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Users Manual for Linear Time-Varying Helicopter Simulation (Program TVHIS)

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FOREWORD

The computer program described in this report was developed by The Analytic Sciences Corporation (TASC) during the period from March 3, 1976 to October 1, 1977 under Contract No. NAS1-14358 for the National Aeronautics and Space Administration, Langley Research Center, Hampton, Virginia. The work was sponsored by the Navigation and Guidance Research Branch of the Flight Instrumentation Division as a contribution to the VTOL Automatic Landing Technology (VALT) Program. Dr. David R. Downing served as Technical Monitor for this contract.

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ABSTRACT

TVHIS, a linear time-varying helicopter simulation program, is described in this report. The program is designed as a realistic yet efficient helicopter simulation. It is based on a linear time-varying helicopter model which includes rotor, actuator, and sensor models, as well as a simulation of flight computer logic. TVHIS can generate a mean trajectory simulation along a nominal trajectory, or propagate covariance of helicopter states, including rigid-body, turbulence, control command, controller states, and rigid-body state estimates.

Rotor and actuator models include dynamic states with actuator displacement and rate limits. Flight computer logic includes state estimation, guidance, and digital-adaptive control laws. Automatic guidance may be specified to cause the helicopter to follow a prestored guidance trajectory, or pilot input may be applied as perturbations on nominal guidance commands. State estimation and guidance algorithms may be by-passed to allow the testing of control algorithms alone.

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1. TVHIS OVERVIEW

TVHIS is designed to simulate the flight path of a helicopter in the neighborhood of a reference flight trajectory. Either a mean trajectory simulation, or a covariance calculation may be performed. Multiple cases may be run, combining different segments of a nominal trajectory, different types of control and guidance for a given trajectory segment, or covariance calculations along different segments of the nominal trajectory.

TVHIS is functionally divided into 6 sections:

(1) Main Executive Controlling Routine

(2) Data Base Modification and Echo

(3) Nominal Trajectory Construction

(4) Propagation Between Way Points
  (a) State Equation Integration
  (b) Covariance Equation Integration

(5) Flight Computer Logic

(6) Time History Summary
  (a) State Time History
  (b) Covariance Time History

When TVHIS is first loaded, the TVHIS data base, consisting of general variables and matrices used for control and flight computer variables, is initialized to default values specified by two BLOCK DATA subprograms. One subprogram specifies defaults for general variables, and a second subprogram specifies defaults for flight computer control settings.

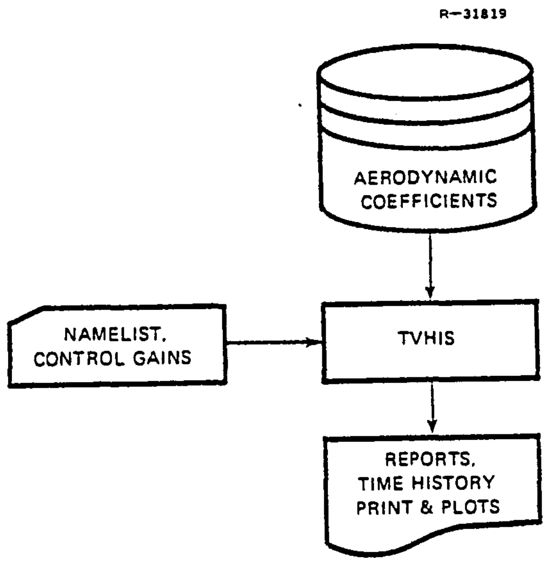

Figure 1-1 TVHIS Data Flow

During execution, TVHIS reads input data from a card-image input file that describes the specific run being performed (Fig. 1-1). Aerodynamic coefficients are read from a permanent disk file, which must be established using the procedure described in Appendix B, before the execution of TVHIS.

1.1 MAIN EXECUTIVE ROUTINE

The main routine (Fig. 1.1-1) reads namelist $STACK, specifying NCASES, the number of cases required in the run. For each of the NCASES steps, the following will be performed:

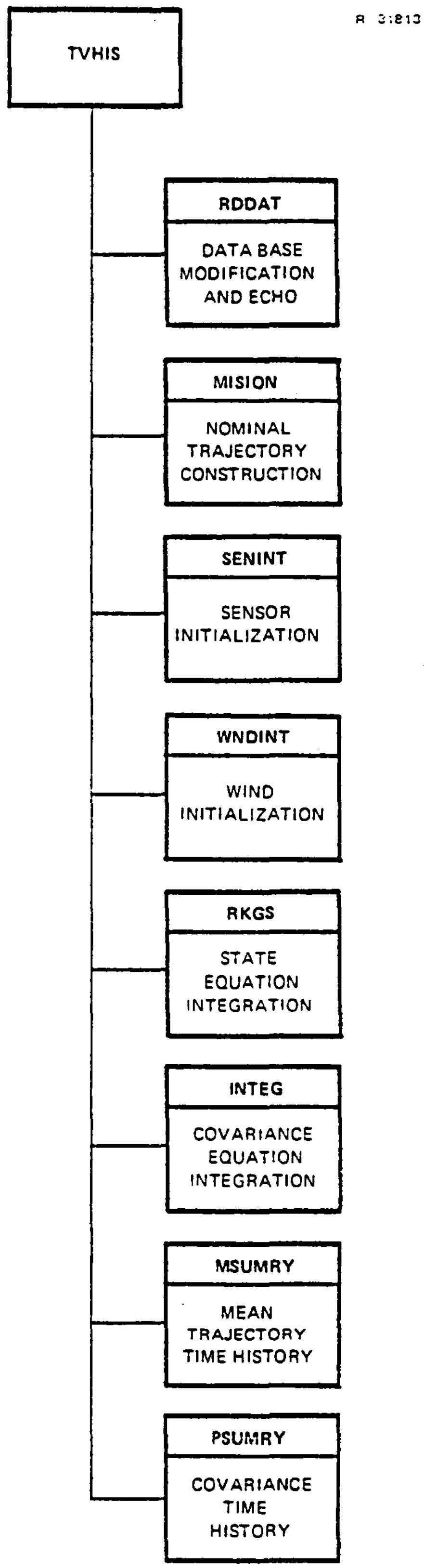

Figure 1.1-1 TVHIS Main Executive Block Diagram

(1) Data Base Modification and Echo (RDDAT)

(2) Nominal Trajectory Construction (MISION)

(3) Wind and Sensor Initialization During First Flight Segment for a Mean Trajectory Simulation (SENINT,WNDINT)

(4) Propagation Between Nominal Waypoints
   (a) State Equation Integration Between Waypoints for Mean Trajectory Simulation (RKGS)
   (b) Covariance Equation Integration Between Waypoints for Covariance Calculator (INTEG)

(5) Final Time History Print and/or Plot
   (a) Mean Trajectory Simulation (MSUMRY)
   (b) Covariance Calculation (PSUMRY)

1.2 DATA BASE MODIFICATION AND ECHO

The data input subroutine RDDAT (Fig. 1.2-1) reads modifications to the TVHIS data base via NAMELIST and issues a report on the initial data base at the beginning of each case. Inputs read by RDDAT are described in Section 2.1.1; outputs are described in Section 2.2.1. In the case of a covariance calculation, RDDAT calls COVPT to produce a report of the initial values of covariance matrices.

1.3 NOMINAL TRAJECTORY CONSTRUCTION

Subroutine MISION (Fig. 1.3-1) calculates system matrices F, G, HT, and nomin al state XVNTRU at two waypoints of the nominal trajectory which bound the current flight segment.

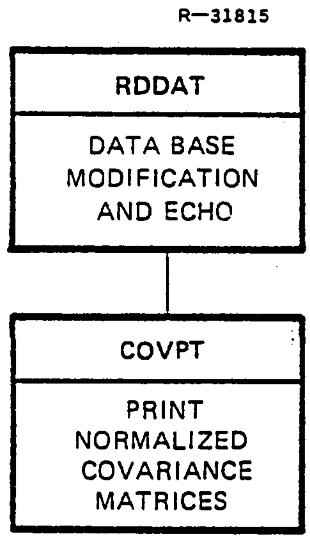

Figure 1.2-1 RDDAT Block Diagram

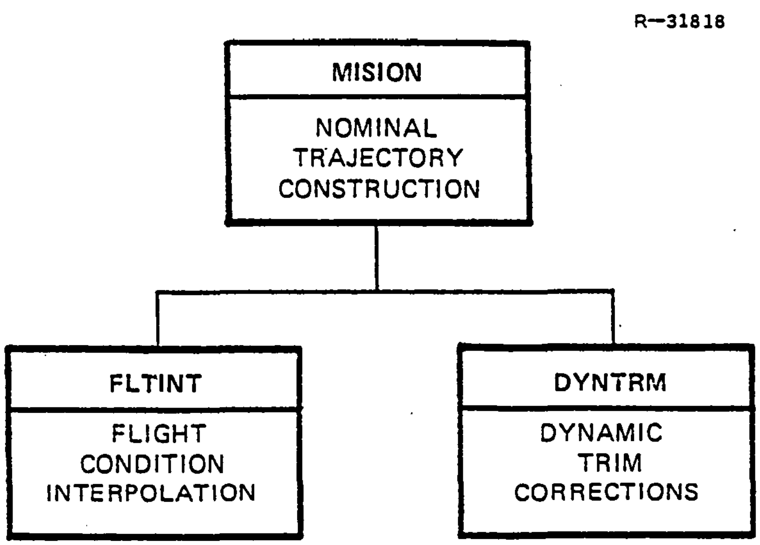

Figure 1.3-1 MISION Block Diagram

FLTINT interpolates values from aerodynamic coefficient data to determine system matrices. Aerodynamic coefficients are read from a permanent disk file on FORTRAN logical unit 1. If required, DYNTRM is called for circular and accelerating trajectories to calculate dynamic trim corrections and dynamic trim Euler angles.

1.4 STATE EQUATION INTEGRATION

RKGS (Fig. 1.4-1) was adapted from the IBM Scientific Subroutine Package (SSP) (Ref. 1). RKGS numerically solves a system of first-order differential equations using the fourth order Runge-Kutta Method with modifications due to Gill. The integration step-size is automatically adjusted to produce the desired degree of accuracy.

Subroutine MCON evaluates the derivatives of continuous states. MDIG records values of continuous states, propagates discrete states, executes sensor transformations, and calls the flight computer logic. MDIG calls MSUMRY if matrices used for intermediate time-history storage are full.

1.5 COVARIANCE EQUATION PROPAGATION

Subroutine INTEG (Fig. 1.5-1) numerically integrates a vector representing a covariance matrix by rectangular or trapezoidal integration techniques. PCON is called to calculate the derivative of covariance of continuous states. PDIG updates the nominal trajectory and calls subroutine PCMPTR to propagate covariance of discrete states from the flight computer. PDIG calls PSUMRY if intermediate time-history storage matrices are full.

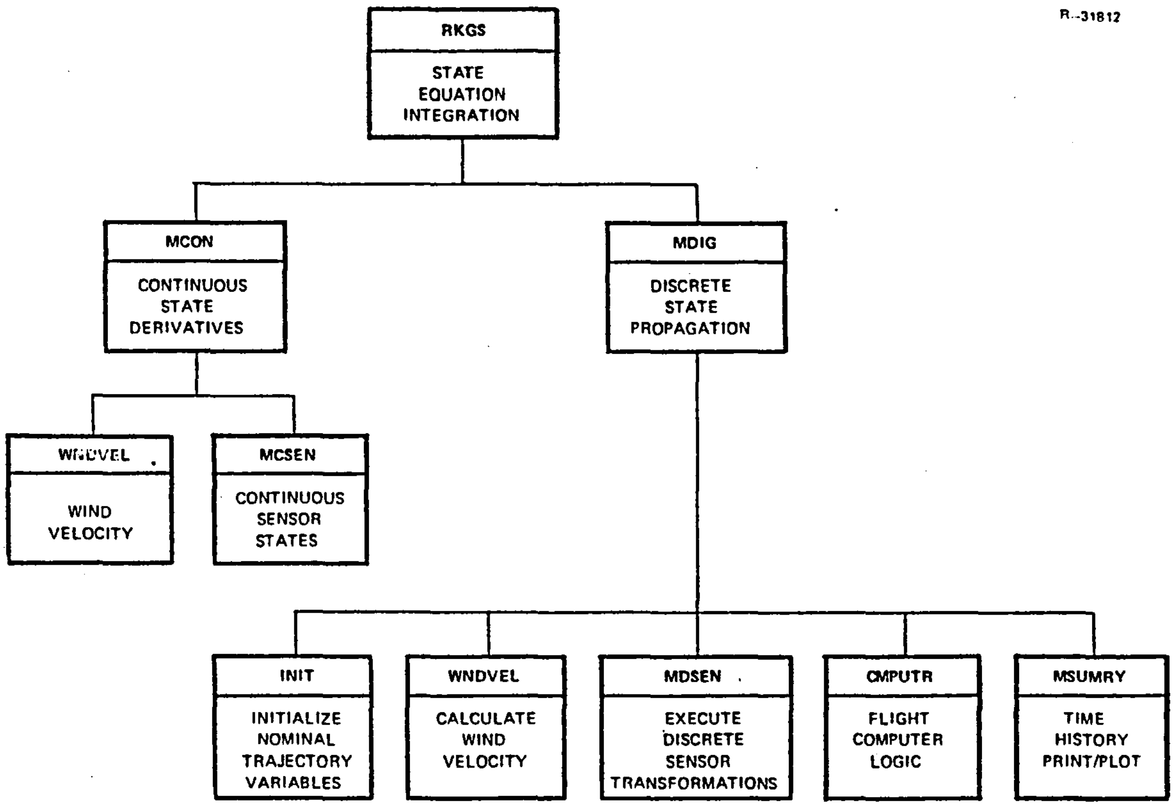

Figure 1.4-1   RKGS Block Diagram

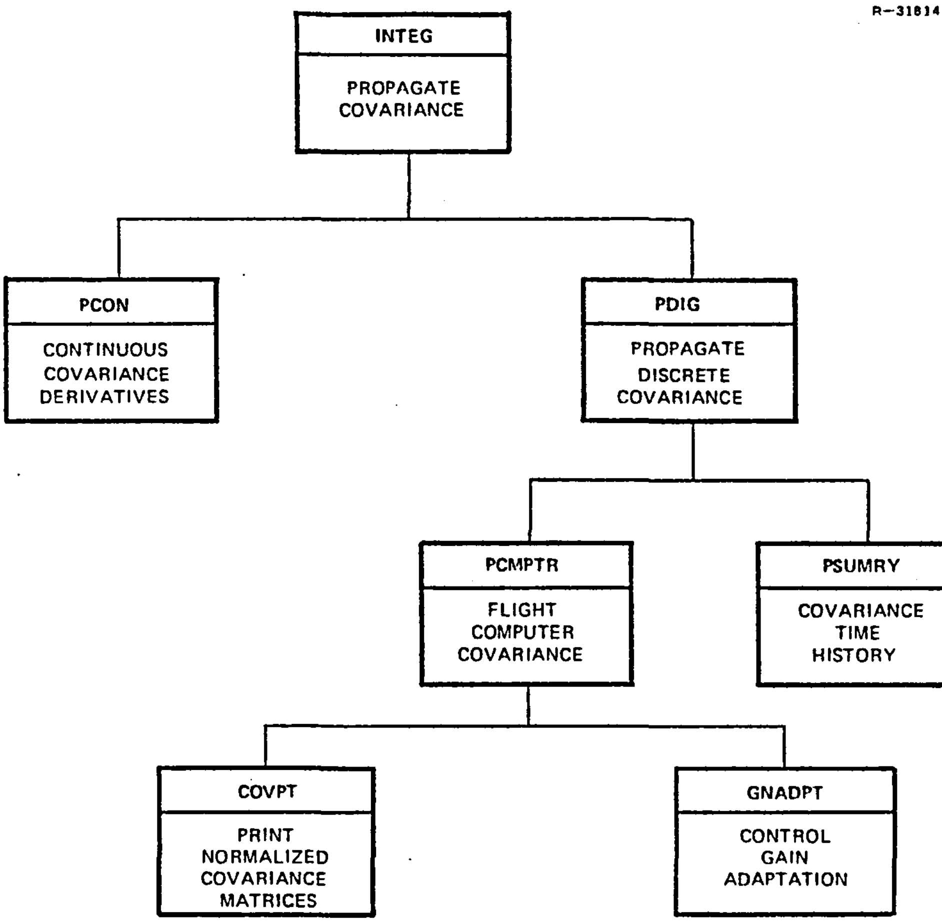

Figure 1.5-1 INTEG Block Diagram

1.6 FLIGHT COMPUTER LOGIC

Subroutine CMPUTR (Fig. 1.6-1) is designed to follow the helicopter flight computer logic described in References 2, 3 and 4.

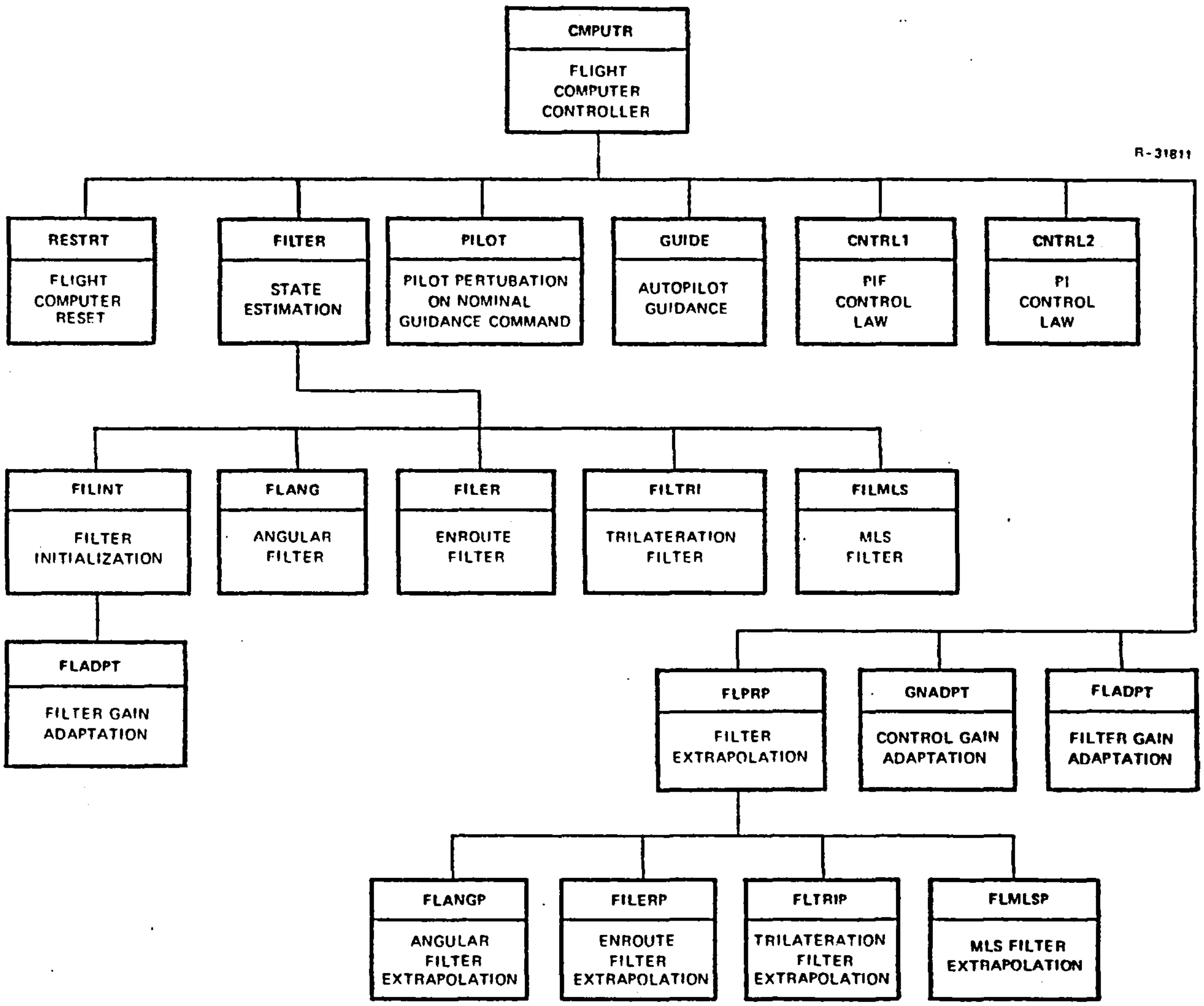

Figure 1.6-1 CMPUTR Block Diagram

The basic functions of CMPUTR, and the subroutines performing these functions are:

(1) Reset of flight computer (RESTRT)

(2) State estimation using sensor outputs (FILTER)

(3) Guidance command calculation
  (a) Nominal plus pilot perturbation (PILOT)
  (b) Autopilot using prestored guidance trajectory (GUIDE)

(4) Control command calculation
  (a) Proportional-Integral-Filter controller (CNTRL1)
  (b) Proportional-Integral controller (CNTRL2)

(5) Control gain scheduling (GNADPT)

(6) Filter gain scheduling (FLADPT)

(7) State estimate extrapolation (FLPRP)

1.7 TIME HISTORY SUMMARY

Subroutine MSUMRY (Fig. 1.7-1) produces a printed state time history,(by calling HPRINT) and plots a time history of selected elements of continuous and discrete state variables (by calling HPLOT).

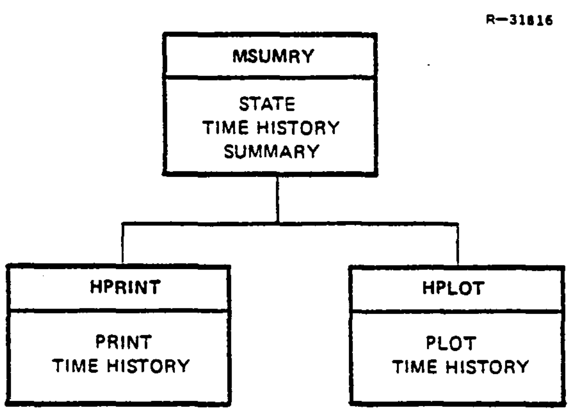

Figure 1.7-1 MSUMRY Block Diagram

PSUMRY (Fig. 1.7-2) prints the time history of selected elements of covariance matrices and plots selected covariance elements.

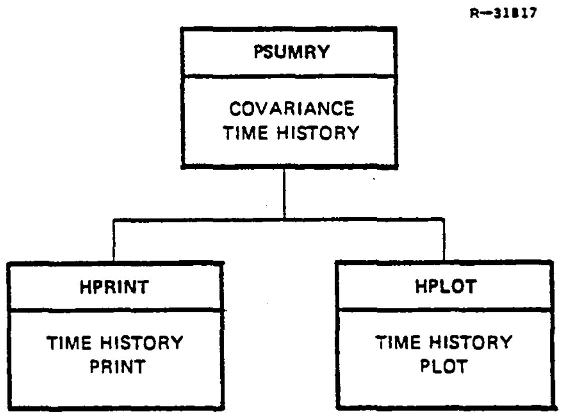

Figure 1.7-2 PSUMRY Block Diagram

2. TVHIS USAGE

TVHIS may be run in one of two modes. A mean trajectory simulation examines the motions of the helicopter in a neighborhood of a reference flight path. Covariance calculation propagates the covariance from initial conditions along a specific flight path, assuming proportional-integral-filter control with velocity guidance. The program can be used to evaluate the design of filters, guidance algorithms, and digital-adaptive control laws.

2.1 TVHIS INPUT

Input to TVHIS is in two parts: card-image input on FORTRAN logical unit 5, and flight aerodynamic coefficients on FORTRAN logical unit 1.

2.1.1 Card-Image Input

Card-image data on logical unit 5 starts with a single NAMELIST ($STACK) read by the main program containing the number of stacked cases (NCASES). It is followed by NCASES blocks of data each containing 14 NAMELISTS and control gain regression coefficients.

There are only a few general rules which govern the specification of values for input parameters through a NAMELIST. Letting STACK represent a general NAMELIST name, the first card in the input deck must contain a blank in the first column, $STACK starting in the second column, and a blank in column 8. The specification of individual data items then begins in column 9 of the first data card and continues on succeeding cards if necessary. A data item for an unsubscripted variable is of the form v = c where v is the program mnemonic and c is a constant (e.g., NCASES=10 and TIMRUN = 10.0). Data items for subscripted variables are of the form a = d_1, ... , d_j or the form a(n) = d_1, ..., d_m where a is the array name, n is an integer constant, and the d_i are simple constants or repeated constants of the form k * c where k is the repetition factor. With an unsubscripted array name, the total number of constants must equal the number of elements in the array (e.g., R = 5.0, 5.0, 15.0). With a subscripted array name, the total number of constants need not equal, but may not exceed, the number of array elements needed to fill the array starting with a(n) (e.g., TIMD(1) = 2.0 and TIMG(8) = 1.E7, 2.5E5). All data items must be separated by commas, and any desired number of blanks may be inserted between data items.

The end of a NAMELIST record is indicated by a $ after the last data item. The $ may appear directly after the last constant in the data item or may be separated by one or more blanks. For convenience in adding data items to a given NAMELIST, a comma may always be inserted after the last data item and the $, signaling the end of the NAMELIST, may be placed on a single card. Furthermore, to make the end of the CDC NAMELIST analogous to the end of the IBM NAMELIST, $END may be used in place of just a $.

Three other important points regarding NAMELIST input data should be made. First, there are no restrictions on the order in which the data items are arranged within the list. Second, the first column of every data card, not just the first card, must be left blank; all other 79 columns may be used. Third, the name of every NAMELIST to be read must appear in the input deck, even if no data items are specified for some NAMELIST.

Assuming a multiple-case run, data input to override defaults for case N become defaults for case N+1 and subsequent cases. For each of the NCASES runs, 14 namelists must appear in the input stream on logical unit 5, followed by control gain regression data. The format of this input deck is indicated in Fig. 2.1-1. NAMELIST input is described in Tables 2.1-1 through 2.1-21 specifying program mnemonic, a description of the variable, the units (if applicable) and a default value.

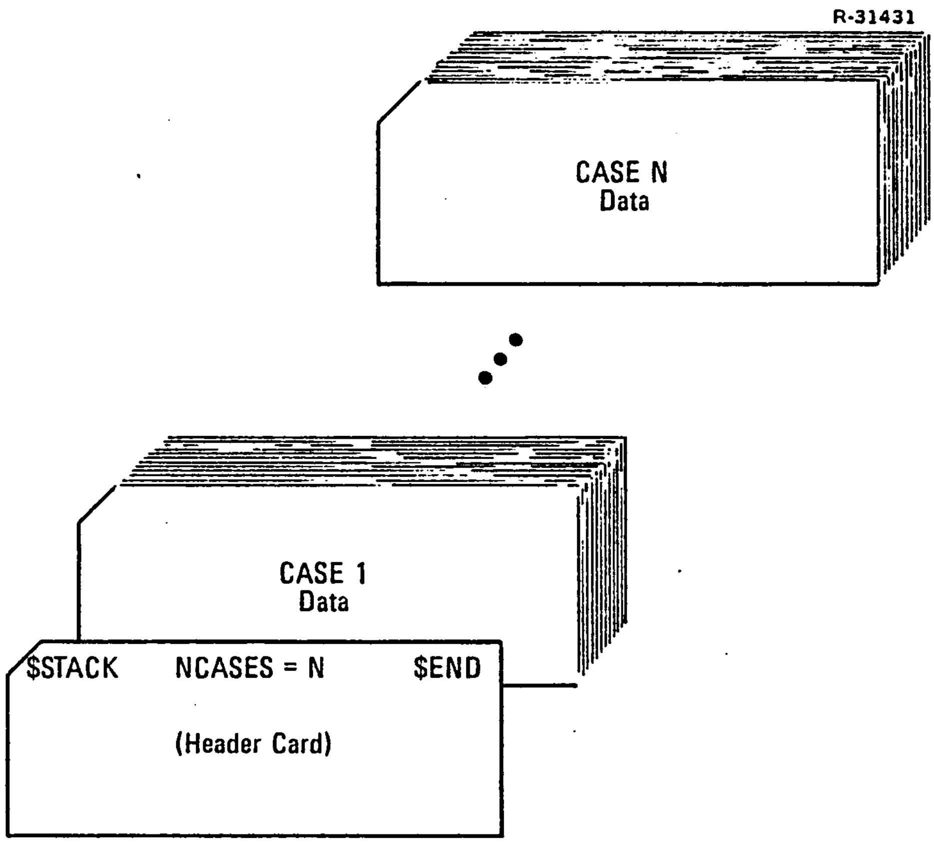

Figure 2.1-1 TVHIS Input on Logical Unit 5

TABLE 2.1-1

NUMBER OF STACKED CASES
(NAMELIST/STACK/)

T-1695

PROGRAM MNEMONIC	DESCRIPTION	UNITS	DEFAULT VALUE
NCASES	Number of stacked cases for this job	-	1

TABLE 2.1-2

INPUT/OUTPUT CONTROL
(NAMELIST/NINOU/)

T-1696

PROGRAM MNEMONIC	DESCRIPTION	UNITS	DEFAULT VALUE
KIN	Logical unit number for card-image input (if modified, subsequent card-image input will be read from logical unit KIN)	-	5
KDAT	Logical unit number for disk file containing aerocoefficient data	-	1
KOUT	Logical unit number for printed output (if modified subsequent print statements will write to KOUT)	-	6
IGNPT	Gain print flag: Produce reports of scheduled control, filter gains if > 0	-	1
INOMPT	Nominal state flag: Print time history of nominal state if > 0	-	1
KPLOT[3]	Plot control key		
KPLOT(1)	Plots produced if > 0	-	0
KPLOT(2)	Not used	-	0
KPLOT(3)	Not used	-	0
KPRINT[2]	Debug print control		
KPLOT(1)	Not used	-	0
KPLOT(2)	Produce filter debug printout if > 0	-	0

TABLE 2.1-3

INTEGRATION CONTROL PARAMETERS
(NAMELIST/NRKINT/)

T-1697

PROGRAM MNEMONIC	DESCRIPTION	UNITS	DEFAULT VALUE
ISTYPE	Simulation type = 1 mean trajectory simulation Runge-Kutta-Gill integration = 2 covariance calculation rectangular integration = 3 covariance calculation trapezoidal integration	-	1
ACCU	Accuracy limit for Runge-Kutta-Gill convergence test	-	0.0003
DXIC[80]	Initial value of state vector for Runge-Kutta-Gill integration	-	80*0.0
WT[80]	Vector of weights on state elements for Runge-Kutta-Gill integration Restriction: $\sum_{i=1}^{NDIM} WT(I) = 1.0$ where NDIM = 24 if actuator/rotor dynamics are on NDIM = 12 if actuator/rotor dynamics are off	-	3*0.03, 3*0.06, 6*0.1621667, 12*0.01, 56*0.0

TABLE 2.1-4

WIND AND SENSOR FLAGS
(NAMELIST/NREF/)

T-1698

PROGRAM MNEMONIC	DESCRIPTION	UNITS	DEFAULT VALUE
KTURB	Wind/turbulence flag = 0 no wind/turbulence = 1 wind/turbulence model	-	0
KSEN[3]	Sensor key	-	
KSEN(1)	= 0 set observation vector ZVCOBS (31-46) to 0.0 = 1 set ZVCOBS (31-46) to true state, control	-	1
KSEN(2)	Regulates angular rate, Euler angle sensors = 0 load true values = 1 corrupt true values with biases, noise	-	0
KSEN(3)	Regulates position/velocity sensors = 0 no position/velocity sensors = 1 "perfect" accelerometer, altimeter, true airspeed, sideslip measurements = 2 corrupted accelerometer, airspeed, altimeter, sideslip measurements = 3 (1) above plus "perfect" MLS measurement = 4 (2) above plus noisy MLS measurement = 5 (not implemented) sensor dynamics = 6 (1) above plus "perfect" trilateration position, velocity = 7 (2) above plus noise trilateration position, velocity	-	0

TABLE 2.1-5

NOMINAL TRAJECTORY
(NAMELIST/NMISS/)

T-1699

PROGRAM MNEMONIC	DESCRIPTION	UNITS	DEFAULT VALUE
XIND[3, 42]	Nominal position		Table 2.1-16
XIND(1, I)	Axial position at waypoint I	feet	
XIND(2, I)	Lateral position at waypoint I	feet	
XIND(3, I)	Normal position at waypoint I (negative of altitude)	feet	
VIND[3, 42]	Nominal velocity		Table 2.1-16
VIND(1, I)	Axial velocity at waypoint I	feet/sec	
VIND(2, I)	Lateral velocity at waypoint I	feet/sec	
VIND(3, I)	Normal velocity at waypoint I (positive down)	feet/sec	
TIMD[42]	Scheduled waypoint times		Table 2.1-16
TIMD(I)	Time at waypoint I	secs	
JTRAJ[42]	Trajectory type		
JTRAJ(I)	Trajectory type following waypoint	-	
	= 5 straight flight path	-	
	= 6 circular flight path	-	
	= 7 linear acceleration	-	
	= 8 turn entry		
NP	Total number of waypoints	-	42

TABLE 2.1-6

WIND INFORMATION
(NAMELIST/NWIND/)

T-1700

PROGRAM MNEMONIC	DESCRIPTION	UNITS	DEFAULT VALUE
TWIND[4]	Array of time keys for wind inputs		0.0, 5.0, 10.0, 15.0
TWIND(I)	Beginning time of I^{th} wind input (relative to initial time of simulation)	secs	
TWIND(I + 1)	Ending time of I^{th} wind input (relative to initial time of simulation)	secs	
VEWIND[3, 3]	Array of wind inputs in earth axes		
VEWIND(1, I)	Axial component of wind between TWIND (I) and TWIND (I + 1)	feet/sec	0.0, 10.0, 0.0
VEWIND(2, I)	Lateral component of wind between TWIND (I) and TWIND (I + 1)	feet/sec	0.0, 0.0, 10.0
VEWIND(3, I)	Normal component of wind between TIMD (I) and TIMD (I + 1)	feet/sec	0.9, 0.0, 0.0
QTURB [3, 3]	Turbulence driving noise covariance used for covariance calculation	-	9*0.0

TABLE 2.1-7

ROTOR/ACTUATOR DATA
(NAMELIST/NLIM/)

T-1701

PROGRAM MNEMONIC	DESCRIPTION	UNITS	DEFAULT VALUE
LIMKEY[2]	Actuator limit flags 0 = off 1 = on		
LIMKEY(1)	Actuator position limit key	-	0
LIMKEY(2)	Actuator rate limit key	-	0
UMIN[4]	Minimum actuator position vector	inches	-2.0, 0.0, -2.0, -2.0
UMAX[4]	Maximum actuator position vector UMAX, UMIN used when LIMKEY(1)=1	inches	2.0, 4.0 2.0, 2.0
UDTLIM[4]	Maximum absolute actuator rate UDTLIM used when LIMKEY(2) = 1	inches/sec.	3.0, 3.0, 3.0, 3.0
FROT[3]	Rotor dynamics description array	-	-576.0, 28.8 1440.0
TACT[4]	Actuator time constants	secs	4*0.0125
KACT	Actuator and rotor key = 0 no rotor, actuator dynamics (state dimension NDIM = 12) = 1 rotor, actuator dynamics modeled (state dimension NDIM = 24)	-	0

TABLE 2.1-8

INERTIAL CONSTANTS
(NAMELIST/NINERT/)

(NOTE: ALL VARIABLES ARE REAL)

T-1702

PROGRAM MNEMONIC	DESCRIPTION	UNITS	DEFAULT VALUE
IX	X-axis reference rotational inertia	slug-ft	37163.0
IY	Y-axis reference rotational inertia	slug-ft	20175.0
IZ	Z-axis reference rotational inertia	slug-ft	190059.0
IXP	Present X-axis rotational inertia	slug-ft	37163.0
IYP	Present Y-axis rotational inertia	slug-ft	20175.0
IZP	Present Z-axis rotational inertia	slug-ft	190059.0
IXZP	Present X-Z product rotational inertia	slug-ft^2	201750.0
MASS	Reference mass	slug	1027.0
MASSP	Present mass	slug	1027.0

TABLE 2.1-9

SENSOR DATA
(NAMELIST/NSENS/)

T-1703

PROGRAM MNEMONIC	DESCRIPTION	UNITS	DEFAULT VALUE
XAACT[3]	Location of MLS azimuth equipment		
XAACT(1)	Axial position	feet	10000.0
XAACT(2)	Lateral position	feet	0.0
XAACT(3)	Normal position	feet	-12.0
XEACT[3]	Location of MLS elevation equipment		
XEACT(1)	Axial position	feet	1000.0
XEACT(2)	Lateral position	feet	300.0
XEACT(3)	Normal position	feet	-12.0
XSACT	Location of on-board accelerometers forward of vehicle center of gravity	feet	0.83333
ZSACT	Location of on-board accelerometers below vehicle center of gravity	feet	1.66667
PHIB[3]	Diagonals of 3 × 3 accelerometer bias transition matrix		3 * 9.99E-1
PHIW[3]	Diagonals of 3 × 3 wind transition		3*9.96672E-1

TABLE 2.1-9 (CONTINUED)

SENSOR DATA
(NAMELIST/NSENS/)

T-1704

PROGRAM MNEMONIC	DESCRIPTION	UNITS	DEFAULT VALUE
Q[22]	Vector containing variance of non-time-varying sensor errors (biases, scale factors)		
Q(1)	MLS range bias	$feet^2$	2.56E02
Q(2)	MLS azimuth bias	$radians^2$	4.3681E-8
Q(3)	MLS elevation bias	$radians^2$	1.2100E-4
Q(4)	MLS range scale factor	-	0.00E00
Q(5)	Accelerometer bias - body x-axis	$(feet/sec^2)^2$	6.40E-1
Q(6)	Accelerometer bias - body y-axis	$(feet/sec^2)^2$	6.40E-1
Q(7)	Accelerometer bias - body z-axis	$(feet/sec^2)^2$	6.40E-1
Q(8)	Accelerometer scale factor - body x-axis	-	6.15E-10
Q(9)	Accelerometer scale factor - body y-axis	-	6.25E-10
Q(10)	Accelerometer scale factor - body z-axis	-	6.25E-10
Q(11)	Barometric altimeter bias	$feet^2$	1.0E-4
Q(12)	Barometric altimeter scale factor	$feet^2$	9.0E-4
Q(13)	Body roll angular rate gyro bias	$(rad/sec)^2$	2.74576E-5
Q(14)	Body pitch angular rate gyro bias	$(rad/sec)^2$	2.74576E-5
Q(15)	Body yaw angular rate gyro bias	$(rad/sec)^2$	2.74576E-5
Q(16)	Body roll angular rate gyro scale factor	-	4.00E-4
Q(17)	Body pitch angular rate gyro scale factor	-	4.00E-4
Q(18)	Body yaw angular rate gyro scale factor	-	4.00E-4
Q(19)	Indicated air speed (IAS) bias	$(feet/sec)^2$	2.50E-1
Q(20)	Indicated air speed (IAS) scale factor	-	2.50E-1
Q(21)	Sideslip (β) bias	$radians^2$	2.74576E-5
Q(22)	Sideslip scale factor	-	1.6E-2

TABLE 2.1-9 (CONTINUED)
SENSOR DATA
(NAMELIST/NSENS/)

T-1705

PROGRAM MNEMONIC	DESCRIPTION	UNITS	DEFAULT VALUE
R[22]	Vector containing variance of sensor noise*		
R(1)**	MLS range or trilateration axial position	$feet^2$	0.0
R(2)	MLS azimuth or trilateration lateral position	$radians^2$ or $feet^2$	0.0
R(3)	MLS elevation or trilateration normal position	$radians^2$ or $feet^2$	0.0
R(4)	Trilateration axial velocity	$(feet/sec)^2$	0.0
R(5)	Trilateration lateral velocity	$(feet/sec)^2$	0.0
R(6)	Trilateration normal velocity	$(feet/sec)^2$	0.0
R(7)	Accelerometer body x-axis	$(feet/sec^2)^2$	4.00E00
R(8)	Accelerometer body y-axis	$(feet/sec^2)^2$	4.00E00
R(9)	Accelerometer body z-axis	$(feet/sec^2)^2$	4.00E00
R(10)	Barometric altimeter	$feet^2$	6.25E02
R(11)	Roll Euler angle ϕ	$radians^2$	8.4681E-6
R(12)	Pitch Euler angle θ	$radians^2$	8.4681E-6
R(13)	Yaw Euler angle ψ	$radians^2$	8.4681E-4
R(14)	Body roll angular rate p	$(rad/sec)^2$	8.4681E-6
R(15)	Body pitch angular rate q	$(rad/sec)^2$	8.4681E-6
R(16)	Body yaw angular rate r	$(rad/sec)^2$	8.4681E-6
R(17)	Indicated airspeed IAS	$(feet/sec)^2$	2.8561
R(18)	Sideslip β	$radians^2$	7.62129E-5
R(19-22)	Control position	$inches^2$	4*0.0

* Interpretation of R for mean trajectory simulation.
**R(1-6) depend on range and are calculated by subroutine SENINT.

TABLE 2.1-9 (CONTINUED)
SENSOR DATA
(NAMELIST/NSENS/)

T-1706

PROGRAM MNEMONIC	DESCRIPTION	UNITS	DEFAULT VALUE
R[22]	Vector containing variance of sensor noise*		
R(1)	Axial position	$feet^2$	2.25
R(2)	Lateral position	$feet^2$	2.25
R(3)	Normal position	$feet^2$	2.25
R(4)	Body x-axis velocity	$(feet/sec)^2$	0.12
R(5)	Body y-axis velocity	$(feet/sec)^2$	0.64
R(6)	Body z-axis velocity	$(feet/sec)^2$	0.25
R(7)	Body roll rate	$(rad/sec)^2$	8.4681E-6
R(8)	Body pitch rate	$(rad/sec)^2$	8.4681E-6
R(9)	Body yaw rate	$(rad/sec)^2$	8.4681E-6
R(10)	Roll Euler angle	$radians^2$	8.4681E-6
R(11)	Pitch Euler angle	$radians^2$	8.4681E-6
R(12)	Yaw Euler angle	$radians^2$	3.0625E-4

*Interpretation of R for covariance run.

TABLE 2.1-10

FLIGHT COMPUTER CONTROL SWITCHES (NAMELIST/NCFWCH)

PROGRAM MNEMONIC	DESCRIPTION	UNITS	DEFAULT VALUE
NRESTR	signals flight computer reset when 1 (set to 0 after reset - should be set to 1 in each case of multiple-case run)	-	1
NAUTO	Guidance indicator = 0 automatic guidance = 1 pilot input	-	1
NCTYPE	Control type selector = 1 proportional integral filter control law = 2 proportional integral control law	-	1
NGTYPE	guidance type selector = 1 velocity guidance = 2 attitude guidance	-	1
KFIL[4]	Filter selection and mode setting		
KFIL(1)	Angular filter control ≤ 0 load true Euler angles, body angular rates as estimated = 1 bypass filter - copy sensed Euler angles, angular rates into estimates = 2 use angular filter with full trigonometric functions = 3 use angular filter with second-order approximations to sine, cosine functions	-	1
KFIL(2)	Controls enroute filter < 0 bypass enroute filter = 0 "perfect" enroute filter states-true values as estimates = 1 enroute filter, full trigonometric functions, sideslip = 2 enroute filter, full trigonometric functions, zero sideslip =3 enroute filter, sideslip, second-order approximate trig functions =4 enroute filter, pseudo-zero sideslip, second-order approximate trig function	-	2
KFIL(3)	Controls trilateration filter < 0 bypass trilateration filter = 0 true states as estimates = 1 filtered states, full trigonometric functions, sideslip = 2 filtered states, full trig functions, zero sideslip = 3 filtered states, sideslip, second-order approximate trig functions = 4 filtered states, zero sideslip, second-order approximate trig functions	-	2
KFIL(4)	Controls MLS filter. Switch settings same as for KFIL(3) - trilateration filter	-	2

TABLE 2.1-11

TIME PARAMETERS
(NAMELIST/NTINT/)

T-1708

PROGRAM MNEMONIC	DESCRIPTION	UNITS	DEFAULT VALUE
DTGUID	Time interval between successive guidance calls (PILOT or GUIDE)	seconds	0.1
DTFIL	Time interval between successive filter calls (measurement data rate)	seconds	0.1
DTCNTR	Time interval between successive calls to controller subroutine	seconds	0.1
DTADPT	Time interval between successive control gain calculations	seconds	1.0
DFADPT	Time interval between successive filter gain calculations	seconds	1.0
DTOUTP	Sample time interval for time history print/plot	seconds	0.05
TIMRUN	Elapsed time for simulation	seconds	1.0
NWPF	Waypoint number of nominal trajectory for start of simulation	-	1
TIMDEL	Time delay between control command calculation and its application	seconds	0.0
DTINT	Starting integration step size	seconds	0.05
TEVENT[6]	Time key for pilot input EVMAG(I) will be applied for all TIME ≥ TEVENT(I)	seconds	6*1.0E10
ITYP[6]	Control command element which EVMAG is to perturb (1-4)	-	6*1
EVMAG[6]	Magnitude of pilot event-will be applied as perturbation on nominal command	-	6*0.0

TABLE 2.1-12

PIF CONTROL COMMAND LIMITS
(NAMELIST/NCNTRL/)

T-1709

PROGRAM MNEMONIC	DESCRIPTION	UNITS	DEFAULT VALUE
COMLIM[2, 4]	Limits on control command output from PIF control law sent to actuators		
COMLIM(1, 1)	Lower limit on first element of control UVCCOM(1)	inches	-5.0
COMLIM(1, 2)	Lower limit on second element of control command UVCCOM(2)	inches	0.0
COMLIM(1, 3)	Lower limit on UVCCOM(3)	inches	-5.0
COMLIM(1, 4)	Lower limit on UVCCOM(4)	inches	-5.0
COMLIM(2, 1)	Upper limit on UVCCOM(1)	inches	5.0
COMLIM(2, 2)	Upper limit on UVCCOM(2)	inches	10.0
COMLIM(2, 3)	Upper limit on UVCCOM(3)	inches	5.0
COMLIM(2, 4)	Upper limit on UVCCOM(4)	inches	5.0

TABLE 2.1-13
PRE-STORED GUIDANCE TRAJECTORY
(NAMELIST/NGUIDE/)

T-1710

PROGRAM MNEMONIC	DESCRIPTION	UNITS	DEFAULT VALUE
TIMG[30]	Scheduled time at guidance waypoints	seconds	Table 2.1-17
XIG[3, 30]	Position at guidance waypoints	feet	Table 2.1-17
XIG(1, I)	Axial position at I^{th} waypoint	feet	
XIG(2, I)	Lateral position at I^{th} waypoint	feet	
XIG(3, I)	Normal position at I^{th} waypoint (negative of altitude)	feet	
VIG[3, 30]	Scheduled velocity at guidance waypoint		
VIG(1, I)	Axial component of velocity at I^{th} waypoint	feet/sec	Table 2.1-17
VIG(2, I)	Lateral component of velocity at I^{th} point	feet/sec	
VIG(3, I)	Normal component of velocity at I^{th} point (positive down)	feet/sec	
GVD[16, 30]	Schedule of guidance gains		
GVD(1-6, I)	4 × 4 guidance gain matrix between waypoint I and waypoint I + 1. This matrix is stored column-wise. Default is the following gain matrix at every waypoint: $\begin{bmatrix} 0.0000 & 0.0000 & 0.0000 & 0.0000 \\ 0.0000 & 0.0000 & 0.0000 & 0.0000 \\ 0.0000 & 0.0435 & 0.0000 & 0.0000 \\ 0.0454 & 0.0000 & 0.0000 & 0.0000 \end{bmatrix}$	-	3*0.0,-0.0454, 2*0.0,-0.0435, 12*0.0

TABLE 2.1-14

FILTER GAIN REGRESSION DATA
(NAMELIST/NFILDT/)

T-1711

PROGRAM MNEMONIC	DESCRIPTION	UNITS	DEFAULT VALUE
CONSTF[115]	Filter gain regression constants		
CONSTF(1-9)	Regression constants for angular filter gains	-	Table 2.1-18
CONSTF(10-20)	Regression constants for enroute filter gains	-	Table 2.1-19
CONSTF(21-54)	Regression constants for trilateration filter gains	-	Table 2.1-20
CONSTF(55-109)	Regression constants for MLS filter gains	-	Table 2.1-21
RCER[11, 2]	Enroute filter gain regression matrix	-	Table 2.1-19
RCTRI[34, 2]	Trilateration filter gain regression matrix	-	Table 2.1-20
RCMLS[55, 2]	MLS filter gain regression matrix	-	Table 2.1-21

TABLE 2.1-15

COVARIANCE MATRIX INITIALIZATION
(NAMELIST/NCOVAR/)

T-1712

PROGRAM MNEMONIC	DESCRIPTION	UNITS	DEFAULT VALUE
P11[12, 12]	Helicopter rigid-body state covariance	-	P11(I,J)=0.0 for I≠J P11(I,I)=1.0
P12[12, 5]	Helicopter state-turbulence covariance	-	60*0.0
P13[12, 4]	Helicopter state-control covariance	-	48*0.0
P14[12, 12]	Helicopter state-measurement covariance	-	144*0.0
P15[12, 4]	Helicopter state-controller state covariance	-	48*0.0
P22[5, 5]	Turbulence covariance	-	P22(I,J)=0.0 for I≠J P22(I,I)=1.0
P23[5, 4]	Turbulence-control covariance	-	20*0.0
P24[5, 12]	Turbulence-state measurement covariance	-	60*0.0
P25[5, 4]	Turbulence-controller state covariance	-	20*0.0
P33[4, 4]	Control covariance	-	16*0.0
P34[4, 12]	Control-state measurement covariance	-	48*0.0
P35[4, 4]	Control-controller state covariance	-	16*0.0
P44[12, 12]	State measurement covariance	-	144*0.0
P45[12, 4]	State measurement-controller covariance	-	48*0.0
P55[4, 4]	Controller state covariance	-	16*0.0

TABLE 2.1-16

HELICOPTER NOMINAL APPROACH TRAJECTORY (DEFAULT)

T-1713

WAYPOINT NUMBER	TIME	POSITION (FEET)			VELOCITY (FEET/SEC)			TRAJECTORY TYPE
(I)	TIMD(I)	XIND(1,J)	XIND(2,I)	XIND(3,I)	VIND(1,I)	VIND(2,I)	VIND(3,I)	JTRAJ(I)
1	0.0	-14000.00	-400.00	-750.00	-77.78	77.78	0.0	5
2	42.22	-17283.16	-716.50	-750.00	-77.78	77.78	0.0	5
3	43.21	-17360.94	-638.72	-750.00	-77.78	77.78	0.0	8
4	44.21	-17439.39	-561.61	-750.00	-79.80	75.76	0.0	6
5	74.00	-20400.00	-600.00	-750.00	-77.78	-77.78	0.0	6
6	104.30	-20400.00	-3600.00	-750.00	77.78	-77.78	0.0	6
7	134.59	-17400.00	-3600.00	-750.00	77.78	77.78	0.0	6
8	164.88	-17400.00	-600.00	-750.00	-77.78	77.78	0.0	6
9	195.17	-20400.00	-600.00	-750.00	-77.78	-77.78	0.0	6
10	225.47	-20400.00	-3600.00	-750.00	77.78	-77.78	0.0	6
11	255.76	-17400.00	-3600.00	-750.00	77.78	77.78	0.0	6
12-34	0.00	0.00	0.00	0.00	0.00	0.00	0.0	5
35	556.24	-3206.47	-0.7380	-482.30	110.00	2.95	8.333	8
36	557.24	-3096.47	0.2460	-473.97	110.00	0.00	8.333	5
37	557.62	-3055.00	0.00	-470.83	110.00	0.00	8.333	7
38	558.62	-2945.00	0.00	-462.84	110.00	0.00	7.640	7
39	592.67	-403.05	0.00	-202.80	40.33	0.00	7.640	7
40	612.17	-0.25	0.00	-53.82	0.01	0.00	7.640	7
41	613.17	0.00	0.00	-50.00	0.00	0.00	0.00	5
42	700.00	0.00	0.00	-50.00	0.00	0.00	0.00	5

Note: Waypoints 12-34 are not specified: default is 0.0

TABLE 2.1-17

GUIDANCE HELICOPTER APPROACH TRAJECTORY (DEFAULTS)

T-1714

WAYPOINT NUMBER (I)	TIME TIMG(I)	POSITION (FEET) XIG(1, I)	XIG(2, I)	XIG(3, I)	VELOCITY (FEET/SEC) VIG(1, I)	VIG(2, I)	VIG(3, I)
1	0.00	-14000.00	-4000.00	-750.00	-77.78	77.78	0.00
2	43.71	-14000.00	-600.00	-750.00	-77.78	77.78	0.00
3	74.00	-20400.00	-600.00	-750.00	-77.78	77.78	0.00
4	104.30	-20400.00	-3600.00	-750.00	-77.78	-77.78	0.00
5	134.59	-17400.00	-3600.00	-750.00	77.78	77.78	0.00
6	164.88	-17400.00	-600.00	-750.00	-77.78	77.78	0.00
7	195.17	-20400.00	-600.00	-750.00	-77.78	-77.78	0.00
8	225.47	-20400.00	-3600.00	-750.00	77.78	-77.78	0.00
9	255.76	-17400.00	-3600.00	-750.00	77.78	77.78	0.00
10	286.05	-17400.00	-600.00	-750.00	-77.78	77.78	0.00
11	306.62	-19000.00	1000.00	-750.00	-77.78	77.78	0.00
12	310.89	-19292.89	1292.89	-750.00	-77.78	77.78	0.00
13	327.62	-2000.00	3000.00	-750.00	0.00	110.00	0.00
14	370.46	-17000.00	6000.00	-750.00	110.00	0.00	0.00
15	379.55	-16000.00	6000.00	-750.00	110.00	0.00	0.00
16	388.65	-15000.00	6000.00	-750.00	110.00	0.00	0.00
17	417.21	-13000.00	4000.00	-750.00	0.00	-110.00	0.00
18	435.39	-13000.00	2000.00	-750.00	0.00	-110.00	0.00
19	452.62	-12292.89	292.89	-750.00	77.78	-77.78	0.00
20	456.39	-12000.00	0.00	-750.00	77.78	-77.78	0.00
21	482.10	-10000.00	-2000.00	-750.00	77.78	-77.78	0.00
22	485.87	-9707.11	-2292.89	-750.00	77.78	-77.78	0.00
23	503.11	-8000.00	-3000.00	-750.00	110.00	0.00	0.00
24	520.34	-6292.887	-2292.89	-750.00	77.78	77.78	0.00
25	524.11	-6000.00	-2000.00	-750.00	77.78	77.78	8.333
26	542.11	-4600.00	-600.00	-600.00	77.78	77.78	8.333
27	556.74	-3151.47	0.00	-478.13	110.00	0.00	7.640
28	558.12	-3000.00	0.00	-50.00	0.00	0.00	0.00
29	612.67	0.00	0.00	-50.00	0.00	0.00	0.00
30	700.00	0.00	0.00	-50.00	0.00	0.00	0.00

TABLE 2.1-18

ANGULAR FILTER GAINS

T-1715

CONSTF (1 - 3) ANGULAR RATE GAINS	CONSTF (4 - 9) EULER ANGLE GAINS
0.96500E00	0.27000E00
0.97200E00	0.27000E00
0.95400E00	0.51000E-1
	0.10000E00
	0.10000E00
	0.10000E00

TABLE 2.1-19

ENROUTE FILTER GAIN REGRESSION COEFFICIENTS

T-1716

INTERCEPT CONSTF (10-20)	Z RCER (1-11, 1)	1(1 + C*VSQ) RCER (1-11, 2)
0.31774E-01	0.14912E-05	-0.96219E-02
0.49825E-02	0.38229E-06	-0.18865E-02
-0.31335E-03	-0.30126E-07	0.12598E-03
0.94919E-01	-0.50738E-08	-0.19297E-02
0.96816E-01	-0.35453E-07	-0.17317E-01
0.10033E 00	0.12026E-06	0.39365E-01
0.62320E-01	0.72011E-07	0.34871E 00
-0.14322E-01	-0.19639E-07	-0.66174E-02
-0.78726E-02	-0.12211E-06	-0.59000E-01
0.49950E-02	0.0	0.0
0.99900E-01	0.0	0.0

TABLE 2.1-20

TRILATERATION FILTER GAIN REGRESSION COEFFICIENTS

INTERCEPT CONSTF (21-54)	1/(1 + (C*R)**E) RCTRI (1-34, 1)	1/(1 + C*R) RCTRI (1-34, 2)
0.87266E-02	0.55180E-01	0.0
0.20945E-02	0.0	0.33055E-01
0.30686E-01	-0.34960E-02	0.0
0.94916E-01	0.0	-0.44178E-01
0.94613E-01	0.0	-0.41878E-01
0.28455E-02	0.87670E-01	0.0
0.0	0.0	0.0
0.0	0.0	0.0
-0.40000E-03	0.0	0.0
-0.35000E-03	0.0	0.0
-0.28600E-02	0.0	0.0
-0.28600E 00	0.0	0.0
-0.16560E 00	-0.72509E-01	0.0
-0.30004E-03	0.0	0.0
0.73000E 00	0.0	0.0
0.83000E 00	0.0	0.0
0.38425E-03	0.17889E-03	0.0
0.37853E-03	0.0	-0.23919E-03
0.43860E-02	0.0	0.23444E-02
0.76756E-01	0.0	0.82652E 00
0.76743E-01	0.0	0.82647E 00
0.10000E-03	0.13964E 00	0.0
0.39584E-02	0.0	-0.39584E-02
0.46956E-02	0.0	-0.46956E-02
-0.16274E-04	-0.45481E-04	0.0
-0.13212E-04	0.0	0.0
-0.23207E-03	0.0	-0.41808E-03
-0.10239E-01	0.0	-0.14056E 00
-0.10229E-01	0.0	-0.14056E 00
-0.10000E-04	-0.19490E-01	0.0
-0.66239E-03	0.0	0.66239E-03
-0.79216E-03	0.0	0.79216E-02
0.49950E-02	0.0	0.0
0.99900E-01	0.0	0.0

TABLE 2.1-21

MLS FILTER GAIN REGRESSION COEFFICIENTS

T-1718

INTERCEPT CONSTF (55-109)	1/(1 + (C/10000)**2) RCMLS (1-55, 1)	1/(1 + (C/4000)**2) RCMLS (1-55, 2)
0.29967E-01	-0.29967E-01	0.0
0.50483E-01	0.0	0.24187E-02
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0
0.84110E-01	0.0	0.92004E-01
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0
0.54753E-01	0.0	0.40720E 00
0.55476E-01	0.0	-0.52387E-01
0.0	0.0	0.0
0.0	0.0	0.0
0.21183E 00	-0.20393E 00	0.0
-0.12830E-02	0.12830E-02	0.0
-0.13687E-01	0.0	0.77826E-02
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0
0.14515E 00	-0.20809E 00	0.0
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0
-0.11400E-02	0.0	-0.13700E-01
0.26239E 00	0.0	-0.24156E 00
0.0	0.0	0.0
0.0	0.0	0.0
0.40207E 00	0.0	-0.32034E 00
0.62502E-02	-0.62502E-02	0.0
0.13175E-01	0.0	0.13108E-02
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	-0.14500E 01
0.37412E-01	0.0	0.11095E 00
0.0	0.0	-0.15930E-02
-0.50568E 01	0.0	-0.94016E 02
0.0	0.0	-0.16427E-02
0.0	0.0	0.81765E 00
0.57857E-01	0.0	-0.55174E-01
0.0	0.0	0.0
0.0	0.0	0.0
0.66158E-01	0.0	-0.61397E-01
-0.48516E-03	0.48516E-03	0.0
-0.11712E-02	0.0	-0.15274E-03
0.0	0.0	0.0
0.0	0.0	0.0
0.11384E-02	0.0	0.27304E 00
-0.42761E-02	0.0	-0.15984E-01
0.0	0.0	0.24866E-03
-0.34148E-01	0.0	0.10587E 02
0.0	0.0	0.25607E-03
0.0	0.0	-0.12598E 00
-0.82047E-02	0.0	0.78379E-02
0.0	0.0	0.0
0.0	0.0	0.0
-0.10233E-01	0.0	0.93169E-02
0.49950E-02	0.0	0.0
0.99900E-01	0.0	0.0

Following all NAMELIST input, subroutine RDDAT reads values for control gain regressions into arrays REGCOF and CONST. Values for REGCOF are read row-wise, followed by values for CONST. If NCTYPE = 1 (PIF controller) 84 rows for REGCOF are read, followed by 84 values for CONSTF. If NCTYPE = 2 (PI controller) 52 rows for REGCOF are read, followed by 52 values for CONSTF. Each row of REGCOF is input using 3 card-image records, as follows:

Record 1	columns 1-10 must be blank or numeric - (I10). The information contained therein is ignored.
Record 2	REGCOF(I,J) J = 1, 2, 3, 4 are read under the FORMAT: E12.6, 6X, E12.6, 6X, E12.6, 6X, E12.6, 6X.
Record 3	REGCOF(I,J) J = 5, 6, 7, 8 are read under the FORMAT: E12.6, 6X, E12.6, 6X, E12.6, 6X, E12.6, 6X.

After 84 or 52 rows of REGCOF have been read (252 or 156 card-image records), values for CONSTF(I) are input, 4 to a record, under FORMAT: E12.6, 6X, E12.6, 6X, E12.6, 6X. CONSTF(I) contains the regression constant for the I^{th} gain. REGCOF(I,J) contains the sensitivity of the I^{th} gain the the J^{th} scheduling variables. The scheduling variables are:

1. VT-Total air-relative velocity (ft/sec)
2. W-Body z-axis velocity (ft/sec)
3. VT**2 Square of air-relative velocity ((ft/sec)**2)
4. PSIDOT-Body yaw Euler angle rate of change (rad/sec)
5. VT**2 * PSIDOT

6. W * PSIDOT
7. VT**2/(1 + C*VT**2)
8. 1/(1 + C*VT**2)

where:

C = 0.123E-3

2.1.2 Permanent Disk File

The disk file referenced by logical unit 1 contains data in a core-image format. It is read by subroutine FLTINT using an unformatted FORTRAN READ statement. The file contains 297 different cases of aerodynamic coefficients. Each case consists of 71 aerodynamic coefficients used to determine stability derivatives for the system matrix F. Each of the 297 different cases corresponds to a specific flight condition. The 3 variables which determine the exact flight condition are:

1. $\dot{\psi}$ -Rate of heading change (rad/sec)
2. VH-Horizontal velocity (knots)
3. VV-Vertical velocity (feet/min)

FLTINT interpolates between the aerodynamic coefficients for the two flight conditions which bracket the current flight condition.

2.2 TVHIS OUTPUT

Output from TVHIS is written to FORTRAN logical unit 6, unless variable KOUT has been changed in the namelist NINOU in which case all output is written to logical unit KOUT.

Output is functionally divided into 5 types:

1. Input data base summary from RDDAT
2. Special event reports from specific subroutines
3. Time history print
4. Time history plot
5. Error messages.

Each of these output types is described below.

2.2.1 Input Data Base Summary

Subroutine RDDAT produces a report on the TVHIS data base at the beginning of each case. Description paragraph numbers correspond to numbered areas in the accompanying figures.

Simulation control variables are printed as shown in Fig. 2.2-1.

1. The first data printed delimits the scope of the flight segment being considered; the initial waypoint on the nominal trajectory, and the final time along the nominal trajectory are printed.

2. The integration state dimension, NDIM, is printed next. For covariance calculation (ISTYPE = 2 or ISTYPE = 3) NDIM = 500. For a mean trajectory simulation, (ISTYPE = 1) NDIM depends on flag KACT from NAMELIST/NLIM/. For KACT = 0, NDIM = 12 (12 rigid-body states will be used). For KACT = 1, NDIM = 24 (12 rigid-body states, 4 actuator states, 8 rotor states).

INPUT REPORT FROM RDDAT

1. FLIGHT FROM WAYPOINT NO. 1 TO A TRAJECTORY TIME OF 2.0 SECS

2. DIMENSION OF STATE: 500

3a. COVARIANCE CALCULATION: ISTYPE = 2

CONTINUOUS STATES

12 RIGID BODY STATES
5 TURBULENCE STATES

DISCRETE STATES

4 CONTROL COMMANDS
12 PIGID-BODY STATE ESTIMATES
4 INTEGRATOR STATES

3b. MEAN TRAJECTORY SIMULATION: ISTYPE = 1

INTEGRATION ACCURACY LIMIT IS 0.3000000E-03

INTEGRATION STATE WEIGHTS

0.3236246E-02	0.3236246E-02	0.3236246E-02	0.6472491E-02	0.6472491E-02
0.6472491E-02	0.1618212E 00	0.1618212E 00	0.1618212E 00	0.1618212E 00
0.1618212E 00	0.1618212E 00			

4. OUTPUT TIME INTERVAL - DTOUTP = 0.05000 SECS

Figure 2.2-1 Simulation Control Variables

3a. For a covariance calculation, ISTYPE indicates the integration method.

ISTYPE = 2 Rectangular Integration

ISTYPE = 3 Trapezoidal Integration

3b. For a mean trajectory simulation, the accuracy limit, ACCU for Runge-Kutta integration, as well as state weighting vector WT, are printed.

4. Output time interval, DTOUPT, is the time between successive samples for time history PRINT/PLOT.

Pilot input time history and the nominal trajectory are printed in the format of Fig. 2.2-2.

5. A pilot perturbation command history is printed if guidance is manual and ISTYPE = 1 .

```
COMMAND VECTOR ELEMENT = ITYPE(I)
TIME                   = TEVENT(I)
PERTURBATION MAGNITUDE = EVMAG(I)
```

The perturbation magnitude EVMAG(I) will be applied as a perturbation on the ITYP(I)th element of the nominal guidance command for all TIME $\geq$ TEVENT(I).

5. PILOT PERTURBATION COMMAND HISTORY

COMMAND VECTOR ELEMENT = 3	TIME = 0.10000E 11	PERTURBATION MAGNITUDE = 0.0
COMMAND VECTOR ELEMENT = 1	TIME = 0.10000E 11	PERTURBATION MAGNITUDE = 0.0
COMMAND VECTOR ELEMENT = 1	TIME = 0.10000E 11	PERTURBATION MAGNITUDE = 0.0
COMMAND VECTOR ELEMENT = 1	TIME = 0.10000E 11	PERTURBATION MAGNITUDE = 0.0
COMMAND VECTOR ELEMENT = 1	TIME = 0.10000E 11	PERTURBATION MAGNITUDE = 0.0
COMMAND VECTOR ELEMENT = 1	TIME = 0.10000E 11	PERTURBATION MAGNITUDE = 0.0

6. NOMINAL TRAJECTORY

```
WAYPOINT NO.  1
TIME =      0.0  SECS   POSITION = -0.1400000E 05     -0.4000000E 04     -0.7500000E 03     FEET
                        VELOCITY = -0.7778000E 02      0.7778000E 02      0.0               FEET PER SEC
                        TRAJECTORY TYPE:   STRAIGHT FLIGHT      JTRAJ =   5

WAYPOINT NO.  2
TIME =     42.21 SECS   POSITION = -0.1728316E 05     -0.7165000E 03     -0.7500000E 03     FEET
                        VELOCITY = -0.7778000E 02      0.7778000E 02      0.0               FEET PER SEC
                        TRAJECTORY TYPE:   STRAIGHT FLIGHT      JTRAJ =   5

WAYPOINT NO.  3
TIME =     43.21 SECS   POSITION = -0.1736094E 05     -0.6387200E 03     -0.7500000E 03     FEET
                        VELOCITY = -0.7778000E 02      0.7778000E 02      0.0               FEET PER SEC
                        TRAJECTORY TYPE:   TURN ENTRY           JTRAJ =   8
```

Figure 2.2-2 Pilot Input, Nominal Trajectory

6. NOMINAL TRAJECTORY is printed in all cases, (Fig. 2.2-2) starting with the initial waypoint, and continuing with all waypoints in the nominal trajectory. WAYPOINT NUMBER I is printed, followed by:

```
TIME                         = TIMD(I)
EARTH-RELATIVE POSITION = XIND(1,I), XIND(2,I), XIND(3,I)
EARTH-RELATIVE VELOCITY = VIND(1,I), VIND(2,I), VIND(3,I)
TRAJECTORY TIME              = trajectory type of the
                               segment between waypoint I
                               and waypoint I+1.
```

If the current case is a covariance calculation, then noise matrices are printed, as described in Fig. 2.2-3.

7. Diagonals of turbulence driving noise, QTURB(3,3) are printed.

8. Variance of sensor noise on 12 rigid-body states R(1-12) is printed. Position noise R(1-3) affects earth-relative position x, y, z. Velocity noise R(4-6) affects body-axis velocity u, v, w. Angular rate noise R(7-9) affects body angular rates p, q, r.

Angular noise R(10-12) affects Euler angles ϕ, θ, ψ. RDDAT will then call COVPT to print the normalized forms of initial covariance matrices.

If the current case is a mean trajectory simulation aircraft and sensor data are printed in the format of Fig. 2.2-4.

9. If no wind inputs are specified (KTURB = 0) this fact is indicated. If KTURB = 1, scheduled wind inputs are printed.

```
7.        TURBULENCE DRIVING NOISE VARIANCE

                    QTURB(1,1) =     0.0
                    QTURB(2,2) =     0.0
                    QTRUB(3,3) =     0.0


8.        EFFECTIVE NOISE ON FILTER OUTPUT :

               POSITION NOISE VARIANCE

                    R(1) =     0.0                FT**2
                    R(2) =     0.0                FT**2
                    R(3) =     0.0                FT**2

               VELOCITY NOISE VARIANCE

                    R(4) =     0.0                FPS**2
                    R(5) =     0.0                FPS**2
                    R(6) =     0.0                FPS**2

               ANGULAR RATE NOISE VARIANCE

                    R(7) =     0.400000E 01       RAD/SEC**2
                    R(8) =     0.400000E 01       RAD/SEC**2
                    R(9) =     0.400000E 01       RAD/SEC**2

               ANGULAR NOISE VARIANCE

                    R(10) =    0.625000E 03       RAD**2
                    R(11) =    0.846810E-05       RAD**2
                    R(12) =    0.846810E-05       RAD**2
```

Figure 2.2-3   Noise Covariance Matrices

9. NO WIND OR TURBULENCE INPUTS

AIRCRAFT DATA

10. PERFECT ANGLE AND ANGULAR RATE MEASUREMENTS

11. PERFECT POSITION AND VELOCITY MEASUREMENTS

13. NO ACTUATOR POSITION LIMITS

14. NO ACTUATOR RATE LIMITS

Figure 2.2-4 Aircraft and Sensor Data

10. If noisy angular rate and angular sensors are in use, the variance of sensor noise on these states is printed.

11. If accelerometers are modeled, their location relative to vehicle center of gravity is printed.

12. If MLS or trilateration sensors are in use, the location of MLS azimuth and elevation towers is printed.

13. If actuator displacement limits are to be used, (LIMKEY(1) = 1) they are printed; if they are not in use, this fact is indicated.

14. If actuator rate limits are to be used, (LIMKEY(2)= 1) the limits are printed; if rate limits are not used, this fact is indicated.

Whether a mean trajectory simulation or a covariance calculation is being processed, the status of flight computer control memory is printed in the format of Fig. 2.2-5 (paragraphs 15 through 20).

15. Flight computer control switches are printed.

NRESTR	should be 1 to indicate flight computer reset at beginning of case
NAUTO	0 indicates automatic guidance 1 indicates manual guidance (nominal plus pilot perturbation)
NCTYPE	CONTROL TYPE = 1 PIF controller = 2 PI controller
NGTYPE	= 1 velocity guidance = 2 attitude guidance
KFIL(1)	controls angular filter

FLIGHT COMPUTER DATA

15. FLIGHT COMPUTER CONTROL SWITCHES

NRESTR = 1

NAUTO = 0

NCTYPE = 1

NGTYPE = 1

KFIL(1) = 1
KFIL(2) = -1
KFIL(3) = -1
KFIL(4) = 1

16. GUIDANCE TIME INTERVAL - DTGUID = 0.10000 SECS

CONTROL TIME INTERVAL - DTCNTR = 0.10000 SECS

FILTER TIME INTERVAL - DTFIL = 0.10000 SECS

GAIN ADAPTATION TIME INTERVAL - DTADPT = 1.00000 SECS

FILTER ADAPTATION INTERVAL - DFADPT = 1.00000 SECS

CONTROL APPLICATION TIME DELAY -TIMDEL = 0.0 SECS

17. CONTROL COMMAND LOWER LIMITS : -5.0000 0.0 -5.0000 -5.0000

CONTROL COMMAND UPPER LIMITS : 5.0000 10.0000 5.0000 5.0000

Figure 2.2-5 Flight Computer Control Settings

KFIL(2)	controls enroute filter
KFIL(3)	controls MLS filter
KFIL(4)	controls trilateration filter

16. Flight computer time intervals are printed.

DTGUID	time between successive guidance calculations
DTCNTR	time between successive control calculations
DTFIL	time between filter calculations-data sample rate
DTADPT	time between successive control gain calculations
DFADPT	time between successive filter gain calculations
TIMDEL	delay between time control command is calculated and time it is sent to actuators

17. Lower and Upper limits on PIF control command push-down are printed.

18. Control gain regression coefficients. CONSTF and REGCOF are printed (Fig. 2.2-5). CONST appears under the heading "Intercept", and REGCOF is printed column-wise, with the gain-scheduling variable for each column as a header.

19. If a mean trajectory simulation is in progress, the filter gain regression coefficients for each of the filters in use (angular, enroute, MLS, trilateration) are printed in the format of Fig. 2.2-6. For the angular filter, all gains are constant. For enroute, MLS, and trilateration filters, regression constants from CONSTF are printed under the heading "Intercept", while regression coefficients RCER, RCMLS, and RCTRI are printed in two columns. The column heading indicates which scheduling variable is involved.

18. CONTROL GAIN PEGRESSION COEFFICIENTS

INTERCEPT	CAPV	W	CAPV-SQ	PSIDOT
-0.30848E-01	-0.20237E-04	0.87452E-04	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.40751E-02	0.95208E-05	-0.76142E-04	0.0	0.0
0.53717E-01	-0.37956E-03	0.0	0.76644E-06	0.0
0.0	0.0	0.0	0.0	0.0
0.30907E-01	0.21606E-05	-0.49992E-04	0.0	0.0
-0.42676E-02	0.34963E-04	0.17552E-04	0.0	0.0
0.28526E-02	-0.17409E-04	-0.50477E-04	0.0	0.0
-0.76382E-01	0.33052E-03	0.0	-0.61299E-06	0.0
-0.13502E-02	0.28716E-04	0.48202E-04	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.54155E 00	-0.10457E-02	-0.24157E-02	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.43587E 00	-0.14592E-01	0.97721E-03	0.0	0.0
0.37982E 01	0.10090E-02	0.22799E-02	0.96354E-05	-0.58140E 00
0.16926E-02	-0.15654E-05	-0.11939E-05	0.0	0.0
0.18015E-02	-0.13856E-04	0.0	0.24608E-07	0.0

PSIDOT*VSQ	PSIDOT*W	VSQ/(1+C*VSQ)	1/(1+C*VSQ)
-0.79836E-06	0.0	-0.98840E-06	0.0
0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0
0.37048E-05	0.0	-0.50554E-06	0.0
0.0	-0.19132E-02	0.0	-0.52693E-01
0.0	0.0	0.0	0.0
0.10280E-05	0.0	-0.56398E-06	0.0
0.21262E-06	0.0	-0.12279E-05	0.0
0.18130E-05	0.0	0.64943E-06	0.0
0.0	0.11408E-03	0.0	0.30802E-01
0.11190E-04	0.0	-0.64132E-06	0.0
0.0	0.0	0.0	0.0
0.39518E-03	0.0	-0.37883E-04	0.0
0.0	0.0	0.0	0.0
-0.16762E-03	0.0	0.36835E-03	0.0
0.0	0.0	0.0	0.0
0.11553E-07	0.0	0.78379E-08	0.0
0.0	-0.55982E-05	0.0	-0.17413E-02

Figure 2.2-6 Control Gain Regression Coefficients

19. ENROUTE FILTER

INTERCEPT	Z	1/(1+C*VSO)
0.31774E-01	0.14912E-05	-0.96219E-02
0.49825E-02	0.38229E-06	-0.18865E-02
-0.31335E-03	-0.30126E-07	0.12598E-03
0.94919E-01	-0.50738E-08	-0.19297E-02
0.96816E-01	-0.35453E-07	-0.17317E-01
0.10033E 00	0.12026E-06	0.39365E-01
0.62320E-01	0.72011E-07	0.34871E 00
-0.14322E-01	-0.19639E-07	-0.66174E-02
-0.78726E-02	-0.12211E-06	-0.59000E-01
0.49950E-02	0.0	0.0
0.99900E-01	0.0	0.0

20. GUIDANCE TRAJECTORY

```
WAYPOINT NO.  1
TIME =      0.0  SECS    POSITION = -0.1400000E 05      -0.4000000E 04      -0.7500000E 03          FEET
                         VELOCITY = -0.7778000E 02       0.7778000E 02       0.0                    FEET PER SEC
GUIDANCE GAINS
 0.0           -0.20500E 01  -0.23200E 01  -0.58400E-01  -0.39200E 00  -0.50000E 00  -0.52000E-01  -0.20700E 00
-0.14400E 00    0.0           0.0           0.0           0.0           0.0           0.0           0.0

WAYPOINT NO.  2
TIME =     43.71 SECS    POSITION = -0.1740000E 05      -0.6000000E 03      -0.7500000E 03          FEET
                         VELOCITY = -0.7778000E 02       0.7778000E 02       0.0                    FEET PER SEC
GUIDANCE GAINS
 0.0           -0.20500E 01  -0.23200E 01  -0.58400E-01  -0.39200E 00  -0.50000E 00  -0.52000E-01  -0.20700E 00
-0.14400E 00    0.0           0.0           0.0           0.0           0.0           0.0           0.0
```

Figure 2.2-7   Filter Gain Regression Coefficients

20. If guidance is automatic (NAUTO = 0), the full guidance trajectory is printed as in Fig. 2.2-7. Earth-relative position and velocity vectors for the I^{th} waypoint are followed by the 4×4 guidance gain matrix printed columnwise, 2 columns per line.

```
WAYPOINT NO = guidance waypoint I
TIME        = TIMG(I)
POSITION    = XIG(1,I), XIG(2,I), XIG(3,I)
VELOCITY    = VIG(1,I), VIG(2,I), VIG(3,I)
```

2.2.2 Special Event Reports

Special event reports from subroutines are described in Tables 2.2-1 through 2.2-11. The contents are: report title, description of variables in the report, and the subroutine originating the report.

2.2.3 Time History Printout

Time history printout appears as a series of pages, each with up to 9 columns of data. The first column is the sample time, and each succeeding column represents the value of a specific variable at the time given in column 1 (Fig. 2.2-8).

2.2.4 Time History Plot

Time history plots are printer plots with the time axis described down the page, and the values of up to 3 variables represented by separate symbols across the page. The distance between the maximum and minimum value of the variable is represented by 120 print positions across the page, Fig. 2.2-9. Labels, descriptions, and program source variables for time history printout and plots are described in Table 2.2-12. Time history prints and plots occur either at the end of a run, or whenever 201 samples of program data have been taken and the intermediate storage arrays TIM, PXC, and PXD are full.

TIME SEC	DEL-B IN	DEL-C IN	XE FT	ZE FT	THETA DEG	U FPS	Q DEG/SEC	W FPS
0.0	-0.7231	3.2171	-14000.0000	-750.0000	2.9380	109.8529	0.0	5.6378
0.0500	-0.7231	3.2171	-14003.8867	-750.0000	2.9380	109.8529	0.0	5.6378
0.1000	-0.7231	3.2171	-14007.7773	-750.0000	2.9380	109.8529	0.0	5.6378
0.1500	-0.7231	3.2171	-14011.6641	-750.0000	2.9380	109.8529	0.0000	5.6378
0.2000	-0.7231	3.2171	-14015.5547	-750.0000	2.9380	109.8529	0.0000	5.6378
0.2500	-0.7231	3.2171	-14019.4414	-750.0000	2.9380	109.8529	0.0000	5.6378
0.3000	-0.7231	3.2171	-14023.3320	-750.0000	2.9380	109.8529	0.0001	5.6378
0.3500	-0.7230	3.2171	-14027.2227	-750.0000	2.9380	109.8529	0.0002	5.6378
0.4000	-0.7230	3.2171	-14031.1094	-750.0000	2.9380	109.8529	0.0003	5.6379
0.4500	-0.7229	3.2171	-14035.0000	-750.0000	2.9380	109.8529	0.0004	5.6379
0.5000	-0.7229	3.2171	-14038.8867	-750.0000	2.9380	109.8529	0.0006	5.6380
0.5500	-0.7229	3.2171	-14042.7773	-750.0000	2.9381	109.8529	0.0008	5.6381
0.6000	-0.7229	3.2171	-14046.6641	-750.0000	2.9381	109.8529	0.0010	5.6382
0.6500	-0.7228	3.2171	-14050.5547	-750.0000	2.9382	109.8529	0.0012	5.6383
0.7000	-0.7228	3.2171	-14054.4453	-749.9998	2.9382	109.8529	0.0015	5.6384
0.7500	-0.7228	3.2171	-14058.3320	-749.9998	2.9383	109.8529	0.0017	5.6386
0.8000	-0.7228	3.2171	-14062.2227	-749.9998	2.9384	109.8528	0.0019	5.6388
0.8500	-0.7228	3.2171	-14066.1094	-749.9998	2.9385	109.8528	0.0022	5.6390
0.9000	-0.7228	3.2171	-14070.0000	-749.9998	2.9386	109.8528	0.0024	5.6392
0.9500	-0.7228	3.2171	-14073.8906	-749.9998	2.9387	109.8528	0.0026	5.6394
1.0000	-0.7228	3.2171	-14077.7773	-749.9998	2.9389	109.8528	0.0028	5.6397
1.0500	-0.7229	3.2171	-14081.6680	-749.9998	2.9390	109.8527	0.0030	5.6400
1.1000	-0.7229	3.2171	-14085.5547	-749.9998	2.9392	109.8527	0.0031	5.6402
1.1500	-0.7229	3.2171	-14089.4453	-749.9998	2.9393	109.8527	0.0033	5.6405
1.2000	-0.7229	3.2171	-14093.3320	-749.9998	2.9395	109.8526	0.0034	5.6408
1.2500	-0.7230	3.2171	-14097.2227	-749.9998	2.9397	109.8526	0.0035	5.6411
1.3000	-0.7230	3.2171	-14101.1094	-749.9998	2.9398	109.8525	0.0036	5.6414
1.3500	-0.7230	3.2171	-14105.0000	-749.9998	2.9400	109.8524	0.0036	5.6417
1.4000	-0.7230	3.2171	-14108.8945	-749.9998	2.9402	109.8524	0.0036	5.6420
1.4500	-0.7231	3.2170	-14112.7813	-749.9998	2.9404	109.8523	0.0036	5.6423
1.5000	-0.7231	3.2170	-14116.6719	-749.9998	2.9406	109.8522	0.0036	5.6426
1.5500	-0.7232	3.2170	-14120.5586	-750.0000	2.9408	109.8522	0.0036	5.6429
1.6000	-0.7232	3.2170	-14124.4492	-750.0000	2.9409	109.8521	0.0036	5.6432
1.6500	-0.7232	3.2170	-14128.3398	-750.0000	2.9411	109.8520	0.0035	5.6435
1.7000	-0.7232	3.2170	-14132.2305	-750.0000	2.9413	109.8519	0.0034	5.6437
1.7500	-0.7233	3.2170	-14136.1172	-750.0000	2.9415	109.8518	0.0033	5.6440
1.8000	-0.7233	3.2170	-14140.0117	-750.0000	2.9416	109.8517	0.0032	5.6442
1.8500	-0.7233	3.2170	-14143.8984	-750.0000	2.9418	109.8516	0.0031	5.6444
1.9000	-0.7233	3.2170	-14147.7891	-750.0000	2.9419	109.8515	0.0030	5.6447
1.9500	-0.7234	3.2170	-14151.6836	-750.0002	2.9421	109.8514	0.0028	5.6449
2.0000	-0.7234	3.2170	-14155.5703	-750.0002	2.9422	109.8513	0.0027	5.6451

Figure 2.2-8 Sample Time History Printout

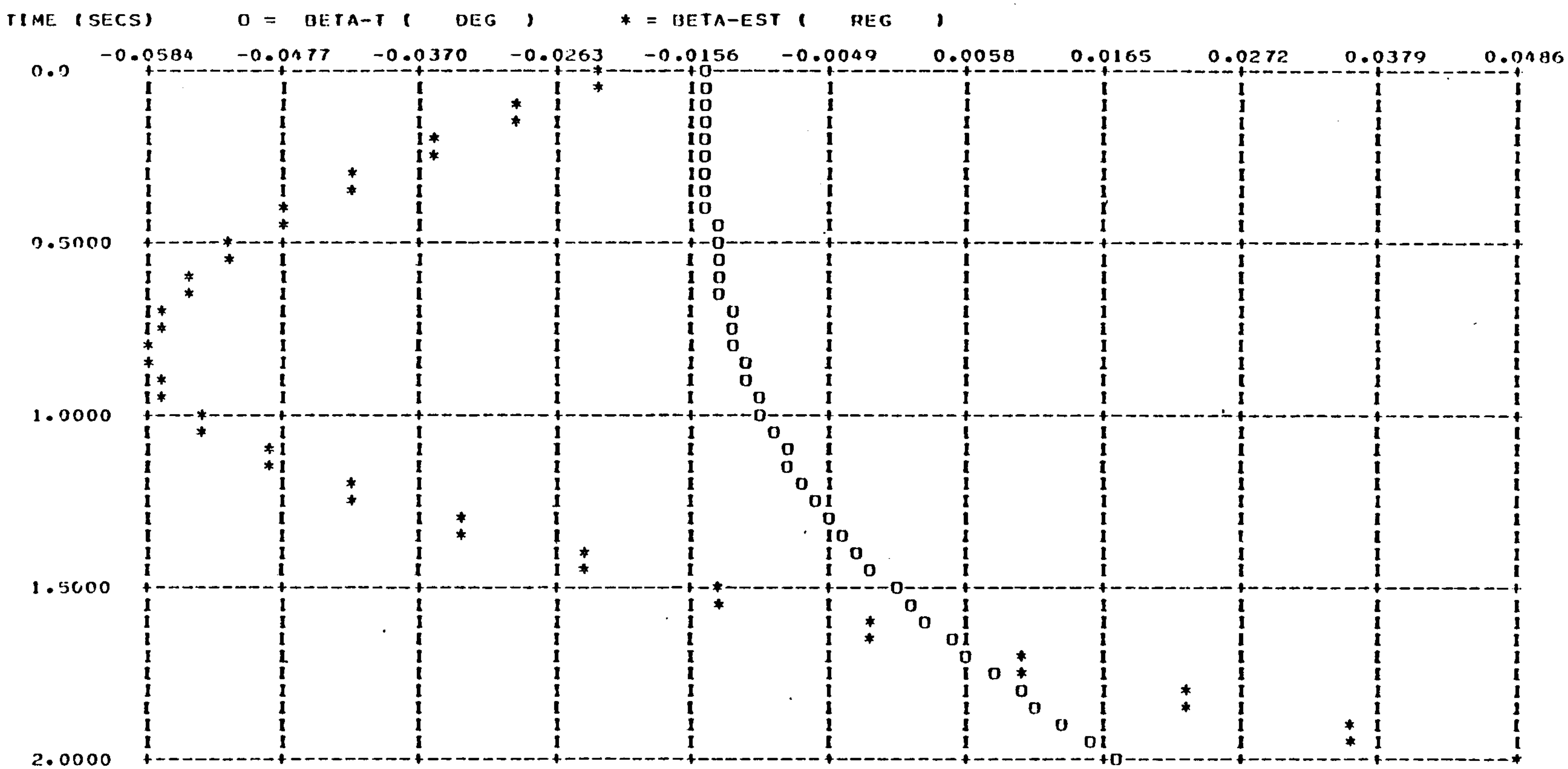

Figure 2.2-9 Sample Time History Plot

2.2.5 Error Messages

There are three possible error messages from TVHIS. All indicate fatal errors, and all will be followed by abnormal program termination. The first error message is caused by an attempt to run a mean trajectory simulation with an invalid control-guidance combination. The three correct combinations of control type and guidance type are printed along with the entered control/guidance type, and program execution is terminated by RDDAT.

A second error message is a result of an attempt to run a covariance calculation with NCTYPE $\neq$ 1 or NGTYPE $\neq$ 1. The covariance routines are only programmed for PIF velocity control. Program is terminated by RDDAT.

A third error message is caused by failure of the Runge-Kutta-Gill integration routine RKGS to converge. Subroutine RKGS first integrates a state vector over a given interval using a step-size of DTINT and then repeats the integration using a step-size of DTINT/2. Letting S1 and S2 represent the state vectors after the two integrations, respectively, the following sum is computed:

$$E = \sum_{I=1}^{NDIM} WT(I)\ (S2(I) - S1(I))$$

If E > ACCU, the specified accuracy limit, the value of DTINT is halved, and the whole process is repeated. If this convergence test fails after 10 bisections of the step-size DTINT, RKGS will return a value of 11 in variable IHLF. If the main program receives a value of 11 for IHLF from RKGS, it will call MSUMRY for the final PRINT/PLOT for this case and then abnormally terminate the program, indicating that there was an error in RKGS.

Corrections for the first 2 types of errors involve entering the proper values of NCTYPE and NGTYPE in NAMELIST /NCFWCH/. The third type of error may be due to one of the following:

- Accuracy limit ACCU in NAMELIST/NRKGS/ was smaller than machine precision allows
- State weight vector WT contained improper values (recall $\sum_{I} WT(I) = 1.0$)
- There was an abrupt discontinuity in the time history of one or more elements of the state vector possibly due to:
  - unreasonable perturbation EVMAG in NAMELIST /NTINT/
  - incorrect control gains input
  - incorrect guidance gains GVD in NAMELIST /NGUIDE/
  - incorrect filter gains in NAMELIST/NFILDT/
  - unreasonable wind magnitude VEWIND in NAMELIST/NWIND/.

TABLE 2.2-1
SPECIAL EVENT REPORT - MISION

T-1694

REPORT TITLE	DESCRIPTION - VARIABLES	SUBROUTINE
DESCRIPTION OF WAYPOINT AT BEGINNING/END OF SEGMENT	TIME HORIZONTAL VELOCITY - VH - magnitude of velocity in horizontal plane VERTICAL VELOCITY - W - velocity in vertical plane HEADING - PSI - course or heading of helicopter HEADING RATE - PSIDOT - time rate of heading change HEADING ACCELERATION- PSIDOT - time rate of change heading rate SYSTEM MATRIX F 12×12 system dynamics matrix INPUT MATRIX G 6×4 matrix determining effect of control input on derivative of "inner 6" states TURBULENCE INPUT MATRIX HT 6×3 matrix determining effect of wind turbulence on derivatives of "inner 6" states NOMINAL STATE - XVNO, XVN1 - nominal helicopter, state vector XVNO (1-3) Helicopter position - x, y, z XVNO (4-6) Body-axis velocity - u, v, w XVNO (7-9) Body angular rates - p, q, r XVNO (10-12) Euler Angles - ϕ, θ, ψ XVNO (13-16) Control Position - δ_B, δ_C, δ_S, δ_R XVNO (17-20) Control rate - $\dot{\delta}_B$, $\dot{\delta}_C$, $\dot{\delta}_S$, $\dot{\delta}_R$ XVNO (21-24) Actuator command - δ_{BA}, δ_{CA}, δ_{SA}, δ_{RA} DYNAMIC TRIM ANGULAR RATES -XDYNO (4-6) or XDYN1 (4-6) DYNAMIC TRIM EULER ANGLES -DNUSTO or DNUST1 DYNAMIC TRIM CONTROL VECTOR - DUSTO or DUST1	MISION

TABLE 2.2-2

SPECIAL EVENT REPORT - SENINT

T-1719

REPORT TITLE	DESCRIPTION - VARIABLES	SUBROUTINE
REPORT FROM SUBROUTINE SENINT	VARIANCE OF NON-TIME-VARYING SENSOR ERRORS. Q[22]is printed. NON-TIME-VARYING SENSOR ERRORS SVCTRU. Actual values of biases and scale factors used in simulation. SVCTRU(I) is a random number drawn from a Gaussian distribution with mean of 0.0 and variance Q(I) VARIANCE OF SENSOR NOISE. Array R[22]is printed. A description of arrays Q, R, and be found in the input description for NAMELIST/NSENS/ (Table 2.1-9)	SENINT

TABLE 2.2-3

SPECIAL EVENT REPORT - MAIN

T-1720

REPORT TITLE	DESCRIPTION - VARIABLES	SUBROUTINE
REPORT FROM MAIN PROGRAM	INITIAL TIME TIM0 Times at 2 waypoints deter- FINAL TIME TIM1 - mining current flight segment INTEGRATION INTERVAL - Initial step-size for integration DTINT STATE INITIAL CONDITION - XVEC-value of perturbation state vector at beginning of integration	MAIN
REPORT FROM MAIN PROGRAM	TOTAL VALUE OF STATE VECTOR AT ENDPOINT - XVCTRU - total state vector at segment end = XVNTRU + XVEC NEW VALUE OF NOMINAL STATE VECTOR - XVNTRU - new nominal state from MISION NEW VALUE OF PERTURBATION STATE VECTOR - XVEC = XVCTRU - XVNTRU	MAIN
NORMAL EOJ	Job has completed processing normally.	MAIN

TABLE 2.2-4

SPECIAL EVENT REPORT - MDIG

T-1721

REPORT TITLE	DESCRIPTION - VARIABLES	SUBROUTINE
THIS IS A STRAIGHT SEGMENT	VELNOM - Nominal velocity vector (linear segment initialization ITRAJ = 5)	MDIG
THIS IS A STEADY SPIRAL SEGMENT	ZDOT - Normal velocity component PSIDOT - Heading rate of change R - Radius of circular path covered/radian of heading change XC - Axial position YC - Lateral position (Circular segment initialization ITRAJ = 6)	MDIG
THIS IS A LINEAR ACCELERATION SEGMENT	VELNOM - Nominal velocity vector ACCNOM - Nominal acceleration ACCBAX - Nominal body-axes acceleration DUVN - Nominal control rate of change PHIDOT - Rate of change of nominal roll Euler angle ϕ THETDT - Rate of change of nominal pitch Euler angle θ (Linear acceleration segment initialization ITRAJ = 7)	MDIG
THIS IS A TURN ENTRY SEGMENT	VELNOM - Nominal velocity ACCNOM - Nominal acceleration ACCBAX - Nominal body-axes acceleration DUVN - Nominal control rate of change PHIDOT - Rate of change of nominal roll Euler angle THETDT - Rate of change of normal pitch Euler angle UDOT - Body angular accelerator PSIDOT - Rate of change of body yaw Euler angle PSIDOT - Rate of change of PSIDOT (Turn entry initialization ITRAJ = 8)	MDIG
REPORT CONCERNING NOMINAL TRAJECTORY INITIALIZATION	TOUTNX: Time of next sample for time history PRINT/PLOT TIME: Current time FDT: 12×12 matrix representing rate of change of system dynamics matrix F GDT: 6×4 matrix representing rate of change of command input matrix G HTDT: 6×3 matrix representing rate of change of turbulence input matrix HT	MDIG

TABLE 2.2-5

SPECIAL EVENT REPORT - FLADPT

T-1723

REPORT TITLE	DESCRIPTION - VARIABLES	SUBROUTINE
REPORT FROM SUBROUTINE FLADPT	ANGULAR FILTER GAINS FILGA FILGA(I) = CONSTF(I), I = 1, 9 MLS FILTER GAINS FLGMLS FLGMLS(I) = CONSTF(54 + I) + (1 + (RE/100000)^2)*RCMLS(1, I) + (1 + (RE/4000)^2)*RCMLS(2, I) where RE = range to MLS elevation equipment TRILATERATION FILTER GAINS FLGTRI FLGTRI(I) = CONSTF(10 + I) + (1 + (R/500)^2)*RCTRI(1, I) + (1 + R/1000)*RCTRI(2, I) where R = total range from (0, 0, 0) ENROUTE FILTER GAINS FILGER FILGER(I) = CONSTF(1 + I) + Z*RCER(1, I) + (1 + V*Z*123.E-6)*RCER(2, I) where Z = estimated normal position (negative of altitude) V = estimated velocity magnitude	FLADPT

TABLE 2.2-6a

SPECIAL EVENT REPORT - CMPUTR

T-1724a

REPORT	DESCRIPTION - VARIABLES	SUBROUTINE
REPORT FROM SUBROUTINE CMPUTR	TIME - Time of call to CMPUTR	CMPUTR

TABLE 2.2-6b

SPECIAL EVENT REPORT - CNTRL1

T-1724b

REPORT	DESCRIPTION - VARIABLES	SUBROUTINE
REPORT FROM SUBROUTINE CNTRL1	CNTRL1 FIRST CALL INITIALIZATION UVCCOM - Control command (true = estimate) YDTCOM - Guidance command push-down (control integrator state) CONTROL COMMAND IS - Control command to be sent to actuators	CNTRL1

TABLE 2.2-6c

SPECIAL EVENT REPORT - CNTRL2

T-1724c

REPORT	DESCRIPTION - VARIABLES	SUBROUTINE
REPORT FROM SUBROUTINE CNTRL2	CNTRL2 FIRST CALL UVCCOM - Control command (true = estimate) YDTCOM - Guidance command CONTROL COMMAND IS - Control command to be sent to actuators	CNTRL2

TABLE 2.2-7

SPECIAL EVENT REPORT - GNADPT

T-1725

REPORT TITLE	DESCRIPTION - VARIABLES	SUBROUTINE
REPORT FROM GNADPT	Only issued if IGNPT = 1 (from NAMELIST/NINOU) Prints three gain scheduling variables, gains AIR RELATIVE VELOCITY MAGNITUDE - VT BODY Z-AXIS VELOCITY - W PSIDOT - $\dot{\phi}$ STATE FEEDBACK MATRIX CX - 4×9 matrix LOW-PASS FILTER MATRIX CV - 4×4 matrix COMMAND INPUT MATRIX CY - 4×4 matrix COMMAND FEED-FORWARD MATRIX CYD - 4×4 matrix	GNADPT

TABLE 2.2-8
SPECIAL EVENT REPORT - FILINT

T-1726

REPORT TITLE	DESCRIPTION - VARIABLES	SUBROUTINE
REPORT FROM SUBROUTINE FILINT	FILTER INITIALIZATION - Initial estimates set to true values (report only if KPRINT(2)>0) EARTH-RELATIVE POSITION - XIP/XIM EARTH-RELATIVE WIND - WIP/WIM BODY-AXES VELOCITY - VBP/VBM ACCELEROMETER BIAS - BBP/BBM BODY ANGULAR RATES - ARP/ARM EULER ANGLES - EAP/EAM AIR-RELATIVE VELOCITY - VAP/VAM EARTH-RELATIVE VELOCITY - VEP/VEM TRUE AIRSPEED - VTASP/VTASM SIDESLIP - BETAP/BETAM MLS MEASUREMENTS - AMLSP/AMLSP IFLAGV - if 0 do not use air data if 1 use air data for all states if 2 use air data only to update wind IFLAGW - 0 propagate wind state 1 do not propagate state K1 - if 1, transition between velocity > 50 kts and < 50 kts TIME1 - end of transition stage - < 50 kts to > 50 kts TIME2 - end of transition stage - > 50 kts to < 50 kts VTAS1 - previous true airspeed estimate IFLGRM - MLS range flag HBE(3×3) - body to earth-axes transformation HEB=(HBE)^T-earth-axes to body-axes transformation HME(3×3) - MLS-to-earth-axes transformation HEM(3×3) - (HME)$^{-1}$ earth-to-MLS transformation HBA(3×3) - body-to-air transformation HAB(3×3) - (HBA)$^{-1}$ air-to-body transformation ALB(3×3) - body angular rate to Euler angular rate transformation	FILINT

TABLE 2.2-9

SPECIAL EVENT REPORT - FILTER

T-1728

REPORT TITLE	DESCRIPTION - VARIABLES		SUBROUTINE
REPORT FROM SUBROUTINE FILTER	If KPRINT(2) is set > 0 (by NAMELIST/NINOU/) then full debug printout (Table 2.2-8) is produced during filter update and filter propagate. The following are printed in all cases:		FILTER
	XEEST	earth-relative position estimate $(\hat{x}, \hat{y}, \hat{z})$	
	XVREST	reduced state vector estimate $(\hat{u}, \hat{v}, \hat{w}, \hat{p}, \hat{q}, \hat{r}, \hat{\sigma}, \hat{\theta}, \hat{\phi})$	
	UVCEST	estimated control $(\hat{\delta}_B, \hat{\delta}_C, \hat{\delta}_S, \hat{\delta}_R)$	
	VEEST	earth-relative velocity estimate $(\hat{\dot{x}}, \hat{\dot{y}}, \hat{\dot{z}})$	
	VWEST	earth-relative wind estimate $(\widehat{wx}, \widehat{wy}, \widehat{wz})$	
	ZVCOBS	observation vector from sensors	
	ZVCOBS(1-3)	MLS or trilateration position	
	ZVCOBS(4-6)	trilateration velocity	
	ZVCOBS(7-9)	accelerometer outputs	
	ZVCOBS(10)	barometric altimeter	
	ZVCOBS(11-13)	Euler angle measurements	
	ZVCOBS(14-16)	body angular rates	
	ZVCOBS(17)	indicated airspeed	
	ZVCOBS(18)	sideslip	
	ZVCOBS(19-22)	control position	
	ZVCOBS(23-27)	not used	
	ZVCOBS(28-30)	wind in body axes (true)	
	ZVCOBS(31-42)	true rigid-body state XVCTRU	
	ZVCOBS(31-46)	true control command UVCTRU	

TABLE 2.2-10

SPECIAL EVENT REPORT - GUIDE

T-1729

REPORT TITLE	DESCRIPTION - VARIABLES	SUBROUTINE
REPORT FROM SUBROUTINE GUIDE	GUIDANCE WAYPOINT NUMBER: INUM, the index into the prestored guidance trajectory such that current time, TIME $\geq$ TIMG(INUM) TIMG - time at current guidance waypoint TIMG(INUM) TIME(NEXT) - time at next guidance waypoint TIMG(INUM + 1) DELTAT - TIMG(INUM + 1) - TIMG(INUM): DT FAC: Fraction of current segment completed XIG - position (x, y, z) at waypoint INUM XIG(NEXT) - position (x, y, z) at waypoint INUM + 1 VIG - scheduled velocity ($\dot{x}$, $\dot{y}$, $\dot{z}$) at waypoint INUM VIG(NEXT) - scheduled velocity ($\dot{x}$, $\dot{y}$, $\dot{z}$) at waypoint INUM + 1 GUIDANCE GAINS - 4×4 guidance gain matrix at waypoint INUM EARTH-RELATIVE POSITION ERROR - DX difference between estimated position XEEST and scheduled guidance position XEG EARTH-RELATIVE VELOCITY ERROR - DV difference between estimated velocity VEEST and scheduled guidance velocity VEG EARTH-RELATIVE ACCELERATION ERROR - DVDOT difference between estimated velocity rate and guidance scheduled velocity rate VELOCITY GUIDANCE COMMAND VECTOR - YDTCOM ($\dot{x}_c$, $\dot{y}_c$, $\dot{z}_c$, $\dot{\psi}_c$) ATTITUDE GUIDANCE COMMAND VECTOR - YDTCOM (θ_c, ϕ_c, $\dot{z}_c$, ψ_c)	GUIDE

TABLE 2.2-11

SPECIAL EVENT REPORT - COVPT

T-1730

REPORT TITLE	DESCRIPTION - VARIABLES	SUBROUTINE
HELICOPTER STATE SDC MATRIX	$X(I,I) = \sqrt{P11(I,I)}$ $X(I,J) = \frac{P11(I,J)}{\sqrt{P11(I,I)\ P11(J,J)}}$ $\quad I \neq J$	COVPT
HELICOPTER TURBULENCE CORRELATION	$X(I,J) = \frac{P12(I,J)}{\sqrt{P11(I,I)\ P12(J,J)}}$	COVPT
HELICOPTER CONTROL CORRELATION MATRIX	$X(I,J) = \frac{P13(I,J)}{\sqrt{P11(I,I)\ P13(J,J)}}$	COVPT
HELICOPTER ESTIMATE CORRELATION MATRIX	$X(I,J) = \frac{P14(I,J)}{\sqrt{P11(I,I)\ P14(J,J)}}$	COVPT
HELICOPTER CONTROLLER CORRELATION MATRIX	$X(I,J) = \frac{P15(I,J)}{\sqrt{P11(I,I)\ P15(J,J)}}$	COVPT
TURBULENCE SDC MATRIX	$X(I,I) = \sqrt{P22(I,I)}$ $X(I,J) = \frac{P22(I,J)}{\sqrt{P22(I,I)\ P11(J,J)}}$ $\quad I \neq J$	COVPT
TURBULENCE CONTROL CORRELATION MATRIX	$X(I,J) = \frac{P23(I,J)}{\sqrt{P22(I,I)\ P33(J,J)}}$	COVPT
TURBULENCE ESTIMATE CORRELATION MATRIX	$X(I,J) = \frac{P24(I,J)}{\sqrt{P22(I,I)\ P44(J,J)}}$	COVPT
TURBULENCE CONTROLLER CORRELATION MATRIX	$X(I,J) = \frac{P25(I,J)}{\sqrt{P22(I,I)\ P55(J,J)}}$	COVPT

TABLE 2.2-11 (CONTINUED)
SPECIAL EVENT REPORT - COVPT

T-1731

REPORT TITLE	DESCRIPTION - VARIABLES	SUBROUTINE
CONTROL SDC MATRIX	$X(I,I) = \sqrt{P33(I,I)}$	
	$X(I,J) = \dfrac{P33(I,J)}{\sqrt{P33(I,I)\ P33(J,J)}}$ $\quad I \neq J$	COVPT
CONTROL ESTI- MATE CORRELA- TION MATRIX	$X(I,J) = \dfrac{P34(I,J)}{\sqrt{P33(I,I)\ P44(J,J)}}$	COVPT
CONTROL CON- TROLLER CORRE- LATION MATRIX	$X(I,J) = \dfrac{P35(I,J)}{\sqrt{P33(I,I)\ P55(J,J)}}$	COVPT
ESTIMATE SDC MATRIX	$X(I,I) = \sqrt{P44(I,I)}$	
	$X(I,J) = \dfrac{P44(I,J)}{\sqrt{P44(I,I)\ P44(J,J)}}$ $\quad I \neq J$	COVPT
ESTIMATE CON- TROLLER CORRE- LATION MATRIX	$X(I,J) = \dfrac{P45(I,J)}{\sqrt{P44(I,I)\ P45(J,J)}}$	COVPT
CONTROLLER SDC MATRIX	$X(I,I) = \sqrt{P55(I,I)}$	COVPT
	$X(I,J) = \dfrac{P55(I,J)}{\sqrt{P55(I,I)\ P55(J,J)}}$ $\quad I \neq J$	

TABLE 2.2-12
TIME HISTORY PRINT/PLOT

T-1732

LABEL	DESCRIPTION		SOURCE VARIABLE
TIME	Time of output sample		TIME
DEL-B	Pitch control-differential collective	δ_B	UVCTRU(1)
DEL-C	Vertical velocity control collective	δ_C	UVCTRU(2)
XE	Earth-relative axial position	x	UVCTRU(1)
ZE	Earth-relative normal position	z	XVCTRU(3)
THETA	Pitch Euler angle	θ	XVCTRU(11)
U	Body x-axis velocity	u	XVCTRU(4)
Q	Body pitch angular rate	q	XVCTRU(8)
W	Body z-axis velocity	w	XVCTRU(6)
V	Body y-axis velocity	v	XVCTRU(5)
R	Body yaw angular rate	r	XVCTRU(9)
P	Body roll angular rate	p	XVCTRU(7)
PHI	Roll Euler angle	ϕ	XVCTRU(10)
PSI	Yaw Euler angle	Ψ	XVCTRU(12)
YE	Earth-relative lateral position	y	XVCTRU(2)
DEL-S	Roll control-cyclic	δ_S	UVCTRU(3)
DEL-R	Yaw control-differential cyclic	δ_R	UVCTRU(4)
XEDOT	Earth-relative axial velocity	$\dot{x}$	$H_B^E\begin{pmatrix}U\\V\\W\end{pmatrix}$
YEDOT	Earth-relative lateral velocity	$\dot{y}$	
ZEDOT	Earth-relative normal velocity	$\dot{z}$	
DB-N	Nominal pitch control-differential collective	δ_B	UVNTRU(1)
DC-N	Nominal vertical velocity control-collective	δ_C	UVNTRU(2)
XE-N	Nominal earth-relative axial position	x	XVNTRU(1)
ZE-N	Nominal earth-relative normal position	z	XVNTRU(3)
THETA-N	Nominal pitch Euler angle	θ	XVNTRU(11)
U-N	Nominal body x-axis velocity	u	XVNTRU(4)
Q-N	Nominal body pitch rate	q	XVNTRU(8)
W-N	Nominal body z-axis velocity	w	XVNTRU(6)
V-N	Nominal body y-axis velocity	v	XVNTRU(5)
R-N	Nominal body yaw rate	r	XVNTRU(9)

TABLE 2.2-12 (CONTINUED)
TIME HISTORY PRINT/PLOT

T-1733

LABEL	DESCRIPTION		SOURCE VARIABLE
P-N	Nominal body roll rate	p	XVNTRU(7)
PHI-N	Nominal roll Euler angle	ϕ	XVNTRU(10)
PSI-N	Nominal yaw Euler angle	ψ	XVNTRU(12)
YE-N	Nominal earth-relative lateral position	y	XVNTRU(2)
DS-N	Nominal roll control-cyclic	δ_S	UVNTRU(3)
DR-N	Nominal yaw control-differential cyclic	δ_R	UVNTRU(4)
DB-S	Sensed control position	δ_B	ZVCOBS(19)
DC-S	Sensed control position	δ_C	ZVCOBS(20)
XE-EST	Estimated earth-relative lateral position	$\hat{x}$	XEEST(1)
ZE-EST	Estimated earth-relative normal position	$\hat{z}$	XEEST(3)
THET-EST	Estimated pitch Euler angle	$\hat{\theta}$	XVREST(8)
U-EST	Estimated body x-axis velocity	$\hat{u}$	XVREST(1)
Q-EST	Estimated body pitch rate	$\hat{q}$	XVREST(5)
W-EST	Estimated body z-axis velocity	$\hat{w}$	XVREST(3)
V-EST	Estimated body y-axis velocity	$\hat{v}$	XVREST(2)
R-EST	Estimated body yaw rate	$\hat{r}$	XVREST(6)
P-EST	Estimated body roll rate	$\hat{p}$	XVREST(4)
PHI-EST	Estimated roll Euler angle	$\hat{\phi}$	XVREST(7)
PSI-EST	Estimated yaw Euler angle	$\hat{\psi}$	XVREST(9)
YE-EST	Estimated earth-relative lateral position	$\hat{y}$	XEEST(2)
DS-S	Sensed control position	δ_S	ZVCOBS(21)
DR-S	Sensed control position	δ_R	ZVCOBS(22)
MLS-R	"True" MLS range - uncorrupted by noise, errors		RAEXYZ
MLS-AZ	"True" MLS azimuth angle		(XVCTRU(1-3))
MLS-EL	"True" MLS elevation angle		
TRI-X	"True" trilateration axial position		XVCTRU(1)
TRI-Y	"True" tirlateration lateral position		XVCTRU(2)
TRI-Z	"True" trilateration normal position		XVCTRU(3)

TABLE 2.2-12 (CONTINUED)
TIME HISTORY PRINT/PLOT

T-1734

LABEL	DESCRIPTION		SOURCE VARIABLE
VEXWND	Actual earth-relative axial wind velocity		H_B^E WINDB(1)
VEYWND	Actual earth-relative lateral wind velocity		H_B^E WINDB(2)
VEZWND	Actual earth-relative normal wind velocity		H_B^E WINDB(3)
BIAS-U	Accelerometer bias - body x-axis	b_u	SVCTRU(5)
BIAS-V	Accelerometer bias - body y-axis	b_v	SVCTRU(6)
BIAS-W	Accelerometer bias - body z-axis	b_w	SVCTRU(7)
DBCOM	Pitch control command from controller		UVCCOM(1)
DCCOM	Vertical velocity command from controller		UVCCOM(2)
DSCOM	Roll control from controller		UVCCOM(3)
DRCOM	Yaw control command from controller		UVCCOM(4)
YD1	Controller integrator state (guidance command 1)		YDTCOM(1)
YD2	Controller integrator state (guidance command 2)		YDTCOM(2)
YD3	Controller integrator state (guidance command 3)		YDTCOM(3)
YD4	Controller integrator state (guidance command 4)		YDTCOM(4)
DBACT	Actuator pitch control dynamic state	δ_{BA}	XVCTRU(21)
DCACT	Actuator vertical velocity control dynamic state	$\delta_{\dot{C}A}$	XVCTRU(22)
DSACT	Actuator roll control dynamic state	δ_{SA}	XVCTRU(23)
DRACT	Actuator yaw control dynamic state	δ_{RA}	XVCTRU(24)
DBDOT	Differential collective rate pitch control rate rate	$\delta_{\dot{B}}$	XVCTRU(17)
DCDOT	Collective rate - vertical velocity control rate	$\delta_{\dot{C}}$	XVCTRU(18)
DSDOT	Cyclic rate - roll control rate	$\delta_{\dot{S}}$	XVCTRU(19)
DRDOT	Differential cyclic rate - yaw control rate	$\delta_{\dot{R}}$	XVCTRU(20)

TABLE 2.2-12 (CONTINUED)
TIME HISTORY PRINT/PLOT

T-1735

LABEL	DESCRIPTION		SOURCE VARIABLE
ACC-XB	Accelerometer output-body y-axis	AU	ZVCOBS(7)
ACC-YB	Accelerometer output-body y-axis	AV	ZVCOBS(8)
ACC-ZB	Accelerometer output-body z-axis	AW	ZVCOBS(9)
ALT	Barometric altimeter output	z_B	ZVCOBS(10)
ROLL-S	Sensed roll Euler angle	ϕ	ZVCOBS(11)
PITCH-S	Sensed pitch Euler angle	θ	ZVCOBS(12)
YAW-S	Sensed yaw Euler angle	ψ	ZVCOBS(13)
P-S	Sensed body roll rate	p	ZVCOBS(14)
Q-S	Sensed body pitch rate	q	ZVCOBS(15)
R-S	Sensed body yaw rate	r	ZVCOBS(16)
IAS	Indicated airspeed	IAS	ZVCOBS(17)
BETA	Sensed sideslip	β	ZVCOBS(18)
XEDT-EST	Estimated earth-relative axial velocity	$\hat{\dot{x}}$	VEEST(1)
YEDT-EST	Estimated earth-relative lateral velocity	$\hat{\dot{y}}$	VEEST(2)
ZEDT-EST	Estimated earth-relative normal velocity	$\hat{\dot{z}}$	VEEST(3)
XEDOT-G	Scheduled guidance axial velocity	$\dot{x}_G$	VEG(1)
YEDOT-G	Scheduled guidance lateral velocity	$\dot{y}_G$	VEG(2)
ZEDOT-G	Scheduled guidance normal velocity	$\dot{z}_G$	VEG(3)

TABLE 2.2-12 (CONTINUED)
TIME HISTORY PRINT/PLOT

T-1736

LABEL	DESCRIPTION		SOURCE VARIABLE
XE-G	Scheduled guidance axial position	x_G	XEG(1)
YE-G	Scheduled guidance lateral position	y_G	XEG(2)
ZE-G	Scheduled guidance normal position	z_G	XEG(3)
K(Q-DR)	Control feedback gain - pitch rate to yaw control		CX(4, 5)
K(R-DS)	Control feedback gain - yaw rate to roll control		CX(3, 6)
S VX-DB	Control input gain - axial velocity to pitch control		CY(1, 1)
D VY-DS	Control feedforward gain - lateral velocity to roll control		CYD(3, 2)
RNG-EST	Estimated range to MLS equipment	$\hat{R}$	XP(27)
AZ-EST	Estimated azimuth to MLS azimuth tower	$\hat{a}$	XP(28)
EL-EST	Estimated elevation angle to MLS elevation tower	$\hat{e}$	XP(29)
VTAS-EST	Estimated air speed	$\hat{V}_a$	XP(25)
BETA-EST	Estimated sideslip	$\hat{\beta}$	XP(26)
WEX-EST	Estimated axial wind-earth-relative	$\hat{w}_x$	VWEST(1)
WEY-EST	Estimated lateral wind-earth-relative	$\hat{w}_y$	VWEST(2)
WEZ-EST	Estimated normal wind-earth-relative	$\hat{w}_z$	VWEST(3)
B-U-EST	Estimated accelerometer bias - body x-axis	$\hat{b}_u$	XP(7)
B-V-EST	Estimated accelerometer bias - body y-axis	$\hat{b}_v$	XP(8)
B-W-EST	Estimated accelerometer bias - body z-axis	$\hat{b}_w$	XP(9)
VTAS	True airspeed		
BETA-T	True sideslip		

TABLE 2.2-12 (CONTINUED)
TIME HISTORY PRINT/PLOT

T-1737

LABEL	DESCRIPTION	SOURCE VARIABLE
RMS: XE	Standard deviation of helicopter axial position	$\sqrt{P11(1,1)}$
RMS: YE	Standard deviation of helicopter lateral position	$\sqrt{P11(2,2)}$
RMS: ZE	Standard deviation of helicopter normal position	$\sqrt{P11(3,3)}$
RMS: U	Standard deviation - body x-axis velocity	$\sqrt{P11(4,4)}$
RMS: V	Standard deviation - body y-axis velocity	$\sqrt{P11(5,5)}$
RMS: W	Standard deviation - body z-axis velocity	$\sqrt{P11(6,6)}$
RMS: P	Standard deviation - body roll rate	$\sqrt{P11(7,7)}$
RMS: Q	Standard deviation - body pitch rate	$\sqrt{P11(8,8)}$
RMS: R	Standard deviation - body yaw rate	$\sqrt{P11(9,9)}$
RMS: PHI	Standard deviation - roll Euler angle	$\sqrt{P11(10,10)}$
RMS: THET	Standard deviation - pitch Euler angle	$\sqrt{P11(11,11)}$
RMS: PSI	Standard deviation - yaw Euler angle	$\sqrt{P11(12,12)}$
RMS: UW	Standard deviation - turbulence on body x-axis	$\sqrt{P22(1,1)}$
RMS: VW	Standard deviation - turbulence on body y-axis	$\sqrt{P22(2,2)}$
RMS: WW	Standard deviation - turbulence on body z-axis	$\sqrt{P22(3,3)}$
COR: U-UW	Correlation - body x-axis velocity to body x-axis turbulence	$\frac{P12(4,1)}{\sqrt{P11(4,4)\ P22(1)}}$
COR: V-VW	Correlation - body y-axis velocity to body y-axis turbulence	$\frac{P12(5,2)}{\sqrt{P11(5,5)\ P22(2,1)}}$
COR: W-WW	Correlation - body z-axis velocity to body z-axis turbulence	$\frac{P12(6,3)}{\sqrt{P11(6,6)\ P22(3,3)}}$
COR: P-VW	Correlation - body roll rate with body y-axis turbulence	$\frac{P12(7,2)}{\sqrt{P11(7,7)\ P22(2,2)}}$
COR: Q-WW	Correlation - body pitch rate with body z-axis turbulence	$\frac{P12(8,3)}{\sqrt{P11(8,8)\ P22(3,3)}}$
COR: R-VW	Correlation - body yaw rate with body y-axis turbulence	$\frac{P12(9,2)}{\sqrt{P11(9,9)\ P22(2,2)}}$
COR: TH-U	Correlation - body pitch Euler angle with body x-axis velocity	$\frac{P11(4,11)}{\sqrt{P11(4,4)\ P11(11,11)}}$
COR: W-Q	Correlation - body z-axis velocity with body pitch rate	$\frac{P11(6,8)}{\sqrt{P11(6,6)\ P11(8,8)}}$
COR: U-W	Correlation - body x-axis velocity with body z-axis velocity	$\frac{P11(4,6)}{\sqrt{P11(4,4)\ P11(6,6)}}$
COR: V-P	Correlation - body y-axis velocity with roll rate	$\frac{P11(5,7)}{\sqrt{P11(5,5)\ P11(7,7)}}$
COR: V-R	Correlation - body y-axis velocity with yaw rate	$\frac{P11(5,9)}{\sqrt{P11(5,5)\ P11(9,9)}}$
COR: V-W	Correlation - body y-axis velocity with body z-axis velocity	$\frac{P11(5,6)}{\sqrt{P11(5,5)\ P11(6,6)}}$

TABLE 2.2-12 (CONTINUED)
TIME HISTORY PRINT/PLOT

T-1738

LABEL	DESCRIPTION	SOURCE VARIABLE
COR: Q-R	Correlation - pitch rate with yaw rate	$\frac{P11(8,9)}{\sqrt{P11(8,8)\ P11(9,9)}}$
COR: Q-DB	Correlation - pitch rate with pitch control	$\frac{P13(8,1)}{\sqrt{P11(8,8)\ P33(1,1)}}$
COR: W-DC	Correlation - body z-axis velocity with vertical control	$\frac{P13(6,2)}{\sqrt{P11(6,6)\ P33(2,2)}}$
COR: V-DS	Correlation - body y-axis velocity with roll control	$\frac{P13(5,3)}{\sqrt{P11(5,5)\ P33(3,3)}}$
COR: P-DS	Correlation - roll rate with roll control	$\frac{P13(7,3)}{\sqrt{P11(7,7)\ P33(3,3)}}$
COR: R-DR	Correlation - yaw rate with yaw control	$\frac{P13(9,4)}{\sqrt{P11(9,9)\ P33(4,4)}}$
RMS: DB	Standard deviation - pitch control	$\sqrt{P33(1,1)}$
RMS: DC	Standard deviation - vertical velocity control	$\sqrt{P33(2,2)}$
RMS: DS	Standard deviation - roll control	$\sqrt{P33(3,3)}$
RMS: DR	Standard deviation - yaw control	$\sqrt{P33(4,4)}$
RMS: XEST	Standard deviation - axial position estimate	$\sqrt{P44(1,1)}$
RMS: YEST	Standard deviation - lateral position estimate	$\sqrt{P44(2,2)}$
RMS: ZEST	Standard deviation - normal position estimate	$\sqrt{P44(3,3)}$
RMS: UEST	Standard deviation - body x-axis velocity estimate	$\sqrt{P44(4,4)}$
RMS: VEST	Standard deviation - body y-axis velocity estimate	$\sqrt{P44(5,5)}$
RMS: WEST	Standard deviation - body z-axis velocity estimate	$\sqrt{P44(6,6)}$
RMS: PEST	Standard deviation - estimated roll rate	$\sqrt{P44(7,7)}$
RMS: QEST	Standard deviation - estimated pitch rate	$\sqrt{P44(8,8)}$
RMS: REST	Standard deviation - estimated yaw rate	$\sqrt{P44(9,9)}$
RMS: PHIE	Standard deviation - estimated roll Euler angle	$\sqrt{P44(10,10)}$
RMS: THEE	Standard deviation - estimated pitch Euler angle	$\sqrt{P44(11,11)}$
RMS: PSIE	Standard deviation - estimated yaw Euler angle	$\sqrt{P44(12,12)}$
RMS: INT1	Standard deviation - guidance commanded axial velocity	$\sqrt{P55(1,1)}$
RMS: INT2	Standard deviation - guidance commanded lateral velocity	$\sqrt{P55(2,2)}$
RMS: INT3	Standard deviation - guidance commanded normal velocity	$\sqrt{P55(3,3)}$
RMS: INT4	Standard deviation - guidance commanded yaw Euler angle	$\sqrt{P55(4,4)}$
CO: DB-I1	Correlation - pitch control with axial velocity command	$\frac{P35(1,1)}{\sqrt{P33(1,1)\ P55(1,1)}}$
CO: DC-I1	Correlation - vertical velocity control with lateral velocity command	$\frac{P35(2,2)}{\sqrt{P33(2,2)\ P55(2,2)}}$
CO: IDS-I3	Correlation - roll control with normal velocity command	$\frac{P35(3,3)}{\sqrt{P35(3,3)\ P55(3,3)}}$
CO. DIR-I4	Correlation - yaw control with yaw angle command	$\frac{P35(4,4)}{\sqrt{P33(4,4)\ P55(4,4)}}$

APPENDIX A

UTILITY ROUTINES

The following utility routines are used by TVHIS to accomplish the described functions.

A.1 MATRIX UTILITY ROUTINES

A.1.1 ADD Computes the sum of 2 matrices.

A.1.2 MNUS Sets a matrix to the negative of a given matrix.

A.1.3 MULT Computes the product of 2 matrices.

A.1.4 INV Inverts a general matrix by Gauss-Jordan elimination.

A.1.5 SUBT Computes the difference of 2 matrices.

A.1.6 TRNP Computes the transpose of a matrix.

A.1.7 EQAT Sets a matrix equal to another matrix.

A.1.8 SMLT Multiplies a matrix by a scalar.

A.1.9 IDEN Sets a square matrix to the identity matrix.

A.1.10 ZERO Sets all elements of a matrix to zero.

A.1.11 CPEQ Computes the cross-product-equivalent matrix for a vector.

A.1.12 NORMAL Normalizes a given covariance matrix.

A.1.13 RESTOR Recovers a symmetric matrix from its lower-triangular representation in a vector.

A.1.14 STORE Stores the lower-triangular representation of a symmetric matrix in a vector.

A.1.15 TADD Computes the sum of a matrix with the transpose of a second matrix.

A.1.16 TMLT Computes the product of a matrix with the transpose of a second matrix.

A.2 COORDINATE TRANSFORMATION ROUTINES

A.2.1 HBAS Calculates body axes to air-relative axes Transformation matrix.

A.2.2 HBES Calculates body axes to earth axes transformation matrix.

A.2.3 HBIR Calculates general body axes to inertial axes Transformation matrix.

A.2.4 HEMS Calculates earth axes to MLS axes transformation matrix.

A.2.5 LBI Calculates body angular rates to Euler angular rates transformation matrix.

A.2.6 LBPR Calculates partial derivative of body angular rates with respect to Euler angle.

A.2.7 LBR Calculates Euler angular rates to body angular rates transformation matrix.

A.2.8 RAEXYZ Transforms earth-relative position to MLS range, azimuth and elevation.

A.3 UTILITY PRINT ROUTINES

A.3.1 PRMR Prints a real-valued matrix in tabular form.

A.3.2 WFHPLT Produces printer-plots.

A.3.3 COVPT Prints a normalized covariance matrix.

A.4 RANDOM-NUMBER GENERATION AND TRIGONOMETRIC FUNCTIONS

A.4.1 GAUSS Generates a normally distributed pseudo-random number.

A.4.2 RANDOM Generates a uniformly distributed pseudo-random number.

A.4.3 TRIGS Calculates second-order Taylor series approximations for sine, cosine, tangent, and secant functions.

APPENDIX B

IMPLEMENTATION OF PERMANENT FILE FOR AERODYNAMIC COEFFICIENTS

The program (AERO) must be run before TVHIS to store aerodynamic coefficients on a permanent disk file. The file consists of 297 different cases of aerodynamic coefficients whose parameter variations are explained below.

The aerodynamic coefficients, corresponding to specific values of $\dot{\psi}$, $\dot{x}$ and $\dot{z}$ are selected by computing a case number (NCASE) defined as:

NCASE = (J-1)*99 + (K-1)*11 + L

J is an index of 3 values for $\dot{\psi}$, K is an index of 9 values for $\dot{z}$, and L in an index of 11 values for $\dot{x}$. The $\dot{\psi}$ (radians/sec) values of 0.0, +0.05, -0.05 correspond to J = 1 to 3. The $\dot{z}$ (feet/min) values of -2000, -1500, -1000, -500, 0, 500, 1000, 1500, 2000 correspond to K = 1 to 9. The $\dot{x}$ (knots) values of -40, -20, 0, 20, 40, 60, 80, 100, 120, 140, 160 correspond to L = 1 to 11. For each case, there are 71 aerodynamic coefficients used in the formulation of the system matrix F.

APPENDIX C
LIST OF DELIVERABLES

Delivered with this document are nine distinct, computer-related items: one magnetic tape, four executable card decks, and four computer-printed listings. These nine items are detailed in the following list.

1. Magnetic tape, 7-track, 556 bpi (HI) containing three files:

   File 1 (binary) TVHIS program library
   File 2 (binary) AERO program library
   File 3 (coded) aerodynamic coefficient data

2. Executable deck which reads Item 1 (above) and creates two permanent files.

   TVHOBJ - TVHIS object code
   AEROB - data file of aerodynamic coefficients, read by TVHIS

3. Executable deck - TVHIS sample execution #1

4. Executable deck - TVHIS sample execution #2

5. Executable deck - TVHIS sample execution #3

6. Computer printout generated by execution of Item 2 -- includes compiler-generated source listings of TVHIS and AERO, and the execution time output of program AERO

7. Computer printout generated by execution of Item 3 - TVHIS sample output #1

8. Computer printout generated by execution of Item 4 - TVHIS sample output #2

9. Computer printout generated by execution of Item 5 - TVHIS sample output #3

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