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COMPUTER PROGRAM FOR POST-FLIGHT EVALUATION OF THE CONTROL SURFACE RESPONSE FOR AN ATTITUDE CONTROLLED MISSILE

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COMPUTER PROGRAM FOR POST-FLIGHT EVALUATION OF THE CONTROL SURFACE RESPONSE FOR AN ATTITUDE CONTROLLED MISSILE

SUMMARY

A FORTRAN IV coded computer program is presented for post-flight analysis of a missile's control surface response. It includes preprocessing of digitized telemetry data for time lags, biases, non-linear calibration changes and filtering. Measurements include autopilot attitude rate and displacement gyro output and four control surface deflections. Simple first order lags are assumed for the pitch, yaw and roll axes of control. Each actuator is also assumed to be represented by a first order lag. Mixing of pitch, yaw and roll commands to four control surfaces is assumed. A pseudo-inverse technique is used to obtain the pitch, yaw and roll components from the four measured deflections.

This program has been used for over 10 years on the NASA/SCOUT launch vehicle for post-flight analysis and was helpful in detecting incipient actuator stall due to excessive hinge moments.

The program is currently set up for a CDC CYBER 175 computer system. It requires 34K words of memory and contains 675 cards. A sample problem presented herein including the optional plotting requires eleven (11) seconds of central processor time.

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LIST OF SYMBOLS

Symbol	Description	Units
$[A]$	transformation matrix for control surface commands	
a_{ij}	elements of control surface transformation matrix $[A]$, 'i' denotes row, 'j' denotes column	
a_θ, a_ψ, a_ϕ	pitch, yaw, and roll displacement cross-coupling of rate coefficient in telemetered data	sec
$\overline{b}$	state equation coefficient vector of input	
e	control error signal	degree
$[F]$	state system matrix for channel response	
K_D	autopilot attitude displacement gain	deg/deg
K_R	autopilot attitude rate gain	sec
p	roll rate gyro output	deg/sec
q	pitch rate gyro output	deg/sec
r	yaw rate gyro output	deg/sec
s	Laplacian operator	
T	transfer function	
t	time	sec
u	state equation input	
x	state variables	
y	general nomenclature for telemetered parameters	

Greek Letters

Symbol	Description	Units
δ	control surface deflection	degrees
θ_e	pitch attitude displacement gyro output	degrees
τ	Butterworth filter parameter	sec
ϕ_e	roll attitude displacement gyro output	degrees

ψ_e	yaw attitude displacement gyro output........degrees
ω	characteristic break frequency...............rad/sec
ω_{co}	Butterworth cutoff frequency................rad/sec

Prefix

Δ	incremental value

Subscripts

act	actuator of control surface
bias	telemetry bias value
c	commanded or calculated
m	measured value
δ	control surface
θ	pitch channel
ϕ	roll channel
ψ	yaw channel

Special Notation

.	dots above denote time derivative
-	dashes above denote a vector
[ ]	matrix
$[\ ]^T$	transpose of a matrix
$[\ ]^{-1}$	inverse of a matrix
#	matrix pseudo-inverse
'	superscript or primes denote a modified or adjusted parameter

1.0 INTRODUCTION

Post-flight analysis of a missile autopilot and control system should include comparison of measured parameters for consistency with preflight mathematical models. For a proportional control system telemetered data may include the autopilot gyro outputs and the measured control surface deflections. Preflight gains applied to the gyro outputs and the model should yield the control surface deflections. Differences between the reconstructed values and measured values may be indicative of anomalies or incipient failures. This report presents a computer program used for post-flight analysis of the NASA/SCOUT Launch Vehicle first stage proportional control system. It has been used to identify anomalous behavior.

The missile autopilot is assumed to contain three axes of information each of which includes a displacement and rate term such as, pitch, yaw and roll axes having angular displacement and rate included in the control law. A block diagram of the system is presented in Figure 1.

In post-flight data reduction and analysis there are sometimes small deviations in time for each parameter, differences between assumed linear calibration for data reduction and actual non-linear calibrations, cross-coupling between on-board telemetry channels, and, higher frequency data and noise. All of these can have a significant effect on the post-flight reconstruction process. Therefore, a large part of the methodology herein involves shifting, adjusting and smoothing of the digitized reduced telemetry data.

The assumptions, methodology, program description and running instructions are presented in the following sections.

2.0 METHODOLOGY

This section contains the methodology and equations which are used to adjust the telemetry data and to reconstruct the control surface response from the measured data. Telemetry data for the autopilot pitch, yaw, and roll channel attitude rates and displacements and four control surface deflections are required. Estimates or preflight measurements of autopilot gains are also required. A proportional control system represented by the block diagram of Figure 1 is assumed. The assumptions and equations are presented in the following paragraphs.

2.1 Assumptions

Major assumptions and approximations are:

- autopilot and control system as presented in Figure 1,
- control gains are constant in time,
- pitch, yaw, and roll channels frequency response can be represented as a first order lag (single break frequency),
- actuator response for each of the four control surfaces can be represented by a first order lag,
- mixing of the pitch, yaw, and roll error signals for commands to the four control surfaces is represented by a constant matrix transformation,
- frequency response of the telemetry data is greater than the autopilot model
- phase shifts in the telemetry data can be represented by an equivalent time shift for each of the parameters,
- telemetry system cross-coupling is limited to the attitude displacement gyro output and is proportional to vehicle rate about that axis
- non-linearities in calibration of the control surfaces are not time dependent

2.2 Equations

2.2.1 Control Surface Response

The control surface response is represented by the block diagram of Figure 1. The pitch, yaw, and roll channel error signals are,

(2.1) $$e_\theta = \left(K_{D_\theta}\,\theta_e + K_{R_\theta}\,q\right)\left\{\frac{\omega_\theta}{s + \omega_\theta}\right\}$$

(2.2) $$e_\psi = \left(K_{D_\psi}\,\psi_e + K_{R_\psi}\,r\right)\left\{\frac{\omega_\psi}{s + \omega_\psi}\right\}$$

(2.3) $$e_\phi = \left(K_{D_\phi}\,\phi_e + K_{R_\phi}\,p\right)\left\{\frac{\omega_\phi}{s + \omega_\phi}\right\}$$

These error signals are processed through a linear transformation to mix the signals to each of four control surfaces. This transformation is,

(2.4) $$\bar{\delta}_c = \left[A\right]\bar{e}$$

where,

$\bar{\delta}_c$ is the four element vector

(2.5) $$\bar{\delta}_c = \begin{bmatrix} \delta_{c1} \\ \delta_{c2} \\ \delta_{c3} \\ \delta_{c4} \end{bmatrix}$$

$[A]$ is the 4 by 3 transformation matrix specified by the autopilot design

(2.6) $$[A] = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \\ a_{41} & a_{42} & a_{43} \end{bmatrix}$$

$\bar{e}$ is the three element error vector

$$\bar{e} = \begin{bmatrix} e_\theta \\ e_\psi \\ e_\phi \end{bmatrix}$$

According to Figure 1 each actuator responds to commands as a simple first order lag, i.e., ,

(2.7) $$\delta = \delta_c\left\{\frac{\omega_{act}}{s + \omega_{act}}\right\}$$

Up to this point the system is linear. It is assummed that each actuator responds with the same break frequency. Therefore, the transfer function of equation (2.7) can be moved and included in the transfer function of equations (2.1), (2.2), and (2.3). This is done in the program to reduce computer time. The commanded pitch, yaw, and roll surface deflections become,

$$(2.8) \qquad \bar{\delta}_c = \left[A \right] \bar{e} \left\{ \frac{\omega_{act}}{s + \omega_{act}} \right\}$$

This will be followed through the derivation for the pitch channel; yaw and roll channel equations are similar. Prior to the mixing of channel error signals via the [A] transformation, the equivalent pitch component of commanded surface deflections is,

$$(2.9) \qquad \delta_{c_\theta} = \left(K_{D_\theta} \ \theta_e + K_{R_\theta} q \right) \left\{ \frac{\omega_\theta}{s + \omega_\theta} \right\} \left\{ \frac{\omega_{act}}{s + \omega_{act}} \right\}$$

This can be put into the state variable form.

$$(2.10) \qquad \dot{\bar{x}} = \left[F \right] \bar{x} + \bar{b} \ u$$

where the input,

$$(2.11) \qquad u = \left(K_{D_\theta} \ \theta_e + K_{R_\theta} \ q \right)$$

$$(2.12) \qquad \bar{x} = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \qquad \text{(two state vector)}$$

$$(2.13) \qquad \left[F \right] = \begin{bmatrix} -\omega_\theta & 0 \\ \omega_{act} & -\omega_{act} \end{bmatrix} \qquad \text{(system matrix)}$$

$$(2.14) \qquad \bar{b} = \begin{bmatrix} \omega_\theta \\ 0 \end{bmatrix} \qquad \text{(input coefficient vector)}$$

and the output is,

$$(2.15) \qquad \delta_{c\theta} = x_2$$

In the program these equations are solved by a linear system time response subroutine (TRESP) which uses a fourth-order RUNGE-KUTTA integration method. After the pitch, yaw, and roll commanded deflections are computed they are transformed by the matrix [A] (Equation 2.6) to provide the calculated or reconstructed deflections of each of the four control surfaces.

2.2.2 Pseudo-Inverse

Commanded individual control surfaces represented by equation 2.4 involves a linear transformation [A] of a 'three-vector' into a 'four-vector'. The pitch, yaw, and roll components of the four control surfaces can be calculated from the measured individual control surface deflections. This is easily done using the pseudo-inverse transformation of [A]. A matrix inverse does not exist for non-square matrices. The pseudo-inverse provides a reverse transformation in a least-squares sense. The pseudo-inverse is,

$$(2.16) \quad [A]^{\#} = ([A]^T[A])^{-1} [A]^T$$

for the overdetermined case where [A] has more rows than columns. Reference "Applied Optimal Estimation" edited by Arthur Gelb, published by the M.I.T. Press, Cambridge, Massachusetts, 1974.

Actual pitch, yaw, and roll control surface deflection components can be computed,

$$(2.17) \quad \begin{bmatrix} \delta_{act_\theta} \\ \delta_{act_\psi} \\ \delta_{act_\phi} \end{bmatrix} = [A]^{\#} \begin{bmatrix} \delta_{act_1} \\ \delta_{act_2} \\ \delta_{act_3} \\ \delta_{act_4} \end{bmatrix}$$

2.2.3 Telemetered Data Adjustments

Reduced telemetry data for the pitch, yaw, and roll displacements and rates and the four control surface deflections may require further adjustments and filtering. These adjustments include biases, time shifts, non-linearities, cross-coupling, and additional filtering.

BIASES

Each parameter is assumed to have a simple bias error which can be estimated from a quiet period of flight such as prior to vehicle liftoff. These are entered in the input to the routine and added to the reduced telemetry data, i.e.,

$$(2.18) \quad y'_m(t) = y_m(t) + \Delta y$$

where, $y_m(t)$ is the reduced measured telemetry parameter
$y_m'(t)$ is the adjusted parameter
Δy is the bias shift required

TIME SHIFTS

Each measured parameter is assumed to have a different time delay due to the telemetry system and ground station playbacks. In order to be consistent each parameter must be shifted to a common time base. This is done by a table lookup versus time such that the parameter (y) is shifted back in time by its peculiar lag, i.e.,

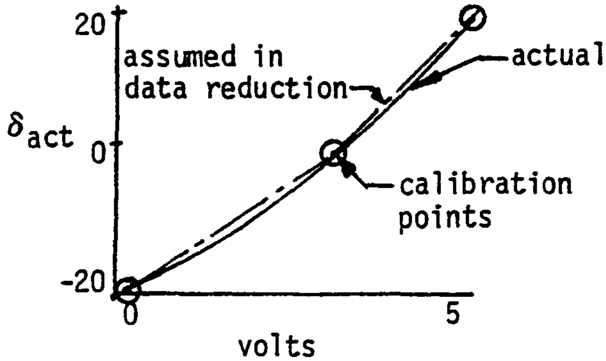
$$(2.19) \quad y''_m(t) = y'_m(t+\Delta t)$$

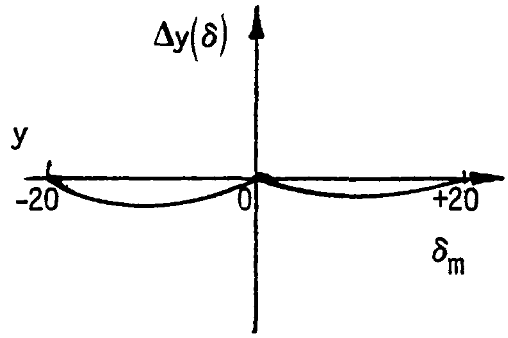
where, $y''_m(t)$ is the measured parameter adjusted for time and bias shifts

Δt is the required time shift for parameter 'y'

NON-LINEARITIES

The four control surface deflections may have a parabolic calibration curve (this is the case for a measurement using a linear potentiometer attached to a bellcrank). In data reduction the calibration applied is usually a straight line or a series of straight lines (see the sketch below).





This can lead to subtle errors in reconstructing the control surface deflections. Therefore, an adjustment is made to the data via a table lookup in the computer program. This adjustment is,

$$\Delta y = \Delta y_{bias} + \Delta y(\delta) \tag{2.20}$$

where, Δy_{bias} is an average bias value
$\Delta y(\delta)$ is a function of the deflection based on the sketches above

The bias shown in Equation (2.20) is inserted into Equation (2.18).

CROSS-COUPLING

Peculiarities in an attitude gyro telemetry pickoff may induce a voltage proportional to the vehicle rate about the input axis (this is peculiar to the SCOUT vehicle using miniature integrating rate gyros to measure attitude displacements). The true attitude displacement is therefore,

$$\begin{aligned} \theta_e &= \theta_{e_m} - a_\theta\, q \\ \psi_e &= \psi_{e_m} - a_\psi\, r \\ \phi_e &= \phi_{e_m} - a_\phi\, p \end{aligned} \tag{2.21}$$

where the coefficients a_θ, a_ψ, and a_ϕ are determined by preflight test of the telemetry and autopilot subsystems.

ADDITIONAL FILTERING

Since the telemetry data may have noise or data at frequencies well above the bandwidth of interest, additional filtering capability is afforded by the computer program. A third order Butterworth filter is supplied. The cutoff frequency is an input variable. Each parameter is filtered with the same algorithm and cutoff frequency. The transfer function is,

$$T(s) = \frac{1}{1 + 2\tau s + 2\tau^2 s^2 + \tau^3 s^3} \tag{2.22}$$

where,

(2.23) $\tau = 0.707 / \omega_{co}$

and,

ω_{co} is the cutoff frequency in radians per second

The equivalent state-space filter equation for this transfer function is,

$$(2.24)\quad \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} -2/\tau & -2/\tau^2 & -1/\tau^3 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 1/\tau^3 \\ 0 \\ 0 \end{bmatrix} u$$

where, x_1, x_2, and x_3 are the filter states.

u is the filter input

x_3 state is the filter output

These equations are solved in the computer program using the time response subroutine (TRESP).

Application of this filter adds a low frequency time delay to the data. This delay is,

(2.25) $t = 1.418 / \omega_{co}$ (seconds)

This time increment is added to the individual telemetry parameter time delays before shifting the data with Equation (2.19).

3.0 PROGRAM DESCRIPTION

3.1 General

This computer program is programmed in FORTRAN IV for a CDC CYBER 175 system. The coding is in the most part compatible with ANSI standards. Non-ANSI statements include the PROGRAM card and the use of EOF (end-of-file) test for transfer from reading input. Another area of limited portability is the use of ten letter words for labeling information. Consult your computer department for changes in these areas.

The computer routine is arranged to operate with standard card input and line printer output. Optional plotting is based on standard CALCOMP plotters and software. The CALTEKA Tektronix terminal plot can also be used without program modification.

A main routine (FINRES) and twelve (12) subroutines require approximately 34K words of computer memory. Input and output is stored in arrays to facilitate time adjustments, filtering, and a well formatted printed and plotted output.

Program flow and user instructions are presented in the following paragraphs. Input and output of a sample problem is illustrated along with detailed descriptions.

3.2 Program Flow

Program flow is straightforward in eight basic parts.

- input data
- telemetry data adjust for calibration and filtering
- reconstruction of pitch, yaw and roll commands
- comparison of individual control surfaces with reconstructed commands
- output of individual surface data
- optional reconstruction of pitch, yaw and roll components of control surface response and output
- plotted output

The interdependence of the main routine and the subroutines is presented in Figure 2. A flow chart of the main routine (FINRES) is presented in Figure 3. A complete listing of the FORTRAN program and subroutines other than the standard CALCOMP library subroutines are presented in Appendix A.

Descriptions of the twelve subroutines are presented in the following paragraphs.

3.3 Subroutine Description

Twelve subroutines are used to support the FINRES main program; CURVE, DASH, ERSIG, FILFIL, FIN, PSEUDO, RUNGE, SIMEQ, TBLN, TRESP, XMULT, and YDOT. A brief description of each is presented below.

CURVE

This subroutine sets up the calcomp plot for one frame of a single control surface deflection comparison. It includes the graph paper description (CAL22) which has a 10 by 16 grid size with 20 divisions per inch. Paper performation size is 11 by 17. All data to be plotted by this routine enters in the argument list. The actual curve plotting is made through calls to the DASH subroutine. The call statement for CURVE is,

CALL CURVE (T, CALC, ACT, NP, NTIT, NM, XS, YS, DS)

where,

T	input array name of time abscissas
CALC	input array name of computed commanded surface deflections (reconstructed)
ACT	input array name of measured control surface deflection
NP	is the number of time points in T, CALC, and ACT arrays to be plotted
NTIT	input array of eight (8) ten-letter words contained 80 character title
NM	input ten letter word variable to identify frame (this is output on second line of title)
XS	abscissa (time) scale factor (units/inch)
YS	ordinate deflection scale factor (units/inch)
DS	ordinate scale factor for difference (CALC-ACT) deflection (units/inch)

Care must be taken in selecting scale factors so that plotted data falls on grid. Limiting of plotted data is automatically invoked in CURVE through the call statements to DASH.

DASH

This subroutine plots a curve on a CALCOMP plotter for a set of ordinates and abscissas. The style and type of line drawn is selected by the user. Note that the CALCOMP plot is specified in inches; plotting on metric paper requires appropriate scaling change before entering this subroutine.

The call statement is,

CALL DASH (X, Y, NP, Z1, Z2, SPACE, XSCALE, YSCALE, LSYMB, XLIM, YLIM)

where,

X	- input array of abscissa values
Y	- input array of ordinate values
NP	- number of points in X and Y to be plotted

Z1	-	for dashed-dot lines this is length of long line measured in inches (see sketch below)
Z2	-	for dashed-dot lines this is length of short line measured in inches (see sketch)
SPACE	-	for dashed style lines this is the length of the space between lines measured in inches. SPACE = 0 gives a solid line plot SPACE = negative gives special CALCOMP symbols at each point
XSCALE	-	abscissa plot scale factor (units per inch)
YSCALE	-	ordinate plot scale factor (units per inch)
LSYMB	-	special CALCOMP symbol code number used if SPACE is negative (see code below)
	-	(+) LSYMB gives straight solid lines between symbol points
	-	(-) LSYMB gives only symbols at each point without lines
XLIM	-	plot limiting of the abscissa (inches) points out of range, range will appear at this limit
YLIM	-	plot range of ordinate (inches)

For ease in use, the following styles are typically possible,

LINE	TYPE	Z1	Z2	SPACE	LSYMB
________________	Solid	--	--	0.	0.
— — — — —	Dashed	0.25	0.25	0.10	0.
- - - - - - - - -	Dashed	0.07	0.07	0.07	0.
—— - —— - ——	Dashed Dot	0.5	0.03	0.07	0.
	Symbols	--	--	-0.1	+2
	Symbols (no line)	--	--	-0.1	-2

ERSIG

This subroutine computes the single axis error signal commanded deflection (pitch, yaw, or roll). It includes adjustment for rate crosscoupling into the displacement telemetry data, the channel break frequency and actuator break frequency time response. The call statement is,

```
CALL ERSIG (FILTER, B, T, Q, TH, NP, NINT, CTH, CTHD, DT, DTTM, DTTMR, AD,
            W, WACT)
```

where,

FILTER	input third order coefficient array for the Butterworth filter states (see Paragraph 2.2.3)
B	telemetry filtering input coefficient vector (Paragraph 2.2.3)
T	input array of time points for telemetry data containing NP points
Q	input array of NP points of telemetered rate data corresponding to (T) times. It is changed to output the filtered error signal.

TH	input array of NP points of telemetered displacement data corresponding to (T) times
NP	number of time points in arrays T, Q, and TH
NINT	number of integration steps per value of time in (T) array to be used in filtering and response histories (e.g., if NINT = 2) the integration step size is one-half of the time between points in (T) array
CTH	attitude displacment gain K_D
CTHD	rate gain K_R
DT	time delay of third order filter (FILTER) and (B) to be used in time corrections
DTTM	time delay of attitude error telemetry data
DTTMR	time delay of rate telemetry data
AD	telemetry cross-coupling coefficient of attitude displacement due to rate
W	break frequency of the control channel
WACT	actuator break frequency

Note that the array (Q) is destroyed by the subroutine and used to return the computed filtered error signal.

FILFIL

This subroutine fills the third order Butterworth filter coefficient arrays and computes the low frequency time lag of this filter as presented in Paragraph 2.2.3. The call statement is,

```
CALL FILFIL (WCO, A, B, DT)
```

where,

WCO	input cutoff frequency of the Butterworth filter (radians per second)
A	output coefficient matrix of the filter (3 by 3)
B	output coefficient vector for filter state inputs
DT	output effective low frequency time lag associated with the filter (seconds)

FIN

This subroutine filters a telemetered control surface deflection time history and adjusts it for time shifts. The call statement is,

```
CALL FIN (FILTER, B, T, D, NP, DTFIL, TC, NINT)
```

where,

FILTER	input (3 by 3) matrix of third order filter coefficient matrix
B	input (3 by 1) coefficient input vector for third order filter
T	input array of NP times for deflection array D
D	input array of NP control surface deflections (also the output filtered time adjusted deflection)
NP	number of time points in T, and D arrays
DTFIL	input low frequency time lag of filter in seconds
TC	input time lag of telemetered control surface deflection for use in adjustment

NINT	number of integration steps to be used between time points in (T) array

PSEUDO

This subroutine computes the pseudo - inverse of the coefficient matrix as described in Paragraph 2.2.2. The call statement is,

CALL PSEUDO (B, A, N, M, NER)

where,

B	output M by N pseudo - inverse matrix of A
A	input matrix having dimensions N by M
N	is number of rows of (A) and number of columns of (B)
M	is number of columns of (A) and number of rows of (B)
NER	is an error indicator
	NER = 1 normal execution
	NER = 0 abnormal condition because of a submatrix singularity (pseudo inverse cannot be computed)

RUNGE

This subroutine aids in the RUNGE-KUTTA integration of the time response (TRESP) subroutine. The call statement is,

CALL RUNGE (N, FN, H, X, Y, L, I)

where,

N	input system order
FN	first derivatives of the state
H	integration step size
X	time variable
Y	state vector
L	control integer
	L = 1 indicates incomplete integration process
	L = 2 indicates completed integration step
I	number of times that RUNGE has been entered on the current integration step (when I = 5 the final answer is computed)

SIMEQ

This subroutine is used to compute the inverse of a square matrix by diagonalization. With modification it can be used to solve a set of simultaneous linear equations. The call statement is,

CALL SIMEQ (A, KC, AINV, IERR)

where,

A	input KC by KC matrix to be inverted
KC	input order of the matrix
AINV	output inverted matrix if computed
IERR	output error variable
	IERR = 1 normal computation
	IERR - 0 abnormal (A matrix is singular)

TBLN

This is a single table lookup subroutine using linear interpolation between points. This subroutine requires separate consistent arrays of abscissas and ordinates. The abscissas must be in ascending order. The call statement is,

CALL TBLN (Y, X, T, A, NT, M)

where,

Y	output ordinate to be found
X	input abscissa value
T	array of abscissas
A	array of ordinates
NT	number of values in (T) and (A) arrays
M	input index 1 to NT to begin the table search. After locating the ordinate the nearest location is returned for future use

TRESP

This subroutine used in conjunction with subroutines RUNGE and YDOT solve a time response for a set of up to three first order linear differential equations by a fourth order RUNGE-KUTTA integration procedure. The call statement is,

CALL TRESP (A, B, T, Y, Z, NP, N, K, NINT)

where,

A	input coefficient matrix
B	input coefficient vector for state equations
T	input array of (NP) forcing function time values
Y	input array of NP forcing function values corresponding to times in (T) array
Z	output array of 'Kth' state variable values corresponding to time in (T) array
NP	input number of values in T, Y, and Z array
N	input order of the system
K	input designation of state variable corresponding to the desired output
NINT	input number of integration steps between time points in (T) array

XMULT

This subroutine multiplies two matrices. The call statement is,

CALL XMULT (A, B, C, N)

where,

A	input premultiplier matrix
B	input postmultiplier matrix

C	output matrix product of (A.B) having order N by N
N	is desired order of the output matrix (if input matrices are non-square they are filled with zeroes where rows or columns are needed)

YDOT

This subroutine computes the first derivative of the system state vector used by TRESP to integrate a set of first order linear differential equations. The call statement is,

```
CALL YDOT (A, Y, XDOT, B, U, N)
```

where,

A	input system coefficient matrix of order N
Y	input state vector
XDOT	input derivative of the state vector and returned updated derivative of the state vector
B	input coefficient vector of the forcing function
U	input value of the forcing function
N	input order of the system

3.4 Input Data Description

Input data descriptions are presented in the following subparagraphs. A sample problem input data listing is presented in Figure 4 for reference. Input data can be separated into the following categories:

1) title card and control options
2) telemetry adjustements
3) control sytem constants
4) control surface deflection adjustment tables for non-linearities
5) plot scale factors
6) time histories of measured telemetry variables

3.4.1 Title and Control Constants

The first card of input contains 80 columns of arbitrary title information. This information is printed at the head of each page of output and at the top of each frame of plotted data. It is input using an array (NTIT) having eight words containing ten characters each.

The second card contains four (4) integer constants right justified without a decimal point. It is input with a format of (4I5). The description is,

FORTRAN NAME	COLUMN	DESCRIPTION
IOC	5	control option IOC = 0 do not compute pitch yaw and roll deflection components using pseudo-inverse IOC = 1 compute pitch, yaw, and roll deflection components using pseudo-inverse
IOP	10	plot option IOP = 0 no plots IOP = 1 plot time histories of control surface deflections
NPRT	11-15	printed output control integer NPRT + 1 time intervals are skipped in output (e.g., NPRT = 2 keeps every other point from being printed)
NINT	16-20	number of integration steps for each increment of time between the equally spaced input data

3.4.2 Telemetry Adjustments

This group contains twenty-four (24) constants used for adjustment of the telemetry data. These are input eight numbers per card in fields of ten columns (format 8E10.3). The descriptions are,

FORTRAN NAME	CARD	COLUMNS	DESCRIPTION
DL(1)	3	1-10	bias adjustment to be added to pitch rate
DL(2)	3	11-20	bias adjustment to be added to yaw rate
DL(3)	3	21-30	bias adjustment to be added to roll rate
DL(4)	3	31-40	bias adjustment to be added to pitch displacement
DL(5)	3	41-50	bias adjustment to be added to yaw displacement
DL(6)	3	51-60	bias adjustment ot be added to roll displacement
DL(7)	3	61-70	bias adjdustment to be added to fin 1 control surface

FORTRAN NAME	CARD	COLUMNS	DESCRIPTION
DL(8)	3	71-80	bias adjustment to be added to fin 2 control surface
DL(9)	4	1-10	bias adjustment to be added to fin 3 control surface
DL(10)	4	11-20	bias adjustment to be added to fin 4 control surface
TCQ	4	21-30	time lag in pitch rate data
TCR	4	31-40	time lag in yaw rate data
TCP	4	41-50	time lag in roll rate data
TCTH	4	51-60	time lag in pitch displacement data
TCPS	4	61-70	time lag in yaw displacement data
TCPH	4	71-80	time lag in roll displacement data
TC1	5	1-10	time lag in fin 1 control surface data
TC2	5	11-20	time lag in fin 2 control surface data
TC3	5	21-30	time lag in fin 3 control surface data
TC4	5	31-40	time lag in fin 4 control surface data
AKTH	5	41-50	pitch displacement to rate telemetry cross coupling coefficient
AKPS	5	51-60	yaw displacement to rate telemetry cross coupling coefficient
AKPH	5	61-70	roll displacement to rate telemetry cross coupling coefficient
WCO	5	71-80	cutoff frequency of third order Butterworth filter to be used on all input time histories (hertz)

3.4.3 Control System Constants

This group of input data includes the autopilot control system gains, break frequencies and error signal mixing matrix for the individual control surface commands. Gains and break frequencies are input in fields of ten with format (8E10.3). They are,

FORTRAN NAME	CARD	COLUMN	SYMBOL	UNITS	DESCRIPTION
CTH	6	1-10	K_{D_θ}	--	pitch attitude displacement gain
CTHD	6	11-20	K_{R_θ}	sec	pitch rate gain
CPS	6	21-30	K_{D_ψ}	--	yaw attitude displacement gain
CPSD	6	31-40	K_{R_ψ}	sec	yaw rate gain
CPH	6	41-50	K_{D_ϕ}	--	roll attitude displacement gain
CPHD	6	51-60	K_{R_ϕ}	sec	roll rate gain
W1Q	6	61-70	ω_θ	rad/sec	pitch channel break frequency
W1R	6	71-80	ω_ψ	rad/sec	yaw channel break frequency
W1P	7	1-10	ω_ϕ	rad/sec	roll channel break frequency
WACT	7	11-20	ω_{act}	rad/sec	control surface actuator break frequency

The next four cards contain the transfer matrix describing the relationship of the four control surfaces to the pitch, yaw and roll error signals. These are input with one card for each surface with three constants relating the components of pitch, yaw and roll error signal to each surface. Input is with format (4E10.3).

FORTRAN NAME	CARD	COLUMNS	DESCRIPTION
A(1,1)	8	1-10	fraction of pitch error for surface no. 1
A(1,2)	8	11-20	fraction of yaw error for surface no. 1
A(1,2)	8	21-30	fraction of roll error for surface no. 1
A(2,1)	9	1-10	fraction of pitch error for surface no. 2
A(2,2)	9	11-20	fraction of yaw error for surface no. 2
A(2,3)	9	21-30	fraction of roll error for surface no. 2
A(3,1)	10	1-10	fraction of pitch error for surface no. 3
A(3,2)	10	11-20	fraction of yaw error for surface no. 3
A(3,3)	10	21-30	fraction of roll error for surface no. 3
A(4,1)	11	1-10	fraction of pitch error for surface no. 4
A(4,2)	11	11-20	fraction of yaw error for surface no. 4
A(4,3)	11	21-30	fraction of roll error for surface no. 4

3.4.4 Control Surface Non-Linear Calibration Adjustment Tables

This group of input includes a table of adjustments for each control surface which allows for non-linearities in calibration not included in the data reduction process. These are read with format (I5/,8E10.3). The first card of each table contains the number of abscissa-ordinate pairs. The abscissa (control surface deflection) must be in ascending order. Four tables, one for each fin control surface includes,

FORTRAN NAME	COLUMN	DESCRIPTION
NT1	1-5	number of pairs of abscissas and ordinates in surface no. 1 adjustment table
CD1(I), ED1(I),	1-10, 11-20, etc	CD1 contains abscissa value of surface no. 1 deflection ED1 contains ordinate value of surface no. 1 to be added to input telemetry data
NT1 CD2(I),ED2(I),	1-5 1-10, 11-20,	(similar to above description for control surface no. 2)
NT3 CD3(I),ED3(I),	1-5 1-10, 11-20,	(similar to above description for control surface no. 3)
NT4 CD4(I),ED4(I),	1-5 1-10,11-20	(similar to above description for control surface no. 4)

3.4.5 Plot Constants

This includes a single card of scale factors for the CALCOMP type plots. This card is input only when (IOP = 1) on the second card of input (Paragraph 3.4.1). Input uses format (8E10.3). The descriptions are,

FORTRAN NAME	COLUMNS	UNITS	DESCRIPTION
XSCALE	1-10	sec/inch	time abscissa scale factor per inch of paper
YSCALE	11-20	deg/inch	control surface ordinate scale factor per inch of plot paper
DSCALE	21-30	deg/inch	control surface deflection difference scale factor per inch of paper

3.4.6 Telemetered Data Time Histories

This group of data is entered with format (11F7.3); each card contains all of the telemetered parameters for a given time point. The time points must be equally spaced. The analysis uses all the input data time points and stops reading input when an 'End-of-File' card is read in the input data stream. The description of this data follows (refer to the sample problem input of Figure 4).

FORTRAN NAME	COLUMN	SYMBOL	UNITS	DESCRIPTION
T(J)	1-7	t	seconds	time
Q(J)	8-14	p	deg/sec	telemetered pitch rate
R(J)	15-21	q	deg/sec	telemetered yaw rate
P(J)	22-28	r	deg/sec	telemetered roll rate
TH(J)	29-35	θ_e	degrees	telemetered pitch displacement error
PS(J)	36-42	ψ_e	degrees	telemetered yaw displacement error
PH(J)	43-49	ϕ_e	degrees	telemetered roll displacement error
D1(J)	50-56	δ_1	degrees	telemetered fin 1 control surface deflection
D2(J)	57-63	δ_2	degrees	telemetered fin 2 control surface deflection
D3(J)	64-70	δ_3	degrees	telemetered fin 3 control surface deflection
D4(J)	71-77	δ_4	degrees	telemetered fin 4 control surface deflection

3.5 Output Data Description

Output includes printed data and optional CALCOMP type plots (if IOP = 1). A detailed description of the output is presented in the following paragraphs with a sample problem for reference. The printed output includes three parts depending on option.

1) individual control surface response
2) pitch yaw and roll control surface response (if IOC = 1)
3) CALCOMP plots (if IOP = 1)

3.5.1 Individual Control Surface Response

Printed output for a sample problem is presented in Figure 5. The first part of the output includes time histories of these parameters for each of the four control surfaces. These parameters are,

OUTPUT LABEL	SYMBOLS	UNITS	DESCRIPTION
COMMAND	δ_c	deg	reconstructed control surface deflection based on the telemetered autopilot data
ACTUAL	δ_{act}	deg	filtered smoothed and adjusted telemetry data for the control surface deflection
DELTA	$\delta_c - \delta_{act}$	deg	difference between the reconstructed and actual deflection data

3.5.2 Pitch, Yaw, and Roll Component Response

If the option (IOC = 1) is chosen the pseudo-inverse of the control surface mixing gain matrix is computed. The pitch, yaw, and roll average components based on the four measured control surfaces are then computed. These are presented in Figure 6 for the sample problem. The parameters for the pitch, yaw, and roll channels are,

OUTPUT LABEL	SYMBOLS	UNITS	DESCRIPTION
COMMAND	δ_c	deg	reconstructed pitch, yaw, and roll control error signal based on the telemetered autopilot data
ACTUAL	δ_{act}	deg	pitch, yaw, and roll component of the control surface deflection based on the telemetered control surface deflection and the pseudo-inverse gain matrix
DELTA	$\delta_c - \delta_{act}$	deg	difference between the above values

3.5.3 CALCOMP Plots

If (IOP = 1) CALCOMP type plots are generated corresponding to the data printed. However, all computed points are plotted, whereas printed output can be suppressed by (NPRT) on the second input card. Sample problem plots are presented in Figure 7 and correspond to the descriptions presented in paragraphs 3.5.1 and 3.5.2.

FIGURE 1
Control System Block Diagram

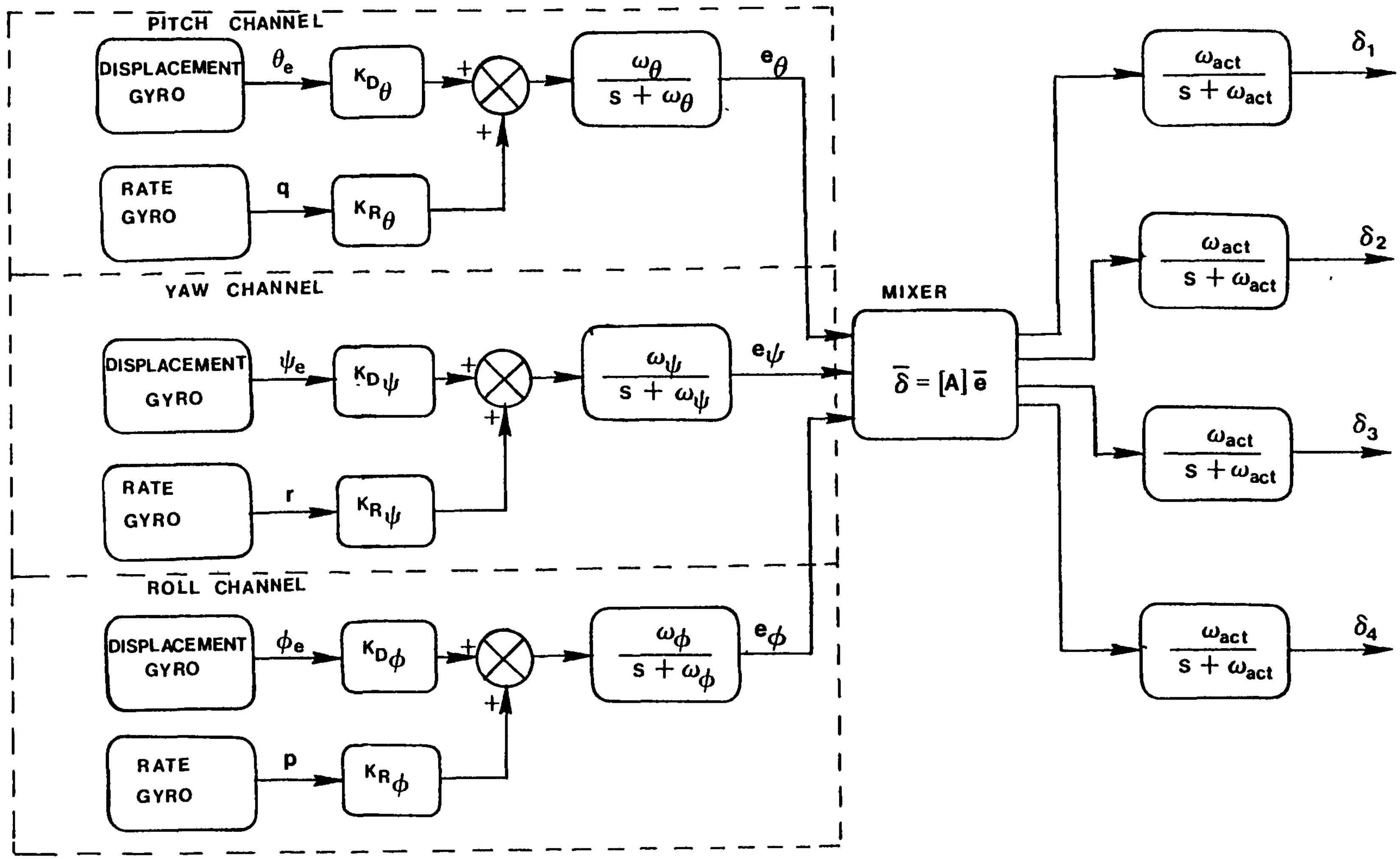


FIGURE 2

PROGRAM SUBROUTINE INTERACTION MAP

	SUBROUTINES CALLED												
	CURVE	DASH	ERSIG	FILFIL	FIN	PSEUDO	RUNGE	SIMEQ	TBLN	TRESP	XMULT	YDOT	CALCOMP LIBRARY
FINRES (MAIN)	X		X	X	X	X							
CURVE		X											X
DASH													X
ERSIG									X	X			
FILFIL													
FIN									X	X			
PSEUDO								X			X		
RUNGE													
SIMEQ													
TBLN													
TRESP							X		X			X	
XMULT													
YDOT													

Figure 3
Flow Chart of FINRES

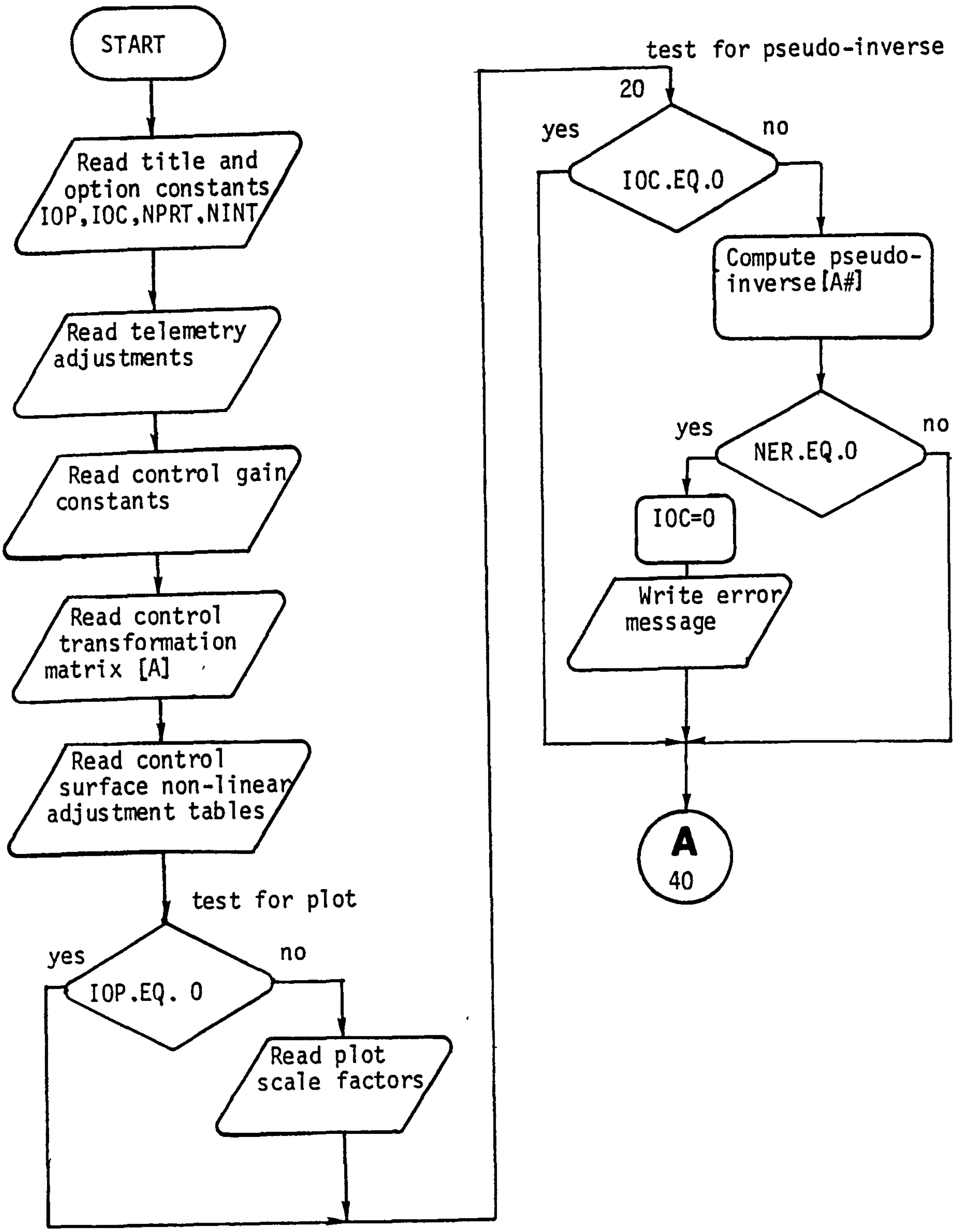


Figure 3 (continued)
Flow Chart of FINRES

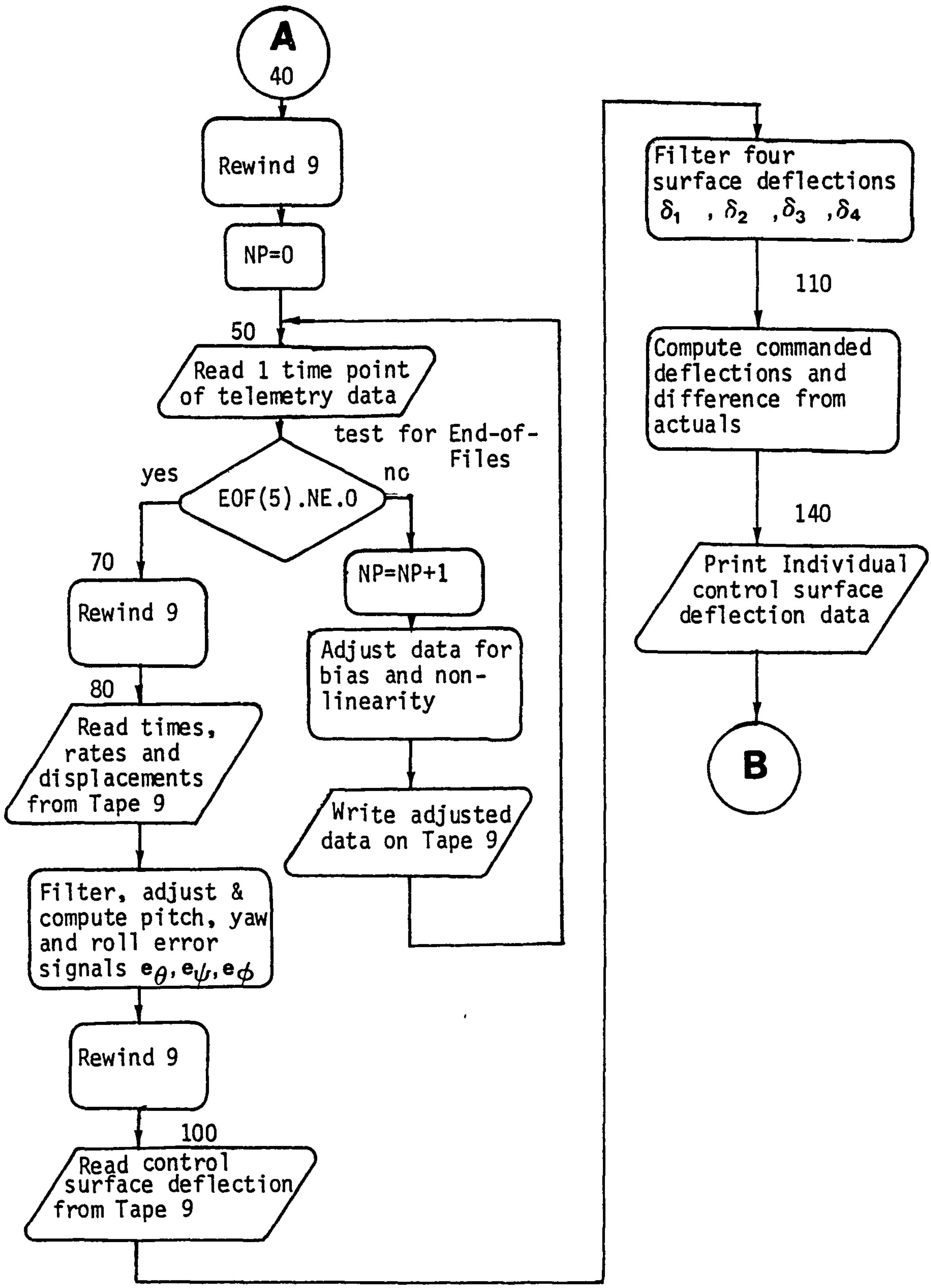


Figure 3 (concluded)
Flow Chart of FINRES

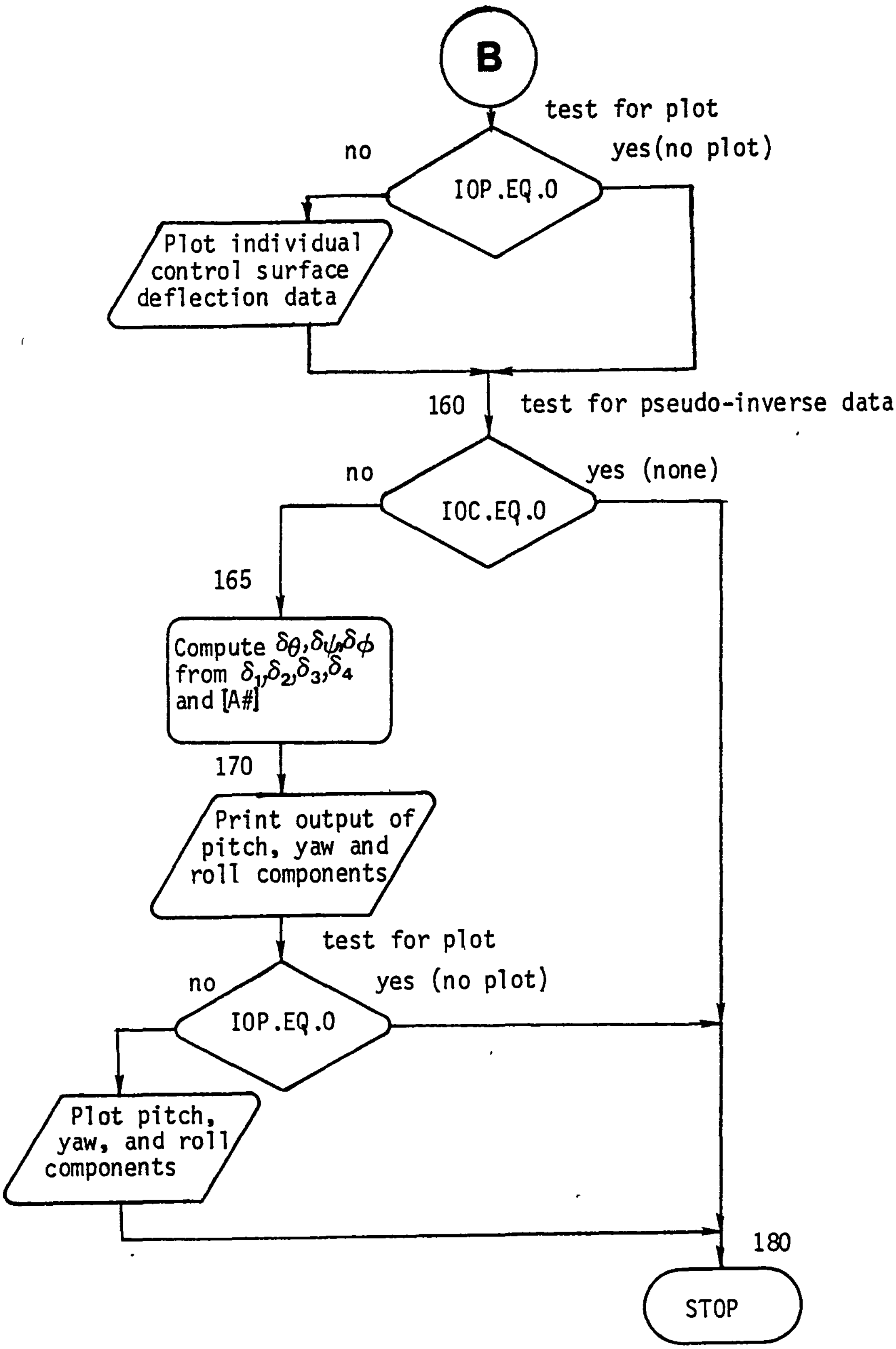


Figure 4
Sample Problem Input Data

```
SAMPLE PROBLEM  SCOUT S-192C FIRST STAGE FIN RESPONSE ANALYSIS   FIRST 15 SEC
    1     1     5     2
         0.          0.          0.          0.          0.          0.          0.          0.
         0.          0.       0.026      0.0283      0.0283          0.          0.          0.
     0.0376      0.0376      0.0477      0.0375        0.04        0.04       0.016          5.
       7.15        2.86        7.00        3.03        2.98        1.17       15.46       15.46
        90.       16.77
         0.          1.         -1.
         1.          0.          0.
         0.          1.          1.
         1.          0.          0.
    4                 FIN 1 NON-LINEAR CALIBRATION ADJUSTMENTS
       -20.          0.        -10.          0.         10.          0.         20.          0.
    4                 FIN 2 NON-LINEAR CALIBRATION ADJUSTMENTS
       -20.          0.        -10.          0.         10.          0.         20.          0.
    4                 FIN 3 NON-LINEAR CALIBRATION ADJUSTMENTS
       -20.          0.        -10.          0.         10.          0.         20.          0.
    4                 FIN 4 NON-LINEAR CALIBRATION ADJUSTMENTS
       -20.          0.        -10.          0.         10.          0.         20.          0.
         1.          4.          2.     PLOT SCALE FACTORS FOR TIME, FIN, AND DELTA
  -.445   .007   .017  -.008  -.021  -.117   .076  -.882   .028  -.341   .026
  -.395  -.005   .001  -.008  -.006  -.064   .100  -.917   .028  -.394   .026
  -.348   .007  -.018  -.005   .016  -.082   .107  -.899   .045  -.502   .044
  -.297   .013  -.021  -.003   .014  -.097   .080  -.934   .045  -.448   .026
  -.246   .029  -.011  -.008   .036  -.111   .046 -1.021   .028  -.573   .044
  -.195   .032  -.011  -.008  0.000  -.069   .096 -1.056   .045  -.591   .044
  -.145   .035  -.018  -.003  0.000  -.114   .097 -1.073   .045  -.555   .026
  -.098   .016  -.018  -.010   .035  -.107   .074 -1.073   .081  -.573   .080
  -.047  -.021  -.021  -.033   .024  -.110   .069 -1.126   .081  -.627   .116
   .004  -.049  -.011   .028   .006  -.134   .084 -1.143   .098  -.627   .098
   .055  -.058  -.008  -.069  -.007  -.147   .095 -1.178   .081  -.609   .170
   .105  -.107  -.008   .272   .002  -.108   .147 -1.247   .010  -.448   .243
   .152  -.734  -.024   .604  -.041  -.130   .130 -1.491  -.025  -.072  -.011
   .203  -.326   .286   .335  -.105  -.083   .140 -1.735  -.007   .125  -.192
   .254  -.255   .023   .315  -.021  -.121   .181 -1.665  -.253   .340  -.609
   .305   .314  -.099   .528  -.016  -.137   .223 -1.474  -.745   .519  -.772
   .355   .255  -.121   .528  -.021  -.122   .252 -1.613  -.833   .483  -.554
   .402  -.348  -.127   .652  -.028  -.086   .315 -2.048  -.376   .340  -.264
   .453  -.342   .145   .776  -.087  -.131   .320 -2.448   .045   .447  -.174
   .504  -.493   .229   .827  -.133  -.061   .392 -2.622  -.060   .769  -.391
   .555  -.332   .232   .891  -.092  -.091   .411 -2.587  -.534  1.342  -.862
   .605   .205   .217   .784  -.107  -.055   .443 -2.500 -1.062  1.682 -1.134
   .652   .261   .004   .685  -.082  -.096   .461 -2.431 -1.237  1.915 -1.062
   .703   .301  -.055   .639  -.025  -.101   .483 -2.396  -.886  1.825  -.627
   .754   .091   .014   .558  -.045  -.119   .513 -2.570  -.341  1.664  -.246
   .805  -.265   .111   .556  -.071  -.057   .532 -2.796   .116  1.521  -.101
   .855  -.234   .264   .492  -.071  -.109   .546 -2.883   .116  1.610  -.210
   .902  -.033   .329   .436  -.065  -.073   .526 -2.831  -.288  1.915  -.464
   .953   .205   .201   .388  -.009  -.094   .584 -2.605  -.640  2.237  -.627
  1.004   .431   .086   .259   .005  -.073   .566 -2.361  -.693  2.291  -.609
  1.055   .357  -.018   .195   .100  -.034   .583 -2.274  -.482  2.165  -.282
  1.105   .103  -.030   .056   .190  -.057   .578 -2.326   .045  1.789   .134
  1.152  -.049   .098   .076   .280  -.059   .615 -2.431   .625  1.575   .551
  1.203  -.101   .223  0.000   .299  -.006   .610 -2.500  1.012  1.539   .841
  1.254   .044   .261  -.036   .446  -.048   .587 -2.413  1.258  1.736  1.203
  1.305   .326   .242  -.102   .570  -.037   .603 -2.135  1.662  1.915  1.801
  1.355   .404   .104  -.104   .711  -.041   .582 -1.839  2.400  2.022  2.852
  1.402   .292   .001  -.152   .803  -.042   .599 -1.717  3.490  1.951  4.030
  1.453   .035   .017  -.162   .872  -.078   .571 -1.752  4.614  1.700  5.078
  1.504  -.261   .095  -.127  1.030  -.030   .533 -1.856  5.580  1.557  5.705
  1.555  -.369   .223  -.096  1.074  -.070   .515 -1.909  6.223  1.575  6.026
  1.605  -.311   .279  -.081  1.129   .026   .562 -1.874  6.476  1.772  6.251
  1.652  -.224   .220  -.162  1.250   .027   .561 -1.717  6.691  1.968  6.653
  1.703  -.200   .136  -.137  1.323  -.021   .523 -1.491  7.139  2.094  7.184
  1.754  -.360   .042  -.132  1.407  -.062   .493 -1.369  7.919  2.004  7.875
  1.805  -.690   .004  -.183  1.447  -.024   .563 -1.369  8.719  1.843  8.437
  1.855  -.959   .098  -.183  1.498  -.019   .514 -1.456  9.304  1.718  8.743
  1.902 -1.091   .217  -.239  1.537  -.002   .507 -1.526  9.479  1.682  8.823
  1.953 -1.104   .295  -.381  1.608   .016   .469 -1.439  9.382  1.754  8.823
  2.004 -1.036   .282  -.454  1.648   .043   .465 -1.126  9.323  1.843  8.855
```

Figure 4 (continued)
Sample Problem Input Data

2.055	-1.070	.179	-.548	1.650	.047	.458	-.778	9.362	1.807	9.048
2.105	-1.295	.057	-.597	1.704	.005	.366	-.517	9.655	1.664	9.305
2.152	-1.573	.048	-.597	1.709	.022	.398	-.395	10.084	1.467	9.514
2.203	-1.832	.104	-.650	1.681	.059	.389	-.377	10.283	1.235	9.546
2.254	-1.977	.257	-.645	1.686	.059	.331	-.325	10.124	1.145	9.353
2.305	-1.968	.348	-.617	1.725	.083	.290	-.186	9.733	1.163	9.048
2.355	-1.968	.304	-.591	1.721	.082	.264	.110	9.343	1.360	8.823
2.402	-2.029	.198	-.680	1.760	.070	.222	.440	9.109	1.449	8.694
2.453	-2.190	.073	-.698	1.756	.050	.170	.667	9.070	1.360	8.614
2.504	-2.443	.029	-.645	1.719	.059	.193	.736	9.031	1.091	8.469
2.555	-2.653	.104	-.467	1.667	.105	.184	.667	8.836	.948	8.116
2.605	-2.752	.195	-.373	1.597	.149	.189	.562	8.368	.930	7.585
2.652	-2.752	.242	-.228	1.600	.127	.170	.527	7.705	1.109	7.055
2.703	-2.724	.198	-.051	1.592	.076	.147	.527	7.061	1.414	6.653
2.754	-2.755	.070	.091	1.611	.062	.141	.545	6.613	1.664	6.348
2.805	-2.893	-.033	.142	1.528	.120	.197	.493	6.340	1.825	6.123
2.855	-3.079	-.036	.117	1.443	.111	.202	.249	6.087	1.736	5.785
2.902	-3.205	.023	.119	1.440	.120	.238	-.012	5.677	1.539	5.239
2.953	-3.251	.129	.112	1.354	.115	.177	-.151	5.036	1.557	4.609
3.004	-3.214	.157	.048	1.340	.118	.188	-.134	4.386	1.628	3.939
3.055	-3.137	.095	-.013	1.260	.135	.208	-.029	3.771	1.843	3.432
3.105	-3.137	-.005	-.058	1.226	.143	.209	.110	3.279	1.843	3.088
3.152	-3.208	-.083	-.084	1.177	.117	.213	.162	2.963	1.700	2.743
3.203	-3.304	-.090	-.043	1.111	.143	.218	.127	2.646	1.539	2.345
3.254	-3.372	-.033	-.051	1.043	.125	.188	.040	2.225	1.414	1.783
3.305	-3.350	.020	-.063	.967	.115	.217	-.064	1.662	1.414	1.203
3.355	-3.254	.036	-.109	.956	.125	.182	-.099	.994	1.431	.642
3.402	-3.159	-.011	-.165	.889	.120	.176	-.064	.485	1.431	.315
3.453	-3.094	-.108	-.203	.862	.120	.171	.040	.151	1.342	.062
3.504	-3.103	-.168	-.226	.815	.087	.171	.075	-.042	1.127	-.156
3.555	-3.143	-.158	-.251	.815	.053	.103	.040	-.218	.948	-.373
3.605	-3.153	-.105	-.284	.722	.099	.123	.005	-.499	.715	-.591
3.652	-3.097	-.049	-.305	.701	.033	.095	-.012	-.798	.662	-1.007
3.703	-2.983	-.040	-.272	.669	.040	.094	-.012	-1.202	.644	-1.315
3.754	-2.856	-.105	-.198	.639	.037	.092	.005	-1.554	.662	-1.551
3.805	-2.798	-.183	-.129	.566	.081	.126	.023	-1.729	.644	-1.659
3.855	-2.770	-.221	-.086	.555	.049	.124	-.047	-1.817	.536	-1.696
3.902	-2.761	-.186	-.043	.551	.019	.080	-.238	-1.888	.357	-1.786
3.953	-2.736	-.133	.056	.522	.023	.093	-.464	-1.940	.286	-1.877
4.004	-2.628	-.099	.145	.472	.059	.182	-.586	-2.081	.322	-2.022
4.055	-2.502	-.099	.211	.456	.055	.173	-.691	-2.221	.465	-2.185
4.105	-2.394	-.152	.297	.470	-.020	.185	-.795	-2.345	.554	-2.149
4.152	-2.335	-.205	.335	.486	-.032	.187	-.934	-2.327	.680	-2.185
4.203	-2.295	-.221	.371	.440	.009	.220	-1.143	-2.204	.572	-2.185
4.254	-2.267	-.186	.388	.470	.002	.222	-1.404	-2.063	.554	-2.040
4.305	-2.215	-.124	.454	.444	-.023	.304	-1.595	-2.011	.554	-1.967
4.355	-2.097	-.068	.520	.442	-.029	.277	-1.752	-1.975	.662	-1.931
4.402	-1.992	-.071	.553	.443	-.001	.348	-1.891	-1.905	.841	-1.804
4.453	-1.903	-.127	.596	.475	-.041	.355	-1.978	-1.747	1.020	-1.678
4.504	-1.844	-.174	.609	.492	-.061	.372	-2.100	-1.431	1.038	-1.424
4.555	-1.832	-.193	.650	.510	-.060	.401	-2.309	-1.114	1.073	-1.170
4.605	-1.798	-.127	.652	.491	-.018	.473	-2.587	-.868	1.056	-.935
4.652	-1.752	-.033	.627	.502	-.047	.492	-2.813	-.657	1.091	-.699
4.703	-1.678	.017	.609	.552	-.076	.517	-2.900	-.499	1.288	-.536
4.754	-1.607	.004	.543	.622	-.079	.511	-2.900	-.341	1.485	-.319
4.805	-1.554	-.049	.447	.615	-.082	.554	-2.900	-.042	1.539	-.065
4.855	-1.530	-.086	.371	.694	-.083	.579	-2.900	.274	1.575	.243
4.902	-1.520	-.071	.325	.691	-.077	.583	-2.900	.643	1.431	.587
4.953	-1.520	-.021	.340	.685	-.086	.577	-2.918	.977	1.414	.841
5.004	-1.499	.054	.330	.702	-.041	.619	-2.970	1.223	1.414	1.131
5.055	-1.462	.120	.241	.755	-.032	.621	-3.005	1.469	1.521	1.348
5.105	-1.425	.095	.137	.761	-.079	.618	-2.953	1.750	1.557	1.656
5.152	-1.406	.048	-.028	.854	-.085	.594	-2.796	2.066	1.610	1.964
5.203	-1.400	.010	-.076	.833	-.058	.613	-2.622	2.383	1.521	2.308
5.254	-1.406	.007	-.066	.864	-.079	.597	-2.535	2.699	1.431	2.616
5.305	-1.419	.061	-.091	.956	-.093	.591	-2.518	3.033	1.396	2.852
5.355	-1.437	.129	-.033	.852	-.093	.591	-2.552	3.279	1.306	3.142
5.402	-1.428	.157	-.028	.860	-.093	.590	-2.518	3.490	1.396	3.396
5.453	-1.422	.161	-.005	.880	-.086	.588	-2.448	3.806	1.610	3.468
5.504	-1.437	.101	.053	.902	-.080	.584	-2.378	3.982	1.557	3.993

Figure 4 (continued)
Sample Problem Input Data

5.555	-1.449	.082	.018	1.091	-.077	.582	-2.170	4.052	1.664	4.102
5.605	-1.493	.126	.020	1.106	-.053	.591	-2.204	4.386	1.718	4.374
5.652	-1.545	.176	.038	1.138	-.074	.622	-2.274	4.632	1.754	4.628
5.703	-1.560	.217	.008	1.172	-.063	.609	-2.239	4.720	1.843	4.736
5.754	-1.576	.211	-.023	1.225	-.062	.564	-2.152	4.843	1.933	4.899
5.805	-1.585	.161	.010	1.227	-.048	.615	-2.030	4.984	2.076	5.044
5.855	-1.585	.114	-.008	1.253	-.034	.617	-1.943	5.170	2.147	5.207
5.902	-1.659	.123	.013	1.279	-.037	.611	-1.943	5.326	2.130	5.351
5.953	-1.727	.173	.051	1.285	-.010	.611	-1.943	5.443	2.130	5.464
6.004	-1.761	.251	.043	1.268	.018	.579	-1.926	5.560	2.183	5.560
6.055	-1.795	.276	.010	1.252	-.015	.591	-1.874	5.619	2.326	5.625
6.105	-1.789	.239	-.003	1.225	-.004	.584	-1.752	5.658	2.452	5.657
6.152	-1.773	.179	-.091	1.163	.053	.608	-1.595	5.677	2.488	5.625
6.203	-1.832	.142	-.157	1.104	.061	.649	-1.508	5.560	2.470	5.480
6.254	-1.903	.148	-.157	1.040	.062	.634	-1.474	5.346	2.416	5.239
6.305	-1.968	.192	-.180	.994	.056	.592	-1.421	5.019	2.416	4.845
6.355	-1.980	.254	-.190	0.959	.090	.459	-1.352	4.632	2.344	4.356
6.402	-1.968	.311	-.058	.931	.072	.538	-1.213	4.122	2.380	3.848
6.453	-1.915	.257	-.096	.886	.096	.557	-1.056	3.683	2.452	3.414
6.504	-1.847	.239	-.312	.748	.298	-.113	-.830	3.349	2.559	3.178
6.555	-1.854	.179	-.241	.807	.098	.536	-.743	2.910	2.720	2.635
6.605	-1.884	.129	-.254	.744	.074	.519	-.569	2.629	2.434	2.526
6.652	-1.900	.148	-.234	.697	.093	.470	-.499	2.418	2.505	2.163
6.703	-1.884	.198	-.168	.693	.096	.497	-.586	2.066	2.434	1.801
6.754	-1.823	.242	-.137	.630	.125	.507	-.604	1.680	2.541	1.457
6.805	-1.749	.223	-.102	.566	.124	.519	-.517	1.311	2.684	1.149
6.855	-1.693	.157	-.081	.531	.128	.495	-.412	.994	2.792	.950
6.902	-1.638	.079	-.084	.524	.158	.552	-.360	.836	2.846	.732
6.953	-1.622	.070	-.109	.499	.141	.507	-.377	.696	2.828	.623
7.004	-1.567	.101	-.119	.443	.171	.493	-.395	.538	2.756	.460
7.055	-1.483	.164	-.140	.423	.165	.483	-.377	.362	2.667	.315
7.105	-1.415	.198	-.203	.412	.175	.473	-.343	.204	2.684	.225
7.152	-1.344	.154	-.267	.411	.179	.434	-.256	.116	2.720	.207
7.203	-1.289	.061	-.294	.377	.173	.448	-.064	.098	2.720	.134
7.254	-1.261	-.002	-.330	.399	.156	.394	.040	.098	2.559	.134
7.305	-1.199	-.008	-.284	.393	.132	.383	.023	.081	2.416	.134
7.355	-1.113	.032	-.211	.350	.160	.390	.023	.063	2.326	.134
7.402	-1.054	.070	-.170	.326	.216	.433	.005	.081	2.326	.116
7.453	-.983	.067	-.190	.358	.192	.362	-.064	.098	2.291	.134
7.504	-.922	.032	-.162	.381	.145	.389	-.047	.133	2.344	.170
7.555	-.872	-.021	-.099	.404	.132	.349	-.012	.256	2.326	.225
7.605	-.817	-.046	-.066	.378	.162	.377	-.029	.379	2.326	.334
7.652	-.761	-.030	-.069	.363	.137	.383	-.134	.520	2.255	.497
7.703	-.709	-.011	-.020	.421	.149	.385	-.203	.696	2.273	.642
7.754	-.647	.010	.015	.429	.135	.359	-.238	.871	2.255	.859
7.805	-.592	.007	.051	.438	.149	.377	-.308	1.047	2.291	1.058
7.855	-.564	-.005	.074	.463	.157	.407	-.325	1.293	2.291	1.258
7.902	-.521	-.011	.122	.492	.098	.372	-.325	1.557	2.326	1.493
7.953	-.496	-.036	.150	.498	.144	.393	-.430	1.785	2.398	1.729
8.004	-.471	-.024	.178	.472	.167	.457	-.534	2.049	2.380	1.946
8.055	-.443	.004	.200	.524	.149	.478	-.621	2.277	2.416	2.200
8.105	-.403	.032	.244	.562	.158	.401	-.708	2.471	2.416	2.417
8.152	-.379	.029	.294	.607	.111	.404	-.743	2.699	2.595	2.671
8.203	-.335	.014	.221	.619	.157	.491	-.795	2.980	2.702	2.870
8.254	-.311	-.005	.175	.612	.145	.499	-.812	3.244	2.738	3.196
8.305	-.329	-.011	.170	.653	.144	.501	-.830	3.525	2.720	3.468
8.355	-.351	.023	.188	.659	.142	.479	-.830	3.806	2.684	3.704
8.402	-.382	.067	.195	.680	.130	.521	-.917	3.999	2.738	3.975
8.453	-.373	.104	.170	.740	.115	.498	-.969	4.158	2.792	4.120
8.504	-.317	.079	.117	.771	.136	.532	-.969	4.281	2.899	4.301
8.555	-.311	.048	.058	.827	.142	.538	-.899	4.474	2.953	4.573
8.605	-.345	.061	.170	.804	.140	.584	-.830	4.720	2.953	4.791
8.652	-.354	.073	.183	.828	.159	.545	-.812	4.966	2.971	4.990
8.703	-.391	.092	.099	.863	.150	.559	-.812	5.190	3.042	5.223
8.754	-.406	.098	.104	.906	.141	.553	-.830	5.326	3.096	5.319
8.805	-.428	.073	.071	.929	.133	.554	-.847	5.443	3.132	5.448
8.855	-.453	.045	.048	.936	.139	.524	-.812	5.560	3.096	5.641
8.902	-.493	.029	.094	.952	.133	.584	-.760	5.716	3.150	5.705
8.953	-.530	.073	.102	.974	.150	.554	-.760	5.833	3.114	5.834
9.004	-.564	.101	.063	.961	.174	.598	-.760	5.950	3.168	5.914

Figure 4 (continued)
Sample Problem Input Data

9.055	-.598	.061	.033	1.010	.166	.615	-.778	6.028	3.150	5.978
9.105	-.626	.042	-.030	1.012	.148	.540	-.760	6.126	3.257	6.043
9.152	-.638	.039	-.046	.998	.160	.559	-.760	6.126	3.168	6.075
9.203	-.650	.029	-.091	.983	.203	.591	-.760	6.164	3.150	6.139
9.254	-.666	.029	-.190	.999	.173	.555	-.743	6.203	3.025	6.187
9.305	-.697	.020	-.228	1.069	.152	.516	-.673	6.242	2.953	6.219
9.355	-.737	.026	-.208	1.082	.130	.496	-.604	6.281	2.810	6.235
9.402	-.792	.045	-.180	1.063	.181	.509	-.551	6.359	2.756	6.284
9.453	-.842	.042	-.160	1.068	.172	.541	-.534	6.398	2.720	6.300
9.504	-.860	.070	-.094	1.056	.164	.529	-.534	6.398	2.774	6.300
9.555	-.872	.061	-.099	1.055	.175	.480	-.517	6.379	2.810	6.300
9.605	-.872	.051	-.066	1.079	.192	.534	-.499	6.340	2.863	6.284
9.652	-.912	.051	.010	1.077	.182	.505	-.464	6.301	2.881	6.268
9.703	-.971	.064	.036	1.068	.157	.519	-.464	6.301	2.935	6.219
9.754	-1.036	.095	.091	1.051	.160	.517	-.499	6.281	3.025	6.219
9.805	-1.070	.107	.066	1.034	.204	.542	-.482	6.242	3.114	6.155
9.855	-1.048	.095	.091	1.000	.203	.575	-.517	6.126	3.239	5.994
9.902	-1.039	.092	.127	1.046	.189	.575	-.499	5.970	3.311	5.914
9.953	-1.073	.082	.190	1.041	.186	.538	-.499	5.814	3.365	5.818
10.004	-1.141	.089	.216	.963	.236	.649	-.517	5.736	3.418	5.769
10.055	-1.199	.117	.223	.971	.232	.613	-.517	5.716	3.490	5.705
10.105	-1.218	.145	.241	.972	.239	.627	-.551	5.580	3.579	5.496
10.152	-1.196	.145	.193	.970	.213	.642	-.551	5.404	3.705	5.319
10.203	-1.184	.120	.173	.946	.221	.632	-.551	5.190	3.830	5.207
10.254	-1.172	.086	.190	.967	.195	.597	-.569	5.001	3.884	5.078
10.305	-1.190	.114	.188	.954	.205	.654	-.569	4.913	3.902	4.990
10.355	-1.218	.167	.216	.928	.226	.620	-.569	4.825	3.955	4.917
10.402	-1.233	.211	.211	.877	.234	.668	-.534	4.737	4.045	4.827
10.453	-1.240	.204	.150	.883	.256	.689	-.517	4.667	4.242	4.664
10.504	-1.209	.145	.135	.873	.261	.702	-.464	4.544	4.385	4.519
10.555	-1.156	.095	.104	.895	.231	.634	-.343	4.351	4.421	4.392
10.605	-1.156	.104	.063	.874	.262	.704	-.308	4.245	4.439	4.301
10.652	-1.162	.157	.122	.859	.251	.703	-.325	4.228	4.421	4.301
10.703	-1.159	.170	.104	.841	.257	.701	-.325	4.158	4.439	4.247
10.754	-1.138	.139	.051	.843	.274	.700	-.308	4.105	4.492	4.138
10.805	-1.101	.089	.094	.861	.269	.686	-.238	4.052	4.510	4.084
10.855	-1.064	.045	.094	.850	.263	.652	-.238	3.999	4.618	4.048
10.902	-1.020	.032	.074	.822	.265	.685	-.256	3.982	4.582	3.993
10.953	-.996	.042	.089	.814	.261	.709	-.256	3.964	4.564	4.012
11.004	-.999	.045	.107	.799	.314	.773	-.273	3.964	4.510	4.030
11.055	-1.005	.032	.112	.778	.301	.762	-.325	3.964	4.582	4.012
11.105	-.987	.001	.109	.821	.255	.751	-.377	3.964	4.510	4.012
11.152	-.897	-.052	.061	.812	.243	.711	-.430	3.982	4.492	4.030
11.203	-.832	-.077	.051	.801	.265	.761	-.499	3.982	4.439	4.030
11.254	-.823	-.102	.010	.864	.258	.762	-.569	3.999	4.278	4.012
11.305	-.838	-.065	0.000	.806	.266	.754	-.656	4.087	4.188	4.102
11.355	-.888	-.018	.013	.809	.258	.694	-.743	4.210	4.116	4.247
11.402	-.916	.004	.003	.822	.245	.763	-.795	4.298	4.081	4.265
11.453	-.872	.010	.043	.815	.229	.737	-.778	4.316	4.099	4.283
11.504	-.823	-.011	.081	.873	.231	.725	-.760	4.298	4.152	4.283
11.555	-.764	-.052	.099	.831	.236	.762	-.760	4.298	4.152	4.283
11.605	-.724	-.052	.089	.830	.213	.780	-.795	4.333	4.188	4.392
11.652	-.774	-.049	.096	.865	.207	.785	-.882	4.421	4.206	4.537
11.703	-.789	-.011	.102	.881	.183	.741	-.952	4.597	4.152	4.646
11.754	-.771	.023	.094	.889	.202	.717	-1.021	4.702	4.188	4.718
11.805	-.764	.023	.094	.885	.234	.816	-1.039	4.702	4.206	4.791
11.855	-.746	-.005	.061	.879	.232	.774	-1.021	4.702	4.278	4.845
11.902	-.730	-.040	.036	.890	.213	.815	-1.039	4.755	4.260	4.936
11.953	-.752	-.052	-.025	.908	.217	.787	-1.039	4.878	4.242	4.972
12.004	-.798	-.058	-.094	.908	.201	.793	-1.004	5.001	4.116	5.044
12.055	-.848	-.036	-.122	.914	.185	.769	-1.039	5.054	3.955	5.142
12.105	-.897	-.011	-.188	.899	.215	.778	-1.021	5.092	3.848	5.126
12.152	-.916	-.036	-.231	.919	.202	.740	-1.021	5.054	3.830	5.159
12.203	-.882	-.086	-.307	.878	.200	.750	-1.004	5.036	3.687	5.142
12.254	-.872	-.136	-.312	.899	.171	.735	-.952	5.036	3.418	5.126
12.305	-.900	-.121	-.287	.919	.160	.715	-.917	5.019	3.329	5.142
12.355	-.943	-.086	-.289	.932	.168	.669	-.899	5.001	3.186	5.126
12.402	-.977	-.046	-.246	.871	.179	.690	-.952	4.984	3.114	5.126
12.453	-.990	-.043	-.195	.882	.178	.670	-.969	4.948	3.114	5.094
12.504	-.962	-.046	-.157	.854	.171	.710	-.969	4.896	3.132	5.026

Figure 4 (concluded)
Sample Problem Input Data

12.555	-.965	-.071	-.127	.879	.147	.675	-.969	4.843	3.132	4.972
12.605	-.977	-.099	-.124	.918	.150	.688	-.969	4.773	3.114	4.936
12.652	-.977	-.074	-.112	.903	.120	.648	-1.021	4.737	3.078	4.917
12.703	-1.008	-.049	-.091	.920	.119	.651	-1.126	4.755	2.971	4.863
12.754	-1.033	-.018	-.074	.884	.144	.643	-1.143	4.737	2.935	4.845
12.805	-1.008	.007	-.041	.860	.141	.684	-1.160	4.702	3.007	4.827
12.855	-1.027	.007	-.015	.860	.127	.686	-1.178	4.685	3.060	4.827
12.902	-1.008	.020	.010	.883	.113	.633	-1.178	4.614	3.114	4.754
12.953	-.968	.026	.061	.871	.131	.657	-1.178	4.597	3.132	4.736
13.004	-1.020	.057	.091	.842	.150	.722	-1.178	4.562	3.275	4.754
13.055	-1.027	.114	.091	.852	.173	.703	-1.160	4.597	3.347	4.718
13.105	-1.014	.123	.089	.882	.155	.705	-1.178	4.597	3.454	4.664
13.152	-1.005	.101	.096	.859	.148	.681	-1.143	4.544	3.544	4.646
13.203	-.946	.095	.089	.832	.180	.728	-1.126	4.474	3.579	4.591
13.254	-.919	.079	.084	.832	.168	.728	-1.108	4.404	3.687	4.591
13.305	-.968	.111	.084	.834	.159	.735	-1.073	4.404	3.705	4.573
13.355	-.968	.195	.114	.850	.174	.723	-1.091	4.421	3.741	4.591
13.402	-.946	.229	.074	.827	.197	.740	-1.091	4.456	3.902	4.609
13.453	-.946	.220	.079	.839	.185	.709	-.952	4.491	4.045	4.573
13.504	-.900	.201	.114	.881	.147	.690	-.812	4.421	4.188	4.591
13.555	-.857	.182	.086	.864	.181	.733	-.743	4.404	4.331	4.591
13.605	-.842	.226	.043	.864	.195	.707	-.725	4.421	4.349	4.609
13.652	-.829	.276	.010	.895	.215	.701	-.638	4.491	4.421	4.609
13.703	-.817	.329	-.023	.847	.259	.739	-.517	4.579	4.528	4.609
13.754	-.832	.339	-.030	.842	.281	.761	-.308	4.650	4.636	4.664
13.805	-.808	.332	-.003	.846	.281	.774	-.099	4.667	4.797	4.718
13.855	-.801	.326	.023	.871	.296	.751	.058	4.685	4.976	4.809
13.902	-.789	.317	.033	.896	.286	.732	.145	4.720	5.155	4.827
13.953	-.783	.339	.048	.939	.314	.745	.214	4.755	5.290	4.899
14.004	-.783	.354	.028	.875	.358	.811	.284	4.861	5.424	4.954
14.055	-.786	.361	.051	.884	.369	.790	.440	4.948	5.525	5.008
14.105	-.798	.364	.028	.891	.382	.767	.545	5.019	5.693	5.094
14.152	-.795	.345	.003	.927	.366	.732	.667	5.092	5.760	5.159
14.203	-.792	.323	-.003	.919	.392	.809	.788	5.112	5.861	5.207
14.254	-.795	.317	.020	.943	.381	.726	.893	5.131	5.995	5.255
14.305	-.805	.342	.018	.948	.412	.760	.980	5.190	6.063	5.287
14.355	-.838	.357	.036	.962	.426	.765	1.032	5.229	6.197	5.319
14.402	-.845	.376	.038	.935	.466	.801	1.102	5.346	6.348	5.351
14.453	-.854	.373	.041	.952	.465	.757	1.223	5.365	6.466	5.351
14.504	-.882	.357	.038	.954	.480	.774	1.363	5.365	6.600	5.351
14.555	-.894	.342	.018	.939	.516	.801	1.484	5.365	6.802	5.368
14.605	-.912	.317	.008	.914	.538	.828	1.606	5.326	6.869	5.400
14.652	-.946	.311	.013	.920	.554	.818	1.693	5.346	6.936	5.384
14.703	-.956	.301	-.015	.940	.552	.816	1.745	5.365	6.986	5.384
14.754	-.968	.292	-.020	.932	.538	.789	1.815	5.346	7.020	5.368
14.805	-.974	.273	0.000	.902	.566	.826	1.902	5.287	7.104	5.319
14.855	-.971	.254	-.041	.886	.602	.823	1.972	5.248	7.171	5.319
14.902	-.993	.217	-.056	.892	.592	.813	2.006	5.209	7.171	5.319
14.953	-.999	.189	-.051	.882	.590	.810	2.041	5.151	7.205	5.351
15.004	-1.005	.167	-.051	.921	.583	.788	2.076	5.112	7.205	5.271

*EOR

Figure 5
Sample Problem Printed Output Data
Individual Control Surfaces

PAGE NO. 1

SAMPLE PROBLEM SCOUT S-192C FIRST STAGE FIN RESPONSE ANALYSIS FIRST 15 SEC

	* FIN ONE			* FIN TWO			* FIN THREE			FIN FOUR		
TIME	COMMAND	ACTUAL	DELTA	COMMAND	ACTUAL	DELTA	COMMAND	ACTUAL	DELTA	COMMAND	ACTUAL	DELTA
-.45	-.52	-.81	.29	-.07	.03	-.09	-.26	-.40	.15	-.07	.03	-.09
-.20	-.82	-1.07	.24	.14	.05	.09	-.40	-.57	.16	.14	.04	.10
.06	-1.13	-1.25	.12	.03	.03	-.00	-.56	-.43	-.14	.03	.19	-.16
.31	-1.69	-1.61	-.08	-.76	-.76	-.01	.30	.48	-.18	-.76	-.61	-.16
.56	-2.38	-2.52	.14	-1.22	-.90	-.33	1.59	1.67	-.08	-1.22	-1.03	-.19
.81	-2.63	-2.85	.22	-.31	.08	-.39	1.65	1.63	.02	-.31	-.19	-.11
1.06	-2.17	-2.32	.14	.37	-.08	.45	1.78	1.84	-.05	.37	.03	.34
1.31	-1.52	-1.93	.41	2.49	2.25	.24	1.93	2.00	-.06	2.49	2.60	-.11
1.56	-1.55	-1.87	.32	5.94	6.42	-.48	1.46	1.76	-.30	5.94	6.22	-.28
1.81	-1.24	-1.43	.19	8.18	9.12	-.94	1.54	1.73	-.19	8.18	8.65	-.47
2.06	-.21	-.59	.38	8.59	9.60	-1.00	1.54	1.67	-.13	8.59	9.24	-.64
2.31	.53	.04	.49	7.57	9.45	-1.89	1.18	1.33	-.15	7.57	8.89	-1.32
2.56	.87	.60	.27	6.46	8.46	-2.01	.77	.95	-.18	6.46	7.72	-1.26
2.81	.43	.31	.12	4.37	6.13	-1.76	1.50	1.73	-.23	4.37	5.85	-1.47
3.06	.44	.07	.38	1.84	3.42	-1.58	1.67	1.83	-.16	1.84	3.17	-1.33
3.31	.30	-.08	.38	-.37	1.17	-1.55	1.38	1.43	-.05	-.37	.80	-1.17
3.56	.27	.02	.25	-1.80	-.43	-1.37	.69	.75	-.06	-1.80	-.56	-1.24
3.81	-.02	-.04	.02	-2.71	-1.80	-.91	.19	.53	-.34	-2.71	-1.69	-1.02
4.06	-.69	-.77	.09	-3.12	-2.30	-.82	.52	.56	-.03	-3.12	-2.17	-.95
4.31	-1.64	-1.71	.08	-2.62	-1.98	-.64	.69	.66	.03	-2.62	-1.93	-.69
4.56	-2.42	-2.51	.09	-1.61	-.93	-.68	1.16	1.07	.09	-1.61	-.99	-.62
4.81	-2.66	-2.90	.24	-.35	.20	-.55	1.56	1.55	.02	-.35	.17	-.52
5.06	-2.53	-2.96	.42	1.02	1.68	-.66	1.68	1.56	.12	1.02	1.58	-.56
5.31	-2.12	-2.54	.42	2.31	3.22	-.91	1.34	1.34	-.00	2.31	3.07	-.76
5.56	-2.04	-2.20	.16	2.76	4.29	-1.53	1.50	1.71	-.22	2.76	4.31	-1.55
5.81	-1.73	-1.97	.24	4.25	5.12	-.87	1.81	2.13	-.33	4.25	5.17	-.91
6.06	-1.36	-1.78	.42	4.61	5.65	-1.04	2.23	2.44	-.20	4.61	5.64	-1.03
6.31	-.86	-1.36	.50	3.22	4.71	-1.49	2.47	2.37	.10	3.22	4.48	-1.25
6.56	.92	-.62	1.54	1.42	2.70	-1.29	2.21	2.52	-.31	1.42	2.52	-1.11
6.81	-.03	-.44	.41	.19	1.09	-.90	2.65	2.78	-.13	.19	.99	-.81
7.06	.04	-.35	.39	-.53	.25	-.78	2.72	2.68	.04	-.53	.25	-.78
7.31	.41	.02	.38	-.46	.07	-.54	2.24	2.34	-.10	-.46	.13	-.60
7.56	.30	-.03	.34	.08	.35	-.27	2.25	2.32	-.07	.08	.31	-.23
7.81	-.13	-.32	.19	1.09	1.23	-.14	2.14	2.30	-.16	1.09	1.21	-.12
8.06	-.52	-.68	.16	2.15	2.43	-.28	2.46	2.44	.02	2.15	2.37	-.22
8.31	-.63	-.84	.21	3.36	3.73	-.37	2.68	2.70	-.02	3.36	3.65	-.29
8.56	-.59	-.85	.26	4.28	4.66	-.38	2.80	2.96	-.16	4.28	4.74	-.45
8.81	-.52	-.82	.30	5.12	5.54	-.41	2.99	3.11	-.13	5.12	5.58	-.45
9.06	-.54	-.77	.22	5.47	6.09	-.62	3.04	3.22	-.18	5.47	6.02	-.55
9.31	-.17	-.62	.46	5.48	6.28	-.80	2.75	2.83	-.08	5.48	6.24	-.76
9.56	-.12	-.50	.38	5.46	6.35	-.89	2.73	2.86	-.13	5.46	6.29	-.82
9.81	-.21	-.50	.29	5.07	6.15	-1.08	3.05	3.23	-.17	5.07	6.04	-.98
10.06	-.33	-.54	.21	4.39	5.61	-1.22	3.72	3.58	.14	4.39	5.55	-1.16
10.31	-.25	-.57	.31	3.84	4.85	-1.00	3.89	3.96	-.06	3.84	4.93	-1.09
10.56	-.04	-.32	.28	3.30	4.28	-.98	4.27	4.43	-.16	3.30	4.33	-1.03
10.81	.01	-.24	.25	3.18	4.02	-.83	4.34	4.59	-.25	3.18	4.05	-.87
11.06	-.25	-.36	.12	3.23	3.97	-.74	4.39	4.53	-.13	3.23	4.01	-.79
11.31	-.59	-.72	.13	3.62	4.18	-.56	3.95	4.12	-.18	3.62	4.20	-.58
11.56	-.66	-.79	.13	3.78	4.33	-.55	3.92	4.18	-.27	3.78	4.37	-.58
11.81	-.92	-1.03	.11	4.23	4.71	-.48	3.78	4.26	-.48	4.23	4.84	-.61
12.06	-.87	-1.03	.16	4.40	5.08	-.67	3.62	3.86	-.24	4.40	5.14	-.73

PAGE NO. 2

SAMPLE PROBLEM SCOUT S-192C FIRST STAGE FIN RESPONSE ANALYSIS FIRST 15 SEC

	* FIN ONE			* FIN TWO			* FIN THREE			FIN FOUR		
TIME	COMMAND	ACTUAL	DELTA	COMMAND	ACTUAL	DELTA	COMMAND	ACTUAL	DELTA	COMMAND	ACTUAL	DELTA
12.31	-.77	-.91	.14	4.16	5.01	-.84	2.96	3.20	-.24	4.16	5.13	-.97
12.56	-.84	-.97	.13	3.83	4.79	-.96	2.91	3.11	-.20	3.83	4.95	-1.11
12.81	-1.04	-1.17	.13	3.82	4.68	-.86	2.74	3.06	-.32	3.82	4.82	-.99
13.06	-1.06	-1.17	.11	3.59	4.59	-1.00	3.24	3.45	-.21	3.59	4.68	-1.09
13.31	-.83	-1.08	.25	3.56	4.42	-.85	3.68	3.76	-.08	3.56	4.59	-1.02
13.56	-.46	-.72	.26	3.72	4.42	-.70	3.98	4.36	-.39	3.72	4.60	-.88
13.81	.30	.01	.28	4.00	4.68	-.68	4.75	4.97	-.22	4.00	4.78	-.78
14.06	.80	.52	.28	4.34	5.00	-.66	5.53	5.67	-.14	4.34	5.07	-.73
14.31	1.31	1.02	.28	4.54	5.23	-.69	5.86	6.19	-.33	4.54	5.31	-.77
14.56	1.85	1.57	.28	4.55	5.34	-.79	6.56	6.87	-.31	4.55	5.39	-.84
14.81	2.22	1.95	.27	4.19	5.26	-1.07	7.00	7.16	-.16	4.19	5.32	-1.13

Figure 6
Sample Problem Printed Output Data
Pitch, Yaw and Roll Components

PAGE NO. 3 PITCH, YAW, ROLL COMMANDS BASED ON MEASURED FINS

SAMPLE PROBLEM SCOUT S-192C FIRST STAGE FIN RESPONSE ANALYSIS FIRST 15 SEC

*	P I T C H		*	Y A W		*	R O L L		*
TIME	COMMAND	ACTUAL	DELTA	COMMAND	ACTUAL	DELTA	COMMAND	ACTUAL	DELTA
-.45	-.07	.03	-.09	-.39	-.61	.22	.13	.20	-.07
-.20	.14	.04	.10	-.61	-.82	.20	.21	.25	-.04
.06	.03	.11	-.08	-.85	-.84	-.01	.28	.41	-.13
.31	-.76	-.68	-.08	-.70	-.56	-.13	.99	1.04	-.05
.56	-1.22	-.96	-.26	-.39	-.43	.03	1.99	2.09	-.11
.81	-.31	-.06	-.25	-.49	-.61	.12	2.14	2.24	-.10
1.06	.37	-.03	.39	-.20	-.24	.04	1.98	2.08	-.10
1.31	2.49	2.43	.06	.20	.03	.17	1.73	1.96	-.24
1.56	5.94	6.32	-.38	-.04	-.06	.01	1.50	1.81	-.31
1.81	8.18	3.89	-.71	.15	.15	.00	1.39	1.58	-.19
2.06	8.59	9.42	-.82	.66	.54	.13	.87	1.13	-.26
2.31	7.57	9.17	-1.60	.86	.68	.17	.33	.65	-.32
2.56	6.46	8.09	-1.63	.82	.77	.05	-.05	.18	-.23
2.81	4.37	5.99	-1.62	.96	1.02	-.06	.54	.71	-.18
3.06	1.84	3.29	-1.45	1.06	.95	.11	.61	.88	-.27
3.31	-.37	.99	-1.36	.84	.67	.17	.54	.76	-.22
3.56	-1.80	-.50	-1.30	.48	.38	.09	.21	.37	-.16
3.81	-2.71	-1.75	-.96	.08	.25	-.16	.11	.29	-.18
4.06	-3.12	-2.23	-.89	-.08	-.11	.03	.61	.67	-.06
4.31	-2.62	-1.95	-.67	-.47	-.52	.05	1.16	1.19	-.03
4.56	-1.61	-.96	-.65	-.63	-.72	.09	1.79	1.79	.00
4.81	-.35	.19	-.53	-.55	-.68	.13	2.11	2.22	-.11
5.06	1.02	1.63	-.61	-.43	-.70	.27	2.11	2.26	-.15
5.31	2.31	3.14	-.84	-.39	-.60	.21	1.73	1.94	-.21
5.56	2.76	4.30	-1.54	-.27	-.24	-.03	1.77	1.96	-.19
5.81	4.25	5.14	-.89	.04	.08	-.04	1.77	2.05	-.29
6.06	4.61	5.64	-1.04	.44	.33	.11	1.80	2.11	-.31
6.31	3.22	4.59	-1.37	.80	.50	.30	1.67	1.86	-.20
6.56	1.42	2.61	-1.20	1.56	.95	.62	.64	1.57	-.93
6.81	.19	1.04	-.85	1.31	1.17	.14	1.34	1.61	-.27
7.06	-.53	.25	-.78	1.38	1.17	.21	1.34	1.51	-.18
7.31	-.46	.10	-.57	1.32	1.18	.14	.92	1.16	-.24
7.56	.08	.33	-.25	1.27	1.14	.13	.97	1.17	-.20
7.81	1.09	1.22	-.13	1.00	.99	.01	1.14	1.31	-.17
8.06	2.15	2.40	-.25	.97	.88	.09	1.49	1.56	-.07
8.31	3.36	3.69	-.33	1.03	.93	.10	1.66	1.77	-.11
8.56	4.28	4.70	-.42	1.10	1.05	.05	1.70	1.91	-.21
8.81	5.12	5.56	-.43	1.23	1.15	.09	1.75	1.97	-.21
9.06	5.47	6.06	-.58	1.25	1.23	.02	1.79	1.99	-.20
9.31	5.48	6.26	-.78	1.29	1.10	.19	1.46	1.73	-.27
9.56	5.46	6.32	-.86	1.31	1.18	.13	1.42	1.68	-.26
9.81	5.07	6.10	-1.03	1.42	1.36	.06	1.63	1.86	-.23
10.06	4.39	5.58	-1.19	1.70	1.52	.18	2.02	2.06	-.04
10.31	3.84	4.89	-1.05	1.82	1.70	.13	2.07	2.26	-.19
10.56	3.30	4.31	-1.01	2.12	2.06	.06	2.16	2.38	-.22
10.81	3.18	4.03	-.85	2.18	2.17	.00	2.16	2.41	-.25
11.06	3.23	3.99	-.76	2.07	2.08	-.01	2.32	2.45	-.12
11.31	3.62	4.19	-.57	1.68	1.70	-.02	2.27	2.42	-.15
11.56	3.78	4.35	-.56	1.63	1.70	-.07	2.29	2.49	-.20
11.81	4.23	4.77	-.55	1.43	1.62	-.18	2.35	2.65	-.30
12.06	4.40	5.11	-.70	1.38	1.42	-.04	2.24	2.44	-.20

PAGE NO. 4 PITCH, YAW, ROLL COMMANDS BASED ON MEASURED FINS

SAMPLE PPOBLEM SCOUT S-192C FIRST STAGE FIN RESPONSE ANALYSIS FIRST 15 SEC

*	P I T C H		*	Y A W		*	R O L L		*
TIME	COMMAND	ACTUAL	DELTA	COMMAND	ACTUAL	DELTA	COMMAND	ACTUAL	DELTA
12.11	4.36	5.11	-.75	1.34	1.39	-.05	2.16	2.41	-.25
12.36	4.16	5.05	-.89	1.01	1.09	-.08	1.82	2.03	-.21
12.61	3.81	4.83	-1.02	.97	1.02	-.05	1.89	2.04	-.15
12.86	3.74	4.71	-.97	.90	.97	-.07	1.95	2.14	-.19
13.11	3.55	4.60	-1.04	1.22	1.19	.03	2.18	2.34	-.16
13.36	3.54	4.52	-.98	1.49	1.41	.08	2.27	2.48	-.21
13.61	3.84	4.54	-.71	1.79	1.89	-.10	2.20	2.54	-.34
13.86	4.00	4.77	-.77	2.68	2.64	.04	2.26	2.51	-.25
14.11	4.33	5.11	-.77	3.32	3.21	.12	2.36	2.56	-.20
14.36	4.59	5.32	-.73	3.68	3.72	-.04	2.29	2.62	-.34
14.61	4.48	5.37	-.89	4.32	4.30	.02	2.39	2.63	-.24
14.86	4.11	5.27	-1.16	4.64	4.59	.05	2.40	2.59	-.19

Figure 7
Sample Problem CALCOMP Plots

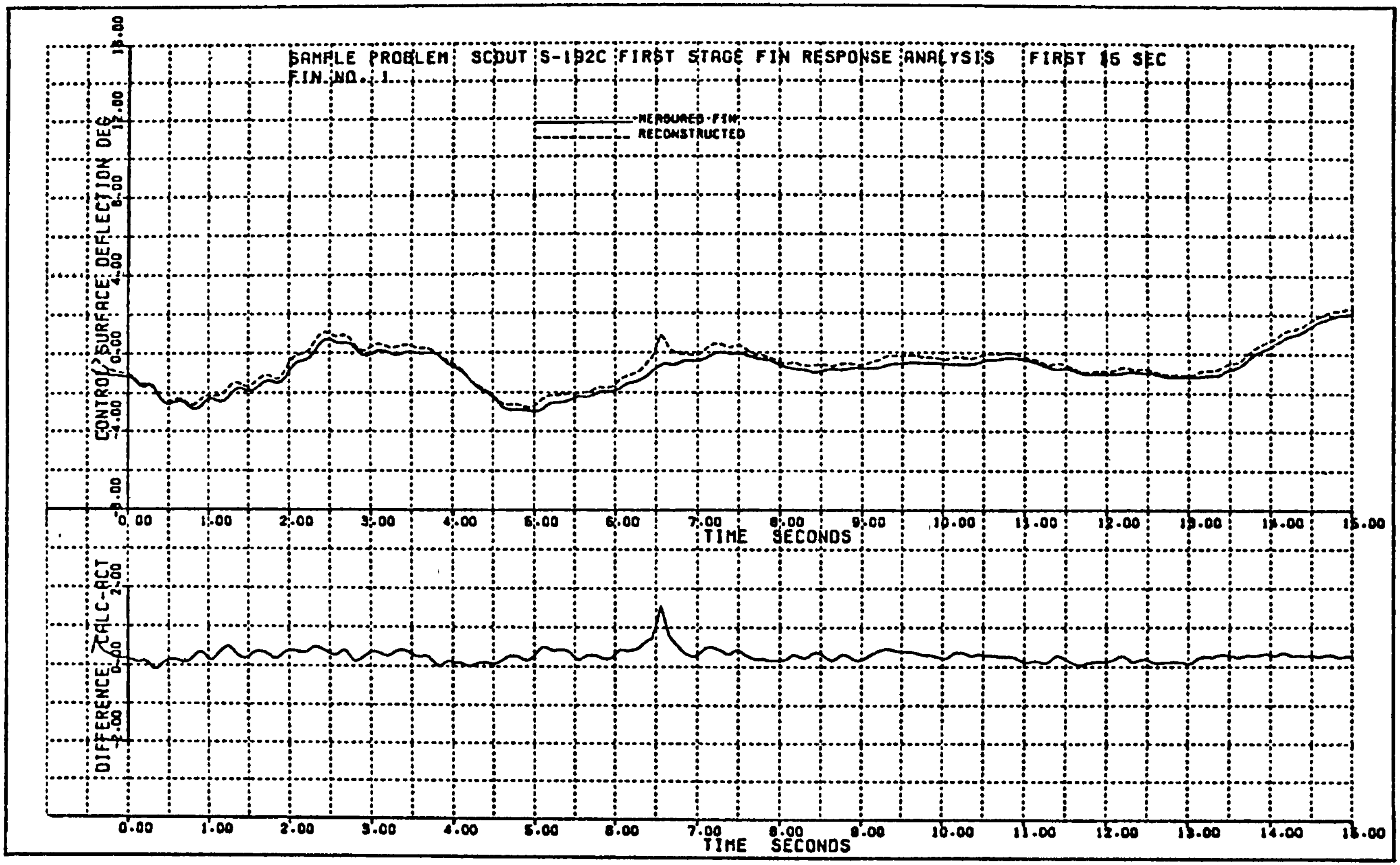


Figure 7 (continued)

Sample Problem CALCOMP Plots

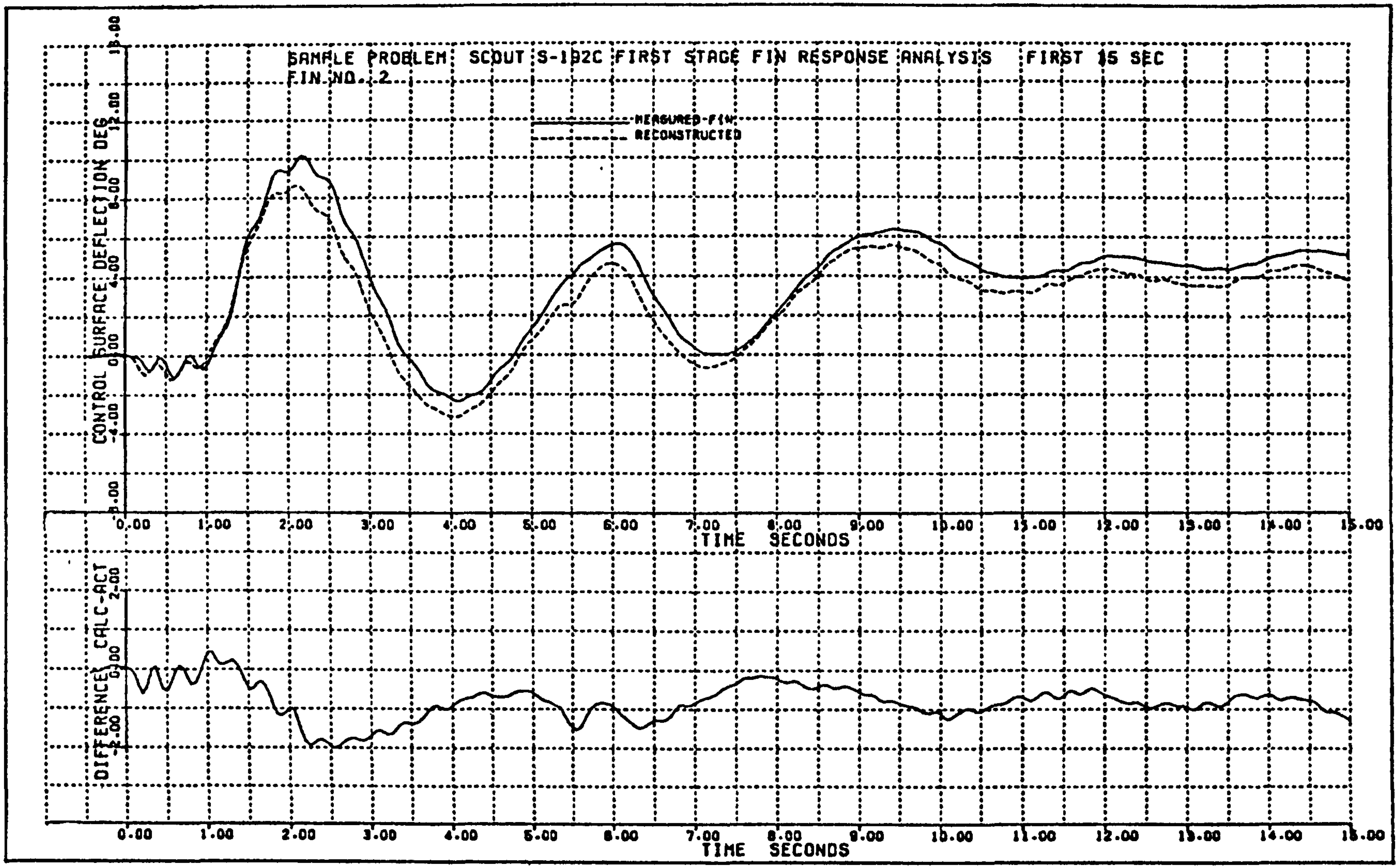


Figure 7 (continued)

Sample Problem CALCOMP Plots

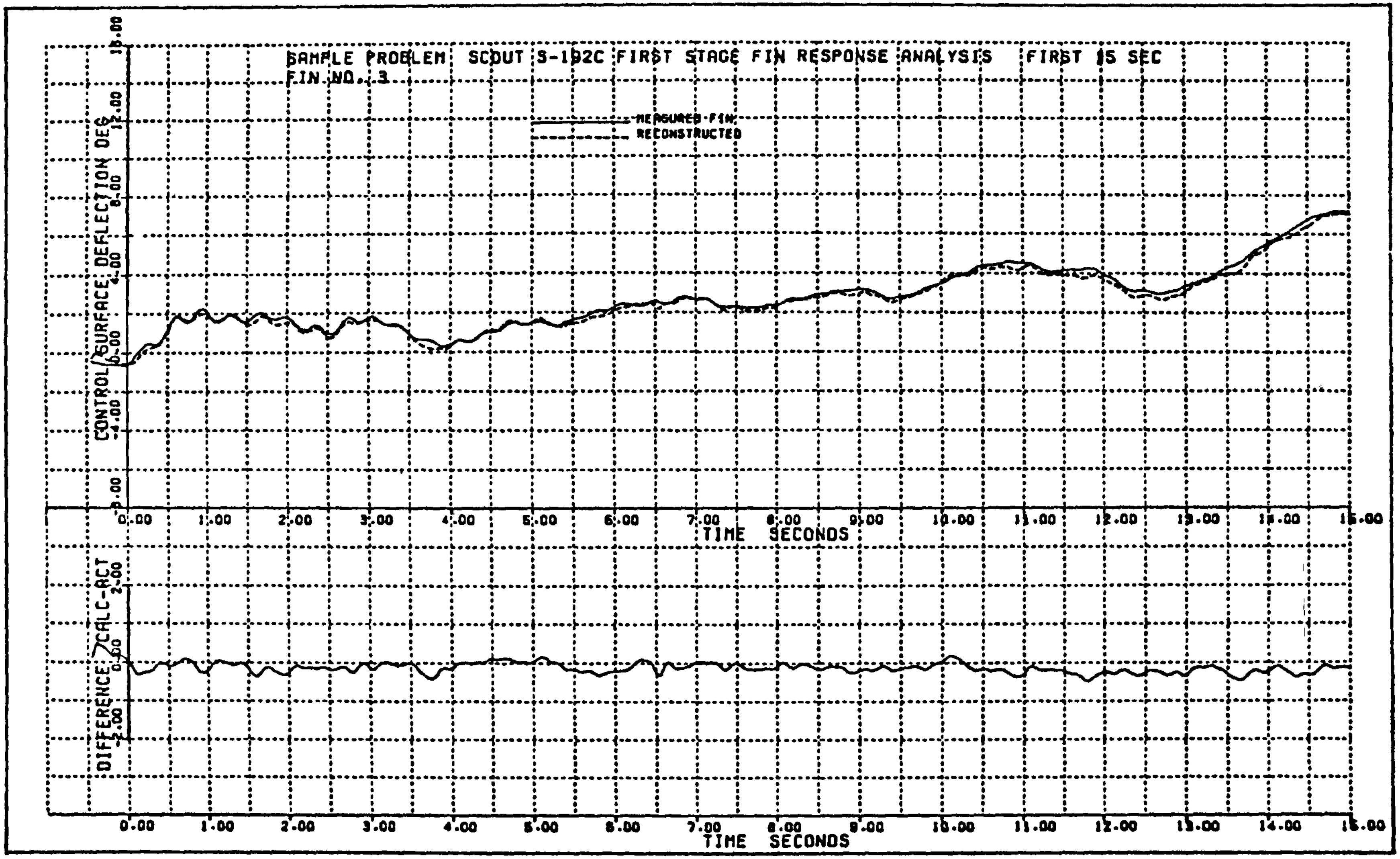


Figure 7 (continued)

Sample Problem CALCOMP Plots

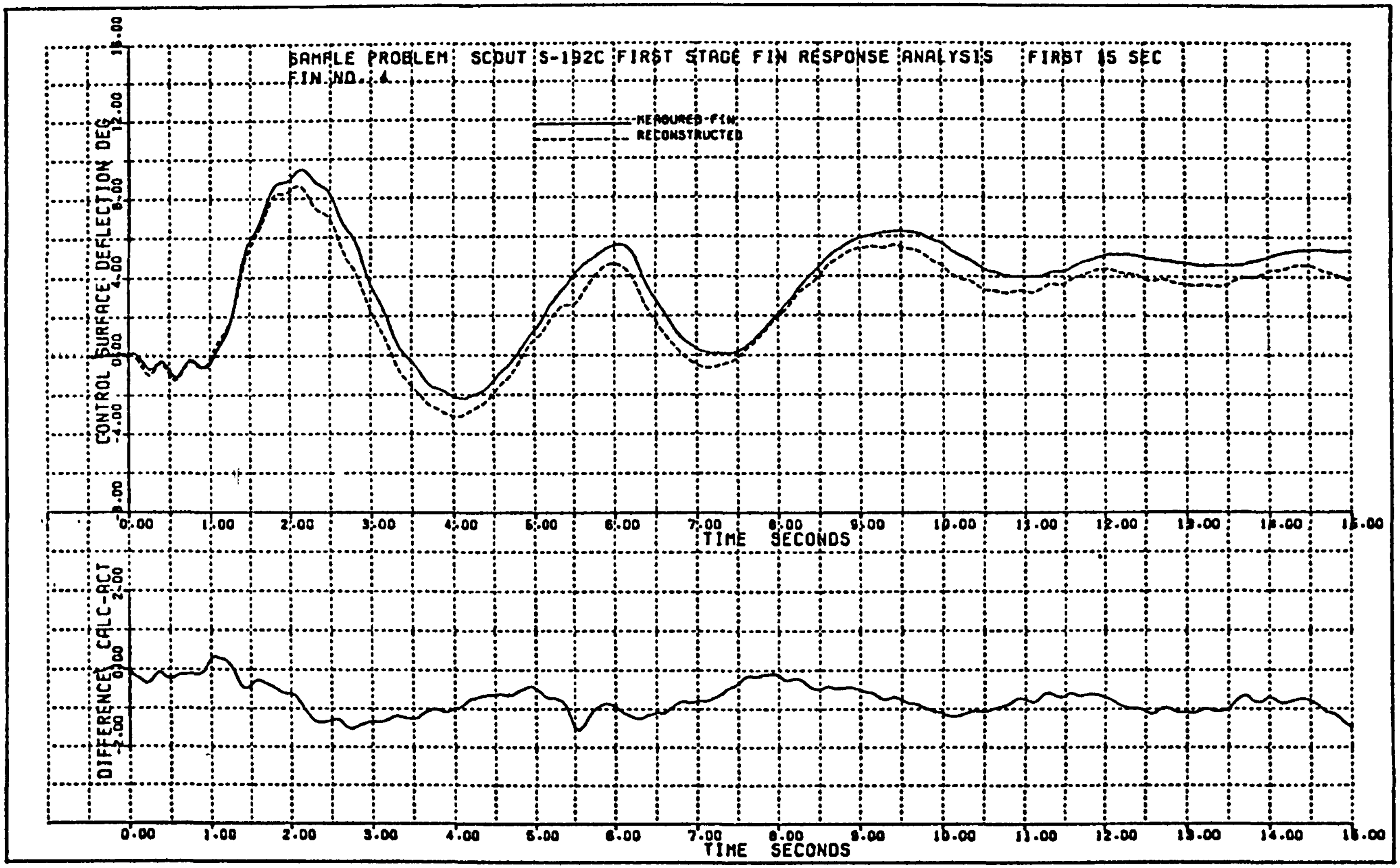


Figure 7 (continued)

Sample Problem CALCOMP Plots

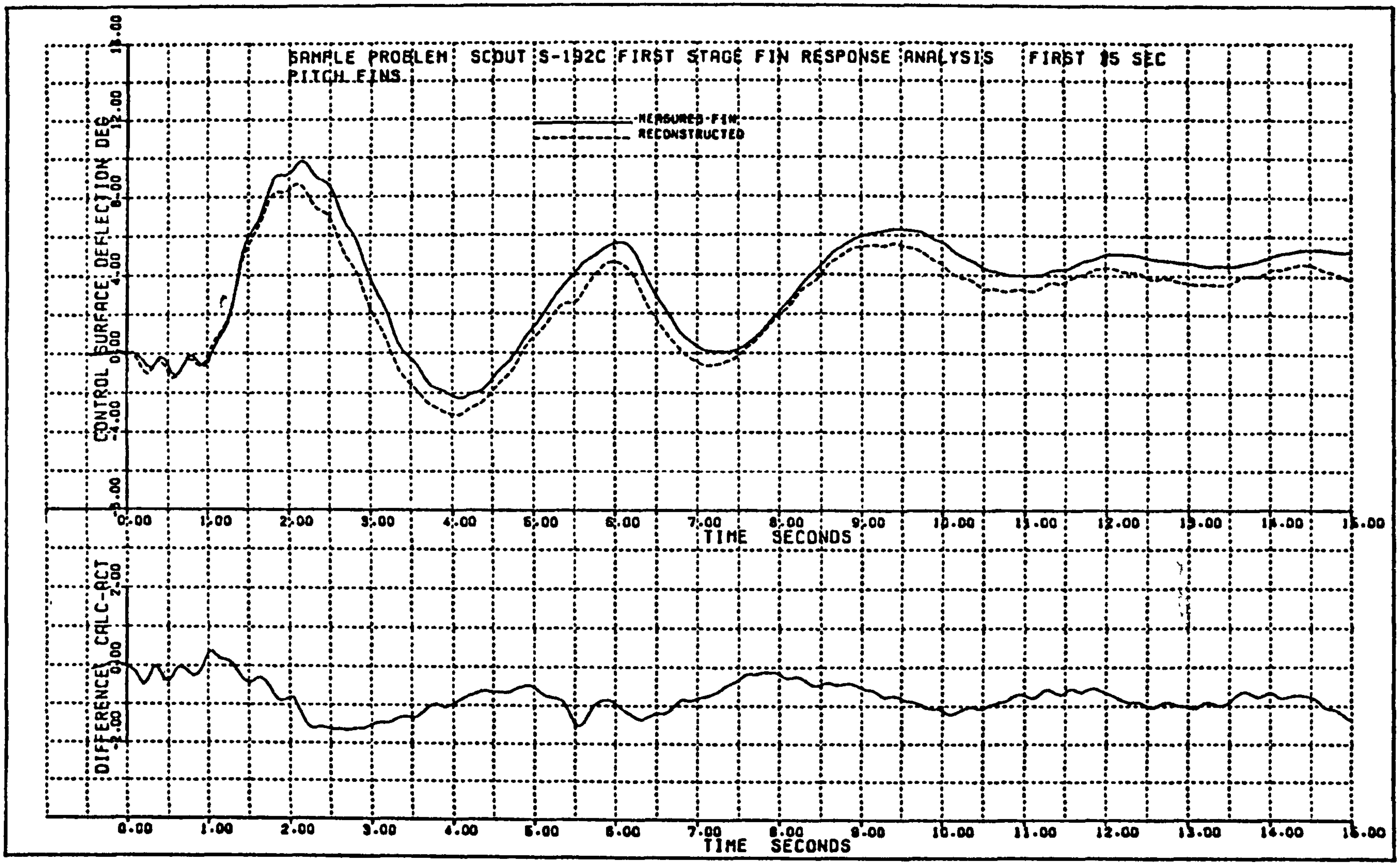


Figure 7 (continued)
Sample Problem CALCOMP Plots

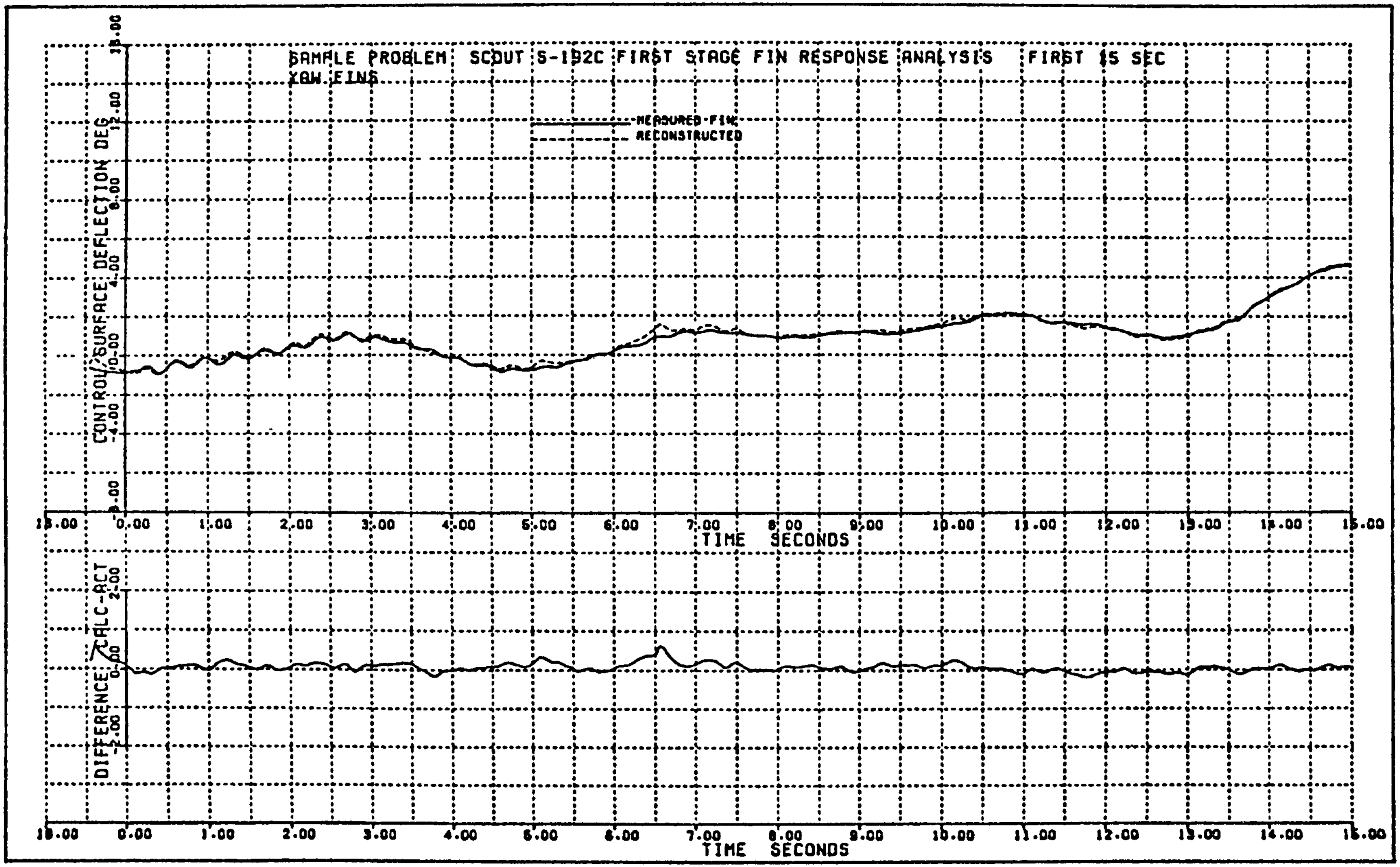
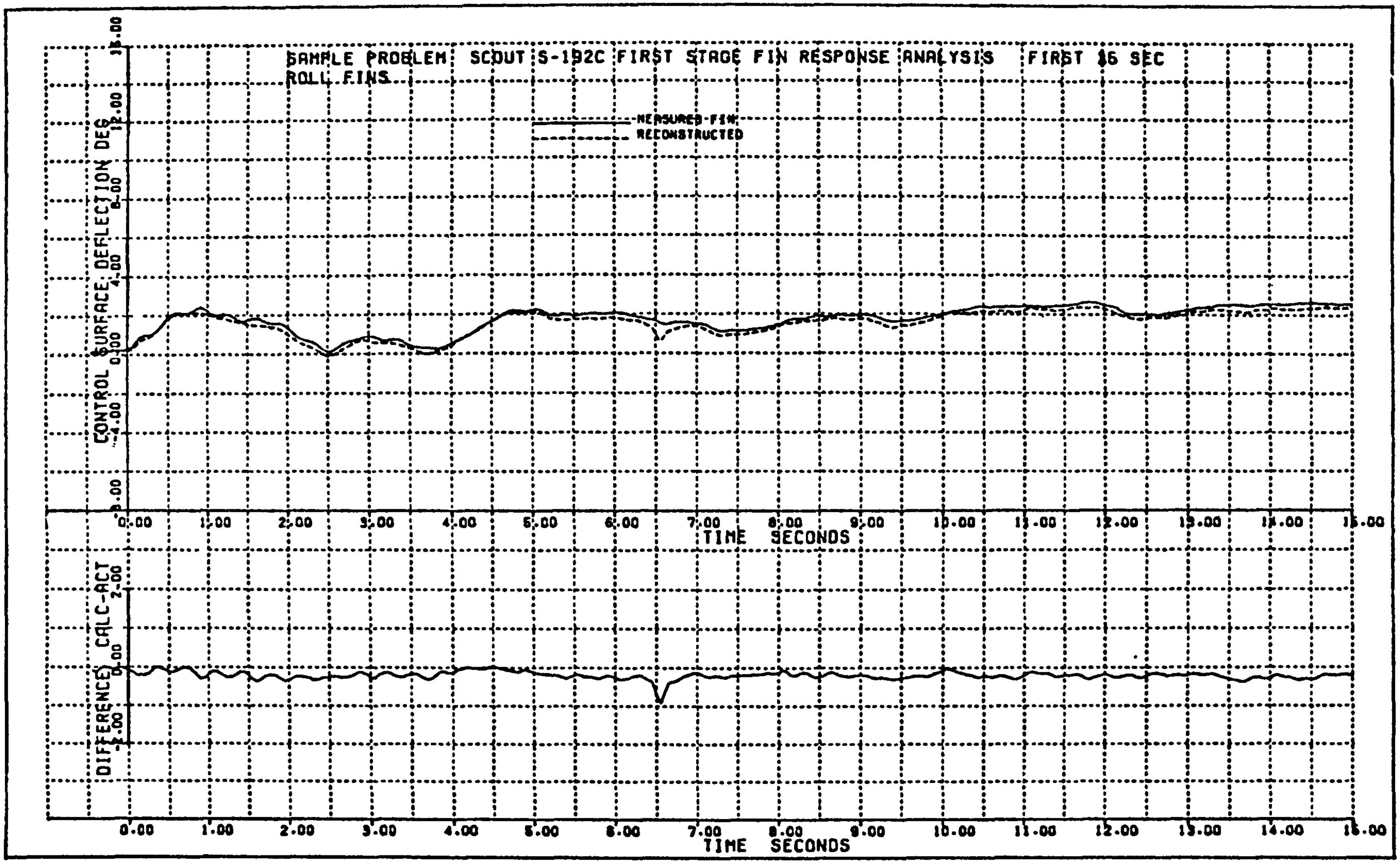


Figure 7 (concluded)

Sample Problem CALCOMP Plots



APPENDIX A

FORTRAN PROGRAM LISTING

A complete FORTRAN source program listing is presented in the following pages. It starts with the main routine (FINRES) and is followed by the subroutines arranged in alphabetical order. There are a total of 182 cards in FINRES. The total program including subroutines (less CALCOMP library) contains 675 cards.

```
      PROGRAM FINRES(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE9)
C     THIS PROGRAM ANALYZES POST-FLIGHT MEASURED CONTROL SURFACE
C     DEFLECTIONS AND AUTOPILOT PARAMETERS.  IT PROVIDES AN ADJUST-
C     MENT CAPABILITY AND DIGITAL FILTERING OF THE REDUCED TELEMETRY
C     DATA INCLUDING TIME SHIFTS.
      DIMENSION CD1(20),ED1(20),CD2(20),ED2(20),CD3(20),ED3(20),CD4(20),
     1        ED4(20),A(4,4),APS(4,4),FILTER(3,3),B(3),DATA(11),DL(10),
     2        NTIT(8),T(2000),Q(2000),R(2000),P(2000),TH(2000),PS(2000)
     3         ,PH(2000),D1(2000),D2(2000),D3(2000),D4(2000),DUM(2000)
      DATA NM1,NM2,NM3,NM4,NM5,NM6,NM7/10HFIN NO. 1 ,10HFIN NO. 2 ,
     1         10HFIN NO. 3 ,10HFIN NO. 4 ,10HPITCH FINS,
     2         10HYAW FINS  ,10HROLL FINS /
C     READ TITLE CARD
      READ(5,199) (NTIT(J),J=1,8)
  199 FORMAT(8A10)
C     READ INTEGER OPTIONS AND CONSTANTS
      READ(5,220) IOC,IOP,NPRT,NINT
  220 FORMAT(4I5)
C     READ TELEMETRY ADJUSTMENT FACTORS AND TIME FACTORS
      READ(5,230) (DL(I),I=1,10),TCQ,TCR,TCP,TCTH,TCPS,TCPH,
     1         TC1,TC2,TC3,TC4,AKTH,AKPS,AKPH,WCO
      WCO=6.2832*WCO
  230 FORMAT(8E10.3)
C     READ AUTOPILOT GAINS AND BREAK FREQUENCIES
      READ(5,230) CTH,CTHD,CPS,CPSD,CPH,CPHD,W1Q,W1R,W1P,WACT
C     READ FIN GAIN MATRIX
      DO 10 J=1,4
   10 READ(5,240) (A(J,I),I=1,3)
  240 FORMAT(4E10.3)
C     READ MEASURED FIN CALIBRATION ADJUSTMENT TABLES
      READ(5,250) NT1,(CD1(J),ED1(J),J=1,NT1)
      READ(5,250) NT2,(CD2(J),ED2(J),J=1,NT2)
      READ(5,250) NT3,(CD3(J),ED3(J),J=1,NT3)
      READ(5,250) NT4,(CD4(J),ED4(J),J=1,NT4)
  250 FORMAT(I5,/(8E10.3))
```

```
C     TEST FOR PLOT OPTION
      IF(IOP.EQ.0) GO TO 20
C     CALCOMP PLOT. READ IN SCALE FACTORS (UNITS PER INCH)
      READ(5,230) XSCALE,YSCALE,DSCALE
      IF(XSCALE.LE.0.) IOP=0
      IF(YSCALE.LE.0.) IOP=0
      IF(DSCALE.LE.0.) IOP=0
C     TEST FOR PSEUDO-INVERSE CALCULATION OF PITCH, YAW, ROLL DEFLECTION
   20 IF(IOC.EQ.0) GO TO 40
C     COMPUTE PSEUDO-INVERSE OF FIN GAIN MATRIX
      N=4
      M=3
      CALL PSEUDO(APS,A,N,M,NER)
      IF(NER.EQ.1) GO TO 40
      IOC=0
      WRITE(6,200)
  200 FORMAT(//,5X,34HMATRIX IS SINGULAR, CANNOT COMPUTE ,
     1     1X,14HPSEUDO-INVERSE ,/)
   40 NP=0
      REWIND 9
      M1=1
      M2=1
      M3=1
      M4=1
C     BEGIN READING THE TELEMETRY DATA
   50 READ(5,104) (DATA(I),I=1,11)
  104 FORMAT(11F7.3)
      IF(EOF(5).NE.0) GO TO 70
      NP=NP+1
C     ADJUST TELEMETRY DATA FOR BIAS AND FIN CAL NON-LINEARITY
      DO 60 I=1,6
   60 DATA(I+1)=DATA(I+1)+DL(I)
      X=DATA(8)
      CALL TBLN(Y,X,CD1,ED1,NT1,M1)
      DATA(8)=DATA(8)+Y+DL(7)
```

```
      X=DATA(9)
      CALL TBLN(Y,X,CD2,ED2,NT2,M2)
      DATA(9)=DATA(9)+Y+DL(8)
      X=DATA(10)
      CALL TBLN(Y,X,CD3,ED3,NT3,M3)
      DATA(10)=DATA(10)+Y+DL(9)
      X=DATA(11)
      CALL TBLN(Y,X,CD4,ED4,NT4,M4)
      DATA(11)=DATA(11)+Y+DL(10)
C WRITE ADJUSTED DATA ON TAPE 9
      WRITE(9,104) (DATA(I),I=1,11)
      GO TO 50
   70 CONTINUE
C     READ TAPE 9 DATA INTO TABLES
      REWIND 9
      DO 80 J=1,NP
   80 READ(9,104) T(J),Q(J),R(J),P(J),TH(J),PS(J),PH(J)
C     INITIALIZE FILTER AND FILTER THESE PARAMETERS
      CALL FILFIL(WCO,FILTER,B,DTFIL)
C     COMPUTE PITCH ERROR SIGNAL AND RETURN IN Q ARRAY
      CALL ERSIG(FILTER,B,T,Q,TH,NP,NINT,CTH,CTHD,DTFIL,
     1          TCTH,TCQ,AKTH,W1Q,WACT)
C     COMPUTE YAW ERROR SIGNAL AND RETURN IN R ARRAY
      CALL ERSIG(FILTER,B,T,R,PS,NP,NINT,CPS,CPSD,DTFIL,
     1          TCPS,TCR,AKPS,W1R,WACT)
C     COMPUTE ROLL ERROR SIGNAL AND RETURN IN  P ARRAY
      CALL ERSIG(FILTER,B,T,P,PH,NP,NINT,CPH,CPHD,DTFIL,
     1          TCPH,TCP,AKPH,W1P,WACT)
C     COMPUTE FOUR CONTROL SURFACE DEFLECTIONS AND FILTER
      REWIND 9
      DO 100 J=1,NP
  100 READ(9,105) T(J),D1(J),D2(J),D3(J),D4(J)
  105 FORMAT(F7.3,42X,4F7.3)
C     FILTER AND ADJUST CONTROL SURFACES
      CALL FIN(FILTER,B,T,D1,NP,DTFIL,TC1,NINT)
```

```
      CALL FIN(FILTER,B,T,D2,NP,DTFIL,TC2,NINT)
      CALL FIN(FILTER,B,T,D3,NP,DTFIL,TC3,NINT)
      CALL FIN(FILTER,B,T,D4,NP,DTFIL,TC4,NINT)
C     THE PITCH, YAW, AND ROLL RECONSTRUCTED AND FILTERED
C     DEFLECTIONS ARE AVAILABLE. NEXT COMPUTE THE COMMANDED
C     INDIVIDUAL FINS AND STORE IN ARRAYS TH,PS,PH,DUM
      DO 110 J=1,NP
      TH(J)=A(1,1)*Q(J)+A(1,2)*R(J)+A(1,3)*P(J)
      PS(J)=A(2,1)*Q(J)+A(2,2)*R(J)+A(2,3)*P(J)
      PH(J)=A(3,1)*Q(J)+A(3,2)*R(J)+A(3,3)*P(J)
  110 DUM(J)=A(4,1)*Q(J)+A(4,2)*R(J)+A(4,3)*P(J)
C     PREPARE AND PRINT OUTPUT OF INDIVIDUAL FINS
      NPAGE=1
      NLINE=59
      KPRT=NPRT
      DO 140 J=1,NP
      IF(NLINE.LT.59) GO TO 130
      WRITE(6,205) NPAGE,(NTIT(I),I=1,8)
      NLINE=8
      NPAGE=NPAGE+1
  205 FORMAT(1H1,2X,8HPAGE NO.,I3,// 1X,8A10,//,9X,16H*   F I N  O N E
     1 ,8X,16H*   F I N  T W O,8X,19H*  F I N  T H R E E ,
     2 5X,18H   F I N   F O U R ,//,3X,6HTIME  ,
     3 4(24H COMMAND ACTUAL  DELTA  ) ,/)
  130 IF(KPRT.LT.NPRT) GO TO 140
      KPRT=0
      DLT1=TH(J)-D1(J)
      DLT2=PS(J)-D2(J)
      DLT3=PH(J)-D3(J)
      DLT4=DUM(J)-D4(J)
      WRITE(6,206) T(J),TH(J),D1(J),DLT1,PS(J),D2(J),DLT2,PH(J),D3(J),
     1          DLT3,DUM(J),D4(J),DLT4
      NLINE=NLINE+1
  140 KPRT=KPRT+1
  206 FORMAT(1X,13F8.2)
```

```
C     TEST FOR PLOT
      IF(IOP.EQ.0) GO TO 160
C     CALCOMP PLOT OF INDIVIDUAL CONTROL SURFACES
      CALL CURVE(T,TH,D1,NP,NTIT,NM1,XSCALE,YSCALE,DSCALE)
      CALL CURVE(T,PS,D2,NP,NTIT,NM2,XSCALE,YSCALE,DSCALE)
      CALL CURVE(T,PH,D3,NP,NTIT,NM3,XSCALE,YSCALE,DSCALE)
      CALL CURVE(T,DUM,D4,NP,NTIT,NM4,XSCALE,YSCALE,DSCALE)
C     TEST FOR ERROR SIGNAL RECONSTRUCTION BASED ON MEASURED FINS
  160 IF(IOC.EQ.0) GO TO 180
C     RECONSTRUCT PITCH, YAW, AND ROLL ERROR SIGNAL FROM MEASURED
C     FIN DEFLECTIONS AND OUTPUT.  PITCH, YAW, AND ROLL DEFLECTIONS
C     BASED ON FINS 1 THRU 4 WILL BE IN ARRAYS TH,PS, AND PH
      NLINE=59
      DO 170 J=1,NP
      IF(NLINE.LT.59) GO TO 165
      WRITE(6,207) NPAGE,(NTIT(I),I=1,8)
      NLINE=8
      NPAGE=NPAGE+1
      KPRT=NPRT
  165 TH(J)=APS(1,1)*D1(J)+APS(1,2)*D2(J)+APS(1,3)*D3(J)+APS(1,4)*D4(J)
      PS(J)=APS(2,1)*D1(J)+APS(2,2)*D2(J)+APS(2,3)*D3(J)+APS(2,4)*D4(J)
      PH(J)=APS(3,1)*D1(J)+APS(3,2)*D2(J)+APS(3,3)*D3(J)+APS(3,4)*D4(J)
C     COMPUTE DIFFERENCES
      DLT1=Q(J)-TH(J)
      DLT2=R(J)-PS(J)
      DLT3=P(J)-PH(J)
      IF(KPRT.LT.NPRT) GO TO 170
      KPRT=0
      WRITE(6,206) T(J),Q(J),TH(J),DLT1,R(J),PS(J),DLT2,P(J),PH(J),DLT3
      NLINE=NLINE+1
  170 KPRT=KPRT+1
  207 FORMAT(1H1,2X,8HPAGE NO.,I3,10X,48HPITCH, YAW, ROLL COMMANDS BASED
     1 ON MEASURED FINS  ,//,8A10,//,8X,1H*,7X,
     2 9HP I T C H ,7X,1H*,9X,5HY A W ,9X,1H*,7X,7HR O L L ,9X,
     3 1H*,/3X,6HTIME  ,3(24H COMMAND  ACTUAL DELTA  ),/)
```

```
      IF(IOP.EQ.0) GO TO 180
C     PLOT CALCOMP PLOT OF PITCH, YAW, AND ROLL FINS
      CALL CURVE(T,Q,TH,NP,NTIT,NM5,XSCALE,YSCALE,DSCALE)
      CALL CURVE(T,R,PS,NP,NTIT,NM6,XSCALE,YSCALE,DSCALE)
      CALL CURVE(T,P,PH,NP,NTIT,NM7,XSCALE,YSCALE,DSCALE)
  180 STOP
      END
```

```
      SUBROUTINE CURVE(T,CALC,ACT,NP,NTIT,NM,XS,YS,DS)
C     THIS SUBROUTINE PLOTS A CALCOMP TYPE PLOT OF THE COMMANDED
C     ACTUAL, AND DIFFERENCE BETWEEN THE COMMANDED AND ACTUAL
C     CONTROL SURFACE DEFLECTION.
      DIMENSION T(2000),CALC(2000),ACT(2000),NTIT(8),X(2),Y(2)
      DATA X(1),X(2),Y(1),Y(2),NPP,ZL,ZK,SPACE,YMAX,DTMAX/5.0,6.2,
     1          2.75,2.75,2,0.07,0.0,0.04,3.,1.5/
      DM=-2.*YS
      DD=-DS
      TF=T(NP)/XS + 1.
      NTF=TF
      TF=NTF
      CALL PLOTS(5HCAL22,0,4HPLOT)
      CALL PLOT(1.,6.,-3)
      CALL SYMBOL(2.,3.75,0.14,NTIT,0.,80)
      CALL SYMBOL(2.,3.5,0.14,NM,0.,10)
      CALL AXIS(0.,-2.,30HCONTROL SURFACE DEFLECTION DEG ,30,6.,90.,DM,
     1    YS)
      CALL AXIS(0.,-2.,13HTIME  SECONDS ,-13,TF,0.,0.,XS)
      CALL DASH(T,ACT,NP,ZL,SPACE,ZK,XS,YS,1,TF,YMAX)
      CALL DASH(T,CALC,NP,ZL,ZK,SPACE,XS,YS,1,TF,YMAX)
      CALL PLOT(5.,2.95,3)
      CALL PLOT(6.2,2.95,2)
      CALL SYMBOL(6.3,2.95,0.10,12HMEASURED FIN ,0.,12)
      CALL SYMBOL(6.3,2.75,0.10,13HRECONSTRUCTED,0.,13)
      CALL PLOT(5.,2.75,3)
      CALL DASH(X,Y,NPP,ZL,ZK,SPACE,1.,1.,1,TF,4.)
      CALL PLOT(0.,-4.,-3)
      CALL AXIS(0.,-2.,13HTIME  SECONDS,-13,TF,0.,0.,XS)
      CALL AXIS(0.,-1.,20HDIFFERENCE  CALC-ACT,20,2.,90.,DD,DS)
C     CALCULATE AND PLOT THE DIFFERENCE (RECONSTRUCTED MINUS ACTUAL)
      DO 10 J=1,NP
   10 CALC(J)=(CALC(J)-ACT(J))/DS
      CALL DASH(T,CALC,NP,ZL,SPACE,ZK,XS,1.,1,TF,DTMAX)
      CALL PLOT(16.,-2.,-3)
      CALL PLOT(0.,0.,999)
      RETURN
      END
```

```
*DECK DASH
      SUBROUTINE DASH (X,Y,NP,Z1,Z2,SPACE,XSCALE,YSCALE,LSYMB,XLIM,YLIM)
C     SYMBOLS,DASHED,DASHED-DOT LINES OR SOLID LINES WITH OR WITHOUT
C     SYMBOLS BASED ON A SET OF SEQUENTIAL POINTS GIVEN IN
C     THE INPUT 'X' ABSCISSA ARRAY AND THE 'Y' ORDINATE ARRAY
      DIMENSION X(1),Y(1)
      DO 10 I=1,NP
      XA=X(I)/XSCALE
      YA=Y(I)/YSCALE
      IF (ABS(XA).GT.XLIM) GO TO 10
      IF (ABS(YA).GT.YLIM) GO TO 10
      CALL PLOT (XA,YA,3)
      GO TO 20
   10 CONTINUE
   20 IF (SPACE) 330,310,30
C     PLOT A BROKEN LINE
   30 K=0
      PI2=1.5708
      Z=Z1
      ZB=Z2
      IF (Z2 .GT. 0.) GO TO 40
      ZB=Z1
   40 ZD=Z
      LZ=0
      SL=0.
      NF=NP-1
      DO 300 J=1,NF
      XA=X(J)/XSCALE
      IF (ABS(XA)-XLIM .GT. 0.) GO TO 300
      XB=X(J+1)/XSCALE
      IF (ABS(XB)-XLIM .GT. 0.) GO TO 300
      YA=Y(J)/YSCALE
      IF (ABS(YA)-YLIM .GT. 0.) GO TO 300
      YB=Y(J+1)/YSCALE
      IF (ABS(YB)-YLIM .GT. 0.) GO TO 300
```

```
      DY=YB-YA
      DX=XB-XA
      IF (DX .NE. 0.) GO TO 80
      IF (DY) 50,60,70
   50 TH=-PI2
      GO TO 90
   60 TH=0.
      GO TO 90
   70 TH=PI2
      GO TO 90
   80 TH=ATAN(DY/DX)
   90 DX=XB-XA
      DY=YB-YA
      DZ=SQRT(DX*DX+DY*DY)
C   TEST TO SEE WHAT IS GOING ON
      IF (K) 100,180,220
  100 K=1
      SL=SPACE
      IF (DZ-SPACE) 110,120,150
C   SPACE IS LARGER THAN DZ
  110 SL=SL-DZ
      CALL PLOT (XB,YB,3)
      GO TO 300
C   NEXT POINT IS EXACTLY ONE SPACE
  120 K=0
      IF (LZ .NE. 0 ) GO TO 130
      ZD=ZB
      LZ=1
      GO TO 140
  130 ZD=Z
      LZ=0
  140 SL=0.
      CALL PLOT (XB,YB,3)
      GO TO 300
C   NEXT POINT MORE THAN ONE SPACE AWAY
```

```
  150 XA=XA+SPACE*COS(TH)
      YA=YA+SPACE*SIN(TH)
      IF (ABS(XA)-XLIM .GE. 0.) GO TO 300
      IF (ABS(YA)-YLIM .GE. 0.) GO TO 300
      K=0
      IF (LZ .NE. 0 ) GO TO 160
      ZD=ZB
      LZ=1
      GO TO 170
  160 ZD=Z
      LZ=0
  170 SL=0.
      CALL PLOT (XA,YA,3)
      GO TO 90
C  K=0 LINE BEING DRAWN ZD LENGTH NOT DRAWN RESUME AS IS LINE STARTING
  180 IF (DZ-ZD) 190,200,210
C   LINE GOES AT LEAST TO NEXT POINT
  190 K=0
      ZD=ZD-DZ
      CALL PLOT (XB,YB,2)
      GO TO 300
C   LINE ENDS AT NEXT POINT
  200 K=-1
      SL=SPACE
      ZD=0.
      CALL PLOT (XB,YB,2)
      GO TO 300
C   LINE ENDS BEFORE NEXT POINT
  210 K=1
      SL=SPACE
      XA=XA+ZD*COS(TH)
      YA=YA+ZD*SIN(TH)
      IF (ABS(XA)-XLIM .GE. 0.) GO TO 300
      IF (ABS(YA)-YLIM .GE. 0.) GO TO 300
      CALL PLOT (XA,YA,2)
```

```
      ZD=0.
      GO TO 90
C   K=1 IS IN SPACE
  220 ZD=0.
      IF (DZ-SL) 230,240,270
  230 K=1
      SL=SL-DZ
      CALL PLOT (XB,YB,3)
      GO TO 300
C  SL=DZ
  240 K=0
      IF (LZ .NE. 0 ) GO TO 250
      ZD=ZB
      LZ=1
      GO TO 260
  250 ZD=Z
      LZ=0
  260 CALL PLOT (XB,YB,3)
      GO TO 300
C   SL IS LESS THAN DZ
  270 K=0
      IF (LZ .NE. 0 ) GO TO 280
      ZD=ZB
      LZ=1
      GO TO 290
  280 ZD=Z
      LZ=0
  290 XA=XA+SL*COS(TH)
      YA=YA+SL*SIN(TH)
      IF (ABS(XA)-XLIM .GE. 0.) GO TO 300
      IF (ABS(YA)-YLIM .GE. 0.) GO TO 300
      SL=0.
      CALL PLOT (XA,YA,3)
      GO TO 90
  300 CONTINUE
```

```
      GO TO 370
C  STRAIGHT LINE PLOT OPTION
  310 DO 320 J=I,NP
      XA=X(J)/XSCALE
      YA=Y(J)/YSCALE
      IF (ABS(XA)-XLIM .GT. 0.) GO TO 320
      IF (ABS(YA)-YLIM .GT. 0.) GO TO 320
      CALL PLOT (XA,YA,2)
  320 CONTINUE
      GO TO 370
C  PLOT SYMBOLS ON LINE  NO LINE IF LYSMB IS NEGATIVE
  330 NSM=IABS(LSYMB)
      IF (LSYMB .LT. 0 ) GO TO 340
      K=-2
      GO TO 350
  340 K=-1
  350 DO 360 J=1,NP
      XA=X(J)/XSCALE
      YA=Y(J)/YSCALE
      IF (ABS(XA)-XLIM .GT. 0.) GO TO 360
      IF (ABS(YA)-YLIM .GT. 0.) GO TO 360
      CALL SYMBOL (XA,YA,0.07,NSM,0.0,K)
  360 CONTINUE
  370 CALL PLOT (0.,0.,3)
      RETURN
      END
```

```
*DECK ERSIG
      SUBROUTINE ERSIG(FILTER,B,T,Q,TH,NP,NINT,CTH,CTHD,DT,
     1          DTTM,DTTMR,AD,W,WACT)
C     THIS SUBROUTINE ADJUSTS THE ATTITUDE RATE AND DISPLACEMENT
C     FOR TELEMETRY CROSS COUPLING, TIME LAGS, AND THEN COMPUTES
C     THE ERROR SIGNAL.  THE DISPLACEMENT AND RATE ARE ENTERED
C     IN ARRAYS TH AND Q.  THE ERROR SIGNAL IS RETURNED IN (Q).
      DIMENSION FILTER(3,3),B(3),T(2000),Q(2000),TH(2000),DUM(2000),
     1          A(3,3),AB(3)
C     FILTER THE DISPLACEMENT TIME HISTORY
      N=3
      K=3
      CT=CTHD-AD*CTH
      CALL TRESP(FILTER,B,T,TH,DUM,NP,N,K,NINT)
      CALL TRESP(FILTER,B,T,Q,TH,NP,N,K,NINT)
      M=1
      DTT=DT+DTTM
      DTR=DT+DTTMR
C     AT THIS POINT THE FILTERED DISPLACEMENT IS IN (DUM) AND THE
C     FILTERED RATE IS IN (TH)
      DO 10 J=1,NP
      TA=T(J)+DTT
      CALL TBLN(DISP,TA,T,DUM,NP,M)
      TB=T(J)+DTR
      CALL TBLN(RATE,TB,T,TH,NP,M)
C     COMPUTE THE ERROR SIGNAL AND PLACE IN (Q)
   10 Q(J)=CTH*DISP+CT*RATE
C     NEXT COMPUTE THE FIRST ORDER AUTOPILOT LAG (W) AND THE FIRST
C     ORDER ACTUATOR LAG (WACT) RESPONSE.
      AB(2)=0.
      A(1,2)=0.
      N=2
      K=2
      AB(1)=W
      A(1,1)=-W
      A(2,1)=WACT
      A(2,2)=-WACT
      CALL TRESP(A,AB,T,Q,DUM,NP,N,K,NINT)
C     PUT RESULTANT ERROR SIGNAL IN (Q) ARRAY.
      DO 30 J=1,NP
   30 Q(J)=DUM(J)
      RETURN
      END
```

```
*DECK FILFIL
      SUBROUTINE FILFIL(WCO,A,B,DT)
C     THIS SUBROUTINE FILLS THE FILTER COEFFICIENTS FOR A THIRD
C     ORDER BUTTERWORTH FILTER HAVING A CUTOFF FREQUENCY OF
C     (WCO) RADIANS PER SECOND.
      DIMENSION A(3,3),B(3)
C     ZERO OUT THE COEFFICIENT ARRAYS
      DO 10 J=1,3
      B(J)=0.
      DO 10 K=1,3
   10 A(J,K)=0.
C     FILL REMAINING CONSTANTS
      TAU=0.7071/WCO
      A(2,1)=1.0
      A(3,2)=1.0
      A(1,1)=-2./TAU
      A(1,2)=A(1,1)/TAU
      A(1,3)=-1./(TAU*TAU*TAU)
      B(1)=-A(1,3)
C     COMPUTE THE LOW FREQUENCY TIME LAG FOR THIS FILTER
      DT=2.*TAU
      RETURN
      END
```

```
*DECK FIN
      SUBROUTINE FIN(FILTER,B,T,D,NP,DTFIL,TC,NINT)
C     THIS SUBROUTINE FILTERS THE CONTROL SURFACE DEFLECTION AND
C     ADJUSTS FOR TIME DELAYS.
      DIMENSION FILTER(3,3),B(3),T(2000),D(2000),DUM(2000)
      N=3
      K=3
      DT=DTFIL+TC
      CALL TRESP(FILTER,B,T,D,DUM,NP,N,K,NINT)
      M=1
C     THE FILTERED DEFLECTION IS NOW IN (DUM)
      DO 10 J=1,NP
      TA=T(J)+DT
      CALL TBLN(FN,TA,T,DUM,NP,M)
   10 D(J)=FN
      RETURN
      END
```

```
*DECK PSEUDO
      SUBROUTINE PSEUDO(B,A,N,M,NER)
C     THIS SUBROUTINE COMPUTES THE PSEUDO INVERSE MATRIX B FROM THE
C     N BY M MATRIX (A). (B)=A*=INB(AT.A).AT
      DIMENSION AS(4,4),A(4,4),B(4,4),AINV(4,4)
      L=M
      LS=N
      IF(N.GT.M) LS=M
      IF(N.GT.M) L=N
C     SET MATRIX ELEMENTS TO ZERO
      DO 10 J=1,L
      DO 10 K=1,L
      B(J,K)=0.
   10 AS(J,K)=0.
C     COMPUTE THE TRANSPOSE OF A
      DO 20 J=1,L
      DO 20 K=1,L
   20 AS(J,K)=A(K,J)
C     MULTIPLY A TRANSPOSE TIMES A, AND STORE IN B
      CALL XMULT(AS,A,B,L)
C     COMPUTE INVERSE OF B AND STORE IN AINV
      CALL SIMEQ(B,LS,AINV,NER)
      IF(NER.NE.0) GO TO 30
C     MATRIX IS SINGULAR RETURN TO CALLING ROUTINE
      RETURN
C     COMPUTE THE PSEUDO INVERSE
   30 CALL XMULT(AINV,AS,B,L)
      RETURN
      END
```

```
*DECK RUNGE
      SUBROUTINE RUNGE (N,F, H, X, Y, L,I)
C     THIS SUBROUTINE PERFORMS THE RUNGE-KUTTA INTEGRATION
C     UPDATES FOR THE TRESP SUBROUTINE.
      DIMENSION Y(1),F(1),SV(3),FF(3)
      I = I + 1
      GO TO ( 1, 2, 3, 4, 5) , I
    1 L = 1
      RETURN
    2 DO 6   J=1,N
      SV(J) = Y(J)
      FF(J) = F(J)
    6 Y(J) = SV(J) + .5*H*F(J)
      X = X + .5*H
      L = 1
      RETURN
    3 DO 7   J=1,N
      FF(J) = FF(J) + 2.*F(J)
    7 Y(J) = SV(J) + .5*H*F(J)
      L = 1
      RETURN
    4 DO 8   J=1,N
      FF(J) = FF(J) + 2.*F(J)
    8 Y(J) = SV(J) + H*F(J)
      X = X + .5*H
      L = 1
      RETURN
    5 DO 9   J=1,N
    9 Y(J) = SV(J) + (H/6.)*(FF(J) + F(J))
      L = 2
      I = 0
      RETURN
      END
```

```
*DECK SIMEQ
      SUBROUTINE SIMEQ (A,KC,AINV,IERR)
      DIMENSION A(4,4),B(4,4),XDOT(5),X(5),AINV(4,4)
C     THIS SUBROUTINE FINDS THE INVERSE OF MATRIX (A) USING
C     DIAGONALIZATION PROCEDURES.
      N=1
      IERR=1
      DO 10 I=1,KC
      DO 10 J=1,KC
      AINV(I,J)=0.
   10 B(I,J)=A(I,J)
      DO 20 I=1,KC
      AINV(I,I)=1.
   20 X(I)=XDOT(I)
      DO 110 I=1,KC
      COMP=0.
      K=I
   30 IF (ABS(B(K,I))-ABS(COMP) .LE. 0.) GO TO 40
      COMP=B(K,I)
      N=K
   40 K=K+1
      IF (K-KC .LE. 0 ) GO TO 30
      IF (B(N,I) .EQ. 0.) GO TO 120
      IF (N-I) 120,70,50
   50 DO 60 M=1,KC
      TEMP=B(I,M)
      B(I,M)=B(N,M)
      B(N,M)=TEMP
      TEMP=AINV(I,M)
      AINV(I,M)=AINV(N,M)
   60 AINV(N,M)=TEMP
      TEMP=X(I)
      X(I)=X(N)
      X(N)=TEMP
   70 X(I)=X(I)/B(I,I)
```

```
      TEMP=B(I,I)
      DO 80 M=1,KC
      AINV(I,M)=AINV(I,M)/TEMP
   80 B(I,M)=B(I,M)/TEMP
      DO 100 J=1,KC
      IF (J-I .EQ. 0 ) GO TO 100
      IF (B(J,I) .EQ. 0.) GO TO 100
      X(J)=X(J)-B(J,I)*X(I)
      TEMP=B(J,I)
      DO 90 N=1,KC
      AINV(J,N)=AINV(J,N)-TEMP*AINV(I,N)
   90 B(J,N)=B(J,N)-TEMP*B(I,N)
  100 CONTINUE
  110 CONTINUE
      RETURN
  120 WRITE( 6,130)
      IERR=0
      RETURN
  130 FORMAT (6X,22HTHE MATRIX IS SINGULAR)
      END
```

```
*DECK TBLN
      SUBROUTINE TBLN (Y,X,T,A,NT,M)
C     THIS  SUBROUTINE IS A TABLE LOOKUP FROM ABSCISSA TABLE 'T'
C     AND ORDINATE TABLE'A'. 'Y' IS ORDINATE AT GIVEN ABSCISSA 'X'.
C     'NT' IS LENGTH OF TABLES'T'AND'A'. 'M' IS LOCATION OF LAST VALUE
      DIMENSION T(1),A(1)
   10 IF (T(M)-X) 50,20,30
   20 Y=A(M)
      RETURN
   30 IF (T(1)-X.LT.0.) GO TO 40
      M=1
      GO TO 20
   40 M=M-1
      GO TO 10
   50 MM=M+1
      IF (MM-NT.LE.0) GO TO 60
      M=NT
      GO TO 20
   60 IF (T(MM)-X.GT.0.) GO TO 70
      M=MM
      GO TO 50
   70 M=MM-1
      DT=T(MM)-T(M)
      IF (DT.NE.0.) GO TO 80
      Y=A(M)
      RETURN
   80 DY=A(MM)-A(M)
      DDT=X-T(M)
      Y=A(M)+DY*DDT/DT
      RETURN
      END
```

```
*DECK TRESP
      SUBROUTINE TRESP(A,B,T,Y,Z,NP,N,K,NINT)
C     THIS SUBROUTINE PERFORMS A RUNGE-KUTTA INTEGRATION OF
C     A SET OF (N) LINEAR FIRST ORDER DIFFERENTIAL EQUATIONS.
C     THE OUTPUT IS THE (K)TH STATE VARIABLE.
      DIMENSION A(3,3),B(3),T(2000),Y(2000),Z(2000),XDOT(3),X(3)
      STP=NINT
      Z(1)=Y(1)
      M=1
      DO 1 J=1,3
      XDOT(J)=0.
    1 X(J)=0.
      DO 20 J=2,NP
      TA=T(J-1)
      DT=T(J)-TA
      H=DT/STP
      DO 10 I=1,NINT
      II=0
    5 CALL RUNGE(N,XDOT,H,TA,X,L,II)
      IF(L.EQ.2) GO TO 10
      CALL TBLN(U,TA,T,Y,NP,M)
      CALL YDOT(A,X,XDOT,B,U,N)
      GO TO 5
   10 CONTINUE
      Z(J)=X(K)
   20 CONTINUE
      RETURN
      END
```

```
*DECK XMULT
      SUBROUTINE XMULT(A,B,C,N)
C     THIS SUBROUTINE COMPUTES THE PRODUCT OF TWO MATRICES A AND B
C     HAVING DIMENSIONS N BY N. THE RESULT IS C
      DIMENSION A(4,4),B(4,4),C(4,4)
C     SET WORKING MATRIX ELEMENTS TO ZERO
      DO 10 J=1,N
      DO 10 K=1,N
   10 C(J,K)=0.
      DO 20 J=1,N
      DO 20 K=1,N
      DO 20 JK=1,N
   20 C(J,K)=C(J,K)+A(J,JK)*B(JK,K)
      RETURN
      END
```

```
*DECK YDOT
      SUBROUTINE YDOT(A,Y,XDOT,B,U,N)
C     THIS SUBROUTINE UPDATES THE STATE VARIABLE EQUATIONS FOR
C     THE TRESP RUNGE-KUTTA INTEGRATION SUBROUTINE.
      DIMENSION Y(3),A(3,3),XDOT(3),B(3)
      DO 2 I=1,N
      XDOT(I)=0.
      DO 1 J=1,N
      XDOT(I)=XDOT(I)+A(I,J)*Y(J)
    1 CONTINUE
      XDOT(I)=XDOT(I)+B(I)*U
    2 CONTINUE
      RETURN
      END
```

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16 Abstract

A FORTRAN IV coded computer program is presented for post-flight analysis of a missile's control surface response. It includes preprocessing of digitized telemetry data for time lags, biases, non-linear calibration changes and filtering. Measurements include autopilot attitude rate and displacement gyro output and four control surface deflections. Simple first order lags are assumed for the pitch, yaw and roll axes of control. Each actuator is also assumed to be represented by a first order lag. Mixing of pitch, yaw and roll commands to four control surfaces is assumed. A pseudo-inverse technique is used to obtain the pitch, yaw and roll components from the four measured deflections.

This program has been used for over 10 years on the NASA/SCOUT launch vehicle for post-flight analysis and was helpful in detecting incipient actuator stall due to excessive hinge moments.

The program is currently set up for a CDC CYBER 175 computer system. It requires 34K words of memory and contains 675 cards. A sample problem presented herein including the optional plotting requires eleven (11) seconds of central processor time.

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