237	0.000587
V_{T_o} (ft/sec)	291	875	875	269	2030
$\bar{q} = \rho V^2/2$ (lb/ft^2)	100	283	283	86	1210
W (lb)	41,230	41,230	35,370	30,000	35,370
m (slugs)	1280	1280	1098	932	1098
I_x (slug-ft^2)	8,700	8,700	10,300	12,600	10,300
I_y (slug-ft^2)	140,000	140,000	140,000	140,000	140,000
I_z (slug-ft^2)	185,000	185,000	181,000	177,000	181,000
I_{xz} (slug-ft^2)	0	0	0	0	0
$x_{c.g.}/\bar{c}$	0.295	0.295	0.308	0.308	0.308
α_o (deg)	7.4	7.2	7.0	5.2	3.5
γ_o (deg)	10.0	0	0	–5.0	0
θ_o (deg)	17.4	7.2	7.0	0.2	3.5

TABLE VIII-B

LONGITUDINAL DIMENSIONAL DERIVATIVES FOR THE F-105B

Note: Data are for body-fixed stability axes.

	FLIGHT CONDITION				
	1 TAKEOFF	2 START CRUISE	3 END CRUISE CLEAN	4 POWER APPROACH CLEAN	5 V_{max} CLEAN
h (ft)	Sea Level	35,000	35,000	Sea Level	40,000
M (–)	0.261	0.9	0.9	0.241	2.1
X_u (1/sec)	–0.029	–0.00582	–0.00565	–0.0263	–0.00751
X_w (1/sec)	0.0793	0.00693	0.0264	0.086	0.0132
X_{δ_e} [(ft/sec^2)/rad]	0	0	0	0	0
Z_u (1/sec)	–0.1585	–0.01386	–0.0527	–0.1719	–0.0265
$Z_{\dot{w}}$ (–)	0	0	0	0	0
Z_w (1/sec)	–0.311	–0.4	–0.466	–0.406	–0.590
Z_{δ_e} [(ft/sec^2)/rad]	–17.3	–65.19	–75.97	–19.88	–135.9
M_u (1/sec-ft)	+0.0000119	0	0	+0.0000101	–0.0000198
$M_{\dot{w}}$ (1/ft)	–0.000259	–0.000117	–0.000117	–0.000259	–0.00000535
M_w (1/sec-ft)	–0.00575	–0.00819	–0.00468	–0.00324	–0.01252
M_q (1/sec)	–0.345	–0.485	–0.485	–0.319	–0.303
M_{δ_e} (1/sec^2)	–2.60	–12.03	–12.03	–2.703	–21.0

TABLE VIII-C

LATERAL DIMENSIONAL DERIVATIVES FOR THE F-105B

Note: Data are for body-fixed stability axes, lateral data not available for flight conditions 1 and 2.

	FLIGHT CONDITION		
	3 END CRUISE CLEAN	4 POWER APPROACH CLEAN	5 V_{max} CLEAN
h (ft)	35,000	Sea Level	40,000
M (–)	0.9	0.241	2.1
Y_v (1/sec)	–0.1497	–0.1878	–0.213
$Y_{\delta_a}^*$ [(1/sec)/rad]	–0.00173	–0.0021	–0.00221
$Y_{\delta_r}^*$ [(1/sec)/rad]	0.0234	0.0241	0.0837
L_β' (1/sec^2)	–41.1	–21.5	–139.8
L_p' (1/sec)	–2.8	–1.185	–3.14
L_r' (1/sec)	1.709	1.251	1.966
L_{δ_a}' (1/sec^2)	10.71	3.72	26.5
L_{δ_r}' (1/sec^2)	14.37	2.86	12.97
N_β' (1/sec^2)	12.39	4.38	18.81
N_p' (1/sec)	0.324	0.0725	0.1341
N_r' (1/sec)	–0.382	–0.242	–0.386
N_{δ_a}' (1/sec^2)	–1.086	–0.277	–1.339
N_{δ_r}' (1/sec^2)	–4.71	–0.975	–1.989

TABLE VIII-D

ELEVATOR LONGITUDINAL TRANSFER FUNCTION FACTORS FOR THE F-105B

Note: Data are for body-fixed stability axes.

		FLIGHT CONDITION				
		1 TAKEOFF	2 START CRUISE	3 END CRUISE CLEAN	4 POWER APPROACH CLEAN	5 V_{max} CLEAN
Mach No., M (—)		0.261	0.9	0.9	0.241	2.1
Altitude h (ft)		Sea Level	35,000	35,000	Sea Level	40,000
CG (% $\bar{c}$)		29.5	29.5	30.8	30.2	30.8
Weight, W (lb)		41,230	41,230	35,370	30,000	35,370
Δ_{long}	ζ_{sp}	0.281	0.1819	0.253	0.398	0.0893
	ω_{sp}	1.338	2.71	2.08	0.998	5.06
	ζ_p	0.0297	0.1295	0.0631	0.1016	0.1869
	ω_p	0.1247	0.0223	0.0429	0.1342	0.0201
$N_{\delta_e}^{\theta}$	A_θ	−2.60	−12.03	−12.02	−2.70	−21.0
	$1/T_{\theta_1}$	0.1026	0.0061	0.00891	0.0742	0.00827
	$1/T_{\theta_2}$	0.200	0.355	0.433	0.335	0.508
$N_{\delta_e}^{u}$	A_u	−1.367	−0.452	−2.002	−1.708	−1.792
	$1/T_{u_1}$	1.018	0.438	1.511	1.266	2.94
	$1/T_{u_2}$	−17.0	−696	−55.8	−15.02	−65.2
$N_{\delta_e}^{w}$	A_w	−17.27	−65.2	−76.0	−19.88	−135.9
	$1/T_{w_1}$	44.2	162	−139	36.9	315
	ζ_w	0.0372	0.129	0.0642	0.1258	0.1838
	ω_w	0.1287	0.0225	0.044	0.1435	0.0204
$N_{\delta_e}^{\dot{h}}$	$A_{\dot{h}}$	17.28	65.2	76.0	19.88	135.9
	$1/T_{\dot{h}_1}$	0.01292	0.00466	0.00439	0.01094	0.00737
	$1/T_{\dot{h}_2}$	−3.37	−7.29	−7.48	−3.49	−12.49
	$1/T_{\dot{h}_3}$	3.80	7.88	8.07	3.89	12.8

TABLE VIII-E

AILERON LATERAL TRANSFER FUNCTION FACTORS FOR THE F-105B

Note: Data are for body-fixed stability axes; lateral data not available for flight conditions 1 and 2.

		FLIGHT CONDITION		
		3 END CRUISE CLEAN	4 POWER APPROACH CLEAN	5 V_{max} CLEAN
Mach No., M (–)		0.9	0.241	2.1
Altitude, h (ft)		35,000	Sea Level	40,000
CG (% $\bar{c}$)		30.8	30.2	30.8
Weight, W (lb)		35,370	30,000	35,370
α_o (deg)		7.0	5.2	3.5
Δ_{lat}	$1/T_s$	–0.00870	0.000676	0.00631
	$1/T_R$	2.13	1.382	2.95
	ζ_d	0.184	0.0545	0.1531
	ω_d	3.29	2.13	4.16
$N^p_{\delta_a}$	A_p	10.71	3.72	26.5
	$1/T_{p_1}$	0	0.0103	0
	ζ_p	0.0635	0.101	0.0744
	ω_p	2.87	1.674	3.44
$N^r_{\delta_a}$	A_r	–1.086	–0.277	–1.339
	$1/T_{r_1}$	–1.524	–1.503	–1.3
	ζ_r	0.465	0.564	0.600
	ω_r	1.398	1.718	1.686
$N^\beta_{\delta_a}$	A_β	–0.00174	–0.00210	–0.00221
	$1/T_{\beta_1}$	–622	0.1427	0.1379
	$1/T_{\beta_2}$ (ζ_β)	(–0.0573)	1.655	0.658
	$1/T_{\beta_3}$ (ω_β)	(0.276)	–133.7	601

TABLE VIII-F

RUDDER LATERAL TRANSFER FUNCTION FACTORS FOR THE F-105B

Note: Data are for body-fixed stability axes; lateral data not available for flight conditions 1 and 2.

		FLIGHT CONDITION		
		3 END CRUISE CLEAN	4 POWER APPROACH CLEAN	5 V_{max} CLEAN
Mach No., M (–)		0.9	0.241	2.1
Altitude, h (ft)		35,000	Sea Level	40,000
CG (% $\bar{c}$)		30.8	30.2	30.8
Weight, W (lb)		35,370	30,000	35,370
α_o (deg)		7.0	5.2	3.5
Δ_{lat}	$1/T_s$	–0.00870	0.000676	0.00631
	$1/T_R$	2.13	1.382	2.45
	ζ_d	0.184	0.0545	0.1531
	ω_d	3.29	2.13	4.16
$N^p_{\delta_r}$	A_p	14.37	2.86	12.97
	$1/T_{p_1}$	0	0.0103	0
	$1/T_{p_2}$	–1.109	–1.82	–1.499
	$1/T_{p_3}$	1.014	1.63	1.738
$N^r_{\delta_r}$	A_r	–4.71	–0.975	–1.989
	$1/T_{r_1}$	1.848	1.463	2.31
	ζ_r	0.1028	–0.246	0.1601
	ω_r	0.259	0.838	0.342
$N^\beta_{\delta_r}$	A_β	0.0233	0.0241	0.00538
	$1/T_{\beta_1}$	–0.0103	–0.0395	0.00369
	$1/T_{\beta_2}$	1.927	1.371	2.36
	$1/T_{\beta_3}$	203	40.6	370

SECTION IX

B-58

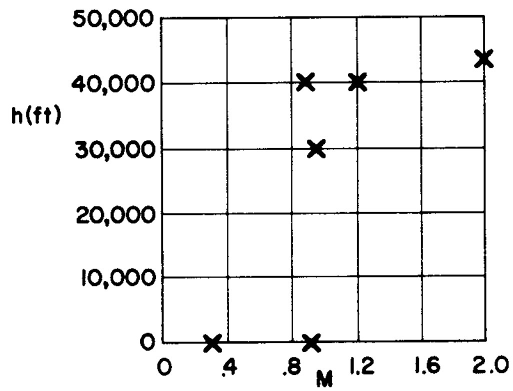
Figure IX-1

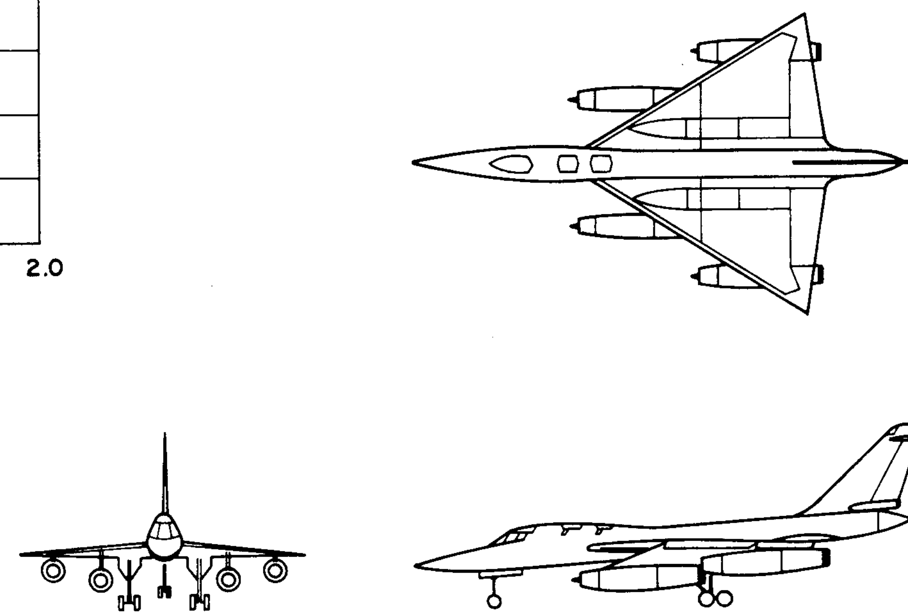
B-58

NOMINAL CRUISE CONFIGURATION

See Table IX-A

FLIGHT CONDITIONS





REFERENCE GEOMETRY

S = 1542 ft²

b = 56.8 ft

c = 36.2 ft

REFERENCES

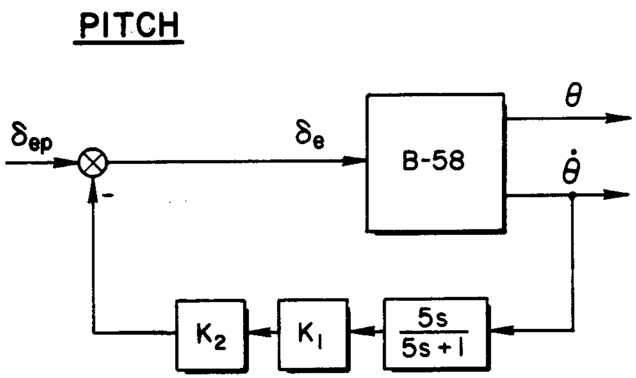
1) Bright, B.E., Ellington, J.D., "Application of the Limit-Cycle Selfadaptive Concept to the B-58 Lateral Directional Stability Augmentation System."
Thesis, Air Force Institute of Technology, GGC/EE/64-5, May 1964

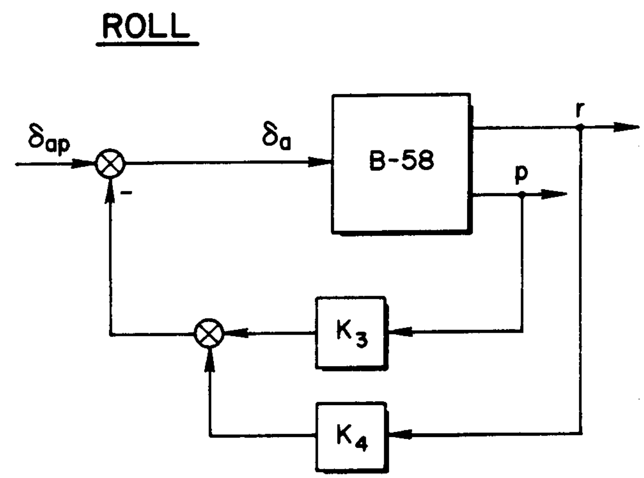
2) Anon., "B-58 Flight Control System", Gen. Dyn. Fort Worth, FZE-4-049, Nov. 1962

3) Jones, L.S., "U.S. Bombers B1-B70" Aero Publishing Inc., 1962

SOURCE

Unknown



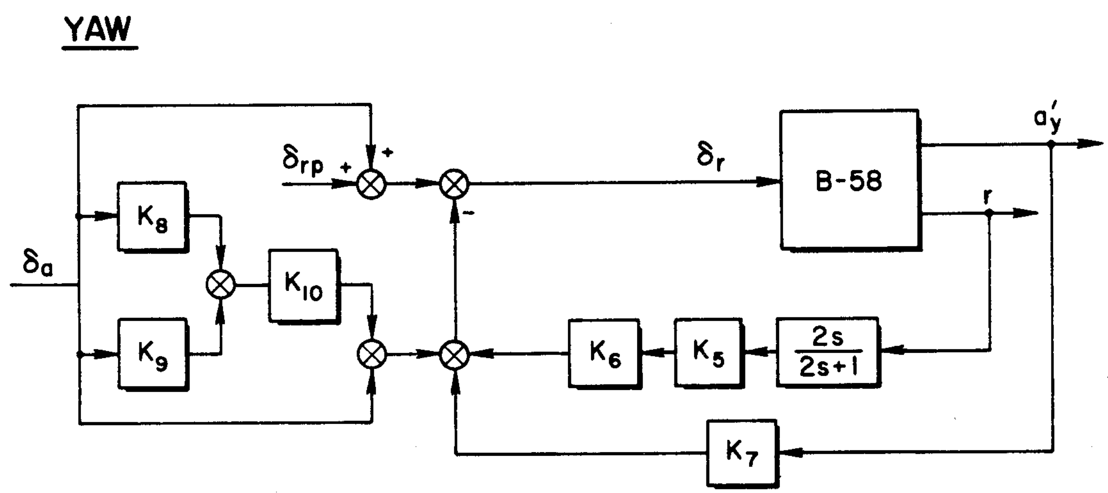


NOTE:

K_1, K_4, K_5, K_7, K_8 ... Gains Scheduled for Mach-Number

K_2, K_3, K_6, K_9, K_{10} ... Gains Scheduled for Altitude

(Air data computer not shown)



The Augmentation System for this airplane is known to have undergone several modifications. The system shown is of 1962 vintage as documented in G.D. Convair Report FZE 4-052, Dec. 1962, being the latest available data

Figure IX-2. B-58 — Stability Augmentation System

TABLE IX-A

GEOMETRICAL PARAMETERS FOR THE B-58

Note: Data for body-fixed stability axes, cruise configuration.

$S = 1,542\ ft^2$; $b = 56.82$ ft: $c = 36.17$ ft

	FLIGHT CONDITION						
	1	2	3	4	5	6	7
h (ft)	0	0	0	40,000	44,200	30,000	40,000
M (–)	0.32	0.91	0.91	0.91	2.0	0.98	1.2
a (ft/sec)	1117	1117	1117	968	968	995	968
ρ (slug/ft^3)	0.002377	0.002377	0.002377	0.000585	0.000478	0.000889	0.000585
V_{T_o} (ft/sec)	357	1016	1016	881	1936	975	1162
$\bar{q} = \rho V_{T_o}^2/2$ (lb/ft^2)	152	1227	1227	228	900	423	396
W (lbs)	150,000	90,000	150,000	150,000	150,000	150,000	150,000
m (slugs)	4655	2788	4655	4655	4655	4655	4655
I_x (slug-ft^2)	430,070	335,344	386,860	363,365	362,502	361,275	361,484
I_y (slug-ft^2)	1,045,000	649,892	1,045,000	1,045,000	1,045,000	1,045,000	1,045,000
I_z (slug-ft^2)	1,402,030	950,080	1,445,230	1,206,610	1,208,110	1,207,210	1,208,490
I_{xz} (slug-ft^2)	–215,646	19,250	51,375	–39,871	27,186	10,722	–553
γ_o (deg)	0	0	0	0	0	0	0
x_{CG}/c	0.28	0.28	0.28	0.30	0.33	0.33	0.33

TABLE IX-B

LATERAL NONDIMENSIONAL STABILITY DERIVATIVES FOR THE B-58

Note: Data are for body-fixed stability axes, cruise configuration.

	FLIGHT CONDITION						
	1	2	3	4	5	6	7
h (ft)	0	0	0	40,000	44,200	30,000	40,000
M (–)	0.32	0.91	0.91	0.91	2.0	0.98	1.2
V_{T_o} (ft/sec)	357.3	1016	1016	880.9	1936.2	975	1161.7
C_{y_β}	−0.6395	−0.6375	−0.674	−0.7665	−0.6275	−0.732	−0.801
$C_{y_{\delta_a}}$	0.1511	0.08655	0.0890	0.1790	0.0187	0.1862	0.1791
$C_{y_{\delta_r}}$	0.0929	0.0527	0.05725	0.0954	0.0232	0.08075	0.0545
C_{ℓ_β}	−0.1584	−0.0551	−0.0851	−0.1345	−0.03942	−0.1096	−0.1158
C_{ℓ_p}	−0.1936	−0.1585	−0.1576	−0.2173	−0.2317	−0.2107	−0.2238
C_{ℓ_r}	0.04479	0.08568	0.08553	0.1102	0.07207	0.09543	0.1071
$C_{\ell_{\delta_a}}$	−0.1112	−0.04043	−0.03892	−0.1041	−0.01782	−0.0729	−0.0010
$C_{\ell_{\delta_r}}$	0.001927	0.00729	0.007395	0.01227	0.003115	0.01328	0.0078
C_{n_β}	0.1014	0.1242	0.0624	0.1029	0.03207	0.0788	0.1117
C_{n_p}	−0.1143	−0.01082	−0.02935	−0.06118	0.01241	−0.03713	−0.04215
C_{n_r}	−0.2494	−0.2449	−0.2312	−0.2868	−0.2132	−0.2611	−0.2823
$C_{n_{\delta_a}}$	−0.0405	−0.03318	−0.03317	−0.0664	−0.02038	−0.0725	−0.09275
$C_{n_{\delta_r}}$	−0.06415	−0.03561	−0.03563	−0.0633	−0.01382	−0.0530	−0.03255

TABLE IX-C

LATERAL DIMENSIONAL DERIVATIVES FOR THE B-58

Note: Data for body-fixed stability axes, cruise configuration.

	FLIGHT CONDITION						
	1	2	3	4	5	6	7
h (ft)	0	0	0	40,000	44,200	30,000	40,000
M (–)	0.32	0.91	0.91	0.91	2.0	0.98	1.2
Y_v	−0.09	−0.426	−0.27	−0.0654	−0.0962	−0.105	−0.09
$Y_{\delta_a}^*$	0.0212	0.0578	0.0356	0.0153	0.00287	0.0267	0.0201
$Y_{\delta_r}^*$	0.0131	0.0382	0.0229	0.00814	0.00356	0.0116	0.00613
L'_β	−5.828	−16.875	−23.14	−7.575	−8.394	−11.163	−11.08
L'_p	−0.469	−1.424	−1.238	−0.381	−0.736	−0.63	−0.524
L'_r	0.221	0.724	0.603	0.212	0.214	0.278	0.251
L'_{δ_a}	−3.516	−13.19	−11.194	−5.597	−3.965	−7.538	−0.953
L'_{δ_r}	0.395	2.108	1.71	0.789	0.608	1.313	0.748
N'_β	1.858	13.71	3.818	1.946	1.895	2.317	3.202
N'_p	−0.0141	−0.0631	−0.105	−0.02	−0.00473	−0.0388	−0.0293
N'_r	−0.222	−0.76	−0.459	−0.159	−0.198	−0.231	−0.198
N'_{δ_a}	0.157	−4.021	−2.865	−0.909	−1.413	−2.29	−2.654
N'_{δ_r}	−0.669	−3.986	−2.589	−1.069	−0.884	−1.614	−0.932

TABLE IX-D

AILERON LATERAL TRANSFER FUNCTION FACTORS FOR THE B-58

Note: Data are for body-fixed stability axes, cruise configuration

		FLIGHT CONDITION						
		1	2	3	4	5	6	7
h (ft)		0	0	0	40,000	44,200	30,000	40,000
M (–)		0.32	0.91	0.91	0.91	2.0	0.98	1.2
Δ	$1/T_s$	0.058	0.00426	0.0334	0.026	0.0134	0.029	0.017
	$1/T_R$	0.698	1.527	1.75	0.556	0.802	0.885	0.687
	ζ_d	0.009	0.144	0.044	0.0086	0.0772	0.0165	0.0296
	ω_d	1.403	3.756	2.126	1.42	1.40	1.58	1.81
$N^p_{\delta_a}$	A_p	–3.516	–13.19	–11.194	–5.597	–3.965	–7.538	–0.953
	$1/T_{p_1}$	0	0	0	0	0	0	0
	ζ_p	0.132	0.168	0.152	0.0784	0.085	0.096	0.104
	ω_p	1.274	4.391	3.151	1.786	2.217	2.398	5.85
$N^r_{\delta_a}$	A_r	0.157	–4.021	–2.865	–0.909	–1.413	–2.29	–2.654
	$1/T_R$	–1.148	1.881	1.498	1.002	0.983	1.082	0.934
	ζ_r	0.678	–0.213	–0.249	–0.420	–0.174	–0.331	–0.295
	ω_r	1.677	1.021	0.897	0.845	0.481	0.757	0.602
$N^\beta_{\delta_a}$	A_β	0.0212	0.0578	0.0356	0.0153	0.00287	0.0267	0.0202
	$1/T_{\beta_1}$ (ζ_β)	0.1624	–0.0838	–0.0941	–0.191	–0.0184	–0.073	–0.0171
	$1/T_{\beta_2}$ (ω_β)	2.1616	1.198	0.798	0.226	0.695	0.467	0.520
	$1/T_{\beta_3}$	–9.008	70.64	81.472	60.03	493.37	86.15	131.87
$N^{a_y}_{\delta_a}$	A_{a_y}	7.594	58.73	36.17	13.46	5.55	26.063	23.42
	$1/T_{a_{y_1}}$ $(\zeta_{a_{y_2}})$	0.12	–0.210	–0.183	0.15	–0.02	–0.161	–0.036
	$1/T_{a_{y_2}}$ $(\omega_{a_{y_2}})$	1.009	0.948	0.593	1.839	0.69	0.35	0.458
CG	$\zeta_{a_{y_3}}$ $(1/T_{a_{y_3}})$	–0.127	(–3.3)	(–3.608)	–0.852	(–6.618)	(–2.255)	(–2.8)
	$\omega_{a_{y_3}}$ $(1/T_{a_{y_4}})$	1.733	(4.744)	(4.896)	0.85	(6.883)	(2.927)	(3.097)

TABLE IX-E

RUDDER LATERAL TRANSFER FUNCTION FACTORS FOR THE B-58

Note: Data for body-fixed stability axes, cruise configuration

		FLIGHT CONDITION						
		1	2	3	4	5	6	7
h (ft)		0	0	0	40,000	44,200	30,000	40,000
M (–)		0.32	0.91	0.91	0.91	2.0	0.98	1.2
Δ	$1/T_s$	0.058	0.00426	0.0334	0.026	0.0134	0.029	0.017
	$1/T_R$	0.698	1.527	1.75	0.556	0.802	0.885	0.687
	ζ_d	0.009	0.144	0.044	0.0086	0.0772	0.0165	0.0296
	ω_d	1.403	3.756	2.126	1.42	1.40	1.58	1.81
$N^p_{\delta_p}$	A_p	0.395	2.108	1.711	0.789	0.608	1.313	0.748
	$1/T_{p_1}$	0	0	0	0	0	0	0
	$1/T_{p_2}$	–2.969	–4.554	–5.859	–2.959	–3.247	–3.433	–3.319
	$1/T_{p_3}$	2.713	4.065	5.365	2.818	3.181	3.329	3.204
$N^r_{\delta_r}$	A_r	–0.669	–3.986	–2.589	–1.069	–0.884	–1.614	–0.932
	$1/T_r$	0.964	1.607	1.615	0.786	0.901	1.0	0.88
	ζ_r	–0.326	0.167	–0.0561	–0.317	–0.10	–0.226	–0.255
	ω_r	0.665	0.436	0.636	0.534	0.362	0.553	0.518
$N^\beta_{\delta_r}$	A_β	0.0131	0.0382	0.0229	0.00814	0.00355	0.0116	0.00613
	$1/T_{\beta_1}$	–0.0149	–0.00685	–0.00709	–0.008	–0.00171	–0.0043	–0.00445
	$1/T_{\beta_2}$	0.546	1.482	1.337	0.431	0.753	0.693	0.574
	$1/T_{\beta_3}$	51.355	150.05	113.43	131.44	248.84	139.37	152.06
$N^{a_y}_{\delta_r}$ CG	A_{a_y}	4.669	38.813	23.266	7.173	6.886	11.303	7.126
	$1/T_{a_{y_1}}$ $(\zeta_{a_{y_2}})$	–0.0966	–0.0122	–0.0167	–0.0225	–0.0032	–0.0135	–0.0131
	$1/T_{a_{y_2}}$ $(\omega_{a_{y_2}})$	0.446	1.46	1.243	0.394	0.748	0.649	0.537
	$\zeta_{a_{y_3}}$ $(1/T_{a_{y_3}})$	(–1.486)	(–5.179)	(–4.926)	(–2.492)	(–4.597)	(–3.394)	(–3.14)
	$\omega_{a_{y_3}}$ $(1/T_{a_{y_4}})$	(1.828)	(5.915)	(5.398)	(2.662)	(4.788)	(3.62)	(3.338)

SECTION X

NAVION

Figure X-1

NAVION

NOMINAL FLIGHT CONDITION

$h(ft) = 0$; $M = .158$; $V_{T_0} = 176$ ft/sec

$W = 2750$ lbs

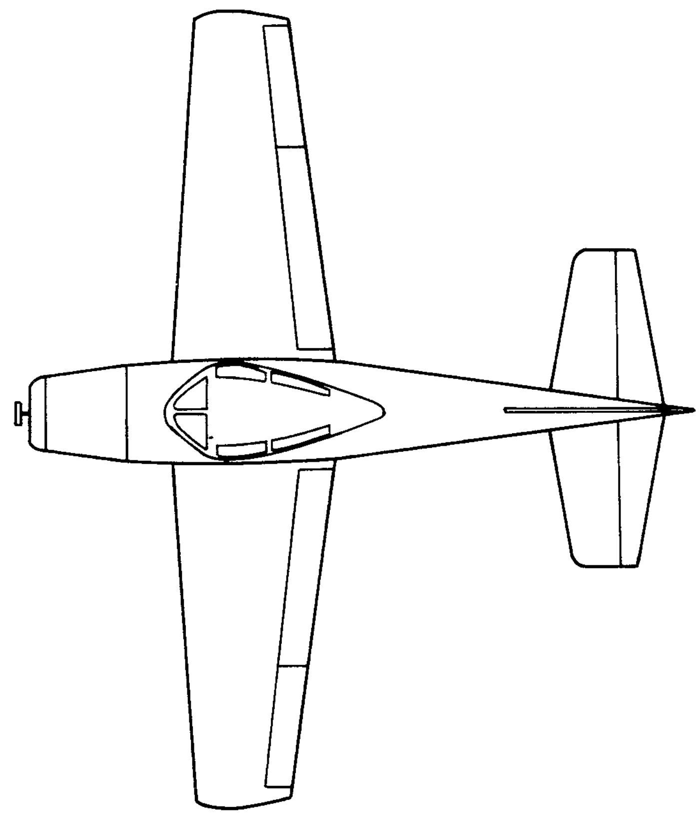
CG at 29.5 % MAC

$I_x = 1048$ slug ft^2

$I_y = 3000$ slug ft^2

$I_z = 3530$ slug ft^2

$I_{xz} = 0$

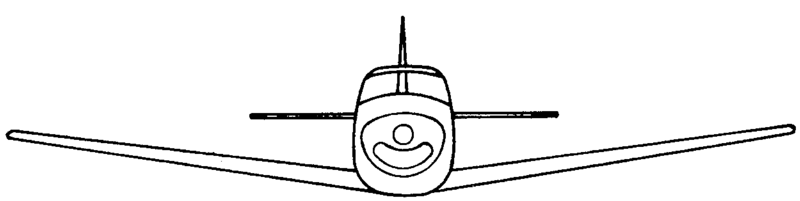


REFERENCE GEOMETRY

$S = 184$ ft^2

$c = 5.7$ ft

$b = 33.4$ ft



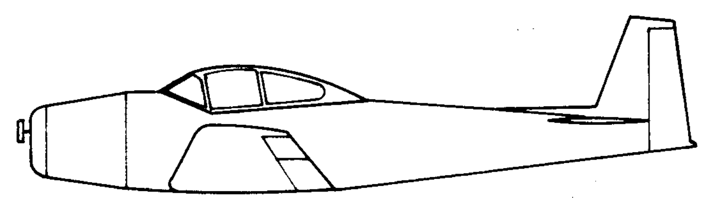


TABLE X-A

GEOMETRICAL PARAMETERS FOR THE NAVION

Note: Data for body-fixed stability axes, level flight	
S (ft^2)	180
b (ft)	33.4
c (ft)	5.7
W (lb)	2,750
m (slugs)	85.4
c.g. (% MAC)	29.5
I_x (slug-ft^2)	1,048
I_y (slug-ft^2)	3,000
I_z (slug-ft^2)	3,530
I_{xz}	0
h (ft)	0
M	0.158
a (ft/sec)	1117
ρ (slugs/ft^3)	0.002378
V_{T_o} (ft/sec)	176
$\bar{q} = \rho V_{T_o}^2/2$ (lb/ft^2)	36.8
α_o (deg)	0.6
γ_o (deg)	0

TABLE X-B

LONGITUDINAL NONDIMENSIONAL DERIVATIVES FOR THE NAVION

Note: Data are for stability axes	
	FLIGHT CONDITION
	1
h (ft)	0
M (–)	0.158
C_L	0.41
C_D	0.05
C_{L_α}	4.44
$C_{L_{\dot{\alpha}}}$	0
C_{L_M}	0
$C_{L_{\delta_e}}$	0.355
C_{D_α}	0.330
C_{D_M}	0
$C_{D_{\delta_e}}$	0
C_{m_α}	–0.683
$C_{m_{\dot{\alpha}}}$	–4.36
C_{m_M}	0
C_{m_q}	–9.96

TABLE X-C

LATERAL NONDIMENSIONAL STABILITY DERIVATIVES FOR THE NAVION

Note: Data are for stability axes	
	FLIGHT CONDITION
	1
h (ft)	0
M (–)	0.158
V_{T_o} (ft/sec)	176
α_o (deg)	
C_{y_β}	–0.564
$C_{y_{\delta_a}}$	0
$C_{y_{\delta_r}}$	0.157
C_{ℓ_β}	–0.074
C_{ℓ_p}	–0.410
C_{ℓ_r}	0.107
$C_{\ell_{\delta_a}}$	0.1342
$C_{\ell_{\delta_r}}$	0.0118
C_{n_β}	0.0701
C_{n_p}	–0.0575
C_{n_r}	–0.125
$C_{n_{\delta_a}}$	–0.00346
$C_{n_{\delta_r}}$	–0.0717

TABLE X-D

LONGITUDINAL DIMENSIONAL DERIVATIVES FOR THE NAVION

	FLT. COND.
X_w	0.03607
X_u	−0.0451
X_{δ_e}	0
Z_w	−2.0244
Z_u	−0.3697
Z_{δ_e}	−28.17
M_w	−0.04997
$M_{\dot{w}}$	−0.005165
M_q	−2.0767
M_u	0
M_{δ_e}	−11.1892

TABLE X-E

LATERAL DIMENSIONAL DERIVATIVES FOR THE NAVION

	FLT. COND.
Y_v	−0.2543
$Y^*_{\delta_a}$	0
$Y^*_{\delta_r}$	0.0708
L'_β	−15.982
L'_p	−8.402
L'_r	2.193
L'_{δ_a}	28.984
L'_{δ_r}	2.548
N'_β	4.495
N'_p	−0.3498
N'_r	−0.7605
N'_{δ_a}	−0.2218
N'_{δ_r}	−4.597

TABLE X-F

ELEVATOR LONGITUDINAL TRANSFER FUNCTION FACTORS FOR THE NAVION

		FLT. COND.
Δ	ζ_{sp}	0.6957
	ω_{sp}	3.6083
	ζ_p	0.0801
	ω_p	0.2137
$N^{\theta}_{\delta_e}$	A_θ	−11.044
	$1/T_{\theta_1}$	0.05231
	$1/T_{\theta_2}$	1.9164
$N^{u}_{\delta_e}$	A_u	−1.0161
	$1/T_{u_1}$	2.401
	$1/T_{u_2}$	−280.39
$N^{w}_{\delta_e}$	A_w	−28.171
	$1/T_w$	71.984
	ζ_w	0.0862
	ω_w	0.2563
$N^{\dot{h}}_{\delta_e}$	A_h	28.171
	$1/T_{h_1}$	−10.108
	$1/T_{h_2}$	0.0165
	$1/T_{h_3}$	13.122
$N^{a_z}_{\delta_e}$	A_{a_z}	−28.171
	$1/T_{a_{z_1}}$	0
	$1/T_{a_{z_2}}$	−10.108
$\ell_x=0$	$1/T_{a_{z_3}}$	0.0165
CG	$1/T_{a_{z_4}}$	13.122

TABLE X-G

AILERON LATERAL TRANSFER FUNCTION FACTORS FOR THE NAVION

		FLT. COND.
Δ	$1/T_s$	0.00876
	$1/T_R$	8.435
	ζ_d	0.204
	ω_d	2.385
$N^{p}_{\delta_a}$	A_p	28.984
	$1/T_{p_1}$	0
	ζ_p	0.2336
	ω_p	2.136
$N^{r}_{\delta_a}$	A_r	−0.2218
	$1/T_{r_1}$	−1.253
	$1/T_{r_2}$	1.543
	$1/T_{r_3}$	54.071
$N^{\beta}_{\delta_a}$	A_β	0.2218
	$1/T_{\beta_1}$	0.2285
	$1/T_{\beta_2}$	77.78

TABLE X-H

RUDDER LATERAL TRANSFER FUNCTION FACTORS FOR THE NAVION

		FLT. COND.
Δ	$1/T_s$	0.00876
	$1/T_R$	8.435
	ζ_d	0.204
	ω_d	2.385
$N^{p}_{\delta_r}$	A_p	2.548
	$1/T_{p_1}$	0
	$1/T_{p_2}$	−6.991
	$1/T_{p_3}$	3.6064
$N^{r}_{\delta_r}$	A_r	−4.597
	$1/T_r$	8.639
	ζ_r	0.1335
	ω_r	0.5345
$N^{\beta}_{\delta_r}$	A_β	0.0707
	$1/T_{\beta_1}$	−0.0366
	$1/T_{\beta_2}$	8.795
	$1/T_{\beta_3}$	65.352
$N^{a_y}_{\delta_r}$	A_{a_y}	12.485
	$1/T_{a_{y_1}}$	−0.0591
	$1/T_{a_{y_2}}$	8.335
CG	$1/T_{a_{y_3}}$	−3.0074
	$1/T_{a_{y_4}}$	3.894

SECTION XI

DC-8

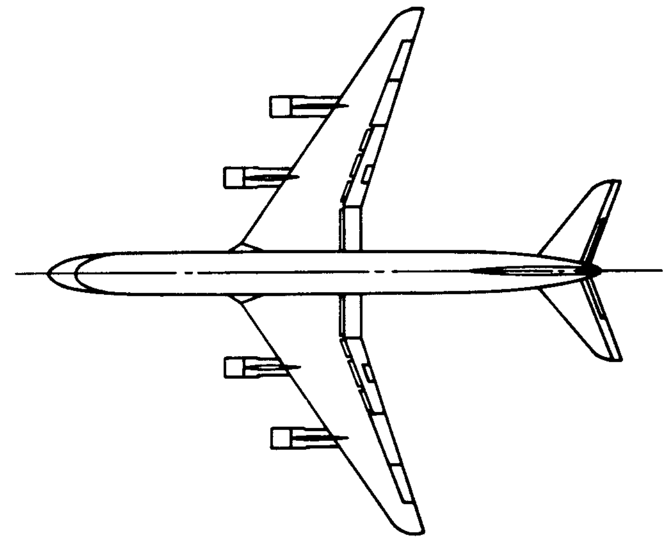
Figure XI-1

DC-8

FLIGHT CONDITIONS

Flight Condition	Approach	Holding	Cruise	V_{NE}
h(ft)	0	15,000	33,000	33,000
M	0.219	0.443	0.84	0.88
W (lbs)	190,000	190,000	230,000	230,000
I_x (slug-ft^2)	3.09×10^6	3.11×10^6	3.77×10^6	3.77×10^6
I_y (slug-ft^2)	2.94×10^6	2.94×10^6	3.56×10^6	3.56×10^6
I_z (slug-ft^2)	5.58×10^6	5.88×10^6	7.13×10^6	7.13×10^6
I_{xz} (slug-ft^2)	28×10^3	-64.5×10^3	45×10^3	53.7×10^3
$X_{cg}/\bar{c}$	0.15	0.15	0.15	0.15

Stability Axes (applies to I_x, I_y, I_z)



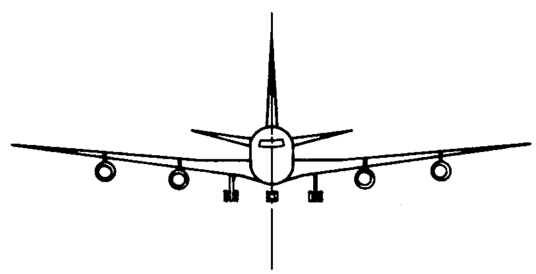
REFERENCE GEOMETRY

$S = 2600\ ft^2$

$b = 142.3\ ft$

$c = 23\ ft$

REFERENCES: Unpublished Data



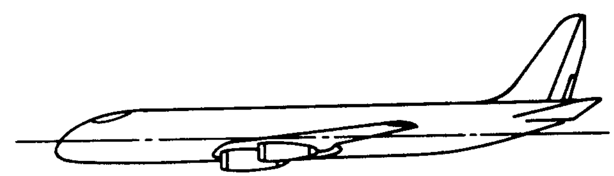


TABLE XI-A

GEOMETRICAL AND INERTIAL PARAMETERS FOR THE DC-8

Note: Data are for body-fixed stability axes

$S = 2600\ ft^2$, $b = 142.3\ ft$, $c = 23\ ft$, $\gamma_o = 0\ deg$

	FLIGHT CONDITION			
	1 APPROACH	2 HOLDING	3 CRUISE	4 V_{NE}
h (ft)	0	15,000	33,000	33,000
M (–)	0.218	0.443	0.84	0.88
a (ft/sec)	1117	1058	982	982
ρ (slugs/ft^3)	0.002378	0.001496	0.000795	0.000795
V_{T_o} (ft/sec)	243.5	468.2	824.2	863.46
$\bar{q} = \rho V^2/2$ (lb/ft^2)	71.02	163.97	270.0	296.36
W (lb)	190,000	190,000	230,000	230,000
m (slugs)	5900	5900	7143	7143
I_x (slug-ft^2)	3,090,000	3,110,000	3,770,000	3,770,000
I_y (slug-ft^2)	2,940,000	2,940,000	3,560,000	3,560,000
I_z (slug-ft^2)	5,580,000	5,880,000	7,130,000	7,130,000
I_{xz} (slug-ft^2)	28,000	−64,500	45,000	53,700
x_{CG}/c	0.15	0.15	0.15	0.15
θ_o (deg)	0	0	0	0
U_o (ft/sec)	243.5	468.2	824.2	863.46
W_o (ft/sec)	0	0	0	0
δ_F (deg)	35	0	0	0

TABLE XI-B

LONGITUDINAL NONDIMENSIONAL DERIVATIVES FOR THE DC-8

Note: Data are for body-fixed stability axes.

	FLIGHT CONDITION			
	1	2	3	4
h	0	15,000	33,000	33,000
M	0.218	0.443	0.840	0.88
C_L	0.98	0.42	0.308	0.279
C_D	0.1095	0.0224	0.0188	0.0276
C_{L_α}	4.81	4.8762	6.7442	6.8989
$C_{L_{\dot{\alpha}}}$	0	0	0	0
C_{L_M}	0.02	0.048	0	−1.2
$C_{L_{\delta_e}}$	0.328	0.328	0.352	0.358
C_{D_α}	0.487	0.212	0.2719	0.4862
C_{D_M}	0.0202	0.00208	0.1005	0.3653
$C_{D_{\delta_e}}$	0	−0.9712	0	0
C_{m_α}	−1.478	−1.5013	−2.017	−2.413
$C_{m_{\dot{\alpha}}}$	−3.84	−4.10	−6.62	−6.83
C_{m_m}	−0.006	−0.02	−0.17	−0.50
C_{m_q}	−0.00117	−0.9712	−14.6	−15.2

TABLE XI-C

LATERAL NONDIMENSIONAL STABILITY DERIVATIVES FOR THE DC-8

Note: Data are for body-fixed stability axes

	FLIGHT CONDITION			
	1	2	3	4
h (ft)	0	15,000	33,000	33,000
M (–)	0.218	0.443	0.84	0.88
V_{T_o} (ft/sec)	243.5	468.2	824.2	863.46
C_{y_β}	–0.87268	–0.6532	–0.7277	–0.7449
$C_{y_{\delta_a}}$	0	0	0	0
$C_{y_{\delta_r}}$	0.18651	0.18651	0.18651	0.18651
C_{ℓ_β}	–0.15815	–0.13752	–0.16732	–0.17362
C_{ℓ_p}	–0.385	–0.416	–0.516	–0.538
C_{ℓ_r}	0.248	0.132	0.147	0.146
$C_{\ell_{\delta_a}}$	–0.08595	–0.08308	–0.07965	–0.07907
$C_{\ell_{\delta_r}}$	0.02189	0.019195	0.021086	0.02166
C_{n_β}	0.1633	0.12319	0.15471	0.16044
C_{n_p}	–0.0873	–0.0307	–0.0107	–0.00587
C_{n_r}	–0.196	–0.161	–0.190	–0.199
$C_{n_{\delta_a}}$	–0.0106	–0.00354	–0.003701	–0.003999
$C_{n_{\delta_r}}$	–0.08337	–0.08337	–0.08337	–0.08337

TABLE XI-D

LONGITUDINAL DIMENSIONAL DERIVATIVES FOR THE DC-8

Note: Data are for body-fixed stability axes

	FLIGHT CONDITION			
	1	2	3	4
h (ft)	0	15,000	33,000	33,000
M (–)	0.218	0.443	0.84	0.88
T_u (1/sec)	−0.000595	−0.0000846	0.000599	0.000733
$X_{u_{aero}}$ (1/sec)	−0.02851	−0.00707	−0.0145	−0.0471
X_u (1/sec)	−0.0291	−0.00714	−0.014	−0.0463
X_w (1/sec)	0.0629	0.0321	0.0043	−0.0259
X_{δ_e} [(ft/sec^2)/rad]	0	0	0	0
$Z_{u_{aero}}$ (1/sec)	−0.2506	−0.1329	−0.0735	0.0622
Z_u (1/sec)	−0.2506	−0.1329	−0.0735	0.0622
$Z_{\dot{w}}$ (–)	0	0	0	0
Z_w (1/sec)	−0.6277	−0.756	−0.806	−0.865
Z_{δ_e} [(ft/sec^2)/rad]	−10.19	−23.7	−34.6	−38.6
$M_{u_{aero}}$ (1/sec-ft)	−0.0000077	−0.000063	−0.000786	−0.00254
M_u (1/sec-ft)	−0.0000077	−0.000063	−0.000786	−0.00254
$M_{\dot{w}}$ (1/ft)	−0.001068	−0.00072	−0.00051	−0.00052
M_w (1/sec-ft)	−0.0087	−0.0107	−0.0111	−0.0139
M_q (1/sec)	−0.7924	−0.991	−0.924	−1.008
M_{δ_e} (1/sec^2)	−1.35	−3.24	−4.59	−5.12

TABLE XI-E

LATERAL DIMENSIONAL DERIVATIVES FOR THE DC-8

Note: Data are for body-fixed stability axes

	FLIGHT CONDITION			
	1	2	3	4
h (ft)	0	15,000	33,000	33,000
M (–)	0.218	0.443	0.84	0.88
Y_v (1/sec)	–0.1113	–0.1008	–0.0868	–0.0931
$Y_{\delta_a}^*$ [(1/sec)/rad]	0	0	0	0
$Y_{\delta_r}^*$ [(1/sec)/rad]	0.0238	0.0288	0.0222	0.0233
L'_β (1/sec^2)	–1.328	–2.71	–4.41	–5.02
L'_p (1/sec)	–0.951	–1.232	–1.181	–1.29
L'_r (1/sec)	0.609	0.397	0.334	0.346
L'_{δ_a} (1/sec^2)	–0.726	–1.62	–2.11	–2.3
L'_{δ_r} (1/sec^2)	0.1813	0.392	0.549	0.612
N'_β (1/sec^2)	0.757	1.301	2.14	2.43
N'_p (1/sec)	–0.124	–0.0346	–0.0204	–0.01715
N'_r (1/sec)	–0.265	–0.257	–0.228	–0.25
N'_{δ_a} (1/sec^2)	–0.0532	–0.01875	–0.0652	–0.0788
N'_{δ_r} (1/sec^2)	–0.389	–0.864	–0.01164	–1.277

TABLE XI-F

ELEVATOR LONGITUDINAL TRANSFER FUNCTION FACTORS FOR THE DC-8

Note: Data are for body-fixed stability axes

		FLIGHT CONDITION			
		1	2	3	4
Mach No., M (–)		0.218	0.443	0.84	0.88
Altitude, h (ft)		0	15,000	33,000	33,000
CG (% $\bar{c}$)		15	15	15	15
Weight, W (lb)		190,000	190,000	230,000	230,000
Δ_{long}	ζ_{sp}	0.522	0.434	0.342	0.325
	ω_{sp}	1.619	2.40	3.15	3.59
	ζ_p $(1/T_{p_1})$	0.0606	0.0310	0.241	(–0.0708)
	ω_p $(1/T_{p_2})$	0.1635	0.0877	0.0243	(0.108)
$N^{\theta}_{\delta_e}$	A_{θ}	–1.338	–3.22	–4.57	–5.1
	$1/T_{\theta_1}$	0.0605	0.01354	0.01436	0.0493
	$1/T_{\theta_2}$	0.535	0.675	0.725	0.76
$N^{u}_{\delta_e}$	A_u	–0.641	–0.761	–0.1489	1.00
	$1/T_{u_1}$	1.08	1.279	0.816	0.449
	$1/T_{u_2}$	–35.3	–72.7	–879	279
$N^{w}_{\delta_e}$	A_w	–10.19	–23.7	–34.6	–38.6
	$1/T_{w_1}$	33.0	65.0	110.2	–0.0364
	ζ_w $(1/T_{w_2})$	0.0781	0.037	0.1362	(0.0827)
	ω_w $(1/T_{w_3})$	0.1798	0.0947	0.0511	(115.5)
$N^{\dot{h}}_{\delta_e}$	$A_{\dot{h}}$	10.19	23.7	34.6	38.6
	$1/T_{\dot{h}_1}$	–3.75	–5.95	–8.24	–8.63
	$1/T_{\dot{h}_2}$	–0.00182	–0.000026	0.0107	0.0531
	$1/T_{\dot{h}_3}$	4.83	7.29	9.59	100.9
$N^{a_z}_{\delta_e}$ CG	A_{a_z}	–10.19	–23.7	–34.6	–38.6
	$1/T_{a_{z_1}}$	0	0	0	0
	$1/T_{a_{z_2}}$	–3.75	–5.95	–8.24	–8.63
	$1/T_{a_{z_3}}$	–0.00182	–0.000026	0.0107	0.0531
	$1/T_{a_{z_4}}$	4.83	7.29	9.59	100.9

TABLE XI-G

AILERON LATERAL TRANSFER FUNCTION FACTORS FOR THE DC-8

Note: Data are for body-fixed stability axes

		FLIGHT CONDITION 1	2	3	4
Mach No., (−)		0.218	0.443	0.84	0.88
Altitude, h (ft)		0	15,000	33,000	33,000
CG (% $\bar{c}$)		15	15	15	15
Weight, W (lb)		190,000	190,000	230,000	230,000
Δ_{lat}	$1/T_s$	−0.013	0.00649	0.00404	0.00447
	$1/T_R$	1.121	1.329	1.254	1.356
	ζ_d	0.1096	0.1061	0.0793	0.0855
	ω_d	0.996	1.197	1.495	1.589
$N^p_{\delta_a}$	A_p	−0.726	−1.62	−2.11	−2.30
	$1/T_{p_1}$	0	0	0	0
	ζ_p	0.223	0.1554	0.1072	0.1094
	ω_p	0.943	1.166	1.515	1.620
$N^\varphi_{\delta_a}$	A_φ	−0.726	−1.62	−2.11	−2.30
	ζ_φ	0.223	0.1554	0.1072	0.1094
	ω_φ	0.943	1.166	1.515	1.620
$N^r_{\delta_a}$	A_r	−0.0532	−0.01875	−0.0652	−0.0788
	$1/T_{r_1}$	0.998	1.589	1.644	1.757
	ζ_r	−0.656	−0.727	−0.392	−0.345
	ω_r	1.242	2.23	1.323	1.269
$N^\beta_{\delta_a}$	A_β	0.0532	0.01875	0.0652	−0.0788
	$1/T_{\beta_1}$	−2.75	−7.9	−1.036	−0.704
	$1/T_{\beta_2}$	0.203	0.197	0.291	0.404
	$1/T_{\beta_3}$	—	—	—	—

TABLE XI-H

RUDDER LATERAL TRANSFER FUNCTION FACTORS FOR THE DC-8

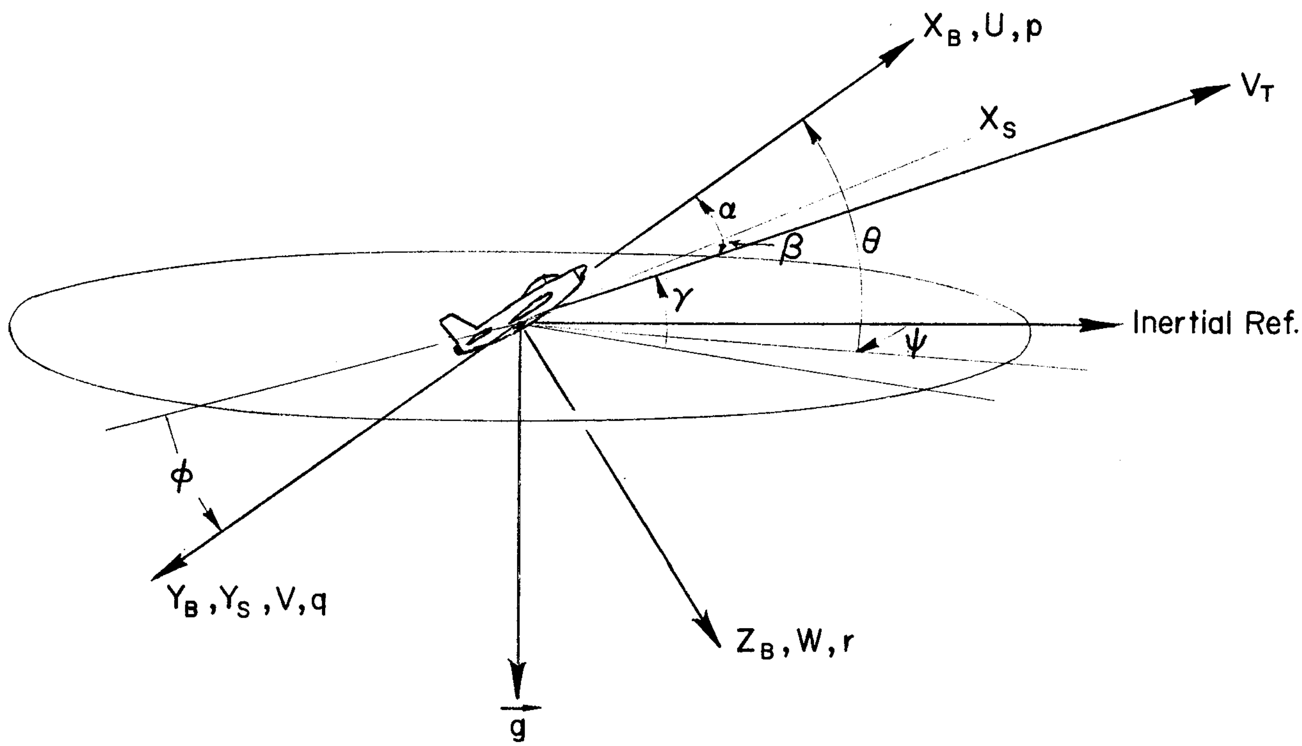
Note: Data are for body-fixed stability axes.

		FLIGHT CONDITION 1	2	3	4
Mach No., M (–)		0.218	0.443	0.84	0.88
Altitude, h (ft)		0	15,000	33,000	33,000
CG (% $\bar{c}$)		15	15	15	15
Weight, W (lb)		190,000	190,000	230,000	230,000
Δ_{lat}	$1/T_s$	–0.013	0.00649	0.00404	0.00447
	$1/T_R$	1.121	1.329	1.254	1.356
	ζ_d	0.1096	0.1061	0.0793	0.0855
	ω_d	0.996	1.197	1.495	1.589
$N^p_{\delta_r}$	A_p	0.1813	0.392	0.545	0.612
	$1/T_{p_1}$	0	0	0	0
	$1/T_{p_2}$	1.028	1.85	2.43	2.57
	$1/T_{p_3}$	–2.13	–2.56	–3.01	–3.15
$N^\varphi_{\delta_r}$	A_φ	0.1813	0.392	0.545	0.612
	$1/T_{\varphi_1}$	1.028	1.85	2.43	2.57
	$1/T_{\varphi_2}$	–2.13	–2.56	–3.01	–3.15
$N^r_{\delta_r}$	A_r	–0.389	–0.864	–1.165	–1.277
	$1/T_{r_1}$	1.124	1.335	1.276	1.377
	ζ_r	–0.0743	–0.0451	–0.0619	–0.0475
	ω_r	0.339	0.330	0.323	0.323
$N^\beta_{\delta_r}$	A_β	0.0238	0.0288	0.0222	0.0233
	$1/T_{\beta_1}$	–0.0559	–0.01475	–0.00726	–0.00637
	$1/T_{\beta_2}$	1.141	1.297	1.217	1.323
	$1/T_{\beta_3}$	16.47	30.2	52.6	55.0
$N^{a_y}_{\delta_r}$ CG	A_{a_y}	5.79	13.48	18.33	20.1
	$1/T_{a_{y_1}}$	–0.819	–0.0347	–0.01883	–0.01746
	$1/T_{a_{y_2}}$	–0.1077	1.535	1.122	1.231
	$1/T_{a_{y_3}}$ (ζ_{a_y})	(0.994)	–1.157	–1.418	–1.494
	$1/T_{a_{y_4}}$ (ω_{a_y})	(1.078)	1.147	1.723	1.819

APPENDIX A

AXIS SYSTEMS, SYMBOLS, AND DERIVATIVE DEFINITIONS

1. AXIS SYSTEMS



X_B, Y_B, Z_B – The Body-Axis System consists of right-handed, orthogonal axes whose origin is fixed at the nominal aircraft center of gravity. It's orientation remains fixed with respect to the aircraft, the X_B and Z_B axes being in the plane of symmetry. The exact alignment of X_B axis is arbitrary, herein it is taken along the body centerline reference.

X_S, Y_S, Z_S – The Stability-Axis System is that particular body-axis system for which the X_S-axis is coincident with the projection of the total steady-state velocity vector (V_{T_O}) on the aircraft's plane of symmetry. It's orientation remains fixed with respect to the aircraft.

2. SYMBOLS

a	Speed of sound in air	ft/sec
a_y	Lateral acceleration along the Y-Body Axis at the center of gravity (positive out right wing)	ft/sec^2
a_y'	Lateral acceleration parallel to the Y-Body Axis at a distance l_x and l_z from the c.g., $a_y' = a_y + l_x\dot{r} - l_z\dot{p}$	ft/sec^2
a_z	Normal acceleration along the Z-Body Axis at the c.g. (positive down)	ft/sec^2
a_z'	Normal acceleration parallel to the Z-Body Axis at a distance l_x from the c.g., $a_z' = a_z - l_x\dot{q}$	ft/sec^2
b	Reference wing span	ft
c	Reference chord	ft
CG	Center of gravity	
D	Aerodynamic force (drag) along the total velocity vector (positive aft)	lbs
g	Acceleration due to gravity	ft/sec^2
h	Altitude	ft
I_x, I_y, I_z	Moments of inertia referred to body axis	slug-ft^2
I_{xz}	Product of inertia referred to body axis	slug-ft^2
$j\omega$	The imaginary portion of the complex variable $s = \sigma \pm j\omega$	rad/sec
l_x	Distance along the X-Body Axis from the c.g. (positive forward)	ft
l_z	Distance along the Z-Body Axis from the c.g. (positive down)	ft
L	Rolling moment about the X-axis due to aerodynamic torques (positive right wing down)	ft-lb

L	Aerodynamic force (lift) perpendicular to the total velocity vector in the aircraft's plane of symmetry (positive up)	lbs
m	Mass	slugs
M	Mach number	
M	Pitching moment about the Y-axis due to aerodynamic torques (positive nose up)	ft-lb
MAC	Mean aerodynamic chord	ft
MGC	Mean geometric chord	ft
N	Aerodynamic normal force along the Z-Body Axis <u>but</u> positive up	lbs
N	Yawing moment about Z-axis due to aerodynamic torques (positive nose right)	ft-lbs
p	Roll rate, angular velocity about X-axis (positive right wing down)	rad/sec
q	Pitch rate, angular velocity about Y-axis (positive nose up)	rad/sec
$\bar{q}$	Dynamic pressure, $1/2\ \rho\ V_{T_o}^2$	lbs/ft^2
r	Yaw rate, angular velocity about Z-axis (positive nose right)	rad/sec
r_{RG}	Yaw rate gyro signal	rad/sec
s	Laplace operator, $\sigma + j\omega$	rad/sec
S	Reference wing area	ft^2
T.E.	Trailing edge	
u	Linear perturbed velocity along the X-axis (positive forward)	ft/sec
U_o	Linear steady-state velocity along the X-axis (positive forward)	ft/sec
v	Linear perturbed velocity along the Y-axis (positive out right wing)	ft/sec
V_{T_o}	Total linear steady-state velocity (positive forward)	ft/sec

w	Linear perturbed velocity along the Z-axis (positive down)	ft/sec
W	Weight	lbs
W_o	Linear steady-state velocity along the Z-axis (positive down)	ft/sec
X	Aerodynamic force along the X-axis (positive forward)	lbs
Y	Aerodynamic force along Y-axis (positive out right wing)	lbs
z_j	Perpendicular distance from c.g. to thrust line (positive for nose up pitching moment due to thrust)	ft
Z	Aerodynamic force along Z-axis (positive down)	lbs
α	Perturbed angle of attack	rad
α_o	Steady-state (trim) angle of attack	deg
β	Sideslip angle	rad
γ_o	Steady-state flight path angle	deg
δ_a	Aileron control surface deflection, (includes spoiler effects, etc.), (positive for positive rolling moment)	rad
δ_e	Elevator surface deflection from trim, (positive for nose down pitching moment for aft surface)	rad
δ_{e_o}	Trim elevator deflection	deg
δ_r	Rudder deflection [positive for nose left yawing moment (negative N)]	rad
Δ	Denominator of airframe transfer function	
ζ_i	Damping ratio of linear second order mode particularized by the subscript	
θ	Pitch angle, $\int q\, dt$ for straight and level flight, positive nose up	rad

ξ_o	Inclination of thrust line with X-axis [positive gives negative (−) Z force]	deg
ρ	Mass density of air	slugs/ft^3
σ	The real portion of the complex variable $s = \sigma \pm j\omega$	rad/sec
φ	Roll angle, $(\cos \theta_o \int p\, dt - \sin \theta_o \int r\, dt)$ in straight and level flight, (positive right wing down)	rad
ω_i	Undamped natural frequency of a second order mode, particularized by subscript	rad/sec

Special Subscript

a	Aileron
d	Dutch roll
e	Elevator
p	Phugoid
r	Rudder
R	Roll subsidence
s	Spiral
sp	Short period

3. NONDIMENSIONAL DERIVATIVE DEFINITIONS

a) Longitudinal Body Axis

$$C_N = \frac{N}{\bar{q}\ S}\ \text{, positive up}$$

$$C_X = -\frac{X}{\bar{q}\ S}\ \text{, positive aft}$$

$$C_{N_\alpha} = \partial C_N/\partial\alpha$$

$$C_{N_{\dot{\alpha}}} = \frac{2V_{T_o}}{c}\ \partial C_N/\partial\dot{\alpha}$$

$$C_{N_M} = \partial C_N/\partial M$$

$$C_{N_\delta} = \partial C_N/\partial\delta$$

$$C_{X_\alpha} = \partial C_X/\partial\alpha$$

$$C_{X_M} = \partial C_X/\partial M$$

$$C_{X_\delta} = \partial C_X/\partial\delta$$

$$C_M = \frac{M}{\bar{q}\ Sc}$$

$$C_{M_\alpha} = \partial C_M/\partial\alpha$$

$$C_{M_{\dot{\alpha}}} = \frac{2V_{T_o}}{c}\ \partial C_M/\partial\dot{\alpha}$$

$$C_{M_M} = \partial C_M/M$$

$$C_{M_q} = \frac{2V_{T_o}}{c}\ \partial C_M/\partial q$$

b) Longitudinal Stability Axis

$$C_L = \frac{L}{\bar{q}\ S}\ \text{, positive up}$$

$$C_D = \frac{D}{\bar{q}\ S}\ \text{, positive aft}$$

$$C_{L_\alpha} = \partial C_L/\partial\alpha$$

$$C_{L_{\dot{\alpha}}} = \frac{2V_{T_o}}{C}\ \partial C_L/\partial\dot{\alpha}$$

$$C_{L_M} = \partial C_L/\partial M$$

$$C_{L_\delta} = \partial C_L/\partial\delta$$

$$C_{D_\alpha} = \partial C_D/\partial\alpha$$

$$C_{D_M} = \partial C_D/\partial M$$

$$C_{D_\delta} = \partial C_D/\partial\delta$$

Pitching moment derivatives are identical to those for body axis

c) **Lateral Body and Stability Axis**

Though physically and numerically different,* see Appendix B, the same symbols are used for body axis and stability axis lateral rolling and yawing moment derivatives. The sideforce derivatives (C_y, etc.) are physically and numerically the same in both axis systems. When the rolling or yawing moment derivatives are given in this report the axis system is specified. When using the following all quantities should be for the same axis system.

$$C_y = \frac{Y}{\bar{q}S} \qquad C_l = \frac{L}{\bar{q}Sb} \qquad C_n = \frac{N}{\bar{q}Sb}$$

$$C_{y_\beta} = \partial C_y/\partial\beta \qquad C_{l_\beta} = \partial C_l/\partial\beta \qquad C_{n_\beta} = \partial C_n/\partial\beta$$

$$C_{y_\delta} = \partial C_y/\partial\delta \qquad C_{l_p} = \frac{2V_{T_o}}{b}\,\partial C_l/\partial p \qquad C_{n_p} = \frac{2V_{T_o}}{b}\,\partial C_N/\partial p$$

$$C_{l_r} = \frac{2V_{T_o}}{b}\,\partial C_l/\partial r \qquad C_{n_r} = \frac{2V_{T_o}}{b}\,\partial C_N/\partial r$$

$$C_{l_\delta} = \partial C_l/\partial\delta \qquad C_{n_\delta} = \partial C_n/\partial\delta$$

*The exception is the zero trim angle of attack condition.

4. DIMENSIONAL STABILITY DERIVATIVE DEFINITIONS

The same symbols are used for body- and stability-axis dimensional derivatives. Care should be exercised so that a consistent set of quantities are used.

a) Longitudinal Body Axis

$$X_u^* = X_u + T_u \cos\xi_o \qquad 1/\text{sec}$$

$$X_u = \frac{\rho S U_o}{m}\left(-\frac{M}{2} C_{X_M} - C_X + \frac{W_o}{2U_o} C_{X_\alpha}\right) \qquad 1/\text{sec}$$

$$X_w = \frac{\rho S U_o}{2m}\left[-C_{X_\alpha} - 2\frac{W_o}{U_o}\left(C_X + \frac{M}{2} C_{X_M}\right)\right] \qquad 1/\text{sec}$$

$$X_{\delta_e} = -\frac{\rho S V_{T_o}^2}{2m} C_{X_{\delta_e}} \qquad \frac{\text{ft}}{\text{sec}^2\text{rad}}$$

$$Z_u^* = Z_u - T_u \sin\xi_o \qquad 1/\text{sec}$$

$$Z_u = \frac{\rho S U_o}{m}\left(-\frac{M}{2} C_{N_M} - C_N + \frac{W_o}{2U_o} C_{N_\alpha}\right) \qquad 1/\text{sec}$$

$$Z_w = \frac{\rho S U_o}{2m}\left[-C_{N_\alpha} - 2\frac{W_o}{U_o}\left(C_N + \frac{M}{2} C_{N_M}\right)\right] \qquad 1/\text{sec}$$

$$Z_{\dot{w}} = -\frac{\rho S c}{4m}\frac{U_o}{V_{T_o}} C_{N_{\dot{\alpha}}}$$

$$Z_{\delta_e} = -\frac{\rho S V_{T_o}^2}{2m} C_{N_{\delta_e}} \qquad \frac{\text{ft}}{\text{sec}^2\text{rad}}$$

$$M_u^* = M_u + \frac{Z_j m}{I_y} T_u \qquad \frac{1}{\text{sec-ft}}$$

$$M_u = \frac{\rho S c U_o}{2I_y}\left[\frac{M}{2} C_{m_M} + C_m - \frac{W_o}{2U_o} C_{m_\alpha}\right] \qquad \frac{1}{\text{sec-ft}}$$

$$M_w = \frac{\rho S c U_o}{2I_y}\left[C_{m_\alpha} + \frac{2W_o}{U_o}\left(C_m + \frac{M}{2} C_{m_M}\right)\right] \qquad \frac{1}{\text{sec-ft}}$$

$$M_{\dot{w}} = \frac{\rho S c^2}{4I_y} \frac{U_o}{V_{T_o}} C_{m_{\dot{\alpha}}} \qquad \frac{1}{\text{sec-ft}}$$

$$M_\alpha = U_o M_w \qquad 1/\text{sec}^2$$

$$M_{\dot{\alpha}} = U_o M_{\dot{w}} \qquad 1/\text{sec}$$

$$M_q = \frac{\rho S c^2 V_{T_o}}{4I_y} C_{m_q} \qquad 1/\text{sec}$$

$$M_{\delta_e} = \frac{\rho S c V_{T_o}^2}{2I_y} C_{m_{\delta_e}} \qquad 1/\text{sec}^2$$

$$T_u = \frac{1}{am} \partial T/\partial M \qquad 1/\text{sec}$$

b) Lateral Body Axis

$$Y_v = (\rho S V_{T_o}/2m) C_{y_\beta} \qquad 1/\text{sec}$$

$$Y_\beta = V_{T_o} Y_v \qquad \text{ft/sec}^2$$

$$Y_{\delta_a} = (\rho S V_{T_o}^2/2m) C_{y_{\delta_a}} \qquad \text{ft/sec}^2$$

$$Y_{\delta_r} = (\rho S V_{T_o}^2/2m) C_{y_{\delta_a}} \qquad \text{ft/sec}^2$$

$$Y_{\delta_r}^* = (\rho S V_{T_o}/2m) C_{y_{\delta_r}} \qquad 1/\text{sec}$$

$$L_\beta = (\rho S V_{T_o}^2 b/2I_x) C_{l_\beta} \qquad 1/\text{sec}^2$$

$$L_p = (\rho S V_{T_o} b^2/4I_x) C_{l_p} \qquad 1/\text{sec}$$

$$L_r = (\rho S V_{T_o} b^2/4I_x) C_{l_r} \qquad 1/\text{sec}$$

$$L_{\delta_a} = (\rho S V_{T_o}^2 b/2I_x)C_{l_{\delta_a}} \qquad 1/sec^2$$

$$L_{\delta_r} = (\rho S V_{T_o}^2 b/2I_x)C_{l_{\delta_r}} \qquad 1/sec^2$$

$$Y_{\delta_a}^* = (\rho S V_{T_o}/2m)C_{y_{\delta_a}} \qquad 1/sec$$

$$N_\beta = (\rho S V_{T_o}^2 b/2I_z)C_{n_\beta} \qquad 1/sec^2$$

$$N_p = (\rho S V_{T_o} b^2/4I_z)C_{n_p} \qquad 1/sec$$

$$N_r = (\rho S V_{T_o} b^2/4I_z)C_{n_r} \qquad 1/sec$$

$$N_{\delta_a} = (\rho S V_{T_o}^2 b/2I_z)C_{n_{\delta_a}} \qquad 1/sec^2$$

$$N_{\delta_r} = (\rho S V_{T_o}^2 b/2I_z)C_{n_{\delta_r}} \qquad 1/sec^2$$

$$L_\beta' = (L_\beta + I_{xz}N_\beta/I_x)G \qquad 1/sec^2$$

$$L_p' = (L_p + I_{xz}N_p/I_x)G \qquad 1/sec$$

$$L_r' = (L_r + I_{xz}N_r/I_x)G \qquad 1/sec$$

$$L_{\delta_r}' = (L_{\delta_r} + I_{xz}N_{\delta_r}/I_x)G \qquad 1/sec^2$$

$$L_{\delta_a}' = (L_{\delta_a} + I_{xz}N_{\delta_a}/I_x)G \qquad 1/sec^2$$

$$N_\beta' = (N_\beta + I_{xz}L_\beta/I_z)G \qquad 1/sec^2$$

$$N_p' = (N_p + I_{xz}L_p/I_z)G \qquad 1/sec$$

$$N_r' = (N_r + I_{xz}L_r/I_z)G \qquad 1/sec$$

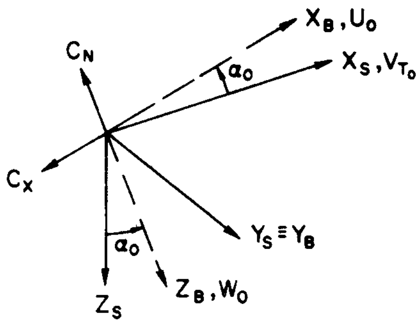
$$N_{\delta_r}' = (N_{\delta_r} + I_{xz}L_{\delta_r}/I_z)G \qquad 1/sec^2$$

$$N_{\delta_a}' = (N_{\delta_a} + I_{xz}L_{\delta_a}/I_z)G \qquad 1/sec^2$$

$$G = \frac{1}{1 - \frac{I_{xz}^2}{I_x I_z}}$$

APPENDIX B

TRANSFORMATION OF NON-DIMENSIONAL STABILITY AXIS DERIVATIVES TO BODY AXIS



$$U_o = V_{T_o} \cos \alpha_o$$

$$W_o = V_{T_o} \sin \alpha_o$$

LONGITUDINAL

Body Axis

$$C_N = C_L \cos \alpha_o + C_D \sin \alpha_o$$

$$C_X = C_D \cos \alpha_o - C_L \sin \alpha_o$$

$$C_{N_\alpha} = C_{L_\alpha} \cos \alpha_o - C_L \sin \alpha_o + C_{D_\alpha} \sin \alpha_o + C_D \cos \alpha_o$$

$$C_{N_{\dot\alpha}} = C_{L_{\dot\alpha}} \cos \alpha_o$$

$$C_{N_M} = C_{L_M} \cos \alpha_o + C_{D_M} \sin \alpha_o$$

$$C_{N_\delta} = C_{L_\delta} \cos \alpha_o + C_{D_\delta} \sin \alpha_o$$

$$C_{X_\alpha} = C_{D_\alpha} \cos \alpha_o - C_D \sin \alpha_o - C_{L_\alpha} \sin \alpha_o - C_L \cos \alpha_o$$

$$C_{X_M} = C_{D_M} \cos \alpha_o - C_{L_M} \sin \alpha_o$$

$$C_{X_\delta} = C_{D_\delta} \cos \alpha_o - C_{L_\delta} \sin \alpha_o$$

C_m, C_{m_α}, $C_{m_{\dot\alpha}}$, C_{m_q}, C_{m_M}, C_{m_δ} - UNCHANGED

LATERAL

Body Axis

$$(C_{l_\beta})_B = C_{l_\beta} \cos \alpha_o - C_{n_\beta} \sin \alpha_o$$

$$(C_{l_p})_B = C_{l_p} \cos^2 \alpha_o - (C_{l_r} + C_{n_p}) \sin \alpha_o \cos \alpha_o + C_{n_r} \sin^2 \alpha_o$$

$$(C_{l_r})_B = C_{l_r} \cos^2 \alpha_o - (C_{n_r} - C_{l_p}) \sin \alpha_o \cos \alpha_o - C_{n_p} \sin^2 \alpha_o$$

$$(C_{l_\delta})_B = C_{l_\delta} \cos \alpha_o - C_{n_\delta} \sin \alpha_o$$

$$(C_{n_\beta})_B = C_{n_\beta} \cos \alpha_o + C_{l_\beta} \sin \alpha_o$$

$$(C_{n_p})_B = C_{n_p} \cos^2 \alpha_o - (C_{n_r} - C_{l_p}) \sin \alpha_o \cos \alpha_o - C_{l_r} \sin^2 \alpha_o$$

$$(C_{n_r})_B = C_{n_r} \cos^2 \alpha_o + (C_{l_r} + C_{n_p}) \sin \alpha_o \cos \alpha_o + C_{l_p} \sin^2 \alpha_o$$

$$(C_{n_\delta})_B = C_{n_\delta} \cos \alpha_o + C_{l_\delta} \sin \alpha_o$$

C_{y_β}, $C_{y_{\delta_r}}$, $C_{y_{\delta_a}}$ - UNCHANGED

APPENDIX C

EQUATIONS OF MOTION, TRANSFER FUNCTIONS, AND COUPLING NUMERATORS

1. Longitudinal

a. Equations

$$\begin{bmatrix} s - X_u^* & -X_w & W_o s + g \cos \theta_o \\ -Z_u^* & (1 - Z_{\dot{w}})s - Z_w & -U_o s + g \sin \theta_o \\ -M_u^* & -(M_{\dot{w}} s + M_w) & s^2 - M_q s \end{bmatrix} \begin{bmatrix} u \\ w \\ \theta \end{bmatrix} = \begin{bmatrix} X_{\delta_e} \\ Z_{\delta_e} \\ M_{\delta_e} \end{bmatrix} \begin{bmatrix} \delta_e \end{bmatrix}$$

$$q = s\theta$$

$$\dot{h} = -w \cos \theta_o + u \sin \theta_o + (U_o \cos \theta_o + W_o \sin \theta_o)\theta$$

$$a_z = sw - U_o q + (g \sin \theta_o)\theta$$

$$a_z' = a_z - l_x s^2 \theta$$

b. Transfer Functions

$$\frac{\theta}{\delta_e} = \frac{N_{\delta_e}^{\theta}}{\Delta}$$

1) Denominator, $\Delta = As^4 + Bs^3 + Cs^2 + Ds + E$

$$A = (1 - Z_{\dot{w}})$$

$$B = -(M_q + X_u^*)(1 - Z_{\dot{w}}) - Z_w - M_{\dot{\alpha}}$$

$$C = M_q Z_w - M_\alpha + X_u^*[(M_q)(1 - Z_{\dot{w}}) + Z_w + M_{\dot{\alpha}}]$$
$$- X_w Z_u^* + W_o[M_{\dot{w}} Z_u^* + M_u^*(1 - Z_{\dot{w}})] + gM_{\dot{w}} \sin \theta_o$$

$$D = -X_u^*(M_q Z_w - M_\alpha) - M_u^* X_\alpha + M_q X_w Z_u^* + g\left[M_{\dot{w}} Z_u^* + M_u^*(1 - Z_{\dot{w}})\right]\cos\theta_o + W_o(M_w Z_u^* - M_u^* Z_w)$$
$$+ g(M_w - M_{\dot{w}} X_u^*)\sin\theta_o$$

$$E = g(M_w Z_u^* - M_u^* Z_w)\cos\theta_o + g(M_u^* X_w - M_w X_u^*)\sin\theta_o$$

2) δ Numerators

$$N_\delta^\theta = A_\theta s^2 + B_\theta s + C_\theta$$

$$A_\theta = Z_\delta M_{\dot{w}} + M_\delta(1 - Z_{\dot{w}})$$

$$B_\theta = X_\delta\left[M_{\dot{w}} Z_u^* + M_u^*(1 - Z_{\dot{w}})\right] + Z_\delta(M_w - M_{\dot{w}} X_u^*) - M_\delta\left[Z_w + X_u^*(1 - Z_{\dot{w}})\right]$$

$$C_\theta = X_\delta(M_w Z_u^* - M_u^* Z_w) + Z_\delta(M_u^* X_w - M_w X_u^*) + M_\delta(Z_w X_u^* - X_w Z_u^*)$$

$$N_\delta^u = A_u s^3 + B_u s^2 + C_u s + D_u$$

$$A_u = X_\delta(1 - Z_{\dot{w}})$$

$$B_u = -X_\delta\left[M_q(1 - Z_{\dot{w}}) + Z_w + M_{\dot{\alpha}}\right] + Z_\delta X_w - W_o\left[Z_\delta M_{\dot{w}} + M_\delta(1 - Z_{\dot{w}})\right]$$

$$C_u = X_\delta(M_q Z_w - M_\alpha) - Z_\delta(g M_{\dot{w}}\cos\theta_o + M_q X_w) + M_\delta\left[X_\alpha - (g\cos\theta_o)(1 - Z_{\dot{w}})\right]$$
$$+ W_o(Z_w M_\delta - M_w Z_\delta) + g X_\delta M_{\dot{w}}\sin\theta_o$$

$$D_u = g(Z_w M_\delta - M_w Z_\delta)\cos\theta_o + g(X_\delta M_w - M_\delta X_w)\sin\theta_o$$

$$N_\delta^w = A_w s^3 + B_w s^2 + C_w s + D_w$$

$$A_w = Z_\delta$$

$$B_w = -Z_\delta(M_q + X_u^*) + U_o M_\delta + X_\delta Z_u^*$$

$$C_w = X_u^*(Z_\delta M_q - U_o M_\delta) + W_o(Z_\delta M_u^* - M_\delta Z_u^*) - g M_\delta\sin\theta_o + X_\delta(M_u^* U_o - Z_u^* M_q)$$

$$D_w = g(Z_\delta M_u^* - M_\delta Z_u^*)\cos\theta_o + g M_\delta X_u^*\sin\theta_o - X_\delta M_u^* g\sin\theta_o$$

$N_{\delta}^{\dot{h}} = A_{\dot{h}}s^3 + B_{\dot{h}}s^2 + C_{\dot{h}}s + D_{\dot{h}}$
$A_{\dot{h}} = -\cos\theta_o A_w + \sin\theta_o A_u$
$B_{\dot{h}} = -\cos\theta_o B_w + \sin\theta_o B_u + (U_o\cos\theta_o + W_o\sin\theta_o)A_\theta$
$C_{\dot{h}} = -\cos\theta_o C_w + \sin\theta_o C_u + (U_o\cos\theta_o + W_o\sin\theta_o)B_\theta$
$D_{\dot{h}} = -\cos\theta_o D_w + \sin\theta_o D_u + (U_o\cos\theta_o + W_o\sin\theta_o)C_\theta$

$N_{\delta}^{a'_z} = A_{a'_z}s^4 + B_{a'_z}s^3 + C_{a'_z}s^2 + D_{a'_z}s + E_{a'_z}$
$A_{a'_z} = A_w - l_x A_\theta$
$B_{a'_z} = B_w - l_x B_\theta - U_o A_\theta$
$C_{a'_z} = C_w - l_x C_\theta - U_o B_\theta + g\sin\theta_o A_\theta$
$D_{a'_z} = D_w - U_o C_\theta + g\sin\theta_o B_\theta$
$E_{a'_z} = +g\sin\theta_o C_\theta$

To obtain a_z, let $l_x = 0$.

2. Lateral

a. Equations

$$\begin{bmatrix} s - Y_v & -\frac{W_o s + g\cos\theta_o}{V_{T_o}} & \frac{U_o s - g\sin\theta_o}{V_{T_o}s} \\ -L'_\beta & s(s - L'_p) & -L'_r \\ -N'_\beta & -N'_p s & s - N'_r \end{bmatrix} \begin{bmatrix} \beta \\ \frac{p}{s} \\ r \end{bmatrix} = \begin{bmatrix} Y^*_{\delta_a} & Y^*_{\delta_r} \\ L'_{\delta_a} & L'_{\delta_r} \\ N'_{\delta_a} & N'_{\delta_r} \end{bmatrix} \begin{bmatrix} \delta_a \\ \delta_r \end{bmatrix}$$

$$v = V_{T_o}\beta \qquad a_y = sv + U_o r - W_o p - g(\cos\theta_o)\varphi$$

$$\varphi = \frac{p}{s} + \frac{r}{s}\tan\theta_o \qquad a'_y = a_y + l_{x_{lat}} sr - l_z sp$$

$$\psi = \frac{1}{\cos\theta_o}\frac{r}{s}$$

b. Transfer Functions

$$\frac{\varphi}{\delta_a} = \frac{N^{\varphi}_{\delta_a}}{\Delta_{lat}} \quad ; \quad \frac{r}{\delta_r} = \frac{N^{r}_{\delta_r}}{\Delta_{lat}} \quad ; \quad \text{etc.}$$

1) Denominator, $\Delta_{lat} = as^4 + bs^3 + cs^2 + ds + e$

$$a = 1$$

$$b = -(Y_v + L'_p + N'_r)$$

$$c = \frac{U_o}{V_{T_o}} N'_\beta + L'_p(Y_v + N'_r) - N'_p L'_r + Y_v N'_r - \frac{W_o L'_\beta}{V_{T_o}}$$

$$d = \frac{U_o}{V_{T_o}} (N'_p L'_\beta - L'_p N'_\beta) + Y_v(N'_p L'_r - L'_p N'_r) - \frac{g}{V_{T_o}} (L'_\beta \cos \theta_o + N'_\beta \sin \theta_o) + \frac{W_o}{V_{T_o}} (L'_\beta N'_r - N'_\beta L'_r)$$

$$e = \frac{g}{V_{T_o}} [(L'_\beta N'_r - N'_\beta L'_r) \cos \theta_o - (N'_p L'_\beta - L'_p N'_\beta) \sin \theta_o]$$

2) δ (δ_a or δ_r) Numerators

$$N^{\beta}_{\delta} = A_\beta s^3 + B_\beta s^2 + C_\beta s + D_\beta$$

$$A_\beta = Y^*_\delta$$

$$B_\beta = -Y^*_\delta[L'_p + N'_r] - N'_\delta \frac{U_o}{V_{T_o}} + \frac{W_o}{V_{T_o}} L'_\delta$$

$$C_\beta = Y^*_\delta (L'_p N'_r - N'_p L'_r) + L'_\delta \frac{g}{V_{T_o}} \cos \theta_o + (N'_\delta L'_p - L'_\delta N'_p) \frac{U_o}{V_{T_o}} + \frac{W_o}{V_{T_o}} (N'_\delta L'_r - L'_\delta N'_r) + N'_\delta \frac{g}{V_{T_o}} \sin \theta_o$$

$$D_\beta = \frac{g}{V_{T_o}} (N'_\delta L'_r - L'_\delta N'_r) \cos \theta_o + \frac{g}{V_{T_o}} (N'_p L'_\delta - N'_\delta L'_p) \sin \theta_o$$

$N_\delta^p = A_p s^3 + B_p s^2 + C_p s + D_p$
$A_p = L'_\delta$
$B_p = Y^*_\delta L'_\beta - L'_\delta(N'_r + Y_v) + N'_\delta L'_r$
$C_p = Y^*_\delta(L'_r N'_\beta - L'_\beta N'_r) + L'_\delta Y_v N'_r - N'_\delta Y_v L'_r + (L'_\delta N'_\beta - N'_\delta L'_\beta)\dfrac{U_o}{VT_o}$
$D_p = -\dfrac{g}{VT_o}(L'_\delta N'_\beta - N'_\delta L'_\beta)\sin\theta_o$

$N_\delta^r = A_r s^3 + B_r s^2 + C_r s + D_r$
$A_r = N'_\delta$
$B_r = Y^*_\delta N'_\beta + L'_\delta N'_p - N'_\delta(Y_v + L'_p)$
$C_r = Y^*_\delta(L'_\beta N'_p - N'_\beta L'_p) - L'_\delta Y_v N'_p + N'_\delta Y_v L'_p + \dfrac{W_o}{VT_o}(L'_\delta N'_\beta - N'_\delta L'_\beta)$
$D_r = \dfrac{g}{VT_o}(L'_\delta N'_\beta - N'_\delta L'_\beta)\cos\theta_o$

$N_\delta^\varphi = A_\Phi s^2 + B_\Phi s + C$
$A_\Phi = A_p + A_r \tan\theta_o$
$B_\Phi = B_p + B_r \tan\theta_o$
$C_\Phi = C_p + C_r \tan\theta_o$

$$N_{\delta}^{a_y'} = A'_{a_y}s^4 + B'_{a_y}s^3 + C'_{a_y}s^2 + D'_{a_y}s + E'_{a_y}$$

$$A'_{a_y} = V_{T_o}A_\beta + l_{x_{lat}}A_r - l_zA_p$$

$$B'_{a_y} = V_{T_o}B_\beta + U_oA_r - W_oA_p + l_{x_{lat}}B_r - l_zB_p$$

$$C'_{a_y} = V_{T_o}C_\beta + U_oB_r - W_oB_p - g\cos\theta_oA_\phi + l_{x_{lat}}C_r - l_zC_p$$

$$D'_{a_y} = V_{T_o}D_\beta + U_oC_r - W_oC_p - g\cos\theta_oB_\phi + l_{x_{lat}}D_r - l_zD_p$$

$$E'_{a_y} = U_oD_r - W_oD_p - g\cos\theta_oC_\phi$$

To obtain a_y, let $l_{x_{lat}} = l_z = 0$.