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COLLOCATION FLUTTER ANALYSIS STUDY II

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VOLUME II

UNSTEADY AERODYNAMIC GENERALIZED FORCE PROGRAMS FOR SUBSONIC, TRANSONIC, AND SUPERSONIC FLIGHT REGIMES

APRIL 1970

MISSILE SYSTEMS DIVISION
HUGHES
HUGHES AIRCRAFT COMPANY

COFA II

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VOLUME II

UNSTEADY AERODYNAMIC GENERALIZED FORCE PROGRAMS

FOR SUBSONIC, TRANSONIC, AND SUPERSONIC FLIGHT REGIMES

PREPARED BY DYNAMICS & ENVIRONMENTS SECTION PERSONNEL, HUGHES AIRCRAFT COMPANY, MISSILE SYSTEMS DIVISION, CONTRACT NO. 00019-69-C-0427

APRIL 1970

Wash, D.C. 20360

TABLE OF CONTENTS

Section		Page No.
1.0	Introduction	1
2.0	Unsteady Aerodynamics Generalized Forces	2
3.0	Subsonic Unsteady Aerodynamics Program	4
	3.1 Theoretical Derivation	4
	3.2 Program Description	7
	3.3 Input Instructions	10
	3.4 Sample Problem	15
	3.5 Program Listing	22
4.0	Transonic Unsteady Aerodynamics Program	38
	4.1 Theoretical Derivation	38
	4.2 Program Description	41
	4.3 Input Instructions	44
	4.4 Sample Problem	48
	4.5 Program Listing	56
5.0	Supersonic Unsteady Aerodynamics Program	69
	5.1 Theoretical Derivation	69
	5.2 Program Description	73
	5.3 Input Instructions	76
	5.4 Sample Problem	80
	5.5 Program Listing	88
6.0	References	99

1.0 INTRODUCTION

The flutter problem can be solved with either a collocation or normal-mode formulation. The collocation approach is attractive if an accurate stiffness and aerodynamic influence coefficient matrix can be formed for the system. The normal-mode method merits consideration when mode shapes and natural frequencies for the structure are known. The normal-mode method requires the aerodynamics to be presented as generalized forces. The normal-mode formulation is generally presented in the following manner

$$\left(\lceil \bar{M} \rfloor + [\bar{Q}] - \frac{1+ig}{\omega^2} \lceil \omega_n^{\ 2} \rfloor \lceil \bar{M} \rfloor \right) \left\{ \psi \right\} = 0$$

Where

$\lceil \bar{M} \rfloor$ = Generalized Mass Matrix

$[\bar{Q}]$ = Generalized Aerodynamic Force Matrix

g = Artifical Structural Damping

i = $\sqrt{-1}$

ω = Flutter Frequency

ω_n = Natural Vibration Frequency

ψ = Generalized Coordinate

This volume presents three computer programs that calculate the generalized aerodynamic forces for the three flight regimes: Subsonic Flight, Transonic Flight, Supersonic Flight and may be used with the Modal Flutter Analysis Program of Vol. III. The subsonic program is based upon Kernel Function formulation. The transonic and supersonic programs are based upon the Mach Box technique.

2.0 UNSTEADY AERODYNAMIC GENERALIZED FORCES

The generalized force Q_{ij} is defined as the work done in mode i by the pressures due to motion of mode j. If $z^i(x,y)$ is the deformation pattern of mode i and $\Delta P_j(x,y)$ is the pressure distribution of mode j then

$$Q_{ij} = \int\int z^i(x,y)\ \Delta P_j(x,y)\,dxdy \qquad 2.0.1$$

Oscillation of a lifting surface creates a phase lead (or lag) between the pressure and motion of the surface thereby making Q_{ij} a complex quantity.

The frequency dependency of the generalized force makes the flutter solution a trial and error procedure. Different frequencies must be tried until the flutter frequency and the generalized force frequency coincides. Fortunately, the flutter frequencies are usually near the natural frequencies. This is especially true for a stable structure with modes which remain fairly uncoupled; there is little drifting of oscillatory frequencies with the presence of aerodynamic forces.

Various lifting surface theories were employed to determine the pressure distribution $\Delta P_j(x,y)$ for generalized force calculations. This was required to correctly account for the high degree of chordwise and spanwise deformation associated with mode shapes of low aspect ratio surfaces. Also, it was necessary to include aerodynamic interaction effects between tandem surfaces.

The methods are based on the linearized equation of fluid motion which describe the flow patterns for a compressible, inviscid, isentropic and irrotational fluid. The boundary conditions are consistent with thin wing theory. The effects of high angles of attack and missile body influence on the aerodynamics of the lifting surfaces were not considered in the analysis.

The linearized equation for time dependent disturbances is

$$\bar{\phi}_{XX} + \bar{\phi}_{YY} + \bar{\phi}_{ZZ} = M^2\ \left(\bar{\phi}_{XX} + \frac{2}{U}\ \bar{\phi}_{XT} + \frac{1}{U}\ \bar{\phi}_{TT}\right) \qquad 2.0.2$$

where $\bar{\phi}$ is the perturbation velocity potential at the point (X, Y, Z). M and U are the free stream Mach number and velocity, respectively. Imposing the requirement of harmonic motion, this time dependency can be expressed as

$$\bar{\phi} = b\phi e^{i\omega t}$$

where ϕ is the nondimensional complex amplitude of the velocity potential and b is a reference semi-chord. The equation may be cast in a nondimensional form by substitution of the following dimensionless parameters:

$$x = X/b$$

$$y = Y/b$$

$$z = Z/b$$

$$k = \omega b/U$$

This yields

$$\phi_{xx} + \phi_{yy} + \phi_{zz} = M^2 (\phi_{xx} + 2ik\, \phi_x - k^2 \phi) \qquad 2.0.3$$

It is this relationship which must be satisfied for $M<1$, $M=1$, and $M>1$. A brief description of the analytical techniques employed for each ~~speed~~ regime is presented in the following sections. The numerical and computational schemes used are similar to those which are described in detail in References 5, 6, and 7.

3.0 SUBSONIC UNSTEADY AERODYNAMICS PROGRAM

3.1 Theoretical Derivation

Subsonic aerodynamic loads were derived by the kernel function method and the resulting loads were then used to compute generalized forces. The subsonic kernel function relationship for the downwash (x,y) on a surface in terms of the pressure over the entire surface is

$$w(x,y) = -\frac{1}{8\pi}\iint \frac{\Delta P}{1/2\rho U^2} K(x-\xi, y-\eta)d\xi d\eta \qquad 3.1.1$$

This relationship is derived by noting that the potential equation for subsonic flow,

$$(1-M^2)\phi_{xx} + \phi_{yy} + \phi_{zz} = M^2 (2ik\phi_x - k^2\phi) \qquad 3.1.2$$

is satisfied at (x,y,z) by the pulsating pressure doublet

$$\phi = -A \frac{\partial}{\partial \zeta} e^{-ik(x-\xi)} \int_{-\infty}^{x-\xi} \frac{1}{R'} \exp\left[\frac{ik}{1-M^2} (\lambda - MR')\right] d\lambda \qquad 3.1.3$$

where

$$R' = \sqrt{\lambda^2 + (1-M^2) (y-\eta)^2 + (z-\xi)^2} \qquad 3.1.4$$

and the pressure doublet strength is given by

$$A = \frac{1}{4\pi} \left[\frac{\Delta P (\xi,\eta)}{1/2\rho U^2} \right] d\xi d\eta \qquad 3.1.5$$

The velocity normal to the lifting surface is given by

$$w(x,y) = \lim_{z \to 0} \frac{\partial \phi}{\partial z} \qquad 3.1.6$$

Substituting equation (3.1.3) into the equation above and integrating over the area yields the kernel function relationship, equation (3.1.1). For tandem surfaces, the integration extends over both surfaces:

$$w(x,y) = -\frac{1}{8\pi} \underbrace{\int_{-s}^{+s} \int_{l.e.}^{t.e.}}_{wing} \frac{\Delta P_{W(\xi,\eta)}}{1/2\rho U^2} K(x-\xi, y-\eta) d\xi d\eta$$

$$- \frac{1}{8\pi} \underbrace{\int_{-s}^{+s} \int_{l.e.}^{t.e.}}_{control\ surface} \frac{\Delta P_{cs} (\xi,\eta)}{1/2 \rho U^2} K(x-\xi, y-\eta) d\xi d\eta \qquad 3.1.7$$

The kernel function at any point is given by

$$K(x-\xi,y-\eta) = \lim_{\substack{\zeta\to o\\ z\to o}} \left\{ e^{-ik(x-\xi)} \frac{\partial}{\partial z} \frac{\partial}{\partial \zeta} \int_{-\infty}^{x-\xi} \frac{1}{R'} e^{i\left[\frac{1}{1-M^2}(\lambda - MR')\right]} d\lambda \right\} \tag{3.1.8}$$

Equation (3.1.7) then represents the integral equation wherein given the downwash $w(x,y)$ over the wing and control surface, ΔP_w and ΔP_{cs} must then be determined.

The pressure distribution is approximated as the sum of a series of functions which have the proper behavior as inferred from steady state and two-dimensional solutions. The pressure on each surface can be approximated in the form

$$\Delta P = \frac{1}{2} \rho U^2 \frac{\sqrt{s^2 - \eta^2}}{b(\eta)} \sum_{n=o}^{N} \sum_{m=o}^{M} a_{nm} P_m(\underline{\eta}) f_n(\tilde{\xi}) \tag{3.1.9}$$

where

$$f_o(\tilde{\xi}) = \sqrt{\frac{1-\tilde{\xi}}{1+\tilde{\xi}}} \qquad f_n(\tilde{\xi}) = \sqrt{1-\tilde{\xi}^2}\, T_{n-1}(\tilde{\xi}); \quad n \geq 1$$

$$P_o(\underline{\eta}) = 1.0 \qquad P_m(\underline{\eta}) = \underline{\eta}^2\, T_{m-1}(\underline{\eta}); \quad m \geq 1 \tag{3.1.10}$$

$$T_o(x) = 1.0$$

$$T_1(x) = 2x$$

$$T_k(x) = 2xT_{k-1}(x) - T_{k-2}(x); \quad k \geq 2$$

$$\tilde{\xi} = \frac{\xi - \bar{\xi}}{b(\eta)} \qquad \bar{\xi} = 1/2\,(\xi_{l.e.} + \xi_{t.e.})$$

$$\underline{\eta} = \frac{\eta}{s}$$

s is the starboard coordinate of the surface tip and $b(\eta)$ is the local semi-chord. The functions T_n are Chebyshev polynomials and are introduced for purposes of convenience.

Substituting equation (3.1.8, 3.1.9, and 3.1.10) into equation (3.1.7) yields a set of equations relating the pressure coefficients for the wing, a_{nm}^{w}, and the control surface, a_{nm}^{cs}, to the downwashes. In matrix notation this gives

$$\begin{Bmatrix} \{W^{w}\} \\ \{W^{cs}\} \end{Bmatrix} = \begin{bmatrix} D_{nm}^{ww} & D_{nm}^{w-cs} \\ D_{nm}^{cs-w} & D_{nm}^{cs} \end{bmatrix} \times \begin{Bmatrix} a_{nm}^{w} \\ a_{nm}^{cs} \end{Bmatrix} \qquad (3.3.11)$$

The integrals involved in evaluating the D's were solved by the methods of Hsu (Reference 5). In this procedure the integrals are numerically evaluated using the Gauss-Mehler quadrature. Upon determining values for the D's, the pressure coefficients are found by direct inversion and the generalized forces are found by application of equation (2.0.1).

3.2 Program Description

The Subsonic Generalized Force Unsteady Aerodynamics Program calculates generalized forces for up to 10 deformation modes. The computer solution, which is based upon the kernel function formulation, is applicable to a variety of configurations. The various configurations which can be analyzed are shown in Figure 3.2.1 and Table 3.2.2. The analysis includes interaction effects between tandem surfaces and wake effects on the trailing surface. The number of integration stations are chosen, and they are automatically located. The collocation stations are then interdigitated between the integration stations, according to Hsu (Reference 5), internally in the program. The solutions at the collocation stations are then matched to terms in the downwash series by a least squares method and the surface pressure are determined. The method of solution programmed does not allow for a single surface to be analyzed separately; however, an option to isolate and eliminate interference effects between the two surfaces is available. Thus, a single surface can be analyzed by using the option ISØLAT and inputing a dummy second surface.

The solution for the generalized aerodynamic forces requires the input of the deformation modes due to vibration. The program considers the modes to be expressed as analytic functions of the form:

$$w(x, y) = \sum_{m=0}^{N} \sum_{n=0}^{n} C_{(n-m),\ m} x^{(n-m)} y^{m}$$

To meet this requirement only the coefficients "c" are required as input into the program. These coefficients can be obtained in several ways, the most common way is to surface fit the modes by the least-square technique.

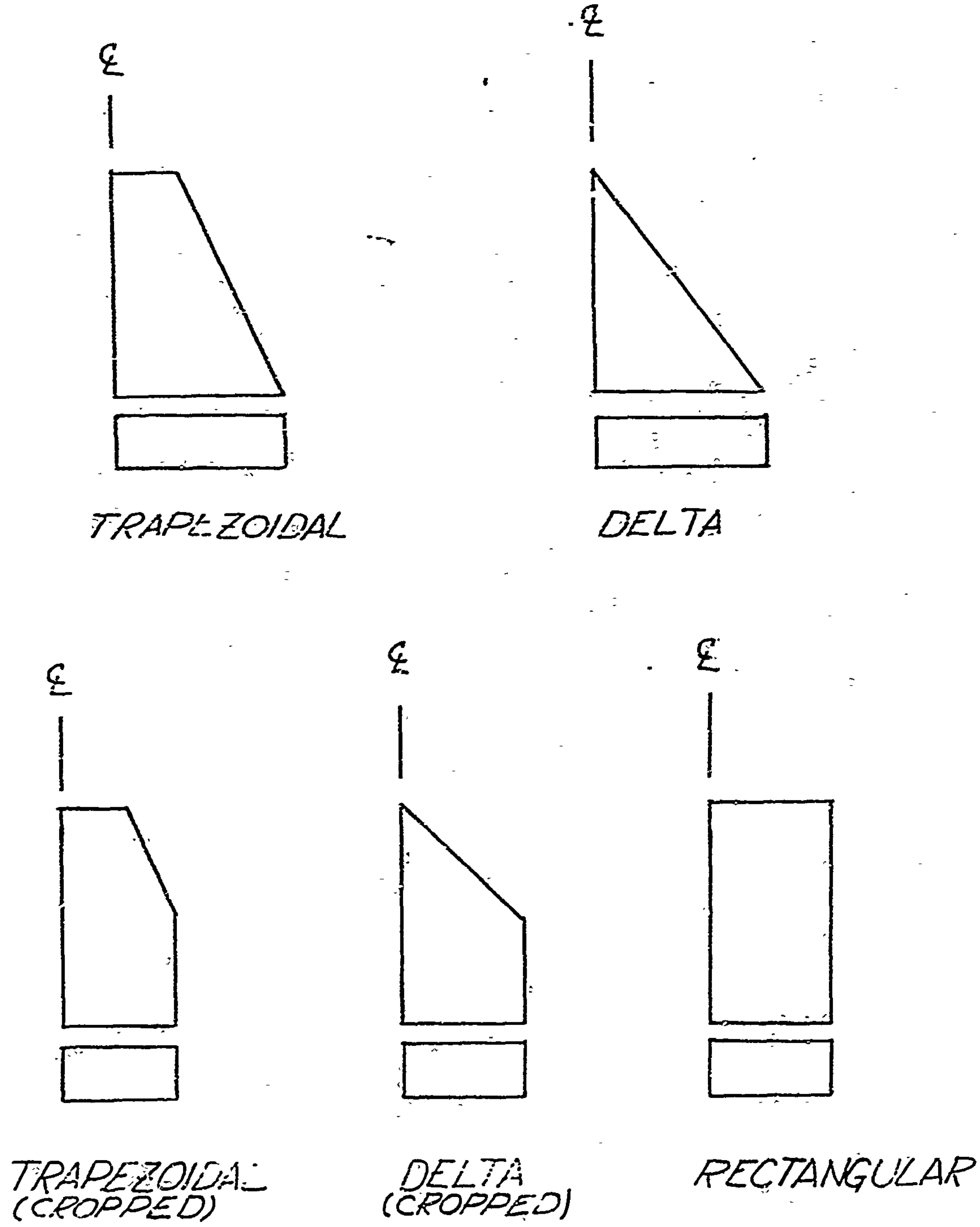

FIGURE 3.2.1
TANDEM COPLANAR CONFIGURATIONS AT SUBSONIC MACH NUMBER

TABLE 3.2.2 - OPTIONAL CONFIGURATIONS

Configuration	Chordwise Coordinates	Spanwise Coordinates
Rectangular	X(1) = 0.0 X(2) = 0.0 X(3) > 0.0 X(4) > X(3) X(5) > X(4)	Y(1) = 0.0 Y(2) = 0.0 Y(3) > 0.0
Delta	X(1) = 0.0 X(2) > 0.0 X(3) = X(2) X(4) > X(3) X(5) > X(4)	Y(1) = 0.0 Y(2) = 0.0 Y(3) > 0.0
Trapezoidal	X(1) = 0.0 X(2) > 0.0 X(3) = X(2) X(4) > X(3) X(5) > X(4)	Y(1) = 0.0 Y(2) > 0.0 Y(3) > Y(2)
Trapezoidal (Cropped)	X(1) = 0.0 X(2) > X(1) X(3) > X(2) X(4) > X(3) X(5) > X(4)	Y(1) = 0.0 Y(2) > 0.0 Y(3) > Y(2)
Delta (Cropped)	X(1) = 0.0 X(2) > 0.0 X(3) > X(2) X(4) > X(3) X(5) > X(4)	Y(1) = 0.0 Y(2) = 0.0 Y(3) > Y(2)

3.3 INPUT INSTRUCTIONS

Instructions for preparing input data for the subsonic computer program are presented here. The field location and format for each input quantity is specified. Any set of units may be used for geometric dimensions and acoustic velocity as long as they are consistent, e.g., if feet is used for length then the acoustic velocity must have dimensions of feet per second.

1. Streamwise Coordinates (6E12.5 format)

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	X(1)	X(2)	X(3)	X(4)	X(5)	
Item	(1)	(2)	(3)	(4)	(5)	

(1) X(1) Wing root leading edge streamwise coordinate (See Figure 3.3.1)
(2) X(2) Wing tip leading edge streamwise coordinate
(3) X(3) Wing trailing edge streamwise coordinate
(4) X(4) Control surface leading edge streamwise coordinate
(5) X(5) Control surface trailing edge streamwise coordinate

The technique for generating various configurations is shown in Table 3.2.1

The origin for the planform and AIC station coordinates must be at the leading edge root of the wing therefore X(1) and Y(1), described below, must always be 0.0.

2. Spanwise Coordinates and Acoustic Velocity (6E12.5 format)

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	Y(1)	Y(2)	Y(3)	SOUND	RHO	
Item	(1)	(2)	(3)	(4)	(5)	

(1) Y(1) Wing root spanwise coordinate
(2) Y(2) Wing leading edge spanwise coordinate
(3) Y(3) Wing (and control surface) tip spanwise coordinate
(4) SOUND Acoustic velocity for altitude at which analysis is performed
(5) RHO density of fluid * 1000.0 (M/L^3)

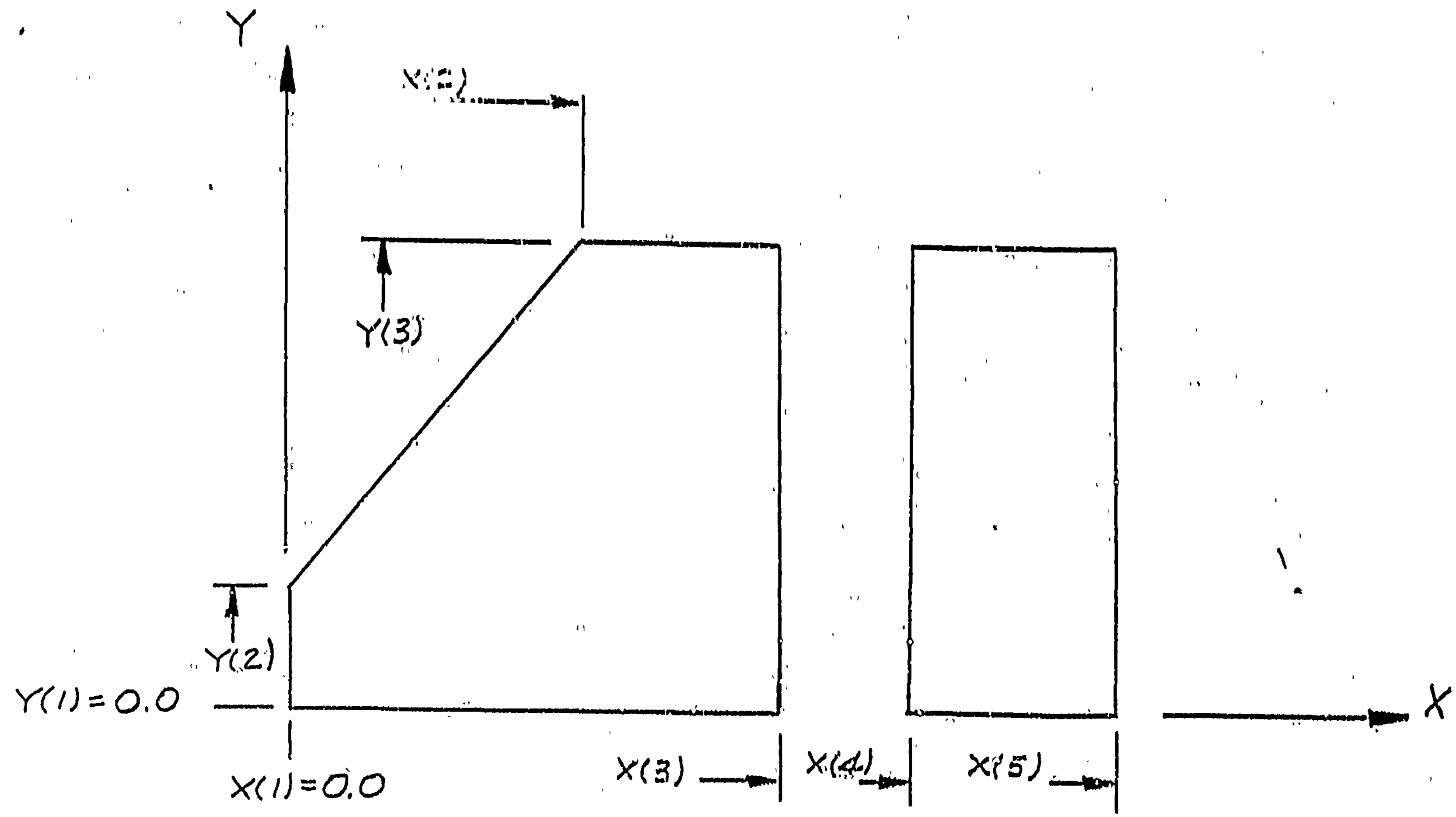

FIGURE 3.3.1
GEOMETRY DESCRIPTION

3. General Information (6I12 format)

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	NMACH	NFREQ	NMØDES	LCØLL	LPRWSH	LPRCØ
Item	(1)	(2)	(3)	(4)	(5)	(6)

(1) NMACH Number of Mach numbers (max 6)
(2) NFREQ Number of frequencies at each Mach number (max 10)
(3) NMØDES Number of deformation modes (max 10)
(4) LCØLL Print collocation stations; 1 ~ Yes; 0 ~ No
(5) LPRWSH Print pressures and downwashes; 1 ~ Yes; 0 ~ No
(6) LPRCØ Print pressure coefficients; 1 ~ Yes; 0 ~ No

4. General Information (6I12 format)

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	NWCX	NWPX	NCCX	NCPX	NIØNCX	
Item	(1)	(2)	(3)	(4)	(5)	(6)

(1) NWCX Number of chord collocation stations - wing(max 10)
(2) NWPX Number of chord pressure series terms - wing(max 10)
(3) NCCX Number of chord collocation stations - control surface(max 10)
(4) NCPX Number of chord pressure series terms - control surface(max 10)
(5) NIØNCX Choose a value of NIØNCX such that NIØNCX *(NWCX or NCCX) equals the number of chordwise integration stations

$$\left(\text{Max } \frac{40}{NWCX} \text{ or } \frac{40}{NCCX}\right)$$

5. General Information (6I12 format)

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	NIY	NWCY	NPY	INWTS	ISØLAT	
Item	(1)	(2)	(3)	(4)	(5)	(6)

(1) NIY Number of spanwise integration stations (max 11)
(2) NWCY Number of spanwise collocation stations - wing (max 11)
(3) NPY Number of spanwise pressure series terms (max 10)
(4) INWTS Read downwash error weighting factors; 1 ~ Yes; 0 ~ No
(5) ISØLAT Isolate wing and control surface; 1 ~ Yes; 0 ~ No

6. Weighting Factors (6E12.5 format)(omit these cards when INWTS = 0)

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	WT(1)	WT(2)	WT(3)	WT(4)	WT(5)	WT(6)
Item	(1)	(2)	(3)	(4)	(5)	(6)

Continue on successive cards until WT(i) = WT(NWTS)
Where NWTS = NWCY * NWCX + NIY * NCCX

7. NØMIT (6I12 format) (omit these cards when NWCY = NIY)

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	NØM(1)	NØM(2)	NØM(3)	NØM(4)	NØM(5)	NØM(6)
Item	(1)	(2)	(3)	(4)	(5)	(6)

Continue on successive cards until NØM(i) = NØM(NØMIT) where NØMIT = NIY-NWCY. For the solution to be carried out, NWCY must equal NIY. When an excessive number of collocation stations exist, they must be eliminated by spanwise rows. NØM(i) is the spanwise row number to be eliminated. NØMIT = NIY-NWCY is the number of spanwise rows to be eliminated.

8. Mach Numbers (6E12.5 format)

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	FMACH(1)	FMACH(2)	FMACH(3)	FMACH(4)	FMACH(5)	FMACH(6)
Item	(1)	(2)	(3)	(4)	(5)	(6)

(1) FMACH(1) Mach number
(2) FMACH(2) Mach number
. . . .
. . . .
. . . .
. . . .

(NMACH) FMACH(NMACH) Mach number

NMACH values of Mach number must be input. Mach numbers must be greater than zero and less than 0.95.

9. Frequencies (6E12.5 format)

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	FREQ(1)	FREQ(2)	FREQ(3)	FREQ(4)	FREQ(5)	FREQ(6)
Item	(1)	(2)	(3)	(4)	(5)	(6)

(1) FREQ(1) f(cps)
(2) FREQ(2) f(cps)
. . .
. . .
. . .
. . .

(NFREQ) FREQ(NFREQ)

For NFREQ 6, continue input on new card.

Repeat the following cards i = 1,. . ., NMØDES

10. Number of Deformation Mode Polynomial Coefficients to be Read for the i^{th} Mode First Surface

Format(6I12)

Column	1-12	13-24
Name	NZCØ(1,i)	
Item	(1)	(2)

(1) NZCØ(1,i) Number of polynomial coefficients to be read for the first surface, the i^{th} mode.

Format (6E12.5)

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	CØ(0,0)	CØ(1,0)	CØ(0,1)	CØ(2,0)	CØ(1,1)	CØ(0,2)
Item	(1)	(2)	(3)	(4)	(5)	(6)

CØ(i,j) Deformation polynomial coefficients for the first surface in the order: 0,0; 1,0; 0,1; 2,0; 1,1; 2,0; etc. where the first integer is the power of "x" and the second is the power of "y"

Format(6I12)

Column	1-12	13-24
Name	NZCØ(2,i)	
Item	(1)	(2)

(1) NZCØ(2,i) Number of polynomial coefficients to be read for the second surface and the i^{th} mode.

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	CØ(0,0)	CØ(1,0)	CØ(0,1)	CØ(2,0)	CØ(1,1)	CØ(0,2)
Item	(1)	(2)	(3)	(4)	(5)	(6)

CØ(i,j) Deformation polynomial coefficients for the second surface in the order: 0,0; 1,0; 0,1; 2,0; 1,1; 2,0; etc.; where the first integer is the power of "x" and the second is the power of "y"

3.4 SAMPLE PROBLEM

The generalized forces are calculated for the configuration below. The flight parameters and pertinent input data are presented on the first page of the computer print out.

The coefficients of the deformation modes for the forward suface are shown on the second page of the computer print out, and for the aft surface on the third page of the computer print out.

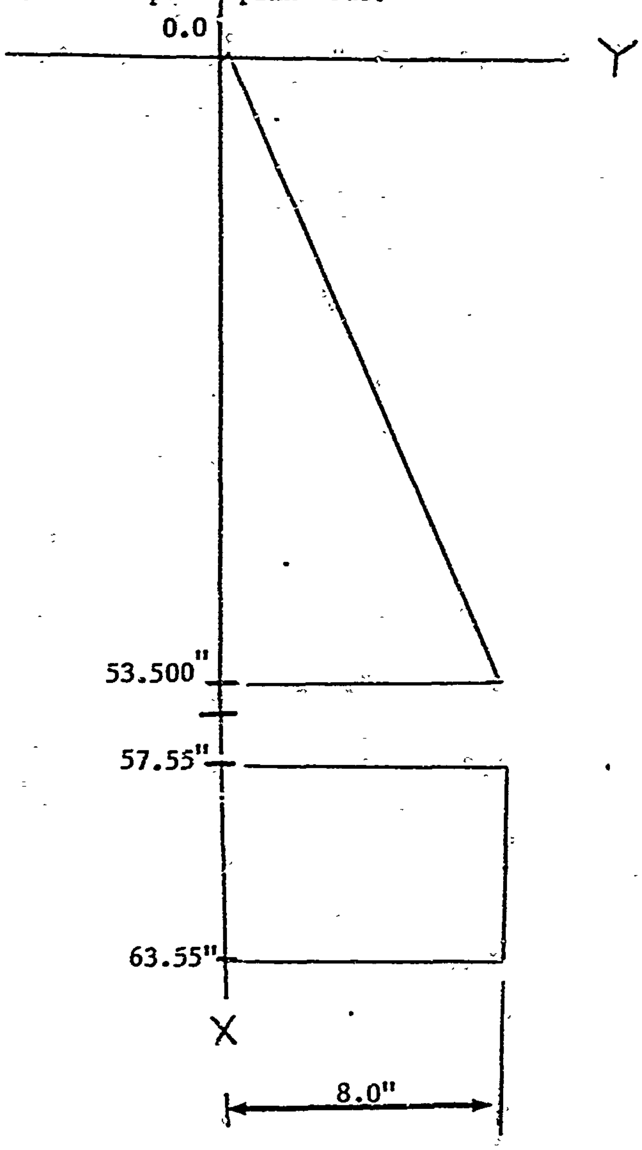

Figure 3.4.1

HAC/NAA MISSILE SUBSONIC AIRLOADS PROGRAM

FLIGHT CONDITIONS AND GEOMETRY

MACH NUMBER = 0.75000   SPEED OF SOUND = 13392.000 L/T   RHO=0.11460000E-06

	WING	TAIL
L.E. STATION (L)	0.	57.550
ROOT CHORD (L)	53.500	6.000
L.E. SPAN (L)	0.	8.000
T.E. SPAN (L)	8.000	8.000
TIP CHORD (L)	0.	6.000
TOTAL AREA (L*L)	428.000	96.000
SPAN COLL. STA.	5	5
CHORD COLL. STA.	5	4
CHORD INTG. STA.	25	20
SPAN PRES MODES	5	5
CHORD PRES MODES	5	4

MISSILE SUBSONIC AIRLOADS PROGRAM (CONT'D)

OSCILLATORY FREQUENCY (CPS) 175.00000 5 DEFLECTION MODES

REDUCED FREQUENCY (SEMI CHORD) 2.92843 FREE STREAM MACH NUMBER 0.750

INPUT MODE SHAPE POLYNOMIAL COEFFICIENTS FOR WING

REFERENCED TO THE SURFACE LEADING EDGE-CENTERLINE INTERSECTION

MODE	COEFFS.						
1	2.0521E-04	-5.1369E-03	-1.7297E-01	6.6410E-04	1.2377E-02	9.4315E-02	-4.0663E-05
	3.4901E-04	-1.8280E-02	4.4315E-02	1.0269E-06	-2.7631E-05	7.0302E-04	-2.4386E-03
	1.7143E-03	-8.7203E-09	3.4448E-07	-7.6417E-06	3.2771E-05	-4.2944E-05	1.4335E-05
2	-2.0230E-02	6.6160E-03	5.4738E-01	5.5723E-04	-1.2727E-01	1.1243E-01	-1.1355E-04
	1.1767E-02	-6.1689E-02	2.1984E-01	3.9306E-06	-3.6816E-04	3.0863E-03	-1.4335E-02
	1.2788E-02	-3.8299E-08	3.5697E-06	-3.7881E-05	2.0408E-04	-3.1845E-04	1.9772E-04
3	-8.8265E-03	1.5226E-03	-1.3938E 00	2.2485E-03	1.2298E-01	6.1586E-01	-2.4958E-04
	2.5723E-03	-1.2793E-01	3.4273E-01	7.6501E-06	-2.4579E-04	5.1801E-03	-1.9536E-02
	1.3232E-02	-7.0887E-08	3.0849E-06	-5.6882E-05	2.4816E-04	-2.3222E-04	-7.4070E-05
4	-2.3616E-03	-9.5670E-03	-1.2947E-01	8.8089E-04	2.8617E-02	5.8725E-02	-4.8745E-05
	7.3151E-04	-5.9538E-02	2.1428E-01	1.1771E-06	-5.9277E-05	2.1117E-03	-6.0253E-03
	-9.0423E-03	-8.8432E-09	6.9796E-07	-1.9536E-05	4.5021E-05	1.1500E-04	1.5178E-04
5	-1.8034E-04	-1.8284E-05	1.3879E-02	-1.0982E-05	-2.9642E-03	-3.9850E-04	7.7560E-07
	1.5355E-04	3.0570E-04	-9.9055E-04	-1.6682E-08	-3.5623E-06	1.1936E-06	-5.9706E-05
	2.6742E-04	1.1484E-10	3.0569E-08	-1.4258E-07	2.1170E-06	-1.1500E-05	1.9655E-05

MISSILE SUBSONIC AIRLOADS PROGRAM (CONT'D)

OSCILLATORY FREQUENCY (CPS) 175.00000 5 DEFLECTION MODES

REDUCED FREQUENCY (SEMI CHORD) 2.92843 FREE STREAM MACH NUMBER 0.750

INPUT MODE SHAPE POLYNOMIAL COEFFICIENTS FOR TAIL

REFERENCED TO THE SURFACE LEADING EDGE-CENTERLINE INTERSECTION

MODE	COEFFS.						
1	-2.5045E-01	1.3407E-02	-2.0109E-02	9.0702E-04	-1.5111E-03	-1.3471E-02	-4.2571E-04
	-5.1564E-04	8.8247E-04	-1.6279E-03	3.9499E-05	4.6416E-05	1.1246E-06	-5.2663E-05
	2.6874E-04						
2	-6.0722E-02	1.3622E-02	-5.0481E-03	-5.7007E-03	1.1958E-03	-1.3226E-03	1.7459E-03
	-4.4974E-04	2.4416E-05	2.8156E-04	-1.5632E-04	4.2814E-05	8.0306E-06	3.5725E-06
	-2.5385E-05						
3	-1.6215E-02	1.1602E-02	7.1003E-03	3.8815E-04	-1.5586E-03	8.7454E-05	-2.9670E-04
	4.8260E-05	1.9642E-04	2.5398E-04	3.4503E-05	-2.3779E-05	3.0552E-05	-3.5626E-05
	-2.3265E-05						
4	1.3420E-01	-2.2355E-01	-3.9674E-02	9.4683E-02	3.2691E-02	1.8561E-02	-1.7439E-02
	-8.4577E-03	-1.4563E-03	-2.6337E-05	1.0735E-03	7.1000E-04	1.5943E-04	-1.6472E-06
	-1.3343E-04						
5	-6.0398E-01	3.1261E-01	-1.2775E-02	-4.3907E-02	1.2655E-02	-4.9283E-03	9.3476E-03
	-3.9443E-03	6.1969E-04	9.6992E-04	-8.0275E-04	3.4466E-04	3.4043E-04	-1.8608E-04
	-4.9674E-05						

MISSILE SUBSONIC AIRLOADS PROGRAM (CONT'D)

OSCILLATORY FREQUENCY (CPS) 175.00000 5 DEFLECTION MODES

REDUCED FREQUENCY (SEMI CHORD) 2.92843 FREE STREAM MACH NUMBER 0.750

GENERALIZED FORCES FOR WING

DEFL	LOAD	REAL PART	IMAG PART	ABS VALUE	PHASE ANGLE
1	1	1.78433E 00	-1.20375E-01	1.78839E 00	-3.859 DEG
1	2	-4.19576E 00	1.94784E 00	4.62580E 00	155.097 DEG
1	3	9.34031E-01	-1.27098E 01	1.27441E 01	-85.797 DEG
1	4	1.03725E 01	6.67475E 00	1.23345E 01	32.762 DEG
1	5	-5.40024E-02	6.39892E-01	6.42167E-01	94.824 DEG
2	1	-7.67248E 00	-2.67310E 00	8.12480E 00	-160.792 DEG
2	2	1.58403E 01	-6.01938E 00	1.69455E 01	-20.807 DEG
2	3	-2.68136E 01	3.93086E 01	4.75829E 01	124.299 DEG
2	4	-2.46347E 01	-3.70716E 01	4.45103E 01	-123.605 DEG
2	5	8.50254E 00	-9.48398E 00	1.27373E 01	-48.123 DEG
3	1	4.08041E 00	2.08681E 01	2.12633E 01	78.936 DEG
3	2	1.35203E 01	-2.18268E 01	2.56750E 01	-58.225 DEG
3	3	1.99015E 02	-7.14507E 00	1.99143E 02	-2.056 DEG
3	4	-9.86493E 01	1.51302E 02	1.80621E 02	123.104 DEG
3	5	-2.47112E 01	3.74608E 01	4.48771E 01	123.411 DEG
4	1	6.04738E 00	-1.57318E 01	1.68541E 01	-68.973 DEG
4	2	-3.81082E 01	2.17331E 01	4.38699E 01	150.304 DEG
4	3	-1.44431E 02	-7.27240E 01	1.61707E 02	-153.274 DEG
4	4	1.36556E 02	-6.84736E 01	1.52762E 02	-26.631 DEG
4	5	1.99313E 01	-3.09072E 01	3.67765E 01	-57.183 DEG
5	1	-1.62374E-01	-9.08498E-02	1.86062E-01	-150.773 DEG
5	2	2.19044E-01	2.21553E-01	3.11554E-01	45.326 DEG
5	3	-9.00154E-01	1.64998E 00	1.87955E 00	118.615 DEG
5	4	-6.57931E-01	-1.65552E 00	1.78147E 00	-111.674 DEG
5	5	1.48400E-03	-2.23596E-01	2.23601E-01	-89.620 DEG

MISSILE SUBSONIC AIRLOADS PROGRAM (CONT'D)

OSCILLATORY FREQUENCY (CPS) 175.00000 5 DEFLECTION MODES

REDUCED FREQUENCY (SEMI CHORD) 2.92643 FREE STREAM MACH NUMBER 0.750

GENERALIZED FORCES FOR TAIL

DEFL	LOAD	REAL PART	IMAG PART	ABS VALUE	PHASE ANGLE
1	1	1.68414E 01	-2.35843E 01	2.89802E 01	-54.470 DEG
1	2	-2.64029E 01	8.04695E 00	2.76019E 01	163.050 DEG
1	3	1.10991E 02	9.07857E 01	1.43392E 02	39.282 DEG
1	4	-1.18085E 02	1.10429E 01	1.18600E 02	174.657 DEG
1	5	9.33634E 01	4.66232E 01	1.04357E 02	26.536 DEG
2	1	1.08962E 00	-3.90206E 00	4.05134E 00	-74.390 DEG
2	2	-3.30264E 00	1.18511E 00	3.50883E 00	160.260 DEG
2	3	1.04867E 01	1.49847E 01	1.82897E 01	55.015 DEG
2	4	-1.68185E 01	-2.94656E 00	1.70746E 01	-170.063 DEG
2	5	1.51049E 01	-1.46800E-02	1.51049E 01	-0.056 DEG
3	1	-1.75394E 00	8.69312E-01	1.95755E 00	153.635 DEG
3	2	1.67228E 00	-5.81288E-01	1.77043E 00	-19.168 DEG
3	3	-9.53124E 00	-2.84436E 00	9.94660E 00	-163.384 DEG
3	4	5.84535E 00	-4.02413E 00	7.09660E 00	-34.545 DEG
3	5	-3.34095E 00	-6.99428E 00	7.75125E 00	-115.532 DEG
4	1	-7.04105E 00	9.89088E 00	1.21411E 01	125.446 DEG
4	2	8.45155E 00	3.31667E-01	8.45928E 00	2.450 DEG
4	3	-4.93566E 01	-2.94018E 01	5.74504E 01	-149.218 DEG
4	4	4.77750E 01	-1.16789E 01	4.91818E 01	-13.737 DEG
4	5	-4.49855E 01	-1.79246E 01	4.84258E 01	-158.275 DEG
5	1	-9.85154E 00	-3.42133E 01	3.56034E 01	-106.063 DEG
5	2	-9.00265E 00	-2.54141E 00	9.35449E 00	-164.236 DEG
5	3	1.16454E 01	9.67320E 01	9.74304E 01	83.135 DEG
5	4	-1.00822E 02	-5.30842E 01	1.13943E 02	-152.233 DEG
5	5	1.42165E 02	-9.58511E 01	1.71459E 02	-33.989 DEG

MISSILE SUBSONIC AIRLOADS PROGRAM (CONT'D)

OSCILLATORY FREQUENCY (CPS) 175.00000 — 5 DEFLECTION MODES

REDUCED FREQUENCY (SEMI CHORD) 2.92843 — FREE STREAM MACH NUMBER 0.750

GENERALIZED FORCES FOR WING + TAIL

DEFL	LOAD	REAL PART	IMAG PART	ABS VALUE	PHASE ANGLE
1	1	1.86258E 01	-2.37847E 01	3.01468E 01	-51.842 DEG
1	2	-3.05986E 01	9.99479E 00	3.21896E 01	161.911 DEG
1	3	1.11925E 02	7.80759E 01	1.36467E 02	34.899 DEG
1	4	-1.07712E 02	1.77176E 01	1.09160E 02	170.659 DEG
1	5	9.33094E 01	4.72631E 01	1.04597E 02	26.863 DEG
2	1	-6.58286E 00	-6.57516E 00	9.30412E 00	-135.034 DEG
2	2	1.25177E 01	-4.83428E 00	1.34374E 01	-21.006 DEG
2	3	-1.63268E 01	5.42933E 01	5.66951E 01	106.737 DEG
2	4	-4.14532E 01	-4.00181E 01	5.76178E 01	-136.009 DEG
2	5	2.36074E 01	-9.49866E 00	2.54467E 01	-21.918 DEG
3	1	2.32647E 00	2.17374E 01	2.18616E 01	83.891 DEG
3	2	1.51926E 01	-2.24881E 01	2.70728E 01	-55.963 DEG
3	3	1.89483E 02	-9.98943E 00	1.89747E 02	-3.018 DEG
3	4	-9.28040E 01	1.47278E 02	1.74078E 02	122.216 DEG
3	5	-2.80521E 01	3.04665E 01	4.14141E 01	132.637 DEG
4	1	-9.93673E-01	-5.84095E 00	5.92487E 00	-99.655 DEG
4	2	-2.96567E 01	2.20948E 01	3.69824E 01	143.313 DEG
4	3	-1.93708E 02	-1.02126E 02	2.19051E 02	-152.211 DEG
4	4	1.84331E 02	-8.01525E 01	2.01004E 02	-23.501 DEG
4	5	-2.50541E 01	-4.88318E 01	5.48840E 01	-117.161 DEG
5	1	-1.00139E 01	-3.43842E 01	3.57359E 01	-106.273 DEG
5	2	-8.78360E 00	-2.31966E 00	9.08479E 00	-165.205 DEG
5	3	1.07453E 01	9.83820E 01	9.89670E 01	83.767 DEG
5	4	-1.01480E 02	-5.47397E 01	1.15300E 02	-151.657 DEG
5	5	1.42167E 02	-9.60747E 01	1.71586E 02	-34.050 DEG

```
$       OPTION  FORTRAN
$       FORTRAN HLSTOU,DECK
$       INCODE  IBMF
CHAIN       MAIN
      COMPLEX A,AA,ANM,CZERO,GFORC,DELP,WASH,APR,DWASH,CWASH,PR
      DIMENSION DWASH(90,10),PR(90,10),CWASH(90,10)
      DIMENSION GFORC(10,10,3),DELP(10),WASH(10)
      COMMON/C1/A(60),AA(50,60),ANM(50,10),CZERO
      COMMON/C2/CLEN,SN,NIY,NWCX,NCCX,NWPX,NCPX,WKER(20),ZKER(20),NGSKRN
      COMMON/C3/NPY,SOUND,NMACH,FMACH(6),NFREQ,FREQ(10),MAUG,NIONCX,RHO
      COMMON/C4/NMODES,LCOLL,LPRWSH,LPRCO,NOM(5),IIY,IIX,NSURF,ISOLAT
      COMMON/C5/FW,FC,NCOLS,NOMIT,ALPHA(10),IL(50),HCOR(6),ZCOR(6),MACH
      COMMON/C6/WXCHN(11),WBCN(11),WBIN(11),WT(90),XCOLL,YCOLL,PI,U
      COMMON/C7/CO(10,20,2),NZCO(10,2),EM,EK,B2,NWIX,NCIX,WBO,CBOM,NWCY
      COMMON/C8/IFR,XE(5),YE(3),UX(10),UY(10),WXIMN(11),E1,E2
      COMMON/C9/SIX(40,2),SCX(10,2),Y(11),ETA(11),QWY,QWWX,QWCX,CXMN
      COMMON/CPR/APR(90,60),IMOD,IROW
      EQUIVALENCE (GFORC,AA),(A,WASH),(WASH,DELP)
      EQUIVALENCE (DWASH(1,1),APR(1,51)),(PR(1,1),APR(1,11))
      EQUIVALENCE (CWASH(1,1),APR(1,41))
      WRITE(6,66)
   66 FORMAT(1H1)
    1 CALL KFDA
      FW = 2*NWIX + 1
      FC = 2*NCIX + 1
      QWWX = 2.0*PI/FW
      QWCX = 2.0*PI/FC
      QWY = PI/FLOAT(2*NIY)
      CALL GEOM
      DO 100 MACH=1,NMACH
      MACH = MACH
      EM = FMACH(MACH)
      CALL KOUT(1)
      U = EM*SOUND
      IF(LCOLL.NE.0)  CALL KOUT(2)
      BOU = WBO/U
      B2 = 1.0 - EM*EM
      DO 100 IFR=1,NFREQ
      IFR = IFR
      EK = 2.0*PI*FREQ(IFR)*BOU
C     NSURF = 1 (WING) OR 2 (CONTROL)
      NCX = NWCX
      MOMIT = 1
      MAUG = NCOLS + NMODES
      DO 4 J=1,NCOLS
      IL(J) = 0
      DO 4 K=1,MAUG
    4 AA(J,K) = CZERO
      IROW = 1
      DO 15 NSURF=1,2
      NSURF = NSURF
      CALL KOUT(6)
C     KOUT (6) PRINTS COEFFICIENTS OF DEFLECTION SERIES
      DO 14 IY=1,NIY
      IIY = IY
      IF(NOMIT-MOMIT.LT.0)  GO TO 7
      IF(IY-NOM(MOMIT).EQ.0)  GO TO 13
    7   YCOLL = SN*Y(IY)
        DO 12 IX=1,NCX
      IIX = IX
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      XCOLL = XS(1,NSURF,IX,IY)
      CALL CORB
C     *** CORD FILLS OUT A ROW OF THE DOWNWASH MATRIX EACH TIME CALLED
      DO 58 M = 1,NMODES
      CALL ZBZX(M,SLOPE,DEFL)
      MNC = NCOLS +M
   58 WASH(MNC) = CMPLX(SLOPE,DEFL*EK/WB0)
      DO 40 K=1,MAUG
      K1 = K
      IF(K.GT.NCOLS)  K1 = 50 + K - NCOLS
   40 APR(IROW,K1) = A(K)
      DO 60 N=1,NCOLS
   60 CALL CGRED(A,N,N)
      DO 70 L=1,NMODES
      ML = NCOLS + L
   70 ALPHA(L) = SQRT(ALPHA(L)**2 + CABS(A(ML))**2)
      IROW = IROW + 1
   12 CONTINUE
        GO TO 14
   13   MOMIT = MOMIT +1
   14 CONTINUE
      NCX = NCCX
   15 CONTINUE
      CALL XLSQ
C     *******************************************************************
      IF(LPRCO.EQ.0) GO TO 17
C     *******************************************************************
      DO 16 IMOD=1,NMODES
      IMOD = IMOD
   16 CALL KOUT(3)
C     KOUT(3) PRINTS COEFFICIENTS OF PRESSURE SERIES FOR EACH MODE
C     *******************************************************************
   17 IF(LPRWSH.EQ.0) GO TO 69
C     *******************************************************************
C     COMPUTE AND STORE THE PRESSURE DOWNWASHES
      MOMIT = 1
      IROW = 1
      NCX = NWCX
      DO 115 NSURF=1,2
      DO 114 IY=1,NIY
      IF(NOMIT.LT.MOMIT) GO TO 107
      IF(IY.EQ.NOM(MOMIT)) GO TO 113
  107 DO 112 IX=1,NCX
            DO 140 IM=1,NMODES
            A(IM) = CZERO
            DO 140 JC=1,NCOLS
  140       A(IM) = A(IM) +APR(IROW,JC)*ANM(JC,IM)
            DO 150 IM=1,NMODES
  150       CWASH(IROW,IM) = A(IM)
      IROW = IROW +1
  112 CONTINUE
      GO TO 114
  113 MOMIT = MOMIT +1
  114 CONTINUE
      NCX = NCCX
  115 CONTINUE
C
   69 CALL FORC(NWIX,NCIX,NIY,ETA,SIX,WBIN,0)
      IF(LPRWSH.EQ.0) GO TO 77
      CALL FORC(NWCX,NCCX,NIY,Y,SCX,WBCN,LPRWSH)
      DO 99 IMOD=1,NMODES
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      IMOD = IMOD
      NCX = NWCX
      MOMIT = 1
      IROW = 1
      DO 99 NSURF=1,2
      NSURF = NSURF
      CALL KOUT (7)
C     KOUT (7) PRINTS THE HEADER FOR THE PRESSURE AND DOWNWASH ARRAYS
   90 DO 98 IY=1,NIY
      IF(NOMIT.LT.MOMIT) GO TO 91
      IF(IY.EQ.NOM(MOMIT)) GO TO 97
   91 YCOLL = WBO*SN*Y(IY)
      DO 96 IX=1,NCX
      XCOLL = WBO*XS(1,NSURF,IX,IY)
      CALL KOUT(9)
C     KOUT (9) PRINTS THE X AND Y COORDINATES OF EACH COLLOCATION
C     POINT, THE LOCAL PRESSURE, THE DOWNWASH CREATED THERE BY THE
C     PRESSURE FIELD, AND THE DOWNWASH OF THE SURFACE AT THE POINT.
C     THE DEGREE TO WHICH THE TWO SETS OF DOWNWASHES MATCH IS A MEASURE
C     OF THE ACCURACY OF THE SOLUTION OF THE BOUNDARY VALUE PROBLEM.
C     THE ROOT-MEAN-SQUARE OF THE ERRORS IS GIVEN IN THE ARRAY ALPHA.
   96 IROW = IROW +1
      GO TO 98
   97 MOMIT = MOMIT +1
   98 CONTINUE
      NCX = NCCX
   99 CONTINUE
C     ******************************************************************
   77 DO 78 L=1,3
      NSURF = L
   78 CALL KOUT(8)
C     KOUT(8) PRINTS THE GENERALIZED FORCES
  100 CONTINUE
      GO TO 1
      END
$      FORTRAN NLSTOU,DECK
$       INCODE  IBMF
CCONS1        CONS1
      BLOCK DATA
      COMPLEX A,AA,ANM,CZERO
      COMMON/C1/A(60),AA(50,60),ANM(50,10),CZERO
      COMMON/C2/CLEN,SN,NIY,NWCX,NCCX,NWPX,NCPX,HKER(20),ZKER(20),NGSKRN
      COMMON/C3/NPY,SOUND,NMACH,FMACH(6),NFREQ,FREQ(10),MAUG,NIONCX,RHO
      COMMON/C4/NMODES,LCOLL,LPRWSH,LPRCO,NOM(5),IIY,IIX,NSURF,ISOLAT
      COMMON/C5/FW,FC,NCOLS,NOMIT,ALPHA(10),IL(50),HCOR(6),ZCOR(6),MACH
      COMMON/C6/WXCMN(11),WBCN(11),WBIN(11),WI(90),XCOLL,YCOLL,PI,U
      COMMON/C7/CO(10,28,2),NZCO(10,2),EM,EK,E2,NWIX,NCIX,WBO,CBON,NWCY
      COMMON/C8/IFR,XE(5),YE(5),UX(10),UY(10),WXIMN(11),E1,E2
      COMMON/C9/SIX(40,2),SCX(10,2),Y(11),ETA(11),QWY,QWWX,QWCX,CXMN
      DATA PI/3.14159265/
      DATA HCOR/0.08566225,0.18038079,0.23395697,0.23395697,0.18038079,
     10.08566225/
      DATA ZCOR/0.03376524,0.16939531,0.38069041,0.61930959,0.83060469,
     10.96623476/
C     ******************************************************************
C     NGSKRN SHOULD BE COMPATIBLE WITH HKER AND ZKER LISTS
      DATA NGSKRN/8/
      DATA (HKER(I),I=1,8)/0.05061427,0.11119052,0.15685332,0.18134189
     X,0.18134189,0.15685332,0.11119052,0.05061427/
      DATA (ZKER(I),I=1,8)/0.01985507,0.10166676,0.23723380,0.40828268
     X,0.59171732,0.76276620,0.89833324,0.98014493/
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C      ***************************************************************SUB70290
       DATA E1/0.0000001/,E2/0.0000001/,CZERO/(0.0,0.0)/                SUB70300
       END                                                              SUB70310
$       FORTRAN NLSTOU,DECK                                             SUB71870
$       INCODE  IBMF                                                    SUB71880
CKFDA         KFDA                                                      SUB71890
       SUBROUTINE KFDA                                                  SUB71900
       COMPLEX A,AA,ANM,CZERO                                           SUB71910
       COMMON/C1/A(60),AA(50,60),ANM(50,10),CZERO                       SUB71920
       COMMON/C2/CLEN,SN,NIY,NWCX,NCCX,NWPX,NCPX,HKER(20),ZKER(20),NGSKRNSUB71930
       COMMON/C3/NPY,SOUND,NMACH,FMACH(6),NFREQ,FREQ(10),MAUG,NIONCX,RHO SUB71940
       COMMON/C4/NMODES,LCOLL,LPRWSH,LPRCO,NOM(5),IIY,IIX,NSURF,ISOLAT   SUB71950
       COMMON/C5/FW,FC,NCOLS,NOMIT,ALPHA(10),IL(50),HCOR(6),ZCOR(6),MACH SUB71960
       COMMON/C6/WXCMN(11),WBCN(11),WBIN(11),WT(90),XCOLL,YCOLL,PI,U     SUB71970
       COMMON/C7/CO(10,28,2),NZCO(10,2),EM,EK,B2,NWIX,NCIX,WBO,CBON,NWCY SUB71980
       COMMON/C8/IFR,XE(5),YE(3),UX(10),UY(10),WXIMN(11),E1,E2           SUB71990
       COMMON/C9/SIX(40,2),SCX(10,2),Y(11),ETA(11),QWY,QWWX,QWCX,CXMN    SUB72000
       READ(5,11)(XE(I),I=1,5)                                          SUB72010
       READ(5,11) (YE(I),I=1,3),SOUND,RHO                               SUB72020
       RHO = RHO/1000.0                                                 SUB72030
       READ(5,12) NMACH,NFREQ,NMODES,LCOLL,LPRWSH,LPRCO                 SUB72040
       READ(5,12) NWCX,NWPX,NCCX,NCPX,NIONCX                            SUB72050
       READ(5,12) NIY,NWCY,NPY,INWTS,ISOLAT                             SUB72060
       NWTS = NWCY*NWCX +NIY*NCCX                                       SUB72070
       DO 40 I=1,NWTS                                                   SUB72080
    40 WT(I) = 1.0                                                      SUB72090
       IF(INWTS.NE.0)  READ(5,11) (WT(I),I=1,NWTS)                      SUB72100
       NCOLS = NPY * (NWPX + NCPX)                                      SUB72110
       NCIX =    NCCX*NIONCX                                            SUB72120
       NWIX=    NWCX*NIONCX                                             SUB72130
       NOMIT = 0                                                        SUB72140
       DO 4 I=1,5                                                       SUB72142
     4 NOM(I) = 0                                                       SUB72144
       IF(NWCY.GE.NIY)  GO TO 5                                         SUB72150
       NOMIT = NIY-NWCY                                                 SUB72160
       READ(5,12) (NOM(I),I=1,NOMIT)                                    SUB72170
     5 READ(5,11) (FMACH(I),I=1,NMACH)                                  SUB72180
       DO 7 I=1,NMACH                                                   SUB72190
       IF(FMACH(I).LE.0.99)  GO TO 7                                    SUB72200
       WRITE(6,13)                                                      SUB72210
    13 FORMAT(71H    A MACH NUMBER GREATER THAN 0.99 HAS BEEN READ IN----SUB72220
      1CASE TERMINATED)                                                 SUB72230
       CALL EXIT                                                        SUB72240
     7 CONTINUE                                                         SUB72250
       READ(5,11)(FREQ(I),I=1,NFREQ)                                    SUB72260
       DO 20 I = 1,NMODES                                               SUB72270
       DO 20 L = 1,2                                                    SUB72280
       DO 10 K = 1,28                                                   SUB72290
    10 CO(I,K,L) = 0.0                                                  SUB72300
       READ(5,12) NCO                                                   SUB72310
       NZCO(I,L) = NCO                                                  SUB72320
    20 READ(5,11) (CO(I,K,L),K=1,NCO)                                   SUB72330
       DO 30 I=2,5                                                      SUB72340
    30 XE(I) = XE(I) -XE(1)                                             SUB72350
       YE(2) = YE(2) -YE(1)                                             SUB72360
       YE(3) = YE(3) -YE(1)                                             SUB72370
    11 FORMAT(6E12.8)                                                   SUB72380
    12 FORMAT(6I12)                                                     SUB72390
       IF(NCIX.GT.40.OR.NWIX.GT.40)  GO TO 86                           SUB72400
       IF(NWCX*NWCY+NCCX*NIY.GT.90)  GO TO 86                           SUB72410
       IF(NPY*(NWPX+NCPX).GT.50)  GO TO 86                              SUB72420
```

```
      IF(NWPX.GT.10.OR.NCPX.GT.10.OR.NPY.GT.10)  GO TO 86
      RETURN
   86 EM = FMACH(1)
      CALL KOUT(1)
      CALL KOUT(5)
      RETURN
      END
$       FORTRAN NLSTOU,DECK
$        INCODE  IBMF
CGEOM         GEOM
      SUBROUTINE GEOM
      COMPLEX A,AA,ANM,CZERO
      COMMON/C1/A(60),AA(50,60),ANM(50,10),CZERO
      COMMON/C2/CLEN,SN,NIY,NWCX,NCCX,NWPX,NCPX,HKER(20),ZKER(20),NGSKRN
      COMMON/C3/NPY,SOUND,NMACH,FMACH(6),NFREQ,FREQ(10),MAUG,NIONCX,RHO
      COMMON/C4/NMODES,LCOLL,LPRWSH,LPRCO,NOM(5),IIY,IIX,NSURF,ISOLAT
      COMMON/C5/FW,FC,NCOLS,NOMIT,ALPHA(10),IL(50),HCOR(6),ZCOR(6),MACH
      COMMON/C6/WXCMN(11),WBCN(11),WBIN(11),WT(90),XCOLL,YCOLL,PI,U
      COMMON/C7/CO(10,28,2),NZCO(10,2),EM,EK,B2,NWIX,NCIX,WBO,CBON,NWCY
      COMMON/C8/IFR,XE(5),YE(3),UX(10),UY(10),WXIMN(11),E1,E2
      COMMON/C9/SIX(40,2),SCX(10,2),Y(11),ETA(11),QWY,QWWX,QWCX,CXMN
C     WBO = WING ROOT SEMI-CHORD
C     S = SEMI-SPAN
C     WTCN = WING TIP CHORD - NORMALIZED ON WBO
C     WTLEN = WING TIP L.E. - NORMALIZED
C     SN = SEMI-SPAN - NORMALIZED
C     CBO = CONTROL SEMI-CHORD
C     FW = 2*NWIX+1
C     FC = 2*NCIX+1
      WBO = XE(3)/2.0
      CLEN = XE(4)/WBO
      S = YE(3)
      WTCN = (XE(3)-XE(2))/WBO
      WTLEN = XE(2)/WBO
      SN = S/WBO
      CBO = (XE(5)-XE(4))/2.0
      F1=FW
      F2 = F1*PI/2.
      J = NWIX
C    COMPUTE CHORDWISE INTEGRATION AND COLLOCATION STATIONS
C    FIRST ON THE WING SURFACE
      DO 5 I=1,NWIX
      F2 = F2 -2.*PI
      SIX(J,1) = SIN(F2/F1)
      I1 = FLOAT(I)/FLOAT(NIONCX) + 0.99
      SCX(I1,1) = -SIX(J,1)
    5 J=J-1
      F1=FC
      F2 = F1*PI/2.
      J = NCIX
C     THEN ON THE CONTROL SURFACE
      DO 6 I=1,NCIX
      F2 = F2 -2.*PI
      SIX(J,2) = SIN(F2/F1)
      I1 = FLOAT(I)/FLOAT(NIONCX) + 0.99
      SCX(I1,2) = -SIX(J,2)
    6 J=J-1
      F1 = 4*NIY
      F2=0.0
C    COMPUTE SPANWISE INTEGRATION AND COLLOCATION STATIONS
```

```
      DO 8 I=1,NIY
      Y(I) = SIN(F2/F1)
      F2 = F2 +PI
      ETA(I) = SIN(F2/F1)
    8 F2 = F2 +PI
C     COMPUTE WING SEMI-CHORDS AND MID-CHORD LOCATIONS AT THE
C     SPANWISE COLLOCATION AND INTEGRATION STATIONS
      PIB = YE(2)/YE(3)
      POB =1.0-PIB
      CBON = (XE(5)-XE(4))/(2.0*WBO)
      CXMN = CBON +XE(4)/WBO
      DO 16 I=1,NIY
      IF(ETA(I).LE.PIB)  GO TO 12
      F1 = WTLEN*(ETA(I)-PIB)/POB
      IF(Y(I).LE.PIB)   GO TO 13
      F2 = WTLEN*(Y(I)-PIB)/POB
      GO TO 14
   12 F1 = 0.0
   13 F2 = 0.0
   14 WBIN(I) = 0.5*(2.0-F1)
      WXIMN(I) = WBIN(I) +F1
      WBCN(I) = 0.5*(2.0-F2)
   16 WXCMN(I) = WBCN(I) +F2
   36 RETURN
      END
$      FORTRAN NLSTOU,DECK
$       INCODE  IBMF
CXS           XS
      FUNCTION XS(L,NS,I3,J3)
      COMPLEX A,AA,ANM,CZERO
      COMMON/C1/A(60),AA(50,60),ANM(50,10),CZERO
      COMMON/C2/CLEN,SN,NIY,NWCX,NCCX,NWPX,NCPX,HKER(20),ZKER(20),NGSKRN
      COMMON/C3/NPY,SOUND,NMACH,FMACH(6),NFREQ,FREQ(10),MAUG,NIONCX,RHO
      COMMON/C4/NMODES,LCOLL,LPRWSH,LPRCO,NOM(5),IIY,IIX,NSURF,ISOLAT
      COMMON/C5/FW,FC,NCOLS,NOMIT,ALPHA(10),IL(50),HCOR(6),ZCOR(6),MACH
      COMMON/C6/WXCMN(11),WBCN(11),WBIN(11),WI(90),XCOLL,YCOLL,PI,U
      COMMON/C7/CO(10,28,2),NZCO(10,2),EM,EK,B2,NWIX,NCIX,WBO,CBON,NWCY
      COMMON/C8/IFR,XE(5),YE(3),UX(10),UY(10),WXIMN(11),E1,E2
      COMMON/C9/SIX(40,2),SCX(10,2),Y(11),ETA(11),QWY,QWWX,QWCX,CXMN
      GO TO (10,40),L
   10 GO TO (20,30),NS
   20 XS = WXCMN(J3) + WBCN(J3) * SCX(I3,1)
      RETURN
   30 XS = CXMN + CBON * SCX(I3,2)
      RETURN
   40 GO TO (50,60),NS
   50 XS = WXIMN(J3) + WBIN(J3) * SIX(I3,1)
      RETURN
   60 XS = CXMN + CBON * SIX(I3,2)
      RETURN
      END
$      FORTRAN NLSTOU,DECK
$       INCODE  IBMF
CBESL         BESL
      FUNCTION BESL(X)
      IF(X.GT.2.0)  GO TO 50
      T=X/3.75
      T=T*T
      BSI1=0.5+T*(0.87890594+T*(0.51498869+T*(0.15084934+T*(0.02658733+T
     1*(0.00301532+T*(0.00032411))))))
      BSI1=BSI1*X
```

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      Y=X/2.0                                                           SUB73640
      BSK1=X*ALOG(Y)*BSI1+1.0                                           SUB73650
      Y=Y*Y                                                             SUB73660
      BSK1=BSK1+Y*(0.15443144+Y*(-0.67278579+Y*(-0.18156897+Y*          SUB73670
     1(-0.01919402+Y*(-0.00110404+Y*(-0.00004686))))))                  SUB73680
      BESL =BSK1/X                                                      SUB73690
      GO TO 60                                                          SUB73700
   50 Y=2.0/X                                                           SUB73710
      BSK1=1.25331414+Y*(0.23498619+Y*(-0.03655620+Y*(0.01504268+Y*     SUB73720
     1(-0.00780353+Y*(0.00325614+Y*(-0.00068245))))))                   SUB73730
      BESL =BSK1/(SQRT(X)*EXP(X))                                       SUB73740
   60 RETURN                                                            SUB73750
      END                                                               SUB73760
$      FORTRAN NLSTOU,DECK                                              SUB73770
$      INCODE  IBMF                                                     SUB73780
CCRNL          CRNL                                                     SUB73790
      COMPLEX FUNCTION CRNL(CK,X,Y,CM,B2)                               SUB73800
      COMMON/C2/CLFN,SN,NIY,NWCX,NCCX,NWPX,NCPX,HKER(20),ZKER(20),NGSKRNSUB73810
      R=ABS(Y)                                                          SUB73820
      R2=R*R                                                            SUB73830
      CK1 = CK*R                                                        SUB73840
      G1 = 0.0                                                          SUB73850
      G3 = 0.0                                                          SUB73860
      G4 = 0.0                                                          SUB73870
    5 S2 = X*X + B2*R2                                                  SUB73880
      S =  SQRT(S2)                                                     SUB73890
      U1 = (CM*S-X)/(B2*R)                                              SUB73900
      UK = CK1*U1                                                       SUB73910
      DO 20 I = 1,NGSKRN                                                SUB73920
      UZ = U1*ZKER(I)                                                   SUB73930
      UZ2 = UZ**2                                                       SUB73940
      G=UK*ZKER(I)                                                      SUB73950
      F = HKER(I)/ SQRT(1.0+UZ2)*UZ*U1                                  SUB73960
      G3=G3+F*COS(G)                                                    SUB73970
      G4=G4+F*SIN(G)                                                    SUB73980
      V = 1.0 - ZKER(I)**2                                              SUB73990
      F = HKER(I)*2.0*V* EXP(-CK1*V)/ SQRT(1.0+V)                       SUB74000
   20 G1=G1+F                                                           SUB74010
      G7 = G1 + G3                                                      SUB74020
      XS = X/S                                                          SUB74030
      IF(CK.NE.0.0)  GO TO 22                                           SUB74040
      F14 = 1.0                                                         SUB74050
      GO TO 23                                                          SUB74060
   22 F14 = CK1*BESL(CK1)                                               SUB74070
   23 G1=CK1*G4-F14-XS*COS(UK)                                          SUB74080
      G2=CK1*G7+XS*SIN(UK)                                              SUB74090
      XK = CK*X                                                         SUB74100
      CO =  COS(XK)                                                     SUB74110
      SI =  SIN(XK)                                                     SUB74120
      CRNL = CMPLX((CO*G1+SI*G2)/R2,(CO*G2-SI*G1)/R2)                   SUB74130
      RETURN                                                            SUB74140
      END                                                               SUB74150
$      FORTRAN NLSTOU,DECK                                              SUB74530
$      INCODE  IBMF                                                     SUB74540
CCORD          CORD                                                     SUB74550
      SUBROUTINE CORD                                                   SUB74560
      COMPLEX A,AA,ANM,CZERO                                            SUB74570
      COMPLEX AK,H2,TRM,D1,CRNL                                         SUB74580
      COMMON/C1/A(60),AA(50,60),ANM(50,10),CZERO                        SUB74590
      COMMON/C2/CLFN,SN,NIY,NWCX,NCCX,NWPX,NCPX,HKER(20),ZKEP(20),NGSKRNSUB74600
      COMMON/C3/NPY,SOUND,NMACH,FMACH(6),NFREQ,FREQ(10),MAUG,NIONCX,RHO SUB74610
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      COMMON/C4/NMODES,LCOLL,LPRWSH,LPRCO,NOM(5),IIY,IIX,NSURF,ISOLAT
      COMMON/C5/FW,FC,NCOLS,NOMIT,ALPHA(10),IL(50),HCOR(6),ZCOR(6),MACH
      COMMON/C6/WXCMN(11),WBCN(11),WBIN(11),WT(90),XCOLL,YCOLL,PI,U
      COMMON/C7/CO(10,28,2),NZCO(15,2),EM,EK,B2,NWIX,NCIX,WBO,CBON,NWCY
      COMMON/C8/IFR,XE(5),YE(3),UX(10),UY(10),WXIMN(11),E1,E2
      COMMON/C9/SIX(40,2),SCX(10,2),Y(11),ETA(11),QWY,QWWX,QWCX,CXMN
C     THIS SUBROUTINE CONSTRUCTS A ROW OF THE DOWNWASH MATRIX
C     THE PRESSURE SERIES IS A PRODUCT OF CHEBYSHEV POLYNOMIALS IN THE
C       NEGATIVE OF PERCENT SEMI-CHORD FROM THE MID-CHORD AND PERCENT
C       SEMI-SPAN FROM THE ROOT.
      DO 6 JC=1,NCOLS
    6 A(JC) = CZERO
      IC1 = 0
      NIX = NWIX
      QWX = -QWWX*SN**2/(8.0*PI)
      NPX = NWPX
C     THE DO 14 LOOP COMPUTES THE NON-SINGULAR PORTION OF D(N,M)
C     DUE TO BOTH SURFACES
      DO 14 MSURF=1,2
      IF(MSURF.NE.NSURF.AND.ISOLAT.NE.0) GO TO 13
      DO 12 IY=1,NIY
      ETAI = SN*ETA(IY)
      ET2 = ETA(IY)**2
      IF(NPY.GT.1) CALL CHEB(NPY-1,ETA(IY),UY(2))
      UY(1) = 1.0 -ET2
      DO 3 K=2,NPY
    3 UY(K) = ET2*UY(1)*UY(K)
        DO 10 IX=1,NIX
          XI = XS(2,MSURF,IX,IY)
          XID = XCOLL -XI
      AK = CRNL(EK,XID,YCOLL-ETAI,EM,B2) + CRNL(EK,XID,YCOLL+ETAI,EM,B2)
          IC = IC1 +1
      H2 = AK*QWX*QWY
      IF(NPX.GT.1) CALL CHEB(NPX-1,-SIX(IX,MSURF),UX(2))
      UX(1) = 1.0 -SIX(IX,MSURF)
      DO 4 K=2,NPX
    4 UX(K) = (1.0 +SIX(IX,MSURF))*UX(1)*UX(K)
C     ** ADD AN INCREMENT TO EACH ELEMENT OF THE ROW FOR (XI,ETAI) **
          DO 10 NY=1,NPY
      TRM = H2 * UY(NY)
      DO 10 NX=1,NPX
      A(IC) = A(IC) +TRM*UX(NX)
   10 IC = IC+1
C     ** IC EQUALS NPY*NWPX+1 AT THE END OF THE FIRST PASS **
   12 CONTINUE
   13   NIX = NCIX
      QWX = -QWCX*SN**2/(8.0*PI)
        NPX = NCPX
   14   IC1 = NPY*NWPX
      IC1 = 0
      NPX = NWPX
      XCOLS = XS(1,NSURF,IIX,IIY)
      Y2 = Y(IIY)**2
      CALL CHEB(NPY-1,Y(IIY),UY(2))
      UY(1) = -2.0
      DO 15 K=2,NPY
   15 UY(K) = -2.0*Y2*UY(K)
      DO 40 MSURF=1,NSURF
C     ** THIS LOOP ADDS THE CONTRIBUTION OF THE SINGULAR INTEGRAL
C        ALONG THE LINE FROM THE WING L.E. TO THE COLLOCATION POINT
      IF(MSURF.NE.NSURF.AND.ISOLAT.NE.0) GO TO 23
```

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      IF(NSURF.LE.NSURF)  GO TO 16                                     SUB75230
      UPLIM = PI                                                       SUB75240
      GO TO 18                                                         SUB75250
   16 XT = SCX(IIX,NSURF)                                              SUB75260
      UPLIM = -ATAN(SQRT(1.0-XT**2)/XT)                                SUB75270
      IF(UPLIM.LT.0.0)  UPLIM=UPLIM+PI                                 SUB75280
   18 QWSNG = FLOAT(2*NIY)*UPLIM/8.0                                   SUB75290
      DO 22 N=1,6                                                      SUB75300
      IC = IC1+1                                                       SUB75310
C       ** THIS LOOP CONSTRUCTS D(0,M) ,M=0,1,....NPX-1                SUB75320
        VINT = UPLIM*ZCOR(N)                                           SUB75330
        C = COS(VINT)                                                  SUB75340
      CALL CHEB(NPX-1, C,UX(2))                                        SUB75350
      UX(1) = 1.0 +C                                                   SUB75360
      DO 19 K=2,NPX                                                    SUB75370
   19 UX(K) = (1.0 -C)*UX(1)*UX(K)                                     SUB75380
      ARG = EK*(XCOLS -WXCMN(IIY) +C*WBCN(IIY))                        SUB75390
      IF(NSURF.EQ.2) ARG=EK*(XCOLS-CXMN+C*CBON)                        SUB75395
        C1 = COS(ARG)                                                  SUB75400
        S1 = SQRT(1.0 -C1**2)                                          SUB75410
      B1 = CMPLX(C1,-S1)*HCOR(N)                                       SUB75420
      DO 22 NY=1,NPY                                                   SUB75430
      TRM = QWSNG*UY(NY)*B1                                            SUB75440
      DO 22 NX=1,NPX                                                   SUB75450
      A(IC) = A(IC) +TRM*UX(NX)                                        SUB75460
   22 IC = IC+1                                                        SUB75470
   23 IC1 = NPY*NWPX                                                   SUB75480
   40 NPX = NCPX                                                       SUB75490
      RETURN                                                           SUB75500
      END                                                              SUB75510
$      FORTRAN NESTOU,DECK                                             SUB74160
$      INCODE  IBMF                                                    SUB74170
CZDZX         ZDZX                                                     SUB74180
      SUBROUTINE ZDZX(MODE,DZ,Z)                                       SUB74190
      COMPLEX A,AA,ANM,CZERO                                           SUB74200
      COMMON/C1/A(60),AA(50,60),ANM(50,10),CZERO                       SUB74210
      COMMON/C2/CLEN,SN,NIY,NWCX,NCCX,NWPX,NCPX,HKER(20),ZKER(20),NGSKRNSUB74220
      COMMON/C3/NPY,SOUND,NMACH,FMACH(6),NFREQ,FREQ(10),MAUG,NIONCX,RHO SUB74230
      COMMON/C4/NMODES,LCOLL,LPRWSH,LPRCO,NOM(5),IIY,IIX,NSURF,ISOLAT   SUB74240
      COMMON/C5/FW,FC,NCOLS,NOMIT,ALPHA(10),IL(50),HCOR(6),ZCOR(6),MACH SUB74250
      COMMON/C6/WXCMN(11),WBCN(11),WBIN(11),WI(90),XCOLL,YCOLL,PI,U     SUB74260
      COMMON/C7/CO(10,28,2),NZCO(10,2),EM,EK,N2,NWIX,NCIX,WBO,CBON,NWCY SUB74270
      COMMON/C8/IER,XE(5),YE(3),UX(10),UY(10),WXIMN(11),E1,E2           SUB74280
      COMMON/C9/SIX(40,2),SCX(10,2),Y(11),ETA(11),QWY,QWWX,QWCX,CXMN    SUB74290
      PX = XCOLL * WBO                                                 SUB74300
      IF(NSURF.GT.1)  PX=PX-CLEN*WBO                                   SUB7431?
      PY = YCOLL * WBO                                                 SUB74320
      Z= CO(MODE,1,NSURF)                                              SUB74330
      DZ = 0.0                                                         SUB74340
      K = 2                                                            SUB74350
      YX = PY/PX                                                       SUB74360
      PPX = PX                                                         SUB74370
      DO 40 N = 2,7                                                    SUB74380
      PXY = PPX                                                        SUB74390
      F  = N-1                                                         SUB74400
      DO 30 M = 1,N                                                    SUB74410
      IF(K.GT.NZCO(MODE,NSURF))  GO TO 50                              SUB74420
      ZP = PXY * CO(MODE,K,NSURF)                                      SUB74430
      Z = Z + ZP                                                       SUB74440
      DZ = DZ + ZP * F                                                 SUB74450
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      PXY = PXY*YX                                                      SUB74460
      F  = F  - 1.0                                                     SUB74470
   30 K = K + 1                                                         SUB74480
   40 PPX = PPX * PX                                                    SUB74490
   50 DZ = DZ/PX                                                        SUB74500
      RETURN                                                            SUB74510
      END                                                               SUB74520
$      FORTRAN NLSTOU,DECK                                              SUB75520
$      INCODE  IBMF                                                     SUB75530
CCGRED       CGRED                                                      SUB75540
      SUBROUTINE CGRED(V,IR,IC)                                         SUB75550
      COMPLEX ANM,CZERO                                                 SUB75560
      DIMENSION V(2,1)                                                  SUB75570
      COMMON/C1/A(2,60),AA(2,50,60),ANM(50,10),CZERO                    SUB75580
      COMMON/C2/CLEN,SN,NIY,NWCX,NCCX,NWPX,NCPX,HKER(20),ZKER(20),NGSKRNSUB75590
      COMMON/C3/NPY,SOUND,NMACH,FMACH(6),NFREQ,FREQ(10),MAUG,NIONCX,RHO SUB75600
      COMMON/C4/NMODES,LCOLL,LPRWSH,LPRCO,NOM(5),IIY,IIX,NSURF,ISOLAT   SUB75610
      COMMON/C5/FW,FC,NCOLS,NOMIT,ALPHA(10),II(50),HCOR(6),ZCOR(6),MACH SUB75620
      COMMON/C6/WXCMN(11),WBCN(11),WBIN(11),WI(90),XCOLL,YCOLL,PI,U     SUB75630
      COMMON/C7/CO(10,28,2),NZCO(10,2),EM,EK,B2,NWIX,NCIX,WBO,CBON,NWCY SUB75640
      COMMON/C8/IFR,XE(5),YE(3),UX(10),UY(10),WXIMN(11),E1,E2           SUB75650
      COMMON/C9/SIX(40,2),SCX(10,2),Y(11),ETA(11),QWY,QWWX,QWCX,CXMN    SUB75660
      RMN = SQRT(AA(1,IR,IC)**2 + AA(2,IR,IC)**2)                       SUB75670
      IF(AA(2,IR,IC).LE.E2)  GO TO 30                                   SUB75680
      CR = AA(1,IR,IC)/RMN                                              SUB75690
      CI = AA(2,IR,IC)/RMN                                              SUB75700
      DO 20 N=IC,MAUG                                                   SUB75710
      TI = CR*AA(1,IR,N) + CI*AA(2,IR,N)                                SUB75720
      AA(2,IR,N) = CR*AA(2,IR,N) - CI*AA(1,IR,N)                        SUB75730
   20 AA(1,IR,N) = TI                                                   SUB75740
   30 RAN = SQRT(V(1,IC)**2 + V(2,IC)**2)                               SUB75750
      IF(RAN.LE.E2)  GO TO 60                                           SUB75760
      RAN = SQRT(RAN**2 + RMN**2)                                       SUB75770
      CR = V(1,IC)/RAN                                                  SUB75780
      CI = V(2,IC)/RAN                                                  SUB75790
      RMN = RMN/RAN                                                     SUB75800
      DO 50 N=IC,MAUG                                                   SUB75810
      AIR = RMN*AA(1,IR,N) + CR*V(1,N) + CI*V(2,N)                      SUB75820
      AII = RMN*AA(2,IR,N) + CR*V(2,N) - CI*V(1,N)                      SUB75830
      VR = RMN*V(1,N) - CR*AA(1,IR,N) + CI*AA(2,IR,N)                   SUB75840
      VI = RMN*V(2,N) - CR*AA(2,IR,N) - CI*AA(1,IR,N)                   SUB75850
      AA(1,IR,N) = AIR                                                  SUB75860
      AA(2,IR,N) = AII                                                  SUB75870
      V(1,N) = VR                                                       SUB75880
   50 V(2,N) = VI                                                       SUB75890
   60 RETURN                                                            SUB75900
      END                                                               SUB75910
$      FORTRAN NLSTOU,DECK                                              SUB75920
$      INCODE  IBMF                                                     SUB75930
CXLSQ        XLSQ                                                       SUB75940
      SUBROUTINE XLSQ                                                   SUB75950
      COMPLEX A,AA,ANM,CZERO                                            SUB75960
      COMMON/C1/A(60),AA(50,60),ANM(50,10),CZERO                        SUB75970
      COMMON/C2/CLEN,SN,NIY,NWCX,NCCX,NWPX,NCPX,HKER(20),ZKER(20),NGSKRNSUB75980
      COMMON/C3/NPY,SOUND,NMACH,FMACH(6),NFREQ,FREQ(10),MAUG,NIONCX,RHO SUB75990
      COMMON/C4/NMODES,LCOLL,LPRWSH,LPRCO,NOM(5),IIY,IIX,NSURF,ISOLAT   SUB76000
      COMMON/C5/FW,FC,NCOLS,NOMIT,ALPHA(10),II(50),HCOR(6),ZCOR(6),MACH SUB76010
      COMMON/C6/WXCMN(11),WBCN(11),WBIN(11),WI(90),XCOLL,YCOLL,PI,U     SUB76020
      COMMON/C7/CO(10,28,2),NZCO(10,2),EM,EK,B2,NWIX,NCIX,WBO,CBON,NWCY SUB76030
      COMMON/C8/IFR,XE(5),YE(3),UX(10),UY(10),WXIMN(11),E1,E2           SUB76040
      COMMON/C9/SIX(40,2),SCX(10,2),Y(11),ETA(11),QWY,QWWX,QWCX,CXMN    SUB76050
```

```
      I1 = 1
      DO 136 I=1,NCOLS
      RII = CABS(AA(I1,I))
      IF(RII.LE.E2) GO TO 135
      IL(I) = I1
      I1 = I1 + 1
      GO TO 136
  135 IL(I) = -1
      II2 = NCOLS - 1 - (I-I1)
      DO 1135 II=I1,II2
 1135 CALL CGRED(AA(II+1,I),II,I+1)
      DO 2135 L=1,NMODES
      ML = NCOLS + L
 2135 ALPHA(L) = SQRT(ALPHA(L)**2 + CABS(AA(II2+1,ML))**2)
  136 CONTINUE
C     SOLVE FOR THE COEFFICIENTS BY BACK SUBSTITUTION
  140 II = NCOLS
      DO 150 I = 1,NCOLS
      DO 150 L=1,NMODES
  150 ANM(I,L) = CZERO
      DO 210 J=1,NCOLS
      IF(IL(II).LE.0) GO TO 210
      JI = IL(II)
      DO 200 L=1,NMODES
      ML = NCOLS + L
      IF(II-NCOLS) 170,190,220
  170 IK = II + 1
      DO 180 K=IK,NCOLS
  180 ANM(II,L) = ANM(II,L) - AA(JI,K)*ANM(K,L)
  190 ANM(II,L) = (ANM(II,L) + AA(JI,ML))/AA(JI,II)
  200 CONTINUE
  210 II = II - 1
  220 RETURN
      END
$       FORTRAN NLSTOU,DECK
$       INCODE  IBMF
CCHEB       CHEB
      SUBROUTINE CHEB(N1,X,UX)
      DIMENSION UX(1)
      DO 10 I=1,N1
   10 UX(I) = 0.0
      UX(1) = 1.0
      UX(2) = 2.0*X
      IF(N1.LT.3)  RETURN
      DO 20 I=3,N1
   20 UX(I) = 2.0*X*UX(I-1) -UX(I-2)
      RETURN
      END
$       FORTRAN NLSTOU,DECK
$       INCODE  IBMF
CFORC       FORC
      SUBROUTINE FORC(NWICX,NCICX,NICY,YETA,SICX,WBICN,LPR)
      COMPLEX A,AA,ANM,CZERO,GFORC,DELP,WASH,APR,DWASH,CWASH,PR
      DIMENSION YETA(1),SICX(1),WBICN(1)
      DIMENSION DWASH(90,10),PR(90,10),CWASH(90,10)
      DIMENSION GFORC(10,10,3),DELP(10),WASH(10)
      COMMON/C1/A(60),AA(50,60),ANM(50,10),CZERO
      COMMON/C2/CLEN,SN,NIY,NWCX,NCCX,NWPX,NCPX,HKER(20),ZKER(20),NGSKRN
      COMMON/C3/NFY,SOUND,NMACH,FMACH(6),NFREQ,FREQ(10),MAUG,NIONCX,RHO
      COMMON/C4/NMODES,LCOLL,LPRWSH,LPRCO,NOM(5),IIY,IIX,NSURF,ISOLAT
```

```
      COMMON/C5/FW,FC,NCOLS,NONIT,ALPHA(10),IL(58),HCOR(6),ZCOR(6),MACH SUB76660
      COMMON/C6/WXCMN(11),WBCN(11),WBIN(11),WT(90),XSOLL,YCOLL,PI,U     SUB76670
      COMMON/C7/CO(10,28,2),NZCO(10,2),EM,EK,H2,NWIX,NCIX,WBO,CBON,NWCY SUB76680
      COMMON/C8/IFR,XE(5),YE(3),UX(10),UY(10),WXIMN(11),E1,E2           SUB76690
      COMMON/C9/SIX(40,2),SCX(10,2),Y(11),ETA(11),QWY,QWWX,QWCX,CXMN    SUB76700
      COMMON/CPR/APR(90,60),IMOD,IROW                                   SUB76710
      EQUIVALENCE (GFORC,AA),(A,WASH),(WASH,DELP)                       SUB76720
      EQUIVALENCE (UWASH(1,1),APR(1,51)),(PR(1,1),APR(1,11))            SUB76730
      EQUIVALENCE (CWASH(1,1),APR(1,41))                                SUB76740
      QWF = 0.5*RHO*(U*WBO*SN)**2 *QWY                                  SUB76750
      IF(LPR.NE.0) GO TO 2                                              SUB76760
      DO 1 I=1,NMODES                                                   SUB76770
      DO 1 J=1,NMODES                                                   SUB76780
      DO 1 K=1,2                                                        SUB76790
    1 GFORC(I,J,K) = CZERO                                              SUB76800
    2 IC1 = 0                                                           SUB76810
      NICX = NWICX                                                      SUB76820
      NPX = NWPX                                                        SUB76830
      QWFORC = QWF*QWWX                                                 SUB76840
      IROW = 1                                                          SUB76850
      LMNT1 = 40                                                        SUB76860
      IF(LPR.NE.0) LMNT1 = 10                                           SUB76870
      DO 1000 NS=1,2                                                    SUB76880
      NSURF = NS                                                        SUB76890
        PFAC = SN/CBON                                                  SUB76900
        DO 900 IIY=1,NICY                                               SUB76910
          YCOLL = YFTA(IIY)                                             SUB76920
C     ** YCOLL, AND LATER XCOLL, ARE USED HERE TO DENOTE INTEGRATION    SUB76930
C        STATIONS BECAUSE WE USE SUBROUTINE Z0ZX TO COMPUTE THE         SUB76940
C        DISPLACEMENT THROUGH WHICH THE PRESSURE ACTS TO DO WORK        SUB76950
          Y2 = YCOLL**2                                                 SUB76960
      IF(NPY.GT.1)  CALL CHER(NPY-1,YCOLL,UY(2))                        SUB76970
      UY(1) = 1.0 -Y2                                                   SUB76980
      IF(LPR.NE.0) UY(1)=SQRT(1.0-Y2)                                   SUB76990
      DO 3 K=2,NPY                                                      SUB77000
    3 UY(K) = Y2*UY(1)*UY(K)                                            SUB77010
          IF(NSURF.EQ.1) PFAC=SN/WBICN(IIY)                             SUB77020
      YCOLL = SN*YCOLL                                                  SUB77025
         DO 800 IIX=1,NICX                                              SUB77030
           LMNT = IIX +LMNT1*(NSURF-1)                                  SUB77040
           XCOLL = SICX(LMNT)                                           SUB77050
      IF(NPX.GT.1) CALL CHEB(NPX-1,-XCOLL,UX(2))                        SUB77060
      UX(1) = 1.0 -XCOLL                                                SUB77070
      IF(LPR.NE.0) UX(1)=SQRT(UX(1)/(1.0+XCOLL))                        SUB77080
      DO 4 K=2,NPX                                                      SUB77090
    4 UX(K) = (1.0 +XCOLL)*UX(1)*UX(K)                                  SUB77100
            IC = IC1 +1                                                 SUB77110
            DO 10 J=1,NMODES                                            SUB77120
   10 DELP(J) = CZERO                                                   SUB77130
      DO 200 NY=1,NPY                                                   SUB77140
      DO 200 NX=1,NPX                                                   SUB77150
        DO 20 J=1,NMODES                                                SUB77160
      DELP(J) = DELP(J) +UX(NX)*UY(NY)*ANM(IC,J)                        SUB77170
        IF(LPR.NE.0) PR(IROW,J) = DELP(J)*PFAC                          SUB77180
   20 CONTINUE                                                          SUB77190
  200 IC = IC+1                                                         SUB77200
C     ** IC = NPY*NWPX+1 AT THE END OF THE NS=1 PASS                    SUB~7210
C        AND DP CONTAINS DELTA P/Q AT (XCOLL,YCOLL)                     SUB77220
      IROW = IROW + 1                                                   SUB77230
           IF(LPR.NE.0) GO TO 800                                       SUB77240
      XCOLL = XS(2,NS,IIX,IIY)                                          SUB77245
```

```
          DO 400 I=1,NMODES
            CALL ZDZX(I,SLOPE,DISP)
            DO 400 J=1,NMODES
  400 GFORC(I,J,NS) = GFORC(I,J,NS) +QWFORC*DISP*DELP(J)*2.0
  800      CONTINUE
  900     CONTINUE
        NICX = NCICX
        NPX = NCPX
        IC1 = IC+1
        QWFORC = UWI*QWCX
 1000   CONTINUE
      RETURN
      END
$      FORTRAN NLSTOU,DECK
$      INCODE  IBMF
CKOUT        KOUT
      SUBROUTINE KOUT(IND)
      COMPLEX A,AA,ANM,CZERO,GFORC,DELP,WASH,APR,DWASH,CWASH,PR
      DIMENSION CARDS(25,50)
      DIMENSION GFORC(10,10,3),DELP(10),WASH(10)
      DIMENSION DWASH(90,10),PR(90,10),CWASH(90,10)
      DIMENSION SURF(2,3),XPR(50)
      COMMON/C1/A(60),AA(50,60),ANM(50,10),CZERO
      COMMON/C2/CLFN,SN,NIY,NWCX,NCCX,NWPX,NCPX,HKER(20),ZKER(20),NGSKRN
      COMMON/C3/NPY,SOUND,NMACH,FMACH(6),NFREQ,FREQ(10),MAUG,NIONCX,RHO
      COMMON/C4/NMODES,LCOLL,LPRWSH,LPRCO,NUM(5),IIY,IIX,NSURF,ISOLAT
      COMMON/C5/FW,FC,NCOLS,NOMIT,ALPHA(10),IL(50),HCOR(6),ZCOR(6),MACH
      COMMON/C6/WXCHN(11),WBCN(11),WBIN(11),WI(90),XCOLL,YCOLL,PI,U
      COMMON/C7/CO(10,28,2),NZCO(10,2),EM,EK,K2,NWIX,NCIX,WBO,CBON,NWCY
      COMMON/C8/IFR,XE(5),YE(3),UX(10),UY(10),WXIHN(11),E1,E2
      COMMON/C9/SIX(40,2),SCX(10,2),Y(11),ETA(11),QWY,QWWX,QWCX,CXMN
      COMMON/CPR/APR(90,60),IMOD,IROW
      EQUIVALENCE (GFORC,AA),(A,WASH),(WASH,DELP)
      EQUIVALENCE (DWASH(1,1),APR(1,51)),(PR(1,1),APR(1,11))
      EQUIVALENCE (CWASH(1,1),APR(1,41))
      EQUIVALENCE  (XPR,IL)
      DATA (SURF(1,I),I=1,3)/6HWING    ,8HTAIL    ,11HWING + TAIL /
      GO TO (10,20,30,40,50,60,70,80,90),IND
C     ***************************************************************
   10 XV = XE(5) - XE(4)
      XX = XE(3) - XE(2)
      AW = 2.0*XE(3)*YE(3) - XE(2)*(YE(3)-YE(2))
      AT = 2.0*XV*YE(3)
      WRITE(6,11)EM,SOUND,RHO,XE(1),XE(4),XE(3),XV,YE(2),YE(3),YE(3),
     1YE(3),XX,XV,AW,AT,NWCY,NIY,NWCX,NCCX,NWIX,NCIX,NPY,NPY,NWPX,NCPX
   11 FORMAT(1H1//// 31X,41HHAC/NAA MISSILE SUBSONIC AIRLOADS PROGRAM
     1 ///37X,30HFLIGHT CONDITIONS AND GEOMETRY/1H0//15X, 13HMACH NUMBER
     2 =,F8.5,4X,16HSPEED OF SOUND =F10.3,4H L/T,4X,4HRHO=,E14.8//1H0/
     X54X,4HWING,18X,
     3 4HTAIL///22X,16HL.E. STATION (L),2F22.3//22X,16HROOT CHORD   (L),
     4 2F22.3// 22X,16HL.E. SPAN     (L),2F22.3//22X,16HT.E. SPAN     (L),
     5 2F22.3// 22X,16HTIP CHORD     (L),2F22.3//22X,16HTOTAL AREA (L*L)
     6 2F22.3//22X,16HSPAN  COLL. STA.,I19,I22,//22X,16HCHORD COLL. STA.
     7 I19,I22//22X,16HCHORD INTG. STA.,I19,I22//22X,16HSPAN  PRES MODES
     8,I19,I22//22X,16HCHORD PRES MODES,I19,I22)
      IF(FMACH(MACH).LE.0.95)  GO TO 15
      WRITE(6,14)
   14 FORMAT(92H   A MACH NUMBER GREATER THAN 0.95 HAS BEEN USED--------
     1USE CAUTION IN APPLYING CASE RESULTS)
   15 IF(NOMIT.EQ.0) RETURN
```

```
      WRITE(6,12)(NOM(I),I=1,NOMIT)                                     SUB77840
   12 FORMAT(1H0,15X,51HTHE SPANWISE COLLOCATION STATION(S) OMITTED ON WSUB77850
     1ING,9I5)                                                          SUB77860
      RETURN                                                            SUB77870
C     ******************************************************************SUB77880
   20 NCX = NWCX                                                        SUB77890
      NIX = NWIX                                                        SUB77900
      DO 150 NS=1,2                                                     SUB77910
      WRITE(6,22)(SURF(I,NS),I=1,2)                                     SUB77920
   22 FORMAT(1H1,31X,42HMISSILE SUBSONIC AIRLOADS PROGRAM (CONT-D)/1H / SUB77930
     1 25X,39HCOLLOCATION STATION COORDINATES ON THE 2A6/1H0,12H    S STSUB77940
     2A NO,7X,2HYC,8X,7X,11HXC VALUES--)                                SUB77950
      DO 123 IY=1,NIY                                                   SUB77960
      YC = WBO*SN*Y(IY)                                                 SUB77970
      DO 120 IX=1,NCX                                                   SUB77980
  120 XPR(IX) = WBO*XS(1,NS,IX,IY)                                      SUB77990
  123 WRITE(6,124) IY,YC,(XPR(IX),IX=1,NCX)                             SUB78000
  124 FORMAT(1H0,I12,5E17.6/(1H ,29X,4E17.6))                           SUB78010
      WRITE(6,105) (SURF(I,NS),I=1,2)                                   SUB78020
  105 FORMAT(1H0,24X,39HINTEGRATION STATION COORDINATES ON THE 2A6/1H0, SUB78030
     112H    S STA NO,7X,2HYI,8X,7X,11HXI VALUES--)                     SUB78040
      DO 106 IY=1,NIY                                                   SUB78050
      YI = WBO*SN*ETA(IY)                                               SUB78060
      DO 126 IX=1,NIX                                                   SUB78070
  126 XPR(IX) = WBO*XS(2,NS,IX,IY)                                      SUB78080
  106 WRITE(6,124) IY,YI,(XPR(IX),IX=1,NIX)                             SUB78090
      NCX = NCCX                                                        SUB78100
      NIX = NCIX                                                        SUB78110
  150 CONTINUE                                                          SUB78120
      RETURN                                                            SUB78130
C     ******************************************************************SUB78140
   30 DO 34 NS = 1,2                                                    SUB78150
      WRITE(6,21)FREQ(IER),NMODES,EK,EM                                 SUB78160
   21 FORMAT(1H1,31X,42HMISSILE SUBSONIC AIRLOADS PROGRAM (CONT-D)//1H /SUB78170
     1 9X,27HOSCILLATORY FREQUENCY (CPS),F12.5,13X,I2,17H DEFLECTION MODSUB78180
     2ES/1H0,8X,30HREDUCED FREQUENCY (SEMI CHORD),F9.5,14X,23HFREE STREASUB78190
     3M MACH NUMBER,F9.3/1H )                                           SUB78200
      WRITE(6,31) IMOD                                                  SUB78210
   31 FORMAT(34X,34HPRESSURE COEFFICIENTS FOR MODE NO.I3//19X,1HI11X,10HSUB78220
     1R COEFF(I)12X,10HI COEFF(I) 9X,9HSPAN MODE 3X,10HCHORD MODE,)     SUB78230
      WRITE(6,32)(SURF(KI,NS),KI=1,2)                                   SUB78240
   32 FORMAT(1H0,9X,2A6//)                                              SUB78250
      GO TO(2,3),NS                                                     SUB78260
    2 NL = NWPX                                                         SUB78270
      ML = NPY                                                          SUB78280
      IK = 1                                                            SUB78290
      GO TO 4                                                           SUB78300
    3 NL = NCPX                                                         SUB78310
      ML = NPY                                                          SUB78320
      IK = NWPX*NPY+1                                                   SUB78330
    4 DO 6 IM = 1,ML                                                    SUB78340
      DO 6 IN = 1,NL                                                    SUB78350
      WRITE(6,33)IK,ANM(IK,IMOD),IM,IN                                  SUB78360
   33 FORMAT(1H0,I19,1P2E22.5,2I13)                                     SUB78370
    6 IK = IK + 1                                                       SUB78380
   34 CONTINUE                                                          SUB78390
      RETURN                                                            SUB78400
C     ******************************************************************SUB78410
   40 WRITE(6,41)                                                       SUB78420
   41 FORMAT(1H0,20X,38HERROR IN INPUT DATA (NO TAIL) REQUIRES//,21X,19HSUB78430
     1TERMINATION OF CASE)                                              SUB78440
```

```
      CALL EXIT                                                         SUB78450
C     ******************************************************************SUB78460
   50 WRITE(6,51)                                                       SUB78470
   51 FORMAT(1H0,20X,63HNUMBER OF COLLOCATION OR INTEGRATION STATIONS ORSUB78480
     1 PRESSURE TERMS//21X,25HEXCEEDS ALLOWABLE MAXIMUM///35X,18HCASE ISSUB78490
     2 TERMINATED)                                                      SUB78500
      CALL EXIT                                                         SUB78510
C     ******************************************************************SUB78520
   60 WRITE(6,21)FREQ(IFR),NMODES,EK,EM                                 SUB78530
      WRITE(6,101) SURF(1,NSURF)                                        SUB78540
  101 FORMAT(1H0,27X,45HINPUT MODE SHAPE POLYNOMIAL COEFFICIENTS FOR ,A6SUB78550
     1//22X,62HREFERENCED TO THE SURFACE LEADING EDGE-CENTERLINE INTERSESUB78560
     2CTION //2X,4HMODE,20X, 7HCOEFFS.)                                 SUB78570
      DO 69 L=1,NMODES                                                  SUB78580
      NTM = NZCO(L,NSURF)                                               SUB78590
      WRITE(6,66) L,(CO(L,K,NSURF),K=1,NTM)                             SUB78600
   66 FORMAT(1H0,I4,4X,1P7E13.4/(9X,1P7E13.4))                          SUB78610
   69 CONTINUE                                                          SUB78620
      RETURN                                                            SUB78630
C     ******************************************************************SUB78640
   70 WRITE(6,21)FREQ(IFR),NMODES,EK,EM                                 SUB78650
      WRITE(6,35) ALPHA(IMOD)                                           SUB78660
   35 FORMAT(24X,47HRMS ERROR OF DOWNWASHES AT COLLOCATION POINTS =,1E13SUB78670
     X.6)                                                               SUB78680
      WRITE(6,36) IMOD                                                  SUB78690
   36 FORMAT(1H0,23X,57HPRESSURES AND UPWASHES AT COLLOCATION POINTS FORSUB78700
     X MODE NO.I3)                                                      SUB78710
      WRITE(6,32)(SURF(L,NSURF),L=1,2)                                  SUB78720
      WRITE(6,37)                                                       SUB78730
   37 FORMAT(1H0,/X,1HX,8X,1HY,9X,8HR P(X,Y),5X,8HI P(X,Y),6X,          SUB78740
     1 9HR CW(X,Y),4X,9HI CW(X,Y),6X,9HR DW(X,Y),4X,9HI DW(X,Y))        SUB78750
      RETURN                                                            SUB78760
C     ******************************************************************SUB78770
   80 WRITE(6,21)FREQ(IFR),NMODES,EK,EM                                 SUB78780
      WRITE (6,61) (SURF(L,NSURF),L=1,2)                                SUB78790
   61 FORMAT(35X,23HGENERALIZED FORCES FOR 2A6/1H0,6X,4HDEFL,3X,4HLOAD,1SUB78800
     10X,9HREAL PART,10X,9HIMAG PART,10X,9HABS VALUE,10X,11HPHASE ANGLE/SUB78810
     2/)                                                                SUB78820
      DO 78 I=1,NMODES                                                  SUB78830
      DO 78 J=1,NMODES                                                  SUB78840
      IF(NSURF.EQ.3) GO TO 76                                           SUB78850
      G1 = REAL(GFORC(I,J,NSURF))                                       SUB78860
      G2 = AIMAG(GFORC(I,J,NSURF))                                      SUB78870
      GO TO 77                                                          SUB78880
   76 G1 = REAL(GFORC(I,J,1)) + REAL(GFORC(I,J,2))                      SUB78890
      G2 = AIMAG(GFORC(I,J,1)) + AIMAG(GFORC(I,J,2))                    SUB78900
      KKK=2*NMODES                                                      ********
      NNN=2*J-1                                                         ********
      NNNN=2*J                                                          ********
      CARDS(I,NNN)=G1                                                   ********
      CARDS(I,NNNN)=G2                                                  ********
   77 G3 = SQRT(G1**2+G2**2)                                            SUB78910
      G4 = 0.0                                                          SUB78920
      IF(G3.NE.0.0)  G4 = 57.2957795*ATAN2(G2,G1)                       SUB78930
      WRITE(6,71) I,J,G1,G2,G3,G4                                       SUB78940
      IF (NSURF .NE. 3) GO TO 78                                        ********
      IF (I .NE. NMODES) GO TO 78                                       ********
      IF (J .NE. NMODES) GO TO 78                                       ********
      PUNCH 6969, ((CARDS(II,JJ),JJ=1,KKK), II=1,NMODES)                ********
 6969 FORMAT (1P6E12.5)
   71 FORMAT(1H0,I9,I7,2X,1P3E19.5,0PF16.3,4H DEG)                      SUB78950
```

```
   78 CONTINUE
      RETURN
C     ************************************************************************
   90 WRITE(6,19) XCOLL,YCOLL,PR(IROW,IMOD),CWASH(IROW,IMOD),
     X            DWASH(IROW,IMOD)
   19 FORMAT(1H0,2X,2F9.3,2X,2E13.4,2X,2E13.4,2X,2E13.4)
      RETURN
      END
```

4.0 TRANSONIC UNSTEADY AERODYNAMICS PROGRAM

4.1 Theoretical Derivation

When the flight speed approaches $M = 1.0$, the velocity potential equation can be written as

$$\phi_{yy} + \phi_{zz} = M^2 \left(2ik\phi_x - k^2\phi\right) \tag{4.1.1}$$

which is valid if $k >> |M-1|$. The linearized equation is applicable when the lifting surfaces are oscillating rapidly such that non-linear disturbances in the flow do not have time to accumulate.

Equation (4.1.1) is satisfied by a pulsating doublet which produces a velocity potential at (x,y,z) given by

$$\phi_D = \frac{i\,k\,(z-\zeta)}{2\,(x-\xi)^2} \exp\left\{-1/2\; ik\left[(x-\xi) + \frac{(y-\eta)^2 + (z-\zeta)^2}{(x-\xi)}\right]\right\} \tag{4.1.2}$$

where the doublet is positioned at (ξ,η,ζ). The doublet has no influence at points upstream of the line $x = \xi$ and, consequently, the potential is zero in that region.

A solution to equation (4.1.1) may be obtained by superposition. This solution will be represented in the form

$$\phi(x,y,z) = \iint \phi(\xi,\eta,)\phi_D(x,y,z,\xi,\eta,o)\,d\xi\,d\eta \tag{4.1.3}$$

where $\phi(\xi,\eta)$ is the doublet strength of point (ξ,η).

To compute the velocity potential distribution, the wing, wake and control surface is divided into a lattice of square boxes as shown in Figure 4.1.1. The potential function is replaced by a set of point values at the box centers. The potential function and downwash value is assumed constant over each box and equal to the central value.

The problem reduces to imposing boundary conditions and determining the doublet strength for each box to satisfy the boundary conditions. The boundary value problem becomes

1. Tangential Flow Condition

$$w(x,y)_{wing} = \iint_{wing} \phi(\xi,\eta) \lim_{z\to o} \frac{\partial \phi_D}{\partial z}\, d\xi\, d\eta \tag{4.1.4}$$

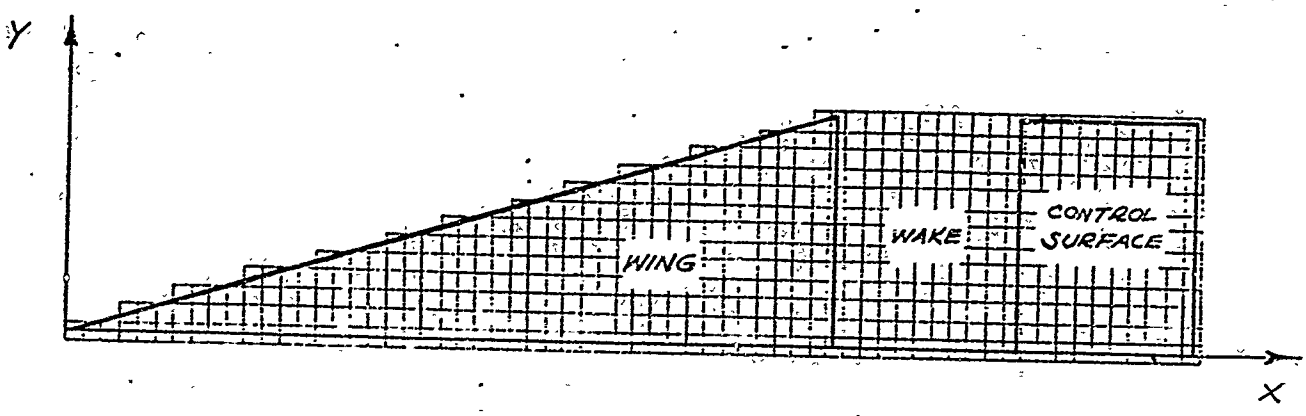

Figure 4.1.1 Sonic Box Overlay Pattern

$$w(x,y)_{\substack{\text{control}\\ \text{surface}}} = \iint_{\substack{\text{wing +}\\ \text{wake +}\\ \text{control}\\ \text{surface}}} \phi(\xi,\eta) \lim_{z\to o} \frac{\partial \phi_D}{\partial z} \, d\xi d\eta \tag{4.1.5}$$

2. Zero Pressure Jump in Wake

$$\frac{\partial \phi}{\partial x} - ik\phi = 0 \tag{4.1.6}$$

Equation (4.1.6) is an ordinary homogeneous differential equation subjected to the condition ϕ is equal to the value of the velocity potential at the wing trailing edge for $x = x_{wing\ t.e.}$. This gives the solution

$$\phi_{wake} = \phi_{wing\ t.e.} e^{-ik(x-x_{wing\ t.e.})} \tag{4.1.7}$$

Equations (4.1.4), and (4.1.5) and (4.1.7) form a system of equations from which the point values of the potential functions can be found at the box centers. The pressure distribution is then determined from the relationship

$$\Delta P(x,y) = \frac{1}{2}\rho U^2 (2\frac{\partial \phi}{\partial x} + 2ik\phi) \tag{4.1.8}$$

and the generalized forces are found from equation (2.0.1).

4.2 PROGRAM DESCRIPTION

The Sonic Unsteady Aerodynamics Program calculates generalized forces for up to 10 deformation modes. The computer solution is based upon the Mach box technique. The various configurations which can be analyzed are shown in Figure 4.2.1 and Table 4.2.2. The analysis includes interaction effects between tandem surfaces and wake effects on the trailing surface. Single surfaces may be analyzed by inputing a second surface with a zero chord length.

The transonic box method calculates the unsteady potentials from which the pressure distributions may be obtained for arbitrary modes of surface motion. The method used was suggested by the successes of the supersonic box methods of Pines and others, Reference 11. The potential is generated by a doublet distribution rather than by a source distribution because the latter method would involve diaphragm regions of infinite extent, whereas the doublet distribution is confined to the wing and its wake. As with the subsonic problem, the differential equation solution is an integral equation. The integral equation is approximated numerically by a matrix equation so that the basic step in the box method is the solution of the system of simultaneous equations which determine a set of values of potential on the surface from a corresponding array of upwash values. The solution procedure obtains the velocity potential over the surface one spanwise row of boxes at a time until the trailing edge row is completed. The numerical complexity is not increased, however, by a large number of box rows over the configuration because the influence coming from more than 15 rows away has been found to be negligible. The results are valid for high reduced frequency, k, such that $k \gg |M-1|$ where M is the Mach number.

The solution for the generalized aerodynamic forces requires the input of the deformation modes due to vibration. The program considers the modes to be expressed as analytic functions of the form:

$$w(x, y) = \sum_{m=0}^{N} \sum_{m=0}^{n} C_{(n-m),m} x^{(n-m)} y^{m}$$

To meet this requirement only the coefficients "c" are required as input into the program. These coefficients can be obtained in several ways, the most common way is to surface fit the modes by the least-square technique.

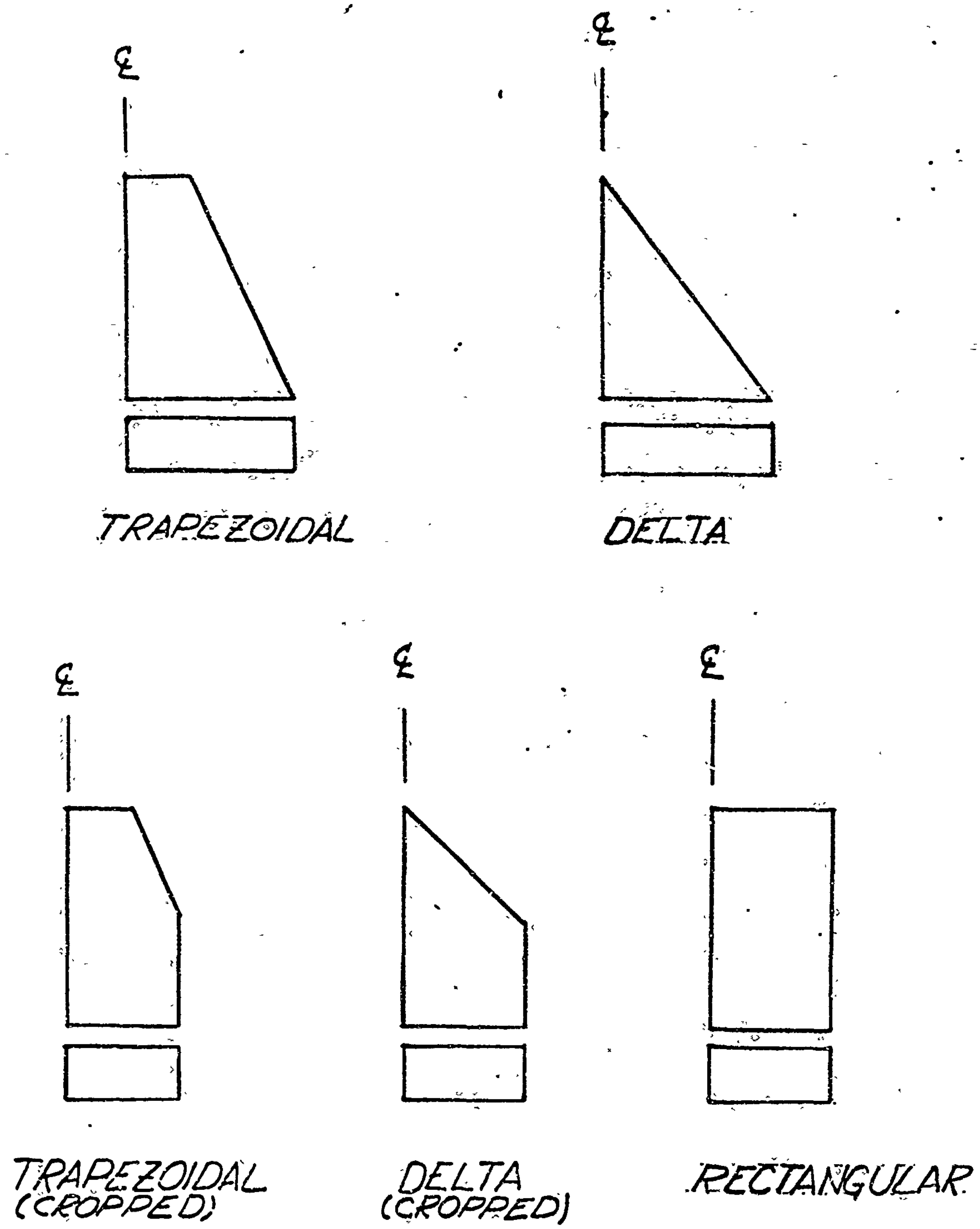

FIGURE 4.2.1
TANDEM COPLANAR CONFIGURATIONS AT SONIC MACH. NUMBER

TABLE 4.2.2 OPTIONAL CONFIGURATIONS

CONFIGURATION	CHORDWISE COORDINATE	SPANWISE COORDINATE
RECTANGULAR	X(1) = 0.0	Y(1) = 0.0
	X(2) = 0.0	Y(2) = 0.0
	X(3) > 0.0	Y(3) > 0.0
	X(4) ≧ X(3)	
	X(5) ≧ X(4)	
DELTA	X(1) = 0.0	Y(1) = 0.0
	X(2) > 0.0	Y(2) = 0.0
	X(3) = X)2)	Y(3) > 0.0
	X(4) ≧ X(3)	
	X(5) ≧ X(4)	
TRAPEZOIDAL	X(1) = 0.0	Y(1) = 0.0
	X(2) > 0.0	Y(2) > 0.0
	X(3) = X(2)	Y(3) > Y(2)
	X(4) ≧ X(3)	
	X(5) ≧ X(4)	
TRAPEZOIDAL (CROPPED)	X(1) = 0.0	Y(1) = 0.0
	X(2) > X(1)	Y(2) > 0.0
	X(3) > X(2)	Y(3) > Y(2)
	X(4) ≧ X(3)	
	X(5) ≧ X(4)	
DELTA (CROPPED)	X(1) = 0.0	Y(1) = 0.0
	X(2) > 0.0	Y(2) = 0.0
	X(3) > X(2)	Y(3) > Y(2)
	X(4) ≧ X(3)	
	X(5) ≧ X(4)	

4.3 INPUT INSTRUCTIONS

Instructions for preparing input data for the transonic computer program are presented here. The field location and format for each quantity is specified. Any set of units may be used for geometric dimensions and acoustic velocity as long as they are consistent, e.g., if inches is used for length, then the acoustic velocity must have dimensions of inches per second. The required data and the sequence in which the information is entered is as follows:

1. Streamwise Coordinates (6E12.5 format)

Column	1-12	13-24	25-36	37.48	49-60	61-72
Name	X(1)	X(2)	X(3)	X(4)	X(5)	
Item	(1)	(2)	(3)	(4)	(5)	

(1) X(1) Wing root leading edge coordinate (See Figure 4.3.1)
(2) X(2) Wing tip leading edge coordinate
(3) X(3) Wing trailing edge coordinate
(4) X(4) Control surface leading edge coordinate
(5) X(5) Control surface trailing edge coordinate

A single surface, the wing, may be analyzed by setting X(4) and X(5) equal to X(3). The various configurations are generated as shown in Table 4.2.1. The origin for the planform and AIC station coordinates must be at the leading edge root of the wing, therefore X(1) and Y(1), described below, must always be zero.

2. Spanwise Coordinates and Acoustic Velocity (6E12.5 format)

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	Y(1)	Y(2)	Y(3)	SOUND	RHO	
Item	(1)	(2)	(3)	(4)	(5)	

(1) Y(1) Wing root spanwise coordinate
(2) Y(2) Wing leading edge spanwise coordinate
(3) Y(3) Wing (and control surface) tip spanwise coordinate
(4) SOUND Speed of sound at altitude for which analysis is performed
(5) RHO density of fluid * 1000.0 $(M./L^3)$

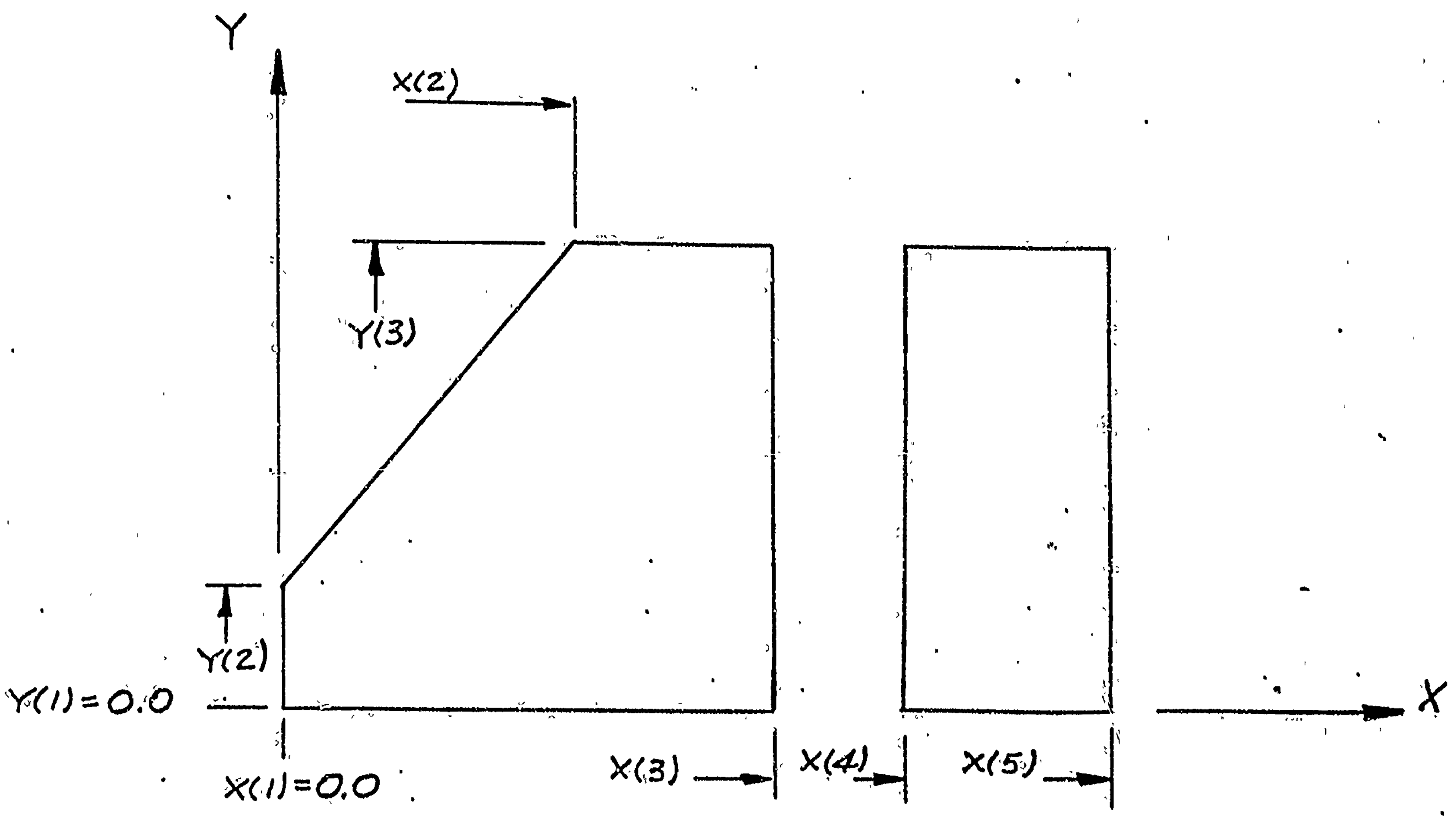

FIGURE 4.3.1
GEOMETRY DESCRIPTION

3. General Information (6I12 format)

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	NMACH	NFREQ	NMODES	NBW	LVPIC	LSSVP
Item	(1)	(2)	(3)	(4)	(5)	(6)

(1) NMACH Number of Mach numbers (max 6)
(2) NFREQ Number of input frequencies (max 10)
(3) NMØDES Number of input modes (max 10)
(4) NBW Number of chordwise wing boxes (max 10)
(5) LVPIC Print velocity potential influence coefficients; 0 ~ No, 1 ~ Yes
(6) LSSVP Print upwashes; 0 ~ No, 1 ~ Yes

4. Mach Numbers (6E12.5 format)

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	FMACH(1)	FMACH(2)	FMACH(3)	FMACH(4)	FMACH(5)	FMACH(6)
Item	(1)	(2)	(3)	(4)	(5)	(6)

(1) FMACH(i) Mach numbers for which the analysis is to be performed.

5. Frequency (6E12.5 format)

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	FREQ(1)	FREQ(2)	FREQ(3)	FREQ(4)	FREQ(5)	FREQ(6)
Item	(1)	(2)	(3)	(4)	(5)	(6)

(1) FREQ Frequencies for which the analysis is to be performed. Continue on next card for FREQ(i) 6.

6. Deformation Modes. Repeat the Following Cards NMØDES Times

(6I12) Format

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	NTM1(i)	NFI				
Item	(1)	(2)				

(1) NTM1(i) Number of deformation mode coefficients for the wing, mode i
(2) NFI Compute generalize forces; 0 ~ No, 1 ~ Yes

If NFI = 0 the program will compute the VPIC's and stop.

(6E12.5) Format

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	CØ(1)	CØ(2)	CØ(3)	CØ(4)	CØ(5)	CØ(6)
Item	(1)	(2)	(3)	(4)	(5)	(6)

(1) CØ(i) i = 1, NTM deformation polynomial coefficients to be input in the following order: 0,0; 1,0; 0,1; 2,0; 1,1; 0,2; 3,0; where the first integer is the power of "x" and the second is the power of "y". Continue on successive cards until all polynomial coefficients are input.

(6I12) Format

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	NTM	NFI				
Item	(1)	(2)				

(1) NTM2(i) Number of deformation mode coefficients for the control surface, mode (i)

(2) NFI Compute generalized forces; 0 ~ No; 1 ~ Yes. If NFI = 0, the program will compute the VPIC's and stop.

(6E12.5) Format

Column	1-12	13-24	25-36	37-48	49-60	
Name	CØ(1)	CØ(2)	CØ(3)	CØ(4)	CØ(5)	
Item	(1)	(2)	(3)	(4)	(5)	

CØ(i) i - 1, NTM deformation polynomial coefficients to be input in the following order: 0,0; 1,0; 0,1; 2,0; 1,1; 0,2; 3,0; etc. where the first integer is the power of "x" and the second is the power of "y". Continue on successive cards until all polynomial coefficients are input.

4.4 SAMPLE PROBLEM

The generalized forces are calculated for the configuration below. The flight parameters and pertinent input data are presented on the first page of the computer print out.

The coefficients of the deformation modes for the forward surface are shown on the third page of the computer print out, and for the aft surface on the fifth page of the computer print out.

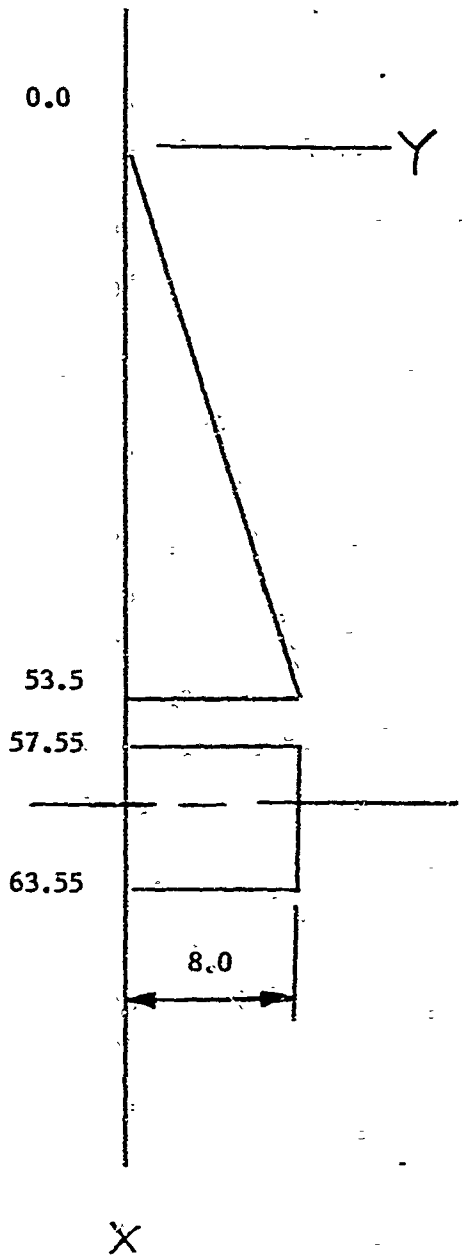

FIGURE 4.4.1

HAC/NAA MISSILE TRANSONIC AIRLOADS PROGRAM

FLIGHT CONDITIONS AND GEOMETRY

MACH NUMBER = 1.00000   SPEED CF SOUND = 13392.000 L/T   RHO=0.11460000E-06

	WING	TAIL
L.E. STATION (L)	0.	57.550
ROOT CHORD (L)	53.500	6.000
L.E. SPAN (L)	0.	8.000
T.E. SPAN (L)	8.000	8.000
TIP CHORD (L)	0.	6.000
TOTAL AREA (L*L)	428.000	96.000
CHORDWISE BOXES	48	5
SPANWISE BOXES	7	7

TOTAL CHORDWISE BOXES = 53   BOX CHORD = 1.20225E 00 L   BOX SPAN = 1.20225E 00 L

MISSILE TRANSONIC AIRLOADS PROGRAM (CONT'D)

```
MAP OF SONIC BOX OVERLAY        S
ON WING, TAIL AND WAKE          S
            (S) - WING          S
            ($) - TAIL          S
            (.) - WAKE          S
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                                S
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                                $$$$$$$
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MISSILE TRANSONIC AIRLOADS PROGRAM (CONT'D)

OSCILLATORY FREQUENCY (CPS) 110.00000 — 53 BOXES IN CHORD DIRECTION

REDUCED FREQUENCY (SEMI CHORD) 1.38055 — FREE STREAM MACH NUMBER 1.000

INPUT MODE SHAPE POLYNOMIAL COEFFICIENTS FOR WINGS
REFERENCED TO THE SURFACE LEADING EDGE-CENTERLINE INTERSECTION

MODE	COEFFS,						
1	6.2231E-01	4.6476E-03	2.1714E 00	-1.1796E-02	1.1765E-01	-2.3426E 00	1.3893E-03
	-5.7624E-02	7.9094E-01	-2.5125E 00	-4.5847E-05	2.4591E-03	-3.5940E-02	1.4666E-01
	-9.2425E-02	4.4647E-07	-2.7338E-05	4.4296E-04	-2.5737E-03	7.8341E-03	-1.7714E-02
2	8.9494E-04	-1.4724E-03	-1.5229E-02	1.3060E-04	1.4047E-03	2.5887E-02	-1.7714E-06
	-3.0455E-04	1.0010E-03	-1.8106E-02	-5.8051E-08	1.4540E-05	-1.7126E-04	1.5541E-03
	-1.9612E-03	1.0317E-09	-1.6695E-07	2.2909E-06	-1.3876E-05	-3.8650E-05	2.1062E-04
3	-2.0277E-03	-1.8600E-03	-4.0090E-01	2.8495E-03	-5.4255E-02	5.2506E-01	-3.2033E-04
	1.5004E-02	-1.7053E-01	5.3718E-01	1.0353E-05	-6.0834E-04	7.9328E-03	-3.2827E-02
	2.2924E-02	-1.0013E-07	6.6433E-06	-9.9828E-05	5.9923E-04	-1.9292E-03	4.3643E-03
4	6.8155E-03	-6.2155E-03	-1.0847E 00	2.4746E-03	9.3898E-02	4.8655E-01	-2.3470E-04
	2.7715E-03	-1.1654E-01	3.2703E-01	7.1836E-06	-2.3984E-04	5.1428E-03	-2.1053E-02
	1.9833E-02	-6.7781E-08	3.0791E-06	-6.1616E-05	3.4012E-04	-8.7292E-04	1.4206E-03
5	2.2147E-03	9.1320E-04	1.8393E-03	-6.5138E-04	1.7097E-02	-8.4167E-02	6.8571E-05
	-3.3292E-03	3.8491E-02	-1.3252E-01	-2.1796E-06	1.3006E-04	-1.7763E-03	7.4320E-03
	-3.9610E-03	2.0953E-08	-1.3987E-06	2.1637E-05	-1.2205E-04	3.2906E-04	-7.4633E-04

MISSILE TRANSONIC AIRLOADS PROGRAM (CONT'D)

OSCILLATORY FREQUENCY (CPS) 110.00000 53 BOXES IN CHORD DIRECTION

REDUCED FREQUENCY (SEMI CHORD) 1.38055 FREE STREAM MACH NUMBER 1.000

GENERALIZED FORCES FOR WING

DEFL	LOAD	REAL PART	IMAG PART	ABS VALUE	PHASE ANGLE
1	1	3.16858E 02	-1.37658E 02	3.45469E 02	-23.482 DEG
1	2	-5.52591E-01	2.66777E 00	2.72440E 00	101.703 DEG
1	3	-5.62170E 01	2.07533E 01	5.99254E 01	159.738 DEG
1	4	-8.10722E 00	3.26216E 01	3.36139E 01	103.957 DEG
1	5	1.16660E 01	-6.65916E 00	1.34328E 01	-29.719 DEG
2	1	-2.44726E 00	2.26683E 00	3.33214E 00	137.133 DEG
2	2	8.84216E-01	-2.39821E-01	9.16162E-01	-15.175 DEG
2	3	-5.69430E 00	2.64395E 00	6.27818E 00	155.094 DEG
2	4	-1.55191E 00	-2.19162E 00	2.68545E 00	-125.303 DEG
2	5	2.87546E-01	-2.50006E-02	2.88631E-01	-4.969 DEG
3	1	-6.65830E 01	2.52397E 01	7.12063E 01	159.240 DEG
3	2	-7.04967E 00	-1.50816E 00	7.20919E 00	-167.925 DEG
3	3	7.38453E 01	-1.35683E 01	7.50815E 01	-10.411 DEG
3	4	2.91514E 01	1.99798E 01	3.53412E 01	34.426 DEG
3	5	-7.90048E 00	-2.34443E-01	7.90395E 00	-178.300 DEG
4	1	1.59553E 01	2.36006E 01	2.84879E 01	55.939 DEG
4	2	-2.71097E 00	3.88001E 00	4.73326E 00	124.942 DEG
4	3	3.77450E 00	-3.69283E 01	3.71207E 01	-84.164 DEG
4	4	-2.14405E 01	-1.64663E 01	2.70339E 01	-142.476 DEG
4	5	2.98952E 00	5.23504E 00	6.02850E 00	60.271 DEG
5	1	6.76158E 00	-7.51507E 00	1.01092E 01	-48.021 DEG
5	2	5.48742E-01	-3.20824E-01	6.35646E-01	-30.313 DEG
5	3	-4.27173E 00	4.95884E 00	6.54506E 00	130.743 DEG
5	4	4.30316E 00	2.14755E 00	4.80928E 00	26.522 DEG
5	5	1.87838E-01	-9.02441E-01	9.21782E-01	-78.242 DEG

MISSILE TRANSONIC AIRLOADS PROGRAM (CONT'D)

OSCILLATORY FREQUENCY (CPS) 110.00000 — 53 BOXES IN CHORD DIRECTION

REDUCED FREQUENCY (SEMI CHORD) 1.38055 — FREE STREAM MACH NUMBER 1.000

INPUT MODE SHAPE POLYNOMIAL COEFFICIENTS FOR TAIL
REFERENCED TO THE SURFACE LEADING EDGE-CENTERLINE INTERSECTION

MODE	COEFFS.						
1	-1.0091E 00	3.6669E-02	2.0342E-02	2.5379E-02	2.2663E-03	-6.3951E-03	-3.9767E-03
	-2.0287E-03	9.8702E-04	1.1172E-03	1.9252E-04	3.7068E-04	-2.0327E-04	1.7562E-06
	-6.7077E-05						
2	-1.2752E-01	8.2139E-02	-8.3996E-02	-1.7451E-02	-2.6948E-02	-2.0262E-02	1.2913E-03
	7.7354E-03	1.6668E-03	2.9726E-03	3.1356E-05	-2.7508E-04	-5.4809E-04	1.6180E-05
	-1.0213E-04						
3	-8.3787E-02	4.9086E-02	-8.5200E-03	-1.6733E-02	-1.4954E-03	-1.2620E-03	4.0742E-03
	1.5179E-05	2.7897E-04	2.8296E-04	-3.1325E-04	4.5623E-06	-6.0549E-07	-1.7126E-05
	-1.9476E-05						
4	-7.2257E-03	8.2141E-03	-4.9131E-03	-1.1390E-03	-2.5306E-04	7.4449E-04	9.5326E-05
	1.7613E-05	-3.0224E-06	-2.4853E-04	1.6233E-07	1.5745E-05	-2.1877E-05	1.2826E-05
	1.7159E-05						
5	-5.8014E-01	1.5199E-01	2.4793E-02	8.4246E-02	5.0903E-03	-1.8510E-02	-1.9336E-02
	-9.6255E-05	4.2392E-05	3.4434E-03	1.3989E-03	-1.1667E-04	5.2220E-05	-1.5344E-05
	-2.0522E-04						

MISSILE TRANSONIC AIRLOADS PROGRAM (CONT'D)

OSCILLATORY FREQUENCY (CPS) 110.00000 53 BOXES IN CHORD DIRECTION

REDUCED FREQUENCY (SEMI CHORD) 1.38055 FREE STREAM MACH NUMBER 1.000

GENERALIZED FORCES FOR TAIL

DEFL	LOAD	REAL PART	IMAG PART	ABS VALUE	PHASE ANGLE
1	1	3.20570E 02	-1.64106E 02	3.60133E 02	-27.109 DEG
1	2	1.78757E 02	-1.52709E 02	2.35104E 02	-40.507 DEG
1	3	1.35618E 02	-3.12913E 01	1.39181E 02	-12.993 DEG
1	4	1.40816E 02	-6.58142E 01	1.55437E 02	-25.050 DEG
1	5	1.03474E 03	-7.16951E 01	1.03722E 03	-3.964 DEG
2	1	1.65340E 02	-8.80348E 01	1.87316E 02	-28.033 DEG
2	2	1.24794E 02	-9.42609E 01	1.56393E 02	-37.065 DEG
2	3	8.75103E 01	-1.55398E 01	8.88793E 01	-10.069 DEG
2	4	9.66705E 01	-3.27417E 01	1.02065E 02	-18.711 DEG
2	5	5.96996E 02	6.51462E 00	5.97032E 02	0.625 DEG
3	1	1.17162E 01	-2.23877E 01	2.52681E 01	-62.376 DEG
3	2	1.64673E 00	-1.09465E 01	1.10696E 01	-81.445 DEG
3	3	1.07777E 01	-6.32983E 00	1.24990E 01	-30.426 DEG
3	4	1.24434E 01	-6.77308E 00	1.41673E 01	-28.560 DEG
3	5	8.18177E 01	-4.11626E 01	9.15887E 01	-26.707 DEG
4	1	1.29545E 00	-4.67704E 00	4.85313E 00	-74.518 DEG
4	2	8.41320E-01	-2.50315E 00	2.64076E 00	-71.422 DEG
4	3	2.58365E 00	-1.28241E 00	2.88441E 00	-26.398 DEG
4	4	3.05965E 00	-1.28912E 00	3.32013E 00	-22.847 DEG
4	5	1.71697E 01	-7.84607E 00	1.88775E 01	-24.559 DEG
5	1	-1.23287E 02	-1.61959E 02	2.03545E 02	-127.279 DEG
5	2	-1.78991E 02	5.78304E 00	1.79084E 02	178.149 DEG
5	3	-2.08674E 00	-5.89137E 01	5.89507E 01	-92.029 DEG
5	4	3.43775E 00	-3.42119E 01	3.43842E 01	-84.262 DEG
5	5	1.29038E 02	-5.72898E 02	5.87251E 02	-77.307 DEG

MISSILE TRANSONIC AIRLOADS PROGRAM (CONT'D)

OSCILLATORY FREQUENCY (CPS) 110.00000   53 BOXES IN CHORD DIRECTION

REDUCED FREQUENCY (SEMI CHORD) 1.38059   FREE STREAM MACH NUMBER 1.000

GENERALIZED FORCES FOR WING + TAIL

DEFL	LOAD	REAL PART	IMAG PART	ABS VALUE	PHASE ANGLE
1	1	6.37428E 02	-3.01764E 02	7.05249E 02	-25.333 DEG
1	2	1.78204E 02	-1.50041E 02	2.32957E 02	-40.096 DEG
1	3	7.94010E 01	-1.05381E 01	8.00972E 01	-7.560 DEG
1	4	1.32709E 02	-3.31926E 01	1.36797E 02	-14.042 DEG
1	5	1.04641E 03	-7.83542E 01	1.04934E 03	-4.282 DEG
2	1	1.62898E 02	-8.57680E 01	1.84097E 02	-27.767 DEG
2	2	1.25678E 02	-9.45007E 01	1.57243E 02	-36.940 DEG
2	3	8.18160E 01	-1.28959E 01	8.28261E 01	-8.957 DEG
2	4	9.51186E 01	-3.49333E 01	1.01331E 02	-20.166 DEG
2	5	5.97284E 02	6.48962E 00	5.97319E 02	0.623 DEG
3	1	-5.48668E 01	2.85198E 00	5.49409E 01	177.024 DEG
3	2	-5.40294E 00	-1.24546E 01	1.35761E 01	-113.452 DEG
3	3	8.46230E 01	-1.98982E 01	8.69310E 01	-13.232 DEG
3	4	4.15948E 01	1.32068E 01	4.36411E 01	17.615 DEG
3	5	7.39172E 01	-4.13970E 01	8.47200E 01	-29.251 DEG
4	1	1.72507E 01	1.89236E 01	2.56064E 01	47.648 DEG
4	2	-1.86965E 00	1.37685E 00	2.32192E 00	143.631 DEG
4	3	6.35815E 00	-3.82107E 01	3.87361E 01	-80.553 DEG
4	4	-1.83808E 01	-1.77554E 01	2.55560E 01	-135.992 DEG
4	5	2.01593E 01	-2.61103E 00	2.03276E 01	-7.380 DEG
5	1	-1.16525E 02	-1.69474E 02	2.05669E 02	-124.511 DEG
5	2	-1.78442E 02	5.46221E 00	1.78526E 02	178.247 DEG
5	3	-6.35847E 00	-5.39549E 01	5.43283E 01	-96.721 DEG
5	4	7.74090E 00	-3.20643E 01	3.29855E 01	-76.427 DEG
5	5	1.29226E 02	-5.73801E 02	5.88172E 02	-77.308 DEG

4.5 PROGRAM LISTING

```
$      FORTRAN NLSTOU,DECK
CCSIS        CSTS
      BLOCK DATA
      COMPLEX CZERO,PHI,PHITE,DPHI,SPHI
      COMMON/C3/CO(10,28,2),NI(10,2),NF(10,2),NTMAX(2),FN(28),DXE(6),TPI
      COMMON/C7/CZERO,PHI,PHITE,DPHI,SPHI
      COMMON/C8/RHO
      DATA CZERO/(0.0,0.0)/,TPI/6.2831853/,FN/0.,1.,0.,2.,1.,0.,3.,2.,
     1 1.,0.,4.,3.,2.,1.,0.,5.,4.,3.,2.,1.,0.,6.,5.,4.,3.,2.,1.,0./
      END
$      FORTRAN NLSTOU,DECK
CMAIN        MAIN
      COMPLEX VPIC,DS,DQ,Q,PHIW,CK,CZERO,PHI,PHITE,DPHI,SPHI,ASQ,EXF
      DIMENSION ASQ(40,40)
      COMMON/C1/KBOX(2000),XE(5),YE(3),AR(3),X1,X2,X3,X4,Y1,Y2,BETA,NBS
      COMMON/C2/AS,NMACH,FMACH(6),NFREQ,FREQ(10),NMODE,NSURF,LVPIC,LSSVP
      COMMON/C3/CO(10,28,2),NI(10,2),NF(10,2),NTMAX(2),FN(28),DXE(6),TPI
      COMMON/C4/VPIC(40,15),DS(2000),DQ(28,2),Q(10,10,3),PHIW(50),CK(40)
      COMMON/C5/MOB(100),NBL(100),FC    ,IFR,XL,NS,NIM,K,J,QR,QI,QAB,QAN
      COMMON/C6/X,Y,DX,DY,FM,FK,FKB,FKR,NP,MP,NB,NBOX,KODE,MODE,NBR,NBT
      COMMON/C7/CZERO,PHI,PHITE,DPHI,SPHI
      COMMON/C8/RHO
    1 CALL MAIN
      DO 1000 MACH=1,NMACH
      FM = FMACH(MACH)
      IF(ABS(FM-1.0).GT.0.05) GO TO 1000
      CALL CODE
      CALL POUT(1)
      TPU=TPI/(AS*FM)
      RFU = DX
      DO 900 IFR =1,NFREQ
      FK=FREQ(IFR)*TPU
      IF(FK.EQ.0.0) GO TO 900
      FKB  =FK*RF
      FKR = FK*X1/2.0
      CALL POT2H
      IF(LVPIC.NE.0) CALL POUT(2)
      ARG=FK*DX
      EXF=CMPLX(COS(ARG),-SIN(ARG))
      DO 500 MODE=1,NMODE
      DO 10 J=1,50
   10 DQ(J,1)=CZERO
      IF(NF(MODE,1).EQ.0) GO TO 210
      X=0.5*DX
      NB=1
      IF(LSSVP.NE.0) CALL POUT(3)
      DO 200 NP=1,NBOX
      NR=MOB(NP)
      Y=0.0
      KODE = KBOX(NR)
      NS =1
      GO TO (12,11,12,11,11,120),KODE
   11 NS =2
   12 DO 20 MP=1, B
      SPHI = CZERO
      IF(MP.GT.1) CALL PHIR
      CALL WASH
      CK(MP)=DS(NR)
      DS(NR) = DS(NR) - SPHI
      Y = Y+DY
```

```
   20 NB = NB+1
      NB = NB-MB
      DO 30 IO=1,MB
      DO 30 JO=1,MB
      IJO = IABS(IO-JO)+1
   25 ASO(IO,JO) = VPIC(IJO,1)
      IF(JO.EQ.1) GO TO 30
      IJO=IO+JO-1
      ASO(IO,JO)=ASO(IO,JO)+VPIC(IJO,1)
   30 CONTINUE
      ISQ = MSIMEQ(40,MB,1,ASO,DS(NB))
      IF(ISQ.EQ.1) GO TO 39
      CALL POUT(8)
      GO TO  900
   39 CONTINUE
      Y = 0.0
      IF(NP.NE.1) GO TO 50
      DO 45 MP=1,MB
   45 DS(MP) = DS(MP)*2.0/3.1415927
   50 CONTINUE
      IF (KODE.NE.4) GO TO 80
      DO 60 MP=1,MB
      DS(NB) = PHIW(MP)+(DS(NB)-PHIW(MP))*2.0/3.1415927
   60 NB=NB+1
      NB=NB-MB
   80 CONTINUE
      DO 100 MP=1,MB
      IF(KODE.EQ.3) PHIW(MP)=DS(NB)*EXF
      IF(MP.EQ.NBOX-1) PHIW(MP)=DS(NB)
      PHIIE = DS(NB)
      IF(MP.EQ.NBOX) PHITE = PHITE+(PHIIE-PHIW(MP))*DXE(5)
      PHI = DS(NB)
      IF(ISSVP.NE.0) CALL POUT(4)
      CALL DOIJ
      NB = NB + 1
  100 Y=Y+DY
      GO TO 200
  120 DO 130 MP=1,MB
      DS(NB)=PHIW(MP)
      PHIW(MP) = EXF*PHIW(MP)
      CK(MP)=CZERO
      IF(ISSVP.NE.0) CALL POUT(4)
  130 NB = NB+1
  200 X = X+DX
  210 DO 400 MO =1,NMODE
      DO 300 NS=1,NSURF
      Q(MODE,MO,NS)=CZERO
      NTM=NT(MO,NS)
      DO 300 N=1, TM
  300 Q(MODE,MO,NS)=Q(MODE,MO,NS)+CU(MO,N,NS)*DQ(N,NS)
      Q(MODE,MO,3) = CZERO
  400 Q(MODE,MO,3)=Q(MODE,MO,1)+Q(MODE,MO,2)
  500 CONTINUE
      DO 800 NS=1,3
      CALL POUT(6)
      DO 700 J=1,NMODE
      DO 700 K=1,NMODE
      QR = FQ*REAL(Q(K,J,NS))
      QI = FQ*AIMAG(Q(K,J,NS))
      CAP=SQRT(QI*QI+QR*QR)
```

```
      QAN=0.0                                                           SON71280
      IF(QAB.NE.0.0) QAN=57.29578*ATAN2(QI,QR)                          SON71290
  700 CALL PCOUT(7)                                                     SON71300
      IF(NSURF.EQ.1) GO TO  900                                         SON71310
  800 CONTINUE                                                          SON71320
  900 CONTINUE                                                          SON71330
 1000 CONTINUE                                                          SON71340
      GO TO 1                                                           SON71350
      END                                                               SON71360
$      FORTRAN NLSTOU,DECK                                              SON71370
CDAIN        DAIN                                                       SON71390
      SUBROUTINE DAIN                                                   SON71400
      COMMON/C1/KBOX(2000),XE(5),YE(3),AR(3),X1,X2,X3,X4,Y1,Y2,BETA,NBS SON71410
      COMMON/C2/AS,NMACH,FMACH(6),NFREQ,FREQ(10),NMODE,NSURF,LVPIC,LSSVPSON71420
      COMMON/C3/CO(10,28,2),NT(10,2),NF(10,2),NTMAX(2),FN(28),DXE(6),TPISON71430
      COMMON/C6/X,Y,DX,DY,EM,EK,EKB,EKR,NP,MP,NB,NBOX,KODE,MODE,NBW,NBT SON71440
      COMMON/C8/RHO                                                     SON71450
      READ(5,11) (XE(I),I=1,5)                                          SON71460
      READ(5,11) (YE(I),I=1,3),AS,RHO                                   SON71470
      RHO = RHO/1000.0                                                  SON71480
      READ(5,12) NMACH,NFREQ,NMODE,NBW,LVPIC,LSSVP                      SON71490
      READ(5,11) (FMACH(I),I=1,NMACH)                                   SON71500
      READ(5,11) (FREQ(I),I=1,NFREQ)                                    SON71510
      NSURF=2                                                           SON71520
      IF(XE(4).LT.XE(5)) GO TO 10                                       SON71530
      NSURF=1                                                           SON71540
      XE(4)=XE(3)                                                       SON71550
      XE(5)=XE(3)                                                       SON71560
   10 NTMAX(1)=0                                                        SON71570
      NTMAX(2)=0                                                        SON71580
      DO 30 MODE=1,NMODE                                                SON71590
      DO 30 I=1,NSURF                                                   SON71600
      DO 20 J=1,28                                                      SON71610
   20 CO(MODE,J,I)=0.0                                                  SON71620
      READ(5,12)  NTM,NFI                                               SON71630
      NT(MODE,I)=NTM                                                    SON71640
      NTMAX(I)=MAX0(NTMAX(I),NTM)                                       SON71650
      NF(MODE,I)=NFI                                                    SON71660
   30 READ(5,11) (CO(MODE,J,I),J=1,NTM)                                 SON71670
   11 FORMAT(6E12.8)                                                    SON71680
   12 FORMAT(6I12)                                                      SON71690
      RETURN                                                            SON71700
      END                                                               SON71710
$      FORTRAN NLSTOU,DECK                                              SON71720
CCODE        CODE                                                       SON71740
      SUBROUTINE CODE                                                   SON71750
      COMMON/C1/KBOX(2000),XE(5),YE(3),AR(3),X1,X2,X3,X4,Y1,Y2,BETA,NBS SON71760
      COMMON/C2/AS,NMACH,FMACH(6),NFREQ,FREQ(10),NMODE,NSURF,LVPIC,LSSVPSON71770
      COMMON/C3/CO(10,28,2),NT(10,2),NF(10,2),NTMAX(2),FN(28),DXE(6),TPISON71780
      COMMON/C5/NBB(100),NBL(100),FQ    ,IFR,XL,NS,NTM,K,J,QR,QI,QAB,QAN SON71790
      COMMON/C6/X,Y,DX,DY,EM,EK,EKB,EKR,NP,MP,NB,NBOX,KODE,MODE,NBW,NBT SON71800
      COMMON/C8/RHO                                                     SON71810
      BETA = EM                                                         SON71820
      X1 = XE(3) - XE(1)                                                SON71830
      X2 = XE(3) - XE(2)                                                SON71840
      X3 = XE(4) - XE(1)                                                SON71850
      X4 = XE(5) - XE(4)                                                SON71860
      X5 = XE(5) - XE(1)                                                SON71870
      Y1 = YE(2) - YE(1)                                                SON71880
      Y2 = YE(3) - YE(1)                                                SON71890
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      IF(X2.GT.X1.OR.X1.GT.X3.OR.X3.GT.X5.OR.X2.LT.0.0) GO TO 50          SON71900
      IF(Y1.GT.Y2.OR.Y1.LT.0.0) GO TO 50                                   SON71910
      THL = 0.0                                                            SON71920
      IF(Y2.NE.Y1)  THL = (X1 - X2) / (Y2 - Y1)                            SON71930
      AR(1) =        (Y2*(X2+X1) - Y1 * (X2-X1))                           SON71940
      AR(2) = Y2*X4*2.0                                                    SON71950
      AR(3) = AR(1) + AR(2)                                                SON71960
   10 DX = X1/(FLOAT(NBW) -0.5)                                            SON71970
      IF (200.0* DX .GT. X5) GO TO 20                                      SON71980
   15 NBW = NBW-1                                                          SON71990
      GO TO 10                                                             SON72000
   20 DY = DX/BETA                                                         SON72010
      YN1 = Y1/DY                                                          SON72020
      YN2 = Y2/DY                                                          SON72030
      XNL = YN2 - (X1-X2) / DX                                             SON72040
      XNT = YN2 + X5/DX                                                    SON72050
      XNLE = X3/DX                                                         SON72060
      XNTE      = X5/DX                                                    SON72070
      NBOX = XNTE     + 0.5                                                SON72080
      NBS = Y2/DY + 1.0                                                    SON72090
      NBT = X4/DX + 0.5                                                    SON72100
      DXF(1) = 1.0                                                         SON72110
      DXF(2) = 1.0                                                         SON72120
      DXF(3) = 0.5                                                         SON72130
      DXF(4) = AINT(XNLE + 1.5) - XNLE                                     SON72140
      DXF(5) = XNLE     - FLOAT(NBOX-1)                                    SON72150
      DXF(6) = 0.0                                                         SON72160
      X = 0.5 * DX                                                         SON72170
      NB = 0                                                               SON72180
      KODE = 1                                                             SON72190
      DO 40 NP = 1,NBOX                                                    SON72200
      XN = FLOAT(NP) - 0.5                                                 SON72210
      YN = YN2                                                             SON72220
      IF (THL .GT. 0.0) YN=AMIN1(YN,YN1+XN/(THL/BETA))                     SON72230
      MB = IFIX(YN)+1                                                      SON72240
   28 MOR(NP) = MB                                                         SON72250
      IF(MB.GT.40) GO TO 15                                                SON72260
      IF (NP .EQ. NBW) KODE =3                                             SON72270
      IF (NSURF .EQ.1) GO TO 29                                            SON72280
      IF (X .GT. X1) KODE =6                                               SON72290
      IF (X .GT. X3   ) KODE =4                                            SON72300
      IF (X .GT. X3+DX) KODE=2                                             SON72310
      IF (NP .EQ. NBOX) KODE =5                                            SON72320
   29 IF(NB+MB.GT.2000) GO TO 15                                           SON72330
      NBI(NP) = NB                                                         SON72340
      DO 30 MP = 1,MB                                                      SON72350
      NB = NB +1                                                           SON72360
   30 KBOX (NB    ) = KODE                                                 SON72370
   40 X = X+DX                                                             SON72380
      QORHO = 0.5*(AS*EM)**2                                               SON72390
      FO = -8.0*DX*DY*QORHO/FM*RHO                                         SON72400
      RETURN                                                               SON72410
   50 CALL EXIT                                                            SON72420
      RETURN                                                               SON72430
      END                                                                  SON72440
$      FORTRAN NLSTOU,DECK                                                 SON72450
CPOT2H       POT2H                                                         SON72470
      SUBROUTINE POT2H                                                     SON72480
      COMPLEX VPTC,DS,DQ,Q,PHIW,CK,CEX                                     SON72490
      COMMON/C4/VPTC(50,15),DS(2000),DQ(28,2),Q(10,10,3),PHIW(50),CK(40)SON76460
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      COMMON/C5/MOB(100),NBL(100),FU    ,IFR,XL,NS,NTM,K,J,QR,QI,QAB,QAN SON72510
      COMMON/C6/X,Y,DX,DY,EM,EK,EKB,EKR,NP,PP,NB,NBOX,KODE,MODE,NBW,NBT SON72520
      COMMON/C8/RHO                                                     SON72530
      M=2*MOB(NBOX)                                                     SON72540
      N=MIN0(NBOX,15)                                                   SON72550
      DK=EKB                                                            SON72560
      DK2=DK**2                                                         SON72570
      M1=M-1                                                            SON72580
      DK8=DK2/8.0                                                       SON72590
      DK4=2.0*DK8                                                       SON72600
      DK12=DK2/12.0                                                     SON72610
      CM=0.5                                                            SON72620
      DH=DK*0.5                                                         SON72630
      DM=0.5*DH                                                         SON72640
      DD=2.0*DK                                                         SON72650
      DDM=DD                                                            SON72660
      D1=0.25*DK2                                                       SON72670
      B5=DK2/24.0                                                       SON72680
      DO 3 I=1,M                                                        SON72690
      B1=0.0                                                            SON72700
      B4=2.0/DM                                                         SON72710
      B2=B5/B4-DH                                                       SON72720
      B3=-0.5*B5                                                        SON72730
      D3=DH*B4+B5                                                       SON72740
      D4=DK8*B4                                                         SON72750
      DD4=2.0*D4                                                        SON72760
      CN=1.0                                                            SON72770
      C3=0.0                                                            SON72780
      C4=0.0                                                            SON72790
      C7=0.0                                                            SON72800
      C8=0.0                                                            SON72810
      DO 2 J=1,N                                                        SON72820
      A1=DM/CN                                                          SON72830
      C1=CM* COS(A1)                                                    SON72840
      C2=-CM* SIN(A1)                                                   SON72850
      CALL CSIN(A1,C5,C6)                                               SON72860
      C5=CM*C5                                                          SON72870
      C6=-CM*C6                                                         SON72880
      C9=C1-C3                                                          SON72890
      C10=C2-C4                                                         SON72900
      C11=C5-C7                                                         SON72910
      C12=C6-C8                                                         SON72920
      VRE=B3*C9-B4*C10-B5*C3-B1*C11-B2*C12                              SON72930
      VIM=B4*C9+B3*C10-B5*C4+B2*C11-B1*C12                              SON72940
      VPIC(I,J)=CMPLX(VRE,VIM)                                          SON72950
   23 C3=C1                                                             SON72960
      C4=C2                                                             SON72970
      C7=C5                                                             SON72980
      C8=C6                                                             SON72990
      B1=B1-D1                                                          SON73000
      B3=B3-D3                                                          SON73010
      B4=B4-D4                                                          SON73020
      D4=D4+DD4                                                         SON73030
      CN=CN+2.0                                                         SON73040
    2 CONTINUE                                                          SON73050
      CM=CM+1.0                                                         SON73060
      DM=DM+DDM                                                         SON73070
    3 DDM=DDM+DD                                                        SON73080
      DO 5 J=1,N                                                        SON73090
      DO 4 I=1,M1                                                       SON73100
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 6  K=M-I                                                    SON73110
  4 VPIC(K+1,J)=VPIC(K+1,J)-VPIC(K,J)                        SON73120
  5 VPIC(1,J)=2.0*VPIC(1,J)                                  SON73130
    CM=0.0                                                   SON73140
    DM=0.0                                                   SON73150
    DDM=DK                                                   SON73160
    DO 12 I=1,M                                              SON73170
    C7=0.0                                                   SON73180
    C8=0.0                                                   SON73190
    C9=0.0                                                   SON73200
    C10=0.0                                                  SON73210
    P1=0.0                                                   SON73220
    P2=0.0                                                   SON73230
    CN=1.0                                                   SON73240
    B6=0.5*DK12                                              SON73250
    DO 10 J=1,N                                              SON73260
    A1=CM/CN                                                 SON73270
    A2=DM/CN                                                 SON73280
    IF (A1-0.2) 7,7,8                                        SON73290
  7 B1=2.0-A1**2/3.0                                         SON73300
    B2=-DK/(6.0*CN)                                          SON73310
    GO TO 9                                                  SON73320
  8 B3= SIN(A1)/A1                                           SON73330
    B1=2.0*B3                                                SON73340
    B2=(B3- COS(A1))/A2-DM/CN*B3                             SON73350
  9 B3= COS(A2)/CN                                           SON73360
    B4= SIN(A2)/CN                                           SON73370
    C3=B1*B3+B2*B4                                           SON73380
    C4=B2*B3-B1*B4                                           SON73390
    B5=DM*CN                                                 SON73400
    C1=B5*C4-2.0*C3                                          SON73410
    C2=-2.0*C4-B5*C3                                         SON73420
    C5=C1-C7                                                 SON73430
    C6=C2-C8                                                 SON73440
    P3=P2-B6*CN                                              SON73450
    P4=P3+2.0*DK12*(CN-1.0)                                  SON73460
    VRE=C5-P1*C6+P3*C3-P4*C9                                 SON73470
    VIM=C6+P1*C5+P3*C4-P4*C10                                SON73480
    VPIC(I,J)=VPIC(I,J)+CMPLX(VRE,VIM)                       SON73490
    P1=P1+DM                                                 SON73500
    P2=P2+CN*DK4                                             SON73510
    CN=CN+2.0                                                SON73520
    C7=C1                                                    SON73530
    C8=C2                                                    SON73540
    C9=C3                                                    SON73550
    C10=C4                                                   SON73560
    B6=B6+DK12                                               SON73570
 10 CONTINUE                                                 SON73580
    CM=CM+DK                                                 SON73590
    DM=DM+DDM                                                SON73600
 12 DDM=DDM+DD                                               SON73610
    D3=DK/(2.0*3.14159265)                                   SON73620
    A1=0.0                                                   SON73630
    DO 14 J=1,N                                              SON73640
    CEX=D3*CMPLX(SIN(A1), COS(A1))                           SON73650
    DO 13 I=1,M                                              SON73660
 13 VPIC(I,J)=CEX*VPIC(I,J)                                  SON73670
 14 A1=A1+DH                                                 SON73680
    RETURN                                                   SON73690
    END                                                      SON73700
```

```
$        FORTRAN NLSTOU,DECK                                           SON73710
CCSIN          CSIN                                                    SON73730
      SUBROUTINE CSIN(XI,U,S)                                          SON73740
C     SINE AND COSINE INTEGRAL SUBROUTINE                              SON73750
C                                                                      SON73760
C     C AND S ARE THE INTEGRALS OVER T FROM 1 TO INFINITY OF           SON73770
C         COS(XT)/T  AND  SIN(XT)/T                                    SON73780
C                                                                      SON73790
      SG=1.0                                                           SON73800
      X=XI                                                             SON73810
      IF (X) 1,2,2                                                     SON73820
    1 SG=-SG                                                           SON73830
      X=-X                                                             SON73840
    2 X2=X*X                                                           SON73850
      IF (X-1.0) 3,3,4                                                 SON73860
C                                                                      SON73870
C     FOR ABS(X) LESS THAN 1 A SERIES EXPANSION IS USED                SON73880
C                                                                      SON73890
    3 V=(((X2/98.0-0.6)*.05*X2+1.0)*X2/18.0-1.0)*X+1.57079633          SON73900
      U=((X2/45.0-1.0)*X2/24.0+1.0)*X2/4.0-.57721566 5-ALOG(X)         SON73910
      GO TO 5                                                          SON73920
C                                                                      SON73930
C     FOR ABS(X) GREATER THAN 1 APPROXIMATIONS OF HASTINGS ARE USED    SON73940
C                                                                      SON73950
    4 P=(((X2+19.894119)*X2+47.411538)*X2+8.493336)/((((X2+21.361055)  SON73960
     1  *X2+70.375496)*X2+30.038227)*X)                                SON73970
      Q=(((X2+21.383724)*X2+49.719775)*X2+5.089504)/((((X2+27.177958)  SON73980
     1  *X2+119.918932)*X2+76.707876)*X2)                              SON73990
      CO=COS (X)                                                       SON74000
      SI=SIN (X)                                                       SON74010
      U=Q*CO-P*SI                                                      SON74020
      V=P*CO+Q*SI                                                      SON74030
    5 S=V*SG                                                           SON74040
      RETURN                                                           SON74050
      END                                                              SON74060
$        FORTRAN NLSTOU,DECK                                           SON74070
CWASH          WASH                                                    SON74090
      SUBROUTINE WASH                                                  SON74100
      COMPLEX VPIC,DS,DQ,Q,PHIW,CK                                     SON74110
      COMMON/C1/KBOX(2000),XE(5),YE(3),AR(3),X1,X2,X3,X4,Y1,Y2,BETA,NBS SON74120
      COMMON/C3/CQ(10,28,2),NT(10,2),NF(10,2),NTMAX(2),FN(28),DXE(6),TPISON74130
      COMMON/C4/VPIC(30,15),DS(2000),DQ(28,2),Q(10,10,3),PHIW(50),CK(40)SON76460
      COMMON/C5/MOR(100),NBL(100),FQ    ,IFR,XL,NS,NIM,K,J,QR,QI,QAB,QAN SON74150
      COMMON/C6/X,Y,DX,DY,EM,FK,EKB,EKR,NP,MP,NB,NBOX,KODE,MODE,NBW,NBT SON74160
      COMMON/C8/RHO                                                    SON74170
      XP = X                                                           SON74180
      IF(NS.EQ.2) XP = X - X3                                          SON74190
      NTM = NT(MODE,NS)                                                SON74200
      Z = CQ(MODE,1,NS)                                                SON74210
      DZ = 0.0                                                         SON74220
      IF(NTM.EQ.1) GO TO 70                                            SON74230
      K = 1                                                            SON74240
      IF(XP.EQ.0.0) GO TO 50                                           SON74250
      PX = XP                                                          SON74260
      YX = Y/XP                                                        SON74270
      DO 40 N=2,7                                                      SON74280
      PXY     = PX                                                     SON74290
      DO 30 M = 1,N                                                    SON74300
      K = K + 1                                                        SON74310
      IF(K.GT.NTM) GO TO 20                                            SON74320
```

```
      ZP=PXY*CO(MODE,K,NS)                                              SON74330
      Z=Z+ZP                                                            SON74340
      DZ=DZ+EN(K)*ZP                                                    SON74350
   30 PXY=PXY*YX                                                        SON74360
   40 PX=PX*XP                                                          SON74370
   20 DZ=DZ/XP                                                          SON74380
      GO TO 70                                                          SON74390
   50 PX=1.0                                                            SON74400
      DO 60 N=2,7                                                       SON74410
      K=K+N                                                             SON74420
      KK=K-1                                                            SON74430
      IF(KK.LE.NTM) DZ=DZ+PX*CO(MODE,KK,NS)                             SON74440
      PX=PX*Y                                                           SON74450
      IF(K.GT.NTM) GO TO 70                                             SON74460
   60 Z=Z+PX*CO(MODE,K,NS)                                              SON74470
   70 GO TO (80,90),NS                                                  SON74480
   80 DS(NB) = CMPLX(DZ,EK*Z)                                           SON74490
      RETURN                                                            SON74500
   90 DS(NB) = CMPLX(DZ,EK*Z)                                           SON74510
      RETURN                                                            SON74520
      END                                                               SON74530
$      FORTRAN NLSTOU,DECK                                              SON74540
CPHIB          PHIB                                                     SON74560
      SUBROUTINE PHIB                                                   SON74570
      COMPLEX VPIC,DS,DQ,G,PHIW,CK,CZERO,PHI,PHITE,DPHI,SPHI            SON74580
      COMMON/C4/VPIC(40,15),DS(2000),DQ(28,2),G(10,10,3),PHIW(50),CK(40)SON76460
      COMMON/C5/MOB(100),NBL(100),FQ    ,IER,XL,NS,NTM,K,J,QR,QI,QAB,QAN SON74600
      COMMON/C6/X,Y,DX,DY,EM,EK,EKB,EKR,NP,MP,NB,NBOX,KODE,MODE,NBW,NBT SON74610
      COMMON/C7/CZERO,PHI,PHITE,DPHI,SPHI                               SON74620
      COMMON/C8/REQ                                                     SON74630
      NO=MIN0(NP,15)                                                    SON74640
      DO 20 I=2,NO                                                      SON74650
      NU=NP-I+1                                                         SON74660
      JR=MOB(NU)                                                        SON74670
      NJ=NBL(NU)+1                                                      SON74680
      DO 20 J=1,JR                                                      SON74690
      K=1+IABS(MP-J)                                                    SON74700
      DPHI=VPIC(K,I)                                                    SON74710
      IF (J.EQ.1) GO TO 10                                              SON74720
      K=MP+J-1                                                          SON74730
      DPHI=DPHI+VPIC(K,I)                                               SON74740
   10 SPHI=SPHI+DPHI*DS(NJ)                                             SON74750
   20 NJ=NJ+1                                                           SON74760
      RETURN                                                            SON74770
      END                                                               SON74780
$      FORTRAN NLSTOU,DECK                                              SON74790
CMSIMEC      MSIMEC                                                     SON74810
      FUNCTION MSIMEC(M,N,L,A,B)                                        SON74820
      COMPLEX A,B,G                                                     SON74830
      DIMENSION A(M,1),B(M,1)                                           SON74840
      DO 30 I = 1,N                                                     SON74850
      C = 0.0                                                           SON74860
      DO 10 J = 1,N                                                     SON74870
   10 C=AMAX1(C,ABS(REAL(A(I,J))),ABS(AIMAG(A(I,J))))                   SON74880
      IF(C.EQ.0.0) GO TO 1000                                           SON74890
      DO 20 J = 1,N                                                     SON74900
   20 A(I,J) = A(I,J)/C                                                 SON74910
      DO 30 J = 1,L                                                     SON74920
   30 B(I,J) = B(I,J)/C                                                 SON74930
      IF(N.EQ.1) GO TO 205                                              SON74940
```

```
      NM = N - 1                                                        SON74950
      DO 200 J = 1,NM                                                   SON74960
      C = 0.0                                                           SON74970
      K = 0                                                             SON74980
      DO 40 I = J,N                                                     SON74990
      D=ABS(REAL(A(I,J)))+ABS(AIMAG(A(I,J)))                            SON75000
      IF(C.GE.D) GO TO 40                                               SON75010
      K = I                                                             SON75020
      C = D                                                             SON75030
   40 CONTINUE                                                          SON75040
      IF(K.EQ.0.OR.C.LT.1.E-7) GO TO 1000                               SON75050
      IF(K.EQ.J) GO TO 70                                               SON75060
      DO 50 JJ = J,N                                                    SON75070
      G=A(J,JJ)                                                         SON75080
      A(J,JJ) = A(K,JJ)                                                 SON75090
   50 A(K,JJ)=G                                                         SON75100
      DO 60 JJ = 1,L                                                    SON75110
      G=B(J,JJ)                                                         SON75120
      B(J,JJ) = B(K,JJ)                                                 SON75130
   60 B(K,JJ)=G                                                         SON75140
   70 G=1.0/A(J,J)                                                      SON75150
      JP = J + 1                                                        SON75160
      DO 80 JJ = JP,N                                                   SON75170
   80 A(J,JJ)=A(J,JJ)*G                                                 SON75180
   90 DO 100 JJ = 1,L                                                   SON75190
  100 B(J,JJ)=B(J,JJ)*G                                                 SON75200
      DO 200 I = 1,N                                                    SON75210
      IF(I.EQ.J) GO TO 200                                              SON75220
      G=A(I,J)                                                          SON75230
      DO 110 JJ = JP,N                                                  SON75240
  110 A(I,JJ)=A(I,JJ)-G*A(J,JJ)                                         SON75250
      DO 120 JJ = 1,L                                                   SON75260
  120 B(I,JJ)=B(I,JJ)-G*B(J,JJ)                                         SON75270
  200 CONTINUE                                                          SON75280
  205 G=A(N,N)                                                          SON75290
      IF (ABS(REAL(G))+ABS(AIMAG(G)).LT.1.E-7) GO TO 1000               SON75300
      DO 210 J = 1,L                                                    SON75310
  210 B(N,J)=B(N,J)/G                                                   SON75320
      IF(N.EQ.1) GO TO 230                                              SON75330
      DO 220 I = 1,NM                                                   SON75340
      DO 220 JJ = 1,L                                                   SON75350
  220 B(I,JJ)=B(I,JJ)-A(I,N)*B(N,JJ)                                    SON75360
  230 MSIMEC=1                                                          SON75370
      RETURN                                                            SON75380
 1000 MSIMEC=2                                                          SON75390
      RETURN                                                            SON75400
      END                                                               SON75410
*      FORTRAN NLSTOU,DECK                                              SON75420
CDCIJ          DOIJ                                                     SON75440
      SUBROUTINE IOIJ                                                   SON75450
      COMPLEX VPIC,DS,DQ,Q,PHIW,CK,CZERO,PHI,PHIIE,DPHI,SPHI            SON75460
      COMMON/C1/KI,DX(2000),XF(5),YE(3),AR(3),X1,X2,X3,X4,Y1,Y2,BETA,NBS SON75470
      COMMON/C3/C (10,26,2),NI(10,2),NF(10,2),NIMAX(2),FN(28),DXE(6),IPISON75480
      COMMON/C4/VPIC(30,15),DS(2000),DQ(28,2),Q(10,10,3),PHIW(500),CK(40)SON76460
      COMMON/C5/MOB(100),MBL(100),FO    ,IFR,XL,NS,NIM,K,J,QR,QI,QAB,QAN SON75500
      COMMON/C6/X,Y,DX,DY,EM,EK,EKB,EKR,NP,MP,NB,NBOX,KODE,MODE,NBW,NBT SON75510
      COMMON/C7/CZERO,PHI,PHIIE,DPHI,SPHI                               SON75520
      COMMON/C8/RHO                                                     SON75530
      DPHI = PHI*XF(KODE)                                               SON75540
      IF(MP.EQ.1) DPHI = 0.5*DPHI                                       SON75550
```

```
      XP = X
      IF(NS.EQ.2) XP = X - X3
      PX = XP
      K = 1
      NIM = NIMAX(NS)
      DO(1,NS) = DO(1,NS) + DPHI*CMPLX(0.0,-EK)
      IF(NIM.EQ.1) GO TO 50
      IF(XP.EQ.0.0) GO TO 30
      YX = Y/XP
      DO 20 N = 2,7
      Z = PX
      DO 10 M = 1,N
      K = K + 1
      IF(K.GT.NIM) GO TO 50
      DO(K,NS) = DO(K,NS) + DPHI*Z*CMPLX(FN(K)/XP,-EK)
   10 Z = Z*YX
   20 PX = PX*XP
      GO TO 50
   30 PX = 1.0
      DO 40 N = 2,7
      K = K + N
      KK = K - 1
      IF(KK.LE.NIM) DO(KK,NS) = DO(KK,NS) + DPHI*PX
      PX = PX*Y
      IF(K.GT.NIM) GO TO 50
   40 DO(K,NS) = DO(K,NS) + DPHI*CMPLX(0.0,-EK*PX)
   50 IF(KODE.NE.3) GO TO 90
      DPHI = DPHI/DXF(KODE)
      K = 1
      YX = Y/XP
      PX = 1.0/DX
      DO 70 N = 1,7
      Z = PX
      DO 60 M = 1,N
      DO(K,NS) = DO(K,NS) - DPHI*Z
      K = K + 1
      IF(K.GT.NIM) GO TO 80
   60 Z = Z*YX
   70 PX = PX*XP
   80 ARG = EK*(X3 - X1)
      DPHI = -DPHI*CMPLX(COS(ARG),-SIN(ARG))
      XL = 0.0
      CALL QEGE
   90 IF(MODE.NE.5) RETURN
      XL = X4
      IF(MP.EQ.1) PHIWE = 0.5*PHITE
      DPHI = PHITE
      CALL QEGE
      RETURN
      END
$       FORTRAN NLSTOU,DECK
CQEGE          QEGE
      SUBROUTINE QEGE
      COMPLEX VPIC,DS,DO,Q,PHIW,CK,CZERO,PHI,PHITE,DPHI,SPHI
      COMMON/C4/VPIC(80,15),DS(2000),DO(28,2),Q(10,10,3),PHIW(50),CK(40)
      COMMON/C5/MBR(100),NBL(100),FQ     , IHR,XL,NS,NIM,K,J,QR,QI,QAB,QAN
      COMMON/C6/X,Y,DX,DY,EM,EK,EKB,ENR,NP,MP,NB,NROX,KODE,MODE,NBW,NBT
      COMMON/C7/CZERO,PHI,PHITE,DPHI,SPHI
      COMMON/C8/RHO
      PX=1.0/DX
```

```
      IF(XL.EQ.0.0) GO TO 30                                            SON76170
      YX=Y/XL                                                           SON76180
      K=1                                                               SON76190
      DO 20 N=1,7                                                       SON76200
      PY=PX                                                             SON76210
      DO 10 M=1,N                                                       SON76220
      DQ(K,2) = DQ(K,2) - DPHI*PY                                       SON76230
      IF(K.EQ.NTM) RETURN                                               SON76240
      K=K+1                                                             SON76250
   10 PY=PY*YX                                                          SON76260
   20 PX=PX*XL                                                          SON76270
      RETURN                                                            SON76280
   30 K = 0                                                             SON76290
      DO 40 N = 1,7                                                     SON76300
      K = K + N                                                         SON76310
      IF(K.GT.NTM) RETURN                                               SON76320
      DQ(K,2) = DQ(K,2) - DPHI*PX                                       SON76330
   40 PX = PX*Y                                                         SON76340
      RETURN                                                            SON76350
      END                                                               SON76360
*       FORTRAN NESTOD,DECK                                             SON76370
GPCUT          POUT                                                     SON76390
      SUBROUTINE POUT(IND)                                              SON76400
      COMPLEX VPIC,DS,DQ,Q,PHIW,CK,CZERO,PHI,PHITE,DPHI,SPHI            SON76410
      DIMENSION SW(5,6),SURF(2,3),COD(7),C(50)                          SON76420
      DIMENSION CARDS(25,50)                                            ********
      COMMON/C1/K,BOX(2000),XE(5),YE(3),AR(3),X1,X2,X3,X4,Y1,Y2,BETA,NBS SON76430
      COMMON/C2/AS,MAC,EMACH(6),NFREQ,FREQ(10),NMODE,NSURF,LVPIC,LSSVPSON76440
      COMMON/C3/CP(10,28,2),NI(10,2),NF(10,2),NIMAX(2),FN(28),DXE(6),TPISON76450
      COMMON/C4/VPIC(80,15),DS(2000),DQ(28,2),Q(10,10,3),PHIW(50),CK(40)SON76460
      COMMON/C5/MUB(100),MBL(100),FO    ,IFR,XL,NS,NTM,K,J,QR,QI,QAB,QAN SON76470
      COMMON/C6/X,Y,DX,DY,EM,EK,EKB,EKR,NP,MP,NB,NBOX,KODE,MODE,NBW,NBT SON76480
      COMMON/C7/CZERO,PHI,PHITE,DPHI,SPHI                               SON76490
      COMMON/C8/RHO                                                     SON76500
      DATA (SW(1,I),I=1,6)/26HMAP OF SONIC BOX OVERLAY   ,              SON76510
     1                     26HON WING, TAIL AND WAKE     ,              SON76520
     2                     26H          (S) - WING       ,              SON76530
     3                     26H          ($) - TAIL       ,              SON76540
     4                     26H          (,) - WAKE       ,              SON76550
     5                     26H                           /              SON76560
      DATA (SURF(I,J),I=1,3)/8HWING    ,8HTAIL    ,11HWING + TAIL /     SON76570
      DATA COD/1HS,1H ,1HS,1H$,1H$,1H,,1H./                             SON76580
      GO TO (10 ,20 ,30 ,40 ,50 ,60 ,70 ,80 ),IND                       SON76590
   10 WRITE(6,11)  EM,AS,RHO,XE(1),XE(4),X1,X4,Y1,Y2,Y2,Y2,X2,X4,      SON76600
     1AR(1),AR(2),NBW,NBT,NBS,NBS                                       SON76610
   11 FORMAT(1H1//////3 X,43HMAC/NAA MISSILE TRANSONIC AIRLOADS PROGRAM SON76620
     1 ///37X,30HFLIGHT CONDITIONS AND GEOMETRY/1H0//15X, 13HMACH NUMBERSON76630
     2 =,F8.5,4X,16HSPEED OF SOUND =F10.3,4H L/T,4X,4HRHO=,E14.8//1H0/  SON76640
     X54X,4HWING,18X,                                                   SON76650
     3 4HTAIL///22X,16HL.E. STATION (L),2F22.3//22X,16HROOT CHORD   (L),SON76660
     4 2F22.3// 22X,16HL.E. SPAN    (L),2F22.3//22X,16HT.E. SPAN    (L),SON76670
     5 2F22.3// 22X,16HTIP CHORD    (L),2F22.3//22X,16HTOTAL AREA (L*L),SON76680
     6 2F22.3// 22X,16HCHORDWISE BOXES ,I19,I22//                       SON76690
     7          22X,16HSPANWISE BOXES  ,I19,I22)                        SON76700
      WRITE(6,12) BOX,DX,DY                                             SON76710
   12 FORMAT(1H0/,11X,23HTOTAL CHORDWISE BOXES =,I3, 5X,11HBOX CHORD =, SON76720
     1 1P1E12.5,2H L, 5X,10HBOX SPAN =,1P1E12.5,2H L/   )               SON76730
      WRITE(6,91)                                                       SON76740
      NB = 1                                                            SON76750
      DO 17 NP = 1,NBOX                                                 SON76760
```

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      MB = MOB(NP)                                                      SON76770
      DO 13 MP = 1,MB                                                   SON76780
      K = KBOX(NB)                                                      SON76790
      C(MP) = COD(K)                                                    SON76800
   13 NB = NB + 1                                                       SON76810
      IF(NP.GT.6) GO TO 15                                              SON76820
      WRITE(6,14)(SH(I,NP),I=1,5),(C(MP),MP=1,MB)                       SON76830
   14 FORMAT(10X,5A6,50A1)                                              SON76840
      GO TO 17                                                          SON76850
   15 WRITE(6,16) (C(MP),MP=1,MB)                                       SON76860
   16 FORMAT(40X,50A1)                                                  SON76870
   17 CONTINUE                                                          SON76880
      GO TO 1000                                                        SON76890
   20 WRITE(6,51)FREQ(IFR),NBOX,EKR    ,EM                              SON76900
      WRITE(6,21)           EM,EKB                                      SON76910
   21 FORMAT(1H ,28X,48HPLANAR VELOCITY POTENTIAL INFLUENCE COEFFICIENTSSON76920
     1 /1H0,30X,9HMACH NO. =,F8.5,10X, 6HKBAR =,F9.5/1H0,13X,1HI,5X,1HJSON76930
     2 10X,5HNUBAR,5X,5HMUBAR,11X,14HREAL VPIC(J,I),8X,14HIMAG VPIC(J,I)SON76940
     3 /1H )                                                            SON76950
      JBOX = 2*MOB(NBOX)-1                                              SON76960
      IBOX = MIN0(NBOX,15)                                              SON76970
      DO 22 I = 1,IBOX                                                  SON76980
      DO 22 J = 1,JBOX                                                  SON76990
      BARNU = I - 1                                                     SON77000
      BARMU = J - 1                                                     SON77010
   22 WRITE(6,23) I,J,BARNU,BARMU,VPIC(J,I)                             SON77020
   23 FORMAT(9X,2I6,4X,2F10.1,2X,1P2E22.5)                              SON77030
      GO TO 1000                                                        SON77040
   30 WRITE(6,51) FREQ(IFR),NBOX,EKR    ,EM                             SON77050
      WRITE(6,31)MODE                                                   SON77060
   31 FORMAT(1H ,21X,59HUPPER VELOCITY POTENTIALS AND SURFACE UPWASHES FSON77070
     1OR MODE NO.,I3/ 1H0,9X,1HN,6X,1HM,5X,2HNB,7X,10HR PHI(N,M),7X,10HISON77080
     2 PHI(N,M),10X,9HR  W(N,M), 8X,9HI  W(N,M)/1H )                    SON77090
      GO TO 1000                                                        SON77100
   40 SPHI = DS(NB)/E1                                                  SON77110
      WRITE(6,41)NP,MP,NB,SPHI,CK(MP)                                   SON77120
   41 FORMAT(4X,3I7,1P2E17.5, 3X, 1P2E17.5)                             SON77130
      GO TO 1000                                                        SON77140
   60 IF(NS.EQ.3) GO TO 100                                             SON77150
   50 WRITE(6,51)FREQ(IFR),NBOX,EKR    ,EM                              SON77160
   51 FORMAT(1H1,33X,43HMISSILE TRANSONIC AIRLOADS PROGRAM (CONT-D)//1H0SON77170
     1 8X,27HOSCILLATORY FREQUENCY (CPS),F12.5,14X,I2,25H BOXES IN CHORDSON77180
     2 DIRECTION /1H0,8X,30HREDUCED FREQUENCY (SEMI CHORD),F9.5,14X,    SON77190
     3 23HFREE STREAM MACH NUMBER,F9.3,/1H )                            SON77200
      WRITE(6,101) SURF(1,NS)                                           SON77210
  101 FORMAT(28X,45HINPUT MODE SHAPE POLYNOMIAL COEFFICIENTS FOR ,A6/   SON77220
     1 22X,62HREFERENCED TO THE SURFACE LEADING EDGE-CENTERLINE INTERSECSON77230
     2TION //2X,4HMODE,20X, 7HCOEFFS.)                                  SON77240
      DO 102 I=1,NMODE                                                  SON77250
      NTM=NT(I,NS)                                                      SON77260
  102 WRITE(6,103) I,(CO(I,J,NS),J=1,NTM)                               SON77270
  103 FORMAT(1H0,I4,4X,1P7E13.4/(9X,1P7E13.4))                          SON77280
  100 WRITE(6,51)FREQ(IFR),NBOX,EKR    ,EM                              SON77290
      WRITE(6,61)(SURF(I,NS),I=1,2)                                     SON77300
   61 FORMAT(1H ,35X,23HGENERALIZED FORCES FOR ,2A6/1H0,6X,4HDEFL,3X,   SON77310
     1 4HLOAD,10X,9HREAL PART,10X,9HIMAG PART,10X,9HABS VALUE,10X,      SON77320
     2 11HPHASE ANGLE //)                                               SON77330
      GO TO 1000                                                        SON77340
   70 WRITE(6,71)J,K,QR,QI,QAB,QAN                                      SON77350
      KKK=2*NMODE                                                       ********
```

```
      NNN=2*K                                                           ********
      NNNN=NNN-1                                                        ********
      CARDS(J,NNNN)=QR                                                  ********
      CARDS(J,NNN)=QI                                                   ********
      IF (NSURF .EQ. 1) GO TO 667
      IF (NS.NE.3) GO TO 1000                                           ********
  667 IF (J.NE.NMODE) GO TO 1000                                        ********
      IF (K.NE.NMODE) GO TO 1000                                        ********
      KKK=2*NMODE                                                       ********
      PUNCH 666,((CARDS(II,JJ),JJ=1,KKK),II=1,NMODE)                    ********
  666 FORMAT(6E12.5)                                                    ********
   71 FORMAT(1H0,I9,I7,2X,1P3E19.5,0PF16.3,4H DEG)                      SON77360
      GO TO 1000                                                        SON77370
   80 WRITE(6,91)                                                       SON77380
      WRITE(6,81) FREQ(IFR)                                             SON77390
   81 FORMAT(1H0//////24X,56HUNABLE TO OBTAIN COMPLEX SIMULTANEOUS EQUATSON77400
     1IONS SOLUTION//31X,42HCOMPUTATIONS FOR THIS FREQUENCY TERMINATED,/SON77410
     2/45X, 6HFREQ. =,F9.3)                                             SON77420
   91 FORMAT(1H1,30X,53HMISSILE TRANSONIC AIRLOADS PROGRAM (CONT-D)//)  SON77430
 1000 RETURN                                                            SON77440
      END                                                               SON77450
```

5.0 SUPERSONIC UNSTEADY AERODYNAMICS

5.1 Theoretical Derivation

For Mach numbers greater than 1.0, the linearized flow equation becomes a hyperbolic differential equation:

$$(M^2-1)\ \phi_{xx} - \phi_{yy} - \phi_{zz} = -M^2 \left[2ik\ \phi_x - k^2\ \phi \right] \qquad (5.1.1)$$

The equation only has solutions within characteristic regions called Mach cones. Linearized supersonic flow theory has led to closed-form solutions for many types of lifting surfaces in steady flow. These solutions are easily derived because the influence of a small perturbation is confined to its downstream or aft Mach cone. Conversely, the only disturbances that can influence a particular point are confined to its upstream or fore Mach cone.

Equation (5.1.1) is satisfied by a pulsating source. The source, placed at (ξ,η,ζ), emanates spherical disturbances and has a velocity potential induced at (x, y, z) given by

$$\phi_s = A\ (\xi,\ \eta,\ \zeta)\ G\ (x-\xi,\ y-\eta,\ z-\zeta) \qquad (5.1.2)$$

where

$$G\ (x-\xi,\ y-\eta,\ z-\zeta) = -\frac{1}{\pi R} \exp\ [-\ i\bar{k}\ (x-\xi)]\ \cos\left[\frac{\bar{k}}{M} R\right] \qquad (5.1.3)$$

$$R = \sqrt{(x-\xi)^2 - (M^2-1)[(y-\eta)^2 + (z-\zeta)^2]} \qquad (5.1.4)$$

$$\bar{k} = k\ M^2\ /\ (M^2-1) \qquad (5.1.5)$$

and $A\ (\xi,\ \eta,\ \zeta)$ = source strength

This type of disturbance has no influence outside the downstream Mach cone and is discontinuous at the point $(\xi,\ \eta,\ \zeta)$. To provide the necessary antisymmetry of disturbances associated with lifting surfaces, we place a pair of sources on either side of the z = 0 plane and require the lower source strength to be equal in magnitude but opposite in sense to the upper source strength.

Applying this source superposition technique to the wing, wake and control surface, the entire $z = 0$ plane is covered above and below with source sheets. The strength of the opposing sheets are equal in magnitude but opposite in sense; $A(\xi, \eta, 0^+) = -A(\xi, \eta, 0^-)$. The strength distribution has been shown by Garrick and Rubinow (Reference 8) to be equal everywhere to the local downwash. Using this condition, we have

$$A\ (\xi,\ \eta,\ o^+) = w\ (\xi,\ \eta,\ o^+) \qquad (5.1.6)$$

The velocity potential at $(x, y, 0^+)$ can be written as

$$\phi = \iint w(\xi,\ \eta)\ G\ (x - \xi,\ y - \eta)\ d\xi d\eta \qquad (5.1.7)$$

The range of integration extends over the region contained in the fore Mach cone of the point.

In the wake region between the wing and control surface, the downwash must be determined to satisfy the continuous pressure condition. This is the same relationship given by Equation (4.1.7) in the transonic unsteady aerodynamics discussion. Substituting Equation (5.1.7) in the wake condition gives

$$\iint w\ (\xi,\ \eta)\ G\ (x - \xi,\ y - \eta)\ d\xi d\eta = \phi_{wing\ t.e.} \left[\exp -ik\left(x - x_{wing\ t.e.}\right)\right] \qquad (5.1.8)$$

This relationship which requires knowledge of the upstream downwash within the fore Mach cone to solve for the local downwash.

The preceding discussion applies only to lifting surfaces with supersonic leading edges. When the leading edges are supersonic, the fluid flow over the top and bottom of the lifting surfaces are completely isolated from one another. To treat the problem of subsonic leading edges, the concept of a diaphragm of unknown downwash is added to the planform. The diaphragm region is between the Mach envelope and subsonic edge. The diaphragm downwash is found by applying the condition of zero pressure:

$$0 = \iint w\ (\xi,\ \eta)\ G\ (x - \xi,\ y - \eta)\ d\xi d\eta \qquad (5.1.9)$$

The downwash of the diaphragm creates an additional contribution to the pressure profile over the planform.

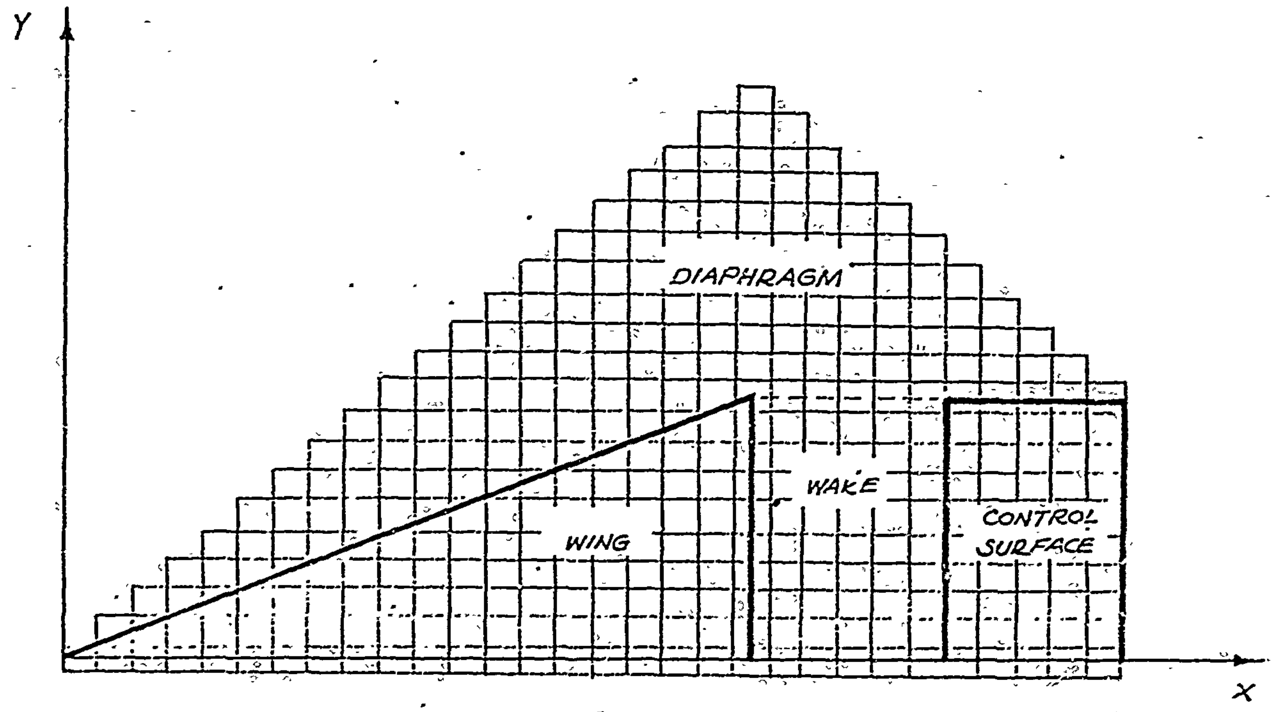


Figure 5.1.1 Mach Box Overlay Pattern

The velocity potential distribution is found by the so called Mach box method. The wing, control surface, wake and diaphragm regions are covered with a grid of rectangular boxes of length Δ. The width of the boxes is set equal to $\Delta / \sqrt{M^2-1}$ thus making the box diagonals parallel to the Mach lines. The source strength (downwash) is assumed constant over each box and equal to the value at the box center. A typical Mach box overlay is shown in Figure (5.1.1).

From the conditions imposed on the planform, the downwash can be numerically evaluated for the diaphragm and wake boxes and the velocity potential profile can be established for any deformation mode. The pressure can then be calculated from Equation 4.1.8 and generalized forces can be evaluated with Equation 2.0.1.

5.2 PROGRAM DESCRIPTION

The Supersonic Unsteady Aerodynamics Program calculates generalized forces for up to 10 deformation modes. The computer solution is based upon the Mach box technique. The various configurations which can be analyzed are shown in Figure 5.2.1 and Table 5.2.1. The analysis includes interaction effect between tandem surfaces and wake effects on the trailing surface. Single surfaces may be analyzed by inputing a second surface with a zero chordlength.

The supersonic Mach box method uses source superposition method to approximate the aerodynamic forces on an oscillating thin planar surface. The diaphragm concept was employed to handle subsonic leading edges and gaps between the aerodynamic surfaces. For purposes of calculating pressures, it was assumed that the source strength over the area of each box is a constant value which satisfies the condition of tangential flow at the center of the box. The Mach box procedure is basically the same as the method of Pines, <u>et al</u>, Reference II, differing only in that the surface and diaphragm is overlaid with a grid of rectangular boxes, the diagonals of which are parallel to Mach lines. As in the subsonic and transonic cases, the potential equation is written as an integral equation (this time relating the downwash to the source strengths) and approximated by a matrix equation. The numerical difficulties are primarily ones of computer logic since the zones of influence of a given Mach box is limited to the region within the aft Mach lines. The matrix formulation leads to a partitioned form since there are two boundary conditions to be matched. The first boundary condition is the downwash on the surface, and the second is that there be no pressure difference off of the surface in the diaphragm regions. The zero pressure conditions leads to a relationship between the diaphragm potentials and the surface potentials, and the surface downwash condition then leads to the surface potentials. The surface pressures then follow from the surface potentials.

The solution for the generalized aerodynamic forces requires the input of the deformation modes due to vibration. The program considers the modes to be expressed as analytic functions of the form:

$$w(x, y) = \sum_{m=0}^{N} \sum_{m=0}^{n} C_{(n-m),\, m} x^{(n-m)} y^{m}$$

To meet this requirement only the coefficients "c" are required as input into the program. These coefficients can be obtained in several ways, the most common way is to surface fit the modes by the least-square technique.

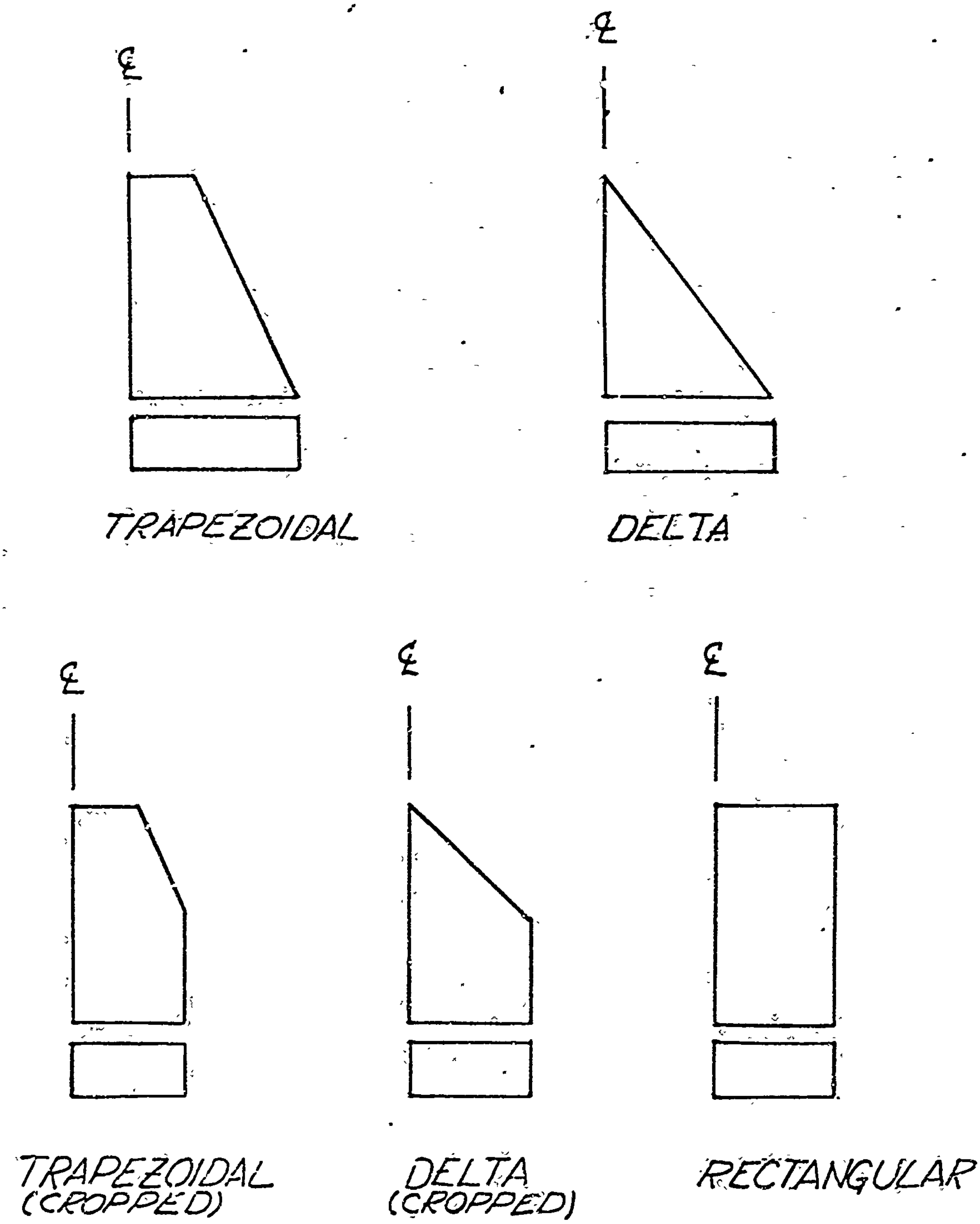


FIGURE 5.2.1
TANDEM COPLANAR CONFIGURATIONS AT SUPERSONIC MACH NUMBER

TABLE 5.2.1- OPTIONAL CONFIGURATIONS

CONFIGURATION	CHORDWISE COORDINATE	SPANWISE COORDINATE
RECTANGULAR	X(1) = 0.0 X(2) = 0.0 X(3) > 0.0 X(4) ≥ X(3) X(5) ≥ X(4)	Y(1) = 0.0 Y(2) = 0.0 Y(3) > 0.0
DELTA	X(1) = 0.0 X(2) > 0.0 X(3) = X(2) X(4) ≥ X(3) X(5) ≥ X(4)	Y(1) = 0.0 Y(2) = 0.0 Y(3) > 0.0
TRAPEZOIDAL	X(1) = 0.0 X(2) > 0.0 X(3) = X(2) X(4) ≥ X(3) X(5) ≥ X(4)	Y(1) = 0.0 Y(2) > 0.0 Y(3) > Y(2)
TRAPEZOIDAL (CROPPED)	X(1) = 0.0 X(2) > X(1) X(3) > X(2) X(4) ≥ X(3) X(5) ≥ X(4)	Y(1) = 0.0 Y(2) > 0.0 Y(3) > Y(2)
DELTA (CROPPED)	X(1) = 0.0 X(2) > 0.0 X(3) > X(2) X(4) ≥ X(3) X(5) ≥ X(4)	Y(1) = 0.0 Y(2) = 0.0 Y(3) > Y(2)

5.3 INPUT INSTRUCTIONS

Instructions for preparing input data for the supersonic computer program are presented here. The field location and format for each quantity is specified. Any set of units may be used for geometric dimensions and acoustic velocity as long as they are consistent, e.g., if inches is used for length, then the acoustic velocity must have dimensions of inches per second. The required data and the sequence in which the information is entered is as follows:

1. Streamwise Coordinates (6E12.5 format)

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	X(1)	X(2)	X(3)	X(4)	X(5)	
Item	(1)	(2)	(3)	(4)	(5)	

(1) X(1) Wing root leading edge coordinate **(see Figure 5.3.1)**
(2) X(2) Wing tip leading edge coordinate
(3) X(3) Wing trailing edge coordinate
(4) X(4) Control surface leading edge coordinate
(5) X(5) Control surface trailing edge coordinate

A single surface, the wing, may be analyzed by setting X(4) and X(5) equal to X(3). The various configurations are generated as shown in Table 5.2.1. **The origin for the planform and AIC station coordinates** must be at the leading edge root of the wing, therefore X(1) and Y(1) described below, must always be zero.

2. Spanwise Coordinates and Acoustic Velocity (6E12.5 format)

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	Y(1)	Y(2)	Y(3)	SOUND	RHØ	
Item	(1)	(2)	(3)	(4)	(5)	

(1) Y(1) Wing root spanwise coordinate
(2) Y(2) Wing leading edge spanwise coordinate
(3) Y(3) Wing (and control surface) tip spanwise coordinate
(4) SOUND Speed of sound at altitude for which analysis is performed
(5) RHØ Density of fluid * 1000.0 $(M./L^3)$

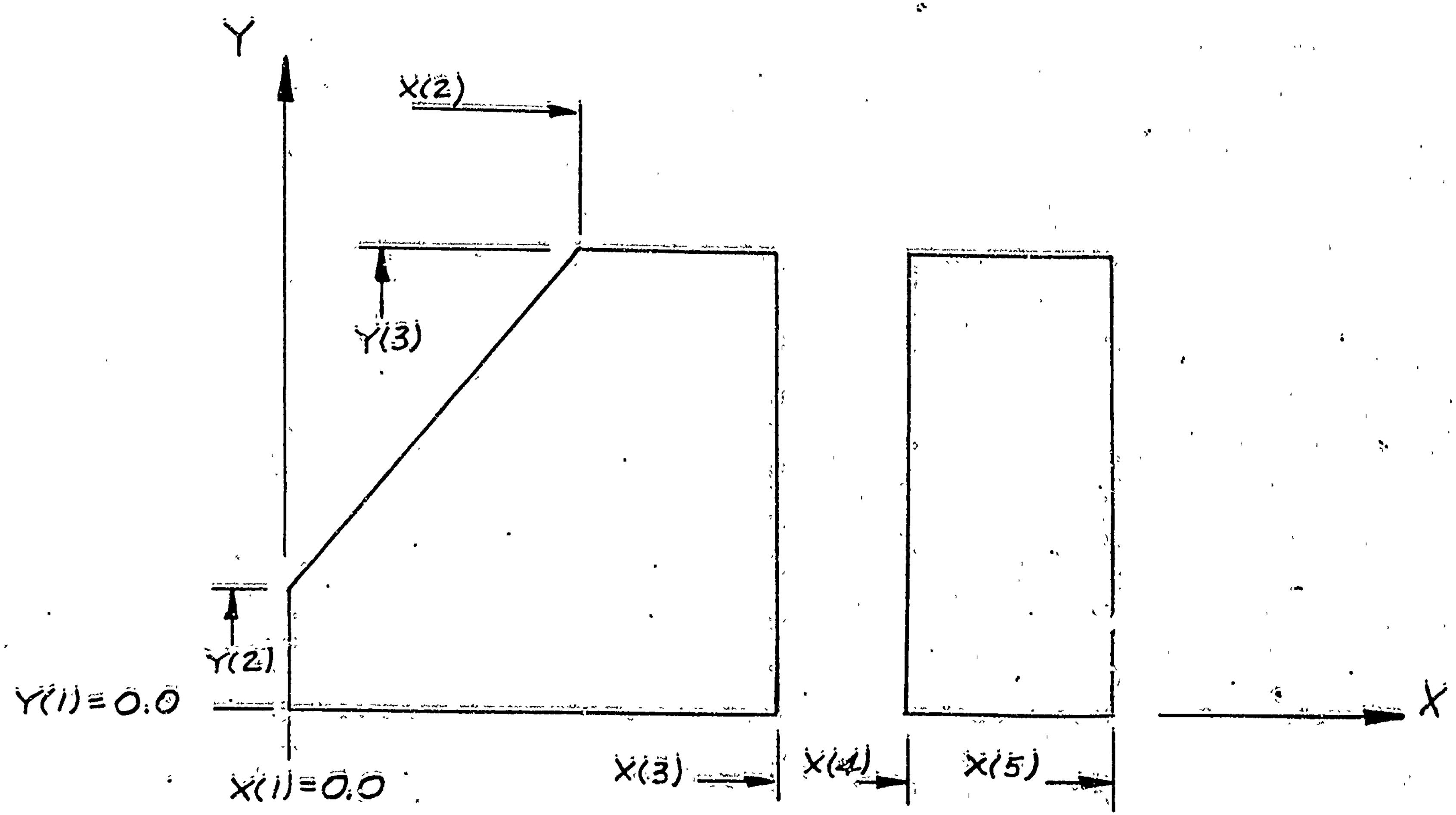


FIGURE 5.3.1
GEOMETRY DESCRIPTION

3. General Information (6I12 format)

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	NMACH	NFREQ	NMODES	NBW	LYPIC	LSSVP
Item	(1)	(2)	(3)	(4)	(5)	(6)

(1) NMACH Number of Mach numbers (max 6)
(2) NFREQ Number of input frequencies (max 10)
(3) NMODES Number of input modes (max 10)
(4) NBW Number of chordwise wing boxes (max 10)
(5) LVPIC Print velocity potential influence coefficients; 0 ~ No, 1 ~ Yes
(6) LSSVP Print upwashes; 0 ~ No, 1 ~ Yes

4. Mach Numbers (6E12.5 format)

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	FMACH(1)	FMACH(2)	FMACH(3)	FMACH(4)	FMACH(5)	FMACH(6)
Item	(1)	(2)	(3)	(4)	(5)	(6)

(1) FMACH(i) Mach numbers for which the analysis is to be performed

5. Frequency (6E12.5 format)

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	FREQ(1)	FREQ(2)	FREQ(3)	FREQ(4)	FREQ(5)	FREQ(6)
Item						

(1) FREQ Frequencies for which the analysis is to be performed.
Continue on next card for FREQ(i) > 6

6. Deformation Modes. Repeat the following Cards NMODES Times

(6I12) Format

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	NTM1(i)	NFI				
Item	(1)	(2)				

(1) NTM1(i) Number of deformation mode coefficients for the wing, mode i
(2) NFI Compute generalize forces; 0 ~ No, 1 ~ Yes
If NFI = 0, the program will compute the VPIC's and stop.

(6E12.5) Format

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	CØ(1)	CØ(2)	CØ(3)	CØ(4)	CØ(5)	CØ(6)
Item	(1)	(2)	(3)	(4)	(5)	(6)

(1) CØ(i) i = 1, NTM deformation polynomial coefficients to be input in the following order: 0,0; 1,0; 0,1; 2,0; 1,1; 0,2; 3,0; where the first integer is the power of x and the second is the power of y. Continue on successive card until all polynomial coefficients are input.

(6I12) Format

Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	NTM(i)	NFI				
Item	(1)	(2)				

(1) NTM2(i) Number of deformation mode coefficients for the control surface, mode (i)

(2) NFI Compute generalized forces; 0 ∼ No; 1 ∼ Yes. If NFI = 0, the program will compute the VPIC's and stop.

(6E12/5) Format

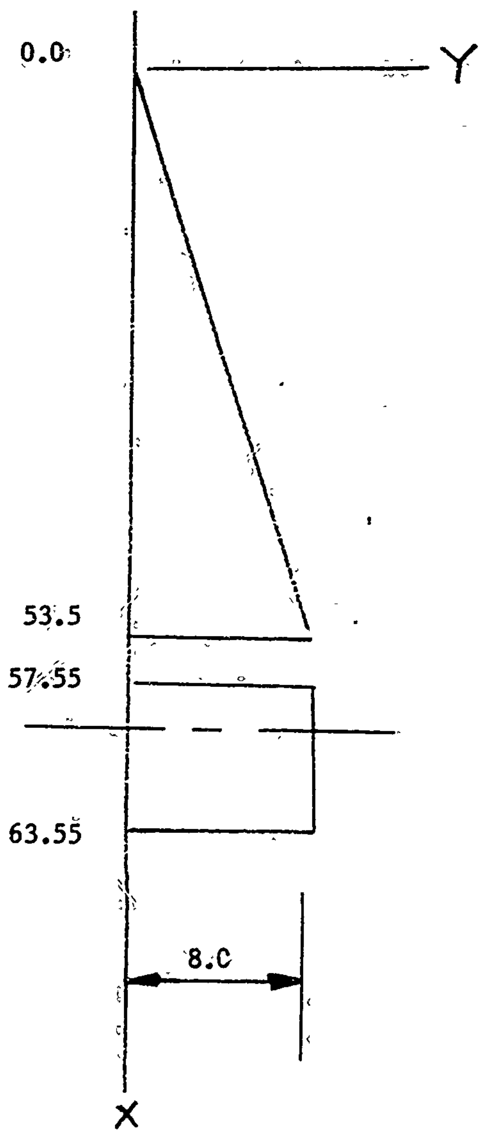
Column	1-12	13-24	25-36	37-48	49-60	61-72
Name	CØ(1)	CØ(2)	CØ(3)	CØ(4)	CØ(5)	CØ(6)
Item	(1)	(2)	(3)	(4)	(5)	(6)

CØ(i) i - 1, NTM deformation polynomial coefficients to be input in the following order; 0,0; 1,0; 0,1; 2,0; 1,1; 0,2; 3,0; etc. where the first integer is the power of "x" and the second is the power of "y". Continue on successive cards until all polynomial coefficients are input.

5.4 SAMPLE PROBLEM

The generalized forces are calculated for the configuration below. The flight parameters and pertinent input data are on the first page of the computer print out.

The coefficients of the deformation modes for the forward surface are shown on the third page of the computer print out, and for the aft surface on the fifth page of the computer print out.



HAC/NAA MISSILE SUPERSONIC AIRLOADS PROGRAM

FLIGHT CONDITIONS AND GEOMETRY.

MACH NUMBER = 1.50000   SPEED OF SOUND = 13392.000 L/T   RHO=0.11460000E-06

	WING	TAIL
L.E. STATION (L)	0.	57.550
ROOT CHORD (L)	53.500	6.000
L.E. SPAN (L)	0.	8.000
T.E. SPAN (L)	8.000	8.000
TIP CHORD (L)	0.	6.000
TOTAL AREA (L*L)	428.000	96.000
CHORDWISE BOXES	40	4
SPANWISE BOXES	7	7

TOTAL CHORDWISE BOXES = 47   BOX CHORD = 1.35443E 00 L   BOX SPAN = 1.21144E 00 L

MISSILE SUPERSONIC AIRLOADS PROGRAM (CONT'D)

```
MAP OF MACH BOX OVERLAY ON     S
WING, TAIL, AND DIAPHRAGM      S.
        (S) - WING             S..
        ($) - TAIL             S...
        (,) - WAKE             S....
        (.) - DIAPHRAGM        S.....
                               SS.....
                               SS......
                               SS.......
                               SS........
                               SS.........
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MISSILE SUPERSONIC AIRLOADS PROGRAM (CONT'D)

OSCILLATORY FREQUENCY (CPS)   200.00000   47 BOXES IN CHORD DIRECTION

REDUCED FREQUENCY (SEMI CHORD) 1.67339   FREE STREAM MACH NUMBER   1.500

INPUT MODE SHAPE POLYNOMIAL COEFFICIENTS FOR WING
REFERENCED TO THE SURFACE LEADING EDGE-CENTERLINE INTERSECTION

MODE	COEFFS.						
1	-2.7643E-03	-2.3968E-03	1.0698E-01	3.3227E-04	-1.7350E-02	-3.6455E-02	-2.0567E-05
	1.0242E-03	-1.5649E-03	2.5596E-02	5.4159E-07	-2.8225E-05	2.0969E-04	-1.7662E-03
	1.4567E-03	-4.8146E-09	2.6893E-07	-3.0507E-06	2.2374E-05	-1.5766E-05	-2.0292E-05
2	5.0081E-04	1.1346E-02	-1.4269E-01	-1.9870E-03	1.7391E-02	-5.2818E-02	1.2097E-04
	-2.0628E-03	3.7740E-02	-1.1759E-01	-2.9744E-06	7.7451E-05	-1.5215E-03	4.6965E-03
	1.1664E-03	2.4952E-08	-8.3941E-07	1.6896E-05	-7.6407E-05	2.3531E-04	-7.3812E-04
3	1.6687E-02	-1.9542E-02	-1.5043E 00	3.1005E-03	2.2035E-01	1.6944E-01	-1.9229E-04
	-9.0043E-03	-2.6816E-02	8.1504E-02	4.8204E-06	1.3340E-04	9.4618E-04	-2.3806E-03
	-7.3799E-03	-4.0844E-08	-5.5376E-07	-1.4601E-05	1.3599E-04	-9.1914E-04	3.1280E-03
4	1.3375E-01	-6.8015E-03	1.4319E 00	3.0046E-03	-3.8145E-01	6.0607E-01	-2.9098E-04
	2.8713E-02	-1.2993E-01	3.2289E-01	9.6282E-06	-8.5727E-04	6.9968E-03	-3.3429E-02
	5.8256E-02	-9.6391E-08	8.2378E-06	-8.4006E-05	3.9512E-04	-1.0736E-04	-2.7726E-03
5	-2.3479E-04	-5.1973E-03	2.3344E-01	3.7865E-04	-3.3701E-04	-2.7195E-01	-6.4710E-06
	-8.1025E-04	1.3782E-02	5.7945E-02	-4.9236E-08	2.7581E-05	-2.6211E-04	-1.5177E-03
	-5.0560E-03	1.3471E-09	-2.6464E-07	2.2137E-06	-1.5098E-08	1.5586E-04	-1.3277E-04

MISSILE SUPERSONIC AIRLOADS PROGRAM (CONT'D)

OSCILLATORY FREQUENCY (CPS) 200.00000   47 BOXES IN CHORD DIRECTION

REDUCED FREQUENCY (SEMI CHORD) 1.67339   FREE STREAM MACH NUMBER 1.500

GENERALIZED FORCES FOR WING

DEFL	LOAD	REAL PART	IMAG PART	ABS VALUE	PHASE ANGLE
1	1	-4.05330E-01	1.41647E-01	4.29367E-01	160.737 DEG
1	2	2.48826E 00	-2.46939E 00	3.50561E 00	-44.782 DEG
1	3	5.69256E 00	2.42253E-01	5.69771E 00	2.437 DEG
1	4	-6.52083E 00	-1.33247E 00	6.66342E 00	-168.465 DEG
1	5	3.65956E-01	-5.45114E-02	3.69994E-01	-8.472 DEG
2	1	5.42497E 00	1.01807E-01	5.42593E 00	1.075 DEG
2	2	-1.13634E 02	5.50276E 01	1.26256E 02	154.161 DEG
2	3	-1.17337E 02	-9.03881E 01	1.48114E 02	-142.392 DEG
2	4	3.85767E 01	7.90880E 01	8.79948E 01	63.998 DEG
2	5	-1.54986E 01	1.65535E 00	1.55868E 01	173.904 DEG
3	1	-3.47591E 00	-4.56201E 00	5.73532E 00	-127.305 DEG
3	2	4.30375E 01	5.02509E 01	6.61678E 01	49.426 DEG
3	3	5.43115E 01	1.55744E 02	1.64942E 02	70.775 DEG
3	4	-8.58316E 01	-6.56561E 01	1.08064E 02	-142.586 DEG
3	5	2.34054E 01	9.49312E 00	2.52574E 01	22.077 DEG
4	1	3.10905E-01	4.44125E 00	4.45212E 00	85.996 DEG
4	2	-6.41152E 01	-8.88772E 00	6.47282E 01	-172.108 DEG
4	3	-4.63360E 01	-1.24207E 02	1.32569E 02	-110.458 DEG
4	4	-3.63002E 01	8.41059E 01	9.16052E 01	113.345 DEG
4	5	-1.47609E 01	-2.25630E 00	1.49323E 01	-171.309 DEG
5	1	-1.45288E-01	-5.12284E-02	1.54055E-01	-160.577 DEG
5	2	-8.22063E 00	7.77921E 00	1.13179E 01	136.580 DEG
5	3	2.71663E 00	1.56198E 00	3.13366E 00	29.898 DEG
5	4	-1.62163E 01	3.83596E 00	1.66638E 01	166.691 DEG
5	5	8.47165E-01	1.39315E 00	1.63051E 00	58.697 DEG

MISSILE SUPERSONIC AIRLOADS PROGRAM (CONT'D)

OSCILLATORY FREQUENCY (CPS) 200.00000 47 BOXES IN CHORD DIRECTION

REDUCED FREQUENCY (SEMI CHORD) 1.67339 FREE STREAM MACH NUMBER 1.500

INPUT MODE SHAPE POLYNOMIAL COEFFICIENTS FOR TAIL
REFERENCED TO THE SURFACE LEADING EDGE-CENTERLINE INTERSECTION

MODE	COEFFS.						
1	-2.9509E-01	4.3922E-02	-6.5762E-02	-7.3360E-03	-2.6048E-03	-8.2124E-03	3.9367E-03
	-1.4897E-03	5.5863E-03	-6.6256E-04	-5.0795E-04	3.6026E-04	-2.1683E-04	-4.8161E-04
	1.5973E-04						
2	-5.2445E-03	-1.8889E-02	-1.4280E-03	9.7705E-03	5.1856E-04	-5.6169E-03	-2.6629E-03
	-1.8634E-04	-6.7727E-04	1.2652E-03	2.2149E-04	4.6749E-05	-9.4713E-06	6.8936E-05
	-9.1426E-05						
3	3.6644E-02	-2.5725E-02	-9.3449E-03	5.2614E-03	3.2757E-03	-3.2647E-05	-1.4688E-03
	-2.6833E-04	-7.2607E-04	1.7027E-04	1.3103E-04	-1.3270E-05	5.1347E-05	2.3310E-05
	-1.2438E-05						
4	-9.8849E-02	-6.4342E-03	4.6537E-02	8.2901E-04	1.8417E-02	3.7439E-04	-2.0627E-03
	2.5576E-03	-8.0436E-03	1.7425E-03	2.8345E-04	-1.8412E-04	-9.9538E-05	6.3188E-04
	-1.2428E-04						
5	-5.7341E-01	3.1192E-01	-9.6235E-03	-5.6429E-02	2.0184E-02	-2.2471E-03	1.4691E-02
	-2.9503E-03	-2.7418E-03	8.1679E-04	-1.2591E-03	1.8190E-04	1.6698E-04	1.7044E-04
	-6.1575E-05						

MISSILE SUPERSONIC AIRLOADS PROGRAM (CONT'D)

OSCILLATORY FREQUENCY (CPS) 200.00000   47 BOXES IN CHORD DIRECTION

REDUCED FREQUENCY (SEMI CHORD) 1.67339   FREE STREAM MACH NUMBER 1.500

GENERALIZED FORCES FOR TAIL

DEFL	LOAD	REAL PART	IMAG PART	ABS VALUE	PHASE ANGLE
1	1	-2.38915E 02	1.28104E 02	2.71093E 02	151.800 DEG
1	2	3.49540E 01	8.58831E 01	9.27237E 01	67.854 DEG
1	3	-7.81328E 01	-1.35909E 01	7.93060E 01	-170.132 DEG
1	4	1.81209E 02	-3.54137E 01	1.84637E 02	-11.058 DEG
1	5	-9.35040E 02	9.55015E 01	9.39905E 02	174.168 DEG
2	1	-3.06021E 01	1.54966E 01	3.43021E 01	153.143 DEG
2	2	4.00729E 00	1.35986E 01	1.41767E 01	73.581 DEG
2	3	-1.60314E 01	6.41368E-01	1.60443E 01	177.709 DEG
2	4	3.01083E 01	-6.17353E 00	3.07347E 01	-11.588 DEG
2	5	-1.24952E 02	7.03793E 00	1.25150E 02	176.776 DEG
3	1	-1.43359E 01	7.51749E 00	1.61874E 01	152.328 DEG
3	2	1.61241E 00	7.73430E 00	7.90059E 00	78.224 DEG
3	3	-1.05254E 01	1.96083E 00	1.07064E 01	169.447 DEG
3	4	1.81686E 01	-4.84012E 00	1.88022E 01	-14.917 DEG
3	5	-6.27252E 01	1.56343E 00	6.27447E 01	178.572 DEG
4	1	7.90217E 01	-3.60158E 01	8.68422E 01	-24.502 DEG
4	2	-1.19493E 01	-2.54166E 01	2.80854E 01	-115.180 DEG
4	3	4.69554E 01	5.26476E 00	4.72496E 01	6.397 DEG
4	4	-8.27282E 01	2.59885E 00	8.67142E 01	162.560 DEG
4	5	2.76223E 02	-8.07811E 00	2.76342E 02	-1.675 DEG
5	1	-1.26964E 01	3.06803E 00	1.30620E 01	166.413 DEG
5	2	5.47163E 00	-2.04461E 01	2.11655E 01	-75.018 DEG
5	3	5.91118E 01	-2.80330E 01	6.54221E 01	-25.372 DEG
5	4	-6.53213E 01	2.68424E 01	7.06214E 01	157.661 DEG
5	5	1.87717E 01	3.74297E 01	4.18731E 01	63.365 DEG

MISSILE SUPERSONIC AIRLOADS PROGRAM (CONT'D)

OSCILLATORY FREQUENCY (CPS) 200.00000   47 BOXES IN CHORD DIRECTION

REDUCED FREQUENCY (SEMI CHORD) 1.67339   FREE STREAM MACH NUMBER 1.500

GENERALIZED FORCES FOR WING + TAIL

DEFL.	LOAD	REAL PART	IMAG PART	ABS VALUE	PHASE ANGLE
1	1	-2.39521E 02	1.28246E 02	2.71517E 02	151.814 DEG
1	2	3.74423E 01	8.34137E 01	9.14318E 01	65.826 DEG
1	3	-7.24402E 01	-1.30486E 01	7.36598E 01	-169.559 DEG
1	4	1.74680E 02	-3.67462E 01	1.78504E 02	-11.880 DEG
1	5	-9.34674E 02	9.54470E 01	9.39535E 02	174.169 DEG
2	1	-2.51771E 01	1.55984E 01	2.96175E 01	148.220 DEG
2	2	-1.09626E 02	6.86261E 01	1.29335E 02	147.953 DEG
2	3	-1.33368E 02	-8.97468E 01	1.60753E 02	-146.062 DEG
2	4	6.86850E 01	7.29145E 01	1.00171E 02	46.711 DEG
2	5	-1.40450E 02	8.69328E 00	1.40719E 02	176.458 DEG
3	1	-1.78118E 01	2.95548E 00	1.80554E 01	170.579 DEG
3	2	4.46499E 01	5.79932E 01	7.31903E 01	52.407 DEG
3	3	4.37861E 01	1.57705E 02	1.63671E 02	74.483 DEG
3	4	-6.76632E 01	-7.04962E 01	9.77140E 01	-133.825 DEG
3	5	-3.93198E 01	1.10566E 01	4.08447E 01	164.294 DEG
4	1	7.93326E 01	-3.15745E 01	8.53851E 01	-21.703 DEG
4	2	-7.60644E 01	-3.43043E 01	8.34421E 01	-155.725 DEG
4	3	6.19323E-01	-1.18942E 02	1.18944E 02	-89.702 DEG
4	4	-1.19028E 02	1.10094E 02	1.62137E 02	137.233 DEG
4	5	2.61463E 02	-1.03344E 01	2.61667E 02	-2.263 DEG
5	1	-1.28417E 01	3.01741E 00	1.31914E 01	166.777 DEG
5	2	-2.74901E 00	-1.26669E 01	1.29617E 01	-102.245 DEG
5	3	6.18284E 01	-2.64710E 01	6.72567E 01	-23.178 DEG
5	4	-8.15376E 01	3.06784E 01	8.71180E 01	159.381 DEG
5	5	1.96189E 01	3.88229E 01	4.34985E 01	63.191 DEG

5.5 PROGRAM LISTING

```
$       FORTRAN NLSTOU,DECK
$       INCODE  IBMF
CDRIV        DRIV
      COMPLEX CZERO,VPIC,SS,DQ,Q,PHIW,SPHI,PHI,PHITE,DPHI,FXF
      COMMON/C1/KBOX(2000),XE(5),YE(3),AS(3),X1,X2,X3,X4,Y1,Y2,BETA,NBS
      COMMON/C2/AS,NMACH,FMACH(6),NFREQ,FREQ(10),NMODE,NSURF,LVPIC,LSSVP
      COMMON/C3/CF(10,28,2),NT(10,2),NF(10,2),NTMAX(2),PXY(28),FN(28)
      COMMON/C4/VPIC(1275),SS(2000),DQ(28,2),Q(10,10,3),PHIW(50),SPHI
      COMMON/C5/MOB(51),NBL(50),KC(50),KL(28),BSL(20),DXE(7),TPI,U
      COMMON/C6/X,Y,DX,DY,EM,EK,EKB,EKR,NP,MP,NB,NBOX,KODE,MODE,NBW,NBT
      COMMON/C7/CZERO,PHI,PHITE,DPHI,XL,NS,NTM,K,J,QR,QI,QAJ,QAN,IFR,TWL
      COMMON/C8/RHO
    1 CALL DAIN
      DO 1000 MACH=1,NMACH
      FM=FMACH(MACH)
      IF (FM.LT.1.1) GO TO 1000
      CALL COOL
      TOB = TWL/BETA
      CALL POUT(1)
      U = AS*FM
      TPU = TPI/U
      RFM=DX*(FM/BETA)**2
      DO 900 IFR =1,NFREQ
      FK=FREQ(IFR)*TPU
      EKB = FK*RF
      EKR = FK*X1/2.0
      CALL CAFI
      IF(LVPIC.NE.0) CALL POUT(2)
      ARG=EK*DX
      FXF=CMPLX(COS(ARG),-SIN(ARG))
      DO 500 MODE=1,NMODE
      DO 10 J=1,56
   10 DQ(J,1)=CZERO
      IF(NF(MODE,1).EQ.0) GO TO 210
      X=0.5*DX
      NB=1
      IF(LSSVP.NE.0) CALL POUT(3)
      DO 200 NP=1,NBOX
      KD = KBOX(NP)
      NS = 1
      GO TO (70,60,70,60,60,70,70),KD
   60 NS = 2
   70 MB = MOB(NP)
      Y=0.0
      DO 100 MP=1,MB
      MP = MP
      KODE=KBOX(NB)
      SPHI=CZERO
      IF(NP.GT.1)CALL PHIB
      SPHI=SPHI*DY
      PHI=CZERO
      GO TO (40,40,40,40,40,20,30),KODE
   20 SPHI=SPHI-PHIW(MP)
      PHI=PHIW(MP)
      PHIW(MP)=PHIW(MP)*FXF
      GO TO 50
   30 IF(KD.EQ.6) GO TO 40
   50 SS(NB)=-SPHI/VPIC/DY
      GO TO 90
   40 CALL WASH
```

```
      IF(KD.LT.6) SS(NB) = SS(NB)-ARLECTOBS*(SS(NB)+SPHI/VPIC/DY)
      IF(KODE.GE.6) GO TO 90
      PHI=SPHI+SS(NB)*VPIC*DY
      IF(KODE.EQ.5) PHIW(MP)=PHI*EXF
      IF(NP.EQ.NBOX-1) PHIW(MP)=PHI
      IF(NP.EQ.NBOX) PHITE=PHI+(PHI-PHIW(MP))*DXE(5)
      CALL DOIJ
   90 IF(LSSVP.NE.0) CALL POUT(4)
      NB = NB + 1
      KO = KODE
  100 Y=Y+DY
  200 X=X+DX
  210 DO 400 MO =1,NMODE
      DO 300 NS=1,NSURF
      Q(MODE,MO,NS)=CZERO
      NTM=NT(MO,NS)
      DO 300 N=1,NTM
  300 Q(MODE,MO,NS)=Q(MODE,MO,NS)+CO(MO,N,NS)*DQ(N,NS)
      Q(MODE,MO,3) = CZERO
  400 Q(MODE,MO,3)=Q(MODE,MO,1)+Q(MODE,MO,2)
  500 CONTINUE
      QF = 2.0*DX*DY*RHO
      DO 800 NS=1,3
      CALL POUT(6)
      DO 700 J=1,NMODE
      DO 700 K=1,NMODE
      QR = QF*REAL(Q(K,J,NS))
      QI = QF*AIMAG(Q(K,J,NS))
      QAB=SQRT(QI*QI+QR*QR)
      QAN=0.0
      IF(QAB.NE.0.0) QAN=57.29578*ATAN2(QI,QR)
  700 CALL POUT(7)
      IF(NSURF.EQ.1) GO TO 900
  800 CONTINUE
  900 CONTINUE
 1000 CONTINUE
      GO TO 1
      END
$       FORTRAN NLSTOD,DECK
$       INCODE  IBMF
CDAIN          DAIN
      SUBROUTINE DAIN
      COMMON/C1/KODX(2000),XE(5),YE(3),AR(3),X1,X2,X3,X4,Y1,Y2,BETA,NBS
      COMMON/C2/AS,NMACH,FMACH(6),NFREQ,FREQ(10),NMODE,NSURF,LVPIC,LSSVP
      COMMON/C3/CO(10,28,2),NT(10,2),NF(10,2),NTMAX(2),PXY(28),FN(28)
      COMMON/C6/X,Y,DX,DY,FM,EK,EKB,EKR,NP,MP,NB,NBOX,KODE,MODE,NBW,NBT
      COMMON/C8/RHO
      READ(5,11) (XE(I),I=1,5)
      READ(5,11) (YE(I),I=1,3),AS,RHO
      RHO = RHO/1000.0
      READ(5,12) NMACH,NFREQ,NMODE,NBW,LVPIC,LSSVP
      READ(5,11) (FMACH(I),I=1,NMACH)
      READ(5,11) (FREQ(I),I=1,NFREQ)
      NSURF=2
      IF(XE(4).LT.XE(5)) GO TO 10
      NSURF=1
      XE(4)=XE(3)
      XE(5)=XE(3)
   10 NTMAX(1)=0
      NTMAX(2)=0
```

```
      DO 30 MODE=1,NMODE                                                SUP71410
      DO 30 I=1,NSURF                                                   SUP71420
      DO 20 J=1,28                                                      SUP71430
   20 CO(MODE,J,I)=0.0                                                  SUP71440
      READ(5,12)  NTM,NFI                                               SUP71450
      NT(MODE,I)=NTM                                                    SUP71460
      NTMAX(I)=MAX0(NTMAX(I),NTM)                                       SUP71470
      NF(MODE,I)=NFI                                                    SUP71480
   30 READ(5,11) (CO(MODE,J,I),J=1,NTM)                                 SUP71490
   11 FORMAT(6E12.8)                                                    SUP71500
   12 FORMAT(6I12)                                                      SUP71510
      RETURN                                                            SUP71520
      END                                                               SUP71530
$       FORTRAN NLSTOU,DECK                                             SUP70030
$       INCODE  IBMF                                                    SUP70040
CCONS         CONS                                                      SUP70050
      BLOCK DATA                                                        SUP70060
      COMPLEX CZERO,VPIC,SS,DQ,Q,PHIW,SPHI,PHI,PHITE,DPHI               SUP70070
      COMMON/C3/CO(10,28,2),NT(10,2),NF(10,2),NTMAX(2),PXY(28),FN(28)   SUP70080
      COMMON/C4/VPIC(1275),SS(2000),DQ(28,2),Q(10,10,3),PHIW(50),SPHI   SUP75050
      COMMON/C5/MOB(50),NBL(50),KC(50),KL(28),BSL(20),DXE(7),TPI,U      SUP70100
      COMMON/C7/CZERO,PHI,PHITE,DPHI,XL,NS,NTM,K,J,QR,QI,QAB,QAN,IFR,IWLSUP70110
      COMMON/C8/RHO                                                     SUP70120
      DATA KC/1,2,4,7,11,16,22,29,37,46,56,67,79,92,106,121,137,154,172,SUP70130
     1191,211,232,254,277,301,326,352,379,407,436,466,497,529,562,596,  SUP70140
     2631,667,704,742,781,821,862,904,947,991,1036,1082,1129,1177,1226/,SUP70150
     3FN/0.,1.,0.,2.,1.,0.,3.,2.,1.,0.,4.,3.,2.,1.,0.,5.,4.,3.,2.,1.,0.,SUP70160
     4 6.,5.,4.,3.,2.,1.,0./,TPI/6.2831853/,CZERO/(0.0,0.0)/            SUP70170
      DATA KL/1,1,4,2,3,1,4,5,6,1,7,8,9,10,1,11,12,13,14,15,1,16,17,18, SUP70180
     1 19,20,21,1/                                                      SUP70190
      END                                                               SUP70200
$       FORTRAN NLSTOU,DECK                                             SUP71540
$       INCODE  IBMF                                                    SUP71550
CCODE         CODE                                                      SUP71560
      SUBROUTINE CODE                                                   SUP71570
      COMPLEX CZERO,VPIC,SS,DQ,Q,PHIW,SPHI,PHI,PHITE,DPHI               SUP71580
      COMMON/C1/KBOX(2000),XE(5),YE(3),AR(3),X1,X2,X3,X4,Y1,Y2,BETA,NBS SUP71590
      COMMON/C2/AS,NMACH,FMACH(6),NFREQ,FREQ(10),NMODE,NSURF,LVPIC,LSSVPSUP71600
      COMMON/C3/CO(10,28,2),NT(10,2),NF(10,2),NTMAX(2),PXY(28),FN(28)   SUP71610
      COMMON/C4/VPIC(1275),SS(2000),DQ(28,2),Q(10,10,3),PHIW(50),SPHI   SUP75050
      COMMON/C5/MOB(50),NBL(50),KC(50),KL(28),BSL(20),DXE(7),TPI,U      SUP71630
      COMMON/C6/X,Y,DX,DY,EM,EK,EKB,EKR,NP,MP,NB,NBOX,KODE,MODE,NBW,NBT SUP71640
      COMMON/C7/CZERO,PHI,PHITE,DPHI,XL,NS,NTM,K,J,QR,QI,QAB,QAN,IFR,IWLSUP71650
      COMMON/C8/RHO                                                     SUP71660
      BETA = SQRT(EM * EM)-1.0)                                         SUP71670
      X1 = XE(3) - XE(1)                                                SUP71680
      X2 = XE(3) - XE(2)                                                SUP71690
      X3 = XE(4) - XE(1)                                                SUP71700
      X4 = XE(5) - XE(4)                                                SUP71710
      X5 = XE(5) - XE(1)                                                SUP71720
      Y1 = YE(2) - YE(1)                                                SUP71730
      Y2 = YE(3) - YE(1)                                                SUP71740
      IF(X2.GT.X1.OR.X1.GT.X3.OR.X3.GT.X5.OR.X2.LT.0.0) GO TO 50        SUP71750
      IF(Y1.GT.Y2.OR.Y1.LT.0.0) GO TO 50                                SUP71760
      TWI = 0.0                                                         SUP71770
      IF(Y2.NE.Y1)  TWI = (X1 - X2) / (Y2 - Y1)                         SUP71780
      AR(1) =       (Y2*(X2+X1) - Y1 * (X2+X1))                         SUP71790
      AR(2) = Y2*X4*2.0                                                 SUP71800
      AR(3) = AR(1) + AR(2)                                             SUP71810
   10 DX = X1/(FLOAT(NBW) -0.5)                                         SUP71820
```

```
      IF (50.0 * DX .GT. X5) GO TO 20                                   SUP71830
   15 NBW = NBW-1                                                       SUP71840
      GO TO 10                                                          SUP71850
   20 DY = DX/BETA                                                      SUP71860
      YN1 = Y1/DY                                                       SUP71870
      YN2 = Y2/DY                                                       SUP71880
      XNL = YN2 - (X1-X2) / DX                                          SUP71890
      XNT = YN2 + X5/DX                                                 SUP71900
      XNLE = X3/DX                                                      SUP71910
      XNTE=X5/DX                                                        SUP71920
      NBOX=XNTE+0.5                                                     SUP71930
      NBS = Y2/DY + 1.0                                                 SUP71940
      NBT = X4/DX + 0.5                                                 SUP71950
      DXE(1) = 1.0                                                      SUP71960
      DXE(2) = 1.0                                                      SUP71970
      DXE(3) = 0.5                                                      SUP71980
      DXE(4) = AINT(XNLE + 1.5) - XNLE                                  SUP71990
      DXE(5)=XNTE-FLOAT(NBOX-1)                                         SUP72000
      DXE(6) = 0.0                                                      SUP72010
      DXE(7) = 0.0                                                      SUP72020
      X = 0.5 * DX                                                      SUP72030
      NB = 0                                                            SUP72040
      DO 40 NP = 1,NBOX                                                 SUP72050
      XN = FLOAT(NP) - 0.5                                              SUP72060
      YW = YN2                                                          SUP72070
      IF (TWL .GT. 0.0) YW=AMIN1(YW,YN1+XN/(TWL/BETA))                  SUP72080
      IF(X.GT.XE(2)) GO TO 24                                           SUP72090
      MB = MIN1(AMAX1(YW,XN+YN1),XNT-XN)+1                              SUP72100
      GO TO 28                                                          SUP72110
   24 MB = MIN1(AMAX1(XNL+XN,XN+YN1),XNT-XN)+1                          SUP72120
   28 MOB(NP) = MB                                                      SUP72130
      KODE = 1                                                          SUP72140
      IF (NP .EQ. NBW) KODE =3                                          SUP72150
      IF (NSURF .EQ.1) GO TO 29                                         SUP72160
      IF (X .GT. X1) KODE =6                                            SUP72170
      IF (X .GT. X3    ) KODE =4                                        SUP72180
      IF (X .GT. X3+DX) KODE=2                                          SUP72190
      IF (NP .EQ. NBOX) KODE =5                                         SUP72200
   29 IF(NB+MB.GT.2000) GO TO 15                                        SUP72210
      NBL(NP) = NB                                                      SUP72220
      DO 30 MP = 1,MB                                                   SUP72230
      YN = MP-1                                                         SUP72240
      NB = NB + 1                                                       SUP72250
      IF (YN .GT. YW) KODE =7                                           SUP72260
   30 KBOX (NB    ) = KODE                                              SUP72270
   40 X = X+DX                                                          SUP72280
      RETURN                                                            SUP72290
   50 CALL EXIT                                                         SUP72300
      RETURN                                                            SUP72310
      END                                                               SUP72320
$      FORTRAN NLSTOU,DECK                                              SUP72330
$      INCODE  IBMF                                                     SUP72340
CCAFI          CAFI                                                     SUP72350
      SUBROUTINE CAFI                                                   SUP72360
      COMPLEX CZERO,VPIC,SS,DQ,Q,PHIW,SPHI,PHI,PHITE,DPHI               SUP72370
      DIMENSION P(5),W(5)                                               SUP72380
      COMMON/C4/VPIC(1275),SS(2000),DQ(28,2),Q(10,10,3),PHIW(50),SPHI   SUP75050
      COMMON/C5/MOB(50),NBL(50),KC(50),KL(28),BSL(20),DXE(7),TPI,U      SUP72400
      COMMON/C6/X,Y,DX,DY,EM,EK,EKB,EKR,NP,MP,NB,NBOX,KODE,MODE,NBW,NBT SUP72410
      COMMON/C7/CZERO,PHI,PHITE,DPHI,XL,NS,NTM,K,J,UR,QI,QAB,QAN,IFR,TWLSUP72420
```

```
      COMMON/C8/RHO
      DATA P/0.95308992,0.76923465,0.5,0.23076535,0.04691008/
     1    , W/0.11846344,0.23931434,0.28444444,0.23931434,0.11846344/
      PI = TPI/2.0
      IF(EKB.GT.0.0) GO TO 10
      VPIC = (-1.0,0.0)
      GO TO 30
   10 VPIC = CZERO
      DO 20 I = 1,5
      ARG = EKB*P(I)/2.0
      F = -(0.5*ARG/E4)**2
      ZJ = 1.0
      FI = 1.0
      AE = 1.0
      DO 15 K = 1,20
      AE = AE * F/FI**2
      FI = FI + 1.0
      IF(ABS(AE).LE.1.E-5) GO TO 20
   15 ZJ = ZJ + AE
   20 VPIC = VPIC - ZJ*W(I)*CMPLX(COS(ARG),-SIN(ARG))
   30 DO 80 NP = 2,NBOX
      K1 = KC(NP)
      K2 = KC(NP+1) - 1
      DO 40 K = K1,K2
   40 VPIC(K) = CZERO
      NU = NP - 1
      DO 80 I = 1,5
      X = FLOAT(NU) - 0.5 + P(I)
      ARG = EKB*X
      PHI = W(I)*CMPLX(-COS(ARG),SIN(ARG))*2.0/PI
      CALL BSLS(ARG/E4,N)
      K = KC(NP)
      DO 70 MP = 1,NU
      EOX = (FLOAT(MP) - 0.5)/X
      C = SQRT(1.0 - EOX**2)
      AE = 2.0*ATAN(EOX/(1.0 + C))
      S = 2.0*EOX*C
      C = 2.0*C*C - 1.0
      SO = 0.0
      VIN = BSL*AE
      F = 1.0
      FI = 1.0
      DO 50 L = 1,N
      VIN = BSL(L+1)*S/FI - VIN
      SN = 2.0*S*C - SO
      SO = S
      S = SN
      F = -F
   50 FI = FI + 1.0
      DPHI = PHI*VIN*F
      VPIC(K) = VPIC(K) + DPHI
      VPIC(K+1) = VPIC(K+1) - DPHI
      IF(MP.EQ.1) VPIC(K) = VPIC(K) + DPHI
   70 K = K + 1
   80 VPIC(K) = VPIC(K) +PI*BSL*PHI/2.0
      RETURN
      END
$       FORTRAN NLSTOU,DECK
$       INCODF  IBCF
CBSLS       BSLS
```

```
      SUBROUTINE BSLS(ARG,N)
      COMMON/C5/MUB(50),NBL(50),KC(50),KL(28),BSL(20),DXE(7),TPI,U
      COMMON/C8/RHO
      DO 1  I=1,20
    1 BSL(I) = 0.0
      ASQ = ARG**2
      IF(ASQ.LT.0.01) GO TO 50
      N = MIN1(17.0,(ARG + 10.0))
      F = 2*N + 4
      BSL(N+2) = (4.0*F*(F-1.0)/ASQ-(F-1.0)/F)*0.3E-30
      PF = 0.0
      J = 0
      DO 10 I = J,N
      M = N - I + 1
      F = 2*M + 1
      BSL(M)=(4.0*(F-1.0)/ASQ-1.0/F-1.0/(F-2.0))*BSL(M+1)-BSL(M+2)/F
   10 PF = PF + 2.0*(F-2.0)*BSL(M+1)
      PF = PF + BSL(1)
      F = 0.0
      IF(ABS(PF).GT.1.0)  F = ABS(PF)*1.E-10
      N = N + 2
      DO 30 I = 1,N
      IF(F.GE.ABS(BSL(I))) GO TO 20
      BSL(I) = BSL(I)/PF
      GO TO 30
   20 BSL(I) = 0.0
   30 CONTINUE
      DO 40 I = 1,N
      IF(ABS(BSL(N)).GT.1.0 E-7) RETURN
   40 N = N - 1
      RETURN
   50 BSL(2) = 0.125*ASQ
      BSL(1) = 1.0 - 2.0*BSL(2)
      N = 2
      RETURN
      END
$       FORTRAN NESTOU,DECK
$       INCODE  IBMF
CARLE         ARLE
      FUNCTION ARLE(TOB)
      COMMON/C1/KBOX(2000),XF(5),YE(3),AR(3),X1,X2,X3,X4,Y1,Y2,BETA,NBS
      COMMON/C6/X,Y,DX,DY,EM,EK,EKB,EKR,NP,MP,NB,NBOX,KODE,MODE,NBW,NBT
      COMMON/C8/RHO
      IF(X-0.5*DX.GE.X1-X2) GO TO 10
      YT = (Y-Y1)/DY+0.5-(X/DX-0.5)/TOB
      XR = YT*TOB
      YB = AMAX1(0.0,AMIN1(1.0,YT-1.0/TOB))
      YT = AMIN1(1.0,AMAX1(0.0,YT))
      XL = AMAX1(0.0,AMIN1(1.0,XR-TOB))
      XR = AMIN1(1.0,AMAX1(0.0,XR))
      ARLE = AMAX1(0.5*(YT*(XR+XL)+YB*(XR-XL)),0.0)
      IF(MP.EQ.1) ARLE = 2.0*ARLE
      RETURN
   10 ARLE = AMIN1(1.0,AMAX1(0.0,(Y-Y2)/DY+0.5))
      RETURN
      END
$       FORTRAN NESTOU,DECK
$       INCODE  IBMF
CPHIB         PHIB
      SUBROUTINE PHIB
```

```
      COMPLEX CZERO,VPIC,SS,DQ,Q,PHIW,SPHI,PHI,PHITE,DPHI               SUP73630
      COMMON/C4/VPIC(1275),SS(2000),DQ(28,2),Q(10,10,3),PHIW(50),SPHI   SUP75050
      COMMON/C5/MOB(50),NBL(50),KC(50),KL(28),BSL(28),DXE(7),TPI,U      SUP73650
      COMMON/C6/X,Y,DX,DY,EM,EK,EKB,EKR,NP,MP,NB,NBOX,KODE,MODE,NBW,NBT SUP73660
      COMMON/C7/CZERO,PHI,PHITE,DPHI,XL,NS,NTM,K,J,QR,QI,QAB,QAN,IFR,TWLSUP73670
      COMMON/C8/RHO                                                     SUP73680
      DO 20 I=2,NP                                                      SUP73690
      NU=NP-I+1                                                         SUP73700
      JL=MAX0(1,MP-I+1)                                                 SUP73710
      JR=MIN0(MOB(NU),MP+I-1)                                           SUP73720
      NJ=NBL(NU)+JL                                                     SUP73730
      DO 20 J=JL,JR                                                     SUP73740
      K=KC(I)+IABS(MP-J)                                                SUP73750
      DPHI=VPIC(K)                                                      SUP73760
      IF (J.GT.I-MP+1.OR.J.EQ.1) GO TO 10                               SUP73770
      K=KC(I)+MP+J-2                                                    SUP73780
      DPHI=DPHI+VPIC(K)                                                 SUP73790
   10 SPHI=SPHI+DPHI*SS(NJ)                                             SUP73800
   20 NJ=NJ+1                                                           SUP73810
      RETURN                                                            SUP73820
      END                                                               SUP73830
$       FORTRAN NLSTOU,DECK                                             SUP73840
$       INCODE  IBMF                                                    SUP73850
CDQIJ          DQIJ                                                     SUP73860
      SUBROUTINE DQIJ                                                   SUP73870
      COMPLEX CZERO,VPIC,SS,DQ,Q,PHIW,SPHI,PHI,PHITE,DPHI               SUP73880
      COMMON/C1/KBOX(2000),XE(5),YE(3),AR(3),X1,X2,X3,X4,Y1,Y2,BETA,NBS SUP73890
      COMMON/C3/CQ(10,28,2),NI(10,2),NF(10,2),NTMAX(2),PXY(28),FN(28)   SUP73900
      COMMON/C4/VPIC(1275),SS(2000),DQ(28,2),Q(10,10,3),PHIW(50),SPHI   SUP75050
      COMMON/C5/MOB(50),NBL(50),KC(50),KL(28),BSL(20),DXE(7),TPI,U      SUP73920
      COMMON/C6/X,Y,DX,DY,EM,EK,EKB,EKR,NP,MP,NB,NBOX,KODE,MODE,NBW,NBT SUP73930
      COMMON/C7/CZERO,PHI,PHITE,DPHI,XL,NS,NTM,K,J,QR,QI,QAB,QAN,IFR,TWLSUP73940
      COMMON/C8/RHO                                                     SUP73950
      NTM = NTMAX(NS)                                                   SUP73960
      DPHI=PHI                                                          SUP73970
      IF(MP.EQ.1) DPHI=0.5*DPHI                                         SUP73980
      CON = U*DXE(KODE)                                                 SUP73990
      DO 20 K=1,NTM                                                     SUP74000
      KK=KL(K)                                                          SUP74010
   20 DQ(K,NS) = DQ(K,NS) + DPHI*CON*CMPLX(PXY(KK)*FN(K),-EK*PXY(K))    SUP74020
      IF(KODE.NE.3) GO TO 50                                            SUP74030
      DO 30 K = 1,NTM                                                   SUP74040
   30 DQ(K,1) = DQ(K,1) -U*DPHI*PXY(K)/DX                               SUP74050
      ARG = EK*(X3 - X1)                                                SUP74060
      DPHI = -DPHI*CMPLX(COS(ARG),-SIN(ARG))                            SUP74070
      XL = 0.0                                                          SUP74080
      CALL QEGE                                                         SUP74090
   50 IF(KODE.NE.5) RETURN                                              SUP74100
      XL = X4                                                           SUP74110
      IF(MP.EQ.1)PHITE = 0.5*PHITE                                      SUP74120
      DPHI = PHITE                                                      SUP74130
      CALL QEGE                                                         SUP74140
      RETURN                                                            SUP74150
      END                                                               SUP74160
$       FORTRAN NLSTOU,DECK                                             SUP74170
$       INCODE  IBMF                                                    SUP74180
CQEGE          QEGE                                                     SUP74190
      SUBROUTINE QEGE                                                   SUP74200
      COMPLEX CZERO,VPIC,SS,DQ,Q,PHIW,SPHI,PHI,PHITE,DPHI               SUP74210
      COMMON/C4/VPIC(1275),SS(2000),DQ(28,2),Q(10,10,3),PHIW(50),SPHI   SUP75050
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      COMMON/C5/MOB(50),NBL(50),KC(50),KL(28),BSL(20),DXE(7),TPI,U      SUP74230
      COMMON/C6/X,Y,DX,DY,EM,EK,EKB,EKR,NP,MP,NB,NBOX,KODE,MODE,NBW,NBT SUP74240
      COMMON/C7/CZERO,PHI,PHITE,DPHI,XL,NS,NTM,K,J,QR,QI,QAB,QAN,IFR,THLSUP74250
      COMMON/C8/RHO                                                     SUP74260
      PX=1.0/DX                                                         SUP74270
      IF(XL.EQ.0.0)  GO TO 30                                           SUP74280
      YX=Y/XL                                                           SUP74290
      K=1                                                               SUP74300
      DO 20 N=1,7                                                       SUP74310
      PY=PX                                                             SUP74320
      DO 10 M=1,N                                                       SUP74330
      DQ(K,2) = DQ(K,2) -U*DPHI*PY                                      SUP74340
      IF(K.EQ.NTM) RETURN                                               SUP74350
      K=K+1                                                             SUP74360
   10 PY=PY*YX                                                          SUP74370
   20 PX=PX*XL                                                          SUP74380
      RETURN                                                            SUP74390
   30 K=0                                                               SUP74400
      DO 40 N=1,7                                                       SUP74410
      K=K+N                                                             SUP74420
      IF(K.GT.NTM) RETURN                                               SUP74430
      DQ(K,2) = DQ(K,2) -U*DPHI*PX                                      SUP74440
   40 PX=PX*Y                                                           SUP74450
      RETURN                                                            SUP74460
      END                                                               SUP74470
$      FORTRAN NLSTOU,DECK                                              SUP74480
$       INCODE  IBMF                                                    SUP74490
CWASH          WASH                                                     SUP74500
      SUBROUTINE WASH                                                   SUP74510
      COMPLEX CZERO,VPIC,SS,DQ,Q,PHIW,SPHI,PHI,PHITE,DPHI               SUP74520
      COMMON/C1/KBOX(2000),XE(5),YE(3),AR(3),X1,X2,X3,X4,Y1,Y2,BETA,NBS SUP74530
      COMMON/C3/CO(10,28,2),NT(10,2),NF(10,2),NTMAX(2),PXY(28),FN(28)   SUP74540
      COMMON/C4/VPIC(1275),SS(2000),DQ(28,2),Q(10,10,3),PHIW(50),SPHI   SUP75050
      COMMON/C5/MOB(50),NBL(50),KC(50),KL(28),BSL(20),DXE(7),TPI,U      SUP74560
      COMMON/C6/X,Y,DX,DY,EM,EK,EKB,EKR,NP,MP,NB,NBOX,KODE,MODE,NBW,NBT SUP74570
      COMMON/C7/CZERO,PHI,PHITE,DPHI,XL,NS,NTM,K,J,QR,QI,QAB,QAN,IFR,THLSUP74580
      COMMON/C8/RHO                                                     SUP74590
      XP = X                                                            SUP74600
      IF(NS.EQ.2) XP = X - X3                                           SUP74610
      PXY = 1.0                                                         SUP74620
      DO 10 N = 2,28                                                    SUP74630
   10 PXY(N) = 0.0                                                      SUP74640
      TM = NTMAX(NS)                                                    SUP74650
      ID = SQRT(2.0*TM) - 0.5                                           SUP74660
      IF(ID.EQ.0) GO TO 60                                              SUP74670
      K = 1                                                             SUP74680
      IF(XP.EQ.0.0) GO TO 40                                            SUP74690
      YX = Y/XP                                                         SUP74700
      PX = XP                                                           SUP74710
      DO 30 N = 1,ID                                                    SUP74720
      K = K + 1                                                         SUP74730
      PXY(K) = PX                                                       SUP74740
      DO 20 M = 1,N                                                     SUP74750
      K = K + 1                                                         SUP74760
   20 PXY(K) = PXY(K-1)*YX                                              SUP74770
   30 PX = PX*XP                                                        SUP74780
      GO TO 60                                                          SUP74790
   40 PX = 1.0                                                          SUP74800
      DO 50 N = 1,ID                                                    SUP74810
      PXY(K) = PX                                                       SUP74820
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      K = K + N + 1                                                     SUP74830
   50 PX = PX*Y                                                         SUP74840
   60 NTM = NT(MODE,NS)                                                 SUP74850
      Z = CO(MODE,1,NS)                                                 SUP74860
      DZ = 0.0                                                          SUP74870
      IF(NTM.EQ.1) GO TO 80                                             SUP74880
      DO 70 K = 2,NTM                                                   SUP74890
      Z = Z + PXY(K)*CO(MODE,K,NS)                                      SUP74900
      KK = KL(K)                                                        SUP74910
   70 DZ = DZ + PXY(KK)*CO(MODE,K,NS)*FN(K)                             SUP74920
   80 SS(NB) = U*CMPLX(DZ,EK*Z)                                         SUP74930
      RETURN                                                            SUP74940
      END                                                               SUP74950
$      FORTRAN NLSTOU,DECK                                              SUP74960
CPOUT          POUT                                                     SUP74980
      SUBROUTINE POUT(IND)                                              SUP74990
      COMPLEX CZERO,VPIC,SS,DQ,Q,PHIW,SPHI,PHI,PHITE,DPHI               SUP75000
      DIMENSION CARDS (25,50)                                           ********
      DIMENSION SW(5,6),SURF(2,3),COD(7),C(50)                          SUP75010
      COMMON/C1/KBOX(2000),XE(5),YE(3),AR(3),X1,X2,X3,X4,Y1,Y2,BETA,NBS SUP75020
      COMMON/C2/AS,HMACH,FMACH(6),NFREQ,FREQ(10),NMODE,NSURF,LVPIC,LSSVPSUP75030
      COMMON/C3/CO(10,28,2),NT(10,2),NF(10,2),NTMAX(2),PXY(28),FN(28)   SUP75040
      COMMON/C4/VPIC(1275),SS(2000),DQ(28,2),Q(10,10,3),PHIW(50),SPHI   SUP75050
      COMMON/C5/MOB(50),NBL(50),KC(50),KL(28),BSL(20),DXE(7),IPI,U      SUP75060
      COMMON/C6/X,Y,DX,DY,EM,EK,EKB,EKR,NP,MP,NB,NBOX,KODE,MODE,NBW,NBT SUP75070
      COMMON/C7/CZERO,PHI,PHITE,DPHI,XL,NS,NTM,K,J,QR,QI,QAB,QAN,IFR,TWLSUP75080
      COMMON/C8/RHO                                                     SUP75090
      DATA (SW(1,I),I=1,6)/26HMAP OF MACH BOX OVERLAY ON,               SUP75100
     1                     26HWING, TAIL, AND DIAPHRAGM ,               SUP75110
     2                     26H         (S) - WING       ,               SUP75120
     3                     26H         ($) - TAIL       ,               SUP75130
     4                     26H         (,) - WAKE       ,               SUP75140
     5                     26H         (.) - DIAPHRAGM  /               SUP75150
      DATA (SURF(1,I),I=1,3)/8HWING    ,8HTAIL    ,11HWING + TAIL /     SUP75160
      DATA COD/1HS,1H$,1HS,1H$,1H$,1H,,1H./                             SUP75170
      GO TO (10 ,20 ,30 ,40 ,50 ,60 ,70 ),IND                           SUP75180
   10 WRITE(6,11)FM,AS,RHO,XE(1),XE(4),X1,X4,Y1,Y2,Y2,Y2,X2,X4,AR(1),   SUP75190
     1 AR(2),NBW,NBT,NBS,NBS                                            SUP75200
   11 FORMAT(1H1/////30X,43HNAC/NAA MISSILE SUPERSONIC AIRLOADS PROGRAMSUP75210
     1 ///37X,30HFLIGHT CONDITIONS AND GEOMETRY/1H0//15X, 13HMACH NUMBERSUP75220
     2 =,F8.5,4X,16HSPEED OF SOUND =F10.3,4H L/T,4X,4HRHO=,E14.8//1H0/  SUP75230
     X54X,4HWING,18X,                                                   SUP75240
     3 4HTAIL///22X,16HL.E. STATION (L),2F22.3//22X,16HROOT CHORD   (L),SUP75250
     4 2F22.3// 22X,16HL.E. SPAN    (L),2F22.3//22X,16HT.E. SPAN    (L),SUP75260
     5 2F22.3// 22X,16HTIP CHORD    (L),2F22.3//22X,16HTOTAL AREA (L*L),SUP75270
     6 2F22.3// 22X,16HCHORDWISE BOXES ,I19,I22//22X,                   SUP75280
     /16HSPANWISE BOXES  ,I19,I22)                                      SUP75290
      WRITE(6,12)NBOX,DX,DY                                             SUP75300
   12 FORMAT(1H0/,11X,23HTOTAL CHORDWISE BOXES =,I3, 5X,11HBOX CHORD =, SUP75310
     1 1P1E12.5,2H L, 5X,10HBOX SPAN =,1P1E12.5,2H L/    )              SUP75320
      WRITE(6,91)                                                       SUP75330
      NB = 1                                                            SUP75340
      DO 17 NP = 1,NBOX                                                 SUP75350
      MB = MOB(NP)                                                      SUP75360
      IF(MB.GT.50)  GO TO 800                                           SUP75370
      DO 13 MP = 1,MB                                                   SUP75380
      K = KBOX(NB)                                                      SUP75390
      C(MP) = COD(K)                                                    SUP75400
   13 NB = NB + 1                                                       SUP75410
      IF(NP.GT.6) GO TO 15                                              SUP75420
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      WRITE(6,14)(SH(I,NP),I=1,5),(C(MP),MP=1,MB)                       SUP75430
   14 FORMAT(10X,5A6,50A1)                                              SUP75440
      GO TO 17                                                          SUP75450
   15 WRITE(6,16) (C(MP),MP=1,MB)                                       SUP75460
   16 FORMAT(40X,50A1)                                                  SUP75470
   17 CONTINUE                                                          SUP75480
      GO TO 1000                                                        SUP75485
  800 WRITE(6,801)                                                      SUP75490
  801 FORMAT(9X,52HWHEN MOB EXCEEDS 50 THE MAP PRINTING IS DISCONTINUED SUP75500
     1//1H0,48H          CALCULATIONS PROCEED IN NORMAL MANNER      )   SUP75510
      GO TO 1000                                                        SUP75520
   20 WRITE(6,51)FREQ(IFR),NBOX,EKR   ,EM                               SUP75530
      WRITE(6,21)EM,EKB                                                 SUP75540
   21 FORMAT(1H ,28X,48HPLANAR VELOCITY POTENTIAL INFLUENCE COEFFICIENTSSUP75550
     1 /1H0,30X,10HMACH NO. =,F8.5,10X, 6HKBAR =,F9.5/1H0,13X,1HI,5X,1HJSUP75560
     2 10X,5HNUBAR,5X,5HMUBAR,11X,14HREAL VPIC(I,J),8X,14HIMAG VPIC(I,J)SUP75570
     3 /1H )                                                            SUP75580
      K = 0                                                             SUP75590
      DO 22 I = 1,NBOX                                                  SUP75600
      DO 22 J = 1,I                                                     SUP75610
      BARNU = I - 1                                                     SUP75620
      BARMU = J - 1                                                     SUP75630
      K=K+1                                                             SUP75640
   22 WRITE(6,23) I,J,BARNU,BARMU,VPIC(K)                               SUP75650
   23 FORMAT(9X,2I6,4X,2F10.1,2X,1P2E22.5)                              SUP75660
      GO TO 1000                                                        SUP75670
   30 WRITE(6,51) FREQ(IFR),NBOX,EKR   ,EM                              SUP75680
      WRITE(6,31)MODE                                                   SUP75690
   31 FORMAT(1H ,21X,  59HUPPER VELOCITY POTENTIALS AND SOURCE STRENGTHSSUP75700
     1 FOR MODE NO.I3/1H0,9X,1HN,6X,1HM,5X,2HNB,7X,10HR PHI(N,M),7X,10HISUP75710
     2 PHI(N,M)10X,9HR SS(N,M),8X,9HI SS(N,M)/1H )                      SUP75720
      GO TO 1000                                                        SUP75730
   40 WRITE(6,41)NP,MP,NB,PHI,SS(NB)                                    SUP75740
   41 FORMAT(4X,3I7,1P2E17.5,3X,1P2E17.5)                               SUP75750
      GO TO 1000                                                        SUP75760
   60 IF(NS.EQ.3) GO TO 100                                             SUP75770
   50 WRITE(6,51)FREQ(IFR),NBOX,EKR   ,EM                               SUP75780
   51 FORMAT(1H1,33X,44HMISSILE SUPERSONIC AIRLOADS PROGRAM (CONT-D)//  SUP75790
     X1H0                                                               SUP75800
     1 8X,27HOSCILLATORY FREQUENCY (CPS),F12.5,14X,I2,25H BOXES IN CHORDSUP75810
     2 DIRECTION /1H0,8X,30HREDUCED FREQUENCY (SEMI CHORD),F9.5,14X,    SUP75820
     3 23HFREE STREAM MACH NUMBER,F9.3,/1H )                            SUP75830
      WRITE(6,101) SURF(1,NS)                                           SUP75840
  101 FORMAT(28X,45HINPUT MODE SHAPE POLYNOMIAL COEFFICIENTS FOR ,A6/   SUP75850
     1 22X,62HREFERENCED TO THE SURFACE LEADING EDGE-CENTERLINE INTERSECSUP75860
     2TION //2X,4HMODE,20X, 7HCOEFFS.)                                  SUP75870
      DO 102 I=1,NMODE                                                  SUP75880
      NTM=NT(I,NS)                                                      SUP75890
  102 WRITE(6,103) I,(CO(I,J,NS),J=1,NTM)                               SUP75900
  103 FORMAT(1H0,I4,4X,1P7E13.4/(9X,1P7E13.4))                          SUP75910
  100 WRITE(6,51)FREQ(IFR),NBOX,EKR   ,EM                               SUP75920
      WRITE(6,61)(SURF(I,NS),I=1,2)                                     SUP75930
   61 FORMAT(1H ,35X,23HGENERALIZED FORCES FOR ,2A6/1H0,6X,4HDEFL,3X,   SUP75940
     1 4HLOAD,10X,9HREAL PART,10X,9HIMAG PART,10X,9HABS VALUE,10X,      SUP75950
     2 11HPHASE ANGLE //)                                               SUP75960
      GO TO 1000                                                        SUP75970
   70 WRITE(6,71)J,K,QR,QI,QAB,QAN                                      SUP75980
      IF (NSURF .EQ. 1) GO TO 632
      IF (NS.NE.3) GO TO 1000                                           ********
  632 KKK=2*NMODE
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      NNN=2*K                                                          ********
      NNNN=NNN-1                                                       ********
      CARDS(J,NNNN)=QR                                                 ********
      CARDS(J,NNN)=QI                                                  ********
      IF (J.NE.NMODE) GO TO 1000                                       ********
      IF (K.NE.NMODE) GO TO 1000                                       ********
      PUNCH 6969, ((CARDS(II,JJ),JJ=1,KKK), II=1,NMODE)                ********
 6969 FORMAT(6E12.5)                                                   ********
   71 FORMAT(1H0,I9,I7,2X,1P3E19.5,0PF16.3,4H DEG)                     SUP75990
   91 FORMAT(1H1,30X,44HMISSILE SUPERSONIC AIRLOADS PROGRAM (CONT-D)//) SUP76000
 1000 RETURN                                                           SUP76010
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