DOCUMENT NO. 67SD4428

NASA Contract NAS2-4063
Grumman Aircraft Engineering Corp.
Purchase Order to General Electric # PO 5-13492

FINAL REPORT, PART 2
STABILITY CRITERIA FOR THE OAO COARSE POINTING MODE

BY

SAMUEL E. MOSKOWITZ

NOVEMBER 1967

GENERAL ELECTRIC

SPACECRAFT DEPARTMENT

A Department of the Missile and Space Division

Valley Forge Space Technology Center

P. O. Box 8555 • Philadelphia, Penna. 19101

TABLE OF CONTENTS

Section		Page
1	INTRODUCTION	1-1
2	COMPUTING SYSTEM REQUIREMENTS	2-1
3	GENERALIZED LOGIC FLOW	3-1
4	DESCRIPTION OF INPUT VARIABLES	4-1
5	SAMPLE INPUT	5-1
6	DECK SETUP	6-1
7	SAMPLE OUTPUT	7-1
8	PROGRAM LISTING	8-1
APPENDIX A.	EQUATION REFERENCES	A-1

LIST OF ILLUSTRATIONS

Figure		Page
3-1	Main Program	3-2
	Main Program (contd)	3-3
3-2	TASK3 Subroutine	3-4
	TASK3 Subroutine (contd)	3-5
3-3	TASK4 Subroutine	3-6
6-1	Deck Setup	6-1

SECTION 1

INTRODUCTION

This document describes a computer program written to assist in the analysis of the Stability Criteria for the OAO Coarse Pointing Mode. The program was originally constructed in two independent segments which were then consolidated into the final version identified here.

The computer language utilized is FORTRAN IV. The computer used was the GE 635, although any other computer offering the standard FORTRAN IV language may be used.

SECTION 2

COMPUTING SYSTEM REQUIREMENTS

HARDWARE

IBM 7090/7094 Data Processing System

or

GE 625/635 Data Processing System

SOFTWARE

IBM 7090/7094 IBSYS Operating System
FORTRAN IV Language

or

GE 625/635 GECOS Operating System
FORTRAN IV Language

SECTION 3

GENERALIZED LOGIC FLOW

The following flow diagrams identify the overall calculation sequence of the program. The numbers to the right of the various boxes identify the corresponding equations which are being solved from Part 1 of the Final Report.

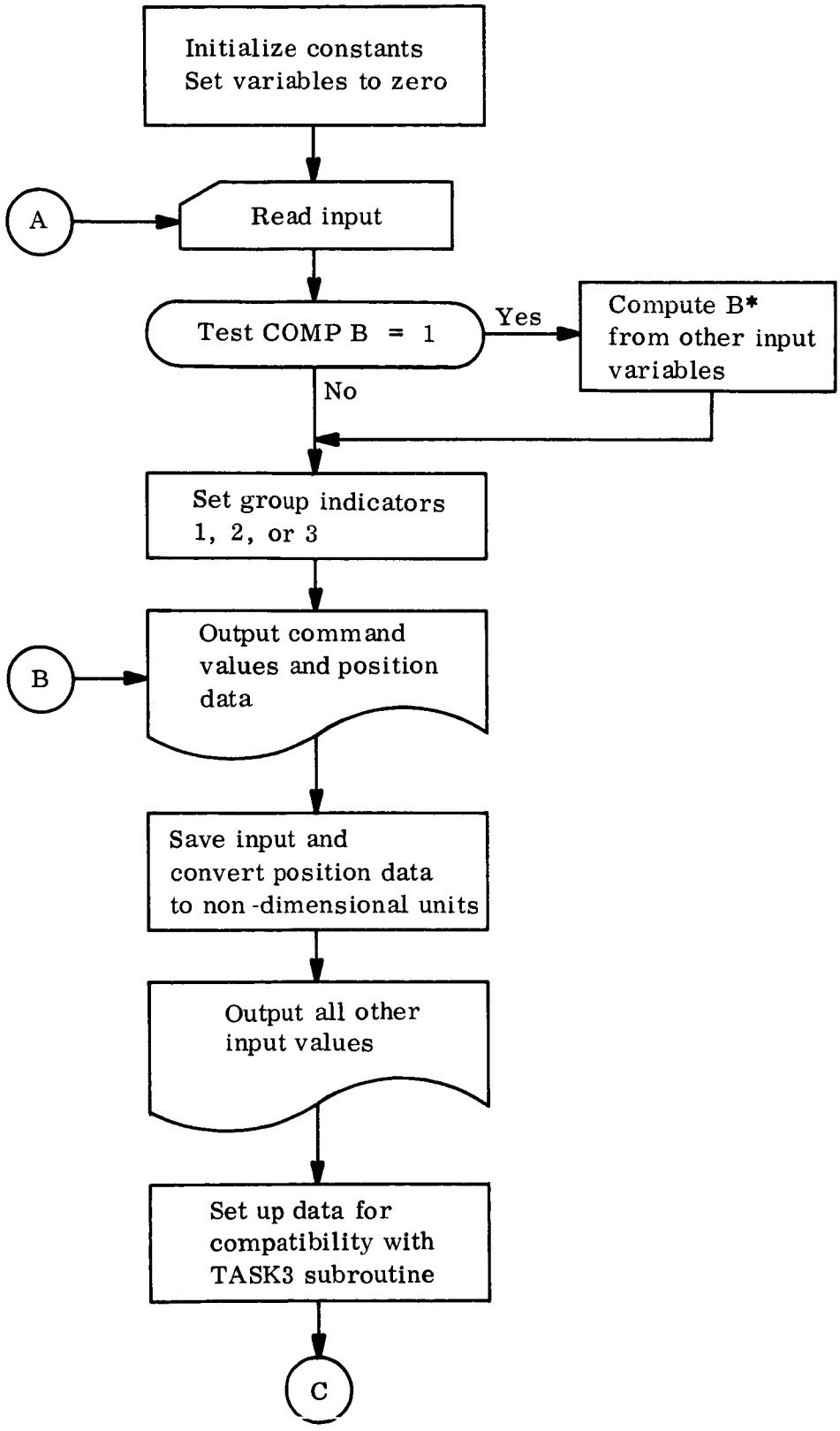


Figure 3-1. Main Program

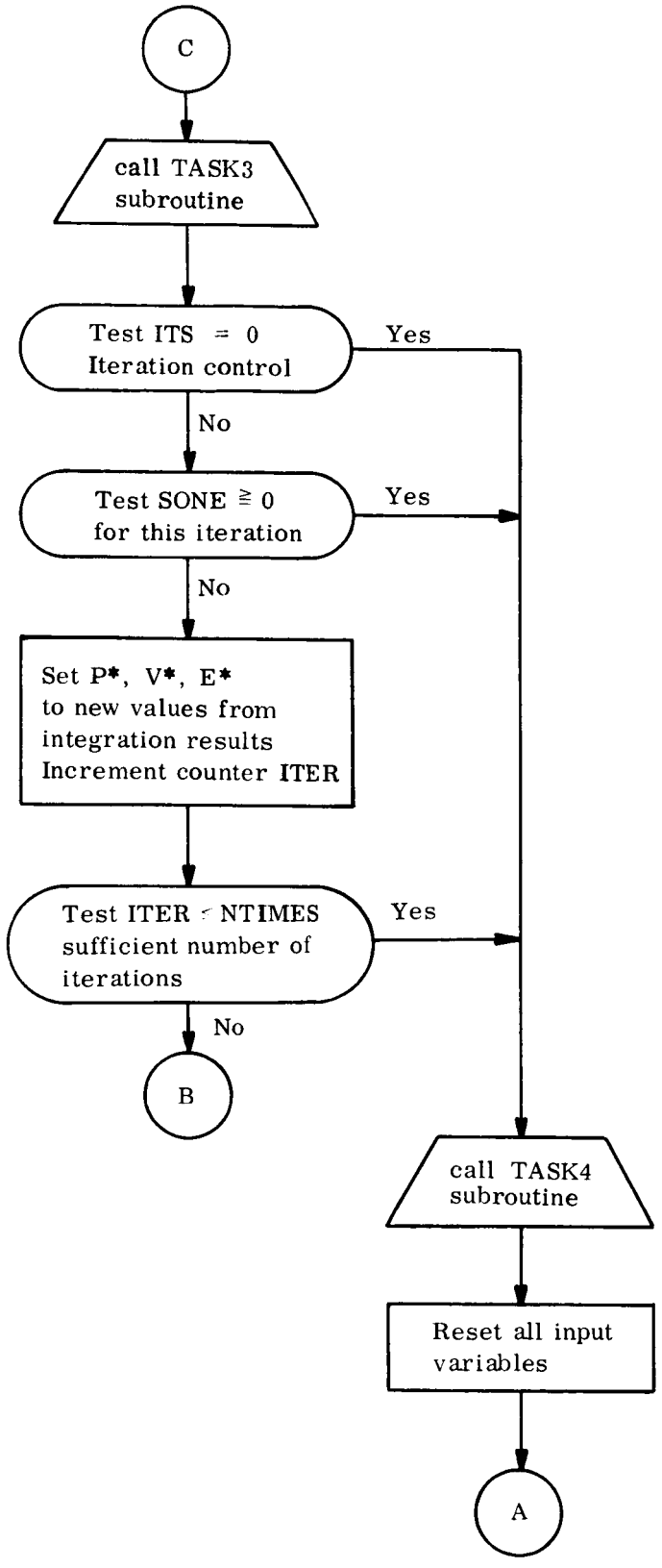
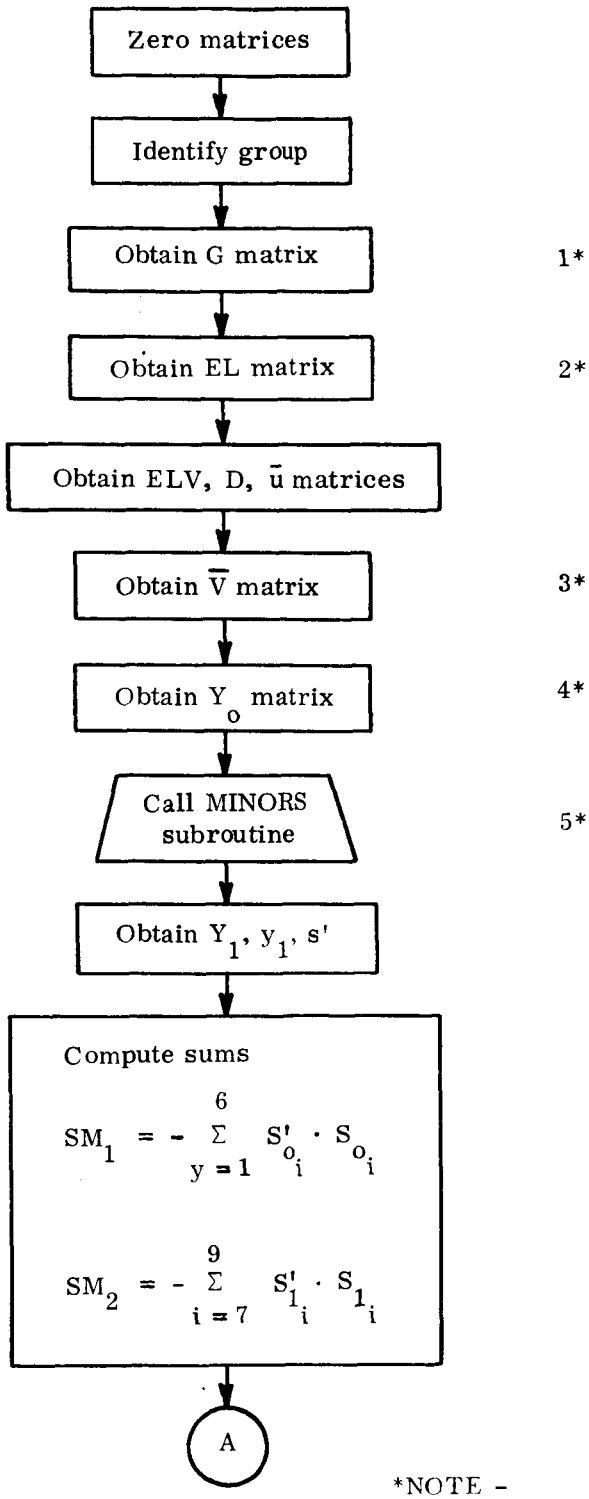


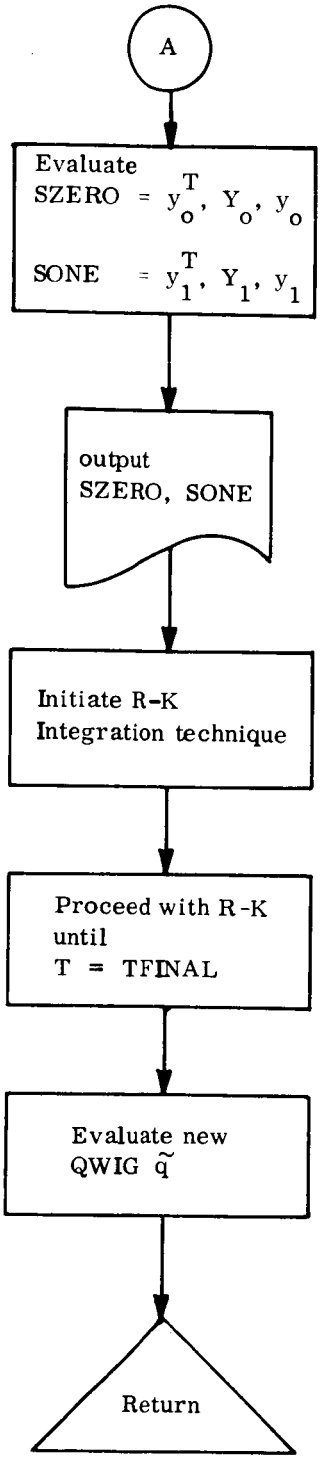
Figure 3-1. Main Program (contd)



*NOTE -

See Appendix A for equation reference.

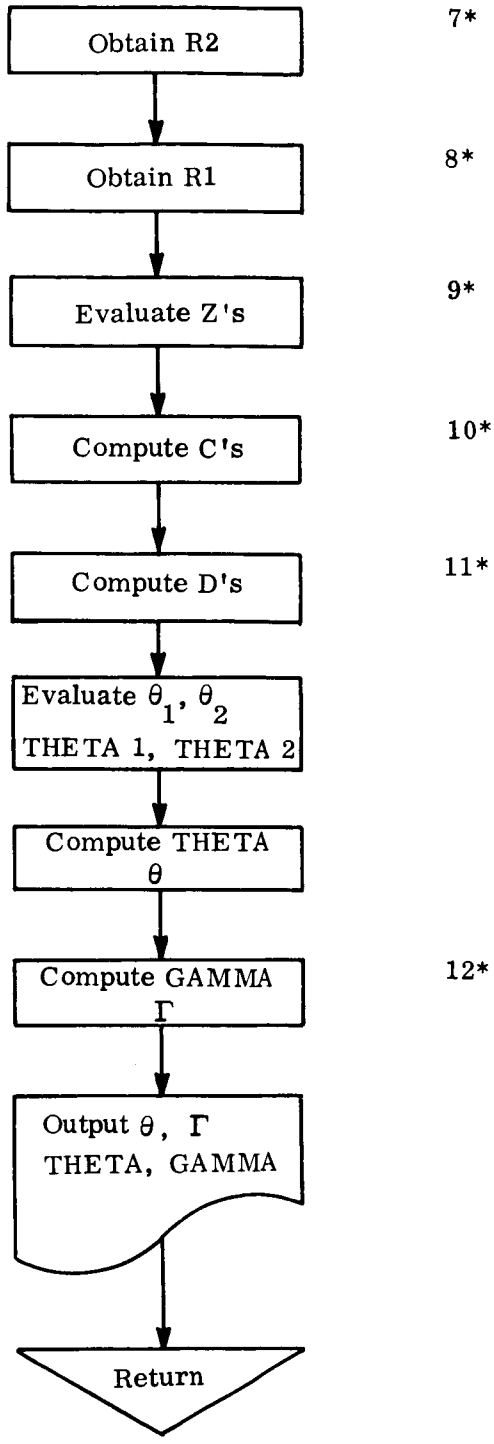
Figure 3-2. TASK3 Subroutine



6*

*Note
see Appendix A
for equation
reference

Figure 3-2. TASK3 Subroutine (contd)



*NOTE

See Appendix A
for equation reference

Figure 3-3. TASK4 Subroutine

SECTION 4

DESCRIPTION OF INPUT VARIABLES

Variable Name	Symbol	Used by	Definition
ZSTDY(10)	Z_s	MAIN TASK4	The steady-state position vector $\begin{pmatrix} o \\ V_s \\ b_s \end{pmatrix} = Z_s$
ES(3)	e_s	TASK3	as
P(3)	p_s	TASK3	amps
V(3)	V_s	TASK3	volts
B(4)	b	MAIN	The angles $\beta_{J_e}, \beta_{K_e}, \gamma_{J_e}, \gamma_{K_e}$ where J and K are the following pairs 1, 3 3, 5 4, 6
DEL1, DEL3 DEL4, DEL5, DEL6	δ	TASK3	controls for the chosen pair e.g., (3, 5) DEL3 = DEL5 = 1.0 all others = 0.0
COMVAL(4)			command values COMVAL (1)= β_{c1} (groupI) β_{c3} (groupII) β_{c4} (groupIII) (2) β_{c3} β_{c5} β_{c6} (3) γ_{c1} γ_{c3} γ_{c4} (4) γ_{c3} γ_{c5} γ_{c6}
RHO	ρ	TASK3	constant
KAP2, KAP3, KAP4, KAP5, KAP7, KAP8	$\kappa_2 \ldots$	TASK3	constants
NU	ν	TASK3	parameter
NORMK	/k/	MAIN TASK3	parameter
D1(3)	D_1	TASK3	parameters D_1 = DIAG of a (3x3) matrix
XI(6)	$X_{i,\, i=1,6}$	TASK3	parameters
SCALE		TASK3	scale factor usually 1.0
COMPB		MAIN	control for decision to input or compute $\beta_{Kc}, \gamma_{Jc}, \gamma_{Kc}$ where J, K are one of the pairs (1, 3), (3, 5), (4, 6)
TFINAL		TASK3	upper limit of integration
DT		TASK3	increment of integration
NTIMES		MAIN	The loop through TASK3 and the R-K integration will terminate if either of the following conditions are met: 1) - NTIMES - a maximum number of iteration desired. 2) - The small gimbal angle error SONE is positive

SECTION 5

SAMPLE INPUT

A listing of the data cards for a sample case follows. All data input is accomplished by using the NAMELIST feature.

```
$INPUT          ESTAR= 20.. 2*7.9894015.
   COMVAL= -35.. 40.. 25.. 40..
RHO = 1500.0.
KAP2 = 5.370E5.   KAP3 = 2.685E6.   KAP4 = -2.0.    KAP5 = 1.002E-3.
KAP7 = 8.681E-6.  KAP8 = 26.0.
XI (1) = 1.50772733E3.1.50772733E3.7.53863663E2.4.74363958E4.
XI(5)= 4.74363958E4.9.48727915E4.
 NU=2.0.
  SCALE=1.0.
NORMK= 1.73205081.
D1 = 2*1.00819723E5.5.04101114E4.
 ZSTDY= 3*0.. 3*10.4. 21.0. 11.2378224.-6.957219506.   19.2987772.
ES=     3*7.98940149.
 P=3*0.. V=3*10.4. B=21.. 3*0..
  DEL1=1..  DEL3=1..
TFINAL=0.130215.  DT= .130215E-3.   NTIMES=1.
 COMPB=1..      $
```

SECTION 6

DECK SETUP
(GE 625/635)

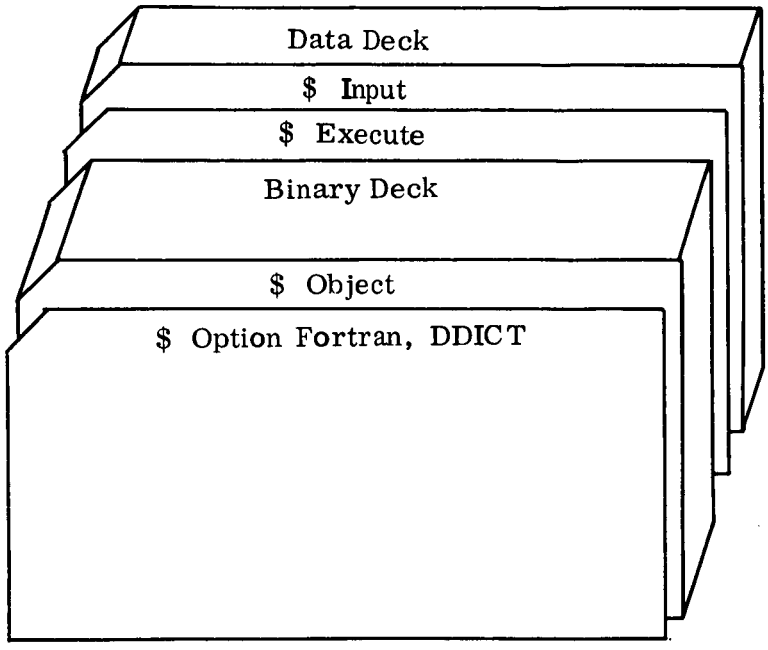


Figure 6-1. Deck Setup

SECTION 7

SAMPLE OUTPUT

```
NAMELIST    INPUT
ZSTDY (I)
     1   0.                0.                0.                1.0400000E 01   1.0400000E 01   1.0400000E 01
     7   2.1000000E 01     1.1237822E 01    -6.9572195E 00     1.9298777E 01
ES     (I)
     1   7.9894015E 00     7.9894015E 00     7.9894015E 00
P      (I)
     1   0.                0.                0.
V      (I)
     1   1.0400000E 01     1.0400000E 01     1.0400000E 01
B      (I)
     1   2.1000000E 01     0.                0.                0.
ESTAR (I)
     1   0.                0.               -2.0000000E 01
DEL1     1.0000000E 00        DEL3     1.0000000E 00        DEL4     0.                   DEL5     0.
DEL6     0.
COMVAL(I)
     1  -3.5000000E 01     4.0000000E 01     2.5000000E 01     4.0000000E 01
RHO      1.5000000E 03        KAP2     5.3700000E 05        KAP3     2.6850000E 06        KAP4    -2.0000000E 00
KAP5     1.0020000E-03        KAP7     8.6810001E-06        KAP8     2.6000000E 01        NU       2.0000000E 00
NORMK    1.7320508E 00
D1     (I)
     1   1.0081972E 05     1.0081972E 05     5.0410111E 04
XI     (I)
     1   1.5077273E 03     1.5077273E 03     7.5386366E 02     4.7436396E 04   4.7436396E 04   9.4872791E 04
SCALE    1.0000000E 00        COMAND   0.                   COMPB    1.0000000E 00        TFINAL   1.3021500E-01
DT       1.3021500E-03
NTIMES              1
END   NAMELIST    INPUT

 COMMAND VALUES   DEGREES

BETA C1 =-35.00000000    BETA C3 = 40.00000000 GAMMA C1 = 25.00000000    GAMMA C3 = 40.00000000

          P STAR              V STAR              B STAR              E STAR
           AMPS                VOLTS                AM                  AS

        0.                  0.10400000E 02      0.21000000E 02      0.                  BETA E1
        0.                  0.10400000E 02      0.11585469E 02      0.                  BETA E3
        0.                  0.10400000E 02     -0.74469957E 01     -0.20000000E 02      GAMMA E1
                                                0.18365799E 02                           GAMMA E3

        P STEADY            V STEADY            B STEADY            E STEADY
           AMPS                VOLTS                AM                  AS

        0.                  0.10400000E 02      0.21000000E 02      0.79894015E 01      BETA E1
        0.                  0.10400000E 02      0.11237822E 02      0.79894015E 01      BETA E3
        0.                  0.10400000E 02     -0.69572194E 01      0.79894015E 01      GAMMA E1
                                                0.19298777E 02                           GAMMA E3

 RHO =  0.15000000E 04

 KAP2 =  0.53700000E 06   KAP3 =  0.26850000E 07   KAP4 = -0.20000000E 01

 KAP5 =  0.10020000E-02   KAP7 =  0.86810001E-05   KAP8 =  0.26000000E 02

 NU =  0.20000000E 01     NORM K=  0.17320508E 01  SCALE =  0.10000000E 01

                                                  DIAG H0
  0.15077273E 04  0.15077273E 04  0.75386366E 03  0.47436396E 05  0.47436396E 05  0.94872791E 05

                                                  DIAG D1
  0.10081972E 06  0.10081972E 06  0.50410111E 05


                              STABILITY CRITERIA

 SMALL GIMBAL ANGLE ERRORS
       S ZERO    0.19628469E 04      SONE     0.42427670E-09


 LARGE GIMBAL ANGLE ERRORS
       CAP LAMBDA    0.10403944E-08      CAP GAMMA    -0.17751959E-18
```

SECTION 8

PROGRAM LISTING

```
$       FORTRAN DECK,STAB
CTASK2
      DIMENSION OUT(13)
       DIMENSION SAVES(13), SAVEP(10), SAVE(3)
      COMMON/BLK/DZERO(6,6), JZERO(6,6), QWIG(9), IT3,TFINAL,DT
      COMMON/BLK1/
     1        Z(10,10,10),ZK(10),R(13),ZSTDY(10),
     2        C(13,13,13),D(13,13)
     3,DEL1,DEL3,DEL4,DEL5,DEL6,DTR,COMVAL(4)

      COMMON/BLK2/SONE,SZERO
      COMMON /INPT/RHO,KAP2,KAP3,KAP4,KAP5,KAP7,KAP8,
     1NU,NORMK,D1(3),GROUP,GAM(6),BETA(6),XI(6),SCALE
      COMMON /INPTN/ PSTAR(3),VSTAR(3),ESTAR(3),PS(3),VS(3),ES(3)

      DIMENSION PSI(6),HZERO(6,6),TEMP(6,6),TEMP1(6,6),SUMM(6,6)

      DIMENSION R2(10),P(3),V(3),B(4)
      DIMENSION HOLGM(5), HOLB(5)
      REAL KAP2,KAP3,KAP4,KAP5,KAP7,KAP8,NU,NORMK
      REAL JZERO

      EQUIVALENCE (ZK,P),(ZK(4),V),(ZK(7),B),(R2,R(4))
      DATA HOLGM/2HC1,2HC3,2HC4,2HC5,2HC6/,
     1HOLB/2HE1,2HE3,2HE4,2HE5,2HE6/
C*****        INPUT COMMAND VALUES IN COMVAL
```

```
      NAMELIST/INPUT/ZSTDY,ES,P,V,B,ESTAR,DEL1,DEL3,DEL4,DEL5,DEL6,
     1COMVAL, RHO, KAP2,KAP3,KAP4,KAP5,KAP7,KAP8,NU,NORMK,D1,XI,SCALE
     2,COMPB
     2     ,TFINAL,DT, NTIMES
C     INITIALIZE
      DTR = .017453292
      DO 5 I = 1,6
      GAM(I) = 0.0
    5 BETA(I) = 0.0
      DO 9 I = 1,3
      ES(I)=0.
      P(I)=0.
      V(I)=0.
      B(I)=0.
    9 ZSTDY(I) = 0.
      B(10)=0.
    1 DEL1=0.
      DEL3=0.
      DEL4=0.
      DEL5=0.
      DEL6=0.
      IT3=0
      ITER=0
      READ (5,INPUT)
      WRITE(6,1000)
      WRITE(6,INPUT)
      DO  10    I=1,10
```

```
   10 SAVES(I)= ZSTDY(I)
      IF( COMPB.EQ.1.)  CALL COMP
      DO  101    I=1,3
      SAVE(I)= ESTAR(I)
      SAVES(I+10)= ES(I)
      SAVEP(I)= P(I)
      SAVEP(I+3)= V(I)
  101 SAVEP(I+6)= B(I)
      SAVEP(10)= B(4)
      WRITE(6,1000)
      IF (DEL1.NE.1.)     GO TO 11
C     GROUP = 1(SETS1+3)
      IX=1
      IY=2
      GROUP=1.
   11 IF(DEL5.NE.1.)      GO TO 12
C     GROUP = 2(SETS3+5)
      IX=2
      IY=4
      GROUP=2.
   12 IF( DEL4.NE.1.)     GO TO 14
C     GROUP = 3(SETS4+6)
      IX=3
      IY=5
      GROUP=3.
   14 WRITE(6,1004) HOLGM(IX), COMVAL(1), HOLGM(IY), COMVAL(2),
     1                HOLGM(IX), COMVAL(3), HOLGM(IY), COMVAL(4)
```

```
C****     CONVERT DATA TO NON-DIMENSIONAL UNITS AND SAVE INPUT
      PX=44.76462
      VX=26.
      BX=3437.74677
      DO  16   I=1,3
      OUT(I)= P(I)
      P(I)= P(I)/PX
      OUT(I+3)= V(I)
      V(I)=V(I)/VX
      OUT(I+6)= B(I)
      B(I)= B(I)/BX
      OUT(I+10)= ESTAR(I)
   16 ESTAR(I) = ESTAR(I)*4.8481361E-6
      OUT(10)=B(4)
      B(4)= B(4)/BX
   17 WRITE (6,1001)
      WRITE(6,1016)
      WRITE(6,1014) OUT(1), OUT(4), OUT(7), OUT(11),HOLB(IX), OUT(2),
     1 OUT(5), OUT(8), OUT(12),HOLB(IY), OUT(3), OUT(6), OUT(9),OUT(13),
     2HOLB(IX), OUT(10),HOLB(IY)
      DO  18   I=1,3
      OUT(I)=ZSTDY(I)
      ZSTDY(I)=ZSTDY(I)/PX
      OUT(I+3)= ZSTDY(I+3)
      ZSTDY(I+3)=ZSTDY(I+3)/VX
      OUT(I+6)=ZSTDY(I+6)
      ZSTDY(I+6)=ZSTDY(I+6)/BX
```

```
      OUT(I+10)= ES(I)
   18 ES(I) = ES(I)*4.8481361E-6
      OUT(10)= ZSTDY(10)
      ZSTDY(10)=ZSTDY(10)/BX
      WRITE (6,1002)
      WRITE(6,1016)
      WRITE(6,1014) OUT(1), OUT(4), OUT(7), OUT(11),HOLB(IX), OUT(2),
     1 OUT(5), OUT(8), OUT(12),HOLB(IY), OUT(3), OUT(6), OUT(9),OUT(13),
     2HOLB(IX), OUT(10),HOLB(IY)
   19 WRITE(6,1005) RHO,KAP2, KAP3, KAP4, KAP5, KAP7, KAP8, NU,NORMK,
     1SCALE
C*****     SET UP INPUT DATA FOR TASKIII
      DO  20    I=1,3
      PSTAR(I)=P(I)
      VSTAR(I)= V(I)
      PS(I)= ZSTDY(I)
   20 VS(I)= ZSTDY(I+3)
      IF (GROUP-2.) 22,24,26
   22 BETA(1)= COMVAL(1)*DTR
      BETA(3)= COMVAL(2)*DTR
      GAM(1)= COMVAL(3)*DTR
      GAM(3)=COMVAL(4)*DTR
      GO TO 28
   24 BETA(3)= COMVAL(1)*DTR
      BETA(5)= COMVAL(2)*DTR
      GAM(3) = COMVAL(3)*DTR
      GAM(5) = COMVAL(4)*DTR
```

```
      GO TO 28
26    BETA(4)= COMVAL(1)*DTR
      BETA(6)= COMVAL(2)*DTR
      GAM(4) = COMVAL(3)*DTR
      GAM(6) = COMVAL(4)*DTR
 28   N=6
      DO  29  I=1,N
      DO   29   J=1,N
      JZERO(I,J)=0.
      HZERO(I,J)=0.
 29   DZERO(I,J)=0.
      PX= KAP4/(RHO*KAP7)
      DO 30 I = 1,3
      JZERO(I,I) = PX
 30   JZERO(I+3,I+3) = -1.0

      DO 40 I = 1,3
      PSI(I) = -0.5*XI(I)/PX
 40   PSI(I+3) = 0.5*XI(I+3)

      DO 50 I = 1,N
      HZERO(I,I) = XI(I)
 50   DZERO(I,I) = PSI(I)
      WRITE(6,1006) (HZERO(I,I),I=1,N)
      WRITE(6,1007) (D1(I),I=1,3)

      CALL MTMPY(0,JZERO,DZERO,TEMP,-6,6,6,6,6)
```

```
      CALL MTMPY(0.DZERO.JZERO.TEMP1.6.6.6.6.6)
      DO 60 I = 1.N
      DO 60 J = 1.N
   60 SUMM(I.J) = TEMP(I.J)+TEMP1(I.J)

      CALL TASK3
      IF( IT3.EQ.0)  GO TO 90
      IF (SONE.GE.0.)  GO TO 90
C*****   OUTPUT FOR TASKIII
      DO   70   I=1.3
      V(I)= QWIG(I)+VS(I)
      OUT(I+3)= V(I)*VX
      P(I)= QWIG(I+3) +PS(I)
      OUT(I)= P(I)*PX
      ESTAR(I)= QWIG(I+6)+ ES(I)
      OUT(I+10)= ESTAR(I)/4.8481361E-6
      ES(I)= SAVES(I+10)
   70 B(I)= SAVEP(I+6)
      B(4)= SAVEP(10)
      DO   75    I=1.10
   75 ZSTDY(I)= SAVES(I)
      ITER= ITER+1
      IF (ITER.GT. NTIMES)  GO TO 90
      WRITE(6.1000)
      GO TO 17

   90 CALL TASK4
```

```
 105 DO    110    I=1,10
 110 ZSTDY(I)= SAVES(I)
     DO    111    I=1,3
     P(I)= SAVEP(I)
     V(I)= SAVEP(I+3)
     B(I)= SAVEP(I+6)
     ESTAR(I)= SAVE(I)
 111 ES(I)= SAVES(I+10)
     B(4)= SAVEP(10)
1000 FORMAT(1H1)
1001 FORMAT (1H0,9X,6HP STAR,13X,6HV STAR,14X,6HB STAR,14X,6HE STAR/)
1002 FORMAT (1H0,6X,8HP STEADY,12X,8HV STEADY,12X,8HB STEADY,12X,8HE ST
    1EADY/)
1004 FORMAT (1H0,     14HCOMMAND VALUES   ,3X, 7HDEGREES/
    1                                                          /5HBETA
    2A2,2H = F12.8, 4X, 5HBETA A2,2H =F12.3,
    3 7H GAMMA A2,2H = F12.8, 4X, 6HGAMMA A2,2H = F12.8//)
1005 FORMAT(6H0RHO =E16.8/7H0KAP2 =E16.8,3X,6HKAP3 =E16.8,3X,6HKAP4 =
    1E16.8/7H0KAP5 =E16.8,3X,6HKAP7 =E16.8,3X,6HKAP8 =E16.8/5H0NU =
    2E16.8,5X,7HNORM K= E16.8,2X,7HSCALE = E16.8/)
1006 FORMAT(1H0,47X,7HDIAG H0/6(E16.8))
1007 FORMAT(1H0,47X,7HDIAG D1/3(E16.8))
1014 FORMAT(1H0,4E20.8,3X, 5HBETA A2/ 1X,4E20.8,3X,5HBETA A2/
    1 1X,4E20.8,3X,6HGAMMA A2/ 41X,E20.8,23X6HGAMMA A2/)
1016 FORMAT(1H ,10X,4HAMPS,14X,5HVOLTS,16X,2HAM,16X,2HAS//)
     GO TO 1
     END
```

```
$       FORTRAN DECK,STAB
CTASK3
      SUBROUTINE TASK3

      COMMON/BLK/DZERO(6,6), JZERO(6,6), QWIG,IT3, TFINAL,DT
      COMMON/BLK2/SONE,SZERO
      COMMON/BLK3/ DDEP(9), SDEP(9), TEMP2
      COMMON/BLK4/EL, GWIG, BBAR
      COMMON /INPT/RHO,KAP2,KAP3,KAP4,KAP5,KAP7,KAP8,
     1NU,NORMK,D1(3),GROUP,GAM(6),BETA(6),XI(6),SCALE
      COMMON /INPTN/ PSTAR(3),VSTAR(3),ESTAR(3),PS(3),VS(3),ES(3)

      DIMENSION DELTA(6)
      DIMENSION BWIG(9,3),CWIG(3,9),G(3,3),Y11(6,6),YZZ(9,9)
      DIMENSION BBAR(9,3),CBAR(3,9),UBAR(3,3),D(9,9),TEMP(3,9)
      DIMENSION VBAR(3,9),YZ(9,9),Y1(6,6),TEMP1(6,6),TEMP2(6,6)
      DIMENSION EL(9,9),ELV(9,9),JAY(9,9)
      DIMENSION SG(6),CG(6),TB(6),EYE(3,3),SP(9)
      DIMENSION TEMP3(3,9)
      DIMENSION QWIG(9),S(9,9)
      DIMENSION YONE(6),SPR(9),RES(9),GWIG(3)
      DIMENSION  SYZ(9),TEMP4(9,9)
      DIMENSION TEMPD(37)
      REAL KAP2,KAP3,KAP4,KAP5,KAP7,KAP8,NU,NORMK
      REAL JAY
      REAL JZERO
```

```
      EXTERNAL DERIV

      DO 6 I = 1,6
    6 DELTA(I) = 0.0

      DO 7 I = 1,3
      DO 7 J = 1,9
      BWIG (J,I) = 0.0
    7 CWIG (I,J) = 0.0

      IF (GROUP-2.0) 10,20,30
   10 K = 1
      GO TO 40
   20 K = 3
      GO TO 40
   30 K = 4
   40 DELTA (K) = 1.0
      DELTA (K+2) = 1.0

      P = -(KAP5*KAP8)/(RHO*(RHO*KAP7)**2)
      DO 50 I = 1,3
      BWIG (I+3,I) = P
   50 CWIG (I,I) = 1.0

      DO 60 I = 1,6
      SG(I) = SIN(GAM (I))
      CG(I) = COS(GAM (I))
```

```
60 TB(I) = TAN(BETA(I))

   G(1,1) = (DELTA(1)*SG(1)**2+DELTA(3)*CG(3)**2+DELTA(4)+DELTA(5)*CG
  1(5)**2+DELTA(6))/2.0
   G(1,2) = (-DELTA(3)*CG(3)*SG(3)+DELTA(4)*CG(4)*TB(4)+DELTA(6)*SG(6
  1)*TB(6))/2.0
   G(1,3) = (-DELTA(1)*CG(1)*SG(1)-DELTA(4)*SG(4)*TB(4)-DELTA(5)*CG(5
  1)*SG(5)+DELTA(6)*CG(6)*TB(6))/2.0
   G(2,1) = (-DELTA(1)*CG(1)*TB(1)-DELTA(3)*CG(3)*SG(3)+DELTA(5)*SG(5
  1)*TB(5))/2.0
   G(2,2) = (DELTA(1)+DELTA(3)*SG(3)**2+DELTA(4)*SG(4)**2+DELTA(5)+DE
  1LTA(6)*CG(6)**2)/2.0
   G(2,3) = (-DELTA(1)*SG(1)*TB(1)+DELTA(4)*CG(4)*SG(4)+DELTA(5)*CG(5
  1)*TB(5)-DELTA(6)*CG(6)*SG(6))/2.0
   G(3,1) = (-DELTA(1)*CG(1)*SG(1)-DELTA(3)*SG(3)*TB(3)-DELTA(5)*CG(5
  1)*SG(5))/2.0
   G(3,2) = (-DELTA(3)*CG(3)*TB(3)+DELTA(4)*CG(4)*SG(4)-DELTA(6)*CG(6
  1)*SG(6))/2.0
   G(3,3) = (DELTA(1)*CG(1)**2+DELTA(3)+DELTA(4)*CG(4)**2+DELTA(5)*SG
  1(5)**2+DELTA(6)*SG(6)**2)/2.0

   P = (KAP2-RHO*KAP7*KAP3)/(KAP8*(RHO*KAP7+KAP4))
   Q = KAP2/(KAP4*KAP8)
   RR = (RHO*KAP7/KAP4)*((KAP2+KAP3*KAP4)/(KAP8*(RHO*KAP7+KAP4)))

   DO 70 I = 1,9
   DO 70 J = 1,9
```

```
      JAY(I,J) = 0.0
      EL(I,J) = 0.0
   70 ELV(I,J) = 0.0

      DO 80 I = 1,3
      EL(I,I) = 1.0
      ELV(I,I) = 1.0
      EL(I+3,I+3) = 1.0
      ELV(I+3,I+3) = 1.0
      EL(I+6,I+6) = 1.0
      ELV(I+6,I+6) = 1.0
      EL(I,I+6) = -Q
      ELV(I,I+6) = Q
      DO 80 J = 1,3
      EL(I,J+3) = P*G(I,J)
      ELV(I,J+3) = RR*G(I,J)
      EL(I+6,J+3) = -G(I,J)
      ELV(I+6,J+3) = G(I,J)
      EYE(I,J) = 0.0
   80 EYE(I,I) = 1.0

      DO 100 I = 1,6
  100 JAY(I,I) = JZERO(I,I)

      CALL MTMPY(0,ELV,BWIG,BBAR,9,9,3,9,9)
      CALL MTMPY(0,CWIG,EL,CBAR,3,9,9,3,9)
```

```
      DO 110 I = 1,9
      DO 110 J = 1,9
      D(I,J) = 0.0
  110 YZ(I,J) = 0.0
      DO 120 I = 1,6
  120 D(I,I) = DZERO(I,I)
      D(7,7) = D1(1)
      D(8,8) = D1(2)
      D(9,9) = D1(3)
      DO 130 I = 1,3
      DO 130 J = 1,3
  130 UBAR(I,J) = 0.0

      DO 135 I = 1,9
      DO 135 J = 1,3
  135 TEMP(J,I) = BBAR(I,J)
      CALL MTMPY(0,TEMP,D,TEMP3,3,9,9,3,9)
      CALL MTMPY(0,CBAR,JAY,VBAR,3,9,9,3,9)

      DO 140 I = 1,3
      DO 140 J = 1,9
  140 VBAR(I,J) = TEMP3(I,J)+( NU/2.0)*VBAR(I,J)

      CALL MTMPY(0,JZERO,DZERO,TEMP1,-6,6,6,6,6)
      CALL MTMPY(0,DZERO,JZERO,TEMP2,6,6,6,3,6)
      DO 150 I = 1,6
      DO 150 J = 1,6
```

```
      Y1(I,J) = 0.0
  150 YZ(I,J) = -TEMP1(I,J)-TEMP2(I,J)

      DO 160 I = 1,3
      DO 160 J = 1,3
  160 YZ(I+6,J+6) = (EYE(I,J)/NORMK)-UBAR(I,J)
      DO 170 I = 1,6
      DO 170 J = 1,3
      YZ(I,J+6) = -1.0*VBAR(J,I)
  170 YZ(J+6,I) = -1.0*(VBAR(J,I)+CBAR(J,I))

      DO 175 I = 1,9
      DO 175 J = 1,9
  175 YZZ(I,J) = (YZ(J,I)+YZ(I,J))/2.0

      DO 177 I = 1,9
      DO 177 J = 1,9
  177 YZZ(I,J) =SCALE*YZZ(I,J)

      CALL MINORS(YZZ,9,SP)

      DO 180 J = 1,3
      DO 180 I = 1,3
      Y1(J,I+3) = -1.0*VBAR(I,J+6)
      Y1(I+3,J) = -1.0*(VBAR(I,J+6) + CBAR(I,J+6))
  180 Y1(I+3,J+3) = 0.0
```

```
      DO 185 I = 1,6
      DO 185 J = 1,6
  185 Y11(I,J) = (Y1(I,J) + Y1(J,I))/2.0

      DO 210 I = 1,3
      QWIG(I) = VSTAR(I)-VS(I)
      QWIG(I+3) = PSTAR(I)-PS(I)
  210 QWIG(I+6) = ESTAR(I)-ES(I)

  215 DO 220 I = 1,3
  220 GWIG(I) = TANH(VSTAR(I))-TANH(VS(I))

      CALL MTMPY(0,ELV,QWIG,S,9,9,1,9,9)

      DO 230 I = 1,3
      YONE(I) = S(I+6,1)
  230 YONE(I+3) = GWIG(I)

      CALL MTMPY(0,JZERO,S,TEMP1,6,6,1,6,9)
      CALL MTMPY(0,BBAR,GWIG,TEMP2,6,3,1,9,3)
      DO 240  I = 1,6
  240 SPR(I) = TEMP1(I,1)+TEMP2(I,1)

      DO 250 I = 1,3
      DO 250 J = 1,3
  250 TEMP1(I,J) = BBAR(I+6,J)
      CALL MTMPY(0,TEMP1,GWIG,TEMP2,3,3,1,6,3)
```

```
      DO 260 I = 1,3
  260 SPR(I+6) = TEMP2(I,1)

      CALL MTMPY (0,Y11,YONE,TEMP1,6,6,1,6,6)

      SUM = 0.0
      DO 270 I = 1,6
  270 SUM = SUM + TEMP1(I,1)*YONE(I)
      SONE=SUM

      DO 280 I = 1,9
  280 RES(I) = -1.0*SPR(I)*S(I,1)

      DO 310 I = 1,3
      SYZ(I) = S(I,1)
      SYZ(I+3) = S(I+3,1)
  310 SYZ(I+6) = GWIG(I)

      CALL MTMPY(0,YZZ,SYZ,TEMP4,9,9,1,9,9)
      SUM = 0.0
      DO 320 I = 1,9
  320 SUM = SUM + TEMP4(I,1)*SYZ(I)
      SZERO=SUM
      WRITE(6,1008)
      WRITE(6,1009) SZERO,SONE
      SUM1 = 0.0
```

```
      SUM2 = 0.0
      DO 330 I = 1,6
  330 SUM1 = SUM1 + SPR(I)*S(I,1)
      SUM1 = -SUM1
      DO 340 I = 1,3
  340 SUM2 = SUM2+SPR(I+6)*S(I+6,1)
      SUM2 = -SUM2
      IF (SONE.GE. 0.) GO TO 5001
      IT3= IT3+1
C****   SET UP INITIAL CONDITIONS FOR RUNGE-KUTTA
      DO   350   I=1,9
  350 SDEP(I)= S(I,1)
      XF=TFINAL
      DX= DT
      X=0.
      CALL RKPB(DERIV, TEMPD, X, DX, SDEP, DDEP,9)
  365 CALL RKPB1
      IF (X-XF) 370, 380,380
  370 CALL RKPB2
      GO TO  365
C*****    EVALUATE NEW QWIG
  380 DO 385 I=1,9
  385 S(I,1)= SDEP(I)
      DO   395    I=1,9
      SUM=0.
      DO  390   J=1,9
  390 SUM= SUM+ EL(I,J)*S(J,1)
```

```
 395 QWIG(I)= SUM
5001 RETURN

1008 FORMAT(1H0//30X,18HSTABILITY CRITERIA //)
1009 FORMAT(1H0,25HSMALL GIMBAL ANGLE ERRORS/7X,6HS ZERO,2X,E16.8,5X,
    14HSONE,2X,E16.8//)
     END
```

```
$       FORTRAN DECK.STAB
CTASK4
      SUBROUTINE TASK4
C****       DOMAIN OF ATTRACTION
      DIMENSION  OUT(10)
      COMMON/BLK1/
     1         Z(10.10.10).ZK(10).R(13).ZSTDY(10).
     2         C(13.13.13).D(13.13)
     3.DEL1.DEL3.DEL4.DEL5.DEL6.DTR.COMVAL(4)
      COMMON/BLK2/SONE.SZERO
      DIMENSION R2(10).P(3).V(3).B(4)
      DIMENSION TVSTDY(3)
      EQUIVALENCE (ZK.P).(ZK(4).V).(ZK(7).B).(R2.R(4))
      XCONS=3.
      LIM = 13
C             COMPUTE R2
   14 DO 15 I = 1.10
   15 R2(I) = ZK(I)-ZSTDY(I)
C             COMPUTE R1
      R(1) = R(7)
      R(2) = R(8)
      R(3) = R(9)
      DO 20 K = 1.10
      DO 20 J = 1.10
      DO 20 I = 1.10
   20 Z(I.J.K) = 0.
```

```
C      K = KTH MATRIX
C        I-ROW INDICATOR OF KTH MATRIX
C            J-COLUMN INDICATOR OF KTH MATRIX
C     PRELIMINARY CALCULATION
       IF(DEL1.NE.1.)      GO TO 23
       BETAC1= COMVAL(1)*DTR
       BETAC3 =COMVAL(2)*DTR
       GAMC1  = COMVAL(3)*DTR
       GAMC3  = COMVAL(4)*DTR
       COSG1  = COS(GAMC1)
       COSG3  = COS(GAMC3)
       SING1  = SIN(GAMC1)
       SING3  = SIN(GAMC3)
       SIN2G1  = 2.*SING1*COSG1
       SIN2G3  = 2.*SING3*COSG3
       COS2G1  = 2.*COSG1**2-1.
       COS2G3  = 2.*COSG3**2-1.
       TANB1  = TAN(BETAC1)
       TANB3  = TAN(BETAC3)
       SEC2B1  = (1./COS(BETAC1))**2
       SEC2B  = (1./COS(BETAC3))**2
       GO TO 29
    23 IF(DEL5.NE.1.)  GO TO 26
       BETAC3= COMVAL(1)*DTR
       BETAC5 =COMVAL(2)*DTR
       GAMC3  = COMVAL(3)*DTR
       GAMC5  = COMVAL(4)*DTR
```

```
      COSG3 = COS(GAMC3)
      COSG5= COS(GAMC5)
      SING3 = SIN(GAMC3)
      SING5= SIN(GAMC5)
      SIN2G3 = 2.*SING3*COSG3
      SIN2G5= 2.*SING5*COSG5
      COS2G3 = 2.*COSG3**2-1.
      COS2G5= 2.*COSG5**2-1.
      TANB3 = TAN(BETAC3)
      TANB5 = TAN(BETAC5)
      SEC2B3= (1./COS(BETAC3))**2
      SEC2B5 = (1./COS(BETAC5))**2
      GO TO 29
   26 IF(DEL4.NE.1.)  GO TO 29
      BETAC4= COMVAL(1)*DTR
      BETAC6 =COMVAL(2)*DTR
      GAMC4 = COMVAL(3)*DTR
      GAMC6 = COMVAL(4)*DTR
      COSG4 = COS(GAMC4)
      COSG6= COS(GAMC6)
      SING4= SIN(GAMC4)
      SING6= SIN(GAMC6)
      SIN2G4= 2.*SING4*COSG4
      SIN2G6= 2.*SING6*COSG6
      COS2G4= 2.*COSG4**2-1.
      COS2G6= 2.*COSG6**2-1.
      TANB4= TAN(BETAC4)
```

```
      TANB6= TAN(BETAC6)
      SEC2B4= (1./COS(BETAC4))**2
      SEC2B6 =(1./COS(BETAC6))**2
   29 DO 200 K = 1,10
      GO TO (30,40,50,60,70,80,90,30,40,50),K
C     K = 1 AND 8
   30 IF(DEL1.NE.1.)   GO TO 35
      Z(1,9,K) = .5*SIN2G1
      Z(9,1,K) = Z(1,9,K)
      Z(1,10,K) = -.5*SIN2G3
      Z(10,1,K) = Z(1,10,K)
      Z(2,10,K) = -.5*COS2G3
      Z(10,2,K) = Z(2,10,K)
      Z(3,9,K) = -.5*COS2G1
      Z(9,3,K) = Z(3,9,K)
      Z(1,7,K) = -.5*(COSG1**2)*TANB1
      Z(7,1,K) = Z(1,7,K)
      Z(1,8,K) = -.5*SING3**2*TANB3
      Z(8,1,K) = Z(1,8,K)
      Z(2,7,K) = .5*COSG1
      Z(7,2,K) = Z(2,7,K)
      Z(2,8,K) = -.25*SIN2G3*TANB3
      Z(8,2,K) = Z(2,8,K)
      Z(3,7,K) = -.25*SIN2G1*TANB1
      Z(7,3,K) = Z(3,7,K)
      Z(3,8,K) = .5*SING3
      Z(8,3,K) = Z(3,8,K)
```

```
      GO TO 200
C****     FOR DEL3=1. DEL5=1
   35 IF(DEL5.NE.1.)   GO TO 37
      Z(1.9.K)  = -.5*SIN2G3
      Z(9.1.K)= Z(1.9.K)
      Z(2.9. K) = -.5*COS2G3
      Z(9.2.K)= Z(2.9.K)
      Z(1.7.K) = -.5*SING3**2*TANB3
      Z(7.1.K)= Z(1.7.K)
      Z(2.7.K)=  -.25*SIN2G3*TANB3
      Z(7.2.K)= Z(2.7.K)
      Z(3.7.K) = .5*SING3
      Z(7.3.K)= Z(3.7.K)
      Z(1.10.K)=-.5*SIN2G5
      Z(10.1.K)= Z(1.10.K)
      Z(3.10.K)=-.5*COS2G5
      Z(10.3.K)= Z(3.10.K)
      Z(1.8.K)=-.5*SING5**2*TANB5
      Z(8.1.K)= Z(1.8.K)
      Z(2.8.K)=-.5*SING5
      Z(8.2.K)= Z(2.8.K)
      Z(3.8.K)=-.25*SIN2G5*TANB5
      Z(8.3.K)= Z(3.8.K)
      GO TO 200
C*********      FOR DEL4=1.  DEL6=1
   37 IF (DEL4.NE.1.) GO TO 2
      Z(2.9.K)=-.5*SING4*TANB4
```

```
      Z(9,2,K)= Z(2,9,K)
      Z(2,10,K)=  .5*COSG6*TANB6
      Z(10,2,K)= Z(2,10,K)
      Z(3,9,K)=-.5*COSG4*TANB4
      Z(9,3,K)=Z(3,9,K)
      Z(3,10,K)=-.5*SING6*TANB6
      Z(10,3,K)= Z(3,10,K)
      Z(2,7,K)=  .5*COSG4*SEC2B4
      Z(7,2,K)= Z(2,7,K)
      Z(2,8,K)=  .5*SING6*SEC2B6
      Z(8,2,K)= Z(2,8,K)
      Z(3,7,K)=-.5*SING4*SEC2B4
      Z(7,3,K)= Z(3,7,K)
      Z(3,8,K)=  .5*COSG6*SEC2B6
      Z(8,3,K)= Z(3,8,K)
      GO TO 200
C          K = 2 AND 9
   40 IF(DEL1.NE.1.)   GO TO 45
      Z(1,9,K) = .5*SING1*TANB1
      Z(9,1,K) = Z(1,9,K)
      Z(1,10,K) = -.5*COS2G3
      Z(10,1,K) = Z(1,10,K)
      Z(2,10,K) = .5*SIN2G3
      Z(10,2,K) = Z(2,10,K)
      Z(3,9,K) = -.5*COSG1*TANB1
      Z(9,3,K) = Z(3,9,K)
      Z(1,7,K) = -.5*COSG1*SEC2B1
```

```
      Z(7,1,K) = Z(1,7,K)
      Z(1,8,K) = -.25*SIN2G3*TANB3
      Z(8,1,K) = Z(1,8,K)
      Z(2,8,K) = -.5*COSG3**2*TANB3
      Z(8,2,K) = Z(2,8,K)
      Z(3,7,K) = -.5*SING1*SEC2B1
      Z(7,3,K) = Z(3,7,K)
      Z(3,8,K) = .5*COSG3
      Z(8,3,K) = Z(3,8,K)
      GO TO 200
   45 IF(DEL5.NE.1.)   GO TO 47
C******   FOR DEL3=1.  AND DEL5=1
      Z(1,9,K)  = -.5*COS2G3
      Z(9,1,K)= Z(1,9,K)
      Z(2,9,K)  = .5*SIN2G3
      Z(9,2,K)= Z(2,9,K)
      Z(1,7,K) = -.25*SIN2G3*TANB3
      Z(7,1,K)= Z(1,7,K)
      Z(2,7,K)=  -.5*COSG3**2*TANB3
      Z(7,2,K)= Z(2,7,K)
      Z(3,7,K) = .5*COSG3
      Z(7,3,K)= Z(3,7,K)
      Z(1,10,K)=  .5*COSG5*TANB5
      Z(10,1,K)= Z(1,10,K)
      Z(3,10,K)=-.5*SING5*TANB5
      Z(10,3,K)= Z(3,10,K)
      Z(1,8,K)=  .5*SING5*SEC2B5
```

```
      Z(8,1,K)= Z(1,8,K)
      Z(3,8,K)=  .5*COSG5*SEC2B5
      Z(8,3,K)= Z(3,8,K)
      GO TO 200
C******     FOR DEL4=1,  DEL6=1
   47 IF(DEL4.NE.1.)  GO TO 2
      Z(2,9,K)=  .5*SIN2G4
      Z(9,2,K)= Z(2,9,K)
      Z(2,10,K)=-.5*SIN2G6
      Z(10,2,K)= Z(2,10,K)
      Z(3,9,K)=  .5*COS2G4
      Z(9,3,K)=Z(3,9,K)
      Z(3,10,K)=-.5*COS2G6
      Z(10,3,K)= Z(3,10,K)
      Z(1,7,K)=-.5*COSG4
      Z(7,1,K)= Z(1,7,K)
      Z(1,8,K)=-.5*SING6
      Z(8,1,K)= Z(1,8,K)
      Z(2,7,K)=-.5*COSG4**2*TANB4
      Z(7,2,K)= Z(2,7,K)
      Z(2,8,K)=-.5*SING6**2*TANB6
      Z(8,2,K)= Z(2,8,K)
      Z(3,7,K)=  .25*SIN2G4*TANB4
      Z(7,3,K)= Z(3,7,K)
      Z(3,8,K)=-.25*SIN2G6*TANB6
      Z(8,3,K)= Z(3,8,K)
      GO TO 200
```

```
C          K = 3 AND 10
   50 IF( DEL1.NE.1.)  GO TO 55
      Z(1,9,K) = -.5*COS2G1
      Z(9,1,K) = Z(1,9,K)
      Z(1,10,K) = -.5*COSG3*TANB3
      Z(10,1,K) = Z(1,10,K)
      Z(2,10,K) = .5*SING3*TANB3
      Z(10,2,K) = Z(2,10,K)
      Z(3,9,K) = -.5*SIN2G1
      Z(9,3,K) = Z(3,9,K)
      Z(1,7,K) = -.25*SIN2G1*TANB1
      Z(7,1,K) = Z(1,7,K)
      Z(1,8,K) = -.5*SING3*SEC2B
      Z(8,1,K) = Z(1,8,K)
      Z(2,7,K) = .5*SING1
      Z(7,2,K) = Z(2,7,K)
      Z(2,8,K) = -.5*COSG3*SEC2B
      Z(8,2,K) = Z(2,8,K)
      Z(3,7,K) = -.5*SING1**2*TANB1
      Z(7,3,K) = Z(3,7,K)
      GO TO 200
   55 IF(DEL5.NE.1.)   GO TO 57
C*******     FOR DEL3=1.  AND DEL5=1
      Z(1,9, K) = -.5*COSG3*TANB3
      Z(9,1,K)= Z(1,9,K)
      Z(2,9, K) = .5*SING3*TANB3
      Z(9,2,K)= Z(2,9,K)
```

```
      Z(1,7,K) = -.5*SING3*SEC2B3
      Z(7,1,K)= Z(1,7,K)
      Z(2,7,K) = -.5*COSG3*SEC2B3
      Z(7,2,K)= Z(2,7,K)
      Z(1,10,K)=-.5*COS2G5
      Z(10,1,K)= Z(1,10,K)
      Z(3,10,K)=  .5*SIN2G5
      Z(10,3,K)= Z(3,10,K)
      Z(1,8,K)=-.25*SIN2G5*TANB5
      Z(8,1,K)= Z(1,8,K)
      Z(2,8,K)=-.5*COSG5
      Z(8,2,K)= Z(2,8,K)
      Z(3,8,K)= -.5*COSG5**2*TANB5
      Z(8,3,K)= Z(3,8,K)
   57 IF (DEL4.NE.1.)  GO TO 200
C*******      FOR DEL4=1, DEL6=1
      Z(2,9,K)=  .5*COS2G4
      Z(9,2,K)= Z(2,9,K)
      Z(2,10,K)= -.5*COS2G6
      Z(10,2,K)= Z(2,10,K)
      Z(3,9,K)=-.5*SIN2G4
      Z(9,3,K)=Z(3,9,K)
      Z(3,10,K)=  .5*SIN2G6
      Z(10,3,K)= Z(3,10,K)
      Z(1,7,K)=  .5*SING4
      Z(7,1,K)= Z(1,7,K)
      Z(1,8,K)=-.5*COSG6
```

```
      Z(8,1,K)= Z(1,8,K)
      Z(2,7,K)=  .25*SIN2G4*TANB4
      Z(7,2,K)= Z(2,7,K)
      Z(2,8,K) =-.25*TANB6*SING6**2
      Z(8,2,K)= Z(2,8,K)
      Z(3,7,K)= -.5*SING4**2*TANB4
      Z(7,3,K)= Z(3,7,K)
      Z(3,8,K)= -.5*COSG6**2*TANB6
      Z(8,3,K)= Z(3,8,K)
      GO TO 200
C           K = 4
   60 IF(DEL1.NE.1.)  GO TO 63
C*            DEL1,  DEL3  =1
      Z(1,9,K) = .5*COSG1
      Z(9,1,K) = Z(1,9,K)
      Z(3,9,K) = .5*SING1
      Z(9,3,K) = Z(3,9,K)
      GO TO 200
   63 IF( DEL5.NE.1.)   GO TO 66
      Z(1,9,K)= .5*SING3
      Z(9,1,K)= Z(1,9,K)
      Z(2,9,K)= .5*COSG3
      Z(9,2,K)= Z(2,9,K)
      GO TO 200
   66 IF( DEL4.NE.1.)  GO TO 200
      Z(2,9,K)= -.5*COSG4
      Z(9,2,K)= Z(2,9,K)
```

```
      Z(3,9,K)= .5*SING4
      Z(9,3,K)= Z(3,9,K)
      GO TO 200
C           K = 5
   70 IF(DEL1.NE.1.)  GO TO  74
C*            DEL1,  DEL3  =1
      Z(1,10,K) = .5*SING3
      Z(10,1,K) = Z(1,10,K)
      Z(2,10,K) = .5*COSG3
      Z(10,2,K) = Z(2,10,K)
      GO TO 200
   74 IF( DEL5.NE.1.)  GO TO 76
C*           DEL3, DEL5 =1
      Z(1,10,K)=  .5*SING5
      Z(10,1,K)= Z(1,10,K)
      Z(3,10,K)= .5*COSG5
      Z(10,3,K)= Z(3,10,K)
      GO TO 200
   76 IF( DEL6.NE.1.)  GO TO 200
C*          DEL4, DEL6= 1
      Z(2,10,K)= -.5*SING6
      Z(10,2,K)= Z(2,10,K)
      Z(3,10,K)= -.5*COSG6
      Z(10,3,K)= Z(3,10,K)
      GO TO 200
C          K = 6
   80 IF(DEL1.NE.1.)  GO TO 83
```

```
C*            DEL1.  DEL3  =1
      Z(1.9.K) = .5*SING1*TANB1
      Z(9.1.K) = Z(1.9.K)
      Z(1.7.K) = -.5*COSG1*SEC2B1
      Z(7.1.K) = Z(1.7.K)
      Z(3.7.K) = -.5*SING1*SEC2B1
      Z(7.3.K) = Z(3.7.K)
      Z(3.9.K) = -.5*COSG1*TANB1
      Z(9.3.K) = Z(3.9.K)
      GO TO 200
   83 IF (DEL5.NE.1.)   GO TO 86
      Z(1.9.K)= -.5*COSG3*TANB3
      Z(9.1.K)= Z(1.9.K)
      Z(1.7.K)= -.5*SING3*SEC2B3
      Z(7.1.K)= Z(1.7.K)
      Z(2.7.K)= -.5*COSG3*SEC2B3
      Z(7.2.K)= Z(2.7.K)
      Z(2.9.K)= .5*SING3*TANB3
      Z(9.2.K)= Z(2.9.K)
      GO TO 200
   86 IF( DEL4.NE.1.)  GO TO 200
      Z(2.9.K)=-.5*SING4*TANB4
      Z(9.2.K)= Z(2.9.K)
      Z(2.7.K)= .5*COSG4*SEC2B4
      Z(7.2.K)= Z(2.7.K)
      Z(3.7.K)= -.5*SING4*SEC2B4
      Z(7.3.K)= Z(3.7.K)
```

```
      Z(3,9,K)= -.5*COSG4*TANB4
      Z(9,3,K)= Z(3,9,K)
      GO TO 200
C           K = 7
   90 IF( DEL1.NE.1.)  GO TO 93
      Z(1,10,K) = -.5*COSG3*TANB3
      Z(10,1,K) = Z(1,10,K)
      Z(1,8,K) = -.5*SING3*SEC2B
      Z(8,1,K) = Z(1,8,K)
      Z(2,8,K) = -.5*COSG3*SEC2B
      Z(8,2,K) = Z(2,8,K)
      Z(2,10,K) = .5*SING3*TANB3
      Z(10,2,K) = Z(2,10,K)
      GO TO 200
   93 IF(DEL5.NE.1.)  GO TO 95
C*          DEL3, DEL5 =1
      Z(1,10,K)= -.5*COSG5*TANB5
      Z(10,1,K)= Z(1,10,K)
      Z(1,8,K)= -.5*SING5*SEC2B5
      Z(8,1,K)= Z(1,8,K)
      Z(3,8,K)= -.5*COSG5*SEC2B5
      Z(8,3,K)= Z(3,8,K)
      Z(3,10,K)= .5*SING5*TANB5
      Z(10,3,K)= Z(3,10,K)
      GO TO 200
   95 IF(DEL4.NE.1.)  GO TO 2
C*          DEL4, DEL6= 1
```

```
      Z(2,10,K)= .5*COSG6*TANB6
      Z(10,2,K)= Z(2,10,K)
      Z(2,8,K)= .5*SING6*SEC2B6
      Z(8,2,K)= Z(2,8,K)
      Z(3,8,K)= .5*COSG6*SEC2B6
      Z(8,3,K)= Z(3,8,K)
      Z(3,10,K)= -.5*SING6*TANB6
      Z(10,3,K)= Z(3,10,K)
  200 CONTINUE
C***************   COMPUTE C(I,J,L)     ****************
  210 DO 300 L = 4,13
      DO 300 J = 4,13
      IF (J.NE.L) GO TO 250
C********     CASE    J = L
      DO 240 I = 4,13
      IF (I.NE.J) GO TO 220
C           I = J = L
      K = L-3
      C(L,L,L) = Z(K,K,K)
      GO TO 240
C        I NOT EQUAL TO L, J = L
  220 K = L-3
      C(I,L,L) = Z(I-3,K,K)
  240 CONTINUE
      GO TO 300
C*****          CASE J NOT EQUAL TO L
  250 DO 270 I = 4,13
```

```
      IF (I.NE.J) GO TO 260
C             I = J
      K = I-3
      C(I,I,L) = Z(K,K,L-3)
      GO TO 270
C          I NOT EQUAL TO J
  260 C(I,J,L) = Z(I-3,J-3,L-3)
  270 CONTINUE
  300 CONTINUE
C******************* COMPUTE D(I,L)
      DO 330 L = 4,13
      DO 330 I = 4,13
      DS = 0.
      IF (I.EQ.L) GO TO 315
C****         I NOT EQUAL TO L
      DO 310 J = 1,10
  310 DS = DS+Z(I-3,J,L-3)*ZSTDY(J)
      D(I,L) = DS
      GO TC 330
C****          I = L
  315 DO 320 J = 1,10
      K = L-3
  320 DS = DS+Z(K,J,K)*ZSTDY(J)
      D(I,L) = DS
  330 CONTINUE
C*****        EVALUATE THETA1
      P1 = 0.
```

```
      P6 = 0.
  340 DO 350 L = 4,LIM
      P1 = P1+C(L,L,L)*R(L)**3/3.
  350 P6 = D(L,L)*R(L)**2+P6
  355 P2 = 0.
      P3 = 0.
      P5 = 0.
      DO 360 L = 5,LIM
      LM1 = L-1
      DO 360 I = 4,LM1
      P2 = C(I,I,L)*R(I)**2*R(L)+P2
      P3 = C(I,L,L)*R(I)*R(L)**2+P3
  360 P5 = 2.*D(I,L)*R(I)*R(L)+P5
      P4 = 0.
  365 DO 380 L = 6,LIM
      LM1 = L-1
      DO 380 I = 4,LM1
      DO 380 J = 4,LM1
      IF (I.EQ.J) GO TO 380
      P4 = C(I,J,L)*R(I)*R(J)*R(L)+P4
  380 CONTINUE
      THETA = P1+P2+P3+P4+P5+P6
      THETA1 = THETA
C*****        COMPUTE THETA2
  390 THETA2 = 0.
      DO 400 L = 1,3
      CVK = COSH(V(L))
```

```
      CVSTDY = COSH(ZSTDY(L+3))
      TVSTDY(L) = TANH(ZSTDY(L+3))
  400 THETA2 = THETA2+ALOG(CVK)-ALOG(CVSTDY)-R(L)*TVSTDY(L)
      THETA = THETA2-THETA1
C*******      EVALUATE GAMMA
      OKON = 1./SQRT(XCONS)
      GAMMA = 0.
      DO 410 I = 1,3
      VDIF = TANH(V(I))-TVSTDY(I)
  410 GAMMA = GAMMA+(R(I)-OKON*VDIF)*VDIF
C****************** K = 1,2,3
      DO 425 K = 1,3
      P1 = 0.
C         SUM OVER I AND J.    (4,13)
      DO 415 I = 4,13
      IM3 = I-3
      DO 415 J = 4,13
      JM3 = J-3
  415 P1 = P1+Z(IM3,JM3,K)*R2(JM3)*R2(IM3)+2.*Z(IM3,JM3,K)*ZSTDY(JM3)*R2
     1(IM3)
      P1 = (ZK(K)-OKON*P1)*P1
  425 GAMMA = GAMMA+P1
C********        K = 4,5,6
  430 DO 440 K = 4,6
      P2 = 0.
      DO 435 I = 4,13
      IM3 = I-3
```

```
      DO 435 J = 4,13
      JM3 = J-3
  435 P2 = P2+Z(IM3,JM3,K)*R2(JM3)*R2(IM3)+2.*Z(IM3,JM3,K)*ZSTDY(JM3)*R2
     1(IM3)
      P2 = (R2(K)-OKON*P2)*P2
  440 GAMMA = GAMMA+P2
C************** K = 7,8,9,10
  445 DO 460 K = 7,10
      P3 = 0.
      DO 450 I = 4,13
      IM3 = I-3
      DO 450 J = 4,13
      JM3 = J-3
  450 P3 = P3+Z(IM3,JM3,K)*R2(JM3)*R2(IM3)+2.*Z(IM3,JM3,K)*ZSTDY(JM3)*R2
     1(IM3)
      P3 = (R2(K)-OKON*P3)*P3
  460 GAMMA = GAMMA+P3
      WRITE(6,1012) THETA,GAMMA
      WRITE(6,1016)
C************FORMAT STATEMENTS
 1003 FORMAT (3HOK= I3/(10(10F12.3/)))
 1010 FORMAT(1H0,25HSMALL GIMBAL ANGLE ERRORS/7X,6HS ZERO,2X,E16.8,5X,
     14HSONE,2X,E16.8//)
 1011 FORMAT(1H0//30X,18HSTABILITY CRITERIA //)
 1012 FORMAT(1H0/25HLARGE GIMBAL ANGLE ERRORS /7X,10HCAP LAMBDA,2X,E16.8
     1,5X,9HCAP GAMMA,2X,E16.8/)
 1015 FORMAT (1H0, 55X,8HR VECTOR/15(50X,E16.8/))
```

```
1016 FORMAT(1H1)
 501 RETURN
     END
```

```
$       FORTRAN DECK,STAB
CCOMP
      SUBROUTINE COMP
      COMMON/BLK1/
     1        Z(10,10,10),ZK(10),R(13),ZSTDY(10),
     2        C(13,13,13),D(13,13)
     3,DEL1,DEL3,DEL4,DEL5,DEL6,DTR,COMVAL(4)
      COMMON /INPTN/ PSTAR(3),VSTAR(3),ESTAR(3),PS(3),VS(3),ES(3)
      DIMENSION R2(10),P(3),V(3),B(4)
      DIMENSION E(3)
      EQUIVALENCE (ZK,P),(ZK(4),V),(ZK(7),B),(R2,R(4))
      I=1
      DO  10  I=1,3
   10 E(I)= ESTAR(I)*4.8481361E-6
      B1= B(1)/3437.74677
      G3= COMVAL(4)*DTR
      SG3= SIN(G3)
      CG3= COS(G3)
      G1= COMVAL(3)*DTR
      SG1= SIN(G1)
      CG1= COS(G1)
      PART1= B1*SG1*SG3
      GAM1E= 1./CG3*(2.*(E(1)*SG3+E(2)*CG3)-PART1)
      BETA3E= 1./CG3* (-2.*E(1)+ B1*SG1)
      GAM3E= 2.*E(3)+B1*CG1
      BFAC= 0.290888166E-3
```

```
      B(2)= BETA3E/BFAC
      B(3)= GAM1E/BFAC
      B(4)= GAM3E/BFAC
 5001 RETURN
      END
```

```
$       FORTRAN DECK,STAB
CDERIV
      SUBROUTINE DERIV
      COMMON/BLK/DZERO(6,6), JZERO(6,6), QWIG(9), IT3, TFINAL,DT
      COMMON/BLK3/ DDEP(9), SDEP(9), TEMP2(6,6)
      COMMON/BLK4/ EL(9,9), GWIG(3), BBAR(9,3)
      COMMON /INPTN/ PSTAR(3),VSTAR(3),ESTAR(3),PS(3),VS(3),ES(3)
      DIMENSION V(3), TEMP1(6)
      REAL JZERO
C****       EVALUATE NEW VBAR
      DO    10    I=1,3
      SUM=0.
      DO  9    J=1,6
    9 SUM= SUM+ EL(I,J)*SDEP(J)
   10 V(I)= SUM+ VS(I)
      DO    15    I=1,3
   15 GWIG(I)= TANH(V(I))-TANH(VS(I))
      DO    17    I=1,6
      SUM=0.
      DO    16    J=1,6
   16 SUM= SUM+ JZERO(I,J)*SDEP(J)
   17 DDEP(I)= SUM
      DO    19    I=1,6
      SUM=0.
      DO    18     J=1,3
   18 SUM= BBAR(I,J)*GWIG(J)+ SUM
```

```
   19 TEMP1(I)= SUM
C******       EVALUATE DERIV FOR SZEROP
      DO    20    I=1,6
   20 DDEP(I) = DDEP(I)+ TEMP1(I)
C*****     EVALUATE DERIVE FOR SONEP
      DO    25    I=1,3
      IK= I+6
      SUM=0.
      DO    24    J=1,3
   24 SUM= SUM+ BBAR(IK, J)*GWIG(J)
   25 DDEP(IK)= SUM
      RETURN
      END
```

```
$       FORTRAN DECK
CMINOR
      SUBROUTINE MINORS(TM,M,SP)
      DIMENSION TEMP(9,9),TM(9,9),SP(9)
      DO 30 I = 1,M
      DO 20 J = 1,I
      DO 20 K = 1,I
   20 TEMP(J,K) = TM(J,K)
   30 SP(I) = DETE(TEMP,I,9)
      RETURN
      END
```

APPENDIX A

EQUATION REFERENCES

The equations evaluated in this Program are contained in Final Report, Part 1, Stability Criteria for the OAO Coarse Pointing Mode, by S. E. Moskowitz.

Reference No.	Equation	Page Number	Description
1	11a, 11b, 11c	2-7	
2	14	3-3	
3		3-5	
4		3-5	
5			MINORS subroutine computes all principal minors of the Y_o matrix
6	18	3-5	
7		A-4	
8		A-4	
9	27, 28	A-5	
10		A-7	
11		A-7	
12	29	A-7	

GENERAL
ELECTRIC

SPACECRAFT DEPARTMENT
MISSILE AND SPACE DIVISION
VALLEY FORGE COMPLEX
P.O. Box 8555 • Phila. Penna., 19101