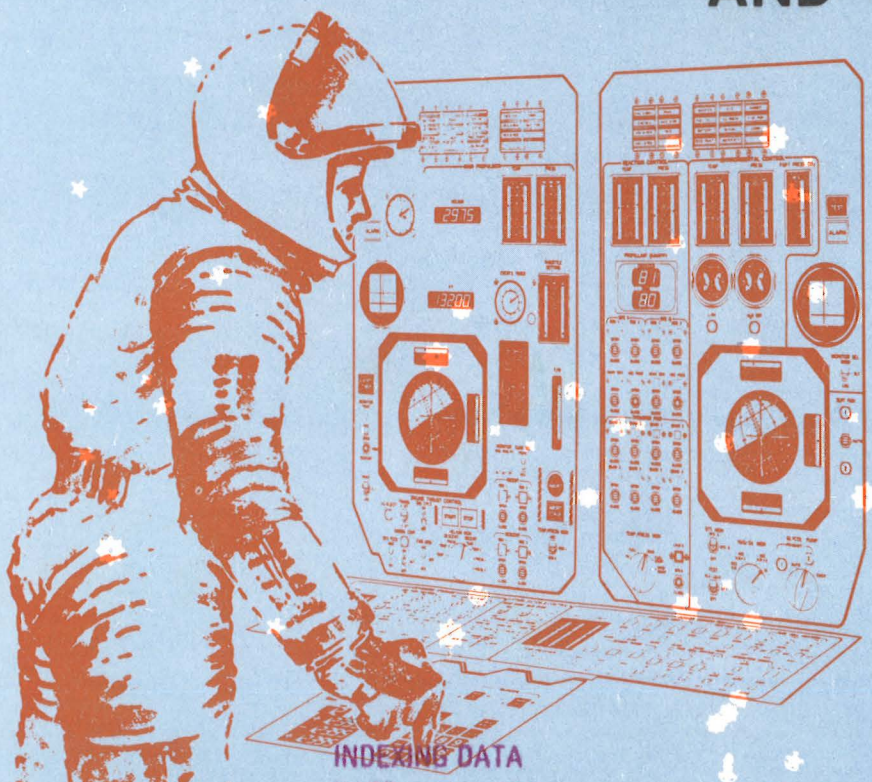
* APOLLO GUIDANCE AND NAVIGATION SYSTEM STUDY GUIDE

LM PRIMARY GUIDANCE NAVIGATION AND CONTROL SYSTEM



INDEXING DATA

DATE	OPR	#	T	PGM	SUBJECT	SIGNATOR	LOC
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* LM DIGITAL AUTOPILOT

PROGRAM SUNDANCE

REVISION 302

AC ELECTRONICS DIVISION GENERAL MOTORS CORPORATION

APOLLO

LUNAR MODULE

PRIMARY GUIDANCE, NAVIGATION AND CONTROL SYSTEM

STUDENT STUDY GUIDE

THE LM DIGITAL AUTOPILOT

PROGRAMED LOGIC DESCRIPTION

DAP 3100

PREPARED BY

FIELD SERVICE TRAINING DEPARTMENT

AC ELECTRONICS

DIVISION OF GENERAL MOTORS

MILWAUKEE, WISCONSIN

1 SEPTEMBER 1968

PREFACE

This student study guide has been prepared by AC Electronics in response to:

Contract NAS 9-497

for

System Assembly and Test, Inertial

Measurement Unit, Coupling Display Unit

Power and Servo Assembly - Project APOLLO

This study guide contains training material and should be used for INSTRUCTIONAL PURPOSES ONLY.

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* To be added at a later date

OBJECTIVES

The primary objective of this study guide is to provide a detailed description of the LM Digital Autopilot logic structure, as assembled in the Apollo guidance program Sundance. Other objectives of this study guide are to provide the student with:

a. A base for understanding the Autopilot's overall hardware, software and operational mission compatibility.

b. A ready reference to the overall control capabilities of the LM DAP, for use in and out of the classroom.

c. a logic description of some of the primary DAP software interfaces.

d. A guide for understanding and reading the coded Digital Autopilot in the Sundance listing.

REFERENCES

AGC Program Sundance, Rev. 302	2021110-021
Guidance System Operations Plan	R557

SECTION I

LM DAP CONTROL INTRODUCTION

LM DAP CONTROL SUMMARY

DAP ACTIVATED:	Guidance Control Switch - PGNS Mode Control Switch - AUTO or ATT. HOLD IMU Operate Circuit Breaker - CLOSED
ASTRONAUT DATA LOAD:	Key in V48E for Load Routine (R03) Flashing V01N46 R1 = ABCDE

Code	Description
A = 1	CSM docked
A = 0	CSM not docked
B = 0	Two jet X-Axis translation (System A Jets)
B = 1	Two jet X-Axis translation (System B Jets)
B = 2	Four jet X-Axis translation (Both Systems)
C = 0	Manual rate CMD. fine scaling (4°/sec max.)
C = 1	Manual rate CMD. coarse scaling (20°/sec max.)
D = 0	Attitude deadband of 0.3 degrees
D = 1	Attitude deadband of 5.0 degrees
E = 0	Kalcmanu rate of 0.2 degrees/second
E = 1	Kalcmanu rate 0.5 degrees/second
E = 2	Kalcmanu rate of 2 degrees/second
E = 3	Kalcmanu rate of 10 degrees/second

SELECTED FOR AUTOMATIC MANEUVERS

CONTROL MODES:

Automatic Modes

1. Automatic Maneuver - An attitude change commanded in coasting flight by an external program or by astronaut via DSKY.
2. Automatic Steering - An attitude change commanded in powered flight by a thrusting program.
3. Attitude Hold - Holding the attitude, within a deadband to a specified value (also holding the attitude rate to within a deadband).

Manual Modes

1. Rate Command - acquires an attitude rate proportional to the rotational hand control deflection.
2. Rate Damp - reduces the rate to a deadband as a result of zero rate command (stick in detent). Reverts to ATT. HOLD then.
3. X-axis Override - a rate command (for x-axis only) to override any automatic mode control, except Auto Maneuver.
4. Min. Impulse - commands a minimum jet firing pulse per each rotational hand control deflection. No attitude or rate hold while in this mode.

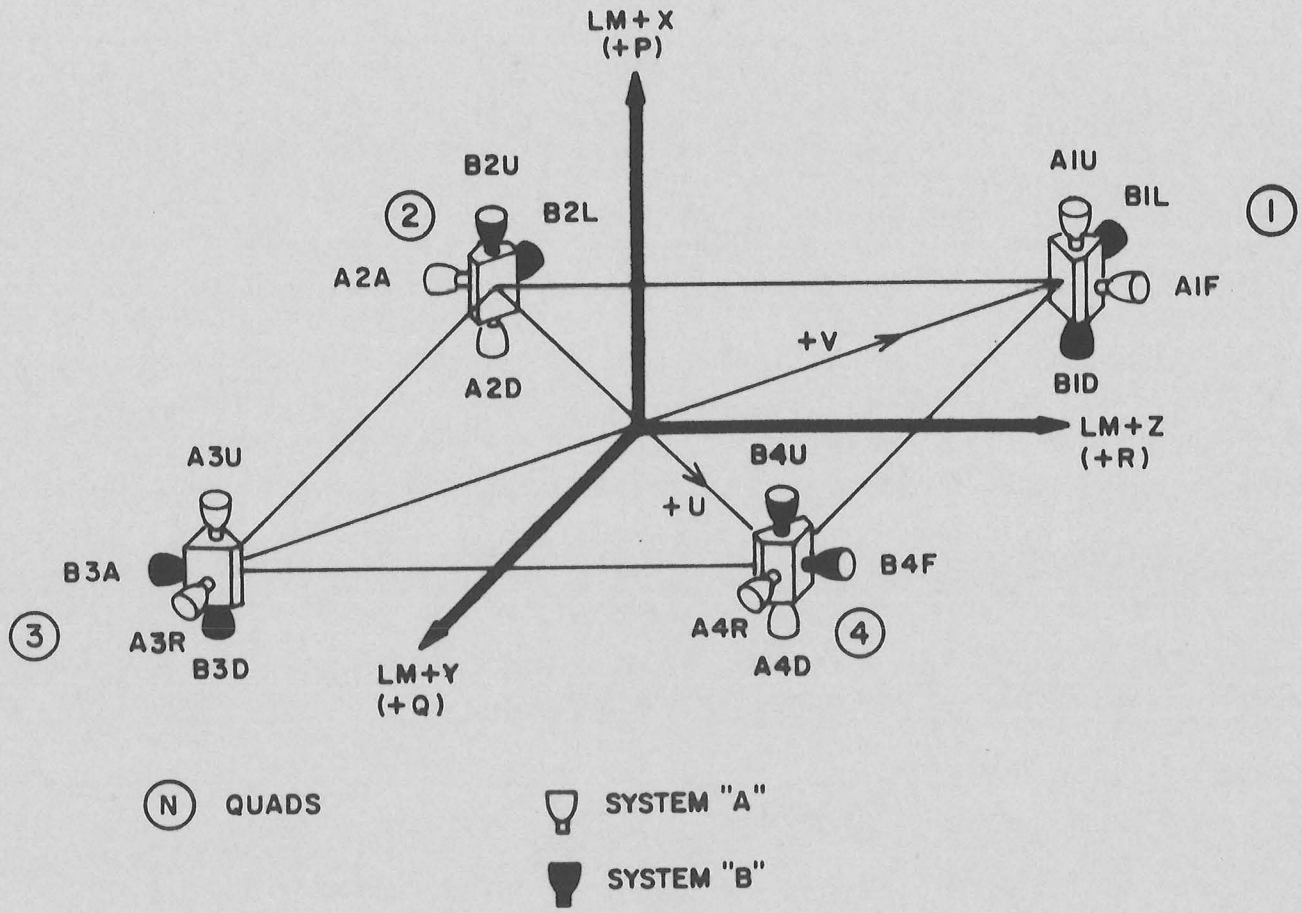
con't next page

LM DAP CONTROL SUMMARY (cont)

MODE SELECTION:

MODE	MODE CONTROL SWITCH	FLIGHT STATUS	ADDITIONAL REQUIREMENTS/COMMENTS
AUTO MANEUVER	Auto	Coasting	For Astronaut defined maneuver - V49E
AUTO STEERING	Auto or Att. Hold	Powered	External program controlled. Employs DPS trim steering.
ATTITUDE HOLD	Auto or Att. Hold	Coasting	V77E and ACA in - detent
	Att. Hold	Powered	No steering commands being produced.
Rate Command	Att. Hold	Coasting or Powered	V77E, ACA out-of-detent, overrides auto steering commands
X-AXIS OVERRIDE	Auto	Coasting or Powered	ACA out-of-detent Can be inhibited by external programs
RATE DAMP	Att. Hold (or Auto if for X-Axis override)	Coasting or Powered	ACA in - detent Damps rate and goes to Att. Hold mode.
MIN. IMP	Att. Hold	Coasting (possible in powered but not recom-mended)	V76E, Disables all other modes except auto steering SO WATCH IT!

Manual-translation control or automatic-ullage request are allowed during all of the above operational modes. The DAP OFF mode, or IDLE mode, occurs when any of the activation requirements are not present.



JET DESIGNATION

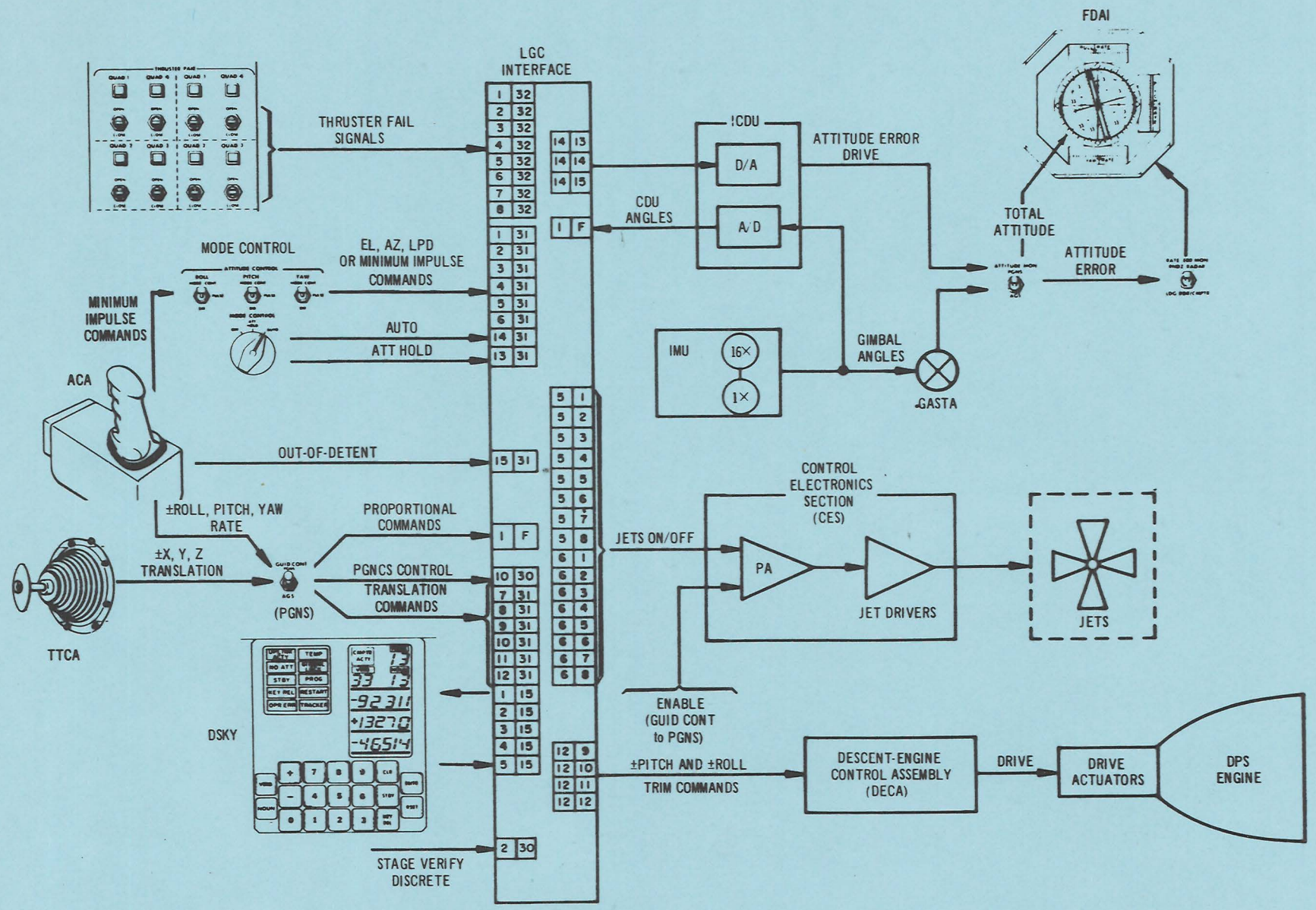
A 4 D

RCS FUEL SYSTEM — QUAD — EXHAUST DIRECTION

The P, Q & R axis designations are used with rotations and the X, Y & Z designations are used with translations. U & V are used with both.

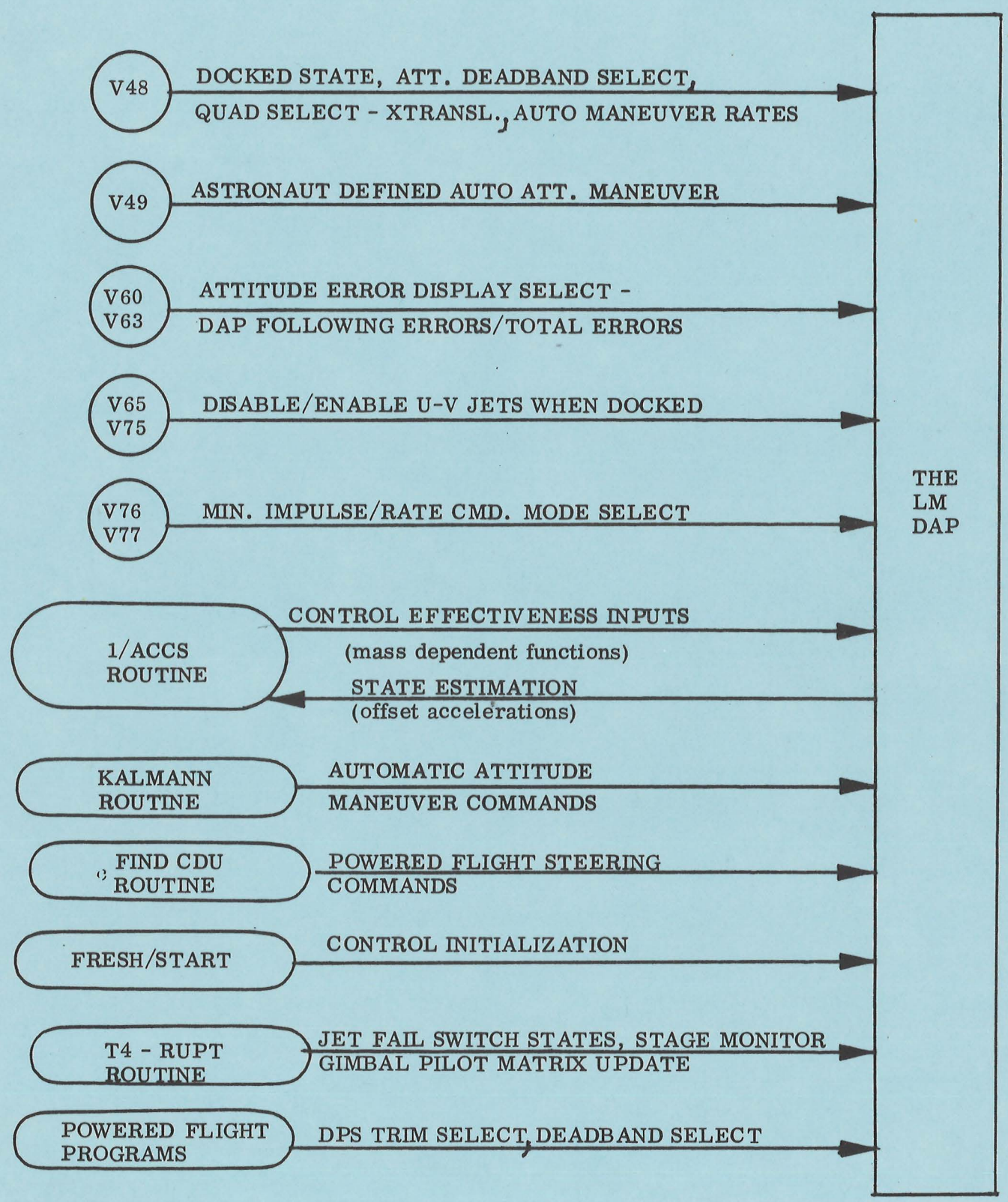
The astronaut can disable jets on each QUAD <u>only in pairs</u> and according to RCS fuel systems.

LM RCS JET CONTROL AXES

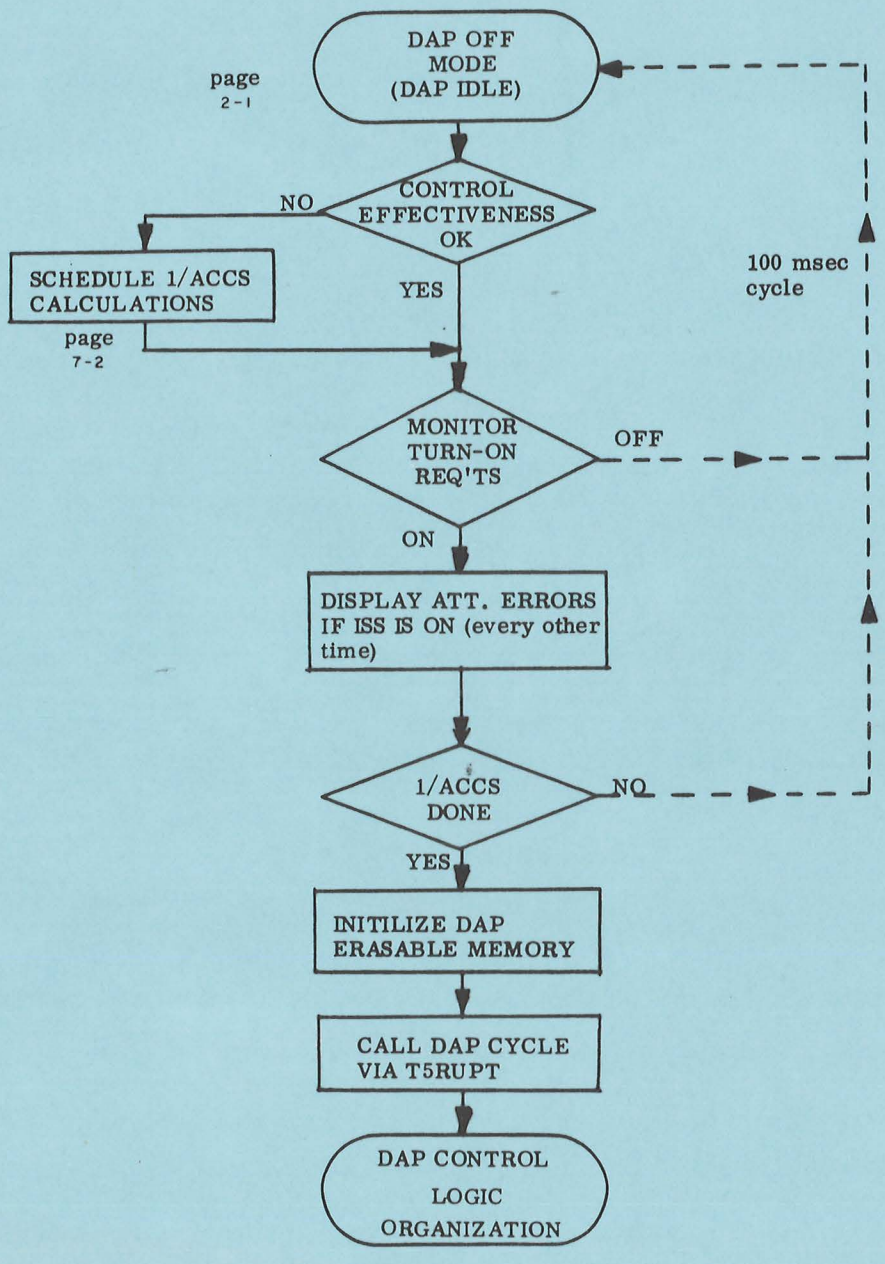


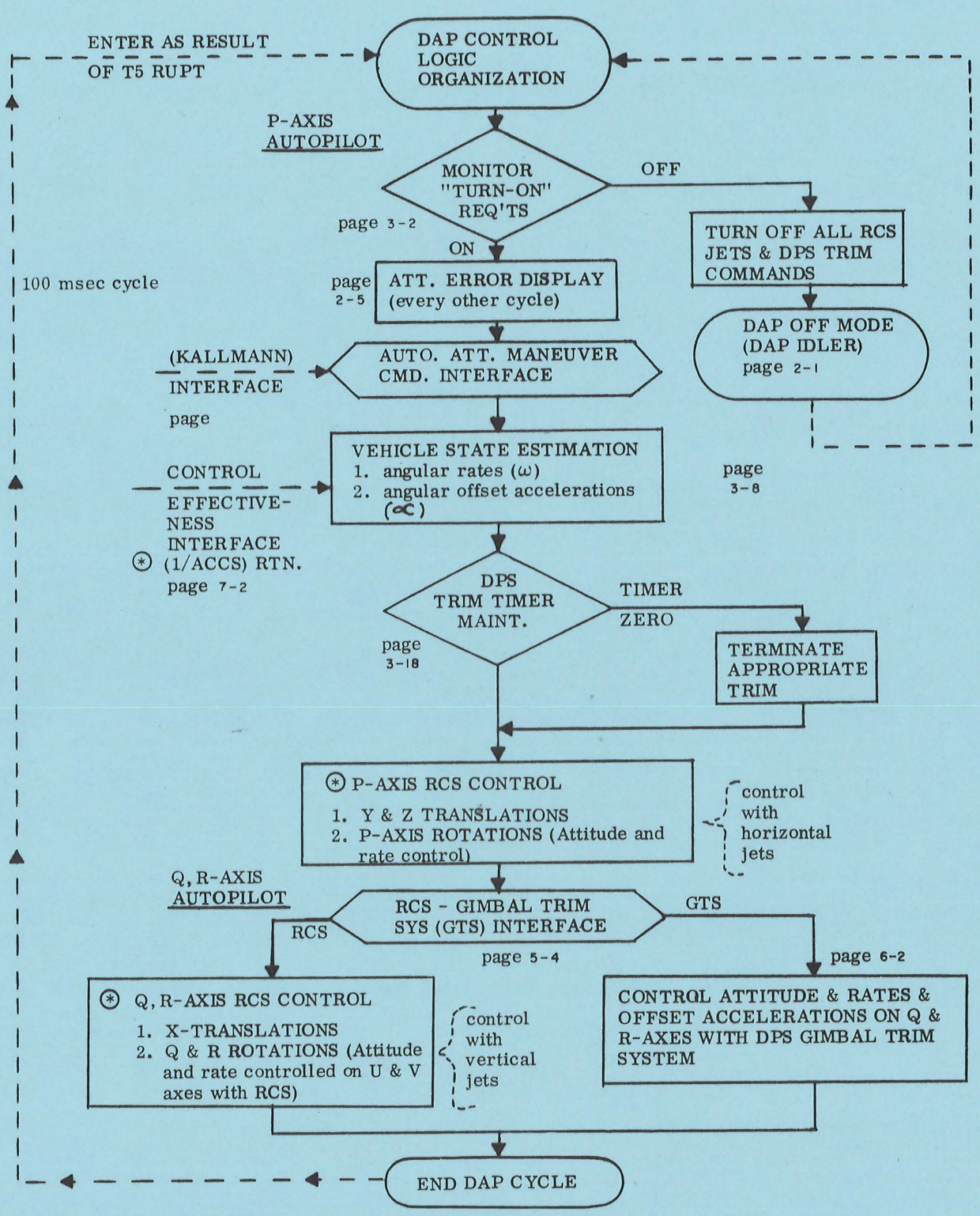
LM DAP HARDWARE INTERFACES

LM DAP SOFTWARE INTERFACES



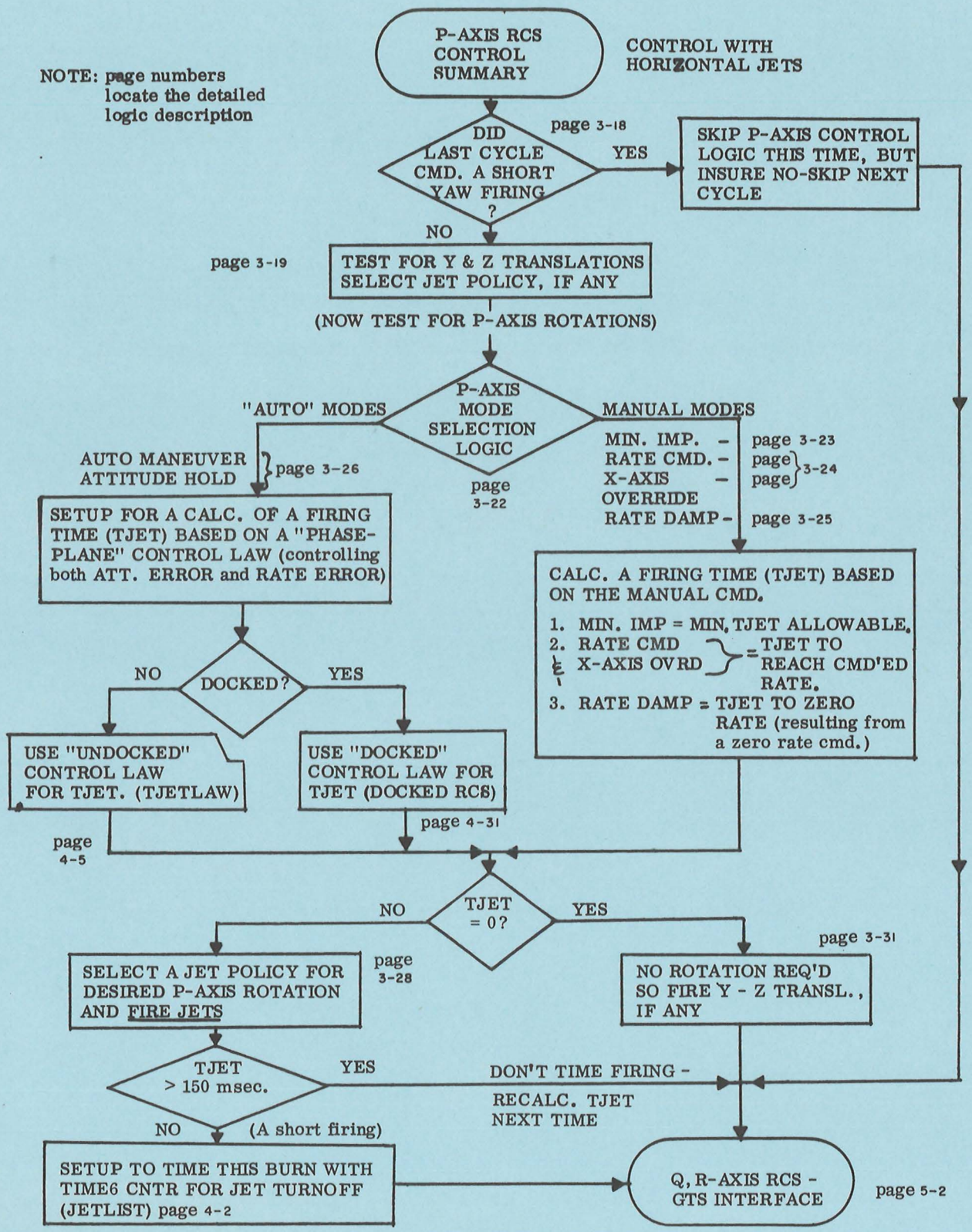
LOGIC SUMMARY - DAP IDLE

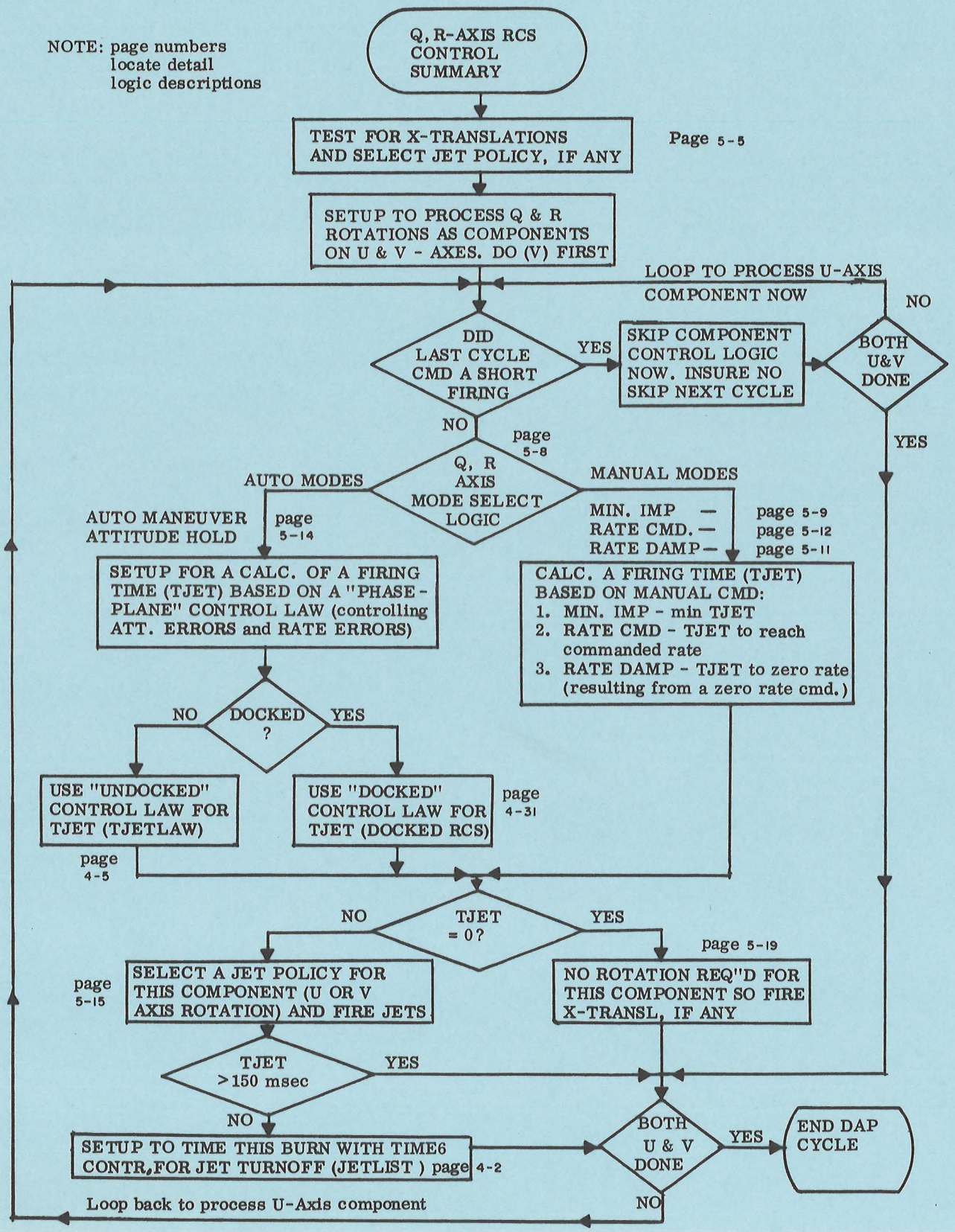




(*) Expanded summaries on following pages

NOTE: page numbers locate the detailed logic descriptions


P-AXIS RCS CONTROL SUMMARY
CONTROL WITH HORIZONTAL JETS
NOTE: page numbers locate the detailed logic description
DID LAST CYCLE CMD. A SHORT YAW FIRING ?
page 3-18
YES
SKIP P-AXIS CONTROL LOGIC THIS TIME, BUT INSURE NO-SKIP NEXT CYCLE
NO
page 3-19
TEST FOR Y & Z TRANSLATIONS SELECT JET POLICY, IF ANY
(NOW TEST FOR P-AXIS ROTATIONS)
P-AXIS MODE SELECTION LOGIC
page 3-22
"AUTO" MODES
AUTO MANEUVER ATTITUDE HOLD
page 3-26
SETUP FOR A CALC. OF A FIRING TIME (TJET) BASED ON A "PHASE-PLANE" CONTROL LAW (controlling both ATT. ERROR and RATE ERROR)
MANUAL MODES
MIN. IMP. - page 3-23
RATE CMD. - page
X-AXIS - page
3-24
OVERRIDE
RATE DAMP - page 3-25
CALC. A FIRING TIME (TJET) BASED ON THE MANUAL CMD.
1. MIN. IMP = MIN. TJET ALLOWABLE.
2. RATE CMD & X-AXIS OVRD = TJET TO REACH CMD'ED RATE.
3. RATE DAMP = TJET TO ZERO RATE (resulting from a zero rate cmd.)
DOCKED?
NO
YES
USE "UNDOCKED" CONTROL LAW FOR TJET. (TJETLAW)
page 4-5
USE "DOCKED" CONTROL LAW FOR TJET (DOCKED RCS)
page 4-31
TJET = 0?
NO
YES
SELECT A JET POLICY FOR DESIRED P-AXIS ROTATION AND FIRE JETS
page 3-28
page 3-31
NO ROTATION REQ'D SO FIRE Y - Z TRANSL., IF ANY
TJET > 150 msec.
YES
DON'T TIME FIRING - RECALC. TJET NEXT TIME
NO
(A short firing)
SETUP TO TIME THIS BURN WITH TIME6 CNTR FOR JET TURNOFF (JETLIST) page 4-2
Q, R-AXIS RCS - GTS INTERFACE
page 5-2


NOTE: page numbers locate detail logic descriptions
Q, R-AXIS RCS CONTROL SUMMARY
TEST FOR X-TRANSLATIONS AND SELECT JET POLICY, IF ANY
Page 5-5
SETUP TO PROCESS Q & R ROTATIONS AS COMPONENTS ON U & V - AXES. DO (V) FIRST
LOOP TO PROCESS U-AXIS COMPONENT NOW
NO
DID LAST CYCLE CMD A SHORT FIRING
YES
SKIP COMPONENT CONTROL LOGIC NOW. INSURE NO SKIP NEXT CYCLE
BOTH U&V DONE
YES
NO
page 5-8
Q, R AXIS MODE SELECT LOGIC
AUTO MODES
MANUAL MODES
AUTO MANEUVER ATTITUDE HOLD
page 5-14
MIN. IMP — page 5-9
RATE CMD. — page 5-12
RATE DAMP — page 5-11
SETUP FOR A CALC. OF A FIRING TIME (TJET) BASED ON A "PHASE-PLANE" CONTROL LAW (controlling ATT. ERRORS and RATE ERRORS)
CALC. A FIRING TIME (TJET) BASED ON MANUAL CMD:
1. MIN. IMP - min TJET
2. RATE CMD - TJET to reach commanded rate
3. RATE DAMP - TJET to zero rate (resulting from a zero rate cmd.)
NO
DOCKED ?
YES
USE "UNDOCKED" CONTROL LAW FOR TJET (TJETLAW)
USE "DOCKED" CONTROL LAW FOR TJET (DOCKED RCS)
page 4-31
page 4-5
NO
TJET = 0?
YES
page 5-19
page 5-15
SELECT A JET POLICY FOR THIS COMPONENT (U OR V AXIS ROTATION) AND FIRE JETS
NO ROTATION REQ"D FOR THIS COMPONENT SO FIRE X-TRANSL, IF ANY
TJET >150 msec
YES
NO
SETUP TO TIME THIS BURN WITH TIME6 CONTR,FOR JET TURNOFF (JETLIST) page 4-2
BOTH U & V DONE
YES
END DAP CYCLE
NO
Loop back to process U-Axis component

LM DAP JET SELECTION - ROTATION
(ORDER OF SELECTION - FROM TOP)

+YAW	-YAW
1. A4R - B2L - A1F - B3A	1. B1L - A3R - A2A - B4F
2. A1F - B3A	2. B1L - A3R
3. A4R - B2L	3. A2A - B4F
4. A4R - B3A	4. A3R - A2A
5. B2L - B3A	5. B1L - A2A
6. B2L - A1F	6. B1L - B4F
7. A4R - A1F	7. A3R - B4F

+ ROLL		- ROLL	
(+V)	+(U)	(-V)	(-U)
B4U - A2D	B1D - A3U	B2U - A4D	A1U - B3D
B4U	B1D	B2U	B3D
A2D	A3U	A4D	A1U

+PITCH		-PITCH	
(-V)	(+U)	(+V)	(-U)
B2U - A4D	B1D - A3U	B4U - A2D	A1U - B3D
B2U	B1D	B4U	B3D
A4D	A3U	A2D	A1U

*For Roll & Pitch, a combination of the U-V lists will be selected.

LM DAP JET SELECTION - TRANSLATION
(X-POLICY SELECTED IN DAP LOAD)

+X

1. B1D - B3D - A4D - A2D
2. B1D - B3D
3. A4D - A2D

-X

1. A1U - A3U - B2U - B4U
2. B2U - B4U
3. A1U - A3U

+Y

1. B1L - B2L
   B2L - B4F/A2A*
   B1L - A1F/B3A*

-Y

1. A4R - A3R
   A3R - B3A/A1F*
   A4R - B4F/A2A*

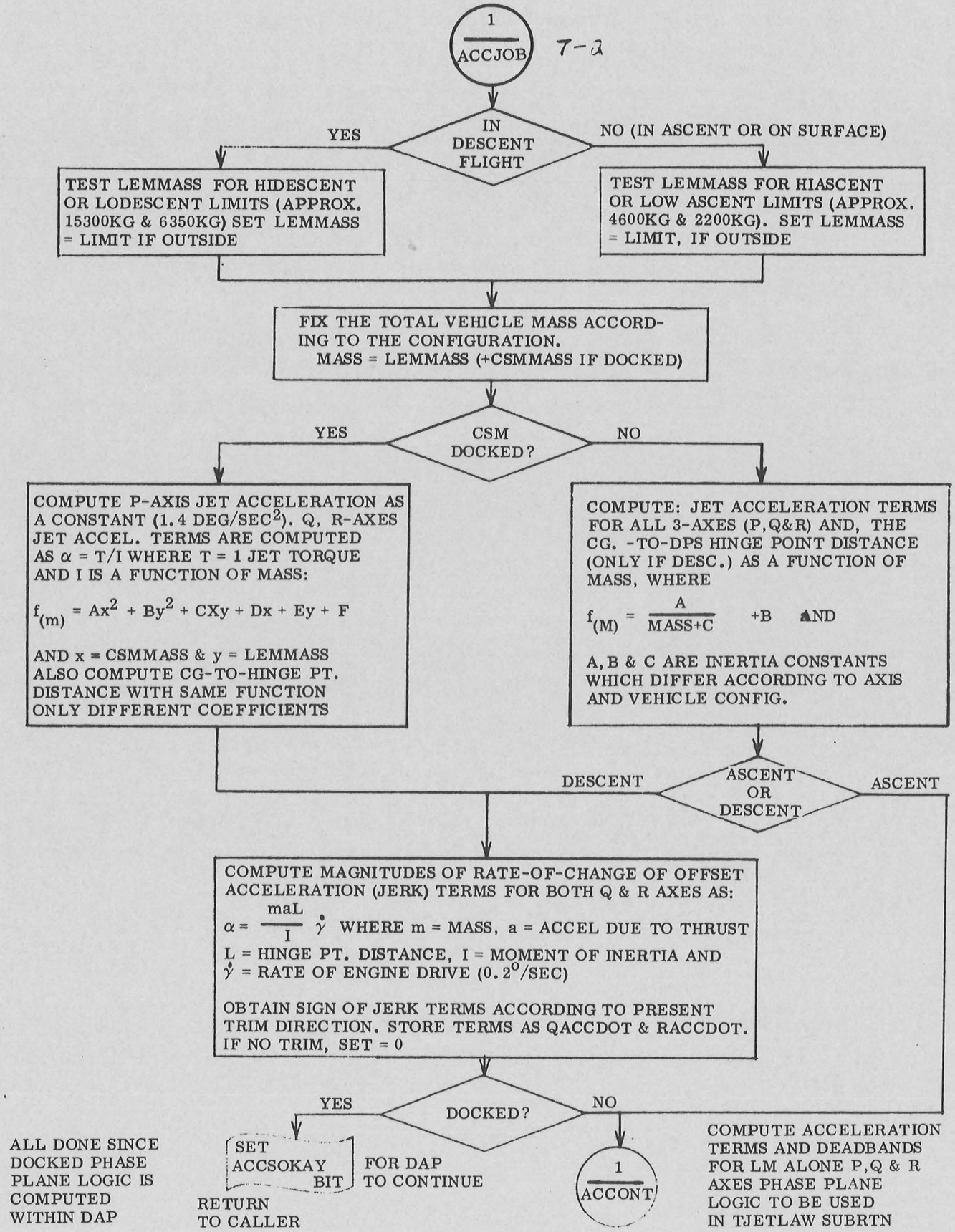
+Z

1. B3A - A2A
   B3A - A3R/B1L*
   A2A - B2L/A4R*

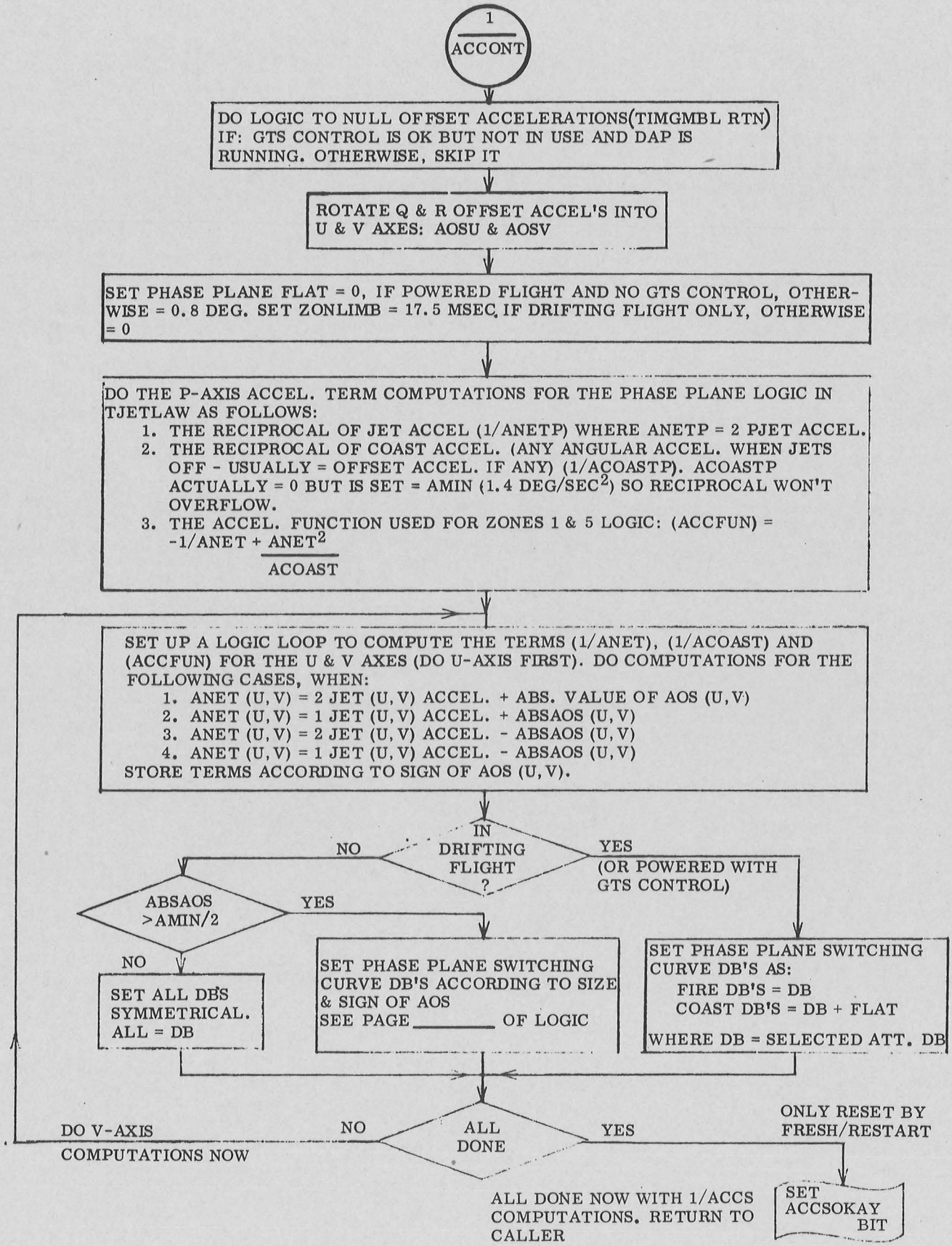
-Z

1. A1F - B4F
   B4F - A4R/B2L*
   A1F - B1L/A3R*

*These are alternate translation policies that result in a tacking maneuver. Two jets alternate (/) on-off, the third remains on.



PART I OF 1/ACCJOB OVERVIEW

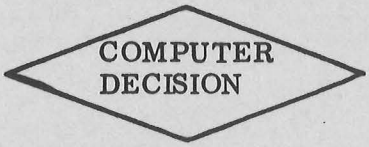


PART II OF 1/ACCS OVERVIEW

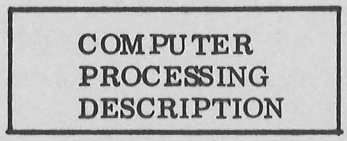
HOW TO READ THE LOGIC DESCRIPTIONS

An attempt has been made to organize the logic descriptions for ease in reading and understanding. Standard logic symbols are not necessarily employed, however, those used should be readily understood. The primary symbols used are:

Used to connect the logic flow from subroutine to subroutine and from page to page. The logic entry and exit points on each page.



Used to branch the logic flow based on a computer processing decision.



Usually encloses a description of an actual computer process; such as storage of some value in a memory register or a mathematical manipulation. May be various sizes.

Abbreviated description of some computer operations where description of the actual processing is not significant

NEUMONICS:

Connector Neumonics - the neumonics in the connector symbols generally reflect the subroutine neumonics used in the program listing. In some cases, however, the author uses his own neumonics to better describe the logic operation that follows In these cases, the listing neumonics are placed to the near upper right of the bubble as such:

Page numbers near the bubble locate that logic description if it is not the following page.

SPSRCS

listing neumonics defining the sub-routine entry

Memory Neumonics - in all cases, the neumonics used as tags for specific memory registers (fixed or erasable) are the same as in the listing.

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DESCRIPTIONS:

Computer Processing - almost all the computer processing descriptions are setting the contents of some erasable memory register to equal some numerical term or, reading the contents of some memory location. Parenthesis are used to describe "the contents of" a memory register. Thus, the descriptions:

Set: (NEUMONICS) = 0 would read "set the contents of this register equal to zero".

(NEUMONICS) = 0? would read "does the contents of this register equal zero?" this would be a branching description.

Form: (NEUMONICS1) (NEUMONICS2) 5 - this is a typical mathematical manipulation which would read "the contents of register 1 times the contents of register 2 times decimal 5". The 5 would be a fixed memory constant whose decimal equivalent = 5

Many times the words in the decision blocks will be the authors description of the decision in operational terms. In these cases, the computer operation as coded in the listing will be stated just outside the decision block. Other times the opposite will be true but this will be apparent.

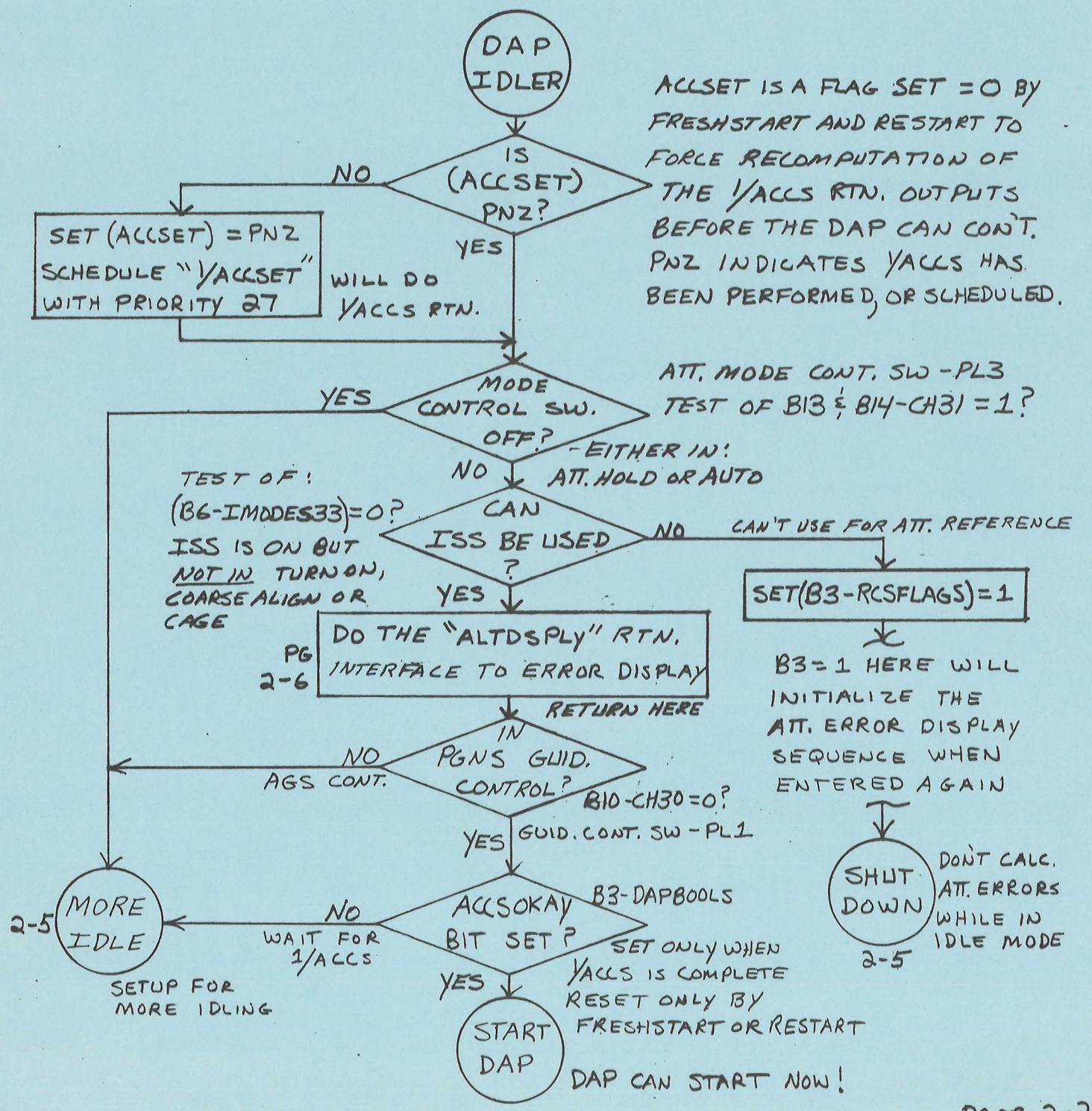
Broken Line Flow - where logic line flow is broken, such as $\longrightarrow\!\!\!

SECTION II

DAP ON-OFF MODE INTERFACE

LM DAP OFF MODE

WHEN THE LM DAP CYCLE IS IDLE, OR OFF, THE RTN. "DAPIDLER IS RUN TEN TIMES A SECOND TO CHECK FOR THE CONDITIONS WHICH WILL ALLOW THE DAP TO RUN. WHEN THESE CONDITIONS DO EXIST, "DAPIDLER" WILL INITIALIZE SOME ERRASABLES USED BY THE DAP AND THEN SETUP FOR THE START OF THE DAP CYCLE. "DAPIDLER" WILL ALSO CALL THE SUBRTN. THAT DISPLAYS ATTITUDE ERRORS. HOWEVER, THE IMU MUST BE USEABLE AND THE MODE CONT. SWITCH (PANEL 3) MUST NOT BE OFF. "DAPIDLER IS CALLED BY: FRESHSTART, RESTART AND BY THE DAP LOGIC IF DAP "ON" CONDITIONS ARE NOT MET.



START DAP

INITIALIZE SOME DAP ERASABLES AS FOLLOWS:

1.
ZERO ANY ATT. ERROR, SET:
(CDUXD) = (CDUX)
(CDUYD) = (CDUY)
(CDUZD) = (CDUZ)
DESIRED ANGLES = PRESENT

2.
ZERO THE FOLLOWING AUTO MANEUVER (KALCMANU)/DAP INTERFACE REGS.:
a) THE DESIRED RATES; (OMEGAPD), (OMEGAQD) & (OMEGARD) = +0
b) THE COMMANDED ANGLE INCREMENTS: (DELCDUX), (DELCDUY) & (DELCDUZ) = +0
c) THE ATTITUDE LAG ANGLES FOR ERRORS; (DELPERDR), (DELQERDR) & (DELRERDR) = +0

3.
ZERO THE FOLLOWING TERMS USED BY THE STATE ESTIMATOR:
a) THE JET FIRING TIMES; (TJP), (TJU) & (TJV) = +0
b) THE ESTIMATED BODY RATES; (OMEGAP), (OMEGAR) & (OMEGAQ) = +0
c) THE ACCUMULATED DEVIATION VALUES: (TRAPEDP), (TRAPEDQ) & (TRAPEDR) = +0
d) THE OFFSET ACCELERATION EST.'S; dp(AOSQ) & dp(AOSR) = +0
e) DOWNLINK COPIES OF AOS; (ALPHAQ) & (ALPHAR) = +0
f) THE RATES DUE TO THE AOS; (AOSQTERM) & (AOSRTERM) = +0
g) THE DPS JERK TERMS (QACCDOT) & (RACCDOT) = +0

4.
INITIALIZE FLAGS FOR RCS-TRIM GIMBAL CONTROL INTERFACE:
(ALLOWGTS) = +0 disallow GTS
(COTROLER) = +0 branch to try GTS USE ANYWAY
(INGTS) = +0

5.
ZERO DPS ENGINE TRIM TIMERS:
(QGIMTIMR) & (RGIMTIMR) = +0
THIS WILL STOP ANY TRIMMING

6.
ZERO THE STICK RETURN DETECTORS FOR MINIMUM IMPULSE MODE:
(OLDPMIN) & (OLDQRMIN) = +0

7.
INITIALIZE THE OLD CDU SNAPSHOT REGS. USED BY STATE ESTIMATOR:
(OLDXFORP) = (CDUX)
(OLDYFORP) = (CDUY)
(OLDZFORQ) = (CDUZ)

8.
STORE ADDRESS OF CHKVISFZ IN (PJUMPADR). THIS WILL INSURE PATH FOR P-AXIS PROCESSING ON FIRST DAP CYCLE

9.
INSURE Q, R-AXES PROCESSING ON FIRST DAP CYCLE, SET:
(SKIPU) & (SKIPV) = PNZ

START DAP +

DO MORE INITIALIZING

START DAP +

STARTDAP CON'T.

10.

INITIALIZE THE 3 T6 WAITLIST MEMBERS: (TIME6), (T6NEXT) & (T6FURTHA) = 37777_8

USED FOR TIMING JET FIRINGS < 150 MSEC.

TIME6 IS THE CLOCK. POSMAX WILL DISABLE WAITLIST

INITIALIZE THE ASSOCIATED AXIS IDENTIFIERS: (NXT6ADR), (T6NEXT+1) & (T6FURTHA+1) = +0

IDENTIFIES THE AXIS FOR THE JET TIMING

11.

ZERO THE REGS. WHICH HOLD THE TRANSLATION POLICIES: (NEXTP), (NEXTU) & (NEXTV) = +0

INITIALIZE THE "JASK" CONTROL INDICATOR: (DAPZRUPT) = NNZ

AFTER THE STATE ESTIMATION IS COMPLETED IN THE DAP CYCLE, THE REMAINDER OF THE DAP PROCESSING IS RUN IN A "JASK" CONTROL MODE OR, INTERRUPT NOT-INHIBITED MODE. NNZ INDICATES THE JASK IS <u>NOT</u> IN PROCESSES

INITIALIZE THE 3 COUNTERS FOR NO. OF NONUSED ACCUMULATED DEVIATIONS IN THE RATE ESTIMATE: (NPTRAPS), (NQTRAPS) & (NRTRAPS) = +2

STORE ADDRESS OF "P-AXIS" IN (T5ADR) FOR T5-RUPT

WHEN THE T5 COUNTER RUPTS, PROCESSING WILL GO TO THE ADDRESS IN (T5ADR)

SET THE TIME5 COUNTER FOR A RUPT IN 100 MSEC.

RESUME

THE DAP CYCLE WILL START NOW, IN 100 MSEC AT P-AXIS, PAGE <u>3-2</u>

CALLED BY:
"P-AXIS" OR
"DAPIDLER"

MORE IDLE

CALC. THE P, Q & R-AXIS FOLLOWING ATTITUDE ERRORS, SET:

$$(QERROR) = [(CDUY)-(CDUYD)]M21 + [(CDUZ)-(CDUZD)]M22 + (DELQERROR)$$

$$(RERROR) = [(CDUY)-(CDUYD)]M31 + [(CDUZ)-(CDUZD)]M32 + (DELRERROR)$$

$$(PERROR) = [(CDUY)-(CDUYD)]M11 + [(CDUX)-(CDUXD)] + (DELPERROR)$$

THESE ARE USED FOR ATT. ERROR DISPLAY ⊛

SHUT DOWN

SET ADDRESS FOR "DAPIDLER" INTO (T5ADR)

(T5ADR) CONTROLS THE PATH WHEN T5 RUPTS

SET: (NEXTP), (NEXTU) & (NEXTV) = +0

TRANSLATION POLICYS ARE KILLED

COMMAND ALL RCS JETS OFF.
SET: CH5 & CH6 BITS = 0

COMMAND DPS ENGINE TRIM OFF.
SET: B9, B10, B11 & B12 - CH12 = 0

SET THE TIME5 COUNTER FOR A RUPT IN 100 MSEC.

RESUME

RETURN TO DAPIDLER IN 10 SCEC.

⊛ M21, M22, M31, M32 & M11 ARE COMPONENTS FROM THE GIMBAL-TO-PILOT MATRIX WHICH IS UPDATED BY T4-RUPT EVERY 240 MSEC.

The routine "ALTDSPLY" is the control interface between the DAP processing cycle and the attitude error display sequence which is controlled by the subrtn, "NEEDLER". Entry into "ALTDSPLY" is every 0.1 sec when the DAP is on (or in DAP Idle). However, "ALTDSPLY" allows update of the error displays every 0.2 sec by alternating the entry to "NEEDLER" on each pass. Also, a test is made for which of two types of attitude errors should be displayed on the FDAI error needles. The desired type is selected by the astronaut via a DSKY request. They are defined as:

TYPE I (V60E) - These are called AUTOPILOT FOLLOWING ERRORS. They are computed by the DAP and reflect:

(a) The DAPS own ability to control the vehicle attitude, within the selected deadband, when only the att. hold mode prevails (either in auto or att. hold position on mode control switch). If the DAP response is proper the error display will not greatly exceed the deadband value. or:

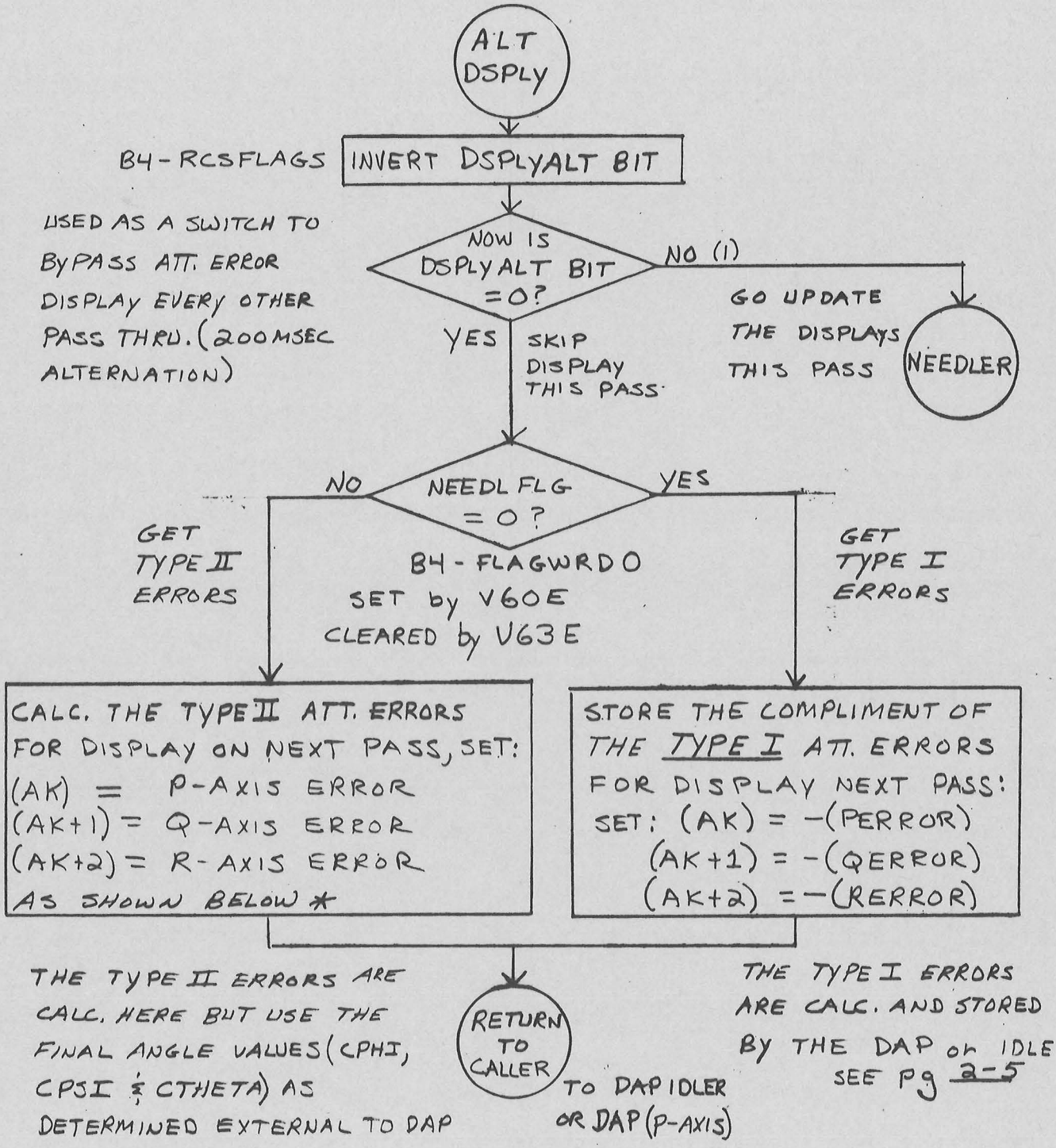
(b) The DAPS ability to command the vehicle to follow an attitude change command originating from sources external to the DAP (like the auto att. maneuver rtn. 1 sec. cmd. increment or the powered flight auto steering 2 second command increment). For the auto att. maneuver, the display should be negligible except for starting and stopping. Type I errors will be zeroed if the DAP is in a manual mode (rate CMC or min. 1M pulse).

Type II (V63E) - These are called TOTAL ATTITUDE ERRORS. They are computed by "ALTDSPLY" when V63E requests and simply reflect the total difference between the present vehicle attitude and a predetermined final attitude computed external to the DAP. The source for the final attitude value could be from:

(a) The auto. att. maneuver rtn as requested either by a controlling program or by the astronaut (V49E) who must define the final att. by DSKY entry; or

(b) The powered flight auto steering cmd. which is a 2 sec. increment. In this case, Type I & Type II displays would give the same information. Type II errors are displayed in the rate cmd manual mode, also, to provide the attitude-to-be-gained indication for a manually initiated or manual takeover att. maneuver.

NEXT PAGE



* TYPE II ERRORS ARE CALC. AS:

$$\text{P-AXIS} = \left[(\text{CTHETA}) - (\text{CDUY})\right]\text{M11} + \left[(\text{CPHI}) - (\text{CDUX})\right]$$

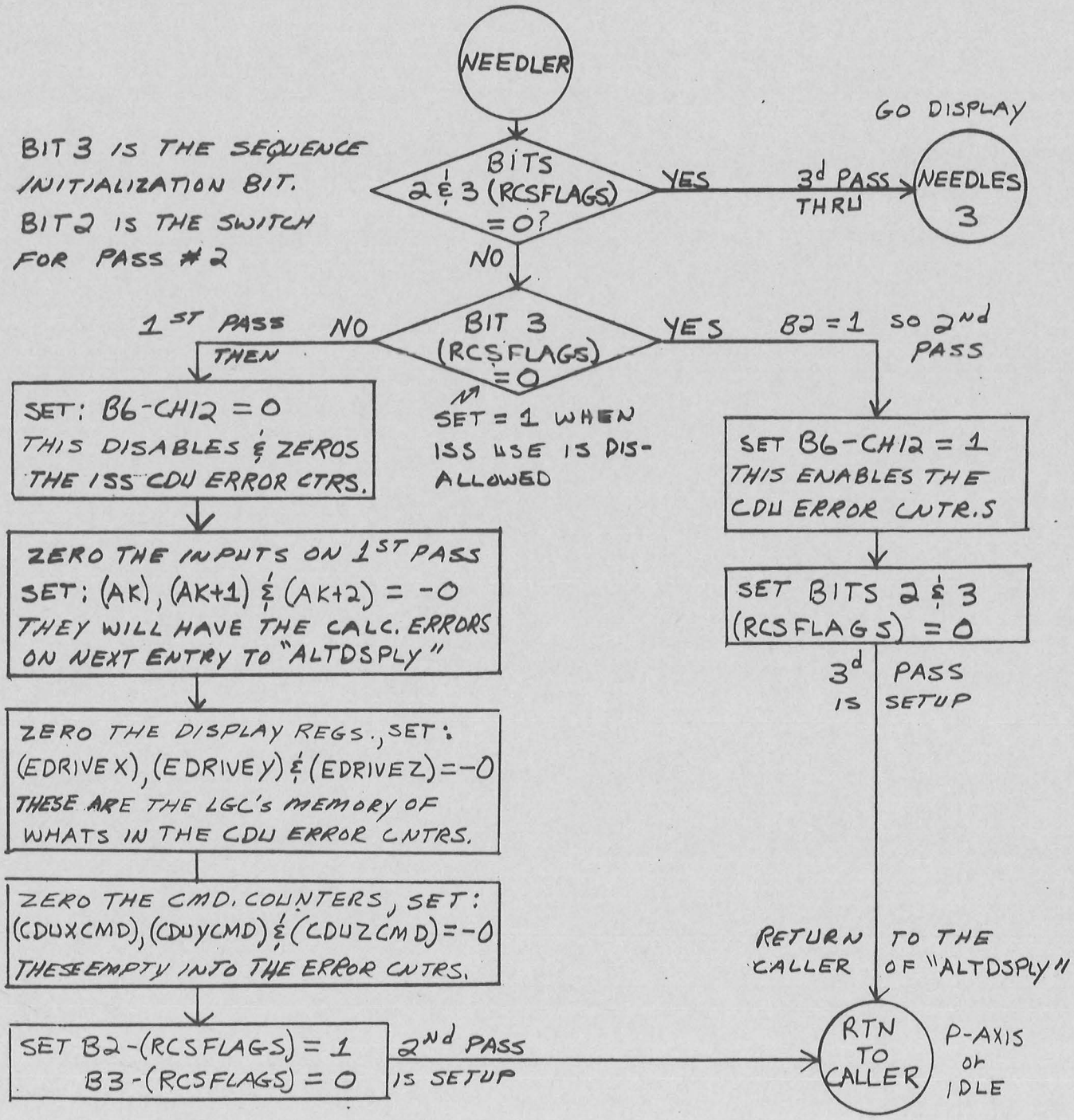
$$\text{Q-AXIS} = \left[(\text{CTHETA}) - (\text{CDUY})\right]\text{M21} + \left[(\text{CPHI}) - (\text{CDUZ})\right]\text{M22}$$

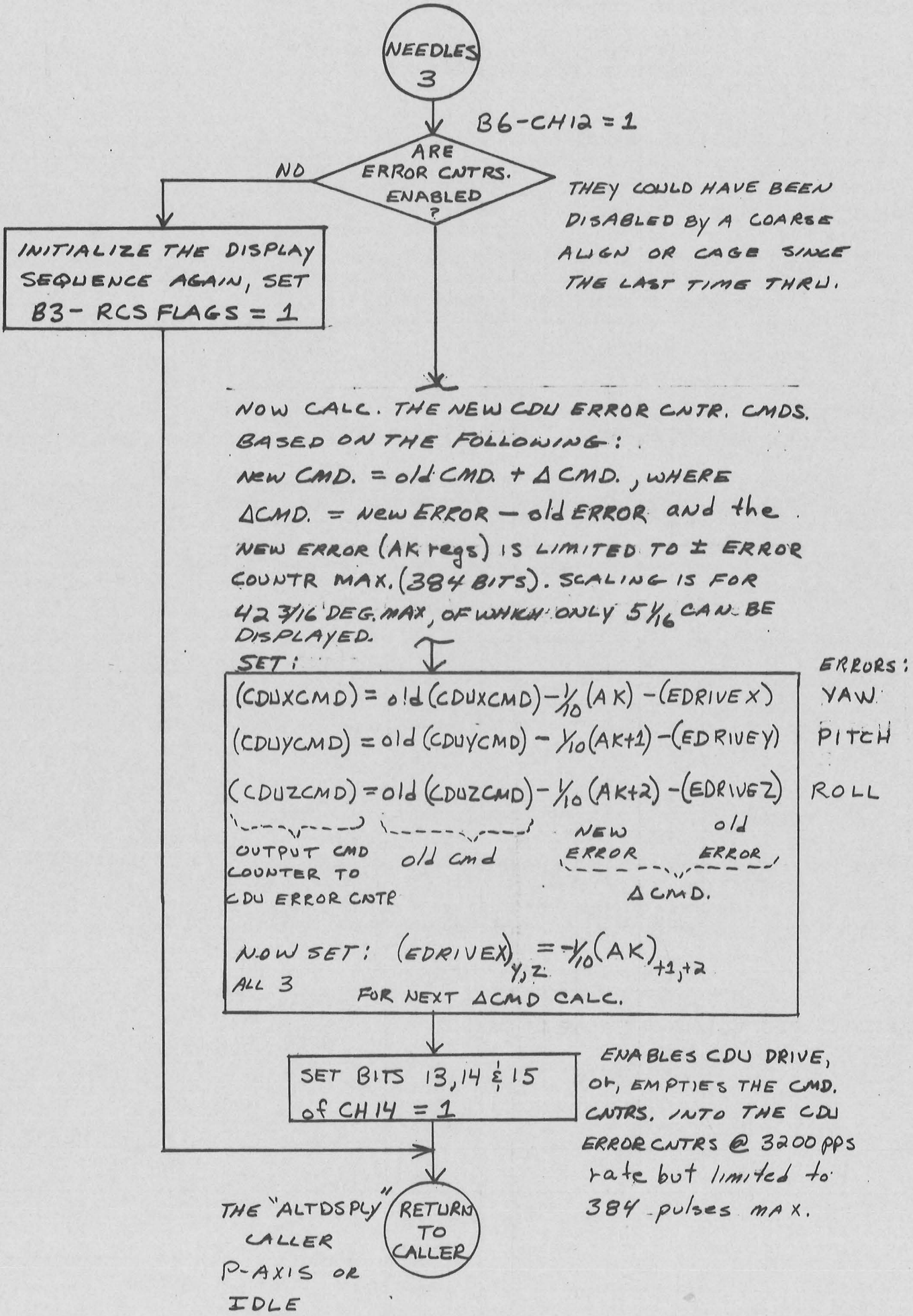
$$\text{R-AXIS} = \left[(\text{CTHETA}) - (\text{CDUY})\right]\text{M31} + \left[(\text{CPSI}) - (\text{CDUZ})\right]\text{M32}$$

WHICH ARE IMU GIMBAL ANGLE ERRORS TRANSFORMED TO BODY ERRORS

"NEEDLER" is the subrtn. that actually performs the attitude error display sequence. It uses the computed errors (Type I or Type II) to calculate updated error commands and then enables the CDU error counters to accept them. The CDU's, in turn, convert the digital commands to analog drive signals which then drive the FDAI error needles. The drive commands are scaled such that the maximum capability of the error counters (384 bits) represent an error of 42 3/16 deg. However, the error needles are scaled down to a max. deflection = 5 1/16 deg. (only in the PGNS mode). Thus, if the wide att. deadband (±5 deg) is selected for att. hold, the needles will saturate while the DAP operation is normal.

Whenever the DAP is turned off (due to disallowing use of the ISS) the display sequence within "NEEDLER" is initialized. This means that when the ISS is useable for the DAP again, at least 3 entries to "NEEDLER" are required (600 msec. worth) before any errors can be displayed on the needles. After that, the error displays will be updated every 200 msec.



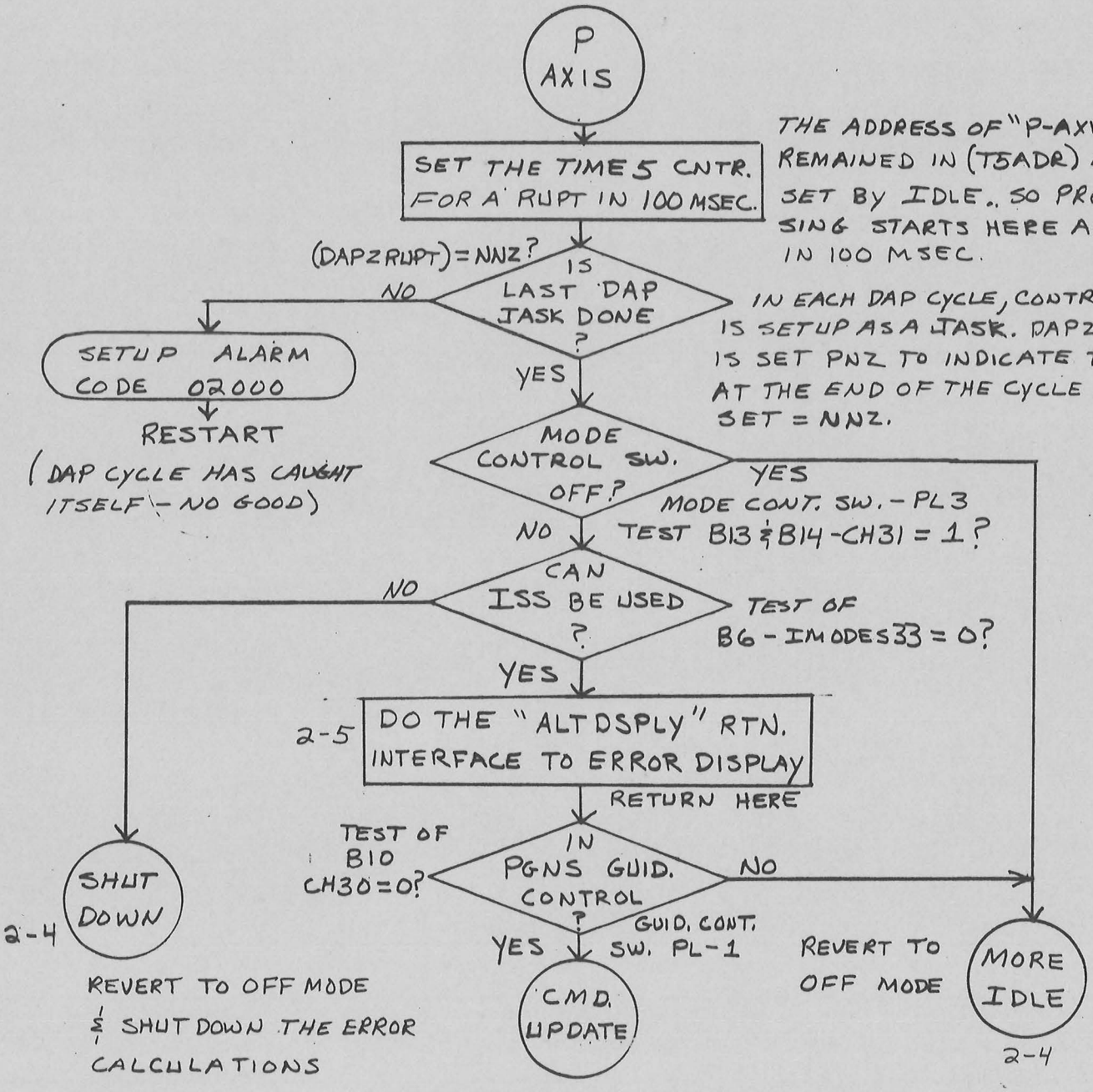

NEEDLES 3
B6-CH12 = 1
ARE ERROR CNTRS. ENABLED ?
NO
THEY COULD HAVE BEEN DISABLED BY A COARSE ALIGN OR CAGE SINCE THE LAST TIME THRU.
INITIALIZE THE DISPLAY SEQUENCE AGAIN, SET B3- RCS FLAGS = 1
NOW CALC. THE NEW CDU ERROR CNTR. CMDS. BASED ON THE FOLLOWING:
NEW CMD. = old CMD. + Δ CMD., WHERE
ΔCMD. = NEW ERROR − old ERROR and the NEW ERROR (AK regs) IS LIMITED TO ± ERROR COUNTR MAX. (384 BITS). SCALING IS FOR 42 3/16 DEG. MAX, OF WHICH ONLY 5 1/16 CAN BE DISPLAYED.
SET:
(CDUXCMD) = old (CDUXCMD) − 1/10 (AK) − (EDRIVEX)
(CDUYCMD) = old (CDUYCMD) − 1/10 (AK+1) − (EDRIVEY)
(CDUZCMD) = old (CDUZCMD) − 1/10 (AK+2) − (EDRIVEZ)
ERRORS:
YAW
PITCH
ROLL
OUTPUT CMD COUNTER TO CDU ERROR CNTR
old cmd
NEW ERROR
old ERROR
ΔCMD.
NOW SET: (EDRIVEX)Y,Z = −1/10 (AK)+1,+2
ALL 3
FOR NEXT ΔCMD CALC.
SET BITS 13, 14 & 15 of CH14 = 1
ENABLES CDU DRIVE, OR, EMPTIES THE CMD. CNTRS. INTO THE CDU ERROR CNTRS @ 3200 pps rate but limited to 384 pulses MAX.
THE "ALTDSPLY" CALLER
P-AXIS OR IDLE
RETURN TO CALLER

SECTION III

P-AXIS AUTOPILOT LOGIC DESCRIPTION

ENTRY TO "P-AXIS" IS FROM A T5-RUPT AND ESTABLISHES THE BEGINNING OF THE DAP 100MSEC. CYCLE. "P-AXIS", ITSELF, IS THE START OF THE <u>P-AXIS AUTOPILOT</u> PORTION OF THE TOTAL LM DAP CONTROL FUNCTION. BASICALLY, THE <u>P-AXIS AUTOPILOT</u> INCLUDES THE CONTROL LOGIC FOR:

1. MONITOR OF DAP "ON" CONDITIONS
2. THE VEHICLE STATE ESTIMATOR
3. THE TRIM TIMERS FOR TRIM GIMBAL CONTROL
4. MONITOR OF Y & Z-AXIS TRANSLATION CMDS. AND THE SELECTION OF THE ASSOCIATED JET FIRING POLICIES
5. YAW RCS CONTROL OF THE VEHICLE (MANUAL & AUTO MODES).



CMD. UPDATE

UPDATE THE REFERENCE ANGLE WITH THE AUTO. ATT. MANEUVER 0.1 SECOND "SMOOTHING" COMMAND INCREMENT, SET:

(CDUXD) = (CDUXD) − (DELCDUX)
(CDUYD) = (CDUYD) − (DELCDUY)
(CDUZD) = (CDUZD) − (DELCDUZ)

"KALCMANU" INTERFACE

TO THE DAP, THE REGISTERS CDUXD, CDUYD & CDUZD ALWAYS REFLECT THE REFERENCE, OR DESIRED, IMU GIMBAL ANGLES. THE DAP WILL TRY TO HOLD ATTITUDE OR CHANGE ATTITUDE TO WHAT EVER VALUE THESE REGS. CONTAIN. THEREFORE, TO COMMAND THE DAP TO CHANGE THE ATTITUDE OF THE VEHICLE, THE AUTO. ATT. MANEUVER RTN. (KALCMANU) WILL PERFORM THE FOLLOWING (EVERY 1 SEC.) WHEN RUNNING:

1. COMPUTE THE ANGLE(S) IT DESIRES THE VEHICLE TO BE AT 1 SEC. <u>IN THE FUTURE</u> (NCDU'S). THESE ARE DETERMINED FROM KNOWING THE FINAL ANGLES TO BE ACQUIRED AND THE RATE DESIRED TO ACQUIRE THEM (ω SELECTED BY THE ASTRONAUT IN DEG/SEC).
2. COMPUTE THE "SMOOTHING" COMMAND INCREMENTS (DELCDU'S) AS 1/10 THE DIFFERENCE BETWEEN THE NEW (NCDU) AND THE OLD (NCDU). <u>THEY ARE STORED AS NEGATIVE VALUES</u> AND ZEROED AT END OF MANEUVER WHEN THE FINAL ATT. IS AQUIRED.
3. SET (CDUD'S) = OLD (NCDU) VALUES.

THE OLD(NCDU) VALUES ARE ACTUALLY THE ANGLES KALCMANU "ASSUMES" THE VEHICLE HAS ACQUIRED AT THE PRESENT. SINCE KALCMANU DOES NOT USE A MEASUREMENT OF THE ACTUAL ANGLES (CDU'S), EXCEPT FOR THE FIRST CYCLE, THESE OLD(NCDU) VALUES ARE NOT NECESSARILY EQUAL TO THE ACTUAL (CDU) ANGLES. IN FACT, THEY WILL NOT BE EQUAL. <u>IN THE COMMAND UPDATE ABOVE</u>, THEREFORE, THE (CDUD'S) ARE SET FOR A VALUE TO BE ACQUIRED 0.1 SEC IN THE FUTURE (ASSUMED BY KALCMANU) BY ADDING (DELCDU'S). THE DAP WILL DETECT THIS COMMAND INCREMENT, AND ANY ERRORS IN KALCMANU ASSUMPTIONS, IN LOGIC FOLLOWING WHEN ATT. ERRORS ARE COMPUTED, ON THE BASIS OF: (CDUD − CDU) = E OR THE ATT. COMMAND.

START "STATE ESTIMATOR" COMPUTATIONS NOW

NEXT PAGE

ACTUAL LOGIC STARTS ON page 3-8

THE STATE ESTIMATOR

The following dissertation is only a simplified explanation of the equations and terms used in the following state estimator logic. It is not an attempt to explain all the design criteria, methods, constraints and assumptions used to develope the LM's state estimator. The only purpose is to provide an aid for the user to better understand the state estimator coding portion of the DAP logic flow.

The basic outputs of this state estimator are the best estimates of:

a. the angular rate of the vehicle about all three axes (OMEGA).

b. the angular offset acceleration bias (AOS) about the pitch and roll axes; due primarily to a main engine thrust vector being misaligned with the vehicle's center-of-gravity during powered flight.

The estimations are obtained from the basic expression:

ESTIMATION = PREDICTION + DEVIATION where;

the DEVIATION term is a correction value that is proportional to the difference between the PREDICTED value and a MEASURED value. Since there are no angular rate or acceleration measuring devices available for the DAP, the MEASURED value must be derived from IMU-CDU angle, or attitude, measurements. The PREDICTED value is obtained by previous knowledge (at t_{N-1}) of the state estimate and the time history of the DAP control outputs between control sample times t_{N-1} and t_N. The Control Sample Period is, of course, equivalent to the DAP cycle or: $T = t_N - t_{N-1}$ = 0.1 sec thus, the new estimate of the vehicle state can be expressed as:

ESTIMATE = PREDICTION + K(MEASUREMENT - PREDICTION)

where K is a proportionality factor.

In deriving the state estimates, it is assumed the vehicle state is represented by the following differential equations:

NOTE: the DOT means the time derivative.

$$\dot{\theta} = \omega$$
$$\dot{\omega} = \alpha + a_J$$
$$\dot{\alpha} = u_G$$

where;
- θ = the vehicle attitude
- ω = the angular rate of the vehicle
- α = the angular offset acceleration bias due to thrust vector - CG misalignment
- a_J = the angular acceleration due to jets firing - (assumed constant while jets are on which may be equal to or less than the sample period).
- u_G = the rate-of-change of α, or AOS, due to gimbaling the descent engine (assumed constant during sample period T)

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Thus, the vehicle's state can be extrapolated, or PREDICTED, over the sample period by integrating the above equations and substituting the resulting terms. The PREDICTED terms are:

$$\alpha'_N = \tilde{\alpha}_{N-1} + U_G T \qquad \text{SUBSTITUTING;}$$

$$\omega'_N = \tilde{\omega}_{N-1} + \tilde{\alpha}_{N-1} T + U_G \frac{T^2}{2} + a_J T_J \qquad \text{AND;}$$

$$\theta'_N = \tilde{\theta}_{N-1} + \tilde{\omega}_{N-1} T + \tilde{\alpha}_{N-1} \frac{T^2}{2} + U_G \frac{T^3}{6} + a_J T_J \left(T - \frac{T_J}{2}\right)$$

where; the $(\tilde{\ })_{N-1}$ values are the old state estimates,

T_J is the total jet firing time since t_{N-1} ,

and the last term of θ' or $a_J T_J \left(T - \frac{T_J}{2}\right)$ is obtained by integrating $a_J T_J$ over two intervals, one from t_{N-1} to T_J and the other from T_J to t_N

During the first interval $a_J T_J$ is a variable (JETRATE) where during the second it is a constant (JETSOFF).

Of course, if $T_J = T$ then the last term becomes $\frac{1}{2} a_J T^2$.

Now then, if an attitude (angle) measurement is taken every sample period, the predicted attitude θ'_N can be compared directly to the measured θ_m and the attitude deviation term formed. This provides for a correction, or new estimate, of the attitude as:

$$\tilde{\theta}_N = \theta'_N + K_\theta (\theta_m - \theta'_N)$$

Successive differentiations of the attitude DEVIATION term $(\theta_m - \theta'_N)$ can therefore be made to form the new estimates of ω and α , which are the basic state estimator outputs:

$$\tilde{\omega}_N = \omega'_N + K_\omega \frac{(\theta_m - \theta'_N)}{T}$$

$$\tilde{\alpha}_N = \alpha'_N + K_\alpha \frac{(\theta_m - \theta'_N)}{T^2}$$

NEXT PAGE

Since the DEVIATION term uses a CDU measurement which, for practical purposes, contains undesirable noise, the state estimator attempts to trap or reject this noise by use of non linear filter logic. This logic forces the magnitude of the RATE DEVIATION term $\left(\frac{\theta_m - \theta_N'}{T}\right)$ to exceed a certain threshold value before it is incorporated in the new rate estimate or differentiated for the acceleration estimate. This term is calculated each sample period and is allowed to accumulate over each sample period (T) until the total value exceeds the threshold. Thus, the filter gains or proportionality factors K_ω & K_α are chosen as functions of the number of sample periods (NTRAPS) since the last incorporation, whenever the accumulation exceeds the threshold. Then the estimate of the state will be corrected with the "gained" deviation term.

Since the filter, or trap, rejects the measurement noise for the rate estimate, and subsequent acceleration estimate, the attitude estimate need not be corrected. This esseentially allows a K_θ of unity to be selected for the attitude filter gain, which gives:

$$\tilde{\theta}_N = \theta_N' + K_\theta(\theta_m - \theta_N')$$

$$= \theta_N' + \theta_m - \theta_N' \quad = \theta_m$$

Thus, the new attitude estimate is always equal to the new measured value in this estimator.

One more item of explanation. It was mentioned above that the RATE DEVIATION term is the value upon which the filter operates. Expanding this term by substituting for θ_N' we have:

$$\frac{\theta_m - \theta_N'}{T} = \frac{1}{T}\left[\theta_m - \tilde{\theta}_{N-1} - \tilde{\omega}_{N-1}T - \tilde{\alpha}_{N-1}\frac{T^2}{2} - U_G\frac{T^3}{6} - a_J T_J\left(T - \frac{T_J}{2}\right)\right]$$

With the knowledge that $\tilde{\theta}_N = \theta_m$ from above, it can be seen that the first two terms represent the $\Delta\theta$ from t_{N-1} to t_N. Now dividing thru by T, we have:

$$\frac{\Delta\theta}{T} - \omega_{N-1} - \tfrac{1}{2}\alpha_{N-1}T - \tfrac{1}{6}U_G T^2 - a_J T_J\left(1 - \frac{T_J}{2T}\right)$$

The estimator term for this RATE DEVIATION is called (TRAPED) and the equation used illiminates the $\frac{1}{6}U_G T^2$ term and approximates the last term as follows:

$$TRAPED = \frac{\Delta\theta}{T} - \tilde{\omega}_{N-1} - \tfrac{1}{2}\tilde{\alpha}_{N-1}T - \tfrac{1}{2}a_J T_J$$

The value (NTRAPS) is the counter for the number of sample periods TRAPED has been accumulated and is always set equal to one period ahead, or (NTRAPS +1). In DAP IDLE it is initialized at (NTRAPS = 2). To obtain the desired dynamic characteristics in the state estimate, NTRAPS is combined with a pad loaded value (N_ω, N_α) and different for docked and undocked config.). The combination then is used for the gain terms K_ω & K_α where

$$K_\omega = \frac{1}{NTRAPS + N_\omega} \quad ; \quad K_\alpha = \frac{1}{NTRAPS + N_\omega + N_\alpha} K_\omega$$

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The first term calculated in the STATE ESTIMATOR is the $a_J T_J$ value or (JETRATE). This is computed for each control axis (P, Q & R) and represents the predicted addition to the vehicle rate, during the last control sample period, due to the jets firing. The JETRATE value for each axis is determined as:

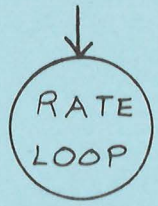
JETRATE = [the acceleration (JACC) expected from one jet firing] times

[the total number of jets firing (NO. JETS) for that axis] times

[the length of time fired (TJET) during the 0.1 sec period]

Since the DAP operates with control axes rotated 45 deg. in the plane of the Q & R axes, the TJET values are for these axes (TJU & TJV). Thus, the JETRATE for Q & R must be obtained by resolving these TJET's into Q & R components. TJET values are computed within the DAP control logic anytime the DAP establishes the vehicle must be torqued to acquire a desired state. They may be greater than 100 msec, however, the JETRATE logic will use 100 msec max. The JACC terms are computed external to the DAP as part of the control effectiveness calculations in the 1/ACCS rtn.

Now to the STATE ESTIMATOR LOGIC !



SETUP A LOGIC LOOP FOR COMPONENTS OF THE JETRATE VALUES. START WITH THE LOOP INDEXER SET FOR V-AXIS CALCULATIONS. NOTE: USE OF THE INDEXER IS REFLECTED BY THE SUBSCRIPT i, WHERE i IS SET TO LOCATE THE PROPER SIDE-BY-SIDE E-MEM. LOCATION CORRESPONDING TO THE PROPER AXIS. THE MNEMONICS USED IN THE LOGIC REFLECTS THE P-AXIS LOCATIONS. EX. $(NO.PJETS)_i$ WHEN i IS set for U-AXIS SHOULD READ (NO.UJETS) or, $(TJET)_i$ SHOULD READ (TJU), etc.

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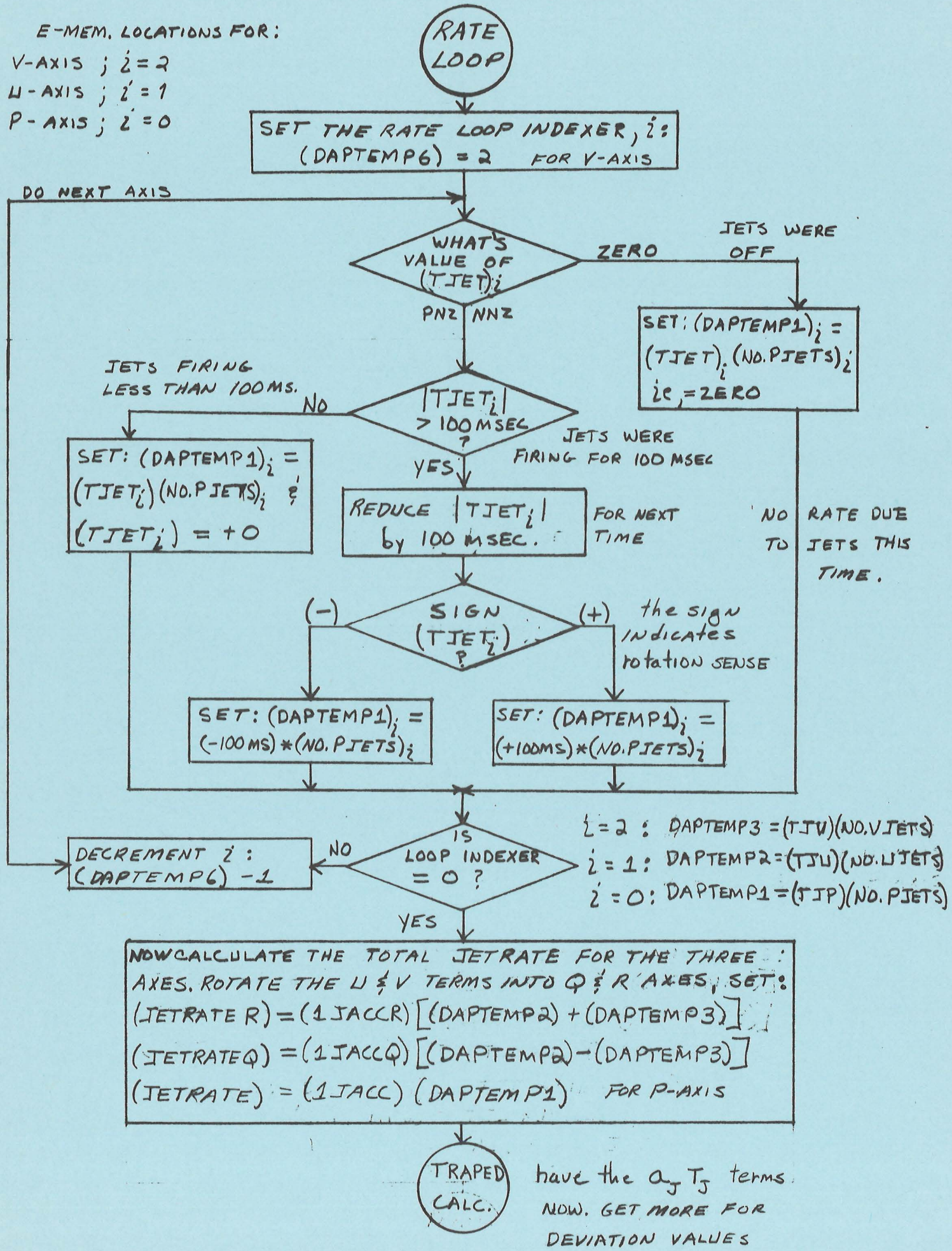
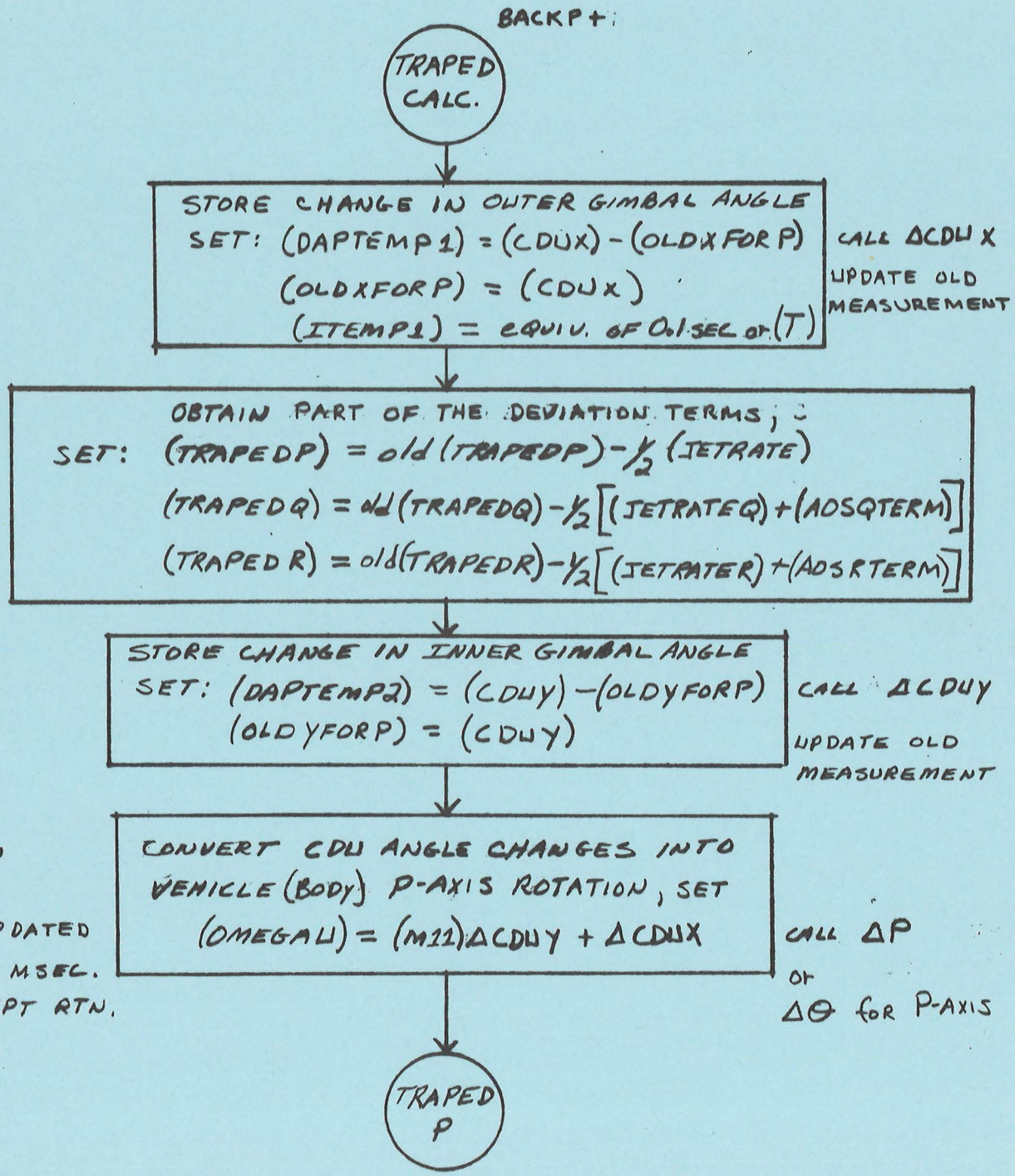
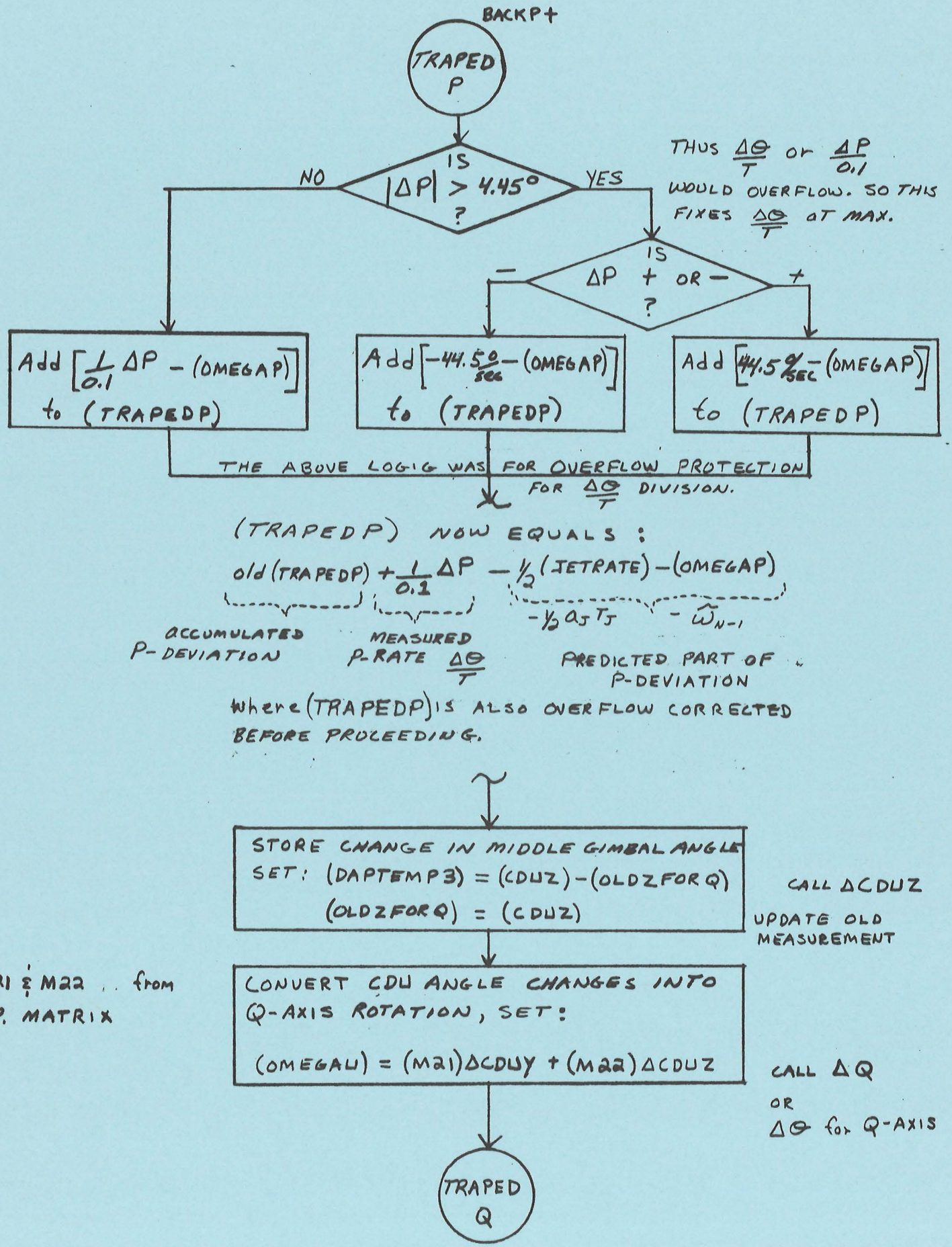
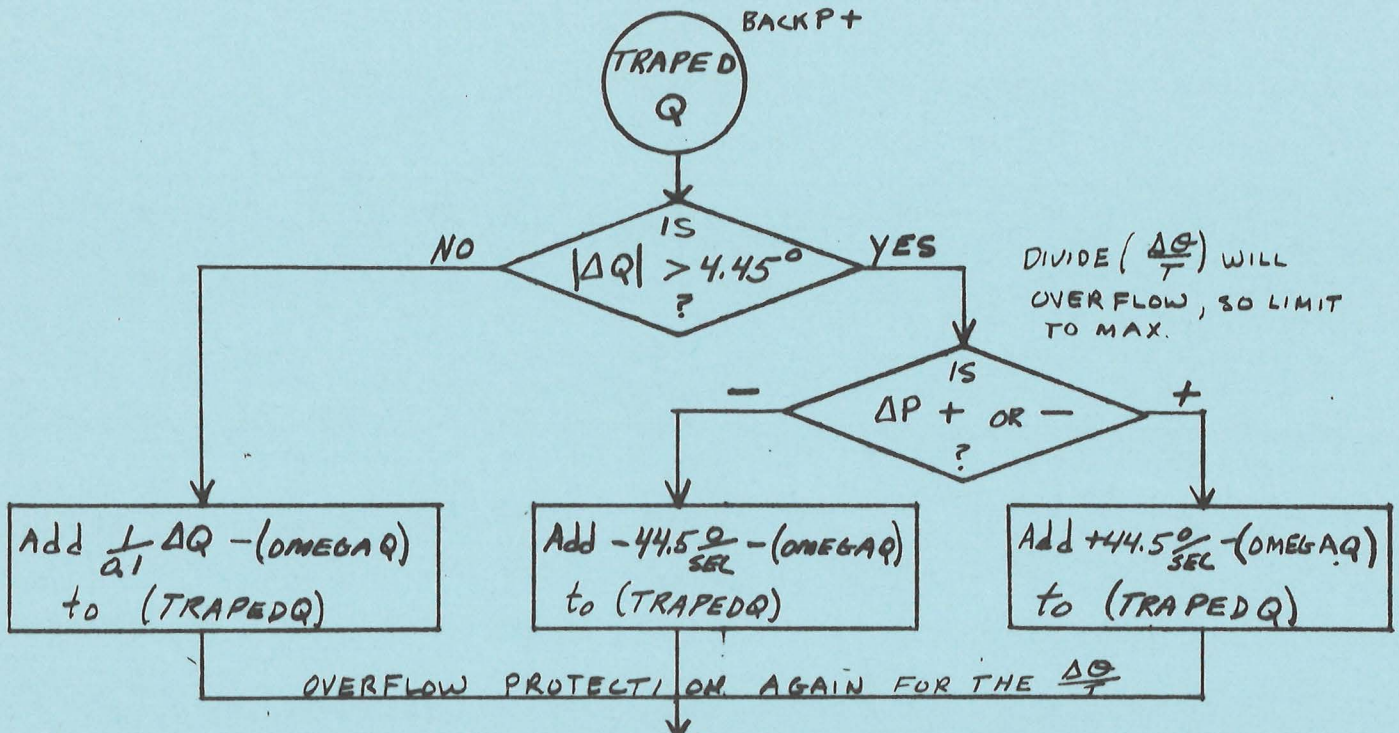

E-MEM. LOCATIONS FOR:
V-AXIS ; i = 2
U-AXIS ; i = 1
P-AXIS ; i = 0
RATE LOOP
SET THE RATE LOOP INDEXER, i:
(DAPTEMP6) = 2 FOR V-AXIS
DO NEXT AXIS
WHAT'S VALUE OF (TJET)i
ZERO
JETS WERE OFF
SET: (DAPTEMP1)i = (TJET)i (NO.PJETS)i
ic, = ZERO
PNZ
NNZ
JETS FIRING LESS THAN 100MS.
NO
|TJETi| > 100 MSEC ?
JETS WERE FIRING FOR 100 MSEC
YES
SET: (DAPTEMP1)i = (TJETi)(NO.PJETS)i & (TJETi) = +0
REDUCE |TJETi| by 100 MSEC.
FOR NEXT TIME
NO RATE DUE TO JETS THIS TIME.
(-)
SIGN (TJETi) ?
(+)
the sign indicates rotation SENSE
SET: (DAPTEMP1)i = (-100 MS) * (NO.PJETS)i
SET: (DAPTEMP1)i = (+100MS) * (NO.PJETS)i
DECREMENT i : (DAPTEMP6) -1
NO
IS LOOP INDEXER = 0 ?
YES
i = 2 : DAPTEMP3 = (TJV)(NO.VJETS)
i = 1 : DAPTEMP2 = (TJU)(NO.UJETS)
i = 0 : DAPTEMP1 = (TJP)(NO.PJETS)
NOW CALCULATE THE TOTAL JETRATE FOR THE THREE AXES. ROTATE THE U & V TERMS INTO Q & R AXES, SET:
(JETRATE R) = (1JACCR) [(DAPTEMP2) + (DAPTEMP3)]
(JETRATEQ) = (1JACCQ) [(DAPTEMP2) - (DAPTEMP3)]
(JETRATE) = (1JACC) (DAPTEMP1) FOR P-AXIS
TRAPED CALC.
have the $a_J T_J$ terms NOW. GET MORE FOR DEVIATION VALUES

BEGINING OF THE DEVIATION TERM CALCULATIONS (TRAPED) FOR THE P, Q & R-AXES. THE OLD CDU ANGLE MEASUREMENTS ARE IN OLDXFORP, OLDYFORP & OLDZFORQ. THE NEW MEASUREMENTS ARE, OF COARSE, CDUX, CDUY & CDUZ. THE Δ MEASUREMENT OR Δ ANGLES ARE RESOLVED INTO VEHICLE AXES TO OBTAIN THE Δ ATTITUDE, OR Δθ TERM, FOR EACH AXIS.

ALSO, ACCELERATION BIAS FOR THE P-AXIS IS ALWAYS ASSUMED = 0. THEREFORE, THERE WILL BE NO $\tilde{\alpha}_{N-1}\frac{T}{2}$ TERM IN THE P-AXIS ESTIMATION.




BACKP+
TRAPED P
IS |ΔP| > 4.45° ?
NO
YES
THUS ΔΘ/T or ΔP/0.1 WOULD OVERFLOW. SO THIS FIXES ΔΘ/T AT MAX.
IS ΔP + OR − ?
−
+
Add [1/0.1 ΔP − (OMEGAP)] to (TRAPEDP)
Add [−44.5°/sec − (OMEGAP)] to (TRAPEDP)
Add [44.5°/sec − (OMEGAP)] to (TRAPEDP)
THE ABOVE LOGIC WAS FOR OVERFLOW PROTECTION FOR ΔΘ/T DIVISION.
(TRAPEDP) NOW EQUALS:
old (TRAPEDP) + 1/0.1 ΔP − 1/2 (JETRATE) − (OMEGAP)
ACCUMULATED P-DEVIATION
MEASURED P-RATE ΔΘ/T
−1/2 a_J T_J
− ω̃_{N-1}
PREDICTED PART OF P-DEVIATION
where (TRAPEDP) IS ALSO OVERFLOW CORRECTED BEFORE PROCEEDING.
STORE CHANGE IN MIDDLE GIMBAL ANGLE
SET: (DAPTEMP3) = (CDUZ) − (OLDZFORQ)
(OLDZFORQ) = (CDUZ)
CALL ΔCDUZ
UPDATE OLD MEASUREMENT
M21 & M22 from G.P. MATRIX
CONVERT CDU ANGLE CHANGES INTO Q-AXIS ROTATION, SET:
(OMEGAU) = (M21)ΔCDUY + (M22)ΔCDUZ
CALL ΔQ OR ΔΘ for Q-AXIS
TRAPED Q



(TRAPEDQ) NOW EQUALS:

$$\underbrace{\text{old (TRAPEDQ)}}_{\text{ACCUMULATED Q-DEVIATION}} + \underbrace{\frac{1}{a_1}\Delta Q}_{\text{MEASURED Q-RATE } \frac{\Delta\Theta}{T}} - \underbrace{\tfrac{1}{2}(\text{JETRATEQ}) - \tfrac{1}{2}(\text{AOSQTERM}) - (\text{OMEGAQ})}_{-\frac{1}{2}a_J T_J \;-\; \frac{1}{2}\tilde{\alpha}_{N-1}T \;-\; \tilde{\omega}_{N-1}}$$

PREDICTED PART OF Q-DEVIATION

WHERE, (TRAPEDQ) IS OVERFLOW CORRECTED AND THE AOSQTERM IS SET = 0.1(AOSQ) AFTER EACH AOS ESTIMATE (see LATER).

M31 & M32 from G.P. MATRIX

CONVERT CDU ANGLE CHANGES INTO R-AXIS ROTATION, SET:

(OMEGAU) = (M31) ΔCDUY + (M32) ΔCDUZ

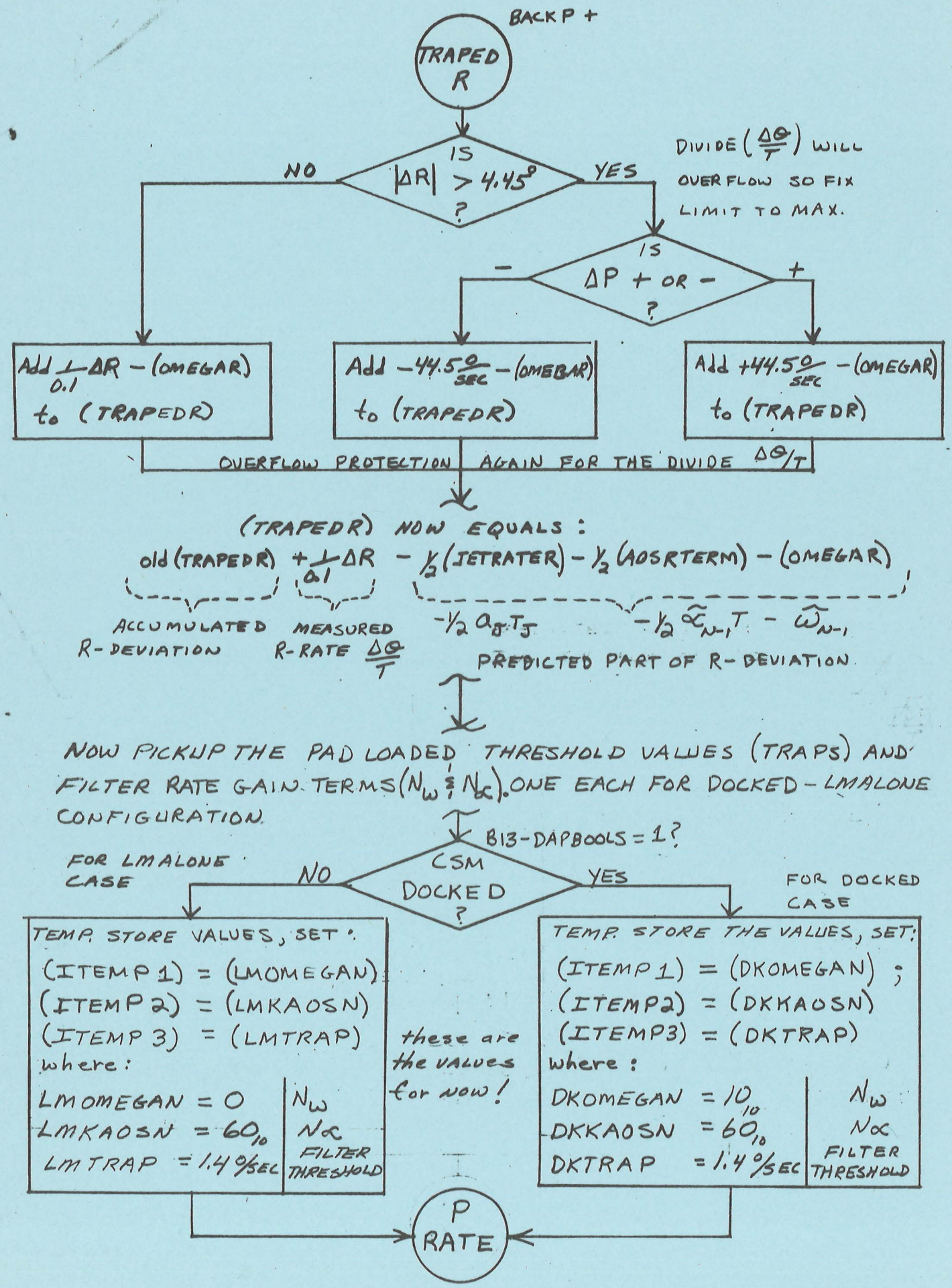
CALL ΔR or ΔΘ FOR R-AXIS

TRAPED R

G.P. M*

$$\begin{bmatrix} P \\ Q \\ R \end{bmatrix} = \begin{bmatrix} M11 & 0 & 1 \\ M21 & M22 & 0 \\ M31 & M32 & 0 \end{bmatrix} * \begin{bmatrix} \Delta CDUY \\ \Delta CDUZ \\ \Delta CDUX \end{bmatrix}$$

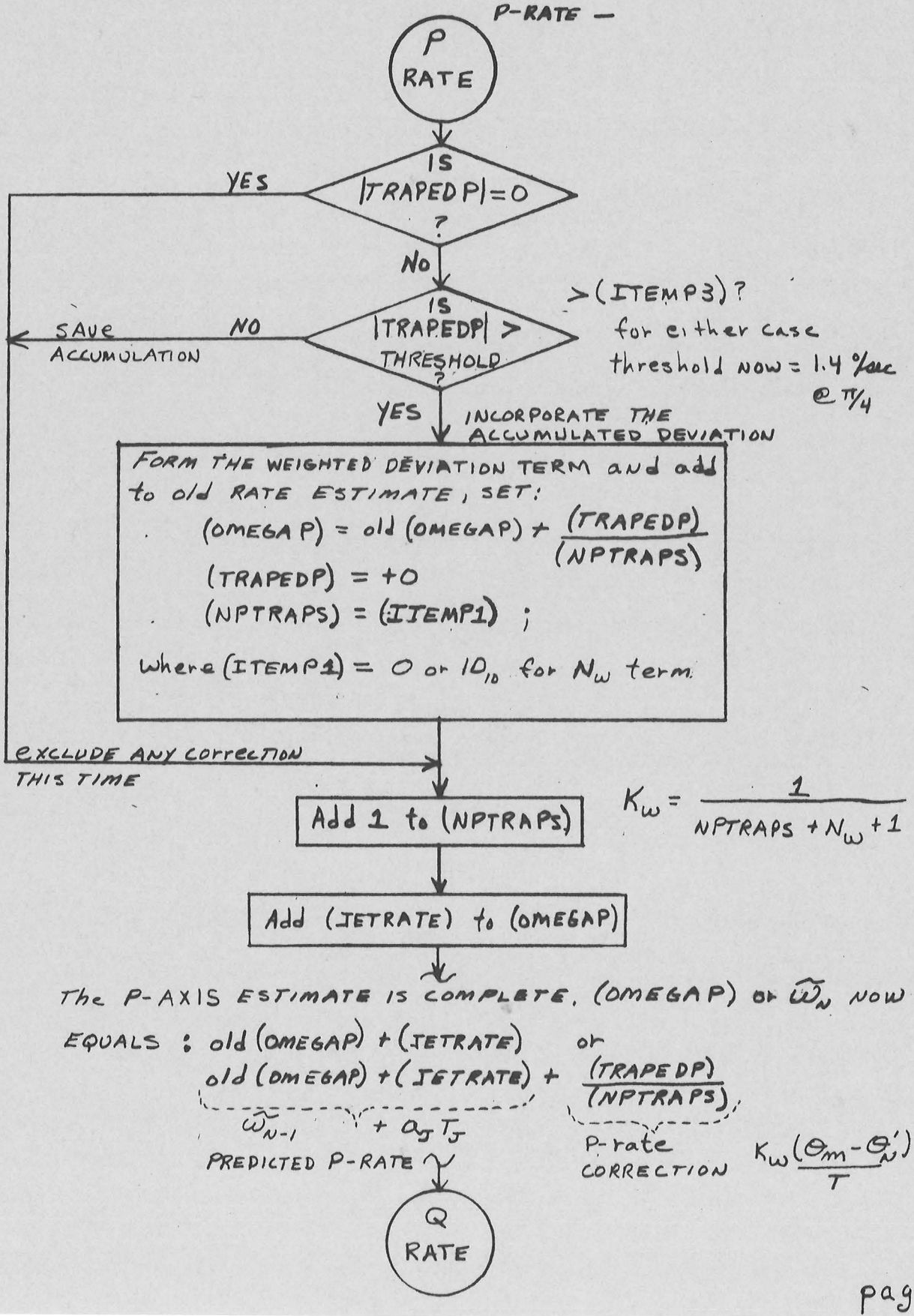
UPDATED BY T4-RUPT RTN EVERY 240 MSEC.


BACKP +
TRAPED R
IS |ΔR| > 4.45° ?
NO
YES
DIVIDE (ΔΘ/T) WILL OVERFLOW SO FIX LIMIT TO MAX.
IS ΔP + OR − ?
−
+
Add 1/0.1 ΔR − (OMEGAR) to (TRAPEDR)
Add −44.5°/SEC − (OMEGAR) to (TRAPEDR)
Add +44.5°/SEC − (OMEGAR) to (TRAPEDR)
OVERFLOW PROTECTION AGAIN FOR THE DIVIDE ΔΘ/T
(TRAPEDR) NOW EQUALS :
old (TRAPEDR) + 1/0.1 ΔR − ½(JETRATER) − ½(AOSRTERM) − (OMEGAR)
ACCUMULATED R-DEVIATION
MEASURED R-RATE ΔΘ/T
−½ a_J T_J
−½ α̃_{N-1} T − ω̃_{N-1}
PREDICTED PART OF R-DEVIATION
NOW PICKUP THE PAD LOADED THRESHOLD VALUES (TRAPS) AND FILTER RATE GAIN TERMS (N_ω & N_α). ONE EACH FOR DOCKED - LMALONE CONFIGURATION.
B13-DAPBOOLS = 1?
CSM DOCKED ?
FOR LMALONE CASE
NO
YES
FOR DOCKED CASE
TEMP. STORE VALUES, SET:
(ITEMP 1) = (LMOMEGAN)
(ITEMP 2) = (LMKAOSN)
(ITEMP 3) = (LMTRAP)
where:
LMOMEGAN = 0
LMKAOSN = 60₁₀
LMTRAP = 1.4°/SEC
N_ω
N_α
FILTER THRESHOLD
these are the values for now!
TEMP. STORE THE VALUES, SET:
(ITEMP 1) = (DKOMEGAN) ;
(ITEMP2) = (DKKAOSN)
(ITEMP3) = (DKTRAP)
where:
DKOMEGAN = 10₁₀
DKKAOSN = 60₁₀
DKTRAP = 1.4°/SEC
N_ω
N_α
FILTER THRESHOLD
P RATE

NOW THE ESTIMATED RATES ARE CALC. FOR ALL 3 AXES (P, Q & R).

$$\tilde{\omega}_N = \omega'_N + K_\omega \frac{(\theta_m - \theta'_N)}{T} \text{ or just } = \omega'_N$$

WHERE THE PREDICTED RATE $\omega'_N = \tilde{\omega}_{N-1} + \tilde{\alpha}_{N-1} T + a_J T_J$



Q RATE

P-RATE +

IS |TRAPEDQ| = 0 ?

YES

NO

IS |TRAPEDQ| > THRESHOLD ?

>(ITEMP3) ? WHICH IS = 1.4°/SEC FOR EITHER CASE

NO — SAVE ACCUMULATION

YES — INCORPORATE THE ACCUMULATED DEVIATION

THE WEIGHTED Q-RATE DEVIATION TERM IS NOW FORMED ADD Added TO THE OLD ESTIMATE,

SET: $(OMEGAQ) = old(OMEGAQ) + \frac{(TRAPEDQ)}{(NQTRAPS)}$

ALSO $(SUMRATEQ) = old(SUMRATEQ) + \frac{(TRAPEDQ)}{(NQTRAPS)}$

AND SAVE $\frac{(TRAPEDQ)}{(NQTRAPS)}$ for below.

NOW SET: (TRAPEDQ) = 0 INITIALIZE THE TRAP

OVERFLOW PROTECTED

$\tilde{\omega}_{N-1} + K_\omega \frac{(\theta_{mn} - \theta'_N)}{T}$

ACCUMULATED DEV. FOR DOWNLINK; could OVERFLOW

SINCE IT IS CONVENIENT AT THIS TIME, THE WEIGHTED DEVIATION TERM FOR THE Q-AXIS AOS ESTIMATE IS FORMED & added TO OLD ESTIMATE,

Add $\left[\left(\frac{1}{0.1}\right)\frac{(TRAPEDQ)}{(NQTRAPS)} \quad \frac{1}{(NQTRAPS)+(ITEMP2)}\right]$ to (AOSQ) ;

where $ITEMP2 = 60_{10}$ and is N_α for either case

SET: (NQTRAPS) = (ITEM1) ; $N_\omega = 0$ or 10_{10}

PART OF AOS EST. USED LATER.

$\tilde{\alpha}_{N-1} + K_\alpha \frac{(\theta_{mn} - \theta'_N)}{T^2}$

where K_α is formed:

$\frac{1}{NQTRAPS + N_\omega + N_\alpha} K_\omega$

EXCLUDE ANY CORRECTION

Add 1 to (NQTRAPS)

GET REST OF Q-RATE EST.

Add; (JETRATEQ) + (AOSQTERM) to (OMEGAQ)

THE Q-RATE ESTIMATE IS COMPLETE NOW. (OMEGAQ) NOW EQUALS:

$old(OMEGAQ) + (JETRATEQ) + (AOSQTERM)$

OR; $\underbrace{old(OMEGAQ)}_{\tilde{\omega}_{N-1}} + \underbrace{(JETRATEQ)}_{+ a_J T_J} + \underbrace{(AOSQTERM)}_{+ \tilde{\alpha}_{N-1} T} + \underbrace{\frac{(TRAPEDQ)}{(NQTRAPS)}}_{\text{Q-RATE CORRECTION } K_\omega \frac{(\theta_{mn} - \theta'_N)}{T}}$;

PREDICTED Q-RATE

R RATE

Q-RATE +

R RATE

IS |TRAPEDR| = 0 ?

YES → EXCLUDE ANY CORRECTION

NO

IS |TRAPEDR| > THRESHOLD ?

> (ITEMP3) ? 1.4 °/SEC for either case

NO → SAVE ACCUMULATION

YES → INCORPORATE THE ACCUMULATED DEVIATION

The weighted R-RATE DEVIATION TERM is formed and added to the old rate & a downlink register.

Add $\frac{(TRAPEDR)}{(NRTRAPS)}$ to (OMEGAR) & (SUMRATER) D.L. reg.

SET: (TRAPEDR) = +0

OMEGAR = $\tilde{\omega}_{N-1} + K_\omega \frac{(\theta_m - \theta'_N)}{T}$

SUMRATER IS LIKE SUMRATEQ; COULD OVERFLOW

The weighted deviation term for the R-AXIS OFFSET ACCELERATION ESTIMATE is now formed and added to the old estimate.

Add; $\left[\left(\frac{1}{0.1}\right)\frac{(TRAPEDR)}{(NRTRAPS)} \quad \frac{1}{(NRTRAPS)+(ITEMP2)}\right]$ to (AOSR)

SET: (NRTRAPS) = (ITEMP1) ; $N_\omega = 0$ or 10_{10}

PART OF AOS EST. USED LATER.

$\tilde{\alpha}_{N-1} + K_\alpha \frac{(\theta_m - \theta'_N)}{T^2}$

K_α is same

ITEMP2 = N_α

Add 1 to (NRTRAPS)

Add [(JETRATER) + (AOSRTERM)] to (OMEGAR)

THE R-AXIS RATE ESTIMATE IS COMPLETE. (OMEGAR) NOW EQUALS:

old (OMEGAR) + (JETRATER) + (AOSRTERM)

OR, $\underbrace{\text{old (OMEGAR)}}_{\tilde{\omega}_{N-1}} + \underbrace{(\text{JETRATER})}_{+\,a_J T_J} + \underbrace{(\text{AOSRTERM})}_{+\,\tilde{\alpha}_{N-1} T} + \underbrace{\frac{(TRAPEDR)}{(NRTRAPS)}}_{K_\omega \frac{(\theta_m - \theta'_N)}{T}}$

ACCEL EST.

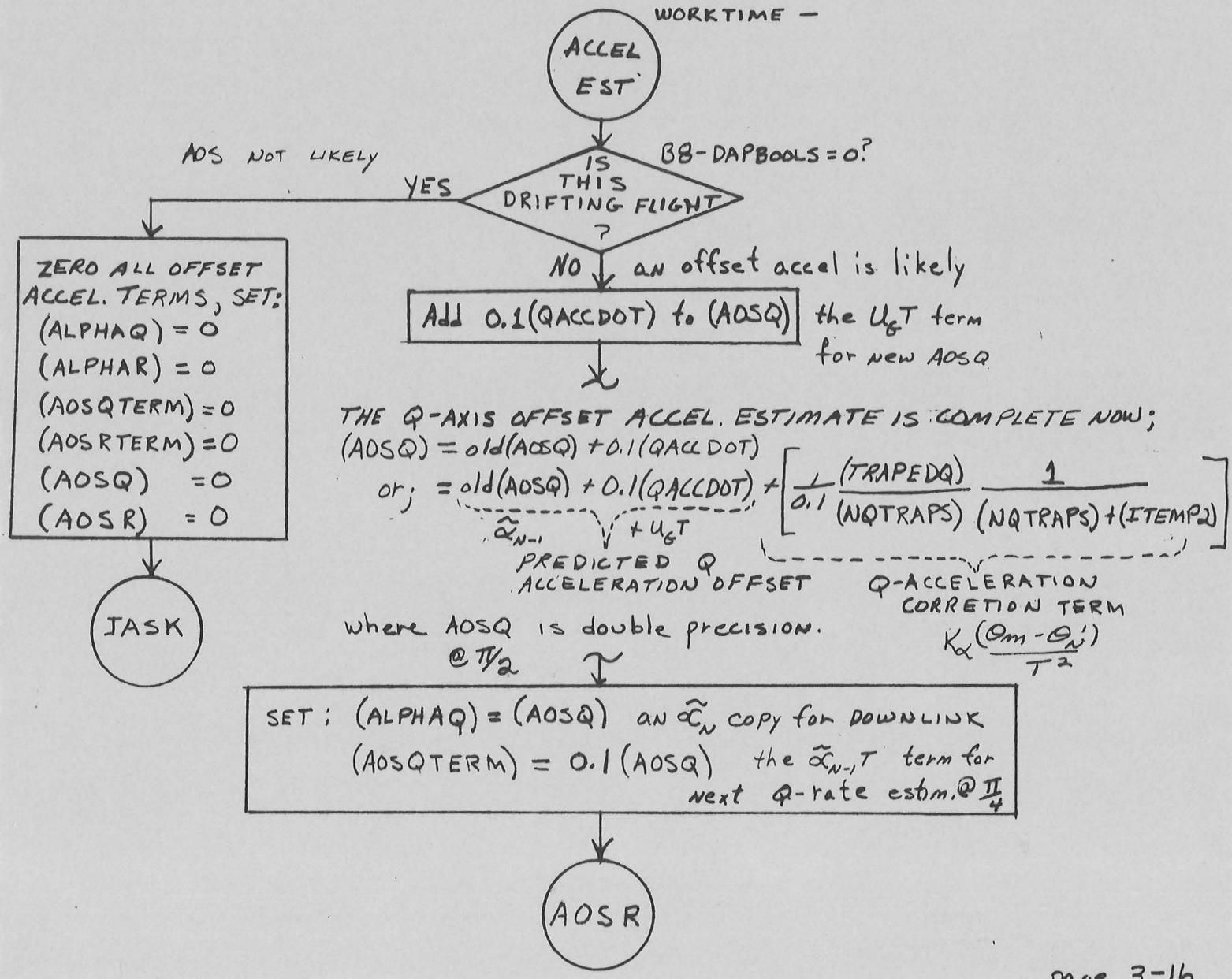
NOTE ALL ADDITIONS TO (OMEGA P, Q & R) ARE OVERFLOW PROTECTED, IN WHICH CASE, OMEGA WILL BE SET TO ± MAX. THIS MEANS A RATE LIMIT OF ± 45 °/SEC.

NOW the OFFSET ACCELERATION ESTIMATES will be calculated. OF course, the offset acceleration is the angular accel., about the Q & R axes, which is caused by the DPS engine thrust and center-of-gravity misalignment. The estimate, again, is equal to: $\tilde{\alpha}_N = \alpha'_N + K_\alpha \frac{(\theta_m - \theta'_N)}{T^2}$; or JUST $= \alpha'_N$

WHERE THE PREDICTED AOS IS; $\alpha'_N = \tilde{\alpha}_{N-1} + U_G T$

The PREDICTED ACCEL. is obtained from the old estimate plus the integral of the rate-of-change of acceleration due to gimballing the DPS egine. This rate-of-change (U_G) is CALLED ACCDOT is calculated external to the DAP IN the 1/ACCS RTN.

The DEVIATION TERM is actually the derivative of the rate deviation term times an additional weighting factor.



WORKTIME +

AOSR

JASK

Add 0.1(RACCDOT) to (AOSR)

the $U_G T$ term for new AOSR

THE R-AXIS OFFSET ACCELERATION ESTIMATE IS COMPLETE.

(AOSR) = old (AOSR) + 0.1 (RACCDOT)

$$\text{or; } = \underbrace{\text{old (AOSR)} + 0.1(\text{RACCDOT})}_{\tilde{\alpha}_{N-1} + U_G T} + \underbrace{\left[\frac{1}{0.1}\,\frac{(\text{TRAPEDR})}{(\text{NRTRAPS})}\,\frac{1}{(\text{NRTRAPS})+(\text{ITEMP2})}\right]}_{K_\alpha\frac{(\theta_m-\theta_N')}{T^2}}$$

where AOSR @ $\pi/2$ is double precision.

THE PREDICTED Q-ACCEL OFFSET

THE Q-ACCEL CORRECTION

SET: (ALPHAR) = (AOSR) an $\tilde{\alpha}_N$ copy for downlink

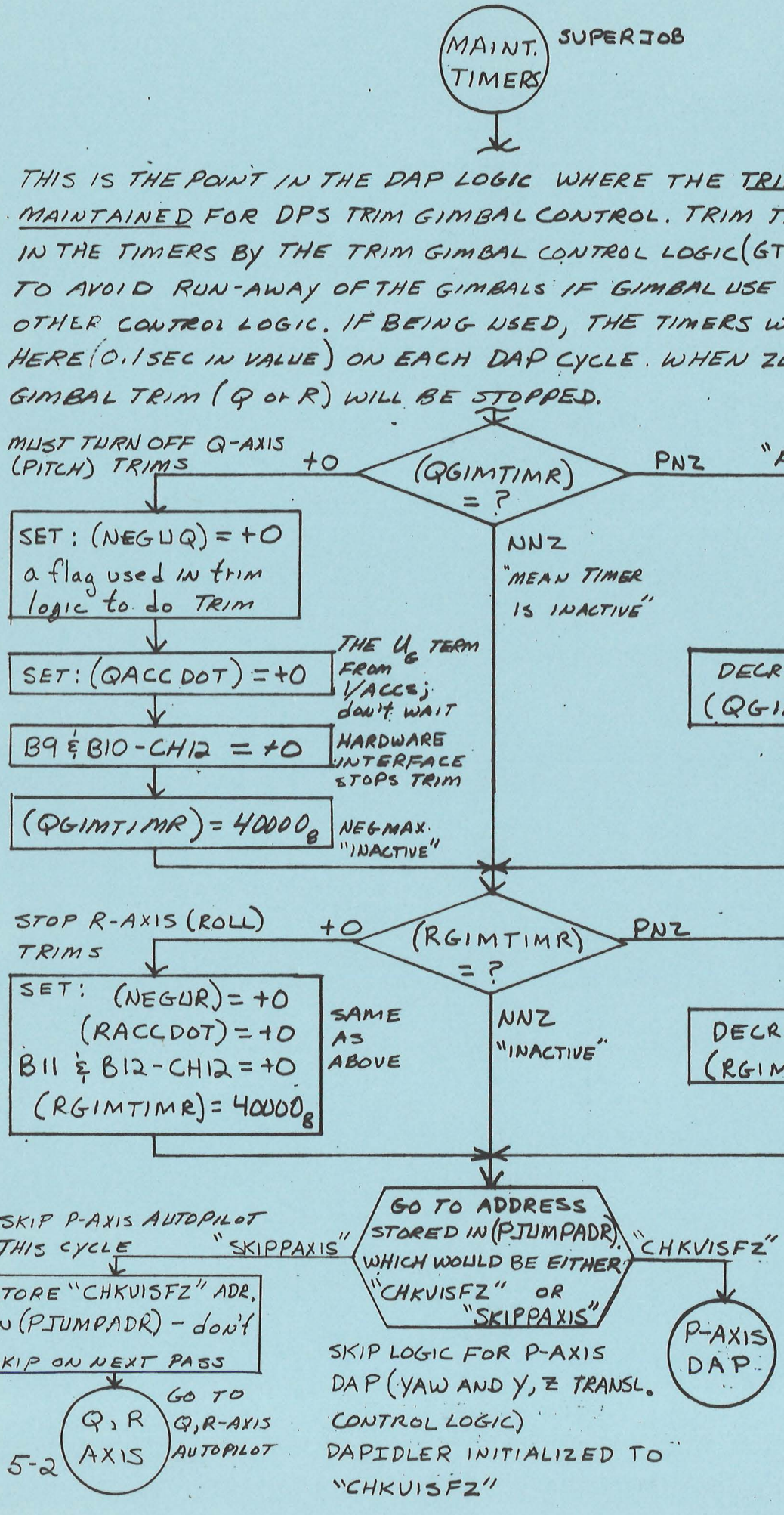
(AOSRTERM) = 0.1 (AOSR) $\tilde{\alpha}_{N-1} T$ term for next R-RATE ESTIM. @ $\pi/4$

"END OF STATE ESTIMATOR"

SETUP THE REMAINDER OF THIS DAP CYCLE AS A JASK AND CON't.

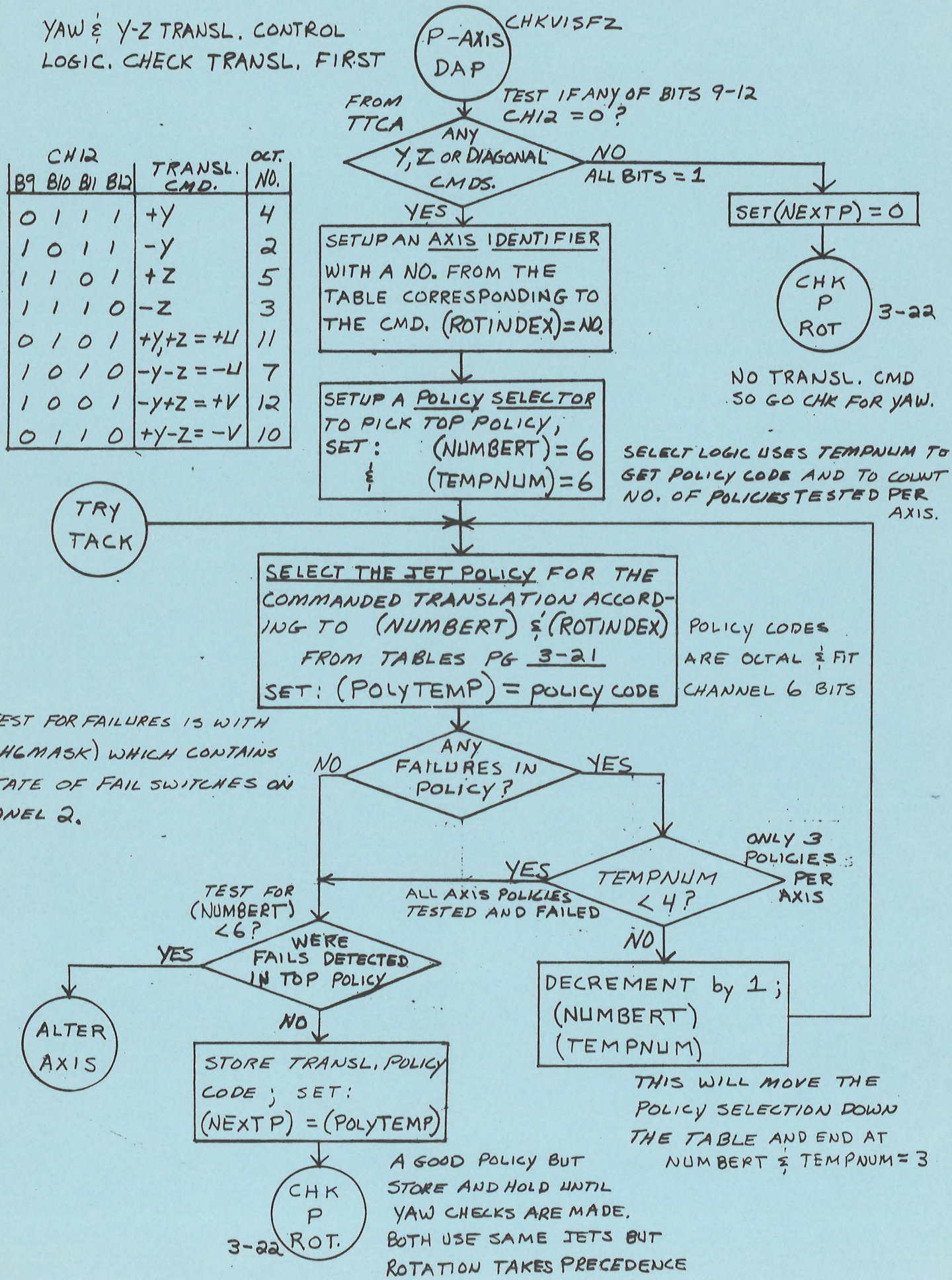
LGC PROCESSING OF THE DAP HAS BEEN IN AN INTERRUPT INHIBITED STATE (TSRUPT) UNTIL NOW. JASK CONTROL ESSENTIALLY ALLOWS PROGRAM INTERRUPTS BUT DISALLOWS THE PROCESSING OF ANY SCHEDULED JOB UNTIL THE JASK IS ENDED.

MAINT. TIMERS

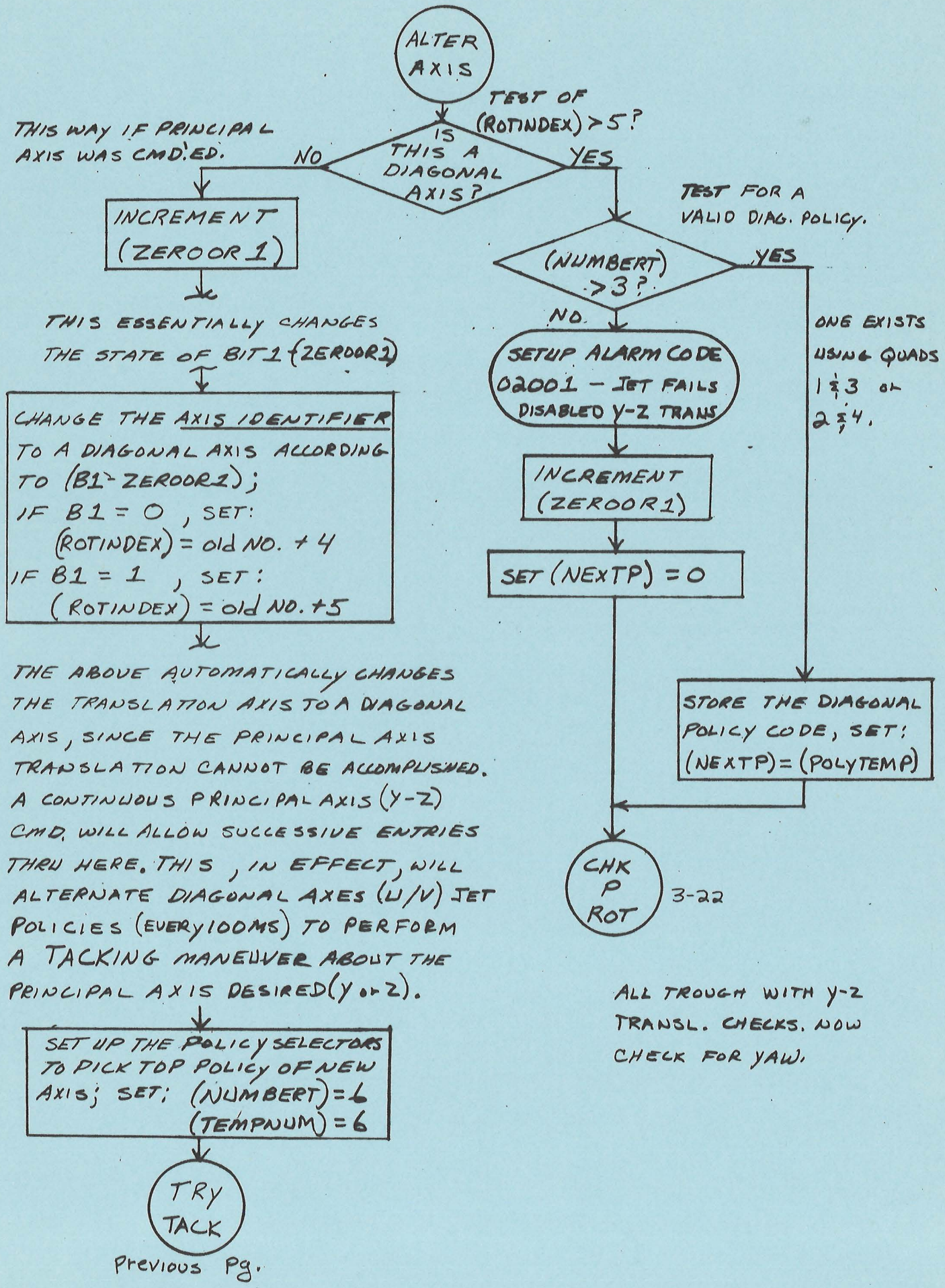

MAINT. TIMERS
SUPERJOB
THIS IS THE POINT IN THE DAP LOGIC WHERE THE TRIM TIMERS ARE MAINTAINED FOR DPS TRIM GIMBAL CONTROL. TRIM TIMES ARE ENTERED IN THE TIMERS BY THE TRIM GIMBAL CONTROL LOGIC (GTS OR TIMEGMBL MTN'S) TO AVOID RUN-AWAY OF THE GIMBALS IF GIMBAL USE IS DISALLOWED BY OTHER CONTROL LOGIC. IF BEING USED, THE TIMERS WILL BE DECREMENTED HERE (0.1 SEC IN VALUE) ON EACH DAP CYCLE. WHEN ZERO, THE APPROPRIATE GIMBAL TRIM (Q or R) WILL BE STOPPED.
MUST TURN OFF Q-AXIS (PITCH) TRIMS
+0
(QGIMTIMR) = ?
PNZ
"ACTIVE"
SET: (NEGUQ) = +0
a flag used in trim logic to do TRIM
NNZ
"MEAN TIMER IS INACTIVE"
COUNT DOWN 0.1 SEC WORTH
SET: (QACC DOT) = +0
THE U_G TERM FROM VACCS; don't WAIT
DECREMENT (QGIMTIMR
B9 & B10-CH12 = +0
HARDWARE INTERFACE STOPS TRIM
MAX PNZ VALUE WOULD BE = 2.5 SEC
(QGIMTIMR) = 40000_8
NEGMAX "INACTIVE"
STOP R-AXIS (ROLL) TRIMS
+0
(RGIMTIMR) = ?
PNZ
"ACTIVE"
SET: (NEGUR) = +0
(RACC DOT) = +0
B11 & B12-CH12 = +0
(RGIMTIMR) = 40000_8
SAME AS ABOVE
NNZ
"INACTIVE"
DECREMENT (RGIMTIMR)
PNZ VALUE = 2.5 SEC MAX.
GO TO ADDRESS STORED IN (PJUMPADR), WHICH WOULD BE EITHER "CHKVISFZ" OR "SKIPPAXIS"
SKIP P-AXIS AUTOPILOT THIS CYCLE
"SKIPPAXIS"
"CHKVISFZ"
STORE "CHKVISFZ" ADR. IN (PJUMPADR) - don't SKIP ON NEXT PASS
Q, R AXIS
GO TO Q, R-AXIS AUTOPILOT
P-AXIS DAP
SKIP LOGIC FOR P-AXIS DAP (YAW AND Y, Z TRANSL. CONTROL LOGIC)
DAPIDLER INITIALIZED TO "CHKVISFZ"
"SKIPPAXIS" IS STORED ONLY IF P-AXIS AUTOPILOT FIRED JETS LAST CYCLE & CALC. FIRING TIME FOR YAW ≤ 150 MSEC. THUS, FIRING IS BEING TIMED BY T6 TO SHUT OFF JETS. SO NEED NOT KEEP TRACK OF THEM.

5-2

YAW & Y-Z TRANSL. CONTROL LOGIC. CHECK TRANSL. FIRST



CH12 B9	B10	B11	B12	TRANSL. CMD.	OCT. NO.
0	1	1	1	+Y	4
1	0	1	1	-Y	2
1	1	0	1	+Z	5
1	1	1	0	-Z	3
0	1	0	1	+Y,+Z = +U	11
1	0	1	0	-Y-Z = -U	7
1	0	0	1	-Y+Z = +V	12
0	1	1	0	+Y-Z = -V	10


ALTER AXIS
TEST OF (ROTINDEX) > 5?
IS THIS A DIAGONAL AXIS?
NO
YES
THIS WAY IF PRINCIPAL AXIS WAS CMD'ED.
INCREMENT (ZEROOR1)
THIS ESSENTIALLY CHANGES THE STATE OF BIT 1 (ZEROOR1)
CHANGE THE AXIS IDENTIFIER TO A DIAGONAL AXIS ACCORDING TO (B1 ~ ZEROOR1);
IF B1 = 0, SET:
(ROTINDEX) = old NO. + 4
IF B1 = 1, SET:
(ROTINDEX) = old NO. + 5
THE ABOVE AUTOMATICALLY CHANGES THE TRANSLATION AXIS TO A DIAGONAL AXIS, SINCE THE PRINCIPAL AXIS TRANSLATION CANNOT BE ACCOMPLISHED. A CONTINUOUS PRINCIPAL AXIS (Y-Z) CMD. WILL ALLOW SUCCESSIVE ENTRIES THRU HERE. THIS, IN EFFECT, WILL ALTERNATE DIAGONAL AXES (U/V) JET POLICIES (EVERY 100MS) TO PERFORM A TACKING MANEUVER ABOUT THE PRINCIPAL AXIS DESIRED (Y or Z).
SET UP THE POLICY SELECTORS TO PICK TOP POLICY OF NEW AXIS; SET: (NUMBERT) = 6
(TEMPNUM) = 6
TRY TACK
Previous Pg.
TEST FOR A VALID DIAG. POLICY.
(NUMBERT) > 3?
YES
NO
SETUP ALARM CODE 02001 - JET FAILS DISABLED Y-Z TRANS
INCREMENT (ZEROOR1)
SET (NEXTP) = 0
ONE EXISTS USING QUADS 1 & 3 or 2 & 4.
STORE THE DIAGONAL POLICY CODE, SET: (NEXTP) = (POLYTEMP)
CHK P ROT
3-22
ALL TROUGH WITH Y-Z TRANSL. CHECKS. NOW CHECK FOR YAW.

JET POLICY TABLE FOR Y AND Z TRANSLATIONS
(P-AXIS RCS AUTOPILOT)

policy selector no. (NUMBERT)	+Z axis I, D No. (ROTINDEX) = 5	-Z (ROTINDEX) = 3	+Y (ROTINDEX) = 4	-Y (ROTINDEX) = 2
6	B3A - A2A (011)	A1F - B4F (006)	B1L - B2L (220)	A3R - A4R (140)
5 results in diagonal policy	B3A tacks with jets: A3R/B1L (+V/+U)	A1F tacks with jets: A3R/B1L (-U/-V)	B1L tacks with jets: A1F/B3A (-V/+U)	A3R tacks with jets: B3A/A1F (+V/-U)
4 results in diagonal policy	A2A tacks with jets: A4R/B2L (+V/+U)	B4F tacks with jets: B2L/A4R (-V/-U)	B2L tacks with jets: B4F/A2A (-V/+U)	A4R tacks with jets: A2A/B4F (+V/-U)
ALARM - code 0200 1 setup for astronaut				

NOTE: If top policy above fails, then policies from table below are tried for tacking. The good jet above, is used constantly while the other two burn alternately every DAP cycle.

JET POLICY TABLE FOR DIAGONAL (U-V) TRANSLATIONS

policy selector no. (NUMBERT)	+V axis I.D. No. (ROTINDEX) = 12	-V (ROTINDEX) = 10	+U (ROTINDEX) = 11	-U (ROTINDEX) = 7
6	B3A - A3R A4R - A2A (151)	B1L - A1F B2L - B4F (226)	B1L - B3A A2A - B2L (231)	A3R - A1F B4F - A4R (146)
5	B3A - A3R (041)	B1L - A1F (204)	B1L - B3A (201)	A3R - A1F (044)
4	A4R - A2A (110)	B2L - B4F (022)	A2A - B2L (030)	B4F - A4R (102)
ALARM - code 0200 1 setup for astronaut				

Numbers in parenthesis are (NEXT P) octal codes to fit CH 6 bits

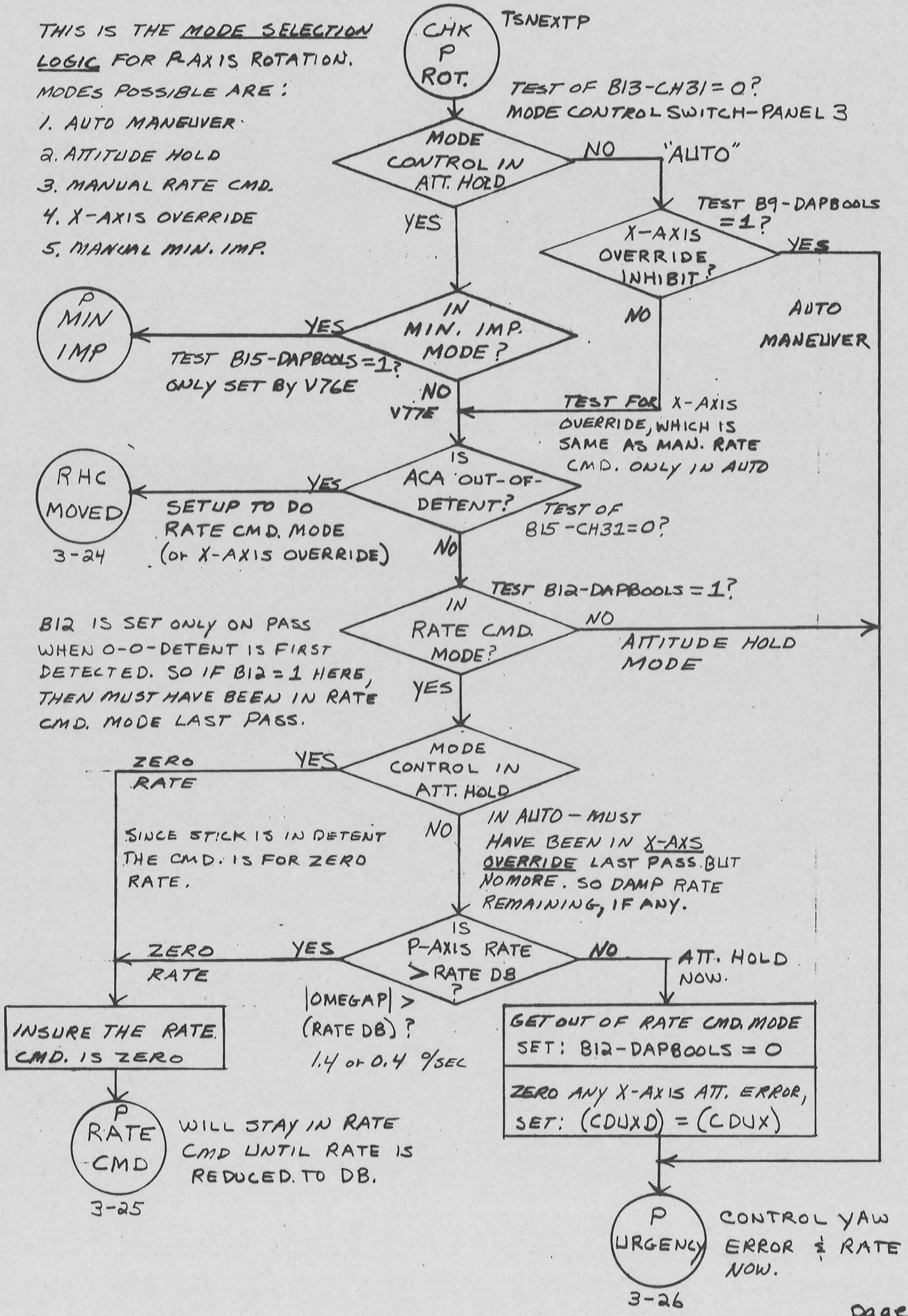
CHANNEL 6 BIT ASSIGNMENTS

CH 6 BIT NO.	8	7	6	5	4	3	2	1
JET IDENTIFIER	B1L	A4R	A3R	B2L	A2A	A1F	B4F	B3A
JET REFERENCE NO.	#16	#4	#8	#12	#11	#15	#3	#7

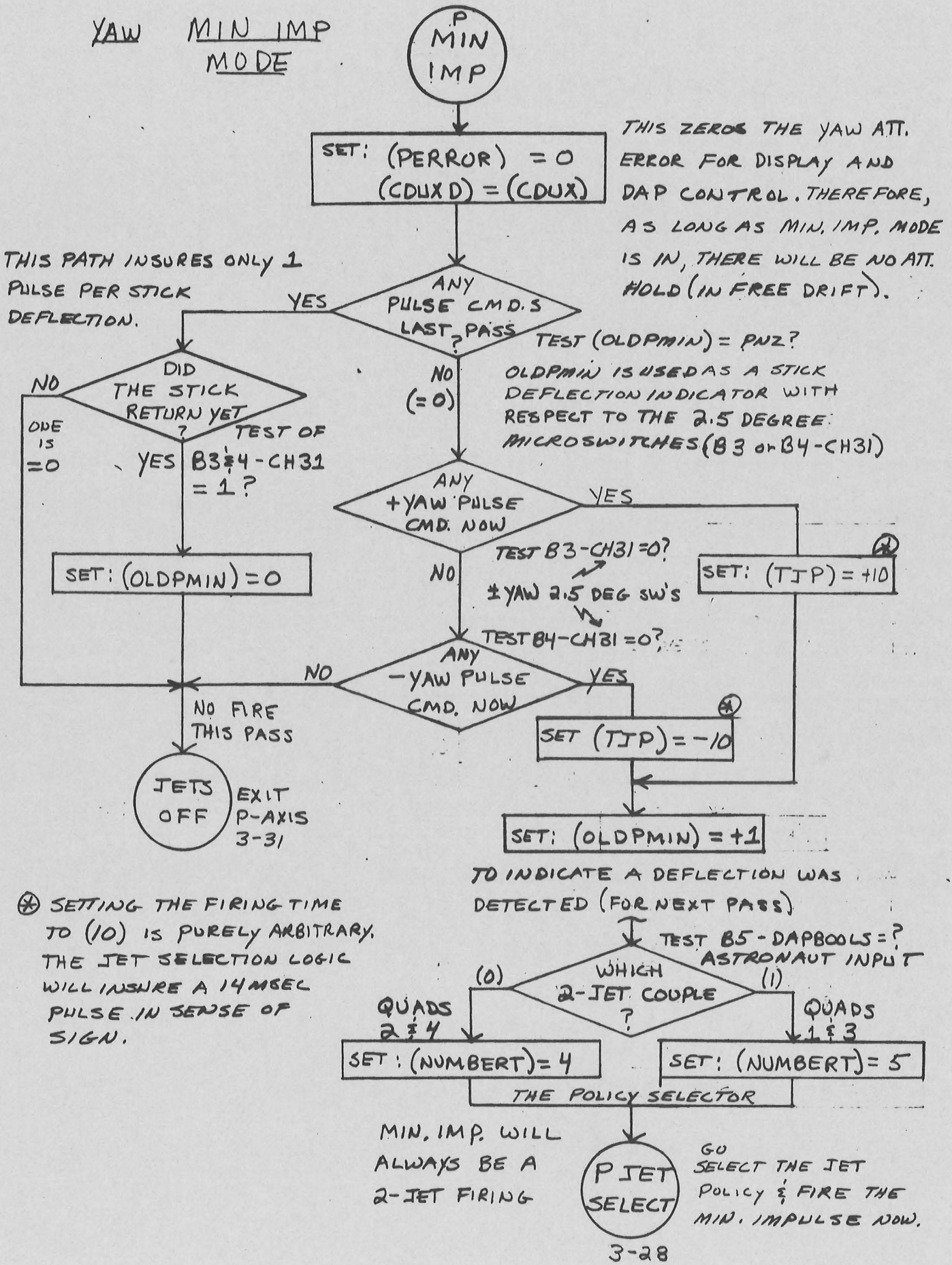
THIS IS THE MODE SELECTION LOGIC FOR P-AXIS ROTATION.

MODES POSSIBLE ARE:

1. AUTO MANEUVER
2. ATTITUDE HOLD
3. MANUAL RATE CMD.
4. X-AXIS OVERRIDE
5. MANUAL MIN. IMP.

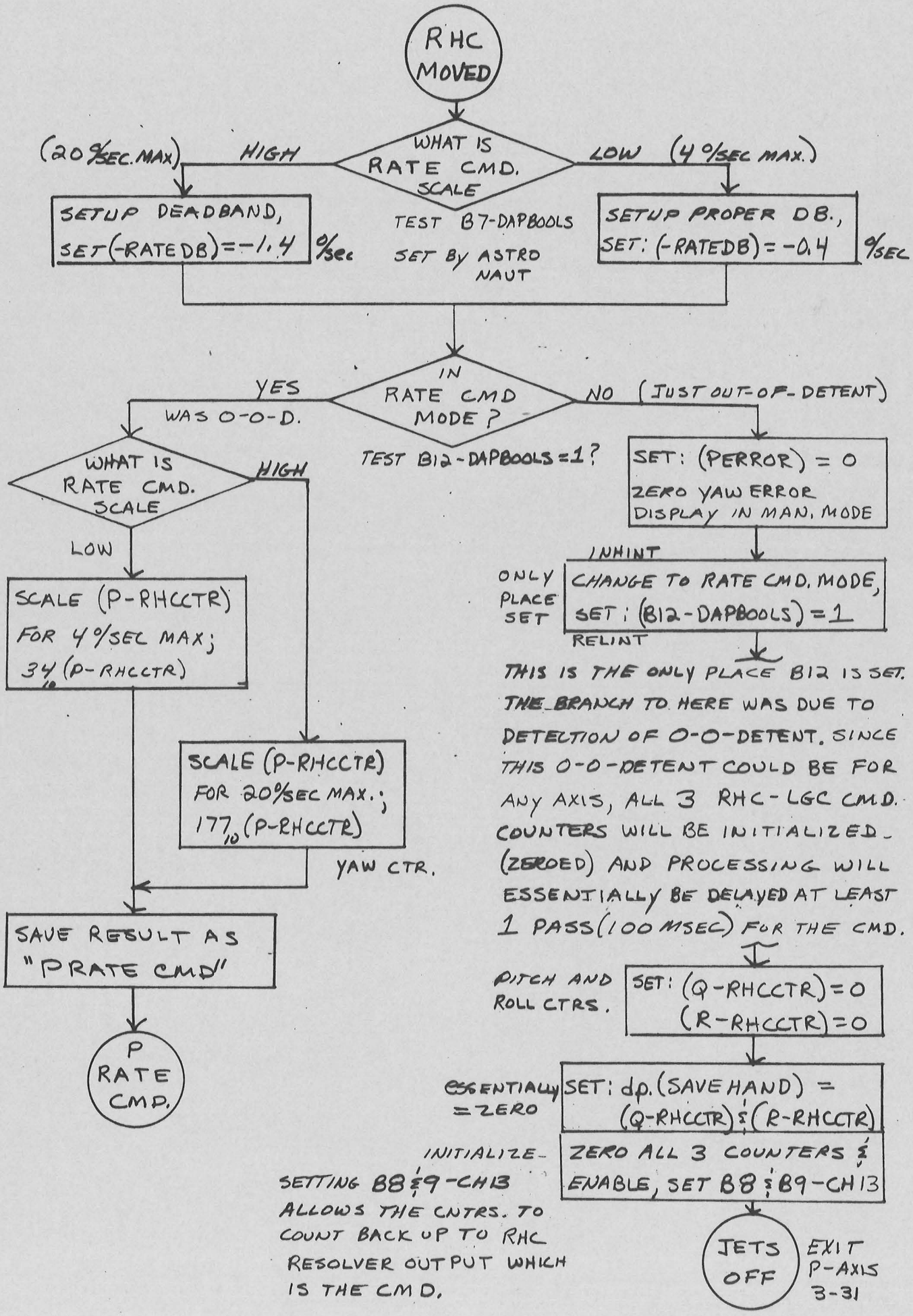


YAW MIN IMP MODE



(*) SETTING THE FIRING TIME TO (10) IS PURELY ARBITRARY. THE JET SELECTION LOGIC WILL INSURE A 14 MSEC PULSE IN SENSE OF SIGN.

3-28


RHC MOVED
WHAT IS RATE CMD. SCALE
HIGH
(20 °/SEC. MAX)
LOW
(4 °/SEC MAX.)
SETUP DEADBAND, SET (-RATEDB) = -1.4 °/sec
TEST B7-DAPBOOLS
SET BY ASTRONAUT
SETUP PROPER DB., SET: (-RATEDB) = -0.4 °/SEC
IN RATE CMD MODE ?
YES
WAS O-O-D.
NO (JUST OUT-OF-DETENT)
TEST B12-DAPBOOLS = 1 ?
WHAT IS RATE CMD. SCALE
HIGH
LOW
SCALE (P-RHCCTR) FOR 4 °/SEC MAX; 34 (P-RHCCTR)
SCALE (P-RHCCTR) FOR 20 °/SEC MAX.; 177 (P-RHCCTR)
YAW CTR.
SAVE RESULT AS "PRATE CMD"
P RATE CMD.
SET: (PERROR) = 0
ZERO YAW ERROR DISPLAY IN MAN. MODE
INHINT
ONLY PLACE SET
CHANGE TO RATE CMD. MODE, SET: (B12-DAPBOOLS) = 1
RELINT
THIS IS THE ONLY PLACE B12 IS SET. THE BRANCH TO HERE WAS DUE TO DETECTION OF O-O-DETENT. SINCE THIS O-O-DETENT COULD BE FOR ANY AXIS, ALL 3 RHC-LGC CMD. COUNTERS WILL BE INITIALIZED (ZEROED) AND PROCESSING WILL ESSENTIALLY BE DELAYED AT LEAST 1 PASS (100 MSEC) FOR THE CMD.
PITCH AND ROLL CTRS.
SET: (Q-RHCCTR) = 0 (R-RHCCTR) = 0
ESSENTIALLY = ZERO
SET: dp. (SAVE HAND) = (Q-RHCCTR) & (R-RHCCTR)
INITIALIZE-
ZERO ALL 3 COUNTERS & ENABLE, SET B8 & B9-CH13
SETTING B8 & 9-CH13 ALLOWS THE CNTRS. TO COUNT BACK UP TO RHC RESOLVER OUTPUT WHICH IS THE CMD.
JETS OFF
EXIT P-AXIS 3-31

YAW RATE CMD. MODE
or X-AXIS OVERRIDE
or RATE DAMPING

P RATE CMD. — JOEY

FORM THE RATE ERROR, SET:
(EDOTP) = "PRATECMD" − (OMEGAP)

FOR RATE CMD, "PRATECMD" IS THE RHC RATE CMD.

FOR RATE DAMP, "PRATECMD" WAS ZEROED. THUS, THE RATE ERROR TO DAMP OUT IS EQUAL, BUT OPPOSITE, TO THE PRESENT BODY RATE. −(OMEGAP)

STORE THE ABSOLUTE VALUE OF $\dot{E}$, SET: (ABSEDOT) = |E DOT|

IS ABSEDOT > RATEDB?

RATEDB SET EARLIER TO 1.4 or 0.4 °/SEC

NO — YES (EITHERWAY)

STORE AWAY ANY PITCH AND/OR ROLL RATE CMD FOR USE LATER, SET:
dp(SAVEHAND) = (Q−RHCCTR) & (R−RHCCTR)

THIS IS WHERE PITCH OR ROLL RATE CMD. IS READ. THEN, THIS SAVEHAND VALUE IS USED LATER IN THE Q, R-AXIS AUTOPILOT LOGIC FOR THE RATE CMD.

ZERO ALL 3 COUNTERS NOW, SET:
(P−RHCCTR), (Q−RHCCTR) & (R−RHCCTR) = 0
ENABLE ALL CTRS AGAIN, SET:
B8 & B9 − CH13 = 1

ENABLES CNTRS TO COUNT BACK UP TO RHC CMD. VALUE

NO $\dot{E} \leq$ DB → JETS OFF

EXIT P-AXIS 3-31

YES, $\dot{E}$ > DB

ZERO X-AXIS ATT. ERROR DURING RATE CMD, SET:
(CDUXD) = (CDUX)

CALC. THE FIRING TIME IT WOULD TAKE FOR 4-JETS TO ZERO THE RATE ERROR, SET:
(TJP) = 4(EDOTP)(1/2 JTSP)(100) IN CSEC.

(1/2 JTSP) IS AN INVERSE OF A 2 JET ACCEL. FROM YACCS RTN.

DOES $\dot{E}$ REQUIRE 4-JETS

TEST OF (ABSEDOT) > (−2JETLIM)?

WHERE YACCS SETS −2JETLIM = NEGMAX FOR ASCENT. THIS FORCES 2 JET USE HERE FOR ASCENT. OTHERWISE ITS A 1.4 °/SEC LIMIT

NO — USE 2-JETS

DOUBLE (TJP)

ASTRO INPUT TEST B5-DAPBOOLS = ?

WHICH 2-JET COUPLE?

QUADS 2-4 → SET: (NUMBERT) = 4

QUADS 1-3 → SET: (NUMBERT) = 5

YES

SETUP POLICY SELECTOR FOR A 4 JET POLICY:
(NUMBERT) = 6

P JET SELECT

3-28

YAW AUTO MANEUVER
or ATTITUDE HOLD MODE

P
URGENCY

M11 & M13 ARE FROM G.P. MATRIX

CALC. & STORE THE YAW ATTITUDE ERROR, SET:

$$(E) = [(CDUYD) - (CDUY)]M11 + [(CDUXD) - (CDUX)]M13 + (DELPERROR)$$

$$(PERROR) = (E)$$

(E) IS USED IN TJETLAW
(PERROR) IS FOR DISPLAY LOGIC.

REFER TO PAGE _____ FOR THE DEFINITION OF THE AUTO MANEUVER CMD. REPRESENTED BY CDU'D REGS. AS FOR (DELPERROR), THIS IS AN OUTPUT OF THE AUTO MANEUVER RTN. "KALCMANU". IT ACTS AS A LAG ANGLE INCREMENT IN THE ABOVE EQUATION TO PREVENT OVERSHOOTING THE DESIRED ATTITUDE DEFINED IN KALCMANU. IN OTHER WORDS, IT FAKES THE DAP INTO THINKING IT IS ACTUALLY KEEPING UP WITH THE CMD. WHILE IN FACT THE RESPONSE IS LAGGING THE COMMAND. THIS ALSO PREVENTS THE DAP FROM EXCEEDING THE DESIRED RATE TO CATCH UP TO THE CMD. SINCE THE CMD. STARTS INSTANTANEOUSLY. (DELERRORS) ARE SET = 0 WHEN THE AUTO MANEUVER IS OVER. THEREFORE, ATTITUDE HOLD MODE DOES NOT SEE THEM EVEN THOUGH THE CALC. ABOVE IS STILL MADE

(OMEGAPD) = 0 IF NOT IN AUTO. MAN.

CALC. THE YAW RATE ERROR, SET:
(EDOTP) = (OMEGAP) - (OMEGAPD)

(OMEGAPD) IS ALSO AN OUTPUT OF KALCMANU. IT BASICALLY REPRESENTS THE DESIRED RATE LOADED BY THE ASTRO IN R03

(AXISCTR) IS AN AXIS IDENTIFIER, INDEXER, USED IN THE FOLLOWING RCS CONTROL LAW LOGIC. (-1 IDENTIFIES P-AXIS).

SET: (AXISCTR) = -1

TEST B13-DAPBOOLS = 1?

IS CSM DOCKED ?

NO

SET: (SENSETYP) = 0

INHINT

GO DO "TJETLAW" SUBRTN PG 4-5. THE RCS CONTROL LAW FOR UNDOCKED CASE

RELINT

P
TJLAW
RT

RETURNS HERE WITH A FIRING TIME - TJP

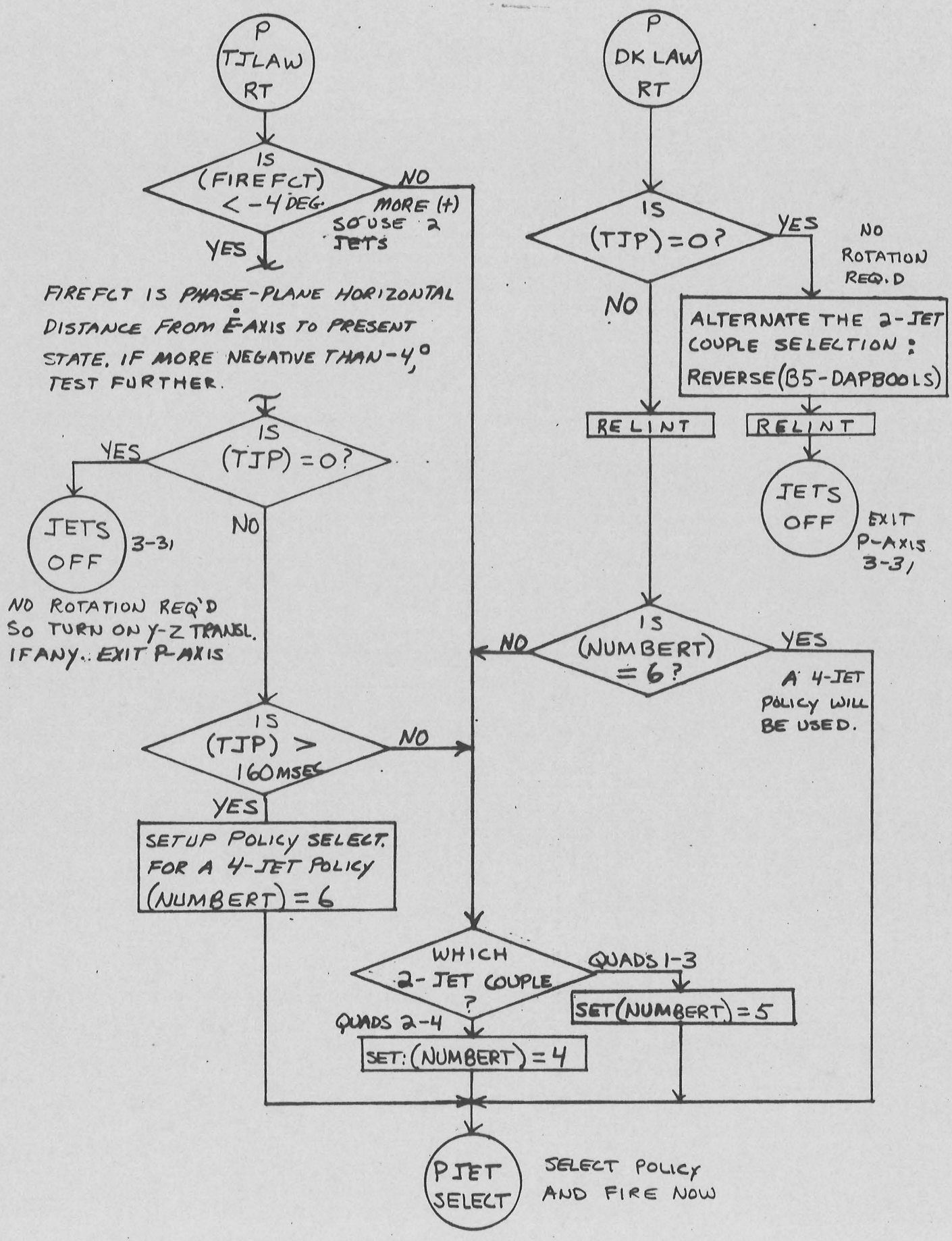
YES

INHINT

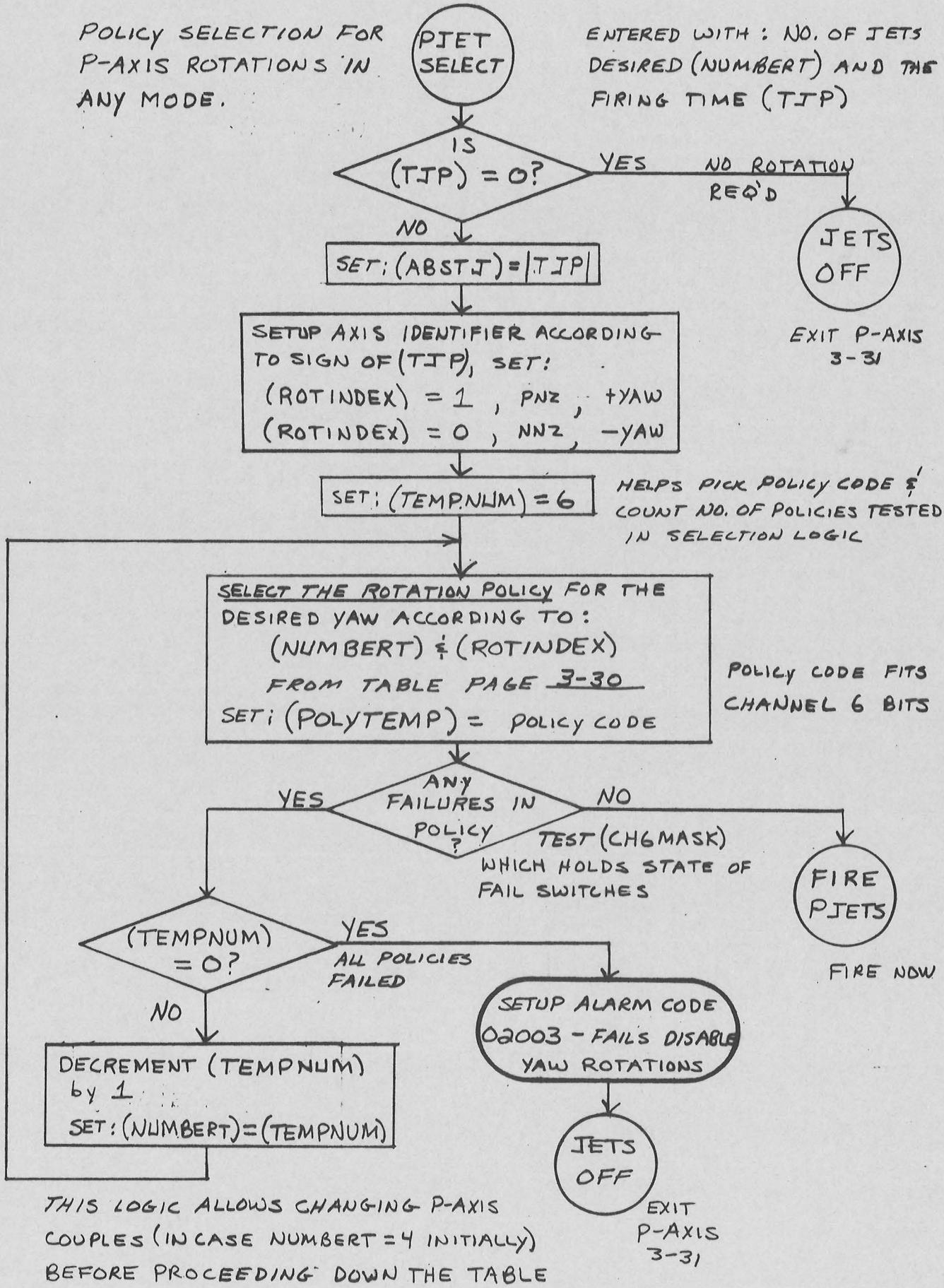
GO DO "DOCKED RCS" LOGIC PG 4-31. THE CONTROL LAW FOR THE DOCKED CASE

P
DKLAW
RT

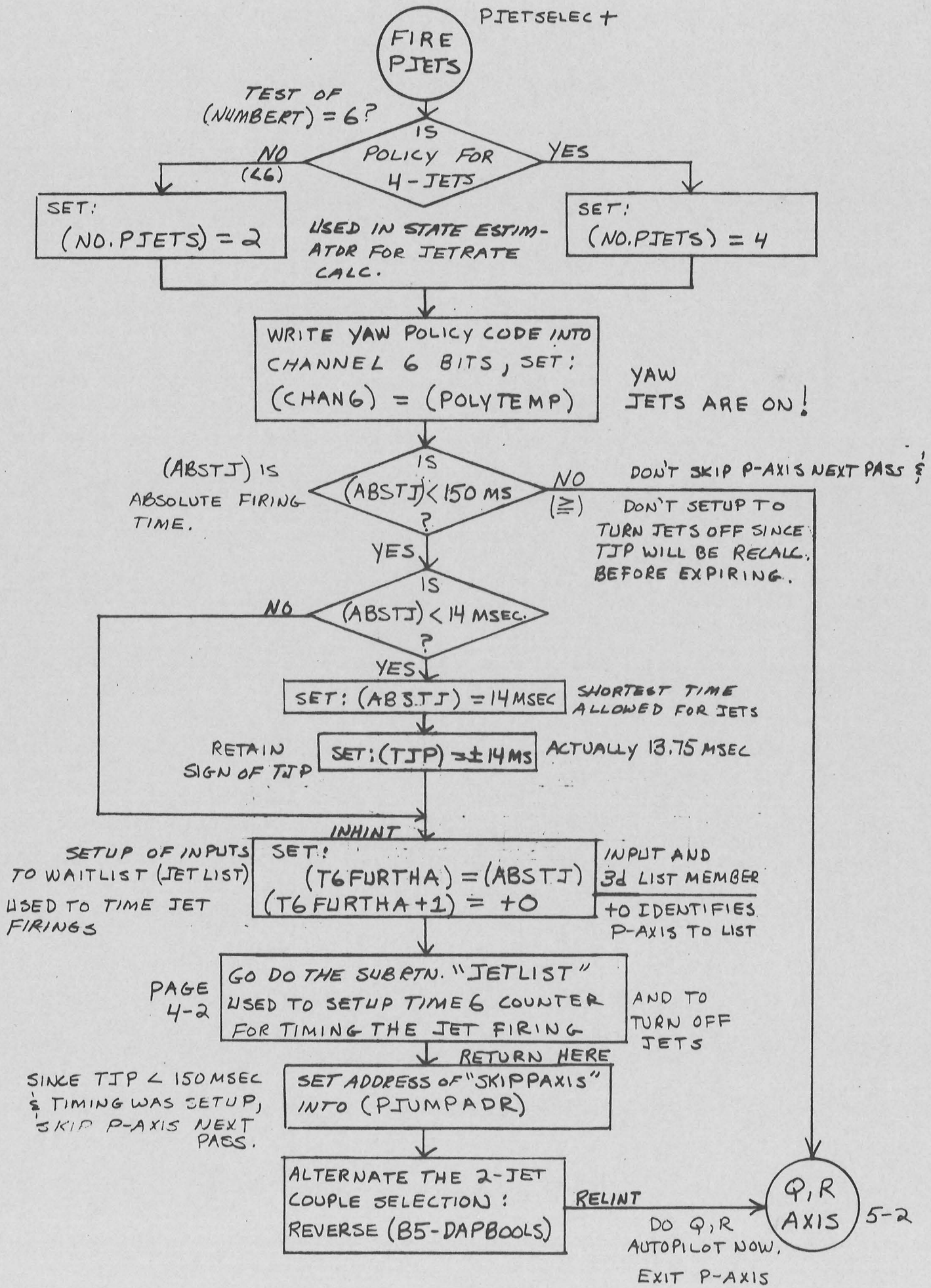
RETURNS WITH A FIRING TIME TO HERE


P TJLAW RT
IS (FIREFCT) < -4 DEG.
NO
MORE (+) SO USE 2 JETS
YES
FIREFCT IS PHASE-PLANE HORIZONTAL DISTANCE FROM Ė-AXIS TO PRESENT STATE. IF MORE NEGATIVE THAN -4,° TEST FURTHER.
IS (TJP) = 0?
YES
JETS OFF
3-31
NO ROTATION REQ'D SO TURN ON Y-Z TRANSL. IF ANY.. EXIT P-AXIS
NO
IS (TJP) > 160 MSEC
NO
YES
SETUP POLICY SELECT. FOR A 4-JET POLICY (NUMBERT) = 6
P DK LAW RT
IS (TJP) = 0?
YES
NO ROTATION REQ.D
NO
ALTERNATE THE 2-JET COUPLE SELECTION: REVERSE (B5-DAPBOOLS)
RELINT
RELINT
JETS OFF
EXIT P-AXIS 3-31
IS (NUMBERT) = 6?
NO
YES
A 4-JET POLICY WILL BE USED.
WHICH 2-JET COUPLE?
QUADS 1-3
SET (NUMBERT) = 5
QUADS 2-4
SET: (NUMBERT) = 4
P JET SELECT
SELECT POLICY AND FIRE NOW

POLICY SELECTION FOR P-AXIS ROTATIONS IN ANY MODE.



THIS LOGIC ALLOWS CHANGING P-AXIS COUPLES (IN CASE NUMBERT = 4 INITIALLY) BEFORE PROCEEDING DOWN THE TABLE


PJETSELEC +
FIRE PJETS
TEST OF (NUMBERT) = 6?
IS POLICY FOR 4-JETS
NO (≤6)
YES
SET: (NO.PJETS) = 2
USED IN STATE ESTIMATOR FOR JETRATE CALC.
SET: (NO.PJETS) = 4
WRITE YAW POLICY CODE INTO CHANNEL 6 BITS, SET: (CHANG) = (POLYTEMP)
YAW JETS ARE ON!
(ABSTJ) IS ABSOLUTE FIRING TIME.
IS (ABSTJ) < 150 MS ?
NO (≥)
DON'T SKIP P-AXIS NEXT PASS!
DON'T SETUP TO TURN JETS OFF SINCE TJP WILL BE RECALC. BEFORE EXPIRING.
YES
IS (ABSTJ) < 14 MSEC. ?
NO
YES
SET: (ABSTJ) = 14 MSEC
SHORTEST TIME ALLOWED FOR JETS
RETAIN SIGN OF TJP
SET: (TJP) = ±14 MS
ACTUALLY 13.75 MSEC
INHINT
SETUP OF INPUTS TO WAITLIST (JET LIST)
USED TO TIME JET FIRINGS
SET: (T6FURTHA) = (ABSTJ)
(T6FURTHA+1) = +0
INPUT AND 3d LIST MEMBER
+0 IDENTIFIES P-AXIS TO LIST
PAGE 4-2
GO DO THE SUBRTN. "JETLIST" USED TO SETUP TIME 6 COUNTER FOR TIMING THE JET FIRING
AND TO TURN OFF JETS
RETURN HERE
SINCE TJP < 150 MSEC & TIMING WAS SETUP, SKIP P-AXIS NEXT PASS.
SET ADDRESS OF "SKIPPAXIS" INTO (PJUMPADR)
ALTERNATE THE 2-JET COUPLE SELECTION: REVERSE (B5-DAPBOOLS)
RELINT
DO Q, R AUTOPILOT NOW, EXIT P-AXIS
Q, R AXIS
5-2

JET POLICY TABLE FOR X-AXIS ROTATIONS
(P-AXIS RCS AUTOPILOT)

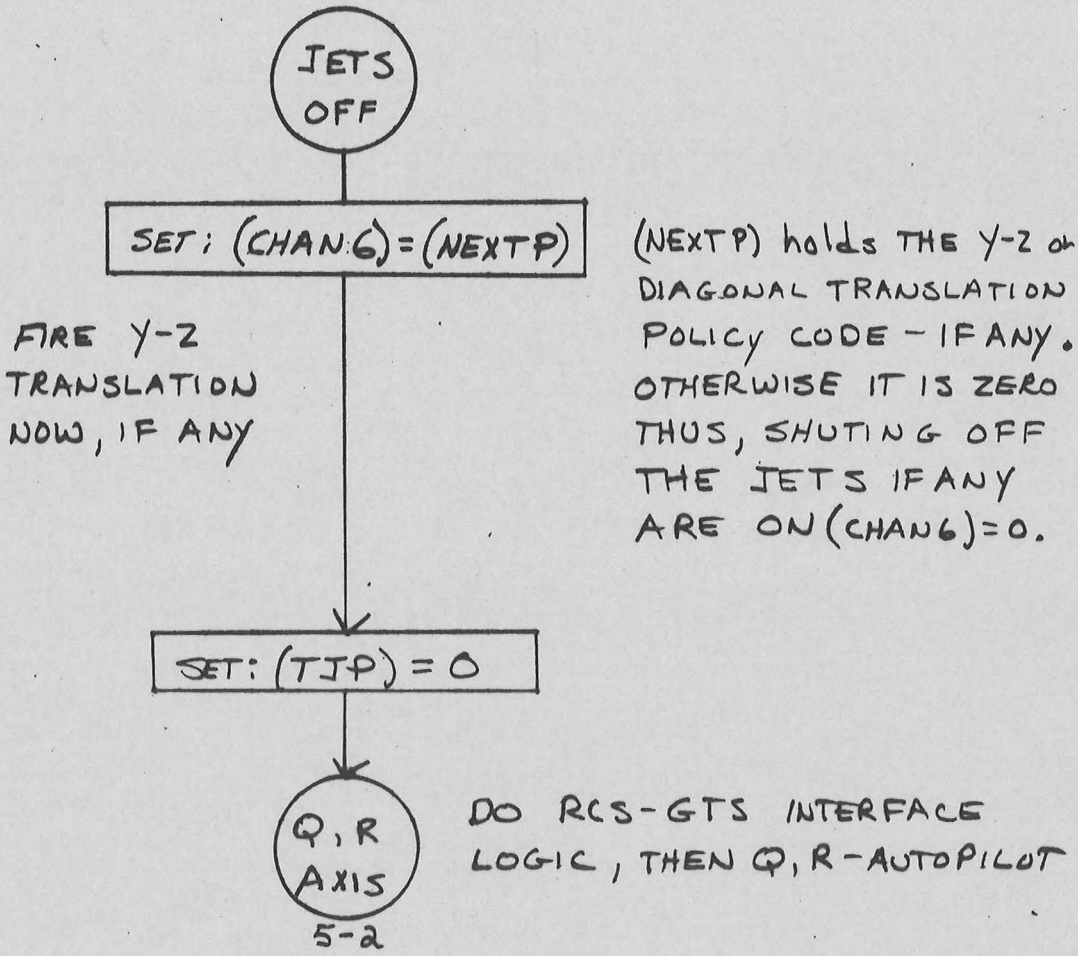
	policy selector no. (NUMBERT)	+ YAW axis identifier (ROTINDEX) = 1	- YAW axis identifier (ROTINDEX) = 0
	6	A1F - B3A - A4R - B2L (125)	B1L - A3R - A2A - B4F (252)
balanced couples used alternately	5	A1F - B3A (005)	B1L - A3R (240)
	4	A4R - B2L (120)	A2A - B4F (012)
	3	A4R - B3A (101)	A3R - A2A (050)
	2	B2L - B3A (021)	B1L - A2A (210)
	1	B2L - A1F (024)	B1L - B4F (202)
	0	A4R - A1F (104)	A3R - B4F (042)
	ALARM - code 02003 setup for astronaut		

NOTE: numbers in parenthesis are the (POLYTEM P) octal codes which fit channel 6 bits.

CHANNEL 6 BIT ASSIGNMENTS
(LGC interface controling the HORIZONTAL RCS JETS)

CH6 BIT NO.	8	7	6	5	4	3	2	1
JET IDENTIFIER	B1L	A4R	A3R	B2L	A2A	A1F	B4F	B3A
JET REFERENCE NO.	#16	#4	#8	#12	#11	#15	#3	#7

THE EXIT FOR P-AXIS AUTOPILOT LOGIC WHEN NO YAW ROTATIONS ARE REQUIRED.



SECTION IV

COMMON AUTOPILOT CONTROL LOGIC
(P-Axis/U, V-Axis RCS Control)

JETLIST

This is a waitlist for T6RUPTS, i.e., a priority list of times-to-go for turning off jets associated with maneuver policies written into channels 5 and 6. The total burn time (TJET), where TJET = TJP, TJU or TJV for each policy is determined prior to entering jetlist. Naturally, the shortest burn time becomes the highest priority item. However, a (TJET) ≧ 150 msec. will not be put in the waitlist, but will be recalculated on the next pass through the associated DAP axis loop (P, U-V).

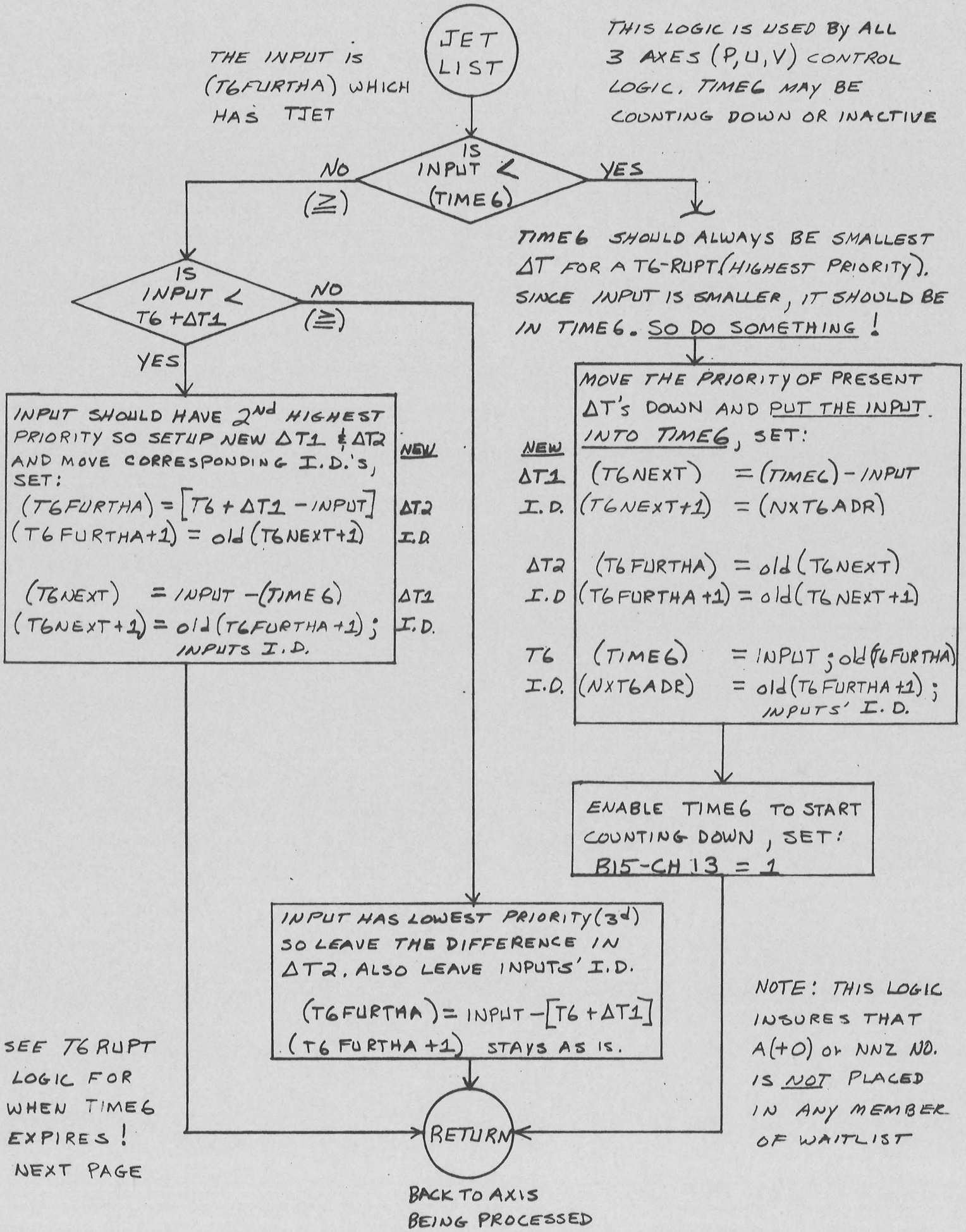
The list is identified as follows (3 members tot.):

1. TIME 6 (the actual counter) - contains the time to the next event or the next T6RUPT (highest priority member) or 1st event.
2. T6NEXT (will be called ΔT1) - will contain the DELTA time to the second event or second T6RUPT (next highest priority)
3. T6FURTHA (will be called ΔT2) - will contain the DELTA time from the second to the third event or T6RUPT (3rd highest). Also T6FURTHA will be the initial input to the jetlist function as (ABSTJ).

The members are initialized in DAPIDLE to contain POSMAX, (37777). TIME6 must be enabled, when use is desired, to begin counting down for a T6RUPT. Associated with each member is a location used to identify the axis for WHOSE delta time the list member contains. These locations are called the jetlist indexers and are named:

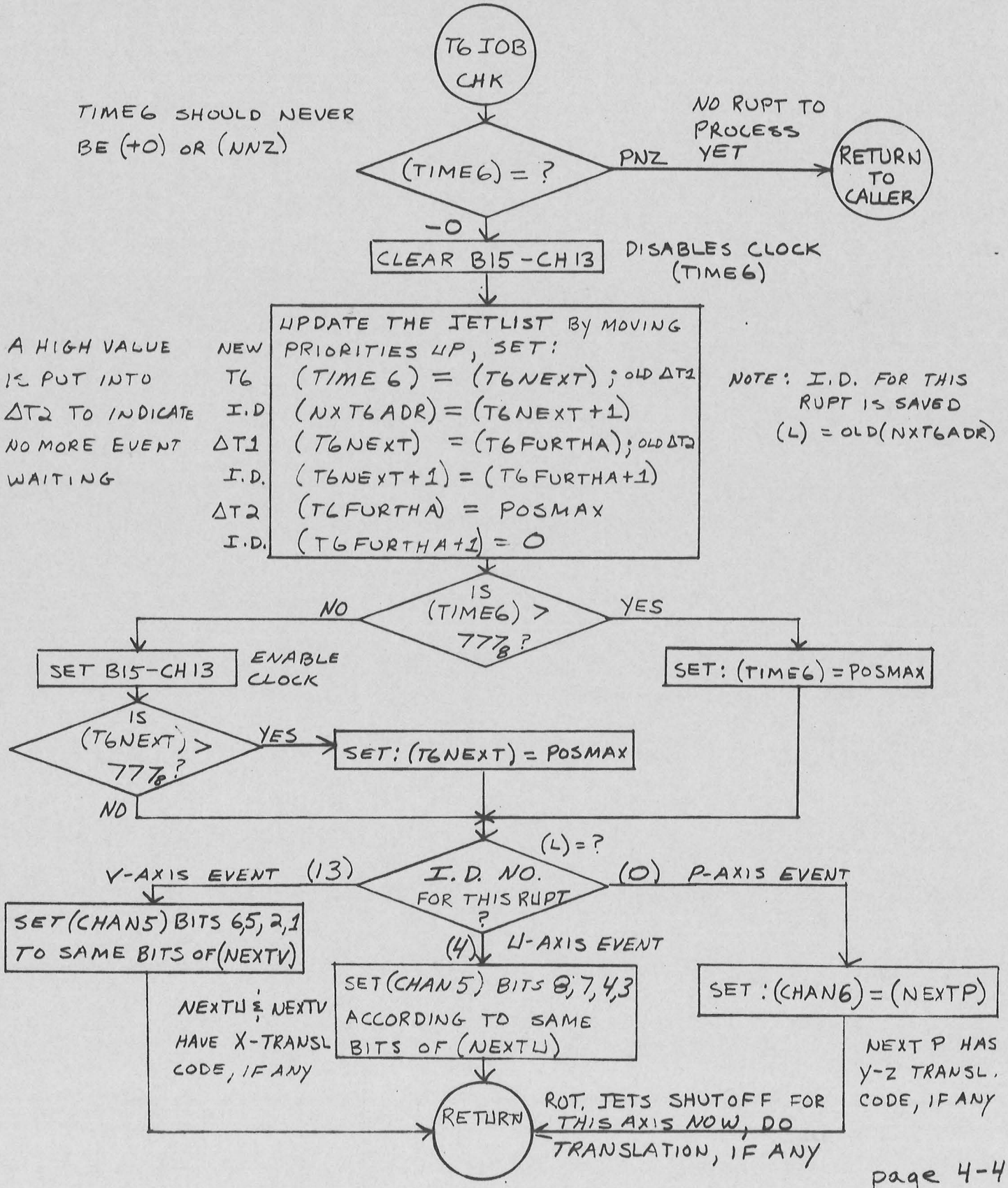
	IDENTIFICATION CODES
1. NXT6ADR - used with TIME6	0 - For P-Axis
2. T6NEXT +1 - used with T6NEXT	4 - For U-Axis
3. T6FURTHA +1 - used with T6FURTHA	13 - For V-Axis

NEXT PAGE


JET LIST
THE INPUT IS (T6FURTHA) WHICH HAS TIET
THIS LOGIC IS USED BY ALL 3 AXES (P, U, V) CONTROL LOGIC. TIME6 MAY BE COUNTING DOWN OR INACTIVE
IS INPUT < (TIME6)
NO (≧)
YES
TIME6 SHOULD ALWAYS BE SMALLEST ΔT FOR A T6-RUPT (HIGHEST PRIORITY). SINCE INPUT IS SMALLER, IT SHOULD BE IN TIME6. SO DO SOMETHING !
IS INPUT < T6 + ΔT1
NO (≧)
YES
INPUT SHOULD HAVE 2ND HIGHEST PRIORITY SO SETUP NEW ΔT1 & ΔT2 AND MOVE CORRESPONDING I.D.'S, SET:
(T6FURTHA) = [T6 + ΔT1 − INPUT]
(T6FURTHA+1) = old (T6NEXT+1)
(T6NEXT) = INPUT − (TIME6)
(T6NEXT+1) = old (T6FURTHA+1); INPUTS I.D.
NEW ΔT2 I.D. ΔT1 I.D.
MOVE THE PRIORITY OF PRESENT ΔT's DOWN AND PUT THE INPUT INTO TIME6, SET:
NEW ΔT1 (T6NEXT) = (TIME6) − INPUT
I.D. (T6NEXT+1) = (NXT6ADR)
ΔT2 (T6FURTHA) = old (T6NEXT)
I.D (T6FURTHA+1) = old (T6NEXT+1)
T6 (TIME6) = INPUT; old (T6FURTHA)
I.D. (NXT6ADR) = old (T6FURTHA+1); INPUTS' I.D.
ENABLE TIME6 TO START COUNTING DOWN, SET:
B15-CH13 = 1
INPUT HAS LOWEST PRIORITY (3d) SO LEAVE THE DIFFERENCE IN ΔT2. ALSO LEAVE INPUTS' I.D.
(T6FURTHA) = INPUT − [T6 + ΔT1]
(T6FURTHA+1) STAYS AS IS.
SEE T6 RUPT LOGIC FOR WHEN TIME6 EXPIRES ! NEXT PAGE
NOTE: THIS LOGIC INSURES THAT A(+0) OR NNZ NO. IS NOT PLACED IN ANY MEMBER OF WAITLIST
RETURN
BACK TO AXIS BEING PROCESSED

T6RUPT

The DAP maintains exclusive control over the TIME6 counter and its corresponding interrupt. Since T6RUPT is a program interrupt, all programs operating in interrupt control or with interrupts inhibited must call the T6RUPT maintenance routine "T6JOBCHK" every 5 millisec. to process a possible waiting T6RUPT (the TIME6 cntr = -0). "T6JOBCHK" will lead to turnoff of rotation jets.



TJET
LAW

"OR, LIFE IN THE PHASE PLANE"

This subroutine of the LM RCS DAP is called to calculate a jet-firing-time (TJET) for the axis identified by the indexer AXISCTR. Reference to AXISCTR is made by the subscript (i). Thus, $TJET_i$ represents either (TJU), (TJP) or (TJV) if i = 0, -1 or +1 respectively.

TJETLAW is used only when the LM is <u>not docked</u> and the autopilot is in "AUTO MANEUVER MODE" or holding attitude in the "ATT HOLD" MODE. Upon entry, the registers (E) and (EDOT) already contain the att. error and rate error as computed by the RCS logic. Also, various functions of acceleration and various deadbands are computed and stored away by the external routine 1/ACCS. TJETLAW accesses these locations, which are separate blocks for each axis, by use of two indexers (ADRSDIF1) and (ADRSDIF2). These are referenced by the subscripts (i1) and (i2) rsptvly. They are initialized according to (i).

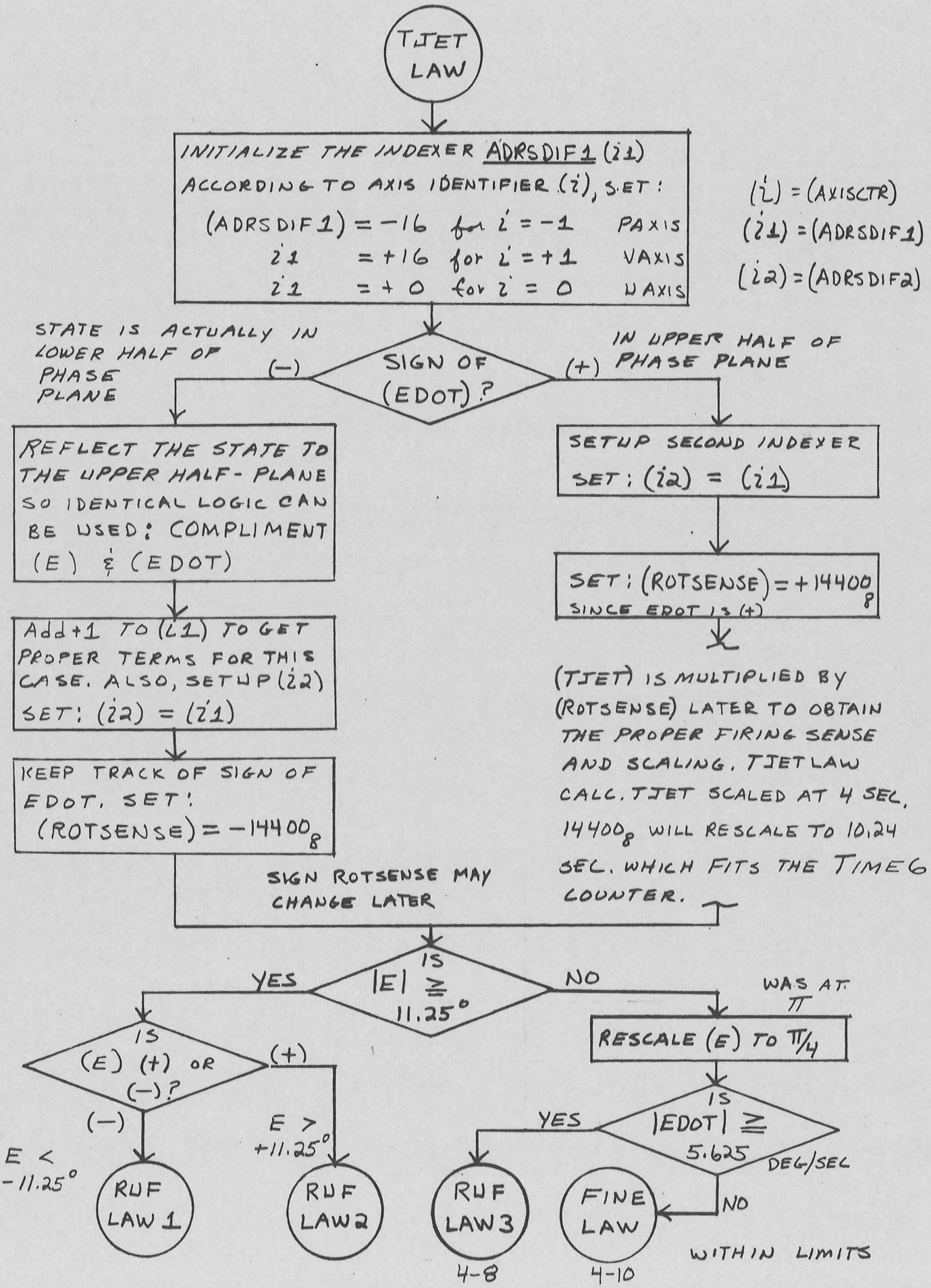
The sign of the required rotation or firing sense is stored in (ROTSENSE) and applied to the computed magnitude just prior to TJETLAW exit.

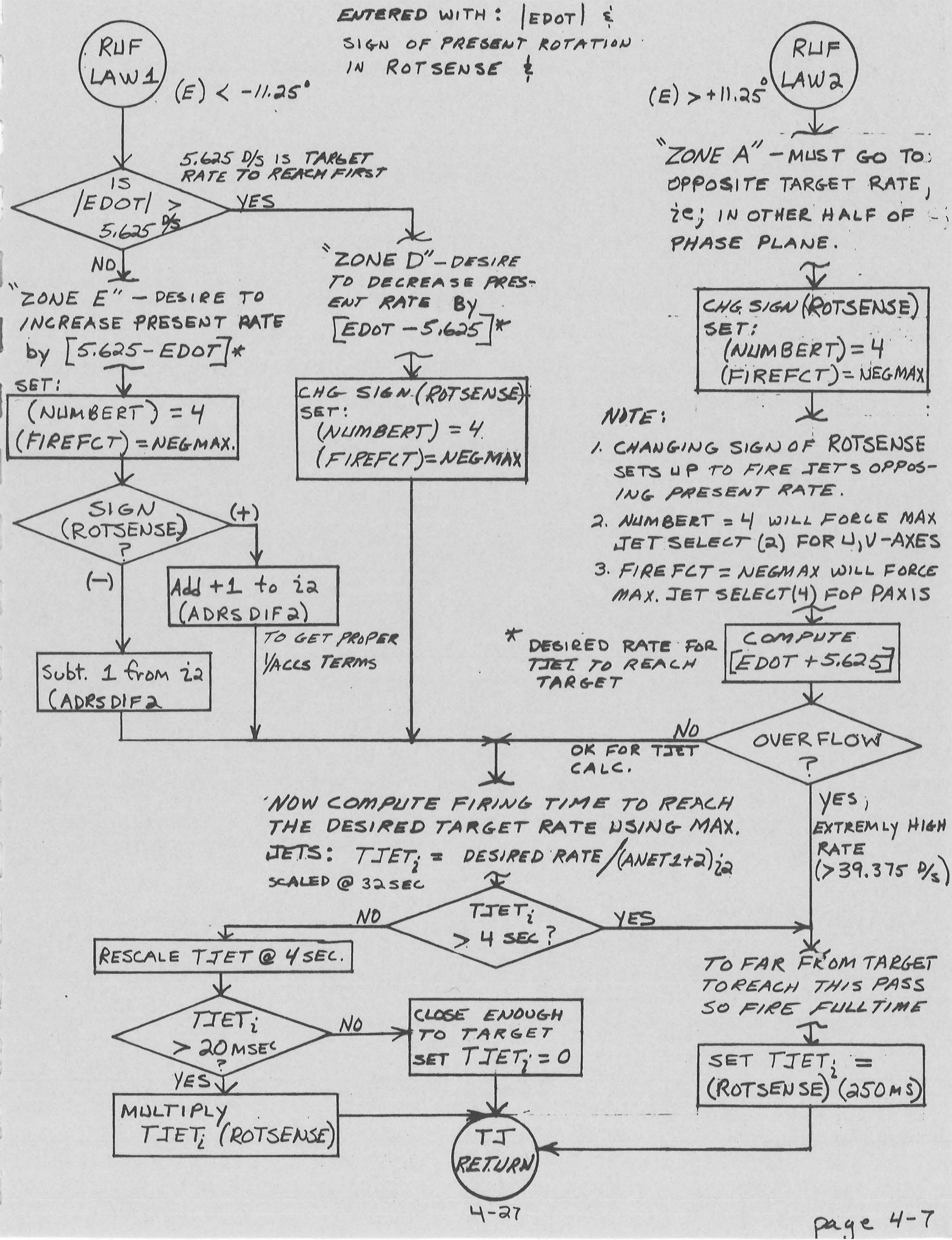
If (E) $\geq$ 11.25 deg and/or (EDOT) $\geq$ 5.625 deg/sec, a simplified or rough computation of TJET is performed just to carry the vehicle state to within these boundries. This part of TJETLAW is called ROUGHLAW. When the state is within these limits, then a more accurate computation logic is used - called FINELAW. In summary:

<u>INPUTS TO TJETLAW ARE</u>: (E), (EDOT), axis identifier (AXISCTR), the old $(TJET)_i$, and 48 eraseables (16 for each axis) stored by 1/ACCS rtn and accessed by (i1) or (i2).

<u>OUTPUTS WILL BE:</u> $(TJET)_i$, (NUMBERT) and (FIREFCT). NUMBERT is the number of jets to be used for the axis. Two jets for P-AXIS will always be assumed by TJETLAW logic. One or two for U, V. FIREFCT is the distance of the present vehicle state, defined by E & EDOT, to a switching curve on the phase plane.

NEXT PAGE


TJET LAW
INITIALIZE THE INDEXER ADRSDIF1 (i1)
ACCORDING TO AXIS IDENTIFIER (i), SET:
(ADRSDIF1) = −16 for i = −1 PAXIS
i1 = +16 for i = +1 VAXIS
i1 = +0 for i = 0 UAXIS
(i) = (AXISCTR)
(i1) = (ADRSDIF1)
(i2) = (ADRSDIF2)
SIGN OF (EDOT)?
(−)
STATE IS ACTUALLY IN LOWER HALF OF PHASE PLANE
(+)
IN UPPER HALF OF PHASE PLANE
REFLECT THE STATE TO THE UPPER HALF-PLANE SO IDENTICAL LOGIC CAN BE USED: COMPLIMENT (E) & (EDOT)
Add +1 TO (i1) TO GET PROPER TERMS FOR THIS CASE. ALSO, SETUP (i2) SET: (i2) = (i1)
KEEP TRACK OF SIGN OF EDOT. SET: (ROTSENSE) = −14400₈
SETUP SECOND INDEXER SET: (i2) = (i1)
SET: (ROTSENSE) = +14400₈ SINCE EDOT IS (+)
(TJET) IS MULTIPLIED BY (ROTSENSE) LATER TO OBTAIN THE PROPER FIRING SENSE AND SCALING. TJET LAW CALC. TJET SCALED AT 4 SEC, 14400₈ WILL RESCALE TO 10.24 SEC. WHICH FITS THE TIME6 COUNTER.
SIGN ROTSENSE MAY CHANGE LATER
IS |E| ≧ 11.25°
YES
NO
WAS AT π
RESCALE (E) TO π/4
IS (E) (+) OR (−)?
(+)
(−)
E > +11.25°
E < −11.25°
RUF LAW 1
RUF LAW 2
IS |EDOT| ≧ 5.625 DEG/SEC
YES
NO
RUF LAW 3
4-8
FINE LAW
4-10
WITHIN LIMITS


ENTERED WITH: |EDOT| &
SIGN OF PRESENT ROTATION
IN ROTSENSE &
RUF LAW 1
(E) < -11.25°
5.625 D/S IS TARGET RATE TO REACH FIRST
IS |EDOT| > 5.625 D/S
YES
NO
"ZONE E" - DESIRE TO INCREASE PRESENT RATE by [5.625 - EDOT]*
SET:
(NUMBERT) = 4
(FIREFCT) = NEGMAX.
SIGN (ROTSENSE) ?
(+)
(-)
Add +1 to i2 (ADRS DIF 2)
Subt. 1 from i2 (ADRS DIF 2
TO GET PROPER 1/ACCS TERMS
"ZONE D" - DESIRE TO DECREASE PRESENT RATE By [EDOT - 5.625]*
CHG SIGN (ROTSENSE)
SET:
(NUMBERT) = 4
(FIREFCT) = NEGMAX
RUF LAW 2
(E) > +11.25°
"ZONE A" - MUST GO TO OPPOSITE TARGET RATE, ie; IN OTHER HALF OF PHASE PLANE.
CHG SIGN (ROTSENSE)
SET:
(NUMBERT) = 4
(FIREFCT) = NEGMAX
NOTE:
1. CHANGING SIGN OF ROTSENSE SETS UP TO FIRE JETS OPPOSING PRESENT RATE.
2. NUMBERT = 4 WILL FORCE MAX JET SELECT (2) FOR U, V-AXES
3. FIREFCT = NEGMAX WILL FORCE MAX. JET SELECT (4) FOR PAXIS
* DESIRED RATE FOR TJET TO REACH TARGET
COMPUTE [EDOT + 5.625]
OVER FLOW ?
NO
OK FOR TJET CALC.
YES, EXTREMLY HIGH RATE (> 39.375 D/S)
NOW COMPUTE FIRING TIME TO REACH THE DESIRED TARGET RATE USING MAX. JETS: TJET_i = DESIRED RATE / (ANET1+2)_i2
SCALED @ 32 SEC
TJET_i > 4 SEC ?
NO
YES
RESCALE TJET @ 4 SEC.
TJET_i > 20 MSEC ?
NO
YES
CLOSE ENOUGH TO TARGET SET TJET_i = 0
MULTIPLY TJET_i (ROTSENSE)
TO FAR FROM TARGET TO REACH THIS PASS SO FIRE FULLTIME
SET TJET_i = (ROTSENSE)_i (250 MS)
TJ RETURN
4-27

ENTERED WITH : $|E| < 11.25°$, $|EDOT| \geq 5.625$ D/S & SIGN OF ROTATION IN ROTSENSE

RWF LAW3

"ZONE B OR C" — ATT. ERROR IS WITHIN LIMITS BUT RATE IS OUT.

CHG. SIGN (ROTSENSE) — TO OPPOSE RATE
SET: (NUMBERT) = 4 — FORCE MAX. U, V JETS
(FIREFCT) = NEGMAX — FORCE MAX. P JETS

NOW, FIND OUT WHICH SIDE OF THE SWITCH CURVE, (FIREFCT = 0 CURVE), THE PRESENT STATE IS; COMPUTE THE FIREFCT AS :

$$FIREFCT = (E) + (EDOT)^2 (1/ANET1 + 2)_{21} - (FIREDB)_{21}$$

IS RESULT PNZ?

"ZONE C" NO (Z OR −)

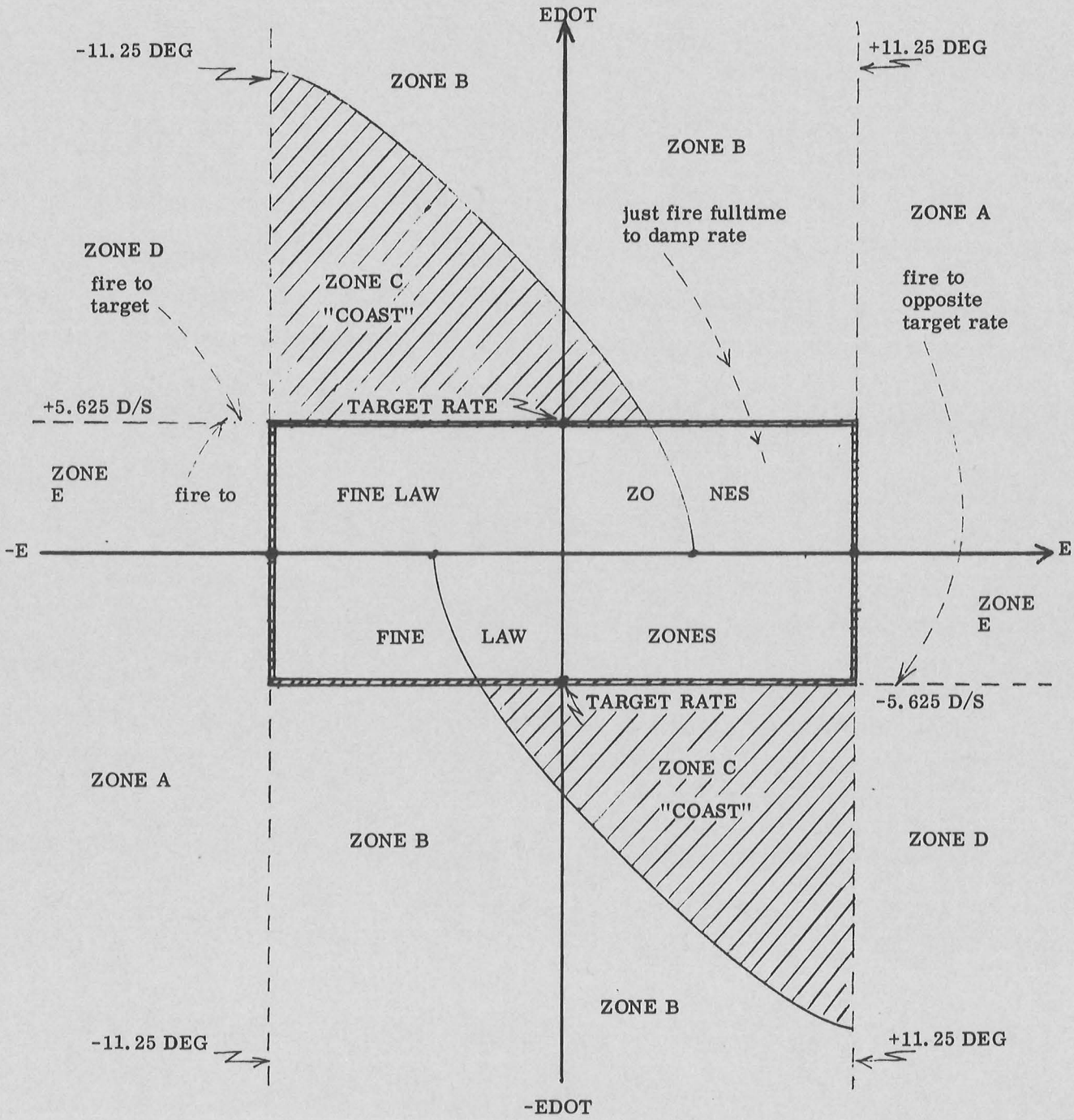
YES "ZONE B"

IN COAST ZONE
SET: $TJET_i = 0$

FIRE FOR A FULL CYCLE ATLEAST,
SET: $TJET_i$ = (ROTSENSE)(250 MS)

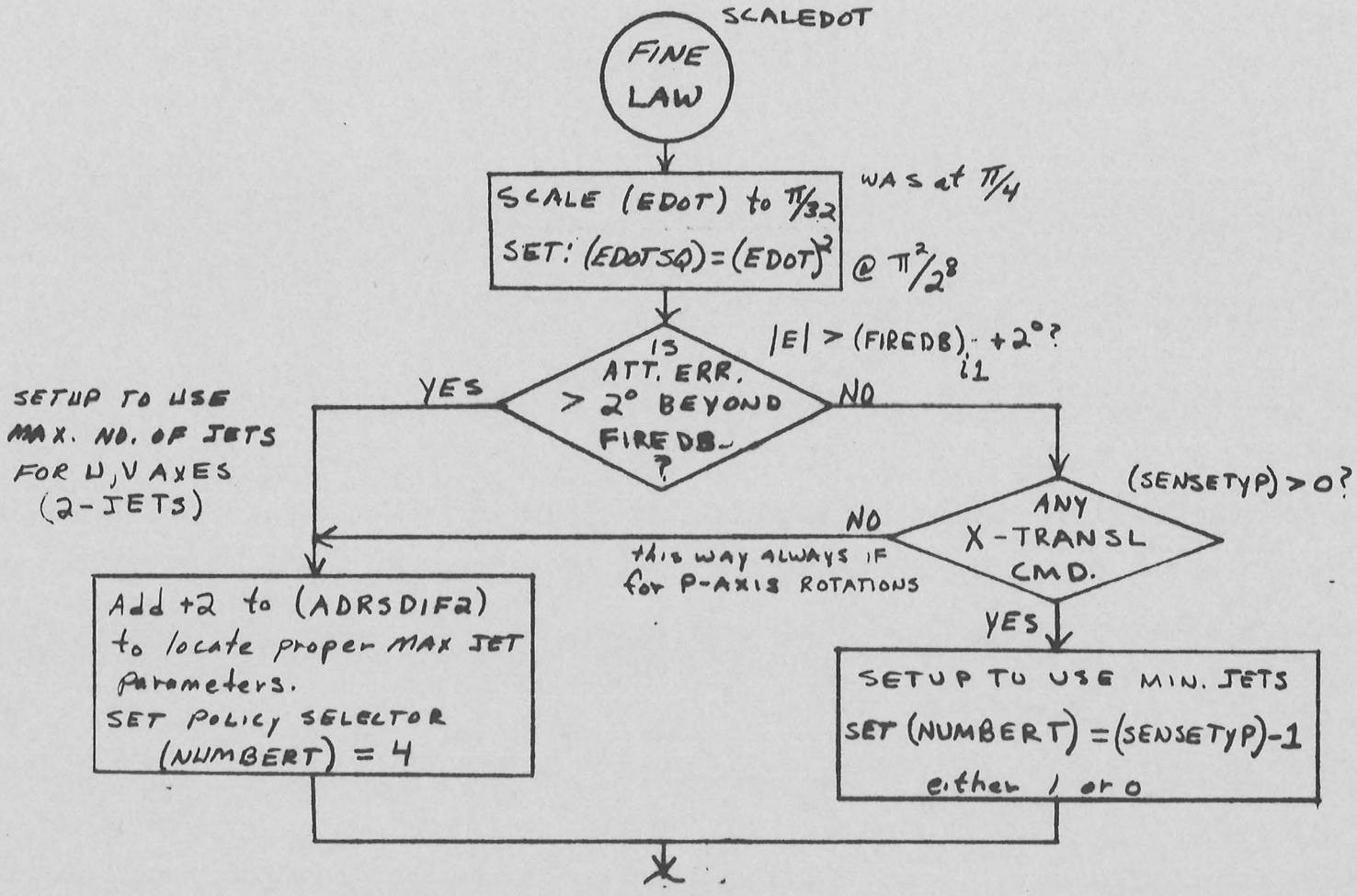
TJ RETURN

4-27



ROUGH LAW PHASE PLANE

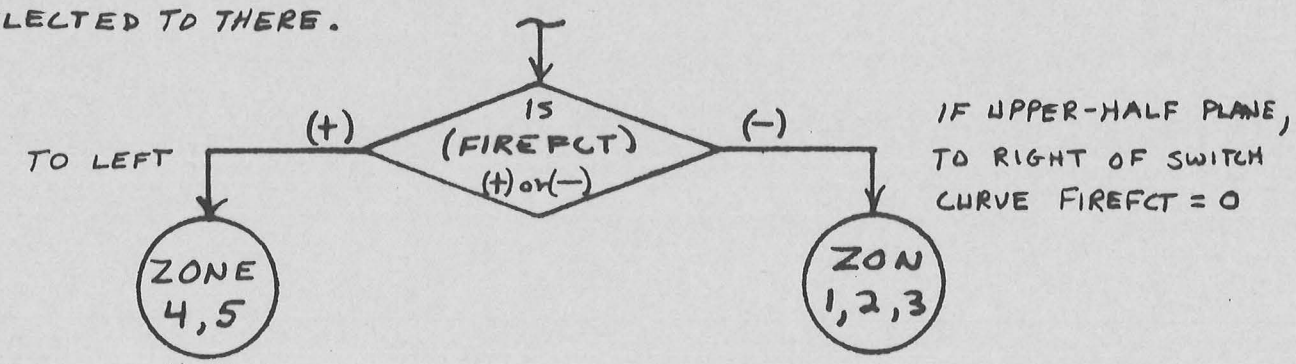
(only upper-half firing sense shown, lower half uses opposite firing sense in related zones)



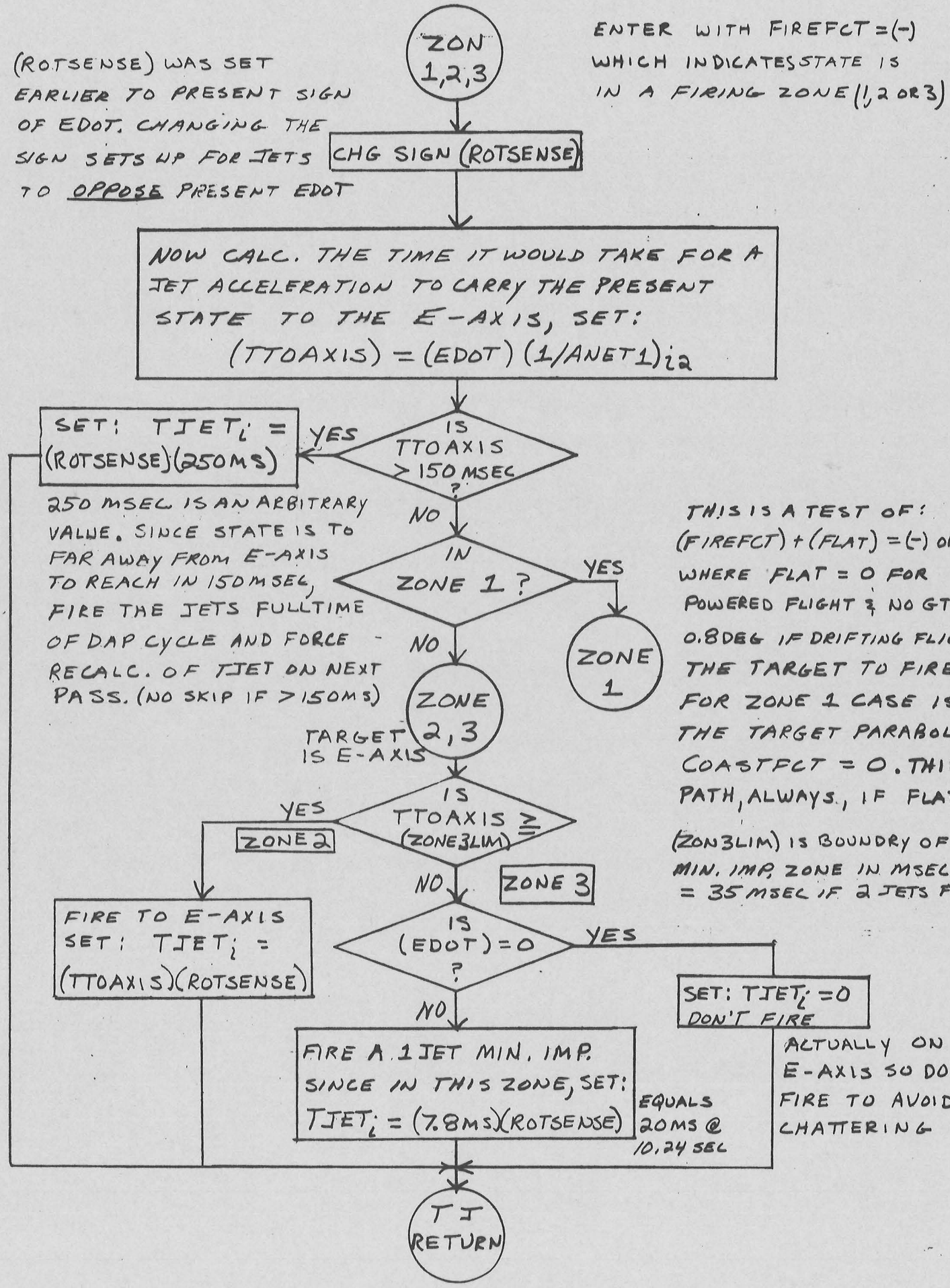
NOW COMPUTE THE HORIZONTAL PHASE PLANE DISTANCE OF THE VEHICLE'S STATE FROM THE SWITCH CURVE THAT DEFINES THE JET FIRING ZONE. THIS SWITCH CURVE IS DEFINED AS FIREFCT = $-E - 0.5(1/ANET)\dot{E}^2 + FIREDB = 0$ WHERE FIREDB IS THE E-AXIS CROSSING OF THIS CURVE. SUBSTITUTING THE PRESENT E & $\dot{E}$ VALUES; WE HAVE:

$$(FIREFCT) = -(E) - (EDOTSQ)(1/ANET1)_{i2} + (FIREDB)_{i1}$$

WHERE THE (i) TERMS ARE COMPUTED AND STORED IN VACLS RTN. THIS FUNCTION IS FOR THE UPPER-HALF PLANE CASE SINCE THE STATE WAS REFLECTED TO THERE.



NOTE: FOLLOW ZONE (1,2,3) CASE FIRST TIME THRU LOGIC FOR BETTER UNDERSTANDING OF TERM DEFINITIONS


ZON 1,2,3
ENTER WITH FIREFCT = (-) WHICH INDICATES STATE IS IN A FIRING ZONE (1, 2 OR 3)
(ROTSENSE) WAS SET EARLIER TO PRESENT SIGN OF EDOT. CHANGING THE SIGN SETS UP FOR JETS TO OPPOSE PRESENT EDOT
CHG SIGN (ROTSENSE)
NOW CALC. THE TIME IT WOULD TAKE FOR A JET ACCELERATION TO CARRY THE PRESENT STATE TO THE E-AXIS, SET:
(TTOAXIS) = (EDOT) (1/ANET1)i2
IS TTOAXIS > 150 MSEC ?
YES
SET: TJETi = (ROTSENSE)(250MS)
250 MSEC IS AN ARBITRARY VALUE. SINCE STATE IS TO FAR AWAY FROM E-AXIS TO REACH IN 150 MSEC, FIRE THE JETS FULLTIME OF DAP CYCLE AND FORCE RECALC. OF TJET ON NEXT PASS. (NO SKIP IF > 150 MS)
NO
IN ZONE 1 ?
YES
ZONE 1
THIS IS A TEST OF: (FIREFCT) + (FLAT) = (-) OR 0 WHERE FLAT = 0 FOR POWERED FLIGHT & NO GTS OR 0.8 DEG IF DRIFTING FLIGHT. THE TARGET TO FIRE TO FOR ZONE 1 CASE IS THE TARGET PARABOLA COASTFCT = 0. THIS PATH, ALWAYS, IF FLAT = 0
NO
ZONE 2,3
TARGET IS E-AXIS
IS TTOAXIS ≥ (ZONE3LIM)
YES
ZONE 2
NO
ZONE 3
(ZON3LIM) IS BOUNDRY OF MIN. IMP. ZONE IN MSEC. = 35 MSEC IF 2 JETS FIRE
FIRE TO E-AXIS SET: TJETi = (TTOAXIS)(ROTSENSE)
IS (EDOT) = 0 ?
YES
SET: TJETi = 0 DON'T FIRE
ACTUALLY ON E-AXIS SO DON'T FIRE TO AVOID CHATTERING
NO
FIRE A 1 JET MIN. IMP. SINCE IN THIS ZONE, SET:
TJETi = (7.8MS)(ROTSENSE)
EQUALS 20MS @ 10.24 SEC
TJ RETURN

4-27

DERIVATION

ZONE 1

LOGIC FLOW CONTINUES ON PAGE 4-17

IT MAY BE CONVENIENT AT THIS TIME TO REVIEW THE BASIC DERIVATION OF THE TJETLAW ALGORITHM FOR JET TIME CALCULATIONS IN ZONE 1 OF THE PHASE PLANE. FOR CLARITY AND CONTINUITY IN THE FOLLOWING DISCRIPTION, JUST THE RIGHT HALF-PLANE WILL BE REFERENCED. USE PAGE ___ FOR REFERENCE.

THE OBJECT IS TO COMPUTE THE FIRING TIME REQUIRED TO TAKE THE VEHICLE STATE FROM ITS PRESENT STATE, IN ZONE 1, TO THE SWITCHING CURVE (or TARGET PARABOLA) WHICH BOUNDS THE COAST ZONE. THE FIRING TIME WILL BE COMPUTED IN TWO PARTS: ① FROM PRESENT STATE (at $t=0$) TO THE E-AXIS AND, ② FROM E-AXIS (t = time-to-AXIS TTOAXIS) TO THE TARGET PARABOLA (t = TJET) ALONG THE ACCEL. PATH. NOW, FOR PART #1, WE LET:

$$TTOAXIS = \dot{E}_{(0)}(1/ANET) \quad \text{where}$$

$\dot{E}_{(0)}$ = EDOT @ $t=0$ or present rate & (1/ANET1) = reciprocal of the NET ACCEL., AS COMPUTED IN 1/ACCS RTN., for this case.

FOR PART #2 WE LET:

THE GENERAL EXPRESSION FOR THE TARGET PARABOLA AS A FUNCTION OF TIME (t), TO BE

$$COASTFCT_{(t)} = -E_{(t)} + 0.5(1/ACOAST)\dot{E}^2_{(t)} + FIREDB - AXISDIST$$

WHERE THE SOLUTION OF (t) TO MAKE $COASTFCT_{(t)} = 0$ IS THE SOLUTION OF PART # 2 OF TJET. THE TERM (1/ACOAST) IS THE RECIPROCAL OF ANY ACCEL EXISTING (COAST ACCEL) AFTER REACHING THE COAST BOUNDRY AND ASSUMING THE JETS ARE TURNED OFF. THE TERMS (1/ACOAST), FIREDB & AXIS DISTANCE ARE ALL COMPUTED IN THE 1/ACCS RTN. FIREDB = DB1, AXISDIST = DB1 − DB3 FOR THIS CASE.

NOW, SINCE THE DERIVATION FOR PART #2 STARTS AT THE E-AXS, LET'S CHANGE THE TIME REFERENCE FROM (t) to (τ) WHERE (τ) = 0 AT THE E-AXIS AND THE SOLUTION OF τ IS THE TIME FOR PART #2 OF TJET.

NEXT PAGE

THUS: $COASTFCT_{(t)}$ CAN BE TRANSFORMED INTO $COASTFCT_{(\tau)}$

OR $$COASTFCT_{(\tau)} = -E_{(\tau)} + 0.5(1/ACOAST)\dot{E}^2_{(\tau)} + FIREDB - AXISDIST$$

NOW, THE DESIRED FIRING TIME IS OBTAINED BY EXTRAPOLATING THE STATE FROM $\tau = 0$ TO WHERE τ CAUSES $COASTFCT = 0$. THIS EXTRAPOLATION CAN BE EXPRESSED AS A POWER SERIES OF THE FORM:

$$COASTFCT_{(\tau)} = COASTFCT_{(0)} + \frac{d}{d\tau}[COASTFCT_{(0)}]\tau + \frac{d^2[COASTFCT_{(0)}]}{d\tau^2}\frac{\tau^2}{2!}\cdots$$

(0) NOW MEANS AT $\tau = 0$

WHERE:

$$COASTFCT_{(0)} = -E_{(0)} + 0.5(1/ACOAST)\dot{E}^2_{(0)} + FIREDB - AXISDIST.$$

and $$\frac{d}{d\tau}COASTFCT_{(0)} = -\dot{E}_{(0)} + \frac{0.5}{0.5}(1/ACOAST)\dot{E}_{(0)}\ddot{E}_{(0)}$$

$$= \dot{E}_{(0)}\left[-1 + \frac{\ddot{E}_{(0)}}{ACOAST}\right]$$ where $\ddot{E}_{(\tau)} = -ANET$, ANET IS NET ACCEL AND $\ddot{E}$ IS (−) NOW

$$= \dot{E}_{(0)}\left[-1 - \frac{ANET}{ACOAST}\right]$$ NOW, MULT. THRU BY $\frac{ANET}{ANET}$ WE HAVE,

$$= \frac{\dot{E}_{(0)}}{ANET}\left[-ANET - \frac{ANET^2}{ACOAST}\right]$$

then $$\frac{d^2}{d\tau^2}[COASTFCT_{(0)}] = \frac{\ddot{E}_{(0)}}{ANET}\left[-ANET - \frac{ANET^2}{ACOAST}\right]$$ where again $\ddot{E} = -ANET$

$$\therefore \frac{d^2}{d\tau^2}[\ \ ] = ANET + \frac{ANET^2}{ACOAST}$$

ANET AND ACOAST ARE ASSUMED CONSTANTS FOR THE COMPUTATION PERIOD HERE. THEREFORE, ADDITIONAL DERIVATIVES FOR COASTFCT WOULD BE ZERO.

NEXT PAGE

LOOKING AT THE TERM $\frac{d}{d\tau}$COASTFCT, IT IS SEEN THAT $\dot{E}_{(0)}$ IS EDOT AT $\tau = 0$, OR THE E-AXIS. HERE, EDOT = 0 THEREFORE $\frac{d}{dt}$COASTFCT = 0

NOW THEN, $$COASTFCT_{(\tau)} = COASTFCT_{(0)} + \frac{\frac{d^2}{d\tau^2}\left[COASTFCT_{(0)}\right]}{2!}\tau^2$$

OR $$COASTFCT_{(\tau)} = COASTFCT_{(0)} + \tfrac{1}{2}\left[ANET + \frac{ANET^2}{ACOAST}\right]\tau^2$$

IF WE SAY $ACCFCTZ1 = -1 / ANET + \frac{ANET^2}{ACOAST}$: WHICH IS COMPUTED AS SUCH IN VACCS RTN.

THEN $$COASTFCT_{(\tau)} = COASTFCT_{(0)} - \frac{0.5\,\tau^2}{ACCFCTZ1}$$

$$= \frac{1}{ACCFCTZ1}\left[\underbrace{(COASTFCT_{(0)})(ACCFCTZ1)}_{\text{call this term } H} - 0.5\,\tau^2\right]$$

OR $$COASTFCT_{(\tau)} = \frac{1}{ACCFCTZ1}\left[H - 0.5\,\tau^2\right]$$ THEREFORE,

WHEN $[H - 0.5\,\tau^2]$ goes to ZERO, $COASTFCT_{(\tau)} = 0$ and the TARGET PARABOLA IS DEFINED. SOLVING FOR (τ) FROM $H - 0.5\,\tau^2 = 0$ WILL BE THE PART #2 TJET SOLUTION.

$$\tau = \sqrt{2H}$$

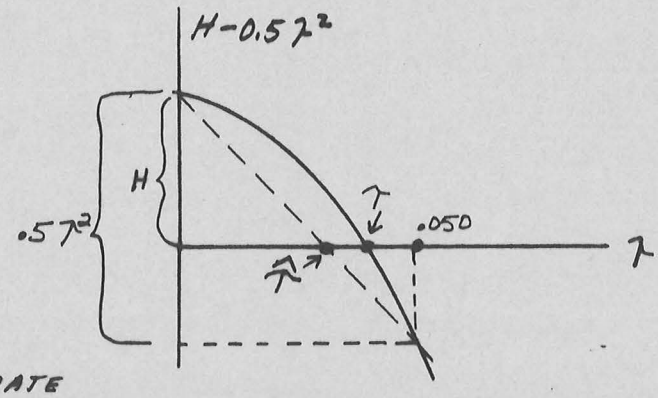
THIS IS THE TRUE SOLUTION TO (τ), WHICH IS THE FIRING TIME FROM THE E-AXIS TO THE TARGET <u>ALONG</u> THE ACCEL. PATH. THE ACCEL. PATH ON A PHASE PLANE IS ALWAYS PARABOLIC. HOWEVER, THIS IS NOT THE SOLUTION USED BY TJETLAW LOGIC. INSTEAD, A STRAIGHT LINE APPROXIMATION OF (τ) IS OBTAINED FROM THE CURVE DEFINED BY $[H - 0.5\,\tau^2]$. THUS, AN ESTIMATE OF (τ) OR $\hat{\tau}$ IS THE END RESULT.

NEXT PAGE

THERE ARE TWO VALUES USED FOR $\hat{\tau}$, DEPENDING ON THE VALUE OF (τ). THESE VALUES ARE DERIVED AS FOLLOWS:

FOR $(\tau) < 0.050$ sec. CASES

PLOTTING $H - 0.5\tau^2$ vs. (τ)



SET UP THE STRAIGHT LINE RELATIONSHIPS AS:

$$\frac{\hat{\tau}}{.050} = \frac{H}{0.5\tau^2}$$ & SUBSTITUTING $\tau = 0.05$ SEC

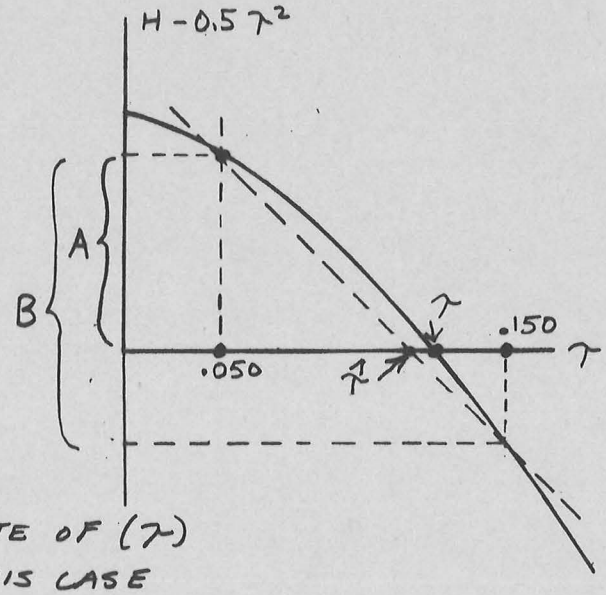
$$\frac{\hat{\tau}}{.050} = \frac{H}{0.5(.050)^2}$$

$$\hat{\tau} = \frac{H}{0.025} = 40H$$ OR ESTIMATE OF (τ) FOR THIS CASE

THEREFORE, TOTAL $\widehat{TUET}$ = TTOAXIS + 40H (ESTIMATE)

FOR $0.050 < (\tau) < 0.150$ SEC. CASES

SETUP THE STRAIGHT LINE RELATIONSHIPS AS:



$$\frac{\hat{\tau} - 0.050}{(.150 - 0.050)} = \frac{H - 0.5(0.050)^2}{0.5\left[(0.15)^2 - (0.050)^2\right]} = \frac{A}{B}$$

$$\frac{\hat{\tau} - 0.050}{0.1} = \frac{H - 0.00125}{0.01}$$

$$\hat{\tau} - 0.050 = 10H - 0.0125$$

$$\hat{\tau} = 10H + 0.0375$$ ESTIMATE OF (τ) FOR THIS CASE

THEREFORE, TOTAL $\widehat{TUET}$ = TTOAXIS + 10H + 0.0375

NOTICE, FOR BOTH CASES H IS PART OF THE ESTIMATE. H WAS PREVIOUSLY DEFINED AS = COASTFCT $(\tau=0)$ (ACCFCTZ1)

NEXT PAGE

(ACCFCT21) IS THE ACCEL. FUNCTION FOR THIS ZONE 1 CASE AS COMPUTED IN THE 1/ACCS RTN. $COASTFCT_{(\tau=0)}$, NOW, CAN BE EXPRESSED AS A FUNCTION OF $FIREFCT_{(t=0)}$. THIS WOULD BE CONVENIENT SINCE FIREFCT @ $t=0$ HAS ALREADY BEEN COMPUTED IN THE BEGINNING OF TJETLAW AND, THEREFORE, COULD BE USED IN THE ZONE 1 LOGIC TO COMPUTE H. THEN COASTFCT @ $\tau=0$ COMPUTATION IS NOT REQUIRED. <u>REMEMBER</u>! $t=0$ point is the present ZONE 1 STATE & $\tau=0$ point is AT EAXIS. THUS, TRANSFERING $FIREFCT_{(t=0)}$ to $t=$ TTOAXIS or $\tau=0$

MUST BE ACCOMPLISHED BEFORE IT CAN BE USED FOR $COASTFCT_{(\tau=0)}$. THIS CAN BE DONE BY EXTRAPOLATING FIREFCT TO THE E-AXIS. TAKING THE DERIVATIVE;

$$\frac{d}{dt} FIREFCT_{(t=0)} = \frac{d}{dt}\left[-E - 0.5(1/ANET)\dot{E}^2 + FIREDB\right]$$ WHICH

IS THE EXPRESSION FOR THE ZONE 1 FIREFCT.

THIS BECOMES: $$\frac{d}{dt} FIREFCT_{(t=0)} = -\dot{E} - (1/ANET)\dot{E}\ddot{E}$$

LOOKING CLOSLY, WE DEFINED $\ddot{E} = -ANET$ STARTING AT EAXIS

THUS, THE DERIVATIVE FALLS TO ZERO UPON SUBSTITUTION.

THIS MEANS $FIREFCT_{t=0} = FIREFCT_{t=TTOAXIS} = FIREFCT_{\tau=0}$

LOOKING AT THE PHASE PLANE, THE E-AXIS CROSSING OF FIREFCT, (DB1), AND THE COASTFCT CROSSING (DB3) ARE SEPARATED BY AXISDIST. SINCE WE ESTABLISHED FIREFCT FOR THIS CASE, THEN

$$FIREFCT_{(t=0)} = COASTFCT_{(\tau=0)} + AXISDIST$$ OR

$$COASTFCT_{(\tau=0)} = FIREFCT_{(t=0)} - AXISDIST$$, THEREFORE

THIS TERM IS USED TO DERIVE H FOR TJET CALC. IN ZONE 1. SEE THE LOGIC NOW.

LOGIC

ZONE 1

ENTER WITH (FIREFCT + FLAT) IF FROM ZON123, pg 4-11 OR WITH JUST (FIREFCT) IF FROM ZONE 4, pg 4-20

COMPUTE "H" AS A DOUBLE PRECISION QUATITY, SET:

$$(HH) = (ACCFCTZ1)_{22} \underbrace{\left[(FIREFCT) + (FLAT) - (AXISDIST)\right]_{21}}_{COASTFCT\ @\ \tau = 0}$$

SCALED @ 8 SEC²

WHERE,

IN DRIFTING FLIGHT (OR POWERED WITH GTS CONTROL)

FLAT = DB3 − DB1 = 0.8 DEG

AXISDIST = 0

IN POWERED: FLAT = 0, AXISDIST = DB1 − DB3

NOW THE EXPRESSION $[H - 0.5\tau^2 = 0]$ IS TESTED TO SEE IF THE TOTAL TJET WILL BE GREATER THAN 150 MSEC. SINCE TJET = TTOAXIS + (τ), THE MAXIMUM (τ) CAN BE IS τ = (150 MSEC − TTOAXIS) FOR TJET ≤ 150MS. THEREFORE, THE TEST FOR TJET > 150 MSEC IS MADE BY TESTING FOR $H \geq 0.5\tau^2$ where $\tau^2 = [150MS - TTOAXIS]^2$.

REMEMBER! (TTOAXIS) HAS ALREADY BEEN COMPUTED EARLIER ALSO, H USED HERE IS HIGH ORDER PART OF (HH)

IS $H \geq .5[150MS - TTOAXIS]^2$?

NO → TJET < 150MSEC → TEST t_1

YES →

SET:

TJET = 250 MS (ROTSENSE)

SETUP TO FIRE FULLTIME AND RECOMPUTE TJET ON NEXT PASS. TO FAR AWAY FROM TARGET NOW

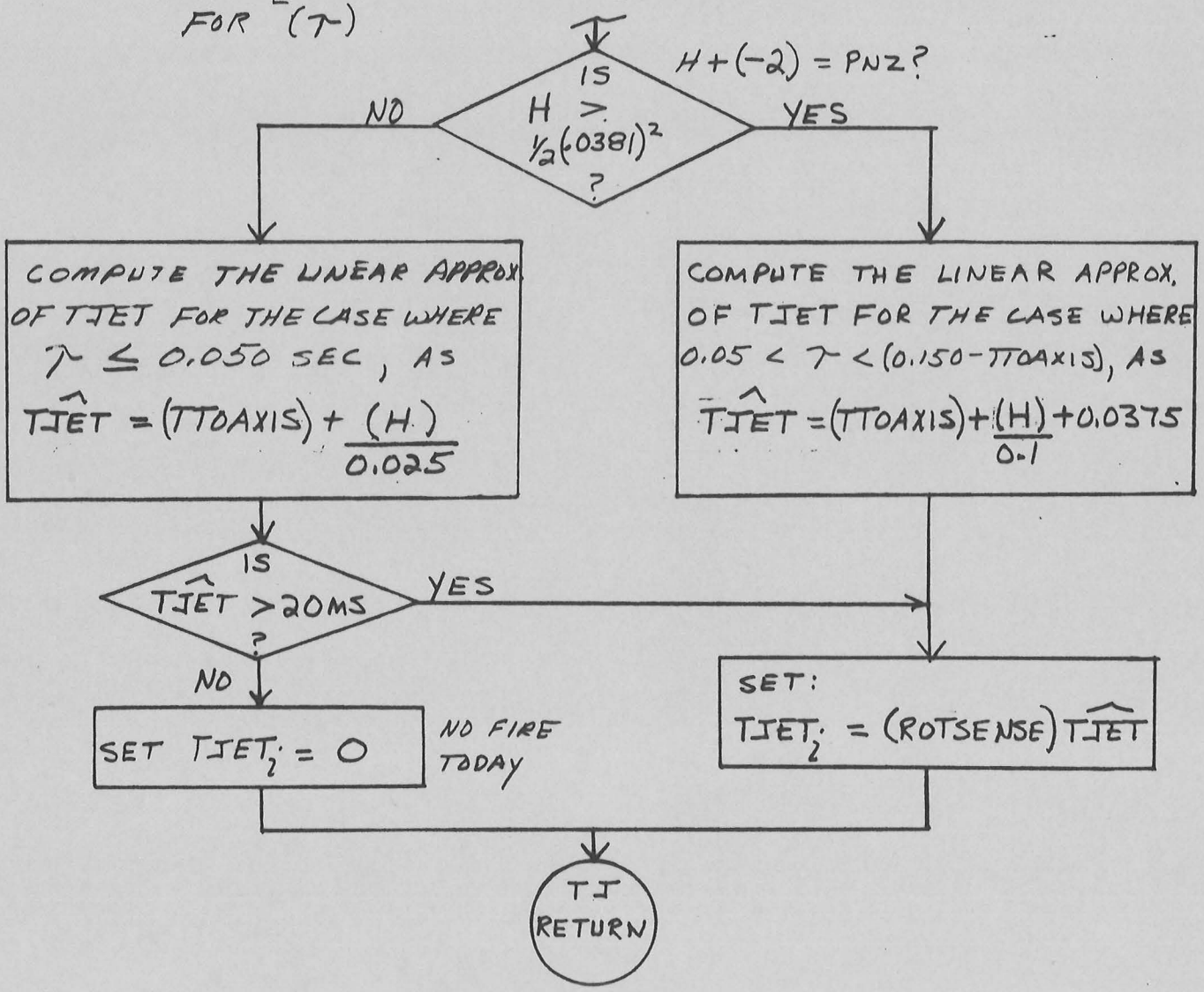
TJ RETURN

4-27

ZONE 1+

TEST t_1

NOW THE EXPRESSION $[H - 0.5\tau^2 = 0]$ IS TESTED TO SEE IF $\tau > 50$ MSEC. ACTUALLY THE TEST IS FOR $\tau > 38.1$ MSEC. THIS IS DUE TO THE FACT THAT UPON SUBSTITUTION, THE QUANTITY $0.5(.0381)^2$ HAPPENS TO BE EQUAL TO OCTAL 02 SCALED AT 8 SEC^2, WHICH IS A CONVENIET VALUE. THEREFORE, AS LONG AS $H > .5(.0381)^2$ THE $[0.05 < \tau < 0.150]$ APPROXIMATION WILL BE USED FOR (τ)



4-27

ZONE 4,5

ENTER WITH (FIREFCT) = (+)

NOW COMPUTE THE DISTANCE OF THE VEHICLE'S STATE WITH RESPECT TO THE SWITCH CURVE (OR TARGET PARABOLA) THAT BOUNDS THE "JETS OFF" OR COAST ZONE ON THE PHASE PLANE. THIS TARGET PARABOLA IS THE CURVE $COASTFCT_{(t)} = E + 0.5(1/ACOAST)\dot{E}^2 + COASTDB = 0$

SUBSTITUTING THE PRESENT E & $\dot{E}$ (@ $t=0$) WE HAVE:

$$COASTFCT_{(0)} = (E) + (1/ACOAST)_{i1} \cdot (EDOTSQ) + (COASTDB)_{i1}$$

where $i1$ TERMS ARE COMPUTED AND STORED BY THE YACCS RTN. FOR THIS AXIS. ALSO, THIS IS THE EXPRESSION FOR THE UPPER HALF-PLANE SINCE THE STATE WAS REFLECTED TO THIS CASE EARLIER FOR USE BY THE LOGIC.

IS COASTFCT (−) OR (+)

(−) or ZERO — BEYOND THE BOUNDRY → ZONE 5 (4-22)

(+) — WITHIN THE BOUNDRY BUT JETS MAY BE FIRING. → ZONE 4

TEST OF: $-(TJET_i)(ROTSENSE) = PNZ$?

ARE JETS FIRING TOWARD A TARGET

YES → JETS ON — TEST SOMEMORE

NO — THEY ARE OFF OR FIRING AWAY FROM A TARGET

IF THE TEST = 0, THEN TJET MUST = 0 INDICATING JETS OFF.

IF THE TEST = NNZ, THEN SIGN OF (TJET) MUST BE AIDING PRESENT EDOT SIGN, (ROTSENSE), WHICH IS NOT GOOD. THIS MEANS A TARGET (EITHER E-AXIS OR PARABOLA) HAS ALREADY BEEN REACHED AND NOW ARE FIRING BEYOND.

SET: $TJET_i = 0$

KEEP COASTING, OR SHUT JETS OFF QUICK LIKE!

TJ RETURN (4-27)

ENTERED WITH JETS FIRING IN ZONE 4 AND TOWARD A LEGAL TARGET

JETS ON

WHATS (FLAT)

0.8 DEG — IN DRIFTING FLIGHT → DRIFT ON

MORE TEST

(0) IN POWERED FLIGHT AND NO GTS CONTROL

CAN THE TARGET BE INTERCEPTED ?

NO

THE TEST = 0 OR NNZ WHICH INDICATES THE ACCEL. WOULD TAKE THE STATE WITHIN THE TARGET CURVE AND THEREFORE WOULD NOT INTERCEPT IT.

SET: $TJET_i = 0$ TO SHUT OFF JETS

TJ RETURN 4-27

YES

THIS WAS A TEST OF: $(AXISDIST)_{21} - (FIREFCT)$. FIREFCT IS THE PRESENT HORIZONTAL DISTANCE FROM THE FIREFCT = 0 CURVE AND AXISDIST IS THE DISTANCE BETWEEN THIS CURVES' EAXIS CROSSING (DB1 OR DB2) AND THE TARGETS' EAXIS CROSSING (DB3 OR DB4). THUS, <u>IF TEST = PNZ</u>, THE PRESENT ACCEL. WOULD TAKE THE STATE ACROSS THE E-AXIS <u>OUTSIDE</u> THE TARGET CROSSING (DB3 OR DB4). THEN, THE TARGET CAN BE INTERCEPTED FOR THE JETS TO TURN OFF. THEREFORE, CALC. THE FIRING TIME TO THE TARGET CURVE (TJET) AS IF THIS WERE A ZONE <u>1</u> CASE

SETUP FOR ZONE 1 LOGIC:
CHG SIGN (ROTSENSE)
CALC. AND SET:
$(TTOAXIS = (EDOT)(1/ANET1))_{22}$

TTOAXIS > 150 MSEC ?

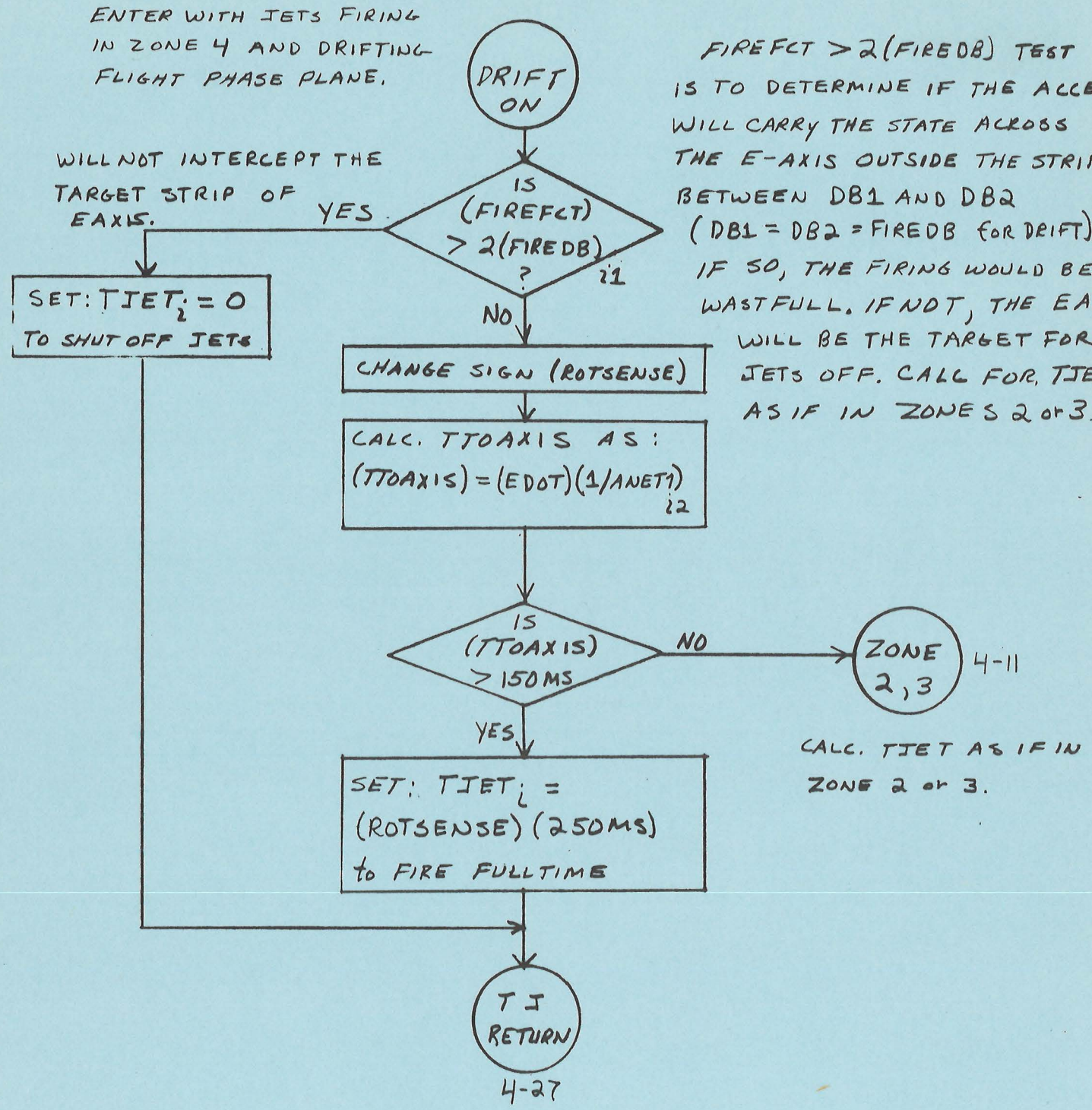
YES → SET: $TJET_i$ = (ROTSENSE)(250 MS)

NEVER REACH THE TARGET THIS PASS SO FIRE FULLTIME

NO → PICKUP (FIREFCT)

ZONE 1 4-17

(FLAT) = 0 SO ENTER ZONE 1 WITH JUST FIREFCT


ENTER WITH JETS FIRING IN ZONE 4 AND DRIFTING FLIGHT PHASE PLANE.
DRIFT ON
FIREFCT > 2(FIREDB) TEST IS TO DETERMINE IF THE ACCEL. WILL CARRY THE STATE ACROSS THE E-AXIS OUTSIDE THE STRIP BETWEEN DB1 AND DB2 (DB1 = DB2 = FIREDB FOR DRIFT). IF SO, THE FIRING WOULD BE WASTFULL. IF NOT, THE EAXIS WILL BE THE TARGET FOR JETS OFF. CALC FOR TJET AS IF IN ZONES 2 or 3.
WILL NOT INTERCEPT THE TARGET STRIP OF EAXIS.
YES
IS (FIREFCT) > 2(FIREDB) ?
i1
SET: TJET_i = 0 TO SHUT OFF JETS
NO
CHANGE SIGN (ROTSENSE)
CALC. TTOAXIS AS: (TTOAXIS) = (EDOT)(1/ANET1)
i2
IS (TTOAXIS) > 150 MS
NO
ZONE 2, 3
4-11
CALC. TJET AS IF IN ZONE 2 or 3.
YES
SET: TJET_i = (ROTSENSE)(250MS) to FIRE FULLTIME
TJ RETURN
4-27

INORDER TO PROPERLY UNDERSTAND THE FOLLOWING DERIVATION FOR ZONE 5, ONE SHOULD READ THE DERIVATION FOR ZONE 1 FIRST. THE PRESENT VEHICLE STATE (@ $t=0$) IS ASSUMED TO BE IN ZONE 5 BY TESTING THE COMPUTATION OF $COASTFCT_{(0)}$ AND FINDING IT IS BEYOND THE BOUNDRY THAT DEFINES THE "JETSOFF OR COAST" ZONE. THE BOUNDRY IS WHERE $[COASTFCT_{(t)} = 0]$ AND A NEGATIVE NON-ZERO VALUE OF $COASTFCT_{(0)}$ PLACES THE VEHICLE STATE OUTSIDE THIS TARGET.

IT SHOULD BE NOTED THAT THE LOGIC ALWAYS TRANSFORMS THE STATE TO THE UPPER HALF OF THE PHASE PLANE AND COMPUTES THE STATE FUNCTIONS (FIREFCT & COASTFCT) FOR THIS CASE. HOWEVER, THE ACTUAL STATE IS NOT LOST DUE TO KEEPING THE SIGN OF EDOT IN (ROTSENSE), WHICH DEFINES EITHER UPPER HALF-PLANE OR LOWER-HALF PLANE. <u>THUS</u>, TO BE COMPATABLE WITH THE ASSUMPTIONS USED IN THE ZONE 1 DERIVATION, THE <u>RIGHT</u> HALF-PLANE CASE WILL AGAIN BE REFERENCED FOR THE FOLLOWING ZONE 5 ALGORITHM.

THE PRESENT STATE (at $t=0$) IS SOMEWHERE IN ZONE 5. EXTRAPOLATION OF THE STATE TO THE TARGET PARABOLA ($COASTFCT_{(t)} = 0$) MUST BE ACCOMPLISHED TO OBTAIN A FIRING TIME WHICH WILL CARRY THE STATE TO THE TARGET. THIS EXTRAPOLATION WAS DEFINED IN ZONE 1 DERIVATION AS:

$$COASTFCT_{(t)} = COASTFCT_{(0)} + \frac{d}{dt}\left[COASTFCT_{(0)}\right]t + \frac{d^2}{dt^2}\frac{\left[COASTFCT_{(0)}\right]}{2!}t^2 \ldots$$

THE SAME CAN BE USED HERE ONLY NOW, WE ARE DEALING WITH A TOTAL TIME (t) FROM THE START AND, THEREFORE, THE FUNCTION IS EXPRESSED AS A FUNCTION OF (t). ALSO, (0) MEANS at $t=0$.

USING THE DEFINITIONS OF THE DERIVATIVES FROM ZONE 1, WE HAVE:

NEXT PAGE

$$\frac{d}{dt} COASTFCT_{(0)} = \frac{\dot{E}_{(0)}}{ANET}\left[-ANET \frac{-ANET^2}{ACOAST}\right] \quad \text{AND}$$

$$\frac{d^2}{dt^2} COASTFCT_{(0)} = ANET + \frac{ANET^2}{ACOAST} \quad \text{THEN}$$

$$COASTFCT_{(t)} = COASTFCT_{(0)} + \frac{\dot{E}_{(0)}}{ANET}\left[-ANET - \frac{ANET^2}{ACOAST}\right]t + \tfrac{1}{2}\left[ANET + \frac{ANET^2}{ACOAST}\right]t^2$$

IN ZONE 1 IT WAS ESTABLISHED THAT $\dot{E}$ AT THE TIME REF. ($T=0$) EQUALED 0, SINCE THAT WAS THE E-AXIS. THEREFORE, THE $\frac{d}{dt}$ TERM DROPPED OUT. NOT SO IN THIS CASE! IN ZONE 5, @ $t=0$, $\dot{E}_{(0)}$ HAS SOME VALUE - BUT IS NEGATIVE. THUS,

$$COASTFCT_{(t)} = COASTFCT_{(0)} + \frac{\dot{E}_{(0)}}{ANET}\left[ANET + \frac{ANET^2}{ACOAST}\right]t \quad + etc\ldots$$

ALSO, IT WAS ESTABLISHED THAT ACCFCT21 =

$-1/ANET + \frac{ANET^2}{ACOAST}$. RELATING THIS TO ZONE 5 ALLOWS THE SAME TERM TO EQUAL ACCFCT25. THEREFORE,

$$COASTFCT_{(t)} = COASTFCT_{(0)} + \frac{\dot{E}_{(0)}}{ANET}\left[\frac{-1}{ACCFCT25}\right]t + \tfrac{1}{2}\left[\frac{-1}{ACCFCT25}\right]t^2\ldots$$

LOOKING CLOSELY AT $\frac{\dot{E}_{(0)}}{ANET}$ WE FIND THIS IS THE EXPRESSION USED TO DEFINE TTOAXIS.

WE CAN SAY THEN:

$$COASTFCT_{(t)} = COASTFCT_{(0)} - \frac{TTOAXIS}{ACCFCT25}t - \frac{0.5}{ACCFCT25}t^2$$

TO SOLVE FOR t, WE SET THIS TO ZERO (WHICH DEFINES THE BOUNDRY CURVE) AND MULT. THRU BY ACCFCT25. THUS,

$$COASTFCT_{(t)} = COASTFCT_{(0)}(ACCFCT25) - TTOAXIS\,t - 0.5t^2 = 0$$

LOOKING FAMILIAR?

NEXT PAGE

IN ZONE 1, "H" WAS DEFINED AS $COASTFCT_{(0)} \times ACCFCTZ1$.

NOW WE LET $H = COASTFCT_{(0)} \times ACCFCTZ5$ where

ACCFCTZ5 IS ALSO COMPUTED IN THE VACCS RTN. NOW, BY SUBSTITUTION WE HAVE THE EXPRESSON:

$$H - TTOAXIS\,t - 0.5t^2 = 0 \quad \text{where}$$

THE SOLUTION OF t IS THE FIRING TIME (TJET) TO TAKE THE PRESENT VEHICLE STATE, IN ZONE 5, TO THE SWITCH CURVE.

$$t = TJET = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$ HOWEVER,

INSTEAD OF DOING THIS SOLUTION, THE LOGIC WILL USE A LINEAR APPROXIMATION OF $H - TTOAXIS\,t - 0.5t^2$ FOR 1 OF 2 CASES:

<u>FOR TJET < 50MSEC CASE - FIG 1</u>

$$\frac{\widehat{TJET}}{0.05} = \frac{H}{(TTOAXIS)\,t + 0.5t^2} \quad \text{subt. } t = .05$$

$$\widehat{TJET} = \frac{(.05)\,H}{TTOAXIS(.05) + .5(.05)^2}$$

$$\widehat{TJET} = \frac{H}{TTOAXIS + 0.025}$$

PLOTTING THE EXPRESSION VS. t

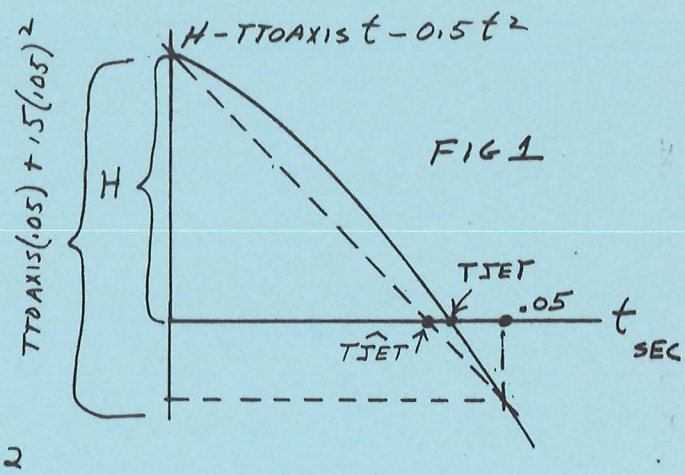


FIG 1

<u>FOR 50MS < TJET < 150MS CASE - FIG 2</u>

$$\frac{\widehat{TJET} - .05}{.150 - .05} = \frac{A}{B} \quad \text{WHERE}$$

$A = H - TTOAXIS(.05) - .5(.05)^2$ &

$B = TTOAXIS(.15 - .05) + .5\left[(.15)^2 - (.05)^2\right]$

SOLVING FOR $\widehat{TJET}$;

$$\widehat{TJET} = \frac{H + 0.00375}{TTOAXIS + 0.1}$$

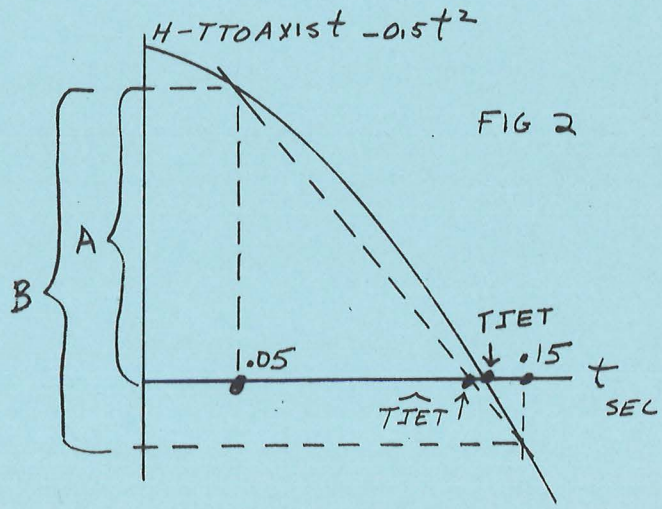


FIG 2

SEE LOGIC NOW (NEXT PAGE)

LOGIC

ZONE 5

ENTERED WITH COASTFCT AS ZERO OR(−) AND SAVED

SIGN (ROTSENSE) ?

IN LOWER HALF-PLANE ZONE 5 (−)

SUBTRACT (2) FROM i2-(ADRSDIF2) to get PROPER YACCS terms for this CASE

(+) IN UPPER HALF-PLANE, i2 IS ALREADY SET FOR THIS CASE

COMPUTE "H" AS A DOUBLE PRECISION VALUE, SET: $(HH) = COASTFCT(ACCFCTZ5)_{i2}$.

SCALED @ $8\ SEC^2$

COMPUTE THE TERM TTOAXIS, SET: $(TTOAXIS) = (EDOT)(1/ANET2)_{i2}$.

SCALED @ 4 SEC

NOW THE EXPRESSION $H-(TTOAXIS)t-0.5t^2$ IS TESTED TO SEE IF $t > 50$ MSEC. SUBSTITUTION OF $t = 0.05$ SEC. WE FORM: $(HH)-(TTOAXIS)(0.05)-0.00125$ @ $8\ SEC^2$

HH = high ORDER VALUE OF (HH)

IS VALUE PNZ ?

NO ZERO or (−) → FORM ULA1 (TJET ≤ 50MS)

YES TJET > 50MSEC

NOW SUBSTITUTE $t = 150$ MSEC TO TEST IF TJET > 150 MSEC

THUS FORMING: $(HH)-(TTOAXIS)(0.15)-0.01125$ @ $8\ SEC^2$

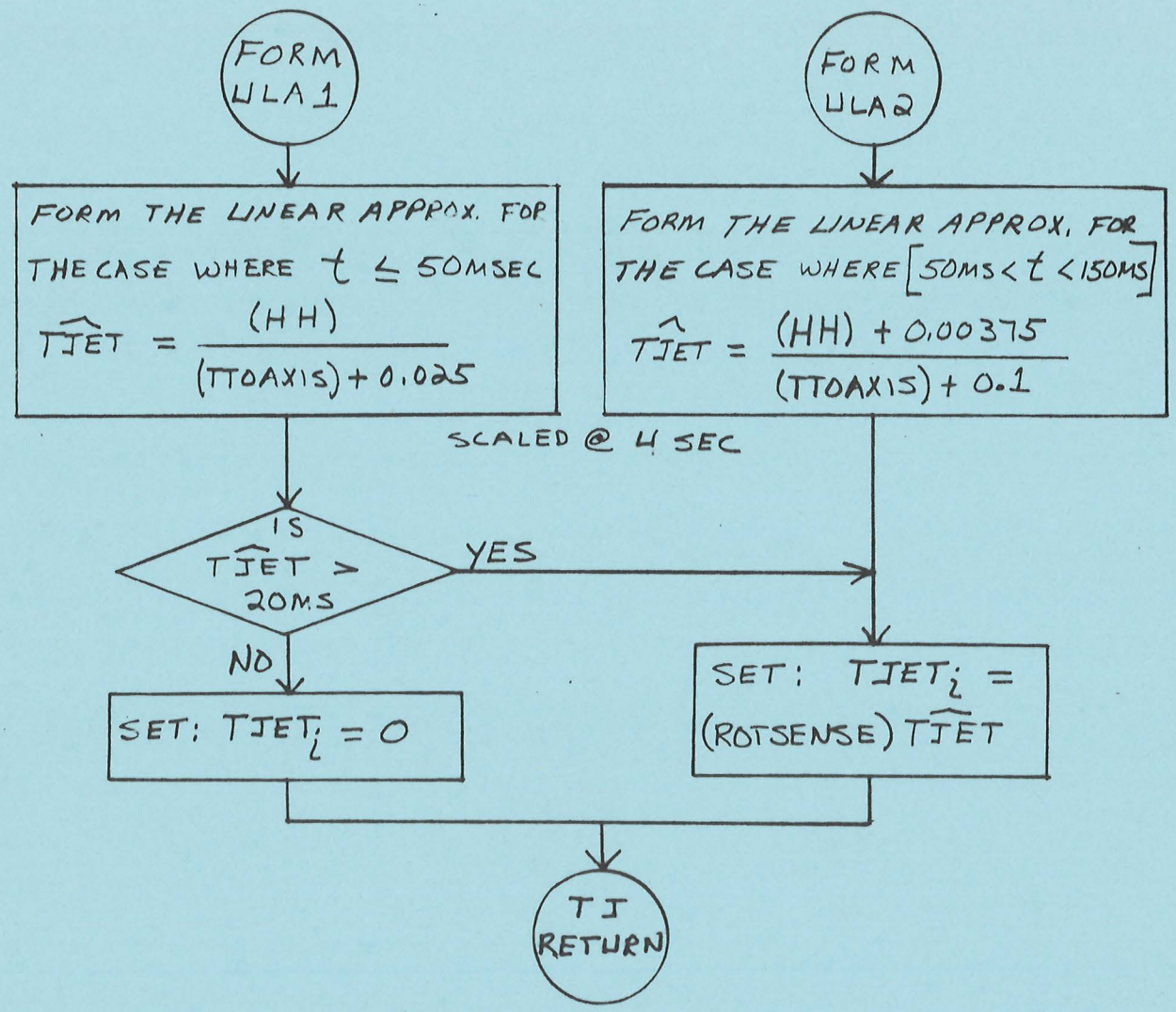
IS VALUE PNZ?

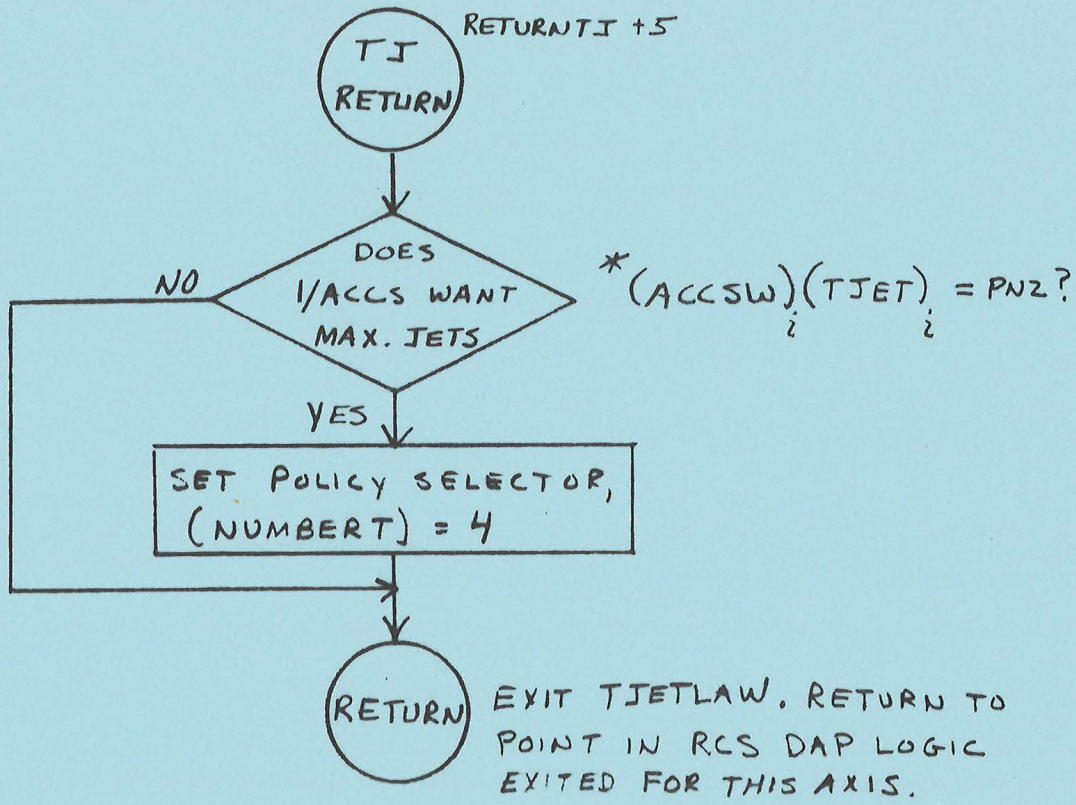
TJET > 150 MS YES → SET: $TJET_i = (ROTSENSE)(250MS)$

NO ZERO or (−) → FORM ULA2 (50MS < TJET < 150MS)

TJ RETURN 4-27

FIRE FULLTIME, RECOMPUTE NEXT PASS.

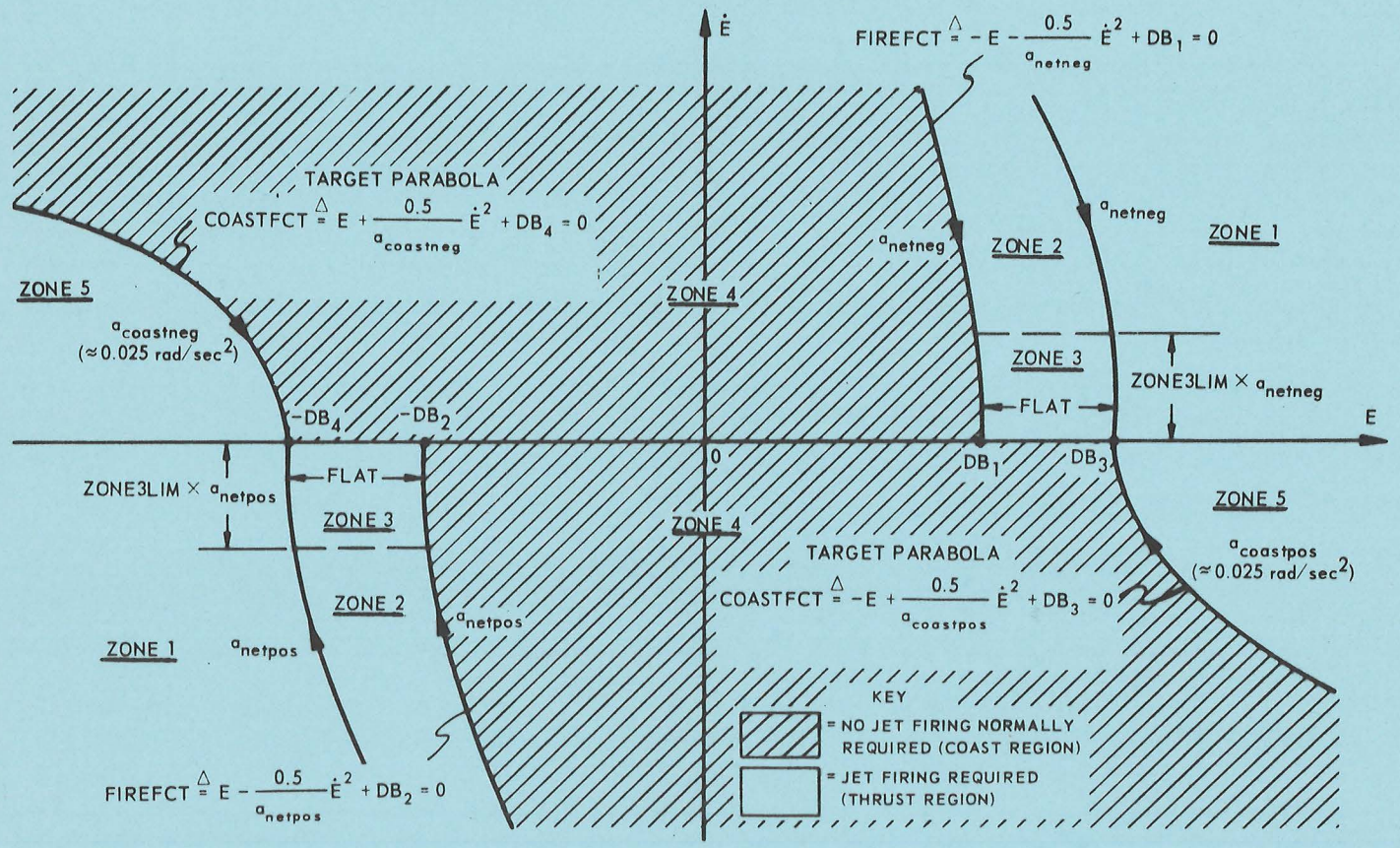

FORM ULA1
FORM ULA2
FORM THE LINEAR APPROX. FOR THE CASE WHERE $t \leq 50$ MSEC
$\widehat{TJET} = \frac{(HH)}{(TTOAXIS) + 0.025}$
FORM THE LINEAR APPROX. FOR THE CASE WHERE [50MS < t < 150MS]
$\widehat{TJET} = \frac{(HH) + 0.00375}{(TTOAXIS) + 0.1}$
SCALED @ 4 SEC
IS $\widehat{TJET}$ > 20MS
YES
NO
SET: $TJET_i = 0$
SET: $TJET_i$ = (ROTSENSE) $\widehat{TJET}$
TJ RETURN



ENTRY HERE IS WITH TJET$_i$ WHICH REPRESENTS EITHER (TJP), (TJN) OR (TJV) DEPENDING ON i, OR (AXISCTR), AND SCALED AT 10.24 SEC WITH THE PROPER FIRING SENSE ESTABLISHED BY THE SIGN OF (ROTSENSE).

EXIT, THEN, IS WITH THE FIRING TIME STORED IN THE PROPER LOCATION FOR THE INDICATED AXIS, THE SCALING IS READY FOR USE IN THE T6 COUNTER, IF NECESSARY

* THE 1/ACCS RTN. SETS (ACCSW) ACCORDING TO WHETHER MIN. JETS (FOR U & V AXES) CAN OFFSET AN OPPOSING OFFSET ACCEL, OR AOS. 1/ACCS RTN. SETS THE SIGN OF (ACCSW) OPPOSITE TO SIGN AOS. THEREFORE, IF THE SIGN (ACCSW) AND THE SIGN (TJN) AGREE, THEN USE OF MAX. JETS ON U, V-AXES IS FORCED BY SETTING NUMBERT = 4. MAX. P-AXIS JETS (4) ARE NOT FORCED, HOWEVER.



VEHICLE MOTION IS ALWAYS CLOCKWISE ON THE PHASE PLANE

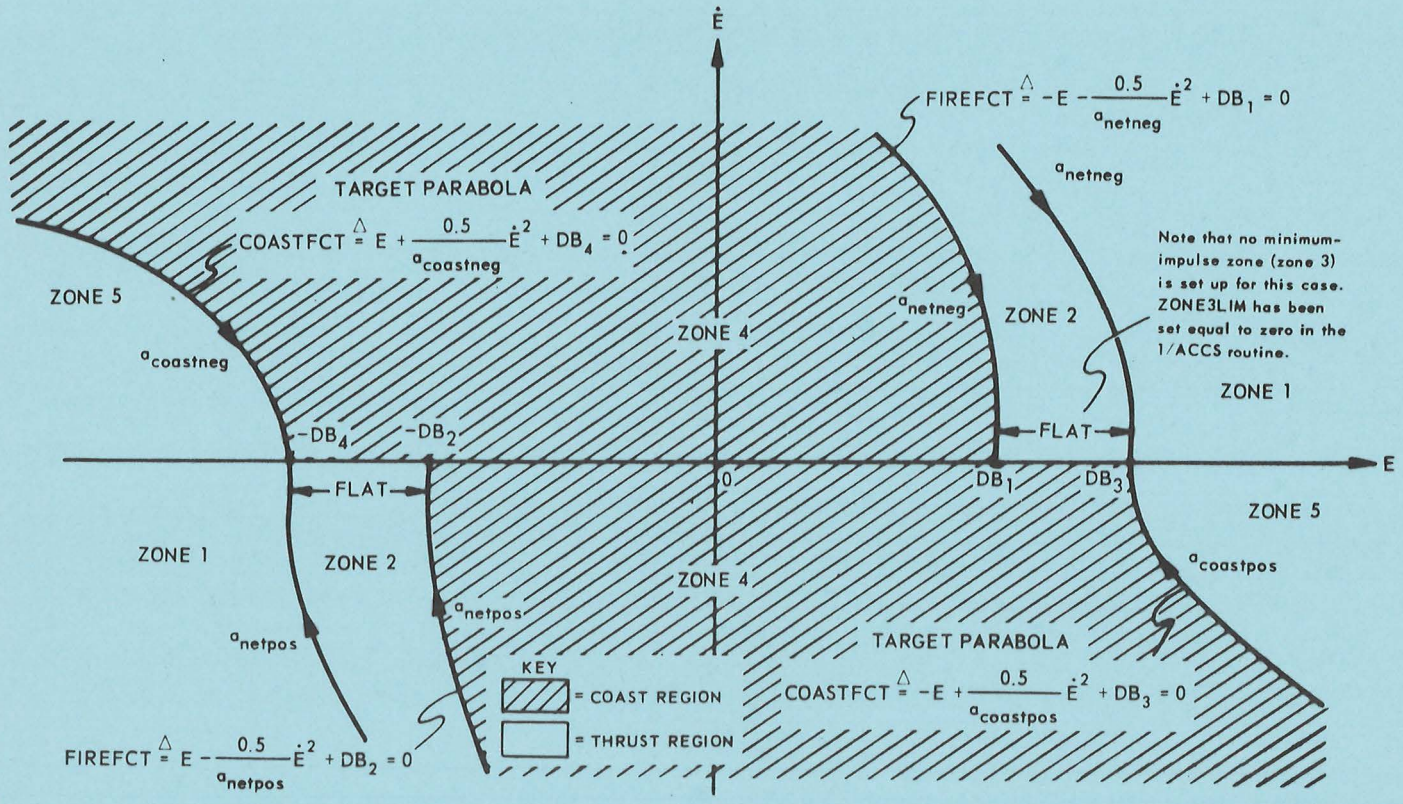
FOR A + ACCELERATION, MOTION IS UPWARD AND PARABOLIC

FOR A - ACCELERATION, MOTION IS DOWNWARD AND PARABOLIC

NOTES:

1. FIREFCT = 0 is the switching parabola in the upper or lower half-plane used as the boundary to TURN-ON the JETS
2. COASTFCT = 0 is the switching parabola in the upper or lower half-plane used as the boundary to TURN-OFF the JETS
3. Jet firing is allowed in the coast region only if the jets are driving the vehicles state to intersect the E-axis between DB1 and -DB2
4. DB1 = DB2 = DB; DB3 = DB4 = DB+ FLAT where FLAT = 0.8 deg. and DB = 0.3 deg or 5.0 deg
5. anetneg, anetpos are equal to the jet acceleration only. (there is no AOS in drifting flight)

The FINELAW phase plane for DRIFTING FLIGHT



VEHICLE MOTION IS ALWAYS CLOCKWISE ON THE PHASE PLANE

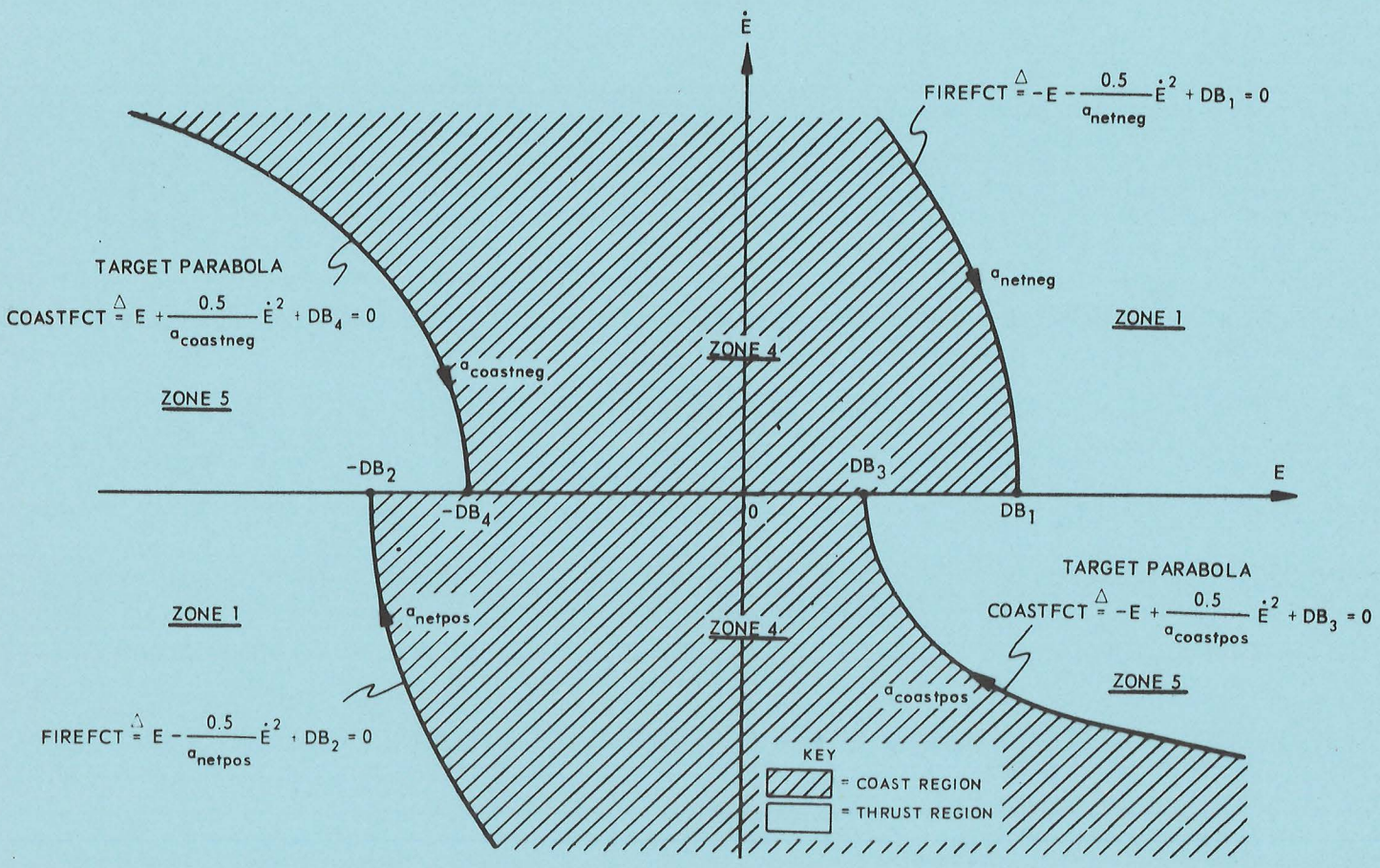
FOR A + ACCELERATION, MOTION IS UPWARD AND PARABOLIC

FOR A - ACCELERATION, MOTION IS DOWNWARD AND PARABOLIC

NOTES:

1. Notes 1, 2, 3 and 4 of drifting flight phase-plane apply.
2. Anetneg and anetpos, in general, are not equal (the offset acceleration is considered here)
3. acoastnet and acoastpos also are not, in general, equal as in drifting flight.

The FINELAW phase plane for DESCENT POWERED FLIGHT with small offset accelerations (nulling trim times or less than 2 seconds).



VEHICLE MOTION IS ALWAYS CLOCKWISE ON THE PHASE PLANE

FOR A + ACCELERATION, MOTION IS UPWARD AND PARABOLIC

FOR A - ACCELERATION, MOTION IS DOWNWARD AND PARABOLIC

NOTES:

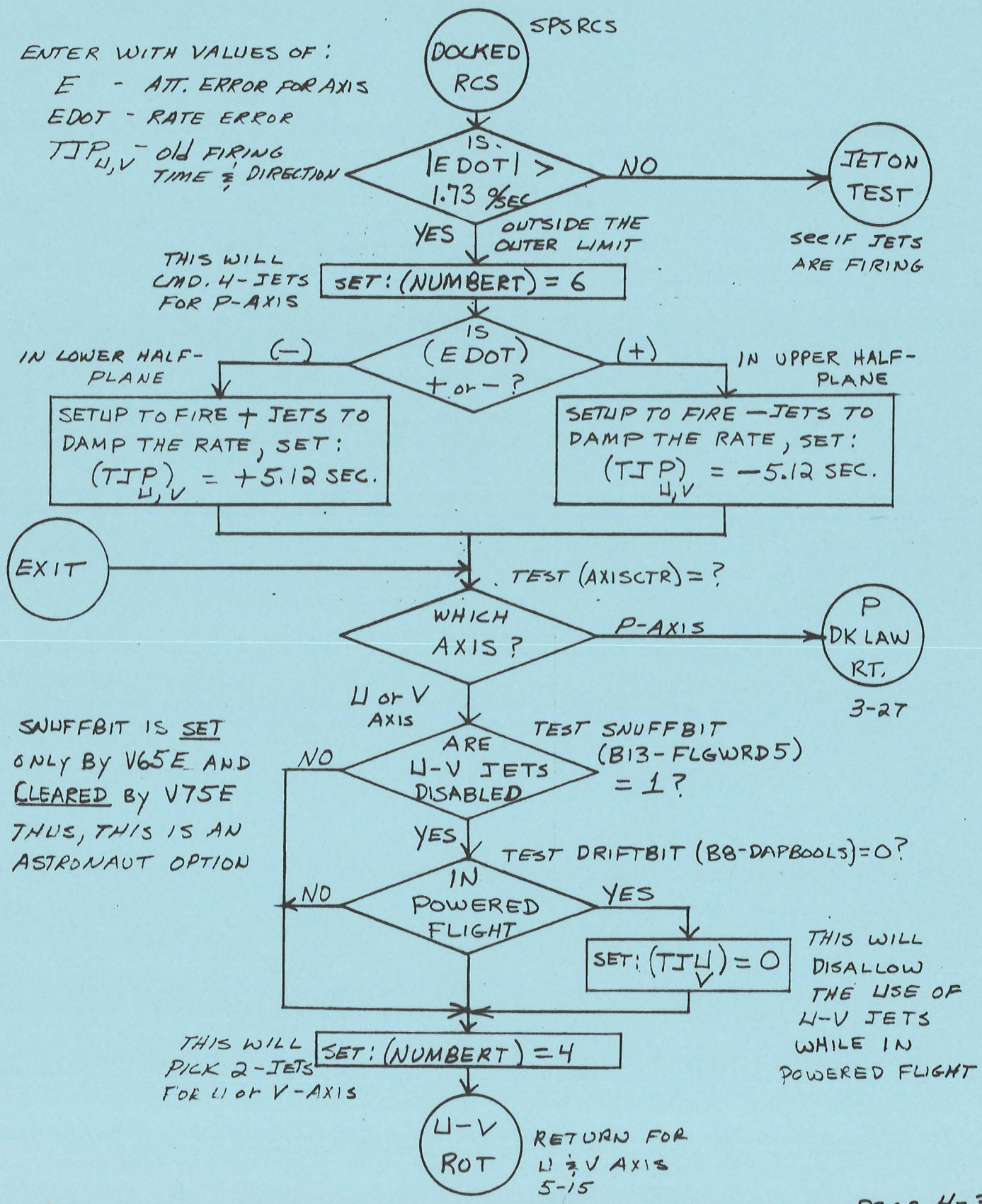
1. This is only a general phase-plane representation for this case. The relative positions of the switching parabolas are not representative due to the many possible variations in the deadband positions and the AOS magnitude.
2. Notes 1, 2 and 3 of drifting flight phase-plane apply
3. FLAT = 0 for this case (no ZONES 2 or 3).
4. The attitude deadbands are formed as follows (where DB = 1 deg)
   a. if AOS > amin. ; DB1 = DB, DB2 = DB4 = 2DB, DB3 = -0.75DB
   b. if AOS < -amin; DB2 = DB, DB1 = DB3 = 2DB, DB4 = -0.75DB
   c. if amin > AOS > 0.5 amin; DB1 = DB2 = DB4 = DB, DB3 = 0.5 DB
   d. if -0.5 amin > AOS > -amin; DB1 = DB2 = DB3 = DB, DB4 = 0.5 DB
   e. if 0.5 amin > AOS > -0.5 amin; DB1 = DB2 = DB3 = DB4 = DB

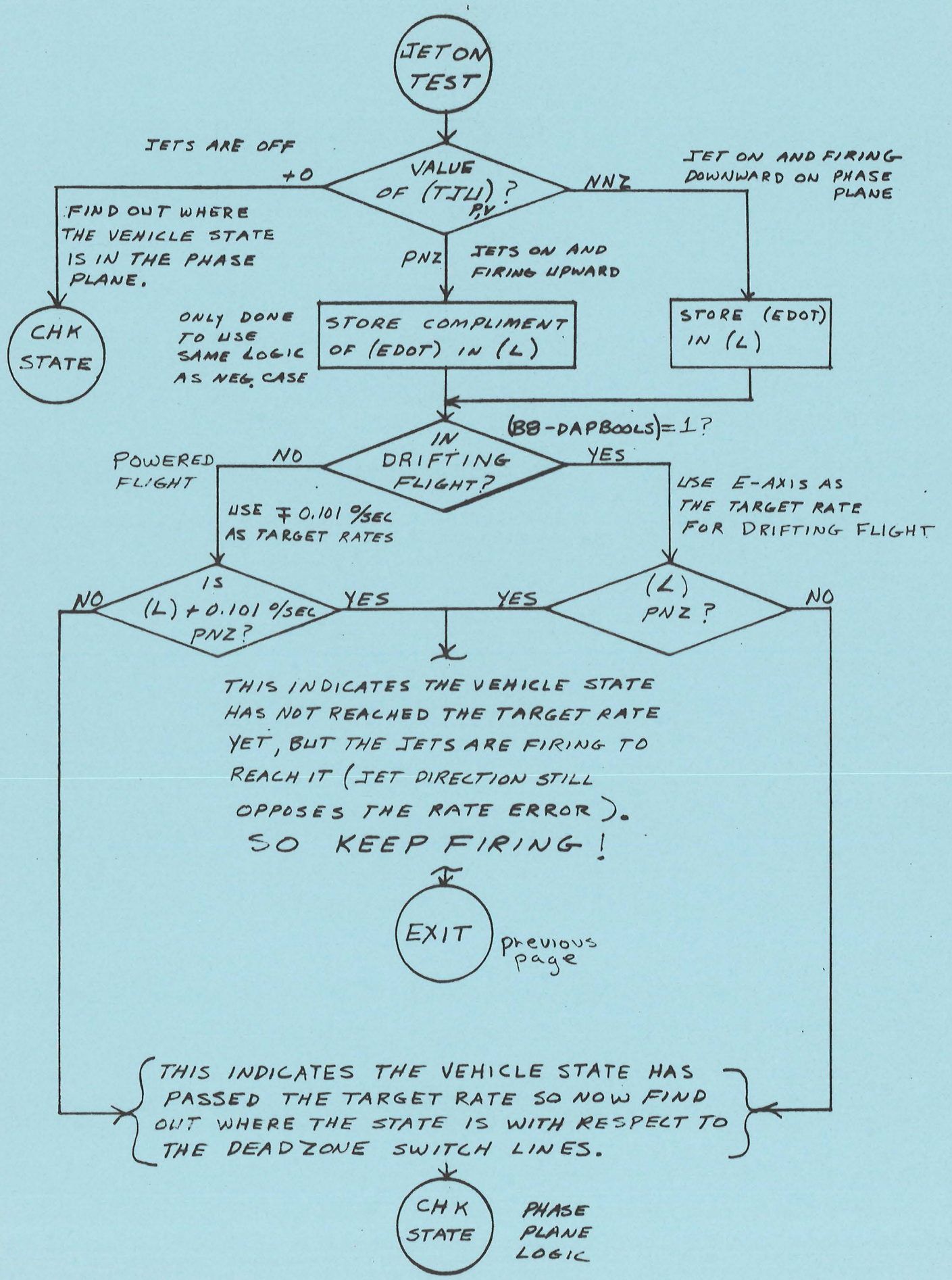
The FINELAW phase plane for POWERED ASCENT and for POWERED DESCENT (only when DPS engine trim times or greater than 2 seconds)

THIS IS THE RCS CONTROL LAW FOR ROTATION CONTROL WHEN THE CSM IS DOCKED. THE AXIS FOR WHICH THIS SUBRTN. IS ENTERED IS IDENTIFIED BY (AXISCTR). ENTRY HERE OCCURS NOMINALLY WHENEVER THE ASTRONAUT IS NOT CONTROLLING (NOT IN RATE CMD. MODE) AND EVERY:

a) 100 MSEC FOR ALL 3 AXES DURING DRIFTING FLIGHT OR,

b) 100 MSEC FOR P-AXIS AND 200 MSEC FOR U & V AXES IN POWERED FLIGHT.




JET ON TEST
VALUE OF (TJU) P,V ?
+0
JETS ARE OFF
FIND OUT WHERE THE VEHICLE STATE IS IN THE PHASE PLANE.
CHK STATE
PNZ
JETS ON AND FIRING UPWARD
ONLY DONE TO USE SAME LOGIC AS NEG. CASE
STORE COMPLIMENT OF (EDOT) IN (L)
NNZ
JET ON AND FIRING DOWNWARD ON PHASE PLANE
STORE (EDOT) IN (L)
IN DRIFTING FLIGHT?
(B8-DAPBOOLS)=1?
NO
POWERED FLIGHT
YES
USE ∓ 0.101 °/SEC AS TARGET RATES
USE E-AXIS AS THE TARGET RATE FOR DRIFTING FLIGHT
IS (L) + 0.101 °/SEC PNZ?
NO
YES
YES
(L) PNZ ?
NO
THIS INDICATES THE VEHICLE STATE HAS NOT REACHED THE TARGET RATE YET, BUT THE JETS ARE FIRING TO REACH IT (JET DIRECTION STILL OPPOSES THE RATE ERROR).
SO KEEP FIRING!
EXIT
previous page
THIS INDICATES THE VEHICLE STATE HAS PASSED THE TARGET RATE SO NOW FIND OUT WHERE THE STATE IS WITH RESPECT TO THE DEADZONE SWITCH LINES.
CHK STATE
PHASE PLANE LOGIC

SPSSTART

CHK STATE

THE PHASE PLANE DEADZONE (AREA FOR NO JET FIRINGS) FOR THE DOCKED DAP IS A FIXED AREA DEFINED BY THE BOUNDRIES SHOWN ON PAGE 4-34. THE PRESENT VEHICLE STATE, E & EDOT, IS NOW TESTED TO SEE IF IT FALLS WITHIN THE TWO SWITCH LINES THAT HAVE A SLOPE OF $-1/4 \frac{\text{DEG/SEC}}{\text{DEG.}}$ AND CROSS THE E-AXIS AT (+) & (-) 1.4 DEG.

THE TEST IS MADE BY COMPARING THE E-AXIS CROSSING OF A LINE, ON WHICH THE VEHICLE STATE LIES, TO THE 1.4 DEG SWITCH LINE CROSSING. REMEMBER! WE ALREADY KNOW THE STATE IS WITHIN THE 1.73 °/SEC BOUNDRY.

E IS SCALED AT π RADIANS
EDOT AT $\pi/4$ RAD/SEC
INHERENTLY EDOT BECOMES
$K \cdot EDOT$ WHERE $K = \frac{1}{\text{SLOPE}} \frac{\text{RAD.}}{\text{RAD/SEC}}$
& SLOPE $= -\frac{1}{4} \frac{\text{DEG/SEC}}{\text{DEG}}$

IS $|E + EDOT| > 1.4°$

NO → IN DEADZONE BETWEEN SLOPED SWITCH LINES.

YES → THE 1.4° IS A PAD LOADED DB IN (DKDB)

IS E + EDOT PNZ?

NO → TO LEFT OF SLOPED SWITCH LINES

YES → TO RIGHT OF SLOPED SWITCH LINES

IS (EDOT) < +1.125 °/SEC

NO → IN DEADZONE BETWEEN RATE LIMITS

YES → BELOW +1.125 °/SEC LINE. FIRE UP

SET $(TJU)_{P,V}$ = +5.12 SEC.

IS (EDOT) > −1.125 °/SEC

NO → IN DEADZONE BETWEEN RATE LIMS.

YES → ABOVE −1.125 °/SEC LINE. FIRE DOWN

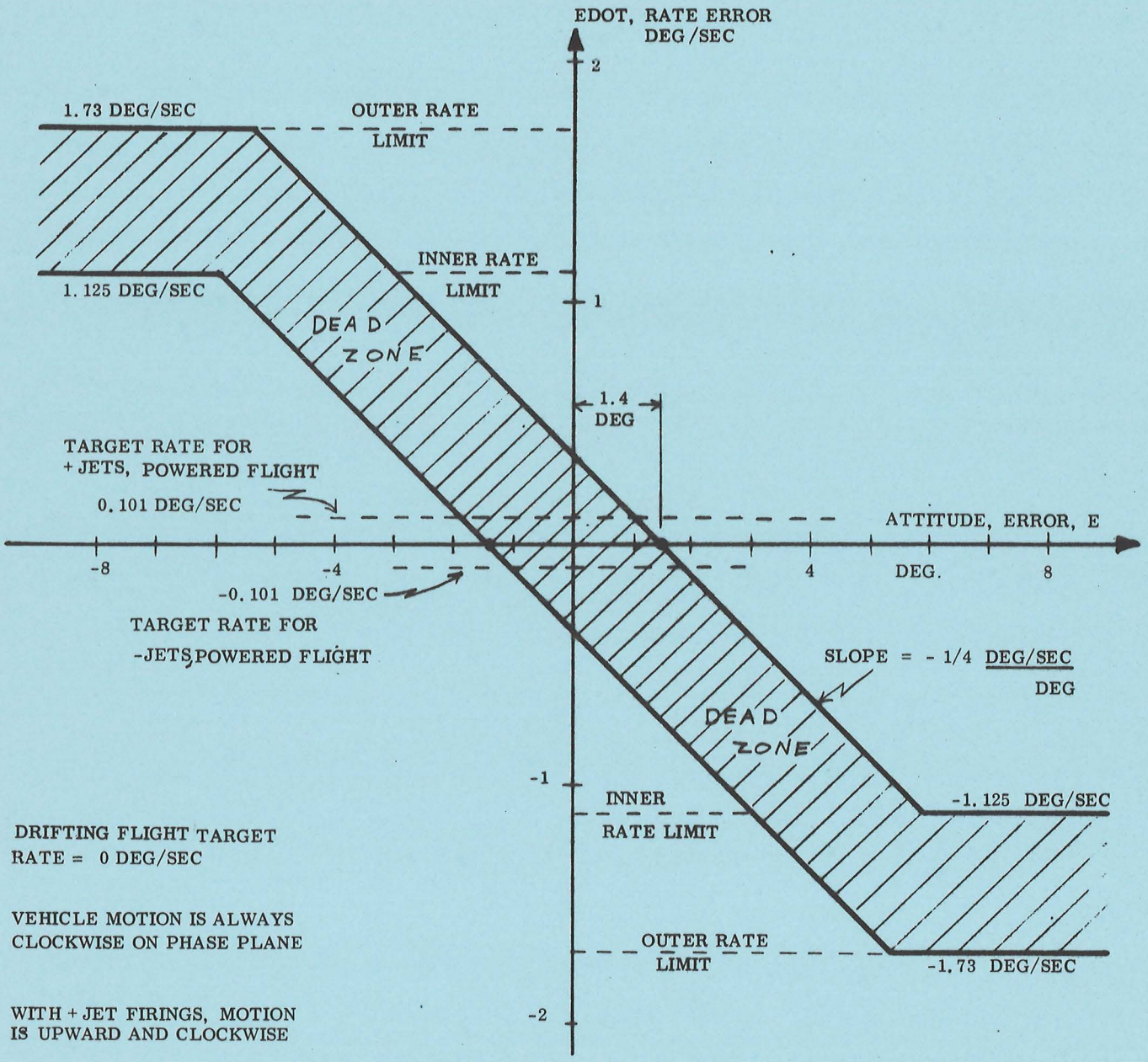
SET $(TJU)_{P,V}$ = −5.12 SEC.

SET $(TJU)_{P,V}$ = +0 → SHUT OFF JETS

SET $(TJU)_{P,V}$ = +0 → SHUT OFF JETS

EXIT

DOCKED LM DAP PHASE PLANE
FOR RCS JET FIRINGS



DRIFTING FLIGHT TARGET
RATE = 0 DEG/SEC

VEHICLE MOTION IS ALWAYS
CLOCKWISE ON PHASE PLANE

WITH + JET FIRINGS, MOTION
IS UPWARD AND CLOCKWISE

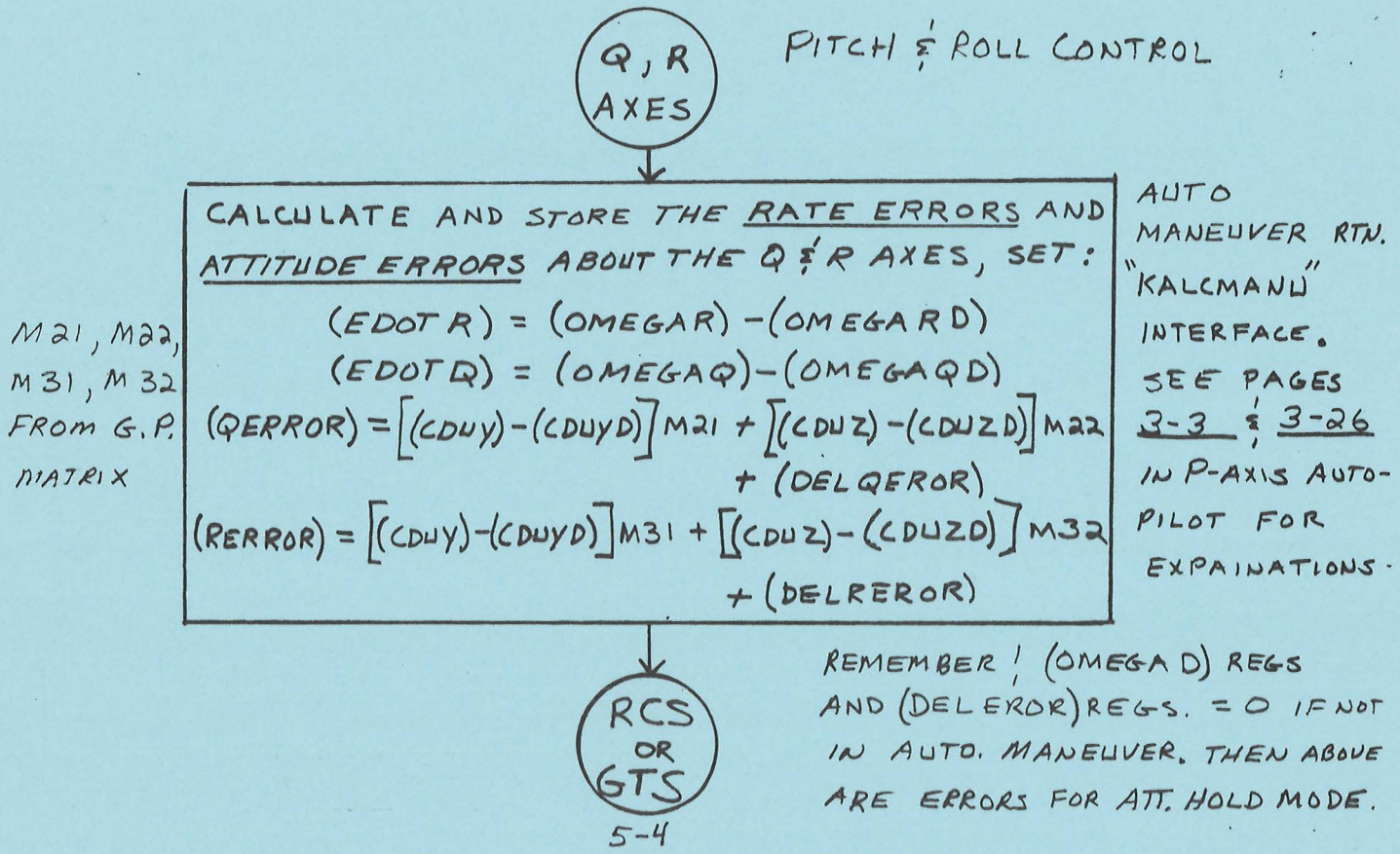
WITH -JET FIRINGS, MOTION
IS DOWNWARD AND CLOCKWISE

DOCKED PHASE PLANE

SECTION V

Q, R-AXIS AUTOPILOT
(RCS Control Logic Description)

ENTRY TO Q & R AXES AUTOPILOT



The RCS jets are normally used to control the attitude errors and rates about the pitch and roll axes. However, during a DPS powered flight, this control responsibility can be shared with the TRIM GIMBAL CONTROL SYSTEM in order to conserve RCS use. At this point in the logic, the DAP checks to see if the TRIM GIMBAL CONTROL SYSTEM can be used for this purpose. Also, control of the thrust vector through the CG. (any misalignment of which causes an angular offset accel - AOS) is the sole responsibility of the TRIM GIMBAL CONTROL SYSTEM when DPS is being used. Thus, the trim gimbal is operated in one of the two following modes:

1. PITCH/ROLL ATTITUDE CONTROL MODE

   (controls att. errors and rate along with controlling the thrust vector)

2. ANGULAR OFFSET ACCELERATION NULLING MODE

   (controls the thrust vector only)

NEXT PAGE

SUMMARY - TRIM GIMBAL CONTROL SYSTEM USE

ATTITUDE CONTROL MODE - PITCH/ROLL — see Section VI

1. Subroutine used is called "GTS" and is only called by the DAP logic (RCS-GTS INTERFACE)

2. "GTS" computes a drive function to control pitch/roll att. errors, rates and accelerations (the later due to the thrust vector - CG. misalignment)

3. The trim direction of the DPS engine is set according to the sign (drive function). Timers are used only to stop the trim (when zero) if use of "GTS" is disallowed by the DAP, or elsewhere.

4. When in use, "GTS" is normally alternated (every 200 ms) with the pitch/roll jet logic. Interlacing of "GTS" and RCS control can occur provided RCS jet firings are < 100 msec (relatively small att. errors or rates). Otherwise, "GTS" use is disallowed.

5. "GTS" use is also disallowed when:

   a) DAP state is in a manual mode (att. hold mode) or
   b) relatively large offset accelerations existing (as reflected by trim times $\geq$ 5 sec. computed in the subrtn "TIMEGMBL" - see below) or
   c) not in a DPS burn

ACCELERATION NULLING MODE — see Section VI

1. Subroutine used is called "TIMEGMBL" and is called by the DAP (RCS-GTS INTERFACE) or by 1/ACCS routine

2. "TIMEGMBL" computes a trim time to control only the thrust vector (offset acceleration nulling). Timers are set to the calk trim time. Trimming stops when T = 0. The DAP control logic controls the timers (reduced 100 ms every DAP cycle).

3. "TIMEGMBL" is normally called (once every 2 sec.) by the 1/ACCS rtn. during a DPS burn. It allows use of "GTS" only if the trim times are < 5 sec. otherwise, it will control the AOS.

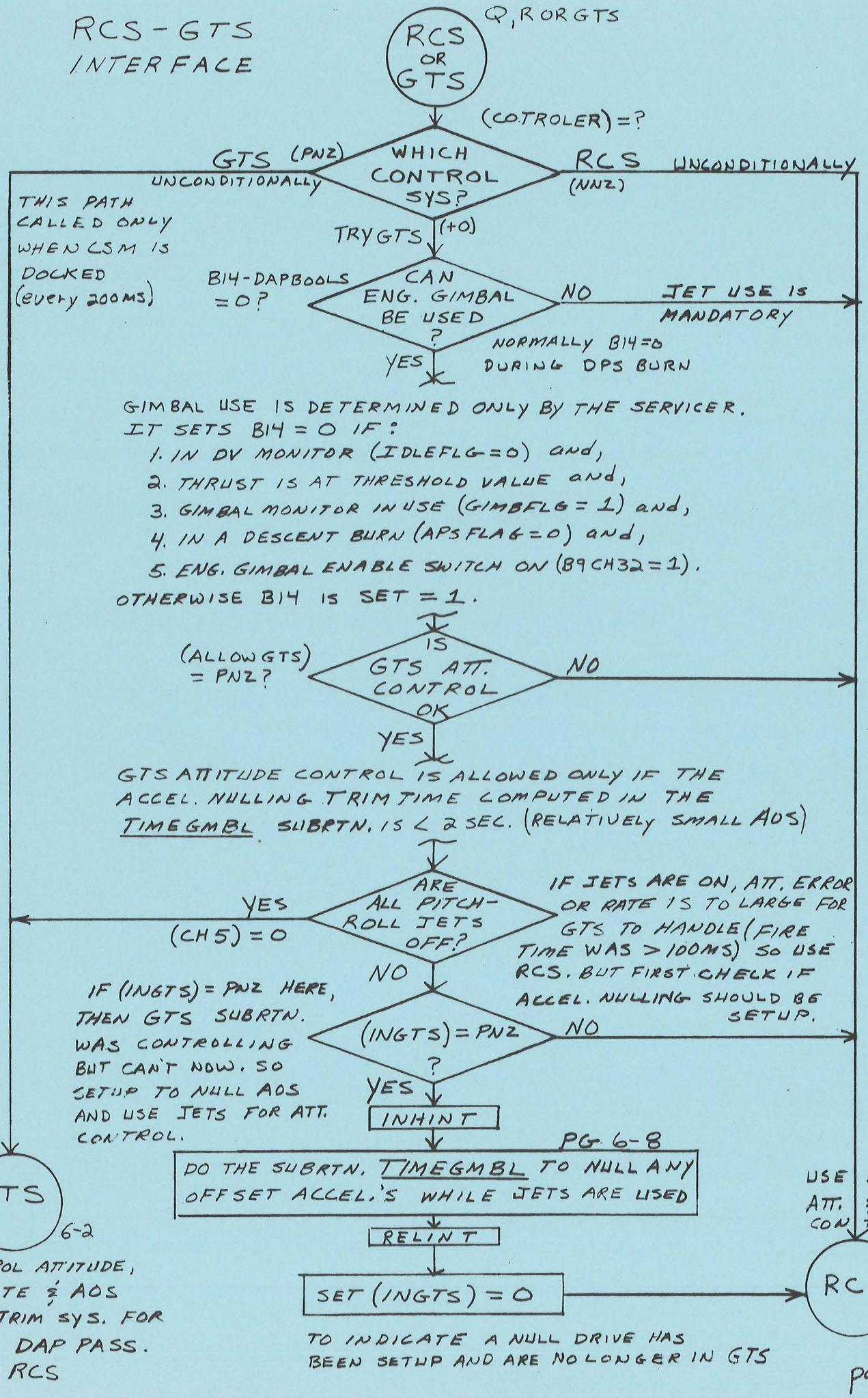
4. "TIMEGMBL" will not be used if:

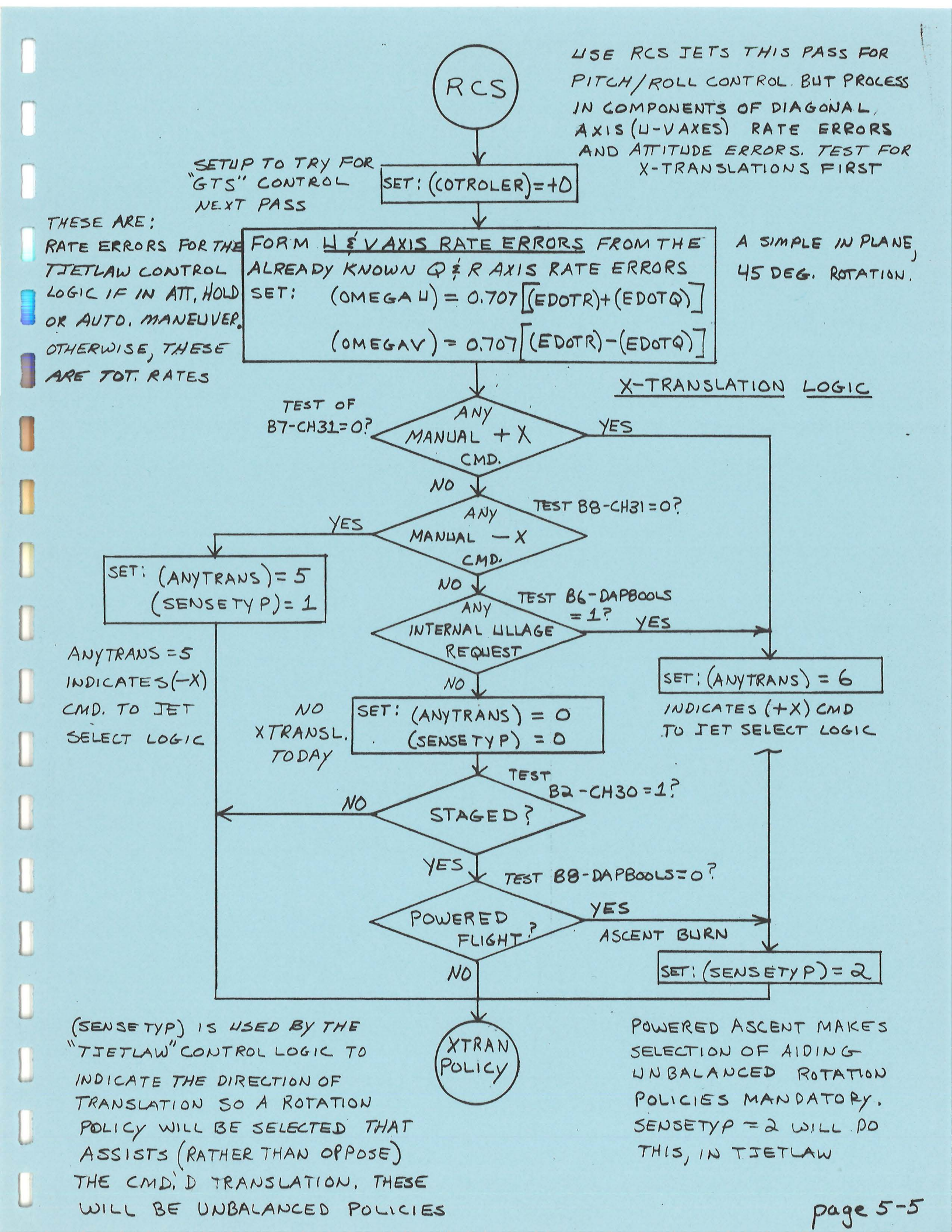
   a) "GTS" is in control
   b) The CSM is docked

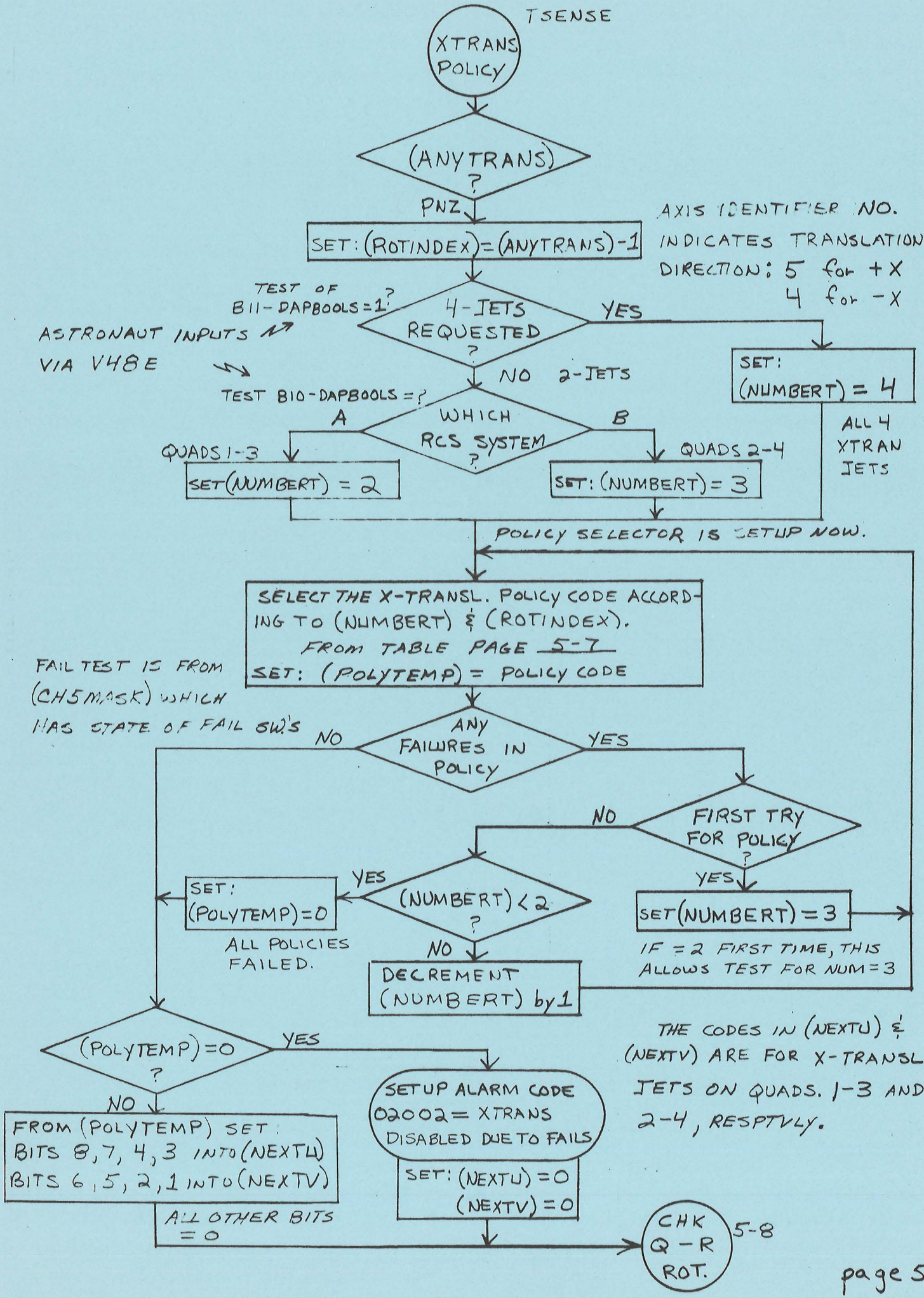
5. Only the DAP (RCS-GTS INTERFACE) can perform the transition from "GTS" use to "TIMEGMBL" use in case "GTS" is disallowed. 1/ACCS calls only if "GTS" is not in use.

NEXT PAGE

RCS - GTS INTERFACE




RCS
USE RCS JETS THIS PASS FOR PITCH/ROLL CONTROL. BUT PROCESS IN COMPONENTS OF DIAGONAL AXIS (U-V AXES) RATE ERRORS AND ATTITUDE ERRORS. TEST FOR X-TRANSLATIONS FIRST
SETUP TO TRY FOR "GTS" CONTROL NEXT PASS
SET: (COTROLER)=+0
THESE ARE: RATE ERRORS FOR THE TJETLAW CONTROL LOGIC IF IN ATT. HOLD OR AUTO. MANEUVER. OTHERWISE, THESE ARE TOT. RATES
FORM U & V AXIS RATE ERRORS FROM THE ALREADY KNOWN Q & R AXIS RATE ERRORS
SET: (OMEGA U) = 0.707 [(EDOTR)+(EDOTQ)]
(OMEGAV) = 0.707 [(EDOTR)-(EDOTQ)]
A SIMPLE IN PLANE, 45 DEG. ROTATION.
X-TRANSLATION LOGIC
TEST OF B7-CH31=0?
ANY MANUAL +X CMD.
YES
NO
TEST B8-CH31=0?
ANY MANUAL -X CMD.
YES
SET: (ANYTRANS)=5
(SENSETYP)=1
NO
TEST B6-DAPBOOLS =1?
ANY INTERNAL ULLAGE REQUEST
YES
SET: (ANYTRANS) = 6
INDICATES (+X) CMD TO JET SELECT LOGIC
ANYTRANS=5 INDICATES (-X) CMD. TO JET SELECT LOGIC
NO
NO XTRANSL. TODAY
SET: (ANYTRANS) = 0
(SENSETYP) = 0
TEST B2-CH30=1?
STAGED?
NO
YES
TEST B8-DAPBOOLS=0?
POWERED FLIGHT?
YES
ASCENT BURN
SET: (SENSETYP)=2
NO
XTRAN POLICY
(SENSETYP) IS USED BY THE "TJETLAW" CONTROL LOGIC TO INDICATE THE DIRECTION OF TRANSLATION SO A ROTATION POLICY WILL BE SELECTED THAT ASSISTS (RATHER THAN OPPOSE) THE CMD'D TRANSLATION. THESE WILL BE UNBALANCED POLICIES
POWERED ASCENT MAKES SELECTION OF AIDING UNBALANCED ROTATION POLICIES MANDATORY. SENSETYP=2 WILL DO THIS, IN TJETLAW


TSENSE
XTRANS POLICY
(ANYTRANS) ?
PNZ
SET: (ROTINDEX) = (ANYTRANS) - 1
AXIS IDENTIFIER NO. INDICATES TRANSLATION DIRECTION: 5 for +X
4 for -X
TEST OF B11-DAPBOOLS = 1?
4-JETS REQUESTED ?
YES
SET: (NUMBERT) = 4
ALL 4 XTRAN JETS
ASTRONAUT INPUTS VIA V48E
NO 2-JETS
TEST B10-DAPBOOLS = ?
WHICH RCS SYSTEM ?
A
B
QUADS 1-3
QUADS 2-4
SET (NUMBERT) = 2
SET: (NUMBERT) = 3
POLICY SELECTOR IS SETUP NOW.
SELECT THE X-TRANSL. POLICY CODE ACCORDING TO (NUMBERT) & (ROTINDEX).
FROM TABLE PAGE 5-7
SET: (POLYTEMP) = POLICY CODE
FAIL TEST IS FROM (CH5MASK) WHICH HAS STATE OF FAIL SW'S
ANY FAILURES IN POLICY
NO
YES
FIRST TRY FOR POLICY ?
NO
YES
SET: (POLYTEMP) = 0
ALL POLICIES FAILED.
YES
(NUMBERT) < 2 ?
NO
SET (NUMBERT) = 3
IF = 2 FIRST TIME, THIS ALLOWS TEST FOR NUM = 3
DECREMENT (NUMBERT) by 1
THE CODES IN (NEXTU) & (NEXTV) ARE FOR X-TRANSL. JETS ON QUADS. 1-3 AND 2-4, RESPTVLY.
(POLYTEMP) = 0 ?
YES
NO
SETUP ALARM CODE 02002 = XTRANS DISABLED DUE TO FAILS
SET: (NEXTU) = 0
(NEXTV) = 0
FROM (POLYTEMP) SET:
BITS 8, 7, 4, 3 INTO (NEXTU)
BITS 6, 5, 2, 1 INTO (NEXTV)
ALL OTHER BITS = 0
CHK Q-R ROT.
5-8

JET POLICY TABLE FOR X-AXIS TRANSLATIONS
(Q, R-AXIS RCS AUTOPILOT)

policy selector no. (NUMBERT)	+X TRANSL (ROTINDEX) = 5	(NEXT U,V) codes	-X TRANSL (ROTINDEX) = 4	(NEXT U,V) codes
4	B1D - B3D A2D - A4D	210 042	A1U - A3U B2U - B4U	104 021
3 (sys B)	B1D - B3D	210 000	B2U - B4U	021 000
2 (sys A)	A2D - A4D	000 042	A1U - A3U	000 104
ALARM - code 02002 setup for astronaut				

NOTE: The numbers in (NEXT U, V) column are the octal codes to fit channel 5 bits. The top codes are (NEXTU), or U - jets for X - transl. and bottom codes are (NEXTV), or V - jets for X - transl. Where zeroes are indicated, CH-5 bits are unchanged when code is entered.

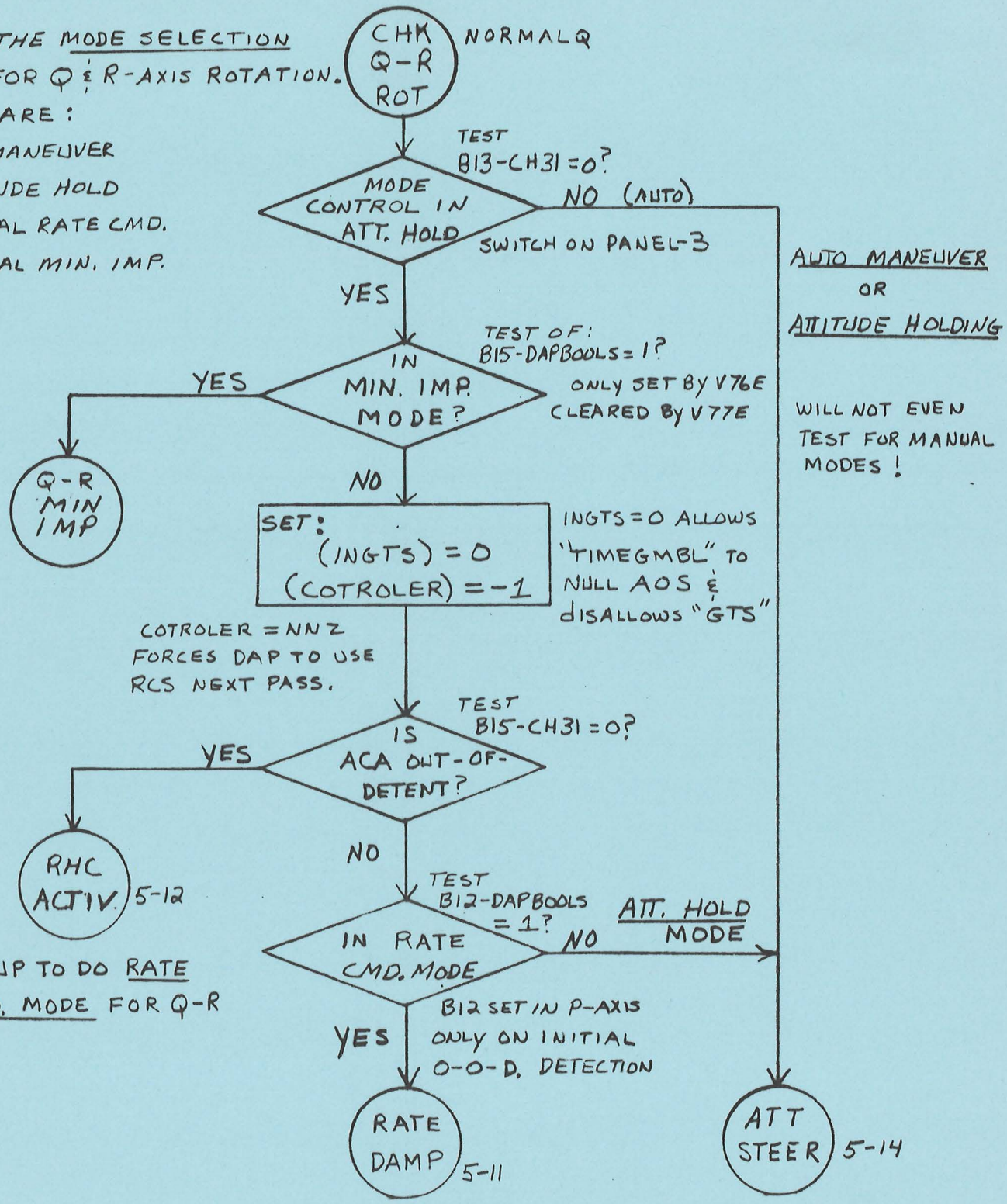
CHANNEL 5 BIT ASSIGNMENTS
(LGC interface controling the VERTICAL JETS)

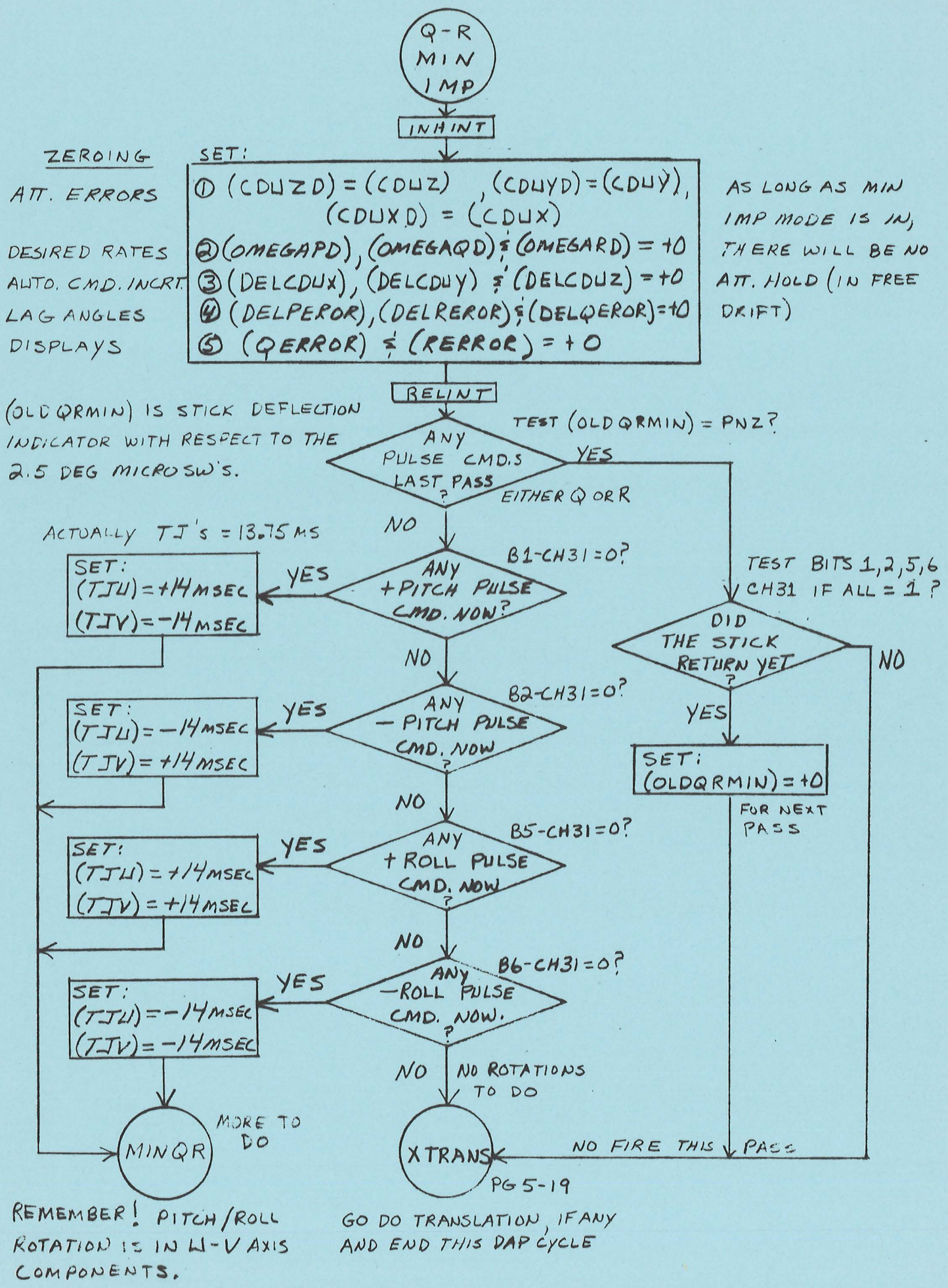
CH5-BIT NO.	8	7	6	5	4	3	2	1
JET IDENTIFIER	B1D	A1U	A2D	B2U	B3D	A3U	A4D	B4U
JET REFERENCE NO.	#14	#13	#10	#9	#6	#5	#2	#1

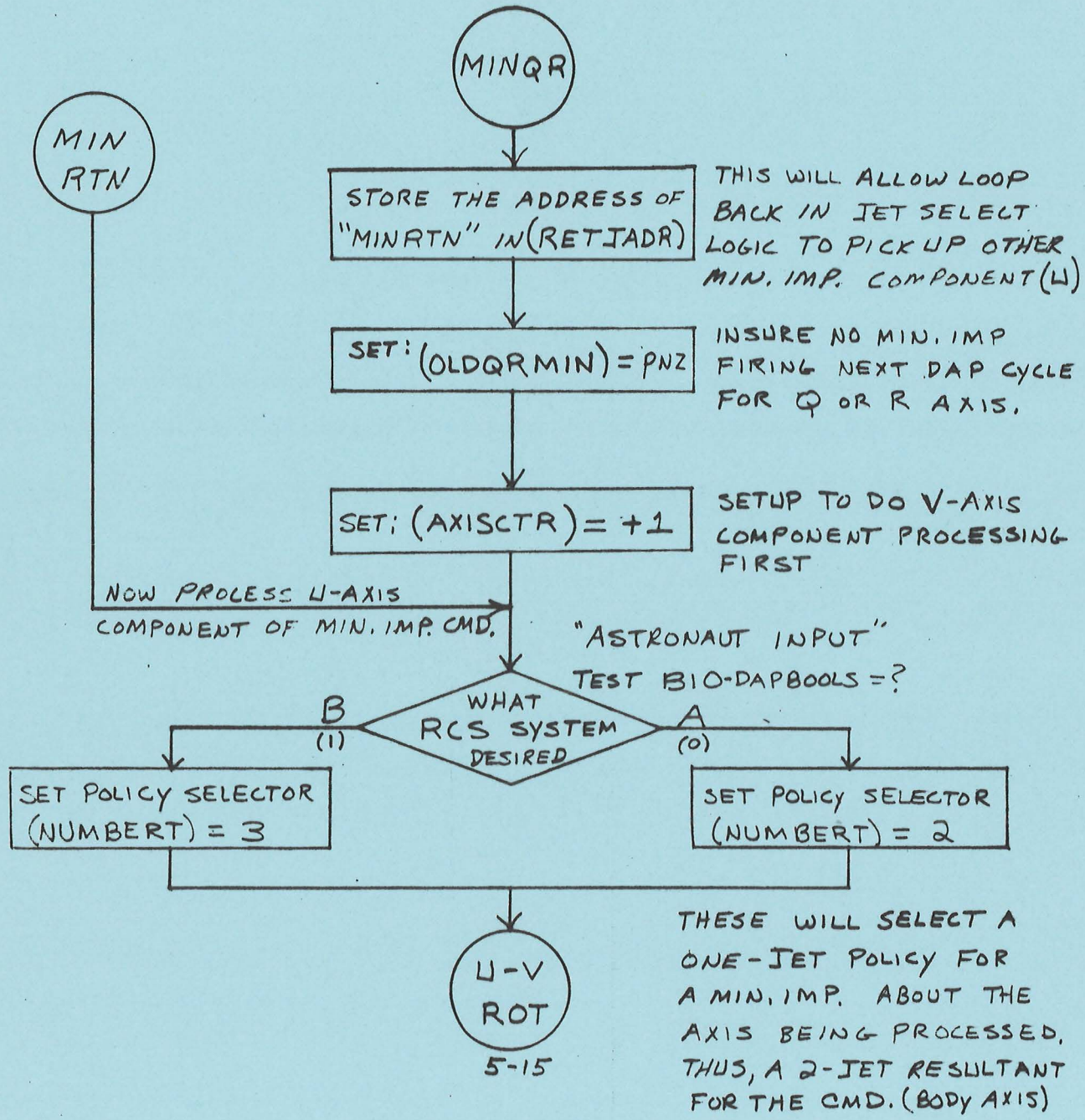
THIS IS THE MODE SELECTION LOGIC FOR Q & R-AXIS ROTATION.

MODES ARE:

1. AUTO MANEUVER
2. ATTITUDE HOLD
3. MANUAL RATE CMD.
4. MANUAL MIN. IMP.




Q-R MIN IMP
INHINT
ZEROING
ATT. ERRORS
DESIRED RATES
AUTO. CMD. INCRT.
LAG ANGLES
DISPLAYS
SET:
① (CDUZD) = (CDUZ), (CDUYD) = (CDUY), (CDUXD) = (CDUX)
② (OMEGAPD), (OMEGAQD) & (OMEGARD) = +0
③ (DELCDUX), (DELCDUY) & (DELCDUZ) = +0
④ (DELPEROR), (DELREROR) & (DELQEROR) = +0
⑤ (QERROR) & (RERROR) = +0
AS LONG AS MIN IMP MODE IS IN, THERE WILL BE NO ATT. HOLD (IN FREE DRIFT)
RELINT
(OLDQRMIN) IS STICK DEFLECTION INDICATOR WITH RESPECT TO THE 2.5 DEG MICROSW'S.
ANY PULSE CMD.S LAST PASS? EITHER Q OR R
TEST (OLDQRMIN) = PNZ?
YES
NO
ACTUALLY TJ's = 13.75 MS
ANY +PITCH PULSE CMD. NOW?
B1-CH31 = 0?
YES
SET: (TJU) = +14 MSEC (TJV) = -14 MSEC
NO
ANY -PITCH PULSE CMD. NOW?
B2-CH31 = 0?
YES
SET: (TJU) = -14 MSEC (TJV) = +14 MSEC
NO
ANY +ROLL PULSE CMD. NOW?
B5-CH31 = 0?
YES
SET: (TJU) = +14 MSEC (TJV) = +14 MSEC
NO
ANY -ROLL PULSE CMD. NOW.?
B6-CH31 = 0?
YES
SET: (TJU) = -14 MSEC (TJV) = -14 MSEC
NO
NO ROTATIONS TO DO
TEST BITS 1,2,5,6 CH31 IF ALL = 1?
DID THE STICK RETURN YET?
NO
YES
SET: (OLDQRMIN) = +0
FOR NEXT PASS
MINQR
MORE TO DO
XTRANS
NO FIRE THIS PASS
PG 5-19
REMEMBER! PITCH/ROLL ROTATION IS IN W-V AXIS COMPONENTS.
GO DO TRANSLATION, IF ANY AND END THIS DAP CYCLE



(AXISCTR) WILL BE USED AS AN INDEXER TO PICK THE PROPER LOCATIONS IN THE FOLLOWING LOGIC FOR THE ROTATION (MIN. IMP.) COMPONENT TO BE PROCESSED: AXISCTR = 1 FOR V-AXIS
= 0 FOR W-AXIS

IT WILL BE SET = 0 LATER WHEN V-AXIS IS PROCESSED.

ENTERED FROM MODE SELECTION LOGIC

RATE DAMP

DBCHECK –

RATE DAMP IS DONE ONLY IF IN THE RATE CMD MODE AND ZERO RATE IS COMMANDED. IN OTHER WORDS, THE ASTRONAUT WAS COMMANDING SOME RATE WITH THE STICK BUT NOW IT IS RETURNED TO IN-DETENT TO DAMP THE RATE (FIRE IN OPPOSITE DIRECTION) CAUSING THE VEHICLE TO STOP ROTATING. THEN ATTITUDE HOLD WILL COMMENCE.

RATEDB = 1.4 or 0.4 DEG/SEC

TESTING P-RATE HERE FORCES DAP TO STAY IN RATE DAMPING UNTIL ALL RATES ARE WITHIN DB. HOWEVER, P-AXIS AUTOPILOT TAKES CARE OF P-RATE DAMPING.

IS (OMEGAP) > RATEDB — YES

NO

IS (OMEGAU) > RATEDB — YES

NO

IS (OMERAV) > RATEDB — YES

NO

"RCS" SETS UP OMEGAU V

SET:
(URATEDIF) = –(OMEGAU)
(VRATEDIF) = –(OMEGAV)

THIS WILL DO IT!

ENTER U V

GET FIRING TIME ACCORDING TO AMT. OF RATE TO DAMP & FIRE

ALL THE RATES ARE WITHIN DB SO GET OUT OF RATE CMD. MODE.

INHINT

SET: B12-DAPBOOLS = 0

ZEROING ATTITUDE ERRORS

"AUTO MANEUVER" DESIRED RATES

CMD. INCREMENTS

LAG ANGLE INCRTS

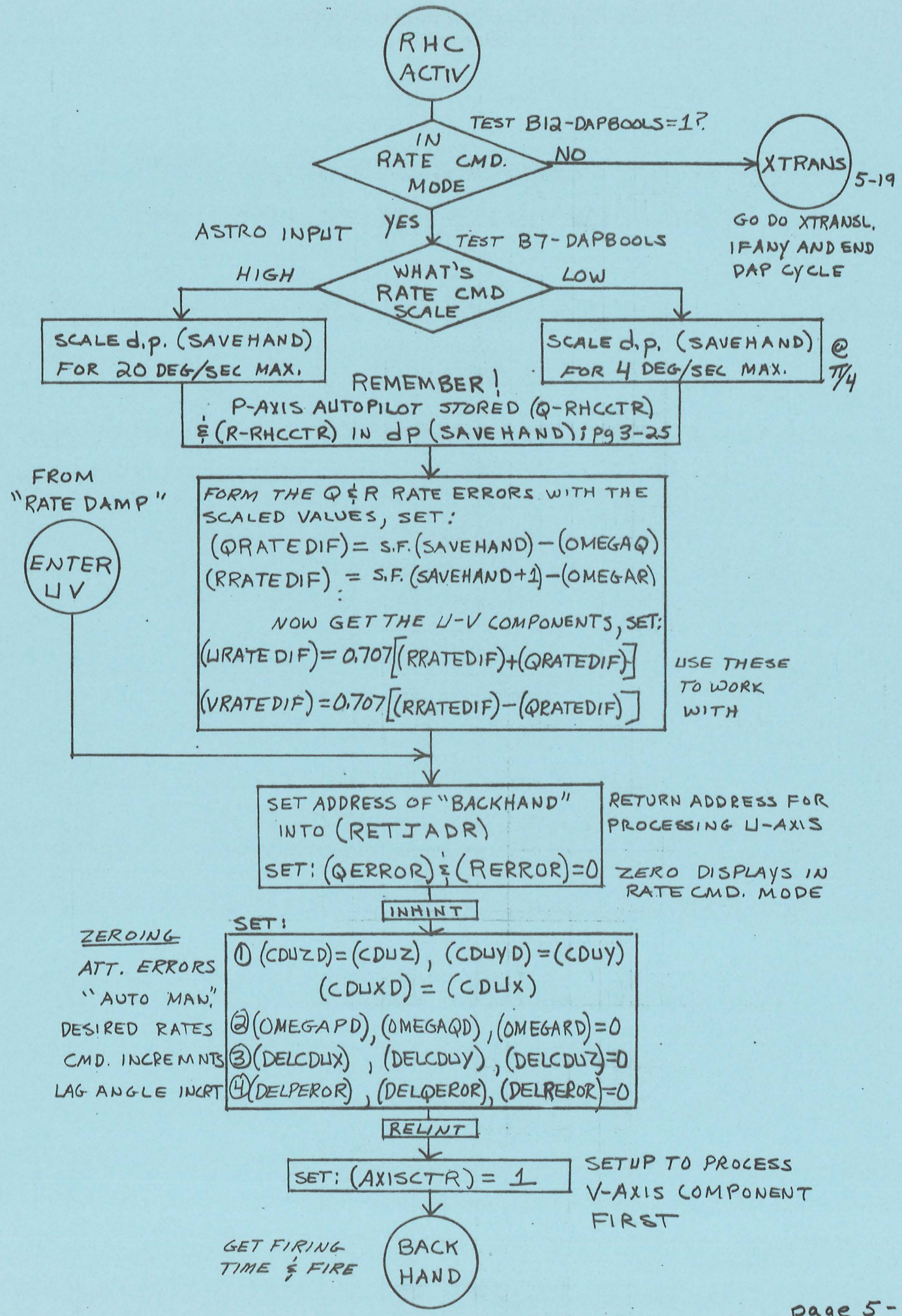
SET:
1. (CDUZD) = (CDUZ), (CDUYD) = (CDUY)
   (CDUXD) = (CDUX)
2. (OMEGAPD), (OMEGAQD), (OMEGARD) = 0
3. (DELCDUX), (DELCDUY), (DELCDUZ) = 0
4. (DELPEROR), (DELQEROR), (DELREROR) = 0

RELINT

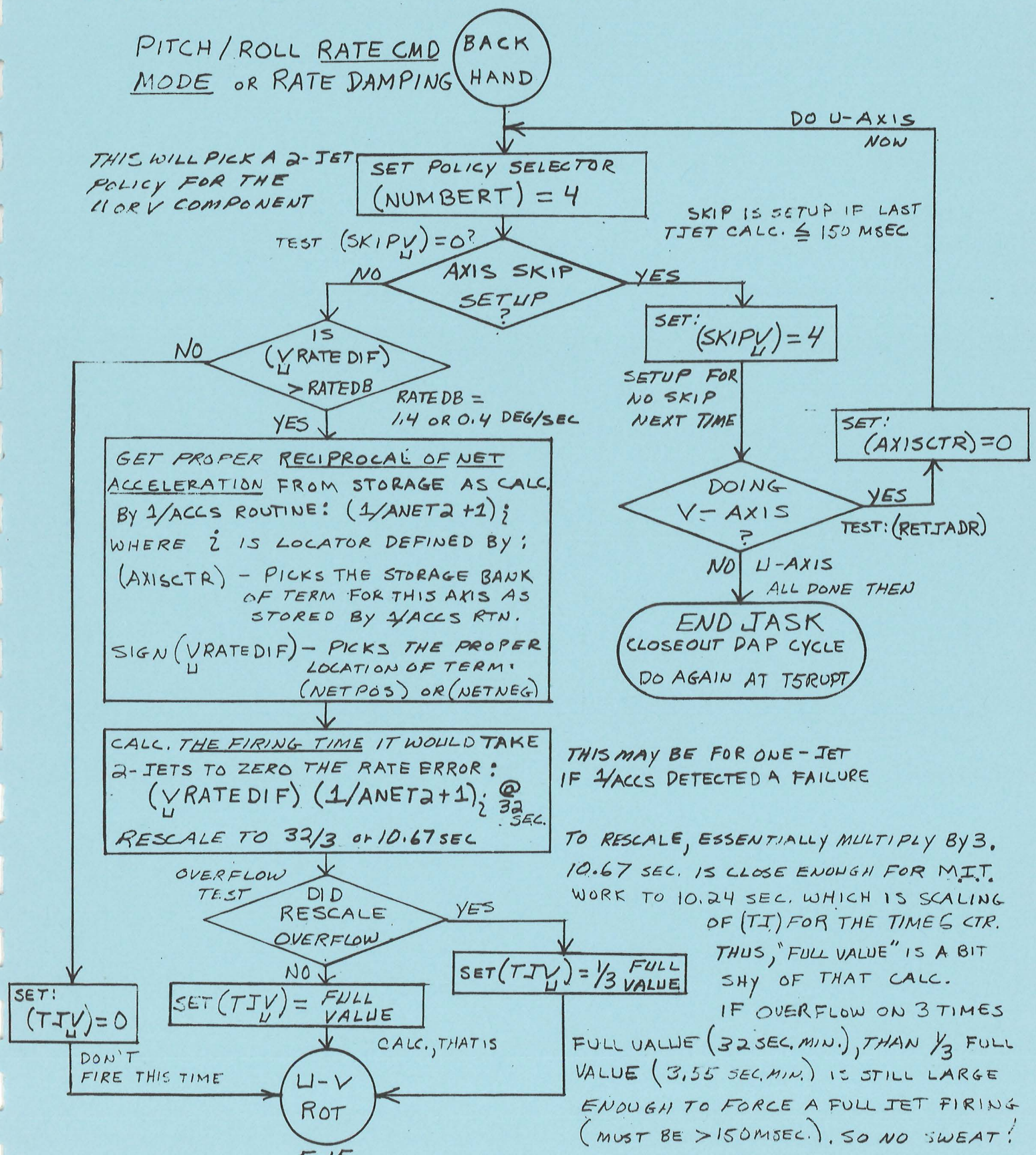
ATT STEER

HOLD ATT. AT THIS ATTITUDE (CDUD'S) NOW

5-14


RHC ACTIV
TEST B12-DAPBOOLS=1?
IN RATE CMD. MODE
NO
XTRANS
5-19
GO DO XTRANSL. IF ANY AND END DAP CYCLE
YES
ASTRO INPUT
TEST B7-DAPBOOLS
WHAT'S RATE CMD SCALE
HIGH
LOW
SCALE d.p. (SAVEHAND) FOR 20 DEG/SEC MAX.
SCALE d.p. (SAVEHAND) FOR 4 DEG/SEC MAX.
@ π/4
REMEMBER!
P-AXIS AUTOPILOT STORED (Q-RHCCTR) & (R-RHCCTR) IN dp (SAVEHAND); pg 3-25
FROM "RATE DAMP"
ENTER UV
FORM THE Q & R RATE ERRORS WITH THE SCALED VALUES, SET:
(QRATEDIF) = S.F. (SAVEHAND) − (OMEGAQ)
(RRATEDIF) = S.F. (SAVEHAND+1) − (OMEGAR)
NOW GET THE U-V COMPONENTS, SET:
(URATEDIF) = 0.707[(RRATEDIF)+(QRATEDIF)]
(VRATEDIF) = 0.707[(RRATEDIF)−(QRATEDIF)]
USE THESE TO WORK WITH
SET ADDRESS OF "BACKHAND" INTO (RETJADR)
RETURN ADDRESS FOR PROCESSING U-AXIS
SET: (QERROR) & (RERROR) = 0
ZERO DISPLAYS IN RATE CMD. MODE
INHINT
SET:
ZEROING
ATT. ERRORS "AUTO MAN."
DESIRED RATES
CMD. INCREMNTS
LAG ANGLE INCRT
① (CDUZD) = (CDUZ), (CDUYD) = (CDUY)
(CDUXD) = (CDUX)
② (OMEGAPD), (OMEGAQD), (OMEGARD) = 0
③ (DELCDUX), (DELCDUY), (DELCDUZ) = 0
④ (DELPERROR), (DELQERROR), (DELRERROR) = 0
RELINT
SET: (AXISCTR) = 1
SETUP TO PROCESS V-AXIS COMPONENT FIRST
GET FIRING TIME & FIRE
BACK HAND

THIS LOGIC WILL BE PROCESSED FOR THE RATE CMD. MODE, ONCE FOR EACH COMPONENT (U OR V). (AXISCTR) IS USED TO IDENTIFY WHICH AXIS AND EQUALS 0 FOR U-AXIS, 1 FOR V-AXIS. ITS USE WILL BE IMPLIED BY USING DOUBLE NEUMONICS FOR DESCRIBING LOCATIONS; SUCH AS: (SKIPV_U) READS (SKIPV) IF AXISCTR = 1 OR (SKIPU) IS AXISCTR = 0.



TO RESCALE, ESSENTIALLY MULTIPLY BY 3. 10.67 SEC. IS CLOSE ENOUGH FOR M.I.T. WORK TO 10.24 SEC. WHICH IS SCALING OF (TJ) FOR THE TIME 6 CTR. THUS, "FULL VALUE" IS A BIT SHY OF THAT CALC. IF OVERFLOW ON 3 TIMES FULL VALUE (32 SEC. MIN.), THAN 1/3 FULL VALUE (3.55 SEC. MIN.) IS STILL LARGE ENOUGH TO FORCE A FULL JET FIRING (MUST BE > 150 MSEC.). SO NO SWEAT!

5-15

AUTO MANEUVER MODE
OR ATTITUDE HOLD MODE

ATT STEER — STILL RCS

FORM THE U AND V COMPONENTS OF THE Q & R ATTITUDE ERRORS, SET:
(UERROR) = 0.707[(RERROR) + (QERROR)]
(VERROR) = 0.707[(RERROR) − (QERROR)]

QERROR & RERROR CALC. EARLIER AT ENTRY OF Q, R AUTO-PILOT

STORE ADDRESS OF "TJLAW+3" IN (RETJADR).
SET: (AXISCTR) = 1

SETUP RETURN TO PROCESS U-AXIS COMPONENT
DO V-AXIS COMPONENT FIRST

THIS LOGIC WILL BE USED FOR THE ABOVE MODES TWICE, ONCE TO PROCESS EACH COMPONENT OF ROTATION (U OR V). AGAIN, (AXISCTR) DEFINE WHICH COMPONENT: 0 FOR U-AXIS, 1 FOR V-AXIS. ITS USE WILL BE IMPLIED BY USING DOUBLE NEUMONICS.

TJLAW +3

TEST U-AXIS SKIP NOW

TEST (SKIPV) = 0?

AXIS SKIP SETUP?

NO

SETUP ATTUDE ERROR & RATE ERROR FOR THE RCS CONTROL LAW LOGIC, SET:
(E) = (VERROR)
(EDOT) = (OMEGAV)

YES

SET: (SKIPV) = 4

SKIP SETUP IF LAST TJET CALC. WAS ≤ 150 MSEC

SET: (AXISCTR) = 0

DOING V-AXIS?

YES

NO — U-AXIS

END TASK
CLOSEOUT DAP CYCLE.
DO AGAIN AT T5RUPT

TEST B13-DAPBOOLS = 1?

IS CSM DOCKED?

NO

GO DO "TJETLAW" RTN pg 4-5. THE RCS CONTROL LAW FOR UN-DOCKED CASE.

RETURN WITH TJET

U-V ROT

YES

CAN ENG. GIMBAL BE USED

NO

TEST B14-DAPBOOLS = 0?

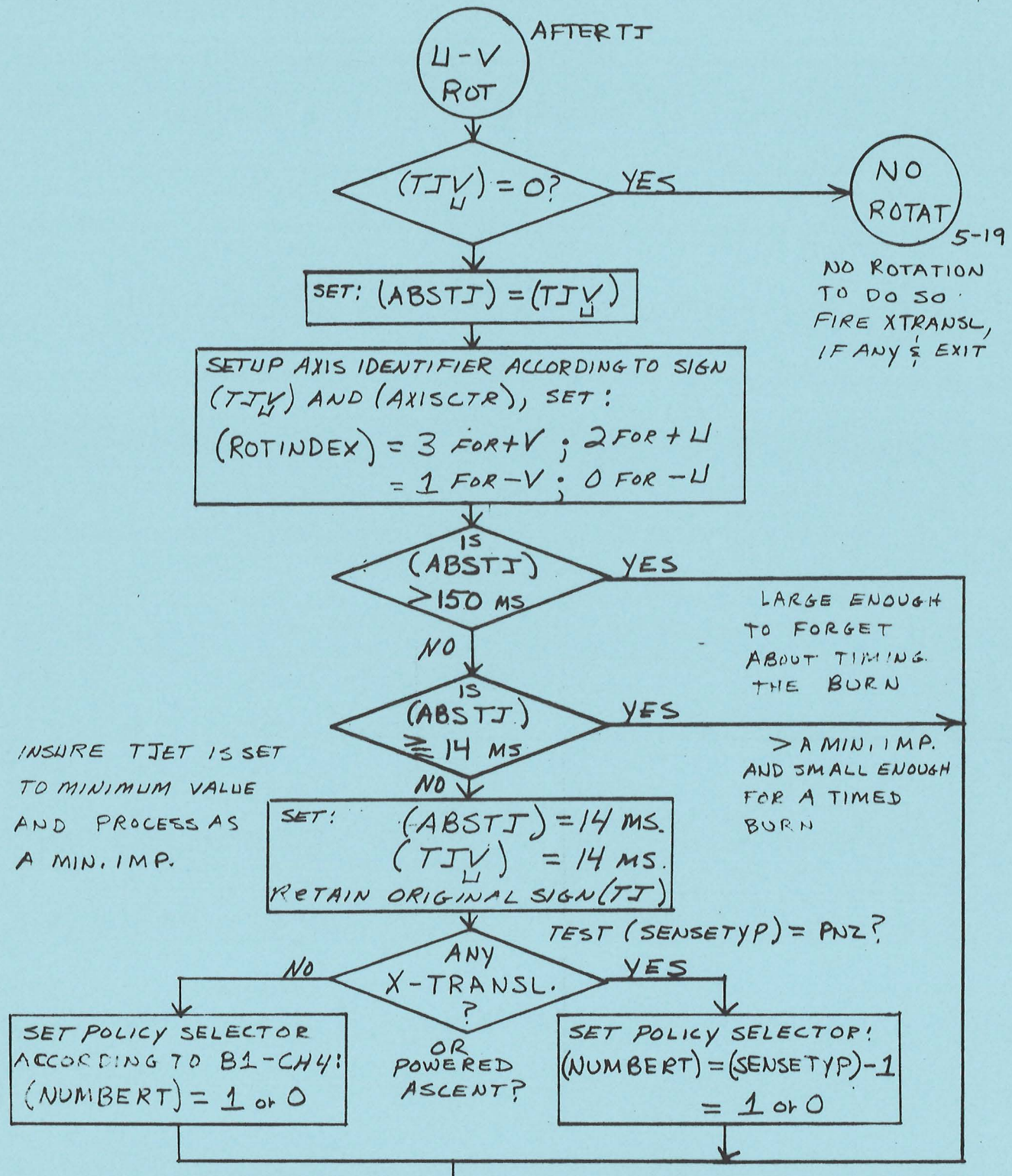
YES

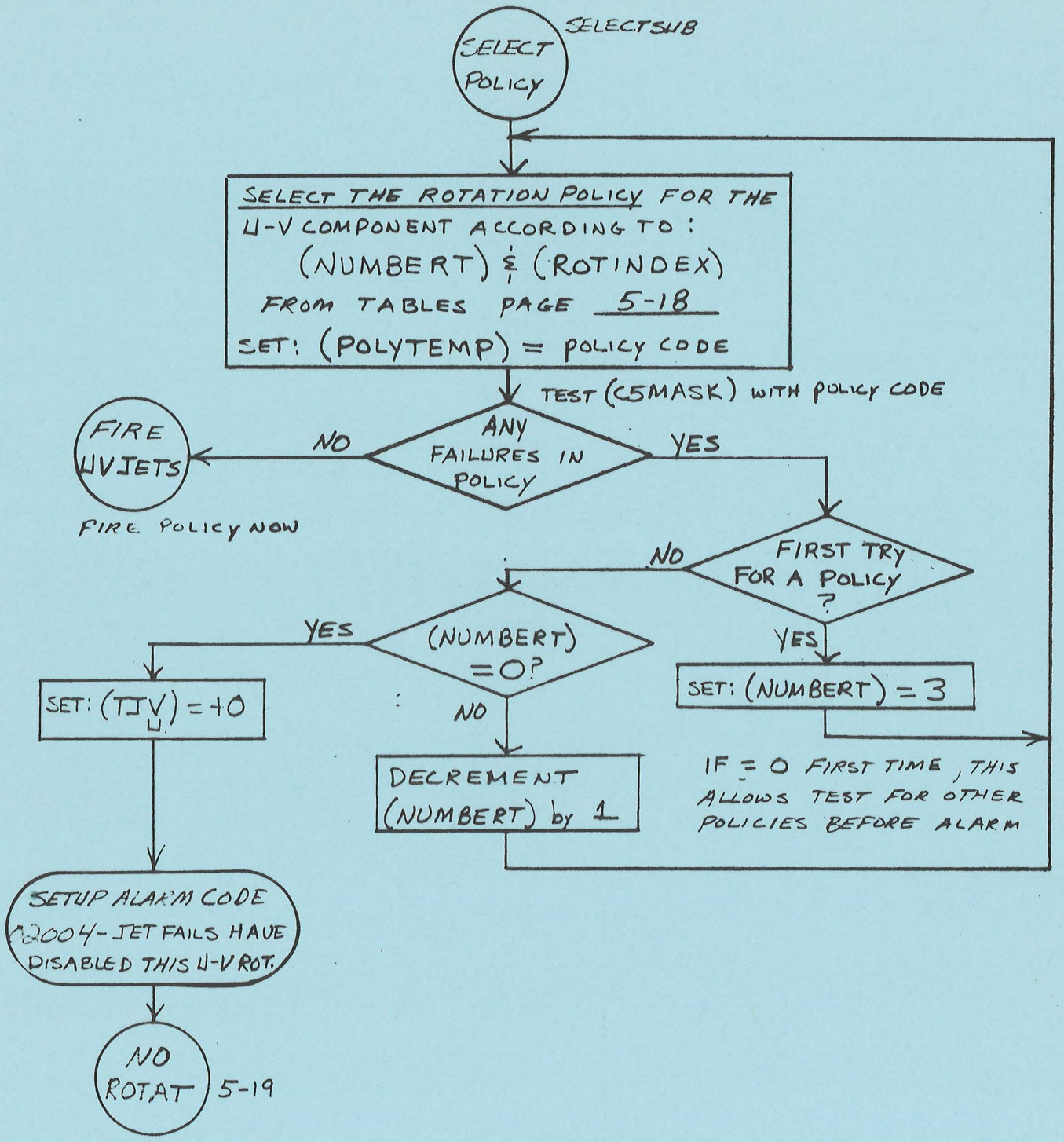
SET: (COTROLER) = PNZ

GO DO "DOCKED RCS" RTN pg 4-31. THE CONTROL LAW FOR DOCKED CASE

PNZ-WHEN DOCKED AND IN POWERED FLIGHT, "GTS" WILL ALWAYS BE USED ALTERNATELY WITH RCS (EVER 200 MSEC)

The processing for U-V rotational components, resulting from all modes, leads to the logic below. At this point, the firing time has been computed by the particular mode in process. Now the logic below will select the jet policy for the appropriate U or V component. Thus, this logic is done once for each component and reference to (AXISCTR) is implied by using double neumonics.

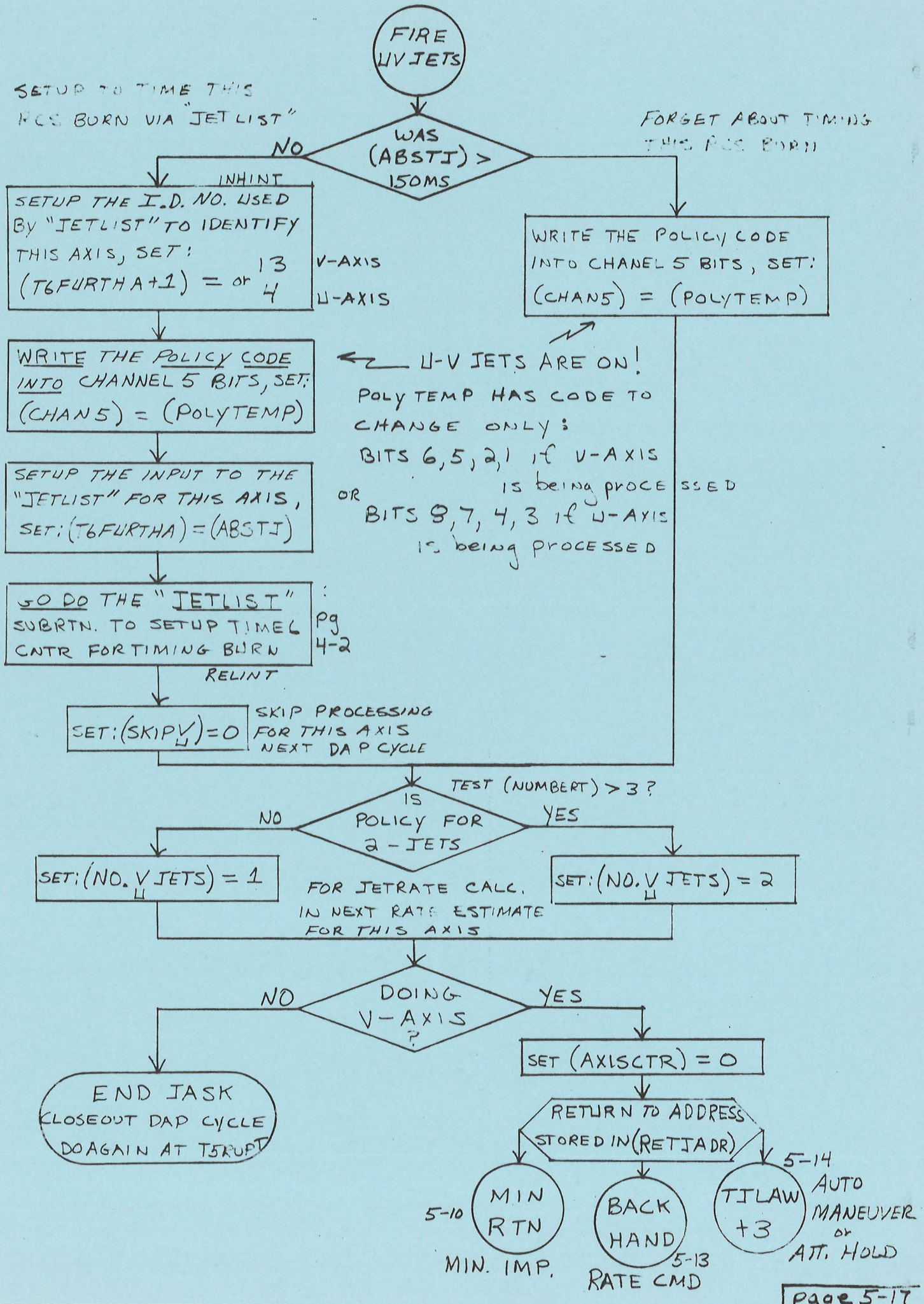




SETUP ALARM CODE
2004 - JET FAILS HAVE DISABLED THIS U-V ROT.

NO ROTAT 5-19

CAN'T DO THE U OR V COMPONENT ROTATION, SO FIRE THE X-TRANSL., IF ANY & EXIT


FIRE UV JETS
SETUP TO TIME THIS RCS BURN VIA "JETLIST"
WAS (ABSTI) > 150MS
NO
FORGET ABOUT TIMING THIS RCS BURN
INHINT
SETUP THE I.D. NO. USED BY "JETLIST" TO IDENTIFY THIS AXIS, SET: (T6FURTHA+1) = 13 or 4
V-AXIS
U-AXIS
WRITE THE POLICY CODE INTO CHANEL 5 BITS, SET: (CHAN5) = (POLYTEMP)
WRITE THE POLICY CODE INTO CHANNEL 5 BITS, SET: (CHAN5) = (POLYTEMP)
U-V JETS ARE ON!
POLY TEMP HAS CODE TO CHANGE ONLY:
BITS 6, 5, 2, 1 if V-AXIS is being processed
OR
BITS 8, 7, 4, 3 if U-AXIS is being processed
SETUP THE INPUT TO THE "JETLIST" FOR THIS AXIS, SET: (T6FURTHA) = (ABSTI)
GO DO THE "JETLIST" SUBRTN. TO SETUP TIMEL CNTR FOR TIMING BURN
pg 4-2
RELINT
SET: (SKIPV) = 0
SKIP PROCESSING FOR THIS AXIS NEXT DAP CYCLE
TEST (NUMBERT) > 3 ?
IS POLICY FOR 2-JETS
NO
YES
SET: (NO. V JETS) = 1
SET: (NO. V JETS) = 2
FOR JETRATE CALC. IN NEXT RATE ESTIMATE FOR THIS AXIS
DOING V-AXIS ?
NO
YES
END JASK
CLOSEOUT DAP CYCLE
DO AGAIN AT T5RUPT
SET (AXISCTR) = 0
RETURN TO ADDRESS STORED IN (RETJADR)
5-10
MIN RTN
MIN. IMP.
BACK HAND
5-13
RATE CMD
TILAW +3
5-14
AUTO MANEUVER or ATT. HOLD

JET POLICY TABLE FOR U-V ROTATION COMPONENTS
(Q, R-AXIS RCS AUTOPILOT)

policy selector no. (NUMBERT)	+V	-V	+U	-U
	(ROTINDEX) = 3	(ROTINDEX) = 1	(ROTINDEX) = 2	(ROTINDEX) = 0
4	B4U - A2D (041)	B2U - A4D (022)	B1D - A3U (204)	B3D - A1U (110)
3	B4U (001)	B2U (020)	B1D (200)	B3D (100)
2	A2D (040)	A4D (002)	A3U (004)	A1U (010)
1	A2D	A4D	B1D	B3D
0	B4U	B2U	A3U	A1U
ALARM - code 02004 setup for astronaut				

Y-AXIS ROTATIONS (PITCH) and Z-AXIS ROTATIONS (ROLL) result from the following U-V policy combinations:

+ROLL = +V and ±U
-ROLL = -V and -U

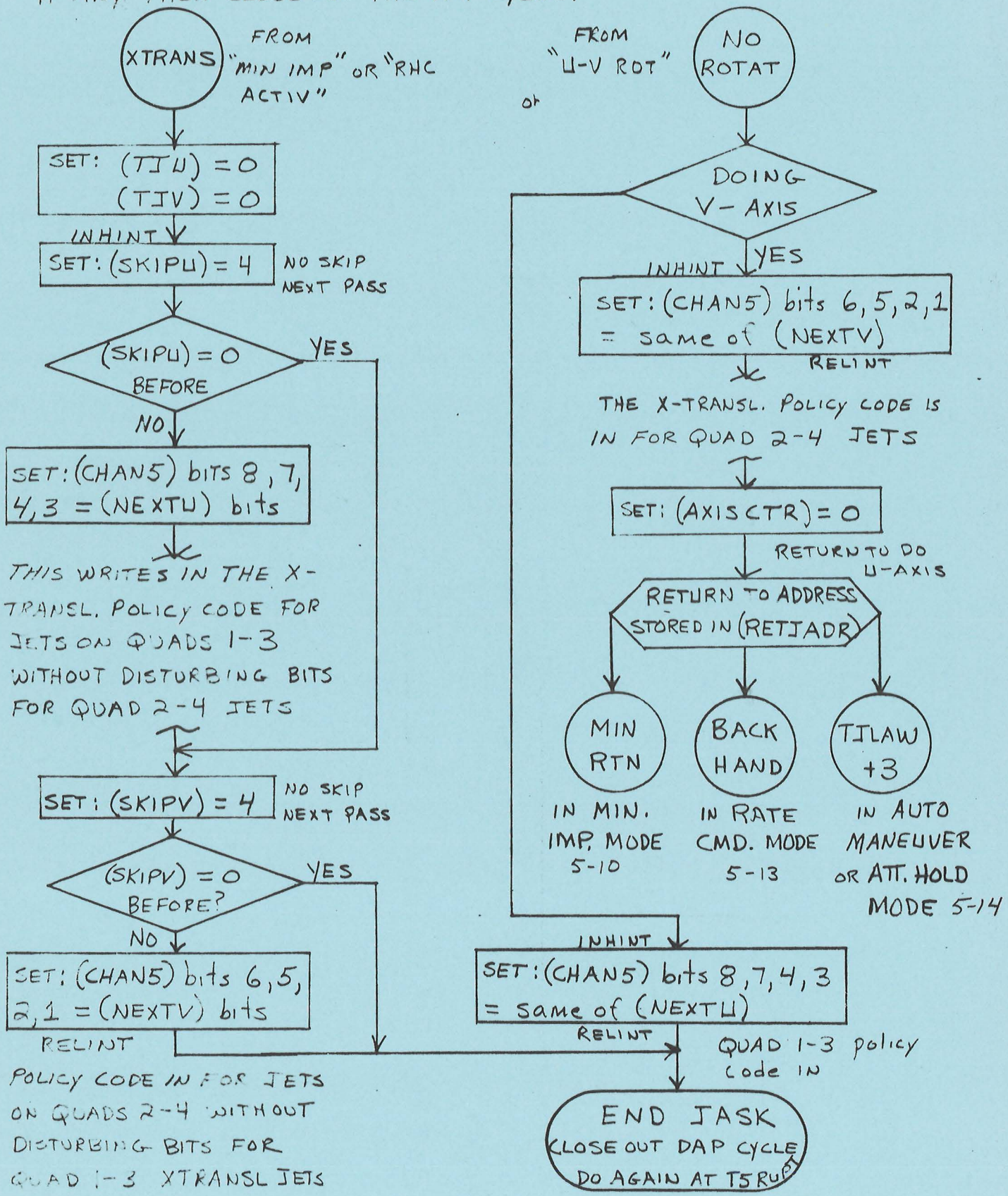
+PITCH = -U and +U
-PITCH = +V and -U

NOTE: The numbers in parenthesis are (POLYTEMP) octal codes to fit channel 5. The zeroes mean no bit change when set in. The 1 - JET policies are repeated in the table due to the kind of selection logic for minimum impulse rotation/ X-translation directional compatability (see page 5-15).

CHANNEL 5 BIT ASSIGNMENTS
(LGC interface controling the VERTICAL RCS JETS)

CH5 BIT NO.	8	7	6	5	4	3	2	1
JET IDENTIFIER	B1D	A1U	A2D	B2U	B3D	A3U	A4D	B4U
JET REFERENCE NO.	#14	#13	#10	#9	#6	#5	#2	#1

THESE ARE THE EXIT ROUTINES FROM THE Q-R RCS CONTROL LOGIC WHEN NO ROTATION IS REQUIRED. THEY WILL FIRE THE X-TRANSL. POLICY, IF ANY THEN CLOSE OUT THE DAP CYCLE.



SECTION VI

Q, R-AXIS AUTOPILOT
(Trim Control Logic Description)

GTS IS THE SUBRTN. USED AS THE GIMBAL TRIM ATTITUDE CONTROL MODE BY THE LM DAP. IT IS USED WHEN CERTAIN POWERED FLIGHT CONDITIONS DETERMINE THAT ENGINE TRIMMING CAN CONTROL THE ATTITUDE ERRORS AND RATES, AS WELL AS ANY EXISTING ANGULAR ACCELERATIONS, ABOUT THE PITCH (Q) AND ROLL (R) AXES. GTS COMPUTES THE ATTITUDE CONTROL LAW AND SETS THE GIMBAL TRIM ACCORDING TO — SIGN OF THE DRIVE FUNCTION. THE DRIVE FUNCTION BEING OF THE FORM:

$$K^2\theta + \Delta\sqrt{2}\left(K\omega\Delta + \frac{\alpha^2}{2}\right)^{3/2} + \alpha\left(\frac{\alpha^2}{3} + K\omega\Delta\right)$$

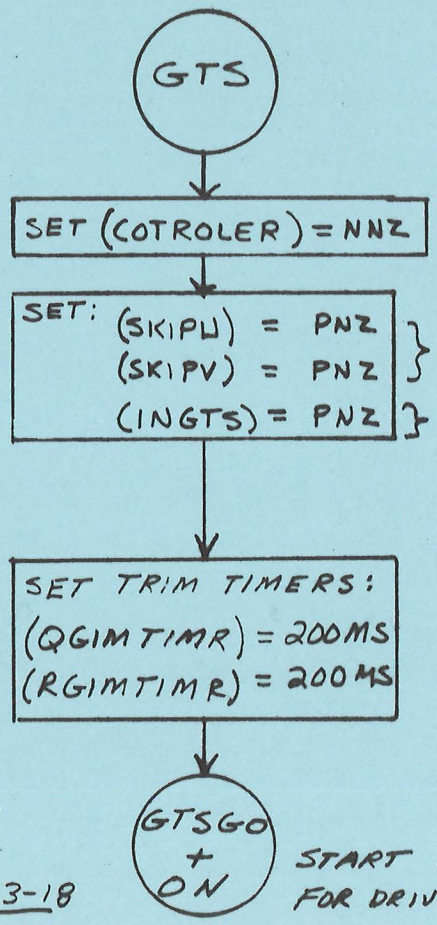
where: $K = 0.3\,\frac{FL\dot{\tau}}{I}$ or THE "GAINED" JERK MAGNITUDES AS DEFINED IN VACCJOB. 0.3 is USED FOR A GAIN REDUCTION FACTOR

$$\Delta = \text{SIGN}\left(K\alpha + \frac{\alpha|\alpha|}{2}\right)$$

θ, ω, α = ATT. ERROR & FIRST & SECOND DERIVATIVES

THUS,

TRIM = — SIGN (DRIVE FUNCTION)



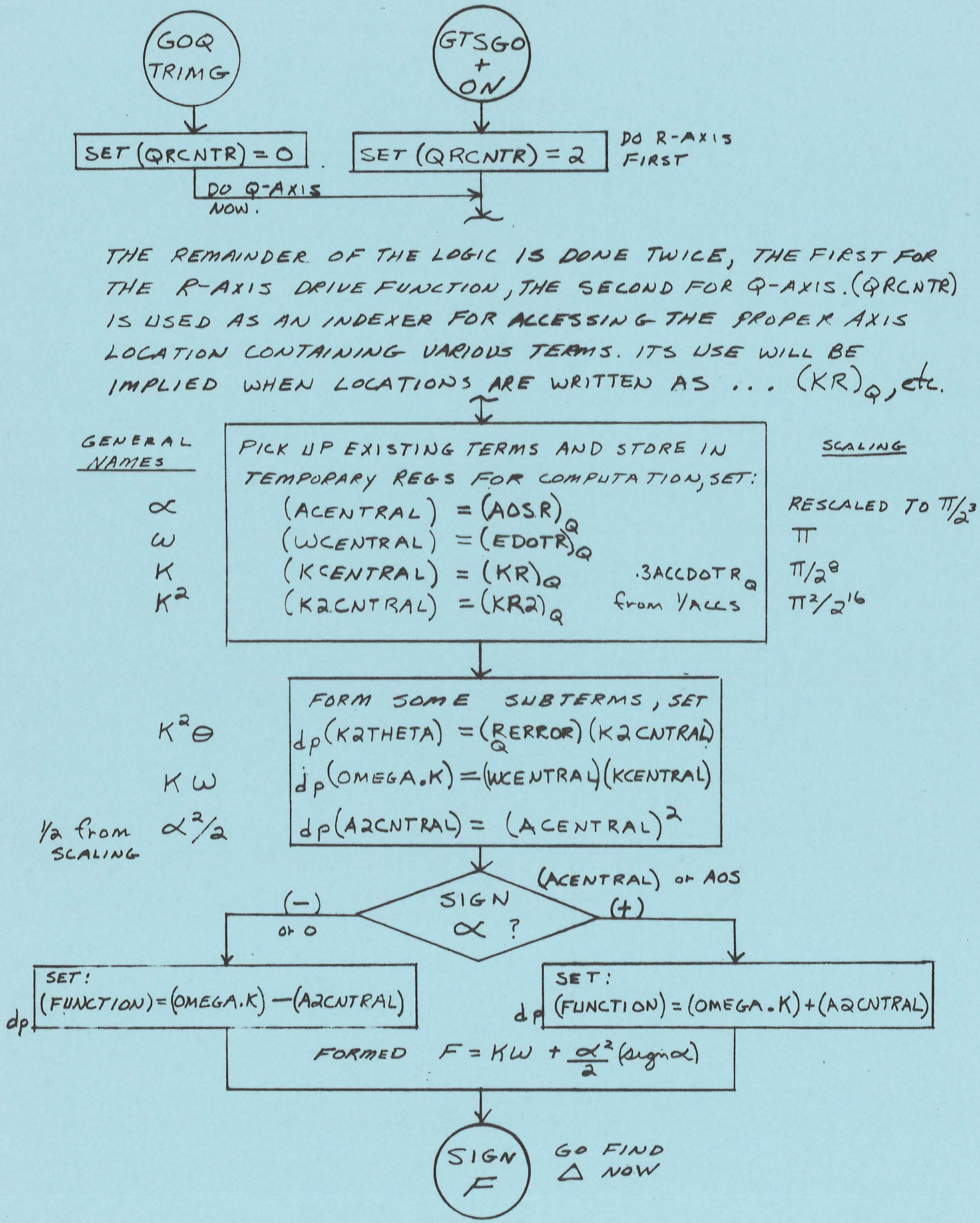
SETUP TO USE JETS ON NEXT PASS (RCS CONTROL SYS)

INSURE NO SKIP FOR U-V RCS CONTROL

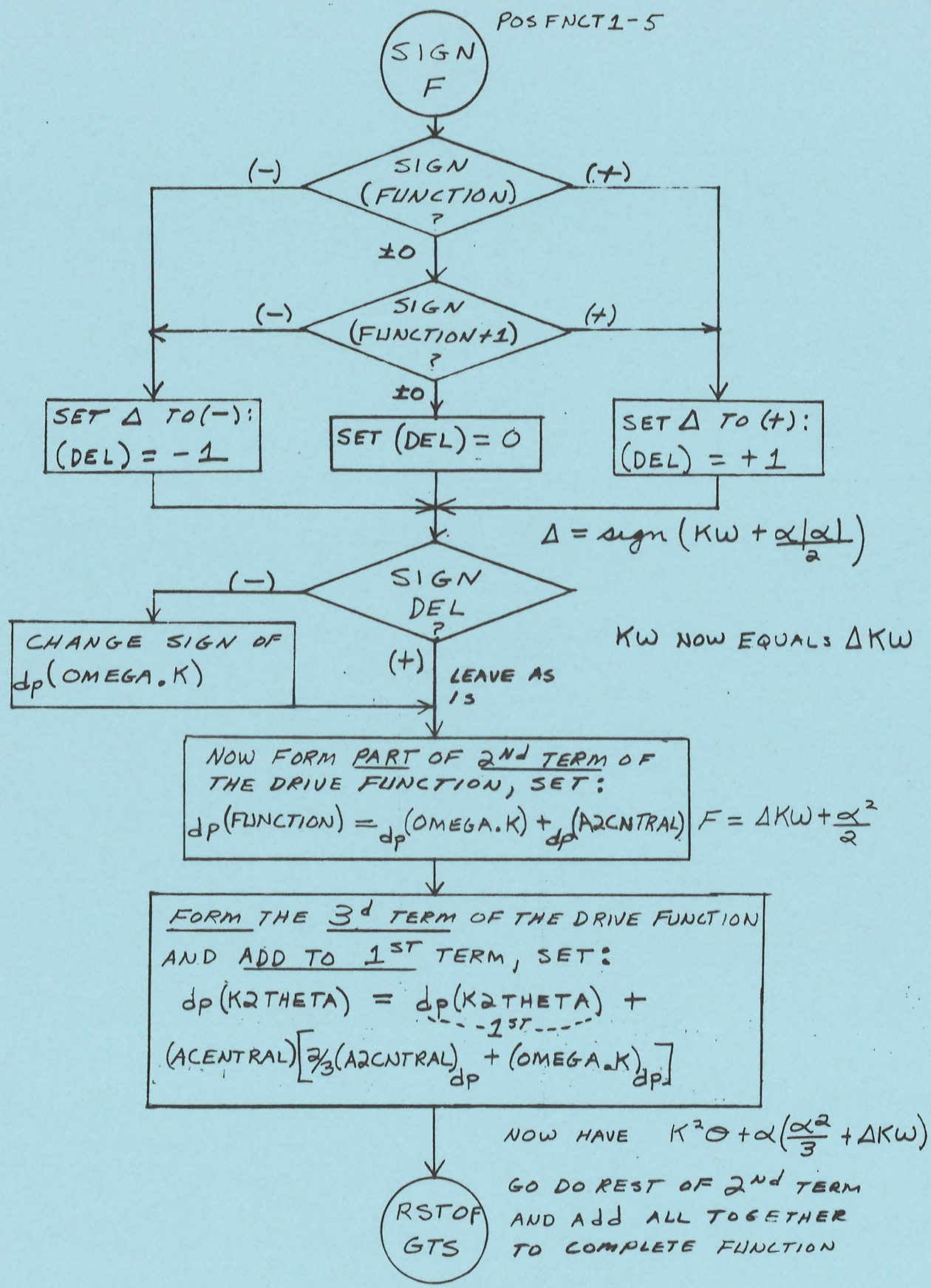
TO INDICATE - IN GTS ATT. CONTROL MODE (ONLY PLACE SET PNZ)

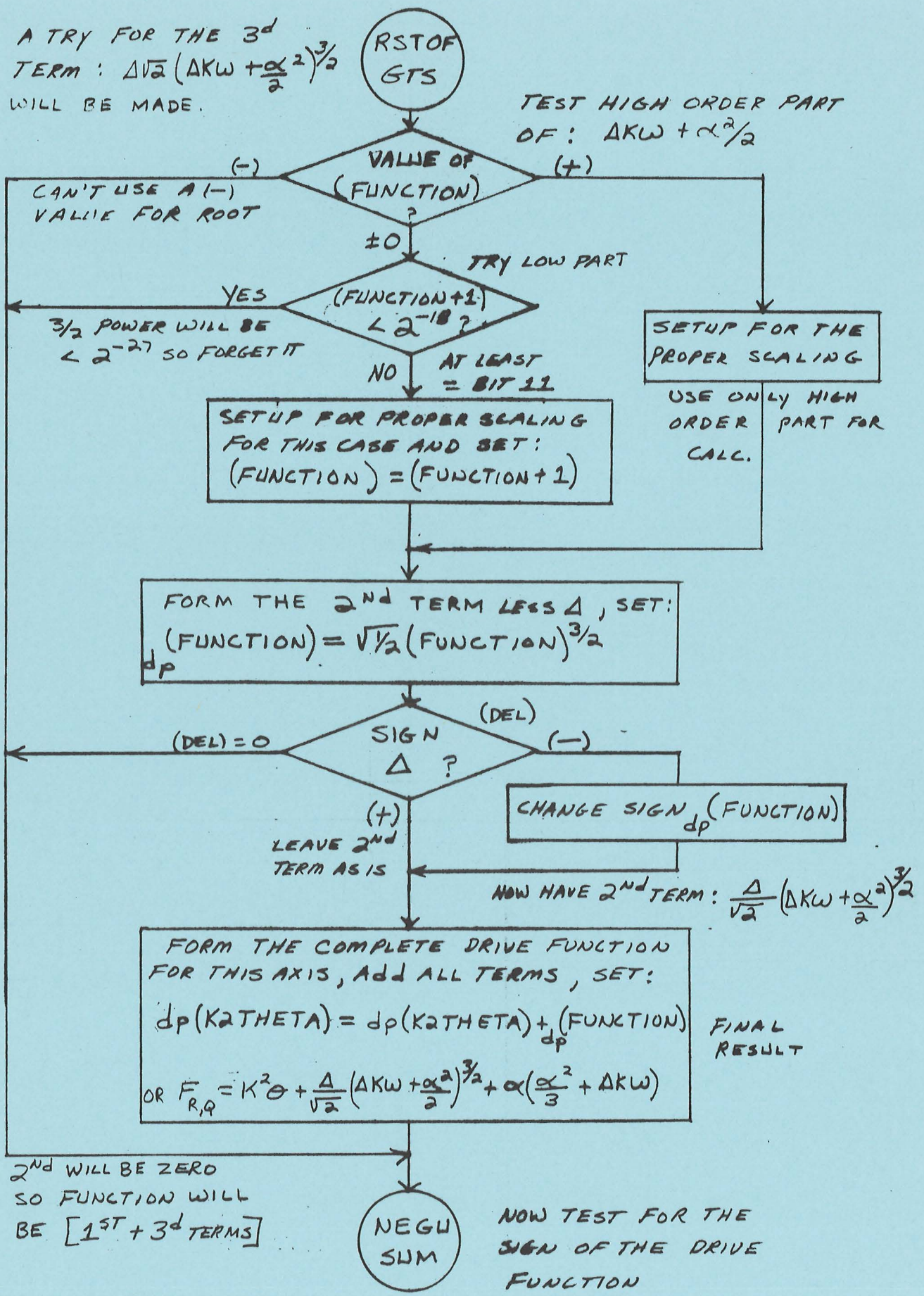
TIMERS ARE USED TO CONTROL GIMBAL TRIM. THEY ARE SET HERE TO PREVENT UNCONTROLLED TRIM IN CASE USE OF GTS IS DISALLOWED. WHEN ZERO, THE TRIM WILL BE STOPPED, SEE P-AXIS AUTOPILOT PG 3-18

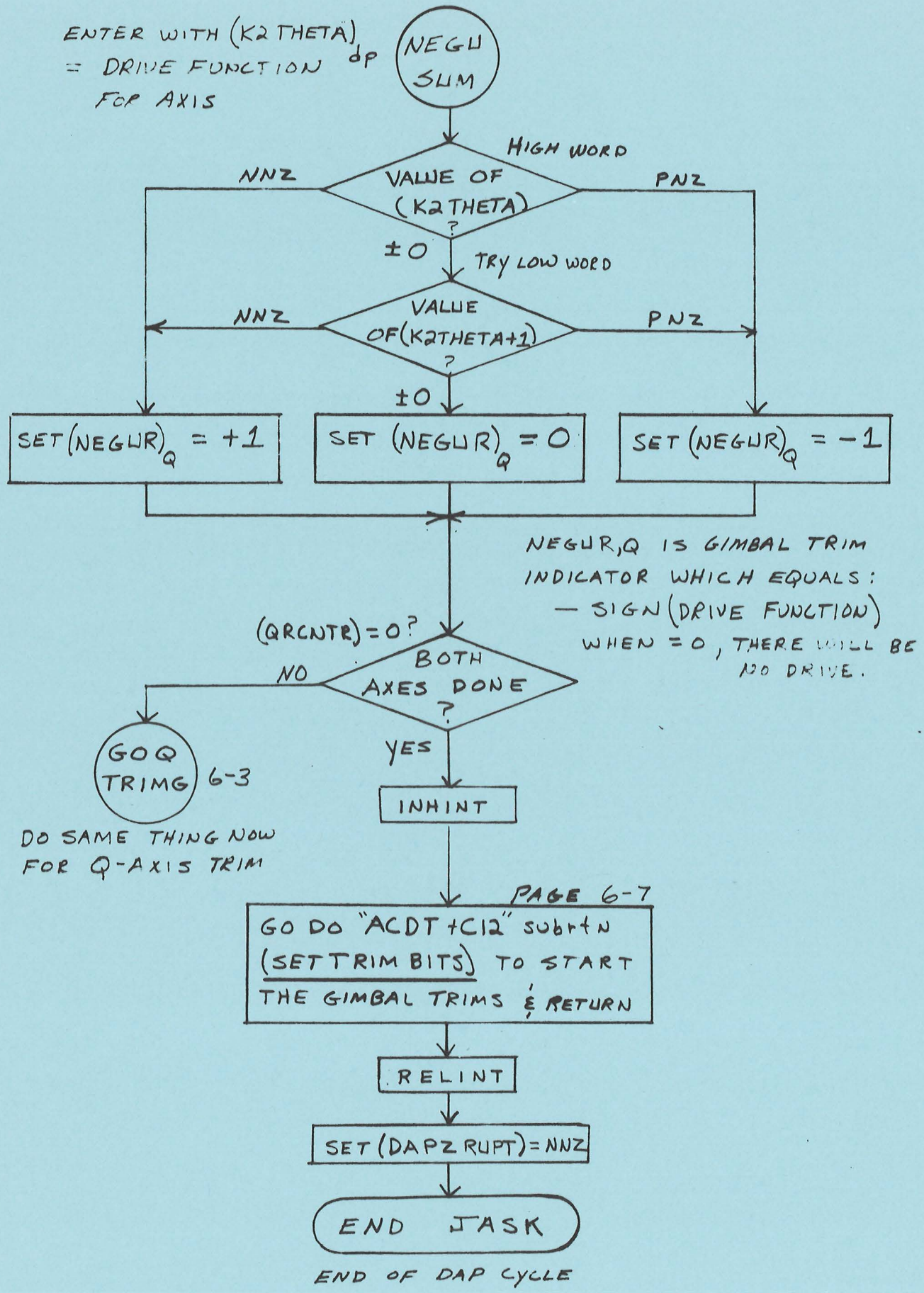
START INITIALIZATION FOR DRIVE FUNCTION CALC.


GOQ TRIMG
GTSGO + ON
SET (QRCNTR) = 0
SET (QRCNTR) = 2
DO R-AXIS FIRST
DO Q-AXIS NOW.
THE REMAINDER OF THE LOGIC IS DONE TWICE, THE FIRST FOR THE R-AXIS DRIVE FUNCTION, THE SECOND FOR Q-AXIS. (QRCNTR) IS USED AS AN INDEXER FOR ACCESSING THE PROPER AXIS LOCATION CONTAINING VARIOUS TERMS. ITS USE WILL BE IMPLIED WHEN LOCATIONS ARE WRITTEN AS ... (KR)Q, etc.
GENERAL NAMES
SCALING
PICK UP EXISTING TERMS AND STORE IN TEMPORARY REGS FOR COMPUTATION, SET:
α (ACENTRAL) = (AOS.R)Q RESCALED TO π/2^3
ω (WCENTRAL) = (EDOTR)Q π
K (KCENTRAL) = (KR)Q .3ACCDOTRQ π/2^8
K² (K2CNTRAL) = (KR2)Q from 1/ACCS π²/2^16
FORM SOME SUBTERMS, SET
K²θ dp(K2THETA) = (RERROR)Q (K2CNTRAL)
Kω dp(OMEGA.K) = (WCENTRAL)(KCENTRAL)
1/2 from SCALING α²/2 dp(A2CNTRAL) = (ACENTRAL)²
SIGN α ?
(ACENTRAL) or AOS
(−) or 0
(+)
SET: (FUNCTION) = (OMEGA.K) − (A2CNTRAL)
dp
SET: (FUNCTION) = (OMEGA.K) + (A2CNTRAL)
dp
FORMED F = Kω + α²/2 (sign α)
SIGN F
GO FIND Δ NOW

POS FNCT 1-5


SIGN F
SIGN (FUNCTION) ?
(−)
(+)
±0
SIGN (FUNCTION+1) ?
(−)
(+)
±0
SET Δ TO (−): (DEL) = −1
SET (DEL) = 0
SET Δ TO (+): (DEL) = +1
Δ = sign (Kω + α|α|/2)
SIGN DEL ?
(−)
(+)
CHANGE SIGN OF dp(OMEGA.K)
LEAVE AS IS
Kω NOW EQUALS ΔKω
NOW FORM PART OF 2ND TERM OF THE DRIVE FUNCTION, SET:
dp(FUNCTION) = dp(OMEGA.K) + dp(A2CNTRAL)
F = ΔKω + α²/2
FORM THE 3d TERM OF THE DRIVE FUNCTION AND ADD TO 1ST TERM, SET:
dp(K2THETA) = dp(K2THETA) + (ACENTRAL)[2/3(A2CNTRAL)dp + (OMEGA.K)dp]
1ST
NOW HAVE K²θ + α(α²/3 + ΔKω)
RSTOF GTS
GO DO REST OF 2ND TERM AND ADD ALL TOGETHER TO COMPLETE FUNCTION


A TRY FOR THE 3d TERM : $\Delta\sqrt{2}\left(\Delta K\omega + \frac{\alpha^2}{2}\right)^{3/2}$ WILL BE MADE.
RSTOF GTS
TEST HIGH ORDER PART OF : $\Delta K\omega + \alpha^2/2$
VALUE OF (FUNCTION) ?
(-)
(+)
CAN'T USE A (-) VALUE FOR ROOT
±0
TRY LOW PART
(FUNCTION+1) < 2^{-18} ?
YES
3/2 POWER WILL BE < 2^{-27} SO FORGET IT
NO
AT LEAST = BIT 11
SETUP FOR THE PROPER SCALING
USE ONLY HIGH ORDER PART FOR CALC.
SETUP FOR PROPER SCALING FOR THIS CASE AND SET: (FUNCTION) = (FUNCTION + 1)
FORM THE 2nd TERM LESS Δ, SET: $(\text{FUNCTION})_{dp} = \sqrt{1/2}\,(\text{FUNCTION})^{3/2}$
SIGN Δ ?
(DEL)
(DEL) = 0
(-)
CHANGE SIGN$_{dp}$(FUNCTION)
(+)
LEAVE 2nd TERM AS IS
NOW HAVE 2nd TERM : $\frac{\Delta}{\sqrt{2}}\left(\Delta K\omega + \frac{\alpha^2}{2}\right)^{3/2}$
FORM THE COMPLETE DRIVE FUNCTION FOR THIS AXIS, ADD ALL TERMS, SET:
$dp(K2THETA) = dp(K2THETA) +_{dp} (\text{FUNCTION})$
OR $F_{R,Q} = K^2\theta + \frac{\Delta}{\sqrt{2}}\left(\Delta K\omega + \frac{\alpha^2}{2}\right)^{3/2} + \alpha\left(\frac{\alpha^2}{3} + \Delta K\omega\right)$
FINAL RESULT
2nd WILL BE ZERO SO FUNCTION WILL BE [1st + 3d TERMS]
NEGU SUM
NOW TEST FOR THE SIGN OF THE DRIVE FUNCTION


ENTER WITH (K2THETA) dp = DRIVE FUNCTION FOR AXIS
NEGU SUM
HIGH WORD
VALUE OF (K2THETA) ?
NNZ
PNZ
±0
TRY LOW WORD
VALUE OF(K2THETA+1) ?
NNZ
PNZ
±0
SET (NEGUR)Q = +1
SET (NEGUR)Q = 0
SET (NEGUR)Q = -1
NEGUR,Q IS GIMBAL TRIM INDICATOR WHICH EQUALS: — SIGN (DRIVE FUNCTION) WHEN = 0, THERE WILL BE NO DRIVE.
(QRCNTR) = 0?
BOTH AXES DONE ?
NO
YES
GO Q TRIMG
6-3
DO SAME THING NOW FOR Q-AXIS TRIM
INHINT
PAGE 6-7
GO DO "ACDT+C12" subrtn (SETTRIM BITS) TO START THE GIMBAL TRIMS & RETURN
RELINT
SET (DAPZRUPT) = NNZ
END TASK
END OF DAP CYCLE

CALLED BY
GTS OR TIMEGMBL

SET TRIM BITS

ACDT + C12

CAN ENG. GIMBAL BE USED ?

B14 - DAPBOOLS = 0?

NO

DISALLOW ANY TRIMMING

SET TRIM INDICATORS TO ZERO: (NEGUQ) & (NEGUR) = 0

YES

UPDATE THE "SIGNED" JERK TERMS TO REFLECT THE NEW TRIM REQUESTS, SET:

(QACCDOT) = −(NEGUQ)(ACCDOTQ)

(RACCDOT) = −(NEGUR)(ACCDOTR)

ACCDOT = JERK MAGNITUDES AS CALC. IN 1/ACCS

PITCH TRIM INDICATOR

(NEGUQ) = ?

(−)

+ VEHICLE PITCH

SET B9 (CHNL12) FOR A −Q GIMBAL TRIM

±0

SET (CHNL12) = 0 FOR NO TRIM

(+)

− VEHICLE PITCH

SET B10 (CHNL12) FOR A +Q GIMBAL TRIM

THE LOCATION (CHNL12) IS A TEMPORARY STORAGE REG AND NOT OUTPUT CH-12. ALSO, FOR BOTH PITCH & ROLL TRIM, A (+) GIMBAL TRIM MEANS THE ENGINE WILL GIMBAL POSITIVE ABOUT THE SPECIFIED AXIS RESULTING IN A (−) ACCEL. OR VEHICLE ROTATION. VISA-VERSA FOR (−) GIMBAL TRIM.

(NEGUR) = ?

ROLL TRIM IND.

(−)

+ VEHICLE ROLL

SET B11 (CHNL12) FOR A −R TRIM

±0

SET (CHNL12) = 0 FOR NO TRIM

(+)

− VEHICLE ROLL

SET B12 (CHNL12) FOR A +R TRIM

CLEAR BITS 9-12 OF OUTPUT CH-12

WRITE BITS 9-12 OF (CHNL12) INTO CH-12

GIMBAL TRIMS ARE TURNED ON! (OR OFF)

RETURN TO CALLER

TIMEGMBL IS THE SUBRTN. USED FOR THE OFFSET <u>ACCELERATION NULLING MODE</u> BY THE LM DAP OR BY THE YACCS ROUTINE WHICH IS CALLED EVERY 2 SECONDS DURING POWERED FLIGHT. TIMEGMBL IS PERFORMED WHENEVER THE LM DAP HAS DETERMINED THERE IS AN ACCELERATION OFFSET (AOS) AND HAS DISALLOWED USE OF THE GTS SUBRTN. TO NULL THE OFFSET. TIMEGMBL COMPUTES A <u>TRIM TIME</u> FOR POSITIONING THE ENGINE BELL SO AS TO NULL THE AOS THAT WOULD BE ABOUT THE PITCH AND/OR ROLL AXES. THE TRIM TIME COMPUTATION IS OF THE FORM:

$$T = 0.4 \left| \frac{\ddot{\theta}}{FL\dot{\gamma}/I} \right| = \frac{\text{ACCEL}}{\text{JERK}}$$

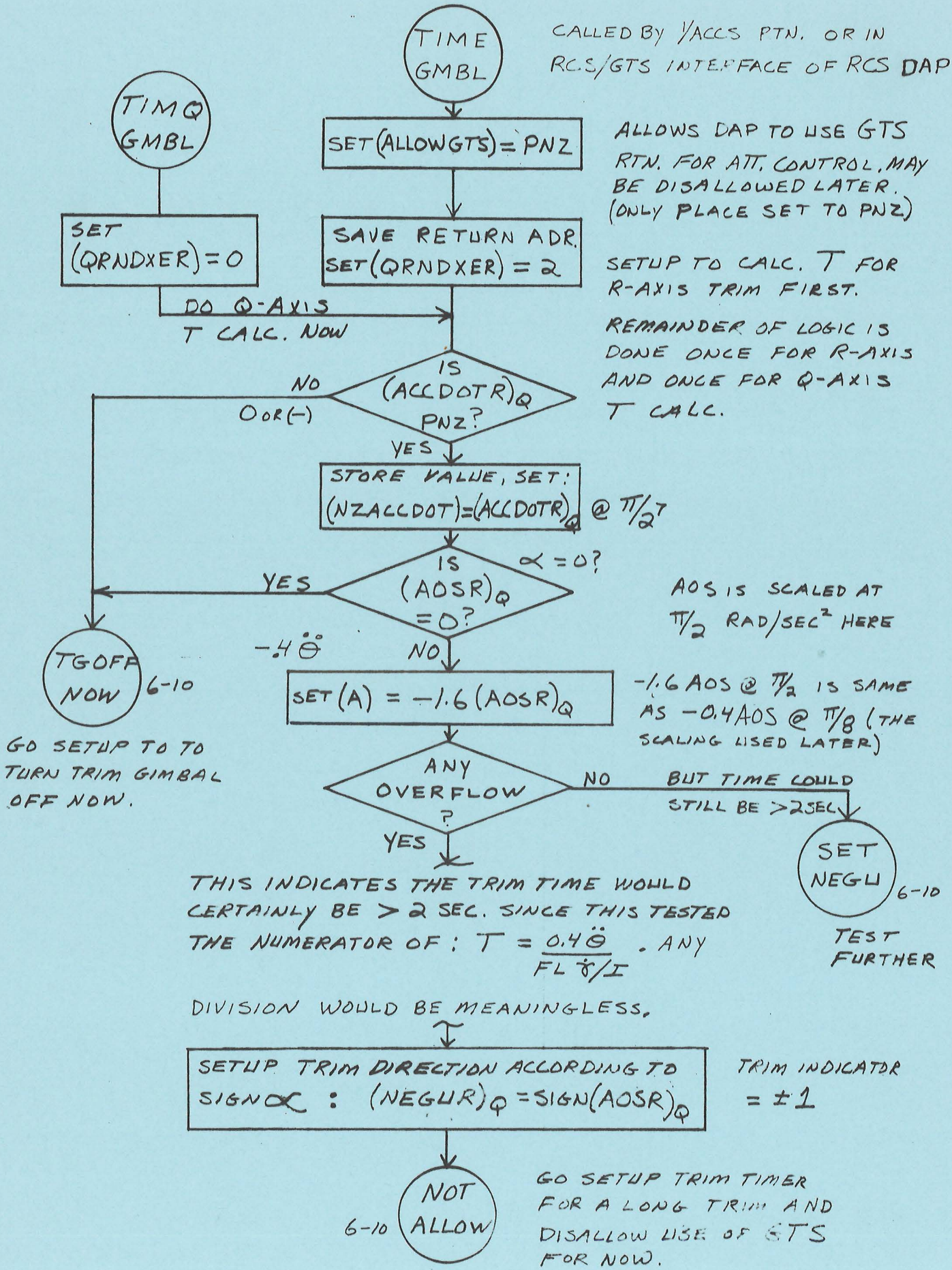
WHERE: $\ddot{\theta}$ = 2nd DERIVATIVE OF ATT ERROR OR (AOS) and,

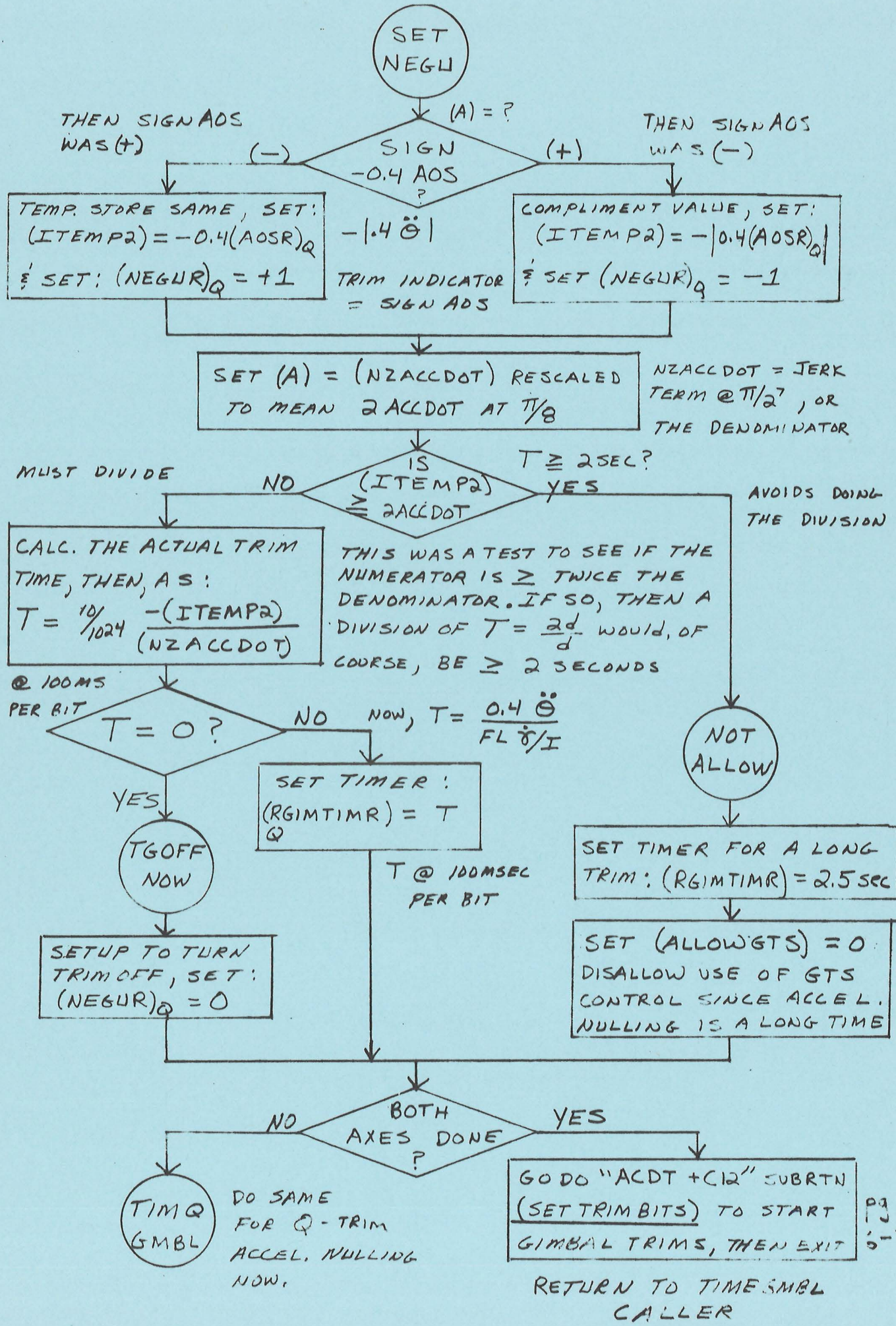
denominator = JERK TERM OR RATE OF CHANGE OF ACCEL. DUE TO ENGINE TRIMMING FOR THRUST VECTOR CONTROL

0.4 = A DAMPING FACTOR USED TO ENSURE NO TRIM OVERSHOOT

THE TIME (T) IS SET INTO A TRIM TIMER (ONE FOR EACH AXIS) AND REDUCED BY 100MSEC EVERY LM DAP CYCLE (see P-AXIS AUTOPILOT). SINCE TIMEGMBL IS GENERALLY CALLED EVERY 2 SEC, THEN THE TRIMMING, OR NULLING, WILL BE CONTINUOUS AS LONG AS T IS GREATER THAN 2 SEC. HOWEVER, IT IS VERY POSSIBLE CERTAIN CONDITIONS CAN DISALLOW USE OF THE ENGINE GIMBAL BETWEEN T COMPUTATIONS. THUS, WHENEVER T EXCEEDS 2 SEC, THE TRIM TIMERS ARE SET TO 2.5 SEC. TO ENSURE A LONG TRIM IS STOPPED WHILE ALLOWING A SMOOTH TRANSITION.

NEXT PAGE


TIME GMBL
CALLED BY 1/ACCS PTN. OR IN RCS/GTS INTERFACE OF RCS DAP
TIMQ GMBL
SET (ALLOWGTS) = PNZ
ALLOWS DAP TO USE GTS RTN. FOR ATT. CONTROL, MAY BE DISALLOWED LATER. (ONLY PLACE SET TO PNZ)
SET (QRNDXER) = 0
SAVE RETURN ADR. SET (QRNDXER) = 2
SETUP TO CALC. T FOR R-AXIS TRIM FIRST.
DO Q-AXIS T CALC. NOW
REMAINDER OF LOGIC IS DONE ONCE FOR R-AXIS AND ONCE FOR Q-AXIS T CALC.
IS (ACCDOTR)Q PNZ?
NO
0 OR (-)
YES
STORE VALUE, SET: (NZACCDOT) = (ACCDOTR)Q @ π/2
IS (AOSR)Q = 0? α = 0?
YES
AOS IS SCALED AT π/2 RAD/SEC² HERE
TGOFF NOW
6-10
-.4 θ̈
NO
SET (A) = -1.6 (AOSR)Q
-1.6 AOS @ π/2 IS SAME AS -0.4 AOS @ π/8 (THE SCALING USED LATER)
GO SETUP TO TO TURN TRIM GIMBAL OFF NOW.
ANY OVERFLOW ?
NO
BUT TIME COULD STILL BE >2SEC
SET NEGU
6-10
TEST FURTHER
YES
THIS INDICATES THE TRIM TIME WOULD CERTAINLY BE > 2 SEC. SINCE THIS TESTED THE NUMERATOR OF: T = 0.4 θ̈ / FL γ̇/I . ANY DIVISION WOULD BE MEANINGLESS.
SETUP TRIM DIRECTION ACCORDING TO SIGN α : (NEGUR)Q = SIGN (AOSR)Q
TRIM INDICATOR = ±1
NOT ALLOW
6-10
GO SETUP TRIM TIMER FOR A LONG TRIM AND DISALLOW USE OF GTS FOR NOW.


SET NEGU
(A) = ?
SIGN -0.4 AOS ?
(−)
(+)
THEN SIGN AOS WAS (+)
THEN SIGN AOS WAS (−)
TEMP. STORE SAME, SET: (ITEMP2) = −0.4(AOSR)Q & SET: (NEGUR)Q = +1
−|.4 Ö|
TRIM INDICATOR = SIGN AOS
COMPLIMENT VALUE, SET: (ITEMP2) = −|0.4(AOSR)Q| & SET (NEGUR)Q = −1
SET (A) = (NZACCDOT) RESCALED TO MEAN 2 ACCDOT AT π/8
NZACCDOT = JERK TERM @ π/2^7, OR THE DENOMINATOR
IS (ITEMP2) ≥ 2ACCDOT
T ≥ 2SEC?
NO
YES
MUST DIVIDE
AVOIDS DOING THE DIVISION
CALC. THE ACTUAL TRIM TIME, THEN, AS: T = 10/1024 −(ITEMP2)/(NZACCDOT)
THIS WAS A TEST TO SEE IF THE NUMERATOR IS ≥ TWICE THE DENOMINATOR. IF SO, THEN A DIVISION OF T = 2d/d WOULD, OF COURSE, BE ≥ 2 SECONDS
@ 100MS PER BIT
T = 0 ?
NO
NOW, T = 0.4 Ö / FL γ̇/I
YES
NOT ALLOW
SET TIMER: (RGIMTIMR)Q = T
T @ 100MSEC PER BIT
TGOFF NOW
SET TIMER FOR A LONG TRIM: (RGIMTIMR) = 2.5 sec
SETUP TO TURN TRIM OFF, SET: (NEGUR)Q = 0
SET (ALLOWGTS) = 0 DISALLOW USE OF GTS CONTROL SINCE ACCEL. NULLING IS A LONG TIME
BOTH AXES DONE ?
NO
YES
TIMQ GMBL
DO SAME FOR Q-TRIM ACCEL. NULLING NOW.
GO DO "ACDT +C12" SUBRTN (SET TRIM BITS) TO START GIMBAL TRIMS, THEN EXIT
pg 5-7
RETURN TO TIMESMBL CALLER

SECTION VII

INTERFACING SOFTWARE LOGIC DESCRIPTIONS

1/ACCS SUBROUTINE

This subroutine provides the interface between the guidance programs and the LM DAP. Data is communicated to the DAP by 1/ACCS whenever there is a change in:

a) mass - due to powered flight fuel consumption or
- due to a vehicle configuration change
(ASCENT, DESCENT or DOCKED config.)

or b) selected DEADBAND

and during a FRESHSTART or RESTART.

The inputs to 1/ACCS are:

(1) total vehicle mass (MASS)
(2) acceleration due to thrust (ABDELV)
(3) attitude deadband (DB) either astronaut selected as 5 deg. or 0.3 deg.) or thrust program selected as 1 deg
(4) the offset acceleration estimates (AOSQ) & (AOSR)
(5) stage verify bit (B2-CH30)
(6) the DOCKED BIT (B13-DAPBOOLS) - set by astronaut
(7) the DRIFTBIT (B8-DAPBOOLS) - } set by powered flight programs.
(8) USEQRJTS BIT (B14-DAPBOOLS) }
(9) the state of the jet fail switches (CH5MASK)

The 1/ACCS subroutine, in turn, calculates the complete control-effectiveness terms for the vehicle, both for docked and undocked configurations.

Some of these terms are:

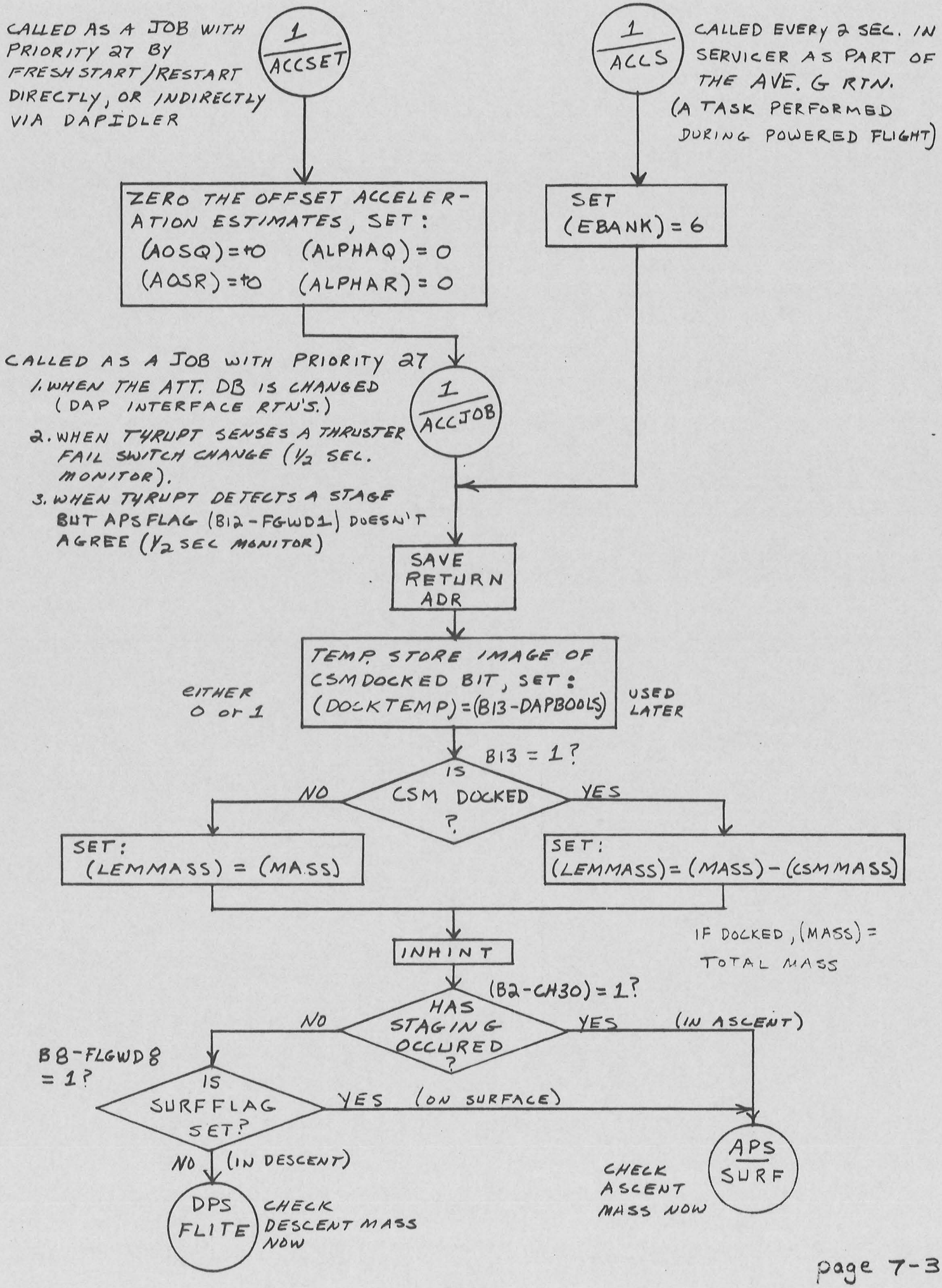
For DOCKED or UNDOCKED cases

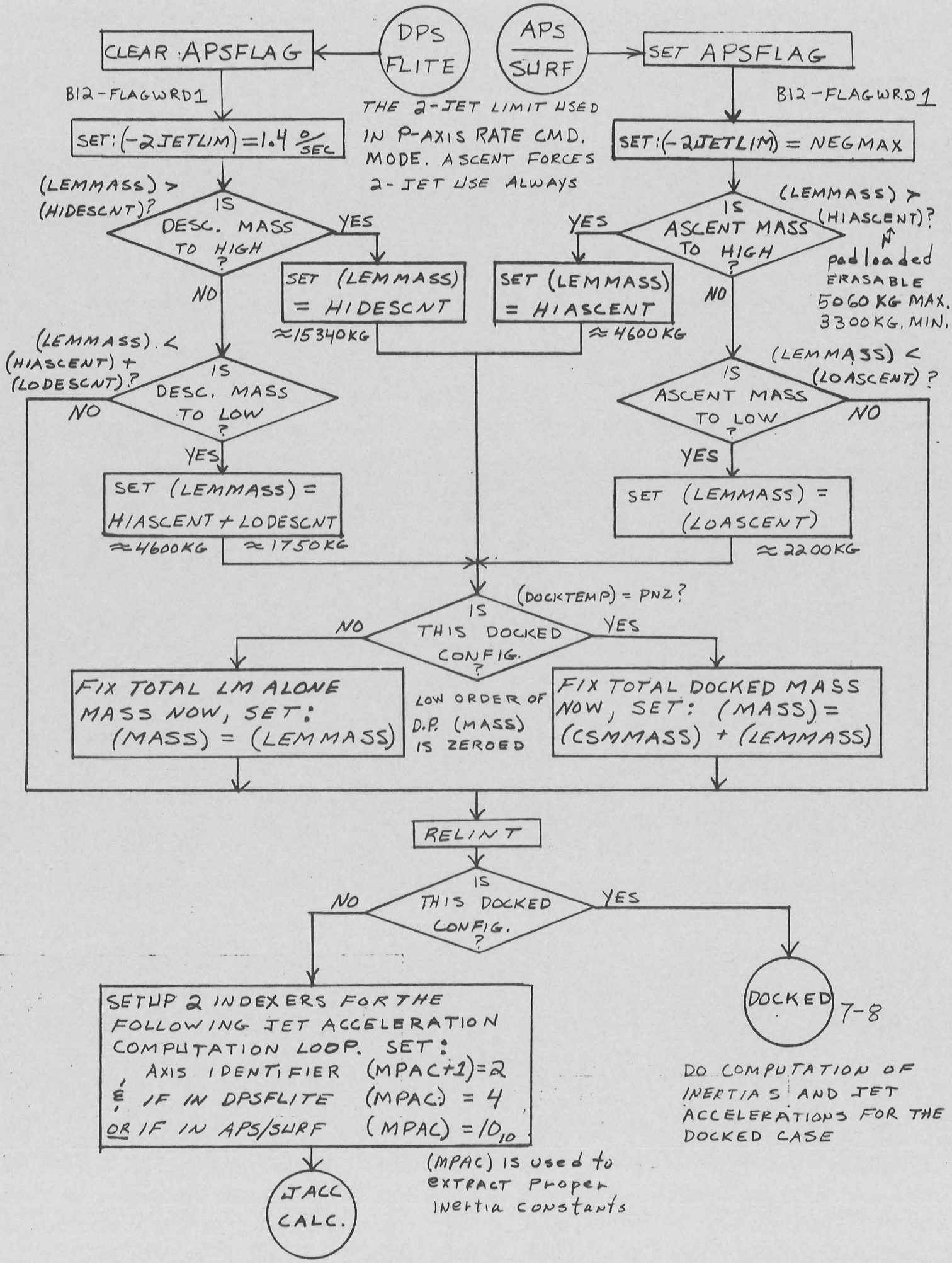
1. the jet accelerations for each axis (1JAC terms)
2. if in descent, the C.G. - ENG. PIVOT distance
3. the rate-of-change of acceleration due to engine rotation (the ACCDOT terms)

For UNDOCKED cases only (phase plane terms):

1. the reciprocal of net accelerations about P, U & V axes (the 1/ANET terms)
2. the reciprocal of coast accelerations (the 1/ACOAST terms)
3. the acceleration functions for phase plane firing boundaries (the ACCFCT terms)
4. the height and width of the minimum impulse zone on the phase plane (ZONE 3 LIM & FLAT terms)
5. the various phase plane switch curve deadbands (FIRE DB and COAST DB terms)

1/ACCS will call the angular acceleration nulling routine "TIMEGMBL" whenever the trim gimbal attitude control mode is not in use (GTS) and the CSM is not docked.


CALLED AS A JOB WITH PRIORITY 27 BY FRESH START/RESTART DIRECTLY, OR INDIRECTLY VIA DAPIDLER
1/ACCSET
1/ACCS
CALLED EVERY 2 SEC. IN SERVICER AS PART OF THE AVE. G RTN. (A TASK PERFORMED DURING POWERED FLIGHT)
ZERO THE OFFSET ACCELERATION ESTIMATES, SET:
(AOSQ) = +0 (ALPHAQ) = 0
(AOSR) = +0 (ALPHAR) = 0
SET (EBANK) = 6
CALLED AS A JOB WITH PRIORITY 27
1. WHEN THE ATT. DB IS CHANGED (DAP INTERFACE RTN'S.)
2. WHEN TYRUPT SENSES A THRUSTER FAIL SWITCH CHANGE (1/2 SEC. MONITOR).
3. WHEN TYRUPT DETECTS A STAGE BUT APS FLAG (B12-FGWD1) DOESN'T AGREE (1/2 SEC MONITOR)
1/ACCJOB
SAVE RETURN ADR
TEMP. STORE IMAGE OF CSM DOCKED BIT, SET:
(DOCKTEMP) = (B13-DAPBOOLS)
EITHER 0 or 1
USED LATER
B13 = 1?
IS CSM DOCKED ?
NO
YES
SET: (LEMMASS) = (MASS)
SET: (LEMMASS) = (MASS) - (CSMMASS)
IF DOCKED, (MASS) = TOTAL MASS
INHINT
(B2-CH30) = 1?
HAS STAGING OCCURED ?
NO
YES
(IN ASCENT)
B8-FLGWD8 = 1?
IS SURFFLAG SET?
YES (ON SURFACE)
NO (IN DESCENT)
DPS FLITE
CHECK DESCENT MASS NOW
CHECK ASCENT MASS NOW
APS SURF


DPS FLITE
APS SURF
CLEAR APSFLAG
SET APSFLAG
B12-FLAGWRD1
B12-FLAGWRD1
THE 2-JET LIMIT USED IN P-AXIS RATE CMD. MODE. ASCENT FORCES 2-JET USE ALWAYS
SET: (-2JETLIM) = 1.4 °/SEC
SET: (-2JETLIM) = NEGMAX
(LEMMASS) > (HIDESCNT)?
IS DESC. MASS TO HIGH ?
YES
NO
SET (LEMMASS) = HIDESCNT
≈15340KG
IS ASCENT MASS TO HIGH ?
(LEMMASS) > (HIASCENT)?
padloaded ERASABLE 5060 KG MAX. 3300 KG. MIN.
SET (LEMMASS) = HIASCENT
≈4600KG
(LEMMASS) < (HIASCENT) + (LODESCNT)?
IS DESC. MASS TO LOW ?
SET (LEMMASS) = HIASCENT + LODESCNT
≈4600KG
≈1750KG
IS ASCENT MASS TO LOW ?
(LEMMASS) < (LOASCENT) ?
SET (LEMMASS) = (LOASCENT)
≈2200KG
(DOCKTEMP) = PNZ?
IS THIS DOCKED CONFIG. ?
FIX TOTAL LM ALONE MASS NOW, SET: (MASS) = (LEMMASS)
LOW ORDER OF D.P. (MASS) IS ZEROED
FIX TOTAL DOCKED MASS NOW, SET: (MASS) = (CSMMASS) + (LEMMASS)
RELINT
IS THIS DOCKED CONFIG. ?
SETUP 2 INDEXERS FOR THE FOLLOWING JET ACCELERATION COMPUTATION LOOP. SET:
AXIS IDENTIFIER (MPAC+1) = 2
& IF IN DPSFLITE (MPAC) = 4
OR IF IN APS/SURF (MPAC) = 10₁₀
(MPAC) is used to extract proper inertia constants
JACC CALC.
DOCKED
7-8
DO COMPUTATION OF INERTIAS AND JET ACCELERATIONS FOR THE DOCKED CASE

AXIS	(MPAC)		A - kg rad/sec²	B - rad/sec²	C - kg
R	ASCENT	10	+.0056946631	+.009312	-.023608
Q		8	+.0035784354	+.162862	+.002588
P		6	+.0065443852	+.000032	-.006923
R	DESCENT	4	+.0010451889	+.021345	-.066027
Q		2	+.0014979264	+.018791	-.068163
P		-0	+.0059347674	+.002989	+.008721

(MPAC+1)	AXIS	STORAGE
2	R	1 JACC R
1	Q	1 JACC Q
0	P	1 JACC

MAGNITUDES ONLY @ $\pi/4$ R/S²

STCTR1

LM ALONE CASE

JACC CALC

SET: (LEMMASS) = (MASS)

NOW THE JET ACCELERATION – THE ANGULAR ACCELERATION EXPECTED FROM FIRING A SINGLE RCS JET – IS CALCULATED FOR THE AXIS INDICATED BY (MPAC+1). THE ACCELERATION IS A FUNCTION OF THE VEHICLE MASS, f(m), where f(m) is A hyperbolic APPROXIMATION OF THE FORM:

$$JACC = f(m) = \frac{A}{(MASS) + C} + B \qquad \text{where}$$

A, B AND C ARE STORED CONSTANTS AND SELECTED ACCORDING TO (MPAC) FOR THE COMPUTATION. THE JET ACCELERATION IS THEN STORED IN THE LOCATION INDICATED BY (MPAC+1). SEE TABLES ABOVE.

(MPAC+1) = 0?

NO → CALC. JACC FOR NEXT AXIS, SUBTRACT:
1 from (MPAC+1)
2 from (MPAC)

YES (all done) → U, V JACC

COMMEQS

U, V
JACC

U-V COMPONENTS AT 45° FROM Q-R AXES

CALCULATE THE JET ACCELERATIONS EXPECTED ON THE U & V AXES. SET:

$$(1JACCU) \;\&\; (1JACCV) = 0.707\left[(1JACCQ) + (1JACCR)\right]$$

@ $\pi/2$ R/S²

CALCULATE THE INVERSE OF THE ACCELERATION EXPECTED FROM 2 P-AXIS JETS FIRING. SET:

$$(1/2JTSP) = \frac{1}{2\,(1JACC)}$$

USED IN P-AXIS RATE CMD MODE LOGIC TO CALC. FIRING TIME

IN ASCENT OR DESCENT ?

(MPAC) = ? 6 or -0

ASCENT → 1/ACCONT

7-11

DESCENT

NOW THE LENGTH, L, FROM THE DPS ENGINE PIVOT TO THE CENTER-OF-GRAVITY IS CALCULATED. L IS ALSO A FUNCTION OF MASS AND IS APPROXIMATED BY THE SAME FORM AS JACC. SET:

$$(L, PVT\text{-}CG) = \frac{A}{(MASS) + C} + B \quad \text{FEET, where}$$

A = +.0410511917 , B = +.155044 , C = −.025233

L,PVT-CG IS USED IN THE NEXT COMPUTATION.

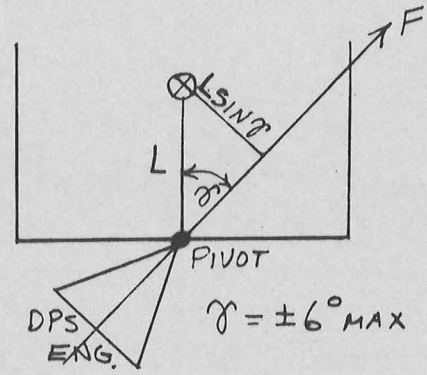
THE <u>MAGNITUDES</u> OF THE RATE-OF-CHANGE OF ANGULAR ACCELERATION, JERK, ABOUT THE Q & R AXES ARE NOW COMPUTED. THESE JERK TERMS ARE DUE TO:

THE THRUST VECTOR MISALIGNMENT WITH THE C.G. & THE DPS ENGINE ROTATION WHILE THRUSTING

ABS
ACCDOT

ABS ACCDOT

LRESC



THE JERK TERMS ARE BASICALLY OF THE FORM: $\dot{\alpha} = \frac{d\alpha}{dt}$ WHERE

$\alpha = T/I$ or TORQUE / INERTIA AND

T = FORCE × MOMENTARM = $F \times L \sin\gamma$

AND F = MASS × LINEAR ACCEL. = ma.

IF γ IS SMALL, THEN $\sin\gamma \cong \gamma$ IN RADIANS. THEREFORE,

$$T/I = \frac{maL\gamma}{I}$$ WHERE ALL TERM EXCEPT γ ARE

ASSUMED CONSTANT FOR THE COMPUTATION CYCLE (THEY ARE BASICALLY UPDATED EVERY 2 SEC. DURING POWERED FLIGHT). SINCE IT IS THE CHANGE IN γ, OR $\frac{d\gamma}{dt}$, THAT CAUSES α TO CHANGE ($\dot{\alpha}$), THEN

$$\dot{\alpha} = \frac{maL}{I}\frac{d\gamma}{dt} \quad \text{or} \quad \frac{maL}{I}\dot{\gamma}.$$ IT SO HAPPENS THAT

$\dot{\gamma}$ IS MECHANICALLY HELD A CONSTANT (DPS GIMBAL DRIVE RATE = 0.2 °/SEC) THE INERTIA, I, IS FOR EITHER THE Q OR R-AXIS. SINCE THE AXIS JET ACCELERATION IS ALREADY KNOWN, THE INERTIA FOR THE JERK TERM CALC. BELOW CAN BE OBTAINED FROM $\alpha = T/I$ where T = A KNOWN TORQUE OF A SINGLE RCS JET. THUS,

INHINT

STORE THE JERK MAGNITUDES, SET:

$$(ACCDOTR) = \frac{(ABDELV)(MASS)(L,PVT\text{-}CG)(1JACCR)}{(GFACTM)\qquad(TORKJET1)}$$

$$(ACCDOTQ) = \frac{(ABDELV)(MASS)(L,PVT\text{-}CG)(1JACCQ)}{(GFACTM)\qquad(TORKJET1)}$$

THE DIVISION IS OVER FLOW PROTECTED (WILL NOT BE 0)

where: (ABDELV) = THE ACCEL. DUE TO THRUST

(GFACTM) = A CONVERSION CONSTANT $\cong 445 \frac{\text{CM Kg}}{\text{slug FT.}}$

$$(TORKJET1) = \frac{1\ \text{JET TORQUE}}{\text{DRIVE RATE}} = \frac{550\ \text{FT-LBS}}{0.00349\ \text{R/S}}$$

JERK SIGNS

DOCKED

NOW THE JET ACCELERATION FOR DOCKED CONFIGURATION IS COMPUTED FOR USE BY THE LM DAP. THE P-AXIS JACC WILL BE ASSUMED A CONSTANT BUT, THE Q & R-AXES JACC WILL BE COMPUTED AS A FUNCTION OF BOTH LM MASS AND CSM MASS. THE Q & R-AXIS JACC'S WILL BE EQUAL AND COMPUTED DIRECTLY FROM: $\alpha_{Q,R} = \frac{T}{I}(1\ \text{JET})$. THE MOMENT OF INERTIA

I, IS COMPUTED TO FIT THE CURVE OF THE FORM:

$$I = Ax^2 + By^2 + Cxy + Dx + Ey + F$$

WHERE $x = (\text{CSMMASS})$, $y = (\text{LEMMASS})$ AND OTHERS ARE COEFFICIENTS, or CONSTANTS FOR THE CURVE FIT AND LISTED IN THE TABLE BELOW. THUS, I IS COMPUTED AND STORED AS:

Kg cm² @ 2^{38} | (MPAC+1) = I | USE SUBSCRIPT (I) COEFFICIENTS. FROM TABLE NEXT PAGE

Also, FOR COMPUTATION OF THE Q, R-AXIS JERK TERMS, THE GENERAL EXPRESSION $L\dot{\gamma}$ IS NOW COMPUTED. L IS THE DISTANCE FROM THE ENGINE PIVOT TO THE CG. AND $\dot{\gamma}$ IS THE GIMBAL DRIVE RATE (.2 DEG/SEC). $L\dot{\gamma}$ IS COMPUTED TO FIT THE SAME CURVE AS I (above expression) ONLY WITH COEFFICIETS SUBSCRIPTED (CG) AND IS STORED AS:

(MPAC) = $L\dot{\gamma}$ | RAD-CM/SEC @ 4π

DOCKED JACC

COEFFICIENT TABLE FOR I & $L\dot{\gamma}$ EXPRESSIONS (DOCKED CASE)

COEFF.	NAME	EQUALS
$A_{(I)}$	COEFF+3	-.03709
$B_{(I)}$	COEFF+2	-.17670
$C_{(I)}$	COEFF	.19518
$D_{(I)}$	COEFF+5	.02569
$E_{(I)}$	COEFF+4	.06974
$F_{(I)}$	COEFF+1	-.00529
$A_{(CG)}$	COEFF+9	-.37142
$B_{(CG)}$	COEFF+8	.75704
$C_{(CG)}$	COEFF+6	.20096
$D_{(CG)}$	COEFF+11	.41179
$E_{(CG)}$	COEFF+10	-.63117
$F_{(CG)}$	COEFF+7	.13564

DOCKED JACC

ASSUMED a CONSTANT

SET P-AXIS JET ACCEL. (1JACC) = 1.4063 DEG/SEC² @ π/4

INHINT

$\alpha = \frac{T}{I}$ R/S² @ π/4

FORM AND STORE THE Q, R JACC'S

SET: (1JACCQ), (1JACCR) = (TORQCONS) / (MPAC+1)

TORQCONS = 550 FT-LBS (1JET TORQUE)

$\dot{\alpha} = \frac{maL\dot{\gamma}}{I}$ R/sec³ @ π 2⁷

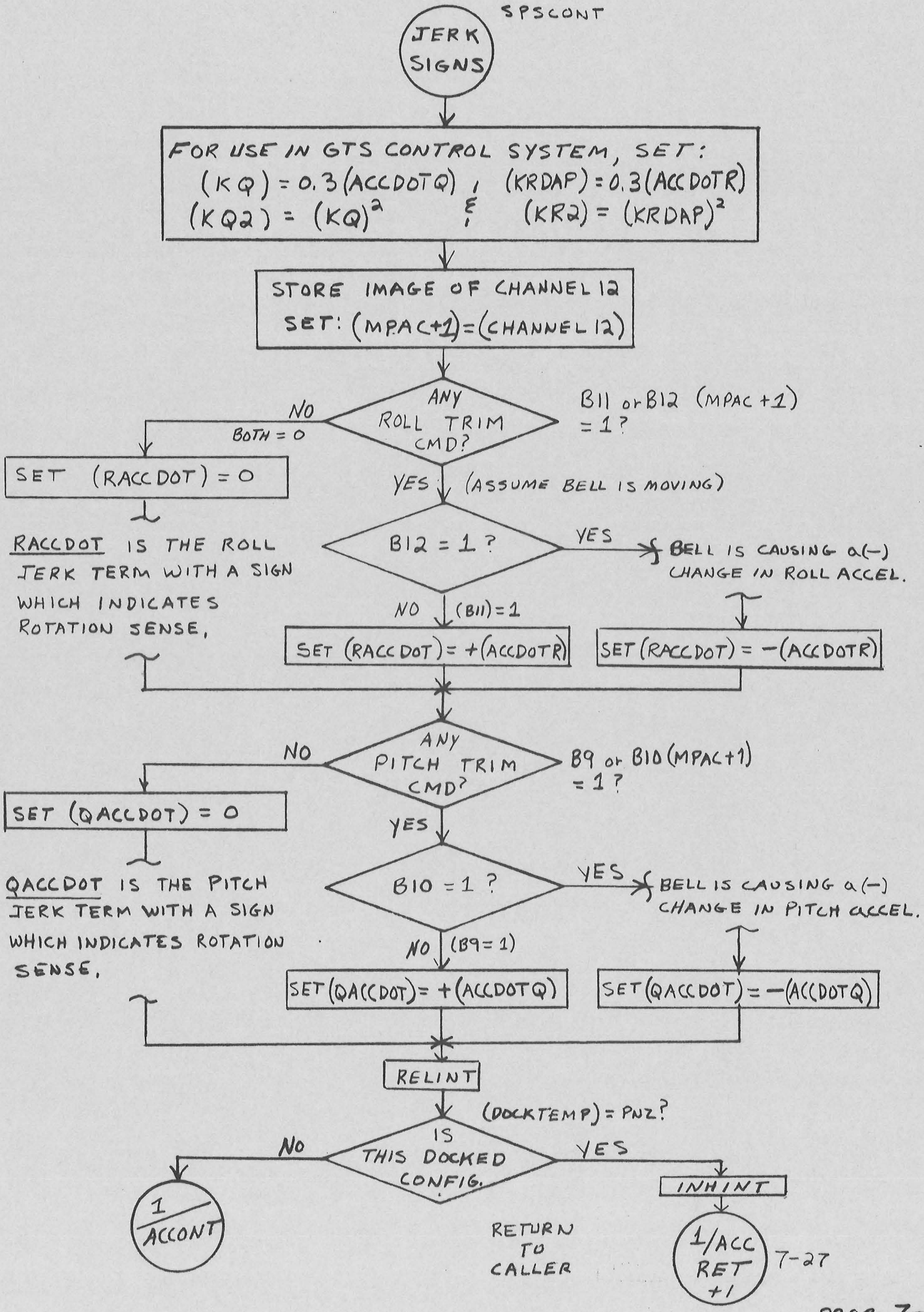
FORM AND STORE THE JERK MAGNITUDES:

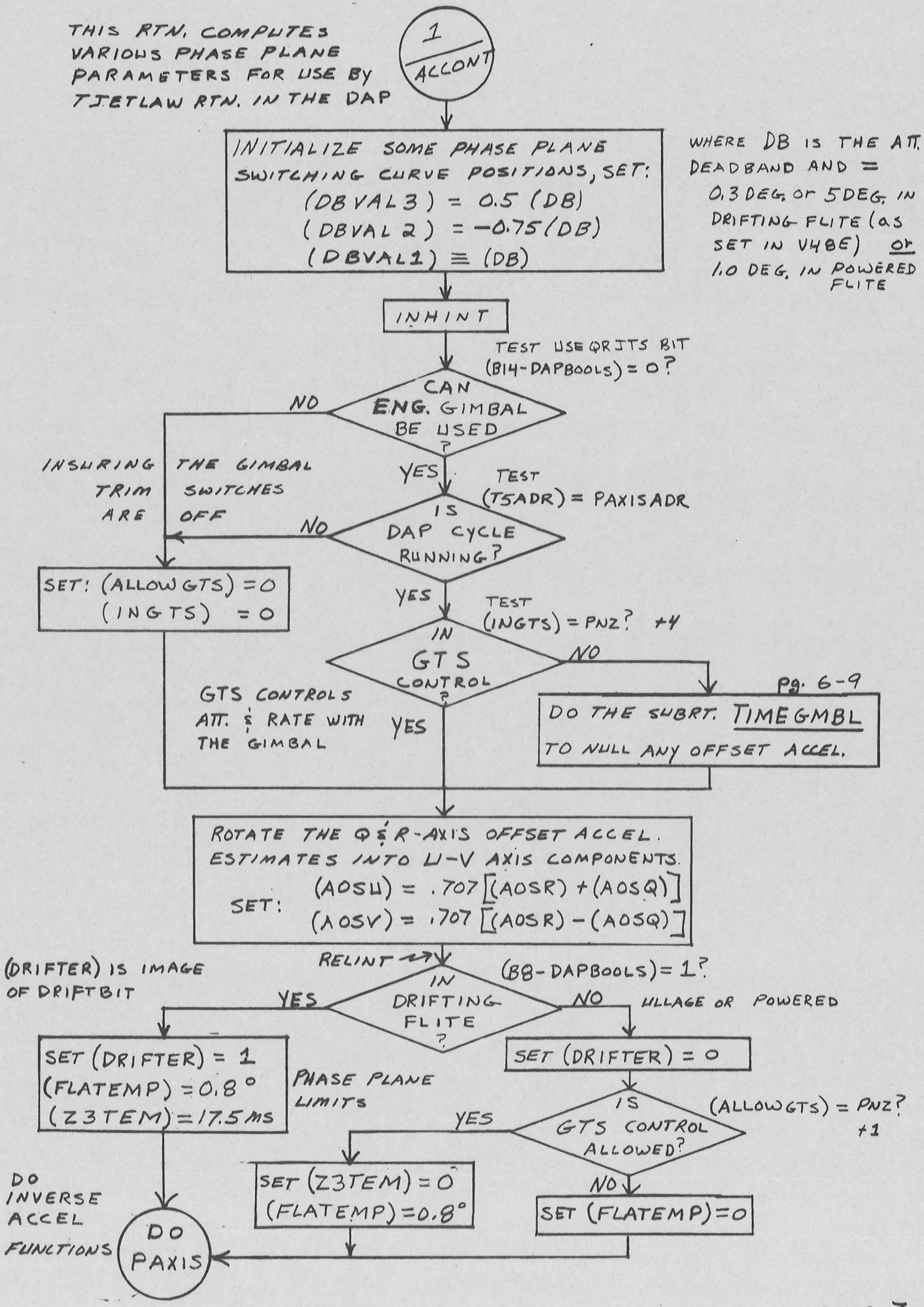
SET: (ACCDOT R), (ACCDOTQ) = (MASS)(ABDELV)(MPAC) / (MPAC+1)

JERK SIGNS

FIND THE SIGN OF THE JERK FROM GIMBAL DRIVE DIRECTION.

SYMMETRY ABOUT X-AXIS IS ASSUMED. THUS THE MOMENT OF INERTIA FOR Q AND R AXES IS THE SAME, MAKING JACC'S THE SAME


SPSCONT
JERK SIGNS
FOR USE IN GTS CONTROL SYSTEM, SET:
(KQ) = 0.3(ACCDOTQ) , (KRDAP) = 0.3(ACCDOTR)
(KQ2) = (KQ)² & (KR2) = (KRDAP)²
STORE IMAGE OF CHANNEL 12
SET: (MPAC+1) = (CHANNEL 12)
ANY ROLL TRIM CMD?
B11 or B12 (MPAC +1) = 1?
NO
BOTH = 0
SET (RACCDOT) = 0
YES
(ASSUME BELL IS MOVING)
B12 = 1?
YES
BELL IS CAUSING a(−) CHANGE IN ROLL ACCEL.
RACCDOT IS THE ROLL JERK TERM WITH A SIGN WHICH INDICATES ROTATION SENSE,
NO
(B11) = 1
SET (RACCDOT) = +(ACCDOTR)
SET (RACCDOT) = −(ACCDOTR)
ANY PITCH TRIM CMD?
B9 or B10 (MPAC+1) = 1?
NO
SET (QACCDOT) = 0
YES
B10 = 1?
YES
BELL IS CAUSING a(−) CHANGE IN PITCH ACCEL.
QACCDOT IS THE PITCH JERK TERM WITH A SIGN WHICH INDICATES ROTATION SENSE,
NO
(B9 = 1)
SET (QACCDOT) = +(ACCDOTQ)
SET (QACCDOT) = −(ACCDOTQ)
RELINT
(DOCKTEMP) = PNZ?
IS THIS DOCKED CONFIG.
NO
YES
1/ACCONT
INHINT
RETURN TO CALLER
1/ACC RET +1
7-27


THIS RTN. COMPUTES VARIOUS PHASE PLANE PARAMETERS FOR USE BY TJETLAW RTN. IN THE DAP
1/ALCONT
INITIALIZE SOME PHASE PLANE SWITCHING CURVE POSITIONS, SET:
(DBVAL3) = 0.5 (DB)
(DBVAL2) = -0.75 (DB)
(DBVAL1) ≡ (DB)
WHERE DB IS THE ATT. DEADBAND AND = 0.3 DEG. or 5 DEG. IN DRIFTING FLITE (as SET IN V48E) or 1.0 DEG. IN POWERED FLITE
INHINT
TEST USE QRJTS BIT (B14-DAPBOOLS) = 0?
CAN ENG. GIMBAL BE USED ?
NO
YES
INSURING TRIM ARE
THE GIMBAL SWITCHES OFF
TEST (TSADR) = PAXISADR
IS DAP CYCLE RUNNING?
NO
YES
SET: (ALLOWGTS) = 0
(INGTS) = 0
TEST (INGTS) = PNZ? +4
IN GTS CONTROL ?
NO
YES
GTS CONTROLS ATT. & RATE WITH THE GIMBAL
Pg. 6-9
DO THE SUBRT. TIMEGMBL TO NULL ANY OFFSET ACCEL.
ROTATE THE Q & R-AXIS OFFSET ACCEL. ESTIMATES INTO U-V AXIS COMPONENTS.
SET: (AOSU) = .707 [(AOSR) + (AOSQ)]
(AOSV) = .707 [(AOSR) - (AOSQ)]
RELINT
(B8-DAPBOOLS) = 1?
IN DRIFTING FLITE ?
YES
NO
ULLAGE OR POWERED
(DRIFTER) IS IMAGE OF DRIFTBIT
SET (DRIFTER) = 1
(FLATEMP) = 0.8°
(Z3TEM) = 17.5 ms
PHASE PLANE LIMITS
SET (DRIFTER) = 0
IS GTS CONTROL ALLOWED?
(ALLOWGTS) = PNZ? +1
YES
NO
SET (Z3TEM) = 0
(FLATEMP) = 0.8°
SET (FLATEMP) = 0
DO INVERSE ACCEL FUNCTIONS
DO PAXIS

DO PAXIS

BELOW, THE INVERSE ACCELERATION TERMS AND FUNCTIONS ARE COMPUTED FOR THE 3 AXES. THESE VALUES ARE USED WITHIN THE TJETLAW SUBRTN. OF THE 100 MSEC DAP CYCLE TO COMPUTE THE LOCATION OF THE VEHICLE'S STATE IN THE PHASE PLANE. THEY ARE COMPUTED HERE TO SAVE COMPUTATION TIME IN THE DAP, STARTING WITH THE P-AXIS VALUES.

THE GENERAL SUBTERMS THAT FORM THE INVERSE COMPUTATIONS HAVE NEUMONICS THAT ARE REFERED TO AS:

NET ACCELERATION (ANET) = THE NET SUM OF THE JET ACCELERATION AND THE OFFSET ACCELERATION FOR THE AXIS (2 JET ACCEL. IS USED FOR P-AXIS AND BOTH 2 AND 1 JET ACCEL. FOR THE U & V-AXES). VALUES ARE COMPUTED FOR THE CASES WHERE THE OFFSET AIDS THE JET ACCEL. (CALLED POS. CASES) AND FOR CASES WHEN THE AOS OPPOSES (CALLED NEG. CASES).

COAST ACCELERATION (ACOAST) = THE ANGULAR ACCELERATION EXISTING WHEN NO JETS ARE FIRING, WHICH IS ACTUALLY THE OFFSET ACCEL. FOR THE AXIS.

NOTE: THE P-AXIS IS ASSUMED TO HAVE ZERO OFFSET ACCEL. AT ALL TIMES.

BOTH (ANET) AND (ACOAST) ARE SCALED AT $\pi/2$. HOWEVER, THEIR INVERSES WILL BE SCALED AT $2^7/\pi$ SEC^2/RAD. ALSO, THERE WILL BE CASES WHERE THE OFFSET ACCEL. WILL BE ZERO (ALL THE TIME IN P-AXIS). SINCE THE INVERSE OF THIS IS INFINITY AND THEREFORE CANNOT BE USED IN THE LGC, A MINIMUM VALUE (AMIN) OF .02454 RAD/SEC^2 IS USED INSTEAD. THIS IS THE SMALLEST NUMBER WHOSE RECIPROCAL WILL NOT OVERFLOW, SCALED AT 2^7. THUS, THE VALUE OF $1/AMIN = 1/0.02454 = 2^7/\pi$ OR POSMAX AT $2^7/\pi$, WHICH IS THE SCALING FOR THE INVERSE OF ACOAST.

DO PAXIS CON'T

CON'T.

DO PAXIS

INHINT

COMPUTE THE RECIPROCAL OF ANET FOR P-AXIS

SET: $(1/ANETP) = 1/(1JACC)$ @ $2^7/\pi$
$(1/ANETP+1) = 1/(1JACC)$

TWO LOCATIONS, ONE FOR + ROTATIONS, ONE FOR − ROTATIONS

1JACC IS THE SINGLE JET ACCEL. FOR THE P-AXIS, SCALED AT $\pi/4$. OR, THE SAME VALUE IN 1JACC IS A 2 JET ACCEL. IF SCALING OF $\pi/2$ IS ASSUMED. THIS IS THE SCALING OF ANET, THEREFORE, 1JACC CAN BE USED FOR ANET (NO AOS FOR P-AXIS). ALSO, SINCE THERE IS NO P-AXIS OFFSET ACCEL., ACOAST FOR P-AXIS = AMIN OR, 1/ACOAST FOR P-AXIS = 1/AMIN = $2^7/\pi$ @ $2^7/\pi$ SCALING. THUS, THE VALUE OF 1JACC CAN ALSO BE CONSIDERED EQUAL TO THE TERM ANET/ACOAST (FOR P-AXIS) IF SCALING OF 2^6 IS ASSUMED ($\pi/2 \times 2^7/\pi = 2^6$) THIS TERM IS ESTABLISHED BELOW.

THE P-AXIS ACCELERATION FUNCTION FOR TJETLAW IS NOW COMPUTED. SET:

$$\left.\begin{matrix}(PACCFUN)\\(PACCFUN+1)\end{matrix}\right\} = \frac{-1(1/ANETP)}{1+(1JACC)} \text{ @ } 2^7/\pi$$

WHICH BECOMES: $\dfrac{-1}{ANET\,[1+ANET/ACOAST]}$ IN GENERAL TERMS

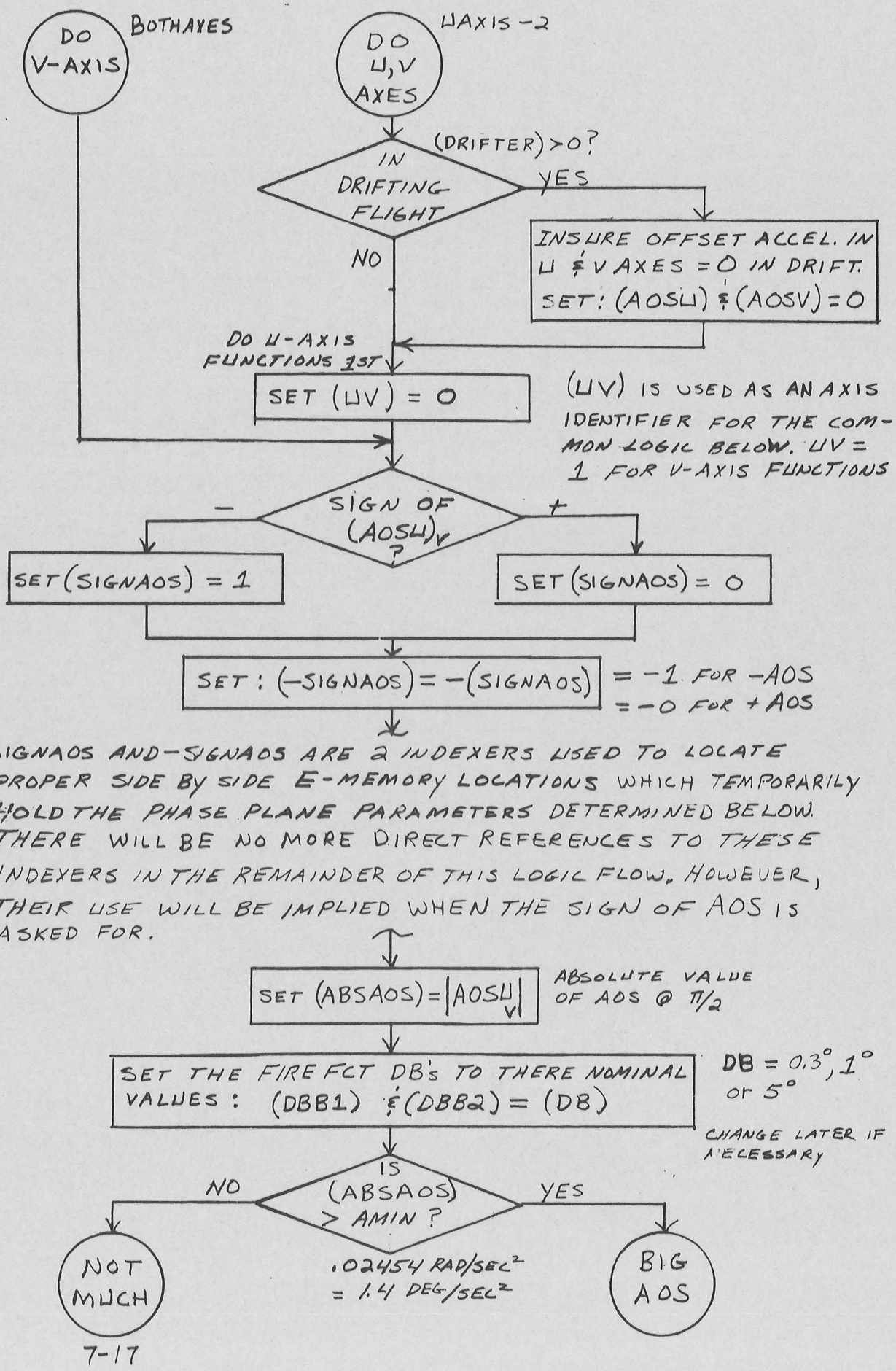
STORE THE RECIPROCAL TERM OF ACOAST FOR P-AXIS

SET: $\left.\begin{matrix}(1/ACOSTP)\\(1/ACOSTP+1)\end{matrix}\right\} = (1/.03) = POSMAX$

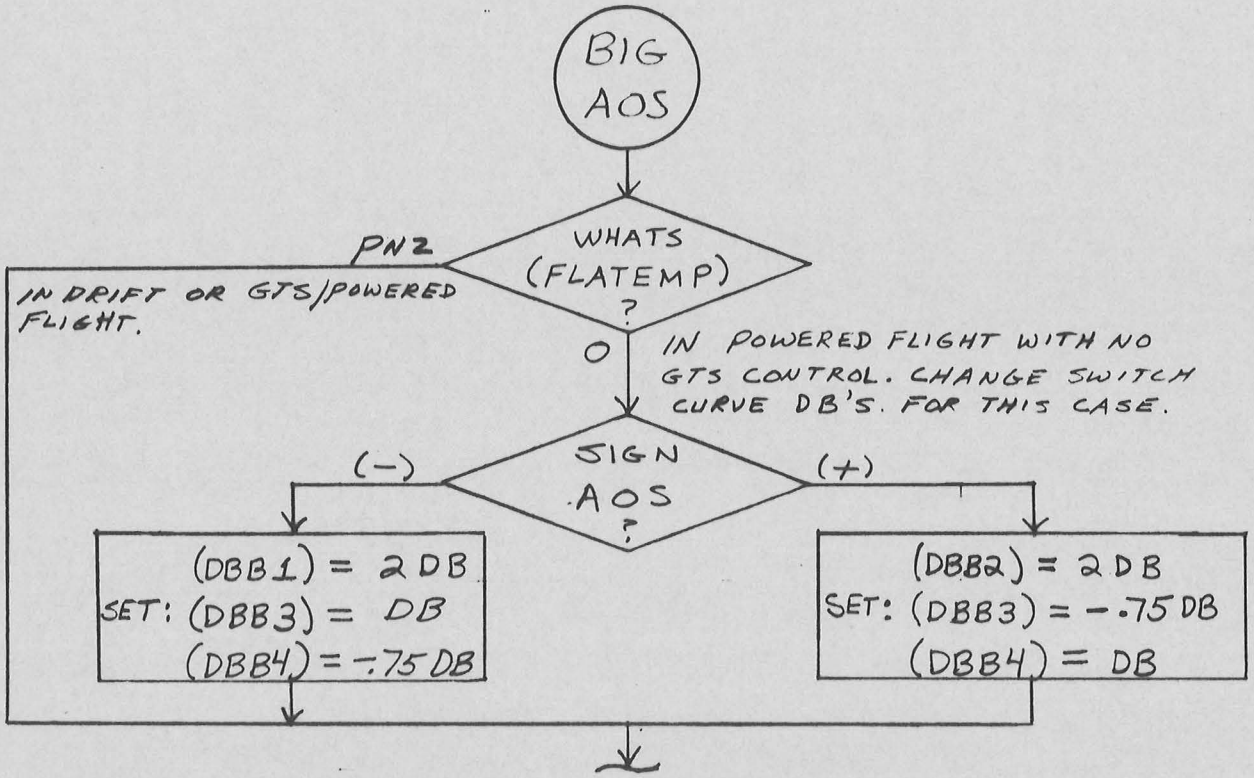
1/.03 IS TAG NAME FOR 1/AMIN OR 1/.0245 $\frac{RAD}{SEC^2}$

RELINT

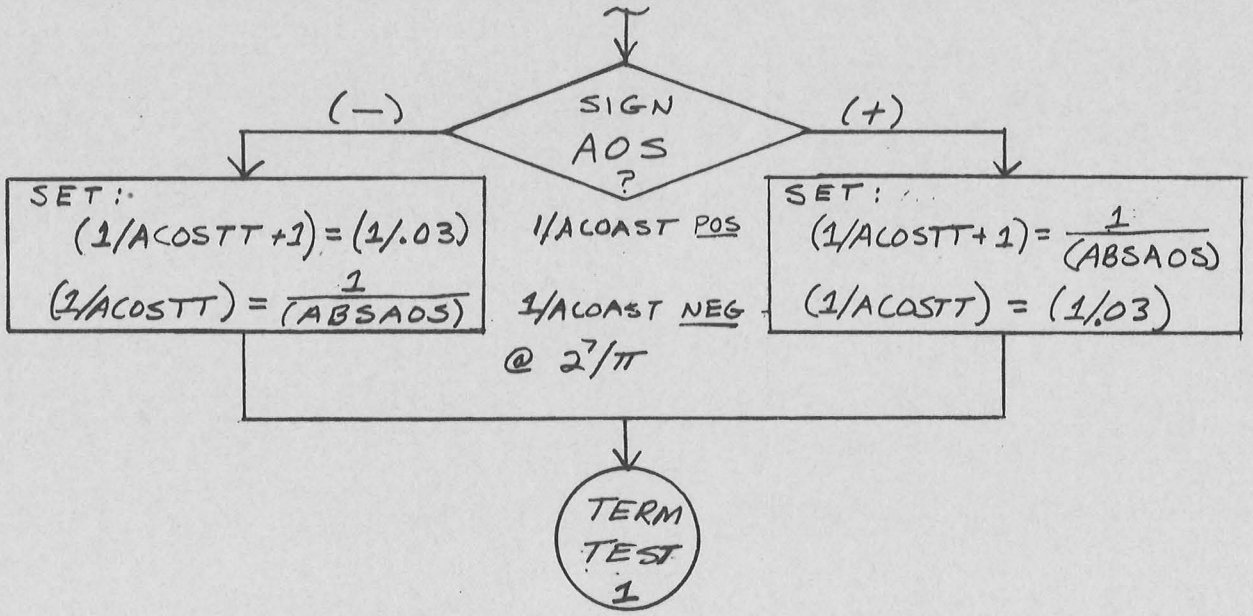
DO U,V AXES

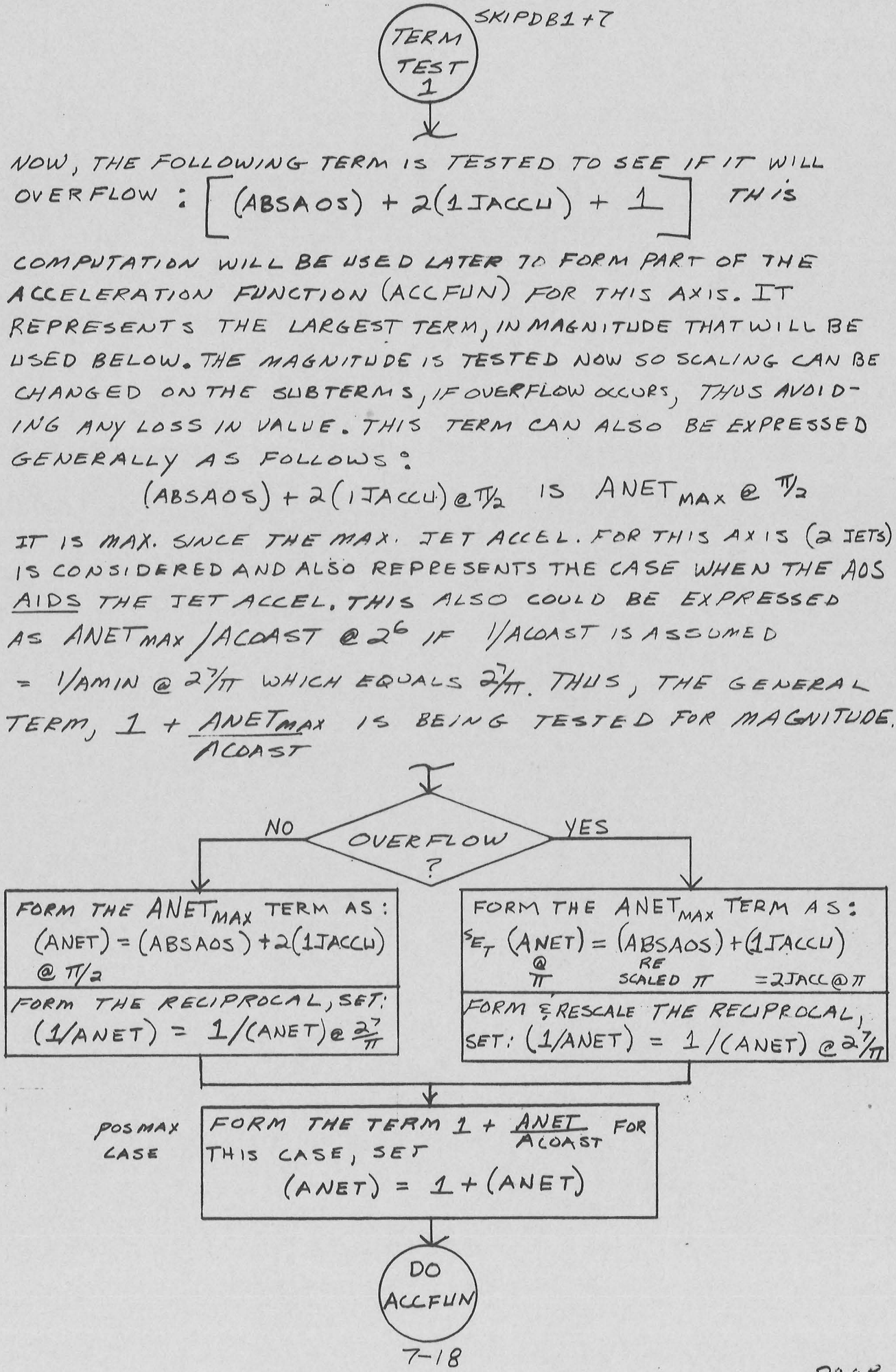

DO V-AXIS
BOTHAXES
DO U,V AXES
UAXIS -2
IN DRIFTING FLIGHT
(DRIFTER) > 0?
YES
NO
INSURE OFFSET ACCEL. IN U & V AXES = 0 IN DRIFT.
SET: (AOSU) & (AOSV) = 0
DO U-AXIS FUNCTIONS 1ST
SET (UV) = 0
(UV) IS USED AS AN AXIS IDENTIFIER FOR THE COMMON LOGIC BELOW. UV = 1 FOR V-AXIS FUNCTIONS
SIGN OF (AOSU)V ?
−
+
SET (SIGNAOS) = 1
SET (SIGNAOS) = 0
SET: (−SIGNAOS) = −(SIGNAOS)
= −1 FOR −AOS
= −0 FOR +AOS
SIGNAOS AND −SIGNAOS ARE 2 INDEXERS USED TO LOCATE PROPER SIDE BY SIDE E-MEMORY LOCATIONS WHICH TEMPORARILY HOLD THE PHASE PLANE PARAMETERS DETERMINED BELOW. THERE WILL BE NO MORE DIRECT REFERENCES TO THESE INDEXERS IN THE REMAINDER OF THIS LOGIC FLOW. HOWEVER, THEIR USE WILL BE IMPLIED WHEN THE SIGN OF AOS IS ASKED FOR.
SET (ABSAOS) = |AOSUV|
ABSOLUTE VALUE OF AOS @ π/2
SET THE FIRE FCT DB's TO THERE NOMINAL VALUES: (DBB1) & (DBB2) = (DB)
DB = 0.3°, 1° or 5°
CHANGE LATER IF NECESSARY
IS (ABSAOS) > AMIN ?
NO
YES
.02454 RAD/SEC²
= 1.4 DEG/SEC²
NOT MUCH
BIG AOS

7-17



NOW THE RECIPROCALS OF ACOAST FOR THIS AXIS ARE COMPUTED AND STORED IN TEMORARY LOCATIONS. THERE ARE 2 VALUES, ONE REPRESENTING a POSITIVE ACOAST AND THE OTHER REPRESENTING A NEGATIVE ACOAST. (POS. & NEG MEANING SENSE OF ROTATION CAUSED BY AN AOS). THE VALUE WHICH REPRESENTS THE OPPOSITE SENSE OF THE PRESENT AOS IS ALWAYS SET TO 1/AMIN, SINCE THERE IS NO ACOAST IN THAT DIRECTION.

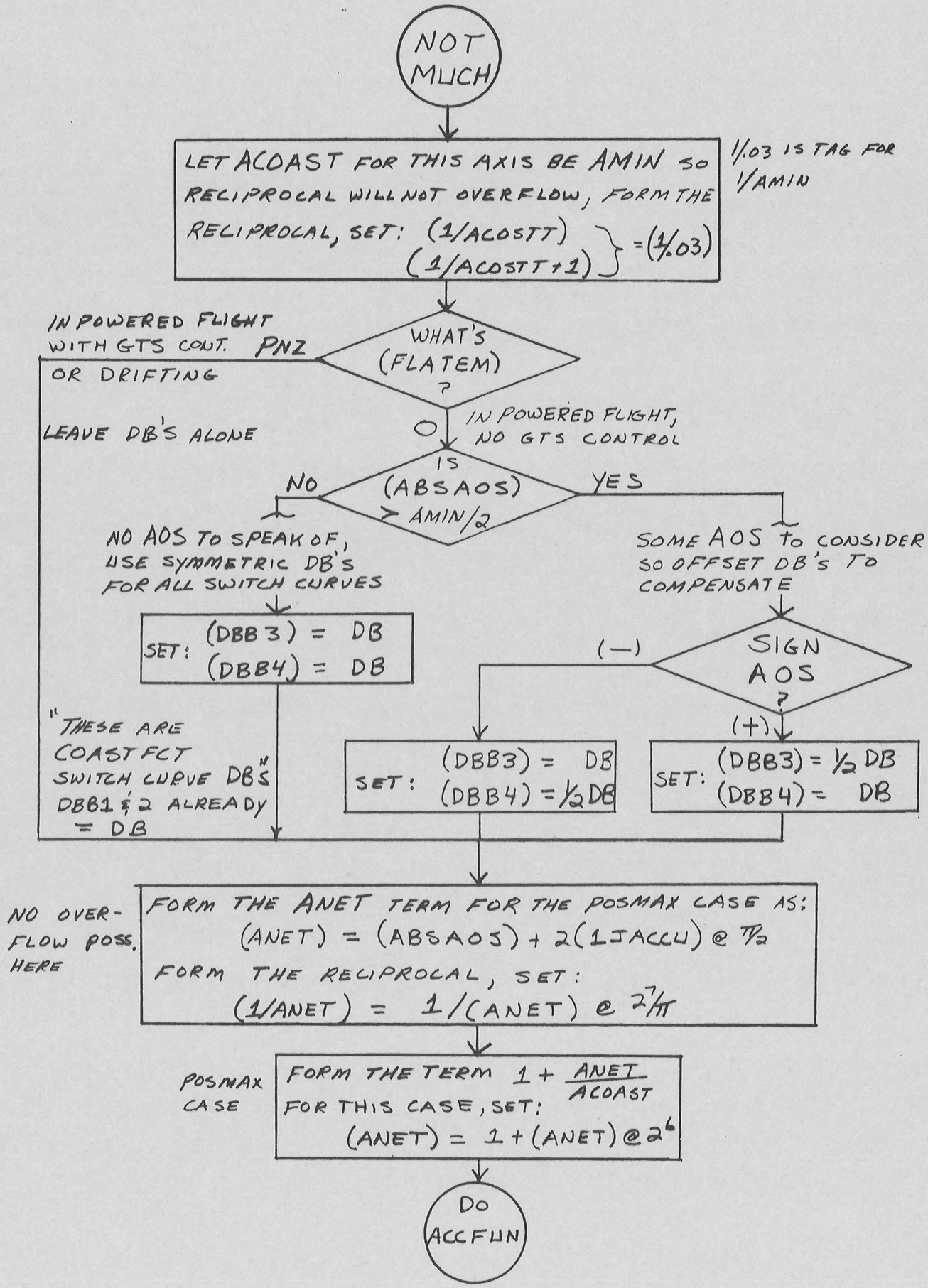




NOW, THE FOLLOWING TERM IS TESTED TO SEE IF IT WILL OVERFLOW: $\left[(ABSAOS) + 2(1JACCU) + 1\right]$ THIS COMPUTATION WILL BE USED LATER TO FORM PART OF THE ACCELERATION FUNCTION (ACCFUN) FOR THIS AXIS. IT REPRESENTS THE LARGEST TERM, IN MAGNITUDE THAT WILL BE USED BELOW. THE MAGNITUDE IS TESTED NOW SO SCALING CAN BE CHANGED ON THE SUBTERMS, IF OVERFLOW OCCURS, THUS AVOIDING ANY LOSS IN VALUE. THIS TERM CAN ALSO BE EXPRESSED GENERALLY AS FOLLOWS:

$$(ABSAOS) + 2(1JACCU) @ \pi/2 \quad \text{IS} \quad ANET_{MAX} @ \pi/2$$

IT IS MAX. SINCE THE MAX. JET ACCEL. FOR THIS AXIS (2 JETS) IS CONSIDERED AND ALSO REPRESENTS THE CASE WHEN THE AOS <u>AIDS</u> THE JET ACCEL. THIS ALSO COULD BE EXPRESSED AS $ANET_{MAX}/ACOAST @ 2^6$ IF $1/ACOAST$ IS ASSUMED $= 1/AMIN @ 2^7/\pi$ WHICH EQUALS $2^7/\pi$. THUS, THE GENERAL TERM, $1 + \frac{ANET_{MAX}}{ACOAST}$ IS BEING TESTED FOR MAGNITUDE.


NOT MUCH
LET ACOAST FOR THIS AXIS BE AMIN SO RECIPROCAL WILL NOT OVERFLOW, FORM THE RECIPROCAL, SET: (1/ACOSTT) (1/ACOSTT+1) = (1/.03)
1/.03 IS TAG FOR 1/AMIN
WHAT'S (FLATEM) ?
PNZ
IN POWERED FLIGHT WITH GTS CONT. OR DRIFTING
LEAVE DB'S ALONE
0
IN POWERED FLIGHT, NO GTS CONTROL
IS (ABSAOS) > AMIN/2
NO
YES
NO AOS TO SPEAK OF, USE SYMMETRIC DB'S FOR ALL SWITCH CURVES
SET: (DBB3) = DB (DBB4) = DB
"THESE ARE COAST FCT SWITCH CURVE DB'S DBB1 & 2 ALREADY = DB
SOME AOS TO CONSIDER SO OFFSET DB'S TO COMPENSATE
SIGN AOS ?
(−)
(+)
SET: (DBB3) = DB (DBB4) = ½ DB
SET: (DBB3) = ½ DB (DBB4) = DB
NO OVER-FLOW POSS. HERE
FORM THE ANET TERM FOR THE POSMAX CASE AS: (ANET) = (ABSAOS) + 2(1JACCU) @ π/2
FORM THE RECIPROCAL, SET: (1/ANET) = 1/(ANET) @ 2^7/π
POSMAX CASE
FORM THE TERM 1 + ANET/ACOAST
FOR THIS CASE, SET: (ANET) = 1 + (ANET) @ 2^6
DO ACCFUN

DO ACCFUN

ACCFUN IS ACTUALLY A NEGATIVE RECIPROCAL OF THE GENERAL TERM $ANET + \frac{ANET^2}{ACOAST}$ AND IS USED IN ZONE 1 AND ZONE 5 PHASE PLANE COMPUTATIONS IN THE TJETLAW SUBRTN. DERIVATION OF THIS TERM IS EXPLAINED IN THE TJETLAW SECTION. ACCFUN IS COMPUTED HERE TO SAVE COMPUTATION TIME IN THE DAP.

THIS IS FOR POS. MAX. JET CASE

FORM ACCFUN FOR THIS CASE
AS: $-1(1/ANET)/(ANET)$
SCALED @ $2^7/\pi$

WHERE (ANET) has $1 + \frac{ANETMAX}{ACOAST}$ TERM.

SIGN AOS ?

(−)

STORE ACCFUN & 1/ANET
SET: (Z5TEM+1) = ACCFUN
(1/ATEM2+1) = (1/ANET)

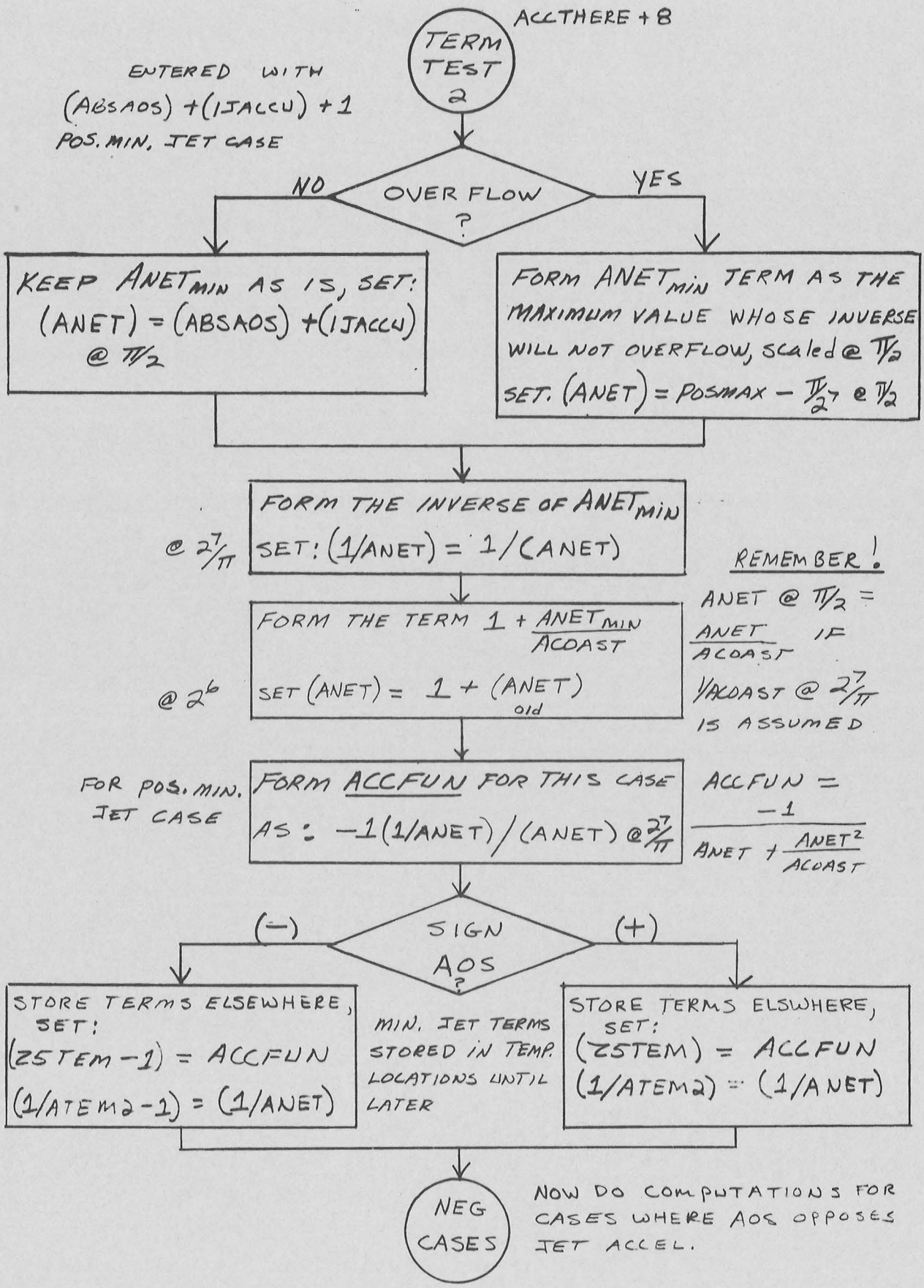
(+)

STORE ACCFUN & 1/ANET
SET: (Z5TEM+2) = ACCFUN
(1/ATEM2+2) = (1/ANET)

STORED IN TEMP. LOCATIONS FOR NOW, WILL BE TRANSFERED TO PERM. LOCATIONS LATER, FOR THIS AXIS

NOW ACCFUN AND THE RECIPROCAL OF ANET FOR THE CASE WHEN MINIMUM JETS (1) ARE USED WILL BE COMPUTED. BUT FIRST, THE TERM [(ABSAOS) + (1JACCU) + 1], WHICH IS THE LARGEST MAGNITUDE TO BE USED FOR THE MIN. CASE COMPUTATIONS, IS TESTED FOR OVERFLOW PRIOR TO BEING USED. THIS TERM, AS IN THE MAX. CASE, IS EXPRESSED GENERALLY AS $1 + \frac{ANETMIN}{ACOAST}$

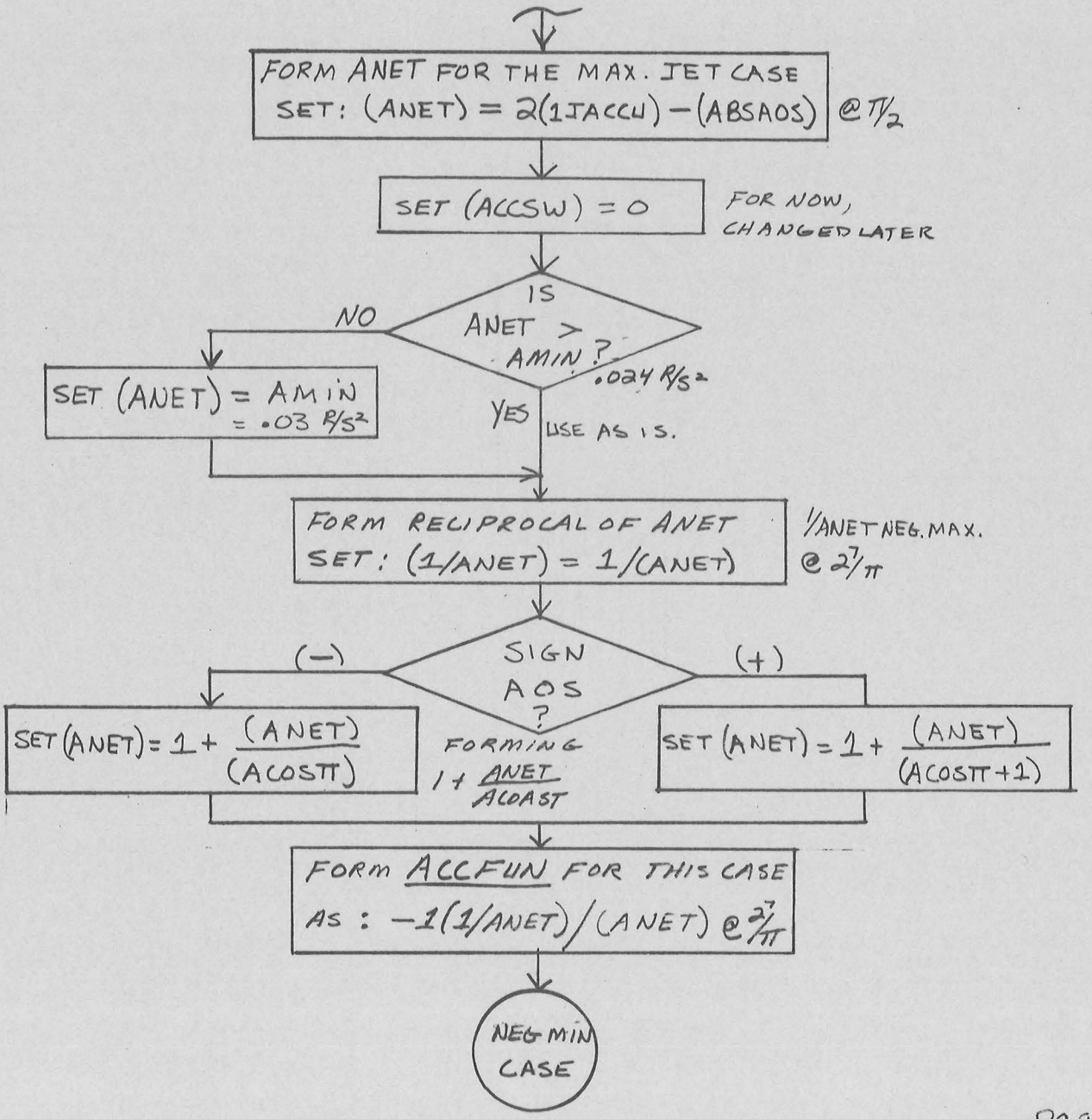
TERM TEST 2

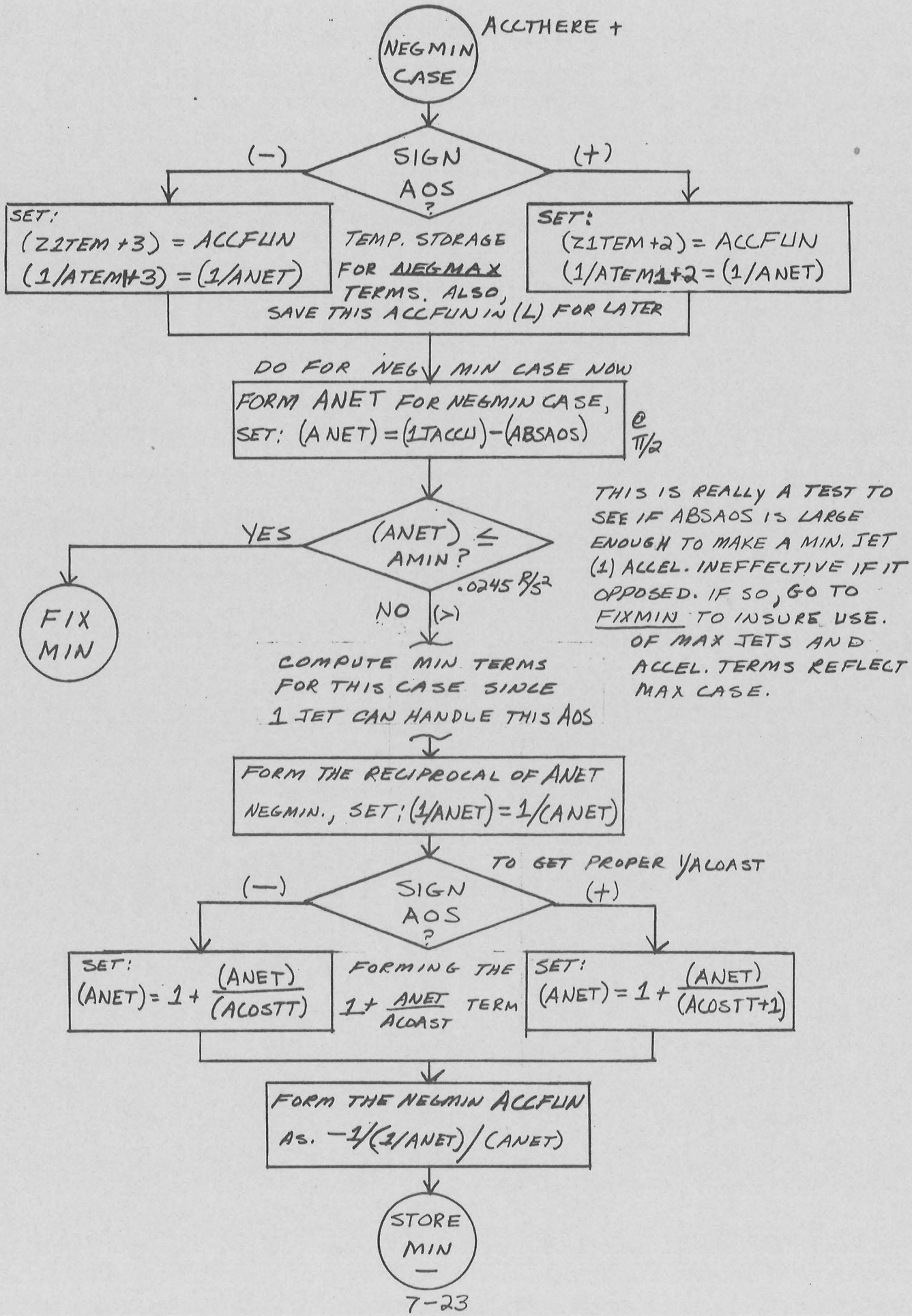

ACCTHERE + 8
TERM TEST 2
ENTERED WITH
(ABSAOS) + (IJACCU) + 1
POS. MIN. JET CASE
OVER FLOW ?
NO
YES
KEEP ANET MIN AS IS, SET:
(ANET) = (ABSAOS) + (IJACCU)
@ π/2
FORM ANET MIN TERM AS THE MAXIMUM VALUE WHOSE INVERSE WILL NOT OVERFLOW, SCALED @ π/2
SET. (ANET) = POSMAX − π/2^7 @ π/2
FORM THE INVERSE OF ANET MIN
SET: (1/ANET) = 1/(ANET)
@ 2^7/π
REMEMBER!
ANET @ π/2 = ANET/ACOAST IF 1/ACOAST @ 2^7/π IS ASSUMED
FORM THE TERM 1 + ANET MIN/ACOAST
SET (ANET) = 1 + (ANET) old
@ 2^6
FOR POS. MIN. JET CASE
FORM ACCFUN FOR THIS CASE
AS: −1(1/ANET)/(ANET) @ 2^7/π
ACCFUN = −1 / (ANET + ANET^2/ACOAST)
SIGN AOS ?
(−)
(+)
STORE TERMS ELSEWHERE, SET:
(ZSTEM−1) = ACCFUN
(1/ATEM2−1) = (1/ANET)
MIN. JET TERMS STORED IN TEMP. LOCATIONS UNTIL LATER
STORE TERMS ELSWHERE, SET:
(ZSTEM) = ACCFUN
(1/ATEM2) = (1/ANET)
NEG CASES
NOW DO COMPUTATIONS FOR CASES WHERE AOS OPPOSES JET ACCEL.

NEG CASES

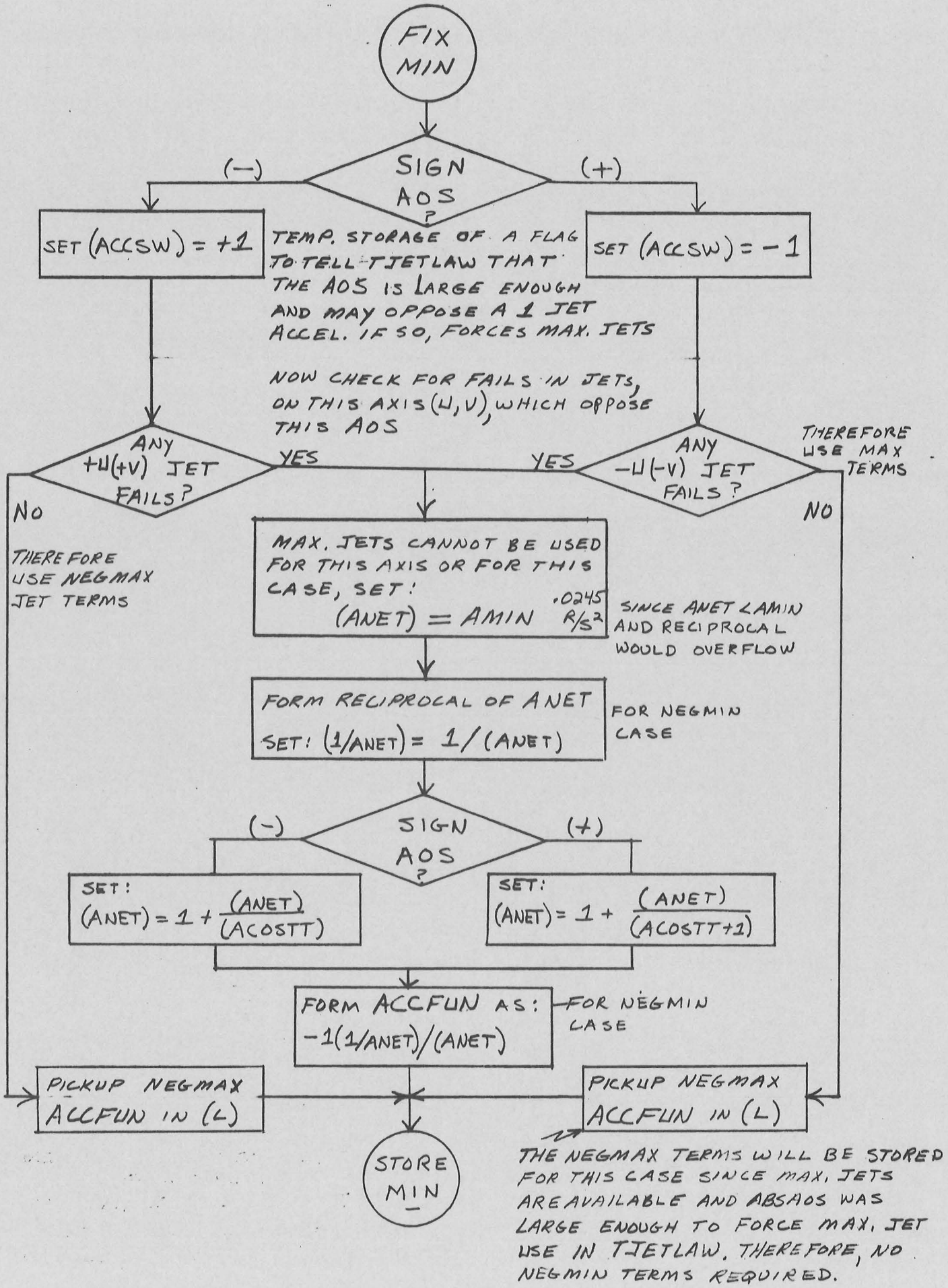
ACCTHERE +19

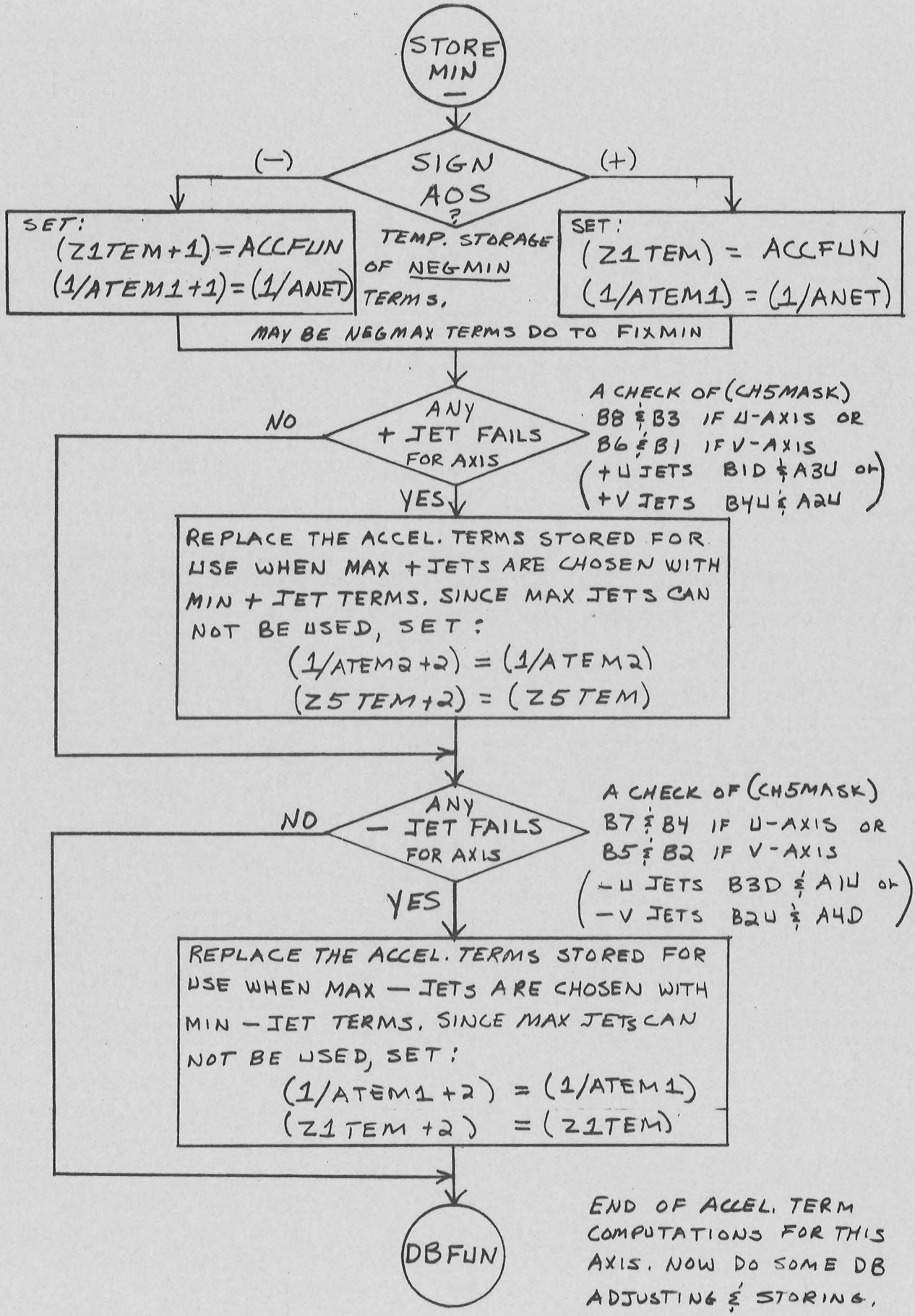
UP TO NOW, THE COMPUTATIONS OF ACCFUN AND 1/ANET HAVE BEEN FOR THE CASE WHEN THE OFFSET ACCEL., AOS, AIDS THE JET ACCEL., WITH BOTH MIN. JETS AND MAX. JETS CONSIDERED (refered to as POSMAX & POSMIN CASES, MEANING ABSAOS IS ADDED (+) TO THE JET ACCEL.). NOW, THE COMPUTATIONS WILL BE REPEATED FOR THE CASE WHEN THE AOS OPPOSES THE JET ACCEL., AGAIN CONSIDERING BOTH MIN. JETS AND MAX. JETS FOR THE AXIS. (refered to as NEGMAX & NEGMIN CASES, MEANING ABSAOS IS SUBTRACTED FROM JET ACCEL.).




NEGMIN CASE
ACCTHERE +
SIGN AOS ?
(−)
(+)
SET: (Z2TEM +3) = ACCFUN
(1/ATEM+3) = (1/ANET)
TEMP. STORAGE FOR NEGMAX TERMS. ALSO, SAVE THIS ACCFUN IN (L) FOR LATER
SET: (Z1TEM +2) = ACCFUN
(1/ATEM1+2 = (1/ANET)
DO FOR NEG MIN CASE NOW
FORM ANET FOR NEGMIN CASE, SET: (ANET) = (1JACCU) − (ABSAOS)
@ π/2
(ANET) ≤ AMIN ?
.0245 R/S²
YES
FIX MIN
NO (>)
THIS IS REALLY A TEST TO SEE IF ABSAOS IS LARGE ENOUGH TO MAKE A MIN. JET (1) ACCEL. INEFFECTIVE IF IT OPPOSED. IF SO, GO TO FIXMIN TO INSURE USE. OF MAX JETS AND ACCEL. TERMS REFLECT MAX CASE.
COMPUTE MIN TERMS FOR THIS CASE SINCE 1 JET CAN HANDLE THIS AOS
FORM THE RECIPROCAL OF ANET NEGMIN., SET: (1/ANET) = 1/(ANET)
TO GET PROPER 1/ACOAST
SIGN AOS ?
(−)
(+)
SET: (ANET) = 1 + (ANET)/(ACOSTT)
FORMING THE 1 + ANET/ACOAST TERM
SET: (ANET) = 1 + (ANET)/(ACOSTT+1)
FORM THE NEGMIN ACCFUN AS. −1/(1/ANET)/(ANET)
STORE MIN −

7-23


FIX MIN
SIGN AOS ?
(−)
(+)
SET (ACCSW) = +1
SET (ACCSW) = −1
TEMP. STORAGE OF A FLAG TO TELL TJETLAW THAT THE AOS IS LARGE ENOUGH AND MAY OPPOSE A 1 JET ACCEL. IF SO, FORCES MAX. JETS
NOW CHECK FOR FAILS IN JETS, ON THIS AXIS (U, V), WHICH OPPOSE THIS AOS
ANY +U(+V) JET FAILS?
YES
NO
ANY −U(−V) JET FAILS?
YES
NO
THEREFORE USE MAX TERMS
THEREFORE USE NEGMAX JET TERMS
MAX. JETS CANNOT BE USED FOR THIS AXIS OR FOR THIS CASE, SET:
(ANET) = AMIN .0245 R/S²
SINCE ANET < AMIN AND RECIPROCAL WOULD OVERFLOW
FORM RECIPROCAL OF ANET
SET: (1/ANET) = 1/(ANET)
FOR NEGMIN CASE
SIGN AOS ?
(−)
(+)
SET: (ANET) = 1 + (ANET)/(ACOSTT)
SET: (ANET) = 1 + (ANET)/(ACOSTT+1)
FORM ACCFUN AS: −1(1/ANET)/(ANET)
FOR NEGMIN CASE
PICKUP NEGMAX ACCFUN IN (L)
PICKUP NEGMAX ACCFUN IN (L)
STORE MIN
THE NEGMAX TERMS WILL BE STORED FOR THIS CASE SINCE MAX. JETS ARE AVAILABLE AND ABSAOS WAS LARGE ENOUGH TO FORCE MAX. JET USE IN TJETLAW. THEREFORE, NO NEGMIN TERMS REQUIRED.


STORE MIN —
SIGN AOS ?
(−)
(+)
SET:
(Z1TEM+1) = ACCFUN
(1/ATEM1+1) = (1/ANET)
TEMP. STORAGE OF NEGMIN TERMS.
SET:
(Z1TEM) = ACCFUN
(1/ATEM1) = (1/ANET)
MAY BE NEGMAX TERMS DO TO FIXMIN
ANY + JET FAILS FOR AXIS
NO
YES
A CHECK OF (CH5MASK)
B8 & B3 IF U-AXIS OR
B6 & B1 IF V-AXIS
(+U JETS B1D & A3U OR
+V JETS B4U & A2U)
REPLACE THE ACCEL. TERMS STORED FOR USE WHEN MAX + JETS ARE CHOSEN WITH MIN + JET TERMS. SINCE MAX JETS CAN NOT BE USED, SET:
(1/ATEM2+2) = (1/ATEM2)
(Z5TEM+2) = (Z5TEM)
ANY — JET FAILS FOR AXIS
NO
YES
A CHECK OF (CH5MASK)
B7 & B4 IF U-AXIS OR
B5 & B2 IF V-AXIS
(−U JETS B3D & A1U OR
−V JETS B2U & A4D)
REPLACE THE ACCEL. TERMS STORED FOR USE WHEN MAX — JETS ARE CHOSEN WITH MIN — JET TERMS. SINCE MAX JETS CAN NOT BE USED, SET:
(1/ATEM1+2) = (1/ATEM1)
(Z1TEM+2) = (Z1TEM)
DBFUN
END OF ACCEL. TERM COMPUTATIONS FOR THIS AXIS. NOW DO SOME DB ADJUSTING & STORING.

NOW THE TERM AXISDIST IS computed. THIS IS THE DISTANCE, ON THE PHASE PLANE E-AXIS, BETWEEN THE FIRE SWITCH CURVE (FIREFCT=0) AND THE COAST SWITCH CURVE (COASFCT=0). AXISDIST IS USED IN TJETLAW IN THE ZONE 1 COMPUTATIONS. TWO TERMS ARE OBTAINED, ONE FOR −ACCEL ZONES (RIGHT SIDE ON PHASE PLANE) AND ONE FOR +ACCEL ZONES (LEFT SIDE).

OBTAIN RIGHT SIDE AXISDIST: SET

(AXDSTEM) = (DBB1)+(FLATEMP)−(DBB3)

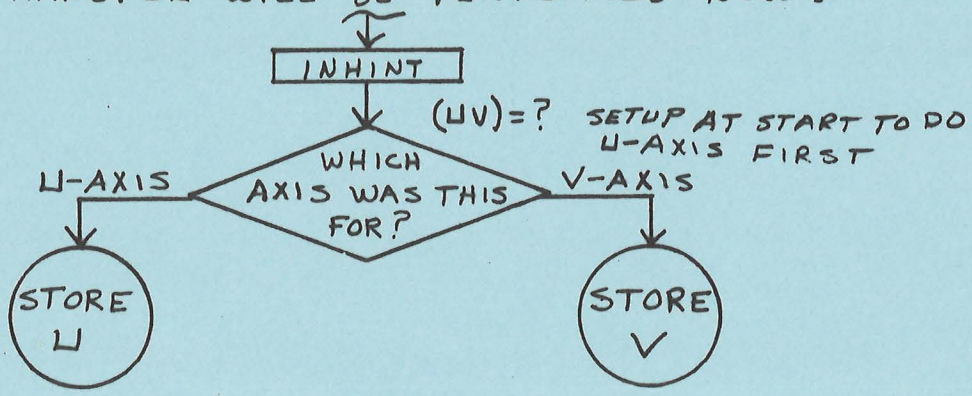
OBTAIN LEFT SIDE AXISDIST: SET

(AXDSTEM+1) = (DBB2)+(FLATEMP)−(DBB4)

AGAIN, ONLY TEMP STORAGE, MOVED LATER

ALL OF THE COMPUTATIONS ARE NOW FINISHED, FOR THIS AXIS. THE LOCATIONS USED, THUS FAR, FOR STORAGE OF ALL THE COMPUTED TERMS ARE IN LOGIC THAT IS COMMON TO BOTH U-AXIS AND V-AXIS COMPUTATIONS. THEREFORE, ALL THESE TERMS MUST BE TRANSFERRED TO PERMANENT LOCATIONS, RESERVED FOR THE AXIS BEING PROCESSED, TO MAKE WAY FOR THE OTHER AXIS THAT WILL BE DONE NEXT. THE PERMANENT LOCATIONS ARE LOCATED IN EBANK 6, STARTING CONSECUTIVELY AT BLOCKTOP FOR U-AXIS, AND V-AXIS TERMS STARTING 16D PLACES BEYOND.

TRANSFER WILL BE PERFORMED NOW!



STORE U

SET:
(ACCSWU) = (ACCSW)

MAX. JET FLAG FOR TJETLAW

STORE V

SET:
(ACCSWV) = (ACCSW)

THE FOLLOWING 10 LOCATIONS ARE TRANSFERRED VIA THE GENTRAN RTN. FROM ADDRESS STARTING AT 1/ATEM1 TO ADDRESSES STARTING AT 1/ANET1 (FOR U-AXIS TERMS) OR 1/ANET1 + 16D (FOR V-AXIS TERMS).

SET:

(ACCFCT Z5+2) = (Z5TEM+2)
(ACCFCTZ1+2) = (Z1TEM+2)
(ACCFCTZ5) = (Z5TEM)
(ACCFCTZ1) = (Z1TEM)
(1/ACOAST+1) = (1/ACOSTT+1)
(1/ACOAST) = (1/ACOSTT)
(1/ANET2+2) = (1/ATEM2+2)
(1/ANET1+2) = (1/ATEM1+2)
(1/ANET2) = (1/ATEM2)
(1/ANET1) = (1/ATEM1)

RELINT

STORE THE U-AXIS DB'S TEMP. FOR NOW. WAIT UNTIL V-AXIS DB'S ARE DONE, THEN STORE ALL AT ONCE, PERMANENTLY.

SET: (UDB1) = (DBB1)
(UDB2) = (DBB2)
(UDB3) = (DBB3)
(UDB4) = (DBB4)
(UAXDIST) = (AXDSTEM)
(UAXDIST+1) = (AXDSTEM+1)

SET (UV) = 1

DO V-AXIS

RETURN TO DO V-AXIS PARAMETERS NOW.

SET:

(ACCFCTZ5+18) = (Z5TEM+2)
(ACCFCTZ1+18) = (Z1TEM+2)
(ACCFCTZ5+16) = (Z5TEM)
(ACCFCTZ1+16) = (Z1TEM)
(1/ACOAST+17) = (1/ACOSTT+1)
(1/ACOAST+16) = (1/ACOSTT)
(1/ANET2+18) = (1/ATEM2+2)
(1/ANET1+18) = (1/ATEM1+2)
(1/ANET2+16) = (1/ATEM2)
(1/ANET1+16) = (1/ATEM1)

STORE REST

REMAINDER OF TERMS TO BE USED BY TJETLAW ARE STORED NOW IN PERMANENT LOCATIONS

STORV+6

STORE REST

ZONE3LIM = 17.5 MSEC FOR HEIGHT OF MINIMP ZONE IN DRIFTING FLIGHT. EQUALS 0 IN POWERED.

SET: (FLAT) = (FLATEM)
(ZONE3LIM) = (Z3TEM)

FLAT = 0.8 DEG IF IN DRIFTING FLIGHT, OR POWERED WITH GTS CONTROL. OTHERWISE = 0 (WIDTH OF MINIMP ZONE)

P-AXIS SWITCH CURVE E-AXIS CROSSINGS (SYMETRICAL IN DRIFT FLITE)

STORE THE DB'S FOR P-AXIS PHASE PLANE NOW, SET:
(PDB1) = (DBVAL1) = DB
(PDB2) = SAME
(PDB3) = (DBVAL1)+(FLAT)
(PDB4) = SAME
(PAXDIST) & (PAXDIST+1) = 0

IN POWERED FLIGHT AND NO GTS CONT. STORE OFFSET DB'S SET!

(FLAT) = 0 ?

NO → **DRFDB** (IN DRIFT OR GTS POWERED FLIGHT)

YES ↓

		PHASE PLANE	IN TERMS OF DB (.3°, 5° or 1°) ⊛ #1	#2	#3	#4	#5
U-AXIS	(FIREDB) = (UDB1)	DB1	DB	2 DB	DB	DB	DB
	(FIREDB+1) = (UDB2)	DB2	2 DB	DB	DB	DB	DB
	(COASTDB) = (UDB4)	DB4	DB	$-\frac{3}{4}$ DB	DB	1/2 DB	DB
	(COASTDB+1) = (UDB3)	DB3	$-\frac{3}{4}$ DB	DB	1/2 DB	DB	DB
	(AXISDIST) = (UAXDIST)	DB1-DB3	1.75 DB	DB	1/2 DB	0	0
	(AXISDIST+1) = (UAXDIST+1)	DB4-DB2	DB	1.75 DB	0	1/2 DB	0
V-AXIS	(FIREDB+16) = (DBB1)	DB1	S	S	S	S	S
	(FIREDB+17) = (DBB2)	DB2	A	A	A	A	A
	(COASTDB+16) = (DBB4)	DB4	M	M	M	M	M
	(COASTDB+17) = (DBB3)	DB3	E	E	E	E	E
	(AXISDIST+16) = (AXDSTEM)	DB1-DB3	↓	↓	↓	↓	↓
	(AXISDIST+17) = (AXDSTEM+1)	DB4-DB2					

↓

1/ACC RET +1

⊛ FOR THE CASES DEFINED BY:

#1 ABSAOS > AMIN, AOS IS (+)

#2 ABSAOS > AMIN, AOS IS (−)

#3 1/2 AMIN < ABSAOS < AMIN, AOS IS (+)

#4 1/2 AMIN < ABSAOS < AMIN, AOS IS (−)

#5 ABSAOS < 1/2 AMIN

SINCE IN DRIFT OR GTS CONTROL STORE SYMMETRICAL DB'S

DRFDB

DBVAL1 ≡ DB

SET:

			FOR	
(FIREDB)	=	(DBVAL1)	DB 1	U AXIS
(FIREDB+1)	=	"	DB 2	
(FIREDB+16)	=	"	DB 1	V AXIS
(FIREDB+17)	=	"	DB 2	
(COASTDB)	=	(DBVAL1)+(FLAT)	DB 4	U AXIS
(COASTDB+1)	=	"	DB 3	
(COASTDB+16)	=	"	DB 4	V AXIS
(COASTDB+17)	=	"	DB 3	
(AXISDIST)	=	0		U AXIS
(AXISDIST+1)	=	0		
(AXISDIST+16)	=	0		V AXIS
(AXISDIST+17)	=	0		

1/ACC RET +1

INHINT

B3 DAPBOOLS

SET ACCS OKAY BIT

ONLY RESET BY FRESH START -RESTART

ALL DONE NOW, DATA IS OK, SO DAP CAN USE 1/ACC TERMS

RELINT

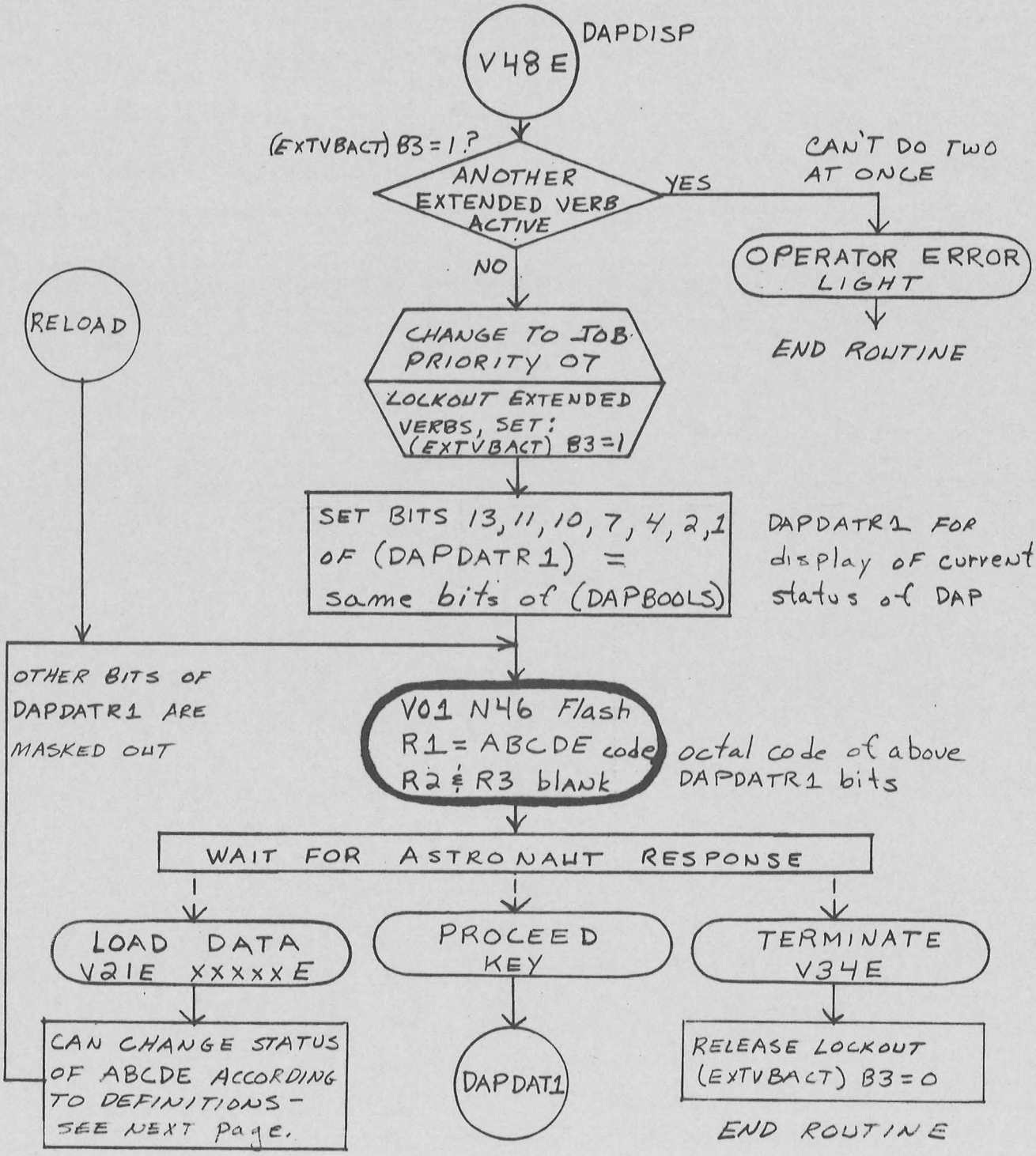
RETURN

TO THOSE WHO CALLED SO VALIANTLY

The DAP DATA LOAD routine (R03) is the primary astronaut interface with the LM Digital Autopilot. Its purpose is to:

a) provide a means for the crew to select various DAP response criteria
b) allow the crew to verify or update the vehicle masses (LM and CSM),
c) provide the capability for a manually initiated DPS engine trim.

This routine is selected manually from the DSKY by an extended verb entry (V48E).



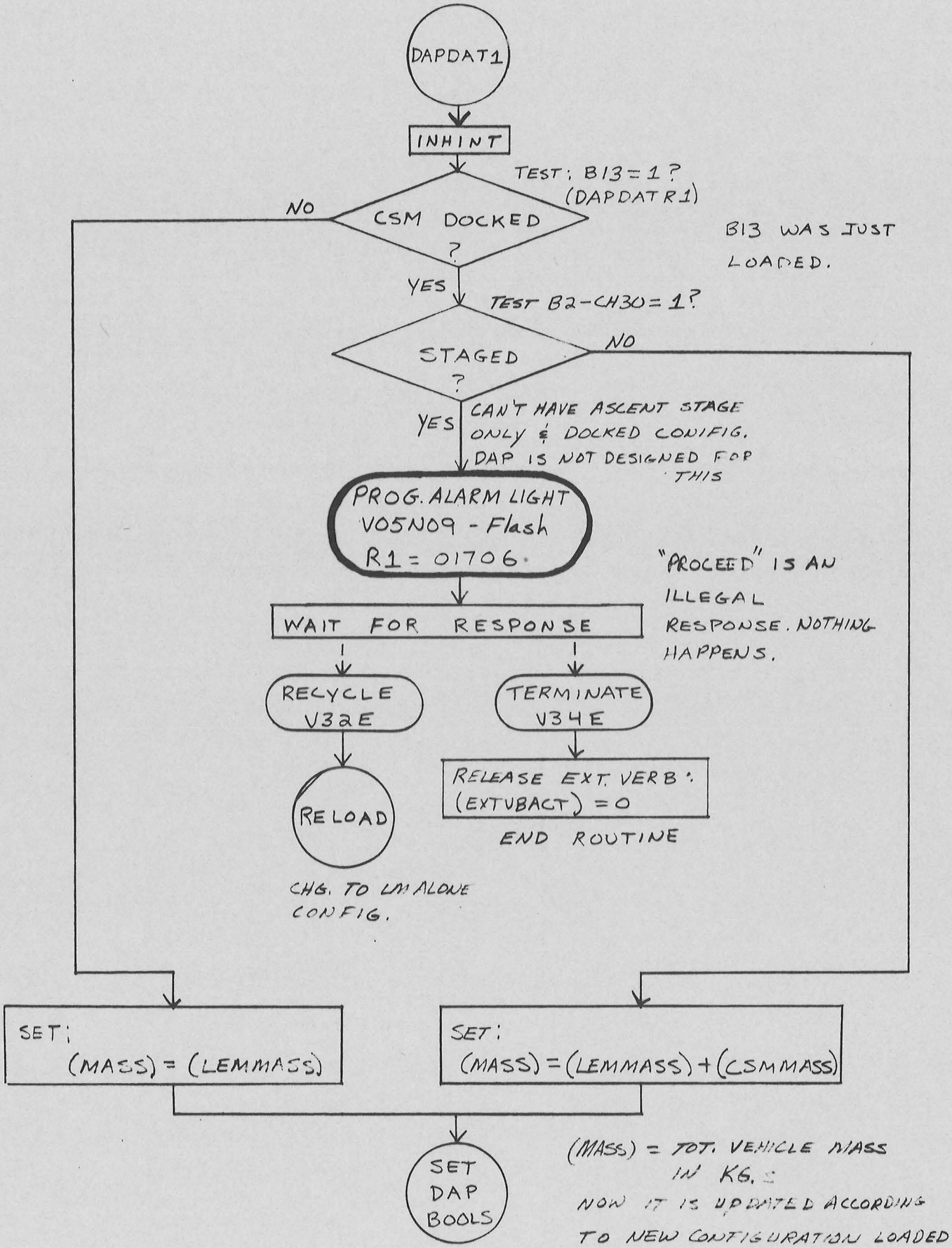
ASTRONAUT LOADED DAP RESPONSE DATA

Combinations for the ABCDE octal code

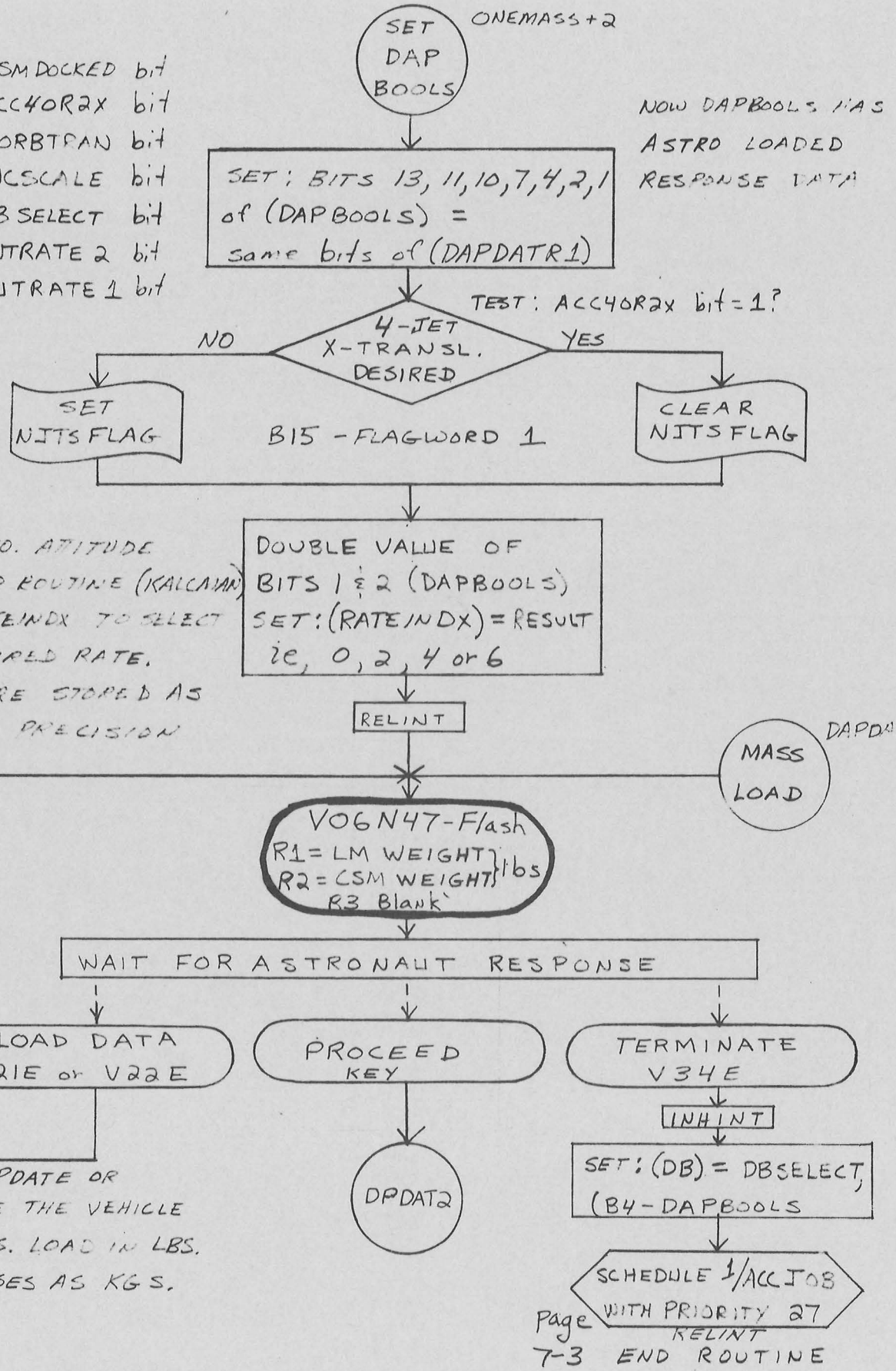
The ASTRONAUT CAN ENTER THE FOLLOWING NUMERICAL VALUES FOR EACH DIGIT TO DEFINE THE DESIRED RESPONSE (changes DAPDATR1 bits):

DIGIT	NO.		
A : VEHICLE CONFIGUATION			
(bit 13)	0	indicates	– LM ALONE CONFIGURATION
	1	"	– CSM DOCKED WITH LM (THIS IS THE ONLY METHOD TO TELL DAP THE CSM IS DOCKED)
B : X-TRANSLATION JET POLICY			
(bits 11,10)	0	indicates	– 2 JETS, FUEL sys. A
	1	"	– 2 JETS, FUEL sys. B
	2	"	– 4 JETS
C : SCALING FOR MANUAL RATE COMMAND			
(bit 7)	0	indicates	– LOW SCALE (4 DEG/SEC. MAX)
	1	"	– HIGH SCALE (20 DEG/SEC. MAX)
D : COASTING FLIGHT ATTITUDE DEADBAND			
(bit 4)	0	indicates	– 0.3 DEGREE DB
	1	"	– 5.0 DEGREE DB
E : AUTOMATIC ATTITUDE MANEUVER RATE			
(bits 1,2)	0	indicates	– 0.2 DEG./SEC.
	1	"	– 0.5 DEG./SEC.
	2	"	– 2.0 DEG./SEC.
	3	"	– 10.0 DEG./SEC

NOTE: Since each digit above is a 3 place binary number, numerical values up to 7 could be entered with only afecting the meaningful bits since the others are MASKED OUT (EX: FOR E, entering a 5 would be the same as entering a 1, etc). IT IS RECOMMENED TO USE THE ABOVE NO.S, HOWEVER.


DAPDAT1
INHINT
TEST: B13 = 1 ?
(DAPDAT R1)
CSM DOCKED ?
NO
YES
B13 WAS JUST LOADED.
TEST B2-CH30 = 1?
STAGED ?
NO
YES
CAN'T HAVE ASCENT STAGE ONLY & DOCKED CONIFIG. DAP IS NOT DESIGNED FOR THIS
PROG. ALARM LIGHT
V05N09 - Flash
R1 = 01706.
"PROCEED" IS AN ILLEGAL RESPONSE. NOTHING HAPPENS.
WAIT FOR RESPONSE
RECYCLE
V32E
TERMINATE
V34E
RELEASE EXT. VERB:
(EXTVBACT) = 0
END ROUTINE
RELOAD
CHG. TO LM ALONE CONFIG.
SET:
(MASS) = (LEMMASS)
SET:
(MASS) = (LEMMASS) + (CSMMASS)
SET DAP BOOLS
(MASS) = TOT. VEHICLE MASS IN KG.
NOW IT IS UPDATED ACCORDING TO NEW CONFIGURATION LOADED

B13 = CSMDOCKED bit
B11 = ACC4OR2X bit
B10 = AORBTRAN bit
B7 = RHCSCALE bit
B4 = DBSELECT bit
B2 = AUTRATE 2 bit
B1 = AUTRATE 1 bit



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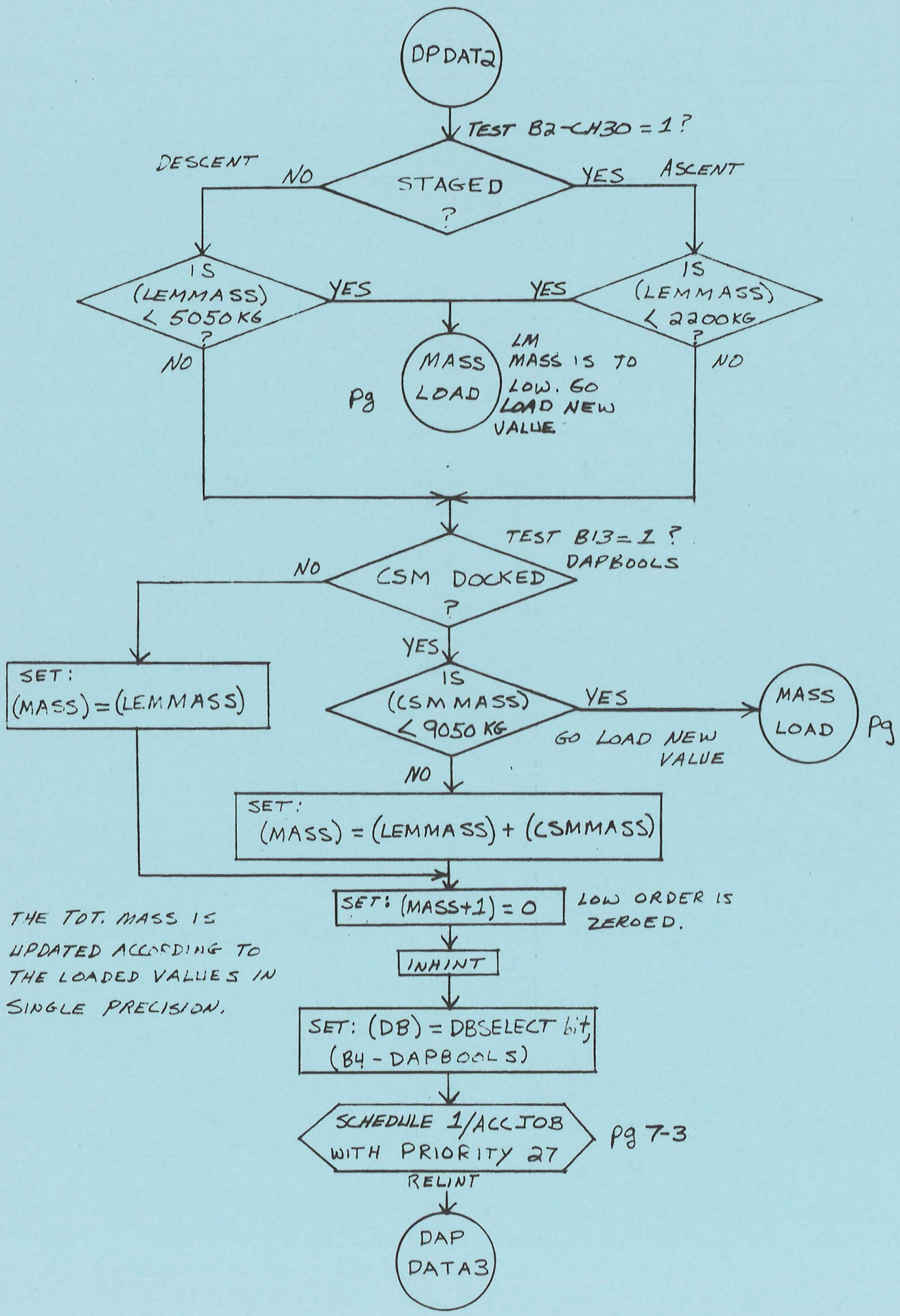
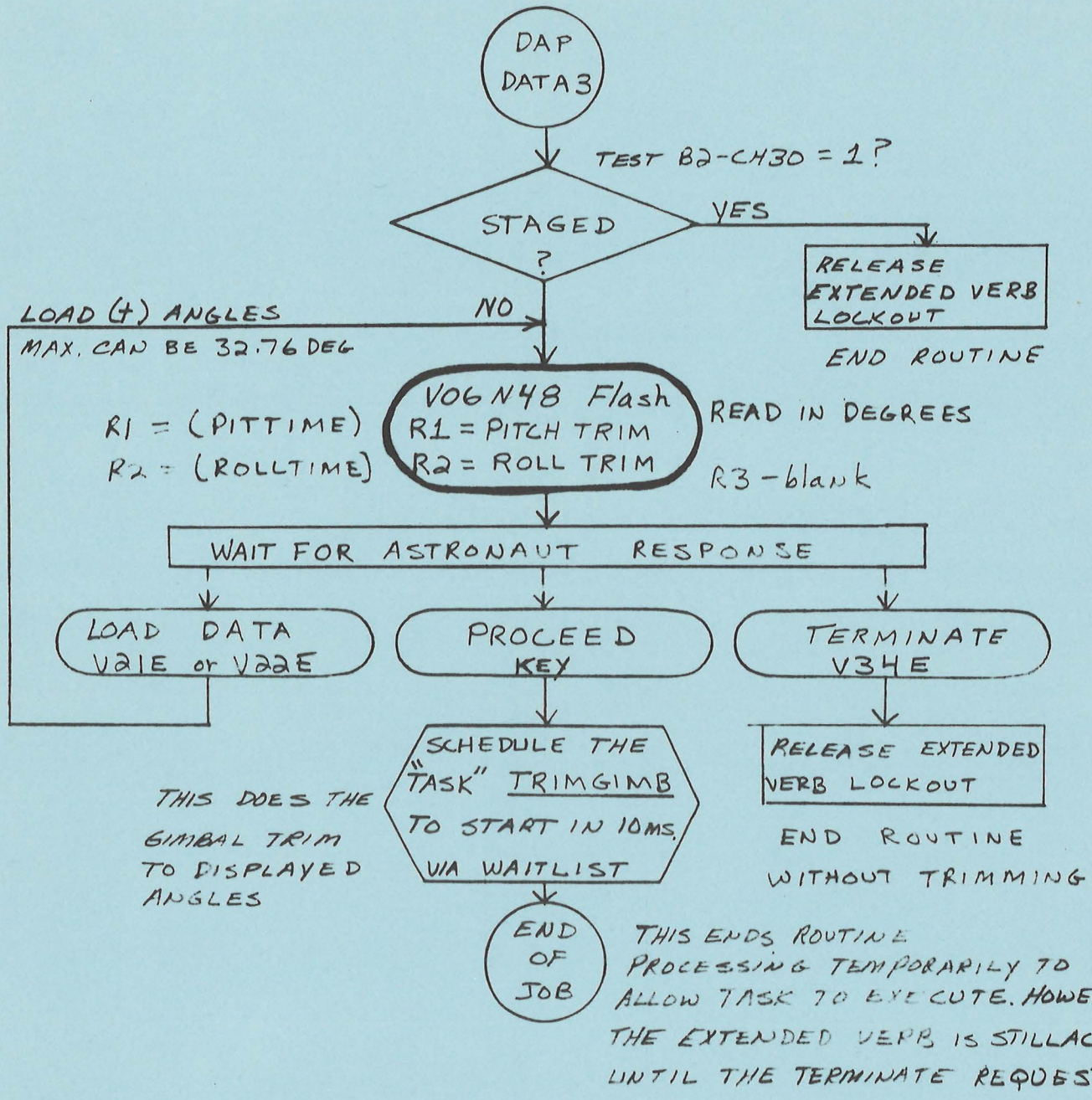

DPDAT2
TEST B2-CH30 = 1?
STAGED ?
DESCENT
NO
YES
ASCENT
IS (LEMMASS) < 5050 KG ?
YES
YES
IS (LEMMASS) < 2200 KG ?
NO
NO
MASS LOAD
Pg
LM MASS IS TO LOW. GO LOAD NEW VALUE
TEST B13 = 1 ? DAPBOOLS
CSM DOCKED ?
NO
YES
SET: (MASS) = (LEMMASS)
IS (CSM MASS) < 9050 KG
YES
MASS LOAD
Pg
GO LOAD NEW VALUE
NO
SET: (MASS) = (LEMMASS) + (CSMMASS)
SET: (MASS+1) = 0
LOW ORDER IS ZEROED.
THE TOT. MASS IS UPDATED ACCORDING TO THE LOADED VALUES IN SINGLE PRECISION.
INHINT
SET: (DB) = DBSELECT bit, (B4 - DAPBOOLS)
SCHEDULE 1/ACCJOB WITH PRIORITY 27
Pg 7-3
RELINT
DAP DATA3



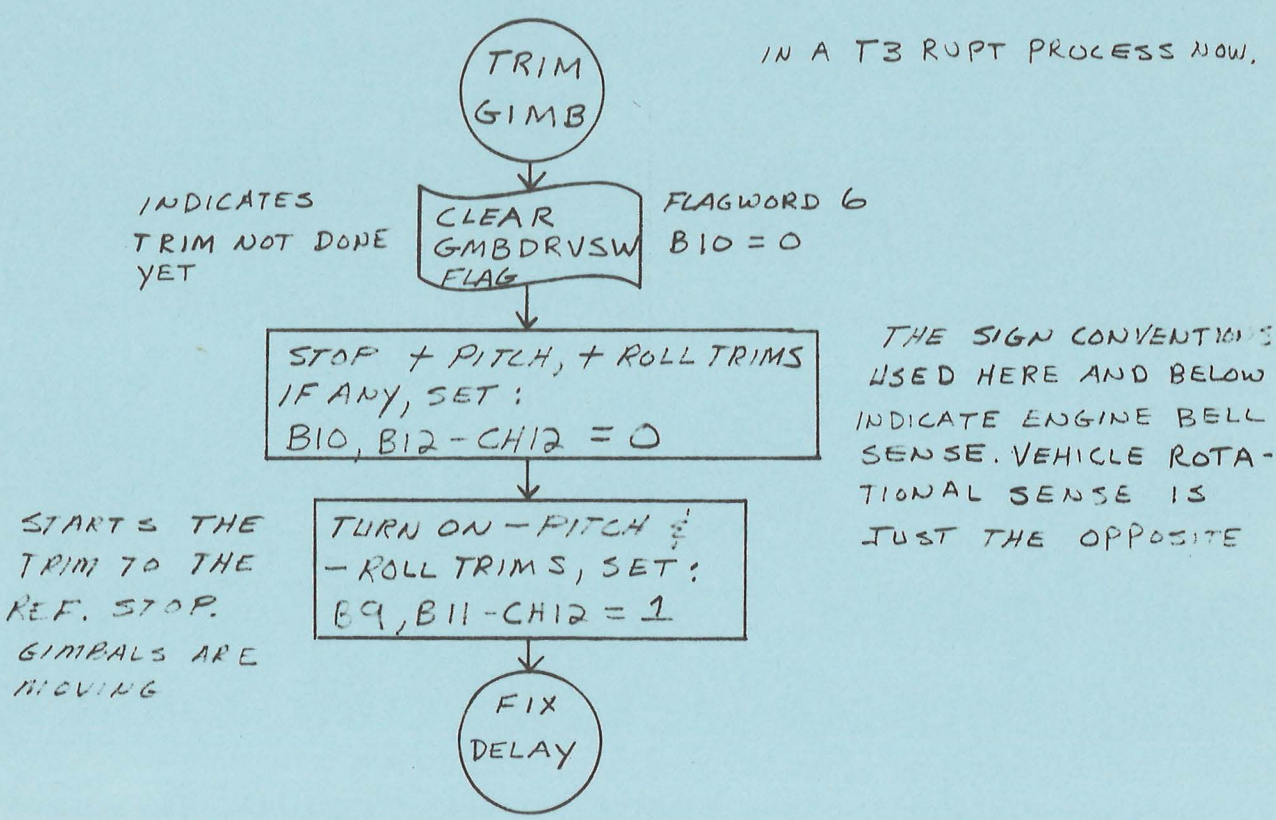
NOTE:

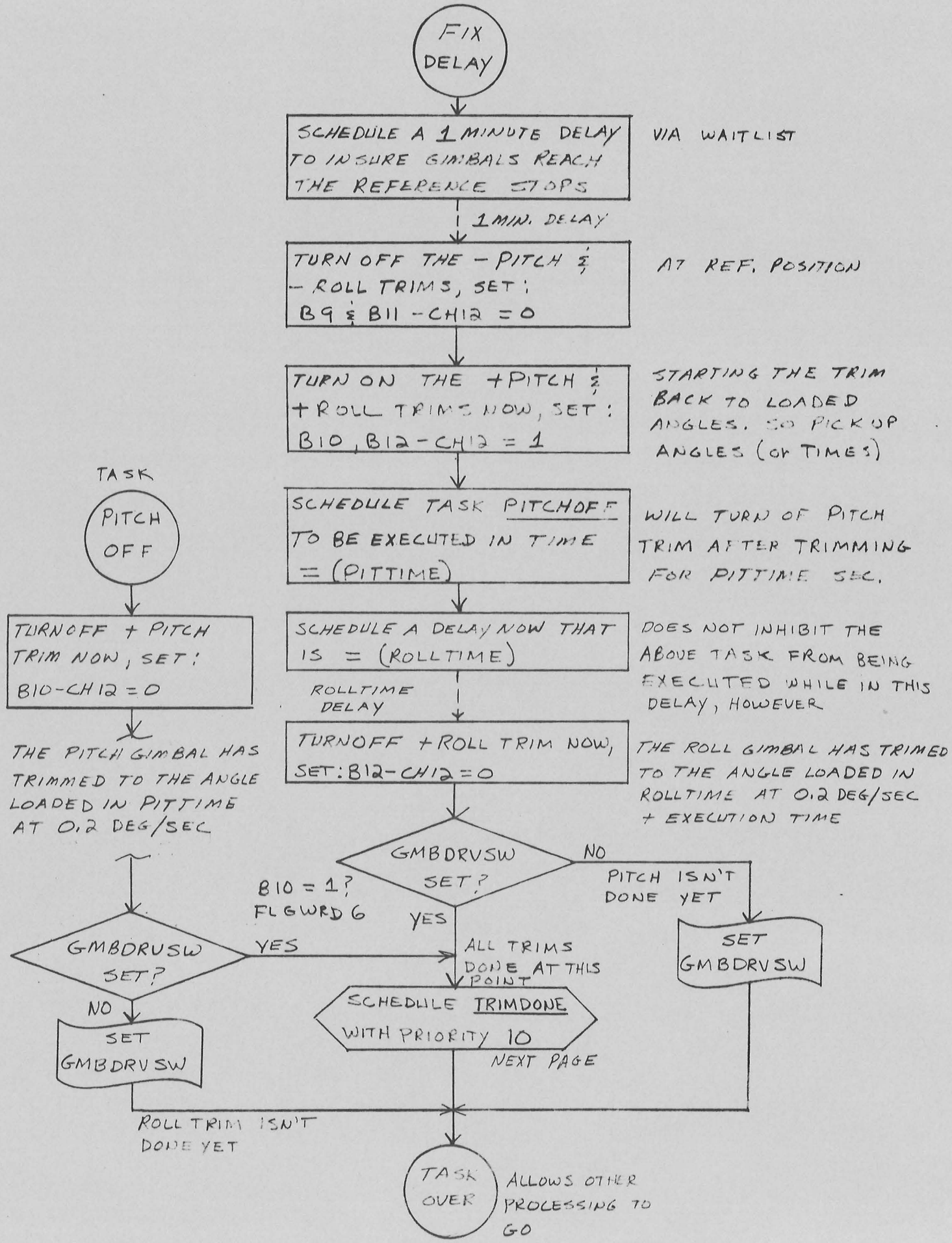
THE TRIM ANGLE DISPLAYS ARE READ AND LOADED AS THE NO. OF DEGREES THE ENGINE BELL IS FROM ITS (−) STOPS OR THE (+) VEHICLE PITCH/ROLL SENSE (USING RIGHT HAND RULE WITH VEHICLE AXES). PITTIME & ROLLTIME ARE PAD LOADED ERASEABLES AND ARE THE DISPLAYED VALUES. THUS, THEY ARE CHANGED ACCORDING TO THE LOAD. THE LGC TREATS THESE VALUES AS TIMES, NOT ANGLES, BY ASSUMING A CONSTANT TRIM RATE OF 0.2 DEG/SEC. THUS, THE ACTUAL TRIMMING IS A "TIMED" OPERATION USING THE LOADED VALUES IN PITTIME & ROLLTIME (INHERENTLY THE NO. OF DEG./0.2 = SEC).

NEXT PAGE

PITTIME & ROLLTIME ARE ONLY CHANGED VIA A MANUAL LOAD, EITHER VIA DSKY OR UPLINK. THE TRIM LOOPS ARE OPEN LOOPS, THUS, THERE IS NO WAY TO UPDATE THESE VALUES AS THE ENGINE IS BEING TRIMMED. THE LGC CAN ONLY ASSUME THE BELL IS POSITIONED ACCORDINGLY AND THE ASTRONAUT CAN ONLY ASSUME THIS ALSO. THEIR IS NO DISPLAY TO TELL ACTUAL POSITION.

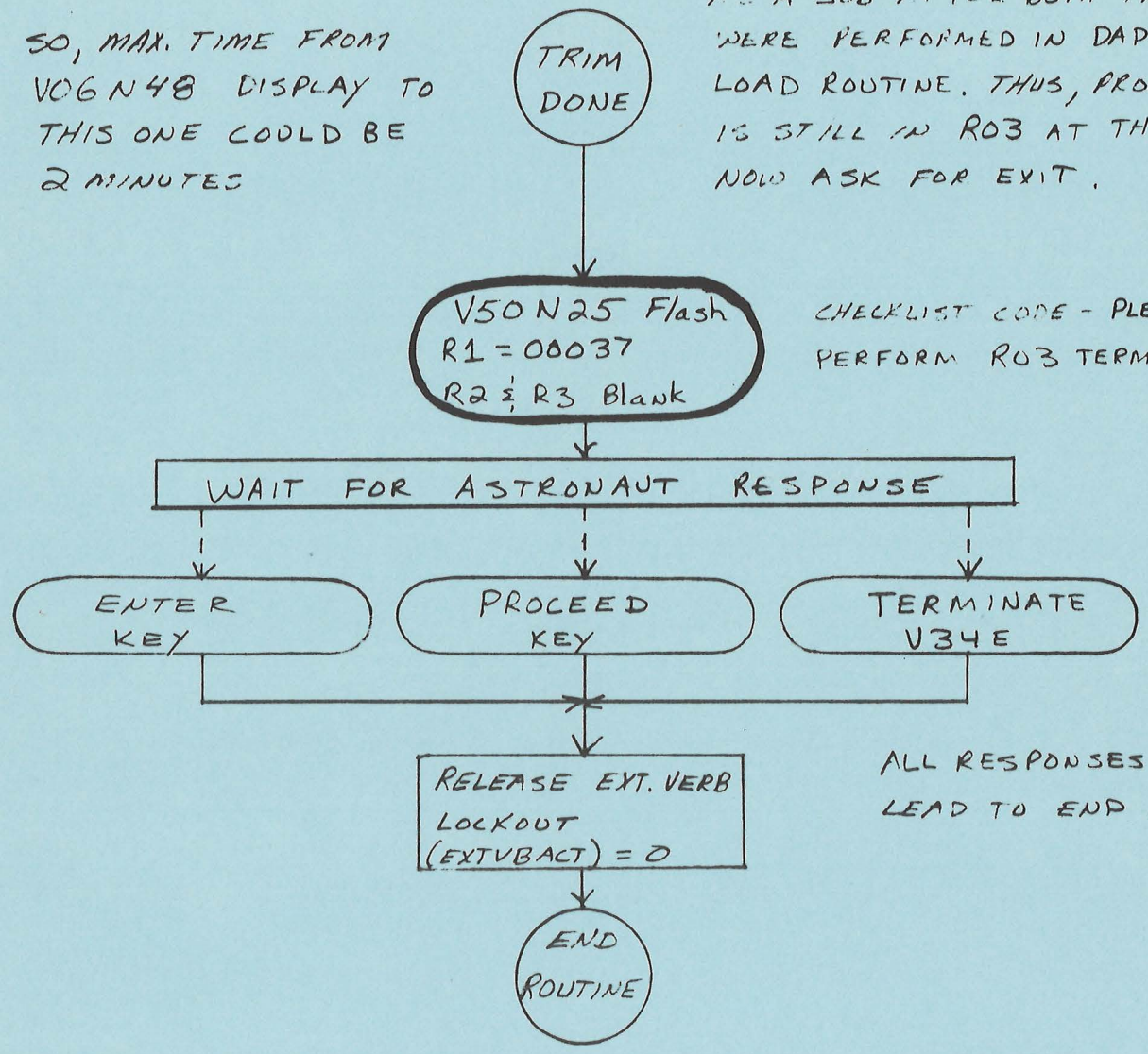
THE TRIM TASK, <u>TRIMGIMB</u>, WILL ALWAYS POSITION THE BELL TO THE (−) TRIM STOPS FOR A REFERENCE BEFORE TRIMMING TO THE SPECIFIED (LOADED) ANGLES. ONE MINUTE IS SCHEDULED FOR THIS REFERENCE DRIVE. THUS, IF THE GIMBAL(S) WAS AT THE OTHER STOP (12 DEG. AWAY), ONE MINUTE WOULD BRING IT JUST TO THE REF. OR (−) STOP (12 DEG / 0.2 $\frac{DEG}{SEC}$ = 60 SEC). IF, FOR SOME REASON, IT IS DESIRED TO TRIM TO THE (+) TRIM STOP, THE TOT. OF 12 DEG WOULD BE LOADED AND THE TOT. TIME FOR TRIMMING WOULD BE 120 SEC. (60 SEC FOR REF. AND 60 SEC FOR THE MAX. TRIM). REMEMBER! BOTH GIMBALS HAVE A MAX. EXCURSION OF 12 DEG or ± 6 DEG FROM THE X-AXIS. THUS, OPERATIONALLY, ONLY ANGLES BETWEEN 0 − 12 DEG. WILL BE LOADED. ANYTHING GREATER WOULD HAVE THE SAME EFFECT AS 12 DEG. NORMALLY, THE BELL WILL BE POSITION CLOSE TO THE X-AXIS or NULL LINE WHICH IS A +6 DEG LOAD.




FIX DELAY
SCHEDULE A 1 MINUTE DELAY TO INSURE GIMBALS REACH THE REFERENCE STOPS
VIA WAITLIST
1 MIN. DELAY
TURN OFF THE -PITCH & -ROLL TRIMS, SET: B9 & B11 -CH12 = 0
AT REF. POSITION
TURN ON THE +PITCH & +ROLL TRIMS NOW, SET: B10, B12 -CH12 = 1
STARTING THE TRIM BACK TO LOADED ANGLES. SO PICK UP ANGLES (OR TIMES)
SCHEDULE TASK PITCHOFF TO BE EXECUTED IN TIME = (PITTIME)
WILL TURN OF PITCH TRIM AFTER TRIMMING FOR PITTIME SEC.
SCHEDULE A DELAY NOW THAT IS = (ROLLTIME)
DOES NOT INHIBIT THE ABOVE TASK FROM BEING EXECUTED WHILE IN THIS DELAY, HOWEVER
ROLLTIME DELAY
TURNOFF +ROLL TRIM NOW, SET: B12-CH12 = 0
THE ROLL GIMBAL HAS TRIMED TO THE ANGLE LOADED IN ROLLTIME AT 0.2 DEG/SEC + EXECUTION TIME
TASK
PITCH OFF
TURNOFF +PITCH TRIM NOW, SET: B10-CH12 = 0
THE PITCH GIMBAL HAS TRIMMED TO THE ANGLE LOADED IN PITTIME AT 0.2 DEG/SEC
GMBDRVSW SET?
NO
PITCH ISN'T DONE YET
SET GMBDRVSW
B10 = 1? FLGWRD 6
YES
GMBDRVSW SET?
YES
ALL TRIMS DONE AT THIS POINT
NO
SET GMBDRVSW
SCHEDULE TRIMDONE WITH PRIORITY 10
NEXT PAGE
ROLL TRIM ISN'T DONE YET
TASK OVER
ALLOWS OTHER PROCESSING TO GO

SO, MAX. TIME FROM V06N48 DISPLAY TO THIS ONE COULD BE 2 MINUTES

ENTRY HERE WAS SCHEDULED AS A JOB AFTER BOTH TRIMS WERE PERFORMED IN DAP DATA LOAD ROUTINE. THUS, PROCESSING IS STILL IN R03 AT THIS POINT. NOW ASK FOR EXIT.



CHECKLIST CODE - PLEASE PERFORM R03 TERMINATION

ALL RESPONSES LEAD TO END R03

TABLE I

LM DAP FLAGS AND DEFINITIONS

Tag (Bit/Location)	Meaning: Set	Meaning: Cleared
ACC4OR2X (11/DAPBOOLS)	X-axis translation to use 4 jets.	X-axis translation to use 2 jets.
ACCSET	1/ACCS has been set up since the last fresh start or restart.	1/ACCS must be set up in DAPIDLER.
ACCSOKAY (3/DAPBOOLS)	Control-authority values from 1/ACCS usable.	Restart or fresh start since last 1/ACCS; outputs suspect.
ACCSWU ACCSWV	+1 or -1 indicates 1-jet acceleration less than $\pi/2^7$ rad/sec^2 in rotational sense corresponding to sign.	0 indicates 1-jet control authority in both directions exceeds the minimum. Can use 1-jet.
ALLOWGTS	Thrust offset small enough to use GTS for attitude control.	Thrust offset too large to use GTS for attitude control.
AORBSYST (5/DAPBOOLS)	Prefer P-axis jet couples 7, 15 and 8, 16 (not related to fuel systems).	Prefer P-axis couples 4, 12 and 3, 11.
AORBTRAN (10/DAPBOOLS)	Prefer B-system jets for X translation. (Fuel system)	Prefer A-system jets for X translation.
APSFLAG (12/FLAGWRD1)	LM stages or on lunar surface.	LM unstaged and not on lunar surface
AUTRATE1 AUTRATE2 (1/DAPBOOLS) (2/DAPBOOLS)	KALCMANU maneuver rates chosen by crew: 00 indicates 0.2 deg/sec 01 indicates 0.5 deg/sec 10 indicates 2.0 deg/sec 11 indicates 10.0 deg/sec	
CH5MASK CH6MASK	Jets which have been disabled by crew; in channel 5(6) format.	
COTROLER	Indicator of control system employed in current DAP pass: = 0 indicates attempt to use GTS; LM-alone case. > 0 indicates attempt to use GTS; CSM-docked case. < 0 indicates RCS to be used (Q, R-Axis Autopilot.)	
CSMDOCKD (13/DAPBOOLS	CSM docked to LM.	CSM not attached to LM.

TABLE I - APPENDIX A

TABLE I

LM DAP FLAGS AND DEFINITIONS (CONT)

Tag Bit/Location	Meaning: Set	Meaning: Cleared
DAPBOOLS	Autopilot flag word containing the following bits: Bit 1 - AUTRATE1 Bit 2 - AUTRATE2 Bit 3 - ACCSOKAY Bit 4 - DBSELECT Bit 5 - AORBSYST Bit 6 - ULLAGER Bit 7 - RCHSCALE Bit 8 - DRIFTBIT Bit 9 - LPDPHASE (XOVINHIB) Bit 10 - AORBTRAN Bit 11 - ACC4OR2X Bit 12 - OURRCBIT Bit 13 - CSMDOCKD Bit 14 - USEQRJTS Bit 15 - PULSES	individually defined in the table
DBSELECT (4/DAPBOOLS)	Maximum (5.0 deg) deadband selected by crew.	Minimum (0.3 deg) deadband selected by crew.
DRIFTBIT (8/DAPBOOLS)	Null offset acceleration estimate.	Use offset acceleration estimate.
INGTS	GTS presently controlling attitude.	RCS presently controlling attitude.
LPDPHASE (9/DAPBOOLS)	X-axis override locked out	X-axis override permitted.
NEXTP NEXTU NEXTV	Jets to be turned on (for translation) at the end of the corresponding rotation in channel 5(6) format.	
OURRHCBIT (12/DAPBOOLS)	Current DAP pass is rate command.	Current DAP pass is not rate command.
PJUMPADR	Controls skip of P-rotation evaluation after a short P-axis firing.	
PULSES (15/DAPBOOLS)	Minimum impulse command mode in "Att hold" (Verb 76).	Not minimum-impulse command mode (Verb 77).
RHCSCALE (7/DAPBOOLS)	High (20-deg/sec) rotational-hand-controller scaling selected by crew.	Low (4 deg/sec) rotational-hand-controller scaling selected by crew.

TABLE I - APPENDIX A

TABLE I

LM DAP FLAGS AND DEFINITIONS (CONT)

Tag Bit/Location	Meaning: Set	Meaning: Cleared
SENSETYP	X-translational sense desirable during U and V rotations: 0 indicates balanced couples 1 indicates -X translational sense 2 indicates +X translational sense TJETLAW requires SENSETYP = 0 for P axis	
SKIPU SKIPV	4 indicates RCS control about the corresponding axis is to be exercised in the current DAP pass.	0 indicates RCS control about the corresponding axis is not to be re-evaluated in the current DAP pass because a short (< 150 millisec), non-zero firing was started in the last pass.
SURFFLAG (8/FLAGWRDS)	On the lunar surface (never set in SUNDANCE missions).	Not on the lunar surface.
ULLAGER (6/DAPBOOLS)	Ullage requested by mission program.	No internal ullage request.
USEQRJTS (14/DAPBOOLS)	Trim gimbal unusable; use jets only.	DPS Engine Gimbals may be used for trim.
XOVINHIB (9/DAPBOOLS)	(Same as LPDPHASE)	

TABLE I - APPENDIX A