

DPS PROGRAM (P4C)

REV 02 12/03/69

## PURPOSE:

- (1) TO COMPLETE A PREFERRED IMU ORIENTATION AND A VEHICLE ATTITUDE FOR A LM DPS THRUSTING MANEUVER.
- (2) TO DO THE VEHICLE MANEUVER TO THE THRUSTING ATTITUDE.
- (3) TO CONTROL THE PGNS DURING COUNTDOWN, IGNITION, THRUSTING, AND THRUST TERMINATION OF A PGNS CONTROLLED DPS MANEUVER.

## ASSUMPTIONS:

- (1) THE TARGET PARAMETERS HAVE BEEN CALCULATED AND STORED IN THE LGC BY PRIOR EXECUTION OF A PRE-THRUSTING PROGRAM.

(2) THE REQUIRED STEERING EQUATIONS ARE IDENTIFIED BY THE PRIOR PRE-THRUST PROGRAM, WHICH EITHER RESET ("ASTEER") OR SET (EXT DELTA V) THE EXTERNAL DELTA V FLAG. FOR EXTERNAL DELTA V STEERING, VG IS CALCULATED ONCE FOR THE SPECIFIED TIME OF IGNITION. THEREAFTER BOTH DURING DPS THRUSTING AND UNTIL THE CREW NOTIFIES THE LGC THAT RCS TRIM THRUSTING HAS BEEN COMPLETED, THE LGC UPDATES VG ONLY AS A RESULT OF ACCELEROMETER INPUTS.

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+02  
+EDIT  
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FOR STEERING CONTROL WHEN USING "ASTEER", THE VELOCITY REQUIRED IS CALCULATED FROM FIGURE 3.3-13A IN SECTION 5 OF R-567. THE LAMBERT ROUTINE PERIODICALLY RE-COMPUTES THE INTERCEPT TRAJECTORY SEMI-MAJOR AXIS FOR THE "ASTEER" CALCULATIONS. THE INTERVAL BETWEEN LAMBERT SOLUTIONS IS CONTROLLED BY AN ERASABLE LOADED VALUE (UT).

(3) THE IMU IS ON AND MUST BE AT A KNOWN ORIENTATION BEFORE THIS PROGRAM MAY BE COMPLETED. IT IS NORMALLY REQUIRED THAT THE ISS BE ON FOR A MINIMUM OF 15 MINUTES PRIOR TO A THRUSTING MANEUVER.

(4) THE EVENT TIMER IS SET TO COUNT TO ZERO AT TIG.

(5) ENGINE IGNITION MAY BE SLIPPED BEYOND THE ESTABLISHED TIG IF DESIRED BY THE CREW, OR IF STATE VECTOR INTEGRATION CANNOT BE COMPLETED IN TIME.

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+EDIT  
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(6) IF A THRUSTING MANEUVER IS PERFORMED WITH THE GUIDANCE CONTROL SWITCH IN PGNS AND THE MODE CONTROL SWITCH IN AUTO, THE PGNS WILL CONTROL THE TOTAL VEHICLE ATTITUDE AND GENERATE EITHER MODE I OR MODE II ATTITUDE ERRORS AND VEHICLE ATTITUDE RATES (SEE ASSUMPTION (7)) FOR DISPLAY ON THE FDI. THE CREW MAY EXERCISE CONTROL AROUND THE YAW AXIS ONLY WITH THE ACA (X-AXIS OVERRIDE) IF THE X-AXIS OVERRIDE CAPABILITY IS PERMITTED BY THE PROGRAM IN PROCESS. THIS MANUAL CONTROL WILL BE IN THE RATE COMMAND/ATTITUDE HOLD MODE.

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+EDIT  
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+02  
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IF A THRUSTING MANEUVER IS PERFORMED WITH THE GUIDANCE CONTROL SWITCH IN PGNS AND THE MODE CONTROL SWITCH IN ATTITUDE HOLD THE PGNS WILL HOLD THE VEHICLE ATTITUDE AND WILL GENERATE EITHER MODE I OR MODE II ATTITUDE ERRORS FOR DISPLAY ON THE FDI. THE CREW MAY EXERCISE MANUAL ATTITUDE CONTROL ABOUT ALL VEHICLE AXES WITH THE ACA IN EITHER THE RATE COMMAND OR MINIMUM IMPULSE MODE DEPENDING UPON THE STATUS OF THE PULSES FLAG. HOWEVER, IT IS STRONGLY RECOMMENDED THAT POWERED FLIGHT NOT BE ATTEMPTED IN THE MINIMUM IMPULSE MODE. THE PULSES FLAG IS SET OR RESET BY EXTENDED VERBS 76 (MINIMUM IMPULSE) AND 77 (RATE COMMAND) RESPECTIVELY. THE PULSES FLAG IS ALSO RESET BY P12, P40, P41, P42, P63, P70, P71, AND R40 AT MAIN ENGINE IGNITION; WITH THE EXCEPTION OF THESE CASES, MODE SELECTION IS ALWAYS BASED UPON THE LAST ENTRY MADE IN THE DSKY. DURING A THRUSTING MANEUVER IN THE PGNS/ATTITUDE HOLD MODE THE PGNS WILL NOT BE RESPONSIBLE IF REGISTER OVERFLOWS OCCUR WITHIN THE LGC. IN THE EVENT THAT THE GUIDANCE CONTROL SWITCH IS CHANGED FROM PGNS TO AGS DURING A THRUSTING MANEUVER, THE LGC WILL CONTINUE COMPUTATION OF POSITION, VELOCITY, THE DESIRED THRUST VECTOR, AND THE DESIRED ATTITUDE ERRORS. HOWEVER, THE PGNS WILL NOT BE RESPONSIBLE IF REGISTER OVERFLOWS OCCUR WITHIN THE LGC.

(7) THE PGNS CAN GENERATE TWO TYPES OF ATTITUDE ERRORS FOR DISPLAY ON THE FDI:

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MODE I - SELECTED BY EXTENDED VERB 61. AUTOPILOT FOLLOWING ERRORS USED AS A MONITOR OF THE DAP'S ABILITY TO TRACK AUTOMATIC STEERING COMMANDS.

MODE II - SELECTED BY EXTENDED VERB 62. TOTAL ATTITUDE ERRORS USED TO ASSIST CREW IN MANUALLY MANEUVERING THE VEHICLE.

PGNS-DERIVED VEHICLE ATTITUDE RATES MAY ALSO BE DISPLAYED VIA SELECTION BY EXTENDED VERB 60.

MODE II ATTITUDE ERROR DISPLAYS ARE AUTOMATICALLY SELECTED AT THE BEGINNING OF R60. WITH THE EXCEPTIONS INDICATED

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+02  
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IN ASSUMPTION (6) ABOVE, DISPLAY SELECTION IS ALWAYS BASED UPON THE LAST ENTRY MADE IN THE DSKY.  
FOR A MORE DETAILED DESCRIPTION OF THESE DISPLAYS REFER TO SECTION 3 OF R567, PARA. 3.2.6

(8) THE X-AXIS OVERRIDE OPTION PROVIDES THE CREW WITH THE ABILITY TO EXERCISE MANUAL CONTROL ABOUT THE LM X AXIS WITH THE ATTITUDE CONTROLLER EVEN THOUGH THE PGNC'S ATTITUDE CONTROL MODE IS AUTO. WHEN THE CONTROLLER IS RETURNED TO DETENT THE PGNC'S DAMPS THE YAW RATE, STORES THE YAW ATTITUDE WHEN THE YAW RATE IS DAMPED, AND THEN MAINTAINS THAT ATTITUDE.

THE X-AXIS OVERRIDE OPTION IS ALWAYS AVAILABLE TO THE CREW, HOWEVER IT SHOULD NOT BE EXERCISED WHEN THE LGC IS SPECIFYING A DESIRED YAW ATTITUDE, I.E.: DURING THE ATTITUDE MANEUVER TO THE THRUSTING ATTITUDE (SEE R60).

(9) WHEN THE THRUST/TRANSLATION CONTROLLER IS SET TO MINIMUM THRUST POSITION AND THE LGC THROTTLE COMMAND IS ZERO THE DPS WILL START AT 10 PER CENT THRUST.

(10) THE LOAD DAP DATA ROUTINE (R03) HAS BEEN PERFORMED PRIOR TO SELECTION OF THIS PROGRAM AND THE DPS ENGINE GIMBAL HAS BEEN PREVIOUSLY DRIVEN TO THE CORRECT TRIM POSITION. IF THIS BURN IS OF SUFFICIENT DURATION THAT VEHICLE TRANSIENTS AT IGNITION DUE TO CG/THRUST DOES NOT AFFECT ACCOMPLISHMENT OF MANEUVER AIM CONDITIONS, THEN GIMBAL DRIVE TO TRIM POSITION NEED NOT BE DONE BEFORE TIG. GIMBAL DRIVE TO TRIM POSITION IN WORST CASE COULD REQUIRE 2 MINUTES.

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+02  
+EDIT  
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(11) DURING DPS BURNS ONLY, THE PITCH-ROLL RCS JET AUTOPILOT (U AND V JETS) MAY BE DISABLED (V65) OR ENABLED (V75) BY EXTENDED VERB AS SHOWN. THIS CAPABILITY IS INTENDED TO BE USED TO PREVENT LM AND DESCENT STAGE THERMAL CONSTRAINT VIOLATIONS DURING CSM-DOCKED DPS BURNS (P40). THE CAPABILITY EXISTS DURING P63 AND P70 ALSO. PERFORMANCE OF FRESH START (V36E) WILL ALWAYS ENABLE THE PITCH-ROLL JETS.

(12) FOR EACH BURN AN IGNITION TOTAL ALLOWABLE TIME DELAY WILL BE SPECIFIED IN THE MISSION RULES. THIS DELAY TIME IS THE TOTAL TIME WHICH THE THRUSTING MANEUVER MAY BE DELAYED BEYOND THE LGC CALCULATED TIME OF IGNITION. IF ENGINE RESTARTS ARE INVOLVED, THE ACCOUNTING OF THIS TOTAL TIME DELAY IS UP TO THE CREW.

(13) LGC AND CREW PROCEDURES IN CASES OF LGC-ASSUMED THRUST FAILURE ARE DEFINED BY THE DPS/APS THRUST FAIL ROUTINE (R4C). THIS ROUTINE IS CALLED AT DPS IGNITION BY THIS PROGRAM.

(14) THE LGC WILL NEITHER DESIGNATE NOR READ THE RENDEZVOUS RADAR (RR) DURING THIS PROGRAM.

(15) THIS PROGRAM SHOULD BE SELECTED BY THE ASTRONAUT BY DSKY ENTRY AT LEAST 5 MIN. BEFORE THE ESTIMATED TIME OF IGNITION.

(16) THIS PROGRAM IS SELECTED MANUALLY BY DSKY ENTRY.

PROG  
CNT

LGC

GROUND

CREW

. CREW  
. PROGRAM  
. SELECTION

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START DPS  
PROGRAM (P40)  
DISPLAY P40

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KEY IN DPS  
PROGRAM (P40)  
V37E 40E  
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#10

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227

MONITOR DSKY:  
OBSERVE DISPLAY OF  
P40

#20

IS THE APS FLAG SET?

.N .Y

POSS  
HOLD  
SNAP

FLASH VERB-NOUN  
TO REQUEST RE-  
SPONSE AND DIS-  
PLAY ALARM CODE  
C17C6 TO INDICA-  
TE THAT APS FLAG  
SHOWS THAT DPS  
HAS BEEN STAGED;  
V05M09  
R1-XXXXX  
R2-XXXXX  
R3-XXXXX

DOES VERB-NOUN FLASH  
TO REQUEST RESPONSE  
AND DISPLAY OF ALARM  
CODE INDICATE THAT  
APS FLAG SHOWS  
THAT DPS HAS BEEN  
STAGED?

(NOTE:  
THIS ALARM CODE  
MAY BE DISPLAYED IN  
EITHER R1, R2, OR  
R3, DEPENDING ON  
THE PRESENCE OR  
ABSENCE OF OTHER  
ALARM CODES.)

#30

.Y .N

#50

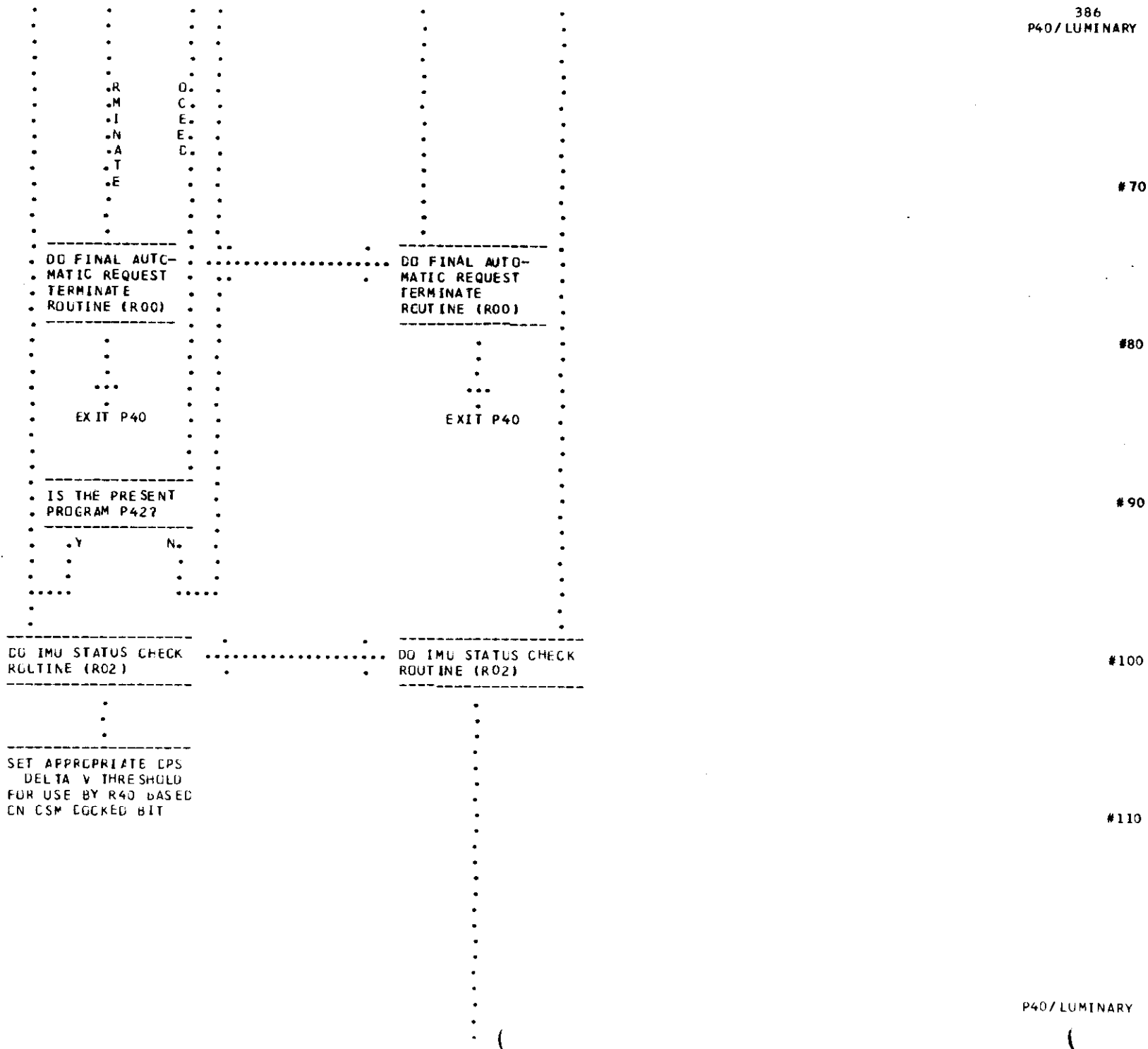
WAIT FOR KEY-  
BOARD ENTRY

KEY IN TERMINATE  
V34E

TERMINATE FLASH  
UPON RECEIPT OF  
TERMINATE OR  
PRCCCEED

#60

.T P.  
.E R.



IN DAP.

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SET DELTA V  
COUNTER=4 FOR USE  
BY R40

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RESET NO THROTTLE  
FLAG

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COMPUTE INITIAL  
THRUST DIRECTION  
AND INITIAL VALUE OF  
VG VECTOR AND STORE  
VG(LV) IN N81 AND  
N86 FOR POSSIBLE  
MANUAL SELECTION:

R1-VGX(LV)  
R2-VGY(LV)  
R3-VGZ(LV)

VGX(LV)-COMPONENT OF  
VG AT TIG ALONG  
(RXV)XR. IN FPS TO  
NEAREST .1 FPS.

VGY(LV)-COMPONENT OF  
VG AT TIG ALONG VXR.  
IN FPS TO NEAREST  
.1 FPS.

VGZ(LV)-COMPONENT OF  
VG AT TIG ALONG -R.  
IN FPS TO NEAREST  
.1 FPS.

#120

#130

#140

#150

WHERE R IS GEO-  
CENTRIC (EARTH  
ORBIT) OR SELENO-  
CENTRIC (LUNAR  
ORBIT) RADIUS VECTOR  
AND V IS VEHICLE  
INERTIAL VELOCITY  
VECTOR AT TIC.  
(NOTE: N81 WILL NOW  
DIFFER FROM N81 DIS-  
PLAY OF P30, P32,  
AND P33 BECAUSE OF  
ROTATION OF VG  
VECTOR).

#160

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COMPUTE PREFERRED  
IMU ORIENTATION:

#180

X = UNIT (T)  
-SM -

Y = UNIT (T X R)  
-SM - -

Z = UNIT(X X Y )  
-SM -SM -SM

WHERE:

#190

T = THE INITIAL  
- THRUST VECTOR  
AT TIG

R = THE GEOCENTRIC  
- (EARTH ORBIT)  
OR SELENO-  
CENTRIC (LUNAR  
ORBIT) RADIUS  
VECTOR AT TIG.

#200

(NOTE: IF T X R IS  
SMALL (REFER SECTION

5.3.3.3 OF R567),

THEN Y =

- SM

UNIT (T X V)

WHERE V = VEHICLE

INERTIAL VELOCITY  
VECTOR AT TIG.)

#210

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#220

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STORE DESIRED ATTITUDE SPECIFICATION FOR USE BY ATTITUDE MANEUVER ROUTINE (R60). THE FINAL ATTITUDE WILL BE COMPUTED DURING R60 AND WILL POINT THE LM +X AXIS IN THE INITIAL THRUST DIRECTION. HOWEVER, IN ORDER TO CONSERVE RCS FUEL AND NOT CONSTRAIN THE NON-CRITICAL ATTITUDE ABOUT THE THRUST VECTOR, WINGS MAY NOT BE LEVEL IN THE COMPUTED FINAL ATTITUDE.

#230

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SET PREFERRED-ATTITUDE-COMPLETED FLAG

#240

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COMMAND ZERO ATTITUDE ERRORS

#250

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SET 1 DEGREE  
DEADBAND.

#260

RESET 3-AXIS FLAG

#270

DO ATTITUDE MANEUVER  
ROUTINE (R60)

DO ATTITUDE MANEUVER  
ROUTINE (R60)

#280

HAVE PGNS CONTROL  
AND AUTO ATTITUDE  
CONTROL MODES BEEN  
SELECTED?

#290

.Y N.

IS THE APS FLAG  
SET?

#300

.Y N.



-----  
HAS THE AUTO  
THROTTLE MODE  
BEEN SELECTED?  
-----

.Y .N.

#310

POSS  
HOLD  
.....  
SNAP

-----  
FLASH VERB-NOUN  
TO REQUEST PLEASE  
PERFORM PGNS  
CONTROL, AUTO  
ATTITUDE CONTROL,  
AND AUTO THROTTLE  
MODE SELECTION:  
V50 N25  
R1 - 00203  
R2 - BLANK  
R3 - BLANK  
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MONITOR DSKY:  
GOES VERB-NOUN  
FLASH TO REQUEST  
PLEASE PERFORM  
PGNS CONTROL, AUTO  
ATTITUDE CONTROL,  
AND AUTO THROTTLE  
MODE SELECTION?  
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.Y .N

#320

-----  
HAVE REQUESTED  
MODES BEEN  
SELECTED?  
-----

.N .Y

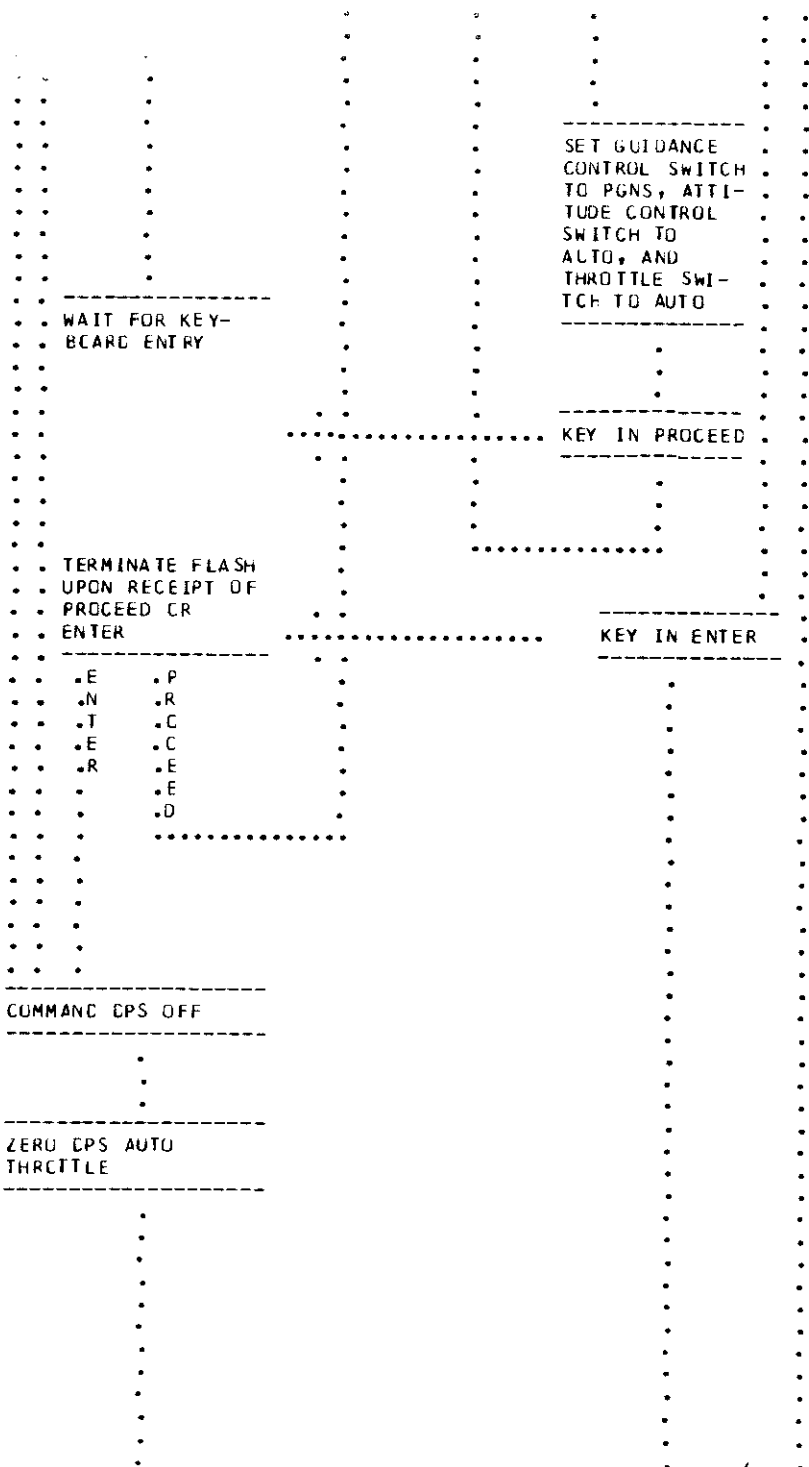
#330

-----  
DO I WISH TO  
HAVE THESE  
MODES SELECTED  
DURING THE  
THRUSTING  
MANEUVER?  
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.Y .N

#340

#350



#360

#370

#380

#390

#400

307

TEMP  
HOLD .  
-----  
..... DISPLAY ON DSKY:  
MON . VC6 N40  
R1-TFI  
R2-VG  
R3-DELTA VM

-----  
MONITOR DSKY:  
OBSERVE DISPLAY OF  
TFI, VG, AND DELTA  
VM.  
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TFI - TIME FROM  
DPS IGNITION. IN  
MIA, SEC TO NEAR-  
EST SEC. MAX  
READING IS 59B59.  
SIGN IS - BEFORE  
NOMINAL TIG, +  
THEREAFTER.

-----  
UPDATE EVENT TIMER  
IF DESIRED.  
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VG - MAGNITUDE OF  
THE VELOCITY TO BE  
GAINED BY THRUST-  
ING MANEUVER. IN  
FPS TO NEAREST .1  
FPS

DELTA VM-MEASURED  
DELTA V MAGNITUDE.  
IN FPS TO NEAREST  
.1 FPS. THIS DIS-  
PLAY WILL BE 0000  
UNTIL TIG-30 SEC  
AND THEN SHOULD  
CHANGE ONLY DUE TO  
PIPA BIAS UNTIL  
ULLAGE IS STARTED.

-----  
SET TDEC1 = TIG -30  
SECCNCS  
-----

#410

#420

#430

#440

#450

DO STATE VECTOR  
INTEGRATION (MID TO  
AVE) ROUTINE (R41).  
(NOTE: ENTER R41 AT  
"A".)

DO STATE VECTOR  
INTEGRATION (MID TO  
AVE) ROUTINE (R41)  
OBSERVE THAT THE  
COMPUTER ACTIVITY  
LIGHT IS ON UNTIL  
COMPLETION OF R41.

#460

.NO            TIG  
.TIG           SLIP  
.SLIP

VERIFY/SET THRUST/  
TRANSLATION CONTROL-  
LER TO MINIMUM  
THRUST POSITION.

#470

ARM DPS (AUTO  
THROTTLE SIGNAL IS  
ENABLED TO DPS AND  
THRUST INDICATOR.)

#480

CHECK THRUST INDICA-  
TOR (RIGHT SIDE) TO  
ENSURE AUTO THROTTLE  
COMMAND IS ZEROED (0  
PERCENT INDICATION).

#490

.Y            .N

GO TO  
BACKUP  
PROCED-  
URES.

#500

CHECK STATUS OF  
C/W LAMPS

#510

(NOTE: R41 WILL  
DEFINE TIG TO BE  
THE TIME TO WHICH  
R41 DID INTEGRATE  
THE LM STATE VEC-  
TOR PLUS 30  
SECONDS)

#520

WAIT UNTIL TIG -35  
SEC.

#530

BLANK THE DSKY DIS-  
PLAY (V, N, R1, R2,  
AND R3).

MONITOR DSKY:  
AT TFI = -00B35  
OBSERVE DSKY DISPLAY  
GO BLANK FOR 5  
SECONDS.

#540

WAIT UNTIL TIG -30  
SEC.

.....  
RETURN VC6N4C  
DISPLAYS  
-----

.....  
IS THE PRESENT  
PROGRAM P42?  
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.Y                    N.  
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-----  
SET APS FLAG  
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-----  
START AVERAGE G  
INTEGRATION  
-----

.....  
++  
+02  
+EDIT  
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-----  
AT TFI ==-7.5 SEC  
SET ULLAGE  
FLAG  
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.....  
MONITOR DSKY:  
AT TFI = -00B29  
OBSERVE RETURN OF  
VO6N40 DISPLAYS TO  
INDICATE THAT  
AVERAGE G INTEGRA-  
TION HAS STARTED.  
(NOTE: IF TIG HAS  
BEEN SLIPPED BY R41,  
THE TFI DISPLAY (R1)  
AT THIS TIME WILL BE  
REFERRED TO THE NEW  
TIG).  
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.....  
MONITOR DSKY:  
IN THE PERIOD FROM  
TFI ==-00B30 UNTIL  
TFI ==-00B15  
DOES DELTA VM BECOME  
GREATER THAN .5 FPS  
INDICATING EXCESSIVE  
PIPA BIAS ERROR?  
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.N                    .Y  
.  
.  
-----  
GO TO BACKUP  
PROCEDURES  
-----

.....  
AT TFI ==-00B07  
MONITOR START OF +X  
TRANSLATION.  
-----

#550

#560

#570

#580

#590

WAIT UNTIL  
TIG -5 SEC.

RF "  
FROM  
R40

RESET IGNITION FLAG

RESET ASTRONAUT FLAG

CALCULATE DURATION  
OF BURN

RESET IMPULSE FLAG

IS TG LESS THAN 6  
SECONDS, BASED ON  
ASSUMED 10% CPS

#600

#610

#620

#630

#640

THRST?

.N Y.

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. .

. SET IMPULSE FLAG

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. .

IS TG LESS THAN  
95 SECONDS, BASED  
ON ASSUMED 10%  
DPS THRST?

.N Y.

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. . . . .  
. .  
. .

. SET NO THROTT-  
. LE FLAG TO  
. INHIBIT THROT-  
. TLE COMMAND TO  
. MAXIMUM AT  
. TIG +  
. "ZOOMTIME"  
. SEC.  
. (NOTE: THE  
. VALUE  
. "ZOOMTIME" IS  
. IN ERASABLE  
. STORAGE HAVING  
. BEEN LOADED  
. PRIOR TO  
. LAUNCH OR BY  
. P27).

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. .

CALL VERB 99 DISPLAY  
(SEE "A" BELOW)

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. .

WAIT UNTIL TIG-C

. .  
. .  
. .  
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#650

#660

#670

#680

#690

#700



SET IGNITION FLAG

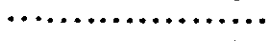
IS ASTRONAUT FLAG  
SET?

Y N  
GO TO EXIT  
"B" (NOTE: THIS  
BELOW IS NOT A P40  
EXIT. REFER  
DISPLAY RES-  
PONSE AT "A"  
BELOW.)

"A"  
FROM  
ABCDE

"F"  
FROM  
R40

HOLD . CHANGE VERB BUT  
..... RETAIN PRESENT NOUN  
MCN . AND DISPLAYS IN R1,  
R2, R3, FLASH VERB-  
NOUN TO REQUEST  
PLEASE PERFORM  
ENGINE CN ENABLE:  
V99N40



MONITOR DSKY:  
AT TFI = -00BC5  
OBSERVE VERB-NOUN  
FLASH TO REQUEST  
PLEASE PERFORM  
ENGINE CN ENABLE

MONITOR DSKY:  
WAIT FOR INCREASE OF

#710

#720

#730

#740

#750

-----  
WAIT FOR KEYBOARD  
ENTRY

DELTA VM INDICATING  
SUFFICIENT ULLAGE.  
REQUIRED ULLAGE  
DELTA V IS A  
FUNCTION OF VEHICLE  
WEIGHT.

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#760

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SHALL I ATTEMPT TO  
COMPLETE THE  
THRUSTING MANEUVER  
WITH THE RCS?

.Y                    N.  
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#770

.....  
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-----  
KEY IN ENTER

#780

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.  
GC TO  
"A"  
BELOW

#790

-----  
SHALL I PERMIT  
IGNITION?

.N                    .Y  
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.....  
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KEY IN PRUCEED

#800

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TERMINATE FLASH UPON  
RECEIPT OF ENTER,  
PROCEED OR TERMINATE.

KEY IN  
TERMINATE  
V34E

.P	.T	.E
.R	.E	.N
.G	.R	.T
.C	.M	.E
.E	.I	.R
.E	.N	.
.D	.A	.
.	.T	.
.	.E	.
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.	.	.
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RESET  
ULLAGE  
FLAG

GC TO  
"C"  
BELOW

DO FINAL AUTO-  
MATIC REQUEST  
TERMINATE ROU-  
TINE (RCO).

DO FINAL AUTO-  
MATIC REQUEST  
TERMINATE ROU-  
TINE (RCO).

#810

#820

#830

#840

#850

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EXIT P40  
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EXIT P40  
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SET ASTRONAUT FLAG  
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#860

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IS IGNITION FLAG  
SET?  
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.Y .N  
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MONITOR DSKY:  
IS R1 DISPLAY OF TFI  
NEGATIVE AND  
NON-ZERO?  
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.Y .N  
. .  
. .  
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#870

. RESUME STATIC  
DISPLAY OF  
V06N40  
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. MONITOR DSKY:  
OBSERVE RE-  
TURN OF STATIC  
VERB-NOUN  
(V06N40)  
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#880

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EXIT  
(NOTE: THIS IS  
NOT A P40 EXIT.  
REFER TIG-0  
LOGIC ABOVE.)  
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. .  
. .  
"B"  
FRM  
ABOVE  
. .  
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STANDBY FOR  
THRUST ON  
WHEN TFI= -00800  
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#890

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COMMAND DPS CN  
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. STANDBY FOR  
THRUST ON  
IMMEDIATELY  
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. .  
. .  
. .  
. .  
-----

#900

376

-----  
RESET PULSES FLAG  
-----

TEMP HOLD .  
-----  
MON . . . . . CHANGE TFI DISPLAY  
TO TFC IN R1;  
V06 N40  
R1 - TFC  
R2 - VG  
R3 - DELTA VM

-----  
TFC - TIME FROM  
ENGINE CUTOFF. IN  
MIN AND SEC TO NEAR-  
EST SEC. SIGN IS -  
BEFORE, AND + AFTER  
CUTOFF.  
-----

-----  
MONITOR DSKY:  
OBSERVE CHANGE OF  
TFI DISPLAY TO TFC  
IN R1. (NOTE: TFC IS  
INITIALLY CALCULATED  
ONCE AND DISPLAYED  
BASED ON 10% DPS  
THRUST. THIS DISPLAY  
WILL COUNT DOWN WITH  
ELAPSED TIME UNTIL  
TVC STEERING IS IN-  
ITIATED (WHEN STEER  
FLAG IS SET BY R40.)  
AT WHICH TIME TFC IS  
RECALCULATED AND  
DISPLAYED EVERY 2  
SECCNDS BY THE GUID-  
ANCE EQUATIONS.)  
-----

#910

#920

-----  
IS TFC AT IGNITION  
LESS THAN 6 SECCNDS?  
-----

.N                Y.  
.                    .  
.                    .  
.                    .  
.                    .  
.                    .  
.                    .  
.                    .  
.                    .  
.                    .  
GO TO  
"E"  
BELOW

#930

#940

-----  
IS THE NO THROTTLE  
FLAG SET?  
-----

.Y                N.  
.                    .  
.                    .  
.                    .  
-----  
. CALL FOR MAXIMUM  
THROTTLE COMMAND  
-----

-----  
IS TFC AT IGNITION  
LESS THAN 95  
SECCNDS?  
-----

.N                Y.  
.                    .  
.                    .  
.                    .  
.                    .  
.                    .  
GO TO  
GC TC

#950

. IN "ZOOMTIME"  
. SECONDS FROM NOW.  
. (SEE "D" BELOW)  
. (NOTE: THE VALUE  
. "ZOOMTIME" IS IN  
. ERASABLE STORAGE,  
. HAVING BEEN LOAD-  
. ED PRIOR TO LAU-  
. NCH OR BY P27).

"G"  
BELOW

#960

.  
. .  
. .  
. .  
. .  
. .  
. .  
. .  
. .  
. .  
. .  
. .

#970

IS IMPULSE FLAG SET?

.N                    Y.  
.                    .  
.                    .  
.                    .  
.                    .

#990

. CALL FOR ENGINE  
. OFF COMMAND AT  
. CALCULATED CUTCFF  
. TIME (SEE "H"  
. BELOW) (NOTE:  
. PGNS WILL COMMAND  
. INERTIAL VEHICLE  
. ATTITUDE HOLD  
. THROUGHOUT THRUST-  
. ING MANEUVER).

#1000

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. .  
. .  
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. .  
. .  
. .  
. .  
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.  
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.  
.  
.  
SEE "H" BELOW.)  
.  
.

-----  
RESET IGNITION FLAG  
-----

#1060

.  
.  
.  
.

-----  
RESET ASTRONAUT FLAG  
-----

#1070

.  
.  
.  
.

-----  
RE SET  
IDLE FLAG  
-----

#1080

.  
.  
.  
.

-----  
CALL FOR RESET  
OF ULLAGE FLAG IN  
C.5 SECONDS.  
(SEE "D"  
BELOW.)  
-----

#1090

.  
.  
.  
.  
.  
EXIT  
(NOTE: THIS IS  
NOT A P40 EXIT.  
SEE "D" BELOW).

#1100

"D"



FRM  
ABOVE

-----  
AT ACTUAL TIG PLUS  
"ZOOMTIME" SEC  
COMMAND THROTTLE  
TO MAXIMUM.  
-----

-----  
"ZOOMTIME" SECONDS  
AFTER ACTUAL TIG  
OBSERVE THRUST  
INDICATOR TO INDI-  
CATE XX PERCENT  
AUTO THROTTLE COM-  
MAND (RIGHT SIDE)  
AND 100 PERCENT  
CHAMBER PRESSURE  
(LEFT SIDE).  
(NOTE: THE VALUE  
"ZOOMTIME" IS IN  
ERASABLE STORAGE  
HAVING BEEN LOADED  
PRIOR TO LAUNCH  
OR BY P27).  
-----

#1110

#1120

#1130

-----  
"G"  
FROM  
ABOVE  
-----

-----  
MAXIMUM THROTTLE  
WILL NOT BE  
COMMANDED.  
-----

#1140

"E"  
FROM  
ABOVE

#1150

-----  
THIS MANEUVER  
IS AN IMPULSE  
MANEUVER AND  
WILL BE DONE  
AT AN INERTI-  
ALLY FIXED  
VEHICLE  
ATTITUDE.  
-----

#1160

-----  
MONITOR DPS  
THRUSTING:

1. DSKY:  
R1-TFC  
SHOULD BE  
DECREASING

R2-VG SHOULD BE  
DECREASING

#1180

R3-DELTA VM  
SHOULD INCREASE

2. FDI-ATT. ERRORS  
SHOULD BE LESS THAN  
OR EQUAL TO XX  
DEGREE.

ATT RATES SHOULD BE  
LESS THAN OR EQUAL  
TO XX DEGREE/SEC.

#1190

3. THRUST INDICATOR  
LEFT SIDE: XX PER-  
CENT MAX CHAMBER

202

(

(



-----  
CONTINUE GUIDANCE  
CONTROL  
-----

#1250

-----  
CALL ENGINE OFF COM-  
MAND AT COMPUTED  
REQUIRED TIME.  
-----

SEE DPS/APS  
THRUST FAIL  
ROUTINE  
(R40) FOR  
REQUIRED  
RESPONSE

#1260

-----  
COMMAND ZERO ATTI-  
TUDE RATES  
-----

#1270

-----  
SET IDLE FLAG  
-----

#1280

-----  
WAIT UNTIL COMPUTED  
TIME OF CUTOFF.  
-----

#1290

FRM  
ABOVE

-----  
COMMAND ENGINE OFF  
-----

#1300

-----  
ZERO DPS AUTO  
THRUSTLE  
-----

#1310

-----  
COMMAND ZERO ATTITUDE RATES  
-----

-----  
SET DEADBAND  
TO PREVIOUS VALUE  
DEFINED BY R03.  
-----

#1320

-----  
MAINTAIN VG  
COMPUTATIONS AFTER  
CUTOFF FOR POSSIBLE  
NULLING BY RCS  
TRIMMING MANEUVER  
(NOTE: SEE ASSUMPTION (2) ABOVE).  
-----

#1330

DISARM DPS

#1340

"C"  
FROM  
ABOVE

"A"  
FROM  
ABOVE

#1350

COMMAND  
ZERO  
ATTITUDE  
RATES

#1360

SET DEAD-  
BAND  
TO  
PREVIOUS  
VALUE  
DEFINED  
BY R03.

#1370

RESET  
ULLAGE  
FLAG

#1380

FLASH VERB-NDUN TO  
REQUEST PROCEED.  
HOLD DISPLAY OF TFC  
AT ITS FINAL VALUE:  
V16 N4C  
R1 - TFC  
R2 - VG  
R3 - DELTA VM

MONITOR OSKY:  
OBSERVE VERB-NDUN  
FLASH TO REQUEST  
PROCEED AND DISPLAY  
OF TFC, VG AND DELTA  
VM.

#1390

HOLD  
MON

NOTE: SEE ASSUMPTION (2) ABOVE).

#1400

RECORD THESE VALUES AS DESIRED.

#1410

WAIT FOR KEYBOARD ENTRY  
TERMINATE FLASH UPON RECEIPT OF PROCEED, RECYCLE, CR TERMINATE.

KEY IN PROCEED

#1420

.P .T .R  
.R .E .E  
.G .R .C  
.C .M .Y  
.E .I .C  
.E .N .L  
.D .A .E  
. .T .  
. .E .....

#1430

GC TO  
"C"  
BELOW

COMMAND ZERO ATTITUDE ERRORS

#1440

SET .3 DEGREE DEADBAND

#1450

HOLD . . . . .  
.....  
MGN . . . . .  
FLASH VERB-NCUN TO  
REQUEST RESPONSE AND  
DISPLAY COMPONENTS  
OF VG(LM):  
V16 N85  
R1-VGX(LM)  
R2-VGY(LM)  
R3-VGZ(LM)

MONITOR DSKY:  
OBSERVE VERB-NCUN  
FLASH TO REQUEST  
RESPONSE AND DISPLAY  
COMPONENTS OF VG(LM)

#1460

COMPONENTS OF THE  
PRESENT VG VECTOR  
RESOLVED ALONG THE  
LM X, Y, AND Z AXES.  
THE VG VECTOR WILL  
BE UPDATED BY THE  
STEERING LOOPS  
DURING EACH COMPUTA-  
TION CYCLE. IN FPS  
TO NEAREST .1 FPS.  
(NOTE: SEE ASSUMP-  
TION (2) ABGVE).

TO NULL OUT VG  
COMPONENTS COMMAND  
MANUAL TRANSLATIONS  
AND ROTATIONS.  
(NOTE: THIS MANEUVER  
IS AT THE OPTION OF  
THE CREW.)

#1470

THE ORBITAL PARA-  
METER DISPLAY  
ROUTINE (R30) MAY BE  
SELECTED AT THIS  
TIME (V82E) TO  
MONITOR CONTINUOUSLY  
UPDATED VALUES OF  
APU ALT, PER ALT,  
AND TFF.

#1480

WAIT FOR KEYBOARD  
ENTRY  
TERMINATE FLASH UPON  
RECEIPT OF PROCEED,  
RECYCLE, OR TERMIN-

KEY IN PROCEED

#1490



ATE.

```

.P      .T      .R
.R      .E      .E
.G      .R      .C
.C      .M      .Y
.E      .I      .C
.E      .N      .L
.D      .A      .E
      .T
      .E
  
```

"D"  
FROM  
ABOVE

ZERO RENDEZ VOUS  
TRACKING MARK  
COUNTER.

SET DEADBAND  
TO PREVIOUS VALUE  
DEFINED BY RC3.

DO FINAL AUTOMATIC  
REQUEST TERMINATE  
ROUTINE (RC0)

DO FINAL AUTOMATIC  
REQUEST TERMINATE  
ROUTINE (RC0)

#1500

#1510

#1520

#1530

#1540

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EXIT P40

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EXIT P40

#1550

CHANGE CONTROL NOTES

REV 00 PCR 30,31  
REV 01 PCR 85,86,144,164,186,401,419,539,609,637  
REV 00(LUM 1A) PCR 647,648  
REV 01(LUM 1B) PCR 838,841,EDITORIAL  
REV 02 ECITORIAL

330

RCS PROGRAM (P41)

REV 02 12/03/69

PURPOSE: (1) TO COMPUTE A PREFERRED IMU ORIENTATION AND A VEHICLE ATTITUDE FOR AN RCS THRUSTING MANEUVER.  
 (2) TO PERFORM THE VEHICLE MANEUVER TO THE THRUSTING ATTITUDE.  
 (3) TO PROVIDE SUITABLE DISPLAYS FOR MANUAL EXECUTION OF THE THRUSTING MANEUVER IN THE ATTITUDE HOLD MODE.

ASSUMPTIONS: (1) THE TARGET PARAMETERS HAVE BEEN CALCULATED AND STORED IN THE LGC BY PRIOR EXECUTION OF A PRE-THRUSTING PROGRAM.  
 (2) THE REQUIRED STEERING EQUATIONS ARE IDENTIFIED BY THE PRIOR PRE-THRUST PROGRAM, WHICH EITHER RESET ("ASTEER") OR SET (EXT DELTA V) THE EXTERNAL DELTA V FLAG. FOR EXTERNAL DELTA V STEERING, VG IS CALCULATED ONCE FOR THE SPECIFIED TIME OF IGNITION. THEREAFTER UNTIL THE CREW NOTIFIES THE LGC THAT RCS THRUSTING HAS BEEN COMPLETED, THE LGC UPDATES VG ONLY AS A RESULT OF ACCELEROMETER INPUTS.  
 FOR STEERING CONTROL WHEN USING "ASTEER", THE VELOCITY REQUIRED IS CALCULATED FROM FIGURE 3.3-13A IN SECTION 5 OF R-567. THE LAMBERT ROUTINE PERIODICALLY RE-COMPUTES THE INTERCEPT TRAJECTORY SEMI-MAJOR AXIS FOR THE "ASTEER" CALCULATIONS. THE INTERVAL BETWEEN LAMBERT SOLUTIONS IS CONTROLLED BY AN ERASABLE LOADED VALUE (UT).

(3) WITH THE GUIDANCE CONTROL SWITCH IN PGNS AND THE MODE CONTROL SWITCH IN ATTITUDE HOLD THE PGNS WILL HOLD THE VEHICLE ATTITUDE AND WILL GENERATE EITHER MODE I OR MODE II ATTITUDE ERRORS AND VEHICLE ATTITUDE RATES (SEE ASSUMPTION (4)) FOR DISPLAY ON THE FDAI. THE CREW MAY EXERCISE MANUAL ATTITUDE CONTROL ABOUT ALL VEHICLE AXES WITH THE ACA IN EITHER THE RATE COMMAND OR MINIMUM IMPULSE MODE DEPENDING UPON THE STATUS OF THE PULSES FLAG. HOWEVER, IT IS STRONGLY RECOMMENDED THAT POWERED FLIGHT NOT BE ATTEMPTED IN THE MINIMUM IMPULSE MODE. THE PULSES FLAG IS SET OR RESET BY EXTENDED VERBS 76 (MINIMUM IMPULSE) AND 77 (RATE COMMAND) RESPECTIVELY. THE PULSES FLAG IS ALSO RESET BY P12, P40, P41, P42, P63, P70, P71, AND R40 AT MAIN ENGINE IGNITION; WITH THE EXCEPTION OF THESE CASES, MODE SELECTION IS ALWAYS BASED UPON THE LAST ENTRY MADE IN THE DSKY. DURING A THRUSTING MANEUVER IN THE PGNS/ATTITUDE HOLD MODE THE PGNS WILL NOT BE RESPONSIBLE IF REGISTER OVERFLOWS OCCUR WITHIN THE LGC.

(4) THE PGNS CAN GENERATE TWO TYPES OF ATTITUDE ERRORS FOR DISPLAY ON THE FDAI;  
 MODE I - SELECTED BY EXTENDED VERB 61. AUTOPILOT FOLLOWING ERRORS USED AS A MONITOR OF THE DAPI'S ABILITY TO TRACK AUTOMATIC STEERING COMMANDS.  
 MODE II - SELECTED BY EXTENDED VERB 62. TOTAL ATTITUDE ERRORS USED TO ASSIST CREW IN MANUALLY MANEUVERING THE VEHICLE.  
 PGNS-DERIVED VEHICLE ATTITUDE RATES MAY ALSO BE DISPLAYED VIA SELECTION BY EXTENDED VERB 60.  
 MODE II ATTITUDE ERROR DISPLAYS ARE AUTOMATICALLY SELECTED AT THE BEGINNING OF R60. WITH THE EXCEPTIONS INDICATED IN ASSUMPTION (3) ABOVE, DISPLAY SELECTION IS ALWAYS BASED UPON THE LAST ENTRY MADE IN THE DSKY. FOR A MORE DETAILED DESCRIPTION OF THESE DISPLAYS REFER TO SECTION 3 OF R-567, PARA 3.2.6.

(5) THE IMU IS ON AND MUST BE AT A KNOWN ORIENTATION BEFORE THIS PROGRAM MAY BE COMPLETED. IT IS NORMALLY REQUIRED THAT THE ISS BE ON FOR A MINIMUM OF 15 MINUTES PRIOR TO A THRUSTING MANEUVER.

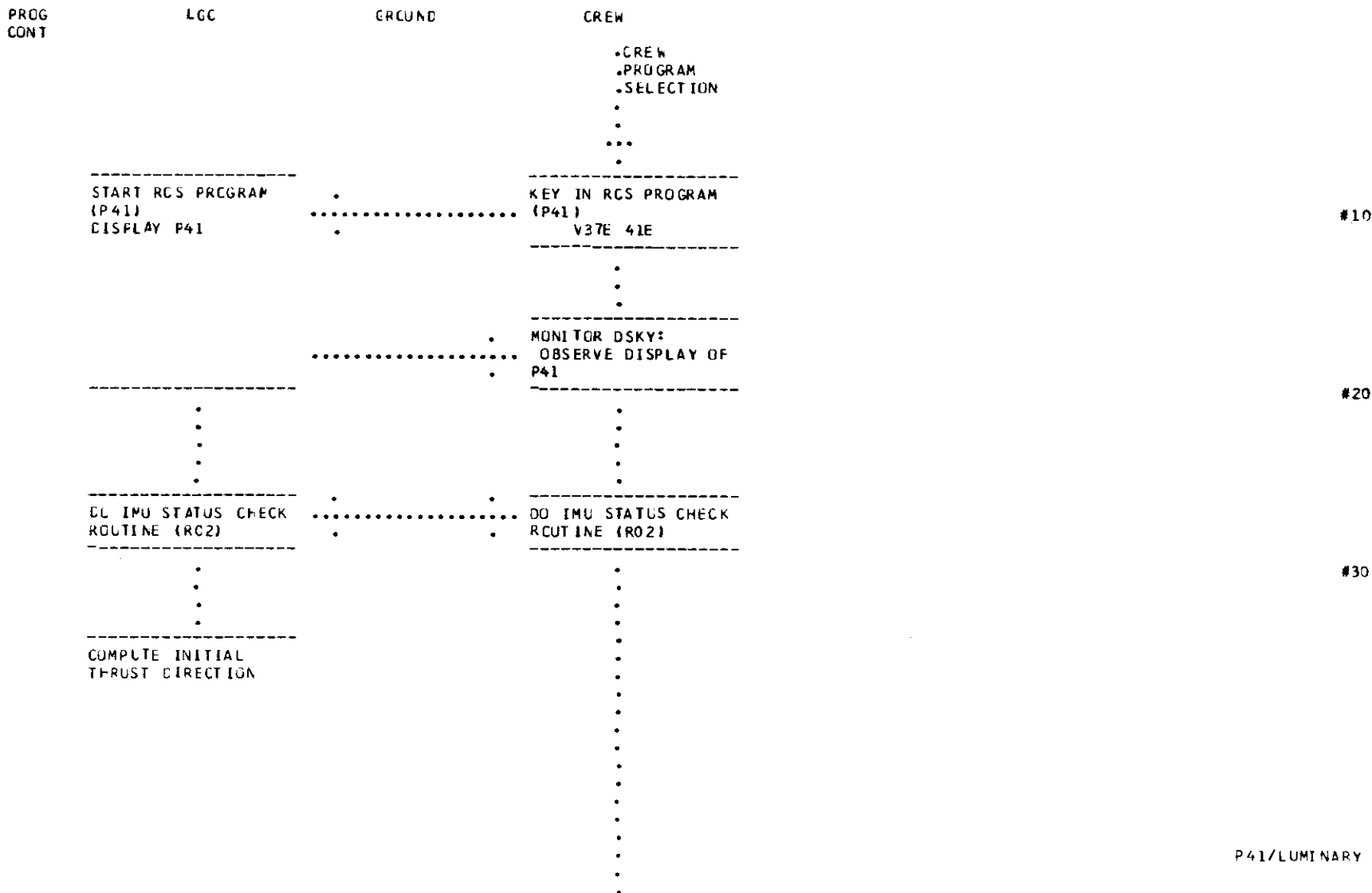
(6) THE EVENT TIMER IS SET TO COUNT TO ZERO AT TIG.

(7) RCS IGNITION MAY BE SLIPPED BEYOND THE ESTABLISHED TIG IF DESIRED BY THE CREW, OR IF STATE VECTOR INTEGRATION CANNOT BE COMPLETED ON TIME.

(8) THE X - AXIS OVERRIDE OPTION PROVIDES THE CREW WITH THE ABILITY TO EXERCISE MANUAL CONTROL ABOUT THE LM X AXIS WITH THE ATTITUDE CONTROLLER EVEN THOUGH THE PGNS ATTITUDE CONTROL MODE IS AUTO. WHEN THE CONTROLLER IS RETURNED TO DETENT THE PGNS DAMPS THE YAW RATE, STORES THE YAW ATTITUDE WHEN THE YAW RATE IS DAMPED, AND THEN MAINTAINS THAT ATTITUDE.  
 THE X - AXIS OVERRIDE OPTION IS ALWAYS AVAILABLE TO THE CREW, HOWEVER IT SHOULD NOT BE EXERCISED WHEN THE LGC IS SPECIFYING A DESIRED YAW ATTITUDE, I.E.: DURING THE ATTITUDE MANEUVER TO THE THRUSTING ATTITUDE (SEE R60).

- (9) THE LOAD DATA ROUTINE (R03) HAS BEEN PERFORMED PRIOR TO SELECTION OF THIS PROGRAM.
- (10) THE LGC WILL NEITHER DESIGNATE NOR READ THE RENDEZVOUS RADAR (RR) DURING THIS PROGRAM.
- (11) THIS PROGRAM IS SELECTED MANUALLY BY DSKY ENTRY.

++  
+02  
+EDIT  
++



(

(

AND INITIAL VALUE  
OF VG VECTOR AND  
STORE VG(LV) IN N81  
AND N86 FOR POSSIBLE  
MANUAL SELECTION:

#40

R1-VGX(LV)  
R2-VGY(LV)  
R3-VGZ(LV)

VGX(LV)-COMPONENT OF  
VG AT TIG ALONG  
(RXV)XR. IN FPS TO  
NEAREST .1 FPS.

#50

VGY(LV)-COMPONENT OF  
VG AT TIG ALONG VXR.  
IN FPS TO NEAREST  
.1 FPS.

VGZ(LV)-COMPONENT OF  
VG AT TIG ALONG -R.  
IN FPS TO NEAREST  
.1 FPS.

#60

WHERE R IS GEOCENT-  
RIC (EARTH ORBIT) OR  
SELENOCENTRIC (LUNAR  
ORBIT) RADIUS VECTOR  
AND V IS VEHICLE  
INERTIAL VELOCITY  
VECTOR AT TIG.  
(NOTE: N81 WILL NOW  
DIFFER FROM N81 DIS-  
PLAY OF P30, P32,  
AND P33 BECAUSE OF  
ROTATION OF VG  
VECTOR).

#70

-----  
.  
.  
.  
-----

COMPUTE PREFERRED  
IML ORIENTATION:

#80

X = UNIT T  
-SM -

Y = UNIT (T X R)  
-SM - -

Z = UNIT (X X Y )  
-SM -SM -SM

WHERE:

T = THE INITIAL  
-  
THRUST VECTOR.

R = THE GECCENTRIC  
-  
(EARTH ORBIT) OR  
SELENOCENTRIC  
(LUNAR ORBIT)  
RADIUS VECTOR AT  
TIG.  
(NOTE: IF T X R IS

SMALL (REFER SECTION  
5.3.3.3.3 OF R567),  
THEN Y =  
-SM

UNIT (T X V)

WHERE V = VEHICLE  
-

INERTIAL VELCCITY  
VECTOR AT TIG.)

-----

.  
. .  
. .  
. .

-----  
STORE DESIRED ATTI-  
TUDE SPECIFICATION  
FOR USE BY ATTITUDE  
MANEUVER ROUTINE  
(R60). THE FINAL  
ATTITUDE WILL BE  
COMPUTED DURING R60

#90

#100

#110

#120

#130

AND WILL POINT THE  
LM +X AXIS IN THE  
INITIAL THRUST DI-  
RECTION.  
HOWEVER, IN ORDER TO  
CONSERVE RCS FUEL  
AND NOT CONSTRAIN  
THE NON-CRITICAL  
ATTITUDE ABOUT THE  
THRUST VECTOR, WINGS  
MAY NOT BE LEVEL IN  
THE COMPUTED FINAL  
ATTITUDE.

#140

-----  
.  
.  
SET PREFERRED-ATT-  
ITUDE-COMPUTED FLAG.  
-----

#150

-----  
.  
.  
COMMAND ZERO ATTI-  
TUDE ERRORS  
-----

#160

-----  
.  
.  
SET 0.3 DEGREE  
DEADBAND  
-----

#170

-----  
.  
.  
RESET 3-AXIS FLAG  
-----

-----  
.  
.  
DO ATTITUDE MANEUVER  
ROUTINE (R60)  
-----

.....  
.  
.  
DO ATTITUDE MANEUVER  
ROUTINE (R60)  
-----

#180

TEMP  
HOLD

MON

-----  
DISPLAY ON DSKY:

V16 N85  
R1-VGX(LM)  
R2-VGY(LM)  
R3-VGZ(LM)

-----  
MONITOR DSKY:  
OBSERVE DISPLAY OF  
VG COMPONENTS.  
-----

(VGX(LM), VGY(LM)  
VGZ(LM) - COMPON-  
ENTS OF THE VG  
VECTOR AT TIG RESOL-  
VED ALONG LM X, Y,  
AND Z AXES RESPEC-  
TIVELY. UPDATED  
W.R.T. VEHICLE ATT I-  
TUDE EVERY 1 SECCAD.  
IN FPS TO NEAREST  
.1 FPS. (NOTE: SEE  
ASSUMPTION (2)  
ABOVE.)

-----  
SET TDEC1=TIG-30  
SEC.  
-----

-----  
DO STATE VECTOR  
INTEGRATION (MID TO  
AVE) ROUTINE (R41).  
(NOTE: ENTER R41  
AT "A".)

-----  
DO STATE VECTOR  
INTEGRATION (MID TO  
AVE) ROUTINE (R41).  
-----

.NC            TIG.  
.TIG           SLIP.

#190

#200

#210

#220



. . . . .  
SLIP  
. . . . .

# 230

-----  
. DEFINE TIG TO BE  
. THE TIME TO WHICH  
. R41 DID INTEGRATE  
. THE LM STATE VEC-  
. TOR PLUS 30  
. SECONDS.  
-----  
. . . . .

#240

-----  
WAIT UNTIL TIG  
-35 SEC.  
-----  
. . . . .

# 250

-----  
BLANK THE DSKY DIS-  
PLAY (V,N,R1,R2, AND  
R3)  
-----  
. . . . .

-----  
. MONITOR DSKY:  
. AT TIG-35 SEC OB-  
. SERVE DSKY DISPLAY  
. TO GO BLANK FOR 5  
. SECONDS  
-----  
. . . . .

# 260

-----  
WAIT UNTIL TIG-30  
SEC.  
-----  
. . . . .

-----  
. MONITOR DSKY:  
. AT TIG-30 SEC OB-  
. SERVE RETURN OF  
. V16N85 DISPLAYS  
. TO INDICATE THAT  
-----  
. . . . .

# 270

-----  
RETURN V16N85 DIS-  
PLAYS  
-----  
. . . . .

AVERAGE G INTEGRATION HAS STARTED.  
OBSERVE COMPUTER ACTIVITY LIGHT BLINKS ON EVERY 2 SECONDS DURING AVERAGE G.

#280

START AVERAGE G INTEGRATION

#290

WAIT UNTIL TIG-5 SEC

#300

RESET IGNITION FLAG

#310

RESET ASTRONAUT FLAG

#320

WAIT UNTIL TIG-0 SEC

SET IGNITION FLAG

IS ASTRONAUT FLAG SET?

(NOTE: IN P41 THE ANSWER IS ALWAYS NO BECAUSE ASTRONAUT HAS NO V99 TO RESPOND TO).

N.

#330

-----  
RESET PULSES FLAG  
-----

-----  
COMMAND ZERO ATTITUDE ERRORS  
-----

#340

-----  
SET .3 DEGREE DEADBAND  
-----

#350

HOLD . . . . . FLASH PRESENT VERB-  
MON . . . . . NOUN (V16N85) TO RE-  
QUEST RESPONSE.  
MAINTAIN DISPLAY OF  
VG (LM) COMPONENTS.  
(NOTE: SEE ASSUMPTION (2) ABOVE).

-----  
MONITOR DSKY:  
OBSERVE VERB-NOUN  
FLASH TO REQUEST  
RESPONSE AT LGC  
ASSUMED TIG.  
-----

#360

-----  
COMMAND MANUAL  
RGT AT IGNS AND  
-----

#370

TRANSLATIONS TO NULL  
VG COMPONENTS

·  
·  
·

THE ORBITAL PARAMET-  
ER DISPLAY ROUTINE  
(R30) MAY BE SELECT-  
ED AT THIS TIME  
(V82E) TO MONITOR  
CONTINUOUSLY UPDATED  
VALUES OF APD ALT,  
PER ALT, AND TFF.

#380

·  
·  
·

#390

WALT FOR KEYBOARD  
ENTRY

WHEN MANEUVER IS  
COMPLETE KEY IN  
PROCEED

TERMINATE VERB-NOUN  
FLASH UPON RECEIPT  
OF PROCEED, RECYCLE,  
OR TERMINATE

#400

·P ·T ·R  
·R ·E ·E  
·O ·R ·C  
·C ·M ·Y  
·E ·I ·C  
·E ·N ·L  
·C ·A ·E

#410

ZERO RENDEZVOUS  
TRACKING MARK  
COUNTER

#420

SET DEADBAND  
TO PREVIOUS VALUE

DEFINED BY R03.

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.  
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-----  
DO FINAL AUTOMATIC  
REQUEST TERMINATE  
ROUTINE (ROO).  
-----

EXIT P41

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.  
-----  
DO FINAL AUTOMATIC  
REQUEST TERMINATE  
ROUTINE (ROO).  
-----

EXIT P41

#430

#440

CHANGE CONTRCL NOTES

REV 01 PCR 85,86,164,401,605,637  
REV 00(LUM 1A) PCR 647  
REV 01(LUM 1B) PCR 838,841,EDITORIAL  
REV 02 EDITORIAL

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APS PROGRAM (P42)

REV 02 12/03/69

PURPOSE: (1) TO COMPUTE A PREFERRED IMU ORIENTATION AND A VEHICLE ATTITUDE FOR A LM APS THRUSTING MANEUVER.

(2) TO DC THE VEHICLE MANEUVER TO THE THRUSTING ATTITUDE.

(3) TO CONTROL THE PGNS DURING COUNTDOWN, IGNITION, THRUSTING, AND THRUST TERMINATION OF A PGNS CONTROLLED APS MANEUVER.

ASSUMPTIONS: (1) THE TARGET PARAMETERS HAVE BEEN CALCULATED AND STORED IN THE LGC BY PRIOR EXECUTION OF A PRE-THRUSTING PROGRAM.

(2) THE REQUIRED STEERING EQUATIONS ARE IDENTIFIED BY THE PRIOR PRE-THRUST PROGRAM, WHICH EITHER RESET ("ASTEER") OR SET (EXT DELTA V) THE EXTERNAL DELTA V FLAG. FOR EXTERNAL DELTA V STEERING, VG IS CALCULATED ONCE FOR THE SPECIFIED TIME OF IGNITION. THEREAFTER BOTH DURING APS THRUSTING AND UNTIL THE CREW NOTIFIES THE LGC THAT RCS TRIM THRUSTING HAS BEEN COMPLETED, THE LGC UPDATES VG ONLY AS A RESULT OF ACCELEROMETER INPUTS.

++ FOR STEERING CONTROL WHEN USING "ASTEER", THE VELOCITY REQUIRED IS CALCULATED FROM FIGURE 3-3-13A IN SECTION  
+02 5 OF R-567. THE LAMBERT ROUTINE PERIODICALLY RE-COMPUTES THE INTERCEPT TRAJECTORY SEMI-MAJOR AXIS  
+EDIT FOR THE "ASTEER" CALCULATIONS. THE INTERVAL BETWEEN LAMBERT SOLUTIONS IS CONTROLLED BY AN ERASABLE LOADED VALUE (UT).  
++

(3) THE IMU IS ON AND MUST BE AT A KNOWN ORIENTATION BEFORE THIS PROGRAM MAY BE COMPLETED. IT IS NORMALLY REQUIRED THAT THE ISS BE ON FOR A MINIMUM OF 15 MINUTES PRIOR TO A THRUSTING MANEUVER.

(4) THE EVENT TIMER IS SET TO COUNT TO ZERO AT TIG.

(5) ENGINE IGNITION MAY BE SLIPPED BEYOND THE ESTABLISHED TIG IF DESIRED BY THE CREW OR IF STATE VECTOR INTEGRATION CANNOT BE COMPLETED IN TIME.

++ (6) IF A THRUSTING MANEUVER IS PERFORMED WITH THE GUIDANCE CONTROL SWITCH IN PGNS AND THE MODE CONTROL SWITCH  
+02 IN AUTO, THE PGNS WILL CONTROL THE TOTAL VEHICLE ATTITUDE AND GENERATE EITHER MODE I OR MODE II ATTITUDE ERRORS  
+EDIT AND VEHICLE ATTITUDE RATES (SEE ASSUMPTION (7)) FOR DISPLAY ON THE FDAI. THE CREW MAY EXERCISE CONTROL AROUND THE YAW  
++ AXIS ONLY WITH THE ACA (X-AXIS OVERRIDE) IF THE X-AXIS OVERRIDE CAPABILITY IS PERMITTED BY THE PROGRAM IN PROCESS.  
THIS MANUAL CONTROL WILL BE IN THE RATE COMMAND/ATTITUDE HOLD MODE.

IF A THRUSTING MANEUVER IS PERFORMED WITH THE GUIDANCE CONTROL SWITCH IN PGNS AND THE MODE CONTROL SWITCH IN ATTITUDE HOLD THE PGNS WILL HOLD THE VEHICLE ATTITUDE AND WILL GENERATE EITHER MODE I OR MODE II ATTITUDE ERRORS FOR DISPLAY ON THE FDAI. THE CREW MAY EXERCISE MANUAL ATTITUDE CONTROL ABOUT ALL VEHICLE AXES WITH THE ACA IN EITHER THE RATE COMMAND OR MINIMUM IMPULSE MODE DEPENDING UPON THE STATUS OF THE PULSES FLAG. HOWEVER

++ IT IS STRONGLY RECOMMENDED THAT POWERED FLIGHT NOT BE ATTEMPTED IN THE MINIMUM IMPULSE MODE. THE PULSES FLAG IS SET OR  
+02 RESET BY EXTENDED VERBS 76 (MINIMUM IMPULSE) AND 77 (RATE COMMAND) RESPECTIVELY. THE PULSES FLAG IS ALSO RESET BY P12,  
+EDIT P40, P41, P42, P63, P70, P71, AND R40 AT MAIN ENGINE IGNITION. WITH THE EXCEPTION OF THESE CASES, MODE SELECTION IS  
++ ALWAYS BASED UPON THE LAST ENTRY MADE IN DSKY. DURING A THRUSTING MANEUVER IN THE PGNS/ATTITUDE HOLD MODE THE PGNS  
WILL NOT BE RESPONSIBLE IF REGISTER OVERFLOWS OCCUR WITHIN THE LGC.

IN THE EVENT THAT THE GUIDANCE CONTROL SWITCH IS CHANGED FROM PGNS TO ACS DURING A THRUSTING MANEUVER, THE LGC WILL CONTINUE COMPUTATION OF POSITION AND VELOCITY, THE DESIRED THRUST VECTOR, AND THE DESIRED ATTITUDE ERRORS, HOWEVER THE PGNS WILL NOT BE RESPONSIBLE IF REGISTER OVERFLOWS OCCUR WITHIN THE LGC.

(7) THE PGNS CAN GENERATE TWO TYPES OF ATTITUDE ERRORS FOR DISPLAY ON THE FDAI:

MODE I - SELECTED BY EXTENDED VERB 61. AUTOPILOT FOLLOWING ERRORS USED AS A MONITOR OF THE DAP'S ABILITY TO TRACK AUTOMATIC STEERING COMMANDS.

++ MODE II - SELECTED BY EXTENDED VERB 62. TOTAL ATTITUDE ERRORS USED TO ASSIST CREW IN MANUALLY MANEUVERING  
+02 THE VEHICLE.  
+EDIT  
+  
PGNS-DERIVED VEHICLE ATTITUDE RATES MAY ALSO BE DISPLAYED VIA SELECTION BY EXTENDED VERB 60.  
+  
+  
+  
+

+  
+  
+  
+  
+  
+  
+ 02  
+  
+  
++

MODE II ATTITUDE ERROR DISPLAYS ARE AUTOMATICALLY SELECTED AT THE BEGINNING OF R60. WITH THE EXCEPTIONS INDICATED IN ASSUMPTION (6) ABOVE, DISPLAY SELECTION IS ALWAYS BASED UPON THE LAST ENTRY MADE IN THE DSKY. FOR A MORE DETAILED DESCRIPTION OF THESE DISPLAYS REFER TO SECTION 3 OF R567, PARA. 3.2.6.

(8) THE X-AXIS OVERRIDE OPTION PROVIDES THE CREW WITH THE ABILITY TO EXERCISE MANUAL CONTROL ABOUT THE LM X AXIS WITH THE ATTITUDE CONTROLLER EVEN THOUGH THE PGNS ATTITUDE CONTROL MODE IS AUTO. WHEN THE CONTROLLER IS RETURNED TO DETENT THE PGNS DAMPS THE YAW RATE, STORES THE YAW ATTITUDE WHEN THE YAW RATE IS DAMPED, AND THEN MAINTAINS THAT ATTITUDE.

THE X-AXIS OVERRIDE OPTION IS ALWAYS AVAILABLE TO THE CREW, HOWEVER IT SHOULD NOT BE EXERCISED WHEN THE LGC IS SPECIFYING A DESIRED YAW ATTITUDE, I.E.: DURING THE ATTITUDE MANEUVER TO THE THRUSTING ATTITUDE (SEE R60).

(9) FOR EACH BURN AN IGNITION TOTAL ALLOWABLE TIME DELAY WILL BE SPECIFIED IN THE MISSION RULES. THIS DELAY TIME IS THE TOTAL TIME WHICH THE THRUSTING MANEUVER MAY BE DELAYED BEYOND THE LGC CALCULATED TIME OF IGNITION. IF ENGINE RESTARTS ARE INVOLVED, THE ACCOUNTING OF THIS TOTAL TIME DELAY IS UP TO THE CREW.

(10) THE LOAD DAP DATA ROUTINE (R03) MAY HAVE BEEN PERFORMED PRIOR TO SELECTION OF THIS PROGRAM.

(11) LGC AND CREW PROCEDURES IN CASES OF LGC-ASSUMED THRUST FAILURE ARE DEFINED BY THE OPS/APS THRUST FAIL ROUTINE (R40). THIS ROUTINE IS CALLED AT APS IGNITION BY THIS PROGRAM.

(12) THE LGC WILL NEITHER DESIGNATE NOR READ THE RENDEZVOUS RADAR (RR) DURING THIS PROGRAM.

(13) THIS PROGRAM SHOULD BE SELECTED BY THE ASTRONAUT BY DSKY ENTRY AT LEAST 5 MINUTES BEFORE THE ESTIMATED TIME OF IGNITION.

(14) THIS PROGRAM IS SELECTED MANUALLY BY DSKY ENTRY.

PROG  
CONT

LGC

GROUND

CREW

.CREW  
.PROGRAM  
.SELECTION

.

...

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-----  
START APS PROGRAM  
(P42) DISPLAY  
P42

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KEY IN APS  
PROGRAM (P42)  
V37E 42E  
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#10

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MONITOR DSKY:  
OBSERVE DISPLAY OF  
P42

#20

IS THE APS FLAG  
SET?

.Y .N  
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.  
.  
.  
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#30

POSS  
HOLD .  
.....  
SNAP .

..FLASH VERB-NOUN  
..TO REQUEST RES-  
..PONSE AND DISPLAY  
..ALARM CODE 01706  
..TO INDICATE THAT  
..APS FLAG SHOWS  
..THAT THE DPS  
..HAS NOT BEEN  
..STAGED:  
.. V05 N09  
.. R1-XXXXX  
.. R2-XXXXX  
.. R3-XXXXX

DOES VERB-NOUN FLASH  
TO REQUEST RESPONSE  
AND DISPLAY OF ALARM  
CODE INDICATE THAT  
APS FLAG SHOWS  
THAT THE DPS HAS NOT  
BEEN STAGED?  
(NOTE:  
THIS ALARM CODE  
MAY BE DISPLAYED IN  
EITHER R1, R2, OR  
R3, DEPENDING ON THE  
PRESENCE OR ABSENCE  
OF OTHER ALARM  
CODES.)

#40

.Y .N  
.  
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#50

DO I WISH TO  
CONTINUE WITH  
P42 ALTHOUGH THE  
DPS HAS NOT BEEN  
STAGED?  
(NOTE: IF CONTI-  
NUATION IS

#60

SELECTED,  
STAGING MUST BE  
PERFORMED AFTER  
TIG -30 SECONDS  
AND BEFORE  
IGNITION.)

.N .Y.

# 70

..WAIT FOR KEYBOARD  
..ENTRY

KEY IN  
TERMINATE  
V34E

..TERMINATE FLASH  
..UPON RECEIPT OF  
..TERMINATE OR  
..PROCEED

KEY IN  
PROCEED

#80

..P I.  
..R E.  
..D K.  
..C M.  
..E I.  
..E N.  
..D A.  
.. T.  
.. E.

#90

..IS THE PRESENT  
..PROGRAM P42?

..N .Y.

#100

..DC FINAL AUTOMA-  
..TIC REQUEST TER-  
..MINATE ROUTINE  
..(R30)

..DU FINAL AUTO-  
..MATIC REQUEST  
..TERMINATE  
..ROUTINE (R00)

#110

347

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EXIT P42  
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EXIT P42 . . .  
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DC IMU STATUS CHECK  
ROUTINE (R02)  
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DO IMU STATUS CHECK  
ROUTINE (R02)  
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SET APS DELTA V  
THRESHOLD FOR USE  
BY R4C.  
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SET DELTA V  
COUNTER = 4 FOR USE  
BY R40  
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COMPUTE INITIAL  
THRUST DIRECTION AND  
INITIAL VALUE OF VG  
VECTOR AND STORE  
VG(LV) IN N81 AND  
N86 FOR POSSIBLE  
MANUAL SELECTION:

R1-VGX(LV)  
R2-VGY(LV)  
R3-VGZ(LV)

VGX(LV)-COMPONENT OF  
VG AT TIG ALONG  
{RXV}XR. IN FPS TO  
NEAREST .1 FPS.

#120

#130

#140

#150

#160

VG1(LV)-COMPONENT OF  
VG AT TIG ALONG VXR.  
IN FPS TO NEAREST  
.1 FPS.

#170

VG2(LV)-COMPONENT OF  
VG AT TIG ALONG -R.  
IN FPS TO NEAREST  
.1 FPS.

WHERE R IS GECCENT-  
RIC (EARTH ORBIT)  
OR SELENOCENTRIC  
(LUNAR ORBIT) RADIUS  
VECTOR, AND V IS  
VEHICLE INERTIAL  
VELOCITY VECTOR AT  
TIG.

#180

(NOTE: N81 WILL NOW  
DIFFER FROM N81  
DISPLAY OF P30, P32,  
AND P33 BECAUSE OF  
ROTATION OF VG  
VECTOR).

#190

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\*  
-----  
COMPLETE PREFERRED  
IMU ORIENTATION:

X = UNIT(T)  
-SM -

#200

Y = UNIT(T X R)  
-SM - -

Z = UNIT(X X Y )  
-SM -SM -SM

WHERE:

T = THE INITIAL  
- THRUST VECTOR

#210

3+9

AT IGNITION

R = THE GEOCENTRIC  
- (EARTH ORBIT)  
OR SELENOCENT-  
RIC (LUNAR  
ORBIT) RADIUS  
VECTOR AT TIG.

(NOTE: IF T X R IS

SMALL (REFER SECTION  
5.3.3.3.3 OF R567),  
THEN Y =

-SM  
UNIT (T X V).

WHERE V = VEHICLE

INERTIAL VELOCITY AT  
TIG.)

#220

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STORE DESIRED ATTITUDE SPECIFICATION FOR USE BY ATTITUDE MANEUVER ROUTINE (R60). THE FINAL ATTITUDE WILL BE COMPUTED DURING R60 AND WILL POINT THE LM +X AXIS IN THE INITIAL THRUST DIRECTION. HOWEVER, IN ORDER TO CONSERVE RCS FUEL AND NOT CONSTRAIN THE NON-CRITICAL ATTITUDE ABOUT THE THRUST VECTOR, WINGS MAY NOT BE LEVEL IN THE COMPUTED FINAL ATTITUDE.

#240

#250

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-----  
SET PREFERRED-  
ATTITUDE-COMPUTED

#260

FLAG

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•  
•

#270

COMMAND ZERO ATTITUDE ERRORS

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•

#280

SET 1 DEGREE DEAD-BAND

•  
•

RESET 3-AXIS FLAG

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•  
•  
•  
•  
•

#290

CG ATTITUDE MANEUVER ROUTINE (R60)

DU ATTITUDE MANEUVER ROUTINE (R60)

#300

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#310

HAVE PGNS CONTROL AND AUTO ATTITUDE

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350

CONTROL MODES BEEN  
SELECTED?

.Y .N

#320

IS THE APS FLAG  
SET?

.Y .N

#330

HAS THE AUTO  
THROTTLE MODE  
BEEN SELECTED?

.Y .N

#340

POSS  
HOLD .  
.....  
SNAP .

FLASH VERB-  
NOUN TO RE-  
QUEST PLEASE  
PERFORM PGNS  
CONTROL AND  
AUTO ATTITUDE  
CONTROL MODE  
SELECTION:  
V50N25  
R1-OC203  
R2-BLANK  
R3-BLANK

MONITOR DSKY:  
DOES VERB-NOUN  
FLASH TO REQUEST  
PLEASE PERFORM PGNS  
CONTROL AND AUTO  
ATTITUDE CONTROL  
MODE SELECTION?

#350

.Y .N

HAVE REQUESTED  
MODES BEEN  
SELECTED?

#360

.N .Y

DO I WISH TO  
HAVE THESE

#370

MODES SELECTED  
DURING THE  
THRUSTING  
MANEUVER?

-----  
.Y .N  
-----

SET GUIDANCE  
CONTROL SWITCH  
TO PGNS AND  
ATTITUDE CON-  
TROL SWITCH TO  
AUTO.

-----  
WAIT FOR KEY-  
BOARD ENTRY  
-----

-----  
KEY IN PROCEED  
-----

TERMINATE  
FLASH UPON RE-  
CEIPT OF PRC-  
CEED OR ENTER  
-----

-----  
KEY IN ENTER  
-----

.E .P  
.N .R  
.T .O  
.E .C  
.R .E  
. .E  
. .D  
-----

-----  
COMMAND APS CFF  
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#380

#390

#400

#410

#420

352



TEMP  
HOLD

..... DISPLAY ON DSKY:  
MON . VC6 N40  
R1 - TFI  
R2 - VG  
R3 - DELTA VM

MONITOR DSKY:  
OBSERVE DISPLAY OF  
TFI, VG AND DELTA VM

#430

TFI - TIME FROM  
APS IGNITION. IN  
MIN, SEC TO NEAR-  
EST SEC. MAX  
READING IS 59859.  
SIGN IS - BEFORE  
NOMINAL TIG, +  
THEREAFTER.

UPDATE EVENT TIMER  
IF DESIRED

#440

VG - MAGNITUDE OF THE  
VELOCITY TO BE  
GAINED BY THRUSTING  
MANEUVER. IN FPS  
TO NEAREST .1 FPS

DELTA VM-MEASURED  
DELTA V MAGNITUDE  
IN FPS TO NEAREST  
.1 FPS. THIS  
DISPLAY WILL BE  
0000 UNTIL TIG-30  
SEC AND THEN  
SHOULD CHANGE ONLY  
DUE TO PIPA BIAS  
UNTIL ULLAGE IS  
STARTED.

#450

-----  
SET TDECI = TIG-30  
SECCNCS  
-----

#460

#470

.....  
DO STATE VECTOR  
INTEGRATION (MID TO  
AVE) ROUTINE (R41)  
(NOTE: ENTER R41  
AT "A".)

.NG TIG.  
.TIG SLIP.  
.SLIP .  
. .  
. .  
. .  
. .

.....  
(NOTE: R41 WILL  
DEFINE TIG TO BE  
THE TIME TO WHICH  
R41 DID INTEGRATE  
THE LM STATE VEC-  
TOR PLUS 30  
SECONDS.)  
.....  
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. .  
. .  
. .  
. .

.....  
WAIT UNTIL TIG  
-35 SEC  
.....  
. .  
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. .  
. .  
. .

.....  
BLANK THE DSKY DIS-  
PLAY (V,N,R1,R2, AND  
R3).  
.....  
. .  
. .  
. .

.....  
WAIT UNTIL TIG  
-30 SEC.  
.....  
. .  
. .  
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.....  
DO STATE VECTOR  
INTEGRATION (MID TO  
AVE) ROUTINE (R41)  
OBSERVE THAT THE  
COMPUTER ACTIVITY  
LIGHT IS ON UNTIL  
COMPLETION OF R41.  
.....  
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. .  
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.....  
ARM APS  
.....  
. .  
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. .  
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.....  
CHECK STATUS OF C/W  
LAMPS  
.....  
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.....  
MONITOR DSKY:  
AT TIG -35 SEC OB-  
SERVE DSKY DISPLAY  
TO GO BLANK FOR 5  
SECONDS.  
.....  
. .  
. .  
. .  
. .  
. .

#480

#490

#500

#510

#520

355

RETURN VC6N40 DIS-  
PLAYS

IS THE PRESENT  
PROGRAM P42?

.N                    Y.

. SET THE APS FLAG

START AVERAGE G  
INTEGRATION.

CALL 1/ACCS AND  
INITIALIZE THE DAP.  
(NOTE: NORMALLY THE  
DAP IS INITIALIZED  
BY DATA SELECTED VIA  
R03, WHERE THE APS  
FLAG IS SET OR RESET.  
FOR THIS PROGRAM,  
THE APS FLAG IS SET,  
CAUSING THE CORRECT  
DAP INITIALIZATION  
DATA TO BE SELECTED  
WITHOUT RECOURSE TO  
R03.)

MONITOR DSKY:  
AT TFI = - 00B29  
OBSERVE RETURN OF  
V06N40 DISPLAYS TO  
INDICATE THAT AVER-  
AGE G INTEGRATION  
HAS STARTED.  
(NOTE: IF TIG HAS  
BEEN SLIPPED BY R41,  
THE TFI DISPLAY (R1)  
AT THIS TIME WILL BE  
REFERRED TO THE NEW  
TIG.)

IS THE PRESENT  
PROGRAM P42?

.Y                    N.

PERFORM DPS  
STAGING IF IT HAS  
NOT ALREADY BEEN  
DONE

#530

#540

#550

#560

#570

MONITOR DSKY:  
IN THE PERIOD FROM  
TFI ==00830 UNTIL  
TFI ==00815  
DOES DELTA VM BECOME  
GREATER THAN .5 FPS  
INDICATING EXCESSIVE  
PIPA BIAS ERROR?

#580

.N .Y

#590

GO TO BACKUP  
PROCEDURES

#600

++  
+02  
+EDIT  
++

WAIT UNTIL TIG  
-5 SEC.

"F"  
FROM  
R40

#610

RESET IGNITION FLAG

#620

RESET ASTRONAUT FLAG

#630

RESET IMPULSE FLAG

352

.....  
WILL ACTIVE STEERING  
BE ATTEMPTED DURING  
THIS MANEUVER?  
(REFER PARA. 5.3.3.-  
3.3 OF SECTION 5 OF  
R567)

#640

.....  
Y N  
.....  
SET IMPULSE FLAG  
.....

#650

.....  
CALL VERB 59 DIS-  
PLAYS (SEE "A"  
BELCW)

.....  
CALL SET OF ULLAGE  
FLAG AT TIG-3.5 SEC

#660

.....  
WAIT UNTIL TIG -0  
.....

#670

.....  
SET IGNITION FLAG  
.....

#680

-----  
IS ASTRONAUT FLAG  
SET?  
-----

.Y                    .N  
.  
.  
.....

GC TO  
"B"  
BELOW

EXIT  
(NOTE: THIS  
IS NOT A  
P42 EXIT.  
REFER DIS-  
PLAY RE-  
SPONSE AT  
"A" BELOW)

#690

"A"  
FROM  
ABOVE

"F"  
FROM  
R40

#710

-----  
MONITOR DSKY:  
AT TFI = - 00805  
OBSERVE VERB-NOUN  
FLASH TO REQUEST  
PLEASE PERFORM  
ENGINE ON ENABLE  
-----

#720

HOLD .  
.....  
MUN .

-----  
CHANGE VERB BUT RE-  
TAIN PRESENT NOUN  
AND DISPLAYS IN R1,  
R2, R3, FLASH VERB-  
NOUN TO REQUEST  
PLEASE PERFORM ENG-  
INE ON ENABLE:  
V99N40  
-----

#730

342

-----  
WAIT FOR KEYBOARD  
ENTRY

.....  
. AT TFI =-00B03 MONI-  
TOR START OF +X  
. TRANSLATION.  
-----

#740

-----  
MONITOR DSKY:  
WAIT FOR INCREASE OF  
DELTA VM INDICATING  
SUFFICIENT ULLAGE.  
REQUIRED ULLAGE  
DELTA V IS A  
FUNCTION OF VEHICLE  
WEIGHT.  
-----

#750

-----  
SHALL I ATTEMPT  
TO COMPLETE THE  
THRUSTING MANEU-  
VER WITH THE RCS?  
-----

#770

.Y                                  N.  
.   .  
.   .

.....  
KEY IN ENTER  
-----

#780

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...                                     .  
.   .  
GO TO                                 .  
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.....

"A"  
BELOW

-----  
SHALL I PERMIT  
IGNITION?  
-----

#790

.N .Y  
.  
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-----  
KEY IN PROCEED  
-----

#800

TERMINATE FLASH UPON  
RECEIPT OF ENTER,  
PROCEED OR TERMINATE.

-----  
KEY IN  
TERMINATE  
V34E  
-----

#810

.P .T .E  
.R .E .N  
.C .R .T  
.C .M .E  
.E .I .R  
.E .N  
.D .A  
. .T  
. .E  
. .  
. .

-----  
RESET  
ULLAGE  
FLAG  
-----

#820

#830

300



-----  
 . TERMINATE  
 . CALL FOR  
 . SET CF  
 . ULLAGE  
 . FLAG AT  
 . TIG-3.5  
 . SEC IF  
 . CALL NOT  
 . YET DCNE  
 -----

#840

.....  
 . GO TO  
 . "C"  
 . BELOW  
 -----

#850

-----  
 . DO FINAL AUTO-  
 . MATIC REQUEST  
 . TERMINATE  
 . ROUTINE (ROO)  
 -----

-----  
 . DO FINAL AUTO-  
 . MATIC REQUEST  
 . TERMINATE  
 . ROUTINE (ROO)  
 -----

#860

.....  
 . EXIT P42  
 -----

.....  
 . EXIT P42  
 -----

#870

-----  
 . SET ASTRONAUT FLAG  
 -----  
 .  
 .  
 -----

-----  
 . IS IGNITION FLAG  
 . SET?  
 -----

-----  
 . MONITOR DSKY:  
 . IS RI DISPLAY OF TFI  
 . NEGATIVE AND  
 . NON-ZERO?  
 -----

#880

.Y .N  
 .  
 .  
 .  
 .  
 -----

.Y .N  
 .  
 .  
 .  
 -----

-----  
 . RESUME STATIC DI- ..... MONITOR DSKY  
 -----  
 .  
 .  
 -----

SPLAY OF V06N40

EXIT  
(NOTE: THIS  
IS NOT A  
P42 EXIT.  
REFER TIG  
-C LOGIC  
ABOVE.)

"B"  
FROM  
ABOVE

COMMAND APS ON

RESET PULSES FLAG

OBSERVE RETURN  
OF STATIC VERB-  
NGUN DISPLAY  
(V06N40)

STANDBY FOR  
THRUST ON  
WHEN TFI = -00BC0

STANDBY FOR  
THRUST ON  
IMMEDIATELY

#890

#900

#910

#920

#930

#940

362

TEMP  
 HOLD . CHANGE TFI DISPLAY  
 ..... TO TFC IN R1  
 MCN . V06 N40  
 R1 - TFC  
 R2 - VG  
 R3 - DELTA VM

TFC - TIME FROM  
 ENGINE CUTOFF.  
 IN MIN AND SEC TO  
 NEAREST SEC. SIGN IS  
 - BEFORE AND + AFTER  
 CUTOFF.

MONITOR DSKY:  
 OBSERVE CHANGE OF  
 TFI DISPLAY TO TFC  
 IN R1  
 (NOTE: TFC IS IN-  
 ITIALLY CALCULATED  
 ONCE AND DISPLAYED.  
 THIS DISPLAY WILL  
 COUNT DOWN WITH  
 ELAPSED TIME UNTIL  
 TVC STEERING IS  
 INITIATED (STEER  
 FLAG IS SET BY R40)  
 AT WHICH TIME TFC IS  
 RECALCULATED AND  
 DISPLAYED EVERY 2  
 SECONDS BY THE  
 GUIDANCE EQUATIONS.)

#950

IS TFC AT IGNITION  
 LESS THAN 6 SECONDS?

.N            Y.

#970

IS IMPULSE FLAG SET?

.N            Y.

CALL FOR ENGINE  
 OFF COMMAND AT

#990

• CALCULATED CUTOFF  
• TIME. (SEE "D"  
• BELOW)  
• (NOTE: PGNS WILL  
• COMMAND INERTIAL  
• VEHICLE ATTITUDE  
• HOLD THROUGHOUT  
• THRUSTING MAN-  
• EUVER.)

-----

•  
•  
•

-----

• RESET IGNITION  
• FLAG

-----

•  
•  
•

-----

• RESET ASTRONAUT  
• FLAG

-----

•  
•  
•

-----

• RESET IMPULSE  
• FLAG

-----

•  
•  
•

-----

• WAIT 0.5 SECONDS

-----

•  
•  
•  
•  
•  
•

-----

• RESET ULLAGE  
• FLAG

-----

•  
•  
•  
•  
•  
•  
•  
•  
•

#1000

#1010

#1020

#1030

#1040

364

365

EXIT  
(NOTE: THIS IS  
NOT A P42 EXIT.  
SEE "C" BELOW).

-----  
RESET IGNITION FLAG  
-----

-----  
RESET ASTRONAUT FLAG  
-----

-----  
RESET IDLE FLAG  
-----

-----  
CALL FOR RESET OF  
ULLAGE FLAG IN 0.5  
SEC.  
-----

-----  
THIS BURN IS A  
MINIMUM IMPULSE  
MANEUVER AND  
WILL BE DONE AT  
AN INERTIALLY  
FIXED VEHICLE  
ATTITUDE  
-----

#1050

#1060

#1070

#1080

#1090





REQUIRED TIME

·  
·  
·

COMMAND ZERO ATTITUDE RATES

·  
·  
·

SET IDLE FLAG

·  
·  
·  
·  
·  
·

WAIT UNTIL COMPLETED TIME OF CUTOFF

·  
·  
·  
·  
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·  
·  
·  
·  
·

"D"  
FROM  
ABOVE  
·  
·  
·  
·  
·

COMMAND ENGINE OFF

·  
·  
·

COMMAND ZERO ATTITUDE RATES

·  
·  
·  
·

SET DEADBAND TO PREVIOUS VALUE

#1190

#1200

#1210

#1220

#1230

#1240



DEFINED BY R03.

MAINTAIN VG  
COMPUTATIONS AFTER  
CUTOFF FOR POSSIBLE  
NULLING BY RCS  
TRIMMING MANEUVER  
(NOTE: SEE ASSUMP-  
TION (2) ABOVE).

"C"  
FROM  
ABOVE

DISARM APS

COMMAND  
ZERO ATT-  
ITUDE  
RATES

SET DEAD-  
BAND TO  
PREVIOUS  
VALLE DE-  
FINED BY  
R03

RESET  
ULLAGE

#1250

#1260

#1270

#1280

FLAG

#1290

-----  
TERMINATE  
CALL FOR  
SET CF  
LLAGE  
FLAG AT  
TIG-3.5  
SEC IF  
CALL NOT  
YET DONE  
-----

#1300

"A"  
FROM  
ABOVE

#1310

HOLD

MON

-----  
FLASH VERB-NOUN TO  
REQUEST PROCEED.  
HOLD DISPLAY OF TFC  
AT ITS FINAL VALUE:  
V16 N40  
R1 - TFC  
R2 - VG  
R3 - DELTA VM  
-----

-----  
MONITOR DSKY:  
OBSERVE VERB-NCUN  
FLASH TO REQUEST  
PROCEED AND DISPLAY  
OF TFC, VG, AND  
DELTA VM  
-----

#1320

{NOTE: SEE ASSUMP-  
TION (2) ABOVE).  
-----

-----  
RECORD THESE VALUES  
AS DESIRED.  
-----

#1330

-----  
WAIT FOR KEYBOARD  
ENTRY  
TERMINATE FLASH UPON  
RECEIPT OF PROCEED,  
-----

-----  
KEY IN PROCEED  
-----

RECYCLE, OR  
TERMINATE

.P	.T	.K
.R	.E	.E
.O	.R	.C
.C	.M	.Y
.E	.I	.C
.E	.N	.L
.D	.A	.E
.	.T	.
.	.E	.....

#1340

GO TO  
"EM"  
BELOW

#1350

COMMAND ZERO ATT-  
ITUDE ERRORS

#1360

SET 0.3 DEGREES  
DEADBAND

#1370

HOLD . . . . . FLASH VERB-NGUN TO  
MON . . . . . REQUEST RESPONSE AND  
          . . . . . DISPLAY COMPONENTS  
          OF VG(LM):  
          V16 N85  
          R1-VGX(LM)  
          R2-VGY(LM)  
          R3-VGZ(LM)

MONITOR DSKY:  
OBSERVE VERB-NGUN  
FLASH TO REQUEST  
RESPONSE AND DISPLAY  
OF VG(LM) COMPONENTS

#1380

COMPONENTS OF THE  
PRESENT VG VECTOR  
RESOLVED ALONG THE  
LM X,Y, AND Z AXES.  
THE VG VECTOR WILL  
BE UPDATED BY THE  
STEERING LOOPS  
DURING EACH COMPUTA-  
TION CYCLE. IN FPS  
TO NEAREST .1 FPS.  
(NOTE: SEE ASSUMP-  
TION (2) ABOVE).

-----  
TO NULL OUT VG  
COMPONENTS COMMAND  
MANUAL TRANSLATIONS  
AND ROTATIONS.  
(NOTE: THIS MANEUVER  
IS AT THE OPTION OF  
THE CREW.)  
-----

#1390

#1400

-----  
THE ORBITAL PARAME-  
TER DISPLAY ROUTINE  
(R30) MAY BE SELECT-  
ED AT THIS TIME  
(V82E) TO MONITOR  
CONTINUOUSLY UPDATED  
VALUES OF APD ALT,  
PER ALT, AND TFF.  
-----

#1410

-----  
WAIT FOR KEYBOARD  
ENTRY  
TERMINATE FLASH UPON  
RECEIPT OF PROCEED,  
RECYCLE, OR  
TERMINATE  
-----

-----  
KEY IN PROCEED  
-----

#1420

.P .T .R  
.R .E .E  
.O .R .C  
.C .M .Y  
.E .I .C  
.E .N .L  
.C .A .E  
. .T .  
. .E .....

#1430

#1440

372



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THRUST MONITOR PROGRAM (P47)

REV 02 08/07/69

- PURPOSE: (1) TO MONITOR VEHICLE ACCELERATION DURING A NON-PGNC CONTROLLED THRUSTING MANEUVER.  
 (2) TO DISPLAY THE DELTA V APPLIED TO THE VEHICLE BY THIS THRUSTING MANEUVER.
- ASSUMPTIONS: (1) THE IMU IS ON AND MUST BE AT A KNOWN ORIENTATION BEFORE THIS PROGRAM MAY BE COMPLETED. IT IS NORMALLY REQUIRED THAT THE ISS BE ON FOR A MINIMUM OF 15 MINUTES PRIOR TO A THRUSTING MANEUVER.  
 (2) THE RESPONSIBILITY OF AVOIDING GIMBAL LOCK DURING EXECUTION OF THIS PROGRAM IS UPON THE ASTRONAUT.  
 (3) THIS PROGRAM IS NORMALLY USED DURING RENDEZVOUS FINAL PHASE. IF THE CREW DESIRES TO DO ANY FINAL PHASE THRUSTING MANEUVERS AUTOMATICALLY UNDER PGNC CONTROL THEY MUST BE ACCOMPLISHED VIA SELECTION OF TRANSFER PHASE INITIATION (TPI) PROGRAM (P34) AND THEN THE DPS THRUSTING PROGRAM (P40) OR THE APS THRUSTING PROGRAM (P42).  
 (4) RANGE, RANGE RATE, AND THETA MAY BE DISPLAYED DURING THIS PROGRAM BY CALLING THE RENDEZVOUS PARAMETER DISPLAY ROUTINE (R31).  
 (5) THIS PROGRAM IS SELECTED BY THE ASTRONAUT BY DSKY ENTRY. THE PROGRAM SHOULD BE TURNED ON JUST PRIOR TO THE PLANNED THRUSTING MANEUVER AND TERMINATED AS SOON AS POSSIBLE AFTER THE MANEUVER IN ORDER TO KEEP ERRORS ASSOCIATED WITH AVERAGE G INTEGRATION AT A MINIMUM.

++  
+02  
+EDIT  
++

PROG  
CONT

LGC

GROUND

CREW

- .CREW
- .PROGRAM
- .SELECTION
- .
- ...
- .

-----  
 .  
 START THRUST  
 MONITOR PROGRAM  
 (P47).  
 .  
 DISPLAY P47.

.....

-----  
 .  
 KEY IN THRUST  
 MONITOR PROGRAM  
 (P47)  
 V37E47E  
 -----

#10

- .
- .
- .

.....

-----  
 .  
 MONITOR DSKY:  
 OBSERVE DISPLAY  
 OF P47.  
 -----

#10

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- .

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.....  
-----  
DL IMU STATUS  
CHECK ROUTINE  
(RC2)  
-----

.....  
.....  
.....  
.....  
.....  
.....  
-----  
DO IMU STATUS  
CHECK ROUTINE  
(RO2)  
-----

.....  
.....  
.....  
.....  
.....  
.....  
-----  
DO STATE VECTOR INT-  
TEGRATION (MIDTCAVE)  
ROUTINE (R41)  
(NOTE: ENTER R41 AT  
"B")  
-----

.....  
.....  
.....  
.....  
.....  
.....  
-----  
DO STATE VECTOR INT-  
TEGRATION (MIDTCAVE)  
ROUTINE (R41). OB-  
SERVE THAT THE COM-  
PUTER ACTIVITY LIGHT  
IS ON UNTIL COMPLE-  
TION OF R41.  
-----

.....  
.....  
.....  
.....  
.....  
.....  
-----  
START AVERAGE G  
INTEGRATION  
-----

.....  
.....  
.....  
.....  
.....  
.....  
-----  
FLASH VERB-NOUN TO  
REQUEST RESPONSE AND  
DISPLAY DELTA V  
(LM):  
    V16A83  
    R1-DELTA VX(LM)  
    R2-DELTA VY(LM)  
    R3-DELTA VZ(LM)  
-----

.....  
.....  
.....  
.....  
.....  
.....  
-----  
MONITOR DSKY:  
    OBSERVE FLASHING  
    VERB-NOUN TO REQUEST  
    RESPONSE AND DISPLAY  
    OF EACH COMPONENT OF  
    DELTA V(LM).  
-----

.....  
.....  
.....  
.....  
.....  
.....  
-----  
DELTA VX(LM) - COM-  
PONENT OF INTEGRATED  
ACCELERATION ALONG  
LM +X AXIS. IN FPS  
TO NEAREST .1 FPS.  
-----

HOLD ..  
.....  
MON ..

#30

#40

#50

#60



DELTA VY(LM) - COM-  
 PONENT OF INTEGRATED  
 ACCELERATION ALONG  
 LM +Y AXIS. IN FPS  
 TO NEAREST .1 FPS.

DELTA VZ(LM) - COM-  
 PONENT OF INTEGRATED  
 ACCELERATION ALONG  
 LM +Z AXIS. IN FPS  
 TO NEAREST .1 FPS.

NOTE: R1,2, AND 3  
 WILL READ 0000 IN-  
 ITIALLY AND WILL RE-  
 MAIN SC EXCEPT FOR  
 PIPA BIAS ACCUMLLAT-  
 IONS UNTIL A THRUST-  
 ING MANEUVER IS  
 STARTED. THEY WILL  
 BE UPDATED EVERY  
 2 SEC.

WAIT FOR KEYBOARD  
 ENTRY

PERFORM THRUSTING  
 MANEUVER(S) AS  
 DESIRED.  
 MONITOR FDAI BALL  
 TO AVOID GIMBAL  
 LOCK

THE ORBITAL PARAMET-  
 ER DISPLAY ROUTINE  
 (R30) MAY BE SELECT-  
 ED AT THIS TIME  
 (VB2E) TO MONITOR  
 CONTINUOUSLY UPDATED  
 VALUES OF APO ALT,  
 PER ALT AND TFF.

SHALL I TERMINATE  
 THIS PROGRAM?

.Y .N

SHALL I ZERO  
 THE DISPLAY IN  
 ORDER TO MONIT-  
 OR ANOTHER  
 BURN?

.Y .N

KEY IN RECY-  
 CLE (V32E)

#70

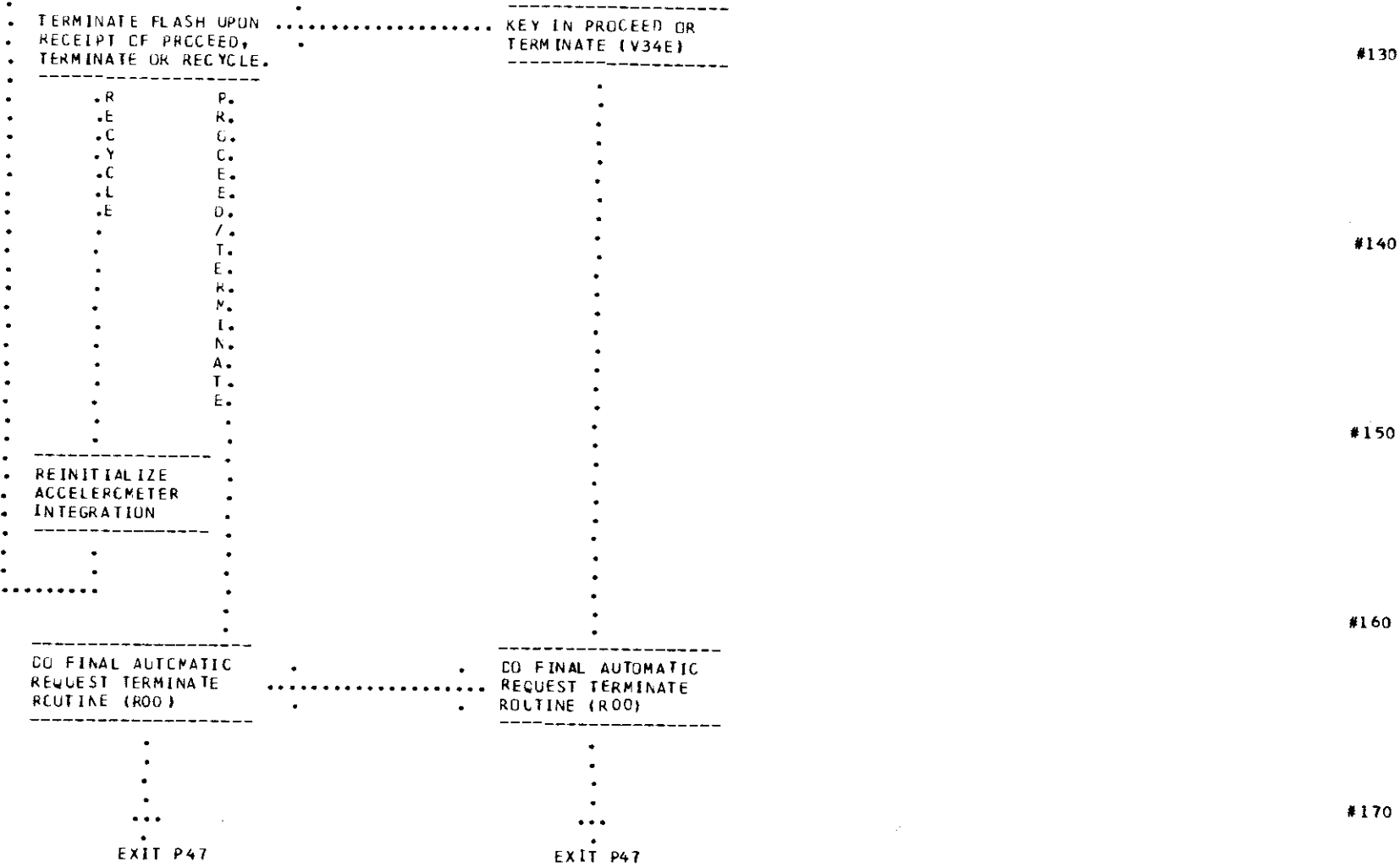
#80

#90

#100

#110

#120



CHANGE CONTRCL NOTES

LOGIC REV 01    PCK 401,437  
REV 02        EDITCRIAL

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IMU ORIENTATION DETERMINATION PROGRAM (P51)

REV 02 08/07/69

PURPOSE: (1) TO DETERMINE THE INERTIAL ORIENTATION OF THE IMU USING SIGHTINGS ON TWO CELESTIAL BODIES WITH THE ADT OR A BACKUP OPTICAL SYSTEM.

ASSUMPTIONS: (1) THIS PROGRAM MAY ONLY BE PERFORMED WHILE THE LM IS IN FLIGHT.

(2) THE ISS MAY BE:

(A) OFF (STANDBY)

(B) ON, AND ALIGNED OR NOT ALIGNED SINCE TURN ON.

IF (A) IS TRUE, THE IMU MUST BE TURNED ON BEFORE THIS PROGRAM CAN BE PERFORMED. IF (B) IS TRUE THIS PROGRAM CAN BE COMPLETED.

(3) THERE ARE NO RESTRAINTS UPON THE LM ATTITUDE CONTROL MODES UNTIL THE CREW WISHES TO MANUALLY MANEUVER THE VEHICLE.

(4) TIME AND RCS FUEL MAY BE SAVED, AND SUBSEQUENT IMU ALIGNMENT DECISIONS GREATLY SIMPLIFIED IF THIS PROGRAM IS PERFORMED IN SUCH A WAY AS TO LEAVE THE IMU INERTIALLY STABILIZED AT AN ORIENTATION AS CLOSE AS POSSIBLE TO THE OPTIMUM ORIENTATION REQUIRED BY FUTURE LGC PROGRAMS.

(5) EXTENDED VERBS SHOULD NOT BE EXERCISED DURING THIS PROGRAM BECAUSE OF POSSIBLE INTERFERENCE WITH R53.

(6) THE PROGRAM IS SELECTED BY THE ASTRONAUT BY CSKY ENTRY.

PROG  
CONT

LGC

GROUND

CREW

.CREW  
.PROGRAM  
.SELECTION  
.  
...  
.

-----  
START IMU ORIENTATION  
DETERMINATION  
PROGRAM (P51)  
DISPLAY P51

.  
.....  
.

-----  
KEY IN IMU  
ORIENTATION DETERMI-  
NATION PROGRAM (P51)  
V37E 51E  
-----

.  
.  
.  
.  
.  
.  
.  
.  
.

#10

MONITOR DSKY:  
OBSERVE DISPLAY OF  
P51

#20

IS THE ISS ON?

.Y .N

#30

SET IMUSE FLAG

++  
+02  
+EDIT  
++

TURN ON PROGRAM  
ALARM LIGHT AND  
STORE ALARM CODE.  
(NOTE: IF CALLED,  
ALARM CODE WILL  
BE 00210.)

MONITOR DSKY:  
DOES PROGRAM ALARM  
LIGHT COME ON INDIC-  
ATING THAT THE IMU  
IS NOT ON?

#40

.Y .N

TURN ON IMU  
AND RESELECT  
P51 VIA ROO

#50

DO FINAL AUTOMATIC  
REQUEST TERMINATE  
ROUTINE (ROO).

DO FINAL  
AUTOMATIC  
REQUEST TER-  
MINATE ROU-  
TINE (ROO).

#60

EXIT  
P51

EXIT  
P51

#70

HOLD . FLASH VERB-NOUN TO  
..... REQUEST PLEASE PER-  
SNAP . FORM CELESTIAL BCDY  
ACQUISITION:  
V50 N25  
R1-CCC15  
R2-BLANK  
R3-BLANK

MONITOR DSKY:  
OBSERVE VERB-NOUN  
FLASH TC REQUEST  
PLEASE PERFORM  
CELESTIAL BODY  
ACQUISITION

#80

SHALL I MANEUVER (OR  
CONTINUE TO MANEU-  
VER) THE LM TO POSI-  
TION THE IMU INNER  
GIMBAL AXIS IN A  
PREFERRED DIRECTION?

#90

.N .Y  
.  
.

#100

WITH THE ROTATION  
CONTRCL RCTATE  
THE LM UNTIL THE  
PITCH AXIS IS IN  
THE PREFERRED  
DIRECTION

#110

ARE 2 CELESTIAL  
BODIES VISIBLE IN

THE OPTICAL SYS-  
TEM FIELD OF  
VIEW ?

.Y .N

#120

WITH THE ROTATION CONTROL  
ORIENT THE LM  
UNTIL 2 CELESTIAL BODIES  
ARE VISIBLE IN THE OPTICAL  
SYSTEM

#130

SHALL I COARSE ALIGN IMU TO  
0,0,0 GIMBAL ANGLES?

#140

N. .Y

MONITOR FDAI BALL IS GIMBAL LOCK  
IMPENDING?

#150

.Y .N

WAIT FOR KEYBOARD  
ENTRY

KEY IN ENTER

#160



TERMINATE FLASH UPON  
RECEIPT OF PROCEED  
CR ENTER

KEY IN PROCEED

.P .E  
.R .N  
.O .T  
.C .E  
.E .R  
.E .  
.C .

#170

TEMP  
HOLD .  
.....  
SNAP .

-----  
DISPLAY ON DSKY:  
V41 N22  
R1-00000  
R2-00000  
R3-00000

-----  
MONITOR DSKY:  
OBSERVE DISPLAY  
OF COARSE ALIGN  
VERB AND ICDO  
ANGLES (ALL  
00000) FOR COARSE  
ALIGNMENT

#180

-----  
WHERE R1, R2,  
AND R3 REPRESENT  
ICDO/GIMBAL ANG-  
LES TO BE COARSE  
ALIGNED TO (OG,  
IG, MG, RESPEC-  
TIVELY).  
IN DEGREES TO  
NEAREST .01 DE-  
GREE

#190

-----  
COMMAND ISS TO  
COARSE ALIGN  
MODE

#200

-----  
TURN ON "NO ATT"  
LIGHT

-----  
OBSERVE "NO ATT"  
LIGHT TO INDICATE  
THAT IMU IS IN  
COARSE ALIGN MODE

#210

-----  
DISABLE CAP

#220

-----  
RESET TRACK FLAG  
-----

-----  
RESET DRIFT FLAG  
-----

-----  
RESET REFSMMAT  
FLAG  
-----

-----  
COARSE ALIGN ISS  
-----

-----  
(NOTE: IF, AT  
THE END OF COAR-  
SE ALIGNMENT,  
THE GIMBALS ARE  
NOT WITHIN 2 DE-  
GREES OF 0,0,0,  
THE LGC WILL  
TURN ON THE PRO-  
GRAM ALARM LIGHT  
AND STORE ALARM  
CODES 00211 AND  
00217.)  
-----

-----  
TERMINATE COARSE  
ALIGN MODE IN  
-----

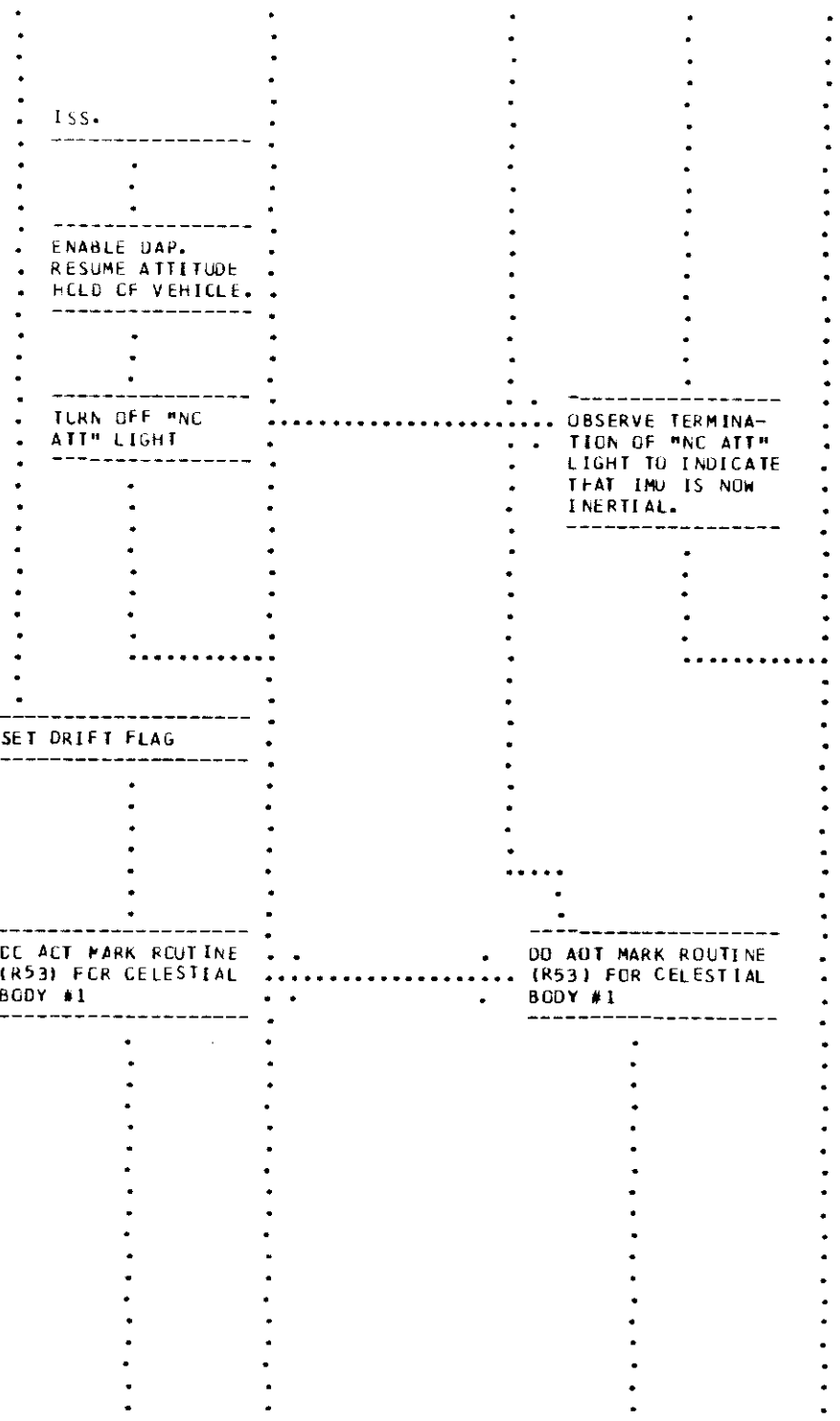
-----  
(NOTE: IF, AT THE  
END OF COARSE  
ALIGNMENT, THE  
GIMBALS ARE NOT  
WITHIN 2 DEGREES  
OF 0,0,0, THE LGC  
WILL TURN ON THE  
PROGRAM ALARM  
LIGHT AND STORE  
ALARM CODES  
00211 AND 00217.)  
-----

#230

#240

#250

#260



# 270

#280

#290

#300

# 310

DO CELESTIAL BODY  
DEFINITION ROUTINE  
(R58) FOR CELESTIAL  
BODY USED.

DO CELESTIAL BODY  
DEFINITION ROUTINE  
(R58) FOR CELESTIAL  
BODY USED.

# 320

DO ADT MARK ROUTINE  
(R53) FOR CELESTIAL  
BODY #2

DO ADT MARK ROUTINE  
(R53) FOR CELESTIAL  
BODY #2

#330

DO CELESTIAL BODY  
DEFINITION ROUTINE  
(R58) FOR CELESTIAL  
BODY USED.

DO CELESTIAL BODY  
DEFINITION ROUTINE  
(R58) FOR CELESTIAL  
BODY USED.

#340

DO SIGHTING DATA  
DISPLAY ROUTINE  
(R54)

DO SIGHTING DATA  
DISPLAY ROUTINE  
(R54)

# 350

.E .E  
.X .X  
.I .I  
.T .T  
."A" ."B"  
.....

.E .E  
.X .X  
.I .I  
.T .T  
."A" ."B"  
.....

CALCULATE IMC INERTIAL  
ORIENTATION W.R.T.  
CELESTIAL COORDIN-  
ATES AS DEFINED BY  
CELESTIAL BODIES # 1

#360

AND # 2 . STORE AS  
PRESENT PLATFORM  
ORIENTATION  
(REFSMAT)

·  
·  
·

-----  
SET REFSMAT FLAG  
-----

·  
·  
·

-----  
DO FINAL AUTOMATIC  
REQUEST TERMINATE  
ROUTINE (RCO).  
-----

·  
·  
·  
·  
EXIT P51

·  
··········  
·

-----  
DO FINAL AUTOMATIC  
REQUEST TERMINATE  
ROUTINE (ROO).  
-----

·  
·  
·  
·  
EXIT P51

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#370

#380

CHANGE CONTROL NOTES

LOGIC REV 00 PCR 7  
REV 01 EDITORIAL  
REV 02 EDITORIAL

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IMU REALIGN PROGRAM (P52)

REV 02 12/03/69

## PURPOSE:

(1) TO ALIGN THE IMU FROM A "KNOWN" (SEE ASSUMPTION 5) ORIENTATION TO ONE OF FOUR ORIENTATIONS SELECTED BY THE ASTRONAUT USING SIGHTINGS ON TWO CELESTIAL BODIES WITH THE AOT OR A BACKUP OPTICAL SYSTEM.

## (A) PREFERRED ORIENTATION (OPTION 00001)

AN OPTIMUM ORIENTATION FOR A PREVIOUSLY CALCULATED MANEUVER. THIS ORIENTATION MUST BE CALCULATED AND STORED BY A PREVIOUSLY SELECTED PROGRAM.

## (B) LANDING SITE ORIENTATION (OPTION 00004)

$$X = \text{UNIT}(R) \\ \text{-SM} \quad \text{-LS}$$

$$Y = \text{UNIT}(Z \times X) \\ \text{-SM} \quad \text{-SM} \quad \text{-SM}$$

$$Z = \text{UNIT}(H \times X) \\ \text{-SM} \quad \text{-CSM} \quad \text{-SM}$$

## WHERE:

THE ORIGIN IS THE CENTER OF THE MOON.

$R$  = THE POSITION VECTOR OF THE LM ON THE LUNAR SURFACE AT A LANDING SITE AND A TIME  
 $-LS$   
 $T(\text{ALIGN})$  SELECTED BY THE CREW.

$H$  = THE ANGULAR MOMENTUM VECTOR OF THE CSM ( $R \times V$ ).  
 $-CSM$   $-CSM$   $-CSM$

A SPECIAL CASE OF THE LANDING SITE ORIENTATION OCCURS WHEN  $T(\text{ALIGN})$  IS DEFINED AS THE TIME OF LUNAR LANDING  $T(\text{LAND})$ . THIS CASE OCCURS ONLY IF  $T(\text{LAND})$  HAS BEEN DEFINED BY THE MSFN, TRANSMITTED TO THE CREW, AND THE CREW HAS THEN DEFINED  $T(\text{ALIGN})$  TO BE  $T(\text{LAND})$  IN THIS PROGRAM.

## (C) NOMINAL ORIENTATION (OPTION 00002)

$$X = \text{UNIT}(R) \\ \text{-SM} \quad \text{-}$$

$$Y = \text{UNIT}(V \times R) \\ \text{-SM} \quad \text{-} \quad \text{-}$$

$$Z = \text{UNIT}(X \times Y) \\ \text{-SM} \quad \text{-SM} \quad \text{-SM}$$

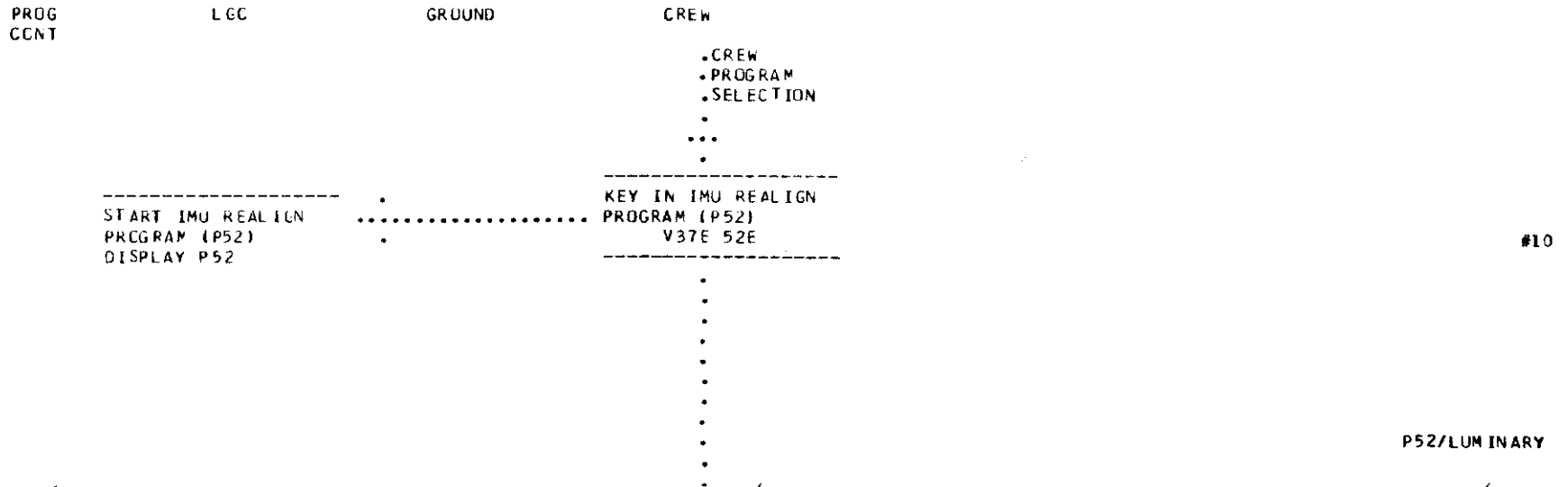
## WHERE:

$R$  = THE GECCENTRIC (EARTH ORBIT) OR SELECCENTRIC (LUNAR ORBIT) RADIUS VECTOR AT TIME  $T(\text{ALIGN})$   
 $-$   
 SELECTED BY THE ASTRONAUT.

V = THE INERTIAL VELOCITY VECTOR AT TIME T(ALIGN) SELECTED BY THE ASTRONAUT.

(E) REFSMMAT (OPTION 00003)  
SEE ASSUMPTION (5)

- ASSUMPTIONS: (1) THIS PROGRAM MAY ONLY BE PERFORMED WHILE THE LM IS IN FLIGHT.
- (2) THE CONFIGURATION MAY BE DOCKED (LM/CSM) OR UNDOCKED (LM ALONE). THE PRESENT CONFIGURATION SHOULD HAVE BEEN ENTERED INTO THE LGC BY COMPLETION OF THE GAP DATA LOAD ROUTINE (R03).
- (3) THERE ARE NO RESTRAINTS UPON THE LM ATTITUDE CONTROL MODES UNTIL A PGNS CONTROLLED MANEUVER IS CALLED BY A PROGRAM OR THE CREW WISHES TO MANUALLY MANEUVER THE VEHICLE. THE GUIDANCE CONTROL SWITCH MAY BE AT PGNS OR AGS AND IF AT PGNS, THE MODE MAY BE AUTO OR ATTITUDE HOLD. PRIOR TO PGNS CONTROLLED MANEUVERS THE LGC WILL REQUEST THE CORRECT MODE IF IT IS NOT IN EFFECT. FOR MANUALLY CONTROLLED MANEUVERS THE CREW MUST SELECT THE CORRECT MODES.
- (4) THIS PROGRAM MAKES NO PROVISION FOR AN ATTITUDE MANEUVER TO RETURN THE VEHICLE TO A SPECIFIC ATTITUDE. SUCH A MANEUVER, IF DESIRED, MUST BE DONE MANUALLY. AN OPTION IS PROVIDED HOWEVER TO ALLOW POINTING OF THE AOT AT ASTRONAUT OR LGC SELECTED STARS EITHER MANUALLY BY THE CREW OR AUTOMATICALLY BY AN LGC CONTROLLED ATTITUDE MANEUVER.
- (5) THE ISS IS ON AND HAS BEEN ALIGNED TO A "KNOWN" ORIENTATION WHICH IS STORED IN THE LGC (REFSMMAT). THE PRESENT IMU ORIENTATION DIFFERS FROM THAT TO WHICH IT WAS LAST ALIGNED ONLY DUE TO GYRO DRIFT (I.E. NEITHER GIMBAL LOCK NOR IMU POWER INTERRUPTION HAS OCCURRED SINCE THE LAST ALIGNMENT).
- (6) AN OPTION IS PROVIDED TO REALIGN THE IMU TO THE PREFERRED, NOMINAL, OR LANDING SITE ORIENTATIONS WITHOUT MAKING CELESTIAL BODY SIGHTINGS (SEE LOGIC FLOW).
- (7) EXTENDED VERBS SHOULD NOT BE EXERCISED DURING THIS PROGRAM BECAUSE OF POSSIBLE INTERFERENCE WITH R53.
- (8) THE PROGRAM IS SELECTED BY THE ASTRONAUT BY DSKY ENTRY.







VC4 NO6  
R1-00001  
R2-0000X  
R3-BLANK

ASSUMED IMU ORIEN-  
TIGN SELECTION

#70

R1 IS THE  
OPTION CODE  
FOR ASSUMED  
IMU ORIENTATION  
SELECTION.

IS THIS THE IMU ORI-  
ENTATION I DESIRE?

#80

R2 IS THE  
LGC ASSUMED OPTION:  
00001-PREFERRED  
00002-NOMINAL  
00003-REFSMAT  
00004-LANDING SITE

.Y .N

WAIT FOR KEYBOARD  
ENTRY

KEY IN  
PROCEED

#90

TERMINATE FLASH UPON  
RECEIPT OF PROCEED  
OR NEW DATA

KEY IN V22E  
AND LOAD THE  
DESIRED ORIEN-  
TATION CODE IN  
R2

#100

.P .NEW  
.R .CODE  
.C .  
.C .  
.E  
.E STORE CODE  
.D

#110



HOLD . . . . . FLASH VERB-NCUN TO  
..... REQUEST RESPONSE AND  
SNAP . . . . . DISPLAY T(ALIGN);  
                  V06N34  
                  R1- T(ALIGN)-HRS  
                  R2- T(ALIGN)-MINS  
                  R3- T(ALIGN)-SECS

T(ALIGN)- TIME(GET)  
AT WHICH LM POSITION  
AND VELOCITY VECTORS  
ARE TO BE DEFINED  
FOR A NOMINAL OR  
LANDING SITE IMU  
ORIENTATION. IN  
HRS, MINS, SECS, TO  
NEAREST .01 SEC.

MONITOR DSKY:  
OBSERVE VERB-NCUN  
FLASH TO REQUEST  
RESPONSE AND DISPLAY  
OF T(ALIGN).

#170

#180

#190

FOR OPTION 2  
T(ALIGN) WILL APPEAR  
HERE AS 00000,  
00000, 00000, WHICH  
IF ACCEPTED WILL  
INDICATE THAT THE  
NOMINAL OR LANDING  
SITE ORIENTATION  
WILL BE DEFINED FOR  
A T(ALIGN) AUTCMAT-  
ICALLY SELECTED AS  
THE PRESENT TIME.  
FOR OPTION 4,  
T(ALIGN) WILL BE  
DEFINED AS T(LAND).

#200

DO I WISH TO ALIGN  
THE IML TO AN

#210





STORED LANDING SITE VECTOR (IN "PRIMARY" STORAGE) AND SPECIFIED T(ALIGN). (NOTE: THE "PRIMARY" STORAGE OF THE LANDING SITE CAN BE MODIFIED ONLY BY PRELAUNCH ERASABLE LOAD, P27, P57, OR P68. SHOULD THE CREW WRITE OVER THE FOLLOWING DISPLAY, THE NEWLY DEFINED LANDING SITE IS EFFECTIVE ONLY TO DEFINE A LANDING SITE ORIENTATION FOR THE IMU.)

++  
+02  
+EDIT  
++

#310

#320

#330

HOLD

SNAP

FLASH VERB-NOUN TO REQUEST RESPONSE AND DISPLAY THE LGC-STORED OR THE NEWLY-DEFINED LANDING SITE COORDINATES.

V06N89  
R1-LAT  
R2-LONG/2  
R3-ALT

LAT-SELENGGRAPHIC LATITUDE OF THE DESIGNATED LANDING SITE. POLARITY INDICATES NORTH(+) OR SOUTH(-). IN DEGREES TO NEAREST .001 DEGREES.

MONITOR DSKY: OBSERVE VERB-NOUN FLASH TO REQUEST RESPONSE AND DISPLAY OF THE LGC-STORED OR THE NEWLY-DEFINED LANDING SITE COORDINATES.

#340

ARE THESE THE DESIRED LANDING SITE COORDINATES?

#350

.Y N.

LCAG/2-SELENGRAPHIC  
LONGITUDE DIVIDED BY  
TWO OF THE LGC-STO-  
RED OR THE NEWLY-  
DEFINED LANDING SITE.  
POLARITY INDICATES  
EAST(+) OR WEST(-).  
IN DEGREES TO NEAR-  
EST .001 DEGREE.

#360

ALT-THE ALTITUDE OF  
THE LGC-STORED OR  
THE NEWLY-DEFINED  
LANDING SITE ABOVE  
THE RADIUS AT THE  
DESIGNATED  
LANDING SITE. IN  
NAUTICAL MILES TO  
NEAREST .01 NM.

#370

-----  
.  
.  
.  
-----  
WAIT FOR KEYBOARD  
ENTRY

-----  
KEY IN PROCEED  
-----

#380

-----  
TERMINATE FLASH UPON  
RECEIPT OF PROCEED  
OR NEW DATA

-----  
KEY IN V25E AND  
LOAD THE CORRECT  
COORDINATES.  
-----

#390

.PROCEED     .NEW  
              .DATA

-----  
STORE DATA  
-----

#400

-----  
COMPUTE LANDING SITE  
ORIENTATION FOR THE

400



LGC-STORED OR THE  
NEWLY-DEFINED  
LANDING SITE COOR-  
DINATES AND T(ALIGN).  
SELECT THIS ORIENTA-  
TION FOR GIMBAL  
ANGLE COMPUTATION.  
(NOTE: AT THIS TIME  
ANY PREFERRED ORIENT-  
TATION PREVIOUSLY  
STORED IN THE LGC  
IS LOST)

#410

"A"  
FROM  
ABOVE

#420

. READ PRESENT VEHICLE  
ATTITUDE FROM THE  
PRESENT GIMBAL  
ANGLES

#430

. COMPUTE GIMBAL  
ANGLES AT DESIRED  
IMU ORIENTATION AND  
PRESENT VEHICLE  
ATTITUDE

#440

"A"  
FROM  
ABOVE

#450

HOLD . . . FLASH VERB-NOUN TO  
REQUEST RESPONSE AND  
SNAP . . . DISPLAY THE RESULT-  
ING ICDU/GIMBAL  
ANGLES:

. MONITOR DSKY:  
OBSERVE VERB-NOUN  
FLASH TO REQUEST  
RESPONSE AND DISPLAY  
OF ICDU/GIMBAL

#460

V06 N22  
R1-CG  
R2-IG  
R3-MG

ANGLES AFTER PRO-  
POSED LM/IMU ALIGN-  
MENT

ALL GIMBAL ANGLES IN  
DEGREES TO NEAREST  
C1 DEGREE

WAIT FOR KEYBOARD  
ENTRY

DO I WISH TO  
MANEUVER VEHICLE  
TO AN ATTITUDE  
WHICH WILL PRO-  
VIDE A MORE  
SUITABLE MGA?

.N .Y

MANEUVER VEH-  
ICLE WITH  
ROTATION  
CONTRCLLER

UPDATE THE  
DISPLAY OF

#470

#480

#490

#500

#510

402

RESULTING  
GIMBAL  
ANGLES:  
KEY IN  
RECYCLE  
V32E

#520

TERMINATE FLASH UPON  
RECEIPT OF PROCEED  
OR RECYCLE

KEY IN PROCEED

#530

.R .P  
.E .R  
.C .D  
.Y .C  
.C .E  
.L .E  
.E .D

#540

HOLD

SNAP

FLASH VERB NOUN TO  
REQUEST PLEASE PER-  
FORM NORMAL OR GYRO  
TORQUE COARSE ALIGN;  
V5CN25  
R1-00013  
R2-BLANK  
R3-BLANK

MONITOR DSKY:  
OBSERVE VERB NOUN  
FLASH TO REQUEST  
PLEASE PERFORM  
NORMAL OR GYRO TOR-  
QUE COARSE ALIGN

#550

THE NORMAL METHOD  
OF ACHIEVING IMU  
REALIGNMENT IS TO  
ACCEPT THIS REQUEST  
BY KEYING IN PROCEED

#560



405

TERMINATE FLASH UPON  
RECEIPT OF PROCEED  
OR ENTER

..... KEY IN PROCEED

..... KEY IN ENTER

.P .ENTER  
.R .  
.C .  
.C .  
.E .  
.E .  
.D .  
. .  
. .

.....  
COMPUTE TORQUING  
ANGLES REQUIRED  
TO ACHIEVE NEW  
ORIENTATION.

.....  
RESET REFSMMAT  
FLAG

.....  
RESET DRIFT FLAG

.....  
PULSE IRIGS  
THROUGH TORQUING  
ANGLES AND DIS-  
PLAY PRESENT ICUL  
ANGLES UNTIL

.....  
MONITOR DSKY:  
OBSERVE VERB-NOUN  
DISPLAY OF PRE-  
SENT GIMBAL  
ANGLES UNTIL CCM-

#620

#630

#640

#650

POSS  
TEMP  
HOLD .  
.....  
MON .

COMPLETION.  
V16N20  
R1-OG  
R2-IG  
R3-MG  
  
ALL GIMBAL ANGLES  
IN DEGREES TO  
NEAREST .01  
DEGREE.

-----  
DEFINE REFSMMAT  
TO BE THE DESIRED  
IMU ORIENTATION  
-----

-----  
RESET PREFERRED-  
ATTITUDE-COMPUTED  
FLAG.  
-----

PLETION OF PULSE  
TORQUING.  
(NOTE: UNLESS THE  
DAP IS OFF ("MODE  
CONTROL-PGNS"  
SWITCH TO "OFF")  
OR IN A MODE  
WHERE IT DOES NOT  
MAINTAIN ATTITUDE  
(I.E.: MINIMUM  
IMPULSE MODE VIA  
V76E) THERE IS A  
HIGH PROBABILITY  
THAT RCS JETS  
WILL BE FIRED AS  
THE INERTIAL RE-  
FERENCE IS CHANG-  
ED (GYROS TOR-  
QUED). HOWEVER,  
THE GYROS MAY BE  
TORQUED SO AS TO  
DRIVE THE GIMBALS  
INTO GIMBAL LOCK.  
THEREFORE THE  
CREW SHOULD MAN-  
UALLY MANEUVER  
THE SPACECRAFT IN  
THE MINIMUM IM-  
PULSE MODE OR  
UNDER CONTROL OF  
THE AGS TO AVOID  
GIMBAL LOCK.)

#660

#670

#680

#690

#700

406

407

.  
.  
.  
.  
.  
.  
.  
.

SET REFSMMAT FLAG

.  
.  
.  
.  
.

SET DRIFT FLAG

.  
.  
.  
.  
.

POSS  
HOLD .  
.....  
SNAP .

FLASH VERB-NOUN  
TC REQUEST PLEASE  
PERFORM FINE  
ALIGN:  
V50 N25  
R1-CC014  
R2-BLANK  
R3-BLANK

.  
.  
.  
.

WAIT FOR KEYBOARD  
ENTRY

.  
.  
.  
.  
.  
.  
.  
.  
.  
.  
.

TERMINATE FLASH  
UPON RECEIPT OF  
PROCEED OR ENTER

.P .E  
.R .N  
.C .T  
.C .E  
.E .R

.  
.  
.  
.  
.  
.  
.  
.

MONITOR DSKY:  
OBSERVE VERB-NOUN  
FLASH TO REQUEST  
PLEASE PERFORM  
FINE ALIGN

.  
.  
.  
.

DO I WISH TO AT-  
TEMPT TO FINE  
ALIGN THE IMU?

.Y N.  
.  
.  
.

KEY IN PROCEED

.  
.  
.  
.

KEY IN ENTER

.  
.  
.  
.

GO TO GC TC

#710

#720

#730

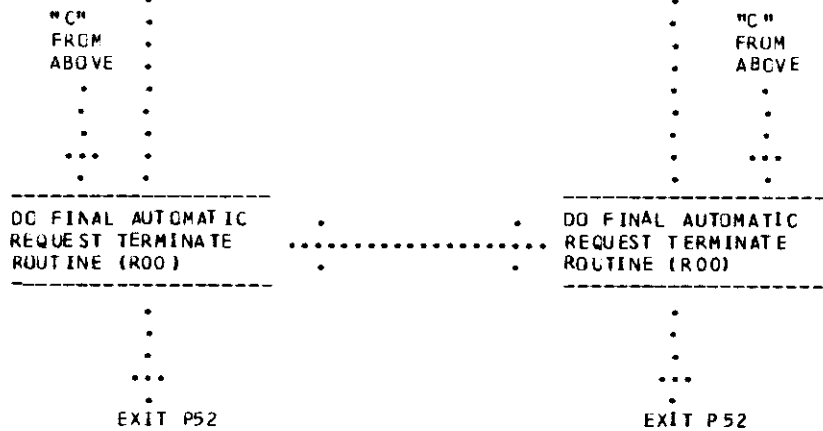
#740

#750





409



#810

#820

CHANGE CONTROL NOTES

- REV 01 PCR 134,439
- REV 00(LUM 1A) PCR 740
- REV 01(LUM 1B) PCR 825.2
- REV 02 EDITORIAL

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LUNAR SURFACE ALIGN PROGRAM (P57)

REV 03 12/03/69

++  
+03  
PURPOSE:  
+EDIT  
++

(1) WHILE ON THE SURFACE OF THE MOON TO ALIGN OR REALIGN THE IMU TO ONE OF THREE TYPES OF ORIENTATIONS:

## (A) LANDING SITE ORIENTATION

X = UNIT ( R )  
-SM -LS

Y = UNIT ( Z X X )  
-SM -SM -SM

Z = UNIT ( H X X )  
-SM -CSM -SM

WHERE:

- (1) THE ORIGIN IS THE CENTER OF THE MOON
- (2) R = THE POSITION VECTOR OF THE LM ON THE LUNAR SURFACE AT THE MOST RECENTLY DESIGNATED LANDING SITE AND A TIME T(ALIGN) SELECTED BY THE CREW.  
-LS
- (3) H = THE ANGULAR MOMENTUM VECTOR OF THE CSM ( R X V ).  
-CSM -CSM -CSM

## (B) PREFERRED ORIENTATION

AN IMU ORIENTATION SPECIFIED BY THE GROUND AND LOADED INTO THE LGC BY THE LGC UPDATE PROGRAM (P27).

## (C) PRESENT REFSMMAT

++  
+03  
+EDIT  
++

- ASSUMPTIONS:
- (1) THERE ARE SEVERAL TECHNIQUES AVAILABLE TO THE CREW FOR COMPLETING AN IMU ALIGNMENT. THE RESULTANT ACCURACY OF THE IMU TO THE SPECIFIED DESIRED ORIENTATION (I.E. THAT ORIENTATION DEFINED BY THE FINAL REFSMMAT) IS DEPENDENT UPON THE ALIGNMENT TECHNIQUE WHICH THE CREW SELECTS. THIS SELECTION WILL BE DICTATED BY THE CIRCUMSTANCES AT THE TIME OF ALIGNMENT.
  - (2) THE LM HAS LANDED ON THE LUNAR SURFACE. THE LM YAW ANGLE WITH RESPECT TO THE INERTIAL ORIENTATION OF THE IMU AT LANDING WAS NOT CONSTRAINED DURING LANDING.
  - (3) ALL POSSIBLE EFFORTS HAVE BEEN MADE BY THE CREW TO ENSURE THAT THE LM WILL NOT SHIFT ITS POSITION WITH RESPECT TO THE LUNAR SURFACE. NO PROVISION HAS BEEN MADE TO INCORPORATE IN THE LGC ANY MEASUREMENT OF LM SETTling ON THE LUNAR SURFACE. HOWEVER A SHIFTING OF THE LM WILL RESULT IN A MISALIGNED IMU ONLY IN THE CASE WHERE AN ALIGNMENT IS MADE FROM A STORED LM ATTITUDE WITH RESPECT TO THE LUNAR SURFACE (OPTION CODES 0000 AND 0001; SEE LOGIC BELOW), AND THE IMU IS NOT SUBSEQUENTLY ALIGNED BY REFERENCE TO CELESTIAL BODIES AND/OR LUNAR GRAVITY.
  - (4) THE ISS IS ON AND MAY BE:

- (A) AT AN INERTIAL ORIENTATION "UNKNOWN" TO THE LGC; I.E.: IT MAY HAVE BEEN SHUT DOWN AND RESTARTED SINCE





ED PUSH KEY  
RELEASE.

PRESS ALARM RESET  
TO RESET PROGRAM  
ALARM.

DO FINAL AUTO-  
MATIC REQUEST  
TERMINATE ROUTINE  
(R00)

DO FINAL AUTO-  
MATIC REQUEST  
TERMINATE ROUTINE  
(R00)

EXIT P57

EXIT P57

SET LGC ASSUMED  
OPTICN CODE FOR  
IMU ORIENTATION  
TO = C0003  
(REFSMAT)

HOLD . . . . . FLASH VERB-NOUN TO  
..... REQUEST RESPONSE AND  
SNAP . . . . . DISPLAY OPTICN CODE  
FOR ASSUMED IMU OR-

MONITOR DSKY:  
OBSERVE VERB-NOUN  
FLASH TO REQUEST  
RESPONSE AND DISPLAY

#70

#80

#90

#100

414

ORIENTATION SELECTION  
V04N06  
R1-CCCC1  
R2-0000X  
R3-BLANK

OF OPTION CODE FOR  
ASSUMED IMU ORIENTA-  
TION SELECTION

#110

R1 IS THE OPTION  
CODE FOR ASSUMED  
IMU ORIENTATION  
SELECTION.

IS THIS THE DESIRED  
IMU ORIENTATION?

#120

R2 IS THE LGC  
ASSUMED IMU ORIENTA-  
TION SELECTION  
OPTION:  
00001-PREFERRED  
00002-NOMINAL  
00003-REFSMAT  
00004-LANDING SITE

. Y . N .

#130

WAIT FOR KEYBOARD  
ENTRY

KEY IN PROCEED

#140

TERMINATE FLASH UPON  
RECEIPT OF PROCEED  
OR NEW DATA

KEY IN V22E  
AND LOAD THE  
DESIRED ORIENTA-  
TION OPTION IN  
R2

#150

.P NEW  
.R DATA  
.D  
STORE  
.C NEW  
.E OPTION  
.E  
.D

WAS THE NOMINAL  
OPTION SELECTED?

#160

. N . Y .

IS THE LGC ASSUMED  
OPTIGN = 00002?

.N                    Y.

IS THE LGC ASSUMED  
OPTIGN = 00003?

.Y                    N.

DEFINE THE DESIR-  
ED IMU ORIENTA-  
TION TO BE  
REFSMMAT.

GO TO  
"E"  
BELOW

IS THE LGC ASSUMED  
OPTIGN = 00001?

.Y                    N.

GO TO  
"E"

WAS THE REFSMMAT  
OPTION SELECTED?

.Y                    N.

GO TO  
"E"  
BELOW

WAS THE PREFERRED  
OPTION SELECTED?

.Y                    N.

NOTE: IF CREW  
SELECTS ALIGNMENT  
TO A PREFERRED

#170

#180

#190

#200



417

BELOW

ORIENTATION  
(00001), AND NONE  
HAS BEEN DEFINED,  
NO ALARM WILL  
RESULT, BUT THE  
RESULTING ALIGN-  
MENT WILL BE  
WORTHLESS.

#210

GC TO  
"E"  
BELOW

#220

-----  
OBTAIN CONTENTS OF  
TIG REGISTER FROM  
STORAGE FOR DISPLAY  
AS T(ALIGN)  
(NOTE: IF P12 WAS  
PARTIALLY PERFORMED  
IMMEDIATELY AFTER  
THE LUNAR LANDING,  
TIG WILL CONTAIN  
TIG(AS)).  
-----

#230

#240

-----  
HOLD . FLASH VERB-NOUN TO  
..... REQUEST RESPONSE AND  
SNAP . DISPLAY T(ALIGN):  
          V06N34  
          R1-T(ALIGN)-HRS  
          R2-T(ALIGN)-MINS  
-----

-----  
MONITOR DSKY:  
OBSERVE VERB-NOUN  
FLASH TO REQUEST  
RESPONSE AND DISPLAY  
OF T(ALIGN) WHICH IS  
EQUAL TO THE PRES-  
-----

#250

R3-T(ALIGN)-SECS  
T(ALIGN)-TIME(GET)  
AT WHICH LM POSITION  
VECTOR IS DEFINED  
FOR A LANDING SITE  
ORIENTATION. IN HRS  
MINS AND SECS TO  
NEAREST .01 SEC.

ENTLY DEFINED TIG  
(AS).  
(NOTE: IT IS ASSUMED  
THAT P12 WAS PAR-  
TIALLY PERFORMED  
IMMEDIATELY AFTER  
THE LUNAR LANDING.  
AT THAT TIME TIG(AS)  
WAS DEFINED.)

#260

#270

WAIT FOR KEYBOARD  
ENTRY

#280

#290

IF T(ALIGN) IS  
DEFINED TO BE  
00000, 00000,  
00000, THE LAND-  
ING SITE  
ORIENTATION  
WILL BE DE-  
FINED FOR A

#300

118

(

(

T(ALIGN)  
AUTOMATICALLY  
SELECTED BY  
THE LGC AS THE  
PRESENT TIME.

#310

DO I WISH TO  
ALIGN THE IMU TO  
A LANDING SITE  
ORIENTATION DE-  
FINED BY THE T  
(ALIGN) PRESENTLY  
DISPLAYED?

#320

.Y .N

KEY IN V25E  
AND LOAD THE  
DESIRED T  
(ALIGN) IN R1,  
R2 AND R3

#330

TERMINATE FLASH UPON  
RECEIPT OF PROCEED  
OR NEW DATA

KEY IN PROCEED

#340

.P .NEW  
.R .DATA  
.Q  
.C  
.E STORE DATA  
.E  
.C

#350



#21

BLE USE BY  
P12 AS  
TIG(AS).

#400

COMPUTE LANDING  
SITE ORIENTATION  
FOR DEFINED 1  
(ALIGN).  
(NOTE: AT THIS  
TIME ANY PRE-  
FERRED ORIENTA-  
TION PREVIOUSLY  
STORED IN THE LGC  
IS LOST.)

#410

"E"  
FROM  
ABOVE

#420

SET LGC ASSUMED  
ALIGNMENT TECHNIQUE  
OPTICN CODE TO  
0000 (SEE BELOW).

#430

"E"  
FROM  
ABOVE

#440

HOLD . FLASH VERB-NOUN TO  
..... REQUEST RESPONSE AND  
SNAP . DISPLAY OPTICN CODE  
FOR ASSUMED ALIGN-

MONITOR DSKY:  
OBSERVE FLASHING  
VERB-NOUN TO REQUEST  
RESPONSE AND DISPLAY



423 +  
+  
+  
+  
++

ECTED USING AGT  
SIGHTINGS TO TWO  
CELESTIAL BODIES.

++  
+03  
+EDIT  
++

CCCC3-ALIGN TO  
THE DESIRED  
ORIENTATION  
PREVIOUSLY SEL-  
ECTED USING AGT  
SIGHTINGS TO ONE  
CELESTIAL BODY AND  
DETERMINATION OF  
THE LUNAR GRAVITY  
VECTOR.

#500

R3 IS DATCODE-A  
TWO DIGIT CODE. R3  
WILL CONTAIN A "1"  
IN THE "C" DIGIT IF  
A REFSMMAT IS  
DEFINED, OR  
A "0" IF NO REFSMMAT  
IS DEFINED.

#510

R3 WILL CONTAIN A  
"1" IN THE "D"  
DIGIT TO INDICATE  
THAT A STORED LM  
ATTITUDE IS AVAIL-  
ABLE, OR A "0" IF IT  
IS NOT AVAILABLE.

#520

OPTIMALLY DATCODE  
SHOULD THEREFORE  
READ 00110.

#530

-----  
IS THE LGC-ASSUMED  
ALIGNMENT TECHNIQUE  
OPTICN CODE CORRECT  
(R2)?  
-----

Y.                    N.

#540

-----  
WAIT FOR KEYBOARD  
ENTRY

-----  
KEY IN PROCEED  
-----

KEY IN V2ZE AND  
LOAD THE DESIRED  
LGC-ASSUMED ALI-  
GNMENT TECHNIQUE  
OPTION CODE IN  
R2.

#550

TERMINATE FLASH UPON  
RECEIPT OF PROCEED  
OR NEW DATA

.P .NEW  
.R .DATA  
.O  
.C  
.E  
.E  
.D

STORE DATA

#560

#570

IS REFSMMAT FLAG  
SET?

.Y .N

IS ATTITUDE FLAG  
SET?

.Y N.

IS REFSMMAT FLAG  
SET?

Y. .N

IS ATTITUDE FLAG  
SET?

Y. .N

#580

#590

424



#25

GO TO  
"B"  
BELGW

IS ALIGNMENT  
TECHNIQUE OPTION  
CODE = 0C002  
OR 00003?

.Y .N

GO TO  
"B"  
BELGW

IS ALIGNMENT  
TECHNIQUE OPTION  
CODE = 00002  
OR 00003?

.Y .N

POSS

HOLD  
SNAP

FLASH VERB-NGUN  
TO REQUEST RE-  
SPONSE AND DIS-  
PLAY ALARM CODE  
00701:  
V05N09  
R1-XXXXX  
R2-XXXXX  
R3-XXXXX  
(NOTE: ALARM CODE  
MAY BE DISPLAYED  
IN R1, R2, OR R3,  
DEPENDING ON PRE-  
SENCE OR ABSENCE  
OF OTHER ALARM  
CODES.)

MONITOR DSKY:  
DISPLAY OF  
ALARM CODE INDIC-  
ATES THAT OPTION  
00000 OR 00001  
HAS BEEN SELECTED  
BUT THE LGC CAN-  
NOT CONTINUE  
BECAUSE NEITHER  
PRESENT REFSMMAT  
NOR A STORED LM  
ATTITUDE ARE  
AVAILABLE.  
DO I WISH TO SEL-  
ECT ANOTHER  
OPTIGN?

.N .Y

WAIT FOR KEYBOARD  
ENTRY

KEY IN  
RECYCLE  
V32E

#600

#610

#620

#630

#640

#650

TERMINATE FLASH  
UPON RECEIPT OF  
RECYCLE OR  
TERMINATE

KEY IN TERMINATE  
V34E

T.            .R  
E.            .E  
R.            .C  
M.            .Y  
I.            .C  
N.            .L  
A.            .E  
T.  
E.

#660

#670

DO FINAL AUTO-  
MATIC REQUEST  
TERMINATE ROUTINE  
(ROO)

DO FINAL AUTO-  
MATIC REQUEST  
TERMINATE ROUTINE  
(ROO)

#680

EXIT P57

EXIT P57

#690

COMPUTE AND STORE  
LP ATTITUDE IN HCON-  
FIXED COORDINATES  
USING REFSMMAT

426

#27

SET ATTITUDE FLAG

#700

"B"  
FROM  
ABOVE

#710

SET INITIAL ALIGN  
FLAG

#720

IS ALIGNMENT TECH-  
NIQUE OPTION CODE =  
00001 OR 00003?

IS ALIGNMENT TECH-  
NIQUE OPTION CODE =  
00001 OR 00003?

.N .Y  
GO TO  
"C"  
BELOW

.Y .N  
GO TO  
"C"  
BELOW

#730

SET DESIRED GIMBAL  
ANGLES AS FOLLOWS:

#740

OG = +42 DEG  
IG = -42 DEG  
MG = +35.25 DEG

-----  
COMMAND ISS TO  
COARSE ALIGN MODE.  
-----

-----  
TURN ON "NO ATT"  
LIGHT  
-----

-----  
RESET TRACK FLAG  
-----

-----  
RESET DRIFT FLAG  
-----

-----  
RESET REFSMMAT FLAG  
-----

-----  
COARSE ALIGN ISS.  
-----

-----  
(NOTE: IF AT THE END  
OF COARSE ALIGNMENT,  
THE GIMBALS ARE NOT  
WITHIN 2 DEGREES OF

-----  
OBSERVE "NO ATT"  
LIGHT TO INDICATE  
THAT IMU IS IN  
COARSE ALIGN MODE  
FOR ALIGNMENT TO THE  
FIRST POSITION FOR  
LUNAR GRAVITY DETER-  
MINATION  
-----

-----  
(NOTE: IF AT THE END  
OF COARSE ALIGNMENT,  
THE GIMBALS ARE NOT  
WITHIN 2 DEGREES OF

#750

#760

#770

#780

#790

428

429

THE DESIRED VALUES,  
THE LGC WILL TURN ON  
THE PROGRAM ALARM  
LIGHT AND STORE  
ALARM CCDES 00211  
AND 00217).

THE DESIRED VALUES,  
THE LGC WILL TURN ON  
THE PROGRAM ALARM  
LIGHT AND STORE  
ALARM CCDES 00211  
AND 00217).

#800

TERMINATE COARSE  
ALIGN MODE IN ISS.

#810

TURN OFF "NO ATT"  
LIGHT

OBSERVE TERMINATION  
OF "NO ATT" LIGHT TO  
INDICATE THAT IMU IS  
NOW INERTIAL.

#820

DETERMINE GRAVITY  
VECTOR, G, BY READ-  
ING ACCELEROMETER  
OUTPUTS

#830

STORE 1/2 UNIT (G)  
IN NAV BASE  
COORDINATES AS G1

#840

.....  
.....  
.....  
.....  
.....  
-----  
CALCULATE DESIRED  
ICDL/GIMBAL ANGLES  
TO ROTATE IMU STABLE  
MEMBER 180 DEGREES  
ABOUT G  
-----

#850

.....  
.....  
.....  
-----  
COMMAND ISS TO  
COARSE ALIGN MODE.  
-----

#860

.....  
-----  
TURN ON "NO ATT"  
LIGHT  
-----

.....  
-----  
OBSERVE "NO ATT"  
LIGHT TO INDICATE  
THAT IMU IS IN  
COARSE ALIGN MODE,  
FOR ALIGNMENT TO THE  
SECOND POSITION FOR  
LUNAR GRAVITY DETER-  
MINATION.  
-----

#870

.....  
-----  
RESET TRACK FLAG  
-----

.....  
-----  
RESET DRIFT FLAG  
-----

#880

.....  
-----  
RESET REFSMMAT FLAG  
-----

.....  
-----  
COARSE ALIGN ISS.  
-----

#890

113

.....  
 (NOTE: IF AT THE END  
 OF COARSE ALIGNMENT,  
 THE GIMBALS ARE NOT  
 WITHIN 2 DEGREES OF  
 THE DESIRED VALUES,  
 THE LGC WILL TURN ON  
 THE PROGRAM ALARM  
 LIGHT AND STORE  
 ALARM CODES 00211  
 AND 00217).  
 -----

.....  
 (NOTE: IF AT THE END  
 OF COARSE ALIGNMENT,  
 THE GIMBALS ARE NOT  
 WITHIN 2 DEGREES OF  
 THE DESIRED VALUES,  
 THE LGC WILL TURN ON  
 THE PROGRAM ALARM  
 LIGHT AND STORE  
 ALARM CODES 00211  
 AND 00217).  
 -----

#900

.....  
 TERMINATE COARSE  
 ALIGN MODE IN ISS.  
 -----

#910

.....  
 TURN OFF "NO ATT"  
 LIGHT  
 -----

.....  
 OBSERVE TERMINATION  
 OF "NO ATT" LIGHT TO  
 INDICATE THAT IMU IS  
 NOW INERTIAL.  
 -----

#920

.....  
 DETERMINE NEW GRA-  
 VITY VECTOR G BY  
 READING ACCELERO-  
 METER OUTPUTS  
 -----

#930

.....  
 STORE 1/2 UNIT (G)  
 -----

IN NAV BASE  
COORDINATES AS G2

#940

-----  
:  
:  
-----  
DEFINE THE 1/2 UNIT  
LUNAR GRAVITY VECTOR  
TO BE THE UNITIZED  
SUM OF G1 AND G2  
-----  
:  
:  
-----

#950

POSS  
HOLD . FLASH VERB-NOUN TO  
..... REQUEST RESPONSE  
SNAP . AND DISPLAY GRAV ERR  
ANGLE:  
V06 N04  
R1-GRAV ERR ANGLE  
R2-BLANK  
R3-BLANK

GRAV ERR ANGLE - THE  
ANGULAR DIFFERENCE  
BETWEEN PRESENT AND  
ANY PREVIOUSLY DE-  
FINED GRAVITY VECTOR.  
POLARITY IS ALWAYS +.  
IN DEGREES TO NEAR-  
EST .01 DEGREES  
(NOTE: UNTIL THIS  
PROGRAM IS PERFORMED  
THE FIRST TIME THE  
LGC WILL ASSUME THE  
LUNAR GRAVITY VECTOR  
TO BE PARALLEL TO  
THE LM X AXIS IF P68  
WAS PREVIOUSLY COM-  
PLETED. IF P68 WAS  
NOT PREVIOUSLY COM-  
PLETED, THIS DISPLAY  
IS MEANINGLESS ON

-----  
MONITOR DSKY:  
OBSERVE VERB-NOUN  
FLASH TO REQUEST  
RESPONSE AND DISPLAY  
OF GRAV ERR ANGLE.  
(NOTE: UNTIL THIS  
PROGRAM IS PERFORMED  
THE FIRST TIME THE  
LGC WILL ASSUME THE  
LUNAR GRAVITY VECTOR  
TO BE PARALLEL TO  
THE LM X AXIS.)  
-----

#960

#970

#980



THE FIRST PASS).  
 (NOTE: A PREVIOUSLY  
 DEFINED GRAVITY  
 VECTOR HAS ONLY BEEN  
 RETAINED FOR COMPA-  
 RISON IF THIS DIS-  
 PLAY WAS NOT TERMI-  
 NATED AT THAT TIME  
 BY V34E).

#990

DO I WISH TO COM-  
 PLETE ALIGNMENT NOW?

#1000

.N .Y

DO I WISH TO  
 REMEASURE THE  
 LUNAR GRAVITY  
 VECTOR?

#1010

.Y N.

WAIT FOR KEYBOARD  
 ENTRY

KEY IN  
 RECYCLE  
 V32E

#1020

KEY IN  
 TERMINATE  
 V34E

#1030

TERMINATE FLASH UPON  
RECEIPT OF PROCEED,  
RECYCLE, OR  
TERMINATE

-----  
KEY IN PROCEED  
-----

.P .T .R  
.R .E .E  
.O .R .C  
.C .M .Y  
.E .I .C  
.E .N .L  
.D .A .E  
. .T .  
. .E .  
. . . . .  
. . . . .  
. . . . .

#1040

-----  
. DO FINAL AUTO-  
MATIC REQUEST  
TERMINATE ROUTINE  
(ROO)

-----  
. DO FINAL AUTO-  
MATIC REQUEST  
TERMINATE ROUTINE  
(ROO)

#1050

EXIT P57

FROM  
ABOVE  
EXIT P57

#1060

FROM ABOVE

-----  
CONSIDER THIS TO BE  
THE FIRST PASS  
THROUGH THE ALIGN-  
MENT PROGRAM.  
WAS A STORED LM  
ATTITUDE OR REFSMMAT  
AVAILABLE AT THE  
START OF THIS  
PROGRAM?

#1070

IS THE ATTITUDE FLAG  
SET?

.Y .N  
. .  
. .  
. .  
. .  
. .  
. .  
. .  
. .  
. .  
. .  
. .  
. .  
. .

.N .Y  
. .  
. .  
. .  
. .  
. .  
. .  
. .  
. .  
. .  
. .  
. .  
. .  
. .

#1080

434

#1090

-----  
RE SET THE INITIAL  
ALIGN FLAG.  
-----

#1100

-----  
CHECK THE TECHNI-  
QUE OPTION CODE  
-----

-----  
CHECK THE TECHNI-  
QUE OPTION CODE  
-----

.00000 .0 .0  
.00001 .0 .0  
(NOTE: .C .C  
ON THE .0 .0  
.FIRST .2 .3  
.PASS . .  
.THIS . .  
.LOGIC . .  
.PATH . .  
.EXISTS . .  
.IN THE . .  
.PROGRAM . .  
.AS SHOWN . .  
.IT IS . .  
.NEVER . .  
.USED . .  
.HOWEVER . .  
.AS IT . .  
.HAS BEEN . .  
.PRECLUDED BY . .  
.PREVIOUS . .  
.LOGIC . .  
.SEE . .  
.ABCVE).

.00002 00000.  
.00003 00001.  
(NOTE: ON  
THE FIRST  
PASS THIS  
LOGIC PATH  
EXISTS IN  
THE PROGRAM  
AS SHOWN.  
IT IS NEVER  
USED HOWEVER.  
AS IT HAS  
BEEN PRE-  
CLUDED BY  
PREVIOUS  
LOGIC. SEE  
ABCVE).

#1110

#1120

#1130

-----  
DEFINE UNIT  
LOS VECTORS AS  
DESCRIBED IN  
SECTION  
5.6.2.2 OF  
R567.  
-----

#1140

-----  
SET STAR INDI-  
CATOR = 0.  
-----

#1150

-----  
SET STAR INDI-  
CATOR = 1  
-----

#1160

-----  
DO LUNAR SURFACE  
SIGHTING MARK  
ROUTINE (R59)  
-----

-----  
DO LUNAR SURFACE  
SIGHTING MARK  
ROUTINE (R59) FOR  
CELESTIAL BODY #1  
-----

#1170

-----  
DO CELESTIAL BODY  
DEFINITION ROU-  
TINE (R58) FOR  
CELESTIAL BODY  
-----

-----  
DO CELESTIAL BODY  
DEFINITION ROUTINE  
(R58) FOR CELES-  
TIAL BODY ACTUALLY  
-----

#1180

<p>ACTUALLY USED</p> <hr/> <p>IS STAR INDICATOR GREATER THAN ZERO?</p> <hr/> <p>.Y            .N</p>	<p>USED.</p> <hr/> <p>IS TECHNIQUE OP- TION CODE = 00002?</p> <hr/> <p>.Y            N.</p>	#1190
<p>DEFINE UNIT LOS VECTOR AS DESCRIBED IN SECTION 5.6.2.2 OF R567</p> <hr/> <p>DO R59 FOR CELESTIAL BODY #2</p> <hr/> <p>DO R58 FOR CELE- STIAL BODY #2 ACTUALLY USED.</p> <hr/> <p>TRANSFORM LOS VEC- TORS IN REFERENCE COORDINATES TO DE- SIRED IMU COOR- DINATES</p> <hr/> <p>IS INITIAL ALIGN FLAG SET?</p> <hr/> <p>.Y            N.</p>	<p>DO R59 FOR CELESTIAL BODY #2</p> <hr/> <p>DO R58 FOR CELE- STIAL BODY #2 ACTUALLY USED.</p> <hr/> <p>IS THIS THE FIRST PASS THROUGH THE ALIGNMENT PROGRAM?</p> <hr/> <p>.N            Y.</p>	#1200  #1210      #1220      #1230

DO SIGHTING DATA  
DISPLAY ROUTINE  
(R54)

.E .E  
.X .X  
.I .I  
.T .T  
" "  
.A .B  
" "

GO TO  
"D"  
BELOW

DO SIGHTING DATA  
DISPLAY ROUTINE  
(R54)

.E E.  
.X X.  
.I I.  
.T T.  
" "  
.B A.  
" "

GO TO  
"D"  
BELOW

#1240

#1250

#1260

COMPUTE DESIRED GYRO  
TORQUING ANGLES.

#1270

IS INITIAL ALIGN  
FLAG SET?

.Y N.

IS THIS THE FIRST  
PASS THROUGH THE  
ALIGNMENT PROGRAM?

.N Y.

#1280

FLASH VERB-NOUN  
TO REQUEST RESPO-  
NSE AND DISPLAY  
GYRO TORQUING

MONITOR DSKY:  
OBSERVE VERB-NOUN  
FLASH TO REQUEST  
RESPONSE AND DIS-

++  
+03  
+EDIT

POSS  
HOLD

SNAP

438

439

ANGLES:  
V06N93  
R1-X GYRO  
R2-Y GYRC  
R3-Z GYRC  
IN DEGREES TO  
NEAREST .001 DEG-  
REE.

WAIT FOR KEYBOARD  
ENTRY

TERMINATE FLASH  
UPON RECEIPT OF  
PROCEED OR RE-  
CYCLE

P R  
R E  
D C  
C Y  
E C  
E L  
D E  
GO TO  
"D"  
BELOW

IS ANY GYRC TORQUING  
ANGLE GREATER THAN

PLAY OF GYRO TOR-  
QUING ANGLES.  
THESE ANGLES WILL  
BE APPLIED TO THE  
IMU UNLESS I RECY-  
CLE. DO I WISH TO  
PERMIT GYRO TOR-  
QUING?

Y N

KEY IN PROCEED

KEY IN REC YCLE,  
V32E

GO TO  
"D"  
BELOW

WAS ANY GYRO TORQU-  
ING ANGLE GREATER

#1290

#1300

#1310

#1320

#1330

5 DEGREES?

.N Y.

-----  
CALCULATE DESIRED  
ICDU/GIMBAL ANG-  
LES TO ALIGN THE  
IMU TO THE DESI-  
RED ORIENTATION  
-----

-----  
IS THE INITIAL  
ALIGN FLAG SET?  
-----

.N Y.

-----  
FLASH VERB-NOUN  
TO REQUEST RE-  
SPONSE AND DIS-  
PLAY THE RESULT-  
ING ICDU GIMB-  
AL ANGLES:  
V06 N22  
R1 - OG  
R2 - IG  
R3 - MG  
-----

-----  
ALL GIMBAL AN-  
GLES IN DEGREES  
TO NEAREST .01  
-----

THAN 5 DEGREES?

.Y .N

-----  
IS THIS THE FIRST  
PASS THROUGH THE  
ALIGNMENT PRO-  
GRAM?  
-----

.Y N.

-----  
MONITOR DSKY:  
OBSERVE VERB-  
NOUN FLASH TO  
REQUEST RESPONSE  
AND DISPLAY OF  
ICDU GIMBAL AN-  
GLES AFTER PRO-  
POSED LM IMU  
ALIGNMENT  
-----

#1340

#1350

#1360

#1370

#1380

HOLD .

SNAP .

440



44

DEGREE

WAIT FOR KEY-  
BOARD ENTRY

TERMINATE FLASH  
UPON RECEIPT OF  
PROCEED

.P  
.R  
.O  
.C  
.E  
.E  
.D

COMMAND ISS TO  
COARSE ALIGN MODE

TURN ON "NO ATT"  
LIGHT

RESET TRACK FLAG.

RESET DRIFT FLAG.

KEY IN PROCEED

OBSERVE "NO ATT"  
LIGHT TO INDICATE  
THAT IMU IS IN  
COARSE ALIGN MODE

#1390

#1400

#1410

#1420

#1430

-----  
• RESET REFSMMAT  
• FLAG.  
-----

-----  
• COARSE ALIGN ISS  
-----

-----  
• (NOTE: IF AT END  
• OF COARSE ALIGN-  
• MENT THE GIMBALS  
• ARE NOT WITHIN 2  
• DEGREES OF THE  
• DESIRED VALUES,  
• THE LGC WILL TURN  
• ON THE PROGRAM  
• ALARM LIGHT AND  
• STORE ALARM CODES  
• 00211 AND 00217).  
-----

-----  
• TERMINATE COARSE  
• ALIGN MODE IN ISS  
-----

-----  
• TURN OFF "NO ATT"  
• LIGHT  
-----

-----  
• SET DRIFT FLAG.  
-----

-----  
• (NOTE: IF AT END  
• OF COARSE ALIGN-  
• MENT THE GIMBALS  
• ARE NOT WITHIN 2  
• DEGREES OF THE  
• DESIRED VALUES,  
• THE LGC WILL TURN  
• ON THE PROGRAM  
• ALARM LIGHT AND  
• STORE ALARM CODES  
• 00211 AND 00217).  
-----

-----  
• OBSERVE TERMINA-  
• TION OF "NO ATT"  
• LIGHT TO INDICATE  
• THAT IMU IS NOW  
• INERTIAL  
-----

#1440

#1450

#1460

#1470

#1480

443

+03  
++

COMPLTE DESIRED  
GYRO TORQUING  
ANGLES.

PULSE GYROS THROUGH  
DESIRED ANGLES TO  
ALIGN IMU.

SET THE REFSMMAT  
FLAG

DEFINE REFSMMAT TO  
BE THE DESIRED IMU  
ORIENTATION.

IS TECHNIQUE OPTION  
CODE = 00000?

.N .Y  
GO TO

IS TECHNIQUE OPTION  
CODE = 00000?

.Y N.  
GO TO

#1490

#1500

#1510

#1520

"D"  
BELOW

"C"  
BELOW

#1530

IS INITIAL ALIGN  
FLAG SET?

WAS THIS THE FIRST  
PASS THROUGH THE  
ALIGNMENT PROGRAM?

.N                    Y.

.Y                    N.

#1540

THE NEXT PASS IS  
THE SECOND PASS.

COMPUTE AND STORE  
PRESENT LM ATTITUDE  
IN MOON FIXED COOR-  
DINATES.

#1550

SET ATTITUDE FLAG.

#1560

"D"  
FROM  
ABOVE

"C"  
FROM ABOVE

#1570

HOLD . FLASH VERB-NCUN TO  
..... REQUEST PLEASE PER-  
SNAP . FORM FINE ALIGNMENT:  
          V5CN25

. MONITOR DSKY:  
OBSERVE VERB-NCUN  
FLASH TO REQUEST  
PLEASE PERFORM FINE

444

R1 - 00014  
R2 - BLANK  
R3 - BLANK

ALIGNMENT

.  
.  
.  
.

#1580

DO I WANT TO TRY THE  
ALIGNMENT AGAIN OR  
CHECK THE FINE  
ALIGNMENT?

.Y .N.

#1590

WAIT FOR KEY BOARD  
ENTRY

KEY IN PROCEED

#1600

DO I WISH TO DETER-  
MINE THE LM LUNAR  
SURFACE POSITION  
VECTOR?  
(NOTE: THIS IS ONLY  
APPLICABLE IF IN  
OPTION #2, AND THIS  
PROGRAM (P57) HAS  
BEEN PREVIOUSLY COM-  
PLETED USING EITHER  
OPTION #1 OR OPTION  
#3.)

#1610

.N .Y.

#1620

KEY IN ENTER

TERMINATE FLASH UPON  
RECEIPT OF PROCEED,  
ENTER, OR TERMINATE.

.E .T .P  
.N .E .R  
.T .R .O  
.E .M .C  
.R .I .E  
. .N .E  
. .A .D  
. .T .  
. .E .  
. . .  
. . .  
. . .

KEY IN TERM-  
INATE, V34 E

#1630

DO FINAL AUTO-  
MATIC REQUEST  
TERMINATE ROUTINE  
(ROO)

EXIT P57

DO FINAL AUTO-  
MATIC REQUEST  
TERMINATE  
ROUTINE (ROO)

EXIT P57

#1640

#1650

IS TECHNIQUE OPTION  
CODE = 00002?

.N Y.  
. .  
. .  
... .  
. .  
GO TO  
"A"  
BELOW .  
. .  
. .

IS TECHNIQUE OPTICN  
CODE = 00002?

.N Y.  
. .  
. .  
... .  
. .  
GO TO  
"A"  
BELOW .  
. .  
. .

#1660

#1670

CALCULATE THE PRES-  
ENT LM LUNAR SURFACE

446

POSITION VECTOR IN REFERENCE COORDINATES FROM THE STORED LUNAR GRAVITY VECTOR, LATEST R-LS MAGNITUDE, AND THE JUST-COMPUTED REFSMMAT

#1680

#1690

#1700

#1710

#1720

HOLD SNAP

FLASH VERB-NOUN TO REQUEST RESPONSE AND DISPLAY STORED LANDING SITE COORDINATES. VO6N89 R1 - LAT R2 - LONG/2 R3 - ALT

MONITOR DSKY: OBSERVE VERB-NOUN FLASH TO REQUEST RESPONSE AND DISPLAY OF COMPUTED LANDING SITE COORDINATES.

LAT-SELENOGRAPHIC LATITUDE OF THE LM LUNAR SURFACE POSITION VECTOR. POLARITY INDICATES NORTH (+) OR SOUTH (-). IN DEGREES TO NEAREST .001 DEGREE.

MONITOR LGC DOWNLINK TELEMETRY OF LAT, LONG/2, AND ALT. COORDINATE EVALUATIONS OF LGC-COMPUTED PARAMETERS WITH THE CREW.

COORDINATE EVALUATION OF THE LGC-COMPUTED PARAMETERS WITH THE GROUND.

LONG/2-SELENOGRAPHIC LONGITUDE (DIVIDED BY TWO) OF THE LM LUNAR SURFACE POSITION

IS THE DISPLAYED DATA ACCEPTABLE?

.Y N.

VECTOR.  
POLARITY INDIC-  
ATES EAST (+),  
OR WEST (-). IN  
DEGREES TO  
NEAREST .001  
DEGREE.

-----  
DO I HAVE BETTER  
DATA FROM ANOTHER  
SOURCE?  
-----

. N                    Y.

#1730

ALT-THE ALTI-  
TUDE OF THE LM  
LUNAR SURFACE  
POSITION VECTOR  
ABOVE THE RAD-  
IUS AT THE MOST  
RECENTLY DEFIN-  
ED LANDING  
SITE. IN NAUT-  
ICAL MILES TO  
NEAREST .01 NM.

#1740

-----  
WAIT FOR KEY-  
BOARD ENTRY

-----  
KEY IN V25E  
AND LOAD THE  
CORRECT CO-  
ORDINATES  
-----

#1750

TERMINATE FLASH  
UPON RECEIPT OF  
PROCEED, TERM-  
INATE, OR NEW  
DATA

-----  
KEY IN TERMINATE,  
V34E  
-----

#1760

-----  
KEY IN PROCEED  
-----

#1770

. P . T NEW  
. R . E DATA.

448



449

.O .R .  
 .C .M .  
 .E .I .  
 .E .N .-----  
 .D .A . STORE  
 . . T . DATA  
 . . E .  
 . . .  
 . . .  
 . . .  
 . . .  
 . . .  
 . . .  
 . . .  
 . . .

-----  
 . DO FINAL AUTO-  
 . Matic REQUEST  
 . TERMINATE ROUTINE  
 . (R00)  
 -----

-----  
 . DO FINAL AUTO-  
 . Matic REQUEST  
 . TERMINATE ROUTINE  
 . (R00)  
 -----

.  
 .  
 .  
 .  
 . . .  
 . EXIT  
 . P57

.  
 .  
 .  
 .  
 . . .  
 . EXIT  
 . P57

-----  
 . CALCULATE (BASED ON  
 . CREW-APPROVED N89)  
 . AND STORE NEW VALUE  
 . OF PRESENT R IN  
 . -LS  
 . MCCN-FIXED COORDI-  
 . NATES IN PLACE OF  
 . PREVIOUS R .  
 . -LS  
 . TRANSFORM R TO  
 . -LS  
 . BASIC REFERENCE  
 . COORDINATES AND

#1780

#1790

#1800

#1810

#1820

STORE FOR THE DOWN-  
LINK IN THE "LM  
STATE VECTOR"  
LOCATION, WITH TIME  
OF TRANSFORMATION.

.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....

"A"  
FROM  
ABOVE

.....  
.....  
.....  
.....  
.....  
.....

EXIT  
P57

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P57



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CHANGE CCNTRCL NCTES

- REV 01 PCR 106,138,234,439,469,489,608
- REV 00(LUM 1A) PCR 696, 698
- REV 01(LUM 1A) PCR 754, 755
- REV 02 EDITORIAL
- REV 03 EDITORIAL

450

## BRAKING PHASE PROGRAM (P63)

REV 03 12/03/69

## PURPOSE:

- (1) TO CALCULATE THE REQUIRED TIME OF DPS IGNITION (TIG) AND OTHER INITIAL CONDITIONS REQUIRED BY THE LGC FOR A PGNCS-CONTROLLED, DPS-EXECUTED, BRAKING PHASE OF THE POWERED LANDING MANEUVER.
- (2) TO PROVIDE OPTION TO FINE ALIGN THE IMU TO AN EXISTING REFSMMAT.
- (3) TO ALIGN THE LM TO THE THRUSTING IGNITION ATTITUDE.
- (4) TO CONTROL THE PGNCS DURING COUNTDOWN, IGNITION, AND THRUSTING OF THE POWERED LANDING MANEUVER UNTIL HI GATE.
- (5) TO INDICATE THAT HI GATE HAS BEEN REACHED (TGO LESS THAN TENDBRAK) BY AUTOMATIC SELECTION OF THE APPROACH PHASE PROGRAM (P64).

## ASSUMPTIONS:

- (1) THE LM IS ON A DESCENT COAST ORBIT (HOHMANN TRANSFER) APPROACHING THE BRAKING IGNITION POINT WHICH IS NOMINALLY 50,000 FT. ABOVE THE LUNAR RADIUS AT THE DESIGNATED LANDING SITE. THE DESCENT COAST ORBIT IS APPROXIMATELY COPLANAR WITH THE CSM ORBITAL PLANE. IF THE DESIGNATED LANDING SITE IS NOT IN THE DESCENT COAST PLANE AT THE NOMINAL TIME OF LANDING THE PLANE CHANGE WILL BE ACCOMPLISHED BY THE POWERED LANDING MANEUVER (BRAKING PROGRAM (P63) AND APPROACH PROGRAM (P64)).
- (2) THE CSM IS IN A NEAR-CIRCULAR ORBIT AROUND THE MOON AT A NOMINAL ALTITUDE OF 60 NAUTICAL MILES. THE CSM IS MAINTAINING A PREFERRED TRACKING ATTITUDE FOR OPTICAL TRACKING OF THE LM.
- (3) THE IMU IS ON AND ALIGNED TO A LANDING SITE ORIENTATION DEFINED FOR THE DESIGNATED LANDING SITE AND THE NOMINAL TIME OF LANDING (T(LAND)), BUT SHOULD BE FINE ALIGNED TO THIS ORIENTATION AS CLOSELY AS POSSIBLE PRIOR TO DPS IGNITION. THE LM HAS NOT YET BEEN ALIGNED TO THE CORRECT ATTITUDE FOR IGNITION FOR THE POWERED LANDING MANEUVER.
- (4) THE LANDING RADAR (LR) WAS ENERGIZED AND CHECKED OUT, AND MADE READY AT LR POSITION #1 PRIOR TO SELECTION OF THIS PROGRAM. RADAR DATA WILL NOT BE INCORPORATED INTO THE LM STATE VECTOR UNTIL THE ASTRONAUT SETS THE LR PERMIT FLAG VIA V57E INDICATING HE IS SATISFIED WITH THE QUALITY OF THE DATA (THE LR PERMIT FLAG IS RESET BY RCC, OR BY EXTENDED VERBS V57 GR V58).
- (5) THE LGC WILL NEITHER DESIGNATE NOR READ THE RENDEZVOUS RADAR (RR) DURING THIS PROGRAM.
- (6) THE LANDING ANALOG DISPLAYS ROUTINE (R10) IS ENABLED AT DPS IGNITION AND IS TERMINATED UPON TERMINATION OF AVERAGE G. THE POWERED FLIGHT DESIGNATE ROUTINE (R29) IS NOT ENABLED DURING THE LUNAR DESCENT.
- (7) THE ENTIRE POWERED LANDING MANEUVER (BRAKING, APPROACH, AND LANDING) WILL BE ACCOMPLISHED USING THE DPS ENGINE.
- (8) THE AIM CONDITIONS FOR THE BRAKING PHASE ARE STORED IN THE LGC.
- (9) THE FOLLOWING PARAMETERS REQUIRED BY THIS PROGRAM HAVE BEEN STORED BY THE LGC SINCE LGC INITIALIZATION BY ERASABLE REGISTER LOAD.
  - (A) THE LM AND CSM STATE VECTORS. THE LGC HAS UPDATED THESE AS REQUIRED. NO FURTHER STATE VECTOR UPDATES FROM ANY EXTERNAL SOURCE OTHER THAN THE LR WILL BE ACCEPTED BY THIS PROGRAM.
  - (B) THE NOMINAL LANDING TIME AT THE DESIGNATED LANDING SITE (T(LAND)) AND THE POSITION (RLS)
- (10) THE DPS IS NOT THROTTLEABLE OVER THE WHOLE RANGE FROM 0 TO MAXIMUM. IT MUST BE OPERATED EITHER AT MAXIMUM THROTTLE OR OVER A SPECIFIC THROTTLE RANGE OF LOWER SETTINGS. THESE THROTTLE SETTINGS ARE SPECIFIED IN SECTION 5.3.4 OF R567 AND ARE TOTAL THROTTLE SETTINGS, I.E.: THE SUM OF THE MANUAL SETTING (WHOSE MINIMUM IS ABOUT 10 PERCENT) AND

THE PGNC'S COMMANDED SETTING.

THIS PROGRAM ASSUMES THE THROTTLE CONTROL TO BE IN "AUTO" (THE DPS RECEIVES THE SUM OF THE MANUAL AND PGNC'S COMMANDED SETTINGS) AND THE MANUAL THROTTLE TO BE SET AT MINIMUM FOR "ZOOMTIME" SECONDS OF THRUSTING, AND THEREAFTER AT A LEVEL LESS THAN THAT REQUIRED BY THE LGC. THE VALUE "ZOOMTIME" IS IN ERASABLE STORAGE, HAVING BEEN LOADED PRIOR TO LAUNCH OR BY P27.

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DUE TO THE REGION OF FORBIDDEN THROTTLING, THRUST COMMAND LOGIC IN CONJUNCTION WITH THE INTERIM TERMINAL CONDITIONS (SEE ASSUMPTION (8)) ASSURE THAT THE COMMANDED THROTTLE REMAINS AT MAXIMUM UNTIL THE GUIDANCE EQUATIONS FIRST REQUIRE IT TO BE WITHIN THE ALLOWABLE THROTTLE RANGE. THEREAFTER IT SHOULD REMAIN WITHIN THE ALLOWABLE THROTTLE RANGE. THIS PRINCIPLE IS DESCRIBED IN MORE DETAIL IN SECTION 5.3.4 OF R567. THE RESULT IS A SMOOTH AND EFFICIENT THRUST ATTITUDE PROFILE THROUGHOUT THE BRAKING PHASE.

FURTHERMORE THE DPS MUST BE STARTED IN THE FOLLOWING SEQUENCE: +X AXIS 2 JET ULLAGE FOR 7.5 SEC; IGNITION AT MINIMUM THROTTLE; ULLAGE OFF 0.5 SECONDS AFTER IGNITION; MINIMUM THRUST UNTIL TIG (AS DEFINED BY R41) + "ZOOMTIME"; AND THEN MAXIMUM THROTTLE. THE THROTTLE SETTING THEN BECOMES CONTROLLED BY THE GUIDANCE EQUATIONS.

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(11) DURING THE POWERED LANDING MANEUVER, THE LGC WILL MONITOR THE PRESENCE OR ABSENCE OF THE "NON-ATTITUDE HOLD" DISCRETE. THIS DISCRETE IS ISSUED TO THE LGC WHEN THE ATTITUDE MODE CONTROL SWITCH IS IN THE AUTO POSITION.

SHOULD THIS DISCRETE APPEAR DURING THE POWERED LANDING MANEUVER, THE LGC ASSUMES THAT IT NO LONGER HAS COMPLETE AUTOMATIC CONTROL OF THE MANEUVER.

THE MONITOR AND THE ASSOCIATED LGC LOGIC IS INCLUDED IN THE LANDING AUTO MODES MONITOR ROUTINE (R13) WHICH WILL BE CALLED BY THIS PROGRAM.

(12) THE X-AXIS OVERRIDE OPTION PROVIDES THE CREW WITH THE ABILITY TO EXERCISE MANUAL CONTROL ABOUT THE LM X AXIS WITH THE ATTITUDE CONTROLLER EVEN THOUGH THE PGNC'S ATTITUDE CONTROL MODE IS AUTO. WHEN THE CONTROLLER IS RETURNED TO DETENT THE PGNC'S DAMPS THE YAW RATE, STORES THE YAW ATTITUDE WHEN THE YAW RATE IS DAMPED, AND THEN MAINTAINS THAT ATTITUDE.

THE X-AXIS OVERRIDE OPTION IS AVAILABLE TO THE CREW (UNTIL THE ESTIMATED ALTITUDE IS BELOW 30,000 FEET), HOWEVER IT SHOULD NOT BE EXERCISED WHEN THE LGC IS SPECIFYING A DESIRED YAW ATTITUDE, I.E.: DURING THE ATTITUDE MANEUVER TO THE THRUSTING ATTITUDE (SEE R60). THE OPTION IS INHIBITED BY THIS PROGRAM FROM MIDWAY IN THE PROGRAM (SEE ASSUMPTION (13) BELOW) TO THE END.

(13) THE LGC SPECIFIES LM ATTITUDE DURING THE POWERED LANDING MANEUVER BASED UPON THE REQUIREMENTS OF THRUST VECTOR CONTROL, LANDING SITE VISIBILITY, AND LR ORIENTATION. AFTER DPS IGNITION, THRUST VECTOR CONTROL IS REQUIRED THROUGH THE REMAINDER OF THIS PROGRAM. THE LANDING SITE BECOMES VISIBLE AT THE BEGINNING OF THE APPROACH PHASE.

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THRUST VECTOR CONTROL DOES NOT CONSTRAIN THE LM ORIENTATION ABOUT THE THRUST AXIS (YAW ATTITUDE). ROTATION ABOUT THE LM Y AND LM Z AXES IS USED TO POINT THE MEASURED THRUST VECTOR ALONG THE DESIRED THRUST VECTOR.

THE FIRST RESTRAINT UPON THE LM YAW ATTITUDE TO OCCUR IS THAT OF LR ORIENTATION. THE LGC WILL NOT ATTEMPT TO USE LR DATA UNTIL THE LGC ESTIMATION OF ALTITUDE IS 30,000 FT.. AUTOMATIC X-AXIS OVERRIDE LOCKOUT (DONE BY R12) AND YAW ATTITUDE SPECIFICATION BY THE LGC WILL NOT OCCUR UNTIL THE LGC ESTIMATED ALTITUDE IS 30,000 FT.. BEFORE THIS TIME, THE ASTRONAUT MUST MANEUVER TO A ROUGHLY-WINDOW-UP YAW ORIENTATION TO PREVENT SUBSEQUENT LOSS OF S-BAND LOCK-ON. THE LGC WILL THEN COMMAND THE VEHICLE TO THE LGC-SPECIFIED YAW ATTITUDE.

SUBSEQUENT TO X-AXIS OVERRIDE LOCKOUT, CONTROL OF THE VEHICLE ABOUT THE LM X AXIS IS GOVERNED BY LR ORIENTATION REQUIREMENTS DURING THIS PROGRAM. THE LANDING SITE BECOMES VISIBLE TO THE COMMAND PILOT IF THE LOOK ANGLE (THE ANGLE BETWEEN THE LM -X AXIS AND THE LOS TO THE LANDING SITE) IS GREATER THAN 25 DEGREES AND THE LOS IS IN OR NEAR THE LM X/Z PLANE.

AT ANY TIME DURING P63, P64 OR P65, THE MAGNITUDE OF THE LOOK ANGLE AND THE ORIENTATION OF THE LOOK ANGLE PLANE (THAT PLANE CONTAINING THE LOS AND THE LM X AXIS) ARE DEFINED BY THE INERTIAL ORIENTATION OF THE LM X AXIS AND THE POSITION OF THE LM WITH RESPECT TO THE LANDING SITE.

(14) THE CREW HAS THE CAPABILITY TO DISPLAY LGC CALCULATED VALUES OF FORWARD VELOCITY, LATERAL VELOCITY, ALTITUDE AND ALTITUDE RATE ON CERTAIN LM METERS DURING THIS PROGRAM. THE CALCULATION OF THESE PARAMETERS IS UNDER THE CONTROL OF THE LANDING ANALOG DISPLAYS ROUTINE (R10) WHICH IS ENABLED AT DPS IGNITION.

(15) THE RATE OF DESCENT (ROD) MODE IS NOT ENABLED DURING THIS PROGRAM (SEE LANDING (ROD) PROGRAM (P66), ASSUMPTION 12 FOR DEFINITION OF ROD MODE).

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(16) AN ABORT FROM THE LUNAR DESCENT MAY BE REQUIRED AT ANY TIME DURING THE DESCENT ORBIT INJECTION, THE DESCENT CCAST, OR THE POWERED DESCENT (P63), (P64), (P65), OR (P66).

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FOR ABORTS AFTER DPS IGNITION FOR THE POWERED LANDING MANEUVER, TIME IS CRITICAL. DURING THIS PERIOD AN ABORT IS NOMINALLY COMMANDED BY PUSHING ONE OF TWO BUTTONS IN THE LM. THE ABORT MAY BE COMMANDED TO USE THE DESCENT STAGE (ABORT BUTTN) OR THE ASCENT STAGE (ABORT STAGE BUTTN). IF THE DESCENT STAGE IS SELECTED, AND THE DPS PROPELLANT APPROACHES EXHAUSTION, CONTROL MUST BE SWITCHED TO THE ASCENT STAGE BY THE CREW BY ASCENT STAGE SELECTION (ABORT STAGE BUTTN).

DURING THE POWERED LANDING MANEUVER THE LGC WILL CONTINUOUSLY MONITOR THE ABORT AND ABORT STAGE DISCRETES, AND UPON RECEIPT OF EITHER WILL TERMINATE THE PROGRAM IN PROCESS AND CALL THE APPROPRIATE ABORT PROGRAM (DPS ABORT PROGRAM (P70) OR APS ABORT PROGRAM (P71)). BOTH ABORT PROGRAMS WILL GUIDE THE LM TO AN ORBIT AS SPECIFIED IN SECTION 5.4.3 OF R567.

THE MONITOR OF THE ABORT AND ABORT STAGE PUSHBUTTONS IS CONTROLLED BY THE ABORT DISCRETES MONITOR ROUTINE (R11) WHICH WILL BE ENABLED BY THIS PROGRAM.

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(17) IF A THRUSTING MANEUVER IS PERFORMED WITH THE GUIDANCE CONTROL SWITCH IN PGNS AND THE MODE CONTROL SWITCH IN AUTO, THE PGNS WILL CONTROL THE TOTAL VEHICLE ATTITUDE AND GENERATE EITHER MODE I OR MODE II ATTITUDE ERRORS AND VEHICLE ATTITUDE RATES (SEE ASSUMPTION (19)) FOR DISPLAY ON THE FDAI. THE CREW MAY EXERCISE CONTROL AROUND THE YAW AXIS ONLY WITH THE ACA (X-AXIS OVERRIDE) IF THE X-AXIS OVERRIDE CAPABILITY IS PERMITTED BY THE PROGRAM IN PROCESS. THIS MANUAL CONTROL WILL BE IN RATE COMMAND/ATTITUDE HOLD MODE.

IF A THRUSTING MANEUVER IS PERFORMED WITH THE GUIDANCE CONTROL SWITCH IN PGNS AND THE MODE CONTROL SWITCH IN ATTITUDE HOLD THE PGNS WILL HOLD THE VEHICLE ATTITUDE AND WILL GENERATE EITHER MODE I OR MODE II ATTITUDE ERRORS FOR DISPLAY ON THE FDAI. THE CREW MAY EXERCISE MANUAL ATTITUDE CONTROL ABOUT ALL VEHICLE AXES WITH THE ACA IN EITHER THE RATE COMMAND OR MINIMUM IMPULSE MODE DEPENDING UPON THE STATUS OF THE PULSES FLAG. THIS FLAG IS RESET BY P12, P40, P41, P42, P63, P70, P71 AND R40 AT MAIN ENGINE IGNITION. IT IS STRONGLY RECOMMENDED THAT POWERED FLIGHT NOT BE ATTEMPTED IN THE MINIMUM IMPULSE MODE. THE PULSES FLAG IS ALSO SET OR RESET BY EXTENDED VERBS 76 (MINIMUM IMPULSE) AND 77 (RATE COMMAND) RESPECTIVELY. DURING A THRUSTING MANEUVER IN THE PGNS/ATTITUDE HOLD MODE THE ASTRONAUT IS RESPONSIBLE FOR MAINTAINING SMALL ENOUGH ATTITUDE ERRORS TO ACHIEVE GUIDANCE OBJECTIVES.

(18) CONTROL OF THE LM DPS, RCS AND APS IS TRANSFERRED FROM THE PGNS TO THE ABORT GUIDANCE SYSTEM (AGS) BY PLEADING THE GUID CONT SWITCH FROM PGNS TO AGS.

THE AGS WILL BE CAPABLE OF TAKING OVER CONTROL OF THE LM DURING ANY PORTION OF THE LUNAR DESCENT OR ASCENT OR DURING EITHER OF THE ABORT PROGRAMS (P70 OR P71). THE AGS WILL GUIDE THE LM TO A SAFE ORBIT.

THE AGS MAY BE INITIALIZED BY THE LGC AT ANY TIME BY MANUAL SELECTION OF THE AGS INITIALIZATION ROUTINE (R471).

IN THE EVENT THAT THE GUIDANCE CONTROL SWITCH IS CHANGED FROM PGNS TO AGS DURING A THRUSTING MANEUVER, THE LGC WILL CONTINUE COMPUTATION OF POSITION AND VELOCITY, THE DESIRED THRUST VECTOR, AND THE DESIRED ATTITUDE ERRORS. HOWEVER THE PGNS WILL NOT BE RESPONSIBLE IF REGISTER OVERFLOWS OCCUR WITHIN THE LGC.

(19) THE PGNS CAN GENERATE TWO TYPES OF ATTITUDE ERRORS FOR DISPLAY ON THE FDAI;

MODE I - SELECTED BY EXTENDED VERB 61. AUTCPILCT FOLLOWING ERRORS USED AS A MONITOR OF THE DAP'S ABILITY TO TRACK AUTOMATIC STEERING COMMANDS.

MODE II - SELECTED BY EXTENDED VERB 62. TOTAL ATTITUDE ERRORS USED TO ASSIST CREW IN MANUALLY MANEUVERING THE VEHICLE.

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PGNS - DERIVED VEHICLE ATTITUDE RATES MAY ALSO BE DISPLAYED VIA SELECTION BY EXTENDED VERB 60. MODE II ATTITUDE ERROR DISPLAYS ARE AUTOMATICALLY SELECTED AT THE BEGINNING OF R60. WITH THE EXCEPTIONS INDICATED IN ASSUMPTION (17) ABOVE, DISPLAY SELECTION IS ALWAYS BASED UPON THE LAST ENTRY MADE IN THE DSKY. FOR A MORE DETAILED DESCRIPTION OF THESE DISPLAYS REFER TO SECTION 3 OF R567, PARA. 3.2.6

(20) THE EVENT TIMER WAS SET PRIOR TO SELECTION OF THIS PROGRAM TO COUNT TO ZERO AT T BRAK BASED ON A TIME FROM IGNITION PROVIDED BY THE GROUND.

(21) THE LOAD CAP DATA ROUTINE (R03) HAS BEEN PERFORMED PRIOR TO SELECTION OF THIS PROGRAM. AT THAT TIME THE DPS ENGINE GIMBAL SHOULD HAVE BEEN DRIVEN TO THE CORRECT TRIM POSITION.

(22) DURING DPS BURNS ONLY, THE PITCH-ROLL RCS JET AUTOPILOT (U AND V JETS) MAY BE DISABLED (V65) OR ENABLED (V75) BY EXTENDED VERB AS SHOWN. THIS CAPABILITY IS INTENDED TO BE USED TO PREVENT LM AND DESCENT STAGE THERMAL CONSTRAINT VIOLATIONS DURING CSM-DOCKED DPS BURNS (P40). THE CAPABILITY EXISTS DURING P63 AND P70 ALSO. PERFORMANCE OF FRESH START (V36E) WILL ALWAYS ENABLE THE PITCH-ROLL JETS.

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(23) THE ASTRONAUT MAY MONITOR THE FOLLOWING ADDITIONAL PARAMETERS DURING THIS PROGRAM (AFTER COMPLETION OF THE IGNITION ALGORITHM) BY KEYING IN V57E (SEE LOGIC DESCRIPTION OF V57);

- (A) V06 N68
- R1-RANGE
- R2-TG
- R3-DELTA H

RANGE - SLANT RANGE FROM THE LM TO THE DESIGNATED LANDING SITE. IN NAUTICAL MILES TO NEAREST .1 NM.

TG - THE ESTIMATED TIME OF FLIGHT FROM THE PRESENT TIME TO THE ACCOMPLISHMENT OF THE CURRENT AIM CONDITIONS. IN MINS AND SECS TO NEAREST SEC. MAX READING IS 59859. SIGN IS -.

DELTA H - THE PRESENT LR INDICATED ALTITUDE MINUS THE LGC CALCULATED ALTITUDE OF THE LM ABOVE THE LUNAR RADIUS AT THE DESIGNATED LANDING SITE. IN FEET TO THE NEAREST FOOT.

(NOTE: DELTA H IS INITIALLY SET TO 99999 WHERE IT WILL REMAIN UNTIL R12 CALCULATES A VALUE BASED ON LR DATA)

(24) LGC AND CREW PROCEDURES IN CASES OF LGC-ASSUMED THRUST FAILURE ARE DEFINED BY THE OPS/APS THRUST FAIL ROUTINE (R40). THIS ROUTINE IS ENABLED AT OPS IGNITION BY THIS PROGRAM.

(25) THIS PROGRAM IS SELECTED BY THE ASTRONAUT BY DSKY ENTRY. IT SHOULD BE SELECTED AT LEAST 20 MINUTES BEFORE THE NOMINAL TIME OF IGNITION FOR THE POWERED LANDING MANEUVER (T BRAK).

(26) IT IS NORMALLY REQUIRED THAT THE ISS BE ON FOR A MINIMUM OF 15 MINUTES PRIOR TO A THRUSTING MANEUVER.

(27) ENGINE IGNITION MAY BE SLIPPED BEYOND THE ESTABLISHED TIG IF DESIRED BY THE CREW OR IF STATE VECTOR INTEGRATION CANNOT BE COMPLETED IN TIME. FOR A SUCCESSFUL LANDING, NO SLIP SHOULD BE PERMITTED.

(28) TWO ALARM CONDITIONS MAY BE ORIGINATED BY THE PGNC'S POWERED LANDING EQUATIONS:

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(A) IF SUBROUTINE ROOTPSRS IN THE RG/VG CALCULATION FAILS TO CONVERGE IN 8 PASSES THE LGC WILL TURN ON THE PROGRAM ALARM LIGHT, STORE PROGRAM ALARM 1406, STOP ALL VEHICLE ATTITUDE RATES, AND CONTINUE. THIS ALARM COULD ONLY OCCUR IN P63 OR P64. (NOTE: IF THIS CONDITION OCCURS BEFORE IGNITION DURING THE IGNITION ALGORITHM, THE RESULT WILL BE A P0000 ALARM, 21406).

(B) IF AN OVERFLOW OCCURS ANYWHERE IN THE LANDING EQUATIONS THE LGC WILL TURN ON THE PROGRAM ALARM LIGHT, STORE ALARM CODE 1410, STOP ALL VEHICLE ATTITUDE RATES AND CONTINUE. THIS ALARM COULD ONLY OCCUR IN P63, P64, P65.

(29) THIS PROGRAM ALLOWS MANUAL CONTROL OF LM ATTITUDE AND THE SELECTION OF P66. DURING P63 (AND P64 AND P65) THE ASTRONAUT CAN DISPLAY THE PGNC'S TOTAL GUIDANCE ERROR ON THE FDAI ERROR NEEDLES (ATTITUDE MON SWITCH IN PGNC'S) BY HAVING KEYED IN V62 THRU THE DSKY. HE CAN THEN STEER OUT THE PGNC'S P63 ATTITUDE ERRORS WITH THE AGS MANUALLY (GUID CNT IN AGS AND AGS MODE CONTROL IN ATT HOLD); OR WITH THE PGNC'S MANUALLY (GUID CNT IN PGNC'S AND PGNC'S MODE CONTROL IN ATT HGLD) OR AUTOMATICALLY (PGNC'S MODE CONTROL IN AUTO). THUS THERE ARE THREE ATTITUDE CONTRL SUBMODES IN P63 (AND P64 AND P65): AGS MANUAL; PGNC'S MANUAL; OR PGNC'S AUTO. A CAUTIONARY NOTE: IF THE ASTRONAUT HITS THE ROD (RATE-OF-DESCENT) SWITCH WHILE HE IS IN PGNC'S ATT HOLD, THE LGC WILL IRREVOCABLY TRANSFER HIM OUT OF THE AUTO GUIDANCE PROGRAM MODES INTO THE ROD PROGRAM MODE, P66.

(30) THE ASTRONAUT MAY MONITOR THE FOLLOWING PARAMETERS BY KEYING IN V16 N92E:

- (A) V16 N92
- R1- THRCMD
- R2- HCOT
- R3- H

THRCMD- THE PERCENT THROTTLE DESIRED BY THE LGC, BASED ON THE OPS RATED THRUST OF 10,500 POUNDS. IN PERCENT

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+03  
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TO NEAREST PERCENT. (NOTE: IN P63 MORE THRUST IS DESIRED THAN CAN BE DELIVERED BY THE DPS; THEREFORE, R1 MAY SHOW MORE THAN 100 PERCENT (WHILE THROTTLE IS AT 100 PERCENT DELIVERED). AT THROTTLE RECOVERY (THROTTLE DOWN) R1 WILL DISPLAY +00055; AT HALF-THROTTLE, R1 WILL DISPLAY +00050).

HGDT - THE PRESENT RATE OF CHANGE OF ALTITUDE (H). IN FPS TO NEAREST .1 FPS.

H - THE PRESENT ALTITUDE OF THE LM ABOVE THE LUNAR RADIUS AT THE INITIALLY DESIGNATED LANDING SITE. IN FEET TO NEAREST FOOT.

PROG  
CONT

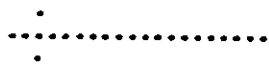
LGC

GROUND

CREW

.CREW  
.PROGRAM  
.SELECTION  
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START BRAKING PHASE  
PROGRAM (P63)  
DISPLAY P63



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KEY IN BRAKING PHASE  
PROGRAM (P63)  
V37E 63E  
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#10

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MONITOR DSKY:  
OBSERVE DISPLAY OF  
P63  
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#20

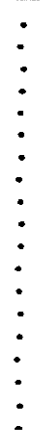
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DO IMU STATUS  
CHECK ROUTINE (R02)



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DO IMU STATUS  
CHECK ROUTINE (R02)  
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#30

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SET CPS DELTA V  
THRESHOLD FOR USE BY



R40

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SET DELTA V COUNTER  
= 4 FOR USE BY R40  
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#40

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REMOVE RR TRACK  
ENABLE DISCRETE FROM  
THE RR.  
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#50

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RE SET NC THROTTLE  
FLAG  
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#60

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RE SET REDESIGNATION  
FLAG  
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RE SET LR BYPASS FLAG  
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#70

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SET MUNFLAG  
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#80

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RE SET P25 FLAG  
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RE SET RENDEZVOUS  
FLAG  
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#90

456



CALL IGNITION ALGORITHM TO DEFINE NOMINAL TIME OF IGNITION (TIG) FOR THE POWERED LANDING MANEUVER, TIME TO GO (TG) FROM DPS FULL THRUST (NOMINAL TIG + "ZOOMTIME" SEC) TO THE AIM CONDITIONS (HI GATE), AND THE THRUST VECTOR ALIGNMENT AT TIG. (REFER SECTION 5.3.4 OF R567) (NOTE: IF THE IGNITION ALGORITHM DOES NOT CONVERGE, A PROGRAM ALARM (01412) WILL RESULT.)

.GOOD ALARM.  
.EXIT EXIT.

TURN ON PROGRAM ALARM LIGHT AND STORE ALARM CODE 01412

N69 PROVIDES THREE-COMPONENT CORRECTIONS TO THE LANDING SITE VECTOR IN STABLE MEMBER COORDINATES. IF THE NCUN IS LOADED BEFORE THE IGNITION ALGORITHM, THE CHANGE WILL BE INCORPORATED IN THE IGNITION ALGORITHM, THIS INFLUENCING LIGHT-UP TIME; IF THE NCUN IS LOADED BETWEEN THE IGNITION ALGORITHM AND THE START OF GUIDANCE, THE CORRECTION WILL BE INCORPORATED AT THE START OF GUIDANCE; IF THE NCUN IS LOADED AFTER THE START OF GUIDANCE (AT THROTTLE-UP), THE CORRECTION WILL BE INCORPORATED IMMEDIATELY. (NOTE: SINCE RLS IS NOT CHANGED, RESELECTION OF P63 WILL DESTROY ANY CHANGES MADE USING THIS TECHNIQUE.)

DOES PROGRAM ALARM LIGHT INDICATE PROGRAM ABNORMALITY?

.Y N.

#100

#110

#120

#130

#140

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 STORE THE DESIRED  
 ATTITUDE SPECIFI-  
 CATION FOR USE  
 BY THE ATTITUDE  
 MANEUVER ROUTINE  
 (R6C).  
 THE FINAL ATTITUDE  
 WILL BE COMPUTED TO  
 POINT THE LM +X AXIS  
 IN THE INITIAL  
 THRUST DIRECTION.  
 HOWEVER, IN ORDER TO  
 CONSERVE RCS FUEL  
 AND NOT CONSTRAIN  
 THE NON-CRITICAL  
 ATTITUDE ABOUT THE  
 THRUST VECTOR, WINGS  
 MAY NOT BE LEVEL  
 IN THE COMPUTED  
 FINAL ATTITUDE.  
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 KEY IN V05N09  
 AND IDENTIFY  
 ALARM CODE. CODE  
 01412 INDICATES  
 THAT THE IGNI-  
 TION ALGORITHM  
 WILL NOT CON-  
 VERGE. CREW MUST  
 RESPOND WITH  
 V96E OR NEW PRO-  
 GRAM SELECTION  
 (V37EXXE). CON-  
 SULT BACKUP PRO-  
 CEDURES.  
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#150

#160

#170

HOLD . . . FLASH VERB-NOUN TO  
 . . . . . REQUEST RESPONSE AND  
 MGN . . . DISPLAY MANEUVER  
 . . . . . PARAMETERS COMPUTED  
 . . . . . FOR IGNITION TIME:  
 . . . . . V06N61  
 . . . . . R1-TG  
 . . . . . R2-TFI  
 . . . . . R3-CROSSRANGE

-----  
 MONITOR DSKY:  
 OBSERVE VERB-  
 NOUN FLASH TO  
 REQUEST RESPONSE  
 AND DISPLAY OF  
 TG, TFI, AND CROSS-  
 RANGE.  
 -----

#180

TG-THE ESTIMATED

TIME OF FLIGHT TO  
THE ACCOMPLISHMENT  
OF THE AIM CONDI-  
TIONS (HI GATE). IN  
MINS AND SECS TO  
NEAREST SEC. MAX  
READING IS 59859.

-----  
RESET EVENT TIMER  
WITH TFI.  
-----

#190

SIGN -.  
THIS VALUE WILL INI-  
TIALY BE THE TIME  
FROM FULL THRUST TO  
HI GATE, AND WILL  
REMAIN UNCHANGED  
UNTIL FULL THRUST  
IS COMMANDED.

#200

TFI-TIME FROM  
NOMINAL OPS IGNITION  
(TIG). IN MINS AND  
SECS TO  
NEAREST SEC. MAX  
READING IS 59859.  
SIGN IS - BEFORE  
NOMINAL TIG, +  
THEREAFTER.

#210

CROSSRANGE-  
THE OUT-OF-PLANE  
DISTANCE BETWEEN THE  
INITIAL LM ORBITAL  
PLANE AND THE PRE-  
SENTLY DESIGNATED  
LANDING SITE. POLAR-  
ITY INDICATES THE  
DESIGNATED SITE  
IS NORTH (+)  
OR SOUTH (-) OF THE  
ORBITAL PLANE. IN  
NAUTICAL MILES TO  
THE NEAREST .1 NM.

#220

-----  
WAIT FOR KEY BOARD  
ENTRY

..... KEY IN PROCEED  
-----

#230

TERMINATE FLASH UPON  
RECEIPT OF PROCEED.

#240

HOLD  
SNAP

FLASH VERB-NOUN TO  
REQUEST PLEASE PER-  
FORM IMU FINE ALIGN-  
MENT:  
V50 N25  
R1-00014  
R2-BLANK  
R3-BLANK

MONITOR DSKY:  
OBSERVE VERB-NOUN  
FLASH TO REQUEST  
PLEASE PERFORM IMU  
FINE ALIGNMENT.

#250

DO I WISH TO BYPASS  
THE ALIGNMENT?

#260

.N .Y.

WAIT FOR KEYBOARD  
ENTRY

KEY IN PROCEED

TERMINATE FLASH UPON  
RECEIPT OF PROCEED  
OR ENTER

KEY IN  
ENTER

#270

.ENTER .PROCEED

SELECT PRESENT  
REFSMAT (LAND-  
ING SITE OR-  
IENTATION DE-  
FINED FOR THE

#280

460

DESIGNATED LAND-  
ING SITE AND THE  
NOMINAL TIME OF  
LANDING(T(LAND))  
AS FINAL DESIRED  
IML ORIENTATION.

DO INFLIGHT FINE  
ALIGN ROUTINE  
(R51)

DO INFLIGHT FINE  
ALIGN ROUTINE  
(R51)

(NOTE: THERE ARE  
A LIMITED NUMBER  
OF STARS WHICH  
MAY BE USED AT  
THIS TIME WHEN  
THE FOLLOWING  
CONSTRAINTS ARE  
CONSIDERED:

(A) THE SUN  
ANGLE OF INCI-  
DENCE (FROM  
SUN/MOON LINE  
TO LUNAR SUR-  
FACE) BELOW  
THIS POINT IN  
THE TRAJECTORY  
IS NEARLY 90  
DEGREES.

(B) THE EDGE  
OF THE AOT  
FIELD OF VIEW  
MUST BE AT  
LEAST 15 DEG-  
REES FROM THE  
SUNLIT SURFACE  
OF THE MOON TO  
ELIMINATE  
LIGHT REFLEC-  
TIONS FOR SAT-  
ISFACTORY STAR

#290

#300

#310

#320

#330

SIGHTING.

(C) THE MOON  
SUBTENDS AN  
ANGLE GREATER  
THAN 140 DEG  
AT THE PRESENT  
ALTITUDE OF  
THE LM.

#340

(D) THE EARTH  
SUBTENDS AN  
ANGLE OF ABOUT  
2 DEG AT THE  
PRESENT RANGE  
OF THE LM.

(E) THE SUN  
ANGLE OF INCI-  
DENCE (FROM  
SUN/AOT LINE  
TO EXTERNAL  
AOT PRISM  
FACE) UPON  
THE AOT MUST  
BE LESS THAN  
0 DEGREES  
UNLESS THE AOT  
IS SHADED BY  
THE LM STRUCT-  
URE.

#350

#360

THE ABOVE CONS-  
TRAINTS, COUPLED  
WITH THE DESIRA-  
BILITY OF ALIGN-  
ING THE IMU AS  
SHORTLY BEFORE  
DPS IGNITION AS  
FEASIBLE, RESULT  
IN A LIMITED NUM-  
BER OF ACCEPTABLE  
STARS. IT IS  
ASSUMED THAT THE  
CREW HAVE THE  
IDENTIFICATION OF  
TWO OR MORE OF

#370

462

THESE STARS. THE  
 IDENTITY OF TWO  
 OF THESE STARS  
 MAY HAVE BEEN  
 LOADED INTO THE  
 LGC PRIOR TO  
 LAUNCH BY P27,  
 OR MAY BE  
 LOADED DURING THE  
 AUTO OPTICS POSI-  
 TIONING ROUTINE  
 (R52) (CALLED BY  
 THE FINE ALIGN  
 ROUTINE (R51)),  
 OR DURING THE LGC  
 UPDATE PROGRAM  
 (P27).

#380

#390

#400

-----  
 COMMAND ZERO ATTITUDE ERRORS  
 -----

-----  
 SET 1 DEGREE DEAD-  
 BAND.  
 -----

#410

#420

-----  
 DO ATTITUDE MANEUVER  
 ROUTINE (R60)  
 (NOTE: THE 3-AXIS  
 FLAG WAS ASSUMED TO  
 BE RESET BY RCC AND

-----  
 DO ATTITUDE MANEUVER  
 ROUTINE (R60)  
 -----

WILL NOT BE RESET  
AGAIN AT THIS TIME  
FOR THIS MANEUVER).

#430

IS THE LANDING RADAR  
POSITION #1 DISCRETE  
PRESENT?

#440

.Y .N

POSS  
HOLD .  
.....  
SNAP .

FLASH VERB-NCUN  
TO REQUEST  
PLEASE PERFORM  
LR DESCENT POS-  
ITION SELEC-  
TION:  
V50N25  
R1-00500  
R2-BLANK  
R3-BLANK

MONITOR DSKY:  
DOES VERB-NCUN  
FLASH TO REQUEST  
PLEASE PERFORM LR  
DESCENT POSITCN  
SELECTION?

#450

.Y .N

HAS LR BEEN  
MANUALLY COMMAN-  
DED TO DESCENT  
POSITION?

#460

.N .Y

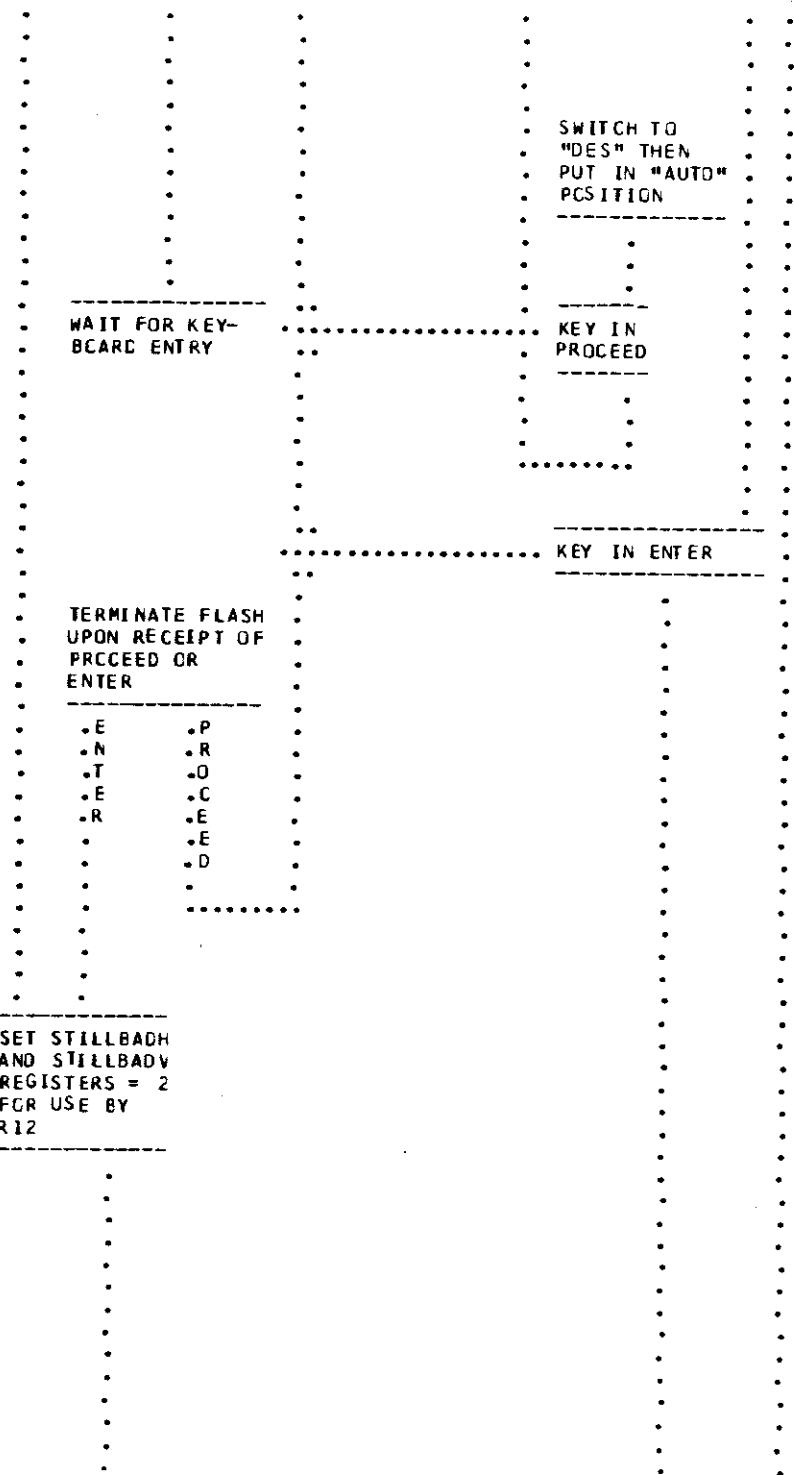
MOMENTARILY  
PUT LDG ANT

#470

464



465



#480

#490

#500

#510

#520

-----  
SET L, M, R,  
AND S COUNT-  
ERS = C FOR  
USE BY R12  
-----

#530

-----  
HAVE PGNS CONTROL  
AND AUTO ATTITUDE  
CONTROL MODES BEEN  
SELECTED?  
-----

#540

.Y N.

#550

-----  
IS THE APS FLAG  
SET?  
-----

.Y N.

#560

-----  
HAS THE AUTO  
THROTTLE MODE  
BEEN SELECTED?  
-----

.Y N.

#570

POSS  
HOLD .  
-----  
SNAP .

-----  
FLASH VERB-  
NOUN TO RE-  
QUEST PLEASE  
PERFORM PGNS  
-----

-----  
MONITOR DSKY:  
DOES VERB-NOUN  
FLASH TO REQUEST  
PLEASE PERFORM  
-----

466

467

CONTROL, AUTO  
ATTITUDE CON-  
TROL, AND AUTO  
THROTTLE MODE  
SELECTION:  
V50 N25  
R1-00203  
R2-BLANK  
R3-BLANK

PGNS CONTROL, AUTO  
ATTITUDE CONTROL,  
AND AUTO THROTTLE  
MODE SELECTION?

#580

.Y N.

HAVE REQUESTED  
MODES BEEN SELE-  
CTED?

#590

.N .Y

DO I WISH TO  
HAVE THESE  
MODES SELECTED  
DURING THE  
THRUSTING  
MANEUVER?

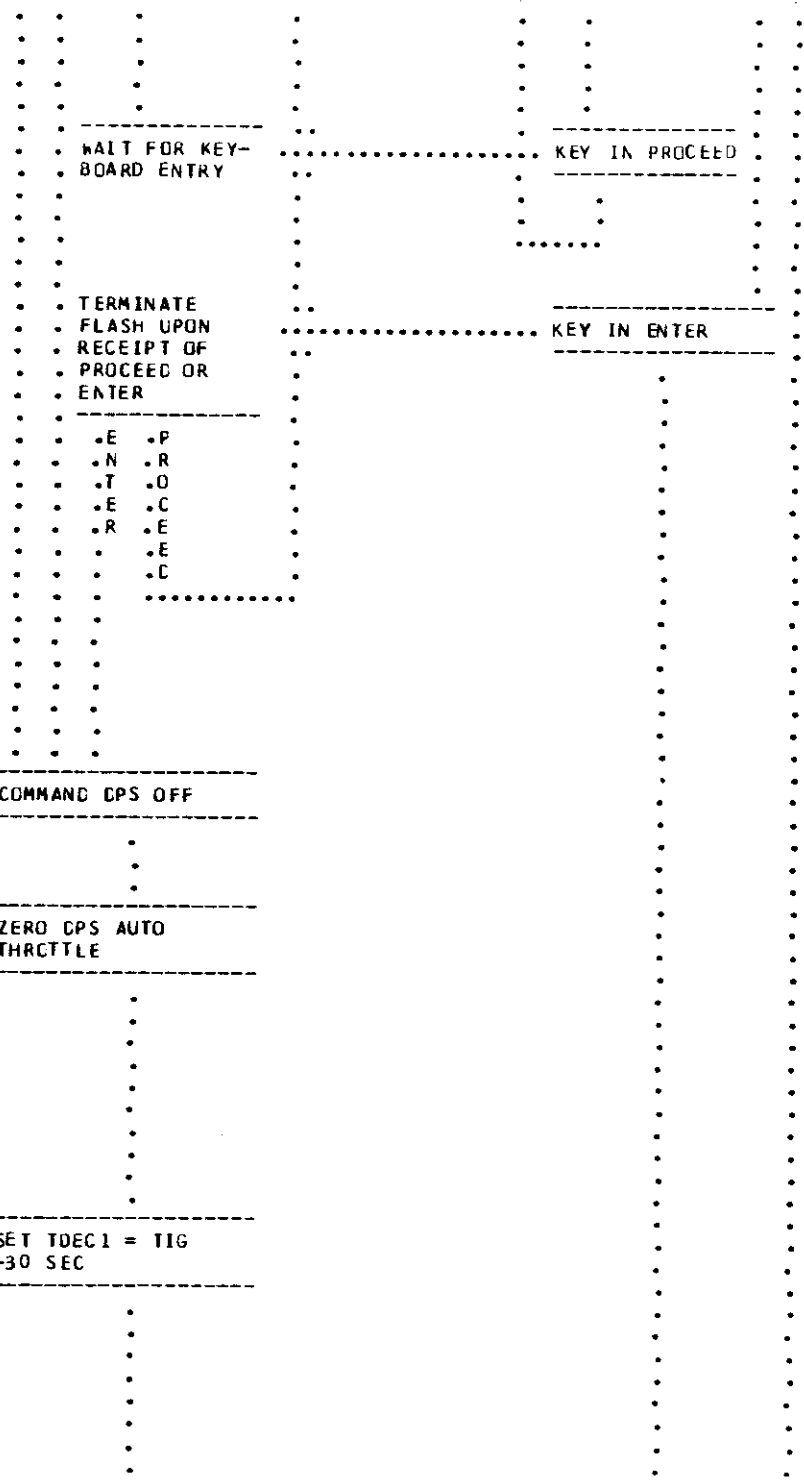
#600

.Y .N

SET GUIDANCE  
CONTROL SWITCH  
TO PGNS, ATT-  
ITUDE CONTROL  
SWITCH TO  
AUTO, AND  
THROTTLE  
SWITCH TO AUTO

#610

#620



#630

#640

#650

#660

#670

#680

468

460

++  
+03  
+EDIT  
++

-----  
INTEGRATE CSM STATE  
VECTOR TO TDEC1  
-----

-----  
DO STATE VECTOR IN-  
TEGRATION (MIDICAVE)  
ROUTINE (R41)  
(NOTE: ENTER R41 AT  
"A")  
-----

.NC            TIG.  
.TIG           SLIP.  
.SLIP           .  
.               .  
.               .  
.               .

-----  
. (NOTE: R41 WILL  
. DEFINE TIG TO BE  
. THE TIME TO WHICH  
. R41 DID INTEGRATE  
. THE LM STATE  
. VECTOR PLUS 30  
. SECCNS.)  
-----

-----  
CALL BLANKING OF  
DSKY AT TIG-35  
SEC. (SEE "A"  
BELOW)  
-----

TEMP  
HOLD  
MON

-----  
DISPLAY ON DSKY:  
V06 N62  
R1 - VI  
R2 - TFI  
-----

-----  
DO STATE VECTOR IN-  
TEGRATION (MIDTOAVE)  
ROUTINE (R41).  
OBSERVE THAT THE  
COMPUTER ACTIVITY  
LIGHT IS ON UNTIL  
COMPLETION OF R41  
-----

#690

#700

#710

#720

#730

-----  
MONITOR DSKY:  
OBSERVE DISPLAY OF  
VI, TFI, AND DELTA  
VM.  
-----

R3 - DELTA VM

VI - MAGNITUDE OF LM  
INERTIAL VELOCITY  
WITH RESPECT TO THE  
REFERENCE COORDINATE  
SYSTEM. IN FPS TO  
NEAREST .1 FPS.  
(NOTE: THIS DISPLAY  
(R1) REMAINS CON-  
STANT AT THE VALUE  
APPROPRIATE TO AVER-  
AGE-G INITIATION,  
UNTIL TIG-30 THE  
VALUE IS AN EXTRA-  
POLATED VALUE GOOD  
AT TIG-30.)

TFI - SEE DEFINITION  
ABOVE

DELTA VM - MEASURED  
DELTA V MAGNITUDE.  
IN FPS TO NEAREST  
.1 FPS. THIS DIS-  
PLAY WILL BE 00000  
UNTIL TIG-30 SEC AND  
THEN SHOULD CHANGE  
ONLY DUE TO PIPA  
BIAS UNTIL ULLAGE IS  
STARTED.

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.  
EXIT  
(NOTE: THIS IS  
NOT A P63 EXIT.  
SEE "A" BELOW.)

(NOTE: IF TIG HAS  
BEEN SLIPPED BY R41,  
THE TFI DISPLAY (R2)  
AT THIS TIME WILL BE  
REFERRED TO THE NEW  
TIG.)

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UPDATE EVENT TIMER  
IF DESIRED.  
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-----  
VERIFY/SET THRUST/  
TRANSLATION CONTROL-  
LER TO MINIMUM  
THRUST POSITION.  
-----

#740

#750

#760

#770

#70

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-----  
ARM DPS. (AUTO  
THROTTLE SIGNAL IS  
ENABLED TO DPS AND  
THRUST INDICATOR).  
-----

#780

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-----  
CHECK THRUST INDICA-  
TOR (RIGHT SIDE) TO  
ENSURE AUTO THROTTLE  
COMMAND IS ZEROED  
TO PERCENT INDICA-  
TION).  
-----

#790

.Y .N

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-----  
. GO TO  
. BACKUP  
. PROCED-  
. URES.  
-----

#800

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-----  
CHECK STATUS OF C/W  
LAMPS  
-----

#810

"A"  
FROM  
ABOVE

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#820

-----  
BLANK THE DSKY DIS-  
PLAY (V, N, R1, R2  
AND R3).  
-----

.....  
MONITOR DSKY:  
AT TFI = -00B35  
OBSERVE DSKY DISPLAY  
TO GO BLANK FOR 5  
SECONDS.  
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#830

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-----  
WAIT UNTIL TIG -30  
SEC.  
-----  
.....

#840

-----  
RETURN VC6N62  
DISPLAYS  
-----  
.....

.....  
-----  
MONITOR DSKY:  
AT TFI = -00B29  
OBSERVE RETURN OF  
V06N62 DISPLAYS TO  
INDICATE THAT  
AVERAGE G INTEGRA-  
TION HAS STARTED.  
-----  
.....

#850

-----  
START AVERAGE G  
INTEGRATION (NOTE:  
THE R10/R11/R12  
SERVICE ROUTINE  
(RCS) AND THE DE-  
SCENT STATE VECTOR  
UPDATE ROUTINE (R12)  
WILL BE CALLED ONCE  
EVERY 2 SECONDS BY  
AVERAGE G DURING  
P63,P64,P65 AND  
P66. HOWEVER THE  
OPERATION OF R10  
AND R11 IS NOT  
ENABLED UNTIL  
IGNITION.  
-----  
.....

#860

++  
+03  
+285  
++

#870

#880

472





CALL VERB 99 DISPLAY  
(SEE "B" BELOW)

#940

WAIT UNTIL TIG - 0

#950

SET IGNITION FLAG

#960

IS ASTRONAUT FLAG  
SET?

.Y	N.
.	.
.	.
...	...
.	.
GO TO	EXIT
"C"	(NOTE: THIS
BELOW	IS NOT A
	P63 EXIT.
	REFER
	DISPLAY
	RESPONSE
	AT "B"
	BELOW).

#970

"B"  
FROM  
ABOVE

"F"  
FROM R40

#980

474

475

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#990

HOLD .  
.....  
MON .  
CHANGE VERB BUT MA-  
INTAIN PRESENT NCUN  
AND DISPLAY IN R1,  
R2, AND R3, FLASH  
VERB-NCUN TO REQUEST  
PLEASE PERFORM ENG-  
INE ON ENABLE:  
V59N62

-----  
MONITOR DSKY:  
AT TFI = -00805  
OBSERVE VERB-NOUN  
FLASH TO REQUEST  
PLEASE PERFORM  
ENGINE ON ENABLE  
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#1000

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#1010

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MONITOR DSKY:  
WAIT FOR INCREASE IN  
DELTA VM INDICATING  
SUFFICIENT ULLAGE.  
REQUIRED ULLAGE  
DELTA V IS A  
FUNCTION OF VEHICLE  
WEIGHT.  
-----

#1020

-----  
WAIT FOR KEYBOARD  
ENTRY

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-----  
SHALL I PERMIT  
IGNITION?  
-----

#1030

.N .Y

-----  
KEY IN PROCEED  
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TERMINATE FLASH UPON  
RECEIPT OF PROCEED,  
ENTER, CR TERMINATE

KEY IN  
TERMINATE  
V34E

#1040

.P .T .E  
.R .E .N  
.O .R .T  
.C .M .E  
.E .I .R  
.E .N  
.D .A  
. .T  
. .E

RESET ULLAGE  
FLAG

#1050

DO FINAL AUTO-  
MATIC REQUEST  
TERMINATE ROU-  
TINE (ROO)

DO FINAL AUTO-  
MATIC REQUEST  
TERMINATE ROU-  
TINE (ROO)

#1060

EXIT P63

EXIT P63

#1070

SET ASTRONAUT FLAG

#1080

476

471

IS IGNITION FLAG  
SET?

.Y                    N.

.....  
.....  
.....

RESUME STATIC  
DISPLAY OF  
VC6N62

.....  
.....  
.....  
.....

EXIT  
(NOTE: THIS IS  
NOT A P63 EXIT.  
REFER TIG - 0  
LOGIC ABOVE.)

.....  
.....  
.....  
.....  
.....

NCN  
FROM  
ABOVE

COMMAND DPS EN

.....  
.....  
.....  
.....  
.....

MONITOR DSKY:  
IS R2 DISPLAY OF  
TFI NEGATIVE AND  
NON-ZERO?

.Y                    N.

.....  
.....

MONITOR DSKY:  
OBSERVE RE-  
TURN OF STATIC  
VERB-NOUN  
(V06N62).

.....  
.....  
.....  
.....

STANDBY FOR  
THRUST ON  
WHEN TFI =  
-00B00

STANDBY FOR  
THRUST ON IMMEDI-  
ATELY.

.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....

#1090

#1100

#1110

#1120

#1130

-----  
RESET PULSES FLAG  
-----

#1140

TEMP  
HOLD

MON

-----  
..... CHANGE VERB-NCUN AND  
..... CHANGE DISPLAY OF  
MON ..... TFI IN R2 TO H COT  
AND DELTA VM IN R3  
TO H;  
V06N63  
R1-VI  
R2-H COT  
R3-H

-----  
..... MONITOR DSKY:  
..... OBSERVE VERB-NCUN  
..... CHANGE AND CHANGE OF  
..... TFI IN R2 TO H COT  
..... AND DELTA VM IN R3  
..... TO H.  
-----

#1150

VI - SEE DEFINITION  
ABOVE.

#1160

H COT-THE PRESENT  
RATE OF CHANGE OF  
ALTITUDE (H). POL-  
ARITY INDICATES DES-  
CENT (-) OR ASCENT  
{+}. IN FPS TO NEAR-  
EST .1 FPS.

H - THE PRESENT AL-  
TITUDE OF THE LM  
ABOVE THE LUNAR  
RADIUS AT THE DESIG-  
NATED LANDING SITE.  
POLARITY IS + FOR  
ALTITUDES GREATER  
THAN THE ABOVE  
RADIUS. IN FEET TO  
NEAREST FOOT.

#1170

#1 180

470

.....  
-----  
SET ABORT ENABLE  
FLAG  
-----

#1190

.....  
-----  
SET LANDING ANALOG  
DISPLAYS FLAG  
-----

#1200

++  
+03  
+EDIT  
++

.....  
-----  
RESET IDLE FLAG  
-----

#1210

.....  
-----  
IS IMPULSE FLAG SET?  
(NOTE: ANSWER WILL  
ALWAYS BE NO FOR  
P63)  
-----

#1220

.N  
.....

.....  
-----  
RESET IGNITION FLAG  
-----

#1230

.....  
-----  
RESET ASTRONAUT FLAG  
-----

.....  
-----  
CALL FOR RESET OF  
LLAGE FLAG  
-----

#1240

IN 0.5 SEC.

START MONITOR OF  
BRAKING PHASE OF  
POWERED LANDING  
MANEUVER AS INCI-  
CATED BY LM AND  
DSKY DISPLAYS

#1250

START MONITOR OF THE  
LGC/LR OPERATIGN AS  
DESCRIBED IN THE  
DESCENT STATE VECTOR  
UPDATE ROUTINE (R12)

#1260

AT TIG (AS DEFINED  
BY R41) + "ZOOMTIME"  
SEC COMMAND THRATTLE  
TO MAXIMUM.  
(NOTE: THE VALUE  
"ZOOMTIME" IS IN  
ERASABLE STORAGE,  
HAVING BEEN LOADED  
PRIOR TO LAUNCH OR  
BY P27.)

"ZOOMTIME" SECONDS  
AFTER TIG (AS DEFIN-  
ED BY R41) DE-  
SERVE THRUST IN-  
DICATOR TO INDICATE  
XX PERCENT AUTO  
THRATTLE COMMAND  
(RIGHT SIDE) AND 100  
PERCENT CHAMBER  
PRESSURE (LEFT SIDE)  
(NOTE: THE VALUE  
"ZOOMTIME" IS IN  
ERASABLE STORAGE  
HAVING BEEN  
LOADED PRIOR TO  
LAUNCH OR BY P27).  
(NOTE: IF IGNITION

#1270

#1280

CALL LANDING AUTO  
MODES MONITOR



ROUTINE (R13)

HAS NOT BEEN AUTHOR-  
IZED BY THE CREW  
UNTIL AFTER TIG (AS  
DEFINED BY R41)  
+ "ZOOMTIME", THE  
ENGINE WILL THROTTLE  
UP AT IGNITION).

#1290

-----  
COMMENCE POWERED  
LANDING GUIDANCE  
TO ATTAIN BRAKING  
PHASE AIM CON-  
DITICNS.  
-----

SOMETIME BEFORE  
ALTITUDE REACHES  
30,000 FEET, YAW THE  
LM TO A ROUGHLY  
WINDOW-UP ORIENTA-  
TION TAKING THE  
ROUTE ABOUT THE  
X-AXIS THAT DOES NOT  
RESULT IN LOSS OF  
S-BAND LOCK-ON

#1300

#1310

-----  
WHEN H IS EQUAL  
TO + 30000 THE  
X-AXIS OVERRIDE  
OPTION IS REMOVED  
BY R12. THE LGC WILL  
AUTOMATICALLY COM-  
MAND THE LM TO AN  
ATTITUDE AROUND THE  
LM X AXIS AS SPECIF-  
IED BY THE GUIDANCE  
EQUATIONS. THE CREW  
NO LONGER HAS ANY  
MANUAL ATTITUDE  
CONTROL OF THE LM  
WHILE IN THE AUTO  
ATTITUDE CONTRL

#1320

#1330

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MODE.

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#1340

-----  
WAIT UNTIL TG  
IS LESS THAN  
"TENDBRAK".  
(NOTE: THE VALUE  
"TENDBRAK" IS IN  
ERASABLE STORAGE  
HAVING BEEN LOADED  
PRIOR TO LAUNCH OR  
BY P27).  
-----

-----  
WAIT UNTIL TG IS  
LESS THAN "TENDBRAK"  
(NOTE: THE VALUE  
"TENDBRAK" IS IN ER-  
ASABLE STORAGE HAV-  
ING BEEN LOADED  
PRIOR TO LAUNCH OR  
BY P27).  
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#1350

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GO TO APPROACH PHASE  
PROGRAM (P64)  
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GO TO APPROACH PHASE  
PROGRAM (P64)  
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#1360

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EXIT P63

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EXIT P63

#1370

CHANGE CONTRCL NOTES

LOGIC REV 00 PCR 13,30,31  
LOGIC REV 01 PCR 85,86,118,144,164,186,234,246,253,401,419,437,  
497,529,542,568,637  
LOGIC REV 00(LUM 1A) PCR 670, 737, 751  
REVS 01,C2(LUM 1B) PCR 814,838,841,854, EDITORIAL  
REV 03(LUM 1C) PCR 285, EDITORIAL

## APPROACH PHASE PROGRAM (P64)

REV 02 12/03/69

## PURPOSE:

- (1) TO CONTROL THE PGNC'S DURING THE THRUSTING OF THE POWERED LANDING MANEUVER BETWEEN HI GATE AND LO GATE.
- (2) TO CONTROL THE DPS THRUST AND ATTITUDE BETWEEN HI GATE AND LO GATE.
- (3) TO PROVIDE THE CREW WITH THE CAPABILITY OF REDESIGNATING THE LANDING SITE TO WHICH THE PGNC'S IS GUIDING THE LM.
- (4) TO SELECT P65 AUTOMATICALLY WHEN TC IS LESS THAN TENDAPPR (TIME-TO-END-APPROACH-PHASE).

## ASSUMPTIONS:

- (1) THE LM IS ON THE POWERED LANDING DESCENT BETWEEN HI GATE AND LO GATE (SEE BRAKING PHASE PROGRAM (P63), AND SECTION 5.3.4 OF R567).
- (2) THE CSM IS IN A NEAR CIRCULAR ORBIT AROUND THE MOON AT A NOMINAL ALTITUDE OF 60 NAUTICAL MILES. THE CSM IS MAINTAINING A PREFERRED TRACKING ATTITUDE FOR OPTICAL TRACKING OF THE LM.
- (3) THE IMU IS ON AND ACCURATELY ALIGNED TO A LANDING SITE ORIENTATION DEFINED FOR THE DESIGNATED LANDING SITE AND THE NOMINAL TIME OF LANDING (T(LAND)). THE MOST RECENT IMU ALIGNMENT TOOK PLACE DURING THE BRAKING PHASE PROGRAM (P63) PRIOR TO DPS IGNITION.
- (4) THE LANDING RADAR (LR) IS ON, CHECKED OUT, AND SHOULD HAVE BEEN PROVIDING TO THE LGC VELOCITY AND RANGE INFORMATION WITH RESPECT TO THE MOON. THIS INFORMATION SHOULD HAVE BEEN INCORPORATED INTO THE LM STATE VECTOR. THE LGC/LR OPERATION IS UNDER THE CONTROL OF THE DESCENT STATE VECTOR UPDATE ROUTINE (R12) WHICH IS ALREADY IN PROCESS.
- (5) THE LGC WILL NEITHER DESIGNATE NOR READ THE RENDEZVOUS RADAR (RR) DURING THIS PROGRAM.
- (6) THE ENTIRE POWERED LANDING MANEUVER (BRAKING, APPROACH AND LANDING) WILL BE ACCOMPLISHED USING THE DPS ENGINE.
- (7) THE AIM CONDITIONS (LO GATE) FOR THE APPROACH PHASE ARE STORED IN THE LGC.
- (8) THE FOLLOWING PARAMETERS REQUIRED BY THIS PROGRAM HAVE BEEN STORED IN THE LGC SINCE LGC INITIALIZATION BY ERASABLE REGISTER LOAD.
  - (A) THE LM STATE VECTOR. THE LGC HAS UPDATED THIS AS REQUIRED DURING THRUSTING. NO FURTHER STATE VECTOR UPDATES FROM ANY SOURCE OTHER THAN THE LR WILL BE ACCEPTED BY THIS PROGRAM.
- (9) THE DPS IS NOT THROTTLEABLE OVER THE WHOLE RANGE FROM 0 TO MAXIMUM. IT MUST BE OPERATED EITHER AT MAXIMUM THROTTLE OR OVER A SPECIFIC THROTTLE RANGE OF LOWER SETTINGS. THESE THROTTLE SETTINGS ARE SPECIFIED IN SECTION 5.3.4 OF R567 AND ARE TOTAL THROTTLE SETTINGS, I.E.: THE SUM OF THE MANUAL SETTING (WHOSE MINIMUM IS ABOUT 10 PERCENT) AND THE PGNC'S COMMANDED SETTING.
 

THIS PROGRAM ASSUMES THE THROTTLE CONTROL TO BE IN AUTO (THE DPS RECEIVES THE SUM OF THE MANUAL AND PGNC'S COMMANDED SETTINGS) AND THE MANUAL THROTTLE TO BE SET AT A LEVEL LESS THAN THAT REQUIRED BY THE LGC.

NOMINALLY, IF THE APPROACH PHASE PROGRAM IS COMPLETED WITHOUT ANY REDESIGNATION OF THE LANDING SITE (SEE ASSUMPTION (12)), THE THROTTLE WILL REMAIN WITHIN THE ALLOWABLE THROTTLE RANGE THROUGHOUT THE PHASE. EXCESSIVE TARGET REDESIGNATIONS DURING THIS PROGRAM HOWEVER MAY RESULT IN REQUIRED THROTTLE EXCURSIONS OUTSIDE THE ALLOWABLE RANGE. IN SUCH CASES THE LGC WILL COMMAND MAXIMUM THROTTLE FOR AT LEAST 2 SEC, AND UNTIL THE REQUIRED THROTTLE SETTING RETURNS TO THE PERMITTED THROTTLE REGION.
- (10) DURING THE POWERED LANDING MANEUVER, THE LGC WILL MONITOR THE PRESENCE OR ABSENCE OF THE "NON-ATTITUDE HOLD" DISCRETE. THIS DISCRETE IS ISSUED TO THE LGC WHEN THE ATTITUDE MODE CONTROL SWITCH IS IN THE AUTO POSITION. SHOULD THIS DISCRETE APPEAR DURING THE POWERED LANDING MANEUVER, THE LGC ASSUMES THAT IT NO LONGER HAS COMPLETE AUTOMATIC CONTROL OF THE MANEUVER.

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THE MONITOR AND THE ASSOCIATED LGC LOGIC IS INCLUDED IN THE LANDING AUTO MODES MONITOR ROUTINE (R13) WHICH IS ALREADY IN PROCESS.

(11) THE X-AXIS OVERRIDE OPTION IS NOT PROVIDED THE CREW WHENEVER THE LGC-ESTIMATED ALTITUDE IS LESS THAN 30,000 FT. (REFER R12 AND ASSUMPTION 13 OF P63).

(12) DURING MOST OF THE APPROACH PHASE, THE LGC PROVIDES THE CREW THE OPTION TO REDESIGNATE THE LANDING SITE TO WHICH THE PGNC'S IS GUIDING THE LM. THIS OPTION IS CALLED THE LANDING POINT DESIGNATOR (LPD) MODE. IT IS WORTH NOTING THAT THE PGNC'S MODE CONTROL SWITCH MUST BE IN AUTO FOR THE ACA TO FUNCTION AS A LANDING SITE RE-DESIGNATOR. IF THIS SWITCH IS IN ATT HOLD THE ACA FUNCTIONS AS A RATE COMMAND/ATTITUDE HOLD STICK.

THE LANDING POINT REDESIGNATION, IF EXERCISED, IS BASED UPON VISUAL ASSESSMENT OF THE LUNAR TERRAIN WITH RESPECT TO THE PRESENTLY DESIGNATED LANDING SITE. DURING THE LPD MODE THE PRESENT LANDING SITE IS DISPLAYED ON THE DSKY IN TERMS OF COORDINATES ON THE LPD SIGHTING GRID ON THE LEFT HAND LM WINDOW (LPD ANGLE). LANDING SITE REDESIGNATIONS ARE MANUALLY PUT INTO THE COMPUTER VIA THE ATTITUDE CONTROLLER ON AN INCREMENTAL BASIS, I.E.: A LIMIT SWITCH ACTUATION IN THE ATTITUDE CONTROLLER CAUSES THE LGC TO REDESIGNATE THE LANDING SITE A FIXED ANGULAR INCREMENT (1/2 DEGREE IN ELEVATION, 2 DEGREES IN AZIMUTH) FROM THE PRESENT LM/LANDING SITE LOS. THE APPLICABLE ATTITUDE CONTROLLER POLARITIES ARE:

- (A) - PITCH ROTATION GIVES - LPD ELEVATION (NEW SITE BEYOND PRESENT SITE)
- (B) + PITCH ROTATION GIVES + LPD ELEVATION (NEW SITE SHORT OF PRESENT SITE)
- (C) + ROLL ROTATION GIVES + LPD AZIMUTH (NEW SITE TO RIGHT OF PRESENT SITE)
- (D) - ROLL ROTATION GIVES - LPD AZIMUTH (NEW SITE TO LEFT OF PRESENT SITE)

THE LPC MODE IS MORE COMPLETELY DESCRIBED IN SECTION 5.3.4 OF R567.

(13) THE INITIAL MANEUVER OF THE APPROACH PHASE IS THE LM ATTITUDE TRANSITION FROM THE LM ATTITUDE AT THE START OF P64 TO A SATISFACTORY ATTITUDE FOR LANDING SITE VISIBILITY. AFTER THE COMPLETION OF THIS MANEUVER THE LM ATTITUDE IS CONSTRAINED BY THRUST POINTING REQUIREMENTS AND IS CONTROLLED ABOUT THE THRUST AXIS SO AS TO MAINTAIN THE CURRENT LANDING SITE IN THE LM X/Z PLANE. THE CONDITIONS ACHIEVED BY THE START OF P64 SHOULD BE SUCH THAT THE THRUST POINTING REQUIREMENTS OF THE APPROACH PHASE WILL YIELD SATISFACTORY VISIBILITY AND RADAR ORIENTATIONS.

THE LANDING SITE BECOMES VISIBLE TO THE COMMAND PILOT IF THE LOOK ANGLE (THE ANGLE BETWEEN THE LM -X AXIS AND THE LOS TO THE LANDING SITE) IS LESS THAN 65 DEGREES AND THE LOS IS IN OR NEAR THE LM X/Z PLANE.

AT ANYTIME DURING P63, P64 OR P65, THE MAGNITUDE OF THE LOOK ANGLE AND THE ORIENTATION OF THE LOOK ANGLE PLANE (THAT PLANE CONTAINING THE LOS AND THE LM X AXIS) ARE DEFINED BY THE INERTIAL ORIENTATION OF THE LM X AXIS AND THE POSITION OF THE LM WITH RESPECT TO THE LANDING SITE.

THE INERTIAL ORIENTATION OF THE LM X AXIS IS CONTROLLED BY REQUIREMENTS OF THRUST VECTOR CONTROL. THE ORIENTATION OF THE LM WINDOWS WITH RESPECT TO THE LOOK ANGLE PLANE IS CONTROLLED BY ROTATION OF THE VEHICLE ABOUT THE LM X AXIS. THIS CONTROL IS EXERCISED AS SHOWN IN SECTION 5.3.4 OF R567.

(14) THE CREW HAS THE CAPABILITY TO DISPLAY LGC CALCULATED VALUES OF FORWARD VELOCITY, LATERAL VELOCITY, ALTITUDE AND ALTITUDE RATE ON CERTAIN LM METERS DURING THIS PROGRAM. THE CALCULATION OF THESE PARAMETERS IS UNDER THE CONTROL OF THE LANDING ANALOG DISPLAYS ROUTINE (R10) WHICH IS ALREADY IN PROCESS.

(15) THE RATE OF DESCENT (ROD) MODE IS NOT ENABLED DURING THIS PROGRAM (SEE LANDING PHASE (RCD) PROGRAM (P66), ASSUMPTION (12) FOR DEFINITION OF RCD MODE).

(16) AN ABORT FROM THE LUNAR DESCENT MAY BE REQUIRED AT ANY TIME DURING THE DESCENT ORBIT INJECTION, THE DESCENT COAST, OR THE POWERED DESCENT (P63), (P64), (P65), OR (P66).

FOR ABORTS FROM THE DESCENT ORBIT INJECTION OR THE DESCENT COAST IT IS ASSUMED THAT SUFFICIENT TIME EXISTS TO PERFORM A TPI MANEUVER (SEE TERMINAL PHASE INITIATION (TPI) PROGRAM (P34)) TO INTERCEPT THE CSM DIRECTLY.

FOR ABORTS AFTER DPS IGNITION FOR THE POWERED LANDING MANEUVER, TIME IS CRITICAL. DURING THIS PERIOD AN ABORT IS NOMINALLY COMMANDED BY PUSHING ONE OF TWO BUTTONS IN THE LM. THE ABORT MAY BE COMMANDED TO USE THE DESCENT STAGE (ABORT BUTTON) OR THE ASCENT STAGE (ABORT STAGE BUTTON). IF THE DESCENT STAGE IS SELECTED, AND THE DPS PROPELLANT APPROACHES EXHAUSTION, CONTROL MUST BE SWITCHED TO THE ASCENT STAGE BY THE CREW BY ASCENT STAGE SELECTION (ABORT STAGE BUTTON).

DURING THE POWERED LANDING MANEUVER THE LGC WILL CONTINUOUSLY MONITOR THE ABORT AND THE ABORT STAGE DISCRETES, AND UPON RECEIPT OF EITHER WILL TERMINATE THE PROGRAM IN PROCESS AND CALL THE APPROPRIATE ABORT PROGRAM (DPS ABORT

PROGRAM (P70) OR APS ABORT PROGRAM (P71)). BOTH ABORT PROGRAMS WILL GUIDE THE LM TO AN ORBIT AS SPECIFIED IN SECTION 5.4.3 OF R567.

THE MONITOR OF THE ABORT AND ABORT STAGE PUSHBUTTONS IS CONTROLLED BY THE ABORT DISCRETES MONITOR ROUTINE (R11) WHICH IS ALREADY IN PROCESS.

++ (17) IF A THRUSTING MANEUVER IS PERFORMED WITH THE GUIDANCE CONTROL SWITCH IN PGNS AND THE MODE CONTROL SWITCH IN  
+02 AUTC, THE PGNS WILL CONTROL THE TOTAL VEHICLE ATTITUDE AND GENERATE EITHER MODE I OR MODE II ATTITUDE ERRORS AND  
+EDIT VEHICLE ATTITUDE RATES (SEE ASSUMPTION (19)) FOR DISPLAY ON THE FDAI. THE CREW MAY EXERCISE CONTROL AROUND THE YAW  
+ AXIS ONLY WITH THE ACA (X-AXIS OVERRIDE) IF THE X-AXIS OVERRIDE CAPABILITY IS PERMITTED BY THE PROGRAM IN PROCESS.  
+ THIS MANUAL CONTROL WILL IN THE RATE COMMAND/ATTITUDE HOLD MODE.  
+ IF A THRUSTING MANEUVER IS PERFORMED WITH THE GUIDANCE CONTROL SWITCH IN PGNS AND THE MODE CONTROL SWITCH IN  
+ ATTITUDE HOLD THE PGNS WILL HOLD THE VEHICLE ATTITUDE AND WILL GENERATE EITHER MODE I OR MODE II ATTITUDE ERRORS  
+ FOR DISPLAY ON THE FDAI. THE CREW MAY EXERCISE MANUAL ATTITUDE CONTROL ABOUT ALL VEHICLE AXES WITH THE ACA IN EITHER  
+ THE RATE COMMAND OR MINIMUM IMPULSE MODE DEPENDING UPON THE STATUS OF THE PULSES FLAG. IT IS STRONGLY RECOMMENDED  
+ THAT POWERED FLIGHT NOT BE ATTEMPTED IN THE MINIMUM IMPULSE MODE. THE PULSES FLAG IS SET OR RESET BY EXTENDED VERBS  
+ 76 (MINIMUM IMPULSE) AND 77 (RATE COMMAND) RESPECTIVELY. THE PULSES FLAG IS ALSO RESET BY P12,P40,P41,P42,P63,P70,P71  
+ AND R40 AT MAIN ENGINE IGNITION. WITH THE EXCEPTION OF THESE CASES, MODE SELECTION IS ALWAYS BASED UPON THE LAST  
+ ENTRY MADE IN THE DSKY. DURING A THRUSTING MANEUVER IN THE PGNS/ATTITUDE HOLD MODE THE PGNS WILL NOT BE RESPONSIBLE  
+02 IF REGISTER OVERFLOWS OCCUR WITHIN THE LGC.  
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(18) CONTROL OF THE LM DPS, RCS, AND APS IS TRANSFERRED FROM THE PGNS TO THE ABORT GUIDANCE SYSTEM (AGS) BY PLACING THE GUID CNT SWITCH FROM PGNS TO AGS.

THE AGS WILL BE CAPABLE OF TAKING OVER CONTROL OF THE LM DURING ANY PORTION OF THE LUNAR DESCENT OR ASCENT OR DURING EITHER OF THE ABORT PROGRAMS (P70 OR P71). THE AGS WILL GUIDE THE LM TO A SAFE ORBIT.

THE AGS MAY BE INITIALIZED BY THE LGC AT ANY TIME DURING THIS PROGRAM BY MANUAL SELECTION OF THE AGS INITIALIZATION ROUTINE (R47).

IN THE EVENT THAT THE GUIDANCE CONTROL SWITCH IS CHANGED FROM PGNS TO AGS DURING A THRUSTING MANEUVER, THE LGC WILL CONTINUE COMPUTATION OF POSITION AND VELOCITY, THE DESIRED THRUST VECTOR AND THE DESIRED ATTITUDE ERRORS, HOWEVER THE PGNS WILL NOT BE RESPONSIBLE IF REGISTER OVERFLOWS OCCUR WITHIN THE LGC.

(19) THE PGNS CAN GENERATE TWO TYPES OF ATTITUDE ERRORS FOR DISPLAY ON THE FDAI;

++ MODE I - SELECTED BY EXTENDED VERB 61. AUTOPILOT FOLLOWING ERRORS USED AS A MONITOR OF THE DAP'S  
+02 ABILITY TO TRACK AUTOMATIC STEERING COMMANDS.  
+EDIT MODE II - SELECTED BY EXTENDED VERB 62. TOTAL ATTITUDE ERRORS USED TO ASSIST CREW IN MANUALLY  
+ MANEUVERING THE VEHICLE.  
+ PGNS-DERIVED VEHICLE ATTITUDE RATES MAY ALSO BE DISPLAYED VIA SELECTION BY EXTENDED VERB 60.  
+ MODE II ATTITUDE ERROR DISPLAYS ARE AUTOMATICALLY SELECTED AT THE BEGINNING OF R60. WITH THE EXCEPTIONS  
+ INDICATED IN ASSUMPTION (17) ABOVE, DISPLAY SELECTION IS ALWAYS BASED UPON THE LAST ENTRY MADE IN THE DSKY. FOR A  
+ MORE DETAILED DESCRIPTION OF THESE DISPLAYS REFER TO SECTION 3 OF R567, PARA. 3.2.6.  
+02  
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(20) THE LOAD CAP DATA ROUTINE (R03) HAS BEEN PERFORMED PRIOR TO THE START OF THE POWERED LANDING MANEUVER AND SHOULD NOT BE REQUIRED DURING THIS PROGRAM.

(21) LGC AND CREW PROCEDURES IN CASES OF LGC-ASSUMED THRUST FAILURE ARE DEFINED BY THE DPS/APS THRUST FAIL ROUTINE (R4C). THIS ROUTINE IS IN EFFECT DURING THIS PROGRAM, HAVING BEEN ENABLED BY P63.

(22) THIS PROGRAM IS AUTOMATICALLY SELECTED BY THE BRAKING PHASE PROGRAM (P63) WHEN TG DURING THE PHASE BECOMES LESS THAN TENDBRAK (TIME-TC-END-BRAKING-PHASE).

(23) TWO ALARM CONDITIONS MAY BE ORIGINATED BY THE PGNC'S POWERED LANDING EQUATIONS:

(A) IF SUBROUTINE ROOTPSRS IN THE TIME-TO-GO CALCULATION FAILS TO CONVERGE IN 8 PASSES THE LGC WILL TURN ON THE PROGRAM ALARM LIGHT, STORE PROGRAM ALARM 1406, STOP ALL VEHICLE ATTITUDE RATES, AND CONTINUE. THIS ALARM COULD OCCUR ONLY IN P63 AND P64.

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+02  
+EDIT  
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(B) IF AN OVERFLOW OCCURS ANYWHERE IN THE LANDING EQUATIONS THE LGC WILL TURN ON THE PROGRAM ALARM LIGHT, STORE ALARM CODE 1410, STOP ALL VEHICLE ATTITUDE RATES AND CONTINUE. THIS ALARM COULD ONLY OCCUR IN P63, P64, OR P65.

(24) THIS PROGRAM ALLOWS MANUAL CONTROL OF THE LM ATTITUDE. IF MANUAL CONTROL IS DESIRED, PUT THE MODE CONTROL SWITCH IN ATT HOLD AND USE THE ACA TO CONTROL THE LM ATTITUDE.

IF P66 IS DESIRED, CLICK THE ROD SWITCH WHILE THE MODE CONTROL SWITCH IS IN ATT HOLD. THE ACA DOES NOT RE-DESIGNATE THE LANDING SITE WHILE THE MODE CONTROL SWITCH IS IN ATT HOLD. TO USE THE ACA TO RE-DESIGNATE THE LANDING SITE, PUT THE MODE CONTROL SWITCH IN AUTO AND ROTATE THE ACA IN THE DESIRED DIRECTION. ONCE CONTROL IS TRANSFERRED FROM P64 TO P66, P64 CANNOT BE RE-ENTERED.

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+02  
+EDIT  
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+02  
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(25) THE ASTRONAUT MAY MONITOR THE FOLLOWING ADDITIONAL PARAMETERS DURING THIS PROGRAM (AFTER COMPLETION OF THE IGNITION ALGORITHM) BY KEYING IN V57E; (SEE LOGIC DESCRIPTION OF V57)

(A) V06 N68  
R1-RANGE  
R2-TG  
R3-DELTA H

RANGE - SLANT RANGE FROM THE LM TO THE DESIGNATED LANDING SITE. IN NAUTICAL MILES TO NEAREST .1 NM.

TG - THE ESTIMATED TIME OF FLIGHT FROM THE PRESENT TIME TO THE ACCOMPLISHMENT OF THE CURRENT AIM CONDITIONS. IN MINS AND SECS TO NEAREST SEC. MAX READING IS 59859. SIGN IS --.

DELTA H - THE PRESENT LR INDICATED ALTITUDE MINUS THE LGC CALCULATED ALTITUDE OF THE LM ABOVE THE LUNAR RADIUS AT THE DESIGNATED LANDING SITE. IN FEET TO THE NEAREST FOOT.

(NOTE: DELTA H IS INITIALLY SET TO 99999 WHERE IT WILL REMAIN UNTIL R12 CALCULATES A VALUE BASED ON LR DATA).

(26) THE ASTRONAUT MAY MONITOR THE FOLLOWING PARAMETERS BY KEYING IN V16 N92E:

(A) V16 N92  
R1 - THR CMD  
R2 - FCGT  
R3 - H

THR CMD - THE PERCENT THROTTLE DESIRED BY THE LGC, BASED ON THE DPS RATED THRUST OF 10,500 POUNDS. IN PERCENT TO NEAREST PERCENT.

FCGT - THE PRESENT RATE OF CHANGE OF ALTITUDE (H). IN FPS TO NEAREST .1 FPS.

H - THE PRESENT ALTITUDE OF THE LM ABOVE THE LUNAR RADIUS AT THE INITIALLY DESIGNATED LANDING SITE. IN FEET TO NEAREST FOOT.

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+02  
+285  
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+  
+  
+  
+02  
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PROG                    LGC                    GROUND                    CREW



#50

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 -----  
 CALCULATE LPD FOR  
 THE DESIGNATED  
 LANDING SITE.  
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#60

HOLD . . .  
 .....  
 MON . . . FLASH VERB-NOUN TO  
 REQUEST RESPONSE AND  
 DISPLAY PRESENT  
 VALUE OF TR/LPD, H  
 DOT AND H:  
 V06N64  
 R1-TR/LPD  
 R2-H DOT  
 R3-+

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 +02  
 +EDIT  
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TR/LPD - A SPLIT  
 DISPLAY WITH TR IN  
 THE LEFT TWO DIGITS,  
 THE MIDDLE DIGIT  
 ALWAYS BLANK, AND  
 LPD IN THE RIGHT TWO  
 DIGITS.  
 WHERE:

TR-THE ESTIMATED  
 TIME REMAINING  
 UNTIL END OF  
 REDESIGNATION  
 CAPABILITY. IN  
 SECONDS TO NEAR-  
 EST SECOND. PO-  
 LARITY IS ALWAYS  
 +. MAXIMUM  
 READING IS 99,  
 FOR EXAMPLE:

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 MONITOR DSKY:  
 OBSERVE VERB-NOUN  
 FLASH TO REQUEST  
 RESPONSE AND DISPLAY  
 OF TR/LPD, H DOT  
 AND H.  
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#70

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 MONITOR FDAI AND OUT  
 THE WINDOW:  
 OBSERVE ATTITUDE  
 TRANSIENT TO BRING  
 LM TO A SATISFACTORY  
 ATTITUDE FOR LANDING  
 SITE VISIBILITY  
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#80

#90



130 SECONDS IS  
DISPLAYED AS 99.  
(NOTE: TR IS A  
POSITIVE NUMBER  
EQUAL TO:  
-TG-(TCGFAPR+4),  
WHERE TCGFAPR IS  
THE TIME-TC-GC AT  
WHICH ERECTION OF  
THE GUIDANCE CO-  
ORDINATE FRAME IS  
SUSPENDED.)

#100

LPD-THE ANGLE BE-  
LOW THE LM +Z  
AXIS TO THE LOS  
TO THE PRESENTLY  
DESIGNATED LAND-  
ING SITE. IN DE-  
GREES TO NEAREST  
DEGREE.

#110

(NOTE: THE DISPLAY  
IN R1 APPEARS AS  
XXYY WHERE: XX IS  
TR AND YY IS LPD).

#120

H DOT - THE PRESENT  
RATE OF CHANGE OF  
ALTITUDE (H). POLAR-  
ITY INDICATES DES-  
CENT (-) OR ASCENT  
(+). IN FT/SEC TO  
NEAREST .1 FT/SEC.

#130

H - THE PRESENT  
ALTITUDE OF THE LM  
ABOVE THE LUNAR  
RADIUS AT THE INIT-  
IALLY DESIGNATED  
LANDING SITE.  
POLARITY IS + FOR  
ALTITUDES GREATER  
THAN THE ABOVE  
RADIUS. IN FEET TO  
NEAREST FOOT.

#140

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#150

DO I WISH TO  
EXERCISE THE LPD  
CAPABILITY?

.Y .N

WAIT FOR KEYBOARD  
ENTRY OR FOR TR=0

KEY IN  
PROCEED

#160

TERMINATE FLASH  
UPON RECEIPT OF  
PROCEED OR CHANGE TO  
NON-FLASHING DISPLAY  
IF TR=0

#170

.P .TR=C  
.R  
.G  
.C  
.E  
.E  
.D

CONTINUE  
POWERED  
LANDING  
GUIDANCE  
USING P64  
AIM  
CONDITIONS  
REFERRED  
TO THE  
PRESENTLY  
DESIGNATED  
LANDING

#180

#190

491

SITE.

CALCULATE  
LPD FOR  
THE PRE-  
SENTLY DE-  
SIGNATED  
LANDING  
SITE.

#200

TEMP  
HOLD

MON

DISPLAY ON  
DSKY:  
V06N64  
R1-TR/LPD  
R2-H DOT  
R3-F

NOTE: FOR  
DEFINITIONS,  
SEE ABOVE

USING LPD  
(R1) AND THE LPD  
SCALE ON THE COM-  
MAND PILOT'S WIN-  
DOW OBSERVE THE  
PRESENTLY  
DESIGNATED  
LANDING SITE.

#210

USING THE ATT I-  
TUDE CONTROLLER  
REDESIGNATE THE  
LANDING SITE.  
THIS WILL INCRE-  
MENT THE APPRO-  
PRIATE REDESIGNA-  
TION COUNTER IN  
THE LGC.  
OBSERVE THE  
FOLLOWING GROUND  
RULES:

#220

(A) SITE REDESIC-  
NATION TOWARDS  
THE LM (+ PITCH  
ROTATION) WILL  
REDUCE THIS SITE  
VISIBILITY CLEAR-  
ANCE WHICH IS

#230

ORIGINALLY ONLY  
10 DEGREES.

#240

(B) LARGE REDES-  
IGNATIONS SHOULD  
BE MADE AS EARLY  
IN THE APPROACH  
PHASE AS POSS-  
IBLE TO CONSERVE  
FUEL AND MINIMIZE  
ATTITUDE TRANS-  
IENTS.

#250

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IS TR = 0?  
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.N .Y

(C) WHEN TR IS  
EQUAL TO 0  
SEC THE LGC  
WILL NO LONGER  
RESPOND TO LPD  
REDESIGNATIONS.

(NOTE: DISPLAYED  
LPD ANGLES AND  
VEHICLE YAW MAY BE  
BIASED TO MAKE UP  
FOR ERRORS IN THE  
ALIGNMENT OF  
THE LPD RETICLE  
AND FOR WINDOW  
BENDING WHEN THE  
LM IS PRESSURIZED.  
THAT PART OF  
WINDOW ERROR  
WHICH CANNOT BE  
RESOLVED INTO  
ROTATIONS ABOUT  
THE BODY Y AND X  
AXES WILL REMAIN  
UNCOMPENSATED,  
EXCEPT AT A CHOSEN  
SPOT ALONG THE  
RETICLE- THE MEAN  
LPD ANGLE OF THE  
APPROACH PHASE).

#260

#270

#280

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+02  
+968  
+  
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+  
+  
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+  
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+  
+  
+  
+  
+  
+  
+  
+  
+02  
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493

++  
+02  
+EDIT  
+  
+  
+02  
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ZERO AZI-  
MUTH AND  
ELEVATION  
RECESIG-  
NATION REG-  
ISTERS  
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#290

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SET RECES-  
IGNATION  
FLAG  
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#300

-----  
HAVE ANY MANU-  
AL LPG CCMANDS  
BEEN ISSUED  
SINCE THE LAST  
PASS?  
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#310

.N Y.

-----  
WAIT 2 SEC  
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#320

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USING PERTUR-  
BATION EQA-  
TIONS AND LPG  
CCMANDS ACCU-  
MLATED SINCE  
LAST PASS,  
CCMPUTE POSIT-

#330

ION OF NEW AIM  
POINT. (REFER  
TO SECTION  
5.3.4 OF R567  
FOR DETAILED  
DESCRIPTION)

#340

TRANSFER AIM  
CONDITIONS TO  
NEW AIM POINT.

#350

ZERO THE  
REDESIGNATION  
COUNTER

#360

WAIT 2 SEC

#370

RESET REDESIGNATION  
FLAG

#380

WAIT FOR TG TO BE  
LESS THAN TENDAPPR



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## LANDING PHASE (AUTO) PROGRAM (P65)

REV 02 12/03/69

## PURPOSE:

(1) TO CONTROL THE PGNC'S DURING THE THRUSTING OF THE POWERED LANDING MANEUVER FROM THE PERIOD IMMEDIATELY AFTER COMPLETION OF THE APPROACH PHASE AIM CONDITIONS (LO GATE) UNTIL TOUCHDOWN ON THE LUNAR SURFACE.

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## ASSUMPTIONS:

(1) THE LM IS ON THE POWERED LANDING DESCENT HAVING JUST ARRIVED AT THE LO GATE CONDITIONS (SEE APPROACH PHASE PROGRAM (P64) AND SECTION 5.3.4 OF R567).

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(2) THE CSM IS IN A NEAR CIRCULAR ORBIT AROUND THE MOON AT A NOMINAL ALTITUDE OF 60 NAUTICAL MILES. THE CSM'S POSITION WITH RESPECT TO THE LM IS APPROXIMATELY 0 DEGREES CENTRAL ANGLE ABOVE THE LM. THE CSM IS MAINTAINING A PREFERRED TRACKING ATTITUDE FOR OPTICAL TRACKING OF THE LM.

(3) THE IMU IS ON AND ACCURATELY ALIGNED TO A LANDING SITE ORIENTATION DEFINED FOR THE DESIGNATED LANDING SITE AND THE NOMINAL TIME OF LANDING (T(LAND)). THE MOST RECENT IMU ALIGNMENT (FINE) TOOK PLACE DURING THE BRAKING PROGRAM (P63) PRIOR TO CPS IGNITION.

(4) THE LANDING RADAR (LR) IS ON, CHECKED OUT, AND SHOULD HAVE BEEN PROVIDING TO THE LGC VELOCITY AND RANGE INFORMATION WITH RESPECT TO THE MOON. THIS INFORMATION SHOULD HAVE BEEN INCORPORATED INTO THE LM STATE VECTOR. THE LGC/LR OPERATION IS UNDER THE CONTROL OF THE DESCENT STATE VECTOR UPDATE ROUTINE (R12) WHICH IS ALREADY IN PROCESS.

(5) THE LGC WILL NEITHER DESIGNATE NOR READ THE RENDEZVOUS RADAR (RR) DURING THIS PROGRAM.

(6) THE ENTIRE POWERED LANDING MANEUVER (BRAKING, APPROACH AND LANDING) WILL BE ACCOMPLISHED USING THE DPS ENGINE.

(7) THE FOLLOWING PARAMETERS REQUIRED BY THIS PROGRAM HAVE BEEN STORED IN THE LGC SINCE LGC INITIALIZATION BY ERASABLE REGISTER LOAD.

(A) THE LM STATE VECTOR. THE LGC HAS UPDATED THIS AS REQUIRED DURING THRUSTING. NO FURTHER STATE VECTOR UPDATES FROM ANY SOURCE OTHER THAN THE LR WILL BE ACCEPTED BY THIS PROGRAM.

(8) THE DPS IS NOT THROTTLEABLE OVER THE WHOLE RANGE FROM 0 PERCENT TO MAXIMUM. IT MUST BE OPERATED EITHER AT MAXIMUM THROTTLE OR OVER A SPECIFIC THROTTLE RANGE OF LOWER SETTINGS. THESE THROTTLE SETTINGS ARE SPECIFIED IN SECTION 5.3.4 OF R567 AND ARE TOTAL THROTTLE SETTINGS. I.E.: THE SUM OF THE MANUAL SETTING (WHOSE MINIMUM IS ABOUT 10 PERCENT) AND THE PGNC'S COMMANDED SETTING.

THIS PROGRAM ASSUMES THE THROTTLE CONTROL TO BE IN AUTO (THE DPS RECEIVES THE SUM OF THE MANUAL AND PGNC'S COMMANDED SETTINGS) AND THE MANUAL THROTTLE TO BE SET AT A LEVEL LESS THAN THAT REQUIRED BY THE LGC. NOMINALLY THE THROTTLE WILL REMAIN WITHIN THE ALLOWABLE THROTTLE RANGE THROUGHOUT THIS PROGRAM.

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(9) DURING THE POWERED LANDING MANEUVER, THE LGC WILL MONITOR THE PRESENCE OR ABSENCE OF THE "AUTO STABILIZATION" DISCRETE. THIS DISCRETE IS ISSUED TO THE LGC WHEN THE ATTITUDE MODE CONTROL SWITCH IS IN THE AUTO POSITION.

SHOULD THIS DISCRETE APPEAR DURING THE POWERED LANDING MANEUVER, THE LGC ASSUMES THAT IT NO LONGER HAS COMPLETE AUTOMATIC CONTROL OF THE MANEUVER.

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THE MONITOR AND THE ASSOCIATED LGC LOGIC IS INCLUDED IN THE LANDING AUTO MODES MONITOR ROUTINE (R13) WHICH IS

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(10) THE X-AXIS OVERRIDE OPTION PROVIDES THE CREW WITH THE ABILITY TO EXERCISE MANUAL CONTROL ABOUT THE LM X AXIS WITH THE ATTITUDE CONTROLLER EVEN THOUGH THE PGNC'S ATTITUDE CONTROL MODE IS AUTO. WHEN THE CONTROLLER IS RETURNED TO DETENT THE PGNC'S DAMPS THE YAW RATE, STORES THE YAW ATTITUDE WHEN THE YAW RATE IS DAMPED, AND THEN MAINTAINS THAT ATTITUDE.

THE X-AXIS OVERRIDE OPTION IS ALWAYS AVAILABLE TO THE CREW EXCEPT WHEN THE LGC IS SPECIFYING A DESIRED YAW ATTITUDE. THUS THE OPTION IS NOT INHIBITED BY THIS PROGRAM.

(11) THE LPD OPTION IS NOT PROVIDED THE CREW DURING THIS PROGRAM.

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(12) THE INITIAL MANEUVER OF THE AUTO LANDING PHASE IS THE LM ATTITUDE TRANSIENT FROM THE LM ATTITUDE AT LO GATE TO THE HOVER ATTITUDE (LM X AXIS ALONG THE LOCAL VERTICAL). THE FINAL DESIGNATED LANDING SITE REMAINS IN THE LM X/Z PLANE DURING THIS TRANSIENT.

THE LM ALTITUDE RATE IS MAINTAINED AT A CONSTANT RATE UNTIL TOUCHDOWN (NORMALLY 3 FT/SEC DOWNWARD).

(13) THE CREW HAS THE CAPABILITY TO DISPLAY LGC CALCULATED VALUES OF FORWARD VELOCITY, LATERAL VELOCITY, ALTITUDE AND ALTITUDE RATE ON CERTAIN LM METERS DURING THIS PROGRAM. THE CALCULATION OF THESE PARAMETERS IS UNDER THE CONTROL OF THE LANDING ANALOG DISPLAYS ROUTINE (R1C) WHICH IS ALREADY IN PROCESS.

(14) THE RATE OF DESCENT (ROD) MODE IS NOT ENABLED DURING THIS PROGRAM (SEE LANDING PHASE (ROD) PROGRAM (P66), FOR DEFINITION OF ROD MODE).

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(15) AN ABORT FROM THE LUNAR DESCENT MAY BE REQUIRED AT ANY TIME DURING THE DESCENT ORBIT INJECTION, THE DESCENT COAST, OR THE POWERED DESCENT (P63), (P64), (P65), OR (P66).

FOR ABORTS FROM THE DESCENT ORBIT INJECTION OR THE DESCENT COAST IT IS ASSUMED THAT SUFFICIENT TIME EXISTS TO PERFORM A TPI MANEUVER (SEE TERMINAL PHASE INITIATION (TPI) PROGRAM (P34)) TO INTERCEPT THE CSM DIRECTLY.

FOR ABORTS AFTER DPS IGNITION FOR THE POWERED LANDING MANEUVER, TIME IS CRITICAL. DURING THIS PERIOD AN ABORT IS COMMANDED BY PUSHING ONE OF TWO BUTTONS IN THE LM. THE ABORT MAY BE COMMANDED TO USE THE DESCENT STAGE (ABORT BUTTON) OR THE ASCENT STAGE (ABORT STAGE BUTTON). IF THE DESCENT STAGE IS SELECTED, AND THE DPS PROPELLANT APPROACHES EXHAUSTION, CONTROL MUST BE SWITCHED TO THE ASCENT STAGE BY THE CREW BY ASCENT STAGE SELECTION (ABORT STAGE BUTTON).

DURING THE POWERED LANDING MANEUVER, THE LGC WILL CONTINUOUSLY MONITOR THE ABORT AND ABORT STAGE DISCRETES, AND UPON RECEIPT OF EITHER WILL TERMINATE THE PROGRAM IN PROCESS AND CALL THE APPROPRIATE ABORT PROGRAM (DPS ABORT PROGRAM (P70) OR APS ABORT PROGRAM (P71)). BOTH ABORT PROGRAMS WILL GUIDE THE LM TO AN ORBIT AS SPECIFIED IN SECTION 5.4.3 OF R567.

THE MONITOR OF THE ABORT AND ABORT STAGE PUSHBUTTONS IS CONTROLLED BY THE ABORT DISCRETES MONITOR ROUTINE (R11) WHICH IS ALREADY IN PROCESS.

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(16) IF A THRUSTING MANEUVER IS PERFORMED WITH THE GUIDANCE CONTROL SWITCH IN PGNS AND THE MODE CONTROL SWITCH IN AUTO, THE PGNS WILL CONTROL THE TOTAL VEHICLE ATTITUDE AND GENERATE EITHER MODE I OR MODE II ATTITUDE ERRORS AND VEHICLE ATTITUDE RATES (SEE ASSUMPTION (18)) FOR DISPLAY ON THE FDAI. THE CREW MAY EXERCISE CONTROL AROUND THE YAW AXIS ONLY WITH THE ACA (X-AXIS OVERRIDE) IF THE X-AXIS OVERRIDE CAPABILITY IS PERMITTED BY THE PROGRAM IN PROCESS. THIS MANUAL CONTROL WILL BE IN THE RATE COMMAND/ATTITUDE HOLD MODE.

IF A THRUSTING MANEUVER IS PERFORMED WITH THE GUIDANCE CONTROL SWITCH IN PGNS AND THE MODE CONTROL SWITCH IN ATTITUDE HOLD THE PGNS WILL HOLD THE VEHICLE ATTITUDE AND WILL GENERATE EITHER MODE I OR MODE II ATTITUDE ERRORS FOR DISPLAY ON THE FDAI. THE CREW MAY EXERCISE MANUAL ATTITUDE CONTROL ABOUT ALL VEHICLE AXES WITH THE ACA IN EITHER THE RATE COMMAND OR MINIMUM IMPULSE MODE DEPENDING UPON THE STATUS OF THE PULSES FLAG. IT IS STRONGLY RECOMMENDED THAT POWERED FLIGHT NOT BE ATTEMPTED IN THE MINIMUM IMPULSE MODE. THE PULSES FLAG IS SET OR RESET BY EXTENDED VERBS 76 (MINIMUM IMPULSE) AND 77 (RATE COMMAND) RESPECTIVELY. THE PULSES FLAG IS ALSO RESET BY P12, P40, P41, P42, P63, P70, P71 AND R40 AT MAIN ENGINE IGNITION. WITH THE EXCEPTION OF THESE CASES MODE SELECTION IS ALWAYS BASED UPON THE LAST ENTRY MADE IN THE DSKY. DURING A THRUSTING MANEUVER IN THE PGNS/ATTITUDE HOLD MODE THE PGNS WILL NOT BE RESPONSIBLE IF REGISTER OVERFLOWS OCCUR WITHIN THE LGC.

(17) CONTROL OF THE LM DPS, RCS AND APS IS TRANSFERRED FROM THE PGNS TO THE ABORT GUIDANCE SYSTEM (AGS) BY PLACING THE GUID CONT SWITCH FROM PGNS TO AGS.

THE AGS WILL BE CAPABLE OF TAKING OVER CONTROL OF THE LM DURING ANY PORTION OF THE LUNAR DESCENT OR ASCENT OR DURING EITHER OF THE ABORT PROGRAMS (P70 OR P71). THE AGS WILL GUIDE THE LM TO A SAFE ORBIT.

THE AGS MAY BE INITIALIZED BY THE LGC AT ANY TIME BY MANUAL SELECTION OF THE AGS INITIALIZATION ROUTINE (R47). IN THE EVENT THAT THE GUIDANCE CONTROL SWITCH IS CHANGED FROM PGNS TO AGS DURING A THRUSTING MANEUVER, THE LGC WILL CONTINUE COMPUTATION OF POSITION AND VELOCITY, THE DESIRED THRUST VECTOR AND THE DESIRED ATTITUDE ERRORS, HOWEVER THE PGNS WILL NOT BE RESPONSIBLE IF REGISTER OVERFLOWS OCCUR WITHIN THE LGC.

(18) THE PGNS CAN GENERATE TWO TYPES OF ATTITUDE ERRORS FOR DISPLAY ON THE FDAI;  
MODE I - SELECTED BY EXTENDED VERB 61. AUTOPILOT FOLLOWING ERRORS USED AS A MONITOR OF THE DAP'S ABILITY TO TRACK AUTOMATIC STEERING COMMANDS.

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MODE II - SELECTED BY EXTENDED VERB 62. TOTAL ATTITUDE ERRORS USED TO ASSIST CREW IN MANUALLY MANEUVERING THE VEHICLE.

PGNCS-DERIVED VEHICLE ATTITUDE RATES MAY ALSO BE DISPLAYED VIA SELECTION BY EXTENDED VERB 60. MODE II ATTITUDE ERROR DISPLAYS ARE AUTOMATICALLY SELECTED AT THE BEGINNING OF R60. WITH THE EXCEPTIONS INDICATED IN ASSUMPTION (16) ABOVE, DISPLAY SELECTION IS ALWAYS BASED UPON THE LAST ENTRY MADE IN THE DSKY. FOR A MORE DETAILED DESCRIPTION OF THESE DISPLAYS REFER TO SECTION 3 OF R567, PARA. 3.2.6.

(19) THE LOAD DAP DATA ROUTINE (R03) HAS BEEN PERFORMED PRIOR TO THE START OF THE POWERED LANDING MANEUVER AND SHOULD NOT BE REQUIRED DURING THIS PROGRAM.

(20) LGC AND CREW PROCEDURES IN CASES OF LGC-ASSUMED THRUST FAILURE ARE DEFINED BY THE DPS/APS THRUST FAIL ROUTINE (R40). THIS ROUTINE IS IN EFFECT DURING THIS PROGRAM UNTIL P68 SELECTION (VIA R00), HAVING BEEN ENABLED BY P63.

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(21) THIS PROGRAM IS AUTOMATICALLY SELECTED BY THE APPROACH PHASE PROGRAM (P64) AT THE COMPLETION OF THE LO GATE AIM CONDITIONS-TG LESS THAN TENDAPPR (TIME-TO-END-APPROACH-PHASE).

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(22) TWO ALARM CONDITIONS MAY BE ORIGINATED BY THE PGNCS POWERED LANDING EQUATIONS:  
(A) IF SUBROUTINE ROOTPSRS IN THE RG/VG CALCULATION FAILS TO CONVERGE IN 8 PASSES THE LGC WILL TURN ON THE PROGRAM ALARM LIGHT, STORE PROGRAM ALARM 21406 AND GO IMMEDIATELY TO THE FINAL AUTOMATIC REQUEST TERMINATE ROUTINE (R00). THIS ALARM COULD ONLY OCCUR IN P63 DURING IGNITION COMPUTATIONS.  
(B) IF AN OVERFLOW OCCURS ANYWHERE IN THE LANDING EQUATIONS THE LGC WILL TURN ON THE PROGRAM ALARM LIGHT, STORE ALARM CODE 1410, STOP ALL VEHICLE ATTITUDE RATES AND CONTINUE. THIS ALARM COULD OCCUR IN P63, P64, OR P65.

(23) THIS PROGRAM ALLOWS MANUAL CONTROL OF LM ATTITUDE AND THE SELECTION OF P66. DURING P65 (AND P63 AND P64) THE ASTRONAUT CAN DISPLAY THE PGNCS TOTAL GUIDANCE ERROR ON THE FDAI ERROR NEEDLES (ATTITUDE MON SWITCH IN PGNCS) BY HAVING KEYED IN V62 THRU THE DSKY. HE CAN THEN STEER OUT THE PGNCS P63 ATTITUDE ERRORS WITH THE AGS MANUALLY (GUID CONT IN AGS AND AGS MODE CONTROL IN ATT HOLD); OR WITH THE PGNCS MANUALLY (GLID CONT IN PGNCS AND PGNCS MODE CONTROL IN ATT HOLD) OR AUTOMATICALLY (PGNCS MODE CONTROL IN AUTO). THUS THERE ARE THREE ATTITUDE CONTROL SUBMODES IN P65 (AND P63 AND P64): AGS MANUAL; PGNCS MANUAL; OR PGNCS AUTO. A CAUTIONARY NOTE: IF THE ASTRONAUT HITS THE ROD (RATE-OF-DESCENT) SWITCH WHILE HE IS IN PGNCS ATT HOLD, THE LGC WILL IRREVOCABLY TRANSFER HIM OUT OF THE AUTO GUIDANCE PROGRAM MODES INTO THE ROD PROGRAM MODE (P66).

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(24) THE ASTRONAUT MAY MONITOR THE FOLLOWING PARAMETERS BY KEYING IN V16 N92E:

- (A) V16 N92
  - R1-THRCMD
  - R2-HDOT
  - R3-H

THRCMD-THE PERCENT THROTTLE DESIRED BY THE LGC BASED ON THE DPS RATED THRUST OF 10,500 POUNDS. IN PERCENT TO NEAREST PERCENT.

HDOT-THE PRESENT RATE OF CHANGE OF ALTITUDE (H). IN FPS TO NEAREST .1 FPS.

H-THE PRESENT ALTITUDE OF THE LM ABOVE THE LUNAR RADIUS AT THE INITIALLY DESIGNATED LANDING SITE. IN FEET TO NEAREST FOOT.

PROG                    LGC                    CREW                    CREW

CONT

.LGC  
.PROGRAM  
.SELECTION

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START LANDING PHASE  
(AUTC) PROGRAM  
(P65). DISPLAY P65  
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MONITOR DSKY:  
OBSERVE DISPLAY  
OF P65  
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#10

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RESET X-AXIS OVER-  
RIDE INHIBIT FLAG  
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#20

HOLD

.....  
MON . FLASH VERB-NOUN TO  
. REQUEST RESPONSE AND  
. DISPLAY ON DSKY:  
++ . VC6 N60  
+02 . R1-FORVEL  
+882 . R2-F DOT  
+ . R3-H

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MONITOR DSKY:  
OBSERVE VERB-NOUN  
FLASH TO REQUEST RE-  
SPONSE AND DISPLAY  
OF FORVEL, H DOT  
AND H.

#30

+ .  
+ . FORVEL-THE FORWARD  
+ . COMPONENT OF THE  
+ . HORIZONTAL VELOCITY  
+ . OF THE VEHICLE WITH  
+ . RESPECT TO THE MOON,  
+ . WHICH IS ESSENTIALLY  
+ . PARALLEL TO THE X-Z  
+ . PLANE OF THE VEHICLE  
+ . (FOR SMALL PITCH  
+02 . DISPLACEMENTS).  
++ . IN FPS TO NEAREST  
. +1 FPS.

(NOTE: THIS DISPLAY  
WILL CONTINUE FLASH-  
ING TO ALLOW THE  
ASTRONAUT TO ZERO  
ATTITUDE ERRORS ON  
THE LUNAR SURFACE  
AS OFTEN AS  
DESIRED).  
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#40

500

501

H DOT-THE PRESENT  
RATE OF CHANGE OF  
ALTITUDE (H). POLA-  
RITY INDICATES DES-  
CENT (-) OR ASCENT  
(+). POLARITY IS  
NOMINALLY - DURING  
THIS PROGRAM. IN FPS  
TO NEAREST .1 FPS

#50

H-THE PRESENT ALTI-  
TUDE OF THE LM ABOVE  
THE LUNAR RADIUS AT  
THE INITIALLY DESIG-  
NATED LANDING SITE.  
POLARITY IS + FOR  
ALTITUDES GREATER  
THAN THE ABOVE  
RADIUS. IN FEET TO  
NEAREST FOOT.

#60

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MONITOR FDAI AND OUT  
THE WINDOW:  
OBSERVE ATTITUDE  
TRANSIENT TO BRING  
LM TO LOCAL VERTICAL  
ATTITUDE WITH LM +Z  
AXIS DOWNRANGE.  
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#70

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START AUTOMATIC DES-  
CENT. NULL THE HORI-  
ZONTAL VELOCITY RE-  
LATIVE TO THE  
SURFACE AND MAINTAIN  
RATE OF DESCENT AT 3  
FEET PER SECOND.  
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MONITOR AUTOMATIC  
DESCENT USING ALL  
PGNCS AND LM DIS-  
PLAYS AND OUT THE  
WINDOW REFERENCES  
AS DESIRED.  
OBSERVE H DOT  
TO BE -00030.  
THIS PROGRAM DOES  
NOT ALLOW MANUAL  
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#80

#90

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CONTROL OF LM ATTITUDE OR THROTTLE.

IF MANUAL ATTITUDE CONTROL IS DESIRED PUT ATTITUDE CONTROL MODE SWITCH IN ATTITUDE HOLD.

#100

THE LGC WILL AUTOMATICALLY SELECT LANDING PHASE (ROD) PROGRAM (P66) AND MAINTAIN THE PRESENT RATE OF DESCENT AND PRESENT LM ATTITUDE. ATTITUDE AND RATE OF DESCENT MAY THEN BE MODIFIED BY MANUAL CONTROL. THE MODE II ATTITUDE ERROR NEEDLES WILL CONTINUE TO DISPLAY THE LAST ERROR WHEN EXIT WAS MADE FROM P65.

#110

IF MANUAL THROTTLE CONTROL IS DESIRED, ADVANCE THRUST/TRANSLATION CONTROLLER UNTIL LGC CONTRIBUTION TO TOTAL THRUST IS ZERO (THRUST INDICATOR- RIGHT SIDE), AND PUT THROTTLE CONTROL IN MANUAL. THE LGC WILL MAINTAIN THE PRESENT LM INERTIAL ATTITUDE. THROTTLE CONTROL WILL REVERT TO THE LEVEL COMMANDED BY THE THRUST/TRANSLATION CONTROLLER.

#120

THE LGC WILL MAINTAIN THE PRESENT LM INERTIAL ATTITUDE. THROTTLE CONTROL WILL REVERT TO THE LEVEL COMMANDED BY THE THRUST/TRANSLATION CONTROLLER.

#130

RATE OF DESCENT MAY THEN BE MODIFIED BY MANUAL THROTTLE CONTROL. LM ATTITUDE

#140

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WILL REMAIN INERTIA-  
LLY FIXED UNLESS  
MANUAL ATTITUDE  
CONTROL IS EXERCISED  
HOWEVER MANUAL ATT-  
ITUDE CONTROL CAN-  
NOT BE EXERCISED  
UNLESS THE ATTITUDE  
CONTROL MODE SWITCH  
IS IN ATTITUDE  
CONTROL.

#150

ONCE THIS PRO-  
GRAM IS EXITED IT  
MAY NOT BE RETURNED  
TO FROM P66.

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#160

MONITOR DSKY:  
WHEN H IS  
APPROXIMATELY XX FT  
OBSERVE TRACKER FAIL  
LIGHT TO COME ON  
INDICATING THAT LR  
IS NO LONGER RETURN-  
ING GOOD DATA.

#170

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MONITOR DSKY:  
WHEN ACTUAL ALTI-  
TUDE IS APPROXI-  
MATELY 4.4 FT,  
OBSERVE LUNAR  
CONTACT LIGHT TO  
COME ON INDICATING  
THAT THE PROBE(S) ON  
THE LM LANDING GEAR  
HAVE MADE CONTACT

#180





505

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+02  
+EDIT

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WAIT FOR KEYBOARD  
ENTRY

-----  
AM I FINISHED WITH  
THE DISPLAY?

.N .Y

-----  
KEY IN TERMINATE

-----  
TERMINATE FLASH UPON  
RECEIPT OF V37E68E

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WHEN LANDING HAS  
BEEN SUCCESSFULLY  
COMPLETED, KEY IN  
V37E68E TO SELECT  
THE LANDING CON-  
FIRMATION PROGRAM  
(P68).

.P	.V	.T	.V
.R	.3	.E	.3
.D	.2	.R	.7
.C	.E	.M	.E
.E	.	.I	.6
.E	.	.N	.8
.D	.	.A	.E
.	.	.T	.
.	.	.E	.

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COMMAND  
ZERO AT-  
TITUDE  
ERRORS

-----  
COMMAND  
ZERO

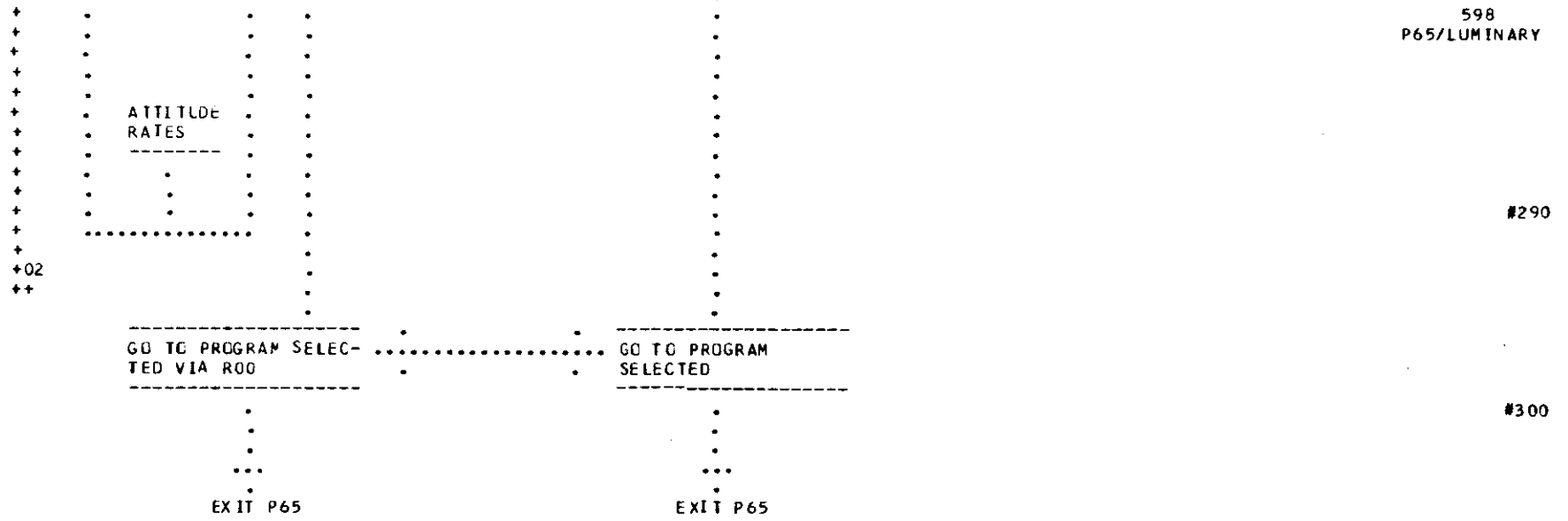
#240

#250

#260

#270

#280



CHANGE CONTROL NOTES

REV 00 PCR 31  
REV 01 PCR 85, 164, 470, 542  
REV 00(LUM 1A) PCR 737  
REV 01(LUM 1B) PCR 838, 841, EDITORIAL  
REV 02(LUM 1C) PCR 285, 882, EDITORIAL

506

## LANDING PHASE (ROD) PROGRAM (P66)

REV 02 12/03/69

- PURPOSE:
- (1) TO MODIFY THE RATE OF DESCENT OF THE LM (WITH RESPECT TO THE LUNAR SURFACE) IN RESPONSE TO ASTRONAUT ORIGINATED INPUTS TO THE LGC VIA THE LM RATE OF DESCENT SWITCH.
  - (2) TO MODIFY THE INERTIAL ATTITUDE OF THE LM IN RESPONSE TO ASTRONAUT ORIGINATED INPUTS VIA THE ATTITUDE CONTROLLER ONLY IF THE ATTITUDE CONTROL SWITCH IS IN ATTITUDE HOLD.
  - (3) TO MAINTAIN A CONSTANT RATE OF DESCENT AND LM INERTIAL ATTITUDE IN THE ABSENCE OF MANUAL CONTROL INPUTS.
  - (4) TO UPDATE THE LM STATE VECTOR WITH VEHICLE ACCELERATION AND LANDING RADAR (LR) DATA.

- ASSUMPTIONS:
- (1) THE LM IS IN THE LATE STAGES OF LANDING, WITH A RELATIVELY LOW INERTIAL VELOCITY.
  - (2) THE IMU IS ON AND ACCURATELY ALIGNED TO A LANDING SITE ORIENTATION DEFINED FOR THE DESIGNATED LANDING SITE AND THE NOMINAL TIME OF LANDING (T(LAND)).
  - (3) THE LANDING RADAR (LR) IS ON, CHECKED OUT, AND SHOULD HAVE BEEN PROVIDING TO THE LGC VELOCITY AND RANGE INFORMATION WITH RESPECT TO THE MOON. THIS INFORMATION SHOULD HAVE BEEN INCORPORATED INTO THE LM STATE VECTOR. THE LGC/LR OPERATION IS UNDER THE CONTROL OF THE DESCENT STATE VECTOR UPDATE ROUTINE (R12) WHICH IS ALREADY IN PROCESS.
  - (4) THE LGC WILL NEITHER DESIGNATE NOR READ THE RENDEZVOUS RADAR (RR) DURING THIS PROGRAM.
  - (5) THE ENTIRE POWERED LANDING MANEUVER (BRAKING, APPROACH AND LANDING) WILL BE ACCOMPLISHED USING THE DPS ENGINE.
  - (6) THE FOLLOWING PARAMETERS REQUIRED BY THIS PROGRAM HAVE BEEN STORED IN THE LGC SINCE LGC INITIALIZATION BY ERASABLE REGISTER LOAD.
    - (A) THE LM STATE VECTOR. THE LGC HAS UPDATED THIS AS REQUIRED DURING THRUSTING. NO FURTHER STATE VECTOR UPDATES FROM ANY SOURCE OTHER THAN THE LR WILL BE ACCEPTED BY THIS PROGRAM.
  - (7) THE DPS IS NOT THROTTLEABLE OVER THE WHOLE RANGE FROM 0 PERCENT TO MAXIMUM. IT MUST BE OPERATED EITHER AT MAXIMUM THROTTLE OR OVER A SPECIFIC THROTTLE RANGE OF LOWER SETTINGS. THESE THROTTLE SETTINGS ARE SPECIFIED IN SECTION 5.3.4 OF R567 AND ARE TOTAL THROTTLE SETTINGS, I.E.: THE SUM OF THE MANUAL SETTING (WHOSE MINIMUM IS 10 PERCENT), AND THE PGNC'S COMMANDED SETTING.
 

THIS PROGRAM ASSUMES THE THROTTLE CONTROL TO BE IN AUTO (THE DPS RECEIVES THE SUM OF THE MANUAL AND PGNC'S COMMANDED SETTINGS) AND THE MANUAL THROTTLE TO BE SET AT A LEVEL LESS THAN THAT REQUIRED BY THE LGC. NOMINALLY THE THROTTLE WILL REMAIN WITHIN THE ALLOWABLE THROTTLE RANGE THROUGHOUT THIS PROGRAM.
  - (8) DURING THE POWERED LANDING MANEUVER, THE LGC WILL MONITOR THE PRESENCE OR ABSENCE OF THE "NON-ATTITUDE HOLD" DISCRETE. THIS DISCRETE IS ISSUED TO THE LGC WHEN THE ATTITUDE MODE CONTROL SWITCH IS IN THE AUTO POSITION. SHOULD THIS DISCRETE APPEAR DURING THE POWERED LANDING MANEUVER, THE LGC ASSUMES THAT IT NO LONGER HAS COMPLETE AUTOMATIC CONTROL OF THE MANEUVER.
 

THE MONITOR AND THE ASSOCIATED LGC LOGIC IS INCLUDED IN THE LANDING AUTO MODES MONITOR ROUTINE (R13) WHICH IS ALREADY IN PROCESS.
  - (9) THE LPD OPTION IS NOT PROVIDED THE CREW DURING THIS PROGRAM.
  - (10) THE LGC ASSUMES ALL ATTITUDE CHANGES TO BE MANUAL THROUGHOUT THIS PROGRAM. THE LGC WILL HOLD INERTIAL ATTITUDE IN EITHER MODE, HOWEVER ONLY IN THE ATTITUDE HOLD MODE MAY THE ATTITUDE BE CHANGED BY MANUAL CONTROL VIA THE ATTITUDE CONTROLLER.

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(11) THE CREW HAS THE CAPABILITY TO DISPLAY LGC CALCULATED VALUES OF FORWARD VELOCITY, LATERAL VELOCITY, ALTITUDE AND ALTITUDE RATE ON CERTAIN LM METERS DURING THIS PROGRAM. THE CALCULATION OF THESE PARAMETERS IS UNDER THE CONTROL OF THE LANDING ANALOG DISPLAYS ROUTINE (R1C) WHICH IS ALREADY IN PROCESS.

(12) DURING THIS PROGRAM THE LGC MONITORS THE OUTPUT OF THE RATE OF DESCENT (ROD) SWITCH IN THE LM. THIS SWITCH IS OPERATED BY THE ASTRONAUT IN RESPONSE TO HIS ASSESSMENT OF THE PRESENT LM RATE OF DESCENT BASED ON OUT-THE-WINDOW REFERENCES AND LM/DSKY DISPLAYS.

SWITCH OPERATION IS ON AN INCREMENTAL BASIS, EITHER - (INCREASE ROD) OR + (DECREASE ROD). EACH COMMAND RESULTS IN AN LGC-COMMANDED CHANGE OF "RODSCALE" FT/SEC IN THE LM RATE OF DESCENT. ("RODSCALE" IS A VALUE LOADED INTO ERASABLE STORAGE PRIOR TO FLIGHT)

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(13) AN ABORT FROM THE LUNAR DESCENT MAY BE REQUIRED AT ANY TIME DURING THE POWERED DESCENT (P63), (P64), (P65), OR (P66).

FOR ABORTS AFTER DPS IGNITION FOR THE POWERED LANDING MANEUVER, TIME IS CRITICAL. DURING THIS PERIOD AN ABORT IS COMMANDED BY PUSHING ONE OF TWO BUTTONS IN THE LM. THE ABORT MAY BE COMMANDED TO USE THE DESCENT STAGE (ABORT BUTTON) OR THE ASCENT STAGE (ABORT STAGE BUTTON). IF THE DESCENT STAGE IS SELECTED, AND THE DPS PROPELLANT APPROACHES EXHAUSTION, CONTROL MUST BE SWITCHED TO THE ASCENT STAGE BY THE CREW BY ASCENT STAGE SELECTION (ABORT STAGE BUTTON).

DURING THE POWERED LANDING MANEUVER, THE LGC WILL CONTINUOUSLY MONITOR THE ABORT AND ABORT STAGE DISCRETES, AND UPON RECEIPT OF EITHER WILL TERMINATE THE PROGRAM IN PROCESS AND CALL THE APPROPRIATE ABORT PROGRAM (DPS ABORT PROGRAM (P70) OR APS ABORT PROGRAM (P71)). BOTH ABORT PROGRAMS WILL GUIDE THE LM TO AN ORBIT AS SPECIFIED IN SECTION 5.4.3 OF R567.

THE MONITOR OF THE ABORT AND ABORT STAGE PUSHBUTTONS IS CONTROLLED BY THE ABORT DISCRETES MONITOR ROUTINE (R11) WHICH IS ALREADY IN PROCESS.

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+02  
+EDIT  
+  
+02  
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(14) IF A THRUSTING MANEUVER IS PERFORMED WITH THE GUIDANCE CONTROL SWITCH AT PGNS AND THE MODE CONTROL SWITCH AT ATTITUDE HOLD THE PGNS WILL HOLD THE VEHICLE ATTITUDE AND WILL GENERATE EITHER MODE I OR MODE II ATTITUDE ERRORS AND VEHICLE ATTITUDE RATES FOR DISPLAY ON THE FDAI. THE CREW MAY EXERCISE MANUAL ATTITUDE CONTROL ABOUT ALL VEHICLE AXES WITH THE ACA IN EITHER THE RATE COMMAND OR MINIMUM IMPULSE MODE DEPENDING UPON THE STATUS OF THE PULSES FLAG. IT IS STRONGLY RECOMMENDED THAT POWERED FLIGHT NOT BE ATTEMPTED IN THE MINIMUM IMPULSE MODE. THE PULSES FLAG IS SET OR RESET BY EXTENDED VERBS 76 (MINIMUM IMPULSE) AND 77 (RATE COMMAND) RESPECTIVELY. THE PULSES FLAG IS ALSO RESET BY P12,P40,P41,P42,P63,P70,P71 AND R40 AT MAIN ENGINE IGNITION. WITH THE EXCEPTION OF THESE CASES, MODE SELECTION IS ALWAYS BASED UPON THE LAST ENTRY MADE IN THE DSKY. DURING A THRUSTING MANEUVER IN THE PGNS/ATTITUDE HOLD MODE, THE PGNS WILL NOT BE RESPONSIBLE IF REGISTER OVERFLOWS OCCUR WITHIN THE LGC.

(15) CONTROL OF THE LM DPS, RCS, AND APS IS TRANSFERRED FROM THE PGNS TO THE ABORT GUIDANCE SYSTEM (AGS) BY PLACING THE GUID CONT SWITCH FROM PGNS TO AGS.

THE AGS WILL BE CAPABLE OF TAKING OVER CONTROL OF THE LM DURING ANY PORTION OF THE LUNAR DESCENT OR ASCENT OR DURING EITHER OF THE ABORT PROGRAMS (P70 OR P71). THE AGS WILL GUIDE THE LM TO A SAFE ORBIT.

THE AGS MAY BE INITIALIZED BY THE LGC AT ANY TIME BY MANUAL SELECTION OF THE AGS INITIALIZATION ROUTINE (R47). IN THE EVENT THAT THE GUIDANCE CONTROL SWITCH IS CHANGED FROM PGNS TO AGS DURING A THRUSTING MANEUVER, THE LGC WILL CONTINUE COMPUTATION OF POSITION AND VELOCITY, THE DESIRED THRUST VECTOR, AND THE DESIRED ATTITUDE ERRORS; HOWEVER THE PGNS WILL NOT BE RESPONSIBLE IF REGISTER OVERFLOWS OCCUR WITHIN THE LGC BECAUSE THE AGS IS NOT MAINTAINING REASONABLE ATTITUDE CONTROL.

(16) THE LOAD DAP DATA ROUTINE (R03) HAS BEEN PERFORMED PRIOR TO THE START OF THE POWERED LANDING MANEUVER AND SHOULD NOT BE REQUIRED DURING THIS PROGRAM.

(17) LGC AND CREW PROCEDURES IN CASES OF LGC-ASSUMED THRUST FAILURE ARE DEFINED BY THE DPS/APS THRUST FAIL ROUTINE (R40). THIS ROUTINE IS IN EFFECT DURING THIS PROGRAM UNTIL SELECTION (VIA ROD) OF THE LANDING CONFIRMATION PROGRAM (P66), HAVING BEEN ENABLED BY P63.

(18) THIS PROGRAM IS AUTOMATICALLY SELECTED BY THE LANDING AUTO MODES MONITOR ROUTINE (R13) DURING THE POWERED LANDING MANEUVER WHEN:

(A) ATTITUDE CONTROL IS FIRST TRANSFERRED TO MANUAL (ATTITUDE CONTROL SWITCH TO ATTITUDE HOLD) IF THE THROTTLE CONTROL REMAINS AUTO (THROTTLE SWITCH IN AUTO) AND THE ASTRONAUT COMMANDS A NET CHANGE IN THE RATE OF DESCENT BY MEANS OF THE ROD SWITCH.



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DD STOPRATE TO TER-  
MINATE MANEUVER (IF  
ANY) IN PROCESS  
-----

.....  
-----  
RESET X-AXIS OVER-  
RIDE INHIBIT FLAG.  
(NOTE: DEPENDING UP-  
ON THE TIME OF SELE-  
CTION OF THIS PRG-  
RAM THE X-AXIS OVER-  
RIDE OPTION MAY NOT  
BE INHIBITED AND  
THIS FUNCTION IS RE-  
DUNDANT.)  
-----

.....  
-----  
COMPUTE FOR VEL,  
H DGT, AND H  
-----

++  
+02  
+285  
+882

.....

+02

510

#30

#40

#50

#60

#70

511

+  
+  
+  
+  
++

HOLD

MON

++  
+02  
+882

+  
+  
+  
+  
+  
+02  
++

FLASH VERB-NOUN TO  
REQUEST RESPONSE AND  
DISPLAY ON DSKY:

V06 N60  
R1-FORVEL  
R2-H DOT  
R3-H

FORVEL-THE FORWARD  
COMPONENT OF THE  
HORIZONTAL VELOCITY  
OF THE VEHICLE WITH  
RESPECT TO THE MCON  
WHICH IS ESSENTIALLY  
PARALLEL TO THE X-Z  
PLANE OF THE VEHICLE  
(FOR SMALL PITCH  
DISPLACEMENTS).

IN FPS TO NEAREST .1  
FPS

H DOT-THE PRESENT  
RATE OF CHANGE OF  
ALTITUDE (H). POLA-  
RITY INDICATES DES-  
CENT (-), OR ASCENT  
(+). POLARITY IS  
NOMINALLY - DURING  
THIS PROGRAM. IN FPS  
TO NEAREST .1 FPS

H-THE PRESENT RADAR  
UPDATED ALTITUDE OF  
THE LM ABOVE THE  
LUNAR SURFACE.  
POLARITY IS +  
FOR ALTITUDES  
GREATER THAN THE  
ABOVE RADIUS. IN  
FEET TO NEAREST

MONITOR DSKY:  
OBSERVE VERB-NOUN

FLASH TO REQUEST RE-  
SPONSE AND DISPLAY  
OF FORVEL, H DOT  
AND H.

(NOTE: THIS DISPLAY  
WILL CONTINUE FLASH-  
ING TO ALLOW THE  
ASTRONAUT TO ZERO  
ATTITUDE ERRORS ON  
THE LUNAR SURFACE AS  
OFTEN AS DESIRED).

#80

#90

#100

#110

FCCT.

#120

MONITOR RATE OF  
DESCENT INPUTS TO  
THE LGC

MONITOR PROGRESS OF  
POWERED LANDING  
MANEUVER USING LM  
DISPLAYS, DSKY DIS-  
PLAYS AND WINDOW.  
USING RATE OF  
DESCENT SWITCH,  
COMMAND DESIRED RATE  
OF DESCENT.

#130

COMPUTE REQUIRED  
CHANGE IN THROTTLE  
SETTING FOR PRESENT-  
LY DESIRED ROD.

IF MANUAL ATTIT-  
UDE CONTROL IS DE-  
SIRED USE ATTITUDE  
CONTROLLER.

#140

COMMAND REQUIRED  
THROTTLE SETTING

MONITOR THRUST  
INDICATOR (RIGHT  
SIDE) TO ENSURE THAT  
LGC THROTTLE COMMAND  
DOES NOT EXCEED XX  
PERCENT. (NOTE: THE  
LGC WILL NOT INTEN-  
TIONALLY COMMAND A  
THRUST LEVEL LARGER  
THAN THAT SPECIFIED  
BY A PAD-LOADED  
LIMIT (NOMINALLY 60  
PERCENT) NO MATTER  
WHAT THE CIRCUM-  
STANCES ARE.

#150

WAIT ONE  
SECOND

IF MANUAL THROTT-  
LE CONTROL IS DESIR-  
ED, ADVANCE THRUST/  
TRANSLATION CONTROL-  
LER UNTIL LGC CON-  
TRIBUTION TO TOTAL  
THRUST IS ZERO  
(THRUST INDICATOR-  
RIGHT SIDE), AND PUT  
THROTTLE SWITCH TO  
MANUAL. THE LGC WILL

#160



513  
+  
+  
+  
+  
+  
+02  
+285  
+02  
++

MAINTAIN THE PRESENT  
LM INERTIAL ATTITUDE.  
THROTTLE CONTROL WILL REVERT TO  
THE LEVEL COMMANDED  
BY THE THRUST/TRANSLATION  
CONTROLLER.

#170

RATE OF DESCENT  
MAY THEN BE MODIFIED  
BY MANUAL THROTTLE  
CONTROL. LM ATTITUDE  
WILL REMAIN INERTIALLY  
FIXED UNLESS MANUAL  
ATTITUDE CONTROL IS  
EXERCISED, HOWEVER  
MANUAL ATTITUDE CONTROL  
CANNOT BE EXERCISED  
UNLESS THE ATTITUDE  
CONTROL MODE SWITCH IS  
IN ATTITUDE HOLD.

#180

ONCE THIS PROGRAM IS  
EXITED IT MAY BE RETURNED  
TO BY PLACING THE THROTTLE  
SWITCH IN AUTO.

#190

•  
•  
•

MONITOR DSKY:  
WHEN H IS APPROXIMATELY  
XX FT OBSERVE TRACKER  
FAIL LIGHT TO COME ON  
INDICATING THAT LR IS  
NO LONGER RETURNING  
GOOD DATA.

#200

•  
•  
•

MONITOR DSKY:  
WHEN ACTUAL ALTI-

#210

TUDE IS APPROXI-  
MATELY 4.4 FT,  
OBSERVE LUNAR  
CONTACT LIGHT TO  
COME ON INDICATING  
THAT THE PROBE(S) ON  
THE LM LANDING GEAR  
HAVE MADE CONTACT  
WITH THE LUNAR SUR-  
FACE.

#220

-----  
:  
:  
-----  
PUSH ENGINE STOP  
SWITCH TO TERMINATE  
DPS THRUST

#230

-----  
:  
:  
-----  
KEY IN PROCEED OR  
V32E ITC COMMAND  
ZERO ATTITUDE ERRORS  
AND RATES. THIS WILL  
PREVENT RCS JET FIR-  
INGS ON THE LUNAR  
SURFACE UNTIL P68  
PLACES THE DAP IN  
THE MINIMUM IMPULSE  
MCCE)

#240

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:  
:  
-----  
CHECK THRUST INDICA-  
TOR (LEFT SIDE) TO  
INDICATE 0 PERCENT  
CHAMBER PRESSURE.

#250

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:  
:  
-----  
STANDBY ABORT STAGE  
PUSHBUTTON IN CASE

#260

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+02  
+EDIT  
+  
+  
+  
+  
+  
+  
+  
+02  
++

5"

LM STARTS TO TIP  
OVER WHILE LANDING.

AM I FINISHED WITH  
THE DISPLAY?

#270

WAIT FOR KEY BOARD  
ENTRY

KEY IN TERMINATE

#280

TERMINATE FLASH UPON  
RECEIPT OF V37E68E

WHEN LANDING HAS  
BEEN SUCCESSFULLY  
COMPLETED, KEY IN  
V37E68E TO SELECT  
THE LANDING CON-  
FIRMATION PROGRAM  
(P68).

#290

.P	.V	.T	.V
.R	.3	.E	.3
.O	.2	.R	.7
.C	.E	.M	.E
.E	.	.I	.6
.E	.	.N	.8
.D	.	.A	.E
.	.	.T	.
.	.	.E	.

#300

COMMAND  
ZERO AT-  
TITUDE  
ERRORS

#310

-----  
COMMAND  
ZERC  
ATTITUDE  
RATES  
-----

#320

-----  
GO TO PROGRAM SELEC-  
TED VIA ROO  
-----

-----  
GO TO PROGRAM  
SELECTED  
-----

#330

EXIT P66

EXIT P66

CHANGE CONTRCL NOTES

REV 00 PCR 31  
REV 01 PCR 85,210,470,542  
REV 00(LUM 1A) PCR 700,737  
REV 01(LUM 1B) PCR 838,841, EDITORIAL  
REV 02(LUM 1C) PCR 285,882, EDITORIAL

517

LANDING CONFIRMATION PROGRAM (P68)

REV 03 12/03/69

- PURPOSE:
- (1) TO TERMINATE LANDING PROGRAM AND CAP FUNCTIONS.
  - (2) TO INITIALIZE THE LGC FOR LUNAR SURFACE OPERATION.
  - (3) TO PERMIT THE ASTRONAUT TO PREVENT RCS JET FIRINGS ON THE LUNAR SURFACE.

ASSUMPTIONS: (1) THE FOLLOWING DISPLAY IS AVAILABLE DURING THE PROGRAM BY KEYING IN V85E (SEE EXTENDED VERBS).

V16N56  
 R1 - RR LOS AZIMUTH  
 R2 - RR LOS ELEVATION  
 R3 - BLANK

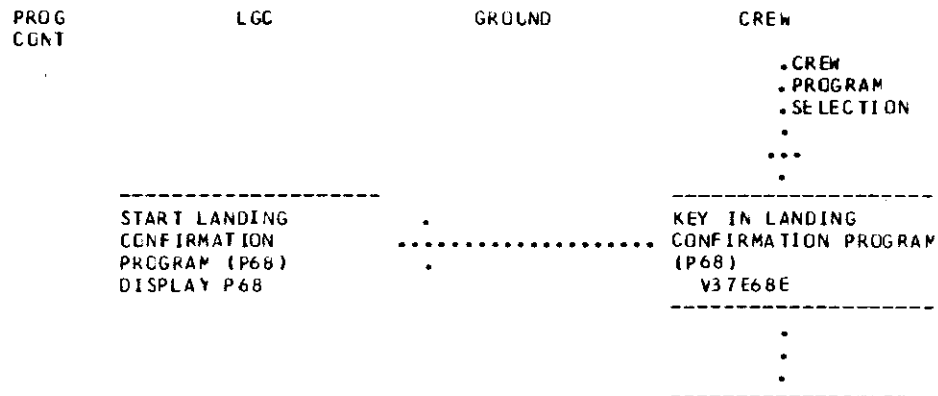
WHERE: RR LOS AZIMUTH - THE ANGLE BETWEEN THE LM X/Z PLANE AND THE RR LOS VECTOR. POSITIVE ROTATION IS FROM THE LM +Z AXIS TO THE LM +Y AXIS. IN DEGREES TO THE NEAREST .01 DEGREE.

RR LOS ELEVATION - THE ANGLE BETWEEN THE LM +Z AXIS AND THE PROJECTION OF THE RR LOS VECTOR ON THE LM X/Z PLANE. POSITIVE ROTATION IS POSITIVE ROTATION ABOUT THE LM +Y AXIS.

++  
 +03  
 +285  
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- (2) THIS PROGRAM IS SELECTED BY THE ASTRONAUT BY DSKY ENTRY. IT IS TO BE SELECTED ONLY AFTER THE LM HAS LANDED ON THE LUNAR SURFACE (P65 OR P66).
- (3) V37E68E SELECTION OF P68 WILL TERMINATE AVERAGE G AND COMMAND THE ENGINE OFF (REFER TO R00).
- (4) THE SELECTION OF THIS PROGRAM PLACES THE DAP IN THE MINIMUM IMPULSE COMMAND MODE. AS LONG AS THE ASTRONAUT KEEPS THE MODE CONT SWITCH IN ATT HCLD, RCS JET FIRINGS WILL NOT OCCUR, EVEN WHILE THE PLATFORM IS BEING GYRO TORQUED (IN P57).

++  
 +C3  
 +EDIT  
 ++



#10

MONITOR DSKY  
DISPLAY OF P68

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COMMAND ZERO  
ATTITUDE ERRORS

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SET PULSES  
FLAG

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+03  
+EDIT  
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(AT THIS TIME THE  
DAP IS PLACED IN THE  
MINIMUM IMPULSE  
COMMAND MODE).  
PLACE THE MODE CONT  
SWITCH IN ATT HOLD  
AND THE DAP WILL NOT  
FIRE RCS JETS. P12  
WILL AUTOMATICALLY  
PLACE THE DAP BACK  
INTO RATE COMMAND/  
ATTITUDE HOLD MODE  
AT MAIN ENGINE  
IGNITION.  
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SET SURFACE FLAG

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RESET ABRFT ENABLE  
FLAG

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#20

#30

#40

#50

#60

517

-----  
SET APS FLAG  
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-----  
RESET LANDING ANALOG  
DISPLAYS FLAG  
-----

-----  
SET LR BYPASS FLAG  
-----

-----  
STORE PRESENT POSI-  
TION VECTOR AS LAND-  
ING SITE IN LUNAR  
FIXED COORDINATES  
(REFER TO SECTION  
5.3.4 OF R567).  
-----

HOLD .  
..... SNAP .

-----  
FLASH VERB-NOUN TO  
REQUEST RESPONSE AND  
DISPLAY LGC CALCUL-  
ATED LANDING SITE  
COORDINATES:  
VC6N43  
R1-LAT  
R2-LONG  
R3-ALT

LAT-SELENOGRAPHIC  
LATITUDE OF THE LGC-  
ASSUMED PRESENT  
LANDING SITE. PCLA-  
RITY INDICATES NORTH  
(+) OR SOUTH (-).

-----  
OBSERVE VERB-NCUN  
FLASH TO REQUEST  
RESPONSE AND DISPLAY  
OF LGC CALCULATED  
LANDING SITE COORDI-  
NATES.  
-----

-----  
RECORD THESE VALUES.  
-----

#70

#80

#90

#100

#110

IN DEGREES TO NEAR-  
EST .01 DEGREES .

LONG-SELENOGRAPHIC  
LONGITUDE OF THE  
LGC-ASSUMED PRESENT  
LANDING SITE. POLA-  
RITY INDICATES EAST  
(+) OR WEST (-). IN  
DEGREES TO NEAREST  
.01 DEGREES .

#120

ALT-THE PRESENT  
ALTITUDE OF THE LM  
ABOVE THE LUNAR  
RADIUS AT THE  
INITIALLY DESIGNATED  
LANDING SITE (IF RE-  
START OCCURS-ABOVE  
THE LUNAR RADIUS AT  
THE LGC-ASSUMED  
PRESENT LANDING  
SITE, I.E. = 0).  
THIS VALUE SHOULD  
NOMINALLY BE 0000  
EXCEPT FOR ACCRUED  
ERRORS FROM THE LR  
IN THE LAST PHASES  
OF THE LANDING. IN  
NAUTICAL MILES TO  
NEAREST .1 NM.

#130

#140

-----  
ENSURE THAT THE LM  
IS STABILIZED UPON  
THE SURFACE OF THE  
MOON AS WELL AS  
POSSIBLE.  
-----

#150

-----  
WAIT FOR KEYBOARD  
ENTRY

..... KEY IN PROCEED  
-----

#160

TERMINATE FLASH UPON

520



521

RECEIPT OF PROCEED

.P  
.R  
.D  
.C  
.E  
.E  
.D  
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#170

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FROM LGC CALCULATED  
LANDING SITE COORDI-  
NATES AND THE PRE-  
SENT ICU/GIMBAL  
ANGLES COMPLETE AND  
STORE THE PRESENT  
LM ATTITUDE WITH RE-  
SPECT TO THE LUNAR  
SURFACE.  
DEFINE LUNAR GRAVITY  
VECTOR TO BE  
PARALLEL TO THE  
LM X AXIS FOR USE  
BY P57.  
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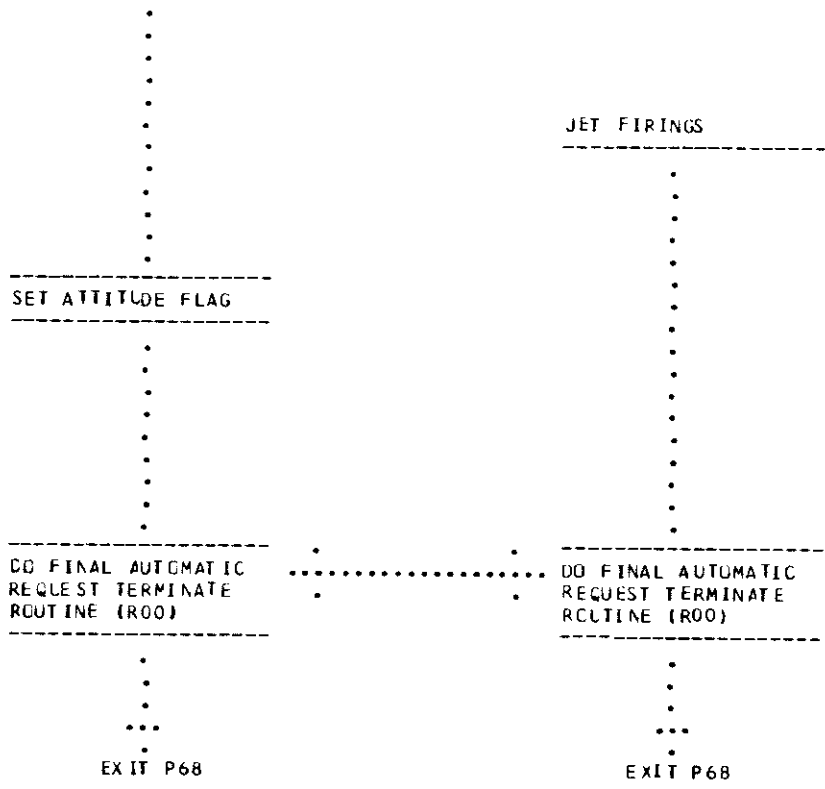
#180

#190

#200

++  
+03  
+EDIT  
++

-----  
NOTE: THE ASTRONAUT  
MUST SWITCH ATTITUDE  
CONTROL FROM AUTO  
TO ATT HOLD TO TURN  
OFF THE DAP IN ORDER  
TO PREVENT SPURIOUS



#210

#220

#230

#240

CHANGE CONTROL NOTES

LOGIC REV 0C PCR 470  
 REV 01 PCR 99, 419, 546, 547, 623  
 REV 02 (LUM 1B) PCR 838, EDITORIAL  
 REV 03 (LUM 1C) PCR 285, EDITORIAL

522