

APOLLO GUIDANCE COMPUTER

Information Series

Issue 21

SYSTEM TEST

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21-1. INTRODUCTION

21-2. This is the twenty-first issue of the AGCIS which is published to inform the technical staff at MIT/IL and Raytheon about the Apollo guidance computer (AGC) subsystem. This issue contains a description of program section System Test which is used to measure certain performance parameters of the Inertial Measurement Unit (IMU). (Issue 15 contains a general description of all Block I AGC programs and program sections in paragraph 15-98 through 15-203.)

21-3. System Test has the characteristic of a Mission Function in that it updates the DSKY PROGRAM displays. However, System Test differs from the other Mission Functions because it has no Phases and therefore has no restart capability. System Test provides for two major tests under the auspices of Jobs LGNTEST1 and PIPTEST1. These Jobs are requested during the execution of Extended Verb Routines DOGDRIFT and DOPIPTST respectively, initiated via keyboard entries (paragraphs 14-227 and 14-232). These Jobs are terminated only by the operator when he takes a VERB, 3, 4, (Verb Terminate) ENTER keyboard action in response to the flashing of the VERB and NOUN displays. (If a GOJAM occurs during the execution of a System Test Job, the Job is terminated although instruction TC ENDOFJOB is never executed. For further detail refer to Issue 16.)

21-4. Job LGNTEST1 (figure 21-1) performs the following operations:

- a. Displays test site latitude and specified test position on the DSKY's (Routines LGNTEST1, LGNTEST4, and DSPLLOAD).
- b. Determines navigation base position (FINDNB2).
- c. Aligns stable member to the specified test position (PUTPOS).
- d. Calculates earth-rate correction vector (LGNINIT).
- e. Corrects stable member position for earth-rate compensation every 10 sec for 30 sec. (LGNTEST3, WAITLOP4, EARTHTRAS and OUTGYRO).
- f. Applied earth-rate correction to gyro on the vertical axis every 10 sec for two 5-min intervals (LGNTEST3, WAITLOP4, EARTHTRAS and OUTGYRO).
- g. Calculates and displays the first 5 min. time interval during which earth-rate correction was applied to the gyro on the vertical axis (LGNTEST5, PIPDSPLY, and DISPLAYR).

- h. Calculates and displays the change in the PIPA counters for the PIPA's on the east and south axes during the first time interval. (LGNTTEST5, PIPDSPLY, and DISPLAYR).
- i. Repeats steps g and h for the second 5 min time interval.
- j. Repeats steps a through i for test positions as specified by the operator.

From the information displayed as a result of executing Job LGNTTEST1 for each of the nine test positions, the following IRIG parameters can be determined:

- a. Noncompensated bias drift of the X, Y, and Z IRIG's (NBD_N) which is defined as the gyro drift not dependent on gravity.
- b. Drift of the X, Y, and Z IRIG's due to 1 g acceleration along the positive input axis ($ADIAN$).
- c. Drift of the X, Y, and Z IRIG's due to 1 g acceleration along the positive spin reference axis ($ADSRAN$).

The procedures for performing this System Test are defined in JDC 10030-D of Assembly Test Procedure 1015000D. However, before the results obtained and displayed by Job LGNTTEST1 can be utilized, System Test Job PIPTEST1 must have been performed according to JDC 10029-E and the displayed test results recorded and used to determine the PIPA scale factors.

21-5. JOB PIPTEST1 (figure 21-1) performs the following operations:

- a. Determines navigation base position (FINDNB2).
- b. Displays latitude of Test Site to the operator (PIPTTEST1, PIPTEST4 and DSPLLOAD).
- c. Aligns stable member to specified test position (PUTPOS).
- d. Calculates earth-rate correction vector (LGNINIT).
- e. Sets up a 5 min settling loop during which time vertical erection and earth rate torquing are performed every 10 sec.
- f. Synchronizes the reading of the time counters with the reception of a PIPA pulse from the PIPA on the vertical axis. (CATCHAPP).
- g. Sets up a 90 sec loop during which time vertical erection and earth rate torquing are performed every 10 sec.
- h. Repeats steps f.
- i. Calculates and displays $g = 5.85 \frac{\Delta v}{\Delta t}$ where Δv is the difference in PIPA readings from the beginning to the end of the 90 sec interval Δt .
- j. Increments test position and repeats steps b through i for test positions 2 through 6 as directed by the operator.

From the information displayed as a result of executing JOB PIPTTEST1 for each of the six positions, the operator is able to determine the X, Y, and Z PIPA scale factors. These scale factors convert the output of the PIPA counters from pulses to velocity in cm/sec.

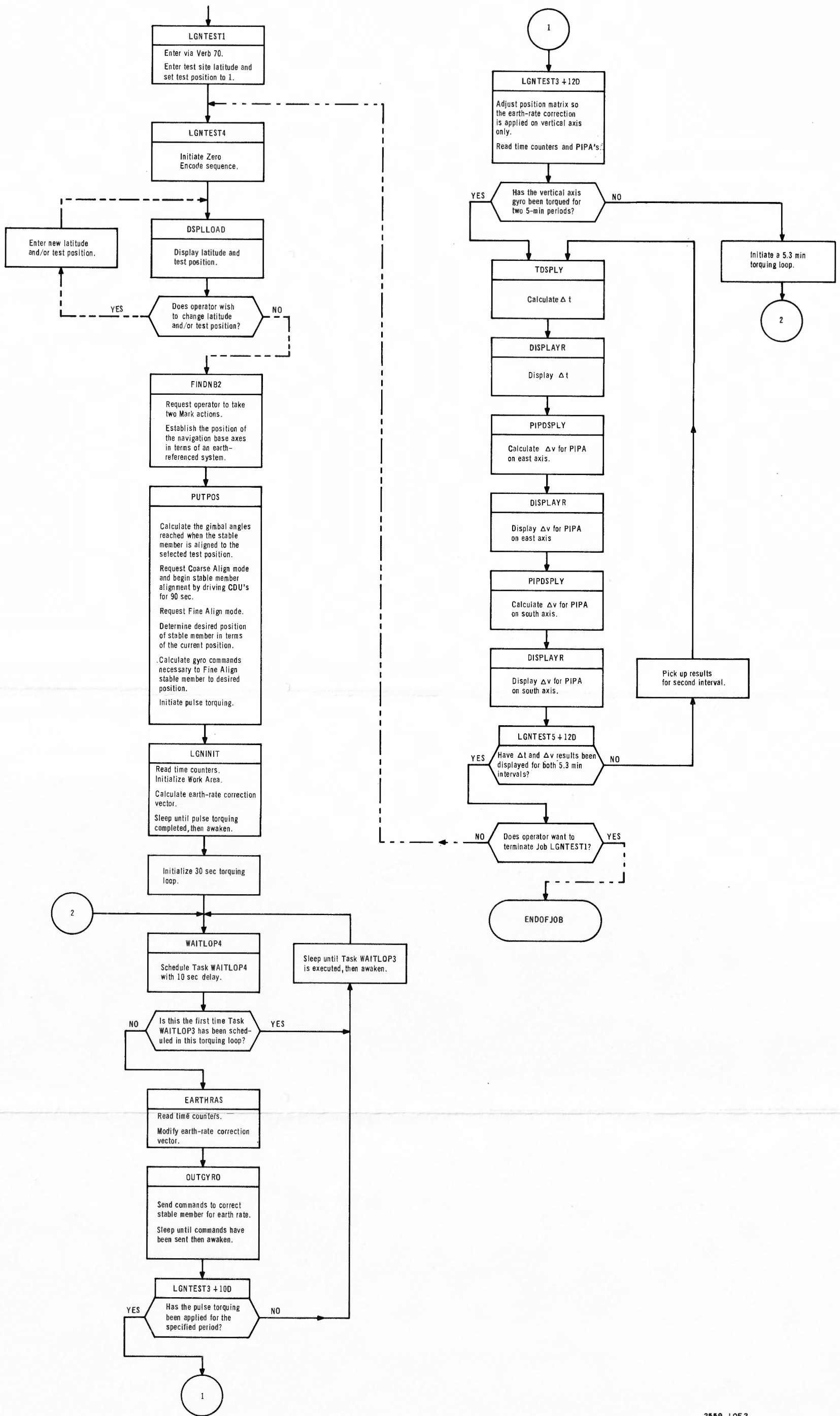
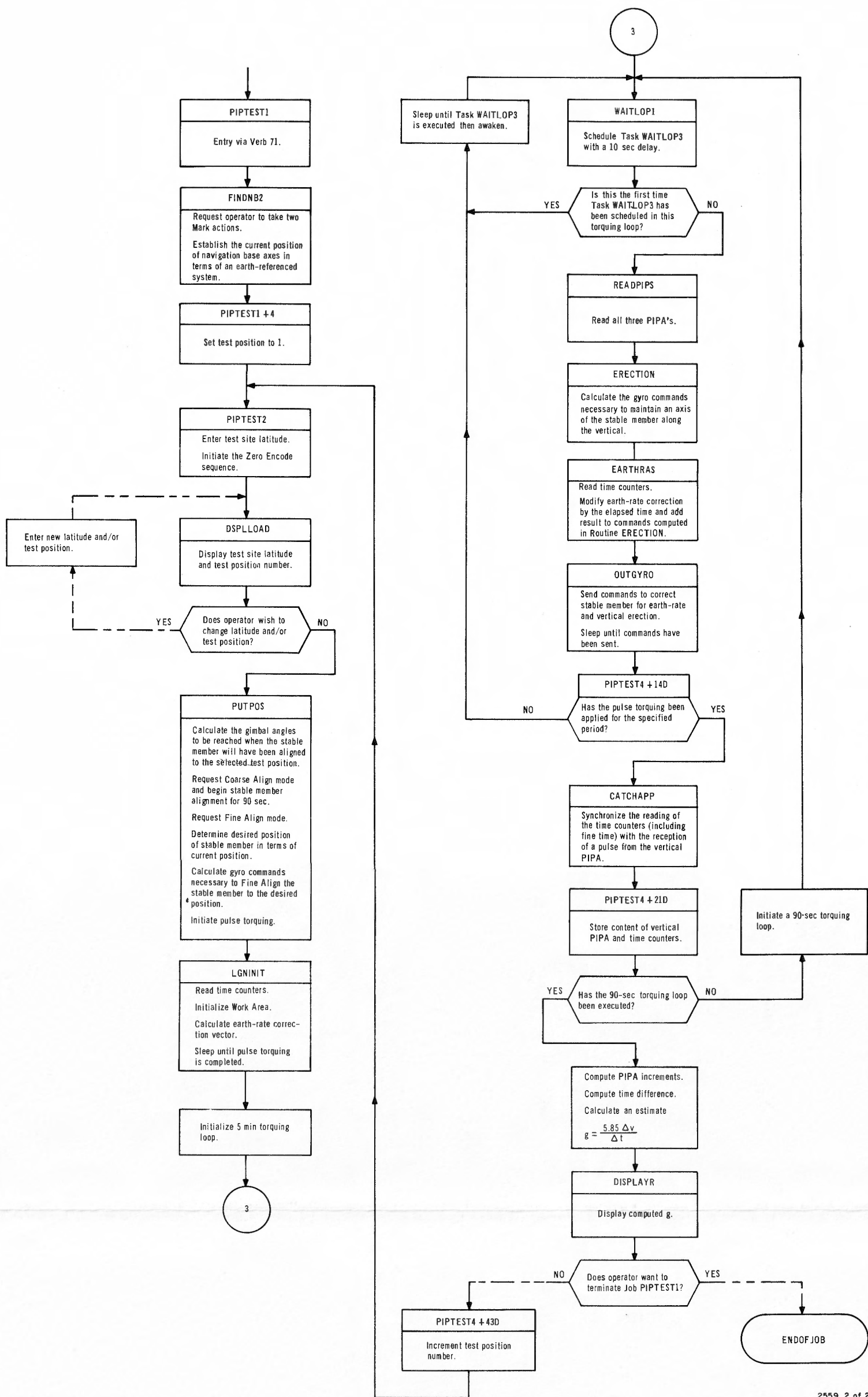


Figure 21-1. Jobs LGNTEST1 and PIPTEST1 (Sheet 1 of 2)



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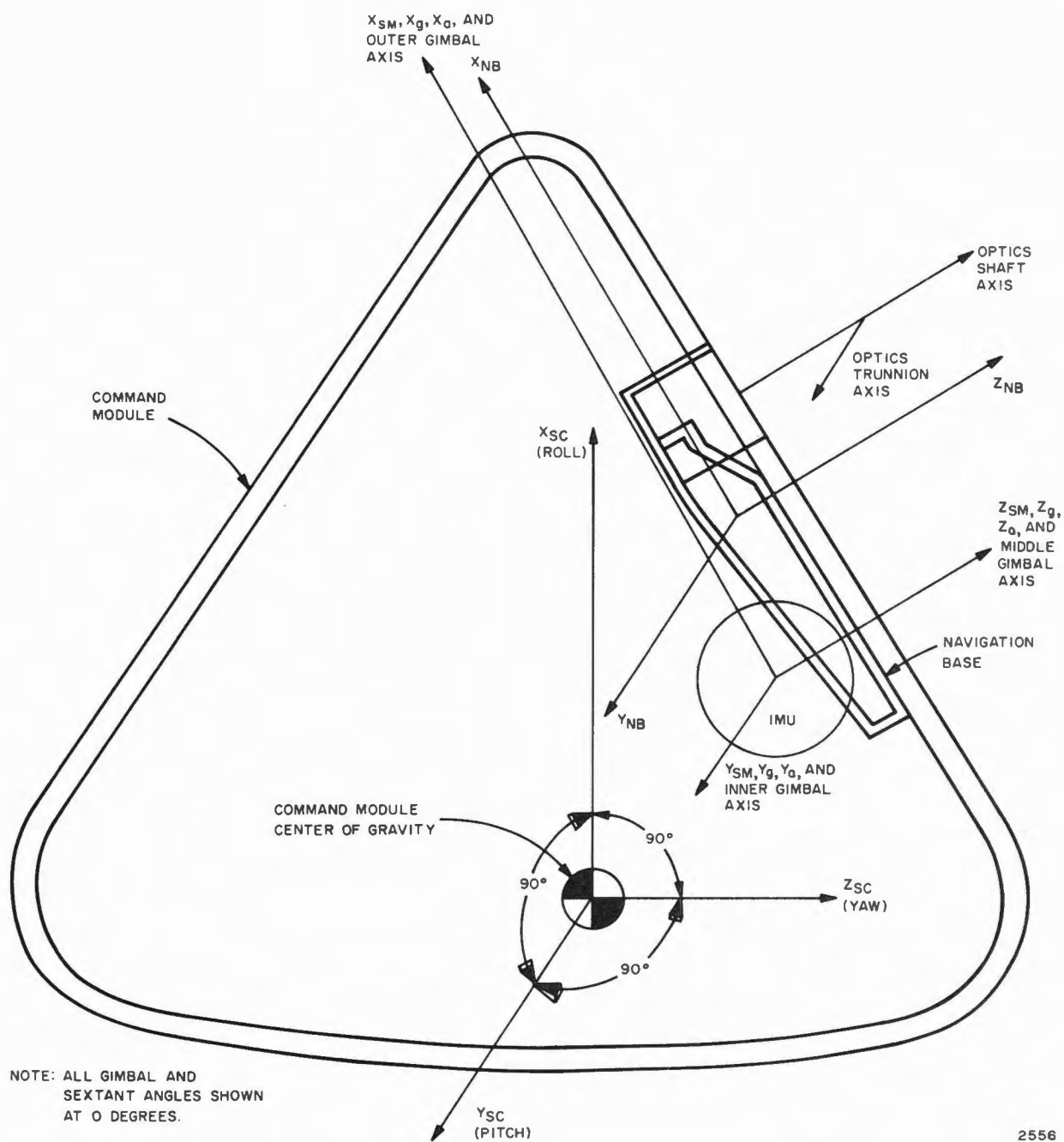
Figure 21-1. Jobs LGNTEST1 and PIPTEST1 (Sheet 2 of 2)

21-6. JOB LGNTEST1

21-7. FUNCTIONAL DESCRIPTION

21-8. Prior to requesting System Test Job LGNTEST1, the operator is advised to ensure that the Guidance and Navigation Mounting Fixture is tilted to $32.5 (\pm 0.5)$ degrees. [The Spacecraft body axes are orthogonal and fixed to the Spacecraft at its center of gravity. The Y axis of the Spacecraft (Y_{SC}) is parallel to the Y axis of the navigation base (Y_{NB}) while the X and Z axes of the Spacecraft (X_{SC} and Z_{SC}) are displaced from the X and Z axes of the navigation base (X_{NB} and Z_{NB}) by approximately 33° , figure 21-2]. The operator is then instructed to set the TRANSFER switch on the IMU Control Panel to COMPUTER. The operator requests the execution of Job LGNTEST1 by keying in VERB, 7, 0, (Do Gyro Drift Test) ENTER. Upon depressing key ENTER, Job CHARIN executes Routine DOGDRIFT (paragraph 14-227) which displays the quantity 04 (System Test) in the PROGRAM displays and requests the execution of Job LGNTEST1. Since it is probable that there are no other Jobs awaiting execution, Job LGNTEST1 begins execution almost immediately and the ZERO ENCODER indicator on the Condition Annunciator (figure 14-5) should be illuminated. As the ZERO ENCODE sequence is executed, indicator switches ZERO ENC, COARSE ALIGN, FINE ALIGN, ATT CONT, and FINE ALIGN on the IMU Control Panel (figure 14-2) should be illuminated sequentially. While the Job is executing the Zero Encode Sequence, Verb code 06 (Display in decimal all components of) is displayed in the VERB displays and Noun Code 66 (System Test results) is displayed in the NOUN displays. The quantities +01928, +04047, and +00001 are displayed in display registers R1, R2, and R3 respectively for operator verification. The quantities in R1 and R2 represent the test site latitude and the quantity in R3 represents the current test position. Simultaneously the VERB and NOUN displays flash to alert the operator to the fact that he must take a keyboard action.

21-9. If the operator is at MIT/IL and if he wishes to perform the test with the stable member in position 1, he takes a VERB, 3, 3, (Proceed) ENTER keyboard action. Should the operator wish to modify either the test site latitude or the stable member test position, he must take either or both of the following two actions. If the operator is at a test site, other than MIT/IL he must key in VERB, 2, 4, (Write 1st and 2nd components into) NOUN, 0, 1, (Specify machine address fractional) ENTER, 0, 0, 7, 6, 3, (machine address) ENTER, +, X, X, X, X, X, ENTER +, Y, Y, Y, Y, Y,



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Figure 21-2. Spacecraft Axes

ENTER where the X's and Y's represent the high and low order parts of the test site latitude respectively, scaled by 2π . Upon depressing key ENTER the fourth time, the quantity displayed in R2 is the same as the Y quantity keyed in; however, the quantity displayed in R1 is derived from the X's keyed in but due to the scaling specified by Verb 06 and Noun 66, the display is not the same as the quantity keyed in. (Refer to JDC 10030-D for the correct quantities to key in and the quantities displayed if the operator is not at MIT/IL.) When display registers R1, R2, and R3 contain the correct information, the operator keys in Verb Proceed.

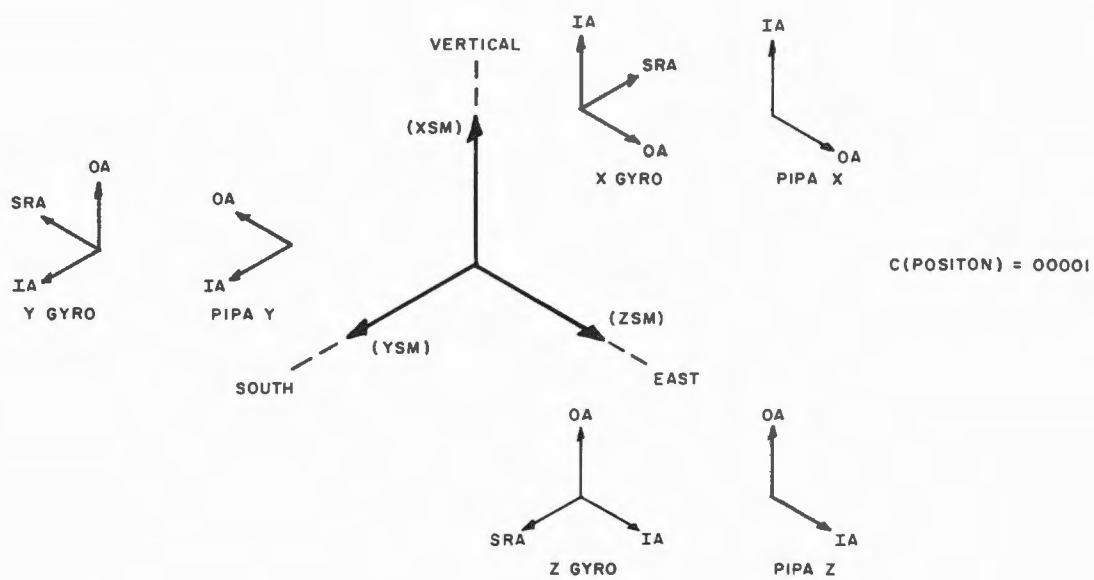
21-10. If the operator does not wish to align the stable member to the test position specified by R3, he keys in VERB, 2, 1, (Write 1st component into) NOUN, 0, 2, (Specify machine address whole) ENTER, 0, 1, 2, 0, 5, ENTER, +, 0, 0, 0, 0, Z, ENTER where Z is a digit from one to nine indicating the new test position to be specified. (The alignment positions of the stable member are shown in figure 21-3.) The IRIG coefficient to be tested as a result of this alignment is shown in table 21-1. Upon depressing key ENTER the third time, the quantity keyed in (Z) is displayed in R3. When the quantities displayed in R1, R2, and R3 are correct, the operator keys in Verb Proceed. The test position number is recorded by the operator from display R3.

21-11. Upon keying in Verb Proceed, Verb code 51 (Please Mark) is displayed in the VERB displays, NOUN code 30 (Star Numbers) is displayed in the NOUN displays, and the VERB and NOUN displays flash. The quantity 00001 is displayed in R1 and the quantity 00002 is displayed in R2. These quantities are codes referring to stars (in this case collimators) upon which Marks are to be taken. (The flashing of the VERB and NOUN displays is initiated to alert the operator to the fact that he must take a Mark action.)

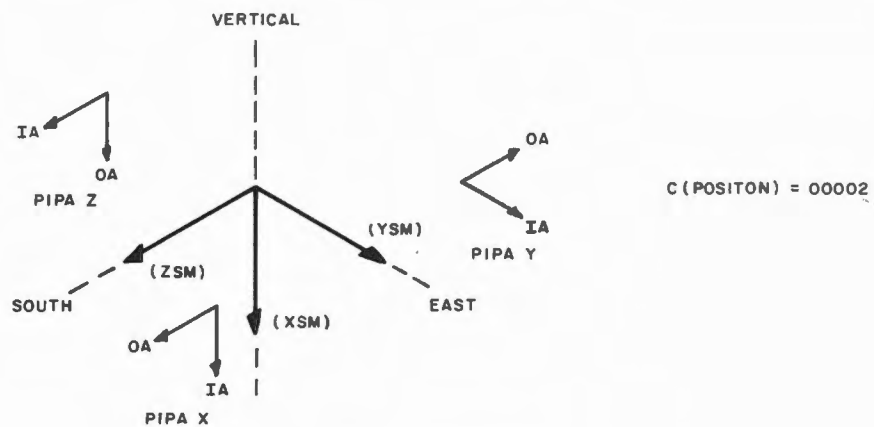
21-12. When the operator recognizes the request to take a Mark action, he ensures that the following controls on the Optics Control Panel (figure 21-4) are in the positions indicated:

- a. Sextant Power Switch to ON.
- b. Optics Controller Mode Switch to DIRECT.
- c. Optics Mode Selector to ZERO OPTICS.
- d. Controller Speed Switch to MED.

When the ZERO ENCODER indicator on the Condition Annunciator is extinguished, the Optics Mode Selector is set to MANUAL and the operator begins to position the sextant (by use of the CDU thumbwheels, the Control Stick, and the sextant eyepiece) to the positions indicated by the

R₃ Display = +00001

Job	Read	Determine
LGNTST1 PIPTST1	PIPA Z, PIPA Y * PIPA X	NBD _Y PIPA X Scale Factor

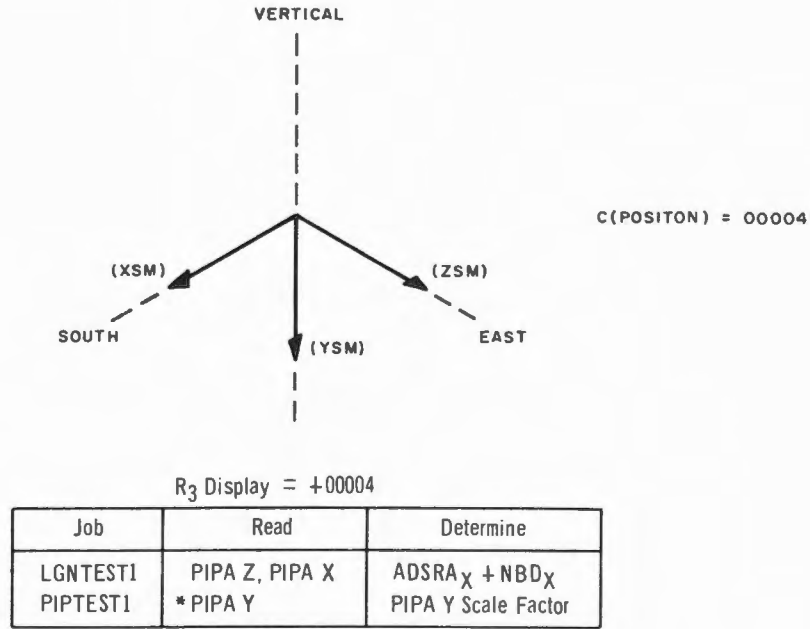
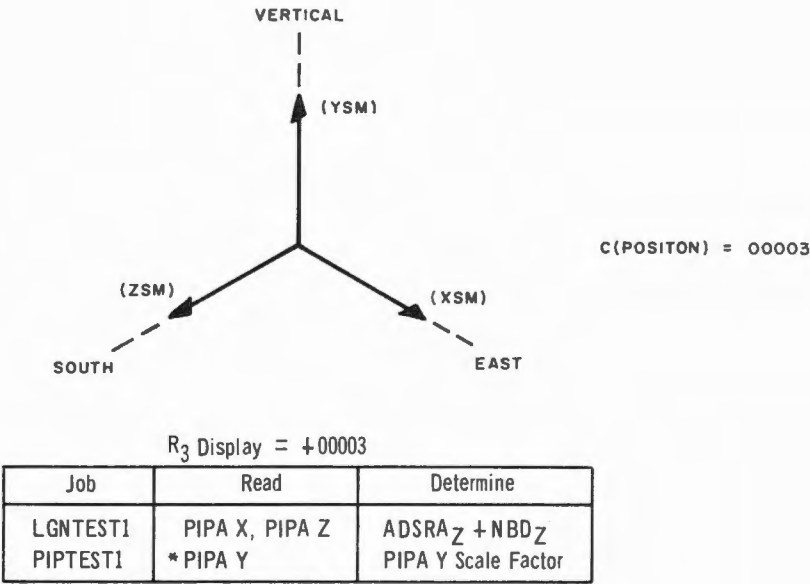
R₃ Display = +00002

Job	Read	Determine
LGNTST1 PIPTST1	PIPA Y, PIPA Z * PIPA X	NBD _Z PIPA X Scale Factor

* Other PIPA's read but not for calculation of Scale Factor.

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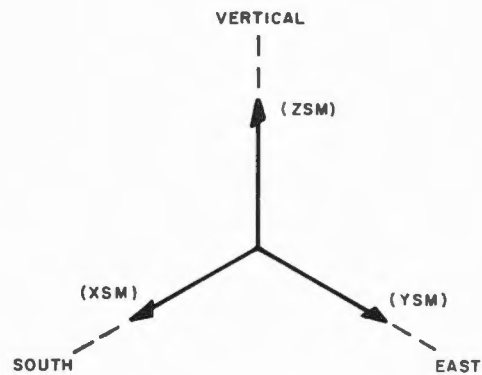
Figure 21-3. Stable Member Alignment Positions (Sheet 1 of 4)



* Other PIPA's read but not for calculation of Scale Factor.

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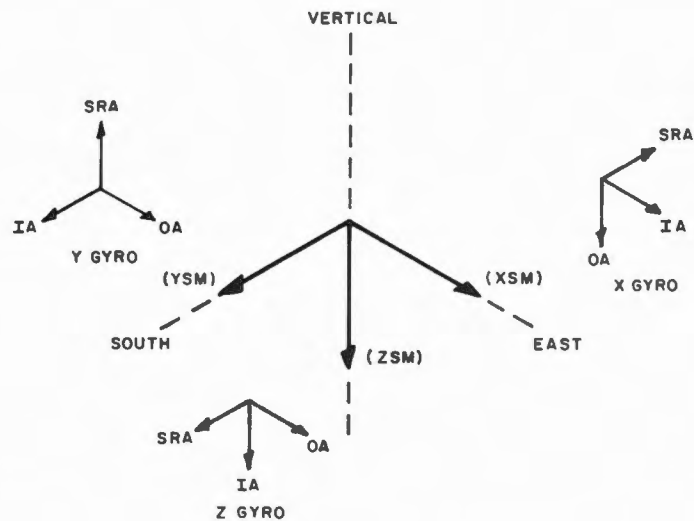
Figure 21-3. Stable Member Alignment Positions (Sheet 2 of 4)



C(POSITON) = 00005

R₃ Display = +00005

Job	Read	Determine
LGNTST1 PIPTST1	PIPA Y, PIPA X *PIPA Z	NBD _X PIPA Z Scale Factor



C(POSITON) = 00006

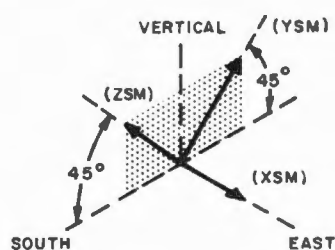
R₃ Display = +00006

Job	Read	Determine
LGNTST1 PIPTST1	PIPA X, PIPA Y *PIPA Z	ADSRAY + NBD _Y PIPA Z Scale Factor

* Other PiPA's read but not for calculation of Scale Factor.

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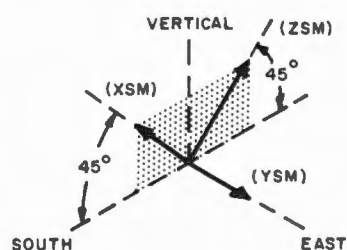
Figure 21-3. Stable Member Alignment Positions (Sheet 3 of 4)



C (POSITON) = 00007

R₃ Display = +00007

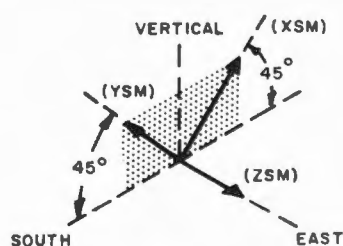
Job	Read	Determine
LGNTTEST1	PIPA X	$1/2 \text{ ADIA}_{Z-Y} + 1/2 \text{ ADSRA}_Z + Y + \frac{\sqrt{2}}{2} \text{ NBD}_{Z-Y}$



C (POSITON) = 00010

R₃ Display = +00008

Job	Read	Determine
LGNTTEST1	PIPA Y	$1/2 \text{ ADIA}_{X-Z} + \frac{\sqrt{2}}{2} \text{ NBD}_{X-Z}$



C (POSITON) = 00011

R₃ Display = +00009

Job	Read	Determine
LGNTTEST1	PIPA Z	$1/2 \text{ ADIA}_{-X} + Y + 1/2 \text{ ADSRA}_X + \frac{\sqrt{2}}{2} \text{ NBD}_{-X} + Y$

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Figure 21-3. Stable Member Alignment Positions (Sheet 4 of 4)

content of R1. (R1 contains 00001 indicating collimator #1. Refer to JDC 10030-D of ATP 1015000D for further details on positioning the Sextant.) When the operator is satisfied with the alignment, he depresses the MARK button and then keys in Verb 52 (Mark Accept). (Refer to paragraphs 17-15 and 17-23 for the action taken by the AGC when the operator depresses key MARK or keys in Verb 52.) The operator then aligns the sextant to collimator #4 as specified by the contents of R2 (00002). When the alignment is satisfactory, he again depresses the MARK button and keys in Verb 52.

21-13. After the requested Mark information has been entered into the computer, the AGC controls the alignment of the stable member to the specified position. While the alignment takes place, the IMU is switched into the Coarse Align and the Fine Align modes. (The GIMBAL LOCK indicator on the Condition Annunciator may light.) After the alignment, the stable member position is corrected for earth rate three times, (every 10 sec for 30 sec). Then the gyro with its input axis vertical is torqued every 10 sec to correct for earth rate for two 5-min intervals. The PIPA's (on the nonvertical axes) and the Time counter readings are taken at the beginning and at the end of both intervals. This procedure takes about 16 min including alignment.

21-14. When the alignment is complete, the VERB and NOUN displays flash Verb code 06 and Noun code 66 respectively, the high order time difference of the first interval (about 300 sec) is displayed in R1 (interpreted as TTTT.0 sec) and the low order time difference is displayed in R2 (interpreted as 0. TTTT sec). The quantity +01000 is displayed in R3 to identify the quantities in R1 and R2 as the Δt for the first torquing interval. The operator is then instructed to record the information displayed in R1 and R2 and to key in Verb Proceed. (If at any time the operator keys in Verb Terminates in response to the flashing of the VERB and NOUN displays, the quantity 00 would be displayed in the PROGRAM displays and the System Test Job would be terminated.) Upon keying in Verb Proceed, the difference (ΔV) in the readings of one of the PIPA's (from the beginning to the end of the first time interval) is displayed in R1. The quantity 00000 is displayed in R2 and identification number +01001 is displayed in R3 to identify the quantity in R1 as the ΔV of the PIPA on the east axis during the first torquing interval. The content of the VERB and NOUN displays remains unchanged. The operator is instructed to record the data in R1 and R3 and to key in Verb Proceed in response to the flashing of the VERB and NOUN displays. Upon keying in Verb Proceed, the difference (ΔV) in the readings of the other PIPA is displayed in R1 (R2 remains unchanged) and the identification quantity +01002 is displayed in R3 to identify the quantity in R1 as the ΔV of the PIPA on the south axis during the first torquing interval.

21-15. The operator is then instructed to record the data in R1 and in R3 and then to key in Verb Proceed. The high order time difference of the second torquing interval (about 300 sec) is displayed in R1 and the low order part in R2. The identification quantity +01003 is displayed in R3 to identify the quantity in R1 and R2 as the Δt for the second torquing interval. The operator is instructed to record the data in R1 and in R2 and to key in Verb Proceed. The difference in the counter readings (ΔV) of one of the PIPA's between the beginning and the end of the second time interval is displayed in R1 and the identification quantity +01004 in R3 to identify the quantity in R1 as the ΔV of the PIPA on the east axis for the second torquing interval. The quantity 00000 is displayed in R2. The operator is instructed to record the data in R1 and in R3 and to key in Verb Proceed. The difference of the other PIPA counter readings is displayed in R1 and the identification quantity +01005 is displayed in R3 to identify the quantity in R1 as the ΔV of the PIPA on the south axis for the second torquing interval. At this point if the operator wishes to terminate the System Test Job, he keys in Verb Terminate in response to the flashing of the VERB and NOUN displays. Otherwise he keys in Verb Proceed which causes the System Test Job to redisplay the site latitude and current test position to the operator. At this point, the operator must change the test position (paragraph 21-10) if he wishes the System Test Job to continue with the stable member in another position. However, he need not again specify the test site location.

21-16. PRELIMINARY INITIALIZATION

21-17. Job LGNTEST1 (attachment 21-1), scheduled whenever the operator keys in VERB, 7, 0, ENTER, begins execution at Routine LGNTEST1. Routine LGNTEST1 enters the quantity 00001 into register POSITON to indicate that testing will normally begin at test position 1 and transfers program control to Routine GRABUSY (paragraph 17-213) to "grab" program section Pinball for its use. If Pinball is being used by another non-CHARIN Job, Routine PREGBSY (paragraph 17-212) is executed to put Job LGNTEST1 into the dormant state until the Job that had previously grabbed Pinball frees it. Once Job LGNTEST1 has grabbed Pinball for its own use, the double precision quantity [03610; 01224], which represents the MIT/IL latitude scaled by 2π , is transferred to registers LATITUDE and LATITUDE+1.

21-18. Routine LGNTEST4 forces the quantity 77777 into register CDUIND to indicate that the IMU CDU's are available for driving without checking their current status. (There is no need to check the status of the IMU CDU's as there should be no other Job using them when a

Table 21-1
SIGNIFICANCE OF c(POSITON)

c(POSITON) as displayed in R3	Alignment Position (Vertical, South, East)		IRIG Coefficient to be Tested
	XSM axis	YSM axis	
+00001	(1, 0, 0)	(0, 1, 0)	Non-compensated bias drift of the Y IRIG (+NBD _Y). This is the drift which is not dependent on g.
+00002	(-1, 0, 0)	(0, 0, 1)	Non-compensated bias drift of the Z IRIG (+NBD _Z).
+00003	(0, 0, 1)	(1, 0, 0)	ADSRA _Z + NBD _Z where ADSRA _Z is the drift of the Z IRIG due to 1g acceleration along the positive spin reference axis.
+00004	(0, 1, 0)	(-1, 0, 0)	ADSRA _X + NBD _X where ADSRA _X is the drift of the X IRIG due to 1g acceleration along the positive spin reference axis.
+00005	(0, 1, 0)	(0, 0, 1)	Non-compensated bias drift of the X IRIG (+NBD _X).
+00006	(0, 0, 1)	(0, 1, 0)	ADSRA _Y + NBD _Y where ADSRA _Y is the drift of the Y IRIG due to 1g acceleration along the positive spin reference axis.

Table 21-1
SIGNIFICANCE OF c(POSITON) (cont)

c(POSITON) as displayed in R3	Alignment Position (Vertical, South, East)		IRIG Coefficient to be Tested
	XSM axis	YSM axis	
+00007	(0, 0, 1)	$(\frac{\sqrt{2}}{2}, -\frac{\sqrt{2}}{2}, 0)$	$1/2 (ADIA_X - ADIA_Y) + 1/2 (ADSRA_Z + ADSRA_Y) + \frac{\sqrt{2}}{2} (NBD_Z - NBD_Y)$ where $ADIA_n$ is the drift of the nth IRIG due to 1g acceleration along the positive input axis.
+00008	$(\frac{\sqrt{2}}{2}, \frac{\sqrt{2}}{2}, 0)$	(0, 0, 1)	$1/2 (ADIA_X - ADIA_Z) + \frac{\sqrt{2}}{2} (NBD_X - NBD_Z)$
+00009	$(\frac{\sqrt{2}}{2}, -\frac{\sqrt{2}}{2}, 0)$	$(\frac{\sqrt{2}}{2}, \frac{\sqrt{2}}{2}, 0)$	$1/2 (ADIA_Y - ADIA_X) + 1/2 ADSRA_Y + \frac{\sqrt{2}}{2} (NBD_Y - NBD_X)$

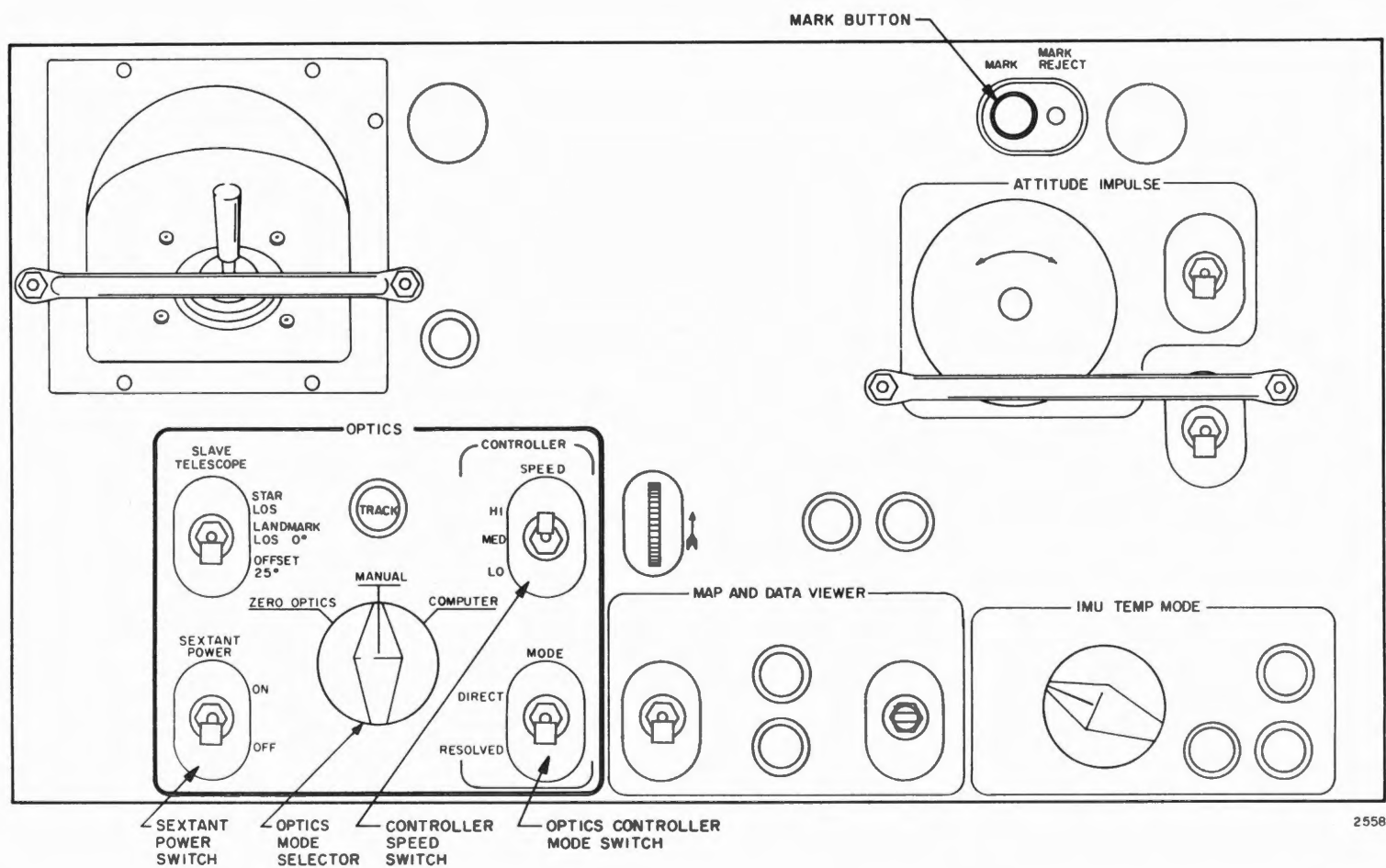


Figure 21-4. Optics Control Panel

System Test Job is executed.) Program control is then transferred to Routine IMUZERO via Routine BANKCALL to request that the Zero Encode Sequence (paragraph 14-17) be initiated. After the request has been initiated, program control is transferred to Routine DSPLLOAD to request a decimal display of the content of registers LATITUDE, LATITUDE+1, and POSITON and to allow the operator the option of changing the content of these locations if he is not at MIT/IL or if he does not wish to continue IRIG tests with the test position displayed.

21-19. Routine DSPLLOAD (figure 21-5) transfers the content of registers LATITUDE, LATITUDE+1 and POSITON to registers DSPTEM2, DSPTEM2+1 and DSPTEM2+2 respectively. The flashing of the DSKY VERB and NOUN displays is initiated (as described in paragraph 17-269) to alert the operator to the fact that he must take a keyboard action. The quantity 00666 is transferred to register A and program control is transferred to Routine NVSUB (paragraph 17-194). If the operator is using Pinball, program control is transferred to Routine PRENVBSY to put Job LGNTEST1 into the dormant state until the operator releases Pinball for internal use by depressing key KEY RLSE. Throughout the rest of this issue, whenever a call is made to Routine NBSUB, it will be assumed that the operator does not have control over Pinball. This assumption is valid since, although the operator uses Pinball when he responds to the flashing of the VERB and NOUN displays, the routines executed as a result of this response release Pinball for internal use prior to terminating (paragraph 17-436). If the operator is not using Pinball, Routine NVSUB decodes the quantity 00666 yielding Verb 06 Noun 66. Since the Verb code is 06, Routine NVSUB transfers program control to Verb Routine DECDSP (paragraph 17-343) to request a decimal display. Since the Noun code is 66, the content of registers DSPTEM2, DSPTEM2+1 and DSPTEM2+2 is scaled whole, fractional, and whole. Thus the quantity displayed in R1 is +01928, in R2 +04047, and in R3 +00001. Routine DSPLLOAD then transfers program control to Routine ENDIDLE to put System Test Job LGNTEST1 into the dormant state until the operator responds to the flashing of the VERB and NOUN displays which at this point indicate 06, 66 respectively. When the operator responds to the flashing, Job LGNTEST1 is reactivated and the flashing of the VERB and NOUN displays is terminated.

21-20. If the operator is at MIT/IL and he wishes to perform the system tests at the position displayed, he keys in VERB, 3, 3, (Proceed) ENTER. When the System Test Job is reactivated, program control is transferred back to Routine LGNTEST1 (attachment 21-1) where Routine FINDNB2 is executed to establish the position of the navigation base and of the stable member (as described in paragraph 21-26).

21-21. If the operator is not at MIT/IL, he may request a data load of the LATITUDE registers by taking a VERB, 2, 4, NOUN, 0, 1, ENTER, 00763, ENTER, +, X, X, X, X, X, ENTER, +, Y, Y, Y, Y, Y, ENTER keyboard action where the double precision quantity [XXXXXX; YYYYYY] represents the latitude, scale by 2π , of the site at which the test is to be performed. Upon depressing key ENTER the fourth time, Job LGNTEST1 is reactivated and program control is again transferred to Routine DSPLLOAD and the new latitude is displayed in R1 and R2. (Due to the scaling used by Noun 66, the quantity displayed in R1 is not the same as the quantity keyed in. For example, if the operator were to key in the scaled latitude for ACSP then XXXXX = +11916 and YYYYY = +45195.) Upon depressing key ENTER the fourth time, R1 would display the quantity +01952, R2 would display the quantity +45195, and R3 would remain unchanged.

21-22. If the operator does not wish to perform a test with the position displayed, he may enter the desired position number into register POSITON by keying in VERB, 2, 1, NOUN, 0, 2, ENTER, +, 0, 0, 0, 0, Z, ENTER where Z is a digit from 1 to 9 indicating the desired test position. Upon depressing key ENTER the second time, the System Test Job is reactivated; when this Job is executed, program control is transferred back to Routine DSPLLOAD to display the new content of register POSITON.

21-23. If the operator wants to terminate the System Test Job, he keys in VERB, 3, 4, (Terminate) ENTER. When Job LGNTEST1 continues execution, program control is transferred to Routine ENDTSDSP. Routine ENDTSDSP transfers program control to Routine FREEDSP (paragraph 17-202) to free Pinball for internal use. A ZERO is entered into bit position 3 of register MODREG indicating that the System Test Job is being terminated and program control is transferred to Routine DSPMM (paragraph 17-470) to display the updated content of register MODREG to the operator. Then the quantity 77777 is entered into register CDUIND to indicate that the CDU's are available for driving. Finally, program control is transferred to Routine MKRELEAS (paragraph 14-132) to free the Mark system for other users and instruction TC ENDOFJOB is executed to terminate System Test Job LGNTEST1.

21-24. ESTABLISHING THE NAVIGATION BASE POSITION

21-25. Routine FINDNB2 is executed after the operator keys in Verb Proceed in response to a display of the content of the LATITUDE registers and register POSITON. This routine uses the sextant to find the position of the navigation base and the stable member.

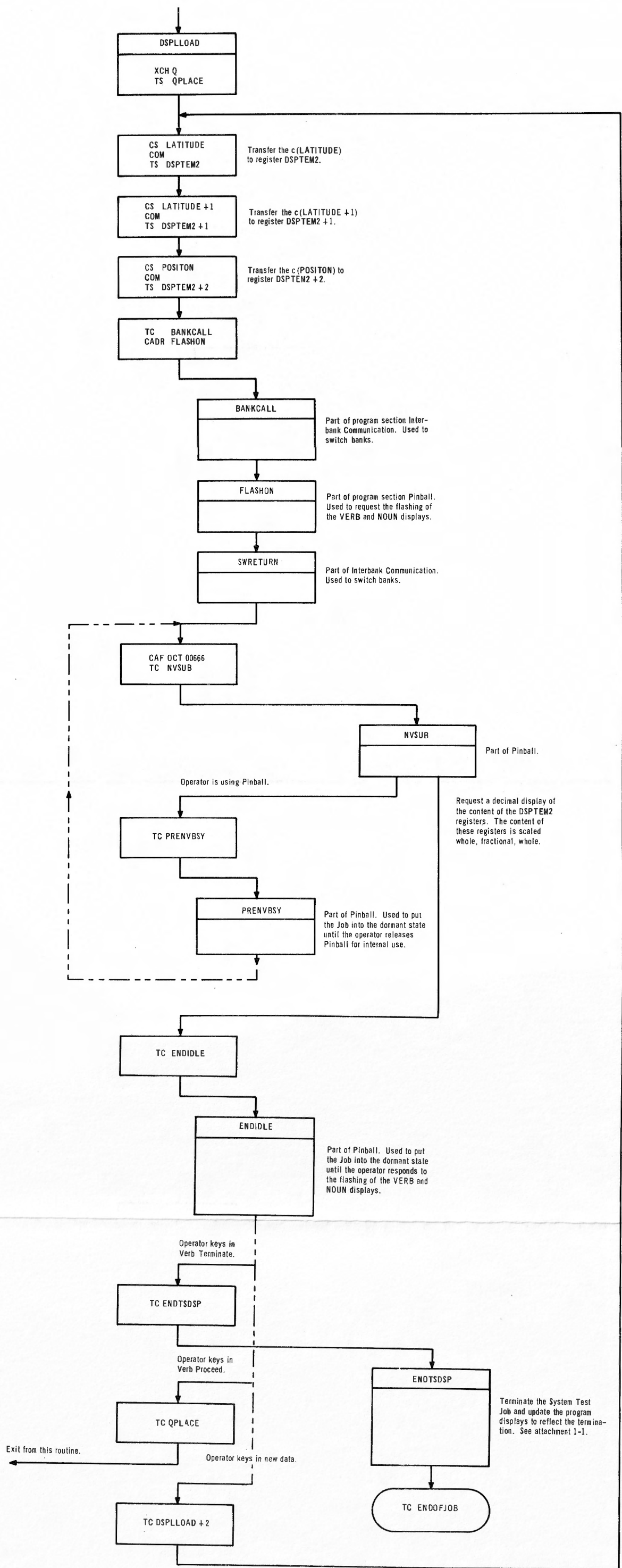


Figure 21-5. Routine DSPLLOAD

21-26. Routine FINDNB2 (figure 21-6) enters the star numbers 00001 and 00002 into registers DSPTEM1 and DSPTEM1+1 respectively. Program control is then transferred to Routine NVSUB to request (via Verb 04 and Noun 30) a two-component octal display of these star numbers thus identifying the stars on which Mark actions are to be taken. Program control is transferred to Routine SXTMARK via Routine BANKCALL with the quantity 00002 in register A indicating that two Mark actions are required.

21-27. Routine SXTMARK (paragraph 14-62) assigns a vacant Work Area in which to enter Mark information, initiates the flashing of the VERB and NOUN displays, and then requests that the quantity 51 be displayed in the VERB displays. Job LGNTEST1 now has two Work Areas assigned to it: one because the Job was initially requested via a FINDVAC call in Routine DOGDRIFT, and the other because Routine SXTMARK needs the additional storage. Program control is then transferred to Routine OPTSTALL via Routine FINDNB2 to put Job LGNTEST1 into the dormant state until the operator completes the required Mark actions. When the operator sees the Mark command (Verb 51) flashing, he aligns the sextant line of sight with collimator #1 (south) as the quantity 00001 is displayed in R1. When the sextant is aligned, the operator depresses the MARK button and if he is satisfied that the Mark is accurate he depresses keys VERB, 5, 2, (Mark Accept) ENTER. Since Routine SXTMARK was executed to request that two Mark actions be taken (content of A upon entry to Routine SXTMARK), the Mark command continues to flash. (The quantity displayed in the VERB displays is now 52.) Since the quantity 00002 is displayed in R2, the operator aligns the sextant line of sight with collimator #4 (southeast). When the sextant is aligned, the operator depresses the MARK button and, if he is satisfied that the Mark is accurate, he keys in VERB, 5, 2, ENTER thus terminating the flashing of the VERB and NOUN displays and reactivating Job LGNTEST1. If a failure occurred while the operator was taking the requested Mark actions, the reactivating address of Job LGNTEST1 would have been set so that when Job LGNTEST1 is executed, program control is transferred to Routine ENDTSDSP (paragraph 21-23) to terminate the System Test Job. Otherwise, when Job LGNTEST1 is executed, the interpretive mode is requested and the information obtained by the Mark action is processed.

21-28. The location of the Mark information is obtained by transferring the complemented content of register MARKSTAT (the address of the first location of the Work Area in complement form as set during Routine SXTMARK) to index register 1. (In the interpretive mode, the content of the index register is subtracted from the operand address to

yield a new address.) Program control is then transferred to Routine SXTNB which is a part of program section Inflight Alignment.

21-29. Routine SXTNB is used to convert the angular information obtained by marking with the sextant on collimator #1 into a star vector expressed in navigation-base coordinates. The input to this routine is the c(OPTX), and the c(OPTY) stored in positions 3 and 5 of the assigned Word Area. The output from this routine is a half-unit vector stored in locations STARM through STARM+5. The transformation used is the standard matrix to convert from spherical to cartesian coordinates.

21-30. After the execution of Routine SXTNB, Routine FINDNB2 transfers the content of the STARM registers to the STARAD registers. Index register one is updated by decrementing it by seven and program control is again transferred to Routine SXTNB, this time to convert the angular information obtained by marking with the sextant on collimator #4 into a star vector expressed in navigation-base coordinates. This vector is stored in locations STARAD+6 through STARAD+11D. Then the known positions (half-unit vectors) of the stars (in this case collimators) in earth-referenced coordinates (vertical, south, east) are transferred from Fixed Memory to locations 6 through 17D of the Pushlist. Program control is then transferred to Routine AXISGEN.

21-31. Routine AXISGEN (part of program section Inflight Alignment) is executed to compute the coordinates of the navigation base in terms of the earth-referenced coordinate system. Inputs to this routine are the two vectors expressing the star positions in navigation-base coordinates in locations STARAD through STARAD+11D and the two vectors expressing the same star positions in earth-referenced coordinates in locations 6 through 17D of the Pushlist. The output of Routine AXISGEN is three half-unit row vectors expressing the navigation-base position in terms of the earth-referenced coordinate system. Upon exiting from Routine AXISGEN, the vectors are stored in locations XDC through XDC+17D. (Locations XDC and XDC+1 refer to the double-precision magnitude of the X-vector component in the vertical direction, XDC+2 and XDC+3 refer to the magnitude in the southerly direction and XDC+4 and XDC+5 refer to the magnitude in the easterly direction.) These components define the position of the navigation base X-axis. The content of registers XDC+6 through XDC+11D and XCD+12D through XDC+17D are broken down in the same way to give the position of the Y and Z axes.

21-32. After the execution of Routine AXISGEN, Routine FINDNB2 transfers the content of the XDC registers to the STARAD registers. A request is made to exit from the interpretive mode and program control is transferred back to the routine from which the TC FINDNB2 was done.

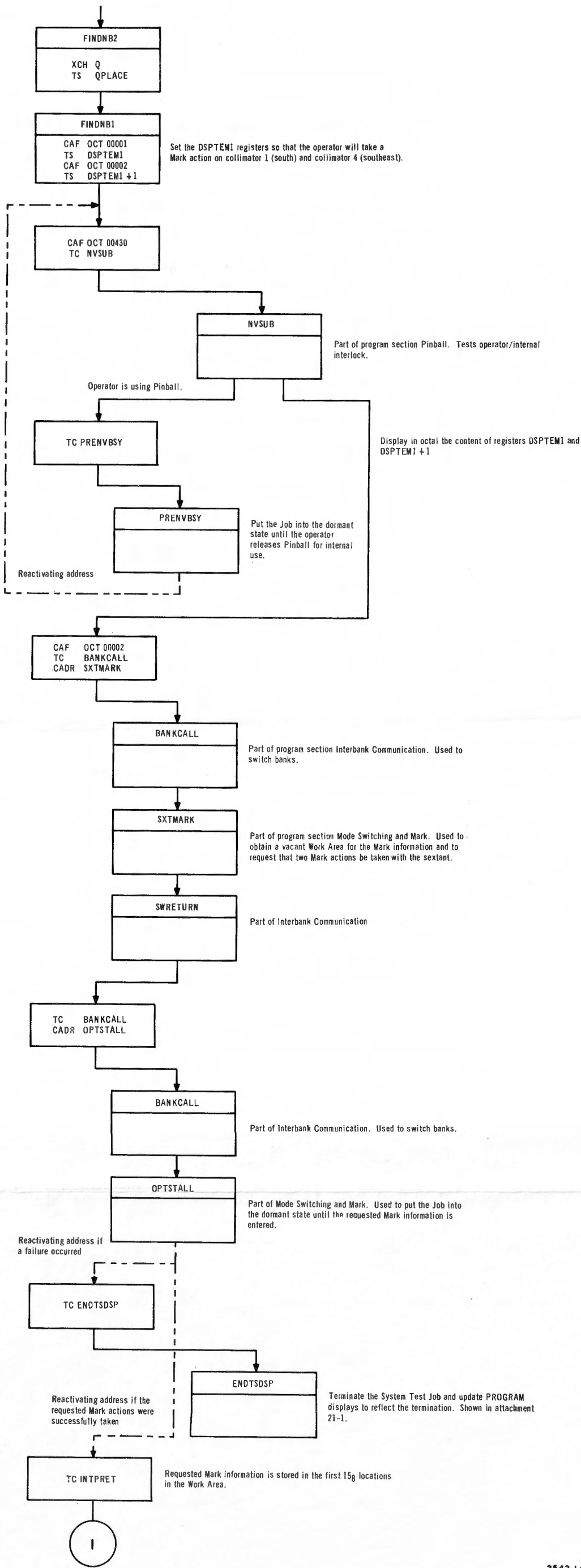


Figure 21-6. Routine FINDNB2 (Sheet 1 of 2)

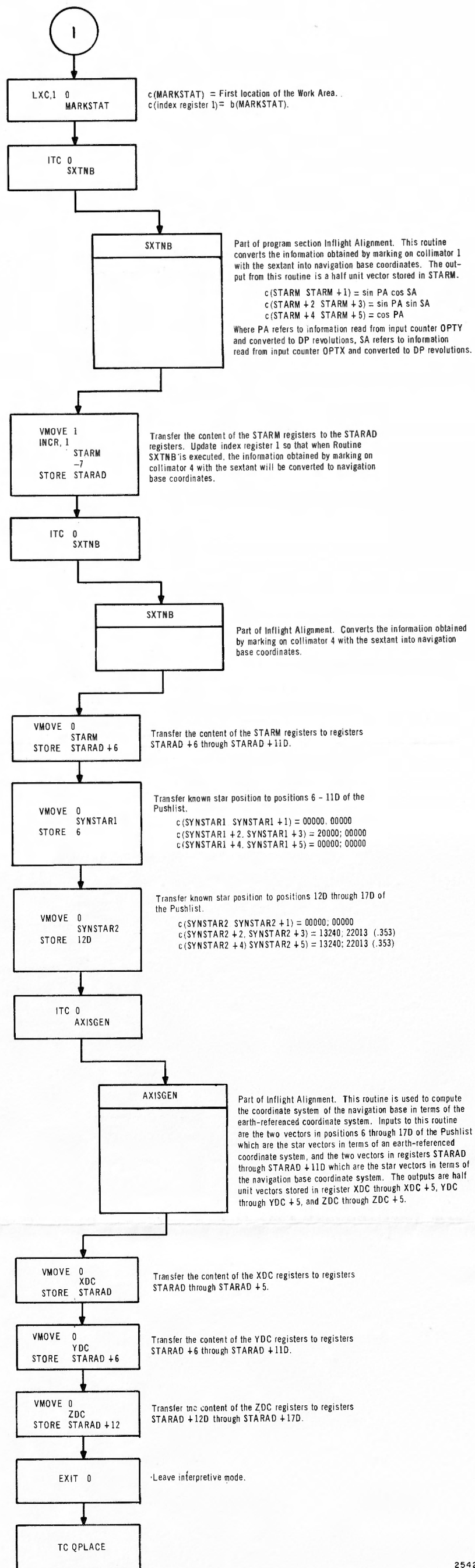


Figure 21-6. Routine FINDNB2 (Sheet 2 of 2)

21-33. After the execution of Routine FINDNB2, Routine LGNTEST4 (attachment 21-1) transfers program control to Routine IMUSTALL via Routine BANKCALL. Routine IMUSTALL (paragraph 14-99) checks to see whether the Zero Encode sequence which was initiated during the execution of the action defined in paragraph 21-18 has been completed. If it has, and if it was successful, program control is transferred to Routine PUTPOS (paragraph 21-36) via Routine LGNTEST4. If it has been completed, and if a mode switch was unsuccessful, program control is transferred to Routine ENDTSDSP (paragraph 21-23) via Routine LGNTEST4 to terminate System Test Job LGNTEST1. If the Zero Encode sequence has not had time to be completed, Routine IMUSTALL puts Job LGNTEST1 into the dormant state. The Job is later reactivated by a Task associated with the Zero Encode sequence. When Job LGNTEST1 is reactivated, program control is transferred to either Routine PUTPOS or Routine ENDTSDSP depending upon whether or not all mode switch requests were successful.

21-34. ALIGNING THE STABLE MEMBER TO A SPECIFIED POSITION

21-35. Routine PUTPOS is executed to request that the stable member be aligned to a specified position. The position to which the stable member is to be aligned depends upon the content of register POSITON, displayed to the operator during the action described in paragraph 21-19. The position to which each axis is aligned, the content of register POSITON, and the IRIG coefficient tested are shown in table 21-1.

21-36. Prior to transferring the desired position of the stable member in earth-referenced coordinates from Fixed Memory to registers XSM through XSM+17D, Routine PUTPOS (attachment 12-2) enters the quantity 00000 into registers XSM through XSM+17D, initializing all elements not subsequently modified. (XSM+6 through XSM+11D = YSM through YSM+5, and XSM+12D through XSM+17D = ZSM through ZSM+5.) Program control is then transferred to one of 10 routines depending upon the content of register POSITON. The actions taken by these routines are shown in table 21-2. Program control is then transferred to Routine PUTPOS2 where the interpretive mode is requested and program control is transferred to Routine CALCGA.

21-37. Routine CALCGA (part of program section Inflight Alignment) calculates the gimbal angles of the stable member when it will have been aligned to the desired position. The inputs to this routine are the half-unit vectors contained in locations XSM through XSM+17D that express the desired position of the stable member in earth-referenced

Table 21-2

DESIRED STABLE MEMBER POSITION

c(POSITON)	Routine Executed	Action Taken \triangle
00000	ENDTSDSP	The System Test Job is terminated
00001	POSITON1	c(XSM) = 20000 c(PIPINDEX) = 00002 c(YSM+2) = 20000 c(PIPINDEX+1) = 00001 c(ZSM+4) = 20000 c(RESULTCT) = 77777
00002	POSITON2	c(YSM+4) = 20000 c(PIPINDEX) = 00001 c(ZSM+2) = 20000 c(PIPINDEX+1) = 00002 c(XSM) = 57777 c(RESULTCT) = 47777
00003	POSITON3	c(XSM+4) = 20000 c(PIPINDEX) = 00000 c(ZSM+2) = 20000 c(PIPINDEX+1) = 00002 c(YSM) = 20000 c(RESULTCT) = 00001
00004	POSITON4	c(XSM+2) = 20000 c(PIPINDEX) = 00002 c(ZSM+4) = 20000 c(PIPINDEX+1) = 00000 c(YSM) = 57777 c(RESULTCT) = 50000
00005	POSITON5	c(YSM+4) = 20000 c(PIPINDEX) = 00001 c(XSM+2) = 20000 c(PIPINDEX+1) = 00000 c(ZSM) = 20000 c(RESULTCT) = 00002
00006	POSITON6	c(XSM+4) = 20000 c(PIPINDEX) = 00000 c(YSM+2) = 20000 c(PIPINDEX+1) = 00001 c(ZSM) = 57777 c(RESULTCT) = 50001

Table 21-2

DESIRED STABLE MEMBER POSITION (cont)

c(POSITON)	Routine Executed	Action Taken ¹
00007	POSITON7	c(ZSM; ZSM+1) = 13240; 23632 c(ZSM+2; ZSM+3) = 13240; 23632 c(YSM; YSM+1) = 13240; 23632 c(PIPINDEX) = 00000 c(YSM+2; YSM+3) = 64537; 54145 c(XSM+4) = 20000
00010	POSITON8	c(XSM; XSM+1) = 13240; 23632 c(XSM+2; XSM+3) = 13240; 23632 c(ZSM; ZSM+1) = 13240; 23632 c(PIPINDEX) = 00001 c(ZSM+2; ZSM+3) = 64537; 54145 c(YSM+4) = 20000
00011	POSITON9	c(YSM; YSM+1) = 13240; 23632 c(YSM+2; YSM+3) = 13240; 23632 c(XSM; XSM+1) = 13240; 23632 c(PIPINDEX) = 00002 c(XSM+2; XSM+3) = 64537; 54145 c(ZSM+4) = 20000
¹ The c(PIPINDEX) and c(PIPINDEX+1) are used only during the execution of Job LGNTEST1. The c(RESULTCT) is used only during the execution of Job PIPTEST1.		

coordinates (vertical, south, east) and the half-unit vectors in locations STARAD through STARAD+17D that express the position of the navigation base in earth-referenced coordinates. The output is left in registers OGC, MGC and IGC in single precision TWO's complement form. A middle gimbal angle in excess of 60° causes alarm code 00401 to be displayed to the operator; however, the System Test Job continues.

21-38. After the execution of Routine CALCGA, Routine PUTPOS2 returns the program to the basic mode. The content of registers CDUX, CDUY and CDUZ is transferred to registers THETAD, THETAD+1 and THETAD+2. Since $c(\text{CDUX}) = c(\text{THETAD})$ etc., no initial error will exist when the CDU drive loop is enabled by Task BEGINCOM. The gain registers KH and KG are set to the quantities 00000 and 05605 respectively. These registers are used by Routine T4RUPT in the driving of the CDU's. Program control is then transferred to Routine IMUCOARS (paragraph 14-33) via Routine BANKCALL to request that the system be put into the Coarse Align mode. When program control is transferred from Routine IMUCOARS back to Routine PUTPOS2 via Routine SWRETURN, instruction INHINT is given and a request is made via program section Waitlist for the scheduling of Task PUTPOS1 (attachment 21-2) with a time delay of 0.5 sec.

21-39. After the request is made for Task PUTPOS1, program control is transferred to Routine IMUSTALL via Routine BANKCALL to put Job LGNTEST1 into the dormant state until the Inertial Subsystem is established in the Coarse Align mode and the CDU's have been driven for 60 sec. (Driving the CDU's begins with Task PUTPOS1.) When Task PUTPOS1 is executed, the content of registers OGC, MGC and IGC (the desired gimbal angles) are transferred to registers THETAD, THETAD+1 and THETAD+2 respectively. When the Inertial Subsystem is established in the Coarse Align mode and the CDU drive loops enabled, differences between the THETAD registers and the CDU input counters cause commands to be sent to drive the CDU's. Since the system is in the Coarse Align mode, the gimbals follow. Job LGNTEST1 is reactivated by Task COARSDON (paragraph 14-41). If the system failed to be established in the Coarse Align mode, the awakening address is set so that when Job LGNTEST1 is executed, program control is transferred to Routine ENDTSDSP to terminate the Job. Otherwise, when Job LGNTEST1 is executed, program control is transferred to Routine IMUFINE (paragraph 14-43) via Routine BANKCALL to request that the Inertial Subsystem be put into the Fine Align mode. Presumably the desired gimbal angles have been approximated at this time. When the Inertial Subsystem is established in the Fine Align Mode, the CDU's are slaved to the IMU gimbal angles. After Routine IMUFINE

is executed, program control is transferred to Routine IMUSTALL via Routine BANKCALL to put Job LGNTEST1 into the dormant state until the subsystem is established in the Fine Align mode. The Job is re-activated by Task IMUFINE which is requested for scheduling during the execution of Routine IMUFINE. If the subsystem fails to achieve the desired mode, the reactivated Job executes Routine ENDTSDSP to request termination. Otherwise when Job LGNTEST1 is executed, the torquing commands necessary to complete the alignment of the stable member to the desired position are calculated.

21-40. Job LGNTEST1 calculates the torquing commands by transferring the content of registers CDUX, CDUY, and CDUZ (the current gimbal angles) into positions 6, 2, and 4 of the second Work Area assigned as requested by Routine SXTMARK. The location of the c(CDUY) is stored in step register S1. The interpretive mode is then requested. The desired position of the stable member X axis in earth-referenced coordinates is transformed to navigation-base coordinates by multiplying the content of registers XSM through XSM+5 (the X-axis row vector) by the matrix in locations STARAD through STARAD+17D. The resulting row vector is then shifted left one position to compensate for the fact that the X-axis vector was stored as a 1/2-unit vector. Program control is then transferred to Routine NBSM.

21-41. Routine NBSM (part of program section Inflight Alignment) translates the desired position of the stable member axis (in this case the X axis) from navigation-base coordinates to current stable-member coordinates. Inputs to this routine are a vector expressing the desired position of the X axis in navigation-base coordinates and the base address in register S1 of the registers in the second Work Area (that assigned to the Mark information) containing the readings of the CDU input counters. The output from this routine is left in locations VAC through VAC+5.

21-42. After the execution of Routine NBSM, the content of registers VAC through VAC+5, which is the desired position of the X axis expressed in current stable-member coordinates, is transferred to locations XDC through XDC+5. Next, the desired position of the stable member Y axis is translated to navigation-base coordinates by multiplying the content of registers YSM through YSM+5 (the desired position of the Y axis of the stable member in earth-referenced coordinates) by the matrix stored in locations STARAD through STARAD+17D (the navigation-base matrix). The result of this multiplication, which is the desired position of the stable member Y axis in navigation-base coordinates, is shifted left one position (multiplied by 2). Program

control is then transferred to Routine NBSM to transform the desired position of the stable member Y axis from navigation-base coordinates to current stable-member coordinates. This resulting vector is stored in locations YDC through YDC+5.

21-43. Obtaining the vector that expresses the desired position of the stable member Z axis in current stable-member coordinates is done by computing the vector cross-product of the vectors in locations XDC through XDC+5 and YDC through YDC+5. This resulting vector is stored in locations ZDC through ZDC+5. Once the vectors expressing the desired position of the stable member axes in current stable-member coordinates are computed, program control is transferred to Routine CALCGTA.

21-44. Routine CALCGTA (part of program section Inflight Alignment) calculates the torquing commands required to move the stable member to the desired position. Inputs to this routine are the three coordinates axes of the desired stable member orientation, referred to current stable member position (i. e. the content of registers YDC through YDC+5, ZDC through ZDC+5, and XDC through XDC+5). The output is three torquing angles scaled $2\pi/2^{28}$ radians/bit. These torquing angles are sequentially applied about the Y, Z, and X axes of the stable member and are stored in locations IGC, MGC, and OGC respectively.

21-45. After the torquing angles have been computed, program control is transferred via an interpretive TC to Routine OUTGYRO (paragraph 21-59) to initiate the pulse torquing of the gyros according to the commands just computed. After the pulse torquing has been initiated, the subsystem is returned to the basic mode and program control is transferred from Routine PUTPOS back to Routine LGNTEST4.

21-46. CALCULATING EARTH RATE CORRECTION VECTOR

21-47. After the execution of Routine PUTPOS, Routine LGNTEST4 (attachment 21-2) transfers program control to Routine LGNINIT to initialize the Work Area assigned to Job LGNTEST1. (This Work Area should not be confused with the Work Area assigned by Routine SXTMARK for the storing of Mark information.) Routine LGNINIT also reads the Time Counters, computes the earth-rate correction vector and zeros the PIPA counters.

21-48. Routine LGNINIT (figure 21-7) requests the interpretive mode; however, before the execution of an interpretive instruction, the basic mode is requested and Routine ZEROVAC, which is part of program

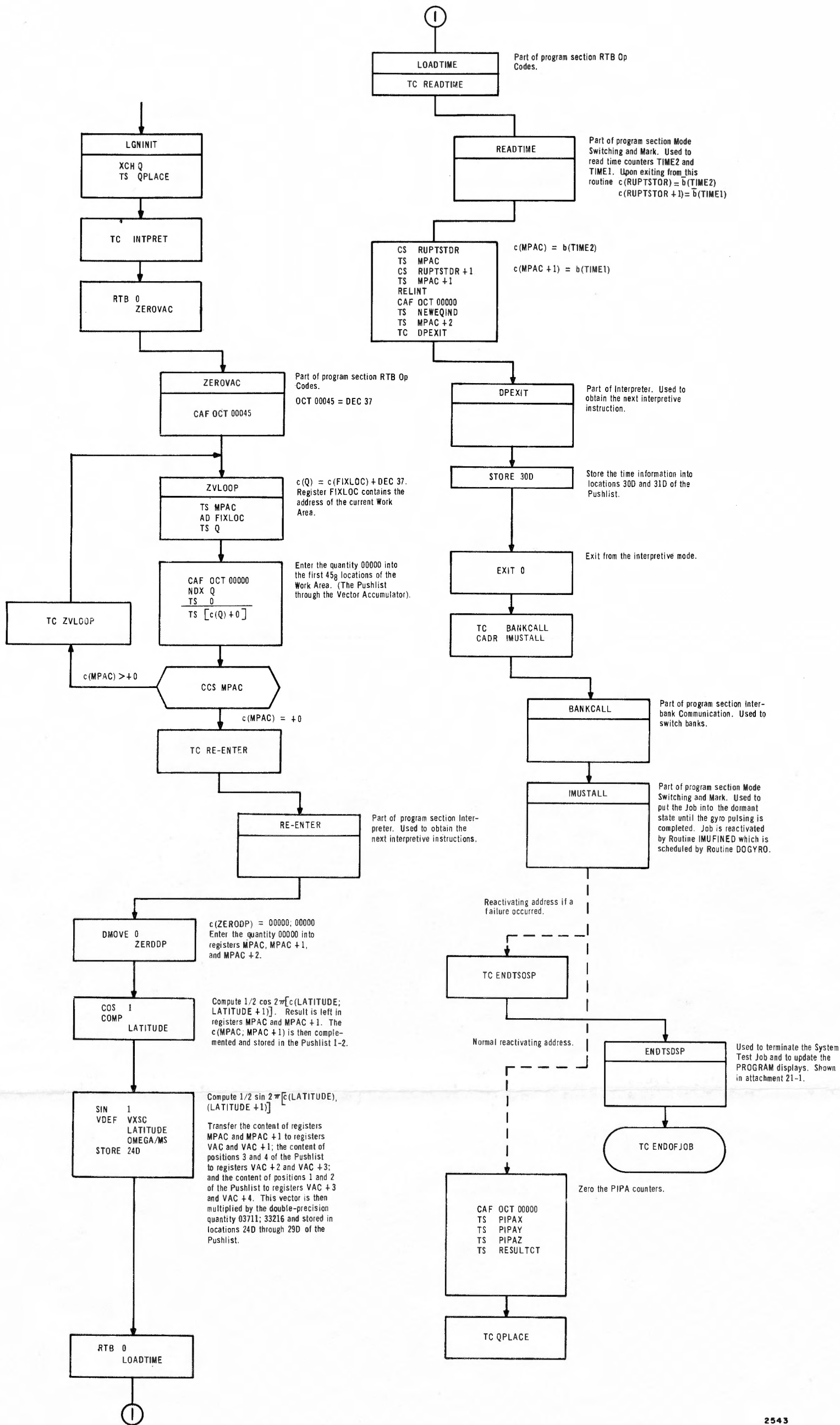


Figure 21-7. Routine LGNINIT

section RTB Op Codes, is executed to enter the quantity 00000 into the first 458 locations of the Work Area. (The index and step registers are not initialized. The address of the Work Area to be initialized is contained in register FIXLOC, which was set during the execution of Routine FINDVAC when called by Routine DOGDRIFT, paragraph 14-228.) Routine ZEROVAC then transfers program control to Routine RE-ENTER part of program section Interpreter, which is used to begin decoding the next instruction in Routine LGNINIT.

21-49. The first component of the earth-rate correction vector is obtained by computing $1/2 \sin(2\pi L)$ where L represents the content of registers LATITUDE and LATITUDE+1. The result is stored in registers VAC and VAC+1. (The content of registers LATITUDE and LATITUDE+1 represents the latitude of the test site scaled by 2π .) The second component is found by computing $1/2 \cos(2\pi L)$. This result is complemented and stored in registers VAC+2 and VAC+3. The third component is obtained by transferring the quantity 00000; 00000 to registers VAC+4 and VAC+5. The scaled vector is obtained by multiplying the vector in locations VAC through VAC+5 by the double-precision scale factor (03711; 33261) which represents earth rate in gyro pulses per 10 msec interval where:

$$\begin{aligned} \text{Earth rate} &= 15.04 \frac{\widehat{\text{sec}}}{\text{sec}} \times \frac{1 \text{ gyro pulse}}{1.2345 \widehat{\text{sec}}} \\ &\approx \frac{12.2 \text{ pulses}}{\text{sec}} = \frac{.122 \text{ pulses}}{10 \text{ msec}} \\ &= 0.12169524_{10} \text{ or } [03711; 33261]_8 \end{aligned}$$

The resulting vector, which will henceforth be written as

$$\begin{bmatrix} \omega \sin \lambda \\ -\omega \cos \lambda \\ 0 \end{bmatrix}$$

(where ω is the earthrate constant and λ is the test site latitude), is stored in locations 24D through 29D of the Pushlist.

21-50. After the earth rate correction vector has been computed, the basic mode is requested and program control is transferred to Routine LOADTIME, part of program section RTB Op Codes. Routine LOADTIME transfers program control to Routine READTIME, part of program section Mode Switching and Mark, where instruction INHINT is given and

the content of counters TIME2 and TIME1 are transferred to registers RUPTSTOR and RUPTSTOR+1 respectively. Routine LOADTIME then transfers the content of the RUPTSTOR registers to registers MPAC and MPAC+1. This time marks the beginning of the interval for which earth-rate compensation must be applied after the stable member has been fine-aligned to the desired position. Fine-alignment requires a finite interval before completion, during which the stable member experiences earthrate. Instruction RELINT is given and after the quantity 00000 is entered into registers MPAC+2 and NEWEQIND, program control is transferred to Routine DPEXIT (part of program section Interpreter) which obtains the next instruction in Routine LGNINIT.

21-51. This next instruction is a command to store the content of the MPAC registers into locations 30D through 32D of the Pushlist. The basic mode is then requested and program control is transferred to Routine IMUSTALL (paragraph 14-99) via Routine BANKCALL to put the System Test Job into the dormant state until the gyro pulse torquing commands necessary to achieve the desired stable member position have been transmitted. The Job is reactivated during the execution of Routine IMUFINED which is called by Task DOGYRO, TWEAKGY, or GYROADV when the pulse torquing command to fine-align the stable member is completed. (The pulse torquing was indicated during the actions described in paragraph 21-45.) When the reactivated System Test Job is executed, a successful mode switch results in entering the quantity 00000 into registers PIPAX, PIPAY, PIPAZ, and RESULTCT; and program control being transferred back to Routine LGNTEST4 at address LGNTEST3 (attachment 21-2). It is possible that, when Routine IMUSTALL is executed, there will be no need to put the System Test Job into the dormant state as the pulse torquing command may already have been completed. In this case, the PIPA input counters would be zeroed immediately. The dual purpose of Routine IMUSTALL has been previously described (paragraphs 14-100 through 14-102), and throughout the remainder of this issue it will be assumed that the reader is familiar with its use. Also, unless otherwise specified, it is assumed that an unsuccessful mode switch results in a transfer of program control to Routine ENDTSDSP (paragraph 21-23) when the System Test Job continues its execution.

21-52. TORQUING GYROS FOR EARTH RATE CORRECTION

21-53. After the execution of Routine LGNINIT, Routine LGNTEST3 (attachment 21-1) transfers the quantity 00003 to register A and transfers program control to Routine WAITLOP1 to establish a 30 sec waiting loop in which the gyros are pulses every 10 sec to correct for

earth rate. Routine WAITLOP1 (figure 21-8) utilizes the content of register A to determine the number of 10,000 msec intervals the System Test Job is to remain in a waiting loop. Thus, the content of register A is complemented and transferred to register COUNTPL and the execution of Routine WAITLOP4 is begun.

21-54. About every 10 sec, while the System Test Job is in the waiting loop, program control is transferred to Routine WAITLOP4 which tests the content of register COUNTPL. If the c(COUNTPL) equals +0 the Job has been in the waiting loop the desire length of time, and program control is transferred back to Routine LGNTEST3 where the action described in paragraph 21-57 is initiated. If the c(COUNTPL) equals -0, the quantity 00000 (+0) is entered into register COUNTPL before program control is transferred back to Routine LGNTEST3. If the content of this register is greater than +0 or less than -0, instruction INHINT is given and a request is made to program section WAITLIST to schedule Task WAITLOP3 with a time delay of 10 sec. When this Task is executed, it transfers program control to Routine JOBWAKE to reactivate the System Test Job. The System Test Job is put into the dormant state by Routine WAITLOP2, executed after the gyros on the stable member have been torqued to correct for earth rate. The awakening address of this Job is Routine WAITLOP4.

21-55. After Task WAITLOP3 has been requested, instruction RELINT is given and if the c(COUNTPL) is greater than +0, program control is transferred back to Routine LGNTEST3 where the action described in paragraph 21-57 is initiated. This is the exit from the waiting loop when it is entered directly at Routine WAITLOP4. When entry is at Routine WAITLOP1, the waiting loop is being initiated and register COUNTPL contains a negative quantity. If the c(COUNTPL) is less than -0, program control is transferred to Routine WAITLOP2 with c(A) equal to the recomplemented content of COUNTPL decremented by one. Then Routine WAITLOP2 puts the System Test Job into the dormant state and it is reactivated by Task WAITLOP3 in about 10 secs.

21-56. Routine WAITLOP2 is initially called by Routine WAITLOP4 and subsequently by Routine LGNTEST3 after the gyro pulsing commands to correct for earth rate have been transmitted. Routine WAITLOP2 enters the content of register A into register COUNTPL. Then, it transfers the complete address of Routine WAITLOP4 to register A and transfers program control to Routine JOBSLEEP, in program section Executive, where the System Test Job is put into the dormant state until the execution of Task WAITLOP3.

21-57. When program control is transferred back to Routine LGNTEST3 (attachment 21-1) from Routine WAITLOP4, the interpretive mode is requested and program control is transferred to Routine EARTHTRAS. Routine EARTHTRAS (figure 21-9) requests the basic mode and transfers program control to Routine LOADTIME which is part of program section RTB Op Codes. Upon exiting from Routine LOADTIME, the $c(\text{TIME2})$ and the $c(\text{TIME1})$ are contained in registers MPAC and MPAC+1 respectively. Register MPAC+2 contains 00000. (For further detail refer to paragraph 21-50.) Routine EARTHTRAS stores the content of the MPAC registers into locations 40D through 42D of the Pushlist. Then, the content of locations 30D through 32D is subtracted from the content of the MPAC registers. (Locations 30D through 32D contain time counter readings taken in Routine LGNINIT after the stable member torquing commands were computed in Routine PUTPOS, paragraph 21-35. Locations 40D through 42D contain the current time counter readings.) The difference (Δt), which is the interval during the fine align torquing process for which earthrate already accrued must be compensated, is then shifted left 10 binary places. This shift is necessary since:

- a. A shift left of two places (multiplying by four) is necessary because the gyro command is to be obtained by multiplying a half-unit matrix by a half-unit column vector. Thus, the result is a quarter-unit vector.
- b. A shift left of 8D places is necessary to compensate for the shift right 8D places that will be done by Routine OUTGYRO. When Routine OUTGYRO is called after the execution of Routine CALCGTA, it is necessary to shift right 8D places to compensate for the fact that the torquing angles are scaled $2\pi/2^{28}$ radians/bit instead of as gyro pulses which are scaled $2\pi/2^{20}$ radians/bit.

21-58. Routine EARTHTRAS then multiplies the scalar Δt (shifted left ten binary places) by the vector

$$\begin{bmatrix} \omega \sin \lambda \\ -\omega \cos \lambda \\ 0 \end{bmatrix}$$

(where ω = earth rate in gyro pulses/10 msec and λ = latitude of the test site) computed during the execution of Routine LGNINIT. To obtain the gyro command, this resulting vector is multiplied by the matrix giving the desired stable member earth-referenced position after fine alignment ignoring earthrate (i. e., the desired position to which the stable member has been aligned). This matrix, stored in locations XSM through XSM+17D is

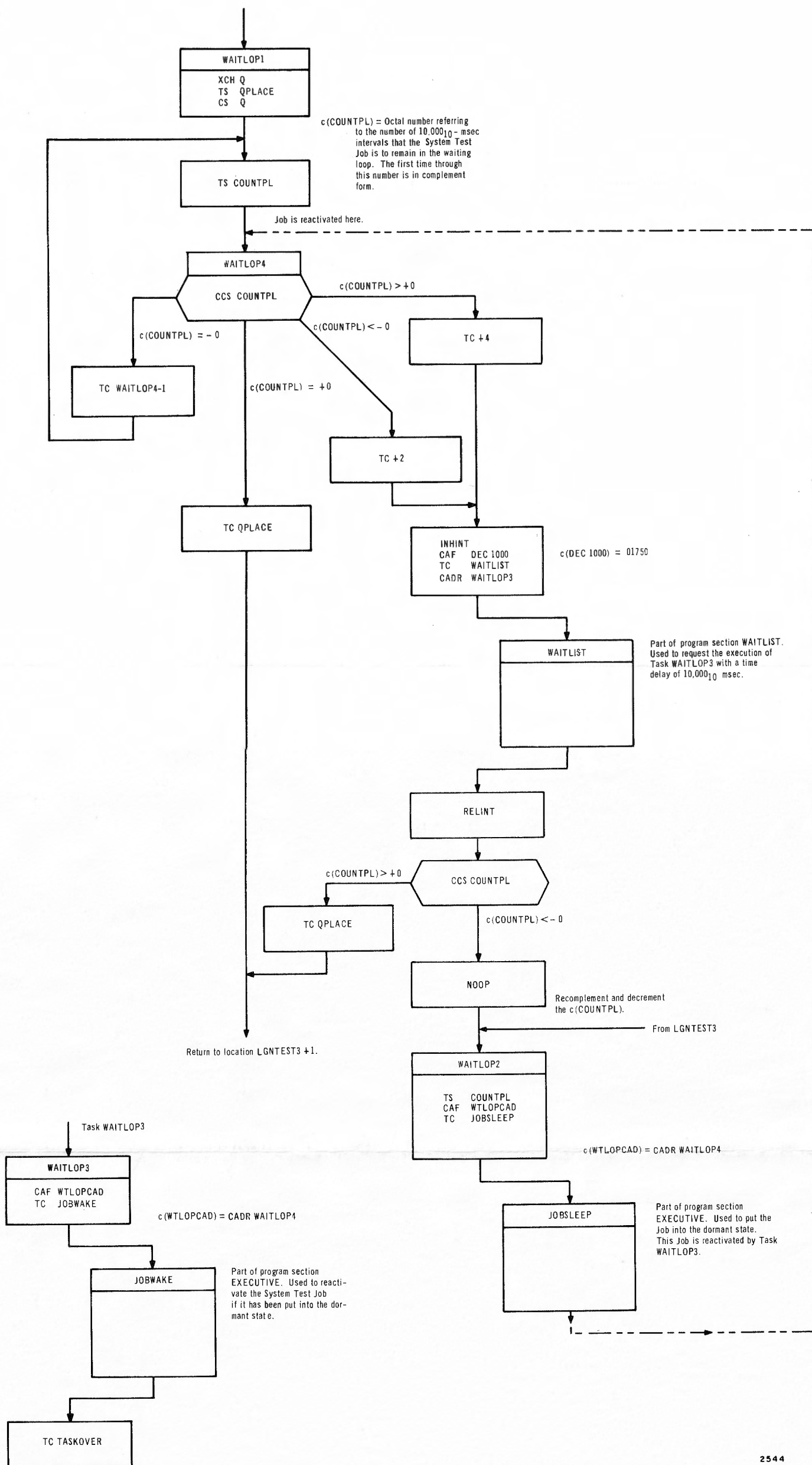


Figure 21-8. Routine WAITLOPI and Task WAITLOP3

$$\begin{bmatrix} X_V & X_S & X_E \\ Y_V & Y_S & Y_E \\ Z_V & Z_S & Z_E \end{bmatrix} = [M] \quad \text{where } X_V, X_S, X_E \text{ is the vector giving the position of the X axis of the stable member and vectors } Y_V, Y_S, Y_E, \text{ and } Z_V, Z_S, Z_E \text{ give the positions of the Y and Z axes respectively.}$$

The resulting command is

$$[M] \begin{bmatrix} \omega \Delta t \sin \lambda \\ -\omega \Delta t \cos \lambda \\ 0 \end{bmatrix} = \begin{bmatrix} X_V \omega \Delta t \sin \lambda - X_S \omega \Delta t \cos \lambda \\ Y_V \omega \Delta t \sin \lambda - Y_S \omega \Delta t \cos \lambda \\ Z_V \omega \Delta t \sin \lambda - Z_S \omega \Delta t \cos \lambda \end{bmatrix}$$

and the first component is added to the content of locations OGC and OGC+1. The previous content of registers OGC and OGC+1 is the residual command that was not sent during previous executions of Routine OUTGYRO. Similarly the second and third components are added to the content of locations IGC and IGC+1 and locations MGC and MGC+1 respectively. These are the commands in gyro pulses to the gyros on the X, Y, and Z axes respectively of the stable member. Prior to returning program control to Routine LGNTEST3, the quantity 00000 is entered into Pushlist locations 40D through 42D (where the Δt was stored) and the second time readings are entered into Pushlist locations 30D through 32D (where the original time readings were stored).

21-59. After the execution of Routine EARTHTRAS, Routine LGNTEST3 (attachment 21-2) transfers program control to Routine OUTGYRO to initiate the pulse torquing of the gyros for earthrate compensation. Routine OUTGYRO (figure 21-10) shifts the content of registers OGC and OGC+1 eight binary positions to the right and then transfers this shifted quantity into registers GYROD and GYROD+1. The bits lost by shifting the product right are saved in registers OGC and OGC+1. These bits are used in computing the gyro command the next time Routine EARTHTRAS is executed. The same procedure is followed in transferring the content of registers IGC and IGC+1 to registers GYROD+2 and GYROD+3, and transferring the content of registers MGC and MGC+1 to registers GYROD+4 and GYROD+5. After the commands have been transferred to the GYROD registers, the basic mode is requested and program control is transferred to Routine PULSEIMU. Routine PULSEIMU transfers program control to Routine IMUPULSE (paragraph 14-52) via Routine BANKCALL and initiates the pulse torquing of the gyros. After the execution of Routine IMUPULSE to correct for earth rate, program control is returned to Routine PULSEIMU. Routine PULSEIMU calls Routine RE-ENTER, part of program section Interpreter, to pick up the next interpretive instruction in Routine

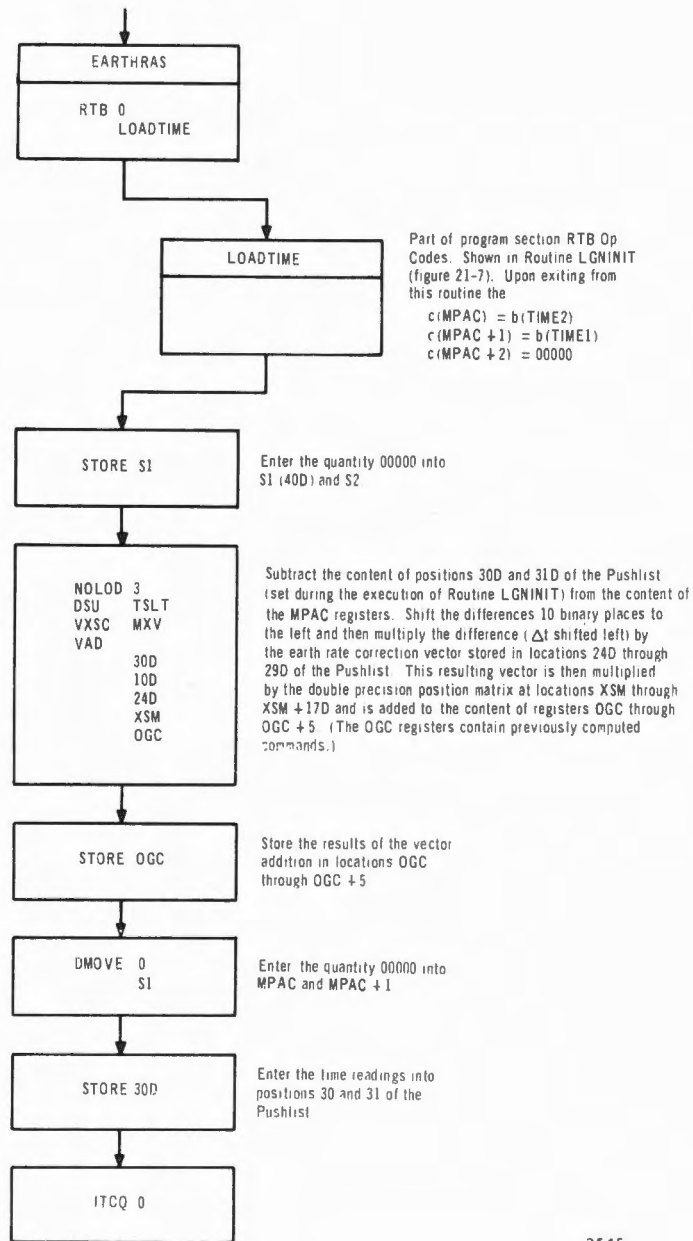
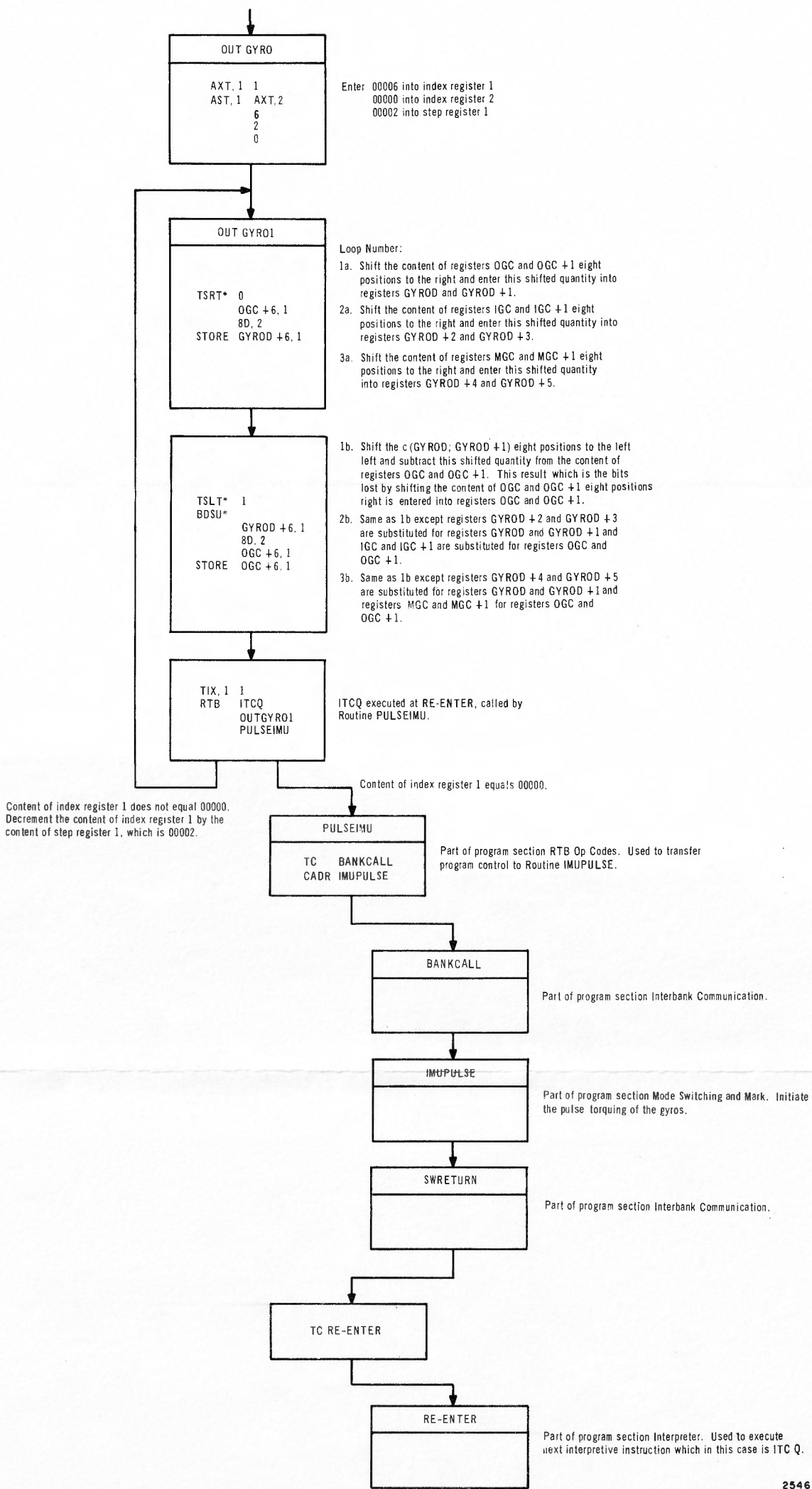


Figure 21-9. Routine EARTHTRAS



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Figure 21-10. Routine OUTGYRO

OUTGYRO which is a command to return program control to Routine LGNTEST3.

21-60. When program control is returned to Routine LGNTEST3, the basic mode is requested and program control is transferred to Routine IMUSTALL via Routine BANKCALL to put the Job into the dormant state until the gyro pulse torquing commands have been completed. When the commands have been sent, the System Test Job is reactivated during the execution of Routine IMUFINED. When the System Test Job continues, if pulse torquing the gyros was not successful, program control is transferred to Routine ENDTSDSP (paragraph 21-23) to terminate the System Test Job. If the pulse torquing of the gyros was successful, the content of register COUNTPL is tested to determine if the System Test Job should remain in the waiting loop where earth rate corrections are made every 10 sec.

21-61. If the content of Register COUNTPL is greater than +0, indicating that the Job should remain in the waiting loop, program control is transferred to Routine WAITLOP2 with the content of register A equal to the b(COUNTPL) decremented by one. Routine WAITLOP2 (paragraph 21-54) transfers the content of register A to register COUNTPL and then puts the System Test Job into the dormant state until Task WAITLOP3, requested during the execution of Routine WAITLOP4 is executed. (Since the c(A), upon execution of Routine WAITLOP1, was 00003, the c(COUNTPL) will equal 00000 after 30 sec has elapsed.) When the System Test Job is reactivated, Routines EARTHRA and OUTGYRO are executed to pulse torque the gyros, thus correcting for earth rate. This loop will continue until the c(COUNTPL) = +0 at which time Routine LGNTEST3 adjusts the position matrix, reads the time counters and the PIPA's, and sets up another loop so that earth rate corrections are applied to correct only for vertical displacement every 10 sec for 5 min.

21-62. The position matrix is adjusted by entering the quantity 00000 into registers XSM +2, XSM + 4, XSM + 8D, XSM + 10D, XSM + 14D, and XSM +16D, leaving the matrix as follows:

$$\begin{bmatrix} X_V & 0 & 0 \\ Y_V & 0 & 0 \\ Z_V & 0 & 0 \end{bmatrix}$$

where X_V , Y_V , and Z_V are the vertical components of the X, Y, Z axes of the stable member when it is aligned to the desired position. (The low-order part of these elements need not also be set to 00000.)

The time counters are read by transferring program control to Routine READTIME (paragraph 14-140). Upon exiting from Routine READTIME,

the $c(\text{RUPTSTOR}) = b(\text{TIME } 2)$ and the $c(\text{RUPTSTOR} + 1) = b(\text{TIME } 1)$. Then the content of register PIPAX, PIPAY, or PIPAZ, whichever is on the east axis, is transferred to register GENPLACE+2, GENPLACE + 6, or GENPLACE + 10D depending upon the content of registers PIPINDEX and RESULTCT. The content of register PIPINDEX (00000, 00001, or 00002) specifies which PIPA (X, Y, or Z) is on the east axis; the content of register RESULTCT (00000, 00004, or 00010) specifies which GENPLACE register is the recipient of the PIPA information. Register RESULTCT contains 00000 the first time through the waiting loop (paragraph 21-53), 00004 the second time, and 00010 the third time. The content of register PIPAX, PIPAY or PIPAZ, whichever is on the south axis, is transferred to register GENPLACE +3, GENPLACE + 7 or GENPLACE + 11D depending upon the content of registers PIPINDEX + 1 and RESULTCT. In this case, the content of register PIPINDEX + 1 specifies which PIPA is on the south axis and again register RESULTCT specifies which GENPLACE register receives the PIPA information. Similarly, the content of registers RUPTSTOR and RUPTSTOR + 1 are transferred to registers GENPLACE and GENPLACE + 1, GENPLACE + 4 and GENPLACE + 5, or GENPLACE + 8D and GENPLACE + 9D depending upon the contents of register RESULTCT. Refer to table 21-3 for the content of the GENPLACE registers after all the data has been stored.

21-63. Instruction RELINT is given (the INHINT was executed in Routine READTIME) and the $c(\text{RESULTCT})$ is subtracted from the octal quantity 00010 (8D). If this result is greater than +0, which it will be the first and second times through this loop, the $c(\text{RESULTCT})$ is incremented by four. Thus, register RESULTCT now contains 00004 the second time through the loop and 00010 the third (and last) time through. Program control is now transferred to Routine LGNTEST2 where quantity 00040 is transferred to register A and program control is transferred back to Routine LGNTEST3 (paragraph 21-53) to initiate the vertical-axis earth-rate correction loop. The System Test Job remains in this loop for $320 \text{ sec} \approx 5.3 \text{ min}$ since the $c(A)$ equals 00040. The $c(A)$, upon execution of Routine LGNTEST3, indicates the length of time (number of 10,000 msec intervals) the Job is to remain in the loop where earth-rate corrections are applied every 10 sec.

21-64. When Routine LGNTEST3 has been executed three times (once to initiate a 30-sec correction loop and twice to initiate a 5.3-min measurement loop), the content of register RESULTCT is 00010 and when it is subtracted from quantity 8D, the result is -0. At this point, Routine LGNTEST3 transfers the quantity 01750₈ (1000₁₀) to register COUNTPL and transfers the quantity 00000 to register A. Program

Table 21-3
CONTENTS OF GENPLACE REGISTERS

GENPLACE REGISTERS	c(PIPINDEX)	c(PIPINDEX+1)	c(RESULTCT)	c(GENPLACE+n)
GENPLACE GENPLACE+1			00000	b(TIME2) b(TIME1)
GENPLACE+2	00000		00000	b(PIPAX) on east axis
GENPLACE+3		00000	00000	b(PIPAX) on south axis
GENPLACE+4 GENPLACE+5			00004	b(TIME2) b(TIME1)
GENPLACE+6	00001		00004	b(PIPAY) on east axis
GENPLACE+7		00001	00004	b(PIPAY) on south axis
GENPLACE+8D GENPLACE+9D			00010	b(TIME2) b(TIME1)
GENPLACE+10D	00002		00010	b(PIPAZ) on east axis
GENPLACE+11D		00002	00010	b(PIPAZ) on south axis

control is then transferred to Routine LGNTEST5 to display the ΔV of the PIPA's and Δt of the time counters on the DSKY's.

21-65. CALCULATING AND DISPLAYING ΔV and Δt

21-66. Routine LGNTEST5 is executed twice. Both times it enters the content of register A into register RESULTCT (indexing quantity for GENPLACE registers) and then transfers program control to Routine TDSPLY. (The first time Routine LGNTEST5 is executed register A contains 00000; the second time register A contains 00004.) Routine TDSPLY obtains the time difference (Δt) for the first or second measurement loops of Routine LGNTEST3 and enters this time information into the DSPTEM2 registers. Since Verb 06 and Noun 66 are to be used to display the information to the operator, the data in register DSPTEM2 must be converted from time counter scaling (which means that the high order part is scaled by 2^{-14} and the low order by 2^{-28}) so that it appears to represent whole information and the data in register DSPTEM2+1 must appear as fractional information.

21-67. Routine TDSPLY (figure 21-11) requests the interpretive mode and then transfers the c(RESULTCT) which is either 00000 or 00004 to index register 1. (Since the system is in the interpretive mode, the content of the index register is subtracted from the address to yield the new address; the c(RESULTCT) is complemented before the transfer is made to index register 1.) If c(RESULTCT) is 00000, Routine TDSPLY subtracts the c(GENPLACE; GENPLACE+1) from the c(GENPLACE+4; GENPLACE+5) to form the first Δt . If c(RESULTCT) is 00004, the c(GENPLACE+4; GENPLACE+5) is subtracted from the c(GENPLACE+8D; GENPLACE+9D) to form the second Δt . The result of this subtraction (the Δt of the time counter) is multiplied by the double precision quantity (24365; 32044) which is 0.64_{10} or $2^6/10^2$ and is then shifted left eight bit positions or multiplied by 2^8 . This operation is necessary since, for display purposes, the high order part of the time information is to be scaled as whole data and the low order part is to be scaled as fractional data. Thus, if one thinks of the multiplication and shift as multiplying by the octal equivalent of the scale factor $2^6/10^2 \times 2^8 = 2^{14}/10^2$ the result of this operation is that the c(MPAC) = [whole number of sec] and the c(MPAC+1) = [fractional number of sec]. Prior to multiplying by the scale factor, register MPAC+1 could contain up to 163.83 sec. The factor 2^{14} moves the data from register MPAC+1 to register MPAC and the factor 10^{-2} converts from 10 msec = .01 sec to whole sec. Program control is then transferred to Routine SGNAGREE (part of program section Interpreter) to force sign agreement among the MPAC registers. Then the content of registers MPAC,

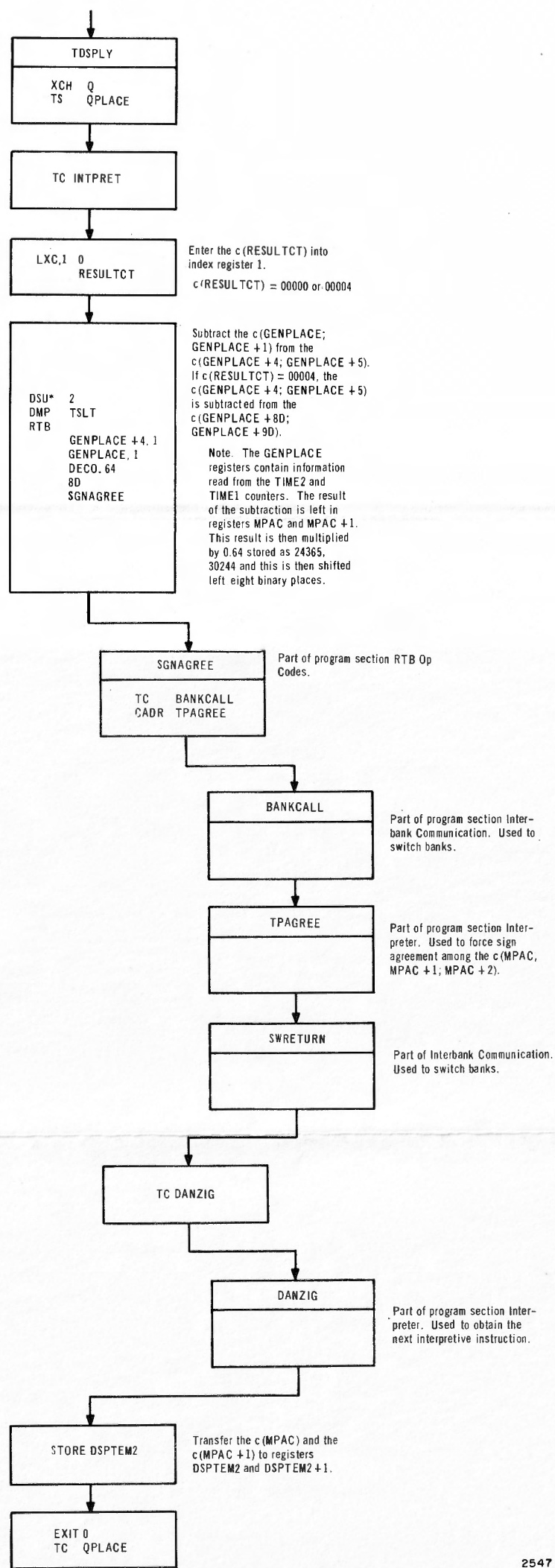


Figure 21-II. Routine TDSPLY

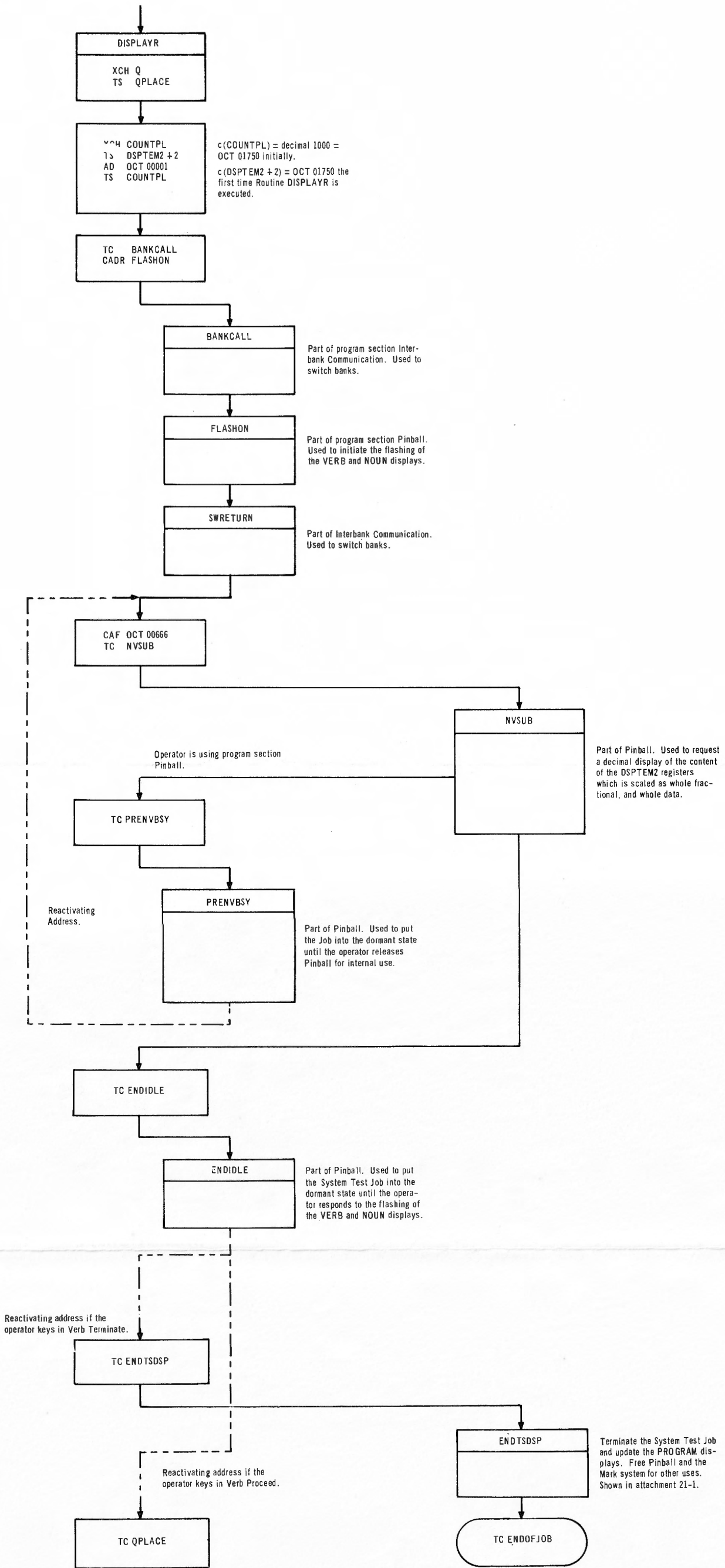


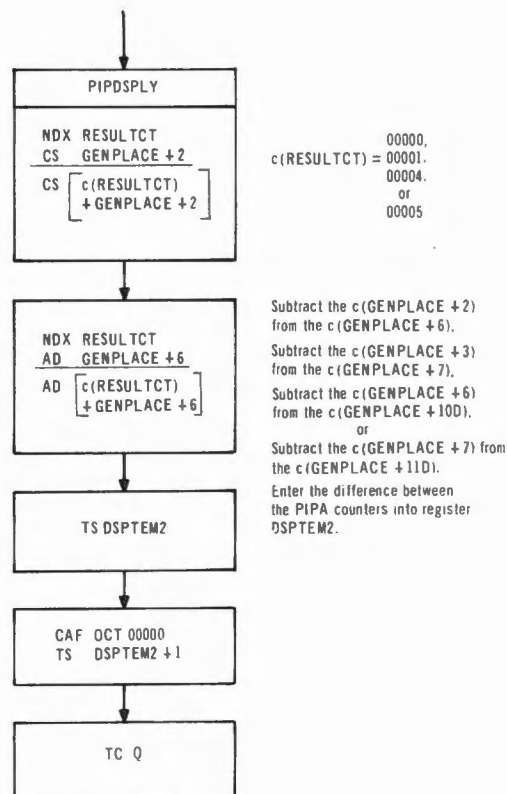
Figure 21-12. Routine DISPLAYR

MPAC+1, and MPAC+2 is transferred to registers DSPTEM2, DSPTEM2+1, and DSPTEM2+2 respectively. (The content of the DSPTEM2 registers will be used to display the Δt . Register DSPTEM2+2 which at this point contains 00000 will be set by Routine DISPLAYR.) Routine TDSPLY then requests the basic mode and returns program control to Routine LGNTEST3.

21-68. After the execution of Routine TDSPLY, program control is transferred to Routine DISPLAYR (figure 21-12) to initiate the flashing of the VERB and NOUN displays and to request a display of the c(DSPTEM2) registers. Routine DISPLAYR sets register DSPTEM2+2 with the b(COUNTPL), incremented by one. (Register COUNTPL was initially set to 01750₈, as described in paragraph 21-64.) The flashing of the VERB and NOUN displays is initiated by transferring program control to Routine FLASHON via Routine BANKCALL as described in paragraph 17-269. When program control is returned via Routine SWRETURN to Routine DISPLAYR, the quantity 00666, representing Verb 06 Noun 66, is transferred to register A and program control is transferred to Routine NVSUB to request a decimal display of the content of the DSPTEM2 registers. If the operator is using program section Pinball, program control is transferred to Routine PRENVBSY (paragraph 17-204) to put the System Test Job into the dormant state until the operator releases Pinball for internal use. If the operator is not using Pinball, Routine NVSUB begins decoding the Verb and Noun codes and takes the appropriate action. In this case, the action is a request for a decimal display of the contents of the DSPTEM2 registers which are to be scaled as whole, fractional, and whole data respectively. After the request has been initiated, Routine ENDIDLE is executed to put the System Test Job into the dormant state until the operator responds to the flashing of the VERB and NOUN displays.

21-69. If the operator keys in Verb Terminate, the awakening address is set so that when the System Test Job is executed, program control is transferred to Routine ENDTSDSP to terminate the System Test Job. If the operator keys in Verb Proceed, the awakening address is set so that when the System Test Job is executed, program control is transferred back to Routine LGNTEST5. The operator is instructed to record the content of display registers R1 and R2 before he keys in Verb Proceed. The quantity displayed in R1 is recorded as +TTTTT.0 sec; the quantity in R2 as +0.TTTTT sec. The quantity in R3, an identification number +01000 (paragraph 21-14), is not recorded. This number identifies the data displayed in R1 and R2 as the Δt of the first measurement loop for any test positions.

21-70. After the execution of Routine DISPLAYR, Routine LGNTEST5 transfers program control to Routine PIPDSPLY (figure 21-13) to enter the ΔV of the PIPA into register DSPTEM2. If register RESULTCT contains 00000, Routine PIPDSPLY obtains the ΔV of the PIPA by subtracting the $c(\text{GENPLACE}+2)$ from the $c(\text{GENPLACE}+6)$. (These GENPLACE registers were set during the action described in paragraph 21-62.) Routine PIPDSPLY is called three more times by Routine LGNTEST5 for this test position. When this happens, the $c(\text{RESULTCT})$ equals 00001, 00004, and 00005 respectively. In these cases, the $c(\text{GENPLACE}+3)$ is subtracted from the $c(\text{GENPLACE}+7)$, the $c(\text{GENPLACE}+6)$ is subtracted from the $c(\text{GENPLACE}+10D)$, and the $c(\text{GENPLACE}+7)$ is subtracted from the $c(\text{GENPLACE}+11D)$ respectively. Each of these differences of PIPA readings is then entered into register DSPTEM2. Then the quantity 00000 is entered into register DSPTEM2+1 and program control is transferred to Routine LGNTEST5.



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Figure 21-13. Routine PIPDSPLY

21-71. Routine LGNTEST5 then transfers program control to Routine DISPLAYR (paragraph 21-68) where an identification quantity, in this case the quantity 01751g, is entered into register DSPTEM2+2, the flashing of the VERB and NOUN displays is initiated, and Routine NVSUB is executed to request a decimal display of the content of the DSPTEM2 registers. Routine ENDIDLE is executed to put the Job into the dormant state until the operator responds to the flashing of the VERB and NOUN displays. Display register R3 contains the identification quantity +01001 at this time. The operator is instructed to record the quantities in R1 and in R3, and ignore the +00000 contained in display register R2.

21-72. If the operator keys in Verb Terminate, the reactivating address of the System Test Job is set so that when the Job continues execution, program control is transferred to Routine ENDTSDSP (paragraph 21-23) to terminate the System Test Job. If the operator keys in Verb Proceed, the c(RESULTCT) is incremented by one and program control is transferred to Routine PIPDSPLY (paragraph 21-70), where the ΔV of the second PIPA is computed and transferred to register DSPTEM2. The quantity 00000 is entered into register DSPTEM2+1. After the execution of Routine PIPDSPLY for the second time, Routine LGNTEST5 executes Routine DISPLAYR to request a decimal display of the content of the DSPTEM2 registers, to initiate the flashing of the VERB and NOUN displays and to put the Job into the dormant state until the operator responds to the flashing of the VERB and NOUN displays. At this time, R1 contains the ΔV of the second PIPA; R2 contains +00000; R3 contains an identification quantity +01002. The operator records the content of R1 and R3.

21-73. If the operator keys in Verb Terminate, the reactivating address is set so that, when the System Test Job is executed, program control is transferred to Routine ENDTSDSP to terminate the System Test Job. If the operator keys in Verb Proceed, the reactivating address is set so that when the System Test Job is executed the content of register RESULTCT is tested. If register RESULTCT contains 00001 indicating that the results (i. e., the Δt and the ΔV of the two PIPA's) of the gyro pulse torquing for the first 5 minutes have been displayed but not the results for the second five minutes, the quantity 00004 is transferred to register A. Program control is then transferred back to Routine LGNTEST5 (paragraph 21-66) to initiate a display of the results of the second five minutes of gyro torquing along the vertical to correct for earth rate. Display register R3 will contain identification quantities +01003 thru +01005 as the second set of results are displayed. When Routine LGNTEST5 is executed, the content of register A is used as an indexing quantity to reference the GENPLACE registers to obtain

the time and PIPA readings. If register RESULTCT contains 00005, indicating that the results for both 5-min intervals have been displayed to the operator, Routine LGNTEST5 transfers program control to Routine SYSPATCH. Routine SYSPATCH transfers program control to Routine MKRELEAS via Routine BANKCALL to release the Mark system for other users. (Routine MKRELEAS, part of program section Mode Switching and Mark, is described in paragraph 14-132.) After the execution of Routine MKRELEAS, Routine SYSPATCH transfers program control back to Routine LGNTEST4 (paragraph 21-18) to redisplay the latitude and test position to the operator. The operator may then select a new test position and continue the execution of the System Test Job, or terminate the test.

21-74. ESTIMATING IRIG PARAMETERS

21-75. This section concerns itself with determining the IRIG coefficients based on the data displayed as a result of performing Job LGNTEST1 at the 9 test positions. For each position, the operator records:

- a. The test position number.
- b. The Δt_1 of the first time interval. (R3 contains +01000.)
- c. The ΔV_{1E} of the PIPA on the east axis for the first time interval. ¹(R3 contains +01001.)
- d. The ΔV_{1S} of the PIPA on the south axis for the first time interval. ²(R3 contains +01002.)
- e. The Δt_2 of the second time interval ($\Delta t_2 = \Delta t_1$). ¹(R3 contains +01003.)
- f. The ΔV_{2E} of the PIPA on the east axis for the second time interval. ¹R3 contains +01004.)
- g. The ΔV_{2S} of the PIPA on the south axis for the second time interval. ²(R3 contains +01005.)

Using the data specified, the operator calculates

$$X \text{ in meru} = \left[\frac{1 \text{ meru}}{7.29029 \times 10^{-8} \text{ rad/sec}} \right] \left[\frac{5.8XXX \frac{\text{cm/sec}}{\text{pulse}}}{g_L \text{ cm/sec}^2} \right]$$

$$\left[\frac{\frac{\Delta V_{2E}}{\Delta t_2} - \frac{\Delta V_{1E}}{\Delta t_1}}{\text{sec}} \right] \left[\frac{1}{\Delta t_2 \text{ sec}} \right]$$

¹ Data used in computation of IRIG parameters, as opposed to data recorded but not used.

² Undefined for test positions 7, 8, and 9.

where

$$5.8XXX \frac{\text{cm/sec}}{\text{pulse}}$$

is the scale factor (computed in accordance with JDC 10029) for the PIPA on the east axis, g_L is local gravity as defined in table 3 of JDC 10030 and X is given in meru (milli-earth-rate units). Once the value of X in meru is determined, the earth rate constant $\omega \cos \lambda$, obtained from the same table, is subtracted from X. The interpretation of the resulting quantity (in meru) depends upon the specific test position (i. e., the relative position of the SRA, IA and OA of each of the gyros) as follows:

$$\begin{aligned} X \text{ meru} - \omega \cos \lambda &= \text{NBD}_Y \text{ for position 1} \\ &= \text{NBD}_Z \text{ for position 2} \\ &= \text{ADSRA}_Z + \text{NBD}_Z \text{ for position 3} \\ &= \text{ADSRA}_X + \text{NBD}_X \text{ for position 4} \\ &= \text{NBD}_X \text{ for position 5} \\ &= \text{ADSRA}_Y + \text{NBD}_Y \text{ for position 6} \\ &= 1/2 (\text{ADIA}_Z - \text{ADIA}_Y) + 1/2 (\text{ADSRA}_Z \\ &\quad + \text{ADSRA}_Y) + \sqrt{2}/2 (\text{NBD}_Z - \text{NBD}_Y) \text{ for} \\ &\quad \text{position 7} \\ &= 1/2 (\text{ADIA}_X - \text{ADIA}_Z) + \sqrt{2}/2 (\text{NBD}_X - \text{NBD}_Z) \\ &\quad \text{for position 8} \\ &= 1/2 (\text{ADIA}_Y - \text{ADIA}_X) - 1/2 (\text{ADSRA}_X) + \sqrt{2}/2 \\ &\quad (\text{NBD}_Y - \text{NBD}_X) \text{ for position 9.} \end{aligned}$$

For definitions of these quantities and associated test positions, refer to table 21-1 and figure 21-3 respectively. (NBD_N may be obtained by using the results obtained at one test position, while ADSRA_N requires the results obtained at two test positions, and ADIA_N requires the results obtained at more than two test positions.)

21-76. JOB PIPTEST1

21-77. FUNCTIONAL DESCRIPTION

21-78. Prior to requesting System Test Job PIPTEST1, the operator is instructed to ensure the Guidance and Navigation Mounting Fixture is tilted to $32.5 (\pm 0.5)$ degrees and the TRANSFER switch on the IMU CONTROL panel is set to COMPUTER. The operator then keys in VERB, 4, 0, (Zero) NOUN, 2, 0, (IMU CDU) ENTER to executed Routine VBZERO (paragraph 14-147) which initiates the Zero Encode Sequence, thus driving the IMU CDU display dials as well as the CDU counters to reflect the current gimbal angles. The operator then keys in VERB, 4, 1, (Coarse Align) NOUN, 2, 0, (IMU CDU) ENTER to request that the Inertial Subsystem be put into the Coarse Align mode and that the CDU's be driven to the desired position. Since the gimbals are slaved to the CDU's, the gimbals are also driven.

21-79. This keyboard action causes the execution of Routine VBCOARK (paragraph 14-154) and IMUCOARK (paragraph 14-157) to request a data load of the THETAD registers. When the operator sees Verb 21 (Write first component into) and Noun 22 (New Angles IMU CDU) flashing on the DSKY's, he keys in +, 0, 0, 0, 0, 0, ENTER which causes Verb 22 (Write second component into), Noun 22 to flash. The operator then keys in -, 0, 2, 1, 5, 0, ENTER which causes Verb 23 (Write third component into), Noun 22 to flash. Finally the operator keys in +, 0, 3, 8, 2, 5, ENTER which causes the VERB and NOUN displays to cease flashing and indicate Verb 41, Noun 22. Coarse alignment of the stable member to the desired position (just specified by loading the THETAD registers) is initiated. After the stable member has been coarse aligned to the specified position, various analog measurements are taken. (For further details, refer to steps 8 through 23 of JDC 10029-E.)

21-80. The operator then requests that the stable member be coarse aligned to a different position by keying in VERB, 2, 5, (Write all three components into) NOUN, 2, 2, (New Angles IMU CDU) ENTER to request an additional three-component data load of the THETAD registers. When Verb 21, Noun 22 flashes in the VERB and NOUN displays, the operator keys in +, 0, 0, 0, 0, 0, ENTER causing Verb 22, Noun 22 to flash. The operator then keys in +, 1, 6, 7, 5, 0, ENTER causing

Verb 23, Noun 22 to flash. Finally the operator keys in -, 0, 3, 8, 2, 5, ENTER causing the quantities keyed in to be transferred to the THETAD registers and the stable member coarse alignment to the new position to begin. When the stable member is aligned to this position, additional analog measurements are made. These two specified positions are independent of the test site or the test position subsequently chosen.

21-81. The operator then initiates System Test Job PIPTEST1 by keying in VERB, 7, 1 (Do PIPA Scale Factor Test), ENTER. Upon depressing key ENTER, Job CHARIN executes Routine DOPIPTST (paragraph 14-233) which displays the quantity 04 (System Test) in the PROGRAM displays and requests the execution of Job PIPTEST1. Since it is probable that there will be no other Job awaiting execution, the Job PIPTEST1 begins execution immediately. The operator should see the VERB and NOUN displays flash indicating 51 (Please Mark) and 30 (Star Numbers). (Display registers R1 and R2 contain quantities that are to be ignored. Usually these register(s) contain numbers identifying the star or stars on which a Mark is to be performed.) The operator then prepares to take a Mark action by ensuring that the following switches on the Optics Control Panel (figure 21-4) are set to the position specified below:

- a. SEXTANT switch to ON.
- b. CONTROLLER MODE switch to DIRECT.
- c. Optics Mode Selector to MANUAL.
- d. CONTROLLER SPEED switch to MED.

The Optics Zero Encode sequence is then requested by setting the Optics Mode Selector to ZERO OPTICS causing the ZERO ENCODER indicator on the Condition Annunciator (figure 14-5) to be illuminated. When the ZERO ENCODER indicator is extinguished, indicating the Zero Encode Sequence is completed, the operator sets the Optics Mode Selector to MANUAL. Then, by using the Sextant eyepiece, the Optics Hand Controller (figure 14-3) and the CDU thumbwheels (figure 14-4), the operator positions the Sextant line of sight (LOS) so that the center of the Sextant reticle is coincident with the reticle dot of collimator #1. (The details of the alignment are given in JDC 10029-E, steps 33 through 44.) When the operator is satisfied with the alignment, he depresses the MARK button, thus causing the content of the IMU CDU counters, Optics CDU counters, and Time counters to be read. If the operator is satisfied that the Mark was accurate, he keys in VERB, 5, 2 (Mark Accept), ENTER. Since two Marks have been requested, the flashing of the VERB and NOUN displays continues. The operator prepares to take the second Mark action by setting the Optics Mode Selector to ZERO OPTICS and after the Zero Encoder indicator on the Condition Annunciator is extinguished, the operator sets the Optics Mode Selector to MANUAL.

and aligns the Sextant to collimator #4. When he is satisfied with the alignment, he depresses the MARK button and if he feels the Mark is accurate, he depresses keys VERB, 5, 2 (Mark Accept), ENTER.

21-82. After the two Marks have been taken, Job PIPTEST1 utilizes the Mark information to obtain the matrix giving the Navigation Base position in earth-referenced coordinates. Job PIPTEST1 then requests that the Zero Encode sequence be performed on the Inertial Subsystem. Thus, the operator should see in succession the illumination of indicators ZERO ENC, FINE ALIGN, ATT CONT, and FINE ALIGN on the IMU Control Panel (figure 14-2). The ZERO ENCODER indicator on the Condition Annunciator will be illuminated throughout.

21-83. Job PIPTEST1 then requests a decimal display of the content of those registers containing the test site latitude. Both a quantity pertaining to the latitude at MIT/IL and the test position number are displayed to give the operator the option of changing this information if it is not appropriate. Thus, Verb 06 (Display in decimal all components of), Noun 66 (System Test Results) flashes and the quantities +01928, +04047 and +00001 appear in R1, R2, and R3 respectively. If the operator is at MIT/IL, he keys in Verb Proceed; otherwise, he keys in VERB, 2, 4 (Write 1st and 2nd components into) NOUN, 0, 1 (Specified machine address fractional), ENTER, 0, 0, 0, 7, 6, 3 (machine address of register LATITUDE), ENTER, X, X, X, X, X, ENTER, Y, Y, Y, Y, ENTER where XXXXX and YYYYY are the high and low order parts respectively of the scaled test site latitude. (The quantities the operator keys in for the various test sites are shown in table 3 of JDC 10029-E.) Upon depressing key ENTER the fourth time, Verb 06, Noun 66 flashes again and the content of display registers R1 and R2 changes. Display register R2 contains the quantity Y keyed in; however, the quantity displayed in R1 is derived from the X's keyed in but due to the scaling specified by Verb 06, Noun 66 the display is not the same as the quantity X keyed in. (The quantity keyed in differs from the quantity displayed by a factor of 2^{14} .) The operator then keys in Verb Proceed and the flashing of the Verb and Noun displays terminates.

21-84. In one respect, Job PIPTEST1 differs from Job LGNTEST1 in that the operator never has to change the content of register R3. The first time through Job PIPTEST1, R3 contains +00001. Prior to each subsequent pass through the Job, R3 is incremented by one until the Job has been performed for all six test positions. (The correspondence between the test position number and the PIPA being tested is shown on figure 21-3. The correspondence between the position number and the alignment position is shown in table 21-2.) If the operator is not

at MIT/IL, he must re-enter the latitude of the local test site each time Job PIPTEST1 executes a test at a different position.

21-85. After the operator keys in Verb Proceed in response to the display of the test site latitude and the test position number, Job PIPTEST1 begins the alignment of the stable member to the specified test position. At this time the COARS ALIGN indicator on the IMU Control Panel is illuminated; the ZERO ENCODER indicator is extinguished; and coarse alignment of the stable member to the specified position begins. Thereafter, the FINE ALIGN indicator on the IMU CONTROL panel is illuminated and the stable member is fine aligned to the specified position. When the stable member has been aligned, the content of the PIPA counters is used to compute the pulse torquing commands necessary to maintain the alignment of a stable member axis along the local vertical. (The specific axis aligned to local vertical depends upon the specified test position to which the stable member has just been aligned.) The position of the stable member is corrected for earth rate; maintenance and correction commands are calculated and applied every 10 sec for a settling period of five min. Then the vertical PIPA and Time counters are read and every ten sec for a period of 90 sec the maintenance and correction commands are applied to the stable member position. At the end of the 90-sec interval the PIPA and Time counters are read and the component of gravity experienced by the vertical PIPA (which should be $\pm 1g$) is computed by

$$g = 5.85 \frac{\Delta V}{\Delta t}$$

where ΔV is the difference in the PIPA readings, Δt is the difference in the Time readings, and 5.85 is an assumed nominal scale factor.

21-86. After about 10 min, Verb 06 (Display in decimal all components of), Noun 66 (System Test Results) flashes and data is displayed in all three display registers. The quantity displayed in R1 is the whole part of the computed g interpreted as XXXXX.0 cm/sec², the quantity displayed in R2 is the fractional part of g interpreted as 0.XXXXX cm/sec², and the quantity displayed in R3 is the identification quantity +01001 for test position 1. Display register R3 contains +01002 for test position 2, etc. The operator records the data in R1 and in R2 for each test position.

21-87. If R3 does not contain +01006, the operator keys in Verb Proceed thus continuing Job PIPTEST1 at the next test position. If R3 contains +01006, the operator keys in Verb Terminate to end the Job. Prior to using the recorded data to obtain the PIPA scale factor for

each PIPA, the operator sets the TRANSFER switch to MANUAL and then depresses the COARSE ALIGN button on the IMU CONTROL panel. When the Inertial Subsystem is in the Coarse Align mode, the operator takes additional analog measurements. A description of the use of the analog measurements is beyond the scope of this Issue.

21-88. PRELIMINARY INITIALIZATION

21-89. Job PIPTEST1 is scheduled by Routine DOPIPTST (paragraph 14-233) whenever the operator keys in VERB, 7, 1, ENTER. This Job begins execution at Routine PIPTEST1 (attachment 21-3) with a transfer of program control to Routine GRABDSP to "grab" Pinball for its own use. If Pinball is being used by another non-CHARIN Job, Routine PREGBSY is executed to put Job PIPTEST1 into the dormant state until the Job that had previously grabbed Pinball frees it. Once Job PIPTEST1 has reserved Pinball for its own use, program control is transferred to Routine FINDNB2 where the current position of the navigation base is established through observations made with the sextant.

21-90. ESTABLISHING THE NAVIGATION BASE POSITION

21-91. Routine FINDNB2, paragraphs 21-25 through 21-33, requests a display of c(DSPTEM1; DSPTEM1+1), star numbers; however, unlike in Job LGNTEST1, registers DSPTEM1 and DSPTEM1+1 have not been preloaded with the desired star numbers. Thus, the quantities displayed in R1 and R2 have no significance for the operator and are ignored. Routine FINDNB2 next executes Routine SXTMARK (paragraph 14-118) to request that the operator take two Mark actions. Routine SXTMARK requests a Mark action by assigning a vacant Work Area for the Mark information to be entered, initiating the flashing of the VERB and NOUN displays, and displaying the quantity 51 (Please Mark) in the VERB displays. Routine FINDNB2 then executes Routine OPTSTALL to put Job PIPTEST1 into the dormant state until the operator completes the required Mark actions. Since the quantities displayed in R1 and in R2 are to be ignored, the operator must refer to JDC 10029-E to obtain the position and procedure for aligning the Sextant. (The operator is instructed to align the Sextant to collimator #1.) When the operator is satisfied with the alignment, he depresses the MARK button to record the content of input counters CDUX, CDUY, CDUZ, OPTX, OPTY, TIME2 and TIME1. (For further detail, refer to paragraph 17-15.) If the operator is satisfied that the Mark is accurate, he then depresses keys VERB, 5, 2 (Mark Accept), ENTER; otherwise, he must realign the Sextant and continue Marking until he is satisfied with its accuracy.

21-92. Since Routine SXTMARK was executed to request that two Mark actions be taken, the flashing of the VERB and NOUN displays continues. The operator then refers to JDC 10029-E which instructs him to align the Sextant to collimator #4. When the Sextant is aligned to this position, the operator depresses the MARK button and, if he is satisfied that the Mark is accurate, he keys in VERB, 5, 2 (Mark Accept), ENTER thus terminating the flashing of the VERB and NOUN displays and reactivating Job PIPTEST1. If a failure occurred while the operator was taking the requested Mark actions, the reactivating address of Job PIPTEST1 would have been set so that, when Job PIPTEST1 is executed, program control is transferred to Routine ENDTSDSP (paragraph 21-23) to terminate the Job. Otherwise, when Job PIPTEST1 is executed, Routine FINDNB2 converts the angular input from the Mark actions into two star vectors that express the position of the collimators in navigation-base coordinates. This routine then utilizes the known fixed positions of the collimators in earth-referenced coordinates (vertical, south, east) to compute the matrix giving the position of the navigation-base axes in earth-referenced coordinates. This matrix is stored in locations STARAD through STARAD+17D and program control is then transferred back to Routine PIPTEST1 where the quantity 00001 is transferred to register A. Program control is then transferred to Routine PIPTEST2.

21-93. FURTHER INITIALIZATION

21-94. Routine PIPTEST2 transfers the content of register A to register POSITON. The first time this routine is executed, the quantity 00001 is entered into register POSITON, while on successive executions of this routine the quantity 00002, 00003 00006 is entered into register POSITON. The double precision octal quantity (03610; 01224), which represents the latitude at MIT/IL scaled by 2π , is entered into registers LATITUDE and LATITUDE+1. The quantity 77777 is then entered into register CDUIND to make the CDU's available and program control is transferred to Routine IMUZERO (paragraph 14-17) via Routine BANKCALL to request that the Zero Encode Sequence be initiated. (The Zero Encoder indicator on the Condition Annunciator is then illuminated.) In order to execute the Zero Encode Sequence, the quantity 77777 must be contained in register CDUIND or an alarm display will be generated and Job PIPTEST1 terminated. After the execution of Routine IMUZERO, Routine PIPTEST2 calls Routine DSPLLOAD (paragraph 21-19) to initiate Verb-Noun flashing, to display the content of registers LATITUDE, LATITUDE+1, and POSITON in R1, R2 and R3 respectively and to provide the operator with the option of changing the content of these locations. The action required of the operator if

he is not at MIT/IL and must therefore change the content of registers LATITUDE is described in paragraph 21-21. If the operator desires to change the c(POSITON), he should take the action described in paragraph 21-22. However, since the PIPA Scale Factor Test is a six-position test, the quantity Z mentioned in paragraph 21-10 can only be a digit from one to six. In the absence of any change to c(POSITON) by the operator, this Job sequences through the six positions; the Job must be manually terminated after the test performed at position 6 has been completed.

21-95. When the operator keys in Verb Proceed in response to the displays mentioned in the preceding paragraph, Routine PIPTEST2 executes Routine IMUSTALL (paragraph 14-99) to put Job PIPTEST1 into the dormant state until the Zero Encode Sequence, initiated during the action described in paragraph 21-18, is completed. When Job PIPTEST1 is reactivated, program control is transferred to Routine ENDTSDSP (paragraph 21-23) to terminate the System Test Job if a failure has occurred during the Zero Encode Sequence. If no failure has occurred, Routine PIPTEST2 transfers program control to Routine PUTPOS to commence alignment of the stable member.

21-96. ALIGNING THE STABLE MEMBER TO A SPECIFIED POSITION

21-97. Routine PUTPOS (paragraph 21-35) is executed to request that the stable member be aligned to a specified test position. This position depends upon the content of register POSITON, an octal number from 00001 to 00006. (When Routine PUTPOS is called by Routine LGNTEST4 within Job LGNTEST1, register POSITON can also contain 00007, 00010, or 00011.) The correspondence between the c(POSITON) and the desired alignment position is shown in table 21-1. From the table it can be seen that for this test each PIPA input axis is aligned up and down the local vertical axis. After Routine PUTPOS extracts from memory the desired alignment position of the stable member (in earth-referenced coordinates) and stores it in matrix form in locations XSM through XSM + 17D, the gimbal angles required for alignment are calculated. Routine PUTPOS then executes Routine IMUCOARS (paragraph 14-33) to request that the Inertial Subsystem be established in the Coarse Align mode. Once the mode is established, the CDU's and thus the gimbals are driven so that after about 40 sec the desired gimbal angles have been approximated. At this point Routine PUTPOS executes Routine IMUFINE (paragraph 14-43) to request that the Inertial Subsystem be established in the Fine Align mode. After the system is established in the Fine Align mode, Routine PUTPOS (paragraph 21-35) calculates the torquing commands necessary to Fine Align the stable member to the desired position and Routine OUTGYRO (paragraph 21-59) is

executed to initiate the sending of the torquing commands. Program control is then transferred from Routine PUTPOS back to Routine PIPTTEST2.

21-98. CALCULATING EARTH RATE CORRECTION VECTOR

21-99. Routine PIPTTEST2 transfers the content of register RESULTCT (set during the execution of Routine PUTPOS) to register PIPINDEX and then transfers program control to Routine LGNINIT (paragraph 21-47) to read the time counters, initialize the Work Area locations, evaluate the earth-rate correction vector, and put Job PIPTTEST1 into the dormant state until the gyro torquing necessary to Fine Align the stable member is completed. If a failure occurs during the pulse torquing, the reactivating address of Job PIPTTEST1 is set so that, when the Job is executed, program control is transferred to Routine ENDTSDSP to terminate the Job. Otherwise, when the Job is reactivated (by Task IMUFINE) and continues execution, the quantity 00000 is entered into registers RESULTCT, PIPAX, PIPAY, and PIPAZ; the quantity 00036 is entered into register A; and program control is transferred to Routine PIPTTEST4. At this point, the stable member has been aligned to the desired position, as of the time the fine align commands were computed.

21-100. MAINTAINING VERTICAL ORIENTATION

21-101. Routine PIPTTEST4 controls the torquing loop in which the stable member gyros are torqued. The loop maintains the vertical orientation of the stable member axis by torquing every 10 sec. When Routine PIPTTEST4 is initiated, the content of register A determines the octal number of 10,000-msec (10-sec) intervals that Job PIPTTEST1 is to remain in the torquing loop. Since the content of register A is 00036 at this time, the Job will remain in the waiting loop 5 min (300 sec). Routine PIPTTEST4 transfers program control to Routine WAITLOP1 (paragraph 21-53) and Task WAITLOP3 (paragraph 21-54) is scheduled with a time delay of 10 sec. Task WAITLOP3 reactivates Job PIPTTEST1 which is put into the dormant state after the gyros have been torqued to correct for vertical orientation and earth rate. After Routine WAITLOP1 has been executed, the interpretive mode is requested and Routine READPIPS is then executed in the basic mode via an RTB instruction.

21-102. Routine READPIPS (figure 21-14), part of program section RTB Op Codes, executes instruction INHINT and then transfers the c(PIPAX), c(PIPAY) and the c(PIPAZ) to registers VAC, VAC+2, and VAC+4 respectively of the original Work Area assigned to Job PIPTTEST1.

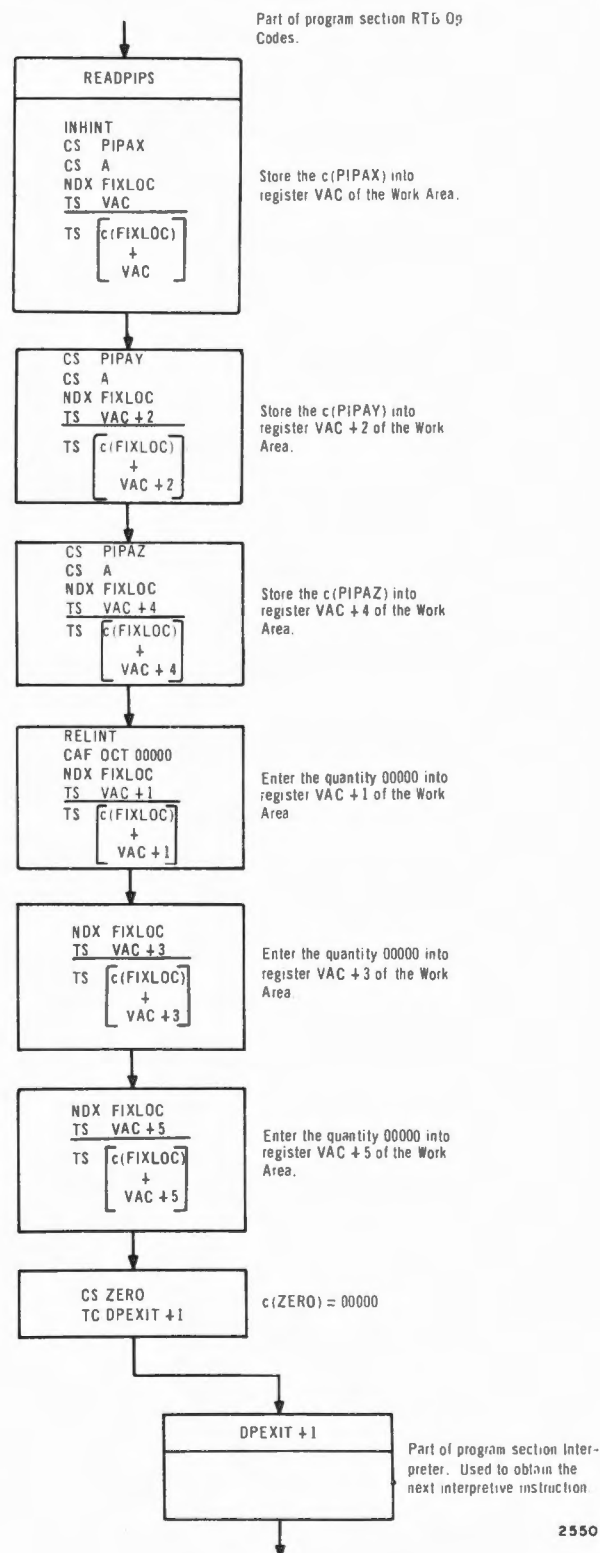
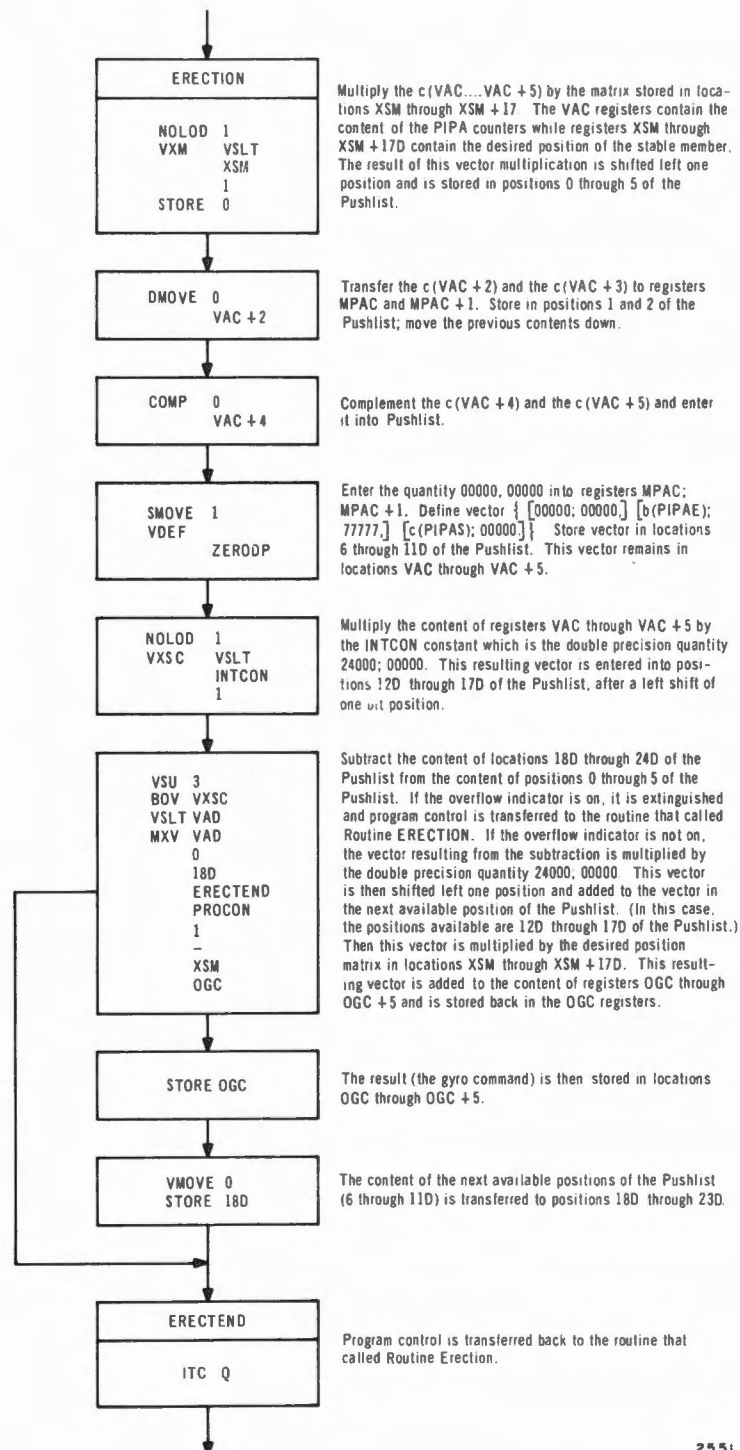


Figure 21-14. Routine READPIPS

(Not to be confused with the second Work Area assigned for storing Mark information.) Instruction RELINT is given and the quantity 00000 is entered into registers VAC+1, VAC+3, and VAC+5. Routine READPIPS then enters the quantity 77777 into register A and then transfers program control to Routine DPEXIT+1 to obtain the next interpretive instruction in Routine PIPTST4 which is a transfer of program control to Routine ERECTION.

21-103. Routine ERECTION (figure 21-15) uses the content of the PIPA counters (as measures of the angular displacement of the stable member axes) to compute the torquing commands necessary for maintaining the position of the stable member. (Earth rate correction will be added by a subsequent routine to the commands computed in this routine.) Routine ERECTION post multiplies the row vector contained in registers VAC through VAC+5 (set during the execution of Routine READPIPS) by the matrix in locations XSM through XSM+17D. (Locations XSM through XSM+17D contain the desired stable member position in earth-referenced coordinates.) The result of this multiplication is a row vector whose first component is the content of the PIPA on the vertical axis ($PIPA_V$), whose second component is $PIPA_S$ and whose third component is $PIPA_E$. The low-order part of each component is 00000. This vector, which is expressed as $[c(PIPA_V), c(PIPA_S), c(PIPA_E)]$, is shifted left one position (because XSM is a half-unit matrix) and is entered into locations 0 through 5 of the Pushlist. Thus the X, Y, Z sequence of reading the PIPA's has been resolved into a V, S, E sequence independent of the particular test position in use. Routine ERECTION further utilizes the content of the PIPA counters to obtain the vector expressed as $[0, -c(PIPA_E), c(PIPA_S)]$. This vector is entered into the next available locations in the Pushlist which are 6 through 11D. This vector is also multiplied by the double precision quantity (24000; 00000) which represents the scalar 0.625_{10} or $40_{10} \times 2^8$; the factor 2^8 is included because of the right shift 8 bit positions in Routine OUTGYRO. The vector is then shifted left one position (because the matrix to be used in paragraph 21-82 is a half-unit matrix) and is entered into the next available positions of the Pushlist which are 12D through 17D. Routine EARTHRA then subtracts the content of locations 18D through 23D of the Pushlist from the vector in locations 0 through 5. The first time Routine ERECTION is executed at a specified test position, locations 18D through 23D contain zeros, as the PIPA's were zeroed in Routine LGNINIT (paragraph 21-47). In subsequent executions of this routine, these locations contain a correction vector.

21-104. If the vector subtraction yields overflow, program control is transferred to Routine PIPTST1 via Routine ERECTEND as during this 10-sec interval no correction is to be applied to the stable member for



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Figure 21-15. Routine ERECTION

maintaining one axis vertical. If the vector subtraction does not yield overflow, the resulting vector is multiplied by the scalar 0.625_{10} or $40_{10} \times 2^8$. Thus, the vector computed is:

$$0.625 \left\{ [c(\text{PIPA}_V); 00000] - c[18D; 19D], [c(\text{PIPA}_S); 00000] - c[20D; 21D], [c(\text{PIPA}_E); 00000] - c[22D; 23D] \right\}$$

This vector is then shifted left one position and added to that vector entered last into the pushdown list (i. e., the contents of 12D through 17D). The components of this resulting vector are as follows:

$$\begin{aligned} \text{first component} & \quad 40_{10} \times 2^9 \left\{ [c(\text{PIPA}_V); 00000] - c[18D; 19D] + [00000; 00000] \right\} = 40_{10} \times 2^9 \times c(\text{PIPA}_V) \\ \text{second component} & \quad 40_{10} \times 2^9 \left\{ [c(\text{PIPA}_S); 00000] - c[20D; 21D] - [c(\text{PIPA}_E); 00000] \right\} \\ \text{third component} & \quad 40_{10} \times 2^9 \left\{ [c(\text{PIPA}_E); 00000] - c[22D; 23D] + [c(\text{PIPA}_S); 00000] \right\} \end{aligned}$$

This vector is referred to as V1. The last two terms of each component represent the net change in the PIPA readings during the 10-sec interval between passes through the loop.

21-105. Vector V1 is premultiplied by the double-precision matrix representing the desired stable member position in half-unit vectors. (The vector which is multiplied by the matrix has been doubled to compensate for the fact that the matrix is in half-unit vectors.) This matrix is stored in locations XSM through XSM+17D. Vector V1 is multiplied by the position matrix to ensure that the first component (the vertical component) is sent to the gyro on the vertical axis (be it X, Y, or Z); the second (south) is sent to the gyro on the south axis (be it Y, Z, or X) and the third (east) is sent to the gyro on the east axis (be it Z, X, or Y) to resolve the vector from a V, S, E system into an X, Y, Z system. (The transpose of the position matrix equals the inverse of this matrix.) This resulting column vector, each component of which represents a gyro command, is then added to the vector in locations OGC through OGC+5 and restored to these locations. Locations OGC and OGC+1 contain a command that is to be sent to the gyro on the outer gimbal axis (X axis), OGC+2 and OGC+3 a command to be sent to the gyro on the inner gimbal axis (Y axis), and OGC+4 and OGC+5 a command to be sent to the gyro on the middle gimbal axis (Z axis). Before the gyro commands are sent, the content of registers OGC and OGC+1,

OGC+2 and OGC+3, and OGC+4 and OGC+5 are shifted right 8 places. (Refer to Routine OUTGYRO, paragraph 21-59.) This in part explains the scaling constant [24000; 00000] which equals 0.625 but which is to be thought of as $40_{10} \times 2^8$. (The 40 is a damping constant.) Before program control is transferred to Routine PIPTEST4, the content of locations 6 through 11D of the Pushlist, which is the vector $[0, -c(\text{PIPA}_S), c(\text{PIPA}_E)]$, is transferred to locations 18D through 23D. Observe that locations 18D and 19D will always contain 00000.

21-106. After Routine ERECTION has been executed, the gyro torquing commands (scaled by 2^8) that depend upon the content of PIPAX, PIPAY, and PIPAZ are contained in registers OGC through OGC+5. (Registers OGC and OGC+1 contain the command that will be sent to the gyro on the X axis, OGC+2 and OGC+3 contain the command to the gyro on the Y axis, and OGC+4 and OGC+5 contain the command to the gyro on the Z axis.) Routine PIPTEST4 (attachment 21-3) transfers program control to Routine EARTHTRAS (paragraph 21-57) to read the time counters and to add the earth-rate correction vector to the content of the OGC registers. The earth-rate correction vector,

$$\begin{bmatrix} \omega\Delta t \sin \lambda \\ -\omega\Delta t \cos \lambda \\ 0 \end{bmatrix}$$

which is expressed in earth-referenced coordinates and scaled by 2^{10} , is multiplied by the desired stable member position matrix stored in locations XSM through XSM+17D. (Scaling by 2^{10} has been described in paragraph 21-57.) This resulting vector, which is the repositioned components of the original earth rate vector (now in stable member coordinates), is added to the content of registers OGC through OGC+5.

21-107. After the execution of Routine EARTHTRAS, program control is transferred to Routine OUTGYRO (paragraph 21-59) to shift the content of the OGC registers eight positions to the right, to transfer the content of these registers to the proper GYROD registers and to execute Routine IMUPULSE which initiates pulse torquing of the gyros according to the commands contained in the GYROD registers. (That portion of the command lost by shifting the content of the OGC registers eight positions to the right is saved in the OGC registers.) A request is then made to return to the basic mode and Routine PIPTEST4 transfers program control to Routine IMUSTALL (paragraph 14-56) via Routine BANKCALL to put Job PIPTEST1 into the dormant state until the pulse torquing of the gyros has been completed. If the mode switch failed, the system is in a state of change, the CDU failed or the IMU failed during the pulse torquing of the gyros, program control is transferred to Routine ENDTSDSP when Job PIPTEST is continued. If none of these occurred the content of register COUNTPL is tested when Job PIPTEST1 is continued. Program control is transferred to Routine WAITLOP2 (paragraph 21-56) if the content of register COUNTPL is greater than +0 indicating that the Job is to remain in the gyro torquing loop. If the content of register COUNTPL is equal to +0, the magnitude (positive form) of the c(PIPAX), c(PIPAY) or c(PIPAZ) depending upon the c(PIPINDEX) is obtained, incremented by one, and entered into register PIPANO. (If register PIPINDEX contains 77777 or 47777, PIPAX is read; if register PIPINDEX contains 00001 or 50000, PIPAY is read;

if register PIPINDEX contains 00002 or 50001, PIPAZ is read. Register PIPINDEX is set during the action described in paragraph 21-77.) Program control is then transferred to Routine CATCHAPP.

21-108. Routine CATCHAPP (figure 21-16) sets up a loop to wait until a PIPA pulse is detected, saves the return address, and then executes Routine CATCHAP1. Routine CATCHAP1 executes instruction RELINT and then tests the content of register NEWJOB. If register NEWJOB contains a positive quantity indicating that there is a Job of higher priority awaiting execution, program control is transferred to Routine CHANG1 in program section Executive. Routine CHANG1 initiates the execution of the Job of higher priority, displacing Job PIPTEST1 until it becomes the highest priority Job awaiting execution. Since Job PIPTEST1 is for laboratory use only, there should be no other Jobs active at this time. Thus, when the content of register NEWJOB is tested it should equal 00000 and the execution of Routine CATCHAP1 continues. Routine CATCHAP1 then executes instruction INHINT, and the content of PIPAN, which is the magnitude of the b(PIPAX), b(PIPAY), or b(PIPAZ) incremented by one, is compared to the current magnitude of the c(PIPAX), c(PIPAY) or c(PIPAZ) as specified by the c(PIPINDEX).

21-109. If this comparison indicates that the content of the two registers is equal, program control is transferred to Routine TOOFARAP to update the c(PIPANO) according to the current content of the PIPA being read and to transfer program control to Routine CATCHAP1. The execution of Routine TOOFARAP implies that the PIPA being read had already been incremented before Routine CATCHAPP was able to synchronize the timing of the pulse to 0.625 msec. If the comparison indicates that register PIPAX, PIPAY, or PIPAZ has not been incremented since the last time the PIPA was read, the octal quantity 00040 is transferred to register A and program control is transferred to Routine CATCHAP4.

21-110. Routine CATCHAP4 enters the content of register A into register OVCTR to establish a short loop in which the c(PIPAX), c(PIPAY), or c(PIPAZ) depending upon the c(PIPINDEX) is read every eight instructions until a PIPA pulse is detected. (A PIPA pulse should be detected every 6 msec.) Thus, Routine CATCHAP4 compares the magnitude of the c(PIPAX), c(PIPAY) or c(PIPAZ) with the c(PIPANO). If the comparison indicates a PIPA pulse has not been received, program control is transferred to Routine CATCHAP5 where the c(OVCTR) is decremented and tested. If register OVCTR contains a positive quantity, program control is transferred back to Routine CATCHAP4 to again test the c(PIPAX), c(PIPAY) or c(PIPAZ). If register OVCTR contains 00000, program control is transferred to Routine CATCHAP1 (para-

graph 21-108) to pick up a Job breakpoint and to initiate the testing of the PIPA counter. This should happen at most once per synchronization. The content of register OVCTR may be decremented 32_{10} times (equal 00000) as it might be necessary to execute Routine CATCHAP4 a maximum of 36_{10} times before a pulse is detected. When Routine CATCHAP4 finds that the PIPA register has been incremented, program control is transferred to Routine CATCHAP3 to read the time counters. Provision has been made for the case in which an interrupt occurs, delaying the comparison until the PIPA has been incremented two or more times. When Routine CATCHAP4 compares the c(PIPANO) with the magnitude of the content of the PIPA register and finds that the latter has been incremented, program control is transferred to Routine TOOFARAP to update register PIPANO and to transfer program control back to Routine CATCHAP1. (An interrupt could only occur in Routine CATCHAP1, where instruction RELINT is given prior to testing the content of register NEWJOB. However, program interrupts are serviced only in the $24 \mu\text{sec}$ interval required for execution of instruction CCS NEWJOB. Instruction INHINT is given as soon as register NEWJOB is found to contain 00000.)

21-111. Routine CATCHAP3, executed as soon as a PIPA pulse is detected, transfers the content of registers TIME2 and TIME1 to registers MPAC and MPAC+1 respectively and then clears register IN2. (After register IN2 is cleared, it is immediately reset by hardware to reflect the presence of signals from the Scaler.) The next instruction in Routine CATCHAP3 reads the low 4 bits of register IN2 (Fine Time) and transfers this information to register MPAC+2. If the low 4 bits of register IN2 contain a positive quantity, program control is transferred immediately to Routine CATCHAP2 as it is not necessary to re-read counters TIME2 and TIME1. If the low 4 bits of register IN2 contain zero, the content of counters TIME2 and TIME1 are read again and entered into registers MPAC and MPAC+1 respectively as it is possible that the time counters could have been incremented since they were read at the start of Routine CATCHAP3. Program control is then transferred to Routine CATCHAP2.

21-112. Routine CATCHAP2 executes instruction RELINT, multiplies the c(MPAC+2), Fine Time, by the octal quantity 02000, and transfers the content of register LP to register MPAC+2. This multiplication has the effect of shifting the Fine Time bits from positions 4 through 1 to positions 14 through 11 of register MPAC+2. Program control is then returned to Routine PIPTEST4.

21-113. Routine PIPTEST4 (attachment 21-3) transfers the content of registers MPAC, MPAC+1, and MPAC+2 to registers GENPLACE,

GENPLACE+1, and GENPLACE+2 respectively. (A subsequent execution of Routine PIPTEST4 causes the second set of time readings to be transferred from the MPAC registers to registers GENPLACE+4, GENPLACE+5, and GENPLACE+6.) Then the c(PIPANO), which represents the magnitude of the content of the PIPA being tested when the time counters were read, is transferred to register GENPLACE+3. (When PIPTEST4 is executed again, the content of register PIPANO is transferred to register GENPLACE+7.) After the proper quantities have been entered into the GENPLACE registers, the content of register RESULTCT is tested. At this point, register RESULTCT contains 00000 if the 5 min settling loop has been executed but the 90-sec torquing loop which obtains the ΔV of the PIPA has not been executed. Register RESULTCT contains 00004 when the 90-sec torquing loop has been executed. Thus, if register RESULTCT contains 00000, the quantity 00004 is transferred to register RESULTCT, the quantity 00011 is transferred to register A, and program control is transferred back to Routine PIPTEST4 to initiate the 90-sec loop during which the content of the PIPA registers are used to compute commands necessary to pulse torque the gyros to correct for earth rate, while the ΔV and Δt of the selected PIPA are being measured.

21-114. CALCULATING AND DISPLAYING LOCAL GRAVITY

21-115. If register RESULTCT contains 00004, the ΔV of the selected PIPA is obtained by subtracting the c(GENPLACE+3) from the c(GENPLACE+7). If the result is a positive quantity, it is stored directly into position 4 of the Pushlist. If this result is negative, indicating the PIPA counter had overflowed during the 90-sec interval, the result is incremented by one and added to the quantity 37777. This result, which is the difference in the two PIPA readings, is entered into position 4 of the Pushlist. (For example, if the first PIPA reading is 37772 and the second PIPA reading is 00010, the quantity 00016 is entered into the Pushlist.) After the ΔV of the PIPA has been obtained, the interpretive mode is requested. The Δt of the Time counters is found by subtracting (in triple precision) the content of GENPLACE, GENPLACE+1, and GENPLACE+2 from the content of GENPLACE+4, GENPLACE+5, and GENPLACE+6. This result, which is in registers MPAC, MPAC+1, and MPAC+2, is shifted left 14 binary places which has the effect of moving the c(MPAC+1) into MPAC and the c(MPAC+2) into MPAC+1. The b(MPAC) is 00000 since the Δt is approximately 90 sec. The content of the MPAC registers is rounded to double precision and is stored into the next available positions in the Pushlist.

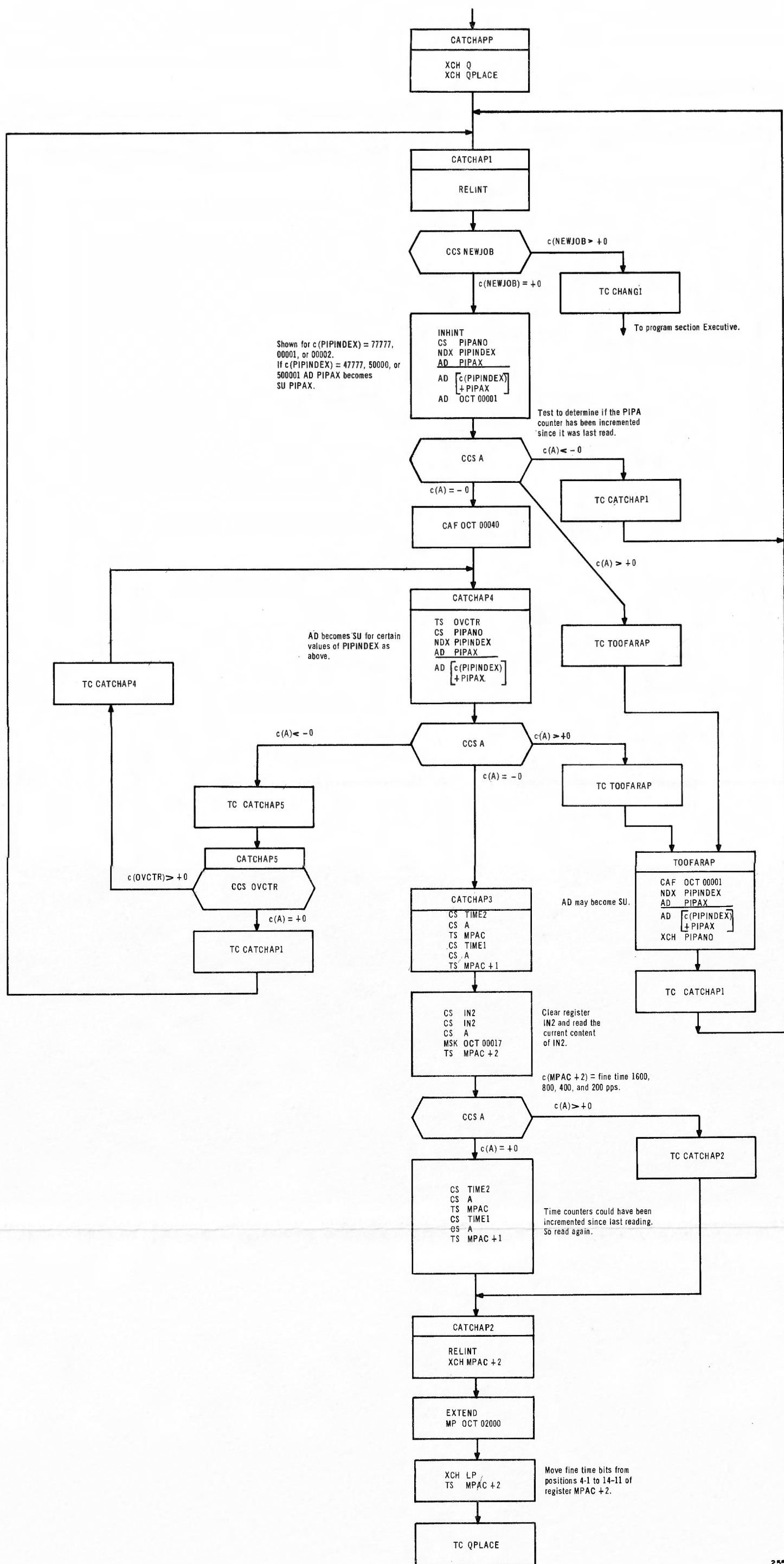


Figure 21-16 Routine CATCHAPP

21-116. After Δt has been found, Routine PIPTEST4 calculates a nominal gravity vector

$$g = \frac{\Delta V (5.85)}{\Delta t}$$

assuming no PIPA bias and a nominal scale factor. Thus, Routine PIPTEST4 moves the content of Pushlist position 4, PIPA ΔV , to register MPAC. This quantity is then multiplied by the double precision quantity [01111; 00000] which represents the nominal PIPA scale factor 5.85 cm/sec/pulse scaled by 10^2 and by 2^{14} . (The factor 2^{14} forces the results of the multiplication into the high-order MPAC registers.) This product is then divided by the Δt previously stored in the Pushlist. The factor 10^2 , which appears in the nominal PIPA scale factor used, is required because Δt is expressed in units of 10 msec or (sec) (10^{-2}). This result, the magnitude of the gravity vector, is entered into registers DSPTEM2 and DSPTEM2+1. The c(DSPTEM2) represents the whole part of the magnitude while the c(DSPTEM2+1) represents the fractional part.

21-117. After computing nominal gravity, the quantity 01750₈ (1000₁₀) is transferred to register A. The content of register POSITON, which is an octal number between 00001 and 00006, is added to the content of register A and this sum is entered into register COUNTPL. Program control is then transferred to Routine DISPLAYR (paragraph 21-68) which transfers the c(COUNTPL) to register DSPTEM2+2, to initiate the flashing of the VERB and NOUN displays and to request a decimal display of the content of the DSPTEM2 registers via Verb 06, Noun 66. Program control is then transferred to Routine PIPTEST4 where Routine ENDIDLE is executed to put Job PIPTEST1 into the dormant state until the operator responds to the flashing of the VERB and NOUN displays.

21-118. After the operator records the quantities displayed in R1 and R2, he keys in Verb Proceed if R3 does not contain the quantity +01006. Keying in Verb Proceed causes the Job PIPTEST1 to be continued at a location that increments by one the content of register POSITON and then transfers program control back to Routine PIPTEST2 where the latitude at MIT/IL and c(POSITON) are displayed to the operator (paragraph 21-9) in preparation for beginning a test at the next test position. If R3 does contain +01006, indicating that the test has been performed at all six positions, the operator must key in Verb Terminate. Keying in Verb Terminate causes Job PIPTEST1 to execute Routine ENDTSDSP (paragraph 21-23) thus terminating the Job and updating the PROGRAM displays to reflect the termination.

21-119. ESTIMATING PIPA SCALE FACTORS

21-120. In order to obtain the scale factor for the PIPA on the X axis, the operator must use the data obtained by executing System Test Job PIPTTEST1 at positions 1 and 2. (Executing Job PIPTTEST1 at position 1 aligns the PIPA on the X axis so that its input axis senses +lg. Executing Job PIPTTEST1 at position 2 aligns the PIPA on the X axis so that its input axis senses -lg.) In this description the data displayed in R1 and R2 as a result of aligning to position 1 is referred to as g_{+X} and the data displayed as a result of aligning to position 2 is referred to as g_{-X} . Then the operator is instructed to do the following:

- a. Record R1 for position 1 XXXXX.00000
Record R2 for position 1 +00000.XXXXXX
 $g_{+X} = \text{XXXXX.XXXXX cm/sec}^2$
- b. Record R1 for position 2 YYYYY.00000
Record R2 for position 2 +00000.YYYYYY
 $g_{-X} = \text{YYYYY.YYYYYY cm/sec}^2$

where g_{+X} and g_{-X} are estimates of local g assuming no bias and a nominal PIPA scale factor of exactly 5.85 cm/sec/pulse. (Only the absolute value of the computed g is recorded.)

- c. Calculate average estimated g $g_{AV} = \frac{g_{+X} + g_{-X}}{2}$
 - d. Calculate $5.85g_L$ where g_L is the actual test site local gravity the operator obtains from table 5 in JDC 10029-E.
 - e. Calculate the average scale factor $SF_X = \frac{5.85 g_L}{g_{AV}}$ for PIPAX
- (A minimum and maximum value of SF_X are given in JDC 10029-E.)
- f. Calculate scale factor deviation $\frac{SF_X - 5.85000}{5.85 \times 10^{-6}} = \text{--- parts per million}$
 - g. Calculate current PIPA bias $BIAS: X-PIPA = g_{+X} - g_{AV}$
 - h. Calculate bias deviation $BIAS-DEV: X-PIPA = (\text{PIPA bias recorded from most recent previous test}) - g_{AV}$
(Minimum and maximum values for BIAS DEV are given in JDC 10029-E.)

In a similar manner, the data obtained by performing the System Test Job at positions 3 and 4 is used to obtain the scale factor and bias for the PIPA on the Y axis. The data obtained by performing the System Test Job at positions 5 and 6 is used to obtain the scale factor for the PIPA on the Z axis.