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TRACE TRAJECTORY ANALYSIS AND ORBIT DETERMINATION PROGRAM. VOLUME VII. USAGE GUIDE, PART A: INPUT DATA (REISSUE B)

Willard D. Downs, III, et al

Aerospace Corporation

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Approved

A. R. Sims, Director
Mathematics and Programming Subdivision
Information Processing Division
Engineering Science Operations

D. C. Walker, Senior Staff Engineer
Project Management Staff
Information Processing Division
Engineering Science Operations

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The TRACE Trajectory Analysis and Orbit Determination Program is a general-purpose orbital analysis program. It was written and continues to be developed specifically to assist technical personnel in the analysis and design of satellite orbits and tracking systems. Volume VII is intended to serve as in input usage guide that defines all input required to perform TRACE functions such as trajectory generation, data/observation generation, orbit determination, and statistical analysis. A comprehensive

19. KEY WORDS (Continued)

Recursive Filter
Sequential Batch
Simultaneous Vehicle
TRACE
TRACE66
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Vehicle Attitude

20. ABSTRACT (Continued)

description for each specific input item is given, and input data structures are shown. The Usage Guide is published in two parts, A and B.

The TRACE documentation series is summarized as follows:

Volume I: General Program Objectives, Description, and Summary
Volume II: Coordinate and Timekeeping Systems with Associated Transformations
Volume III: Trajectory Generation Equations and Methods
Volume IV: Measurement Data Generation and Observational Measurement Partials
Volume V: Differential Correction Procedure and Techniques
Volume VI: Orbital Statistics via Covariance Analysis
Volume VII: Usage Guide, Parts A and B
Volume VIII: Not to be published
Volume IX: Detailed Program Structure
Volume X: Lunar Gravity Analysis
Volume XI: LGA Data Processor
Volume XII: Sequential Least Squares Procedures and Techniques

PREFACE

Certain volumes of the TRACE documentation series were published by The Aerospace Corporation as Technical Operating Reports. Volume III: Trajectory Generation Equations and Methods was published as TOR-0066(9320)-2, Vol. III, and Volume V: Differential Correction Procedure and Techniques was published as TOR-0066(9320)-2, Vol. V.

Volume I: General Program Objectives, Description, and Summary was published as TR-0059(9320)-1, Vol. I, and Volume X: Lunar Gravity Analysis was published as TR-0059(9320)-1, Vol. X. Future volumes in this series will be published as Technical Reports.

This report is published in two parts, A and B.

The TRACE Program could not have been developed to its present status without the assistance of many people working in the fields of astrodynamics and software design. The authors acknowledge with gratitude the analysis and/or programming efforts of A. B. Bierman, R. J. Farrar, W. A. Feess, E. H. Fletcher, R. B. Freund, T. P. Gabbard, C. G. Gibson, P. T. Gray, P. T. Guttman, J. A. Pearson, C. M. Price, W. F. Rearick, N. W. Rhodus, A. J. Rusick, L. J. Tedeschi, L. Wong, and K. R. Young. In addition, consultations with W. T. Kyner, A. Troesch, and H. H. Wertz have led to many significant improvements and added capabilities in the program.

This report supersedes TR-0059(9320)-1, Vol. VII, Reissue A, Part A, 15 December 1972. AD766 260

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TABLES (Continued)

PRESET VALUES OF MODEL VARIABLES

Name	Value	Unit
ACØN	0	-
ADELT	1.	min
AE	1.	er
AEXP	1.	nmi
AF	5812.705	$(ft/sec^2)/(er/min^2)$
AM	2.72506277E-1	er
CKEP	1.E-11	-
CMFSC	0	-
CNT1	1048574.	cycle
CRASH	300000.	ft
D1	6.83	-
D2	-15.684	-
DCF	3443.9336	nmi/er
DCØNV	3280.8399	ft/km
DF	20925738.	ft/er
DGREE	57.295779513082	deg/rad
DØPRF	300.	-
DØVER	0	er
ELEDD	0	deg
ER	1.E-11	-
ERFT	20925738.	ft
ERKM	6378.1649	km
ERNM	3443.9336	nmi
ETTA1	32.15	sec
F	3.352329869E-3	-
FEDIT	0	-
FLUX	0	10^{-22} $W/m^2/Hz$

PRESET VALUES OF MODEL VARIABLES (Continued)

Name	Value	Unit
FØVER	1.	-
FREQ	1.8E+8	cps
FTKM	3280.8399	ft/km
FTNM	6076.1155	ft/nmi
GDELT	1.	min
GM	5.5303935E-3	er^3/min^2
GMLAT	78.3	deg
GMKM	0	km^3/sec^2
GM17	5.530417744E-3	er^3/min^2
GMLNG	291.	deg
GPLØT(1)	0	-
GPLØT(2)	4.	sec
GSUB0	32.174	ft/sec^2
H0	1.	min
HEXP	0	nmi
HH69	50.	%
HMAX	64.	min
HMIN	1.5625E-2	min
HMØØN	3000.	ft
IR	8	-
JMAX	10	-
JSGLS(1)	0	-
JSGLS(2)	350E-6	-
KEDIT	0	-
MAXIT	0	-
NEDIT	100	-
NCØF	0	-

PRESET VALUES OF MODEL VARIABLES (Continued)

Name	Value	Unit
NFØRM	0	-
NPCMP	0	-
NPDØT	0	-
NSTEP	0	-
NTERM	0	-
NTL	0	-
ØMEGA	4.3752691E-3	rad/min
ØMEGE	4.3752691E-3	rad/min
PATA	0	-
PEXP	0	slug/ft^3
PH0	0.125	min
PHMIN	19.53125E-4	min
PH69	980	mbar
PI	3.1415926535898	-
PRHØ	0	-
PRIØR	100	-
PTNS	1000	-
RAREF(1)	350.E-6	-
RCØN	1.E-3	-
RE	1.	er
REFR(1)	312.E-6	-
RM	2.725063E-1	er
RS	109.1218	er
SEPS	1.	cycle
SFDBD	0.5	-
SFIBD	1.5	-
SFREQ	0	cps

PRESET VALUES OF MODEL VARIABLES (Continued)

Name	Value	Unit
SGM	6.8023265E-5	er^3/min^2
SLT	2820.1763	er/min
SSCL	1.	-
TBAR	0	min
TEST	0	-
TFREQ	0	cps
TH69	15.	°C
TREFD	0	min
TRØPH	20.	km
UTD	35.	sec
VALT	0	nmi
VCØNV	3280.8399	ft/km
VF	348762.3	(ft/sec)/(er/min)
VMIN	0	nmi

PRESET VALUES OF VEHICLE VARIABLES

Name	Value	Unit
ATIME	0	min
ATMK	1	-
BTIME	0	MME
DALPH	0	deg
DAY	0	day
DSTØP	0	MME
DSTRT	0	MME
EPSDF	0	min
FBAR	0	10^{-22} W/m^2/H_z
HDTAB	0	ft
HR	0	hr
IDRAG	0	-
IFORM	1	-
IVGMS	1	-
MIN	0	min
MNTH	0	month
REV	0	-
SEC	0	sec
SØRD	1.5	-
SSTEP	100	-
THMIN	0	deg
TZNE	0	-
WMIN	0	lb
WTIMF	0	MME
WTIMI	0	MME
WZERØ	1	lb
YEAR, YR	0	yr

GLOSSARY INDEX

	A	Page
A1	Atomic time	11-12
A	Parameter name for initial vehicle semimajor axis a	11-59
ABIA	Parameter name for azimuth measurement bias	5-3
AC	Coefficients used to compute temperature effects (Jacchia 1964 Atmosphere Model)	2-15
ACCT	Input for accelerometer models	11-45
ACELS	Sigmas for accelerometer scale factor deweighting	7-4
ACI	Mars-centered inertial	11-9
ACØN	Absolute convergence criterion for orbit determination	2-56
ADBI	Parameter name for azimuth rate measurement bias	5-3
ADELT	Step size for analytic trajectory generation	2-36
ADWM	Constant portion of additive deweighting matrix	7-3
ADWT	Type of additive deweighting matrix	7-3
AE	Mean equatorial earth radius	2-3
AEXP	Constants used in the Exponential Atmosphere Model (scale height); parameter name for the earth constant	2-11; 2-44
AF	Input/output acceleration conversion factor; parameter name for initial condition a_f	2-4; 11-59
AG	Parameter name for initial condition a_g	11-59
AJN	Coefficients of the polynomial used in the Jacchia 1964 Atmosphere Model	2-17
AL	Right ascension of launch a_L; its parameter name	11-66; 11-67
ALPHA	Parameter name for initial right ascension of vehicle α	11-59
ALT	Parameter name for station altitude	5-3

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		Page
ALTPR	Table of vehicle altitudes at which trajectory information is printed	11-81
AM	Mean equatorial lunar radius	2-4
AØFF	Parameter name for boresight offsets for x- and y-antenna angle measurements	5-5
APSIG	Indicator that saves the computed a priori sigmas and bounds	2-53
APTAB	Table of planetary geomagnetic amplitudes a_p or fcn (t) (JKP ≠ 0)	11-24
ASPCT	Time-dependent increments for yaw, pitch, and roll angles for generating aspect angles	11-95
ATA	Data Block that contains A^TA and $(A^TA)^{-1}$ input	6-1
ATIME	Time bias for accelerometer model; its parameter name	11-45; 11-60
ATMK	Constant scale factor applied to atmospheric density; its parameter name	11-22; 11-60
AXBI	Parameter name for x-antenna angle measurement bias	5-4
AXIS	Vehicle roll axis [PRCDE(B)]	11-82
AXM	Parameter name for x-antenna angle measurement scale factor	5-5
AYBI	Parameter name for y-antenna angle measurement bias	5-4
AYM	Parameter name for y-antenna angle measurement scale factor	5-5
AZ	Parameter name for initial vehicle azimuth A	11-59
AZi	Parameter name for roll axis azimuth for ith stage	11-67

B

BCDIN	Card image observation tape input indicator	11-69, 11-99
BCI	Body-centered inertial	2-32
BEAC	Initial time offset for time-of-arrival data; its parameter name	2-72; 5-4

		Page
BETA	Parameter name for initial vehicle flight path angle β	11-59
BETAi	Parameter name for roll axis pitch attitude for i^{th} stage	11-67
BETAM	Minimum angle between moon and vehicle-to vehicle line of sight for angle visibility	2-100
BETAS	Minimum angle between sun and vehicle-to vehicle line of sight for angle visibility	2-100
BR	Parameter name for range bias associated with a vehicle receiving from another vehicle	5-5
BRD	Parameter name for linear range bias drift associated with a vehicle receiving from another vehicle	5-5
BRDD	Parameter name for the second-order range bias drift associated with a vehicle receiving from another vehicle	5-5
BT	Parameter name for the range bias associated with a vehicle transmitting to another vehicle	5-4
BTAPE	Binary observation tape generation indicator	11-93
BTD	Parameter name for the linear range bias drift associated with a vehicle transmitting to another vehicle	5-4
BTDD	Parameter name for the second-order range bias drift associated with a vehicle transmitting to another vehicle	5-5
BTIME	Last observation time	11-68, 11-98

C

CAPT	Inner pulse period for time-of-arrival data; its parameter name	2-72, 2-99, 2-119; 5-4
cc	Card column	4-3
CC3B	Parameter name for JPL two- or three-way doppler measurement bias	5-4

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CC3S	Parameter name for JPL two-or-three-way doppler measurement scale factor	5-4
CDAHT	Two-dimensional array showing drag as a function of height and temperature (Jacchia 1974 Atmosphere Model)	11-32
CDAS	Table showing drag as a function of speed ratio (Jacchia 1964 Atmosphere Model)	11-33
$C_D A/W$	Reciprocal ballistic coefficient	11-37
CDCD0	Table of angles of attack and their associated scale factors used to modify the drag value obtained from CDAHT or CDAS	11-35
CDFT	Time and coefficients for the second-order polynomial applied to drag acceleration	11-23
CEP	Circular error probability	2-107
CEPF	CEP-SEP vehicle selection flag	2-109
CHI	Parameter name for initial condition χ	11-59
Ci	Parameter name for the i^{th} coefficient of the temperature equation (Jacchia 1964 Atmosphere Model)	2-44
CKEP	Kepler equation convergence criterion	2-3
CLASS	Input station location print option	2-54, 2-89, 2-107
CMSFC	Covariance matrix scale factor indicator	2-108
CNT1	N_1, the number of cycles used with SGLS range rate measurements	2-66, 2-96, 2-114
CONSTRAINT	Data Block that contains the input for linear parameter constraints	9-1
COVQ	Data Block that contains the C(Q) matrix input	8-1
CPAW	Solar radiation pressure coefficient; its parameter name	11-21; 11-60
CRASH	ECI vehicle crash altitude	2-36
CRTK	Parameter name for tracking vehicle crosstrack bias for vehicle-to-vehicle angles	5-6

D

D1, D2	Density coefficients used in the Lockheed-Jacchia Atmosphere Model	2-11

		Page
DALPH	Correction in right ascension of Greenwich needed to transform from mean to true equinox	11-10
DATA GENERATION	Data Block that contains the input for generating simulated measurements	12-1
DAY	Day of epoch date	11-3
DAYNT	Table of day and night values (SGLS range rate measurements)	2-67
DCF	Conversion factor for distance output units (data generation runs)	2-86
DCLK	Direction cosines of roll axis for look angle generation	11-94
DCØNV	Distance conversion factor between the non-TRACE and TRACE formats	2-47
DELTA	Parameter name for vehicle geocentric latitude	11-59
DEWM	Data Block that contains the deweighting data input	7-1
DF	Input/output distance conversion factor	2-3
DGBI	Parameter name for geocentric declination measurement bias	5-3
DGREE	Input/output angle conversion factor (degrees to radians)	2-3
DIAG	Option to compute only the diagonal elements of the A^TA matrix	2-65, 2-113
DIVF	Termination indicator for diverging orbit determinations	2-57
DL	Declination of launch δ_L; its parameter name	11-66, 11-67
DNØDE	SLS best-fit ephemeris node times	11-72
DØPRF	Index of refraction for JPL two-or-three-way doppler data	2-68, 2-115
DØVER	Planetary coordinate system switchover indicator	2-35
DPBI	Parameter name for doppler measurement bias	5-4
DPDH	Table of approximate ρ' values used when the specified atmospheric routine cannot compute ρ' directly	2-20

		Page
DPH	Anomaly step size for SDEWT=1	7-5
DPi	Parameter name for ballistic coefficient $(C_DA/W)_i$ used with segmented drag; parameter name for C_DA or A for the i^{th} stage	11-60; 11-67
DRAG	Variables associated with NANSB; the reciprocal ballistic coefficient or its components; coefficients of C_DA/W when it is computed as a polynomial in time; parameter name for C_DA/W; table of vehicle drag and lift reference area coefficients	11-20; 11-39; 11-40; 11-60; 11-65
DRAGF	Theoretical C_DA/W used to compute density ratio at perigee height plus one-half scale height used with PRCDE(Q) = X or Y	11-83
DRAGi	Parameter name for the coefficient C_i used to compute the ballistic drag coefficient as a polynomial in time	11-60
DRIFT	Oscillator drift rate for time-of-arrival data; its parameter name	2-72, 2-117; 5-4
DSTØP	Stop time applied to DRAGF	11-82
DSTRT	Start time applied to DRAGF	11-82
DTAB1	Table of C_DA/W components as a function of height or time	11-42
DTAB2	Table of C_DA/W components as a function of Mach No.	11-43
DTBI	Parameter name for topocentric declination measurement bias	5-3
DTPLT	Time scale used in TPLØT	11-88
DX	Parameter name for initial vehicle velocity Cartesian coordinate $\dot{x}$	11-59
DY	Parameter name for initial vehicle velocity Cartesian coordinate $\dot{y}$	11-59
DZ	Parameter name for initial vehicle velocity Cartesian coordinate $\dot{z}$	11-59

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E

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F

F	Earth ellipticity	2-3
FBAR	The 90-day average of solar flux indices $\overline{F}_{10.7}$	11-30
fcn(h)	Function of height	11-42
fcn(t)	Function of time	2-16
FEDIT	Residual editing indicator	2-58, 2-80
FJDAT	Final Julian date for the UBET tape (Lockheed-Jacchia Atmosphere Model)	2-84
FLUX	The 10.7-cm solar radiation flux	2-11
FØM	Parameter name for cumulative doppler oscillator frequency	5-4
FØRD	Ford Refraction Model factors	2-63
FØVER	Planetary coordinate system switchover indicator	2-35
FREQ	The frequency used with the SGLS range rate data; its parameter name	2-66, 2-96, 2-114; 5-4
FTEN	Table of solar flux indices $F_{10.7}$	11-29
FTKM	Number of feet per kilometer	2-3
FTM	Parameter name for cumulative doppler transmission frequency	5-4
FTNM	Number of feet per nautical mile	2-3

G

GCRB	Parameter name for geoceiver range difference satellite frequency bias	5-4
GDCS	Crosstrack velocity component scale factor (SDEWT = 2)	7-6
GDELT	Time difference between geoceiver observations	2-71, 2-116

		Page
GDPLT	Measurement data tape generation indicator	2-88
GDRS	Radial velocity component scale factor (SDEWT = 2)	7-6
GM17	Earth gravitational constant for analytic trajectories	2-3
GM	Earth gravitational constant μ; its parameter name	2-2; 2-44
GMKM	Earth gravitational constant μ	2-2
GMLAT	Geodetic latitude of geomagnetic North pole	2-3
GMLNG	East longitude of geomagnetic North pole	2-3
GMT	Greenwich Mean Time	11-3
GPLØT	Residual printer plot or special residual plot tape variables (n and time scale)	2-54, 2-77
GPRAM	C and S parameter matrix	2-42
GSUB0	Surface gravity	2-3

H

H0	Initial integration step size	2-34
h	Satellite height	2-20
HABI	Parameter name for topocentric hour angle measurement bias	5-3
HAE	Simultaneous-vehicle visibility constraint altitude	2-90
HBIA	Parameter name for height measurement bias	5-3
HCI	Sun-centered inertial	11-9
HDTAB	Height of the earth above which DTAB1 is used	11-42
HEXP	Constants used in the Exponential Atmosphere Model (reference altitude)	2-12
HH69	1969 Hopfield Tropospheric Model humidity	2-64, 2-82, 2-95
HIGHT	Table of heights associated with CDAHT and TINF	11-32
HMAX	Maximum absolute value of the integration step size	2-34

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HMIN	Minimum absolute value of the integration step size	2-34
HMØØN	MCI vehicle crash altitude	2-36
HØMØG	Dynamic parameter selector flag	11-18
HR	Hour of epoch time	11-3
HTINF	Table showing height as a function of temperature associated with CDAHT and CDAS	11-36

I

I	Parameter name for initial vehicle inclination i	11-59
IAPR	A priori indicator for $A^T WB$	2-73
IC	Initial conditions	11-4
ICBF	Selenographic initial condition indicator	11-10
ICC	Sinultaneous-vehicle correlated measurement indicator	2-91
ICTYP	Initial condition type	11-5
IDRAG	Atmospheric density model indicator	11-22, 11-65
IDTAB	DTAB1 or DTAB2 usage indicator	11-42
IFØRM	Special option regarding time as an independent variable in integration; indicator of analytic trajectory models	11-17
INTK	Parameter name for tracking vehicle intrack bias for vehicle-to-vehicle angles	5-6
IØBSF	Input observation format indicator	2-46
IØTPF	Initial roll axis orientation alignment type	11-66
IR	Ratio of Runge-Kutta to Cowell integration steps	2-34
ISGLS	Ionospheric refraction correction constants for SGLS range rate	2-67
IT	Integration time	11-12
ITIN	Itinerary of functions	2-1
ITRP	Interpolation indicator for APTAB, KPTAB, KCTAB, and FTEN; for ACCT	11-22; 11-46

		Page
IUTC	Print time referenced to UTC indicator	11-75, 11-98
IVGMS	Vehicle dependent gravity model indicator	11-19
IVIS	Simultaneous-vehicle visibility print indicator	2-90

J

JBCI	Coordinate frame (central body) in which the orbit is initially numerically integrated	11-9
JCBDY	Central body to which the initial conditions refer	11-9
JCI	Jupiter-centered inertial	11-9
ji	Parameter name for a coefficient for the i^{th} term in the polynomial forcing function	2-44
JKP	Density modification indicator	2-11
JMAX	Maximum number of iterations for computing the JPL two- or three-way doppler measurement; maximum number of iterations used for generating SGLS data	2-68, 2-115; 2-97, 2-115
JØCC	Occultation test indicator	2-89
JRIST	Rise-set only indicator	11-92
JSGLS	Type and index of refractivity for tropospheric refraction to apply to the generated SGLS range rate measurement; type and index of refraction to apply to the range, elevation, and SLGS measurement (SLS algorithm)	2-67; 2-81
JSØRT	Data generation output sequence indicator	11-91
JSUM	Optional generated data pass summary indicator	2-86

K

KCTAB	Table of planetary range indices K_c (Cambridge Research Laboratory Atmosphere Model)	11-27
KD	Parameter name for range rate measurement scale factor	5-3

		Page
KDCS	Sigmas for crosstrack component of orbit adjust deweighting	7-4
KDP	Parameter name for doppler measurement scale factor	5-4
KDRAG	Flag signaling the type of angle of attack computation; drag and lift table indicator	11-37; 11-66
KDRS	Sigmas for radial component of orbit adjust deweighting	7-4
KDTS	Sigmas for intrack component of orbit adjust deweighting	7-4
KEDIT	Azimuth and elevation residual editing criterion for SLS	2-80
KFEZ	Parameter name for any range measurement scale factor (MULTV = 1)	5-4
KFØUR	Range rate inclusion indicator for the non-TRACE observations	2-47
KINC	Eigenvalue solution print indicator	2-52
K1j	Parameter name for the accelerometer scale factor for the j^{th} model	11-60
K2j	Parameter name for the accelerometer bias for the j^{th} model	11-60
KP	Parameter name for the P measurement scale factor	5-3
KPD	Parameter name for the P dot measurement scale factor	5-4
KPjk	Parameter names for the PKCK components	11-60
KPTAB	Table of planetary range indices K_p (LMSC 1967 Atmosphere Model)	11-25
KQ	Parameter name for the Q measurement scale factor	5-3
KQD	Parameter name for the Q dot measurement scale factor	5-4
KR	Parameter name for the range measurement scale factor	5-3

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KRANK	Rank of the eigenvector analysis solution	2-52
KSIG	List defining sigma set and data type	2-60, 2-92, 2-111
KSRR	Parameter name for SGLS range rate scale factor	5-4
KTW	Parameter name for two-way doppler measurement scale factor	5-4

L

L	Parameter name for initial condition L	11-59
LAT	Parameter name for station latitude	5-3
LATPR	Table of vehicle latitudes at which trajectory information is requested	11-80
LEMSP	Trajectory integration print option	2-36
LGA	The ΔV accelerometer model flag	11-46
LGT	Speed-of-light time correction indicator	2-59, 2-82, 2-91, 2-110
LNØRM	Normalization flag for MCI coefficients	2-7
LØNG	Parameter name for station longitude	5-3
LØNPR	Table of vehicle longitudes at which trajectory information is requested	11-80
LPACK	Timesaving flag (SLS algorithm)	2-74
LPAi	Parameter name for $C_{L_\alpha}A$ or A for the i^{th} stage	11-67
LPZi	Parameter name for $C_{L_0}A$ or A for the i^{th} stage	11-67

M

MASS	Data Block that contains the point mass input	3-1
MAXA	Order of the polynomial used in the Jacchia 1964 Atmosphere Model	2-17

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MAXIT	Number of iterations to be made in a differential correction run	2-56
MCI	Moon-centered inertial	2-32, 11-9
MDRAG	Indicator to compute $C_D A/W$ as a polynomial in time	11-40
MDWM	Multiplicative deweighting matrix	7-3
MDWT	Type of multiplicative deweighting matrix	7-3
MEAS	Data Block that contains signal processing measurement data	10-1
MEE	Mean equinox and mean equator	11-16
METE	Mean equinox and true equator	11-86
MIN	Minute of epoch time	11-3
MME	Minutes from midnight of epoch	11-23
MNTH	Month of epoch date	11-3
MODEL	Data Block that contains the model input	2-1
MPRAM	Point mass parameter matrix	2-40
MSGLS	Method indicator for SGLS range rate data	2-66, 2-99, 2-116
MSYS	Coordinate system in which the vehicle ephemerides are printed	11-85
MULTV	Simultaneous-vehicle indicator	2-45, 2-73
MVET	Best-fit ephemeris indicator (SLS)	2-78
MVMAT	The $(\partial \ddot{\underline{r}}/\partial \underline{r})$ matrix indicator	2-5

N

N	Parameter name for initial condition n	11-59
NACCT	Number of sensed accelerometer models used	11-45
NANSB	Specifier of the analytic trajectory model	11-19

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NASA	TRACE reference coordinate system option	2-37
NATAP	Output indicator (error analysis)	2-104
NAVSPASUR	U. S. Naval Space Surveillance	11-19
NCDAW	Number of entries to the DRAG vector	11-38
NCLØS	Automatic closure indicator	2-83
NCØF	Order+1 of the polynomial for local gravity variations	2-24
NCVEF	Earth-fixed variance-covariance matrices output indicator	2-108
NCVØB	Variance-covariance matrices output indicator	2-107
NDPRT	The n^{th} print time for ØPBØX(F)	2-104
NEDIT	Residual editing indicator for orbit determination runs	2-58, 2-80
NFØRM	Vector of normalization flags for spherical harmonic coefficients	2-6
NØDPR	Node print output option	2-36
NØISE	Noise data generation indicator	11-92
NØM	Designator of reference or difference orbit	11-86
NPCMP	Recomputation flag during integration	2-34
NPDØT	Period decay rate print option	2-39
NPFRP	Total number of stages (primary and secondary), including powered and free flight stages	11-63
NPKCK	Number of orbit adjusts in PKCK	11-48
NSPR	The n for the $\pm n\sigma$ residual distributions	2-56
NSTEP	Integration step output indicator	2-33
NSYS	User-specified initial conditions coordinate system flag	11-11
NTERM	Vector of numbers of terms (pairs of C and S coefficients) in the harmonic expansions	2-7
NTHST	Number of finite thrusts	11-53
NTL	Number of MCI terms (pairs of C and S coefficients)	2-8

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NWL	NWL Atmosphere Model inputs	11-28
NWTAB	Number of instantaneous vehicle weight losses	11-56
NXE	Number of values input for each orbit adjust in XKCK	11-50
NXKCK	Number of orbit adjusts in XKCK	11-50, 11-51

O

∅	Parameter name for initial right ascension of the ascending nodes Ω	11-59
OBS	Observation	15-6
OBSERVATION	Data Block that contains the observational measurements	15-1
∅MEGA	Atmospheric rotation rate ω_a; its parameter name	2-3; 2-44
∅MEGE	Earth rotation rate	2-3
∅PB∅X	A^TA input/output indicator	2-48, 2-76, 2-101
∅PRAM	Matrix that specifies model parameters other than spherical harmonic and point mass parameters	2-43
OPT	Optional	1-4
OT	Observation time	11-13

P

PAE	Vector of mean equatorial radii for solar system bodies	2-31
PANDR	Input/output option vector for orbit determination and covariance analysis	2-48, 2-75, 2-104
PATA	A^TA, $(A^TA)^{-1}$, and vehicle orbit plane covariance matrices print indicator	2-48, 2-76

		Page
PBIA	Parameter name for P measurement bias	5-3
PCA	Point of closest approach	11-84
PCRAS	Vector of crash altitudes for solar system bodies	2-32
PDBI	Parameter name of P dot measurement bias	5-4
PDIFF	Parameter perturbation used for variational equation verification	11-90
PEPH	Ephemerides print suppression indicator	2-109
PERI	Period for Vehicle i when SDEWT = 1	7-6
PEXP	Constant used in Exponential Atmosphere Model (reference density)	2-12
PFRP	Powered flight staging variables indicator	11-63
PH0	Powered flight initial step size	2-39
PH69	1969 Hopfield Tropospheric Model pressure	2-64, 2-82, 2-95
PHASE	Coordinate system (ECI, MCI, or BCI) indicator for vehicle trajectory integration	11-17
PHMIN	Powered flight minimum step size	2-39
PI	The quantity π	2-3
PITCH	Vehicle pitch angle for aspect angle generation	11-95
PKCK	Array for instantaneous orbit adjusts	11-49
PLANT	Planetary ephemeris indicators and conversion factors	2-27
PLNØP	Planetary ephemeris print options	11-84
PØBS	Punch indicator for non-TRACE observation data	2-47
PØLY0	The quantities r_0 and λ_0 for the local gravity field (or how to compute them)	2-23
PØLY	Matrix for computing coefficients of force due to local variations	2-23, 2-24
PØMEG	Vector of solar system body rotation rates	2-30
PØWER	Powered flight trajectory generation indicator	11-63

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PRCDE	Special ephemeris generation output options	11-76
PRCØV	Variance-covariance matrix print option	2-104
PRESD	Sigmas for pre-update deweighting of drag or solar radiation pressure parameters	7-4
PRHØ	Atmospheric density print option	2-10
PRIØR	Maximum a priori RMS for SLS	2-79
PSGLS	Partials computation flag for SGLS measurements	2-68, 2-114
PSI	Parameter name for initial condition ψ	11-59
PSTSD	Sigmas for post-update deweighting of drag or solar radiation pressure parameters	7-4
PTAPE	Special earth-fixed tape generation indicator	2-84
PTIM	Print time vector	11-74, 11-97
PTNS	Trajectory equations print option	2-39
PUNMS	Updated point mass and state vector punch indicator; updated state vector punch indicator	2-53; 2-76
PWAND	Pole-wander coordinates	11-14
PZERØ	Vector of P-parameter corrections associated with IAPR	2-73

Q

QBIA	Parameter name for Q measurement bias	5-3
QDBI	Parameter name for Q dot measurement bias	5-4

R

R	Parameter name for initial vehicle geocentric radius R	11-59
r	Magnitude of the geocentric position vector at time t	2-5
$\underline{r}$	Position vector at time t	2-5

		Page
$\dot{\underline{r}}$	Velocity vector at time t	11-51
$\ddot{\underline{r}}$	Acceleration due to thrusting	11-51
RADL	Parametric name for tracking vehicle radial bias for vehicle-to-vehicle angles	5-6
RANGE	Table of ranges to search for during visibility	2-87
RAREF	Refraction index used with range measurement data	2-63, 2-94
RBIA	Parameter name for range bias	5-3
RBD	Parameter name for linear range bias drift for a station (MULTV $\neq$ 0)	5-4
RBDD	Parameter name for the second-order range bias drift for a station (MULTV $\neq$ 0)	5-4
RCØN	Relative convergence criterion for orbit determination	2-56
RDBI	Parameter name for range rate measurement bias	5-3
RDMAX	Maximum line-of-sight rate for vehicle-to-vehicle angle visibility	2-100
RDMIN	Minimum line-of-sight rate for vehicle-to-vehicle angle visibility	2-100
RE	Effective earth radius	2-21
REFR	Refraction index used with elevation data	2-63, 2-94
REJECT	Data Block that contains the observational measurement rejection input	13-1
REV	Initial revolution count	11-83
RFNWL	Tropospheric refraction correction variables	2-64, 2-70, 2-82, 2-95
RFSF	Parameter name for refraction scale factor for SGLS range rate and Tranet doppler	5-5
RGBI	Parameter name for geocentric right ascension measurement bias	5-3
RHØ	Scale factor for eigenvalue analysis	2-52

		Page
RJDAT	Reference Julian date in the inertial frame in which the equations of motion are solved	2-37
RM	Effective lunar radius (eclipsing calculations)	2-84
R2MU	Criteria for point mass acceleration	2-5
RND	Rounding indicator for the seconds field of the input observation time	2-46
RØLL	Vehicle roll angle for aspect angle generation	11-95
RRATE	Table of range rates to search for during visibility	2-88
RRSF	Parameter name for range measurement refraction scale factor (MULTV = 0)	5-5
RS	Effective solar radius	2-21
RSPLT	Visibility printer plot time scale	2-85
RTBI	Parameter name for topocentric right ascension measurement bias	5-3
RTC	Radial, intrack, crosstrack	

S

S	State vector $(x, y, z, \dot{x}, \dot{y}, \dot{z})$	11-90
SCI	Saturn-centered inertial	11-9
SDCG	Sigmas for crosstrack velocity perturbation when SDEWT = 1	7-6
SDEWT	Type of dynamically computed geopotential additive deweighting factor	7-5
SDRG	Sigmas for radial velocity perturbation when SDEWT = 1	7-5
SEC	Second of epoch time	11-3
SENSOR	Data Block that contains the sensor parameter input	5-1
SEP	Spherical error probability	2-107
SEPS	Convergence criterion ϵ used when SGLS range rate data is generated	2-97, 2-115
SFDBD	Scale factor for decreasing parameter bounds after a diverging iteration	2-57

		Page
SFIBD	Scale factor for increasing parameter bounds after a converging solution	2-57
SFREQ	Satellite frequency for geoceiver range difference data	2-71, 2-98, 2-116
SGLS	Space-ground link subsystem	2-62
SGM	Selenographic gravitational constant	2-4
SGP	Simplified general perturbations	11-19
SG2R	The quantity σ_R^2 associated with range for the computation of intrack time bias error	2-52
SG2RD	The quantity $\sigma_{\dot{R}}^2$ associated with the SGLS range rate for the computation of intrack time bias error	2-52
SIGMA	Observational measurement weights or standard deviations	2-60, 2-92, 2-111
SLS	Sequential least squares	2-45
SLT	Speed of light	2-3
SMALL	Auroral bulge conditions	2-13, 2-19
SMIN	Termination criterion for SLS	2-79
SØRD	Exponent in the transformation equation for the regularized time variable	11-18
SOS	Sum of squares	2-56
SRCB	Parameter name for station (C-band) receiver range bias	5-5
SRLB	Parameter name for station (L-band) receiver range bias	5-5
SRRB	Parameter name for SGLS range rate bias	5-4
SSCL	Scale factor applied to geoceiver or CCID sigmas input on OBSERVATION cards	2-72, 2-117
SSPR	Residual output option	2-55, 2-77
SSTEP	Number of integration steps per revolution when the regularized time variable IFØRM is used	11-18

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U

U	Parameter name for initial argument of perigee ω	11-59
UBET	Requestor of BLAMEX tape interface	2-84
UBIA	Parameter name for argument of latitude measurement bias	5-3
UT1	Universal time	11-12
UTC	Broadcast time	11-13
UTD	Integration time/ephemeris time conversion factor	2-38 11-12

V

V	Parameter name for initial vehicle velocity V	11-59
VALT	Simultaneous-vehicle visibility constraint altitude	2-90
VAMP	Parameter name for amplitude of sinusoidal range bias for station-to-vehicle range leg	5-6
VBIA	Parameter name for crossplane measurement bias	5-3
VCI	Venus-centered inertial	11-9
VCØNV	Velocity conversion factor between the non-TRACE and TRACE formats	2-47
VEHICLE	Data Block that contains the vehicle input	11-1
VEHID	Vehicle identification number	11-2
VF	Input/output velocity conversion factor	2-4
VFAS	Parameter name for phase angle of sinusoidal range bias for station-to-vehicle range leg	5-6
VLIM	Altitude and temperature extremes indicator (Jacchia 1964 Atmosphere Model)	2-15
VMIN	Control for double-group integration	2-38
VPER	Parameter name for frequency of sinusoidal range bias for station-to-vehicle range leg	5-6

		Page
VPRAM	Vehicle parameter-matrix	11-59
VRCB	Parameter name for vehicle (C-band) receiver range bias	5-5
VSB	Parameter name for range bias associated with a vehicle receiving from a station	5-5
VSBD	Parameter name for linear range bias drift associated with a vehicle receiving from a station	5-5
VSDD	Parameter name for the second-order range bias drift associated with a vehicle receiving from a station	5-5
VTBI	Parameter name for vehicle transponder bias	5-5
VTCB	Parameter name for vehicle (C-band) transmitter range bias	5-5
VTLB	Parameter name for vehicle (L-band) transmitter range bias	5-5

W

WDØT	Rate of vehicle weight decay	11-58
WJN	Input for the Walker analytic form of the Jacchia 1964 Atmosphere Model	2-19
WLSDT	Intrack time bias error flag	2-53
WMIN	Minimum vehicle weight for weight loss	11-55
WMØD	Atmospheric model form indicator (Jacchia 1964 Atmospher Model)	2-15
WPi	Parameter name for ω_p or k_p for the i^{th} stage	11-67
WRi	Parameter name for ω_r or k_r for the i^{th} stage	11-67
WTAB	Times and corresponding weight changes; flow rate and minimum weight for the i^{th} thrust	11-56; 11-57
WTIMF	Time at which the linear weight loss is to be terminated	11-57
WTIMI	Time at which the linear weight loss is to be initialized	11-57

		Page
WWVET	Polynomial coefficients relating atomic time to broadcast time	11-13
WYi	Parameter name for ω_y or k_y for the i^{th} stage	11-67
WZERØ	Initial vehicle weight for weight loss	11-55

X

X	Parameter name for initial vehicle position Cartesian coordinate x	11-59
XBIA	Parameter name for $\hat{x}$ measurement bias	5-3
XKCK	Array for instantaneous orbit adjusts	11-50, 11-51
XLØC	Parameter name for $\hat{x}$ location of stations	5-3

Y

Y	Parameter name for initial vehicle position Cartesian coordinate y	11-59
YAW	Vehicle yaw angle for aspect angle generation	11-95
YBIA	Parameter name for $\hat{y}$ measurement bias	5-3
YEAR } YR }	Year of epoch date	11-3
YLØC	Parameter name for $\hat{y}$ location of station	5-3

Z

Z	Parameter name for initial vehicle position Cartesian coordinate z	11-59
ZBIA	Parameter name for $\hat{z}$ measurement bias	5-3
ZLØC	Parameter name for $\hat{z}$ location of station	5-3

GREEK LETTERS

ρ	Density	2-20
ρ'	The quantity $(\partial \rho/\partial h)(h/\rho)$	2-20

1. INTRODUCTION

FIGURES

TABLES

1. INTRODUCTION

1.1 PURPOSE, SCOPE, AND LIMITATIONS

TRACE is The Aerospace Corporation's trajectory analysis and orbit determination program; its applications encompass a wide range of problems in orbital mechanics. TRACE is a general-purpose orbital analysis program used to assist corporate personnel in the analysis of tracking operations and orbital motion of artificial satellites about the earth, moon, and other bodies within the solar system. This volume is one in a series of documents describing the program and its uses. In it are defined all input data required to perform any of the TRACE functions (Fig. 1-1) associated with the following major areas of application:

- Orbit determination and estimation of orbital, model, and sensor parameters
- Vehicle ephemeris generation
- Simulated measurement data generation
- Orbital statistics via covariance analysis

Each input item is defined, and all basic data deck structures necessary to execute TRACE are described. This document describes the use of the production version of the program (Version 7.27, 2 November 1973). TRACE is currently used on the following computer systems:

- CDC 3600/3800, 6000, and 7000 series
- IBM 360 and 370 series

Additions and improvements are constantly being made; they will be described on replacement pages obtainable from the Vehicle Analysis Programming Department or from Aerospace Reports Control.

1.2 INPUT DATA DECK PHILOSOPHY

Any data deck input to TRACE is partitioned into an ordered set of data blocks. Each data block is identified by a name punched on a separate

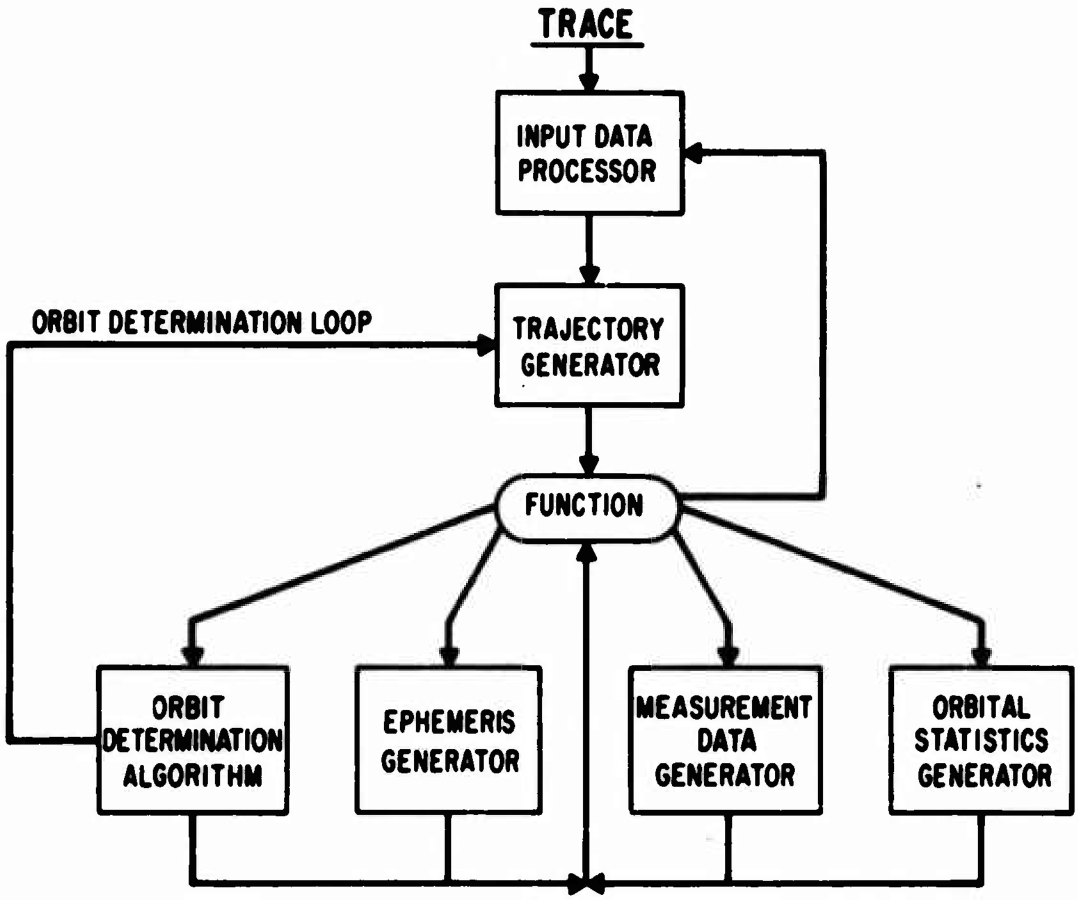

Fig. 1-1. Schematic of Major Functions

card, beginning in Column 1. The following names are possible:

- MØDEL
- MASS
- STATIØN
- SENSØR
- ATA
- DEWM
- CØVQ
- CØNSTRAINT
- MEAS
- VEHICLE
- DATA GENERATIØN
- REJECT
- STAGE
- ØBSERVATIØN

Within any input data deck, the relative order of the data blocks is important; their arrangement must follow the order shown above and in Fig. 1-2. The structure of a particular input data deck depends on the function(s) to be performed. Data blocks required for each function are shown in Table 1-1. Although some data blocks are not used for a particular function, their presence will not cause a run to fail. The user may, for example, leave the STATION and SENSOR data blocks in the deck for an ephemeris generation run after an orbit determination run.

1.3 DATA BLOCK DESCRIPTIONS

Each data block consists of a set of data input cards followed by an "END" card (punched on a separate card, beginning in Column 1). These cards are in one of the following formats:

- GAIL1, which is a general-purpose input routine (Appendix A). The GAIL1 format is used for MODEL, ATA, DEWM, COVQ, and VEHICLE input data.

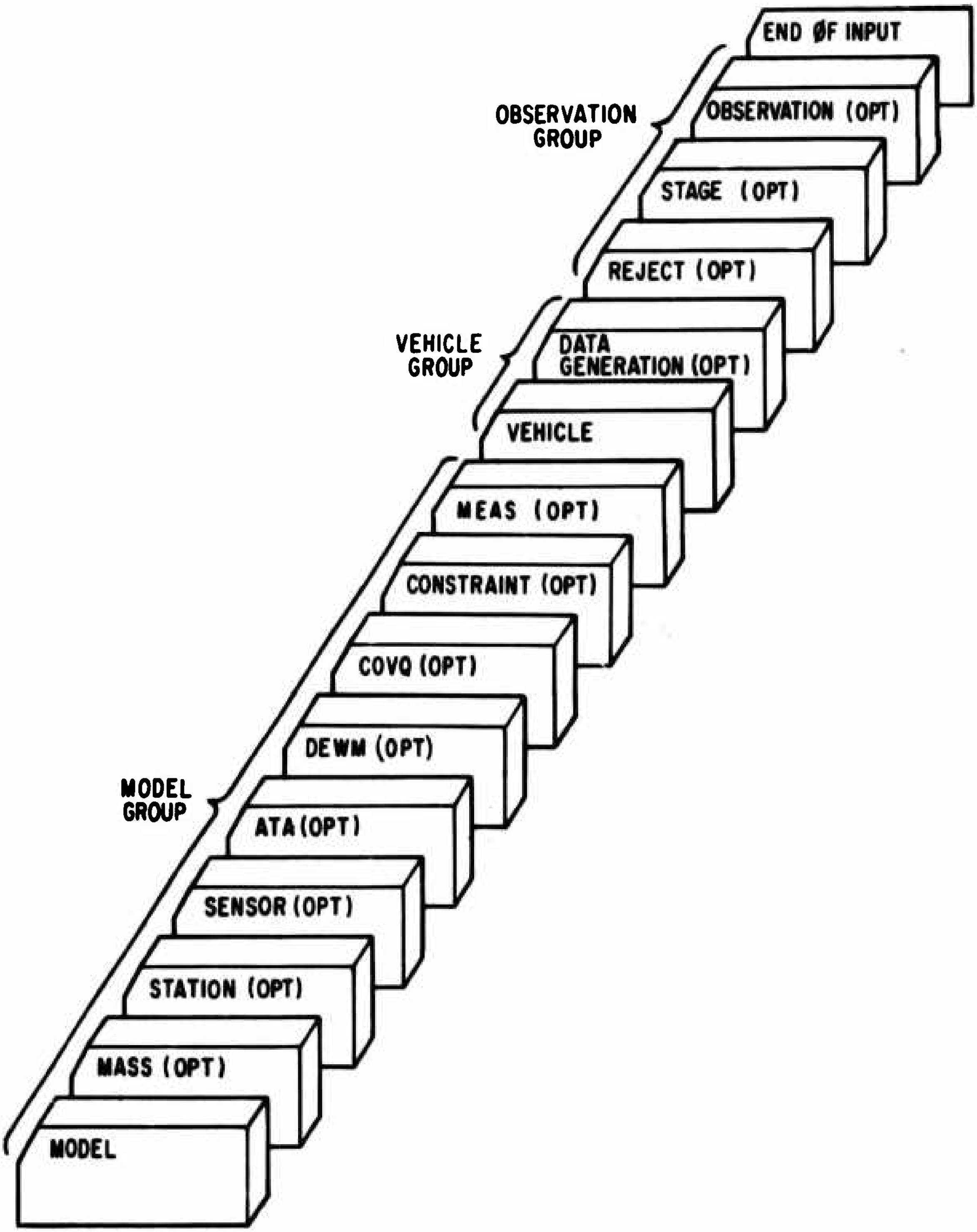

Fig. 1-2. Relative Order of Data Blocks

Table 1-1. Data Blocks Required, by Function

Data Block Name	Function			
	Orbit Determination ITIN = 2	Ephemeris Generation ITIN = 3	Data Generation ITIN = 4	Covariance Analysis ITIN = 5
MØDEL	Required	Required	Required	Required
MASS	Optional	Optional	Optional	Optional
STATIØN	Required	Not used	Required	Optional
SENSØR	Optional	Not used	Optional	Optional
ATA	Optional	Not used	Not used	Optional
DEWM	Optional	Not used	Not used	Optional
CØVQ	Not used	Not used	Not used	Optional
CØNSTRAINT	Optional	Not used	Not used	Not used
MEAS	Optional	Not used	Optional	Optional
VEHICLE	Required	Required	Required	Required
DATA GENERATIØN	Not used	Not used	Required	Optional
REJECT	Optional	Optional	Not used	Optional
STAGE	Optional	Not used	Not used	Optional
ØBSERVATIØN	Required	Optional	Not used	Optional

- A format unique to the particular input data set. Unique formats are used for MASS, STATION, SENSOR, CONSTRAINT, MEAS, DATA GENERATION, REJECT, STAGE, and OBSERVATION input data.

In the following subsections, the basic contents of the input set associated with each particular data block is indicated.

1.3.1 MODEL Input

MODEL input (Sec. 2) consists of:

- Function indicator
- Simultaneous-vehicle inputs
- Physical constants
- Force model coefficients and constants
- Planetary ephemeris constants
- Numerical integration constants and indicators
- Model parameter specifications
- Model data peculiar to orbit determination runs
- Model data peculiar to ephemeris generation runs
- Model data peculiar to measurement data generation runs
- Model data peculiar to covariance analysis runs

1.3.2 MASS Input

MASS input (Sec. 3) specifies the data necessary to define the point mass acceleration model used in the equations of motion.

1.3.3 STATION Input

STATION input (Sec. 4) specifies the data associated with the tracking stations used in orbit determination, data generation, or covariance analysis runs (e.g., station names, locations, and other items related to refraction models and measurement sigmas).

1.3.4 SENSOR Parameter Input

SENSOR input (Sec. 5) specifies station location, measurement bias, and measurement scale factor parameters.

1.3.5 ATA Input

ATA input (Sec. 6) provides the option of specifying the P-parameter portion of an initial (a priori) A^TA matrix for orbit determination or covariance analysis runs.

1.3.6 DEWM Input

DEWM input (Sec. 7) provides the option of specifying an additive and/or multiplicative deweighting of the covariance matrix used in an SLS (sequential least squares) run at prespecified update times.

1.3.7 COVQ Input

COVQ input (Sec. 8) provides the option of specifying a Q-parameter a priori covariance matrix $C(Q)_o$ for covariance analysis runs.

1.3.8 CONSTRAINT Input

CONSTRAINT input (Sec. 9) specifies the linear parameter constraints used in the orbit determination algorithm.

1.3.9 MEAS Input

MEAS input provides a method of symbolically defining measurements that consist of sums and differences of ranges between stations and vehicles.

1.3.10 VEHICLE Input

VEHICLE input (Sec. 11) consists of:

- Epoch date and time of day
- Initial state conditions
- Coordinate and timekeeping system specifications
- Ballistic coefficient
- Atmospheric model specifications
- Orbit adjust data
- Finite thrusting data
- Accelerometer model data
- Weight losses
- Solar radiation pressure coefficient
- Vehicle parameter specifications

- Specifications peculiar to powered flight
- Vehicle data peculiar to orbit determination runs
- Vehicle data peculiar to ephemeris generation runs
- Vehicle data peculiar to data generation runs
- Vehicle data peculiar to covariance analysis runs

This data block must be provided for each vehicle considered in a given run. If the run involves more than one vehicle, each corresponding VEHICLE data block input is followed by an END card.

1.3.11 DATA GENERATION Input

DATA GENERATION input (Sec. 12) specifies the information required to generate simulated tracking data for each station (e.g., data rate, visibility restrictions, start and stop times, and measurement types).

1.3.12 REJECT Input

REJECT input (Sec. 13) specifies the observational measurement editing information associated with orbit determination or covariance analysis runs.

1.3.13 STAGE Input

STAGE input (Sec. 14) provides the option of separating the observational data into a sequence of batches (or stages) when the measurement data is being processed by the SLS algorithm. Update times and specifications relating to the type of deweighting to apply in SLS runs are also included in the STAGE input.

1.3.14 OBSERVATION Input

OBSERVATION input (Sec. 15) specifies station, observation time, measurement type(s), and the actual measurements. These data are used (as a whole or in part) in orbit determination, ephemeris generation, or covariance analysis runs.

1.3.15 File Usage

The primary files used by the TRACE Program are defined in Sec. 16. A detailed format is given for each major input/output file.

1.4 USAGE OVERVIEW

The order of the sections in this document corresponds to the relative order of the data blocks required to perform a given function. Wherever appropriate, each section is divided into subsections that define the data inputs common to the following:

- All TRACE functions
- Orbit determination runs
- Ephemeris generation runs
- Measurement data generation runs
- Covariance analysis runs

The TRACE user can thus select the necessary inputs for each required data block, according to the function(s) to be performed.

1.4.1 Important Usage Concepts

Effective use of the TRACE program requires an understanding of a few of its major concepts and a few important terms. When the program's ability to execute several functions automatically from the same data base is exploited, extensive and coherent analyses become routine. This is discussed in Sec. 1.4.1.1.

It must be understood that input data are logically separated into three groups (Fig. 1-2) of data blocks:

- Model group
  - MODEL
  - MASS
  - STATION
  - SENSOR
  - ATA
  - DEWM
  - COVQ
  - CONSTRAINT
  - MEAS

- Vehicle group
  - VEHICLE
  - DATA GENERATION
- Observation group
  - REJECT
  - STAGE
  - OBSERVATION

As further defined (Sec. 1.4.1.1), a case consists of one set of appropriate input blocks from the model group plus a set of appropriate blocks from the vehicle and observation groups for each space vehicle involved. The primary distinction among the three data block groups is that the model group data apply to all vehicles of the case, but the vehicle and observation group inputs apply mainly to one space vehicle (some interactions are described in subsequent sections).

1.4.1.1 Multiple Function Sequences

In a typical simple case, the program reads all input blocks, generates the trajectory (vehicle ephemeris) file, and then processes it for the desired output. This may be a printed ephemeris, simulated tracking data, or a covariance analysis.

Much more complicated cases, or a series of cases, can also be executed. The trajectory file may simply be an integration from given inital values, or it may be the result of a trajectory reconstruction from observational measurement data; in fact, both kinds of trajectory generations may appear in a single case. Several processing functions may be executed with each case. Finally, cases may be stacked indefinitely within a single job on the computer.

This basic sequence of operations is controlled by the MODEL input item ITIN. Its digits order the performance of the (briefly described) functions for a single case (Table 1-2).

Table 1-2. ITIN Functions for a Single Case

ITIN Value	Function or Itinerary
2	Reconstruct a trajectory from observational measurement data (i.e., perform an orbit determination)
3	Print vehicle ephemeris information
4	Generate visibility information and simulated tracking data
5	Perform a covariance analysis

A case is defined as all compuations specified by ITIN. The input for a case starts with MØDEL and ends with END ØF INPUT. When stacking cases, remember that no values are saved from case to case; all inputs must be provided for each case.

The following examples illustrate the power (and limitations) of multiple-function ITIN sequences:

- Example A: ITIN=323
  - A trajectory is generated from input initial conditions, and a printed trajectory is obtained. Another trajectory is then reconstructed from observational data, and a comparable trajectory is printed. This combination might be used to generate both the nominal and actual ground tracks for a satellite or missile. The VEHICLE data specifies the nominal initial conditions for the trajectory, the amount of printed output, and the parameters to be differentially corrected in the reconstruction. An example of the deck setup for this case is shown in Appendix B (Sec. B.5.3).
  - Note that this ITIN sequence cannot be used to generate the ground tracks of two different space vehicles. Only one set of VEHICLE data is input, and it must contain

the nominal initial conditions for the (one) space vehicle. These initial conditions also serve as initial values for the trajectory reconstruction. Differences between the nominal and actual trajectories cannot be plotted within one case because there is no way to identify one trajectory as a reference and the other as a variation when only one set of VEHICLE data is input. However, these differences can be plotted by stacking cases. With ITIN=3, followed by ITIN=23, the trajectory file for the first case can be identified as the reference and that for the second as the variation.

- The program cannot both predict and backtrack a trajectory within one case because changes in both MODEL and VEHICLE data are required. Again, the desired result can be obtained by using stacked cases with identical initial conditions. However, not even with stacked cases can a trajectory be both reconstructed and backtracked in one job, for there is no way to carry over the differentially corrected initial conditions from one case to another.

- Example B: ITIN=3452345
  - This long but reasonable sequence is intelligible to the program; the first three digits (3, 4, and 5) cause the generation of a nominal trajectory, look angles, and a covariance analysis, respectively. Starting from the nominal initial values, an orbit determination (using actual data) takes place. When the iterative process terminates, the trajectory corresponding to the converged solution is used to repeat the three processing functions. See Appendix B (Sec. B.5.2) for an example of this deck setup.

- Example C: ITIN=23
  - To determine the parameters for five orbital arcs from multiple-arc tracking data and to generate the resulting ephemerides, the function indicator ITIN could be expressed as ITIN=23. This sequence of function code numbers causes TRACE to iterate with the differential correction procedure until a minimum RMS solution to the multiple-arc fit is obtained (or until a prespecified number of iterations is reached). Then, the ephemeris generator will produce the printed ephemerides from the final trajectories used by the orbit determination function.

- Example D: ITIN=3234
  - The function indicator ITIN=3234 causes TRACE to generate a nominal ephemeris file and output, using a set of orbital initial conditions, and to differentially correct the sensor and orbital parameters, using a specified set of tracking data. The program would then generate ephemeris information, using the determined orbital conditions, and produce simulated tracking data with rise/set information, using the derived orbital and sensor parameter values.

1.4.1.2 Single-Vehicle Mode

In its most elementary mode, TRACE generates or processes data from a single space vehicle. The input deck contains the appropriate data blocks from the model group and, at most, one of each of the data blocks from the vehicle group (VEHICLE and DATA GENERATION) and the observation group (REJECT, STAGE, and OBSERVATION) for each case. The observational measurement data pertain only to the space vehicle and its relationship to the tracking stations or to the earth itself.

1.4.1.3 Multiple-Arc Mode

In the simple multiple-arc mode, TRACE can generate or process data from several space vehicles, but each item of data is associated with only one vehicle. In this mode, the vehicles are independent and need not be in orbit simultaneously. The data may actually be associated with only one vehicle, yet be processed separately in different arcs.

In this mode, a proper solution for a sensor or model parameter (e.g., a station location or a gravitational anomaly) can be derived from the data obtained from several vehicles during different time periods. Normally, a reconstruction in this mode has common parameters, either naturally or as the result of an imposed constraint; otherwise, the reconstructions could be done separately.

The multiple-arc mode is simply an extension of the single-vehicle mode and requires no special identification. The deck consists of the appropriate data blocks from the model group, followed by n sets (n equals the number of arcs) of vehicle group data (VEHICLE and DATA GENERATION) and n sets of observation group data (REJECT, STAGE, and OBSERVATION). The last card is an END ØF INPUT card (see the deck structure diagrams in Appendix B). Note that in this mode all vehicles are assumed to be independent. Therefore, complete sets of data blocks from both the vehicle and observation groups should be provided for each vehicle. As a matter of input convenience only, input data in the VEHICLE block not overridden will carry over from one vehicle to the next.

1.4.1.4 Simultaneous-Vehicle Mode

When data concern the positions or velocities of two or more space vehicles orbiting simultaneously, the program is run in its simultaneous-vehicle mode. The input deck must then include consecutive VEHICLE blocks for the various vehicles. The observations are merged and read in one OBSERVATION block after the last VEHICLE block. Since DATA GENERATION cards must identify all vehicles involved in the data, their format is different from that used in the single-vehicle or multiple-arc modes. These changes in program operation require that a flag be set to identify this mode (input item MULTV in the MODEL data block).

1.4.2 Auxiliary Information

To assist the TRACE user, appendices containing discussion and clarification of many program details are included in this document (Part B). A comprehensive description of the general-purpose input processor GAIL1 is given in Appendix A. Examples of typical data deck structures are presented in Appendix B. Sample TRACE outputs are described in Appendix C. Sample input load sheets and engineering specification forms useful in expediting the preparation of TRACE input data cards are described in Appendix D.

1.5 DOCUMENTATION SERIES

The TRACE documentation series is summarized as follows:

Volume I: General Program Objectives, Description, and Summary is directed towards the potential user or nonuser interested in obtaining an overview of TRACE capabilities.

Volume II: Coordinate and Timekeeping Systems with Associated Transformations (Ref. 1) is a technical reference for the coordinate and timekeeping systems and related transformations used within TRACE.

Volume III: Trajectory Generation Equations and Methods (Ref. 2) serves as a technical reference for the trajectory generation function of TRACE.

Volume IV: Measurement Data Generation and Observational Measurement Partials (Ref. 3) is a technical reference for the measurement data generation function and associated observational measurement partial derivatives in TRACE.

Volume V: Differential Correction Procedures and Techniques serves as a technical reference for the batch differential correction procedure and associated techniques used with TRACE.

Volume VI: Orbital Statistics via Covariance Analysis is a technical reference for the orbital statistics generation or covariance analysis function of TRACE.

Volume VII: Usage Guide serves as a reference defining all input data required to perform any of the TRACE functions. Each input item is defined, and all basic data deck structures necessary to execute TRACE are described. Note that constant changes and improvements are being made to the program. This volume is published in two parts.

Volume IX: Detailed Program Structure describes the program structure to the subroutine level.

Volume X: Lunar Gravity Analysis serves as a technical reference for the Lunar Gravity Field Analyzer of TRACE.

Volume XI: LGA Data Processor serves as a technical reference for the LGA data processing function of TRACE.

Volume XII: Sequential Least Squares Procedures and Techniques (Ref. 4) is a technical reference for the sequential least squares (SLS) procedures and associated techniques used within TRACE to perform orbit determination.

2. MODEL INPUT

TABLES

2. MODEL INPUT

In this section, all MODEL inputs are defined, and the following categories are discussed:

- Function indicator (ITIN)
- Physical constants
- Force model coefficients and constants
- Planetary ephemeris constants
- Numerical integration constants and indicators
- Model parameter specifications
- Simultaneous-vehicle indicators
- Model data peculiar to orbit determination runs
- Model data peculiar to ephemeris generation runs
- Model data peculiar to measurement data generation runs
- Model data peculiar to covariance analysis runs

2.1 DATA COMMON TO ALL TRACE FUNCTIONS

The values in the following example are not built into TRACE (preset to zero):

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
D	ITIN	34

ITIN — Selects the functions to be performed according to the code numbers (2, 3, 4, or 5), which correspond to differential correction, ephemeris generation, data generation, or covariance analysis, respectively. Multiple functions are requested on the same case by simply sequencing the code numbers of the desired functions in the ITIN list.

After completion of the function(s) selected in ITIN, TRACE resets all standard values and options and prepares to run another case if input has been supplied. Nothing is retained between cases; all data must be reinput.

2.1.1 Physical Constants

The following physical constants used in TRACE are preset to the values shown, but they may be changed by input:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	GM	.55303935E-2
	GMKM	0.
	GM17	.5530417744E-2
	ØMEGE	.43752691E-2
	ØMEGA	.43752691E-2
	F	.3352329869E-2
	SLT	2820.1763
	CKEP	1.E-11
	DGREE	57.295779513082
	PI	3.1415926535898
	GSUB0	32.174
	GMLAT	78.3
	GMLNG	291.

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	AE	1.
	ERFT	20925738.
	ERNM	3443.9336
	ERKM	6378.1649
	FTNM	6076.1155
	FTKM	3280.8399
	DF	20925738.
	VF	348762.3
	AF	5812.705
	SGM	.68023265E-4
	AM	.272506277

GM — Earth gravitational constant, er^3/min^2.

GMKM — Earth gravitational constant, km^3/sec^2:

- = 0 — GM is used.
- ≠ 0 — GMKM is converted to er^3/min^2 and stored in GM, replacing any other value.

GM17	Earth gravitational constant for analytic trajectories, er^3/min^2 (Sec. 11.1.6).
OMEGE	Earth rotation rate, rad/min.
OMEGA	Atmospheric rotation rate, rad/min.
F	Earth ellipticity.
SLT	Speed of light, er/min.
CKEP	Kepler equation convergence criterion; used if classical elements are input for initial conditions.
DGREE	Angle conversion factor, deg/rad.
PI	The quantity π.
GSUB0	Surface gravity, ft/sec^2.
GMLAT	Geodetic latitude of the geomagnetic North pole, deg.
GMLNG	East longitude of the geomagnetic North pole, deg.
AE	Mean equatorial earth radius, er.
ERFT	± Mean equatorial earth radius, ft.
ERNM	± Mean equatorial earth radius, nmi.
ERKM	± Mean equatorial earth radius, km.
FTNM	Number of feet per nautical mile.
FTKM	Number of feet per kilometer.
DF	Input/output distance conversion factor used to convert from external to internal or from internal to external units (e.g., from ft to er or from er to ft).

VF — Input/output velocity conversion factor used to convert from external to internal or from internal to external units (e.g., from ft/sec to er/min or from er/min to ft/sec).

AF — Input/output acceleration conversion factor used to convert from external to internal or from internal to external units (e.g., from ft/sec^2 to er/min^2 or from er/min^2 to ft/sec^2).

SGM — Selenographic gravitational constant, er^3/min^2.

AM — Mean equatorial lunar radius, er.

Since all TRACE computations are made in rad, er, er/min, or er/min^2; the values not input in these units are divided by DGREE, DF, VF, or AF, respectively. If any one earth radius (ERKM, ERFT, or ERNM) is input negative, all three are recomputed and internally reset, using the absolute value of the input radius. DF, VF, and AF are also recomputed, assuming external units of ft, ft/sec, and ft/sec^2.

2.1.2 Force Models

The following subsections define the inputs for the force models used to evaluate the equations of motion.

2.1.2.1 Point Mass Model

When point mass accelerations are used (Sec. 3), it is necessary to provide values for R2MU and MVMAT. These values are preset as shown:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	R2MU	1.E+10
	2	1.E-6
	MVMAT	0

R2MU Criteria for point mass acceleration:

(1) Distance criterion, km (>0).

(2) Ratio criterion in relative masses such that if

$$\frac{\mu_i}{|r - r_{0_i}|^2} \geq \frac{[R2MU(2)]}{[R2MU(1)^2]}$$

the i^{th} point mass is used (i = 1, . . . , 20).

MVMAT The $(\partial \ddot{\underline{r}}_0 / \partial \underline{r})$ matrix indicator:

= 0 This matrix is not included in the variational equations.

≠ 0 This matrix is included.

2.1.2.2 Central Body Gravity Model

In TRACE, the central body's gravitational potential is represented by a spherical harmonic expansion with C and S coefficients. The values shown in the following example are not built into TRACE (if no input is provided in the MODEL data, spherical bodies are used). This example contains one spherical harmonic term for the earth and one for the moon:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	NFØRM	1
I	LNØRM	1
I	NTERM	1
I	NTL	1
M	TERMS	04,350
D	01.01	02.00
	03.01	-1082.3E-6
	04,01	0.
D	01.02	02.00
	03.02	-.2E-3
	04.02	0.

NFØRM — Vector of normalization flags for the spherical harmonic expansion coefficients. Normally, NFØRM(i) is the normalization flag for the i^{th} sola·· system body. When integration is exclusively in the ECI mode and IVGMS is nonzero, NFØRM(i) is the flag for the vehicle-dependent gravity model indicated by IVGMS = i, where $1 \le i \le 7$ (Sec. 11.1.6):

LNØRM or	(1) Earth or first model flag		±1 = No normalization
	(2) Sun or second model flag		±2 = APL normalization
	(3) Moon or third model flag		±3 = Kaula normalization
	(4) Venus or fourth model flag		
	(5) Mars or fifth model flag		
	(6) Jupiter or sixth model flag		
	(7) Saturn or seventh model flag		

Positive values of NFØRM cause the terms to be sequenced in the order necessary for the program and then printed. Negative values cause all terms to be printed before they are sequenced.

NTERM Vector of numbers of terms (pairs of coefficients) in the spherical harmonic expansions. Normally, NTERM(i) is the number of terms for the i^{th} solar system body. When integration is exclusively in the ECI mode and IVGMS is nonzero, NTERM(i) is the number of terms in the vehicle-dependent gravity model selected by IVGMS = i, where $1 \le i \le 7$ (Sec. 11.1.6). The sum of NTERM(1) through NTERM(7) must not exceed 350:

	(1)	Number of terms for the earth or first gravity model.
	(2)	Number of terms for the sun or the second model.
NTL or	(3)	Number of terms for the moon or the third model.
	(4)	Number of terms for Venus or the fourth model.
	(5)	Number of terms for Mars or the fifth model.
	(6)	Number of terms for Jupiter or the sixth model.
	(7)	Number of terms for Saturn or the seventh model.

TERMS — A 4 × 350 matrix containing in each column the degree n, the order m, and the C_{nm} and S_{nn} coefficients for each term. The inputs for the ECI (or first gravity model) coefficients must be in the first NTERM(1) columns of the matrix; the HCI (or second gravity model) coefficients are in the next NTERM(2) columns starting at the NTERM(1)+1 column and ending at the NTERM(1)+NTERM(2) column; etc. The total number of terms entered in TERMS must not exceed 350.

For analytic trajectory generation (Sec. 11.1.6), it is possible to input the earth's zonal harmonic coefficients J_2, J_3, and J_4, which are preset as shown:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	EJ2	1.082549E-3
	EJ3	-2.435E-6
	EJ4	-1.232E-6

EJ2 The earth's zonal harmonic coefficient J_2.

EJ3 The earth's zonal harmonic coefficient J_3.

EJ4 The earth's zonal harmonic coefficient J_4.

2.1.2.3 Planetary Gravity Model

The inputs for including planetary perturbations in the equations of motion are described in Sec. 2.1.3

2.1.2.4 Atmospheric Drag Models

The inputs in the following example are used whenever density is computed. These values are built into TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	TMATX	2
	PRHØ	0

TMATX U and T matrix indicator. Indicates whether or not the U ($\partial \ddot{\underline{r}}_2 / \partial \underline{r}$) and T ($\partial \ddot{\underline{r}}_3 / \partial \underline{r}$) matrices are included in the variational equations:

> 0 Both the U and T matrices are included in the variational equations.

= 0 The U matrix is included in the variational equations, but the T matrix is not.

< 0 Neither matrix is included.

PRHØ Atmospheric density print option:

= 0 The atmospheric density is not printed during integration.

≠ 0 The density and the vehicle altitude are printed at every integration step.

2.1.2.4.1 ARDC 1959, U.S. Standard 1962, Lockheed-Jacchia, and Exponential Models

The inputs described in this section are preset to the values shown in the following example:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	D1	6.83
	D2	-15.684
	FLUX	0
	JKP	0
	AEXP	1
	HEXP	0
	PEXP	0

D1 D2	Density coefficients used in the Lockheed-Jacchia Model.
FLUX	The 10.7-cm solar radiation flux (Lockheed-Jacchia Model):

= 0 — The 10.7-cm solar radiation flux is computed, $10^{-20} W/m^2/Hz$.

≠ 0 — The input FLUX value is used for the 10.7-cm solar radiation flux.

JKP — Density modification indicator (ARDC 1959, U.S. Standard 1962, Lockheed-Jacchia, or Exponential Models):

= 0 — $\rho = \rho_0$ (ρ is the density actually used in the drag acceleration calculation, and ρ_0 is the density obtained from the atmospheric model).

≠ 0 — The computed density is modified by the function

$$\rho = \rho_0 [1 + (JKP) \, fcn(t)]$$

where fcn(t) is the value obtained from the APTAB table (Sec. 11.1.8) by using linear interpolation, with time as the independent variable.

AEXP — Vector of scale heights used in the Exponential Model, nmi:

(1) — Scale height for the earth.

(2) — Scale height for the sun.

(3) — Scale height for the moon.

(4) Scale height for Venus.

(5) Scale height for Mars.

(6) Scale height for Jupiter.

(7) Scale height for Saturn.

AEXP(2) through AEXP(7) are all preset to 1. and are used for the central body only when in the interplanetary mode; i. e., PHASE = 2 (Sec. 11. 1. 6).

HEXP Vector of reference altitudes used in the Exponential Model, nmi:

(1) Reference altitude for the earth.

(2) Reference altitude for the sun.

(3) Reference altitude for the moon.

(4) Reference altitude for Venus.

(5) Reference altitude for Mars.

(6) Reference altitude for Jupiter.

(7) Reference altitude for Saturn.

PEXP Vector of reference densities used in the Exponential Model, slug/ft^3:

(1) Reference density for the earth.

(2) Reference density for the sun.

(3) Reference density for the moon.

(4) Reference density for Venus.

(5) Reference density for Mars.

(6) Reference density for Jupiter.

(7) Reference density for Saturn.

PEXP(2) through PEXP(7) are used only for the central body when PHASE = 2.

2.1.2.4.2 LMSC 1967 Model

The values shown in the following example are not built into TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	SMALL	156
	2	30
	3	68
	4	331

If the auroral zone effect is to be included in the computation of the heating parameter, it is in the form

$$\Delta S = C \cos\left[(\pi/2)(\gamma/\gamma_0)\right]$$

SMALL Auroral bulge conditions:

(1) = C If C = 0, the auroral zone effect is not included; if C ≠ 0, the effect is included.

(2) = γ_0 Half-angle of the bulge, deg; $\Delta S = 0$ if $\gamma > \gamma_0$ (γ is the angle between the bulge and the vehicle, computed internally).

(3) Geographic latitude of the bulge, deg.

(4) East longitude of the bulge, deg.

When the LMSC 1967 Model is used, it is necessary to input the SMALL data and the following VEHICLE input (Sec. 11.1.8):

$$K_p = \text{fcn}(t)\ (\text{KPTAB})$$

$$F_{10.7} = \text{fcn}(t)\ (\text{FTEN})$$

$$\overline{F}_{10.7} = \text{FBAR}$$

$$\text{IDRAG} = 6$$

2.1.2.4.3 Jacchia 1964 Model

Three forms of the Jacchia 1964 Model are available in TRACE: the log ρ polynomial form (Ref. 5), the Walker analytic form, and the Walker form modified by Bruce. Only one form can be used in any given TRACE run because certain input components are used differently in the different forms. A planetary ephemeris file is required (Sec. 2.1.3). The input common to all three forms is indicated below. Note that the values in the following examples are built into TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	AC	.28
	2	2.5
	3	2.5
	4	1.
	5	897
	6	3.6
	7	0
	8	1.8
	9	.37
	10	.14
	11	152
	12	60
	13	-45
	14	12
	15	45

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	16	125
	17	.08
	18	0
	19	0
	20	0
	21	0
	22	0
	23	0
	24	0
	WMØD	1
	VLIM	120.
	2	1000.
	3	650.
	4	2100.

WMØD Atmospheric model form indicator (Jacchia 1964):

- = 0 — The log ρ polynomial form is used.
- ≠ 0 — The Walker analytic or the Walker-Bruce form is used.

VLIM Altitude and temperature extremes indicator (Jacchia 1964 Model):

- (1) — The minimum altitude, km. If the vehicle altitude is lower than this, the U.S. Standard 1962 Model is used.
- (2) — The maximum altitude, km (log ρ form). If the altitude exceeds this maximum, the density is set to zero.
- (3) — The minimum temperature, K (log ρ form). If the temperature falls below this minimum, the density is set to zero.
- (4) — The maximum temperature, K (log ρ form). If the temperature exceeds this maximum, the density is set to zero.

AC Coefficients used to compute the indicated effects on temperature:

- (5) through (7) — The 11-year solar cycle effect.
- (8) — The 27-day effect.
- (9) through (12) — The semiannual effect.

(1) through (3) and (13) through (15)	The diurnal effect.
(4) (16) (17)	The geomagnetic effect.
(18) through (20) and (22) through (24)	The auroral zone effect, where AC(18) = C_1; AC(19) = C_2; AC(20) = K; AC(22) is the geomagnetic latitude of the auroral ring, deg; AC(23) is the geodetic latitude of the geomagnetic pole, deg; and AC(24) is the East longitude of the geomagnetic pole, deg.

In addition to the WMØD, VLIM, and AC inputs to the MODEL data, the following VEHICLE data must be provided when the Jacchia 1964 Model is used (Sec. 11.1.8):

$$a_p = \text{fcn}(t) \text{ (APTAB)}$$

$$F_{10.7} = \text{fcn}(t) \text{ (FTEN)}$$

$$\overline{F}_{10.7} = \text{FBAR}$$

$$\text{IDRAG} = 2$$

2.1.2.4.3.1 Input for the Log ρ Polynomial Form

The following inputs are not built into TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	MAXA	4
M	AJN	05.05
	01.01	-6.8421347
	02.01	-2.4345754E-3
	03.01	2.1556411E-6
	04.01	-1.0761995E-9
	05.01	2.2011699E-13
	01.02	-1.7875638E-2
	02.02	-3.6169243E-5
	03.02	3.2935674E-8
	04.02	-1.1521156E-11
	05.02	1.2048447E-15

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	01.03	-1.5047684E-4
	02.03	5.0637146E-7
	03.03	-4.4517023E-10
	04.03	1.7016873E-13
	05.03	-2.3485236E-17
	01.04	3.6791761E-7
	02.04	-1.0840772E-9
	03.04	9.9843619E-13
	04.04	-4.0034973E-16
	05.04	5.8649712E-20
	01.05	-2.1168013E-10
	02.05	6.1812845E-13
	03.05	-5.8913701E-16
	04.05	2.4350334E-19
	05.05	-3.6789750E-23

MAXA — The order of the polynomial used to compute log ρ.

AJN — The coefficients of the polynomial used.

MAXA and AJN cannot be used when WJN is input (Sec. 2.1.2.4.3.2).

2.1.2.4.3.2 Input for the Walker Analytic Forms

The values shown in the following example are built into TRACE:

C (1, 27, 53)	LOCATION (2, 28, 54)	VALUE (7, 33, 59)
	WJN	6.0228E+23
	2	28.016
	3	32.
	4	16.
	5	4.003
	6	1.008
	7	4.0E+11
	8	7.5E+10
	9	7.6E+10
	10	3.4E+7
	11	0
	12	0
	13	0
	14	0
	15	-.38
	16	0
	17	355.
	18	9.43972
	19	1.38E-23
	20	3.
	21	2.2
	22	120.
	23	2.461070615E-11

WJN = A
2 = m_{N_2}
3 = m_{O_2}
4 = m_O
5 = m_{He}
6 = m_H
7 = n_{N_2}
8 = n_{O_2}
9 = n_O
10 = n_{He}
11 = n_H
12 = α_{N_2}
13 = α_{O_2}
14 = α_O
15 = α_{He}
16 = α_H
17 = T_{120}
18 = g_{120}
19 = k
20 = a
21 = b
22 = H_{max}
23 = ρ_{120}

WJN Inputs for the Walker analytic form of the Jacchia 1964 Atmosphere Model.

When H_{max} = 120 is input, the Walker analytic form is used. When H_{max} > 120 is input, the Walker-Bruce analytic form is used for all altitudes between 120 and H_{max} km (the Walker form is used for all other altitudes). If H_{max} is input greater than 280 km, it is internally reset to 280 km. WJN cannot be used when MAXA or AJN is input (Sec. 2.1.2.3.1).

2.1.2.4.4 Cambridge Research Laboratory Model (Champion 1968)

To include the auroral zone effect, the following vector must be input (the values shown in the example are not built into TRACE):

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	SMALL	
	2	30
	3	68
	4	331

SMALL Auroral bulge conditions:

(2) = γ_0 Half-angle of the auroral bulge, deg. If $\gamma_0 \le \gamma$, the vehicle is considered outside the zone (γ is the angle between the bulge and the vehicle, computed internally); if $\gamma_0 > \gamma$, the vehicle is considered inside the zone.

(3) Geographic latitude of the bulge, deg.

(4) East longitude of the bulge, deg.

When the Cambridge Research Laboratory Atmospheric Model is used, it is necessary to provide the SMALL input data and the following VEHICLE input (Sec. 11.1.8):

K_c = fcn(t) (KCTAB)

IDRAG = 8

$F_{10.7}$ = fcn(t) (FTEN)

$\overline{F}_{10.7}$ = FBAR

The inputs in the following example are built into TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	DPDH	-10.5
	2	-8.6
	3	-5.55
	4	0

DPDH Table of approximate ρ' values used if the atmospheric density routine is unable to compute ρ' directly [ρ' = (∂ρ/∂h)(h/ρ)], where ρ is the density and h the satellite height:

(1) The value of ρ' used below 76 nmi.

(2) The value of ρ' used if 76 ≤ h ≤ 108 nmi.

(3) The value of ρ' used if 108 < h ≤ 376 nmi.

(4) The value of ρ' used if h > 376 nmi.

2.1.2.5 Thrust Models

The thrust models are defined in Sec. 11.1.12. No MODEL inputs are necessary.

2.1.2.6 Solar Radiation Pressure Input

The inputs in the following example are built into TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	RE	1.
	RS	109.1218

RE — Effective earth radius, er (see AE, Sec. 2.1.1 and PAE(1), Sec. 2.1.3), used when solar radiation effects are included in the equations of motion (CPAW, Sec. 11.1.7).

RS — Effective solar radius, er (see PAE(2), Sec. 2.1.3), used with solar radiation effects.

It is also necessary to input the PLANT array (Sec. 2.1.3).

2.1.2.7 Local Gravity Anomaly Model

There are two methods of using polynomials to express the local variations in the gravitational attractions experienced by a vehicle. The method used is determined by the input variable PØLY0(1). If PØLY0(1) = 0, the local gravity field is not used. If its value is 10 or 11, Method 2 is used; for any other value, Method 1 is used.

2.1.2.7.1 Method 1

The local variations in the gravitational attractions experienced by a synchronous vehicle orbiting the earth are modeled as a polynomial in the variations of the vehicle in geocentric radius, latitude, and longitude from some nominal point (r_0, ϕ_0, λ_0), where ϕ_0 is assumed to be zero. A total of 30 coefficients can be supplied, 10 each for the radial, intrack, and crosstrack directions. The values shown in the following example are not built into TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	PØLY0	-1
	2	0
M	PØLY	10,3
	01.01	1.E-8
	02.01	1.E-8
	03.01	1.E-8
	04.01	1.E-8
	01.02	1.E-8
	02.02	1.E-8
	03.02	1.E-8
	04.02	1.E-8
	01.03	1.E-8
	02.03	1.E-8
	03.03	1.E-8
	04.03	1.E-8

PØLYO — The quantities r_0 and λ_0 for the local gravity field or the method of computing them:

(1) = 0 — The local gravity field is not used.

> 0 — The geocentric radius of the initial point r_0, nmi.

< 0 — The quantities r_0 and λ_0 are computed from the vehicle initial conditions.

(2) — The reference longitude λ_0, deg, when PØLY0(1) is input > 0.

PØLY — A 10 × 3 matrix containing the radial, intrack, and cross-track coefficients used to compute the coefficients of force due to local variations. The coefficients are for the constant terms in the expansion: 1, $\Delta\phi$, $\Delta\lambda$, Δr, $(\Delta\phi)^2$, $(\Delta\lambda)^2$, $(\Delta r)^2$, $\Delta\phi\Delta\lambda$, $\Delta\phi\Delta r$, and $\Delta r\Delta\lambda$; where $\Delta\phi$, $\Delta\lambda$, and Δr represent the variations in latitude, longitude, and radius, respectively.

2.1.2.7.2 Method 2

Local variations in the gravitational attractions are modeled as orthogonal polynomials in time. If PØLY0(1) = 10, the polynomials give accelerations in the inertial frame. If PØLY0(1) = 11, the polynomials give accelerations in the Up-East-North system. In either system, accelerations are given by

$$\ddot{\underline{r}}_i = \sum_{i=1}^{NC\emptyset F} \begin{bmatrix} C_{x_{i-1}} \\ C_{y_{i-1}} \\ C_{z_{i-1}} \end{bmatrix} P_{i-1}(\tau)$$

where

$$\tau = (T - TBAR)$$

$$P_0 = 1$$

$$P_1 = \tau$$

$$P_j = (\tau - a_j)P_{j-1} - b_j P_{j-2} \qquad (j \geq 2)$$

For this option, PØLY is input as a 10 × 7 matrix defined as

PØLY	1	2	3	4	5	6	7
1	C_{x0}	C_{y0}	C_{z0}	a_2	b_2	NCØF	*
2	C_{x1}	C_{y1}	C_{z1}	a_3	b_3	TBAR	*
3	C_{x2}	C_{y2}	C_{z2}	a_4	b_4	*	*
4	C_{x3}	C_{y3}	C_{z3}	a_5	b_5	*	*
5	C_{x4}	C_{y4}	C_{z4}	a_6	b_6	*	*
6	C_{x5}	C_{y5}	C_{z5}	a_7	b_7	*	*
7	C_{x6}	C_{y6}	C_{z6}	a_8	b_8	PCØNV	*
8	C_{x7}	C_{y7}	C_{z7}	a_9	b_9	*	*
9	C_{x8}	C_{y8}	C_{z8}	*	*	*	*
10	C_{x9}	C_{y9}	C_{z9}	*	*	*	*

where C_{xi}, C_{yi}, C_{zi}, a_i, and b_i are polynomial coefficients; NCØF is the order of the polynomial + 1; TBAR is the reference time, min; PCØNV is the unit conversion factor that converts C_{x0}, C_{y0}, and C_{z0} to er/min^2; and the symbol * indicates that the location is used by the program but is not input. Note that NCØF, which must be input as an integer, and TBAR can be input under those same names and that PCØNV is never input.

The C_i coefficients are acceptable as differentially correctable parameters and are specified in the same manner as the coefficients of Method 1 (Sec. 2.1.5.3). The units of any C_i are the acceleration units specified by PCØNV divided by sec^i (seconds raised to the i^{th} power). The values shown in the following example are not built into TRACE:

	C (1, 27, 53)	LOCATION (2, 28, 54)	VALUE (7, 33, 59)
	I	PØLY0	10
	M	PØLY	10, 7
		01, 01	-6.15077
		02, 01	1.61100E-2
		03, 01	-1.88908E-5
		04, 01	2.155562E-8
		05, 01	1.260563E-11
		06, 01	-1.183194E-13
		01, 02	-1.67370
		02, 02	-6.34375E-4
		03, 02	2.02923E-5
		04, 02	4.53755E-8
		05, 02	9.74035E-11
		06, 02	-6.64653E-14
		01, 03	1.010335E1
		02, 03	-2.84027E-2
		03, 03	1.985092E-5
		04, 03	-4.001543E-8
		05, 03	-2.979148E-11
		06, 03	2.527756E-14
		01, 04	3.21277E+2
		02, 04	3.264521
		03, 04	2.576319
		04, 04	2.257486
		01, 05	2.66086E+5
		02, 05	1.46705
		03, 05	1.58632
		04, 05	1.81499
NCØF or	I	01, 06	6
TBAR or		02, 06	210.
		07, 06	1.

2.1.3 Planetary Ephemeris Constants

TRACE options that require the planetary ephemeris file (Sec. 16.5) and the use of much of the PLANT array are listed as follows:

- Planetary perturbations in the equations of motion
- Solar radiation pressure in the equations of motion
- The Jacchia 1964 Atmospheric Model
- Planetary print options on ephemeris generation runs
- Vehicle eclipsing computations
- Lunar and interplanetary integration modes
- NASA $\neq 0$ (Sec. 2.1.4)

The value of TAPE7 (preset to zero) indicates how the planetary ephemerides are made available:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	TAPE7	0

TAPE7 Planetary ephemeris tape usage indicator:

= 0 A special EPHEM file (Aerospace File Service) has been linked to TRACE. If cases are being stacked, the dates used in all cases after the first must be later than the first date of the first case and earlier than the last date of the last case.

<0 A planetary ephemeris tape must be used for TAPE7.

TRACE is preset to use either a sun and moon ephemeris file or a special ephemeris file with sun, moon, nutation, and nutation rate information, e.g.:

C	LOCATION	VALUE
	PLANT	0
	2	1
	3	1
	4	0
	5	0
	6	0
	7	0
	8	332951.3

C	LOCATION	VALUE
	9	.0122999
	14	23454.865
	15	23454.865
	16	1.
	17	1.
	18	6.9444444E-4
	23	16.28
	24	6.9444444E-4

PLANT   Planetary ephemeris indicators and conversion factors:

(1) = 0   Planetary perturbations are not included in the equations of motion.

$\neq$ 0   Planetary perturbations are included; PLANT(8) through (28) input must correspond to PLANT(2) through (7) input.

(2) through (7)   The indicators used to select the bodies to be included in the planetary perturbations. If the indicator is zero, the body is not used; if non-zero, the body is used. These indicators must be input in the order in which the bodies appear on the planetary ephemeris file.

(8) through (28)	Constants and scale factors used to convert the planetary ephemerides to TRACE integration units. These quantities must be input in the order in which the bodies appear on the file.
(8) through (13)	The relative masses of the planetary bodies $(\mu_B/\mu_e)_i$ in earth masses. For the BCI integration mode, the gravitational constants μ_{B_i} for the planetary bodies are internally computed from the expression $$\mu_{B_i} = \mu_e(\mu_B/\mu_e)_i$$
(14)	The number of earth radii per astronomical unit.
(15) through (14+n)	Distance scale factors used to convert ephemeris file values to earth radii.
(15+n)	Conversion factor for nutation.
(16+n)	Conversion factor for nutation rate.
(23) through (22+n)	Velocity scale factors used to convert ephemeris file values to er/min.

Note that n is the number of bodies in the file, not including nutation or nutation rate information.

The following example shows how the entire PLANT array would be input if sun and moon perturbations were desired and if the planetary ephemeris file being used contained data for the sun, moon, Venus, Mars, Jupiter, Saturn, nutation, and nutation rate:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	PLANT	1
	2	1
	3	1
	4	0
	5	0
	6	0
	7	0
	8	332951.3
	9	.0122999
	10	.814979
	11	.107821
	12	317.887
	13	95.129
	14	23454.865

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	15	23454.865
	16	1.00002516
	17	23454.865
	18	23454.865
	19	23454.865
	20	23454.865
	21	1.
	22	6.9444444E-4
	23	16.28810076
	24	6.9444444E-4
	25	0.
	26	0.
	27	0.
	28	0.

For interplanetary integration, the following vector of rotation rates for the solar system bodies is used; the following values are preset, rad/min:

1 27 53 C	2 28 54 LOCATION	7 33 59 VALUE
	PØMEG	.43752691E-2
	2	0.
	3	.15970197E-8
	4	0.
	5	.42529306E-2
	6	0.
	7	0.

PØMEG Vector of rotation rates for the solar system bodies:

(1) Earth.

(2) Sun.

(3) Moon.

(4) Venus.

(5) Mars.

(6) Jupiter.

(7) Saturn.

For interplanetary integration and the eclipsing print option during interplanetary inegration, the following vector of the mean equatorial radii for solar system bodies is used; the following values are preset in er:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	PAE	1.
	2	0.
	3	.272506277
	4	0.
	5	0.
	6	0.
	7	0.

PAE Vector of mean equatorial radii for sclar system bodies:

(1) Earth (see AE, Sec. 2.1.1 and RE, Sec. 2.1.2.6).

(2) Sun (see RS, Sec. 2.1.2.6).

(3) Moon (see AM, Sec. 2.1.1 and RM, Sec. 2.3.2).

(4) Venus.

(5) Mars.

(6) Jupiter.

(7) Saturn.

For interplanetary integration, crash altitudes for the solar system bodies must be input (preset value, ft):

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	PCRAS	300000.
	2	0.
	3	3000.
	4	0.
	5	0.
	6	0.
	7	0.

The planetary crash altitudes can be input in the PCRAS array in units consistent with DF (Sec. 2.1.1). PCRAS is used for the BCI integration mode, whereas CRASH and HMØØN are used for the ECI and MCI integration modes, respectively.

PCRAS Vector of crash altitudes for solar system bodies:

(1) Earth (see CRASH, Sec. 2.1.4).

(2) Sun.

(3) Moon (see HMØØN, Sec. 2.1.4).

(4) Venus.

(5) Mars.

(6) Jupiter.

(7) Saturn.

Note that for both PAE and PCRAS, the planetary ephemeris file is assumed to be in the following order: sun, moon, Venus, Mars, Jupiter, and Saturn.

2.1.4 Numerical Integration Constants and Indicators

The values shown in the following example are built into TRACE:

C	LOCATION	VALUE
I	NSTEP	2
I	NPCMP	0
I	IR	8
	ER	1.E-11
	HMIN	.015625
	HMAX	64.
	H0	1.
	FØVER	1.
	DØVER	0.
	TAPE2	0
	TELEM	0
	NØDPR	0

C	LOCATION	VALUE
	ADELT	1
	CRASH	300000
	HMØØN	3000
	LEMSP	0
I	NASA	0
	RJDAT	1
	TREFD	0
	UTD	35
	ETTA1	32.15
	TEST	0
	VMIN	0
	NPDØT	0
I	PTNS	1000
	PH0	0.125
	PHMIN	0.001953125

NSTEP Integration step output indicator:

= 0 NSTEP is set to 1.

= n Every n^{th} integration step is written on the trajectory file (TAPE2 or TAPE21, . . . , TAPE40).

NPCMP Recomputation flag during integration:

= 0 Only the central term is recomputed during the corrector step of the Gauss-Jackson predictor-corrector method used in TRACE. The accelerations are then formed by using the recomputed central term and the values from the predictor step for the perturbing forces.

≠ 0 The perturbing forces are also recomputed during the corrector step.

IR Ratio of Runge-Kutta to Cowell integration steps, where H (Runge-Kutta) = H0/IR.

ER Integrator error ratio significant digit control value 1×10^{-S}, where S is the approximate number of significant figures desired for the relative error criterion used within the integrator.

HMIN Minimum absolute value of the integration step size, min.

HMAX Maximum absolute value of the integration step size, min.

H0 Initial step size used, min (positive for forward and negative for backward integration). Note that no accelerometer models are allowed during a backward integration (Sec. 11.1.10). Note also that the print intervals must be in descending order, the print time steps must be negative in PTIM (Secs. 11.3.1.1 and 11.5.1), the last observation time, MME, must be input in BTIME (Secs. 11.2.1 and 11.5.2), and the earliest observation time in each flock of observation data must be later than the latest time in the next flock (Sec. 15) when backward integration is performed.

FØVER
DØVER

Coordinate system switchover indicators. The orbit may be integrated in the ECI, MCI, and BCI coordinate systems (PHASE, Sec. 11.1.6). When a combination mode is being run, FØVER and DØVER are available to control the transfer from one system to the other.

In the lunar mode, FØVER specifies the ratio of the gravitational attractions of the earth and the moon at the time the transfer orbit is to switch coordinate systems. Thus, if FØVER is input = 1, switchover occurs when the earth's attraction equals the moon's. DØVER specifies the radius of the sphere of influence of the moon, er. If the vehicle enters this sphere of influence, the orbit is integrated in MCI. If both FØVER and DØVER are specified, only DØVER is used.

In the interplanetary mode, the switchover criterion for coordinate systems is FØVER(r_{BCI}) vs r^i_{BCI}, where r_{BCI} is the distance of the satellite from the central body and r^i_{BCI} is the distance of the other bodies from the satellite (PLANT(15), (16), etc., Sec. 2.1.3). If FØVER $(r_{BCI}) < r^i_{BCI}$, switchover does not occur, and if (FØVER)$(r_{BCI}) \geq r^i_{BCI}$, switchover occurs.

TAPE2

Trajectory tape input option:

$\neq 0$ The vehicle ephemeris file generated by TRACE has been saved from some previous run and is being used as an input trajectory for the current run. If MULTV = 1 or 2 (Sec. 2.1.6), the ephemerides for all vehicles must be on files resulting from previous TRACE runs. The numerical integration is skipped.

TELEM TELEM Program output tape option:

$\neq 0$ A special density profile tape for the TELEM Program is written on TAPE10 (Sec. 16.10).

NØDPR Node print output option:

$\neq 0$ The node prints are suppressed during trajectory integration.

ADELT Step size, min, for writing data on the vehicle ephemeris file when IFØRM = 3 (Sec. 11.1.6).

CRASH The altitude for ECI orbits at which numerical integration is terminated (see PCRAS(1), Sec. 2.1.3), in units consistent with DF (preset in ft).

HMØØN The altitude for MCI orbits at which numerical integration is terminated (see PCRAS(3), Sec. 2.1.3), in units consistent with DF (preset in ft).

LEMSP Trajectory integration print option:

= 0 Trajectory information is printed at initial, final, and all nodal points during the integration.

= 1 All trajectory integration printing is suppressed

= 2 All trajectory integration printing is suppressed except at the initial and final points.

= 3 All trajectory integration printing is suppressed except at the nodes.

NASA — TRACE reference coordinate system option:

= 0 — The reference inertial frame in which the equations of motion are solved is the TRACE standard coordinate system (true equator of instant and mean equinox at midnight day of epoch).

= 1 — The effects of precession and nutation are included in coordinate frame transformations. In addition, timing polynomials are used to compute corrections among A1 (atomic time), UT1 (universal time), and UTC (broadcast time). This option requires the input of RJDAT, TREFD, ETTA1, an ephemeris file containing nutation and nutation rates, and ETUT and WWVET in the VEHICLE data (Sec. 11.1.5).

= 2 — Same as NASA = 1 except that pole-wander effects are added. This option applies only to the ECI mode and requires the PWAND table in the VEHICLE data (Sec. 11.1.5).

RJDAT — The reference Julian date of the inertial frame in which the equations of motion are solved, i.e., mean equator and mean equinox of reference Julian date (preset to one):

= 0 — Julian date of 1950.0 is used.

= 1 — Julian date of midnight day of epoch is used.

≠ 0 or 1 — RJDAT is interpreted as a Julian date and is used directly.

TREFD Increment for updating precession, nutation, and pole-wander matrices, min.

ETTA1 The correction that relates ephemeris time to atomic time, sec.

UTD The correction that relates integration time to ephemeris time, sec. The integration time may be any uniform time with an arbitrary epoch:

= 0	Integration time equals ephemeris time.
= 32.15	Integration time equals atomic time.
= 36.6	Integration time equals a uniform time system that is within two seconds of universal time for the late 1960s.

Other time relations are discussed in Sec. 11.1.5.

TEST Double-group integration mode indicator. Since the double-group mode works only in the fixed-step mode, it is suggested that HMIN = HMAX = the desired step size for the integration of the equations of motion:

≥ 2	Variational equations can be integrated at $2^{(TEST-1)}$ times the step size of the equations of motion. VMIN input is required, and TEST ≤ 3 is recommended.

VMIN Control for double-group integration:

≥ 10	The doubling procedure for the variational equations can be controlled when TEST ≥ 2. A larger VMIN reduces the accuracy requirements for the equations and thus allows them to be integrated at a larger step size ($10 \le \text{VMIN} \le 10^5$ is recommended).

NPDØT Period decay rate print option:

= 0 Period decay is not printed.

= n The period decay rate is printed every n integration steps.

PTNS Trajectory equations print option:

= 0 Trajectory information is not printed.

= n The trajectory position, velocity, and acceleration information is printed every n integration steps.

PH0 Powered flight initial step size, min (Sec. 11.1.15).

PHMIN Powered flight minimum step size, min.

2.1.5 Parameter Specification

Model-dependent parameters for orbit determination, ephemeris generation, or error analysis runs are divided into three categories: point mass parameters, gravity parameters, and other model parameters. They are specified in the MPRAM, GPRAM, and ØPRAM matrices, respectively, as described in the following subsections.

2.1.5.1 Point Mass Parameters

If any components of the point masses used (Sec. 3) are selected as parameters, they must be specified in MPRAM. The values shown in the following example are not built into TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
M	MPRAM	04, 60
D	01, 01	M001 (6) Q
	03, 01	1. E-5
	04, 01	0
D	01, 02	R001 (6) P
	03, 02	.005
	04, 02	0
D	01, 03	P001 (6) P
	03, 03	1.
	04, 03	0
D	01, 04	L001 (6) Q
	03, 04	1.
	04, 04	0

MPRAM A 4 × 60 matrix specifying up to 60 point mass parameters:

(01, k) The identification for the k^{th} parameter must be in the form

MPRAM(01, k) = XYYY(6)P-Q indicator

where X = M indicates the relative mass μ, X = R indicates the radius $\underline{r}_0$, X = P indicates the geocentric latitude φ, or X = L indicates the longitude λ. YYY is the point mass number (any number from 001 to 020) corresponding to the relative position of the point mass card in MASS (Sec. 3), the symbol ⑥ indicates six spaces, and the P-Q indicator is a P or a blank to indicate a P-parameter or a Q to indicate a Q-parameter.

(03, k) The bound for the k^{th} parameter (used only on orbit determination runs).

(04, k) The a priori sigma for the k^{th} parameter (ØPBØX, Secs. 2.2.1 and 2.5.1).

2.1.5.2 Gravity Parameters

If any of the C and S terms in the gravity model are specified as parameters, the following input must be provided in GPRAM. The values shown in the example are not built into TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
M	GPRAM	06.60
D	01, 01	02.00 ⑤ P
	03, 01	1. E-6
	04, 01	0
	05, 01	.5E-7
	06, 01	0
D	01, 02	03.03 ⑤ Q
	03, 02	1. E-6
	04, 02	1. E-6
	05, 02	.5 E-7
	06, 02	.5 E-7

GPRAM — A 6 × 60 matrix containing specifications for each term selected as a pair of parameters:

(01, i) — The identification for the i^{th} parameter in the format n, m ⑤ P-Q indicator. The degree n must be of the form XX or 0X and the order m of the form YY or 0Y. The symbol ⑤ indicates five spaces, and the P-Q indicator is a blank or a P to indicate a P-parameter or a Q to indicate a Q-parameter.

(03, i)	The bound for C_{nm}	Used only on an orbit determination run with a P-parameter.
(04, i)	The bound for S_{nm}	
(05, i)	The sigma for C_{nm}	(ØPBØX, Secs. 2.2.1 and 2.5.1)
(06, i)	The sigma for S_{nm}	

When C and S parameters are input, the following relationships exist: If m = 0, only C_{n0} is a parameter; the inputs for S_{n0} may be ignored. If a corresponding n, m term cannot be found in the TERMS input, an error message is printed and the run is terminated (Sec. 2.1.2.2).

A run that integrates exclusively in the ECI mode may have only ECI coefficients specified as parameters, even though both ECI and MCI coefficients may be input by TERMS. However, a run that integrates exclusively in the MCI mode may have MCI coefficients specified as parameters only if there are no ECI coefficients input by TERMS. If vehicle-dependent gravity models are indicated (IVGMS, Sec. 11.1.6) during an exclusively ECI integration mode, no coefficients can be specified as parameters.

2.1.5.3 Other Model Parameters

The ØPRAM input matrix specifies parameters other than spherical harmonic and point mass parameters. The values shown in the following example are not built into TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
M	ØPRAM	04, 60
D	01, 01	GM ⑧ P
	03, 01	1.E-9
	04, 01	1.E-8
D	01, 02	ØMEGA ⑤ Q
	03, 02	1.E-10
	04, 02	0
D	01, 03	203
	03, 03	1.E-10
	04, 03	0.

ØPRAM — A 4 × 60 matrix containing the parameter identification, P-Q indicator, bound, and sigma for each parameter. Input for the k^{th} parameter is:

(01, k) — A parameter name from the list below is specified, and the P-Q indicator is specified in the eleventh character. Note again that a P or a blank indicates a P-parameter and a Q indicates a Q-parameter.

(03,k)	The bound for the parameter (used only for a P-parameter during an orbit determination run) is specified.
(04,k)	The parameter sigma or a priori information for orbit determination and covariance analysis runs is specified (ØPBØX, Secs. 2.2.1 and 2.5.1).

The following are acceptable parameter names:

GM	The earth gravitational constant μ.
ØMEGA	The atmospheric rotation rate ω_a.
Ci	The i^{th} coefficient of the temperature equation in the Jacchia 1964 Atmosphere Model (i = 1, 2, · · · , 24) (Sec. 2.1.2.4.3).
AEXP	The scale height used in the Exponential Atmosphere Model (Sec. 2.1.2.4.1).
ji	In Method 1 of the polynomial forcing function (Sec. 2.1.2.7.1), i specifies the coefficient for the i^{th} term (i = 01, 02, · · · , 10). The radial, intrack, or crosstrack direction is specified by j = 1, 2, or 3, respectively. In Method 2 (Sec. 2.1.2.7.2), j = 1, 2, or 3 indicates x, y, or z, respectively; i = 01, 02, · · · , 10 indicates the 0^{th} through the 9^{th} coefficient, respectively.

2.1.6 Data Peculiar to Simultaneous-Vehicle Uses

TRACE can consider simultaneous vehicles when it performs its basic functions. A nonzero input value for the simultaneous-vehicle indicator MULTV implies that vehicle ephemeris information is used for more than one vehicle at some "time" (e.g., correlated measurement observation times). The following values are preset:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	MULTV	0
	TAPE2	0

MULTV — Simultaneous-vehicle indicator. In an ephemeris generation run, the ephemerides are printed sequentially, not simultaneously. In an orbit determination or covariance analysis run, the measurement types allowed in this mode are limited (Sec. 15). The data deck setup for this mode is illustrated in Appendix B. If the function specified by ITIN requires the use of an orbit determination algorithm, the user must select one of the following:

= 1 — Batch differential correction by the weighted least squares procedure.

= 2 — The SLS (sequential least squares) procedure with prespecified update times (Sec. 2.2.11).

TAPE2 Input option regarding trajectory tape. Input nonzero if all vehicle ephemeris files generated by TRACE on previous runs were saved and are being used as trajectories for the current run. No integration is performed.

2.1.7 Observation Input/Output Constants and Indicators

The only values preset in the following examples are DCØNV and VCØNV:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	IØBSF	1
	RND	1
I	KFØUR	-1

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	DCØNV	3280.8399
	VCØNV	3280.8399
I	PØBS	1

IØBSF Input observation format indicator:

= 0 TRACE format (preset value).

= 1 KOMPACT format.

= 2 DECOR format.

= 3 SPADATS format.

RND Rounding indicator for the seconds field of the observation time:

≠ 0 The seconds field of the observation time is rounded on KOMPACT and DECOR observations.

KFØUR Range rate inclusion indicator for the KOMPACT and DECOR formats:

= 0 Range rate is not included.

	> 0 — TRACE Type 7 $\dot{R}$ is included (Table 15-2).
	< 0 — SGLS range rate is included.
DCØNV	Distance conversion factor among the non-TRACE formats and the TRACE format, preset to ft/km.
VCØNV	Velocity conversion factor among the non-TRACE formats and the TRACE format, preset to ft/km.
PØBS	Punch indicator for non-TRACE observation data:
	= 0 — No TRACE-formatted cards are punched.
	≠ 0 — OBSERVATION cards are punched after they are converted to the TRACE format.

2.2 DATA FOR ORBIT DETERMINATION RUNS (ITIN = 2)

Input/output options for orbit determination runs are described below.

2.2.1 Input/Output Options

All options except PANDR and ØPBØX are preset as in the following examples:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	PATA	0
D	ØPBØX	A
D	PANDR	ABCDEFGHIJKLMNØ
I	KRANK	0
I	KINC	2
	RHØ	1.E-6
	SG2R	0
	SG2RD	0
I	WLSDT	0

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	PUNMS	0.
	APSIG	0.
	GPLØT	0.
	2	4.
	TAPE5	0.
	CLASS	0.

PATA — The A^TA and $(A^TA)^{-1}$ print indicator:

= 0 — The A^TA and $(A^TA)^{-1}$ matrices are not printed.

= 1 — These matrices are printed after each iteration.

= 2 — These matrices are printed only after the last iteration.

ØPBØX — The A^TA matrix input indicator:

<u>Position</u>

A = 0 or blank — No initial A^TA is input.

A = 1 — The diagonal elements of the $(A^TA)^{-1}$ matrix are input in the sigma of the parameter cards (variance input).

= 2 — The square roots of the diagonal elements of the $(A^TA)^{-1}$ matrix are input in the sigma field of the parameter cards (standard deviation input).

= 3 — The A^TA matrix is input (Sec. 6.1).

= 4 — The $(A^TA)^{-1}$ matrix is input (Sec. 6.2).

PANDR — A 20-character vector that controls certain input/output options. An X in the proper position, except where otherwise indicated, results in the following:

<u>Position</u>

A = X — Printing of the measurement residuals is suppressed.

A = Y	Residuals are printed only on the first and last iterations, where the last iteration is either equal to MAXIT or is anticipated whenever (RMS/200 + RMS/PRMS) < 2, whichever occurs first. Note that RMS is the root mean square of the weighted residuals for the current solution and PRMS is the predicted RMS (based on the linearity assumption) for the predicted solution.
B	The measurement partials are printed.
C = X	Cards with the current and predicted solutions for each parameter are punched after the last iteration. The format is:

Column	Description
1-7	Station name or vehicle number
8-15	Parameter name
17-31	Current value
33-47	Predicted value

These cards cannot be used as TRACE input.

C = Y	Cards with the current solution of initial conditions (ICTYP = -1), drag (single or segmented) and finite thrusting (Sec. 11.1.12), are punched after the last iteration. The format is such that the cards may be input to TRACE; their images are printed at the time they are punched.
D	Not used.

E	Printing of the input observational measurements is suppressed.
F	Cards with the predicted solution for the sensor parameters are punched after the last completed iteration. Current values for the bounds and input sigmas are also punched. The format is that of the sensor parameter cards (Sec. 5), which is acceptable as TRACE input.
G	The partials of range and SGLS range rate with respect to radial, intrack, and crosstrack positions are computed and printed. This is done for all stations with nonzero sigmas for range and SGLS range rate measurements.
H	The Ford refraction model for range and SGLS range rate is used; normal range refraction and any SGLS range rate tropospheric refraction are not used. Scale factors are necessary in FØRD (Sec. 2.2.7.2), as are range refraction indices in the STATION cards (Sec. 4).
I	The A^TA matrix is punched on cards after the last iteration when MULTV = 0. The card format is that of the A^TA input, which is acceptable as TRACE input (Sec. 6.1).
J = X	The ordered correlation matrix, with the associated parameter names, is printed after every iteration. The order is by absolute value, from largest to smallest.
J = Y	Printing of the correlation matrix is suppressed.

J = Z	Same as J = X, but for the last iteration only.
K	Time-of-arrival errors and residuals for the range and/or SGLS range rate measurements are printed in addition to the residuals. In this case, only one iteration is made.

L — The least squares process is modified in that the normal equations are solved as a system of rank k, where k may be less than full rank. The rank k may be specified by inputting KRANK or from the relationship $\lambda_k \le \rho\lambda_1$, where ρ is input variable RHØ and where λ_1 is the largest eigenvalue and λ_k is the smallest eigenvalue satisfying the inequality. Only the solution for rank k is used to update the differentially correctable parameters. For each iteration, the following is output:

- Eigenvalues of the normal matrix A^TWA
- S-matrix (columns of eigenvectors of A^TWA)
- Y-vector (full rank solution in the eigenvalue space)
- X-vectors (solutions for ranks k-KINC through k+KINC in the original parameter space)
- Predicted RMS for each solution (X-vector).

	M	An edit summary by vehicle and a total summary are printed when multiple vehicles (arcs) are run.
	N	The intrack time bias errors, requested by PANDR(K) = X, are computed by a weighted least squares process. When WLSDT = 3 or 4, the related variables θ, Δt, $\overline{\Delta t}$, and ΔN are also computed.
	Ø	Not used.

KRANK — The rank k of the solution when PANDR(L) = X.

KINC — The solution print indicator for PANDR(L) = X. Solutions for ranks k-KINC through k+KINC are computed and printed.

RHØ — The scale factor ρ for the eigenvalue analysis, used to determine the rank of the normal matrix.

SG2R — The quantity σ_R^2, associated with the range, for the computation of the intrack time bias errors requested by PANDR(N) = X. If this quantity is input zero, the program computes σ_R^2, using the input sigma as σ_R (Sec. 2.2.6).

SG2RD — The quantity $\sigma_{\dot{R}}^2$, associated with the SGLS range rate, for the computation of the intrack time bias errors requested by PANDR(N) = X. If this quantity is input zero, the program computes $\sigma_{\dot{R}}^2$, using the input SGLS sigma as $\sigma_{\dot{R}}$ (Sec. 2.2.6).

WLSDT	Intrack time bias error computation measurement flag, used when PANDR(N) = X:	
	= 0	Only nonzero and nonedited range and SGLS range rate measurements are used.
	= 1	Only nonzero and nonedited range measurements are used.
	= 2	Only nonzero and nonedited SGLS range rate measurements are used.
	= 3	Only nonzero and nonedited range and SGLS range rate measurements that occur as pairs (i.e., at the same time) are used.
	= 4	Same as WLSDT = 3 except that the variable Δt is not computed as a function of θ.
PUNMS	Punch indicator for point masses and the state vector during orbit determination:	
	$\neq 0$	The point masses and the state vector (Cartesian coordinates) are punched after the last iteration in format acceptable as TRACE input if point masses and/or components of the state vector are specified as parameters.
APSIG	Indicator that saves the computed a priori sigmas and bounds:	
	$\neq 0$	The computed a priori sigmas and bounds are saved. If PUNMS $\neq 0$, the sigmas are also punched as indicated by PUNMS.

GPLØT	Residual printer plot indicator or the special residual plot tape variables:	
	(1) = 0	No measurement residual plot tape is generated.
	(1) ≠ 0	When PANDR(N) = X, a plot tape is generated for the range and SGLS range rates used in the weighted least squares computation of the intrack time bias errors. In this case, GPLØT(2) is not used.
	(1) = ±n	When PANDR(N) is blank, the n for the $\pm n\sigma/2$ printer plot of measurement residuals to be generated on TAPE9 (Sec. 16). If n is positive, σ is the station measurement type RMS. If n is negative, σ is input (Sec. 2.2.6).
	(2)	When GPLØT(1) = n, the Δt for the printer plot time scale, in whole seconds.
TAPE5	Orbit determination summary punch option:	
	≠ 0	A special orbit determination summary is punched.
CLASS	Input station location print option:	
	≠ 0	Station locations and input sensor parameters are not printed.

After the last iteration is completed, TRACE, on request, prints the measurement residuals by station, rather than by time (the residuals for each station are still in time sequence; i.e., all residuals for the first station are printed, then all for the second, etc.). The mean and RMS of the residuals are also available, as well as the distribution about the mean and about zero for each measurement data type encountered for each station.

For this option, input is required to SSPR and NSPR (which are preset blank and to zero, respectively), e.g.:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
D	SSPR	ABCD
	NSPR	10.

SSPR Residual output option (by station, rather than by time). Four characters control this option:

<u>Position</u>

A = 0 or blank	No data is generated or printed.
A = X	The output requested by Positions B, C, and D is generated.
B = 0 or blank	Station-sorted residuals are printed.
B = X	Station-sorted residuals are not printed.
C = 0 or blank	The mean, the RMS, and the distribution about the mean and about zero for each measurement data type encountered for each station are computed and printed. Only nonedited data is used.
C = X	No output is generated.
D	Same as Position C except that both edited and unedited data are used.

NSPR — The n for the ±nσ residual distributions, used if SSPR(C) or (D), or both, are requested. The sigma used is the computed RMS for each measurement type for each station.

2.2.2 Termination and Convergence Criteria

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	MAXIT	10

MAXIT — The number of iterations to be made in a differential correction run. If MAXIT = 0 (preset value), one iteration is made.

The values shown in the following example are built into TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	RCØN	.00001
	ACØN	0.
	DIVF	0.

RCØN — Relative convergence criterion for orbit determination.

ACØN — Absolute convergence criterion for orbit determination.

A differential correction run is considered converged and is terminated after an iteration in which

$$(SOS - SOS_p)/SOS \leq RC\emptyset N \quad \text{or} \quad (SOS - SOS_p) \leq AC\emptyset N$$

where SOS is the sum of the normalized measurement residuals squared for the current iteration and SOS_p is the predicted sum of the normalized measurement residuals squared.

DIVF — Termination indicator for diverging orbit determination solutions:

$\neq 0$ — A differential correction run is terminated when

$$SOS_b/N_b \leq SOS/N \quad \text{(i.e., diverging)}$$

where SOS_b is the sum squared for the best iteration, N_b is the number of residuals in that sum, and N is the number of residuals in SOS.

2.2.3 Input for Recomputing Bounds

The following values are built into TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	SFIBD	1.5
	SFDBD	.5

SFIBD — Scale factor for increasing the parameter bounds when a solution is converging (DIVF, Sec. 2.2.2), i.e.

$$SOS/N < SOS_b/N_b$$

SFDBD — Scale factor used when the bounds are decreased after a diverging iteration.

2.2.4 Residual Editing Indicators

Editing occurs only for each of the first 30 stations input and for the first 6 different measurement types encountered by these stations. NEDIT and FEDIT are used for the nσ editor and are internally preset as:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	NEDIT	100
	FEDIT	0

NEDIT Residual editing indicator:

= 0 No editing takes place.

<0 Editing takes place on all iterations using n = |NEDIT| and the input sigmas (Sec. 2.2.6) except when FEDIT = 0; in that case, editing takes place only on the first iteration.

>0 Editing on the first iteration is performed using n = FEDIT and input sigmas (no editing takes place on the first iteration if FEDIT ≤ 0). Editing is performed on subsequent iterations using n = NEDIT and sigmas computed from the residuals of the previous iteration for the same station and measurement type.

2.2.5 Transit Time Correction Indicator

LGT is a transit time correction flag preset as:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	LGT	0

LGT — Speed-of-light (transit) time correction indicator:

= 0 — No change is made to the observation time.

= 1 — A positive transit time correction is made to the observation time.

= -1 — A negative transit time correction is made.

No speed-of-light time correction is made to the observation times of Data Set Types 3, 5, A, or B (Table 15-2); this correction is applied only to the satellite (i.e., not to be station) for Data Set Types H and I. Note that if a nonzero LGT is used to process data generated from an ITIN = 4 run, the sign convention is opposite to that used for an ITIN = 2 run.

2.2.6 Measurement Sigmas

For an orbit determination run, sigmas (weights) must be provided for the measurements. This is accomplished by the SIGMA and KSIG vectors:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	SIGMA	100
	2	.1
	3	.1
	4	200
	5	205
	6	205

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	KSIG	1
I	2	2
I	3	3
I	4	113
I	5	114
I	6	115

SIGMA Observational measurement weights.

KSIG List defining sigma set and data type.

For each entry in SIGMA, a corresponding entry defining the measurement type and sigma set must appear in the KSIG list. The KSIG entries are of the form 100 I + K, where I is the sigma set and K is the measurement type. Ten sets, corresponding to I = 0, 1, 2, . . . , 9, may be entered. The selected value of I is the same as the entry in Column 5 of the STATION cards (Sec. 4). The measurement type K must be one of those listed in Table 2-1.

In the example shown, the sigmas input in SIGMA(1), (2), and (3) are for range, azimuth, and elevation and are to be used with all stations with a zero in Column 5 of the STATION cards. The sigmas input in SIGMA(4), (5), and (6) are for $\hat{x}$, $\hat{y}$, and $\hat{z}$ and are to be used with all stations with a one in Column 5 of the STATION cards.

Table 2-1. Measurement Types for Sigmas

K	Measurement Type	K	Measurement Type
1	Slant range	37	SGLS range rate
2	Azimuth	43	x-antenna
3	Elevation	44	y-antenna
4	Topocentric right ascension	46	JPL two- or three-way doppler
5	Topocentric declination	49	Tranet doppler frequency
6	Topocentric hour angle	50	Tranet doppler base
7	Geocentric right ascension	52	Geoceiver range difference
8	Geocentric declination	55	Vehicle-vehicle range
10	u	56	Vehicle-vehicle range rate
11	v	58	Station-vehicle-vehicle range
12	h, height	59	Station-vehicle-vehicle range rate
13	$\hat{x}$ earth-fixed	61	Station-vehicle-vehicle-vehicle range
14	$\hat{y}$ earth-fixed	64	Station-vehicle-vehicle-vehicle range rate
15	$\hat{z}$ earth-fixed	67	Vehicle-vehicle-vehicle range
16	Slant range	70	Vehicle-vehicle-vehicle range rate
17	P	73	Observation 1 of Data Set Type P
18	Q	76	Observation 1 of Data Set Type Q
19	Range rate	77	Observation 1 of Data Set Type R
20	$\dot{P}$	82	Multipath
21	$\dot{Q}$	85	Two-way range
28	Accelerometer	86	One-way C-band range
29	One-way cumulative doppler	87	One-way L-band range
30	Three-way cumulative doppler	88	Vehicle-vehicle azimuth
31	$\dot{A}$, azimuth rate	89	Vehicle-vehicle elevation
32	$\dot{E}$, elevation rate		
34	Range rate		
35	One-way doppler		
36	Two-way doppler		

If an azimuth sigma is input >0, the azimuth residual and partials for the corresponding sigma set are scaled by the cosine of the elevation. If the azimuth sigma is 0, the residual and partials are not corrected.

The maximum number of entries to each of the SIGMA and KSIG vectors is 100; both vectors are preset to zero.

2.2.7 Refraction Model Indices

TRACE can make the standard TRACE tropospheric refraction corrections to all range and elevation measurements. It can also correct any input range and SGLS range rate data from the Satellite Control Facility tracking stations by using the Ford refraction model. The standard range refraction and the SGLS refraction (Sec. 2.2.9.1) corrections are not made if the Ford model is used. The 1969 Hopfield refraction can be applied to range, elevation, range rate, SGLS range rate, geoceiver, and Tranet measurements.

2.2.7.1 Standard TRACE Model

If the range and elevation data are corrected for tropospheric refraction, RAREF and REFR inputs are necessary and are preset as shown:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	RAREF	350.E-6
	2	0
	3	0
	4	0
	5	0
	6	0
	7	0
	8	0
	9	0
	10	0

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	REFR	312.E-6
	2	0
	3	0
	4	0
	5	0
	6	0
	7	0
	8	0
	9	0
	10	0

RAREF — The refraction indices used with range data. The refraction correction for a station is determined by RAREF(R+1), where R is the range refraction type found in Column 9 of the STATION card for that station ($0 \le R \le 9$).

REFR — The refraction indices used with elevation data. The refraction correction for a station is determined by REFR(E+1), where E is the elevation refraction type found in Column 7 of the STATION card for that station ($0 \le E \le 9$).

For both range and elevation, the correction is zero if the index of refraction selected is zero.

2.2.7.2 Ford Model

When the Ford Tropospheric Refraction Model for range and SLGS range rate measurements is indicated in PANDR(H) (Sec. 2.2.1), it is possible to input factors to be used with the correction. These factors are input in FØRD, which is entirely preset to one:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	FØRD	2.
	2	.5

FØRD — Ford Refraction Model factors:

(j) = 0 — No correction is made.

(j) ≠ 0 — The jth correction factor, where j must be input in Column 9 of the STATION card (Sec. 4) ($1 \le j \le 5$).

2.2.7.3 1969 Hopfield Tropospheric Model

When the Hopfield 1969 Tropospheric Model is used, RFNWL, TH69, PH69, and HH69 must be input. Their values are preset as shown:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	RFNWL	0
	TH69	15.
	PH69	980.
	HH69	50.

RFNWL — Refraction correction indicator (see Sec. 2.2.9.3 for additional usage):

= 2 — The 1969 Hopfield tropospheric refraction correction is applied to range, elevation, range rate, SGLS range rate, geoceiver, and Tranet measurements. No other tropospheric refraction corrections are applied.

TH69 — Model temperature, °C.

PH69 — Model pressure, mbar.

HH69 — Model humidity, %.

2.2.8 Diagonal Matrix Option

The value shown in the following example is preset:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	DIAG	0

DIAG — Option to compute only the diagonal elements of the A^TA matrix:

= 0 — All elements of the A^TA matrix are computed.

≠ 0 — Only the diagonal elements of the A^TA matrix are computed; all off-diagonal elements are assumed to be zero.

This option shortens the computation time when the normal matrix is known to be diagonal (e.g., when the only parameters are radar time biases).

2.2.9 Input for Observational Measurements

Several input observation measurements for an orbit determination run require special input variables. These variables are described in the following subsections.

2.2.9.1 Space-Ground Link Subsystem (SGLS) Range Rate

When SGLS range rate measurements are used, the following variables are required (Ref. 3). All values in the following example are built into TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	MSGLS	1
	FREQ	1800.E6
	CNT1	1048574.0
I	JSGLS	0
	2	350.E-6
I	ISGLS	0
	2	.7068
	3	1.8E6

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	DAYNT	1.83
	2	1.37
	3	-.732
	4	-.305
	5	.3281E6
	6	.82E6
	7	.9843E6
	8	1.1484E6
I	PSGLS	1

MSGLS — Method indicator, used for computing the SGLS count interval δt and the residual for the SGLS range rate:

= 1 — AOES 1967 Method

= 2 — Aerospace 1967 Method.

FREQ — The frequency, cps, used for computing the δt and the residual unless another value is specified on a sensor parameter card.

CNT1 — The quantity N_1, the number of cycles used to compute δt and the measurement residual.

JSGLS — The type and index of refractivity fo: tropospheric refraction to be applied to the generated SGLS range rate measurement (see Sec. 2.2.11.4) for additional usage:

(1) = 0 — No tropospheric refraction correction is made.

(1) = i — Tropospheric refraction type for the residual ($1 \le i \le 5$). Not applicable if PANDR(H) = X.

(2) — The index of refractivity used to apply tropospheric refraction corrections.

ISGLS — Ionospheric refraction correction constants for SGLS range rate measurements:

(1) — Ionospheric refraction correction indicator:

= 0 — No correction is applied.

= 1 — The ionospheric refraction correction is applied.

(2) — The quantity C_I used to compute the ionospheric refraction correction.

(3) — The frequency f used to compute the ionospheric refraction correction, kHz.

DAYNT — Table of day and night values:

(1) — Day β_b'.

(2) — Night β_b'.

(3) — Day β_t'.

(4) — Night β_t'.

(5)	Day h_ℓ.
(6)	Night h_ℓ.
(7)	Day h_m.
(8)	Night h_m.

PSGLS Partials computation flag:

= 1	Partials are computed at the final modified time.
= 2	Partials are computed at two times dependent on δt and then differenced.

2.2.9.2 JPL Doppler

When the JPL two- or three-way doppler data measurements are used, DØPRF and JMAX must be input. The values in the following example are built into TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	DØPRF	300.
I	JMAX	10

DØPRF Index of refraction for JPL two- or three-way doppler data.

JMAX The maximum number of iterations for computing the JPL two- or three-way doppler measurement. (Note that JMAX is also used when the SGLS range rate data is generated (Sec. 2.4.5.1).

2.2.9.3 Tranet

The values in the following examples are preset in TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	TNTY	0
	TRØPH	20.
	ELEDD	0

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	RFNWL	0
	2	.25525E-2
	3	.1238
	4	.6757E-5
	5	.23E-2
	6	1.
	7	.25

TNTY — Computation method indicator used for Tranet doppler data:

- = 0 — The computed frequency contains effects due to relativity considerations and refraction.
- = 1 — The computed frequency difference contains no relativity or refraction effects.

TRØPH — Tropospheric height for the tropospheric refraction correction used with Tranet doppler data, km.

ELEDD — Minimum geometric elevation for Tranet measurement acceptance, deg:

- ≠ 0 — If the satellite is lower than ELEDD at observation time, the measurement is not accepted.

RFNWL Tropospheric correction indicator (NWL, 1963 Hopfield, or 1969 Hopfield) for Tranet data and constants:

(1) Tropospheric correction indicator:

= 0 1963 Hopfield tropospheric refraction correction.

= 1 NWL refraction correction, which requires the constants in (2) through (7).

= 2 1969 Hopfield tropospheric refraction correction. This option overrides every other tropospheric refraction option.

(2) C_0

(3) C_1

(4) C_2

(5) N_j

(2)–(5): Constants used in the computation of the NWL refraction correction.

(6) λ

(7) FAC

(6)–(7): Constants used in the sigma perturbation computation

$$(1/\sigma^2)' = 1/(\sigma^2 + FAC \times REF^2)$$

where σ is the input measurement sigma (Sec. 2.2.6) and REF is the computed refraction correction.

2.2.9.4 Geoceiver or CCID

GDELT is preset as shown in the following example, and SFREQ is preset to zero:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	GDELT	1.
	SFREQ	180.E8

GDELT — The time difference between geoceiver observations, min.

SFREQ — The satellite frequency for geoceiver range difference data, cps.

A nonzero OBSERVATION 3 on the OBSERVATION card (Table 15-2) for Data Set Type I indicates that CCID, rather than geoceiver, data is used. CCID measurements are computed in the same way as geoceiver measurements except that a variable time step is used. OBSERVATION 1 on the first OBSERVATION card of each station pass combination must equal zero; its time is taken as the initial time for this station pass. The time difference for computation is the difference between the last and the current observation times.

For either geoceiver or CCID measurements, if the sigmas are input on OBSERVATION cards (Table 15-2), a scale factor can be applied to the sigmas. This scale factor is input at SSCL as shown in the example (preset to 1):

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	SSCL	1.5

SSCL Scale factor applied to geoceiver or CCID sigmas input on OBSERVATION cards (Sec. 15).

2.2.9.5 Time-of-Arrival

Time-of-arrival measurements use the following variables unless other values are specified on the sensor parameter cards (Sec. 5). The values shown in the example are not preset:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	DRIFT	2
	BEAC	.0001
	CAPT	.025

DRIFT Oscillator drift rate.

BEAC Initial time offset, sec.

CAPT Inner pulse period, sec.

2.2.10 Right-Hand Side A Priori Input

The following inputs are not preset in TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	IAPR	2
	PZERØ	10.
	2	11.
	3	12.
	4	1.
	5	2.
	6	3.

IAPR The a priori indicator for $A^T WB$ (right-hand side) used when MULTV = 0 or 1:

= 0 The weighted SOS of the residuals is minimized (preset value).

= 1 The weighted SOS of the residuals plus the SOS of the total parameter corrections (weighted by the a priori parameter covariance matrix) are minimized.

= 2 Same as IAPR = 1 except that the total parameter corrections include the contents of PZERØ.

PZERØ Vector of P-parameter corrections used when IAPR = 2. Parameter corrections in this vector must be in the same order as the parameter list.

2.2.11 Input for the Sequential Least Squares Algorithm

Special emphasis is given to the input items used when the orbit determination algorithm is the SLS (sequential least squares) process. Those inputs indicated in the following sections are either not applicable to the weighted least squares process, or they are used in a different manner. The values shown in this example are not preset:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	MULTV	2
I	LPACK	1
	STAGE	20

MULTV Simultaneous-vehicle indicator:

= 2 The orbit determination is done by the SLS process. Note that other uses for MULTV are given in Sec. 2.1.6.

LPACK Timesaving flag used when MULTV = 2:

$\neq 0$ To save running time, LPACK should be input nonzero if there are ten or fewer vehicles and if the observations do not contain covariance codes = 4 or 5.

STAGE Constant update interval for the SLS procedure, min:

= 0 Prespecified update intervals are provided by the STAGE data block (Sec. 14).

$\neq 0$ The update interval is defined, and the STAGE data block is not used.

In addition to the above inputs, an $(A^T A)^{-1}$ matrix (Sec. 6) is required; the DEWM data block (Sec. 7) is optional. At present, only the following observational measurements (Table 15-2) are acceptable:

Data Set Type	Definition
1	Range, azimuth, and elevation
2	Topocentric right ascension, declination, and hour angle
7	Range rate
D	SGLS range rate
F	x- and y-antennas
J	Vehicle-to-vehicle range and range rate
K	Station-to-vehicle-to-vehicle range sum and range rate sum
L	Station-to-vehicle-to-vehicle-to-vehicle range sum
M	Station-to-vehicle-to-vehicle-to-vehicle range rate sum
N	Vehicle-to-vehicle-to-vehicle range sum
Ø	Vehicle-to-vehicle-to-vehicle range rate sum
P, Q, R	User-defined measurements (Sec. 10)
S	Multipath
U	Vehicle-to-vehicle azimuth and elevation (or topocentric vehicle-vehicle right ascension and declination).

2.2.11.1 Input/Output Options

All options except PANDR and SSPR are preset as shown:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
D	PANDR	ABCDEFGHIJKLMNOP
	ØPBØX	A
	PATA	0
	PUNMS	0
	GPLØT	0
	2	4.
D	SSPR	ABCDE
	MVET	0

PANDR A 20-character vector used to control certain input and output options (Sec. 2.2.1):

Position

I = X The updated $(A^T A)^{-1}$ matrix is punched after the last iteration of every stage.

I = Y The updated $(A^T A)^{-1}$ matrix is punched only after the last iteration of the last stage.

L = X An eigenvalue analysis is performed in conjunction with the solution of normal equations at less than full rank. This option requires KRANK, KINC, and RHØ (Sec. 2.2.1).

Q = Y Auxiliary least squares data is output.

P = X — The predicted residuals are printed on the first iteration of each stage if PANDR(A) (Sec. 2.2.1) is blank; i.e., if the residuals are being printed.

ØPBØX — The $A^T A$ matrix input indicator:

Position

A = 7 — The $(A^T A)^{-1}$ matrix is preset from the input parameter sigmas. Note that ØPBØX(A) is internally reset to 4 after the first $(A^T A)^{-1}$ matrix is computed. The ATA and END cards from the ATA data block (Sec. 6) must be input.

PATA — The $A^T A$ and $(A^T A)^{-1}$ print indicator:

= 0 — Neither matrix is printed.

= 1 — The $A^T A$ matrix is printed after every iteration.

= 2 — The $(A^T A)^{-1}$ matrix is printed after every iteration.

= 3 — Both matrices are printed after every iteration.

PUNMS — Punch indicator for the updated state vector:

= 0 — No punching.

= 1 — The time (MME) and updated state vector (Cartesian coordinates) are punched after the last iteration of each stage in a format acceptable as TRACE input.

= 2 — The time and vector are punched only after the last stage.

GPLØT	The n and time scale for the $n\sigma/2$ residual printer plot:	
	(1) = 0	No measurement residual plots are printed.
	= n	The n for the $\pm n\sigma/2$ printer plot of the residuals about the mean at convergence of the last stage. The quantity σ is the standard deviation determined by SSPR(E) for the station measurement type. This option also results in a printed total edit summary.
	(2) = Δt	Time scale for the printer plot, sec. If input is zero, the program computes a Δt.
SSPR	Residual output option:	
	Position	
	A = 0 or blank	There is no additional output.
	A = X	Data is output as requested by Positions B through E.
	B = 0 or blank	Measurement residuals on the converged iteration are printed by station; the residuals from each station are still in time sequence (all residuals for the first station are printed, then all those from the second, etc).
	B = X	Station-sorted residuals are not printed.
	C = 0 or blank	No edit summary is printed.

C = X	A total edit summary is printed.
D	Not used.
E = 0 or blank	The computed sigma is used for the plotting requested by GPLØT.
E = X	The input sigma is used (Sec. 2.2.6) unless it equals zero; in that case, the computed sigma is used.

MVET — Best-fit ephemeris indicator for SLS:

= 0	No action.
= 1	A best-fit ephemeris is built over all stages of Vehicle i and is written on TAPE30+i, where $1 \leq i \leq 10$. This option cannot be used concurrently with LPACK (Sec. 2.2.11).
= 2	Fit-predict option. At the convergence of each stage, TRACE uses that vector to predict the satellite position for N revs (N input at DNØDE, Sec. 11.2.3). At the same time, TRACE differences the predicted node times with those input at DNØDE.

2.2.11.2 Termination Criteria

Values shown in the following example are preset:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	SMIN	0.
	PRIØR	100.

SMIN — Termination criterion for SLS. If

$$NOBC/(NOBC + NOBE) < SMIN$$

the current stage is completed, and the SLS process then stops. NOBC is the number of observations accepted, and NOBE is the number of observations edited because of NEDIT and FEDIT (Sec. 2.2.11.3).

PRIØR — Maximum allowable a priori RMS for the continuation of the SLS process.

2.2.11.3 Observation and Residual Editing

The following values are preset in TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	ELEDD	0.
	KEDIT	0.
	FEDIT	0.
	NEDIT	100.

ELEDD — Minimum elevation for measurement acceptance, deg. If the satellite is below this angle at observation time, the following measurements are not accepted: range, azimuth, elevation. and SGLS range rate.

KEDIT — Azimuth and elevation residual editing criterion for SLS. TRACE does not accept these measurements if

$$\sigma_p^2 \Big/ \left(\sigma_p^2 + \sigma_n^2\right) < \text{KEDIT}$$

where σ_p is the residual predicted from the satellite position and velocity covariance matrix and σ_n is the input sigma (Sec. 2.2.6).

FEDIT — Residual editing indicator for the first iteration:

- $= 0$ — No editing is done on the first iteration.
- $\neq 0$ — Residuals are edited during the first iteration, using n = FEDIT and σ_p as σ.

NEDIT — Residual editing indicator for iterations after the first:

- $= 0$ — No editing is done after the first iteration.
- $\neq 0$ — Residual editing is done after the first iteration, using n = NEDIT and the input sigmas (Sec. 2.2.6).

2.2.11.4 Refraction Corrections

Values in the following example are not preset:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	JSGLS	6
	2	350.E-6

JSGLS The tropospheric refraction indicator and index of refractivity:

(1) = 0 Range, elevation, and SGLS range rate measurements are not corrected for tropospheric refraction.

≠ 0 A Hopfield 1969 tropospheric refraction correction is applied to the range and elevation measurements, and different corrections are applied to the SGLS range rate measurement, according to the following:

= 1 Lockheed

= 2 Aerospace

= 3 General Electric

= 4 APL

= 5 JPL

= 6 Hopfield 1969

(2) Index of refractivity used to apply the refraction corrections.

When the Hopfield 1969 Tropospheric Model is used, RFNWL, TH69, PH69, and HH69 must be input. Their values are preset as shown:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	RFNWL	0
	TH69	15.
	PH69	980.
	HH69	50.

RFNWL Refraction correction indicator (see Sec. 2.2.9.3 for additional usage):

= 2 The 1969 Hopfield tropospheric refraction correction is applied to range, elevation, range rate, SGLS range rate, range sums, and multipath measurements. No other tropospheric refraction corrections are applied.

TH69 Model temperature, °C.

PH69 Model pressure, mbar.

HH69 Model humidity, %.

2.2.11.5 Transit Time Correction Indicator

LGT is the speed-of-light (transit) time correction flag, which is preset as:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	LGT	0

LGT Transit time correction indicator:

= 0 No change is made to the observation time.

= 1 A positive transit time correction is made to the observation time.

= -1 A negative transit time correction is made.

This transit time correction is made only for Data Set Types 1, D, F, L and N and only for the range measurements of Data Set Types J and K.

2.3 DATA FOR EPHEMERIS GENERATION RUNS (ITIN = 3)

Input/output options for ephemeris generation runs are described below.

2.3.1 Automatic Closure

For an automatic closure run, NCLØS is input nonzero; e.g.:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	NCLØS	1

This option requires two sets of VEHICLE data. The program integrates to the final time of the first vehicle, takes the state vector from this point, and integrates backwards to epoch. The second set of VEHICLE inputs requires an epoch equal to the final time of the first vehicle (Sec. 11.1.3); a set of initial conditions, which are ignored (Sec. 11.1.4); and a print time vector (PTIM) setup for integrating backwards (Sec. 11.3.1). The first and final times of PTIM must equal the final and first times of PTIM for the first vehicle, and the print time steps must be negative.

2.3.2 Eclipsing

RE, RS (Sec. 2.1.2.6), and RM must be input when output is requested at entry to or exit from the umbra or penumbra of the earth or moon by PRCDE(H) (Sec. 11.3.1) and when the earth is the central body during the integration. The value in the example below is preset as:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	RM	.2725063

RM Effective lunar radius, er, used only for eclipsing calculations (see PAE(3), Sec. 2.1.3).

If a solar system body other than the earth is the central body during integration, its radius for eclipsing is obtained from the PAE vector (Sec. 2.1.3). In this case, the requested output obtains entry to or exit from the umbra or penumbra of the central body or the earth. The radii of the earth and sun are still obtained from RE and RS.

2.3.3 Output Options

The following options are not preset:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	PTAPE	1
	UBET	1
	FJDAT	38623.

PTAPE Special earth-fixed tape generation indicator:

≠ 0 An earth-fixed tape is generated on TAPE 9 if MSYS = 2 or 3 (Sec. 11.3.1.3). Each record contains the Julian date of instant, position, and velocity in earth-fixed coordinates and the matrix used to transform from ECI to EF orbit-plane coordinates (radial, intrack, and crosstrack).

UBET Requestor of BLAMEX interface tape:

≠ 0 A UBET tape is written on TAPE9 to interface with the BLAMEX Program (Ref. 6).

FJDAT Final Julian date for the UBET tape.

2.4 DATA FOR MEASUREMENT DATA GENERATION RUNS (ITIN = 4)

Output options for measurement data generation runs are described below.

2.4.1 Output Options

Several optional output capabilities for data generation runs are controlled by MODEL inputs. These are described in the following subsections.

2.4.1.1 Visibility Printer Plot

TRACE can output a printer plot at the end of a data generation run to indicate the pass visibility of a vehicle to the stations. The beginning and end of each pass are indicated by an R and an S, respectively (an X indicates that the pass begins and ends within the same interval). The value of RSPLT is shown below (not preset):

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	RSPLT	4.

RSPLT Visibility printer plot time scale, min:

= 0 No printer plot is made.

≠ 0 The rate at which the printer plot is output (TAPE9 can be saved for station visibility information, Sec. 16.9).

2.4.1.2 Specification of Distance Output Units

Normally, all generated distances (range, height, surface range, etc.) are printed in nmi, and DCF is preset as follows:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	DCF	3443.9336

DCF Conversion factor (from er) for distance output units for data generation; e.g., if the distances are to be printed in ft, DCF = 20925738.

2.4.1.3 Pass Summary

The value shown in the following example is not built into TRACE and is preset to zero:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	JSUM	1

JSUM Pass summary indicator:

= 0 No pass summary.

≠ 0 A pass summary is printed at the end of each data generation run in the order prescribed by JSØRT (Sec. 11.4.1.1). It contains the following data for each pass: station ID; pass number; rise time; azimuths at the times of rise, maximum elevation, and set; maximum elevation; and duration. Each line contains the current total visibility to both the viewing station and the vehicle.

2.4.1.4 Specific Ranges and Range Rates

To obtain an indication of when the vehicle encounters a certain range or range rate during visibility, the user inputs the values of interest at RANGE or RRATE. The values shown in the following example are not built into TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	RANGE	2
	2	500.
	3	600.
I	RRATE	1
	2	25000.

RANGE Table of ranges to search for during visibility:

(1) = 0 No special range is searched for.

= n The number of ranges for which to search ($1 \leq n \leq 5$).

(2) The first range

.

.

.

(n+1) The n^{th} range.

(2) through (n+1): Each particular range is input in units consistent with DCF (Sec. 2.4.1.2).

RRATE Table of range rates to search for during visibility:

(1) = 0 No special range rate is searched for.

= m The number of range rates for which to search ($1 \leq m \leq 5$).

(2) The first range rate, ft/sec.

.

.

.

(m+1) The m^{th} range rate, ft/sec.

2.4.1.5 Measurement Data Tape Generation

The variable in the following example is preset to zero:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	GDPLT	1.

GDPLT Measurement data tape generation indicator:

$\neq 0$ All data generated for all stations is written on a nonstandard binary tape on TAPE10 (Sec. 16.11).

2.4.1.6 Station Locations

The value in the following example is preset in TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	CLASS	0

CLASS — Input station location print option:

≠ 0 — No station locations or input sensor parameters are printed.

2.4.1.7 Occultation

The value shown in the example is not preset:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	JØCC	1

JØCC — Occultation test indicator:

≠ 0 — The test for occultation of the vehicle by the body indicated at JBCI (Sec. 11.1.4) is made.

2.4.1.8 Simultaneous-Vehicle Data Generation Output Indicators

The following items are input for simultaneous-vehicle data generation visibility output (MULTV > 0). The preset values are shown in the following example:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	IVIS	0
	VALT	0
I	ICC	0

IVIS — Simultaneous-vehicle visibility print indicator:

= 0 — No simultaneous-vehicle visibility prints are output.

= 1 — Visibility matrices, printer plots, and normal measurements are output.

= 2 — Only visibility matrices and printer plots are output.

= 3 — Visibility printer plots are generated between all vehicles and all stations and between each vehicle and every other vehicle. DATA GENERATION II cards are not considered (Sec. 12.2.2), and JRIST must not equal zero (Sec. 11.4.1).

VALT or HAE — Visibility constraint altitude above a spherical earth, nmi. It is used in direct line-of-sight computation between two vehicles.

ICC Simultaneous-vehicle correlated measurement indicator:

= 0 Generated measurements are uncorrelated.

= 1 Correlated measurements are generated; i.e., the covariance code field is set to 4 or 5 (Table 15-1).

2.4.2 Transit Time Correction Indicator

LGT is the transit (speed-of-light) time correction flag and is preset as shown in the example:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	LGT	0

LGT Speed-of-light time correction indicator:

= 0 No change is made in the time at which the observations are generated. This is always true when MULTV is nonzero (Sec. 2.1.6).

≠ 0 The time at which data is generated is corrected for the speed of light. The printout of the observation time does not reflect the correction. Columns 17, 18, 19, 22, 24, 25, 27, 29, 31, 33, 34, and 43 of the DATA GENERATION II card cannot contain an X (Sec. 12.2.1).

= 1 The sign of the correction is positive.

= -1 The sign of the correction is negative.

2.4.3 Measurement Sigmas

Sigmas (standard deviations) must be provided for the data when measurement data is generated with noise. These sigmas are input by the SIGMA and KSIG vectors. A maximum of 100 entries may be made to each of the SIGMA and KSIG vectors; both vectors are preset to zero. An example of input follows:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	SIGMA	100
	2	.1
	3	.1
	4	200
	5	205
	6	205

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	KSIG	1
I	2	2
I	3	3
I	4	113
I	5	114
I	6	115

SIGMA Observational measurement standard deviations.

KSIG List defining sigma set and data type.

For each entry in SIGMA, a corresponding entry defining the measurement type and sigma set must appear in the KSIG list. The KSIG entries are of the form 100 I + K, where I is the sigma set and K is the measurement type. Ten sets corresponding to I = 0, 1, 2, . . . , 9 may be entered. This selected value of I is the same as the entry in Column 5 of the STATION cards (Sec. 4). The measurement type K must be one of those listed in Table 2-1.

In the example shown, the sigmas input in SIGMA(1), (2), and (3) are for range, azimuth, and elevation and are to be used with all stations with a zero in Column 5 of the STATION cards. The sigmas input in SIGMA(4), (5), and (6) are for $\hat{x}$, $\hat{y}$, and $\hat{z}$ and are to be used with all stations with a one punched in Column 5 of the STATION cards.

Table 2-1. Measurement Types for Sigmas

K	Measurement Type	K	Measurement Type
1	Slant range	37	SGLS range rate
2	Azimuth	43	x-antenna
3	Elevation	44	y-antenna
4	Topocentric right ascension	46	JPL two- or three-way doppler
5	Topocentric declination	49	Tranet doppler frequency
6	Topocentric hour angle	50	Tranet doppler base
7	Geocentric right ascension	52	Geoceiver range difference
8	Geocentric declination	55	Vehicle-vehicle range
10	u	56	Vehicle-vehicle range rate
11	v	58	Station-vehicle-vehicle range
12	h, height	59	Station-vehicle-vehicle range rate
13	$\hat{x}$ earth-fixed	61	Station-vehicle-vehicle-vehicle range
14	$\hat{y}$ earth-fixed	64	Station-vehicle-vehicle-vehicle range rate
15	$\hat{z}$ earth-fixed	67	Vehicle-vehicle-vehicle range
16	Slant range	70	Vehicle-vehicle-vehicle range rate
17	P	73	Observation 1 of Data Set Type P
18	Q	76	Observation 1 of Data Set Type Q
19	Range rate	77	Observation 1 of Data Set Type R
20	$\dot{P}$	82	Multipath
21	$\dot{Q}$	85	Two-way range
28	Accelerometer	86	One-way C-band range
29	One-way cumulative doppler	87	One-way L-band range
30	Three-way cumulative doppler	88	Vehicle-vehicle azimuth
31	$\dot{A}$, azimuth rate	89	Vehicle-vehicle elevation
32	$\dot{E}$, elevation rate		
34	Range rate		
35	One-way doppler		
36	Two-way doppler		

2.4.4 Refraction Model Indices

TRACE can make the standard TRACE tropospheric refraction corrections to all range and elevation measurements or it can apply the 1969 Hopfield refraction to certain measurements.

2.4.4.1 Standard TRACE Model

To correct the range and elevation data for tropospheric refraction, RAREF and REFR, respectively, must be input. They are preset as shown in the example:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	RAREF	350.E-6
	2	0
	3	0
	4	0
	5	0
	6	0
	7	0
	8	0
	9	0
	10	0

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	REFR	312.E-6
	2	0
	3	0
	4	0
	5	0
	6	0
	7	0
	8	0
	9	0
	10	0

RAREF — The refraction indices used with range data. The refraction correction for a station is determined by RAREF(R+1), where R is the range refraction type found in Column 9 of the STATION card for that station ($0 \leq R \leq 9$).

REFR — The refraction indices used with elevation data. The refraction correction for a station is determined by REFR(E+1) where E is the elevation refraction type found in Column 7 of the STATION card for that station ($0 \leq E \leq 9$).

For both range and elevation, the correction is zero if the index of refraction selected is zero.

2.4.4.2 1969 Hopfield Tropospheric Model

When the Hopfield 1969 Tropospheric Model is used, RFNWL, TH69, PH69, and HH69 must be input. Their values are preset as shown:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	RFNWL	0
	TH69	15.
	PH69	980.
	HH69	50.

RFNWL — Refraction correction indicator:

= 2 — The 1969 Hopfield tropospheric refraction correction is applied to range, elevation, range rate, SGLS range rate, geoceiver, and antenna angle measurements when MULTV = 0 and to range, elevation, range rate, SGLS range rate, range sums, and multipath measurements when MULTV ≠ 0. No other tropospheric refraction corrections are applied.

TH69 — Model temperature, °C.

PH69 — Model pressure, mbar.

HH69 — Model humidity, %.

2.4.5 Input for Generated Measurements

When certain measurements are requested, special input is required. This special input is described in the following subsections.

2.4.5.1 Space-Ground Link Subsystem (SGLS) Range Rate

Several inputs are required when the SGLS range rate is to be generated (Ref. 3). The values are preset in TRACE as:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	MSGLS	1
	FREQ	1800. E6
	CNT1	1048574. 0
I	JMAX	10
	SEPS	1

MSGLS — Method indicator, used for computing the SGLS count interval δt:

= 1 — AOES 1967 Method.

= 2 — Aerospace 1967 Method.

FREQ — The frequency, cps, used for computing δt unless another value is specified on a sensor parameter card (Sec. 5).

CNT1 — The quantity N_1, the number of cycles used to compute δt.

JMAX — The maximum number of iterations used to generate SGLS data if

$$|N_2^i - N_2^{i-1}| \geq \epsilon$$

where N_2^i is an internally computed number and ϵ = SEPS.

SEPS — The convergence criterion ϵ used during the iterative process of computing N_2^i.

2.4.5.2 Tranet Doppler

The values shown in the following example are not built into TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	TFREQ	107.E8
I	TNTY	1

TFREQ — The satellite base frequency used when Tranet doppler data is generated, cps. Note that TFREQ is used differently in Sec. 2.4.5.4.

TNTY — Computation method indicator for Tranet doppler data:

= 0 — The computed frequency contains effects due to relativity considerations.

= 1 — The computed frequency difference contains no relativity effects.

2.4.5.3 Geoceiver

An example of SFREQ input is shown (preset to zero):

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	SFREQ	108.E8

SFREQ The satellite frequency used to generate geoceiver range difference data, cps.

2.4.5.4 Satellite-Tracker Doppler

The value in the following example is not preset:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	TFREQ	105.E8

TFREQ Frequency used when satellite-tracker doppler data is generated, cps. Other usage of TFREQ is described in Sec. 2.4.5.2.

2.4.5.5 Time-of-Arrival

When time-of-arrival measurements are generated for a single station and when MULTV = 0 or 1, CAPT input is used unless another value is found on the sensor parameter card (Sec. 5). The value in the following example is not preset:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	CAPT	.025

CAPT Inner pulse period, sec.

2.4.5.6 Vehicle-to-Vehicle Angles

Certain visibility constraints are applied when vehicle-to-vehicle azimuth and elevation angles are generated. The values in the following example are not preset:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	TAMN	0.
	TAMX	24.
	BETAS	60.
	BETAM	15.
	RDMIN	0.
	RDMAX	4.

TAMN — Minimum local time constraint for vehicle-to-vehicle angle visibility, hr ($0 \le TAMN \le 24$).

TAMX — Maximum local time constraint for vehicle-to-vehicle angle visibility, hr ($0 \le TAMX \le 24$).

BETAS — Minimum angle between the sun and the vehicle-to-vehicle line of sight for angle visibility, deg ($0 \le BETAS \le 360$).

BETAM — Minimum angle between the moon and the vehicle-to-vehicle line of sight for angle visibility, deg ($0 \le BETAM \le 360$).

RDMIN — Minimum line-of-sight rate for vehicle-to-vehicle angle visibility, deg/sec.

RDMAX — Maximum line-of-sight rate for vehicle-to-vehicle angle visibility, deg

2.5 DATA FOR COVARIANCE ANALYSIS RUNS (ITIN = 5)

Input/output options for covariance analysis runs are described below.

2.5.1 Input/Output Options

The covariance analysis input/output options are determined by the variables (not preset) shown in the following examples:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
D	ØPBØX	ABCDEFGH
I	NATAP	1
D	PRCØV	ABCDEFGHIJKLMNØPQR
I	NDPRT	0
D	PANDR	ABCDEFGHIJK
	CLASS	0

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	NCVØB	0
I	NCVEF	0
	CMFSC	0
	PEPH	0

ØPBØX — $A^T A$ covariance analysis input/output character indicator:

<u>Position</u>

A = 0 or blank	No initial $A^T A$ is input.
= 1	The diagonal elements of the $(A^T A)^{-1}$ matrix are input in the sigma field of the parameter cards (Secs. 2.1.5, 5, and 11.1.14) (variance input).
= 2	The square roots of the diagonal elements of the $(A^T A)^{-1}$ matrix are input in the sigma field of the parameter cards (standard deviation input).
= 3	The $A^T A$ matrix is input (Sec. 6.1).
= 4	The $(A^T A)^{-1}$ matrix is input (Sec. 6.2).
B = 0 or blank	The square roots of the diagonal elements of C(Q) are input in the sigma field of the parameter cards.
= 1	The C(Q) matrix is input (Sec. 8).
C = 0 or blank	$\partial P/\partial Q$ and $\partial P/\partial Q \times \sigma_Q$ are not printed; σ_Q is the sigma input on a Q-parameter card (Secs. 2.1.5, 5, and 11.1.14) or from the $C(Q_o)$ matrix (Sec. 8).
= 1	Only the $\partial P/\partial Q$ matrix is printed.
= 2	Only the $\partial P/\partial Q \times \sigma_Q$ matrix is printed.
= 3	Both matrices are printed.

D = 0 or blank	A complete covariance analysis, using DATA GENERATION cards, is simulated.
= 1	A complete covariance analysis, using input observations (cards, card image file, or binary file), is simulated.
= 2	The covariance analysis simulation is only a time update of an input A^TA or $(A^TA)^{-1}$ matrix. No measurements are used. This option is used with ØPBØX(E) = 1.
E = 0 or blank	A complete covariance analysis with real-time output is simulated (output at time t is based on tracking data up to and including time t).
= 1	The covariance analysis simulation is only a time update of an input A^TA or $(A^TA)^{-1}$ matrix. No measurements are used. This option is used with ØPBØX(D) = 2.
= 2	The covariance analysis with postflight output is simulated (output at time t is based on all tracking data over the entire simulation period).
F = 0 or blank	No covariance analysis sigma plot tape is generated.
= 1	A plot tape is generated on TAPE8 when MULTV = 0 and on TAPE12 when MULTV = 1 or 2 (Secs. 2.1.6 and 16.12).
= 2	When MULTV = 1 or 2, TAPE12 is generated and all printing indicated by PRCØV and ØPBØX is suppressed between the first and last print times unless NDPRT ≠ 0.

G = 0 or blank	The A^TA matrix is not punched or printed.
= 1	The final A^TA matrix is punched.
= 2	The A^TA matrix is punched after every print time.
= 3	The A^TA matrix is punched after every n^{th} print time, where n is specified in NATAP (MULTV = 0). If n = 0, the matrix is printed every print time.
= 4	The final A^TA matrix is printed (MULTV = 1 or 2).
= 5	The A^TA matrix is printed after every print time (MULTV = 1 or 2).
= 7	The final A^TA matrix is printed and punched (MULTV = 1 or 2).
= 8	The A^TA matrix is printed and punched after every print time (MULTV = 1 or 2).
H	When MULTV = 1 or 2, Position H contains an m:
	m = 0 The block diagonals of the state vector covariance matrices are printed.

m = 1 . . . m = 8	The intersatellite covariance (off-diagonal blocks) matrices of all the satellites with respect to the first m satellites are printed.
m = 9	All of the intersatellite covariance matrices are printed.

NATAP The n^{th} time for $A^T A$ output associated with ØPBØX(G) = 3.

NDPRT The n^{th} print time for ØPBØX(F):

= n Output occurs at every n^{th} print time when ØPBØX(F) = 2.

PRCØV Vector of characters used to control variance-covariance matrix output (Table 2-2).

PANDR A vector that controls certain input/output options for covariance analysis studies. An X in the proper position results in the following:

<u>Position</u>

A	Not used.
B	Measurement partials are printed.
C	Not used.
D	This position must not be used.
E	Printing of the input observations is suppressed.

Table 2-2. Variance-Covariance Print Options (PRCØV)

Position	Character	Output Type	Matrix Output
A	A (X for MULTV = 0)	Entire matrix and square roots of the diagonal elements.	$C(P_o) = (A^T A)^{-1}$: Covariance matrix of P-parameters.[b]
	B[a]	Parameter correlation matrix and square roots of the diagonal elements.	
	C[a]	$(A^T A)^{-1}$ and correlation matrices and square roots of the diagonal elements.	
	D	Square roots of the diagonal elements.	
B	X	Entire matrix and square roots of the diagonal elements.	C(X): Cartesian state covariance matrix at the current time.
	D	Square roots of the diagonal elements only.	
C	X	Entire matrix and square roots of the diagonal elements.	$C(\xi)$: Orbit plane state covariance matrix at the current time.
	D	Square roots of the diagonal elements only.	
D	X	Entire matrix and square roots of the diagonal elements.	C(R): Spherical state covariance matrix at the current time.
	D	Square roots of the diagonal elements only.	
	Y	Entire matrix and square roots of the diagonal elements.	C(S): Topocentric (Up-East-North) state covariance matrix at the current time.
	I	Square roots of the diagonal elements only.	

[a] This option is not available when MULTV = 0.

[b] For positions B through F and H through L, the character X yields correlation matrices plus covariance matrices if MULTV = 1, 2 (Sec. 2.1.6).

Table 2-2. Variance-Covariance Print Options (PRCØV) (Continued)

Position	Character	Output Type	Matrix Output
E	X	Entire matrix and square roots of the diagonal elements.	C(E): Classical covariance matrix at the current time.
	D	Square roots of the diagonal elements only.	
F	X	Entire matrix and square roots of the diagonal elements.	Period-apogee-perigee state covariance matrix at the current time if MULTV = 0. If MULTV ≠ 0, f and g covariance matrix at the current time.
	D	Square roots of the diagonal elements only.	
G-L		Same as PRCØV(A-F), but Q-parameter effects are included.	
M-R[a]	A	CEP (circular error probability) and SEP (spherical error probability) calculations.	Based on the covariance matrices selected in PRCØV(A-F) and (G-L), respectively.
	B	CEP calculations only.	
	C	SEP calculations only.	
S[b]	≠O	Output of all observation covariance matrices is suppressed.	
T[b]	≠O	Output of all covariance matrices, other than observations, is suppressed.	

[a]This option applies only to MULTV = 1 or 2. The only covariance matrix that may currently be analyzed is C(ξ), PRCØV(Ø), which is rotated such that the intrack axis is in the direction of the velocity vector.

[b]This option is to be used with the CEP and SEP calculations selected by PRCØV(M-R). It should be used carefully since the output requested by PRCØV(A-L) is suppressed.

	F	Not used.
	G	The partials of range and SGLS range rate with respect to radial, intrack, and crosstrack positions are computed and printed. This is done for all stations with nonzero sigmas for range and SGLS range rate measurements.
	H - K	Not used.
CLASS	Input station location print option:	
	≠ 0	Station locations and input sensor parameters are not printed.
NCVØB	Special variance-covariance matrices output indicator:	
	= 0	There is no additional output.
	≠ 0	Variance-covariance matrices for measurements (range, azimuth, elevation, range rate, and x- and y-antenna angles) and error ellipses in azimuth-elevation and elevation/cross-elevation planes (including only P effects or P plus Q effects) are printed according to the following:
	= 1	Observation covariance matrices and CEP (circular error probability) and SEP (spherical error probability) information are printed.
	= 2	Observation covariance matrices and CEP information are printed.
	= 3	Same as NCVØB = 1 except that it is used only when the elevation angle >0.

= 4	Same as NCVØB = 2 except that it is used only when the elevation angle > 0.
= 5 through 10	Only observation covariance matrices are printed.
= 11	Same as NCVØB = 1; plus a CEP and SEP data tape is generated on TAPE12 (Sec. 16).
= 12	Same as NCVØB = 2; plus the TAPE12 is also generated.
= 13	Same as NCVØB = 3; plus the TAPE12 is also generated.
= 14	Same as NCVØB = 4; plus the TAPE12 is also generated.

If MULTI ≠ 0, only the observation covariance matrices are printed. CEP and SEP information and TAPE12 generation are not available.

NCVEF   EF variance-covariance matrices output indicator:

≠ 0	EF variance-covariance matrices are printed (MULTV = 0 only).

CMSFC   Covariance matrix scale factor indicator:

≠ 0	A scale factor is computed such that, when it is applied to the RTC covariance matrix, the resulting mean intrack variance over the print interval equals $CMSFC^2$. This scale factor is then applied to the Cartesian, RTC, and EF covariance matrices, and the results are printed.

< 0 — The EF vector and the scaled covariance matrix are also punched and are in TRACE OBSERVATION format (Sec. 15).

= ±1 — The scale factor is set to one, rather than computed.

PEPH — Ephemerides print suppression indicator

≠ 0 — Printing of the ephemerides is suppressed during a simultaneous-vehicle run (MULTV > 0, Sec. 2.1.6).

CEPF — CEP-SEP vehicle selection flag:

= 0 — Calculate the CEP and SEP information (see PRCØV) for all vehicles when MULTV = 1 or 2.

= n — Compute CEP and SEP information only for Vehicle n, where n is the relative vehicle number (i.e., not VEHID), where $1 \le n \le 20$.

2.5.2 Transit Time Correction Indicator

LGT is a transit time correction flag built into TRACE (preset to zero). The convention used for the value of LGT for an orbit determination run should also be adopted for a covariance analysis run, e.g.:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	LGT	0

LGT Speed-of-light time correction indicator:

= 0 — No change is made to the observation times. This is always true when MULTV = 0 (Sec. 2.1.6).

≠ 0 — Observation times are corrected for the speed of light. When observations are generated, the printed times do not reflect the correction, and Columns 17, 18, 19, 22, 24, 25, 27, 29, 31, 33, 34, and 43 of the DATA GENERATION II card cannot contain an X (Sec. 12.2.1).

If observations are input, no correction is made to the observation times of Data Set Types 3, 5, A, or B (Sec. 15); the correction is applied only to the satellite (not to the station) for Data Set Types H and I. LGT is used only for Data Set Type 1 if MULTV = 2.

= 1 — The sign of the correction is positive.

= -1 — The sign of the correction is negative.

2.5.3 Measurement Sigmas

Sigmas (weights) must be provided for the measurements of real or simulated data during covariance analysis runs. They are input via the following vectors:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	SIGMA	100
	2	.1
	3	.1
	4	200
	5	205
	6	205

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	KSIG	1
I	2	2
I	3	3
I	4	113
I	5	114
I	6	115

SIGMA Observation measurement weights.

KSIG List defining sigma set and data type.

For each entry in SIGMA, a corresponding entry defining the measurement type and sigma set must appear in the KSIG list. The KSIG entries are of the form 100 I + K, where I is the sigma set and K is the measurement type. Ten sets corresponding to I = 0, 1, 2, · · · ,9 may be entered. This selected value of I is the same as the entry in Column 5 of the STATION card (Sec. 4). The measurement type K must be one of those listed in Table 2-3.

In the example shown, the sigmas input in SIGMA(1), (2), and (3) are for range, azimuth, and elevation and are to be used with all stations with a zero in Column 5 of the STATION cards. The sigmas input in SIGMA(4), (5), and (6) are for $\hat{x}$, $\hat{y}$, and $\hat{z}$ and are to be used with all stations with a one in Column 5 of the STATION cards.

Table 2-1. Measurement Types for Sigmas

K	Measurement Type	K	Measurement Type
1	Slant range	37	SGLS range rate
2	Azimuth	43	x-antenna
3	Elevation	44	y-antenna
4	Topocentric right ascension	46	JPL two- or three-way doppler
5	Topocentric declination	49	Tranet doppler frequency
6	Topocentric hour angle	50	Tranet doppler base
7	Geocentric right ascension	52	Geoceiver range difference
8	Geocentric declination	55	Vehicle-vehicle range
10	u	56	Vehicle-vehicle range rate
11	v	58	Station-vehicle-vehicle range
12	h, height	59	Station-vehicle-vehicle range rate
13	$\hat{x}$ earth-fixed	61	Station-vehicle-vehicle-vehicle range
14	$\hat{y}$ earth-fixed	64	Station-vehicle-vehicle-vehicle range rate
15	$\hat{z}$ earth-fixed	67	Vehicle-vehicle-vehicle range
16	Slant range	70	Vehicle-vehicle-vehicle range rate
17	P	73	Observation 1 of Data Set Type P
18	Q	76	Observation 1 of Data Set Type Q
19	Range rate	77	Observation 1 of Data Set Type R
20	$\dot{P}$	82	Multipath
21	$\dot{Q}$	85	Two-way range
28	Accelerometer	86	One-way C-band range
29	One-way cumulative doppler	87	One-way L-band range
30	Three-way cumulative doppler	88	Vehicle-vehicle azimuth
31	$\dot{A}$, azimuth rate	89	Vehicle-vehicle elevation
32	$\dot{E}$, elevation rate		
34	Range rate		
35	One-way doppler		
36	Two-way doppler		

If an azimuth sigma is input >0, the azimuth partials for the corresponding sigma set are scaled by the cosine of the elevation. If the azimuth sigma is input <0, the partials are not corrected.

A maximum of 100 entries may be made to each of the SIGMA and KSIG vectors; both vectors are preset to zero.

2.5.4 Diagonal Matrix Option

The value shown in the following example is preset:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	DIAG	0

DIAG — Option to compute only the diagonal elements of the normal A^TA matrix:

- $= 0$ — All elements of the A^TA matrix are computed.
- $\neq 0$ — TRACE computes only the diagonal elements; all off-diagonal elements are assumed to be zero.

This option shortens computation time when the normal matrix is known to be diagonal (e.g., when the only parameters are radar time biases).

2.5.5 Input for Observational Measurements

Several observational measurements used during a covariance analysis require special input. This special input is described in the following subsections.

2.5.5.1 Space-Ground Link Subsystem (SGLS) Range Rate

When SGLS range rates are used, the following variables must be input (Ref. 3). All values shown in the following example are built into TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	MSGLS	1
	FREQ	1800.E6
	CNT1	1048574.0
I	PSGLS	1
I	JMAX	10
	SEPS	1.

MSGLS Method indicator for computing the SGLS count interval δt:

= 1 AOES 1967 Method.

= 2 Aerospace 1967 Method.

FREQ The frequency used in the computation of δt, cps.

CNT1 The quantity N_1, the number of cycles used in the computation of δt.

PSGLS Partials computation flag:

= 1 Partials are computed at the final modified time.

= 2 Partials are computed at two times dependent on δt and are then differenced.

JMAX — The maximum number of iterations used to generate SGLS data if

$$|N_2^i - N_2^{i-1}| \geq \epsilon$$

where N_2^i is an internally computed number. Note that JMAX is also used with JPL doppler measurements (Sec. 2.5.5.2).

SEPS — The convergence criterion used during the iterative process of computing N_2^i.

2.5.5.2 JPL Doppler

When the JPL two- or three-way doppler measurements are used, DØPRF and JMAX must be input. The values in the following example are built into TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	DØPRF	300.
I	JMAX	10

DØPRF — Index of refraction for JPL two- or three-way doppler data.

JMAX — The maximum number of iterations for computing the JPL two- or three-way doppler measurement. (Note that JMAX is also used when the SGLS range rate is generated (Sec. 2.5.5.1).

2.5.5.3 Geoceiver or CCID

GDELT is preset as shown in the following example, and SFREQ is preset to zero:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	GDELT	1.
	SFREQ	180.E8

GDELT — The time difference between input geoceiver observations, min; Δt on the DATA GENERATION I card is used when the observation time is being generated.

SFREQ — The satellite frequency for geoceiver range difference data, cps.

A nonzero OBSERVATION 3 on the OBSERVATION card (Table 15-2) for Data Set Type I indicates that CCID, rather than geoceiver, data is used. CCID measurements are computed in the same way as geoceiver measurements except that a variable time step is used. OBSERVATION 1 on the first OBSERVATION card of each station pass combination must equal zero; its time is taken as the initial time for this station pass. The time for computation is the difference between the last and the current observation times.

For either geoceiver or CCID measurements, if the sigmas are input on OBSERVATION cards (Table 15-2), a scale factor can be applied to the sigmas. This scale factor is input to SSCL as shown in the following example (preset to 1):

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	SSCL	1.5

SSCL Scale factor applied to geoceiver or CCID sigmas input on OBSERVATION cards (Sec. 15).

2.5.5.4 Time-of-Arrival

Time-of-arrival measurements use the following variables unless other values are found on sensor parameter cards (Sec. 5). The values in the following example are not preset:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	DRIFT	2
	CAPT	.025

DRIFT Oscillator drift rate used in the measurement partials.

CAPT Inner pulse period, min, used when the measurement and its partials are generated.

3. MASS INPUT

MASS input specifies the data necessary to define the point mass acceleration model used in evaluating the equations of motion. The point mass acceleration is computed by the formula

$$\ddot{\underline{r}}_0 = -\mu \sum_{i=1}^{n} \mu_i \left(\underline{r} - \underline{r}_{0_i}\right) / \left|\underline{r} - \underline{r}_{0_i}\right|^3$$

where

μ = the gravitational constant of the body

μ_i = the ratio of the mass of each point to the mass of the body

n = the number of point masses

$\underline{r}$ = the computed body-centered position vector of the vehicle

$\underline{r}_{0_i}$ = the body-centered position vector of each point

The body used is the current central body.

Point mass input has a prespecified format consisting of μ_i, $|\underline{r}_{0_i}|$ (distance of the point mass from the center of the body), bodycentric latitude φ_i, and East longitude λ_i. An example of the special format with one card per mass follows:

```
MASS
    1.        E-10      1738.       30.                   -40.
    1.        E-06      1728.       35.                   -45.
END
```

Card Column	Description
4-15	μ_i, body masses
16-27	$\|\underline{r}_{o_i}\|$, km
28-39	φ_i, deg
40-51	λ_i, deg

All four fields require decimal points and may have exponents of the form E ± XX in the last four columns.

The (maximum of 20) cards must be preceded by a card with MASS in Columns 1 through 4 and followed by a card with END in Columns 1 through 3. The whole set of point mass cards must follow the MODEL data input.

Point mass acceleration input requires the use of R2MU and MVMAT (Sec. 2.1.2.1).

4. STATION LOCATION INPUT

STATION input specifies the data (e.g., station names, locations, and other data related to refraction models and measurement sigmas) associated with the tracking stations. P and Q station identifications are used by those measurements requiring one or two stations other than the observing station.

The station location inputs must be preceded by a card with STATIØN punched in Columns 1 through 7 and followed by a card with END punched in Columns 1 through 3. The location of a station can be specified as one of four types. Types 0, 1, and 2 require only one card per location and can be intermixed, but Type 3 requires two cards for each location and cannot be mixed with the other types. A maximum of 100 locations may be input; the deck setup is illustrated in Fig. 4-1.

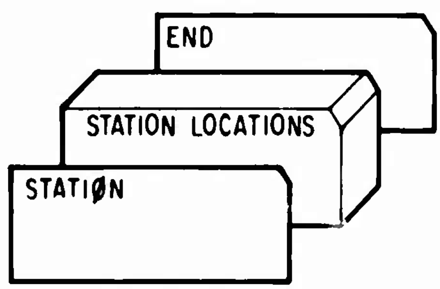

Fig. 4-1. STATION Data Deck Setup

The TRACE STATION card format is shown in Table 4-1 and on page D-13. An example of station location input is:

ST	I	E	R	D	T	FIELD 1	EXP	FIELD 2	EXP	FIELD 3	EXP	P	Q
1 2 3	5	7	9	11	13	15 16 17 18 19 20 21 22 23 24 25 26	27 28 29	31 32 33 34 35 36 37 38 39 40 41 42	43 44 45	47 48 49 50 51 52 53 54 55 56 57 58	59 60 61	64 65 66	68 69 70
STATIØN													
001		1	1			34.8		239.5		600.			
004		1	1			57.6		207.8		426.			
005		1	1			21.6		201.7		941.			
006		1	1			42.9		288.35		784.			
009		1	1			76.5		291.4		396.			
END													

Table 4-1. STATION Card Format

Card Column	Header	Description
1-3	ST	Station identification. No two stations may be identified by the same alphanumeric name and no station may be identified as END.
5	I	Sigma index (Secs. 2.2.6, 2.4.3, and 2.5.3).
7	E	Elevation refraction type for standard TRACE tropospheric refraction corrections (Secs. 2.2.7.1 and 2.4.4).
9	R	Range refraction type for standard TRACE tropospheric refraction corrections (Secs. 2.2.7.1 and 2.4.4).
11	D	Data displacements (currently not used).
13	T	Input type index for the next three fields (T = blank, 0, 1, 2, or 3).[c]
15-29[a]	Field 1	If T = blank or 0, the station geodetic latitude φ^*, deg. If T = 1, the station earth-fixed Cartesian coordinate $\hat{x}$.[b] If T = 2, the station geocentric radius R.[b] If T = 3 (Card 1), the station initial geodetic latitude φ_0^*, deg. If T = 3 (Card 2), the station velocity v[b], measured per minute.
31-45[a]	Field 2	If T = blank or 0, the station East longitude λ, deg. If T = 1, station earth-fixed Cartesian coordinate $\hat{y}$.[b] If T = 2, station geocentric latitude φ, deg. If T = 3 (Card 1), the station initial East longitude λ_0, deg. If T = 3 (Card 2), the station heading elevation γ, deg.
47-61[a]	Field 3	If T = blank or 0, the station height h.[b] If T = 1, the station earth-fixed Cartesian coordinate $\hat{z}$.[b] If T = 2, the station East longitude λ, deg. If T = 3 (Card 1), the station initial height h_0.[b] If T = 3 (Card 2), the station heading azimuth Az, deg.
64-66	P	P-station identification (cc 1-3 of some STATION card).
68-70	Q	Q-station identification (cc 1-3 of some STATION card).

[a]This field requires a decimal and may have an exponent of the form ± XX in the last three columns.

[b]These input units must be consistent with the input/output distance conversion factor DF (Sec. 2.1.1).

[c]T = 3 requires six components, the first three are on the STATION card in the three location fields. The other three are on a following card, which is blank except for the three location fields.

5. SENSOR PARAMETER INPUT

SENSOR input specifies all station location and measurement parameters to be used in data simulation or to be applied to input measurements.

The sensor parameter inputs must be preceded by a card with SENSØR punched in Columns 1 through 6 and terminated by a card with END punched in Columns 1 through 3. The deck setup is illustrated in Fig. 5-1. If these inputs are used, they must be placed immediately behind the STATION data. A maximum of 100 sensor parameters may be specified, but no more than 20 may be input for a given station.

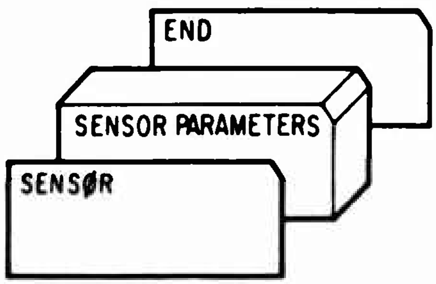

Fig. 5-1. SENSOR Data Deck Setup

The TRACE sensor parameter card format is shown in Table 5-1 and on p. D-14. Note that for a data generation run, only the ST, NAME, and INITIAL VALUE fields are required. For a covariance analysis run, the INITIAL VALUE and BOUND fields are not required.

Table 5-1. SENSOR Card Format

Card Column	Header	Description
1-3	ST	Station identification, as on the STATION card (Sec. 4) or blank[a]
4-7	PASS	Pass identification, as on the OBSERVATION card (Sec. 15), blank, or a vehicle identification (Sec. 11.1.2)[b]
9-12	NAME	Left-justified parameter name (Table 5-2)
14	Q	Blank or P indicates a P-parameter. Q indicates a Q-parameter
16-30	INITIAL VALUE	Initial parameter value (those for station location parameters are taken from the STATION cards)
32-46	BOUND	Bound on the parameter
48-62	SIGMA	Standard deviation of the parameter

[a]The following parameters (Table 5-2) require ST to be blank: KFEZ, BT, BTD, BTDD, VSB, VSBD, VSDD, BR, BRD, BRDD, VTCB, VRCB, VTLB, and VTBI. For RFSF (MULTV=2), ST may or may not be blank.

[b]KFEZ requires PASS to be blank. BT, BTD, BTDD, VSB, VSBD, VSDD, BR, BRD, BRDD, VTCB, VRCB, VTLB, and VTBI require a vehicle identification in PASS. For RFSF (MULTV=2), PASS may or may not contain a vehicle identification.

Note that bias corrections are added to generated data and subtracted from observed data. Time bias corrections are always added to the observation times.

A list of acceptable sensor parameter names is shown in Table 5-2, an example of input is:

ST	PASS	NAME	Q	INITIAL VALUE	EXP	BOUND	EXP	SIGMA	EXP
SENSOR									
001		LAT				.01			
001	0004	RBIA		100.		100.			
005		ABIA	Q	1.		.011			
END									

Table 5-2. Sensor Parameter Names

Name	Description	Units
LAT	Station latitude	deg
LØNG	Station longitude	deg
ALT	Station altitude	distance[a]
XLØC[b]	$\hat{x}$ location of station	distance[a]
YLØC[b]	$\hat{y}$ location of station	distance[a]
ZLØC[b]	$\hat{z}$ location of station	distance[a]
TBIA	Time bias	sec
RBIA	Range bias	distance[a]
KR	Range scale factor	-
ABIA	Azimuth bias	deg
EBIA	Elevation bias	deg
RDBI	Range rate bias	vel[a]
KD	Range rate scale factor	-
ADBI	Azimuth rate bias	deg/sec
EDBI	Elevation rate bias	deg/sec
RTBI	Topocentric right ascension bias	deg
DTBI	Topocentric declination bias	deg
HABI	Topocentric hour angle bias	deg
RGBI	Geocentric right ascension bias	deg
DGBI	Geocentric declination bias	deg
UBIA	Argument of latitude bias	deg
VBIA	Crossplane bias	deg
HBIA	Height bias	distance[a]
XBIA	$\hat{x}$ bias	distance[a]
YBIA	$\hat{y}$ bias	distance[a]
ZBIA	$\hat{z}$ bias	distance[a]
PBIA	P bias	distance[a]
KP	P scale factor	-
QBIA	Q bias	distance[a]
KQ	Q scale factor	-

[a]These units are determined by the input/output conversion factors DF, VF, and AF (Sec. 2.1.1).

[b]This parameter is currently not available in TRACE.

Table 5-2. Sensor Parameter Names (Continued)

Name	Description	Units
PDBI	$\dot{P}$ bias	vel[a]
KPD	$\dot{P}$ scale factor	-
QDBI	$\dot{Q}$ bias	vel[a]
KQD	$\dot{Q}$ scale factor	-
DPBI	Doppler bias	vel[a]
KDP	Doppler scale factor	-
TWBI	Two-way doppler bias	vel[a]
KTW	Two-way doppler scale factor	-
FREQ	Transmitted frequency for SGLS range rate	cps
KSRR	SGLS range rate scale factor	-
SRRB	SGLS range rate bias	vel[a]
DRIF	Time-of-arrival oscillator drift	-
BEAC	Time-of-arrival offset	sec
CAPT	Time-of-arrival inner pulse period	sec
AXBI	x-antenna angle bias	deg
AYBI	y-antenna angle bias	deg
CC3B	JPL two- or three-way doppler bias	cps
CC3S	JPL two- or three-way doppler scale factor	-
TNTB	Tranet doppler bias	cps
FTM	Cumulative doppler transmission frequency	cps
FØM	Cumulative doppler oscillator frequency	cps
GCRB	Geoceiver range difference satellite frequency bias	cps
RBD	Linear range bias drift associated with ST when MULTV ≠ 0 (Sec. 2.1.6)	vel[a]
RBDD	Second-order range bias drift associated with ST when MULTV ≠ 0	acceleration[a]
KFEZ	Scale factor for any range measurement when MULTV = 1 (ST and PASS must be blank)	-
BT[b]	Range bias associated with a vehicle transmitting to another vehicle	distance[a]
BTD[b]	Linear range bias drift associated with a vehicle transmitting to another vehicle	vel[a]

[a]These units are determined by the input/output conversion factors DF, VF, and AF (Sec. 2.1.1).

[b]This parameter requires ST to be blank and PASS to contain a right-justified vehicle identification (Sec. 11.1.2).

Table 5-2. Sensor Parameter Names (Continued)

Name	Description	Units
BTDD[b]	Second-order range bias drift associated with a vehicle transmitting to another vehicle	acceleration[a]
VSB[b]	Range bias associated with a vehicle receiving from a station	distance[a]
VSBD[b]	Linear range bias drift associated with a vehicle receiving from a station	vel[a]
VSDD[b]	Second-order range bias drift associated with a vehicle receiving from a station	acceleration[a]
BR[b]	Range bias associated with a vehicle receiving from another vehicle	distance[a]
BRD[b]	Linear range bias drift associated with a vehicle receiving from another vehicle	vel[a]
BRDD[b]	Second-order range bias drift associated with a vehicle receiving from another vehicle	acceleration[a]
TNTD	Tranet doppler frequency drift	Hz/sec
SRCB	Station (C-band) receiver range bias	distance[a]
STCB	Station (C-band) transmitter range bias	distance[a]
SRLB	Station (L-band) receiver range bias	distance[a]
VTCB[b]	Vehicle (C-band) transmitter range bias	distance[a]
VRCB[b]	Vehicle (C-band) receiver range bias	distance[a]
VTLB[b]	Vehicle (L-band) transmitter range bias	distance[a]
VTBI[b]	Vehicle transponder bias	sec
RFSF	Refraction scale factor for SGLS range rate and Tranet doppler	-
RRSF	Range refraction scale factor when MULTV=0	-
AXM	x-antenna angle scale factor	-
AYM	y-antenna angle scale factor	-
AØFF	Boresight offset for x-antenna and y-antenna angles	deg
ERSF	Elevation refraction scale factor when MULTV=0	-

[a]These units are determined by the input/output conversion factors DF, VF, and AF (Sec. 2.1.1).

[b]This parameter requires ST to be blank and PASS to contain a right-justified vehicle identification (Sec. 11.1.2).

Table 5-2. Sensor Parameter Names (Continued)

Name	Description		Units
RADL	Tracking vehicle radial bias for vehicle-vehicle angles		distance[a]
INTK	Tracking vehicle intrack bias for vehicle-vehicle angles		distance[a]
CRTK	Tracking vehicle crosstrack bias for vehicle-vehicle angles		distance[a]
VAMP[b]	Amplitude	Parameters for a sinusoidal range bias applicable to measurements having a station-vehicle range leg. All three must be input for a vehicle if any one is input. These are applied only when MULTV = 2	distance[a]
VPER[b]	Frequency		deg/sec
VFAS[b]	Phase angle		deg

[a]These units are determined by the input/output conversion factors DF, VF, and AF (Sec. 2.1.1).

[b]This parameter requires ST to be blank and PASS to contain a right-justified vehicle identification (Sec. 11.1.2).

6. ATA INPUT

FIGURE

TABLE

6. ATA INPUT

ATA input allows the option of specifying the P-parameter portion of an initial (a priori) $A^T A$ matrix for orbit determination or covariance analysis runs.

The $A^T A$ or $(A^T A)^{-1}$ input deck is preceded by a card with ATA punched in Columns 1 through 3 and terminated by a card with END punched in Columns 1 through 3 (Fig. 6-1)

The maximum number of entries in the ATA data block is 5151, which corresponds to 100 P-parameters.

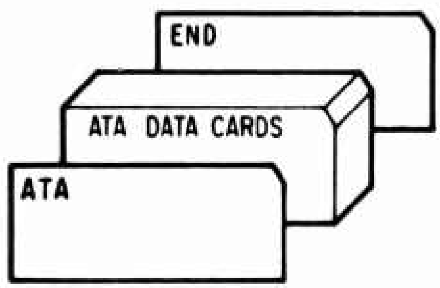

Fig. 6-1. ATA Data Deck Setup

Table 6-1 shows how and when to input the $A^T A$ and $(A^T A)^{-1}$ matrices, depending on ØPBØX (Secs. 2.2.1 and 2.5.1), MULTV (Sec. 2.1.6), and ITIN (Sec. 2.1)

Table 6-1. $A^T A$ and $(A^T A)^{-1}$ Input

Input	ØPBØX(A)	MULTV	ITIN	Description
$A^T A$	3	0, 1	2	Upper triangular, augmented
		0	5	Upper triangular, augmented
		1	5	Lower triangular
		>1	2, 5	Lower triangular
$(A^T A)^{-1}$	4	0, 1	5	Lower triangular
		>1	2, 5	Lower triangular
		0, 1	2	Not available

6.1 INPUT A^TA

When MULTV = 0 or 1 and ITIN = 2 or when MULTV = 0 and ITIN = 5, the P-parameter portion of an A^TA matrix is input as an augmented, upper triangular matrix stored by rows. Position A of ØPBØX must equal 3. For example, if the upper triangular portion of the desired matrix is

$$\begin{bmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} \\ & \alpha_{22} & \alpha_{23} \\ & & \alpha_{33} \end{bmatrix} = \begin{bmatrix} 11 & 12 & 13 \\ & 14 & 15 \\ & & 16 \end{bmatrix}$$

it must first be augmented to

$$\begin{bmatrix} 11 & 12 & 13 & 0 \\ & 14 & 15 & 0 \\ & & 16 & 0 \\ & & & 0 \end{bmatrix}$$

and then be input by rows as

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	ATA	11.
	2	12.
	3	13.
	4	0.
	5	14.
	6	15.
	7	0.
	8	16.
	9	0.
	10	0.

When MULTV = 1 and ITIN = 5 or MULTV > 1 and ITIN = 2 or 5, a partially full A^TA matrix containing the P-parameter portion can be input as a lower triangular matrix stored by rows. Position A of ØPBØX must equal 3. If the lower triangular portion of the desired A^TA matrix is

$$\begin{bmatrix} \alpha_{11} & & \\ \alpha_{21} & \alpha_{22} & \\ \alpha_{31} & \alpha_{32} & \alpha_{33} \end{bmatrix} = \begin{bmatrix} 11 & & \\ 21 & 22 & \\ 31 & 32 & 33 \end{bmatrix}$$

it is input as

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	ATA	11.
	2	21.
	3	22.
	4	31.
	5	32.
	6	33.

6.2 INPUT $(A^TA)^{-1}$

The P-parameter portion of an $(A^TA)^{-1}$ matrix can be input as a lower triangular matrix stored by rows when MULTV = 0 or 1 and ITIN = 5 or when MULTV > 1 and ITIN = 2 or 5. Position A of ØPBØX must equal 4. If

$$(A^TA)^{-1} = \begin{bmatrix} \alpha_{11} & & \\ \alpha_{21} & \alpha_{22} & \\ \alpha_{31} & \alpha_{32} & \alpha_{33} \end{bmatrix} = \begin{bmatrix} 11 & & \\ 21 & 22 & \\ 31 & 32 & 33 \end{bmatrix}$$

is the desired matrix, it is input as

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	ATA	11.
	2	21.
	3	22.
	4	31.
	5	32.
	6	33.

7. DEWM INPUT

DEWM input provides the data used to specify additive and/or multiplicative deweighting of the covariance matrix in an SLS run (MULTV = 2) at prespecified update times (Sec 14). This deweighting is applied according to $C_D^{-1} = F(C + M)^{-1}F^T$, where C_D is the deweighted covariance matrix, C the current covariance matrix at the start of the stage, F the multiplicative deweighting matrix, and M the additive deweighting matrix. The DEWM data cards are preceded by a card with DEWM punched in Columns 1 through 4 and followed by a card with END punched in Columns 1 through 3.

In addition to accepting a constant additive deweighting matrix, TRACE has the capability of dynamically calculating this matrix by one of two methods (Ref. 4).

The deck setup is illustrated in Fig. 7-1. The deweighting inputs must follow the A^TA input. When dynamically computed deweighting is used, the satellite state vector parameters must be in the Cartesian or the f and g coordinate system (ICTYP = 1 or 7, Sec. 11.1.4).

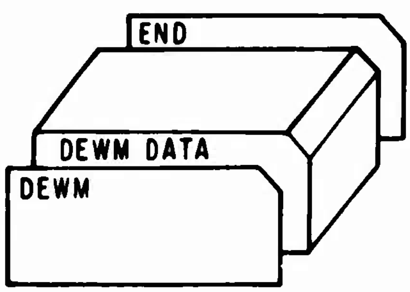

Fig. 7-1. DEWM Data Deck Setup

An example of deweighting input applicable to two vehicles with seven parameters each (six state vector parameters and drag) is shown below. The values in this example are not preset in TRACE; all deweighting inputs are preset to zero.

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
D	EWM	
	MDWT	1
	MDWM	.9
	2	.98
	3	.98
	4	.99
	5	.995
	6	.98
	7	.98
	8	.95
	9	.96
	10	.96
	11	.97
	12	.98
	13	.97
	14	.97
	ADWT	2
	PRESD	0
	2	0

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	PSTSD	2.8E-4
	2	2.8E-4
	ACELS	0
	2	0
	KDRS	1.
	2	0
	KDTS	15.
	2	0
	KDCS	1.
	2	0
I	SDEWT	1
I	2	2
	DPH	5.
	SDRG	.0355
	SDCG	.0346
	PERI	90.
	GDRS	0
	2	.026
	GDCS	0
	2	.018
E	ND	

MDWT — Type of multiplicative deweighting matrix:

- = 0 — No multiplicative deweighting matrix is input.
- = 1 — A diagonal multiplicative deweighting matrix is input.
- = 2 — A lower triangular multiplicative matrix stored by rows is input (currently unavailable).
- = 3 — A symmetric matrix stored lower triangular by rows is input (currently unavailable).
- = 4 — A full matrix stored by columns is input (currently unavailable).

MDWM — A multiplicative deweighting matrix is stored as indicated by MDWT. The maximum number of entries is 100.

ADWT — Type of additive deweighting matrix:

- = 0 — No additive deweighting matrix is used.
- = 1 — A constant diagonal additive deweighting matrix is used.
- = 2 — A symmetric additive deweighting matrix stored lower triangular by rows (constant, dynamically computed, or a combination of the two) is used.

ADWM — The constant portion of the additive deweighting matrix is stored as indicated by ADWT. The maximum number of entries is 5050.

PRESD — Sigmas for pre-update deweighting of drag (or solar radiation pressure) parameters:

(i) For a Vehicle i parameter, σ^2 is added to the appropriate diagonal element of the covariance matrix before the matrix is updated on the converged iteration of each stage. Drag (or solar radiation pressure) deweighting is indicated on the STAGE card (Sec. 14)($1 \le i \le 20$)

PSTSD — Sigmas for post-update deweighting of drag (or solar radiation pressure) parameters:

(i) For a Vehicle i parameter, σ^2 is added to the appropriate diagonal element of the covariance matrix after the matrix is updated on the converged iteration of each stage. Drag (or solar radiation pressure) deweighting is indicated on the STAGE card (Sec. 14)($1 \le i \le 20$)

ACELS — Sigmas for accelerometer scale factor parameter deweighting:

(i) For a Vehicle i accelerometer scale factor parameter, σ^2 is added to the proper diagonal element of the covariance matrix after the matrix is updated on the converged iteration of each stage ($1 \le i \le 20$).

KDRS, KDTS, KDCS — Sigmas for orbit adjust deweighting. KDRS, KDTS, and KDCS are the sigmas for the radial, intrack, and crosstrack components of the orbit adjust deweighting, respectively:

(i) The quantity σ^2 is added to the radial, intrack, and crosstrack velocity components of an RTC covariance matrix and transformed to the i^{th} satellite state vector coordinate system. The result is added to the appropriate positions of the covariance matrix after the matrix is updated on the converged iteration of each stage. Orbit adjust deweighting is indicated on the STAGE card (Sec. 14)($1 \le i \le 20$).

SDEWT Type of dynamically computed geopotential additive deweighting factor (not applicable at the start of the first stage):

(i) = 0 No dynamically computed geopotential additive deweighting is applied for Vehicle i ($1 \le i \le 20$).

= 1 Type 1 computed geopotential additive deweighting is applied for Vehicle i.

= 2 Type 2 computed geopotential additive deweighting is applied for Vehicle i.

The following inputs are for Type 1 computed geopotential additive deweighting:

DPH Anomaly step sizes when SDEWT = 1:

(i) = $\Delta\theta$ Anomaly step size for summing velocity perturbations due to geopotential error for Vehicle i, deg ($1 \le i \le 20$).

SDRG Sigmas for radial velocity perturbation when SDEWT = 1:

(i) = $\sigma_{\dot{r}G}$ Standard deviation for radial velocity perturbation due to geopotential error for Vehicle i, ft/sec ($1 \le i \le 20$).

SDCG Sigmas for crosstrack velocity perturbations when SDEWT = 1:

(i) = $\sigma_{\dot{c}G}$ Standard deviation for crosstrack velocity perturbation due to geopotential error for Vehicle i, ft/sec ($1 \leq i \leq 20$).

PERI Period for Vehicle i when SDEWT = 1:

(i) = 0 The Keplerian period of Vehicle i is computed from the current solution.

$\neq 0$ Period for Vehicle i, min ($1 \leq i \leq 20$).

The following inputs are for Type 2 computed geopotential additive deweighting:

GDRS Radial velocity component scale factors when SDEWT = 2:

(i) Scale factor for Vehicle i ($1 \leq i \leq 20$).

GDCS Crosstrack velocity component scale factors when SDEWT = 2:

(i) Scale factor for Vehicle i ($\leq i \leq 20$).

8. COVQ INPUT

COVQ input allows the option of specifying a Q-parameter a priori covariance matrix $C(Q)_o$ for covariance analysis runs. The COVQ data deck is preceded by a card with CØVQ punched in Columns 1 through 4 and terminated by a card with END punched in Columns 1 through 3 (Fig. 8-1).

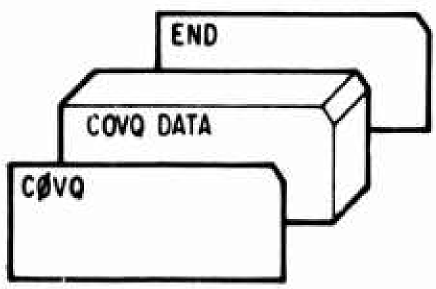

Fig. 8-1. COVQ Data Deck Setup

The maximum number of entries in the COVQ data block is 4500, which corresponds to 94 Q-parameters.

The C(Q) matrix is input as a lower triangular matrix stored by rows. Position B of ØPBØX must equal one (Sec. 2.5.1).

For example, if the lower triangular portion of the desired C(Q) matrix is

$$\begin{bmatrix} \alpha_{11} & & \\ \alpha_{21} & \alpha_{22} & \\ \alpha_{31} & \alpha_{32} & \alpha_{33} \end{bmatrix} = \begin{bmatrix} 11 & & \\ 21 & 22 & \\ 31 & 32 & 33 \end{bmatrix}$$

it is input as

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	CØVQ	11.
	2	21.
	3	22.
	4	31.
	5	32.
	6	33.

9. CONSTRAINT MATRIX INPUT

CONSTRAINT input specifies the data associated with the linear parameter constraints used in differential correction algorithms. These constraints are ignored in covariance analysis applications. Linear constraints used in TRACE are of the form

$$X = BY$$

where

X = the n × 1 vector of corrections to the original P-parameters

= the m × 1 vector of corrections to the effective parameters (m ≤ n)

B = the n × m matrix of constants

Consider an arbitrary constraint (a row of the constraint matrix)

$$x_i = \sum_j b_{ij} y_j \quad (1 \le i \le n)$$

with the inputs x_i, b_{ij}, and y_j on cards (Table 9-1).

Table 9-1. CONSTRAINT Card Format

Card Column	Symbol	Description
1-12	x_i	Name of the i^{th} constrained parameter in the parameter name format (Table 9-2).
13-20 33-40 53-60	b_{ij}	The i^{th} coefficient (floating point) for the parameter y_j indicated in the next field (internal units).
21-32 41-52 61-72	y_j	Name of one of the effective parameters whose b_{ij} coefficient was specified in the preceding field; y_j must be in the parameter name format(Table 9-2).
73-80		Not used.

The constraint matrix parameter name formats are shown in Table 9-2. If it is necessary to use more than one card for an equation, Columns 1 through 12 of the continuing cards are left blank, and the remaining names (y_j) and constants (b_{ij}) are input as indicated in Table 9-1. The number of cards is limited to 100 and the number of constants b_{ij} to 133. If no original parameter name is input in Columns 1 through 12 of any card, its equation is assumed to be $x_i = y_j$ for some j and its coefficient b_{ij} to equal one. No parameter name should appear both as an original parameter and as an effective parameter; such constraints can always be rewritten.

Table 9-2. Constraint Matrix Parameter Name Formats

Parameters	Section Reference	Format	Where:
C and S	2.1.5.2	bbbbbbbXX, YY	b is a blank. 01≤XX≤99. 01≤YY≤99.
Point Mass	2.1.5.1	bbbbbbbXYYYb	b is a blank. X = M, R, P, or L. 001≤YYY≤020.
Other Model	2.1.5.3	bbbbbbbNAMEI	b is a blank. NAMEI is any name acceptable to ØPRAM.
Sensor	5	STAPASSNAMEI	STA is the station identification. PASS is the pass identification. NAMEI is the name of any acceptable sensor parameter.
Vehicle	11.1.14	XXXXbbbNAMEI	XXXX is the vehicle identification number (Sec. 11.1.2), specified so that 0001≤XXXX≤9999 or XXXX = bbbb. NAMEI is any name acceptable to VPRAM.

The CONSTRAINT data must be preceded by a card with CØNSTRAINT punched in Columns 1 through 10 and terminated by one with END punched in Columns 1 through 3, (Fig. 9-1).

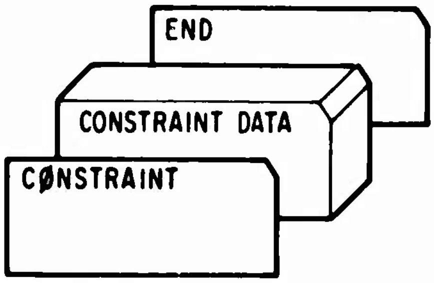

Fig. 9-1. CONSTRAINT Data Deck Setup

For example:

```
0001      ALPHA  =  .0043753 (0001      TZERØ)
0002      DRAG   =           (0001      DRAG)
S1    2B  RBIA   =           (S1    2A  RBIA)  + (S1  1B  RBIA) - (S1  1A  RBIA)
S1        TBIA   =         - (S2        TBIA)  - (S3      TBIA)
```

The input for these constraint equations is shown below:

```
CØNSTRAINT
0001      ALPHA .0043753 0001      TZERØ
0002      DRAG  1.       0001      DRAG
S1    2B  RBIA  1.       S1    2A  RBIA  +1.     S1    1B  RBIA  -1.     S1    1A  RBIA
S1        TBIA  -1.      S2        TBIA  -1.     S3        TBIA
END
```

10. MEASUREMENT INPUT

TRACE has a signal processing option providing SLS (MULTV = 2) solutions and covariance analysis studies with a general capability of handling tracking data measurements that consist of sums and differences of ranges between stations and satellites, e.g., measurements that can be written in the following form:

$$m = \sum_{i=1}^{n} s_i (c_1 R_i + c_2 T_i)$$

where

m = measurement

s_i = an algebraic sign (+ or -)

c_1, c_2 = conversion factors specifying units

R_i = range between a vehicle and a ground station or between two vehicles, i.e., $R_i = |\underline{X}_j - \underline{X}_k|$, where $\underline{X}_j$, $\underline{X}_k$ are position vectors to some satellite or station. (Hereafter, R_i will be termed a "leg.")

n = number of legs in the measurement ($n \leq 9$)

T_i = vehicle transponder delay. (Note that $T_i = 0$ if the i^{th} leg does not involve a vehicle transponder delay.)

The exact configuration of the measurement in a given application is specified symbolically via input to the MEAS data block. The sensor parameters (Sec. 5) currently modeled are the station locations (LAT, LØNG, ALT) and vehicle transponder biases (VTBI). Speed-of-light time corrections can be applied. This option has the following restrictions:

- A measurement of this form may involve no more than two stations and three vehicles.
- A measurement may have no more than nine legs.

Table 10-1. MEAS Card Format

Card Column	Symbol	Description
1	P, Q, or R	Data set type indicator (Table 15-2)
5	1 or 2	= 1 External measurement units in seconds = 2 External measurement units as defined by DF (Sec. 2.1.1)
7	0, R, or T	= 0 No transit time correction = R Time tag relative to the receiver on Leg 1 = T Time tag relative to the transmitter on Leg 1
10	+ or -	Algebraic sign for Leg 1
12-13	SD[a]	Transmitter symbolic designator for Leg 1
18-19	SD[a]	Receiver symbolic designator for Leg 1
22	+ or -	Algebraic sign for Leg 2
24-25	SD[a]	Transmitter symbolic designator for Leg 2
30-31	SD[a]	Receiver symbolic designator for Leg 2
34	+ or -	Algebraic sign for Leg 3
36-37	SD[a]	Transmitter symbolic designator for Leg 3
42-43	SD[a]	Receiver symbolic designator for Leg 3
46	+ or -	Algebraic sign for Leg 3
48-49	SD[a]	Transmitter symbolic designator for Leg 4
54-55	SD[a]	Receiver symbolic designator for Leg 4
58	+ or -	Algebraic sign for Leg 5
60-61	SD[a]	Transmitter symbolic designator for Leg 5
66-67	SD[a]	Receiver symbolic designator for Leg 5
70	+ or -	Algebraic sign for Leg 6
72-73	SD[a]	Transmitter symbolic designator for Leg 6
78-79	SD[a]	Receiver symbolic designator for Leg 6

[a] SD is a symbolic designator: Stations 1 and 2 and Vehicles 1 through 3 on the input OBSERVATION card are denoted by S1, S2, V1, V2, and V3, respectively.

- The input OBSERVATION format is given in Sec. 15. It should be noted that if an observation involves more than one vehicle, the vehicle numbers for Vehicles 2 and 3 must appear in cc60-75 and 46-60, respectively; these fields require decimal points.
- A limit of three different data types (P, Q, and R, Table 15-2) may be defined on a given run. For any given data type, any number of station-vehicle combinations within other program limitations (e.g., 20 vehicles and 100 stations) may be processed simultaneously.
- No pass identifications are currently permitted.
- Only one station per observation can be used when the data set type is P.
- Only two stations per observation can be used when the data set types are Q and R.
- If the transit time correction option is exercised and if the signal cycles back through the same station, the time is reset to the time at which the signal was initially transmitted from the station.

The MEAS data block specifies the observation data set type (P, Q, or R), the conversion factor indicator, the time tag for transit time corrections, and a symbolic description of each leg. This specification of the legs must be in sequential order; i.e., an order corresponding to the path a signal can be thought to travel within a configuration of no more than two stations and three vehicles.

The MEAS data cards must be preceded by a card with MEAS in Columns 1 through 4 and terminated by a card with END in Columns 1 through 3, as shown in Fig. 10-1. The MEAS data card format for Legs 1 through 6 is shown in Table 10-1.

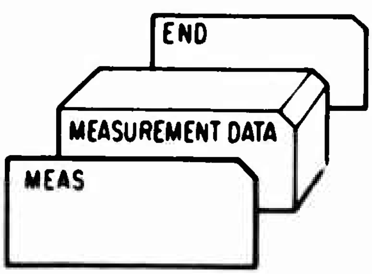

Fig. 10-1. MEAS Data Deck Setup

If 7, 8, or 9 legs are required to describe the measurement, continue on a second card and repeat the format as described in Table 10-1 for Legs 1 through 3 (Columns 10 through 43).

As a simple example to illustrate MEAS input procedures, suppose that the measurement is the transit time in seconds from Station 1 to Vehicle 1 to Station 2 (Fig. 10-2), the time tag is the time of signal transmission from Station 1, and the observation data set type is R.

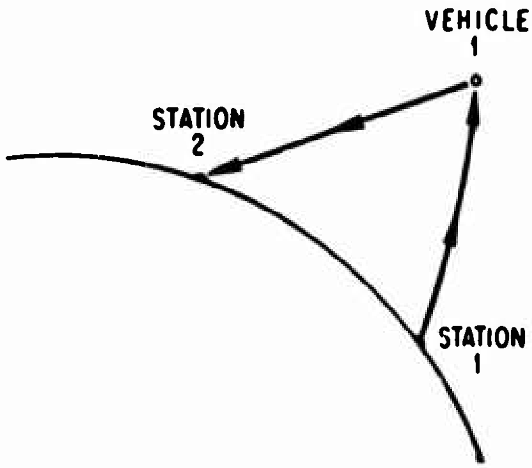

Fig. 10-2. MEAS Observation

The required input is shown below

1–10	11–20	21–30	31–40
R 1 T +	(S 1 T Ø V 1)	+ (V 1 T Ø S	2)

Column 1 contains an R indicating the data set type; Column 5 is a 1, indicating that the external units are seconds; and Column 7 is a T, indicating that the time tag is relative to the transmitter. The symbolic descriptions of Legs 1 and 2 are found in Columns 10 through 20 and 22 through 32. Note that parentheses and TØs have been added to the card for clarity but that these columns (and the corresponding columns for any leg) are ignored.

11. VEHICLE INPUT

11. VEHICLE INPUT

VEHICLE inputs are defined in this section; the following categories are discussed:

- Epoch date and time of day
- Initial state conditions
- Coordinate and timekeeping system specifications
- Ballistic coefficient
- Atmospheric model specifications
- Orbit adjust data
- Finite thrusting data
- Vehicle parameter specifications
- Vehicle data peculiar to powered flight
- Vehicle data peculiar to orbit determination runs
- Vehicle data peculiar to ephemeris generation runs
- Vehicle data peculiar to data generation runs
- Vehicle data peculiar to covariance analysis runs

11.1 DATA COMMON TO ALL TRACE FUNCTIONS

Certain VEHICLE inputs common to all TRACE functions are discussed here. These inputs include initial conditions data, coordinate and timekeeping system specifications, integrator-peculiar indicators, solar radiation pressure and vehicle ballistic coefficients, and atmospheric drag and accelerometer model data. The inputs for instantaneous orbit adjusts, finite thrusting, weight losses, and powered flight are included. In addition, certain vehicle parameter specifications used for ephemeris generation, orbit determination, and error analysis runs are discussed.

11.1.1 Vehicle Header Card

One header card with up to 70 characters of information may be included with the VEHICLE input for each vehicle. This information is printed as a header for all output associated with this vehicle, e.g.:

1	2	7	77
H	1	HEADER TO BE USED FOR THIS VEHICLE	

11.1.2 Vehicle Number

The following example shows how the vehicle identification number is input (0 ≤ VEHID ≤ 9999):

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	VEHID	1016

11.1.3 Epoch

The values in the following example are not preset in TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	YEAR	1967
I	MNTH	8
I	DAY	17
	TZNE	8
	HR	9
	MIN	45
	SEC	22.5

YEAR or YR MNTH DAY	Epoch date (year, month, day).
TZNE HR MIN SEC	Epoch time (time zone, hour, minute, second).

Normally, the year, month, and day define the equinox used to define the direction of the X-axis. If the year is input negative, the X-axis is directed to the longitude of Greenwich at midnight, day of epoch. The hour, minute, and second entries refer to the time since midnight in a particular local time zone. Note that the time zone is used for input purposes only; all output is referenced to GMT.

11.1.4 Initial Conditions and Indicators

The types of initial conditions input in the IC vector are indicated by ICTYP. Various possibilities are shown in Table 11-1. Note that not all input initial types available in TRACE are shown; additional types are defined on the following pages.

Table 11-1. Initial Conditions

IC	ICTYP												
	±1	±2	±3	±4	±5	±6	±7	±8	±11	±12	±13	±16	±17
(1)	x	α	a	ℓ	ι	a	a_f	x_f	x_m	α_m	a_m	a_m	a_{f_m}
(2)	y	δ	e	δ	δ	e	a_g	y_f	y_m	δ_m	e_m	e_m	a_{g_m}
(3)	z	β	i	β	h_p	i	n	z_f	z_m	β_m	i_m	i_m	n_m
(4)	$\dot{x}$	A	Ω	A	h_a	Ω	L	$\dot{x}_f$	$\dot{x}_m$	A_m	Ω_m	Ω_m	L_m
(5)	$\dot{y}$	r	ω	r	i	ω	χ	$\dot{y}_f$	$\dot{y}_m$	r_m	ω_m	ω_m	χ_m
(6)	$\dot{z}$	v	τ	v	zf	M	ψ	$\dot{z}_f$	$\dot{z}_m$	v_m	τ_m	M_m	ψ_m

If a positive value is used for ICTYP, the units of the IC values are assumed to be external and consistent with DF and VF (Sec. 2.1.1). A negative value for ICTYP indicates that the values of IC are input in internal units but are output in external units via the DF and VF conversion factors. The values shown in the following example are not built into TRACE:

1 27 53 C	2 28 54 LOCATION	7 33 59 VALUE
I	ICTYP	2
	IC	126.1
	2	31.23
	3	89.95
	4	14.
	5	22600000.
	6	25117.3

ICTYP Initial conditions type:

= 1 The IC vector contains the ECI or BCI Cartesian coordinates x, y, z, $\dot{x}$, $\dot{y}$, and $\dot{z}$ (ft and ft/sec).

= 2 The IC vector contains the ECI or BCI spherical coordinates α, δ, β, A, r, and v (deg, ft, and ft/sec). If r is negative, it is interpreted as altitude. If v is negative, the circular orbital velocity is computed and used.*

*Differential correction of initial conditions normally alters the input values so that the initial conditions of height, circular velocity, or longitude are not maintained in successive iterations. Constraints (Sec. 9) must be used if such input relations are to be preserved.

= 3	The IC vector contains the ECI or BCI orbital elements a, e, i, Ω, ω, and τ (ft, deg, and min).
= 4	Same as ICTYP = 2 except that longitude replaces right ascension.
= 5	The IC vector contains the perigee initial conditions: longitude, declination, perigee and apogee heights, inclination (deg and nmi), and a unitless direction indicator. A northbound vehicle is indicated by zf > 0 and a southbound vehicle by zf < 0. It is assumed that epoch occurs at perigee and that $h_a \neq h_p$.
= 6	Same as ICTYP = 3 except that mean anomaly replaces τ. When IFØRM = 3 and NANSB ≠ 0, the orbital element a is input differently (see Sec. 11.1.6).
= 7	The IC vector contains the f and g equinoctial elements. These elements are unitless except for n (deg/sec) and L (deg).
= 8	The IC vector contains the earth-fixed Cartesian coordinates (ft and ft/sec).
= -1	Same as ICTYP = 1 except that the input units are er and er/min.
= -2	Same as ICTYP = 2 except that the input units are rad, er, and er/min.

= -3	Same as ICTYP = 3 except that the input units are rad, er, and min.
= -4	Same as ICTYP = 4 except that the input units are rad, er, and er/min.
= -5	Same as ICTYP = 5 except that the input units are rad and er.
= -6	Same as ICTYP = 6 except that the input units are rad, er, and min.
= -7	Same as ICTYP = 7 except that the input units are rad and rad/min.
= -8	Same as ICTYP = 8 except that the input units are er and er/min.
= 11	Same as ICTYP = 1 except that MCI coordinates are used.
= 12	Same as ICTYP = 2 except that MCI coordinates are used.
= 13	Same as ICTYP = 3 except that MCI coordinates are used.
= 15	Same as ICTYP = 5 except that MCI coordinates are used.
= 16	Same as ICTYP = 6 except that MCI coordinates are used.
= 17	Same as ICTYP = 7 except that MCI coordinates are used.

= 18	Same as ICTYP = 8 except that the moon-fixed coordinate system is used.
= -11	Same as ICTYP = -1 except that MCI coordinates are used.
= -12	Same as ICTYP = -2 except that MCI coordinates are used.
= -13	Same as ICTYP = -3 except that MCI coordinates are used.
= -16	Same as ICTYP = -6 except that MCI coordinates are used.
= -17	Same as ICTYP = -7 except that MCI coordinates are used.
= -18	Same as ICTYP = -8 except that the moon-fixed coordinate system is used.

The values in the following example are not built into TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	JCBDY	4
I	JBCI	4
I	ICBF	1

JCBDY — Central body to which the initial conditions refer (preset to zero).

JBCI — Coordinate frame (central body) in which the orbit is initially numerically integrated (preset to zero).

Note that both JCBDY and JBCI must be input when the interplanetary mode is used, although they need not have the same value in any given case. For example, JCBDY = 0 and JBCI = 2 indicates that the vehicle initial conditions are in the ECI frame, while the trajectory is generated in the MCI frame. For both JCBDY and JBCI, the listed values specify the following central bodies and coordinate frames:

Value	Central Body and Coordinate Frame
0	Earth (ECI)
1	Sun (HCI)
2	Moon (MCI)
3	Venus (VCI)
4	Mars (ACI)
5	Jupiter (JCI)
6	Saturn (SCI)

ICBF — Selenographic initial conditions indicator for ICTYP = 13, 15, 16, and 17:

= 0 — Lunar initial conditions are selenocentrically referenced.

≠ 0 — Lunar initial conditions are referenced to an inertial coordinate system with the lunar equator as the reference plane and the moon's prime meridian (at epoch) as the reference axis.

11.1.5 Coordinate and Timekeeping System Specifications

The value in the following example is not preset in TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	DALPH	.5

DALPH — The correction in right ascension of Greenwich needed to transform from mean to true equinox.

The value shown for NSYS is not preset in TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	NSYS	1

NSYS User-specified initial conditions coordinate system flag:

= 0 Input initial conditions are referenced to a user-specified coordinate reference system.

≠ 0 Input initial conditions are referenced to the true equator/true equinox of instant system. This option causes the elements to be printed in true equator/true equinox of instant system during an ITIN = 3 run and is used for the ECI mode only.

The remaining variables in this section are associated with the NASA option (Sec. 2.1.4). When these inputs are used, the timekeeping systems (Refs. 1 and 7) and the effects of precession, nutation, and pole wander are included in the coordinate transformation equations, and timing conventions are computed and applied. The ETUT array (not preset in TRACE) is used to relate atomic time (A1) to universal time (UT1). The values shown in the example are valid for some time around 08/01/70.

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	ETUT	8.5825
	2	2.1968E-10
	3	0.

The ETUT array defines the polynomial coefficients c_0, c_1, and c_2 used in the equation

$$A1 - UT1 = c_0 + c_1 T + c_2 T^2$$

where T is an internally computed function of atomic time, in seconds from the 0^{th} hour of the first day of the current month. This polynomial is used, along with UTD and ETTA1 (Sec. 2.1.4), to relate integration time (IT) to sidereal time (ST); i.e.

$$ST \equiv UT1 = IT + (ET - IT) - (ET - A1) - (A1 - UT1)$$

$$= IT + UTD - ETTA1 - (c_0 + c_1 T + c_2 T^2)$$

The WWVET array shown in the following example is used to relate atomic time to broadcast time (UTC); it is not preset in TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	WWVET	8.5496
	2	3.E-8

The WWVET array defines the polynomial coefficients b_0 and b_1, which are used in the equation

$$A1 - UTC = (b_0 + b_1 T)$$

where T is an internally computed function of time. This polynomial is used, along with UTD and ETTA1 (Sec. 2.1.4), to relate integration time to observation time (OT); i.e.

$$OT \equiv UTC = IT + (ET - IT) - (ET - A1) - (A1 - UTC)$$

$$= IT + UTD - ETTA1 - (b_0 - b_1 T)$$

Therefore, if the observations are tagged with some uniform time other than broadcast time, the WWVET array is set to zero, and UTD is set so that IT = OT.

If NASA = 2, it is necessary to input a table of pole-wander coordinates in PWAND (preset to zero). Note that these coordinates cannot be used with CDAHT inputs (Sec. 11.1.8). The following is an example of PWAND input:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	PWAND	3
	2	39108.5
	3	39126.5
	4	39144.5
	5	.0137
	6	.071
	7	.03
	8	.132
	9	.155
	10	.104

PWAND Pole-wander coordinates:

(1) NCT, the number of ordered triplets of modified Julian dates and their corresponding x- and y-coordinates (3 ≤ NCT ≤ 95).

(2) through (1 + NCT) NCT modified Julian dates

(2 + NCT) through (1 + 2NCT)	NCT x-coordinates, arc sec.
(2 + 2NCT) through (1 + 3NCT)	NCT y-coordinates, arc sec.

The following summarizes the various relationships controlled by the above inputs and by certain pertinent inputs listed in Sec. 2.1.4. Let:

IT ≡ integration time

A1 ≡ atomic time

ET ≡ ephemeris time

UT1 ≡ sidereal time

OT ≡ observation time

T ≡ atomic time (A1), seconds from the 0^{th} hour of the first day of the current month.

Then, if NASA ≠ 0, the following time transformations are performed

$$ET = IT + UTD \text{ (also done if NASA = 0)}$$

$$UT1 = IT + UTD - ETTA1 - (ETUT(1) + ETUT(2) \times T + ETUT(3) \times T^2)$$

$$OT = IT + UTD - ETTA1 - (WWVET(1) + WWVET(2) \times T)$$

and the right ascension of Greenwich as a function of time is computed as

$$\alpha = \alpha_{g_0} + \omega_1 \times UT1 - \omega_2 \times UT1^2 + \Delta\eta$$

where α_{g_0} is the internally computed right ascension of Greenwich at midnight, ω_1 and ω_2 are internally computed earth rotation constants, and $\Delta\eta$ is the internally computed nutation in right ascension.

If NASA = 1, the transformation used to evaluate the geopotential and locating trackers is from mean equinox and mean equator (MEE) of reference date (as specified by RJDAT) to earth-fixed (EF) instantaneous pole

$$\underline{r}_{EF} = R_3(\alpha) \cdot N \cdot P \cdot \underline{r}_{MEE}$$

where P is the precession matrix from reference date to current time, N is the nutation matrix at current time, and $R_3(\alpha)$ is the rotation about the Z axis through the angle α.

If NASA = 2, the transformation used in evaluating the geopotential and locating trackers is from mean equinox and mean equator of reference date to earth-fixed mean pole (EF_M) of 1903

$$\underline{r}_{EF_M} = W \cdot R_3(\alpha) \cdot N \cdot P \cdot \underline{r}_{MEE}$$

where W equals the pole-wander matrix of the current time.

11.1.6 Integrator-Peculiar Indicators

The values in the following example are preset as shown except for NANSB and DRAG, which are preset to zero:

C	LOCATION	VALUE
	PHASE	0
I	IFØRM	1
	SSTEP	100.
	SØRD	1.5
I	HØMØG	0
I	IVGMS	1

C	LOCATION	VALUE
I	NANSB	-1
	DRAG	.031925201
	2	.74462E-20

PHASE — Indicator of the coordinate system (ECI, MCI, or BCI) in which the vehicle trajectory is integrated:

- ≤ 0 — The vehicle trajectory is integrated in ECI.
- $= 1$ — The vehicle trajectory is integrated in MCI.
- $= 2$ — The vehicle trajectory is integrated in BCI.

IFØRM — Option flag controlling the independent variable in numerical integration; indicator of analytic trajectory models:

- $= 0$ or 1 — Time is the independent variable in the integration of the equations of motion and the variational equations.

= 2 Regularized time is the independent variable in the integration of the equations of motion and the variational equations. This option requires the use of SSTEP and SØRD.

= 3 One of several models for analytic trajectory generation is used. This option requires ADELT (Sec. 2.1.4) and NANSB and can be used only when ITIN = 3 or 4.

SSTEP Number of integration steps per revolution when the regularized time variable is used (IFØRM = 2).

SØRD Exponent in the transformation equation for the regularized time variable (IFORM = 2).

HØMØG Dynamic parameter selector flag. The capability exists to artifically force dynamic parameter uncertainties to zero on a selective basis:

= 0 All dynamic parameters have normal effect.

= 1 Set trajectory partial derivatives corresponding to MODEL parameters from GPRAM, ØPRAM and MPRAM (Sec. 2.1.5) to zero for this vehicle.

= 2 Set trajectory partial derivatives corresponding to VEHICLE parameters from VPRAM (Sec. 11.1.4) to zero for this vehicle.

= 3 Set trajectory partial derivatives corresponding to both MODEL and VEHICLE parameters to zero for this vehicle.

IVGMS — Vehicle-dependent gravity model indicator:

= o — A spherical earth is used.

= i — The terms (pairs of coefficients) used in the gravity model are those indicated in NTERM (i) and the normalization flag is NFØRM (i) (Sec. 2.1.2.2), where $1 \leq i \leq 7$. PHASE must equal zero, and the value input for the previous vehicle does not carry over. Since IVGMS is preset to one for each vehicle, the default gravity model is always the first.

NANSB — Specifier of the analytic trajectory model when IFØRM = 3:

= ±1 — SGP Model (Aerospace Code).

= 3 — NAVSPASUR Model.

= 4 — SGP or SEGP Model (NORAD Code).

= 5 — SGP Model, SGP4 Environment.

= 6 — SGP4 Model.

For all values of NANSB, ICTYP must equal ±6. The contents of the IC and DRAG arrays are as follows:

	NANSB					
	1	-1	3	4	5	6
IC	a	n	n	n	n	n
2	e	e	e	e	e	e
3	i	i	i	i	i	i
4	Ω	Ω	Ω	Ω	Ω	Ω
5	ω	ω	ω	ω	ω	ω
6	M	M	M	M	M	M
DRAG	$\dot{a}$	$\dot{n}/2$	M_2	$\dot{n}/2$	$\dot{n}/2$	B^*
2	$\ddot{a}/2$	$\ddot{n}/6$	M_3	$\ddot{n}/6$	$\ddot{n}/6$	0

All angles are in deg or rad for ICTYP = ±6: a is in er; $\dot{a}$, er/day; $\ddot{a}$, er/day^2; n, rev/day; $\dot{n}$, rev/day^2; $\ddot{n}$, rev/day^3 (except for NANSB = 3; in this case, n is in deg/herg**; M_2, deg/herg^2; and M_3, deg/herg^3. B^* is as supplied by NORAD. Note that GM, J_2, J_3, and J_4 may also be input (Secs. 2.1.1 and 2.1.2.2).

With any of these models, the trajectory is computed from an initial time t_i to a final time t_f at some Δt. PTIM (Sec. 11.3.1.1) specifies t_i, t_f, and the print time interval Δt_p. ADELT (Sec. 2.1.4) indicates the Δt for putting the data on the ephemeris file (Sec. 16.2) and replaces h, the current step size.

**A herg (characteristic time) is the time required for a satellite in a circular orbit at unit distance (one earth radius) to move one unit distance along its orbital arc. If time is given in hergs and distance is given in earth radii, the earth's gravitational constant GM = μ_e is unity (μ_e = 1).

11.1.7 Solar Radiation Pressure Coefficient

The solar radiation pressure coefficient $C_p A/W$ is input at CPAW to indicate that solar radiation effects are to be included in the equations of motion. This option requires the PLANT array (Sec. 2.1.3). CPAW is preset to zero; an example of input is:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	CPAW	4.E-9

11.1.8 Atmospheric Drag Model Indicator and Constants

The atmospheric density model used in TRACE is specified by IDRAG as follows:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	IDRAG	2
	ATMK	1
I	ITRP	0
	CDFT	10
	2	1440
	3	1.001
	4	.013
	5	.00025

IDRAG	Atmospheric density model indicator:	
	= 0	ARDC 1959 (preset value).
	= 1	Lockheed-Jacchia.
	= 2	Jacchia 1964.
	= 3	U. S. Standard 1962.
	= 6	LMSC 1967.
	= 7	Exponential.
	= 8	Cambridge Research Laboratory (Champion 1968).
	= 9	NWL.
ATMK	Constant scale factor applied to the atmospheric density (preset as shown).	
ITRP	Flag denoting the type of interpolation used to search for fcn(t) in APTAB, KPTAB, KCTAB, and FTEN:	
	= 0	Linear interpolation (preset value).
	= 1	Quadratic interpolation (four-point least-squares).

For a scale factor s on the drag acceleration between times t_1 and t_2, a second-order polynomial can be applied as

$$s = s_0 + s_1(t - t_1) + s_2(t - t_1)^2$$

where t is the current time, MME, and the other values are input at CDFT as follows (not preset):

CDFT — Time and coefficients for the second-order polynomial applied to drag acceleration:

(1) Time at which to start the application t_1, MME.

(2) Time at which to stop the application t_2, MME.

(3) s_0

(4) s_1 } Coefficients

(5) s_2

When the Jacchia 1964 Atmosphere Model is used, it is necessary to input, via APTAB, a table of planetary geomagnetic amplitudes a_p = fcn(t). When JKP ≠ 0 (Sec. 2.1.2.4.1), APTAB is used to provide fcn(t) for the ARDC 1959, U.S. Standard 1962, Lockheed-Jacchia, and Exponential Atmosphere Models. APTAB is not preset; an example of input is:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	APTAB	0.
	2	10.
	3	15.
	4	200.
	5	18.4
	6	650.
	7	19.6
	8	0.
	9	0.

APTAB Table of planetary geomagnetic amplitudes a_p as fcn(t) used with the JKP indicator. The times must be input in ascending order, and the table must be in the following format:

(1) = 0	Value used for the table look-up procedure.
(2)	Time t_1, MME.
(3)	Planetary geomagnetic amplitude a_{p_1} or fcn(t_1).
.	
.	
.	
(2i)	The i^{th} time ($1 \leq i \leq 50$).
(2i+1)	The i^{th} geomagnetic amplitude or fcn(t_i).
(2i+2) = 0 (2i+3) = 0	Values used to indicate the end of the table.

When the LMSC 1967 Atmosphere Model is used, it is necessary to provide, via KPTAB, a table of planetary range indices K_p = fcn(t). These indices are input as shown in the following example:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	KPTAB	0.
	2	100.
	3	5.5
	4	720.
	5	6.3
	6	1440.
	7	6.
	8	0.
	9	0.

KPTAB Table of planetary range indices K_p. The times must be input in ascending order, and the table must be in the following format:

(1) = 0 Value used by the table look-up procedure.

(2) Time t_1, MME.

(3) Planetary range index K_{p_1}.

.

.

.

(2i) The i^{th} time ($1 \le i \le 50$).

(2i+1) The i^{th} planetary range index.

(2i+2) = 0 }
(2i+3) = 0 } Values used to indicate the end of the table.

When the Cambridge Research Laboratory Atmosphere Model is used, it is necessary to input a table of planetary range indices K_c = fcn(t) at KCTAB, e.g.:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	KCTAB	0.
	2	0.
	3	5.2
	4	720.
	5	8.4
	6	1440.
	7	7.3
	8	0.
	9	0.

KCTAB Table of planetary range indices K_c. The times must be input in ascending order, and the table must be in the following format:

(1) = 0	Value used in the table look-up procedure.
(2)	Time t_1, MME.
(3)	Planetary range index K_{c_1}.
.	
.	
.	
(2i)	The i^{th} time $(1 \le i \le 50)$.
(2i+1)	The i^{th} planetary range index.
(2i+2) = 0	Values used to indicate the end of the table.
(2i+3) = 0	

When the NWL Atmosphere Model is used, it is necessary to input the variables shown in the following example:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	NWL	.01362
	2	-8.355
	3	.1018E-3
	4	1.083
	5	89.39
	6	0
	7	0
	8	0

NWL — NWL Atmosphere Model array:

(1) through (5) — Coefficients for the NWL Density Model equations (preset to zero).

(6) = 0 — Preset value that indicates no atmospheric bulge effect is considered.

$\neq 0$ — Bulge coefficient (the atmospheric bulge effect is considered.

(7) — Exponent for the NWL density bulge calculation (preset to zero).

(8) — Angle by which the atmospheric bulge lags behind the earth-sun vector (preset to zero).

The following example shows values for FTEN and FBAR, which are not preset in TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	FTEN	0.
	2	360.
	3	200.
	4	720.
	5	210.
	6	1440.
	7	220.
	8	0.
	9	0.
	FBAR	220.

FTEN — Table of solar flux indices $F_{10.7} = fcn(t)$ used with the Jacchia 1964, LMSC 1967, and Cambridge Research Laboratory Atmosphere Models. The times must be input in ascending order, and the table must be in the following format:

(1) = 0 — Value used by the table look-up procedure.

(2) — Time t_1, MME.

(3) — First solar flux index $F_{10.7_1}$, $10^{-22} W/m^2/Hz$.

.

.

.

(2i) The i^{th} time ($1 \leq i \leq 12$).

(2i+1) The i^{th} solar flux index.

(2i+2) = 0 }
(2i+3) = 0 } Values used to indicate the end of the table.

FBAR The 90-day average of the solar flux indices $\bar{F}_{10.7}$, 10^{-22}W/m^2/Hz, used with the Jacchia 1964, LMSC 1967, and Cambridge Research Laboratory Atmosphere Models.

Special tables specifying drag changes as functions of height and temperature, speed ratio, and angle of attack can be used with the Jacchia 1964 Atmosphere Model.*

*N. L. B. Anderson, C_D A Calculations for TRACE, ATM-67(2107-45)-3, The Aerospace Corp., El Segundo, Calif. (26 April 1967). Not available outside The Aerospace Corp.

Drag as a function of height and temperature is specified by a bivariant drag table, which is input as the two-dimensional array CDAHT. Twenty-six height values can be input for each of eleven temperatures and are specified in ascending order in the arrays called HIGHT and TINF, respectively. The example below symbolically shows drag values for three temperatures and three heights:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
M	CDAHT	26, 11
	01, 01	$C_DA(h_1, T_1)$
	02, 01	$C_DA(h_2, T_1)$
	03, 01	$C_DA(h_3, T_1)$
	01, 02	$C_DA(h_1, T_2)$
	02, 02	$C_DA(h_2, T_2)$
	03, 02	$C_DA(h_3, T_2)$
	01, 03	$C_DA(h_1, T_3)$
	02, 03	$C_DA(h_2, T_3)$
	03, 03	$C_DA(h_3, T_3)$
	HIGHT	h_1
	2	h_2
	3	h_3
	TINF	T_1
	2	T_2
	3	T_3

CDAHT — Two-dimensional array showing drag as a function of height and temperature used with the Jacchia 1964 Atmosphere Model:

(i, j) — The drag value to be used at the i^{th} height HIGHT(i) and the j^{th} temperature TINF(j) ($1 \le i \le 26$ and $i \le j \le 11$).

HIGHT — Table of heights associated with CDAHT and TINF:

(i) — Height at which $C_D A(h_i, T_j)$ is used, nmi ($1 \le i \le 26$). TINF(j) contains T_j. HIGHT must be input in ascending order.

TINF — Table of temperatures associated with CDAHT and HIGHT:

(j) — Temperature at which $C_D A(h_i, T_j)$ is used, K ($1 \le j \le 11$). HIGHT(i) contains h_i. TINF must be input in ascending order.

Drag as a function of speed ratio is input in CDAS. An example of the use of CDAS is given below:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	CDAS	0.
	.	
	.	
	2i	s_i
	2i+1	$C_DA(s_i)$
	.	
	.	
	.	
	2n+2	0.
	2n+3	0.

CDAS Table showing drag as a function of speed ratio (Jacchia 1964 Atmosphere Model). The entries are pairs of the speed ratio s_i and its associated drag value C_DA_i. The speed ratio must be input in ascending order, and the table must be in the following format:

(1) = 0 Value used by the table look-up procedure.

(2) Speed ratio s_i.

(3) Drag value C_DA_i.

•

•

•

(2i) The i^{th} speed ratio ($1 \leq i \leq 25$).

(2i+1) The i^{th} drag value.

(2i+2) = 0
(2i+3) = 0 } Values used to indicate the end of the table.

The drag value obtained from CDAHT or CDAS is modified by a scale factor, which is input as a function of angle of attack in CDCD0. The use of CDCD0 is shown in the example:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	CDCD0	0.
	•	
	:	
	2i	α_i
	2i+1	$[C_DA/(C_DA)_0]$ (α_i)
	•	
	:	
	2n+2	0.
	2n+3	0.

CDCD0	Table of angles of attack α_i and their associated scale factors $[C_DA/(C_DA)_0](\alpha_i)$ used to modify the drag value obtained from CDAHT or CDAS (Jacchia 1964 Atmosphere Model). Values are input in pairs ($1 \le i \le 50$), with α_i in ascending order, and the table must be in the following format:

(1) = 0	Value used by the table look-up procedure.
(2)	Angle of attack α_i, deg.
(3)	Scale factor $C_DA/(C_DA)_{0_i}$.
.	
.	
.	
(2i)	The i^{th} angle of attack ($1 \le i \le 50$).
(2i+1)	The i^{th} scale factor.
(2i+2) = 0 (2i+3) = 0	Values used to indicate the end of the table.

The value obtained in HTINF for height as a function of temperature determines whether CDAHT or CDAS is used to obtain the drag value. If the interpolated height is greater than the actual height, CDAHT is used; otherwise, drag is obtained from CDAS. The use of HTINF is shown in the following example:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	HTINF	0.
	.	
	:	
	2i	T_i
	2i+1	$h(T_i)$
	.	
	:	
	2n+2	0.
	2n+3	0.

HTINF — Table showing temperatures T_i, K, and their associated heights h_i, nmi, input in pairs, with temperature in ascending order ($1 \le i \le 25$). This table must be in the following format:

(1) = 0 — Value used by the table look-up procedure.

(2) — Temperature T_i, K.

(3) — Height h_i, nmi.

.

.

.

(2i) The i^{th} temperature ($1 \le i \le 25$).

(2i+1) The i^{th} height.

(2i+2) = 0
(2i+3) = 0 } Values used to indicate the end of the table.

The KDRAG option flag specifies the use of the CDCD0 and HTINF tables:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	KDRAG	1 or 2

KDRAG Flag signalling the type of attack angle computation:

= 1 The angle of attack is computed relative to the inertial velocity vector.

= 2 The angle of attack is computed relative to the computed velocity vector.

11.1.9 Vehicle Ballistic Coefficient

In TRACE, the reciprocal ballistic coefficient $C_D A/W$, ft^2/lb, can be specified in any one of three ways: as a constant in the DRAG vector; as a polynomial in time; or as the product of two quantities, only one of which is specified in the DRAG vector. It is usually specified as a constant in the DRAG vector, and NCDAW is input to specify the entries used. The values in the following example are not preset in TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	NCDAW	5
	DRAG	.01
	2	1000
	3	.02
	4	2000
	5	.015
	6	3000
	7	.016
	8	4000
	9	.015

NCDAW The number of entries used in the DRAG vector:

= 0 DRAG(1) contains the single entry used as $C_D A/W$; the rest of the array is not used.

≠ 0 The number of $C_D A/W$ entries (≤50) made to the DRAG vector, along with the switching times.

DRAG	A vector of reciprocal ballistic coefficients C_DA/W and corresponding times:	
	(1)	The ballistic coefficient C_DA/W used from epoch to t_2.
	(2)	Time t_2, MME.
	(3)	The ballistic coefficient C_DA/W used from t_2 to t_3.
	.	
	.	
	.	
	(2i-2)	Time t_i, MME.
	(2i-1)	The ballistic coefficient C_DA/W used from t_i to t_{i+1}.
	.	
	.	
	.	
	(2 × NCDAW-1)	The ballistic coefficient C_DA/W used from t_{NCDAW} to the end of the integration.

If NCDAW and DRAG are not used to specify C_DA/W as a constant in the DRAG vector, C_DA/W can be computed as a polynomial in time by the equation

$$C_DA/W = \sum_{i=0}^{n} C_i(t - t_r)^i$$

where t is the current time, MME, and C_i and t_r are specified in the DRAG vector. To use this option, MDRAG and DRAG are input as shown in the following example:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	MDRAG	3
	DRAG	.01
	2	15
	3	.4 × 10-5
	4	.3 × 10-7
	5	.2 × 10-9

MDRAG Indicator of the option of computing $C_D A/W$ as a polynomial in time:

$\neq 0$ Indicates that this option is to be used and contains the order of the equation ($1 \leq n \leq 5$).

The coefficients C_i and reference times t_{r_i} are input as follows:

DRAG (1) The initial coefficient C_0.

(2) The reference time t_r, MME.

(3) The next coefficient C_1.

.

.

.

(n+2) The last coefficient C_n.

It is also possible to specify the ball'stic coefficient as the product of two quantities; e.g.

$$(C_D A) \times (1/2)$$

$$(C_D A/W) \times (1)$$

$$(C_D) \times (A/W)$$

or as the inverse of these.

When the ballistic coefficient $C_D A/W$ is specified as the product of two quantities, DRAG indicates only one of these quantities, not the entire ballistic coefficient. The other component is specified as a function of height or time, in tabular form.

To illustrate, $(C_D) \times (A/W)$ is used. The DRAG vector specifies C_D, and A/W is input in the DTAB1 or DTAB2 vector. IDTAB indicates which of the two vectors is used. The values in the examples below are not preset:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	IDTAB	1
	HDTAB	300000.
	DTAB1	1
	2	0.
	3	300000.
	4	2.
	5	350000.
	6	1.5
	7	400000.
	8	1.
	9	0.
	10	0.

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	DTAB2	0.
	2	0.
	3	5.
	4	2.
	5	8.
	6	1.5
	7	11.
	8	1.
	9	0.
	10	0.

IDTAB DTAB1 or DTAB2 usage indicator:

= 0 $C_D A/W$ is determined entirely by the DRAG vector.

= 1 DTAB1, a table of A/W as a function of height, is used. HDTAB contains the altitude, ft, above which the A/W = fcn(h) table is to be used. When h < HDTAB, A/W = fcn(Mach No.) is used; this value is found in DTAB2.

= 2 DTAB1, a table of A/W as a function of time is used, and HDTAB is not used.

DTAB1 Table of $C_D A/W$ components as a function of height or time:

(1) = 0 Linear interpolation.

≠ 0 Quadratic interpolation.

(2) = 0 Value used by the table look-up procedure.

(3) The height h_1, ft, or the time t_1, MM.

(4) A/W_1.

.

.

.

(2n+1) h_n or t_n $(n \le 49)$.

(2n+2) A/W_n.

(2n+3) = 0 }
(2n+4) = 0 } Values used to indicate the end of the table.

DTAB2 Table of $C_D A/W$ components as a function of Mach No.:

(1) = 0 Linear interpolation.

≠ 0 Quadratic interpolation.

(2) = 0 Value used by the table look-up procedure.

(3) Mach $No._1$.

(4) A/W_1.

.

.

.

(2n+1) Mach $No._n$ $(n \le 49)$.

(2n+2) A/W_n.

(2n+3) = 0 }
(2n+4) = 0 } Values used to indicate the end of the table.

11.1.10 Accelerometer Model Data

TRACE can account for atmospheric effects with a drag replacement model instead of a density model (Sec. 11.1.8). This requires a non-standard binary data tape on Unit 12; the contents of this tape can be pairs of either (t_s, a_s) or (t_s, ΔV), where t_s is the time of sensed acceleration (seconds from epoch), a_s is the sensed intrack acceleration (ft/sec^2), and ΔV is the sensed intrack velocity (ft/sec).

Each record on the tape contains 2N+1 words:

Word 1 contains N ($1 \leq N \leq 100$).
Word 2 contains t_{s_1}, seconds from epoch.
Word 3 contains a_{s_1} or ΔV_1.
Word 4 contains t_{s_2}, seconds from epoch.
Word 5 contains a_{s_2} or ΔV_2.
.
.
.
Word 2N+1 contains a_{s_n} or ΔV_N.

Accelerometer models can be used only when integrating forward; their times must be in ascending order.

11.1.10.1 Sensed Acceleration Formulation

Effective acceleration is given by the equation

$$a_T = \frac{a_s - K^2}{1 + K^1}$$

where a_s is the sensed intrack acceleration, K^2 is the accelerometer bias, and K^1 is the accelerometer scale factor.

The required inputs are NACCT, ACCT, ATIME, and ITRP. The values shown in the following example are not built into TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	NACCT	2
	ACCT	720.
	2	.01
	3	3.E-4
	4	1400.
	5	.01
	6	2.5E-4
	ATIME	435.
I	ITRP	0

NACCT — The number of accelerometer models used ($1 \le$ NACCT ≤ 20) (preset to zero).

ACCT — Input for the accelerometer models:

[3(i-1)+1] Time to apply Model i, MME ($1 \le i \le 20$).

[3(i-1)+2] The scale factor for Model i K^1, MME.

[3(i-1)+3] The bias for Model i K^2, ft/sec^2.

ATIME — Additive bias for converting the time of sensed acceleration t_s to MME, min; e. g., $t = t_s/60 +$ ATIME.

ITRP Interpolation indicator for ACCT:

= 0 Linear interpolation on intrack acceleration.

= 1 Logarithmic interpolation on intrack acceleration.

11.1.10.2 The ΔV Formulation

The inputs associated with this option are shown in the following example:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	LGA	1
I	NACCT	1
	ACCT	2053.57
	2	.05
	3	3.2174E-6
	ATIME	435.

LGA The ΔV accelerometer model flag:

= 0 The ΔV option is not used (preset value).

≠ 0 The ΔV option is used.

ACCT and ATIME are input exactly as they are for the sensed acceleration formulation (Sec. 11.1.10.1).

11.1.11 Instantaneous Orbit Adjusts

There are two ways to input instantaneous orbit adjusts, PKCK (P-Kicks) and XKCK (X-Kicks). All input velocity units must be consistent with DF (Sec. 2.1.1), even if they are indicated as ft/sec in this writeup.

11.1.11.1 P-Kicks

Up to twenty orbit adjusts may be specified by PKCK (P-Kicks) input; each must be one of the following types, with the associated input:

Type = 1 — The inputs are $\Delta\dot{R}$, $\Delta\dot{T}$, and $\Delta\dot{C}$, which are the changes to the radial, intrack, and crosstrack velocity components, respectively.

Type = ±2 — The inputs are K, θ_p, and θ_y. K is the magnitude of the change in velocity. If Type = +2, θ_p is the pitch deflection measured clockwise from the intrack axis in the orbit plane, and θ_y is the yaw deflection measured counterclockwise from the intrack axis in the intrack-crosstrack plane. If Type = -2, the angles θ_p and θ_y are relative to the velocity vector rather than the intrack axis.

Type = 3 — The inputs are β, A, and v, which are the flight path angle, the aximuth angle, and the velocity desired after the orbit adjust, respectively.

NPKCK, which indicates the number of orbit adjusts, and the PKCK array are input as shown in the following example (the inputs shown are not built into TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	NPKCK	2
	PKCK	20.
	2	1.
	3	.15
	4	.46
	5	.85
	6	300
	7	2.
	8	.98
	9	15.
	10	17.

NPKCK — The number of orbit adjusts in PKCK:

= 0 — No orbit adjusts in PKCK.

≠ 0 — The number of orbit adjusts in the PKCK array (1 ≤ NPKCK ≤ 20).

PKCK The array for instantaneous orbit adjusts is of the form:

[5(i-1)+1] Time to apply the orbit adjust, MME ($1 \le i \le 20$).

[5(i-1)+2] Type of orbit adjust (1, ±2, or 3); input to the next three cells depends on this value.

[5(i-1)+3] $\Delta\dot{R}$, ft/sec (Type 1); K, ft/sec (Type 2); or β, deg (Type 3).

[5(i-1)+4] $\Delta\dot{T}$, ft/sec (Type 1); θ_p, deg (Type 2); or A, deg (Type 3).

[5(i-1)+5] $\Delta\dot{C}$, ft/sec (Type 1); θ_y, deg (Type 2); or v, ft/sec (Type 3).

11.1.11.2 X-Kicks

All orbit adjusts input in the XKCK (X-Kicks) array must be of the $\Delta\dot{R}$, $\Delta\dot{T}$, $\Delta\dot{C}$ type or the $\Delta\dot{T}$-only type (Sec. 11.1.11.1). In either case, NXE, NXKCK, and the XKCK array are all preset to zero. The following is an example of the $\Delta\dot{R}$, $\Delta\dot{T}$, $\Delta\dot{C}$ form:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	NXE	4
I	NXKCK	2
	XKCK	50.
	2	.43
	3	.85
	4	.2
	5	100.
	6	.3
	7	.95
	8	.36

NXE — The number of values input for each orbit adjust in the XKCK array:

= 0 — No values are input.

≠ 0 — The number of values input for each orbit adjust (in this example, four).

NXKCK — The number of orbit adjusts in the XKCK array ($1 \le NXKCK \le 50$).

XKCK — The array for instantaneous orbit adjusts is of the form:

[4(i-1)+1] — Time to apply the orbit adjust, MME ($1 \le i \le 50$).

[4(i-1)+2] — $\Delta\dot{R}$, ft/sec.

[4(i-1)+3] — $\Delta\dot{T}$, ft/sec.

[4(i-1)+4] — $\Delta\dot{C}$, ft/sec.

The following is an example of the $\Delta\dot{T}$-only form. Note that in this example NXE = 2; i.e., two items are input for each orbit adjust.

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	NXE	2
I	NXKCK	3
	XKCK	100.
		.95
		200.
		1.05
		300.
		1.

NXKCK The number of orbit adjusts in the XKCK array ($1 \le NXKCK \le 100$).

XKCK The array for instantaneous orbit adjusts is of the form:

[2(i-1)+1] Time to apply the orbit adjust, MME ($1 \le i \le 100$).

[2(i-1)+2] $\Delta\dot{T}$, ft/sec.

11.1.12 Finite Thrusting

The input for finite thrusting must be for one of the nine models used in TRACE (Ref. 2):

- Model I $\quad \ddot{\underline{r}}_4 = T_1 e^{\left[-T_2(t-t_s)\right]} \dfrac{\dot{\underline{r}}}{|\dot{\underline{r}}|}$

- Model II $\quad \ddot{\underline{r}}_4 = \left[\dfrac{(T/W)g_0}{1 - \dfrac{T}{W} g_0 \dfrac{t-t_s}{C}}\right] \dfrac{\dot{\underline{r}}}{|\dot{\underline{r}}|}$

- Model II′ $\quad \ddot{\underline{r}}_4 = \left[\dfrac{(a/g\ )(r_0^2 / r^2)g_0}{1 - (a/g\ )(r_0^2 / r^2)g_0 \dfrac{t-t_s}{C}}\right] \dfrac{\dot{\underline{r}}}{|\dot{\underline{r}}|}$

- Model III $\quad \ddot{\underline{r}}_4 = [RTC]\ a \begin{pmatrix} \ell \\ m \\ n \end{pmatrix}$

- Model IV $\quad \ddot{\underline{r}}_4 = [RTC]\, a \begin{pmatrix} \sin\theta_p' \cos\gamma + \cos\theta_p' \cos\theta_y' \sin\gamma \\ -\sin\theta_p' \sin\gamma + \cos\theta_p' \cos\theta_y' \cos\gamma \\ \cos\theta_p' \sin\theta_y' \end{pmatrix}$

- Model V $\quad \ddot{\underline{r}}_4 = [RTC]\, a \begin{pmatrix} \sin\theta_p \\ \cos\theta_p \cos\theta_y \\ \cos\theta_p \sin\theta_y \end{pmatrix}$

Thrust Models VI, VII, and VIII are similar to Models III, IV, and V, respectively, except that the acceleration magnitude a is calculated from thrust and flow rate and is not constant during a thrusting interval.

The following definitions apply to all models:

$\ddot{\underline{r}}_4$ = the acceleration due to thrusting
t = the current time, MME
$\dot{\underline{r}}$ = the velocity vector at time t
g_0 = the gravitational force at the earth's surface
[RTC] = the rotation matrix that transforms the acceleration from the orbit-plane to the ECI system
γ = the angle between the velocity and the intrack vectors

and (for Models VI, VII, and VIII):

$$a = \frac{T_{g_0}}{W}$$

$$W = W_0 - \dot{W}(t - t_s)$$

W_0 = the initial vehicle weight input in WZERØ, lb

The reciprocal ballistic coefficient C_DA/W is modified to reflect the new value of W, the vehicle weight. WZERØ, WMIN, and WTAB must be input as described in Sec. 11.1.13.

In the following example of finite thrusting input, the values are not preset in TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	NTHST	2
	THST	1.3078
	2	5.9627
	3	1.
	4	.00010627
	5	.2563
	6	0.
	7	25467.8
	8	10.012
	9	18.267
	10	4.
	11	.00023671
	12	-15.63
	13	1.76
	14	-.01078

NTHST The number of finite thrusts to apply ($1 \le$ NTHST ≤ 15).

THST Input for finite thrusts. Input for the i^{th} thrust must be made according to Table 11-2 ($1 \le i \le 15$). All input velocity and acceleration units must be consistent with VF and AF (Sec. 2.1.1), even if they are given in ft/sec and ft/sec^2.

TRACE is modeled so that $\ddot{\underline{r}}_4$ is applied until t_f is reached or until v is achieved, whichever occurs first, except that in Model II only t_f is considered. No thrusting can be applied during a backward integration if $v < 0$, and only one thrust can be applied at a time.

Table 11-2. Input for ith Thrust

Method	I	II	II′	III(VI[a])	IV(VII[a])	V(VIII[a])
THST[7(i-1)+1]	t_s	t_s	t_s	t_s	t_s	t_s
THST[7(i-1)+2]	t_f	t_f	t_f	t_f	t_f	t_f
THST[7(i-1)+3]	1	2	2	3(6)	4(7)	5(8)
THST[7(i-1)+4]	T_1	T/W	0	a(T)	a(T)	a(T)
THST[7(i-1)+5]	T_2	C	C	ℓ	θ'_y	θ_y
THST[7(i-1)+6]	0	0	a/g	m	θ'_p	θ_p
THST[7(i-1)+7]	±v	±v	+v	n	±v	±v

Value	Description
t_s	Time to start applying thrust i, MME.
t_f	Time to stop applying thrust i, MME.
T_1	Acceleration magnitude used in Model I, ft/sec^2.
T_2	Decay ratio used in Model I, min^{-1}.
T/W	Thrust-to-weight ratio used in Model II.
C	Exhaust velocity used in Models II and II′, ft/sec.
(a/g)	Ratio of acceleration to gravitational force at the earth's surface used in Model II′. The approximation $g = g_o r_o^2/r^2$ is used in this model.
a	Magnitude of the acceleration, ft/sec^2.
ℓ, m, n	Direction cosines of the acceleration vector in the orbit-plane system used in Model III.
θ'_y, θ'_p	Yaw and pitch angles measured from the inertial velocity vector used in Model IV, deg.
T	Thrust for interval i for Models VI, VII, and VIII, lb.
θ_y, θ_p	Yaw and pitch angles needed in Model V and measured in the orbit-plane system, deg.
v < 0	Velocity increment due to thrusting, ft/sec.
v > 0	Total inertial velocity, ft/sec.

[a]THST input for Models VI, VII, and VIII is shown in parentheses when it is different from the input for Models III, IV, and V.

11.1.13 Weight Losses

In TRACE, vehicle weight losses can be specified as either instantaneous or linear. In either case, an initial vehicle weight must be input, and a minimum weight at which the losses are terminated may be input. For example:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	WZERØ	40000
	WMIN	400

WZERØ — The initial vehicle weight for weight loss, lb (preset to 1). This value is used for W_0 in Thrust Models VI, VII, and VIII (Sec. 11.1.12).

WMIN — The minimum vehicle weight for weight loss, lb (preset to zero).

Care should be taken when these values are input because the effective $C_D A/W$ can be the product of values from the C_D tables or the DRAG vector (Sec. 11.1.9) and the reciprocal of WZERØ.

When weight losses are used with Model II finite thrusting, WZERØ must be specified to compute the weight loss due to thrust. The vehicle weight continues to decrease, even after WMIN has been reached.

11.1.13.1 Instantaneous Weight Losses

As many as 45 instantaneous losses may be input. Data for each loss consists of the time to apply the loss and the actual weight change. The values shown in the following example are not built into TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	NWTAB	2
	WTAB	1400.
	2	100
	3	2800
	4	50

NWTAB The number of instantaneous vehicle weight losses:

= 0 No instantaneous vehicle weight losses.

≠ 0 The number of weight losses in WTAB ($1 \leq NWTAB \leq 45$).

WTAB The times and corresponding vehicle weight changes to be subtracted from the current weight. The input for the i^{th} loss is:

[2(i-1)+1] Time to apply the weight loss, MME.

[2(i-1)+2] Weight loss, lb.

11.1.13.2 Weight Losses from Flow Rate for Thrust Models VI, VII, and VIII

If Thrust Models VI, VII, or VII are used, instantaneous weight losses must not be used (NWTAB must equal zero). Instead, WTAB is used to store the flow rate and the minimum weight for the i^{th} thrust interval as follows:

WTAB	[2(i-1)+1]	$\dot{W}$ for the thrust interval, lb/min.
	[2(i-1)+2]	W_{MIN}, the minimum vehicle weight allowed in the thrust interval, lb.

11.1.13.3 Linear Losses

When linear weight losses are applied, it is necessary to input the beginning and final times to apply a loss and the rate of decay during that interval. The values shown in the following example are not built into TRACE (all are preset to zero, indicating no linear weight loss):

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	WTIMI	10
	WTIMF	1440
	WDØT	1

WTIMI Time at which the linear weight loss is to be initialized, MME.

WTIMF Time at which the linear weight loss is to be terminated, MME.

WDØT The rate of vehicle weight decay to be applied during the specified interval, lb/min.

Note that no linear weight losses are allowed if Thrust Models VI, VII, or VIII are used.

11.1.14 Vehicle Parameter Specifications

Vehicle-dependent parameters for ephemeris generation, orbit determination, or error analysis runs must be specified in the VPRAM matrix. The values shown in the following VPRAM example are not built into TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
M	VPRAM	04.60
D	01.01	BETA ⑥ P
	03.01	.05
	04.01	.01
D	01.02	AZ ⑧ Q
	03.02	.01
·	04.02	.001
D	01.03	V
	03.03	1.
	04.03	.5

VPRAM A 4 × 60 matrix that contains the parameter identification (name), P-Q indicator, bound, and sigma for each parameter:

(01,i) Characters one through ten specify the name of the i^{th} parameter, and the eleventh character is the P-Q indicator (a blank or a P indicates a P parameter, and a Q indicates a Q parameter).

(03,i) The i^{th} parameter bound, which is used only for a P parameter during an orbit determination run.

(04,i) The i^{th} parameter a priori sigma, which is never required but which may be used for orbit determination and covariance analysis runs (ØPBØX, Secs. 2.2.1 and 2.5.1).

Vehicle-dependent parameter names acceptable for initial conditions are:

X = x	ALPHA = α	A* = a	AF = a_f
Y = y	DELTA = δ	E = e	AG = a_g
Z = z	BETA = β	I = i	N = n
DX = $\dot{x}$	AZ = A	Ø = Ω	L = L
DY = $\dot{y}$	R = R	U = ω	CHI = χ
DZ = $\dot{z}$	V = V	TAU = τ	PSI = ψ

*The names in this column can be used to solve for the selenographic initial conditions a, e, i, ℓ_Ω, ω, and τ if ICBF is input = 2 (Sec. 11.1.4).

Other acceptable parameter names are:

TZERØ — Parameter name for t_0, the time at epoch.

CPAW — Parameter name for $C_P A/W$, the solar radiation pressure coefficient (Sec. 11.1.7).

DRAG — Parameter name for $C_D A/W$, the reciprocal ballistic coefficient when segmented drag is not used (Sec. 11.1.9).

ATMK — Parameter name for the constant scale factor applied to atmospheric density (Sec. 11.1.8).

DPi — Parameter name for $(C_D A/W)_i$, the ballistic coefficients when segmented drag is used ($1 \le i \le 50$).

DRAGi — Parameter name for the C_i coefficients, which are used to compute the ballistic drag coefficient as a polynomial in time ($0 \le i \le 5$).

ATIME — Parameter name for the additive bias used to convert the time of sensed acceleration (accelerometer) to MME (Sec. 11.1.10).

K1j — Parameter name for the accelerometer scale factor for the j^{th} model (j = 01, 02, . . . , 20, Sec. 11.1.10).

K2j — Parameter name for the accelerometer bias for the j^{th} model (j = 01, 02, . . . , 20, Sec. 11.1.10).

KPjk — Parameter names for the PKCK (P-Kicks) components (Sec. 11.1.11.1), where j = 1, 2, or 3 indicates the j^{th} component of the orbit adjust and k = 1, 2, . . . , 20 indicates the k^{th} input orbit adjust. The PKCK type input is the type solved for.

TPji — Parameter names for the components of the thrust indicators, where j = 1, 2, 3, or 4 indicates the j^{th} component in the last four lines of Table 11-2 other than zero or v (Sec. 11.1.12); i = 1, 2, . . . , 15 indicates the i^{th} input thrust interval.

TSi — Parameter name for the start time of the i^{th} input thrust interval for Thrust Model V (Sec. 11.1.12), where $1 \le i \le 15$.

TFi — Parameter name for the stop time of the i^{th} input thrust interval for Thrust Model V (Sec. 11.1.12), where $1 \le i \le 15$.

All initial condition parameters must be of the same type, but it is not necessary to specify a full set. Nor is it necessary that they be of the same type as the initial conditions in the IC vector; e.g., ICTYP may be input one when the initial condition parameters are ALPHA, BETA, and R. A maximum of 30 delayed vehicle parameters (DPi, K1j, K2j, KPjk, and TPji) is allowed in TRACE.

11.1.15 Powered Flight Input

The user may generate powered flight trajectories using the TRACE powered flight integrator (SEG18). The VEHICLE and MODEL input variables peculiar to this integrator are shown in the examples that follow.

The MODEL input variables required to generate a powered flight trajectory are PH0, the initial powered flight numerical integration step size, and PHMIN, the minimum powered flight numerical integration step size. The values shown in the following example are preset in TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	PH0	.125
	PHMIN	.001908125

The VEHICLE input variables required to generate a powered flight trajectory are PØWER, NPFRP, PFRP, IDRAG, DRAG, KDRAG, CDAS, IØTPF, AL, and DL. A typical powered flight application is shown in the following example:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	PØWER	1
I	NPFRP	2
M	PFRP	16, 15
	01,01	1
	02,01	291.67
	03,01	6000.
	04,01	400000.
	05,01	2400
	06,01	0
	07,01	0.
	08,01	0.
	09,01	0.
	10,01	.167
	01,02	2
	06,02	0
	07,02	0.
	08,02	-5.
	09,02	0.
	10,02	.0178

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	IDRAG	0
	DRAG	80.
		0.
		0.
		80.
		0.
I	KDRAG	-1
	CDAS	0
	2	0
	3	.22
	4	.3
	5	.21
	6	.6
	7	.17
	8	1.15
	9	.55
	10	2.5
	11	.45
	12	12.0
	13	.38
	14	0.
	15	0.
I	IØTPF	1

PØWER Powered flight trajectory generation indicator:

= 0 SEG18 is not used.

≠ 0 SEG18 is used.

NPFRP Total number of stages (primary and secondary), including powered and free flight stages. Note that the value of NPFRP must not exceed 15.

Powered flight input variables associated with the dynamic thrust model are specified for stages (time intervals); these stages can be either primary or secondary. Primary stage inputs must include I_{sp}, A_e, W_0, and $\dot{W}$. These values are used until another primary stage is defined. Secondary stages always follow a primary stage; the values used for I_{sp}, A_e, W_0, and $\dot{W}$ are those defined by the previous primary stage. Note that there must be a one-to-one correspondence between the number of stages and the number of pairs of values in the DRAG table.

PFRP A 16 × 15 matrix that contains the powered flight staging variables associated with each i^{th} stage ($1 \le i \le 15$):

(01,i) Primary or secondary stage indicator:

= 1 Primary stage.
= 2 Secondary stage.

(02,i) Specific impulse I_{sp}, for the i^{th} stage, sec.

(03,i) Exit area A_e for the i^{th} stage, ft^2.

(04, i) Initial weight W_0 of the i^{th} stage, lb, or an indicator:

- ≥0 This weight is exactly known and is used for the i^{th} stage.
- <0 The initial weight of the stage = $W_{0_j} - \dot{W}_j (t_i - t_j)$, where W_{0_j} and $\dot{W}_j$, t_j refer to the stage preceding Stage i.

(05, i) Weight flow rate $\dot{W}$ for the i^{th} stage, lb/sec.

(06, i) Indicator specifying the method of computation of the turning rates for the i^{th} stage:

- = -1 Constant piecewise.
- = 0 Constant.
- = 1 Gravity turn.

(07, i) Constant roll turning rate ω_r, deg/sec, or roll scale factor k_r for tabular rate data specified by (06, i) = -1.

(08, i) Constant pitch turning rate ω_p, deg/sec, or pitch scale factor k_p for tabular rate data specified by (06, i) = -1.

(09, i) Constant yaw turning rate ω_y, deg/sec, or yaw scale factor k_y for tabular rate data specified by (06, i) = -1.

(10, i) Nonzero value Δt required for the i^{th} stage, min.
If $\Delta t_i > 0$, $t_{i+1} = t_i + \Delta t_i$; if $\Delta t_i < 0$, $t_{i+1} = |\Delta t_i|$, MME.

(11, i) Achieved change in velocity ΔV_f during the i^{th} stage, ft/sec.

(12, i) Cutoff altitude h_f for the i^{th} stage, ft.

(13, i) Cutoff angle of attack cos α_f for the i^{th} stage.

(14, i) Achieved weight W_f during the i^{th} stage, lb.

(15, i) Roll axis aximuth for the i^{th} stage, deg.

(16, i) Roll axis pitch attitude for the i^{th} stage, deg.

If any of the items (11, i) through (14, i) are not input, that cutoff criterion is not employed. Otherwise, the first applicable cutoff criterion to occur terminates that particular stage.

IDRAG Atmospheric density model indicator (see Sec. 11.1.8).

DRAG Table of vehicle drag and lift reference area coefficients corresponding to the stage ordering, ft^2:

(1) Drag reference area coefficient C_DA or A.

(2) Constant lift reference area coefficient $C_{L_o}A$ or A.

(3) Lift slope reference area coefficient $C_{L_\alpha}A$ or A.

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(3i-2) Drag reference area coefficient C_DA or A for the i^{th} stage ($1 \leq i \leq 15$).

(3i-1) Constant lift reference area coefficient $C_{L_o}A$ or A for the i^{th} stage.

(3i) Lift slope reference area coefficient $C_{L_\alpha}A$ or A for the i^{th} stage.

KDRAG — Drag and lift table indicator:

- = 0 — Lift and drag coefficients are obtained directly from DRAG.
- = -1 — The drag coefficient C_D and the lift coefficients C_{L_o} and C_{L_α} are computed as functions of Mach No. by using CDAS, a table of C_D vs Mach No. (Sec. 11.1.9), DTAB1, a table of C_{L_o} vs Mach No., and DTAB2, a table of C_{L_α} vs Mach No. These numbers are then multiplied by the appropriate entry in DRAG. Note that this cannot be used with IDTAB≠0.

The type of initial roll axis orientation alignment and the initial values of the roll axis, right ascension, and declination are input using the variables listed below:

IØTPF — Type of initial roll axis orientation alignment:

- = 0 — Right ascension and declination of the roll axis are input (AL, DL).
- = 1 — Values for AL and DL are computed from the vehicle initial conditions relative to geocentric latitude.
- = 2 — Values for AL and DL are computed from the vehicle initial conditions relative to geodetic latitude.
- = -1 — The initial orientation of the roll axis is aligned along the relative velocity vector.

AL — Right ascension of roll axis α_L, deg.

DL — Declination of roll axis δ_L, deg.

VPRAM (Sec. 11. 1. 14) names acceptable for vehicle-dependent powered flight parameters are:

AL	Initial roll axis right ascension angle.
DL	Initial roll axis declination angle.
T_i	Start time for the i^{th} stage $(1 \le i \le 15)$.
TPji	Primary stage parameter names $(1 \le i \le 15)$:

j = 1	The I_{sp} parameter for the i^{th} stage.
j = 2	The A_e parameter for the i^{th} stage.
j = 3	The W_0 parameter for the i^{th} stage.
j = 4	The $\dot{W}$ parameter for the i^{th} stage.

WRi	The ω_r or k_r parameter for the i^{th} stage $(1 \le i \le 15)$.
WPi	The ω_p or k_p parameter for the i^{th} stage $(1 \le i \le 15)$.
WYi	The ω_y or k_y parameter for the i^{th} stage $(1 \le i \le 15)$.
AZ_i	Roll axis azimuth angle for the i^{th} stage, $(1 \le i \le 15)$.
$BETA_i$	Roll axis pitch attitude for the i^{th} stage $(1 \le i \le 15)$.
DPi	The C_DA or A parameter for the i^{th} stage $(1 \le i \le 15)$.
LPZi	The $C_{L_0}A$ or A parameter for the i^{th} stage $(1 \le i \le 15)$.
LPAi	The $C_{L_\alpha}A$ or A parameter for the i^{th} stage $(1 \le i \le 15)$.

11.2 DATA FOR DIFFERENTIAL CORRECTION RUNS (ITIN = 2)

Observation data input, observation spans, and SLS best-fit ephemeris node times are described in this section.

11.2.1 Observation Data Input

Observation data may be input to TRACE by one of three methods:

- OBSERVATION cards (Sec. 15).
- Card image observation tape (Sec. 16.4).
- Binary observation tape (Sec. 16.3).

Only one input method can be used per case. The values in the following example are not built into TRACE, but are preset to zero:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	BTIME	1440
	BCDIN	1

BTIME The last observation time, MME. If BCDIN = 0 and if there are no OBSERVATION cards, it indicates that the binary observation tape (Logical Unit 3) is being used. On the binary tape, the observations must be in time sequence, and the STATION cards (Sec. 4) must be in the same order as they were when TAPE3 was generated. BTIME may also be used under any circumstances to provide a stop time for the numerical integration process. During a backwards integration, BTIME is negative if the last observation time is prior to midnight of epoch.

BCDIN Card image observation tape input indicator:

= 0	The card image observation tape is not used.
≠ 0	Observations are input via card image observation tape on Logical Unit 4. If they are not in TRACE format, IØBSF must be input (Sec. 2.1.7).
>0	TAPE4 contains one file with one record per card image, and the data for each vehicle is separated by an END card image. The tape is always read to the end of the file after the last vehicle.
= -1	There is one file of observations on Logical Unit 4, which is rewound and is read to the one END card for each vehicle.
<-1	The observation file on Logical Unit 4 is not rewound and is read only to STØP (Sec. 11.2.2).

Care should be taken with multi-arc runs to see that START-STØP intervals do not overlap for this option. If the cases are stacked, the BCDIN for the last vehicle can be input >0.

11.2.2 Observation Span

It may be desirable to use only a certain span of input observations when an orbit determination run is made. This cannot be done when the binary observation tape is used (Sec. 11.2.1) but when cards or a card image tape is used (Secs. 15 and 11.2.1), this option is available via the input START AND STØP vectors (preset to zero); e.g.:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	START	1967
	2	10
	3	12
	4	10
	5	4
	6	4
	STØP	1967
	2	10
	3	14
	4	23
	5	52
	6	0

START	Time of the first observation accepted:	
	(1)	Year.
	(2)	Month.
	(3)	Day.
	(4)	Hour.
	(5)	Minute.
	(6)	Second.
STØP	Time of the last observation accepted:	
	(1)	Year.
	(2)	Month.
	(3)	Day.
	(4)	Hour.
	(5)	Minute.
	(6)	Second.

All observations before START and after STØP are rejected. If START is not input, the START observation rejection test is not made, and/or if STØP is not input, the STØP rejection test is not made.

11.2.3 SLS Best-Fit Ephemeris Node Times

The following example is not preset in TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	DNØDE	4
	2	4
	3	90
	4	181
	5	272
	6	363

DNØDE SLS best-fit ephemeris node times:

(1) The number of node times ±n to follow in this vector ($1 \leq n \leq 98$). If n is positive, the times are in minutes; if n is negative, the times are in seconds.

(2) The number of revolutions N to predict when MVET = 2 (Sec. 2.2.11.1)

(3) through (n+2) The descending node times used for differencing when MVET = 2. If they are in ascending order, they are times from epoch; if not, they are from midnight of the current day.

11.3 DATA FOR EPHEMERIS GENERATION RUNS (ITIN = 3)

Output options for ephemeris generation runs are described below.

11.3.1 Vehicle Output

The following sections describe output options for ephemeris generation runs.

11.3.1.1 Specified Print Times

For many ephemeris generation runs, the user may want to vary the output rate to obtain a high rate at times of great interest or a low one at times of little interest. He may, for example, print from t_1 to t_2 every Δt_1 minutes, from t_2 to t_3 every Δt_2 minutes, and from t_3 to t_4 every Δt_3 minutes. In TRACE, this option is provided by the PTIM vector. The values in the following example are not built into TRACE but are preset to zero:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	PTIM	0.
	2	2.
	3	0.
	4	5.
	5	10.
	6	0.
	7	30.
I	IUTC	1

PTIM Print time vector:

(1) = 0 The print times t_i are specified in MME.

= 1 The print times t_i are specified in minutes from epoch.

(2) = n The number of different print time intervals being input ($1 \leq n \leq 20$).

(3) = t_1 The beginning of the first interval.

(4) = Δt_1 The print time step for the first interval, min.

(5) = t_2 The end of the first interval.

(6) = Δt_2 The print time step for the second interval, min.

(7) = t_3 The end of the second interval.

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(2n+2) = Δt_n The print time step for the last interval, min.

(2n+3) = t_{n+1} The end of the last interval.

Note that output always occurs at epoch and that if Δt_i is input $\geq t_{i+1} - t_i$ or if $\Delta t_i = 0$, output occurs at t_i and t_{i+1}, just as it would if Δt_i were input $= t_{i+1} - t_i$. For backward integrations, the print intervals must be in descending order, and the print time steps and H0 (Sec. 2.1.4) must be negative.

IUTC Print time referenced to UTC indicator:

= 0 The print times are referenced to integration time.

= 1 The print times are referenced to UTC (Sec. 11.1.5) when NASA ≠ 0 (Sec. 2.1.4).

11.3.1.2 Event Print Options

For many ephemeris generation runs, the user is interested in output at points on the orbit at which times are not known to the desired degree of accuracy. TRACE provides the option to search for and generate output at a selected set of special orbital conditions, e.g.:

- Equatorial crossings
- Apogee-perigee (β = 90 deg)
- Minimum and maximum heights above the oblate central body
- Geocentric latitude crossings
- Longitude crossings
- Specific heights above the oblate central body
- Eclipsing entry and exit
- Observation times

The user may also be interested in output variables not provided by the standard ephemeris output (which includes the vehicle state vector in body-centric, fixed, and spherical coordinate frames) generated by TRACE. These special outputs are:

- Elements
- Variational equations
- Sun-moon angles
- Geomagnetic latitude and longitude

The special output options are controlled as follows:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
D	PRCDE	ABCDEFGHIJKLMNØPQ

Each position of PRCDE represents a special output option (Table 11-3). When output is requested at special latitudes, longitudes, and altitudes by placing an X in the proper position of PRCDE, inputs are necessary to LATPR, LØNPR, and ALTPR (all preset to zero in TRACE). For example:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	LATPR	2
	2	10.
	3	15.
	LØNPR	2
	2	135.
	3	260.
	ALTPR	2
	2	4000.
	3	5000.

Table 11-3. PRCDE Special Output Options

Position	Option	Character[a]	Description
A	Standard print	A = X or blank	Standard TRACE trajectory output is printed whenever specified by PTIM and at all detected output times.
		A = 7	All printing at descending nodes is suppressed.
		A = 8	All printing at descending and ascending nodes is suppressed.
		A = D	All printing after epoch print and before the first print time (PTIM, Sec. 11.1.1) is suppressed.
		A = N	Same as A = X or blank, except that output is printed only at ascending nodes. Note that the reference ephemeris is written on TAPE8 or, if ephemeris differences are computed (Sec. 11.3.2), this option can be used to suppress output printing without affecting data written on TAPE8.
B[b]	Sun-moon output	B = V	Sun and moon coordinates are computed and printed: they are written on TAPE8 if $1 \le N\emptyset M \le 4$.
		B = W	Local solar time and transverse ecliptic coordinates are computed and printed; they are written on TAPE8 if $1 \le N\emptyset M \le 4$.
		B = X	Right ascension, declination, elevation above the horizon at the sub-vehicle point, and the angles between the radius vector to the vehicle and the radius vectors to the sun and moon are computed and printed at all output times.
		B = Y	In addition to the B = X output, two angles are computed and printed: the angle between the sun vector (relative to the vehicle) and the crosstrack vector and the angle between the sun vector (relative to the vehicle) and an input vector specified by AXIS (Sec. 11.3.1.2).
		B = Z	In addition to the B = X output, four angles are computed and printed for the sun and moon when the angle between the vehicle-earth and vehicle-moon vectors is less than the angle input at THMIN (Sec. 11.3.1.2). They are the angles between the vehicle-earth line and the projection of the vehicle-sun (or moon) line in the orbit plane and the angles between the vehicle-sun (or moon) line and its projection in the orbit plane.

[a] Blank means no action except for A and Ø.

[b] This option requires a planetary ephemeris file (Sec. 2.1.3).

Table 11-3. PRCDE Special Output Options (Continued)

Position	Option	Character[a]	Description
C	Apogee-perigee	C = X	TRACE computes and prints whenever β = 90 deg.
D	Minimum and maximum heights above the oblate earth.	D = X	TRACE computes and prints whenever $\dot{h}$ = 0.
E	Special geocentric latitudes	E = X	TRACE generates output whenever latitudes specified by LATPR (Sec. 11.3.1.2) are encountered.
		E = Y	Output is also generated when $\partial(\sin \delta)/\partial t = 0$ (i.e., at maximum latitudes).
F	Special longitudes	F = X	TRACE generates output whenever longitudes specified by LØNPR (Sec. 11.3.1.2) are encountered.
G	Special altitudes	G = X	TRACE generates output whenever special altitudes specified by ALTPR (Sec. 11.3.1.2) are encountered.
H[b]	Eclipsing	H = X	TRACE generates output when entry or exit to the umbra or penumbra of the earth or moon occurs. On completion of the eclipse cycle (entry through exit), a summary is generated. MODEL input is required (Sec. 2.3.2).
		H = E	In addition to the H = X output, the distance to the sun and the umbra cone half-angle are printed with all other outputs.
I	Observation times	I = X	TRACE generates ephemeris outputs at all observation times.
		I = Y	In the lunar mode, TRACE suppresses all other PRCDE options and generates the following data at each observation time: MME; system time; and moon-fixed latitude, longitude, and altitude.
K	Elements	K = X	TRACE prints the Keplerian elements at all ascending nodes.
		K = Y	The elements are printed at all output times.

[a]Blank means no action except for A and Ø.

[b]This option requires a planetary ephemeris file (Sec. 2.1.3).

Table 11-3. PRCDE Special Output Options (Continued)

Position	Option	Character[a]	Description
L	Variational equations	L = X	The variational equations are printed at each output time.
		L = 2	In addition to the L = X output, the variational equations are output in the orbit-plane system (∂R/∂p, ∂T/∂p, ∂C/∂p, etc.).
		L = 3	In addition to the L = X output, a special partials tape is generated (Logical 8).
		L = 4	In addition to the L = 2 output, a special partials tape is generated (Logical 8).
M	Geomagnetic latitude and longitude	M = X	Geomagnetic latitude and longitude of the satellite are printed at all output times.
N	Abbreviated output format	N = X	The ephemeris output is printed on a single line, which contains the time (MME), the Cartesian position and velocity (ft and ft/sec), and the rev count. If variational equation and/or orbit difference output is requested, each is printed on one line in the Cartesian coordinate system.
Ø	Mode print lines	Ø = X	In the MCI mode, TRACE output is printed in both the ECI and MCI systems.
		Ø = blank	In the MCI mode, TRACE output is printed only in the MCI system.
P	Cartesian coordinates punched	P = X	Cartesian coordinates are punched at each print time, km and km/sec.
Q	Atmospheric density	Q = X	Density prints for the atmospheric models specified by IDRAG = 0, 1, or 2 (Sec. 11.1.8).
		Q = X and PRCDE(C) = X	Density is also printed at perigee + 1/2 scale height, requiring DRAGF input (Sec. 11.3.1.2).
		Q = Y and PRCDE(C) = X	Density is printed for the Jacchia-Nicolet atmosphere with the Walker-Bruce modification only at perigee and at perigee + 1/2 scale height, requiring DSTRT, DSTØP, and DRAGF inputs (Sec. 11.3.1.2). At these times, cards are punched with a special density output (Sec. 16.14).
R[b]	Local noon and midnight	R = X	Print at local noon and midnight.

[a]Blank means no action except for A and Ø.

[b]This option requires a planetary ephemeris file (Sec. 2.1.3).

LATPR Table of vehicle latitudes at which the trajectory information is requested:

(1) Contains ℓ ($1 \le \ell \le 10$), the number of special latitudes to follow.

(2) Contains the first special latitude, deg.

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(ℓ+1) Contains the last special latitude, deg.

LØNPR Table of vehicle longitudes at which the trajectory information is requested:

(1) Contains m ($1 \le m \le 10$), the number of special longitudes to follow.

(2) Contains the first special longitude, deg.

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(m+1) Contains the last special longitude, deg.

ALTPR Table of vehicle altitudes at which trajectory information is requested:

(1) Contains n ($1 \le n \le 10$), the number of special altitudes to follow.

(2) Contains the first special altitude, nmi.

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(n+1) Contains the last special altitude, nmi.

If ephemeris output is desired at observation measurement times [PRCDE(I)], these times are input in one of three ways (Sec. 11.5.2):

- OBSERVATION cards (Sec. 15)
- Card image observation file (Sec. 16.4)
- Binary observation file (Sec. 16.3)

Note that a specific span of observations (Sec. 11.5.3) and REJECT data (Sec. 13) may also be used with an ITIN = 3 run.

Except for DRAGF, which is preset as shown, the values in the following example are not built into TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	AXIS	1.
	2	0.
	3	0.
	THMIN	10.
	DSTRT	25.
	DSTØP	105.
	DRAGF	1.

AXIS — Specifies a direction vector (e.g., vehicle roll axis) in the inertial coordinate system. The program computes the angle between the direction of the sun and this direction. Inertial components of the vector may be input in any units. Used with PRCDE(B) = Y (Table 11-3).

THMIN — Specifies the minimum angle between the vehicle-earth vector and the extension of the vehicle-moon vector; i.e., the vehicle lies within certain limits between the earth and the moon. Used with PRCDE(B) = Z (Table 11-3).

DSTRT, DSTØP — Specify the start and stop times to apply the drag specified in DRAGF, MME. Used with PRCDE(Q) = Y (Table 11-3).

DRAGF — Theoretical C_DA/W value used to compute density ratio at perigee height plus one-half scale height. Used with PRCDE (Q) = X or Y (Table 11-3).

An initial revolution count (preset to zero) can be input at REV, e.g.:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	REV	5.

PLNØP, a vector of characters used to control the planetary ephemeris print options, is used as follows:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
D	PLNØP	ABCDEFGHIJ

PLNØP Planetary ephemeris print options:

<u>Position</u>

A through F — An X in any of these positions requests printing of the vehicle position and velocity relative to the first through the sixth body, respectively, as on ephemeris file TAPE7. The coordinate system is parallel to the ECI frame and is centered on the particular planetary body requested. The magnitude and components of the position and velocity vectors are printed.

If Position J contains an X, a Y in any of these positions requests printing of the PCA (point of closest approach) to the planetary body. A Z requests the position and velocity relative to the body and the PCA to it.

G and H — Not used

I — An X causes the PCA of the two satellites to be computed as an additional print to orbit differencing.

J — An X causes the PCA to a planetary body to be computed for each body on the planetary ephemeris file TAPE7.

11.3.1.3 Coordinate Systems

TRACE can print vehicle state information in additional reference coordinate systems; MSYS is the indicator that allows the user to specify one of several reference frames. The value given in the following example is not preset in TRACE:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	MSYS	1

MSYS — The coordinate system in which vehicle ephemerides are printed:

- = 0 — Standard TRACE BCI reference system.
- ≠ 0 — Vehicle state information is printed in a true equinox and true equator (TEE) coordinate system during an ITIN = 3 run.

11.3.2 Trajectory Differences

On request, TRACE writes the satellite ephemeris information on TAPE8; this information may be used as input to other programs or as a reference orbit with which to compute differences with another satellite. Also on request, TRACE computes and prints the ephemeris differences between a given reference orbit and other orbits, i.e., as the reference minus the other. The ephemeris differences are written on TAPE9 (Sec. 16).

11.3.2.1 Reference Versus Difference Orbits

Orbits are designated as either reference or difference orbits by inputting NØM, as shown in the following example:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	NØM	4

NØM Designator of reference or difference orbit:

= 0 No action is taken with this preset value.

= 1 The current orbit is the first reference orbit written on TAPE8; i.e., TAPE8 is rewound before any data is generated and is not rewound when the case is completed.

= 2 The current orbit is added to TAPE8, which is not rewound before or after the orbit is added.

= 3 The current orbit is the last to be added to TAPE8, which is rewound only after the case is completed.

= 4 The current orbit is the only orbit written on TAPE8, which is rewound before and after the case.

= 5	The current orbit is differenced with the first orbit on TAPE8. The differences are written on TAPE9, which is rewound before any data is generated but not after the case is completed.
= 6	The current orbit is differenced with the first orbit on TAPE8. The differences are added to TAPE9, which is not rewound before or after the case.
= 7	The current orbit is the last differenced with the first orbit on TAPE8. The differences are added to TAPE9, which is rewound only when the case is completed.
= 8	The current orbit is the only orbit differenced with the first orbit on TAPE8. The differences are written on TAPE9, which is rewound both before and after the case.

11.3.2.2 Time-Tag Matching

The reference and the difference orbits must have ephemeris information generated at exactly the same integration time. If the times do not match, a difference is not computed. If it is known that for some reason the times will not match exactly, the tolerable error can be specified in EPSDF, min. EPSDF is internally preset to zero and is input as shown in the example below:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	EPSDF	1.E-6

11.3.2.3 Printer Plot

When trajectory differences are generated; i.e., when NØM > 4, TRACE generates a printer plot of the differences after each case is completed. The coordinate system in which the differences are to be printed and the components are to be plotted is controlled by TPLØT, which is internally preset blank. The time scale is given by DTPLT, in minutes per print character, 100 print characters per page. TPLØT and DTPLT input is shown in the following example:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
D	TPLØT	ABCDEFG
	DTPLT	15.

TPLØT Plotting options for difference runs:

Position

A Selection of the coordinate system to be used for the plot:

= 1 $x, y, z, \dot{x}, \dot{y}, \dot{z}$.

= 2 $\alpha, \delta, \beta, A, r, v$.

= 3 $a, e, i, \Omega, \omega, \tau$.

= 4 longitude, latitude, β, A, r, v.

= 5 $R, T, C, \dot{R}, \dot{T}, \dot{C}$.

= 6 $x, y, z, \dot{x}, \dot{y}, \dot{z}$.

Note that when A = 6, the differences and the second differences (see Sec. 11.3.2.4) are plotted, one component per plot. The first differences are plotted with the numerals 1, 2, . . . , 6, and the second differences × 100 are plotted with the letters A, B, . . . , F.

B First component plot option:

= 0 or blank Do not plot.

= X Plot.

C Second component plot option:

= 0 or blank Do not plot.

= X Plot.

D Third component plot option.

E Fourth component plot option.

F Fifth component plot option.

G Sixth component plot option.

11.3.2.4 Numerical Trajectory Partials

To test the accuracy of the integrated variational equations for a particular parameter of interest p, TRACE can also generate the predicted difference between a reference and a perturbed orbit. The nominal orbit is generated first, and only the parameter of interest is varied on subsequent orbits. When $\Delta p = p_{nominal} - p_{perturbed}$ is input in PDIFF, the predicted difference is computed as $\Delta\tilde{S} = (\partial S/\partial p)\Delta p$, and a second difference representing the accuracy of the prediction is formed as $\epsilon = \Delta S - \Delta\tilde{S}$. These differences are computed at prespecified times (PTIM, Sec. 11.3.1.1). The components of ΔS and ϵ can be displayed in a printer plot by selecting the option A = 6 in the previous section.

PDIFF input is shown in the example (preset to zero):

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	PDIFF	.01

11.4 DATA FOR MEASUREMENT DATA GENERATION RUNS (ITIN = 4)

Output options for measurement data generation runs are described below.

11.4.1 Data Output Options

Normally, all data is printed as it is generated; i.e., in time sequence. If JSØRT is input zero, as in the example, the data is saved and sorted by station before it is printed. This option does not apply when MULTV ≠ 0 (Sec. 2.1.6).

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	JSØRT	0

JSØRT   Data generation output sequence indicator.

JRIST is usually preset to zero to indicate that all data specified on the DATA GENERATION II cards (Sec. 12.2.1) is generated and printed. It is input as shown in the example below:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	JRIST	1

JRIST Rise-set only indicator:

= 1 Output occurs only at the initial and last sightings and at the maximum elevation of a vehicle pass relative to the station. The output consists of the time and the azimuth and elevation angles. Similar output occurs when RANGE and RRATE are input (Sec. 2.4.1.4). The DATA GENERATION II cards (including the END card) must be omitted (Sec. 12.2.1). This option applies when MULTV = 0 (Sec. 2.1.6) and when MULTV ≠ 0 and IVIS = 3 (Sec. 2.4.1.8).

NØISE contains a positive number used to start the generation of random numbers. This number, with standard deviations (Sec. 2.4.3), applies Gaussian noise to the desired generated measurements. Each value of NØISE produces a unique set of Gaussian random numbers. If NØISE is not input, TRACE uses zero, which indicates that noise is not to be added to the data.

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	NØISE	2

Biases may also be added to the generated measurements by including appropriate SENSOR parameter cards (Sec. 5). Note that for this application only the station identification, parameter name, and parameter value are used. On the generated observations, a revolution number is inserted as pass identification.

If BTAPE is input nonzero, as in the following example, a binary tape of the observations, acceptable as TRACE input, is generated on Unit 3 (Sec. 16.3).

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	BTAPE	1

BTAPE Binary observation tape generation indicator.

If ETAPE ic input nonzero, as in the example that follows, a card image tape of the observations, acceptable as TRACE input, is generated on Unit 4 (Sec. 16.4). It contains one file with one record per card image, and the data for each vehicle is separated by an END card image (Sec. 15.1).

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
I	ETAPE	1

ETAPE Optional card image tape of the observations generated.

11.4.2 Input for Look and Aspect Angle Measurements

If look angle generation is indicated on a single-vehicle DATA GENERATION II card (Sec. 12.2.1), DCLK must contain the direction cosines of the roll axis: e.g.:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	DCLK	.8
	2	.6
	3	0

DCLK Direction cosines of roll axis for look angle generation.

If aspect angle generation is indicated on a single-vehicle DATA GENERATION II card and if the yaw, pitch, and roll angles are other than zero, these values, deg, may be indicated in YAW, PITCH, and RØLL:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	YAW	10
	PITCH	15
	RØLL	20

YAW — Vehicle yaw angle for aspect angle generation, deg.

PITCH — Vehicle pitch angle for aspect angle generation, deg.

RØLL — Vehicle roll angle for aspect angle generation, deg.

As many as six sets of time-dependent increments can be input for yaw, pitch, and roll in ASPCT, which is input as follows:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	ASPCT	1
	2	20
	3	25
	4	35
	5	15

ASPCT — Time-dependent increments for yaw, pitch, and roll angles for generating aspect angles. Each set must be input as follows:

[4(i-1)+2] The last time to use set i, MME.

[4(i-1)+3] Δyaw_i, deg/sec.

[4(i-1)+4] $\Delta pitch_i$, deg/sec.

[4(i-1)+5] $\Delta roll_i$, deg/sec.

From epoch to time t_1 YAW, PITCH, and RØLL are incremented by the amounts in the first set; from t_1 to t_2 by the second set, etc. After the final input time, the last values computed for yaw, pitch, and roll are used.

11.5 DATA FOR COVARIANCE ANALYSIS RUNS (ITIN = 5)

Output options for covariance analysis runs are described below.

11.5.1 Specified Print Times

For many covariance analysis runs, the user may want to vary the output rate to obtain a high rate at times of great interest or a low one at times of little interest. For example, he may want to print from t_1 to t_2 every Δt_1 min, from t_2 to t_3 every Δt_2 min, and from t_3 to t_4 every Δt_3 min. This option is provided in TRACE by the PTIM vector. The values in the following example are not built into TRACE but are preset to zero:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	PTIM	0.
	2	2.
	3	0.
	4	5.
	5	10.
	6	0.
	7	30.
I	IUTC	1

PTIM — Print time vector:

(1) = 0 — The print times t_i are specified in MME.

= 1 — The print times t_i are specified in minutes from epoch.

(2) = n — The number of print intervals being input ($1 \le n \le 20$).

(3) = t_1 — The beginning of the first interval.

(4) = Δt_1 — The print time step for the first interval, min.

(5) = t_2 — The end of the first interval.

(6) = Δt_2 — The print time step for the second interval, min.

(7) = t_3 — The end of the second interval.

.

.

.

(2n+2) = Δt_n — The print time step for the last interval, min.

(2n+3) = t_{n+1} — The end of the last interval.

Note that output does not automatically occur at epoch. If $t_i + \Delta t_i > t_{i+1}$ or if = 0, output occurs at t_i and t_{i+1}, just as it would if Δt_i were input $= t_{i+1} - t_i$.

IUTC Print time referenced to UTC indicator (Sec. 11.1.5).

$\neq 0$ The print times are referenced to UTC when NASA $\neq 0$ (Sec. 2.1.4) and MULTV = 0.

11.5.2 Observation Data Tape Input

Observation data may be input to TRACE by one of three methods:

- OBSERVATION cards (Sec. 15)
- Card image observation tape (Sec. 16.4)
- Binary observation tape (Sec. 16.3)

Only one method can be used per case. The values in the following example are not built into TRACE but are preset to zero:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	BTIME	1440
	BCDIN	1

BTIME The last observation time, MME; if BCDIN = 0 and if there are no OBSERVATION cards, the binary observation tape (Logical Unit 3) is being used. On the binary tape, the observations must be in time sequence, and the STATION cards must be in the same order as when TAPE3 was generated. During a backwards integration, BTIME is negative if the last observation time is prior to midnight of epoch.

BCDIN Card image observation tape input indicator:

= 0 The tape is not used.

≠ 0 The observations are input via card image observation tape on Logical Unit 4. If they are not in TRACE format, IØBSF must be input (Sec. 2.1.7).

11.5.3 Specific Observation Spans (START, STØP)

It may be desirable to use only a certain span of input observations when a covariance analysis run is made. This option cannot be used with a binary observation tape (Sec. 11.5.2) but when cards or card image tape is used (Secs. 15 and 11.5.2), this option is available via START and STØP vector input (preset to zero). For example:

1 27 53	2 28 54	7 33 59
C	LOCATION	VALUE
	START	1967
	2	10
	3	12
	4	10
	5	4
	6	4
	STØP	1967
	2	10
	3	14
	4	23
	5	52
	6	0

START	The time of the first accepted observation:	
	(1)	Year.
	(2)	Month.
	(3)	Day.
	(4)	Hour.
	(5)	Minute.
	(6)	Second.
STØP	The time of the last accepted observation:	
	(1)	Year.
	(2)	Month.
	(3)	Day.
	(4)	Hour.
	(5)	Minute.
	(6)	Second.

All observations before START and after STØP are rejected. If START is not provided, the START observation rejection test is not made, and/or if STØP is not provided, the STØP rejection test is not made.

12. DATA GENERATION INPUT

FIGURES

TABLES

12. DATA GENERATION INPUT

DATA GENERATION input specifies data (e.g., data rate, visibility restrictions, start and stop times, and measurement types) required for generating simulated tracking data for each station.

The DATA GENERATION cards must be preceded by a card with DATA GENERATIØN punched in Columns 1 through 15. The DATA GENERATION I cards follow the DATA GENERATIØN card and are terminated by a card with END punched in Columns 1 through 3. The DATA GENERATION II cards, with a second END card, complete the DATA GENERATION deck setup (Fig. 12-1). The number of cards for each set must not exceed the number of STATION cards input for that run (Sec. 4). When multiple arcs are used, the entire set of DATA GENERATION cards must be reinput because no data is retained from the previous vehicle.

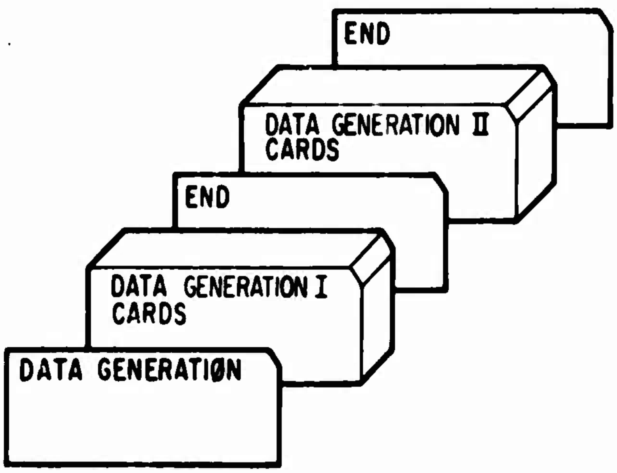


Fig. 12-1. DATA GENERATION I and II Data Deck Setup

12.1 DATA GENERATION I CARDS

The DATA GENERATION I card (p. D-16) indicates visibility restrictions; its format is shown in Table 12-1.

Table 12-1. DATA GENERATION I Card Format

Card Column	Header	Description	Unit
1-3	ST	Station identification, which must correspond to the identification appearing on the STATION card for that station.	
5-12	ΔT	The time interval at which data for a given station is to be generated and the testing interval for rise-set time computations (ΔT is always > 0).	sec
14-19	E_{min}	Minimum elevation at which the vehicle is considered visible.	deg
21-26	E_{max}	Maximum elevation at which the vehicle is considered visible (zero value or blank is set to 90).	deg
28-36	R_{max}	Maximum range at which the vehicle is considered visible (zero value or blank causes this test to be ignored).	n mi
38-39 41-42 44-50	START	Start time, from midnight of epoch date, for generating data (a zero value or blank implies that epoch is the start time).	day hr min
52-53 55-56 58-64	STOP	Stop time, from midnight of epoch date, for generating data.	day hr min
66-71	A_1	Azimuth at which the vehicle is considered visible, used with A_2 ($0 \le A_1 \le 360$ deg).	deg
73-78	A_2	Azimuth at which the vehicle is no longer considered visible; i.e., $A_1 \le Az \le A_2$ must hold ($0 \le A_2 \le 360$). The computed azimuth is Az; all angles are measured positive in the clockwise direction. If $A_1 = A_2 =$ zero or blank, the test is ignored.	deg

All fields except ST, the day and hour for the start time, and the day and hour for the stop time require a decimal point. The maximum range R_{max} may have an exponent of the form ±XX in the last three columns of the field.

The DATA GENERATION I cards are also used if multiple start and stop times are desired. All fields on the cards remain blank except the extra start and stop times; these cards must be placed immediately behind the initial DATA GENERATION I card for the particular station for which the extra time span is desired. A maximum of 200 extra cards may be input in any combination; e.g., 20 for a first station, 80 for a second station, . . . , up to 200.

When one is integrating backwards, it is only necessary to input H0 (Sec. 2.1.4) negative; the start and stop times are interpreted as before midnight of epoch date.

An example of DATA GENERATION I input is:

						START TIME			STOP TIME				
ST	ΔT (sec)*	E_{min} (deg)*	E_{max} (deg)*	R_{max} (nm)*	EXP.	DY	HR	MIN*	DY	HR	MIN*	A_1 (deg)*	A_2 (deg)*
DATA GENERATION													
001	60.	5.					12	24.5		22			
004	60.	5.					12	24.5		22			
005	60.	5.					12	24.5		22			
006	60.	5.					12	24.5		22			
009	60.	5.								17			
							20			22			
END													

12.2 DATA GENERATION II CARDS

The contents and format of the DATA GENERATION II cards are described in this section.

12.2.1 Single-Vehicle DATA GENERATION II CARDS

The DATA GENERATION II cards (p. D-17) specify the measurement types to be simulated and must be in the same station order as the DATA GENERATION I cards. The format is shown in Table 12-2, an example of input is:

ST (1–3)	5 RANGE	6 AZIMUTH	7 ELEVATION	8 RANGE RATE	9 P DOT	10 Q DOT	11 P	12 Q	13 AZIMUTH RATE	14 ELEVATION RATE	15 R DOUBLE DOT	16 MUTUAL VISIBILITY	17 LATITUDE	18 LONGITUDE	19 SURFACE RANGE	20 HEIGHT	21 DOPPLER RATE	22 LOOK ANGLE	23 OBSERVATION VARIANCES	24 KAPPA	25 ASPECT ANGLES	26 ATTENUATION	27 [illegible]	28 TOPOCENTRIC RA, D	29 GEOCENTRIC RA, D	30 HOUR ANGLE	31 U, V	32 ACCELEROMETER	33 A DOUBLE DOT	34 E DOUBLE DOT	35 2 WAY DOPPLER	36 ANTENNA	37	38 TRANET	39 GEOCEIVER	40 SOLS	41	42 SATELLITE-TRACKER DOPPLER	43 TIME OF ARRIVAL	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
001	X	X	X	X							X																																																	
004	X	X	X						X	X																																																		
005	X	X	X																																X																								
006	X	X	X																																																									
009	X	X	X																																																									
END																																																													

If LGT (Secs. 2.2.5, 2.4.2, and 2.5.2) is input nonzero and if there is an X in Columns 17, 18, 19, 22, 24, 25, 27, 29, 31, 33, 34, or 43, an error remark is printed and no data is generated.

When a rise-set run (JRIST ≠ 0, Sec. 11.4.1) is made, the DATA GENERATION II cards and their END card must be omitted from the deck setup (Fig. 12-2).

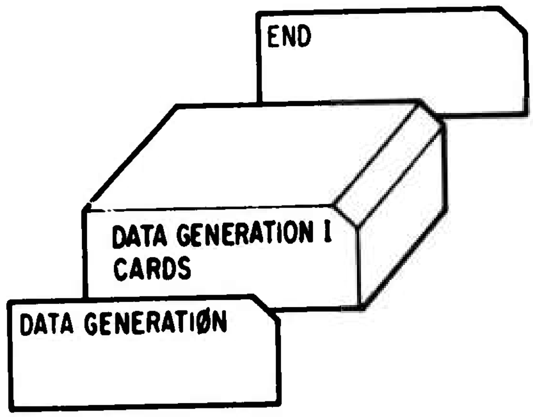


Fig. 12-2. DATA GENERATION Cards for a Rise-Set Only Run

Table 12-2. DATA GENERATION II Card Format

Card Column	Description
1-3	Station identification, which must correspond to the identification appearing on the STATION card for that station
5-43	An X entered in the appropriate column initiates output of the measurement described

Card Column	Measurement Description	Unit[a]
5[b]	Range	distance[c]
6[b]	Azimuth	deg
7[b]	Elevation	deg
8[b]	Range rate	vel
9-12[b]	$\dot{P}$, $\dot{Q}$, P, Q (interferometer data requiring P and Q stations)	vel and distance[c]
13	Azimuth rate	deg/sec
14	Elevation rate	deg/sec
15	Range acceleration	acceleration
16	Mutual visibility (currently not available)	——
17	Vehicle geodetic latitude	deg
18	Vehicle longitude	deg
19	Surface range from station	distance[c]
20[b]	Vehicle height	distance[c]
21[b]	Doppler rate	cps
22	Look angle, the angle between the vehicle roll axis and the station-vehicle line of sight. The direction cosines of the roll axis must be entered in DCLK(1-3) in the VEHICLE inputs (Sec. 11.4.2)	deg
23	Observation variances (currently not available)	——
24	Kappa, the angle between the station line of sight and the geocentric radius vector to the vehicle	deg

[a]All velocity and acceleration units are determined by the conversion factors VF and AF (Sec. 2.1.1).

[b]These quantities are output on ETAPE and BTAPE (Sec. 11.4.1). Distance or velocity units are determined by DF or VF (Sec. 2.1.1).

[c]These printed output units are determined by the conversion factor input item DCF (Sec. 2.4.1.2).

Table 12-2. DATA GENERATION II Card Format (Continued)

Card Column	Measurement Description	Unit
25	Aspect angles. Angle 1 (Φ) is defined as that angle between the vehicle yaw axis and the projection of the station line-of-sight vector in the roll plane. Angle 2 (θ) is defined as that angle between the vehicle roll axis and the line-of-sight vector to the station	deg
26	Signal attenuation = -40 log R × 0.43429448, where R is the vehicle slant range	dB
27[b]	$\hat{x}$, $\hat{y}$, and $\hat{z}$	distance[c]
28[b]	Topocentric right ascension and declination	deg
29[b]	Geocentric right ascension and declination	deg
30[b]	Topocentric hour angle	deg
31[b]	u and v (vehicle-centered argument of latitude and crossplane angles)	deg
32[b]	Accelerometer (currently not available)	———
33	Azimuth acceleration	deg/sec^2
34	Elevation acceleration	deg/sec^2
35[b]	Two-way doppler (requires a P station and a DATA GENERATION I card for that station)	cps
36[b]	x-antenna and y-antenna angles	deg
38[b]	Tranet doppler	cps
39[b]	Geoceiver range difference	distance[c]
40[b,d]	SLGS range rate	vel
42	Satellite-tracker doppler counts, including satellite only and tracker only (requires STATION Data Set Type 3, Sec. 5).	cps
43[b]	Time of arrival and its count N	sec

[a]All velocity and acceleration units are determined by the conversion factors VF and AF (Sec. 2.1.1).

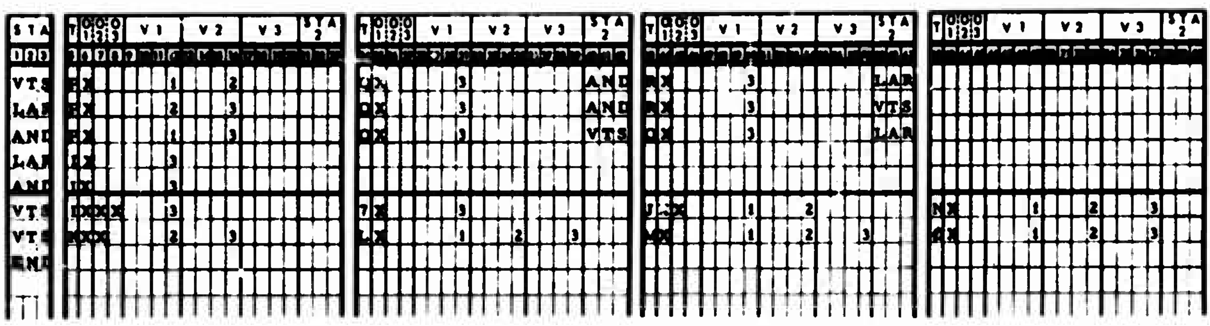
[b]These quantities are output on ETAPE and BTAPE (Sec. 11.4.1). Distance or velocity units are determined by DF or VF (Sec. 2.1.1).

[c]These printed output units are determined by the conversion factor input item DCF (Sec. 2.4.1.2).

[d]ETAPE and BTAPE contain only the SGLS range rate; printed data contains five additional values.

12.2.2 Simultaneous-Vehicle DATA GENERATION II CARDS

The simultaneous-vehicle data generation (MULTV ≠ 0, Sec. 2.1.6) requires a different DATA GENERATION II card (p. D-18). Its format is shown in Table 12-3, an example of input is:



Simultaneous-vehicle generated observations are shown in Table 12-4.

Table 12-3. Simultaneous-Vehicle DATA GENERATION II Card Format

Card Column	Symbol	Description
1 - 3	STA	Primary station identification, which must correspond to the identification appearing on the STATION card for that station (Sec. 4)
5, 24, 43, 62	T	Data set type for simultaneous-vehicle data set types and associated measurements (Table 12-4)
6, 25, 44, 63	O_1	If an X is entered, OBSERVATION 1 of Data Set Type T is generated
7, 26, 45, 64	O_2	If an X is entered, OBSERVATION 2 of Data Set Type T is generated
8, 27, 46, 65	O_3[a]	If an X is entered, OBSERVATION 3 of Data Set Type T is generated
9 - 12 28 - 31 47 - 50 66 - 69	V1	Vehicle 1 identification number (Sec. 11.1.2)
13 - 16 32 - 35 51 - 54 70 - 73	V2	Vehicle 2 identification number
17 - 20 36 - 39 55 - 58 74 - 77	V3	Vehicle 3 identification number
21 - 23 40 - 42 59 - 61 78 - 80	STA_2	Secondary station identification associated with Date Set Type T. It must correspond to the identification appearing on the STATION card for that station

[a]An X in this column for Data Set Type U generates vehicle-to-vehicle topocentric right ascension and declination rather than azimuth and eievation for OBSERVATIONS 1 and 2. The vehicle number in OBSERVATION 3 is set negative.

Table 12-4. Simultaneous-Vehicle Generated Observations

Data Set Type	OBSERVATION 1	Unit[a]	OBSERVATION 2	Unit[a]	OBSERVATION 3	Unit[a]
1	Range	distance	Azimuth	deg	Elevation	deg
7	Range rate	vel	Not used	-	Not used	-
J	Range from Vehicle V1 to Vehicle V2	distance	Range rate for OBS1	vel	Vehicle number V2	-
K	Range from station to Vehicle V1 to Vehicle V2	distance	Range rate for OBS1	vel	Vehicle number V2	-
L	Range from station to Vehicle V1 to Vehicle V2 plus range from Vehicle V2 to Vehicle V3	distance	Vehicle number V3	-	Vehicle number V2	-
M	Range rate for OBS1 of Data Set Type L	vel	Vehicle number V3	-	Vehicle number V2	-
N	Range from Vehicle V1 to Vehicle V2 to Vehicle V3	distance	Vehicle number V3	-	Vehicle number V2	-
Ø	Range rate for OBS1 of Data Set Type N	vel	Vehicle number V3	-	Vehicle number V2	-
P[b]	Time difference of arrival data	sec	Not used	-	Vehicle number V2	-
Q[b]	Time-of-arrival data	sec	Not used	-	Not used	-
R[b]	Three-way range	sec	Not used	-	Not used	-
S	Multipath	sec	Not used	-	Vehicle number V2	-
T	Two-way range	distance	C-band	distance	L-band	distance
U	Azimuth from Vehicle V1 to Vehicle V2	deg	Elevation from Vehicle V1 to Vehicle V2	distance	Vehicle number V2	-

[a]The distance and velocity units are determined by the input/output conversion factors DF and VF (Sec. 2.1.1).

[b]When MULTV = 2 and these generated measurements are used as inputs, they must also be defined via MEAS inputs (Sec. 10).

13. REJECT INPUT

REJECT input specifies observational measurement editing information associated with orbit determination, ephemeris generation, or covariance analysis runs.

When OBSERVATION cards (Sec. 15) or a card image observation tape (Secs. 11.2.1 and 11.5.2) is used, it is possible to reject selected measurements or intervals of observations by providing the following information for each rejection:

ID	Station name associated with the data rejected. If this name is not provided, it is assumed that all data in the interval are rejected, regardless of the station name.
YR1, MO1 DAY1, HR1 MIN1, SEC1	Year, month, day, hour, minute, and second of the start of the interval to be rejected.
YR2, MO2 DAY2, HR2 MIN2, SEC2	Year, month, day, hour, minute, and second of the end of the rejection interval. If this information is not provided, the single point specified as the start of the interval is rejected.
OB1, OB2, OB3	Indicators equal to the three characters YES if the first, second, or third measurement of the set, respectively, is rejected; they are left blank if the measurement is not rejected. Any combination of the three measurements may be rejected.

SAVE An indicator equal to the three characters YES or ØNE:

= YES Residuals are calculated for rejected measurements and printed with an asterisk in the normal residual print for all iterations. Measurements are thus rejected and not used in the differential correction process, but are saved for residual computations.

= ØNE The above process (SAVE = YES) applies only to the first iteration. Thereafter, if the observations are not edited by NEDIT (Sec. 2.2.4), they are used in the differential correction process.

T The data set type (Table 15-2) of the data to be rejected. If this type is not provided, it is assumed that all data in the interval are to be rejected, regardless of the data set type.

The REJECT data must follow the VEHICLE data, must be preceded by a card with REJECT punched in Columns 1 through 6, and must be terminated by a card with END punched in Columns 1 through 3. Currently, a maximum of 100 rejects may be input; their start times must be in chronological order. An example of input is:

```
REJECT
001 1970 8 16 21 33           1970 8 16 21 30               YES  YES  YES            1
004 1970 8 16 12 25           1970 8 16 12 23               YES  YES
END
```

The deck setup for the REJECT data is shown in Fig. 13-1, and the card format is shown in Table 13-1.

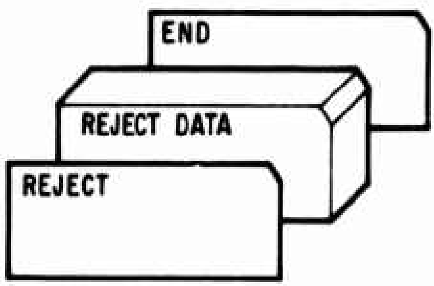


Fig. 13-1. REJECT Data Deck Setup

Table 13-1. REJECT Card Format

Card Column	Symbol	Description
1-3	ID	Station name associated with the data to be rejected
5-8	YR1	Year of the start of the interval to be rejected
10-11	MO1	Month of the start of the interval to be rejected
13-14	DAY1	Day of the start of the interval to be rejected
16-17	HR1	Hour of the start of the interval to be rejected
19-20	MIN1	Minute of the start of the interval to be rejected
22-29[a]	SEC1	Second of the start of the interval to be rejected
31-34	YR2	Year of the end of the rejection interval
36-37	MO2	Month of the end of the rejection interval
39-40	DAY2	Day of the end of the rejection interval
42-43	HR2	Hour of the end of the rejection interval
45-46	MIN2	Minute of the end of the rejection interval
48-55[a]	SEC2	Second of the end of the rejection interval
58-60	OB1	First measurement rejection indicator
63-65	OB2	Second measurement rejection indicator
68-70	OB3	Third measurement rejection indicator
75-77	SAVE	Save for residuals only indicator
80	T	Data set type of the data to be rejected (Table 15-2)

[a]A decimal point must be included.

14. STAGE INPUT

STAGE input allows the separation of observational data into a series of batches, or stages, when the data are to be processed by the SLS algorithm (MULTV = 2, Sec. 2.1.6). If the STAGE data block is present, information from this block overrides the MODEL input variable STAGE (Sec. 2.2.11).

The STAGE inputs must be preceded by a card with STAGE punched in Columns 1 through 5 and ended by a card with END punched in Columns 1 through 3. The deck setup is illustrated in Fig. 14-1. The STAGE inputs must follow the VEHICLE inputs and precede the OBSERVATION input. A maximum of 100 STAGE data cards can be input.

Two methods can be employed to specify the start and stop time for each stage. The first is to specify a Δt to be applied N times. This creates N stages, the start of each being the end of the previous stage (or epoch, in the case of the first stage), and the stop of each being the start plus Δt. If N is set to zero but Δt is not zero, then as many uniform stages of size Δt as are required to exhaust any remaining observational data will be generated.

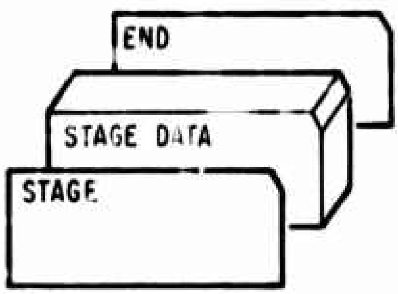


Fig. 14-1. STAGE Data Deck Setup

The second method is to actually specify a start time, stop time, and update time in calendar form on the STAGE card. If start time is zero, the update time from the previous stage (or epoch time, in the case of the first stage) will be used as a start time. If the stop time is zero, the stop time will be set to the update time. If the update time is zero, it will be set to the last observation time less than or equal to the stop time. Note that both the stop time and update time may not be set to zero. The use of all three of these numbers on a single stage provides the capability of rejecting selected measurements (those between the stop time and the next start time) and still specifying exactly an arbitrary epoch for the next stage (with the update time).

The two input methods may be intermixed in a STAGE deck. Thus, a possible staging history requiring m+2 STAGE cards would be n stages at a particular Δt; m stages with specified start, stop, and update times; and ℓ stages at another Δt. If both Method 1 and 2 input quantities are present on one STAGE card, the former will override the latter. When all observational data has been processed according to previous STAGE cards, all remaining STAGE cards are ignored. Conversely, when all stages have been processed, the remaining observations are ignored. It is possible to generate an empty stage, i.e., a stage with no measurements. This, in effect, asks the estimation algorithm for a time update only (i.e., no parameter corrections).

An example of STAGE input is shown below, and the TRACE STAGE card format (p. D-19) is shown in Table 14-1.

(cols 1–4)	N* (cols 6–9)	ΔT* (cols 11–17)	(col 19)	T BEGIN: YR MO DY HR MN SEC* (cols 21–38)	T END: YR MO DY HR MN SEC*	T UPDATE: YR MO DY HR MN SEC*
STAGE						
	2.	90.	0			
			1			70 6 25 19 0 30.
			2		70 6 25 20 29 50.	70 6 25 20 30 0.
			0	70 6 25 21 0 0.	70 6 25 20 57 50.	70 6 25 21 0 0.
	8.	100.	0			
END						

Table 14-1. STAGE Card Format

Card Column	Header	Description
4	M	Not used
6-9[a]	N	Number of fixed-interval stages
11-17[a]	Δt	Interval for fixed-interval stages
19	D	Deweighting type indicator (Sec. 7): 0 implies geopotential deweighting only 1 implies geopotential and drag (or solar radiation pressure) deweighting 2 implies geopotential and maneuver deweighting
21-22	YR	Calendar date of STAGE start time
23-24	MØ	
25-26	DY	
27-28	HR	
29-30	MN	
31-38[a]	SEC	
40-41	YR	Calendar date of STAGE stop time
42-43	MØ	
44-45	DY	
46-47	HR	
48-49	MN	
50-57[a]	SEC	
59-60	YR	Calendar date of STAGE update time
61-62	MØ	
63-64	DY	
65-66	HR	
67-68	MN	
69-76[a]	SEC	

[a]This field requires a decimal and may have an exponent of the form ±XX in the last three columns.

15. OBSERVATION INPUT

FIGURES

TABLES

15. OBSERVATION INPUT

OBSERVATION input specifies station, observation time, measurement type, and actual measurements. These data are used, in part or as a whole, in orbit determination, ephemeris generation, or covariance analysis runs. Various input formats are available and are indicated by IØBSF (Sec. 2.1.7). Currently, they are TRACE, KOMPACT, DECOR, and SPADATS.

The OBSERVATION data cards must be preceded by a card with ØBSERVATIØN punched in Columns 1 through 11. Standard TRACE cards are terminated by a card with END punched in Columns 1 through 3 (Fig. 15-1).

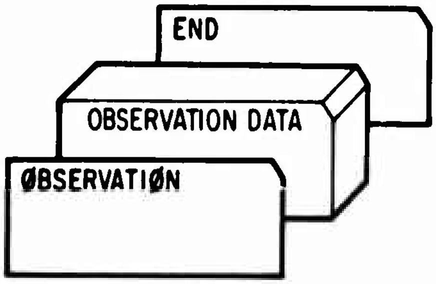


Fig. 15-1. TRACE OBSERVATION Data Deck Setup

Observations in all other formats are terminated with 777777 in Columns 1 through 6 (Fig. 15-2); therefore, 7s should not be used in these columns unless they indicate termination.

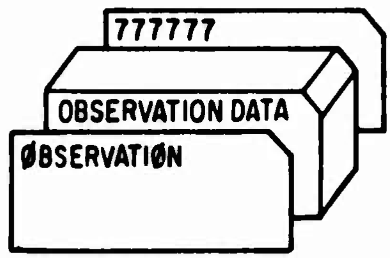


Fig. 15-2. Non-TRACE OBSERVATION Data Deck Setup

If more than 100 observations are being input, flocking (batching) is accomplished by separating the data into sets of 100 or fewer observations. These sets must be arranged in time sequence so that the latest observation time of each set is earlier than the earliest observation time of the next. Sets in the TRACE format are separated by cards with TF punched in Columns 1 and 2, and the last set is terminated with an END card (Fig. 15-3). Flocks in the KOMPACT format are separated by cards with 77 punched in Columns 1 and 2; in the SPADATS format, the 77 must be in Columns 5 and 6; and in the DECOR format, the 77 must be in Columns 4 and 5. The last set is terminated with 777777 punched in Columns 1 through 6 on the last card. If all observations are input in time sequence, it is not necessary to flock the data.

When one is integrating backwards, the flocks of observational measurements must be in reverse order; i.e., the earliest observation time of each set must be later than the latest observation time of the next, and H0 must be input negative (Sec. 2.1.4).

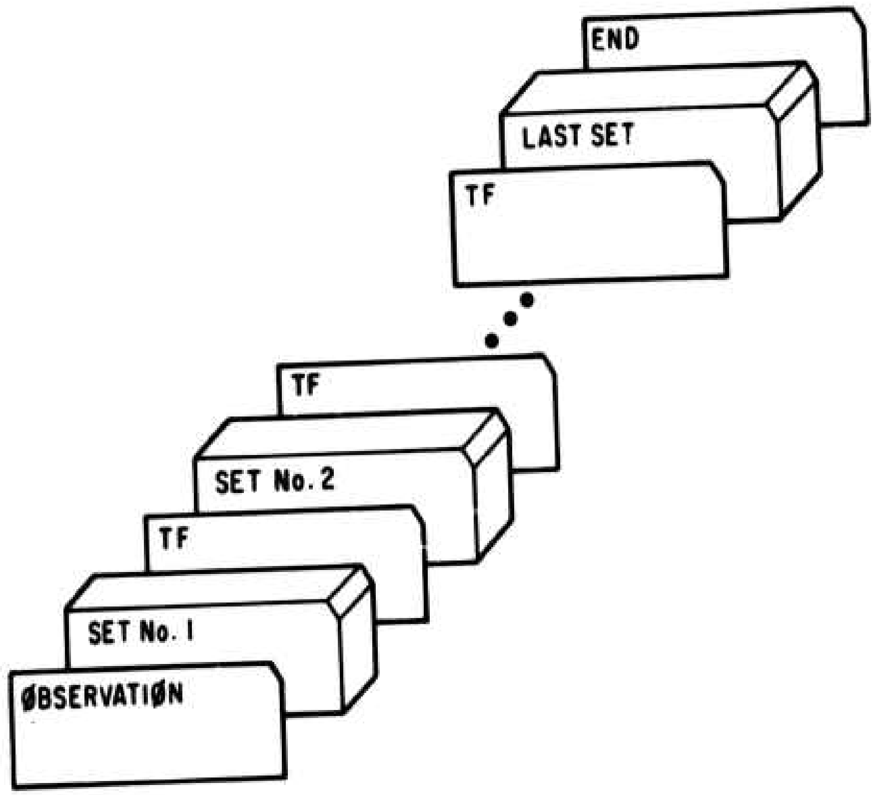


Fig. 15-3. Flocked TRACE OBSERVATION Card Deck Setup

15.1 TRACE OBSERVATION DATA CARDS

Input of TRACE OBSERVATION data cards is indicated by IØBSF = 0 (Sec. 2.1.7); the card format (p. D-20) is shown in Table 15-1. Data set types and their associated measurements, which can be used on the TRACE OBSERVATION data cards, are shown in Table 15-2.

An example of the OBSERVATION input format is:

ST	PASS	YR	MO	DAY	HR	MIN	SECONDS *	C	T	NRA	OBSERVATION 1 *	EXP	OBSERVATION 2 *	EXP	OBSERVATION 3 *	EXP	VEH #
OBSERVATION																	
009	0001	64	8	16	15	28			1		5.8547865	+06	2.7676 1965	+01	3.2563593	-01	1
009	0001	64	8	16	15	29			1		5.509831	+06	4.2878936	+01	1.5396814		1
009	0001	64	8	16	15	30			1		5.53956587	+06	5.87714689	+01	1.66151901		1
009	0001	64	8	16	15	31			1		5.93731692	+06	7.3590588	+01	6.87099005	-01	1
009	0002	64	8	16	16	57			1		4.88932835	+06	3.1792874	+01	3.20500043		1
001	0001	64	8	16	21	39			1		4.01494291	+06	1.580244	+02	9.34616046		1
001	0001	64	8	16	21	39			7		1.54						1
001	0001	64	8	16	21	40			1		5.32200005	+06	1.66077799	+02	3.9239 1042		1
001	0001	64	8	16	21	40			7		1.64	+02					
END																	

Table 15-1. TRACE OBSERVATION Card Format

Card Column	Header	Format	Description
1-3	ST	A3	Station name on the STATION card (Sec 4)
4-7	PASS[a]	A4	Pass identification
9-10	YR	I2	The last two digits of the year (assuming that the first two are 19; i.e., 19II)
11-12	MO	I2	Month
13-14	DAY	I2	Day
15-16	HR	I2	Hour
17-18	MIN	I2	Minute
19-26	SECONDS	F8.5	Second (requires a decimal point)
27	C	I1	Covariance code: C = 0 or blank: The OBSERVATION fields (cc 31-75) contain measurements of Data Set Type T C = 1, 2, or 3: Card Columns 1-26 and 28 must be identical to an OBSERVATION card with C = 0 or blank (cannot be used when MULTV = 2 or 3, Sec. 2.1.6) C = 1: The OBSERVATION fields contain sigmas for the measurements of a matching card if there is no other card with C = 2. The OBSERVATION fields contain variances if there is a similar card with C = 2 C = 2: The OBSERVATION fields contain covariances to be used with the measurements and variances found on the matching cards (with C = 0 or blank and C = 1) C = 3: The OBSERVATION fields contain latitude, longitude, and altitude (as on the STATION cards, Sec. 4) of the location used with the matching OBSERVATION measurement card (C = 0 or blank) C = 4: The OBSERVATIONS are members of a correlated set; NRA (cc 29-30) may be used C = 5: The OBSERVATIONS are the last members of a correlated set; NRA (cc 29-30) may be used
28	T	A1	Data set type (see Table 15-2 for associated measurements)
29-30	NRA	I2	A matrix row indicator when C = 4 or 5 (cc 27)
31-45[b]	OBSER-VATION 1	E15.8	First measurement of Data Set Type T, Sigma 1, Variance 1, Covariance 1, or the latitude
46-60[b]	OBSER-VATION 2	E15.8	Second measurement of Data Set Type T, Sigma 2, Variance 2, Covariance 2, or the longitude
61-75[b]	OBSER-VATION 3	E15.8	Third measurement of Data Set Type T, Sigma 3, Variance 3, Covariance 3, or the altitude
77-80	VEH #	I4	Vehicle number (Sec. 11.1.2)

[a] For Data Set Types Q and R (cc 28), the PASS symbol contains the second station, right adjusted.

[b] This field requires a decimal point and may have an exponent of the form ±XX in the last three columns of the field.

Table 15-2. Observation Data Sets

Data Set Type	OBSERVATION 1	Unit	OBSERVATION 2	Unit	OBSERVATION 3	Unit
1[a]	Range	distance[b]	Azimuth	deg	Elevation	deg
2	Topocentric right ascension	deg	Topocentric declination	deg	Topocentric hour angle	deg
3	Geocentric right ascension	deg	Geocentric declination	deg	Not used	
4	u	deg	v	deg	Height	distance[b]
5	$\hat{x}$	distance[b]	$\hat{y}$	distance[b]	$\hat{z}$	distance[b]
6	Range	distance[b]	P[c]	distance[b]	Q[d]	distance[b]
7[a]	Range rate	vel[b]	$\dot{P}$[c]	vel[b]	$\dot{Q}$[d]	vel[b]
8	Not used		Not used		Not used	
9	Not used		Not used		Not used	
A	Accelerometer	vel[b]	One-way cumulative doppler	cps	Three-way cumulative doppler[c]	cps
B	Azimuth rate	deg/sec	Elevation rate	deg/sec	Not used	
C	Range rate	vel[b]	Doppler	vel[b]	Two-way doppler[c]	vel[b]
D	SGLS range rate	vel[b]	Not used		Not used	
E	Not used		Not used		Not used	
F	x-antenna	deg	y-antenna	deg	Range	distance[b]
G	JPL two- or three-way doppler[c]	cps	Transmitted frequency	cps	Doppler averaging time	sec
H	Tranet doppler, observed	cps	Tranet doppler, base	cps	Not used	
I	Geoceiver (or CCID) range difference	distance[b]	Not used		= 0 implies geoceiver, ≠ 0 implies CCID data	—
J[a]	Range from vehicle (cc77-80) to vehicle (OBS 3)	distance[b]	Range rate for OBS 1	vel[b]	Vehicle number	—
K[a]	Range from station to vehicle (cc77-80) to vehicle (OBS 3)	distance[b]	Range rate for OBS 1	vel[b]	Vehicle number	—
L[a]	Range from station to vehicle (cc77-80) to vehicle (OBS 3) plus range from vehicle (OBS 3) to vehicle (OBS 2)	distance[b]	Vehicle number	—	Vehicle number	—

[a]These are the only data sets that can be used when MULTV = 1 (Sec. 2.1.6); only range rate of Data Set 7 can be used.

[b]These units are determined by the input/output conversion factors DF and VF (Sec. 2.1.1).

[c]Requires a P station on the STATION card.

[d]Requires a Q station on the STATION card.

Table 15-2. Observation Data Sets (Continued)

Data Set Type	OBSERVATION 1	Unit	OBSERVATION 2	Unit	OBSERVATION 3	Unit
M[a]	Range rate from station to vehicle (cc 77-80) to vehicle (OBS 3) plus range rate from vehicle (OBS 3) to vehicle (OBS 2)	vel[b]	Vehicle number	—	Vehicle number	—
N[a]	Range from vehicle (cc 77-80) to vehicle (OBS 3) to vehicle (OBS 2)	distance[b]	Vehicle number	—	Vehicle number	—
O[a]	Range rate from vehicle (cc 77-80) to vehicle (OBS 3) to vehicle (OBS 2)	vel[b]	Vehicle number	—	Vehicle number	—
P	User-defined measurements (Sec. 10)	sec or distance[b]	Vehicle number (optional)	—	Vehicle number (optional)	—
Q[e]	User-defined measurements (Sec. 10)	sec or distance[b]	Vehicle number (optional)	—	Vehicle number (optional)	—
R[f]	User-defined measurements (Sec. 10)	sec or distance[b]	Vehicle number (optional)	—	Vehicle number (optional)	—
S	Multipath	sec	Not used	—	Vehicle number	—
T	Two-way range	distance[b]	C-band	distance[b]	L-band	distance[b]
U	Azimuth from vehicle (cc 77-80) to vehicle (OBS 3)	deg	Elevation from vehicle (cc 77-80) to vehicle (OBS 3)	deg	Vehicle number[g]	—

[a] These are the only data sets that can be used when MULTV = 1 (Sec. 2.1.6); only range rate of Data Set 7 can be used.

[b] These units are determined by the input/output conversion factors DF and VF (Sec. 2.1.1).

[c] Requires a P station on the STATION card.

[d] Requires a Q station on the STATION card.

[e] Acceptable as input when MULTV = 0, 1, or 2. If MULTV = 0 or 1, measurement is time-of-arrival data and N (a cycle count) is input in OBSERVATION 2. If MULTV = 2, cc 5-7 contain a second station rather than a pass identification and OBSERVATION 2 is optionally a vehicle number.

[f] Requires a second station in cc 5-7 instead of a pass identification if measurement is three-way range.

[g] If this vehicle number is negative, OBSERVATION 1 and OBSERVATION 2 contain vehicle-to-vehicle topocentric right ascension and declination.

15.2 KOMPACT OBSERVATION DATA CARDS

Input of KOMPACT OBSERVATION cards is indicated by IØBSF = 1 (Sec. 2.1.7). The data card format is shown in Table 15-3.

Table 15-3. KOMPACT OBSERVATION Card Format

Card Column	Format	Description
1-4	I4	Vehicle number, must agree with VEHID (Sec. 11.1.2). Do not use 7777.
7 11-12	A1 A2	Station type A Station number ST } Convert to TRACE station name STA, as on a STATION card (Sec. 4).
14	F1.0	Last digit of the year y, internally recomputed as 1970 + y.
16-17	F2.0	Month.
19-20	F2.0	Day.
22-23	F2.0	Hour.
25-26	F2.0	Minute.
28-32	F5.3	Second.
34-39	F6.3	Elevation, deg.
41-46	F6.3	Azimuth, deg.
48-56	F9.3	Range, converted by DCØNV (Sec. 2.1.7).
58-66	F9.7	Range rate, converted by VCØNV (Sec 2.1.7).
73-76	A4	Pass or revolution number.

Note that decimal points are not used on these cards and that a card with 777777 in cc 1-6 indicates the end of the observation data.

An example of input follows:

```
OBSERVATION
7568 3 36 0 10 23 23 18 35736 296 118572 -3808 4
7568 3 36 0 10 23 23 18 40206 282 118221 -37994 4
777777
```

These cards are interpreted as the following TRACE data:

Station	=	363
Pass	=	4
Year	=	1970
Month	=	Oct
Day	=	23
Hour	=	23
Minute	=	18
Seconds	=	35.736 and 40.206 (assuming RND = 0, Sec. 2.1.7)
Range	=	0
Azimuth	=	118.572 and 118.221, deg
Elevation	=	0.296 and 0.282, deg
Range Rate	=	-0.3808 and -0.37994, km/sec (in this case $\dot{R}$, assuming KFØUR = 1, Sec. 2.1.7)
Vehicle	=	7568

15.3 DECOR OBSERVATION DATA CARDS

IØBSF = 2 (Sec. 2.1.7) indicates that observations are in the DECOR format, which is shown in Table 15-4.

Table 15-4. DECOR OBSERVATION Card Format

Card Column	Format	Description
2-5	I4	Vehicle number, must agree with VEHID (Sec. 11.1.2). Do not use 7777
8	A1	Station type A } Convert to TRACE station name STA, as on a STATION card (Sec. 4)
12-13	A2	Station number ST }
15	F1.0	Last digit of the year y, internally recomputed as 1970 + y
17-18	F2.0	Month
20-21	F2.0	Day
23-24	F2.0	Hour
26-27	F2.0	Minute
29-33	F5.3	Second
35-40	F6.3	Elevation, deg
42-47	F6.3	Azimuth, deg
49-57	F9.3	Range, converted by DCØNV (Sec. 2.1.7)
59-67	F9.7	Range rate, converted by VCØNV (Sec. 2.1.7)
71	A1	Must equal 1, indicating range, azimuth, elevation and range rate measurements
74-77	A4	Pass or revolution number

Note that decimal points are not used on these cards and that a card with 777777 in cc 1-6 indicates the end of the observation data.

```
OBSERVATION
 7568   3    36  0  10  23  23  18  35736    296  118572          -3808    1      4
 7568   3    36  0  10  23  23  18  40206    283  118221          -37994   1      4
777777
```

The input example given above is interpreted as the following TRACE information:

Station	=	363
Pass	=	4
Year	=	1970
Month	=	Oct
Day	=	23
Hour	=	23
Minute	=	18
Seconds	=	36 and 40 (assuming RND $\neq$ 0, Sec. 2.1.7)
Range	=	0
Azimuth	=	118.572 and 118.221, deg
Elevation	=	0.296 and 0.283, deg
Range Rate	=	-0.3808 and -0.37994, km/sec (in this case, SGLS range rate, assuming KFØUR = -1)
Vehicle	=	7568

15.4 SPADATS OBSERVATIONS DATA CARDS

When IØBSF = 3 (Sec. 2.1.7), the input observations are in the SPADATS format, which is shown in Table 15-5.

Table 15-5. SPADATS OBSERVATION Card Format

Card Column	Format	Description
3-6	I4	Vehicle number, must agree with VEHID (Sec. 11.1.2). Do not use 7777
7-9	A3	Station name, as on the STATION card (Sec. 4)
10-11	F2.0	The last two digits of the year (assuming that the first two are 19; i.e., 19XX)
12-14	F3.0	Day of the year
15-16	F2.0	Hour
17-18	F2.0	Minute
19-23	F5.3	Second
24-29	F6.4	Elevation, deg
31-37	F7.4	Azimuth, deg
39-45	F7.5	Range, converted by DCØNV (Sec. 2.1.7). The value used is range × 10^{IEX}
46	I1	Range exponent IEX (0 ≤ IEX ≤ 5)
48-54	F7.5	Range rate, converted by VCØNV (Sec. 2.1.7). If the value is negative, cc 48 contains the minus as one punch
74	A1	Month: 1 through 9 indicate Jan. through Sept., 0 indicates Oct., - indicates Nov., and + indicates Dec.
75	I1	Blank or any number from 0 through 4

Note that decimal points are not used on these cards and that a card with 777777 in cc 1-6 indicates the end of the observation data.

An example of input is:

```
OBSERVATION
  756836370297231836     2966 118572                                     02
  756836370297231840     2828 118221                                     02
7777777
```

and is interpreted as:

Station	=	363
Year	=	1970
Month	=	Oct
Day	=	23
Hour	=	23
Minute	=	18
Seconds	=	36 and 40
Range	=	0
Azimuth	=	118.572 and 118.221, deg
Elevation	=	0.2966 and 0.2828, deg
Vehicle	=	7568

16. TRACE FILE USAGE DESCRIPTIONS

TABLES

16. TRACE FILE USAGE DESCRIPTIONS

16.1 INTRODUCTION

A general description of each major TRACE file is presented in Sec. 16.1. Sections 16.2 through 16.14 contain detailed formats of the significant input/output files. The standard data tape format is described in Sec. 16.15. Logical File Units 1 through 40 are described in Table 16-1.

Table 16-1. General File Usage

Logical File Unit No.	Usage
1	TRACE Data Base: Generated by the TRACE data base generator (SEG00, SEG01) Read by other TRACE modules Updated by data base reset modules (SEG40, SEG84) when a differential correction (orbit determination) is being made Cannot be saved for later runs; therefore, always on disk
2	Vehicle Ephemeris File: Generated by the numerical integration modules (SEG10 - SEG18) Read by other TRACE modules Can be saved for later runs; therefore, may be on either disk or tape
3	Binary Observation File: May be generated by the data base generator (SEG02) from cards or card image tape (Logical Unit 4, TAPE4) or by the simulated data generation modules (SEG60, SEG61), or it may be updated by SEG84 (the next data stage)

Table 16-1. General File Usage (Continued)

Logical File Unit No.	Usage
3 (continued)	Read by the special MCI integrator (SEG15), the measurement partials modules (SEG20, SEG23, SEG82, SEG85), and the ephemeris output module (SEG50) Can be saved for later runs; therefore, may be on either tape or disk
4	Card Image Observation File: May be generated by the simulated data generation modules (SEG60, SEG61) Read only by the data base generator (SEG02) to build the binary observation file (Logical Unit 3) Can be used for later runs; therefore, may be on either tape or disk
5	Fortran Card Input File
6	Fortran Print File
7	Planetary Ephemeris File: Normally generated from the EPHEM file (Logical Unit 11); therefore, usually on disk If a special tape must be used or if the program is not run at Aerospace, may be on tape
8	Special-Purpose File: Nominal or reference orbit(s) for difference and variational equation verification runs in the ephemeris output module (SEG50). Can be saved and used on later runs; therefore, may be on disk or tape Scratch file for partials generated in the ephemeris output module (SEG50). May be on disk or tape Scratch file for simulated data generation (SEG60) for the optional pass summary. Normally on disk Used as a scratch file for the A^TA in SEG20, SEG23, SEG24, SEG70, SEG72, SEG73, SEG81, SEG82 and as a plot tape in SEG71 during covariance analysis runs. Can be input to other programs; therefore, may be on disk or tape

Table 16-1. General File Usage (Continued)

Logical File Unit No.	Usage
9	Special-Purpose File: File of all $\partial O/\partial P$ in the special MCI integrator (SEG15). Can be saved for later runs; therefore, may be on disk or tape Scratch file for printer plots of residuals and summary punch of differential correction runs (SEG20, SEG23, SEG24, SEG40). Normally on disk Difference file for difference runs in the ephemeris output module (SEG50). May be saved for input to other programs; therefore, normally on tape Special earth-fixed file or UBET file. Both are generated in the ephemeris output module (SEG50). May be saved as input for other programs; therefore, normally on tape Scratch file for printer plot of rise and set times for simulated data generation runs (SEG60). Normally on disk Scratch file for $A^T A)^{-1}$ for covariance analysis runs (SEG70, SEG71). Normally on disk Scratch file for residual printer plotting in the SLS modules. Normally on disk
10	Special-Purpose File: Special binary density profile output file from the integration modules (SEG11, SEG14). May be used as input to the TELEM program; therefore, normally on tape The $A^T A$ is written on it in the special MCI integrator (SEG15); may be on disk or tape Scratch file for normal ($A^T A$) matrix and residual summary of differential correction runs (SEG20, SEG23, SEG24, SEG28, SEG30, SEG40, SEG83, SEG84). Normally on disk Scratch file for printer plot of ephemeris differences generated by ephemeris output runs (SEG50). Normally on disk Special binary observation file from the simulated data generation module (SEG60) for plotting. Not used in TRACE but as input to other programs; therefore, normally on tape

Table 16-1. General File Usage (Continued)

Logical File Unit No.	Usage
10 (cont'd)	Scratch file for covariance analysis runs (SEG70, SEG71, SEG72, SEG73, SEG81, SEG82). Normally on disk Scratch file used with the fit-predict option of the SLS estimator; normally on disk
11	EPHEM File: Special packed planetary ephemeris file (EPHEM file). If a planetary ephemeris file (TAPE7) is needed for a particular TRACE run, the necessary data is extracted from this file (TAPE11) and is written on Logical Unit 7. Always on disk If TRACE is not run at Aerospace, this file is not used as an EPHEM file
12	Special-Purpose File: Scratch file for point mass input in the input modules (SEG00, SEG01) If accelerometer data (rather than an atmospheric model) is to be used in the numerical integration, this file is the source of the accelerometer data in the integration modules (SEG11, SEG14, SEG16). Normally on tape Used as a scratch file in the special MCI integrator (SEG15); therefore, on disk Special plot file generated in the simultaneous-vehicle data generation module (SEG61). Normally on disk Error ellipsoid plot file for single-vehicle covariance analysis (SEG71). Normally on tape Special file for circular and spherical error probability data type (SEG71). Normally on tape Scratch file for scaled covariance matrix option (SEG71); therefore, on disk Used by the simultaneous-vehicle covariance analysis output module (SEG73) if the plot option is used. Normally on tape

Table 16-1. General File Usage (Continued)

Logical File Unit No.	Usage
13	General-Purpose Scratch File: Used as a scratch file throughout TRACE; therefore, always on disk
14	Special-Purpose File: Special plot file in the MCI integrator (SEG15); therefore, may be disk or tape Used in SEG28 as a random access file; always on disk Used as scratch file for data staging for the SLS or filter options; therefore, on disk
15	Random Access File: Used in SEG28; always on disk
20	Special-Purpose File: Scratch file for differential correction runs using OBSERVATION Data Types 8 and 9 (SEG20, SEG28). Normally on disk
21-40	Simultaneous-Vehicle Ephemeris Files: Ephemerides for up to 20 vehicles can be generated by the numerical integration modules (SEG10, SEG11, SEG14, SEG16, SEG17, SEG18) Read by simultaneous-vehicle modules (SEG23, SEG61, SEG72, SEG81, SEG82) Used with the SLS option when building best-fit ephemerides (SEG84) over all stages Files 31-40 can be composite vehicle ephemeris files generated during the filter option (SEG85) but used later as Logical Unit 2 Can be saved for later runs; therefore may be on disk or tape

16.2 VEHICLE EPHEMERIS FILE (TAPE2)

Trajectory data records are described in Table 16-2. Auxiliary data words in the trajectory data records that result from the use of the NASA (Sec. 2.1.4), MSYS (Sec. 11.3.1.3), and PRCDE(J) (Sec. 11.3.1.2) options are described in Table 16-3.

Table 16-2. Trajectory Data Recoreds

Record[a]	Description
1 through 8	ID records (14 words each)
9, start event	ℓ in the first word ℓ - 1 words containing codes and event types at start time t_o, including start (Table 16-4) 0 in the last word
10 to event	Packed records of 500 or fewer words of trajectory points[b] from t_o through t_e (pre-event time). The last word of the last record is EVENT
Event	ℓ in the first word ℓ - 1 words containing codes and event types at t_e 0 in the last word
Post event to next event	Same as Records 10 to event from t_e to the next event time
. . .	. .
Stop event	ℓ in the first word ℓ - 1 words indicating codes and event types at t_f (termination time), including termination 0 in the last word
EOF	End of file

[a]Records 1 through stop event are repeated for each vehicle during a stacked vehicle run.

[b]Each trajectory point consists of: t, the current time (MME); h, the current step size; n, the number of equations being integrated; m, the number of auxiliary words; n position components in the BCI frame; n velocity components in the BCI frame; n acceleration components in the BCI frame; and m auxiliary words (Table 16-3).

Table 16-3. Auxiliary Words in Trajectory Data Records

Generation Segment	Words	Description
SEG11, SEG14, or SEG16 (m=3, NASA=0)	1-3	F3, drag acceleration vector = $\ddot{\underline{r}}_3$
SEG11, SEG14, or SEG16 (m=30, NASA≠0)	1-3	F3, drag acceleration vector = $\ddot{\underline{r}}_3$
	4-9	Filled with 0
	10-18	Precession/nutation matrix ≡ [N][P]
	19-27	Pole-wander matrix ≡ [W]
	28	$\Delta\mu$, nutation in right ascension
	29	ΔWWV
	30	ΔUT
SEG13 (m=3)	1-3	FT, total force vector = $\ddot{\underline{r}}$
SEG12 or SEG15 (m=39, NASA=0, and MSYS=0)	1-9	[S][P]
	10-18	Filled with 0
	19-27	$[\dot{S}]$[P] if PRCDE(J) = X; otherwise 0
	28-30	Filled with 0
	31-33	$\underline{r}_{ECI}$
	34-36	$\dot{\underline{r}}_{ECI}$
	37-39	$\ddot{\underline{r}}_{ECI}$
SEG12 (m=39, NASA or MSYS≠0) or SEG15 (m=39, NASA≠0, and MSYS=0)	1-9	[S] [P]
	10-18	[N][P], precession/nutation matrix
	19-27	[S] [P] if PRCDE(J) = X but if NASA = 2, it contains the pole-wander matrix
	28	$\Delta\mu$
	29	ΔWWV
	30	ΔUT
	31-33	$\underline{r}_{ECI}$
	34-36	$\dot{\underline{r}}_{ECI}$
	37-39	$\ddot{\underline{r}}_{ECI}$
SEG15 (m=39, NASA=0, and MSYS≠0)	1-9	[S] [P]
	10-18	[N][P]
	19-27	[S] [P] if PRCDE(J) = X; otherwise, 0
	28	$\Delta\mu$
	29	Filled with 0
	30	Filled with 0
	31-33	$\underline{r}_{ECI}$
	34-36	$\dot{\underline{r}}_{ECI}$
	37-39	$\ddot{\underline{r}}_{ECI}$

Table 16-4. Trajectory Event Record and Codes

Word	Description		
1	ℓ, the number of words to follow		
2 through ℓ	Sets of k words per event time containing codes, the number k (indicating k words per event), and the event designation (in Hollerith)		
	Code	k	Designation
	10	5	Velocity adjust (XKCK)
	20	5	Ballistic coefficient change
	30	5	Thrust termination
	40	5	Velocity adjust (PKCK)
	50	5	Thrust
	60	5	Accelerometer event
	70	5	Weight change
	80	5	Trajectory termination
	90	5	Trajectory start
	110	5	Thrust terminated on velocity
	120	5	Switch from ECI to MCI
	130	5	Switch from MCI to ECI
	140	5	Vehicle crashed
	200	6	Switch from BCI to BCI[a]
ℓ + 1	0		

[a]BCI may denote any of the following: ECI (earth), HCI (sun), MCI (moon), VCI (Venus), ACI (Mars), JCI (Jupiter), or SCI (Saturn).

16.3 BINARY OBSERVATION FILE (TAPE3)

The binary observation file (TAPE3) is generated during a measurement data generation run (BTAPE, Sec. 11.4.1) or when cards are input for a differential correction or covariance analysis run. It can be used for orbit determination, ephemeris generation, or covariance analysis runs (BTIME, Secs. 11.2.1 and 11.5.2) and contains one file of binary records, each record having up to 20 observations. These records are packed; they are then written in the following order: JK, N, IRR(i,j) (i = 1,5; j = 1, JK), RR(k) (k = 1,N). JK, N, and IRR(i,j) are integers, and RR(i) are real numbers. The following relationships exist:

- JK is always the first word of the record and the number of observations in the record (≤20).
- N is the second word in the record and is equal to the number of words in the RR vector (≤100).
- IRR is the array of observation information (this description is peculiar to the CDC version of TRACE):
  - IRR(1,j) contains the station number $L \times 8^{11} + N\emptyset B3 \times 8^{10} + N\emptyset B2 \times 8^9 + N\emptyset B1 \times 8^8 + NR\emptyset W \times 8^6$ + the pointer to the first word in the RR vector for the j^{th} observation. When L = 0, it indicates a temporary station for this observation (its location is found in the RR vector). NØB1, NØB2, and NØB3 are the reject codes corresponding to the first, second, and third measurements, respectively (if the reject code = 1, the measurement is rejected; if it = 0, the measurement is not rejected), and NRØW points to the n^{th} row of the A matrix.

- IRR(2, j) contains the seven-character station and pass name found in Columns 1 through 7 of the OBSERVATION card.
- IRR(3, j) contains the data set type $\times 8^{10}$ + the covariance code $\times 8^5$ + the vehicle number for the j^{th} observation. If it is written during a data generation run, the covariance code is set to zero.
- IRR(4, j) contains the station and pass name, as in IRR(2, j) unless it is written during a data generation run. In this case, IRR(4, j) is set to zero.
- IRR(5, j) contains packed indicators for Station L, as in ISTAT(2, L). If L = 0, the indicators are from ISTAT(2, NSTAT), where NSTAT is the maximum number of stations input and ISTAT is an array of station information. If it is written during a data generation run, this entire word is set to zero.

- RR contains at least five words for each observation:
  - Julian date
  - Observation time (minutes from midnight of Julian date)
  - First measurement
  - Second measurement
  - Third r asurement

  RR may contain additional words of input information for each observation if TAPE3 is written in the input segment of the program. These additional words can be any of the following:

  - Sigmas: σ_1, σ_2, σ_3 (3 words)
  - Temporary station information: latitude, cosine of the longitude, sine of the longitude, W_1^s, and W_3^s (5 words)

- Lower triangular half of the weight matrix: W_{11}, W_{22}, W_{33}, W_{21}, W_{31}, and W_{32} (6 words)
- The sigmas and temporary station information (8 words)
- The weight matrix and temporary station information (11 words)

The number of words per record depends on the number of observations and the length of the RR vector. The shortest record would be 12 words (for one observation); i.e., JK, N, IRR(1, 1) through IRR(5, 1), and RR(1) through RR(5). The longest record would be 202 words (for 20 observations), with 5 words per observation in the RR vector.

16.4 CARD IMAGE OBSERVATION FILE (TAPE4)

If ETAPE ≠ 0 (Sec. 11.4.1) or if BCDIN ≠ 0 (Secs. 11.2.1 and 11.5.2) and IØBSF = 0 (Sec. 2.1.7), a card image observation file is used. Each record of the file consists of one card image in the format shown in Table 16-5 (note that the last record contains END punched in Columns 1 through 3). Only the following format is generated when ETAPE ≠ 0, but TRACE accepts other input formats when BCDIN ≠ 0 and IØBSF ≠ 0 (Secs. 15.2 through 15.4).

Table 16-5. Card Image Observation Tape Record Format

Card Columns	Type	Format	Description
1-3	Display code	A3	Station name
4-7	Display code	A4	Pass
8	Blank	1X	Not used
9-10	Integer	I2	The last two digits of the year, assuming that the first two are 19, i.e., 19II
11-12	Integer	I2	Month
13-14	Integer	I2	Day
15-16	Integer	I2	Hour
17-18	Integer	I2	Minute
19-26	Real	F8.5	Second
27	Integer	I1	Covariance Code[a]
28	Display code	A1	Observation data set type
29-30	Integer	I2	Row pointer used with covariance code = 4 or 5[a]
31-45	Real	E15.8	First observation measurement
46-60	Real	E15.8	Second observation measurement
61-75	Real	E15.8	Third observation measurement
76	Blank	1X	Not used
77-80	Integer	I4	Vehicle number

[a]If TAPE4 is the result of ETAPE≠0, this covariance code equals zero.

16.5 PLANETARY EPHEMERIS FILE (TAPE7)

The planetary ephemeris file contains the planetary body positions and the second and fourth differences for from two to eight bodies (including nutations and nutation rates). The relative order of the bodies on this file is assumed to be: sun, moon, Venus, Mars, Jupiter, Saturn, nutations, and nutation rates. The file format is shown in Table 16-6.

Table 16-6. Planetary Ephemeris File Format

Record	Word	Type	Description
1	1	Display code	TRACE
	2	Integer	n, the number of bodies tabulated
	3	Display code	Central body name (earth)
	4	Display code	Name of the first tabulated body (sun)
	5, 6	Display code	Name of the second tabulated body (moon), twice
	⋮	⋮	⋮
	2n-1, 2n	Display code	Name of the $(n-1)^{th}$ tabulated body (nutation), twice
	2n+1, 2n+2	Display code	Name of the n^{th} tabulated body (nutation rate), twice
All Remaining	1	Real	Julian date
	2-4	Real	Coordinates of the sun, au
	5-7	Real	Second central differences for the sun
	8-10	Real	Fourth central differences for the sun
	11-13	Real	Coordinates of the moon, er
	14-16	Real	Second central differences for the moon
	⋮	⋮	⋮
	9(n-2)+2 through 9(n-2)+10	Real	Coordinates and second and fourth central differences for the $(n-1)^{th}$ body (nutation)
	9(n-1)+2 through 9(n-1)+10	Real	Coordinates and second and fourth central differences for the n^{th} body (nutation rate)
	9n+2	Real	Not used
EOF			End of file

16.6 REFERENCE (NOMINAL) ORBIT FILE (TAPE8)

When NØM = 1, 2, 3, or 4 (Sec. 11.3.2.1), the reference orbit is written on TAPE8 as a standard data tape (Sec. 16.15). The data record format is shown in Table 16-7, and the reasons for output on TAPE8 in Table 16-8.

Table 16-7. TAPE8 Record Format

Word	Name	Description	Unit[a]
1	ITP	Reason for output	
2	DJ	Julian date	
3	T	Time, min from midnight of Julian date	
4-6 7-9	X, Y, Z XDØT, YDØT, ZDØT	Cartesian coordinates of vehicle position and velocity	ft, ft/sec
10	ALPHA	Right ascension of vehicle	deg
11	DELTA	Geocentric latitude of vehicle	deg
12	BETA	Flight path angle of vehicle	deg
13	AZ	Inertial azimuth of vehicle	deg
14	R	Geocentric radius of vehicle	ft
15	V	Inertial velocity of vehicle	ft/sec
16	A	Semimajor axis	ft
17	E	Eccentricity	
18	I	Inclination	deg
19	Ø	Right ascension of the ascending node	deg
20	U	Argument of perigee	deg

[a]All units listed as ft and ft/sec depend on the input/output conversion factors DF and VF (Sec. 2.1.1) except for those in Words 43 through 45.

Table 16-7. TAPE8 Record Format (Continued)

Word	Name	Description	Unit[a]
21	TAU	Time of last perigee, min from midnight of Julian date	
22	LØN	East longitude of vehicle	deg
23	LAT	Geodetic latitude of vehicle	deg
24	BETA	Same as Word 12	
25-27	AZ, R, V	Same as Words 13, 14, and 15	
28-30 31-33	RADIAL,INTRAC,CRTRAC DRDIAL,DINTRC,DCRTRC	Orbit plane coordinates of vehicle position and velocity	ft, ft/sec
34-36 37-39 40-42	RX, RY, RZ TX, TY, TZ CX, CY, CZ	Direction cosines of the radial, intrack, and crosstrack vectors	
43	HTFT	Height of vehicle above oblate earth	ft
44	HTNM	Height of vehicle above oblate earth	nmi
45	HTKM	Height of vehicle above oblate earth	km
46	REVNUM	Revolution number	
47	UT	Time, from midnight of Julian date	hr
48	LST	Local solar time[b]	hr
49-51	EXX, EYY, EZZ	Ecliptic[b] or sun[c] coordinates	ft
52-54	XMN, YMN, ZMN	Moon[c] coordinates	ft
55	TANØM	True anomaly	deg

[a]All units should be consistent with the input/output conversion factors (Sec. 2.1.1) except for those in Words 43 through 45.

[b]Only if PRCDE(B) contains a W.

[c]Only if PRCDE(B) contains a V.

Table 16-8. Reasons for Output on TAPE8 and TAPE9

ITP Value	Reason	ITP Value	Reason
0	Print time	14	Enter moon's umbra
1	Ascending node	15	Exit moon's umbra
2	Descending node	16	Exit moon's penumbra
3	Beta = 90 deg	17	Observation
4	Minimum and maximum heights	18	Pre-(integration) event
5	Special latitude print	19	Post-(integration) event
6	Special longitude print		
7	Special altitude print	20	PCA (point of closest approach) to another satellite
8	Vehicle crash		
9	Enter earth's penumbra	21	PCA Body 1
		22	PCA Body 2
10	Enter earth's umbra	23	PCA Body 3
11	Exit earth's umbra	24	PCA Body 4
12	Exit earth's penumbra	25	PCA Body 5
13	Enter moon's penumbra	26	PCA Body 6

16.7 OBSERVATION RESIDUAL FILE (TAPE9)

This binary data tape has one file containing only data records in the format shown in Table 16-9. It is generated when GPLØT ≠ 0 and PANDR(N) = blank (Sec. 2.2.1).

Table 16-9. Observation Residual File Record Format[a]

Word	Name	Type	Description
1	L[b]	Integer	Station number ($0 \le L \le 100$)
2	ID	Display code	Station and pass name (seven characters)
3	DJUL	Real	Julian date
4	T	Real	Time of observation, min from midnight of DJUL
5	RØ1	Real	Measurement residual of the type defined by I1
6	RØ2	Real	Measurement residual of the type defined by I2
7	RØ3	Real	Measurement residual of the type defined by I3
8	I1[c]	Integer	Measurement code for RØ1
9	I2[c]	Integer	Measurement code for RØ2
10	I3[c]	Integer	Measurement code for RØ3
11	IXT[d]	Integer	Edit code for Measurement 1
12	IXX[d]	Integer	Edit code for Measurement 2
13	IXY[d]	Integer	Edit code for Measurement 3

[a] There is no vehicle identification in the data to indicate different vehicles.

[b] If $L > 100$, the data record does not contain residuals.

[c] Corresponds to the sigma measurement types used in TRACE (Table 2-1).

[d] The possible values for the edit codes are 1 (indicating acceptance) and 2 (indicating that the measurement has been edited).

16.8 ORBIT DIFFERENCE FILE (TAPE9)

When NØM = 5, 6, 7, or 8 (Sec. 11.3.2.1), the orbit differences are written in standard data tape format on TAPE9 (Sec. 16.15). The difference tape contains n+2 files, where n is the number of cases. The following relationships exist:

- File 1 is the title in one record of display code.
- Files 2 through n+1 contain one file/case, each consisting of one record of names (55 words) in display code and one or more data frame records containing 55 words/record (Table 16-10).
- File n+2 is the END record in display code.

Table 16-10. Difference Tape Record Format

Word	Name	Description	Unit[a]
1	ITP	Output code, integer (Table 16-8)	
2	DJ	Julian date	
3	T	Time, min from midnight of Julian date	
4-6 7-9	X, Y, Z XDØT, YDØT, ZDØT	Cartesian position and velocity differences	ft, ft/sec
10	ALPHA	Right ascension difference	deg
11	DELTA	Geocentric latitude difference	deg
12	BETA	Flight path angle difference	deg
13	AZ	Inertial azimuth difference	deg
14	R	Geocentric radius difference	ft
15	V	Inertial velocity difference	ft/sec
16	A	Semimajor axis difference	ft
17	E	Eccentricity difference	
18	I	Inclination difference	deg
19	Ø	Right ascension of ascending node difference	deg
20	U	Argument of perigee difference	deg
21	TAU	Time of last perigee difference	min
22	LØN	East longitude difference	deg
23	LAT	Geodetic latitude difference	deg
24	BETA	Same as Word 12	
25-27	AZ, R, V	Same as Words 13, 14, and 15	
28-30 31-33	RADIAL, INTRAC, CRTRAC DRDIAL, DINTRC, DCRTRC	Orbit plane position and velocity differences	ft, ft/sec
34-36 37-39	DC1, DC2, DC3 DC4, DC5, DC6	$\partial x/\partial p$, $\partial y/\partial p$, $\partial z/\partial p$, $\partial \dot{x}/\partial p$, $\partial \dot{y}/\partial p$, $\partial \dot{z}/\partial p$	
40-42 43-45	DDC1, DDC2, DDC3 DDC4, DDC5, DDC6	Cartesian coordinate position and velocity second differences	ft, ft/sec
46-48 49-51	DDC1P, DDC2P, DDC3P DDC4P, DDC5P, DDC6P	Errors for second differences	%
52-55		Not used	

[a]The units listed as ft and ft/sec depend on the input/output conversion factors DF and VF (Sec. 2.1.1).

16.9 RISE-SET TIME FILE (TAPE9)

This binary tape contains only one file of data generated during a data generation run when RSPLT ≠ 0 (Sec. 2.4.1.1). It is used for a printer plot. There are no identification records, and there is only one frame of data/physical record; its format is shown in Table 16-11. The manner in which this tape is generated by TRACE currently allows only one vehicle at a time. If more than one vehicle is used, only the data from the last will appear on the tape.

Table 16-11. Record Format of the Station Visibility Information (Rise-Set) File

Word	Name	Type	Description
1	DJ	Real	Julian date
2	T	Real	Time, min from midnight of Julian date
3	L	Integer	Station number ($1 \le L \le 100$)
4	K	Integer	Visibility code (may be any of the following):
			K = 1 Rise time
			K = 2 Set time
			K = 4 Maximum range exceeded
			K = 5 Within maximum range
			K = 6 Visible at initial time
			K = 7 Visible at final time
			K = 9 No longer eclipsed (lunar orbit)
			K = 10 Eclipsed (lunar orbit)
			K = 11 Out of occultation (interplanetary orbit)
			K = 12 Occultated (interplanetary orbit)

16.10 DENSITY PROFILE (TELEM) FILE (TAPE10)

When TELEM $\neq 0$ (Sec. 2.1.4), each case generates one file of data with the record format shown in Table 16-12.

Table 16-12. Record Format of Special TELEM Tape

Word	Symbol	Description	Unit
1	t	Time	MME
2, 3, 4	(x, y, z)	Satellite position components	ft[a]
5, 6, 7	$(\dot{x}, \dot{y}, \dot{z})$	Satellite velocity components	ft/sec[a]
8, 9, 10		Not used	
11, 12, 13	$(\ddot{x}_3, \ddot{y}_3, \ddot{z}_3)$	Drag acceleration components	er/min^2
14	a	Magnitude of drag acceleration	ft/sec^2[a]
15	h	Satellite height	nmi
16	ρ	Density	$slug/ft^3$
17	φ	Geodetic latitude	deg
18	λ	East longitude	deg $(0 \leq \lambda \leq 360)$

[a]This unit depends on the appropriate input/output conversion factor (Sec. 2.1.1).

16.11 BINARY OBSERVATION PLOT FILE (TAPE10)

The record format of the binary observation tape generated during a data generation run when GDPLT ≠ 0 (Sec. 2.4.1.5) is shown in Table 16-13.

Table 16-13. Binary Plot Tape Record Format of Simulated Measurements

Word	Name	Time	Description
1	L	Integer	Station number ($1 \leq L \leq 100$)
2	T	Real	Time, MME
3	JT	Integer	Number of data words in the record (not counting Words 1, 2, or 3)
4	I1	Integer	Code defining type for Measurement 1
5	D1	Real	Measurement 1
6	I2	Integer	Code defining type for Measurement 2
7	D2	Real	Measurement 2
.	.	.	
.	.	.	
.	.	.	
JT+2	In	Integer	Code defining type for Measurement n (n = JT/2)
JT+3	Dn	Real	Measurement n

The record length may differ from station to station if different measurement types are generated for each station; each vehicle occupies one file on the tape.

The measurements (Table 12-2) and their codes are shown in Table 16-14.

Table 16-14. Measurements and Codes on Binary Plot Tape

Measurement	Code
Range	1
Azimuth	2
Elevation	3
Range rate	19
$\dot{P}$	20
$\dot{Q}$	21
P	17
Q	18
Azimuth rate	31
Elevation rate	32
$\bar{R}$	101
Mutual visibility	Not available
Latitude	102
Longitude	103
Surface range	104
Height	12
Doppler rate	35
Look angle	105
Observation variances	Not available
Kappa	106
Aspect angles	107, 108
Attenuation	109
$\hat{x}$, $\hat{y}$, $\hat{z}$	13, 14, 15
Topocentric right ascension and declination	4, 5
Geocentric right ascension and declination	7, 8
Hour angle	6
u, v	10, 11
Accelerometer	Not available
Azimuth acceleration	110
Elevation acceleration	111
Two-way doppler	36
x-antenna and y-antenna angles	43, 44
Tranet doppler	49
Geoceiver range difference	52
SGLS range rate	37
Satellite-tracker doppler counts	112, 113, 114
Time of arrival and its count	76, 77

16.12 COVARIANCE ANALYSIS PLOT FILE (TAPE12)

Formats for covariance analysis plot files and circular and spherical error probability data files are discussed below.

16.12.1 Covariance Matrix Sigma Plot File

The TAPE12 record format for simultaneous-vehicle covariance analysis plot tapes (ØPBØX (F), Sec. 2.5.1) is time-dependent and is shown in Table 16-15.

Table 16-15. Record Format of Covariance Matrix Plot File

Word[a]	Description
1	Time, MME
2 ⋮ p+1	Square roots of the diagonal elements of the matrices, with P-parameter effects only (PRCØV, Sec. 2.5.1)
p+2 ⋮ p+2v+1	RSS of position and velocity for the state covariance matrix C(X) for each vehicle, with P-parameter effects only
p+2v+2 ⋮ p+q+2v+1	Square roots of the diagonal elements of the matrices, with Q-parameter effects included (PRCØV, Sec. 2.5.1)
p+q+2v+2 ⋮ p+q+4v+1	RSS of position and velocity for the state covariance matrix C(X) for each vehicle, with Q-parameter effects included

[a] p = the sum of the row dimensions of all P-parameter matrices requested for printing [PRCØV (A-F)].

q = the sum of the row dimensions of all Q-parameter matrices requested for printing [PRCØV (G-L)].

r = the total number of vehicles.

16.12.2 Circular and Spherical Error Probability Data File

When NCVØB = 11, 12, 13, or 14 and MULTV-0 (Sec. 2.5.1), the format of TAPE12 is one file per case and one record per print time. The record format is shown in Table 16-16.

Table 16-16. Record Format for Circular and Spherical Error Probability Data File

Word	Symbol	Description	Unit
1	t	Time	MME
2	R	Range	nmi
3	A	Azimuth	deg
4	E	Elevation	deg
5	σ_{max}	Standard deviation along the major axis of the A-E probability ellipse	deg
6	σ_{min}	Standard deviation along the minor axis of the A-E probability ellipse	deg
7	θ	Angle from the A axis counterclockwise to the major axis	deg
8	XAz	Cross azimuth = A cos E	deg
9	σ'_{max}	Standard deviation along the major axis of the XAz-E probability ellipse	deg
10	σ'_{min}	Standard deviation along the minor axis of the XAz-E probability ellipse	deg
11	θ'	Angle from the XAz axis counterclockwise to the major axis	deg

16.13 SIMULTANEOUS-VEHICLE TRAJECTORY FILES (TAPE21-TAPE40)

When MULTV ≠ 0 (Sec. 2.1.6), TAPE21 can contain the first vehicle integrated, TAPE22 the second, etc. The record format is shown in Table 16-17.

Table 16-17. Record Format of Simultaneous-Vehicle Trajectory Files

Record	Description
1 through 8	ID records (14 words each)
Start event	ℓ in the first word ℓ - 1 words containing codes for start, the BCD words, TRAJECTORY START, and any other events at this time (Table 16-4) 0 in the last word
10 to pre-event	Trajectory point records from t_o through t_e (pre-event time) as follows: Current time, MME Current step size n (number of equations being integrated) 6 n position components n velocity components n acceleration components The first three words from the drag acceleration vector: ρ, ρ', 0
Pre-event	BCD word EVENT Current step size 1 1 0 0 0 0
Event	ℓ ℓ - 1 words indicating codes and the event types (Table 16-4) 0
Post-event to pre-event	Same as Records 10 to pre-event, as shown above, from t_e (post-event time) through the next pre-event time
⋮	⋮
Pre-stop event	BCD word containing EVENT Current step size 1 1 0 0 0 0
Stop event	ℓ ℓ - 1 words indicating codes and event types, including termination (Table 16-4) 0
End of file	

16.14 DENSITY PUNCHED CARD FORMAT

Density cards are punched when PRCDE(Q) = Y (Sec. 11.3.1.2). Their format is shown in Table 16-18.

Table 16-18. Density Punched Card Format

Columns[a]	Symbol	Format	Description
1-4	YR	I4	
5-6	MO	I2	
7-8	DAY	I2	
9-10	HR	I2	
11-12	MIN	I2	
13-20	SEC	F8.5	
21-22	MO	I2	Data span begins
23-24	DAY	I2	
25-26	HR	I2	
27-28	MIN	I2	
29-33	SEC	F5.2	
34-35	MO	I2	Data span ends
36-37	DAY	I2	
38-39	HR	I2	
40-41	MIN	I2	
42-46	SEC	F5.2	
47	TYPE	A1	Data set type
TYPE = 1			
48-54	DJULM	F7.1	Modified Julian date
55-61	SHT	F7.3	Perigee scale height, km
62-68	HKM	F7.3	Perigee height, km
69-75		F7.3	HKM + 1/2 SHT, km
77-80	VEHID	I4	Vehicle ID
TYPE = 2			
48-54		F7.3	Geocentric latitude, deg
55-61		F7.3	Geocentric longitude, deg
62-72		E11.4	Density at perigee, gm/cm^3
77-80		I4	Vehicle ID
TYPE = 3			
48-54	T_∞	F7.2	Static temperature at perigee, °K
55-61		F7.3	Angle between radius vector to sun and vehicle, deg
62-72		E11.4	Density at perigee + 1/2 scale height
77-80		I4	Vehicle ID

[a] The formats of Columns 48 through 80 depend on the data set type.

16.15 STANDARD DATA TAPE FORMAT

The general specifications for the standard data tape include the following (this format description is peculiar to the CDC version of TRACE):

- Standard data tapes (Ref. 8) are written in an odd-parity, binary mode. The recording density is optional, but a high density is recommended to minimize tape transport time.
- A standard data tape begins with a tape identification file, which is followed by one or more data files, and ends with an end-of-tape file. Each file is terminated by an end-of-file mark.
- The maximum length of any record on the standard data tape is 511 sixty-bit words.
- The first word of each standard data tape record contains the number of words in that record, excluding Words 1 and 2. The second word of each record always contains an integer identifier unique for each record type. The record identifiers and their associated record types are as follows:

Identifier	Record Type
1	Tape identification record
2	Data file identification record
3	Data file commentary record
4	Data file value record
5	End-of-tape record

- Eight types of data words may be recorded on a standard data tape. These types are complex, real, double-precision, integer, octal, logical, Hollerith, and packed octal words. Complex and double-precision data items occupy two words, integers are right-adjusted, Hollerith characters are in display code, and packed octal words contain five 12-bit bytes of information. Word formats and conventions coincide with those of the Aerospace/CDC 6000 Series operating system. The acceptable Hollerith character set is listed in Table 16-19.
- If the amount of data exceeds the capacity of one reel, a sequence of tapes may be written in an end-to-end fashion. Each tape is in the standard format, with indicators to flag the particular type of interruption and continuation.

Table 16-19. Aerospace/CDC 6000 Series Character Set

Character	Display Code	Character	Display Code
A	01	0	33
B	02	1	34
C	03	2	35
D	04	3	36
E	05	4	37
F	06	5	40
G	07	6	41
H	10	7	42
I	11	8	43
J	12	9	44
K	13	+	45
L	14	-	46
M	15	*	47
N	16	/	50
O	17	(	51
P	20	)	52
Q	21	$	53
R	22	=	54
S	23	blank	55
T	24	,	56
U	25	.	57
V	26		
W	27		
X	30		
Y	31		
Z	32		

16.15.1 File Formats

The general characteristics and the formats of the tape identification, data, and end-of-tape files are described in this section.

16.15.1.1 Tape Identification File

The tape identification file has the following general characteristics:

- It contains a single identification record.
- It should contain some item unique to the data tape, e.g., the missile or test number.

The format of the identification file is shown in Table 16-20.

Table 16-20. Identification Record Format

Word	Type	Description
1	Integer	The number of words in this record M, excluding Words 1 and 2
2	Integer	Record identifier: 1
3	Integer	Reel number: the first tape in a sequence is always designated No. 1, the second as No. 2, etc.
4 through (M+2)	Hollerith	Identification information (N words with ten characters per word, $1 \le N \le 508$) describing the data tape content

16.15.1.2 Data File

The general characteristics of the data file are as follows:

- A data file begins with an identification record and contains one or more value records. The data file may also contain a commentary record that describes the file content. This record is optional, but if it is used, it must be placed immediately after the identification record.
- All data file records are written with "normal" record identifiers unless the file is interrupted because a physical end-of-tape is sensed. Interruption and continuation procedures (including the use of "continue" identifiers) are described in Sec. 16.15.2.

16.15.1.2.1 Data File Identification Record

The general characteristics of the data file identification record are as follows:

- The data file identification record contains a single alphanumeric word to identify the entire file and a string of alphanumeric words to identify the variables or constants included in a data frame. A data frame is defined as a group of data elements containing a given number of words or bytes that repeats throughout a set of data value records. (In time histories, a data frame is usually defined as all data words for a particular point in time.) More than one data frame may appear in each value record.
- A data element identifier consists of ten Hollerith characters divided into three fields, as shown below:

59 54	53 18	17 0
TYPE	NAME	NUMBER

  - The first field (one character, bits 59 through 54) contains a type declaration that provides the reading program with information on the word structure of either the variable or the constant data element. The following type declarations are permitted:

Type	Characteristics
C (complex)	Two words per element
D (double-precision)	Two words per element
R (real)	One word per element
I (integer)	One word per element
O (octal)	One word per element
L (logical)	One word per element
H (Hollerith)	One word per element
P (packed octal)	One byte per element

  - The second field (six characters, bits 53 through 18) contains the name of the data element. This may be any combination of consecutive nonblank characters in any order. The data element name is left-adjusted, and the field is filled with blanks.

    - The third field (three digits, bits 17 through 0) specifies the number of elements in a contiguous block, which are defined by the same type and name declaration. This number (right-adjusted with leading zeroes) enables the user to specify an array of variables or constants with a single data element identifier. The example, HTITLEb500 specifies the Hollerith array TITLE containing 500 elements (b defines a Hollerith blank character).

- Packed octal element blocks start in the next available 12-bit byte (in low-order direction) without regard to position within a sixty-bit word. Word and multiword element blocks must begin on a full word boundary. If necessary, fill bytes are inserted between element blocks to accomplish the required realignment.
- A data frame must start on a full word boundary and must consist of an integral number of sixty-bit words. If necessary, fill bytes are added after the last element block to complete the frame.
- The number of words per frame must equal the total number of words and bytes defined by the element identifiers plus the number of fill bytes inserted for element block and data frame realignment. Although fill bytes are not specifically defined within the data file identification record, their presence is inferred from the type and order of the data element identifiers.

The identification record format is shown in Table 16-21.

Table 16-21. Data File Identification Record Format

Word	Type	Description
1	Integer	The number of words in the record M, excluding Words 1 and 2
2	Integer	Record identifier: 2 at the beginning of the file (or -2 if the file is continued from a previous tape)
3	Hollerith	File identification: ten Hollerith characters identify the file, e.g., DATAbbbbbb, PLOTbbbbbb, CALIBRATEb, or PARAMETERb. The identification word COMMENTARY is an indicator that a commentary record (Type 3) follows immediately on the tape. The file identification need not be unique; the file position sufficiently identifies any file on the tape
4	Integer	The number of words per frame N ($N \leq 509$)
5 through (M+2)	Hollerith	First through $(M-2)^{nd}$ data element identifiers. (By tradition, independent variables are listed before their associated dependent variables)

16.15.1.2.2 Data File Commentary Record Format

The format of the commentary record is shown in Table 16-22.

Table 16-22. Data File Commentary Record Format

Word	Type	Description
1	Integer	The number of words in this record M, excluding Words 1 and 2
2	Integer	Record identifier: 3
3 through (M+2)	Hollerith	Identification information: a maximum of 509 words (ten characters per word) describing the data file content.

16.15.1.2.3 Data File Value Record

The general characteristics of the value record are the following:

- If N is the number of words per frame, each value record may contain K frames, providing that all frames are complete and that $KN \leq 509$.
- A value record need not contain the maximum number of frames permitted within the record size limits; however, this practice is recommended for data storage efficiency.
- The length of all value records in a data file must be less than or equal to the length of the first value record in that file.

The format of the value record is shown in Table 16-23.

Table 16-23. Data File Value Record Format

Word	Type	Description
1	Integer	The number of words in this record M, excluding Words 1 and 2
2	Integer	Record identifier: 4
3 through (M+2)	———	Data elements in a many-to-one correspondence, with the words or bytes defined by the data element identifiers in the identification record. The order of the data elements must follow the order of the element identifiers

16.15.1.3 End-of-Tape File

The general characteristics of the end-of-tape file are:

- This file contains a single record.
- If it becomes necessary to terminate a standard data tape because of insufficient reel capacity, the end-of-tape file is written with a "continued" record identifier to indicate that the data continues on the next tape in the sequence.
- The last data tape in a sequence is terminated by an end-of-tape file containing a "normal" record identifier.

The format of the end-of-tape record is shown in Table 16-24.

Table 16-24. End-of-Tape Record Format

Word	Type	Description
1	Integer	The number of words in this record M, excluding Words 1 and 2
2	Integer	Record identifier: 5 (or -5 if data is continued on the next tape)
3	Integer	Reel number: Same as that used in the tape identification file
4	Hollerith	End-of-tape label: ENDOFTAPEb

16.15.2 Interruption and Continuation Procedures

If a physical end-of-tape is detected before the data file identification record is written, an end-of-tape file is written to terminate the current tape. The next tape begins with a tape identification file (reel number advanced by one) and the intended identification record.

If a physical end-of-tape is detected before the data file commentary record is written, the current tape is terminated by an end-of-file mark and an end-of-tape file ("continue" identifier). The next tape begins with a tape identification file (reel number advanced by one), a "continued" data file identification record (initial data file identification record with "continued" identifier), and the intended commentary record.

The procedure for continuing a data value record is similar to that given for continuing a data file commentary record. The intended data value record is substituted for the commentary record in the description above.

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