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PRELAUNCH ALIGNMENT

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22-1. INTRODUCTION

22-2. This is the twenty-second 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 functional description of program section Prelaunch Alignment, one of three Mission Functions contained in program Sunrise 69 that perform major functions for the Apollo G&N System. (Refer to attachments 22-1 and 22-2 for detailed information.) Prelaunch Alignment aligns the IMU such that the X axis points along the local vertical and the Z axis points along a specified azimuth in the plane of the desired trajectory. This orientation is continually maintained until launch which, in a later version of Prelaunch Alignment, will terminate the function.

22-3. Prelaunch Alignment is divided into two parts: initialization and computation. During initialization, the current Phase is determined, certain registers are initialized, the CDU's are zeroed, and the coarse and fine align modes are executed. During computation, earth rate compensation is computed, the gyro compassing commands are computed, vertical erection and gyrocompassing are initiated and the IRIG's are torqued.

22-4. INITIALIZATION

22-5. Prelaunch Alignment has two entrances: one at Routine STARTPL2 and the other at Routine PLRESTT (figure 22-1). The former is used following a keyboard request to change major mode (Verb 37); the latter is used following a GO sequence (GOJAM).

22-6. STARTPL2 ENTRY

22-7. An operator may initiate a change major mode request to initiate the execution of Prelaunch Alignment or to manually change the Phase in which Prelaunch Alignment is operating. This is accomplished by keying in VERB, 3, 7, ENTER, D1, D2, ENTER where D1 is 0, the mission function code for Prelaunch Alignment and D2 can be any digit from 1 to 7 which designates the desired manual Phase. The keyboard entry causes the execution of Routine MODROUT of program section Mode Switching and Mark which requests the execution of Mission Function Prelaunch Alignment at the specified Phase. After Routine MODROUT has been executed, program control ultimately arrives at Routine STARTPL2 from the Executive when Prelaunch Alignment becomes the highest priority Job awaiting execution. Refer to paragraphs 16-22 through 16-26 and paragraph 12-57 for a description of the operations involved from the keyboard entry to the execution of Routine STARTPL2.

22-8. PHASE DETERMINATION

22-9. The manual Phases keyed in during the change major mode request are not an integral part of the Mission Function; however, they do lead to one or more internal Phases as shown in figure 22-2. Manual Phases 1 and 2 lead to internal Phases 11, 12, 13 and 15; manual Phase 3 leads to internal Phase 14; and manual Phase 4 leads to internal Phase 15. Manual Phases 5, 6 and 7 are not used in the Sunrise programs; however, if they are keyed in, the result is the same as if manual Phase 1 was keyed in. The internal Phases and their significance are listed in table 22-1. Refer to paragraph 16-6 for additional information concerning Phases. During the remainder of this discussion, there will be no further reference to manual or internal Phases. Phases less than ten are manual and those greater than 10 are internal.

22-10. When Prelaunch Alignment is entered at Routine STARTPL2 (figure 22-1) as the result of a change major mode request, the keyed in Phase is replaced in the phase tables by pseudo Phase 12. This operation is performed under the auspices of Routine PHASCHNG of program section Progress Control via the calling sequence:

```
TC    PHASCHNG
OCT   01200
```

where OCT 01200 specifies Phase 12 of Prelaunch Alighment (paragraph 16-12). Phase 12 entered into the phase tables at this time is not a significant Phase (i.e. the fine alignment Phase) but rather is just a convenient starting place. In addition to changing the content of the phase tables, Routine PHASCHNG stores the keyed in Phase for later use and determines if there has been a request to terminate Prelaunch Alignment since the change major mode request was initiated. If there has been a termination request, Prelaunch Alignment is terminated as a Job via Routine PRELEXIT which makes the IMU available, Routine MAJEXIT of Progress Control (paragraph 16-27) which requests the termination of the Mission Function and Routine ENDOFJOB of the Executive (paragraph 12-19) which terminates the Job. If termination has not been requested, program control returns to Prelaunch Alignment at Routine PLSTCHK.

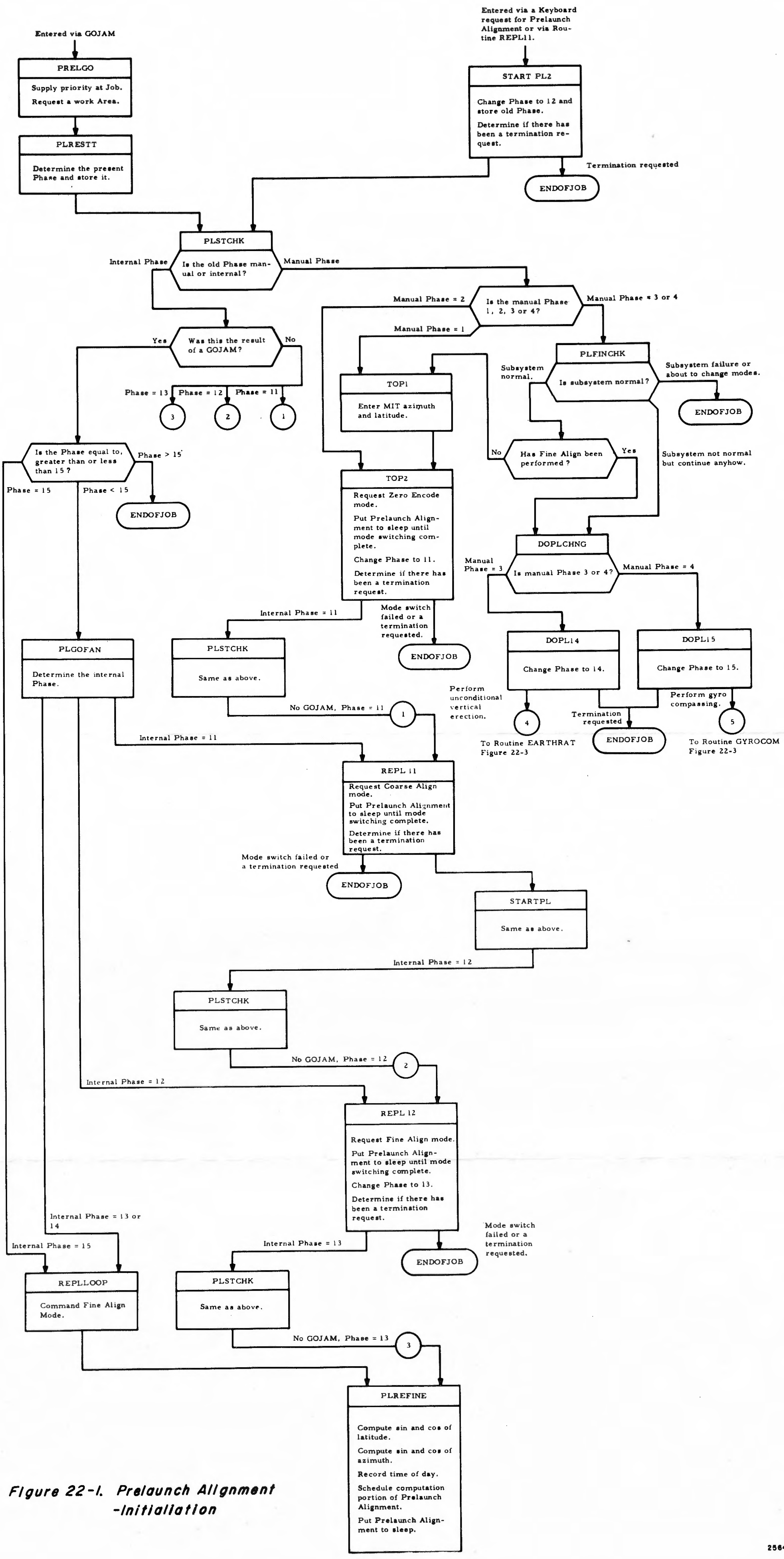

Figure 22-1. Prelaunch Alignment -Initialization

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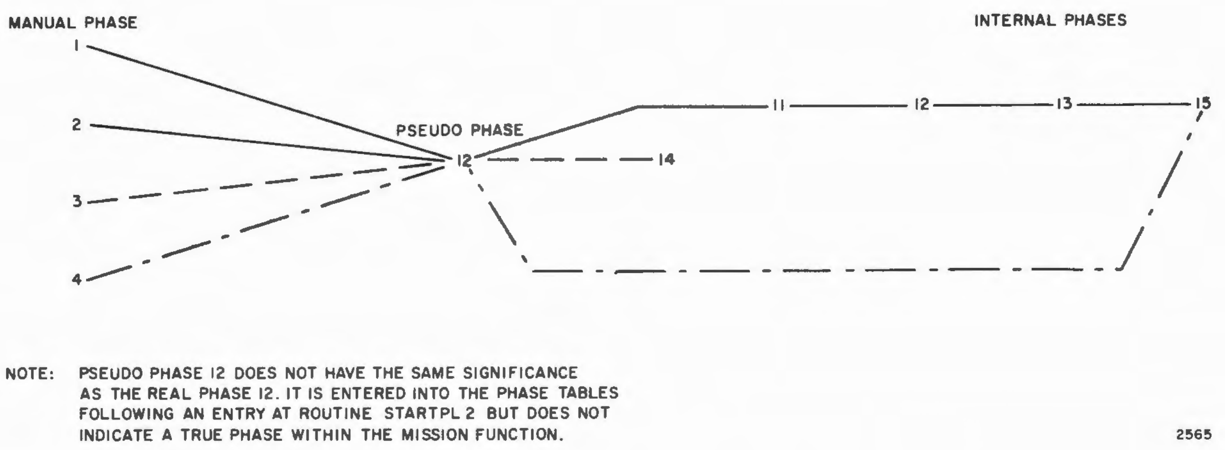

Figure 22-2. Phase Relationships

TABLE 22-1

INTERNAL PHASES FOR PRELAUNCH ALIGNMENT

Phase	Significance
11	Coarse alignment being performed.
12	Fine alignment being performed.
13	System is in vertical erection and is counting five minutes to gyrocompassing.
14	System is in unconditional vertical erection (no counting).
15	System is gyrocompassing.
37	Prelaunch alignment has been terminated.

22-11. Routine PLSTCHK determines if the old Phase, the Phase that was active prior to pseudo Phase 12, is manual or internal. Since, in this case, the old Phase has just been keyed in, it obviously is manual and program control is returned to Routine STARTPL2 which determines the specific manual Phase (1, 2, 3 or 4). The result of this test determines to which internal Phase Prelaunch Alignment will progress. If the Phase is 1 or 2, program control is transferred to Routine TOP1 or TOP2 respectively both of which lead to Phase 11. If the Phase is 3 or 4, program control is transferred to Routine PLFINCHK which leads to Phase 14 from Phase 3 and to Phase 15 from Phase 4.

22-12. PHASES 1 AND 2

22-13. Assuming the keyed in Phase is 1, program control is transferred to Routine TOP1 where the azimuth, gimbal and latitude angles and the gyro drift rates are initialized. The azimuth angle is set to 90 degrees as measured clockwise from north on a horizontal plane; the gimbal angles and the gyro drift rates are set to zero; and the latitude angle is set to correspond to that of MIT (42 degrees, 21 minutes and 51.189 seconds). Program control is then transferred to Routine TOP2.

22-14. Routine TOP2 is entered from Routine TOP1 when the keyed in Phase is 1 or directly from Routine STARTPL2, when the keyed in Phase is 2. The latter entry causes the initialization performed by Routine TOP1 to be bypassed; however, this initialization is still required and must be supplied manually just prior to the change major mode request containing Phase 2. (Refer to table 22-2 for the proper entries.) Thus the significant difference between Phase 1 and Phase 2 is that the former automatically causes initialization data for MIT to be stored in the computer while the latter allows initialization data for any test site to be manually entered into the computer.

22-15. Immediately upon entering Routine TOP2, program control is transferred to Routine IMUZERO of program section Mode Switching and Mark. Routine IMUZERO initially sets the CDU's associated with the IMU to electrical zero and then equates the CDU display dials with the actual IMU gimbal angles as described in paragraphs 14-17 through 14-33. Since the first Task performed by Routine IMUZERO is scheduled to be performed 40 seconds hence, program control is returned to Routine TOP2 to perform additional initialization. This initialization includes establishing the time for vertical erection at 5 minutes, setting up CDU driving constants which limit the amount the IMU CDU's are driven and ensuring that the magnitude of the gyro torquing commands does not exceed 320 pulses. Program control is then transferred to Routine IMUSTALL of Mode Switching and Mark (paragraphs 14-99 through 14-109) which puts Prelaunch Alignment to sleep

TABLE 22-2

INITIALIZATION ENTRIES PRIOR TO PHASE 2

Information	Entry
Azimuth	VERB 24, NOUN 01, ENTER 00765, ENTER +XXXXX, ENTER, +YYYYY, ENTER where X is the high order part and Y is the lower order part of the azimuth respectively.
Gimbal Angles	VERB 25, NOUN 01, ENTER 00706, ENTER ±AAAAA ENTER, ±BBBBB ENTER, ± CCCCC ENTER where A is the Y gimbal angle B is the Z gimbal angle C is the X gimbal angle
Latitude	VERB 24, NOUN 01, ENTER 00763, ENTER +XXXXX, ENTER, +YYYYY ENTER where X is the high order part and Y is the low order part of the latitude respectively
Gyro Drift Rate	VERB 25, NOUN 01, ENTER 00760, ENTER ±AAAAA, ENTER, ±BBBBB, ENTER ±CCCCC, ENTER where A is the gyro drift rate along Y axis B is the gyro drift rate along Z axis C is the gyro drift rate along X axis

until the mode switching performed by Routine IMUZERO has been completed. (While Prelaunch Alignment is dormant other Jobs may be executed according to their priority.) If the mode switching is unsuccessful, Prelaunch Alignment is terminated as a Job as described in paragraph 22-10. If the mode switching is successful, program control is transferred to Routine PHASCHNG of Progress Control via the calling sequence:

```
TC   PHASCHNG
OCT  01100
```

22-16. Routine PHASCHNG changes the Phase of Prelaunch Alignment from 12 (pseudo Phase) to 11, stores Phase 12 and determines if there has been a recent termination request. If such a request has been received, Prelaunch Alignment is terminated as described in paragraph 22-10. If there has been no termination request, program control is returned to Prelaunch Alignment at Routine PLSTCHK. Again Routine PLSTCHK tests to determine if the old Phase was manual or internal. Since the old Phase is internal, a test to determine if Routine PLSTCHK was entered following a GOJAM. This is not the case; therefore, program control is transferred to Routine REPL 11.

22-17. PHASE 11, COARSE ALIGN

22-18. Routine REPL11 uses Routine IMUCOARS of Mode Switching and Mark (paragraphs 14-33 through 14-42) to place the Inertial Subsystem into the Coarse Alignment mode. In this mode the IMU is slaved to the CDU's such that the stable member is oriented with respect to the navigation base as defined by the CDU settings. The execution of Routine IMUCOARS involves two Tasks; the first is scheduled to be executed in 200 milliseconds to verify that the mode switching has been completed, the second is scheduled to be executed 60 seconds after the first to drive the IMU CDU's. Program control is then transferred to Routine IMUSTALL also of Mode Switching and Mark via a return to Prelaunch Alignment.

22-19. Routine IMUSTALL puts Prelaunch Alignment to sleep until the mode switching performed by Routine IMUCOARS has been performed. If the mode switching is unsuccessful, Prelaunch Alignment is terminated as described in paragraph 22-10. If the mode switching is successful, program control is transferred to Routine STARTPL2 via a return to Routine REPL11.

22-20. Routine STARTPL2 transfers program control to Routine PHASCHNG via the calling sequence:

```
TC   PHASCHNG
OCT  01200
```

Routine PHASCHNG changes the Phase from 11 to 12 and tests to determine if there has been a manual request to terminate the Mission Function. If there has been a request, Prelaunch Alignment is terminated. If there has not been a request, program control is transferred to Routine PLSTCHK which determines that the old Phase was internal (Phase 11) and that there was no GOJAM. Program control is then transferred to Routine REPL12.

22-21. PHASE 12, FINE ALIGN

22-22. Routine REPL12 requests that the Inertial Subsystem be placed in the Fine Align mode via a call to Routine IMUFINE of Mode Switching and Mark, (paragraphs 14-43 through 14-51). Routine IMUFINE schedules a Task to be executed in 90 seconds which is sufficient time to drive the IMU CDU's to agree with the gimbal angles. While the mode switching and CDU driving is being performed, program control is transferred to Routine IMUSTALL via a brief return to Prelaunch Alignment. Routine IMUSTALL puts the Mission Function to sleep until the Fine Align operations have been performed. If the mode switching was unsuccessful, Prelaunch Alignment is terminated; otherwise, program control is transferred to Routine PHASCHNG via the calling sequence:

```
TC    PHASCHNG
OCT   01300
```

22-23. Routine PHASCHNG changes the active Phase from 12 to 13 and tests to determine if there has been a manual request to terminate the Mission Function. If there has been a request, Prelaunch Alignment is terminated; otherwise, program control is returned to Prelaunch Alignment at Routine PLSTCHK. Routine PLSTCHK determines that the old Phase was internal (Phase 12) and that there was no GOJAM. Program control is then transferred to Routine PLREFINE.

22-24. Routine PLREFINE computes the sin and cos of the launch site, latitude, records the time of day, schedules the computation portion of Prelaunch Alignment and then puts the Mission Function to sleep until the computation is to begin. Initially Routine PLREFINE initiates the interpretive instruction mode and clears the vector accumulator (VAC) assigned to Prelaunch Alignment. The VAC is cleared via an excursion through Routine ZEROVAC, an RTB Op Code routine. Upon returning to Prelaunch Alignment, Routine PLREFINE computes the sin and the cos of both the latitude and the azimuth of the launch site. (The launch site is MIT if the entry Phase was 1; the launch site is designated via a keyboard entry if the entry Phase was 2.) The content of time counters TIME2 and TIME1 (the time of day) is then recorded and stored. Routine PLREFINE then schedules the computation portion of

Prelaunch Alignment to be executed one-half second hence under the auspices of Routine PRELALTS (a Task). Program control is transferred to the Executive at Routine JOBSLEEP to put Prelaunch to sleep until Task PRELALTS is to be executed.

22-25. PHASES 3 AND 4

22-26. If Phase 3 or 4 is keyed in as part of the change major mode request, the operation of Routines STARTPL2 and PLSTCHK is the same as that described in paragraphs 22-10 and 22-11 with program control being transferred to Routine PLFINCHK. Routine PLFINCHK tests to determine if the Inertial Subsystem is operating normally. There are three possible results found during this test:

a. The subsystem failed or is about to switch modes; Prelaunch Alignment is terminated as a Job via Routines PRELEXIT, MAJEXIT and ENDOFJOB.

b. The subsystem is not operating normally; however, the operator has keyed in a request to continue anyhow. Program control is then transferred to Routine DOPLCHNG.

c. The subsystem is operating normally. An additional test is then made to determine if the subsystem is in Fine Align. If it is, program control is transferred to Routine DOPLCHNG. If it is not, program control is transferred to Routine TOP1 to initiate the moding sequence (Zero Encode, Coarse Align and Fine Align) described in paragraphs 22-12 through 22-24.

Thus, it can be seen that Phases 3 and 4 can only be successfully implemented when the Inertial Subsystem is operating normally and has previously been in the Zero Encode, Coarse Align and Fine Align modes or when the operator chooses to bypass these requirements and continue.

22-27. Routine DOPLCHNG determines if the keyed in Phase was 3 or 4. If the Phase was 3, program control is transferred to Routine DOPL14 to initiate unconditional vertical erection. If the Phase was 4, program control is transferred to Routine DOPL15 to initiate gyro compassing.

22-28. Routine DOPL14 requests that Routine PHASCHNG change the Phase to 14 via the calling sequence:

```
TC     PHASCHNG
OCT    01400
```

Routine PHASCHNG changes the active Phase from 12 to 14 and tests to determine if there has been a manual request to terminate the Mission Function. If there has been a request, Prelaunch Alignment is terminated; otherwise, program control is transferred to Routine EARTHRAT via Routine TJL to initiate unconditional vertical erection.

22-29. Routine DOPL15 requests that Routine PHASCHNG change the Phase to 15 via the calling sequence:

```
TC    PHASCHNG
OCT   01500
```

Routine PHASCHNG changes the active Phase from 12 to 15 and tests to determine if there has been a manual request to terminate the Mission Function. If there has been a request, Prelaunch Alignment is terminated; otherwise, program control is transferred to Routine GYROCOM via Routine DOGYROC to initiate gyro compassing.

22-30. <u>PLRESTT ENTRY</u>

22-31. Prelaunch Alignment is entered at Routine PLRESTT (figure 22-1) following a GO sequence (GOJAM). The entry allows Prelaunch Alignment to be reinitiated at the beginning of the Phase it was in when the GOJAM occurred. When the failure that caused the GOJAM is not serious enough to cause a fresh start, the restart portion of program section Fresh Start and Restart requests the Executive to initiate the execution of Prelaunch Alignment at Routine PRELGO (refer to paragraph 16-120). Routine PRELGO supplies the Job priority of Prelaunch Alignment to the Executive and request that a Work Area be assigned to the Job. Program control is then supplied to Routine PLRESTT which determines the present Phase of Prelaunch Alignment (the Phase it was in when the GOJAM occurred) and transfers control to Routine PLSTCHK.

22-32. Routine PLSTCHK determines if the Phase is manual or internal. If the Phase is manual, program control is transferred to Routine STARTPL2 to determine the manual Phase as described in paragraph 22-11. If the Phase is internal, a test is made to determine if GOJAM occurred. Since this is the case, program control is returned to Routine PLRESTT which determines if the Phase is equal to, greater than or less than 15. If the Phase is greater than 15, Prelaunch Alignment is terminated as a Job via Routines PRELEXIT, MAJEXIT and ENDOFJOB as described in paragraph 22-10. If the Phase is 15, program control is transferred to Routine RELOOP. If the Phase is less than 15, program control is transferred to Routine PLGOFAN.

22-33. Routine PLGOFAN determines the internal Phase (between 11 through 14) that was active when GOJAM occurred and transfers program control to the appropriate routine to activate the Phase. Phase 11 results in the execution of Routine REPL11 (paragraph 22-17), Phase 12 results in the execution of Routine REPL12 (paragraph 22-21), and Phases 13 and 14 result in the execution of Routine REPLLOOP.

22-34. Routine REPLLOOP, which is executed if the Phase is 13, 14 or 15, forces the Inertial Subsystem into the Fine Align mode and then transfers program control to Routine PLREFINE. Routine PLREFINE performs various operations in preparation for the computation portion of Prelaunch Alignment. Refer to paragraph 22-24 for a description of these operations.

22-35. COMPUTATION

22-36. The computation portion of Prelaunch Alignment includes a self perpetuating computation cycle, vertical erection and gyro compassing. The computation cycle is initiated every one-half second until some operator intervention occurs. Vertical erection and gyro compassing are performed under control of the computation cycle. Conditional vertical erection (Phase 13) is five minutes long followed by an indefinite period of gyro compassing (Phase 15). Unconditional vertical erection (Phase 14), once initiated continues indefinitely until interrupted by operator action.

22-37. COMPUTATION CYCLE INITIATION

22-38. Following the scheduling of Task PRELALTS which is described in paragraph 22-24, Prelaunch Alignment is dormant until the scheduled one-half second time period has elapsed. During this time, the Job of highest priority is executed interspersed with interrupt routines and Tasks. When the one-half second period has elapsed, a T3RUPT occurs which causes program control to be transferred to the scheduled Task, Routine PRELALTS (figure 22-3).

22-39. Routine PRELALTS initially records the contents of the PIPA counters for the Y and Z axes and sets these counters to zero. Program control is then transferred to Routine GETPHASE of program section Progress Control (paragraph 16-6) to determine whether or not there has been a manual request to terminate Prelaunch Alignment. (The primary purpose of Routine GETPHASE is not used, that is, to determine the current phase.) If there has not been a termination request, Routine PRELALTS schedules the execution of itself again in one-half second. If there has been a termination request, this scheduling is bypassed. Program control is then transferred to Routine JOBWAKE of program section Executive (paragraph 12-14) to request that Mission Function Prelaunch Alignment be activated at Routine PRAWAKE when the Mission Function is the Job of highest priority awaiting execution.

22-40. When program control is returned to Routine PRELALTS, a test is made to determine if Prelaunch Alignment was put to sleep prematurely. Prelaunch Alignment may have been put to sleep before a request was made to deactivate it which would prevent the Mission Function from being awakened later. If such is the case, Routine PRELALTS is terminated as a Task via Routine TASKOVER of program section Waitlist (paragraph 12-107).

This action allows Prelaunch Alignment to be properly deactivated. If Prelaunch Alignment were put to sleep properly, the PIPA information previously recorded is entered into the Job Area assigned to it and program control is transferred to Routine TASKOVER.

22-41. When Prelaunch Alignment becomes the Job of highest priority, the Executive transfers program control to the Mission Function at Routine PRAWAKE. Routine PRAWAKE zeros hypothetical south gyro and east gyro commands and then transfers program control to Routine GETPHASE. Routine GETPHASE determines the current Phase of Prelaunch Alignment and also determines if there has been a manual request to terminate the Mission Function. If there has been a termination requested, Prelaunch Alignment is terminated as a Job via Routines PRELEXIT of Prelaunch Alignment, MAJEXIT of Progress Control, and ENDOFJOB of the Executive as described in paragraph 22-10. If there has been no termination requested, program control is transferred to Routine PLSTCHK to determine if the Phase is manual (less than 10) or internal (greater than 10). If the Phase is manual, program control is transferred to Routine STARTPL2 as described in paragraph 22-11. If the Phase is internal, and a GOJAM has not occurred, program control is returned to Routine PRAWAKE which determines the current Phase (13, 14 or 15). Program operation as the result of each of these Phases is as follows:

a. Phase 13 causes program control to be transferred to Routine NOGYROCM to initiate or continue five minutes of vertical erection (conditional vertical erection).

b. Phase 14 causes program control to be transferred to Routine EARTHRAT to initiate or continue an indefinite period of vertical erection.

c. Phase 15 causes program control to be transferred to Routine GYROCOM to initiate or continue gyro compassing.

22-42. VERTICAL ERECTION

22-43. As previously described, vertical erection is performed for five minutes or for an indefinite period dependent upon whether the Phase is 13 or 14. The five-minute vertical erection is followed by gyrocompassing (Phase 15); unconditional vertical erection continues for an indefinite period, and is terminated by operator intervention.

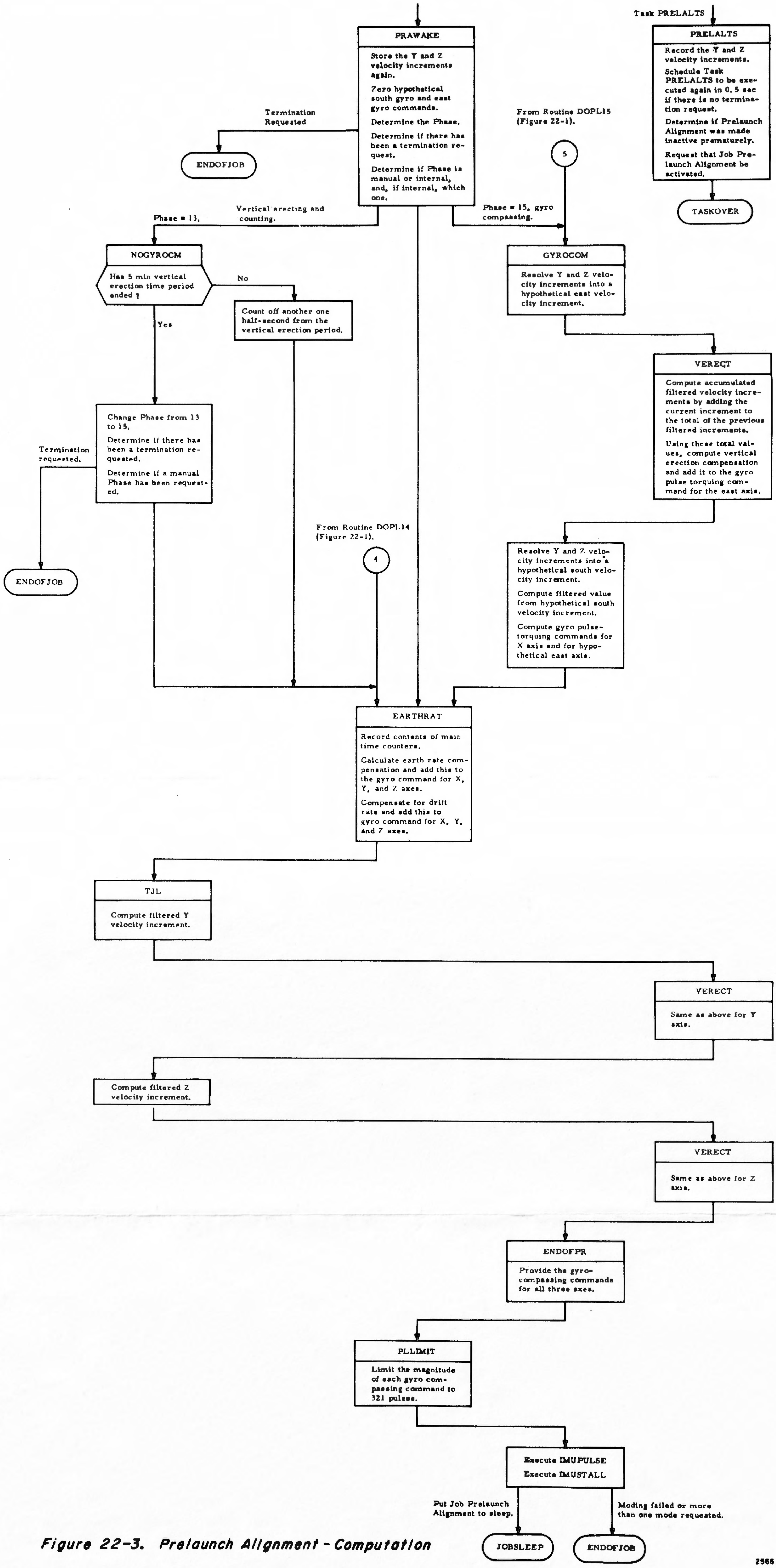

Figure 22-3. Prelaunch Alignment - Computation

22-44. PHASE 13, CONDITIONAL VERTICAL ERECTION

22-45. Conditional vertical erection is initiated when Routine PRAWAKE determines via Routine PLSTCHK that the current Phase is 13. Program control is transferred from Routine PRAWAKE to Routine NOGYROCM to initiate five minutes of vertical erection. Routine NOGYROCM initially tests to determine if the five-minute time period has elapsed. If the period has not elapsed, the remaining time is decreased by one-half second and program control is transferred to Routine EARTHRAT. If the period has elapsed, program control is transferred to Routine PHASCHNG of Progress Control via the calling sequence:

```
TC   PHASCHNG
OCT  01500
```

This operation causes the Phase to be changed from 13 to 15. In addition, Routine PHASCHNG determines if there has been a termination requested. If this is the case, Prelaunch Alignment is terminated as a Job; otherwise, program control is returned to Prelaunch Alignment to determine if a manual Phase has been requested. If there has been a manual Phase requested, program control is transferred to Routine STARTPL; if this is not the case, program control is transferred to Routine EARTHRAT.

22-46. Routine EARTHRAT is executed to calculate additions to the gyro compassing commands which compensate for earth rate. These additions are calculated in the following sequence:

a. Earth rate correction to the X Vertical IRIG command
b. Earth rate correction to the South IRIG command
c. Y IRIG command from the South IRIG and East IRIG commands
d. Z IRIG command from the South IRIG and East IRIG commands.

Prior to making these calculations, Routine EARTHRAT records the time of day via a brief excursion through Routine READTIME of Mode Switching and Mark (paragraph 14-140). This time value is subtracted from the previously recorded time of day to obtain the increment of time (Δt) since the last recording. The Δt value is used in determining the additions to the various IRIG commands. Table 22-3 lists the calculations and an explanation of each. Routing EARTHRAT also calculates the correction to the gyro commands needed to correct for gyro drift which is due to friction in the gimbals. The drift is calculated outside the computer; however, it is supplied to the computer to allow it to modify the gyro commands in all three axes(X, Y and Z). The drift correction is added directly to the appropriate command. Upon the completion of the IRIG command and the gyro drift corrections, program control is transferred to Routine TJL.

TABLE 22-3

IRIG COMMAND CORRECTIONS

Calculation	Explanation
1. $\theta_{X_n} = \theta_{X_{n-1}} + \Omega_e \Delta t \sin \lambda_L$	$\theta_{X_{n-1}}$ = previous X IRIG command Ωe = earth rate in IRIG pulses per 0.01 second Δt = elapsed time since the last time counter reading λL = latitude
2. $\theta_{STH_n} = \theta_{STH_{n-1}} - \Omega_e \Delta t \cos \lambda_L$	$\theta_{STH_{n-1}}$ = previous South IRIG command
3. $\theta_{Y_n} = \theta_{Y_{n-1}} + \theta_E \sin \psi_A + \theta_{STH_n} \cos \psi_A$	$\theta_{Y_{n-1}}$ = previous Y IRIG command * θ_E = East IRIG command θ_{STH} = South IRIG command * ψ_E = Azimuth
4. $\theta_{Z_n} = \theta_{Z_{n-1}} - \theta_{STH_n} \sin \psi_A + \theta_E \cos \psi_A$	$\theta_{Z_{n-1}}$ = previous Z IRIG command.

* Y is approximately East; Z is approximately South

22-47. Routine TJL computes filtered values of the PIPA readings for both the Y and Z axes. This filtering process, which involves the reduction of the PIPA values to smooth out the pulsing of the gyros, prevents jolting the IMU. The Y PIPA value is filtered first then the Z PIPA value. The filtered Y PIPA value is computed by the formula:

$$FIL\Delta V_{Y_n} = 0.1\left[\left(\Delta V_Y - FIL\Delta V_{Y_{n-1}}\right)\right] + FIL\Delta V_{Y_{n-1}}$$

where: $FIL\Delta V_{Y_{n-1}}$ = previous filtered value of Y PIPA reading

ΔV_Y = Y PIPA reading

Following this computation,program control is transferred to Routine VERECT.

22-48. Routine VERECT sums up the filtered values of the PIPA reading for both the Y and the Z axes and also computes the correction to both of the gyro pulse - torquing commands (Z IRIG and Y IRIG). This correction <u>maintains</u> the X axis in the vertical direction in response to the Y and Z PIPA readings. This is in contrast to the previous correction which is based on earth rate, time interval, azimuth and latitude which is used to <u>change</u> the X axis to the vertical position. Routine VERECT is executed twice in near succession, first for the Z axis and then for the Y axis.

22-49. Initially Routine VERECT stores the filtered Y PIPA reading $FIL\Delta V_{Y_n}$ and then computes the cumulative sum of the filtered Y PIPA readings by

$$INT_{Y_n} = INT_{Y_{n-1}} + FIL\Delta V_{Y_n}$$

Then the Z gyro command is computed

$$\theta_{Z_n} = C_1\ (FIL\Delta V_{Y_n}) + C_2\ (INT_{Y_n}) + \theta_{Z_{n-1}}$$

where: C_1 = 2.0 and C_2 = 0.4

$FIL\Delta V_{Y_n}$ = filtered Y PIPA reading

INT_{Y_n} = cumulative filtered Y PIPA readings

$\theta_{Z_{n-1}}$ = previous gyro command.

Thus the running total of the filtered values of the PIPA readings (velocity increments) for the Y axis is updated. Also, the maintenance correction to the gyro pulse-torquing command for the Z axis is computed and added to the Z IRIG command.

22-50. Program control is then returned to Routine TJL where the filtered Z PIPA reading is computed by

$$\mathrm{FIL}\,\Delta V_{Z_n} = 0.1 \left[\Delta V_Z - \mathrm{FIL}\Delta V_{Z_{n-1}}\right] + \mathrm{FIL}\Delta V_{Z_{n-1}}$$

Again program control is transferred to Routine VERECT which stores this value and computes the accumulated sum of the filtered Z PIPA readings and the Y gyro command by the formulas

$$\mathrm{INT}_{Z_n} = \mathrm{INT}_{Z_{n-1}} + \mathrm{FIL}\Delta V_{Z_n}$$

and

$$\theta_{Y_n} = \theta_{Y_{n-1}} - C_1 \left(\mathrm{FIL}\Delta V_{Z_n}\right) + C_2 \left(\mathrm{INT}_{Z_n}\right)$$

Thus the running total of the filtered values of the PIPA readings for the Z axis is updated and the correction to the Y axis gyro-torquing command is computed and added to the Y IRIG command. Program control is transferred to Routine ENDOFPR.

22-51. Routine ENDOFPR provides the gyro pulse-torquing commands for all three axes to Routine IMUPULSE to implement IRIG pulsing. Prior to this operation, a test is made to determine the state of the system. If a request for a mode switch has been made, but the switch has not been completed or there has been a failure, Prelaunch Alignment is terminated as a Job as described in paragraph 22-10. If the system is operating normally or if there has been a manual request to ignore this test, the gyro-pulse commands are provided for action by Routine IMUPULSE. Routine PLLIMIT, acting as a subroutine of Routine ENDOFPR, limits the magnitude of each gyro pulse command to 321 pulses. Program control is then transferred to Routine IMUPULSE of Mode Switching and Mark (paragraph 14-52) to cause the IMU gyros to be torqued the amount determined in Routine ENDOFPR. Routine IMUSTALL (paragraph 14-99) is then entered to put Prelaunch Alignment into a dormant state (to sleep) until the gyros have been pulsed.

22-52. If the moding fails or if another IMU mode is requested before the pulsing is completed, Prelaunch Alignment is terminated. If all is normal, Prelaunch Alignment is activated upon completion of the gyro pulsing; however, it is immediately made dormant again by Routine ENDOFPR and remains so until Task PRELALTS is executed again (every one-half second). Task PRELALTS requests the scheduling of itself again in one-half second and requests that Prelaunch Alignment be activated again as a Job at Routine PRAWAKE.

22-53. Thus one complete cycle during conditional vertical erection consists of:

a. Scheduling Task PRELALTS every one-half second.
b. Activating Prelaunch Alignment at Routine PRAWAKE.
c. Decrementing the five-minute counting period by one-half second.
d. Issuing gyro commands.
e. Putting Prelaunch Alignment to sleep.

This operation is repeated 600 times until the five-minute period has elapsed. On that pass through Routine NOGYROCM in which it is detected that the five minute interval has elapsed, program control is transferred to Routine PHASCHNG to change the Phase from 13 to 15 as described in paragraph 22-45. The next pass through Routine PRAWAKE causes the initiation of gyrocompassing.

22-54. PHASE 14, UNCONDITIONAL VERTICAL ERECTION

22-55. Unconditional vertical erection is initiated as the result of keying in Phase 3 as described in paragraph 22-26. The computation portion of Prelaunch Alignment is initially entered at Routine EARTHRAT when Phase 14 is active. Following this first pass through the computation portion, Prelaunch Alignment operates the same in Phase 14 as in Phase 13 except that Routine NOGYROCM is not utilized since there is no need to keep a record of elapsed time. The cycle described in paragraph 22-52 is continued indefinitely until some operator intervention is initiated.

22-56. GYROCOMPASSING

22-57. Gyrocompassing is initiated following the completion of conditional (5-minute) vertical erection or as the result of keying in Phase 4. The operation is the same in both cases except for the initial entry point into the computation portion of Prelaunch Alignment. Following vertical erection the entry point is Routine PRELALTS, while Phase 4 results in an entry at Routine GYROCOM.

22-58. Routine PRELALTS and Routine PRAWAKE are executed during gyrocompassing as described in paragraphs 22-39 through 22-41 for vertical erection. When it is determined that the current Phase is 15, program control is transferred from Routine PRAWAKE to Routine GYROCOM via Routine DOGYROC. From this point, gyrocompassing is executed the same whether initiated following vertical erection or directly from the keyboard.

22-59. Routine GYROCOM commences the computation of the gyro command used to maintain the Z PIPA axis along an azimuth in the plane of the desired vehicle trajectory. The Y and Z PIPA readings are resolved into a hypothetical East PIPA reading by computing the formula

$$\Delta V_E = \Delta V_Z \cos \psi_A + \Delta V_Y \sin \psi_A$$

where: ΔV_Z = Z PIPA reading

ΔV_Y = Y PIPA reading

ψ_A = azimuth.

Program control is then transferred to Routine VERECT to sum up the hypothetical East PIPA readings. This is accomplished by computing

$$INT_{E_n} = INT_{E_{n-1}} - \Delta V_E$$

where INT_E contains the sum or integrated value of the hypothetical East PIPA readings. Routine VERECT also computes the command for the hypothetical South IRIG by the formula

$$\theta_{STH_n} = \theta_{STH_{n-1}} + C_{12} V_E + C_{22} INT_{E_n}$$

where: $\theta_{STH_{n-1}}$ = previous South IRIG command

C_{12} = 1.0

C_{22} = 0.001

Program control is then returned to Routine GYROCOM.

22-60. Routine GYROCOM next resolves the Y and Z PIPA readings into a hypothetical South PIPA reading by the formula

$$\Delta V_{STH} = \Delta V_Y \cos \psi_A - \Delta V_Z \sin \psi_A$$

A filtered value of this hypothetical South PIPA reading is computed by the formula

$$\text{FILTER} = C_{1G}\ (\Delta V_{STH}) + C_{2G}\ (\text{FILTER})$$

where: $C_{1G} = 2^{28} - 1$

$C_{2G} = 0$

This is followed by a computation of the X IRIG and East IRIG gyrocompassing commands by the formulas

$$\theta_{X_n} = C_{3G}\ (\text{FILTER}) + \theta_{X_{n-1}}$$

where: $C_{3G} = -17$

$\theta_{X_{n-1}}$ = previous X IRIG command

and $\theta_E = C_{4G}$ (FILTER)

where: $C_{4G} = 2$

Upon the completion of these commands, program control is transferred to Routine EARTHRAT.

22-61. Routine EARTHRAT computes additions to the commands for earth rate and for gyro drift as described in paragraph 22-46. The remaining operations performed during gyrocompassing is the same as that described in paragraphs 22-47 through 22-52. Briefly, Routine TJL computes filtered Y and Z velocity increments which Routine VERECT uses to compute the correction to both gyro pulse-torquing commands. Routine ENDOFPR, in conjunction with Routine PLLIMIT, examines the gyro pulsing commands for each axis (X, Y and Z) and ensures that they do not exceed 321 pulses. The IRIG's are then torqued the desired amount and Prelaunch Alignment is put to sleep until Task PRELALTS is to be executed. Thus the first cycle of Phase 15 is complete and the next cycle is ready to begin. This operation continues indefinitely until the operator intervenes via the keyboard.