A REAL-TIME DIGITAL PROGRAM
FOR ESTIMATING AIRCRAFT STABILITY
AND CONTROL PARAMETERS FROM
FLIGHT TEST DATA BY USING
THE MAXIMUM LIKELIHOOD METHOD

by Randall D. Grove and Stanley C. Mayhew

Langley Research Center
Hampton, Va. 23665

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • DECEMBER 1973
A computer program (Langley program C1123) has been developed for estimating aircraft stability and control parameters from flight test data. These parameters are estimated by the maximum likelihood estimation procedure implemented on a real-time digital simulation system, which uses the Control Data 6600 computer. This system allows the investigator to interact with the program in order to obtain satisfactory results. Part of this system, the control and display capabilities, is described for this program. This report also describes the computer program by presenting the program variables, subroutines, flow charts, listings, and operational features. Program usage is demonstrated with a test case using pseudo or simulated flight data.
## CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUMMARY</td>
<td>1</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>SYMBOLS</td>
<td>2</td>
</tr>
<tr>
<td>PROBLEM DESCRIPTION</td>
<td>7</td>
</tr>
<tr>
<td>Aircraft Mathematical Model</td>
<td>7</td>
</tr>
<tr>
<td>Sensitivity Equations</td>
<td>8</td>
</tr>
<tr>
<td>Maximum Likelihood Estimation Equations</td>
<td>9</td>
</tr>
<tr>
<td>PROGRAM DESCRIPTION</td>
<td>11</td>
</tr>
<tr>
<td>Labeled COMMON</td>
<td>11</td>
</tr>
<tr>
<td>Display Arrays</td>
<td>18</td>
</tr>
<tr>
<td>Subroutine Descriptions</td>
<td>32</td>
</tr>
<tr>
<td>OVERLAY Program Descriptions, Flow Charts, and Listings</td>
<td>35</td>
</tr>
<tr>
<td>PROGRAM USAGE</td>
<td>75</td>
</tr>
<tr>
<td>Test Case Setup</td>
<td>75</td>
</tr>
<tr>
<td>Test Case Run Procedure</td>
<td>77</td>
</tr>
<tr>
<td>Output Listings</td>
<td>78</td>
</tr>
<tr>
<td>CONCLUDING REMARKS</td>
<td>93</td>
</tr>
<tr>
<td>APPENDIX A – PROGRAM CONTROL AND DISPLAY CAPABILITIES</td>
<td>94</td>
</tr>
<tr>
<td>APPENDIX B – EQUATIONS OF MOTION AND ACCELEROMETER EQUATIONS</td>
<td>98</td>
</tr>
<tr>
<td>APPENDIX C – SENSITIVITY EQUATIONS AND ACCELEROMETER SENSITIVITY COEFFICIENTS</td>
<td>104</td>
</tr>
<tr>
<td>APPENDIX D – VARIABLE DIMENSIONING</td>
<td>115</td>
</tr>
<tr>
<td>APPENDIX E – CALCOMP PLOT OPTION</td>
<td>119</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>121</td>
</tr>
<tr>
<td>FIGURES</td>
<td>122</td>
</tr>
</tbody>
</table>
A REAL-TIME DIGITAL PROGRAM FOR ESTIMATING AIRCRAFT STABILITY AND CONTROL PARAMETERS FROM FLIGHT TEST DATA BY USING THE MAXIMUM LIKELIHOOD METHOD

By Randall D. Grove and Stanley C. Mayhew
Langley Research Center

SUMMARY

A computer program (Langley program C1123) has been developed for estimating aircraft stability and control parameters from flight test data. These parameters are estimated by the maximum likelihood estimation procedure implemented on a real-time digital simulation system, which uses the Control Data 6600 computer. This system allows the investigator to interact with the program in order to obtain satisfactory results. Part of this system, the control and display capabilities, is described for this program. This report also describes the computer program by presenting the program variables, subroutines, flow charts, listings, and operational features. Program usage is demonstrated with a test case using pseudo or simulated flight data.

INTRODUCTION

A computer program has been developed at the Langley Research Center to improve the capabilities for estimating aircraft stability and control parameters. Improved capabilities result from the combined utilization of the inherent features of the Langley real-time simulation (RTS) system and the maximum likelihood method. The program has been designed to take advantage of the integrated software and hardware features comprising the RTS system. This system allows the analyst to be an integral part in controlling the direction of the parameter identification study, that is, the analyst communicates or interacts with the program. The analyst interacts with the program by selecting the mathematical model to be used, the variables to be matched with the flight test data, and the parameters to be estimated. The RTS display features aid the analyst in determining whether any further interaction is necessary and when to stop the computer run. The analyst uses the results of the computer run as an aid to solve the problems of correlation, uniqueness, and identifiability of the parameters. Parameter estimation is not a straightforward procedure; thus, having the capability of the analyst interacting with the program is highly desirable.

*Electronic Associates, Inc.
The objective of this report is to present the computer program which was written especially for the RTS system at Langley. A description of the system software is beyond the scope of this report; however, the RTS subroutines used are briefly described in order to aid in understanding the flow of the program. The program flow differs from batch programs in that operator action is required. In presenting the program, it becomes necessary to describe the program control station (appendix A) from which the analyst interacts with the program. The maximum likelihood estimation procedure for extracting the stability and control parameters was developed in reference 1.

The program has been dynamically checked by comparing its output with the output of an independently written batch program. Test cases were made by use of simulated flight data with different measurement noise levels to check the estimation procedure. (See ref. 1.) Application of this program is not restricted to the aircraft example being used in this report. The program may be applied to other aircraft as well as other dynamic vehicles satisfying the assumptions of the maximum likelihood estimator. (See ref. 1.) The program developed has been successfully applied to the analysis of flight test data for generically different aircraft. (See refs. 2 to 5.) These reports on the analysis of flight test data also reflect the desirability of analyst program interaction.

SYMBOLS

Symbols on CalComp plots (figs. 2 and 4) are not standard because of the limitations of the computer.

\[ A \] sensitivity coefficient matrix

\[ \bar{a}_I \] accelerometer vector at instrument location

\[ a_{X,I}, a_{Y,I}, a_{Z,I} \] longitudinal, lateral, and normal (positive down) components of \( \bar{a}_I \)

\[ b \] wing span

\[ C_l, C_m, C_n \] rolling-, pitching-, and yawing-moment coefficients

\[ (C_l)_{\beta_t, \delta_a, t, \delta_r, t} \] rolling-moment coefficient at \( \beta = \beta_t, \delta_a = \delta_a, t, \delta_r = \delta_r, t \)

\[ (C_m)_{\alpha_a, t, \delta_e, t} \] pitching-moment coefficient at \( \alpha_a = \alpha_a, t, \delta_e = \delta_e, t \)
(Cn) _β_ a,t, δ_r,t, yawing-moment coefficient at β = β_t, δ_a = δ_a,t, δ_r = δ_r,t

C_T, C_T_o, C_T_B, main-engine thrust coefficients

C_T, C_T_o, C_T_B, tail-rotor thrust coefficients

C_X, C_Y, C_Z, longitudinal-, lateral-, and normal-force coefficients

C_X, o, C_Z, o, longitudinal-force and normal-force coefficients at α_a = δ_e = 0

(C_X) _α_ a,t, δ_e,t, longitudinal-force coefficient at α_a = α_a,t, δ_e = δ_e,t

C_Y_o, lateral-force coefficient at β = δ_a = δ_r = 0

(C_Y) _β_ t, δ_a,t, δ_r,t, lateral-force coefficient at β = β_t, δ_a = δ_a,t, δ_r = δ_r,t

(C_Z) _α_ a,t, δ_e,t, normal-force coefficient at α_a = α_a,t, δ_e = δ_e,t

C, mean aerodynamic chord

D_E, D_T, blade diameters of main engine and tail rotor

F, vector function defined in equations of motion

F_j, components of F, where j = 1, 2, ..., 8

G, sensitivity equation matrix

g, acceleration due to gravity

I_X, I_Y, I_Z, moment of inertia about X-, Y-, and Z-axis, respectively

I_XZ, product of inertia

i, j, k, integers

i_w, wing tilt angle
\( J_N \)  
performance index function

\( \vec{i}, r_b, \vec{T}_p \)  
coefficients in moment equations

\( M_X, M_Y, M_Z \)  
rolling, pitching, and yawing moments

\( m \)  
mass

\( N \)  
number of data points

\( P_E, P_T \)  
normalized throttle settings of main engine and tail rotor

\( p, q, r \)  
roll, pitch, and yaw angular velocities

\( p' \)  
number of parameters

\( R \)  
measurement noise covariance matrix

\( S \)  
wing area

\( T \)  
flight-test time period

\( T_X, T_Y, T_Z \)  
thrust along X-, Y-, and Z-axis, respectively

\( t \)  
time

\( t_i \)  
data point time, where \( i = 1, 2, \ldots, N \)

\( u, v, w \)  
longitudinal, lateral, and vertical velocity components

\( V \)  
true airspeed

\( V_{SS} \)  
slipstream airspeed

\( X, Y, Z \)  
coordinate axes

\( \bar{x} \)  
state vector

\( x_k \)  
components of \( \bar{x} \), where \( k = 1, 2, \ldots, 8 \)
\[ x_X, y_X, z_X \] center-of-gravity offsets of X-axis accelerometer

\[ x_Y, y_Y, z_Y \] center-of-gravity offsets of Y-axis accelerometer

\[ x_Z, y_Z, z_Z \] center-of-gravity offsets of Z-axis accelerometer

\[ \bar{y} \] variables in performance index function

\[ \bar{\alpha} \] parameter vector

\[ \Delta \bar{\alpha} \] parameter change vector

\[ \alpha_a, \beta \] angles of attack and sideslip

\[ \alpha_i \] components of \( \bar{\alpha} \), where \( i = 1, 2, \ldots, 40 \)

\[ \beta_T \] tail-rotor blade angle

\[ \bar{\delta} \] control deflection vector

\[ \delta_a, \delta_e, \delta_r \] aileron, elevator, and rudder control deflections

\[ \bar{\delta}_B, \Delta B \] relationships of blade angles for main engines

\[ \delta_{ik} \] Kronecker delta

\[ \bar{\eta} \] measurement noise vector

\[ \eta_E, \eta_T \] main-engine and tail-rotor speeds

\[ \eta_i \] components of \( \bar{\eta} \), where \( i = 1, 2, \ldots, 11 \)

\[ \rho \] atmospheric density

\[ \rho_{\alpha_i, \alpha_j} \] correlation coefficient of \( \alpha_i \) and \( \alpha_j \)

\[ \sigma_{\alpha_i}^2, \sigma_{\alpha_i} \] variance and standard deviation of \( \alpha_i \)
\( \sigma_{i} \sigma_{j} \) covariance of \( \eta_{i} \) and \( \eta_{j} \)

\( \phi, \theta, \psi \) roll, pitch, and yaw angles

Stability and control derivatives:

\[
C_{X_q} = \frac{\partial C_X}{\partial q}
\]

\[
C_{Y_p} = \frac{\partial C_Y}{\partial p}
\]

\[
C_{Z_q} = \frac{\partial C_Z}{\partial q}
\]

\[
C_{X_{\alpha_a}} = \frac{\partial C_X}{\partial \alpha_a}
\]

\[
C_{Y_{\beta}} = \frac{\partial C_Y}{\partial \beta}
\]

\[
C_{Z_{\alpha_a}} = \frac{\partial C_Z}{\partial \alpha_a}
\]

\[
C_{L_p} = \frac{\partial C_L}{\partial p}
\]

\[
C_{Y_{\delta_e}} = \frac{\partial C_Y}{\partial \delta_e}
\]

\[
C_{Z_{\delta_e}} = \frac{\partial C_Z}{\partial \delta_e}
\]

\[
C_{L_r} = \frac{\partial C_L}{\partial r}
\]

\[
C_{Y_{\delta_r}} = \frac{\partial C_Y}{\partial \delta_r}
\]

\[
C_{Z_r} = \frac{\partial C_Z}{\partial r}
\]

\[
C_{L_{\beta}} = \frac{\partial C_L}{\partial \beta}
\]

\[
C_{m_q} = \frac{\partial C_m}{\partial q}
\]

\[
C_{n_{\beta}} = \frac{\partial C_n}{\partial \beta}
\]

\[
C_{L_{\delta_a}} = \frac{\partial C_L}{\partial \delta_a}
\]

\[
C_{m_{\alpha_a}} = \frac{\partial C_m}{\partial \alpha_a}
\]

\[
C_{n_{\delta_a}} = \frac{\partial C_n}{\partial \delta_a}
\]

\[
C_{L_{\delta_r}} = \frac{\partial C_L}{\partial \delta_r}
\]

\[
C_{m_{\alpha_r}} = \frac{\partial C_m}{\partial \alpha_r}
\]

\[
C_{n_{\delta_r}} = \frac{\partial C_n}{\partial \delta_r}
\]

\[
C_{m_{\delta_e}} = \frac{\partial C_m}{\partial \delta_e}
\]

\[
C_{n_{\delta_r}} = \frac{\partial C_n}{\partial \delta_r}
\]
PROBLEM DESCRIPTION

The stability and control parameters are the unknown coefficients in the differential equations of motion of the aircraft. The maximum likelihood estimation procedure, using the method of quasilinearization, estimates the stability and control parameters by minimizing the difference between the flight test measurements and the calculated solution of the differential equations of motion of the aircraft.

The measured control deflections of the aircraft are used as inputs to the equations of motion, and the flight test measurements are assumed to be the true solution with measurement noise (Gaussian with zero mean). The initial conditions of the state are included as unknown parameters and the accelerometer equations supplement the equations of motion in the estimation procedure.

Aircraft Mathematical Model

The detailed nonlinear aircraft mathematical model is described in appendix B, where the equations of motion are represented in vector notation by

\[ \dot{x} = F(\bar{x}, \bar{\alpha}, \bar{\delta}, V, \alpha_a, \dot{\alpha_a}, \beta, \dot{\beta}) \]  

(1)
For simplicity in describing the estimation procedure, let the equations of motion be written as

$$\ddot{x} = \ddot{F}(\ddot{\alpha}, \ddot{\delta})$$  \hspace{1cm} (1a)$$

where the terms omitted in equation (1a) are auxiliary relationships. The equation variables (states) are

$$\ddot{x}(\ddot{\alpha}, t) = [u, v, w, p, q, r, \theta, \phi]^T$$ \hspace{1cm} (2)$$

The parameter vector is

$$\ddot{\alpha} = [\ddot{\alpha}_1, \ddot{\alpha}_2, \ldots, \ddot{\alpha}_p]^T$$ \hspace{1cm} (3)$$

The control inputs are

$$\ddot{\delta} = [\ddot{\delta}_a, \ddot{\delta}_e, \ddot{\delta}_r]^T = \ddot{\delta}_M$$ \hspace{1cm} (4)$$

Integration of the equations of motion yields the nominal solution $\ddot{x}(\ddot{\alpha}, t)$, where $\ddot{\alpha}$ is the nominal or current value of the parameter vector. These parameters are the aerodynamic coefficients (stability and control parameters) and the initial conditions of the states. The initial values of the coefficients are determined from a prior estimate (wind-tunnel data or analysis) and the initial states are determined from the flight test data.

The accelerometer equations

$$\ddot{a}_I = (a_{X,I}, a_{Y,I}, a_{Z,I})^T$$ \hspace{1cm} (5)$$

are algebraic functions of the states and their derivatives. These equations need only to be evaluated and not integrated.

**Sensitivity Equations**

The sensitivity equations are derived by formally differentiating the equations of motion with respect to each parameter. (See ref. 1.) The sensitivity equations are (by using eq. (1a))

$$\frac{d}{dt} \left( \frac{\partial \ddot{x}}{\partial \ddot{\alpha}_i} \right) = \sum_{k=1}^{8} \frac{\partial \ddot{F}}{\partial \ddot{\alpha}_k} \left( \frac{\partial x_k}{\partial \ddot{\alpha}_i} \right) + \frac{\partial \ddot{F}}{\partial \ddot{\alpha}_i} = G(t) \left( \frac{\partial \ddot{x}}{\partial \ddot{\alpha}_i} \right) + \frac{\partial \ddot{F}}{\partial \ddot{\alpha}_i} \quad (i = 1, 2, \ldots, p')$$ \hspace{1cm} (6)$$
This system of equations represents \( p' \) sets of eight simultaneous differential equations. Integration yields the sensitivity coefficients \( \frac{\partial x_k}{\partial \alpha_i} \). All the initial conditions are zero except for

\[
\left. \frac{\partial x_k}{\partial \alpha_i} \right|_{t=0} = \left. \frac{\partial x_k}{\partial x_1(0)} \right|_{t=0} = \delta_{jk}
\]

The accelerometer sensitivity coefficients \( \frac{\partial \tilde{a}_I}{\partial \alpha_i} \) are functions of the sensitivity equations and coefficients previously defined. The sensitivity equations and accelerometer sensitivity coefficients are presented in detail in appendix C.

### Maximum Likelihood Estimation Equations

The maximum likelihood estimation equations (using quasilinearization) are derived from the likelihood function in reference 1. The maximum likelihood parameter estimation procedure (the accelerometer equations being neglected) is diagramed in figure 1. The estimation procedure is initially formulated by using the complete mathematical model; then, by using variable dimensioning (appendix D), it is reduced to the specific flight test case being analyzed.

The parameter-change equations are

\[
\Delta \tilde{\alpha} = \left[ \sum_{i=1}^{N} A^T(t_i) R^{-1} A(t_i) \right]^{-1} \left[ \sum_{i=1}^{N} A^T(t_i) R^{-1} \tilde{\eta}(t_i) \right]
\]

where

\[
A(t_i) = \left( \frac{\partial \tilde{y}^O}{\partial \alpha_1}, \frac{\partial \tilde{y}^O}{\partial \alpha_2}, \ldots, \frac{\partial \tilde{y}^O}{\partial \alpha_p'} \right)
\]

\[
\tilde{\eta}(t_i) = \tilde{y}^M(t_i) - \tilde{y}^O(t_i)
\]

\[
\tilde{y}^M(t_i) = \begin{bmatrix} \tilde{x}^M(t_i) \\ \tilde{a}_I^M(t_i) \end{bmatrix} \quad \tilde{y}^O(t_i) = \begin{bmatrix} \tilde{x}^O(t_i) \\ \tilde{a}_I^O(t_i) \end{bmatrix}
\]

Here \( \tilde{y}^O \) denotes the variables in the performance index function.
The covariance matrix for the parameters is

\[
\left[ \sum_{i=1}^{N} A^T(t_i) R^{-1} A(t_i) \right]^{-1}
\]

The covariance matrix for the measurement noise is

\[ R^0(N) \triangleq \text{Estimate of } R = \frac{1}{N} \sum_{i=1}^{N} \eta(t_i) \eta^T(t_i) \]

and the performance index function to be minimized is

\[ J_N(\bar{\alpha}^0) = |R^0(N)| \tag{9} \]

The flight test data are composed of the onboard instrument measurements of the aircraft behavior and are assumed to be the output of the aircraft mathematical model superimposed with instrument noise. These data contain many individual aircraft maneuvers stored on one magnetic tape, each maneuver being easily accessible to the central memory of the computer. These data are used for comparison with the mathematical model output and for initialization of and control input to the equations of motion. The measurements \( \tilde{y}^M(t_i) \) and \( \tilde{\delta}^M(t_i) \) for \( i = 1, 2, \ldots, N \) are known for all performance index variables and control deflections corresponding to the aircraft mathematical model.

The steps in the maximum likelihood estimation procedure, corresponding to figure 1, are as follows:

1. Initialize the system parameters where \( \bar{\alpha}^0 \) denotes the nominal or current values of the parameters.

2. Integrate the equations of motion and the sensitivity equations to obtain the nominal solution and the sensitivity coefficient matrix, respectively.

3. Calculate the comparisons of the flight test data and nominal solution for each data point time at \( t_i \) where \( i = 1, 2, \ldots, N \) and \( t_1 = 0 \) and \( t_N = T \).

4. Calculate the maximum likelihood estimation equations from the comparisons in step (3) and the sensitivity coefficient matrix in step (2). (Dashed lines in fig. 1 indicate accumulation of information over the flight test time period \( T \).)

5. Calculate the performance index \( J_N(\bar{\alpha}^0) \).

6. Calculate the parameter changes \( \Delta \bar{\alpha} \) and the statistical information matrix \( R^0(N) \).
(7) Update the nominal parameter values in step (1) to start the next iteration procedure and repeat steps until convergence. Convergence of the estimation procedure is assumed when the change in the performance index is small enough to satisfy the criterion of the analyst.

PROGRAM DESCRIPTION

Labeled COMMON

The following list contains the FORTRAN variables appearing in labeled COMMON and descriptions of each variable:

<table>
<thead>
<tr>
<th>COMMON label</th>
<th>FORTRAN variable(s)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>/INTCOMM/</td>
<td>T</td>
<td>t, updated in subroutine IGRATE1</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>Integration step size used in subroutine IGRATE1 (H = DT)</td>
</tr>
<tr>
<td></td>
<td>INT</td>
<td>Flow control parameter used in subroutine IGRATE1</td>
</tr>
<tr>
<td></td>
<td>NEQ</td>
<td>Number of integrations performed in subroutine IGRATE1, NEQ ≤ 249</td>
</tr>
<tr>
<td></td>
<td>ISCHEME</td>
<td>Selects integration scheme in subroutine IGRATE1</td>
</tr>
<tr>
<td></td>
<td>DERINT(2,249)</td>
<td>Array of integrals and derivatives in subroutine IGRATE1</td>
</tr>
<tr>
<td>/INTINTR/</td>
<td>INTERN(5,249)</td>
<td>Temporary storage array for subroutine IGRATE1</td>
</tr>
<tr>
<td>/REALTIM/</td>
<td>ADC(32)</td>
<td>Analog-to-digital converter input array</td>
</tr>
<tr>
<td></td>
<td>DAC(64)</td>
<td>Digital-to-analog converter output array</td>
</tr>
<tr>
<td></td>
<td>LDISI(108)</td>
<td>Logical discrete input array</td>
</tr>
<tr>
<td>COMMON label</td>
<td>FORTRAN variable(s)</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>---------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>/REALTIM/</td>
<td>LDISO(196)</td>
<td>Logical discrete output array</td>
</tr>
<tr>
<td></td>
<td>NOPER</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NHOLD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NRESET</td>
<td>Return addresses from subroutine RTMODE</td>
</tr>
<tr>
<td></td>
<td>NTERM</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NPRINT</td>
<td>Not used with subroutine PCCEEXEC</td>
</tr>
<tr>
<td></td>
<td>NREAD</td>
<td></td>
</tr>
</tbody>
</table>

| /ALGOR/      | NPAR                | Total number of parameters |
|              | IPAR                | Maximum number of active parameters |
|              | INTP(30)            | Array denoting active parameters |
|              | IP                  | Number of active parameters |
|              | INTV(8)             | Array denoting active equation variables |
|              | IV                  | Number of active equation variables |
|              | INTA(11)            | Array denoting active performance index variables |
|              | IA                  | Number of active performance index variables |
|              | IA1                 | Number of active equation variables which are active performance index variables |
|              | IA2                 | IA-IA1 |

12
<table>
<thead>
<tr>
<th>COMMON label</th>
<th>FORTRAN variable(s)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>/ALGOR/</td>
<td>PARAM(40)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DPARAM(30)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ALV(11)</td>
<td>Arrays of labels for printout</td>
</tr>
<tr>
<td></td>
<td>DVAR(8)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DALG(11)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ALG(40)</td>
<td>Auxiliary storage array for AL</td>
</tr>
<tr>
<td></td>
<td>IAC(40)</td>
<td>Auxiliary storage array for INTEG(I) (I = 1, 2, . . . , 40)</td>
</tr>
<tr>
<td></td>
<td>IEVEN</td>
<td>Used with LOGIC(11)</td>
</tr>
<tr>
<td></td>
<td>WT(11,11)</td>
<td>R_{J}^{O-1} (N)</td>
</tr>
<tr>
<td></td>
<td>COM</td>
<td></td>
</tr>
<tr>
<td></td>
<td>L1</td>
<td>Labels for printout</td>
</tr>
<tr>
<td></td>
<td>L2</td>
<td></td>
</tr>
<tr>
<td>/COMM1/</td>
<td>IRR</td>
<td>Error condition set by subroutine NAMECRT</td>
</tr>
<tr>
<td></td>
<td>IPL</td>
<td>Overlay level numbers used by subroutine PCCEXEC</td>
</tr>
<tr>
<td></td>
<td>ISL</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TABLE(199)</td>
<td>Array of floating-point numbers to be displayed and/or changed</td>
</tr>
<tr>
<td></td>
<td>INTEG(99)</td>
<td>Array of integer numbers to be displayed and/or changed</td>
</tr>
<tr>
<td>COMMON label</td>
<td>FORTRAN variable(s)</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>/COMM1/</td>
<td>LOGIC(20)</td>
<td>Logical array for selecting program options</td>
</tr>
<tr>
<td></td>
<td>NTAB</td>
<td>Dimensions used by subroutines DATABLX and INOUT</td>
</tr>
<tr>
<td></td>
<td>NINT</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NLOG</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NADC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NDAC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NLDI</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NLDO</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NT</td>
<td>Recording frequency for real-time disk file</td>
</tr>
<tr>
<td></td>
<td>AXI</td>
<td>$a_X, I$</td>
</tr>
<tr>
<td></td>
<td>AYI</td>
<td>$a_Y, I$</td>
</tr>
<tr>
<td></td>
<td>AZI</td>
<td>$a_Z, I$</td>
</tr>
<tr>
<td></td>
<td>DRAD</td>
<td>57.2958</td>
</tr>
<tr>
<td></td>
<td>RADD</td>
<td>$(DRAD)^{-1}$</td>
</tr>
<tr>
<td></td>
<td>PI</td>
<td>3.141593</td>
</tr>
<tr>
<td></td>
<td>IR(2)</td>
<td>Array of integers used by subroutine GETTRAN</td>
</tr>
<tr>
<td></td>
<td>NRN</td>
<td>Number of random number sequences</td>
</tr>
<tr>
<td></td>
<td>NPTS</td>
<td>Maximum number of data points</td>
</tr>
<tr>
<td>COMMON label</td>
<td>FORTRAN variable(s)</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>---------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>/COMM1/</td>
<td>ISKIP</td>
<td>Skips initialization statements</td>
</tr>
<tr>
<td></td>
<td>JSKIP</td>
<td></td>
</tr>
<tr>
<td></td>
<td>KSKIP</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MF</td>
<td>Output disk file</td>
</tr>
<tr>
<td></td>
<td>TX</td>
<td>TX</td>
</tr>
<tr>
<td></td>
<td>TY</td>
<td>TY</td>
</tr>
<tr>
<td></td>
<td>TZ</td>
<td>TZ</td>
</tr>
<tr>
<td></td>
<td>AMX</td>
<td>Flag set by subroutine DSPLAY</td>
</tr>
<tr>
<td></td>
<td>AMY</td>
<td>Data format set by subroutine DSPLAY</td>
</tr>
<tr>
<td></td>
<td>AMZ</td>
<td>Buffer used by subroutine DSPLAY</td>
</tr>
<tr>
<td></td>
<td>VARCHNG</td>
<td>Flight data time interval used in program (INC \cdot TT)</td>
</tr>
<tr>
<td></td>
<td>ITYPE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IVARBUF(5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DELX</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NOITSPS</td>
<td>Integration steps per flight data time interval $\frac{\text{DELX}}{\text{DT}}$</td>
</tr>
<tr>
<td></td>
<td>PTSINV</td>
<td>$(N)^{-1}$</td>
</tr>
<tr>
<td>/COMM2/</td>
<td>MAXPAGE</td>
<td>CRT memory allotment</td>
</tr>
<tr>
<td>COMMON label</td>
<td>FORTRAN variable(s)</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>---------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>/COMM2/</td>
<td>LABT</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LABU</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LABV</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LABW</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LABP</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LABQ</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LABR</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LABTH</td>
<td>Axis labels for plotting</td>
</tr>
<tr>
<td></td>
<td>LABPH</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LABAX</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LABAY</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LABAZ</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LABDA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LABDE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LABDR</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FET25(17)</td>
<td>Array containing file environment table for flight data file (TAPE25)</td>
</tr>
<tr>
<td></td>
<td>LUN25</td>
<td>Logical unit number for TAPE25</td>
</tr>
<tr>
<td></td>
<td>NAM25</td>
<td>Name of file TAPE25 used in subroutine CREATEF</td>
</tr>
<tr>
<td>COMMON label</td>
<td>FORTRAN variable(s)</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>/COMM2/</td>
<td>ITRNMLT(7)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IMULTA(7)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INVSEn(7)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IMULTB(7)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INVWT(7)</td>
<td></td>
</tr>
<tr>
<td>/FLIGHT/</td>
<td>UM(201)</td>
<td>(u^M(t_i))</td>
</tr>
<tr>
<td></td>
<td>VM(201)</td>
<td>(v^M(t_i))</td>
</tr>
<tr>
<td></td>
<td>WM(201)</td>
<td>(w^M(t_i))</td>
</tr>
<tr>
<td></td>
<td>PM(201)</td>
<td>(p^M(t_i))</td>
</tr>
<tr>
<td></td>
<td>QM(201)</td>
<td>(q^M(t_i))</td>
</tr>
<tr>
<td></td>
<td>RM(201)</td>
<td>(r^M(t_i))</td>
</tr>
<tr>
<td></td>
<td>THM(201)</td>
<td>(\theta^M(t_i))</td>
</tr>
<tr>
<td></td>
<td>PHM(201)</td>
<td>(\phi^M(t_i))</td>
</tr>
<tr>
<td></td>
<td>AXM(201)</td>
<td>(a^M_{X,I}(t_i))</td>
</tr>
<tr>
<td></td>
<td>AYM(201)</td>
<td>(a^M_{Y,I}(t_i))</td>
</tr>
<tr>
<td></td>
<td>AZM(201)</td>
<td>(a^M_{Z,I}(t_i))</td>
</tr>
<tr>
<td></td>
<td>FDA(201)</td>
<td>(\delta^M_a(t_i))</td>
</tr>
<tr>
<td></td>
<td>FDE(201)</td>
<td>(\delta^M_e(t_i))</td>
</tr>
<tr>
<td></td>
<td>FDR(201)</td>
<td>(\delta^M_r(t_i))</td>
</tr>
</tbody>
</table>

Arrays of matrix operation and dimension information used by subroutine MASCNT.
COMMON label FORTRAN variable(s) Description

/FLIGHT/

FBT(201) $\beta_T(t_i)$
FDB(201) $\delta \bar{B}(t_i)$
FDELB(201) $\Delta \bar{B}(t_i)$
FPPE(201) $P_E(t_i)$
FTPER(201) $P_T(t_i)$
BETAT $\beta_T$
ETA $\eta_E$
ETAT $\eta_T$
FCT(12) Array containing function for $C_T\beta_T\beta_T$

Display Arrays

The real-time simulation program uses specified arrays (subroutine DSPLAY arrays) for displaying and/or changing the value of desired program variables. (See appendix A.) The desired program variables as defined in these specified arrays are assigned display addresses as shown in the following table:

<table>
<thead>
<tr>
<th>Subroutine DSPLAY arrays</th>
<th>Display address</th>
<th>Maximum number of elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>TABLE(I)</td>
<td>I</td>
<td>199</td>
</tr>
<tr>
<td>INTEG(I)</td>
<td>I + 200</td>
<td>99</td>
</tr>
<tr>
<td>LOGIC(I)</td>
<td>I + 300</td>
<td>99</td>
</tr>
<tr>
<td>ADC(I) (not used)</td>
<td>I + 400</td>
<td>99</td>
</tr>
<tr>
<td>DAC(I)</td>
<td>I + 500</td>
<td>99</td>
</tr>
<tr>
<td>LDISI(I)</td>
<td>I + 600</td>
<td>99</td>
</tr>
<tr>
<td>LDISO(I)</td>
<td>I + 700</td>
<td>199</td>
</tr>
</tbody>
</table>
This type of addressing is called "IN TABLES" addressing. For program variables not in subroutine DSPLAY arrays, a type of addressing called "NO TABLES" addressing is used.

Subroutine DSPLAY arrays are listed below with their associated FORTRAN variables and descriptions (elements not mentioned are not used). The array elements are equivalenced to the FORTRAN variables, except where equality signs indicate. TABLE is a floating-point number array, and equivalence between FORTRAN variables is indicated by a semicolon.

<table>
<thead>
<tr>
<th>TABLE element(s)</th>
<th>FORTRAN variable(s)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AL(1);UO</td>
<td>u(0)</td>
</tr>
<tr>
<td>2</td>
<td>AL(2);CXO</td>
<td>(CX)^α_a,t,δ_e,t</td>
</tr>
<tr>
<td>3</td>
<td>AL(3);CXAL</td>
<td>CXα_a</td>
</tr>
<tr>
<td>4</td>
<td>AL(4);CXQ</td>
<td>CXq</td>
</tr>
<tr>
<td>5</td>
<td>AL(5);THEO</td>
<td>θ(0)</td>
</tr>
<tr>
<td>6</td>
<td>AL(6);PHIO</td>
<td>φ(0)</td>
</tr>
<tr>
<td>7</td>
<td>AL(7);WO</td>
<td>w(0)</td>
</tr>
<tr>
<td>8</td>
<td>AL(8);CZO</td>
<td>(CZ)^α_a,t,δ_e,t</td>
</tr>
<tr>
<td>9</td>
<td>AL(9);CZAL</td>
<td>CZα_a</td>
</tr>
<tr>
<td>10</td>
<td>AL(10);CZQ</td>
<td>CZq</td>
</tr>
<tr>
<td>11</td>
<td>AL(11);CZDE</td>
<td>CZδ_e</td>
</tr>
<tr>
<td>12</td>
<td>AL(12);QO</td>
<td>q(0)</td>
</tr>
<tr>
<td>13</td>
<td>AL(13);CMO</td>
<td>(C_m)^α_a,t,δ_e,t</td>
</tr>
<tr>
<td>TABLE element(s)</td>
<td>FORTRAN variable(s)</td>
<td>Description</td>
</tr>
<tr>
<td>------------------</td>
<td>---------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>14</td>
<td>AL(14); CMAL</td>
<td>$C_m\alpha_a$</td>
</tr>
<tr>
<td>15</td>
<td>AL(15); CMALD</td>
<td>$C_m\alpha_a$</td>
</tr>
<tr>
<td>16</td>
<td>AL(16); CMQ</td>
<td>$C_mq$</td>
</tr>
<tr>
<td>17</td>
<td>AL(17); CMDE</td>
<td>$C_m\delta_e$</td>
</tr>
<tr>
<td>18</td>
<td>AL(18); VO</td>
<td>$v(0)$</td>
</tr>
<tr>
<td>19</td>
<td>AL(19); CYO</td>
<td>$(C_Y)_{\beta_t, \delta_a, t, \delta_r, t}$</td>
</tr>
<tr>
<td>20</td>
<td>AL(20); CYB</td>
<td>$C_Y\beta$</td>
</tr>
<tr>
<td>21</td>
<td>AL(21); CYBD</td>
<td>$C_Y\beta$</td>
</tr>
<tr>
<td>22</td>
<td>AL(22); CYP</td>
<td>$C_Yp$</td>
</tr>
<tr>
<td>23</td>
<td>AL(23); CYR</td>
<td>$C_Yr$</td>
</tr>
<tr>
<td>24</td>
<td>AL(24); CYDR</td>
<td>$C_Y\delta_r$</td>
</tr>
<tr>
<td>25</td>
<td>AL(25); PO</td>
<td>$p(0)$</td>
</tr>
<tr>
<td>26</td>
<td>AL(26); CLO</td>
<td>$(C_t)_{\beta_t, \delta_a, t, \delta_r, t}$</td>
</tr>
<tr>
<td>27</td>
<td>AL(27); CLB</td>
<td>$C_t\beta$</td>
</tr>
<tr>
<td>28</td>
<td>AL(28); CLBD</td>
<td>$C_t\beta$</td>
</tr>
<tr>
<td>29</td>
<td>AL(29); CLP</td>
<td>$C_t\rho$</td>
</tr>
<tr>
<td>30</td>
<td>AL(30); CLR</td>
<td>$C_t\eta$</td>
</tr>
<tr>
<td>TABLE element(s)</td>
<td>FORTRAN variable(s)</td>
<td>Description</td>
</tr>
<tr>
<td>------------------</td>
<td>----------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>31</td>
<td>AL(31); CLDR</td>
<td>$C_l\delta_r$</td>
</tr>
<tr>
<td>32</td>
<td>AL(32); CLDA</td>
<td>$C_l\delta_a$</td>
</tr>
<tr>
<td>33</td>
<td>AL(33); RO</td>
<td>$r(0)$</td>
</tr>
<tr>
<td>34</td>
<td>AL(34); CNO</td>
<td>$(C_n)_{\beta t, \delta_a t, \delta_r t}$</td>
</tr>
<tr>
<td>35</td>
<td>AL(35); CNB</td>
<td>$C_n\beta$</td>
</tr>
<tr>
<td>36</td>
<td>AL(36); CNBD</td>
<td>$C_n\delta$</td>
</tr>
<tr>
<td>37</td>
<td>AL(37); CNP</td>
<td>$C_n\delta_p$</td>
</tr>
<tr>
<td>38</td>
<td>AL(38); CNR</td>
<td>$C_n\delta_r$</td>
</tr>
<tr>
<td>39</td>
<td>AL(39); CNDR</td>
<td>$C_n\delta_r$</td>
</tr>
<tr>
<td>40</td>
<td>AL(40); CNDA</td>
<td>$C_n\delta_a$</td>
</tr>
<tr>
<td>50</td>
<td>UMAX</td>
<td></td>
</tr>
<tr>
<td>51</td>
<td>VMAX</td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>WMAX</td>
<td></td>
</tr>
<tr>
<td>53</td>
<td>PMAX</td>
<td></td>
</tr>
<tr>
<td>54</td>
<td>QMAX</td>
<td>CalComp, CRT, and DAC scaling information</td>
</tr>
<tr>
<td>55</td>
<td>RMAX</td>
<td></td>
</tr>
<tr>
<td>56</td>
<td>THMAX</td>
<td></td>
</tr>
<tr>
<td>57</td>
<td>PHMAX</td>
<td></td>
</tr>
<tr>
<td>58</td>
<td>AXMAX</td>
<td></td>
</tr>
<tr>
<td>TABLE element(s)</td>
<td>FORTRAN variable(s)</td>
<td>Description</td>
</tr>
<tr>
<td>------------------</td>
<td>---------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>59</td>
<td>AYMAX</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>AZMAX</td>
<td></td>
</tr>
<tr>
<td>62</td>
<td>DAMAX</td>
<td>CalComp, CRT; and DAC scaling information</td>
</tr>
<tr>
<td>63</td>
<td>DEMAX</td>
<td></td>
</tr>
<tr>
<td>64</td>
<td>DRMAX</td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>UMULT</td>
<td></td>
</tr>
<tr>
<td>66</td>
<td>VMULT</td>
<td></td>
</tr>
<tr>
<td>67</td>
<td>WMULT</td>
<td></td>
</tr>
<tr>
<td>68</td>
<td>PMULT</td>
<td></td>
</tr>
<tr>
<td>69</td>
<td>QMULT</td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>RMULT</td>
<td></td>
</tr>
<tr>
<td>71</td>
<td>THMULT</td>
<td>Flight test data multipliers</td>
</tr>
<tr>
<td>72</td>
<td>PHMULT</td>
<td></td>
</tr>
<tr>
<td>73</td>
<td>AXMULT</td>
<td></td>
</tr>
<tr>
<td>74</td>
<td>AYMULT</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>AZMULT</td>
<td></td>
</tr>
<tr>
<td>76</td>
<td>DAMULT</td>
<td></td>
</tr>
<tr>
<td>77</td>
<td>DEMULT</td>
<td></td>
</tr>
<tr>
<td>78</td>
<td>DRMULT</td>
<td></td>
</tr>
<tr>
<td>TABLE element(s)</td>
<td>FORTRAN variable(s)</td>
<td>Description</td>
</tr>
<tr>
<td>------------------</td>
<td>---------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>79</td>
<td>UBIAS</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>VBIAS</td>
<td></td>
</tr>
<tr>
<td>81</td>
<td>WBIAS</td>
<td></td>
</tr>
<tr>
<td>82</td>
<td>PBIAS</td>
<td></td>
</tr>
<tr>
<td>83</td>
<td>QBIAS</td>
<td></td>
</tr>
<tr>
<td>84</td>
<td>RBIAS</td>
<td>Flight test data biases</td>
</tr>
<tr>
<td>85</td>
<td>THBIAS</td>
<td></td>
</tr>
<tr>
<td>86</td>
<td>PHBIAS</td>
<td></td>
</tr>
<tr>
<td>87</td>
<td>AXBIAS</td>
<td></td>
</tr>
<tr>
<td>88</td>
<td>AYBIAS</td>
<td></td>
</tr>
<tr>
<td>89</td>
<td>AZBIAS</td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>DABIAS</td>
<td>$\delta_{a,t}$</td>
</tr>
<tr>
<td>91</td>
<td>DEBIAS</td>
<td>$\delta_{e,t}$</td>
</tr>
<tr>
<td>92</td>
<td>DRBIAS</td>
<td>$\delta_{r,t}$</td>
</tr>
<tr>
<td>98</td>
<td>RUN</td>
<td>Run number</td>
</tr>
<tr>
<td>99</td>
<td>PASS</td>
<td>Iteration number</td>
</tr>
<tr>
<td>100</td>
<td>AJP</td>
<td>$\sum_{i=1}^{N} \eta_{J}^{T}(t_{i}) \eta_{J}(t_{i})$</td>
</tr>
<tr>
<td>101-104</td>
<td>DRM(4)</td>
<td>Array of desired random means</td>
</tr>
<tr>
<td>TABLE element(s)</td>
<td>FORTRAN variable(s)</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>117</td>
<td>AIX</td>
<td>Ix</td>
</tr>
<tr>
<td>118</td>
<td>AIY</td>
<td>Iy</td>
</tr>
<tr>
<td>119</td>
<td>AIZ</td>
<td>Iz</td>
</tr>
<tr>
<td>120</td>
<td>AIXZ</td>
<td>Ixz</td>
</tr>
<tr>
<td>121</td>
<td>WEIGHT</td>
<td>Weight of aircraft (mg)</td>
</tr>
<tr>
<td>122</td>
<td>GRAV</td>
<td>g</td>
</tr>
<tr>
<td>123</td>
<td>RHO</td>
<td>ρ</td>
</tr>
<tr>
<td>124</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>125</td>
<td>B</td>
<td>b</td>
</tr>
<tr>
<td>126</td>
<td>CBAR</td>
<td>c</td>
</tr>
<tr>
<td>127</td>
<td>DEAMPL</td>
<td>Amplitude of δe for test case</td>
</tr>
<tr>
<td>128</td>
<td>DEFREQ</td>
<td>Frequency of δe for test case</td>
</tr>
<tr>
<td>129</td>
<td>ALPHAT</td>
<td>αa,t</td>
</tr>
<tr>
<td>130</td>
<td>DT</td>
<td>Integration step size (H = DT)</td>
</tr>
<tr>
<td>131</td>
<td>TT</td>
<td>Time interval for flight test data tape</td>
</tr>
<tr>
<td>132</td>
<td>TS</td>
<td>Tape starting time for putting in flight data</td>
</tr>
<tr>
<td>133</td>
<td>TIMF</td>
<td>Final time for CRT display</td>
</tr>
<tr>
<td>134</td>
<td>=T</td>
<td>t</td>
</tr>
<tr>
<td>135</td>
<td>=U</td>
<td>u</td>
</tr>
<tr>
<td>TABLE element(s)</td>
<td>FORTRAN variable(s)</td>
<td>Description</td>
</tr>
<tr>
<td>------------------</td>
<td>---------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>136</td>
<td>=V</td>
<td>v</td>
</tr>
<tr>
<td>137</td>
<td>=W</td>
<td>w</td>
</tr>
<tr>
<td>138</td>
<td>=P</td>
<td>p</td>
</tr>
<tr>
<td>139</td>
<td>=Q</td>
<td>q</td>
</tr>
<tr>
<td>140</td>
<td>=R</td>
<td>r</td>
</tr>
<tr>
<td>141</td>
<td>=THE</td>
<td>θ</td>
</tr>
<tr>
<td>142</td>
<td>=PHI</td>
<td>φ</td>
</tr>
<tr>
<td>143</td>
<td>=PSI</td>
<td>ψ</td>
</tr>
<tr>
<td>144</td>
<td>=UDOT</td>
<td>ēu</td>
</tr>
<tr>
<td>145</td>
<td>=VDOT</td>
<td>ēv</td>
</tr>
<tr>
<td>146</td>
<td>=WDOT</td>
<td>ēw</td>
</tr>
<tr>
<td>147</td>
<td>=PDOT</td>
<td>ēp</td>
</tr>
<tr>
<td>148</td>
<td>=QDOT</td>
<td>ēq</td>
</tr>
<tr>
<td>149</td>
<td>=RDOT</td>
<td>ēr</td>
</tr>
<tr>
<td>150</td>
<td>=THEDOT</td>
<td>ð</td>
</tr>
<tr>
<td>151</td>
<td>=PHIDOT</td>
<td>ðφ</td>
</tr>
<tr>
<td>152</td>
<td>=PSIDOT</td>
<td>ðψ</td>
</tr>
<tr>
<td>154</td>
<td>XX</td>
<td>x_X</td>
</tr>
<tr>
<td>TABLE element(s)</td>
<td>FORTRAN variable(s)</td>
<td>Description</td>
</tr>
<tr>
<td>------------------</td>
<td>---------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>155</td>
<td>YX</td>
<td>yX</td>
</tr>
<tr>
<td>156</td>
<td>ZX</td>
<td>zX</td>
</tr>
<tr>
<td>157</td>
<td>XY</td>
<td>xY</td>
</tr>
<tr>
<td>158</td>
<td>YY</td>
<td>yY</td>
</tr>
<tr>
<td>159</td>
<td>ZY</td>
<td>zY</td>
</tr>
<tr>
<td>160</td>
<td>XZ</td>
<td>xZ</td>
</tr>
<tr>
<td>161</td>
<td>YZ</td>
<td>yZ</td>
</tr>
<tr>
<td>162</td>
<td>ZZ</td>
<td>zZ</td>
</tr>
<tr>
<td>169</td>
<td>CMCON</td>
<td>Constant used with LOGIC(6)</td>
</tr>
<tr>
<td>170</td>
<td>DALMLT</td>
<td>Parameter step size multiplier</td>
</tr>
<tr>
<td>171</td>
<td>UCRTBI</td>
<td>u bias for CalComp, CRT, and DAC presentations</td>
</tr>
<tr>
<td>172</td>
<td>AIW</td>
<td>iW</td>
</tr>
<tr>
<td>173</td>
<td>CTO</td>
<td>C_{T,o}</td>
</tr>
<tr>
<td>174</td>
<td>CTTO</td>
<td>C_{TTo}</td>
</tr>
<tr>
<td>175</td>
<td>CTB</td>
<td>C_{TB}</td>
</tr>
<tr>
<td>176</td>
<td>CTBT</td>
<td>C_{T\beta_T}</td>
</tr>
<tr>
<td>177</td>
<td>D</td>
<td>D_E</td>
</tr>
<tr>
<td>178</td>
<td>CAPDT</td>
<td>D_T</td>
</tr>
</tbody>
</table>
### TABLE element(s) FORTRAN variable(s) Description

<table>
<thead>
<tr>
<th>Element(s)</th>
<th>Variable(s)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>179</td>
<td>ELBAR</td>
<td>( l )</td>
</tr>
<tr>
<td>180</td>
<td>ELTP</td>
<td>( l_{TP} )</td>
</tr>
<tr>
<td>181</td>
<td>RB</td>
<td>( r_b )</td>
</tr>
<tr>
<td>182</td>
<td>PPER</td>
<td>( P_E )</td>
</tr>
<tr>
<td>183</td>
<td>TPER</td>
<td>( P_T )</td>
</tr>
<tr>
<td>184</td>
<td>BTBIAS</td>
<td></td>
</tr>
<tr>
<td>185-186</td>
<td>PPERBI</td>
<td>Flight test data biases</td>
</tr>
<tr>
<td>187</td>
<td>DET1</td>
<td>Inverse determinant of parameter covariance matrix</td>
</tr>
<tr>
<td>188</td>
<td>DET2</td>
<td>(</td>
</tr>
<tr>
<td>191-194</td>
<td>DRSD(4)</td>
<td>Array of desired standard deviations of random numbers</td>
</tr>
</tbody>
</table>

INTEG is an integer number array.

### INTEG element(s) FORTRAN variable(s) Description

<table>
<thead>
<tr>
<th>Element(s)</th>
<th>Variable(s)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-40</td>
<td>INTY(11)</td>
<td>Array denoting activeness of parameters</td>
</tr>
<tr>
<td>51-61</td>
<td>NOPTS</td>
<td>Array denoting activeness of performance index variables</td>
</tr>
<tr>
<td>62</td>
<td>INC</td>
<td>N</td>
</tr>
<tr>
<td>63</td>
<td></td>
<td>Sample rate for flight data tape</td>
</tr>
</tbody>
</table>
INTEGR FORTRAN

element(s) variable(s) Description

64 IPRINT Selects options in overlay level (2,0)

65 NPLOT Density of plotting symbols for CalComp plots

66 IREAD Selects options in overlay level (3,0)

67 KSCAN Scan rate, used by subroutine SCANNER

81-88 INTX(8) Array denoting activeness of equation variables

LOGIC is a logical array and the descriptions are for a true (.T.) value.

LOGIC element(s) Description

1 Calculate \( R_J^{-1} (N) \)

2 Diagonalize \( R_J(N) \)

3 Set \( P_E = FPPER(1) \)

4 Set \( P_T = FTPER(1) \)

5 Calculate \( C_T \beta_T \) from FCT(12) and \( \beta_T \)

6 Set \( CZ_{\delta_e} = CMCON \cdot Cm_{\delta_e} \)

7 Set longitudinal states equal to flight test data

8 Set \( \alpha_{a,t} = \tan^{-1} \frac{w(0)}{u(0)} \)

9 Calculate parameters to trim \( \ddot{x} \) to zero

10 Automate LOGIC(9)

11 Automate two-pass updating
DAC is an output array for the time history recorder.

### DAC element(s) | FORTRAN variable(s) | Description
--- | --- | ---
1 | \((U-UCRTBI)/UMAX\) | Normalized time history recordings
2 | \(V/VMAX\) | 
3 | \(W/WMAX\) | 
4 | \(P/PMAX\) | 
5 | \(Q/QMAX\) | 
6 | \(R/RMAX\) | 
7 | \(THE/THMAX\) | 
8 | \(PHI/PHMAX\) | 

LDISI is a logical discrete input array where the descriptions are for true (.T.) values of the switches.

### LDISI element(s) | FORTRAN variable(s) | Description
--- | --- | ---
1-16 | | Data entry keyboard
17 | | OPERATE (OPER) mode switch
18 | | HOLD mode switch
19 | | RESET mode switch
20 | | TERMINATE (TERM) mode switch
21 | | CHANGE mode switch
22 | | SCAN mode switch
<table>
<thead>
<tr>
<th>LDISI element(s)</th>
<th>FORTRAN variable(s)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td></td>
<td>RELEASE mode switch, releases CHANGE or SCAN mode switch</td>
</tr>
<tr>
<td>27</td>
<td></td>
<td>ERASE mode switch</td>
</tr>
<tr>
<td>29</td>
<td></td>
<td>IDLE mode switch</td>
</tr>
<tr>
<td>30</td>
<td></td>
<td>PRINT mode switch</td>
</tr>
<tr>
<td>31</td>
<td></td>
<td>READ mode switch</td>
</tr>
<tr>
<td>32</td>
<td></td>
<td>RELEASE mode switch, releases ERASE, IDLE, PRINT, or READ mode switch</td>
</tr>
<tr>
<td>33</td>
<td>FSS(1)</td>
<td>Accelerometer variables for CRT display and CalComp plot</td>
</tr>
<tr>
<td>34</td>
<td>FSS(2)</td>
<td>CalComp plot of flight data only</td>
</tr>
<tr>
<td>35</td>
<td>FSS(3)</td>
<td>Fill flight data arrays with pseudo data</td>
</tr>
<tr>
<td>36</td>
<td>FSS(4)</td>
<td>Initialize variable dimensioning</td>
</tr>
<tr>
<td>37</td>
<td>FSS(5)</td>
<td>Iteration printout on MF file</td>
</tr>
<tr>
<td>39</td>
<td>FSS(7)</td>
<td>Lateral variables for CRT display and CalComp plot</td>
</tr>
<tr>
<td>40</td>
<td>FSS(8)</td>
<td>Control variables for CRT display and CalComp plot</td>
</tr>
<tr>
<td>41</td>
<td>FSS(9)</td>
<td>Pseudo flight controls</td>
</tr>
<tr>
<td>42</td>
<td>FSS(10)</td>
<td>Skip update of $\dot{\alpha}$</td>
</tr>
<tr>
<td>43</td>
<td>FSS(11)</td>
<td>Activates typewriter for subroutine DSPLAY</td>
</tr>
<tr>
<td>LDISI element(s)</td>
<td>FORTRAN variable(s)</td>
<td>Description</td>
</tr>
<tr>
<td>------------------</td>
<td>---------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>44</td>
<td>FSS(12)</td>
<td>Retain $\bar{x}(0)$ in ALG array</td>
</tr>
<tr>
<td>45</td>
<td>FSS(13)</td>
<td>Exit CRT or CalComp loop</td>
</tr>
<tr>
<td>46</td>
<td>FSS(14)</td>
<td>Replot the CRT or CalComp plot</td>
</tr>
<tr>
<td>47</td>
<td>FSS(15)</td>
<td>Enter CRT loop</td>
</tr>
<tr>
<td>48</td>
<td>FSS(16)</td>
<td>&quot;IN TABLES&quot; addressing (false (.F.) for &quot;NO TABLES&quot; addressing)</td>
</tr>
</tbody>
</table>

LDISO is a logical discrete output array used to turn the white indicator lights (WL) on (.T.) and off (.F.). The diagnostics are given for .T. value.

<table>
<thead>
<tr>
<th>LDISO element</th>
<th>FORTRAN variable(s)</th>
<th>Diagnostic</th>
</tr>
</thead>
<tbody>
<tr>
<td>61</td>
<td>WL(1)</td>
<td>Default value used for IPRINT</td>
</tr>
<tr>
<td>62</td>
<td>WL(2)</td>
<td>CalComp plot completed</td>
</tr>
<tr>
<td>63</td>
<td>WL(3)</td>
<td>Error in CalComp plot loop</td>
</tr>
<tr>
<td>66</td>
<td>WL(6)</td>
<td>Default value used for IREAD</td>
</tr>
<tr>
<td>67</td>
<td>WL(7)</td>
<td>Attempted to read flight data beyond end of file</td>
</tr>
<tr>
<td>70</td>
<td>WL(10)</td>
<td>$N &gt; NPTS$</td>
</tr>
<tr>
<td>71</td>
<td>WL(11)</td>
<td>$IP &gt; IPAR$</td>
</tr>
<tr>
<td>72</td>
<td>WL(12)</td>
<td>Inactive equation variable in performance index</td>
</tr>
<tr>
<td>73</td>
<td>WL(13)</td>
<td>$</td>
</tr>
<tr>
<td>LDISO element(s)</td>
<td>FORTRAN variable(s)</td>
<td>Diagnostic</td>
</tr>
<tr>
<td>------------------</td>
<td>---------------------</td>
<td>------------</td>
</tr>
<tr>
<td>74</td>
<td>WL(14)</td>
<td>$u &lt; 5$</td>
</tr>
<tr>
<td>75</td>
<td>WL(15)</td>
<td>$</td>
</tr>
<tr>
<td>76</td>
<td>WL(16)</td>
<td>$</td>
</tr>
<tr>
<td>77</td>
<td>WL(17)</td>
<td>Invalid flight data location used</td>
</tr>
<tr>
<td>78</td>
<td>WL(18)</td>
<td>DET1 = 0</td>
</tr>
<tr>
<td>79</td>
<td>WL(19)</td>
<td>DET2 = 0</td>
</tr>
<tr>
<td>80</td>
<td>WL(20)</td>
<td>In CRT loop</td>
</tr>
</tbody>
</table>

**Subroutine Descriptions**

The following are the subroutines used and brief statements describing their functions.

<table>
<thead>
<tr>
<th>Subroutine</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASCALE</td>
<td>Determines origin and scale factor of time axis for CalComp plots</td>
</tr>
<tr>
<td>ATERM</td>
<td>Does final processing and halts execution</td>
</tr>
<tr>
<td>AXES</td>
<td>Draws and annotates axes for CalComp plots</td>
</tr>
<tr>
<td>CALPLT</td>
<td>Moves plotter pen to new location or signals end of CalComp job</td>
</tr>
<tr>
<td>CLRPLLOT</td>
<td>Clears the CRT plot of the calculated variables</td>
</tr>
<tr>
<td>CLRTABL</td>
<td>Clears existing plot parameter tables for CRT variables</td>
</tr>
<tr>
<td>CREATEF</td>
<td>Creates disk file for flight data tape</td>
</tr>
<tr>
<td>CRTPLOT</td>
<td>Establishes plot parameters for CRT variables and/or generates annotated plotting grids</td>
</tr>
<tr>
<td>Subroutine</td>
<td>Description</td>
</tr>
<tr>
<td>------------</td>
<td>-------------</td>
</tr>
<tr>
<td>CYCLE</td>
<td>Sets up return address for subroutine RECYCLE</td>
</tr>
<tr>
<td>DATABLX</td>
<td>Specifies the variable arrays for subroutine DSPLAY</td>
</tr>
<tr>
<td>DAYTIM</td>
<td>Provides date and time of day</td>
</tr>
<tr>
<td>DSPLAY</td>
<td>Activates data entry keyboard and digital decimal display unit</td>
</tr>
<tr>
<td>ENDPLOT</td>
<td>Marks an end to the CRT plot</td>
</tr>
<tr>
<td>ERASE</td>
<td>Erases data on real-time disk file</td>
</tr>
<tr>
<td>GETRAN</td>
<td>Generates Gaussian random numbers</td>
</tr>
<tr>
<td>GRID</td>
<td>Draws grid for CalComp plots</td>
</tr>
<tr>
<td>HALT</td>
<td>Signals completion of real-time portion of program</td>
</tr>
<tr>
<td>IGRATE1</td>
<td>Integrates variables in DERINT(2,J) and stores results in DERINT(1,J) (J = 1, 2, . . ., NEQ)</td>
</tr>
<tr>
<td>INOUT</td>
<td>Sets up arrays for input/output conversion</td>
</tr>
<tr>
<td>LDRSEC</td>
<td>Provides for PRINT and READ mode entries into subroutine RTMODE</td>
</tr>
<tr>
<td>LEROY</td>
<td>Controls CalComp plotting with liquid ink pen</td>
</tr>
<tr>
<td>LINE</td>
<td>CalComp routine to draw a continuous line and/or a symbol</td>
</tr>
<tr>
<td>MASCNT</td>
<td>Performs matrix algebra operations</td>
</tr>
<tr>
<td>NAMECRT</td>
<td>Identifies and initializes usage of the CRT console</td>
</tr>
<tr>
<td>NM218</td>
<td>Initializes usage of typewriter</td>
</tr>
<tr>
<td>NOTATE</td>
<td>Draws alphanumeric characters for CalComp plots</td>
</tr>
<tr>
<td>Subroutine</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>NUMBER</td>
<td>Draws floating-point numbers for CalComp plots</td>
</tr>
<tr>
<td>OPERATE</td>
<td>Causes readout of DAC and LDISO arrays and readin of LDISI array</td>
</tr>
<tr>
<td>PCCEEXEC</td>
<td>Controls overlay loading for RTS jobs</td>
</tr>
<tr>
<td>PLAYBAK</td>
<td>Plays back data recorded on real-time disk file, one frame at a time</td>
</tr>
<tr>
<td>PRINTER</td>
<td>Causes routing of MF disk file to printer</td>
</tr>
<tr>
<td>PSEUDO</td>
<td>Saves plotting information in order to use CalComp postprocessor</td>
</tr>
<tr>
<td>READOUT</td>
<td>Specifies quantities to be recorded and frequency of recording for the real-time disk file</td>
</tr>
<tr>
<td>READY</td>
<td>Signals that the program is ready for real-time operation</td>
</tr>
<tr>
<td>RECIN</td>
<td>Inputs flight test data</td>
</tr>
<tr>
<td>RECORD</td>
<td>Records quantities as specified in subroutine READOUT</td>
</tr>
<tr>
<td>RECYCLE</td>
<td>Signals end of a cycle when in the OPERATE mode and returns to address specified by subroutine CYCLE</td>
</tr>
<tr>
<td>RITECRT</td>
<td>Issues plotting requests to CRT system</td>
</tr>
<tr>
<td>RTMODE</td>
<td>Entry into the mode control routine</td>
</tr>
<tr>
<td>SCANNER</td>
<td>Increments display address</td>
</tr>
<tr>
<td>TYPEVAR</td>
<td>Types out data displayed on DDDU</td>
</tr>
<tr>
<td>UNLODE</td>
<td>Erases data stored on CRT file</td>
</tr>
<tr>
<td>XDSPLAY</td>
<td>Initializes data entry keyboard and DDDU, and routes program listing</td>
</tr>
</tbody>
</table>
OVERLAY Program Descriptions, Flow Charts, and Listings

The program uses RTS central memory overlay capabilities controlled by subroutine PCCEXEC where level (4,0) is the real-time operational level. A brief description, flow chart, and FORTRAN source listing are presented for each overlay level (excluding subroutines previously described).

OVERLAY(XC142FL,0,0). - The main overlay, level (0,0), is always resident in central memory. It includes the labeled COMMON, the initial call to subroutine PCCEXEC, and other system initialization calls.

```
OVERLAY (XC142FL,0,0)

PROGRAM XC142A (INPUT, OUTPUT)

Memory allocation

Call PSEUDO

Call NAMECRT

Initialize overlay
file name XC142FL

Call PCCEXEC

OVERLAY (XC142FL,1,0)

Call DSPLAY

Call CLRTABL

(END

(Not executed but causes loading in this overlay)```
OVERLAY(XC142FL,0,0)

PROGRAM XC142A(INPUT,OUTPUT)

LOGICAL LDISI,LDISO,LOGIC,VARCHNG

COMMON /INTCOMM/T,H,INT,NEG,ISHEME,DERINT(2,249)

COMMON /INTINR/INTERN(5,249)

COMMON /REALTIM/ADC(32),DAC(64),LDISI(108),LDISO(196),NOPER,NHOLD

1,NRESET,INTERM,NPRINT,NREAD

COMMON /ALGOR/NPAR,IPAR,INTP(30),IP,INTV(8),IV,INTA(11),IA,IA1,IA

12,PARAM(40),DPARAM(30),ALV(11),DVAR(8),DALG(11),ALG(40),IAC(40),IE

2VEN,WT(11,11),COM,L1,L2

COMMON /COMMIX/IRR,IPL,ISL,TABLE(199),INTEG(99),LOGIC(20),NTAB,NIN

1,T,NLOG,NAOC,NDAC,NLDI,NLD0,NT,AXI,AYI,AZI,ORAD,RADD,P1,IR(2),NRN,N

2,PTS,JSKIP,JSKIP,JSKIP,JSKIP,MF,TX,TY,TZ,AMX,AMY,AMZ,VARCHNG,ITYPE,IVARBU

3,F(5),DELX,NOTSPS,PTSINV

COMMON /COMM2/MAXPAGE,LABT,LABU,LABV,LABW,LABP,LABQ,LABR,LABTH,LAB

1,BPH,LABAX,LABAY,LABAY,LABDA,LABD,a,LABR,FET25(17),LUN25,NAM25,ITRN

2,MLT(7),IMULTA(7),INVSEN(7),IMULTB(7),INVWT(7)

COMMON /FLIGHT/UM(201),VM(201),WM(201),PM(201),QM(201),RM(201),TH

1,M(201),PHM(201),AXM(201),AYM(201),AZM(201),FDA(201),FDE(201),FDR(2)

201,FBT(201),FDB(201),FDELB(201),FPER(201),FTP(201),BETAT,ETA,E

3,TAT,FCT(12),CTT,CT

CALL PSEUDO

CALL NAMECRT(6LCRTYPE,IRR)

XC142FL=7LXC142FL

CALL PCCEEXEC(XC142FL, MF, 90034S, LDISI, IPL, ISL)

CALL DISPLAY

CALL CLRTABLE

90034 FORMAT (54HXC-142A C1123 13927T S. C. MAYHEW ROOM 2131C)

END
OVERLAY (XC142FL,1,0). - The initialization overlay, level (1,0), is automatically loaded by the initial call to subroutine PCCEXEC. Upon completion of level (1,0), overlay (4,0) is automatically loaded.

```
OVERLAY (XC142FL,1,0)

PROGRAM INIT

Memory allocation

Call DATABLX

Call INOUT

Call NM218

Call READOUT

Program initialization

RETURN

OVERLAY (XC142FL,4,0)

END
```
TABLE(I)=0.
DO 20 I=65,78
20 TABLE(I)=1

NINT=99
DO 30 I=1,NINT
30 INTEG(I)=0

NLOG=20
DO 40 I=1,NLOG
40 LOGIC(I)=.F.
LOGIC(1)=.T.
LOGIC(2)=.T.
NADC=0
NDAC=8
NLDI=48
DO 50 I=1,NLDI
50 LDISI(I)=.F.
NLDO=180
DO 60 I=1,NLDO
60 LDISO(I)=.FALSE.
CALL DATABLX (TABLE,NTAB,INTEG,NINT,LOGIC,NLOG,A DC,NADC, DAC,NDAC,L DISI,NLDI,L DISO,NLDO)
CALL INOUT (ADC,NADC,DAC,NDAC,LDISI,NLDI,LDISO,NLDO)
CALL NM218 (5LOSCAR)
NT=1
CALL READOUT (6*NT,U,V,W,P,Q,R)
CALL READOUT (6*NT,T,THE PHI,AXI,AYI,AZI)

DRAD=57.2958
RADD=1./DRAD
PL=3.141593
IR(1)=13
IR(2)=2357
NRN=4
NPTS=201
ISKIP=JSKIP=KSKIP=0
TY=0.
MAXPAGE=10
LABT=10HTIME (SEC)
LABU=10HU (FT/SEC)
LABV=10HV (FT/SEC)
LABW=10HW (FT/SEC)
LABP=10HP (RAD/SEC)
LABO=10HQ (RAD/SEC)
LABR=10HR (RAD/SEC)
LABTH=10HTHETA (RAD)
LABPH=10PHI (RAD)
LABAX=10HAXI (G)
LABAY=10HAYI (G)
LABAZ=10HAZI (G)
LABDA=10HDA (RAD)
LABDE=10HDE (RAD)
LABDR=10HDR (RAD)
NAME=6LTAPE2S
DO 70 I=1,7
ITRANMLT(I)=0
IMULTA(I)=0
IMULTB(I)=0
INVSEN(I)=0
INVWT(1)=0
ITRNMLT(1)=23
ITRNMLT(5)=ITRNMLT(6)=IMULTA(6)=INVWT(5)=1
ITRNMLT(7)=IMULTA(5)=IMULTA(7)=INVSEN(5)=IMULTB(5)=IMULTB(6)=IPAR
IMULTB(7)=IPAR
IMULTA(1)=IMULTB(1)=20
IMULTA(4)=IMULTB(4)=1
INVSEN(1)=INVWT(1)=10
INVSEN(4)=INVWT(4)=2
UMAX=20
VMAX=40
WMAX=10
PMA=QMAX=RMAX=.2
THMAX=PHMAX=AXMAX=AYMAX=.4
AZMAX=.2
DAMAX=DEMAD=DRMAX=.1
PASS=-1
AIX=150000
AIX=128000
AIZ=270000
WEIGHT=36050
GRAV=32.17
RHO=.002242
S=534
B=67.5
CBAR=8.07
DEFREQ=1
DT=.03125
TT=.03125
TIMF=10
XX=10
YY=2
ZZ=5
XY=7
YY=9
ZY=4
XZ=2
YZ=5
ZZ=7
DALMLT=1
UCRTBI=200
CT0=.03
D=15.5
DO 80 I=1,8
INTX(I)=1
80  INTY(1)=1
  NOPTS=81
  INC=4
  IPRINT=1
  NPRINT=2
  IREAD=1
  KSCAN=2
  ETA=1232.75/60
  UO=120*1.689
  TMP=5*UO**2
  CXO=-8*ETA**2*D**4*CTO/TMP
  CXAL=-0.29
  WO=5.
  CZO=-2.*WEIGHT/(RHO*TMP)
  CZAL=-4.30
  QO=-0.15
  CMAL=-1.49
  CMQ=-31.14
  VO=10.
  CYB=-1.70
  CYP=0.50
  CYR=0.40
  RO=-0.15
  CLB=-0.18
  CLP=-0.72
  CLR=0.20
  RO=0.15
  CNB=0.06
  CNP=0.05
  CNR=0.70

  INTEG(2)=INTEG(8)=INTEG(9)=INTEG(14)=INTEG(16)=INTEG(20)=1
  INTEG(22)=INTEG(23)=INTEG(27)=INTEG(29)=INTEG(30)=INTEG(35)=1
  INTEG(37)=INTEG(38)=1

  DO 90 I=1,NPAR
     ALG(I)=AL(I)
 90  IAC(I)=INTEG(I)

RETURN
END
OVERLAY (XC142FL,2,0).- The print overlay, level (2,0), is loaded when the PRINT mode is selected on the program control console. The integer IPRINT, preset in level (4,0), selects one of the five options in the PRINT overlay. The CalComp plot option is presented in appendix E. The primary overlay, level (4,0), is automatically loaded upon completion of level (2,0).
OVERLAY(XC142FL,2,0)
PROGRAM XPRINT
LOGICAL FSS(16),LDISI,LDISO,LOGIC,VARCHNG,WL(39)
DIMENSION X(203),Y1(203),Y2(203),Y3(203),Y4(203),Z1(203),Z2(004)
1203,Z3(203),Z4(203),DATE(2),DRM(4),DSRD(4),RAN(4,201),RN(4,005)
2),RSD(4)
COMMON /INTCOMM/ T,H,INTNEQ,ISCHM,DERINT(2,249)
COMMON /INTISTR/ INTERN(5,329)
COMMON /REALTIM/ ADC(32),DAC(64),LDISI(108),LDISO(196),NOPER,NHOLD
1,NRESET,TERM,NPRINT,NREAD
COMMON /ALGR/ NPAR,IPAR,INTP(30),IPRINTV(8),INTA(11),IA,IA1,IA
12,PARAM(40),DPARAM(30),AVP(11),DVAP(8),DARG(11),ARG(40),IAC(40),IE
COMMON /COM1/ IRP,IPSL,STABLE(199),INTEG(99),LOGIC(20),NTAB,NIN
1,T,NLOG,NADCNL,NDLN,NL00,NLAX,AY,AZ,DRAD,RADD,PI,L2,PNR,N
2,PTSL,SKIP,JSKIP,KSKIP,LF,TF,TY,TV,TA,AMX,AMY,AMZ,VARCHNG,ITYPE,IVARBO
3F(5),DELX,NOITSPS,PSINV
COMMON /COM2/ MAXPAGE,LABT,LABU,LADV,LABW,LAPL,LBAR,LABTH,LF
1BPL,LABAX,LABAY,LABAZ,LAGRA,LABDE,LABDR,FET25(17),LUN25,NAM25,ITRM,
2MLT(7),IMULTA(7),INSEG(7),IMULTB(7),INVT(7)
COMMON /FLIGHT/ UM(201),VM(201),WM(201),QM(201),RM(201),TM
1M(201),PM(201),AMX(201),AYM(201),AZM(201),FDA(201),FDE(201),FDR(2
201),FET(201),FDB(201),FDLB(201),FPER(201),FPP(201),FPER(201),FETAT,ETAE
3,TAT,FCTC(2),CTCT
EQUIVALENCE (DERINT(1,1),U), (DERINT(1,2),V), (DERINT(1,3),W), (DE
1PRINT(1,4),P), (DERINT(1,5),O), (DERINT(1,6),R), (DERINT(1,7),THE)
1, (DERINT(1,8),PHI), (LDISO(61),WL(1)), (FSS(1),LDISO(33),), (TABLE(64)
2,350),LOWMAX), (TABLE(51),WMAX), (TABLE(52),WMAX), (TABLE(53),PMAX), (C
4TABLE(54),QMAX), (TABLE(55),RMAX), (TABLE(56),TMAX), (TABLE(57),PM
2,5HMAX), (TABLE(58),AMAX), (TABLE(59),AMAX), (TABLE(60),AZMAX), (T
6,6ABL(62),DAMAX), (TABLE(63),DAMAX), (TABLE(64),DRMAX), (TABLE(98)
6,7RUN), (TABLE(99),PASS), (TABLE(101),DRM(1)), (TABLE(171),UCRTB1)
1,BITABLE(191),DRSD(1)), (INTEG(62),NOPTS), (INTEG(64),IPRINT), (INTEG
3G(65),NLNPLOT)

C IPRINT=1 TO PRINT ICS
C IPRINT=2 TO REWIND MF FILE
C IPRINT=3 TO OBTAIN RANDOM NUMBERS
C IPRINT=4 FOR CALCCOMP PLOT (SET VALUE BEFORE EXITING CRT LOOP AND
C ENTERING PRINT - USES FSS(1,2,7,8,13,14))
C IPRINT=5 TO RETURN (ROUTES OUTPUT)
C WL(1) INDICATES DEFAULT VALUE USED FOR IPRINT
C WL(2) INDICATES CALCCOMP PLOT COMPLETED
C WL(3) INDICATES ERROR IN CALCCOMP PLOT LOOP
L=IPRINT
IPRINT=5
IF ((L>GE1) AND L.LE5)) GO TO 10
RETURN
GO TO (20,30,40,120,340,30)
10 IEVEN=-1
20 RUN=RUN+1
PASS=1
WRITE (MF,350) RUN,(L1,L2,LOGIC(1)),1=1,11
WRITE (MF,360) DVAR(1),(COM,DVAR(1)),1=2,IV
WRITE (MF,370) DARG(1),(COM,DARG(1)),1=2,IA
WRITE (MF,380) (PARAM(1),TABLE(1)),INTEG(1),1=1,NPAR
WRITE (MF,390) (TABLE(1),1=65,92)
WRITE (MF,400) (TABLE(1),1=17,133)
WRITE (MF,410) (TABLE(1),1=154,162)
WRITE (MF,420) (TABLE(1),1=169,186)
WRITE (MF,430) TX,TY,TZ,AMX,AMY,AMZ
WRITE (MF,440) INTEG(62),INTEG(63)
RETURN
REWIND MF
RETURN
CALL GETRAN (IR+1,2,DMY*Y1,Y2)
DO 50 I=1,NRN
DO 50 J=1,NPTS
CALL GETRAN (IR+2,2,RAN(I,J)*Y1,Y2)
CONTINUE
DO 60 I=1,NRN
RN(I)=0.
RSD(I)=0.
DO 60 J=1,NPTS
RN(I)=RN(I)+RAN(I,J)
RSD(I)=RSD(I)+RAN(I,J)*RSD(I)**2
DO 70 I=1,NRN
RN(I)=RN(I)*PTSINV
RSD(I)=SQRT(RSD(I)*PTSINV-RN(I)**2)
RSD(I)=RSD(I)/RSD(I)
DO 80 I=1,NRN
DO 80 J=1,NPTS
RAN(I,J)=RAN(I,J)*RSD(I)+RN(I)
CONTINUE
DO 90 I=1,NRN
RN(I)=0.
RSD(I)=0.
DO 90 J=1,NPTS
RN(I)=RN(I)+RAN(I,J)
RSD(I)=RSD(I)+RAN(I,J)*RSD(I)**2
DO 100 I=1,NRN
RN(I)=RN(I)*PTSINV
RSD(I)=SQRT(RSD(I)*PTSINV-RN(I)**2)
CONTINUE
DO 110 I=1,NOPTS
UM(I)=UM(I)+RAN(I,1)
WM(I)=WM(I)+RAN(2,I)
QM(I)=QM(I)+RAN(3,I)
THM(I)=THM(I)+RAN(4,I)
WRITE (MF,450) RUN,NOPTS,((DRM(I),RN(I),DRSD(I),RSD(I)),I=1,NRN)
RETURN
IF (JSKIP.GT.0) GO TO 130
CALL CALPLT (0.,0.,-3)
CALL LEROY
K=1 FOR SYMBOL EVERY DATA POINT
K=2 FOR SYMBOL EVERY OTHER DATA POINT, ETC.
K=-1 FOR SYMBOL EVERY DATA POINT
K=-NPLLOT
JSKIP=JSKIP+1
B1=SF4=0.
IF (*NOT*FSS(1)) GO TO 140
SF1=AZMAX
SF2=AYMAX
SF3=AXMAX
GO TO 170
IF (*NOT*FSS(7)) GO TO 150
SF1=PHMAX
SF2=VMAX
SF3=RMAX
SF4=PMAX
GO TO 170
IF (*NOT*FSS(8)) GO TO 160
SF1=DRMAX
SF2=DEMAX
SF3=DMAX
GO TO 170
160 SF1=THMAX
SF2=QMAX
SF3=WMAX
SF4=UMAX
BI=UCRTBI
170 ZT=BI+SF4
ZB=BI-SF4
IF (FSS(2).OR.FSS(8)) GO TO 220
I=0
J=-1
180 CALL PLAYBAK(215S)
J=J+1
IF (MOD(J+NOITSPS)*GT*0) GO TO 180
I=I+1
IF (.GT.NOITSPS) GO TO 190
Y1(I)=AZ1
Y2(I)=AY1
Y3(I)=AX1
Y4(I)=O
GO TO 210
190 IF (.GT.FSS(7)) GO TO 200
Y1(I)=PHI
Y2(I)=V
Y3(I)=R
Y4(I)=P
GO TO 210
200 Y1(I)=THE
Y2(I)=Q
Y3(I)=W
Y4(I)=U
210 IF (.GT.FSS(1)) Y1(I)=F1
IF (.GT.FSS(2)) Y2(I)=SF2
IF (.GT.FSS(3)) Y3(I)=SF3
IF (.GT.FSS(3)) Y4(I)=ZT
IF (.LT.-SF1) Y1(I)=SF1
IF (.LT.-SF2) Y2(I)=SF2
IF (.LT.-SF3) Y3(I)=SF3
IF (.LT.-ZB) Y4(I)=ZB
GO TO 220
215 IF (.EQ.NOITSPS) GO TO 220
W(3)=T
RETURN
220 D0 270 I=1+NOITSPS
X(I)=DELY#(I-1)
IF (.NOT.FSS(1)) GO TO 230
Z1(I)=AZM(I)
Z2(I)=AYM(I)
Z3(I)=AXM(I)
Z4(I)=O
GO TO 260
230 IF (.NOT.FSS(7)) GO TO 240
Z1(I)=PHM(I)
Z2(I)=VM(I)
Z3(I)=RM(I)
Z4(I)=PM(I)
GO TO 260
240 IF (.NOT.FSS(8)) GO TO 250
Z1(I)=FDR(I)
Z2(I)=FDE(I)
Z3(I)=FDA(I)
Z4(I)=O
GO TO 260
250 Z1(I)=THM(I) C 0192
Z2(I)=GM(I) C 0193
Z3(I)=WM(I) C 0194
Z4(I)=UM(I) C 0195

260 IF (Z1(I) GT SF1) Z1(I)=SF1 C 0196
IF (Z2(I) GT SF2) Z2(I)=SF2 C 0197
IF (Z3(I) GT SF3) Z3(I)=SF3 C 0198
IF (Z4(I) GT ZT) Z4(I)=ZT C 0199
IF (Z1(I) LT SF1) Z1(I)=SF1 C 0200
IF (Z2(I) LT SF2) Z2(I)=SF2 C 0201
IF (Z3(I) LT SF3) Z3(I)=SF3 C 0202
IF (Z4(I) LT ZB) Z4(I)=ZB C 0203

270 CONTINUE C 0204
CALL DAYTIM (DATE) C 0205
CALL NOTATE (-1.5,0.0,.07,DATE1) C 0206
CALL NOTATE (-1.5,2.4,.07,DATE2) C 0207
CALL NOTATE (-1.5,4.8,.07,HRUN NO*90.0.7) C 0208
CALL NUMBER (-1.5,6.5,.07,90.0.9) C 0209
CALL NOTATE (-1.5,7.5,.07,5HITER=.90.0.5) C 0210
CALL NUMBER (-1.5,8.7,.07,PASS=.90.0.1) C 0211
CALL ASCALE (X5.5,NOPTS,1.10.) C 0212
LPT=NOPTS+1 C 0213
JPT=NOPTS+2 C 0214
XM=X(LPT) C 0215
XS=X(JPT) C 0216
CALL GRID (0.0.5.5.10.4) C 0217
CALL AXES (0.0.5.5.0.0.5.10.10.14.10) C 0218
YM=-SF1 C 0219
YS=SF1 C 0220
Y1(LPT)=Z1(LPT)=YM C 0221
Y1(JPT)=Z1(JPT)=YS C 0222
IF (.NOT.FSS(1)) GO TO 280 C 0223
CALL AXES (0.0.90.0.2.0.0.5.10.12MAZI(G UNITS).14.12) C 0224
CALL LINE (X*Z1,NOPTS,1.0.3.0.7) C 0225
IF (.NOT.FSS(2)) CALL LINE (X*Y1,NOPTS,1.0.0.0.7) C 0226
CALL CALPLT (0.2.75.3) C 0227
CALL GRID (0.0.5.5.10.4) C 0228
CALL AXES (0.0.5.5.0.0.5.10.10.14.10) C 0229
YM=-SF2 C 0230
YS=SF2 C 0231
Y2(LPT)=Z2(LPT)=YM C 0232
Y2(JPT)=Z2(JPT)=YS C 0233
CALL AXES (0.0.90.0.2.0.0.5.10.12MAH(Y(G UNITS).14.12) C 0234
CALL LINE (X*Z2,NOPTS,1.0.3.0.7) C 0235
IF (.NOT.FSS(2)) CALL LINE (X*Y2,NOPTS,1.0.0.0.7) C 0236
CALL CALPLT (0.2.75.3) C 0237
CALL GRID (0.0.5.5.10.4) C 0238
CALL AXES (0.0.5.5.0.0.5.10.10.14.10) C 0239
YM=-SF3 C 0240
YS=SF3 C 0241
Y3(LPT)=Z3(LPT)=YM C 0242
Y3(JPT)=Z3(JPT)=YS C 0243
CALL AXES (0.0.90.0.2.0.0.5.10.12MAHI(G UNITS).14.12) C 0244
CALL LINE (X*Z3,NOPTS,1.0.3.0.7) C 0245
IF (.NOT.FSS(2)) CALL LINE (X*Y3,NOPTS,1.0.0.0.7) C 0246
CALL CALPLT (12.-5.5.-3) C 0247
GO TO 310 C 0248

46
IF (*NOT* FSS(7)) GO TO 290
CALL AXES (0.0.0.90.2.\*YM\+YS\+5.10.\*LABPH\+14.10)
CALL LINE (X\+Z1\+NOPTS\+1\+K\+3.\+07)
IF (*NOT* FSS(2)) CALL LINE (X\+Y1\+NOPTS\+1\+0.0.\+07)
CALL CALPLT (0.\+2.75.\+3)
CALL GRID (0.\+0.\+5.\+5.10.4)
CALL AXES (0.\+0.\+0.\+5.\+XM\+XS\+1.\+10.\+LABT\+14.\+10)
YM=SF2
YS=SF2
Y2(LPT)=Z2(LPT)=YM
Y2(JPT)=Z2(JPT)=YS
CALL AXES (0.\+0.\+90.2.\*YM\+YS\+5.10.\*LABV\+14.10)
VMN=YM*3048
VMX=YS*3048
CALL AXES (5.\+0.\+2.\*VMN\+VMX.\+5.\+10.\+9HV (M/SEC)\+14.\+9)
CALL LINE (X\+Z2\+NOPTS\+1\+K\+3.\+07)
IF (*NOT* FSS(2)) CALL LINE (X\+Y2\+NOPTS\+1\+0.0.\+07)
CALL CALPLT (0.\+2.75.\+3)
CALL GRID (0.\+0.\+5.\+5.10.4)
CALL AXES (0.\+0.\+0.\+5.\+XM\+XS\+1.\+10.\+LABT\+14.\+10)
Y3(LPT)=Z3(LPT)=YM
Y3(JPT)=Z3(JPT)=YS
CALL AXES (0.\+0.\+90.2.\*YM\+YS\+5.10.\*LABR\+14.10)
CALL LINE (X\+Z3\+NOPTS\+1\+K\+3.\+07)
IF (*NOT* FSS(2)) CALL LINE (X\+Y3\+NOPTS\+1\+0.0.\+07)
CALL CALPLT (0.\+2.75.\+3)
CALL GRID (0.\+0.\+5.\+5.10.4)
CALL AXES (0.\+0.\+0.\+5.\+XM\+XS\+1.\+10.\+LABT\+14.\+10)
Y4(LPT)=Z4(LPT)=YM
Y4(JPT)=Z4(JPT)=YS
CALL AXES (0.\+0.\+90.2.\*YM\+YS\+5.10.\*LABD\+14.10)
CALL LINE (X\+Z4\+NOPTS\+1\+K\+3.\+07)
IF (*NOT* FSS(2)) CALL LINE (X\+Y4\+NOPTS\+1\+0.0.\+07)
CALL CALPLT (12.\+8.25.\+3)
GO TO 310

IF (*NOT* FSS(8)) GO TO 300
CALL AXES (0.\+0.\+90.2.\*YM\+YS\+5.10.\*LABD\+14.10)
CALL LINE (X\+Z1\+NOPTS\+1\+K\+3.\+07)
CALL CALPLT (0.\+2.75.\+3)
CALL GRID (0.\+0.\+5.\+5.10.4)
CALL AXES (0.\+0.\+0.\+5.\+XM\+XS\+1.\+10.\+LABT\+14.\+10)
Y2(LPT)=Z2(LPT)=YM
Y2(JPT)=Z2(JPT)=YS
CALL AXES (0.\+0.\+90.2.\*YM\+YS\+5.10.\*LABDE\+14.10)
CALL LINE (X\+Z2\+NOPTS\+1\+K\+3.\+07)
CALL CALPLT (0.\+2.75.\+3)
CALL GRID (0.\+0.\+5.\+5.10.4)
CALL AXES (0.\+0.\+0.\+5.\+XM\+XS\+1.\+10.\+LABT\+14.\+10)
Y3(LPT)=Z3(LPT)=YM
Y3(JPT)=Z3(JPT)=YS
CALL AXES (0.\+0.\+90.2.\*YM\+YS\+5.10.\*LABDR\+14.10)
CALL LINE (X\+Z3\+NOPTS\+1\+K\+3.\+07)
CALL CALPLT (0.\+2.75.\+3)
CALL GRID (0.\+0.\+5.\+5.10.4)
CALL AXES (0.\+0.\+0.\+5.\+XM\+XS\+1.\+10.\+LABT\+14.\+10)
Y4(LPT)=Z4(LPT)=YM
Y4(JPT)=Z4(JPT)=YS
CALL AXES (0.\+0.\+90.2.\*YM\+YS\+5.10.\*LABDA\+14.10)
CALL LINE (X\+Z4\+NOPTS\+1\+K\+3.\+07)
CALL CALPLT (12.\+5.\+5.\+3)
GO TO 310
OVERLAY (XC142FL,3,0).- The read overlay, level (3,0), is loaded when the READ mode is selected on the program control console. The primary overlay, level (4,0), is automatically loaded upon completion of level (3,0). The integer IREAD preset in level (4,0) selects one of the six options in the READ overlay, one option being to input flight test data.

The flight test data input option uses a tape that was made by altering the original time records of all runs so that monotonically increasing time serves as the tape index key. Another aspect of the tape is that the time interval between consecutive points is constant for a given run, but does vary from run to run. The analyst can readily determine TS, TT, and NOPTS (tape starting time, tape time interval, and number of points, respectively) from the tape printout, but must consider frequencies involved to determine INC (sample rate of flight data tape). A major factor in determining INC is that DELX (program time interval of flight data, where DELX = TT . INC) must be an integral multiple of DT (program integration step size).

This option also provides the analyst with the opportunity to use biases and multipliers to eliminate certain apparent anomalies in the flight test data. An example of this usage is the putting in of control input trim conditions as biases.

To input flight test data, the determined values for TS, TT, NOPTS, INC, and any multipliers and/or biases must be entered into the computer. Then IREAD is changed to 6 and the READ switch is depressed. Input of flight test data is completed when the READ mode light comes on; if WL(7) is also on, an error in entering these values is apparent. The bottom RELEASE switch is depressed to complete the return to level (4,0).

The flow chart of the flight test data input option follows the flow chart of overlay level (3,0).
PROGRAM XCREAD

Memory allocation

IREAD

<1 or >6

WL(6) = T.

IREAD = 2

RETURN

OVERLAY (XC142FL,4,0)

END

Reset parameter value and activeness
(D0055)

Store parameter value and activeness
(D0059)

Nominal run conditions
(D0072)

Longitudinal run conditions
(D0088)

Lateral run conditions
(D0106)

Flight test data input option
(D0126)
FLIGHT TEST DATA INPUT OPTION

Entry when IREAD = 6

WL(I) = .F.

KSIP > 0

No  (D0128)

KSIP = 1

Yes (D0130)

Rewind LUN25

UM(I) = 1000000

I = 1, 2, . . ., NPTS

Call CREATEF (LUN25)

I = 0

J = -1

(D0115)

I = I + 1

(D0115)

J = J + 1

(D0115)

Call RECIN

END FILE

LUN25

Yes (D0141)

WL(I) = .T.

No (D0142)

Starting time reached

Yes (D0143)

MOD(J, INC) = 0

No

Yes (D0144)

UM(I) = UMULT \cdot (UM(I) - UBIAS)

(see lines D0145 - D0162)

No

Yes

I < NOPTS

(D0164)

\overline{z}(0) = \overline{z}^M(t_1)

No

IRREAD = 2

RETURN

OVERLAY (XC142FL,4,0)
OVERLAY (XC142FL *3.0)  D 0001
PROGRAM XREAD  D 0002
LOGICAL LDISO, LDISI, LOGIC, VARCHNG, WL(39), FSS(16)  D 0003
DIMENSION FWA25(1025), AL(40), INTX(8), INTY(11)  D 0004
COMMON /INTCOMM/ T, INT, NNEG, SCHEME, DERINT(2,249)  D 0005
COMMON /INTINT/ INTERN(5,249)  D 0006
COMMON /REALTIM/ ADC(32), DAC(64), LDISO(108), LDISI(196), NOPER, NHOLD  D 0007
1 *NRESET *TERM *PRINT *READ  D 0008
COMMON /ALGOR/ NPAR, IPAR, INTP(30), IV, INTA(11), IA, IA1, IA  D 0009
12 *PARAM(40), DPARAM(30), ALV(11), DVAR(8), DALG(11), ALG(40), IAC(40), IE  D 0100
2VEN(11), COM*Li, L2  D 0111
COMMON /COMM1/ IRR, IPL, ISL, TABLE(199), INTEG(99), LOGIC(20), NTAB, NIN  D 0122
1 *NLLOG, NADC, NDL0, NINT, AXI, AYI, AZI, DRAD, RADD, P1, IR(2), NRN, N  D 0133
2PTS, ISP, JSKIP, KSkip, MF, TX, TY, TZ, AMX, AMY, AMZ, VARCHNG, ITYPE, IVARBU  D 0144
3F(5), DELX, NOITSPS, PTSINV  D 0155
COMMON /COMM2/ MAXPAGE, LABT, LABU, LABV, LABW, LABP, LABQ, LABR, LABTH, LA  D 0166
18PH, LABAX, LABAY, LABAZ, LABDA, LABBE, LABDR, FET25(17), LUN25, NAM25, ITRN  D 0177
2MLT(7), IMULTA(7), INVSEN(7), IMULTB(7), INVWT(7)  D 0188
COMMON /FLIGHT/ UM(201), VM(201), WM(201), PM(201), QM(201), RM(201), TH  D 0199
1M(201), PHM(201), AXM(201), AYM(201), AZM(201), FDA(201), FDE(201), FDR(201)  D 0200
201, FBT(201), FDB(201), FDELB(201), FPEPER(201), FPER(201), BETAT, ETA, E  D 0211
3AT(12), CCT, CT  D 0222
CO*', EQUIVALENCE (LDISO(61), WL(1)), (LDISO(33), FSS(1)), (AL(1), U0), (AL  D 0233
1(5), THEO), (AL(6), PHI0), (AL(7), W0), (AL(12), GO), (AL(18), VO), (AL  D 0244
2(25), PO), (AL(33), RO), (TABLE(1), AL(1)), (TABLE(65), UMULT), (TABLE  D 0255
3(66), VMULT), (TABLE(67), WMULT), (TABLE(68), PMULT), (TABLE(69), OMUL  D 0266
4T), (TABLE(70), RMULT), (TABLE(71), THMULT), (TABLE(72), PHMULT), (TA  D 0277
5BLE(73), AMULT), (TABLE(74), AYMULT), (TABLE(75), AZMULT), (TABLE(76  D 0288
6), DMULT), (TABLE(77), DEMULT), (TABLE(78), DRMULT), (TABLE(79), UBI  D 0299
75), (TABLE(80), VBIA), (TABLE(81), WBIA), (TABLE(82), PBIA), (TABLE  D 0300
8(83), Qbia), (TABLE(84), Rbia), (TABLE(85), THBIA), (TABLE(86), PHB  D 0311
9), (TABLE(87), AXBIA), (TABLE(88), AYBIA), (TABLE(89), AZBIA), (TAB  D 0322
3S), (TABLE(90), DABIA), (TABLE(91), DEBIA), (TABLE(92), DRBIA), (TAB  D 0333
3E(120), AIXZ), (TABLE(123), RHO), (TABLE(124), S), (TABLE(130), DT), (D  D 0344
3TABLE(131), TT), (TABLE(132), TS), (TABLE(133), TIMP), (TABLE(171), UC  D 0355
3RTB1), (TABLE(175), CTB), (TABLE(176), CBT), (TABLE(178), CAPDT), (T  D 0366
3TABLE(179), EBAR), (TABLE(180), ELP), (TABLE(181), RB), (TABLE(184)  D 0377
3TBBIAS), (TABLE(185), PPERBI), (TABLE(186), TPERBI), (INTEG(51), INT  D 0388
3S(11), (INTEG(62), NOPTS), (INTEG(63), INC), (INTEG(66), IREAD), (INTE  D 0399
3G(81), INTX(1))  D 0400
C IREAD=1 TO STORE ALG IN ALG*ETC*  D 0410
C IREAD=2 TO STORE ALG IN ALG*ETC* USES FSS(12)  D 0420
C IREAD=3 TO GET NOMINAL CONDITIONS  D 0430
C IREAD=4 TO GET LONGITUDINAL CONDITIONS  D 0440
C IREAD=5 TO GET LATERAL CONDITIONS  D 0450
C IREAD=6 TO FILL FLIGHT DATA ARRAYS  D 0460
C WL(6) INDICATES DEFAULT VALUE USED FOR IREAD  D 0470
C WL(7) INDICATES ATTEMPT TO READ FLIGHT DATA BEYOND END FILE  D 0480
L=IREAD  D 0490
IREAD=2  D 0500
WL(6)=F  D 0510
=IF((LGE1) AND (LLE6)) GO TO 10  D 0520
WL(6)=T  D 0530
RETURN  D 0540
10 GO TO (20,40,60,80,110,140) L  D 0550
20 DO 30 I=1, NPAR  D 0560
AL(1)=ALG(1)  D 0570
30 INT(1)=IAC(1)  D 0580
RETURN  D 0590
40 DO 50 I=1, NPAR  D 0600
ALG(1)=TABLE(1)  D 0610
52
50 IAC(1)=INTEG(I)
IF (FSS(12)) RETURN
ALG(1)=UM(1)
ALG(18)=VM(1)
ALG(7)=WM(1)
ALG(25)=PM(1)
ALG(12)=QM(1)
ALG(33)=RM(1)
ALG(5)=TM(1)
ALG(6)=PHM(1)
RETURN

60 AIXZ=8000.
RHO=.002186
S=534.4
DT=.05
TT=.05
TIMF=.8
CTB=.8423
CTBT=.573
CAPDT=.8
ELBAR=.20,.54
ELTP=.32,.09
RB=1.6
INC=9
DO 70 I=154162
TABLE(I)=0.
RETURN

70 DO 90 I=J
IF U.LT.9) INTX(I)=0
INTY(I)=1
INTXO )=INTX3)«INTX(5)«INTX(7)=1
INTY(2)«INTY(4)«INTY(6)«INTY(8)«INTY(10)=0
D1=UO
D2=W0
D3=QO
D4=THEO
DO 100 I=1.NPAR
AL(1)=0.
INTEG(I)=1
IF (I LE.17) INTEG(I)=1
100 CONTINUE
INTEG(6)=0
UO=D1
W0=D2
Q0=D3
THEO=D4
RETURN

110 DO 120 I=1,11
IF (I LE.9) INTX(I)=0
120 INTY(I)=0
INTX(I)=INTX3)«INTX(6)«INTX(8)=1
INTY(2)«INTY(4)«INTY(6)«INTY(8)«INTY(10)=1
D1=UO
D2=V0
D3=PO
D4=RO
D5=PHIO
DO 130 I=1.NPAR
AL(1)=0.
INTEG(I)=1
IF (I LE.17) INTEG(I)=0
130 CONTINUE
   INTEGR(6)=1
   UM=D1
   VM=D2
   PO=D3
   RO=D4
   PHIO=D5
   RETURN
140 WL(7)=*F*
   IF (KSKIP*GT*0) GO TO 150
   KSKIP=1
   CALL CREATEF (LUN25,FWA25,1025,FET25,NAM25)
150 REWIND LUN25
   DO 160 I=1,NPTS
160 UM(I)=E6
   I=0
   J=1
   I=I+1
170 I=I+1
180 J=J+1
190 CALL RECIN (LUN25,I,ICOUNT,X,UM(I),VM(I),WM(I),PM(I),QM(I),RM(I),T
   1HM(I),PHM(I),AXM(I),AYM(I),AZM(I),FDA(I),FDE(I),FDR(I),FBT(I),FDB(2)
   21),FDELB(I),FPER(I),FTPER(I))
   IF (ENDFILE LUN25) 200,210
200 WL(7)=*T*
   RETURN
210 IF (X*LT*(TS-*001)) GO TO 190
   IF (MOD(J,INC)*NE*0) GO TO 180
   UM(I)=UMULT*(UM(I)-UBIAS)
   VM(I)=VMULT*(VM(I)-VBIAS)
   WM(I)=WMULT*(WM(I)-WBIAS)
   PM(I)=PMULT*(PM(I)-PBIAS)
   QM(I)=QMULT*(QM(I)-QBIAS)
   RM(I)=RMULT*(RM(I)-RBIAS)
   THM(I)=THMULT*(THM(I)-THBIAS)
   PHM(I)=PHMULT*(PHM(I)-PHBIAS)
   AXM(I)=AXMULT*(AXM(I)-AXBIAS)
   AYM(I)=AYMULT*(AYM(I)-AYBIAS)
   AZM(I)=AZMULT*(AZM(I)-AZBIAS)
   FDA(I)=DAMULT*(FDA(I)-DABIAS)
   FDE(I)=DEMULT*(FDE(I)-DEBIAS)
   FDR(I)=DRMULT*(FDR(I)-DRBIAS)
   FBT(I)=FTB(I)-BTBIAS
   IF (FDELB(I)*LT*0.0) FDELB(I)=0.*
   FPER(I)=FPER(I)-PPER81
   FTER(I)=FTER(I)-TPER81
   IF (I*LT*NOPTS) GO TO 170
   I=UM(I)
230 UCRTA1=I
   UO=UM(I)
   VO=VM(I)
   WO=WM(I)
   PO=PM(I)
   QO=QM(I)
   RO=RM(I)
240 THEO=THM(I)
   PHIO=PHM(I)
   RETURN
END
OVERLAY (XC142FL,4,0).- Overlay level (4,0) nominally operates in real time and is automatically loaded upon exiting levels (1,0), (2,0), and (3,0). Level (4,0) can cause the loading of levels (2,0) or (3,0) by selecting PRINT or READ mode, respectively, on the program control console. Level (4,0) contains the maximum likelihood estimation procedure (fig. 1) and CRT display loop.

The CRT display loop has been developed to present time history comparisons between flight data and calculated results. The performance index variables and control deflections are divided into four separate displays (each selectable from the program control console). The displays consist of multiple grids and annotated axes with

1. A (.) symbol to represent flight data points
2. Continuous vectors between calculated data points.

Displays available are selected as shown in the following table:

<table>
<thead>
<tr>
<th>Display</th>
<th>FSS(1)</th>
<th>FSS(7)</th>
<th>FSS(8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal (u, w, q, \theta)</td>
<td>.F.</td>
<td>.F.</td>
<td>.F.</td>
</tr>
<tr>
<td>Lateral (p, r, v, \phi)</td>
<td>.F.</td>
<td>.T.</td>
<td>.F.</td>
</tr>
<tr>
<td>Accelerometer (a_{X,I}, a_{Y,I}, a_{Z,I})</td>
<td>.T.</td>
<td>.F.</td>
<td>.F.</td>
</tr>
<tr>
<td>Controls ($\delta_\alpha$, $\delta_\epsilon$, $\delta_\tau$ (flight data only))</td>
<td>.F.</td>
<td>.F.</td>
<td>.T.</td>
</tr>
</tbody>
</table>

The CRT display loop is entered by any of the following methods:

1. Depressing FSS(15) and then releasing when in the RESET mode
2. Depressing FSS(15) and then releasing when an operational error occurs
3. Automatically upon completion of any iteration
4. Automatically upon completion of pseudo data fill.

All four methods result in the program awaiting operator action, but method (4) first clears the existing display and plots the selected display. The operator action awaited is that of either requesting another display or exiting the CRT display loop. Requesting another display is accomplished by setting the appropriate FSS and depressing FSS(14) and then releasing. Exiting the CRT display loop is accomplished by depressing FSS(13).

The flow chart for the CRT display loop follows the flow chart for overlay level (4,0).
OVERLAY (XC142FL,4,0)

PROGRAM XCMAIN

Memory allocation

Call LDRSEC
Call CYCLE

Assignments for subroutine RTMODE

Call XDSPLAY
(E0165) Call READY

90003
Reset program variables
90006
Start of operate loop
90002
Calculation of system dynamics and estimation variables

Calculation of DAC for time-history recording

Call RITECRT

OVERLAY (XC142FL,2,0)

PRINT

OVERLAY (XC142FL,3,0)

READ

Call CALPLT
Call ATERM

TERM

END

Call HALT

Calculation of maximum likelihood estimation equations

(C0922)

CRT display loop

Call IGRATE1

Call RECYCLE
CRT DISPLAY LOOP

(E0932)
WL(20) = .T.

Call ENDPLOT

FSS(3) = .T.

Yes

(E0936)
Call UNLODE
Call CLRTABL

NPASS = 1
(details for plots of flight data)

Call CRTPLOT
(for accelerometer, control, lateral or longitudinal plots)

No

(E0945)
NPASS = 0

Call CRTPLOT
(for calculated data plots of selected option)

Yes

(E017)
Call PLAYBAK

No

(E0982)
Call RITECRT
(for flight data plots of selected option)

Call ENDPLTO

FSS(8) = .T.

Yes

(E1011)
Call CLRTABL

No

NPASS = 0
(details for plots of calculated data)

(E1020)
Call ENDPLTO

Yes

(E1021)
Call DISPLAY
Call OPERATE

FSS(14) = .T.

No

Call RITECRT
(for calculated data plots of selected option)

(E1024)
NPASS = 0

Yes

(E1025)
Call CLRPLOT

No

(E1026)
Call ERASE

IPRINT = 4

No

Yes

(E1027)
WL(30) = .F.

(E0165)
OVERLAY(0X142FL.4.0) E 0001
PROGRAM XCMAIN E 0002
REAL LIX.MIY.NIZ E 0003
LOGICAL FSS<16)»LDISI.LDISO.LOGIC. VARCHNG.WL(39) E 0004
3A(40) E 0008
COMMON /INTCOMM/ T.H.INT.NEQ.I SCHEME.DERINT(2.249) E 0009
COMMON /INT/ INT.NPRINT.NPRINT.NREAD E 0010
1. NRESET. NPRINT.NREAD E 0012
2VEN. WT(11.11). COM.LL2 E 0015
1.-xlOG. NADC.NLDO.NT.AX1.AY1.AZ1.DRAD.RADD.PRI(2). NRN.N E 0017
2PTS.ISKIP.ISKJP.ISKIP.MF.TX.TY.TZ.AMX.AMY.AMZ.VARCHNG.I TYPE. IVARBU E 0018
3F(5). DELX.NOITPS.PSINV E 0019
COMMON /COMM2/ MAXPAGE. LBT.LABU.LABV.LABW.LABP.LABQ.LABR.LA E 0020
1BPH. LABAX.LABAY.LABAZ.LABDA. LABDE. LBD. FET25(17). LUN25. NAM25. ITRN E 0021
2MLT(7) » MULTA(7). INVS(7). MULTB(7). INVWT(7) E 0022
3TACT.FCT(12).CTT.CT E 0025
EQUIVALENCE (PF(1.3).F13). (PF(1.4).F14). (PF(2.19).F219). (PF(2.20) E 0026
5G(2.1).G21). (G(2.2).G22). (G(2.3).G23). (G(2.4).G24). (G(2.5).G26) E 0031
6). (G(2.6).G27). (G(2.8).G28). (G(3.1).G31). (G(3.2).G32). (G(3.3) E 0032
8IS(0.61).WL(11). (FSS(1).LDISI(33)). (DERINT(1.1).U). (DERINT(2.1). E 0034
3UDOT). (DERINT(1.2).V). (DERINT(2.2).VDOT). (DERINT(1.3).W). (DERI E 0035
1N(2.3).WDOT). (DERINT(1.4).P). (DERINT(2.4).PDOT). (DERINT(1.5).Q E 0036
5). (DERINT(2.5).QDOT). (DERINT(1.6).R). (DERINT(2.6).RDOT). (DERIN E 0037
ST(1.7). THE). (DERINT(2.7).THEDOT). (DERINT(1.8). PHI). (DERINT(2.8) E 0038
$). PHIDOT). (DERINT(1.9).PSI). (DERINT(2.9).PSIDOT) E 0040
E 0057
ST). (AL(79).JUBIAS) E 0058
EQUIVALENCE (TABLE(80),VBIAS), (TABLE(81),WBIAS), (TABLE(82),PBIAS,E 0059
1), (TABLE(83),QBIAS), (TABLE(84),RBIAS), (TABLE(85),TBIAS),
2E(86),PHBIAS), (TABLE(87),AXBIAS), (TABLE(88),AYBIAS),
3ZBIAS), (TABLE(90),DABIAS), (TABLE(91),DEBIA), (TABLE(92),DRBIAS,
4), (TABLE(98),RUN), (TABLE(99),PASS), (TABLE(100),AJP),
5), (TABLE(101),E 0063
5), (TABLE(117),AX), (TABLE(118),AY), (TABLE(119),AZ),
6), (TABLE(120),AXZ), (TABLE(121),WEIGHT), (TABLE(122),GRAV),
7), (TABLE(124),S), (TABLE(125),B), (TABLE(126),CBA),
8E(127),DEAML), (TABLE(128),DEREQ), (TABLE(129),ALPHAT),
9), (TABLE(131),TT), (TABLE(132),TS), (TABLE(133),TIMF),
0), (TABLE(155),XX), (TABLE(156),XY), (TABLE(157),YY), (E 0069
1), (TABLE(158),YY), (TABLE(159),ZZ), (TABLE(160),ZX), (TABLE(161),YZ),
2), (TABLE(162),ZZ), (TABLE(169),CMCON), (TABLE(170),DALMLT),
3), (TABLE(172),AIW), (TABLE(173),CLO), (TABLE(174),CTTO),
4), (TABLE(175),CTB), (TABLE(176),CTBT), (TABLE(177),D), (TABLE(178),
5), (TABLE(179),ELBAR), (TABLE(180),ELTP), (TABLE(181),RB),
6), (TABLE(182),PPR), (TABLE(183),TPER), (TABLE(184),BTBIAS),
7), (TABLE(185),PPRBI), (TABLE(186),TPERBI), (TABLE(187),DET),
8), (TABLE(188),D), (E 0076
9), (TABLE(191),DRS(1)), (INTEG(51),INTY(1)), (INTEG(62),
0), INOPTS), (INTEG(63),INC), (INTEG(64),IPRINT), (INTEG(65),NPLT),
1), (E 0079
2), (E 0080
C), ARRAYS DIRECTLY INVOLVED IN ALGORITHM
C), E 0081
C), AL(1) CONTAINS VALUES FOR PARAMETERS (ALPHAS)
C), E 0082
C), INTEG(1) =1 FOR ACTIVE PARAMETER, =0 FOR INACTIVE PARAMETER
C), E 0083
C), INTX(1) =1 FOR ACTIVE STATE, =0 FOR INACTIVE STATES
C), E 0084
C), INTY(1) =1 FOR ACTIVE, =0 FOR INACTIVE ALG. VARIABLE
C), E 0085
C), INTP(1) ACTIVE PARAMETERS
C), E 0086
C), INTV(1) ACTIVE STATE VARIABLES
C), E 0087
C), INTA(1) ACTIVE ALGORITHM VARIABLES
C), E 0088
C), GI(J) SENSITIVITY EQUATION MATRIX
C), E 0089
C), PF(I,J) EXPLICIT PARTIALS IN SENSITIVITY EQUATIONS
C), E 0090
C), PX(I,J) SENSITIVITY COEFFICIENTS
C), E 0091
C), PXD(I,J) DERIVATIVES OF PX
C), E 0092
C), DX(I) DIFFERENCE OF MEASURED AND CALCULATED STATE VARIABLES
C), E 0093
C), DDX(I) PACKED DX ARRAY
C), E 0094
C), XBAR(I) MEAN OF MEASUREMENT NOISE
C), E 0095
C), SD(I,J) STANDARD DEVIATION MATRIX
C), E 0096
C), WT(I,J) WEIGHT MATRIX
C), E 0097
C), PXWT(I,J) INTERMEDIATE CALCULATION
C), E 0098
C), PXDTX(I,J) ACCUMULATED DPXTWX FROM TIME=0 TO END OF ITERATION
C), E 0099
C), PXTPX(I,J) COVARIANCE MATRIX OF PARAMETERS
C), E 0100
C), DPXTWX(I) RIGHT HAND SIDE OF PARAMETER CHANGE EQUATION
C), E 0101
C), DELA(I) PACKED DELA ARRAY
C), E 0102
C), DELA(I) DELTA ALPHAS FOR PARAMETERS (UPDATES)
C), E 0103
C), WL(10) INDICATES NOPTS GT NPTS
C), E 0104
C), WL(11) INDICATES IP GT IPAR
C), E 0105
C), WL(12) INDICATES ERROR IN INITIALIZATION OF STATES
C), E 0106
C), WL(13) INDICATES ABS(ABS) GT 1.5 RADIANS
C), E 0107
C), WL(14) INDICATES U LT 5 FPS
C), E 0108
C), WL(15) INDICATES ABS(V) GT U
C), E 0109
C), WL(16) INDICATES ABS(ALF) GT 1.5 RADIANS
C), E 0110
C), WL(17) INDICATES ATTEMPTING TO USE UNFILLED FLIGHT DATA
C), E 0111
C), WL(18) INDICATES COVARIANCE MATRIX SINGULAR (DET=0)
C), E 0112
C), WL(19) INDICATES WEIGHT MATRIX SINGULAR (DET2=0)
C), E 0113
C), WL(20) INDICATES IN CRT LOOP
C), E 0114
C), FSS(I) GT 0 FOR ACCELERATIONS ON CRT
C), E 0115
C), FSS(2) GT 0 FOR CALCOMP OF FLIGHT DATA ONLY
C), E 0116
C), FSS(3) GT 0 FOR PSEUDO-DATA-FILL
C), E 0117
C), FSS(4) GT 0 TEMPORARILY FOR VARIABLE DIMENSIONS
C), E 0118
C), FSS(5) GT 0 FOR OUTPUT LISTING
C), E 0119
FSS(7)=*T* FOR LATERAL STATES ON CRT
FSS(8)=*T* FOR CONTROLS ON CRT
FSS(9)=*T* FOR PSEUDO FLIGHT FUNCTIONS
FSS(10)=*T* TO SKIP UPDATE OF ALPHAS
FSS(11)=*T* TO ENABLE TYPEWRITER
FSS(12)=*T* TO RETAIN STATE 1*C* S DURING STORING OF AL IN ALG
FSS(13)=*T* TO EXIT CRT LOOP
FSS(14)=*T* TEMP. FOR REPLOT
FSS(15)=*T* TO ENTER CRT LOOP
FSS(16)=*T* FOR TABLES ADDRESSING
FSS(17,8)=*F* FOR LONGITUDINAL STATES ON CRT

LOGIC(1)=*T* TO CALCULATE WEIGHT UPDATES
LOGIC(2)=*T* FOR DIAGONALIZED WEIGHT MATRIX
LOGIC(3)=*T* FOR MAIN PROP=FPER(1)
LOGIC(4)=*T* FOR TAIL = FTER(1)
LOGIC(5)=*T* FOR CTT=F(BETAT)
LOGIC(6)=*T* FOR CZDE=CMDE*CMCON
LOGIC(7)=*T* FOR LONGITUDINAL STATES=FLIGHT DATA
LOGIC(8)=*T* FOR ALFT=ATAN(WO*UO)
LOGIC(9)=*T* FOR TRIM CONDITIONS
LOGIC(10)=*T* FOR AUTOMATIC TRIM
LOGIC(11)=*T* FOR AUTOMATIC 2 PASS SYSTEM

IPRINT=1 TO PRINT ICS
IPRINT=2 TO REWIND MF FILE
IPRINT=3 TO OBTAIN RANDOM NUMBERS
IPRINT=4 FOR CALCOMP PLOT
IPRINT=5 TO RETURN (ROUTES OUTPUT)
IREAD=1 TO STORE ALG IN ALG ETC.
IREAD=2 TO STORE ALG IN ALG ETC.
IREAD=3 TO GET NOMINAL CONDITIONS
IREAD=4 TO GET LONGITUDINAL CONDITIONS
IREAD=5 TO GET LATERAL CONDITIONS
IREAD=6 TO FILL FLIGHT DATA ARRAYS

CALL LDRSEC
IF (.NOT.FSS(4)) GO TO 10
ISKIP=1
CALL CYCLE (900065)
ASSIGN 90001 TO NOPER
ASSIGN 90002 TO NHOLD
ASSIGN 90003 TO NRESET
ASSIGN 90004 TO NTERM
ASSIGN 90014 TO NPRINT
ASSIGN 90015 TO NREAD
CALL XDSPAL (LDISI*LDISO*VARCHNG*TYPE*IVARBUF+FSS(16))

10 CALL READY
90003 CONTINUE
IF (NOPS*LE*NPTS) GO TO 30
WLI(10)=*T*
GO TO 740
30 IF (*NOT.*FSS(4)) GO TO 110
DO 40 I=1,IPAR
DPARAM(I)=10H
40 INTP(1)=0
IF (INTP(1)=0) GO TO 50
IP=IP+1
INTP(IP)=1
DPARAM(IP)=PARAM(I)
CONTINUE
CONTINUE
IF (IP.LE.IPAR) GO TO 60
WL(11)=T
GO TO 740
DO 70 I=1,8
IF (INTY(I).EQ.0) GO TO 70
IF (INTX(I).EQ.1) GO TO 70
WL(12)=T
GO TO 740
70 CONTINUE
IA1=0
IV=0
DO 80 I=1,8
DVAR(I)=10H
INTV(I)=0
IF (INTY(I).EQ.1) IA1=IA1+1
IF (INTX(I).EQ.0) GO TO 80
IV=IV+1
DVAR(IV)=ALV(I)
INTV(IV)=1
80 CONTINUE
IA=0
DO 90 I=1,11
DALG(I)=10H
INTA(I)=0
IF (INTY(I).EQ.0) GO TO 90
IA=IA+1
DALG(IA)=ALV(I)
INTA(IA)=1
90 CONTINUE
IA2=IA-IA1
ITRNLMT(2)=ITRNLMT(4)=IMULTA(3)=INVVT(2)=INVVT(3)=IA
ITRNLMT(3)=IMULTA(2)=INVS(2)=INVS(3)=IMULTB(2)=IMULTB(3)=IP
IF (.NOT.LOGIC(1)) GO TO 110
DO 100 I=1,IA
DO 100 J=1,IA
WT(I,J)=0.
100 CONTINUE
NEG=9+IP+IV
IF (FSS5(3)) NEG=9
DO 120 I=1,IA
XBAR(I)=0.
DO 120 J=1,IA
SD(I,J)=0.
DO 130 I=1,IP
PXTDX(I)=0.
DO 130 J=1,IP
130 PXTPX(I,J)=0.
K=9
DO 210 I=1,IV
II=INTV(I)
DO 210 J=1,IP
JJ=INTP(J)
K=K+1
DERINT(1,K)=0.
GO TO (140,150,160,170,180,190,200,210,11)
140 IF (JJ*EQ.1) 220,230
150 IF (JJ*EQ.18) 220,230
160 IF (JJ*EQ.7) 220,230
170 IF (JJ*EQ.25) 220,230
180 IF (JJ*EQ.12) 220,230
190 IF (JJ*EQ.33) 220,230
200 IF (JJ.EQ.5) 220,230
210 IF (JJ.EQ.6) 220,230
220 DERINT(1:I,K)=1
230 CONTINUE
DO 240 J=1,NPAR
DELA(J)=0
DO 240 I=1,B
IF (I.LT.7) PXD(I,J)=0
IF (J.LT.9) G(I,J)=0
PFU,J>-0
G(8,4)=1
INT=0
H=DT
VARCHING=.FALSE.
T=0
U=U0
V=V0
W=W0
P=P0
Q=Q0
R=R0
THE=THEO
PHI=PHIO
PSI=0
CYCL=2*PI/DEFREQ
ALFT=ALPHAT*RADD
IF (LOGIC(8)) ALFT=ATAN2(WO,U0)
AJ=0
ITS=-1
NOEL=0
DELX=TT*INC
NOITSPS=DELX/DT
TMAXX=DELX*(NOPTS-1)
PTSINV=1./NOPTS
GINV=1./GRAV
AMASINV=GRAV/WEIGHT
AIYINV=1./AIY
BTWO=5*B
CBAR2=5*CBAR
RHOS2=RHO*S2
A1=RHOS2*AMASINV
A2=A1*CBAR2
A3=A1*BTWO
A4=RHOS2*B
A5=A4*BTWO
CONINV=(AIX*AIZ-AIXZ**2)
A6=AIZ*CONIN
A7=(AIZ-AIX)*AIYINV
A8=RHOS2*CBAR*AIYINV
A9=A8*CBAR
VDTCON=1./(1-A3*CYBD)
PF21=A3*VDTCON
A9CMALD=A9*CMALD
B1=AIXZ*CONIN
B2=AIY-AIZ
B3=AIX-AIY
B4=AIXZ*AIYINV
B5=AIX*CONIN
PF41=A5*(A6*CLBD+B1*CNBD)
PF61=A5*(B1*CLBD+B5*CNBD)
B42=2*B4
CIW=COS(AIW)
310  UINV=1./U
    ALF=ATAN2(W*U)-ALFT
    IF (ABS(ALF)*LT.1.5) GO TO 320
    WL(16)=T.
    GO TO 740
320  U2=U*U
    V2=V*V
    W2=W*W
    VR=SQRT(VR2)
    VRINV=1./VR
    BET=ASIN(V*VRINV)
    ETA=1232.*PPER/60.*
    ETAT=40.*TPER
    CT=CTO+CTB*DELB
    IF (.NOT.LOGIC(5)) GO TO 330
    FBET=ABS(BETAT*DRAD)
    IF (FBET*LT.22.) FBET=22.
    IS=FBET*5
    SS=FBET*5-IS
    TDUM=(1.-SS)*FCT(IS+1)+SS*FCT(IS+2)
    IF (BETAT.LT.0.) TDUM=-TDUM
    CTT=TDUM+CTTO
    GO TO 340
CONTINUE
330  CONTINUE
    CTT=CTB*BETAT+CTTO
340  CONTINUE
    TEMP=ETA**2
    TEMP1=CT*TEMP
    TEMP2=DB*TEMP
    TEMP3=ETAT**2*CTT
    TX=CON3*TEMP1
    TZ=-CON4*TEMP1-CON8*TEMP3
    AMX=CON5*TEMP2
    AMY=-CON7*TEMP1-CON9*TEMP3
    AMZ=CON6*TEMP2
    VSS2=DCON*TEMP1
    VSS=SQRT(VSS2)
    VSR=VSS+VR
    VSRV0=VSR*VINV
    VSR2=VSR**2
    STHE=SIN(THE)
    CTHE=COS(THE)
    SPHI=SIN(PHI)
    CPHI=COS(PHI)
    GCTHE=GRAV*CTHE
    GSTHE=GRAV*STHE
    TTHE=TAN(THE)
    TXM=AMASINV*TX
    TYM=AMASINV*TY
    TZM=AMASINV*TZ
    AMYZ=AIMвин*AMY
    A1U=A1*U
    A1V=A1*V
    A1W=A1*W
    A4U=A4*U
    A4V=A4*V
    A4W=A4*W
    A8U=A8*U
    A8V=A8*V
    A8W=A8*W
A1VR=A1*VR
A2VR=A2*VR
A3VR=A3*VR
A4VR=A4*VR
A5VR=A5*VR
A9VR=A9*VR
A1VR2=A1*VR2
A4VR2=A4*VR2
A4VSR2=A4*VSR2
A8VR2=A8*VR2
B2VR=BTWO*VRINV
PF22=PF21*VR
PF42=A6*A5VR
PF43=A4VSR2*DA
PF44=B1*A5VR
PF62=B5*A5VR
CBAR2VR=CBAR2*VRINV
P2=P*P
Q2=Q*Q
R2=R*R
PO=PO*Q
PR=PR*R
QR=QR*R
Q1=Q*A1XZ
CX1=CXO+ALF*CXL
CX2=CXO*CBAR2VR
CY1=CYO+BET*CYB+DR*CYDR
CY2=B2VR*(P*CYP+R*CYR)
CZ1=CZO+ALF*CZAL+DE*CZDE
CZ2=CZO*CBAR2VR
FXM=A1VR2*(CX1+CX2)
FYM=A1VR2*(CY1+CY2)
FZM=A1VR2*(CZ1+CZ2)
UDP=W*Q*W+GSTHE
VDP=P*W-R*U+GCTHE*SPHI
WDP=Q*U-P*V+GCTHE*CPHI
UDOT=UDP+FXM+TXM
VDOT=VDTCON*(VDP+FYM+TYM)
WDOT=WDP+FZM+TZM
IF (INTX(1)*EQ.0) UDOT=0.
IF (INTX(2)*EQ.0) VDOT=0.
IF (INTX(3)*EQ.0) WDOT=0.
IF (.NOT.LOGIC(9)) GO TO 350
CALL HALT
CX1=CX1-CXO
CY1=CY1-CYO
CZ1=CZ1-CZO
TMP1=1./A1VR2
CXO=CXO-UDOT*TMP1
CYO=CYO-VDOT*TMP1/VDTCON
CZO=CZO-WDOT*TMP1
UDOT=0.
VDOT=0.
WDOT=0.
CX1=CX1+CXO
CY1=CY1+CYO
CZ1=CZ1+CZO

E 0427  
E 0428  
E 0429  
E 0430  
E 0431  
E 0432  
E 0433  
E 0434  
E 0435  
E 0436  
E 0437  
E 0438  
E 0439  
E 0440  
E 0441  
E 0442  
E 0443  
E 0444  
E 0445  
E 0446  
E 0447  
E 0448  
E 0449  
E 0450  
E 0451  
E 0452  
E 0453  
E 0454  
E 0455  
E 0456  
E 0457  
E 0458  
E 0459  
E 0460  
E 0461  
E 0462  
E 0463  
E 0464  
E 0465  
E 0466  
E 0467  
E 0468  
E 0469  
E 0470  
E 0471  
E 0472  
E 0473  
E 0474  
E 0475  
E 0476  
E 0477  
E 0478  
E 0479  
E 0480  
E 0481  
E 0482  
E 0483  

65
**350 CONTINUE**

\[
\begin{align*}
\text{ALFD} &= \text{VDOT*VRINV} \\
\text{BETD} &= \text{VDOT*VRINV} \\
\text{BB2VR} &= \text{BETD*B2VR} \\
\text{CL1} &= \text{CLO+BET*CLB+DR*CLDR} \\
\text{CL2} &= \text{(BETD*CLBD+P*CLP+R*CLR)*B2VR} \\
\text{CL3} &= \text{A*CLDAP} \\
\text{CM1} &= \text{CMO+ALF*CMAL+DE*CMDE} \\
\text{CM2} &= \text{(ALFD*CMALD+Q*CMO)*CBAR2VR} \\
\text{CN1} &= \text{CNO+BET*CNB+DR*CNDR} \\
\text{CN2} &= \text{(BETD*CNBD+P*CNP+R*CNR)*B2VR} \\
\text{CN3} &= \text{A*CNDAP} \\
\text{LI} &= \text{A4VR2*(CL1+CL2)+A4VSR2*CL3} \\
\text{MI} &= \text{A8VR2*(CM1+CM2)} \\
\text{NI} &= \text{A4VR2*(CN1+CN2)-A4VSR2*CN3} \\
\text{F6P} &= \text{Q*(B2*R+P*AIXZ)+LIX+AMX} \\
\text{F6P} &= \text{Q*(B3*R-AIXZ)+NIZ+AMZ} \\
\text{PDDOT} &= \text{A6*F4P+B1*F6P} \\
\text{QDDOT} &= \text{A7*PR+B4*(R2-P2)+MIY+AMY} \\
\text{RDOT} &= \text{B1*F4P+B5*F6P} \\
\text{IF} (\text{INTX(4).EQ.0}) \text{ PDOT=0} \\
\text{IF} (\text{INTX(5).EQ.0}) \text{ QDOT=0} \\
\text{IF} (\text{INTX(6).EQ.0}) \text{ RDOT=0} \\
\text{IF} (\text{NOT,LOGIC(9)}) \text{ GO TO 360} \\
\text{LOGIC(9)} &= \text{.F.} \\
\text{CL1} &= \text{CL1-CLO} \\
\text{CM1} &= \text{CM1-CMO} \\
\text{CN1} &= \text{CN1-CNO} \\
\text{TMP4} &= \text{A4VR2} \\
\text{CLO} &= \text{CLO-F4P+TMP4} \\
\text{CMO} &= \text{CMO-QDOT/A8VR2} \\
\text{CNO} &= \text{CNO-F6P+TMP4} \\
\text{PDDOT} &= \text{0} \\
\text{QDDOT} &= \text{0} \\
\text{RDOT} &= \text{0} \\
\text{CL1} &= \text{CL1+CLO} \\
\text{CM1} &= \text{CM1+CMO} \\
\text{CN1} &= \text{CN1+CNO} \\
\text{CALL READY} &
\end{align*}
\]

**360 CONTINUE**

\[
\begin{align*}
\text{AXCG} &= \text{GINV*(UDOT-UDP)} \\
\text{AYCG} &= \text{GINV*(VDOT-VDP)} \\
\text{AZCG} &= \text{GINV*(WDOT-WDP)} \\
\text{AXI} &= \text{AXCG+GINV*(-(R2+Q2)*XX+(PQ-RDOT)*YY+(PR+QDOT)*ZX)} \\
\text{AYI} &= \text{AYCG+GINV*+(PQ+RDOT)*XY-(P2+R2)*YY+(QR-PDOT)*ZY)} \\
\text{AZI} &= \text{AZCG+GINV*+(PR-QDOT)*XZ+(QR+PDOT)*YZ-(P2+Q2)*ZZ)} \\
\text{THEDOT} &= \text{Q*CPHI-R*SPHI} \\
\text{PSIDOT} &= \text{G*SPHI+R*CPHI)/CTHE} \\
\text{PHIDOT} &= \text{P*PSIDOT*THE} \\
\text{IF} (\text{INTX(7).EQ.0}) \text{ THEDOT=0} \\
\text{IF} (\text{INTX(8).EQ.0}) \text{ PHIDOT=0} \\
\text{IF} (\text{NOT,FSSS(3)}) \text{ GO TO 370} \\
\text{IF} (\text{MOD(ITS+NOITSPS)+NE=0}) \text{ GO TO 530} \\
\text{IF} (\text{NOT,LDISI(18)}) \text{ NOEL=NOEL+1} \\
\text{UM(NOEL)} &= \text{U} \\
\text{VM(NOEL)} &= \text{V} \\
\text{WM(NOEL)} &= \text{W} \\
\text{PM(NOEL)} &= \text{P} \\
\text{QM(NOEL)} &= \text{Q} \\
\text{RM(NOEL)} &= \text{R} \\
\text{THM(NOEL)} &= \text{THE} \\
\text{PHM(NOEL)} &= \text{PHI}
\end{align*}
\]
AXM(NOEL) = AXI
AYM(NOEL) = AYI
AZM(NOEL) = AZI
FDA(NOEL) = DA
FDE(NOEL) = DE
FDR(NOEL) = DR
FBT(NOEL) = BETAT
FDB(NOEL) = DB
FDELA(NOEL) = DELB
FPPER(NOEL) = PPER
FTPFR(NOEL) = TPER
GO TO 530
CONTINUE
PF(1,2) = A1VR2
PF(1,3) = A1VR2*ALF
PF(1,4) = A2VR*Q
PF(2,19) = VDOTCON*A1VR2
PF(2,20) = F219*BET
PF(2,21) = PF21*VDOT
PF(2,22) = PF22*P
PF(2,23) = PF22*R
PF(2,24) = F219*DR
PF(3,8) = A1VR2
PF(3,9) = F13
PF(3,10) = F14
PF(3,11) = A1VR2*DE
PF(4,19) = F219*PF41
PF(4,20) = F220*PF41
PF(4,21) = F221*PF41
PF(4,22) = F222*PF41
PF(4,23) = F223*PF41
PF(4,24) = F224*PF41
PF(4,26) = A6*A4VR2
PF(4,27) = F426*BET
PF(4,28) = PF42*BETD
PF(4,29) = PF42*P
PF(4,30) = PF42*R
PF(4,31) = F426*DR
PF(4,32) = PF43*(A6*CIW-B1*SIW)
PF(4,34) = B1*A4VR2
PF(4,35) = F434*BET
PF(4,36) = PF44*BETD
PF(4,37) = PF44*P
PF(4,38) = PF44*R
PF(4,39) = F434*DR
PF(4,40) = -PF43*(B1*CIW+A6*SIW)
PF(5,8) = A1VR2*A9CMALD
PF(5,9) = F39*A9CMALD
PF(5,10) = F310*A9CMALD
PF(5,11) = F311*A9CMALD
PF(5,13) = ABVR2
PF(5,14) = ABVR2*ALF
PF(5,15) = A9VR*ALFD
PF(5,16) = A9VR*Q
PF(5,17) = ABVR2*DE
PF(6,19) = F219*PF61
PF(6,20) = F220*PF61
PF(6,21) = F221*PF61
PF(6,22) = F222*PF61
PF(6,23) = F223*PF61
PF(6,24) = F224*PF61
DO 380 I=1,IV
I1=INTV(I)
DO 390 J=1,IP
L=L+1
JJ=INTP(J)
GPX=0.
DO 380 K=1,IV
KK=INTV(K)
GPX*GPX+G(I1,KK)*PX(K,J)
DERINT(2,L)=GPX*PF(I1,JJ)
IF (I1.LT.7) PXD(I1,JJ)=DERINT(2,L)
CONTINUE
IF (IA1.EQ.1A) GO TO 450
G(1,1)=0*
G(1,2)=-R
G(1,3)=Q
G(1,4)=YX*Q+ZX*R
G(1,5)=-2.*XX*Q+YY*P+W
G(1,6)=-2.*XX*R+ZX*P-V
G(1,7)=GCTHE
G(2,1)=R
G(2,2)=0*
G(2,3)=-P
G(2,4)=-W*XY*Q-2.**YY*P
G(2,5)=XY*P+ZY*R
G(2,6)=U-2.*YY*R+ZY*Q
G(2,7)=GSTHE*SPHI
G(2,8)=-GCTHE*CPHI
G(3,1)=O
G(3,2)=P
G(3,3)=Q*
G(3,4)=V+XX*R-2.*ZZ*P
G(3,5)=-U+YZ*R-2.*ZZ*Q
G(3,6)=ZX*P+YZ*Q
G(3,7)=GSTHE*CPHI
G(3,8)=GCTHE*SPHI
E 0665
E 0666
E 0667
E 0668
E 0669
E 0670
E 0671
E 0672
E 0673
E 0674
E 0675
E 0676
E 0677
E 0678
E 0679
E 0680
E 0681
E 0682
E 0683
E 0684
E 0685
E 0686
E 0687
E 0688
E 0689
E 0690
E 0691
E 0692
E 0693
E 0694
E 0695
E 0696
E 0697
E 0698
E 0699
E 0700
E 0701
E 0702
E 0703
E 0704
E 0705
E 0706
E 0707
E 0708
E 0709
E 0710
E 0711
E 0712
E 0713
E 0714
E 0715
E 0716
E 0717
E 0718
E 0719
E 0720
E 0721
E 0722
E 0723
E 0724
E 0725
E 0726
L=IV
M=IA
DO 440 I=1,IA2
L=L+1
M=M+1
II=INTA(M)-8
DO 440 J=1,IP
JJ=INTP(J)
GPX=0
DO 400 K=1,IV
KK=INTV(K)
GPX=GPX+G(I1*KK)*PX(K,J)
GO TO (410,420,430), II
410 PX(L,J)=(GPX+PXD(1,JJ)+ZX*PXD(5,JJ)-YX*PXD(6,JJ))*GINV
GO TO 440
420 PX(L,J)=(GPX+PXD(2,JJ)-ZY*PXD(4,JJ)+XY*PXD(6,JJ))*GINV
GO TO 440
430 PX(L,J)=(GPX+PXD(3,JJ)+YZ*PXD(4,JJ)-XZ*PXD(5,JJ))*GINV
440 CONTINUE
G(1,4)=G(2,5)=G(3,6)=0
450 CONTINUE
IF (IA1.EQ.1) GO TO 480
J=0
L=0
DO 470 I=1,11
IF (I.LE.8) J=J+INTX(I)
IF (INTY(I).EQ.0) GO TO 470
L=L+1
IF (I.GT.8) J=J+1
DO 460 K=1,IP
460 PX(L,K)=PX(J,K)
470 CONTINUE
480 CONTINUE
IF (MOD(ITS,NOITSPS).NE.0) GO TO 530
IF (.NOT.LDISI(18)) NOEL=NOEL+1
IF (UM(NOEL).LT.1.E5) GO TO 490
WL(17)=T
GO TO 740
490 CONTINUE
DX(1)=UM(NOEL)-U
DX(2)=VM(NOEL)-V
DX(3)=WM(NOEL)-W
DX(4)=PM(NOEL)-P
DX(5)=QM(NOEL)-Q
DX(6)=RM(NOEL)-R
DX(7)=THM(NOEL)-THE
DX(8)=PHM(NOEL)-PHI
DX(9)=AXM(NOEL)-AXI
DX(10)=AYM(NOEL)-AYI
DX(11)=AZM(NOEL)-AZI
DO 500 I=1,IA
II=INTA(I)
DDX(I)=DX(I)
AJ=AJ+DDX(I)**2
500 XBAR(I)=XBAR(I)+DDX(I)*PTSINV
DO 510 I=1,IA
DO 510 J=1,IA
510 SD(I,J)=SD(I,J)+DDX(I)*DDX(J)*PTSINV
C PXTWT=(PX)*T(WT)
CALL MASCNT (ITRNMLT*PX*WT,PXTWT)
C DPXTWDX= (PXTWT)(DDX)
CALL MASCNT (IMULTA,PXTWT,DDX,DPXTWDX)
DO 520 I=1,IIP
PXTDX(I)=PXTDX(I)+DPXTWDX(I)
DO 520 J=I,IIP
DO 520 K=I,IA
520 PXTPX(I,J)=PXTPX(I,J)+PXTWT(I,K)*PX(K,J)
CONTINUE
530
TABLE(<34)=T
TABLE(<35)=U
TABLE(<36)=V
TABLE(<37)=W
TABLE(<38)=P
TABLE(<39)=Q
TABLE(<40)=R
TABLE(<41)=THE
TABLE(<42)=PHI
TABLE(<43)=PSI
TABLE(<44)=UDOT
TABLE(<45)=VDOT
TABLE(<46)=WDOT
TABLE(<47)=PDOT
TABLE(<48)=QDOT
TABLE(<49)=RDOT
TABLE(<50)=THEDOT
TABLE(<51)=PHIDOT
TABLE(<52)=PSIDOT
C DACS FOR TIME HISTORY RECORDERS
DAC(1)=(U-UCRTBI)/UMAX
DAC(2)=V/VMAX
DAC(3)=W/WMAX
DAC(4)=P/PMAX
DAC(5)=Q/QMAX
DAC(6)=R/RMAX
DAC(7)=THE/THMAX
DAC(8)=PHI/PHMAX
C RITECRT PLOTS IN REAL TIME IF T .LE. TMAXX
IF (.NOT.FSS*3).AND.(T.LE.TMAXX)) CALL RITECRT
IF (LDISI*22M CALL SCANNER JKSCAN)
CALL OSPLAY
IF (LDISI17)) GO TO 90050
IF (VARCHNG.AND.FSS*11 ) ) CALL TYPEVAR
IF (FSS*15) ) GO TO 770
90050 CALL RTMODE
90001 CONTINUE
IF (NOEL.GE.NOPTS) GO TO 560
90005 CONTINUE
CALL IGRATE1
INT=1
CALL RECYCLE
560 IF (FSS(3)) GO TO 770
CALL HALT
IF (FSS(10)) GO TO 690
IF (.NOT.LOGIC(11)) GO TO 570
IEVEN=IEVEN+1
IF (MOD(IEVEN+2),EQ,0) GO TO 690
CONTINUE
PASS=PASS+1.
DO 580 J=1,IP
DO 580 I=J,IP
PXTPX(I,J)=PXTPX(J,I)
C PXTPX=(PXTPX)INV
CALL MASCNT (INVSEN,PXTPX,DET1,AA1)
IF (DET1*NE.0.) GO TO 590
WL(18)='T'
GO TO 750
590 AJP=AJ
C DDELA=(PXTPX)(PXTDX)
CALL MASCNT (IMULTB,PXTPX,PXTDX,DDELA)
DO 600 I=1,IP
I=INTP(I)
600 DELA(I)=DDELA(I)*DALMLT
C FSS(5) ON TO WRITE AL AND DELA ON TAPE 50
IF (.NOT.FSS(5)) GO TO 670
WRITE (MF,960) RUN,PASS,DET1,DET2,AJP
WRITE (MF,970) DALG(I),(COM*DALG(I)),I=2,IA)
WRITE (MF,980) WT(I,J),J=1,IA)
WRITE (MF,1000) (SD(I,J),J=1,IA)
610 CONTINUE
WRITE (MF,1010)
DO 620 I=1,IA
WRITE (MF,990) (WT(I,J),J=1,IA)
620 CONTINUE
WRITE (MF,1020) PARAM(I),AL(I),DELA(I),I=1,NPAR)
IERR=0
DO 640 I=1,IP
IF (PXTPX(I,I)*GT.1.E-20) GO TO 630
IERR=1
WRITE (MF,1030) RUN,PASS,AL(I),PXTDX(I)
PXTPX(I,I)=1.E-20
630 CONTINUE
DO 640 DDELA(I)=SORT(PXTPX(I))
IF (IERR.EQ.1) CALL PRINTER
DO 650 J=1,IP
DO 650 I=1,IP
PXTPX(I,J)=PXTPX(I,J)/DDELA(I)*DDELA(J)
IF (I.EQ.J) PXTPX(I,J)=DDELA(J)
650 CONTINUE
WRITE (MF,1040)
DO 660 K=1,IP,B
660 CONTINUE
WRITE (MF,1050) DPARAM(K),K
DO 660 I=1,IP
WRITE (MF,1060) DPARAM(I),(PXTPX(I,J),J=K,KK))
CONTINUE
WRITE (MF,1070)
CONTINUE
DO 680 I=1,NPAR
AL(I)=AL(I)+DELA(I)
IF (LOGIC(6)) CZDE=CMDE*CMCON
CONTINUE
IF (.NOT. LOGIC(1)) GO TO 730
DO 700 I=1,IA
DO 700 J=I,IA
WT(I,J)=SD(I,J)
IF (.NOT. LOGIC(2)) GO TO 720
DO 710 I=1,IA
DO 710 J=1,IA
IF (I.NE.J) WT(I,J)=0.
CONTINUE
WT= (WT)INV
CALL MASCNT (INVWT,WT,DET2,AA2)
IF (DET2.NE.0.) GO TO 730
*L(IQ)=.T.
GO TO 750
CONTINUE
IF (LOGIC(IO)) LOGIC(9)=.T.
GO TO 780
CALL HALT
CALL DSPLAY
CALL OPERATE
IF (.NOT.FSS(15)) GO TO 750
DO 760 1=10,19
WLd^.F.
GO TO 780
CALL HALT
CONTINUE
CALL ENDPLOT
IF (.NOT.FSSO) ) GO TO 920
CALL UNLODE
CALL CLPTABL
NPASS=1
NFREO=1
NRITP=0
NTYPF=0
TGAIN=TIMF*.5
TOFF=-1.*
UOFF=-UCRTBI/UMAX
800 IF (.NOT.FSS(11)) GO TO 810
CALL CRTPLOT (1,3,NFREQ,NTYPE,NRITE,T,TGAIN,TOFF,LABT,AXI,AXMAX,0)
1=LABAX)
CALL CRTPLOT (2,3,NFREQ,NTYPE,NRITE,T,TGAIN,TOFF,LABT,AYI,AYMAX,0)
1=LABAY)
CALL CRTPLOT (3,3,NFREQ,NTYPE,NRITE,T,TGAIN,TOFF,LABT,AZI,AZMAX,0)
1=LABAZ)
GO TO 840
810 IF (.NOT.FSS(7)) GO TO 820
CALL CRTPLOT (1,4,NFREQ,NTYPE,NRITE,T,TGAIN,TOFF,LABT,P,PMAX,0,LA
1=BP)
CALL CRTPLOT (2,4,NFREQ,NTYPE,NRITE,T,TGAIN,TOFF,LABT,R,RMAX,0,LA
1=BR)
CALL CRTPLOT (3,4,NFREQ,NTYPE,NRITE,T,TGAIN,TOFF,LABT,V,VMAX,0,LA
1=BV)
CALL CRTPLOT (4,4,NFREQ,NTYPE,NRITE,T,TGAIN,TOFF,LABT,PHI,PHMAX,0)
1=LABPH)
GO TO 840
820 IF (.NOT.FSS(8)) GO TO 830
CALL CRTPLOT (1,4,NFREQ,NTYPE,NRIT,N,T,GAIN,TOFF,LABT,U,UMAX,UOFF,LABU)
CALL CRTPLOT (2,4,NFREQ,NTYPE,NRIT,N,T,GAIN,TOFF,LABT,W,WMAX,0,LA LABW)
CALL CRTPLOT (3,4,NFREQ,NTYPE,NRIT,N,T,GAIN,TOFF,LABT,Q,QMAX,0,LA LABQ)
CALL CRTPLOT (4,4,NFREQ,NTYPE,NRIT,N,T,GAIN,TOFF,LABT,TH,THMAX,0,LABTH)
CONTINUE
830 CALL CRTPLOT (1,3,NFREQ,NTYPE,NRIT,N,T,GAIN,TOFF,LABT,DA,DAMAX,0,LABDA)
CALL CRTPLOT (2,3,NFREQ,NTYPE,NRIT,N,T,GAIN,TOFF,LABT,DE,DEMAX,0,LABDE)
CALL CRTPLOT (3,3,NFREQ,NTYPE,NRIT,N,T,GAIN,TOFF,LABT,DR,DRMAX,0,LABDR)
GO TO 840
840 CONTINUE
IF (NPASS.EQ.0) GO TO 900
T=T-DELX
IF (LDISK19 .NE. NOEL = NOPTS)
DO 890 I=1, NOEL
T=T+DELX
IF (.NOT.FSS(I)) GO TO 850
AXI=AXM(I)
AYI=AYM(I)
AZI=AQM(I)
GO TO 880
850 CONTINUE
IF (.NOT.FSS(7)) GO TO 860
860 IF (.NOT.FSS(9)) GO TO 870
DA=FDA(I)
DE=FDE(I)
DR=FDR(I)
GO TO 880
870 U=UM(I)
W=WM(I)
Q=QM(I)
THE=THM(I)
880 CALL RITECRT (T,F,MAXPAGE)
890 CONTINUE
CALL ENDPLTOT
IF (FSS(8)) GO TO 910
CALL CLRTABL
NPASS=0
NFREQ=NOITSPS
NRIT=1
NTYPE=1
GO TO 800
900 CALL PLAYBAK(910S)
CALL RITECRT (T,F,MAXPAGE)
GO TO 900
910 CALL ENDPLTOT
The use of the program is demonstrated by showing the setup of the longitudinal equations of motion, run procedure, and output listings for the test case. The test case consists of pseudo flight data, which are generated by integrating the longitudinal equations of motion for fixed parameter values (called the true values) and then adding random number sequences (measurement noise) to the variables. The parameter values are then offset to become the starting point of the estimation program. The integration scheme (from subroutine IGRATE1) used is second-order Adams-Bashforth, a 1-pass integration scheme. (See ref. 1.)

Test Case Setup

The longitudinal equations of motion are

\[ \dot{u} = -qw - g \sin \theta + \frac{1}{2} \frac{\rho}{m} V^2 S(C_{X,0}) \]  \hspace{1cm} (10)

\[ \dot{w} = qu + g \cos \theta + \frac{1}{2} \frac{\rho}{m} V^2 S(C_{Z,0} + C_{Z \alpha_e} \alpha_a + C_{Z \delta_e} \delta_e) \]  \hspace{1cm} (11)
\[
\dot{q} = \frac{1}{2} \frac{\rho}{I_y} v^2 \sin^2 \delta_e \left( C_{m,\theta} + C_m \alpha a + C_m q + \frac{\alpha e}{2V} \right) + C_m \delta_e \delta_e
\]

(12)

\[
\dot{\theta} = q
\]

(13)

where

\[
\delta_e = \begin{cases} 
0.1 \sin 2.5t & \text{for } 0 \leq t \leq \pi/1.25 \\
0 & \text{for } t > \pi/1.25 
\end{cases}
\]

\[
V = \sqrt{u^2 + w^2}
\]

\[
\alpha_a = \tan^{-1} \frac{w}{u}
\]

The longitudinal equations are generated from the equations of motion in appendix B by the variable-dimensioning arrays described in appendix D.

For the active equation variables \( u, w, q, \) and \( \theta, \) the input array \( \text{INTX} \) is

\( \text{INTX} = (1, 0, 1, 0, 1, 0, 1, 0) \)

and hence

\( \text{INTV} = (1, 3, 5, 7, 0, \ldots, 0) \) \hspace{1cm} \( \text{(IV} = 4) \)

For the active performance index variables \( u, w, q, \) and \( \theta, \) the input array \( \text{INTY} \) is

\( \text{INTY} = (1, 0, 1, 0, 1, 0, 1, 0, 0, 0, 0) \)

and hence

\( \text{INTA} = (1, 3, 5, 7, 0, \ldots, 0) \) \hspace{1cm} \( \text{(IA} = \text{IA1} = 4) \)
For the active parameters (see TABLE array in section "Display Arrays"), all the INTEG_40(I) values are 0 except for I = 2, 8, 9, 11, 13, 14, 16, 17, and hence

\[ \text{INTP} = (2, 8, 9, 11, 13, 14, 16, 17, 0, \ldots, 0) \quad (IP = 8) \]

By putting in these arrays and the FORTRAN variables listed in the subroutine DSPLAY arrays, the test case is set up.

Test Case Run Procedure

The program deck or the data cell control cards are read into the computer after selecting RESET mode and both RELEASE switches, and FSS 3, 4, 9, and 16 true. The dynamic check case is then run before the test case or normal use of the parameter estimation program.

The step-by-step procedure for running the test case from the control console is described as follows:

<table>
<thead>
<tr>
<th>Steps</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Change constants, ( \bar{\alpha} ) and activeness by means of DDDU. Depress FSS(3), FSS(4), FSS(5), and FSS(9), and then release FSS(4).</td>
<td>Program initialization.</td>
</tr>
<tr>
<td>(2) Depress PRINT switch.</td>
<td>I.C. printout of true parameters.</td>
</tr>
<tr>
<td>(3) When RESET light comes on, depress lower RELEASE switch.</td>
<td>Return to level (4,0).</td>
</tr>
<tr>
<td>(4) Depress OPER switch.</td>
<td>OPERATE to fill flight-data arrays with pseudo data.</td>
</tr>
<tr>
<td>(5) When WL(20) comes on: release FSS(3) and FSS(9); depress RESET switch and depress FSS(13), then release FSS(13).</td>
<td>End of pseudo data fill and return to RESET mode.</td>
</tr>
<tr>
<td>(6) Change to desired standard deviations and change IPRINT to 3 by means of the DDDU, then depress PRINT switch.</td>
<td>Adds random numbers to pseudo data and prints characteristics.</td>
</tr>
<tr>
<td>(7) When RESET light comes on, depress lower RELEASE switch.</td>
<td>Return to level (4,0).</td>
</tr>
</tbody>
</table>
Steps

(8) Change $\tilde{\alpha}$ to offset values and change IPRINT to 1, then depress PRINT switch.

(9) When RESET light comes on, depress lower RELEASE switch.

(10) Depress FSS(10) and OPER switch.

(11) When WL(20) comes on, release FSS(10) and depress FSS(13).

(12) Release FSS(13) at convergence.

(13) When WL(20) comes on: depress RESET switch; and depress FSS(13), then release.

(14) Depress PRINT switch.

(15) When RESET light comes on, depress lower RELEASE switch.

Task

Inputs $\tilde{\alpha}$ offsets and gets I.C. printout.

Return to level (4,0).

OPERATE to obtain initial weighting.

OPERATE automatically updating $\tilde{\alpha}$.

Stops run.

Return to RESET mode.

Routes maximum likelihood printout.

Return to level (4,0).

Output Listings

Four output listings are presented to illustrate the computer printouts. (Note that variables in $\tilde{y}_j$ are referred to as algorithm variables in the output listings.)

(1) Random number characteristics where RN and RSD denote the means and standard deviations, respectively, used in the program

(2) Initial condition printout
   (a) Showing the true parameter values used to generate the pseudo test case
   (b) Showing the offset parameter values used as the starting point for the estimation procedure
(3) Maximum likelihood printout for each iteration (a total of 11) where the modified covariance matrix for the parameters is

\[
\begin{pmatrix}
\sigma_{\alpha_{i1}} & \rho_{\alpha_{i1}\alpha_{i2}} & \cdots & \rho_{\alpha_{i1}\alpha_{iIP}} \\
\rho_{\alpha_{i2}\alpha_{i1}} & \sigma_{\alpha_{i2}} & \cdots & \rho_{\alpha_{i2}\alpha_{iIP}} \\
\vdots & \vdots & \ddots & \vdots \\
\rho_{\alpha_{iIP}\alpha_{i1}} & \rho_{\alpha_{iIP}\alpha_{i2}} & \cdots & \sigma_{\alpha_{iIP}}
\end{pmatrix}
\]

Tabulated results of the test cases are presented in reference 1. Figure 2 shows the CalComp plot representation of the CRT display of the converged solution and the pseudo data, and the control inputs.

**Random Number Characteristics**

<table>
<thead>
<tr>
<th>RUN#</th>
<th>1</th>
<th>NOPTS= 201</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRM(I)</td>
<td>0.</td>
<td>-7.944999E-15</td>
</tr>
<tr>
<td>DRM(I)</td>
<td>0.</td>
<td>3.641090E-15</td>
</tr>
<tr>
<td>DRM(I)</td>
<td>0.</td>
<td>-3.866648E-17</td>
</tr>
<tr>
<td>DRM(I)</td>
<td>0.</td>
<td>-5.153423E-16</td>
</tr>
</tbody>
</table>
### INITIAL CONDITION PRINTOUT (TRUE PARAMETER VALUES)

**RUN = 1**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>U0</td>
<td>2.999990E+02</td>
<td>F</td>
<td>CXO</td>
<td>1.1200000E-01</td>
<td>T</td>
<td>CAMAL</td>
<td>0.</td>
<td>F</td>
<td>CXQ</td>
<td>0.</td>
<td>F</td>
</tr>
<tr>
<td>PHIO</td>
<td>0.</td>
<td>F</td>
<td>W0</td>
<td>5.0000000E+00</td>
<td>F</td>
<td>CZO</td>
<td>-1.2900000E+00</td>
<td>T</td>
<td>CIAMAL</td>
<td>0.</td>
<td></td>
</tr>
<tr>
<td>CMODE</td>
<td>-4.9300000E+00</td>
<td>T</td>
<td>QO</td>
<td>0.</td>
<td>F</td>
<td>CMO</td>
<td>1.9900000E+02</td>
<td>T</td>
<td>CAMAL</td>
<td>-3.3600000E+00</td>
<td>F</td>
</tr>
<tr>
<td>CMQ</td>
<td>-3.2000000E+01</td>
<td>T</td>
<td>CMQ</td>
<td>-3.1000000E+00</td>
<td>T</td>
<td>V0</td>
<td>0.</td>
<td>F</td>
<td>CYV</td>
<td>0.</td>
<td>F</td>
</tr>
<tr>
<td>CYDB</td>
<td>0.</td>
<td>F</td>
<td>CYP</td>
<td>0.</td>
<td>F</td>
<td>CYR</td>
<td>0.</td>
<td>F</td>
<td>CYOR</td>
<td>0.</td>
<td>F</td>
</tr>
<tr>
<td>CLO</td>
<td>0.</td>
<td>F</td>
<td>CLB</td>
<td>0.</td>
<td>F</td>
<td>CLBD</td>
<td>0.</td>
<td>F</td>
<td>CLR</td>
<td>0.</td>
<td>F</td>
</tr>
<tr>
<td>CLDR</td>
<td>0.</td>
<td>F</td>
<td>CLDA</td>
<td>0.</td>
<td>F</td>
<td>RO</td>
<td>0.</td>
<td>F</td>
<td>CNB</td>
<td>0.</td>
<td>F</td>
</tr>
<tr>
<td>CNBD</td>
<td>0.</td>
<td>F</td>
<td>CNP</td>
<td>0.</td>
<td>F</td>
<td>CNR</td>
<td>0.</td>
<td>F</td>
<td>CNDA</td>
<td>0.</td>
<td>F</td>
</tr>
<tr>
<td>UMULT</td>
<td>1.0000000E+00</td>
<td>T</td>
<td>VMULT</td>
<td>1.0000000E+00</td>
<td>T</td>
<td>WMULT</td>
<td>1.0000000E+00</td>
<td>T</td>
<td>PMULT</td>
<td>1.0000000E+00</td>
<td>T</td>
</tr>
<tr>
<td>TMULT</td>
<td>1.0000000E+00</td>
<td>T</td>
<td>PHMULT</td>
<td>1.0000000E+00</td>
<td>T</td>
<td>AHMULT</td>
<td>1.0000000E+00</td>
<td>T</td>
<td>BAMULT</td>
<td>1.0000000E+00</td>
<td>T</td>
</tr>
<tr>
<td>DEMULT</td>
<td>1.0000000E+00</td>
<td>T</td>
<td>QBIAS</td>
<td>0.</td>
<td>F</td>
<td>RBIAS</td>
<td>0.</td>
<td>F</td>
<td>THBIAS</td>
<td>0.</td>
<td>F</td>
</tr>
<tr>
<td>AKBIAS</td>
<td>0.</td>
<td>F</td>
<td>ADBIAS</td>
<td>0.</td>
<td>F</td>
<td>DBIAS</td>
<td>0.</td>
<td>F</td>
<td>DRBIAS</td>
<td>0.</td>
<td>F</td>
</tr>
<tr>
<td>AIX</td>
<td>1.5000000E+05</td>
<td>T</td>
<td>AIIY</td>
<td>1.2800000E+05</td>
<td>T</td>
<td>AIZ</td>
<td>2.7000000E+05</td>
<td>T</td>
<td>AIKZ</td>
<td>0.</td>
<td></td>
</tr>
<tr>
<td>RNI</td>
<td>2.1800000E+03</td>
<td>T</td>
<td>S</td>
<td>5.3400000E+02</td>
<td>T</td>
<td>B</td>
<td>6.7500000E+01</td>
<td>T</td>
<td>CBAR</td>
<td>8.0700000E+00</td>
<td>T</td>
</tr>
<tr>
<td>XX</td>
<td>0.</td>
<td>V</td>
<td>YY</td>
<td>0.</td>
<td>V</td>
<td>XY</td>
<td>0.</td>
<td>V</td>
<td>YY</td>
<td>0.</td>
<td>V</td>
</tr>
<tr>
<td>XZ</td>
<td>0.</td>
<td>V</td>
<td>YZ</td>
<td>0.</td>
<td>V</td>
<td>ZZ</td>
<td>0.</td>
<td>V</td>
<td>ZZ</td>
<td>0.</td>
<td>V</td>
</tr>
<tr>
<td>CMCON</td>
<td>0.</td>
<td>V</td>
<td>DALMUL</td>
<td>1.0000000E+00</td>
<td>V</td>
<td>UCRTBI</td>
<td>2.1000000E+02</td>
<td>V</td>
<td>AIW</td>
<td>0.</td>
<td></td>
</tr>
<tr>
<td>CTB</td>
<td>0.</td>
<td>V</td>
<td>DB</td>
<td>0.</td>
<td>V</td>
<td>CARPTY</td>
<td>0.</td>
<td>V</td>
<td>ELBAR</td>
<td>0.</td>
<td>V</td>
</tr>
<tr>
<td>R8</td>
<td>0.</td>
<td>V</td>
<td>PPER</td>
<td>0.</td>
<td>V</td>
<td>TPER</td>
<td>0.</td>
<td>V</td>
<td>BTBIAS</td>
<td>0.</td>
<td>V</td>
</tr>
<tr>
<td>TX</td>
<td>0.</td>
<td>V</td>
<td>TY</td>
<td>0.</td>
<td>V</td>
<td>TZ</td>
<td>0.</td>
<td>V</td>
<td>AMX</td>
<td>0.</td>
<td>V</td>
</tr>
<tr>
<td>NOPTS</td>
<td>201</td>
<td>V</td>
<td>INC</td>
<td>1.</td>
<td>V</td>
<td></td>
<td></td>
<td></td>
<td>AMY</td>
<td>0.</td>
<td>V</td>
</tr>
</tbody>
</table>

**ACTIVE EQUATION VARIABLES ARE ... U, W, Q, THE**

**ACTIVE ALGORITHM VARIABLES ARE ... U, W, Q, THE**
### INITIAL CONDITION PRINTOUT (OFFSET PARAMETER VALUES)

**RUN** = 1

<table>
<thead>
<tr>
<th>LOGIC(1) = T</th>
<th>LOGIC(2) = T</th>
<th>LOGIC(3) = F</th>
<th>LOGIC(4) = F</th>
<th>LOGIC(5) = F</th>
<th>LOGIC(6) = F</th>
</tr>
</thead>
</table>

**ACTIVE EQUATION VARIABLES ARE** . . . U . . . M . . . Q . . . THE

**ACTIVE ALGORITHM VARIABLES ARE** . . . U . . . M . . . Q . . . THE

<table>
<thead>
<tr>
<th>PARAM</th>
<th>VALUE</th>
<th>ACT</th>
<th>PARAM</th>
<th>VALUE</th>
<th>ACT</th>
<th>PARAM</th>
<th>VALUE</th>
<th>ACT</th>
</tr>
</thead>
<tbody>
<tr>
<td>UO</td>
<td>2.099000E+02</td>
<td>F</td>
<td>CXO</td>
<td>1.000000E+01</td>
<td>T</td>
<td>CAXL</td>
<td>0.</td>
<td>F</td>
</tr>
<tr>
<td>PHID</td>
<td>0.</td>
<td>F</td>
<td>WO</td>
<td>5.000000E+00</td>
<td>F</td>
<td>C2O</td>
<td>-8.000000E+01</td>
<td>T</td>
</tr>
<tr>
<td>C2DE</td>
<td>-4.000000E+00</td>
<td>T</td>
<td>QQ</td>
<td>0.</td>
<td>F</td>
<td>CMD</td>
<td>1.000000E+02</td>
<td>T</td>
</tr>
<tr>
<td>CNO</td>
<td>-2.500000E+01</td>
<td>T</td>
<td>CMDE</td>
<td>-2.000000E+00</td>
<td>T</td>
<td>VO</td>
<td>0.</td>
<td>F</td>
</tr>
<tr>
<td>CYID</td>
<td>0.</td>
<td>F</td>
<td>CYP</td>
<td>0.</td>
<td>F</td>
<td>CYR</td>
<td>0.</td>
<td>F</td>
</tr>
<tr>
<td>CLO</td>
<td>0.</td>
<td>F</td>
<td>CCLB</td>
<td>0.</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLOD</td>
<td>0.</td>
<td>F</td>
<td>CLOD</td>
<td>0.</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNDO</td>
<td>0.</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>UMLT</th>
<th>1.000000E+00</th>
<th>VMULT</th>
<th>1.000000E+00</th>
<th>WMLT</th>
<th>1.000000E+00</th>
<th>PMULT</th>
<th>1.000000E+00</th>
<th>QMLT</th>
<th>1.000000E+00</th>
<th>RMULT</th>
<th>1.000000E+00</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMULT</td>
<td>1.000000E+00</td>
<td>PHMULT</td>
<td>1.000000E+00</td>
<td>AHMULT</td>
<td>1.000000E+00</td>
<td>AHMULT</td>
<td>1.000000E+00</td>
<td>AZMULT</td>
<td>1.000000E+00</td>
<td>DAMULT</td>
<td>1.000000E+00</td>
</tr>
<tr>
<td>DEMULT</td>
<td>1.000000E+00</td>
<td>DRMULT</td>
<td>1.000000E+00</td>
<td>UBIAS</td>
<td>0.</td>
<td>WBIAS</td>
<td>0.</td>
<td>WBIAS</td>
<td>0.</td>
<td>PBIAS</td>
<td>0.</td>
</tr>
<tr>
<td>QBIAS</td>
<td>0.</td>
<td>RBIAS</td>
<td>0.</td>
<td>THBIAS</td>
<td>0.</td>
<td>PHBIAS</td>
<td>0.</td>
<td>AXBIAS</td>
<td>0.</td>
<td>AXBIAS</td>
<td>0.</td>
</tr>
<tr>
<td>A2BIAS</td>
<td>0.</td>
<td>D2BIAS</td>
<td>0.</td>
<td>D2BIAS</td>
<td>0.</td>
<td>D2BIAS</td>
<td>0.</td>
<td>D2BIAS</td>
<td>0.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AIX</th>
<th>1.500000E+05</th>
<th>AY</th>
<th>1.280000E+05</th>
<th>C5</th>
<th>0.</th>
<th>AIZ</th>
<th>2.700000E+05</th>
<th>A5X</th>
<th>0.</th>
<th>WEIGHT</th>
<th>3.605000E+04</th>
<th>GRAV</th>
<th>3.217000E+01</th>
</tr>
</thead>
<tbody>
<tr>
<td>RHO</td>
<td>2.186000E-03</td>
<td>S</td>
<td>5.344000E+00</td>
<td>B</td>
<td>6.750000E+00</td>
<td>CBAR</td>
<td>8.070000E+00</td>
<td>DEAML</td>
<td>1.000000E-01</td>
<td>DEFREQ</td>
<td>2.500000E+00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALPHAT</td>
<td>0.</td>
<td>DT</td>
<td>2.500000E-02</td>
<td>TT</td>
<td>5.000000E+02</td>
<td>TS</td>
<td>0.</td>
<td>TIMF</td>
<td>1.000000E+01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>XX</th>
<th>0.</th>
<th>YY</th>
<th>0.</th>
<th>XY</th>
<th>0.</th>
<th>YY</th>
<th>0.</th>
<th>ZY</th>
<th>0.</th>
</tr>
</thead>
<tbody>
<tr>
<td>XZ</td>
<td>0.</td>
<td>YZ</td>
<td>0.</td>
<td>ZZ</td>
<td>0.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| CMCON | 0.    | DALWLT| 1.000000E+00 | UCRTHI | 2.100000E+02 | AIW   | 0.    | CTDO  | 0.    | CTTD  | 0.    |
|-------|------|-------|-------------|--------|-------------|-------|------|------|------|------|
| CTB   | 0.    | CTBT  | 0.    | O     | 0.    | CAPOT | 0.    | ELCAR | 0.    | ELTP  | 0.    |
| RB    | 0.    | PPER  | 0.    | TPER  | 0.    | STBIAS| 0.    | PPERBI| 0.    | TPERBI| 0.    |
| TX    | 0.    | TY    | 0.    | TZ    | 0.    | AMX   | 0.    | AMY   | 0.    | AMZ   | 0.    |

**N0PTS** = 201  **INC** = 1
# ALGORITHM PRINTOUT

Run= 1  Pass= 0  Det1= 2.184853E+17  Det2= 2.911344E+00  Ajp= 1.322543E+05

Active algorithm variables are . . . U , W , Q , THE

Packed mean algorithm
-1.7961E+01  -5.1772E+00  2.6770E-02  1.6464E-01

Packed noise covariance matrix
5.9592E+02  4.9857E+01  -3.3688E-01  -4.0594E+00
4.9857E+01  6.2029E+01  -1.1152E-01  -6.6932E-01
-3.3688E-01  -1.1152E-01  2.5438E-03  3.5111E-03
-4.0594E+00  -6.6932E-01  3.5111E-03  3.6962E-02

Packed weight matrix
1.6781E-03  0.
0.
-8.6122E-02  0.
0.
3.9311E+02  0.
0.
3.2298E+01

<table>
<thead>
<tr>
<th>Param</th>
<th>Value</th>
<th>Change</th>
<th>Param</th>
<th>Value</th>
<th>Change</th>
<th>Param</th>
<th>Value</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>UO</td>
<td>2.699000E+02</td>
<td>0.</td>
<td>CXO</td>
<td>1.000000E-01</td>
<td>5.441500E-03</td>
<td>CXAL</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CXO</td>
<td>0.</td>
<td>0.</td>
<td>Theo</td>
<td>8.000000E-02</td>
<td>0.</td>
<td>PHI</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>WO</td>
<td>5.000000E+00</td>
<td>0.</td>
<td>CZO</td>
<td>-8.300000E-01</td>
<td>-4.528000E-01</td>
<td>CIAL</td>
<td>-3.500000E+00</td>
<td>7.836500E-01</td>
</tr>
<tr>
<td>CIO</td>
<td>0.</td>
<td>0.</td>
<td>CZO</td>
<td>-4.000000E+00</td>
<td>-1.115000E-01</td>
<td>QO</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CMD</td>
<td>1.000030E+02</td>
<td>5.925840E-03</td>
<td>CMAL</td>
<td>-5.000000E-01</td>
<td>-2.605790E-01</td>
<td>CMALD</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CMD</td>
<td>-2.500300E+01</td>
<td>-1.671630E+01</td>
<td>CMDE</td>
<td>-2.000000E+00</td>
<td>-1.079040E+00</td>
<td>VO</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CYD</td>
<td>0.</td>
<td>0.</td>
<td>CYB</td>
<td>0.</td>
<td>0.</td>
<td>CYD</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CVD</td>
<td>0.</td>
<td>0.</td>
<td>CYR</td>
<td>0.</td>
<td>0.</td>
<td>CYR</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>PDO</td>
<td>0.</td>
<td>0.</td>
<td>CLO</td>
<td>0.</td>
<td>0.</td>
<td>CLR</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CLOD</td>
<td>0.</td>
<td>0.</td>
<td>CLP</td>
<td>0.</td>
<td>0.</td>
<td>CLP</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CLOD</td>
<td>0.</td>
<td>0.</td>
<td>CLD</td>
<td>0.</td>
<td>0.</td>
<td>RO</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CNB</td>
<td>0.</td>
<td>0.</td>
<td>CNB</td>
<td>0.</td>
<td>0.</td>
<td>CNB</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CNB</td>
<td>0.</td>
<td>0.</td>
<td>CNR</td>
<td>0.</td>
<td>0.</td>
<td>CNR</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CNOA</td>
<td>0.</td>
<td>0.</td>
<td>CNOA</td>
<td>0.</td>
<td>0.</td>
<td>CNOA</td>
<td>0.</td>
<td>0.</td>
</tr>
</tbody>
</table>

Modified parameter covariance matrix

<table>
<thead>
<tr>
<th>Param</th>
<th>Value</th>
<th>Change</th>
<th>Param</th>
<th>Value</th>
<th>Change</th>
<th>Param</th>
<th>Value</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>CXO</td>
<td>1.329714E-02</td>
<td>-5.095304E-02</td>
<td>CZD</td>
<td>-9.696750E-03</td>
<td>-1.822915E-01</td>
<td>CZD</td>
<td>1.331663E-01</td>
<td>2.071965E-01</td>
</tr>
<tr>
<td>CZD</td>
<td>-5.695304E-02</td>
<td>4.170712E-02</td>
<td>CZAL</td>
<td>8.696750E-03</td>
<td>6.407304E-01</td>
<td>4.170712E-02</td>
<td>8.696750E-03</td>
<td>4.170712E-02</td>
</tr>
<tr>
<td>CZAL</td>
<td>-5.696750E-03</td>
<td>4.170712E-02</td>
<td>6.896750E-01</td>
<td>4.170712E-02</td>
<td>8.696750E-03</td>
<td>4.170712E-02</td>
<td>8.696750E-03</td>
<td>4.170712E-02</td>
</tr>
<tr>
<td>CMAL</td>
<td>1.331663E-01</td>
<td>2.071965E-01</td>
<td>CMED</td>
<td>9.175058E-02</td>
<td>1.719726E-01</td>
<td>CMED</td>
<td>9.175058E-02</td>
<td>1.719726E-01</td>
</tr>
<tr>
<td>CMD</td>
<td>1.331663E-01</td>
<td>2.071965E-01</td>
<td>CMAL</td>
<td>9.175058E-02</td>
<td>1.719726E-01</td>
<td>CMED</td>
<td>9.175058E-02</td>
<td>1.719726E-01</td>
</tr>
<tr>
<td>CMAL</td>
<td>2.071965E-01</td>
<td>1.719726E-01</td>
<td>CMED</td>
<td>9.175058E-02</td>
<td>1.719726E-01</td>
<td>CMED</td>
<td>9.175058E-02</td>
<td>1.719726E-01</td>
</tr>
</tbody>
</table>
ALGORITHM PRINTOUT – Continued

RUN= 1 PASS= 1 DET1= 4.566813E+15 DET2= 2.911344E+00 AJP= 3.417685E+03

ACTIVE ALGORITHM VARIABLES ARE • • • U • • • W • • Q • • THE

PACKED MEAN ARRAY
\[-1.9312E+00 \quad -2.7791E-02 \quad 2.6002E-03 \quad 1.5732E-02\]

PACKED NOISE COVARIANCE MATRIX
\[
\begin{bmatrix}
6.6354E+00 & -3.3881E-01 & 1.8591E-04 & -4.4760E-02 \\
-3.8881E-01 & 1.0367E+01 & 3.3539E-03 & 1.0495E-02 \\
1.8591E-04 & 3.3539E-03 & 5.6745E-04 & 3.5200E-05 \\
-4.4760E-02 & 1.0495E-02 & 3.5200E-05 & 7.9216E-04
\end{bmatrix}
\]

PACKED WEIGHT MATRIX
\[
\begin{bmatrix}
6.781E-03 & 0. & 0. & 0. \\
0. & 1.6122E-02 & 0. & 0. \\
0. & 0. & 3.9311E+02 & 0. \\
0. & 0. & 0. & 3.2298E+01
\end{bmatrix}
\]

<table>
<thead>
<tr>
<th>PARAM</th>
<th>VALUE</th>
<th>CHANGE</th>
<th>PARAM</th>
<th>VALUE</th>
<th>CHANGE</th>
<th>PARAM</th>
<th>VALUE</th>
<th>CHANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>UD</td>
<td>2.0990000E+02</td>
<td>0.</td>
<td>CXD</td>
<td>1.054415E-01</td>
<td>1.527980E-03</td>
<td>CKAL</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CIO</td>
<td>0.</td>
<td>0.</td>
<td>THEO</td>
<td>6.000000E-02</td>
<td>0.</td>
<td>PHI0</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>WD</td>
<td>5.000000E+00</td>
<td>0.</td>
<td>CZD</td>
<td>-1.252856E+00</td>
<td>-3.605968E-02</td>
<td>CIAL</td>
<td>0.</td>
<td>-4.283653E+03</td>
</tr>
<tr>
<td>CIO</td>
<td>0.</td>
<td>0.</td>
<td>CZDE</td>
<td>-5.110759E+00</td>
<td>5.150919E-01</td>
<td>QO</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CMO</td>
<td>1.592584E-02</td>
<td>3.606238E-03</td>
<td>CMAL</td>
<td>-7.605739E-01</td>
<td>-4.926042E-02</td>
<td>CMALD</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CMQ</td>
<td>-4.171633E+01</td>
<td>9.767419E+00</td>
<td>CMDE</td>
<td>-3.079041E+00</td>
<td>-2.713502E-02</td>
<td>VQ</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CJO</td>
<td>0.</td>
<td>0.</td>
<td>CYD</td>
<td>0.</td>
<td>0.</td>
<td>CYBD</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CYP</td>
<td>0.</td>
<td>0.</td>
<td>CYR</td>
<td>0.</td>
<td>0.</td>
<td>CYDR</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>PO</td>
<td>0.</td>
<td>0.</td>
<td>CLO</td>
<td>0.</td>
<td>0.</td>
<td>CLB</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CLD</td>
<td>0.</td>
<td>0.</td>
<td>CLP</td>
<td>0.</td>
<td>0.</td>
<td>CLR</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CLBD</td>
<td>0.</td>
<td>0.</td>
<td>CLDA</td>
<td>0.</td>
<td>0.</td>
<td>RO</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CND</td>
<td>0.</td>
<td>0.</td>
<td>CN0</td>
<td>0.</td>
<td>0.</td>
<td>CNBD</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CNP</td>
<td>0.</td>
<td>0.</td>
<td>CNR</td>
<td>0.</td>
<td>0.</td>
<td>CNDR</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CNOA</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
</tr>
</tbody>
</table>

MODIFIED PARAMETER COVARIANCE MATRIX

<table>
<thead>
<tr>
<th>PARAM</th>
<th>VALUE</th>
<th>CHANGE</th>
<th>PARAM</th>
<th>VALUE</th>
<th>CHANGE</th>
<th>PARAM</th>
<th>VALUE</th>
<th>CHANGE</th>
<th>PARAM</th>
<th>VALUE</th>
<th>CHANGE</th>
<th>PARAM</th>
<th>VALUE</th>
<th>CHANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>CJO</td>
<td>1.388403E-02</td>
<td>2.483655E-02</td>
<td>6.178364E-02</td>
<td>-1.566951E-01</td>
<td>3.617779E-01</td>
<td>9.985538E-02</td>
<td>1.099767E-01</td>
<td>1.924658E-01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CMO</td>
<td>2.483655E-02</td>
<td>3.007918E-02</td>
<td>-6.082048E-01</td>
<td>-1.132842E-01</td>
<td>5.954329E-02</td>
<td>2.025015E-01</td>
<td>1.840243E-01</td>
<td>-9.669531E-02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CMO</td>
<td>9.985538E-02</td>
<td>2.025015E-01</td>
<td>-2.416043E-01</td>
<td>-4.783760E-01</td>
<td>-5.953772E-01</td>
<td>6.538141E-02</td>
<td>-1.756323E-01</td>
<td>1.083625E-01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CMO</td>
<td>-1.802458E-01</td>
<td>-9.669531E-02</td>
<td>-1.112003E-02</td>
<td>-3.501976E-01</td>
<td>1.604847E-01</td>
<td>-1.083625E-01</td>
<td>7.731113E-01</td>
<td>2.138615E-01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**ALGORITHM PRINTOUT – Continued**

**RUN** = 1  **PASS** = 2  **DET1** = 4.1794016+24  **DET2** = 3.092048E-05  **AJP** = 1.902637E+03

**ACTIVE ALGORITHM VARIABLES ARE** . . . U , W , Q , THE

**PACKED MEAN ARRAY**

<table>
<thead>
<tr>
<th>VALUE</th>
<th>CHANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.7179E-01</td>
<td>-1.3210E-01</td>
</tr>
</tbody>
</table>

**PACKED NOISE COVARIANCE MATRIX**

<table>
<thead>
<tr>
<th>VALUE</th>
<th>CHANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.8250E-01</td>
<td>2.1328E-02</td>
</tr>
<tr>
<td>2.1328E-02</td>
<td>8.9826E+00</td>
</tr>
<tr>
<td>-3.8777E-04</td>
<td>-2.3407E-03</td>
</tr>
<tr>
<td>-7.9297E-04</td>
<td>-1.4428E-03</td>
</tr>
</tbody>
</table>

**PACKED WEIGHT MATRIX**

<table>
<thead>
<tr>
<th>VALUE</th>
<th>CHANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5071E-01</td>
<td>0.0</td>
</tr>
<tr>
<td>0.0</td>
<td>9.4663E-02</td>
</tr>
<tr>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**PARAM** | **VALUE** | **CHANGE** | **PARAM** | **VALUE** | **CHANGE** | **PARAM** | **VALUE** | **CHANGE**
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>UO</td>
<td>2.099000E+02</td>
<td>0.0</td>
<td>CXO</td>
<td>1.069695E-01</td>
<td>2.453560E-03</td>
<td>CXAL</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>CXO</td>
<td>0.0</td>
<td>0.0</td>
<td>THEO</td>
<td>8.000000E-02</td>
<td>0.0</td>
<td>PHIO</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>WO</td>
<td>5.000000E+00</td>
<td>0.0</td>
<td>CZO</td>
<td>-1.228914E+00</td>
<td>-2.531949E-03</td>
<td>CAMAL</td>
<td>-4.546204E+00</td>
<td>1.77127E-01</td>
</tr>
<tr>
<td>CZO</td>
<td>0.0</td>
<td>0.0</td>
<td>CMAL</td>
<td>-8.098343E-01</td>
<td>-9.922263E-03</td>
<td>MDME</td>
<td>1.069695E+00</td>
<td>2.453560E-03</td>
</tr>
<tr>
<td>CMAL</td>
<td>-1.193395E-04</td>
<td>-1.118078E+00</td>
<td>CYD</td>
<td>0.0</td>
<td>0.0</td>
<td>CYBD</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>CYD</td>
<td>0.0</td>
<td>0.0</td>
<td>CYR</td>
<td>0.0</td>
<td>0.0</td>
<td>CYOR</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>CYP</td>
<td>0.0</td>
<td>0.0</td>
<td>CLQ</td>
<td>0.0</td>
<td>0.0</td>
<td>CLB</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>PO</td>
<td>0.0</td>
<td>0.0</td>
<td>CLP</td>
<td>0.0</td>
<td>0.0</td>
<td>CLR</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>CLRD</td>
<td>0.0</td>
<td>0.0</td>
<td>CLDA</td>
<td>0.0</td>
<td>0.0</td>
<td>RO</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>CMO</td>
<td>0.0</td>
<td>0.0</td>
<td>CNB</td>
<td>0.0</td>
<td>0.0</td>
<td>CNBD</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>CHD</td>
<td>0.0</td>
<td>0.0</td>
<td>CNR</td>
<td>0.0</td>
<td>0.0</td>
<td>CNDR</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**MODIFIED PARAMETER COVARIANCE MATRIX**

<table>
<thead>
<tr>
<th>VALUE</th>
<th>CHANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIZE</td>
<td>-5.138401E-01</td>
</tr>
<tr>
<td>CMAL</td>
<td>1.017347E-01</td>
</tr>
<tr>
<td>CMO</td>
<td>3.995888E-01</td>
</tr>
<tr>
<td>CMDE</td>
<td>3.422932E-01</td>
</tr>
</tbody>
</table>
ALGORITHM PRINTOUT – Continued

RUN = 1  PASS = 3  DET1 = 2.17345E+27  DET2 = 7.034618E-07  AJP = 1.830437E+03

ACTIVE ALGORITHM VARIABLES ARE . . . U , W , Q , THE

PACKED MEAN ARRAY
-1.3953E-02 -1.8858E-02  2.1345E-04  9.9433E-04

PACKED NOISE COVARIANCE MATRIX
2.5447E-01  4.8338E-02  -4.5240E-04  -1.6977E-03
 4.8338E-02  8.8514E+00  -2.5297E-03  -1.5680E-03
 -4.5240E-04  -2.5297E-03  3.9852E-04  5.6834E-06
 -1.6977E-03  -1.5680E-03  6.3084E-06  3.5940E-04

PACKED WEIGHT MATRIX
 2.0726E+00  0.0  0.0  0.0
 0.0  1.1133E-01  0.0  0.0
 0.0  0.0  2.5063E+03  0.0
 0.0  0.0  0.0  2.4582E+03

PARAM  VALUE  CHANGE  PARAM  VALUE  CHANGE  PARAM  VALUE  CHANGE
 UD  2.099900E+02  0.0  CXL  1.094231E-01  6.475541E-04  CXL  0.0  0.0
 CXO  0.0  0.0  THEO  8.030900E-02  0.0  PHI0  0.0  0.0
 WD  5.000000E+00  0.0  CZO  -1.291446E+00  1.668646E-03  CZL  -4.428492E+00  -6.331718E-03
 CZ0  0.0  0.0  CZDE  -4.646839E-00  -2.38607E-01  QQ  0.0  0.0
 CM0  1.941274E-02  1.507396E-04  CMAL  -8.197576E-01  -2.129250E-03  CMALD  0.0  0.0
 CMQ  -3.312989E-01  4.566294E-01  CMQD  -3.090994E-00  1.586320E-02  WD  0.0  0.0
 CY0  0.0  0.0  CBY  0.0  0.0  CYBD  0.0  0.0
 CYP  0.0  0.0  CYR  0.0  0.0  CYDR  0.0  0.0
 PO  0.0  0.0  CLO  0.0  0.0  CLB  0.0  0.0
 CLR0  0.0  0.0  CLR  0.0  0.0  CLR  0.0  0.0
 CLRD  0.0  0.0  CLDA  0.0  0.0  RD  0.0  0.0
 CNO  0.0  0.0  CBW  0.0  0.0  CNBD  0.0  0.0
 CNO  0.0  0.0  CNR  0.0  0.0  CNDR  0.0  0.0
 CNOA  0.0  0.0

MODIFIED PARAMETER COVARIANCE MATRIX

PARAM  CXC  CZD  CXL  CZE  CMD  CMAL  CMQ  CMQDEF
 UD  1.799161E-03  1.027426E-01  1.311502E-01  6.873052E-01  1.212894E-01  1.961179E-01  4.473370E-01  3.312533E-01
 CXO  1.027426E-01  7.926293E-03  6.986143E-03  3.526591E-02  6.651202E-01  2.177046E-03  3.093070E-01  -3.752007E-02
 CZO  1.311502E-01  6.986143E-03  1.212894E-01  1.961179E-01  4.473370E-01  3.312533E-01  1.027426E-01  7.926293E-03
 CZE  1.212894E-01  1.961179E-01  4.473370E-01  3.312533E-01  1.027426E-01  7.926293E-03  6.986143E-03  3.526591E-02
 CMD  3.093070E-01  2.177046E-03  3.093070E-01  1.027426E-01  7.926293E-03  6.986143E-03  1.212894E-01  1.961179E-01
 CMQDEF  -3.526591E-02  -6.651202E-01  -3.752007E-02  -1.212894E-01  -1.961179E-01  -4.473370E-01  -3.312533E-01  -1.027426E-01
 CMQ  1.027426E-01  7.926293E-03  6.986143E-03  3.526591E-02  6.651202E-01  2.177046E-03  3.093070E-01  -3.752007E-02
 CMQDEF  7.926293E-03  6.986143E-03  3.526591E-02  6.651202E-01  2.177046E-03  3.093070E-01  1.027426E-01  7.926293E-03
 CMQ  8.986143E-03  3.526591E-02  6.651202E-01  2.177046E-03  3.093070E-01  -3.752007E-02  -1.212894E-01  -1.961179E-01
 CMQDEF  3.526591E-02  6.651202E-01  2.177046E-03  3.093070E-01  1.027426E-01  7.926293E-03  6.986143E-03  3.526591E-02
Algorithm Printout – Continued

Run = 1 Pass = 4 OEF1 = 1.14056E+28 OEF2 = 3.585114E-07 AJP = 1.838583E+03

Active algorithm variables are . . . U . . W . . Q , THE

Packed Mean Array

-9.0181E-03 -5.4658E-02 2.9479E-04 1.1456E-03

Packed Noise Covariance Matrix

2.4623E-01 4.2017E-02 -4.2549E-04 -1.6382E-03
4.2017E-02 8.9202E+00 -2.8076E-03 -1.3149E-03
-4.2549E-04 -2.8076E-03 3.9913E-04 5.0420E-06
-1.6382E-03 -1.3149E-03 5.0420E-06 3.9828E-04

Packed Weight Matrix

3.9298E+00 0. . 0. .
0. . 1.1268E-01 0. .
0. . 0. . 2.5037E+03
0. . 0. . 0. .

Param Value Change Param Value Change Param Value Change

WQ 2.099000E+02 0. . CXO 1.100710E-01 1.640210E-05 CXAL . . .
C XO 0. . . THEO 8.000000E-02 0. . PHIQ . . .
W D 5.000000E+00 0. . CZD -1.289777E+00 5.805288E-04 CZAL -4.34823E+00 -7.395059E-04
CZD 0. . . C ZDE -4.886999E+00 -3.865240E-02 QD . . .
CMO 1.956740E-02 3.363499E-05 CMAL 8.218868E-01 2.290303E-04 CMALD . . .
CMO 3.267326E+01 -1.190056E-01 CMDE -3.074239E+00 -1.157194E+00 CO . . .
C YO 0. . . CYB 0. . . CYBD . . .
CYP 0. . . CYR 0. . . CYDR . . .
PD 0. . . CLO 0. . . CLB . . .
CLRD 0. . . CLP 0. . . CLR . . .
CLRD 0. . . CLDA 0. . . RO . . .
CNO 0. . . CNB 0. . . CNBD . . .
CNP 0. . . CNR 0. . . CNDR . . .
CNOA 0. . . . . . .

Modified Parameter Covariance Matrix

CZAL -3.183256E-01 -7.045692E-01 2.235314E-01 3.650897E-01 -1.507491E-01 2.977621E-02 -6.420382E-01 -1.491636E-01
CMO 2.555800E-01 1.992884E-02 2.977621E-02 -6.409009E-01 -3.964290E-01 1.658836E-02 -1.821608E-01 -3.305999E-02
C MOE 4.436670E-01 3.089331E-01 -6.409009E-01 -2.405236E-01 7.523306E-02 -1.821608E-01 1.234104E-00 7.327591E-01
CMDE 3.250012E-01 -5.232541E-02 -1.491636E-01 -2.006387E-01 -4.788829E-02 -3.393099E-02 7.327591E-01 5.576479E-02
ALGORITHM PRINTOUT – Continued

RUN= 1  PASS= 5  DET1= 1.225144E+28  DET2= 3.483735E-07  AJP= 1.840700E+03

ACTIVE ALGORITHM VARIABLES ARE + + + U + W + Q , THE

PACKED MEAN ARRAY
-5.6360E-03 -6.9424E-02 3.2014E-04 1.2667E-03

PACKED NOISE COVARIANCE MATRIX
2.4535E-01 4.0423E-02 -4.3564E-04 -1.0238E-03
4.0423E-02 8.9116E+00 -2.8455E-03 -1.2668E-03
-4.3564E-04 -2.8455E-03 3.9910E-04 5.3289E-06
-1.0238E-03 -1.2668E-03 5.3289E-06 3.5881E-04

PACKED WEIGHT MATRIX
4.0613E+00 0. 0. 0.
0. 1.1236E-01 0. 0.
0. 0. 2.5054E+03 0.
0. 0. 2.5108E+03

<table>
<thead>
<tr>
<th>PARAM</th>
<th>VALUE</th>
<th>CHANGE</th>
<th>PARAM</th>
<th>VALUE</th>
<th>CHANGE</th>
<th>PARAM</th>
<th>VALUE</th>
<th>CHANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>UO</td>
<td>2.099000E+02</td>
<td>0.</td>
<td>CKO</td>
<td>1.100850E-01</td>
<td>1.171584E-05</td>
<td>CXAL</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CXQ</td>
<td>0.</td>
<td>0.</td>
<td>TCED</td>
<td>8.000000E-02</td>
<td>0.</td>
<td>PHI0</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>WD</td>
<td>5.000000E+00</td>
<td>0.</td>
<td>CZO</td>
<td>0.</td>
<td>0.</td>
<td>C2ZDE</td>
<td>-4.925352E-00</td>
<td>-3.311569E-03</td>
</tr>
<tr>
<td>CMD</td>
<td>1.959712E-02</td>
<td>2.683831E-06</td>
<td>CMAL</td>
<td>-8.216578E-01</td>
<td>4.584780E-05</td>
<td>CMALD</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CMQ</td>
<td>-3.279227E+01</td>
<td>-6.161114E-03</td>
<td>CMDE</td>
<td>-3.085628E+00</td>
<td>-7.003316E-04</td>
<td>VG</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CYO</td>
<td>0.</td>
<td>0.</td>
<td>CYB</td>
<td>0.</td>
<td>0.</td>
<td>CYBD</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CYP</td>
<td>0.</td>
<td>0.</td>
<td>CYR</td>
<td>0.</td>
<td>0.</td>
<td>CYRD</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>PO</td>
<td>0.</td>
<td>0.</td>
<td>CLO</td>
<td>0.</td>
<td>0.</td>
<td>CLB</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CLBD</td>
<td>0.</td>
<td>0.</td>
<td>CLP</td>
<td>0.</td>
<td>0.</td>
<td>CLR</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CLR</td>
<td>0.</td>
<td>0.</td>
<td>CLDA</td>
<td>0.</td>
<td>0.</td>
<td>RO</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CND</td>
<td>0.</td>
<td>0.</td>
<td>CNB</td>
<td>0.</td>
<td>0.</td>
<td>CNBD</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CNP</td>
<td>0.</td>
<td>0.</td>
<td>CNR</td>
<td>0.</td>
<td>0.</td>
<td>CNDR</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CND</td>
<td>0.</td>
<td>0.</td>
<td>.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MODIFIED PARAMETER COVARIANCE MATRIX

<table>
<thead>
<tr>
<th>PARAM</th>
<th>CIZO</th>
<th>CZAL</th>
<th>C2ZDE</th>
<th>C2ZDE</th>
<th>CMG</th>
<th>CMAL</th>
<th>CMAL</th>
<th>CMQ</th>
<th>CMDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2Z</td>
<td>-3.195700E-01</td>
<td>2.239252E-00</td>
<td>3.640528E-01</td>
<td>1.513223E-01</td>
<td>2.867449E-02</td>
<td>-6.420367E-01</td>
<td>-1.487432E-01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2ZD</td>
<td>-7.364319E-01</td>
<td>-2.590370E-02</td>
<td>3.640528E-01</td>
<td>1.513223E-01</td>
<td>2.867449E-02</td>
<td>-6.420367E-01</td>
<td>-1.487432E-01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CM</td>
<td>4.433490E-01</td>
<td>3.072261E-00</td>
<td>-1.487432E-01</td>
<td>-1.802678E-01</td>
<td>4.278309E-02</td>
<td>-2.936066E-01</td>
<td>-1.999527E-01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CM</td>
<td>4.433490E-01</td>
<td>3.072261E-00</td>
<td>-1.487432E-01</td>
<td>-1.802678E-01</td>
<td>4.278309E-02</td>
<td>-2.936066E-01</td>
<td>-1.999527E-01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CM</td>
<td>4.433490E-01</td>
<td>3.072261E-00</td>
<td>-1.487432E-01</td>
<td>-1.802678E-01</td>
<td>4.278309E-02</td>
<td>-2.936066E-01</td>
<td>-1.999527E-01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CM</td>
<td>4.433490E-01</td>
<td>3.072261E-00</td>
<td>-1.487432E-01</td>
<td>-1.802678E-01</td>
<td>4.278309E-02</td>
<td>-2.936066E-01</td>
<td>-1.999527E-01</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**ALGORITHM PRINTOUT - Continued**

**RUN** = 1  **PASSE** = 6  **DET1** = 1.231132E+28  **DET2** = 3.480124E-07  **AJP** = 1.840942E+03

**ACTIVE ALGORITHM VARIABLES ARE**: U X + Q + THE

**PACKED MEAN ARRAY**
-5.5126E-03 -7.0487E-02 3.2046E-04 1.2668E-03

**PACKED NOISE COVARIANCE MATRIX**

<table>
<thead>
<tr>
<th></th>
<th>2.4931E-01</th>
<th>4.0320E-02</th>
<th>-4.3616E-04</th>
<th>-1.0230E-03</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0320E-02</td>
<td>3.8912E+00</td>
<td>-2.8430E-03</td>
<td>-1.2619E-03</td>
<td>-4.3616E-04</td>
</tr>
<tr>
<td>-1.0230E-03</td>
<td>-1.2619E-03</td>
<td>5.3430E-06</td>
<td>3.5883E-04</td>
<td></td>
</tr>
</tbody>
</table>

**PACKED WEIGHT MATRIX**

<table>
<thead>
<tr>
<th></th>
<th>4.0758E+00</th>
<th>0.</th>
<th>0.</th>
<th>0.</th>
<th>1.1212E-01</th>
<th>0.</th>
<th>0.</th>
<th>0.</th>
<th>2.5056E+03</th>
<th>0.</th>
<th>0.</th>
<th>0.</th>
<th>2.5075E+03</th>
</tr>
</thead>
</table>

**PARAM** | **VALUE** | **CHANGE** | **PARAM** | **VALUE** | **CHANGE** | **PARAM** | **VALUE** | **CHANGE**

| UD    | 2.099000E+02 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| CXD   | 1.100968E-01 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| CXO   | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| WO    | 5.000000E+00 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| C2O   | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| CMO   | 1.959980E-02 | 2.142943E-07 | CMAL | -8.216119E-01 | 1.022085E-05 | CMALO | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| CMQ   | -3.279843E+01 | -1.103374E-03 | CMAL | -3.086337E+00 | -1.348413E+04 | CMO | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| CVO   | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| CYP   | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| PO    | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| CLBD  | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| CLDR  | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| CNP   | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| CNDA  | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |

**MODIFIED PARAMETER COVARIANCE MATRIX**

| C2L | -3.195967E-01 | -7.042382E-01 | 2.230846E-01 | 3.639507E-01 | -1.513518E-01 | 2.859480E-02 | -6.429889E-01 | -1.445731E-01 |
| CZD | -7.368282E-01 | 2.575957E-02 | 3.639507E-01 | -1.513518E-01 | 2.859480E-02 | -6.429889E-01 | -1.445731E-01 |
| CMAL | 2.603217E-01 | 2.256903E-02 | 2.859480E-02 | -6.429889E-01 | -3.930200E-01 | 7.312701E-02 | -6.429889E-01 | -1.445731E-01 |
| CMQ | 4.32652E-01 | 3.070543E-01 | -6.429889E-01 | -3.930200E-01 | 7.312701E-02 | -6.429889E-01 | -1.445731E-01 |
| CMDE | 2.357067E-01 | 3.485731E-01 | 7.312701E-02 | -4.942297E-02 | -3.252243E-02 | 7.327137E-01 | 5.583926E-02 |
ALGORITHM PRINTOUT - Continued

RUN = 1 PASS = 7 DET = 1.231219E+28 DET2 = 3.480109E-07 AJP = 1.84096E+03

ACTIVE ALGORITHM VARIABLES ARE • • U • • W • • THE

PACKED MEAN ARRAY
-5.4923E-03 -7.3866E-02 3.2065E-04 1.2681E-03

PACKED NOISE COVARIANCE MATRIX
2.4530E-04 -4.3630E-04 -1.0229E-03
-4.3630E-04 -9.129E+00 -2.8431E-03
-1.0229E-03 -2.8431E-03 5.3471E-05

PACKED WEIGHT MATRIX
4.0675E+00 0.
0. 1.1220E+01 0.
0. 2.5056E+03 0.
0. 2.5074E+03 0.

PARAM VALUE CHANGE PARAM VALUE CHANGE PARAM VALUE CHANGE
UO 2.099000E+02 0. Cxo 1.100959E-01 1.494661E-07 Cmal 0.
CXO 0. 0. XI E0 9.000000E-02 0.
WO 5.000000E+00 0. CZO -1.289166E+00 4.264216E-07 CIAL -4.435423E+00 -6.973652E-06
CZO 0. 0. CzOE -4.928978E+00 -3.802998E-05 QO 0.
CMO -1.960000E-02 2.126416E-08 CmAL -8.216017E+01 8.095074E-07 CMAO 0.
CMAL -3.227995E+04 6.565006E-07 CmDE -3.086472E+00 5.074042E-06 VD 0.
CYO 0. 0. CYB 0.
CYP 0. 0. CYR 0.
CP 0. 0. CLR 0.
CLO 0. 0. CND 0.
CLOR 0. 0. CNO 0.
CNO 0. 0. CNP 0.
CNP 0. 0. CNO 0.
CNOA 0. 0.

MODIFIED PARAMETER COVARIANCE MATRIX

PARAM VALUE CHANGE PARAM VALUE CHANGE PARAM VALUE CHANGE
CMO 1.173924E-03 7.387842E-02 -3.196039E-01 -7.368498E-01 7.915952E-02 2.603425E-01
CZ0 7.387842E-02 7.802076E-03 -7.042255E-01 -2.574102E-02 6.761395E-01 2.257722E-02
CIAL -3.196039E-01 -7.042255E-01 2.230857E-01 3.639332E-01 -1.513699E-01 2.861341E-02
CMO 7.915952E-02 6.761395E-01 -1.513699E-01 2.257722E-02 6.429485E-01 -3.929913E-01
CMAL 2.603425E-01 -2.574102E-02 6.429485E-01 -3.929913E-01 1.654754E-02 -1.801542E-01
CMAL 2.603425E-01 6.429485E-01 -1.801542E-01 1.654754E-02 -3.253880E-02 -1.801542E-01
CMAL 2.603425E-01 6.429485E-01 -3.253880E-02 -1.801542E-01 7.327155E-01 5.584102E-02
ALGORITHM PRINTOUT – Continued

RUN = 1  PASS = 8  DET1 = 1.231248E+28  DET2 = 3.480198E-07  AJP = 1.840969E+03

ACTIVE ALGORITHM VARIABLES ARE . . . . U . W . Q . THE

PACKED MEAN ARRAY
-5.4913E-03  -7.0656E-02  3.2065E-04  1.2681E-03

PACKED NOISE COVARIANCE MATRIX

PACKED WEIGHT MATRIX
4.0766E+00  0.  0.  0.  1.1220E-01  0.  0.  0.  2.5056E+03  0.  0.  0.  2.5573E+03

<table>
<thead>
<tr>
<th>PARAM</th>
<th>VALUE</th>
<th>CHANGE</th>
<th>PARAM</th>
<th>VALUE</th>
<th>CHANGE</th>
<th>PARAM</th>
<th>VALUE</th>
<th>CHANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>UO</td>
<td>2.09930E+02</td>
<td>0.</td>
<td>CIO</td>
<td>1.10970E-01</td>
<td>-1.71179E-09</td>
<td>CXAL</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CXQ</td>
<td>0.</td>
<td>0.</td>
<td>THEO</td>
<td>8.00000E-02</td>
<td>0.</td>
<td>PHIO</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>WQ</td>
<td>5.00000E+00</td>
<td>0.</td>
<td>CIO</td>
<td>-1.28916E+00</td>
<td>1.33830E-07</td>
<td>CJAL</td>
<td>-6.43543E+00</td>
<td>-1.97236E-06</td>
</tr>
<tr>
<td>CJQ</td>
<td>0.</td>
<td>0.</td>
<td>CIOE</td>
<td>-4.92901E+00</td>
<td>-2.66194E-06</td>
<td>QO</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CMO</td>
<td>-1.96300E-02</td>
<td>-1.20220E-09</td>
<td>CFAL</td>
<td>-8.21608E-01</td>
<td>1.09517E-07</td>
<td>CMAL</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CMQ</td>
<td>-3.27995E+01</td>
<td>-6.12221E-06</td>
<td>CMDE</td>
<td>-3.08647E+00</td>
<td>-1.25759E-06</td>
<td>VQ</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CYO</td>
<td>0.</td>
<td>0.</td>
<td>CYB</td>
<td>0.</td>
<td>0.</td>
<td>CYRD</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CYP</td>
<td>0.</td>
<td>0.</td>
<td>CYR</td>
<td>0.</td>
<td>0.</td>
<td>CLD</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>PD</td>
<td>0.</td>
<td>0.</td>
<td>CLD</td>
<td>0.</td>
<td>0.</td>
<td>CLR</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CLRO</td>
<td>0.</td>
<td>0.</td>
<td>CLDA</td>
<td>0.</td>
<td>0.</td>
<td>RQ</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CNO</td>
<td>0.</td>
<td>0.</td>
<td>CNB</td>
<td>0.</td>
<td>0.</td>
<td>CNBD</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CNP</td>
<td>0.</td>
<td>0.</td>
<td>CNR</td>
<td>0.</td>
<td>0.</td>
<td>CNDR</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>CND</td>
<td>0.</td>
<td>0.</td>
<td>CND</td>
<td>0.</td>
<td>0.</td>
<td>CND</td>
<td>0.</td>
<td>0.</td>
</tr>
</tbody>
</table>

MODIFIED PARAMETER COVARIANCE MATRIX

<table>
<thead>
<tr>
<th>CXQ</th>
<th>CIO</th>
<th>CIAL</th>
<th>CIOE</th>
<th>CMQ</th>
<th>CMAL</th>
<th>CMQ</th>
<th>CMDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1.60346E-01</td>
<td>2.86153E-02</td>
<td>-1.60346E-01</td>
<td>1.48563E-01</td>
<td>4.43251E-01</td>
<td>3.23684E-01</td>
<td>1.48563E-01</td>
<td>-1.99899E-01</td>
</tr>
</tbody>
</table>
ALGORITHM PRINTOUT – Continued

RUN = 1 PASS = 9 DET1 = 1.231248E+28 DET2 = 3.480108E-07 AJP = 1.840969E+03

ACTIVE ALGORITHM VARIABLES ARE ... U ... W ... C ... THE

PACKED MEAN ARRAY

-5.4911E-03 -7.0658E-02 3.2065E-04 1.2682E-03

PACKED NOISE COVARIANCE MATRIX

-4.4530E-01 -4.0311E-02 -4.3630E-04 -1.0229E-03
-4.0311E-02 8.9130E+00 -2.8431E-03 -1.2617E-03
-4.3630E-04 -2.8431E-03 3.9910E-04 5.3472E-06
-1.0229E-03 -1.2617E-03 5.3472E-06 3.5883E-04

PACKED WEIGHT MATRIX

4.0766E+00 0. 0.
0. 1.1220E-01 0.
0. 0. 2.5056E+03 0.
0. 0. 0. 2.5073E+03

PARAM VALUE CHANGE PARAM VALUE CHANGE PARAM VALUE CHANGE

UO 2.099000E+02 0. CXO 1.100976E-01 1.801348E-09 CXAL 0. 0.
CXO 0. 0. TXEO 8.000000E+02 0.
WO 5.000000E+00 0.
CZO 0.
CMO 1.960004E-02 2.537085E-10 CMAL -8.216080E+01 7.563177E-09 CMALD 0.
CMDE -3.527954E+01 5.222571E-07 CMALD 0.
CMDE 3.0386678E+00 -3.447917E-08 VO 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
CMDE 0.
ALGORITHM PRINTOUT — Concluded

RUN = 1  PASS = 10  DET1 = 1.231249E+28  DET2 = 3.480108E-07  AJP = 1.840969E+03

ACTIVE ALGORITHM VARIABLES ARE ... U, W, Q, THE

PACKED MEAN ARRAY
-5.49911E-03  -7.0668E-02  3.2065E-04  1.2628E-03

PACKED NOISE COVARIANCE MATRIX
2.4539E-01  4.0311E-02  -4.3330E-04  -1.0229E-03
4.0311E-02  8.9130E+00  -2.8431E-03  -1.2617E-03
-4.3330E-04  -2.8431E-03  3.9910E-04  5.3472E-06
-1.0229E-03  -1.2617E-03  5.3472E-06  3.9883E-04

PACKED WEIGHT MATRIX
4.0766E+00  0.  0.
0.  1.1202E+01  0.
0.  0.  2.5056E+03  0.
0.  0.  0.  2.5073E+03

PARAM    VALUE    CHANGE    PARAM    VALUE    CHANGE    PARAM    VALUE    CHANGE
UO       2.099003E+02  0.
CBO      0.          0.
CBOO     0.          0.
CDO       5.000000E+00  0.
CZDO      0.          0.
CMD       1.960004E-02  1.147357E-11
CMQ       5.279994E+01  -4.039551E-08
CYD       0.          0.
CYP       0.          0.
CZD       0.          0.
CZDE      4.429019E+00  0.
CDA        0.          0.
CNR        0.          0.
CNP        0.          0.
CND       0.          0.
CNO       0.          0.
CMQ       0.          0.
CMDE      0.          0.

MODIFIED PARAMETER COVARIANCE MATRIX

CZD       9.378289E-02  7.820141E-03  -7.642445E-01  2.573919E-02  6.761419E-01  2.257754E-02  3.070243E-01  -5.369313E-02
CZDE      -7.316037E-01  -7.042254E-01  2.430834E-01  3.639320E-01  -1.513713E-01  2.861588E-02  -6.437348E-01  -1.445637E-01
CMQ       2.603461E-01  2.257754E-02  2.861588E-02  6.429488E-01  -3.929876E-01  1.547555E-02  1.231295E+03  7.377144E-01  5.5841E+05
CMQ       4.492570E-01  3.070243E-01  -6.420839E-01  2.395629E-01  7.312017E-02  -1.401564E-01  1.231295E+03  7.377144E-01  5.5841E+05
CMQ       3.236841E-01  -5.369313E-02  -1.485637E-01  -1.978656E-01  -4.942664E-02  -3.254150E-02  7.327144E-01  5.5841E+05
CONCLUDING REMARKS

A computer program has been developed for estimating aircraft stability and control parameters from flight test data. The maximum likelihood estimation program has been implemented on the Langley real-time simulation system. The control and display capabilities of the system allow the analyst to interact with the program. The interactive capability is highly desirable, as evident in the reports on the analysis of flight test data. Variable dimensioning allows the analyst to activate any part of the nonlinear six-degree-of-freedom aircraft mathematical model, select the variables in the performance index function, and choose which parameters are to be estimated. Although this report uses a particular aircraft example, it is applicable to any dynamic system fitting into the framework of the program.

Langley Research Center,
National Aeronautics and Space Administration,
APPENDIX A

PROGRAM CONTROL AND DISPLAY CAPABILITIES

The computer program has been written in FORTRAN IV (75,000 octal locations) and run on the RTS system of the Control Data series 6000 digital computer complex. The computer program was mechanized into an iterative estimation procedure with manual interactive control and graphic display capabilities through the utilization of the RTS system. Figure 3(a) shows a photograph of the program control station and figure 3(b) shows a closeup of the control panel. The components are listed below as they appear (left to right) in figure 3:

Program control station:
- Graphic display unit
  - Cathode ray tube (CRT)
  - Interactive keyboard
- Time history recorder
- x-y plotter (not used)
- Control console
  - White indicator lights (WL)
  - Red indicator lights, bottom row (not used)
  - Function sense switches (FSS)
  - Mode control switches
  - Data entry keyboard
  - Digital decimal display unit (DDDU)
  - Potentiometers (not used)
  - Output device (typewriter)

The CRT displays the flight test maneuver at the start of each iteration. The response of the equations of motion as it is computed in the digital program is plotted with the flight test maneuver for direct comparison. This display permits quick analysis of each flight test case on an iteration to iteration basis. Figure 4 shows CalComp plots representing three CRT displays; they are part of the dynamic check.

The analyst investigating the stability and control derivatives of the aircraft has direct control of the computer program through the control console. The white indicator lights (WL(1) - WL(39)) are used to indicate program status or diagnostics. The diagnostics are described in the LDISO array of the Display Arrays section. The function sense switches (FSS(1) to FSS(16)) are used to select program options (switch depressed results in logical true value). The options are described in the LDISI array of the Display Arrays section.
APPENDIX A – Continued

The mode control keyboard (shown below) is used to control the running of the RTS computer program.

<table>
<thead>
<tr>
<th>OPER</th>
<th>HOLD</th>
<th>RESET</th>
<th>TERM</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHANGE</td>
<td>SCAN</td>
<td>RELEASE</td>
<td></td>
</tr>
<tr>
<td>IDLE</td>
<td>READ</td>
<td>PRINT</td>
<td>RELEASE</td>
</tr>
</tbody>
</table>

Each switch (mode) is briefly described as to its use (mode nominally active when switch depressed):

OPER (OPERATE) – allows normal running of parameter estimation procedure (integration of equations of motion and sensitivity equations)

HOLD – holds estimation procedure at last time point (stops integration)

RESET – initializes estimation procedure at $t = 0$

TERM (TERMINATE), – terminates program at control console and transfers control to graphic display unit

Activation of one mode automatically deactivates the previous one. The following modes are temporarily activated by the analyst during the parameter estimation study (normally when in RESET or HOLD modes):

CHANGE – changes program variable to the new value entered on the data entry keyboard and displayed on the DDDU

SCAN – scans through the display addresses in conjunction with subroutine SCANNER

RELEASE – releases CHANGE and SCAN modes

ERASE – erases real-time disk file
APPENDIX A – Continued

IDLE – idles the computer (no computations).
READ – loads read overlay
PRINT – loads print overlay
RELEASE – releases the four preceding modes

The data entry keyboard (shown below) is used to input new values for program variables.

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>9</td>
<td>DECIMAL POINT</td>
<td>(-)</td>
</tr>
<tr>
<td>TAB</td>
<td>CR</td>
<td>ERASE</td>
<td>CR</td>
<td></td>
</tr>
</tbody>
</table>

The keyboard is used in conjunction with the DDDU (shown below).

<table>
<thead>
<tr>
<th>(Address field)</th>
<th>(Magnitude field)</th>
<th>(Exponent field)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_1$ $A_2$ $A_3$</td>
<td>$\pm M_1 M_2 M_3 M_4 M_5$</td>
<td>$\pm E_1 E_2$</td>
</tr>
</tbody>
</table>

The procedure for changing a floating-point number is as follows:

1. Enter address field – $A_1 A_2 A_3$
2. Depress TAB
3. Enter magnitude field – $\pm . M_1 M_2 M_3 M_4 M_5$
4. Depress TAB
5. Enter exponent field – $\pm E_1 E_2$
6. Depress TAB
APPENDIX A – Concluded

(7) Depress \textbf{CR}
(8) Depress CHANGE
(9) Depress RELEASE

As the numbers and signs (plus sign assumed) are entered on the keyboard, they are displayed on the DDDU. The DDDU shows the final form of the number entered by the keyboard. Integers and logical variables are entered in a similar manner but with a different format. The switches ERASE and CR are used to erase the data field and character just entered, respectively.

The typewriter is used to type out the new and old values of the program variables. The time history recorder plots the variables defined in the DAC array (Display Arrays section). The interactive keyboard is used to restart and exit the program from the RTS system. A card reader and high-speed printer are located near the program control station and are easily accessible to the program operator.
APPENDIX B

EQUATIONS OF MOTION AND ACCELEROMETER EQUATIONS

The mathematical model is that of a nonlinear six-degree-of-freedom rigid-body aircraft, in particular, a V/STOL tilt-wing aircraft. The equations of motion are

\[
\dot{x} = F(\overline{x}, \overline{\alpha}, \delta, V, \alpha_a, \dot{\alpha}_a, \beta, \dot{\beta})
\]

\[
= \begin{bmatrix} F_1, F_2, \ldots, F_8 \end{bmatrix}^T
\]  

(B1)

The state vector is

\[
\overline{x} = \begin{bmatrix} x_1, x_2, \ldots, x_8 \end{bmatrix}^T
\]

\[
= \begin{bmatrix} u, v, w, p, q, r, \theta, \phi \end{bmatrix}^T
\]  

(B2)

The parameter vector is

\[
\overline{\alpha} = \begin{bmatrix} \alpha_1, \alpha_2, \ldots, \alpha_4 \end{bmatrix}^T
\]

\[
= \begin{bmatrix} u(0), (C_x)_{\alpha, t}, \delta_e, t', \ldots, C_n \delta_a \end{bmatrix}^T
\]  

(B3)

The control deflection vector is

\[
\overline{\delta} = \begin{bmatrix} \delta_a, \delta_e, \delta_r \end{bmatrix}^T
\]  

(B4)

The equations of motion in detail are

\[
\dot{u} = F_1(\overline{x}, \overline{\alpha}, \overline{\delta}, V, \alpha_a)
\]

\[
= -qw + rv - g \sin \theta + a_1 V^2 (C_{x1} + C_{x2}) + \frac{T_X}{m}
\]  

(B5)
\[ \dot{v} = F_2(\bar{x}, \bar{a}, \bar{\delta}, V, \beta) \]
\[ = -ru + pw + g \cos \theta \sin \phi + a_1 V^2 (C_{Y1} + C_{Y2}) + \frac{T_Y}{m} \]
\[ = \frac{-ru + pw + g \cos \theta \sin \phi + a_1 V^2 (C_{Y1} + C_{Y2}) + \frac{T_Y}{m}}{1 - a_3 C_{Y\beta}} \quad (B6) \]

\[ \dot{w} = F_3(\bar{x}, \bar{a}, \bar{\delta}, V, \alpha_a) \]
\[ = -pv + qu + g \cos \theta \cos \phi + a_1 V^2 (C_{Z1} + C_{Z2}) + \frac{T_Z}{m} \quad (B7) \]

\[ \dot{p} = F_4(\bar{x}, \bar{a}, \bar{\delta}, V, \beta, \dot{\beta}) \]
\[ = a_6 F_4(\bar{x}, \bar{a}, \bar{\delta}, V, \beta, \dot{\beta}) + b_1 F_6(\bar{x}, \bar{a}, \bar{\delta}, V, \beta, \dot{\beta}) \]
\[ = a_6 \left[ b_2 qr + I_{XZ} pq + a_4 V^2 (C_{l1} + C_{l2}) + a_4 V_s^2 (C_{l3}) + M_X \right] \]
\[ + b_1 \left[ b_3 pq - I_{XZ} qr + a_4 V^2 (C_{n1} + C_{n2}) - a_4 V_s^2 (C_{n3}) + M_Z \right] \quad (B8) \]

\[ \dot{q} = F_5(\bar{x}, \bar{a}, \bar{\delta}, V, \alpha_a, \dot{\alpha}_a) \]
\[ = a_7 pr + b_4 (r^2 - p^2) + a_8 V^2 (C_{m1} + C_{m2}) + \frac{M_Y}{I_Y} \quad (B9) \]

\[ \dot{r} = F_6(\bar{x}, \bar{a}, \bar{\delta}, V, \beta, \dot{\beta}) \]
\[ = b_1 F_4(\bar{x}, \bar{a}, \bar{\delta}, V, \beta, \dot{\beta}) + b_5 F_6(\bar{x}, \bar{a}, \bar{\delta}, V, \beta, \dot{\beta}) \quad (B10) \]

\[ \dot{\phi} = F_7(\bar{x}) \]
\[ = q \cos \phi - r \sin \phi \quad (B11) \]
\[ \phi = F_8(\bar{x}) \]

\[ = p + (q \sin \phi + r \cos \phi) \tan \theta \]  \hspace{1cm} (B12)

where

\[ a_1 = \frac{1}{2} \rho \frac{s}{m} \] \hspace{1cm} \[ a_2 = a_1 \left( \frac{c}{2} \right) \] \hspace{1cm} \[ a_3 = a_1 \left( \frac{b}{2} \right) \]

\[ a_4 = \frac{1}{2} \rho S_b \] \hspace{1cm} \[ a_5 = a_4 \left( \frac{b}{2} \right) \] \hspace{1cm} \[ a_6 = \frac{I_Z}{I_{XZ} - I_{XZ}^2} \]

\[ a_7 = \frac{I_Z - I_X}{I_Y} \] \hspace{1cm} \[ a_8 = \frac{1}{2} \frac{\rho}{I_Y} S_c \] \hspace{1cm} \[ a_9 = a_8 \left( \frac{c}{2} \right) \]

\[ b_1 = \frac{I_{XZ}}{I_{XZ} - I_{XZ}^2} \] \hspace{1cm} \[ b_2 = I_Y - I_Z \] \hspace{1cm} \[ b_3 = I_X - I_Y \]

\[ b_4 = \frac{I_{XZ}}{I_Y} \] \hspace{1cm} \[ b_5 = \frac{I_X}{I_{XZ} - I_{XZ}^2} \]

and

\[ V_S = V_{SS} + V \]

\[ C_{X1} = (C_X)_{\alpha_a,t,\delta_e,t} + C_X\alpha_a (\alpha_a - \alpha_a,t) \] \hspace{1cm} \[ C_{X2} = C_{Xq} \frac{q_e}{2V} \]

\[ C_{Y1} = (C_Y)_{\beta_t,\delta_e,t,\delta_r,t} + C_Y\beta (\beta - \beta_t) + C_Y\delta_r (\delta_r - \delta_r,t) \] \hspace{1cm} \[ C_{Y2} = \frac{b}{2V} (C_{Yp}p + C_{Yr}r) \]

\[ C_{Z1} = (C_Z)_{\alpha_a,t,\delta_e,t} + C_Z\alpha_a (\alpha_a - \alpha_a,t) + C_Z\delta_e (\delta_e - \delta_e,t) \] \hspace{1cm} \[ C_{Z2} = \frac{b}{2V} (C_{Zp}p + C_{Zr}r) \]

\[ C_{t1} = (C_t)_{\beta_t,\delta_e,t,\delta_r,t} + C_t\beta (\beta - \beta_t) + C_t\delta_r (\delta_r - \delta_r,t) \] \hspace{1cm} \[ C_{t2} = \frac{b}{2V} (C_{tp}p + C_{tr}r) \]

\[ C_{t_a} = C_{t_a} \cos \theta_w - C_{n_a} \sin \theta_w \] \hspace{1cm} \[ C_{t3} = C_{t_a} (\delta_a - \delta_a,t) \]

\[ C_{m1} = (C_m)_{\alpha_a,t,\delta_e,t} + C_m\alpha_a (\alpha_a - \alpha_a,t) + C_m\delta_e (\delta_e - \delta_e,t) \] \hspace{1cm} \[ C_{m2} = \frac{c}{2V} (C_{mq_a}q_a + C_{mq^q}) \]

\[ C_{n1} = (C_n)_{\beta_t,\delta_e,t,\delta_r,t} + C_n\beta (\beta - \beta_t) + C_n\delta_r (\delta_r - \delta_r,t) \] \hspace{1cm} \[ C_{n2} = \frac{b}{2V} (C_{np}p + C_{nr}r) \]

\[ C_{n_a} = C_{n_a} \sin \theta_w + C_{n_a} \cos \theta_w \] \hspace{1cm} \[ C_{n3} = C_{n_a} (\delta_a - \delta_a,t) \]
The auxiliary equations are

\[
\begin{align*}
\dot{\psi} &= q \sin \phi + r \cos \phi \\
V &= \sqrt{u^2 + v^2 + w^2} \\
\alpha_a &= \tan^{-1} \frac{w}{u} \\
\dot{\alpha}_a &\approx \frac{\dot{w}}{u} \\
\beta &= \sin^{-1} \frac{v}{V} \\
\dot{\beta} &\approx \frac{\dot{v}}{V} \\
V_{SS} &= \frac{8}{\pi} \eta_0 E^2 D_E^2 C_T
\end{align*}
\]

(B13)

The trim conditions are

\[
\alpha_{a,t} = \begin{cases} 
\text{ALPHAT} \quad \text{or} \\
\tan^{-1} \frac{w(0)}{u(0)}
\end{cases}
\]

\[
\beta_t = 0
\]

\[
\delta_{a,t} = \text{DABIAS}
\]

\[
\delta_{e,t} = \text{DEBIAS}
\]

\[
\delta_{r,t} = \text{DRBIAS}
\]
The thrust and moment equations are known inputs (flight test data and constants) to the equations of motion.

\[
\begin{align*}
T_x &= 4\rho \eta_E^2 D_E^4 C_T \cos i_w \\
T_y &= 0 \\
T_z &= -4\rho \eta_E^2 D_E^4 C_T \sin i_w - \rho \eta_T^2 D_T^4 C_{T,T} \\
M_x &= 2\rho \eta_E^2 D_E^4 i C_{TB}\delta B \sin i_w \\
M_y &= -4\rho \eta_E^2 D_E^4 r_b C_T - \rho \eta_T^2 D_T^4 l_{TP} C_{T,T} \\
M_z &= 2\rho \eta_E^2 D_E^4 i C_{TB}\delta B \cos i_w
\end{align*}
\]

(B14)

where

\[
C_T = C_{T,0} + C_{TB}\Delta B
\]

\[
C_{T,T} = C_{T,T,0} + C_T\beta_T\beta_T
\]

\[
\eta_E = \frac{1232}{60} \rho_E
\]

\[
\eta_T = \frac{2400}{60} \rho_T
\]

The accelerometer measurements and equations were included in the parameter estimation algorithm to improve the extraction process. They are used with or can replace the linear velocities \( u \), \( v \), and \( w \). The accelerometer equations were transformed to the instrument location from the center of gravity (ref. 6).
APPENDIX B – Concluded

\[ \ddot{a}_I = \begin{bmatrix} a_{x,I} \\ a_{y,I} \\ a_{z,I} \end{bmatrix} \]

\[
\begin{bmatrix}
\dot{u} + qw - rv + g \sin \theta \\
\dot{v} + ru - pw - g \cos \theta \sin \phi \\
\dot{w} + pv - qu - g \cos \theta \cos \phi
\end{bmatrix} = \frac{1}{g} \begin{bmatrix}
(q^2 + r^2)x_X - (pq - \dot{r})y_X + (pr + \dot{q})z_X \\
(pq + \dot{r})x_Y - (p^2 + r^2)y_Y + (qr - \dot{p})z_Y \\
(pr - \dot{q})x_Z + (qr + \dot{p})y_Z - (p^2 + q^2)z_Z
\end{bmatrix}
\]

(B15)

The accelerometer equations need only to be evaluated and not integrated.
APPENDIX C

SENSITIVITY EQUATIONS AND ACCELEROMETER SENSITIVITY COEFFICIENTS

The sensitivity equations for the method of quasilinearization are presented in detail for the equations of motion presented in appendix B.

The sensitivity equations are

\[
\frac{d}{dt} \left( \frac{\partial \bar{x}}{\partial \alpha_i} \right) = \left( \frac{\partial \bar{x}}{\partial \alpha_i} \right)
\]

\[
= \left\{ \sum_{k=1}^{8} \frac{\partial F}{\partial x_k} \left( \frac{\partial x_k}{\partial \alpha_i} \right) + \frac{\partial \bar{F}}{\partial V} \sum_{k=1}^{3} \frac{\partial V}{\partial x_k} \left( \frac{\partial x_k}{\partial \alpha_i} \right) + \frac{\partial \bar{F}}{\partial \alpha_a} \sum_{k=1}^{3} \frac{\partial \alpha_a}{\partial x_k} \left( \frac{\partial x_k}{\partial \alpha_i} \right) \right. \\
+ \frac{\partial \bar{F}}{\partial \alpha_a} \left( \frac{\partial x_1}{\partial \alpha_i} \right) + \frac{\partial \bar{F}}{\partial \beta} \left[ \frac{\partial \beta}{\partial \alpha_2} \left( \frac{\partial x_2}{\partial \alpha_i} \right) + \frac{\partial \beta}{\partial \alpha_1} \right. \\
+ \frac{\partial \bar{F}}{\partial \alpha_a} \left( \frac{\partial x_3}{\partial \alpha_i} \right) + \frac{\partial \bar{F}}{\partial \alpha_2} \left( \frac{\partial x_2}{\partial \alpha_i} \right) \right\} + \frac{\partial \bar{F}}{\partial \alpha_i}
\]

\[
= G'(t) \left( \frac{\partial \bar{x}}{\partial \alpha_i} \right) + \left[ \frac{\partial \bar{F}}{\partial \alpha_a} \frac{\partial \bar{x}_a}{\partial \alpha_i} + \frac{\partial \bar{F}}{\partial \beta} \frac{\partial \bar{x}_2}{\partial \alpha_i} \right] + \frac{\partial \bar{F}}{\partial \alpha_i} \]

where

\[
G'(t) = \left[ g'_{ij}(t) \right] \quad (j, k = 1, 2, \ldots, 8)
\]

The functions \( F_2 \) and \( F_3 \) do not contain \( \dot{\alpha}_a \) or \( \dot{\beta} \). Thus,

\[
\frac{d}{dt} \left( \frac{\partial \bar{x}}{\partial \alpha_i} \right) = \left[ G'(t) \left( \frac{\partial \bar{x}}{\partial \alpha_i} \right) + \sum_{k=1}^{8} g'_{3k} \left( \frac{\partial x_k}{\partial \alpha_i} \right) + \sum_{k=1}^{8} g'_{2k} \left( \frac{\partial x_k}{\partial \alpha_i} \right) \right] \\
+ \left( \frac{\partial \bar{F}}{\partial \alpha_1} + \frac{\partial \bar{F}}{\partial \alpha_3} \frac{\partial \bar{x}_3}{\partial \alpha_i} + \frac{\partial \bar{F}}{\partial \alpha_2} \frac{\partial \bar{x}_2}{\partial \alpha_i} \right)
\]

\[
= G(t) \left( \frac{\partial \bar{x}}{\partial \alpha_i} \right) + \bar{F}(\alpha_i) \quad (i = 1, 2, \ldots, 40)
\]

104
where

\[
\frac{\partial X}{\partial \alpha_i} = \left[ \frac{\partial u}{\partial \alpha_i}, \frac{\partial v}{\partial \alpha_i}, \frac{\partial w}{\partial \alpha_i}, \frac{\partial p}{\partial \alpha_i}, \frac{\partial q}{\partial \alpha_i}, \frac{\partial r}{\partial \alpha_i}, \frac{\partial \theta}{\partial \alpha_i}, \frac{\partial \phi}{\partial \alpha_i} \right]^T
\]

\[
G(t) = \begin{bmatrix} g_{jk}(t) \end{bmatrix} \quad (j, k = 1, 2, \ldots, 8)
\]

\[
\bar{F} (\alpha_i) = \left[ \bar{F}_1 (\alpha_i), \bar{F}_2 (\alpha_i), \ldots, \bar{F}_8 (\alpha_i) \right]^T
\]

(1) Sensitivity equations derived from \(\dot{u}\) equation:

\[
\frac{d}{dt} \left( \frac{\partial u}{\partial \alpha_i} \right) = \sum_{k=1}^{8} g_{1k} \left( \frac{\partial x_k}{\partial \alpha_i} \right) + \frac{\partial F_1}{\partial \alpha_i}
\]

where

\[
g_{11} \approx a_1 u \left( 2C_{X1} + C_{X2} \right) - a_1 C_{X\alpha_a} w
\]

\[
g_{12} = r + a_1 v \left( 2C_{X1} + C_{X2} \right)
\]

\[
g_{13} \approx -q + a_1 w \left( 2C_{X1} + C_{X2} \right) + a_1 C_{X\alpha_a} u
\]

\[
g_{14} = 0
\]

\[
g_{15} = -w + a_2 v C_{X_q}
\]

\[
g_{16} = v
\]

\[
g_{17} = -g \cos \theta
\]

\[
g_{18} = 0
\]
and

\[ \frac{\partial F_1}{\partial \alpha_2} = a_1 V^2 \]

\[ \frac{\partial F_1}{\partial \alpha_3} = a_1 V^2 (\alpha_a - \alpha_{a,t}) \]

\[ \frac{\partial F_1}{\partial \alpha_4} = a_2 V q \]

(2) Sensitivity equations derived from \( \dot{v} \) equation:

\[ \frac{d}{dt} \left( \frac{\partial v}{\partial \alpha_i} \right) = \sum_{k=1}^{n} g_{2k} \left( \frac{\partial x_k}{\partial \alpha_i} \right) + \frac{\partial F_2}{\partial \alpha_i} \]  \hspace{1cm} (C4)

where

\[ g_{21} \approx \frac{-r + a_1 u (2C_{Y_1} + C_{Y_2} - C_{Y_{\beta}})}{1 - a_3 C_{Y_{\beta}}} \]

\[ g_{22} \approx \frac{a_1 v (2C_{Y_1} + C_{Y_2} - C_{Y_{\beta}}) + a_1 V C_{Y_{\beta}}}{1 - a_3 C_{Y_{\beta}}} \]

\[ g_{23} \approx \frac{p + a_1 w (2C_{Y_1} + C_{Y_2} - C_{Y_{\beta}})}{1 - a_3 C_{Y_{\beta}}} \]

\[ g_{24} = \frac{w + a_3 V C_{Y_{\beta}}}{1 - a_3 C_{Y_{\beta}}} \]

\[ g_{25} = 0 \]

\[ g_{26} = \frac{-u + a_3 V C_{Y_{\beta}}}{1 - a_3 C_{Y_{\beta}}} \]


\[ g_{27} = \frac{-g \sin \theta \sin \phi}{1 - a_3 C_{Y\beta}} \]

\[ g_{28} = \frac{g \cos \theta \cos \phi}{1 - a_3 C_{Y\beta}} \]

and

\[ \frac{\partial F_2}{\partial \alpha_{19}} = \frac{a_1 V^2}{1 - a_3 C_{Y\beta}} \]

\[ \frac{\partial F_2}{\partial \alpha_{20}} = \frac{a_1 V^2 (\beta - \beta_t)}{1 - a_3 C_{Y\beta}} \]

\[ \frac{\partial F_2}{\partial \alpha_{21}} = \frac{a_3 \dot{v}}{1 - a_3 C_{Y\beta}} \]

\[ \frac{\partial F_2}{\partial \alpha_{22}} = \frac{a_3 V_p}{1 - a_3 C_{Y\beta}} \]

\[ \frac{\partial F_2}{\partial \alpha_{23}} = \frac{a_3 V_r}{1 - a_3 C_{Y\beta}} \]

\[ \frac{\partial F_2}{\partial \alpha_{24}} = \frac{a_1 V^2 (\sigma_r - \sigma_{r,t})}{1 - a_3 C_{Y\beta}} \]

(3) Sensitivity equations derived from \( \dot{w} \) equation:

\[ \frac{d}{dt} \left( \frac{\partial w}{\partial \alpha_i} \right) = \sum_{k=1}^{8} g_{3k} \left( \frac{\partial x_k}{\partial \alpha_i} \right) + \frac{\partial F_3}{\partial \alpha_i} \]  

(C5)

where

\[ g_{31} = q + a_1 u (2C_{Z1} + C_{Z2}) - a_1 C Z \alpha_w \]

\[ g_{32} = -p + a_1 v (2C_{Z1} + C_{Z2}) \]
APPENDIX C – Continued

\[ g_{33} \approx a_1 v (2C_{Z1} + C_{Z2}) + a_1 C_Z \alpha_a u \]

\[ g_{34} = -v \]

\[ g_{35} = u + a_2 V CZ_q \]

\[ g_{36} = 0 \]

\[ g_{37} = -g \sin \theta \cos \phi \]

\[ g_{38} = -g \cos \theta \sin \phi \]

and

\[ \frac{\partial F_3}{\partial \alpha_8} = a_1 V^2 \]

\[ \frac{\partial F_3}{\partial \alpha_9} = a_1 V^2 (\alpha_a - \alpha_{a,t}) \]

\[ \frac{\partial F_3}{\partial \alpha_{10}} = a_2 V_q \]

\[ \frac{\partial F_3}{\partial \alpha_{11}} = a_1 V^2 (\delta_e - \delta_{e,t}) \]

(4) Sensitivity equations derived from \( \dot{p} \) equation:

\[
\begin{align*}
\frac{d}{dt} \left( \frac{\partial p}{\partial \alpha_i} \right) & = 8 \sum_{k=1}^{8} \left( g_{4k} + a_6 \frac{\partial F_4}{\partial \alpha_i} \right) + b_1 \left( \alpha_{F_4} \frac{\partial \alpha_{F_4}}{\partial \alpha_i} + \beta_{F_4} \frac{\partial \beta_{F_4}}{\partial \alpha_i} \right) \\
& = 8 \sum_{k=1}^{8} g_{4k} \left( \frac{\partial \alpha_i}{\partial \alpha_i} \right) + \bar{F}_4 (\alpha_i) \\
& = 8 \sum_{k=1}^{8} g_{4k} (\delta_{\alpha_i}) + \bar{F}_4 (\alpha_i) 
\end{align*}
\]

\[(C6)\]
APPENDIX C – Continued

where

\[ g''_{41} \approx a_{4u} \left( 2C_{l1} + C_{l2} + 2C_{l3} \frac{V_S}{V} - C_{l\beta} - C_{l\beta} \frac{\beta \dot{b}}{2V} \right) \]

\[ g''_{42} \approx a_{4v} \left( 2C_{l1} + C_{l2} + 2C_{l3} \frac{V_S}{V} - C_{l\beta} - C_{l\beta} \frac{\beta \dot{b}}{2V} \right) + a_{4} V C_{l\beta} \]

\[ g''_{43} \approx a_{4w} \left( 2C_{l1} + C_{l2} + 2C_{l3} \frac{V_S}{V} - C_{l\beta} - C_{l\beta} \frac{\beta \dot{b}}{2V} \right) \]

\[ g''_{44} = I_{XZq} + a_{5} V C_{l_p} \]

\[ g''_{45} = b_{2r} + I_{XZp} \]

\[ g''_{46} = b_{2q} + a_{5} V C_{l_r} \]

\[ g''_{47} = g''_{48} = 0 \]

and

\[ g''_{61} \approx a_{4u} \left( 2C_{n1} + C_{n2} - 2C_{n3} \frac{V_S}{V} - C_{n\beta} - C_{n\beta} \frac{\beta \dot{b}}{2V} \right) \]

\[ g''_{62} \approx a_{4v} \left( 2C_{n1} + C_{n2} - 2C_{n3} \frac{V_S}{V} - C_{n\beta} - C_{n\beta} \frac{\beta \dot{b}}{2V} \right) + a_{4} V C_{n\beta} \]

\[ g''_{63} \approx a_{4w} \left( 2C_{n1} + C_{n2} - 2C_{n3} \frac{V_S}{V} - C_{n\beta} - C_{n\beta} \frac{\beta \dot{b}}{2V} \right) \]

\[ g''_{64} = b_{3q} + a_{5} V C_{n_p} \]

\[ g''_{65} = b_{3p} - I_{XZr} \]
\[ \varepsilon_{66}'' = -I_{XZ} q + a_5 V C n_r \]

\[ \varepsilon_{67}'' = \varepsilon_{68}'' = 0 \]

and

\[ \frac{\partial F_4'}{\partial \alpha_{26}} = \frac{\partial F_6'}{\partial \alpha_{34}} = a_4 V^2 \]

\[ \frac{\partial F_4'}{\partial \alpha_{27}} = \frac{\partial F_6'}{\partial \alpha_{35}} = a_4 V^2 \left( \beta - \beta_t \right) \]

\[ \frac{\partial F_4'}{\partial \alpha_{28}} = \frac{\partial F_6'}{\partial \alpha_{36}} = a_5 V \dot{\beta} \]

\[ \frac{\partial F_4'}{\partial \alpha_{29}} = \frac{\partial F_6'}{\partial \alpha_{37}} = a_5 V \eta \]

\[ \frac{\partial F_4'}{\partial \alpha_{30}} = \frac{\partial F_6'}{\partial \alpha_{38}} = a_5 V \xi \]

\[ \frac{\partial F_4'}{\partial \alpha_{31}} = \frac{\partial F_6'}{\partial \alpha_{39}} = a_4 V^2 \left( \delta_r - \delta_{r,t} \right) \]

\[ \frac{\partial F_4'}{\partial \alpha_{32}} = -\frac{\partial F_6'}{\partial \alpha_{40}} = a_4 V S^2 \cos i_w \left( \delta_a - \delta_{a,t} \right) \]

\[ \frac{\partial F_4'}{\partial \alpha_{40}} = \frac{\partial F_6'}{\partial \alpha_{32}} = -a_4 V S^2 \sin i_w \left( \delta_a - \delta_{a,t} \right) \]

\[ \frac{\partial F_4'}{\partial \beta} = \frac{\partial F_6'}{\partial \beta} = a_5 C \beta \]

\[ \frac{\partial F_6'}{\partial \beta} = \frac{\partial F_6'}{\partial \nu} = a_5 C \nu \]

110
(5) Sensitivity equations derived from $\dot{q}$ equation:

\[
\frac{d}{dt} \left( \frac{\partial q}{\partial \alpha_i} \right) = \sum_{k=1}^{8} \left( g_{5k}^{'} + \frac{\partial F_5}{\partial \alpha_a} \frac{\partial \alpha_a}{\partial \alpha} g_{3k} \right) \left( \frac{\partial x_k}{\partial \alpha_i} \right) + \left( \frac{\partial F_5}{\partial \alpha_i} + \frac{\partial F_5}{\partial \alpha_a} \frac{\partial \alpha_a}{\partial \alpha} \frac{\partial F_3}{\partial \alpha} \right)
\]

\[
= \sum_{k=1}^{8} g_{5k} \left( \frac{\partial x_k}{\partial \alpha_i} \right) + \bar{F}_5 (\alpha_i) \tag{C7}
\]

where

\[
g_{51}^{'} = a_8 u \left( 2C_{m1} + C_{m2} \right) - a_8 C_m \alpha_a w - a_9 C_m \alpha_a \dot{\alpha}_a
\]

\[
g_{52}^{'} = a_8 v \left( 2C_{m1} + C_{m2} \right)
\]

\[
g_{53}^{'} = a_8 w \left( 2C_{m1} + C_{m2} \right) + a_9 C_m \alpha_a u
\]

\[
g_{54}^{'} = a_7 r - 2b_4 \rho
\]

\[
g_{55}^{'} = a_9 V C m q
\]

\[
g_{56}^{'} = a_7 \rho + 2b_4 r
\]

\[
g_{57}^{'} = g_{58}^{'} = 0
\]

and

\[
\frac{\partial F_5}{\partial \alpha_{13}} = a_8 V^2
\]

\[
\frac{\partial F_5}{\partial \alpha_{14}} = a_8 V^2 (\alpha_a - \alpha_{a,t})
\]
\[
\frac{\partial F_5}{\partial \alpha_{15}} = a_g V \dot{\alpha}_a \\
\frac{\partial F_5}{\partial \alpha_{16}} = a_g V q \\
\frac{\partial F_5}{\partial \alpha_{17}} = a_g V^2 (\delta_e - \delta_{e,t}) \\
\frac{\partial F_5}{\partial \dot{\alpha}_a} \frac{\partial \dot{\alpha}_a}{\partial \omega} = a_g C_m \dot{\alpha}_a
\]

(6) Sensitivity equations derived from \( \dot{r} \) equation:

\[
\frac{d}{dt} \left( \frac{\partial r}{\partial \alpha_i} \right) = b_1 \left[ \sum_{k=1}^{8} \left( g_{4k}'' + \frac{\partial F_4'}{\partial \beta} \frac{\partial}{\partial \beta} g_{2k} \right) \frac{\partial x_k}{\partial \alpha_i} \right] + b_5 \left[ \sum_{k=1}^{8} \left( g_{6k}'' + \frac{\partial F_6'}{\partial \beta} \frac{\partial}{\partial \beta} g_{2k} \right) \frac{\partial x_k}{\partial \alpha_i} \right] \\
= \sum_{k=1}^{8} \left( g_{6k}' + \frac{\partial F_4'}{\partial \beta} \frac{\partial}{\partial \beta} g_{2k} + b_5 \frac{\partial F_6'}{\partial \beta} \frac{\partial}{\partial \beta} g_{2k} \right) \frac{\partial x_k}{\partial \alpha_i} + b_1 \tilde{F}_4' (\alpha_i) + b_5 \tilde{F}_6' (\alpha_i) \\
= \sum_{k=1}^{8} g_{6k} \left( \frac{\partial x_k}{\partial \alpha_i} \right) + \tilde{F}_6 (\alpha_i) \\
\tag{C8}
\]

where all the terms have been defined in the derivation of the sensitivity equations for \( \dot{p} \) equation.
(7) Sensitivity equations derived from $\dot{\theta}$ equation:

$$
\frac{d}{dt} \left( \frac{\partial \theta}{\partial \alpha_1} \right) = \sum_{k=1}^{8} g_{7k} \left( \frac{\partial x_k}{\partial \alpha_1} \right)
$$

where

$g_{71} = g_{72} = g_{73} = g_{74} = 0$

$g_{75} = \cos \phi$

$g_{76} = -\sin \phi$

$g_{77} = 0$

$g_{78} = -\psi \cos \theta$

(8) Sensitivity equations derived from $\phi$ equation:

$$
\frac{d}{dt} \left( \frac{\partial \phi}{\partial \alpha_1} \right) = \sum_{k=1}^{8} g_{8k} \left( \frac{\partial x_k}{\partial \alpha_1} \right)
$$

where

$g_{81} = g_{82} = g_{83} = 0$

$g_{84} = 1$

$g_{85} = \sin \phi \tan \theta$

$g_{86} = \cos \phi \tan \theta$
APPENDIX C – Concluded

\[ g_{87} = \frac{\psi}{\cos \theta} \]

\[ g_{88} = \dot{\theta} \tan \theta \]

The accelerometer sensitivity coefficients were derived in terms of the sensitivity equations and coefficients for the equations of motion, and need only to be evaluated and not integrated.

(1) Sensitivity equations derived from \( a_{X,I} \) equation:

\[ \frac{\partial a_{X,I}}{\partial \alpha_1} = \frac{1}{g} \left[ \begin{array}{c}
\frac{\partial v}{\partial \alpha_1} + q \left( \frac{\partial w}{\partial \alpha_1} \right) + \left( x^2 q + z^2 r \right) \left( \frac{\partial p}{\partial \alpha_1} \right) + \left( -2x^2 q + y^2 p + w \right) \left( \frac{\partial q}{\partial \alpha_1} \right) \\
+ \left( -2x^2 r + z^2 p - y \right) \left( \frac{\partial r}{\partial \alpha_1} \right) + g \cos \theta \left( \frac{\partial g}{\partial \alpha_1} \right) + \left( \frac{\partial u}{\partial \alpha_1} \right) + \left( z^2 x \right) \left( \frac{\partial \alpha_1}{\partial \alpha_1} \right) - y^2 \left( \frac{\partial \alpha_1}{\partial \alpha_1} \right)
\end{array} \right] \quad (C11) \]

(2) Sensitivity equations derived from \( a_{Y,I} \) equation:

\[ \frac{\partial a_{Y,I}}{\partial \alpha_1} = \frac{1}{g} \left[ \begin{array}{c}
\frac{\partial v}{\partial \alpha_1} - p \left( \frac{\partial w}{\partial \alpha_1} \right) + \left( -w + x^2 q - 2y^2 p \right) \left( \frac{\partial p}{\partial \alpha_1} \right) + \left( x^2 p + z^2 r \right) \left( \frac{\partial q}{\partial \alpha_1} \right) + \left( u - 2y^2 r + z^2 q \right) \left( \frac{\partial r}{\partial \alpha_1} \right) \\
+ g \sin \theta \cos \phi \left( \frac{\partial g}{\partial \alpha_1} \right) - g \cos \theta \cos \phi \left( \frac{\partial g}{\partial \alpha_1} \right) + \left( \frac{\partial v}{\partial \alpha_1} \right) - \left( \frac{\partial w}{\partial \alpha_1} \right) - z^2 \left( \frac{\partial \alpha_1}{\partial \alpha_1} \right) + x^2 \left( \frac{\partial \alpha_1}{\partial \alpha_1} \right)
\end{array} \right] \quad (C12) \]

(3) Sensitivity equations derived from \( a_{Z,I} \) equation:

\[ \frac{\partial a_{Z,I}}{\partial \alpha_1} = \frac{1}{g} \left[ \begin{array}{c}
\frac{\partial v}{\partial \alpha_1} + p \left( \frac{\partial w}{\partial \alpha_1} \right) + \left( v + x^2 r - 2z^2 p \right) \left( \frac{\partial p}{\partial \alpha_1} \right) + \left( -u + y^2 r - 2z^2 q \right) \left( \frac{\partial q}{\partial \alpha_1} \right) + \left( x^2 p + y^2 q \right) \left( \frac{\partial r}{\partial \alpha_1} \right) \\
+ g \sin \theta \cos \phi \left( \frac{\partial g}{\partial \alpha_1} \right) + g \cos \theta \sin \phi \left( \frac{\partial g}{\partial \alpha_1} \right) + \left( \frac{\partial w}{\partial \alpha_1} \right) + \left( \frac{\partial \alpha_1}{\partial \alpha_1} \right) - x^2 \left( \frac{\partial \alpha_1}{\partial \alpha_1} \right)
\end{array} \right] \quad (C13) \]
APPENDIX D

VARIABLE DIMENSIONING

The flight test runs do not necessitate the use of all the equation variables \( \bar{x} \), variables in the performance index function \( \bar{y} \), and parameters \( \bar{a} \) for specific cases. These cases involve only a specific part of the program, as with an excitation of only the longitudinal motion of the aircraft. Variable dimensioning of the estimation procedure furnishes the analyst with the means of altering the program to meet the specific needs of each flight test run; that is, the mathematical model of the aircraft dynamic response, the variables to be compared with flight test data, and the parameters to be estimated.

Variable dimensioning of the estimation procedure is accomplished by using the three input arrays \( \text{INTX}(8) \), \( \text{INTY}(11) \), and \( \text{INTEG}_{40} \) (\( \text{INTEG}(I) \), \( I = 1, 2, \ldots, 40 \)); the use of these arrays dimension \( \bar{x} \), \( \bar{y} \), and \( \bar{a} \), respectively, in the program. The elements of each array are entered as integers 1 or 0 to indicate whether the variables or parameters are active or inactive, respectively.

The input array \( \text{INTX} \) specifies the activeness for each equation variable in the equations of motion and the sensitivity equations; inactive variables are treated as constants. From the input array \( \text{INTX} \)

\[
\text{INTX} = (1, 0, 1, \ldots, 1, 0)
\]

\[
k_1 \quad k_2, \ldots, k_{IV}
\]

\[
IV = \sum_{K=1}^{8} \text{INTX}(K)
\]

where \( k_1, k_2, \ldots, k_{IV} \) are element locations, \( \text{INTV} \) is generated,

\[
\text{INTV} = (k_1, k_2, \ldots, k_{IV}, 0, \ldots, 0)
\]

which is a sequence of integers denoting the active equation variables in \( \bar{x} \).

The input array \( \text{INTY} \) specifies the activeness for each variable in \( \bar{y} \); inactive variables are ignored. From the input array \( \text{INTY} \)
INTY = \( (1, 0, 1, \ldots, 1, 0) \)

\[ j_1 \ j_2, \ldots, j_{IA} \]

\[ IA = \sum_{J=1}^{11} INTY(J) \]

INTA is generated,

\[ INTA = (j_1, j_2, \ldots, j_{IA}, 0, \ldots, 0) \]

which is a sequence of integers denoting the active variables in \( \bar{y} \). The integer IA1, where

\[ IA1 = \sum_{J=1}^{8} INTY(J) \]

denotes the number of active variables in \( \bar{x} \) that are active variables in \( \bar{y} \).

The input array INTEG40 specifies the activeness of each parameter in the estimation procedure; inactive parameters are treated as constants. From the input array INTEG40

\[ INTEG40 = (0, \ldots, 0, 1, 0, 1, \ldots, 1, 0, \ldots, 0) \]

\[ i_1 \ i_2, \ldots, i_{IP} \]

\[ IP = \sum_{I=1}^{40} INTEG(I) \]

INTP is generated,

\[ INTP = (i_1, i_2, \ldots, i_{IP}, 0, \ldots, 0) \]

which is a sequence of integers denoting the active parameters in \( \tilde{\alpha} \). The program is dimensioned for \( IP \leq 30 \).

The resulting arrays (INTV, INTA, INTP) and numbers (IV, IA, IA1, IP) are used in FORTRAN DO LOOP and matrix operations.
The equations of motion are reduced to the form

\[
\dot{x}_{eq} = \bar{F}_{eq}(\bar{x}, \bar{a}, \delta) = \begin{pmatrix} \dot{x}_{k_1}, \dot{x}_{k_2}, \ldots, \dot{x}_{k_{IV}} \end{pmatrix}^T
\]  

(D1)

by multiplying each of the original equations of motion (eq. (1a)) by their respective element of INTX; that is, inactive equation variables have their derivatives set to zero.

The original sensitivity equations (eq. (6)) are reduced by using the arrays INTP and INTV as indices in the FORTRAN DO LOOP to the form

\[
\frac{d}{dt} \left( \frac{\partial \bar{x}_{INTV(K')}}{\partial \alpha_{INTP(I)}} \right) = \sum_{K=1}^{IV} \frac{\partial \bar{F}_{INTV(K')}}{\partial \bar{x}_{INTV(K)}} \left( \frac{\partial \bar{x}_{INTV(K)}}{\partial \alpha_{INTP(I)}} \right) + \frac{\partial \bar{F}_{INTV(K')}}{\partial \alpha_{INTP(I)}}
\]

(K' = 1, 2, \ldots, IV; \ I = 1, 2, \ldots, IP)  

(D2)

The accelerometer equations and sensitivity coefficients are handled in a similar manner to generate \( \bar{a}_J \) and \( \frac{\partial \bar{a}_J}{\partial \alpha_{INTP(I)}} \), respectively.

The original parameter change equations (eq. (7)) reduce to

\[
\Delta \bar{a}_J = \left[ \sum_{i=1}^{N} A_J^T(t_i) R_J^{-1} A_J(t_i) \right]^{-1} \left[ \sum_{i=1}^{N} A_J^T(t_i) R_J^{-1} \bar{\eta}_J(t_i) \right]
\]

where

\[
A_J(t_i) = \begin{pmatrix} \frac{\partial \bar{y}^O_J}{\partial \alpha_i_1}, \frac{\partial \bar{y}^O_J}{\partial \alpha_i_2}, \ldots, \frac{\partial \bar{y}^O_J}{\partial \alpha_i_{IP}} \end{pmatrix}
\]

\[
\bar{\eta}_J(t_i) = \bar{y}^M_J(t_i) - \bar{y}^O_J(t_i)
\]

\[
\frac{\bar{y}^M_J(t_i)}{\bar{a}^M_J(t_i)} = \frac{\bar{y}^O_J(t_i)}{\bar{a}^O_J(t_i)}
\]
The vector $\frac{\partial \tilde{x}_{eq}}{\partial \alpha_{\text{INTP}(l)}}$ is searched at each $t_i$ for the sensitivity coefficients associated with the active algorithm variables by using the array INTA. The selected sensitivity coefficients are then packed into the vector $\frac{\partial \tilde{x}_J}{\partial \alpha_{\text{INTP}(l)}}$ in order to form $A_J(t)$. If $IA1 = IV$, no search is made, since this condition implies that $\tilde{x}_{eq} = \tilde{x}_J$. The INTA array also selects $\tilde{\eta}_J(t_1)$ from the original vector $\tilde{\eta}(t_1)$.

The covariance matrix for the parameters becomes

$$
\begin{bmatrix}
\frac{N}{\sum_{i=1}^{N} A_J^T(t_i) R_j^{-1} A_J(t_i)}
\end{bmatrix}^{-1} = \begin{bmatrix}
\sigma^2_{\alpha_{i1}} & \rho_{\alpha_{i1}\sigma_{i1}} & \rho_{\alpha_{i1}\sigma_{i2}} & \cdots & \rho_{\alpha_{i1}\sigma_{i}} & \cdots & \rho_{\alpha_{i1}\sigma_{iP}} \\
\rho_{\alpha_{i2}\sigma_{i1}} & \sigma^2_{\sigma_{i2}} & \rho_{\alpha_{i2}\sigma_{i2}} & \cdots & \rho_{\alpha_{i2}\sigma_{i}} & \cdots & \rho_{\alpha_{i2}\sigma_{iP}} \\
\vdots & \vdots & \vdots & \ddots & \vdots & \cdots & \vdots \\
\rho_{\alpha_{iP}\sigma_{i1}} & \rho_{\alpha_{iP}\sigma_{i2}} & \rho_{\alpha_{iP}\sigma_{i}} & \cdots & \sigma^2_{\sigma_{iP}} & \cdots & \rho_{\alpha_{iP}\sigma_{iP}} 
\end{bmatrix} \tag{D4}
$$

The covariance matrix for the measurement noise becomes

$$
R_j^0(N) \triangleq \text{Estimate of } R_j = \frac{1}{N} \sum_{i=1}^{N} \hat{\eta}_j(t_i) \hat{\eta}_j^T(t_i) = \begin{bmatrix}
\sigma^2_{\eta_{j1}} & \cdots & \sigma_{\eta_{j1}\eta_{j2}} & \cdots \\
\sigma_{\eta_{j1}\eta_{j1}} & \sigma^2_{\eta_{j2}} & \cdots & \sigma_{\eta_{j1}\eta_{j2}} \\
\vdots & \vdots & \ddots & \vdots \\
\sigma_{\eta_{j1}\eta_{j1}} & \sigma_{\eta_{j1}\eta_{j2}} & \cdots & \sigma^2_{\eta_{j1}} 
\end{bmatrix} \tag{D5}
$$

and the performance index to be minimized becomes

$$
J_N(\hat{\alpha}_J^0) = \left| R_j^0(N) \right| \tag{D6}
$$
APPENDIX E

CALCOMP PLOT OPTION

CalComp plots similar to the CRT displays can be obtained in overlay level (2,0). The main difference being that the (+) symbol is used to represent flight data points. Other differences are options to plot flight data only (FSS(2) true), and a variable (NPLOT) to alter the density of flight data points to be plotted. Examples of CalComp plots are shown in figures 2 and 4.

The CalComp plot option is entered by setting IPRINT to 4 by means of the DDDU before exiting the CRT display loop. (Replotting of the CRT display just before entering the CalComp plot option causes erasure of the real-time disk file, and thereby prevents CalComp plots of calculated data.) After exiting the CRT loop, set FSS as shown in the CRT discussion of overlay level (4,0), and depress PRINT switch. When processing of the selected plot is completed, WL(2) will come on to signal the need for operator action. Additional plots can be obtained by setting the appropriate FSS before depressing FSS(14) and then releasing. Exiting the CalComp loop is accomplished by depressing FSS(13).

The flow chart of the CalComp plot option follows.
APPENDIX E - Concluded

CALCOMP PLOT OPTION

Entry when IPRINT = 4
(C0104)
WL(3) = .F.

JSKIP > 0
(C0106)
No
Call CALPLOT
Call LEHOC

Yes

(C0110)

JSKIP = JSKIP + 1
Calculate scale factors and biases

Yes

(C0117)

FSS(2) or FSS(8) = .T.

Call PLAYBAK

Fill and limit
Y1(I), Y2(I), Y3(I), and Y4(I),
I = 1, 2, ..., NOPTS
with calculated data

(C0169)

No

I = NOPTS
(C0170)

WL(3) = .T.

Fill and limit
Z1(I), Z2(I), Z3(I), and Z4(I)
I = 1, 2, ..., NOPTS
with flight data

Call DAYTIM; NOTATE; NUMBER;
ASCALE; GRID; AXES; LINE
(to plot y and/or z against t)

WL(2) = .T.

(C0153)

Call DISPLAY
Call OPERATE

Call OPERATE
WL(2) = .F.

(C0356)

Yes
FSS(14) = .T.

No

(C0339)

FSS(13) = .T.

No

(C0359)

Yes

(C0360)

WL(2) = .F.

IPRINT = 5

RETURN

OVERLAY (XC143FL,4,0)
REFERENCES


Equations of motion
\[ \dot{\mathbf{x}} = F(\mathbf{x}, \alpha, \delta) \]

Sensitivity equations
\[ \left( \frac{\partial \mathbf{x}}{\partial \alpha} \right) = G(t) \left( \frac{\partial \mathbf{x}}{\partial \alpha} \right) + \frac{\partial F}{\partial \alpha} \]

Data point times
\[ t = t_i \]

Comparison
\[ \hat{\eta}(t_i) = x^H(t_i) - x^o(t_i) \]

Performance index
\[ J_N(\alpha^0) = \left| R^0(N) \right| \]

Maximum likelihood estimation
\[ \Delta \alpha = \left[ \sum_{i=1}^{N} A^T(t_i) R^{-1} A(t_i) \right]^{-1} \left[ \sum_{i=1}^{N} A^T(t_i) R^{-1} \hat{\eta}(t_i) \right] \]

\[ R^0(N) = \frac{1}{N} \sum_{i=1}^{N} \hat{\eta}(t_i) R(t_i) \]

Figure 1.- Maximum likelihood parameter estimation procedure.
(a) Longitudinal motion.

Figure 2.- CalComp plot of pseudo flight and calculated (converged solution) longitudinal motion, and control inputs.
(b) Control inputs.

Figure 2. - Concluded.
(a) Typical program control station.

Figure 3.- Operational control features.
(a) Longitudinal motion.

Figure 4.- CalComp plot of pseudo and calculated (nonconverged solution) motion.
(b) Lateral motion.

Figure 4.- Continued.
(c) Accelerometer.

Figure 4.- Concluded.
"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."
—National Aeronautics and Space Act of 1958

NASA SCIENTIFIC AND TECHNICAL PUBLICATIONS

TECHNICAL REPORTS: Scientific and technical information considered important, complete, and a lasting contribution to existing knowledge.

TECHNICAL NOTES: Information less broad in scope but nevertheless of importance as a contribution to existing knowledge.

TECHNICAL MEMORANDUMS: Information receiving limited distribution because of preliminary data, security classification, or other reasons. Also includes conference proceedings with either limited or unlimited distribution.

CONTRACTOR REPORTS: Scientific and technical information generated under a NASA contract or grant and considered an important contribution to existing knowledge.

TECHNICAL TRANSLATIONS: Information published in a foreign language considered to merit NASA distribution in English.

SPECIAL PUBLICATIONS: Information derived from or of value to NASA activities. Publications include final reports of major projects, monographs, data compilations, handbooks, sourcebooks, and special bibliographies.

TECHNOLOGY UTILIZATION PUBLICATIONS: Information on technology used by NASA that may be of particular interest in commercial and other non-aerospace applications. Publications include Tech Briefs, Technology Utilization Reports and Technology Surveys.

Details on the availability of these publications may be obtained from:

SCIENTIFIC AND TECHNICAL INFORMATION OFFICE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington, D.C. 20546