

W. A. Shepard
CB / *Neil A. Armstrong*

5520.5-121
REV. 2

PROGRAMMED GUIDANCE EQUATIONS FOR
COLOSSUS 2
COMMAND MODULE EARTH ORBITAL AND LUNAR PROGRAM

NAS 9-8166 20 MAY 1969

BASED ON COMANCHE 55 PROGRAM

Prepared for
MISSION PLANNING AND ANALYSIS DIVISION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
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Change Page Record

The original issue of 5520.5-121 represented a complete re-issue of 3420.5-96, updated to the Colossus 2 (Comanche 45) program. Those pages which were changed in content from the Colossus 1A description (Revision 1 of 3420.5-96) were identified by "Rev. 0" on the same line as the page number.

Revision 1

Revision 1 of 5520.5-121 defined the changes made for "MANCHE 45 Rev. 2" program. Those pages which were changed in content from the original issue of 5520.5-121 are identified by "Rev. 1" on the same line as the page number:

Title	ORBI-19
ii	ORBI-24
iii	ORBI-26
1	ORBI-27
91	

Revision 2

Revision 2 of 5520.5-121 defines the changes made for the "Comanche 55" program. Those pages which were changed in content from the original issue or Rev. 1 of 5520.5-121 are identified by "Rev. 2" on the same line as the page number:

Title	DPRC-28	INFA-20	NNDF-38
ii	DPTV-2	MEAS-4	OPTC-19
iii	DPTV-3	MEAS-17	ORVN-3
1	DPTV-19	MEAS-20	ORVN-15
26	DPTV-20	MEAS-29	ORVN-16
91	DPTV-24	MEAS-30	REND-14
94	ENRY-5	MEAS-34	REND-15
ATTM-14	GENP-23	NNDF-16	REND-35
BOOS-1	GENP-31	NNDF-17	STER-1
BURN-13	INFA-1	NNDF-28	STER-7
BURN-15	INFA-2	NNDF-29	STER-9
BURN-20	INFA-8	NNDF-30	STER-11
COOR-16	INFA-12	NNDF-31	TEST-1
COOR-17	INFA-17	NNDF-33	VBDF-2
DPIR-13	INFA-18	NNDF-34	VBDF-11
DPIR-22	INFA-19	NNDF-37	

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ATTM-14	GENP-23	NNDF-16	REND-35
BOOS-1	GENP-31	NNDF-17	STER-1
BURN-13	INFA-1	NNDF-28	STER-7
BURN-15	INFA-2	NNDF-29	STER-9
BURN-20	INFA-8	NNDF-30	STER-11
COOR-16	INFA-12	NNDF-31	TEST-1
COOR-17	INFA-17	NNDF-33	VBDF-2
DPIR-13	INFA-18	NNDF-34	VBDF-11
DPIR-22	INFA-19	NNDF-37	

Introduction

Under the auspices of TRW Systems MTCP task A-201 ("Support of Apollo Guidance Document Review," J. Garman and J.E. Williams, task monitors), a review of certain portions of the Apollo Guidance Computer program identified as "Colossus 2A" has been conducted. This program is a modified version of the "Colossus 2" program used on the "F" mission, and is intended for use with the Command Module computer on the "G" mission. The major purpose of this review has been to provide more effective support to the Flight Software Branch of MSC in the identification and analysis of various program performance features, and to permit more effective and rapid review of published computer program documentation.

During similar reviews of the AS-202, AS-204, AS-501, IM-1, Sundisk, and Sundance programs, it was found desirable to assemble a set of working-paper information on the equations which seem to have been programmed for these flights. This material has proven to be useful to the various groups associated with these flights, in that it can be used to help bridge the gap between the extreme detail of the program listing and the occasional lack of detail available elsewhere on the guidance equations. Consequently, the material on the following pages has been assembled in a fashion similar to that done for previous flights, and follows the same general format.

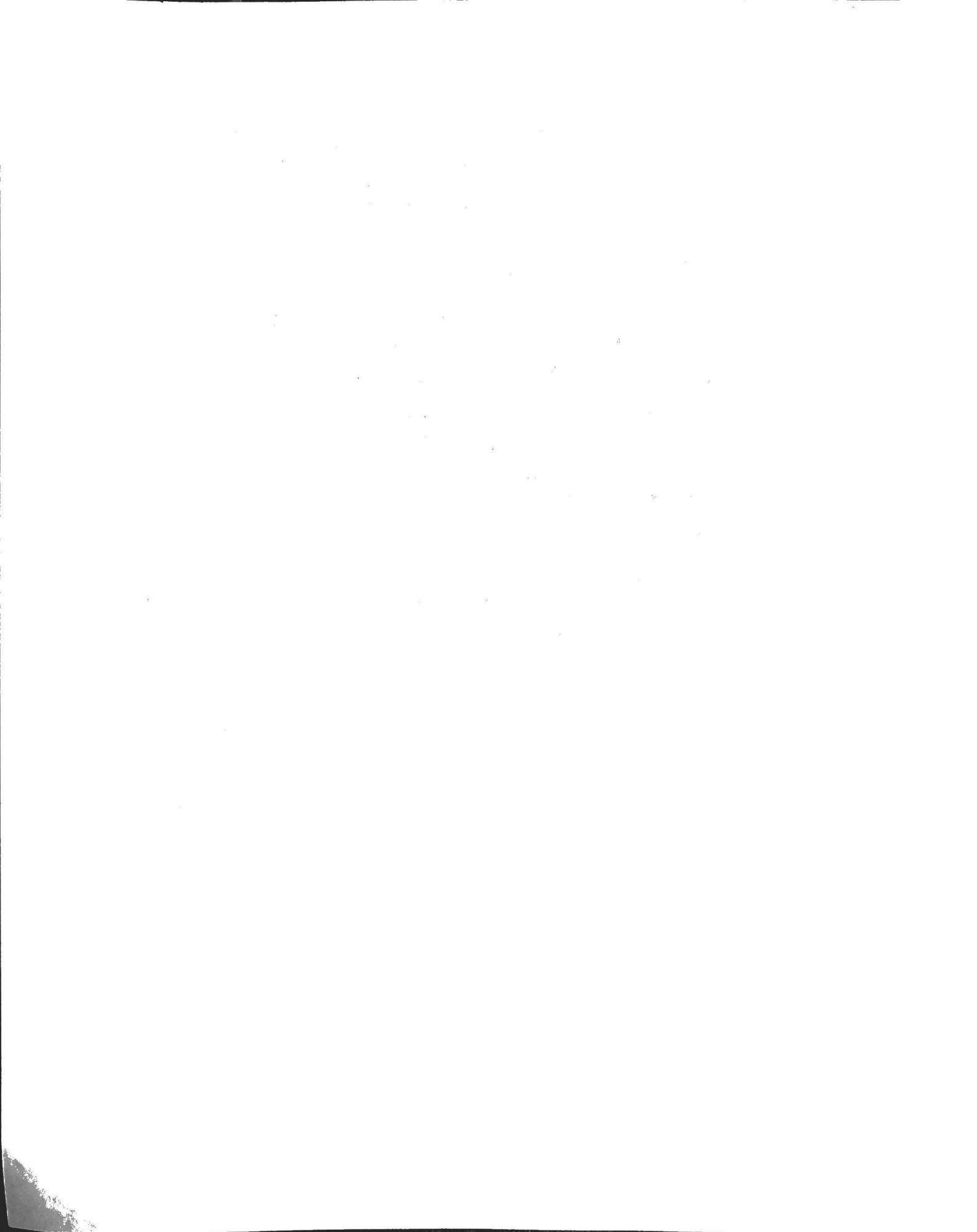
Certain aspects of the program are quite complex, and this programmed guidance equation material should not be considered as a substitute for actual study of the program symbolic listing itself. To assist in such a study, the binary scale factors of equation quantities have been included, as well as the program notation employed for constants (notation for variables follows that, in general, used in the program), and divisions have been made in accordance with the symbolic tags assigned to program steps in the listing. It should be realized that no complete set of equation information was available from the MSC G&N contractor against which the programmed equations could be validated, and in the interests of timely publication the review of the assembled document against the program assembly has not been as detailed as would be desired.

The program assembly listing which was used to prepare the programmed equations information bears the heading print:

REVISION 055 OF AGC PROGRAM COMANCHE BY NASA 2021113-051,
10:28 APR. 1, 1969

The function of virtually all the program steps of interest to the flight is described on the following pages or, for general computer system control (executive and waitlist system, interpretive language, and similar items) in 3420.5-27 (see Notation and Terminology). Only isolated omissions of unreferenced constants and non-executed program steps have been made.

The material on the following pages is intended to be an aid to the review of the symbolic listing, not a substitute for it. Definitive guidance equation information can and should be provided only by the G&N contractor through the appropriate MSC channels.



a series of marks in this program with the option of being able to restore the unmodified state vector, this can be accomplished by performing V66E before the start of the marks (to put the CSM state vector into the "LM" cells), and then, after the marks, performing V47E (which moves the unupdated "LM" cells back into the CSM "permanent" state vector).

The third navigation program is P22, which can be used to perform state vector modification based on the tracking of known or unknown landmarks (on earth or moon): the "landing site" vector can be selected, or a landmark loaded manually (only the manual option is allowed for earth). P22 starts on page ORVN-4 ("PROG22"). After some initial presets and selection of sighting options, "R52" is entered to perform optics pointing to the desired landmark (after R52 starts, N43 could be used to change the coordinates towards which the optics is pointing). After completion of the mark sequence, "DOV5N71" is entered (page ORVN-5) to display the landmark selection for crew approval, and then "S22.1" (page ORVN-8) is entered to do the actual processing of the observation data.

"S22.1" starts by loading a set of buffer cells with the mark data that were obtained (so as to preserve them in the event of a restart). These cells are also telemetered, so a flagword bit is set to indicate that they have been loaded with optics information. Following this, some initialization settings are made, including different ones for known and unknown landmark W-matrix settings, and processing of marks is performed. A flagword bit is set for the processing of the first non-offset mark (22DSPFLG, bit 13 of FLAGWRD2) that causes "S22BOX12" (page ORVN-14) to display (VO6N49) the magnitude of the first update for crew approval: if it is approved, the remainder of the updates (including the second one for that mark) are incorporated with no check on their magnitude (contrary, for example, to R22). Following the incorporation of the last mark, an option is provided (in "S22I=N", page ORVN-15) to update the landing site RLS based on the derived position of the landmark being tracked (which could have been specified as the serial number of OL, meaning RLS). A manual input to the N89 display will be interpreted not as a data load, but instead as a "recycle" (hence latitude/longitude/altitude input cannot be used to change RLS). Finally, the W matrix is reduced to 6x6 (landmark correlation information is not carried over from one landmark to the next, of course) in "9DWTO6DW" (page MEAS-5) and then a new set of marks can be obtained. If desired, the measurement W matrix can be checked, and initialized to different values if desired, by a V67E, which causes "V67CALL", page MEAS-4, to be entered.

Entry

Input of V37 E 61 E will permit P61, page ENTP-1 ("P61"), to be entered. Average-G is turned on via "S61.1" (page ENTP-4) which causes "MIDTOAV2" to be entered (the same routine as used by P47) in

order to get the Average-G computations started (generally in 12.5 seconds from the beginning of the last time step). After this is done, the IMU alignment is checked in "S61.1A" (page ENTP-5), and then a N61 display of target parameters is supplied. Response to this display causes "NEWRNVN", page ENTP-1, to be entered to sample the state vector from the same two-second Average-G cycle (if the sampling is unsuccessful, the process is repeated). Routine "S61.2", page DISP-16, is entered to compute a number of quantities for display purposes, including Entry Monitor System (EMS) information. Following display approval, "P62" (page ENTP-2) is entered. The N63 display (which includes time from EMS interface altitude) has the time information corrected so as to be measured from when the display is started (instead of from when the state vector was sampled). The display can be started again (causing a fresh compensation to be made of the delay between the state vector time tag and now) by an "otherwise" response (e.g. V32E) to the N63 display.

"P62", page ENTP-2, can either be entered from "NEWRNVN" or can be selected directly by V37 means (see page GENP-36). It performs "S61.1" again (if from "NEWRNVN", Average-G is already running), starts the entry DAP going ("READGYMB", page DPEN-1), and then starts a flash of checklist code 00041_g to request separation. A PRO response to this display causes "CM/DAPON" to be entered to activate entry DAP computations (page DPEN-1), and then "P62.1", page ENTP-3, to be entered. Here, after another N61 display of target information, a display of entry angles (via N22) as computed by "P62.3", page ENTP-4, is provided (unless the trim angle already is less than 45°, in which case P63 is entered immediately). Logic in "EXDAP", page DPEN-11, causes "WAKEP62" (page ENTP-4) otherwise to establish "P63".

"P63", page ENTP-4, changes the program number display to P63, sets the verb/noun display to VO6N64 (for use in "ENDEXIT", page ENRY-16), and causes "STARTENT", page ENRY-2, to be entered. This routine sets some initial conditions for the entry program and then causes the computations to enter "SCALEPOP" (page ENRY-3) and then "INITROLL" (page ENRY-5). The "INITROLL" computations monitor the status of the bit indicating 0.05 g (the bit is set/reset in "TARGETNG", entered from "SCALEPOP"), and when it first becomes one changes the program number display to 64 (and the verb-noun to O674). If the velocity at this point is less than 27,000 fps (K_{vfn1}), the exit address from "SCALEPOP" is set to "KEP2" (page ENRY-12): this causes exit to P67 (via "PREFINAL", page ENRY-12) when the drag exceeds 6.5 fps². If velocity is above 27,000 fps, then a more complete set of entry computations can be done (the setting of INRLSW keeps the 27,000 fps check from being performed more than once).

"PREDICT3", page ENRY-13, is the "final phase" of the entry computations, and is entered until the velocity is below 1000 fps, when "P67.1" (page ENRY-16) is entered instead to display V16N67 (computed by "P67.2", same page) until a response is received, when the "GOTOPOOH" routine is entered to stop the computations.

<u>Address</u> (Octal)	<u>Memory</u> <u>Notation</u>	<u>Document</u> <u>Notation</u>	<u>Reference</u>	<u>Comments</u>
*3,1706-10 (1706-10)	TEPHEM	T _{eph}	"P11" pg. BOOS-10	Triple precision time between ephemeris origin and clock origin (updated at liftoff).
*3,1711-2 (1711-2)	AZO	C _{azo}	"EARTHMX" pg. COOR-13	Angle between reference and Greenwich meridian at ephemeris origin.
*3,1713-20 (1713-20)	UNITW	C _{unitw}	"CALCGRAV" pg. GENP-26	Earth polar axis unit vector (scale factor B0) in reference coordinates.
*3,1767-70 (1767-70)	EK1VAL	C _{ek1val}	"S40.13" pg. STER-9	Impulse from first second of SPS thrusting.
*3,1771-2 (1771-2)	EK2VAL	C _{ek2val}	"S40.13" pg. STER-9	Initial value of minimum impulse curve for SPS thrusting (complement).
*3,1773 (1773)	EK3VAL	C _{ek3val}	"S40.13" pg. STER-9	Slope of minimum impulse curve for SPS thrusting.
*3,1774-5 (1774-5)	FANG	C _{fang}	"S40.13" pg. STER-10	SPS thrust for 1-6 seconds after ignition.
*3,1776 (1776)	E3J22R2M	C _{e3j22r2m}	"OBLATE" pg. ORBI-24	J ₂₂ term for lunar gravity model.
*3,1777 (1777)	E32C31RM	C _{e32c31rm}	"OBLATE" pg. ORBI-24	C ₃₁ term for lunar gravity model.
*4,1400 (2000)	WRENDPOS	WRENDPOS	"REND4" pg. MEAS-37	W matrix initialization for rendezvous. Can be changed by V67 processing.
*4,1401 (2001)	WRENDVEL	WRENDVEL	"REND4" pg. MEAS-38	W matrix initialization for rendezvous. Can be changed by V67 processing.
*4,1402 (2002)	RMAX	C _{rmax}	"REND7" pg. MEAS-28	Maximum automatic rendezvous position update.
*4,1403 (2003)	VMAX	C _{vmax}	"REND7" pg. MEAS-28	Maximum automatic rendezvous velocity update.
*4,1404 (2004)	WORBPOS	WORBPOS	"S22.1" pg. MEAS-37	W matrix initialization for orbital navigation. Can be changed by V67 processing.
*4,1405 (2005)	WORBVEL	WORBVEL	"S22.1" pg. MEAS-37	W matrix initialization for orbital navigation. Can be changed by V67 processing.
*4,1406 (2006)	S22WSUBL	C _{s22wsubl}	"S22NXTIN" pg. ORVN-21	W matrix initialization for orbital navigation for known landmark.

<u>Address (Octal)</u>	<u>Memory Notation</u>	<u>Document Notation</u>	<u>Reference</u>	<u>Comments</u>
*4,1407-10 (2007-10)	RPVAR	C _{rpvar}	"S22NXTIN" pg. ORVN-21	Variance of primary body radius vector, used to compute W matrix initialization for orbital navigation for unknown landmark.
*4,1411-6 (2011-6)	504LM	C _{504lm}	"RP-TO-R" pg. COOR-13	Libration correction vector for moon (scale factor BO, units radians).
*4,1417-20 (2017-20)	EMSALT	C _{emsalt}	"S61.2" pg. DISP-21	Entry monitoring system initialization altitude.
*4,1421-2 (2021-2)	ATIGINC	C _{atiginc}	"P35" pg. BURN-38	CSM-active time delay until midcourse maneuver (P35, P39).
*4,1423-4 (2023-4)	PTIGINC	C _{ptiginc}	"P75" pg. BURN-38	CSM-passive (i.e. LM-active) time delay until midcourse maneuver (P75, P79).
*4,1425-32 (2025-32)	RLS	RLS	"SETRE" pg. COOR-19	Landing site position vector. Can be updated (in "S22I=N") in P22.
*4,1433-5 (2033-5)	TIMEMO	C _{timemo}	"LSPOS" pg. COOR-14	Triple precision elapsed time between ephemeris origin and midpoint of interval for which lunar-position polynomial is valid.
*4,1436-43 (2036-43)	VECOEM	C _{vcem00}	"LUNPOS" pg. COOR-14	Vector coefficient of highest-order term (t^9 for position) in lunar-position polynomial.
*4,1444-51 (2044-51)	VECOEM +6	C _{vcem06}	"LUNPOS" pg. COOR-14	Vector coefficient of next highest-order term (t^8 for position) in lunar position polynomial.
*4,1452- 4,1523 (2052- 2123)	VECOEM +12	C _{vcem12} to C _{vcem48}	"LUNPOS" pg. COOR-14	Vector coefficients of subsequent terms (t^7 through t^1 for position) in lunar position polynomial.
*4,1524-31 (2124-31)	VECOEM +54	C _{vcem54}	"LUNPOS" pg. COOR-14	Vector coefficient of constant (non-time dependent) term in lunar position polynomial.
*4,1532-7 (2132-7)	RESO	C _{reso}	"LSPOS" pg. COOR-13	Position vector of sun relative to earth at C _{timemo} .
*4,1540-5 (2140-5)	VESO	C _{veso}	"LSPOS" pg. COOR-14	Velocity vector of sun relative to earth at C _{timemo} .
*4,1546-7 (2146-7)	OMEGAES	C _{omegaes}	"LSPOS" pg. COOR-13	Angular velocity of C _{reso} at C _{timemo} .
*4,1777 (2377)	INTVAR	C _{intvar}	"REND7" pg. MEAS-27	Integration variance employed in R22.

<u>Address</u> (Octal)	<u>Memory</u> <u>Notation</u>	<u>Document</u> <u>Notation</u>	<u>Reference</u>	<u>Comments</u>
5,1400-1 (2400-1)	AZIMUTH	C _{azmth}	"GTSCPSS" pg. PREL-10	Azimuth of vehicle Z-axis.
5,1402-3 (2402-3)	LATITUDE	C _{atd}	"ESTIMS" pg. PREL-10	Launch pad latitude.
5,1432 (2432)	TAZEL1	TAZ ₁	"GCOMPVER" pg. PREL-13	Azimuth of optics target #1.
5,1433 (2433)	TAZEL1 +1	TEL ₁	"GCOMPVER" pg. PREL-13	Elevation of optics target #1.
5,1434 (2434)	TAZEL1 +2	TAZ ₂	"GCOMPVER" pg. PREL-13	Azimuth of optics target #2.
5,1435 (2435)	TAZEL1 +3	TEL ₂	"GCOMPVER" pg. PREL-13	Elevation of optics target #2.
5,1633-4 (2633-4)	LAUNHAZ	LAUNHAZ	"GTSCPSS" pg. PREL-12	Desired launch azimuth. Can be updated using V78E. Should be loaded with same bit pattern as would be produced by V78E, to avoid re-initializing of gyro compassing unnecessarily.
*6,1400 (3000)	WMIDPOS	WMIDPOS	"POINTAXS" pg. MEAS-37	W matrix initialization for midcourse navigation. Can be changed by V67 processing.
*6,1401 (3001)	WMIDVEL	WMIDVEL	"POINTAXS" pg. MEAS-37	W matrix initialization for midcourse navigation. Can be changed by V67 processing.
*6,1402-3 (3002-3)	RVAR	C _{rvar}	"REND7" pg. MEAS-28	Value of (percent error/100) ² for VHF ranging measurement.
*6,1404-6 (3004-6)	RVARMIN	C _{rvarmin}	"REND7" pg. MEAS-28	Triple precision complement of minimum variance for VHF measurement (a negative number in memory for coding ease).
*6,1407 (3007)	LADPAD	C _{adpad}	"STARTENT" pg. ENRY-18	Nominal L/D.
*6,1410 (3010)	LODPAD	C _{odpad}	"STARTENT" pg. ENRY-18	Final phase L/D.
*6,1411 (3011)	ALFAPAD	C _{alfapad}	"P62.1" pg. ENTP-6	Nominal entry trim angle (expected to be negative number).

<u>Address (Octal)</u>	<u>Memory Notation</u>	<u>Document Notation</u>	<u>Reference</u>	<u>Comments</u>
*6,1412 (3012)	ETDECAY	C _{tdecay}	"S40.8" pg. STER-10	Value of thrust decay (cell subtracted from time-to-go).
*6,1413 (3013)	ESTROKER	C _{estroker}	"STRKTSTI" pg. DPTV-18	Amplitude of stroking test increment.
*6,1414 (3014)	EKPRIME	C _{ekprime} ₀	"TVCINIT1" pg. DPTV-17	LM-off cross-product steering gain factor (for TVC DAP input).
*6,1415 (3015)	EKPRIME +1	C _{ekprime} ₁	"TVCINIT1" pg. DPTV-17	LM-on high bandwidth cross- product steering gain factor.
*6,1416 (3016)	EKTLX/I	C _{ektlxdi} ₀	"TVCINIT1" pg. DPTV-17	LM-off TVC DAP nominal gain.
*6,1417 (3017)	EKTLX/I +1	C _{ektlxdi} ₁	"TVCINIT1" pg. DPTV-17	LM-on high bandwidth TVC DAP nominal gain.
*6,1420 (3020)	EKTLX/I +2	C _{ektlxdi} ₂	"SWICHOVR" pg. DPTV-17	LM-on low bandwidth TVC DAP nominal gain.
*6,1421 (3021)	EREPPFRAC	C _{ereppfrac} ₀	"TVCINIT1" pg. DPTV-18	LM-off TVC DAP repetitive c.g. correction fraction.
*6,1422 (3022)	EREPPFRAC +1	C _{ereppfrac} ₁	"TVCINIT1" pg. DPTV-18	LM-on TVC DAP repetitive c.g. correction fraction.
6,1423 (3023)	PACTOFF	PACTOFF	"TVCINIT1" pg. DPTV-26	TVC DAP pitch trim. Loaded by N48.
6,1424 (3024)	YACTOFF	YACTOFF	"TVCINIT1" pg. DPTV-29	TVC DAP yaw trim. Loaded by N48.
*6,1425 (3025)	HBN10	C _{hbn10} ₀	"TVCINIT1" pg. DPTV-18	LM-on high bandwidth filter.
*6,1426 (3026)	HBN11/2	C _{hbn10} ₁	"TVCINIT1" pg. DPTV-18	LM-on high bandwidth filter.
*6,1427 (3027)	HBN12	C _{hbn10} ₂	"TVCINIT1" pg. DPTV-18	LM-on high bandwidth filter.
*6,1430 (3030)	HBD11/2	C _{hbn10} ₃	"TVCINIT1" pg. DPTV-18	LM-on high bandwidth filter.
*6,1431 (3031)	HBD12	C _{hbn10} ₄	"TVCINIT1" pg. DPTV-18	LM-on high bandwidth filter.

Quantities in Computations

See also list of major variables and list of routines

- AM:** Magnitude of required maneuver angle, scale factor B0, units revolutions. The \cos^{-1} routine gives an answer in the range $0^\circ - 180^\circ$.
- ATTCADR:** Cell loaded in 2CADR format (see 3420.5-27) in "GOMANUR" with calling address information for attitude maneuver routine, to permit the calling-address job to be established by "ENDMANU". The most significant half is checked to ensure that more than one routine does not use the attitude maneuver package.
- ATTKALMN:** See Digital Autopilot RCS Routines.
- ATTPRIO:** Priority of job calling "GOMANUR", used in "ENDMANU" to re-establish the job.
- BCDU:** Set of three single precision cells, scale factor B-1, units revolutions, used to contain the previously desired values of CDU angles (or, the first time through "NEWANGL", the present spacecraft angles read at the start of "KALCMAN3").
- BIAS** (components $BIAS_0$, $BIAS_1$, $BIAS_2$): See Digital Autopilot RCS Routines.
- BIAS \underline{TEMP} :** Temporary storage for the values of **BIAS** to be loaded into those cells in "NEWANGL", scale factor B13, units revolutions. Since only the least significant parts of **BIAS \underline{TEMP}** are used, this gives a loading for **BIAS** with the B-1 scaling required.
- BRATE:** Vector giving maneuver rates about the x, y, and z axes, scale factor B-3, units revolutions/decisecond (i.e. revolutions per 0.1 second). Could also be considered scaled B0 in "units" of $450^\circ/\text{second}$. The "axes" are "control" ones (see [QUADROT]).
- CAM:** Cosine of AM, scale factor B1.
- CDUXD** (components CDUXD, CDUYD, CDUZD): Values of desired DAP CDU angles for automatic maneuver, scale factor B-1, units revolutions. See Digital Autopilot RCS Routines.
- COF:** Unit vector, scale factor B1, giving the "eigenvector of rotation when rotating SCAXIS to the desired position." It is computed in "VECPOINT" as the cross-product of the desired (POINTVSM) orientation in navigation base (i.e. spacecraft coordinates) coordinates and the SCAXIS complement, and is recomputed in "KALCMAN3".
- COFSKEW:** Vector, scale factor B2, in direction of COF (before maneuver magnitude checks, and equal to $2 \sin AM$ times maneuver vector). Its unit (giving a scaling of B1) is employed if AM is between K_{mina} and K_{maxa} .

[DEL]: Matrix computed in "DELCOMP", whose elements have scale factor B0. The matrix is a transformation representing the effect of a rotation about the input vector COF by the angle TS (i.e. the matrix taking a vector in initial navigation base/spacecraft coordinates to the same vector in final navigation base coordinates).

DELCDU (DELCDUX, DELCDUY, DELCDUZ): Desired CDU change each 0.1 second, scale factor B-1, units revolutions (or revolutions/decisecond).

HOLDFLAG: See Digital Autopilot Interface Routines.

K_{angtm} : Constant, program notation "ANGLTIME", scale factor B19, used to rescale time from seconds to centi-seconds. Octal value is $00003_8 04000_8$, corresponding to 100×2^{-19} .

K_{arate} : Set of four constants (defined only for $I = 0, 2, 4, 6$) giving allowable maneuver rates, scale factor B-4, units revolutions/second. Program notation for K_{arate_0} is "ARATE".

<u>I</u>	<u>Value Stored</u>	<u>Corresponds to</u>
0	0.0022222222	0.05°/sec
2	0.0088888889	0.2°/sec
4	0.0222222222	0.5°/sec
6	0.0888888889	2.0°/sec

K_{biasc} : Constant, program notation "BIASCALE", scale factor B16, value 0.0002543132. Value corresponds to $(1/0.6) \times 10 \times 2^{-16}$, where first term is reciprocal of "slope of decision line" (boundary of dead zone of plot of rate error vs. angle error has slope of 0.6°/second/°), second converts BRATE from deciseconds to seconds, and third is scale factor.

K_{dplmin} : Constant, program notation "DPLMIN", scale factor B28, units centi-seconds. Value is 6000×2^{-28} , corresponding to 60 seconds or one minute.

K_{maxa} : Constant, program notation "MAXANG", scale factor B0, units revolutions. Octal value is $17071_8 15667_8$, corresponding to an angle of about 170.012° (nominal value 170°). Constant is used double precision, although stored single precision.

K_{mina} : Constant, program notation "MINANG", scale factor B0, units revolutions. Octal value is $00013_8 17071_8$, corresponding to an angle of about 0.252° (nominal value 0.25°). Constant is used double precision, although stored single precision.

Boost Computations

P11 (Entered from "CHKCOMED" after liftoff deduced)

Set $T_{\text{evt}} = T_{\text{now}}$ and $T_{\text{now}} = 0$ (with special provisions for restarts)

$T_{\text{epH}} = T_{\text{epH}} + T_{\text{evt}}$ (special restart provisions)

Inhibit interrupts

Perform "PREREAD1"

Release interrupts

Call "ATERTASK" in 0.5 second

TS = 11 and perform "NEWMODEX"

Set bit 12(NODOPO1) of FLAGWRD1 = 1

DNLSTCOD = 3

Perform "CLEANDSP" (gets rid of backup liftoff, V75)

$\text{ERCOMP} = \text{ERCOMP} + \left[X_{\text{sm}} \right] \text{THETAN}$

TS = T_{evt}

Perform "EARTH*"(starting at second line)

(OGC, IGC, MGC) = CDU , rescaled to scale factor 80 revolutions, double precision

RTX2 = 0 (means earth)

ALT = C_{pgnCSAT}

LONG = C_{pdong}

LAT = C_{atd}

Set bit 13(ERADCOMP) of FLAGWRD1 = 0 (means pad radius altitude base; bit 12(LUNLATLO) of FLAGWRD3 apparently presumed zero from "SLAP1")

TS = 0

Perform "LALOTORV"

$R_{\text{n1}} = \text{ALPHA V}$

TS₂ = 0 (time argument)

TS = 1 (GAMRP value, scaled B1)

Perform "LALOTORV" (starting at 5th line)

Z_r = - unitALPHAV

V_{nl} = K_{merthrt} (R_{nl} * C_{unitw})

TS₁ = unit(Z_r * C_{unitw}) (east)

TS₂ = unit(TS₁ * Z_r) (- south)

X_r = unit(TS₁ sin LAUNHAZ + TS₂ cos LAUNHAZ)

Y_r = - unit(X_r * Z_r)

[REFSMAT] = $\begin{bmatrix} X_r \\ Y_r \\ Z_r \end{bmatrix}$ (cells also used for temporary storage during computation)

SATRLRT = SATRLRT sgn ($\frac{1}{2}$ - LAUNHAZ + C_{azmth})

Set bit 13(REFSMFLG) of FLAGWRD3 = 1

AVEGEXIT = "VHHDOT"

ldPIPADT = K_{2secp}

TS = 200 - TIME1, limited >> 1

Call "READACCS" in TS centi-seconds (i.e. 2 seconds after liftoff deduced)

Proceed to "NORMLIZE"

VHHDOT

VMAGI = |V|

HDOT = unitR · V

TS = K_{rpad}

If bit 2(AMOONFLG) of FLAGWRD0 = 1: (apparently presumed 0 from "SLAP1")

TS = |RLS|, rescaled to scale factor B29

ALTI = |R| - TS

TS = 0662_{vn}

Proceed to "REGODSP"

P34

Set bit 5(IMACTFLG) of FLAGWRD2 = 0

ECSTEER = K_{1b2}

Proceed to second line of "P74"

P74

Set bit 5(IMACTFLG) of FLAGWRD2 = 1

Set bits 7(UPDATFLG) and 5(TRACKFLG) of FLAGWRD1 = 1

TS = 0637_{vn}

Proceed to "GOFFLASH": if terminate, proceed to "GOTOPOOH"
if proceed, proceed
otherwise, proceed to previous line

NN1_{sp} = 0

TS = 0655_{vn}

Proceed to "GOFFLASH": if terminate, proceed to "GOTOPOOH"
if proceed, proceed
otherwise, proceed to previous line

Set bit 7(HAVEELEV) of FLAGWRD2 = 0

T_{ig} = T_{tpi}

If ELEV \neq 0:

Set bit 7(HAVEELEV) of FLAGWRD2 = 1

X1 = -2 (settings for

X2 = 0 earth)

If bit 12(CMOONFLG) of FLAGWRD8 = 1:

X1 = -10 (settings for

X2 = 2 moon)

RTX1 = X1

RTSR1dMU = $K_{mutab_{4-X1}}$

TS = $K_{mutab_{-2-X1}}$ (K_{mutab_0} for earth, K_{mutab_8} for moon)

If bit 12(CMOONFLG) of FLAGWRD8 = 1:

Shift TS right 6 places

RTMU = TS (scale factor B36)

RTX2 = X2

Set bit 6(FINALFLG) of FLAGWRD2 = 0

Perform "VN1645"

Proceed to "P34/P74C"

P34/P74C

Set bit 14(ITSWITCH) of FLAGWRD7 = 1 (means iterate "S33/34.1" below)

If bit 7(HAVEELEV) of FLAGWRD2 = 0:

Set bit 14(ITSWITCH) of FLAGWRD7 = 0

NOMTPI = 0

$T_{decl} = T_{tpi} + NOMTPI$ (enter here from below)

Perform "PRECSET"

Perform "S33/34.1"

If TS \neq 0: (non-zero for error return from "S33/34.1")

Perform "ALARM" (pattern 0611_g)

TS = 0509_{vn}

Proceed to "GOFLASH": if terminate, proceed to "GOTOPOOH"
if proceed, proceed
otherwise, proceed to 2nd previous line
(regenerate alarm again)

Proceed to second line of "P74"

If bit 14(ITSWITCH) of FLAGWRD7 = 1:

Set bit 14(ITSWITCH) of FLAGWRD7 = 0

Proceed to 5th line of "P34/P74C" (T_{decl} loading)

If bit 7(HAVEELEV) of FLAGWRD2 = 1:

TS = 0637_{vn}

Proceed to "GOFLASH": if terminate, proceed to "GOTOPOOH"
if proceed, proceed
otherwise, proceed to previous line

If bit 7(HAVEELEV) of FLAGWRD2 = 0:

TS = 0655_{vn}

Proceed to "GOFLASH": if terminate, proceed to "GOTOPOOH"
if proceed, proceed
otherwise, proceed to previous line

X1 = RTX1 (Tag here "P34/P74E")

X2 = RTX2 (as "least significant half" of X1 and RTX1)

CSTH = cos CENTANG

SNTH = sin CENTANG

RVEC = $\underline{R}_{\text{pass3}}$, shifted left X2 places (B29 earth, B27 moon)

VVEC = $\underline{V}_{\text{pass3}}$, shifted left X2 places (B7 earth, B5 moon)

Set bit 9(RVSW) of FLAGWRD7 = 1 (means new \underline{R} , \underline{V} not desired)

Perform "TIMETHET" (leaves time in T)

INTIME = T_{tpi}

$T_{\text{pass4}} = T_{\text{tpi}} + T$

Perform "S34/35.2"

DELVTPI = $\left| \text{DELVEET3} \right|$

DELVTPIF = $\left| \underline{V}_{\text{pass4}} - \underline{V}_{\text{tprime}} \right|$

X2 = RTX2

VVEC = $\underline{V}_{\text{tprime}}$, shifted left X2 places (B7 earth, B5 moon)

RVEC = $\underline{R}_{\text{act3}}$, shifted left X2 places (B29 earth, B27 moon)

X1 = RTX1

TS = K_{rpad}

If X1 \neq -2: (i.e. not earth)

TS = |RLS|

XXXALT = TS

Perform "APSIDES"

POSTTPI = (TS_{rp} - XXXALT), shifted right RTX2 places (B29)

T_{ig} = T_{tpi}

TS = 0658_{vn}

Proceed to "GOFLASH": if terminate, proceed to "GOTOPOOH"
if proceed, proceed
otherwise, proceed to previous line

Perform "S34/35.5" (page BURN-17)

Perform "VN1645"

Proceed to "P34/P74C"

VN1645 Entered from "DSPLY81", "P32/P72C", "P33/P73B", "P34/P74C",
"P35/P75B", "P37W", "P72", "P73", "P74",
SUBEXIT = Return address "P75", "P78", and "P79"

pMGA = K_{dpm01}

If bit 6(FINALFLG) of FLAGWRD2 = 1:

pMGA = 2 K_{dpm01}

If bit 13(REFSMFLG) of FLAGWRD3 = 1:

If MODREG \leq 64:

TS = DELVEET3 (same cell as DELVSIN)

Perform "MIDGIM" (starting at second line)

Set bit 11(TIMRFLAG) of FLAGWRD7 = 1

NVWORD1 = +0

Call "CLOKTASK" in 0.01 seconds

If bit 12(CMOONFLG) of FLAGWRD8 = 1:

Shift TS right 6 places

RTMU = TS (scale factor B36)

RTX2 = X2

Set bit 6(FINALFLG) of FLAGWRD2 = 0

Perform "VN1645"

Proceed to "P35/P75B"

P35/P75B

$T_{\text{strt}} = T_{\text{now}}$

$T_{\text{ig}} = T_{\text{strt}} + KT$

INTIME = T_{ig}

$T_{\text{decl}} = T_{\text{ig}}$

Perform "PRECSET"

$ULOS = \text{unit}(R_{\text{pass3}} - R_{\text{act3}})$

$UNRM = \text{unit}(R_{\text{act3}} * V_{\text{act3}})$

Perform "S34/35.2"

Perform "S34/35.5" (page BURN-17)

Perform "VN1645"

Proceed to "P35/P75B"

P38

Set bit 5(LMACTFLG) of FLAGWRD2 = 0

ECSTEER = K_{1b2}

Proceed to second line of "P78"

P78

Set bit 5(LMACTFLG) of FLAGWRD2 = 1

Set bits 7(UPDATFLG) and 5(TRACKFLG) of FLAGWRD1 = 1

TS = 0633_{vn}

Proceed to "GOFLASH": if terminate, proceed to "GOTOPOOH"
if proceed, proceed
otherwise, proceed to previous line

TS = 0655_{vn}

Perform "GOFLASHR": if terminate, proceed to "GOTOPOOH"
if proceed, skip next 2 lines
otherwise, proceed to previous line

TS = 011₂ and perform "BLANKET" (R2BLNK, R1BLNK)

End of job

OPTION1 = 5

OPTION2 = 1 (first phase, initiation)

TS = 0406_{vn}

Perform "GOFLASHR": if terminate, proceed to "GOTOPOOH"
if proceed, skip next 2 lines
otherwise, proceed to previous line

TS = 100₂ and perform "BLANKET" (R3BLNK)

End of job

NN1_{sp} = 2

If |OPTION2| > 2:

$T_{\text{intsoi}} = T_{\text{pass4}}$ (T_{pass4} notation also "TINT")

Set bit 7(OPTNSW) of FLAGWRD2 = 0

If |OPTION2| < 1:

Set bit 7(OPTNSW) of FLAGWRD2 = 1

Set bit 7(UPDATFLG) of FLAGWRD1 = 0

Perform "PREC/TT"

Set bit 7(UPDATFLG) of FLAGWRD1 = 1

$T_{\text{pass4}} = T_{\text{ig}} + T$

$DSPTM1_{\text{dp}} = T_{\text{pass4}}$

COSCDUX, COSCDUY, COSCDUZ: Value of cosines of information in CDUSPOT, scale factor B1 (in the same y,z,x order as CDUSPOT). If perform "QUICTRIG", a single-precision cosine routine is used, while if perform "CDUTRIG" the double precision interpretive routine is employed (taking about ten times more execution time). Updated once a second while "CLOCKJOB" is running (via "QUICTRIG" entrance), which includes the times that the TVC DAP is on.

COSTH: Value of argument cosine for "ARCTRIG", stored in push-down list location 16D, scale factor B2. Also used as communication cell with "ARCTAN", in which case only requirement is that scaling be the same as for SINTH to that routine.

CVECTR: Temporary vector used in "MOONMX" routine, scale factor B1, stored in push-down list location 8D.

DCDU: Incremental change in CDU angle due to DTHETASM (computed in "SMCDURES"), same scaling and units as DTHETASM.

DTEAROT: Value of earth rotation time for use in "EARROT2", scale factor B28, units centi-seconds.

DTHETASM: Communication cell with "SMCDURES" containing incremental angle changes measured about stable member axes. Scaling of DCDU (and units) will be the same as the scaling of this quantity: when entered from "R61CSM", scale factor is variable, units revolutions/decisecond.

DVECTR: Temporary vector used in "MOONMX" routine, scale factor B1, stored in push-down list location 8D.

ERADM: Value of radius of earth (from Fischer model or pad base) or moon (of average value or landing site base), scale factor B29, units meters.

FVAL: Value of angle from the mean ascending node of the moon's orbit to the mean moon computed in "MOONMX" routine, scale factor B0, units revolutions, stored temporarily originally in push-down list location 30D, then moved to 6D (where has notation "504F").

GAMRP: Value of square of ratio of polar to equatorial model radius (1.0 for moon), scale factor B1, stored in push-down list location 8D.

IGC: Value of inner gimbal angle, scale factor B0, units revolutions. The inner gimbal angle is identified with the Y axis.

K_{1b1}: Constant, program notation "1B1", scale factor B1, value 1×2^{-1} , corresponding to an equation value of 1.0 (the ratio of polar to equatorial model radius information for the moon).

- K_{ldwie} : Constant, program notation "1/WIE", scale factor B28, units centi-seconds. Value is 8616410×2^{-28} , corresponding to 86164.10 seconds, the earth's rotation period (rounded to the nearest centi-second). Corresponding angular velocity to this time is about $7.292115054E-5$ rad/sec (cf. K_{wearth}).
- K_{10dgm} : Single precision constant, program notation "10DEGS-", scale factor B-2, units revolutions. Value is 3600×2^{-14} , corresponding to about 19.7754° . Notation arises from the fact that would be about 10° for the standard trunnion angle scaling of B-3 revolutions.
- K_{20dgs} : Constant, program notation "20DEGS-", scale factor B-3, units revolutions. Value is -7199×2^{-14} , corresponding to -19.7754° (since used as if it was twos complement, equivalent to -7200×2^{-14} in ones complement).
- K_{20dgsM} : Constant, program notation "20DEG-", scale factor B-2, units revolutions. Value is 3600×2^{-14} , corresponding to about 19.7754° .
- K_{270dg} : Constant, program notation "270DEG", scale factor B-1, units revolutions. Value is $60000_8 00000_8$, corresponding to -90° in twos complement (or $+270^\circ$).
- K_{504rm} : Constant, program notation "504RM", scale factor B29, units meters. Value is 1738090×2^{-29} , corresponding to the mean lunar radius of 1738.09 km.
- K_{b2a2} : Constant, program notation "B2/A2", scale factor B1, value $0.9933064884 \times 2^{-1}$. Value corresponds to $(6356.784/6378.166)^2 \times 2^{-1}$, where terms in parentheses are the Fischer polar and equatorial earth radius values expressed in kilometers, to nearest meter.
- K_{b2xsc} : Constant, program notation "B2XSC", scale factor B51, value 0.0179450689 . Value corresponds to $(6356.784E3)^2 \times 2^{-51}$, where first term is Fischer polar model radius in meters (squared), and second is scale factor.
- K_{bdot} : Constant, program notation "BDOT", scale factor B-28, units revolutions/centi-second. Nominal value is $-3.07500686E-8$, corresponding to $-7.19757301E-14 \times (1/2\pi) \times 10^{-2} \times 2^{28}$, where first term is rate of change of BVAL in radians/sec, second converts to revolutions, third converts to centi-seconds, and fourth is scale factor. Memory value is $-2^{-25} (-2.98023223877E-8)$.
- K_{bsubo} : Constant, program notation "BSUBO", scale factor B0, units revolutions. Value is 0.0651201393 , corresponding to $0.40916190299 \times (1/2\pi)$, where first term is value in radians and second converts to revolutions.
- K_{cosi} : Constant, program notation "COSI", scale factor B1, value 0.99964173×2^{-1} . Value corresponds to cosine $1^\circ 32' 1.5''$ (5521.5 arc seconds), the "angle between the mean lunar equatorial plane and the plane of the ecliptic."

- K_{ee} : Constant, program notation "EE", scale factor B0, value 6.6935116E-3. Value corresponds to $(1 - K_{b2a2})^2$, i.e. the square of Fischer model eccentricity (for K_{b2a2} values).
- K_{erad} : Constant, program notation "ERAD", scale factor B29, units meters. Value is $6,373,338 \times 2^{-29}$, corresponding to 6,373,338 meters (same as K_{rpad} , see Burn Control).
- K_{fdot} : Constant, program notation "FDOT", scale factor B-27, value 0.570863327. Value corresponds to $2.6724041E-6 \times (1/2\pi) \times 10^{-2} \times 2^{27}$, where first term is rate of change of FVAL in radians/sec, second converts to revolutions, third converts to centi-seconds, and fourth is scale factor (hence constant stored in units of revolutions/centi-second).
- K_{fsub0} : Constant, program notation "FSUB0", scale factor B0, units revolutions. Value is 0.829090536, corresponding to $5.20932947829 \times (1/2\pi)$, where first term is value in radians and second converts to revolutions.
- K_{noddot} : Constant, program notation "NODDOT", scale factor B-28, units revolutions/centi-second. Value is $-0.457335121E-2$, corresponding to $-1.07047011E-8 \times (1/2\pi) \times 10^{-2} \times 2^{28}$, where first term is rate of change of OMGIVAL in radians/second, second converts to revolutions, third converts to centi-seconds, and fourth is scale factor.
- K_{nodio} : Constant, program notation "NODIO", scale factor B0, units revolutions. Value is 0.986209434, corresponding to $6.19653663041 \times (1/2\pi)$, where first term is value in radians and second converts to revolutions.
- K_{pl66} : Constant, program notation ".166...", scale factor B0, units revolutions. Value is 0.1666666667, corresponding to 60 degrees.
- K_{qts4} : Constant, program notation "QTSN45", scale factor B2. Value is 0.1768, corresponding to 0.7072×2^{-2} , where first term is $\sin 45^\circ$ and second is scale factor.
- K_{sini} : Constant, program notation "SINI", scale factor B1, value 0.02676579×2^{-1} , corresponding to the sine of the angle whose cosine is K_{cosi} .
- K_{wearth} : Constant, program notation "WEARTH", scale factor B-23, units revolutions/centi-second. Value is 0.973561595, corresponding approximately to $7.29211320E-5 \times (1/2\pi) \times 10^{-2} \times 2^{23}$, where first term is rotation rate of earth in radians/second, second converts to revolutions, third converts to centi-seconds, and fourth is scale factor. Decimal value also corresponds to $7.29211494E-5 \times (1/2\pi) \times 10^{-2} \times (8, 388, 606)$: perhaps an erroneous value for 2^{23} was employed (should be 8, 388, 608).

LAT: Value of vehicle latitude, scale factor B0, units revolutions, positive for northerly latitudes. Notation also "LANDLAT". If earth, geodetic.

LONG: Value of vehicle longitude, scale factor B0, units revolutions, positive for easterly longitudes.

MGC: Value of middle gimbal angle, scale factor B0, units revolutions. The middle gimbal angle is identified with the Z axis.

[MMATRIX]: Value of "modification matrix" for earth (computed in "EARTHMX") or moon (computed in "MOONMX"), scale factor of elements B1, stored in push-down list location 20D.

[NB1NB2]: Matrix of constants, program notation "NB1NB2", scale factor B1. True values of elements (which are multiplied by 2^{-1} for scale factor purposes) are:

$$\begin{bmatrix} 0.843175692 & 0 & 0.5376381241 \\ 0 & 1 & 0 \\ -0.5376381241 & 0 & 0.843175692 \end{bmatrix}$$

Numerical values in first row correspond to the cosine and sine of $32^{\circ} 31' 23.19''$.

[NB2NB1]: Matrix of constants, program notation "NB2NB1", scale factor B1. True values of elements (which are multiplied by 2^{-1} for scale factor purposes) are:

$$\begin{bmatrix} 0.843175692 & 0 & -0.5376381241 \\ 0 & 1 & 0 \\ 0.5376381241 & 0 & 0.843175692 \end{bmatrix}$$

Matrix is the transpose of [NB1NB2].

OGC: Value of outer gimbal angle, scale factor B0, units revolutions. The outer gimbal angle is identified with the X axis. The quantity is stored such that $OGC = (OGC, IGC, MGC)$.

OMGIVAL: Value of the "longitude of the node of the moon's orbit", scale factor B0, units revolutions, computed in "MOONMX". Value is stored temporarily in push-down list location 8D.

PAC: Required trunnion angle to have the star line-of-sight lie along STAR, scale factor B-3, units revolutions (double precision).

\underline{R}_t : Target vector output of "EARROT2", scale factor B1 (a unit vector).

\underline{R}_{tes} : Value of easterly component of \underline{R}_{ti} , scale factor B1 (dimensionless), computed in "EARROT1".

\underline{R}_{ti} : Communication cell with earth rotation routine, containing initial value of target vector (at DTEAROT = 0), scale factor B1 (a unit vector).

<u>Octal Digit</u>	<u>Word Bit</u>	<u>Significance</u>
5	3 2-1	Not used (no effect) Specify maneuver rate for RHC or automatic maneuvers: 00 ₂ for 0.05°/sec 01 ₂ for 0.20°/sec 10 ₂ for 0.50°/sec 11 ₂ for 2.00°/sec

DAPDATR2: Single precision quantity whose individual octal digits are assigned control significance for the RCS DAP only, and which is displayed in R2 of N46. It is processed in "S41.2", with the individual bits having the meanings given below:

<u>Octal Digit</u>	<u>Word Bit</u>	<u>Significance</u>
1	15-14 13	Not used (no effect) Use quad A/C for roll if 1 (if 0, use B/D)
2	12-11 10	Not used (no effect) Quad A may be used if 1 (not to be used if 0)
3	9-8 7	Not used (no effect) Quad B may be used if 1 (not to be used if 0)
4	6-5 4	Not used (no effect) Quad C may be used if 1 (if bit 10 is 1, quad C not to be used if bit 4 is 0)
5	3-2 1	Not used (no effect) Quad D may be used if 1 (if bit 7 is 1, quad D not to be used if bit 1 is 0)

DELCMWT: Value of $(CSMMASS + K_{negbpw})$ computed in "FIXCW", scale factor B15, units kilograms, single precision (the difference between present GSM mass and the "breakpoint" value for use in computing mass-property information). Program notation is "TEMP333".

DELPBAR, DELYBAR: See Digital Autopilot TVC Routines.

EDRIVE: Single precision values of previous scaled AK output information in "NEEDLES", scale factor B14, units output drive pulses (there are 2¹³ pulses per revolution for standard scaling). EDRIVE is the internal computer image of the number contained in the appropriate error counter driven from CDUXCMD, and is required since interface is incremental pulses from a previous setting.

HOLDFLAG: Single precision quantity, scale factor B14, used to control the nature of the attitude hold performed by the RCS DAP. A positive non-zero value means that at the next opportunity ("AHFNOROT" entered not in Free Mode and with rate filter initialized), the present CDU angles should be loaded into THETADX for use as the new attitude reference. A +0 value means that the DAP is in attitude hold about the angles in THETADX. A negative non-zero value means that automatic maneuvers are being performed (and WBODY, CDUXD, BIAS, and DELCDU all have an effect, see Digital Autopilot RCS Routines).

A positive non-zero value is loaded if the DAP's control of the vehicle is removed (bit 15 of channel 31 = 1); when the DAP is initialized; if the IMU data is not usable (i.e. not fine align); if the Free Mode is entered; if RHC commands are provided; if no DAP is desired (by "STABLISH"); and at end of P20. If **HOLDFLAG** is negative non-zero and a switch to Hold Mode is made, attitude hold is also performed (same effect as having **HOLDFLAG** positive non-zero, although setting not made).

A positive zero value is set in "AHFNOROT" after loading THETADX provided that bits 13-11 of RCSFLAGS = 0 (i.e. RHC damping done). A negative non-zero value is set in R61 and also when the attitude maneuver computation (e.g. R60 package) is performed. Programs can check **HOLDFLAG** to conclude, if it is not negative non-zero, that an interruption of the automatic maneuver has taken place.

IAVG: Single precision value of the "average" of moments of inertia about the y and z axes, scale factor B20, units kilogram-meters². It is computed as a function of CSMMASS (and LEMMASS if DAPDATR1 so indicates) in "FIXCW" and is used in "S40.14" to compute quantities for the RCS DAP (the separate quantity IAVGdTLX is used for the TVC DAP). Storage address corresponds to "IXX" +1.

IAVGdTLX: Single precision value of the "average" of moments of inertia about the y and z axes divided by the "thrust moment" (product of engine thrust and the "moment arm from hinge-point to c.g."), scale factor B2, units seconds², used in "S40.15" to multiply KTLXdI to obtain VARX. Program notation is "IAVG/TLX", and storage address corresponds to "IXX" +2. Computed in "FIXCW".

IXX: Single precision value of moment of inertia about the x axis (roll), scale factor B20, units kilogram-meters², computed in "FIXCW". It is used in "S40.14" and "S40.15" to compute quantities for the RCS and TVC DAPs respectively.

JdM (JdM₀, JdM₁, JdM₂): Single precision value of 80% of the reciprocal of one-jet acceleration about roll, pitch, and yaw axes respectively, scale factor B23, units of (revolutions/(deci-second centi-second))⁻¹, so that multiplication of a rate in revolutions/deci-second by JdM yields a time in centi-seconds. The 80% factor is in K_{cntone}, to account for "tolerances in the torque produced by the jets and uncertainties in the vehicle moment of inertia". The quantities are computed in "S40.14", with pitch and yaw values the same.

K_{slopeval_6} : Single precision constant, program notation "SLOPEVAL +6", scale factor B-8, units kilogram-meters² per kilogram per kilogram, used as the slope value to initialize VARST6 for LM-on. Nominal value is $2.21068E-3 \times 2^8$, corresponding to about $0.335472E-3 \times 1.355817948 \times (1/0.45359237)^2 \times 2^8$, where first term is value in slug-ft²/pound per pound. Octal value is 22070₈, corresponding to about $0.33546E-3$ slug-ft²/pound per pound.

K_{slopeval_7} : Single precision constant, program notation "SLOPEVAL +7", scale factor B-26, units seconds²/kilogram per kilogram, used as the slope value to initialize VARST7 for LM-on. Nominal value is $1.5166E-9 \times 2^{26}$, corresponding to about $0.31203E-9 \times (1/0.45359237)^2 \times 2^{26}$, where first term is value in seconds²/pound per pound, second converts to kilograms, and third is scale factor. Octal value is 3204₈, corresponding to about $0.31212E-9$ seconds²/pound per pound.

K_{slopeval_8} : Single precision constant, program notation "SLOPEVAL +8", scale factor B6, units kilogram-meters² per kilogram, used as the slope value to initialize VARST8 for LM-on. Nominal value is -1.284×2^{-6} , corresponding to about $-0.4296 \times 1.355817948 \times (1/0.45359237) \times 2^{-6}$, where first term is value in slug-ft²/pound, second converts to kilogram-meters², third converts to kilograms, and fourth is scale factor. Octal value is 77266₈, corresponding to about -0.4300 slug-ft²/pound.

K_{slopeval_9} : Single precision constant, program notation "SLOPEVAL +9", scale factor B-12, units seconds²/kilogram, used as the slope value to initialize VARST9 for LM-on. Nominal value is $2.00E-5 \times 2^{12}$, corresponding to about $0.9072E-5 \times (1/0.45359237) \times 2^{12}$, where first term is value in seconds²/pound, second converts to kilograms, and third is scale factor. Octal value is 2476₈, corresponding to about $0.90706E-5$ seconds²/pound.

KMJ (KMJ_0 , KMJ_1 , KMJ_2): Single precision value of the one-jet acceleration about roll, pitch, and yaw axes respectively, scale factor B-13, units of revolutions/ (deci-second centi-second), so that multiplication of a time in centi-seconds by KMJ yields a rotation rate in revolutions/deci-second. The quantities are computed in "S40.14", with pitch and yaw values the same.

KTLXdI: See Digital Autopilot TVC Routines.

LEMMASS: Single precision value of LM mass loaded by R2 of N47, and used in "MASSPROP" if bit 13 of DAPDATR1 = 0 to compute LM-attached mass properties constants. If bit 14 of DAPDATR1 = 1, is used in "FIXCW" to compute MASS (if DAPDATR1 set to indicate that LM not attached, cell contents ignored). Scale factor B16, units kilograms, but value should not exceed 2^{15} (or be equal to it) kilograms because of left shift in "MASSPROP": this is about 72000 pounds. For valid MASS computation, sum of CSMMASS and LEMMASS must be less than 2^{16} kilograms.

MASS: Single precision value of vehicle mass, program notation also "WEIGHT/G", scale factor B16, units kilograms, loaded in "FIXCW" as the sum of CSMMASS and (if specified by DAPDATR1) LEMMASS. Note that the value in this cell is not updated by RO3 ("DAPDISP") unless digit #1 of DAPDATR1 is 1, 2, 5, or 6. Cell is used as if it were double precision in "S40.1", "S40.1B", and "S40.13", and used as proper single precision quantity in "P37E". If used as "double precision" quantity, least significant half is AK₀.

MASSTMP: Single precision cell used for temporary storage of information related to CSMMASS, scale factor B16, units kilograms. It is generally used for restart protection purposes, and is also used as a communication cell with "SPSOFF" to contain value of mass of CSM to be corrected by V97VCNTR information (loaded with CSMMASS except if V97 engine-fail logic is exercised, see CSMMASS).

MRKRTMP: See Burn Control.

NVWORD1: See Burn Control.

OPTIND: See Optics Computations.

PACTOFF: See Digital Autopilot TVC Routines.

PMANNDX: Single precision cell, scale factor B14, loaded in "STICKCHK" with bits 2-1 of TS (set before entering routine). These bits correspond to the "pitch" input, with 00₂ meaning no maneuver, 01₂ meaning a positive maneuver, 10₂ meaning a negative maneuver, and 11₂ treated the same as 00₂ except for rate-command use of the RHC (see "T5PHASE2"). TS is set to the "true" values of the input information (which for the controllers have an inversion from the binary values, so that a binary 0 channel input represents a logical 1).

RACFAIL: Single precision cell, scale factor B14, set in "S41.2" based on Quad failure information in DAPDATR2. It is set to 0 if Quads A and C are both indicated as functioning; it is set to +1 if Quad A is indicated as having failed; and it is set to -1 if Quad A is indicated as functioning and Quad C as not functioning. See information below.

RATEINDX: Single precision cell, scale factor B14, set in "S41.2" to bits 2-1 of DAPDATR1 (shifted left one place for convenience in indexing double precision constants). Value is 0 for a specified maneuver rate of 0.05°/second; value is 2 for a specified maneuver rate of 0.2°/second; value is 4 for a specified maneuver rate of 0.5°/second; and value is 6 for a specified maneuver rate of 2.0°/second.

RBDFAIL: Single precision cell, scale factor B14, set in "S41.2" based on Quad failure information in DAPDATR2. It is set to 0 if Quads B and D are both indicated as functioning; it is set to +1 if Quad B is indicated as having failed; and it is set to -1 if Quad B is indicated as functioning and Quad D as not functioning. See information below.

K_{dftm}_i : Set of single precision constants, program notation "DFTMAX",
 scale factor B10, units centi-seconds. Values are:

<u>i</u>	<u>Value</u>	<u>True Value</u>
-3	-480×2^{-14}	-0.3 seconds
-2	-320×2^{-14}	-0.2 seconds
-1	-160×2^{-14}	-0.1 seconds
0	0	0.0 seconds
1	160×2^{-14}	0.1 seconds
2	320×2^{-14}	0.2 seconds
3	480×2^{-14}	0.3 seconds

K_{freetu}_i : Set of single precision constants, program notation "FREETAU",
 scale factor B10, units centi-seconds. Values for $i = 0$ and
 $i = 3$ are zero; for $i = 1$, value is 480×2^{-14} (i.e. 0.3 second);
 and for $i = 2$, value is -480×2^{-14} (i.e. -0.3 second).

K_{gnl}_i : Set of single precision constants, program notation "GAIN1",
 scale factor B0, used in "RCSATT" to obtain a new value of
 DRHQ (from samples taken 10 times/second). Value of index
 given by contents of ATTKALMN.

<u>i</u>	<u>Value</u>	<u>True Value</u>	
10	0.9342	0.93420	True Value obtained by converting octal memory information to decimal.
9	0.8151	0.81512	
8	0.6933	0.69330	
7	0.5970	0.59698	
6	0.5223	0.52228	
5	0.4634	0.46338	
4	0.4161	0.41608	
3	0.3774	0.37738	
2	0.3452	0.34521	
1	0.3180	0.31799	
0	0.0640	0.06403	(steady-state gain)
-1	0.2112	0.21118	(high-rate automatic/RHC maneuvers)
-2	0.8400	0.84003	(LM-off translation)
-3	0.2112	0.21118	(LM-on translation)

K_{gn2}_i : Set of single precision constants, program notation "GAIN2",
 scale factor B0, used in "RCSATT" to obtain a new value of
 ADOT (from DRHQ information acquired 10 times/second). Value
 of index given by contents of ATTKALMN.

<u>i</u>	<u>Value</u>	<u>True Value</u>	
10	0.8683	0.86829	See above note for K_{gnl}_i
9	0.4817	0.48169	
8	0.2955	0.29547	
7	0.1985	0.19849	
6	0.1422	0.14221	
5	0.1069	0.10687	
4	0.0832	0.08319	
3	0.0666	0.06659	
2	0.0545	0.05450	
1	0.0454	0.04541	
0	0.0016	0.00159	
-1	0.0174	0.01740	
-2	0.3600	0.35999	
-3	0.0174	0.01740	

K_{mantab_i} ($i = 0-7$): Set of single precision constants, program notation "MANTABLE", scale factor B-9, units revolutions/decisecond. The single precision constants are shifted right (double precision) by 6 places for loading into WBODY and by 8 places for decrementing MERROR in "T5PHASE2". Nominal values are:

<u>i</u>	<u>Value</u>	<u>Corresponds to</u>	
0	0.0071111	0.05 degree/sec	Nominal value times 3600/512 gives value in degrees/sec.
1	-0.0071111	-0.05 degree/sec	
2	0.0284444	0.20 degree/sec	
3	-0.0284444	-0.20 degree/sec	
4	0.0711111	0.50 degree/sec	
5	-0.0711111	-0.50 degree/sec	
6	0.2844444	2.00 degree/sec	
7	-0.2844444	-2.00 degree/sec	

K_{mintau_i} : Set of single precision constants, program notation "MINTAU", scale factor B10, units centi-seconds. Values for $i = 0$ and $i = 3$ are zero; for $i = 1$, value is 23×2^{-14} (about 14.4 ms); and for $i = 2$, value is -23×2^{-14} (about -14.4 ms).

K_{mptlsc} : Single precision constant, program notation "=-.1SEC", scale factor B10, units centi-seconds. Value is -160×2^{-14} , corresponding to -0.1 second.

K_{njt_i} : Set of single precision constants, program notation "NJET", scale factor B0, used to correct jet burn times (which are derived based on one-jet operation) for the number of jets actually to be used, and also to compensate for polarity of TAU (negative for negative jets). Values are:

<u>i</u>	<u>Value</u>
-3	-0.333333
-2	-0.5
-1	-0.999999
0	0.0
1	0.999999
2	0.5
3	0.333333

K_{p24} : Single precision constant, program notation "=.24", scale factor B-2, value 0.24. Used in "REDAP" as an initial condition setting for SLOPE. Value corresponds to $(-1) \times -0.6 \times 0.1 \times 2^2$, where first term is an equation factor, second is slope of attitude rate error limit line vs attitude error (in units of (revolutions/second)/revolution), third converts to units of deci-seconds, and fourth is scale factor.

K_{ptlsc} : Single precision constant, program notation "=+.1SEC", scale factor B10, units centi-seconds. Value is 160×2^{-14} , corresponding to 0.1 second.

Digital Autopilot TVC Routines

TVCDAPON Entered about 0.41 seconds after "IGNITION" or if
restart (from "CMDSOUT" for TVCPHASE = -1)

TTMP1 = 0
YDELOFF = 0
PDELOFF = 0
DELYBAR = 0
DELPBAR = 0
YEERRB = 0
PEERRB = 0
STROKER = 0
TEMREG = 0
ROLLWORD = 0
ROLLFIRE = 0
YTMPi = 0 (i = 6 - 1)
PTMPi = 0 (i = 6 - 1)
OMEGAB = 0
OMEGAC_z = 0
OMEGAC_y = 0
T5LOC = "TVCINIT1"

Set TIME5 to cause program interrupt #2 in 0.01 second

Resume

TVCINIT1 Entered about 0.42 seconds from start of "IGNITION".

Perform "MASSPROP"

TENMDOT = C_{endot} K_{onethou}

MASSTMP = CSMASS - TENMDOT

j = bit 14 of DAPDATR1 (1 for LM on, 0 for LM off)

If j = 1: (LM on)

$$N1O_i = C_{hbn1O_i} \quad (i = 0 - 14)$$

If j = 0:

$$N1O_i = K_{csmn1O_i} \quad (i = 0 - 14)$$

$$KTLXdI = C_{ektlxdi_j}$$

Perform "S4O.15"

If j = 1:

$$TS_1 = K_{8csd2}$$

If j = 0:

$$TS_1 = K_{4csd2}$$

$$T5TVCDT = 16384 - TS_1$$

Set bit 15(SWTOVER) of FLAGWRD9 = 0

$$KPRIMEDT = 2 C_{ekprime_j} TS_1 \quad (\text{the 2 is due to scaling})$$

$$REPFRAC = C_{erefrac_j}$$

$$CNTR = K_{tcorr_j}$$

STRKTIME = -1 (not used)

VCNTR = 19

V97VCNTR = 19

PDELOFF_{sp} = PACTOFF

PCMD = PACTOFF

DELPBAR_{sp} = PACTOFF

YDELOFF_{sp} = YACTOFF

YCMD = YACTOFF

DELYBAR_{sp} = YACTOFF

If bit 13 of DAPDATR1 = 1: (LM-off)

$$\text{If } |K_{ldattlim} \text{ERRBTMP}+i| \geq 2^{-14}:$$

$$\text{ERRBTMP}+i = K_{attlim} \text{sgn ERRBTMP}+i$$

(i = 0, 1: loaded with
-ERROR₁, -ERROR₂ in
"IGNITION")

(If bit 13 of DAPDATR1 = 1):

PERRB_{sp} = ERRBTMP+0

YERRB_{sp} = ERRBTMP+1

Set bit 3 of RCSFLAGS = 1

Perform "NEEDLER"

Proceed to "TVCINIT4"

TVCINIT4 Can be entered from "CMDSOUT" if restart.

TVCPHASE = +0

OGANOW = CDU_x

If bit 13(SPS Engine On) of channel 11 = 1:

CSMMASS = MASSTMP

Call "TVCEXEC" in 0.5 seconds

T5LOC = "DAPINIT"

TIME5 = T5TVCDT

Resume

DAPINIT Entered about $0.42 + \frac{1}{2}$ DAP cycle sec. after start of "IGNITION"

TIME5 = T5TVCDT + (T5TVCDT - 16384) (gives interrupt in $2 TS_1$ from "TVCINIT1" TS_1)

T5LOC = "PITCHDAP" (entered about $0.42 + 1.5$ DAP cycle rate after start of "IGNITION": for LM-off, 0.48 sec)

PCDUYPST = CDU_y

PCDUZPST = CDU_z

Resume

SWICHOVR Entered from "STABLISH" for V46E with LM-on TVC DAP, or from "CMDSOUT" if TVCPHASE negative but not -1.

PHASETMP = TVCPHASE (interrupts inhibited during routine)

TVCPHASE = -2

YTMP_i = 0 (i = 6 - 1)

PTMP_i = 0 (i = 6 - 1)

Set bit 15(SWTOVER) of FLAGWRD9 = 1

$KTLXdI = C_{ektlxdi_2}$

Perform "S40.15" (starting at second line)

$KPRIMEDT = K_{fkprimdt}$

$REPFRAC = K_{frepfrac}$

$PDELOFF = DELPBAR$

$YDELOFF = DELYBAR$

$NlO_i = K_{lbnlO_i}$ (i = 0 - 14)

$TVCPHASE = PHASETMP$

Return

TVCEXEC Entered first about 0.92 sec after "IGNITION" (see "TVCINIT4").

If bits 15-14 (DAPBIT1, DAPBIT2) of FLAGWRD6 $\neq 10_2$:

$TVCEXPHS = 0$

End of task

Call "TVCEXEC" in 0.5 seconds

$OGAPAST = OGANOW$

$OGANOW = CDU_x$

$AK_0 = OGAD - OGANOW$ (ones complement difference formed)

$OGA = -AK_0$, rescaled to scale factor 80 revolutions

Call "ROLLDAP" in 0.03 seconds

Perform "NEEDLER"

If bit 13 (SPS Engine On) of channel 11 = 0:

$TVCEXPHS = 2$

Proceed to "LSHOTCHK".

If $VCNTR = -0$: (set in "S40.8" for low thrust)

$TVCEXPHS = 2$

Proceed to "LSHOTCHK"

CNTR: Single precision counter, scale factor B14, units counts (of $\frac{1}{2}$ second each), preset in "TVCINIT1" and decremented in "LSHOTCHK". When reduced to 0, the next entrance to "TVCEXEC" causes a "one-shot" correction to PACTOFF and YACTOFF (as well as PDELOFF and YDELOFF), using $K_{fcorfrac}$. CNTR is set to +MAX in "S40.8" when the cutoff decision is made, to inhibit further trim updates after that time (a value of -1 is set in "TEMPSET"/"CNTRCOPY" to signify that the one-shot correction has been made). Since K_{tcorr} (initial condition for LM-on of CNTR) is zero, no decrementing of CNTR is required for that configuration.

COSCDUX, COSCDUZ: See Coordinate Transformations. Updated once a second while "CLOCKJOB" is entered, which includes period of time when TVC DAP is on.

CSMMASS: See Digital Autopilot Interface Routines.

DAP1, DAP2, DAP3: Filter quantities computed in "FWDFLTR", scale factor B-1, units revolutions. If LM off, then DAP3 is set equal to DAP2 (otherwise, it is derived).

DAPDATR1: See Digital Autopilot Interface Routines.

DELBRTMP: Double precision erasable memory cell used to contained the updated value for DELPBAR or DELYBAR (for restart protection purposes), scale factor B14, units CDU actuator output pulses (or scale factor B0 in ASCREV units).

DELOGA: Single precision value of roll attitude error used in "ONROLL", scale factor B0, units revolutions (computed initially in "ROLLDAP" as "distance from switch parabola").

DELOGART: Single precision value of roll attitude rate error used in "ONROLL", scale factor B-4, units revolutions/second.

DELPBAR: Double precision value of estimated "c.g. offset relative to electrical null" in pitch, scale factor B14 in units of CDU actuator pulses (or scale factor B0 in ASCREV units). Initialized to PACTOFF in "TVCINIT1" and updated in "PCOPY" with DELBRTMP (for restart protection purposes). After CNTR reduced to zero, used in "TEMPSET" to updated PDELOFF and PACTOFF (using $K_{fcorfrac}$ and then REPFRAC for weighting). Used in "SPSOFF" to load $K_{fcorfrac}$ PACTOFF if suitable initialization completed (i.e. "TVCINIT1" completed, initializing DELPBAR).

DELYBAR: Double precision value of estimated "c.g. offset relative to electrical null" in yaw, scale factor B14, units CDU actuator output pulses (or scale factor B0 in ASCREV units). See DELPBAR (substitute yaw axis for pitch axis).

ERRBTMP: Value of pitch or yaw error in body coordinates, scale factor B-1, units revolutions, limited to K_{errim} . Could also be considered to be the "integral of body-axis rate error". Value is displayed on FDAI error needles (due to loading of AK_1 or AK_2 by appropriate copy routine). Loaded in "IGNITION" with RCS DAP pitch and yaw negative (single precision) error information for use in "TVCINIT1", after limiting, to initialize PERRB and YERRB for LM-off.

- $K_{ldactsat}$: Single precision constant, program notation "1/ACTSAT", scale factor B_0 , octal value 00101_8 , corresponding to 0.003967285. Effect in equations such as to cause an answer of one least increment (2^{-14} in programmed equations) for an argument of 253 least increments or more (see K_{actsat}).
- $K_{ldattlim}$: Single precision constant, program notation "1/ATTLIM", scale factor B_0 , octal value 00170_8 . Effect in equations such as to cause an answer of one least increment (2^{-14} in programmed equations) for an argument of 137 least increments (at B-1 rev., about 1.505°): see K_{attlim} .
- $K_{lderrim}$: Single precision constant, program notation "1/ERRLIM", scale factor B_0 , octal value 00004_8 . Effect in equations such as to cause an answer of one least increment (2^{-14} in programmed equations) for an argument of 2^{-2} or more (see K_{errim}): the 2^{-2} would correspond to 2^{-3} revolutions.
- K_{ldrtim} : Single precision constant, program notation "1/RTLIM", scale factor B_0 , octal value 00115_8 . Effect in equations such as to cause an answer of one least increment (2^{-14} in programmed equations) for an argument of 213 least increments (at B-1 rev., about 2.34°).
- $K_{ldtmxfir}$: Single precision constant, program notation "1/TMXFIR", scale factor B_0 , octal value 00004_8 . Effect in equations such as to cause an answer of one least increment (2^{-14} in programmed equations) for an argument of 2^{-2} or more (see K_{tmxfir}): the 2^{-2} would correspond to 2.56 seconds.
- K_{4csd2} : Single precision constant, program notation "BIT2", scale factor B_{14} , units centi-seconds, giving the required time interval between DAP computations for different axes for LM-off. Value is 2×2^{-14} , corresponding to 2 centi-seconds: this gives a time interval of 4 centi-seconds from one pitch axis solution to the next.
- K_{8csd2} : Single precision constant, program notation "BIT3", scale factor B_{14} , units centi-seconds, giving the required time interval between DAP computations for different axes for LM-on. Value is 4×2^{-14} , corresponding to 4 centi-seconds: this gives a time interval of 8 centi-seconds from one pitch axis solution to the next.
- K_{actsat} : Single precision constant, program notation "ACTSAT", scale factor B_{14} , units CDU actuator output pulses (one pulse is 85.41 seconds). Value is 253×2^{-14} , corresponding to about 6.0024° . Note that 2^{-14} CDU actuator output pulses correspond to about 1.079751111 revolutions; there are about 42.14963 pulses/degree.
- K_{attlim} : Single precision constant, program notation "ATTLIM", scale factor B-1, units revolutions. Value is 136 least increments (see $K_{ldattlim}$), or octal 00210_8 , corresponding to about 1.494° .

<u>i</u>	<u>Nominal Value</u>	<u>Scale Factor</u>	<u>Nominal True Value</u>	<u>Stored</u>
5	0.03125	B0	0.03125 (N20)	0.03125
6	0.0	B1	0.0 (N21)	0.0
7	0.0	B0	0.0 (N22)	0.0
8	-0.9101	B1	-1.8202 (D21)	-1.82019
9	0.8460	B0	0.8460 (D22)	0.84601
10	0.5000	B0	0.5000 (N30)	0.50000
11	-0.47115	B1	-0.9423 (N31)	-0.94226
12	0.4749	B0	0.4749 (N32)	0.47491
13	-0.9558	B1	-1.9116 (D31)	-1.91162
14	0.9372	B0	0.9372 (D32)	0.93719

See note with K_{csmm10_i} .

K_{maxim} : Single precision constant, program notation "MAXLIM", scale factor B-4, units revolutions/second. Value is 0.01388889×2^4 , corresponding to about 5 degrees/second.

K_{mcrat} : Single precision constant, program notation "LMCRATE", scale factor B-4, units revolutions/second (gives limit cycle roll rate for TVC roll DAP). Value is 0.0111_8 , corresponding to about 0.10025 degree/second.

K_{minim} : Single precision constant, program notation "MINLIM", scale factor B-4, units revolutions/second. Value is 0.00277778×2^4 , corresponding to about 1 degree/second.

K_{mrol} : Single precision constant, program notation "-ROLL1", octal value 00012_8 , corresponding to channel 6 roll jets #10 and #12, giving a SM negative roll using quad B/D.

K_{mro2} : Single precision constant, program notation "-ROLL2", octal value 00240_8 , corresponding to channel 6 roll jets #14 and #16, giving a SM negative roll using quad A/C.

K_{mslope} : Single precision constant, program notation "-SLOPE", scale factor B0, units (revolutions/second)/revolution. Value is 0.2. Notation arises from fact that "true" slope is negative (an increasing attitude error results in a decreasing attitude rate).

$K_{onemeat}$: Single precision constant, program notation "1-E(-AT)", scale factor B0, octal value 00243_8 . Value corresponds to $163/16384$, or approximately 0.01, equivalent to the first term in the series expansion of $(1 - e^{-at})$ for $at = 0.01$.

$K_{onethou}$: Single precision constant, program notation "ONETHOU", scale factor B13, units centi-seconds. Multiplies C_{emd} in "TVCINIT1" to convert from kilograms/centi-second to kilograms/ten seconds (for loading into TENMDOT). Value is 1000×2^{-13} , corresponding to 1000 centi-seconds (10 seconds).

- K_{pro1} : Single precision constant, program notation "+ROLL1", octal value 00005₈, corresponding to channel 6 roll jets #11 and #9, giving a + Roll (for SM). Uses Quad B/D.
- K_{pro2} : Single precision constant, program notation "+ROLL2", octal value 00120₈, corresponding to channel 6 roll jets #15 and #13, giving a + Roll (for SM). Uses Quad A/C.
- K_{rrt} : Single precision constant, program notation "BIT5", scale factor B11, value 2^{-10} , corresponding to 2×2^{-11} , where first term is conversion of rate to units of revolutions/second, and second is scale factor.
- K_{t6sc} : Single precision constant, program notation "T6SCALE", scale factor B7, value 31000₈. Value corresponds to 100×2^{-7} , where first term converts from seconds to centi-seconds and second is scale factor.
- K_{tcorr} : Single precision constant, program notation "TCORR", scale factor B14, units counts (used as a preset for CNTR in "TVCINIT1" for LM-off). Value is 5×2^{-14} , meaning that the "single-shot" correction will take place the 6th time that "TVCEXEC" is entered, or about 3.42 seconds after "IGNITION" is done.
- K_{tcorr} : Single precision constant, program notation "TCORR +1", scale factor B14, units counts (used as a preset for CNTR in "TVCINIT1" for LM-on). Value is 0, meaning that the "single-shot" correction will take place the first time that "TVCEXEC" is entered, or about 0.92 seconds after "IGNITION" is done.
- K_{tminfr} : Single precision constant, program notation "TMINFIRE", scale factor B10, units centi-seconds. Value is 00030₈, corresponding to 1.5 centi-seconds (i.e. 15 milliseconds).
- K_{tmxfir} : Single precision constant, program notation "TMAXFIRE", scale factor B10, units centi-seconds. Value is 250×2^{-10} , corresponding to 250 centi-seconds (i.e. 2.5 seconds). See K_{ldtmxfir} .
- KPRIMEDT: Quantity used in "S40.8" to convert guidance attitude error information into OMEGAC. Scale factor is B-4, units (revolutions/DAP cycle) per radian. Loaded in "TVCINIT1" and "SWICHOVR". Least significant half expected to be 0 (from "TVCINIT1" loading method).
- KTLXDI: Single precision value of appropriate C_{ektlxdi} cell, loaded in "TVCINIT1" or "SWICHOVR" and used in "S40.15". Scale factor is B3, program notation "KTLX/I".
- MASSTMP: See Digital Autopilot Interface Routines.

If $TS - K_{nq} \geq 0$:

$$THETAH = K_{kacs} \sqrt{|2(TS - 1)|}$$

$TS = THETAH$

If bit 8 (GONEBYTG) of FLAGWRD7 = 0:

$TS = -TS$

RTGON67 = TS

If $D - K_{pt05g} < 0$:

Set bit 3(O5GSW) of FLAGWRD6 = 0

Return

Set bit 3(O5GSW) of FLAGWRD6 = 1

$$TS = \frac{|\underline{DELVREF}|^2 - (\underline{DELVREF} \cdot \underline{UXA})^2}{(\underline{DELVREF} \cdot \underline{UXA})^2}$$

If no overflow has taken place (e.g. $|TS| < 1$):

$$LdDCALC = \sqrt{TS}$$

Return

INITROLL

If bit 5(INRLSW) of FLAGWRD6 = 1:

If $RDOT + K_{vrcont} \geq 0$:

DIFFOLD = 0

DLEWD = K_{dlewd0}

LEWD = K_{ewdl}

GOTOADDR = "HUNTEST"

Proceed to "HUNTEST"

If $(KAT - D) < 0$, proceed to "CONSTD"

Proceed to "LIMITL/D"

If bit 3(O5GSW) of FLAGWRD6 = 0, proceed to "LIMITL/D"

$TS = 64$ and perform "NEWMODEX"

$ENTRYVN = 0674_{vn}$

$KAT = K_{ka2} + LEQ^3 / K_{ldkal}$, limited $\leq K_{kalim}$

Set bit 10(GONEPAST) of FLAGWRD6 = 0 ("STARTENT" initialized
this bit to 1)

If $NV - K_{vfn1} < 0$:

GOTOADDR = "KEP2"

Set bit 5(INRLSW) of FLAGWRD6 = 1 (must be 0 to get here)

Proceed to "LIMITL/D"

$DO = K_{ka3} LEQ + K_{ka4}$ (NV at least 27,000 fps to get here)

$GdDO = K_{cone} / DO$

Reset overflow indicator

LdD = LAD

$TS = (RDOT / NV)^3 / K_{ldk44} - K_{vfin} + NV$

If no overflow has taken place since indicator reset:

If $TS \geq 0$:

LdD = - LAD

Set bit 5(INRLSW) of FLAGWRD6 = 1 (must be 0 to get here)

Proceed to "LIMITL/D"

HUNTEST

A1 = D

TS = LAD

If $RDOT \geq 0$:

TS = LEWD

$V1 = NV + RDOT / TS$

$AO = (V1^2 / VSQUARE) (D + RDOT^2 / (K_{2chs} TS))$

If $RDOT < 0$:

A1 = AO

If $LdD < 0$:

$V1 = V1 - K_{vquit}$

Proceed to "HUNTEST1"

Perform "ALARM2" (starting at second line)

Return (address in ALMCADR)

BAILOUT

Inhibit interrupts

ALMCADR = "Calling address +1" (S-register portion)

Perform "VAC5STOR"

LREG = Alarm pattern (quantity in calling address +1)

Perform "ALARM2" (starting at second line)

Inhibit interrupts

If in interrupt mode, return to job status (set appropriate address into cell 0017_g and then do a Resume)

Proceed to "GOPROG2"

POODOO

Inhibit interrupts

ALMCADR = "Calling address +1" (S-register portion)

Perform "VAC5STOR"

LREG = Alarm pattern (quantity in calling address +1)

Perform "ALARM2" (starting at second line)

If bit 6(V37FLAG) of FLAGWRD7 = 0: (Average-G not running)

Set bit 5(STATEFLG) of FLAGWRD3 = 0

Set bit 7(INTGRAB) of RASFLAG = 0 (i.e. FLAGWRD10)

Set bit 1(NODOV37) of FLAGWRD2 = 0

Make all restart groups inactive (by setting PHASE_i = +0 and -PHASE_i = -0 for i = 1-6)

If interrupt mode, return to job status (set appropriate address into cell 0017_g and then do a Resume)

Proceed to "GOPROG2" (if MODREG bit 15 = 0, will get to "GOTOPOOH" if have no active restart groups)

CCSHOLE

Inhibit interrupts

ALMCADR = "Calling address +1" (S-register portion)

Perform "VAC5STOR"

LREG = 1103₈

Proceed to 5th line of "POODOO"

CURTAINS

Inhibit interrupts

ALMCADR = "Calling address +1" (S-register portion)

Perform "ALARM2" (pattern 0217₈)

Return (address in ALMCADR)

SVCT3 This task is used as part of the waitlist control, and is entered every 81.93 seconds for that purpose.

If bit 15(DRIFTFLG) of FLAGWRD2 = 0:

End of task

If IMUCADR = +0:

Establish "NBDONLY" (priority 35₈)

End of task

Delay 5 seconds (since V4ON2OE leaves IMUCADR set for 10.56 seconds, might have to have 3 delays, depending on phasing)

Proceed to "SVCT3" on phasing)

DUMMYJOB This routine is entered from the executive system if no active jobs are found.

NEWJOB = -0

Release interrupts

Set bit 2(Computer Activity) of channel 11 = 0

Proceed to second line of "CHECKNJ"

CHECKNJ

SELFRET = Return address

If NEWJOB = -0:

Return (to address specified by SELFRET, BECON of "SELFCHK")

Set bit 2(Computer Activity) of channel 11 = 1

Perform functions necessary to start new job's computations

K_{rndbt} : Single precision constant, program notation "BIT5", scale factor (as used) B_{23} , units centi-seconds. Value is 00020_g , corresponding to (as used, i.e. added to the least significant half of channel 4 time information) 0.5 centi-seconds. Used to account for the fact that channel 4 bits 5-1 "read 20_g for the first interval after a TIME1 increment", thus causing bit 6 of channel 4 to be incremented 5 ms out of phase with TIME1 increments.

K_{rtu_i} ($i = 0 - 11$): Table of single precision constants, program notation "RELTAB", containing in bits 15-12 the required values to be loaded into bits 15-12 of OUTO for DSPTAB_i. Value in these bits is $(i + 1)$. The least significant 5 bits of these same constants are used for K_{rtb_I} (see Data Input/Output), but program masking operations not shown.

IGYRO: See IMU Computations.

LOC: The 9th cell of job register set (see 3420.5-27) currently active: for interpretive language computations, it contains the address information (S-register portion) which can be used with BANKSET to determine location of computations.

LOCALARM: Single precision cell used to store value of LOC in "ALARM2": it is address 00057_g . Hence VO4 NOLE 57E will display LOCALARM in R1 and BANKALRM in R2 (or cells could be checked for a V74E dump).

LREG: Computer "L" register (address 0001_g) used to retain alarm pattern information in alarm-generation package.

MARKSTAT: See Optics Computations.

MASSTMP: See Digital Autopilot Interface Routines.

MINDEX: Single precision cell, scale factor B_{14} , used to select the appropriate table entries for a V37-selected program change (loaded based on equality of MMNUMBER and bits 7-1 of K_{prml_i} with the value of i).

MMNUMBER: Single precision cell, scale factor B_{14} , used to retain the desired new program number for a V37 program change (it is the number entered in "MMCHANG" or is 0 if "V37" entered from "VERB96"). If the TVC DAP or SPS engine-on are indicated, it is set 0.

MMTEMP: Single precision cell loaded in "V37XEQ" with the value of the appropriate K_{prml} for use in generating appropriate information in connection with the job to be established by V37 processing.

MONSAVE, MONSAVE1: See Data Input/Output.

MRKBUF2: See Optics Computations.

NEWJOB: Cell set positive non-zero to indicate that a job of higher priority than the one presently being performed (the "DUMMYJOB" loop has minimum priority) has been established and is awaiting execution. Cell 0067_g is used for the word, and must be addressed periodically to avoid generating a hardware restart (see hardware documentation for details).

NOUNREG: See Data Input/Output.

NOUT: Single precision cell, scale factor BL_4 , used to provide a count of the number of DSPTAB display outputs ($DSPTAB+0 - DSPTAB+10$) that are remaining to be changed: if is non-zero but none are to be changed, is set 0.

NVWORD+2: See Display Interface Routines.

OPTCADR: See Optics Computations.

OPTIND: See Optics Computations.

OPTMODES: See Optics Computations.

OUTO: Computer output channel 10, used to transmit relay driving information to the display system. Bits 15-12 specify the group of relays to be driven, while bits 11-1 specify their new state.

PHASE i , -PHASE i ($i = 1 - 6$): Set of cells used to contain program octal "phase" information, used to control program restarts (each "i" is called a "group"). To check the validity of erasable memory information (and the phase information itself), a check is made that the information in PHASE i , when complemented, is the same as the information in -PHASE i (for all i). A setting of +0 for PHASE i means that the group restart controlled by that cell is "inactive" (see Section VIIC of 3420.5-27 for details of restart logic computations not covered in this writeup). In the interests of avoiding excessive detail (since the "normal" mode of operation of the computer system does not require restarts), most of the settings for restart groups are not shown in the writeups, although settings in some cases form an integral part of the program control logic, and hence are shown in such cases. As a general guide to allocation of restart groups, the following areas where each group is used are supplied as a partial list:

#1: P20 (setting to 1.11 causes "PIKUP20" to be entered: this is set in "PROG20", "AVGEND", and "MANUEXIT" (after return from R60 in R61), and in "RELINUS"). A setting to 1.7 is done in "CHKLINUS" for R61-specified R60 maneuver. A setting to 1.5 is used to protect "S40.9" (set by "SETUP.9"), which of course only occurs with Average-G on, when P20 doesn't run. If "ROO" concludes that P20 should not run, it resets group 1 to inactive, thus over-riding the "AVGEND" setting.

#2: Orbital integration (including the periodic state vector update started by "STATINT1" for a 2.5 setting). A setting of 2.7 causes "R22" to be established, and 2.13 causes "REDOR22" to be established (the latter setting is done by "AVGEND", and written over by "ROO" if necessary). Group 2 is also used for protection within the R22 computations, which are done at sufficiently high priority that they would not be expected to be interrupted by mission programs except while R22 is performing "WAITONE". Restart priority lower than that at which job runs to permit mission programs to set e.g. TRACKFLG. A 2.11 setting is done by "VERB94" for P23 computations (to permit "V94ENTER" to be established while getting rid of e.g. R52 if it happens to be running in P23 then).

Inflight Alignment

P51 (Tag also "P53")

If bit 9 of IMODES30 = 1: (IMU not on)

Perform "ALARM" (pattern 0210₈)

Proceed to "GOTOPOOH"

Proceed to "P51A"

P51A

Set bit 8(IMUSE) of FLAGWRDO = 1

TS = 00015₈

Proceed to "GOPERF1": if terminate, proceed to "GOTOPOOH"
if proceed, proceed to "P51B"
otherwise, proceed

THETAD = 0

TS = 0622_{vn}

Perform "GODSPRET"

TS = 4100_{vn}

Perform "GODSPRET"

Perform "IMUCOARS"

Perform "IMUSTALL": if error return, perform "CURTAINS"; proceed
otherwise, proceed

Perform "IMUFINE"

Perform "IMUSTALL": if error return, perform "CURTAINS"; proceed
otherwise, proceed

1
Proceed to second line of "P51A"

P51B

STARIND = 0

ldPIPADT = TIME1

GCOMP = 0

Set bit 15(DRIFTFLG) of FLAGWRD2 = 1

Set bit 9(LMKTRG) of FLAGWRD1 = 0

MARKINDX = 1

If MODREG = 53:

 Perform "R56"

If MODREG \neq 53:

 Perform "R53"

Perform "SXTSM"

If STARIND = 0:

 STARSAV1 = TS

 TS = T_{sight}

 Perform "PLANET"

 PLANVEC = TS

 Perform "MKRELEAS"

 STARIND = 1

 Proceed to fourth line of "P51B"

STARSAV2 = TS

Perform "MKRELEAS"

TS = T_{sight}

Perform "PLANET"

STARBC = TS

STARAC = PLANVEC

STARAD = STARSAV1

STARBD = STARSAV2

Perform "R54"

(If X2 > 0):

$$\underline{VMOON} = - \text{unit} \underline{R}_{\text{att}}$$

$$\underline{CMOON} = \cos \left(\sin^{-1} \left(K_{\text{rsubm}} / |\underline{R}_{\text{att}}| \right) + K_{5\text{degs}} \right)$$

$$\underline{CEARTH} = K_{\text{css5}}$$

$$\underline{VELdC} = K_{\text{ldc}} \underline{V}_{\text{att}} + \underline{VSUN} * K_{\text{eclip}}$$

$$\underline{CSUN} = K_{\text{cssun}}$$

Return

S52.2

Perform "CDUTRIG"

Perform "CALCSMSC"

$$\underline{X}_{\text{dc}} = \text{unit} \left(\underline{X}_{\text{dc}} \left[\text{REFSMMAT} \right] \right)$$

$$\underline{Y}_{\text{dc}} = \text{unit} \left(\underline{Y}_{\text{dc}} \left[\text{REFSMMAT} \right] \right)$$

$$\underline{Z}_{\text{dc}} = \text{unit} \left(\underline{Z}_{\text{dc}} \left[\text{REFSMMAT} \right] \right)$$

$$\left[\underline{X}_{\text{sm}} \right] = \left[\underline{X}_{\text{smd}} \right]$$

Perform "CALCGA"

Return

PLANET

$$\underline{T}_{\text{sight}} = \underline{TS}$$

Perform "S50"

Set $\underline{VSUN} = \underline{VEARTH}$ and $\underline{VEARTH} = \underline{VSUN}$ (for indexing below)

$\underline{TS} = 6$ (bits 6-1 of STARCODE)

If STARIND = 0:

$$\underline{BESTI} = \underline{TS}$$

If STARIND = 1:

$$\underline{BESTJ} = \underline{TS}$$

If TS = 0: (means planet)

TS = 0688_{vn}

Proceed to "GOFLASH": if terminate, proceed to "GOTOPOOH"
if proceed, proceed.
otherwise, proceed to previous line

TS = unit(unit(K_{ldsqr3} STARS_{AV3}) + VELdC)

Return

If TS - 228 < 0: (original STARCODE was in range 01-45_g,
meaning a star in star table)

TS = unit(K_{cat_{TS}} + VELdC)

Return

If TS = 228: (original STARCODE was 46_g, meaning sun)

TS = unit(VEARTH + VELdC) (VEARTH has sun location)

Return

If TS = 234: (original STARCODE was 47_g, meaning earth)

TS = unit (VSUN + VELdC) (VSUN has earth location)

Return

If TS = 240: (original STARCODE was 50_g, meaning moon)

TS = unit (VMOON + VELdC)

Return

If TS > 240, meaning STARCODE in range 51_g - 77_g (for low six bits),
improper results. N70/N71 loads check for legal range, however.

SXTSM

X1 = - MARKSTAT

T_{sight} = E_{-X1_{dp}}

If STARIND = 0:

MARKDOWN+i = E_{i-X1} (i = 0 - 6)

If STARIND = 1:

MARK2DWN+i = E_{i-X1} (i = 0 - 6)

STARAD = unit([REFSMMA] TS)

STARAC = STARSAV2

STARBC = STARSAV1

STARBD = PLANVEC

Perform "R54"

If bit 3(FREEFLAG) of FLAGWRDO = 1:

Perform "AXISGEN"

Perform "R55"

Set bit 4(PFRATFLG) of FLAGWRD2 = 0

Proceed to "R51K"

R51K

TS = 00014_g

Proceed to "GOPERF1": if terminate, proceed to "GOTOPOOH"
if proceed, proceed
otherwise, proceed to "GOTOPOOH"

Proceed to "P52C"

R54 (Tag also "CHKSDATA"; entered from "P51B" and "R51DSP")

Set bit 3(FREEFLAG) of FLAGWRDO = 1

$TS_1 = \cos^{-1}(\text{STARAD} \cdot \text{STARBD})$

Set bit 3(FREEFLAG) of FLAGWRDO = 0

$TS_2 = \cos^{-1}(\text{STARAC} \cdot \text{STARBC})$

DSPTM1 = $|\text{TS}_2 - \text{TS}_1|$, with sign agreement forced

Set bit 3(FREEFLAG) of FLAGWRDO = 1

TS = 0

Perform "CLEANDSP"

TS = 0605_{vn}

Proceed to "GOFLASH": if terminate, proceed to "GOTOPOOH"
if proceed, skip next line
otherwise, proceed

Set bit 3(FREEFLAG) of FLAGWRDO = 0 (e.g. a V32E response)

Return

R55

Entered from "R51DSP"

Perform "CALCGTA"

TS = 0693_{vn}

Proceed to "GOFLASH": if terminate, proceed to "GOTOPOOH"
if proceed, proceed
otherwise, Return

TS = "OGC" Note that if torquing time excessive, could get 1203₈
alarm due to "SVCT3" logic, since DRIFTFLG

Perform "IMUPULSE" not reset, contrary to "GYCRS"

Perform "IMUSTALL": if error return, perform "CURTAINS"; proceed
otherwise, proceed

Return

PICAPAR

Perform "CDUTRIG"

Perform "CALCSMSC"

Set bit 10(VFLAG) of FLAGWRD3 = 1 (means no star found)

BESTI = 0

BESTJ = 0

SAX = unit $\left((K_{\sin 33} \frac{X_{dc}}{Z_{dc}} + K_{\cos 33} \frac{Z_{dc}}{Z_{dc}}) [\text{REFSMAT}] \right)$

X1 = 228

Proceed to "PIC1"

PIC1

If X1 \leq 6, Return

X1 = X1 - 6

TS = $\frac{K_{cat}}{X1}$

Perform "OCCULT"

If bit 7(CULTFLAG) of FLAGWRD3 = 1, proceed to "PIC1"

X2 = X1

Proceed to "PIC3"

K_{rsube} : Constant, program notation "RSUBE", scale factor B29, units meters. Value is 6378166×2^{-29} , the Fischer equatorial radius.

K_{rsubm} : Constant, program notation "RSUBM", scale factor B29, units meters. Value is 1738090×2^{-29} , the mean lunar radius.

K_{sin33} : Constant, program notation "SIN33", scale factor B0, value 0.5376381241. Value is the sine of the angle discussed for K_{cos33} .

K_{tsgt1} : Constant, program notation "TSIGHT1", scale factor B28, units centi-seconds. Value is 24000×2^{-28} , corresponding to 240 seconds.

LANDALT, LANDLONG: See Orbital and Rendezvous Navigation.

LONG: See Coordinate Transformations.

MARK2DWN+i (i = 0-6): Set of optics mark information (double precision time, CDU_v, optics shaft, CDU_z, optics trunnion, and CDU_x respectively) loaded for downlink purposes from alignment mark for the body identified by BESTJ (loaded in "SXTSM").

MARKDOWN+i (i = 0-6): See Measurement Incorporation.

MARKINDX: See Optics Computations.

MARKSTAT: See Optics Computations.

OGC: See Coordinate Transformations.

OPTION2: See Display Interface Routines.

PLANVEC: Temporary storage for the output of the "PLANET" routine for the first body that is marked, scale factor B1. In P51/P53 it is in reference coordinates, while in P52/P54 it is converted to IMU coordinates before being stored.

RLS: See Coordinate Transformations.

SAX: Unit vector, scale factor B1, giving the direction of the optics shaft axis: stars are considered visible (for selection purposes) if they lie within 38° of this axis. The quantity is expressed in the reference coordinate system.

STARAC, STARAD, STARBC, STARBD: See Coordinate Transformations.

STARCODE: Single precision cell, scale factor B14, displayed in R1 by N70/N71, and used to contain the serial number of the celestial body being sighted (0 for "planet", N88 input; 01-45_g for star in K_{cat} ; 46_g for sun; 47_g for earth; and 50_g for moon). Six times this number (for double precision vector indexing reasons) is stored in BESTI or BESTJ. N70/N71 loads check for legal range (00_g - 50_g).

STARIND: Single precision cell, scale factor B14, used to cause two stars to be processed (or other bodies). If it is 1, BESTJ is used; if 0, BESTI. Initialized to 0 in "P51B" (P51/P53) for first body and incremented to 1 for second; initialized to 1 in "R51" (P52/P54) for first body and decremented to 0 for second.

STARSAV1: Temporary storage for sighting information (unit vector in IMU coordinates), scale factor B1. Loaded in "P51B" with sighting vector to first body; in "R51", loaded briefly with reference-coordinate information (from "PLANET") for first body, and then loaded with sighting vector to first body. The reference-coordinate information is used in R52 for optics pointing purposes.

STARSAV2: Temporary storage for sighting information (unit vector in IMU coordinates), scale factor B1. See STARSAV1 (STARSAV2 information is for second body instead of first, of course).

STARSAV3: Cells used by N88 for retention of "planet" information. N88 treats decimal input as double precision fraction, and since a unit vector is formed before quantity used (with components previously multiplied by K_{ldsg3}), the DSKY input can be with arbitrary (but consistent) scaling.

T_{sight}: Value of sighting time, scale factor B28, units centi-seconds. It is loaded in "SXTSM" with the time at which the optics mark was made (for use in "PLANET" for computing earth, moon, or sun positions at that time in "S50" if required). It is also used in "P52B" to retain the input time for computation of the landing-site orientation, and in "P52C" to contain present time incremented by K_{tsgt1} for "S50" use in determining "OCCULT" body positions.

VEARTH: Quantity computed in "S50" as the earth position (scale factor B1, a unit vector, when exit from routine) at time T_{sight}. It has storage address the same as "STARAD" (hence at start of "PLANET", VSUN and VEARTH are traded as far as storage locations are concerned, for convenience in subsequent indexing).

VELdC: Vector, scale factor B1, giving "aberration correction vector" (see K_{eclip}), defined as "velocity of vehicle with respect to sun divided by velocity of light." It is computed in "S50" and used in "PLANET".

VMOON: Quantity computed in "S50" as the moon position (scale factor B1, a unit vector, when exit from routine) at time T_{sight}. It has storage address the same as "STARAD" + 12.

VSUN: Quantity computed in "S50" as the sun position (scale factor B1, a unit vector, when exit from routine) at time T_{sight}. It has storage address the same as "STARAD" + 6 (see VEARTH).

X_{smd} , Y_{smd} , Z_{smd} : Unit vectors, scale factor B1, giving desired stable member orientation. Loaded by "P52B" or "S40.2,3(B)", or can be loaded by P27 (X_{smd} address is 0306, the same as "UPBUFF" + 2).

Values of K_{cat} (Star Table)

<u>Display</u>	<u>Index</u>	<u>X Component</u>	<u>Y Component</u>	<u>Z Component</u>	<u>Identification</u>
01	6	0.8748658918	0.0260879174	0.4836621670	α Andromedae
02	12	0.9342640400	0.1735073142	-0.3115219339	β Ceti
03	18	0.4775639450	0.1166004340	0.8708254803	γ Cassiopeiae
04	24	0.4917678276	0.2204887125	-0.8423473935	α Eridani
05	30	0.0130968840	0.0078062795	0.9998837600	α Ursae Minoris
06	36	0.5450107404	0.5314955466	-0.6484410356	θ Eridani
07	42	0.7032235469	0.7075846047	0.0692868685	α Ceti
10	48	0.4105636020	0.4988110001	0.7632988371	α Persei
11	54	0.3507315038	0.8926333307	0.2831839492	α Tauri
12	60	0.2011399589	0.9690337941	-0.1432348512	β Orionis
13	66	0.1371725575	0.6813721061	0.7189685267	α Aurigae
14	72	-0.0614937230	0.6031563286	-0.7952489957	α Carinae
15	78	-0.1820751783	0.9404899869	-0.2869271926	α Canis Majoris
16	84	-0.4118589524	0.9065485360	0.0924226975	α Canis Minoris
17	90	-0.3612508532	0.5747270840	-0.7342932655	γ Velorum
20	96	-0.4657947941	0.4774785033	0.7450164351	ι Ursae Majoris
21	102	-0.7742591356	0.6152504197	-0.1482892839	α Hydrae
22	108	-0.8608205219	0.4636213989	0.2098647835	α Leonis
23	114	-0.9656605484	0.0525933156	0.2544280809	β Leonis
24	120	-0.9525211695	-0.0593434796	-0.2986331746	γ Corvi
25	126	-0.4523440203	-0.0493710140	-0.8904759346	α Crucis
26	132	-0.9170097662	-0.3502146628	-0.1908999176	α Virginis
27	138	-0.5812035376	-0.2909171294	0.7599800468	η Ursae Majoris
30	144	-0.6898393233	-0.4182330640	-0.5909338474	θ Centauri
31	150	-0.7861763936	-0.5217996305	0.3311371675	α Bootis
32	156	-0.5326876930	-0.7160644554	0.4511047742	α Coronae Borealis
33	162	-0.3516499609	-0.8240752703	-0.4441196390	α Scorpii
34	168	-0.1146237858	-0.3399692557	-0.9334250333	α Trianguli Australi
35	174	-0.1124304773	-0.9694934200	0.2178116072	α Ophiuchi
36	180	0.1217293692	-0.7702732847	0.6259880410	α Lyrae
37	186	0.2069525789	-0.8719885748	-0.4436288486	σ Sagittarii
40	192	0.4537196908	-0.8779508801	0.1527766153	α Aquilae
41	198	0.5520184464	-0.7933187400	-0.2567508745	β Capricorni
42	204	0.3201817378	-0.4436021946	-0.8370786986	α Pavonis
43	210	0.4541086270	-0.5392368197	0.7092312789	α Cygni
44	216	0.8139832631	-0.5557243189	0.1691204557	ϵ Pegasi
45	222	0.8342971408	-0.2392481515	-0.4966976975	α Piscis Austrini

The "Display" column gives the star number that is displayed by the program (as an octal quantity). The "Index" column gives the value of BESTI (or BESTJ) for the corresponding star, and is equal to six times the star serial number (i.e. six times the decimal equivalent of the first column).

Stars in Star Table

<u>Display</u>	<u>Name</u>	<u>Catlg.</u>	<u>Magnitude</u>	<u>Right Ascension</u>	<u>Declination</u>
01	Alpheratz	α And	2.1	0 06 49.9	+28 55 29
02	Diphda	β Cet	2.2	0 42 05.0	-18 09 04
03	Navi	γ Cas	Var.	0 54 53.0	+60 33 17
04	Achernar	α Eri	0.6	1 36 35.9	-57 23 20
05	Polaris	α UMi	2.1	2 03 18.9	+89 07 34
06	Acamar	θ Eri	3.4	2 57 07.4	-40 25 27
07	Menkar	α Cet	2.8	3 00 42.5	+ 3 58 23
10	Mirfak	α Per	1.9	3 22 10.3	+49 45 21
11	Aldebaran	α Tau	1.1	4 34 11.8	+16 27 01
12	Rigel	β Ori	0.3	5 13 05.7	- 8 14 06
13	Capella	α Aur	0.2	5 14 28.2	+45 58 10
14	Canopus	α Car	-0.9	6 23 17.1	-52 40 44
15	Sirius	α CMa	-1.6	6 43 49.6	-16 40 25
16	Procyon	α CMi	0.5	7 37 43.9	+ 5 18 11
17	Regor	γ Vel	1.9	8 08 36.4	-47 14 51
20	Dnoces	ϵ UMa	3.1	8 57 09.7	+48 09 38
21	Alphard	α Hya	2.2	9 26 06.8	- 8 31 40
22	Regulus	α Leo	1.3	10 06 46.5	+12 06 52
23	Denebola	β Leo	2.2	11 47 31.8	+14 44 23
24	Gienah	γ Crv	2.8	12 14 15.6	-17 22 32
25	Acrux	α Cru	1.0	12 24 54.9	-62 55 59
26	Spica	α Vir	1.2	13 23 36.6	-11 00 19
27	Alkaid	η UMa	1.9	13 46 21.6	+49 27 45
30	Menkent	θ Cen	2.3	14 04 54.6	-36 13 23
31	Arcturus	α Boo	0.2	14 14 17.5	+19 20 16
32	Alphecca	α CrB	2.3	15 33 25.0	+26 48 53
33	Antares	α Sco	1.2	16 27 33.9	-26 22 01
34	Atria	α TrA	1.9	16 45 28.3	-68 58 31
35	Rasalhague	α Oph	2.1	17 33 32.4	+12 34 50
36	Vega	α Lyr	0.1	18 35 55.3	+38 45 17
37	Nunki	σ Sgr	2.1	18 53 24.3	-26 20 08
40	Altair	α Aql	0.9	19 49 19.1	+ 8 47 16
41	Dabih	β Cap	3.2	20 19 19.6	-14 52 38
42	Peacock	α Pav	2.1	20 23 17.0	-56 49 58
43	Deneb	α Cyg	1.3	20 40 24.4	+45 10 21
44	Enif	ϵ Peg	2.5	21 42 42.7	+ 9 44 12
45	Fomalhaut	α PsA	1.3	22 55 59.7	-29 46 54

"Display" gives the star number that is displayed by the program (as an octal quantity). "Catlg" refers to the name on pp. 282-292 of "The American Ephemeris and Nautical Almanac for the Year 1970," where the magnitude and coordinate information were obtained.

Right ascension is given in hours, minutes, and seconds; Declination is given in degrees, minutes, and seconds. Both are for January 0.767, 1970, the beginning of the Besselian year.

(If overflow has taken place since indicator reset):

Perform "RECTIFY"

Proceed to "FAZAB3"

$T_{DELTA\underline{V}} = T_{\underline{S}}$

$T_{\underline{S}} = T_{NU\underline{V}} + (\text{DELTA}\underline{X}_1 \text{ shifted left } 4 + X2 \text{ places})$

If overflow has taken place:

$V_{\underline{C}\underline{V}} = V_{\underline{C}\underline{V}} + \text{DELTA}\underline{X}_1$

$P_{\underline{B}\underline{O}\underline{D}\underline{Y}} = X2$

Perform "RECTIFY"

Proceed to "FAZAB3"

$T_{NU\underline{V}} = T_{\underline{S}}$

Proceed to "FAZAB3"

FAZAB3

If bit 8(CSMUPDAT) of FLAGWRD1 = 1:

Perform "MOVEACSM"

If bit 1(AVEMIDSW) of FLAGWRD9 = 0:

$R = R_{\underline{C}\underline{V}} + T_{DELTA\underline{V}}$ (X2 used to determine

$V = V_{\underline{C}\underline{V}} + T_{NU\underline{V}}$ necessary shifts)

$T_{pptm} = T_{et}$

If bit 8(CSMUPDAT) of FLAGWRD1 = 0:

Perform "MOVEALEM"

$R_{\text{other}} = R_{\underline{C}\underline{V}} + T_{DELTA\underline{V}}$ (X2 used to determine

$V_{\text{other}} = V_{\underline{C}\underline{V}} + T_{NU\underline{V}}$ necessary shifts)

If bit 9(DMENFLG) of FLAGWRD5 = 1: (9-dimensional incorporation)

$X78\underline{9} = TX78\underline{9}$

$Q_{PRET} = EGRESS$

Proceed to "INTWAKE" (returns to address in QPRET)

V67CALL Established by "V67" for a verb 67.

Reset overflow indicator

Perform "INTSTALL"

WWOPT = 0

$$WWPOS = \sqrt{|W_0|^2 + |W_3|^2 + |W_6|^2 + |W_9|^2 + |W_{12}|^2 + |W_{15}|^2}$$

(i.e. W_{3i} ,
 $i = 0-5$)

$$WWVEL = \sqrt{|W_{27}|^2 + |W_{30}|^2 + |W_{33}|^2 + |W_{36}|^2 + |W_{39}|^2 + |W_{42}|^2}$$

(i.e. W_{3i} ,
 $i = 9-14$)

If overflow has taken place since indicator reset:

WWPOS = +MAX (2¹⁹ - 2⁻⁹ meters)

WWVEL = +MAX (N99 R2 display 328.1 fps)

If WWPOS - K_{ft999} ≥ 0:

WWPOS = K_{ft999} (constant gives display of 99997 feet)

Perform "INTWAKE" (returns to next line)

TS = 0699_{vn}

Proceed to "GOXDSPF": if terminate, proceed to "ENDEXT"
if proceed, proceed
otherwise, proceed to previous line

If WWOPT = 0: (no change in W-matrix initialization cells
desired)

Proceed to "ENDEXT"

TS₁ = WWPOS_{sp}

TS₂ = WWVEL_{sp}

If WWOPT = 2:

WORBPOS = TS₁

WORBVEL = TS₂

(If bit 2(VHF Data Good complement) of channel 33 = 0):

Awaken job put to sleep in "RADSTALL" and cause it to start at (RADCADR +1), indicating a success

RADCADR = +0

Resume (exit via End of task logic)

VHFRANGE = 2 (bit 2 of channel 33 = 1, flag "LIGHTON" to set DSPTAB+11)

Skip next line

VHFRANGE = 0 (UPDATFLG = 0 or PDSPFLAG = 1)

If RADCADR = +0: (error exit)

RADCADR = -0

Resume (exit via End of task logic)

Awaken job put to sleep in "RADSTALL" and cause it to start at (RADCADR), indicating an error

RADCADR = +0

Resume (exit via End of task logic)

RADSTALL

If RADCADR > 0, proceed to "POODOO" (pattern 1210_g)

If RADCADR = +0, set RADCADR = (Calling address +1, in FCADR format) and put present job to sleep

If RADCADR = -0:

RADCADR = +0

Return (to calling address +1, indicating an error)

If RADCADR = -1:

RADCADR = +0

Return (to calling address +2, indicating a success)

If RADCADR < -1, proceed to "POODOO" (pattern 1210_g)

SETINTG

Perform "INTSTALL"

Set bit 5(STATEFLG) of FLAGWRD3 = 1

T_{decl} = MARKTIME_{dp}

Set bits 4(CONICINT), 2(9DIMWMAT), and 1(WMATINT) of FLAGWRD3 = 0

Set bit 3(CSMINTSW) of FLAGWRD3 = 1

Return

P23

Set bit 7(RNDVZFLG) of FLAGWRD0 = 0

MARKINDX = 1

Set bits 10(LMTRG) and 9(LMKTRG) of FLAGWRD1 = 0

STARIND = 0

BESTI = 0

Set bit 8(R57FLAG) of FLAGWRD6 = 0

Set bit 11(V94FLAG) of FLAGWRD9 = 0

Proceed to "P23.00"

P23.00

If bit 13(REFSMFLG) of FLAGWRD3 = 0:

 Perform "R57"

 Perform "R53"

 Proceed to "P23.60"

Set bit 10(SAVECFLG) of FLAGWRD9 = 0 (controls exit from "P23.15")

Proceed to second line of "R23.10"

R23.10

Set bit 7(Operator error) of channel 11 = 1

TS = 0570_{vn} (tag here is "P23.06")

Proceed to "GOFLASH": if terminate, proceed to "GOTOPOOH"
 if proceed, proceed
 otherwise, proceed to previous line

Proceed to "P23.15"

P23.15

If LANDMARK \neq 0:

If HORIZON \neq 0, proceed to "R23.10"

TS = LANDMARK

If LANDMARK = 0:

If HORIZON = 0, proceed to "R23.10"

TS = HORIZON

If bits 9-7 (digit "C") of TS \neq 1 or \neq 2:

Proceed to "R23.10"

If bit 7 of TS = 1: (digit C = 1)

Set bit 12(LUNLATLO) of FLAGWRD3 = 0

If bit 8 of TS = 1: (digit C = 2)

Set bit 12(LUNLATLO) of FLAGWRD3 = 1

If STARCODE \neq 0:

If STARCODE \leq 0, proceed to "R23.10" (only effective if $<$ 0)

If STARCODE $>$ 45_g, proceed to "R23.10"

If STARCODE \neq 0: (redundant check)

BESTI = 6 STARCODE

STARSAV₂ = $\frac{K}{\text{cat}}$ _{BESTI}

If HORIZON = 0: (tag here "P23.176")

Perform "P22SUBRB"

If HORIZON \neq 0:

If bits 6-4 (digit "D") of HORIZON \neq 1 or \neq 2:

Proceed to "R23.10"

If bit 4 of HORIZON = 1: (digit D = 1)

Set bit 11(FARHOR) of FLAGWRD0 = 0

(If HORIZON \neq 0):

If bit 5 of HORIZON = 1: (digit D = 2)

Set bit 11(FARHOR) of FLAGWRDO = 1

If STARCODE = 0: (tag here "P23.30")

TS = 0688_{vn}

Proceed to "GOFLASH": if terminate, proceed to "GOTOPOOH"
if proceed, proceed
otherwise, proceed to previous line

STARSAV₂ = unit(K_{ldsqr3} STARSAV₃)

If bit 10(SAVECFLG) of FLAGWRD₉ = 1: ("P23.15" entered from
"P23.60" to process N71)

Proceed to "P23.85"

TS = 0202_g

Proceed to "GOPERF1": if terminate, proceed to "GOTOPOOH"
if proceed, proceed to "V94ENTER"
otherwise, proceed

Perform "R57"

Proceed to "P23.57"

V94ENTER Entered from "P23.15" for PRO response to 0202_g, and
due to restart group 2.11, set by "VERB94".

MARKTIME = T_{now}

Perform "POINTAXS"

POINTVSM = unit([REFSMMAT] RCLL)

SCAXIS = K_{jcaxis}

Set bit 6(3AXISFLG) of FLAGWRD₅ = 0

CADRFLSH+2 = "R6OCALL" + 3

Set restart group 2 to phase 1 (i.e. 2.1, causing "R6OCALL" to
be entered via "INITDSP" logic if a restart)

Proceed to "R6OCALL"

$\text{DELTA V}_{\text{cm}}$, $\text{DELTA V}_{\text{lm}}$: See Orbital Integration. Component overflows if exceeds 2^{22} meters (earth) or 2^{18} meters (moon).

DELTA X_0 , DELTA X_1 , DELTA X_2 : State vector deviation estimates, scale factor (for DELTA X_0 and DELTA X_2) B29(earth) or B27(moon), units meters; for DELTA X_1 , scale factor B7(earth) or B5(moon), units meters/centi-second. They are for position of vehicle, velocity of vehicle, and position of landmark respectively ($i = 0,1,2$).

EGRESS: Single precision cell used for storage of return address information from "INCORP2" routine.

EMATRIX_i: Temporary storage cells used to store intermediate results from the conversion of W matrix from 6x9 to 6x6. The cells used in the memory for this function correspond to $W_{60} - W_{80}$, but separate notation is used (as in the program) for clarity.

ERADM: See Coordinate Transformations.

FLAGWRD4: See Display Interface Routines.

GAMMA: Quantity computed in "INCORP1", variable scale factor (scale factor information partially contained in cell NORMGAM). If NORMGAM = 0, scale factor of GAMMA equivalent to B-40. NORMGAM subsequently modified to reflect rescaling of Z_i (for use in "INCORP2").

HORIZON: Single precision quantity loaded and displayed in R3 of N70 and N71, used only in P23 (see "P23.15"). If LANDMARK non-zero, then HORIZON must be zero; if LANDMARK = 0, then HORIZON checked to be of form XXCDX, where C = 1 means earth and C = 2 means lunar (other values not allowed); D = 1 means near horizon and D = 2 means far horizon (other values not allowed). If an illegal input is detected (the X's may be of any value, provided LANDMARK = 0), then a N70 display is generated, with operator error light energized, to request proper loading. Since bit 10(SAVECFLG) of FLAGWRD9 retains previous value, however, an improper N71 loading (after mark) would not require that the mark be retaken.

K_{ldsqr3} : See Inflight Alignment.

$K_{2\pi}$: Constant, program notation "PI/4.0", scale factor B3, value 0.785398164. Value corresponds to $2 \times 3.141592656 \times 2^{-3}$, or approximately $2\pi \times 2^{-3}$, to convert between angle measurements in units of revolutions and radians.

$K_{60\text{secdp}}$: Constant, program notation "60SECDP", scale factor B28, units centi-seconds. Value is 6000×2^{-28} , corresponding to 60 seconds: if $T_{\text{now}} - \text{VHFTIME}$ is at least this amount, then an attempt can be made to obtain a new VHF mark in "REND3".

K_{earth} : Constant, program notation "AEARTH", scale factor B29, units meters. Value is 6378166×2^{-29} , the Fischer model equatorial radius.

K_{cat} : See Inflight Alignment.

K_{convrnge} : Constant, program notation "CONVRNGE", scale factor B13, units meters/bit. Value is 18.52×2^{-13} , corresponding to a VHF ranging system bit weight of 18.52 meters (or 0.0100 nmi).

K_{ft999} : Constant, program notation "FT99999", scale factor B19, units meters. Value is 30479×2^{-19} , corresponding to 99,996.72 x 0.3048 x 2^{-19} , where first term is value in feet (display would be expected to show 99997 feet), second converts to meters, and third is scale factor.

K_{imuvar} : Constant, program notation "IMUVAR", scale factor B-16, units radians². Value is $0.04E-6 \times 2^{-16}$, corresponding to 0.04 mr^2 .

K_{jaxis} : Vector constant, program notation "JCAXIS", scale factor B1, value (0.268819062, 0, 0.421587846). True values correspond to (0.537638124, 0, 0.843175692), or $(\sin \theta, 0, \cos \theta)$, where the angle is approximately the same as that defined in [NB1NB2] (see Coordinate Transformations): the octal matrix element for the sine is one least increment larger than that in K_{jaxis} .

K_{onedc} : Constant, program notation "ONE/C", scale factor B-21, units of (meters/centi-second)⁻¹. Value is $0.333564049E-6 \times 2^{21}$, corresponding to $(1/2.997925E6) \times 2^{21}$, where first term is reciprocal of speed of light in meters/centi-second (corresponds to 9.835712E8 fps) and second is scale factor.

K_{radmoon} : Constant, program notation "RADMOON", scale factor B29, units meters. Value is 1738090×2^{-29} , the mean lunar radius.

K_{rangebl4} : Constant, program notation "RANGEBL4", scale factor B27, stored value 303431.5×2^{-27} (nominal value 303431.7×2^{-27}) Value corresponds to $2^{14} K_{\text{convrnge}}$ (i.e. the bit weight for bit 15 of RNRAD = 303431.68 meters), and is in units of meters.

K_{sxtvar} : Constant, program notation "SXTVAR", scale factor B-16, units radians². Value is $0.04E-6 \times 2^{-16}$, corresponding to 0.04 mr^2 .

K_{trunl9} : Constant, program notation "TRUNL9", scale factor B0, units revolutions. Octal value is $01604_8 00000_8$, used to correct TRUNION for the built-in bias. Decimal value is 900×2^{-14} , or $(7200 \times 2^{-3}) \times 2^{-14}$, where the 7200 is the complement of the optics trunnion "zero" value (see $K_{20\text{degs}}$ in Optics Computations), and the 2^{-3} is scale factor compensation (from B-3 to B0 revolutions).

PBODY: See Orbital Integration.

PDA: Value of intermediate quantity "A" in "HORIZ", scale factor B18, stored in push-down list location 16D. The ratio $(\sqrt{A-1})/A$ is stored in push-down list location 28D, scale factor B0.

PDAH: Value of semi-major axis used to define shape of horizon ellipse in "HORIZ", scale factor B29, units meters, stored in push-down list location 2D.

PDALPHA: Value of intermediate quantity computed in "HORIZ", scale factor B29, units meters, stored in push-down list location 24D.

PDAONE: Value of intermediate quantity "A₁" computed in "HORIZ", scale factor B2, stored in push-down list location 24D.

PDAZERO: Value of intermediate quantity "A₀" computed in "HORIZ", scale factor B2, stored in push-down list location 22D.

PDBETA: Value of intermediate quantity computed in "HORIZ", scale factor B29, units meters, stored in push-down list location 26D.

PDBH: Value of semi-minor axis used to define shape of horizon ellipse in "HORIZ", scale factor B29, units meters, stored in push-down list location 0D.

PDRH: Value of RZC transformed to Horizon Coordinate System, scale factor B29, units meters, stored in push-down list location 4D.

PDUSH: Value of STARS₂ transformed to Horizon Coordinate System, scale factor B1, stored in push-down list location 10D.

PDVCT₀: Vector defining "point of tangency from PDRH to horizon", scale factor B29, units meters, stored in push-down list location 28D.

PDVCT₁: Vector defining the other point of tangency to horizon, scale factor B29, units meters, stored in push-down list location 16D.

POINTEX: Single precision cell used to retain return address information from "WAITONE".

POINTVSM: See Attitude Maneuvers.

QPRET: See Orbital Integration.

QREG: Computer Q register (cell 0002_g), loaded with S-register information for computer TC orders, and also used in some cases for temporary storage of other information. As used in "RENDISP2", apparently expected to contain a positive non-zero number (as would be true for a TC order use). The actual sampling of QREG takes place in the program service routine "BANKJUMP", which is entered at the end of "ENDRET" to return to the "PRIODSP" caller.

R_{other}: See Orbital Integration.

R61CNTR: See Orbital and Rendezvous Navigation.

RADCADR: Cell containing control information used in association with "RADSTALL" (which is entered only from "RANGERD"). Significance of cell same as IMUCADR (see IMU Computations), except that the "failure" exit occurs if bit 7(UPDATFLG) of FLAGWRD1 = 0, if bit 12(PDSPFLAG) of FLAGWRD4 = 1, or if bit 2 (VHF Data Good complement) of channel 33 = 1 (only the data good information lights the Tracker light).

RCLL: Value of (RL - RZC) computed in "POINTAXS", scale factor B29, units meters. Not stored in separate memory cell.

RCLP: Value of (LEMPOS - CSMPOS) for R22, scale factor B29 (earth) or B27(moon), units meters.

RCV, RCV_{cm}, RCV_{lm}: See Orbital Integration.

RM: Single precision value of measured range sampled from RNRAD cell, scale factor B14, units counts (one VHF count is 0.01 nmi). The cell is the same as MARKDOWN+7 (for telemetry purposes).

RNRAD: Single precision special erasable memory cell 0046_g, into which VHF range data is shifted under hardware control if bits 4-1 of channel 13 are set to 1001₂. When the shifting is complete, program interrupt #9 is generated, causing entrance to "VHFREAD".

RZC: Value of position vector to the body with which the horizon or landmark measurement in P23 is made, scale factor B29, units meters.

SCAXIS: See Attitude Maneuvers.

STARCODE: See Inflight Alignment.

STARIND: See Inflight Alignment.

STARSAV2: See Inflight Alignment: in P23 is used for K_{cat} value for star specified (and for R52 use), where also has the notation "US". If STARCODE = 0, loaded with N88 information.

STARSAV3: See Inflight Alignment.

T_{et}: See Orbital Integration.

TDELTAV: See Orbital Integration.

- $K_{sfin_{10}}$: Constant, value 07475₈ 16051₈, scale factor B0. Value corresponds to $10^4 \times 10^{-2} \times 0.3048 \times 2^{-7}$, in order to convert between XXXX.X fps and meters/centi-second with scale factor B7.
- $K_{sfin_{11}}$: Constant, value 00001₈ 03434₈, scale factor B14. Value corresponds to $10^2 \times (1/90) \times 2^{-14}$, to convert from XX.XXX° to B-2 revolutions (after performing a left shift of 14 via Routine #3, "ARTHINSF").
- $K_{sfin_{12}}$: Constant, value 00002₈ 22245₈, scale factor B14. Value corresponds to $10^3 \times (3600/85.41) \times 2^{-14} \times 2^{-14}$ minus one least increment, to convert between XXX.XX° and B14 "CDU actuator pulses" (after performing a left shift of 14 via Routine #3, "ARTHINSF"). There are 85.41 arc seconds per CDU actuator pulse.
- $K_{sfin_{13}}$: Constant, value 00014₈ 35607₈, scale factor B14. Value corresponds to $10^7 \times 1.355817948 \times 2^{-20} \times 2^{-14}$, to convert between XXXXXbb. slug-feet² and B20 kilogram-meters² (after performing a left shift of 14 via Routine #3, "ARTHINSF"). The "bb" means that the input is in units of 100 slug-feet². Same constant could also be used to convert between XXXXXbb. foot-pounds and B20 newton-meters. Constant is not used (since functions are computed in "FIXCW" as determined from inputs of vehicle mass).
- $K_{sfin_{14}}$: Constant, value 07606₈ 06300₈, scale factor B3. Value corresponds to one least increment more than $10^5 \times (1/25766.1973) \times 2^{-1} \times 2^{-3}$, to convert between XXXXX. fps and B1 VSAT units (used in entry, where 1 VSAT = 25766.1973 fps), after performing a left shift of 3 via Routine #10, "DPINSF4".
- $K_{sfin_{15}}$: Constant, value 16631₈ 11307₈, scale factor B0. Value corresponds to $10^4 \times (1/21622.4965)$, to convert between XXXX.X nmi and B0 revolutions. The denominator conversion value corresponds to $2\pi \times 6373338 / 1852$, i.e. an earth radius equal to the value of K_{rpad} (see Burn Control) used to derive circumference.
- $K_{sfin_{16}}$: Constant, value 12000₈ 00000₈, scale factor B7. Value corresponds to $10^3 \times (1/25) \times 2^{-7}$, to convert between XXX.XX g's and B0 "G-units" (25 g's, as used in Entry Computations), after performing a left shift of 7 via Routine #5, "DPINSF2".
- $K_{sfin_{17}}$: Constant, value 27176₈ 14235₈, scale factor B0. Value corresponds to $10^4 \times (1/3441.3272) \times 2^{-2}$, to convert between XXXX.X nmi and radians scaled B2 (using the pad radius given for $K_{sfin_{15}}$).

K_{sfin}_{18} : Constant, value 30480×2^{-19} , scale factor B0. Value corresponds to $10^5 \times 0.3048 \times 2^{-19}$, to convert between XXXXX. feet and meters scaled B19 (there are 0.3048 meters in one foot).

K_{sfin}_{19} : Constant, value 30.48×2^{-7} , scale factor B7. Value corresponds to $10^4 \times 0.3048 \times 10^{-2} \times 2^0 \times 2^{-7}$, to convert between XXXX.X fps and B0 meters/centi-second (first term is for XXXX.X fps, second converts to meters, third converts to centi-seconds, fourth is for scaling of final answer, and fifth is scale factor of constant), after a left shift of 7 via Routine #5, "DPINSF2".

K_{sfot}_0 : First of a set of output constants selected in "GTSFOUT", located in consecutive cells starting at "SFOUTAB". Value is $05174_8 13261_8$, scale factor B0, with value corresponding to $10^{-5} \times 2^{14}$, to convert from an integer with scale factor B14 to XXXXX.

K_{sfot}_1 : Constant, value 0, not assigned.

K_{sfot}_2 : Constant, value 0, used to load SFTEMP1 with proper initial value for use in "DEGOUTSF" and "OPDEGOUT".

K_{sfot}_3 : Constant, value $00714_8 31463_8$, scale factor B7. Value corresponds to $(360) \times 10^{-2} \times 2^{-7}$, to convert from B0 revolutions to XX.XXX°. Since there are 2^{21} gyro pulses per revolution, the constant could also be considered to convert from gyro pulses scaled B21.

K_{sfot}_4 : Constant, value $13412_8 07534_8$, scale factor B0. Value corresponds to $(360) \times 10^{-3}$, to convert from B0 revolutions to XXX.XX°.

K_{sfot}_5 : Constant, value $05605_8 03656_8$, scale factor B0. Value corresponds to $(180) \times 10^{-3}$, to convert from B-1 revolutions to XXX.XX°. Constant is not used.

K_{sfot}_6 : Constant, value $00001_8 16170_8$, scale factor B14. Value corresponds to $2^{16} \times (1/0.45359237) \times 10^{-5} \times 2^{-14}$, to convert between B16 kilograms and XXXXX. pounds.

K_{sfot}_7 : Constant, value $00441_8 34306_8$, scale factor B14. Value corresponds to $2^{29} \times (1/1852) \times 10^{-3} \times 2^{-14}$, to convert between B29 meters and XXX.XX nmi.

K_{sfot}_8 : Constant, value $07176_8 21603_8$, scale factor B7. Value corresponds to $(2^{29}) \times (1/1852) \times 10^{-4} \times 2^{-7}$, to convert between B29 meters and XXXX.X nmi (there are 1852 meters in a nautical mile). For N73, converts from units of meters/100 (computed by P21) to XXXXXb. nmi.

- K_{sfot_9} : Constant, value 15340_8 , 15340_8 , scale factor B0 (equality of 9 two halves of constant is correct). Value corresponds to $(100 \times 2^7 / 0.3048) \times 10^{-5}$, to convert from the navigation scaling of velocity (B7 meters/centi-second) to XXXX. fps.
- $K_{\text{sfot}_{10}}$: Constant, value 01031_8 , 21032_8 , scale factor B7. Value corresponds to $(100 \times 2^7 / 0.3048) \times 10^{-4} \times 2^{-7}$ plus one least increment, to convert from the navigation scaling of velocity (B7 meters/centi-second) to XXXX.X fps.
- $K_{\text{sfot}_{11}}$: Constant, value 34631_8 , 23146_8 , scale factor B0. Value corresponds to $(90) \times 10^{-2}$, to convert from B-2 revolutions to XX.XXX°.
- $K_{\text{sfot}_{12}}$: Constant, value 14340_8 , 24145_8 , scale factor B0. Value corresponds to $(85.41 / 3600) \times 2^{14} \times 10^{-3}$, to convert between B14 "CDU actuator pulses" and XXX.XX°. There are 85.41 arc seconds per CDU actuator pulse.
- $K_{\text{sfot}_{13}}$: Constant, value 02363_8 , 03721_8 , scale factor B0. Value corresponds to $2^{20} \times (1 / 1.355817948) \times 10^{-7}$, to convert between B20 kilogram-meters² and XXXXXbb. slug-feet² (the "bb" means that output is in units of 100 slug-feet²). Same constant could also be used to convert between B20 newton-meters and XXXXXbb. foot-pounds. Constant is not used (see $K_{\text{sfin}_{13}}$).
- $K_{\text{sfot}_{14}}$: Constant, value 20373_8 , 02122_8 , scale factor B0. Value corresponds to $2^1 \times 25766.1973 \times 10^{-5}$, to convert between B1 VSAT units and XXXXX. fps (one VSAT is 25766.1973 fps, used in entry).
- $K_{\text{sfot}_{15}}$: Constant, value 00424_8 , 30446_8 , scale factor B7. Value corresponds to $21622.4965 \times 10^{-4} \times 2^{-7}$, to convert between B0 revolutions and XXXX.X nmi (see $K_{\text{sfin}_{15}}$).
- $K_{\text{sfot}_{16}}$: Constant, value 00631_8 , 23146_8 , scale factor B0. Value corresponds to 25×10^3 , to convert between B0 "G-units" (25 g's, as used in entry computations) and XXX.XX g's.
- $K_{\text{sfot}_{17}}$: Constant, value 00260_8 , 06213_8 , scale factor B7. Value corresponds to $3441.3272 \times 2^{28} \times 10^{-4} \times 2^{-7}$, to convert between B2 radians and XXXX.X nmi (using pad radius, see $K_{\text{sfin}_{17}}$).
- $K_{\text{sfot}_{18}}$: Constant, value 17.2010499×2^{-7} , scale factor B7. Value corresponds to $2^{19} \times (1 / 0.3048) \times 10^{-5} \times 2^{-7}$, to convert between B19 meters and XXXXX. feet (with a left shift of 7 places due to scaling of constant).

K_{sfot} ₁₉: Constant, value 0.032808399, scale factor B0. Value corresponds to $2^0 \times 10^2 \times (1/0.3048) \times 10^{-4}$, to convert between B0 meters/centi-second and XXXX.X fps: first term is for original scaling, second converts to seconds, third converts to feet, and fourth is display scale.

K_{whecon} : Constant, program notation "WHOLECON", value 00006,03240g, scale factor B28. Value corresponds to $10^5 \times 2^{-28}$ (to "compensate" for the scaling done in "NUM").

MIXBR: Single precision cell, scale factor B14, set in "LODNNTAB" to 1 for a "normal" noun and to 2 for a "mixed" noun.

NNADTEM: Temporary storage cell, single precision, loaded in "LODNNTAB" with the value of K_{ntbI} corresponding to NOUNREG contents. See information below.

NNTYPTM: Temporary storage cell, single precision, loaded in "LODNNTAB" with the value of K_{ntyI} corresponding to NOUNREG contents. See information below.

NOUNADD, NOUNREG: See Data Input/Output.

OVFINP: See Data Input/Output.

RUTMXTEM: Temporary storage cell, single precision, loaded in "LODNNTAB" with value of K_{rtmtbI} for "mixed nouns" only. See information below.

SFTEMP1: Temporary storage cell used to contain the appropriate value of K_{sfinI} or K_{sfotI} , used for angle bias information (if any) in "DEGOUTSF" and "OPDEGOUT".

VERBSAVE: See Data Input/Output.

YREG, YREGLP: See Data Input/Output (YREGLP described for LPREG).

ZREG, ZREGLP: See Data Input/Output (ZREGLP described for LPREG).

<u>Noun</u>	<u>Cell</u>	<u>No</u>	<u>Dec.</u>	<u>Num-</u>	<u>Rou-</u>	<u>Con-</u>	<u>Decimal</u>	<u>Quantity</u>
		<u>Load</u>	<u>Only</u>	<u>ber</u>	<u>tine</u>	<u>stant</u>	<u>Display</u>	
67			x	3				
	RTGON67				7	15	XXXX.X nmi	Range to target.
	LAT				10	4	XXX.XX ^o	Latitude.
	LONG				10	4	XXX.XX ^o	Longitude.
68			x	3				
	ROLLC				10	4	XXX.XX ^o	Commanded roll angle.
	VMAGI				10	9	XXXXX. fps	Inertial velocity.
	RDOT				10	14	XXXXX. fps	Altitude rate.
69			x	3				
	ROLLC				10	4	XXX.XX ^o	Commanded roll angle.
	Q7				5	16	XXX.XX g	Drag at skip-out.
	VL				10	14	XXXXX. fps	Skip-out velocity.
70				3				
	STARCODE				0	0	Octal	Body code.
	LANDMARK				0	0	Octal	Landmark data.
	HORIZON				0	0	Octal	Horizon data.
71				3				
	STARCODE				0	0	Octal	Body code.
	LANDMARK				0	0	Octal	Landmark data.
	HORIZON				0	0	Octal	Horizon data.
72			x	3				
	THETZERO				10	4	XXX.XX ^o	Delta angle.
	DELHITE				7	8	XXXX.X nmi	Delta altitude.
	OPTION2				3	0	XXXXX.	Search option.

<u>Noun</u>	<u>Cell</u>	<u>No Load</u>	<u>Dec. Only</u>	<u>Num-ber</u>	<u>Rou-tine</u>	<u>Con-stant</u>	<u>Decimal Display</u>	<u>Quantity</u>
73				3				
	P21ALT				7	8	XXXXXb. nmi	Altitude(P21 output in m/100).
	P21VEL				10	9	XXXXX. fps	Velocity.
	P21GAM				10	4	XXX.XX°	Flight path angle.
74				3				
	ROLLC				10	4	XXX.XX°	Commanded roll angle.
	VMAGI				10	9	XXXXX. fps	Inertial velocity.
	D				5	16	XXX.XX g	Drag acceleration.
75		x	x	3				
	DIFFALT				7	8	XXXX.X nmi	CDH Delta Altitude.
	T1TOT2				9	0	mn, ,sc	Delta time (CDH-CSI or TPI-CDH).
	T2TOT3				9	0	mn, ,sc	Delta time (TPI-CDH or TPI-NOMTPI).
76	+0			0	0	0	---	Not assigned.
77-78	+0			0	0	0	---	Not assigned.
79	+0			0	0	0	---	Not assigned.
80		x	x	3				
	T _{togo}				9	0	mn, ,sc	Time from event.
	VGDISP				10	9	XXXXX. fps	V _g value.
	DVTOTAL				10	9	XXXXX. fps	Velocity accumulated.
81			x	3				
	DELVLVC				7	10	XXXX.X fps	Delta-V in local vertical coordinates.
82			x	3				
	DELVLVC				7	10	XXXX.X fps	Delta-V in local vertical coordinates.

<u>Noun</u>	<u>Cell</u>	<u>No</u>	<u>Dec.</u>	<u>Num-</u>	<u>Rou-</u>	<u>Con-</u>	<u>Decimal</u>	<u>Quantity</u>
		<u>Load</u>	<u>Only</u>	<u>ber</u>	<u>tine</u>	<u>stant</u>	<u>Display</u>	
83			x	3				
	DELVIMU				7	10	XXXX.X fps	Delta-V in control coordinates.
84			x	3				
	DELVOV				7	10	XXXX.X fps	Delta-V of other vehicle.
85			x	3				
	V _g body				7	10	XXXX.X fps	V _g in control coordinates.
86			x	3				
	DELVLVC				10	9	XXXXX. fps	Delta-V in local vertical coordinates.
87				2				
	MRKBUF1+3 _{sp}				2	2	XXX.XX ^o	Optics shaft mark data.
	MRKBUF1+5 _{sp}				6	2	XX.XXX ^o	Optics trunnion mark data.
88			x	3				
	STARSAV3				13	0	.XXXXX	"Planet" vector.
89			x	3				
	LAT				7	3	XX.XXX ^o	Latitude of landmark.
	LANDLONG				7	3	XX.XXX ^o	$\frac{1}{2}$ Longitude of landmark.
	LANDALT				4	7	XXX.XX nmi	Altitude of landmark.
90			x	3				
	RANGE				4	7	XXX.XX nmi	Out-of-plane position.
	RRATE				7	10	XXXX.X fps	Out-of-plane velocity.
	RTHETA				10	4	XXX.XX ^o	Out-of-plane angle.
91				2				
	CDUS				2	2	XXX.XX ^o	Optics shaft angle.
	CDUT				6	2	XX.XXX ^o	Optics trunnion angle.

<u>Noun</u>	<u>Cell</u>	<u>No Load</u>	<u>Dec. Only</u>	<u>Num-ber</u>	<u>Rou-tine</u>	<u>Con-stant</u>	<u>Decimal Display</u>	<u>Quantity</u>
92				2				
	SAC				2	2	XXX.XX ⁰	Desired optics shaft angle.
	PAC				6	2	XX.XXX ⁰	Desired optics trunnion angle.
93				3				
	OGC				7	3	XX.XXX ⁰	Gyro torquing angles.
94				2				
	MRKBUF1+3				2	2	XXX.XX ⁰	Alternate LOS shaft.
	MRKBUF1+5				6	2	XX.XXX ⁰	Alternate LOS trunnion.
95				3				
	PRAXIS				2	2	XXX.XX ⁰	Preferred attitude FDAI angles.
96				3				
	CPHIX				2	2	XXX.XX ⁰	+X axis attitude FDAI angles.
97				3				
	DSPTM1 _{sp}				3	0	XXXXX.	System test inputs.
98				3				
	DSPTM2 _{sp}				3	0	XXXXX.	System test results.
	DSPTM2+1 _{sp}				1	0	.XXXXX	System test results.
	DSPTM2+2 _{sp}				3	0	XXXXX.	System test results.
99		x		3				
	WWPOS				7	18	XXXXX. ft	Position W-matrix error/initialization.
	WWVEL				5	19	XXXX.X fps	Velocity W-matrix error/initialization.
	WWOPT				3	0	XXXXX.	Option code.

Quantities in Noun Tables

ACTCENT: See Rendezvous Computations. N52
ALMCADR: See General Program Control. N08
ALT: See Coordinate Transformations. N43
ALTI: See Boost Computations. N62
CDU: Major Variable. N20
CDUS, CDUT: See Optics Computations. N91
CENTANG: See Burn Control. N55
CPHIX: See Digital Autopilot RCS Routines. N17, N96
CSMMASS: See Digital Autopilot Interface Routines. N47
D: See Entry Computations. N64, N74
DAPDATR1, DAPDATR2: See Digital Autopilot Interface Routines. N46
DELHITE: See Rendezvous Computations. N72
DELTAR: See Burn Control. N57
DELVIMU: See Display Computations. N83
DELVLVC: See Burn Control. N81, N82, N86
DELVOV: See Burn Control. N84
DELVTPF, DELVTPI: See Burn Control. N58
DIFFALT: See Rendezvous Computations. N75
DNRNGERR: See Entry Computations. N66
DSPTM1: Major Variable. N05, N25, N26, N29, N30, N31, N34, N41, N97
DSPTM2: Major Variable. N24, N98
DSPTMX: See Display Computations. N16
DVLOS: See Burn Control. N59
DVTOTAL: See General Program Control. N40, N80
ELEV: See Rendezvous Computations. N55
ERCOUNT: See Testing Routines. N08

FAILREG: See General Program Control. N09
GAMMAEI: See Display Computations. N60
GAMMASB: See Display Computations. N51
GMAX: See Display Computations. N60
HAPO: See Burn Control. N42
HAPOX: See Display Computations. N44
HDOT: See Boost Computations. N62
HEADSUP: See Entry Preparation. N61
HORIZON: See Measurement Incorporation. N70, N71
HPER: See Burn Control. N42
HPERX: See Display Computations. N44, N50
LANDALT: See Orbital and Rendezvous Navigation. N89
LANDLONG: See Orbital and Rendezvous Navigation. N89
LANDMARK: See Orbital and Rendezvous Navigation. N70, N71
LAT: See Coordinate Transformations (tag also LANDLAT). N43, N67, N89
LATANG: See Entry Computations (tag also XRNGERR). N66
LATSPL: See Display Computations. N61
LEMMASS: See Digital Autopilot Interface Routines. N47
LNGSPL: See Display Computations. N61
LONG: See Coordinate Transformations. N43, N67
MRKBUF1+3: See Optics Computations. N87, N94
MRKBUF1+5: See Optics Computations. N87, N94
mTPER: See Display Computations. N32
N49DISP, N49DISP+2, N49DISP+4: See Measurement Incorporation. N49
NN1: See Rendezvous Computations. N55
OGC: See Coordinate Transformations. N93

OPTION1: See Display Interface Routines. N06
OPTION2: See Display Interface Routines. N06, N72
OPTIONX: See Display Computations. N12
P21ALT, P21GAM, P21VEL: See Orbital and Rendezvous Navigation. N73
PAC: See Coordinate Transformations. N92
PACTOFF: See Digital Autopilot TVC Routines. N48
PIPA: See IMU Computations. N21
pMGA: See Display Computations. N45
POSTTPI: See Burn Control. N58
PRAXIS: See Orbital and Rendezvous Navigation. N95
Q7: See Entry Computations. N69
RANGE: See Display Computations. N53, N54, N90
RDOT: See Entry Computations. N68
RHOSB: See Display Computations. N51
ROLLC: See Entry Computations. N66, N68, N69, N74
RRATE: See Display Computations. N53, N54, N90
RSPmRREC: See Display Computations. N50
RTEDVD: See Return to Earth Computations. N56
RTEGAM2D: See Return to Earth Computations. N56
RTGO: See Display Computations. N63
RTGON67: See Entry Computations. N64, N67
RTHETA: See Display Computations. N53, N54, N90
SAC: See Coordinate Transformations. N92
SMODE: See Testing Routines. N27
STARCODE: See Optics Computations. N70, N71
STARSAV3: See Inflight Alignment. N88
T_{cdh}: See Rendezvous Computations. N13
T_{csi}: See Rendezvous Computations. N11

T_{et}: See Orbital Integration. N38
T_{ig}: Major Variable. N33
T_{now}: Major Variable. N36
T_{st}: See Data Input/Output. N65
T_{togo}: See Burn Control. N35, N40, N45, N80
T_{tpi}: See Rendezvous Computations. N37
T1TOT2, T2TOT3: See Rendezvous Computations. N75
T3TOT4: See Return to Earth Computations. N39
TFF: See Display Computations. N44, N50
THETAD: Major Variable. N18, N19, N22
THETZERO: See Rendezvous Computations. N72
TRKMKCNT: See Measurement Incorporation. N45
TTE: See Display Computations. N63
V_{gbody}: See Burn Control. N85
VGDISP: See Burn Control. N40, N42, N80
VHFCNT: See Measurement Incorporation. N45
VIO: See Display Computations. N63
VL: See Entry Computations. N69
VMAGI: See Boost Computations and Entry Computations. N62, N64, N68, N74
VPRED: See Display Computations. N60
WWOPT: See Measurement Incorporation. N99
WWPOS: See Measurement Incorporation. N99
WWVEL: See Measurement Incorporation. N99
XREG: See Data Input/Output. NO7
YACTOFF: See Digital Autopilot TVC Routines. N48
YREG: See Data Input/Output. NO7
ZREG: See Data Input/Output. NO7

NounUsing Routine (Verb)

49 "P23.85" (06, R3 blanked); "RENDISP2" (06, priority display);
"S22BOX12" (06, R3 blanked)

50 Manual initiation only (optional R30 display, with R1
computed in P00 and P11 only)

51 "SBANDANT" (06, R3 blanked)

52 Manual initiation only (central angle of transfer computed
in P34/P74, P35/P75, P38/P78, and P39/P79)

53 "R31CALL" (16)

54 "R31CALL" (16)

55 "P34/P74C" (06); "P72" (06); "P74" (06); "P77" (06, R2
blanked); "P78" (06, R1 and R2 blanked)

56 Manual initiation only (P37 targeting data)

57 "P78" (06, R2 and R3 blanked)

58 "P34/P74C" (06); "P77" (06); "TEST3979" (06)

59 "S34/35.5" (06)

60 "NEWRVN" (06); "P37" (06, R1 blanked); "RTEVN" (06, R1 blanked)

61 "P61" (06); "P62.1" (06); "RTEVN" (06, R3 blanked)

62 "VHHDOT" (06)

63 "NEWRVN" (06)

64 "P63" (06)

65 Manual initiation only (sampled computer clock)

66 "PREFINAL" (06)

67 "P67.1" (16)

68 Manual initiation only (entry quantities)

69 "P65.1" (16)

70 "R23.10" (05); "R51DSP" (01, R2 and R3 blanked); "S22N7071"
(05, R1 and R3 blanked)

NounUsing Routine (Verb)

71 "P23.60" (05); "R53C1" (01); "S22N7071" (05, R1 and R3 blanked)
72 "P77" (06)
73 Manual initiation only (quantities computed in P21)
74 "INITROLL" (06)
75 "P32/P72C" (06); "P33/P73B" (06)
80 Manual initiation only (same as N40, but R2 and R3 different scaling)
81 "DSPLY81" (06); "P30" (06); "P31" (06); "P32/P72C" (06);
"P33/P73B" (06); "RTEVN" (06); "S34/35.5" (06)
82 "P32/P72C" (06)
83 "P47BODY" (16)
84 "P76" (06)
85 "P41CSM" (06); "TIGAVEG" (16); "TIGNOW" (16)
86 Manual initiation only (same as N81, but different scaling)
87 "MARKDISP" (06, R1 and R3 blanked)
88 "PLANET" (06); "P23.15" (06)
89 "P22SUBBRB" (06); "P52B" (06); "S22I=N" (06)
90 "R36P3" (06)
91 Manual initiation only (optics CDU angles)
92 "COM52" (06); "VBCOARK" (24)
93 "GCOMPVER" (06); "IMUFINEK" (25); "R55" (06)
94 "R23CSM" (06); "R56" (06)
95 Manual initiation only (preferred attitude FDAI angles)
96 Manual initiation only (+X axis attitude FDAI angles)
97 Manual initiation only (DSPTM1 cells for system test inputs)
98 "SHOW" (06)
99 "GOTOPOOH" (37, which then blanks noun register); "V67CALL" (06)

If STARIND = 0:

BESTI = TS

If STARIND = 1:

BESTJ = TS

Set bit 15(TERMIFLG) of FLAGWRD7 = 1 (no effect for R56)

Proceed to address specified by R53EXIT

R56 Entered from "P51B" and "R51DSP"

R53EXIT = Return address

TS = 0694_{vn}

Proceed to "GOFLASH": if terminate, proceed to "GOTOPOOH"
if proceed, proceed
otherwise, proceed to previous line

Perform "SXTMARK" (exits before using TS information)

TS = 0

Perform "CLEANDSP"

TS = 5300_{vn}

Proceed to "GOMARK2": if terminate, proceed to "GOTOPOOH"
if proceed, proceed to previous line
otherwise, proceed

SAC = MRKBUF1+3 (loaded in R1 of N94)

PAC = MRKBUF1+5 (loaded in R2 of N94)

Inhibit interrupts

$E_{\text{MARKSTAT}} = T_{\text{now}}$

$E_{\text{MARKSTAT}+2} = \text{CDU}_y$

$E_{\text{MARKSTAT}+3} = \text{SAC}_{\text{sp}}$

$E_{\text{MARKSTAT}+4} = \text{CDU}_z$

$E_{\text{MARKSTAT}+5} = \text{PAC}_{\text{sp}}$

$E_{\text{MARKSTAT}+6} = \text{CDU}_x$

Release interrupts

Perform "CLEARMRK"

TS = 00016_g

Proceed to "GOPERF1": if terminate, proceed to "GOTOPOOH"
if proceed, proceed
otherwise, proceed to 5th line of "R56"

Proceed to "R53C1"

R57 Entered from "P23.00", "P23.15", and "R6OCALL" (in P23)

If bits 3-2 of EXTVBACT \neq 0:

Proceed to "BAILOUT" (pattern 1211_g)

Set bit 2 of EXTVBACT = 1

Proceed to "R57A"

R57A

Set bit 12(P23CALIB) of FLAGWRD5 = 1

TS = 5900_{vn}

Perform "GOMARKFR": if terminate, proceed to "GOTOPOOH"
if proceed, skip next 2 lines
otherwise, skip next 2 lines

TS = 111₂ and perform "BLANKET" (R3BLNK, R2BLNK, R1BLNK)

End of job

Proceed to "ENDR57"

(If bit 12(P21FLAG) of FLAGWRD2 = 0):

Set bits 4(CONICINT) and 1(WMATINT) of FLAGWRD3 = 0

Perform "INTEGRV"

If bit 12(P21FLAG) of FLAGWRD2 = 1:

$RCV = P21BASER$ (tag here "P21CONT")

$VCV = P21BASEV$

$T_{et} = P21TIME$

Set bit 1(WMATINT) of FLAGWRD3 = 0 Note that bit 4 not set.

Set bit 12(MOONFLAG) of FLAGWRD0 = 0

If P21ORIG \neq 0:

Set bit 12(MOONFLAG) of FLAGWRD0 = 1

Perform "INTEGRVS"

$P21TIME = T_{att}$ (tag here "P21VSAVE")

$P21BASER = R_{att1}$ (B29 earth, B27 moon)

$P21BASEV = V_{att1}$ (B7 earth, B5 moon)

$TS = |P21BASEV|$ (B7 earth, B5 moon)

Shift TS right X2 places (make B7; X2 set from integration)

$P21VEL = TS$

$P21GAM = \sin^{-1} \left((unitR_{att} \cdot V_{att}) / P21VEL \right)$

$P21ORIG = X2$

Set bit 12(P21FLAG) of FLAGWRD2 = 1

Set bit 12(LUNLATLO) of FLAGWRD3 = 0 (tag here "P21DSP")

If X2 \neq 0: (e.g. 2, meaning moon)

Set bit 12(LUNLATLO) of FLAGWRD3 = 1

$ALPHAV = R_{att}$

Set bit 13(ERADCOMP) of FLAGWRD1 = 0

$TS = T_{att}$

Perform "LAT-LONG"

$P21ALT = K_{kp01} ALT$

$TS = 0643_{vn}$

Proceed to "GOFFLASH": if terminate, proceed to "GOTOPOOH"
if proceed, proceed to "GOTOPOOH"
otherwise, proceed

$DSPTIME_{dp} = P21TIME + K_{600sec}$

Proceed to "P21PROG1"

PROG22

Set bit 7(RNDVZFLG) of FLAGWRD0 = 0

Perform "RO2BOTH"

$T_{decl} = T_{now}$

Perform "CSMCONIC"

$pMGA = \cos^{-1} \left(\left| \text{unit}(\underline{V}_{att} * \underline{R}_{att}) \cdot \text{REFSMAT}_{31} \right| \right)$

Set bit 1(RENDWFLG) of FLAGWRD5 = 0

$TS = 0645_{vn}$

Perform "GOFFLASHR": if terminate, proceed to "GOTOPOOH"
if proceed, proceed to "PROG22A"
otherwise, proceed to previous line

$TS = 011_2$ and perform "BLANKET" (R2BLNK, R1BLNK)

End of job

PROG22A

Set bits 12-10 of LANDMARK = 0 (second octal digit)

Set bit 11(P22MKFLG) of FLAGWRD3 = 0 (for telemetry status of
SVMRKDAT cells; set in "S22.1")

Set bit 13(ERADCOMP) of FLAGWRD1 = 1

If bit 12(CMOONFLG) of FLAGWRD8 = 0: (means earth-centered)

Set bit 12(LUNLATLO) of FLAGWRD3 = 0 (tag here "PROG22B")

Set bit 8(LNDKNOWN) of FLAGWRD6 = 1

Perform "P22SUBRB"

If bit 12(CMOONFLG) of FLAGWRD8 = 1: (means moon-centered)

Set bit 12(LUNLATLO) of FLAGWRD3 = 1

$(TS_1, TS_2) = (0570_{vn}, 1307_8)$

Perform "S22N7071"

S22I=N

If NUM8NN - NUM8KK > 0:

NUM8KK = NUM8KK + 1

S22LOC = S22LOC + 7

Perform "INTSTALL"

Set bits 5(STATEFLG), 3(CSMINTSW), 2(9DIMWMAT), and 1(WMATINT)
of FLAGWRD3 = 1

Set bit 4(CONICINT) of FLAGWRD3 = 0

If bit 9(DMENFLG) of FLAGWRD5 = 1:

Proceed to "S22NXTIN"

Set bit 1(WMATINT) of FLAGWRD3 = 0 (first mark was an
offset if get here)

If bit 6(ORBWFLAG) of FLAGWRD3 = 1:

Set bit 1(WMATINT) of FLAGWRD3 = 1

Set bit 2(9DIMWMAT) of FLAGWRD3 = 0

Proceed to "S22NXTIN"

If CXOFF = 0: (all marks processed if get here, tag "S22F244X")

S22TOFF = $E_{S22LOC_{dp}}$ (i.e. time of last mark)

If CXOFF ≠ 0:

If NUM8NN - CXOFF < 0:

S22TOFF = $E_{S22LOC_{dp}}$

If NUM8NN - CXOFF ≥ 0:

$T_{decl} = S22TOFF$

Perform "CSMPREC"

CSMPOS = R_{att1} (B29 earth, B27 moon)

UM = S22UOFF

TS = \X782|

If bit 12(CMOONFLG) of FLAGWRD8 = 1:

Shift TS right 2 places (B29)

ERADM = TS

(If $\text{NUM\&NN} - \text{CXOFF} \geq 0$):

$$\text{TS} = - \text{unitCSMPOS} \cdot \text{UM}$$

$$\text{TS}_1 = \text{ERADM}$$

If bit 12(CMOONFLG) of FLAGWRD8 = 1:

Shift TS_1 left 2 places (to scale factor B27)

$$\text{S22RHO} = |\text{CSMPOS}| \left(\text{TS} - \sqrt{(\text{TS}_1 / |\text{CSMPOS}|)^2 - (1 - \text{TS}^2)} \right)$$

$$\text{X789} = \text{CSMPOS} + \text{S22RHO} \text{ UM}$$

Set bit 12(LUNLATLO) of FLAGWRD3 = 0 (Tag here is "S22BX44A")

$$\text{TS} = \text{X789}$$

If bit 12(CMOONFLG) of FLAGWRD8 = 1:

Set bit 12(LUNLATLO) of FLAGWRD3 = 1

Shift TS right 2 places (B29)

$$\text{ALPHAV} = \text{TS}$$

$$\text{TS} = \text{S22TOFF}$$

Perform "LAT-LONG"

$$\text{LANDALT} = \text{ALT}$$

$$\text{LANDLONG} = \frac{1}{2} \text{ LONG}$$

$$\text{TS} = 0689_{\text{vn}}$$

Proceed to "GOFLASH": if terminate, proceed to "S22GTP"
if proceed, proceed
otherwise, proceed to "S22.981X"

$$\text{TS}_2 = \text{S22TOFF}$$

$$\text{TS}_1 = \text{X789}$$

$$\text{TS} = \frac{1}{2} \quad (\text{i.e. non-zero, meaning moon})$$

Perform "R-TO-RP"

$$\text{RLS} = \text{TS}$$

Proceed to "S22.981X"

(If $\text{NUM\&NN} - \text{CXOFF} \geq 0$):

$$\text{TS} = - \text{unitCSMPOS} \cdot \text{UM}$$

$$\text{TS}_1 = \text{ERADM}$$

If bit 12(CMOONFLG) of FLAGWRD8 = 1:

Shift TS_1 left 2 places (to scale factor B27)

$$\text{S22RHO} = |\text{CSMPOS}| \left(\text{TS} - \sqrt{(\text{TS}_1 / |\text{CSMPOS}|)^2 - (1 - \text{TS}^2)} \right)$$

$$\text{X789} = \text{CSMPOS} + \text{S22RHO} \text{ UM}$$

Set bit 12(LUNLATLO) of FLAGWRD3 = 0 (Tag here is "S22BX44A")

$$\text{TS} = \text{X789}$$

If bit 12(CMOONFLG) of FLAGWRD8 = 1:

Set bit 12(LUNLATLO) of FLAGWRD3 = 1

Shift TS right 2 places (B29)

$$\text{ALPHAV} = \text{TS}$$

$$\text{TS} = \text{S22TOFF}$$

Perform "LAT-LONG"

$$\text{LANDALT} = \text{ALT}$$

$$\text{LANDLONG} = \frac{1}{2} \text{ LONG}$$

$$\text{TS} = \text{O689}_{\text{vn}}$$

Proceed to "GOFLASH": if terminate, proceed to "S22GTP"
if proceed, proceed
otherwise, proceed to "S22.981X"

$$\text{TS}_2 = \text{S22TOFF}$$

$$\text{TS}_1 = \text{X789}$$

$$\text{TS} = \frac{1}{2} \quad (\text{i.e. non-zero, meaning moon})$$

Perform "R-TO-RP"

$$\text{RLS} = \text{TS}$$

Proceed to "S22.981X"

Proceed to "ADTIME+3"

ADTIME+3

Perform "INTSTALL"

Set bit 4(CONICINT) of FLAGWRD3 = 0

If NOMTPI \neq 0: (as it would be expected to be)

Set bit 4(CONICINT) of FLAGWRD3 = 1

$T_{decl} = \text{NOMTPI}$

Set bit 12(MOONFLAG) of FLAGWRD0 = 1

$X2 = \text{RTX2}$

If bit 12(CMOONFLG) of FLAGWRD8 = 0:

Set bit 12(MOONFLAG) of FLAGWRD0 = 0

$T_{et} = 0$

$\underline{RCV} = \underline{R}_{aprec}$, shifted left X2 places (B29 earth, B27 moon)

$\underline{VCV} = \underline{V}_{aprec}$, shifted left X2 places (B7 earth, B5 moon)

Perform "INTEGRVS"

$\underline{R}_{act3} = \underline{R}_{att}$

$\underline{V}_{act3} = \underline{V}_{att}$

Perform "INTSTALL"

Set bit 4(CONICINT) of FLAGWRD3 = 0

If NOMTPI \neq 0:

Set bit 4(CONICINT) of FLAGWRD3 = 1

$T_{decl} = \text{NOMTPI}$

Set bit 12(MOONFLAG) of FLAGWRD0 = 1

$X2 = \text{RTX2}$

If bit 12(CMOONFLG) of FLAGWRD8 = 0:

Set bit 12(MOONFLAG) of FLAGWRD0 = 0

$$T_{et} = 0$$

$R_{CV} = R_{pprec}$, shifted left X2 places (B29 earth, B27 moon)

$V_{CV} = V_{pprec}$, shifted left X2 places (B7 earth, B5 moon)

Perform "INTEGRVS"

$$R_{pass3} = R_{att}$$

$$V_{pass3} = V_{att}$$

Proceed to "ELCALC"

S34/35.2 (Entered from "P34/P74C" and "P35/P75B")

SUBEXIT = Return address

Perform "INTSTALL"

Set bit 4(CONICINT) of FLAGWRD3 = 0

If $NN1_{sp} = 0$:

Set bit 4(CONICINT) of FLAGWRD3 = 1

$$T_{decl} = T_{pass4}$$

Set bit 12(MOONFLAG) of FLAGWRD0 = 1

X2 = RTX2

If bit 12(CMOONFLG) of FLAGWRD8 = 0:

Set bit 12(MOONFLAG) of FLAGWRD0 = 0

$$T_{et} = INTIME$$

$R_{CV} = R_{pass3}$, shifted left X2 places (B29 earth, B27 moon)

$V_{CV} = V_{pass3}$, shifted left X2 places (B7 earth, B5 moon)

Perform "INTEGRVS"

$$R_{targ} = R_{att}$$

Proceed to "S3435.25"

S3435.25 (Entered from "S34/35.2" and, with SUBEXIT set, from "MAINRTNE")

$$V_{pass4} = V_{att}$$

$$TS_1 = (\text{unit}R_{act3} * \text{unit}R_{targ}) * UNRM$$

$$TS = (\cos^{-1}(\text{unit}R_{act3} * \text{unit}R_{targ})) \text{ sgn } TS_1$$

If $TS < 0$:

$$TS = TS + (1 - 2^{-28})$$

$$ACTCENT = TS$$

$$DELLT4 = T_{pass4} - INTIME$$

$$TS_1 = NN1_{sp}$$

$$TS_2 = K_{epsfour}$$

$$\underline{R}_{init} = \underline{R}_{act3}$$

$$\underline{V}_{init} = \underline{V}_{act3}$$

Perform "INITVEL"

$$TS_2 = - UNRM$$

$$TS_3 = - unitR_{act3}$$

$$TS_1 = TS_3 * UNRM$$

$$DELVLVC = \begin{bmatrix} TS_1 \\ TS_2 \\ TS_3 \end{bmatrix} DELVEET3$$

Proceed to address specified by contents of SUBEXIT

S34/35.3 (Entered from "S34/35.5" if new velocity components input)

$$TS_2 = - UNRM$$

$$TS_3 = - unitR_{act3}$$

$$TS_1 = TS_3 * UNRM$$

$$DELVEET3 = DELVLVC \begin{bmatrix} TS_1 \\ TS_2 \\ TS_3 \end{bmatrix}$$

Perform "INTSTALL"

Set bit 4(CONICINT) of FLAGWRD3 = 0

Set bit 4(CONICINT) of FLAGWRD3 = 1 (superseding previous line)

$$T_{decl} = T_{pass4}$$

Set bit 12(MOONFLAG) of FLAGWRDO = 1

X2 = RTX2

If bit 12(CMOONFLG) of FLAGWRD8 = 0:

Set bit 12(MOONFLAG) of FLAGWRDO = 0

$T_{et} = T_{ig}$

$RCV = R_{act3}$, shifted left X2 places (B29 earth, B27 moon)

$VCV = (V_{act3} + DELVEET3)$, shifted left X2 places (B7 earth, B5 moon)

Perform "INTEGRVS"

$R_{targ} = R_{att}$

$TS_1 = ULOS$

$TS_3 = - \text{unit}(ULOS * UNRM)$

$TS_2 = TS_3 * ULOS$

$DVLOS = \begin{bmatrix} TS_1 \\ TS_2 \\ TS_3 \end{bmatrix} \quad DELVEET3$

Return

PREC/TT (Entered from "P78" and "RECYCLE")

$T_{decl} = T_{ig}$

Perform "PRECSET"

$RVEC = R_{pass3}$, shifted left X2 places (B29 earth, B27 moon)

CSTH = cos CENTANG

Set bit 9(RVSW) of FLAGWRD7 = 1 (means new R, V not desired)

SNTH = sin CENTANG

$VVEC = V_{pass3}$, shifted left X2 places (B7 earth, B5 moon)

Perform "TIMETHET"

$ULOS = \text{unit}(R_{pass3} - R_{act3})$

LOOPCT: Iteration counter for P32/P72 computations, initialized to 0 in "CSI/A" and "SCNDSOL", scale factor B28.

MPAC+O: See Display Interface Routines (contains verb received with response to DSKY display, with 32 being a "recycle" verb).

NN1: Value of "pericenter code" loaded for display in R1 of N55, scale factor B14. A value of 1 means that perigee/perilune will occur (P17/P77) between TPI and TPF; while a value of 2 means this point will occur after TPF (i.e. beyond rendezvous point). Display single precision. Program notation also "NN". Used in P32/P72 (initialized to 0 in "P72") to specify the future apsidal crossing of the active vehicle at which CDH should occur. Used in P34/P74 to specify the number of precision offsets that the "INITVEL" package should employ (initialized to 0 in "P74", and used in "S3435.25"). This same value would be used for the subsequent P35/P75 performance. For P38/P78, set to 2 ("P78") which would be used for subsequent P39/P79 performance.

NOMTPI: Value of computed correction to T_{tpi} , scale factor B28, units centi-seconds, loaded in "ELCALC". This scheme permits $\frac{R_{aprec}}{R_{pprec}}$ state vector time tag to remain T_{tpi} while the iteration continues for the proper updated value of T_{tpi} , using conic integration from the $\frac{R_{aprec}}{R_{pprec}}$ base.

OPTION2: See Display Interface Routines. It is also displayed in R3 of N72, where a value of 1 means KFLAG = 1 ("K = -1"), and otherwise the value is 2, and provides a manual input for the "search option", single precision scale factor B14.

P: See Conic Routines.

PCDGAMMA: Error angle used in P32/P72 iteration, scale factor B1, units revolutions, stored in push-down location OD. It is the central angle between the position vector of the passive vehicle at TPI and PDUB.

PCDK: Value of "weight" for PDUB in computing PDUB, scale factor B29, units meters, corresponding to the lesser (in magnitude) of PCDK1 and PCDK2. Stored in push-down location 1OD.

PCDK1: Value corresponding to one of the solutions of the equation for PCDK, scale factor B29, units meters, stored in push-down location 12D. Equation solved for "k" is: $k^2 + 2c_1 k + r_{a3}^2 - r_{p3}^2 = 0$.

PCDK2: Value corresponding to the other solution of the quadratic equation for PCDK, scale factor B29, units meters, stored in push-down location 1OD (written over with PCDK1 if necessary to determine PCDK).

PDO2R: Value of magnitude of passive vehicle position vector used in "CDHMVR" to compute DIFFALT, scale factor B29, units meters. Stored in push-down location O2D (cell contents replaced by magnitude of R_{act2} after use).

PD18V: Value of passive vehicle velocity vector used in "CDHMVR", scale factor B7, units meters/centi-second. It is the velocity vector at the point corresponding to PDO2R (i.e. radially above/below the active vehicle), and is stored in push-down location 18D.

PD28CS: Value of ratio of active to passive vehicle magnitudes times $\cos \text{ELEV}$ (i.e. times $-\cos(\frac{1}{2} - \text{ELEV})$), scale factor B1, stored in push-down list location 28D.

PDALFMPI: Value of guidance equation quantity α minus π , scale factor B0, units revolutions, stored in push-down list location 18D.

PDC1: Value of equation quantity " c_1 " (see PCDK1) for quadratic equation in "CIRCL", scale factor B29, units meters, stored in push-down location 6D.

PDC2: Value of equation quantity " c_2 " (the quantity under the radical for the quadratic equation defined in PCDK1 definition), scale factor B58, units meters²; square root stored temporarily in push-down list.

PDDELTM: Value of guidance equation quantity δt , scale factor B28, units centi-seconds, stored in push-down list location 12D.

PDOMEGA: Value of active vehicle angular velocity information times radius magnitude ratio (for convenience in scaling), scale factor B37, stored temporarily in push-down list. Push-down(16D) list subsequently modified to contain PDOMEGA - PDOMEGP, with scale factor information in X1 also (i.e. scaling B(37 +X1)).

PDOMEGP: Value of passive vehicle angular velocity information times radius magnitude ratio (for convenience in scaling: the reciprocal of the ratio used for PDOMEGA is employed), scale factor B37, stored as described under PDOMEGA.

PDSEMAA: Value of semi-major axis of active vehicle computed in "CDHMVR", scale factor B29, units meters, stored in push-down location 4D.

PDSEMAP: Value of semi-major axis of passive vehicle computed in "CDHMVR", scale factor B29, units meters, stored temporarily in push-down location 4D (then that location used for PDSEMAA).

PDSL: Value of "slope" function for "CIRCL" iteration (DELDV for next cycle is given by PCDGAMMA / PDSL), scale factor B-6 (for variables already normalized), stored in push-down location 4D.

PDSMA: Value of semi-major axis computed in "ENDEN" for deriving the value of CENTANG (based on passive vehicle state vector), scale factor B29 (earth) or B27 (moon), stored in push-down list location 2D, units meters.

PDUB: Value of equation "b" vector, scale factor B1, stored in push-down location OD. It represents the position where the passive vehicle "should be based on the active vehicle location", and is used to compute PCDGAMMA.

Steering Computations

S40.1 Entered from "P40CSM" and "P41CSM"

Set bit 7(FIRSTFLG) of FLAGWRD2 = 1

$BDI = 0$

If bit 8(XDELVFLG) of FLAGWRD2 = 0, proceed to "S40.1B"

$DELVSAB = |DELVSIN|$

$V_{init} = V_{tig}$

$TS_1 = \text{unit}(V_{tig} * R_{tig})$ (stored in UT cell)

$R_{init} = R_{tig}$

$TS = K_{thetcon} |V_{tig} * R_{tig}|$ (rounded multiplication, least increment
in result 2^{16} meters²/centi-second)

$BURNANG = TS \ DELVSAB \ MASS_{dp} / (CAPF |R_{tig}|^2)$

$TS_2 = (DELVSIN \cdot TS_1) \ TS_1$

$TS_3 = DELVSIN - TS_2$ (in-plane component of specified velocity)

$V_{gtig} = TS_2 + |TS_3| (\text{unit}(TS_3 * TS_1) \sin BURNANG + \text{unit}TS_3 \cos BURNANG)$

$UT = \text{unit}V_{gtig}$

Set bit 5(LMACTFLG) of FLAGWRD2 = 1 (gets local vertical velocity
from "MIDGIM" routine)

$TS = V_{gtig}$

Perform "MIDGIM"

Return

S40.1B

$T_{decl} = T_{ig} - K_{twodt}$

$DELLT4 = T_{pass4} - T_{decl}$

Perform "AGAIN"

$TS_4 = V_{iprime}$ (stored in UT cell)

$T_{decl} = T_{ig}$

$DELLT4 = T_{pass4} - T_{decl}$

Perform "AGAIN"

$V_{gtig} = DELVEET3$

Set bit 5(LMACTFLG) of FLAGWRD2 = 1

$$\underline{TS} = \underline{V}_{gtig}$$

Perform "MIDGIM"

$$\underline{TS} = \underline{R}_{tig}$$

Perform "CALCGRAV"

$$\underline{TS} = \text{CSTEER} \left((\underline{V}_{i\text{prime}} - \underline{TS}_4) / K_{200cs} - \text{GDT}_1 / K_{200cs} \right)$$

$$\underline{QFCT} = \underline{TS} - (\text{unit}\underline{V}_{gtig} \cdot \underline{TS}) \text{unit}\underline{V}_{gtig}$$

$$\underline{TS}_1 = \text{CAPF} / \text{MASS}_{dp}$$

$$\underline{UT} = \text{unit} \left(\underline{QFCT} + \sqrt{\underline{TS}_1^2 - \underline{QFCT}^2} \text{unit}\underline{V}_{gtig} \right)$$

Return

AGAIN

Perform "CSMPREC"

$$\text{RTX2} = \text{X2}$$

$$\text{RTX1} = \text{X1}$$

$$\underline{R}_{tig} = \underline{R}_{att}$$

$$\underline{R}_{init} = \underline{R}_{att}$$

$$\underline{V}_{tig} = \underline{V}_{att}$$

$$\underline{V}_{init} = \underline{V}_{att}$$

$$\underline{TS}_1 = 0$$

$$\underline{TS}_2 = K_{\text{eps45}}$$

If bit 10(NORMSW) of FLAGWRD7 = 0:

$$\underline{TS}_2 = K_{\text{eps10}}$$

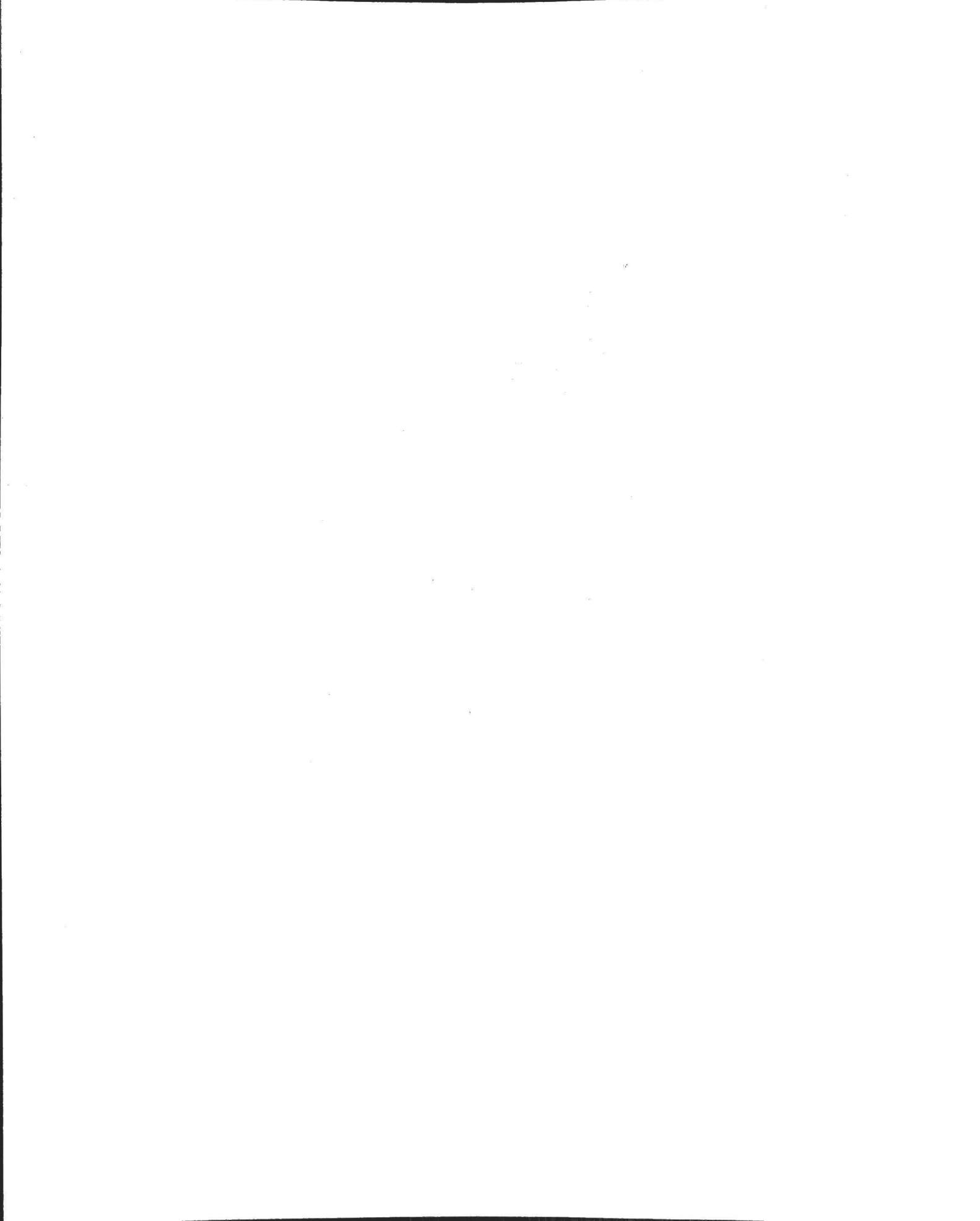
Perform "INITVEL"

Return

S40.2,3 (Entered from "P40CSM" and "P41CSM")

$$\text{POINTVSM} = [\text{REFSMAT}] \underline{UT}$$

If bit 11(RCSBURN) of FLAGWRD1 = 1, proceed to "S40.2,3B"



REDO40.9 (Entered if a restart encountered from time of establishing "S40.9" in "SETUP.9" until return from "INITVEL" in "S40.9", due to restart group 1.5)

$\underline{\text{DELVSUM}} = 0$

$\text{NBRCYCLP} = 0$

$\text{DELVEET}_2 = \underline{V}_{\text{gtig}}$ (for "SETUP.9" restoration)

$\text{NBRCYCLS} = -1$

End of job

S40.13 Established by "TIG-5" and "V97ETASK"

Set bit 9(IMPULSW) of FLAGWRD2 = 1

$\text{TS}_1 = \underline{V}_{\text{gtig}}$

If bit 7(+X translation complement) of channel 31 = 0:

$\text{TS} = K_{2\text{rcsf}} / \text{MASS}$ (all references to MASS are double precision)

If bit 15(2JETSFLG) of FLAGWRD1 = 0:

$\text{TS} = 2 \text{TS}$ (i.e. 4-jet translation)

$\text{TS}_1 = \text{TS}_1 - \text{TS}$

$\text{TS}_2 = \text{TS}_1 - C_{\text{ek1val}} / \text{MASS}$

If $\text{TS}_2 < 0$:

$\text{TS} = (\text{MASS } \text{TS}_1 + C_{\text{ek2val}}) / C_{\text{ek3val}}$, with sign agreement forced

$T_{\text{go}} = (0, \text{TS})$

End of job

$\text{TS}_3 = K_{5\text{sec}} C_{\text{fang}} / (\text{MASS} - K_{3\text{p5sec}} C_{\text{emdodp}})$

If $\text{TS}_2 - \text{TS}_3 \geq 0$:

Set bit 9(IMPULSW) of FLAGWRD2 = 0

End of job

$\text{TS} = K_{1\text{sec2d}} + K_{5\text{sec}} (\text{TS}_2 / \text{TS}_3)$, with sign agreement forced

$T_{\text{go}} = (0, \text{TS})$

End of job

S41.1

Perform "CDUTRIG"

$\underline{TS} = [\text{REFSMMAT}] \underline{TS}$

Perform "TRG*SMNB" (starting at second line)

$\underline{TS} = K_{\text{tenb}_4} [\text{QUADROT}] \underline{TS}$ (now in control coordinates)

Return

Quantities in Computations

See also list of major variables and list of routines

- BDT: "Effect of rate of change of required velocity, and gravity, acting during the two-second computing interval, upon velocity-to-be-gained," scale factor B7, units meters/centi-second. Set 0 in "S40.1".
- BURNANG: Value of one-half the central angle estimated to be traveled during the External Delta-V burn, scale factor B0, units revolutions, stored in push-down location 14D.
- $C_{dvthresh}$: Single precision erasable memory constant, program notation "DVTHRESH", scale factor B-2, units meters/centi-second, giving velocity gate used in "S40.8" for concluding that engine failure has taken place. Program shifts constant right 9 places before use, to scale it B7 meters/centi-second (double precision).
- C_{ek1val} : Erasable memory double precision constant, program notation "EK1VAL" (also "K1VAL"), scale factor B23, units kilogram-meters/centi-second: when divided by MASS, gives velocity increment. For a value in pound-seconds, PSEC, the fraction in the cell may be computed as $PSEC \times 10^{-2} \times 9.80665 \times 0.45359237 \times 2^{-23}$, where first term is value, second converts to centi-seconds, third is g, fourth converts from pounds to kilograms, and fifth is scale factor.
- C_{ek2val} : Erasable memory double precision constant, program notation "EK2VAL" (also "K2VAL"), scale factor B23, units kilogram-meters/centi-second. It gives the initial value of the minimum impulse (completion) for SPS thrusting. For a value in pound-seconds, PNDSEC, the fraction in the cell may be computed as $PNDSEC \times 10^{-2} \times 9.80665 \times 0.45359237 \times 2^{-23}$, where first term is value, second converts to centi-seconds, third is g, fourth converts from pounds to kilograms, and fifth is scale factor. Caution should be observed if value in PNDSEC is less than that due to the 7.96 seconds of RCS jets (see K_{2rcsf}), so as to avoid alarm 1204₈ if $|V_{gtig}|$ small (e.g. engine restart).
- C_{ek3val} : Erasable memory single precision constant, program notation "EK3VAL" (also "K3VAL"), scale factor B9, units of kilogram-meters/centi-second² (or 10⁴ Newtons). Used as double precision number in "S40.13" (with least significant half corresponding to C_{fang}), and gives slope of minimum impulse curve for SPS thrusting. For a value in pound-seconds/second, PNDSSC, the fraction in the cell may be computed as $PNDSSC \times 10^{-4} \times 9.80665 \times 0.45359237 \times 2^{-9}$, where first term is value, second converts to centi-seconds², third is g, fourth converts from pounds to kilograms, and fifth is scale factor.
- C_{emdot} : See Digital Autopilot TVC Routines.
- $C_{erefrac_j}$: See Digital Autopilot TVC Routines.

C_{fang} : Erasable memory double precision constant, program notation "FANG", scale factor B7, units "M. Newtons" (equivalent to expressing force in kilogram-meters/centi-second² or 10⁴ Newtons). Used in "S40.13" as the thrust for the burn from 1 to 6 seconds. For a value in pounds, PNDF, the fraction in the cell may be computed as PNDF x 9.80665 x 0.45359237 x 10⁻⁴ x 2⁻⁷, where first term is value, second is g, third converts pounds to kilograms, fourth converts to centi-seconds², and fifth is scale factor.

C_{tdecay} : Single precision erasable memory constant, program notation "ETDECAY", scale factor B14, units centi-seconds, giving value of thrust decay time (i.e. equivalent full-thrust time). It is subtracted from the "raw" time-to-go, and therefore should be a positive number in the memory. Used in "S40.8" only.

CAPF: See Burn Control.

CNTR: See Digital Autopilot TVC Routines. A setting of +MAX (in "S40.8" for cutoff) corresponds to a time delay of about 2.27 hours, effectively disabling updates in "TVCEXEC".

CSTEER: Scalar in cross-product steering law, scale factor B2. It is set to ECSTEER in "P4OCSM" (provided a Lambert burn specified), and otherwise has most significant half zero. Least significant half is always set 0.

DAPDATR1: See Digital Autopilot Interface Routines.

DELLT4: See Rendezvous Computations.

DELTAM: Value of (CSTEER \underline{BDI} - DELVREF), scale factor B7, units meters/centi-second. Its unit vector (scale factor B1) is stored temporarily in the push-down list.

DELVEET3: See Rendezvous Computations (DELVSIN occupies same cells).

DELVREF: See General Program Control.

DELVSAB: Absolute value of DELVSIN used in "S40.1" in the computation of BURNANG for External Delta-V burns, scale factor B7, units meters/centi-second.

DELVSIN: See Burn Control.

DELVSUM: Value of sum of DELVREF outputs from Average-G computed in "UPDATEVVG" for Lambert burn, used to correct \underline{V}_{gtig} for accelerometer-output velocity gained since "S40.9" established. Scale factor B7, units meters/centi-second. Initialized to 0 in "SETUP.9".

GDT, GDT1: See General Program Control.

GOBL: See General Program Control.

K_{lsec2d} : Constant, program notation "LSEC2D", scale factor B14, units centi-seconds. Value is 100 x 2⁻¹⁴, corresponding to 1 second.

- K_{2rcsf} : Constant, program notation "S40.135", scale factor B23, nominal value $69.6005183 \times 2^{-23}$. Value corresponds to $796 K_{frcs2}$ times 2^{-23} , i.e. the velocity increment (after dividing by MASS) for 7.96 seconds of two-jet RCS thrusting. See Burn Control for K_{frcs2} value. Octal value is $00000_8 04263_8$, corresponding to 69.59375×2^{-23} . Before original ignition, "S40.13" is entered 5 seconds before ignition time, with last Average-G sample made 5.96 seconds before ignition. Program zeros channel 5 (ullage jets) at end of "IGNITION" routine, 2 seconds after ignition.
- K_{2vexh} : Constant, program notation "2VEXHUST", scale factor B7, units meters/centi-second. Value is 63.020792×2^{-7} , corresponding to $2 \times 31.510396 \times 2^{-7}$, where first term is an equation factor of two, second is the exhaust velocity in meters/centi-second, and the third is the scale factor. Exhaust velocity of 3151.0396 meters/second (10338.05643 fps) corresponds to an I_{sp} dividing by 9.80665, of about 321.32 seconds, i.e. $20500/63.8$.
- K_{3p5sc} : Constant, program notation "3.5SEC", scale factor B13, units centi-seconds. Value is 350×2^{-13} , corresponding to 3.5 seconds.
- K_{5sec} : Constant, program notation "5SECOND", scale factor B14, units centi-seconds. Value is 500×2^{-14} , corresponding to 5 seconds.
- K_{200cs} : Constant, program notation "200CS", scale factor B12, units centi-seconds. Value is 200×2^{-12} , corresponding to 2 seconds.
- K_{200csh} : Constant, program notation "200CSHI", scale factor B12, units centi-seconds. Value is 200×2^{-12} , corresponding to 2 seconds.
- $K_{earthmu}$: Constant, program notation "EARTHMU", scale factor B36, value $-3.986032E10 \times 2^{-36}$, corresponding to earth μ (units meters²/centi-second²).
- K_{ep10} : Constant, program notation "EP4(10)L", scale factor B0, units revolutions. Value is 0.027777777, corresponding to ten degrees.
- K_{ep45} : Constant, program notation "EP4(45)L", scale factor B0, units revolutions. Value is 0.125, corresponding to 45 degrees.
- K_{eps10} : Constant, program notation "EP4(10)H", scale factor B0, units revolutions. Value is 0.027777777, the same as K_{ep10} (duplicate storage in "high" part of memory).
- K_{eps45} : Constant, program notation "EP4(45)H", scale factor B0, units revolutions. Value is 0.125, the same as K_{ep45} .
- $K_{foursec}$: Constant, program notation "FOURSEC", scale factor B28, units centi-seconds. Value is 400×2^{-28} , corresponding to four seconds.
- $K_{mfourdt}$: Constant, program notation "-FOURDT", scale factor B16, units centi-seconds. Value is -800×2^{-18} , corresponding to $(-1) \times 200 \times 2^{-16}$, where first term is an equation factor, second is computing interval (i.e. 2 seconds), and third is scaling.

K_{minmag} : See Attitude Maneuvers (equivalent effect achieved to use of explicit constant, by checking most significant half of magnitude for 0).

K_{minmagr} : Dummy constant used to show effect of checking for magnitude of vector information, scale factor B30, units meters. Value is equivalent to 2^{-14} (cf. K_{minmag}), or 2^{16} meters.

K_{pbias} : Constant, program notation "PBIAS", scale factor B0, units revolutions. Value is -0.00597222222, corresponding to -2.15 degrees (the "pitch mechanical bias with thrust on"). Hence a PACTOFF input of +2.15 degrees would be considered to line up the bell in pitch along +X.

K_{tenb4} : Constant, program notation "TENBNK14", scale factor B4, value 10×2^{-4} , corresponding to 10. Used to correct for the fact that matrix elements of [QUADROT] are multiplied by 0.1 because of the cycle rate during Attitude Maneuvers.

K_{thetcon} : Constant, program notation "THETACON", scale factor B6, value 0.31830989×2^{-8} . Value corresponds to $\frac{1}{2} \times (1/2\pi) \times 2^{-6}$, where first term is an equation factor of one-half (to obtain half the central angle traveled during the burn), second converts from radians to revolutions, and third is scale factor.

K_{trims} : Constant, program notation "TRIMSCAL", scale factor B-13, value 1.07975111×2^{-1} . Value corresponds to $85.41 \times 1/(360 \times 3600) \times 2^{13}$, where first term is bit weight in arc seconds for PACTOFF and YACTOFF, second converts to revolutions, and third is scale factor.

K_{twodt} : Constant, program notation "TWO DT", scale factor B28, units centi-seconds. Value is 200×2^{-28} , corresponding to 2 seconds.

K_{ybias} : Constant, program notation "YBIAS", scale factor B0, units revolutions. Value is +0.00263888889, corresponding to +0.95 degrees (the "yaw mechanical bias with thrust on"). Hence a YACTOFF input of -0.95 degrees would be considered to line up the bell in yaw along +X.

KPRIMEDT: See Digital Autopilot TVC Routines.

MASS: See Digital Autopilot Interface Routines. Incorrect "double precision".

NBRCYCLP: Single precision counter, scale factor B14, of the number of cycles of DELVREF information that have been summed in DELVSUM. It is incremented in "UPDATEVVG" and reset in "SETUP.9". It is used for restart protection purposes (with NBRCYCLS, which is in the preceding cell), and also to update V_{gtig} by the suitable amount of BDT for the time elapsed since "S40.9" was established.

Testing Routines

SELFCHK Address set as initial condition for SELFRET in "STARTSB2"

Perform "SMODECHK" (will not return unless self-check is desired)

Proceed to "ERASCHK"

SMODECHK

SKEEP1 = Return address

Perform "CHECKNJ" (returns immediately if no new job waiting,
and otherwise returns after doing job(s))

If SMODE = +0:

Proceed to second line of "SMODECHK"

If |SMODE| ≤ 8:

SCOUNT = SCOUNT + 1

If SMODE = -0, proceed to address specified by SKEEP1

If |SMODE| = 1, 2, 3, 6, 7, or 8: (10₈ = decimal 8)

Proceed to address specified by SKEEP1

If |SMODE| = 4, proceed to "ERASCHK"

If |SMODE| = 5, proceed to "ROPECHK"

SMODE = 0 (magnitude exceeded 8)

Proceed to "SELFCHK"

PRERORS

If ERESTORE = 0, proceed to "ERRORS"

E_{SKEEP7} = SKEEP5_{dp}

ERESTORE = 0

Proceed to "ERRORS"

ERRORS

Inhibit interrupts (released upon return from alarm routine)

SFAIL = Return address (to routine calling "PRERORS" or "ERRORS")

ALMCADR = SFAIL

ERCOUNT = ERCOUNT + 1

Perform "ALARM2" (pattern 1102_g)

If SMODE = -0:

 Proceed to address specified by SFAIL

If SMODE > 0:

 SMODE = +0

Proceed to "SELFCHK"

ERASCHK

SKEEP2 = 1 (flag to check cells 0061_g - 1373_g)

EBANK = 0

SKEEP7 = 1461_g (first cell in bank 0 to be checked, since cells
0 - 60_g are "special" erasable cells)

SKEEP3 = 1777_g (last cell)

Proceed to "ERASLOOP"

ERASLOOP

Inhibit interrupts

SKEEP4 = EBANK (non-zero EBANK loads bits 11-9)

SKEEP5_{dp} = E_{SKEEP7}_{dp} (address also determined by EBANK)

ERESTORE = SKEEP7

E_{SKEEP7} = SKEEP7 (loads with own S-register address)

E_{SKEEP7+1} = SKEEP7 + 1

If E_{SKEEP7} - E_{SKEEP7+1} ≠ -1, perform "PRERORS"

If ERESTORE ≠ 0:

 E_{SKEEP7}_{dp} = - E_{SKEEP7}_{dp}

 If E_{SKEEP7+1} - E_{SKEEP7} ≠ -1, perform "PRERORS"

 If ERESTORE ≠ 0:

 E_{SKEEP7}_{dp} = SKEEP5_{dp}

 ERESTORE = 0

Verb Definitions

VERBFAN

If $\text{VERBREG} - K_{\text{st2cn}} < 0$:

Proceed to address specified by $K_{\text{vbt}}^{\text{VERBREG}}$

$\text{TS} = \text{VERBREG} - K_{\text{st2cn}}$

Perform "RELDSP"

Proceed to address specified by $K_{\text{st2fn}}^{\text{TS}}$

XACTALM

Set bit 7(Operator error) of channel 11 = 1

Proceed to "ENDEXT"

ALM/END

Set bit 7(Operator error) of channel 11 = 1

Proceed to "PINBRNCH"

TESTXACT

If $\text{EXTVBACT} > 0$:

Proceed to "ALM/END"

If bits 14(PRIODLE), 12(PDSPFLAG), and 7(PROWTKEY) of $\text{FLAGWRD4} \neq 0$:

Proceed to "ALM/END" (priority display using DSKY)

$\text{EXTVBACT} = 00024_8$ (sets bits 5 and 3 to 1)

$\text{TS} = -2$ and perform "NVSUB": if busy, proceed (blank R1-R3 and
otherwise, proceed noun)

Return

VBTLTSTS (verb 35)

If MODREG \neq 0, proceed to "ALM/END"
Inhibit interrupts (released as part of End of job)
Set bit 1 of IMODES33 = 1
Set bits 7(Operator error), 6(Flash), 5(Key Release), 4(Temperature Caution), 3(Uplink Activity), and 1(ISS Warning) of channel 11 = 1
DSPTAB+11 = 00650₈ and flag for output at next opportunity
(bit 9 is Program alarm, bit 8 Tracker alarm, bit 6 Gimbal lock, and bit 4 is No attitude)
Set bit 10(Test DSKY lights) of channel 13 = 1
Set DSPTAB+0 to DSPTAB+10 so that all registers display "8" and R1, R2, and R3 display plus signs, and flag for output at next opportunity
NOUT = 11
Call "TSTLTS2" in K_{shots} seconds
End of job

TSTLTS2

Establish "TSTLTS3" (priority 30₈)
End of task

TSTLTS3

Set bits 7, 4, 3, and 1 of channel 11 = 0
Set bit 10 of channel 13 = 0
TS = bit 4(Coarse align) of channel 12
DSPTAB+11 = TS, and flag for output at next opportunity (bit 4 is No attitude)
Set bit 1 of IMODES33 = 0
Set bits 13-11 of IMODES33 = 1
Set bit 15 of IMODES30 = 0
Set bits 13,12,10 of IMODES30 = 1
Set bit 7 of OPTMODES = 1
Establish "DSPMMJB" (priority 30₈)

↑ Note that bit 9, Program alarm, set 0 even if FAILREG+0 \neq 0.

ATTACHIT

Perform "INTSTALL"

Set bit 11(LMOONFLG) of FLAGWRD8 = 1

If bit 12(CMOONFLG) of FLAGWRD8 = 0:

Set bit 11(LMOONFLG) of FLAGWRD8 = 0

Inhibit interrupts

$R_{\text{rectlm}} = R_{\text{rectcm}}$

$V_{\text{rectlm}} = V_{\text{rectcm}}$

$T_{\text{etlm}} = T_{\text{etcm}}$

$\text{DELTA}V_{\text{lm}} = \text{DELTA}V_{\text{cm}}$

$\text{NUV}_{\text{lm}} = \text{NUV}_{\text{cm}}$

$\text{RCV}_{\text{lm}} = \text{RCV}_{\text{cm}}$

$\text{VCV}_{\text{lm}} = \text{VCV}_{\text{cm}}$

$T_{\text{clm}} = T_{\text{ccm}}$

$\text{XKEP}_{\text{lm}} = \text{XKEP}_{\text{cm}}$

Proceed to "TACHEXIT" (NOTE that Average-G cells R and V written over)

V67 (verb 67)

Perform "TESTXACT"

Establish "V67CALL" (priority 05₈)

End of job

STROKON (verb 68)

If bits 15-14 (DAPBIT1, DAPBIT2) of FLAGWRD6 $\neq 10_2$:

Proceed to "ALM/END" (not TVC DAP)

Establish "STRKTSTI" (priority 30₈)

Proceed to "PINBRNCH"

V70UPDAT (verb 70)

See Uplink Processing

V71UPDAT (verb 71)

See Uplink Processing

V72UPDAT (verb 72)

See Uplink Processing

V73UPDAT (verb 73)

See Uplink Processing

DNEDUMP (verb 74)

DNTMGOTO = "DNDUMPI"

Proceed to "PINBRNCH"

LEFTFLGON (verb 75)

Set bit 5(BKUPLO) of FLAGWRD5 = 1

Proceed to "PINBRNCH"

SETPRFLG (verb 76)

Set bit 10(PRFTRKAT) of FLAGWRD5 = 1

Proceed to "PINBRNCH"

RESETPRF (verb 77)

Set bit 10(PRFTRKAT) of FLAGWRD5 = 0

Proceed to "PINBRNCH"

CHAZFOGC (verb 78)

If MODREG \neq 02, proceed to "ALM/END"

Establish "AZMTHCG1" (priority 16_g)

Proceed to "PINBRNCH"

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