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USER'S GUIDE FOR THE PRECISION RECURSIVE ESTIMATOR FOR EPHEMERIS REFINEMENT (PREFER)

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1.0 INTRODUCTION

PREFER is a recursive orbit determination program which is used to refine the ephemerides produced by a batch least squares program (e.g., GTDS). It is intended to be used primarily with GTDS and, thus, is compatible with some of the GTDS input/output files.

The input to PREFER consists of five disk (or tape) files and the card input. The satellite Orbit File contains the nominal satellite ephemerides and the state transition matrix as generated by GTDS. The ephemerides on this file should be accurate to within approximately 50 meters (to minimize linearization errors). PREFER interpolates from this file at the times given on the Measurement Data File. It processes these measurements in a Kalman filter to estimate the corrections to the nominal trajectory. The filter state also includes other parameters which have an effect upon the orbit determination (e.g., drag, perturbing gravitational accelerations, thrust, measurement biases and refraction parameters, etc.).

The measurement data types which PREFER can process include ground range and range rate measurements, TDRS relay measurements (range and range rate), GPSPAC pseudo range and pseudo delta-range measurements, NAVPAC range difference measurements and altimeter measurements. Processing of the ground measurements requires that earth motion be accurately modeled. The Solar/Lunar/Planetary (SLP) File supplies the data which is used in the true of date to 1950 coordinate transformations while a Time Coefficients File supplies data used for time system transformations and polar motion. A GPS Trajectory File supplies the ephemerides of the GPS satellites which are required to process the GPSPAC or NAVPAC measurements. TDRS ORBIT Files supply the required TDRS ephemerides.

After running the Kalman filter forward to the end of the Measurement Data File, PREFER performs optimal smoothing. A file created by the Kalman filter is read backward in time and the smoothed estimates are obtained by using the recursive formulation of Rauch-Tun-Streibel.

The combination of a Kalman filter and a smoother should result in greatly improved estimates of satellite ephemerides as compared to batch estimation. Batch estimation is subject to errors because of errors in the dynamic models (e.g., gravitational). A filter/smoother which properly accounts for dynamic (state) noise should weight the data optimally and reduce the estimation errors. Smoothing will produce better estimates (in the middle of the data span) than just a forward filter because past and future data is used to estimate the state at each point in time (a filter uses only past data). Smoothing also tends to average out any dynamic modeling errors which remain.

It is suggested that the user carefully read Section 3.1 of this guide and the PREFER Mathematical Description before attempting to use the program. An understanding of the dynamic models and correct choice of state noise are essential to proper functioning of the program.

PREFER requires about 370K (base 10) bytes of storage on the IBM 360/95 for a run using only ground tracking. Since the core storage is dynamic, runs using TDRS or GPS tracking may require as much as 500K. Execution time will also vary drastically depending upon the data span and the number of adjusted parameters. It is expected that a one day solution containing 2200 measurements processed in 120 sec "mini-batches" will take less than 2 minutes of 360/95 CPU time and 5 minutes of I/O time. Approximately 60% of the CPU time is spent in filtering. The I/O charge will almost double when the option to output the smoothed covariance is used.

2.0 INPUT FILES

The following sections describe the PREFER input files mentioned in the introduction.

2.1 Satellite ORBIT File (Unit 50)

The satellite ORBIT File is generated by GTDS on unit 21. This file contains the ephemerides and matrix sums used to compute the state transition matrix (partials of current cartesian elements with respect to epoch elements) of the satellite. Although the file may contain partials with respect to many paramenters, PREFER only uses the 6×6 matrix corresponding to the epoch orbital elements.

The ORBIT file consists of three types of records: two header records and the data records. The file is written on a tape (1600 BPI) using a record format of VS, a logical record length of 6664 bytes and a block size of 6668 bytes. The format of the individual records is given on the following pages.

RECORD	RECORD SIZE	BYTES	NAME, DESCRIPTION, ETC.
1	6660 bytes	1-8	SATNAM: Satellite name in EBCDIC
		9-16	AREA: Area of satellite (km^2)
		17-24	SCMASS: Mass of satellite (kg)
		25-32	CSUBR: Satellite reflectivity constant
		33-40	CSUBDZ: Drag coefficient
		41-48	YMDOUT: YYMMDD. of start date
		49-56	HMSOUT: HHMMSS.SSSS of start date
		57-64	YMDFN: YYMMDD. of end date
		65-72	HMSFN: HHMMSS.SSSS of end date
		73-80	YMDIC: YYMMDD. of epoch date
		81-88	HMSIC: HHMMSS.SSSS of epoch date
		89-96	YMDREF: YYMMDD. of reference line for time coordinate system
		97-104	EGHA: Greenwich hour angle at epoch (rad)
		105-112	EJED: Julian ephemeris date of epoch
		113-160	AEINT(K): K=1,6 Keplerian elements in coordinate system of integration
		161-208	SPINT(L): K=1,6 Spherical elements in coordinate system of integration
		209-256	PVINT(K): K=1,6 Position and velocity of satellite of integration

RECORD	RECORD SIZE	BYTES	NAME, DESCRIPTION, ETC.	
1	6660 bytes	257-368	OBLINT(L):	L=1,14 Auxiliary orbital elements in coordinate system of integration: L=1, Eccentric anomaly 2, Period 3, Time derivative of period 4, Mean motion 5, True anomaly 6, Perifocal height 7, Apofocal height 8, Time derivative of argument of perigee 9, Time derivative of ascending node 10, Velocity at apogee 11, Velocity at perigee 12, Latitude 13, Longitude 14, Height
		369-376	OBSYMD:	YYMMDD. of start of fitted data span for element set
		377-384	OBSHMS:	HHMMSS.SSSS of start fitted span for element set
		385-392	OBEYMD:	YYMMDD. of end of fitted data span for element
		393-400	OBEHMS:	HHMMSS.SSSS of end of fitted data span for element set
		401-408	WRMS:	Weighted RMS of fit for element set
		409-576	COVMAT(I):	I=1,21 Upper triangle of state covariance matrix
		577-584	AZERO:	Difference between A.1 time and UTC at epoch
		585-592	TZERO1:	Time from beginning of year in seconds
		593-600	DEPOCH:	Julian date of epoch (A.1 system)

RECORD	RECORD SIZE	BYTES	NAME, DESCRIPTION, ETC.	
1	6660 bytes	601-608	SPARE	Spare location
		609-612	IDSAT:	Satellite number
		613-616	NBRRUN:	Run number
		617-620	NBRELS:	Element set number
		621-624	I50:	Inertial coordinate system reference indicator. 1=1950, 2=TOD
		625-1024	INDSEC (I,J):	I=1,20; J=1,5 Force model indicators
		1025-1048	MODWF(K):	K=1,6 Model identifiers
		1049-1052	NBROBS:	Number of observations in fitted data span for elements sets
		1053-1056	NSTATE:	Number of state partials
		1057-1080	KSTATE(K):	K=1,6 Label numbers of state unknowns
		1081-1084	IPART:	Partial indicator =1 partials on data record =2 no partials on data record
		1085-1088	ICENT	Central body indicator
		1089-1092	IND(1)	Orbit generator indicator = 1, time-regularized Cowell orbit generator = 2, Cowell orbit generator
		1093-6660	Spare	
2	6660 bytes	1-8	DTIM	Dummy time word for internal retrieval use (± 99999999.0)
		9-16	ZERO	Zero word for internal retrieval use
		17-104	GM(I):	I = 1,11 Gravitational constant times the mass of body (km^3/sec^2)

RECORD	RECORD SIZE	BYTES	NAME, DESCRIPTION, ETC.	
2	6660 bytes	105-144	SECMOD(36,I):	I = 1,5 Time regularized exponent of satellite radius for Section I
		145-384	COEF1(I,J):	I = 1,10; J = 1,3 Time conversion coefficients; I indicates date interval
		385-408	SAE(I):	I = 1,3 Drag coefficient times area of spacecraft surfaces I = 1, sphere or end of cylinder I = 2, sides of cylinder I = 3, paddles
		409-608	SPARE	Spare locations
		609-612	IND(40)	State partials indicator 1 = yes, 2 = no
		613-616	IND(41)	Drag partials indicator 1 = yes, 2 = no
		617-620	IND(42)	Solar radiation partials indicator 1 = yes, 2 = no
		621-624	IND(43)	Potential partials indicator 1 = yes, 2 = no
		625-628	IND(44)	Thrust partials indicator 1 = yes, 2 = no
		629-632	NTAB	Time conversion table index
		633-672	JARG1(I):	I = 1,10 Julian dates which define date intervals for time conversion
		673-676	KONFIG	S/C configuration switch 0 = spherical 1 = cylindrical 2 = cylindrical with paddles
		677-680	NEQ	Number of variational equations to be integrated

RECORD	RECORD SIZE	BYTES	NAME, DESCRIPTION, ETC.	
2	6660 bytes	681-684	NCNM	Number of $C_{N,M}$ to be estimated
		685-688	NSNM	Number of $S_{N,M}$ to be estimated
		689-768	NDEG(I):	I = 1,20 N indices (for $C_{N,M}$ and $S_{N,M}$)
		769-848	MORD(I):	I = 1,20 M indices (for $C_{N,M}$ and $S_{N,M}$)
		849-868	INDY(I):	I = 1,5 I = 1, array location for drag partials in the integrator I = 2, array location for drag radiation partials in the integrator I = 3, array location for drag potential partials in the integrator I=4, array location for thrust partials in the integrator 5, spare
		869-872	IND(39)	Transformation Partials required 1 = Partial of state with respect to initial state elements 2 = Partial of state with respect to Keplerian state elements 3 = Partial of state with respect to spherical state elements 4 = Partial of state with respect to DODS state elements
		873-6660	SPARES	

RECORD	RECORD SIZE	BYTES	NAME, DESCRIPTION, ETC.	
All others	6660 bytes	1-8	TN:	Time (from epoch in seconds) of last acceleration in XDD
		9-16	H:	Integrator stepsize, in seconds
		17-280	XDD(I,J):	I=K-10,K; J=1,3 Satellite acceleration vectors K = acceleration array indicator
		281-368	TREG(I):	I=K-10,K Time corresponding to acceleration array
		369-392	SX1(I):	I=1,3 First sum vector of satellite acceleration
		393-416	SX2(I):	I=1,3 Second sum vector of satellite acceleration
		417-5696	XVDD(J1,J2,J3):	J1=K-10,K; J2=1,3; J3=1,20 Array of acceleration partials K = acceleration array indicator
		5697-6176	SV1(I,J):	I=1,3; J=1,20 1st sum matrices for acceleration partials
		6177-6656	SV2(I,J):	I=1,3; J=1,20 2nd sum matrices for acceleration partials
		6657-6660	NSECTN	Current section number

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2.2 GPS Trajectory File (Unit 40)

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The GPS Trajectory File contains the positions and velocities (in ECI) of the GPS satellites. The number of satellites on the file is given on the header record and may vary from 1 to 24.

RECORD	RECORD SIZE	BYTES	NAME, DESCRIPTION, ETC.	
1	180 bytes	1-4	NB:	Record Number = 1
		5-12	YEAR:	Year of epoch of trajectory (2 digit)
		13-20	DAY:	Day of epoch of trajectory
		21-28	SEC:	Seconds of epoch of trajectory (UTC time)
		29-36	TVE-TO:	Time of vernal equinox minus epoch of the trajectory
		37-44	DT:	Interval at which trajectory is written (sec.)
		45-52	TLST:	Last time on trajectory (sec. from epoch)
		53-60	STEP:	Integration interval used when creating the trajectory (sec.)
		61-64	IFLOW:	Kind of trajectory = 4, 5, 6 or 7 (Not Used)
		65-68	I50:	Indicates if trajectory was made using epoch of date = 1 or epoch of 1950 = 0
		69-72	ICYC:	Improvement cycle number (Not Used)
		73-80	DATE:	Time clock value when trajectory was made (A8)
		81-84	NGPS:	number of GPS satellites
		85-88	JGPS(1):	Satellite number of 1st satellite (SV number)
		89-92	JGPS(2):	Satellite number of 2nd satellite
		⋮		
		177-180	JGPS(24):	Satellite number of 24th satellite

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RECORD	RECORD SIZE	BYTES	NAME, DESCRIPTION, ETC.
All others	212 to 1500	1-4	NB: Consecutive record number = 2, 3, n
		5-12	TI: Seconds from epoch
		13-20	X(1,1): X } Inertial components of satellite #1 position at time TI (km)
		21-28	X(2,1): Y
		29-36	X(3,1): Z
		37-44	XD(1,1): X } Inertial components of satellite #1 velocity at time TI (km/sec.)
		45-52	XD(2,1): Y
		53-60	XD(3,1): Z
		61-68	TB(1): Timing bias for satellite #1 (secs.) (TB1 = clock - truth time)
		69-76	X(1,2): X } Satellite #2 position
		77-84	X(2,2): Y
		85-92	X(3,2): Z
		93-100	XD(1,2): X } Satellite #2 velocity
		101-108	XD(2,2): Y
		109-116	XD(3,2): Z
		117-124	TB(2): Timing bias for satellite #2
			. . .
			XD(1,NGPS): X } Satellite # NGPS velocity
			XD(2,NGPS): Y
			XD(3,NGPS): Z
		12+56• NGPS	TB(NGPS): Timing bias for satellite # NGPS
			ABCD(1,1): } Earth Centered Inertial (1950) to Earth Centered Fixed Transformation
			ABCD(2,1):
			. .
			ABCD(3,3):
			ABDCD(1,1): } Transformation of Velocities ($\dot{\underline{x}}_{ECI} = (ABDCD)^T \cdot \underline{x}_{EF}$)
			ABDCD(2,1):
			. .
		156+56• NGPS	ABDCD(3,3):

2.3 Measurement Data File (Unit 9)

The measurement data file input to PREFER is created by GTDS as the Observation Save File (GTDS Unit 46). This file contains all the information necessary to process the observations (e.g. station positions, refraction corrections, etc.).

RECORD	RECORD SIZE	BYTES	NAME, DESCRIPTION, ETC.
1	7200 bytes	1-4	NSET: Number of observation sets contained in data set
		5-144	IPOINT (I,J): I = 1,5; J = 1,7 Pointer array of set related information IPOINT (1,J) = Type indicator for set J J = 1, tracking data = 2, telemetry data = 3, PCE data = 4, relay data = 5, landmark data =6 or 7, spare IPOINT (2,J) = pointer to header record for set J IPOINT (3,J) = pointer to starting block for data from set J IPOINT (4,J) = pointer to starting record within indicated block for data from set J IPOINT (5,J) = Number of observations in set J
		145-164	IPOINT (I,8): I = 1,5 Pointer array of set related information (spare set)
		165-284	IMTYPE(I): I = 1,30 Array of external observation types to be used with input from this data set. Internal observation types 1-30 correspond with IMTYPE(1) to IMTYPE(30).

RECORD	RECORD SIZE	BYTES	NAME, DESCRIPTION, ETC.	
1	7200	285-288	Spare	
		289-432	ISPRE (I):	I = 2,37 Spare locations
		433-480	ISPRE (I):	I = 38,49 Spare locations
		481-576	RHDR1 (I):	I = 1,24 Header information for first observation set
		577-720	RHDR1 (I):	I = 25,420 Header information for first observation set
		721-864	RHDR2 (I):	I = 1,396 Header information for second observation set
		865-960	RHDR2 (I):	I = 397,420 Header information for second observation set
		961-1008	RHDR3 (I):	I = 1,12 Header information for third observation set
		1009-1152	RHDR3 (I):	I = 13,408 Header information for third observation set
		1153-1200	RHDR3 (I):	I = 409,420 Header information for third observation set
		1201-1296	RHDR4 (I):	I = 1,24 Header information for fourth observation set
		1297-1440	RHDR4 (I):	I = 25,420 Header information for fourth observation set
		1441-7200	Spare	

RECORD	RECORD SIZE	BYTES	NAME, DESCRIPTION, ETC.
2	7200	1-144	RHDR5 (I): I = 1,420 RHDR6 (I): I = 1,420 RHDR7 (I): I = 1,420 RHDR8 (I): I = 1,396 Headers for observation sets 5 through 8
		145-240	RHDR8 (I): I = 397,420 Header information for observation set 8 (continued)
		241-7200	Spare
			For a description of header information for an observation set, see data set layout for GTDS Observation Tape, FORTRAN logical unit 29[4].
			*NOTE: Record 2 exists in this format only if there are more than four observation sets on the file. If there are four or less, record 2 is formatted like records 3-N (data records).

RECORD	RECORD SIZE	BYTES	NAME, DESCRIPTION, ETC.	
ALL (data)	7200	1-8	TOBYMD:	Corrected observation time tag (YYMMDD.)
		9-16	TOBHMS:	Corrected observation time tag (HHMMSS.SSS)
		17-24	OM1:	Uncorrected observation measurement No. 1
		25-32		Doppler Count Interval (sec.)
		33-40	SIG1:	Standard deviation of data reduction fit
		41-48	OM1A:	Corrected observation measurement No. 1
		49-56	IBIT(8):	Validity flags
		57-64	DMR:	Observation refraction correction
		65-72	TOBSC:	TOBYMD and TOBHMS converted to A.1 seconds from Jan. 1,; DC closes file zero hour of epoch year
		73-80	DAMTD:	Sum of antenna mount and transponder delay correction
		81-88	JBIT(8):	Identifiction flags
		89-96	TCOR: <u>or</u>	TOBSC corrected for bias and light time (in ET seconds from epoch).
			FREF:	For TDRS data, primary frequency (MHz).
		97-100	NOBS:	Working file observation number
		101-104	IGATE:	Range-Gating indicator
		105-108	MTYPE:	Observation type indicator

RECORD	RECORD SIZE	BYTES	NAME, DESCRIPTION, ETC.
ALL (data)	7200	105-108* (TDRS Data only)	MTYPE: Packed indicator = uplink ID * 1000000. + ground transponder number * 10000. + downlink ID * 100. + MTYPE (ID is 2-digit referenced to 60 byte format)
		109-110	ISOU: Observation source indicator
		111	IBF: Doppler Bias Frequency indicator for SST data. Not used for TDRS data.
		112	IPFO: Primary Frequency Offset indicator for SST data. Not used for TDRS data.
		113-116	IEDIT: Edit flag
		117-120	IBIAS: Bias type indicator
		121-124	ISTA: Station geodetic indicator
		125-128	IUPDTE: Record update indicator or 100*ISTAAT +ISTAA: (TDRS only) ISTAAT = Ground transponder internal index (1, 2, 3 ...) ISTAA = Transmit station internal index (1, 2, 3 ...)
		129-132	IFGP(I): I=1,4; FLags indicating corrections made prior to GTDS/ODS processing
		133-136	WORD1Ø: WORD 1Ø of 6Ø byte record
		137-140	IFGB(I): I=1,4; Flags indicating corrections made during GTDS/ODS processing
		141-144	WORD9: Word 9 of 6Ø byte record
		145-7200	49 additional observations containing duplication of bytes 1-144 definition

2.4 Solar/Lunar/Planetary (SLP) (Unit 20 and 22)

There are two SLP files available to PREFER on the GSFC 360/95. One uses mean of 1950.0 coordinates (Unit 20) while the other uses true-of-date coordinates (Unit 22). PREFER automatically selects the correct file to match the satellite ORBIT file. The current names of the two SLP files are: ORBIT.GTDS.SLP1950.DATA and ORBIT.GTDS.SLPTOD.DATA.

2.5 Time Coefficients File (Unit 21)

The time coefficients file contains information on the time system transformations and polar motion. The current name of the file on the GSFC 360/95 is ORBIT.GTDS.TIMCOF.DATA.

2.6 TDRS ORBIT Files (Units 41, 42, 43)

When TDRS relay measurements are processed, the TDRS ephemerides are obtained from three, direct access, ORBIT files on the GSFC 360/95. The format of these files is identical to that of the Satellite ORBIT File (Unit 50) except for the difference between sequential and direct access. There is no unique relationship between the unit number (41, 42 or 43) and the individual TDRS: PREFER determines this relationship from the 7-digit satellite identifier on the header of the TDRS ORBIT files and on the TDRID cards.

It is important that the TDRS ephemeris coordinate system (1950 or true-of-date) match the coordinate system on the Satellite ORBIT file. If they do not match, the PREFER job will terminate.

PREFER does not actually use the TDRS ORBIT files when processing measurements. At the beginning of the job, PREFER Interpolates the ORBIT files (at a rate determined by the STEP card) and copies the ephemerides to a file (also on unit 40) with the same format as a GPS Trajectory file. This is the file used to process the measurements.

3.0 CARD INPUT

All card input to PREFER consists of 72-column keyword cards which have seven variables per card and are read using IBM's free form input (except for the keyword):

Variable	Type
1	Alphanumeric keyword (this must be located in columns 1-8, left justified)
2	Integer
3	Integer
4	Real
5	Real
6	Real
7	Real

The last six variables may be located anywhere in columns 9-72 since blanks or commas are used to separate the fields. The order of the variables is important and thus unused variables must still be input (a zero or a double comma is suggested). See the IBM Fortran (extended) manual for further information.

There are two general classifications for card types. Run control cards are used to input constants required for the run. Run initialization cards are used to set *a priori* standard deviations, state noise standard deviations and time constants of Markov processes. These cards also determine the parameters to be included in the state vector.

With the exception of the STEP card, any field which is blank will be read as a zero and will override the default values (if any). There are no restrictions on the order in which cards are read.

Before describing the format of the individual cards, it is necessary to discuss the dynamic models and the requirements for the card input.

3.1 Discussion of Models and Card Input

PREFER has the capability to solve for the following set of parameters

1 satellite x-position at epoch
2 satellite y-position at epoch
3 satellite z-position at epoch
4 satellite x-velocity at epoch
5 satellite y-velocity at epoch
6 satellite z-velocity at epoch
7 satellite drag coefficient
8 perturbing gravitational acceleration (vertical)
9 perturbing gravitational acceleration (cross-track)
10 perturbing gravitational acceleration (along-track)
11 acceleration of 1st thrust segment (vertical)
12 acceleration of 1st thrust segment (cross-track)
13 acceleration of 1st thrust segment (along-track)
14 acceleration of 2nd thrust segment (vertical)
15 acceleration of 2nd thrust segment (cross-track)
16 acceleration of 2nd thrust segment (along-track)
17 host satellite clock timing error
18 host satellite clock drift rate
19 altimeter bias
20 ground station measurement bias 1
21 ground station measurement bias 2
22 ground station refraction parameter
23 ground station position error (x)
24 ground station position error (y)
25 ground station position error (z)
26 GPS satellite position error (H)
27 GPS satellite position error (C)
28 GPS satellite position error (L)
29 GPS satellite clock timing error

All the parameters (except the first six) are optional. That is, the user may elect to solve for almost any subset of these parameters in a given run. The only restrictions are that parameters which appear in groups of three (e.g., gravitation, thrust, ground station positions and GPS positions) will be treated as a group (all three will be adjusted or none will be adjusted).

The first nineteen of these parameters are called dynamic parameters because their values may change with time. This may happen simply because they have a non-identity transition matrix or because the parameters are driven by some random process (i.e., they have state noise). Of these nineteen parameters, six (drag, gravitation, clock drift and altimeter bias) are assumed to be first order Markov processes; i.e., if x represents <u>one</u> of these parameters, then

$$\dot{x} = -\frac{1}{\tau}x + u$$

where

τ = the correlation time
u = zero mean white noise .

For these six parameters, it is necessary for the user to input three separate quantities: the standard deviation of the error in the *a priori* parameter estimate, the standard deviation of the process output (σ_x) and the correlation time. For all the other parameters, only the *a priori* standard deviation and the state noise spectral density are required.

Determination of the appropriate values for the *a priori* sigma and the correlation time is usually not difficult. However, calculation of the state noise is frequently done with a bit of hand waving. In fact, the bias that some people have against Kalman filtering is often the result of their misunderstanding of the meaning of state noise (and, consequently, their inappropriate choice of values). This is somewhat understandable since few books elaborate on this subject. The primary purpose of state noise is to account for errors in the dynamic model.

In the PREFER program, the spectral density of u is computed internally from the state noise sigma that the user inputs. That is, the user specifies the standard deviation of x (in the previous equation). The standard deviation on x that results from integration of the first-order Markov process is related to σ_u by the equation

$$\sigma_x = \sqrt{\frac{\tau}{2}}\, \sigma_u \quad .$$

Therefore, $\sigma_u = \sqrt{\frac{2}{\tau}}\, \sigma_x$ will be computed internally by the program.

For the orbital elements and thrust accelerations, (the non-Markov processes), the input quantity for state noise is the expected standard deviation of the <u>time derivative</u> of the parameter. In this case, the standard deviation of the parameter will grow as $\sigma_u \sqrt{t}$ where t is the integration time. Since the thrusting times will generally be short, it should not be necessary to input any state noise for thrust. However, the use of a very small value may help minimize numerical problems.

A similar situation also exists for the orbital elements. If no other force model parameters were adjusted, then it would be necessary to include state noise on the orbital elements (particularly the velocity terms). However, if the gravitation and/or other parameters are adjusted, then the state noise on the orbital elements should just be large enough to alleviate numerical problems.

Notice that no provision was made for specifying state noise on the host clock timing error. This was done because the error is really in the clock frequency (drift rate) and, thus, errors in the clock time can be obtained exactly by integrating the drift rate.

All the remaining parameters are related to the measurements and are not part of the dynamic model. They are all assumed to be constant (identity state transition matrix) and also have no state noise. For these reasons, they come under the general heading of "measurement biases".

These parameters are treated differently than dynamic parameters in several aspects but the most significant difference is their use as "pass parameters". That is, parameters for a particular station or satellite do not actually enter the filter until measurements from that station (satellite) are processed. Once the pass is over, the parameters are dropped freom the filter. This procedure has been shown to produce the same results for the common parameters as if all parameters were carried throughout the run (assuming that all pass parameters are independent between passes).

In the case of station position errors, pass independence is not a valid assumption. Thus, the assumption of pass independence means that some information is not being used and the filter is slightly suboptimal. However, the filter estimate will not be biased because of this assumption.

It should be noted that the original design of PREFER did not attempt to solve for station and GPS position errors and GPS timing errors; they were carried as "consider" parameters. However, problems in implementing a smoother with consider parameters forced their inclusion as adjusted parameters. At this time, it is not known how severe the numerical problems are going to be when many pass parameters are simultaneously adjusted. It was assumed that a maximum of four ground sations and 15 GPS satellites* could be simultaneously observable. If all possible parameters were adjusted, this would result in a state dimension of <u>99</u> (PREFFR allows for 100 states). Numerical problems should not be unexpected with a state vector of this size.

The user should also be wary of runs which simultaneously adjust the drag coefficient <u>and</u> gravitational accelerations. If the orbit is nearly circular, the drag acceleration will probably not be distinguishable from the along-track gravitational acceleration (unless the correlation times are significantly different).

* PREFER also has a total limit of 50 ground stations and 24 GPS satellites in a run.

The description of the STEP card (Section 3.2.10) uses the expression "mini-batch measurement processing". In order to reduce the program running time and disk storage, measurements are processed in small batches, during which time (typically 120 seconds), the dynamic model errors are assumed to be negligible. State noise is included only when the filter proceeds from one mini-batch to the next.

The processing of TDRS relay measurements is handled somewhat differently than that for GPSPAC measurements. First, it is not possible to estimate the TDRS ephemeris errors using the current version of PREFER. Secondly, it is necessary for the user to establish a unique relationship (using the TDRID card) between the TDRS and ground tracking stations. It is assumed that each of these ground stations tracks only one TDRS and nothing else. Thus the deletion of the station position errors and measurement biases (pass parameters) from the state vector is determined by the visibility of the user satellite as viewed from the TDRS (see the ELCUT card description for details).

3.2 Run Control Cards

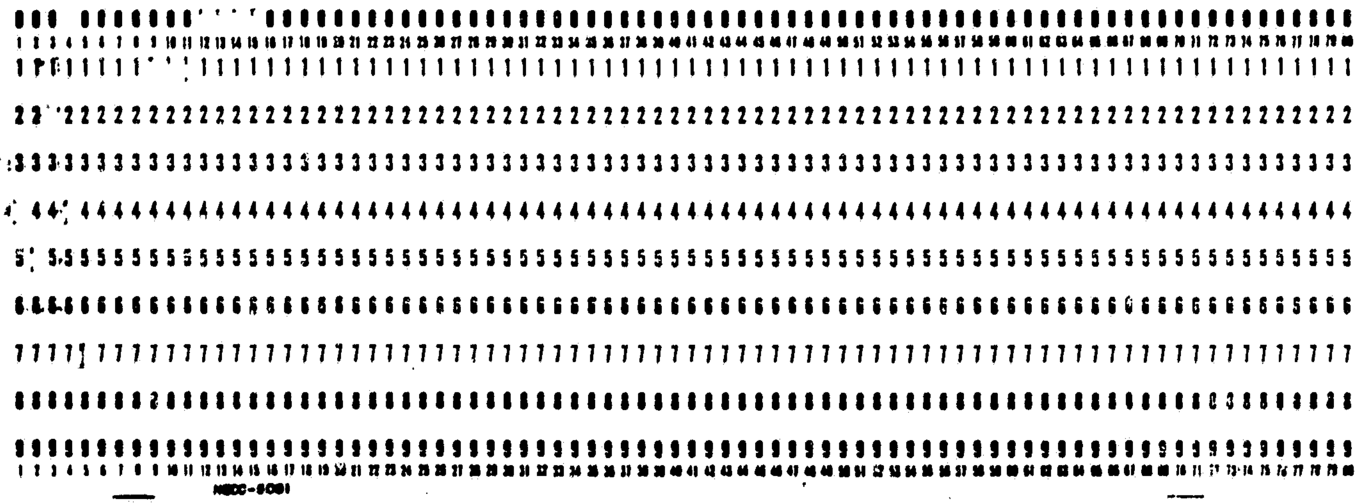
All the following cards are optional.

	Keyword	Description
3.2.1	DEBUG	Turns on debug print
3.2.2	DRAGCON	Coefficients used for atmospheric density modelling
3.2.3	EARTH	Earth ellipsoid parameters, G_m and speed of light
3.2.4	ELCUT	Measurement elevation cutoffs
3.2.5	MEDIT	Editing threshholds
3.2.6	MSIG	Overrides measurement sigmas on measurement file
3.2.7	PRINT	Printout options
3.2.8	SMR	Satellite area to mass ratio
3.2.9	STAPOS	Ground station positions
3.2.10	STEP	Mini-batch step size, stop time and integration step size
3.2.11	TDRID	Defines the relationships between TDRS identifiers and ground tracking stations
3.2.12	THRTIM	Times of thrust events

3.2.1 DEBUG

The DEBUG card turns on the debug printout for specified subroutines.

DEBUG 1110000 ,,,,,,



Variable	Digit	Type	Description
1		Alphanumeric (A8)	Keyword DEBUG.
2	1	7 digit integer	1 in this digit will turn on the debug print for subroutine FILTER.
	2		1 in this digit will turn on the debug print for subroutine MEAS.
	3		1 in this digit will turn on the debug print for subroutine CARD.
	4		1 in this digit will turn on the debug print for subroutine DYNAM.
	5		1 in this digit will turn on the debug print for subroutine SNOISE.
	6		1 in this digit will turn on the debug print for subroutines GETHDR and INTERG.
	7		1 in this digit will turn on the debug print for subroutine EVAL and EARTH.

Notes: (1) The default is no debug print.

(2) A brief description of the debug printout is given in the Appendix. In general, it would be necessary to have a Fortran listing of PREFER to interpret the output.

3.2.2 DRAGCON

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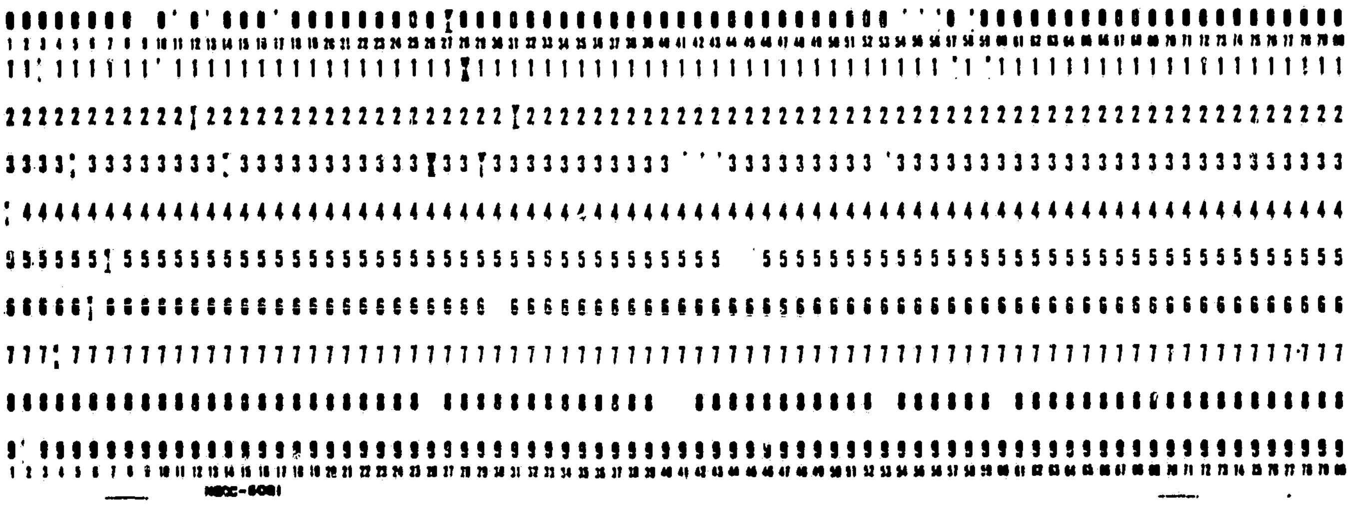
The DRAGCON card allows the user to input the five coefficients which are used to model the density of the earth's atmosphere.

```
DRAGCON 010203  0        .01362       -0.3355       .0001018     ,,
```



Variable	Digit	Type	Description
1		Alphanumeric (A8)	Keyword DRAGCON.
2	1-2	Integer	Index (i) of first coefficient on card.
	3-4	Integer	Index (j) of second coefficient on card.
	5-6	Integer	Index (k) of third coefficient on card.
3		Integer	Not used.
4		Real	Coefficient corresponding to number in digits 1-2 (d_i) .
5		Real	Coefficient corresponding to number in digits 3-4 (d_j) .
6		Real	Coefficient corresponding to number in digits 5-6 (d_k) .

Note: The five coefficients are used in the equation

$$\rho = \exp(d_1 h - d_2 - \sqrt{d_3 h^2 + d_4 h - d_5})$$

where h is the altitude in kilometers and ρ is density in kg/km^3. The defaults for d_1 - d_5 are shown on the sample card. The numbers in columns 9-10 and 11-12 should not be zero (or blank).

3.2.3 EARTH

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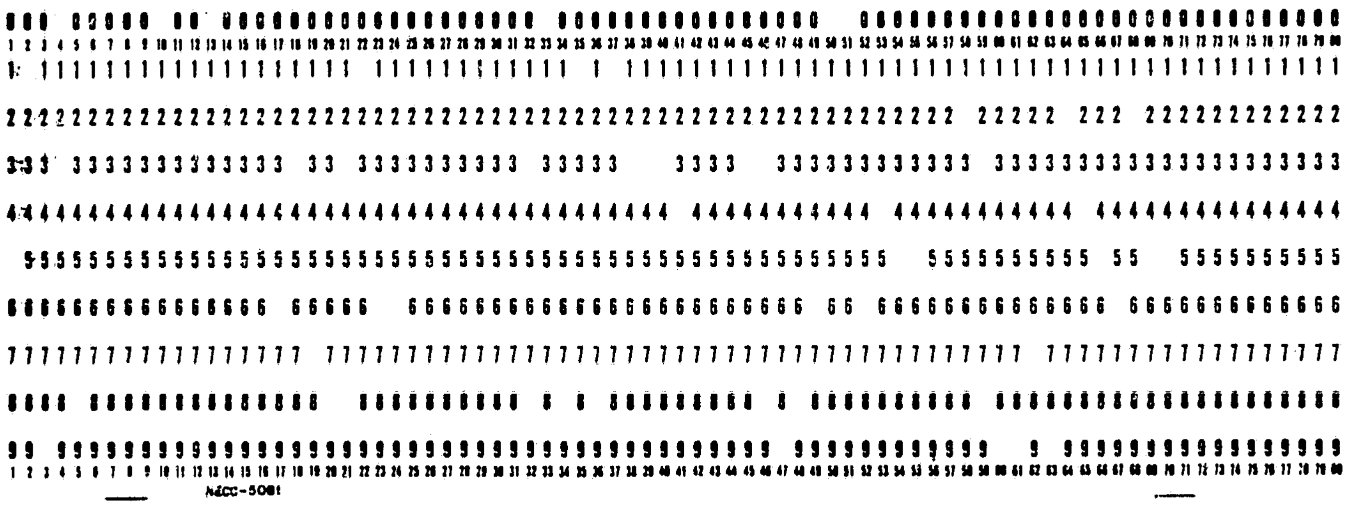
The EARTH card is used to input the Earth's semi-major axis, eccentricity, gravitational constant and the speed of light.

```
EARTH    0  0   6378.166        .081813334   3.9860064E5  2.997924562E5
```



Variable	Type	Description
1	Alphanumeric (A8)	Keyword EARTH.
2	Integer	Polar motion switch: 0 = no polar motion applied, 1 = polar motion applied. Default = 1.
3	Integer	Not used.
4	Real	Earth semi-major axis (km). Default = 6378.166.
5	Real	Earth eccentricity or inverse of flattening. If value is greater than 1, program assumes 1/f. Default = .081813334(e) or 298.3(1/f)
6	Real	Earth gravitational constant (GM) in km^3/sec^2. Default = 3.9860064×10^5.
7	Real	Speed of light (km/sec). Default = 2.997924562×10^5.

3.2.4 ELCUT

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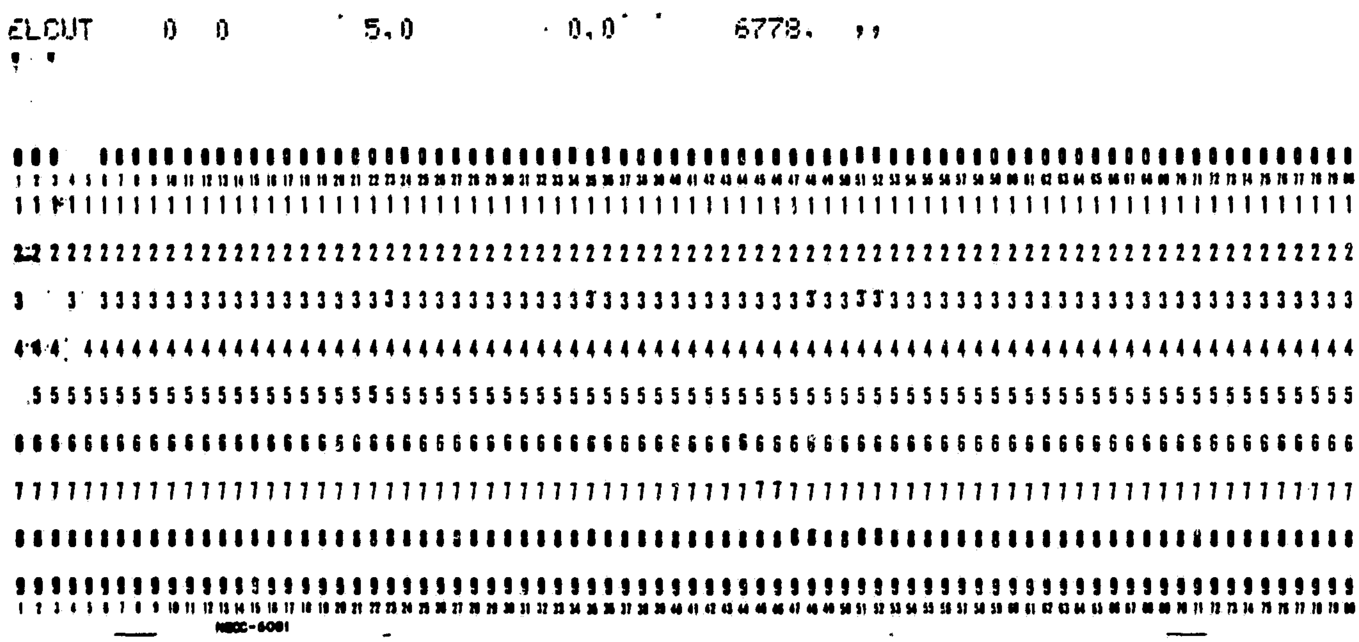
The ELCUT card is used to input the elevation cutoffs for processing ground measurements and GPS measurements.

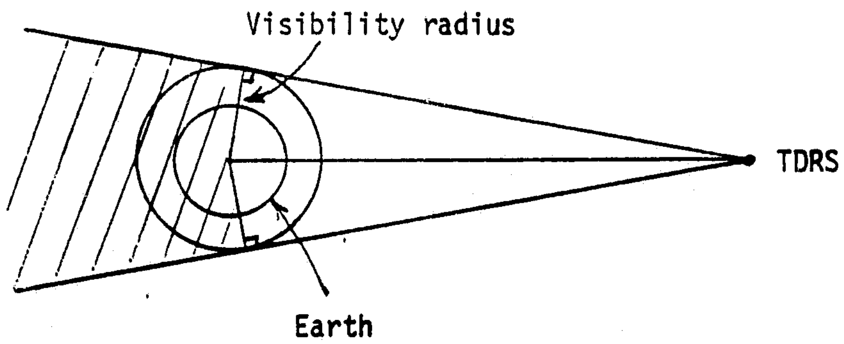


Variable	Type	Description
1	Alphanumeric (A8)	Keyword ELCUT
2	Integer	Not used.
3	Integer	Not used.
4	Real	Elevation cutoff (degrees) for processing ground tracking measurements[1]. All measurements below this cutoff will be deleted. Default = 5°.
5	Real	Elevation cutoff (degrees) as measured at the host satellite for processing GPS measurements. All measurements below this cutoff will be edited. Default = 0°.

Variable	Type	Description
6	Real	Radius of sphere surrounding earth which is used to determine whether a user satellite is "visible" to a TDRS (See note 2). Default = 6778.0 km. This visibility test determines when pass parameters associated with TDRS tracking (e.g. station biases, position errors, etc.) are deleted from the filter state.

Notes: 1) The formula for computing refraction effects will blow up if elevation is less than or equal to zero. Therefore, the elevation cut-off should be greater than zero.

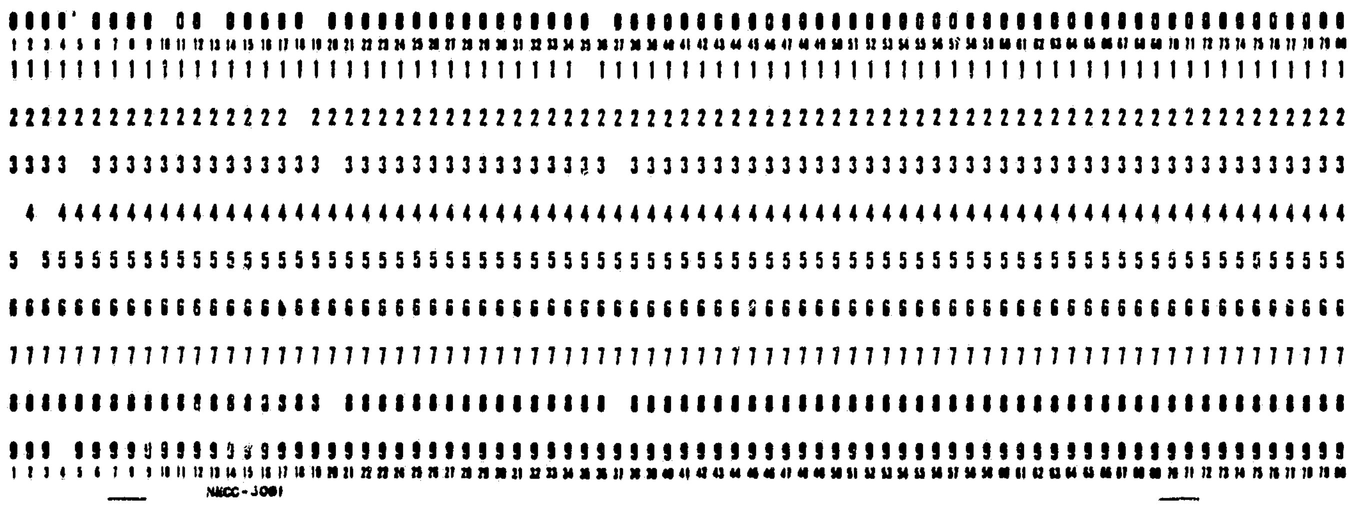
2) The shaded area in the figure is <u>not</u> "visible" from the TDRS.



3.2.5 MEDIT

The MEDIT card is used to set the editing and printing thresholds for outlying measurements.

```
MEDIT     0  0     20.                10.          ,,,
```



Variable	Type	Description
1	A6	Keyword MEDIT
2	Integer	Not used
3	Integer	Not used
4	Real	Measurement editing threshold. Default = 20(1) Measurement is also printed.
5	Real	Measurement printing threshold. Default = 10(1) Measurement is printed but not edited.

NOTE: (1) Editing or printing of outlying measurements will occur when the ratio z^2/σ_z^2 (where z is the measurement residual and σ_z^2 is the residual variance computed by the filter) exceeds the threshold. Note that unlike most batch processors, the procedure includes the uncertainty in the state estimate as well as the measurement noise.

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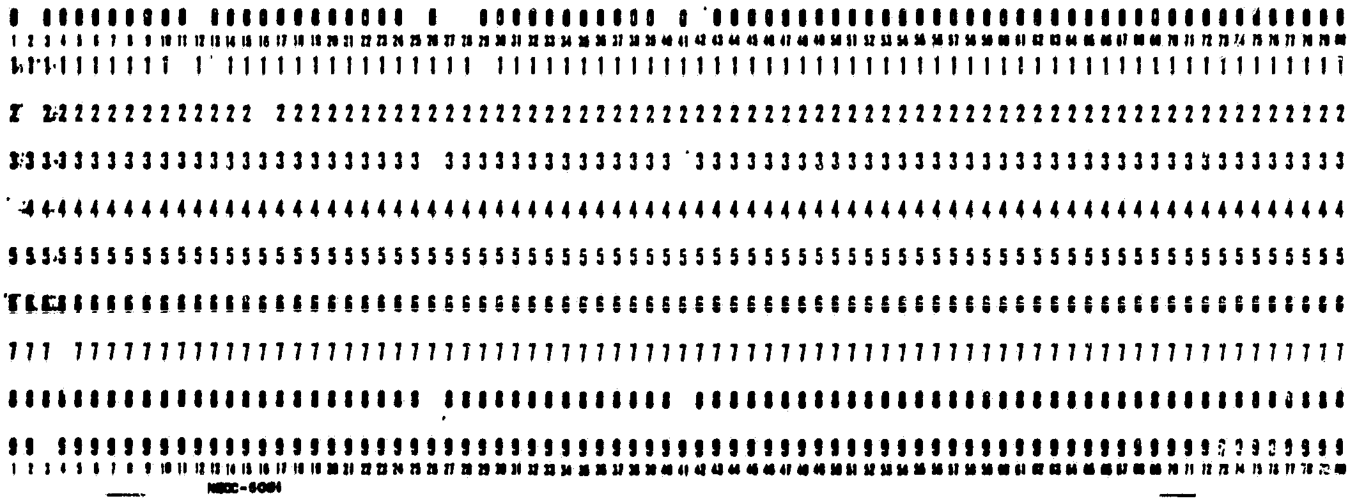
3.2.6 MSIG

The MSIG card is used to override the measurement standard deviations (as given on the measurement tape) for particular stations, GPS satellites or satellite altimetry.

```
MSIG      101  2        0.001          0.0     ,,,
```



Variable	Type	Description
1	Alphanumeric (A8)	Keyword MSIG.
2	Integer	Station or satellite number (maximum of 5 digits and must be positive).
3	Integer	Source of measurement. 1 = GPS satellite 2 = Ground station 3 = Altimeter
4	Real	Measurement standard deviation (kilometers or dimensionless) for the <u>first</u> measurement from a station, satellite or altimeter. Default = SIG1 on Measurement Data File (see page 15).

Variable	Type	Description
5	Real	Measurement standard deviation (kilometer or km/sec) for the second measurement from a satellite which has a pair of measurements. This only applies to the psuedo-delta range from GPS satellites and range rate for ground stations (including TDRS relay measurements). Default = SIG1 on Measurement Data File.

Note: Measurements processed in pairs are:

	Measurement 1:	Measurement 2
Ground range and range rate:	range	range rate
GPSPAC	psuedo range	psuedo delta-range
TDRS	range	range rate

3.2.7 PRINT

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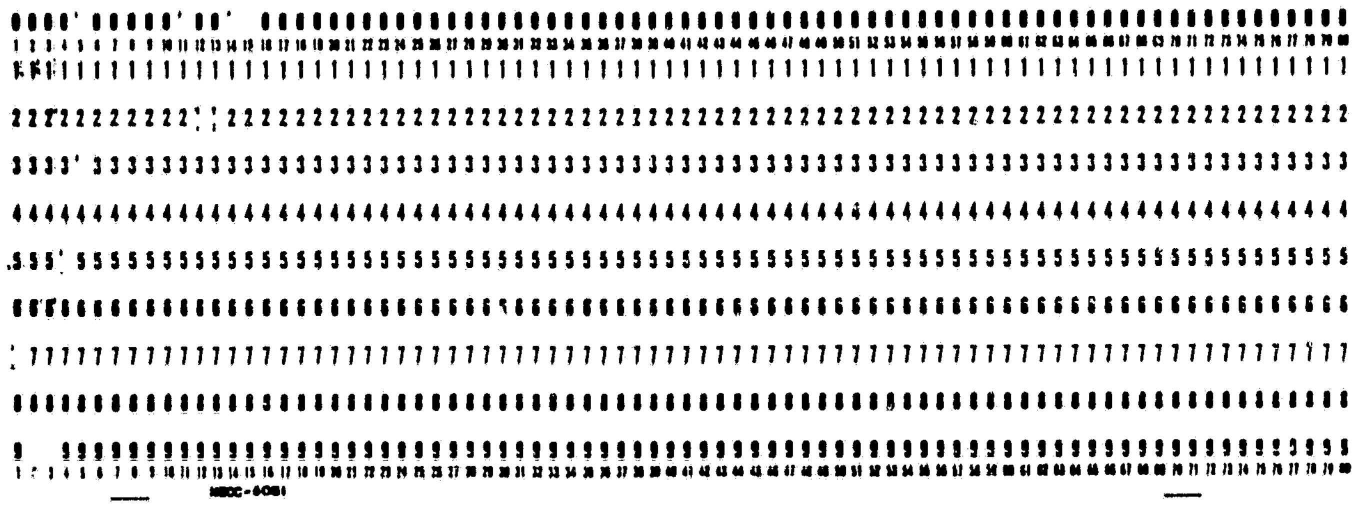
The PRINT card defines the printout options.

```
PRINT     02200          ,,,,,,
```



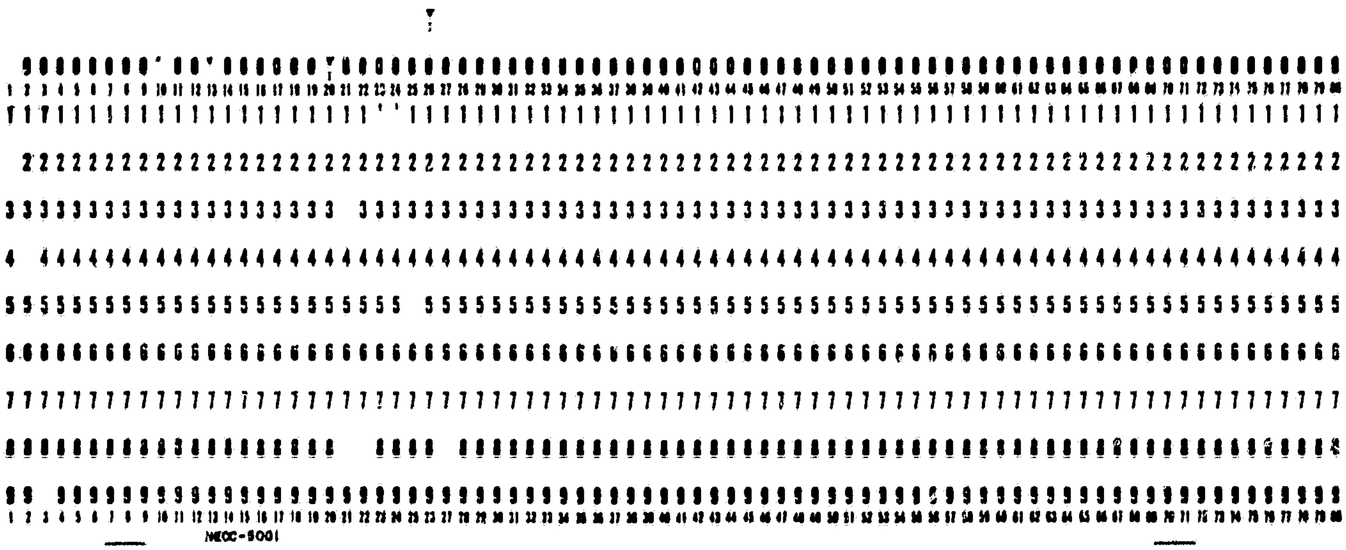
Variable	Digit	Type	Description
1		Alphanumeric (A8)	Keyword PRINT.
2		Integer	5 digit integer.
	1		Defines coordinate system of printed and plotted output: 0 = HCL, 1 = ECI. Default = 0.
	2		Controls filter print: 0 = no state output, 1 = orbital elements only, 2 = full printout. Default = 2.
	3		Controls smoother print: 0 = no state output, 1 = orbital elements only, 2 = full printout. Default = 2.
	4		Controls generation of the smoother covariance (ECI coordinates) on unit 71. 0 = no output, 1 = output. Default = 0. NOTE: The computer I/O charges will approximately double when using this option.

Variable	Digit	Type	Description
2	5	Integer	Controls plotting of filter/smoother standard deviations on position. 0 = no plots, 1 = filter plot only, 2 = smoother plot only, 3 = filter and smoother plots. Default = 0.

3.2.8 SMR

The SMR card is used to input the satellite area to mass ratio.

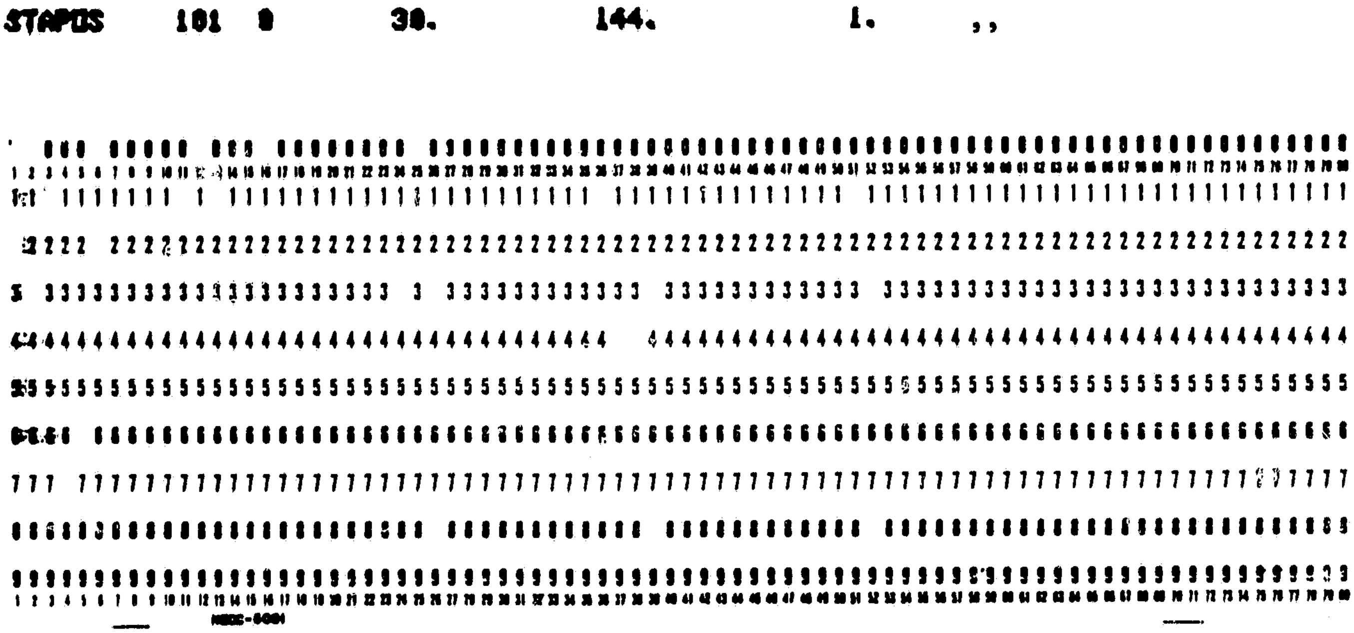
```
SMR      0  0       0.811E-8            ,,,,
```



Variable	Type	Description
1	Alphanumeric (A8)	Keyword SMR.
2	Integer	Not used.
3	Integer	Not used.
4	Real	The satellite area to mass ratio in kilometers^2/kilogram. Default is the ratio of area to mass on the ORBIT file.

3.2.9 STAPOS

The STAPOS card is used to input the positions of the ground tracking stations.



Variable	Type	Description
1	Alphanumeric (A8)	Keyword STAPOS.
2	Integer	Station number (maximum of 5 digits).
3	Integer	Not used.
4	Real	Station geodetic latitude (degrees). ϕ
5	Real	Station East longitude (degrees). λ
6	Real	Station height above ellipsoid (kilometers). h

NOTE: (1) It should not be necessary to input any station positions using the STAPOS card; the header record on the Observation Save File (Unit 9) contains all the station positions. However, if the user wanted to intentionally change station positions, this can be done by using the STAPOS card.

(2) The conversion of geodetic position to earth-fixed cartesian coordinates is

$$x = (\rho_g + h) \cos\phi \cos\lambda$$

$$y = (\rho_g + h) \cos\phi \sin\lambda$$

$$z = ((1-e^2)\, \rho_g + h) \sin\phi$$

where

$$\rho = a \Big/ \sqrt{1-e^2 \sin^2\phi}$$

a = earth's semi-major axis

e = earth's eccentricity

3.2.10 STEP

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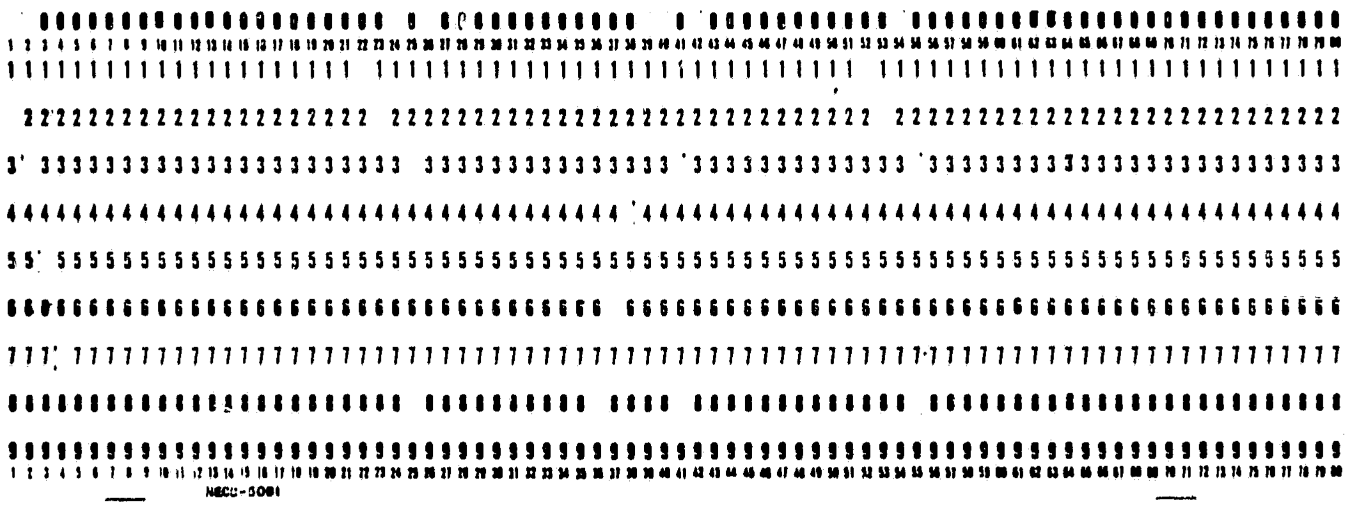
The STEP card controls the step size used for filter/smoother output and also controls the stop time of the run.

```
STEP     0  0       120.0       86400.0       120.     600.
```



Variable	Type	Description
1	A6	Keyword STEP.
2	Integer	Not used.
3	Integer	Not used.
4	Real	Step size (seconds) for mini-batch measurement processing. All filter/ smoother output will use this interval (see note 1) Default is 120 sec.
5	Real	Stop time (seconds) from epoch of host trajectory tape. The default is 86400 seconds but the program will stop at the end of either the host trajectory tape or the measurement tape.

Variable	Type	Description
6	Real	Maximum step size for use in the Taylor series integrator. Default = 120 sec.
7	Real	Step size used in copying TDRS ORBIT files to a TDRS trajectory file. Default = 600 sec.

Notes: (1) This step size should be chosen so that dynamic modelling errors are negligible during the interval because the filter assumes that state noise is zero.

(2) If zeroes or blanks are input on this card, the program will use the default value.

(3) There is an additional restriction that the stop time divided by the mini-batch step size is less than 999. This restriction is imposed because PREFER must have sufficient core storage to store the pointers used in the random-access disk I/O.

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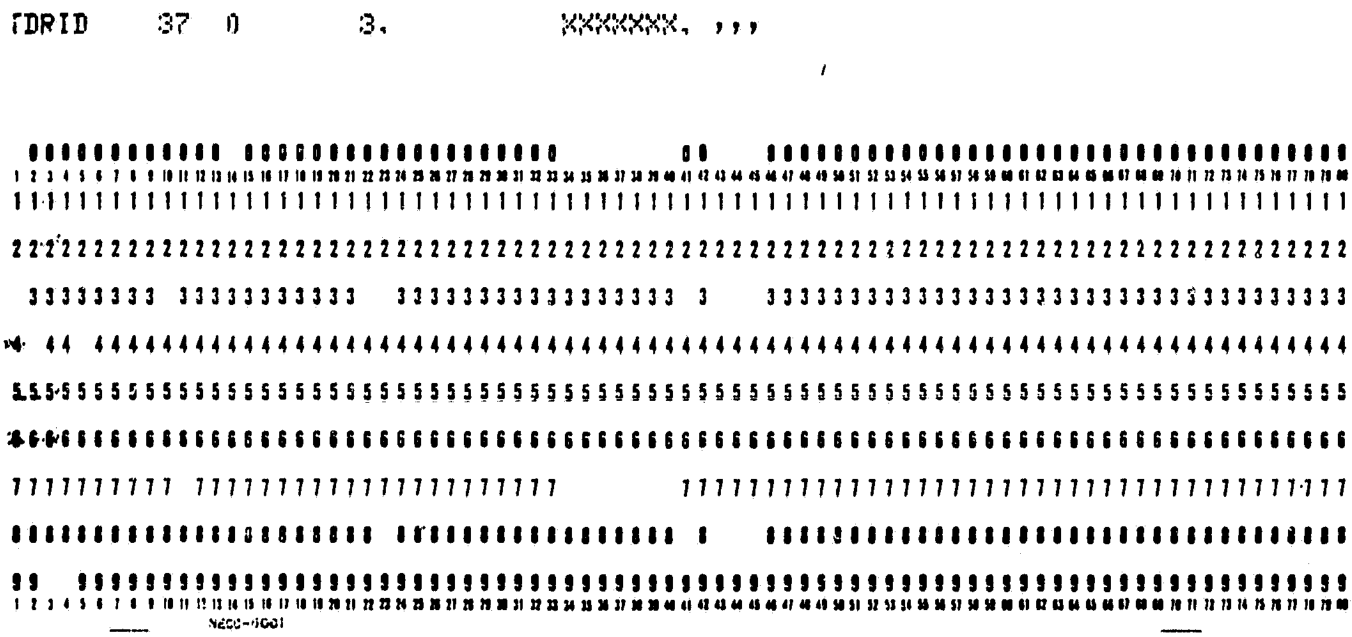
3.2.11 TDRID

TDRID cards are used to define the relationships between the seven-digit and two-digit TDRS identifiers and ground tracking stations. These cards must be input when TDRS relay tracking is processed.

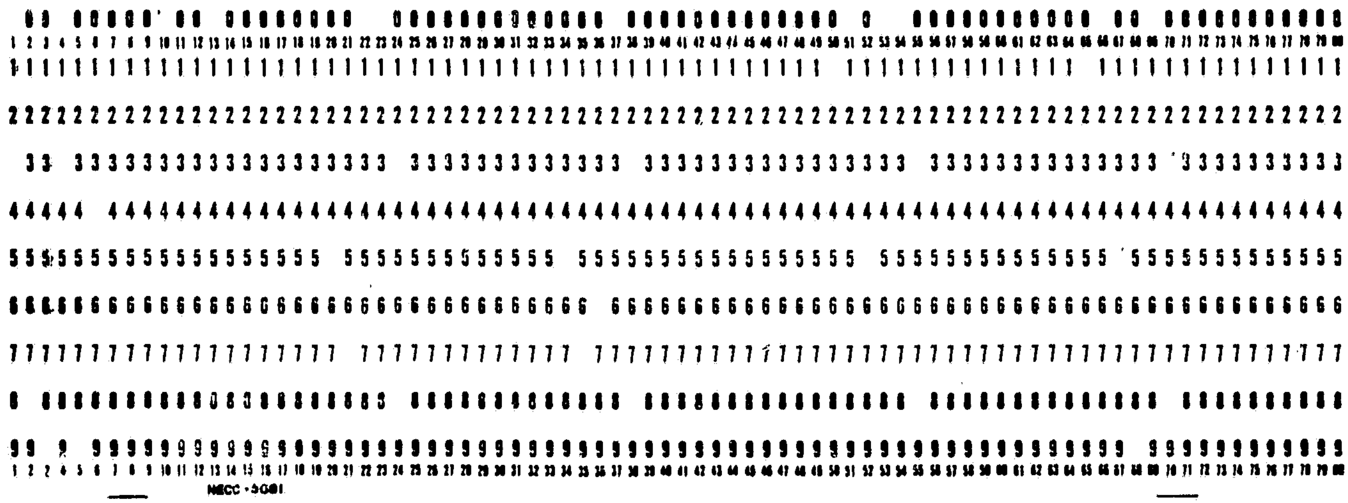


Variable	Type	Description
1	A5	Keyword TDRID.
2	Integer	Tracking station number (two-digit). This number must match the station number on the header of the Measurement Data File.
3	Integer	Not used.
4	Real	Two-digit TDRS identifier. This number must match the TDRS number on the Measurement Data File.
5	Real	Seven-digit TDRS identifier. This number must match the TDRS number on the TDRS ORBIT file.

3.2.12 THRTIM

The THRTIM card is used to input the start and stop times for two thrusting periods. If omitted, no thrusting will be used.

THRTIM 0 0 5700. 5760. 10500. 10590.



Variable	Type	Description
1	A6	Keyword THRTIM.
2	Integer	Not used.
3	Integer	Not used.
4	Real	Start time (seconds from epoch) of first thrust segment.
5	Real	Stop time (seconds from epoch) of first thrust segment.
6	Real	Start time (seconds from epoch) of second thrust segment. Default = 0.
7	Real	Stop time (seconds from epoch) of second thrust segment. Default = 0.

3.3 Run Initialization Cards

All the following cards are optional but it may be unreasonable to make runs without initializing certain parameters.

Because the cards may be read in any order, it is important that the CLOCK and CLOCKQ cards have the same number for variable 3.

	Keyword	Description
3.3.1	ALTIM	*a priori* σ for altimeter bias
3.3.2	ALTIMQ	state noise for altimeter bias
3.3.3	ALTIMT	de-correlation time for altimeter bias
3.3.4	CLOCK	*a priori* σ for host clock timing bias and clock drift rate
3.3.5	CLOCKQ	state noise for host clock timing bias and clock drift rate
3.3.6	CLOCKT	de-correlation time for clock drift rate
3.3.7	CSTA	*a priori* σ for station position errors
3.3.8	DRAG	*a priori* σ for drag coefficient
3.3.9	DRAGQ	state noise for drag coefficient
3.3.10	DRAGT	de-correlation time for drag coefficient
3.3.11	GPSP	*a priori* σ for GPS position errors
3.3.12	GPST	*a priori* σ for GPS timing errors
3.3.13	GRAV	*a priori* σ for perturbing gravitational accelerations
3.3.14	GRAVQ	state noise for perturbing gravitational accelerations
3.3.15	GRAVT	de-correlation time for perturbing gravitational accelerations
3.3.16	MBIAS	*a priori* σ for station biases
3.3.17	REFRAC	*a priori* σ for refraction parameters
3.3.18	STATE1	*a priori* σ for first three orbital elements
3.3.19	STATE1Q	state noise for first three orbital elements
3.3.20	STATE2	*a priori* σ for orbital elements 4-6
3.3.21	STATE2Q	state noise for orbital elements 4-6

	Keyword	Description
3.3.22	THRUST1	*a priori* σ for acceleration of first thrust segment
3.3.23	THRUST1Q	state noise for acceleration of first thrust segment
3.3.24	THRUST2	*a priori* σ for acceleration of second thrust segment
3.3.25	THRUST2Q	state noise for acceleration of second thrust segment.

Because certain parameters require more than one input card (e.g., GRAV, GRAVQ, GRAVT), it is possible to have unusual errors occur if the deck is not correctly set up. For example, suppose that the GRAVQ card was input but no GRAV card was provided. The presence of the GRAVQ card tells PREFER that gravitational parameters are to be adjusted. However, the *a priori* variances will default to zero because no GRAV card was supplied. This will obviously result in problems for the filter.

3.3.1 ALTIM

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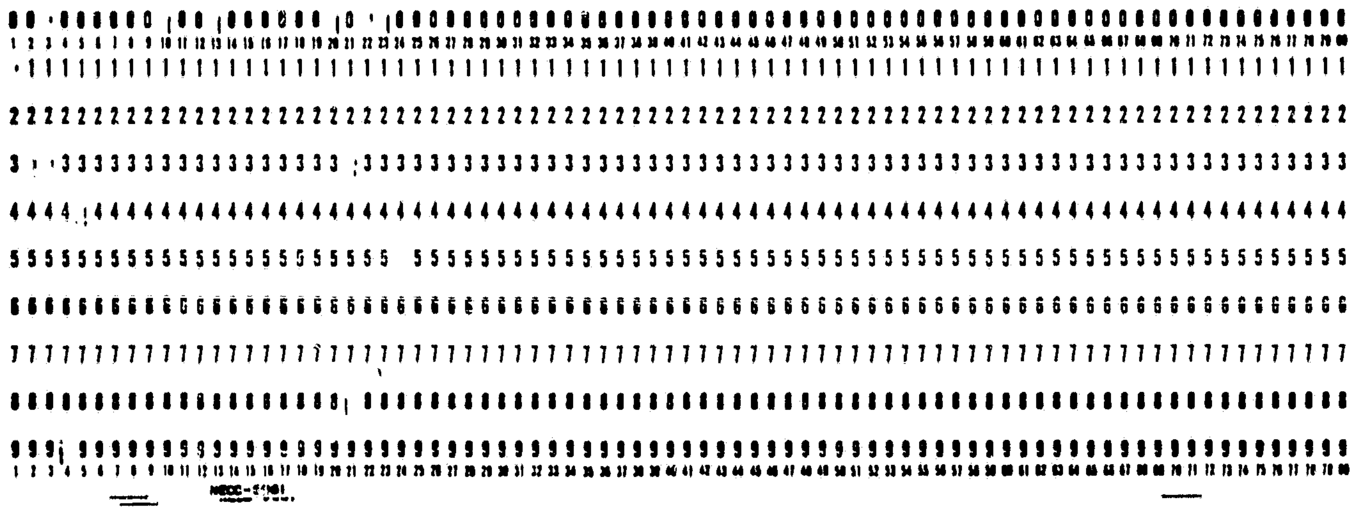
The ALTIM card is used to initialize the standard deviation for the altimeter bias. If omitted, the altimeter bias is not adjusted.

```
ALTIM    0  0      0.005        ,,,,
```



Variable	Type	Description
1	Alphanumeric (A8)	Keyword ALTIM.
2	Integer	Not used.
3	Integer	Not used.
4	Real	*A priori* standard deviation for the altimeter bias (km). No default.

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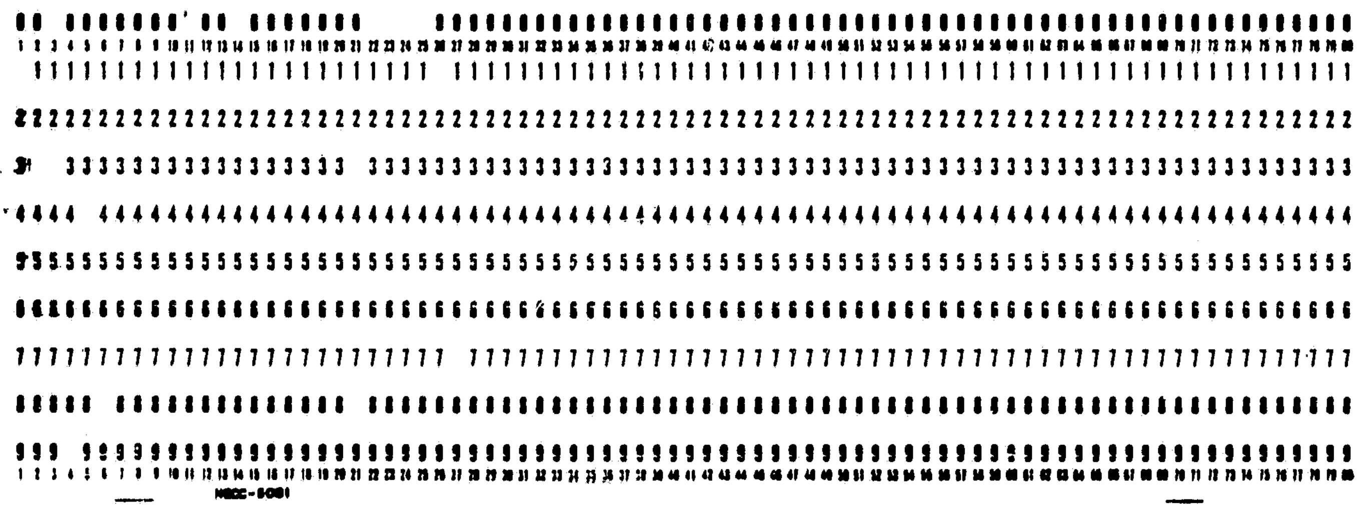
3.3.2 ALTIMQ

The ALTIMQ card is used to input the state noise on the altimeter bias.

ALTIMQ 0 0 .000017 ,,,,

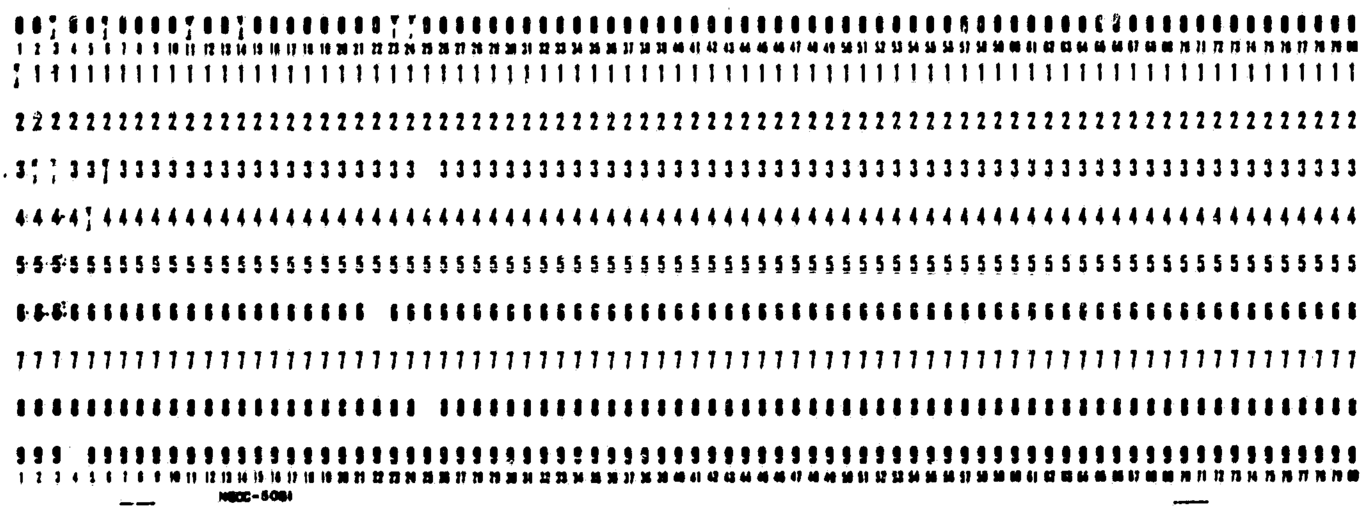


Variable	Type	Description
1	Alphanumeric (A8)	Keyword ALTIMQ.
2	Integer	Not used.
3	Integer	Not used.
4	Real	Steady sigma of the altimeter bias Markov process (in km). Default = 0.

3.3.3 ALTIMT

The ALTIMT card is used to input the time constant of the first-order Markov process for the altimeter bias.

```
ALTIMT    0  0       600.          ,,,,
```

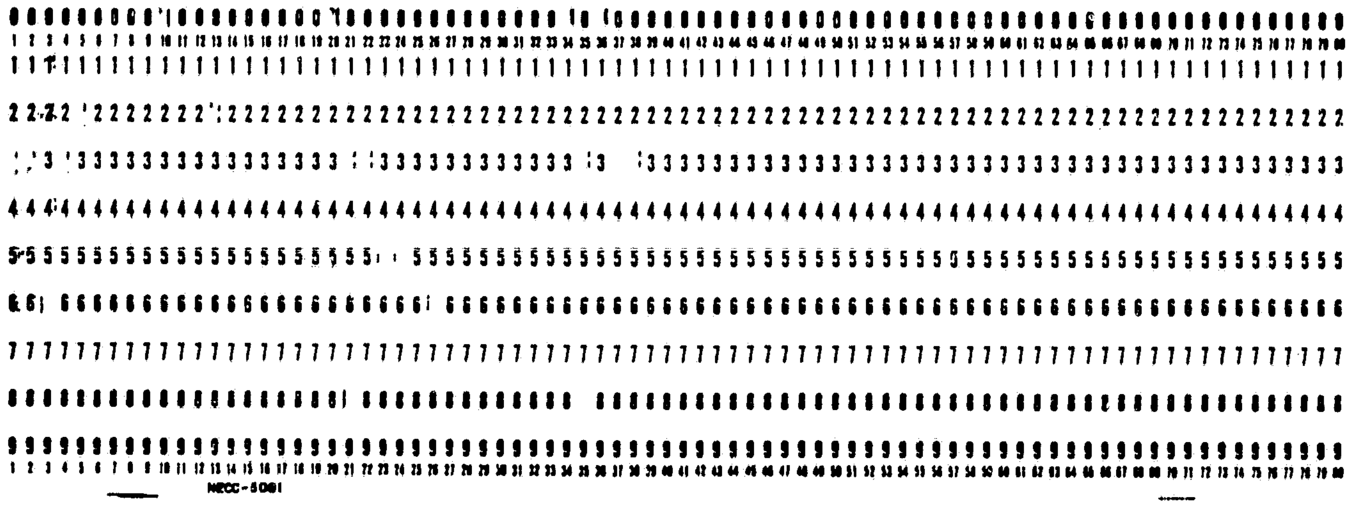


Variable	Type	Description
1	Alphanumeric (A8)	Keyword ALTIMT.
2	Integer	Not used.
3	Integer	Not used.
4	Real	Correlation time (seconds) for changes in the altimeter bias. Default = 1.0 seconds.

3.3.4 CLOCK

The CLOCK card is used to initialize the standard deviations for the host clock timing error and drift rate. It omitted, the clock errors will not be adjusted.

```
CLOCK     0  2       0.35E-6       0.033        ,,,
```



Variable	Type	Description
1	Alphanumeric (A8)	Keyword CLOCK.
2	Integer	Not used.
3	Integer	Number of parameters: 1 = adjust clock drift rate only (e.g. NAVPAC). 2 = adjust clock timing error plus drift rate (e.g. GPSPAC rate).
4	Real	*A priori* standard deviation for host clock drift rate (milliseconds/second). No default.
5	Real	*A priori* standard deviation for host clock timing bias (milliseconds). No default, but this number is not used if column 15 is 1.

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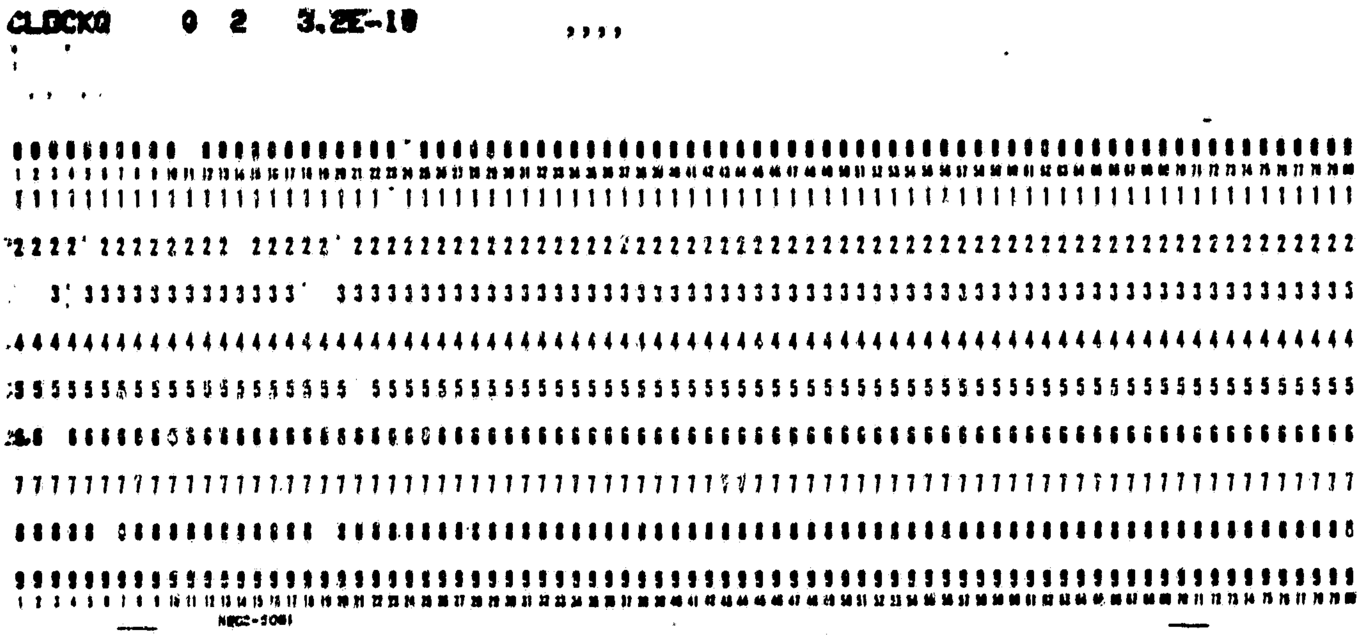
3.3.5 CLOCKQ

The CLOCKQ card is used to input the state noise for the clock drift rate.



Variable	Type	Description
1	Alphanumeric (A8)	Keyword CLOCKQ.
2	Integer	Not used.
3	Integer	Number of parameters:[2] 1 = adjust clock drift rate only 2 = adjust clock timing error plus drift rate.
4	Real	Steady state sigma of the host clock drift rate, Markov process[1] (in milli-seconds/sec). Default = 0.

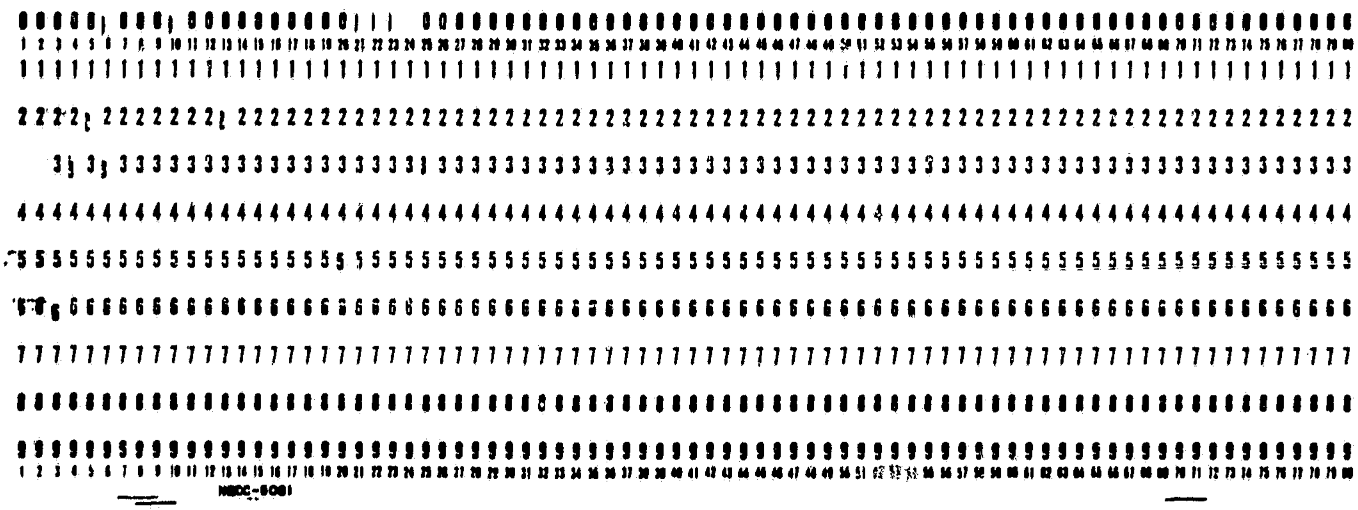
Note: (1) The Markov process only applies to the clock drift rate. The clock timing error is obtained by integrating the rate.

(2) This number should match the number on the CLOCK card.

3.3.6 CLOCKT

The CLOCKT card is used to input the time constant of the first order Markov process for the host clock drift rate.

```
CLOCKT    0  2       50000.     ,,,,
```

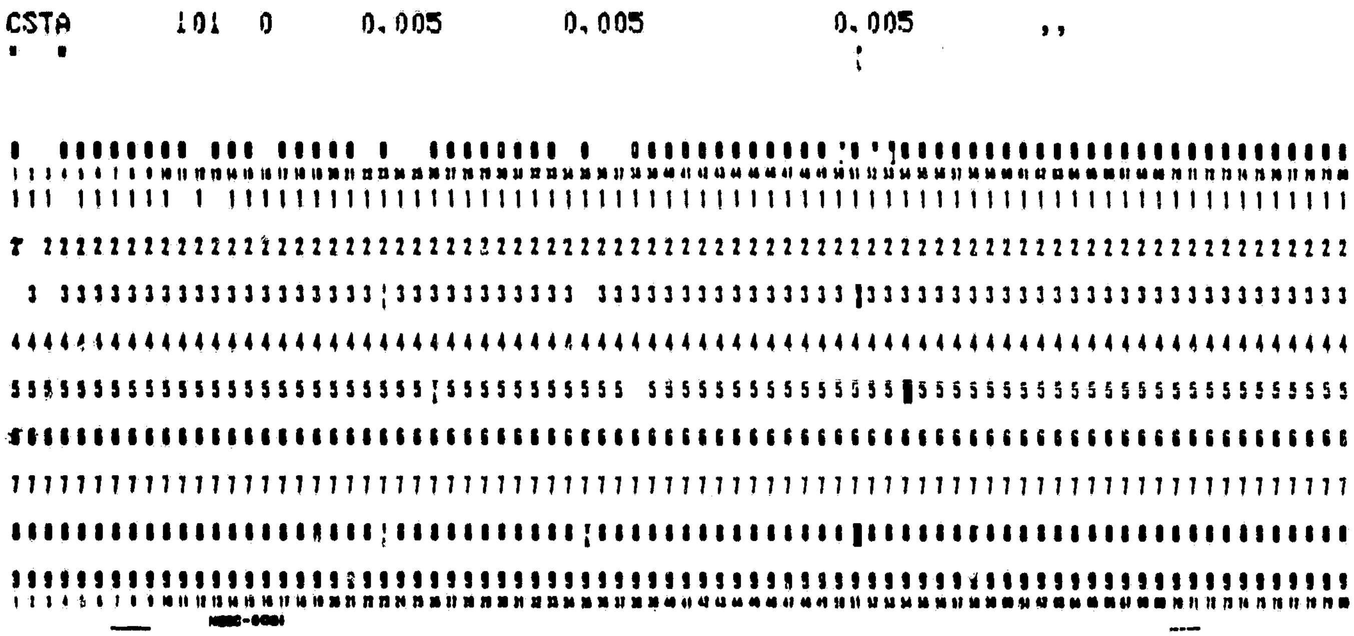


Variable	Type	Description
1	Alphanumeric (A8)	Keyword CLOCKT.
2	Integer	Not used.
3	Integer	Number of parameters: 1 = adjust clock drift rate only 2 = adjust clock timing error plus drift rate.
4	Real	Correlation time (seconds) for changes in the host clock drift rate. Default = 1.0 seconds.

Note: The Markov process only applies to the clock drift rate. The clock timing error is obtained by integrating the rate.

3.3.7 CSTA

The CSTA card is used to initialize the standard deviation for the ground station position errors (in earth-centered fixed Cartesion coordinates). If omitted, ground station position errors will not be adjusted.

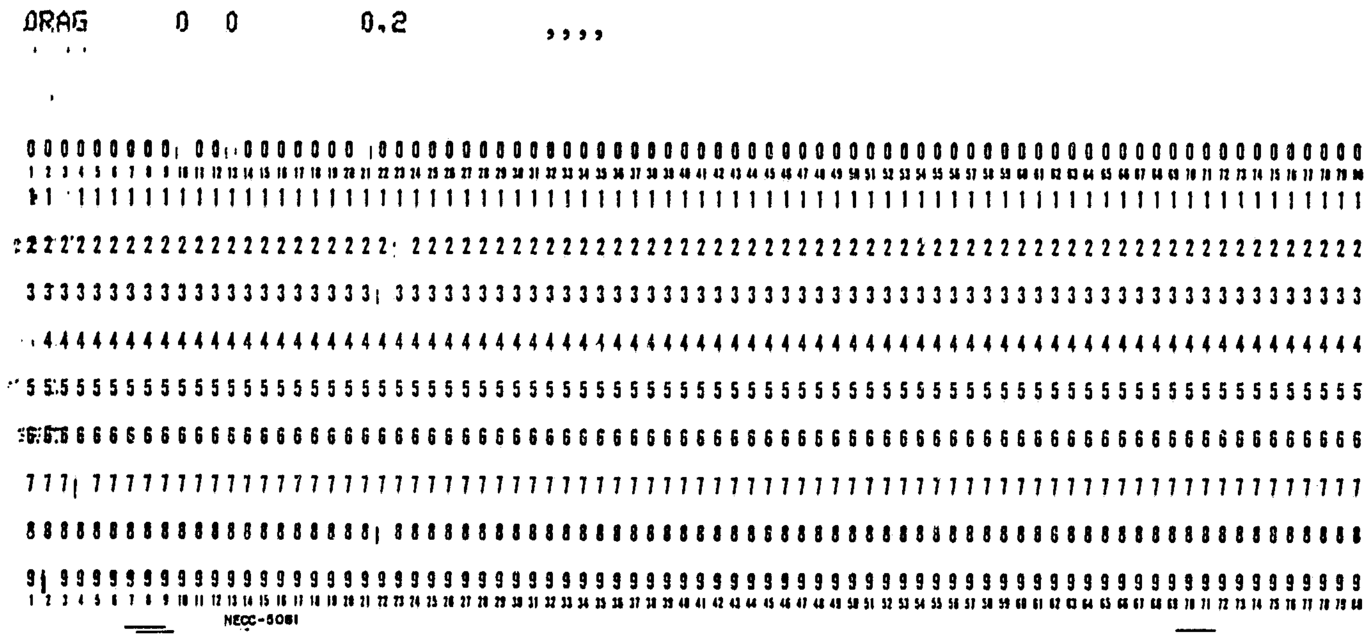


Variable	Type	Description
1	Alphanumeric (A8)	Keyword CSTA.
2	Integer	Station number (if 0, this card will apply to all stations).
3	Integer	Not used.
4	Real	*A priori* standard deviation for the x component of station position error (km). No default.
5	Real	*A priori* standard deviation for the y component of station position error (km). No default.
6	Real	*A priori* standard deviation for the z component of station position error (km). No default.

Note: (1) If it is desired to use the same sigmas for all stations but one or two, then use one card with no station number and the other cards with station numbers.

3.3.8 DRAG

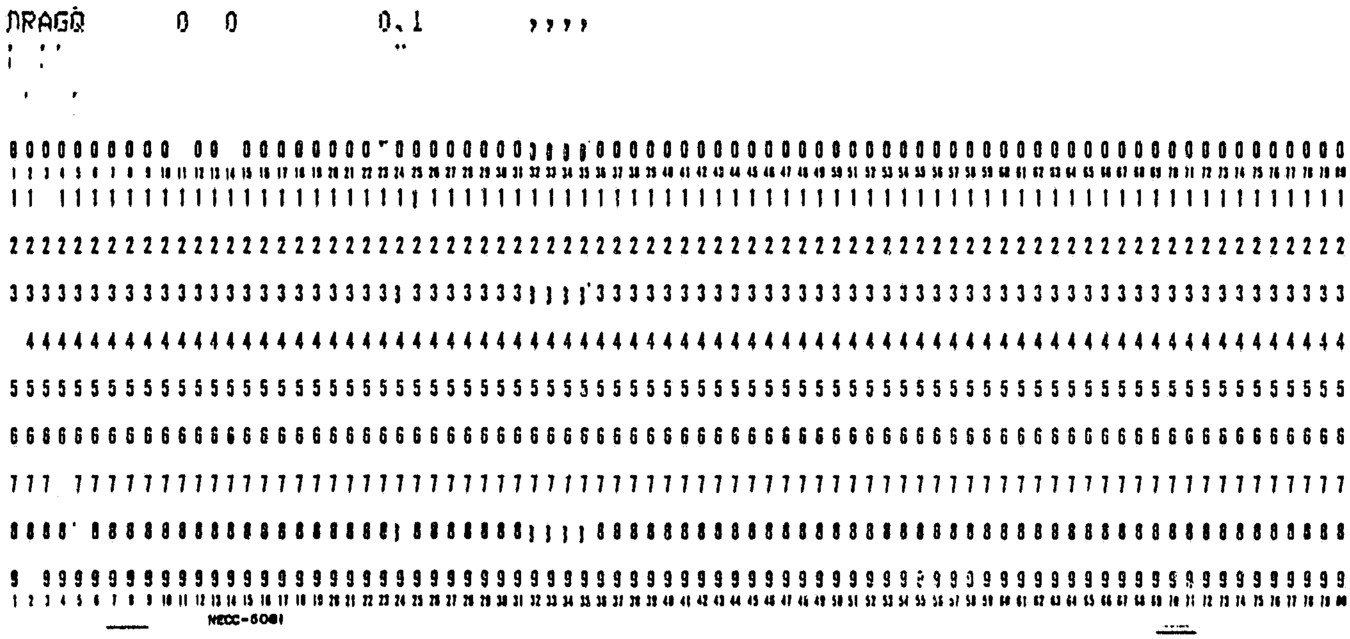
The DRAG card is used to initialize the standard deviations for the drag coefficient. If omitted, the drag coefficient is not adjusted.



Variable	Type	Description
1	Alphanumeric (A8)	Keyword DRAG.
2	Integer	Not used.
3	Integer	Not used.
4	Real	*A priori* standard deviation for the satellite drag coefficient (dimensionless). No default.

3.3.9 DRAGQ

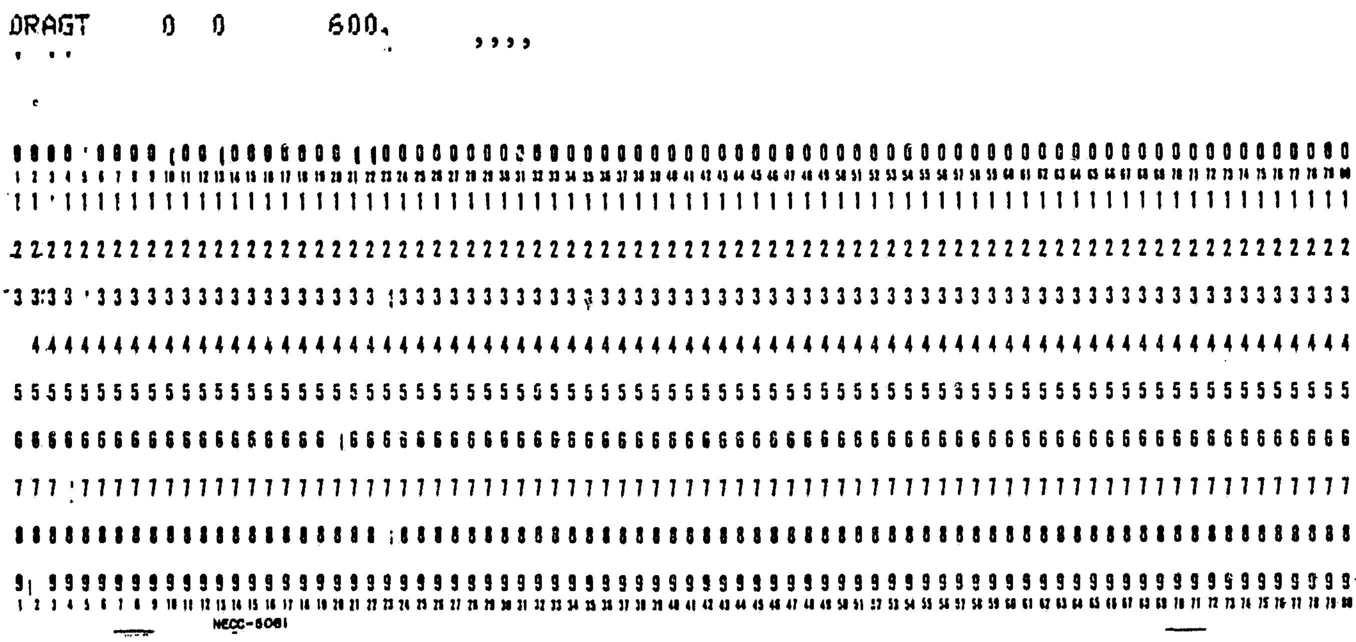
The DRAGQ card is used to input the state noise for the drag coefficient.



Variable	Type	Description
1	Alphanumeric (A8)	Keyword DRAGQ.
2	Integer	Not used.
3	Integer	Not used.
4	Real	Steady state sigma of the drag coefficient Markov process (dimensionless). Default = 0.

3.3.10 DRAGT

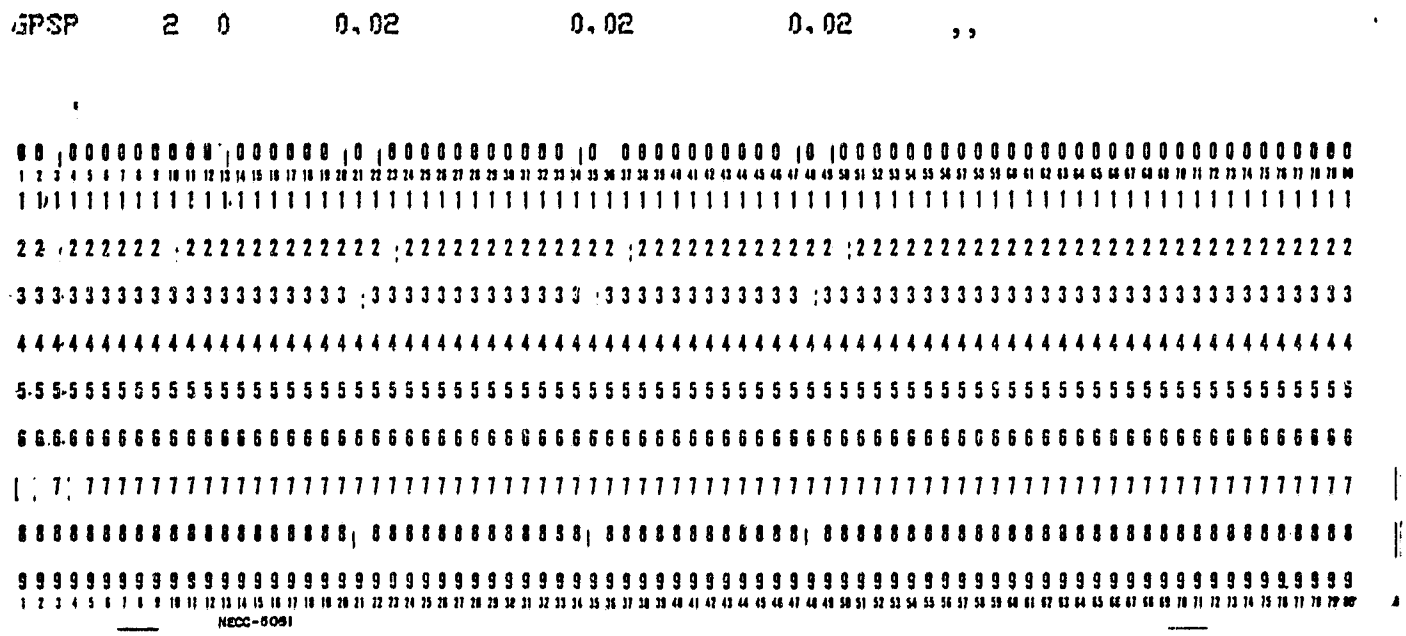
The DRAGT card is used to input the time constant of the first-order Markov process for the drag coefficient.



Variable	Type	Description
1	Alphanumeric (A8)	Keyword DRAGT.
2	Integer	Not used.
3	Integer	Not used.
4	Real	Correlation time (seconds) for changes in the drag coefficient. Default = 1.0 seconds.

3.3.11 GPSP

The GPSP card is used to initialize the standard deviations for the GPS position errors (in earth-centered local corrdinates). If omitted, GPS position errors will not be adjusted.



Variable	Type	Description
1	Alphanumeric (A8)	Keyword GPSP.
2	Integer	GPS satellite number (if 0, this card will apply to all satellites).
3	Integer	Not used.
4	Real	*A priori* standard deviation for the H (vertical) component of GPS position error (km). No default.
5	Real	*A priori* standard deviation for the C (crosstrack) component of GPS position error (km). No default.
6	Real	*A priori* standard deviation for the L (alongtrack) component of GPS position error (km). No default.

Note: (1) Note (1) on the CSTA card also applies.

(2) GPS position errors are treated as "pass" parameters.

3.3.12 GPST

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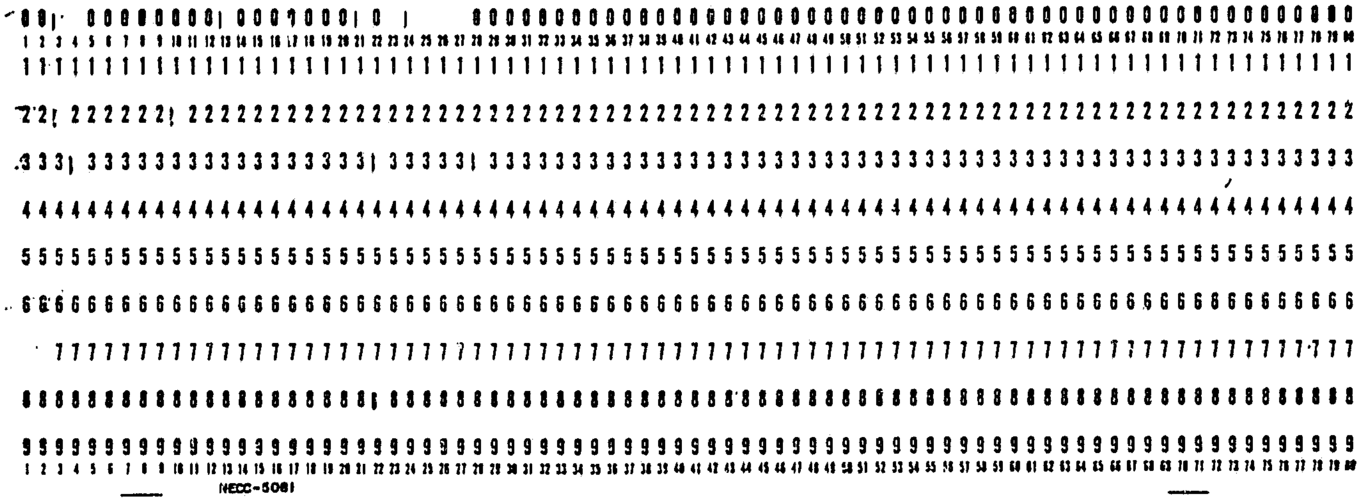
The GPST card is used to initialize the standard deviations for GPS timing error. If omitted, GPS timing errors will not be adjusted.

```
GPST     2  0        0.000003      ,,,,
```



Variable	Type	Description
1	Alphanumeric (A8)	Keyword GPST.
2	Integer	GPS satellite number (if 0, this card will apply to all satellites).
3	Integer	Not used.
4	Real	*A priori* standard deviation for the GPS timing error (milliseconds). No default.

Note: (1) Note (1) on the CSTA card also applies.
(2) GPS position errors are treated as "pass" parameters.

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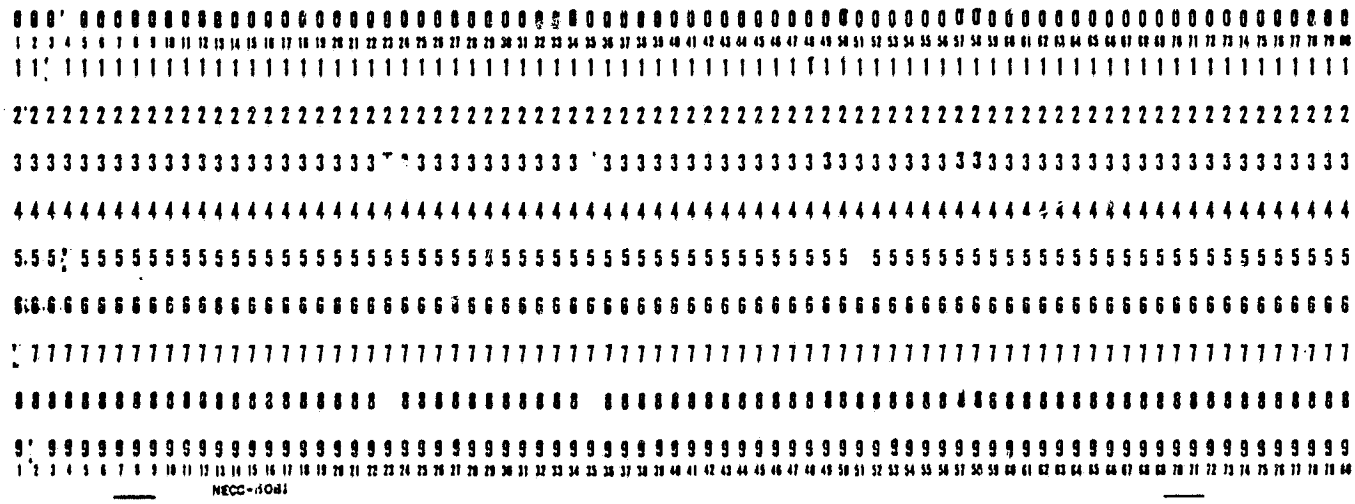
3.3.13 GRAV

The GRAV card is used to initialize the standard deviations for the perturbing gravitational accelerations. If omitted, the perturbing gravitational accelerations are not adjusted.

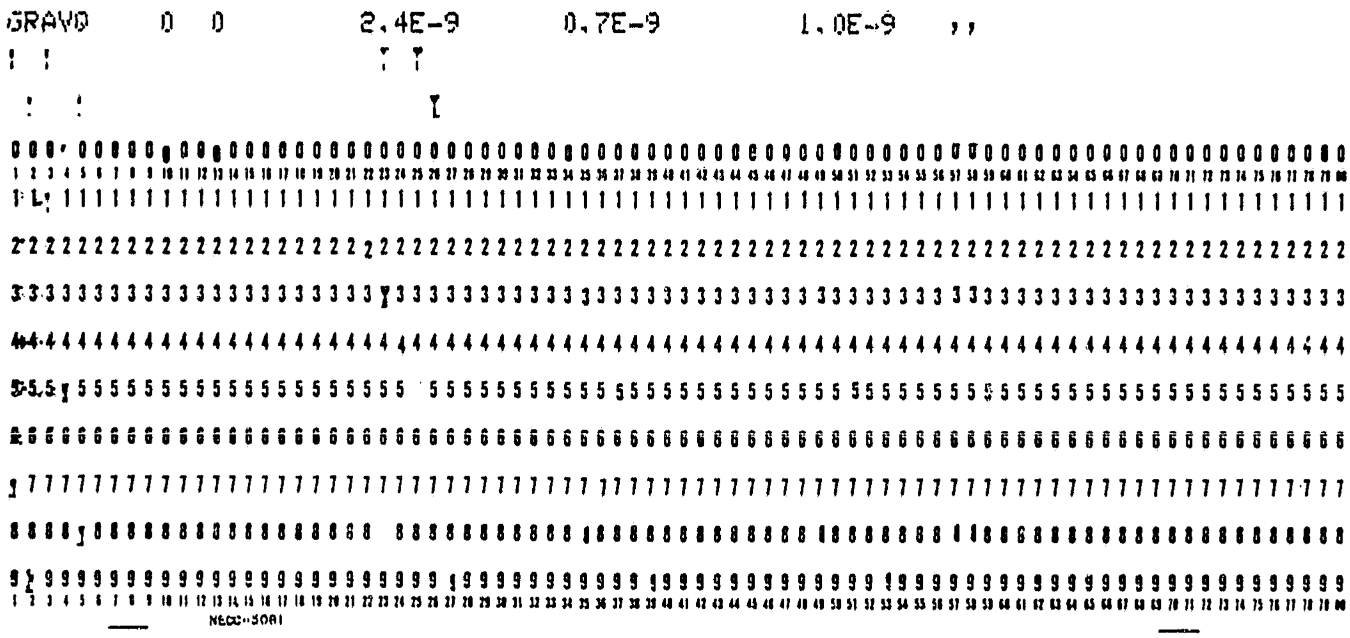
```
GRAV     0  0       2.4E-9      0.7E-9       1.0E-9   ,,
```



Variable	Type	Description
1	Alphanumeric (A8)	Keyword GRAV.
2	Integer	Not used.
3	Integer	Not used.
4	Real	*A priori* standard deviation for the vertical component of gravitational acceleration (km/sec^2). No default.
5	Real	*A priori* standard deviation for the cross-track (perpendicular to the orbit plane) component of gravitational acceleration (km/sec^2). No default.
6	Real	*A priori* standard deviation for the along track component of gravitational acceleration (km/sec^2). No default.

3.3.14 GRAVQ

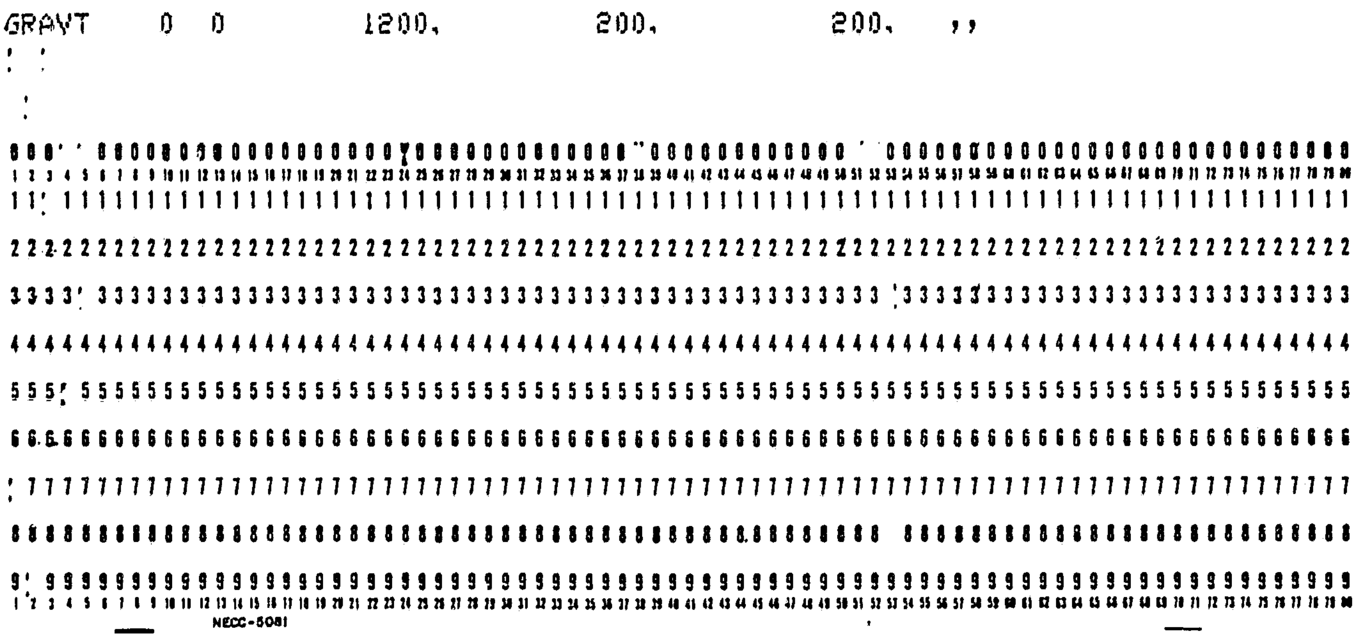
The GRAVQ card is used to input the state noise for the perturbing gravity accelerations.



Variable	Type	Description
1	Alphanumeric (A8)	Keyword GRAVQ.
2	Integer	Not used.
3	Integer	Not used.
4	Real	Steady state sigmas of the vertical gravitational acceleration Markov process (km/sec^2). Default = 0.
5	Real	Steady state sigmas of the cross-track gravitational acceleration Markov process (km/sec^2). Default = 0.
6	Real	Steady state of the along-track gravitational acceleration Markov process (km/sec^2). Default = 0.

3.3.15 GRAVT

The GRAVT card is used to input the time constants for the first-order Markov processes of the perturbing gravitational accelerations.

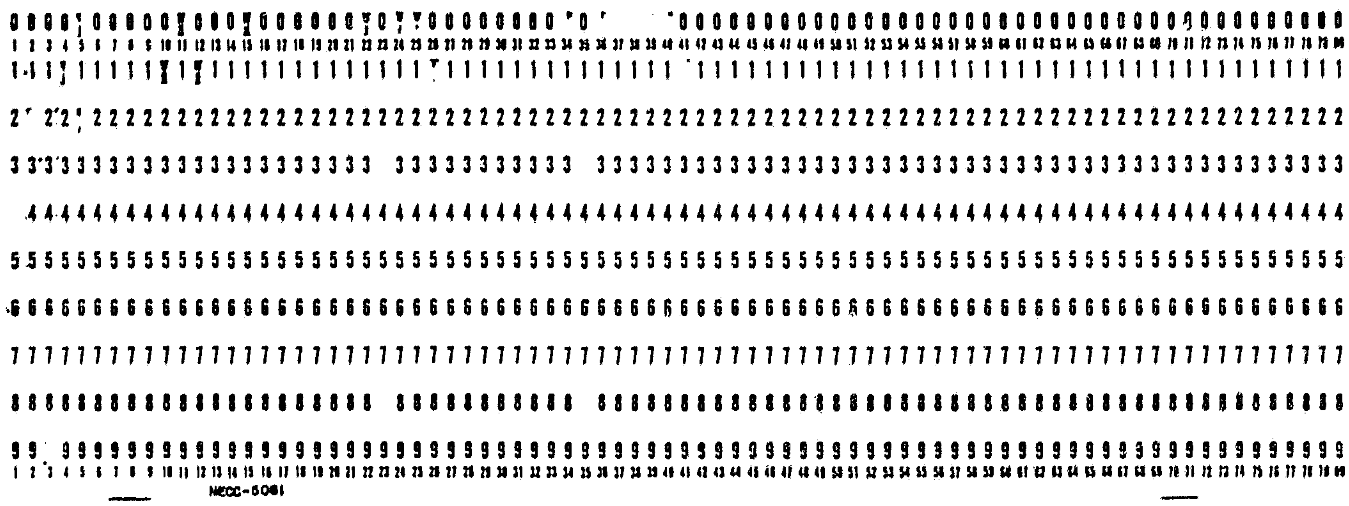


Variable	Type	Description
1	Alphanumeric (A8)	Keyword GRAVT.
2	Integer	Not used.
3	Integer	Not used.
4	Real	Correlation time (seconds) for changes in the vertical gravitational accelerations. Default = 1.0 seconds.
5	Real	Correlation time (seconds) for changes in the cross-track gravitational accelerations. Default = 1.0 seconds.
6	Real	Correlation time (seconds) for changes in the along-track gravitational accelerations. Default = 1.0 seconds.

3.3.16 MBIAS

The MBIAS card is used to initialize the standard deviations for station measurement biases. If omitted, no biases will be adjusted.

```
MBIAS    101  0      0.001        0.000001    ,,,
```



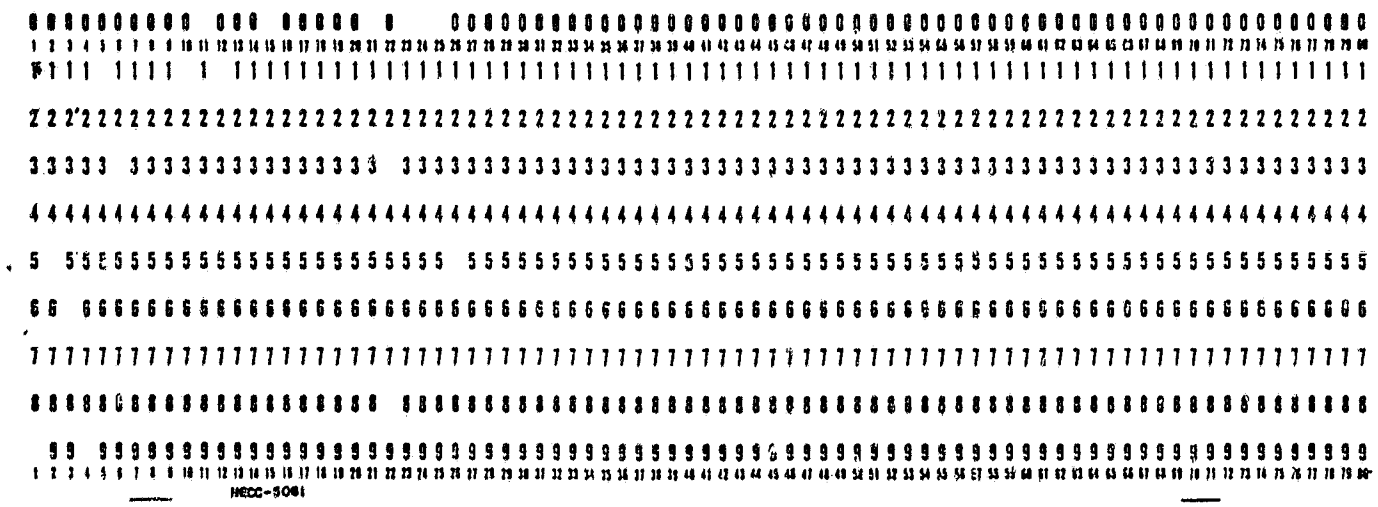
Variable	Type	Description
1	Alphanumeric (A8)	Keyword MBIAS.
2	Integer	Station number (if 0, this card will apply to all stations).
3	Integer	Number of biases (1 or 2). Default=1.
4	Real	*A priori* standard deviation for the first measurement bias (kilometers for range). No default.
5	Real	*A priori* standard deviation for the second measurement bias (km/sec for range rate). No default.

Note: Note (1) on the CSTA card also applies. See also note on MSIG card.

3.3.17 REFRAC

The REFRAC card is used to initialize the standard deviations for station refraction parameters. If omitted, no refraction parameters will be adjusted.

```
REFRAC   101  0     0.0005    ,,,,
```



Variable	Type	Description
1	Alphanumeric (A8)	Keyword REFRAC.
2	Integer	Station number (if 0, this card will apply to all stations).
3	Integer	If this number is greater than 0 on <u>any</u> REFRAC card, then the program will use the refraction correction on the measurement tape as the multiplier of the refraction parameter. Default = 0.
4	Real	*A priori* standard deviation for the measurement refraction parameter (see Note 2). No default.

Note: (1) Note (1) on the CSTA card also applies.

(2) If variable 3 is zero for all REFRAC cards, then the residual refraction error is assumed to be of the form:

$$K/\sin E \qquad \text{(range)}$$

$$K\left(\frac{1}{\sin E_i} - \frac{1}{\sin E_{i-1}}\right)/DT \qquad \text{(range rate)}$$

where K is the refraction parameter and E is the elevation of the ray. Thus the *a priori* sigma on K has units of kilometers. If variable 3 is greater than zero for any REFRAC card, then K will be treated as the multiplier of the total refraction correction which is available on the measurement tape for each measurement. Thus K is dimensionless.

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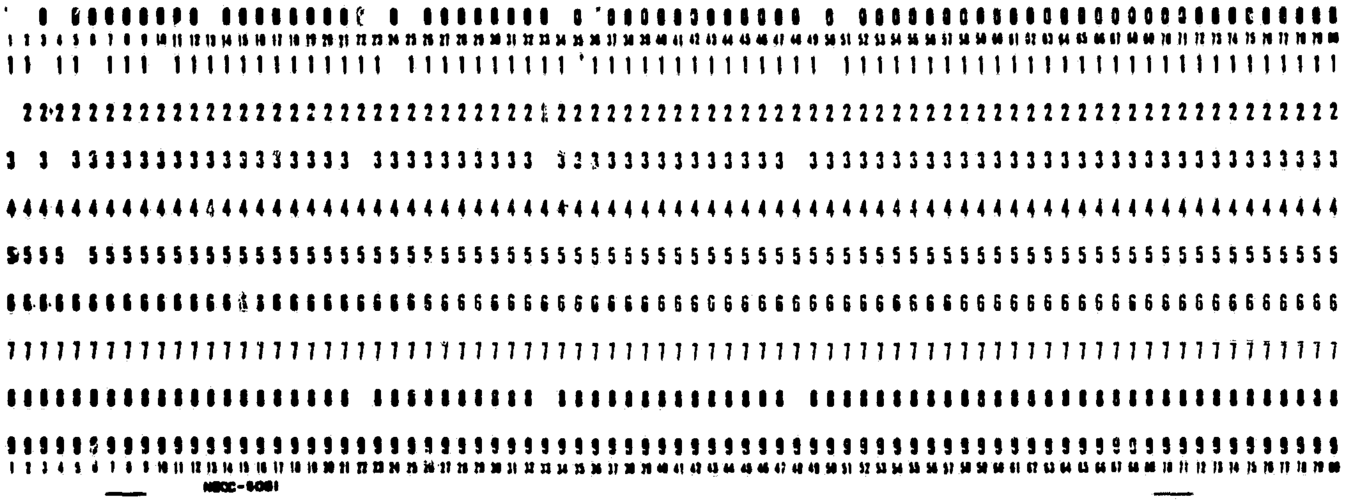
3.3.18 STATE1

The STATE1 card is used to initialize the standard deviations for the first three orbital states.

```
STATE1   1  0        .010       .010           .010     ,,
```



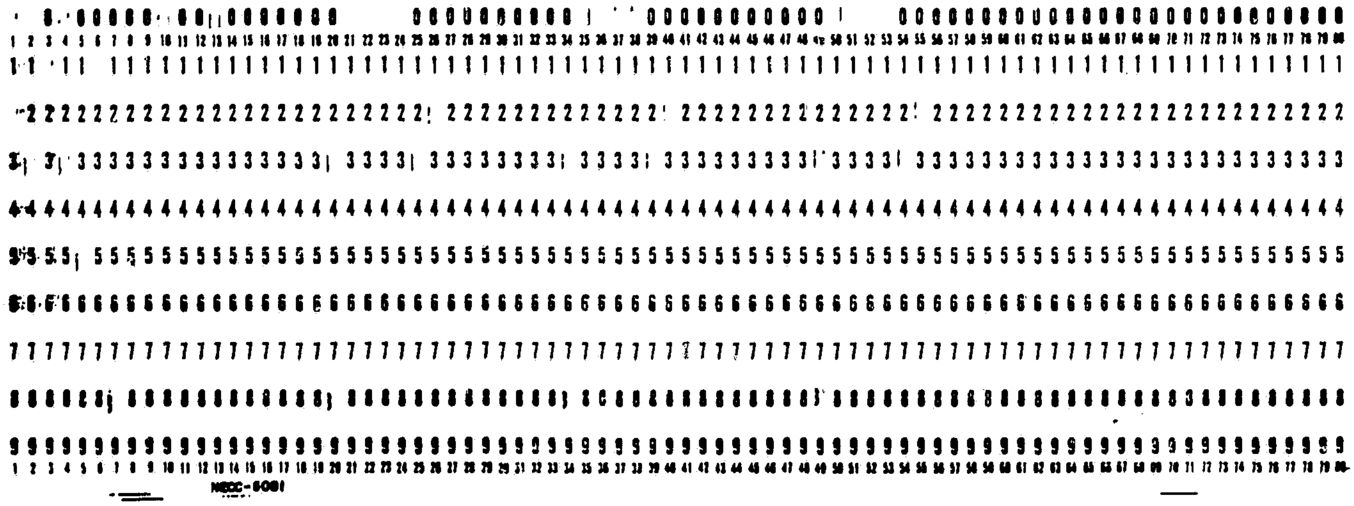
Variable	Type	Description
1	Alphanumeric (A8)	Keyword STATE1.
2	Integer	Defines type of orbital elements: 1 = cartesian elements; 2 = Keplerian elements; 3 = spherical elements. Note, this <u>must</u> match type on ORBIT file. Default = 1
3	Integer	Not used.
4	Real	*A priori* standard deviation for satellite state 1 (km). Default = .01$^{(1)}$.
5	Real	*A priori* standard deviation for satellite state 2. Default = .01$^{(1)}$.
6	Real	*A priori* standard deviation for satellite state 3. Default = .01$^{(1)}$.

Note: (1) Units are kilometers, radians or dimensionless.

3.3.19 STATE1Q

The STATE1Q card is used to input the state noise on the satellite position in earth-centered inertial cartesian coordinates (the program makes the transformation to other types of orbital elements).

```
STATE1Q  0  0      .000032      .000032      .000032 ,,
```



Variable	Type	Description
1	Alphanumeric (A8)	Keyword STATE1Q.
2	Integer	Not used.
3	Integer	Not used.
4	Real	Square root of state noise spectral density for the x component of satellite position (in km/sec$^{1/2}$). Default = 0.
5	Real	Square root of state noise spectral density for the y component of satellite position (in km/sec$^{1/2}$). Default = 0.
6	Real	Square root of state noise spectral density for the z component of satellite position (in km/sec$^{1/2}$). Default = 0.

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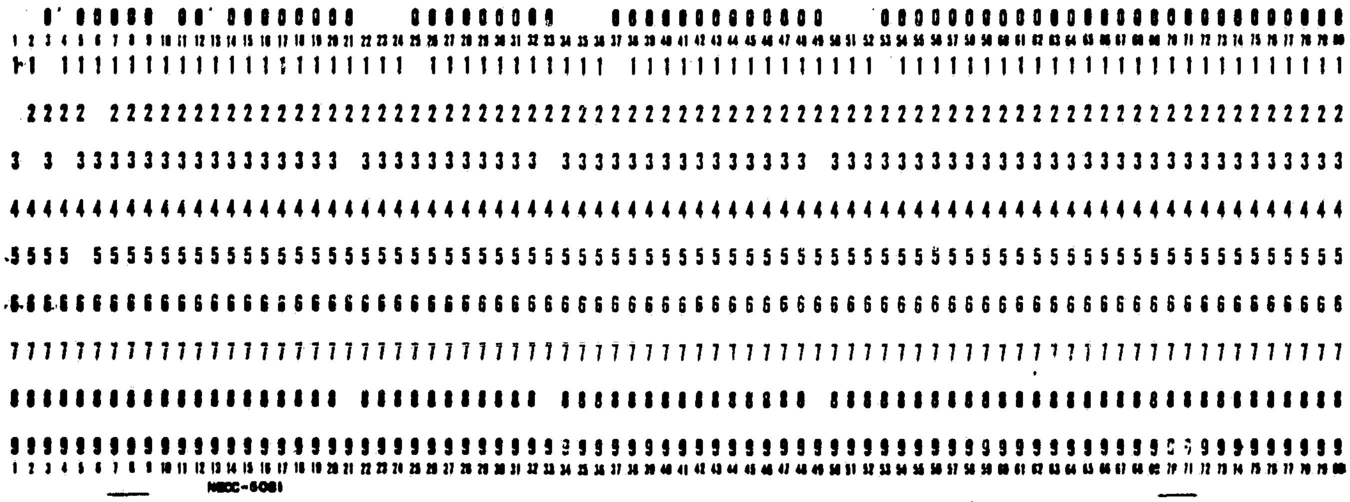
3.3.20 STATE2

The STATE2 card is used to initialize the standard deviations for orbital states four, five and six.

STATE2 0 0 .0001 .0001 .0001 ,,



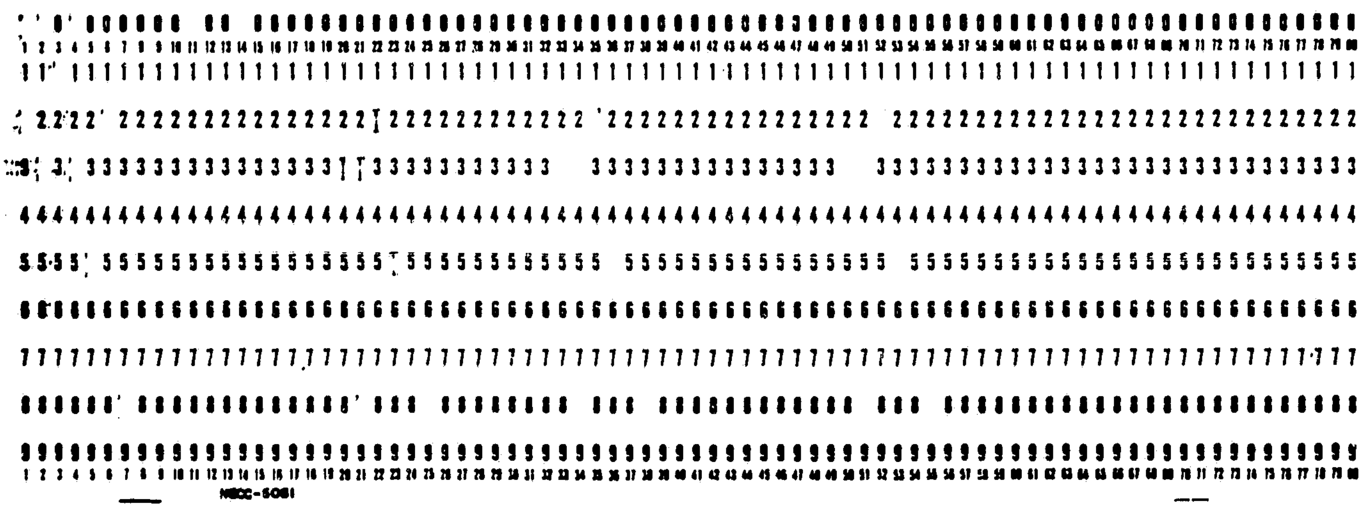
Variable	Type	Description
1	Alphanumeric (A8)	Keyword STATE2.
2	Integer	Not used.
3	Integer	Not used.
4	Real	*A priori* standard deviation for satellite state four. Default = .0001 (1).
5	Real	*A priori* standard deviation for satellite state five. Default = .0001 (1).
6	Real	*A priori* standard deviation for satellite state six. Default = .0001 (1).

Note: (1) Units are km/sec or radians.

3.3.21 STATE2Q

The STATE2Q card is used to input the state noise on the satellite velocity in earth-centered inertial cartesian coordinates (the program makes the transformation to other types of orbital elements).

```
STATE2Q  0  0    3.2E-8    3.2E-8      3.2E-8   ,,
```

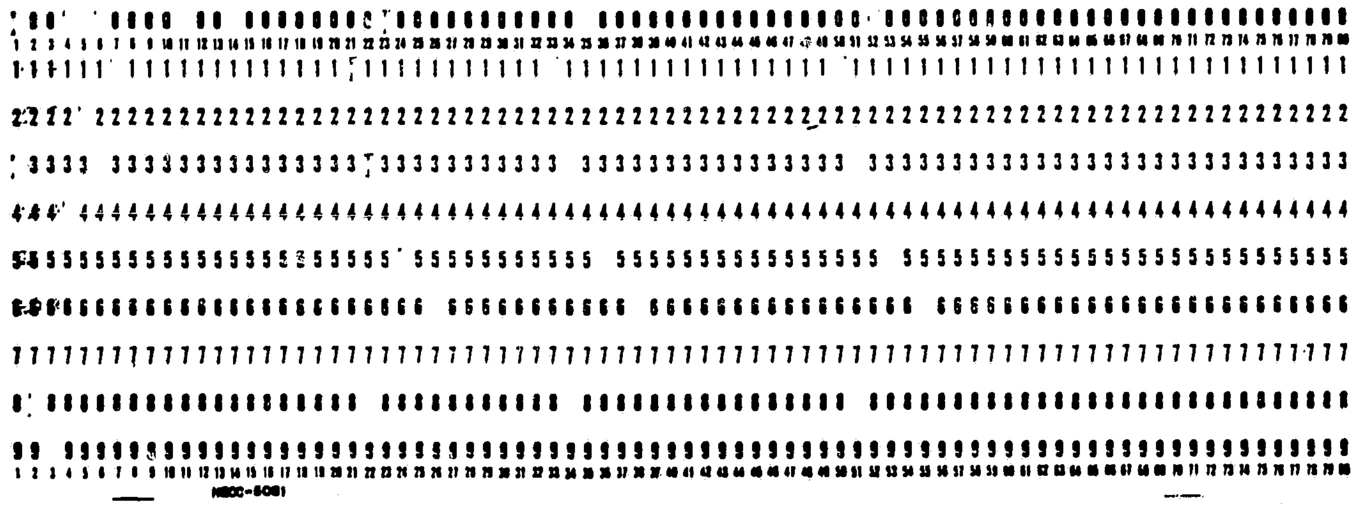


Variable	Type	Description
1	Alphanumeric (A8)	Keyword STATE2Q.
2	Integer	Not used.
3	Integer	Not used.
4	Real	Square root of state noise spectral density for the x component of satellite velocity (in km/sec$^{3/2}$). Default = 0.
5	Real	Square root of state noise spectral density for the y component of satellite velocity (in km/sec$^{3/2}$). Default = 0.
6	Real	Square root of state noise spectral density for the z component of satellite velocity (in km/sec$^{3/2}$). Default = 0.

3.3.22 THRUST1

The THRUST1 card is used to initialize the standard deviation for the perturbing components of the <u>first</u> thrust segment. If omitted, the perturbing thrusts will not be adjusted.

```
THRUST1   0  0       1.0E-6      1.0E-6         1.0E-6        ,,
```



Variable	Type	Description
1	Alphanumeric (A8)	Keyword THRUST1.
2	Integer	Not used.
3	Integer	Not used.
4	Real	*A priori* standard deviation for the vertical component of thrust acceleration (km/sec^2). No default.
5	Real	*A priori* standard deviation for the cross-track component of thrust acceleration (km/sec^2). No default.
6	Real	*A priori* standard deviation for the along track component of thrust acceleration (km/sec^2). No default.

3.3.23 THRUST1Q

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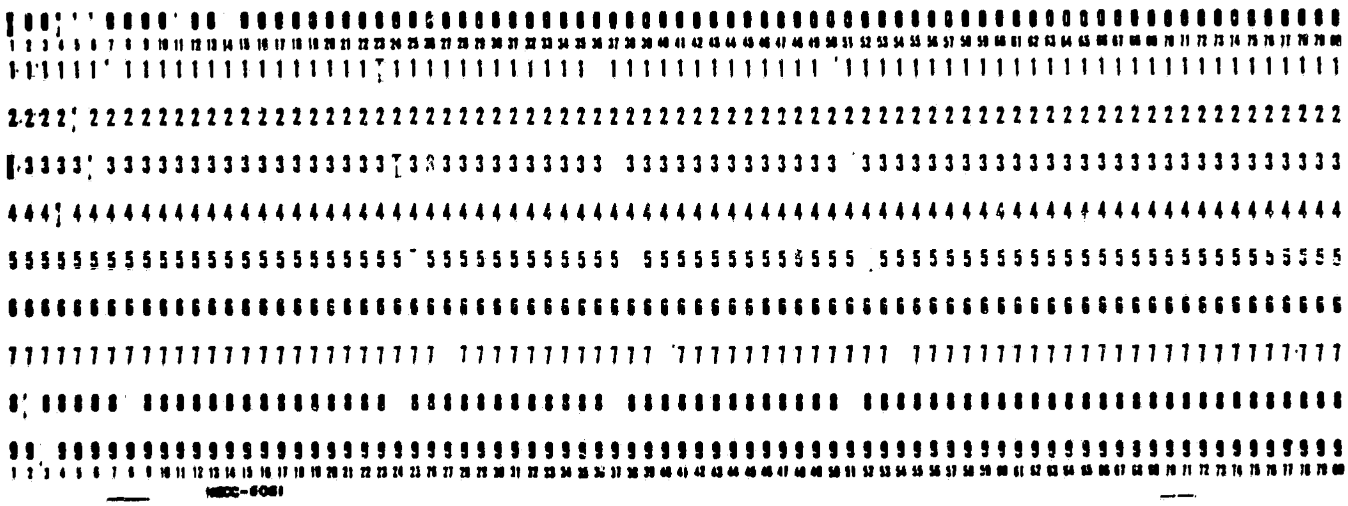
The THRUST1Q card is used to input the state noise for the perturbing components of the first thrust segment.

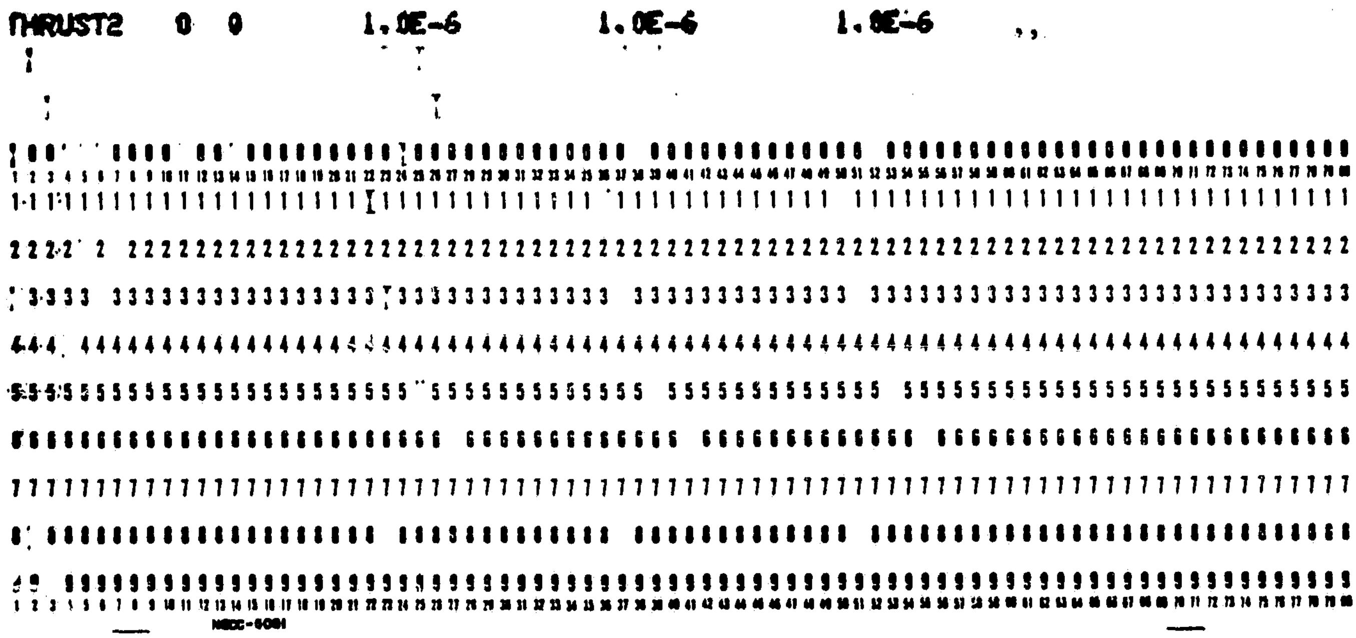
```
THRUST1Q  0  0        1.E-7       1.E-7       1.E-7  ,,
```



Variable	Type	Description
1	Alphanumeric (A8)	Keyword THRUST1Q.
2	Integer	Not used.
3	Integer	Not used.
4	Real	Square root of state noise spectral density for the vertical component of thrust acceleration (km/sec$^{5/2}$). Default = 0.
5	Real	Square root of state noise spectral density for the cross-track component of thrust acceleration (km/sec$^{5/2}$). Default = 0.
6	Real	Square root of state noise spectral density for the along-track component of thrust acceleration (km/sec$^{5/2}$). Default = 0.

3.3.24 THRUST2

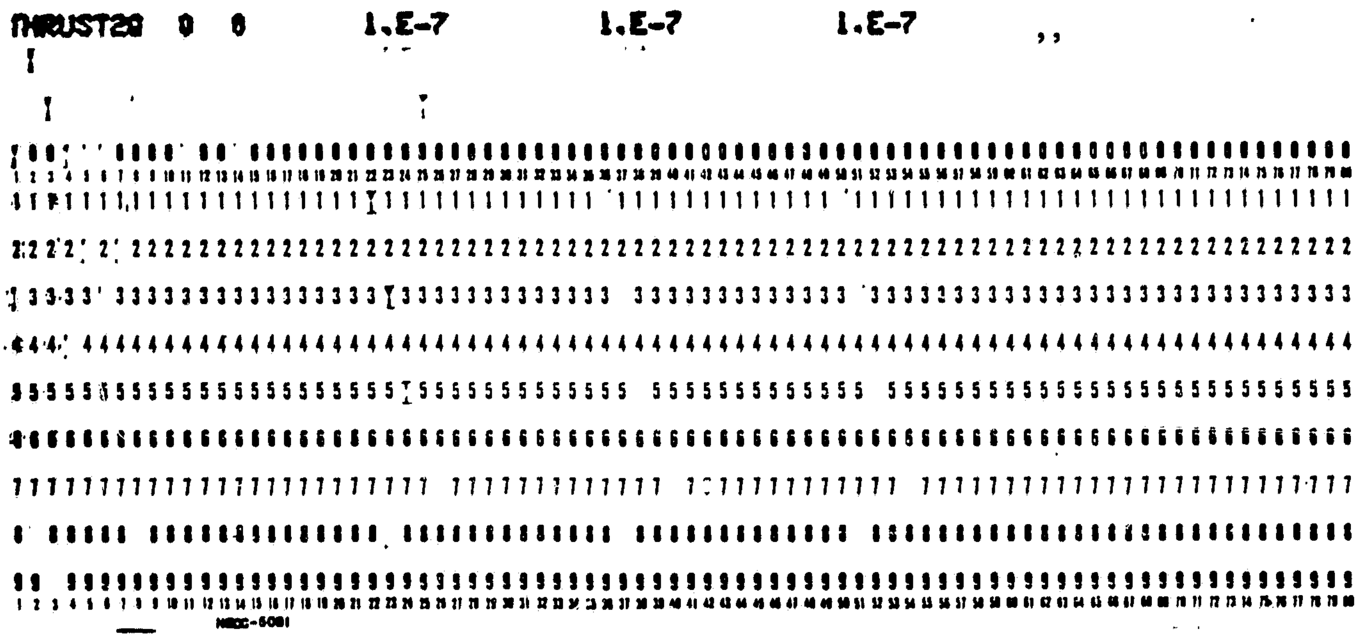
The THRUST2 card is used to initialize the standard deviations for the perturbing components of the second thrust segment. If omitted, the perturbing thrusts will not be adjusted.



Variable	Type	Description
1	Alphanumeric (A8)	Keyword THRUST2.
2	Integer	Not used.
3	Integer	Not used.
4	Real	*A priori* standard deviation for the vertical component of thrust acceleration (km/sec^2). No default.
5	Real	*A priori* standard deviation for the cross-track component of thrust acceleration (km/sec^2). No default.
6	Real	*A priori* standard deviation for the along track component of thrust acceleration (km/sec^2). No default.

3.3.25 THRUST2Q

The THRUST2Q card is used to input the state noise for the perturbing components of the second thrust segment.



Variable	Type	Description
1	Alphanumeric (A8)	Keyword THRUST2Q.
2	Integer	Not used.
3	Integer	Not used.
4	Real	Square root of state noise spectral density for the vertical component of thrust acceleration (km/sec$^{5/2}$). Default = 0.
5	Real	Square root of state noise spectral density for the cross-track component of thrust acceleration (km/sec$^{5/2}$). Default = 0.
6	Real	Square root of state noise spectral density for the along-track component of thrust acceleration (km/sec$^{5/2}$). Default = 0.

4.0 PROGRAM OUTPUT

The printed output from PREFER consists of the filter estimates at the end of each mini-batch, a summary of the measurement residual statistics for each mini-batch, the smoother estimates at the corresponding times, and optional printer plots of the filter and smoother position standard deviations. PREFER also produces an ORB1 File (smoother output) on unit 70 and an optional file (unit 71) containing the smoother covariance matrix in ECI coordinates.

The filter summary includes output in both earth-centered inertial or local coordinates at the current time and epoch elements (cartesian, Keplerian or spherical). The ECI/HCL output consists of the nominal trajectory, the estimated correction and the estimated total. The filter output for the epoch elements is the estimated correction to the nominal elements. Also printed are the estimates for the remaining state parameters and the computed standard deviation for the estimate.

The measurement residual statistics for each mini-batch are printed before the corresponding filter summary. Two lines are printed for measurements which occur in pairs (e.g., GPSPAC, or ground range and range rate). The first line for each GPS satellite lists the statistics for the pseudo range measurements while the second line corresponds to the pseudo delta-range measurements. Ground tracking can be easily distinguished from satellite-to-satellite tracking because GPS satellite numbers are printed as negative. Included in the residual statistics is the "WEIGHTED SIGMA". This is computed as $\sqrt{(\sum_{i}^{n}(z_i^2/\sigma_{z_i}^2))/n}$ where σ_{z_i} is the residual sigma ($\sigma_{z_i} = \sqrt{HPH^T+R}$) as computed by the filter. If all the filter models are correct, the expected value of the WEIGHTED SIGMA should be approximately equal to 1 and the deviation from 1 should be approximately $1/\sqrt{2n}$.

Between the filter summaries may be other messages which indicate when pass parameters are added or removed. Also, any measurement residuals which exceed the editing or printing thresholds will be printed.

A summary of the measurement residual statistics is printed at the end of the filter printout. The following five quantities are printed:

(a) Total number of measurements: n

(b) Weighted sigma: $\sqrt{\left(\sum_{i}^{n}(z_i^2/\sigma_{z_i}^2)\right)/n}$

(c) $\sum_{i=1}^{n} z_i^2/\sigma_{z_i}^2$

(d) $\sum_{i=1}^{n} \ln(\sigma_{z_i}^2)$

(e) $-\frac{1}{2}\sum_{i=1}^{n}(z_i^2/\sigma_{z_i}^2+\ln \sigma_{z_i}^2)$.

The sum of weighted residuals (quantity c) should be chi-square distributed with a mean of n and a standard deviation of $\sqrt{2n}$. If the value printed deviates greatly from $n \pm \sqrt{2n}$, then modeling errors are suspected. Quantity d is the sum of the natural logarithm of the analytically computed residual variances. Quantity e is the log likelihood function (plus a bias) and is computed as the negative of one-half the sum of quantities c and d . This is the quantity which would be maximized in a maximum likelihood estimation program [3]. Thus, the log likelihood can be used as a metric to compare runs made with different model assumptions. Notice that this procedure attempts to minimize the sum of weighted residuals <u>and</u> the residual variances: it is not acceptable to minimize just the sum of weighted residuals since this can be done by making σ_{z_i} large.

The smoother output is printed backward in time after the filtering is completed. The smoother summary is very similar to the filter summary and also includes the filter estimate at each point.

All output is in units of kilometers, km/sec, km/sec^2, radians, milliseconds, Hz/megahertz or dimensionless.

4.1 Format of ORB1 File (Unit 70)

The smoothed ECI positions and velocities are written on Unit 70 in the format of a GTDS ORB1 File. This will be generated in the same coordinate system (TOD or 1950) as the input ORBIT file. The starred quantities are not actually written on the file.

RECORD	RECORD SIZE	BYTES	NAME, DESCRIPTION, ETC.	
1 ORB1 header	2800 bytes	1-8	TITLE(1):	ORB1 identifier = 76796291.
		9-16	IDSAT:	Satellite ID number
		17-24	Not used	
		25-32	STORB1(1):	Start time of ephemeris (YYMMDD.)
		33-40	TITLE(5):	Day count of year for start of ephemeris
		41-48	TITLE(6):	Seconds of day for start of ephemeris
		49-56	ETORB1(1):	End time of ephemeris (YYMMDD.)
		57-64	TITLE(8):	Day count of year for end of ephemeris
		65-72	TITLE(9):	Seconds of day for end of ephemeris
		73-80	TITLE(10):	Time interval between ephemeris points (sec.)
		81-152	HEADER (I,1): I=1,9	Title of current run
		153-160	ICENT:	Central body indicator

RECORD	RECORD SIZE	BYTES	NAME, DESCRIPTION, ETC.	
1 ORB1 header	2800 bytes	161–208	Spares	
		209–216	YMDREF:	Year, month, and day of referenced time of true system
		217–224	TITLE(28):	Day count of year for reference date
		225–232	GHA:	Greenwich hour angle at epoch
		233–632	Spares	
		633–640	CSUBDZ:	Drag coefficient
		641–648	AREA:	Area of spacecraft in cm^2
		649–656	SCMASS:	Mass of spacecraft in grams
		657–800	Spares	
		801–808	TITLE(101):	Time of epoch from reference date in seconds/806.81242
		809–816*	TITLE(102):	Ratio of semimajor axis to mean equatorial radius
		817–824*	AEINT(2):	Eccentricity
		825–832*	OBLINT(5):	True anomaly at t_0: rad.
		833–880	PVINT(I):	I=1,6 Cartesian elements for integration initialization
		881–888	SPINT(5):	Magnitude of radius vector (km)
		889–896	SPINT(6):	Magnitude of velocity vector (km/sec)
		897–904*	TITLE(113):	Sum of mean anomaly and argument of perifocus
		905–912*	AEINT(6):	Mean anomaly
		913–920	Spare	
		921–928*	AEINT(5):	Augment of perifocus
		929–936*	AEINT(3):	Inclination
		937–944*	AEINT(4):	Longitude of ascending node

RECORD	RECORD SIZE	BYTES	NAME, DESCRIPTION, ETC.	
1 ORB1 header	2800 bytes	945–952*	TITLE(119):	Vertical flight path angle minus $\pi/2$
		953–960*	OBLINT(4):	Mean motion at t_0: rad./DUT sec.
		961–968*	OBLINT(1):	Eccentric anomaly at t_0: rad.
		969–976*	OBLINT(8):	Time rate of change of argument of perigee at t_0: rad./DUT sec.
		977–984*	OBLINT(9):	Time rate of change of right ascension of ascending node at t_0: rad./DUT sec.
		985–992*	OBLINT(2):	Period at t_0: DUT sec.
		993–1000*	OBLINT(6):	Perigee height at t_0: km
		1001–1008*	OBLINT(7):	Apogee height at t_0: km
		1009–1520	Spare	
		1521–1528	EY:	Year of elements epoch
		1529–1536	EM:	Month of elements epoch
		1537–1544	ED:	Day of elements epoch
		1545–1552	EH:	Hour of elements epoch
		1553–1560	EMN:	Minute of elements epoch
		1561–1568	ESC:	Seconds of elements epoch
		1569–1592	Spare	
		1593–1600	TITLE (200):	Orbit theory indicator = 2, Cowell or time-regularized Cowell = 3, all others
		1601–2800	Spare	

RECORD	RECORD SIZE	BYTES	NAME, DESCRIPTION, ETC.	
All except first and last two	2800 bytes	1-8	DATA(1):	Date of first ephemeris point (YYMMDD.)
		9-16	DATA(2):	Day count of year for first ephemeris point
		17-24	DATA(3):	Seconds of day for first ephemeris point
ORB1 data		25-32	DATA(4):	Time interval between data points (sec.)
		33-40	DATA(5):	Day count of year for epoch
		41-86	PVINT(I):	I = 1,6; first position vector (km) and velocity vector (km/sec)
		87-2440	PVINT(I):	I = 1,6; J = 2,50 Position and velocity vector sets for data points 2-50. For less than 50 points, the first invalid set is .9999999999999999 x 10^{16} (units km and km/sec)
		2441-2800	Spares	
Last two ORB1 and sentinels	2800 bytes	1-2800	ESNINE(I)	I = 1,350 End of file sentinels, with the value 0.9999999999999999 x 10^{16}

4.2 Format of Smoother ECI Covariance File (Unit 71)

If requested, the entire smoother covariance matrix is written on unit 71 where the entries corresponding to the orbital elements are transformed from epoch osculating elements to current ECI cartesian elements. This file consists of two types of records which are repeated until the end of the trajectory is reached. Notice that the first record (in a pair) contains a variable which defines the length of the second record.

Record Type 1

Word No.	Type	Description
1-2	Double Precision	Time from epoch (sec).
3	Integer	Number of adjusted states (n) at current time.
4	Integer	Length of covariance matrix $\left(\frac{n\cdot(n+1)}{2}\right)$
5	Integer	Numeric label of 1st state.
6	Integer	Numeric label of 2nd state.
.	.	. .
.	.	. .
.	.	. .
.	.	. .
.	.	. .
104	Integer	Numeric label of 100th state.

Record Type 2

This contains the ECI smoother covariance matrix stored as upper triangular by columns.

Word No.	Type	Description
1-2	Double Precision	Variance of 1st state.
3-4	Double Precision	Covariance between 1st and 2nd states.
.	.	.
.	.	.
.	.	.
(n·(n+1)-1) -(n·(n+1))	Double Precision	Variance of nth state.

Notes: (1) Because of numerical problems, it is possible for the state variances to become negative.

(2) The numeric labels of the states are defined as:

Label	Description
1-6	state orbital elements (ECI)
7	drag coefficient
8	perturbing gravitational accelerations (HCL)
9	acceleration of first thrust segment (HCL)
10	acceleration of second thrust segment (HCL)
11	host clock timing error (msec)
12	host clock drift rate (msec/sec)
13	altimeter bias
100000	station bias
200000	station refraction parameter
300000	station position error (ECI)
400000	GPS position error (HCL)
500000	GPS timing error (msec)

The last 5 digits in each number are reserved for the station or satellite number.

5.0 EXAMPLE (LANDSAT)

Orbit - 700 km altitude, e = .0001, 98.3° inclination, 720 minutes (7.3 revolutions)

Simulated Tracking Data - 5 ground stations measuring range and integrated range rate. See Table 5.1 for error parameters.

Nominal Trajectory - Obtained by using GTDS to least squares fit the simulated tracking data over 12 hours. See Table 5.1 for differences between models used in simulating data and models used in batch orbit determination.

Table 5.1 Error Parameters of Example

Parameter	Model Description	
	Simulated Data	Batch Orbit Determination
data noise (range)	1 meter	1 meter (weighting)
data noise (range rate)	0.1 cm/sec	0.1 cm/sec (weighting)
gravitational field	GEM9 (20,20)	WGS72 (16,16)
measurement bias (R)	5 meters	---
measurement bias ($\dot{R}$)	0.1 cm/sec	---
station position errors	±5m each component	---
drag coefficient	2.0	1.5
density model	Flux table #150	Flux table #150
solar radiation pressure	yes	no
refraction-tropospheric	yes	yes
refraction-ionospheric	yes	yes
polar motion modeled	no	yes

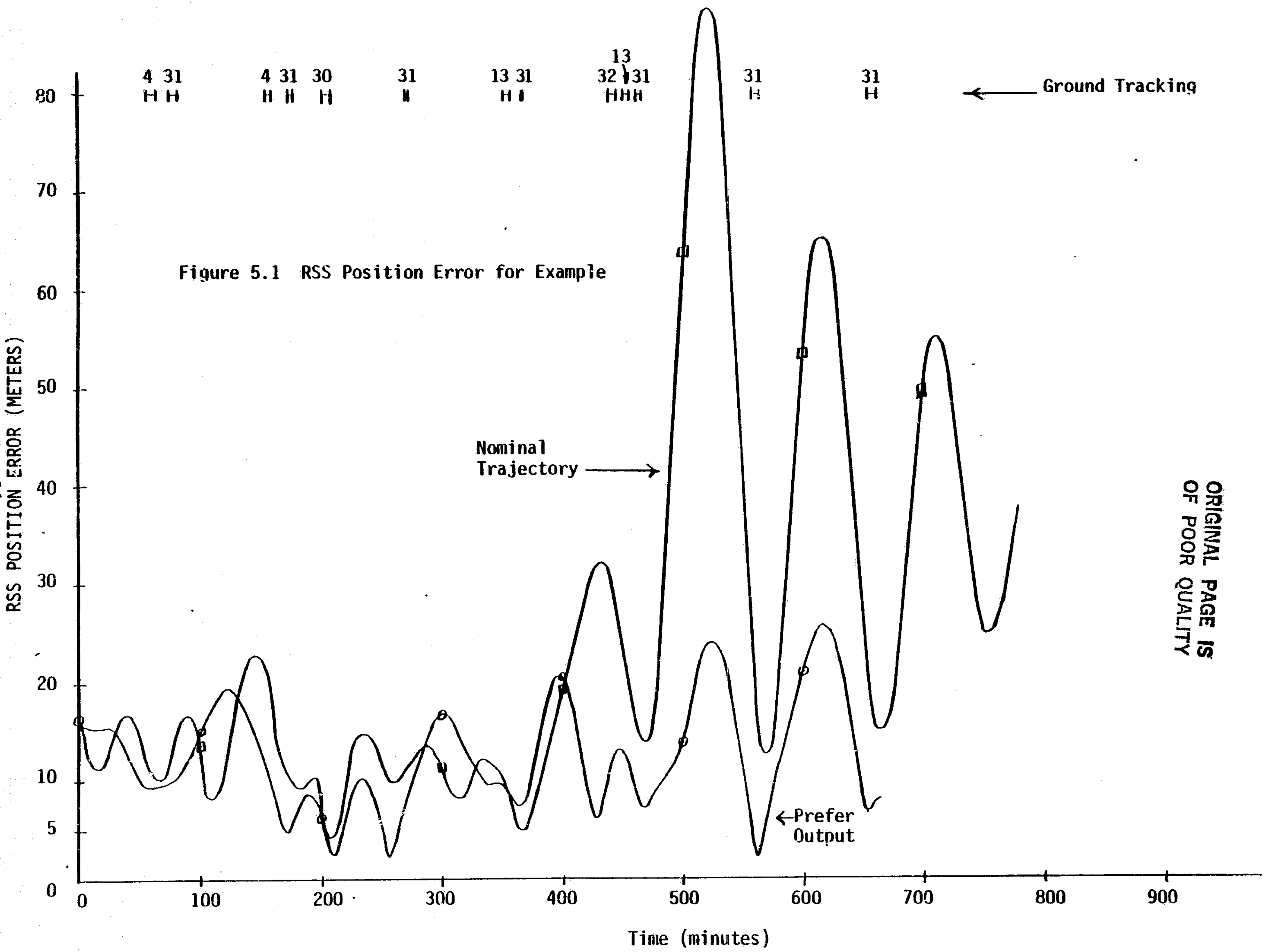


Figure 5.1 RSS Position Error for Example

<u>A priori</u> standard deviations used in PREFER

x,y,z	-	20 meters
$\dot{x},\dot{y},\dot{z}$	-	2 cm/sec
gravitational acceleration	-	2.4×10^{-6}(H), 0.7×10^{-6}(C), 1.0×10^{-6}(L) m/sec^2
station measurement biases	-	5 meter (range), 0.1 cm/sec (range rate)
station refraction	-	50 cm @ zenith
station position errors	-	5 meters (each component)

State noise spectral density - none on orbital elements

Markov process standard deviations

gravitational accelerations - 2.4×10^{-6}(H), 0.7×10^{-6}(C), 1.0×10^{-6}(L) m/sec^2

Time constants of Markov processes

gravitational acceleration - 1200 (H), 200 (C), 200 (L) seconds

Results - See Figure 5.1 and Table 5.2

Table 5.2 Position Errors for Smoothed Trajectory

component	RMS	maximum
radial	3.8	8.1
crosstrack	7.0	13.1
alongtrack	11.4	24.9
total	13.9	26.0

The nominal trajectory has large errors (e.g. 89 meters) in the data gaps hear the end of the orbit. This occurs when only one station (#31) is tracking. In the periods when two or more stations are tracking, the error in the nominal trajectory is less than 32 meters.

The smoothed output of PREFER has errors which are less than 21 meters during the period when two or more stations are tracking. In the last data gap at the end of the trajectory, the peak error is 26 meters (mostly alongtrack). Notice that the total error in the PREFER output tends to be relatively smooth while the error in the nominal trajectory (GTDS output) fluctuates wildly; there are 4 short periods of time when the nominal trajectory is more accurate than the PREFER output but the PREFER output is generally much superior.

These results for PREFER were obtained from one of the best runs in a series of runs in which *a priori* variances, state noise variances, time constants, and the selection of adjusted parameters were varied. Several other runs yielded likelihood functions and ephemeris errors similar to those of the run listed. It was found that the results are not very sensitive to the exact form of the gravitational acceleration model if the parameters of that model are reasonable. Maximization of the likelihood function can generally be relied upon to select the run with the optimum model.

```
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

     THE PRECISION RECURSIVE ESTIMATOR FOR EPHEMERIS REFINEMENT (PREFER) VERSION (IBM) 82.001

OUTPUT FROM ORBIT FILE FOR SATELLITE LS-D
EPOCH DATE/TIME = 811001.  195500.0000
START DATE/TIME = 811001.  195500.0000     END DATE/TIME = 811002.  200000.0000
SATELLITE AREA = 20.000 M**2.  MASS = 1700.00 KG.  CD =  1.500
ORBIT FILE WAS CREATED USING 1950              COORDINATES
EPOCH KEPLERIAN ELEMENTS =    7078.032   0.000099   1.714872   5.846084   0.520692   2.620901
EPOCH CARTESIAN ELEMENTS =   -6413.078   2996.587     -0.687    0.45640    0.97591   -7.42596
```

LISTING OF CARD INPUT

PRINT	2203	0	.0	.0	.0	0
EARTH	0	0	6378.1660	298.30000	398600.64	.299790+06
STEP	0	0	120.00000	43200.000	120.00000	.0
ELCUT	0	0	2.0000000	.0	.0	.0
STATE1	0	0	.200000000D-01	.200000000D-01	.200000000D-01	.0
STATE2	0	0	.200000000D-04	.200000000D-04	.200000000D-04	.0
GRAV	0	0	.240000000D-08	.700000000D-09	.100000000D-08	.0
GRAVQ	0	0	.240000000D-08	.700000000D-09	.100000000D-08	.0
GRAVT	0	0	1200.0000	200.00000	200.00000	.0
MBIAS	0	2	.500000000D-02	.100000000D-05	.0	.0
REFRAC	0	0	.500000000D-03	.0	.0	.0
CSTA	0	0	.500000000D-02	.500000000D-02	.500000000D-02	.0
MSIG	4	2	.100000000D-02	.100000000D-05	.0	.0
MSIG	13	2	.100000000D-02	.100000000D-05	.0	.0
MSIG	30	2	.100000000D-02	.100000000D-05	.0	.0
MSIG	31	2	.100000000D-02	.100000000D-05	.0	.0
MSIG	32	2	.100000000D-02	.100000000D-05	.0	.0

SUMMARY OF CARD INPUT

NUMBER OF DYNAMIC PARAMETERS= 9 (ALSO EQUALS INITIAL NUMBER OF STATES)

MINI-BATCH STEP SIZE= 120.00 SECONDS

MAXIMUM INTEGRATION STEP SIZE= 120.00 SECONDS

INPUT RUN STOP TIME= 43200.00 SECONDS ACTUAL STOP TIME MAY BE LESS THAN THIS

STEP SIZE FOR CREATING TDRS TRAJECTORY FILE = 600.00

SATELLITE AREA TO MASS RATIO= .1176D-07 KM**2/KG

CONSTANTS USED IN THE ATMOSPHERIC DENSITY MODELING= .13620D-01 -8.3355 .10180D-03 1.0830 89.390

EARTH SEMI-MAJOR AXIS = 6378.166 EARTH ECCENTRICITY SQUARED = .66934220-02

EARTH GRAVITATIONAL CONSTANT = 398600.64 KM**3/SEC.**2

SPEED OF LIGHT = 299792.4562 KM/SEC

```
MEASUREMENT ELEVATION CUTOFFS     GROUND MEASUREMENTS:   2.000 DEGREES
                                  GPS MEASUREMENTS:      0.0   DEGREES
                                  TDRS MEASUREMENTS:     0.0   KILOMETERS
```

PRINTOUT OPTIONS
1) FILTER/SMOOTHER OUTPUT AND PLOTS WILL BE IN HCL COORDINATES
2) FILTER OUTPUT - ALL
3) SMOOTHER OUTPUT - ALL
5) PLOTS OF POSITION SIGMAS - FILTER+SMOOTHER

SUMMARY OF STATE PARAMETERS

	LABEL	LABEL	UNITS	A PRIORI SIGMA	SQRT(SPECTRAL DEN.)	TIME CONSTANT	NOISE SIGMA
1	1	X	KM.	.2000D-01	.0		
2	2	Y	KM.	.2000D-01	.0		
3	3	Z	KM.	.2000D-01	.0		
4	4	XDOT	KM/SEC	.2000D-04	.0		
5	5	YDOT	KM/SEC	.2000D-04	.0		
6	6	ZDOT	KM/SEC	.2000D-04	.0		
7	8	GRAV	KM/S**2	.2400D-08	.9798D-10	1200.	2400D-08
8	8	GRAV	KM/S**2	.7000D-09	.7000D-10	200.0	7000D-09
9	8	GRAV	KM/S**2	.1000D-08	.1000D-09	200.0	.1000D-08
10	100000	MBIAS 1	KM.	.5000D-02	.0		
11	200000	MBIAS 2	KM/S	.1000D-05	.0		
12	300000	REFRACT	KM.,-	.5000D-03	.0		
13	400000	STA POS	KM.	.5000D-02	.0		
14	400000	STA POS	KM.	.5000D-02	.0		
15	400000	STA POS	KM.	.5000D-02	.0		

NOTE: FOR A FIRST ORDER MARKOV PROCESS, OUTPUT SIGMA = SQRT(INPUT SPECTRAL DENSITY*TIME CONSTANT/2)

SUMMARY OF GROUND STATIONS (5)

	STATION NO.	STATION POSITION(EFC) X	Y	Z	INPUT MEASUREMENT SIGMAS SIGMA1	SIGMA2
1	4	4847.8243	-353.3178	4117.1445	.10000-02	.10000-05
2	31	-2282.4958	-1453.3850	5756.7222	.10000-02	.10000-05
3	30	-4447.4906	2676.8624	-3595.2795	.10000-02	.10000-05
4	13	1129.8039	-4833.1549	3992.2086	.10000-02	.10000-05
5	32	1263.4446	-6255.0397	-68.8004	.10000-02	.10000-05

```
NOTES ON RESIDUAL STATISTICS
    1) IF ALL MODELS ARE CORRECT, THE WEIGHTED RESIDUAL RMS SHOULD EQUAL 1. WITH A SIGMA OF 1./SQRT(2*N)
    2) UNITS OF RESIDUALS ARE KM. (ALL TYPES EXCEPT DOPPLER) OR DIMENSIONLESS (DOPPLER)

APPROXIMATE REGION SIZE =  383216 BYTES (ASSUMING TWO 7294-BYTE BUFFERS ARE USED FOR UNITS 70 AND 71)

REGION SPECIFIED FOR THIS JOB =  405504      ARRAYS REQUIRE     26360 BYTES

NOTE: PREFER WILL USE ALL THE CORE ALLOCATED FOR THE JOB. IGNORE REGION PRINTED IN SYSTEM MESSAGES
    5288    4496    6040    5288    5288          79689   78351   76429   75081   73545

*************************************************************************************************
FILTER OUTPUT AT TIME      120.00
NOMINAL TRAJECTORY (ECI)= -6306.5691  3089.1352  -889.3853    1.31634    0.56448   -7.36562
ESTIM. TOTAL (ECI)      = -6306.5691  3089.1352  -889.3853    1.31634    0.56448   -7.36562
ESTIM. CORRECTION (HCL) =    0.0        0.0        0.0        0.0        0.0        0.0
ESTIM. SIGMA (HCL)      =    0.02045    0.01998    0.02001    0.00002    0.00002    0.00002

PARAMETER LABELS      =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV
STATION/SATELLITE     =         0          0          0          0          0          0          0          0          0
FILTER STATE (EPOCH) = 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
FILTER SIGMAS (EPOCH)= 0.02000001 0.02000000 0.02000000 0.00002000 0.00002000 0.00002000 0.00000000 0.00000000 0.00000000
*************************************************************************************************


*************************************************************************************************
FILTER OUTPUT AT TIME      240.00
NOMINAL TRAJECTORY (ECI)= -6098.0154  3131.6999 -1763.6533    2.15483    0.14399   -7.18580
ESTIM. TOTAL (ECI)      = -6098.0154  3131.6999 -1763.6533    2.15483    0.14399   -7.18580
ESTIM. CORRECTION (HCL) =    0.0        0.0        0.0        0.0        0.0        0.0
ESTIM. SIGMA (HCL)      =    0.02161    0.01993    0.02021    0.00002    0.00002    0.00002

PARAMETER LABELS      =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV
STATION/SATELLITE     =         0          0          0          0          0          0          0          0          0
FILTER STATE (EPOCH) = 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
FILTER SIGMAS (EPOCH)= 0.02000009 0.02000003 0.02000001 0.00002001 0.00002000 0.00002000 0.00000000 0.00000000 0.00000000
*************************************************************************************************


*************************************************************************************************
FILTER OUTPUT AT TIME      360.00
NOMINAL TRAJECTORY (ECI)= -5790.8142  3123.6042 -2609.3150    2.95823   -0.27871   -6.88950
ESTIM. TOTAL (ECI)      = -5790.8142  3123.6042 -2609.3150    2.95823   -0.27871   -6.88950
ESTIM. CORRECTION (HCL) =    0.0        0.0        0.0        0.0        0.0        0.0
ESTIM. SIGMA (HCL)      =    0.02313    0.01985    0.02107    0.00003    0.00002    0.00002

PARAMETER LABELS      =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV
STATION/SATELLITE     =         0          0          0          0          0          0          0          0          0
FILTER STATE (EPOCH) = 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
FILTER SIGMAS (EPOCH)= 0.02000044 0.02000013 0.02000007 0.00002001 0.00002000 0.00002000 0.00000000 0.00000000 0.00000000
*************************************************************************************************


*************************************************************************************************
FILTER OUTPUT AT TIME      480.00
NOMINAL TRAJECTORY (ECI)= -5389.9667  3064.9966 -3412.6691    3.71349   -0.69674   -6.48164
ESTIM. TOTAL (ECI)      = -5389.9667  3064.9966 -3412.6691    3.71349   -0.69674   -6.48164
ESTIM. CORRECTION (HCL) =    0.0        0.0        0.0        0.0        0.0        0.0
ESTIM. SIGMA (HCL)      =    0.02456    0.01975    0.02319    0.00003    0.00002    0.00003

PARAMETER LABELS      =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV
STATION/SATELLITE     =         0          0          0          0          0          0          0          0          0
FILTER STATE (EPOCH) = 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
FILTER SIGMAS (EPOCH)= 0.02000135 0.02000041 0.02000027 0.00002003 0.00002001 0.00002000 0.00000000 0.00000000 0.00000000
*************************************************************************************************
```

```
FILTER SIGMAS (EPOCH)= 0.02026998 0.02022877 0.02228970 0.00002219 0.00002064 0.00002038 0.00000000 0.00000000 0.00000000
*******************************************************************************************************

*******************************************************************************************************
FILTER OUTPUT AT TIME   2880.00
NOMINAL TRAJECTORY (ECI)=  6421.1216 -2899.1272  -601.8361    0.13095   -1.24688    7.40645
ESTIM. TOTAL (ECI)      =  6421.1216 -2899.1272  -601.8361    0.13095   -1.24688    7.40645
ESTIM. CORRECTION (HCL) =    0.0        0.0        0.0        0.0        0.0        0.0
ESTIM. SIGMA (HCL)      =    0.07318    0.03457    0.26920    0.00018    0.00018    0.00013

PARAMETER LABELS     =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV
STATION/SATELLITE    =         0          0          0          0          0          0          0          0          0
FILTER STATE (EPOCH) = 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
FILTER SIGMAS (EPOCH)= 0.02028040 0.02025262 0.02271158 0.00002248 0.00002073 0.00002040 0.00000000 0.00000000 0.00000000
*******************************************************************************************************

*******************************************************************************************************
FILTER OUTPUT AT TIME   3000.00
NOMINAL TRAJECTORY (ECI)=  6384.6691 -3024.8148   289.4234   -0.73767   -0.84507    7.42769
ESTIM. TOTAL (ECI)      =  6384.6691 -3024.8148   289.4234   -0.73767   -0.84507    7.42769
ESTIM. CORRECTION (HCL) =    0.0        0.0        0.0        0.0        0.0        0.0
ESTIM. SIGMA (HCL)      =    0.12520    0.03706    0.26953    0.00020    0.00021    0.00007

PARAMETER LABELS     =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV
STATION/SATELLITE    =         0          0          0          0          0          0          0          0          0
FILTER STATE (EPOCH) = 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
FILTER SIGMAS (EPOCH)= 0.02028880 0.02027626 0.02316704 0.00002280 0.00002081 0.00002041 0.00000000 0.00000000 0.00000000
*******************************************************************************************************

*******************************************************************************************************
FILTER OUTPUT AT TIME   3120.00
NOMINAL TRAJECTORY (ECI)=  6244.5604 -3101.3954  1175.9713   -1.59429   -0.42955    7.32803
ESTIM. TOTAL (ECI)      =  6244.5604 -3101.3954  1175.9713   -1.59429   -0.42955    7.32803
ESTIM. CORRECTION (HCL) =    0.0        0.0        0.0        0.0        0.0        0.0
ESTIM. SIGMA (HCL)      =    0.17785    0.07287    0.25298    0.00020    0.00024    0.00003

PARAMETER LABELS     =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV
STATION/SATELLITE    =         0          0          0          0          0          0          0          0          0
FILTER STATE (EPOCH) = 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
FILTER SIGMAS (EPOCH)= 0.02029544 0.02029941 0.02365182 0.00002312 0.00002090 0.00002042 0.00000000 0.00000000 0.00000000
*******************************************************************************************************

*******************************************************************************************************
FILTER OUTPUT AT TIME   3240.00
NOMINAL TRAJECTORY (ECI)=  6003.0835 -3127.6322  2043.3798   -2.42483   -0.00716    7.10915
ESTIM. TOTAL (ECI)      =  6003.0835 -3127.6322  2043.3798   -2.42483   -0.00716    7.10915
ESTIM. CORRECTION (HCL) =    0.0        0.0        0.0        0.0        0.0        0.0
ESTIM. SIGMA (HCL)      =    0.22597    0.11701    0.21887    0.00018    0.00026    0.00010

PARAMETER LABELS     =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV
STATION/SATELLITE    =         0          0          0          0          0          0          0          0          0
FILTER STATE (EPOCH) = 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
FILTER SIGMAS (EPOCH)= 0.02030071 0.02032182 0.02416100 0.00002347 0.00002099 0.00002043 0.00000000 0.00000000 0.00000000
*******************************************************************************************************

NEW PASS PARAMETERS ADDED AT TIME   3420.00, STATION/SAT      4, N =  15

$$$$ RESIDUAL STATISTICS FOR TIME    3300.00 TO    3420.00

*******************************************************************************************************
FILTER OUTPUT AT TIME   3360.00
```

```
NOMINAL TRAJECTORY (ECI)=  5664.1891 -3103.1151  2877.5419    -3.21570     0.41519     6.77470
ESTIM. TOTAL (ECI)       =  5664.1860 -3103.1131  2877.5292    -3.21570     0.41519     6.77471
ESTIM. CORRECTION (HCL) =     0.0037[illegible]    0.00244    -0.01243    -0.00000    -0.00000     0.00001
ESTIM. SIGMA (HCL)       =     0.00989    0.01951     0.01065     0.00001     0.00002     0.00002

PARAMETER LABELS      =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV       MBIAS 1
STATION/SATELLITE     =          0          0          0          0          0          0          0          0          0          4
FILTER STATE (EPOCH) = 0.00053431 0.00150118-0.00377666-0.00000354 0.00000254 0.00000171-0.00000000-0.00000000 0.00000000-0.00002852
FILTER SIGMAS (EPOCH)= 0.01611228 0.01901381 0.02153840 0.00002093 0.00001928 0.00001360 0.00000000 0.00000000 0.00000000 0.00499854

PARAMETER LABELS      =   MBIAS 2    REFRACT    STA POS    STA POS    STA POS
STATION/SATELLITE     =          4          4          4          4          4
FILTER STATE          =-0.00000000 0.00002852-0.00001858 0.00002447 0.00014427
FILTER SIGMAS         = 0.00000100 0.00049182 0.00499965 0.00499940 0.00497317
*******************************************************************************************************************************


$$$$ RESIDUAL STATISTICS FOR TIME     3420.00 TO     3540.00
     STATION      4 TYPE     10  N=    12.  MEAN=   .7496D-07  SIGMA=    .2206D-05  WEIGHTED SIGMA=    1.044
     STATION      4 TYPE     13  N=    [illegible]  MEAN=  -.1770D-03  SIGMA=    .7846D-03  WEIGHTED SIGMA=    .6928

*******************************************************************************************************************************
FILTER OUTPUT AT TIME    3480.00
NOMINAL TRAJECTORY (ECI)=  5233.4212 -3028.2663  3664.9082    -3.95398     0.83056     6.33031
ESTIM. TOTAL (ECI)       =  5233.4172 -3028.2677  3664.8985    -3.95398     0.83056     6.33031
ESTIM. CORRECTION (HCL) =     0.00160   -0.00063    -0.01052    -0.00001     0.00000     0.00000
ESTIM. SIGMA (HCL)       =     0.00839    0.01071     0.00528     0.00001     0.00001     0.00002

PARAMETER LABELS      =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV       MBIAS 1
STATION/SATELLITE     =          0          0          0          0          0          0          0          0          0          4
FILTER STATE (EPOCH) = 0.00338635 0.0027[illegible] 0.00288501-0.00000241 0.00000423-0.00000009 0.00000000-0.00000000 0.00000000 0.00125162
FILTER SIGMAS (EPOCH)= 0.01444120 0.01652[illegible] 0.02153933 0.00002060 0.00001751 0.00001337 0.00000000 0.00000000 0.00000000 0.00401336

PARAMETER LABELS      =   MBIAS 2    REFRACT    STA POS    STA POS    STA POS
STATION/SATELLITE     =          4          4          4          4          4
FILTER STATE          = 0.00000011 0.00006394-0.00011810 0.00015171 0.00018990
FILTER SIGMAS         = 0.00000099 0.00009[illegible] 0.00498390 0.00496892 0.00494967
*******************************************************************************************************************************


$$$$ RESIDUAL STATISTICS FOR TIME     3540.00 TO     3660.00
     STATION      4 TYPE     10  N=    12.  MEAN=  -.4470D-06  SIGMA=    .1270D-05  WEIGHTED SIGMA=    .8684
     STATION      4 TYPE     13  N=    12.  MEAN=   .2795D-03  SIGMA=    .1125D-02  WEIGHTED SIGMA=    1.046

*******************************************************************************************************************************
FILTER OUTPUT AT TIME    3600.00
NOMINAL TRAJECTORY (ECI)=  4717.8187 -2904.3301  4392.7114    -4.62769     1.23220     5.78336
ESTIM. TOTAL (ECI)       =  4717.8106 -2904.3358  4392.7041    -4.62770     1.23220     5.78336
ESTIM. CORRECTION (HCL) =    -0.00329   -0.00302    -0.01140    -0.00000     0.00001    -0.00000
ESTIM. SIGMA (HCL)       =     0.00496    0.00877     0.00377     0.0000[illegible]     0.00001     0.00002

PARAMETER LABELS      =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV       MBIAS 1
STATION/SATELLITE     =          0          0          0          0          0          0          0          0          0          4
FILTER STATE (EPOCH) = 0.00926432 0.00488644-0.00270946-0.00000097 0.00000750-0.00000357 0.00000000-0.00000000 0.00000000 0.00566759
FILTER SIGMAS (EPOCH)= 0.01290821 0.01590341 0.02207023 0.00002083 0.00001696 0.00001296 0.00000000 0.00000000 0.00000000 0.00136934

PARAMETER LABELS      =   MBIAS 2    REFRACT    STA POS    STA POS    STA POS
STATION/SATELLITE     =          4          4          4          4          4
FILTER STATE          =-0.00000011 0.00002649-0.00029671 0.00037350 0.00026544
FILTER SIGMAS         = 0.00000093 0.00007315 0.00497750 0.00495770 0.00494365
*******************************************************************************************************************************


$$$$ RESIDUAL STATISTICS FOR TIME     3660.00 TO     3780.00
     STATION      4 TYPE     10  N=    12.  MEAN=   .1396D-06  SIGMA=    .1081D-05  WEIGHTED SIGMA=    .8436
     STATION      4 TYPE     13  N=    12.  MEAN=   .3965D-03  SIGMA=    .1192D-02  WEIGHTED SIGMA=    1.113
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FILTER OUTPUT AT TIME   3720.00
NOMINAL TRAJECTORY (ECI)=  4125.7936 -2733.3490  5049.1735   -5.22598    1 61358    5 14293
ESTIM. TOTAL (ECI)      =  4125.7845 -2733.3557  5049.1667   -5.22596    1 61359    5.14293
ESTIM. CORRECTION (HCL) =   -0.00334   -0.00397   -0.01213   -0.00000    0.00001   -0.00001
ESTIM. SIGMA (HCL)      =    0.00425    0.00675    0.00284    0.00001    0.00001    0.00001

PARAMETER LABELS        =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV       MBIAS 1
STATION/SATELLITE       =          0          0          0          0          0          0          0          0          0          4
FILTER STATE (EPOCH) = 0.01062389 0.00554910-0.00243990-0 00000032 0.00000829-0.00000442 0.00000000-0.00000000 0.00000000 0.00621968
FILTER SIGMAS (EPOCH)= 0.00847158 0.01395388 0.02186394 0.00002117 0.00001695 0.00000756 0.00000000 0.00000000 0.00000000 0.00080044

PARAMETER LABELS        =   MBIAS 2    REFRACT    STA POS    STA POS    STA POS
STATION/SATELLITE       =          4          4          4          4          4
FILTER STATE            =-0.00000071 0.00003685-0.00034057 0.00042868 0.00030179
FILTER SIGMAS           = 0.00000078 0.00006413 0.00497694 0.00495532 0.00491235
***********************************************************************************************************************


$$$$ RESIDUAL STATISTICS FOR TIME     3780.00 TO     3900.00
     STATION       4 TYPE    10  N=    11.  MEAN=   .26350-06  SIGMA=   .87150-06  WEIGHTED SIGMA=   .9014
     STATION       4 TYPE    13  N=    11.  MEAN=  -.39110-03  SIGMA=   .10040-02  WEIGHTED SIGMA=   .9356

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FILTER OUTPUT AT TIME   3840.00
NOMINAL TRAJECTORY (ECI)=  3466 9873 -2518.1269  5623.6961   -5.73923    1 96856    4.41958
ESTIM. TOTAL (ECI)      =  3466.9770 -2518.1306  5623.6885   -5.73924    1 96857    4.41957
ESTIM. CORRECTION (HCL) =   -0.00080   -0.00167   -0.01326    0.00000    0 00001   -0.00001
ESTIM. SIGMA (HCL)      =    0.00454    0.00665    0 00310    0.00001    0 00001    0.00001

PARAMETER LABELS        =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV       MBIAS 1
STATION/SATELLITE       =          0          0          0          0          0          0          0          0          0          4
FILTER STATE (EPOCH) = 0.01119814 0.00398565-0.00366589-0.00000085 0.00000747-0 00000547-0.00000000-0.00000000 0.00000000 0.00571648
FILTER SIGMAS (EPOCH)= 0.00707678 0.01360885 0.02231765 0.00002163 0.00001703 0.00000581 0.00000000 0.00000000 0.00000000 0.00062654

PARAMETER LABELS        =   MBIAS 2    REFRACT    STA POS    STA POS    STA POS
STATION/SATELLITE       =          4          4          4          4          4
FILTER STATE            =-0.00000031 0.00003789-0.00030894 0.00036995 0.00020514
FILTER SIGMAS           = 0.00000067 0.00005586 0.00497669 0.00495474 0.00490711
***********************************************************************************************************************


$$$$ RESIDUAL STATISTICS FOR TIME     3900.00 TO     4020.00
     STATION       4 TYPE    10  N=     3.  MEAN=  -.12890-05  SIGMA=   .21000-05  WEIGHTED SIGMA=  1.455
     STATION       4 TYPE    13  N=     3.  MEAN=   .29920-03  SIGMA=   .8231D-03  WEIGHTED SIGMA=   6638

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FILTER OUTPUT AT TIME   3960.00
NOMINAL TRAJECTORY (ECI)=  2752.1069 -2262 1794  6107 0271   -6 15931    2 29143    3.62514
ESTIM. TOTAL (ECI)      =  2752.0951 -2262.1790  6107.0187   -6.15932    2.29144    3 62514
ESTIM. CORRECTION (HCL) =    0.00244    0.00151   -0.01410    0.00000    0 00001   -0 00001
ESTIM. SIGMA (HCL)      =    0.00488    0.00728    0 00438    0.00001    0.00001    0.00001

PARAMETER LABELS        =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV       MBIAS 1
STATION/SATELLITE       =          0          0          0          0          0          0          0          0          0          4
FILTER STATE (EPOCH) = 0.00747069 0.00299259-0.00381694-0.00000222 0.00000586-0.00000280 0.00000000 0.00000000 0.00000000 0.00515358
FILTER SIGMAS (EPOCH)= 0.00664277 0.01362552 0.02291802 0.00002210 0.00001714 0.00000548 0.00000000 0.00000000 0.00000000 0.00054260

PARAMETER LABELS        =   MBIAS 2    REFRACT    STA POS    STA POS    STA POS
STATION/SATELLITE       =          4          4          4          4          4
FILTER STATE            =-0.00000024-0 00003459-0.00018796 0 00022862 0.00020588
FILTER SIGMAS           = 0.00000064 0.00003997 0.00497624 0.00495414 0.00490696
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AT TIME   4080.00, PARAMETER  10, LABEL  100004 DELETED FROM STATE

AT TIME   4080.00, PARAMETER  10, LABEL  200004 DELETED FROM STATE

AT TIME   4080.00, PARAMETER  10, LABEL  300004 DELETED FROM STATE

AT TIME   4080.00, PARAMETER  10, LABEL  400004 DELETED FROM STATE

AT TIME   4080.00, PARAMETER  10, LABEL  400004 DELETED FROM STATE

AT TIME   4080.00, PARAMETER  10, LABEL  400004 DELETED FROM STATE

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FILTER OUTPUT AT TIME   4080.00
NOMINAL TRAJECTORY (ECI)=  1992.7473 -1969.6734  6491.4027   -6.47558    2.57706    2.77256
ESTIM. TOTAL (ECI)      =  1992.7342 -1969.6718  6491.3937   -6.47959    2.57707    2.77255
ESTIM. CORRECTION (HCL) =    0.00480    0.00193   -0.01516    0.00001    0.00001   -0.00001
ESTIM. SIGMA (HCL)      =    0.00511    0.00829    0.00592    0.00001    0.00001    0.00001

PARAMETER LABELS      =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV
STATION/SATELLITE     =          0          0          0          0          0          0          0          0          0
FILTER STATE (EPOCH) = 0.00746728 0.00299403-0.00380972-0.00000223 0.00000586-0.00000280 0.00000000 0.00000000 0.00000000
FILTER SIGMAS (EPOCH)= 0.00654855 0.01365153 0.02351439 0.00002257 0.00001727 0.00000548 0.00000000 0.00000000 0.00000000
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FILTER OUTPUT AT TIME   4200.00
NOMINAL TRAJECTORY (ECI)=  1201.2029 -1645.3574  6770.6657   -6.69503    2.82090    1.87562
ESTIM. TOTAL (ECI)      =  1201.1884 -1645.3545  6770.6555   -6.69504    2.82091    1.87561
ESTIM. CORRECTION (HCL) =    0.00789    0.00213   -0.01598    0.00001    0.00001   -0.00001
ESTIM. SIGMA (HCL)      =    0.00525    0.00949    0.00734    0.00001    0.00001    0.00001

PARAMETER LABELS      =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV
STATION/SATELLITE     =          0          0          0          0          0          0          0          0          0
FILTER STATE (EPOCH) = 0.00746450 0.00299476-0.00380600-0.00000223 0.00000586-0.00000280 0.00000000 0.00000000 0.00000000
FILTER SIGMAS (EPOCH)= 0.00665892 0.01367380 0.02409559 0.00002303 0.00001739 0.00000549 0.00000000 0.00000000 0.00000000
****************************************************************************************************************


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FILTER OUTPUT AT TIME   4320.00
NOMINAL TRAJECTORY (ECI)=   390.2692 -1294.4844  6940.3567   -6.80232    3.01909    0.94881
ESTIM. TOTAL (ECI)      =   390.2535 -1294.4801  6940.3448   -6.80233    3.01911    0.94879
ESTIM. CORRECTION (HCL) =    0.01166    0.00203   -0.01625    0.00002    0.00001   -0.00001
ESTIM. SIGMA (HCL)      =    0.00544    0.01081    0.00849    0.00001    0.00001    0.00001

PARAMETER LABELS      =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV
STATION/SATELLITE     =          0          0          0          0          0          0          0          0          0
FILTER STATE (EPOCH) = 0.00746213 0.00299513-0.00380134-0.00000223 0.00000586-0.00000279 0.00000000 0.00000000 0.00000000
FILTER SIGMAS (EPOCH)= 0.00667557 0.01369326 0.02465691 0.00002349 0.00001751 0.00000550 0.00000000 0.00000000 0.00000000
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FILTER OUTPUT AT TIME   4440.00
NOMINAL TRAJECTORY (ECI)=  -426.9611  -922.7269  6997.7791   -6.79984    3.16852    0.00699
ESTIM. TOTAL (ECI)      =  -426.9777  -922.7210  6997.7653   -6.79985    3.16853    0.00697
ESTIM. CORRECTION (HCL) =    0.01598    0.00160   -0.01567    0.00002    0.00000   -0.00001
ESTIM. SIGMA (HCL)      =    0.00583    0.01220    0.00926    0.00001    0.00001    0.00001

PARAMETER LABELS      =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV
STATION/SATELLITE     =          0          0          0          0          0          0          0          0          0
FILTER STATE (EPOCH) = 0.00746004 0.00299535-0.00379656-0.00000224 0.00000587-0.00000279 0.00000000 0.00000000 0.00000000
FILTER SIGMAS (EPOCH)= 0.00669897 0.01371054 0.02519511 0.00002394 0.00001764 0.00000552 0.00000000 0.00000000 0.00000000
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FILTER STATE (EPOCH) =-0.01196459 0.00155851 0.01372915-0.00001392 0.00000734 0.00001233-0.00000000-0.00000000 0.00000000-0.00572779
FILTER SIGMAS (EPOCH)= 0.00709953 0.02355629 0.16470665 0.00015902 0.00007499 0.00000475 0.00000000 0.00000000 0.00000000 0.00051518

PARAMETER LABELS     =   MBIAS 2    REFRACT    STA POS    STA POS    STA POS
STATION/SATELLITE    =        31         31         31         31         31
FILTER STATE         = 0.00000134-0.00009739 0.00337072-0.00143922-0.00383002
FILTER SIGMAS        = 0.00000068 0.00004192 0.00389016 0.00481491 0.00419323
*****************************************************************************************************************************

$$$$ RESIDUAL STATISTICS FOR TIME   39660.00 TO   39780.00
     STATION     31 TYPE     10  N=    12.  MEAN=  -.13900-06  SIGMA=    .82170-06  WEIGHTED SIGMA=    .6941
     STATION     31 TYPE     13  N=    12.  MEAN=   .25090-03  SIGMA=    .12660-02  WEIGHTED SIGMA=   1.189

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FILTER OUTPUT AT TIME  39720.00
NOMINAL TRAJECTORY (ECI)=  1289.7009 -1668.0161  6748.8733   -6.69912    2.75112    1.96254
ESTIM. TOTAL (ECI)     =   1289.7066 -1668.0199  6748.8689   -6.69912    2.75111    1.96256
ESTIM. CORRECTION (HCL) =    0.00341    -0.00637    0.00379   -0.00002    0.00000    0.00000
ESTIM. SIGMA (HCL)     =     0.00225     0.00259    0.00216    0.00000    0.00000    0.00000

PARAMETER LABELS     =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV       MBIAS 1
STATION/SATELLITE    =          0          0          0          0          0          0          0          0          0         31
FILTER STATE (EPOCH) =-0.01191212 0.00195711 0.01112740-0.00001062 0.00000559 0.00001239 0.00000000-0.00000000 0.00000000-0.00539569
FILTER SIGMAS (EPOCH)= 0.00724170 0.02345464 0.16543332 0.00015942 0.00007507 0.00000398 0.00000000 0.00000000 0.00000000 0.00036306

PARAMETER LABELS     =   MBIAS 2    REFRACT    STA POS    STA POS    STA POS
STATION/SATELLITE    =        31         31         31         31         31
FILTER STATE         = 0.00000090-0.00009307 0.00256003-0.00112262-0.00340266
FILTER SIGMAS        = 0.00000057 0.00004095 0.00368938 0.00479503 0.00412870
*****************************************************************************************************************************

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$$$$ RESIDUAL STATISTICS FOR TIME   39780.00 TO   39900.00
     STATION     31 TYPE     10  N=     7.  MEAN=   .56920-06  SIGMA=    .11010-05  WEIGHTED SIGMA=    .9007
     STATION     31 TYPE     13  N=     7.  MEAN=   .46660-03  SIGMA=    .15010-02  WEIGHTED SIGMA=   1.365

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FILTER OUTPUT AT TIME  39840.00
NOMINAL TRAJECTORY (ECI)=   477.5626 -1325.3116  6929.1433   -6.81828    2.95292    1.03798
ESTIM. TOTAL (ECI)     =    477.5681 -1325.3157  6929.1406   -6.81828    2.95291    1.03799
ESTIM. CORRECTION (HCL) =    0.00114    -0.00575    0.00442   -0.00002    0.00000    0.00000
ESTIM. SIGMA (HCL)     =     0.00220     0.00265    0.00228    0.00000    0.00000    0.00000

PARAMETER LABELS     =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV       MBIAS 1
STATION/SATELLITE    =          0          0          0          0          0          0          0          0          0         31
FILTER STATE (EPOCH) =-0.01028879-0.00360944 0.04112749-0.00004005 0.00001975 0.00000865-0.00000000-0.00000000 0.00000000-0.00524538
FILTER SIGMAS (EPOCH)= 0.00739320 0.02360592 0.16738533 0.00016126 0.00007591 0.00000342 0.00000000 0.00000000 0.00000000 0.00032576

PARAMETER LABELS     =   MBIAS 2    REFRACT    STA POS    STA POS    STA POS
STATION/SATELLITE    =        31         31         31         31         31
FILTER STATE         = 0.00000052-0.00005719 0.00221876-0.00090583-0.00338876
FILTER SIGMAS        = 0.00000052 0.00002683 0.00363468 0.00478666 0.00412166
*****************************************************************************************************************************


SUMMARY OF RESIDUAL STATISTICS FOR    1082. MEASUREMENTS
WEIGHTED SIGMA =    1.0160     , SUM(RES**2/RVAR) =    1116.8     , SUM(ALOG(RVAR)) =  -21929.     , ALOG LIKELIHOOD =    10406.
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SMOOTHER OUTPUT AT TIME  39720.00

PARAMETER LABELS       =  X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV       MBIAS 1
STATION/SATELLITE      =          0          0          0          0          0          0          0          0          0         31
FILTER STATE (EPOCH) =-0.01191212 0.00195711 0.01112740-0.00001062 0.00000559 0.00001239 0.00000000-0.00000000 0.00000000-0.00539568
SMOOTHER STATE(EPOCH)=-0.01039022-0.00384667 0.04291335-0.00004176 0.00002055 0.00000865-0.00000000-0.00000000 0.00000000-0.00524538
SMOOTHER SIGMAS(EPOCH) 0.00719138 0.02323254 0.16449102 0.00015650 0.00007463 0.00000339 0.00000000 0.00000000 0.00000000 0.00032576

PARAMETER LABELS       =  MBIAS 2    REFRACT    STA POS    STA POS    STA POS
STATION/SATELLITE      =         31         31         31         31         31
FILTER STATE           = 0.00000090-0.00009307 0.00256003-0.00112262-0.00340266
SMOOTHER STATE         = 0.00000052-0.00005719 0.00221876-0.00090583-0.00338876
SMOOTHER SIGMAS          0.00000052 0.00002683 0.00363468 0.00478666 0.00412166

NOMINAL TRAJECTORY (ECI)=  1289.7009 -1668.0161  6748.8733   -6.69912    2.75112    1.96254
SMOOTHER TOTAL  (ECI)   =  1289.7065 -1668.0197  6748.8687   -6.69912    2.75111    1.96256
FILTER ESTIM. (HCL)     =  0.0034109 -0.0063667  0.0037916 -0.0000196  0.0000017  0.0000045
SMOOTHER ESTIM. (HCL)   =  0.0036475 -0.0061407  0.0036228 -0.0000162  0.0000013  0.0000032
SMOOTHER SIGMA (HCL)    =  0.0022143  0.0025912  0.0021084  0.0000040  0.0000030  0.0000025
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SMOOTHER OUTPUT AT TIME  39600.00

PARAMETER LABELS       =  X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV       MBIAS 1
STATION/SATELLITE      =          0          0          0          0          0          0          0          0          0         31
FILTER STATE (EPOCH) =-0.01196459 0.00155251 0.01372915-0.00001392 0.00000734 0.00001233-0.00000000-0.00000000 0.00000000-0.00572779
SMOOTHER STATE(EPOCH)=-0.01048145-0.00404558 0.04442501-0.00004320 0.00002122 0.00000866-0.00000000-0.00000000 0.00000000-0.00524538
SMOOTHER SIGMAS(EPOCH) 0.00699729 0.02283163 0.16142531 0.00015558 0.00007327 0.00000337 0.00000000 0.00000000 0.00000000 0.00032576

PARAMETER LABELS       =  MBIAS 2    REFRACT    STA POS    STA POS    STA POS
STATION/SATELLITE      =         31         31         31         31         31
FILTER STATE           = 0.00000134-0.00009739 0.00337072-0.00143922-0.00383002
SMOOTHER STATE         = 0.00000052-0.00005719 0.00221876-0.00090583-0.00338876
SMOOTHER SIGMAS          0.00000052 0.00002683 0.00363468 0.00478666 0.00412166

NOMINAL TRAJECTORY (ECI)=  2081.0206 -1983.7978  6459.3856   -6.47175    2.50479    2.85583
SMOOTHER TOTAL  (ECI)   =  2081.0262 -1983.8006  6459.3791   -6.47175    2.50479    2.85584
FILTER ESTIM. (HCL)     =  0.0068244 -0.0065368  0.0014804 -0.0000193  0.0000007  0.0000069
SMOOTHER ESTIM. (HCL)   =  0.0060435 -0.0062858  0.0021863 -0.0000161 -0.0000000  0.0000061
SMOOTHER SIGMA (HCL)    =  0.0024619  0.0025332  0.0018484  0.0000039  0.0000030  0.0000028
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SMOOTHER OUTPUT AT TIME  39480.00

PARAMETER LABELS       =  X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV       MBIAS 1
STATION/SATELLITE      =          0          0          0          0          0          0          0          0          0         31
FILTER STATE (EPOCH) =-0.01230410 0.00525684-0.00826364 0.00000937-0.00000419 0.00001339 0.00000000 0.00000000-0.00000000-0.00506149
SMOOTHER STATE(EPOCH)=-0.01056495-0.00422756 0.04581033-0.00004452 0.00002183 0.00000867-0.00000000-0.00000000 0.00000000-0.00524538
SMOOTHER SIGMAS(EPOCH) 0.00680871 0.02241107 0.15823161 0.00015255 0.00007185 0.00000336 0.00000000 0.00000000 0.00000000 0.00032576

PARAMETER LABELS       =  MBIAS 2    REFRACT    STA POS    STA POS    STA POS
STATION/SATELLITE      =         31         31         31         31         31
FILTER STATE           = 0.00000017-0.00010301 0.00162578-0.00079411-0.00286710
SMOOTHER STATE         = 0.00000052-0.00005719 0.00221876-0.00090583-0.00338876
SMOOTHER SIGMAS          0.00000052 0.00002683 0.00363468 0.00478666 0.00412166

NOMINAL TRAJECTORY (ECI)=  2838.7295 -2267.5407  6065.3029   -6.13967    2.21784    3.70344
SMOOTHER TOTAL  (ECI)   =  2838.7348 -2267.5428  6065.2944   -6.13966    2.21784    3.70345
FILTER ESTIM. (HCL)     =  0.0081388 -0.0064660  0.0006029 -0.0000192 -0.0000025  0.0000130
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SMOOTHER ESTIM. (HCL)   =  0.0081972 -0.0061156  0.0001315  0.0000155 -0.0000017  0.0000091
SMOOTHER SIGMA (HCL)    =  0.0028091  0.0024538  0.0015978  0.0000037  0.0000029  0.0000032
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SMOOTHER OUTPUT AT TIME  39360.00

PARAMETER LABELS      =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV       MBIAS 1
STATION/SATELLITE     =          0          0          0          0          0          0          0          0          0         31
FILTER STATE (EPOCH) =-0.01410669 0.00027669 0.02812465-0.00002710 0.00001280 0.00001384 0.00000000-0.00000000-0.00000000-0.00017022
SMOOTHER STATE(EPOCH)=-0.01063542-0.00437357 0.04693069-0.00004558 0.00002233 0.00000868-0.00000000-0.00000000 0.00000000-0.00524538
SMOOTHER SIGMAS(EPOCH) 0.00662439 0.02197792 0.15495235 0.00014944 0.00007040 0.00000336 0.00000000 0.00000000 0.00000000 0.00032576

PARAMETER LABELS      =   MBIAS 2    REFRACT    STA POS    STA POS    STA POS
STATION/SATELLITE     =         31         31         31         31         31
FILTER STATE          = 0.00000000-0.00019862 0.00135949-0.00064712-0.00243527
SMOOTHER STATE        = 0.00000052-0.00005719 0.00221876-0.00090583-0.00338876
SMOOTHER SIGMAS         0.00000052 0.00002683 0.00363468 0.00478666 0.00412166

NOMINAL TRAJECTORY (ECI)=  3550.5578 -2514.6368  5572.9383   -5.70807    1.89483    4.49164
SMOOTHER TOTAL  (ECI)   =  3550.5628 -2514.6380  5572.9278   -5.70807    1.89482    4.49165
FILTER ESTIM. (HCL)     =  0.0081577 -0.0025187 -0.0048125 -0.0000160 -0.0000025  0.0000120
SMOOTHER ESTIM. (HCL)   =  0.0099593 -0.0055595 -0.0024915 -0.0000141 -0.0000038  0.0000121
SMOOTHER SIGMA (HCL)    =  0.0031416  0.0023383  0.0015530  0.0000034  0.0000029  0.0000036
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SMOOTHER OUTPUT AT TIME  39240.00

PARAMETER LABELS      =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV
STATION/SATELLITE     =          0          0          0          0          0          0          0          0          0
FILTER STATE (EPOCH) =-0.01265382 0.00701380-0.01826674 0.00001396-0.00000672 0.00001497-0.00000000-0.00000000-0.00000000
SMOOTHER STATE(EPOCH)=-0.01067324-0.00442226 0.04734736-0.00004596 0.00002250 0.00000870-0.00000000-0.00000000-0.00000000
SMOOTHER SIGMAS(EPOCH) 0.00644052 0.02155520 0.15172483 0.00014639 0.00006898 0.00000337 0.00000000 0.00000000 0.00000000

NOMINAL TRAJECTORY (ECI)=  4204.9572 -2721.0618  4990.2020   -5.18379    1.54090    5.20758
SMOOTHER TOTAL  (ECI)   =  4204.9617 -2721.0621  4990.1895   -5.18378    1.54089    5.20759
FILTER ESTIM. (HCL)     =  0.0282220 -0.0138232 -0.0101672 -0.0000231 -0.0000122  0.0000338
SMOOTHER ESTIM. (HCL)   =  0.0111706 -0.0045501 -0.0055869 -0.0000120 -0.0000063  0.0000147
SMOOTHER SIGMA (HCL)    =  0.0033816  0.0021811  0.0018784  0.0000030  0.0000030  0.0000040
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SMOOTHER OUTPUT AT TIME  39120.00

PARAMETER LABELS      =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV
STATION/SATELLITE     =          0          0          0          0          0          0          0          0          0
FILTER STATE (EPOCH) =-0.01265457 0.00701294-0.01825917 0.00001395-0.00000672 0.00001497-0.00000000-0.00000000-0.00000000
SMOOTHER STATE(EPOCH)=-0.01068227-0.00438753 0.04715851-0.00004577 0.00002241 0.00000872 0.00000000-0.00000000-0.00000000
SMOOTHER SIGMAS(EPOCH) 0.00625964 0.02114227 0.14855694 0.00014341 0.00006759 0.00000340 0.00000000 0.00000000 0.00000000

NOMINAL TRAJECTORY (ECI)=  4791.2909 -2883.4429  4326.4809   -4.57516    1.16175    5.83953
SMOOTHER TOTAL  (ECI)   =  4791.2945 -2883.4422  4326.4663   -4.57515    1.16174    5.83955
FILTER ESTIM. (HCL)     =  0.0291601 -0.0107151 -0.0184131 -0.0000157 -0.0000184  0.0000373
SMOOTHER ESTIM. (HCL)   =  0.0116737 -0.0030324 -0.0090038 -0.0000090 -0.0000092  0.0000168
SMOOTHER SIGMA (HCL)    =  0.0034797  0.0019970  0.0025013  0.0000026  0.0000032  0.0000044
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SMOOTHER OUTPUT AT TIME  39000.00

PARAMETER LABELS      =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV
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SMOOTHER OUTPUT AT TIME  34320.00

PARAMETER LABELS      =   X           Y           Z           XDOT        YDOT        ZDOT        GRAV        GRAV        GRAV
STATION/SATELLITE     =           0           0           0           0           0           0           0           0           0
FILTER STATE (EPOCH) =-0.01288091 0.00667978-0.01551303 0.00001107-0.00000539 0.00001506-0.00000000-0.00000000-0.00000000
SMOOTHER STATE(EPOCH)=-0.01392362-0.00775946 0.07764766-0.00007636 0.00003731 0.00001060-0.00000000 0.00000000-0.00000000
SMOOTHER SIGMAS(EPOCH) 0.00493206 0.01242826 0.08935511 0.00008583 0.00004028 0.00000221 0.00000000 0.00000000 0.00000000

NOMINAL TRAJECTORY (ECI)= -2223.5573    -52.8471  6713.8066    -6.41486     3.27666    -2.09260
SMOOTHER TOTAL  (ECI)   = -2223.5492    -52.8539  6713.9084    -6.41486     3.27666    -2.09258
FILTER ESTIM. (HCL)     = -0.0089958 -0.0045663  0.0057511 -0.0000201  0.0000098 -0.0000152
SMOOTHER ESTIM. (HCL)   = -0.0068559 -0.0053091  0.0062154 -0.0000159  0.0000082 -0.0000134
SMOOTHER SIGMA (HCL)    =  0.0031333  0.0028263  0.0014741  0.0000037  0.0000026  0.0000015
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SMOOTHER OUTPUT AT TIME  34200.00

PARAMETER LABELS      =   X           Y           Z           XDOT        YDOT        ZDOT        GRAV        GRAV        GRAV
STATION/SATELLITE     =           0           0           0           0           0           0           0           0           0
FILTER STATE (EPOCH) =-0.01292766 0.00666988-0.01531427 0.00001087-0.00000530 0.00001510-0.00000000-0.00000000-0.00000000
SMOOTHER STATE(EPOCH)=-0.01410321-0.00762637 0.07735176-0.00007815 0.00003717 0.00001082-0.00000000 0.00000000-0.00000000
SMOOTHER SIGMAS(EPOCH) 0.00480205 0.01244604 0.08908353 0.00008555 0.00004017 0.00000222 0.00000000 0.00000000 0.00000000

NOMINAL TRAJECTORY (ECI)= -1437.9158   -444.5628  6910.0647    -6.66154     3.24315    -1.17230
SMOOTHER TOTAL  (ECI)   = -1437.5068   -444.5693  6910.0639    -6.66155     3.24314    -1.17227
FILTER ESTIM. (HCL)     = -0.0055320 -0.0062105  0.0078919 -0.0000227  0.0000093 -0.0000112
SMOOTHER ESTIM. (HCL)   = -0.0038383 -0.0067623  0.0079470 -0.0000188  0.0000081 -0.0000104
SMOOTHER SIGMA (HCL)    =  0.0027318  0.0026839  0.0014850  0.0000034  0.0000027  0.0000018
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SMOOTHER OUTPUT AT TIME  34080.00

PARAMETER LABELS      =   X           Y           Z           XDOT        YDOT        ZDOT        GRAV        GRAV        GRAV
STATION/SATELLITE     =           0           0           0           0           0           0           0           0           0
FILTER STATE (EPOCH) =-0.01297605 0.00667141-0.01518205 0.00001073-0.00000524 0.00001515-0.00000000-0.00000000-0.00000000
SMOOTHER STATE(EPOCH)=-0.01425524-0.00742048 0.07648873-0.00007737 0.00003677 0.00001105-0.00000000 0.00000000-0.00000000
SMOOTHER SIGMAS(EPOCH) 0.00467897 0.01246169 0.08881470 0.00008530 0.00004007 0.00000223 0.00000000 0.00000000 0.00000000

NOMINAL TRAJECTORY (ECI)=  -629.0865   -829.1093  6994.4987    -6.80080     3.15733    -0.23302
SMOOTHER TOTAL  (ECI)   =  -629.0767   -829.1155  6994.4953    -6.80081     3.15733    -0.23300
FILTER ESTIM. (HCL)     = -0.0015608 -0.0078040  0.0090308 -0.0000250  0.0000086 -0.0000070
SMOOTHER ESTIM. (HCL)   = -0.0003099 -0.0081892  0.0088358 -0.0000215  0.0000076 -0.0000069
SMOOTHER SIGMA (HCL)    =  0.0023868  0.0025538  0.0014495  0.0000031  0.0000027  0.0000022
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PARAMETER RECONSTRUCTION. NO =  9 N = 15
OLD LABELS =       1       2       3       4       5       6       8       8       8
NEW LABELS =       1       2       3       4       5       6       8       8       8 100031 200031 300031 400031 400031 400031

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SMOOTHER OUTPUT AT TIME  33960.00

PARAMETER LABELS      =   X           Y           Z           XDOT        YDOT        ZDOT        GRAV        GRAV        GRAV        MBIAS 1
STATION/SATELLITE     =           0           0           0           0           0           0           0           0           0          31
FILTER STATE (EPOCH) =-0.01302252 0.00669649-0.01520233 0.00001074-0.00000526 0.00001520-0.00000000-0.00000000-0.00000000-0.00516155
SMOOTHER STATE(EPOCH)=-0.01436812-0.00710705 0.07485697-0.00007583 0.00003601 0.00001128-0.00000000-0.00000000-0.00000000-0.00505704
SMOOTHER SIGMAS(EPOCH) 0.00456801 0.01247485 0.08856004 0.00008507 0.00003997 0.00000226 0.00000000 0.00000000 0.00000000 0.00047105

PARAMETER LABELS      =   MBIAS 2     REFRACT     STA POS     STA POS     STA POS
STATION/SATELLITE     =          31          31          31          31          31
FILTER STATE          = 0.00000097-0.00013497-0.00657906 0.00014390-0.00368113
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SMOOTHER STATE          = 0.00000058-0.00012990-0.00740535 0.00008527-0.00344118
SMOOTHER SIGMAS           0.00000050 0.00003847 0.00411089 0.00499719 0.00338917

NOMINAL TRAJECTORY (ECI)=   189.8874 -1200.2840  6965.8335   -6.83039    3.02058    0.71017
SMOOTHER TOTAL  (ECI)   =   189.8978 -1200.2898  6965.8272   -6.83039    3.02057    0.71020
FILTER ESTIM. (HCL)     =  0.0027560 -0.0092531  0.0090843 -0.0000268  0.0000076 -0.0000024
SMOOTHER ESTIM. (HCL)   =  0.0035906 -0.0094970  0.0087669 -0.0000238  0.0000068 -0.0000027
SMOOTHER SIGMA (HCL)    =  0.0021466  0.0024374  0.0013534  0.0000028  0.0000028  0.0000025
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SMOOTHER OUTPUT AT TIME  33840.00

PARAMETER LABELS        =  X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV       MBIAS 1
STATION/SATELLITE       =          0          0          0          0          0          0          0          0          0         31
FILTER STATE (EPOCH) =-0.01025805-0.00352851 0.03989700-0.00003869 0.00002027 0.00000879-0.00000000 0.00000000 0.00000000-0.00420297
SMOOTHER STATE(EPOCH)=-0.01443920-0.00670008 0.07251688-0.00007359 0.00003493 0.00001150-0.00000000 0.00000000-0.00000000-0.00505704
SMOOTHER SIGMAS(EPOCH) 0.00447487 0.01248474 0.08833056 0.00008487 0.00003989 0.00000230 0.00000000 0.00000000 0.00000000 0.00047105

PARAMETER LABELS        =  MBIAS 2    REFRACT    STA POS    STA POS    STA POS
STATION/SATELLITE       =         31         31         31         31         31
FILTER STATE            = 0.00000099 0.00008011-0.00238554 0.00012084-0.00111765
SMOOTHER STATE          = 0.00000058-0.00012990-0.00740535 0.00008527-0.00344118
SMOOTHER SIGMAS           0.00000050 0.00003847 0.00411089 0.00499719 0.00338917

NOMINAL TRAJECTORY (ECI)=  1005.7564 -1552.0961  6824.5052   -6.74978    2.83505    1.64218
SMOOTHER TOTAL  (ECI)   =  1005.8072 -1552.1013  6824.4959   -6.74978    2.83504    1.64221
FILTER ESTIM. (HCL)     =  0.0035039 -0.0096903  0.0069416 -0.0000208  0.0000023  0.0000033
SMOOTHER ESTIM. (HCL)   =  0.0076911 -0.0105755  0.0076408 -0.0000255  0.0000055  0.0000020
SMOOTHER SIGMA (HCL)    =  0.0020379  0.0023340  0.0012256  0.0000027  0.0000029  0.0000026
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SMOOTHER OUTPUT AT TIME  33720.00

PARAMETER LABELS        =  X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV       MBIAS 1
STATION/SATELLITE       =          0          0          0          0          0          0          0          0          0         31
FILTER STATE (EPOCH) =-0.01173550-0.00031796 0.02422561-0.00002062 0.00001225 0.00001148 0.00000000-0.00000000-0.00000000-0.00317798
SMOOTHER STATE(EPOCH)=-0.01454938-0.00648348 0.07147197-0.00007257 0.00003443 0.00001169-0.00000000-0.00000000-0.00000000-0.00505704
SMOOTHER SIGMAS(EPOCH) 0.00439642 0.01248467 0.08806834 0.00008464 0.00003980 0.00000234 0.00000000 0.00000000 0.00000000 0.00047105

PARAMETER LABELS        =  MBIAS 2    REFRACT    STA POS    STA POS    STA POS
STATION/SATELLITE       =         31         31         31         31         31
FILTER STATE            =-0.00000033 0.00007278-0.00029536-0.00002773 0.00050737
SMOOTHER STATE          = 0.00000058-0.00012990-0.00740535 0.00008527-0.00344118
SMOOTHER SIGMAS           0.00000050 0.00003847 0.00411089 0.00499719 0.00338917

NOMINAL TRAJECTORY (ECI)=  1805.4718 -1878.8608  [illegible].7555   -6.56017    2.60367    2.54806
SMOOTHER TOTAL  (ECI)   =  1805.4829 -1878.8654  6572.7431   -6.56017    2.60367    2.54809
FILTER ESTIM. (HCL)     =  0.0041293 -0.0097481  0.0052776 -0.0000215 -0.0000013  0.0000094
SMOOTHER ESTIM. (HCL)   =  0.0117773 -0.0112952  0.0053870 -0.0000264  0.0000035  0.0000074
SMOOTHER SIGMA (HCL)    =  0.0020560  0.0022404  0.0011324  0.0000028  0.0000030  0.0000026
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SMOOTHER OUTPUT AT TIME  33600.00

PARAMETER LABELS        =  X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV       MBIAS 1
STATION/SATELLITE       =          0          0          0          0          0          0          0          0          0         31
FILTER STATE (EPOCH) =-0.01064261-0.00333562 0.04032661-0.00003641 0.00001992 0.00000948-0.00000000-0.00000000 0.00000000-0.0032[illegible]49
SMOOTHER STATE(EPOCH)=-0.01464689-0.00625672 0.07034010-0.00007145 0.00003387 0.00001187-0.00000000-0.00000000-0.00000000-0.00505704
SMOOTHER SIGMAS(EPOCH) 0.00432628 0.01246784 0.08770679 0.00008433 0.00003966 0.00000239 0.00000000 0.00000000 0.00000000 0.00047105
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PARAMETER LABELS      =   MBIAS 2    REFRACT    STA POS    STA POS    STA POS
STATION/SATELLITE     =        31         31         31         31         31
FILTER STATE          = 0.00000001 0.00010116-0.00022424 0.00001401 0.00047121
SMOOTHER STATE        = 0.00000058-0.00012990-0.00740535 0.00008527-0.00344118
SMOOTHER SIGMAS         0.00000050 0.00003847 0.00411089 0.00499719 0.00338917

NOMINAL TRAJECTORY (ECI)=  2575.9927 -2175.2889  6214.6000   -6.26450    2.33011    3.41322
SMOOTHER TOTAL  (ECI)   =  2576.0037 -2175.2926  6214.5843   -6.26449    2.33010    3.41325
FILTER ESTIM. (HCL)     =  0.0071108 -0.0094902  0.0028559 -0.0000184 -0.0000036  0.0000115
SMOOTHER ESTIM. (HCL)   =  0.0155920 -0.0115129  0.0019852 -0.0000262  0.0000008  0.0000131
SMOOTHER SIGMA (HCL)    =  0.0021656  0.0021503  0.0011745  0.0000030  0.0000029  0.0000027
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SMOOTHER OUTPUT AT TIME  33480.00

PARAMETER LABELS      =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV       MBIAS 1
STATION/SATELLITE     =          0          0          0          0          0          0          0          0          0         31
FILTER STATE (EPOCH) =-0.01185935-0.00676767 0.06460779-0.00006069 0.00003149 0.00000923-0.00000000-0.00000000 0.00000000 0.00015798
SMOOTHER STATE(EPOCH)=-0.01469780-0.00593218 0.06844481-0.00006959 0.00003298 0.00001204-0.00000000 0.00000000-0.00000000-0.00505704
SMOOTHER SIGMAS(EPOCH) 0.00425662 0.01243498 0.08722282 0.00008390 0.00003947 0.00000245 0.00000000 0.00000000 0.00000000 0.00047105

PARAMETER LABELS      =   MBIAS 2    REFRACT    STA POS    STA POS    STA POS
STATION/SATELLITE     =        31         31         31         31         31
FILTER STATE          =-0.00000002-0.00009351 0.00020439 0.00002857 0.00137975
SMOOTHER STATE        = 0.00000058-0.00012990-0.00740535 0.00008527-0.00344118
SMOOTHER SIGMAS         0.00000050 0.00003947 0.00411089 0.00499719 0.00338917

NOMINAL TRAJECTORY (ECI)=  3304.8902 -2436.5711  5755.7709   -5.86736    2.01868    4.22368
SMOOTHER TOTAL  (ECI)   =  3304.9008 -2436.5736  5755.7518   -5.86735    2.01867    4.22371
FILTER ESTIM. (HCL)     =  0.0084838 -0.0069912 -0.0018416 -0.0000154 -0.0000047  0.0000115
SMOOTHER ESTIM. (HCL)   =  0.0188414 -0.0110819 -0.0025097 -0.0000246 -0.0000027  0.0000189
SMOOTHER SIGMA (HCL)    =  0.0023157  0.0020543  0.0014257  0.0000031  0.0000028  0.0000029
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SMOOTHER OUTPUT AT TIME  33360.00

PARAMETER LABELS      =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV
STATION/SATELLITE     =          0          0          0          0          0          0          0          0          0
FILTER STATE (EPOCH) =-0.00809563 0.00226557-0.00269560 0.00000623 0.00000016 0.00000884 0.00000000 0.00000000 0.00000000
SMOOTHER STATE(EPOCH)=-0.01478549-0.00580487 0.06788934-0.00006899 0.00003268 0.00001217-0.00000000 0.00000000-0.00000000
SMOOTHER SIGMAS(EPOCH) 0.00418174 0.01238971 0.08662333 0.00008338 0.00003924 0.00000252 0.00000000 0.00000000 0.00000000

NOMINAL TRAJECTORY (ECI)=  3980.3483 -2558.4563  5203.6326   -5.37501    1.67436    4.96626
SMOOTHER TOTAL  (ECI)   =  3980.3581 -2658.4575  5203.6099   -5.37501    1.67435    4.96629
FILTER ESTIM. (HCL)     =  0.0175172 -0.0141730 -0.0011385 -0.0000156 -0.0000136  0.0000245
SMOOTHER ESTIM. (HCL)   =  0.0212109 -0.0098631 -0.0079489 -0.0000213 -0.0000071  0.0000240
SMOOTHER SIGMA (HCL)    =  0.0024536  0.0019452  0.0018710  0.0000031  0.0000027  0.0000032
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SMOOTHER OUTPUT AT TIME  33240.00

PARAMETER LABELS      =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV
STATION/SATELLITE     =          0          0          0          0          0          0          0          0          0
FILTER STATE (EPOCH) =-0.00809529 0.00226591-0.00269871 0.00000623 0.00000016 0.00000884 0.00000000 0.00000000 0.00000000
SMOOTHER STATE(EPOCH)=-0.01489570-0.00581037 0.06823271-0.00006924 0.00003278 0.00001227-0.00000000 0.00000000-0.00000000
SMOOTHER SIGMAS(EPOCH) 0.00410578 0.01233420 0.08594364 0.00008279 0.00003898 0.00000260 0.00000000 0.00000000 0.00000000

NOMINAL TRAJECTORY (ECI)=  4591.3958 -2837.3228  4567.0704   -4.79528    1.30267    5.62882
SMOOTHER TOTAL  (ECI)   =  4591.4044 -2837.3225  4567.0442   -4.79526    1.30265    5.62885
FILTER ESTIM. (HCL)     =  0.0188532 -0.0117729 -0.0069333 -0.0000103 -0.0000173  0.0000255
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SMOOTHER ESTIM. (HCL)   =  0.0223922 -0.0077423 -0.0140761 -0.0000164 -0.0000121  0.0000283
SMOOTHER SIGMA (HCL)    =  0.0025325  0.0018270  0.0024499  0.0000029  0.0000028  0.0000036
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SMOOTHER OUTPUT AT TIME  33120.00

PARAMETER LABELS      =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV
STATION/SATELLITE     =          0          0          0          0          0          0          0          0          0 -
FILTER STATE (EPOCH) =-0.00809495 0.00226631-0.00270220 0.00000623 0.00000015 0.00000884 0.00000000 0.00000000 0.00000000
SMOOTHER STATE(EPOCH)=-0.01501208-0.00589059 0.06906281-0.00006995 0.00003310 0.00001235-0.00000000 0.00000000-0.00000000
SMOOTHER SIGMAS(EPOCH) 0.00403126 0.01226886 0.08520073 0.00008214 0.00003669 0.00000267 0.00000000 0.00000000 0.00000000

NOMINAL TRAJECTORY (ECI)=  5128.0876 -2970.2404  3856.3545   -4.13741    0.90958    6.20046
SMOOTHER TOTAL  (ECI)   =  5128.0944 -2970.2384  3856.3248   -4.13740    0.90957    6.20048
FILTER ESTIM. (HCL)     =  0.0188020 -0.0086115 -0.0126916 -0.0000045 -0.0000209  0.0000251
SMOOTHER ESTIM. (HCL)   =  0.0221167 -0.0046494 -0.0305240 -0.0000099 -0.0000175  0.0000307
SMOOTHER SIGMA (HCL)    =  0.0025182  0.0017293  0.0030997  0.0000025  0.0000029  0.0000040
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SMOOTHER OUTPUT AT TIME  33000.00

PARAMETER LABELS      =   X          Y          Z          XDOT       YCOT       ZDOT       GRAV       GRAV       GRAV
STATION/SATELLITE     =          0          0          0          0          0          0          0          0          0
FILTER STATE (EPOCH) =-0.00809462 0.00226678-0.00270609 0.00000624 0.00000015 0.00000884 0.00000000 0.00000000 0.00000000
SMOOTHER STATE(EPOCH)=-0.01512492-0.00601130 0.07013711-0.00007087 0.00003353 0.00001241-0.00000000 0.00000000-0.00000000
SMOOTHER SIGMAS(EPOCH) 0.00395969 0.01219362 0.08440394 0.00008146 0.00003836 0.00000273 0.00000000 0.00000000 0.00000000

NOMINAL TRAJECTORY (ECI)=  5581.6721 -3055.0214  3082.9785   -3.41202    0.50148    6 67171
SMOOTHER TOTAL  (ECI)   =  5581.6766 -3055.0174  3082.9454   -3.41200    0.50146    6.67174
FILTER ESTIM. (HCL)     =  0.0173428 -0.0047515 -0.0180432  0.0000014 -0.000024[illegible]  0.0000232
SMOOTHER ESTIM. (HCL)   =  0.0201933 -0.0005754 -0.0268249 -0.0000023 -0.000023[illegible]  0.0000309
SMOOTHER SIGMA (HCL)    =  0.0023996  0.0017192  0.0037561  0.0000022  0.0000033  0.0000041
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SMOOTHER OUTPUT AT TIME  32880.00

PARAMETER LABELS      =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV
STATION/SATELLITE     =          0          0          0          0          0          0          0          0          0
FILTER STATE (EPOCH) =-0.00809429 0.00226731-0.00271041 0.00000624 0.00000015 0.0000[illegible]4 0.00000000 0.00000000 0.00000000
SMOOTHER STATE(EPOCH)=-0.01522786-0.00615128 0.07130482-0.00007188 0.00003400 0.00001245-0.00000000 0.00000000-0.00000000
SMOOTHER SIGMAS(EPOCH) 0.00389226 0.01210838 0.08356013 0.00008074 0.00003805 0.00000279 0.00000000 0.00000000 0.00000000

NOMINAL TRAJECTORY (ECI)=  5944.7403 -3090.2596  2259.4758   -2.63086    0.08500    7.03474
SMOOTHER TOTAL  (ECI)   =  5944.7419 -3090.2535  2259.4397   -2.63083    0.08498    7.03476
FILTER ESTIM. (HCL)     =  0.0145296 -0.0002952 -0.0226102  0.0000072 -0.0000271  0.0000197
SMOOTHER ESTIM. (HCL)   =  0.0165448  0.0044128 -0.0324387  0.0000059 -0.0000283  0.0000285
SMOOTHER SIGMA (HCL)    =  0.0022083  0.0018824  0.0043501  0.0000022  0.0000038  0.0000040
***************************************************************************************************

***************************************************************************************************
SMOOTHER OUTPUT AT TIME  32760.00

PARAMETER LABELS      =   X          Y          Z          XDOT       YDOT       ZDOT       GRAV       GRAV       GRAV
STATION/SATELLITE     =          0          0          0          0          0          0          0          0          0
FILTER STATE (EPOCH) =-0.00809398 0.00226794-0.00271521 0.00000625 0.00000015 0.00000884 0.00000000 0.00000000 0.00000000
SMOOTHER STATE(EPOCH)=-0.01531631-0.00629638 0.07246483-0.00007287 0.00003446 0.00001248-0.00000000 0.00000000-0.00000000
SMOOTHER SIGMAS(EPOCH) 0.00383015 0.01201316 0.08267572 0.00007999 0.00003771 0.00000283 0.00000000 0.00000000 0.00000000

NOMINAL TRAJECTORY (ECI)=  6211.3546 -3075.3575  1399.2162   -1.80665   -0.33305    7.28347
```

```
*************************************************************************************************************************
SMOOTHER OUTPUT AT TIME       0.0

PARAMETER LABELS      =   X            Y            Z            XDOT         YDOT         ZDOT         GRAV         GRAV         GRAV
STATION/SATELLITE     =            0            0            0            0            0            0            0            0            0
FILTER STATE (EPOCH) = 0.0         0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
SMOOTHER STATE(EPOCH)=-0.00181402 0.00199352-0.00173660-0.00000111 0.00000421 0.00000391-0.00000000 0.00000000-0.00000000
SMOOTHER SIGMAS(EPOCH) 0.00390116 0.00372853 0.01237418 0.00001099 0.00000587 0.00000394 0.00000000 0.00000000 0.00000000

NOMINAL TRAJECTORY (ECI)= -6413.0778  2996.5868    -0.6872     0.45640     0.97591    -7.42596
SMOOTHER TOTAL  (ECI)   = -6413.0796  2996.5888    -0.6890     0.45640     0.97592    -7.42596
FILTER ESTIM. (HCL)     =  0.0        0.0         0.0         0.0         0.0         0.0
SMOOTHER ESTIM. (HCL)   =  0.0023729  0.0007936  0.0020050  0.0000030  0.0000038 -0.0000033
SMOOTHER SIGMA (HCL)    =  0.0040975  0.0027677  0.0125615  0.0000120  0.0000029  0.0000043
*************************************************************************************************************************
```

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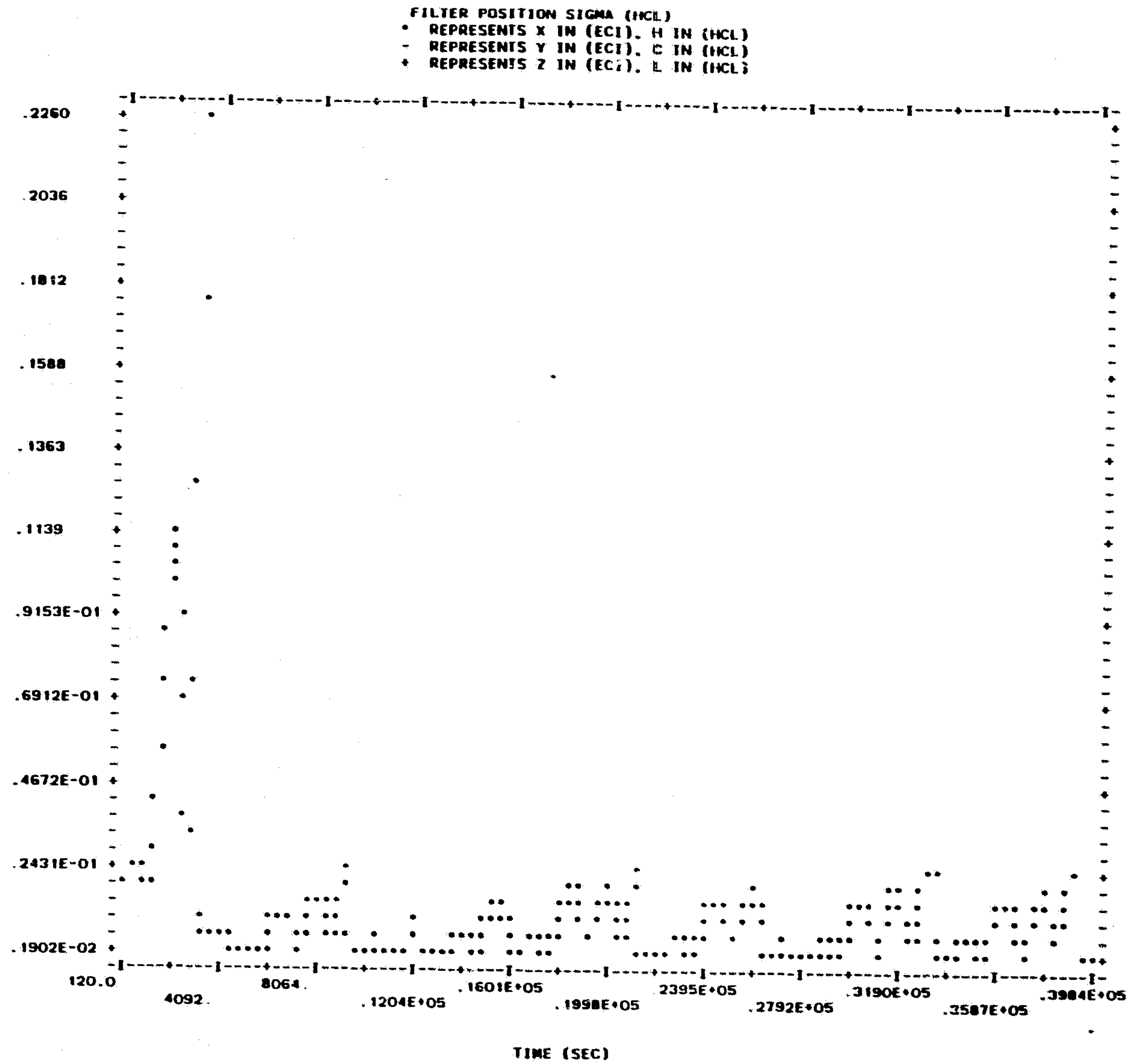
FILTER POSITION SIGMA (HCL)
• REPRESENTS X IN (ECI), H IN (HCL)
- REPRESENTS Y IN (ECI), C IN (HCL)
+ REPRESENTS Z IN (ECI), L IN (HCL)
SIGMA (KM)
.2260
.2036
.1812
.1588
.1363
.1139
.9153E-01
.6912E-01
.4672E-01
.2431E-01
.1902E-02
120.0
4092.
8064.
.1204E+05
.1601E+05
.1998E+05
.2395E+05
.2792E+05
.3190E+05
.3587E+05
.3984E+05
TIME (SEC)

```
* -- MEAN=   .12951866E-01,  SD=   .22307243E-01,  RMS=   .25765587E-01

(USED  332 OF  332 POINTS WITHIN    10. SIGMA)
```

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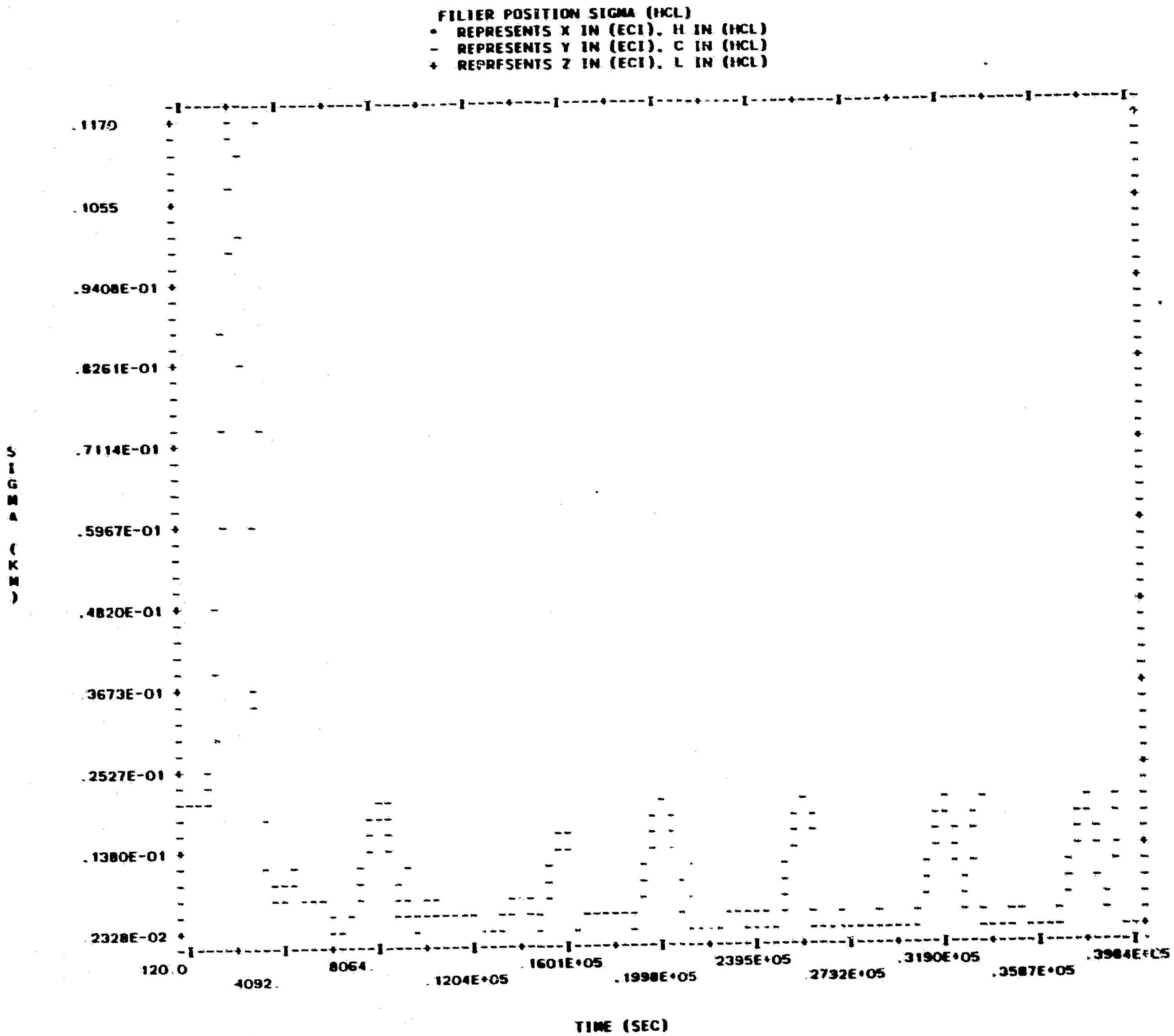

```
* -- MEAN=   .11350453E-01,  SD=   .18261783E-01,  RMS=   .21478388E-01
(USED  332 OF  332 POINTS WITHIN    10. SIGMA)
```

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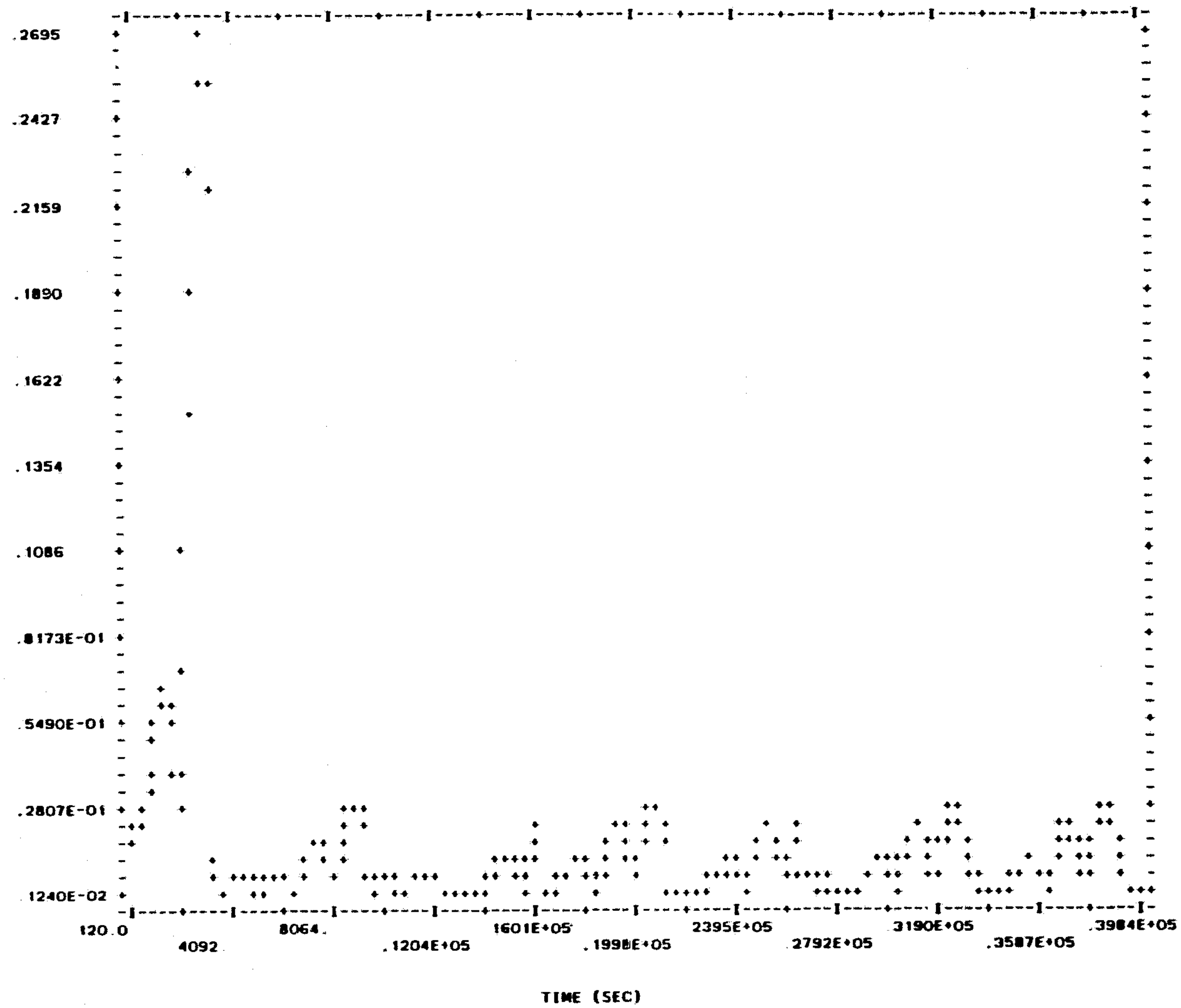
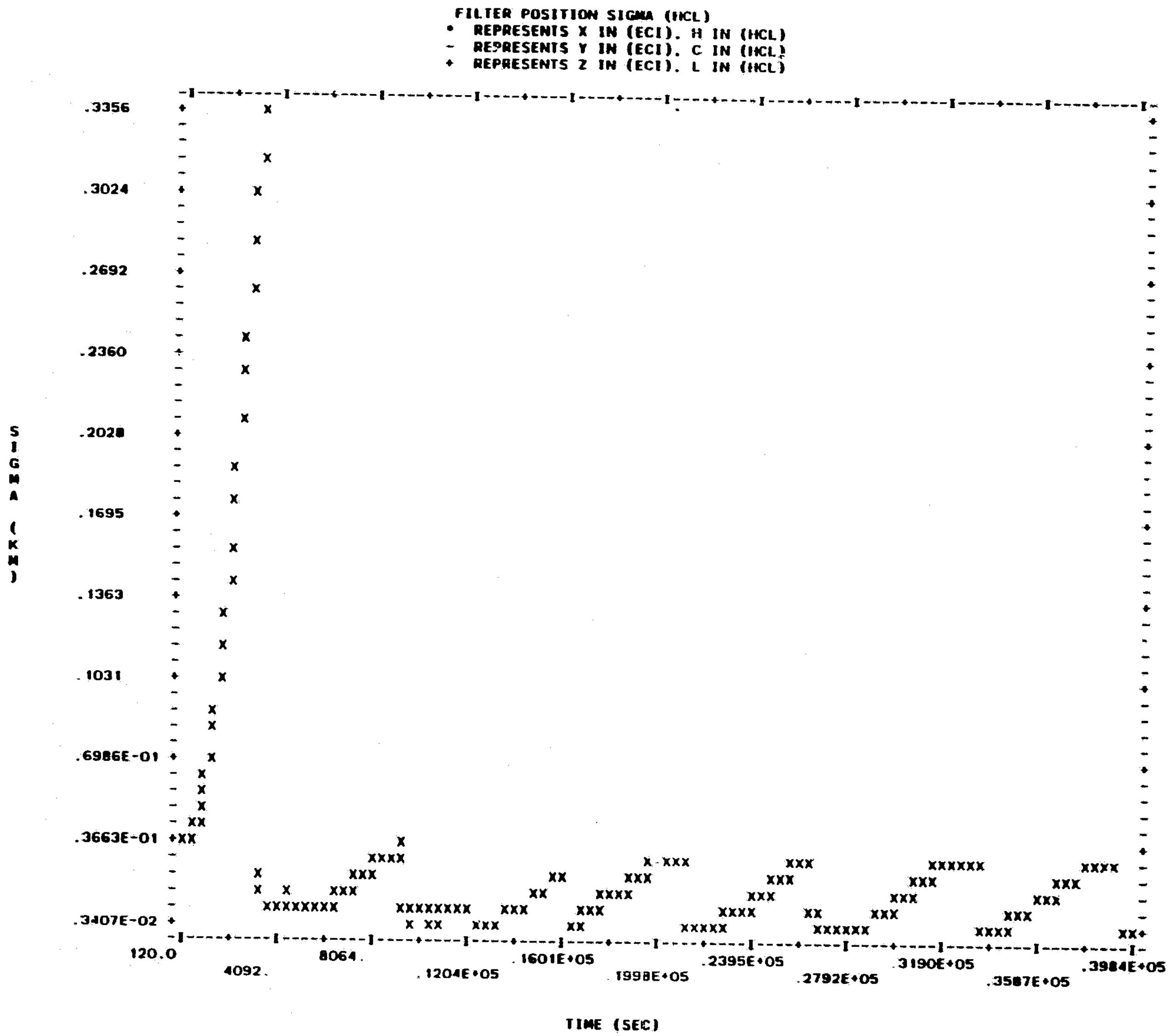
FILTER POSITION SIGMA (HCL)
* REPRESENTS X IN (ECI), H IN (HCL)
- REPRESENTS Y IN (ECI), C IN (HCL)
+ REPRESENTS Z IN (ECI) L IN (HCL)



* -- MEAN= .16926244E-01, SD= .36083471E-01, RMS= .39807796E-01

(USED 332 OF 332 POINTS WITHIN 10. SIGMA)



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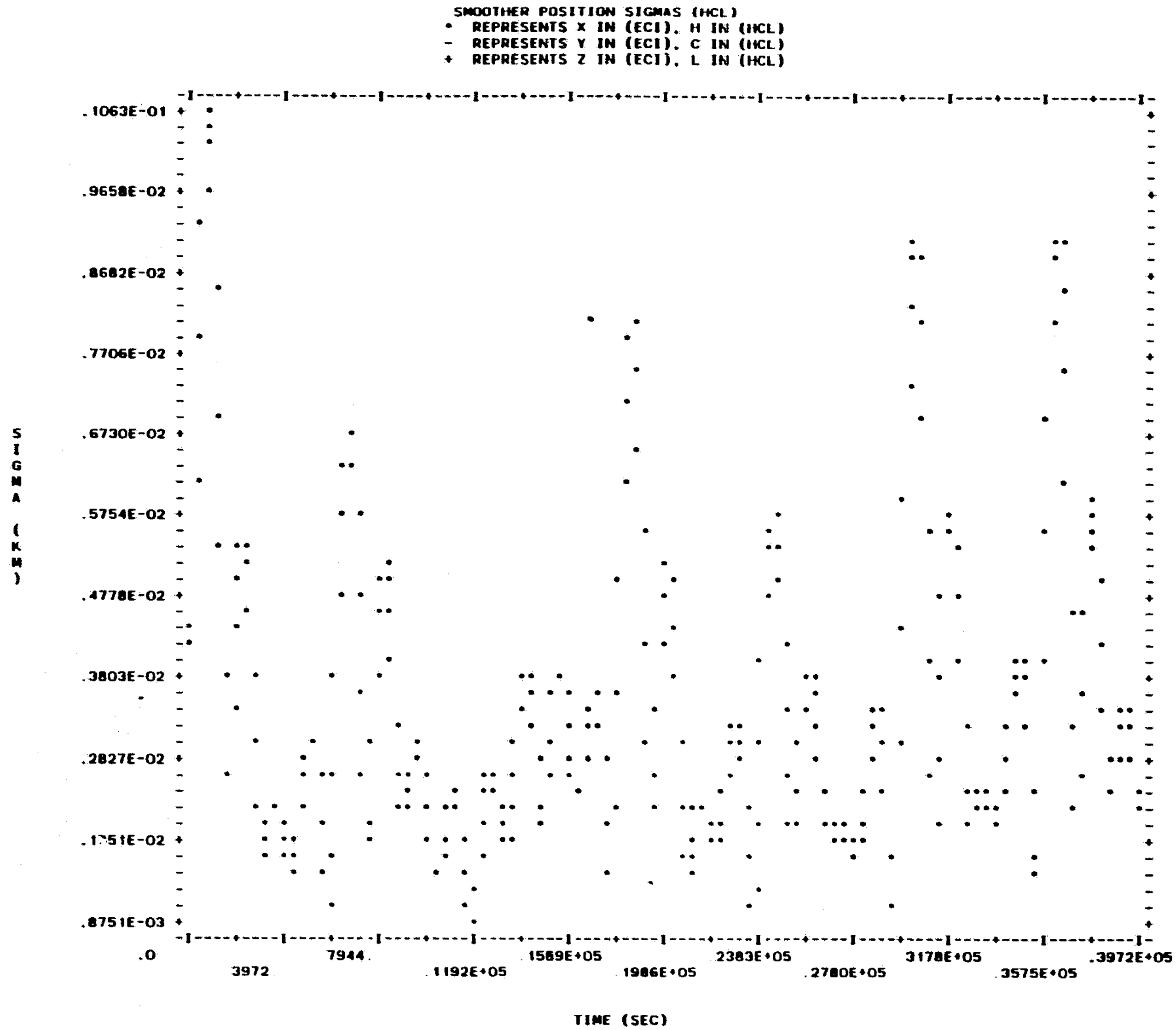
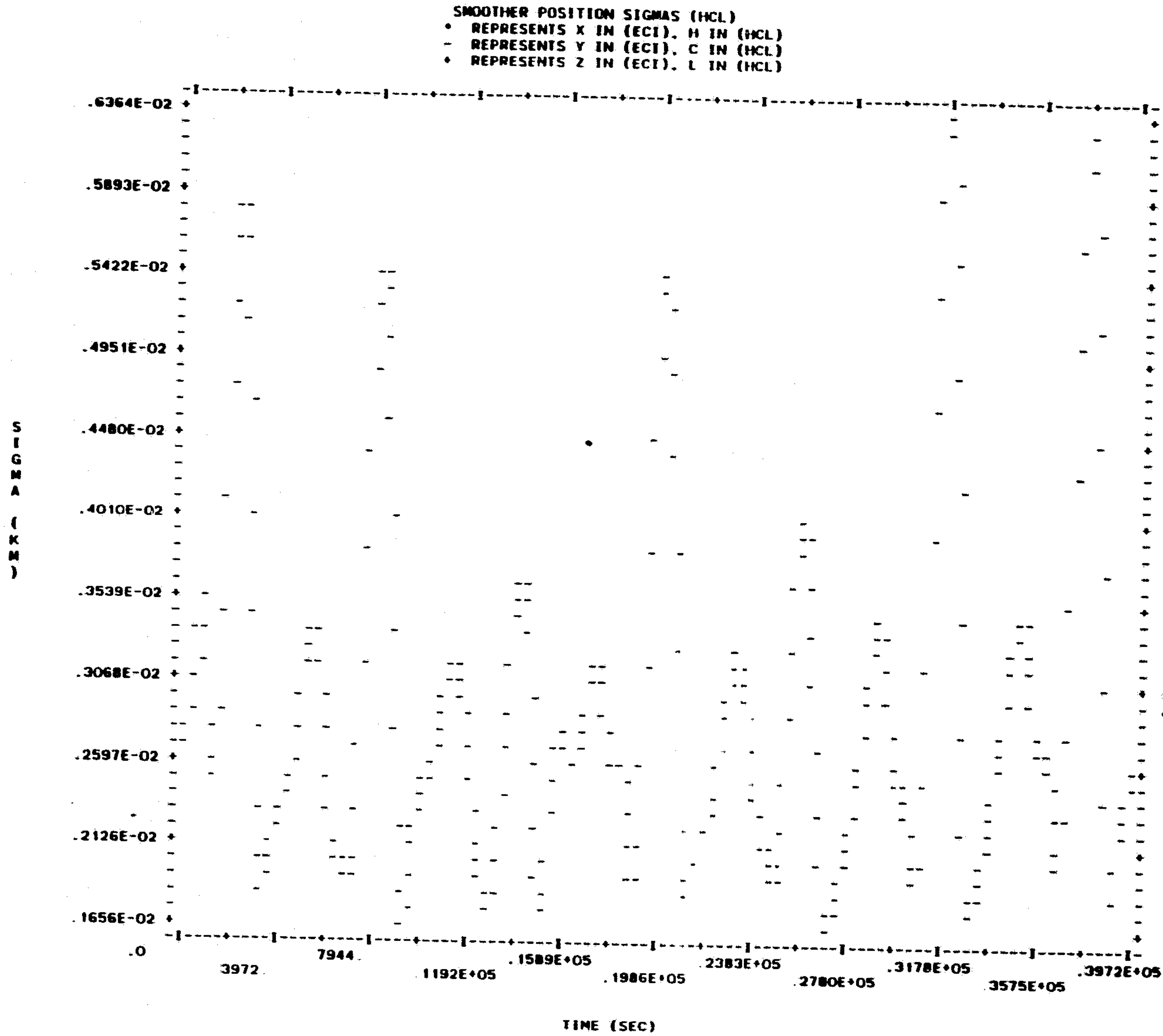
* -- MEAN= .26011597E-01, SD= .45162126E-01, RMS= .52058402E-01

(USED 332 OF 332 POINTS WITHIN 10. SIGMA)


SMOOTHER POSITION SIGMAS (HCL)
• REPRESENTS X IN (ECI), H IN (HCL)
- REPRESENTS Y IN (ECI), C IN (HCL)
+ REPRESENTS Z IN (ECI), L IN (HCL)
.1063E-01
.9658E-02
.8682E-02
.7706E-02
.6730E-02
.5754E-02
.4778E-02
.3803E-02
.2827E-02
.1851E-02
.8751E-03
SIGMA (KM)
.0
3972
7944
.1192E+05
.1589E+05
.1986E+05
.2383E+05
.2780E+05
.3178E+05
.3575E+05
.3972E+05
TIME (SEC)

```
* -- MEAN=   .35237661E-02,  SD=   .19338729E-02,  RMS=   .40181465E-02
(USED  332 OF  332 POINTS WITHIN    10. SIGMA)
```



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```
* -- MEAN=   .29874777E-02,  SD=   .10701504E-02,  RMS=   .31728214E-02
(USED  332 OF  332 POINTS WITHIN    10. SIGMA)
```

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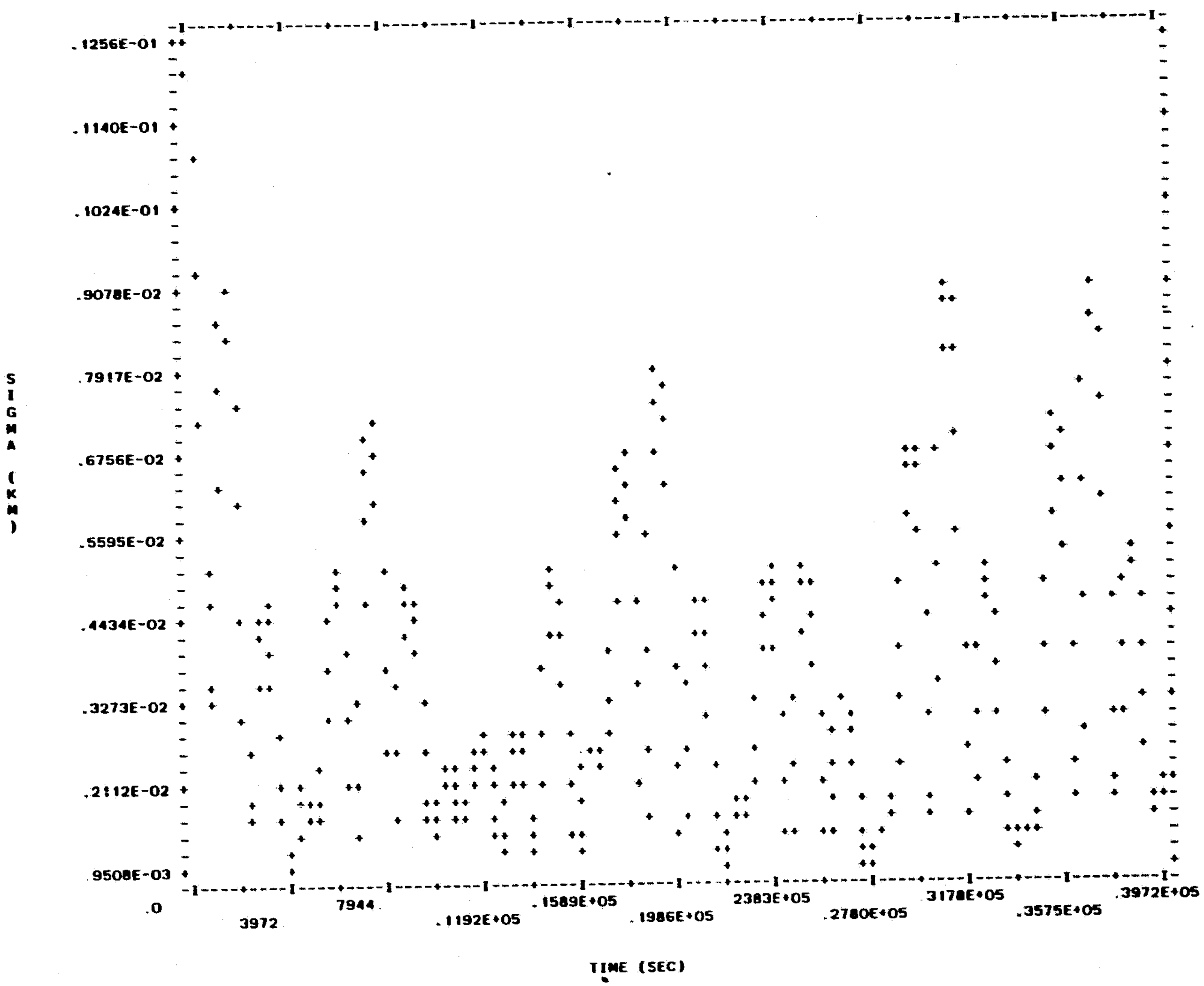
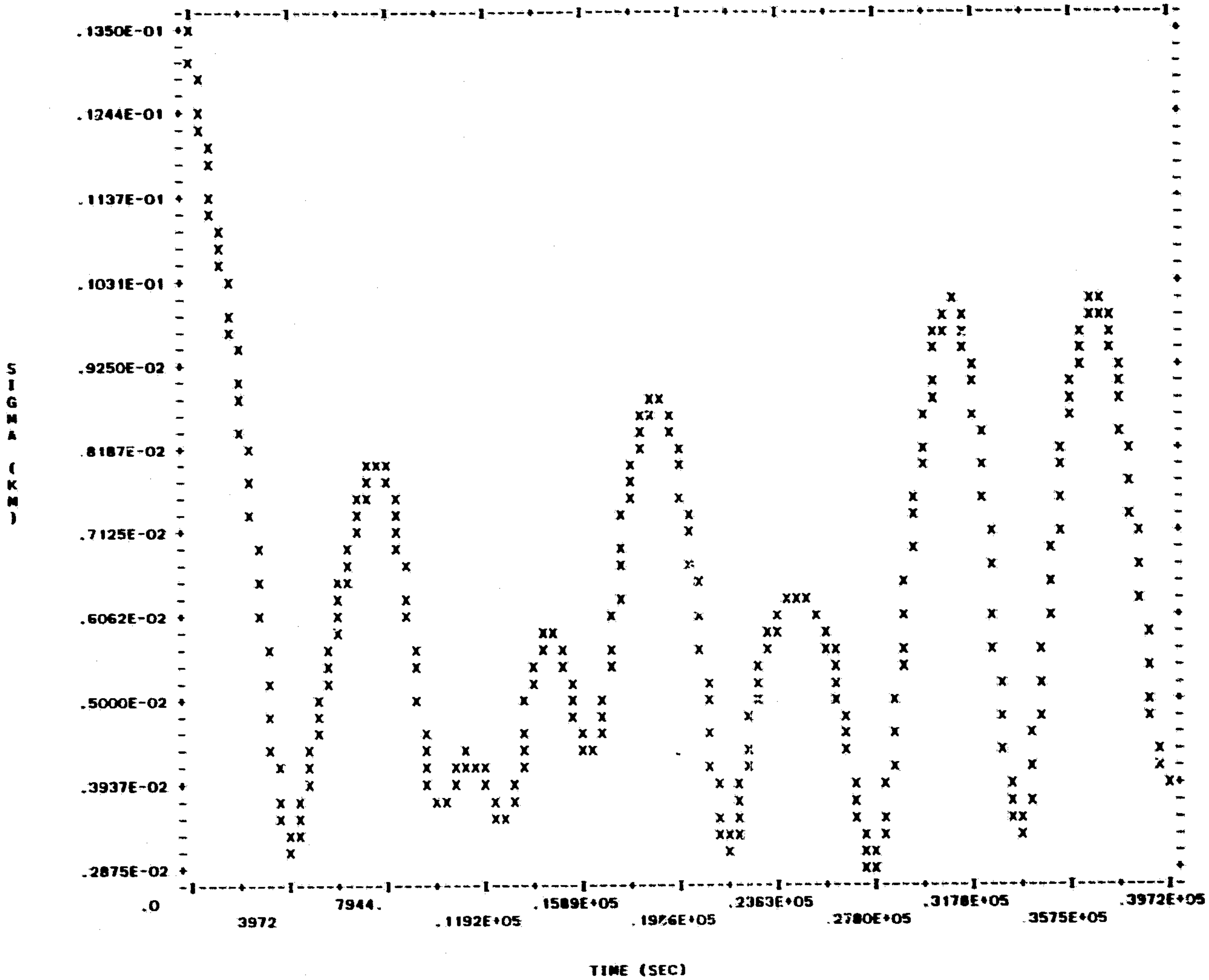
SMOOTHER POSITION SIGMAS (HCL)
* REPRESENTS X IN (ECI), H IN (HCL)
- REPRESENTS Y IN (ECI), C IN (HCL)
+ REPRESENTS Z IN (ECI), L IN (HCL)



```
* -- MEAN=   .62650368E-02,  SD=   .22927150E-02,  RMS=   .56701844E-02

(USED  332 OF  332 POINTS WITHIN    10  SIGMA)
```

SMOOTHER POSITION SIGMAS (HCL)
* REPRESENTS X IN (ECI), H IN (HCL)
\- REPRESENTS Y IN (ECI), C IN (HCL)
\+ REPRESENTS Z IN (ECI), L IN (HCL)



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* -- MEAN= .36805279E-02, SD= .21797807E-02, RMS= .42759106E-02

(USED 332 OF 332 POINTS WITHIN 10. SIGMA)

6.0 JOB CONTROL LANGUAGE

The listing following this paragraph is an example of the JCL required to run PREFER on the IBM 360/95. The core required to run PREFER (without overlays) using the loader is approximately 370K. This will vary somewhat depending upon the program options (e.g. GPSPAC/TDRS measurements, plots, smoothed covariance file) and number of I/O buffers. The use of overlays would only reduce the storage by approximately 50K. When tracking from many GPS satellites is processed, it may be necessary to increase the region to 500K. Printout from the job will define (approximately) the actual region used by PREFER.

```
// EXEC LOADER,REGION.GO=370K,PARM='SIZE=370000,EP=MAIN'
//SYSLIN DD
//         DD DSN=&&OBJ,DISP=(OLD,DELETE)
//         DD DSN=YCBPG.GSPACE.OBJ,DISP=SHR
//         DD DSN=YCBPG.CDCIO.OBJ,DISP=SHR
//GO.FT09F001 DD UNIT=2400-9,VOL=SER=36493,LABEL=(3,NL,,IN),
// DCB=(RECFM=VBS,LRECL=7204,BLKSIZE=7208,BUFNO=1),DISP=(OLD,KEEP)
//GO.FT10F001 DD UNIT=DISK,DSN=&&MEAS,DISP=(NEW,DELETE),
// DCB=(RECFM=VBS,LRECL=7204,BLKSIZE=7208,BUFNO=1),SPACE=(CYL,(2,1))
//GO.FT11F001 DD DUMMY,DCB=BLKSIZE=100
//GO.FT20F001 DD DSN=ORBIT.GTDS.SLP1950.DATA,DISP=SHR,DCB=BUFNO=1
//GO.FT21F001 DD DSN=ORBIT.GTDS.TIMCOF.DATA,DISP=SHR
//GO.FT22F001 DD DSN=ORBIT.GTDS.SLPTOD.DATA,DISP=SHR,DCB=BUFNO=1
//GO.FT30F001 DD UNIT=DISK,DSN=&&U30,DISP=(NEW,DELETE),
// DCB=(RECFM=VBS,LRECL=108,BLKSIZE=3244,BUFNO=1),SPACE=(TRK,(10,2))
//GO.FT40F001 DD DUMMY,DCB=BLKSIZE=100
//GO.FT41F001 DD DUMMY,DCB=BLKSIZE=100
//GO.FT42F001 DD DUMMY,DCB=BLKSIZE=100
//GO.FT43F001 DD DUMMY,DCB=BLKSIZE=100
//GO.FT50F001 DD UNIT=AFF=FT09F001,LABEL=(4,NL,,IN),VOL=SER=36493,
// DCB=(RECFM=VBS,LRECL=6664,BLKSIZE=6668),DISP=(OLD,KEEP)
//GO.MASSTORE DD UNIT=DISK,DSN=&&U60,DISP=(NEW,DELETE),
// SPACE=(CYL,(5,2))
//GO.FT70F001 DD UNIT=DISK,DSN=&&ORB1,SPACE=(TRK,(10,2)),
// DCB=(RECFM=VBS,LRECL=X,BLKSIZE=7294,BUFNO=1),DISP=(NEW,PASS)
//GO.FT71F001 DD UNIT=DISK,DSN=&&TPL1,SPACE=(CYL,(2,2)),
// DCB=(RECFM=VBS,LRECL=X,BLKSIZE=7294),DISP=(NEW,DELETE)
//GO.DATA5 DD *
```

Figure 7.1 Example of PREFER JCL for Processing Ground Tracking

Notice that Fortran units 9 and 50 use the same tape and tape drive. Unit 9 refers to file 1 (the observation file) and unit 50 refers to file 2 (the ORBIT file). PREFER internally copies unit 9 to unit 10 (disk) so that the input files from the GTDS run may be placed on the same tape.

Fortran unit MASSTORE is the scratch disk used by the filter and smoother to store the intermediate covariance matrices and other arrays. The DCB information is internal to PREFER. The space allocation of (5,2) cylinders should be adequate for most jobs. Unfortunately, it is very difficult to compute the storage required in a given run. It depends upon the number of states adjusted at each point in time. Since the number of states varies greatly during the run (as ground stations and GPS satellites change visibility to the satellite), the storage requirements can also vary greatly. In general, it should not be necessary to change the space allocation unless many GPS satellites are included.

Fortran unit 30 is also scratch storage. However, the storage requirements are modest since only the filtered and smoothed state vectors are stored here.

Units 70 and 71 are used for temporary storage of plotting variables and thus they cannot be ignored (e.g., "DUMMY") if plots are requested. Again the storage requirements are modest. Unit 71 is also used to output the smoothed covariance when this option is requested. The storage requirements for the smoothed covariance can be as large as 50 megabytes although 5 megabytes is a more typical number.

7.0 REFERENCES

(1) Gibbs, B. P., "Precision Recursive Estimator for Ephemeris Refinement (PREFER/GALAXY) Mathematical Description", Business and Technological Systems, Inc., FR-81-141, February 1981.

(2) Goddard Trejectory Determination System (GTDS) Users' Guide, NASA/Goddard Space Flight Center, July 1975.

(3) Edwards, A. W. F., "Likelihood: An Account of the Statistical Concept of Likelihood and its Application to Scientific Inference". Cambridge University Press, London 1972.

(4) Goddard Trajectory Determination System (GTDS) Data Sets Layout, NASA/Goddard Space Flight Center, January 1980.

APPENDIX A

PREFER Debug Printout

FILTER (IBUG(1))

ND - number of dynamic parameters

TL - time of last entry to FILTER (sec)

T - current time (epoch of mini-batch) (sec)

X - state vector at epoch time of mini-batch

PHI - state transition matrix (TL to T)

X - state vector (at time T) is printed after each measurement

MEAS (IBUG(2))

TI - time of measurement (referenced to epoch of Host Trajectory)

ISTA - station/satellite number

MTYPE - measurement type

Y - measurement

YD - measurement residual

SIGM - input σ of measurement

PY - partial derivatives of measurement WRT state

SNOISE (IBUG(3))

T - current time (sec)

OLDT - time of last entry to SNOISE (sec)

ND - number of dynamic parameters

X - state vector at time T (only dynamic states are printed)

PHI - state transition matrix (OLDT to T)

F - 6 x NP6 partial array (current cartesian elements WRT state vector) multiplied by DT

A = F · QA where QA is spectral density matrix (state noise)

Q = ND x ND state noise matrix in ECI coordinates

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After transformation to epoch osculating elements, Q is printed again along with PHI4 (the transition matrix from epoch osculating elements to current cartesian elements)

DYNAM (IBUG(4))

TSTART - reference time (start of integration)

TEND - end time of integration

DT = TEND-TSTART

STMAX - maximum allowed step size (with sign) for Taylor series integration

HSTEP - current step size of interated integration

HLFSTP = HSTEP/2

TK - current time of iterated integration

OLDTK - last TK

PHI1 - 6x6 transition matrix - cartesian (OLDTK) to cartesian (TK)

PHI4 - 6x6 transition matrix - epoch osculating to cartesian (TEND)

PHI - NDxND output state transition matrix

XI - nominal cartesian elements at TEND

XOUT - filter estimate of dynamic states at TEND

CARD (IBUG(3)

NUMCDS - number of adjusted parameters initialized

LAB - parameter labels as read in

SIG - *a priori* σ's as read in

QN - state spectral density as read in

STAVAR - station measurement variances as read in

NDRAG - number of drag parameters

NGRAV - number of gravitational parameters

NTHRST - number of thrust parameters

NCLOCK - number of clock parameters

NALT - number of altimeter parameters

NPARM = NDRAG+3·(NTHRST+NGRAV)

NP6 = 6 + NPARM

ND = number of dynamic parameters (NP6+NCLOCK+NALT)

NBIAS - 0 or 1 (1 indicates that biases are adjusted)

NREFR - 0 or 1 (1 indicates that refraction parameters are adjusted)

<u>INTERG</u> (IBUG(6))

NSAT - satellite number (1-24)

TK1 - current time in seconds from epoch of host tape

TK - current time in seconds from epoch of GPS tape

E - interpolated position and velocity at TK

<u>GETVEC</u> (IBUG(6))

REQTIM - interpolation time

XTO - interpolated satellite position and velocity at REQTIM

<u>EARTH</u> (IBUG(7))

T - time from epoch

STAPOS - station positions (Earth Centered Fixed)

XSTA - station positions and velocities (Earth Centered Inertial)

<u>EVAL</u> (IBUG(7))

CETOL - time tolerance for ephemeris computation

NWSLP - Fortran unit number for SLP file

REFDA2 modified Julian date corresponding to January 1950.0

REFDA4 modified Julian date corresponding to initial conditions

NCFDAY - number of days per curve fit

TSEC - time in seconds from start of year to midpoint of this record time interval

PDELH - polynomial coefficients for delta H

IDAY - beginning day of current record

IND13 - polar motion switch (1 - compute polar motion)

USUN(3) - sun vector

A - transformation matrix: selenocentric to selenographic

ADOT - $\dot{A}$

B - transformation matrix: earth inertial (TOD) to earth fixed

C - transformation matrix: mean of 1950.0 to true of date

GHA - Greenwich hour angle

XP - X polar motion angle

YP - Y polar motion angle

TZERO - number of A.1 seconds from 1950 to epoch

TZERO1 - time in seconds from beginnning of ephemeris year to epoch

DEPOCH - Julian date of epoch

AZERO - difference between A.1 and UTC time at epoch

APPENDIX B
Guidelines for Setting Up GTDS Runs

Since PREFER must use files created by GTDS, it is important that the GTDS run be set up correctly. The following guidelines are given.

1) The GTDS run must create an Observation Save File (Unit 46) and an ORBIT file with partial derivatives (Unit 21) on magnetic tape. The input cards required to do this are:

1 - 8	9 - 11	12 - 14	15 - 17	18 - 38	39 - 59	60 - 80
SAVE	1					
OUTOPT	0	1	0	start time	end time	time interval

It is suggested that a time interval of 30 seconds be used.

2) It is strongly recommended that the Observation Save File and the Orbit File be placed on the same tape (with the Observation file first) and tape drive (use UNIT=AFF). This will minimize the number of tapes and drives required for both the GTDS and PREFER runs.

3) Time regularized integration must not be used.

4) Partial derivatives for the ORBIT file should be cartesian orbital elements with respect to epoch orbital elements. The epoch elements may be cartesian, Keplerian or spherical, but cartesian are preferred.

5) Since PREFER is intended to produce accurate ephemerides, it is important that the best models available be used in GTDS. In particular, the refraction corrections should be made in GTDS even though this increases the computer costs of a differential correction run. This is done using an OBSCORR card.

APPENDIX C

Subroutine GSPACE

The subroutine GSPACE gives the user the capability to dynamically allocate core, that is, to allocate core for an array or a number of arrays during the execution of the program. This frees the user from hard-coding the dimension of arrays which will vary in size from run to run.

GSPACE works by taking the amount of core (in bytes) requested by the user, incrementing it up to the next multiple of 8, and then issues a GETMAIN instruction for that amount of core. GSPACE then calculates the offset, in numbers of 4 byte words, from some specific (hard) dimensioned variable to the first location of the space obtained. The user may then access this space by specifying the offset as an index to the (hard) dimension variable.

General Format

```
CALL GSPACE (N, NA, NB, &Y, &Z)
```

where

N = the number of arrays for which core is being requested (INPUT TO GSPACE)

NA = an integer array of dimension N: the 1st element of A is set equal to the amount of core (bytes) requested for the 1st array, the 2nd element is set equal to the amount of core requested for the second array, etc. (INPUT TO GSPACE)

NB = an integer array of dimension N: the 1st element is set equal to the offset in 4 byte words from NA(1) to the storage area for the first array, the 2nd element is set equal to the offset in 4 byte words from NA(1) to the storage area for the second array, etc. (OUTPUT FROM GSPACE)

Y = the line to which control is transferred if the amount of core requested by the user is not available. (OUTPUT FROM GSPACE)

Z = the line to which control is transferred if the call format is incorrect or the input variables contain invalid values (negative or real numbers) (OUTPUT FROM GSPACE)

Example:

```
DIMENSION NA(2), NB(2)
NA(1) = NPARMS * 4
NA(2) = NDEV * 8
CALL GSPACE (2, NA, NB, & 100, & 200)
```


To access the storage area for the 1st array, specify NA(NB(1) + I), I = 1, NPARMS. NPARMS 4-byte words can be stored in this space. To access the storage area for the 2nd array, specify NA(NB(2)+I), I = 1, NDEV*2. Either NDEV*2 4-byte words or NDEV 8-byte words can be stored in this area. Note that the offset to the 2nd storage area will be calculated from NA(1) and not NA(2).

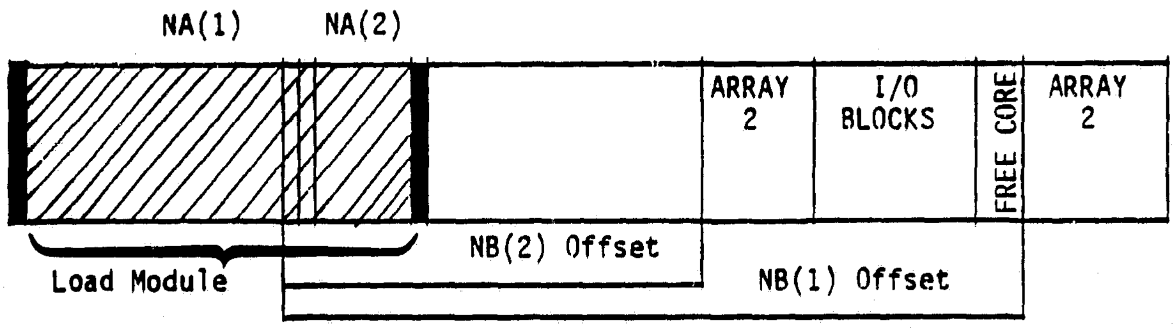
How GSPACE works:

GSPACE first takes the input array NA values and checks to see if they are valid numbers. If they are, it then rounds them up to the next multiple of eight, even if they are already a multiple of eight. GSPACE then calls a routine which issues a separate GETMAIN instruction for each array requested. This will not necessarily result in the different array storage areas (within the same call to GSPACE) being contiguous (if the user has indeed requested multiple array storage areas). If the core is not available for any one of the GETMAIN requests, control is transferred to the line specified for Y. If all the core requested is available, GSPACE then enters a loop to calculate the offsets by the following algorithm:

$$NB(I) = \frac{\begin{pmatrix}\text{Storage address of first location} \\ \text{in array I storage area}\end{pmatrix} - \begin{pmatrix}\text{storage address} \\ \text{of NA(1)}\end{pmatrix}}{4} + 1$$

When the loop is complete, control returns to the calling program. Because the GETMAIN always gets core in the highest location (within the region) that is possible, subsequent GETMAIN's will likely get core closer to the load module (stored in the lowest region locations of core), and therefore the increments will decrease, i.e., NB(1)>NB(2)>NB(3). . . This will not necessarily be true if less core is requested by the subsequent GETMAIN's, i.e., NA(1)>NA(2)>NA(3). . .

REGION AVAILABLE



Other Entry Points

CALL RELESE (N, NA, NB) - releases core allocated in a previous call to GSPACE. N, NA and NB have the same definitions as for GSPACE.

CALL REGION - computes IREG in common block CORE$$.

CALL GCORE - computes MCOR and ICORE in common block CORE$$.

Note: GCORE will allocate the entire region specified on the EXEC statement. Thus the user should ignore the SIZE listed in the job system messages.

Common Block/CORE$$/

IREG - allocated region (in bytes) of current job step (from REGION parameter on EXEC statement).

MCOR - maximum unused region (bytes) in any previous call to GCORE (including the current call).

ICORE - unused region (bytes) at the current call to GCORE.

APPENDIX D

Description of "CDC Type" Disk Random Access I/O Package

PREFER uses an assembly language subroutine which simulates "CDC type" random access disk I/O on an IBM 360. This subroutine has several advantages compared to standard IBM random access (or DAIO) in that the length and number of records can be variable. In fact, it is possible to write over existing records with a different length as long as that length is less than or equal to the old length. Although this routine is not suitable for use with permanent data sets, it is very useful for scratch storage within a program. This routine is documented here since it is general purpose and may be useful for a variety of other applications.

The subroutine has six entry points: OPENMS, ENDMS, WRITSS, WRITMS, READMS AND CLOSMS. A description of each of these functions is given below.

1) CALL OPENMS(IX) - Opens mass storage (DDNAME=MASSTORE) for write/print/sequential access and saves the address of the record index for use by the routines WRITSS, READMS, and WRITMS. IX is an integer array which must be dimensioned as large as the number of records to be written. Note that the DCB information for MASSTORE is obtained internally in the routine. The user need only specify UNIT, DISP and SPACE.

2) CALL WRITSS(IA,IR) - Writes a record to the next available space and stores the relative address in the index. If the entire record will not fit on the current track, then the remainder of the record is segmented and written to subsequent tracks. IA is the data array to be written to disk and IR is the record number. Note: The first 4-byte integer of IA must contain the length of the record in words (4-bytes). The example at the end demonstrates the use of WRITSS and READMS for writing and reading double precision words.

3) CALL ENDMS - closes the mass storage data set for sequential access, alters the macro form of the DCB to read/point and reopens the data set for update.

4) CALL READMS(IA,IR) - reads a record from mass storage. If the record spans several tracks then it will be brought in segment by segment. The point macro is used to position the disk at the beginning of the records. Each read attempts to read an entire track of data (incorrect length is ignored). The actual length of segments read in is computed from the residual count in the CSW, and segments are read in until the total number of bytes read equals the record length. It is assumed that the record length is stored in the 1st fullword of the record. IA is the array to which data will be retrieved from the disk and IR is the record number.

5) CALL WRITMS(IA,IR) - writes an updated record back to mass storage. If the record spans several tracks, then it will be rewritten in segments. The point macro is used to specify the disk address of each segment. On each write, a length of one track is specified, and incorrect length errors are intercepted by the SYNAD routine 'EX'. The actual length of a written segment is determined from the residual count in the CSW. Segments are written until the total number of bytes written equals the record length. The definitions of IA and IR are the same as for WRITSS. Note that the length of the updated record must be less than or equal to the length of the old record.

6) CALL CLOSMS - closes the mass storage dataset.

ERROR CODES

The routines can abend with 5 different error codes. Core dumps are produced by these abends.

103 - error in WRITSS: too many bytes have been written.

104 - error in READMS: too many bytes have been read. Record length was probably incorrect.

105 - error in WRITMS: too many bytes have been written.

106 - error in WRITMS: I/O error other than incorrect length.

999 - error in READMS: ENDMS was not called prior to first call to READMS.