MASSACHUSETTS INSTITUTE OF TECHNOLOGY

APOLLO

GUIDANCE, NAVIGATION AND CONTROL

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APOLLO GUIDANCE AND NAVIGATION PROGRAM

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APOLLO GUIDANCE AND NAVIGATION PROGRAM

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CHARLES STARK DRAPER LABORATORY

E-2471
(Rev. 2)
Volume II of II

APOLLO GUIDANCE AND NAVIGATION

FLOWCHARTS

PROGRAM LUMINARY 1D
(Rev. 173)
JUNE 1970

MIT CHARLES STARK DRAPER LABORATORY
CAMBRIDGE, MASSACHUSETTS, 02139

ACKNOWLEDGEMENT

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Foreword

This document comprises all flowcharts completed by the date of publication for Luminary 1D programs, routines, and subroutines. (Reference Exhibit D, Paragraph 3.3, of M.I.T. Statement of Work, NAS 9-4065, period 1 January 1968 - 30 June 1970.)

Those flowcharts not completed and not included within the current edition are denoted by an asterisk on the table of contents. As they become available, newly completed flowcharts will be forwarded for inclusion, with an updated contents and index. The index to the present volume is an alphabetical listing of flag bits, subroutines, and major entries. In addition to the flowchart and sheet number for each entry, the index gives the flowchart and sheet number where each flag bit is set (S), cleared (C), or tested (T).

Jack C. Reed
Jack C. Reed
Group Leader
Apollo Documentation

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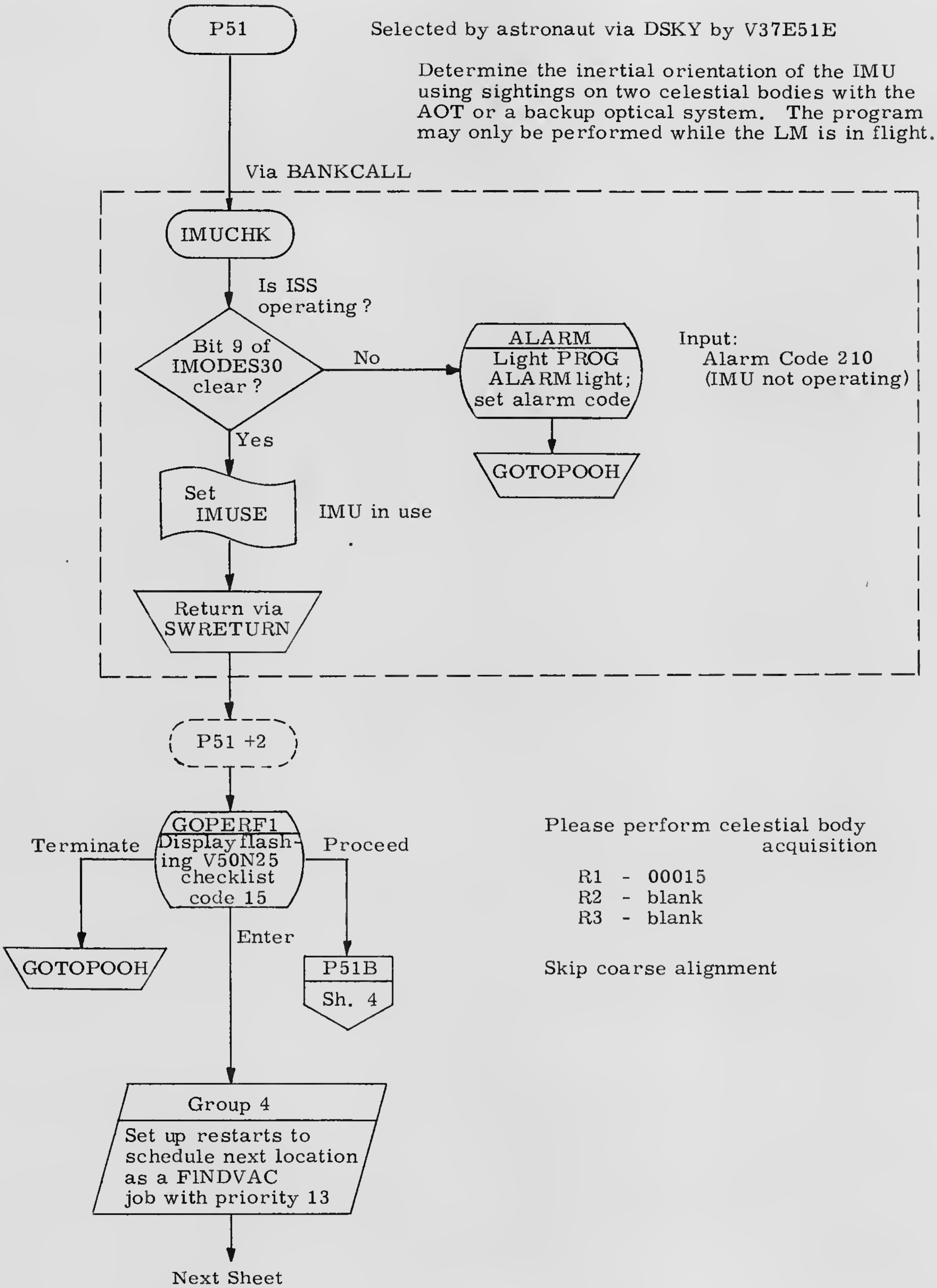
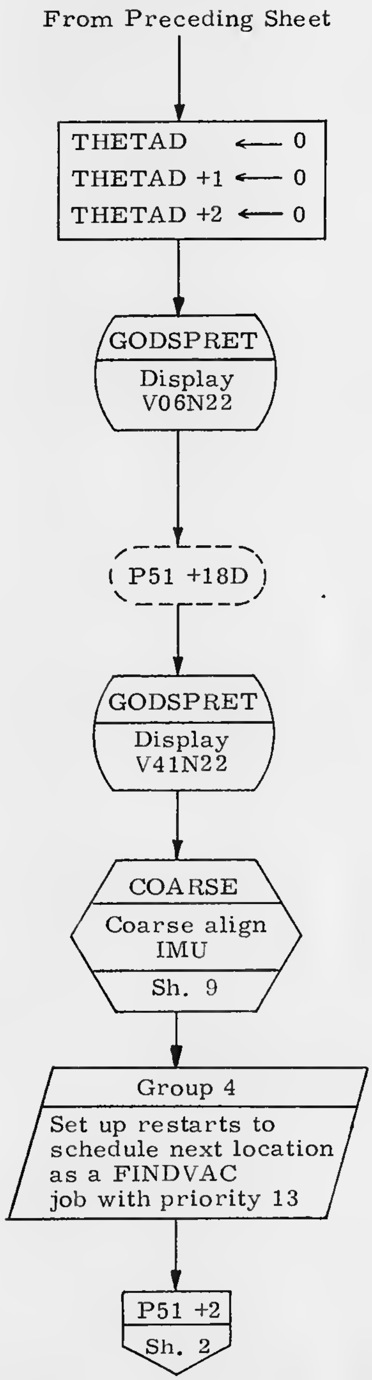
9.0 ALIGNMENT PROGRAMS

IMU Orientation Determination

P51	IMU Orientation Determination Program	Sh. 2
IMUCHK	Make sure ISS is running	Sh. 2
NCOARSE	Initiate gyro compensation	Sh. 4
COARSE	Coarse align IMU	Sh. 9
PLANET	Provide reference vector for sighted celestial body	Sh. 11



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lutkinich	8/27/69	P51 IMU Orientation Determination	
PRGMR D. Millard	9/5/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3500
DOCMR			
APPR'D Roberta M. Entry	9-9-69	REV 2	SHEET 2 OF 24



Zero the desired gimbal angles

Display Noun 22: desired CDU angles

R1 = 000.00 deg (THETAD)

R2 = 000.00 deg (THETAD +1)

R3 = 000.00 deg (THETAD +2)

Now display V41:

coarse align CDU's

Coarse align and return to fine align mode

Input:

THETAD, THETAD +1, THETAD +2: desired IMU gimbal angles

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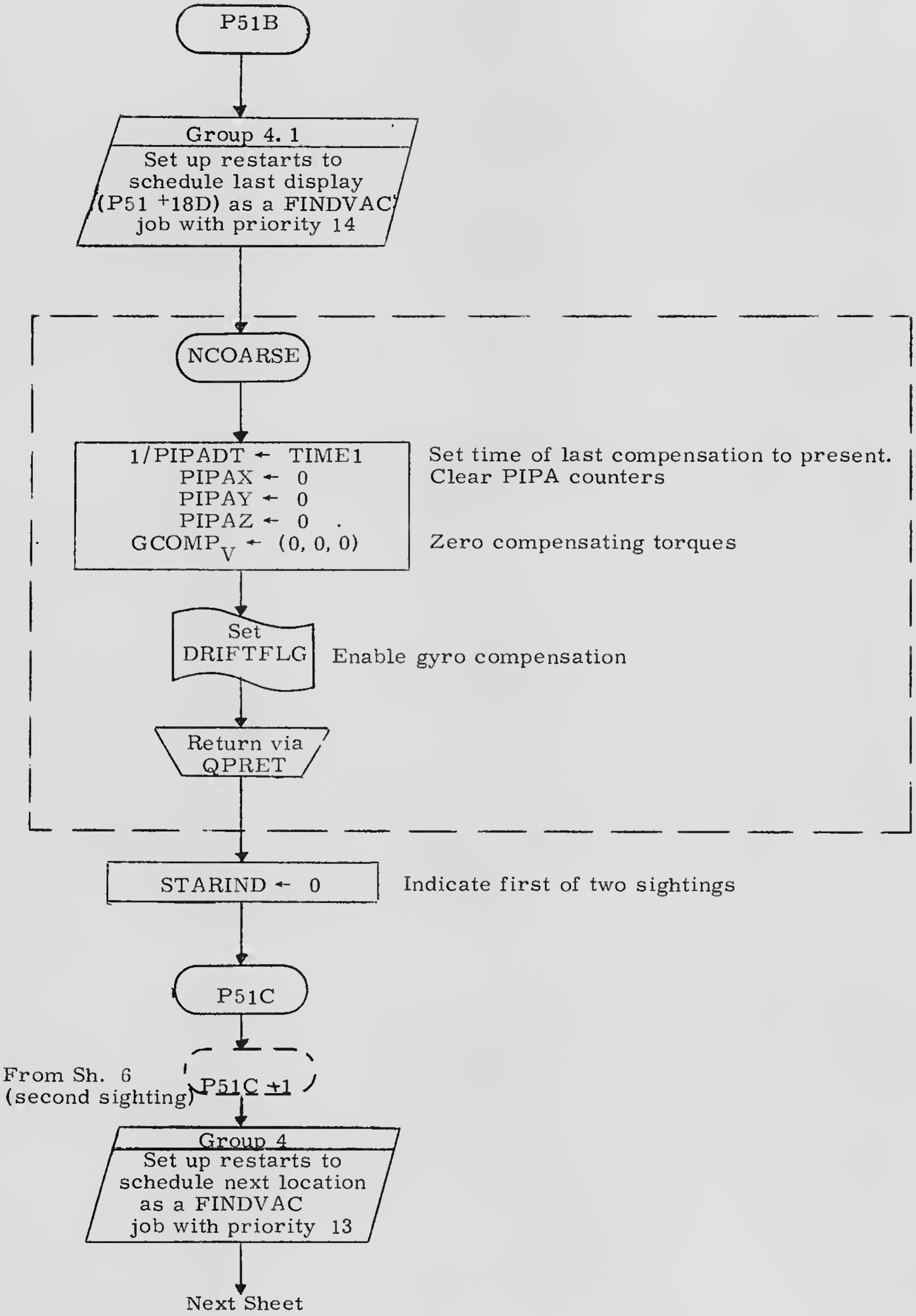

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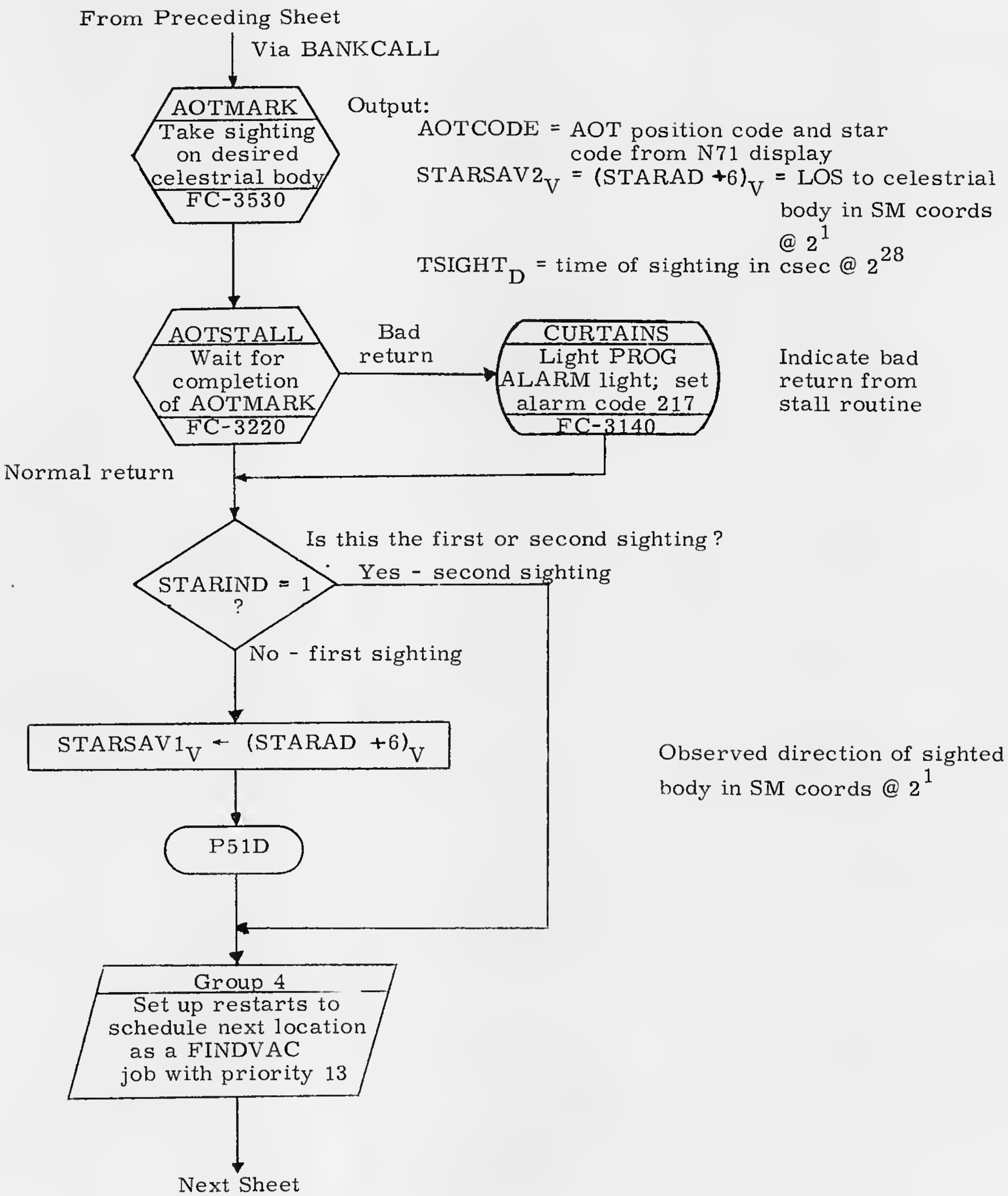

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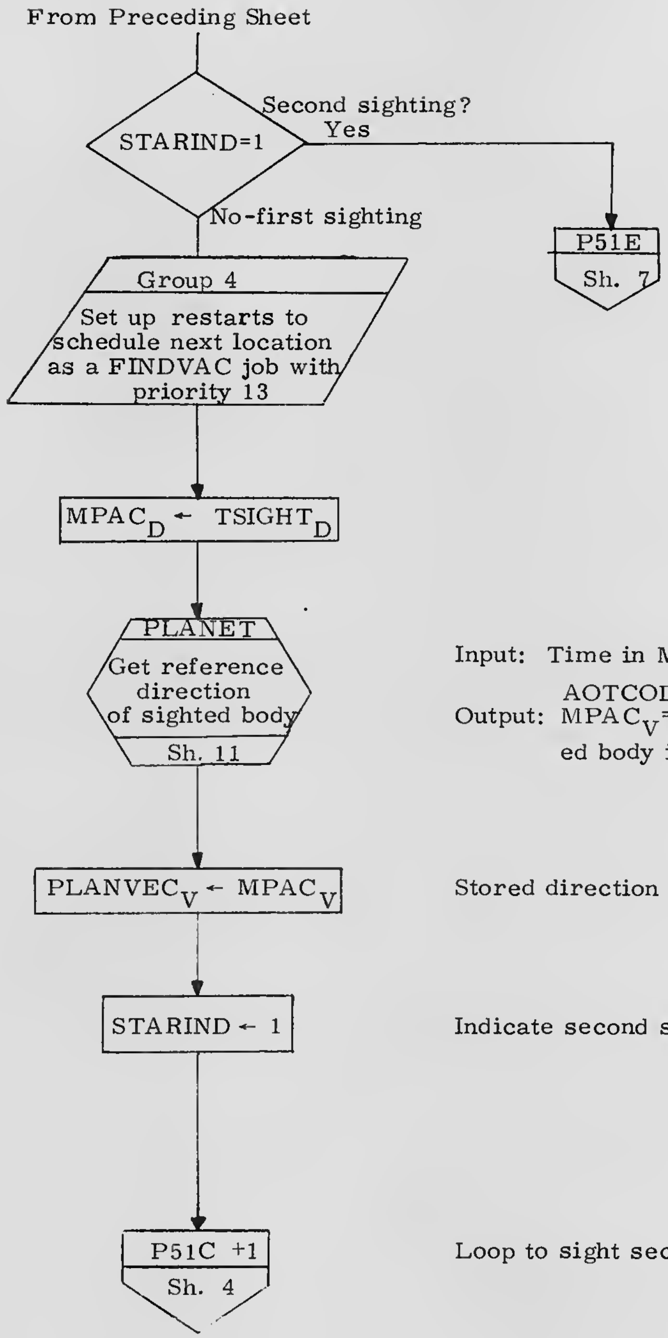


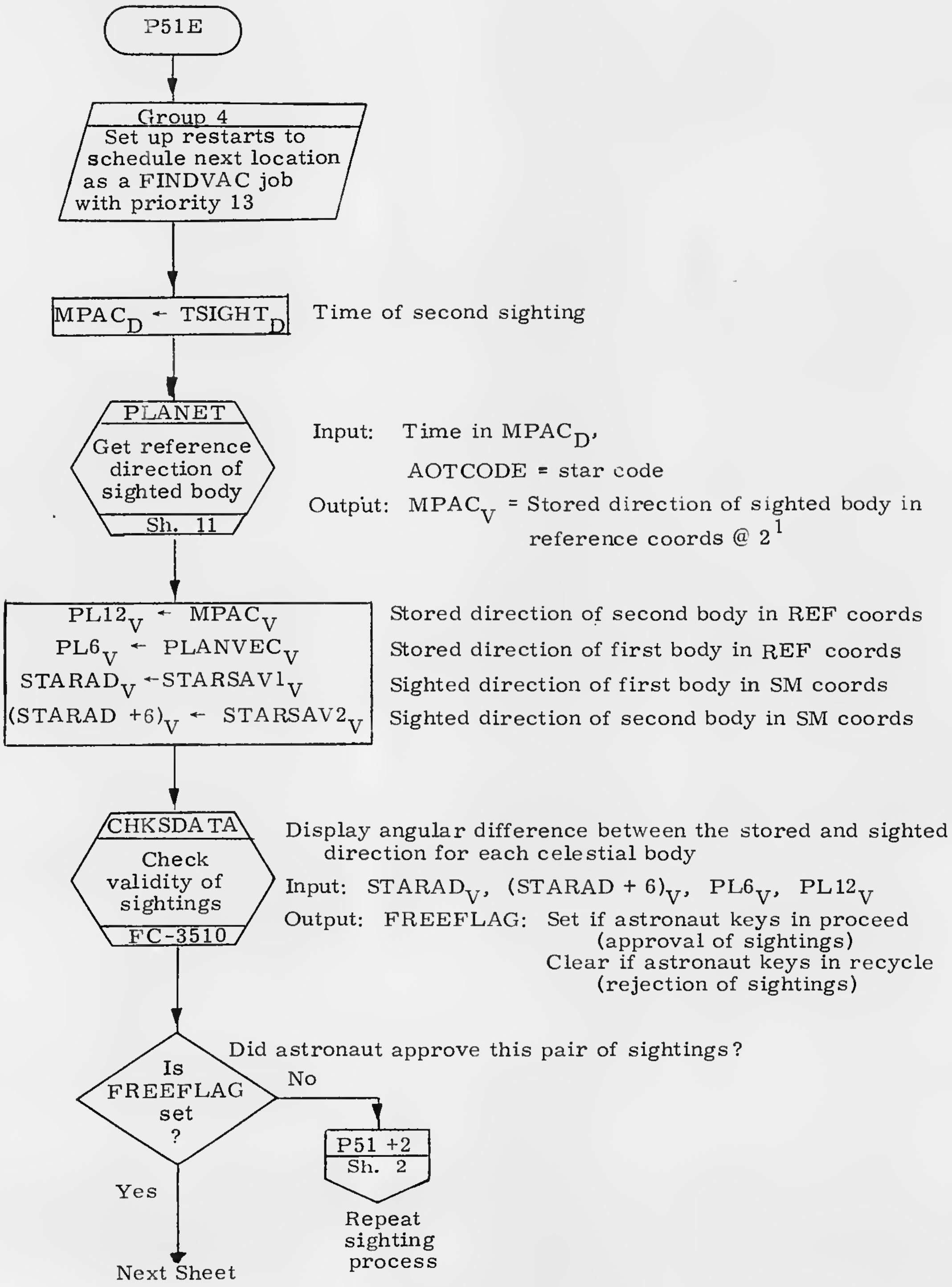
Input: Time in $MPAC_D$,
AOTCODE = star code

Output: $MPAC_V$=stored direction of sighted body in reference coords @ 2^1

Stored direction of first sighted body

Indicate second sighting to be done

Loop to sight second celestial body



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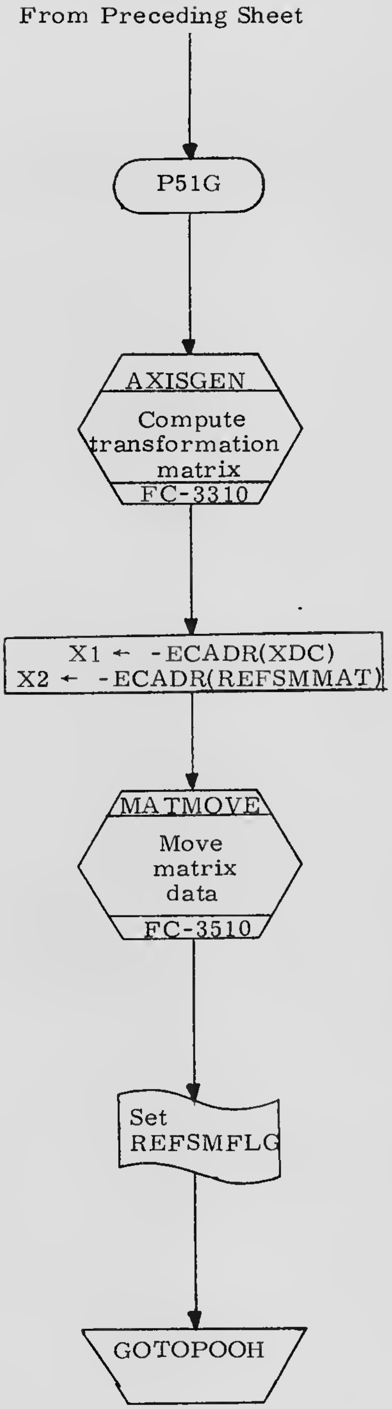

Calculate IMU inertial orientation W.R.T celestial coordinates as defined by celestial bodies #1 and #2

Input: Sighted star vectors in SM coords in $STARAD_V$, $(STARAD+6)_V$; catalogued star vectors in $PL6_V$, $PL12_V$ in ref coords

Output: $XDC_M = \begin{pmatrix} XDC_V \\ YDC_V \\ ZDC_V \end{pmatrix} =$ Transformation matrix between REFGRENCE and SM coordinate systems

Prepare inputs to MATMOVE

Input: X1 = -ECADR(matrix to be moved)
X2 =-ECADR (matrix to be stored into)

Result: $REFSMMAT_M \longleftarrow XDC_M$

REFSMMAT is valid

Terminate program

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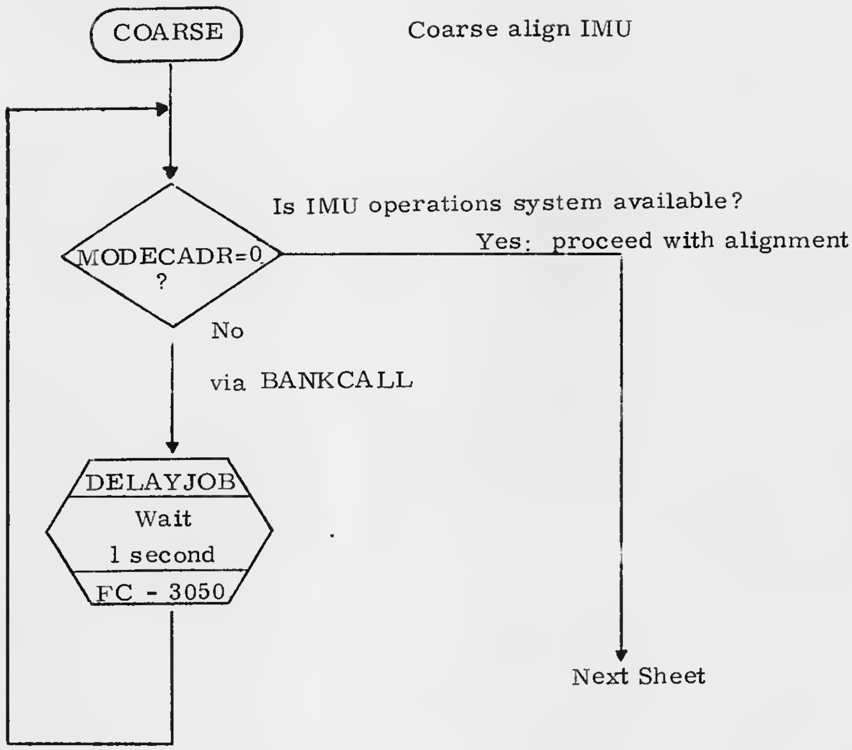

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DRAWN	L. Goldstone	8/27/69	P51 IMU Orientation Determination	
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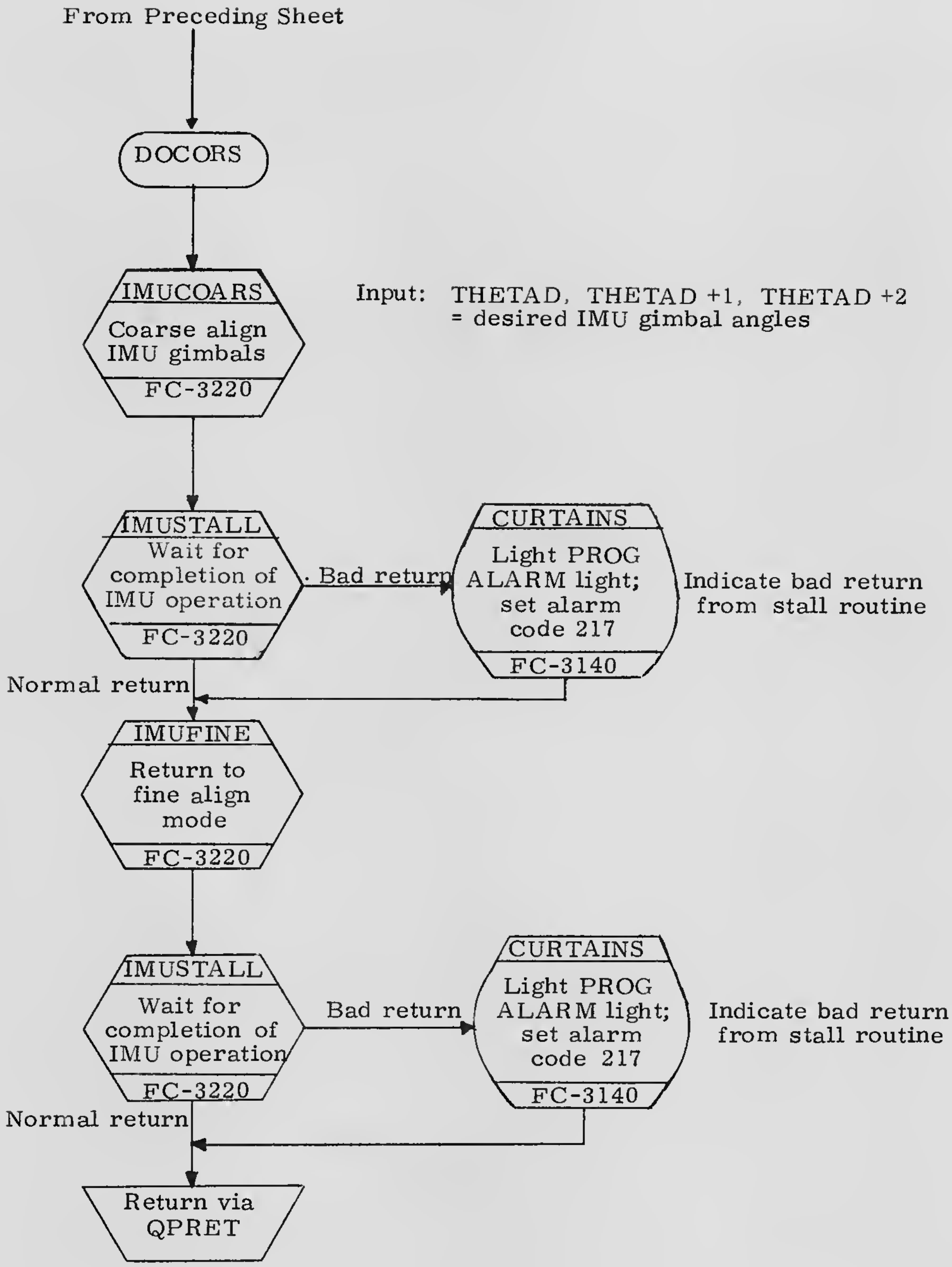
APPR'D	Robert M. Estes	9-9-69	REV 2	SHEET 9 OF 24



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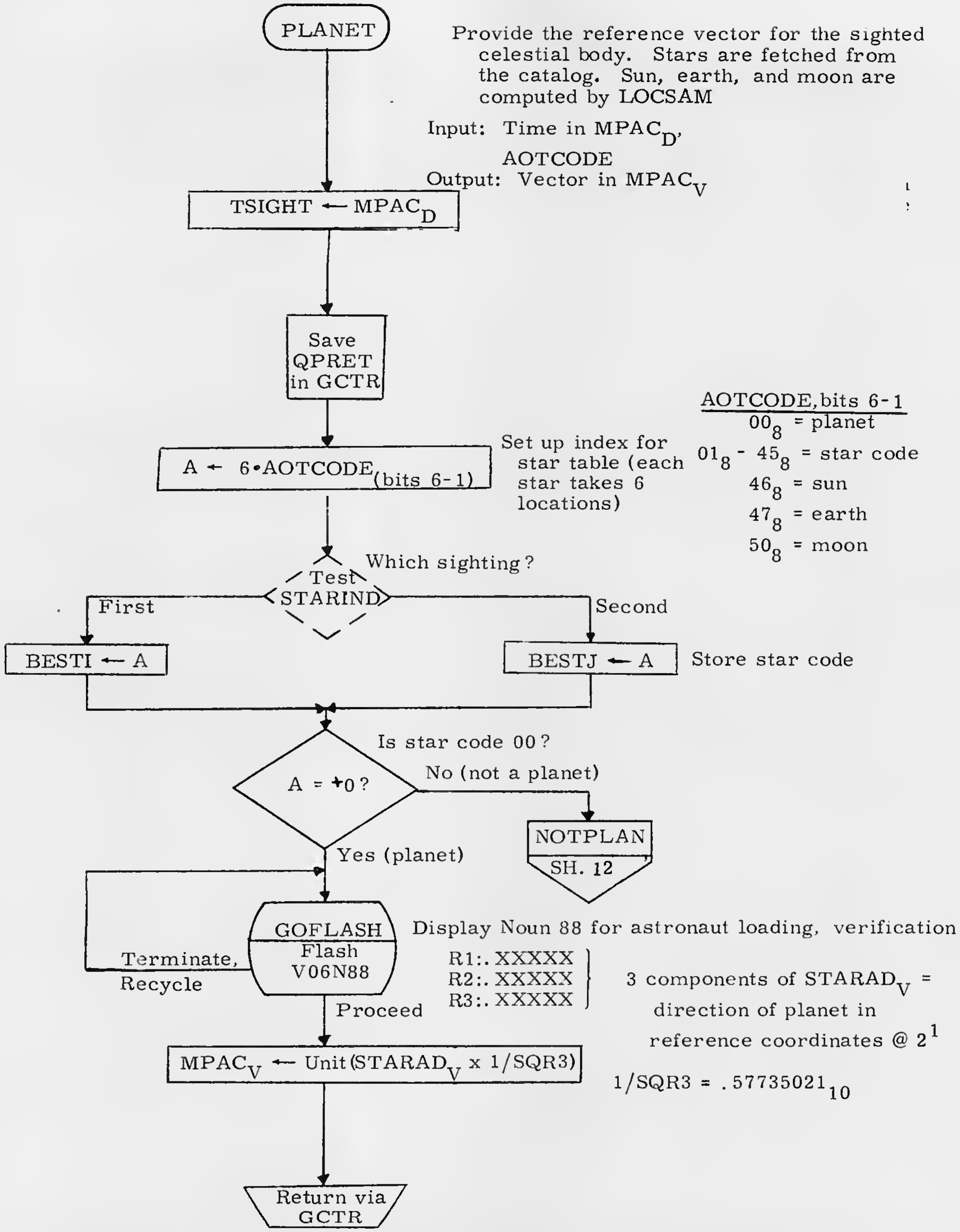

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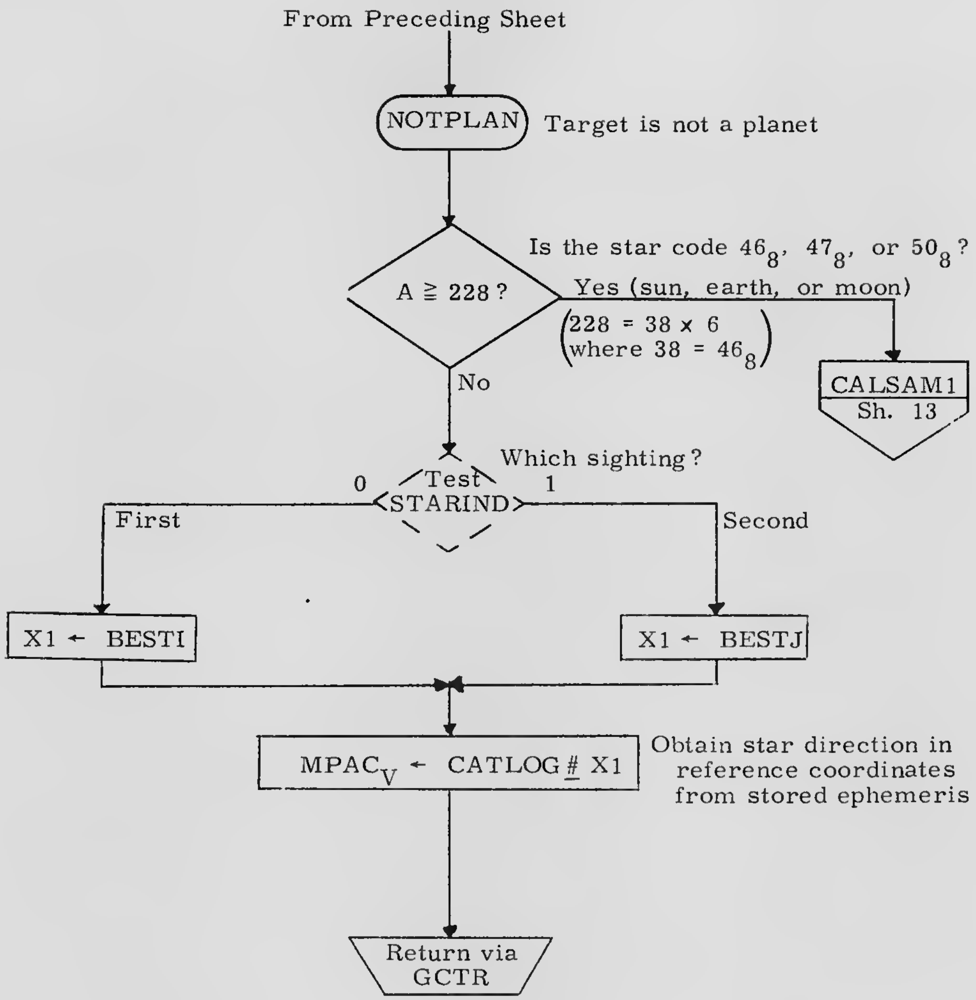
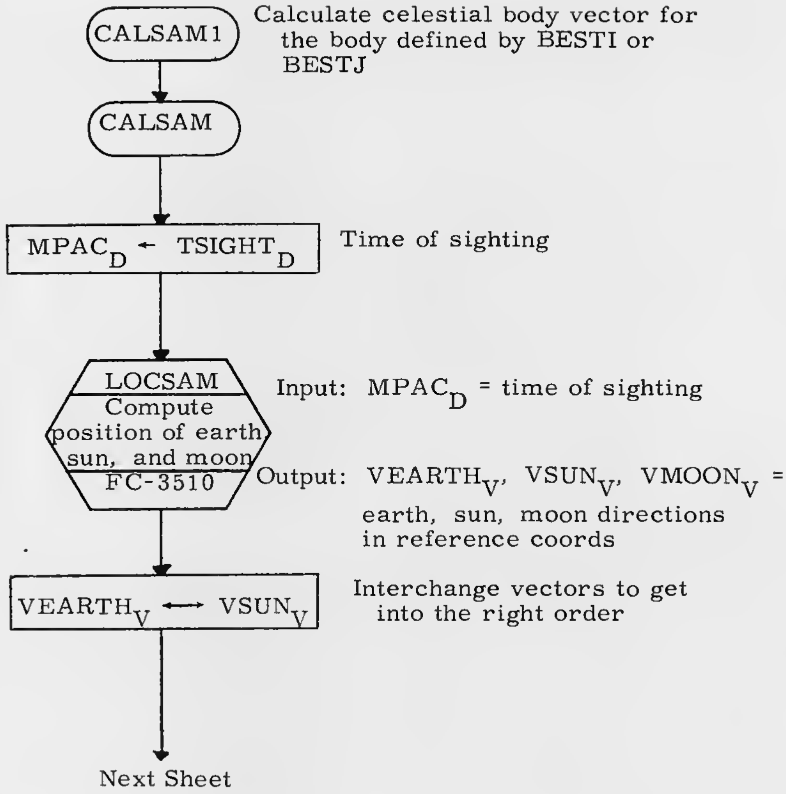

From Preceding Sheet
NOTPLAN
Target is not a planet
A ≧ 228 ?
Is the star code 46_8, 47_8, or 50_8?
Yes (sun, earth, or moon)
(228 = 38 x 6
where 38 = 46_8)
CALSAM1
Sh. 13
No
Which sighting?
Test
STARIND
0
1
First
Second
X1 ← BESTI
X1 ← BESTJ
$MPAC_V$ ← CATLOG # X1
Obtain star direction in
reference coordinates
from stored ephemeris
Return via
GCTR



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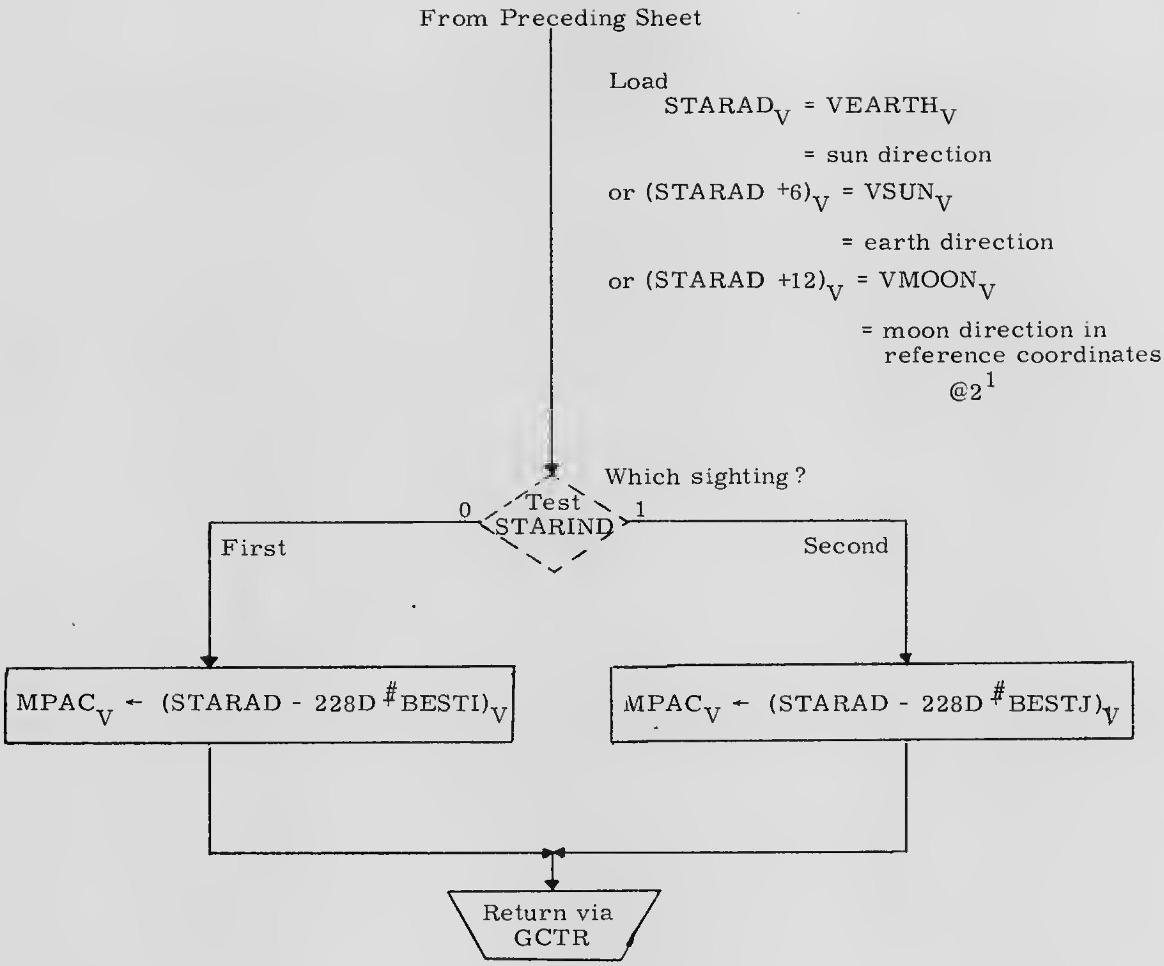
APPR'D Robert M. Estes	9-9-69	REV 2	SHEET 13 OF 24



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DOCMR			
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SUBROUTINES CALLED WHICH ARE
FLOWED ON OTHER FLOW CHARTS

SUBROUTINE NAME	FLOW CHART	DESCRIPTION	WHERE CALLED
AOTMARK	FC-3530	TAKE SIGHTING MARK ON DESIRED CELESTIAL BODY	SH. 5
AOTSTALL	FC-3220	WAIT FOR COMPLETION OF AOT OPERATION	SH. 5
AXISGEN	FC-3310	COMPUTE TRANSFORMATION MATRIX	SH. 8
CHKSDATA	FC-3510	CHECK VALIDITY OF A PAIR OF STAR SIGHTINGS	SH. 7
CURTAINS	FC-3140	LIGHT PROG ALARM LIGHT; SET ALARM CODE 217 (BAD RETURN FROM STALL ROUTINE)	SH. 5,10
IMUCOARS	FC-3220	COARSE ALIGN IMU GIMBALS	SH.10
IMUFINE	FC-3220	RETURN IMU TO FINE ALIGN MODE	SH.10
IMUSTALL	FC-3220	WAIT FOR COMPLETION OF IMU OPERATION	SH.10
LOCSAM	FC-3510	COMPUTE POSITION OF EARTH, SUN, MOON	SH. 13
MATMOVE	FC-3510	MOVE MATRIX	SH. 8

FLAGS

NAME	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
DRIFTFLG FLAGWRD2 BIT 15	GYRO COMPENSATION TO BE DONE	GYRO COMPENSATION TO BE SKIPPED	SH. 4		
FREEFLAG FLAGWRD0 BIT 3	ASTRONAUT KEYED IN "PROCEED" ON V06N05 DISPLAY	ASTRONAUT KEYED IN "RECYCLE" ON V06N05 DISPLAY			SH. 7
IMUSE FLAGWRD0 BIT 8	IMU IN USE	IMU NOT IN USE	SH. 2		
REFSMFLG FLAGWRD3 BIT 13	REFSMMAT MATRIX VALID	REFSMMAT MATRIX NOT VALID	SH. 8		

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ANALST			
DOCMR			
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DISPLAYS

VERB-NOUN	TYPE OF DISPLAY	DESCRIPTION OF EACH REGISTER	WHERE EXECUTED
	ALARM	PROG ALARM LIGHT ON; NO EFFECT ON R1, R2, R3	SH. 2, 5, 10
V06N22	NORMAL	R1: 000,00 DEG DESIRED OUTER IMU GIMBAL ANGLE R2: 000,00 DEG DESIRED INNER IMU GIMBAL ANGLE R3: 000,00 DEG DESIRED MIDDLE IMU GIMBAL ANGLE	SH. 2
V41N22	NORMAL	V41: COARSE ALIGN IMU'S R1, R2, R3 AS IN V06N22 ABOVE	SH. 3
V06N88	FLASHING	R1: .XXXXX R2: .XXXXX R3: .XXXXX 3 COMPONENTS OF DIRECTION OF PLANET IN REFERENCE COORDINATES @2[1]	SH.11

ERASABLE LOCATIONS USED

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
AOTCODE		BITS 6-1 = CODE FOR STAR (OR OTHER CELESTIAL BODY) SIGHTED			2^{14}
BESTI		6 × STAR CODE FOR FIRST STAR SIGHTED (USED AS INDEX VALUE)			2^{14}
BESTJ		6 × STAR CODE FOR SECOND STAR SIGHTED (USED AS INDEX VALUE)			2^{14}
$GCOMP_V$		GYRO COMPENSATION PULSES FOR FREEFALL DRIFT			
MODECADR		INDICATOR OF IMU OPERATION STATUS			
PIPAX		X-COMPONENT OF SENSED $\underline{\Delta V}$ IN SM COORDS	M/SEC	M/CSEC	$.000585 \times 2^{14}$
PIPAY		Y-COMPONENT OF SENSED $\underline{\Delta V}$ IN SM COORDS	M/SEC	M/CSEC	$.000585 \times 2^{14}$
PIPAZ		Z-COMPONENT OF SENSED $\underline{\Delta V}$ IN SM COORDS	M/SEC	M/CSEC	$.000585 \times 2^{14}$
$PLANVEC_V$		DIRECTION OF FIRST SIGHTED BODY IN REFERENCE COORDS			2^{1}
$REFSMMAT_M$	[REFSMMAT]	TRANSFORMATION MATRIX RELATING REFERENCE AND STABLE MEMBER COORDINATE SYSTEMS			2^{1}
$STARAD_V$		SIGHTED DIRECTION OF FIRST SIGHTED BODY IN SM COORDS (ALSO -- SEE $VEARTH_V$ BELOW)			2^{1}

ERASABLE LOCATIONS USED (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
$(STARAD +6)_V$		SIGHTED DIRECTION OF SECOND SIGHTED BODY IN SM COORDS (ALSO -- SEE $VSUN_V$ BELOW)			2^{1}
STARIND		INDICATES WHETHER FIRST OR SECOND STAR SIGHTING, BY VALUE OF 0, 1 RESPECTIVELY			2^{14}
THETAD		DESIRED OUTER IMU GIMBAL ANGLE	DEGREES	REVS	2^{-1}
THETAD +1		DESIRED INNER IMU GIMBAL ANGLE	DEGREES	REVS	2^{-1}
THETAD +2		DESIRED MIDDLE IMU GIMBAL ANGLE	DEGREES	REVS	2^{-1}
$TSIGHT_D$		TIME OF SIGHTING	SEC	CSEC	2^{28}
$TIME2_D$ TIME2, TIME1		PRESENT TIME	SEC	CSEC	2^{28}
$VEARTH_V$ $(=STARAD_V)$		DIRECTION OF EARTH (OR SUN) IN REFERENCE COORDS			2^{1}
$VMOON_V$ $[=(STARAD +12)_V]$		DIRECTION OF MOON IN REFERENCE COORDS			2^{1}
$VSUN_V$ $[=(STARAD +6)_V]$		DIRECTION OF SUN (OR EARTH) IN REFERENCE COORDS			2^{1}

ERASABLE LOCATIONS USED (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
XDC $= \begin{pmatrix} XDC_V \\ YDC_V \\ ZDC_V \end{pmatrix}$		COMPUTED TRANSFORMATION MATRIX RELATION SM AND REFERENCE COORDINATE SYSTEMS			2^1
1/PIPADT		TIME OF LAST GYRO COMPENSATION			2^{14}

PROGRAM CONSTANTS

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING AND AGC VALUE	AGC SCALING
CATLOG -6		DIRECTION OF STAR 1 (α ANDROMEDAE (ALPHERATZ)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.8748658918 \\ +.0260879174 \\ +.4836621670 \end{pmatrix}$	2^1
CATLOG -12D		DIRECTION OF STAR 2 (β CETI (DIPHDA)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.9342640400 \\ +.1735073142 \\ -.3115219339 \end{pmatrix}$	2^1
CATLOG -18D		DIRECTION OF STAR 3 (γ CASSIOPEIAE (NAVI)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.4775639450 \\ +.1166004340 \\ +.8708254803 \end{pmatrix}$	2^1
CATLOG -24D		DIRECTION OF STAR 4 (α ERIDANI (ACHERNAR)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.4917678276 \\ +.2204887125 \\ -.8423473935 \end{pmatrix}$	2^1
CATLOG -30D		DIRECTION OF STAR 5 (α URSAE MINORIS (POLARIS)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.0130968840 \\ +.0078062795 \\ +.9998837600 \end{pmatrix}$	2^1
CATLOG -36D		DIRECTION OF STAR 6 (θ ERIDANI (ACAMAR)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.5450107404 \\ +.5314955466 \\ -.6484410356 \end{pmatrix}$	2^1
CATLOG -42D		DIRECTION OF STAR 7 (α CETI (MENKAR)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.7032235469 \\ +.7075846047 \\ +.0692868685 \end{pmatrix}$	2^1
CATLOG -48D		DIRECTION OF STAR 8 ($=10_8$) (α PERSEI (MIRFAK)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.4105636020 \\ +.4988110001 \\ +.7632988371 \end{pmatrix}$	2^1
CATLOG -54D		DIRECTION OF STAR 9 ($=11_8$) (α TAURI (ALDEBARAN)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.3507315038 \\ +.8926333307 \\ +.2831839492 \end{pmatrix}$	2^1

PROGRAM CONSTANTS (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING AND AGC VALUE	AGC SCALING
CATLOG -60D		DIRECTION OF STAR 10D ($=12_8$) (β ORIONIS (RIGEL)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.2011399589 \\ +.9690337941 \\ -.1432348512 \end{pmatrix}$	2^1
CATLOG -66D		DIRECTION OF STAR 11D ($=13_8$) (α AURIGAE (CAPELLA)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.1371725575 \\ +.6813721061 \\ +.7189685267 \end{pmatrix}$	2^1
CATLOG -72D		DIRECTION OF STAR 12D ($=14_8$) (α CARINAE (CANOPUS)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.0614937230 \\ +.6031563286 \\ -.7952489957 \end{pmatrix}$	2^1
CATLOG -78D		DIRECTION OF STAR 13D ($=15_8$) (α CANIS MAJORIS (SIRIUS)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.1820751783 \\ +.9404899869 \\ -.2869271926 \end{pmatrix}$	2^1
CATLOG -84D		DIRECTION OF STAR 14D ($=16_8$) (α_2 CANIS MINORIS (PROCYON)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.4118589524 \\ +.9065485360 \\ +.0924226975 \end{pmatrix}$	2^1
CATLOG -90D		DIRECTION OF STAR 15D ($=17_8$) (γ VELORUM (REGOR)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.3612508532 \\ +.5747270840 \\ -.7342932655 \end{pmatrix}$	2^1
CATLOG -96D		DIRECTION OF STAR 16D ($=20_8$) (ι URSAE MAJORIS (DNOCES)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.4657947941 \\ +.4774785033 \\ +.7450164351 \end{pmatrix}$	2^1
CATLOG -102D		DIRECTION OF STAR 17D ($=21_8$) (α HYDRAE (ALPHARD)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.7742591356 \\ +.6152504197 \\ -.1482894839 \end{pmatrix}$	2^1
CATLOG -108D		DIRECTION OF STAR 18D ($=22_8$) (α LEONIS (REGULUS)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.8608205219 \\ +.4636213989 \\ +.2098647835 \end{pmatrix}$	2^1

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DOCMR			
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PROGRAM CONSTANTS (CONTINUED)

ASG TAG	GSOP SYMBOL	MEANING	ENGINEERING AND AGC VALUE	AGC SCALING
CATLOG -114D		DIRECTION OF STAR 19D ($=23_8$) (β LEONIS (DENEBOLA)) IN REFERERENCE COORDINATES	$\begin{pmatrix} -.9656605484 \\ +.0525933156 \\ +.2544280809 \end{pmatrix}$	2^1
CATLOG -120D		DIRECTION OF STAR 20D ($=24_8$) (γ CORVI (GIENAH)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.9525211695 \\ -.0593434796 \\ -.2986331746 \end{pmatrix}$	2^1
CATLOG -126D		DIRECTION OF STAR 21D ($=25_8$) (α CRUCIS (ACRUX)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.4523440203 \\ -.0493710140 \\ -.8904759346 \end{pmatrix}$	2^1
CATLOG - 132D		DIRECTION OF STAR 22D ($=26_8$) (α VIRGINIS (SPICA)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.9170097662 \\ -.3502146628 \\ -.1908999176 \end{pmatrix}$	2^1
CATLOG -138D		DIRECTION OF STAR 23D ($=27_8$) (η URSAE MAJORIS (ALKAID)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.5812035376 \\ -.2909171294 \\ +.7599800468 \end{pmatrix}$	2^1
CATLOG - 144D		DIRECTION OF STAR 24D ($=30_8$) (θ CENTAURI (MENKENT)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.6898393233 \\ -.4182330640 \\ -.5909338474 \end{pmatrix}$	2^1
CATLOG -150D		DIRECTION OF STAR 25D ($=31_8$) (α BOOTIS (ARCTURUS)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.7861763936 \\ -.5217996305 \\ +.3311371675 \end{pmatrix}$	2^1
CATLOG -156D		DIRECTION OF STAR 26D ($=32_8$) (α CORONAE BOREALIS (ALPHECCA)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.5326876930 \\ -.7160644554 \\ +.4511047742 \end{pmatrix}$	2^1
CATLOG -162D		DIRECTION OF STAR 27D ($=33_8$) (α SCORPII (ANTARES)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.3516499609 \\ -.8240752703 \\ -.4441196390 \end{pmatrix}$	2^1

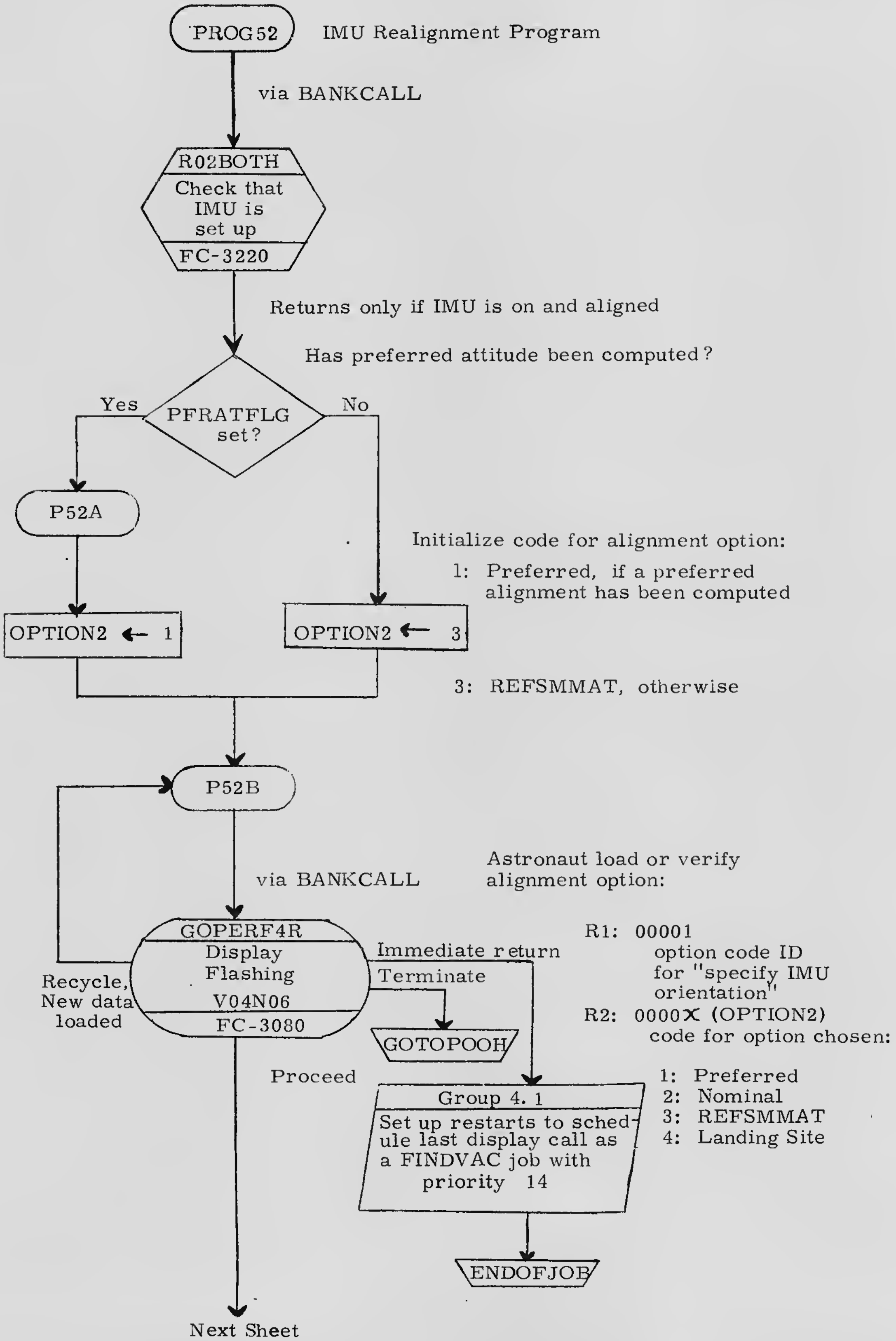
PROGRAM CONSTANTS (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING AND AGC VALUE	AGC SCALING
CATLOG -168D		DIRECTION OF STAR 28D ($=34_8$) (α TRIANGULI AUSTR. (ATRIA)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.1146237858 \\ -.3399692557 \\ -.9334250333 \end{pmatrix}$	2^1
CATLOG -174D		DIRECTION OF STAR 29D ($=35_8$) (α OPHIUCHI (RASALHAGUE)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.1124304773 \\ -.9694934200 \\ +.2178116072 \end{pmatrix}$	2^1
CATLOG -180D		DIRECTION OF STAR 30D ($=36_8$) (α LYRAE (VEGA)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.1217293692 \\ -.7702732847 \\ +.6259880410 \end{pmatrix}$	2^1
CATLOG -186D		DIRECTION OF STAR 31D ($=37_8$) (σ SAGITTARII (NUNKI)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.2069525789 \\ -.8719885748 \\ -.4436288486 \end{pmatrix}$	2^1
CATLOG -192D		DIRECTION OF STAR 32D ($=40_8$) (α AQUILAE (ALTAIR)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.4537196908 \\ -.8779508801 \\ +.1527766153 \end{pmatrix}$	2^1
CATLOG -198D		DIRECTION OF STAR 33D ($=41_8$) (β CAPRICORNI (DABIH)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.5520184464 \\ -.7933187400 \\ -.2567508745 \end{pmatrix}$	2^1
CATLOG -204D		DIRECTION OF STAR 34D ($=42_8$) (α PAVONIS (PEACOCK)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.3201817378 \\ -.4436021946 \\ -.8370786986 \end{pmatrix}$	2^1
CATLOG -210D		DIRECTION OF STAR 35D ($=43_8$) (α CYGNI (DENEB)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.4541086270 \\ -.5392368197 \\ +.7092312789 \end{pmatrix}$	2^1
CATLOG -216D		DIRECTION OF STAR 36D ($=44_8$) (ϵ PEGASI (ENIF)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.8139832631 \\ -.5557243189 \\ +.1691204557 \end{pmatrix}$	2^1

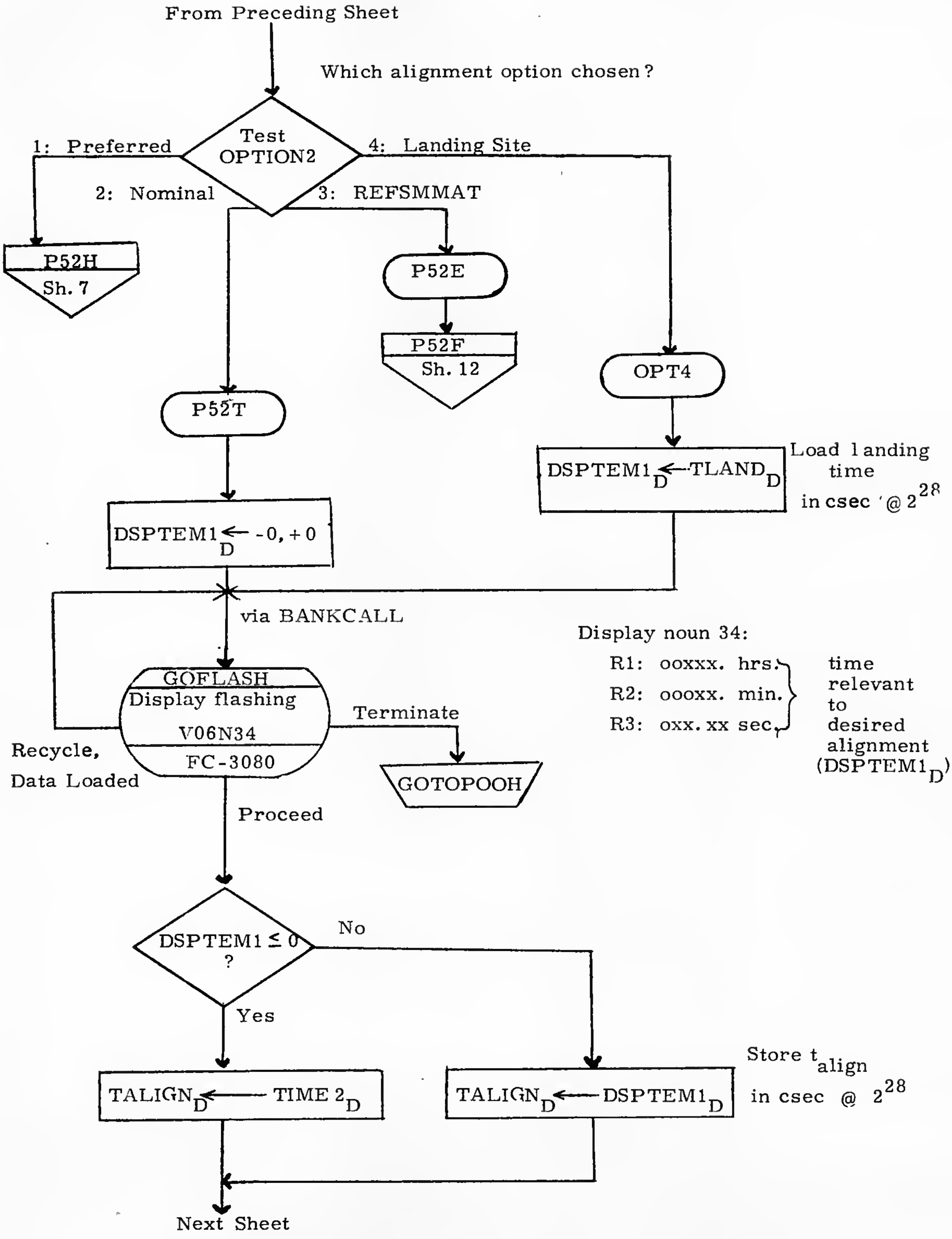
PROGRAM CONSTANTS (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING AND AGC VALUE	AGC SCALING
CATLOG -222D		DIRECTION OF STAR 37D (=45_8) (α PISCIS AUSTR. (FORMALHAUT)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.8342971408 \\ -.2392481515 \\ -.4966976975 \end{pmatrix}$	2^1

P52: IMU REALIGNMENT PROGRAM



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN [signature]	10/9/69	P52	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3510
DOCMR			
APPR'D Roberta M. Estes	3/6/70	REV 1	SHEET 2 OF 55



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	Jane Rusher 10/11/67	P52	
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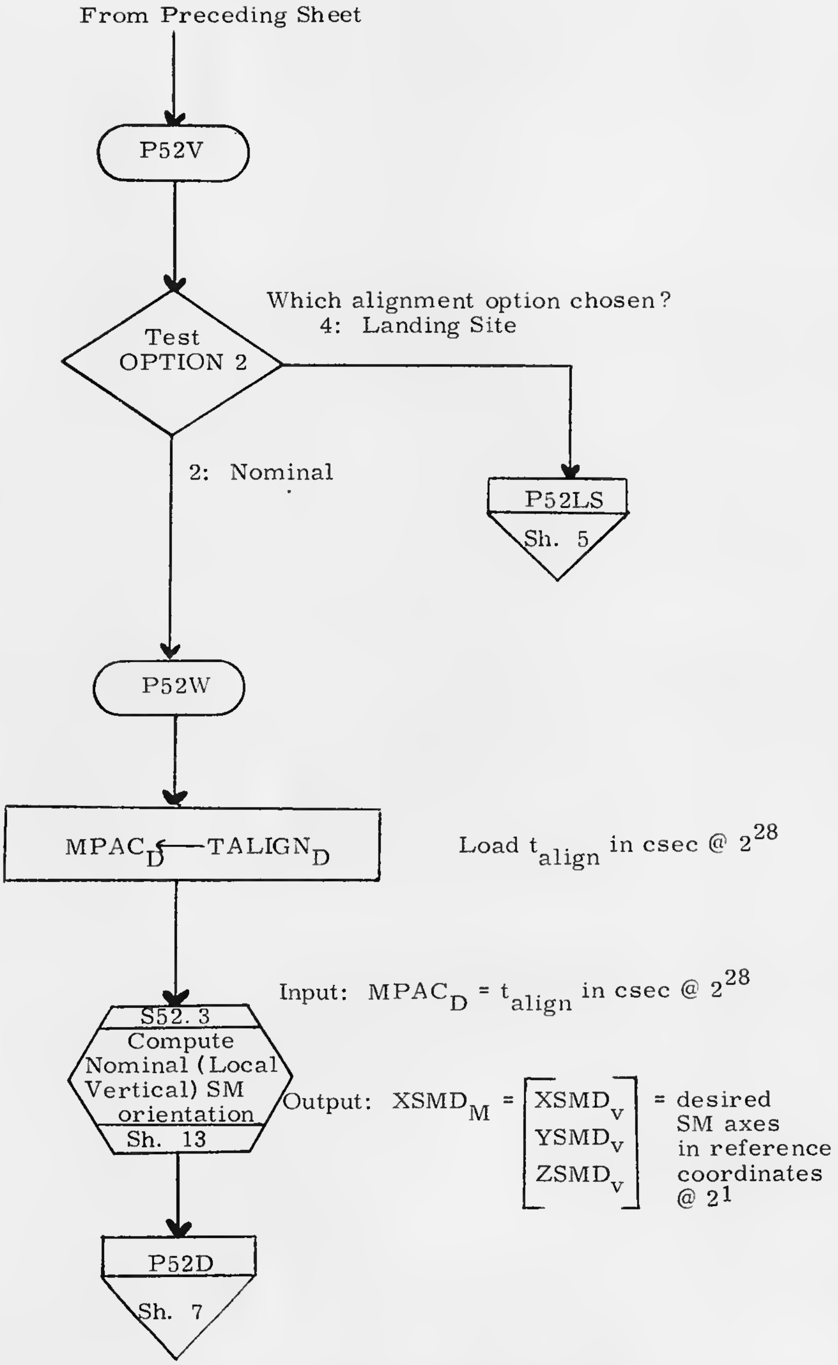
DOCMR		LUMINARY 1D	FC-3510
APPR'D	Robert M Eaton 3/6/70	REV 1	SHEET 3 OF 55



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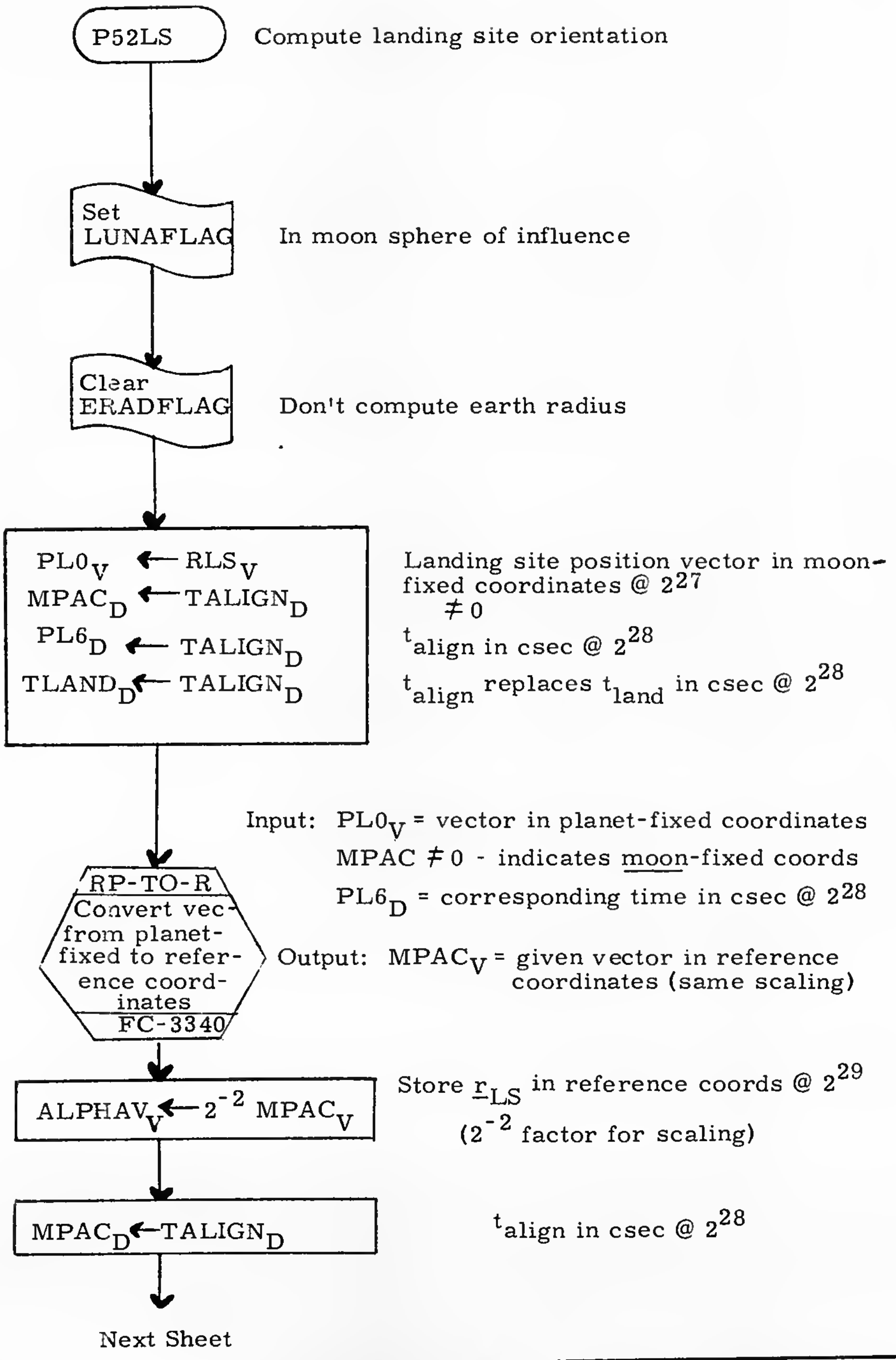
DOCMR			
APPR'D Roberta M Enter	3/6/70	REV 1	SHEET 4 OF 55



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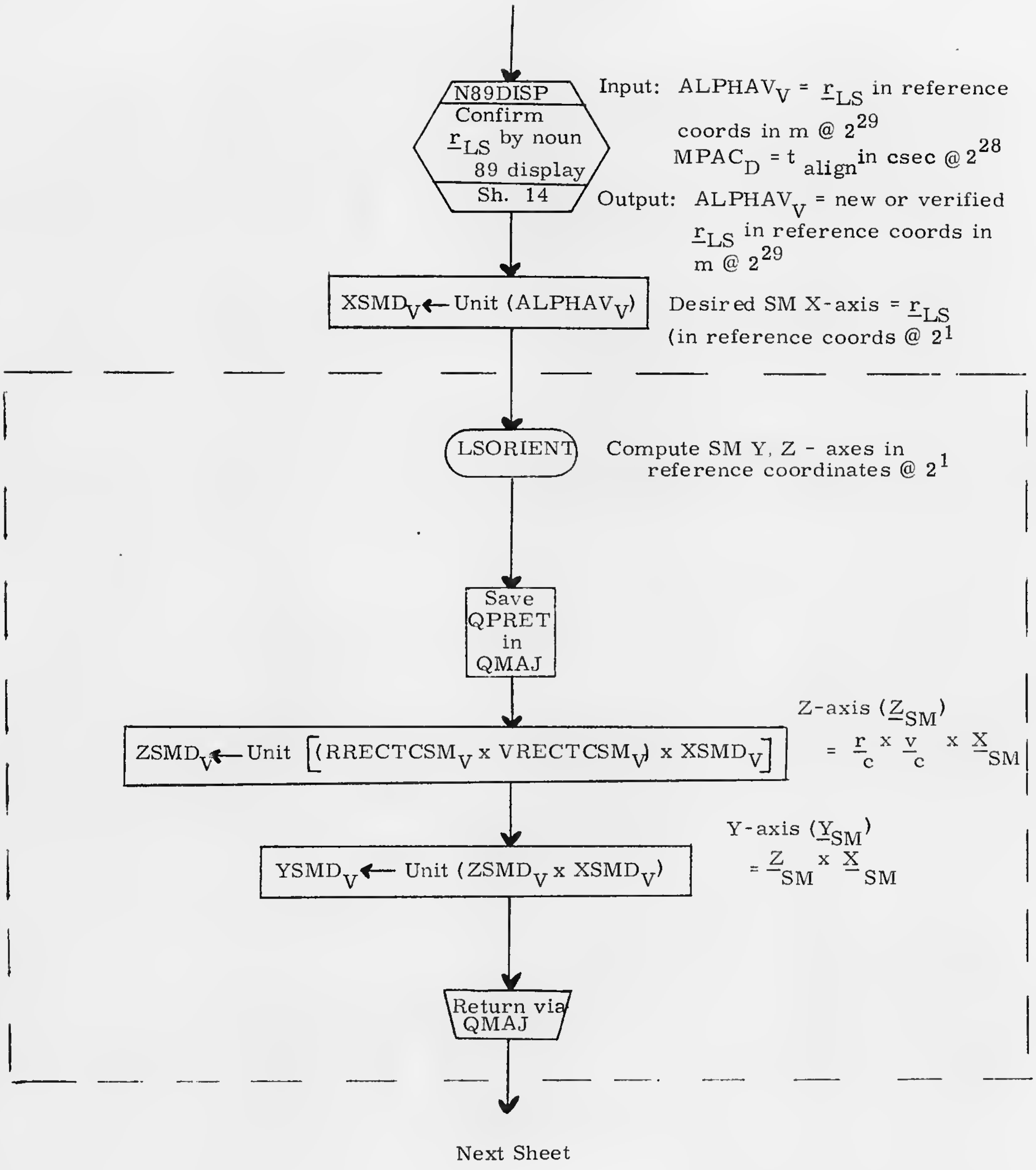
ANALST		LUMINARY 1D	FC-3510
DOCMR			
APPR'D Roberta M Estes	3/6/70	REV 1	SHEET 5 OF 55



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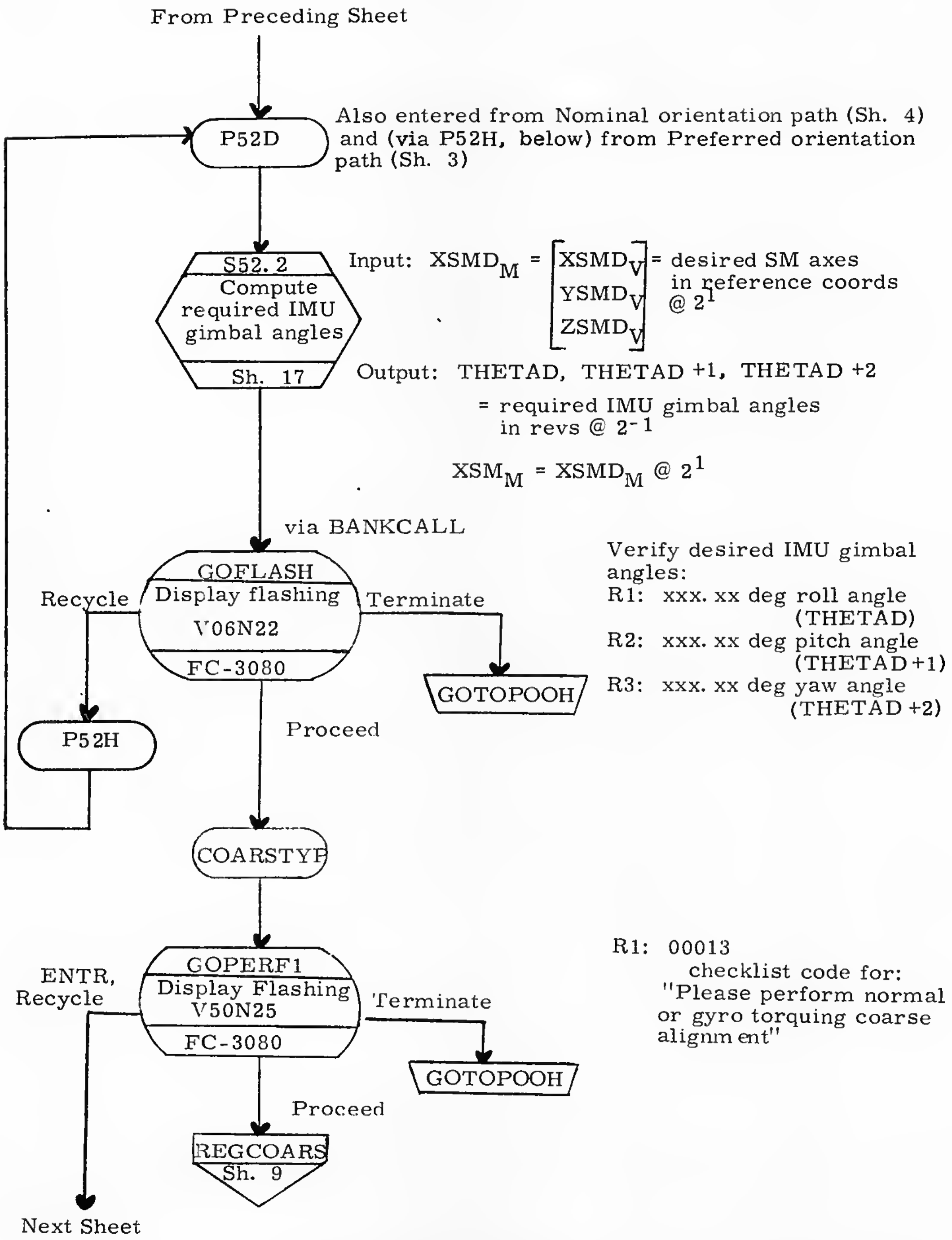
DOCMR		LUMINARY 1D	FC-3510
APPR'D Roberta M Evans	3/6/70	REV 1	SHEET 6 OF 55



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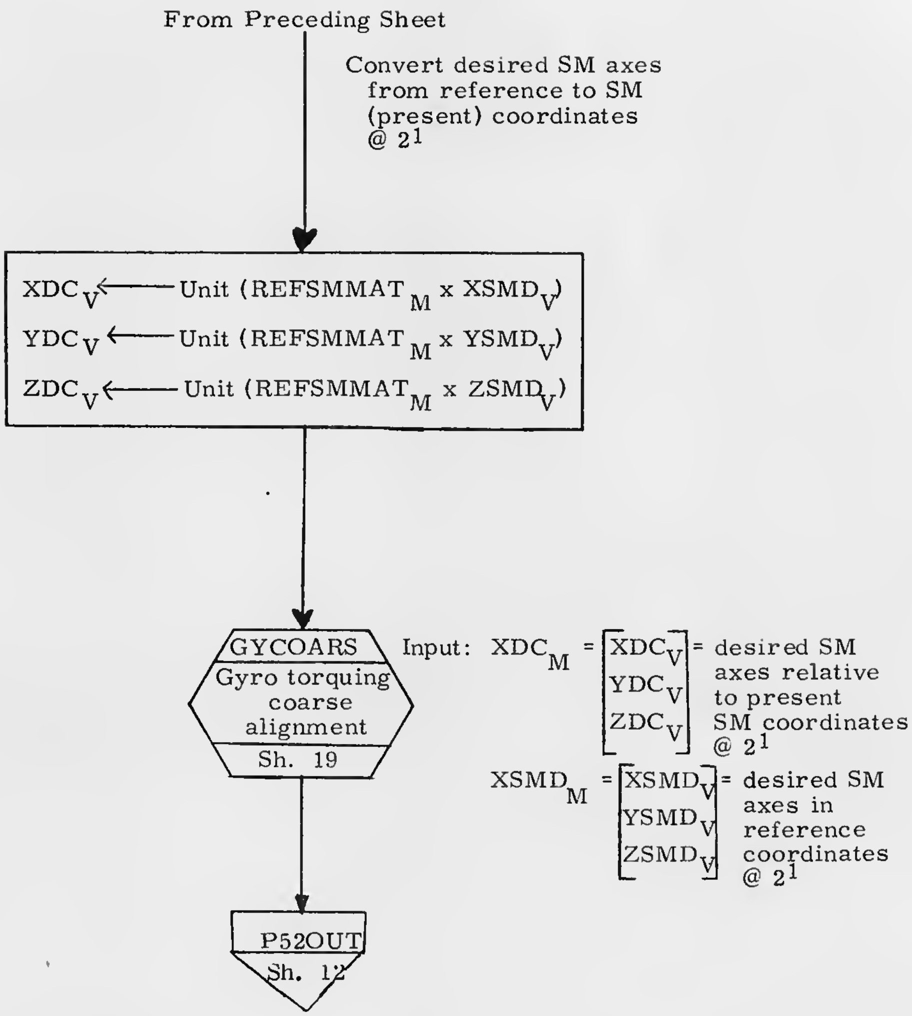
APPR'D [signature]	3/6/70	REV 1	SHEET 7 OF 55



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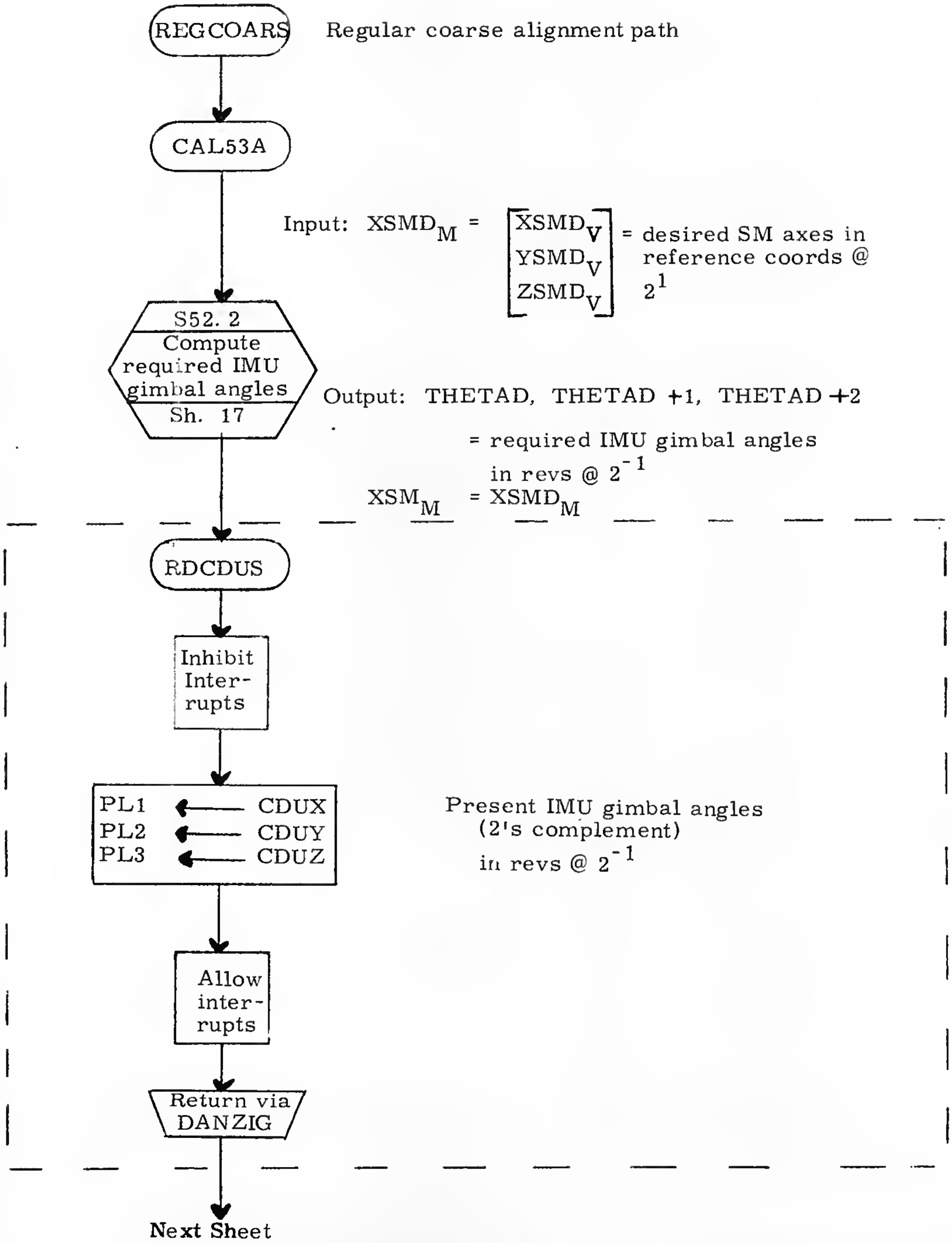
DOCMR		LUMINARY 1D	FC-3510
APPR'D Roberta M Eutes	3/6/70	REV 1	SHEET 8 OF 55



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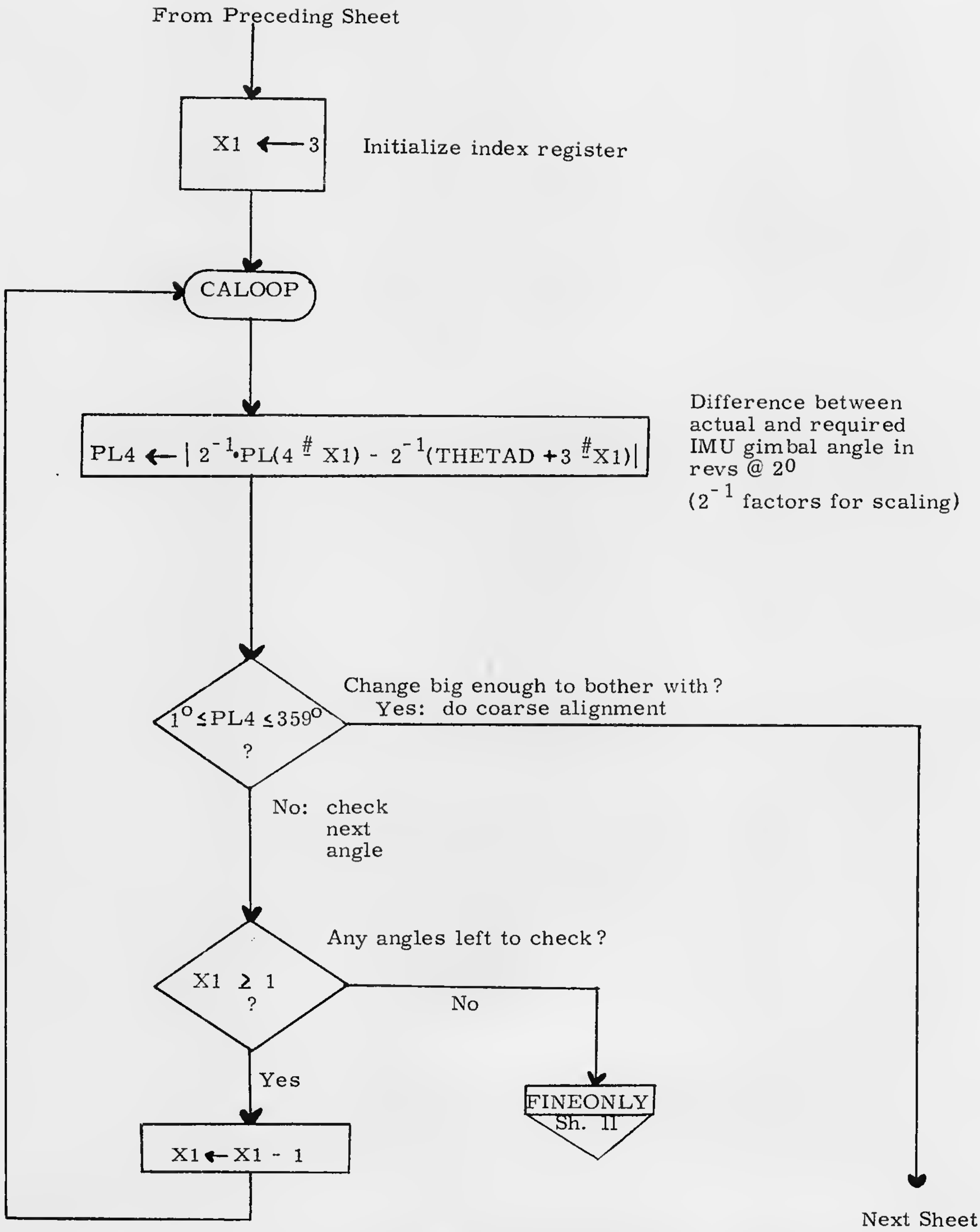

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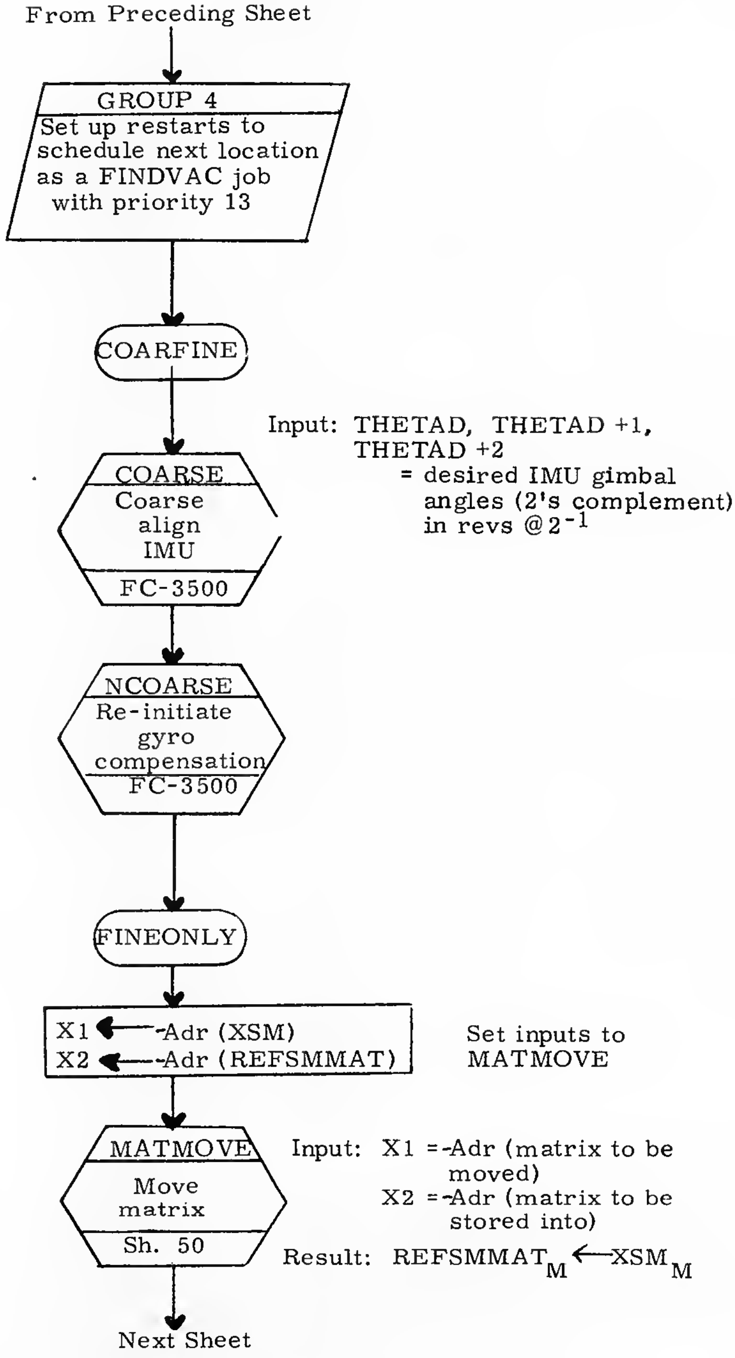
DOCMR		LUMINARY 1D	FC-3510
APPR'D [illegible]	3/6/70	REV 1	SHEET 10 OF 55



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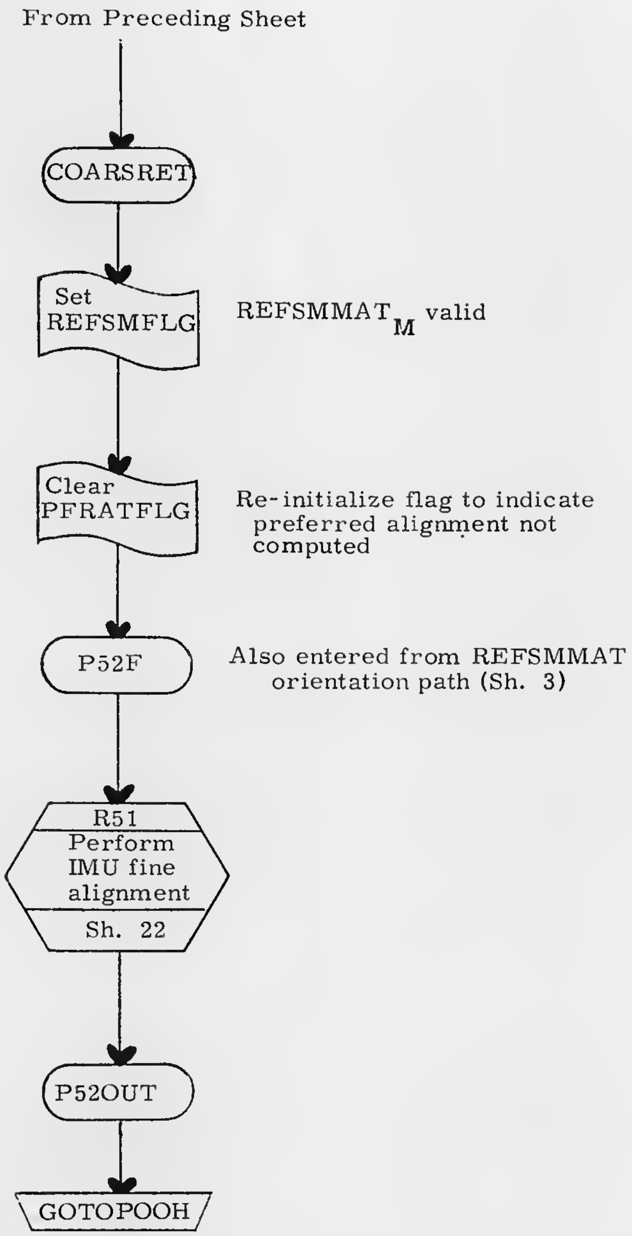
DOCMR	LUMINARY 1D	FC-3510
APPR'D Roberta M Estes 3/6/70	REV 1	SHEET 11 OF 55



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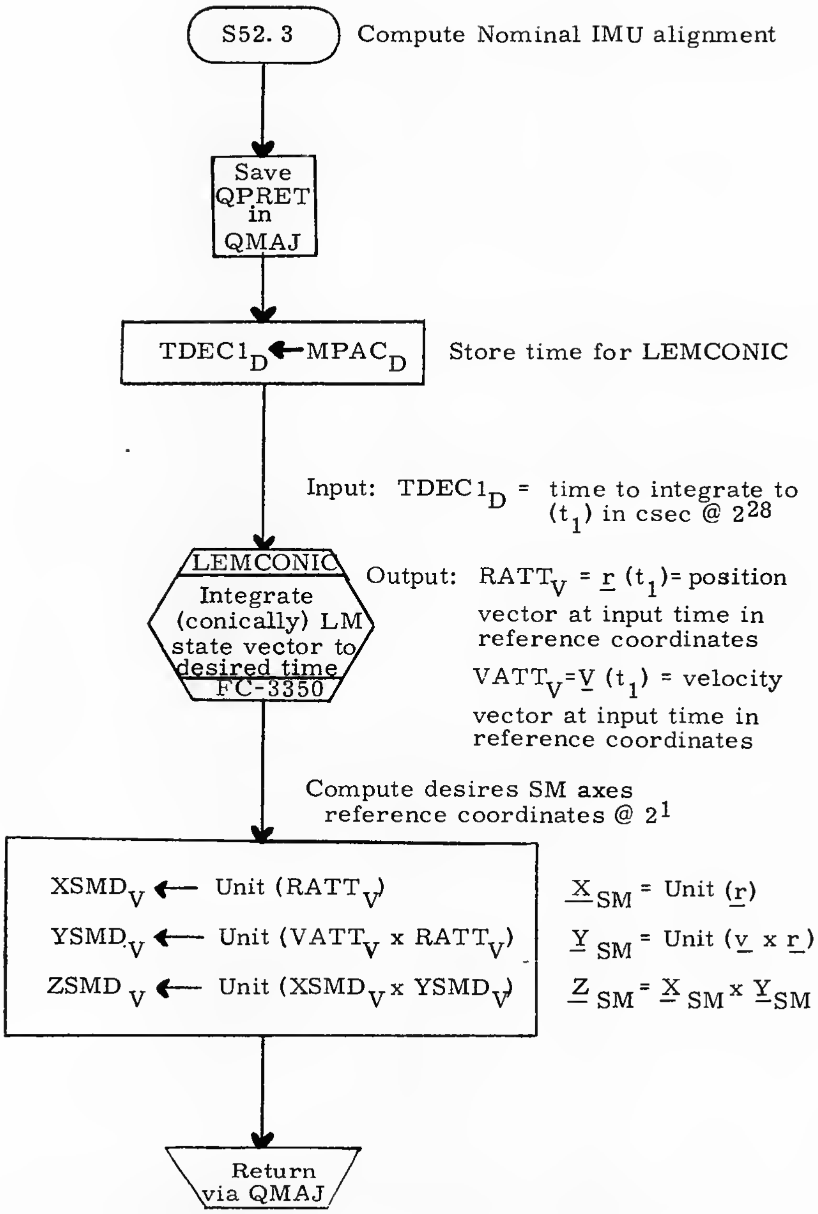
APPR'D Robert M. Estes	3/6/70	REV 1	SHEET 12 OF 55



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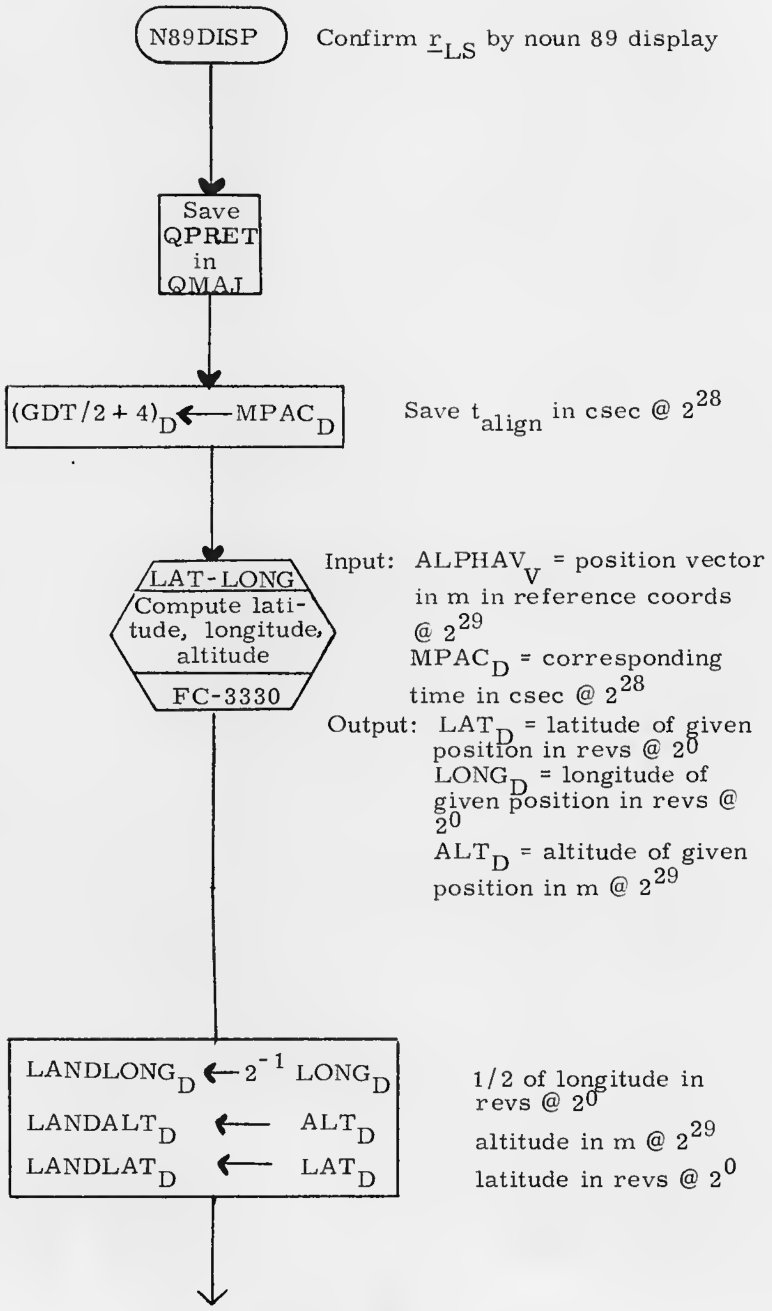
DOCMR			
APPR'D Robert M Euter	3/6/70	REV 1	SHEET 13 OF 55



Next Sheet

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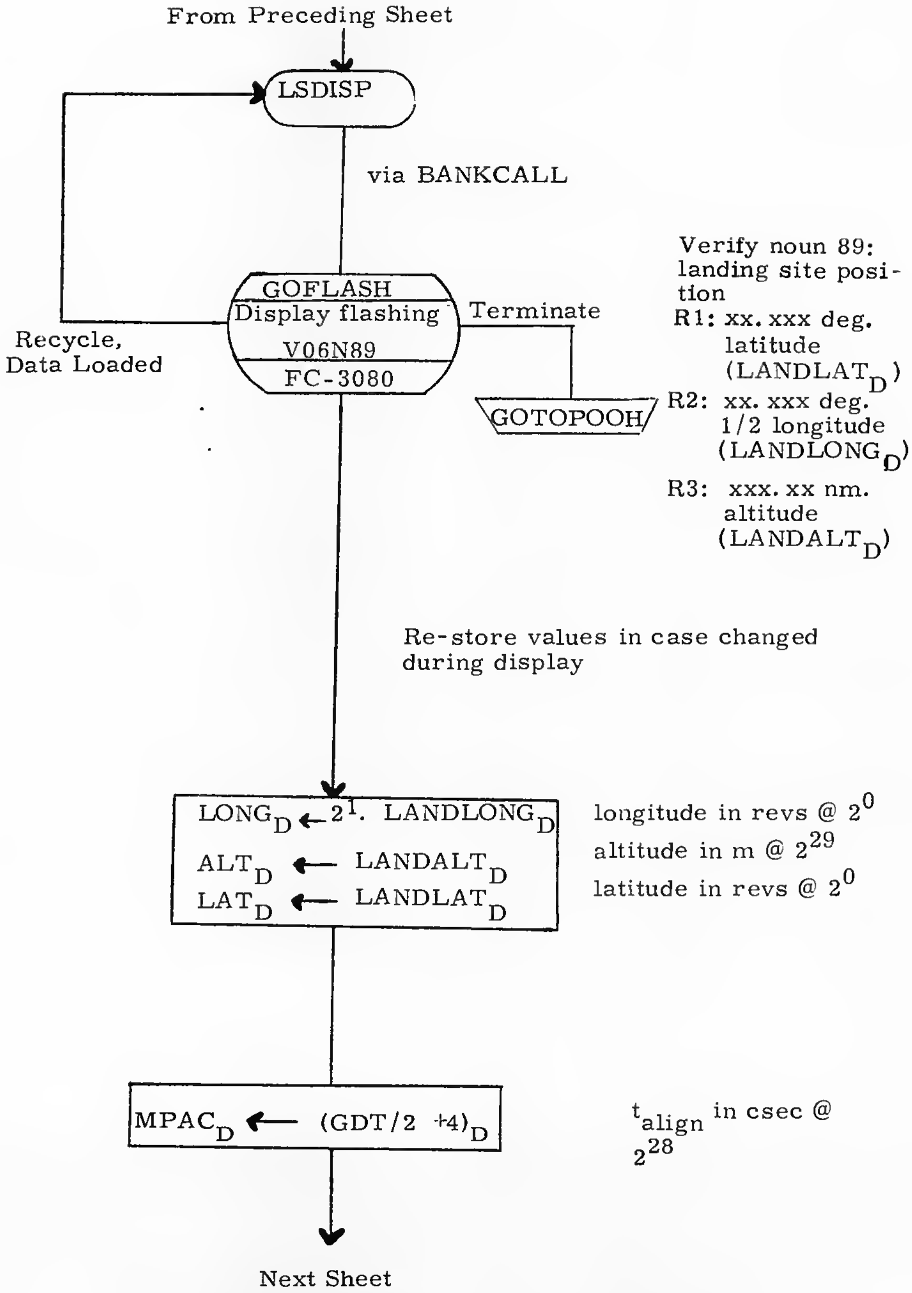
ANALST			
DOCMR		LUMINARY 1D	FC-3510
APPR'D *Roberta M Ester*	3/6/70	REV 1	SHEET 14 OF 55



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
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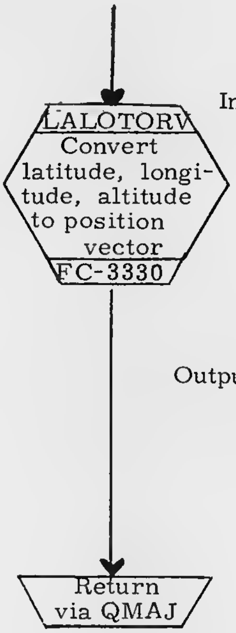
DOCMR			
APPR'D Roberta M. Enters	3/6/70	REV 1	SHEET 15 OF 55

From Preceding Sheet



Input: LAT_D = latitude in revs @2^0

$LONG_D$ = longitude in revs @ 2^0

ALT_D = altitude in m @ 2^{29}

$MPAC_D$ = corresponding time in csec @ 2^{28}

Output: $ALPHAV_V$ = position vector in m. in reference coords @ 2^{29}

S52.2 — Compute gimbal angles required for desired IMU orientation

Save QPRET in QMAJ

CDUTRIG
Determine trigonometric functions of IMU gimbal angles
FC-3320

Output: SINCDUX, COSCDUX; SINCDUY, COSCDUY; SINCDUZ, COSCDUZ — sines, cosine of IMU gimbal angles @ 2^1

Input: SINCDUX, COSCDUX; SINCDUY, COSCDUY; SINCDUZ, COSCDUZ — sines, cosines of IMU gimbal angles @ 2^1

CALCSMSC
Compute NB axes in SM coordinates
FC-3320

Output: $XNB_M = \begin{bmatrix} XNB_V \\ YNB_V \\ ZNB_V \end{bmatrix}$ = NB axes in SM (present) coordinates @ 2^1

S52.2A

$XNB_V \leftarrow \text{Unit}(XNB_V \times REFSMMAT_M)$

$YNB_V \leftarrow \text{Unit}(YNB_V \times REFSMMAT_M)$

$ZNB_V \leftarrow \text{Unit}(ZNB_V \times REFSMMAT_M)$

Convert NB axes from SM to reference coords @ 2^1

Next Sheet

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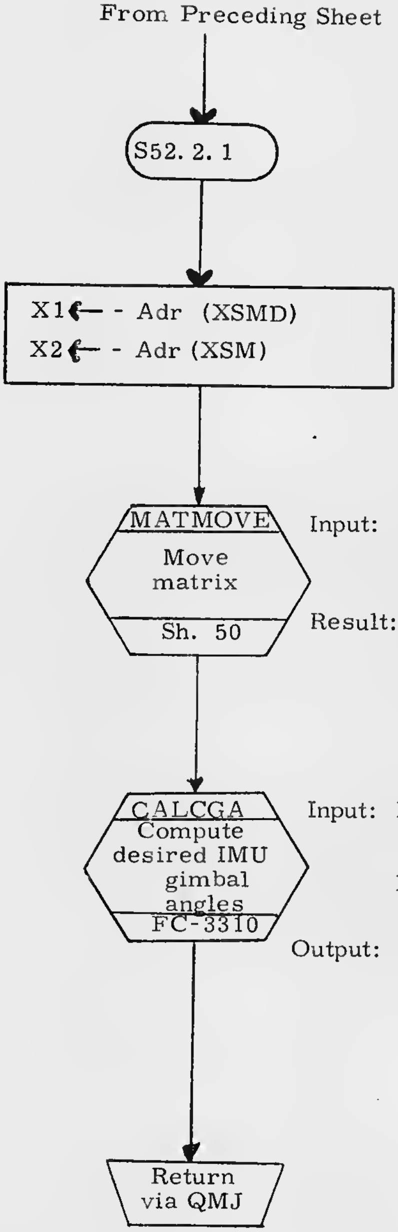
PRGMR			DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3510
DOCMR		REV 1	SHEET 17 OF 55
APPR'D Roberta M Ertes	3/6/70		



Set inputs to MATMOVE

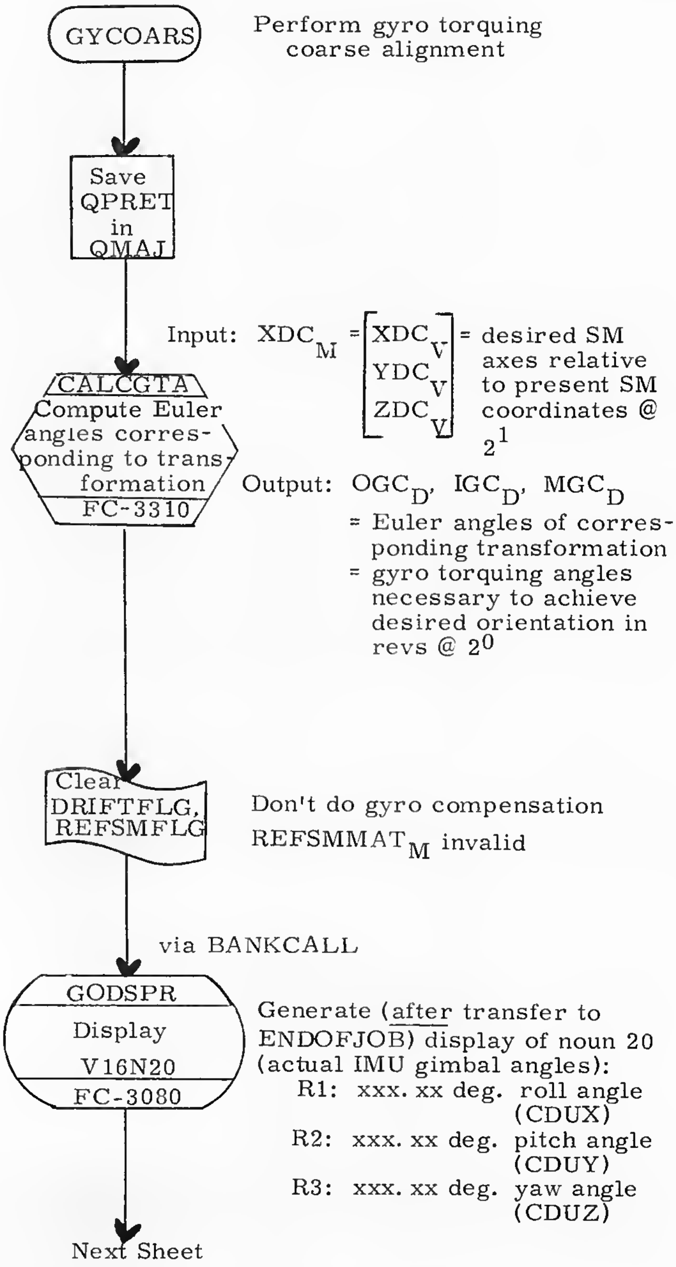
Input: X1 = - Adr (matrix to be moved)
X2 = - Adr (matrix to be stored into)

Result: $XSM_M \leftarrow XSMD_M$

Input: XNB_M = NB axes in reference coordinates @ 2^1

XSM_M = desired SM axes in reference coords @ 2^1

Output: THETAD, THETAD +1, THETAD +2
= IMU gimbal angles necessary to achieve desired orientation (2's complement) in revs @ 2^{-1}



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DRAWN [signature]	10/14/69	P52	
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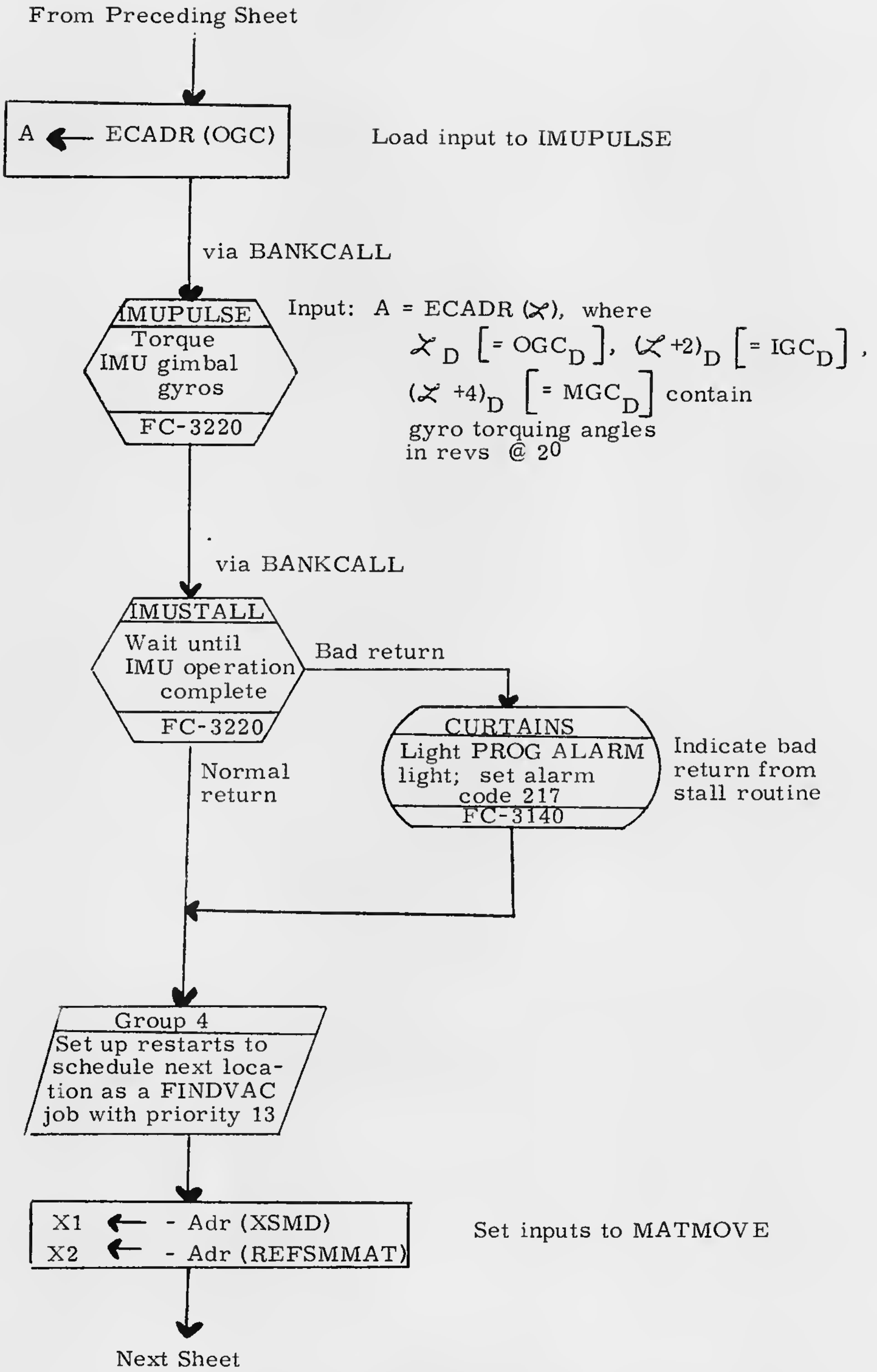
ANALST		LUMINARY 1D	FC-3510
DOCMR			
APPR'D Roberta M Estes	3/6/70	REV 1	SHEET 19 OF 55



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
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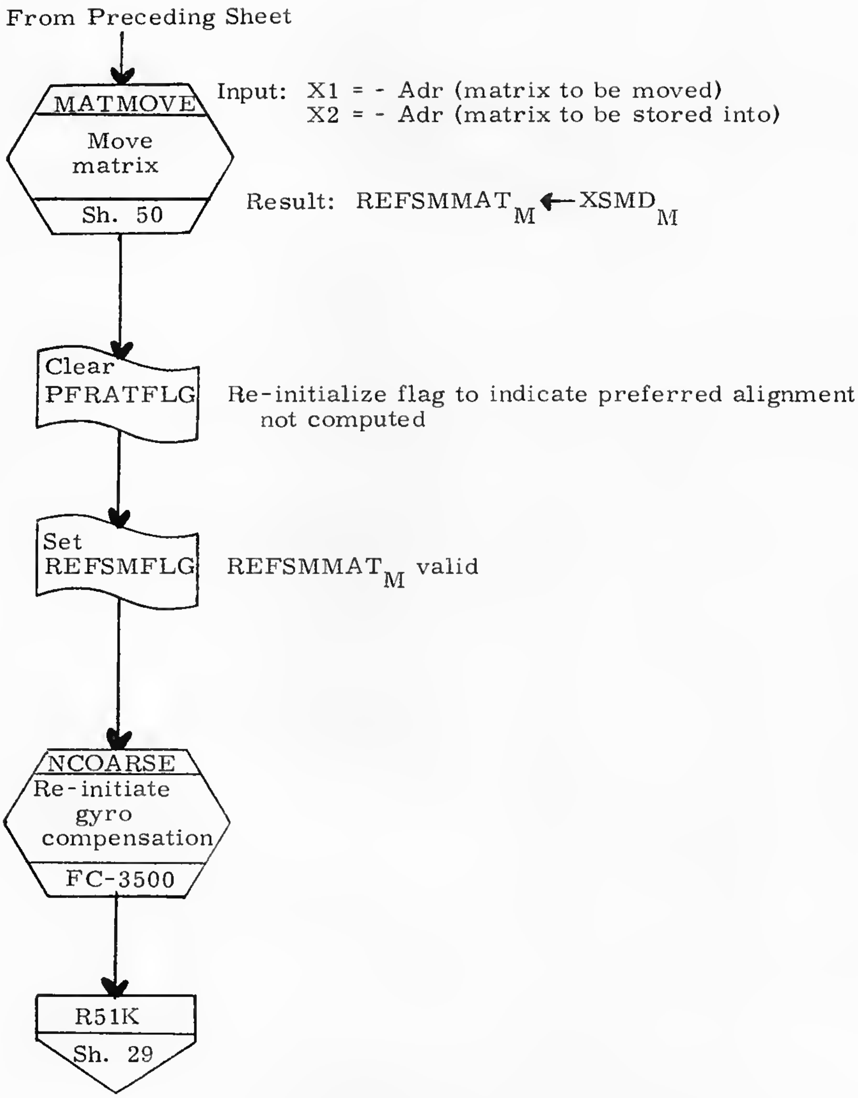
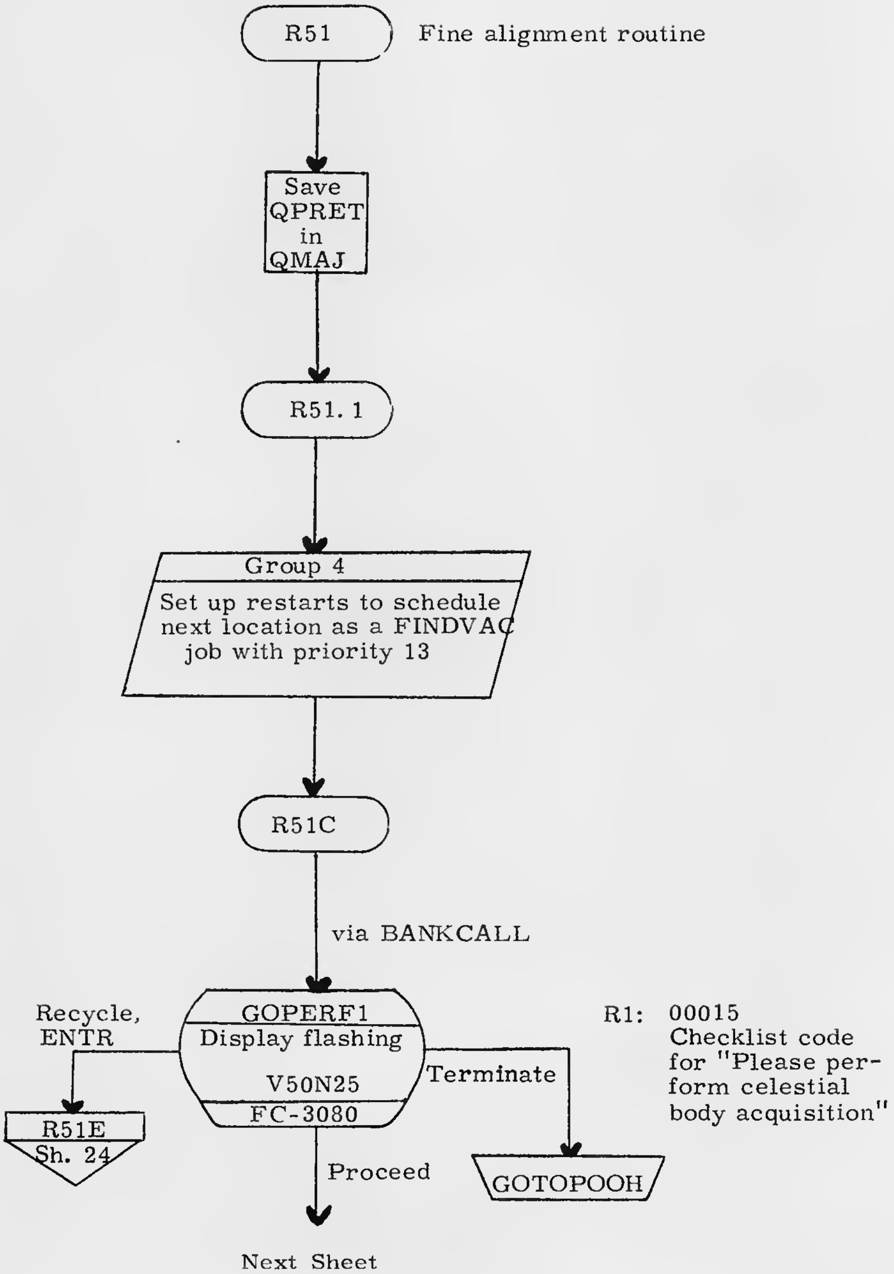
ANALST			
DOCMR			
APPR'D Roberta M Ester	3/6/70	REV 1	SHEET 20 OF 55



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	11/5/67	P52	
PRGMR			DOCUMENT NO.
ANALST			
DOCMR		LUMINARY 1D	FC-3510
APPR'D Roberta M. Evans	3/6/70	REV 1	SHEET 21 OF 55



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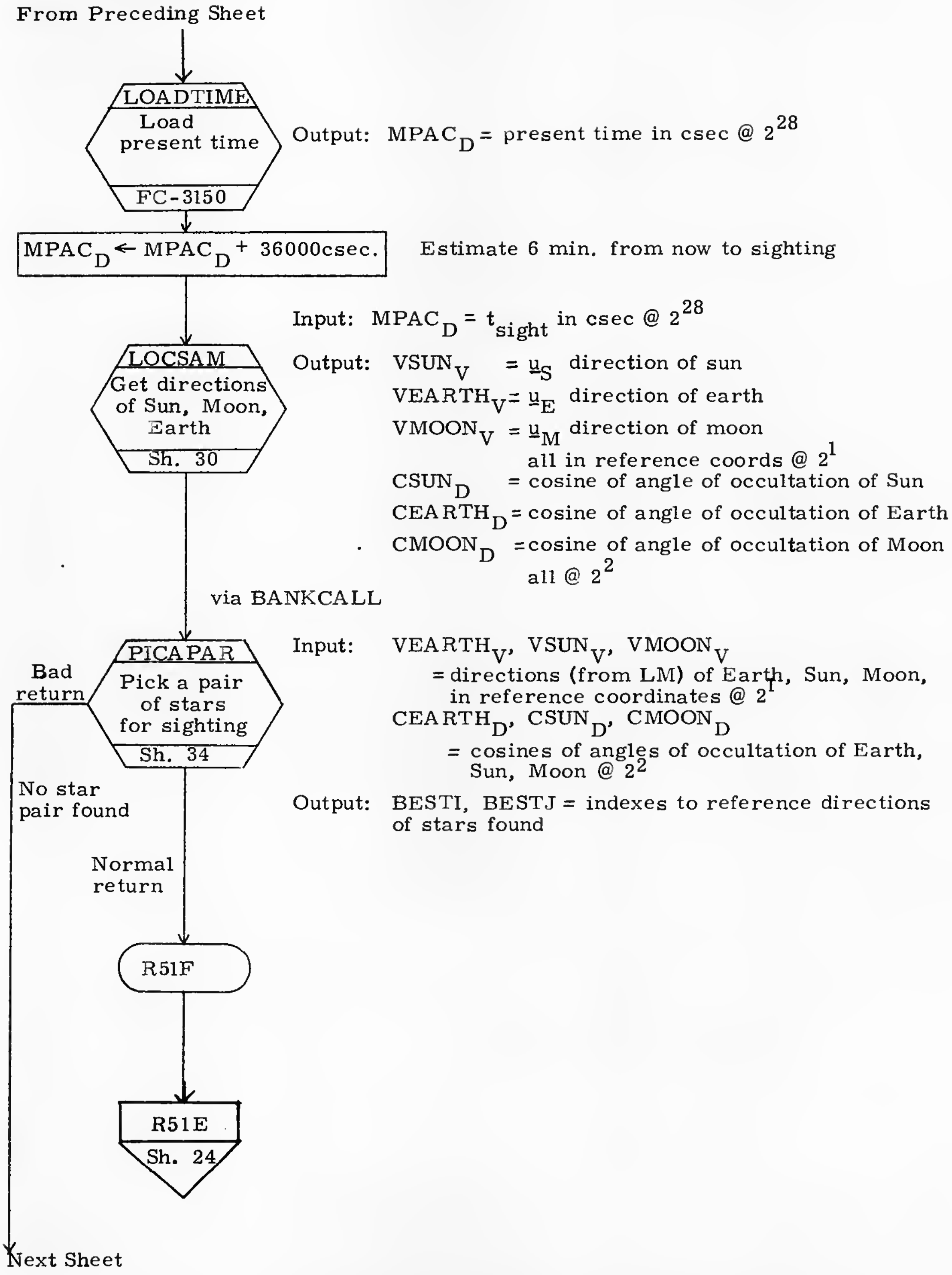
APPR'D Roberta M Exter	3/6/70	REV 1	SHEET 22 OF 55



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DRAWN	D. Littlewood 10/09/69	P52	
PRGMR			
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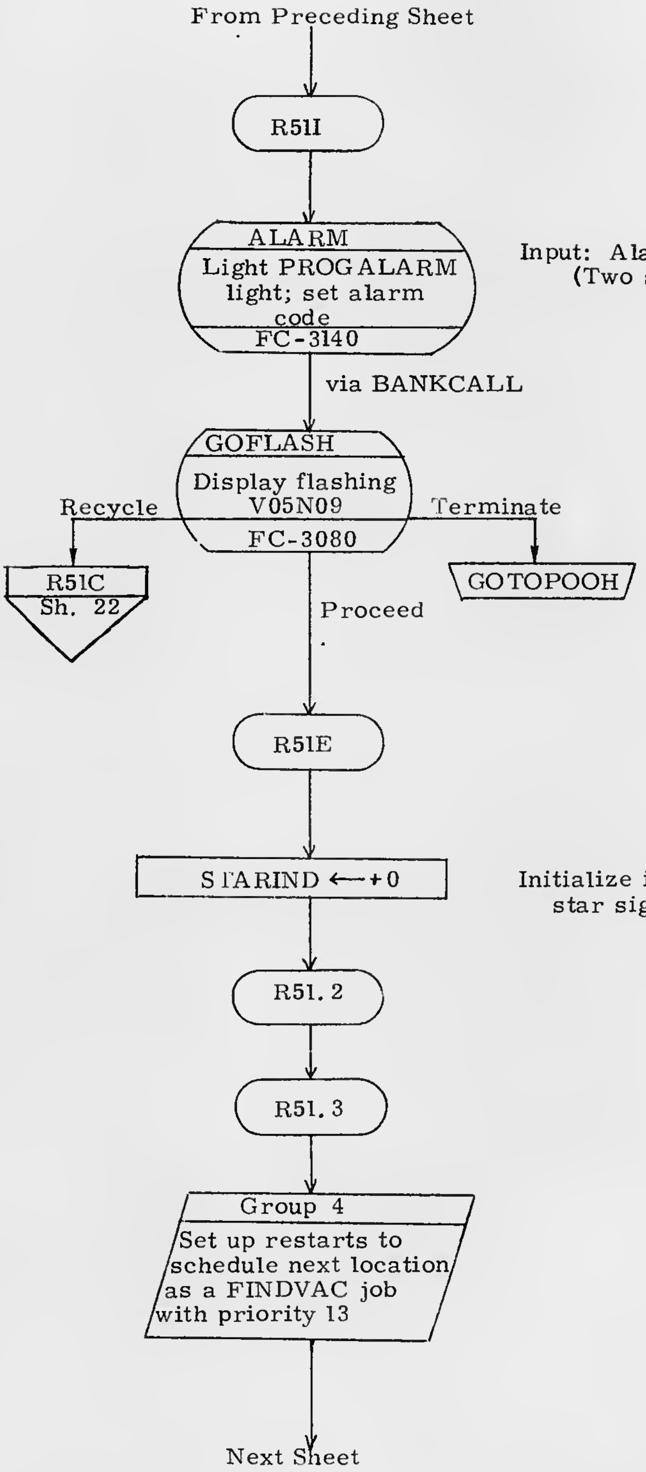
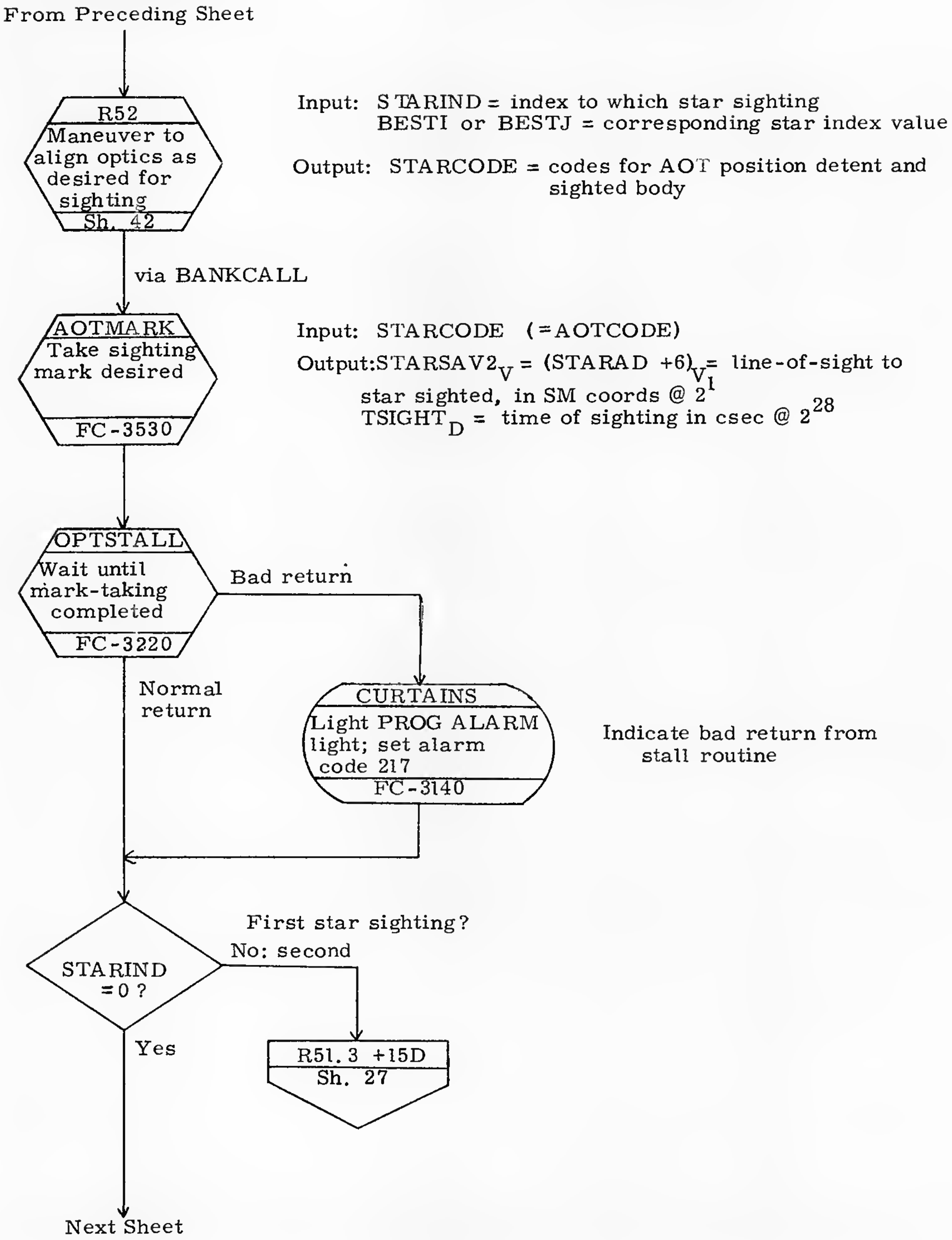
DOCMR			
APPR'D	Robert M Estes 3/6/70	REV1	SHEET 23 OF 55



Input: Alarm code 405
(Two stars not availabe)

Display alarm codes
Most recent is:
00405
(set above)

Initialize index value to indicate first star sighting



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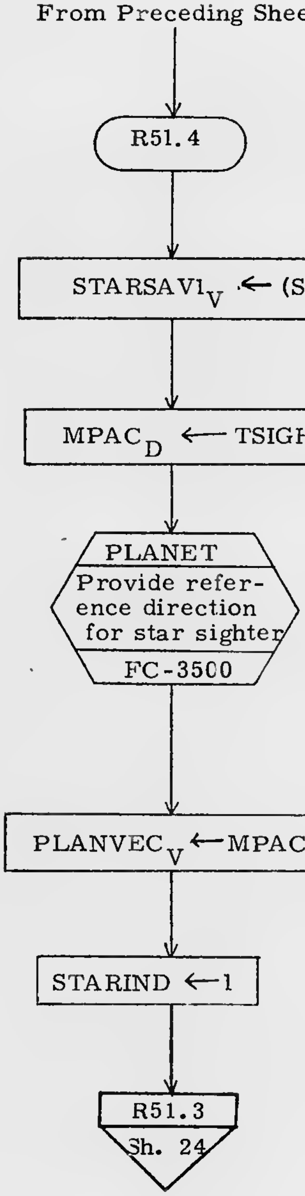
DRAWN D. Lutkevich	10/09/69	P52
PRGMR		
ANALST		LUMINARY 1D — DOCUMENT NO. FC-3510
DOCMR		
APPR'D Roberta M Estes	3/6/70	REV 1 — SHEET 25 OF 55

From Preceding Sheet



Save line-of-sight to first star in SM coords @ 2^1

t_{sight} in case @ 2^{28}

Input: $MPAC_D$ = time of sighting in csec @ 2^{28}

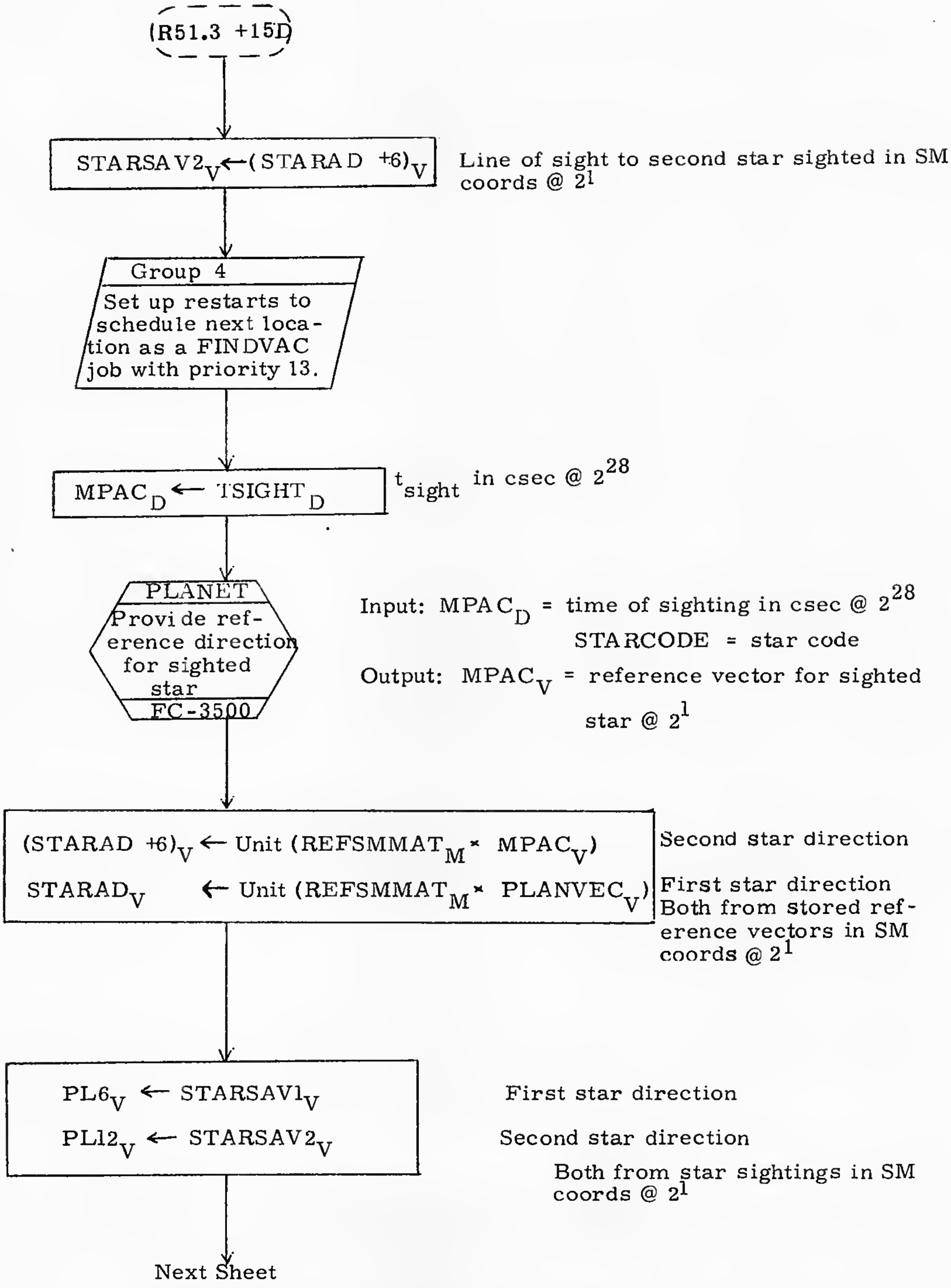
STARCODE = star code

Output: $MPAC_V$ = reference vector for sighted star @ 2^1

Save reference vector for first star @ 2^1

Set index value to indicate second star sighting

Go back to do second star sighting



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DRAWN	Lotkewich	10/09/69	P52	
PRGMR				DOCUMENT NO.
ANALST			LUMINARY 1D	FC-3510
DOCMR				
APPR'D	Roberta M. Estes	3/6/70	REV 1	SHEET 27 OF 55

From Preceding Sheet

CHKSDATA
Check validity of star sightings
Sh. 46

Input: $STARAD_V$, $(STARAD +6)_V$
= 2 star vectors from reference list
$PL6_V$, $PL12_V$
= same 2 star vectors from star sightings

Output: FREEFLAG - indicating astronaut's response to V06N05 display

Did astronaut key in "Proceed"?

FREEFLAG set?

No → **R51K** Sh. 29

Yes

AXISGEN
Compute transformation matrix
FC-3310

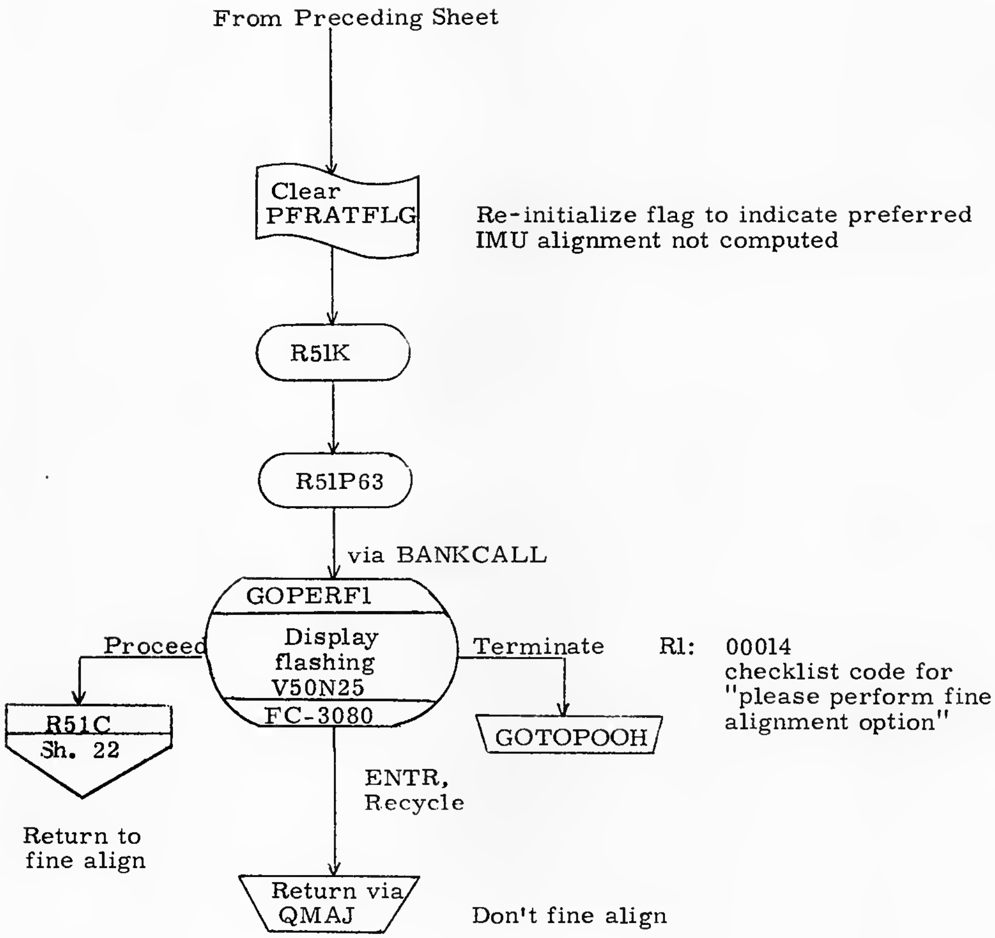
Input: $STARAD_V$, $(STARAD +6)_V$
= 2 star vectors (reference) in SM (desired) coords @2^1
$PL6_V$, $PL12_V$
= same 2 star vectors (sighted) in SM (actual) coords @ 2^1

Output: $XDC_M = \begin{bmatrix} XDC_V \\ YDC_V \\ ZDC_V \end{bmatrix} = STARAD_M$
= transformation matrix giving desired SM axes in terms of present ones @ 2^1

R55
Align IMU as desired
Sh. 48

Input: $XDC_M = \begin{bmatrix} XDC_V \\ YDC_V \\ ZDC_V \end{bmatrix}$ = desired SM axes relative to present SM coords @ 2^1

Next Sheet



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
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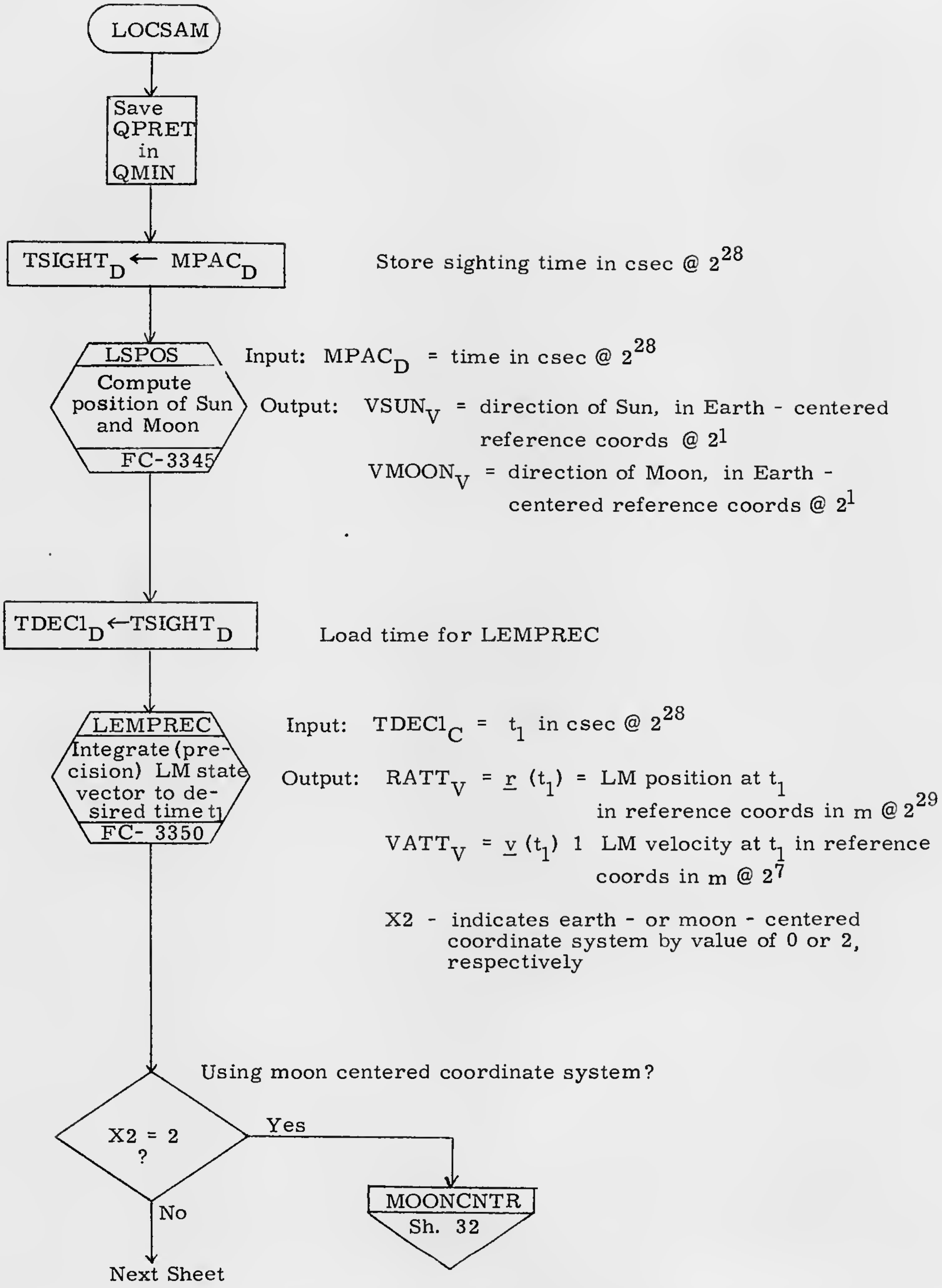
DOCMR			
APPR'D Roberta M. Estes	3/6/70	REV 1	SHEET 29 OF 55



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DRAWN *D. Lutkevich*	*10/9/69*	P52	
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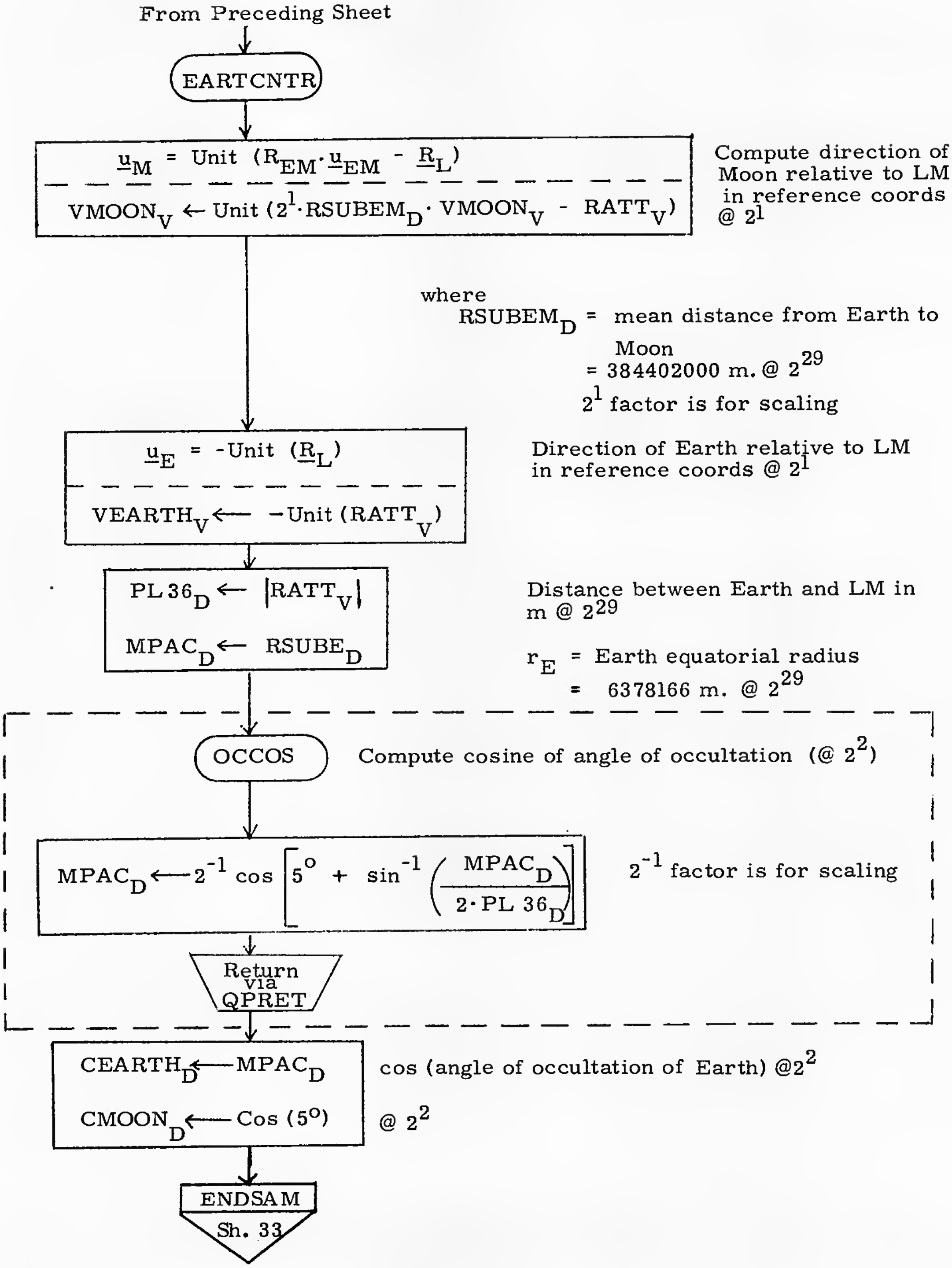
DOCMR			
APPR'D *Robert M Eds*	*3/6/70*	REV 1	SHEET 30 OF 55



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DRAWN D. Lutkenick 11/9/69	P52	
PRGMR		DOCUMENT NO.
ANALST	LUMINARY 1D	FC-3510
DOCMR		
APPR'D Roberta M Eiter 3/6/70	REV 1	SHEET 31 OF 55

MOONCNTR

$\underline{u}_S = \text{Unit}\ (\underline{u}_{ES} - \rho_E \underline{u}_{EM})$

$VSUN_V \leftarrow \text{Unit}\ (VSUN_V - ROE_D\ VMOON_V)$

Convert direction of Sun to Moon - centered coordinates @ 2^1
where $ROE_D = \rho_E$ = ratio of Earth-Sun distance to Earth-Moon distance = .00257125 @ 2^0

$\underline{u}_E = -\text{Unit}\ (1/2 R_{EM}\ \underline{u}_{EM} + \underline{R}_L)$

$VEARTH_V \leftarrow -\text{Unit}\ (RSUBEM_D \cdot VMOON_V + RATT_V)$

Direction of Earth relative to LM in Moon-centered reference coords @2^1
where $RSUBEM_D = R_{EM}$ = mean distance from Earth to Moon = 384402000 m. @ 2^{29}

$\underline{u}_M = -\text{Unit}\ (\underline{R}_L)$

$VMOON_V \leftarrow -\text{Unit}\ (RATT_V)$

Direction of Moon relative to LM in Moon-reference coords @ 2^1

$PL36_D \leftarrow |RATT_V|$

$MPAC_D \leftarrow RSUBM_D$

Distance between Moon and LM in m @ 2^{29}
r_M = Moon equatorial rodius = 1738090 m. @ 2^{29}

OCCOS
Determine angle of occultation
Sh. 31

Input: $PL36_D$ = distance to body in m @ 2^{29}
$MPAC_D$ = radius of body in m @ 2^{29}

Output: $MPAC_D$ = cosine of angle of occultation @ 2^2

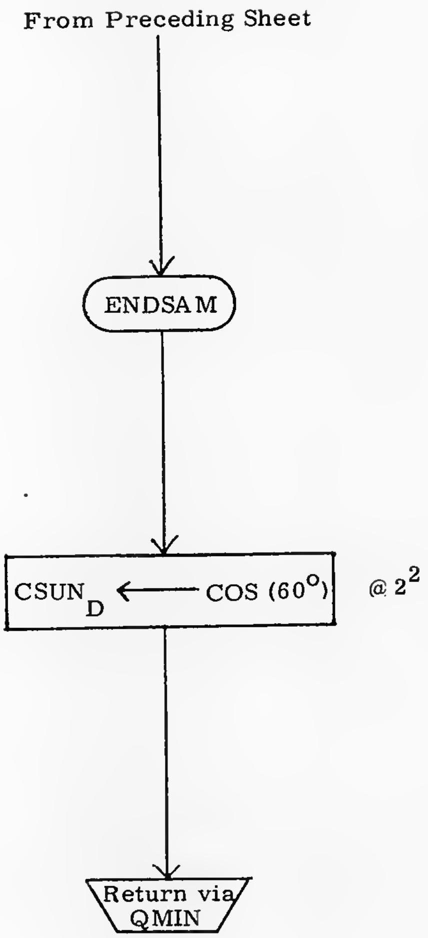
$CMOON_D \leftarrow MPAC_D$

$CEARTH_D \leftarrow \text{Cos}\ (5^\circ)$

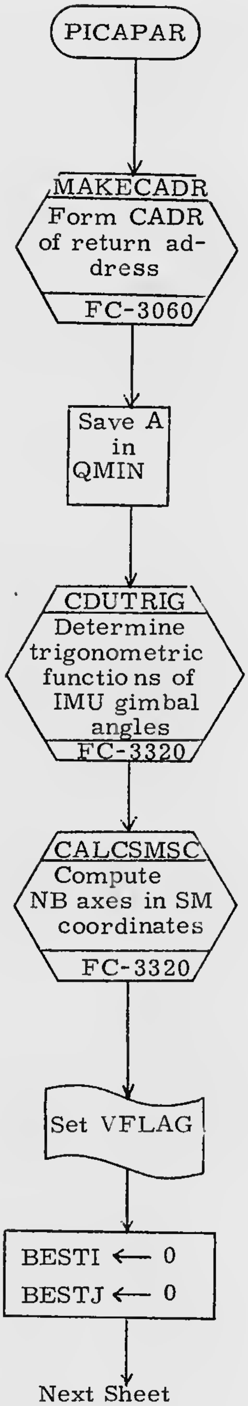
Cos (angle of occultation of Moon) @ 2^2

@ 2^2

Next Sheet



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D Lutkewich	10/9/69	P52	
PRGMR			DOCUMENT NO.
ANALST			
DOCMR		LUMINARY 1D	FC-3510
APPR'D Robert M Estes	3/6/70	REV 1	SHEET 33 OF 55



Pick a pair of stars for sighting

Output: A = CADR $\begin{pmatrix} \text{return location} \\ \text{calling program} \end{pmatrix}$

Output: $\left.\begin{matrix} \text{SINCDUX}, & \text{COSCDUX} \\ \text{SINCDUY}, & \text{COSCDUX} \\ \text{SINCDUZ}, & \text{COSCDUZ} \end{matrix}\right\}$ sines, cosines of IMU gimbal angles @ 2^1

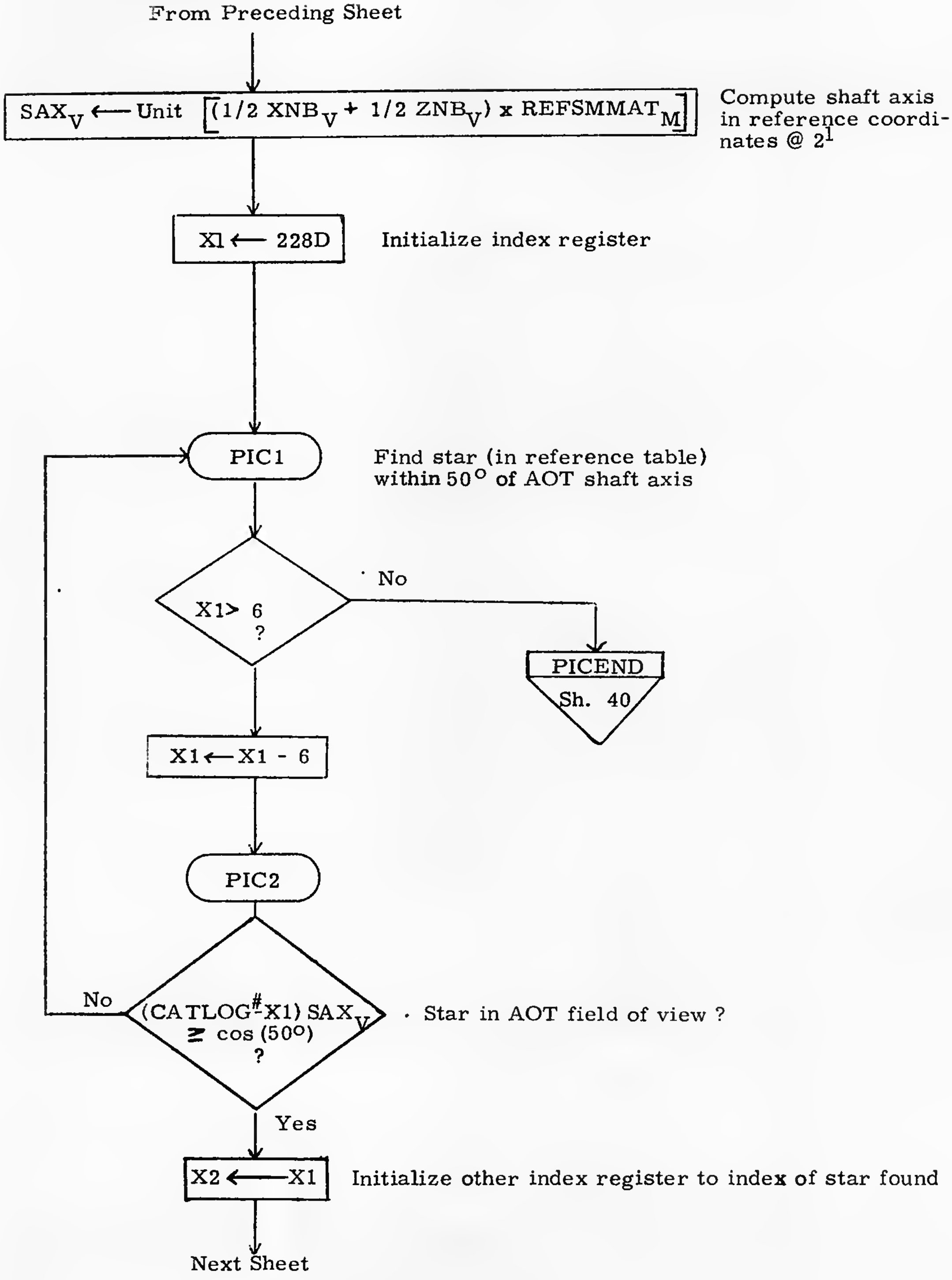
Input: SINCDUX, COSCDUX
SINCDUY, COSCDUY
SINCDU Z, COSCDUZ

Output: $XNB_M = \begin{bmatrix} XNB_V \\ YNB_V \\ ZNB_V \end{bmatrix}$ = NB axes in SM (present) coordinates @ 2^1

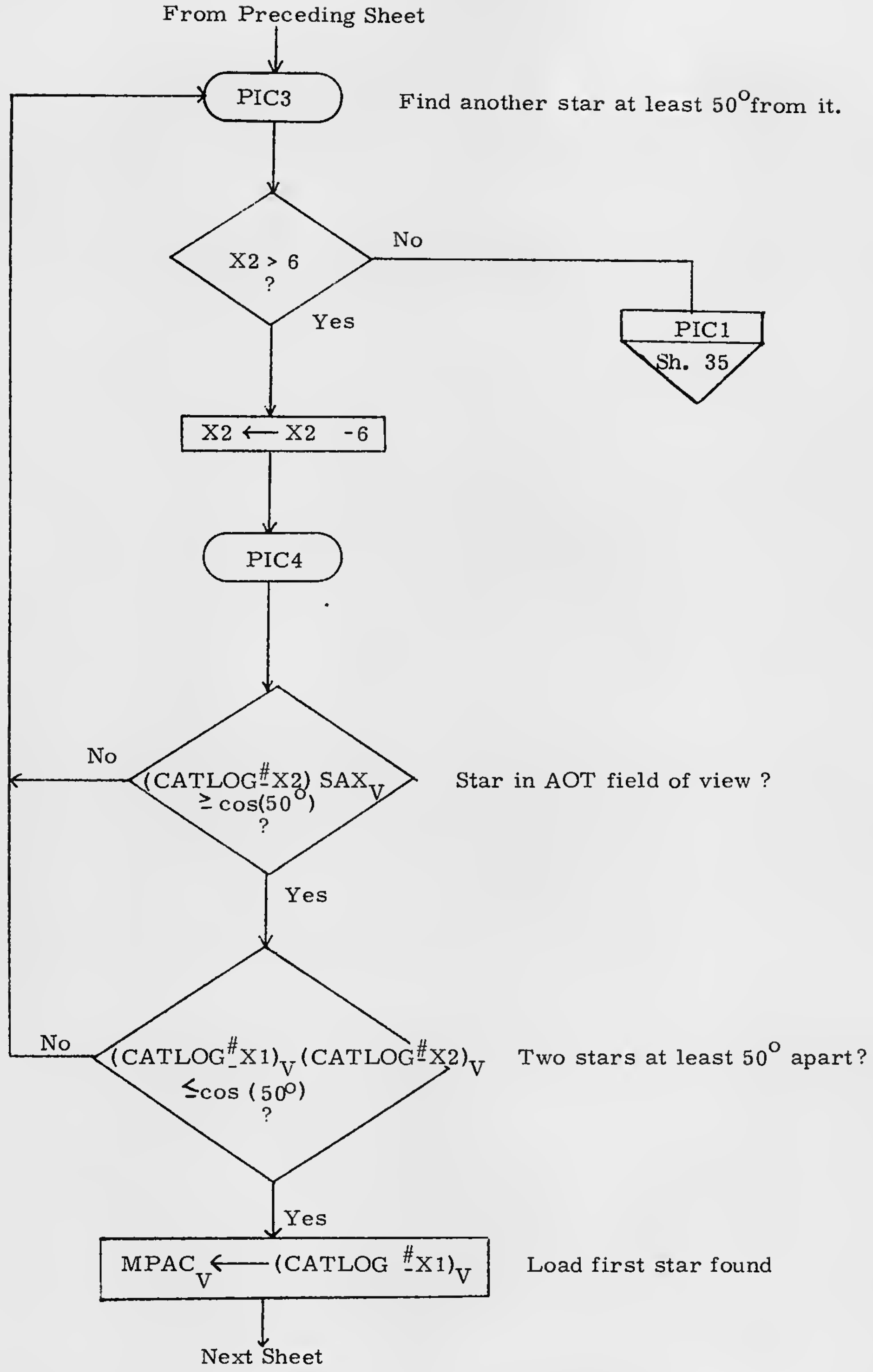
Initialize flag to indicate less than two stars in field of view

Initialize star number registers

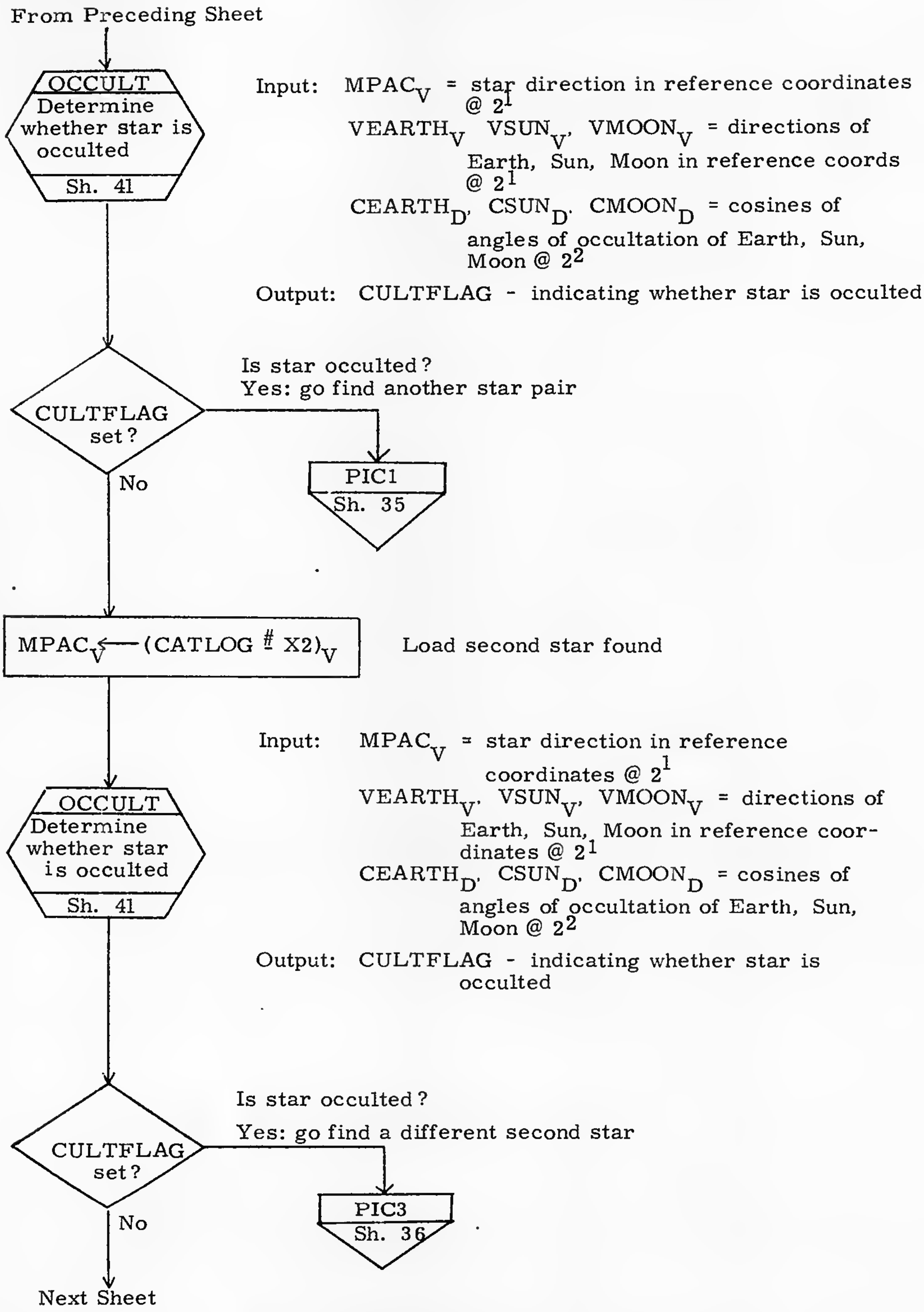
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN I. Lutkenhaus	10/9/69	P52	
PRGMR			
ANALST			DOCUMENT NO.
DOCMR		LUMINARY 1D	FC-3510
APPR'D Roberta M Ewing	3/6/70	REV 1	SHEET 34 of 55



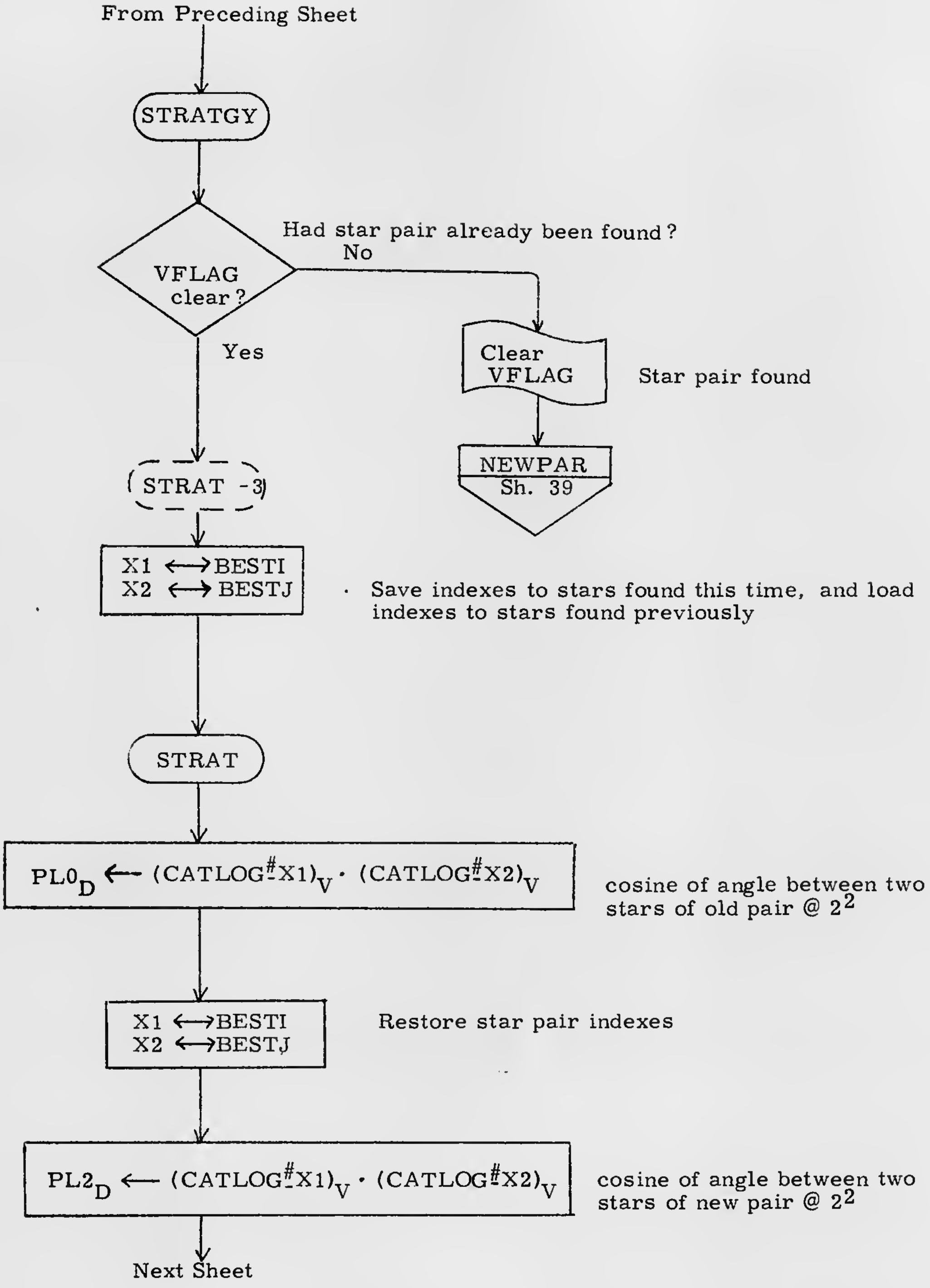
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN J. Latkevich	10/9/69	P52	
PRGMR			DOCUMENT NO.
ANALST			
DOCMR		LUMINARY 1D	FC-3510
APPR'D Roberta M Enter	3/6/70	REV 1	SHEET 35 OF 55



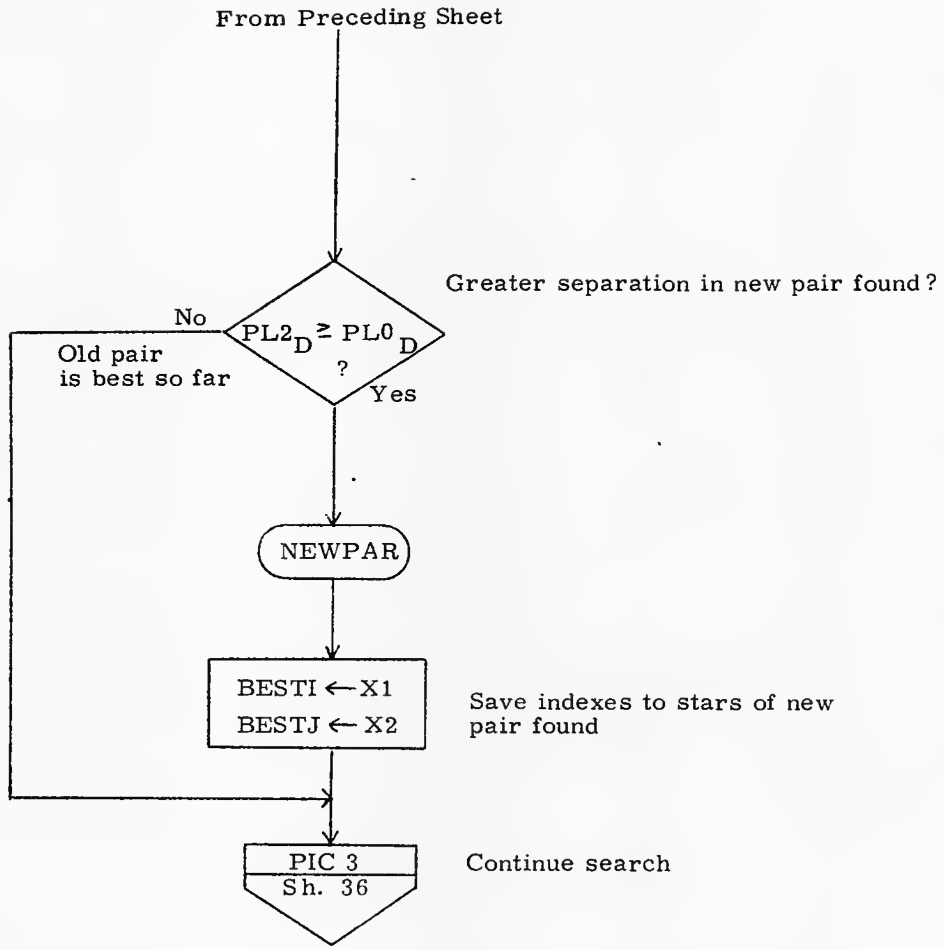
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN I. Lutkevich	11/9/69	P52	
PRGMR			DOCUMENT NO.
ANALST			
DOCMR		LUMINARY 1D	FC-3510
APPR'D Roberta M Estes	3/6/70	REV 1	SHEET 36 OF 55



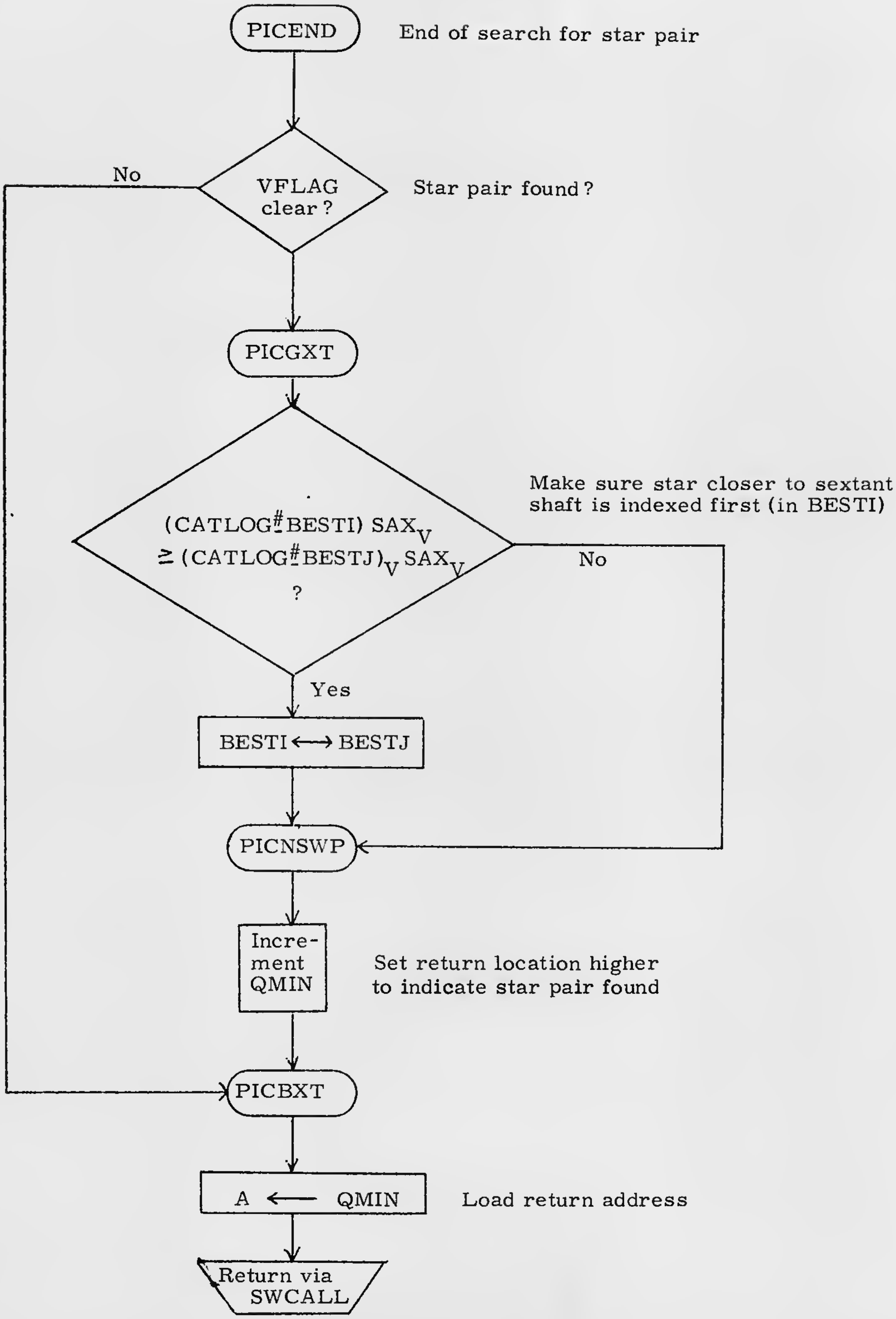
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lutkewich	12/9/69	P52	
PRGMR			DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3510
DOCMR			
APPR'D Roberta M Enter	3/6/70	REV 1	SHEET 37 OF 55



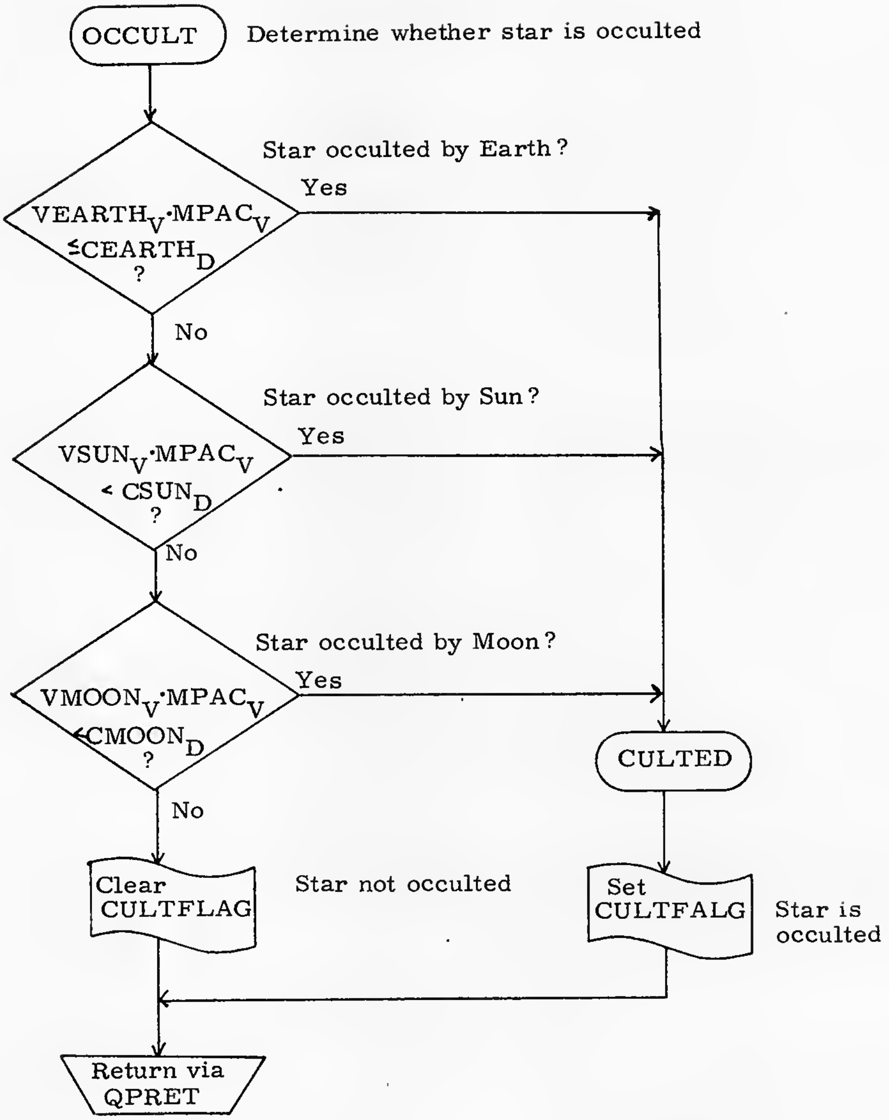
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lutkevich	10/9/69	P52	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3510
DOCMR			
APPR'D Roberto M. Eaton	3/6/70	REV 1	SHEET 38 OF 55



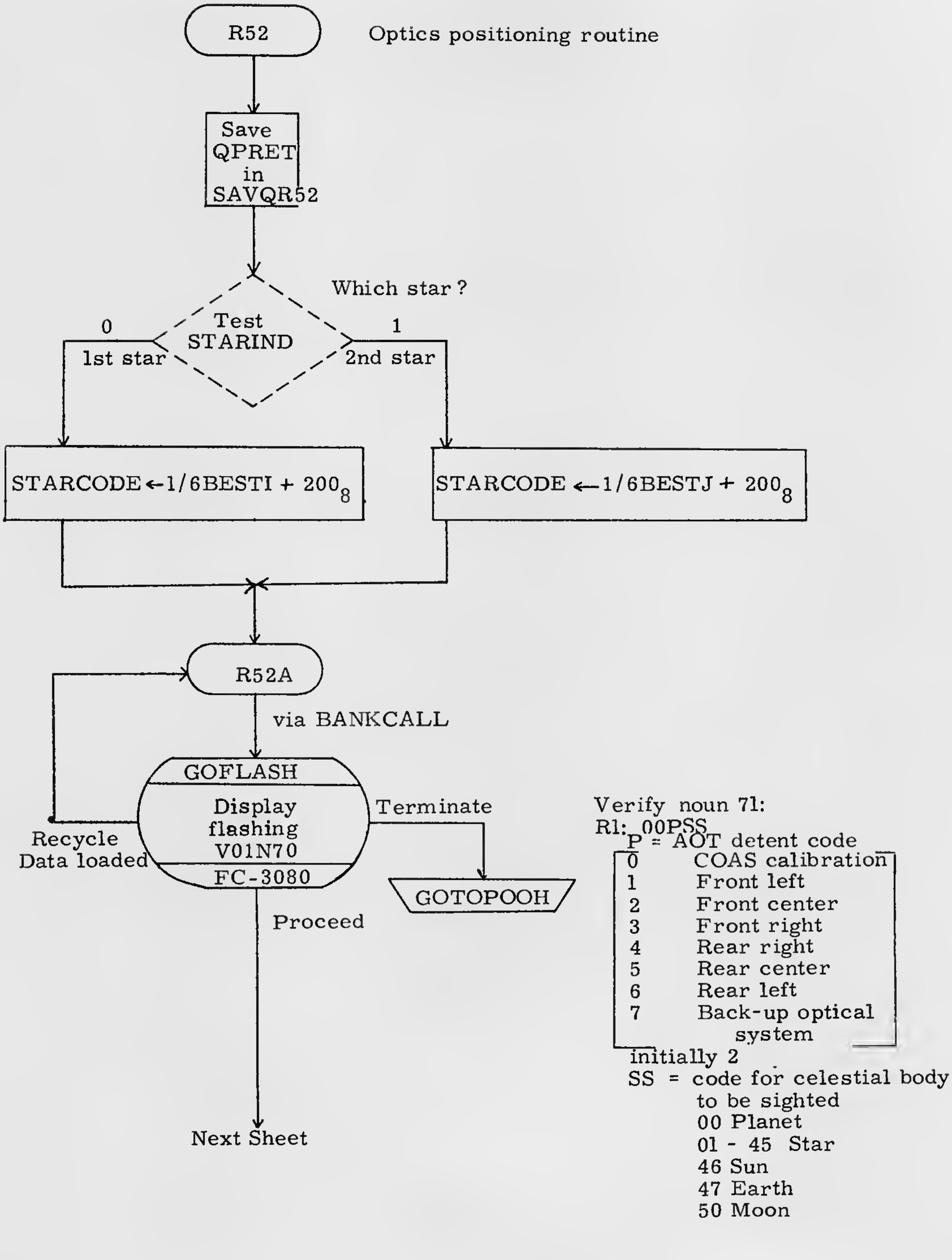
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D Lutkewich	1/9/69	P52	
PRGMR			DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3510
DOCMR			
APPR'D Roberta M Estes	3/6/70	REV 1	SHEET 39 OF 55



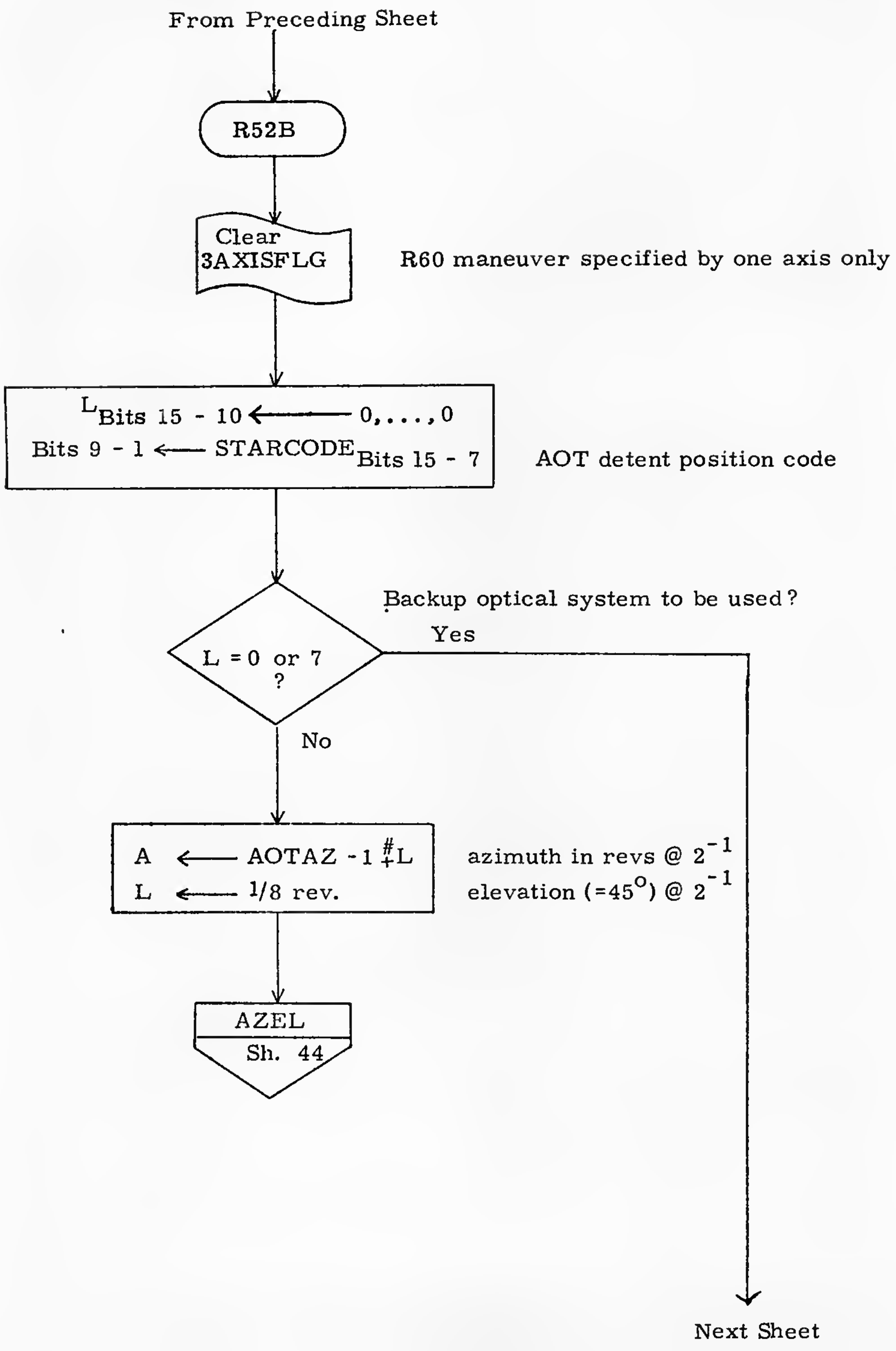
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN D. Lutkevich	10/9/69	P52
PRGMR		
ANALST		LUMINARY 1D DOCUMENT NO. FC-3510
DOCMR		
APPR'D Robert M Estes	3/6/70	REV 1 SHEET 40 OF 55



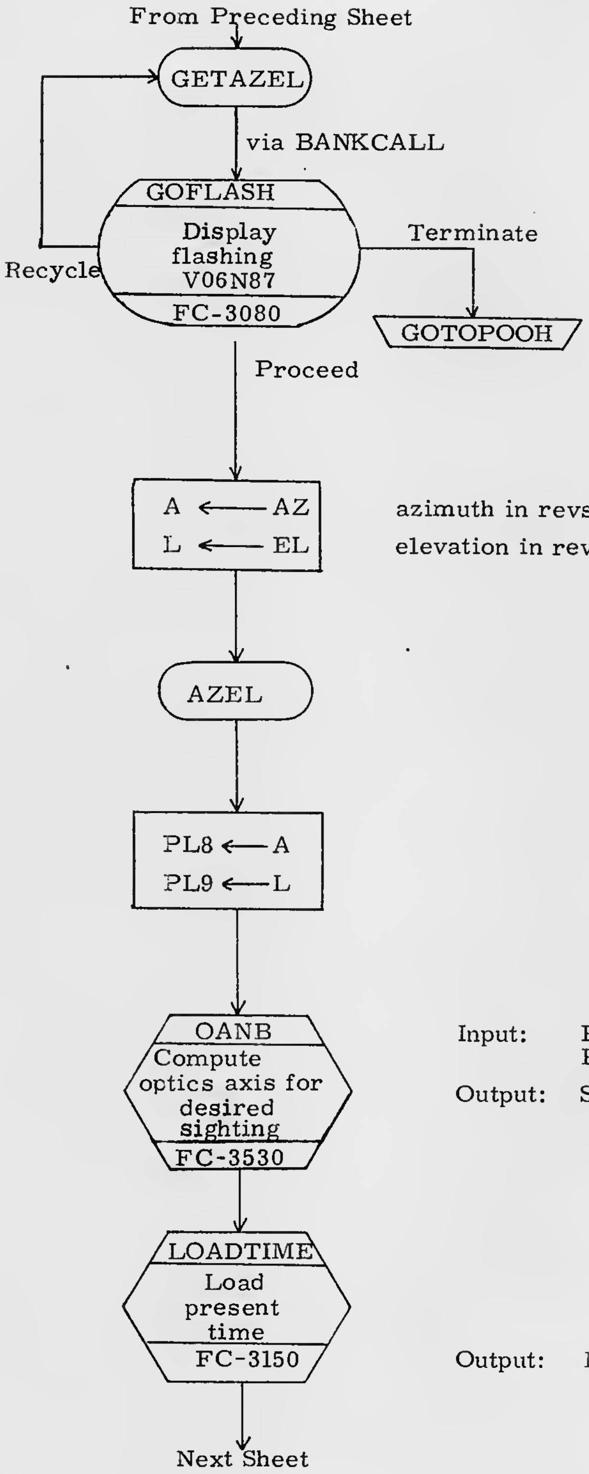
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN D Lutkevich	10/9/69	P52
PRGMR		
ANALST		LUMINARY 1D — DOCUMENT NO. FC-3510
DOCMR		
APPR'D Roberta M Estes	3/6/70	REV 1 — SHEET 41 OF 55



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lutkewich	10/9/69	P52	
PRGMR			DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3510
DOCMR			
APPR'D Roberta M Evans	3/6/70	REV 1	SHEET 42 OF 55



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lutkevich	10/9/69	P52	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3510
DOCMR			
APPR'D Roberta M Estes	3/6/70	REV 1	SHEET 43 OF 55



Load noun 87:

R1: xxx xx deg. azimuth (AZ)

R2: xxx xx deg. elevation (EL)

azimuth in revs @ 2^{-1}

elevation in revs @ 2^{-1}

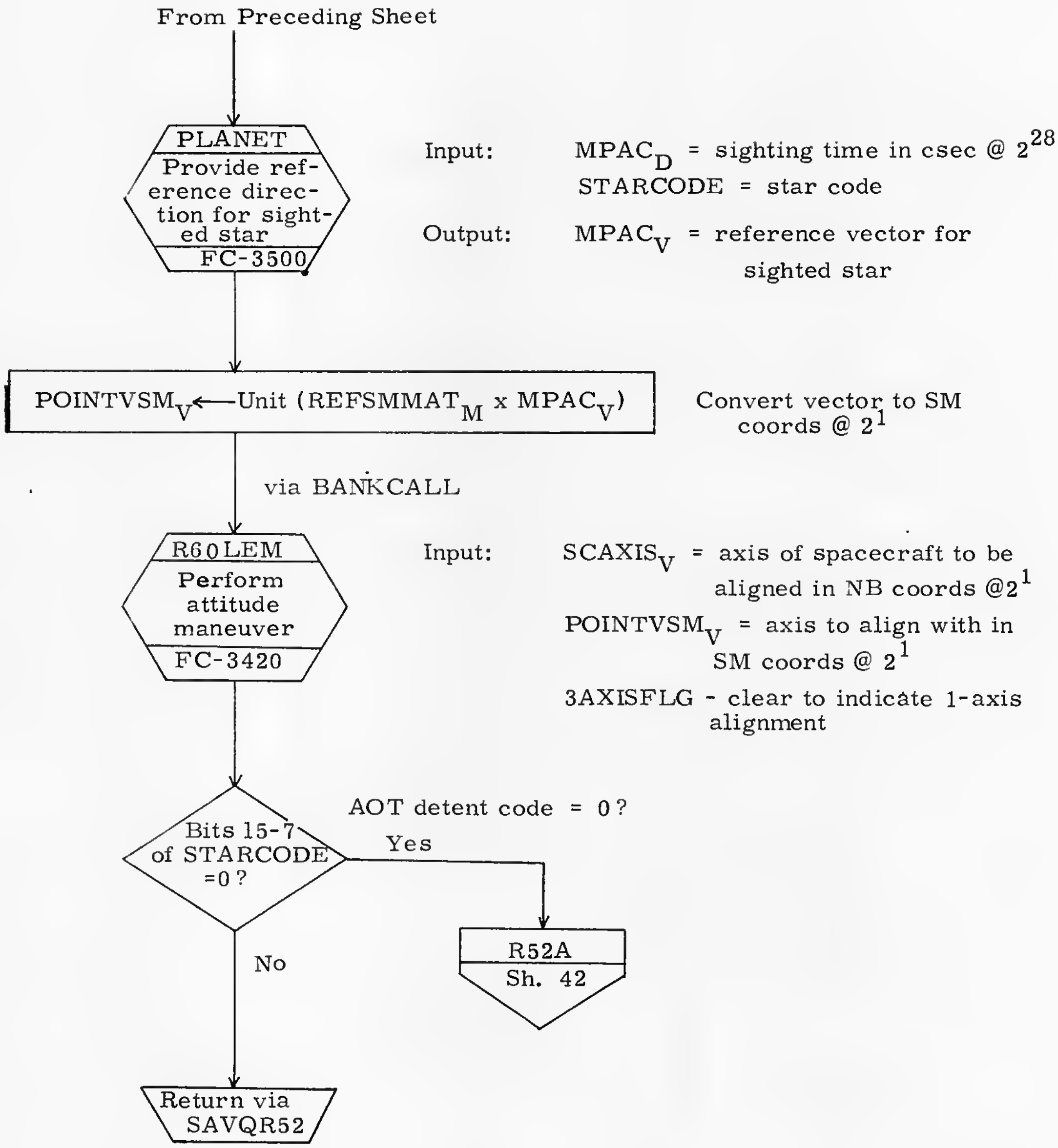
Input: PL8 = azimuth in revs @ 2^{-1}

PL9 = elevation in revs @ 2^{-1}

Output: $SCAXIS_V$ = optics axis in NB coords @ 2^1

Output: $MPAC_D$ = present time in csec @ 2^{28}

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D Lutkewich	10/9/69	P52	
PRGMR			DOCUMENT NO. FC-3510
ANALST		LUMINARY 1D	
DOCMR			
APPR'D Roberta M Estes	3/6/70	REV 1	SHEET 44 OF 55



MIT INSTRUMENTATION LAB
CAMBRIDGE, MASS.

DRAWN D. Lutkevich 10/9/69
PRGMR
ANALST
DOCMR
APPR'D Roberta M Estes 3/6/70

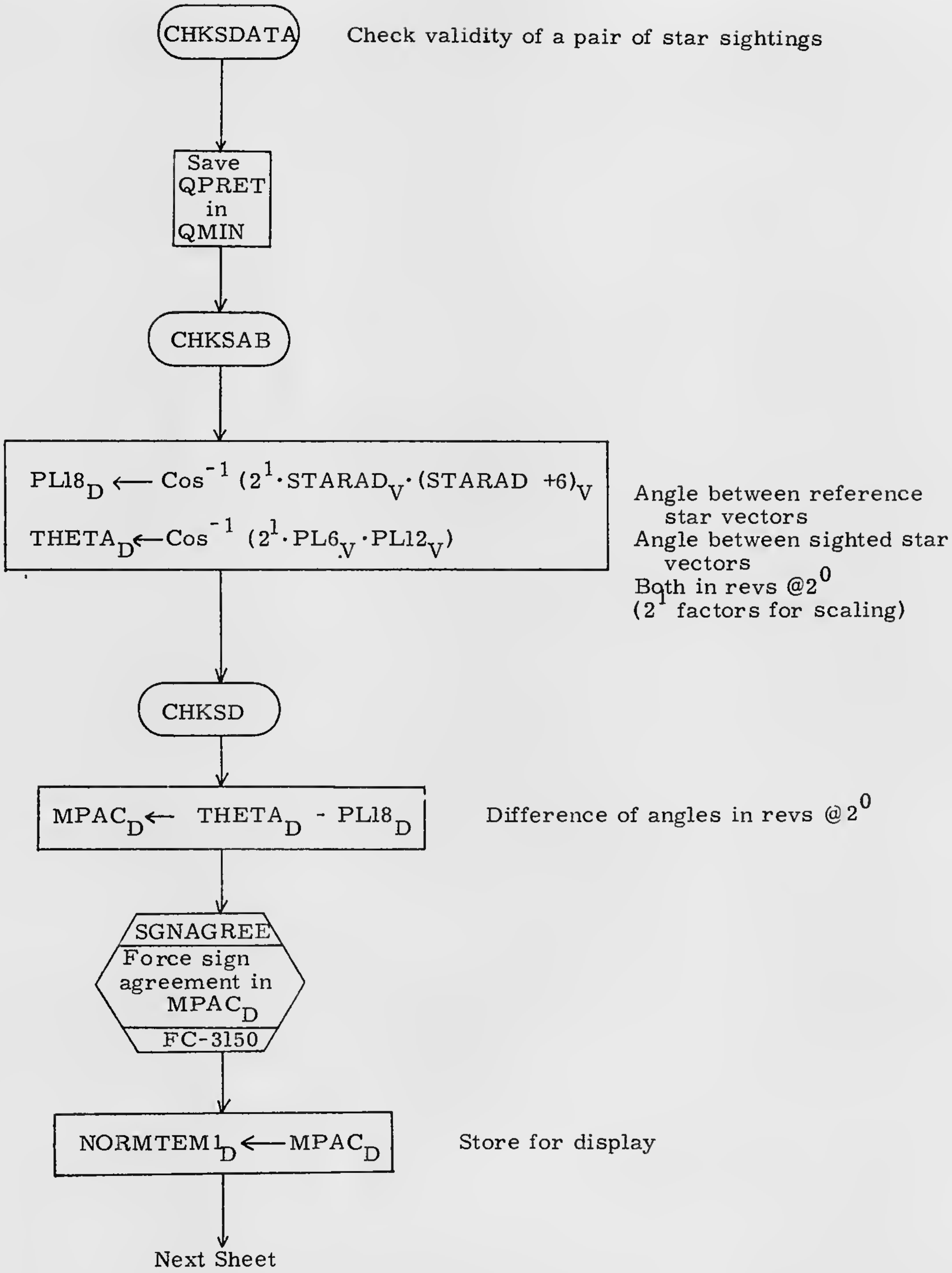
APOLLO GUIDANCE AND NAVIGATION

P52

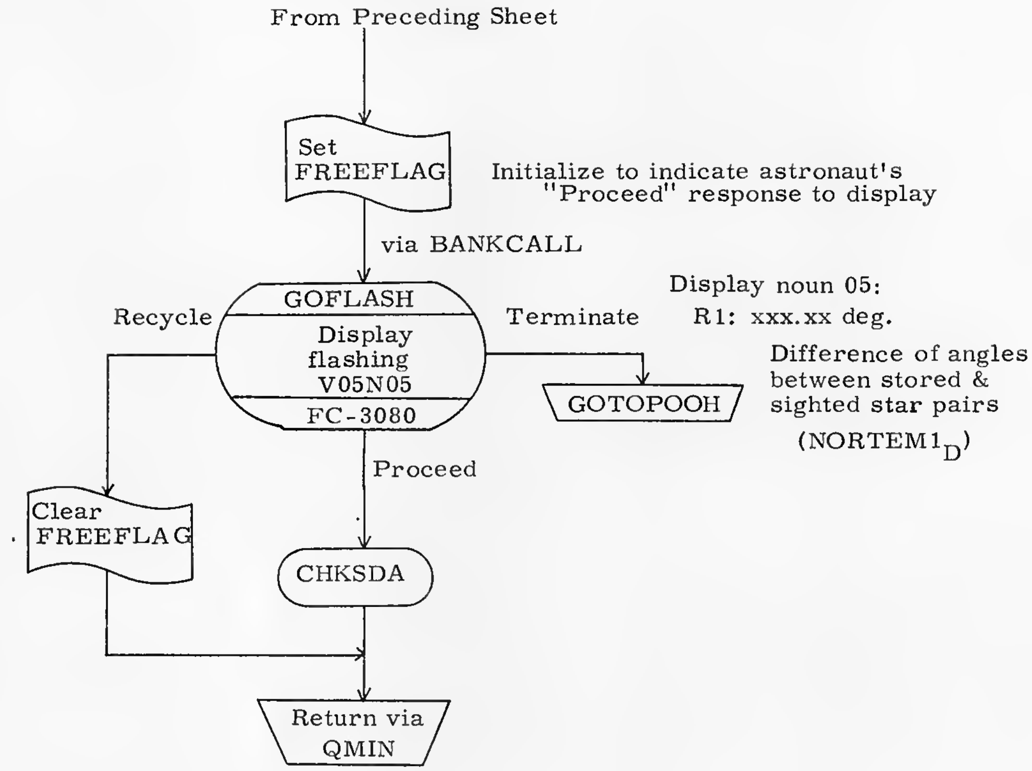
LUMINARY 1D

DOCUMENT NO. FC-3510

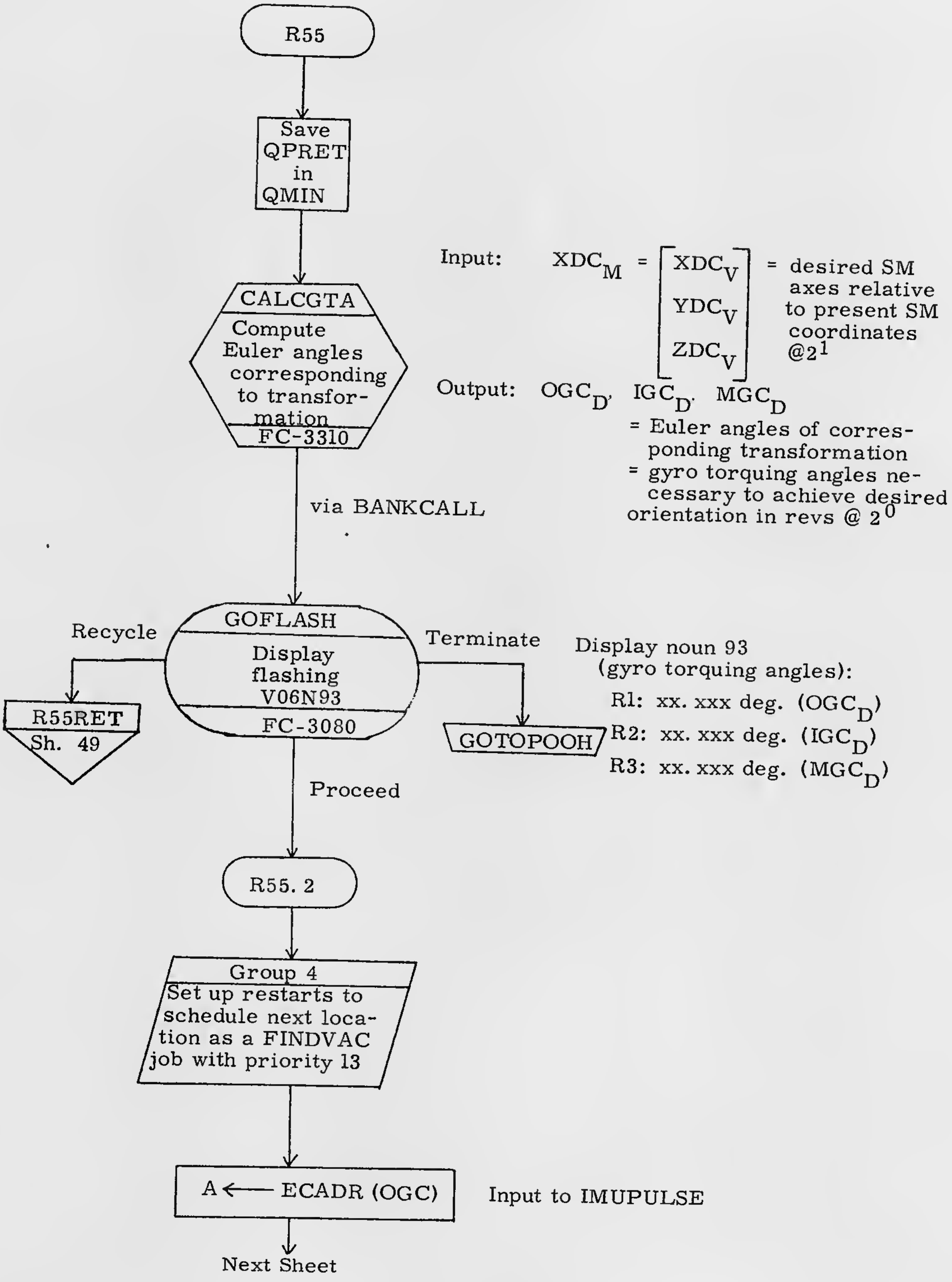
REV 1



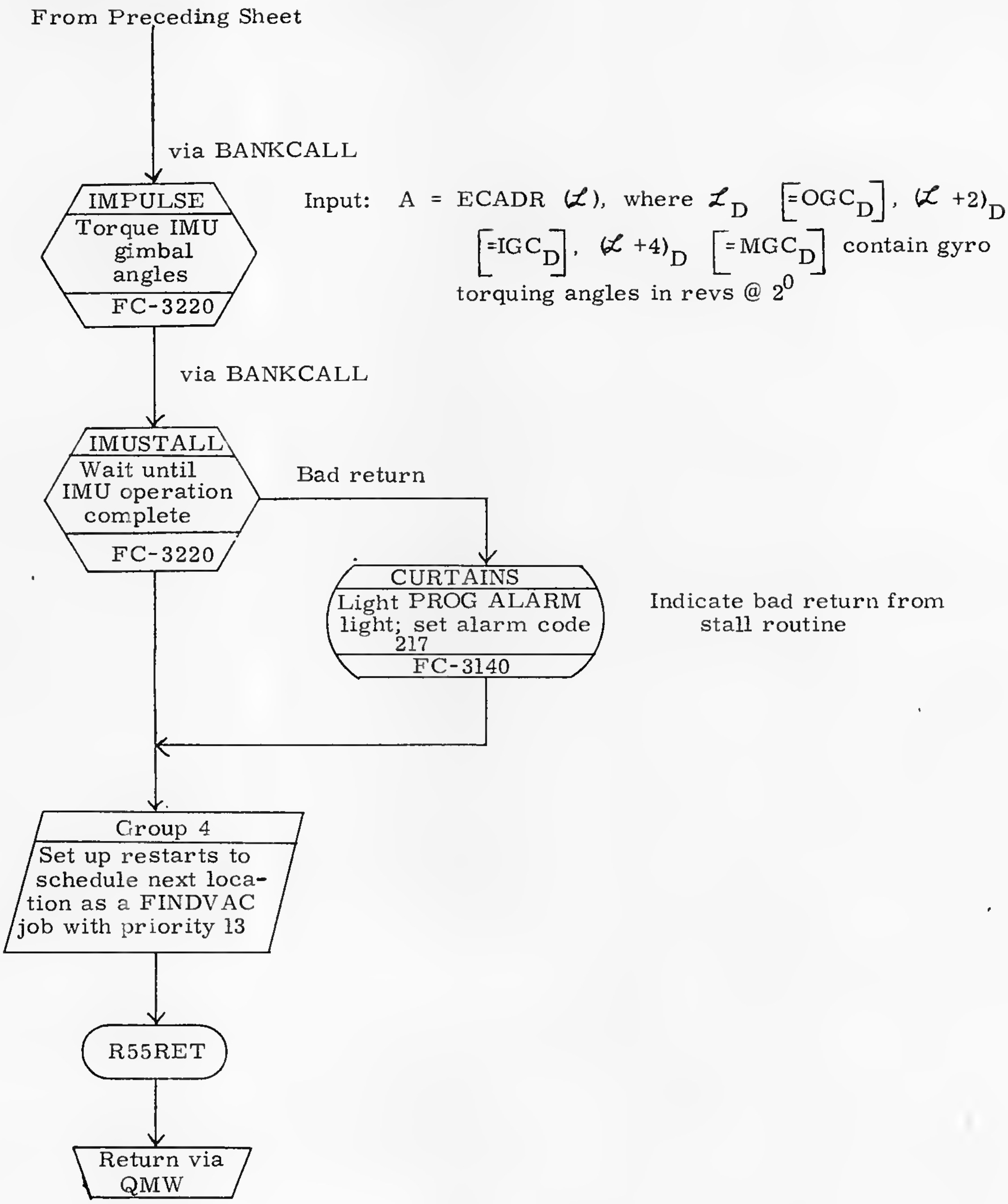
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D Lutkevich	10/9/69	P52	
PRGMR			DOCUMENT NO.
ANALST			
DOCMR		LUMINARY 1D	FC-3510
APPR'D Roberta M Ertes	3/6/70	REV 1	SHEET 46 OF 55



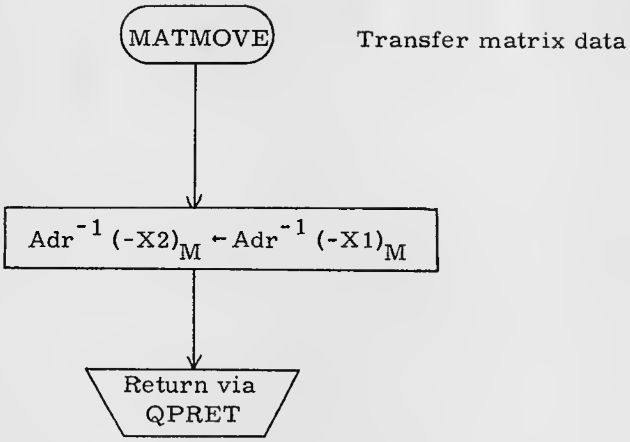
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D Lutkenus	10/9/69	P52	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3510
DOCMR			
APPR'D Roberta M Evans	3/6/70	REV 1	SHEET 47 OF 55



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN I. Lutkewich	11/9/69	P52	
PRGMR			DOCUMENT NO.
ANALST			
DOCMR		LUMINARY 1D	FC-3510
APPR'D Roberta M Estes	3/6/70	REV 1	SHEET 48 OF 55



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN D. Zulkewicz	10/9/69	P52
PRGMR		
ANALST		LUMINARY 1D — DOCUMENT NO. FC-3510
DOCMR		
APPR'D Roberta M Eades	3/6/70	REV 1 — SHEET 49 OF 55


MATMOVE
Transfer matrix data
$Adr^{-1}(-X2)_M \leftarrow Adr^{-1}(-X1)_M$
Return via QPRET

EXTERNAL ROUTINES CALLED

Routine	Flowchart	Where Called
ALARM	FC-3140	Sh. 24
AOTMARK	FC-3530	Sh. 25
AXISGEN	FC-3310	Sh. 28
CALCGA	FC-3310	Sh. 18
CALCGTA	FC-3310	Sh. 19, 48
CALCSMSC	FC-3320	Sh. 17, 34
CDUTRIG	FC-3320	Sh. 17, 34
COARSE	FC-3500	Sh. 11
CURTAINS	FC-3140	Sh. 20, 25, 49
IMPULSE	FC-3220	Sh. 20, 49
IMUSTALL	FC-3220	Sh. 20, 49
LALOTORV	FC-3330	Sh. 16
LAT-LONG	FC-3330	Sh. 14
LEMCONIC	FC-3350	Sh. 13
LEMPREC	FC-3350	Sh. 30
LOADTIME	FC-3150	Sh. 22, 44
LSPOS	FC-3345	Sh. 30
MAKECADR	FC-3060	Sh. 34
NCOARSE	FC-3500	Sh. 11, 21
OANB	FC-3530	Sh. 44
OPTSTALL	FC-3220	Sh. 25
PLANET	FC-3500	Sh. 26, 27, 45
RP-TO-R	FC-3340	Sh. 5
R02BOTH	FC-3220	Sh. 2
R60LEM	FC-3420	Sh. 45
SGNAGREE	FC-3150	Sh. 46
GOPERF4R	FC-3080	Sh. 2
GOFLASH	FC-3080	Sh. 3, 7, 15, 24, 42, 44, 47, 48
GOPERF1	FC-3080	Sh. 7, 29, 22
GODSPR	FC-3080	Sh. 19

FLAGS

Flag Name	Location	Where Set	Where Cleared	Where Tested
CULTFLAG	Bit 7 of FLAGWRD3	Sh. 41	Sh. 41	Sh. 37
DRIFTFLG	Bit 15 of FLAGWRD2		Sh. 19	
ERADFLAG	Bit 13 of FLAGWRD1		Sh. 5	
FREEFLAG	Bit 3 of FLAGWRD0	Sh. 47	Sh. 47	Sh. 28
LUNAFLAG	Bit 12 of FLAGWRD3	Sh. 5		
PFRATFLG	Bit 4 of FLAGWRD2		Sh. 12, 21, 29	Sh. 2
REFSMFLG	Bit 13 of FLAGWRD3	Sh. 12, 21	Sh. 19	
VFLAG	Bit 10 of FLAGWRD3	Sh. 34	Sh. 38	Sh. 38, 40
3AXISFLG	Bit 6 of FLAGWRD5		Sh. 43	

DISPLAYS

Verb-Noun	Type of Display	Where Called
V04N06	Flashing	Sh. 2
V06N34	Flashing	Sh. 3
V06N22	Flashing	Sh. 7
V50N25	Flashing	Sh. 7, 22, 29
V06N89	Flashing	Sh. 15
V16N20	Normal	Sh. 19
	PROG ALARM light	Sh. 20, 24, 25, 49
V05N09	Flashing	Sh. 24
V01N70	Flashing	Sh. 42
V06N87	Flashing	Sh. 44
V06N05	Flashing	Sh. 47
V06N93	Flashing	Sh. 48

ERASABLE LOCATIONS USED

$ALPHAV_V$

ALT_D

AOTCODE
(=STARCODE)

AZ

BESTI

BESTJ

CDUX

CDUY

CDUZ

$CEARTH_D$

$CMOON_D$

COSCDUX

COSCDUY

COSCDUZ

$CSUN_D$

EL

IGC_D

$LANDALT_D$

$LANDLAT_D$

$LANDLONG_D$

LAT_D

$LONG_D$

MGC_D

OGC_D

$OPTION2_D$

$POINTVSM_V$

$RATT_V$

$REFSMMAT_M$

RLS_V

$RRECTCSM_V$

SAX_V

$SCAXIS_V$

SINCDUX

SINCDUY

SINCDUZ

$STARAD_V$

$(STARAD +6)_V$

STARCODE
(= AOTCODE)

STARIND

$STARSAV1_V$

$STARSAV2_V$

$TALIGN_D$

$TDEC1_D$

THETAD

THETAD +1

THETAD +2

$TIME2_D$

$TLAND_D$

$TSIGHT_D$

$VATT_V$

$VEARTH_V$

$VMOON_V$

$VRECTCSM_V$

$VSUN_V$

$$XDC_M = \begin{bmatrix} XDC_V \\ YDC_V \\ ZDC_V \end{bmatrix}$$

$$XNB_M = \begin{bmatrix} XNB_V \\ YNB_V \\ ZNB_V \end{bmatrix}$$

$$XSM_M = \begin{bmatrix} XSM_V \\ YSM_V \\ ZSM_V \end{bmatrix}$$

$$XSMD_M = \begin{bmatrix} XSMD_V \\ YSMD_V \\ ZSMD_V \end{bmatrix}$$

CONSTANTS

$(CATLOG\ -6)_V$

$(CATLOG\ -12D)_V$

.
.
.
.

$(CATLOG\ -216D)_V$

$(CATLOG\ -222D)_V$

$\dot{R}OE_D$

$RSUBE_D$

$RSUBEM_D$

PADLOADS

AOTAZ

AOTAZ +1

AOTAZ +2

AOTAZ +3

AOTAZ +4

AOTAZ +5

AOTEL

AOTEL +1

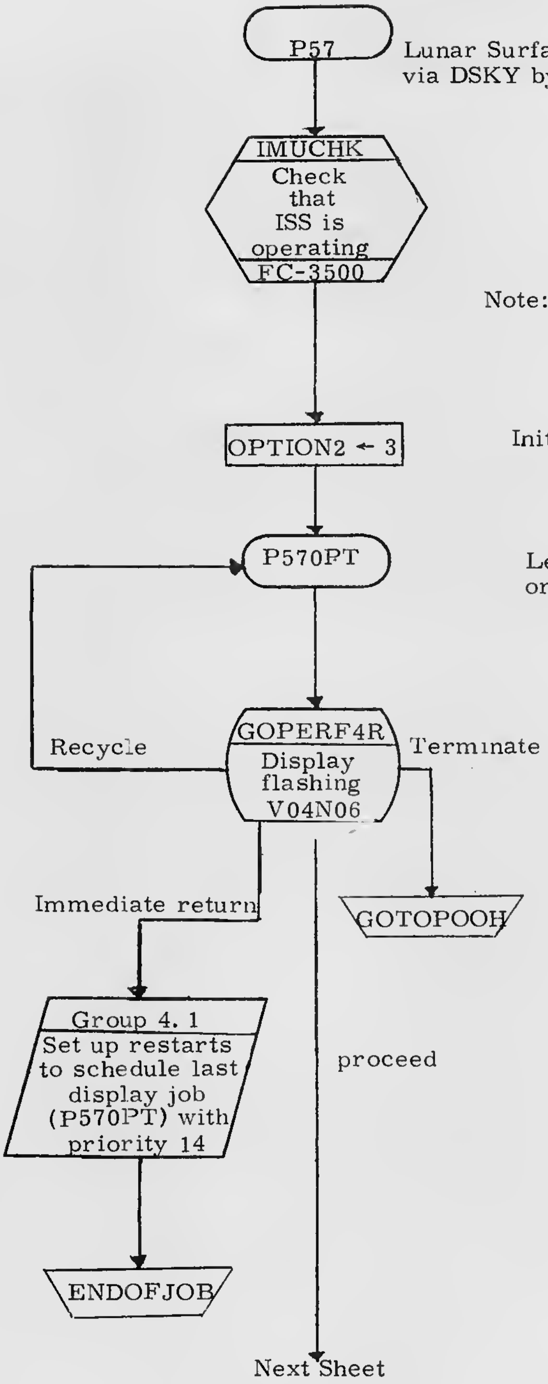
AOTEL +2

AOTEL +3

AOTEL +4

AOTEL +5

P57: Lunar Surface Alignment Program



Lunar Surface Alignment Program called via DSKY by V37E57E.

Note: If ISS is not operating, IMUCHK terminates program.

Initialize IMU orientation option.

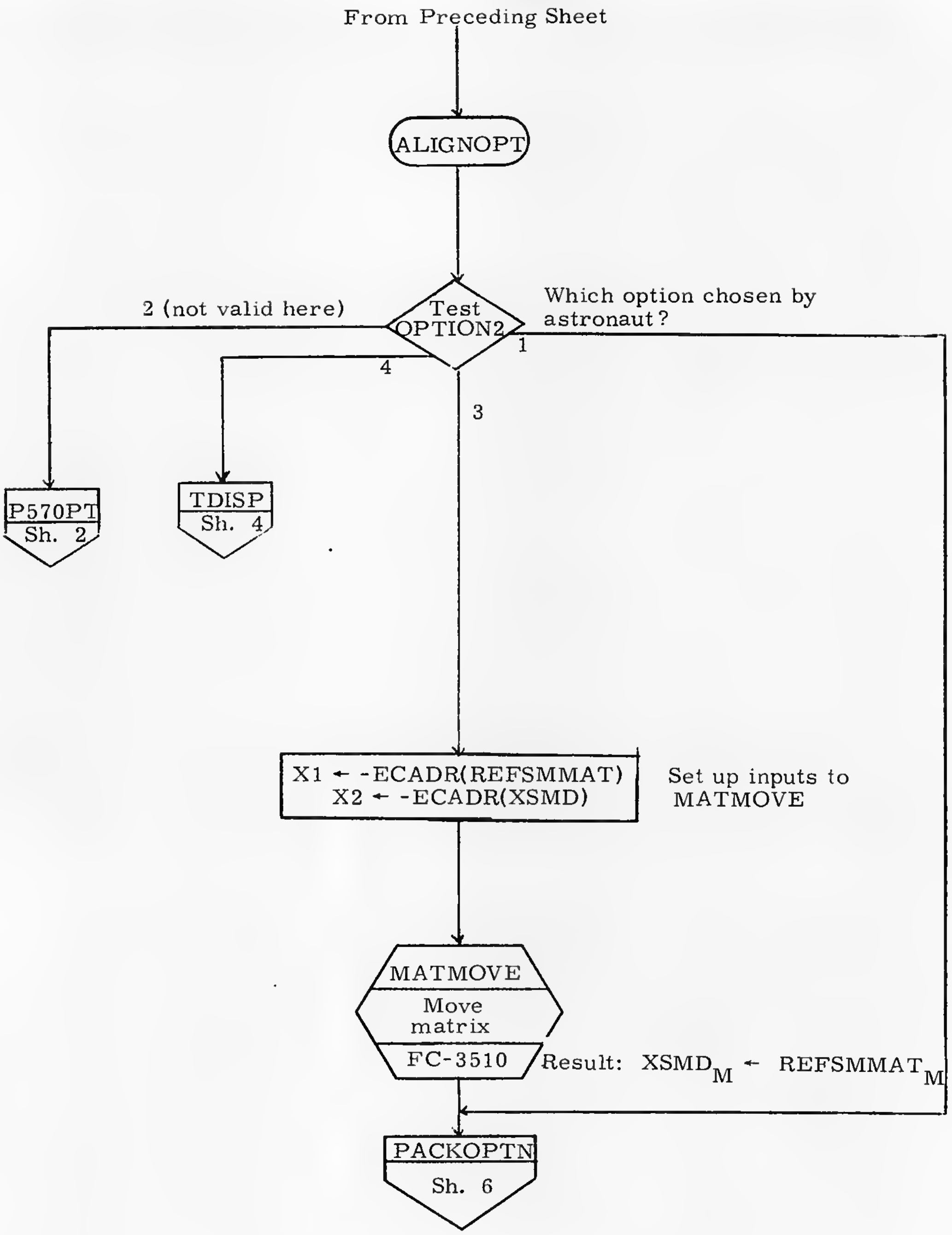
Let astronaut load or verify IMU orientation option.

Display Noun 6:

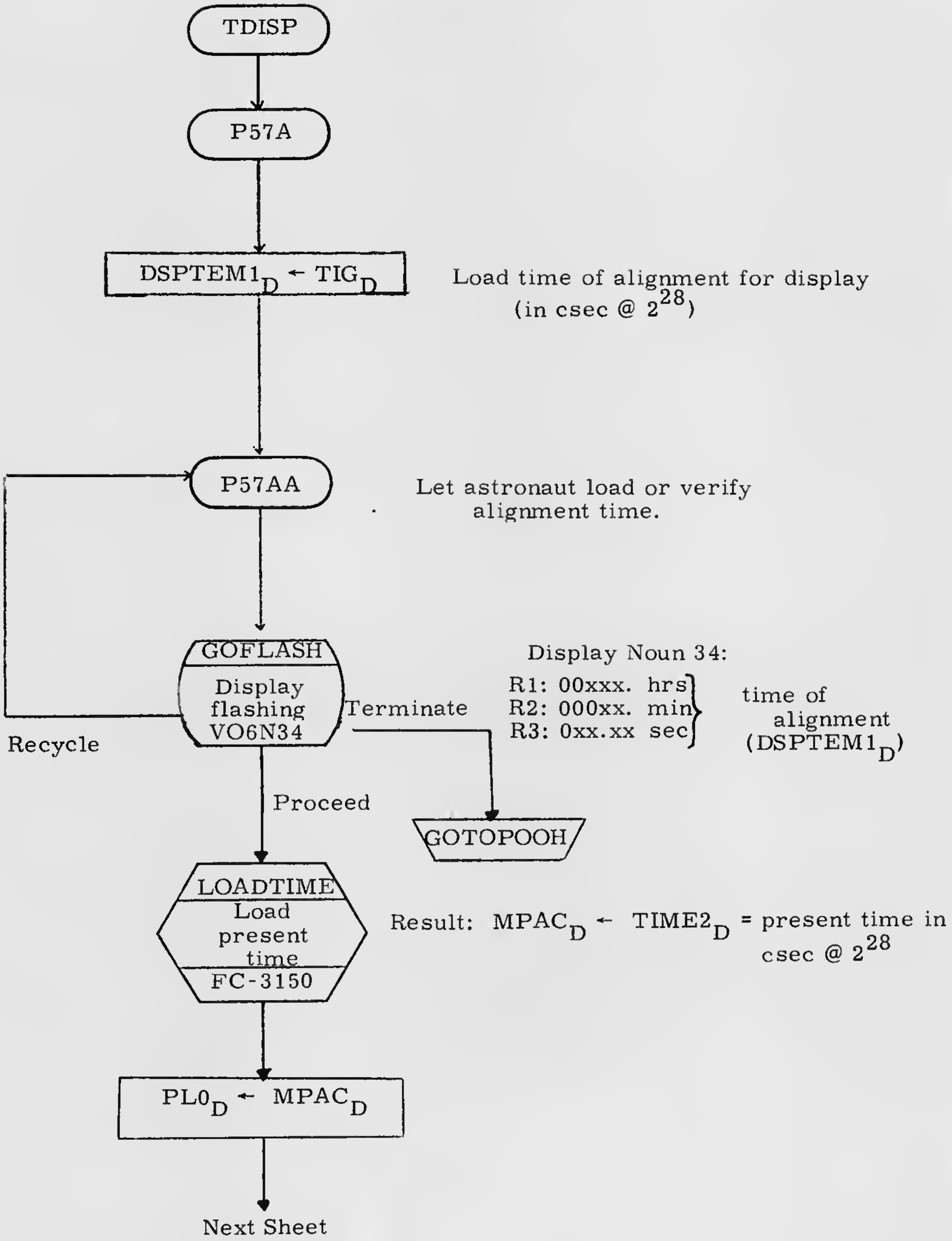
R1: 00001 Option ID (specify IMU orientation)

R2: xxxxx option code (OPTION2)

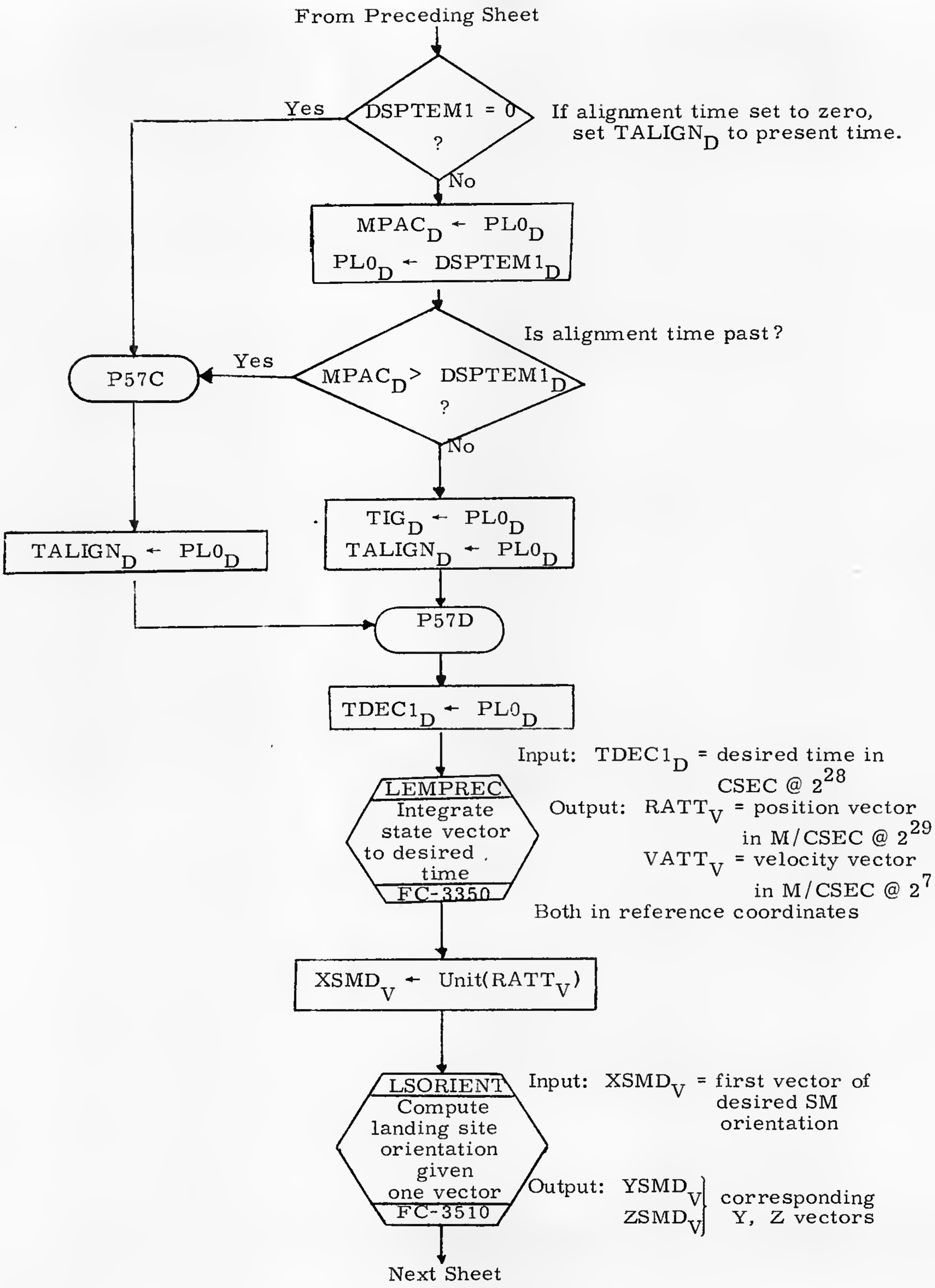
00001	Preferred
00002	Nominal
00003	REFSMMAT
00004	Landing site

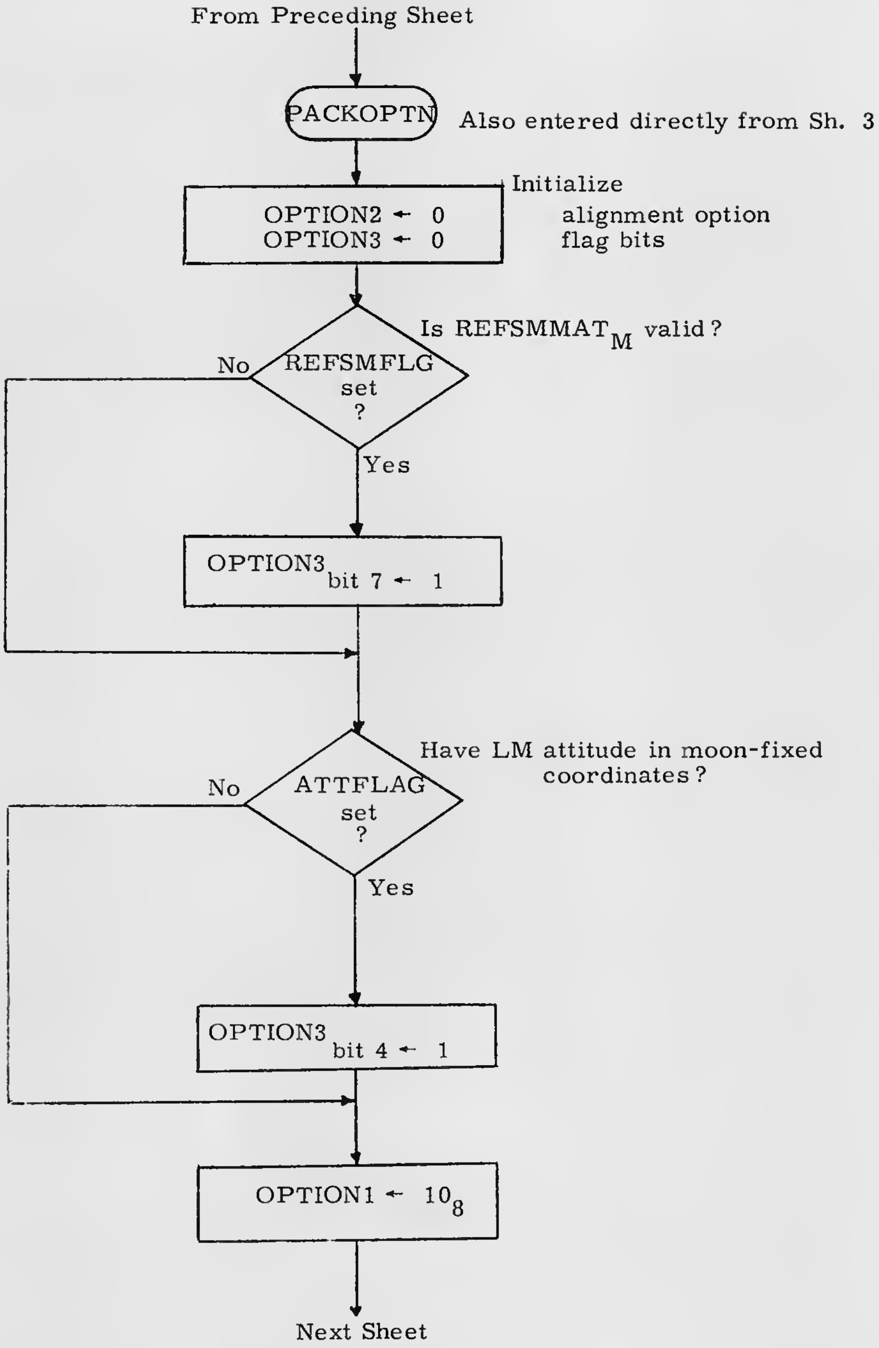


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		P57	
PRGMR	8/29/69	LUMINARY 1D	DOCUMENT NO. FC-3520
ANALST			
DOCMR	8/29/69		
APPR'D	8/29/69	REV 2	SHEET 3 OF 65

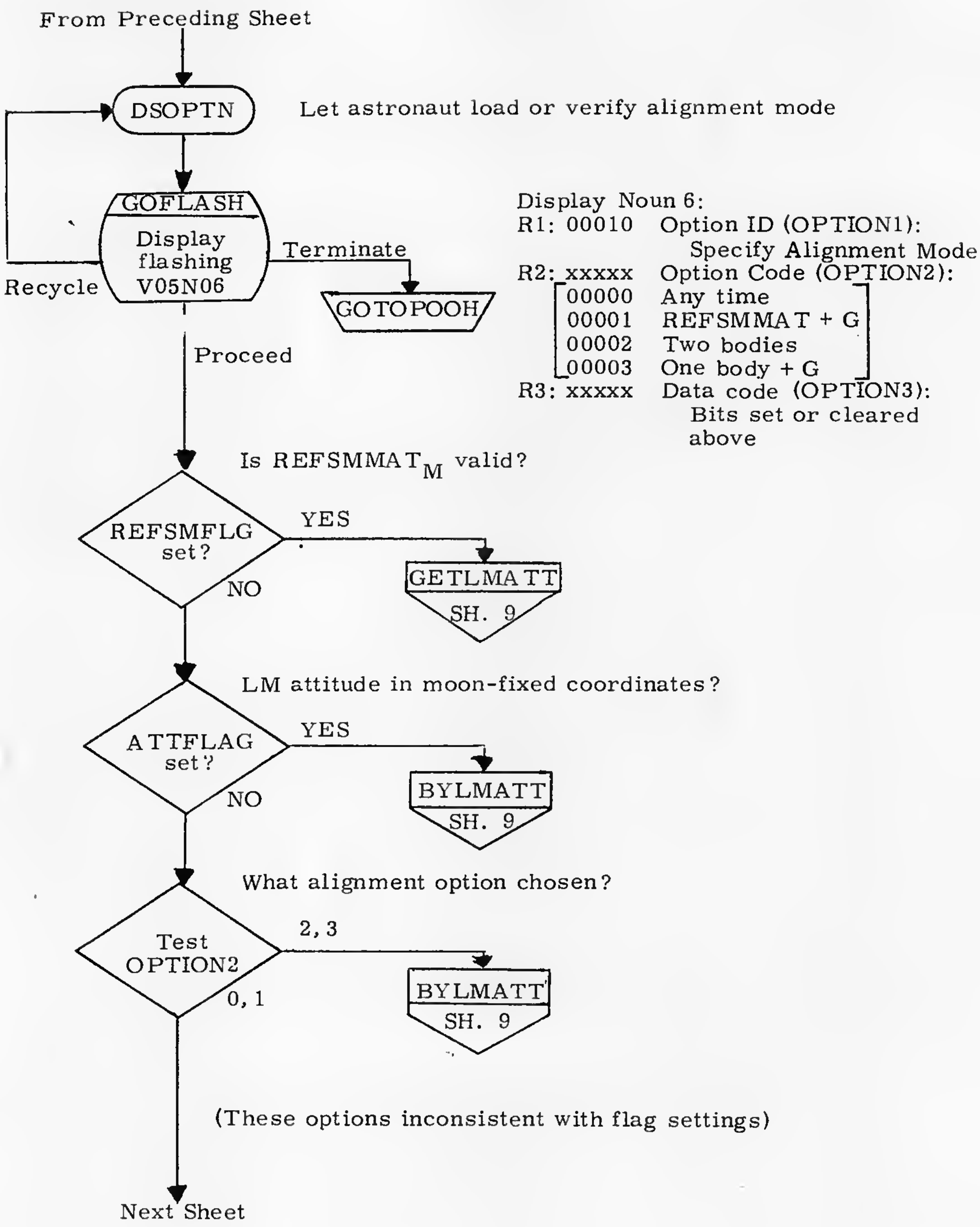


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN J. Cincotta	7-30-68	P57	
PRGMR D. Millard	8/29/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3520
DOCMR A. M. Sorant	8/29/69		
APPR'D A. M. Sorant	8/29/69	REV 2	SHEET 4 OF 65

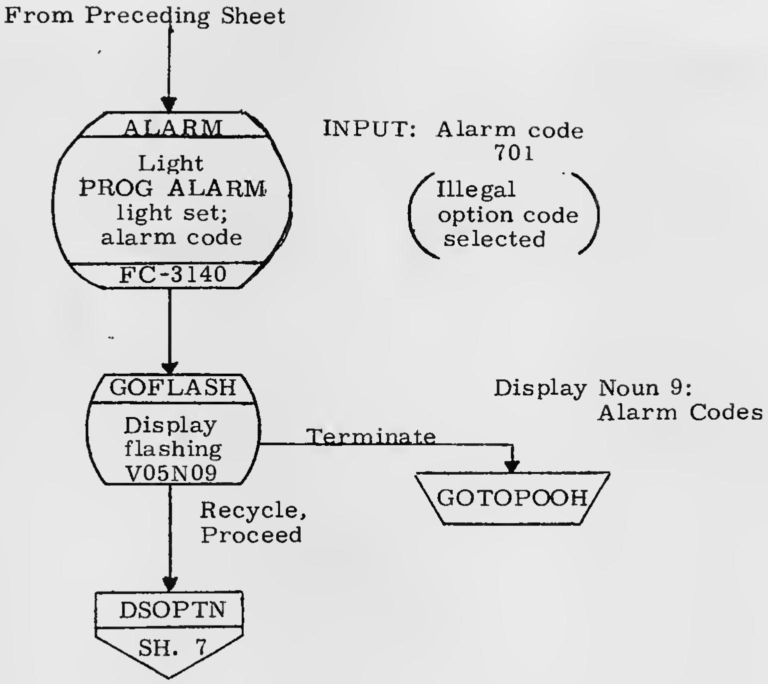

From Preceding Sheet
DSPTEM1 = 0 ?
Yes
No
If alignment time set to zero, set TALIGN_D to present time.
MPAC_D ← PL0_D
PL0_D ← DSPTEM1_D
Is alignment time past?
MPAC_D > DSPTEM1_D ?
Yes
No
P57C
TIG_D ← PL0_D
TALIGN_D ← PL0_D
TALIGN_D ← PL0_D
P57D
TDEC1_D ← PL0_D
LEMPREC
Integrate state vector to desired time
FC-3350
Input: TDEC1_D = desired time in CSEC @ 2^28
Output: RATT_V = position vector in M/CSEC @ 2^29
VATT_V = velocity vector in M/CSEC @ 2^7
Both in reference coordinates
XSMD_V ← Unit(RATT_V)
LSORIENT
Compute landing site orientation given one vector
FC-3510
Input: XSMD_V = first vector of desired SM orientation
Output: YSMD_V, ZSMD_V corresponding Y, Z vectors
Next Sheet

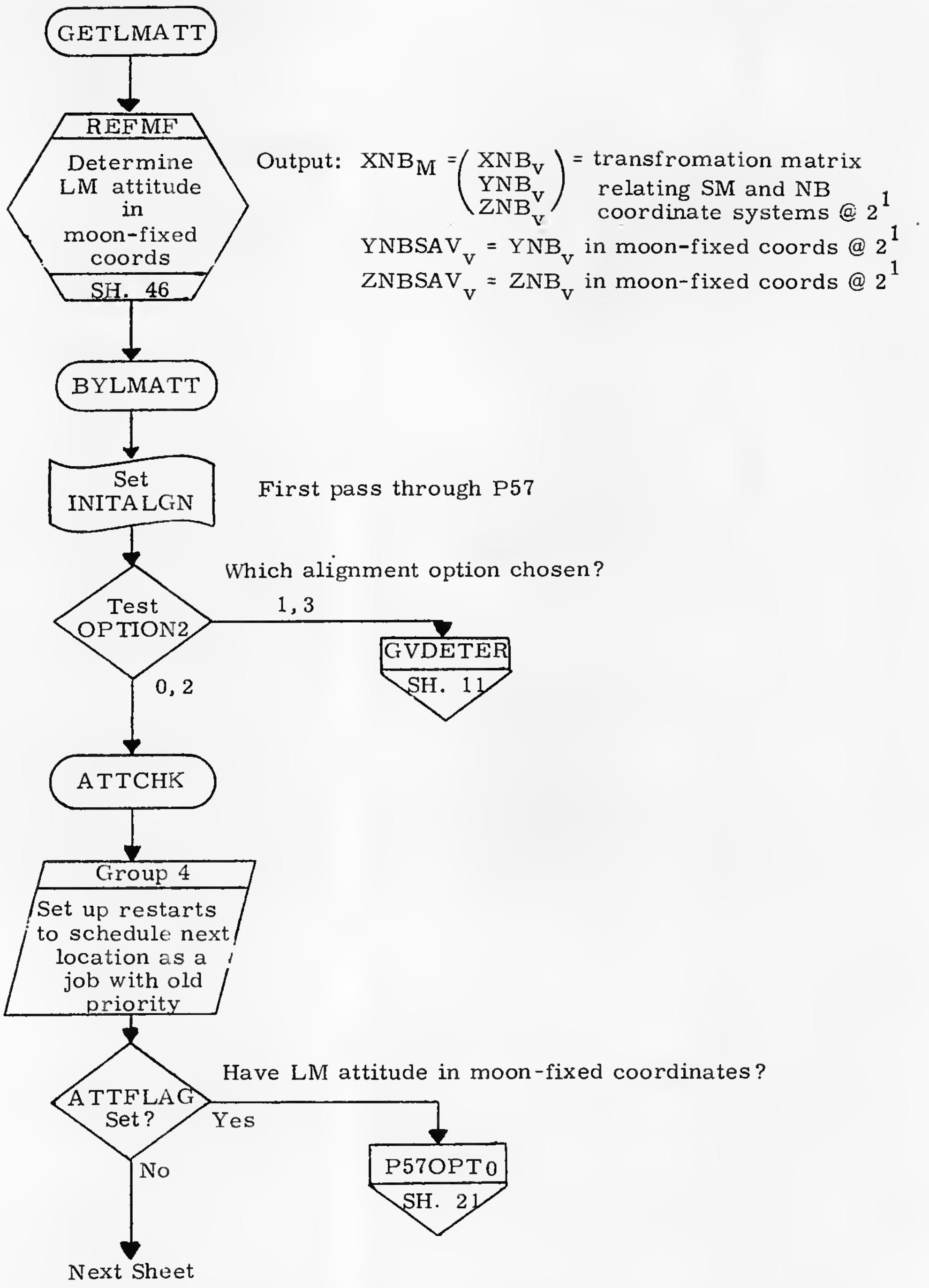


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN J. Cugnetta	7-31-69	P57	
PRGMR D. Millard	8/29/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC -3520
DOCMR Alex McSorant	8/ /69		
APPR'D A.M. Sorant	8/29/69	REV 2	SHEET 6 OF 65

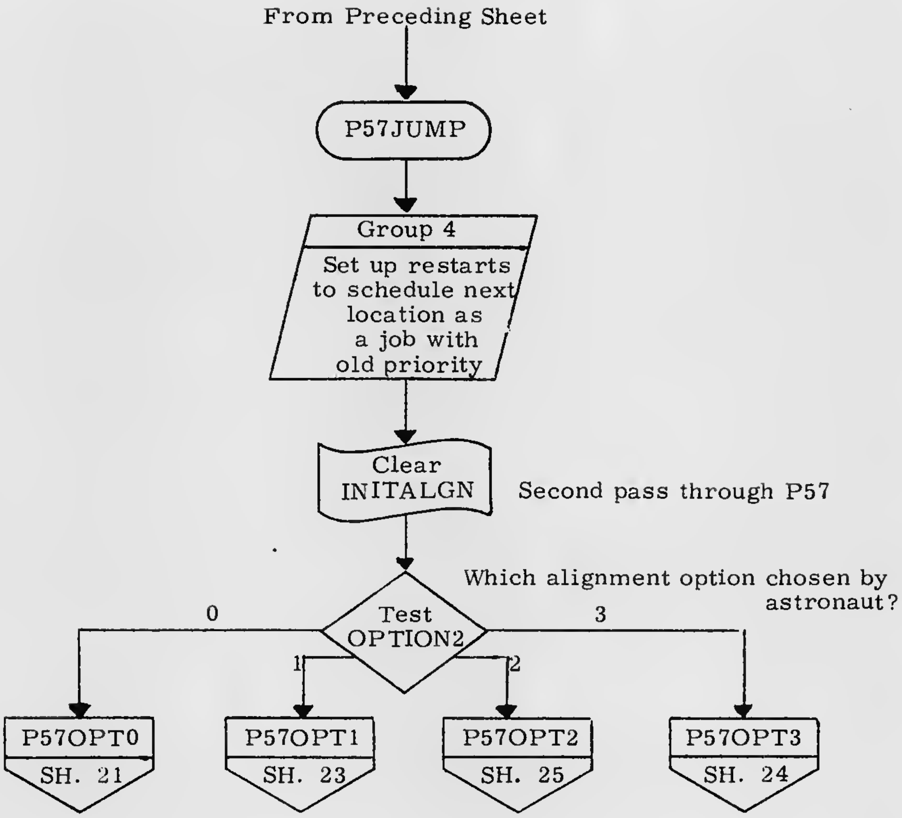


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		P57	
PRGMR	8/23/69	LUMINARY 1D	DOCUMENT NO. FC-3520
ANALST			
DOCMR	8/28/69		
APPR'D	8/29/69	REV 2	SHEET 7 OF 65

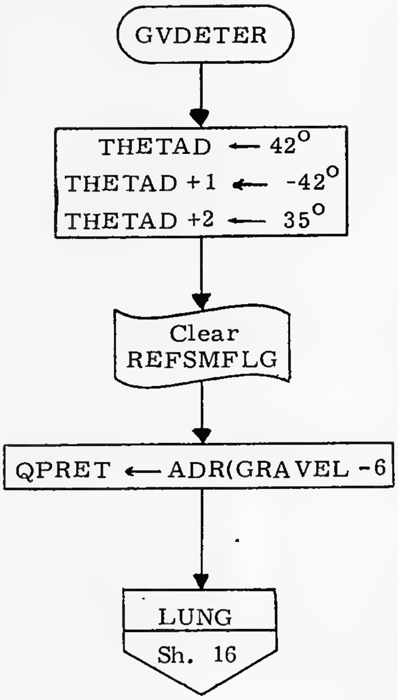

From Preceding Sheet
ALARM
Light PROG ALARM light set; alarm code
FC-3140
INPUT: Alarm code 701
(Illegal option code selected)
GOFLASH
Display flashing V05N09
Terminate
Display Noun 9: Alarm Codes
GOTOPOOH
Recycle, Proceed
DSOPTN
SH. 7



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		P57	
PRGMR	8/28/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3520
DOCMR	8/28/69		
APPR'D	8/29/69	REV 2	SHEET 9 OF 65



From Preceding Sheet
P57JUMP
Group 4
Set up restarts to schedule next location as a job with old priority
Clear INITALGN
Second pass through P57
Which alignment option chosen by astronaut?
Test OPTION2
0
1
2
3
P57OPT0
SH. 21
P57OPT1
SH. 23
P57OPT2
SH. 25
P57OPT3
SH. 24

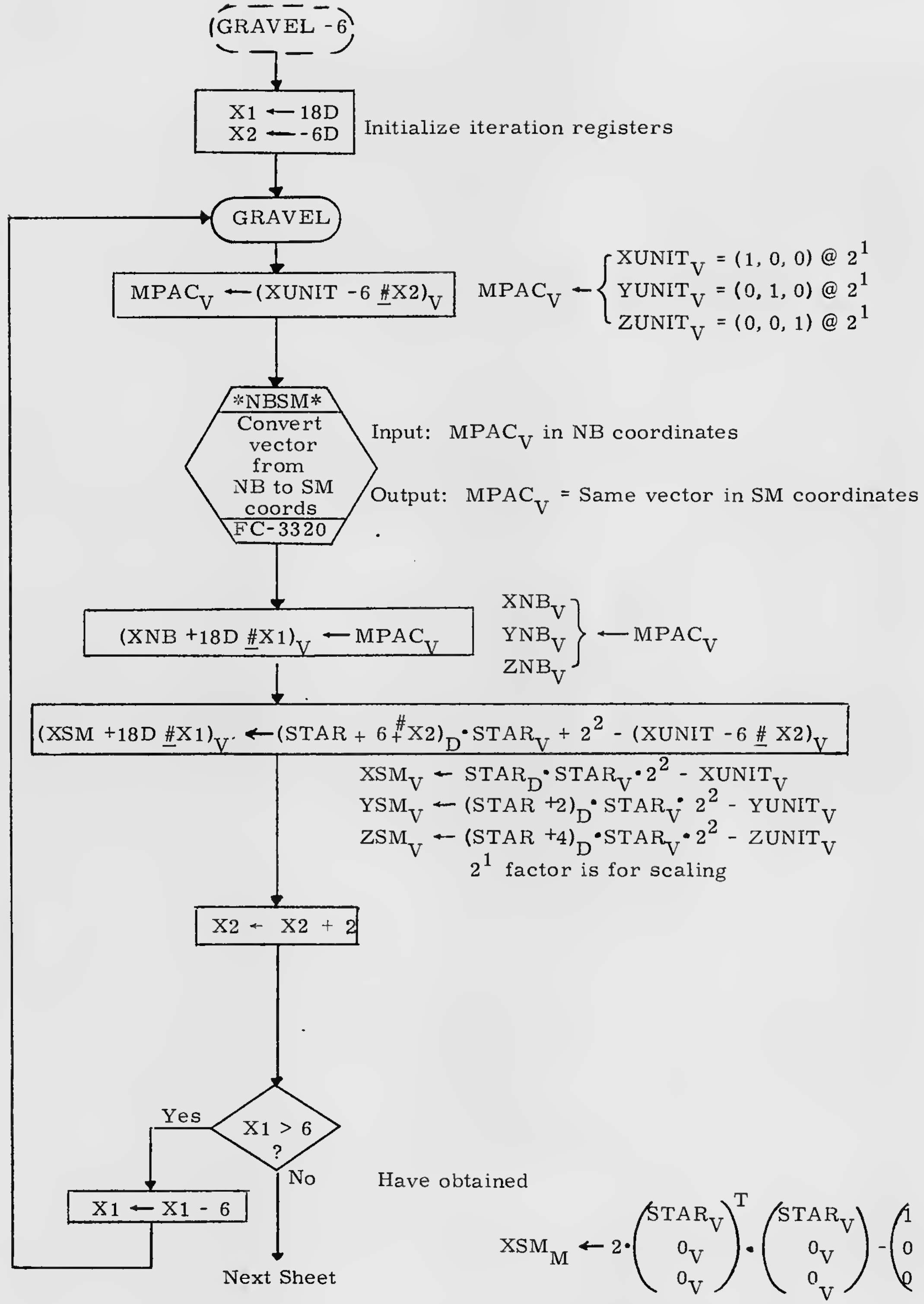


Gravity vector determination

Set up desired IMU gimbal angles in revs @ 2^{-1}

REFSMMAT matrix invalid

Set up return from LUNG sequence to GRAVEL -6 (Sh. 12)



$$XSM_M \leftarrow 2 \cdot \begin{pmatrix} STAR_V \\ 0_V \\ 0_V \end{pmatrix}^T \cdot \begin{pmatrix} STAR_V \\ 0_V \\ 0_V \end{pmatrix} - \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

From Preceding Sheet

Input: $\begin{pmatrix} XNB_V \\ YNB_V \\ ZNB_V \end{pmatrix}$ Relating NB and present SM coordinate systems

$\begin{pmatrix} XSM_V \\ YSM_V \\ ZSM_V \end{pmatrix}$ Giving desired SM orientation relative to present SM coordinates

CALCGA
Compute driving angles needed to align IMU
FC-3310

Output: THETAD, THETAD +1, THETAD +2
= IMU gimbal angles necessary to achieve desired orientation in revs @ 2^1

$(STARAD\ +12D)_V \leftarrow GOUT_V \cdot 2^{-1}$

Save value from first call to LUNG

QPRET ← ADR(GRAVEL +22D)

Set up return from LUNG sequence to GRAVEL + 22D (Sh. 14)

LUNG
Sh. 16

Next Sheet

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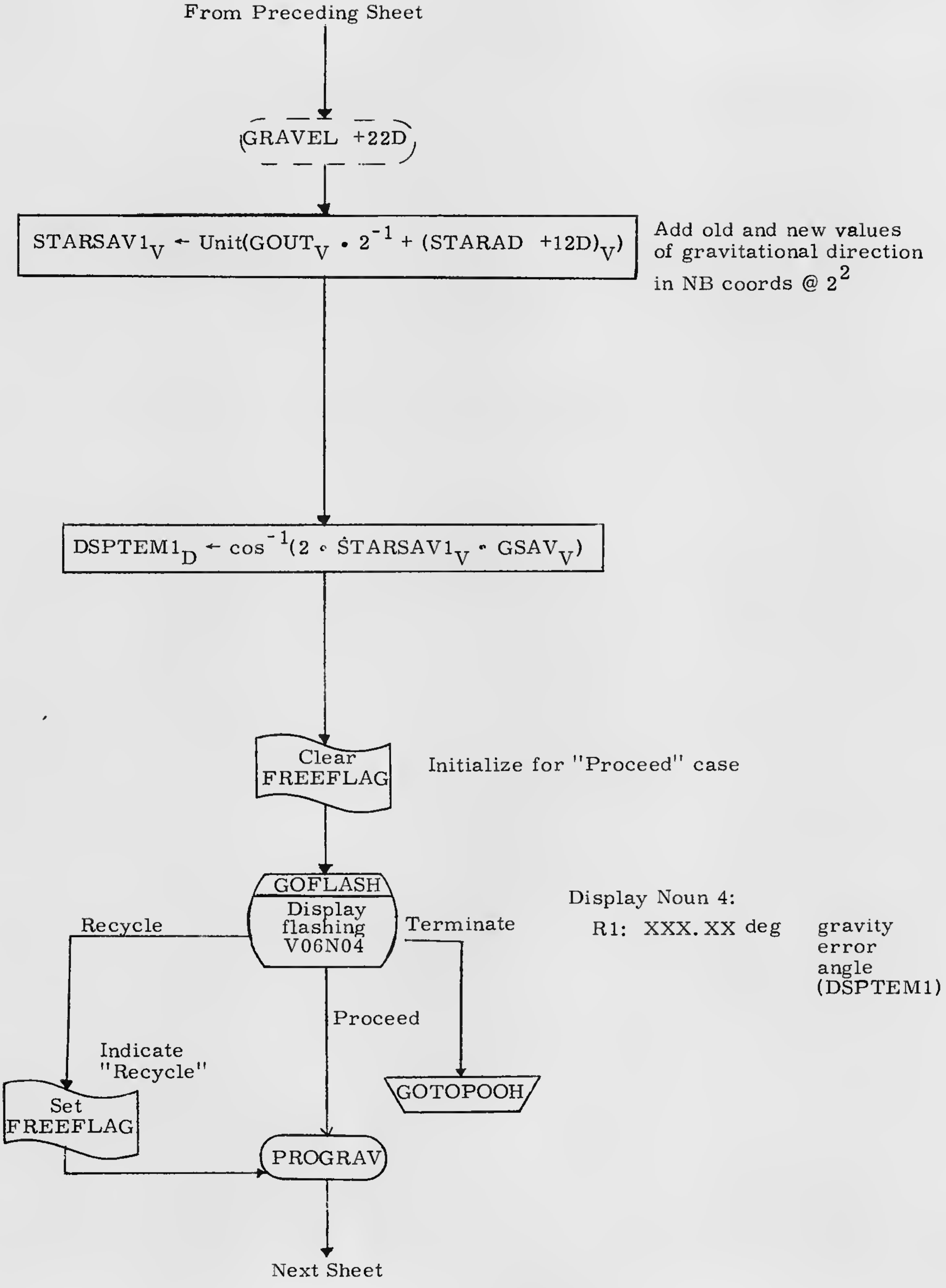
DRAWN S. Cvetko	1-31-69	P57	
PRGMR D. Millard	9/29/69	LUMINARY 1D	DOCUMENT NO. FC-3520
ANALST			
DOCMR A M Sorant	8/29/69		
APPR'D A M Sorant	8/29/69	REV 2	SHEET 13 OF 65



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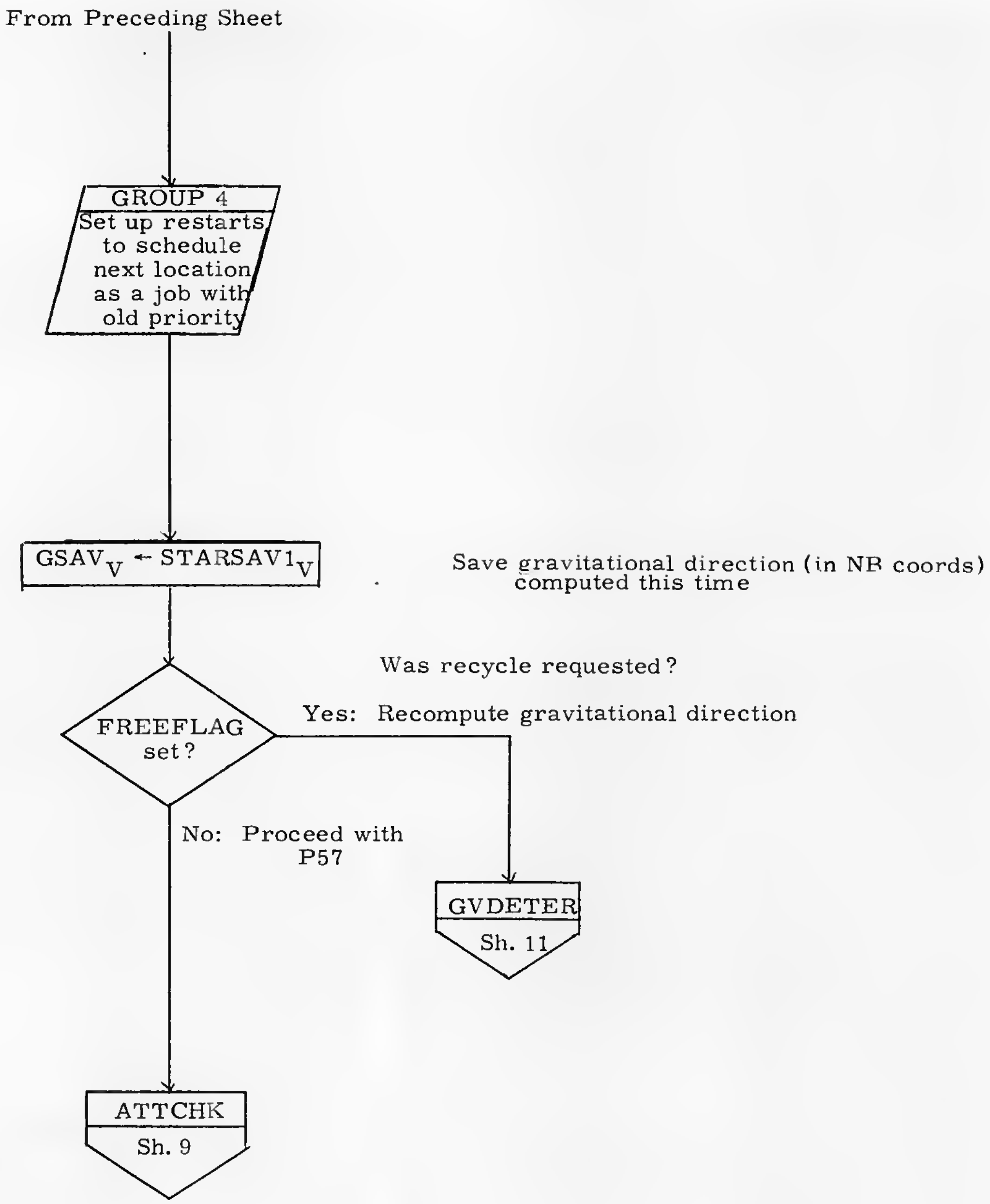
DRAWN J. Cuccitto	1-31-69	P57	
PRGMR [signature]	8/29/69		DOCUMENT NO.
ANALST			
DOCMR [signature]	8/29/69	LUMINARY 1D	FC-3520
APPR'D [signature]	8/29/69	REV 2	SHEET 14 OF 65



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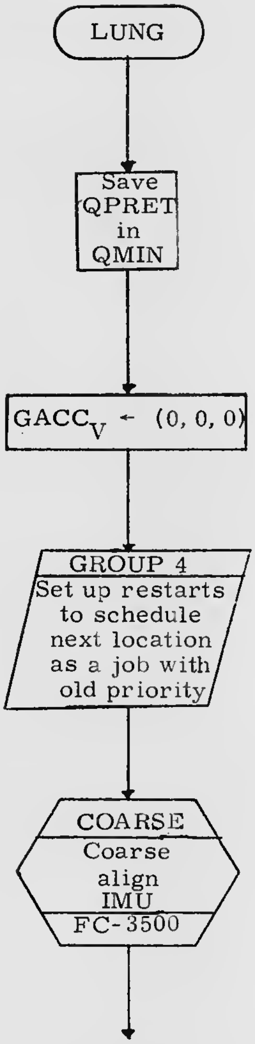
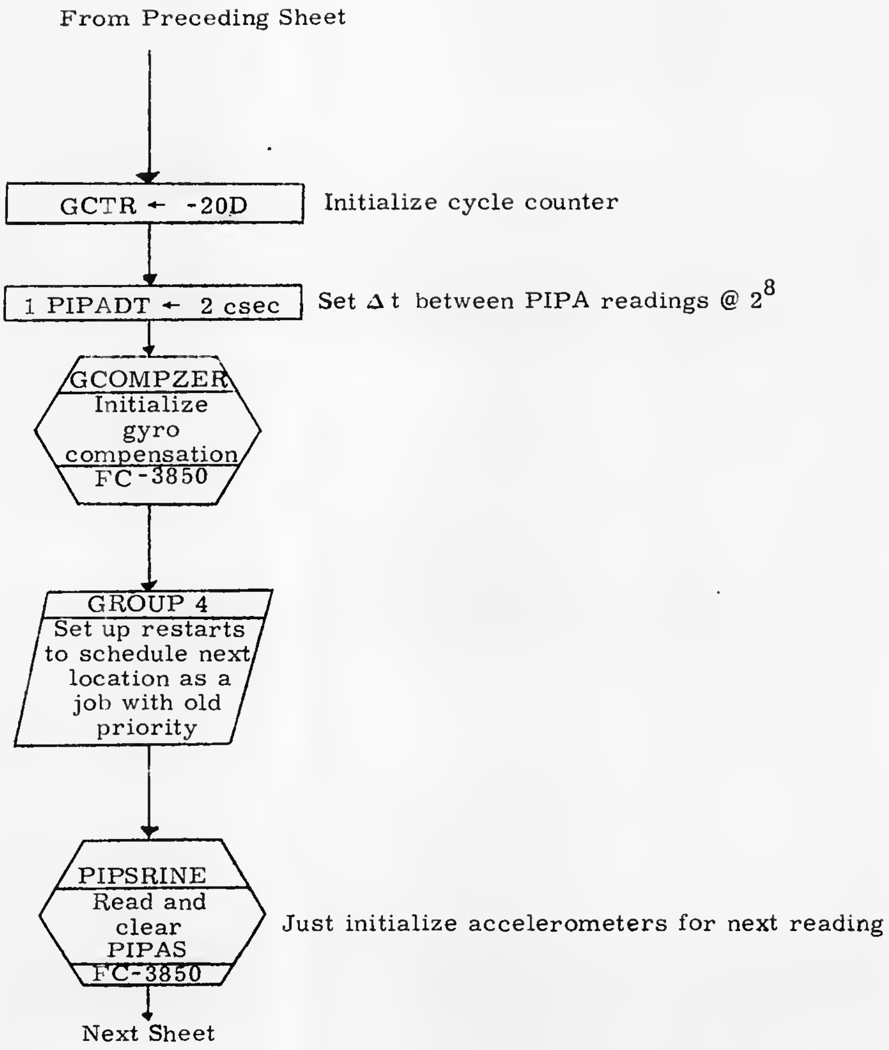
DRAWN J. Cancitto	7-31-69	P57	
PRGMR D. Millard	8/29/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3520
DOCMR A M Sorant	8/29/69		
APPR'D A M Sorant	8/29/69	REV 2	SHEET 15 OF 65



Initialize $\Delta\underline{V}$ accumulation

Input: THETAD, THETAD +1, THETAD +2
= desired IMU gimbal angles
in revs @ 2^{-1}

Next Sheet



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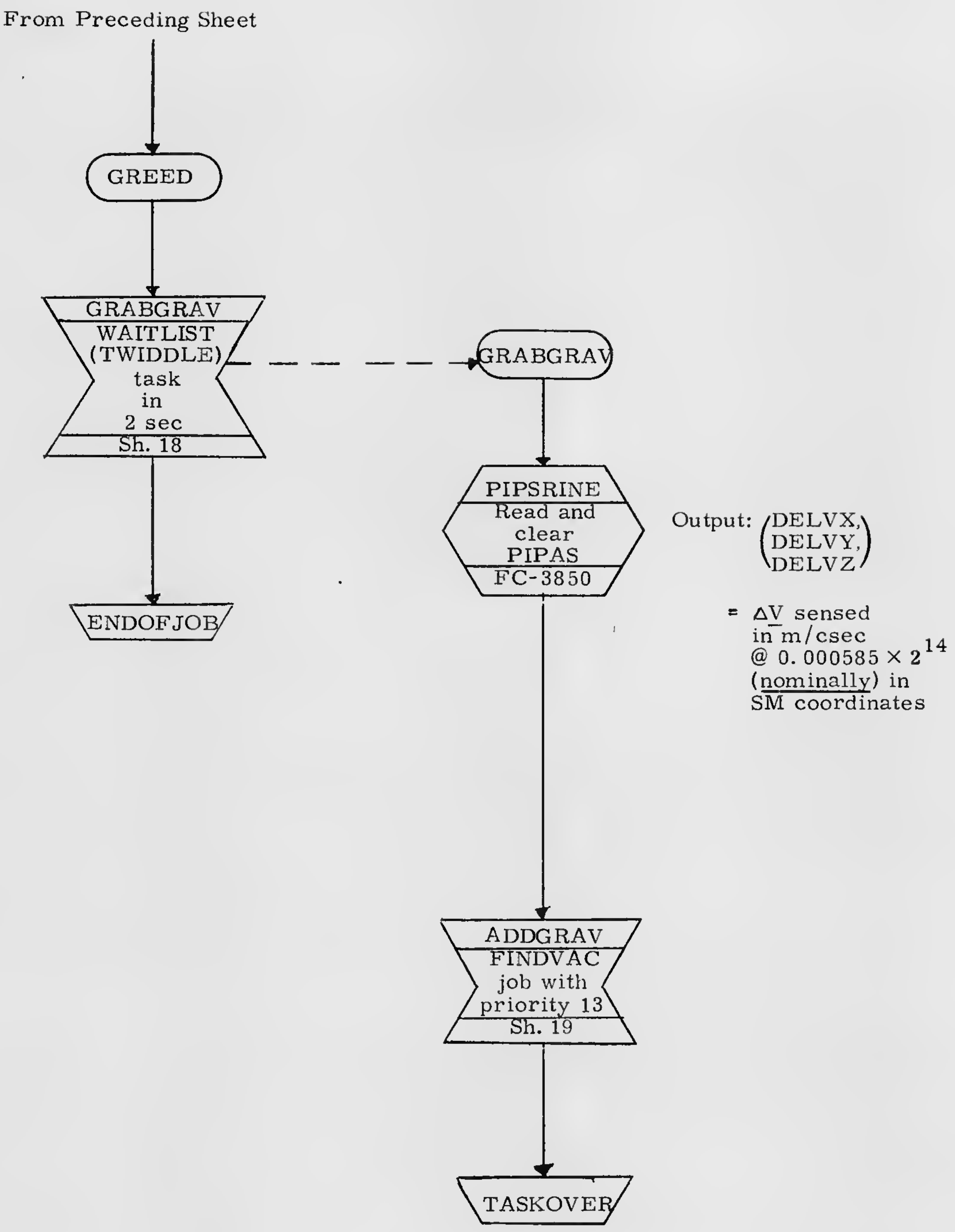
DRAWN	7-3-69	P57	
PRGMR	8/19/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3520
DOCMR	8/29/69		
APPR'D	8/29/69	REV 2	SHEET 17 OF 65



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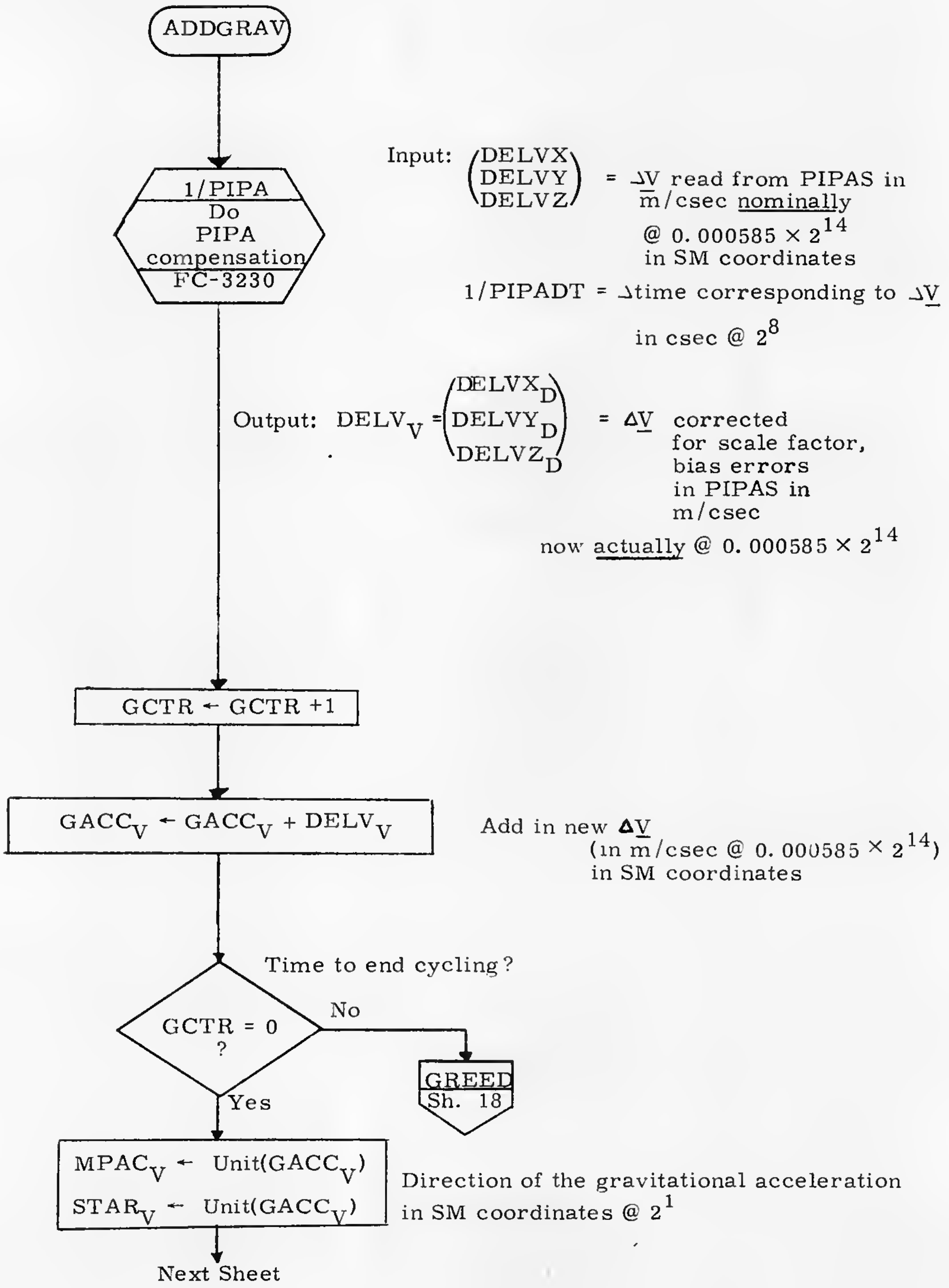
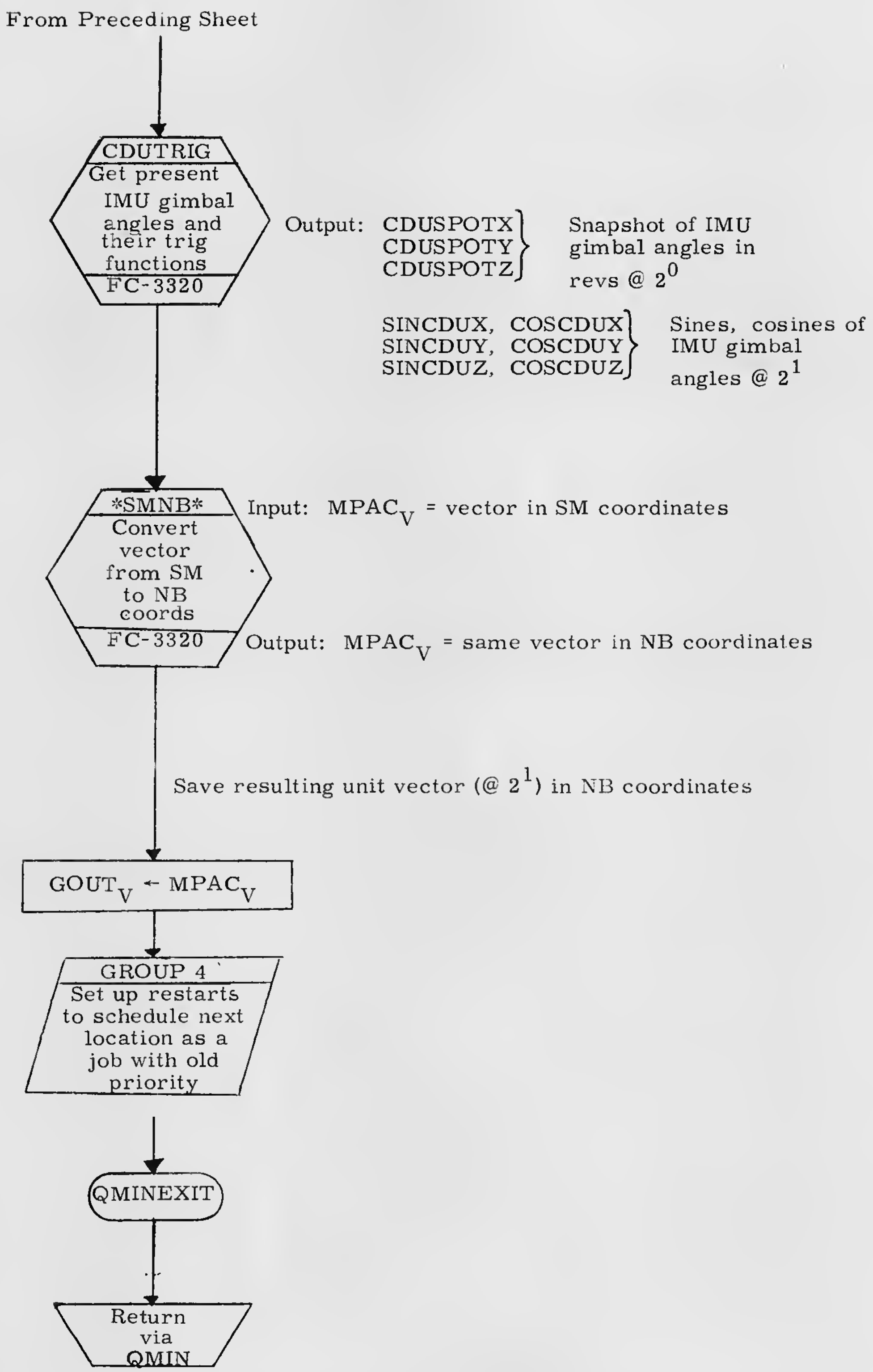
DRAWN J. Concetta	7-31-69	P57	
PRGMR D. Millard	8/25/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3520
DOCMR A.M. Sorant	8/29/69		
APPR'D A.M. Sorant	8/29/69	REV 2	SHEET 18 OF 65



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	7-31-69	P57	
PRGMR	8/21/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3520
DOCMR A M Sorant	8/29/69		
APPR'D A M Sorant	8/29/69	REV 2	SHEET 19 OF 65



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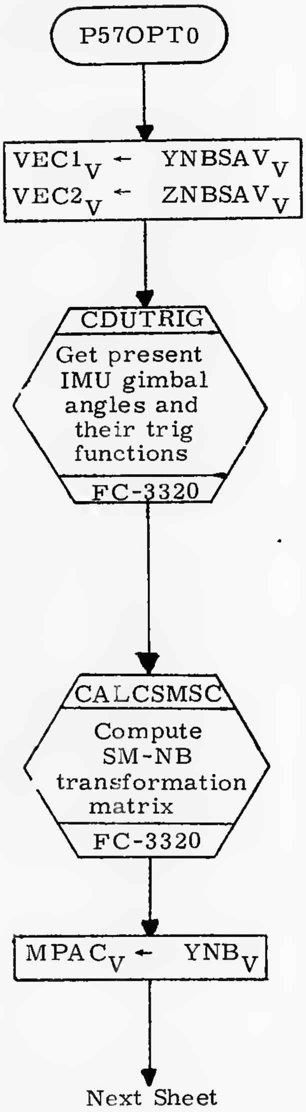
DRAWN J. Cinquita	7-31-69	P57	
PRGMR D. Millard	8/29/69	LUMINARY 1D	DOCUMENT NO. FC-3520
ANALST			
DOCMR A. M. Grant	8/29/69		
APPR'D A. M. Grant	8/29/69	REV 2	SHEET 20 OF 65

Alignment mode 0 sequence:
Y, Z NB axes are reference vectors



Output: CDUSPOTX, CDUSPOTY, CDUSPOTZ } Snapshot of IMU gimbal angles in in revs @ 2^0

SINCDUX, COSCDUX; SINCDUY, COSCDUY; SINCDUZ, COSCDUZ } Sines, cosines of IMU gimbal angles @ 2^1

Input: SINCDUX, COSCDUX; SINCDUY, COSCDUY; SINCDUZ, COSCDUZ } TRIG functions of present IMU gimbal angles @ 2^1

Output: $XNB_M = \begin{pmatrix} XNB_V \\ YNB_V \\ ZNB_V \end{pmatrix}$ = Transformation matrix relating SM and NB coordinate systems @ 2^1

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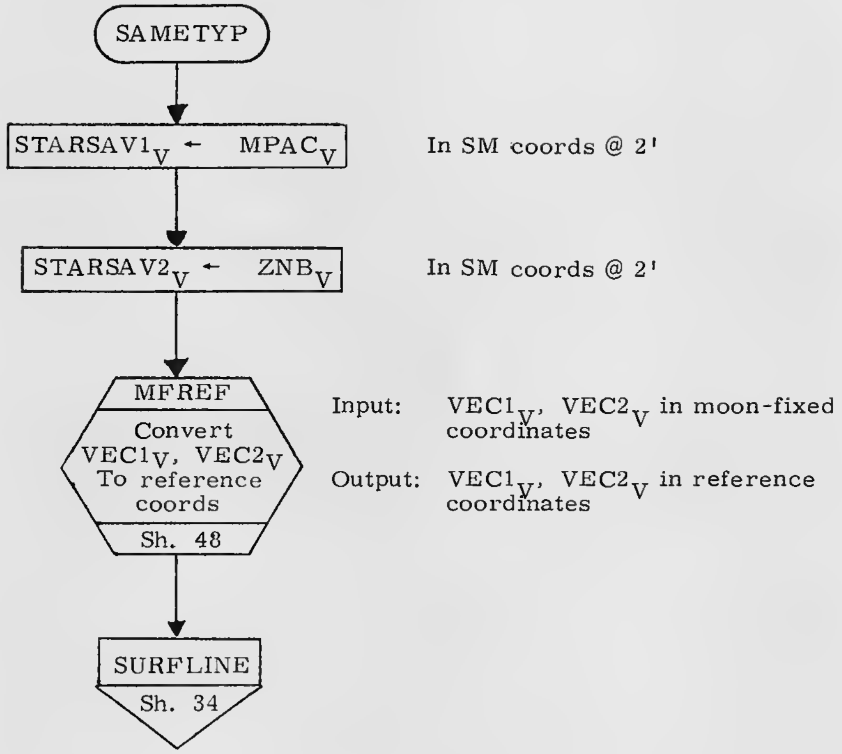
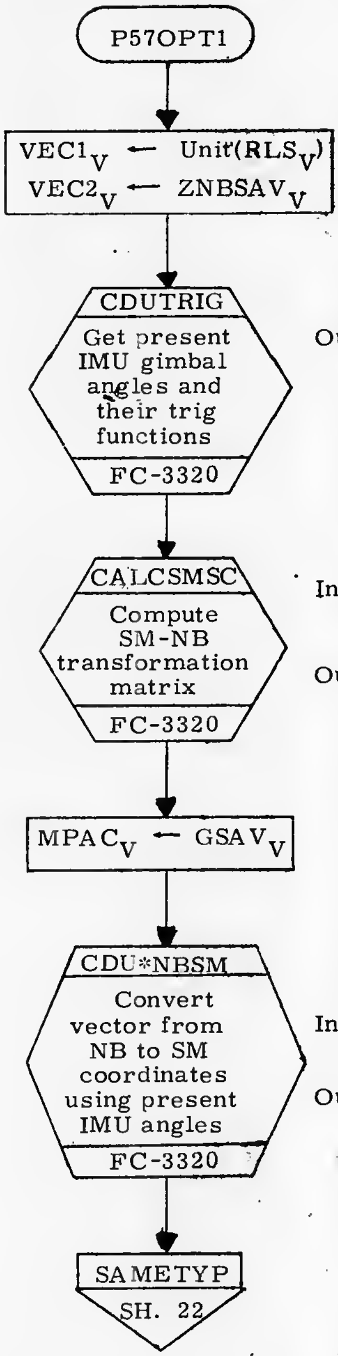
ANALST			
DOCMR [signature]	8/29/69		
APPR'D [signature]	8/29/69	REV 2	SHEET 21 OF 65


SAMETYP
STARSAV1$_V$ ← MPAC$_V$
In SM coords @ 2^1
STARSAV2$_V$ ← ZNB$_V$
In SM coords @ 2^1
MFREF
Convert VEC1$_V$, VEC2$_V$ To reference coords
Sh. 48
Input: VEC1$_V$, VEC2$_V$ in moon-fixed coordinates
Output: VEC1$_V$, VEC2$_V$ in reference coordinates
SURFLINE
Sh. 34



Alignment mode 1 sequence:
Gravity direction, Z NB axis are reference vectors

RLS_V = Landing site position in moon-fixed coordinates

Output: CDUSPOTX, CDUSPOTY, CDUSPOTZ } Snapshot of IMU gimbal angles in revs @ 2^0

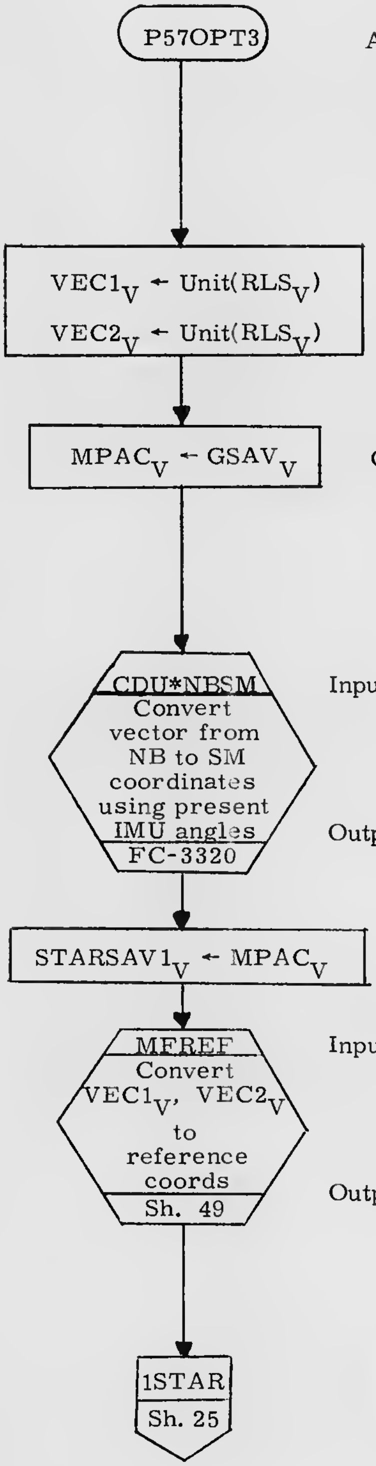
SINCDUX, COSCDUX; SINCDUY, COSCDUY; SINCDUZ, COSCDUZ } Sines, cosines of IMU gimbal angles @2^1

Input: SINCDUX, COSCDUX
SINCDUY, COSCDUY
SINCDUZ, COSCDUZ

Output: $XNB_M = \begin{pmatrix} XNB_V \\ YNB_V \\ ZNB_V \end{pmatrix}$ = Transformation matrix relating SM and NB coordinate systems @2^1

Input: $MPAC_V$ = vector in NB coordinates

Output: $MPAC_V$ = same vector in SM coordinates



Alignment mode 3 sequence:
gravity direction, 1 sighted star direction are reference vectors

RLS_V = landing site position vector in moon-fixed coordinates

Gravity direction in NB coords @ 2^1

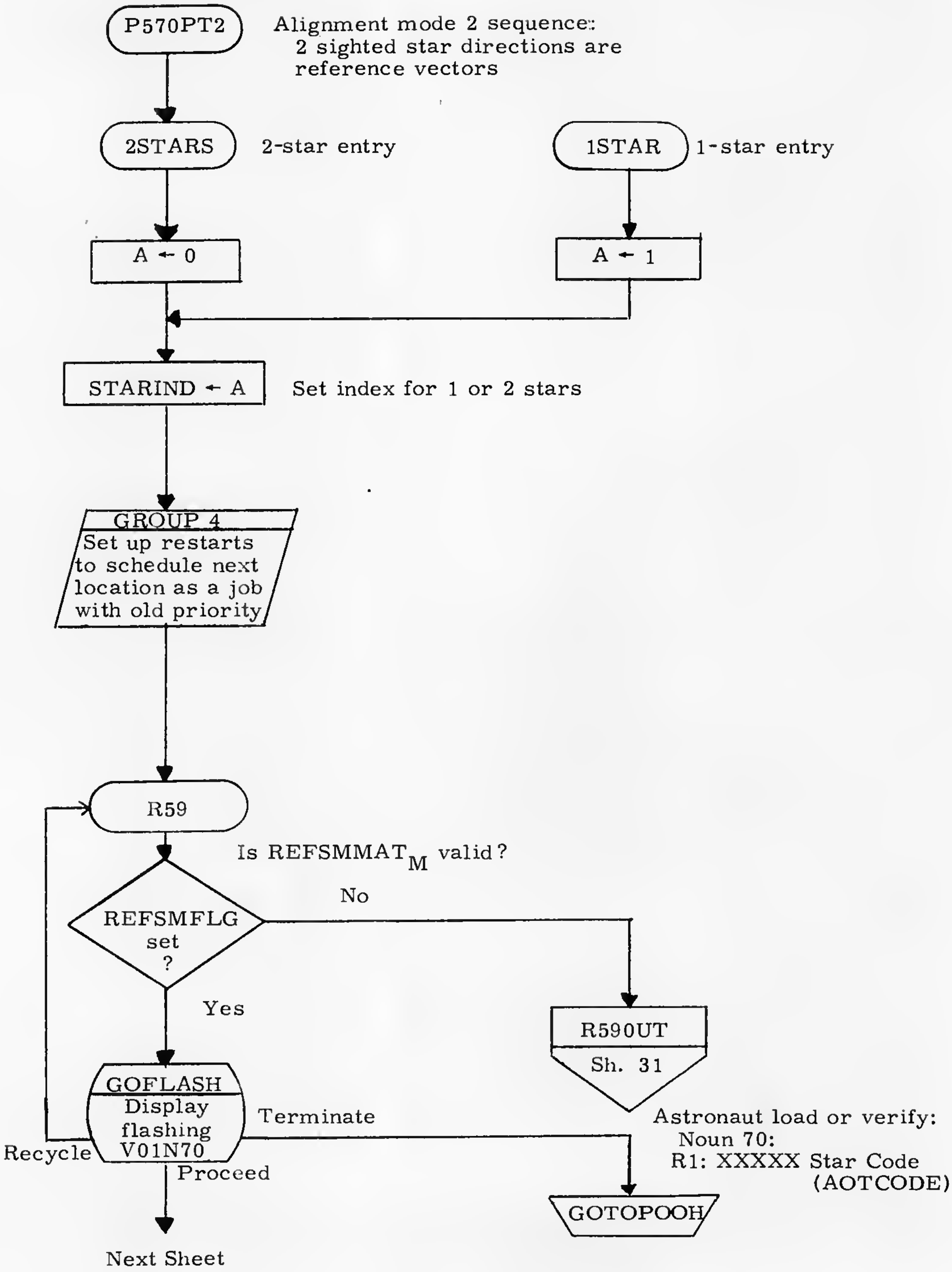
Input: $MPAC_V$ = vector in NB coordinates

Output: $MPAC_V$ = same vector in SM coordinates

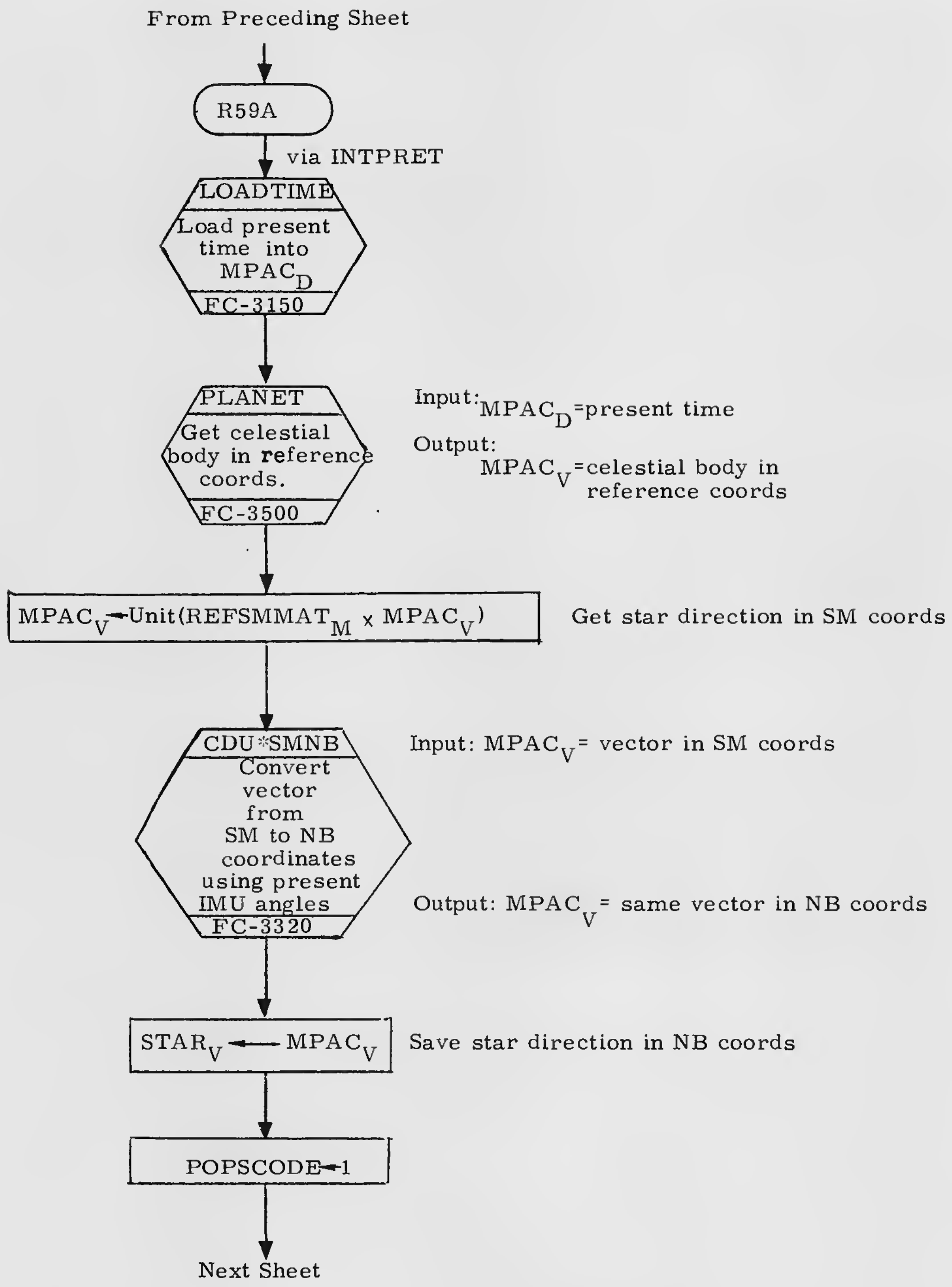
in SM coords @ 2^1

Input: $VEC1_V$, $VEC2_V$ in moon-fixed coordinates

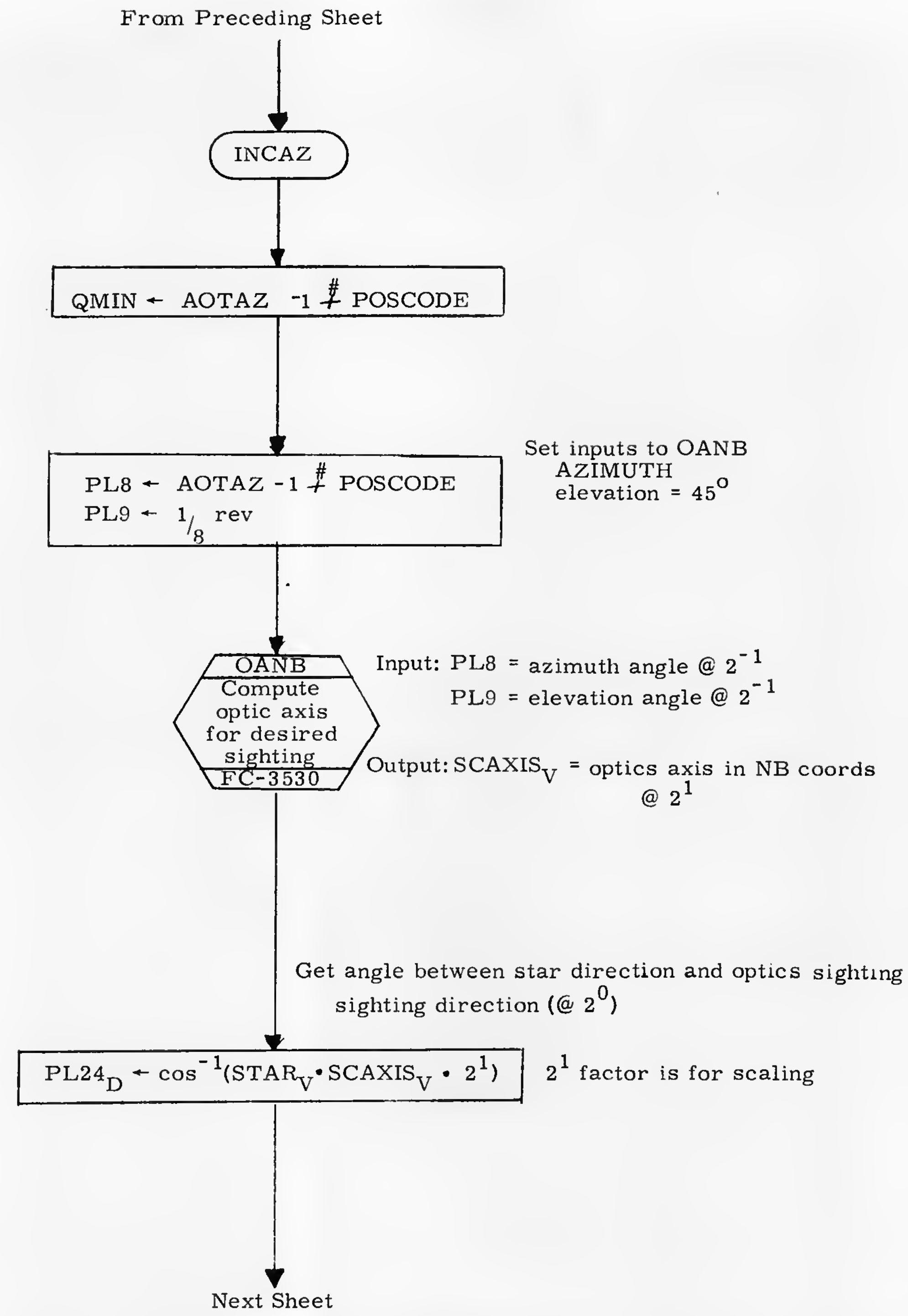
Output: $VEC1_V$, $VEC2_V$ in reference coordinates

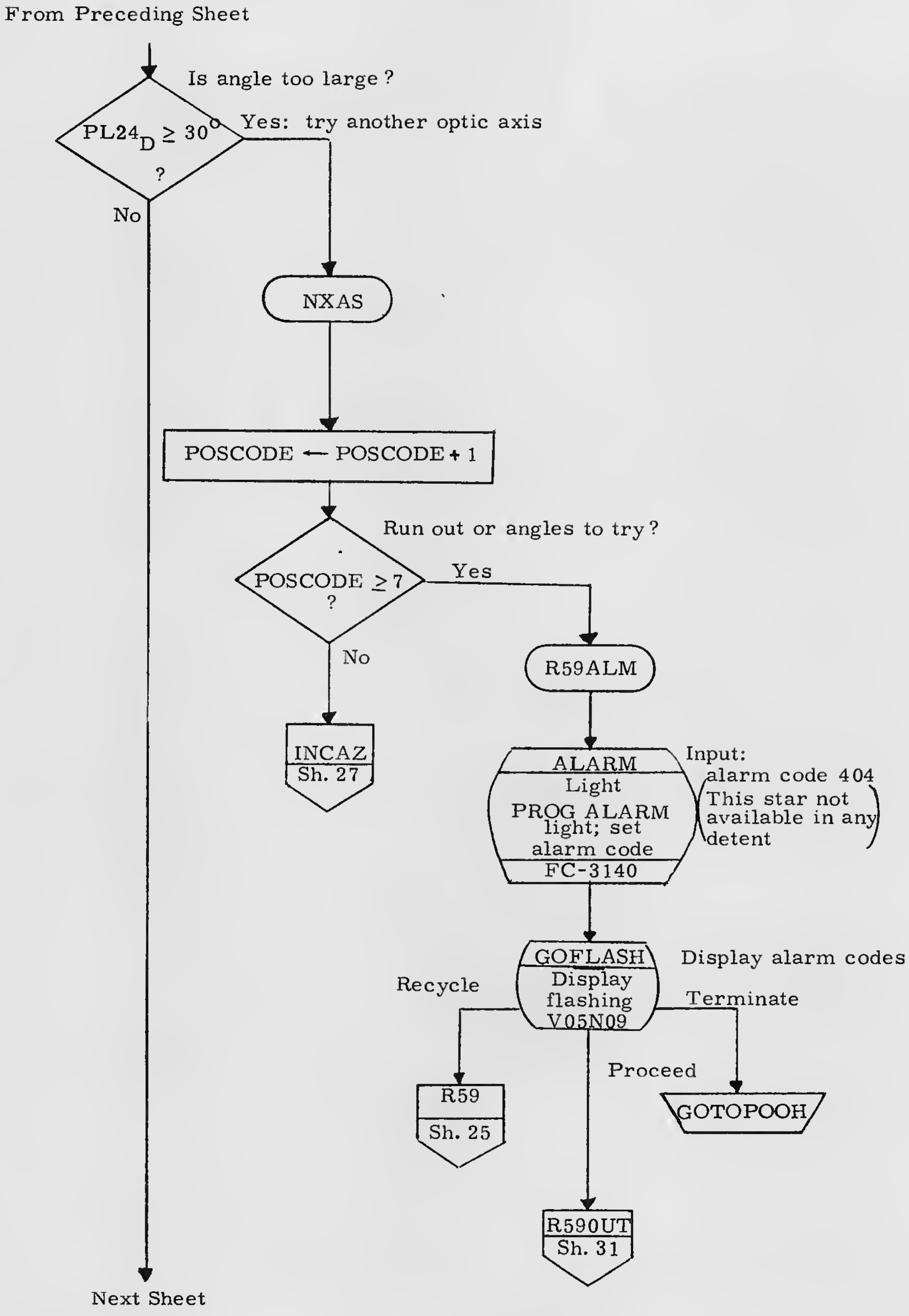


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN J. Cincotta	8-1-69	P57	
PRGMR [illegible]	8/19/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3520
DOCMR [illegible]	8/29/69		
APPR'D [illegible]	8/29/69	REV 2	SHEET 25 OF 65

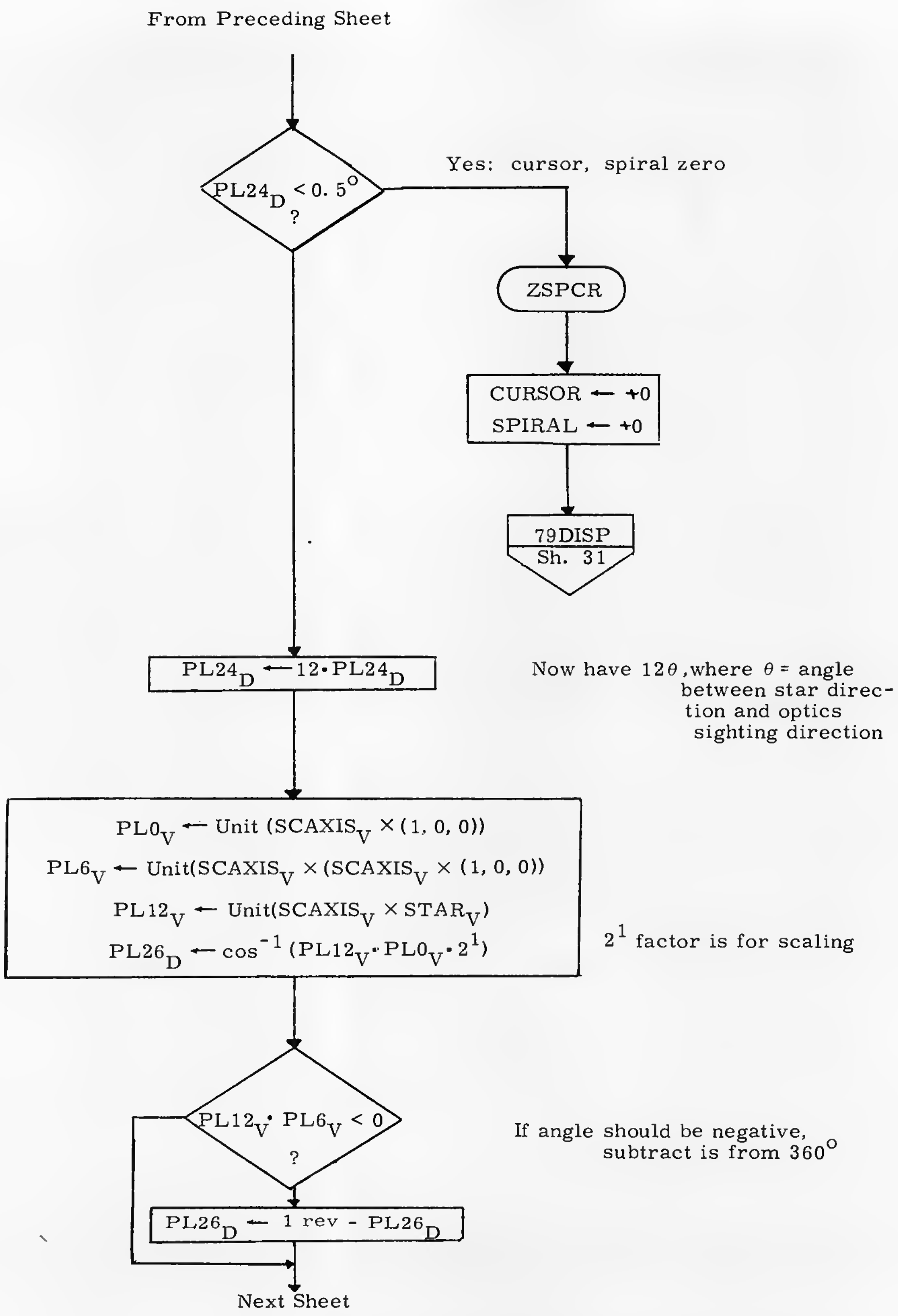


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E. Matta	5/28/70	P57	
PRGMR D. Millard	6/9/70		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3520
DOCMR R.M. Enters	6/9/70		
APPR'D R.M. Enters	6/9/70	REV 2	SHEET 26 OF 65

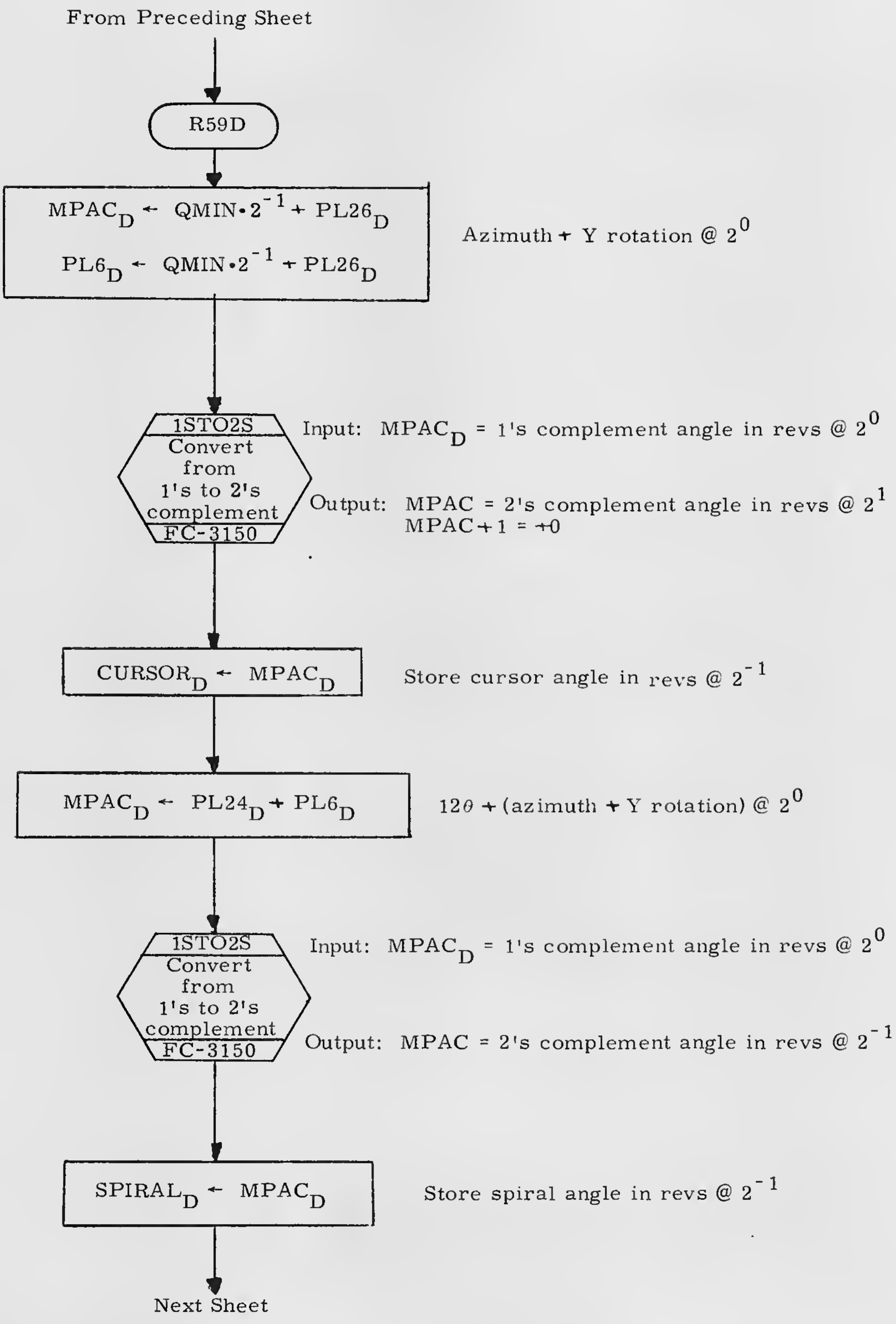

From Preceding Sheet
INCAZ
QMIN ← AOTAZ -1 ⋕ POSCODE
PL8 ← AOTAZ -1 ⋕ POSCODE
PL9 ← 1/8 rev
Set inputs to OANB AZIMUTH elevation = 45°
OANB
Compute optic axis for desired sighting
FC-3530
Input: PL8 = azimuth angle @ 2^-1
PL9 = elevation angle @ 2^-1
Output: SCAXIS_V = optics axis in NB coords @ 2^1
Get angle between star direction and optics sighting sighting direction (@ 2^0)
PL24_D ← cos^-1(STAR_V • SCAXIS_V • 2^1)
2^1 factor is for scaling
Next Sheet



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN J. Ciaccetto 8-1-69 PRGMR [illegible] 8/29/69 ANALST DOCMR A M Grant 8/29/69 APPR'D A M Grant 8/29/69	P57
	LUMINARY 1D — DOCUMENT NO. FC-3520
	REV 2 — SHEET 28 OF 65



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		P57	
PRGMR	8/29/69		
ANALST			
DOCMR	8/29/69	LUMINARY 1D	DOCUMENT NO. FC-3520
APPR'D	8/29/69	REV 2	SHEET 29 OF 65



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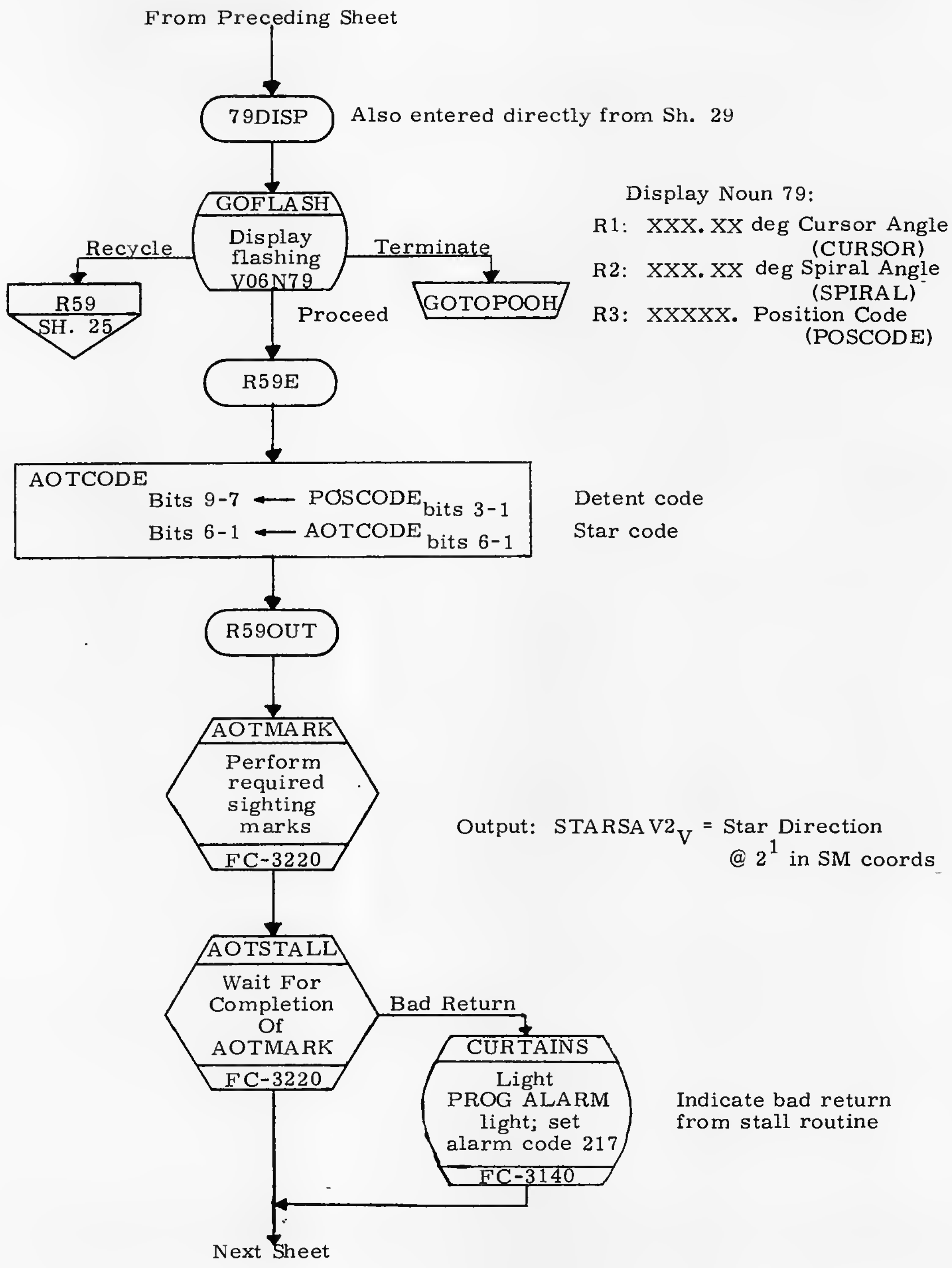
DRAWN J. Cuccotto	8-1-69	P57	
PRGMR D. Millard	8/29/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3520
DOCMR A. McSnant	8/29/69		
APPR'D A. McSnant	8/29/69	REV 2	SHEET 30 OF 65



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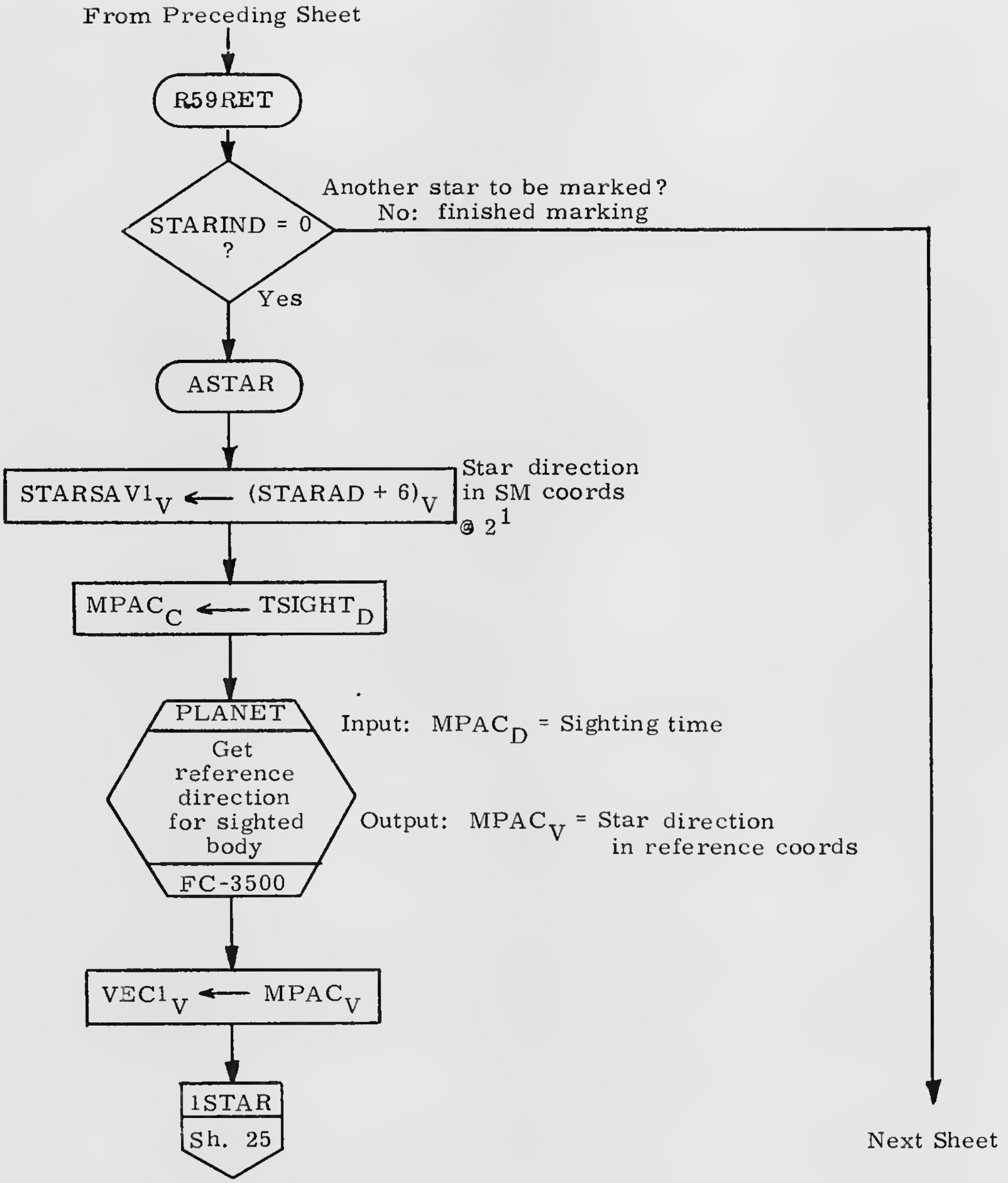
DRAWN		P57	
PRGMR	8/29/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3520
DOCMR	8/29/69		
APPR'D	8/29/69	REV 2	SHEET 31 OF 65



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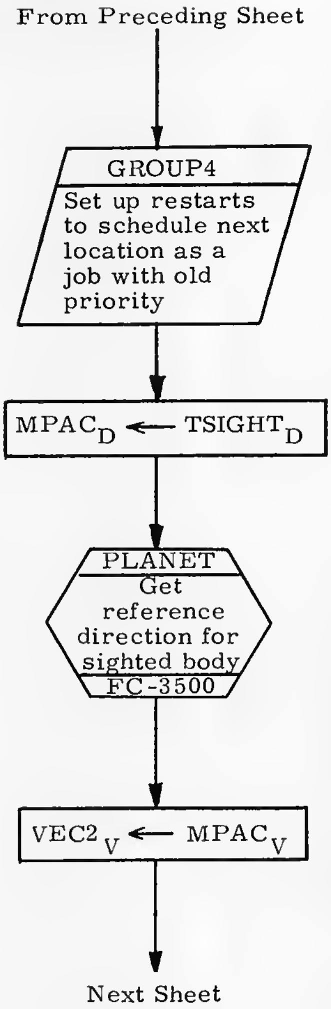
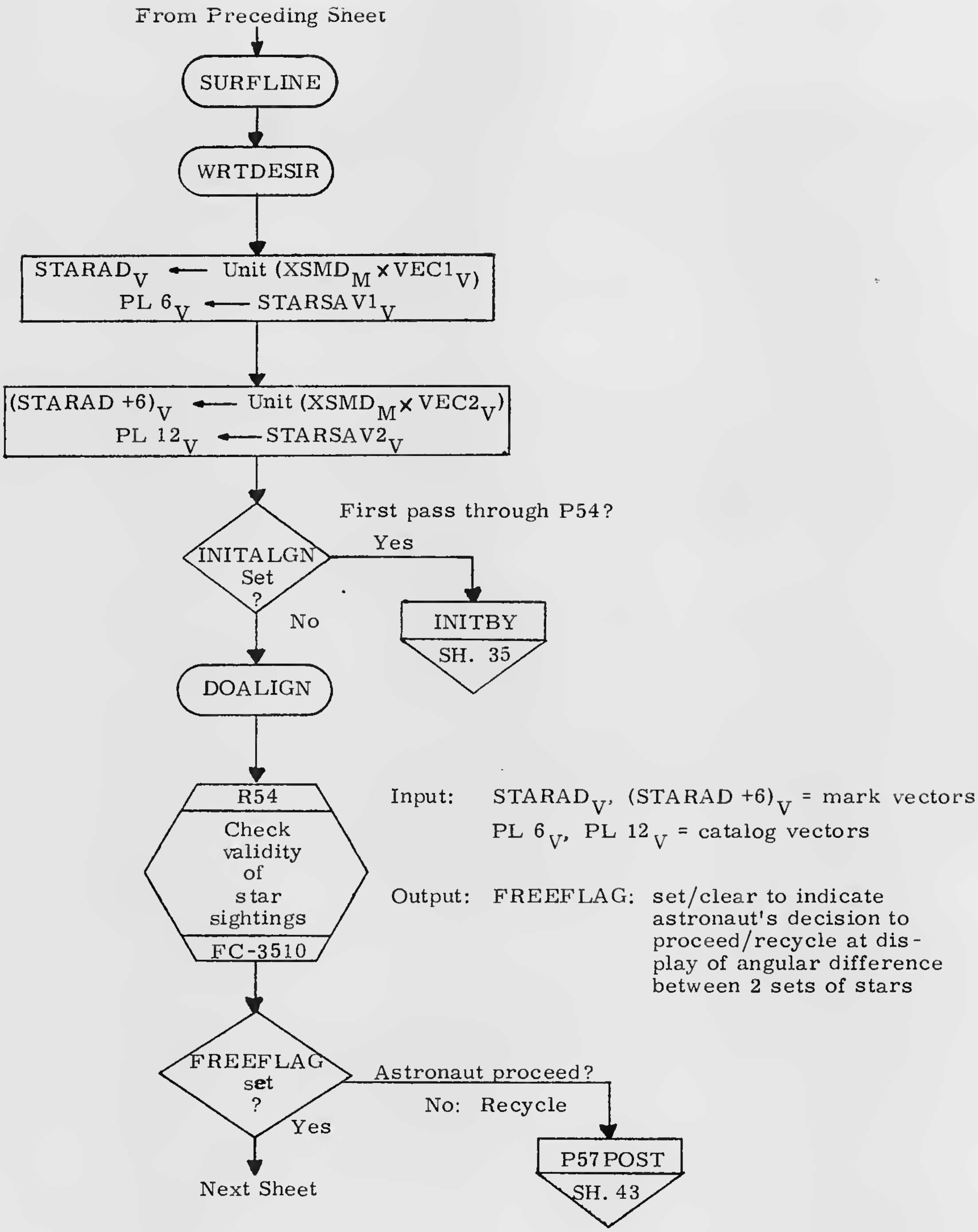
DRAWN R. D. Hart	7-30-68	P57	
PRGMR D. Millard	8/18/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3520
DOCMR A M Sorant	8/29/69		
APPR'D A M Sorant	8/29/69	REV 2	SHEET 32 OF 65

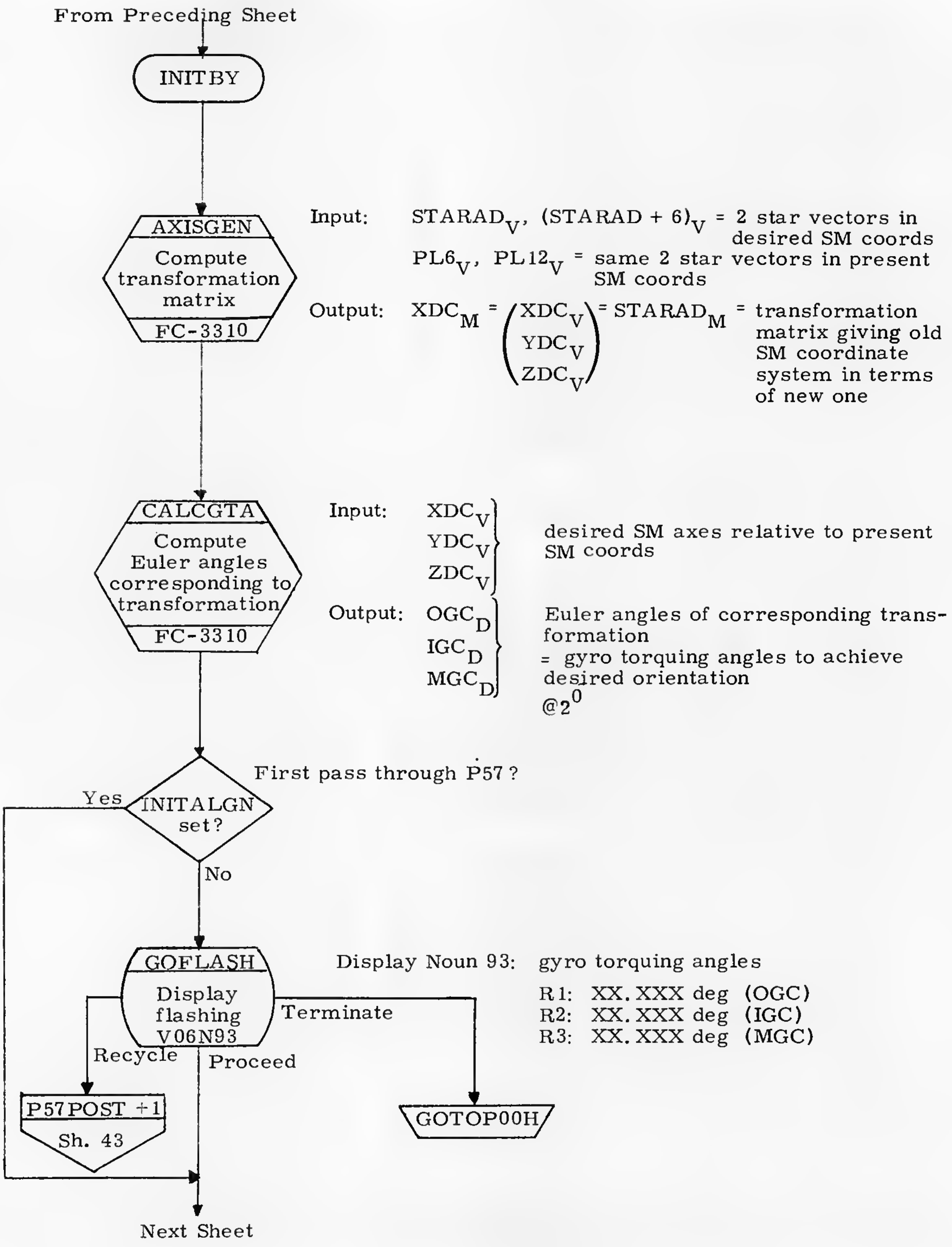


Input: $MPAC_D$ = Sighting time

Output: $MPAC_V$ = Star direction in reference coords



From Preceding Sheet
SURFLINE
WRTDESIR
STARAD$_V$ ← Unit (XSMD$_M$ × VEC1$_V$)
PL 6$_V$ ← STARSAV1$_V$
(STARAD +6)$_V$ ← Unit (XSMD$_M$ × VEC2$_V$)
PL 12$_V$ ← STARSAV2$_V$
First pass through P54?
INITALGN Set ?
Yes
No
INITBY
SH. 35
DOALIGN
R54
Check validity of star sightings
FC-3510
Input: STARAD$_V$, (STARAD +6)$_V$ = mark vectors
PL 6$_V$, PL 12$_V$ = catalog vectors
Output: FREEFLAG: set/clear to indicate astronaut's decision to proceed/recycle at display of angular difference between 2 sets of stars
FREEFLAG set ?
Astronaut proceed?
No: Recycle
Yes
Next Sheet
P57POST
SH. 43



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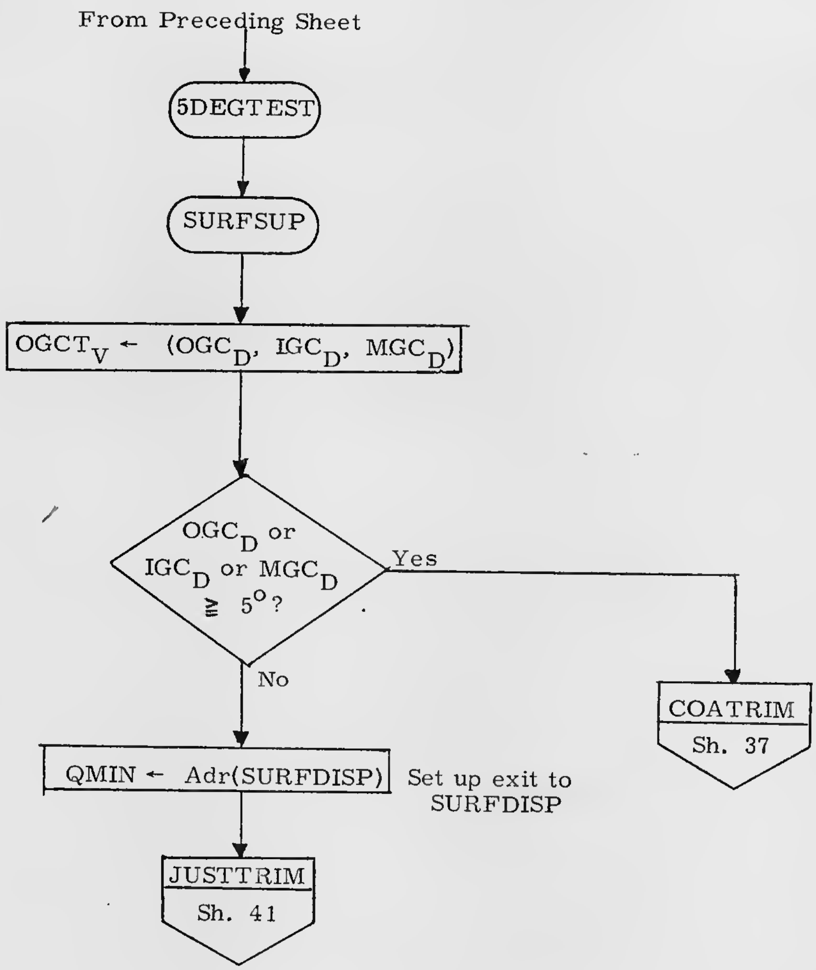
DRAWN		P57	
PRGMR	4/29/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3520
DOCMR	8/29/69		
APPR'D	8/29/69	REV 2	SHEET 35 OF 65



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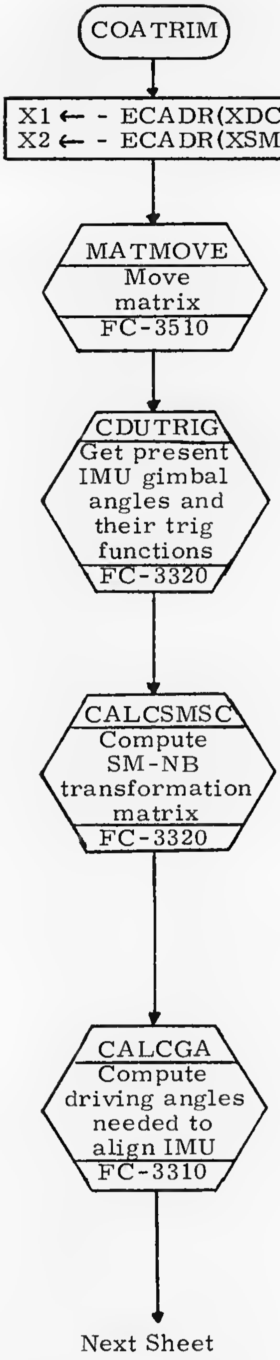
DRAWN		P57	
PRGMR	8/29/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3520
DOCMR	8/29/69		
APPR'D	8/29/69	REV 2	SHEET 36 OF 65



Set up inputs to MATMOVE

Result: $XSM_M \leftarrow XDC_M$

Output: CDUSPOTX, CDUSPOTY, CDUSPOTZ } Snapshot of IMU gimbal angles in revs @2^0

SINCDUX, COSCDUX
SINCDUY, COSCDUY
SINCDUZ, COSCOUZ } Sines, cosines of IMU gimbal, angles @ 2^1

Input: SINCDUX, COSCDUX
SINCDUY, COSCDUY
SINCDUZ, COSCDUZ

Output: $XNB_M = \begin{pmatrix} XNB_V \\ YNB_V \\ ZNB_V \end{pmatrix}$ = Transformation matrix relating SM and NB coordinate systems @ 2^1

Input: XNB_M relating NB and present SM coordinate systems

XSM_M relating desires SM orientation and present SM coordinate system

Output: THETAD, THETAD +1, THETAD +2
= IMU gimbal angles necessary to achieve desired orientation in revs @2^{-1}

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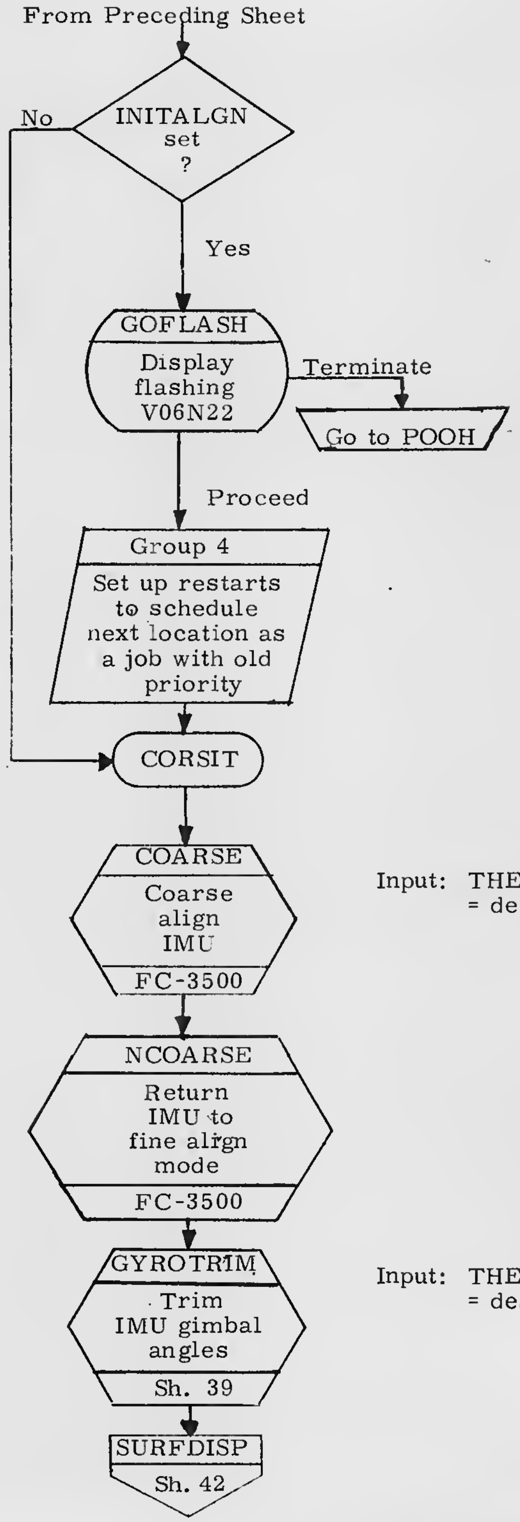
DRAWN		P57	
PRGMR	8/2/69	LUMINARY 1D	DOCUMENT NO. FC-3520
ANALST			
DOCMR	8/29/69		
APPR'D	8/29/69	REV 2	SHEET 37 OF 65

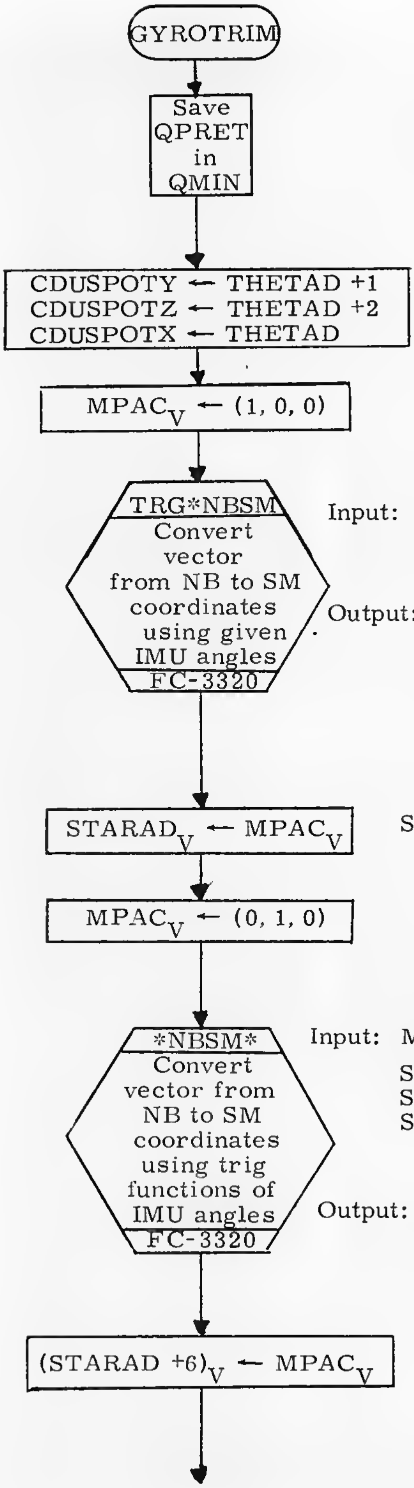


R1: XXX.XX deg Outer gimbal angle (THETAD)
R2: XXX.XX deg Inner gimbal angle (THETAD +1)
R3: XXX.XX deg Middle gimbal angle (THETAD +2)

Input: THETAD, THETAD +1, THETAD +2
= desired IMU gimbal angles in revs @ 2^{-1}

Input: THETAD, THETAD +1, THETAD +2
= desired IMU gimbal angles in revs @ 2^{-1}

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R.D. Donnell		P57	
PRGMR D.H. Millard	8/29/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3520
DOCMR A.M. Sorant	8/29/69		
APPR'D A.M. Sorant	8/29/69	REV 2	SHEET 38 OF 65



Input: $MPAC_V$ = vector in NB coords
CDUSPOTX, CDUSPOTY, CDUSPOTZ = IMU gimbal angles @ 2^{-1} (desired)

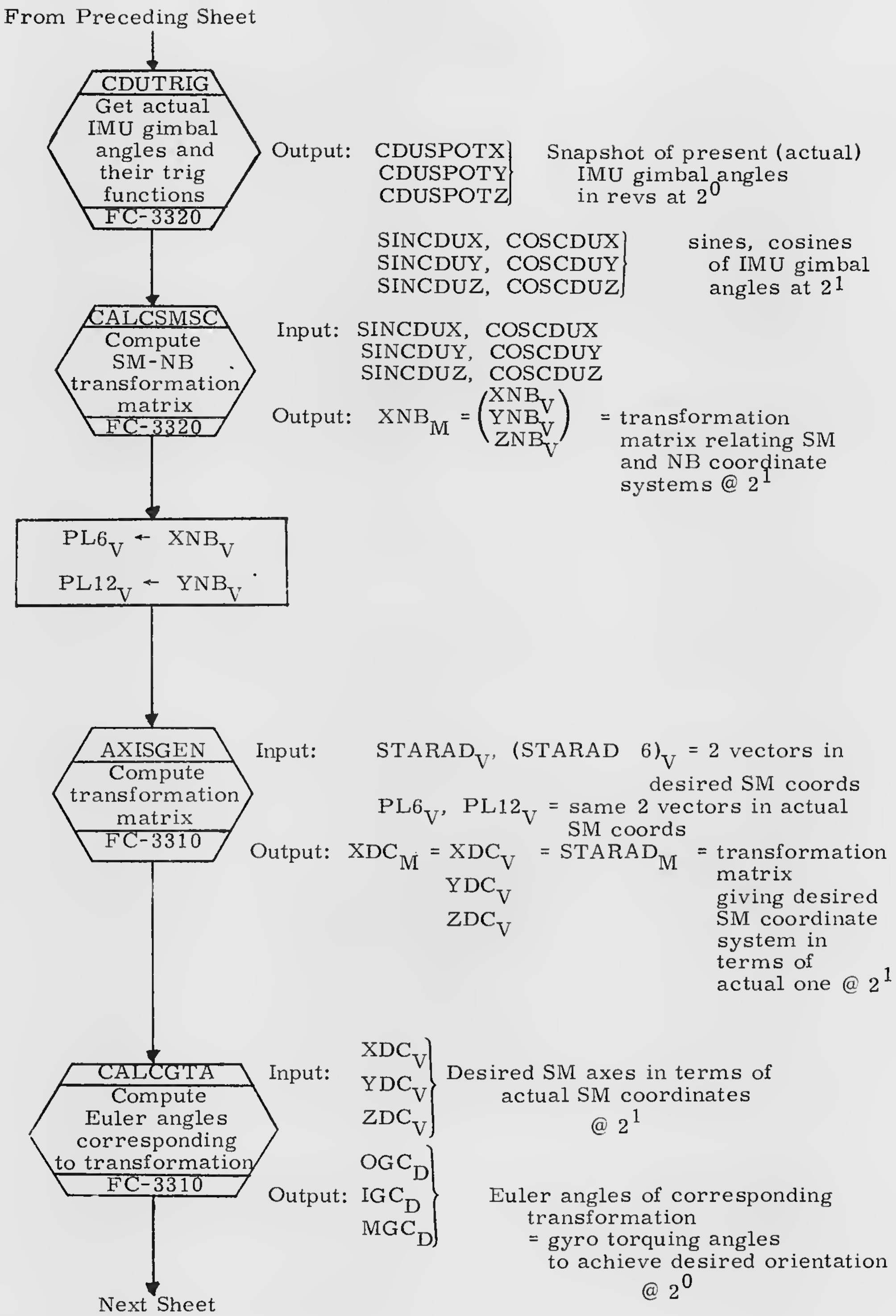
Output: $MPAC_V$ = same vector in SM coords
SINCDUX, COSCDUX; SINCOUY, COSCDUY; SINCDUZ, COSCDUZ } sines, cosines of IMU gimbal angles given @ 2^1

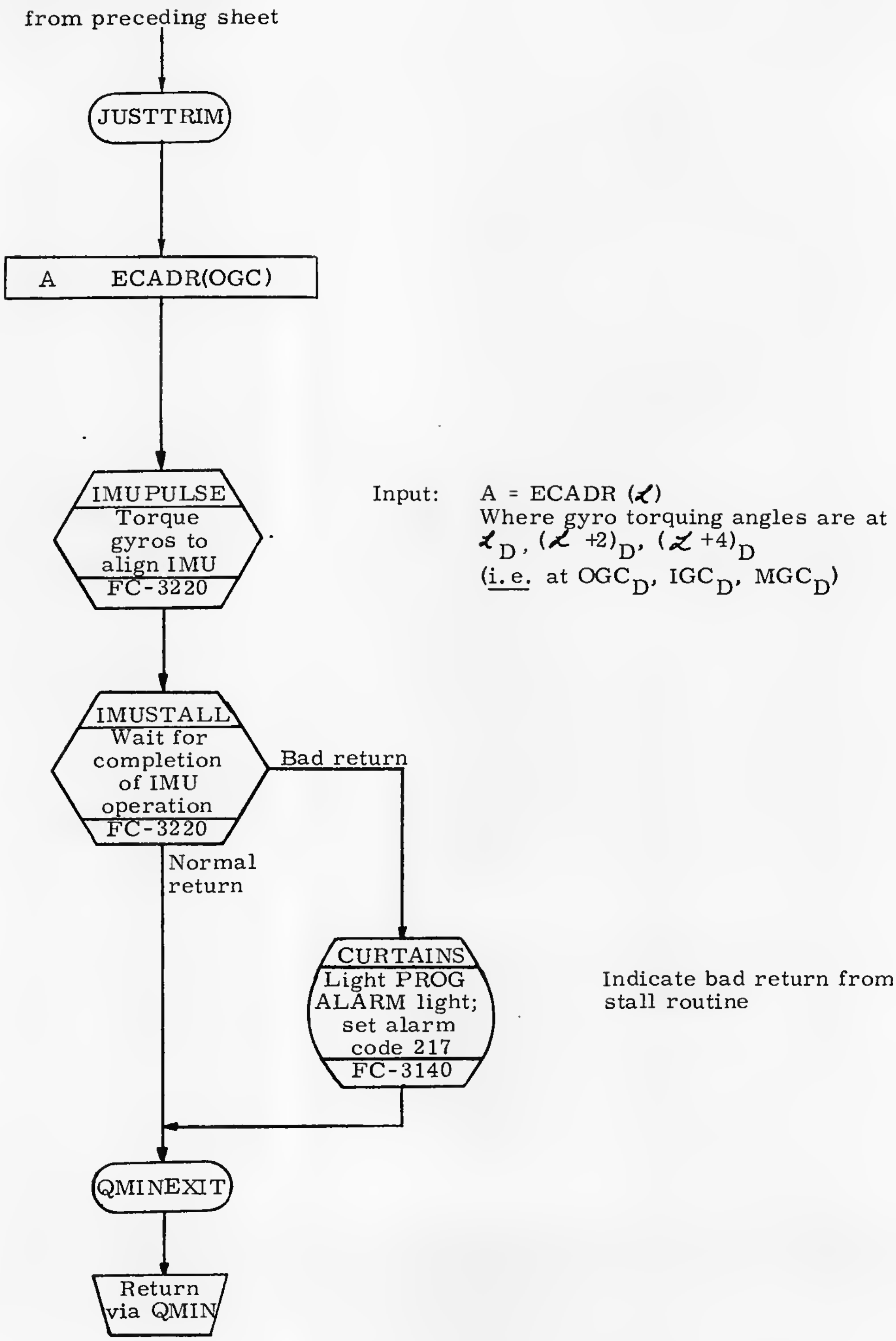
Save vector in SM coordinates

Input: $MPAC_V$ = vector in NB coordinates
SINCDUX, COSCDUX; SINCDUY, COSCDUY; SINCDUZ, COSCDUZ } Trig functions of IMU gimbal angles @ 2^1

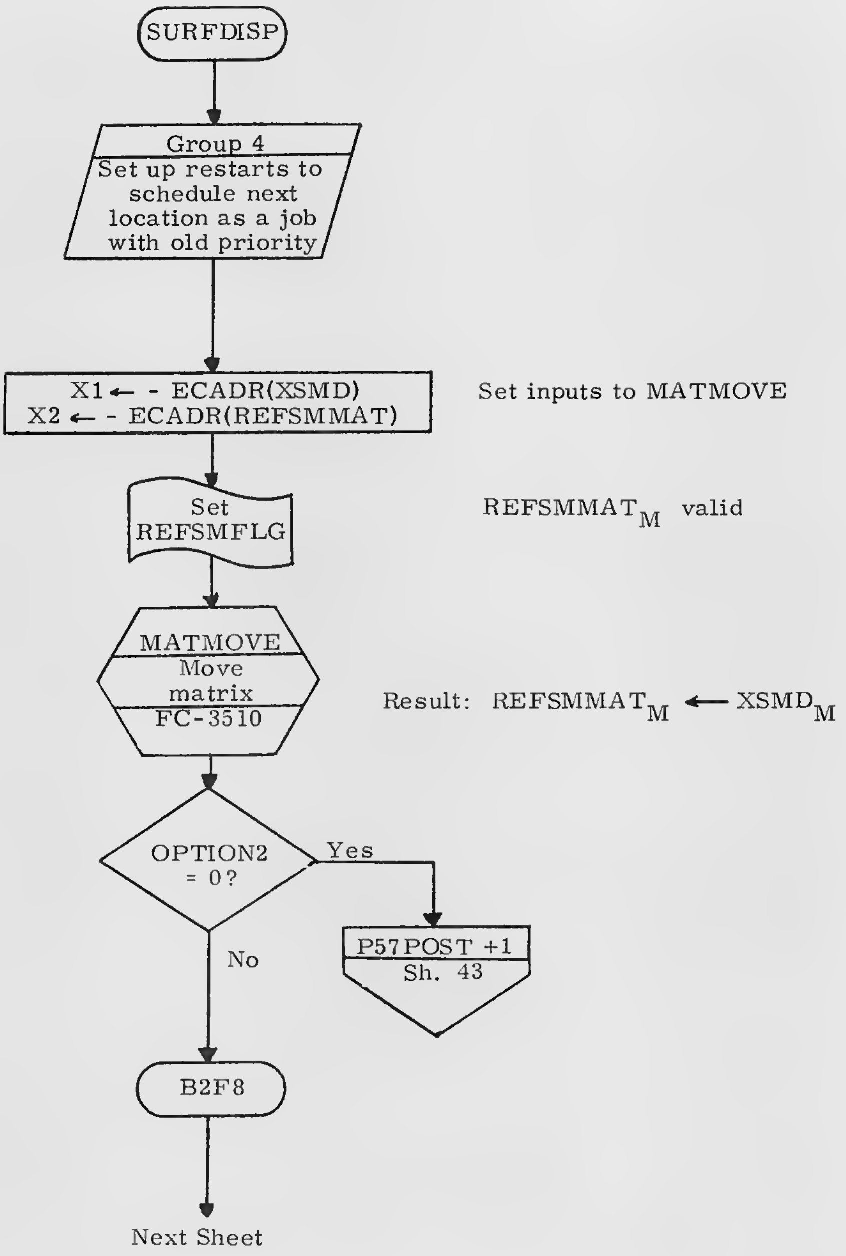
Output: $MPAC_V$ = given vector in SM coords

Save vector in SM coordinates

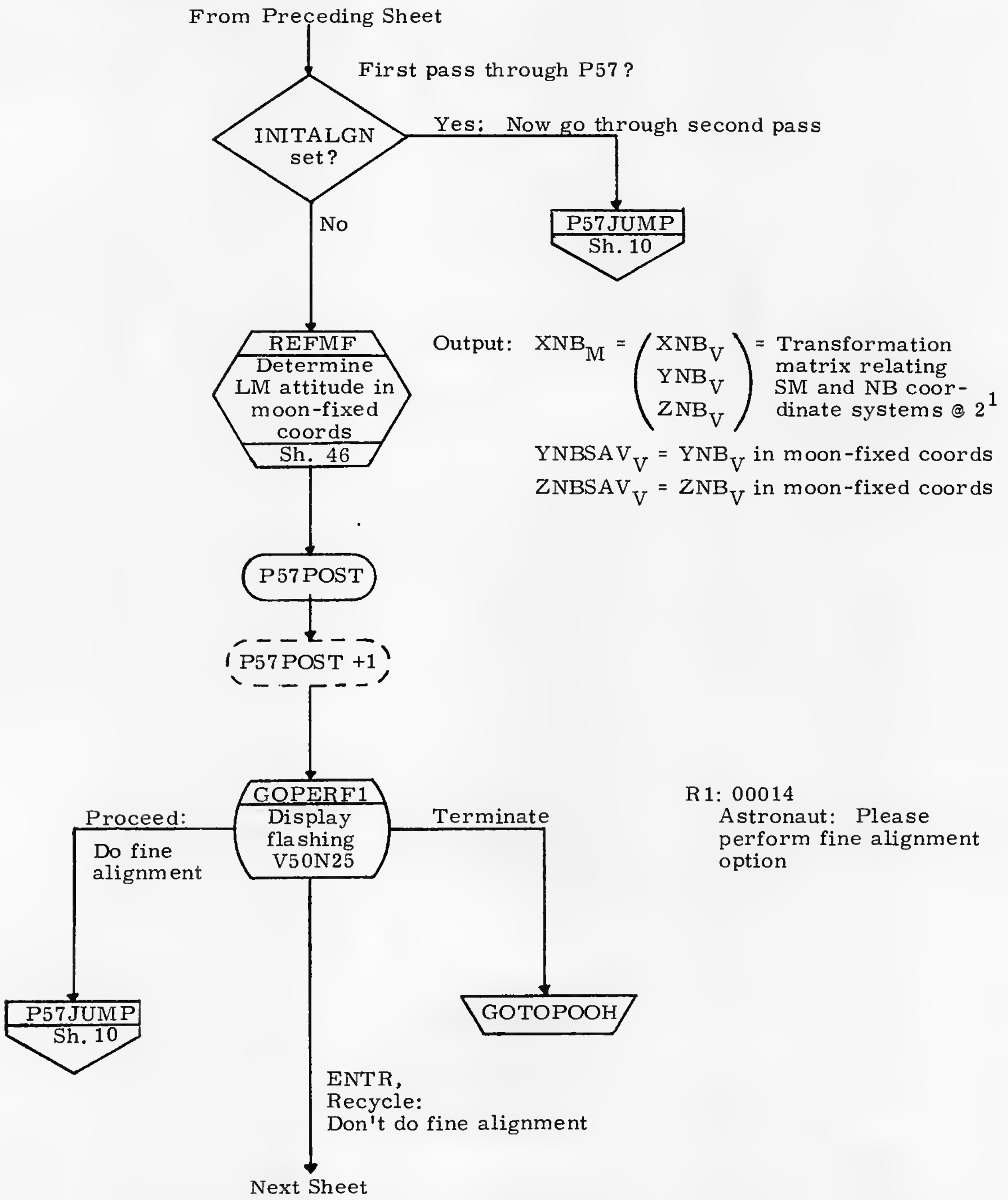

From Preceding Sheet
CDUTRIG
Get actual IMU gimbal angles and their trig functions
FC-3320
Output: CDUSPOTX, CDUSPOTY, CDUSPOTZ
Snapshot of present (actual) IMU gimbal angles in revs at 2^0
SINCDUX, COSCDUX
SINCDUY, COSCDUY
SINCDUZ, COSCDUZ
sines, cosines of IMU gimbal angles at 2^1
CALCSMSC
Compute SM-NB transformation matrix
FC-3320
Input: SINCDUX, COSCDUX
SINCDUY, COSCDUY
SINCDUZ, COSCDUZ
Output: $XNB_M = \begin{pmatrix} XNB_V \\ YNB_V \\ ZNB_V \end{pmatrix}$ = transformation matrix relating SM and NB coordinate systems @ 2^1
$PL6_V \leftarrow XNB_V$
$PL12_V \leftarrow YNB_V$
AXISGEN
Compute transformation matrix
FC-3310
Input: $STARAD_V$, $(STARAD\ 6)_V$ = 2 vectors in desired SM coords
$PL6_V$, $PL12_V$ = same 2 vectors in actual SM coords
Output: $XDC_M = XDC_V, YDC_V, ZDC_V = STARAD_M$ = transformation matrix giving desired SM coordinate system in terms of actual one @ 2^1
CALCGTA
Compute Euler angles corresponding to transformation
FC-3310
Input: XDC_V, YDC_V, ZDC_V Desired SM axes in terms of actual SM coordinates @ 2^1
Output: OGC_D, IGC_D, MGC_D Euler angles of corresponding transformation = gyro torquing angles to achieve desired orientation @ 2^0
Next Sheet



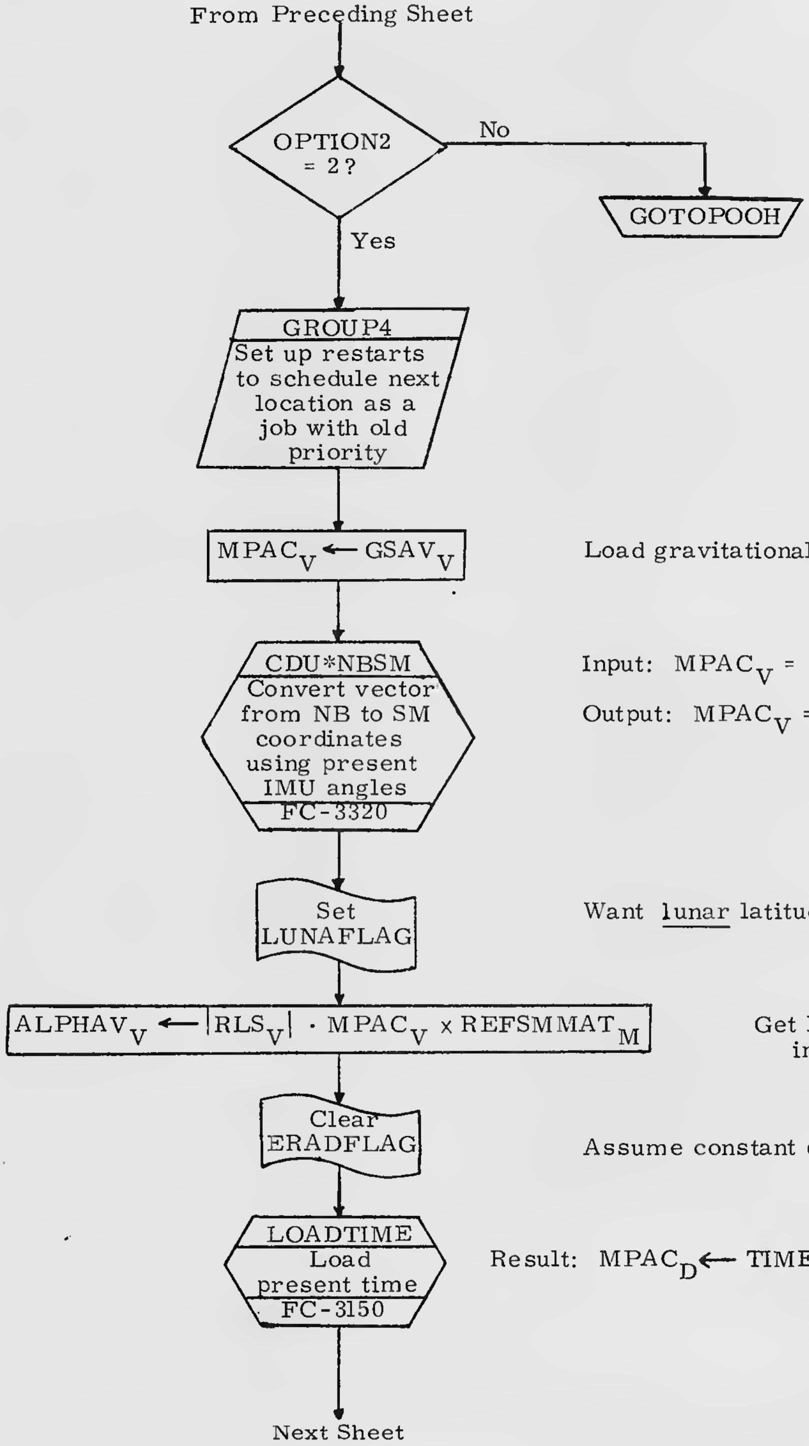
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D Lutkewicz	8/26/69	P57	
PRGMR D Millard	8/19/69		
ANALST			DOCUMENT NO.
DOCMR AM Soant	8/29/69	LUMINARY 1D	FC-3520
APPR'D AM Soant	8/29/69	REV 2	SHEET 41 OF 65



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		P57	
PRGMR	[signature] 8/29/68	LUMINARY 1D	DOCUMENT NO. FC-3520
ANALST			
DOCMR	[signature] 8/29/68		
APPR'D	[signature] 8/29/68	REV 2	SHEET 42 OF 65



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		P57	
PRGMR	8/29/69	LUMINARY 1D	DOCUMENT NO. FC-3520
ANALST			
DOCMR A M Sprant	8/29/69		
APPR'D A M Sprant	8/29/69	REV 2	SHEET 43 OF 65



Load gravitational direction in NB coords 2^1

Input: $MPAC_V$ = vector in NB coordinates

Output: $MPAC_V$ = same vector in SM coords

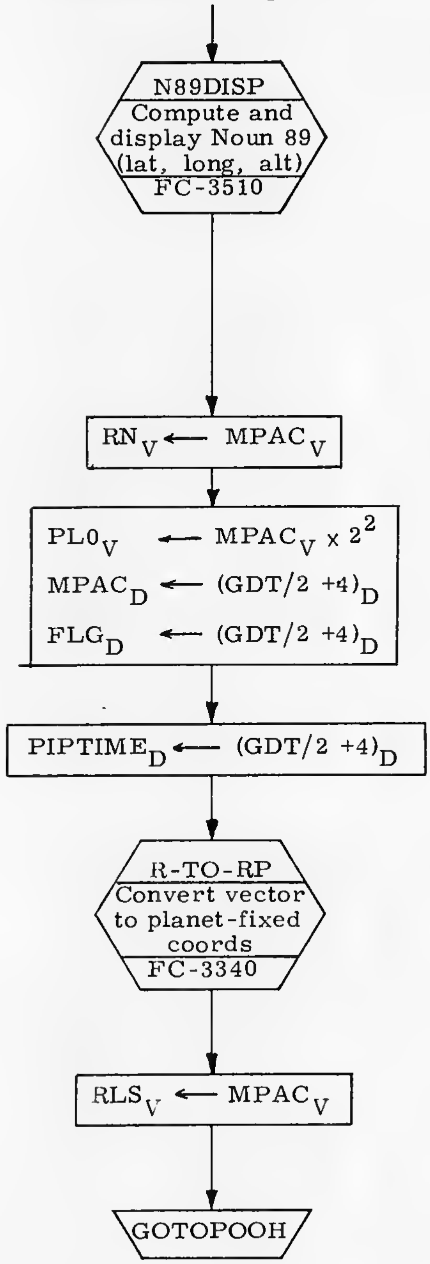
Want lunar latitude, longitude

Get landing site position vector in reference coordinates in M @ 2^{29}

Assume constant earth radius

Result: $MPAC_D \leftarrow TIME2_D$ = present time in csec @ 2^{28}

From Preceding Sheet



Input: $ALPHAV_V$ = Position vector in reference coords in m @ 2^{29}

$MPAC_D$ = Corresponding time in csec @ 2^{28}

ERADFLAG, LUNAFLAG

Output: $MPAC_V$ = Position vector in reference coords in m @ 2^{29}

$(GDT/2 +4)_D$ = Corresponding time in csec @ 2^{28}

Save position vector

Set up inputs to R-TO-RP:

Position vector in m @ 2^{27}

$\neq 0$

Time in csec @ 2^{28}

Store time corresponding to position vector

Input: $PL0_V$ = Vector in reference coords

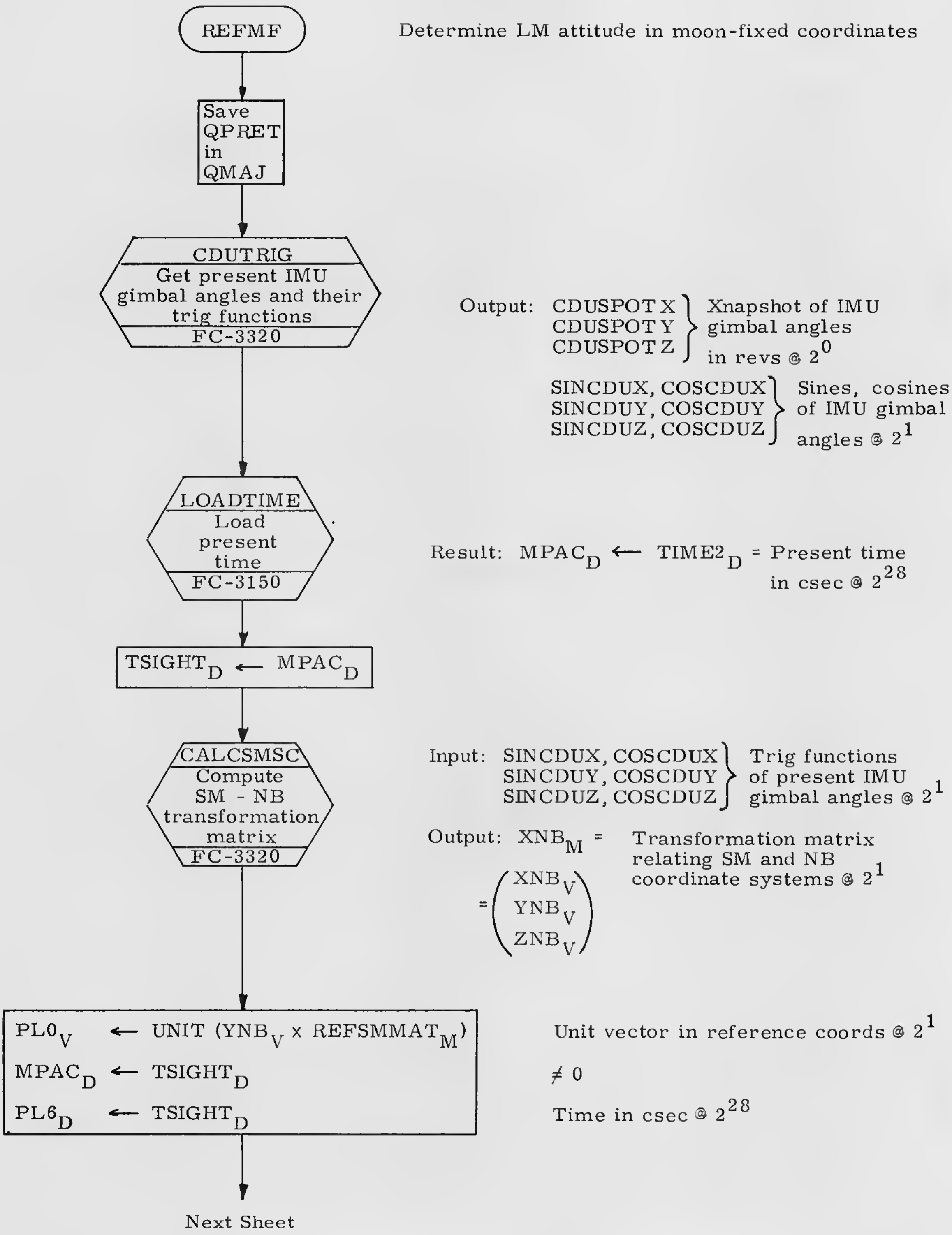
$PL6_D$ = Corresponding time in csec @ 2^{28}

MPAC $\neq 0$ -- indicates moon-fixed coordinates desired

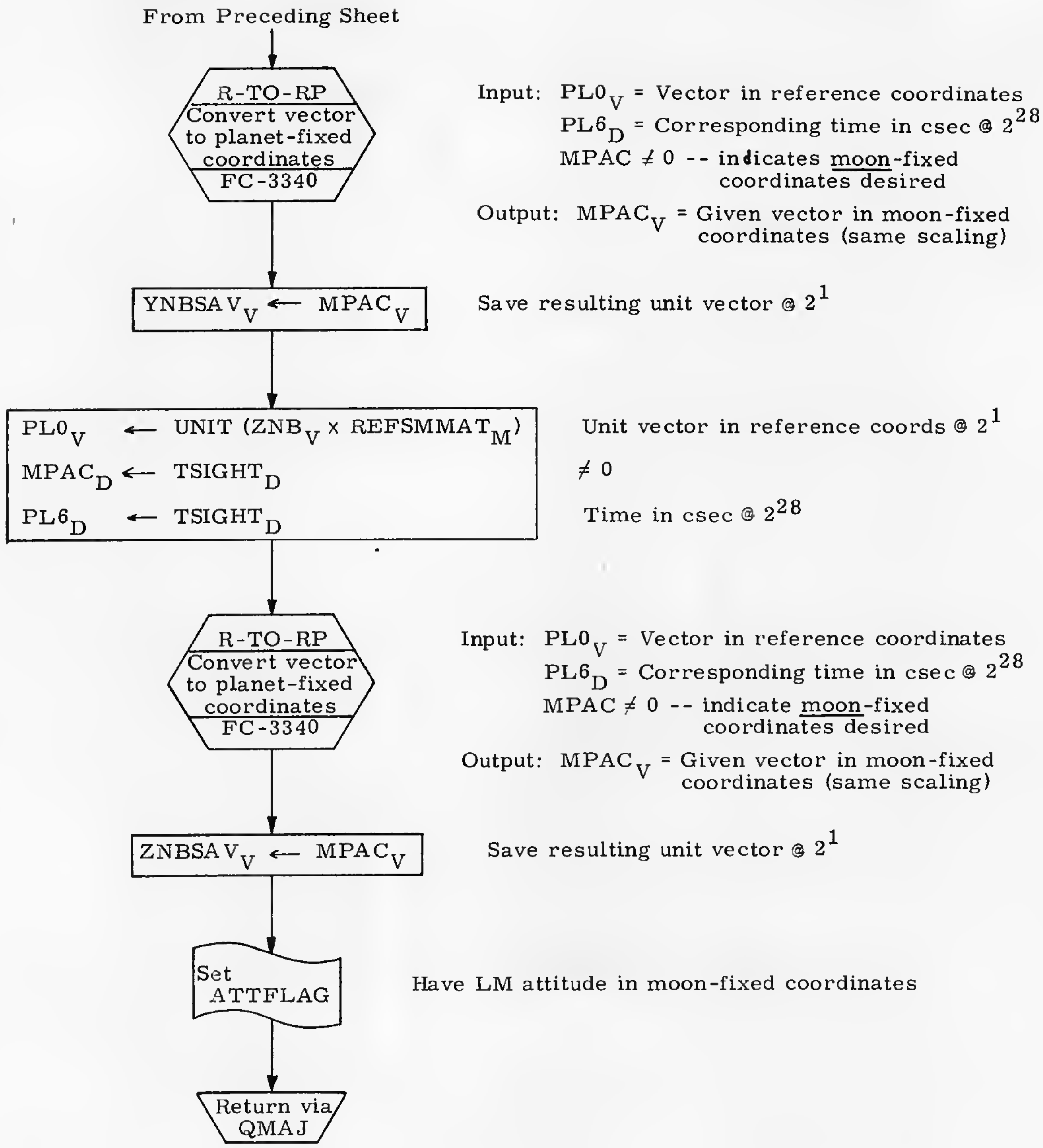
Output: $MPAC_V$ = Given vector in moon-fixed coordinates (same scaling)

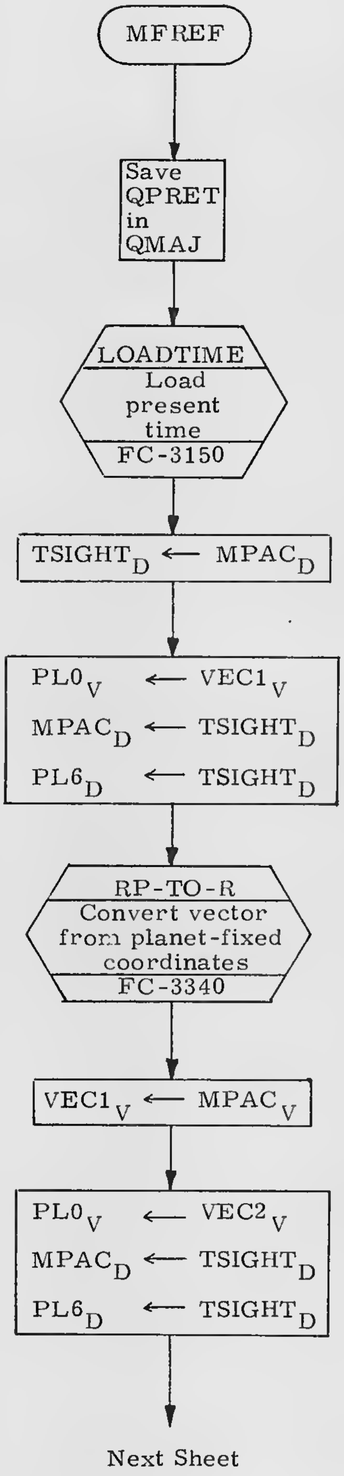
Store position vector in moon-fixed coordinates in m @ 2^{27}

Terminate major mode P57



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. P. Ward	7-28-69	P57	
PRGMR D. Millard	8/22/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3520
DOCMR A M Sorant	8/29/69		
APPR'D A. M. Sorant	8/29/69	REV 2	SHEET 46 OF 65


From Preceding Sheet
R-TO-RP
Convert vector to planet-fixed coordinates
FC-3340
Input: $PL0_V$ = Vector in reference coordinates
$PL6_D$ = Corresponding time in csec @ 2^{28}
MPAC ≠ 0 -- indicates moon-fixed coordinates desired
Output: $MPAC_V$ = Given vector in moon-fixed coordinates (same scaling)
$YNBSAV_V \leftarrow MPAC_V$
Save resulting unit vector @ 2^1
$PL0_V \leftarrow$ UNIT ($ZNB_V \times REFSMMAT_M$)
$MPAC_D \leftarrow TSIGHT_D$
$PL6_D \leftarrow TSIGHT_D$
Unit vector in reference coords @ 2^1
≠ 0
Time in csec @ 2^{28}
R-TO-RP
Convert vector to planet-fixed coordinates
FC-3340
Input: $PL0_V$ = Vector in reference coordinates
$PL6_D$ = Corresponding time in csec @ 2^{28}
MPAC ≠ 0 -- indicate moon-fixed coordinates desired
Output: $MPAC_V$ = Given vector in moon-fixed coordinates (same scaling)
$ZNBSAV_V \leftarrow MPAC_V$
Save resulting unit vector @ 2^1
Set ATTFLAG
Have LM attitude in moon-fixed coordinates
Return via QMAJ



Convert VEC1, VEC2 from moon-fixed to reference coordinates

Result: $MPAC_D \leftarrow TIME2_D$ = Present time in csec @ 2^{28}

Unit vector in moon-fixed coords @ 2^1

$\neq 0$

Time in csec @ 2^{28}

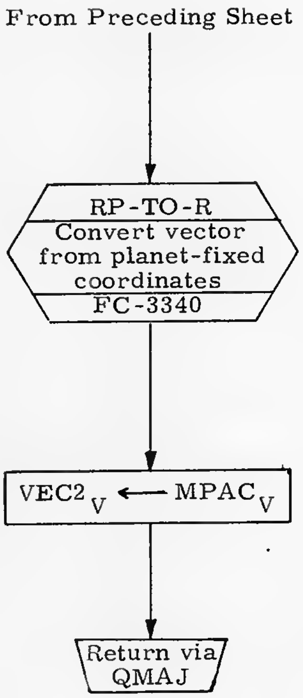
Input: $PL0_V$ = Vector in moon-fixed coords
$PL6_D$ = Corresponding time in csec @ 2^{28}
MPAC $\neq 0$ -- indicates moon-fixed coords

Output: $MPAC_V$ = Given vector in reference coordinates (same scaling)

Unit vector in moon-fixed coords @ 2^1

$\neq 0$

Time in csec @ 2^{28}



Input: $PL0_V$ = Vector in moon-fixed coords

$PL6_D$ = Corresponding time in csec @ 2^{28}

MPAC $\neq$ 0 -- indicates moon-fixed coordinates

Output: $MPAC_V$ = Given vector in reference coordinates (same scaling)

SUBROUTINES CALLED WHICH ARE
FLOWED ON OTHER FLOW CHARTS

SUBROUTINE NAME	FLOW CHART	DESCRIPTION	WHERE CALLED
ALARM	3140	Light PROG ALARM light; set alarm code	Sh. 8, 28
AOTMARK	3530	Perform required sighting marks	Sh. 31
AOTSTALL	3220	Wait for completion of AOT operation	Sh. 31
AXISGEN	3310	Compute transformation matrix, given two vectors in each coordinate system	Sh. 35, 40
CALCGA	3310	Compute IMU gimbal angles necessary to achieve desired orientation	Sh. 13, 37
CALCGTA	3310	Compute gyro torquing angles to achieve desired IMU orientation	Sh. 35, 40
CALCSMSC	3320	Compute SM - NB coordinate transformation matrix	Sh. 21, 23, 37 40, 46
CDUTRIG	3320	Get present IMU gimbal angles and their trigonometric functions	Sh. 20, 21, 23 37, 40, 46
CDU*NBSM	3320	Convert vector from NB to SM coordinates using present IMU gimbal angles	Sh. 23, 24, 44
CDU*SMNB	3320	Convert vector from SM to NB coordinates using present IMU gimbal angles	Sh. 26
COARSE	3500	Coarse align IMU	Sh. 16, 38
CURTAINS	3140	Light PROG ALARM light; set alarm code 217, indicating bad return from stall routine	Sh. 31 41
GCOMPZER	3230	Initialize gyro compensation	Sh. 17

SUBROUTINES CALLED WHICH ARE FLOWED ON OTHER FLOW CHARTS

SUBROUTINE NAME	FLOW CHART	DESCRIPTION	WHERE CALLED
IMUCHK	3500	Check that ISS is running	Sh. 2
IMUPULSE	3220	Torque gyros to align IMU	Sh. 42
IMUSTALL	3220	Wait for completion of IMU operation	Sh. 41
LEMPREC	3350	Integrate LM state vector to desired time	Sh. 5
LOADTIME	3150	Load $MPAC_D$ with present time	Sh. 4, 26, 44, 46, 48
LSORIENT	3510	Complete three-vector coordinate system given one vector	Sh. 5
MATMOVE	3510	Transfer matrix data to desired location	Sh. 3, 37, 42
NCOARSE	3500	Return IMU to fine align mode	Sh. 38
N89DISP	3510	Compute and display Noun 89	Sh. 45
OANB	3530	Compute optic axis for desired sighting	Sh. 27
PIPSRINE (=PIPASR +3)	3850	Read and clear PIPAs	Sh. 17, 18
PLANET	3500	Get reference direction for sighted body	Sh. 26, 32, 33
R-TO-RP	3340	Convert given vector to planet-fixed coordinates from reference coordinates	Sh. 45, 47

SUBROUTINES CALLED WHICH ARE
FLOWED ON OTHER FLOW CHARTS

SUBROUTINE NAME	FLOW CHART	DESCRIPTION	WHERE CALLED
RP-TO-R	3340	Convert given vector from planet-fixed coordinates to reference coordinates	Sh. 48, 49
R54 (=CHKSDATA)	3510	Check validity of star sightings	Sh. 34
TRG*NBSM	3320	Convert vector from NB to SM coordinates, using given IMU gimbal angles	Sh. 39
1/PIPA	3230	Do PIPA compensation	Sh. 18
1STO2S	3150	Convert scalar from 1's to 2's complement	Sh. 30
NBSM	3320	Convert given vector from NB to SM coordinates	Sh. 12, 39
SMNB	3320	Convert given vector from SM to NB coordinates	Sh. 20

FLAGS

NAME	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
ATTFLAG Bit 1 of FLAGWRD6	LM attitude known in moon-fixed coordinates	LM attitude not known in moon-fixed coordinates	Sh. 47		Sh. 6, 7, 9
ERADFLAG Bit 13 of FLAGWRD1	Earth radius to be computed	Constant Earth radius to be assumed		Sh. 44	
FREEFLAG Bit 3 of FLAGWRD0	Astronaut keyed in "RECYCLE" on V06N04 display or "PROCEED" on V06N05	Astronaut keyed in "PROCEED" on V06N04 display or "RECYCLE" on V06N05	Sh. 14	Sh. 14	Sh. 15, 34
INITALGN Bit 2 of FLAGWRD8	First pass through P57	Second pass through P57	Sh. 9	Sh. 10	Sh. 34, 35 38, 43
LUNAFLAG Bit 12 of FLAGWRD3	Lunar latitude, longitude desired	Earth latitude, longitude desired	Sh. 44		
REFSMFLG Bit 13 of FLAGWRD3	REFSMMAT matrix valid	REFSMMAT matrix invalid	Sh. 43	Sh. 11	Sh. 6, 7 25

DISPLAYS

VERB-NOUN	TYPE OF DISPLAY	DESCRIPTION OF EACH REGISTER	WHERE EXECUTED
V04N06	Flashing	R1: 00001 Option ID for: "specify IMU orientation" R2: xxxxx IMU orientation option code	Sh. 2
V06N34	Flashing	R1: 00xxx. hrs R2: 000xx. min R3: 0xx. xx sec Time of alignment	Sh. 4
V05N06	Flashing	R1: 00010 Option ID for: "specify IMU alignment mode" R2: xxxxx IMU alignment mode option code R3: xxxxx Data code (flag bits)	Sh. 7
	Alarm	PROG ALARM light on; no change to registers R1, R2, R3	Sh. 8, 28 31, 41
V05N09	Flashing	R1: xxxxx R2: xxxxx R3: xxxxx Alarm codes	Sh. 8, 28
V06N04	Flashing	R1: xxx. xx deg Gravity error angle	Sh. 14
V01N70	Flashing	R1: xxxxx Star code (AOTCODE)	Sh. 25
V06N79	Flashing	R1: xxx. xx deg Cursor angle (CURSOR) R2: xxx. xx deg Spiral angle (SPIRAL) R3: xxxxx. Position code (POSCODE)	Sh. 31
V06N93	Flashing	R1: xx. xxx deg (OGC) R2: xx. xxx deg (IGC) R3: xx. xxx deg (MGC) Gyro torquing angles	Sh. 35
V06N22	Flashing	R1: xxx. xx deg Outer gimbal angle (THETAD) R2: xxx. xx deg Inner gimbal angle (THETAD +1) R3 R3: xxx. xx deg Middle gimbal angle (THETAD +2) Desired IMU gimbal angles	Sh. 38

DISPLAYS

VERB-NOUN	TYPE OF DISPLAY	DESCRIPTION OF EACH REGISTER	WHERE EXECUTED
V50N25	Flashing	R1: 00014 Please perform fine alignment option	Sh. 43

ERASABLE LOCATIONS USED

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
$ALPHAV_V$		Position vector in reference coordinates used as input to LAT-LONG routine	m	m	2^{29}
AOTCODE		Code number for star sighted			2^{14}
BESTI		6 · Star code for first of two stars sighted			2^{14}
BESTI +1		6 · Star code for second or only star sighted			2^{14}
CDUSPOTX		Snapshot of outer IMU gimbal angle	degrees	revs	2^{0}
CDUSPOTY		Snapshot of inner IMU gimbal angle	degrees	revs	2^{0}
CDUSPOTZ		Snapshot of middle IMU gimbal angle	degrees	revs	2^{0}
COSCDUX		Cosine of outer IMU gimbal angle			2^{1}
COSCDUY		Cosine of inner IMU gimbal angle			2^{1}
COSCDUZ		Cosine of middle IMU gimbal angle			2^{1}
CURSOR		2's complement cursor angle	degrees	revs	2^{-1}

ERASABLE LOCATIONS USED (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
$DELV_V$ $\begin{pmatrix} DELVX_D \\ DELVY_D \\ DELVZ_D \end{pmatrix}$	$\Delta \underline{v}$	Change in velocity sensed by PIPAs, in SM coordinates	m/sec	m/csec	$.000585 \times 2^{14}$
$GACC_V$		Accumulated change in velocity	m/sec	m/csec	$.000585 \times 2^{14}$
$(GDT/2 +4)_D$		Time corresponding to $ALPHAV_V$	sec	csec	2^{28}
$GOUT_V$		Direction of gravitational acceleration, in NB coordinates			2^1
$GSAV_V$		Latest estimate of gravitational direction, in NB coordinates			2^1
IGC_D		Gyro torquing angle for inner IMU gimbal angle needed (with OGC_D, MGC_D (below)) to achieve desired IMU orientation	degrees	revs	2^0
MGC_D		Gyro torquing angle for middle IMU gimbal angle needed (with IGC_D (above) and OGC_D (below)) to achieve desired IMU orientation	degrees	revs	2^0

ERASABLE LOCATIONS USED (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
OGC_D		Gyro torquing angle for outer IMU gimbal angle needed (with IGC_D, MGC_D (above)) to achieve desired IMU orientation	degrees	revs	2^0
OPTION1		Code specifying situation requiring option choice (see OPTION2 (below)) used with Noun 6			
OPTION2		Option code specifying choicc of action in situation specified by OPTION1 (above); used with Noun 6			
OPTION3		Data code used with Noun 6 to display certain flag bits			
$PIPTIME_D$	t	Time corresponding to state vector RN_V (below), VN_V	sec	csec	2^{28}
POSCODE		Code indicating which of six AOT detent positions is being considered			
$RATT_V$	$\underline{r}(t_1)$	Position vector (in reference coordinates) at time specified by $TDEC1_D$ (below)	m	m	2^{29}

ERASABLE LOCATIONS USED (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
$REFSMMAT_M$	[REFSMMAT]	Transformation matrix relating reference and stable member coordinate systems			2^1
RLS_V	$\underline{r}_{LS}$	Landing site position vector in moon-fixed coordinates	m	m	2^{27}
RN_V	$\underline{r}(T)$	Position vector (in reference coordinates) at time specified by $PIPTIME_D$ (above)	m	m	2^{29}
$SCAXIS_V$		Optics axis in NB coordinates			2^1
SINCDUX		Sine of outer IMU gimbal angle			2^1
SINCDUY		Sine of inner IMU gimbal angle			2^1
SINCDUZ		Sine of middle IMU gimbal angle			2^1
SPIRAL		2's complement spiral angle	degrees	revs	2^{-1}
$STAR_V$		Direction of star sighted in SM or NB coordinates			2^1
$STARAD_V$, $(STARAD +6)_V$		Two vectors in a desired SM coordinates input to AXISGEN to be compared with same two vectors in actual SM coordinates			2^1

ERASABLE LOCATIONS USED (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
STARIND		Index used to distinguish between two star sightings			
$STARSAV1_V$		First of 2 reference vectors in SM coordinates			2^1
$STARSAV2_V$		Second of 2 reference vectors in SM coordinates			2^1
$TALIGN_D$		Alignment time	sec	csec	2^{28}
$TDEC1_C$	t_1	Time input to precision integration -- corresponds to position vector $RATT_V$ (above)	sec	csec	2^{28}
THETAD		Desired outer IMU gimbal angle	degrees	revs	2^{-1}
THETAD +1		Desired inner IMU gimbal angle	degrees	revs	2^{-1}
THETAD +2		Desired middle IMU gimbal angle	degrees	revs	2^{-1}
TIG_D		Initial value for time of alignment	sec	csec	2^{28}
$TIME2_D$		Present time	sec	csec	2^{28}
$TSIGHT_D$		Time of star sighting	sec	csec	2^{28}
$VEC1_V$		First of 2 reference vectors in moon-fixed coordinates			2^1
$VEC2_V$		Second of 2 reference vectors in moon-fixed coordinates			2^1

ERASABLE LOCATIONS USED (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
$XDC_M = \begin{pmatrix} XDC_V \\ YDC_V \\ ZDC_V \end{pmatrix}$		Up-to-date version of XSM_M (below)			2^1
$XNB_M = \begin{pmatrix} XNB_V \\ YNB_V \\ ZNB_V \end{pmatrix}$		Transformation matrix giving NB coordinate axes in terms of SM coordinates			2^1
$XSM_M = \begin{pmatrix} XSM_V \\ YSM_V \\ ZSM_V \end{pmatrix}$		Transformation matrix giving desired SM axes in terms of actual SM coordinates			2^1
$XSMD_M = \begin{pmatrix} XSMD_V \\ YSMD_V \\ ZSMD_V \end{pmatrix}$		Transformation matrix giving desired SM axes in terms of reference coordinates			2^1
$YNBSAV_V$		NB Y-coordinate axis in terms of moon-fixed coordinates			2^1

ERASABLE LOCATIONS USED (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
$ZNBSAV_V$		NB Z-coordinate axis in terms of moon fixed coordinates			2^1
1/PIPADT		ΔTime corresponding to $DELV_V$ (above) sensed	sec	csec	2^{28}

PROGRAM CONSTANTS

AGC TAG	MEANING	ENGINEERING AND AGC VALUE	AGC SCALING
CATLOG -6	Direction of star 1 (α Andromedae (Alpheratz)) in Reference coords	$\begin{pmatrix} +.8748658918 \\ +.0260879174 \\ +.4836621670 \end{pmatrix}$	2^1
CATLOG -12D	Direction of star 2 (β Ceti (Diphda)) in Reference coords	$\begin{pmatrix} +.9342640400 \\ +.1735073142 \\ -.3115219339 \end{pmatrix}$	2^1
CATLOG -18D	Direction of star 3 (γ Cassiopeiae (Navi)) in Reference coords	$\begin{pmatrix} +.4775639450 \\ +.1166004340 \\ +.8708254803 \end{pmatrix}$	2^1
CATLOG -24D	Direction of star 4 (α Eridani (Achernar)) in Reference coords	$\begin{pmatrix} +.4917678276 \\ +.2204887125 \\ -.8423473935 \end{pmatrix}$	2^1
CATLOG -30D	Direction of star 5 (α Ursae Minoris (Polaris)) in Reference coords	$\begin{pmatrix} +.0130968840 \\ +.0078062795 \\ +.9998837600 \end{pmatrix}$	2^1
CATLOG -36D	Direction of star 6 (θ Eridani (Acamar)) in Reference coords	$\begin{pmatrix} +.5450107404 \\ +.5314955466 \\ -.6484410356 \end{pmatrix}$	2^1
CATLOG -42D	Direction of star 7 (α Ceti (Menkar)) in Reference coords	$\begin{pmatrix} +.7032235469 \\ +.7075846047 \\ +.0692868685 \end{pmatrix}$	2^1
CATLOG -48D	Direction of star 8 (= 10_8) (α Persei (Mirfak)) in Reference coords	$\begin{pmatrix} +.4105636020 \\ +.4988110001 \\ +.7632988371 \end{pmatrix}$	2^1
CATLOG -54D	Direction of star 9 (= 11_8) (α Tauri (Aldebaran)) in Reference coords	$\begin{pmatrix} +.3507315036 \\ +.[illegible] \\ +.2831839492 \end{pmatrix}$	2^1
CATLOG -60D	Direction of star 10D (= 12_8) (β Orionis (Rigel)) in Reference coords	$\begin{pmatrix} +.2011399585 \\ +.9690337941 \\ -.1432348512 \end{pmatrix}$	2^1
CATLOG -66D	Direction of star 11D (= 13_8) (α Aurigae (Capella)) in Reference coords	$\begin{pmatrix} +.1371725575 \\ +.6813721061 \\ +.7189685267 \end{pmatrix}$	2^1
CATLOG -72D	Direction of star 12D (= 14_8) (α Carinae (Canopus)) in Reference coords	$\begin{pmatrix} -.0614937230 \\ +.6031563286 \\ -.7952489957 \end{pmatrix}$	2^1
CATLOG -78D	Direction of star 13D (= 15_8) (α Canis Majoris (Sirius)) in Reference coords	$\begin{pmatrix} -.1820751783 \\ +.9404899869 \\ -.2869271926 \end{pmatrix}$	2^1
CATLOG -84D	Direction of star 14D (= 16_8) (α_2 Canis Minoris (Procyon)) in Reference coords	$\begin{pmatrix} -.4118589524 \\ +.9065485360 \\ +.0924226975 \end{pmatrix}$	2^1
CATLOG -90D	Direction of star 15D (= 17_8) (γ Velorum (Regor)) in Reference coords	$\begin{pmatrix} -.3612508532 \\ +.5747270840 \\ -.7342932655 \end{pmatrix}$	2^1
CATLOG -96D	Direction of star 16D (= 20_8) (ι Ursae Majoris (Dnoces)) in Reference coords	$\begin{pmatrix} -.4557947941 \\ +.4774785033 \\ +.7450164351 \end{pmatrix}$	2^1
CATLOG -102D	Direction of star 17D (= 21_8) (α Hydrae (Alphard)) in Reference coords	$\begin{pmatrix} -.7742591356 \\ +.6152504197 \\ -.1482803830 \end{pmatrix}$	2^1
CATLOG -108D	Direction of star 18D (= 22_8) (α Leonis (Regulus)) in Reference coords	$\begin{pmatrix} -.8608205219 \\ +.4636213989 \\ +.2098647835 \end{pmatrix}$	2^1

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DRAWN	R.L. Schmidt	P57	
PRGMR	D. Millard 8/25/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3520
DOCMR	A.M. Sorant 8/29/69		
APPR'D	A.M. Sorant 8/29/69	REV 2	SHEET 63 OF 65

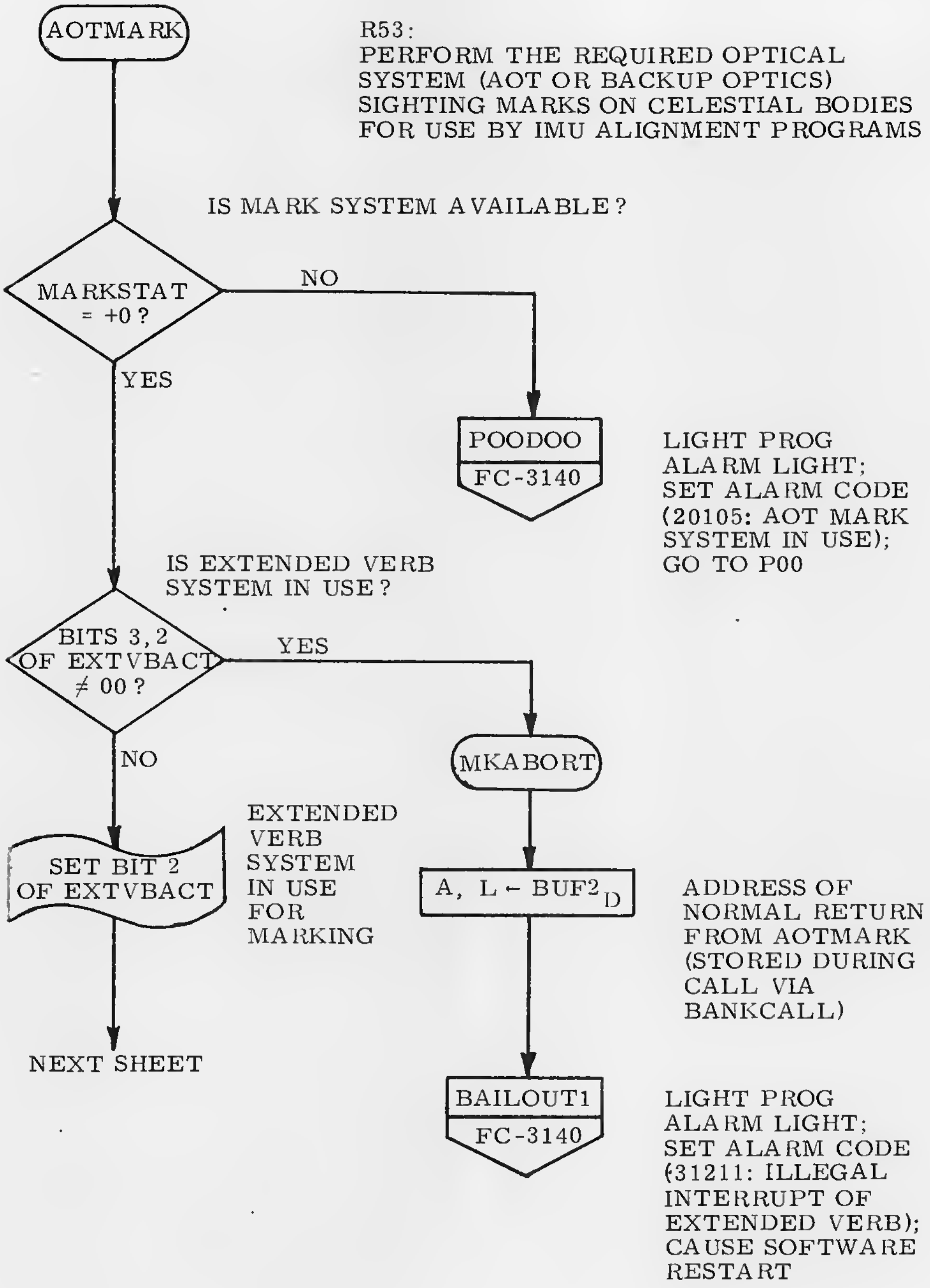
AGC TAG	MEANING	ENGINEERING AND AGC VALUE	AGC SCALING
CATLOG -114D	Direction of star 19D ($=23_8$) (β Leonis (Denebola)) in Reference coords	-.9656605484 +.0525933156 +.2544280809	2^1
CATLOG -120D	Direction of star 20D ($=24_8$) (γ Corvi (Gienah)) in Reference coords	-.9525211695 -.0593434796 -.2986331746	2^1
CATLOG -126D	Direction of star 21D ($=25_8$) (α Crucis (Acrux)) in Reference coords	-.4523440203 -.0493710140 -.8904759346	2^1
CATLOG -132D	Direction of star 22D ($=26_8$) (α Virginis (Spica)) in Reference coords	-.9170097662 -.3502146628 -.1908999176	2^1
CATLOG -138D	Direction of star 23D ($=27_8$) (η Ursae Majoris (Alkaid)) in Reference coords	-.5812035376 -.2909171294 +.7599800468	2^1
CATLOG -144D	Direction of star 24D ($=30_8$) (θ Centauri (Menkent)) in Reference coords	-.6898393233 -.4182330640 -.5909338474	2^1
CATLOG -150D	Direction of star 25D ($=31_8$) (α Bootis (Arcturus)) in Reference coords	-.7861763936 -.5217996305 +.3311371675	2^1
CATLOG -156D	Direction of star ($=32_8$) (α Coronae Borealis (Alphecca)) in Reference coords	-.5326876930 -.7160644554 +.4511047742	2^1
CATLOG -162D	Direction of star 27D ($=33_8$) (α Scorpii (Antares)) in Reference coords	-.3516499609 -.8240752705 -.4441196390	2^1
CATLOG -168D	Direction of star 28D ($=34_8$) (α Trianguli Austr. (Atria)) in Reference coords	-.1145237858 -.3399602557 -.9334250333	2^1
CATLOG -174D	Direction of star 29D ($=35_8$) (α Ophiuchi (Rasalhague)) in Reference coords	-.1124304773 -.9694934200 +.2178116072	2^1
CATLOG -180D	Direction of star 30D ($=36_8$) (α Lyrae (Vega)) in Reference coords	+.1217293692 -.7702732847 +.6259880410	2^1
CATLOG -186D	Direction of star 31D ($=37_8$) (σ Sagittarii (Nunki)) in Reference coords	+.2069525789 -.8719885748 -.4436288486	2^1
CATLOG -192D	Direction of star 32D ($=40_8$) (α Aquilae (Altair)) in Reference coords	+.4537196908 -.8779508801 +.1527766153	2^1
CATLOG -198D	Direction of star 33D (41_8) (β Capricorni (Dabih)) in Reference coords	+.5520184464 -.7933187400 -.2567508745	2^1
CATLOG -204D	Direction of star 34D ($=42_8$) (α Pavonis (Peacock)) in Reference coords	+.3201817378 -.4436021946 -.8370786936	2^1
CATLOG -210D	Direction of star 35D ($=43_8$) (α Cygni (Deneb)) in Reference coords	+.4541036270 -.5392369197 +.7032312789	2^1
CATLOG -216D	Direction of star 36D ($=44_8$) (ϵ Pegasi (Enif)) in Reference coords	+.8139832631 -.5557243189 +.1691204557	2^1

PROGRAM CONSTANTS (CONTINUED)

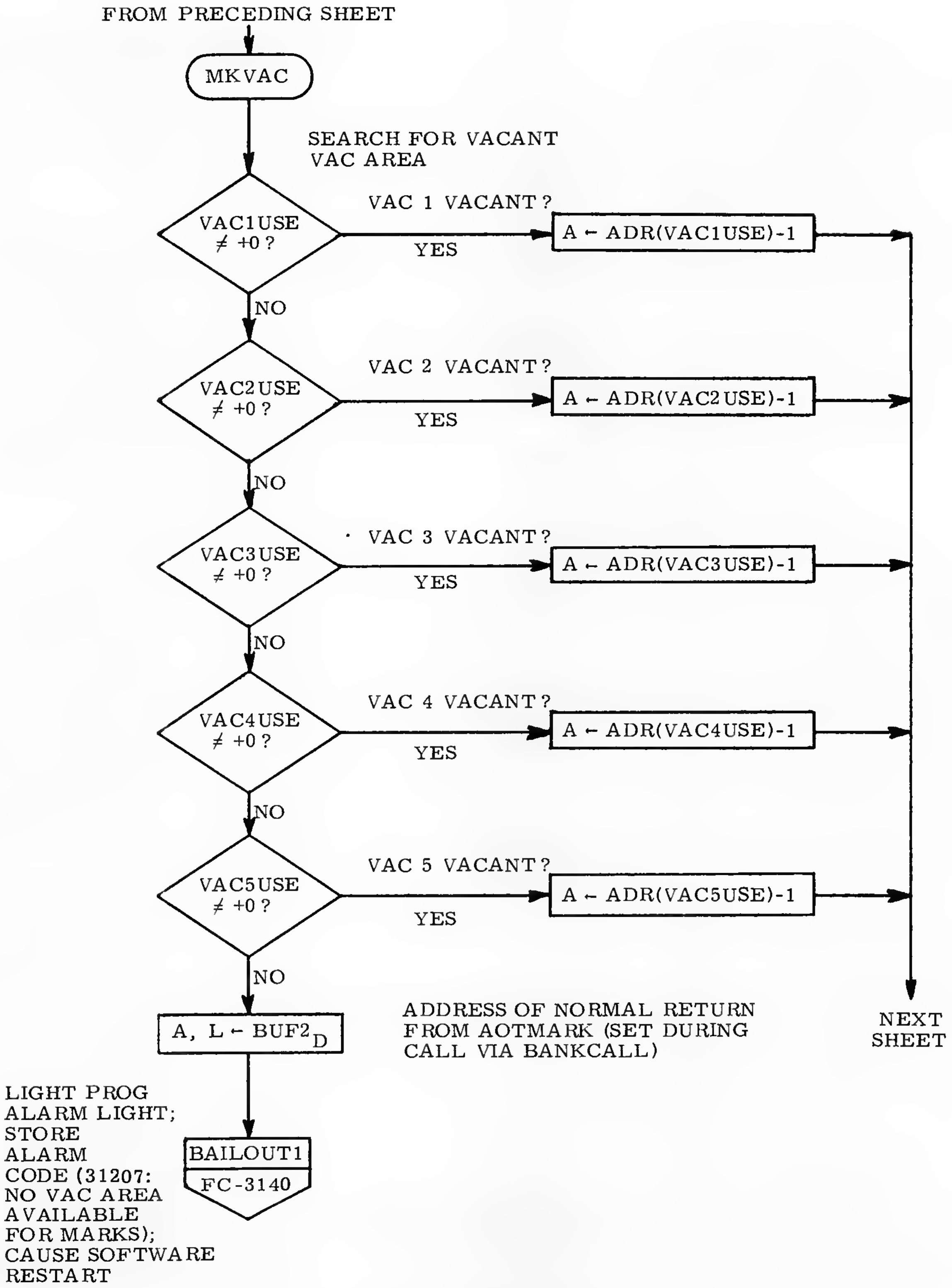
AGC TAG	MEANING	ENGINEERING AND AGC VALUE	AGC SCALING
CATLOG -222D	Direction of star 37D ($=45_8$) (α Piscis Austr. (Formalhaut)) in Reference coords	$\begin{pmatrix} .8342971408 \\ -.2392481515 \\ -.4966976975 \end{pmatrix}$	2^1

PAD LOADS

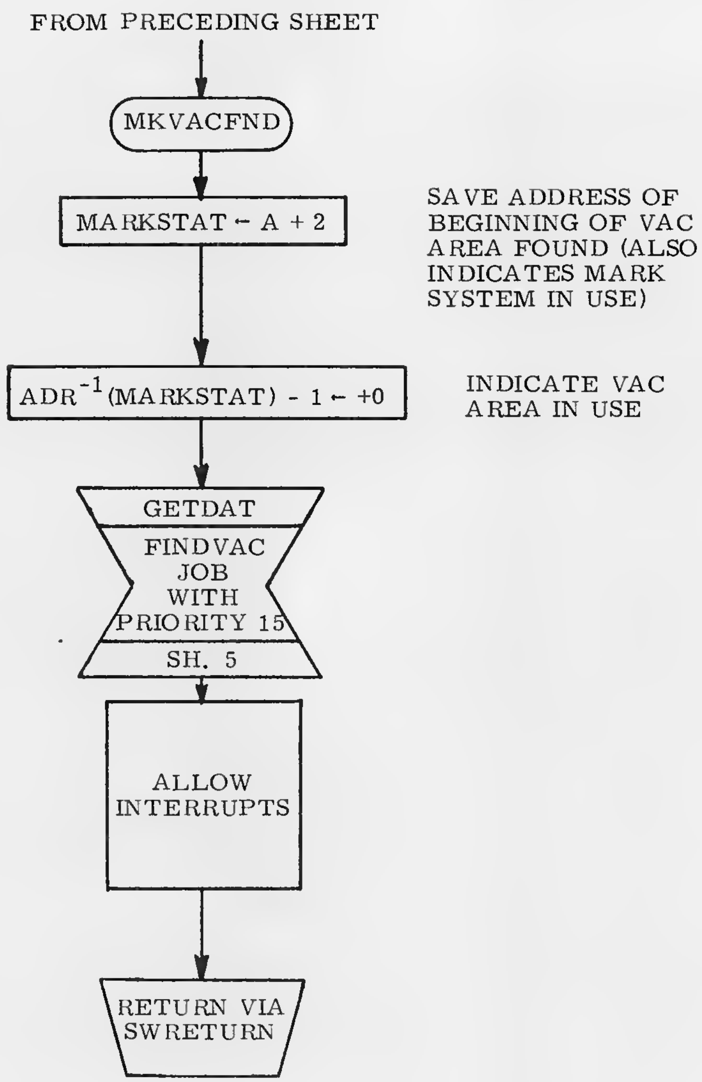
AGC TAG	GSOP TAG	MEANING	ENGINEERING VALUE AND UNITS	AGC VALUE AND UNITS	AGC SCALING	OCTAL VALUE
AOTAZ, . . . AOTAZ +5		Azimuth angles corresponding to 6 AOT detent positions	degrees	revs	2^{-1}	



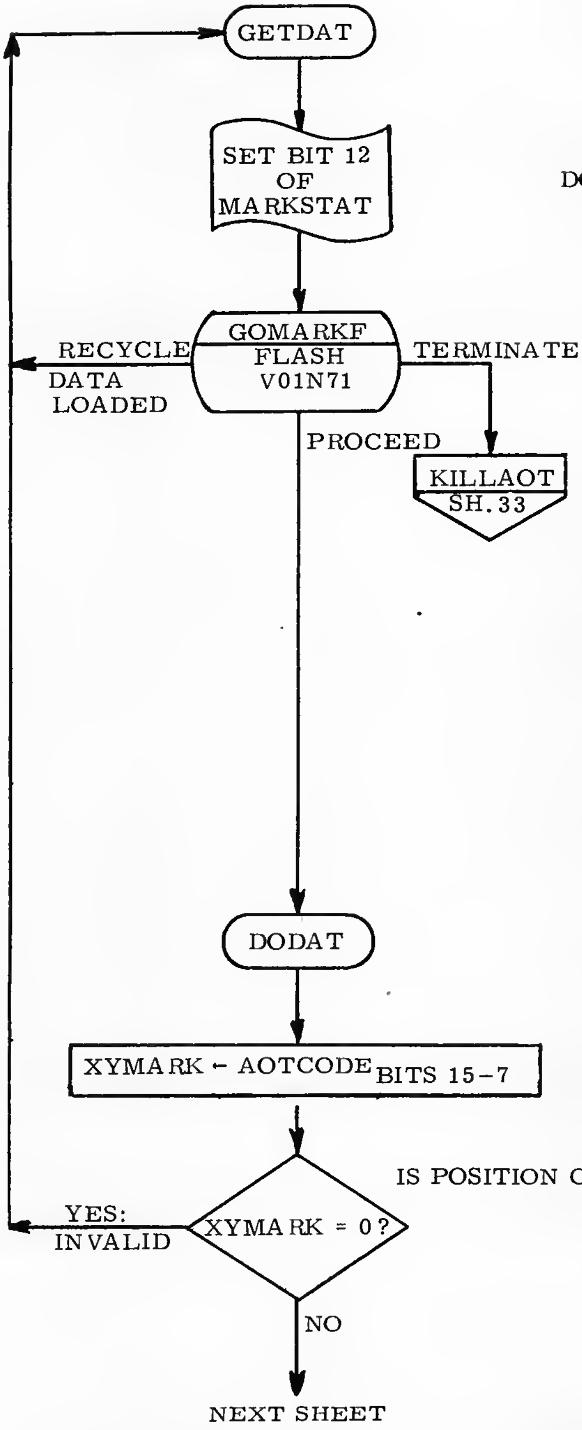
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lutkevich	7/69	Mark Taking Routines	
PRGMR D. Millard	7/69	Luminary 1D	DOCUMENT NO. FC-3530
ANALST			
DOCMR A. M. Sorant	7/25/69		
APPR'D A. M. Sorant	7/25/69	REV 3	SHEET 2 OF 45



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lutkevich	7/69	Mark Taking Routines	
PRGMR	7/69		
ANALST		Luminary 1D	DOCUMENT NO. FC-3530
DOCMR A. M. Sorant	7/25/69		
APPR'D A. M. Sorant	7/25/69	REV 3	SHEET 3 OF 45



FROM PRECEDING SHEET
MKVACFND
MARKSTAT ← A + 2
SAVE ADDRESS OF BEGINNING OF VAC AREA FOUND (ALSO INDICATES MARK SYSTEM IN USE)
ADR^{-1}(MARKSTAT) - 1 ← +0
INDICATE VAC AREA IN USE
GETDAT
FINDVAC JOB WITH PRIORITY 15
SH. 5
ALLOW INTERRUPTS
RETURN VIA SWRETURN



DON'T ACCEPT MARKS YET

DISPLAY (FOR LOADING OR VERIFICATION) NOUN 71:

R1: 00PSS (AOTCODE)

P = AOT POSITION (DETENT) CODE

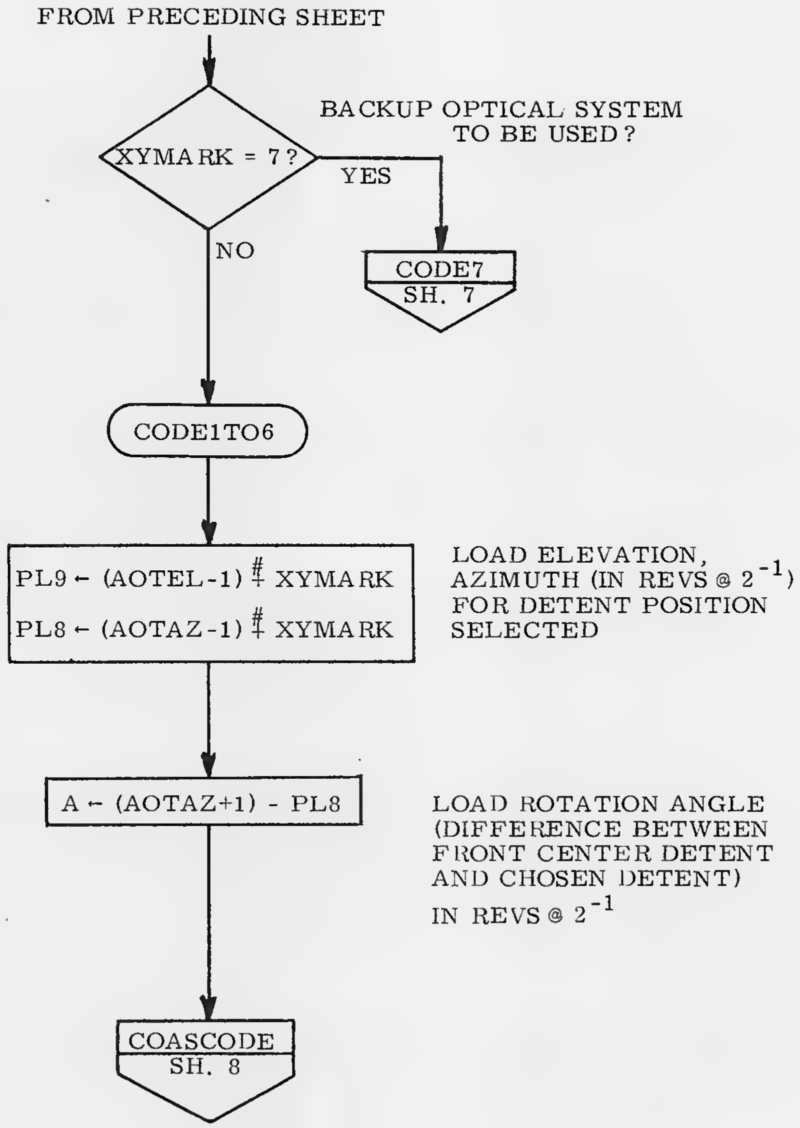
1	FRONT LEFT
2	FRONT CENTER
3	FRONT RIGHT
4	REAR RIGHT
5	REAR CENTER
6	REAR LEFT
7	BACKUP OPTICAL SYSTEM

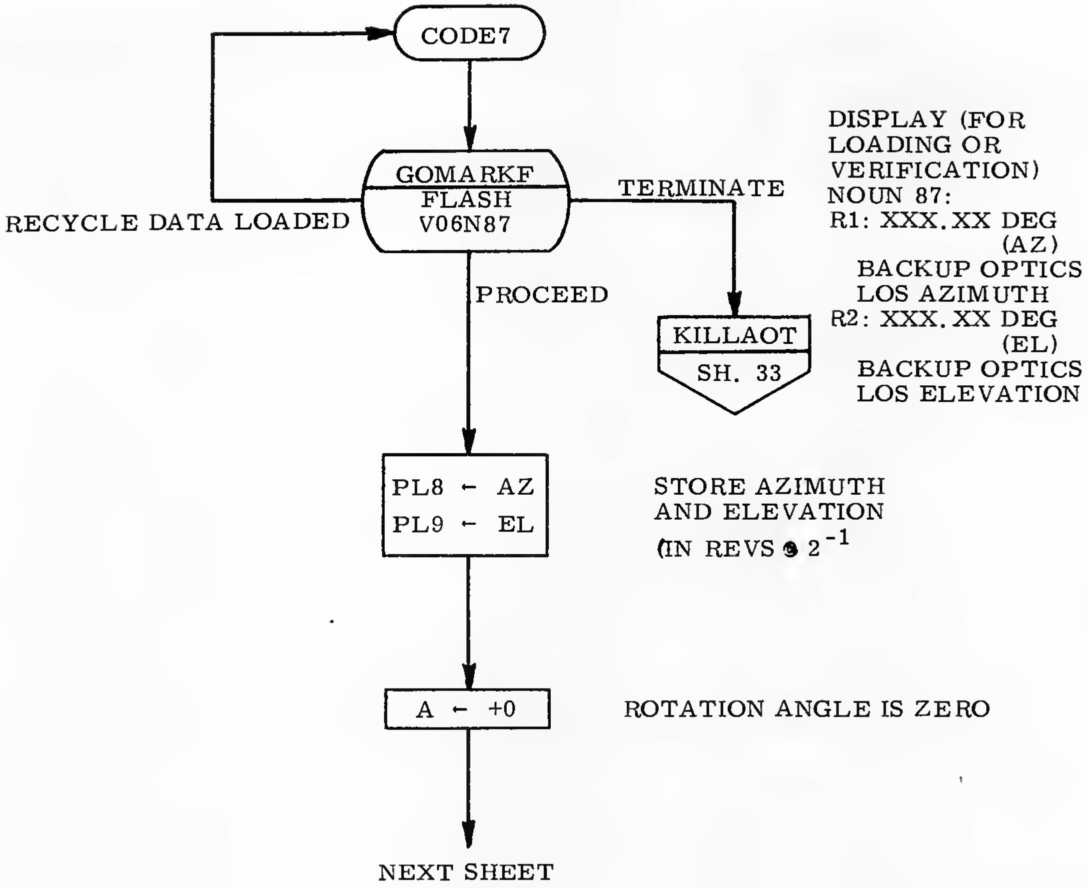
SS = CODE FOR CELESTIAL BODY TO BE SIGHTED

00	PLANET
01-45	STAR
46	SUN
47	EARTH
50	MOON

SAVE POSITION CODE

IS POSITION CODE = 0?


FROM PRECEDING SHEET
XYMARK = 7?
BACKUP OPTICAL SYSTEM TO BE USED?
YES
CODE7
SH. 7
NO
CODE1TO6
PL9 ← (AOTEL-1) ‡ XYMARK
PL8 ← (AOTAZ-1) ‡ XYMARK
LOAD ELEVATION, AZIMUTH (IN REVS @ 2^-1) FOR DETENT POSITION SELECTED
A ← (AOTAZ+1) - PL8
LOAD ROTATION ANGLE (DIFFERENCE BETWEEN FRONT CENTER DETENT AND CHOSEN DETENT) IN REVS @ 2^-1
COASCODE
SH. 8


CODE7
GOMARKF
FLASH
V06N87
RECYCLE DATA LOADED
TERMINATE
PROCEED
KILLAOT
SH. 33
DISPLAY (FOR LOADING OR VERIFICATION) NOUN 87:
R1: XXX.XX DEG (AZ) BACKUP OPTICS LOS AZIMUTH
R2: XXX.XX DEG (EL) BACKUP OPTICS LOS ELEVATION
PL8 ← AZ
PL9 ← EL
STORE AZIMUTH AND ELEVATION (IN REVS @ 2^-1
A ← +0
ROTATION ANGLE IS ZERO
NEXT SHEET

FROM PRECEDING SHEET

COASCODE

PL10 ← A — STORE ROTATION ANGLE IN REVS @ 2^{-1}

OPTAXIS

OANB
COMPUTE OPTICS AXIS FOR DESIRED SIGHTING
SH. 31

INPUT: PL8 = AZIMUTH IN REVS @ 2^{-1}
PL9 = ELEVATION IN REVS @ 2^{-1}

OUTPUT: $SCAXIS_V$ = OPTICS AXIS IN NB COORDS @ 2^1
$PL24_V$ = X-PLANE PROJECTION OF $SCAXIS_V$ IN NB COORDS @ 2^1
$PL18_V$ = Y-PLANE PROJECTION $SCAXIS_V$ IN NB COORDS @ 2^1

$PL12_V \leftarrow COS(PL10 \times 2^{-1}) \cdot PL18_V - SIN(PL10 \times 2^{-1}) \cdot PL24_V$

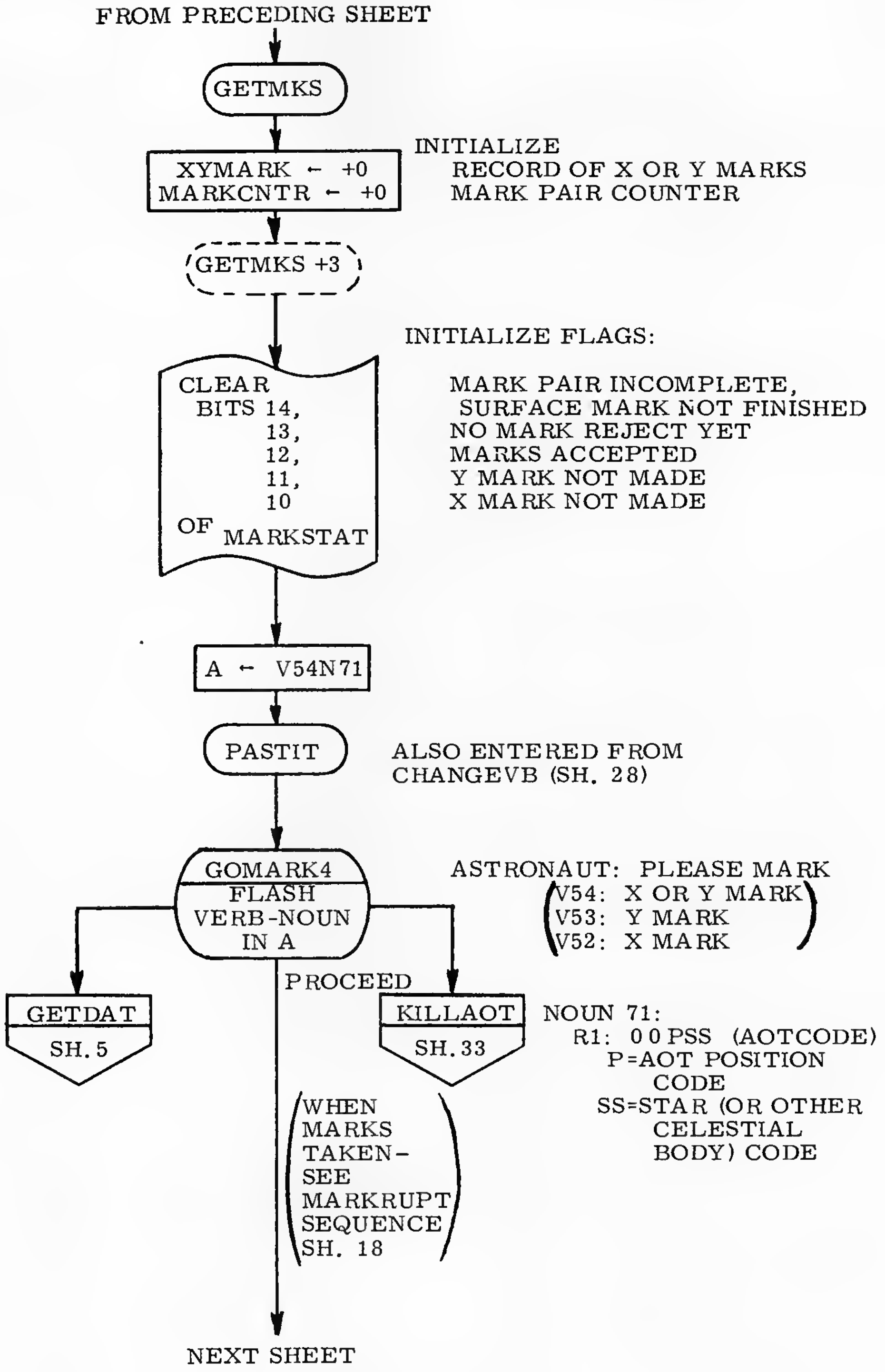
$PL18_V \leftarrow SIN(PL10 \times 2^{-1}) \cdot PL18_V + COS(PL10 \times 2^{-1}) \cdot PL24_V$

TAKE ROTATION INTO ACCOUNT
Y-MARK PLANE VECTOR IN NB COORDS @ 2^2
X-MARK PLANE VECTOR IN NB COORDS @ 2^2
(2^{-1} FACTORS FOR SCALING)

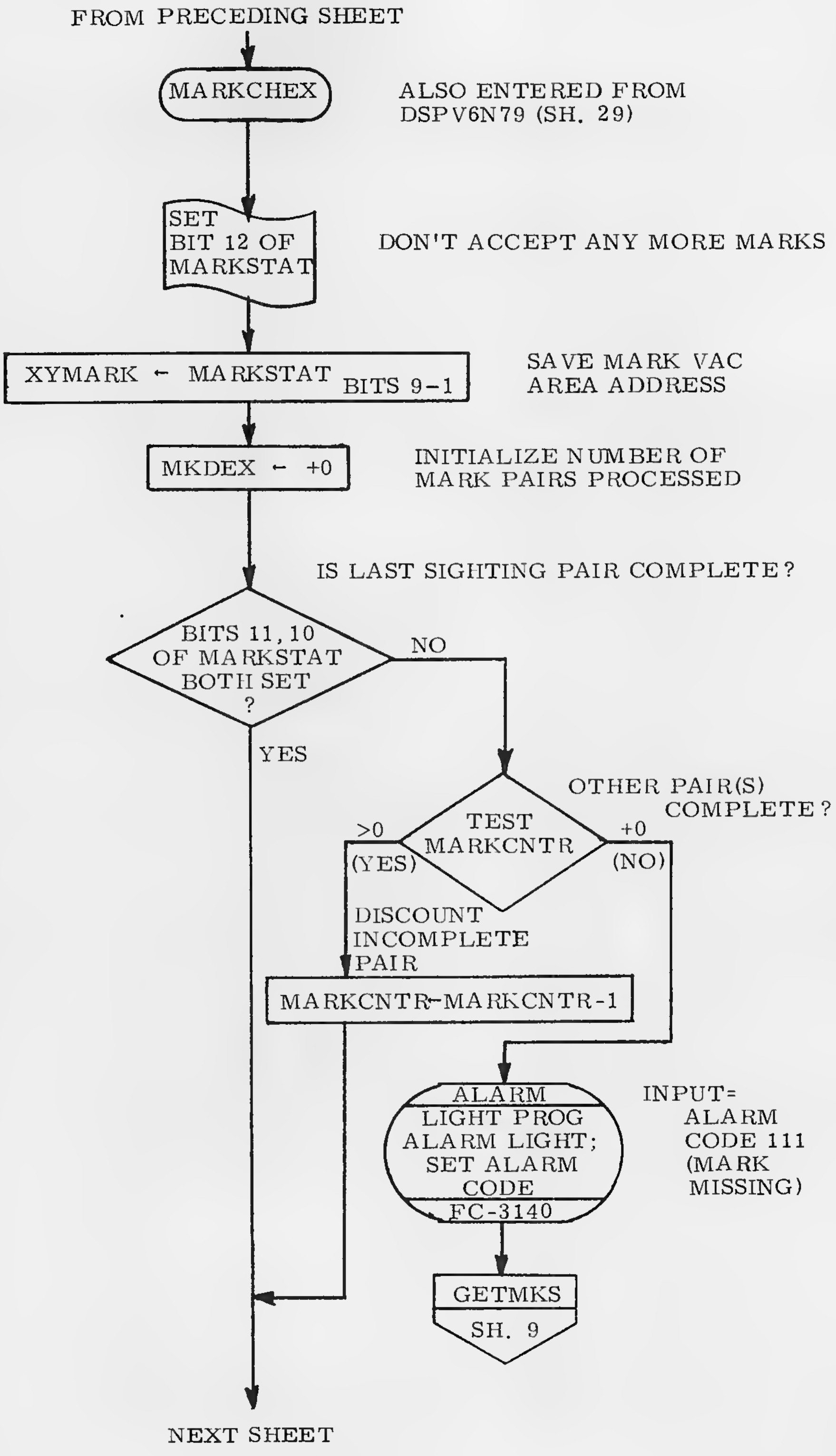
$(STARAD + 6)_V \leftarrow (0, 0, 0)$ — INITIALIZE AVERAGE LOS VECTOR

NEXT SHEET

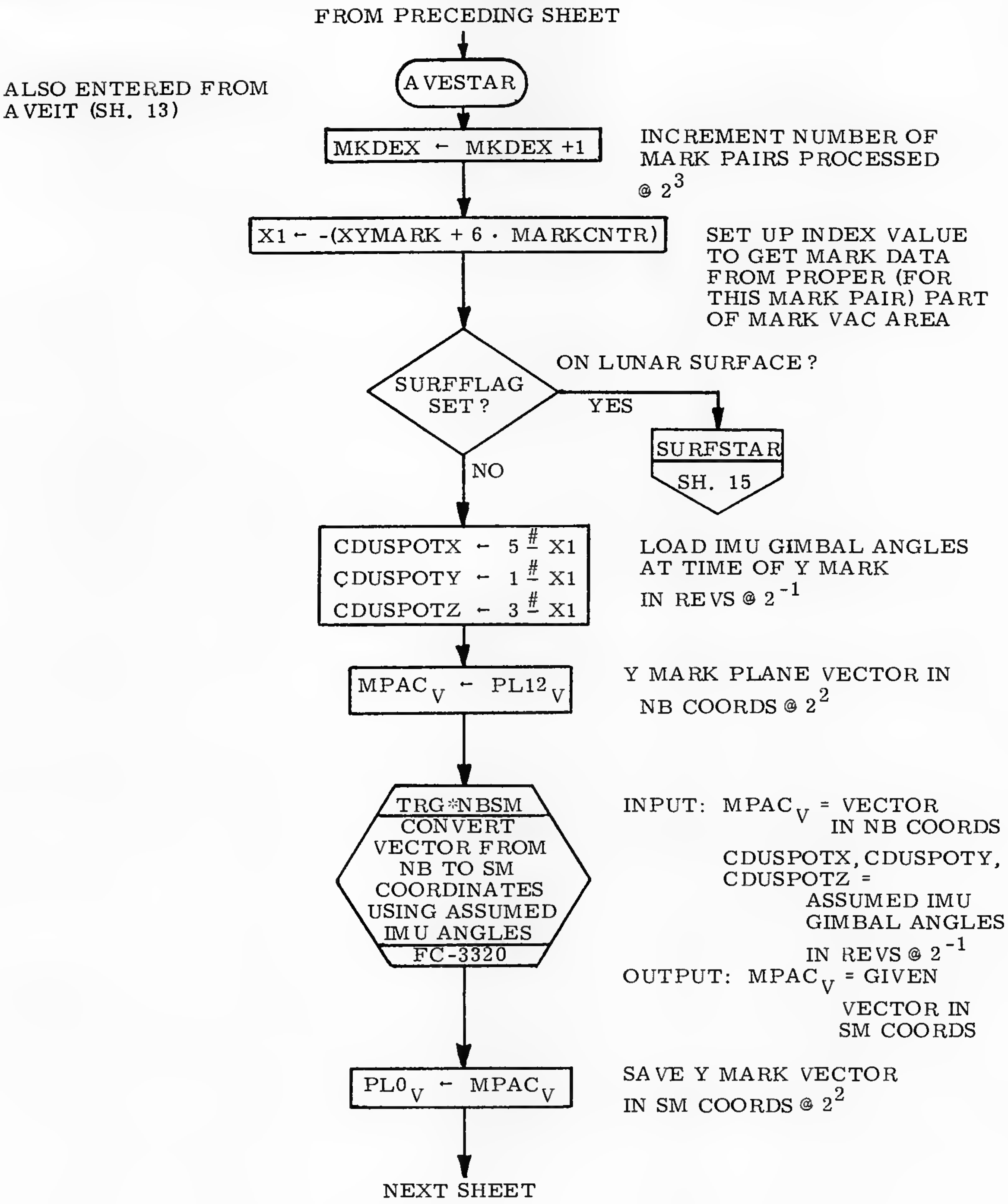
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN [illegible]	7/69	Mark [illegible]king R[illegible]utines	
PRGMR [illegible]	7/69		DOCUMENT NO.
ANALST		Luminary 1D	FC-[illegible]
DOCMR Alexa M. Sorant	7/25/69		
APPR'D Alexa M. Sorant	7/25/69	REV 3	SHEET 8 OF 45



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lutkevich	7/69	Mark Taking Routines	
PRGMR D. Millard	7/69		
ANALST		Luminary 1D	DOCUMENT NO. FC-3530
DOCMR Alesa M. Sprant	7/25/69		
APPR'D Alesa M. Sprant	7/25/69	REV 3	SHEET 9 OF 45



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	7/69	Mark Taking Routines	
PRGMR	7/69		
ANALST		Luminary 1D	DOCUMENT NO. FC-3530
DOCMR	7/25/69		
APPR'D	7/25/69	REV 3	SHEET 10 OF 45



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lutkevich	7/69	Mark Taking Routines	
PRGMR [illegible]	7/69		
ANALST		Luminary 1D	DOCUMENT NO. FC-3530
DOCMR A. M. Sorant	7/25/69		
APPR'D A. M. Sorant	7/25/69	REV 3	SHEET 11 OF 45

FROM PRECEDING SHEET

CDUSPOTX ← 4 $\frac{\#}{}$ X1
CDUSPOTY ← 0 $\frac{\#}{}$ X1
CDUSPOTZ ← 2 $\frac{\#}{}$ X1

LOAD IMU GIMBAL ANGLES
AT TIME OF X MARK
IN REVS @ 2^{-1}

$MPAC_V$ ← $PL18_V$

X MARK PLANE VECTOR IN NB
COORDS @ 2^2

TRG*NBSM
CONVERT
VECTOR FROM
NB TO SM
COORDINATES
USING ASSUMED
IMU ANGLES
FC-3320

INPUT: $MPAC_V$ = VECTOR IN NB
COORDS

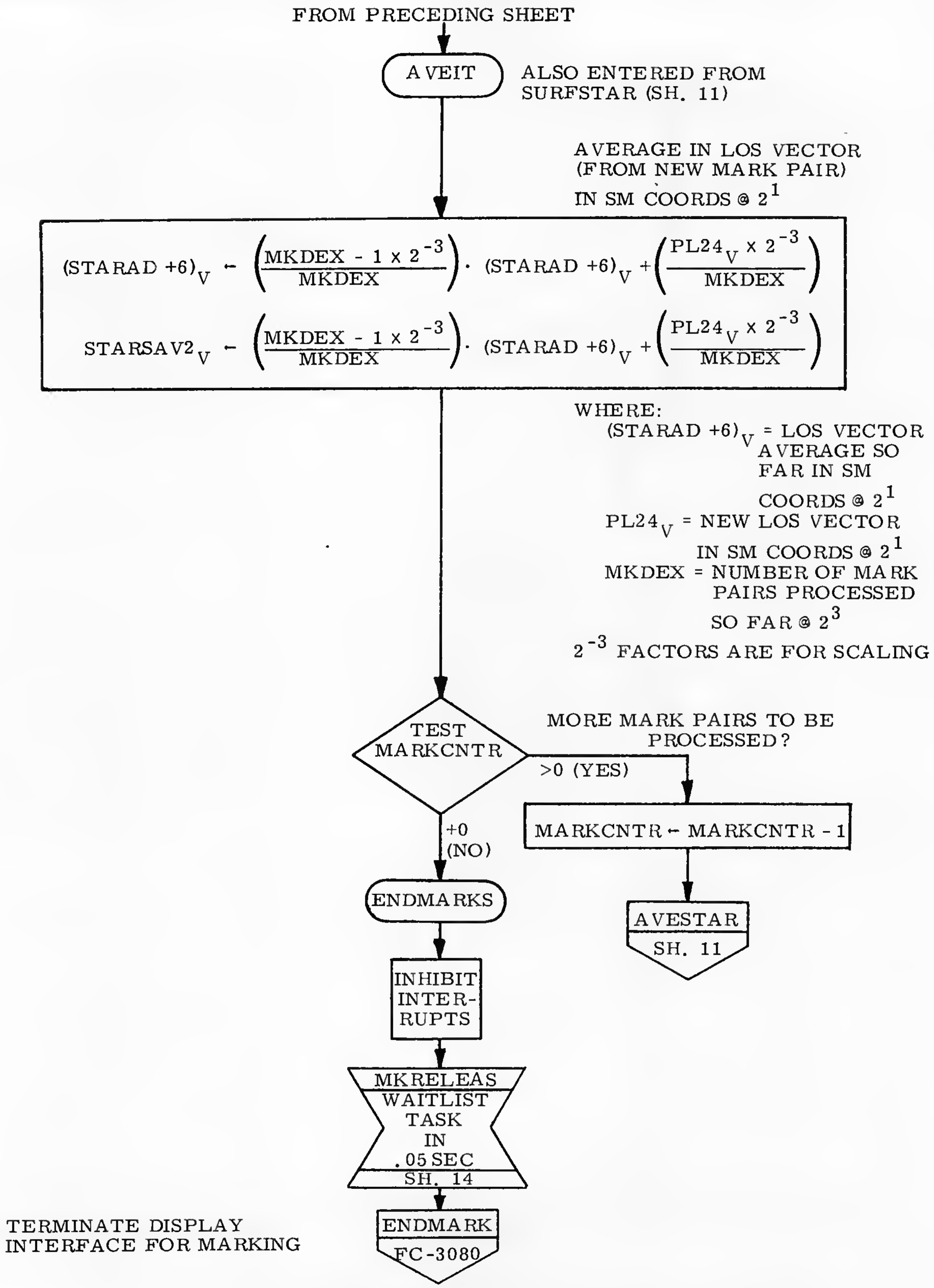
CDUSPOTX, CDUSPOTY, CDUSPOTZ
= ASSUMED IMU GIMBAL
ANGLES IN REVS @ 2^{-1}

OUTPUT: $MPAC_V$ = GIVEN VECTOR IN SM
COORDS
(HERE = X MARK VECTOR
IN SM COORDINATES @ 2^2)

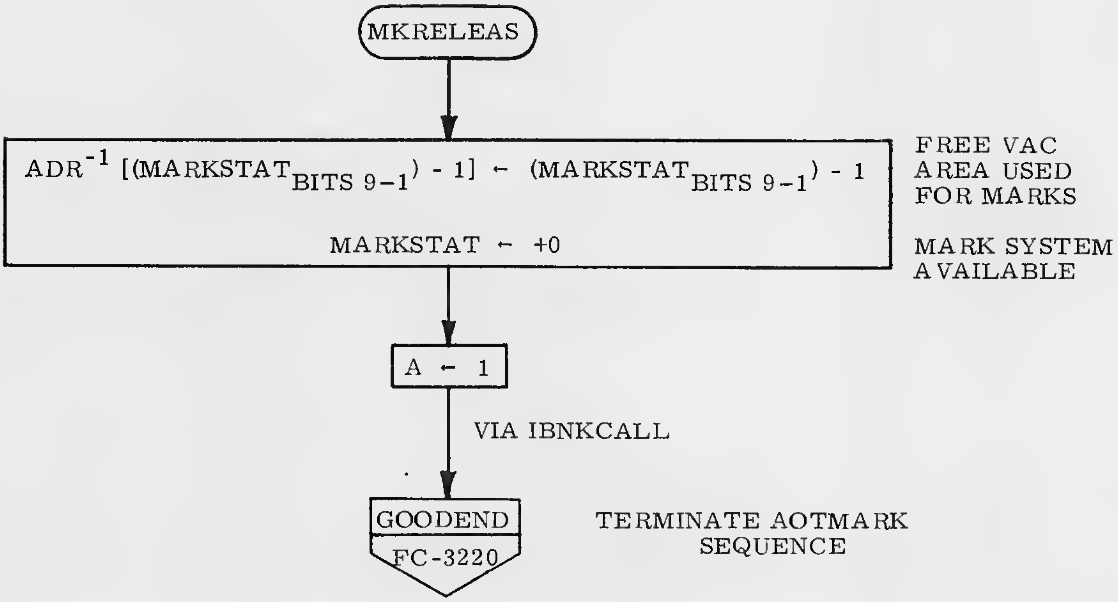
$PL24_V$ ← UNIT($MPAC_V$ x $PL0_V$)

LOS FOR THIS MARK PAIR:
UNIT ($X_{MP(SM)}$ x $Y_{MP(SM)}$) @ 2^1

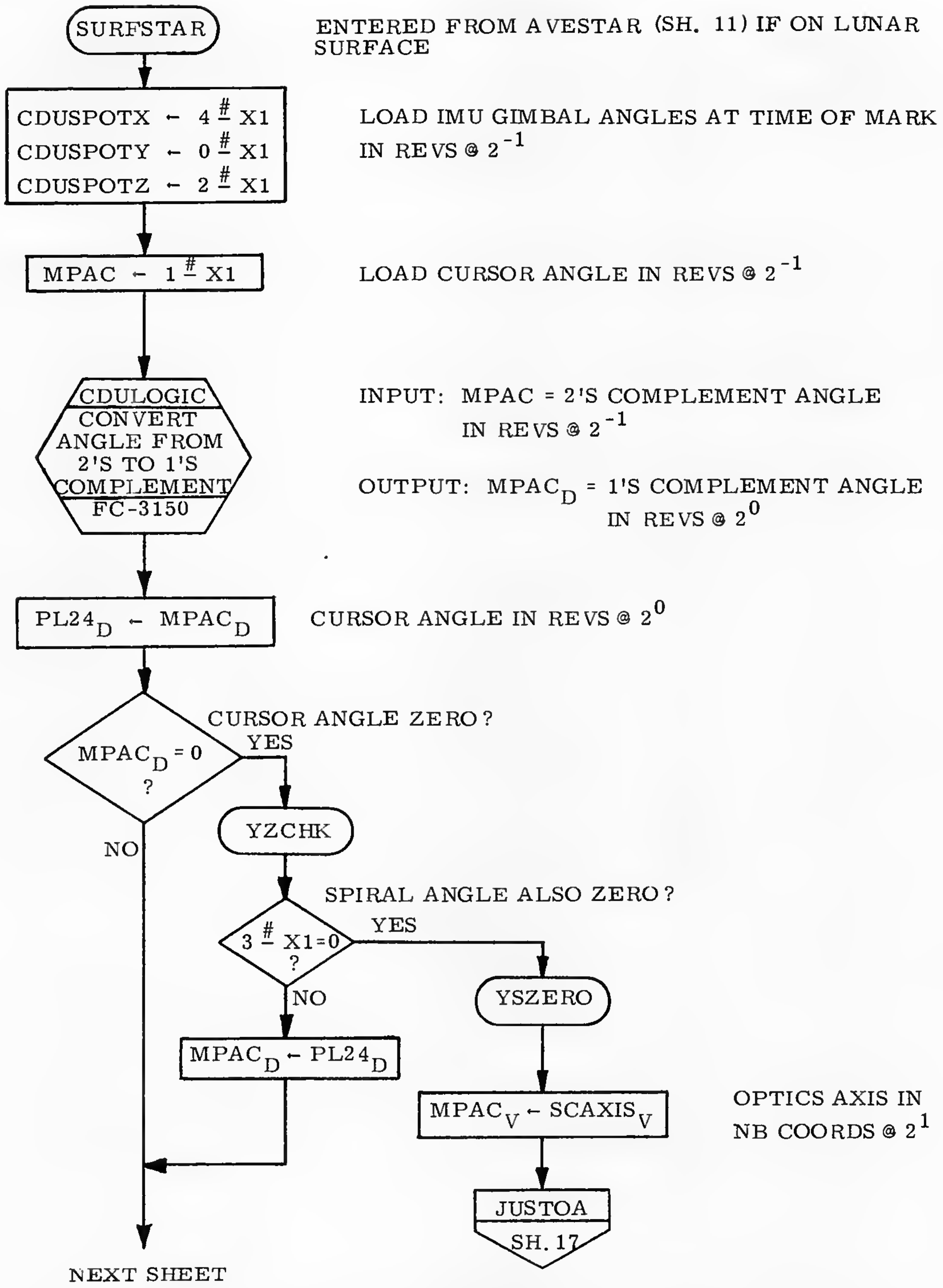
NEXT SHEET



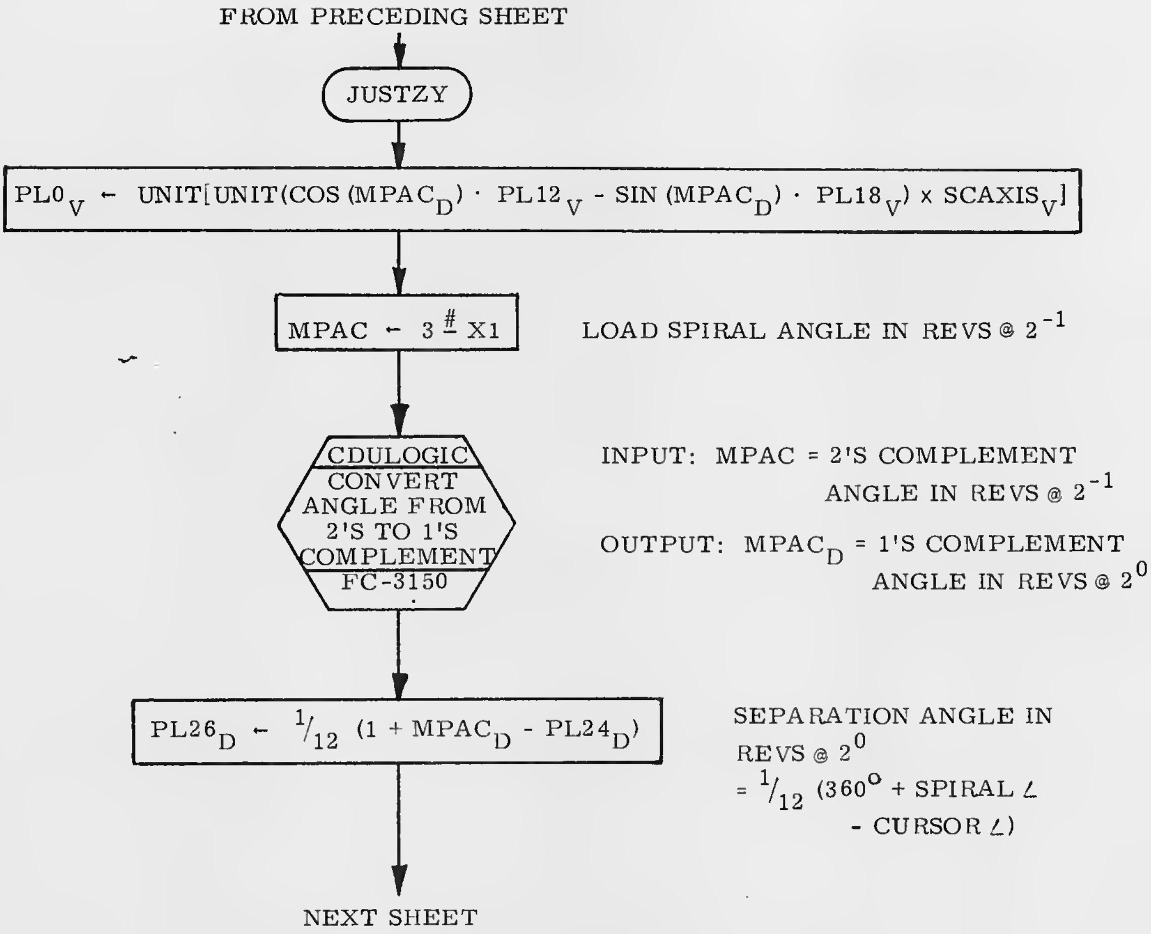
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	D. Lutkewich	7/69	Mark Taking Routines	
PRGMR	L. Melbard	7/69		DOCUMENT NO.
ANALST			Luminary 1D	FC-3530
DOCMR	A. M. Sprant	7/25/69		
APPR'D	A. M. Sprant	7/25/69	REV 3	SHEET 13 OF 45



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D Lutkevich	7/69	Mark Taking Routines	
PRGMR D Millard	7/69		DOCUMENT NO.
ANALST		Luminary 1D	FC-3530
DOCMR A. M. Sorant	7/25/69		
APPR'D A. M. Sorant	7/25/69	REV 3	SHEET 14 OF 45



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lutkevich	7/69	Mark Taking Routines	
PRGMR P. Pollard	7/69		
ANALST		Luminary 1D	DOCUMENT NO. FC-3530
DOCMR A. M. Sorant	7/25/69		
APPR'D A. M. Sorant	7/25/69	REV 3	SHEET 15 OF 45



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lutkevich	7/69	Mark Taking Routines	
PRGMR S. Millard	6/69		
ANALST		Luminary 1D	DOCUMENT NO. FC-3530
DOCMR A. M. Sorant	7/25/69		
APPR'D A. M. Sorant	7/25/69	REV 3	SHEET 16 OF 45

FROM PRECEDING SHEET

$MPAC_V \leftarrow 2^1 \cdot [COS(PL26_D) \cdot SCAXIS_V + SIN(PL26_D) \cdot PL0_V]$

JUSTOA

$MPAC_V \leftarrow UNIT(MPAC_V)$

STAR LOS VECTOR IN NB COORDS @ 2^1

TRG*NBSM
CONVERT VECTOR FROM NB TO SM COORDINATES USING ASSUMED IMU ANGLES
FC-3320

INPUT: $MPAC_V$ = VECTOR IN NB COORDINATES
CDUSPOTX, CDUSPOTY, CDUSPOTZ
= ASSUMED IMU GIMBAL ANGLES IN REVS @ 2^{-1}

OUTPUT: $MPAC_V$ = GIVEN VECTOR IN SM COORDS

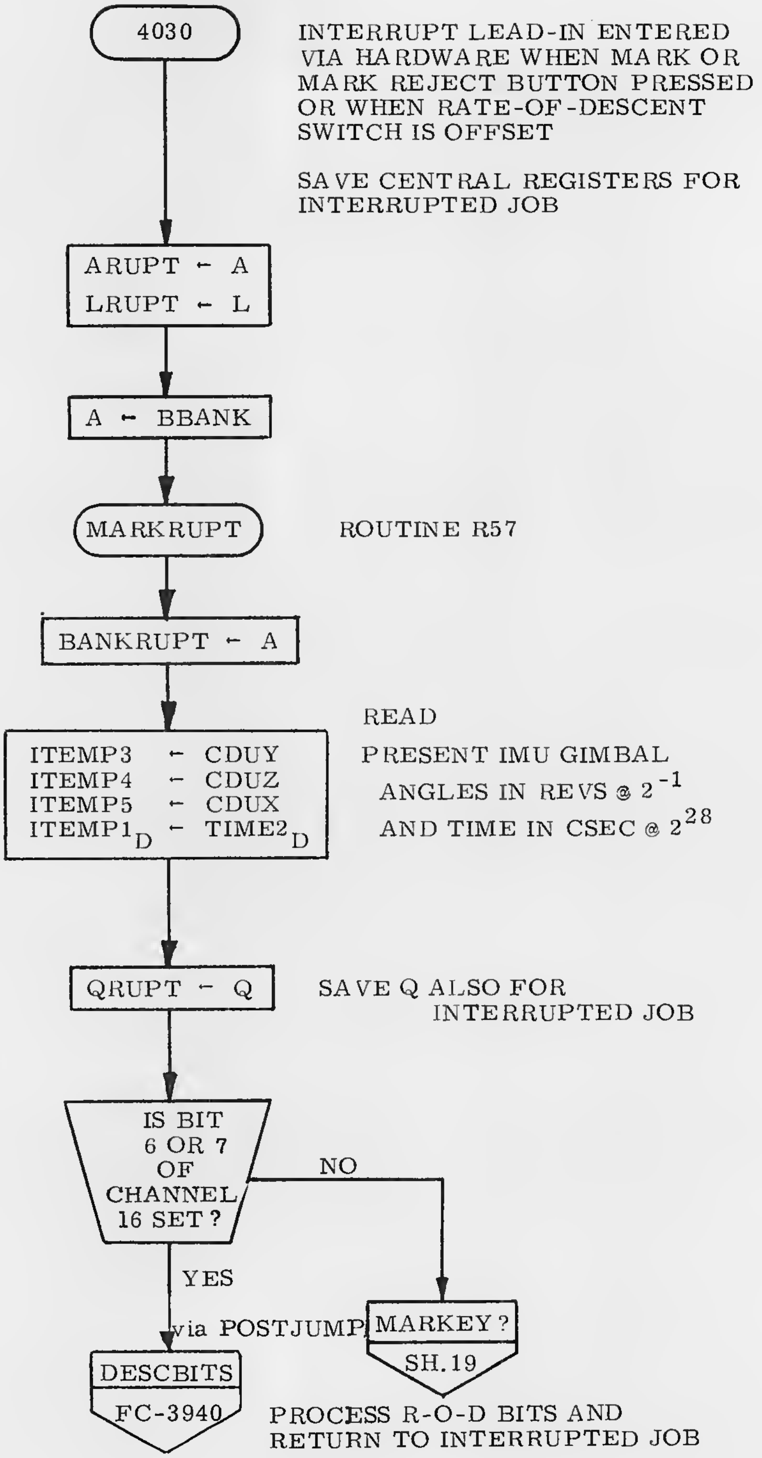
$PL24_V \leftarrow MPAC_V$

LOS VECTOR IN SM COORDS @ 2^1

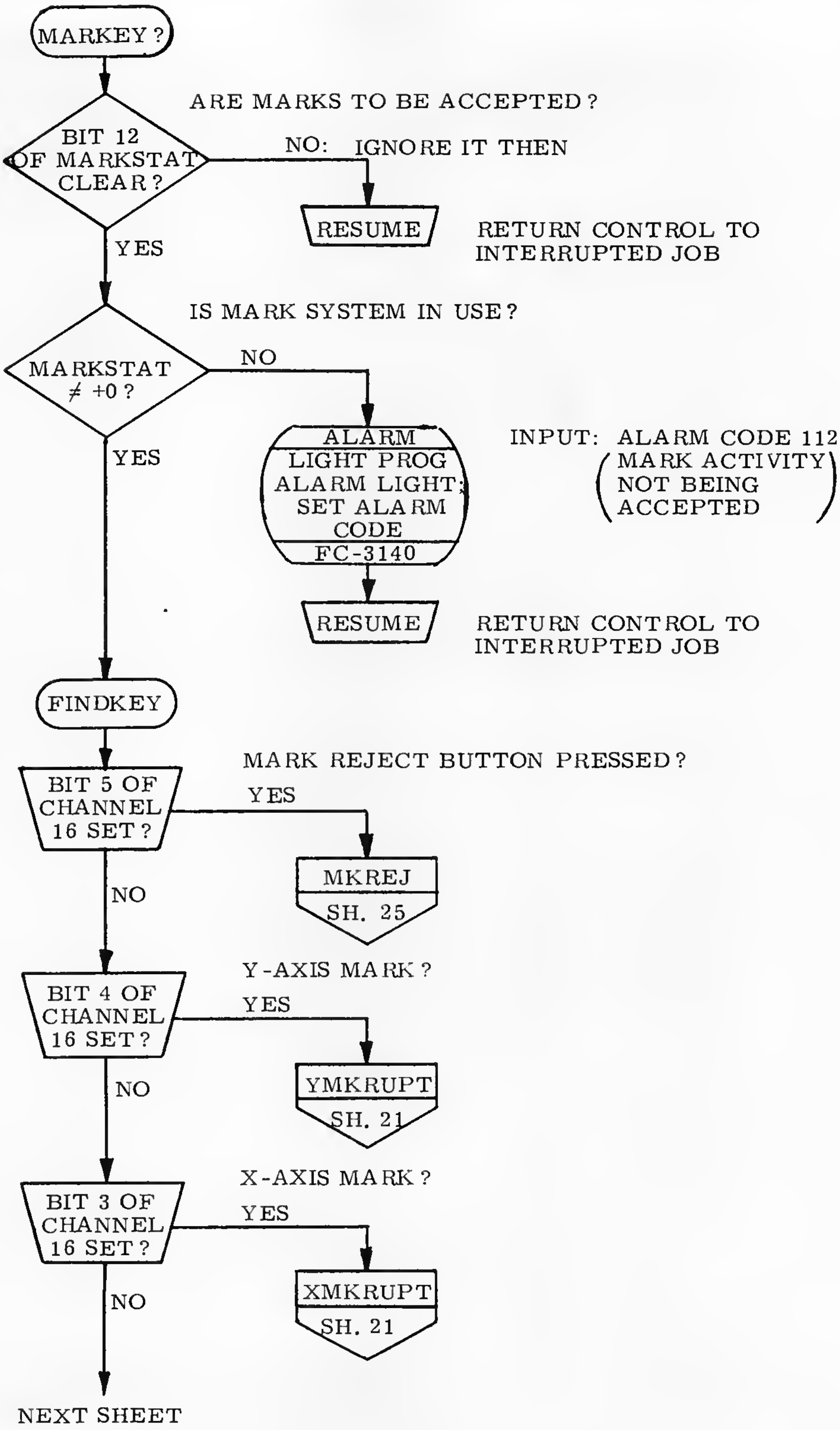
$= COS(SEP \angle)\underline{u}_O$

$+ (COS(CURSOR \angle)\underline{Y}_{MP} - SIN(CURSOR \angle)\underline{X}_{MP}) \times \underline{u}_O$

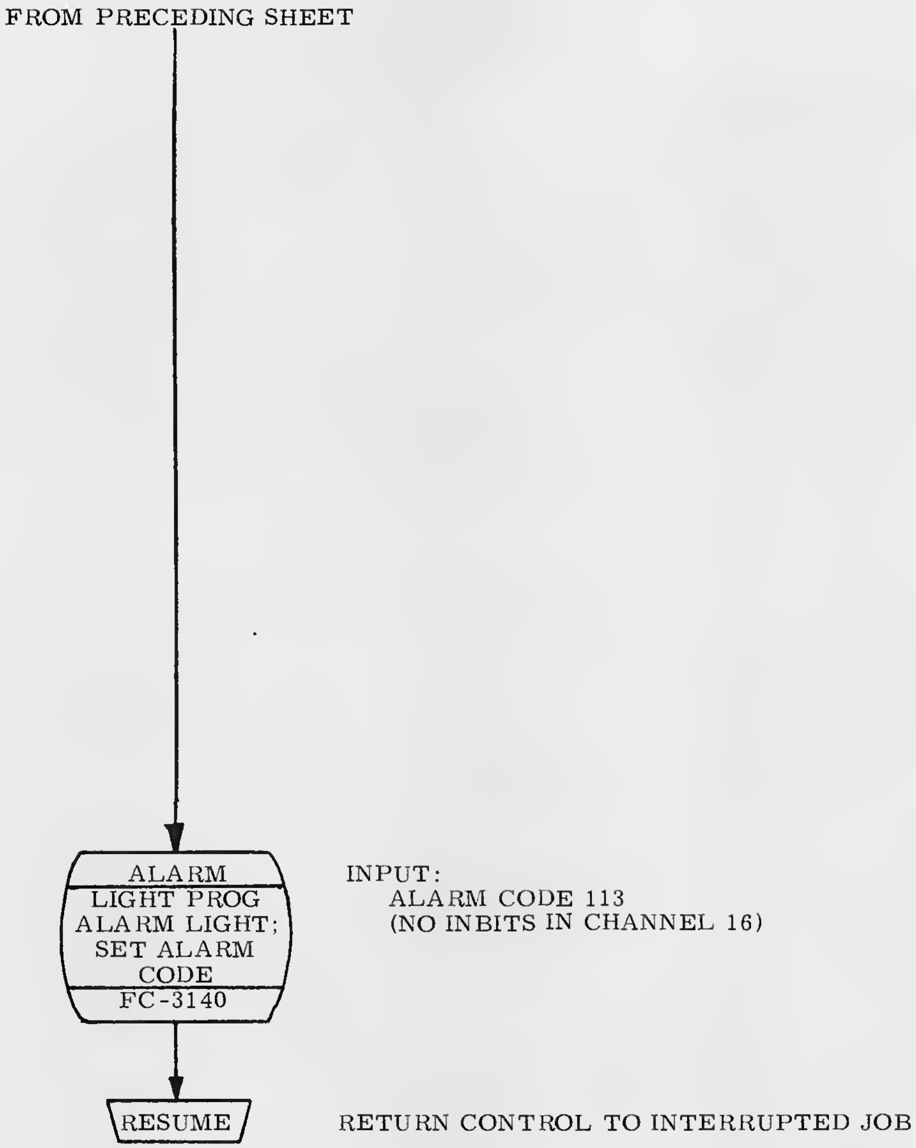
AVEIT
SH. 13

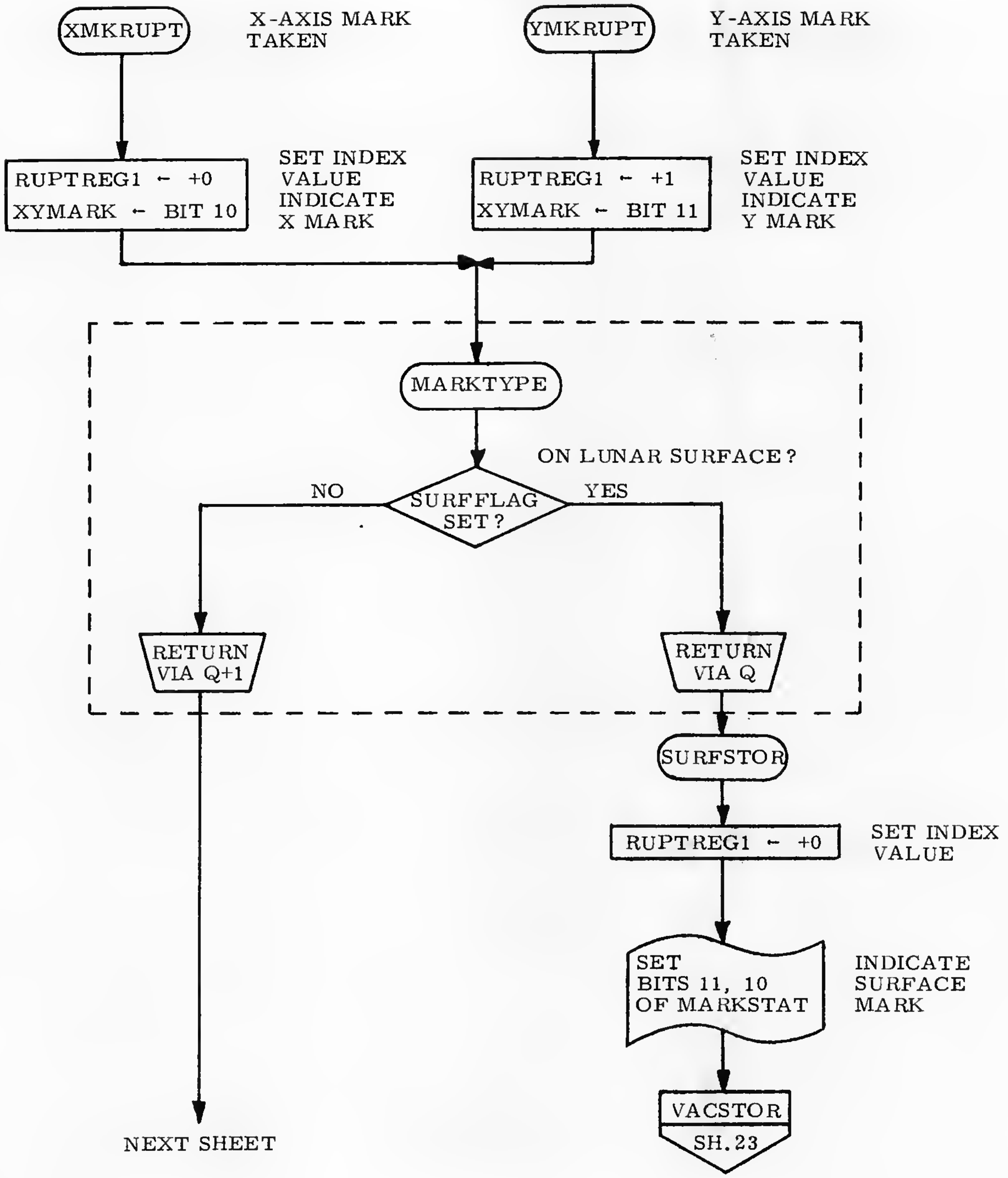


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN D. Lutkevich	7/69	Mark Taking Routines
PRGMR L. Millard	7/69	
ANALST		DOCUMENT NO.
DOCMR A. M. Sorant	7/25/69	Luminary 1D — FC-3530
APPR'D A. M. Sorant	7/25/69	REV 3 — SHEET 18 OF 45

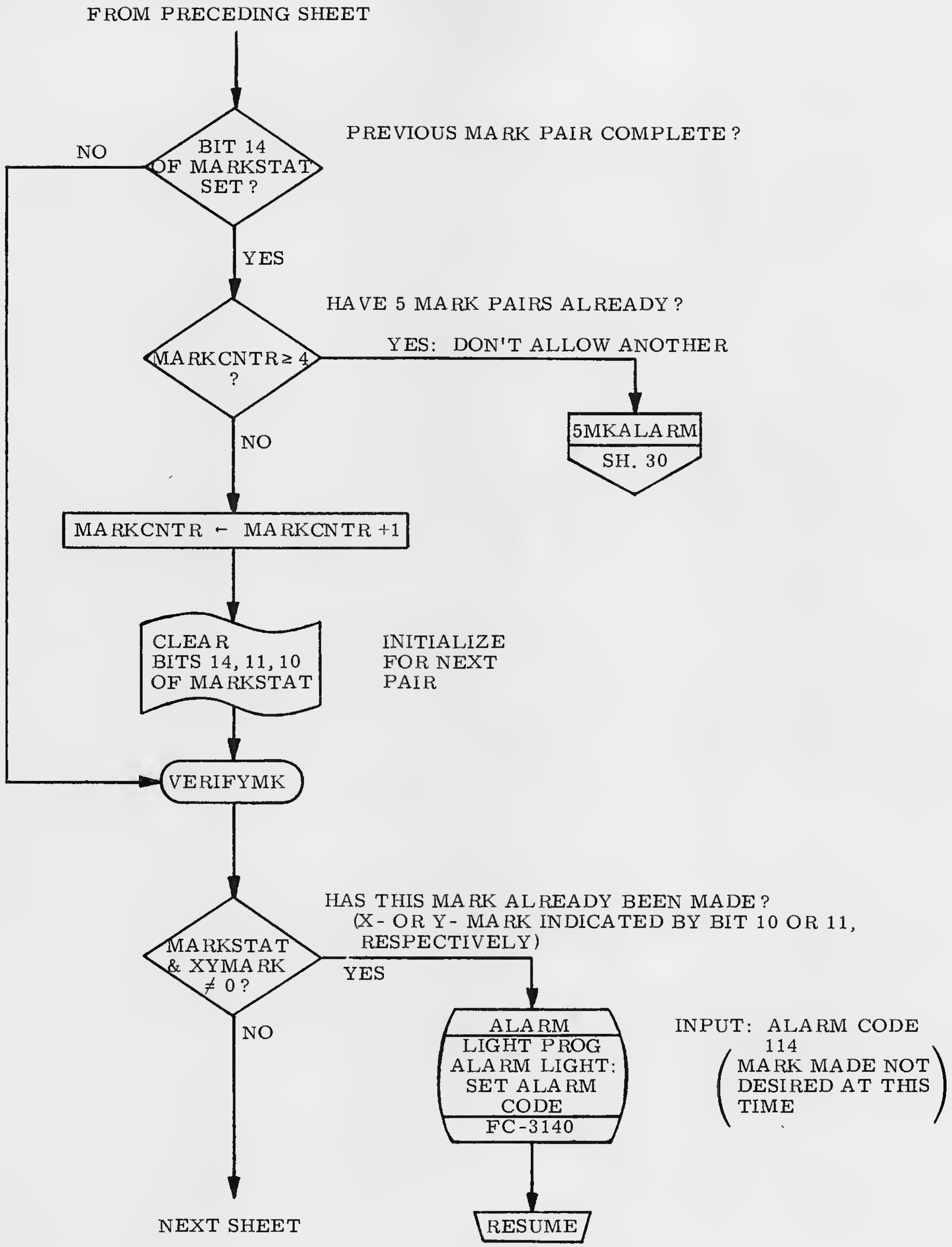


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lutkevich	7/69	Mark Taking Routines	
PRGMR D. Millard	7/69		DOCUMENT NO.
ANALST		Luminary 1D	FC-3530
DOCMR A. M. Grant	7/25/69		
APPR'D A. M. Grant	7/25/69	REV 3	SHEET 19 OF 45

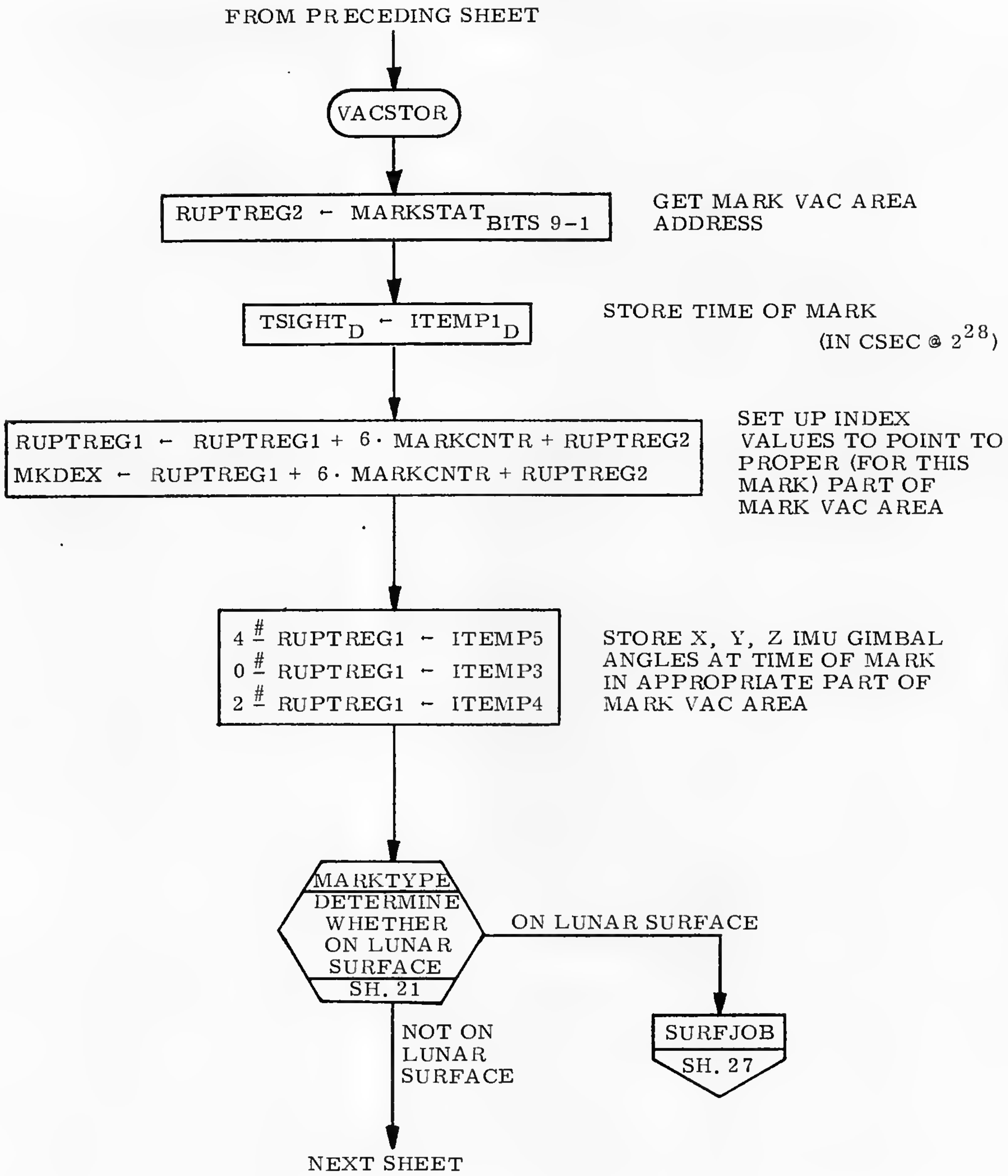

FROM PRECEDING SHEET
ALARM
LIGHT PROG ALARM LIGHT; SET ALARM CODE
FC-3140
INPUT:
ALARM CODE 113
(NO INBITS IN CHANNEL 16)
RESUME
RETURN CONTROL TO INTERRUPTED JOB



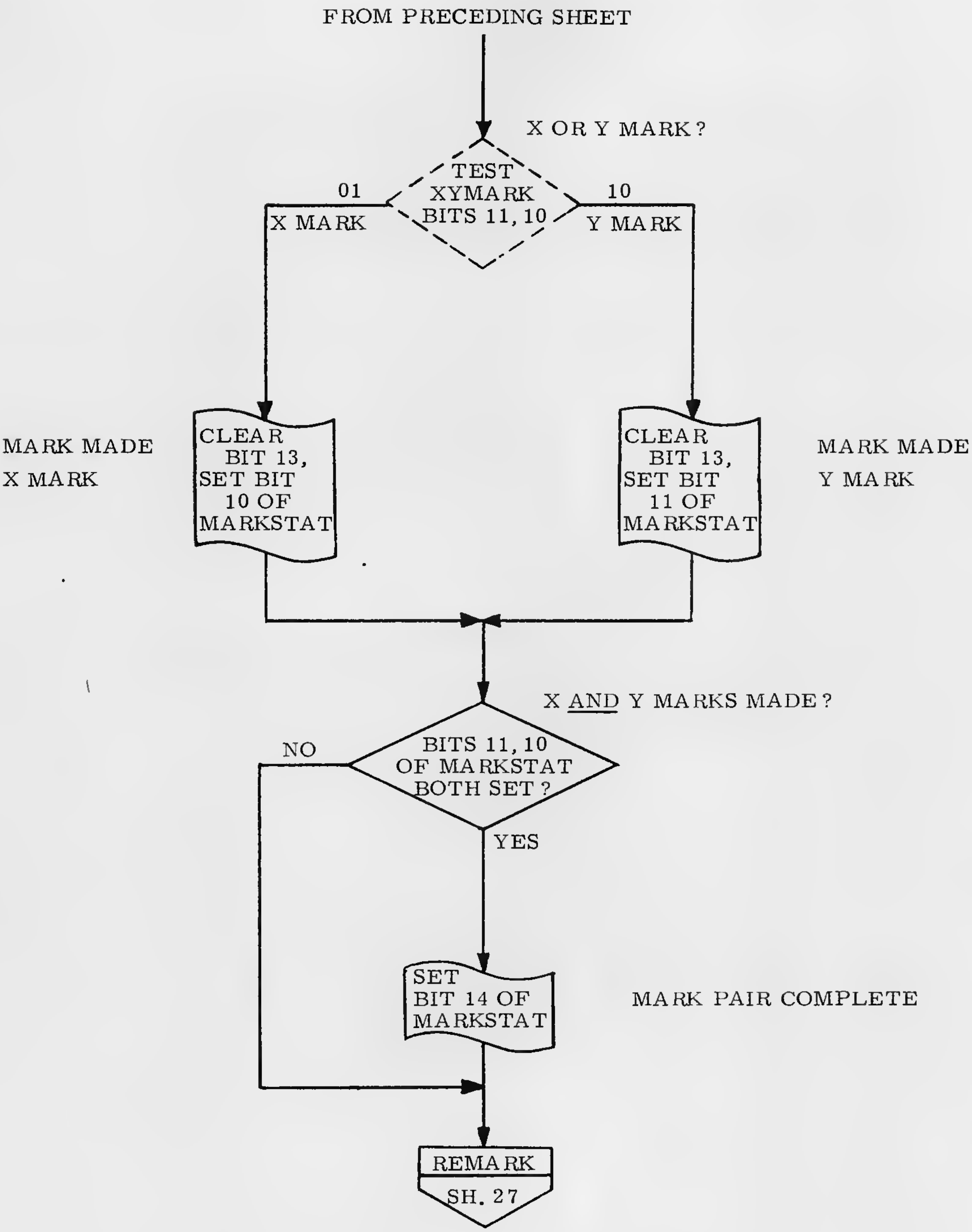
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lutkevich	7/69	Mark Taking Routines	
PRGMR F. Millard	7/69		
ANALST		Luminary 1D	DOCUMENT NO. FC-3530
DOCMR A. M. Grant	7/25/69		
APPR'D A. M. Grant	7/25/69	REV 3	SHEET 21 OF 45



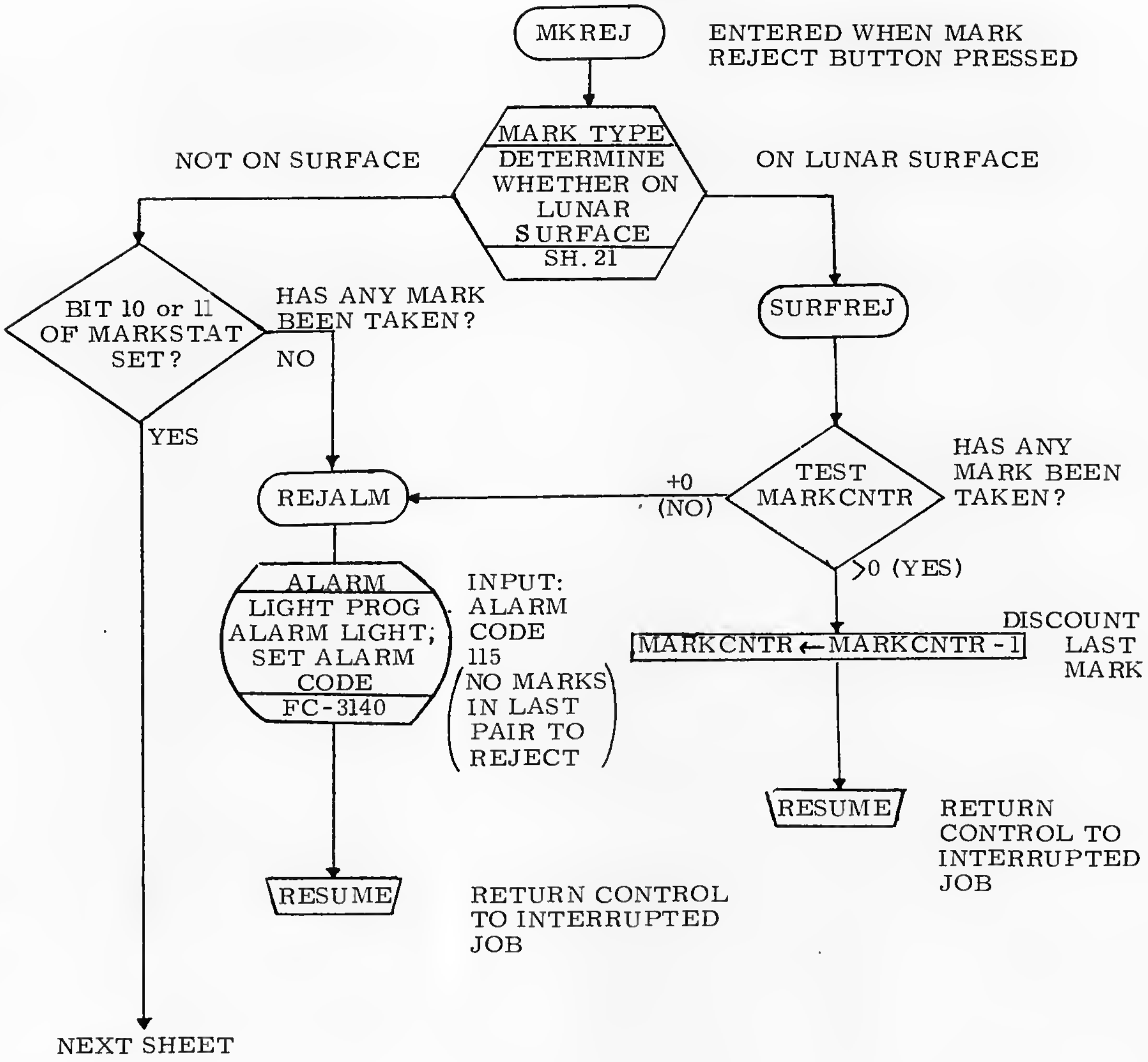
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Luttermich	7/69	Mark Taking Routines	
PRGMR F. Millard	7/69		
ANALST		Luminary 1D	DOCUMENT NO. FC-3530
DOCMR A. M. Sorant	7/25/69		
APPR'D A. M. Sorant	7/25/69	REV 3	SHEET 22 OF 45



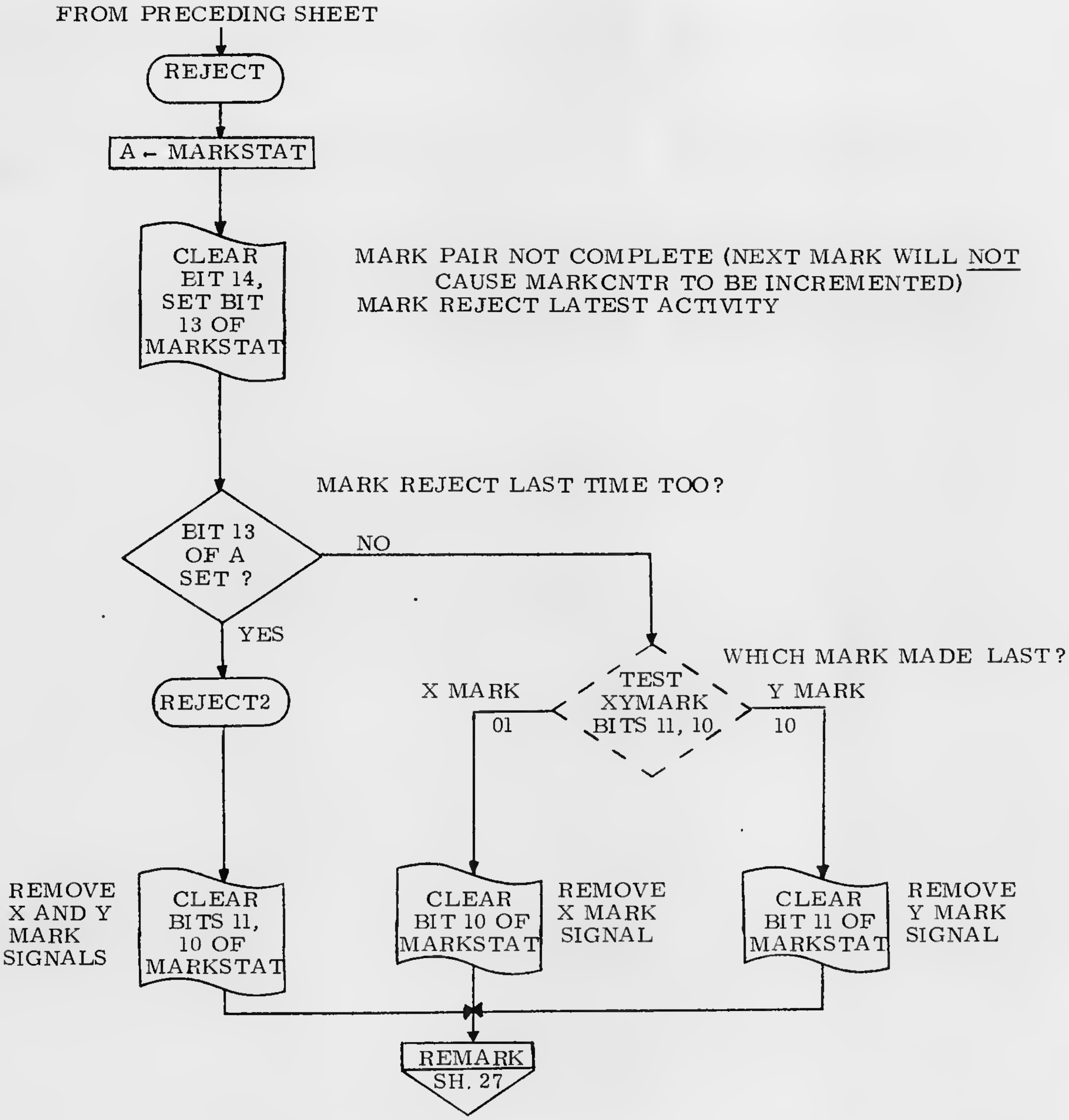
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lutkevich	7/69	Mark Taking Routines	
PRGMR P. McClod	7/69		
ANALST		Luminary 1D	DOCUMENT NO. FC-3530
DOCMR G. M. Sorant	7/25/69		
APPR'D G. M. Sorant	7/25/69	REV 3	SHEET 23 OF 45



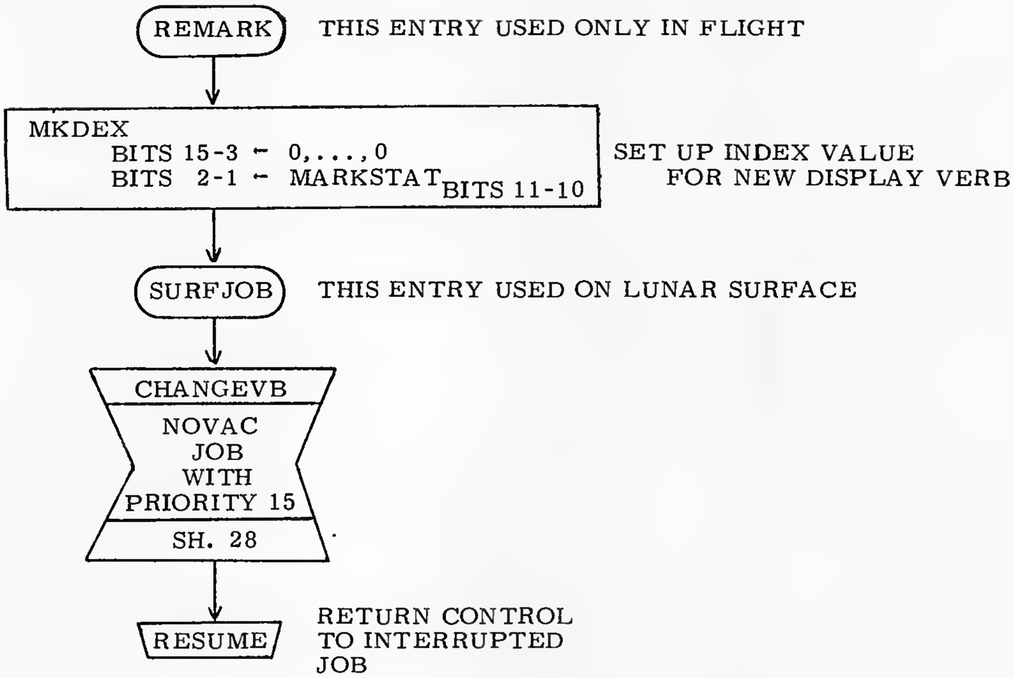
FROM PRECEDING SHEET
X OR Y MARK?
TEST XYMARK BITS 11, 10
01
X MARK
10
Y MARK
MARK MADE X MARK
CLEAR BIT 13, SET BIT 10 OF MARKSTAT
CLEAR BIT 13, SET BIT 11 OF MARKSTAT
MARK MADE Y MARK
X AND Y MARKS MADE?
BITS 11, 10 OF MARKSTAT BOTH SET?
NO
YES
SET BIT 14 OF MARKSTAT
MARK PAIR COMPLETE
REMARK
SH. 27



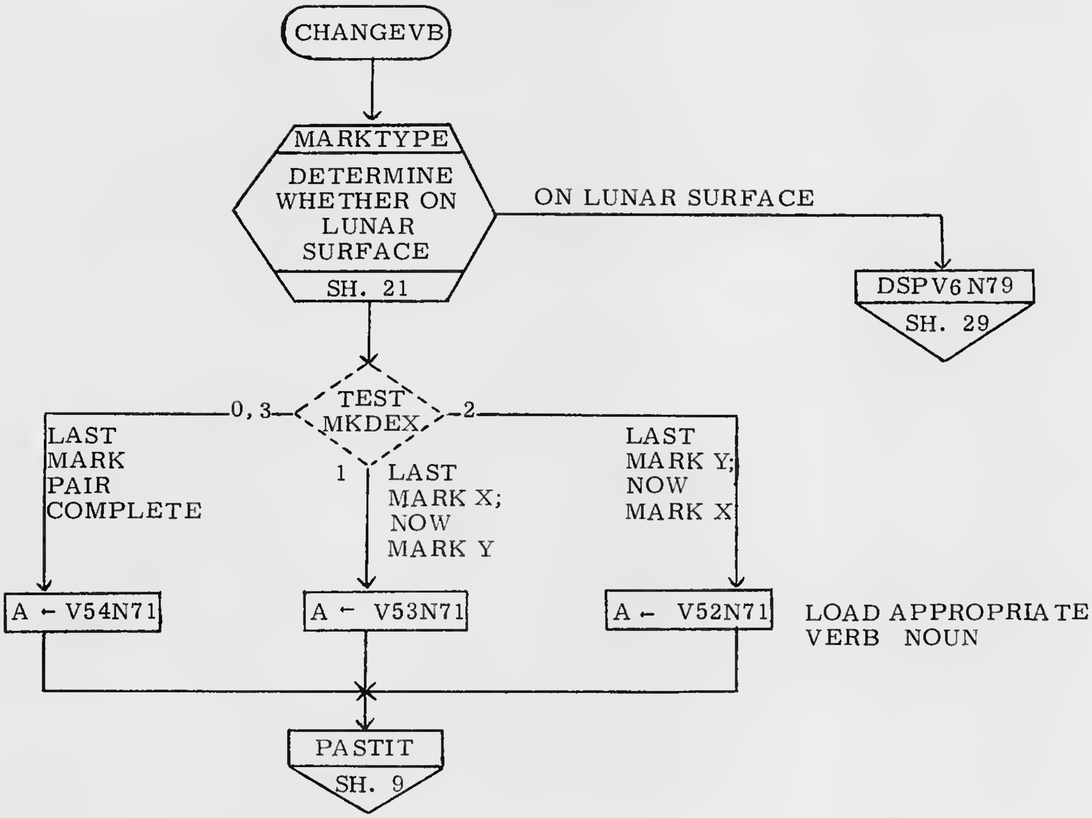
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Sutkevich	7/69	Mark Taking Routines	
PRGMR J. Millard	7/69	Luminary 1D	DOCUMENT NO. FC-3530
ANALST			
DOCMR A. M. Sprant	7/25/69		
APPR'D A. M. Sprant	7/25/69	REV 3	SHEET 25 OF 45



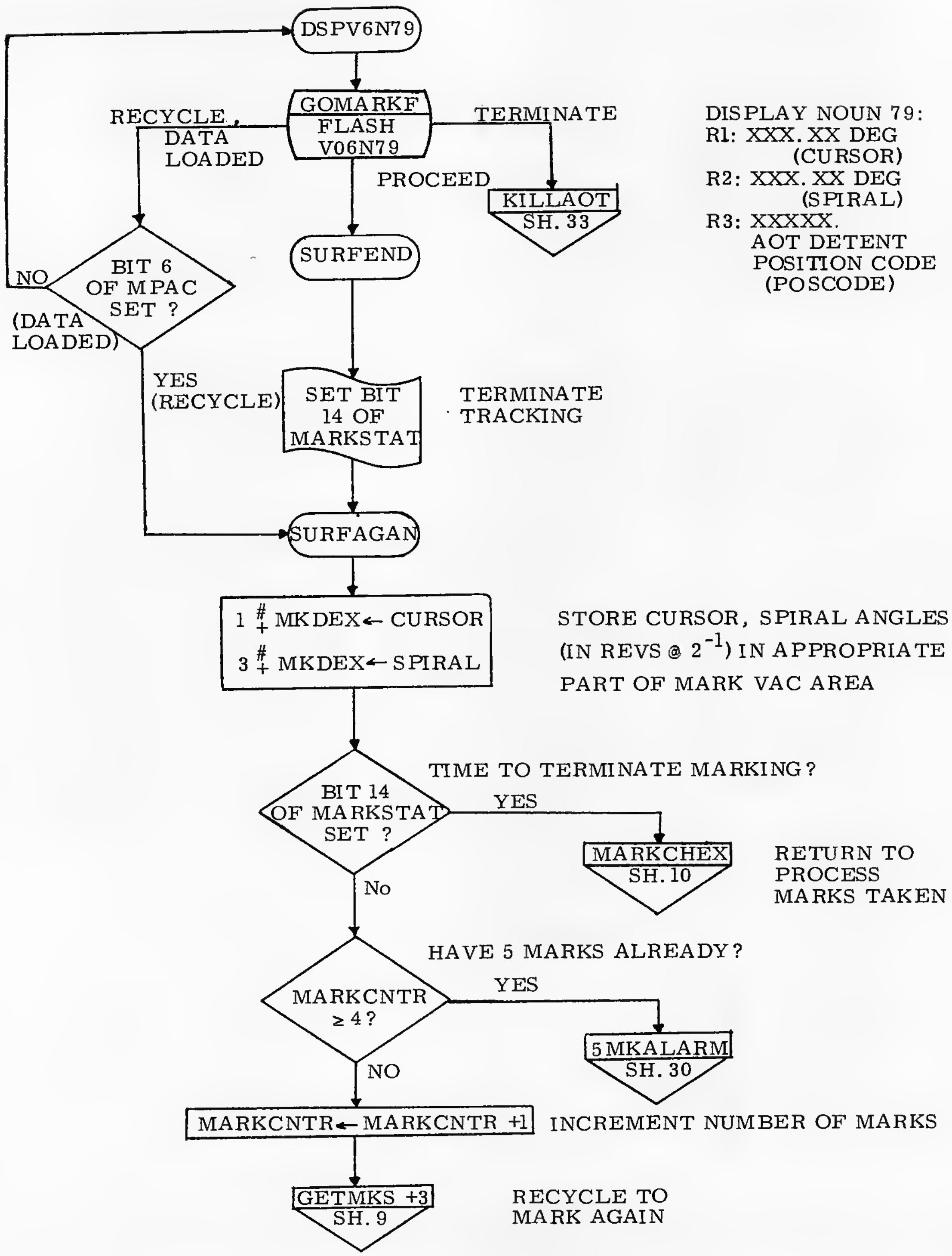
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN [illegible]	7/69	Mark Taking Routines	
PRGMR [illegible]	7/69		
ANALST		Luminary 1D	DOCUMENT NO. FC-3530
DOCMR [illegible]	7/25/69		
APPR'D [illegible]	7/25/69	REV 3	SHEET 26 OF 45

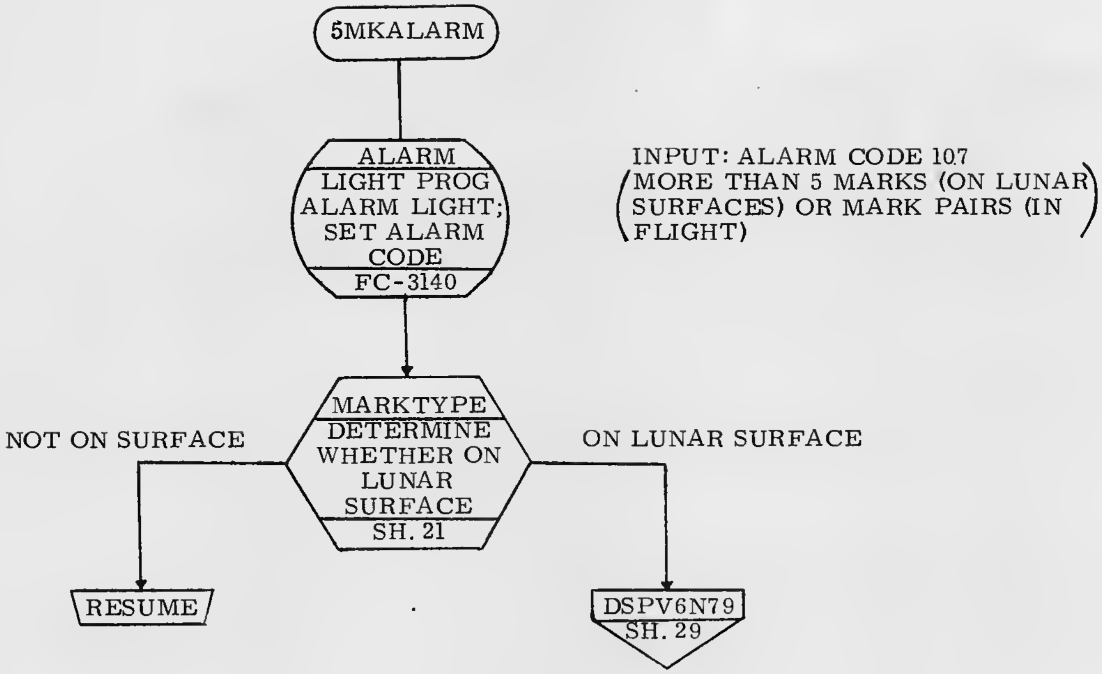


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lutkevich	7/69	Mark Taking Routines	
PRGMR L. Millard	7/69		DOCUMENT NO.
ANALST		Luminary 1D	FC-3530
DOCMR A. M. Sorant	7/25/69		
APPR'D A. M. Sorant	7/25/69	REV 3	SHEET 27 OF 45

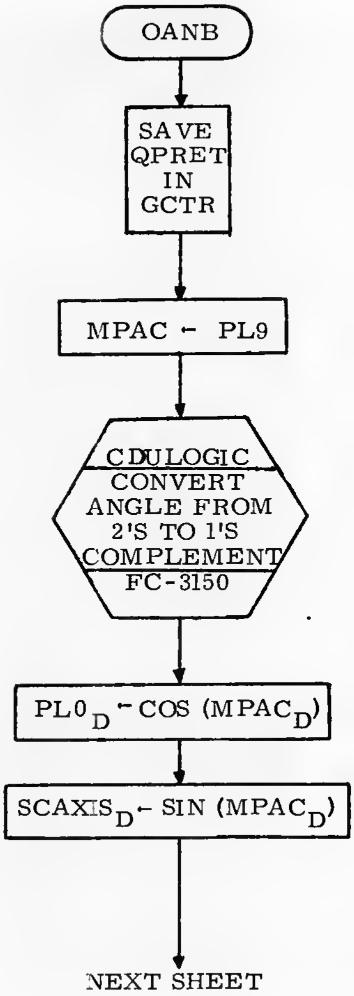


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	D. Lutkewich	7/69	Mark Taking Routines	
PRGMR	J. Millard	7/69		
ANALST			Luminary 1D	DOCUMENT NO. FC-3530
DOCMR	A. M. Grant	7/25/69		
APPR'D	A. M. Grant	7/25/69	REV 3	SHEET 28 OF 45


DSPV6N79
GOMARKF
FLASH
V06N79
RECYCLE,
DATA
LOADED
TERMINATE
PROCEED
KILLAOT
SH. 33
DISPLAY NOUN 79:
R1: XXX. XX DEG
(CURSOR)
R2: XXX. XX DEG
(SPIRAL)
R3: XXXXX.
AOT DETENT
POSITION CODE
(POSCODE)
NO
BIT 6
OF MPAC
SET ?
(DATA
LOADED)
SURFEND
YES
(RECYCLE)
SET BIT
14 OF
MARKSTAT
TERMINATE
TRACKING
SURFAGAN
1 ‡ MKDEX ← CURSOR
3 ‡ MKDEX ← SPIRAL
STORE CURSOR, SPIRAL ANGLES
(IN REVS @ 2^{-1}) IN APPROPRIATE
PART OF MARK VAC AREA
TIME TO TERMINATE MARKING?
BIT 14
OF MARKSTAT
SET ?
YES
MARKCHEX
SH. 10
RETURN TO
PROCESS
MARKS TAKEN
No
HAVE 5 MARKS ALREADY?
MARKCNTR
≥ 4?
YES
5MKALARM
SH. 30
NO
MARKCNTR ← MARKCNTR +1
INCREMENT NUMBER OF MARKS
GETMKS +3
SH. 9
RECYCLE TO
MARK AGAIN



5MKALARM
ALARM
LIGHT PROG ALARM LIGHT; SET ALARM CODE
FC-3140
INPUT: ALARM CODE 107 (MORE THAN 5 MARKS (ON LUNAR SURFACES) OR MARK PAIRS (IN FLIGHT)
MARKTYPE
DETERMINE WHETHER ON LUNAR SURFACE
SH. 21
NOT ON SURFACE
ON LUNAR SURFACE
RESUME
DSPV6N79
SH. 29



COMPUTE OPTICS AXIS FOR DESIRED SIGHTING ($SCAXIS_V$ @ 2^1)

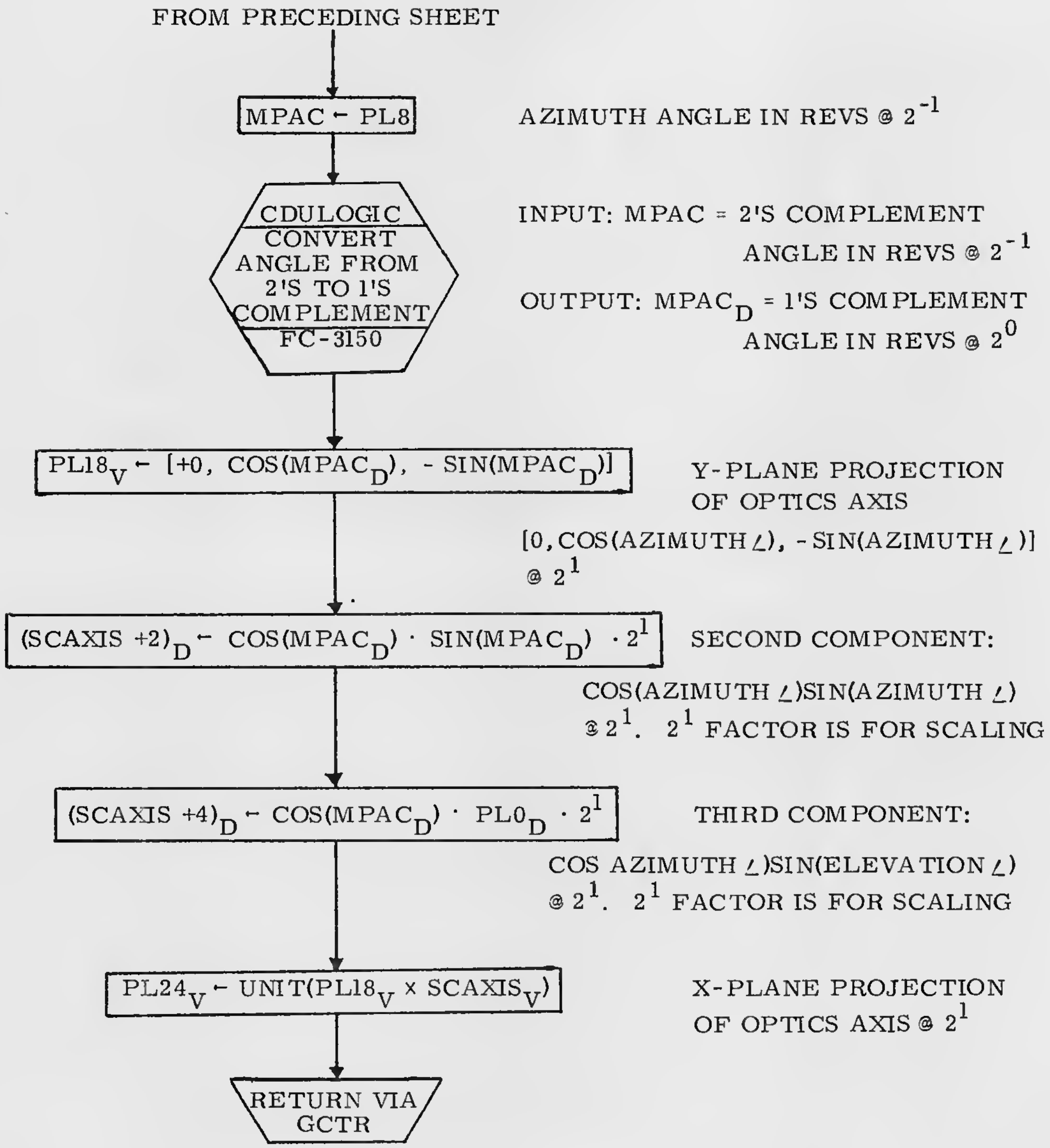
ELEVATION ANGLE IN REVS @ 2^{-1}

INPUT: MPAC = 2'S COMPLEMENT ANGLE IN REVS @ 2^{-1}

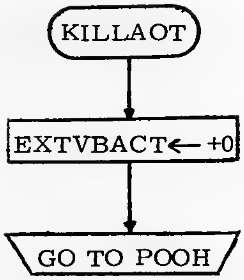
OUTPUT: $MPAC_D$ = 1'S COMPLEMENT ANGLE IN REVS @ 2^0

COS (ELEVATION ∠) @ 2^1

FIRST COMPONENT: SIN (ELEVATION ∠) @ 2^1



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lutkemuth	7/69	Mark Taking Routines	
PRGMR L. Millard	7/69		
ANALST		Luminary 1D	DOCUMENT NO. FC-3530
DOCMR Alida M. Sorant	7/25/69		
APPR A. M. Sorant	7/25/69	REV 3	SHEET 32 OF 45



TERMINATE PROGRAM

ALLOW EXTENDED VERB ACTIVITY

TERMINATE MAJOR MODE

SUBROUTINES CALLED WHICH ARE FLOWED ON OTHER FLOW CHARTS

SUBROUTINE NAME	FLOW CHART	DESCRIPTION	WHERE CALLED
ALARM	FC-3140	LIGHT PROG ALARM LIGHT; SET ALARM CODE	SH. 10, 19 20, 22, 25, 30
BAILOUT1	FC-3140	LIGHT PROG ALARM LIGHT; SET ALARM CODE; CAUSE SOFTWARE RESTART	SH. 2, 3
CDULOGIC	FC-3150	CONVERT ANGLE FROM 2'S TO 1'S COMPLEMENT	SH. 15, 16 31, 32
DESCBITS	FC-3940	PROCESS RATE-OF-DESCENT SWITCH CHANGE	SH. 18
ENDMARK	FC-3080	TERMINATE DISPLAY INTERFACE FOR MARKING	SH. 13
GOODEND	FC-3220	GOOD END OF STALL ROUTINE	SH. 14
POODOO	FC-3140	LIGHT PROG ALARM LIGHT; SET ALARM CODE; GO TO P00	SH. 2
TRG*NBSM	FC-3320	CONVERT VECTOR FROM NB TO SM COORDINATES USING ASSUMED IMU GIMBAL ANGLES	SH. 11, 12 17

FLAGS

NAME	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
EXTVBACT BIT 3	EXTENDED VERB SYSTEM IN USE FOR EXTENDED VERB	EXTENDED VERB SYSTEM NOT IN USE FOR EXTEND-ED VERB		SH. 33	SH. 2
EXTVBACT BIT 2	EXTENDED VERB SYSTEM IN USE FOR MARKING	EXTENDED VERB SYSTEM NOT IN USE FOR MARK-ING	SH. 2	SH. 33	SH. 2
MARKSTAT BIT 14	IF IN FLIGHT: MARK PAIR COMPLETE IN ON LUNAR SURFACE: MARKING TO BE TERMI-NATED	IF IN FLIGHT: MARK PAIR INCOMPLETE IF ON LUNAR SURFACE: MARKING NOT TO BE TERMI-NATED	SH. 24, 29	SH. 9, 22 26	SH. 22 29
MARKSTAT BIT 13	MARK REJECTED	MARK MADE	SH. 26	SH. 9, 24	SH. 26
MARKSTAT BIT 12	MARKS NOT ACCEPTED	MARKS ACCEPT-ED	SH. 5 10	SH. 9	SH. 19
MARKSTAT BIT 11	Y MARK MADE	Y MARK NOT MADE	SH. 21 24	SH. 9, 22 26	SH. 10 22, 24 25
MARKSTAT BIT 10	X MARK MADE	X MARK NOT MADE	SH. 21 24	SH. 9, 22 26	SH. 10 22, 24 25
SURFFLAG FLAGWRD8 BIT 8	LM ON LUNAR SURFACE	LM NOT ON LUNAR SURFACE			SH. 11 21

CHANNEL BITS

CHANNEL BIT	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
BIT 5	OPTICS MARK REJECT SIGNAL	NO OPTICS MARK REJECT SIGNAL			SH. 18, 19
BIT 4	OPTICS Y-AXIS MARK SIGNAL	NO OPTICS Y-AXIS MARK SIGNAL			SH. 18, 19
BIT 3	OPTICS X-AXIS MARK SIGNAL	NO OPTICS X-AXIS MARK SIGNAL			SH. 18, 19

DISPLAYS

VERB-NOUN	TYPE OF DISPLAY	DESCRIPTION OF EACH REGISTER	WHERE EXECUTED
	ALARM	PROG ALARM LIGHT ON; REGISTERS NOT AFFECTED	SH. 2, 3, 10, 19, 20, 22, 25, 30
V01N71	FLASHING	R1: 00PSS (AOT CODE) P = AOT POSITION CODE SS = STAR CODE	SH. 5
V06N87	FLASHING	R1: XXX. XX DEG BACKUP OPTICS LOS AZIMUTH (AZ) R2: XXX. XX DEG BACKUP OPTICS LOS ELEVATION (EL)	SH. 7
V54N71	FLASHING PLEASE MARK (X OR Y)	R1: AS IN V01N71 ABOVE	SH. 9
V53N71	FLASHING PLEASE MARK (Y)	R1: AS IN V01N71 ABOVE	SH. 9
V52N71	FLASHING PLEASE MARK (X)	R1: AS IN V01N71 ABOVE	SH. 9
V06N79	FLASHING	R1: XXX. XX DEG CURSOR R2: XXX. XX DEG SPIRAL R3: XXXXX. POSITION CODE (POSCODE)	SH. 29

ERASABLE LOCATIONS USED

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
A		ACCUMULATOR REGISTER USED BY CENTRAL PROCESSOR			
AOTCODE		BITS 10-7: AOT POSITION (DETENT) CODE BITS 6-1: CODE FOR CELESTIAL BODY TO BE SIGHTED			
ARUPT		TEMPORARY STORAGE FOR A (ABOVE) DURING INTERRUPT			
AZ		AZIMUTH FOR BACKUP OPTICS LOS	DEGREES	REVS	2^{-1}
BANKRUPT		TEMPORARY STORAGE FOR BBANK (BELOW) DURING INTERRUPT			
BBANK		CENTRAL PROCESSOR REGISTER USED FOR ADDRESS INFORMATION			
$BUF2_D$		ADDRESS OF NORMAL RETURN VIA SWRETURN (SET DURING CALL VIA BANKCALL)			
CDUSPOTX		SNAPSHOT OF OUTER IMU GIMBAL ANGLE	DEGREES	REVS	2^{-1}
CDUSPOTY		SNAPSHOT OF INNER IMU GIMBAL ANGLE	DEGREES	REVS	2^{-1}
CDUSPOTZ		SNAPSHOT OF MIDDLE IMU GIMBAL ANGLE	DEGREES	REVS	2^{-1}
CDUX		OUTER IMU GIMBAL ANGLE	DEGREES	REVS	2^{-1}
CDUY		INNER IMU GIMBAL ANGLE	DEGREES	REVS	2^{-1}
CDUZ		MIDDLE IMU GIMBAL ANGLE	DEGREES	REVS	2^{-1}
CURSOR		AOT CURSOR ANGLE	DEGREES	REVS	2^{-1}

ERASABLE LOCATIONS USED (CONT.)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
EL		ELEVATION FOR BACKUP OPTICS LOS	DEGREES	REVS	2^{-1}
$ITEMP1_D$		SNAPSHOT OF TIME (AT MARK)	SECONDS	CSEC	2^{28}
ITEMP3		SNAPSHOT OF INNER IMU GIMBAL ANGLE (AT MARK TIME)	DEGREES	REVS	2^{-1}
ITEMP4		SNAPSHOT OF MIDDLE IMU GIMBAL ANGLE (AT MARK TIME)	DEGREES	REVS	2^{-1}
ITEMP5		SNAPSHOT OF OUTER IMU GIMBAL ANGLE (AT MARK TIME)	DEGREES	REVS	2^{-1}
L		LOW-ORDER ACCUMULATOR USED BY CENTRAL PROCESSOR			
LRUPT		TEMPORARY STORAGE FOR L (ABOVE) DURING INTERRUPT			
MARKCNTR		M-1, WHERE M=NUMBER OF MARKS (IF ON LUNAR SURFACE) OR MARK PAIRS (IF IN FLIGHT)			2^{14}
MARKSTAT		BITS 14-10: USED AS FLAGS (SEE SH. 35); BITS 9-1 : ADDRESS OF BEGINNING OF MARK VAC AREA			
MKDEX		SEVERAL USES: 1) NUMBER OF MARKS (ON SURFACE) OR MARK PAIRS (IN FLIGHT) PROCESSED (DATA AVERAGED IN) 2) (ON LUNAR SURFACE) POINTER TO PROPER PART OF MARK VAC AREA FOR PARTICULAR MARK 3) (IN FLIGHT) INDEX TO NEW VERB, DEPENDING ON WHICH MARK OF A PAIR HAS BEEN MADE			2^{14}

ERASABLE LOCATIONS USED (CONT.)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
POSCODE		AOT DETENT POSITION CODE			
Q		CENTRAL PROCESSOR REGISTER USED FOR RETURNS FROM SUBROUTINES			
QRUPT		TEMPORARY STORAGE FOR Q (ABOVE) DURING INTERRUPT			
RUPTREG1		POINTER TO PROPER PART OF MARK VAC AREA FOR PARTICULAR MARK			
RUPTREG2		POINTER TO BEGINNING OF MARK VAC AREA			
$SCAXIS_V$		OPTICS AXIS FOR DESIRED SIGHTING IN NB COORDINATES			2^1
SPIRAL		AOT SPIRAL ANGLE	DEGREES	REVS	2^{-1}
$(STARAD+6)_V$		LOS VECTOR AVERAGE (FROM MARKS PROCESSED SO FAR) IN SM COORDINATES			2^1
$STARSAV2_V$		LOS VECTOR AVERAGE (FROM MARKS PROCESSED SO FAR) IN SM COORDINATES			2^1
$TIME2_D$		PRESENT TIME	SECONDS	CSEC	2^{28}
$TSIGHT_D$		TIME OF OPTICAL SIGHTING	SECONDS	CSEC	2^{28}
VAC1USE		LOCATION BEFORE START OF VAC AREA #1			
VAC2USE		LOCATION BEFORE START OF VAC AREA #2			
VAC3USE		LOCATION BEFORE START OF VAC AREA #3			
VAC4USE		LOCATION BEFORE START OF VAC AREA #4			
VAC5USE		LOCATION BEFORE START OF VAC AREA #5			

ERASABLE LOCATIONS USED (CONT.)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
XYMARK		SEVERAL USES: 1) AOT POSITION CODE 2) ADDRESS OF START OF MARK VAC AREA 3) RECORD OF WHICH (X OR Y) MARK JUST MADE			

PAD LOADS

AGC TAG	GSOP TAG	MEANING	ENGINEERING VALUE AND UNITS	AGC VALUE AND UNITS	AGC SCALING	OCTAL VALUE
AOTAZ		AZIMUTH OF FRONT LEFT AOT DETENT	-60 DEGS	-1/6 REV	2^{-1}	65252
AOTAZ +1		AZIMUTH OF FRONT CENTER AOT DETENT	0 DEGS	0 REV	2^{-1}	00000
AOTAZ +2		AZIMUTH OF FRONT RIGHT AOT DETENT	+60 DEGS	+1/6 REV	2^{-1}	12525
AOTAZ +3		AZIMUTH OF REAR RIGHT AOT DETENT	+120 DEGS	+1/3 REV	2^{-1}	25252
AOTAZ +4		AZIMUTH OF REAR CENTER AOT DETENT	+180 DEGS	+1/2 REV	2^{-1}	40000
AOTAZ +5		AZIMUTH OF REAR LEFT AOT DETENT	+240 DEGS	+2/3 REV	2^{-1}	52525
AOTEL		ELEVATION OF FRONT LEFT AOT DETENT	+300 DEGS	+5/6 REV	2^{-1}	10000
AOTEL +1		ELEVATION OF FRONT CENTER AOT DETENT	+45 DEGS	+1/8 REV	2^{-1}	10000
AOTEL +2		ELEVATION OF FRONT RIGHT AOT DETENT	+45 DEGS	+1/8 REV	2^{-1}	10000
AOTEL +3		ELEVATION OF REAR RIGHT AOT DETENT	+45 DEGS	+1/8 REV	2^{-1}	10000
AOTEL +4		ELEVATION OF REAR CENTER AOT DETENT	+45 DEGS	+1/8 REV	2^{-1}	10000
AOTEL +5		ELEVATION OF REAR LEFT AOT DETENT	+45 DEGS	+1/8 REV	2^{-1}	10000

PROGRAM CONSTANTS

AGC TAG	MEANING	ENGINEERING AND AGC VALUE	AGC SCALING
CATLOG -6	Direction of star 1 (α Andromedae (Alpheratz)) in Reference coords	$\begin{pmatrix}+.8748658918\\+.0260879174\\+.4836621670\end{pmatrix}$	2^1
CATLOG -12D	Direction of star 2 (β Ceti (Diphda)) in Reference coords	$\begin{pmatrix}+.9342640400\\+.1735073142\\-.3115219339\end{pmatrix}$	2^1
CATLOG -18D	Direction of star 3 (γ Cassiopeiae (Navi)) in Reference coords	$\begin{pmatrix}+.4775639450\\+.1166004340\\+.8708254803\end{pmatrix}$	2^1
CATLOG -24D	Direction of star 4 (α Eridani (Achernar)) in Reference coords	$\begin{pmatrix}+.4917678276\\+.2204887125\\-.8423473935\end{pmatrix}$	2^1
CATLOG -30D	Direction of star 5 (α Ursae Minoris (Polaris)) in Reference coords	$\begin{pmatrix}+.0130968840\\+.0078062795\\+.9998837600\end{pmatrix}$	2^1
CATLOG -36D	Direction of star 6 (θ Eridani (Acamar)) in Reference coords	$\begin{pmatrix}+.5450107404\\+.5314955466\\-.6484410356\end{pmatrix}$	2^1
CATLOG -42D	Direction of star 7 (α Ceti (Menkar)) in Reference coords	$\begin{pmatrix}+.7032235469\\+.7075846047\\+.0692868685\end{pmatrix}$	2^1
CATLOG -48D	Direction of star 8 ($=10_8$) (α Persei (Mirfak)) in Reference coords	$\begin{pmatrix}+.4105636020\\+.4988110001\\+.7632988371\end{pmatrix}$	2^1
CATLOG -54D	Direction of star 9 ($=11_8$) (α Tauri (Aldebaran)) in Reference coords	$\begin{pmatrix}+.3507315038\\+.8926333307\\+.2831839492\end{pmatrix}$	2^1
CATLOG -60D	Direction of star 10D ($=12_8$) (β Orionis (Rigel)) in Reference coords	$\begin{pmatrix}+.2011399589\\+.9690337941\\-.1432348512\end{pmatrix}$	2^1
CATLOG -66D	Direction of star 11D ($=13_8$) (α Aurigae (Capella)) in Reference coords	$\begin{pmatrix}+.1371725575\\+.6813721061\\+.7189685267\end{pmatrix}$	2^1
CATLOG -72D	Direction of star 12D ($=14_8$) (α Carinae (Canopus)) in Reference coords	$\begin{pmatrix}-.0614937230\\+.6031563286\\-.7952489957\end{pmatrix}$	2^1
CATLOG -78D	Direction of star 13D ($=15_8$) (α Canis Majoris (Sirius)) in Reference coords	$\begin{pmatrix}-.1820751783\\+.9404899869\\-.2869271926\end{pmatrix}$	2^1
CATLOG -84D	Direction of star 14D ($=16_8$) (α_2 Canis Minoris (Procyon)) in Reference coords	$\begin{pmatrix}-.4118589524\\+.9065485360\\+.0924226975\end{pmatrix}$	2^1
CATLOG -90D	Direction of star 15D ($=17_8$) (γ Velorum (Regor)) in Reference coords	$\begin{pmatrix}-.3612508532\\+.5747270840\\-.7342932655\end{pmatrix}$	2^1
CATLOG -96D	Direction of star 16D ($=20_8$) (ι Ursae Majoris (Dnoces)) in Reference coords	$\begin{pmatrix}-.4657947941\\+.4774785033\\+.7450164351\end{pmatrix}$	2^1
CATLOG -102D	Direction of star 17D ($=21_8$) (α Hydrae (Alphard)) in Reference coords	$\begin{pmatrix}-.7742591356\\+.6152504197\\-.1482892839\end{pmatrix}$	2^1
CATLOG -108D	Direction of star 18D ($=22_8$) (α Leonis (Regulus)) in Reference coords	$\begin{pmatrix}-.8608205219\\+.4636213989\\+.2098647835\end{pmatrix}$	2^1

PROGRAM CONSTANTS (CONTINUED)

AGC TAG	MEANING	ENGINEERING AND AGC VALUE	AGC SCALING
CATLOG -114D	Direction of star 19D (=23_8) (β Leonis (Denebola)) in Reference coords	(-.9656605484, +.0525933156, +.2544280809)	2^1
CATLOG -120D	Direction of star 20D (=24_8) (γ Corvi (Gienah)) in Reference coords	(-.9525211695, -.0593434796, -.2986331746)	2^1
CATLOG -126D	Direction of star 21D (=25_8) (α Crucis (Acrux)) in Reference coords	(-.4523440203, -.0493710140, -.8904759346)	2^1
CATLOG -132D	Direction of star 22D (=26_8) (α Virginis (Spica)) in Reference coords	(-.9170097662, -.3502146628, -.1908999176)	2^1
CATLOG -138D	Direction of star 23D (=27_8) (η Ursae Majoris (Alkaid)) in Reference coords	(-.5812035376, -.2909171294, +.7599800468)	2^1
CATLOG -144D	Direction of star 24D (=30_8) (θ Centauri (Menkent)) in Reference coords	(-.6898393233, -.4182330640, -.5909338474)	2^1
CATLOG -150D	Direction of star 25D (=31_8) (α Bootis (Arcturus)) in Reference coords	(-.7861763936, -.5217996305, +.3311371675)	2^1
CATLOG -156D	Direction of star (=32_8) (α Coronae Borealis (Alphecca)) in Reference coords	(-.5326876930, -.7160644554, +.4511047742)	2^1
CATLOG -162D	Direction of star 27D (=33_8) (α Scorpii (Antares)) in Reference coords	(-.3516499609, -.8240752703, -.4441196390)	2^1
CATLOG -168D	Direction of star 28D (=34_8) (α Trianguli Austr. (Atria)) in Reference coords	(-.1146237858, -.3399692557, -.9334250333)	2^1
CATLOG -174D	Direction of star 29D (=35_8) (α Ophiuchi (Rasalhague)) in Reference coords	(-.1124304773, -.9694934200, +.2178116072)	2^1
CATLOG -180D	Direction of star 30D (=36_8) (α Lyrae (Vega)) in Reference coords	(+.1217293692, -.7702732847, +.6259880410)	2^1
CATLOG -186D	Direction of star 31D (=37_8) (σ Sagittarii (Nunki)) in Reference coords	(+.2069525789, -.8719885748, -.4436288486)	2^1
CATLOG -192D	Direction of star 32D (=40_8) (α Aquilae (Altair)) in Reference coords	(+.4537196908, -.8779508801, +.1527766153)	2^1
CATLOG -198D	Direction of star 33D (41_8) (β Capricorni (Dabih)) in Reference coords	(+.5520184464, -.7933187400, -.2567508745)	2^1
CATLOG -204D	Direction of star 34D (=42_8) (α Pavonis (Peacock)) in Reference coords	(+.3201817378, -.4436021946, -.8370786986)	2^1
CATLOG -210D	Direction of star 35D (=43_8) (α Cygni (Deneb)) in Reference coords	(+.4541086270, -.5392368197, +.7092312789)	2^1
CATLOG -216D	Direction of star 36D (=44_8) (ϵ Pegasi (Enif)) in Reference coords	(+.8139832631, -.5557243189, +.1691204557)	2^1

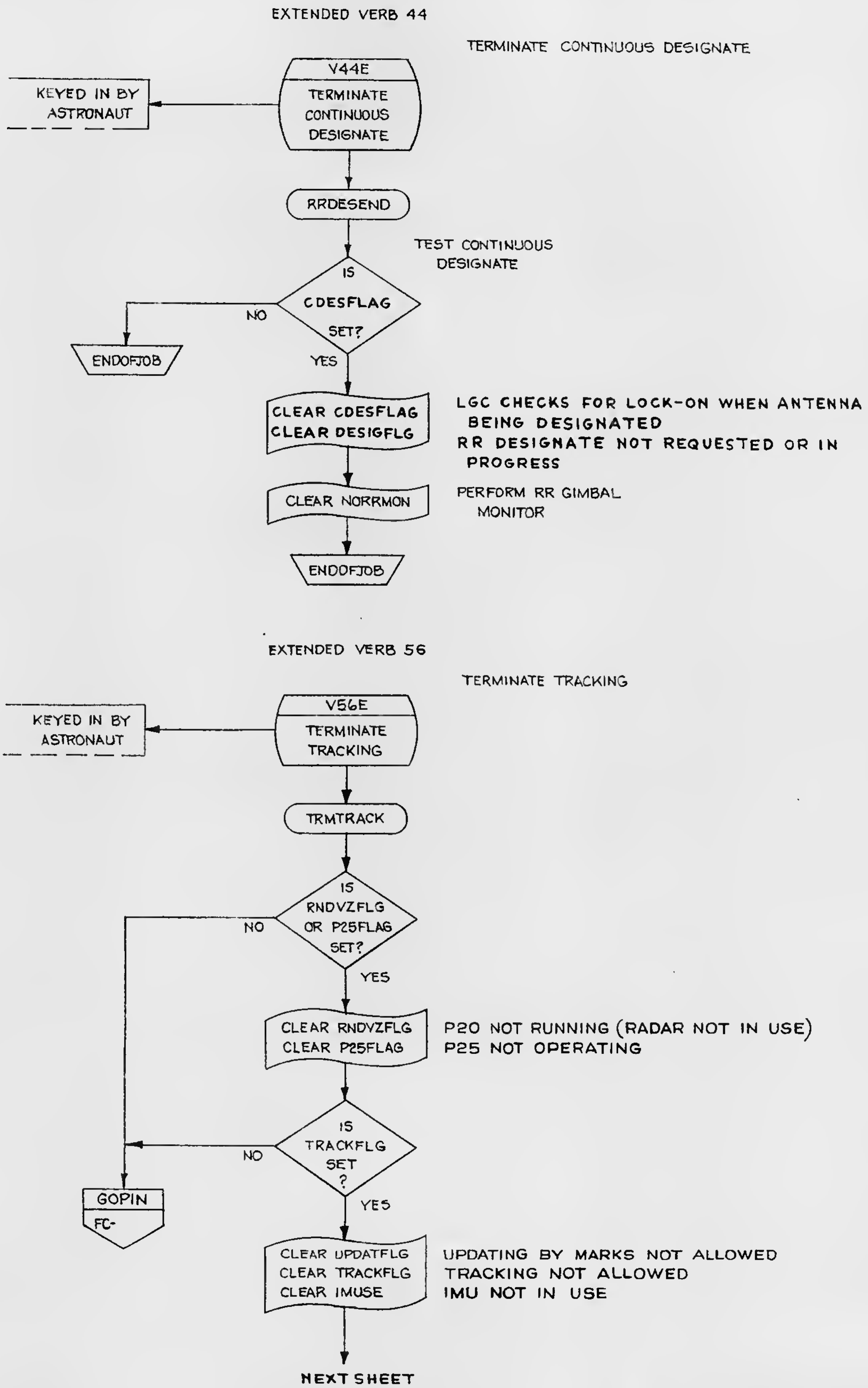
PROGRAM CONSTANTS (CONTINUED)

AGC TAG	MEANING	ENGINEERING AND AGC VALUE	AGC SCALING
CATLOG -222D	Direction of star 37D (=45_8) (α Piscis Austr. (Formalhaut)) in Reference coords	$\begin{pmatrix} +.8342971408 \\ -.2392481515 \\ -.4966976975 \end{pmatrix}$	2^1

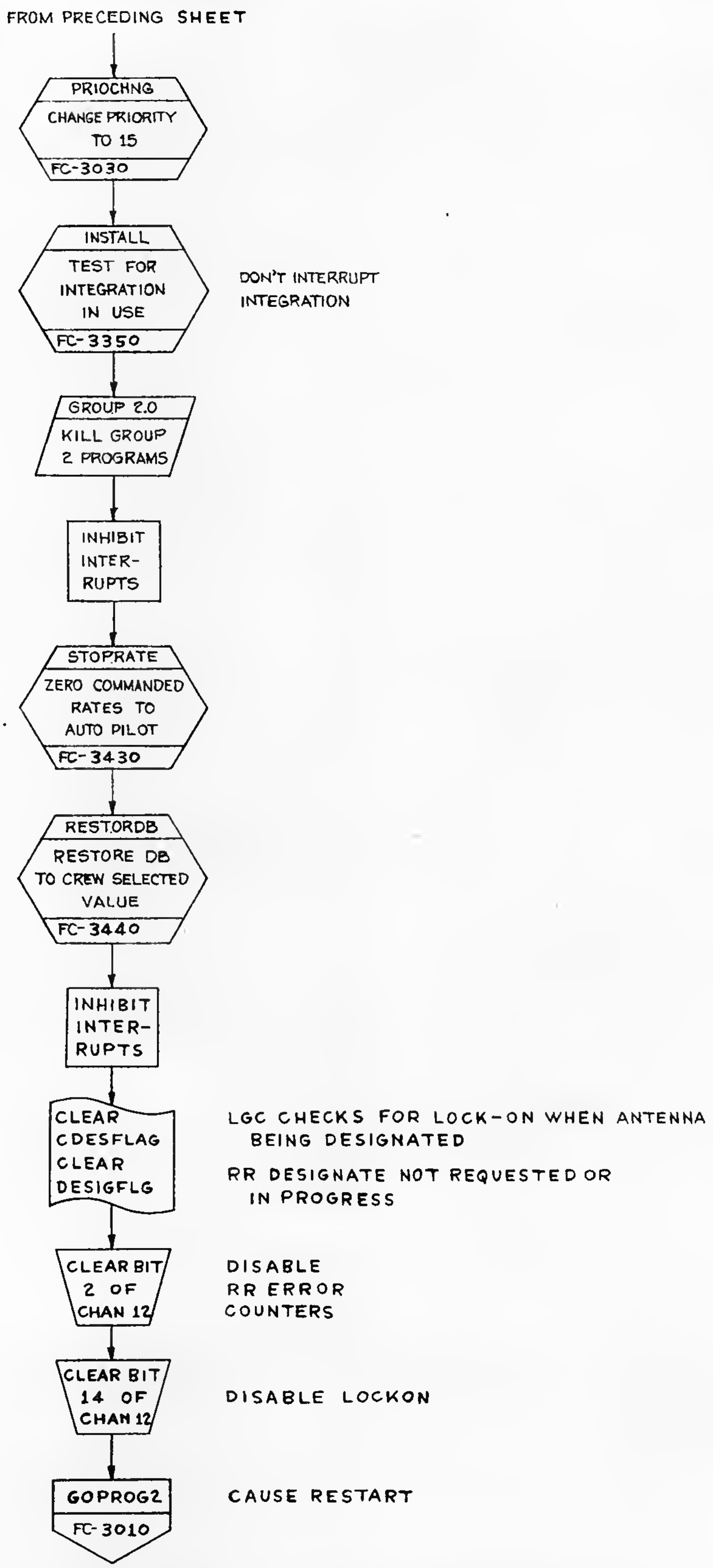
10.0 NAVIGATION PROGRAMS

P20, P22 RENDEZVOUS AND LUNAR SURFACE NAVIGATION

SUBROUTINES ON THIS FLOW CHART		
EXTENDED VERBS		SHEET
44 RRDESEND	TERMINATE CONTINUOUS DESIGNATE	2
56 TRMTRACK	TERMINATE TRACKING	2
67 V67	W-MATRIX MONITOR	4
85 VERB 85	DISPLAY RR LOS, AZIMUTH & ELEVATION	7
93 WMATRXNG	CLEAR RENDWFLG	10
95 UPDATOFF	NO STATE VECTOR UPDATE ALLOWED	10
PROG20	RENDEZVOUS NAVIGATION	11
PROG22	LUNAR SURFACE NAVIGATION	11
REMODE	CHANGE RR ANTENNA MODE	45
RRSONLY	SINGLE AXIS RR SHAFT MANEUVER	47
RRTONLY	SINGLE AXIS RR TRUNNION MANEUVER	47
RROUT	CONVERT INPUT GYRD COMMANDS TO OUTPUT CDU COMMANDS	48
BEGDES	CHECKS DESIGNATE REQUEST AND INITIATES DESIGNATION	39
RRNB	COMPUTE RR DIRECTION IN NB COORDINATES	53
RRRANGE	RR RANGE READ INITIALIZATION	62
RRRDOT	RR RANGE RATE READ INITIALIZATION	62



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	5-28-68	P20,P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PROGMR Peter Volante	8-16-68	LUMINARY 1D
ANALST		DOCUMENT NO. FC-3600
DOCMR	6-3	REV
APPR'D John A. Moore	19 Oct 68	SHEET 2 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

DRAWN	A.C. WILLIAMS	5-28-68
PROGMR	Peter Volante	8-16-68
ANALST		
DOCMR	W. Doyle	6-5-...
APPR'D	John A. Moore	29 Oct 68

APOLLO GUIDANCE AND NAVIGATION

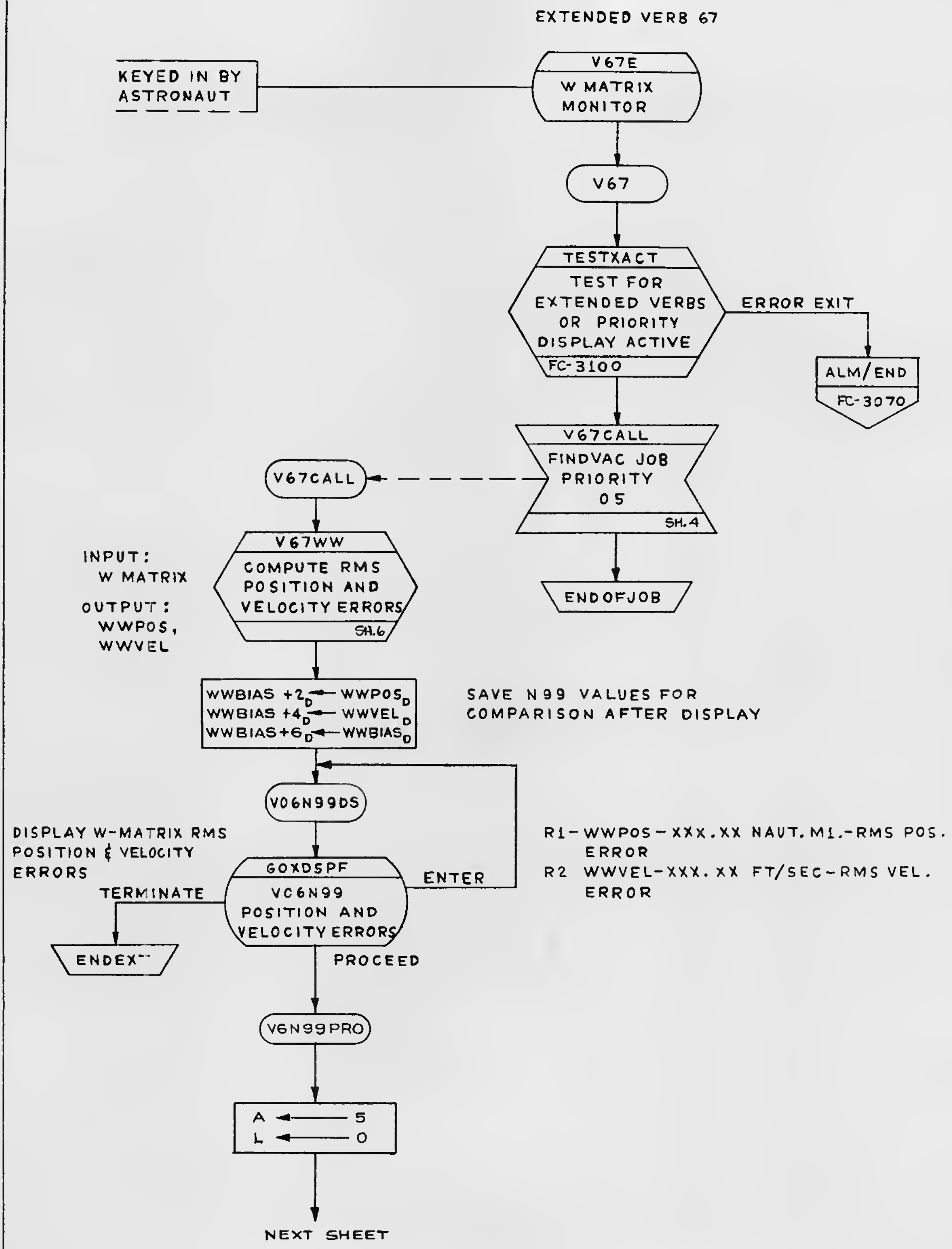
P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION

LUMINARY 1D

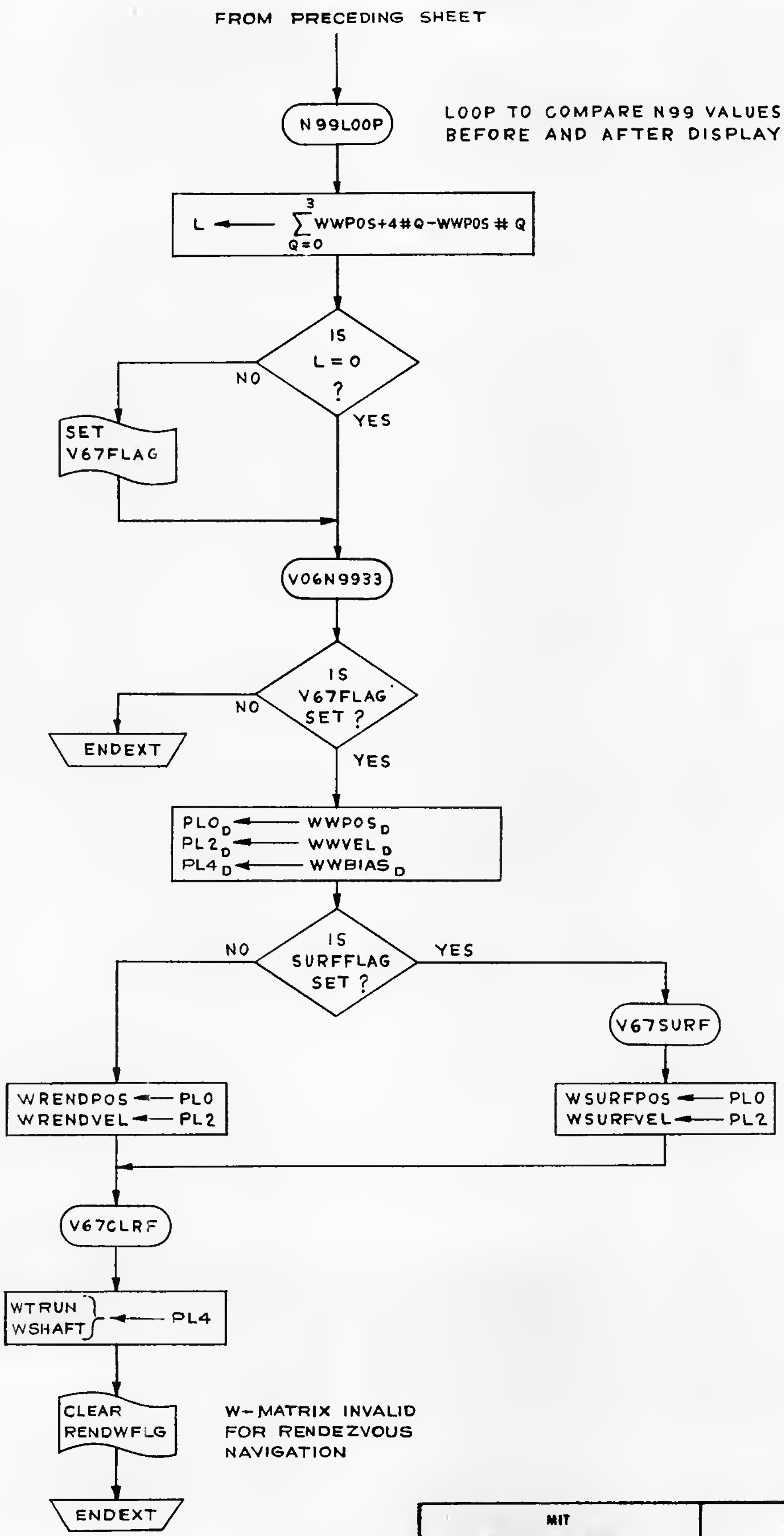
DOCUMENT NO. FC-3600

REV

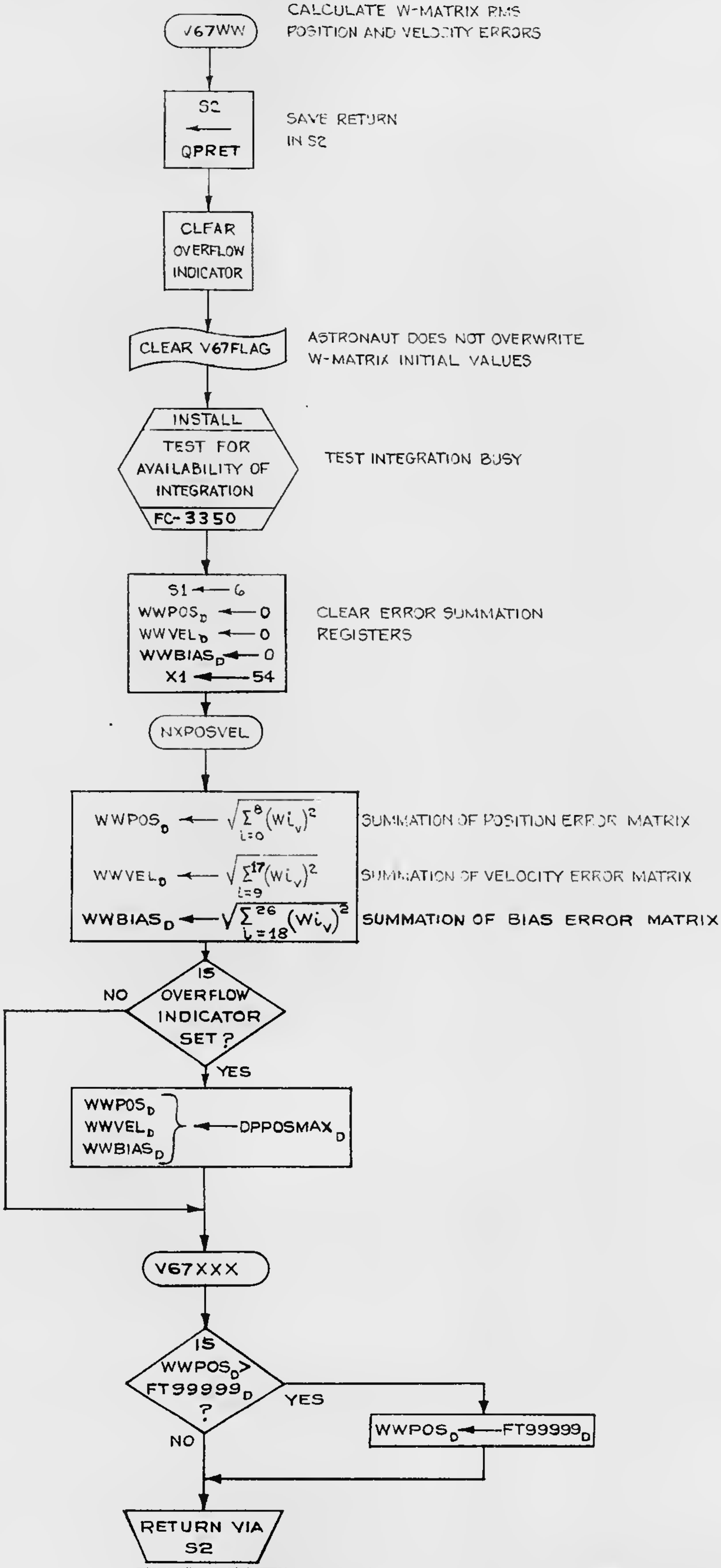
SHEET 3 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN 4 MAR69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR 10/21/69	
ANALST	LUMINARY 1D — DOCUMENT NO. FC-3600
DOCMR 4-7-69	
APPR'D Roberta M. Estes 10/21/69	REV 2 — SHEET 4 OF 103

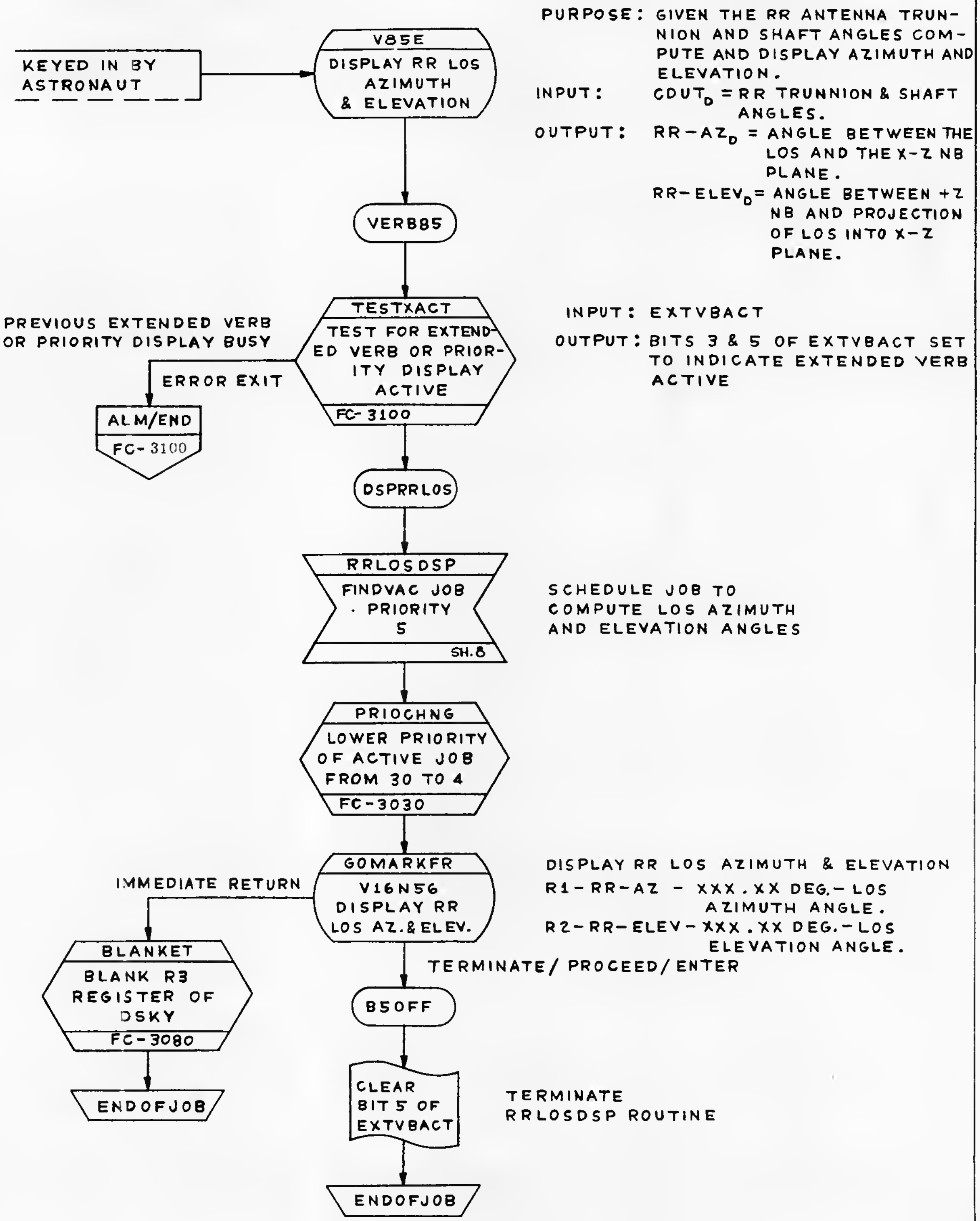


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	4 MAR69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGMR	10/21/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3600
DOCMR	4-7-69		
APPR'D	10/21/69	REV 2	SHEET 5 OF 103

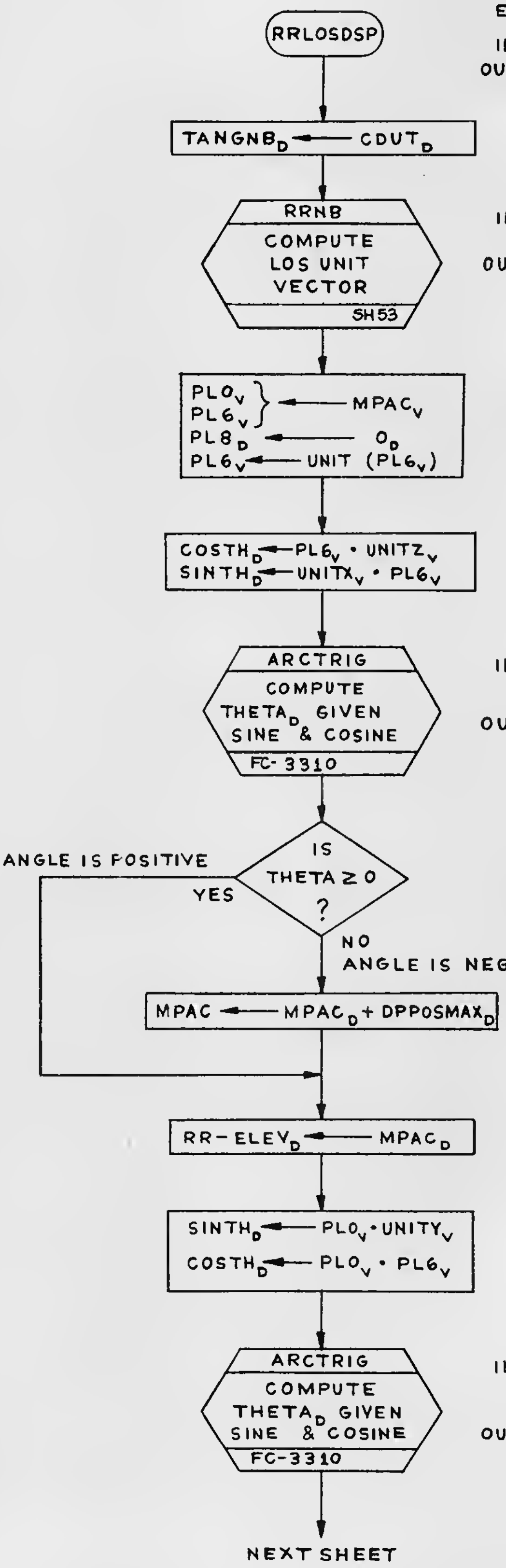


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	6-26-68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR Peter Volante	8-16-68	LUMINARY 1D
ANALST		DOCUMENT NO. FC-3600
DOCMR W.C. Wright Jr.	6-28-68	
APPR'D John A. Moss	29 Oct 68	REV 2 — SHEET 6 OF 103

EXTENDED VERB 95 : DISPLAY RR LOS AZIMUTH AND ELEVATION



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN G. J. Longille 5MAR69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR 10/21/69	LUMINARY 1D
ANALST	DOCUMENT NO. FC-3600
DOCMR McDonald 4-7-69	REV 2
APPR'D Robert M. Eaves 10/21/69	SHEET 7 OF 103



SUBROUTINE TO COMPUTE LOS AZIMUTH AND ELEVATION ANGLES FOR V16N56 DISPLAY.

INPUT: $CDUT_D$ = RR TRUNNION & SHAFT ANGLES.
OUTPUT: $RR\text{-}AZ_D$ = RR LOS AZIMUTH ANGLE.
$RR\text{-}ELEV_D$ = RR LOS ELEVATION ANGLE.

LOAD RR TRUNNION & SHAFT ANGLES FOR RRNB ROUTINE

INPUT : $TANGNB_D$ = RR TRUNNION & SHAFT CDU ANGLES.
OUTPUT : $\left.\begin{array}{l} PL32_V \\ MPAC_V \end{array}\right\}$ RR LOS UNIT VECTOR IN NB COORD.

STORE LOS VECTOR

ZERO Y COMPONENT

UNIT OF LOS PROJECTION INTO X-Z PLANE

COMPUTE ELEVATION ANGLE

STORE SINE AND COSINE OF ELEVATION ANGLE FOR ARCTRIG ROUTINE (ANGLE BETWEEN +Z NB AND PROJECTION OF LOS INTO X-Z NB PLANE)

INPUT : $SINTH_D$ = SINE OF THETA
$COSTH_D$ = COSINE OF THETA
OUTPUT : $\left.\begin{array}{l} THETA_D \\ MPAC_D \end{array}\right\}$ ANGLE THETA IN REV. $(-.5 \leq \theta \leq .5)$

INSURE DISPLAY OF 0-360 DEG. ABOUT +Y

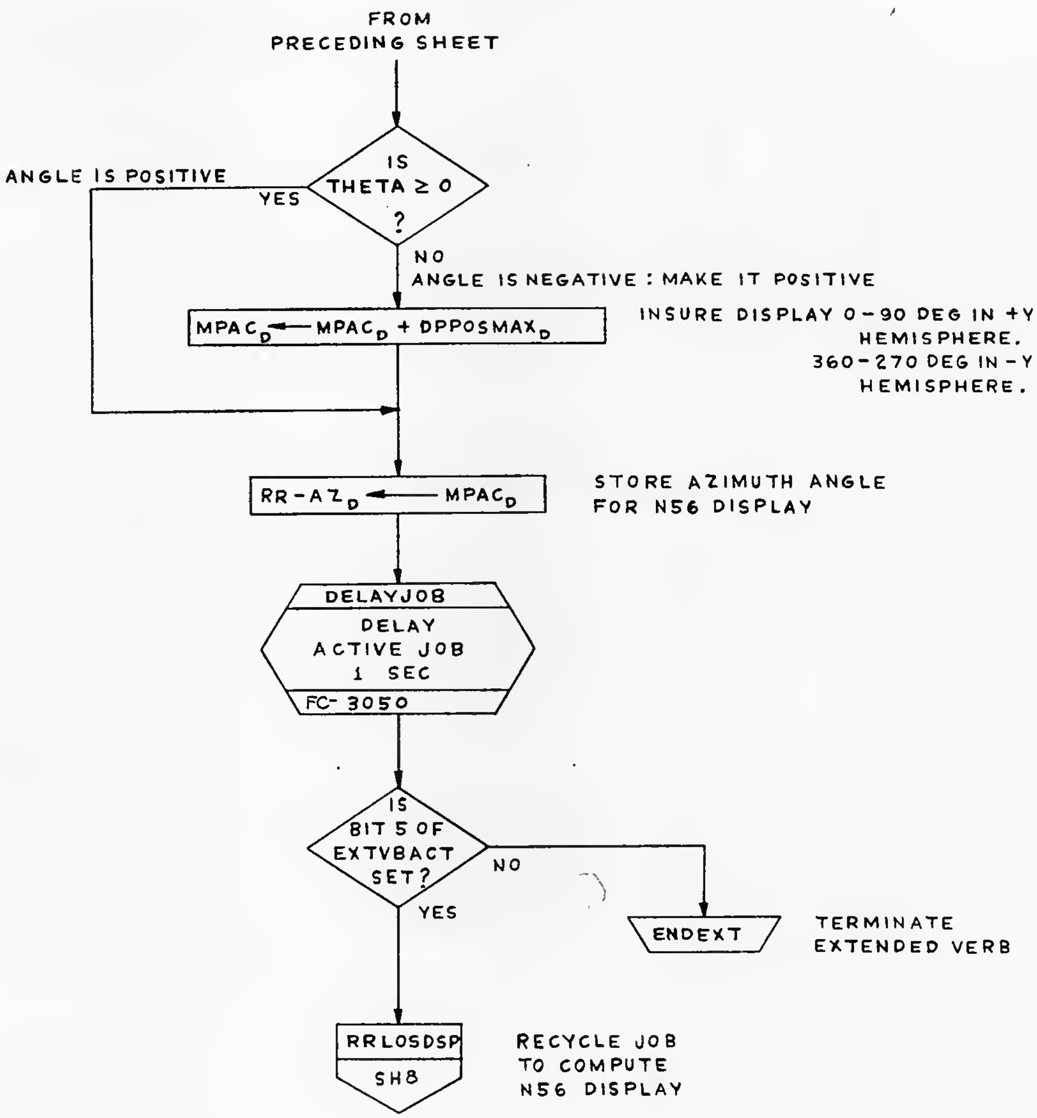
STORE ELEVATION ANGLE FOR N56 DISPLAY

COMPUTE AZIMUTH ANGLE

STORE SINE AND COSINE OF AZIMUTH ANGLE FOR ARCTRIG ROUTINE (ANGLE BETWEEN THE LOS AND THE X-Z NB PLANE)

INPUT : $SINTH_D$ = SINE OF THETA
$COSTH_D$ = COSINE OF THETA
OUTPUT : $\left.\begin{array}{l} THETA_D \\ MPAC_D \end{array}\right\}$ = ANGLE THETA IN REV. $(-.5 \leq \theta \leq .5)$

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A. J. Langillo	5 MAR 68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGMR P. Volante	10/21/69	LUMINARY 1D	DOCUMENT NO. FC-3600
ANALST			
DOCMR W C Deshmit	4-7-69		
APPR'D Roberta M Eisen	10/21/69	REV 2	SHEET 8 OF 103



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CAMBRIDGE, MASS.

DRAWN 5MAR69
PRGMR 10/21/69
ANALST
DOCMR 4-7-69
APPR'D 10/21/68

APOLLO
GUIDANCE AND NAVIGATION

P20, P22
RENDEZVOUS & LUNAR SURFACE
NAVIGATION

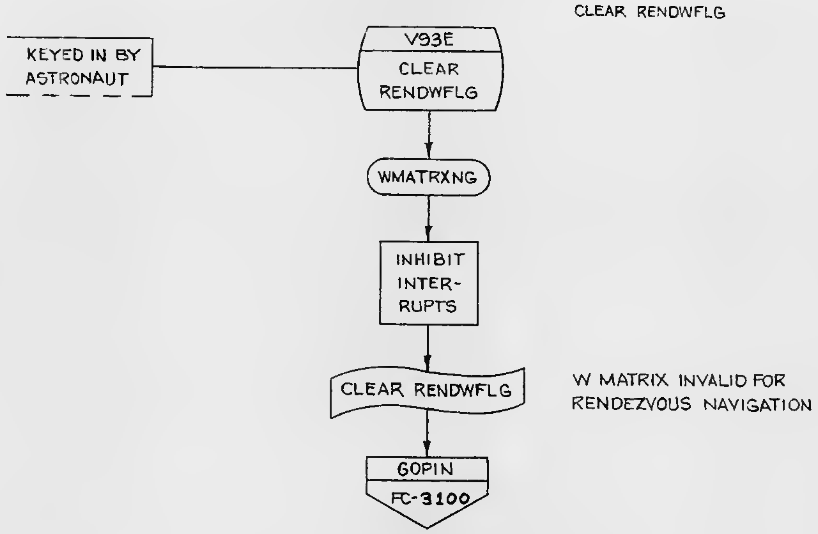
LUMINARY 1D

DOCUMENT NO.
FC-3600

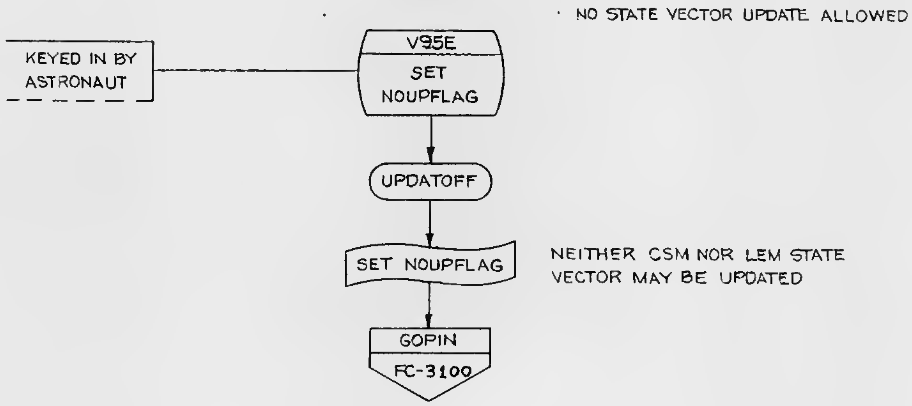
REV 2

SHEET 9 OF 103

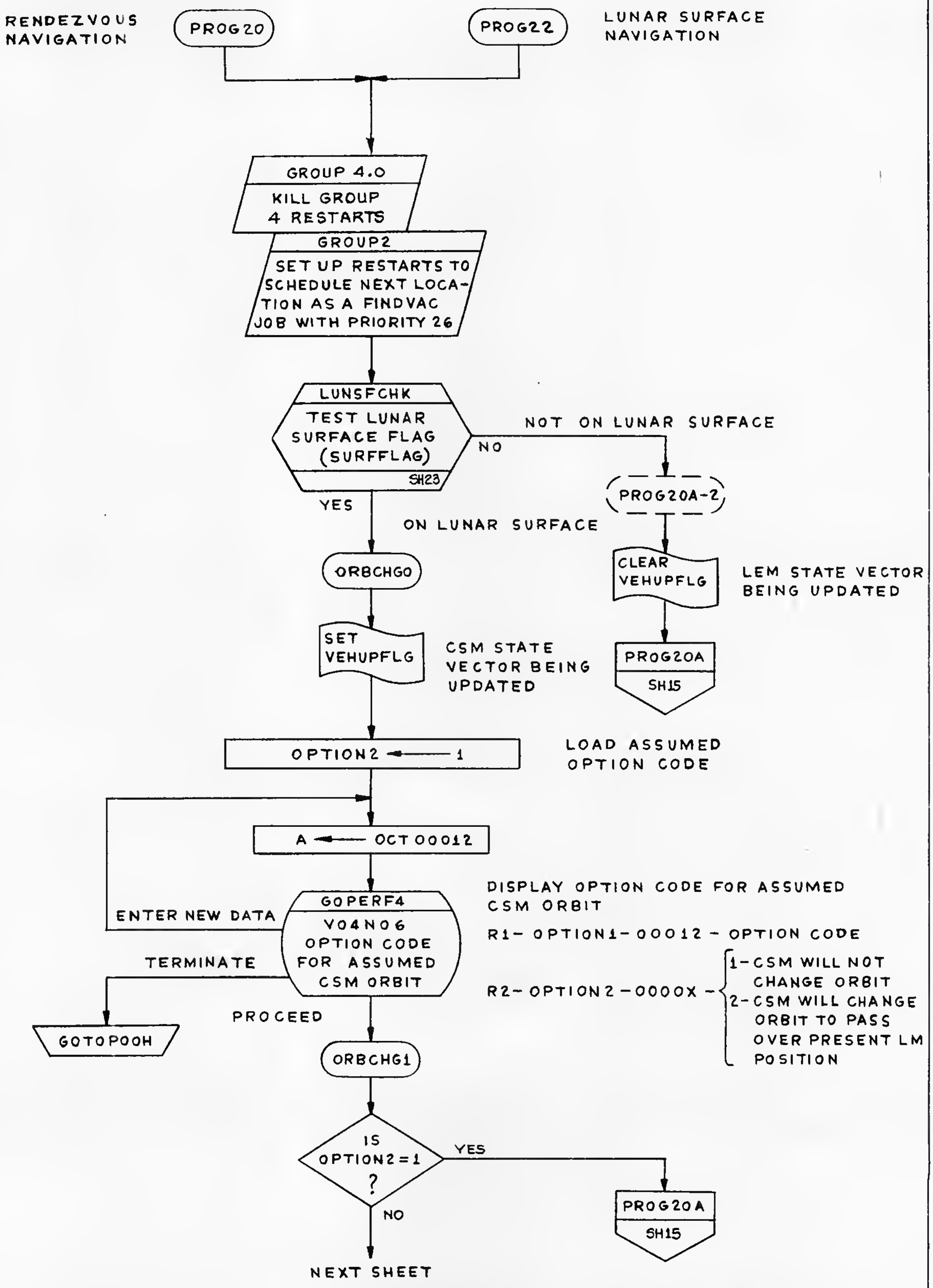
EXTENDED VERB 93



EXTENDED VERB 95



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS 5-29-68	P20,P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGMR Peter Volante 8-16-68	LUMINARY 1D	DOCUMENT NO. FC-3600
ANALST		
DOCMR W. Dogruth 6-5-6		
APPR'D John A. Moore 9 Oct 68	REV 2	SHEET 10 OF 103



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DRAWN		6 MAR69
PRGMR		10/21/69
ANALST		
DOCMR		4-7-69
APPR'D		10/21/69

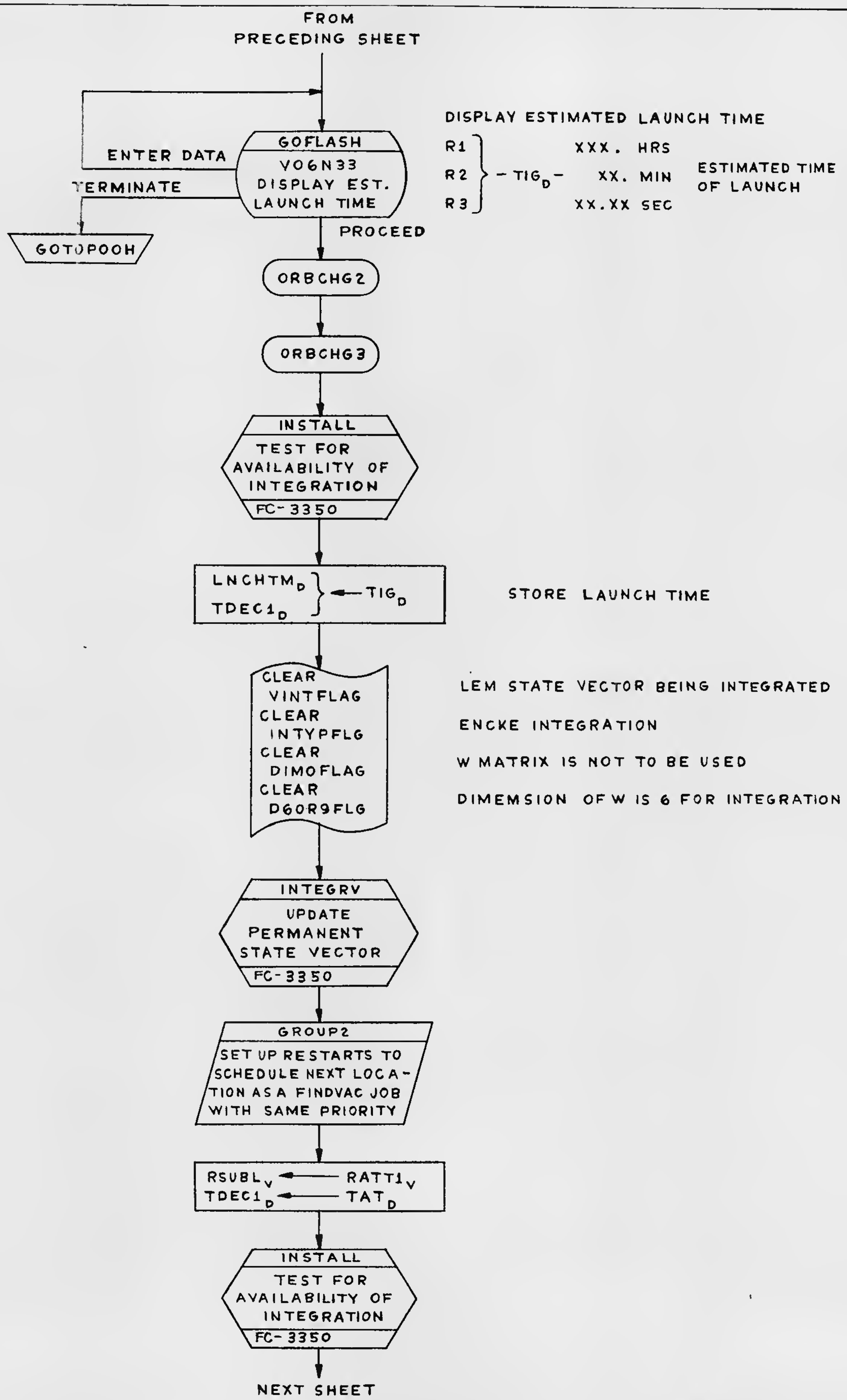
APOLLO
GUIDANCE AND NAVIGATION

P20, P22
RENDEZVOUS & LUNAR SURFACE NAVIGATION

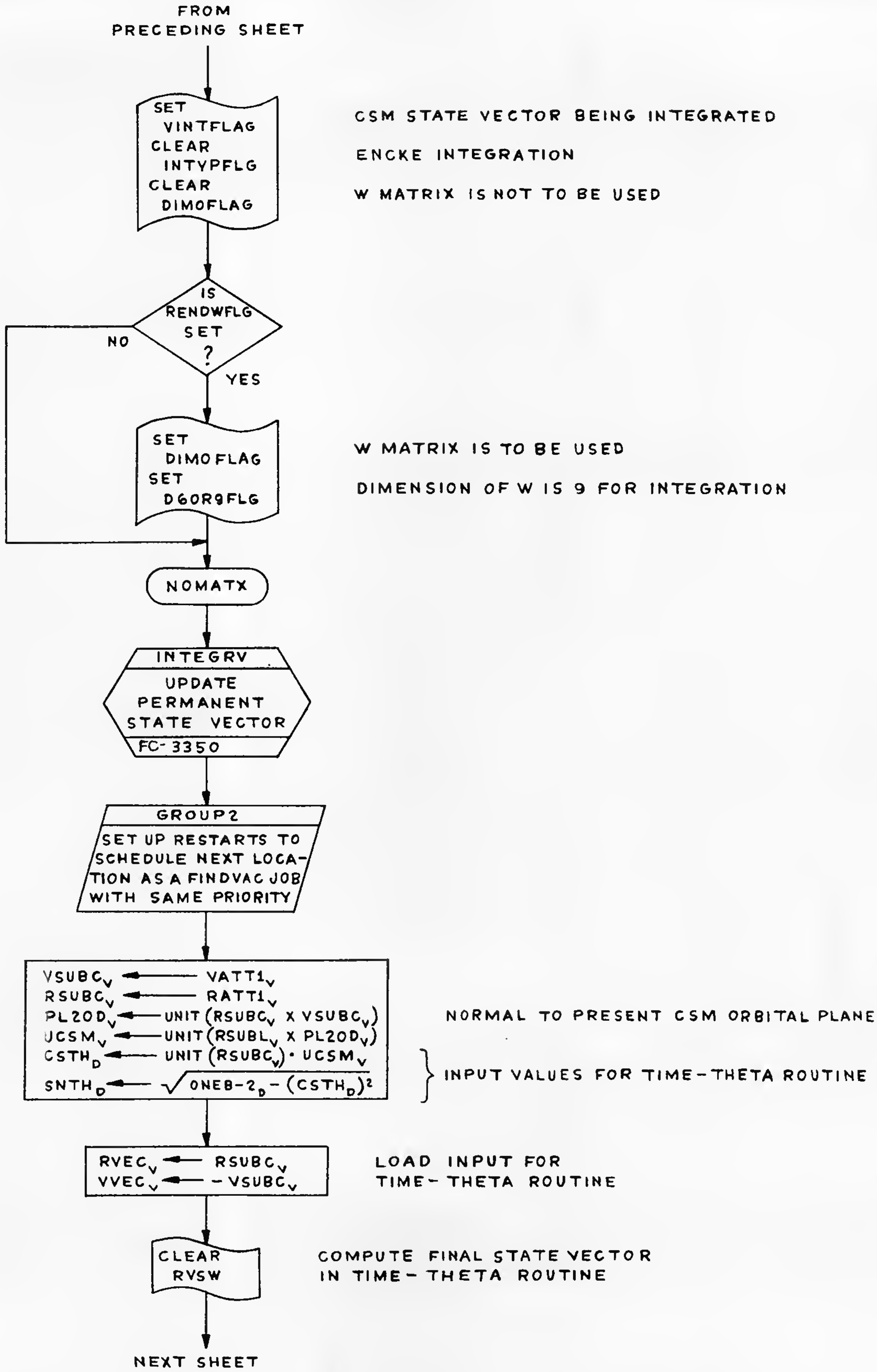
LUMINARY 1D

DOCUMENT NO. FC-3600

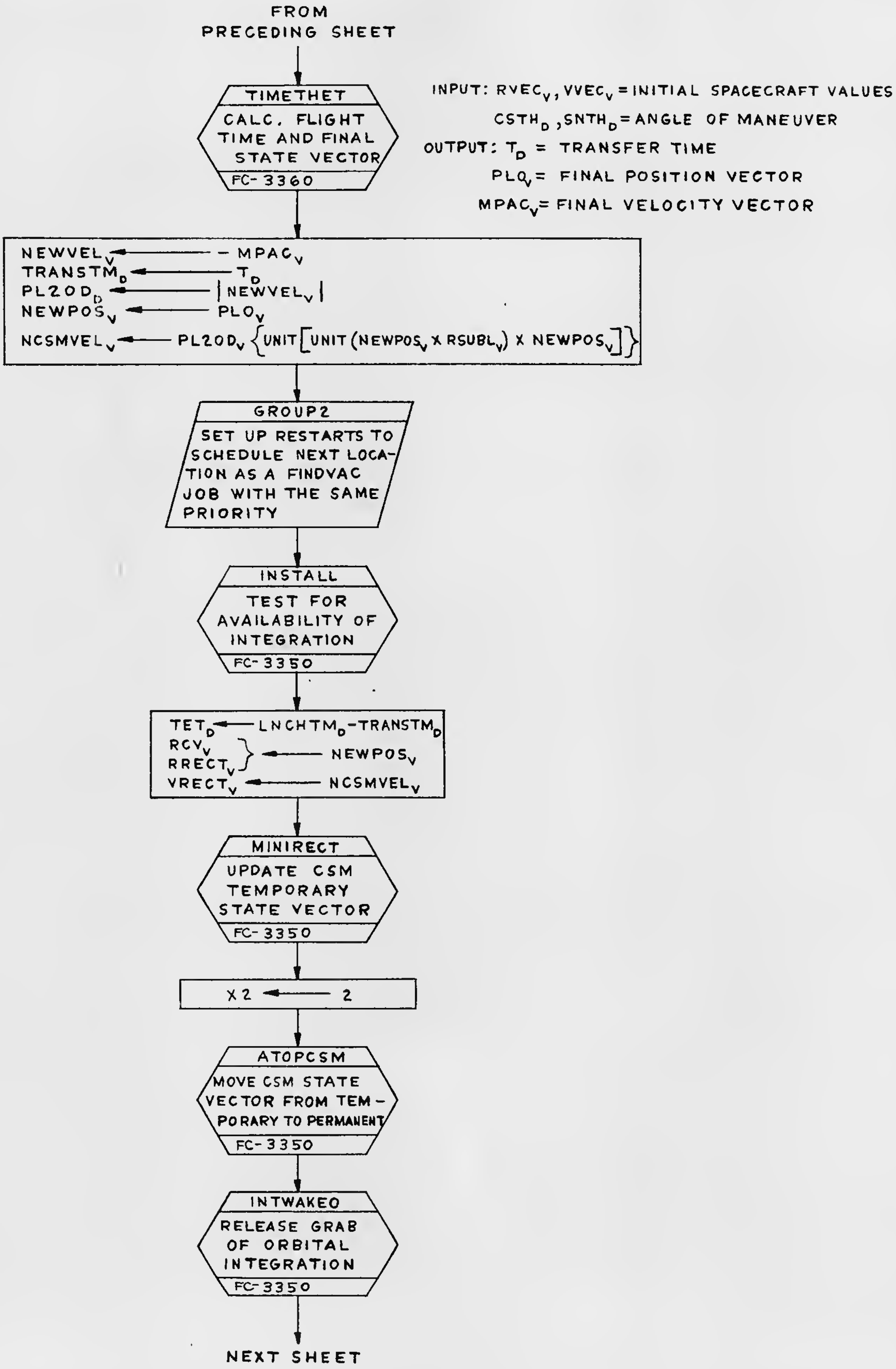
REV 2



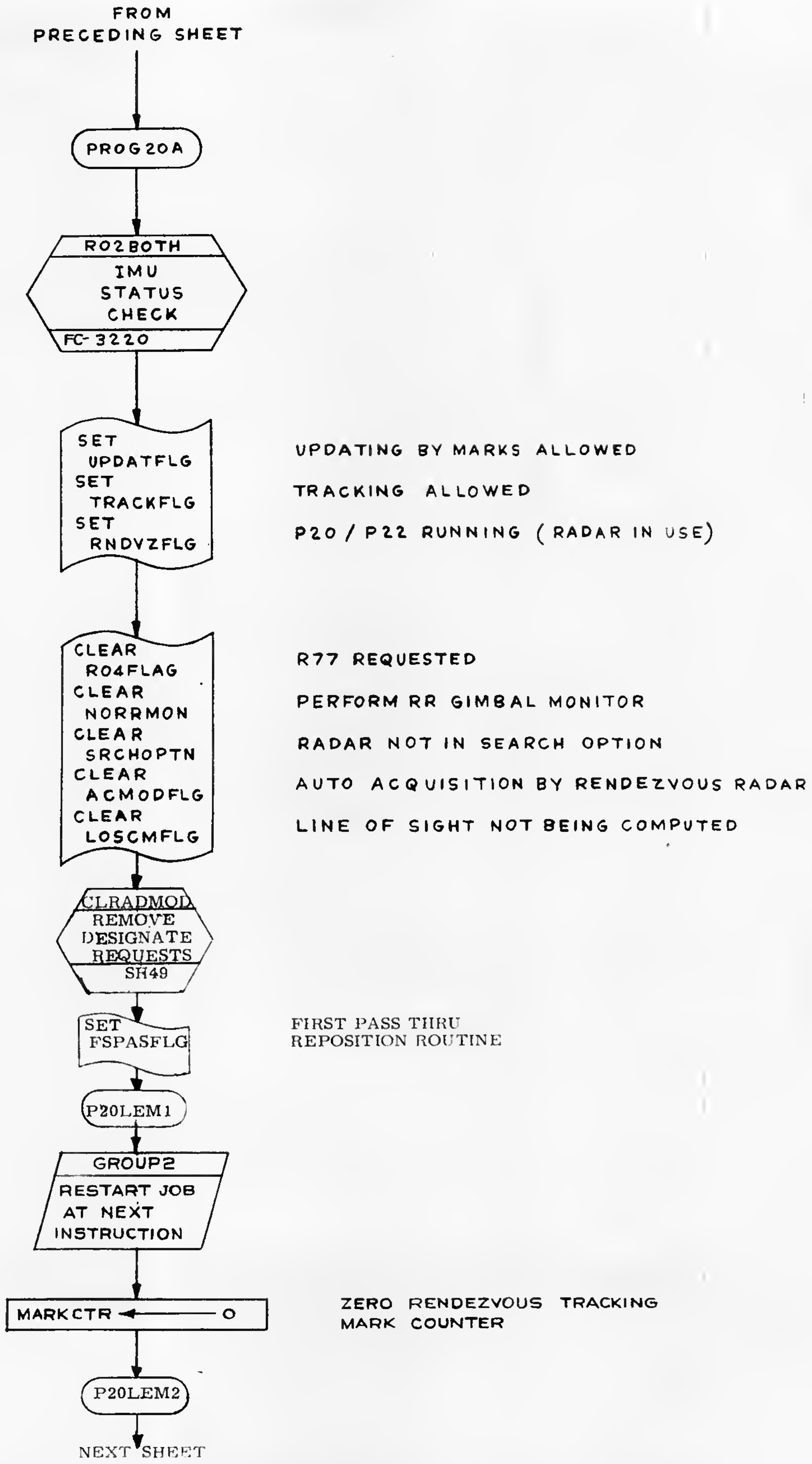
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN	6MAR69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR	10/21/69	
ANALST		LUMINARY 1D — DOCUMENT NO. FC-3600
DOCMR	4-7-69	
APPR'D	10/21/69	REV 2 — SHEET 12 OF 103



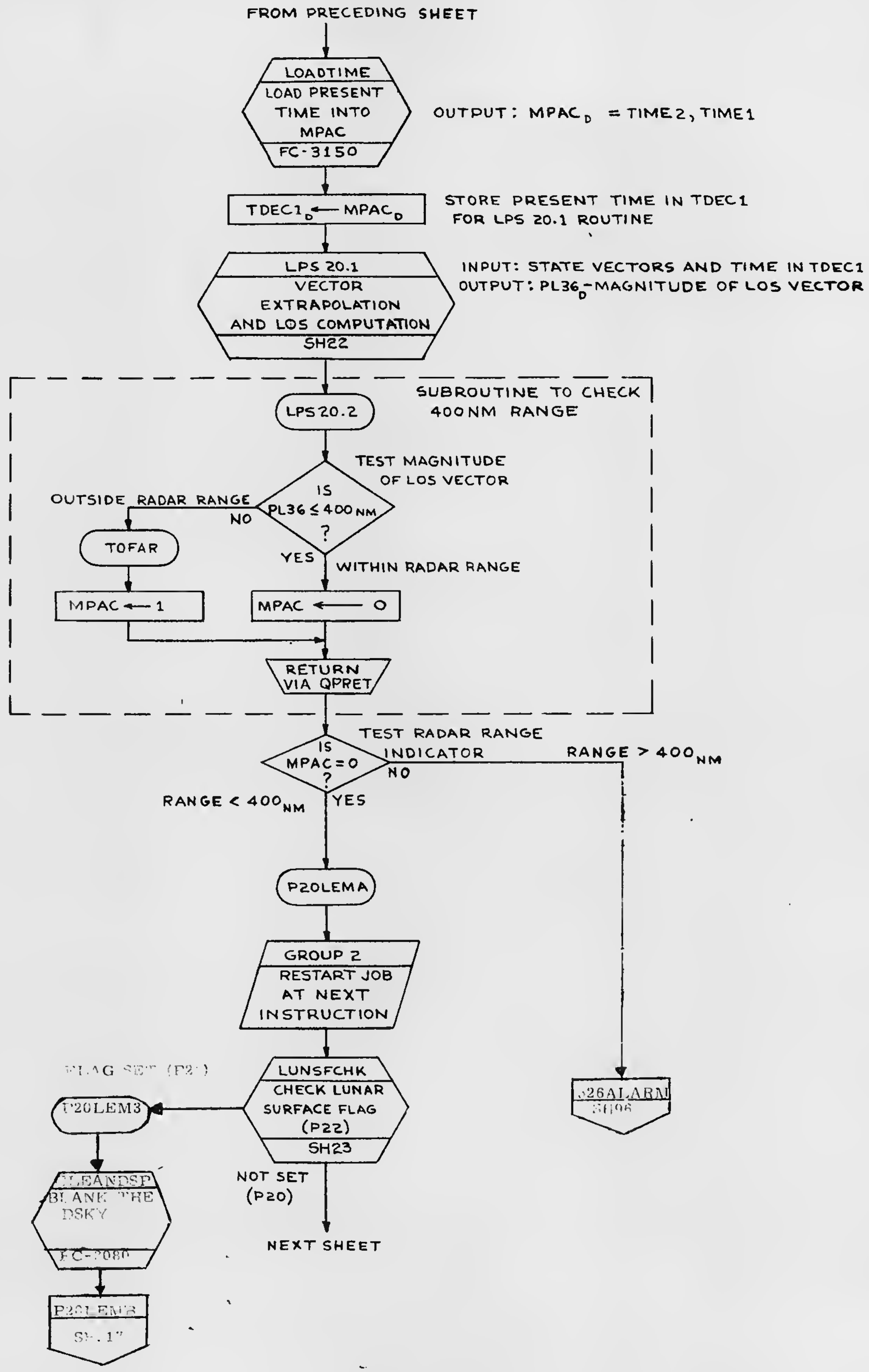
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN G. J. Langille	6 MAR69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR [illegible]	10/21/69	
ANALST		LUMINARY 1D / DOCUMENT NO. FC-3600
DOCMR M C Dextet	4-7-69	
APPR'D Roberta M. Estes	10/21/69	REV 2 / SHEET 13 OF 103



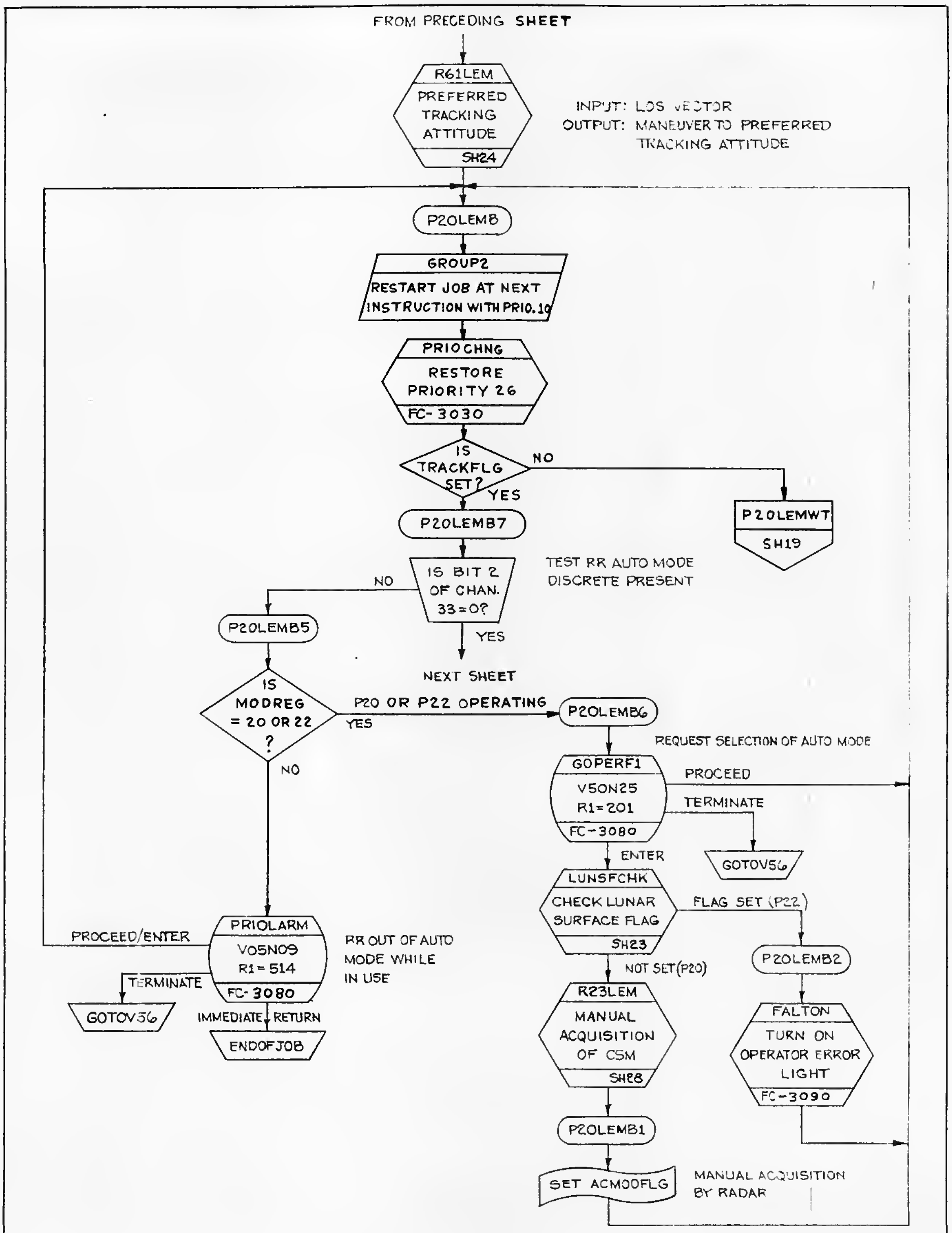
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN G. J. Langille	7MAR69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR T. Vitolo	10/21/69	LUMINARY 1D — DOCUMENT NO. FC-3600
ANALST		
DOCMR W. C. Dybott	4-7-69	
APPR'D Roberto M. Eitas	10/21/69	REV 2 — SHEET 14 OF 103



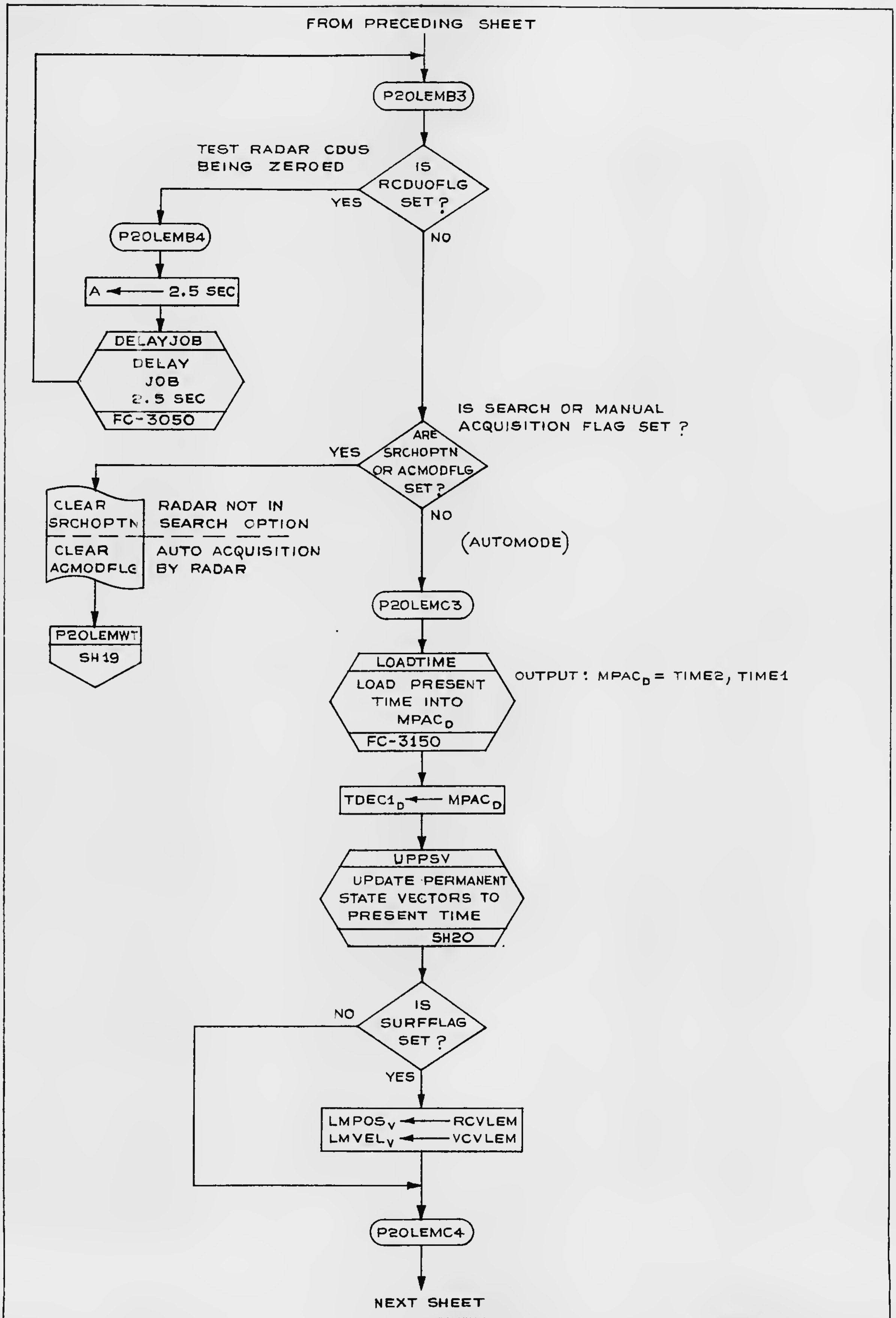
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN	7MAR69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR	10/21/69	
ANALST		LUMINARY 1D — DOCUMENT NO. FC-3600
DOCMR	4-7-69	
APPR'D	10/21/69	REV 2 — SHEET 15 OF 103



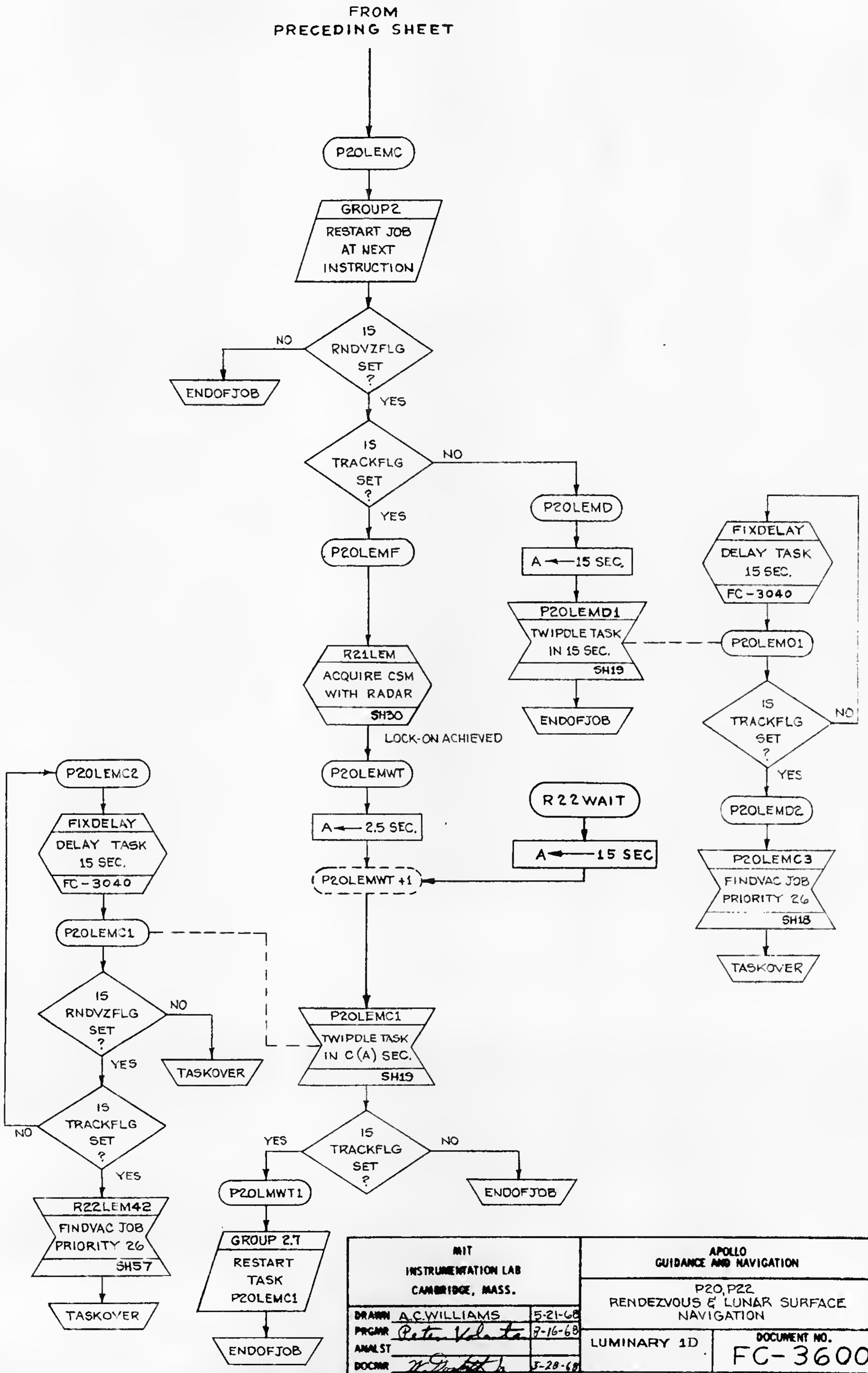
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	7 Pearson Jr	9JAN68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGMR	Pete Volante	10/21/69	LUMINARY 1D	DOCUMENT NO. FC-3600
ANALST				
DOCMR	W Daybith Jr	17MAY68		
APPR'D	John A. Moore	29 OCT 69	REV 2	SHEET 16 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS 5-20-68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGMR Peter Volante 8-16-68	LUMINARY 1D	DOCUMENT NO. FC-3600
ANALST		
DOCMR W. Goforth Jr. 1-28-68		
APPR'D John A. Moore 29 Oct 68	REV 2	SHEET 17 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN 17JUNE69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR 10/21/69	
ANALST	LUMINARY 1D — DOCUMENT NO. FC-3600
DOCMR 18 JULY 69	
APPR'D 10/21/69	REV 2 — SHEET 18 OF 103



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APOLLO
GUIDANCE AND NAVIGATION

P20, P22
RENDEZVOUS & LUNAR SURFACE
NAVIGATION

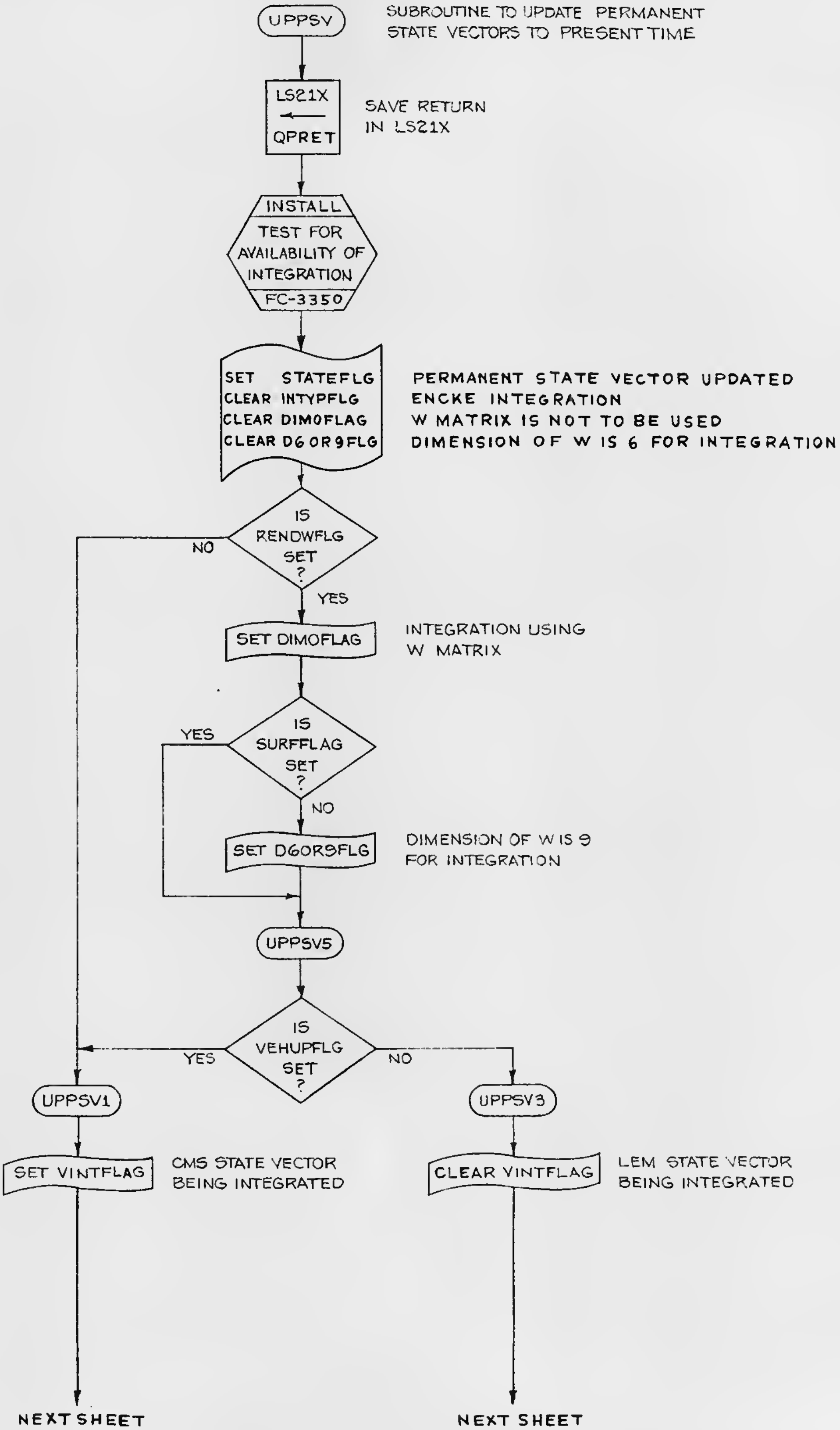
DRAWN	A.C. WILLIAMS	5-21-68
PRGMR	Peter Volante	7-16-68
ANALST		
DOCMR	W. Haggett Jr	5-28-68
APPR'D	John A. Miller	29 Oct 68

LUMINARY 1D

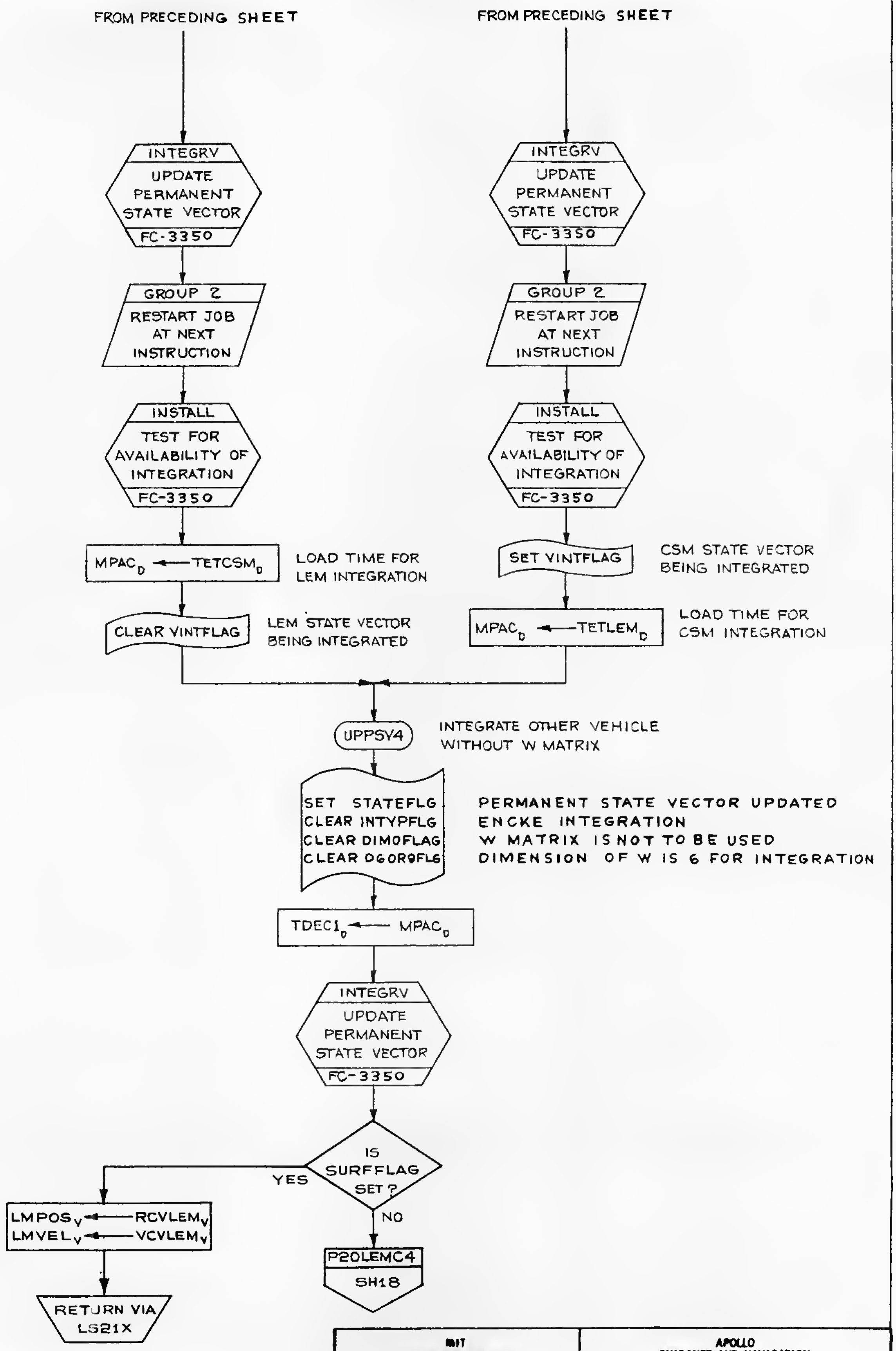
DOCUMENT NO. FC-3600

REV 2

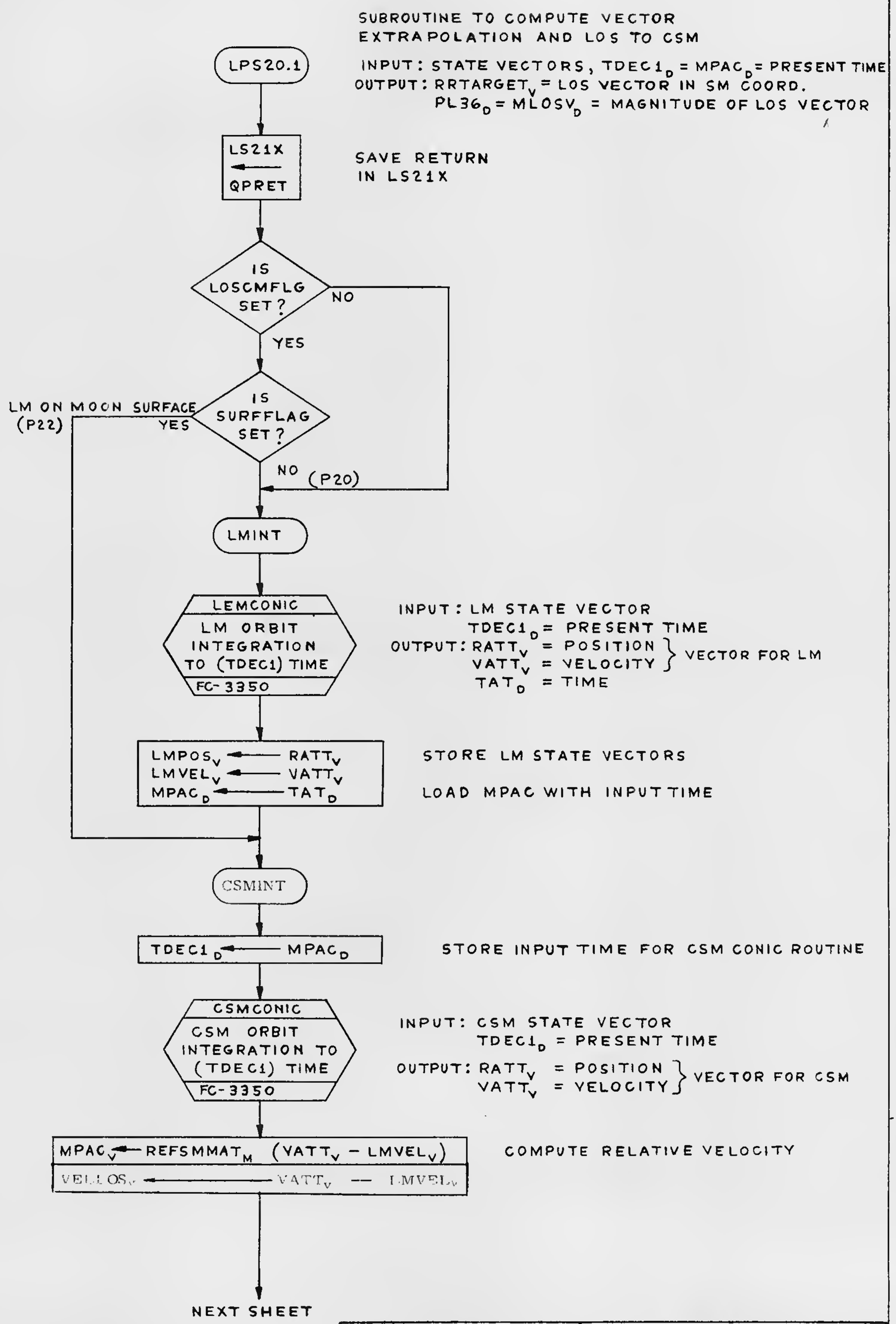
SHEET 19 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS	4-1-68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGMR Peter Volante	8-16-68	LUMINARY 1D	DOCUMENT NO. FC-3600
ANALST			
DOCMR W. Danforth	5-17-68		
APPR'D John A. Morse	29 Oct 68	REV2	SHEET 20 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
DRAWN A.C.WILLIAMS	4-1-68	LUMINARY 1D — DOCUMENT NO. FC-3600
PROGMR	8-16-68	
ANALST		
DOCMR	5-17-68	
APPR'D John A. Moore	29 Oct 68	REV 2 — SHEET 21 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

DRAWN G. J. Lanzillo 11MAR69
PRGMR 10/01/69
ANALST
DOCMR 4-7-69
APPR'D 10/21/69

APOLLO GUIDANCE AND NAVIGATION

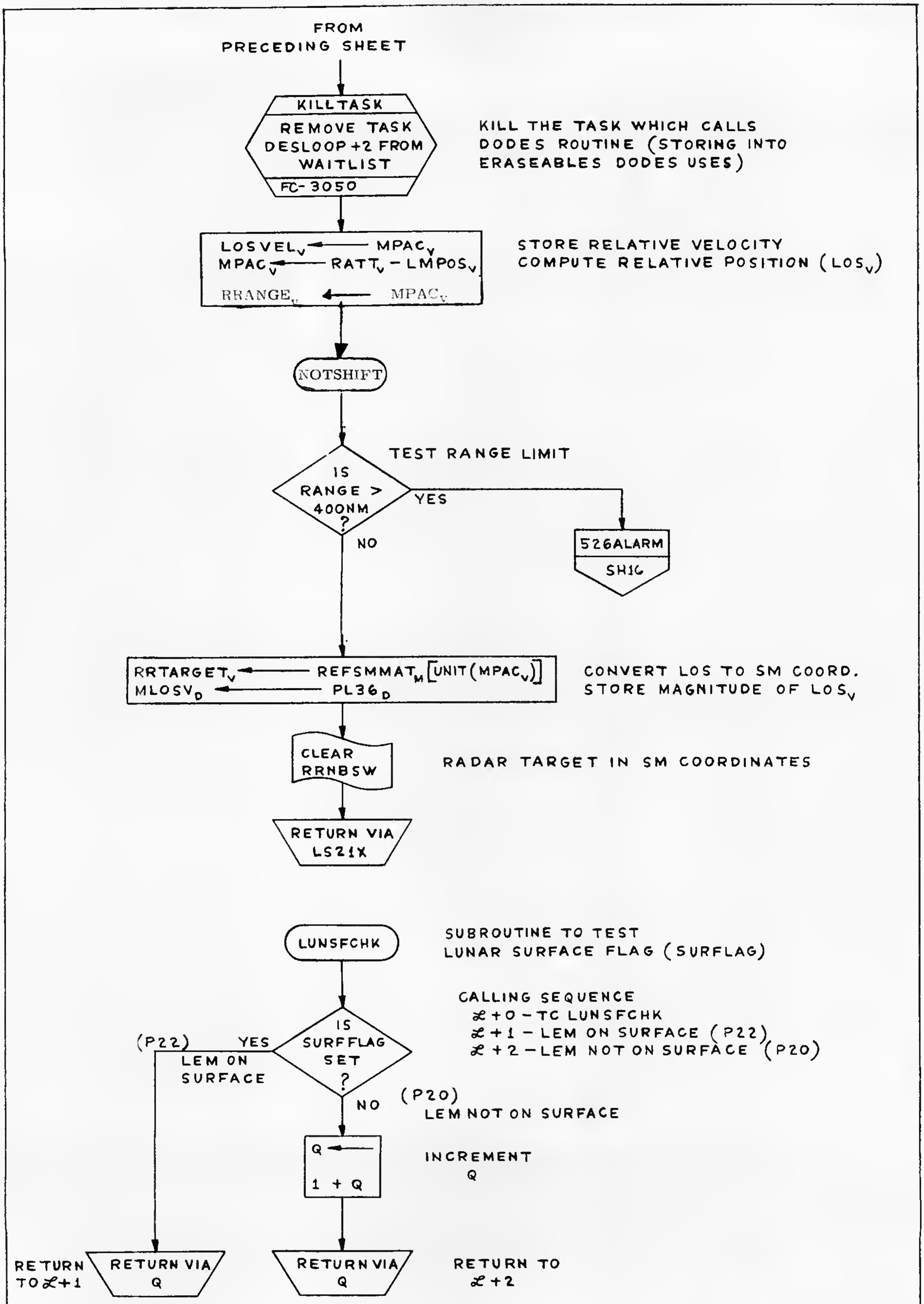
P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION

LUMINARY 1D

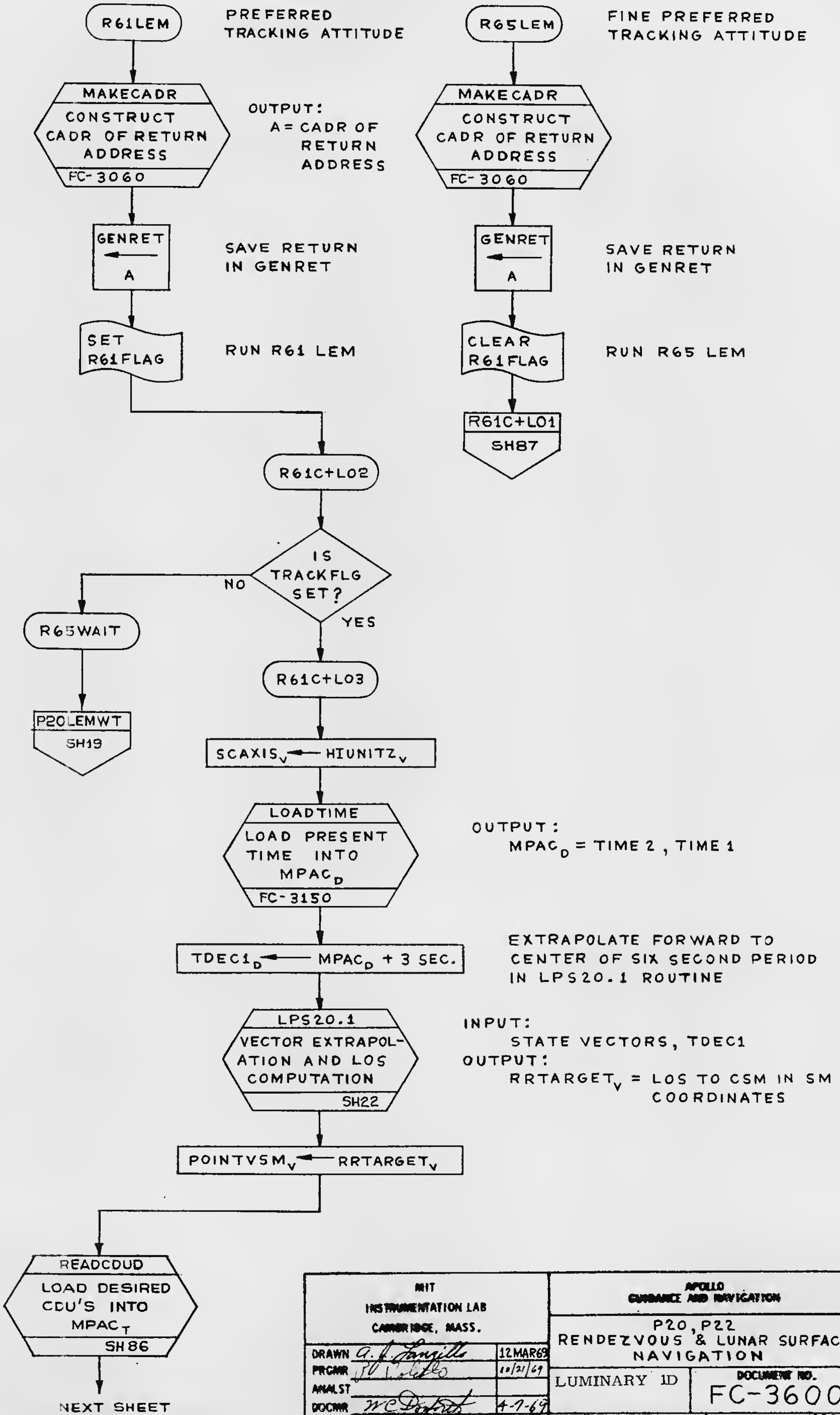
DOCUMENT NO. FC-3600

REV 2

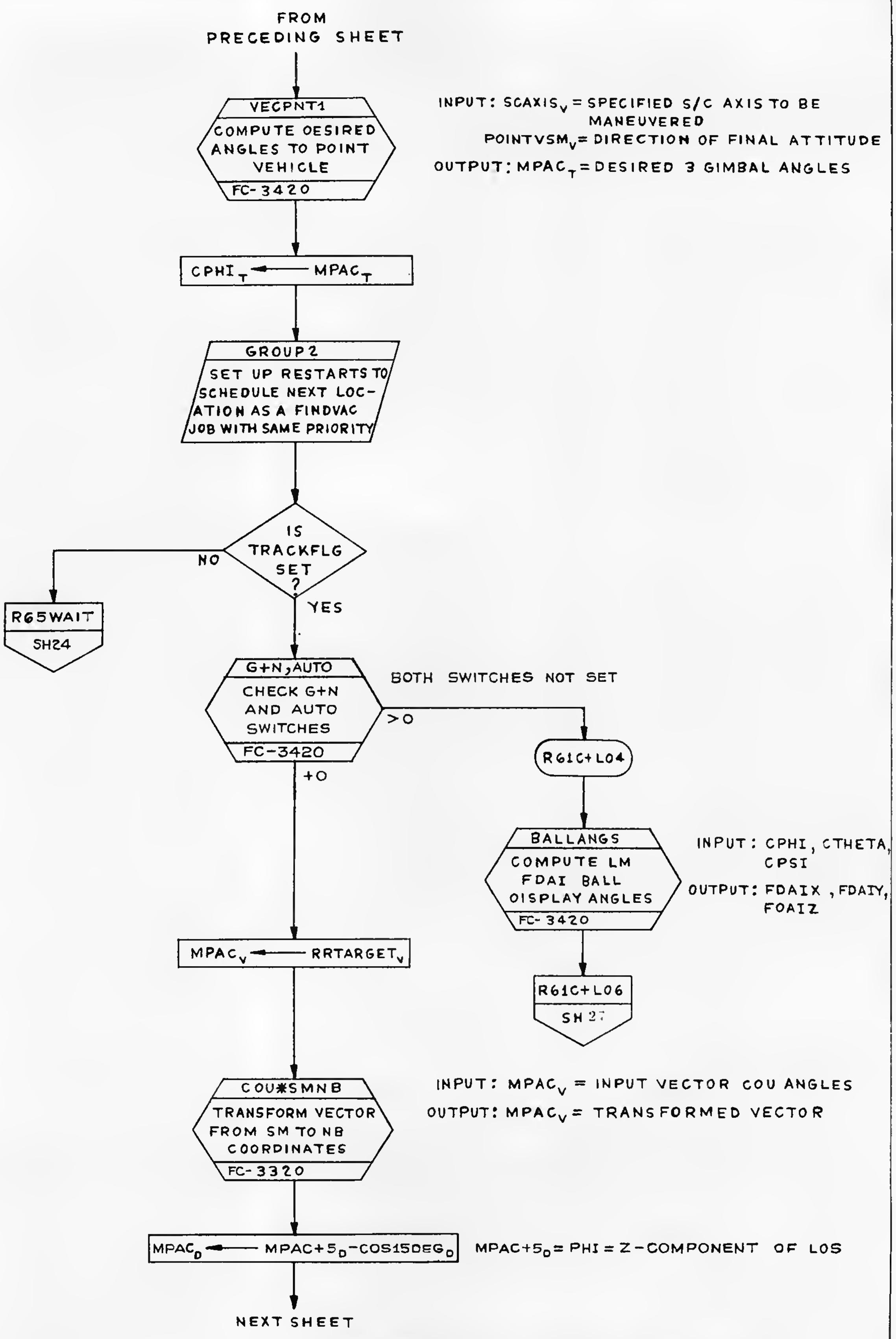
SHEET 22 OF 103



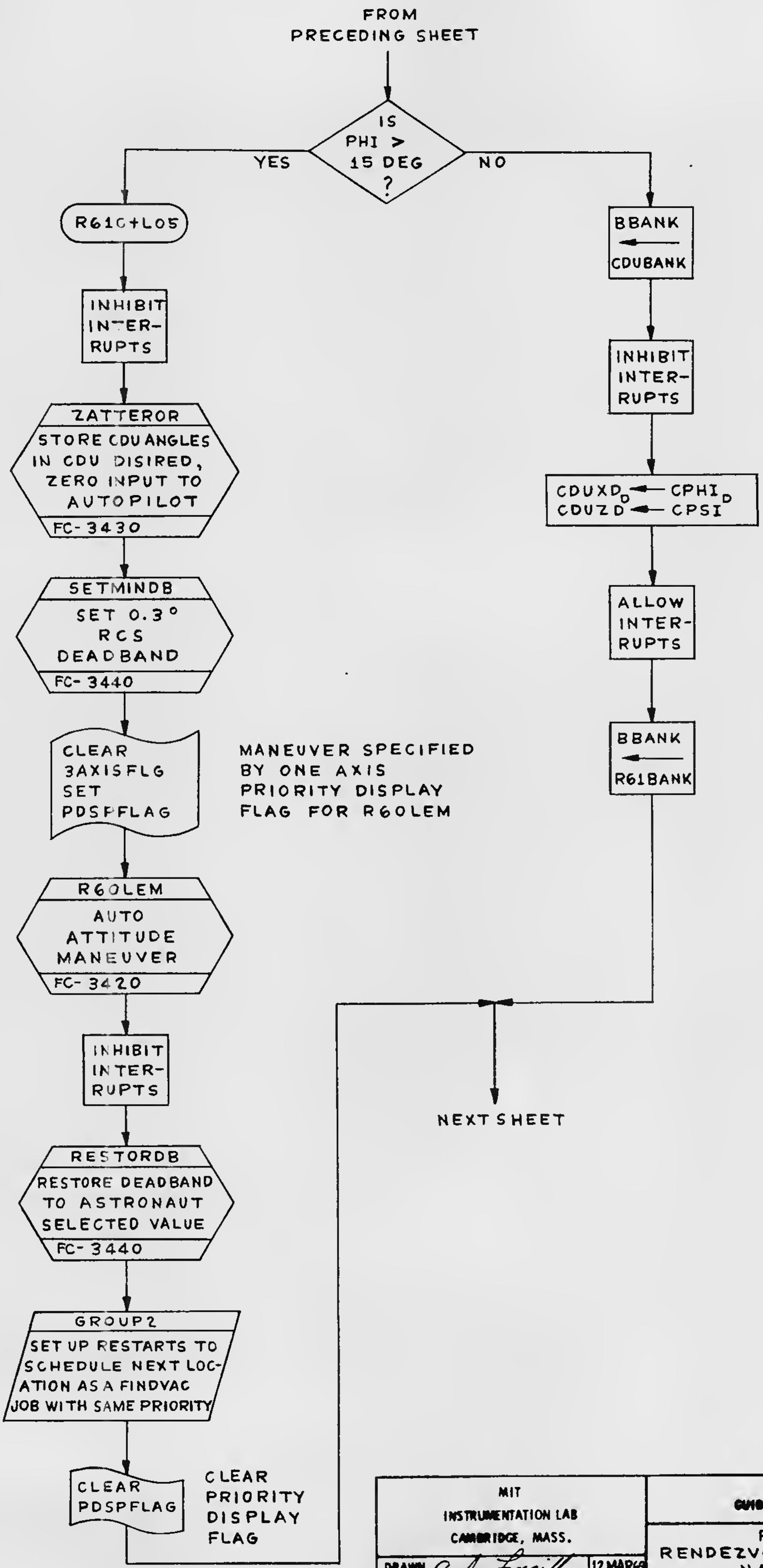
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN A. J. Lonzillo 11 MARCH	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGMR 10/21/69		
ANALST	LUMINARY 1D	DOCUMENT NO. FC-3600
DOCMR W C Dobert 4-7-69		
APPR'D 10/21/69	REV 2	SHEET 23 OF 103



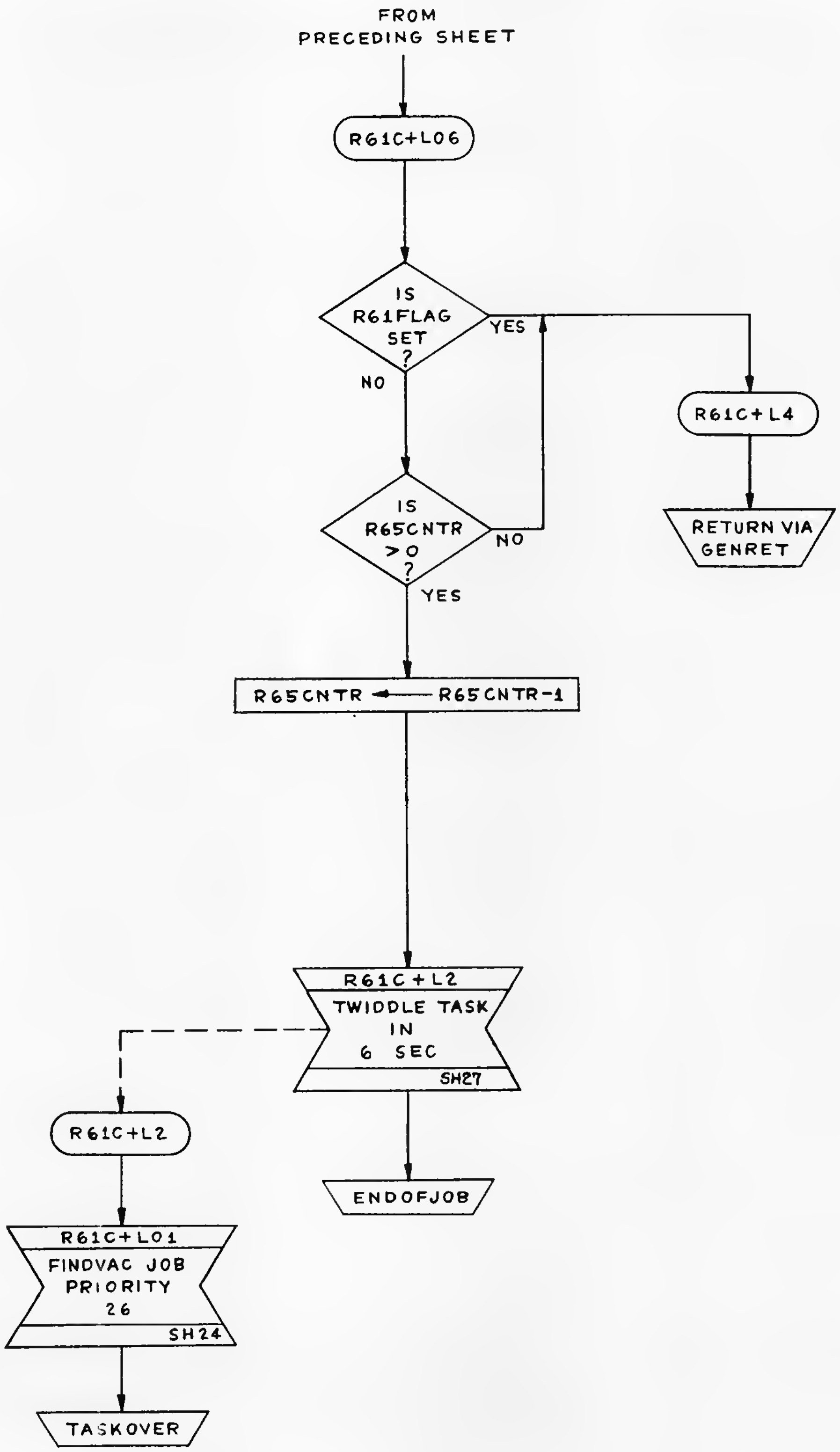
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A. J. Langille 12MAR69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR R. V. Coletto 10/21/69	LUMINARY 1D
ANALST	DOCUMENT NO. FC-3600
DOCMR W C Dostert 4-7-69	
APPR'D S. M. Estes 10/21/69	REV 2 — SHEET 24 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN [illegible]	12MAR69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGMR [illegible]	10/21/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3600
DOCMR [illegible]	4-7-69		
APPR'D [illegible]	10/21/69	REV 2	SHEET 25 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN 12 MAR 69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGMR 10/21/69	LUMINARY 1D	DOCUMENT NO. FC-3600
ANALST		
DOCMR 4-7-69		
APPR'D 10/21/69	REV 2	SHEET 26 OF 103



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DRAWN		12 MAR 69
PRGMR		10/21/69
ANALST		
DOCMR		4-7-69
APPR'D		10/21/69

APOLLO
GUIDANCE AND NAVIGATION

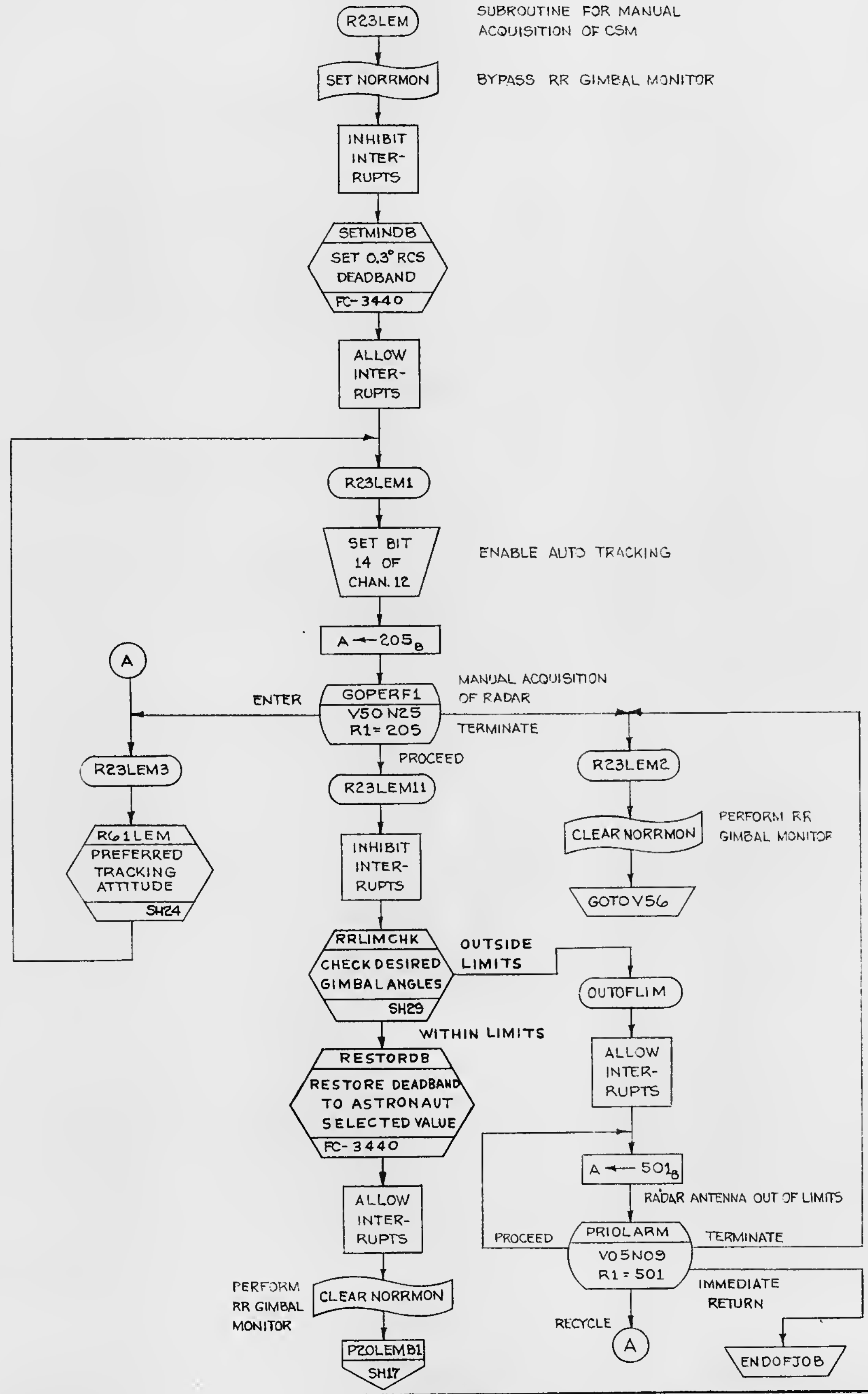
P20, P22
RENDEZVOUS & LUNAR SURFACE
NAVIGATION

LUMINARY 1D

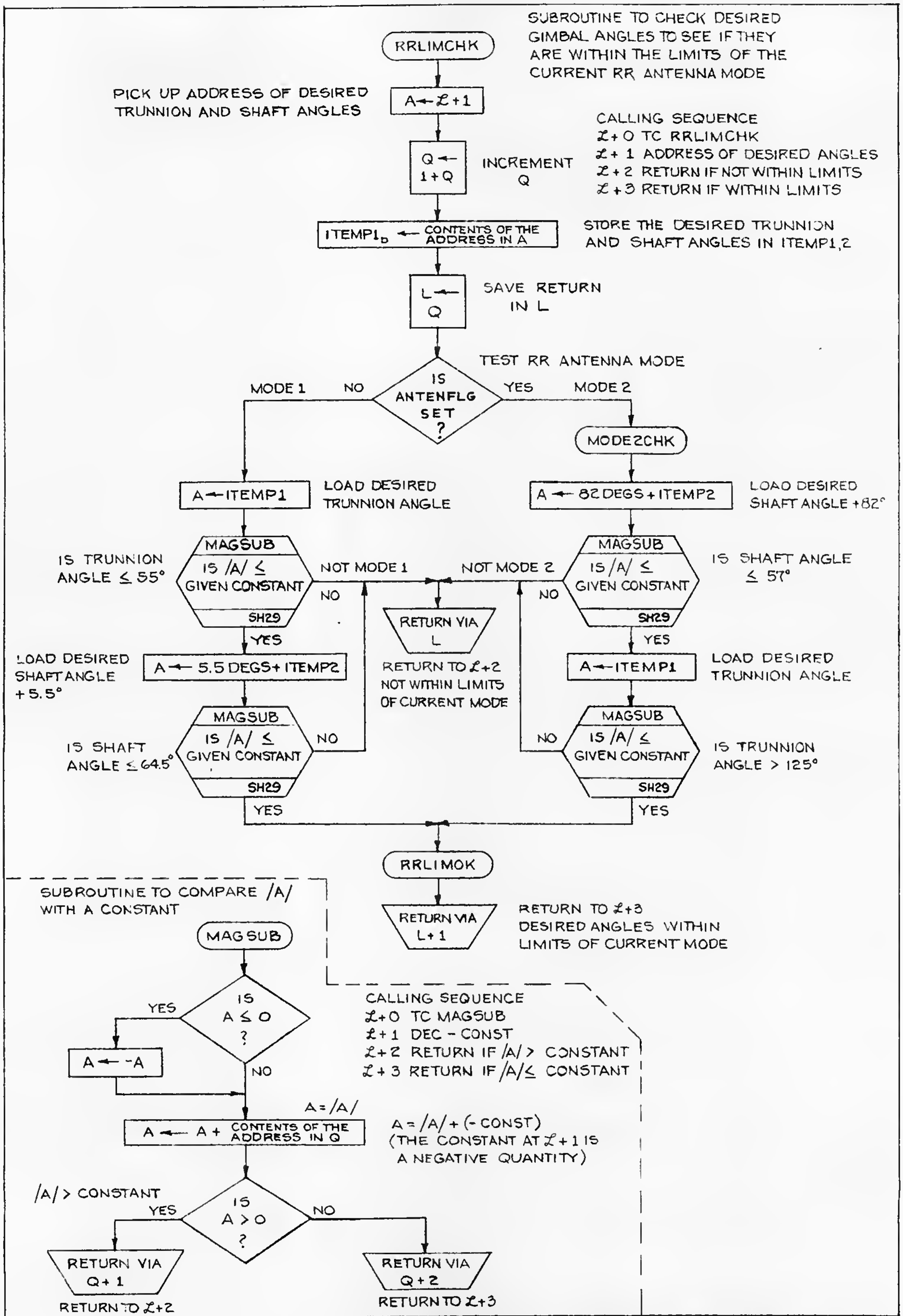
DOCUMENT NO. FC-3600

REV 2

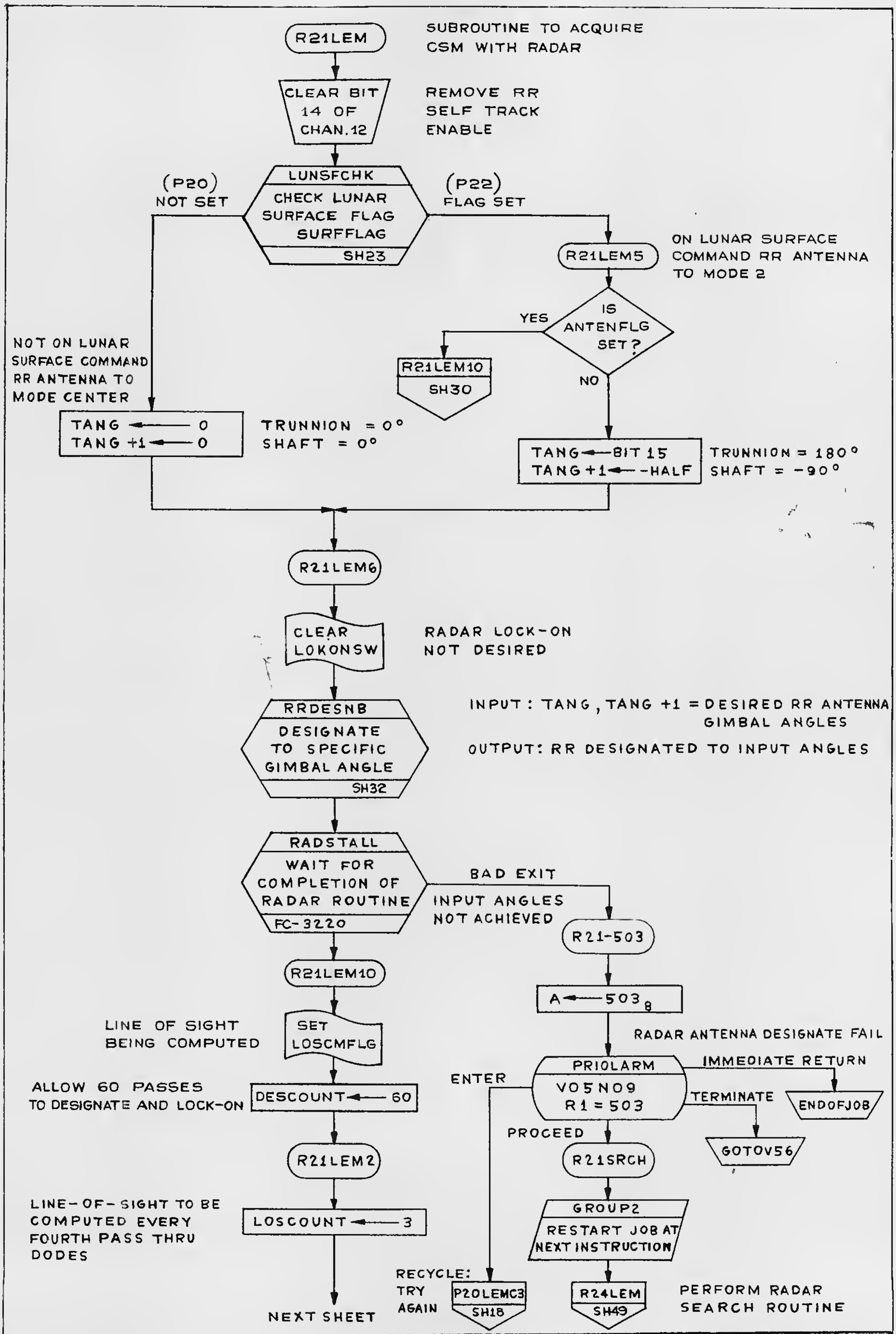
SHEET 27 OF 103



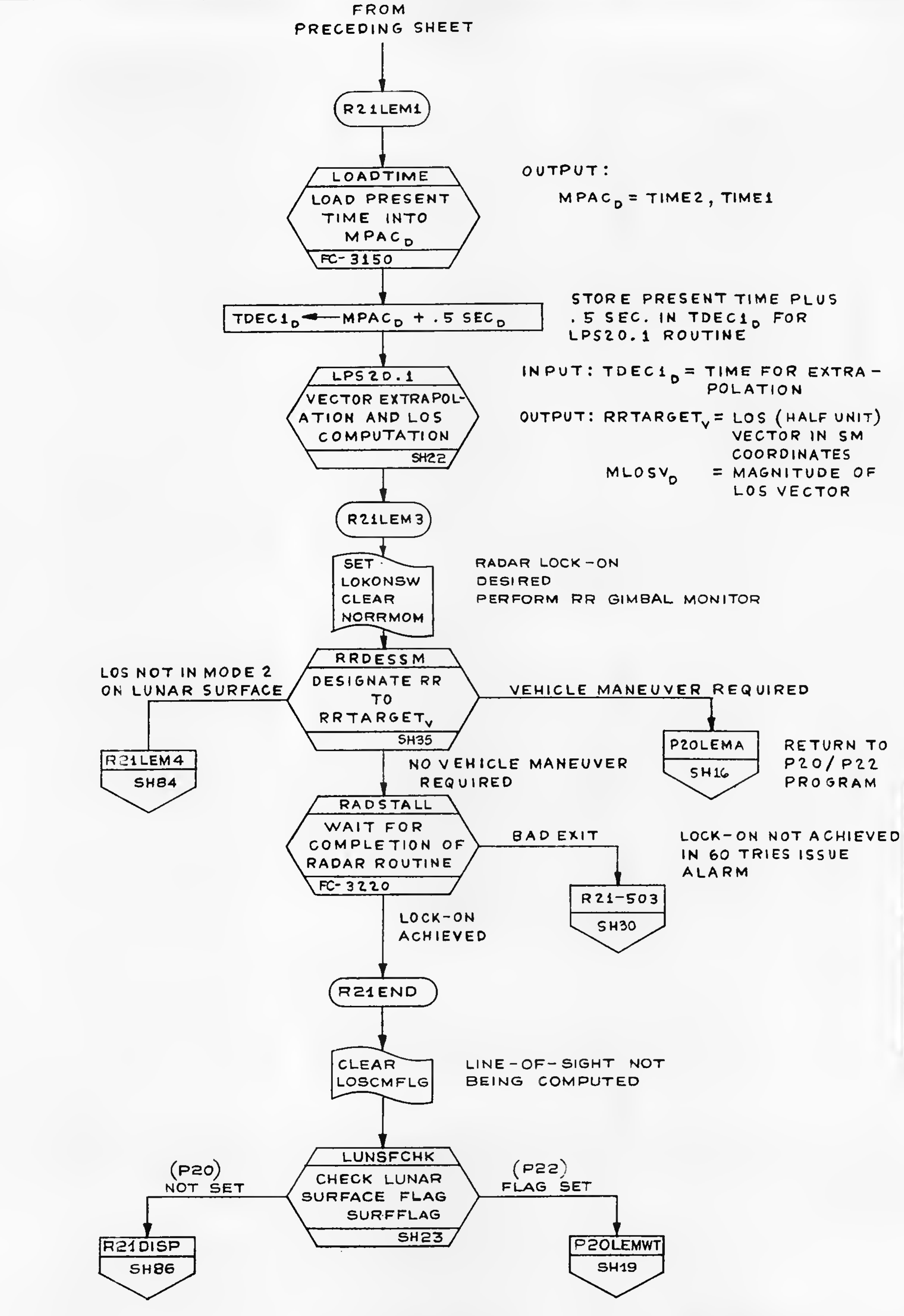
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
DRAWN A.C.WILLIAMS	5-24-68	LUMINARY 1D	DOCUMENT NO. FC-3600
PRGMR Peter Volante	8-16-68		
ANALST			
DOCMR N. Dougherty	5-28-68		
APPR'D Alan A. Moss	29 Oct 68	REV 2	SHEET 28 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 3-4-68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR Peter Volante 8-16-68	LUMINARY 1D
ANALST	DOCUMENT NO. FC-3600
DOCMR W Daghita 5-17-68	REV 2
APPR'D John A. Moore 29 Oct 68	SHEET 29 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A. J. Longillo 13MAR69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR 10/21/69	
ANALST	LUMINARY 1D — DOCUMENT NO. FC-3600
DOCMR W C Dabritz 4-7-69	
APPR'D 10/21/69	REV 2 — SHEET 30 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	A. J. Lanzillo 13MAR67	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGMR	10/21/69	LUMINARY 1D	DOCUMENT NO. FC-3600
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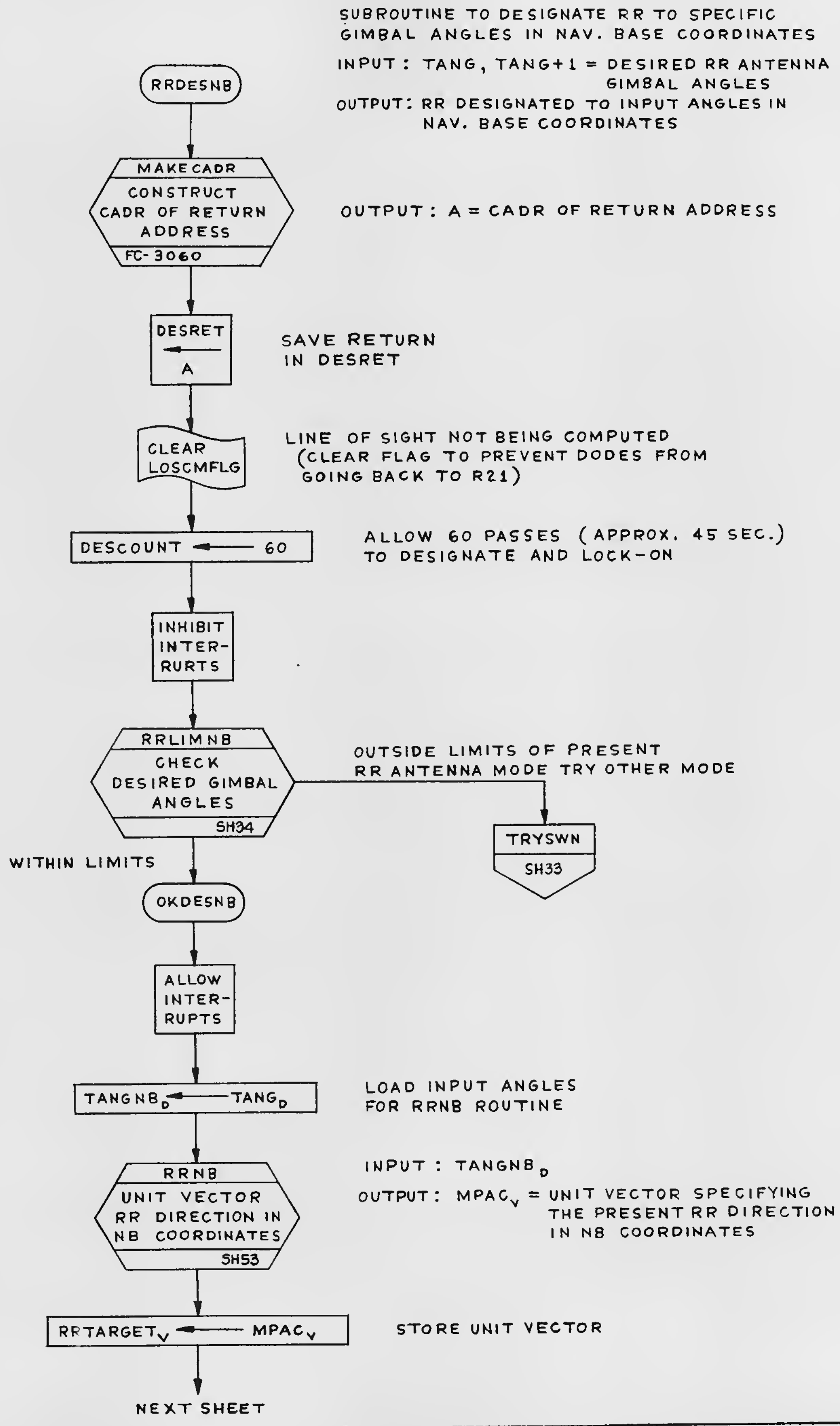
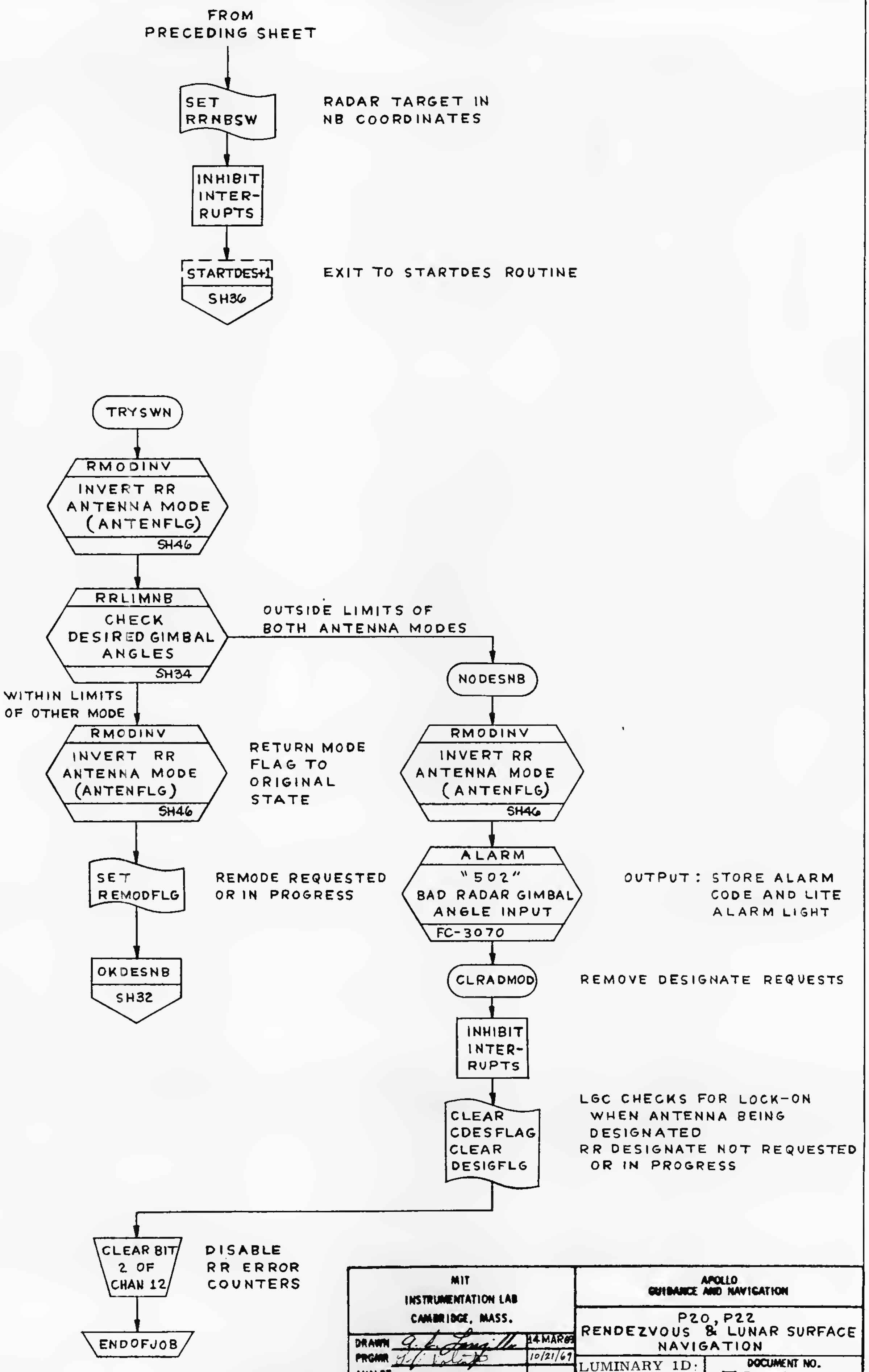
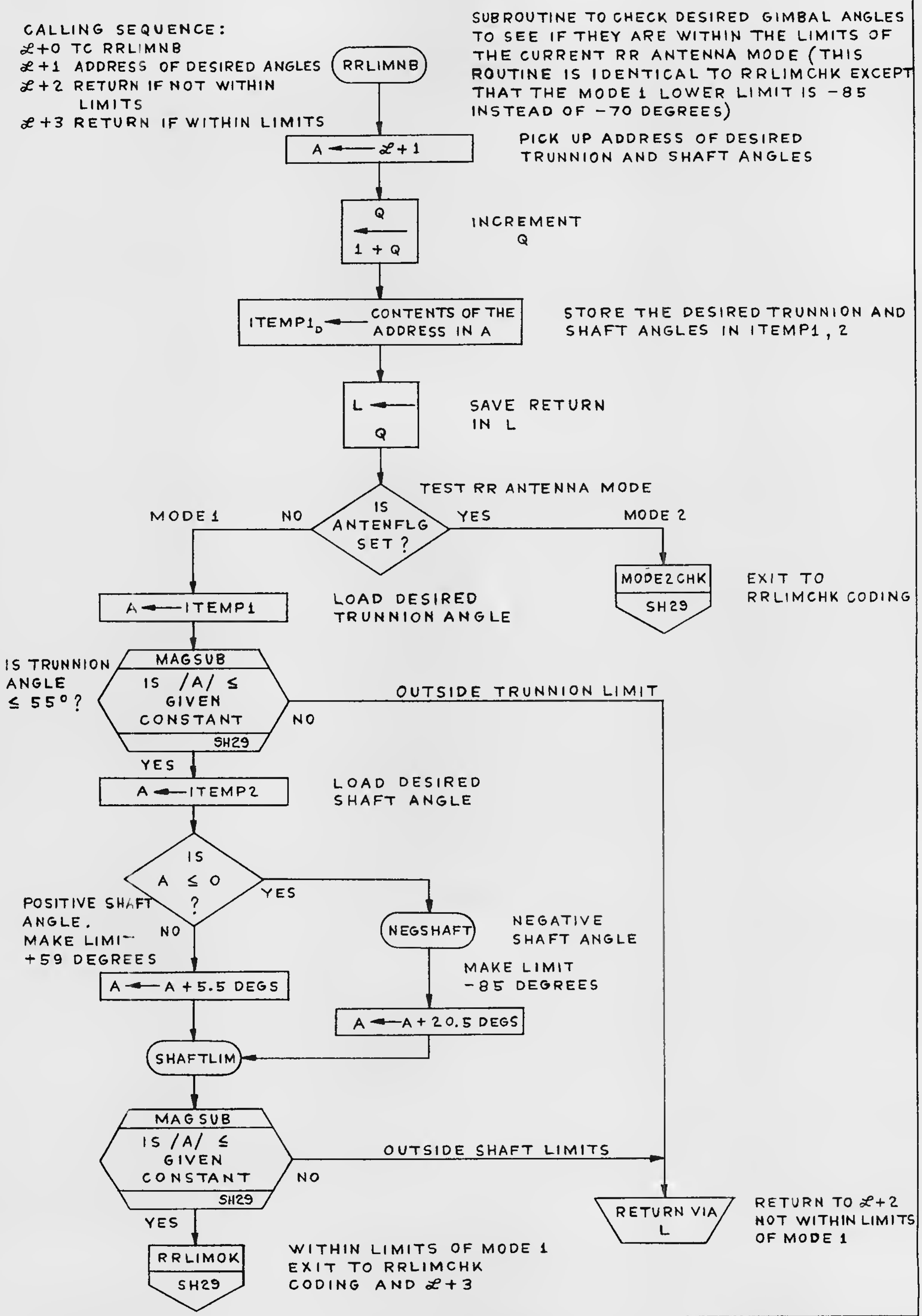
DOCMR	W.C. Deford 4-7-67		
APPR'D	J. M. Estes 10/21/69	REV 2	SHEET 31 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN 14MAR69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PROGMR 10/21/69	LUMINARY 1D — DOCUMENT NO. FC-3600
ANALST	
DOCMR 4-7-69	
APPR'D 10/21/69	REV 2 — SHEET 32 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN G. L. Langille	14 MAR 69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR	10/21/69	LUNARY 1D:
ANALST		DOCUMENT NO. FC-3600
DOCMR W. C. Dreftstt	4-7-69	
APPR'D B. M.	10/21/69	REV 2 — SHEET 33 OF 103

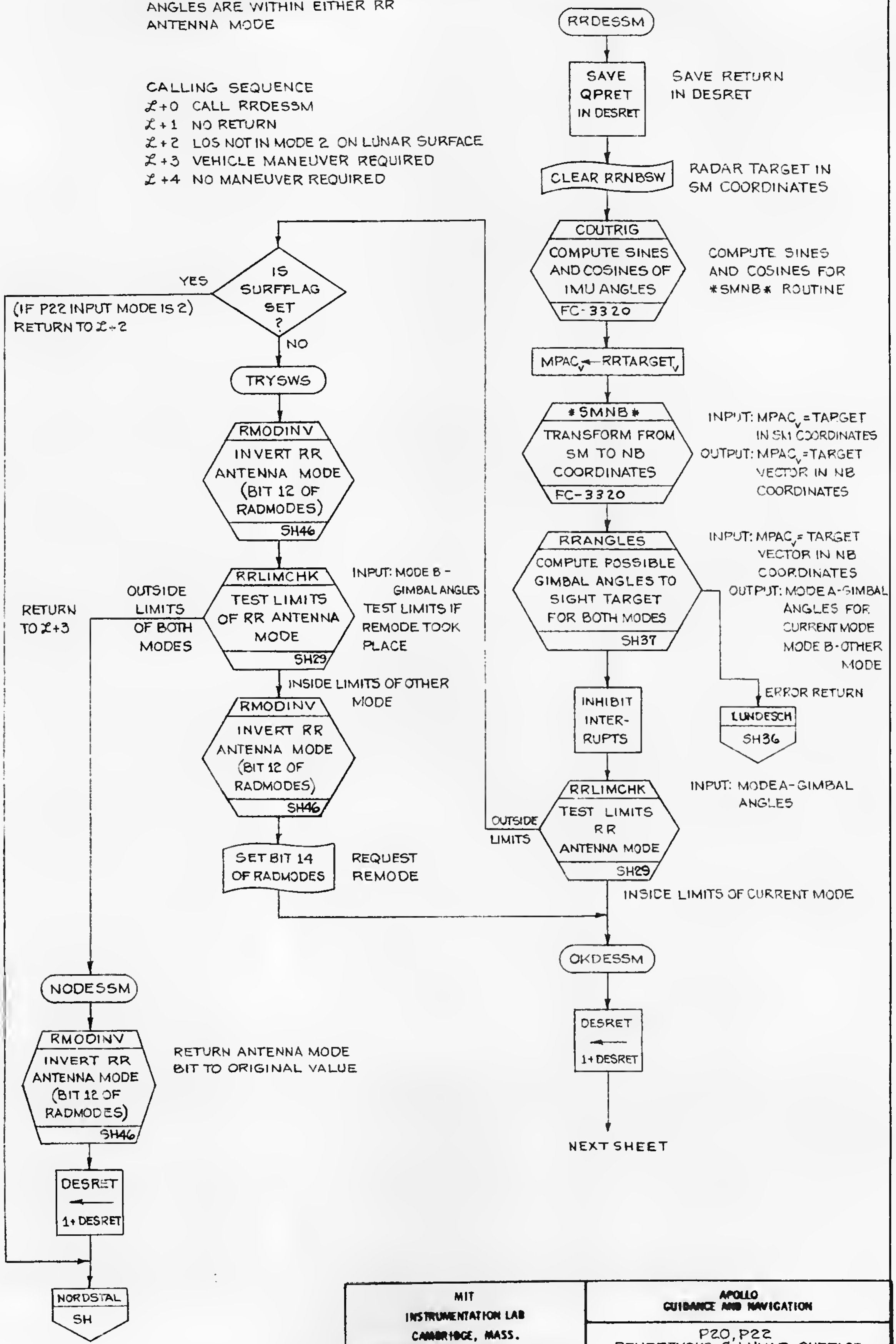


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	A. A. Lonigro 14MAR69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGMR	10/21/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3600
DOCMR	W.C. Doherty 4-7-69		
APPR'D	10/21/69	REV 2	SHEET 34 OF 103

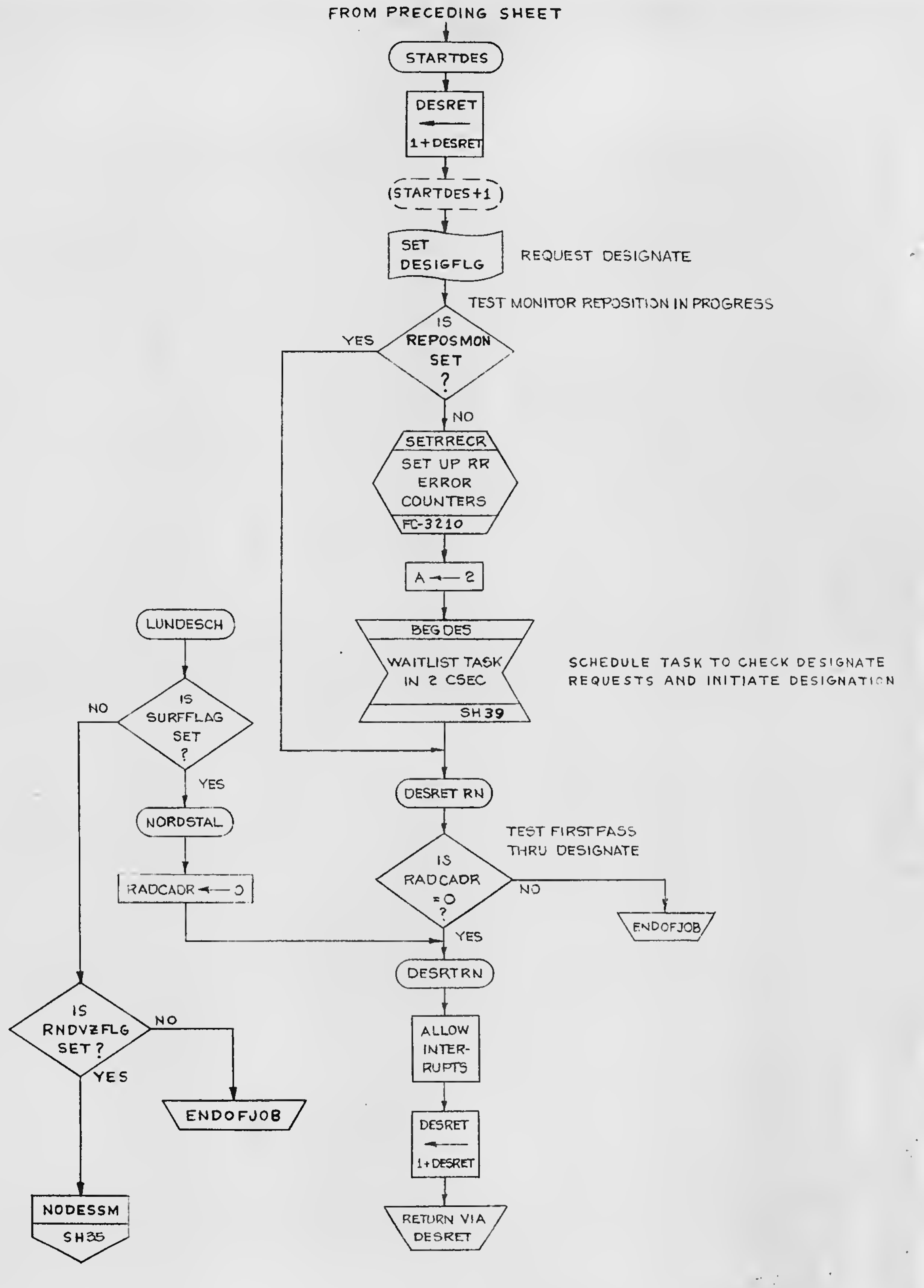
SUBROUTINE TO DESIGNATE IF DESIRED ANGLES ARE WITHIN EITHER RR ANTENNA MODE

CALLING SEQUENCE

- $\mathcal{L}+0$ CALL RRDESSM
- $\mathcal{L}+1$ NO RETURN
- $\mathcal{L}+2$ LOS NOT IN MODE 2 ON LUNAR SURFACE
- $\mathcal{L}+3$ VEHICLE MANEUVER REQUIRED
- $\mathcal{L}+4$ NO MANEUVER REQUIRED



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C. WILLIAMS 3-8-68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR Peter Volante 10/21/69	LUMINARY 1D — DOCUMENT NO. FC-3600
ANALST	
DOCMR W. Dyhrst 5-17-68	
APPR'D John A. Moore 29 Oct 68	REV 2 — SHEET 35 OF 103



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INSTRUMENTATION LAB
CAMBRIDGE, MASS.

DRAWN	A.C.WILLIAMS	3-11-68
PROGMR	Pete Volante	10/21/67
ANALST		
DOCMR	W. Doolittle	5-17-68
APPR'D	John A. Moore	29 Oct 68

APOLLO
GUIDANCE AND NAVIGATION

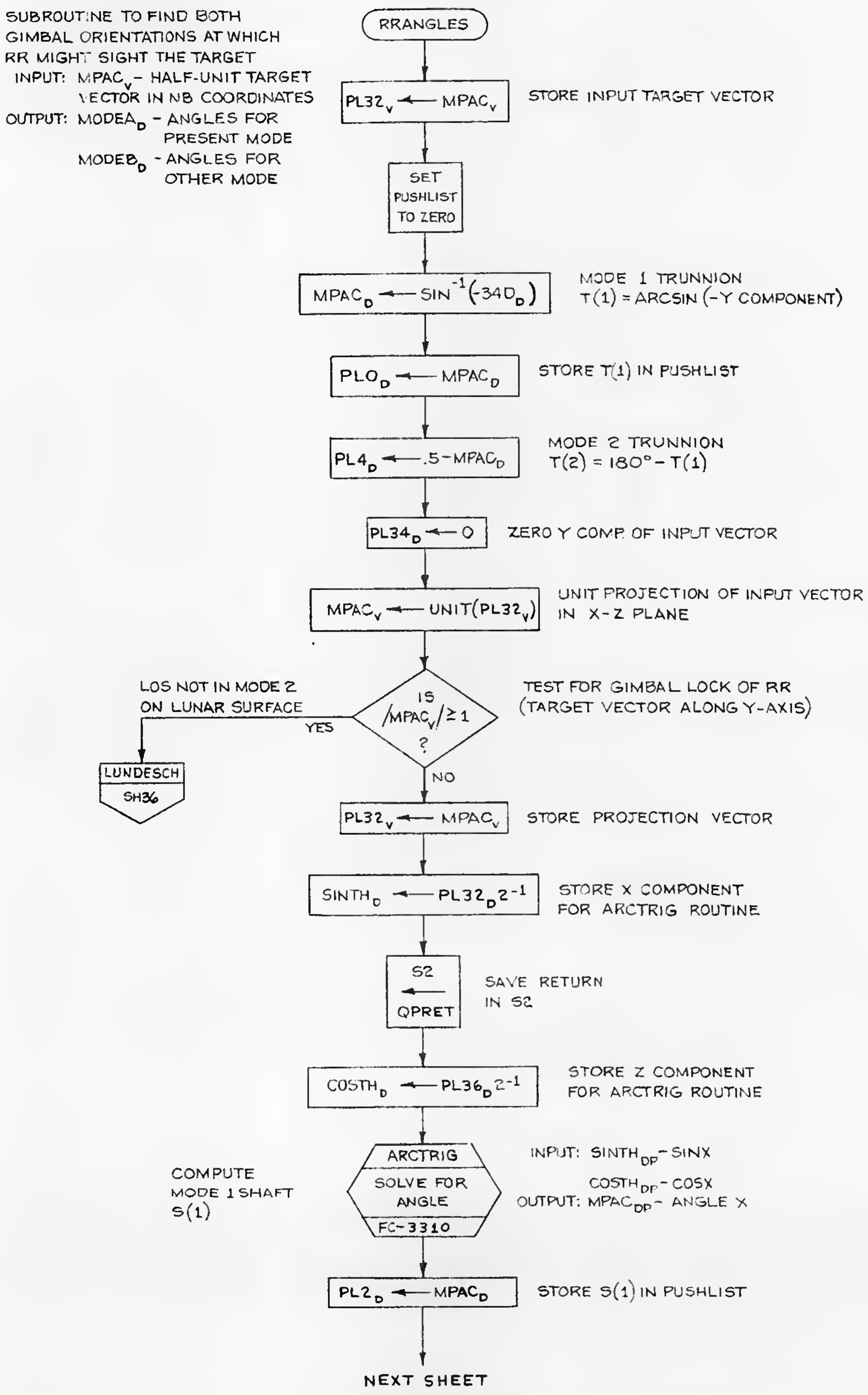
P20, P22
RENDEZVOUS & LUNAR SURFACE NAVIGATION

LUMINARY 1D

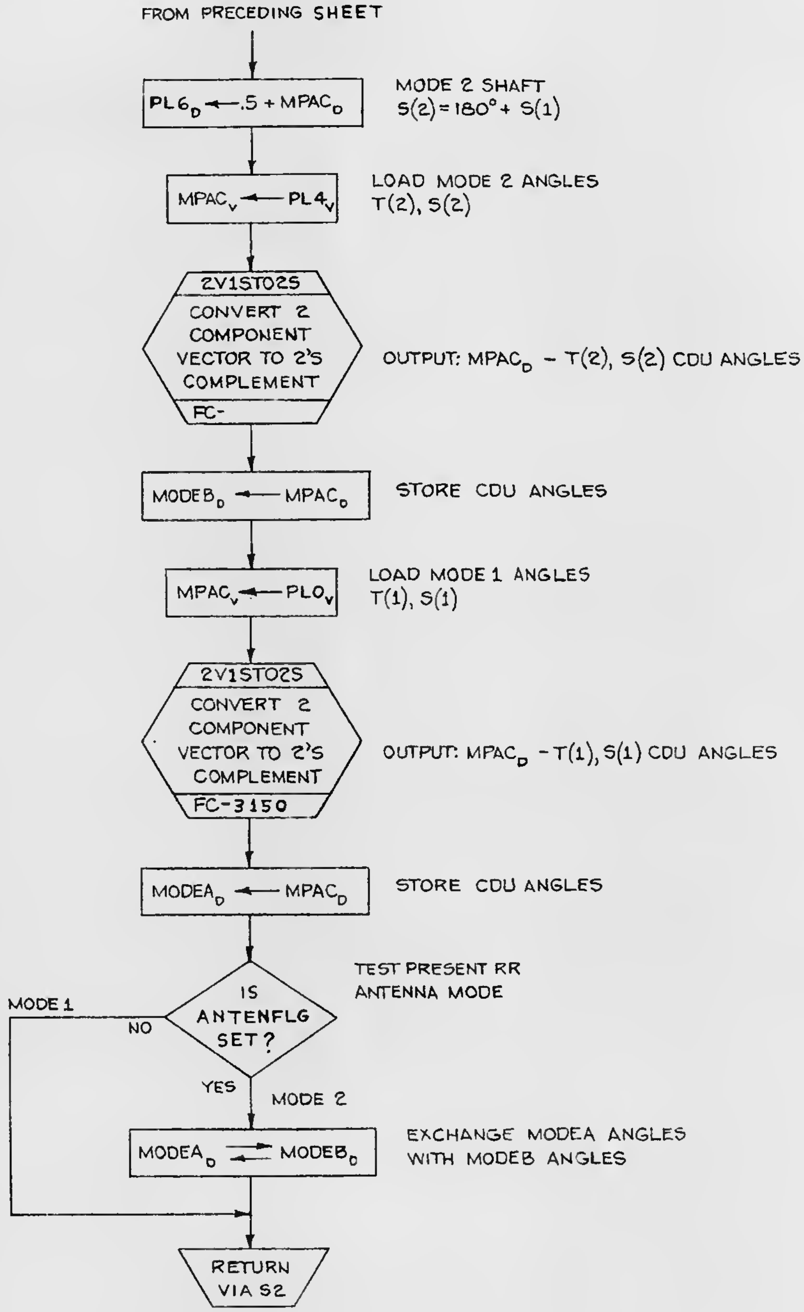
DOCUMENT NO. FC-3600

REV 2

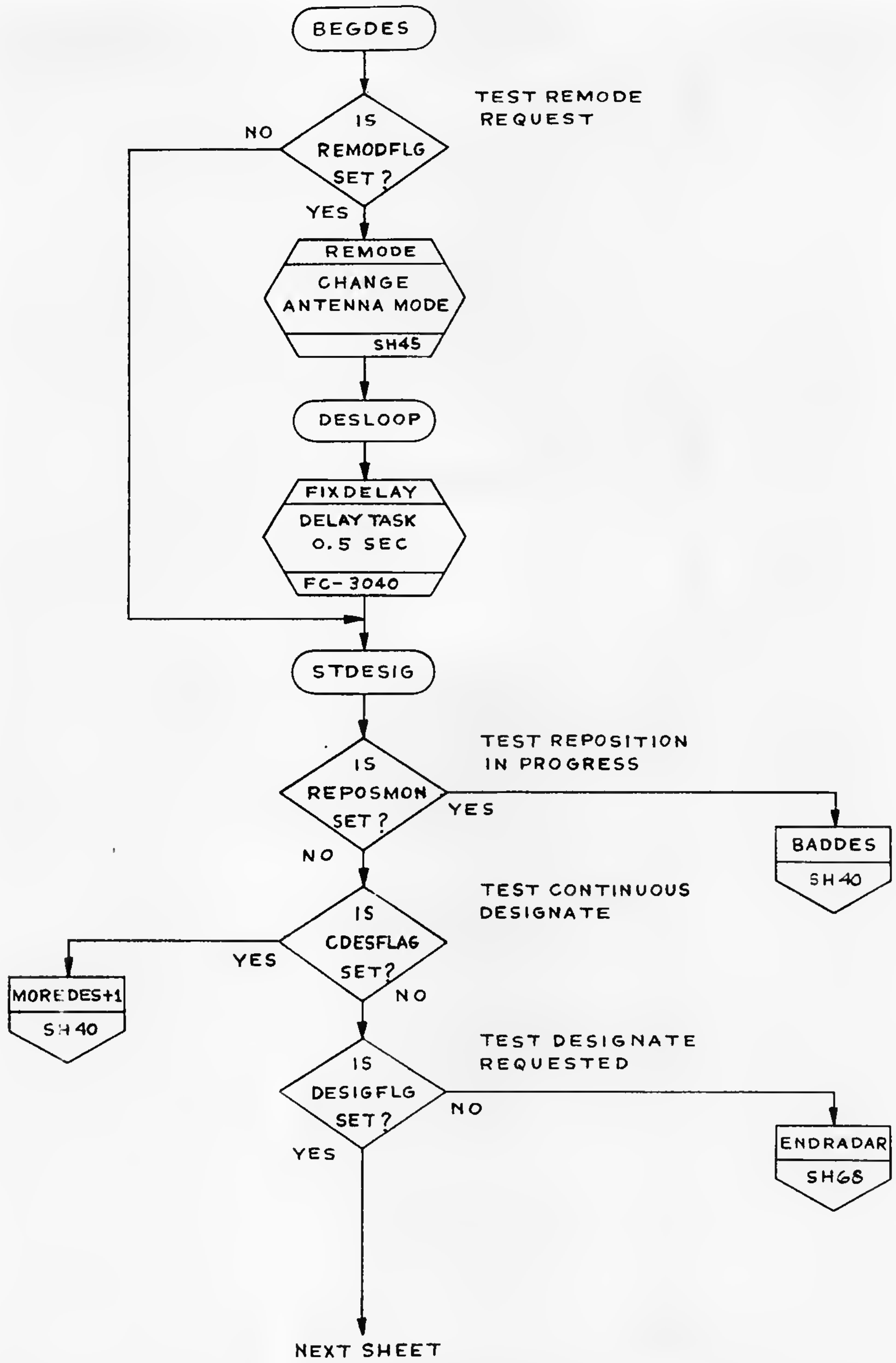
SHEET 36 OF 103



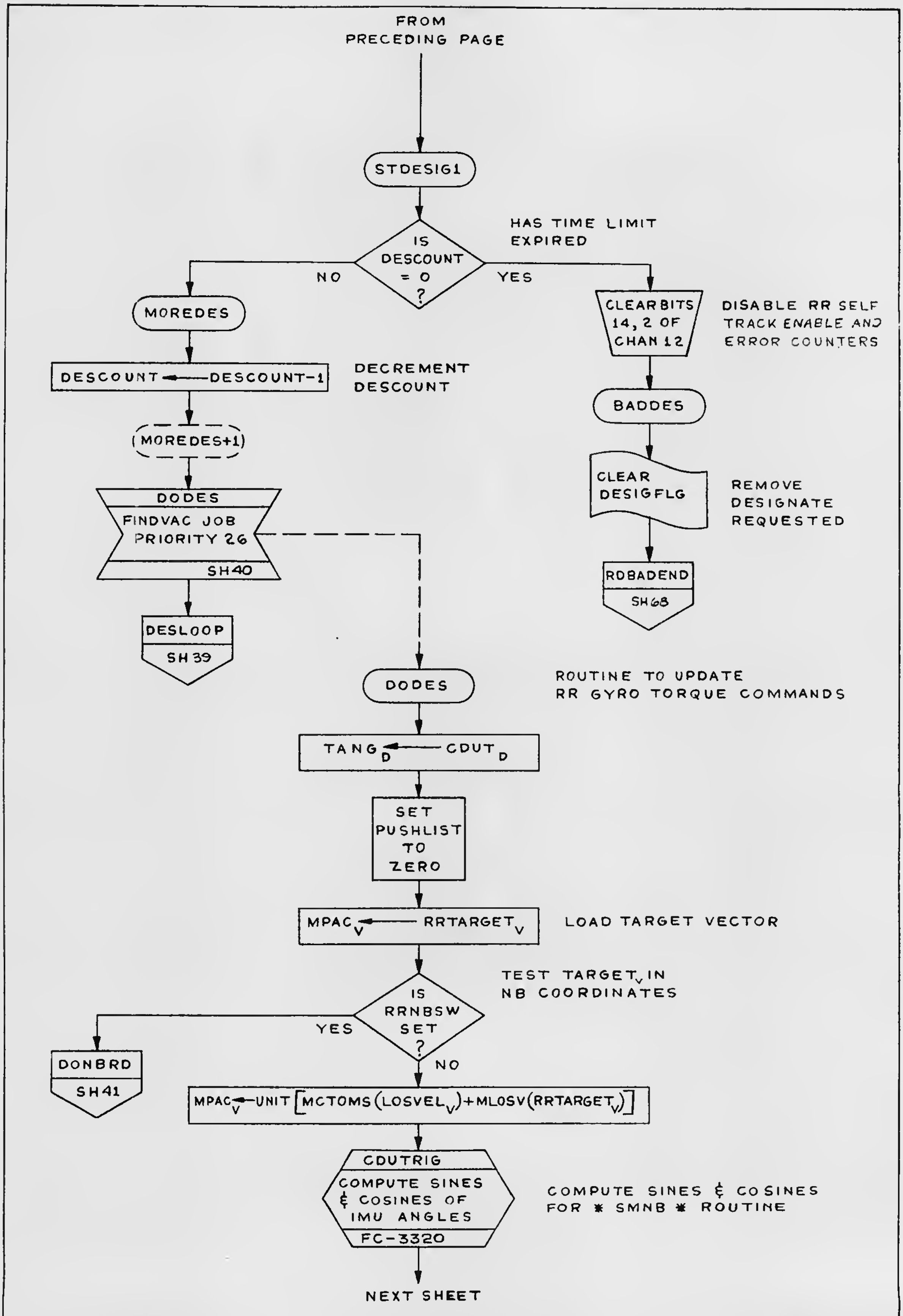
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C. WILLIAMS 4-2-68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR Peter Volante 8-16-68	LUMINARY 1D
ANALST	DOCUMENT NO. FC-3600
DOCMR W. Dykstra 5-17-68	
APPR'D John A. Moore 29 Oct 68	REV 2 — SHEET 37 OF 103



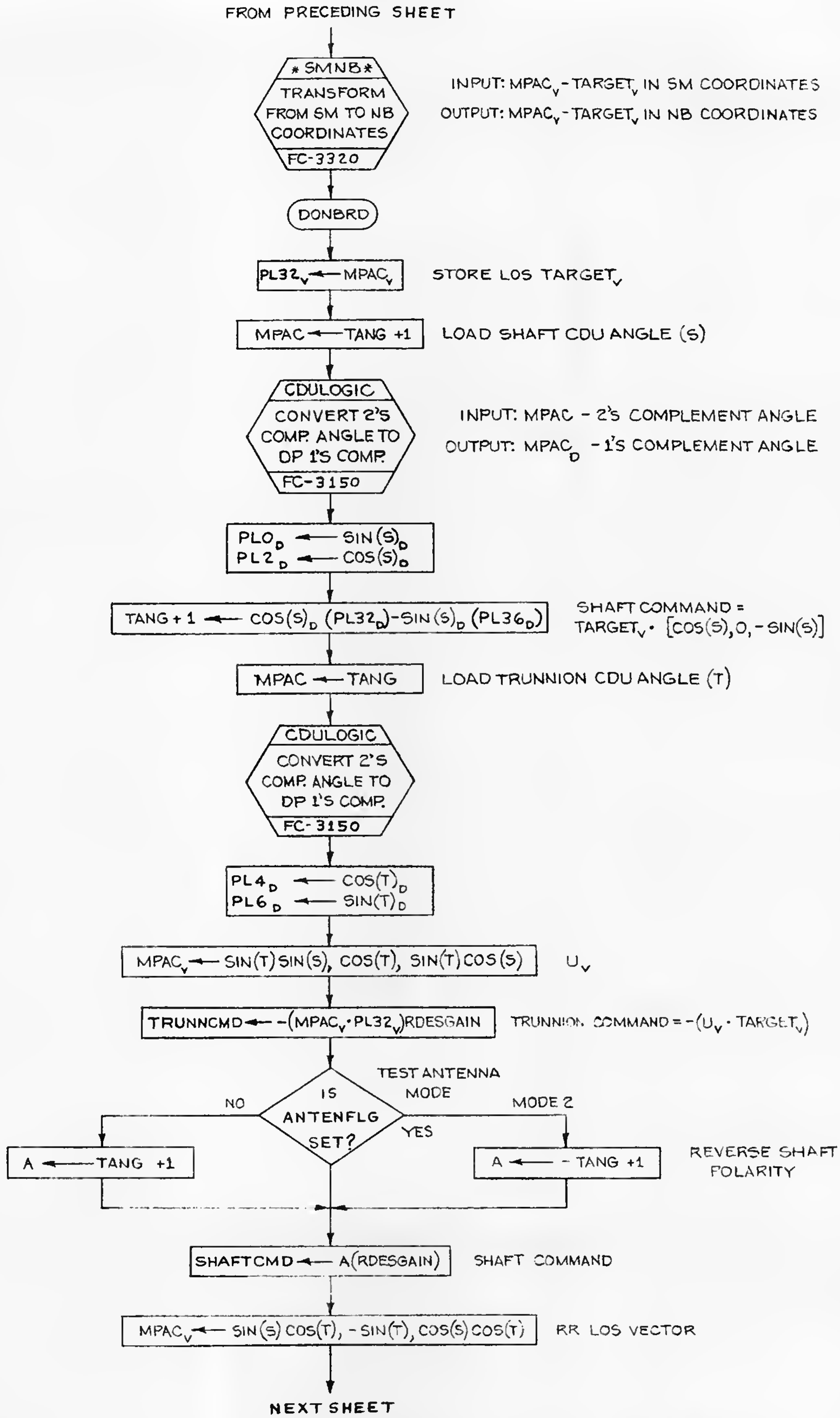
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS	4-2-68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGMR Pete Volante	8-16-68	LUMINARY 1D	DOCUMENT NO. FC-3600
ANALYST			
DOCMNR W. Doolittle	3-17.68		
APPR'D John A. Moore	29 Oct 68	REV 2	SHEET 38 OF 103



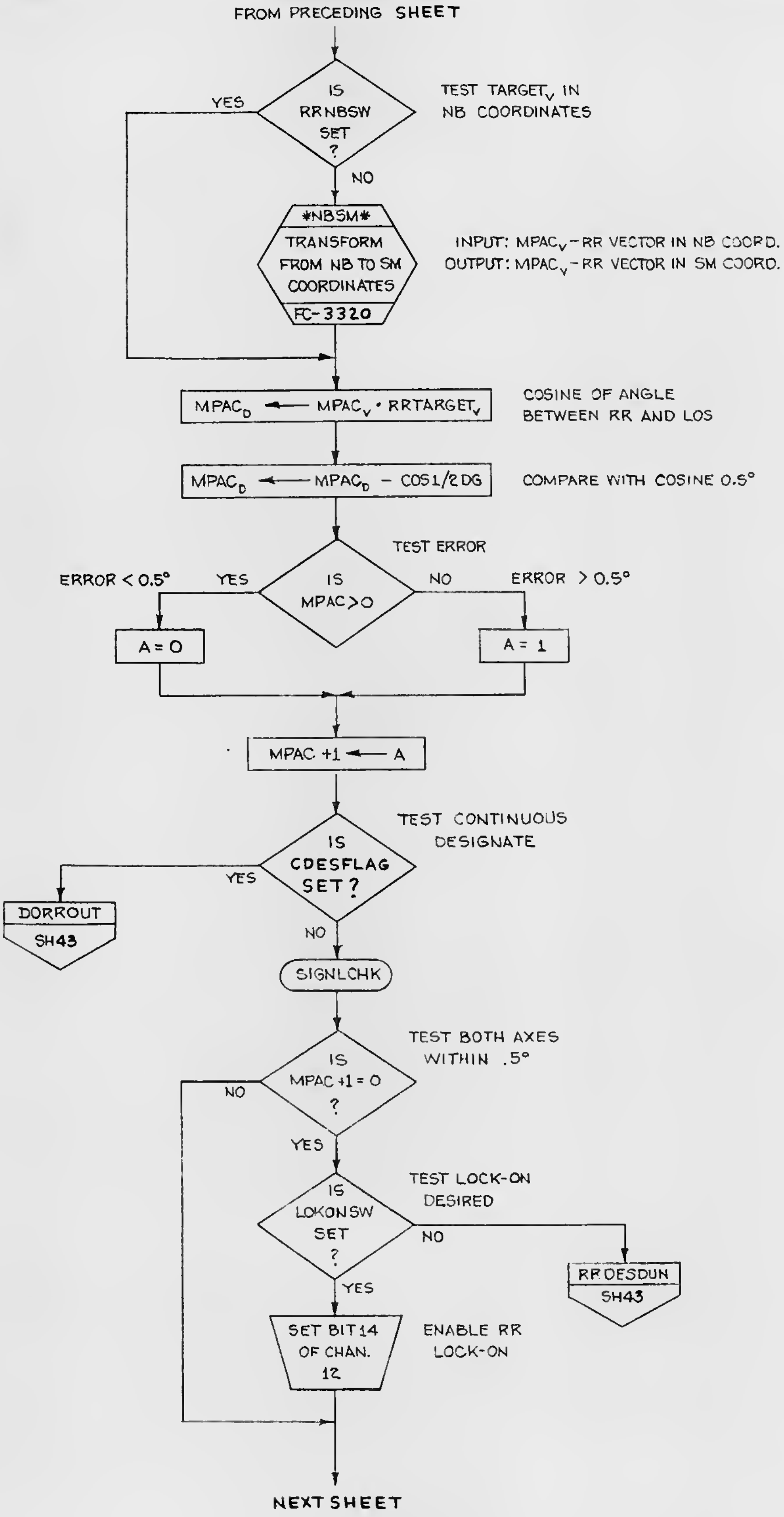
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN 12 MARCH	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR 16 AUG 68	LUMINARY 1D
ANALST	DOCUMENT NO. FC-3600
DOCMR 17 MAY 68	
APPR'D 29 Oct 68	REV 2 — SHEET 39 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN 12 MAR	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGMR 16 AUG 68	LUMINARY 1D	DOCUMENT NO. FC-3600
ANALST		
DOCMR 19 MAY 68		
APPR'D 29 Oct 68	REV 2	SHEET 40 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C. WILLIAMS 3-13-68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR [signature] 8-16-68	LUMINARY 1D
ANALST	DOCUMENT NO. FC-3600
DOCMR [signature] 5-17-69	
APPR'D [signature] 24 Oct 68	REV 2 — SHEET 41 OF 103



MIT
INSTRUMENTATION LAB
CAMBRIDGE, MASS.

DRAWN	A.C.WILLIAMS	5-24-68
PRGMR	Peter Volante	8-16-68
ANALST		
DOCMR	W. Stanforth	5-28-68
APPR'D	John A. Moore	29 Oct 68

APOLLO
GUIDANCE AND NAVIGATION

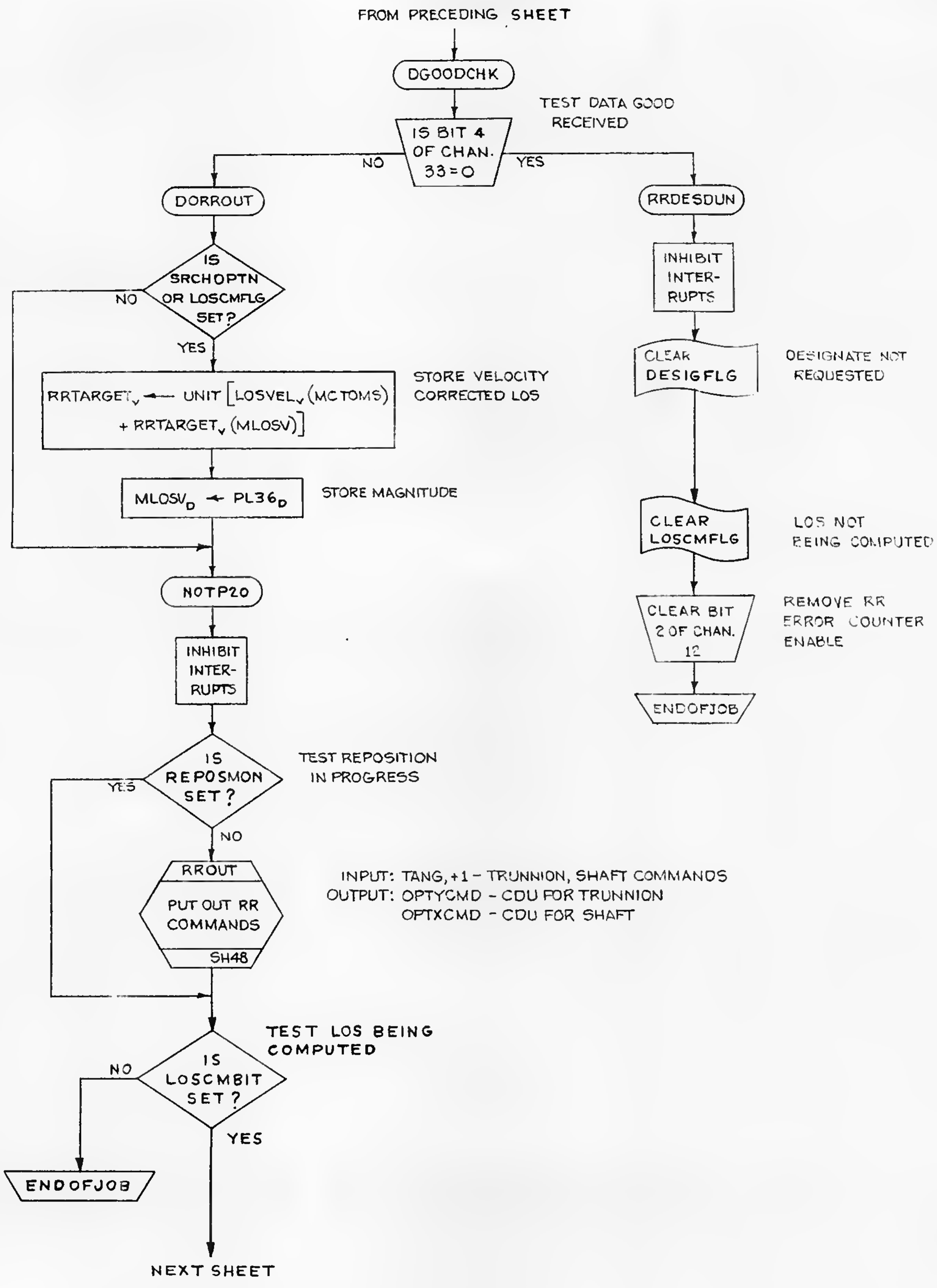
P20, P22
RENDEZVOUS & LUNAR SURFACE NAVIGATION

LUMINARY 1D

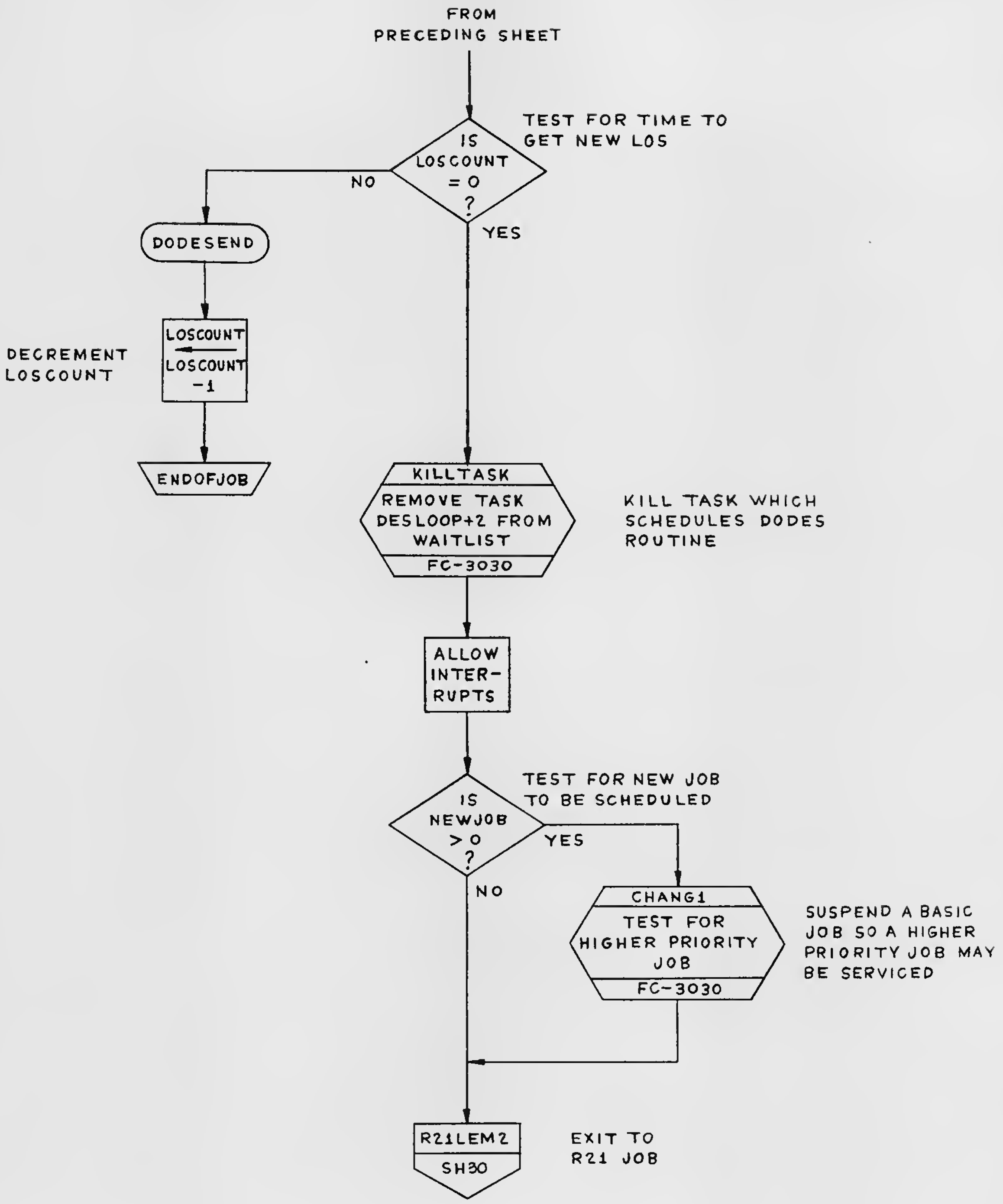
DOCUMENT NO. FC-3600

REV 2

SHEET 42 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 3-14-68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PROGMR Peter Volante 8-16-68	LUMINARY 1D
ANALST	DOCUMENT NO. FC-3600
DOCMR W. Doyle 5-17-68	
APPR'D John A. Moore 29 Oct 68	REV 2 | SHEET 43 OF 103



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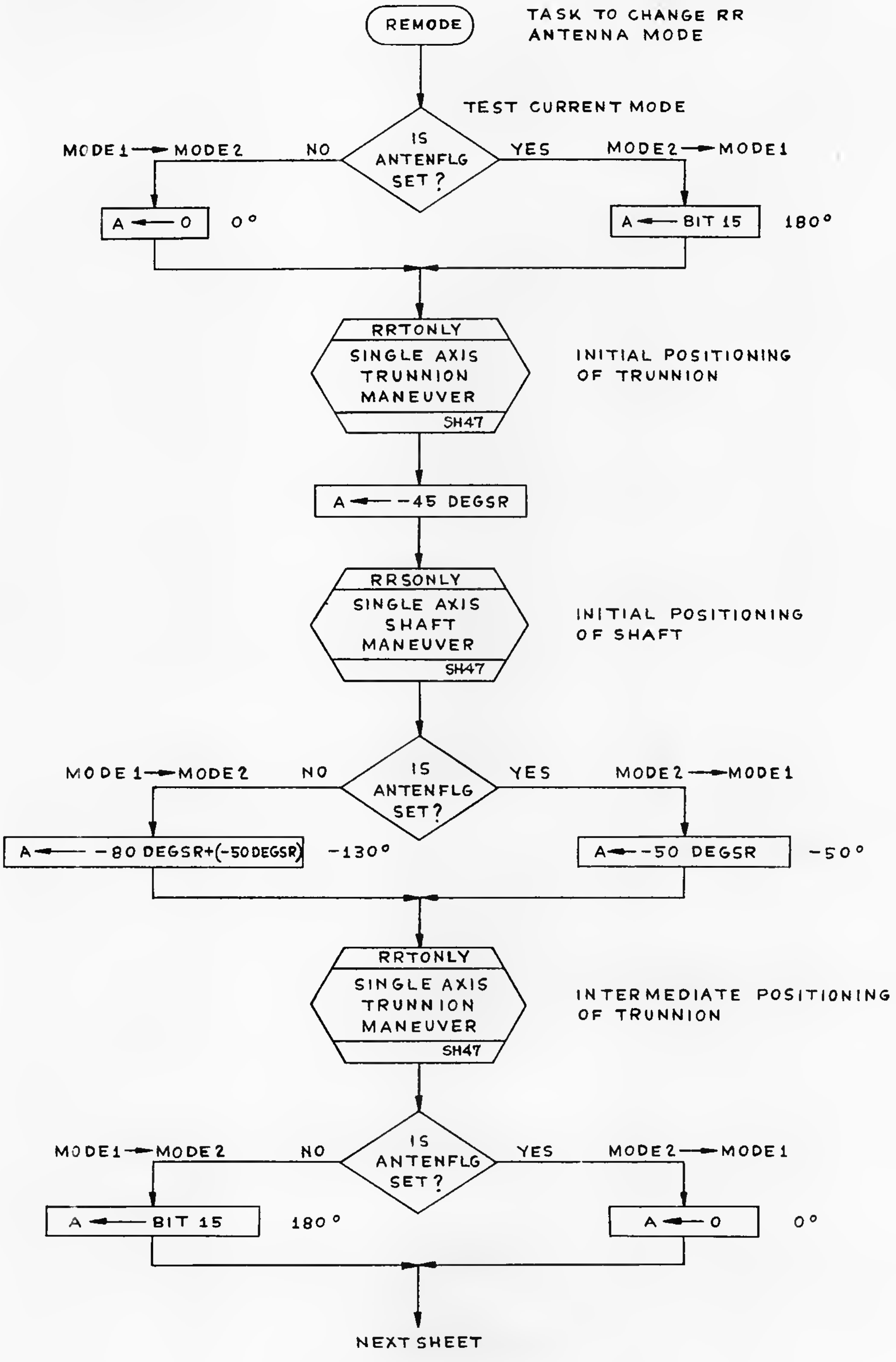
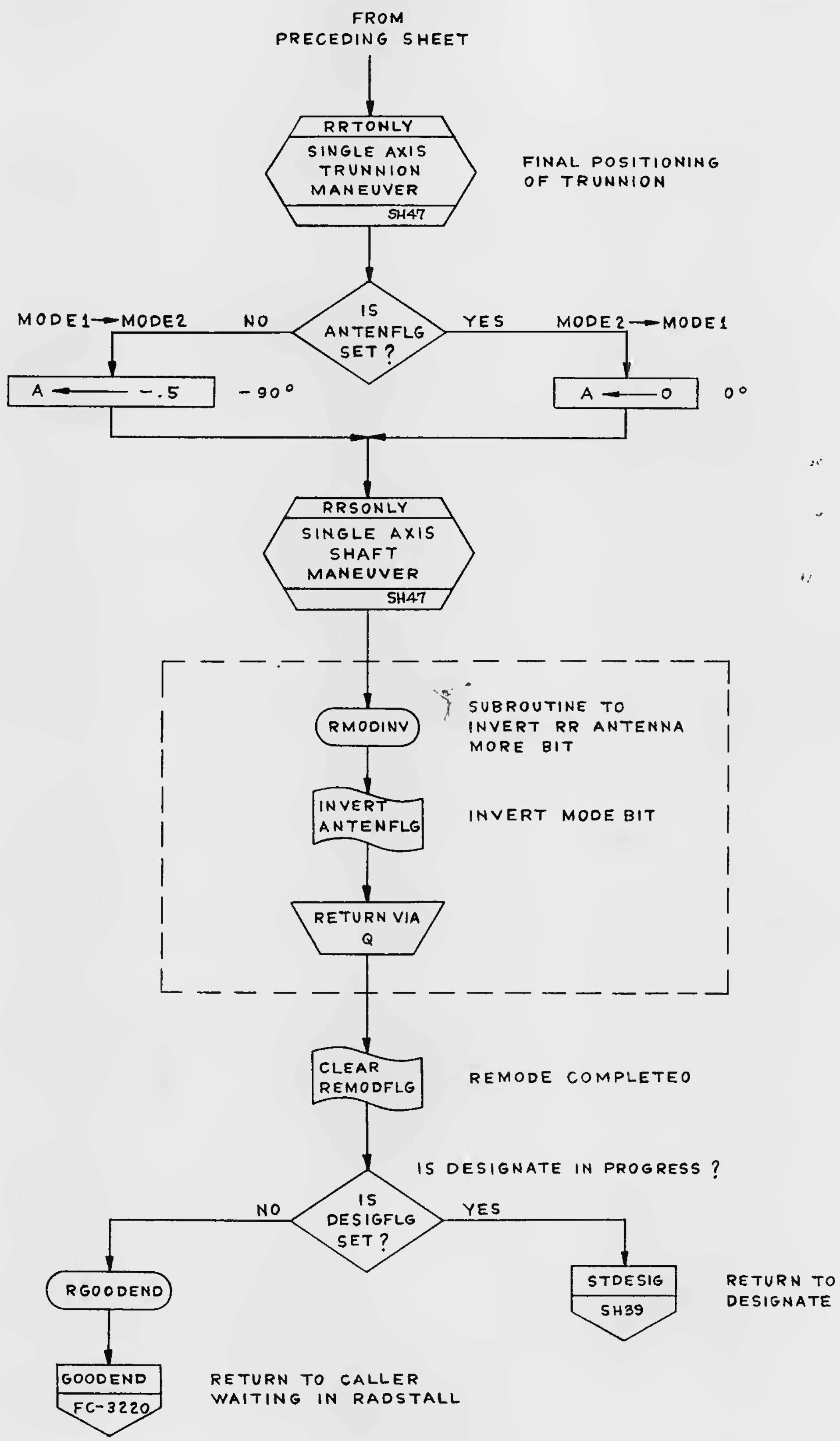
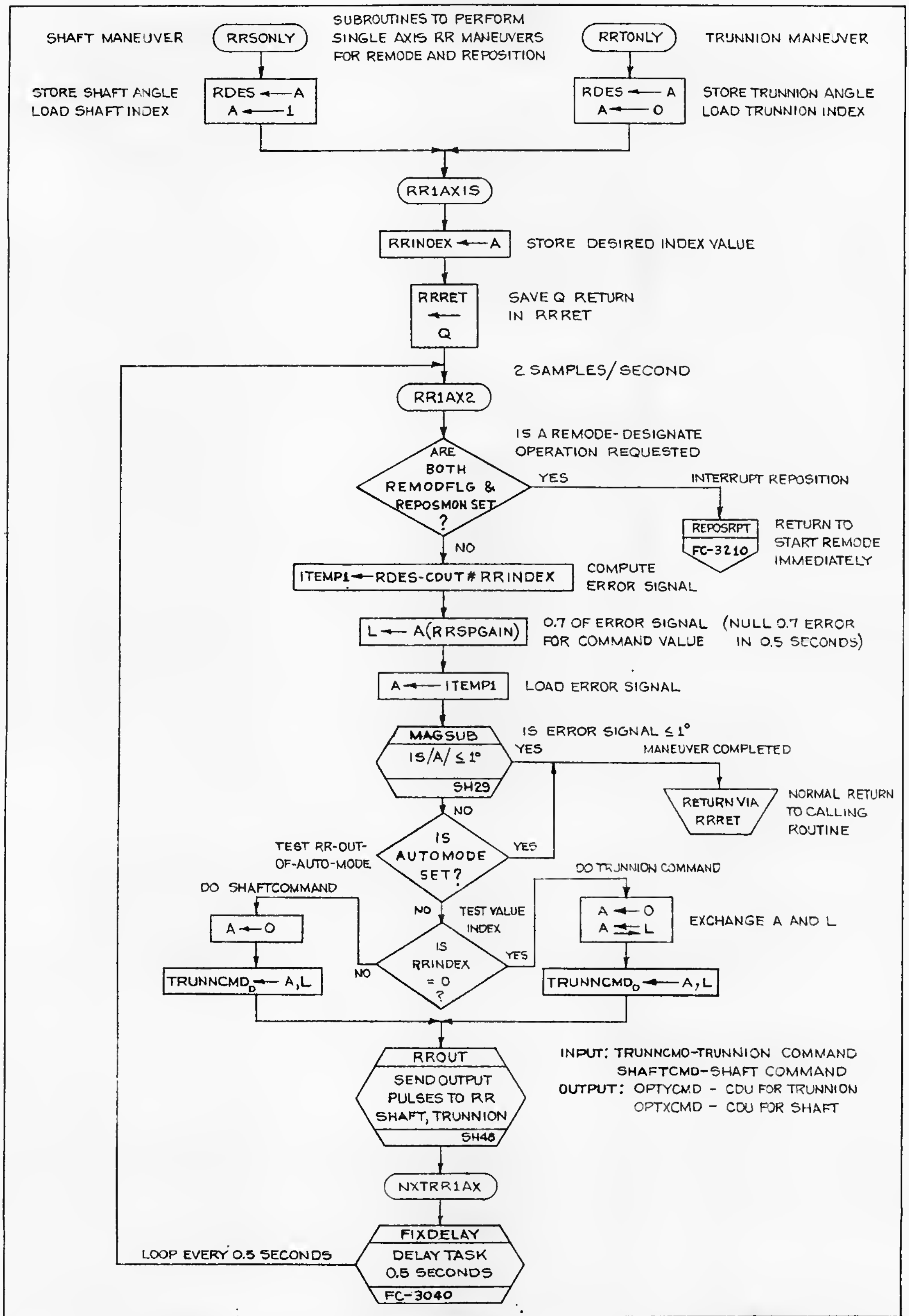
DRAWN	18MAR69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGMR	10/21/69	LUMINARY 1D	DOCUMENT NO. FC-3600
ANALST			
DOCMR	4-7-69		
APPR'D	10/21/69	REV 2	SHEET 44 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN 19 MAR 69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR 10/21/69	LUMINARY 1D — DOCUMENT NO. FC-3600
ANALST	
DOCMR 4-7-69	
APPR'D 10/21/69	REV 2 — SHEET 45 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A. J. Lanzillo	19 MAR 69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR	10/21/69	
ANALST		LUMINARY 1D — DOCUMENT NO. FC-3600
DOCMR W. C. Dodsworth	4-7-69	
APPR'D	10/21/69	REV 2 — SHEET 46 OF 103



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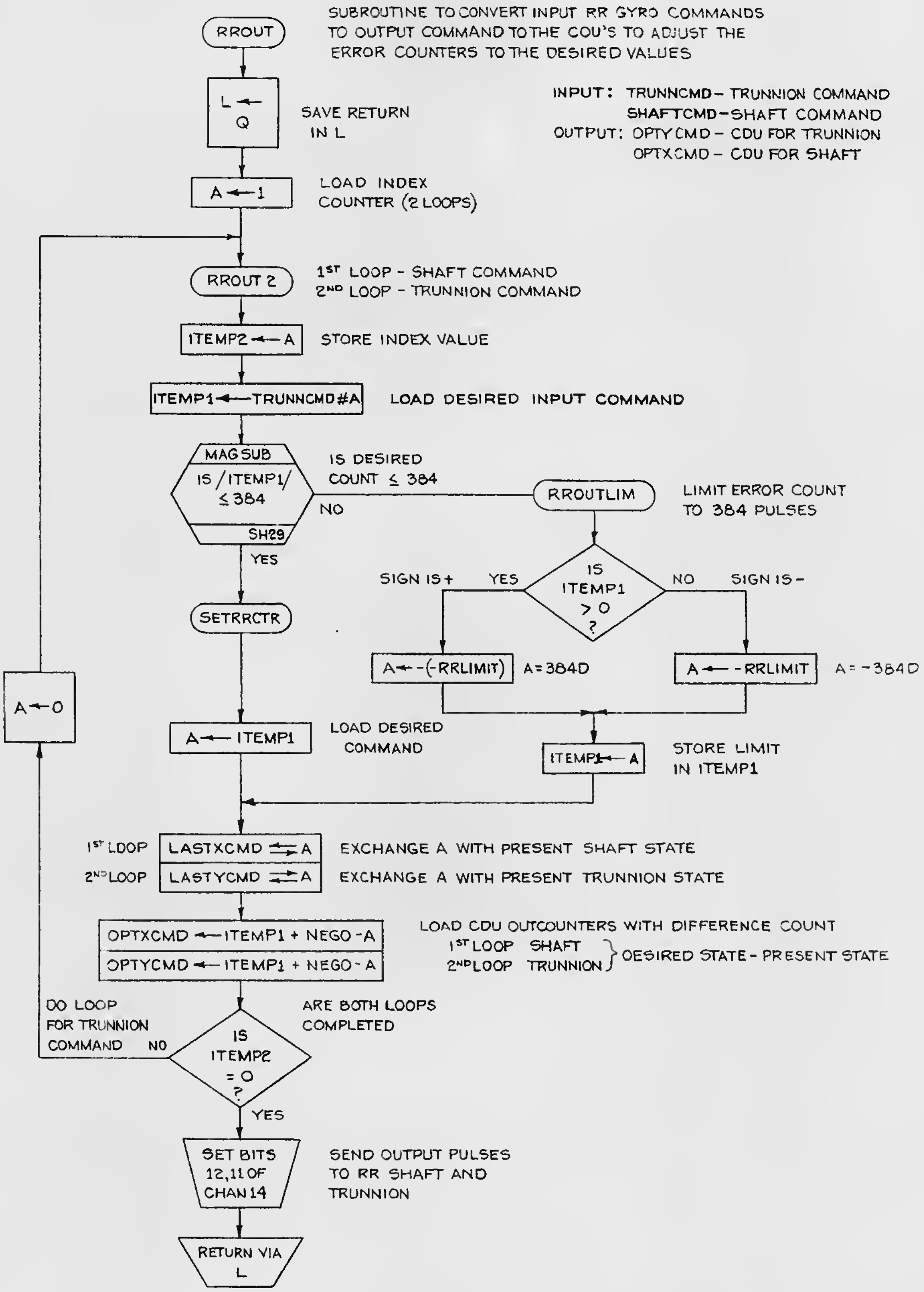
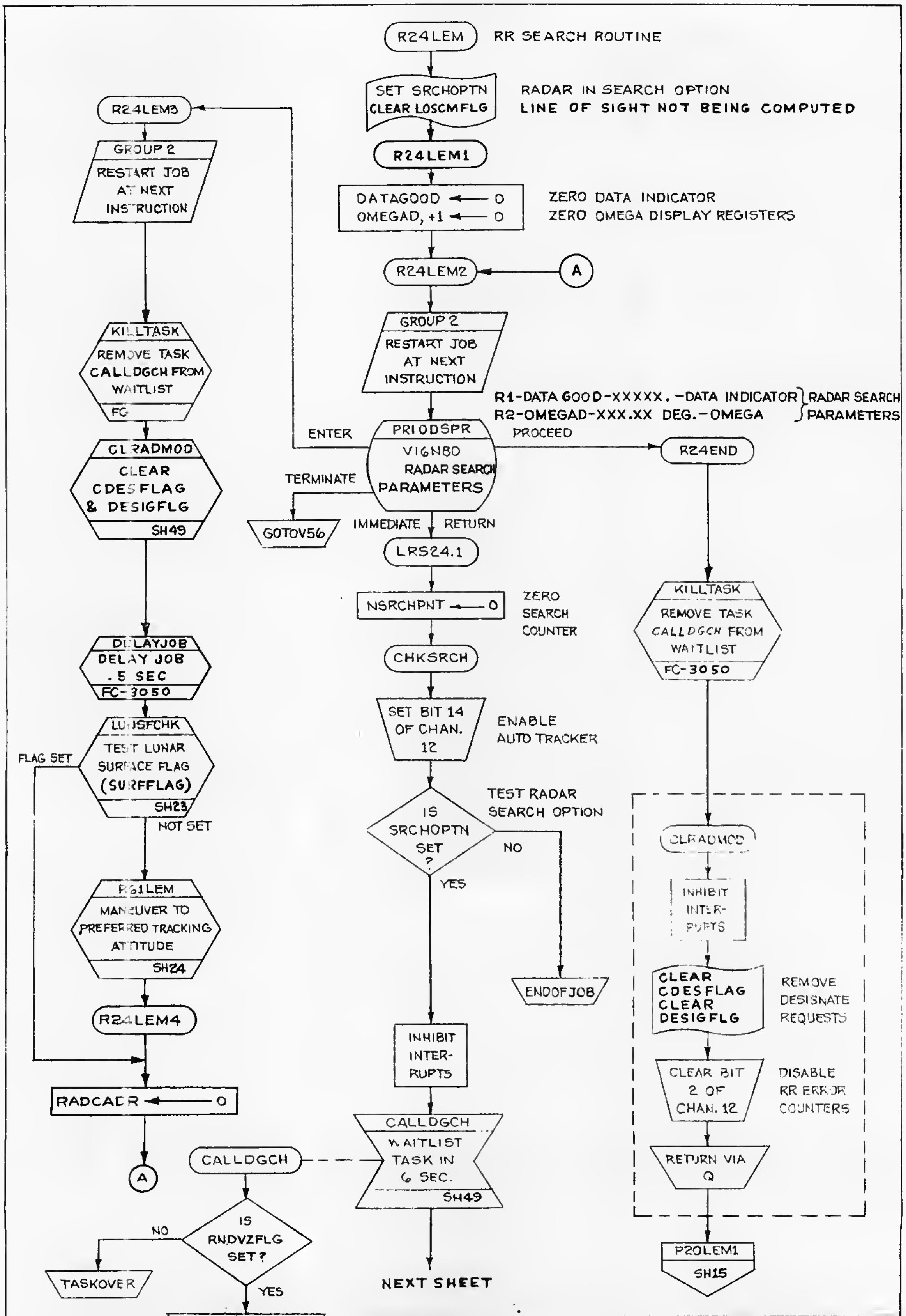
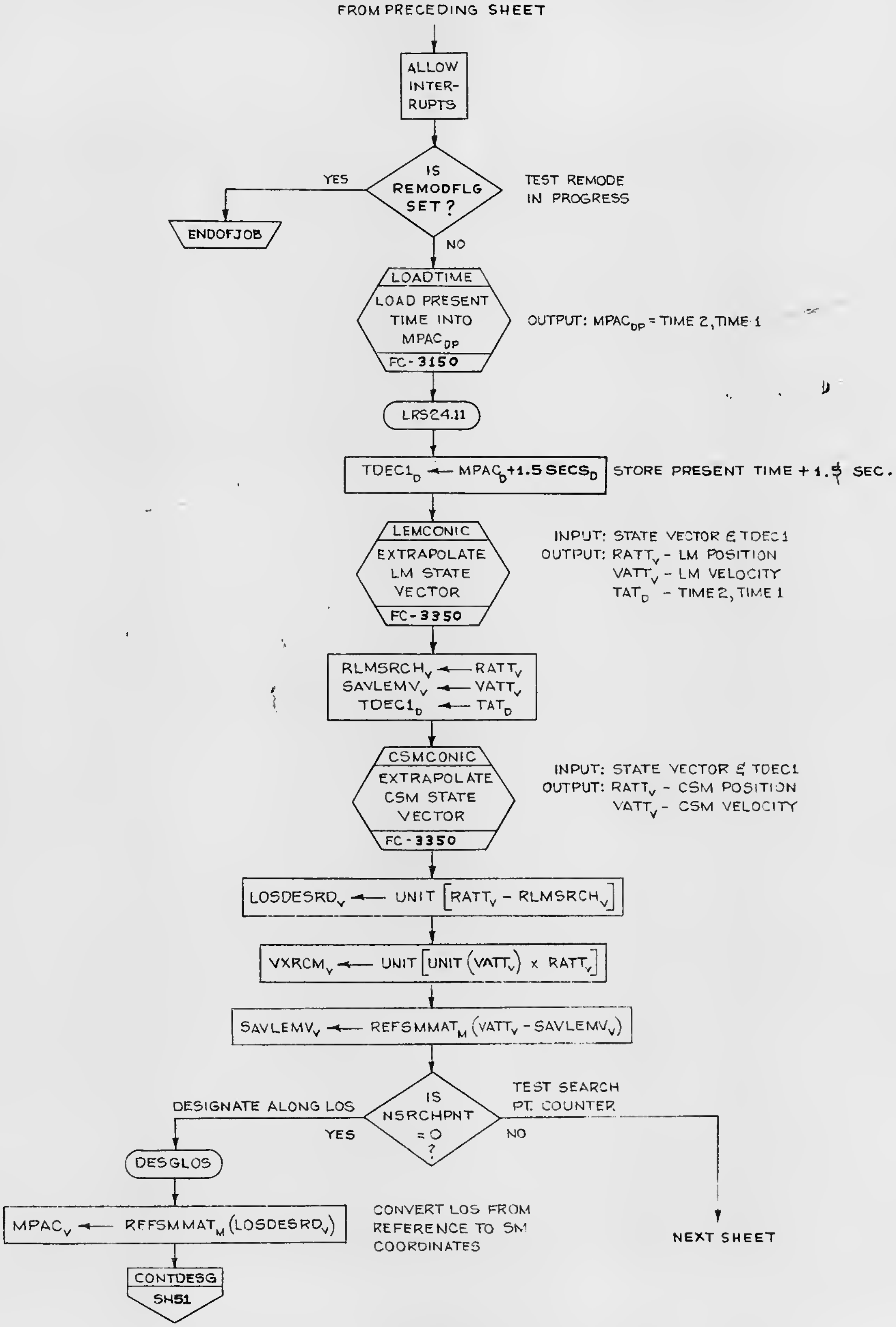
DRAWN	A.C. WILLIAMS	3-6-68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PROGMR	Peter Volante	8-16-68	
ANALST			LUMINARY 1D
DOCMR	M. Dobbit	5-17-6[illegible]	DOCUMENT NO. FC-3600
APPR'D	John A. Moore	29 Oct 6[illegible]	REV 2 — SHEET 47 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
DRAWN A.C.WILLIAMS	3-7-68	
PRGMR Peter Volante	8-16-68	LUMINARY 1D — DOCUMENT NO. FC-3600
ANALST		
DOCMR W. Ggbitt	5-17-6?	
APP'D John A. Moss	?-?-68	REV 2 — SHEET 48 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 5-15-68	P20,P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PROGMR Pete Volante 8-16-68	LUMINARY 1D
ANALYST	DOCUMENT NO. FC-3600
DOCMR 5-17-68	
APPR'D John A. Moore 29 Oct 68	REV 2 · SHEET 49 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION

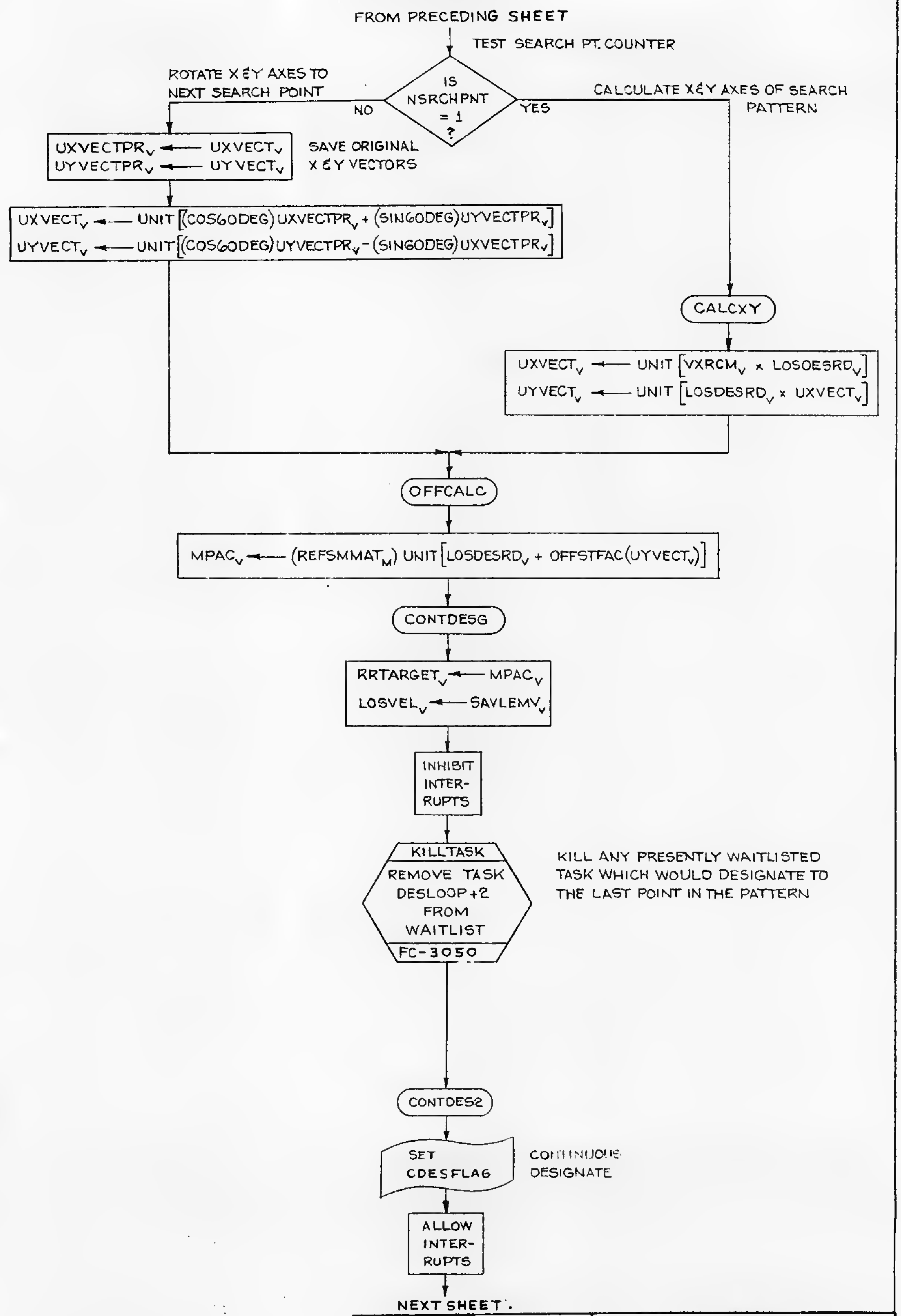
DRAWN	A.C.WILLIAMS	5-15-68
PRGMR	Peter Volante	8-16-68
ANALST		
DOCMR	[illegible]	5-17-68
APPR'D	John a. Morse	29 Oct 68

LUMINARY 1D

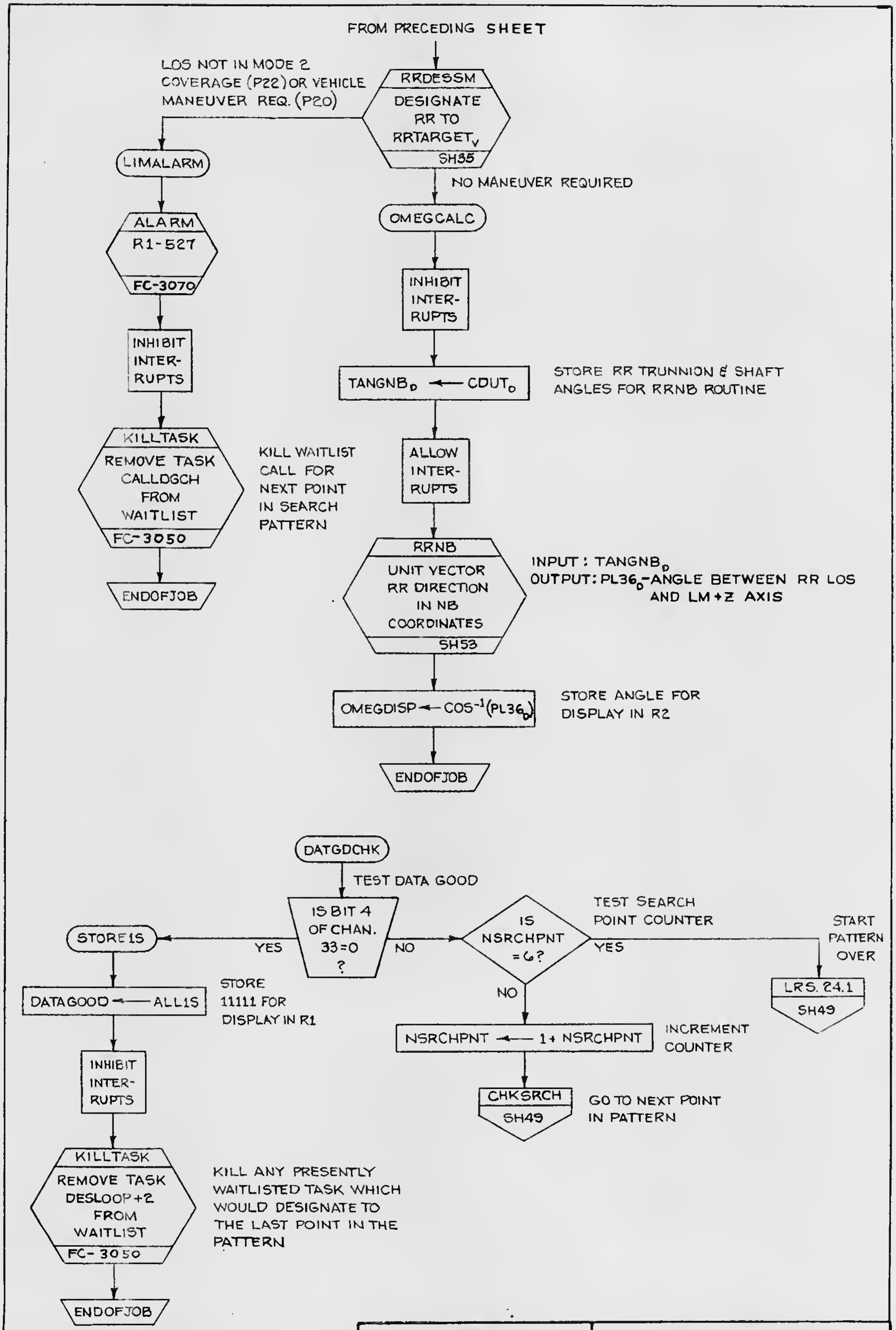
DOCUMENT NO. FC-3600

REV 2

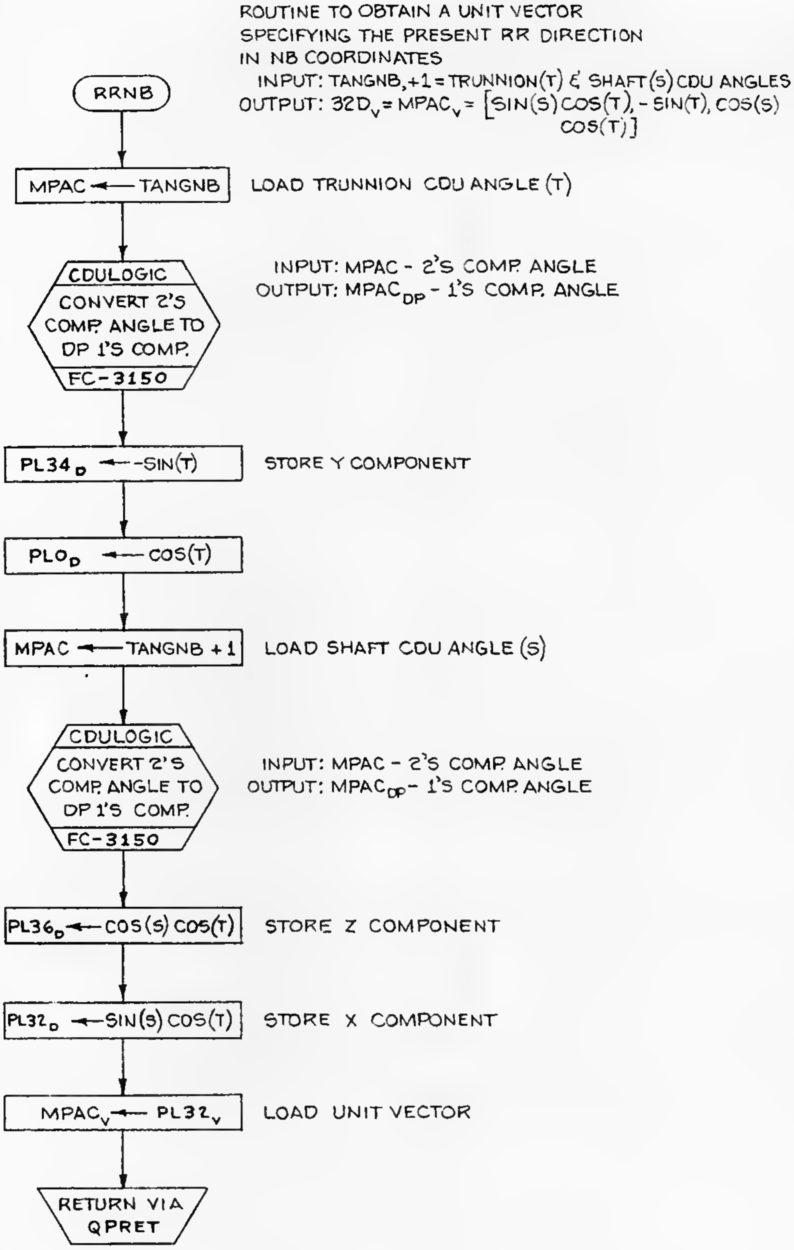
SHEET 50 OF 103



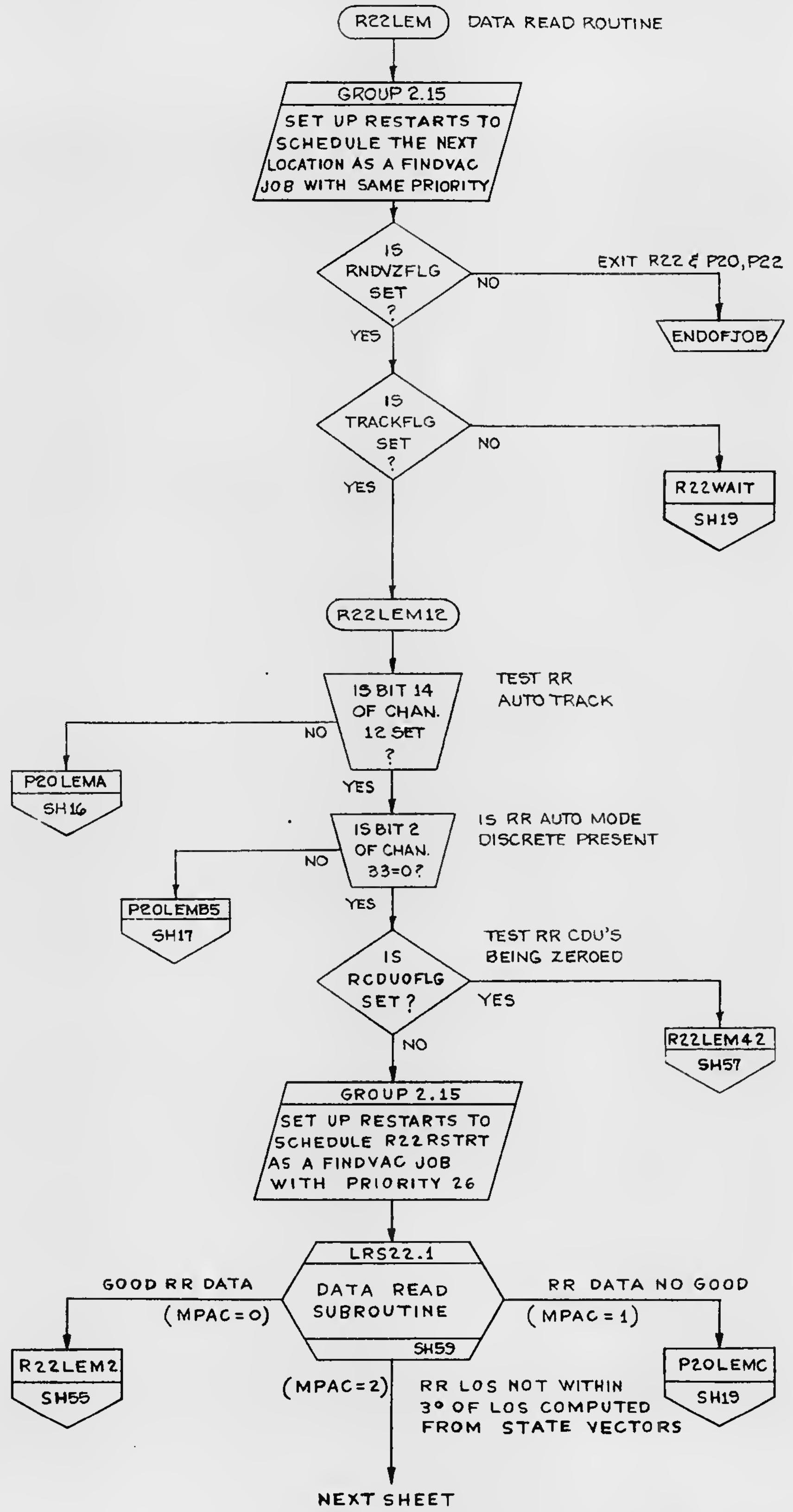
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C. WILLIAMS 3-19-68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR Peter Volante 8-16-68	LUMINARY 1D
ANALST	DOCUMENT NO. FC-3600
DOCMR [signature] 5-1?	REV 2
APPR'D John A. Moore	SHEET 51 OF 103



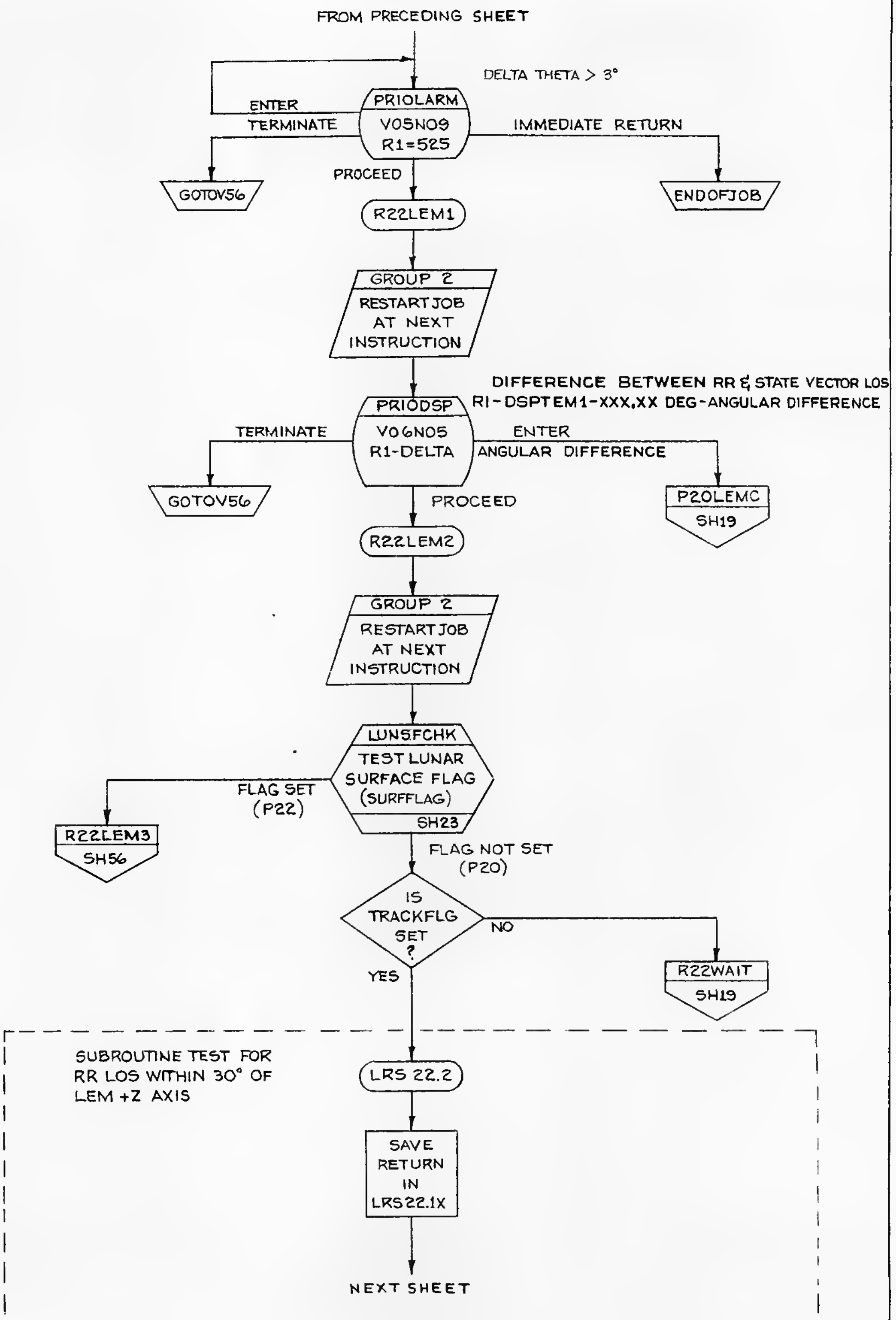
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 3-20-68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR Peter Volante 8-16-68	LUMINARY 1D — DOCUMENT NO. FC-3600
ANALST	
DOCMR W. Dangett 5-17-68	
APPR'D John A. Moore 21 Oct 68	REV 2 — SHEET 52 OF 103



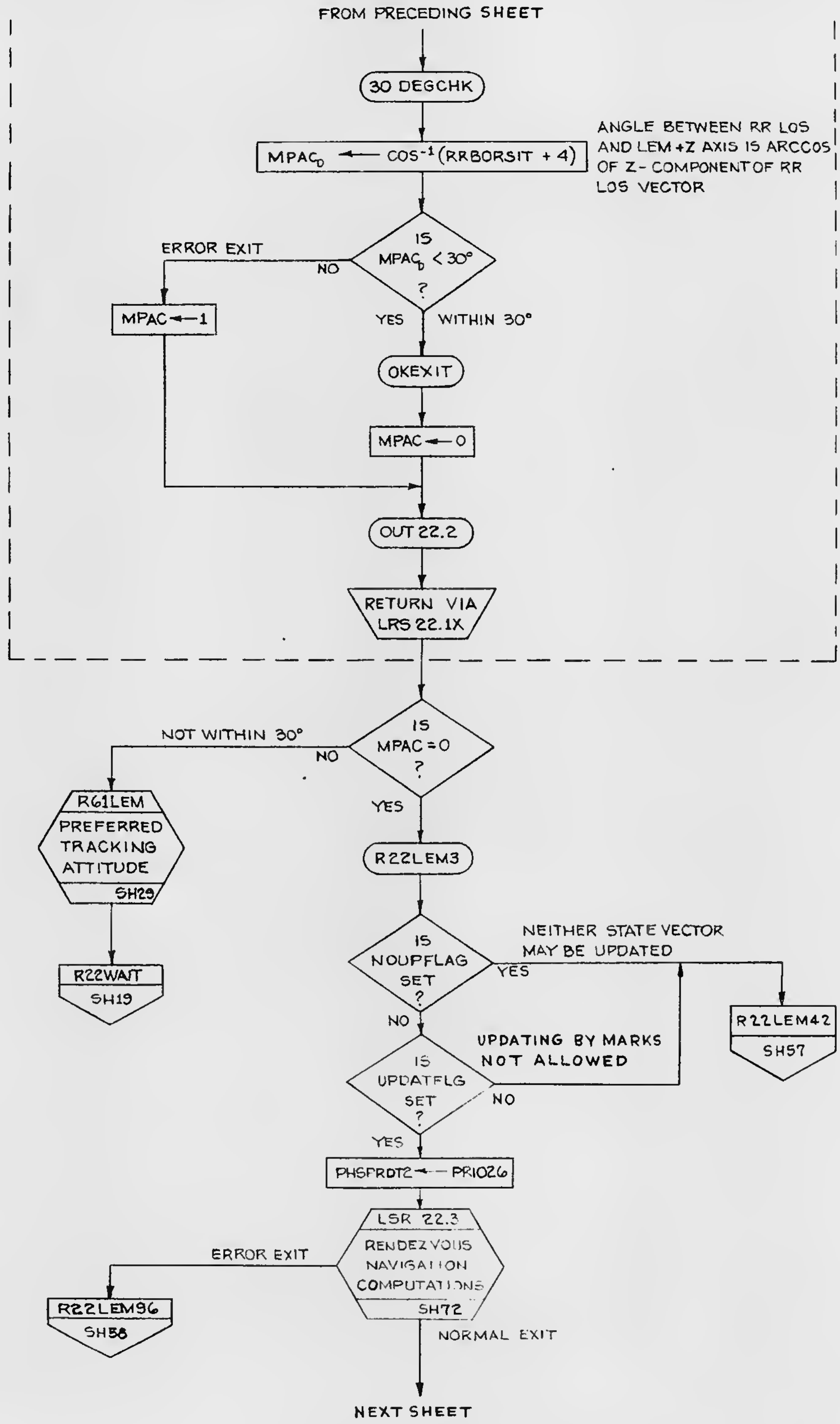
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 3-20-68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PROG'R 8-16-68	LUMINARY 1D — DOCUMENT NO. FC-3600
ANALYST	
DOC'MR 5-17-68	
APPR'D 29 Oct 68	REV 2 — SHEET 53 OF 103



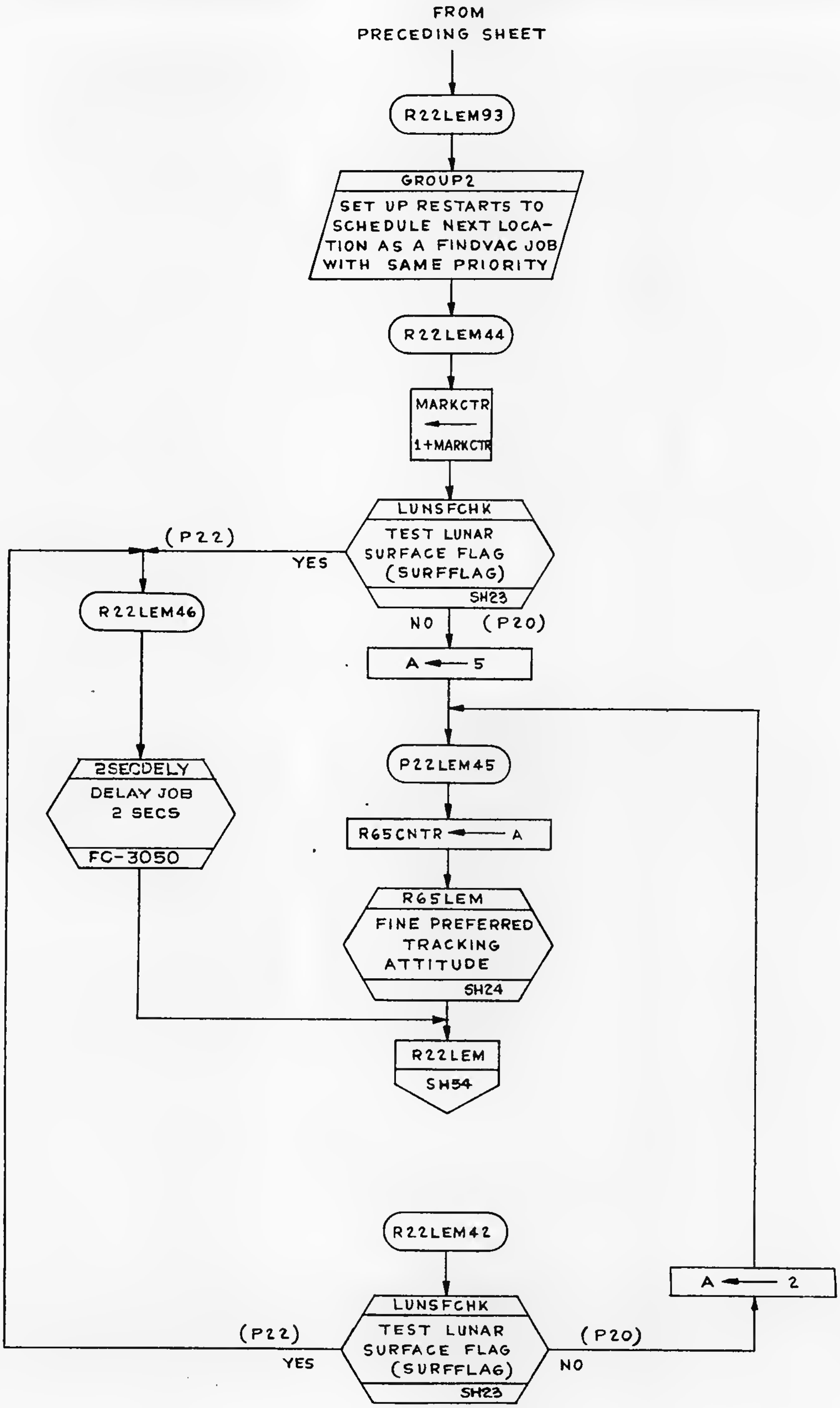
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 3-25-68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR Peter Volante 8-16-68	LUMINARY 1D — DOCUMENT NO. FC-3600
ANALST	
DOCMR W. Yaskitt 5-17-68	REV 2
APPR'D John A. Mann 29 Oct 68	SHEET 54 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 3-25-68	P20,P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR Peter Volante 8-16-68	LUMINARY 1D
ANALST	DOCUMENT NO. FC-3600
DOCMR W. Goodwin 3-17-68	REV 2
APPR'D John A. Moore 29 Oct 68	SHEET 55 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 3-26-68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR Peter Volante 10/21/69	LUMINARY 1D
ANALST	DOCUMENT NO. FC-3600
DOCMR W. Doyle 5-17-68	
APPR'D John A. Moore 29 Oct 68	REV 2 — SHEET 56 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

DRAWN	20MAR69
PRGMR	10/21/69
ANALST	
DOCMR	4-7-69
APPR'D	10/21/69

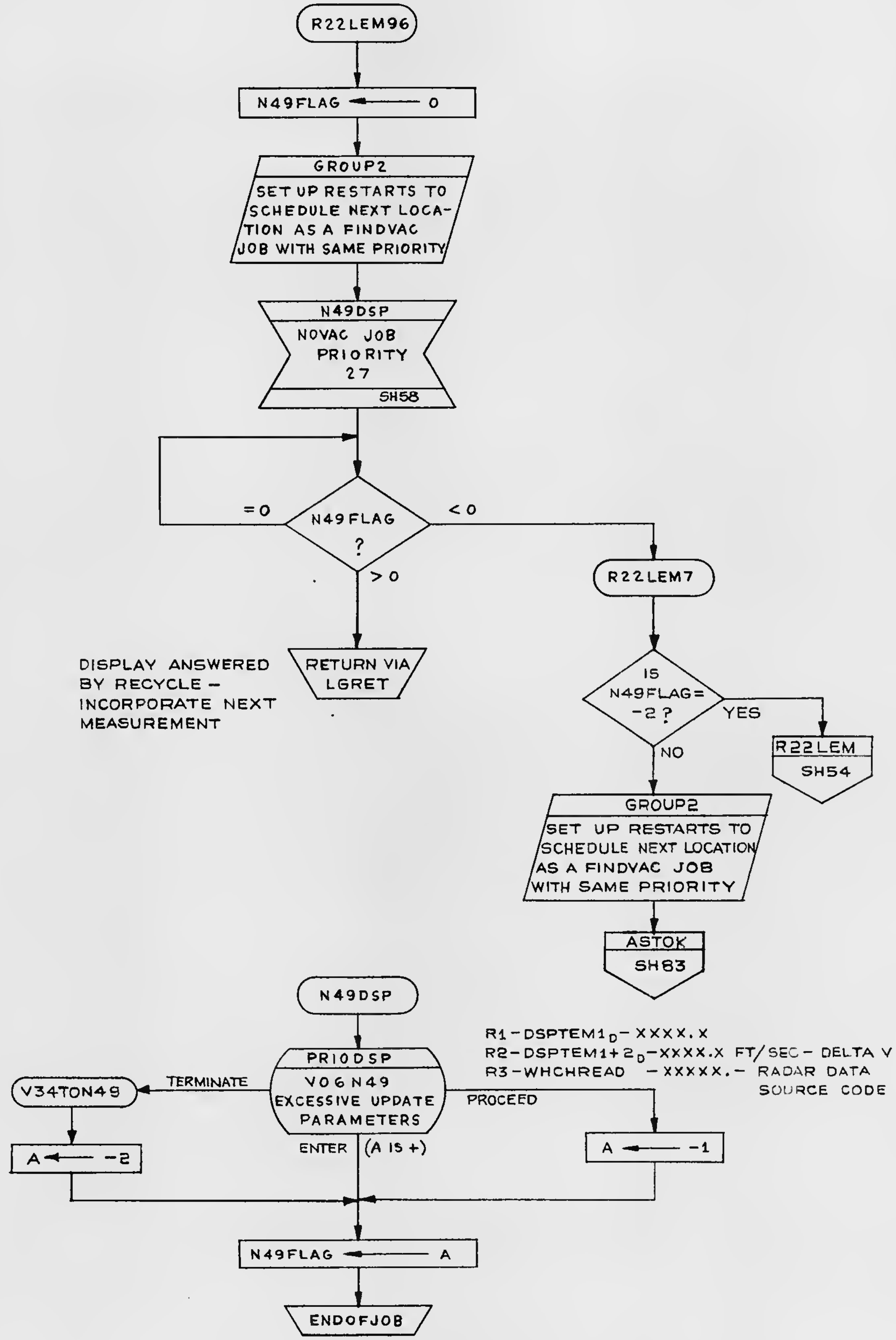
APOLLO GUIDANCE AND NAVIGATION

P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION

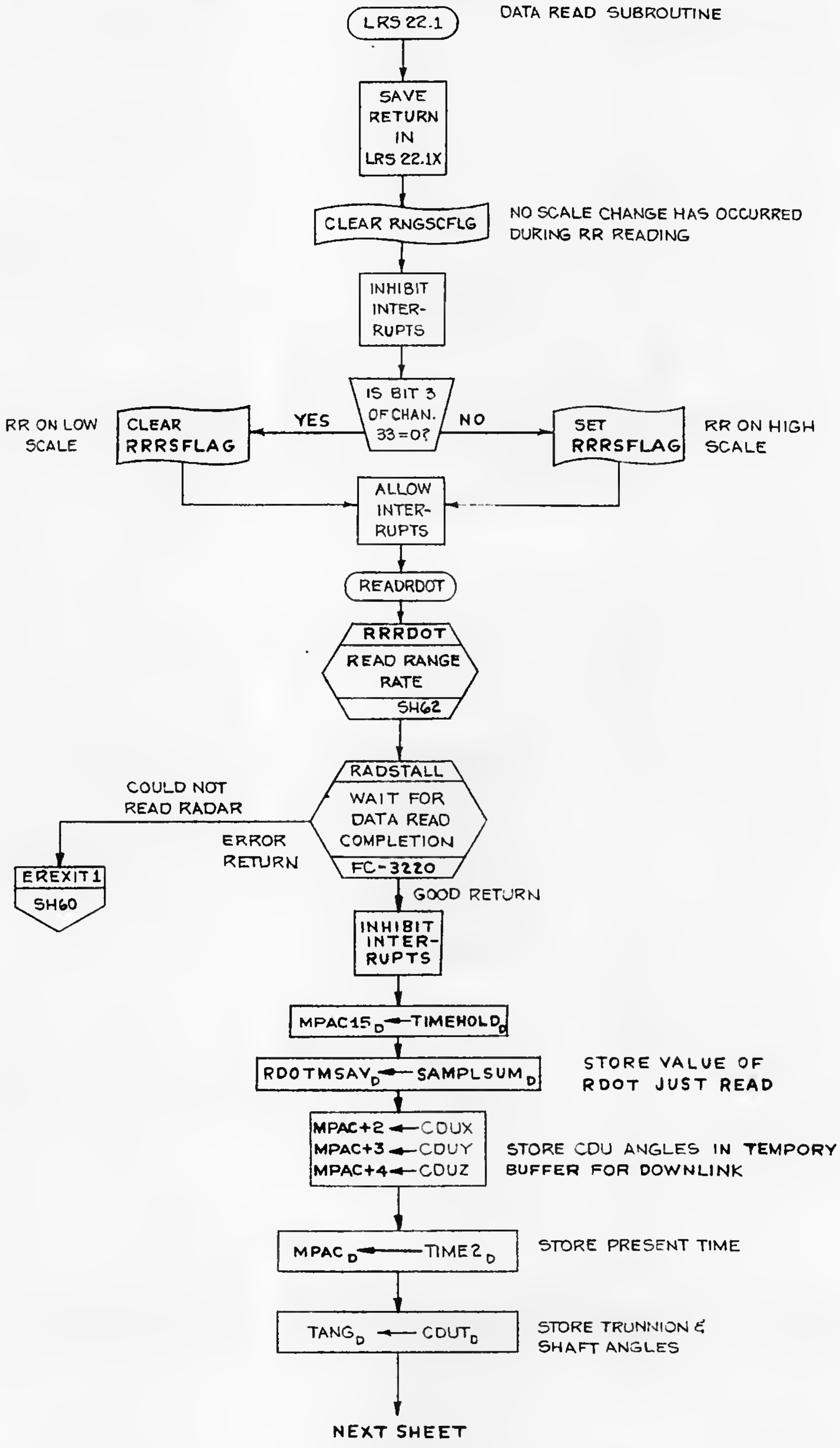
LUMINARY 1D

DOCUMENT NO. FC-3600

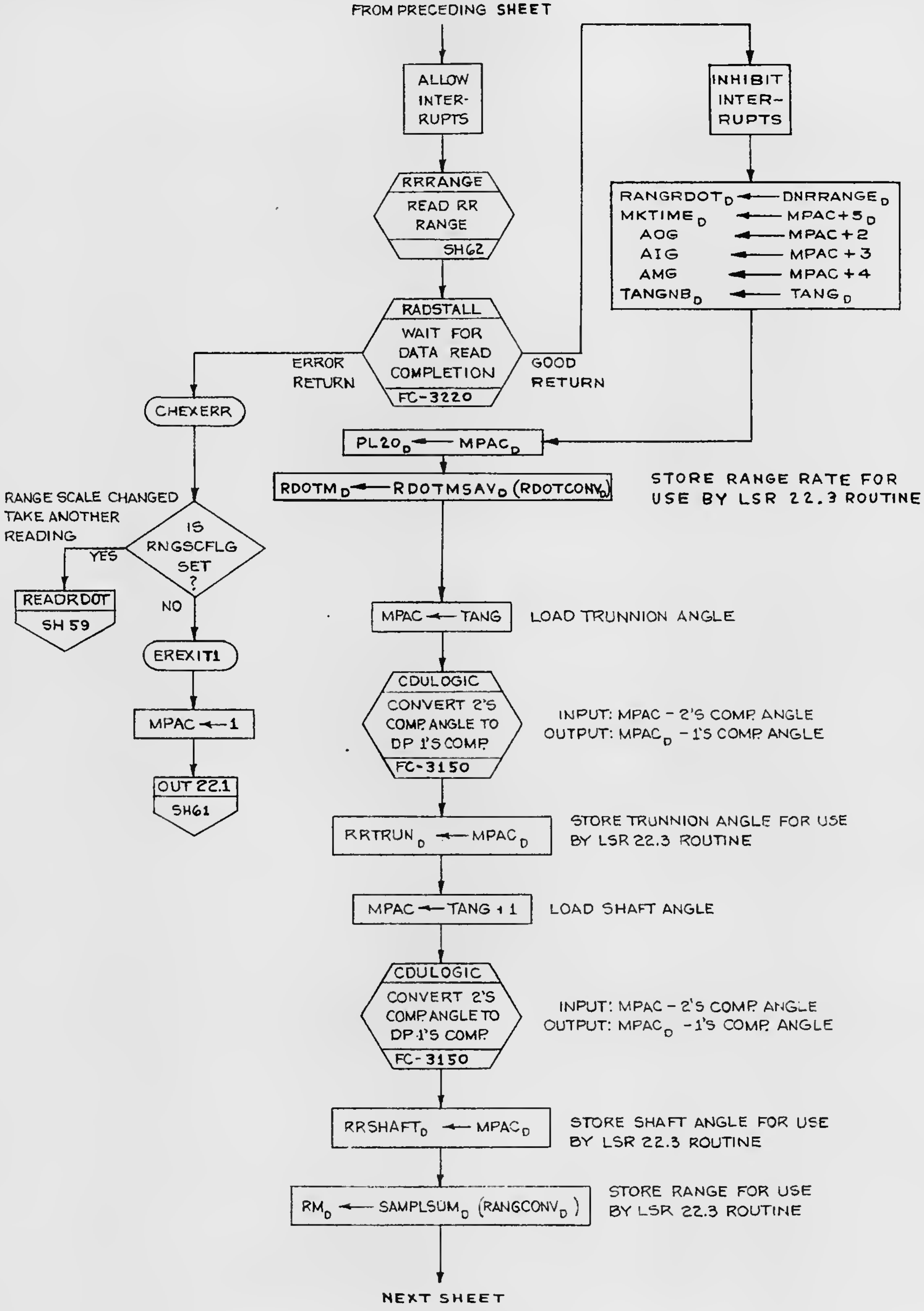
REV 2



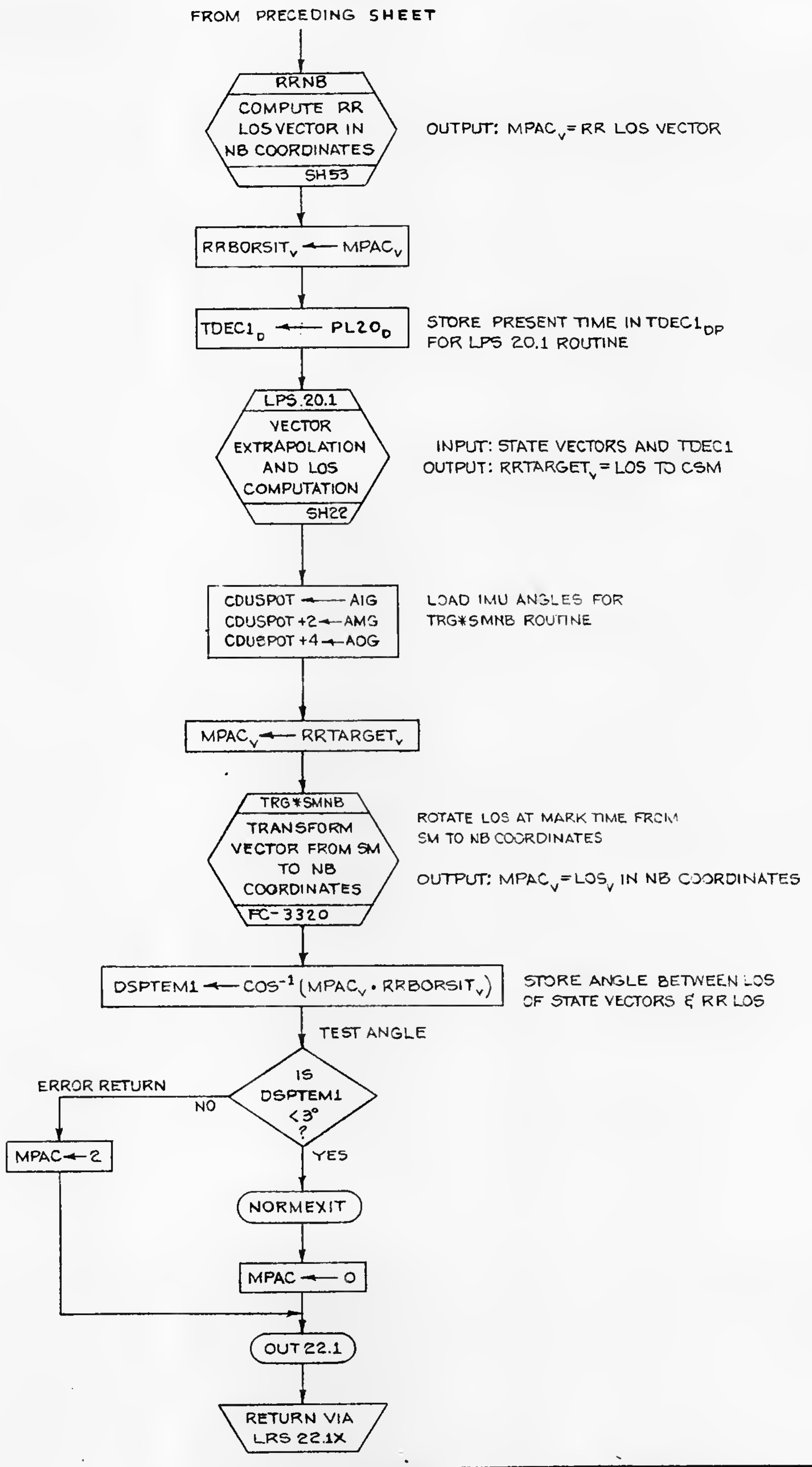
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	21MAR69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGMR	10/21/69	LUMINARY 1D	DOCUMENT NO. FC-3600
ANALST			
DOCMR	4-7-69		
APPR'D R. M. Ewing	10/21/69	REV 2	SHEET 58 OF 103



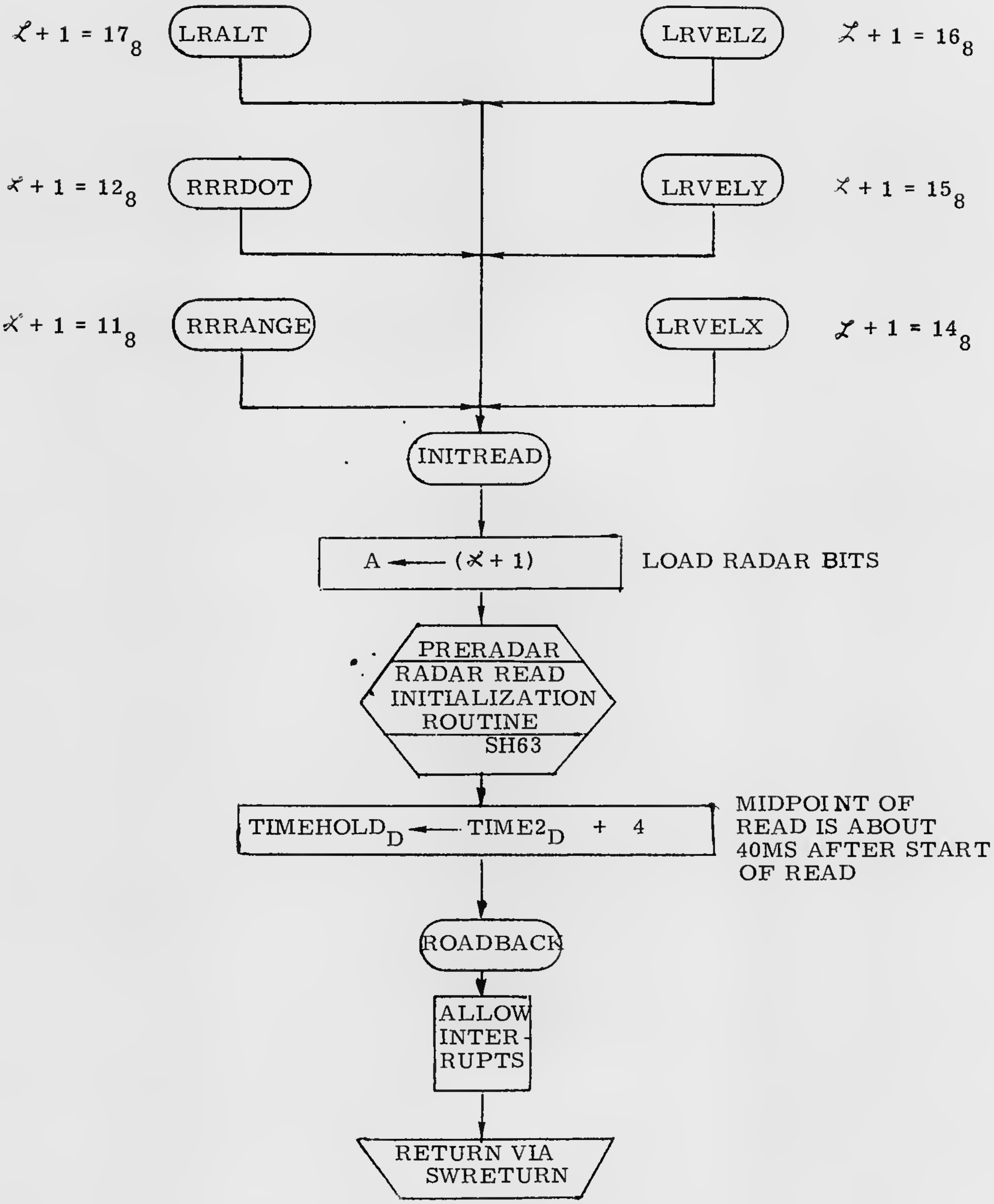
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	5-17-68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR Pete Volante	8-16-68	LUMINARY 1D
ANALST		DOCUMENT NO. FC-3600
DOCMR W. Doolittle	5-17-68	
APPR'D John A. Moore	29 Oct 68	REV 2 · SHEET 59 OF 103



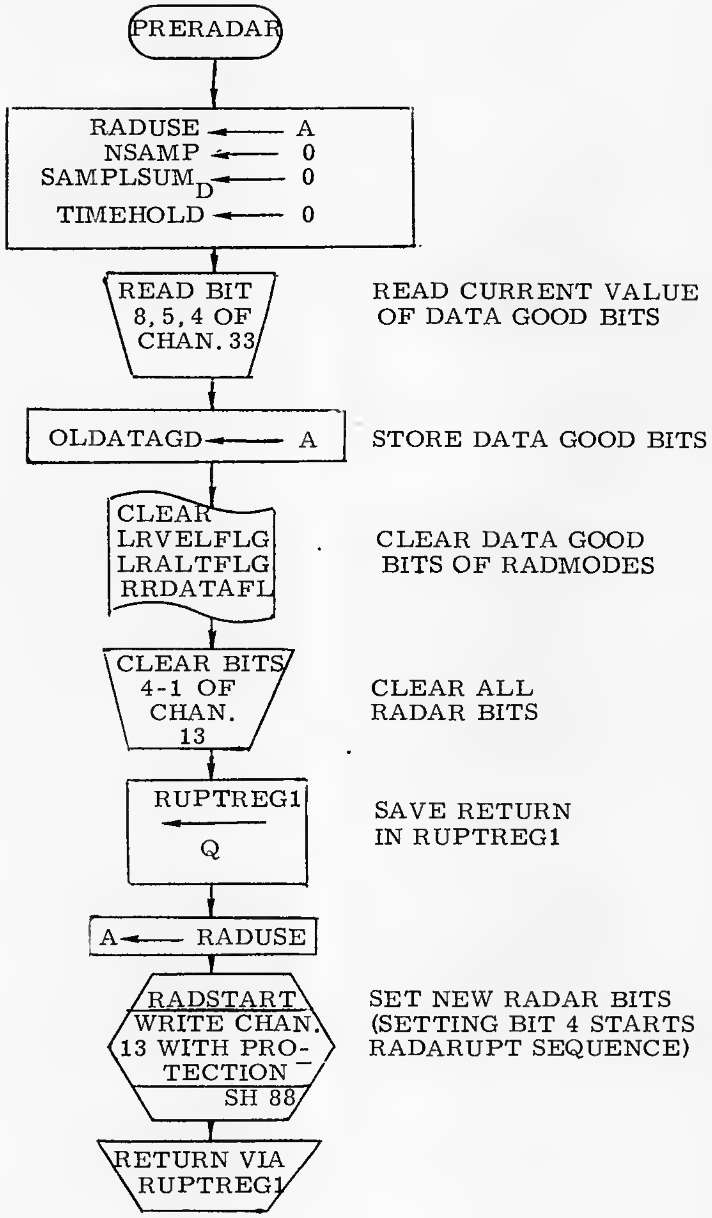
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
DRAWN A.C.WILLIAMS	3-27-68	
PRGMR Peter Volante	8-16-68	LUMINARY 1D / DOCUMENT NO. FC-3600
ANALST		
DOCMR W. Talbott	5-17-68	
APPR'D John A. Moore	29 Oct 68	REV 2 / SHEET 60 OF 103



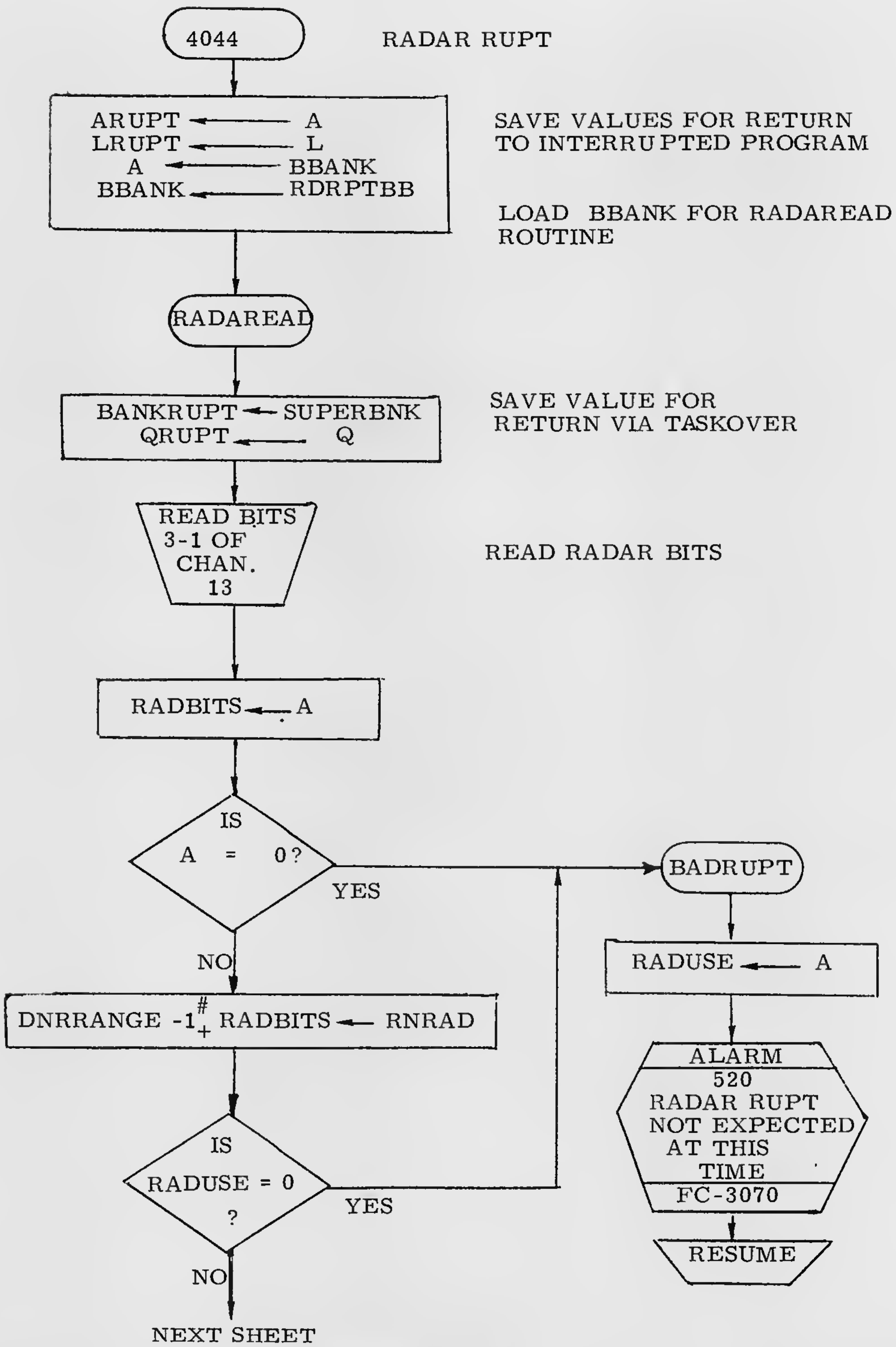
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION
DRAWN	A.C.WILLIAMS	3-28-68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PROGMR	[illegible]	8-16-68	LUMINARY 1D
ANALST			DOCUMENT NO. FC-3600
DOCMR	[illegible]	5-17-68	
APPR'D	[illegible]	[illegible]	REV 2 — SHEET 61 OF 103



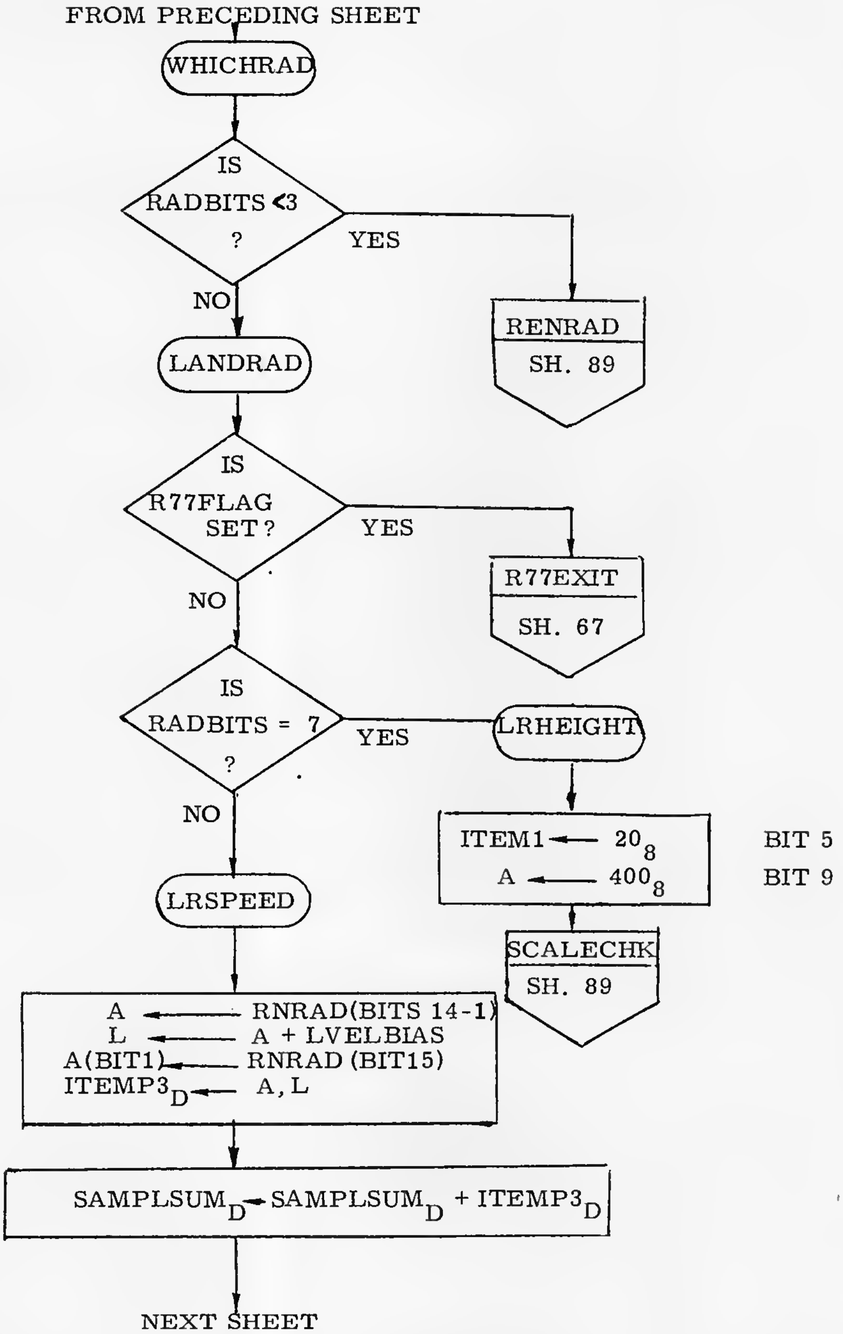
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E. Matta	6/3/70	P20, P22	
PRGMR P. Volante	6/19/70		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3600
DOCMR W. Danforth	6/9/70		
APPR'D L. McEntee	6/18/70	REV 2	SHEET 62 OF 103



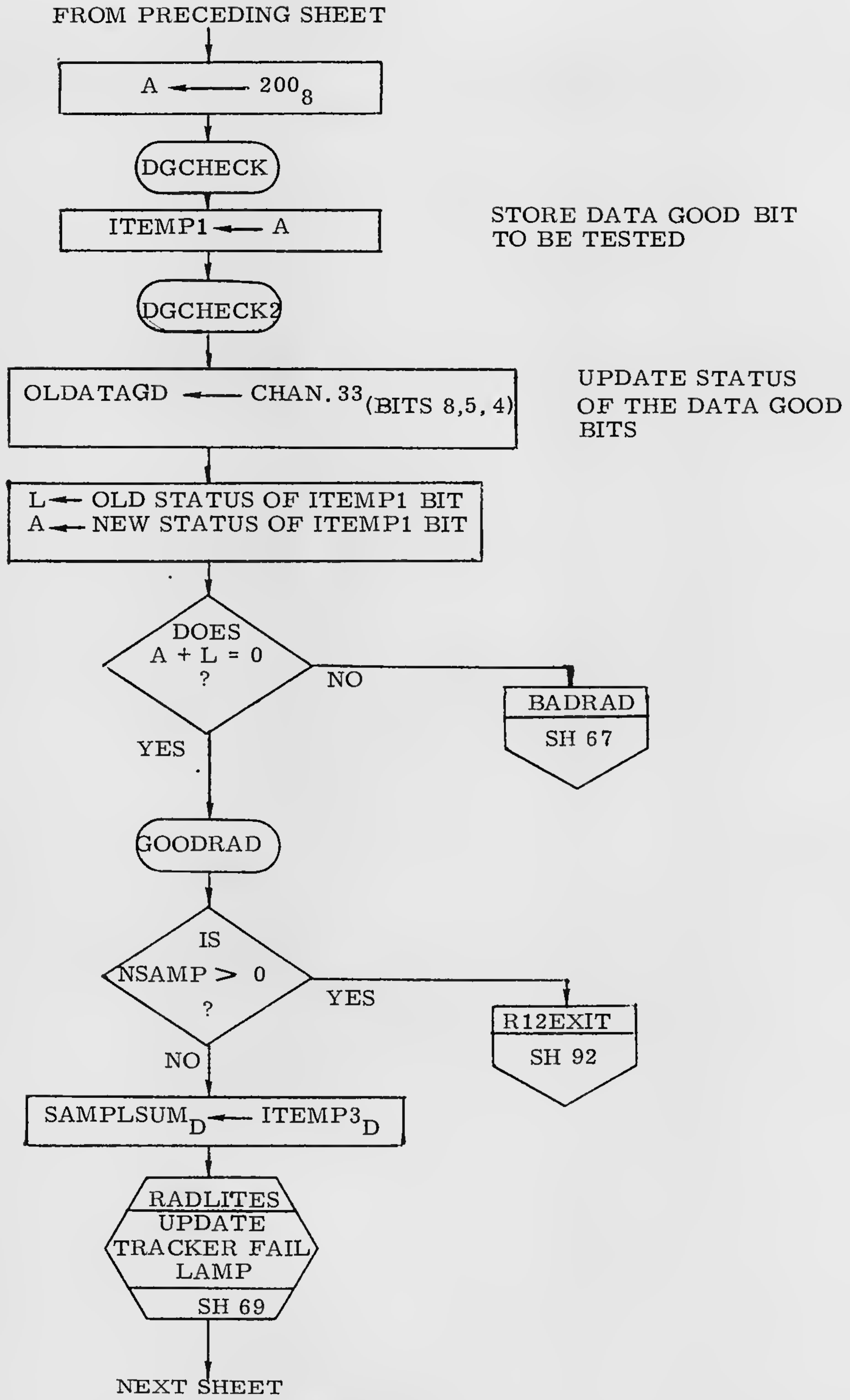
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN [illegible]	6/3/70	P20, P22	
PRGMR [illegible]	6/13/70		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3600
DOCMR [illegible]	6/9/70		
APPR'D [illegible]	6/18/70	REV 2	SHEET 63 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E. Motta	6/3/70	P20, P22	
PRGMR B. Volante	6/18/70	LUMINARY 1D	DOCUMENT NO. FC-3600
ANALST			
DOCMR	6/10/70		
APPR'D	6/18/70	REV 2	SHEET 64 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E. Matta	6/3/70	P20, P22	
PRGMR P. Volante	6/18/70		
ANALST		LUMINARY 1D	DOCUMENT NO. FC- 3600
DOCMR W. Danforth	6/10/70		
APPR'D R M Enter	6/18/70	REV 2	SHEET 65 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E Matta	6/4/70	P20, P22	
PRGMR P. Volante	6/18/70		DOCUMENT NO.
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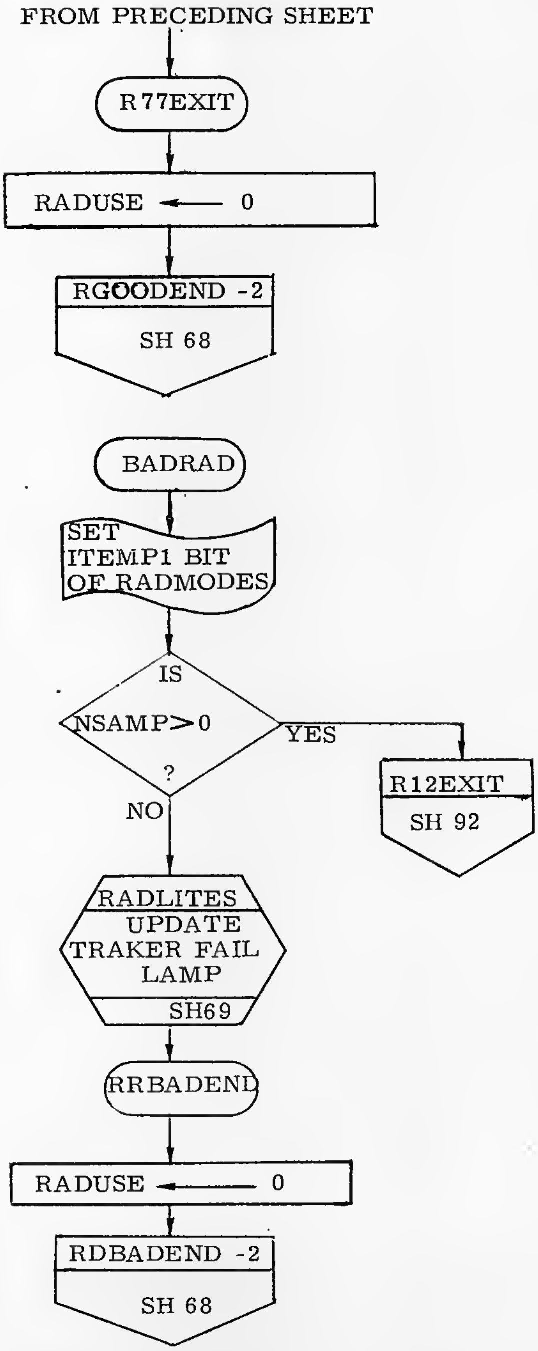
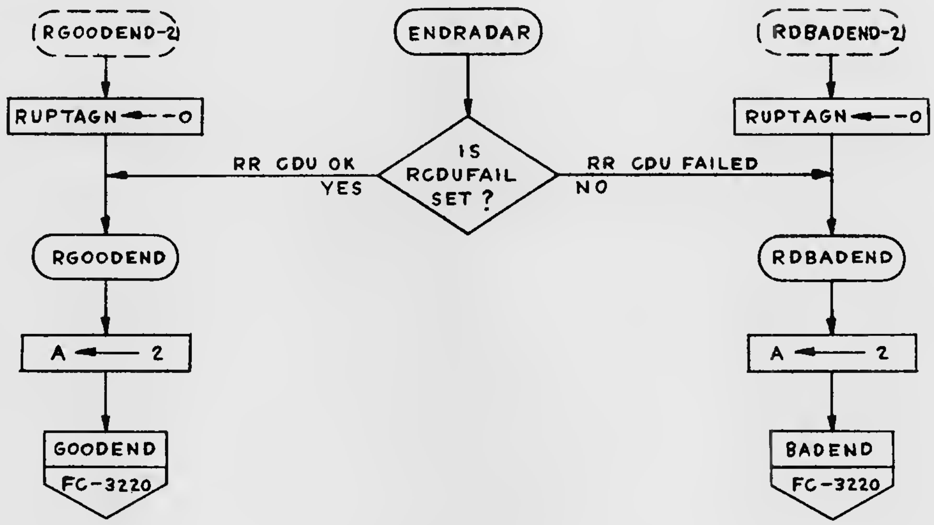
DOCMR [illegible]	6/10/70		
APPR'D [illegible]	6/18/70	REV 2	SHEET 66 OF 103

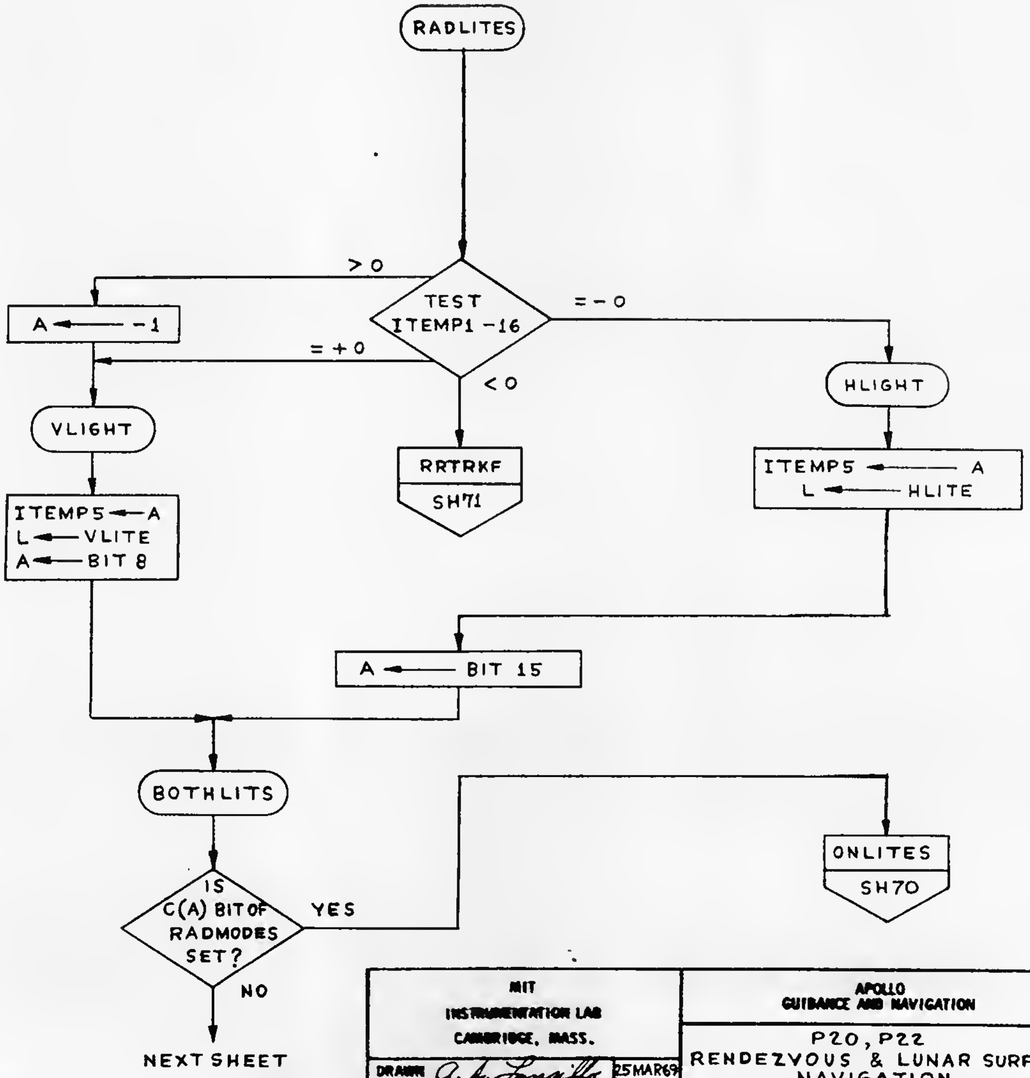


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E. Matta	6/4/70	P20, P22	
PRGMR P. Volante	6/18/70		DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3600
DOCMR W. Dayforth	6/10/70		
APPR'D R. McEntee	6/18/70	REV 2	SHEET 67 OF 103

ROUTINES TO TERMINATE RR OPERATIONS



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN 24MAR69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PROGRM 10/31/69	
ANALYST	LUMINARY 1D
DOCUMENT NO. FC-3600	
APPR'D 10/21/69	REV 2
SHEET 68 OF 103	



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION

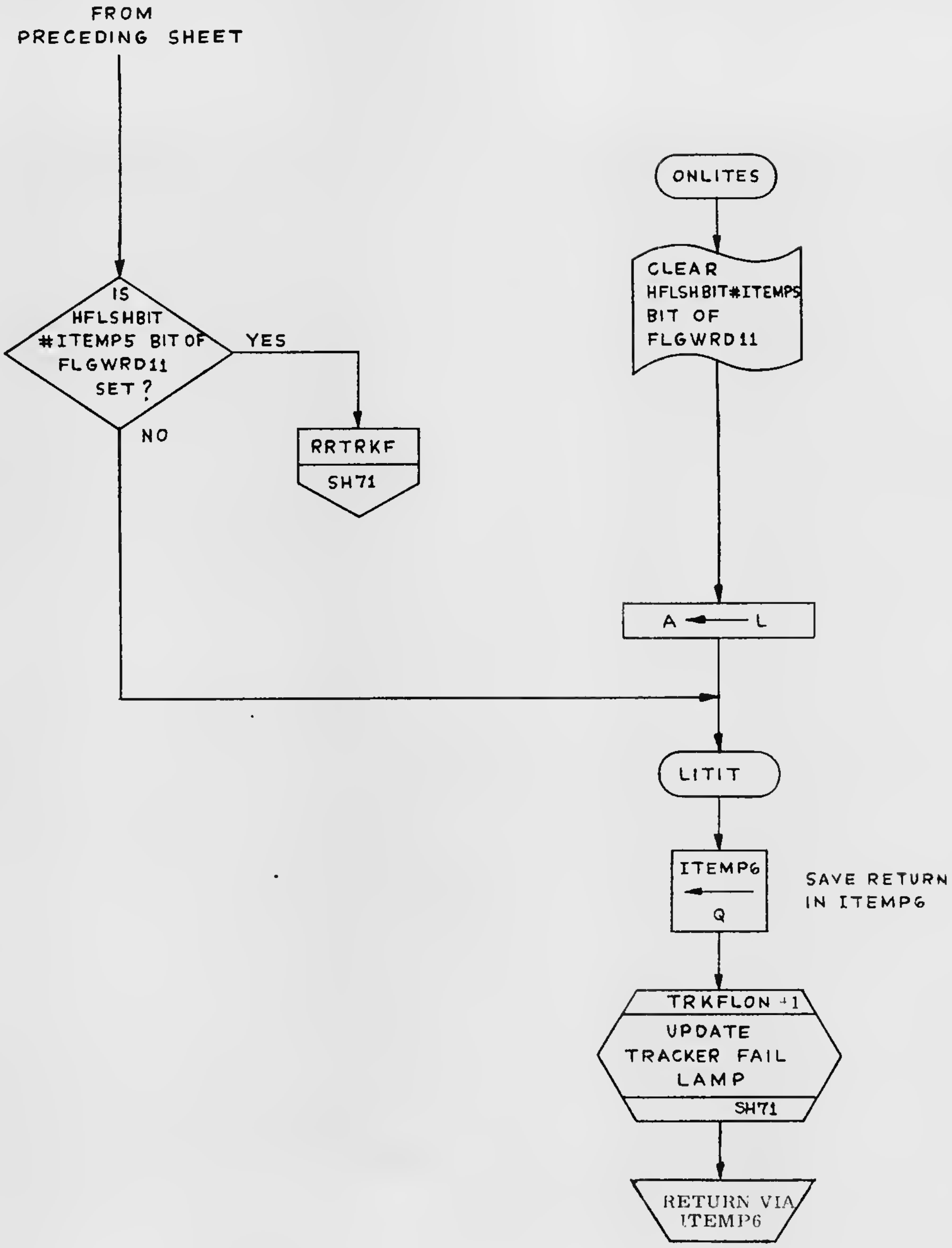
DRAWN		25MAR69
PRGMR		10/21/69
ANALST		
DOCMR		7-7-69
APPR'D		10/21/69

LUMINARY 1D

DOCUMENT NO. FC-3600

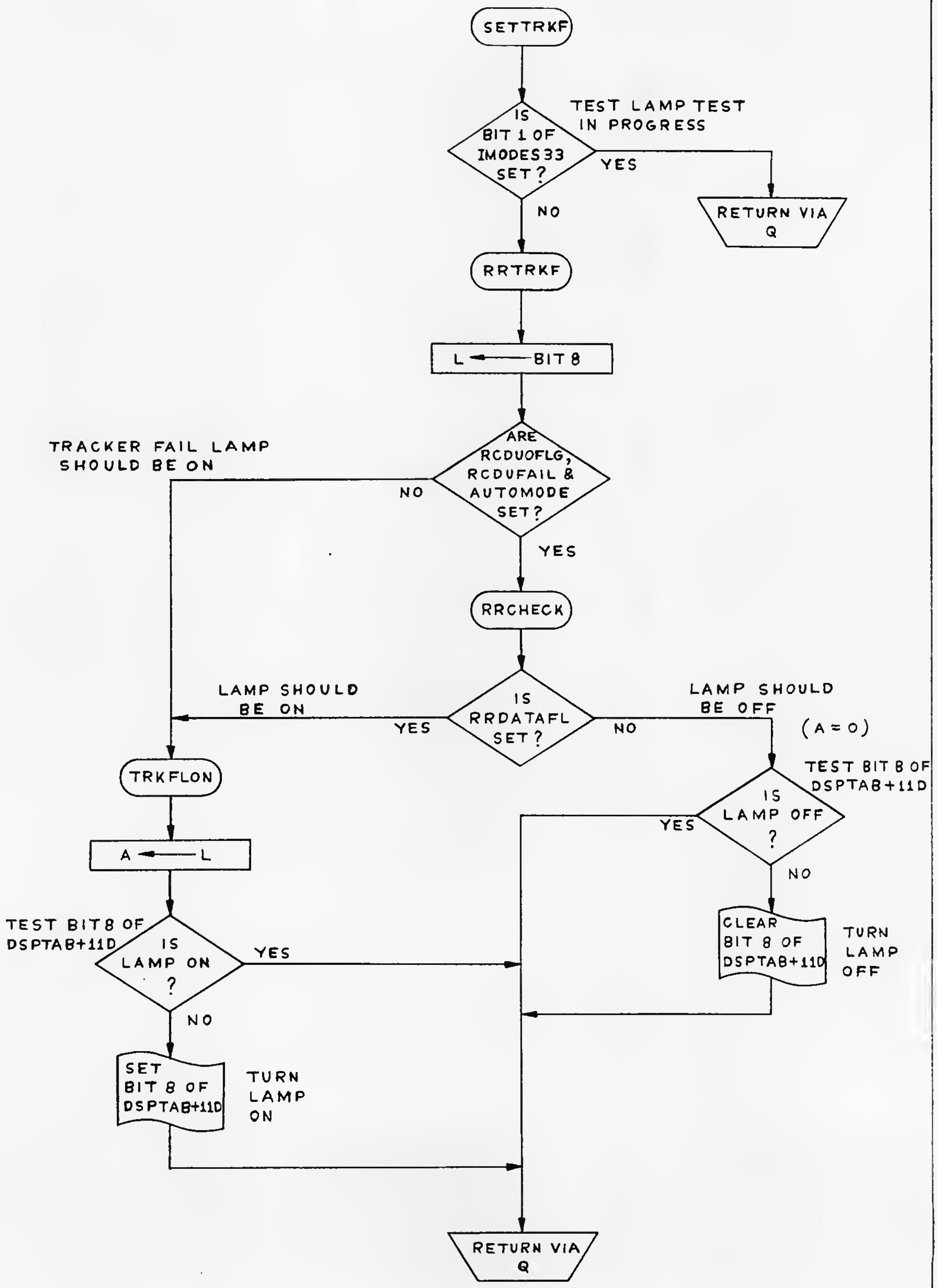
REV 2

SHEET 69 OF 103

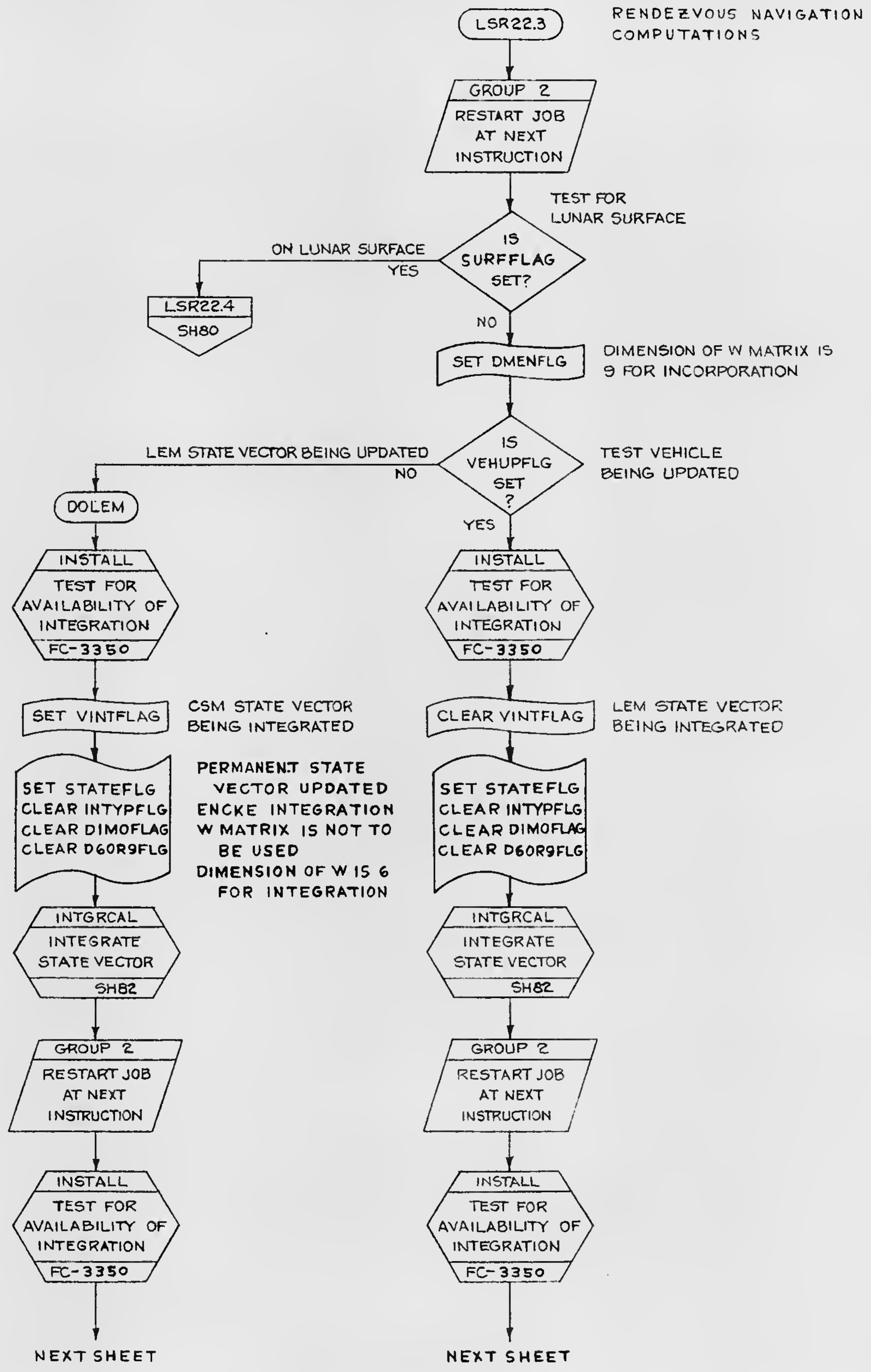


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	25MAR69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGMR	10/21/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3600
DOCMR	4-7-69		
APPR'D	10/21/69	REV 2	SHEET 70 OF 103

UPDATE TRACKER FAIL LAMP



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN	25MAR69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PROGMR	10/21/69	LUMINARY 1D
ANALST		DOCUMENT NO. FC-3600
DOCMR	4-7-69	REV 2
APPR'D	10/21/69	SHEET 71 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION

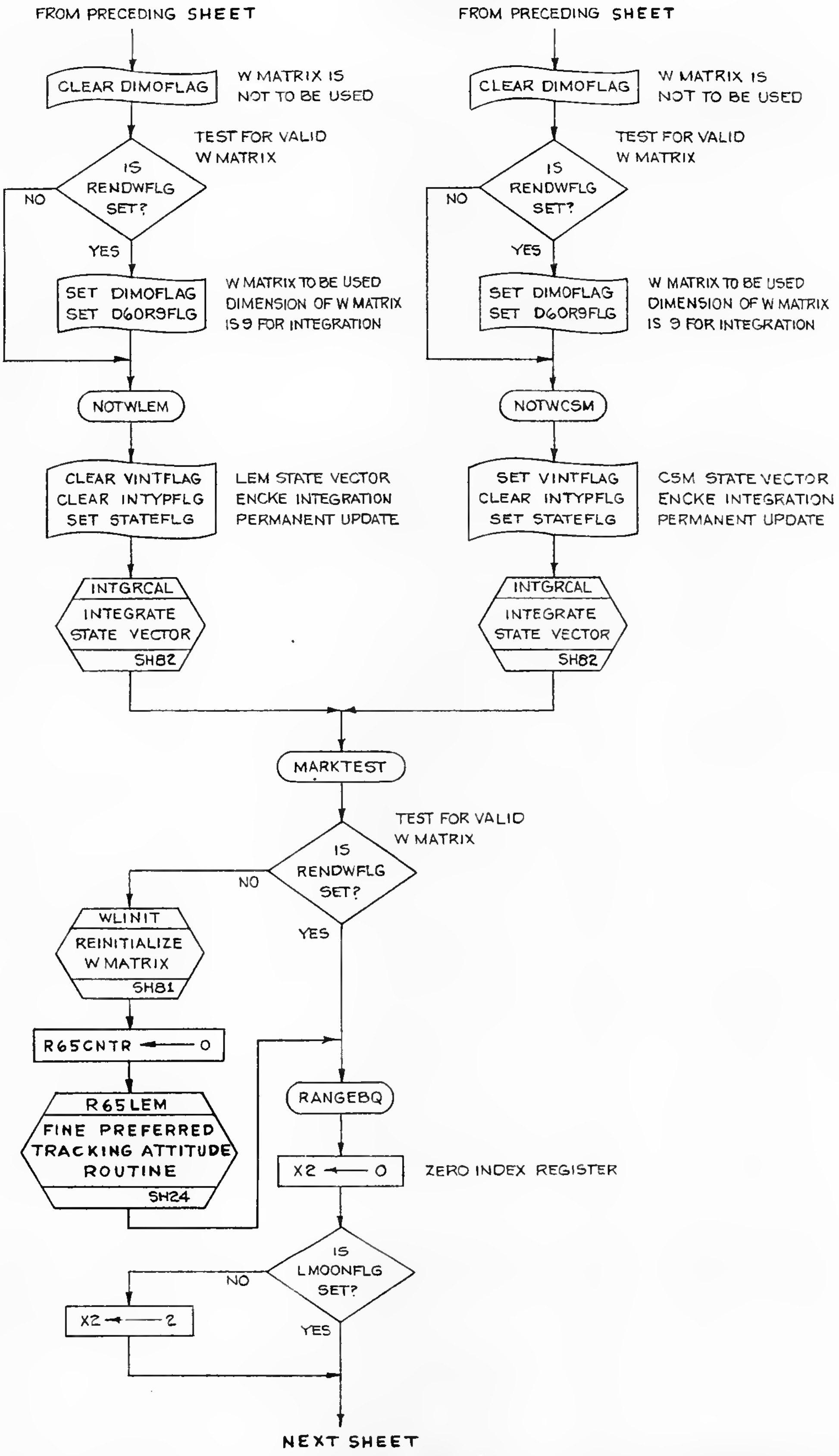
DRAWN	A.C. WILLIAMS	4-4-68
PRGMR	Peter Volante	10/21/69
ANALST		
DOCMR	W. Danforth	5-17-68
APPR'D	John A. Moore	29 Oct. 69

LUMINARY 1D

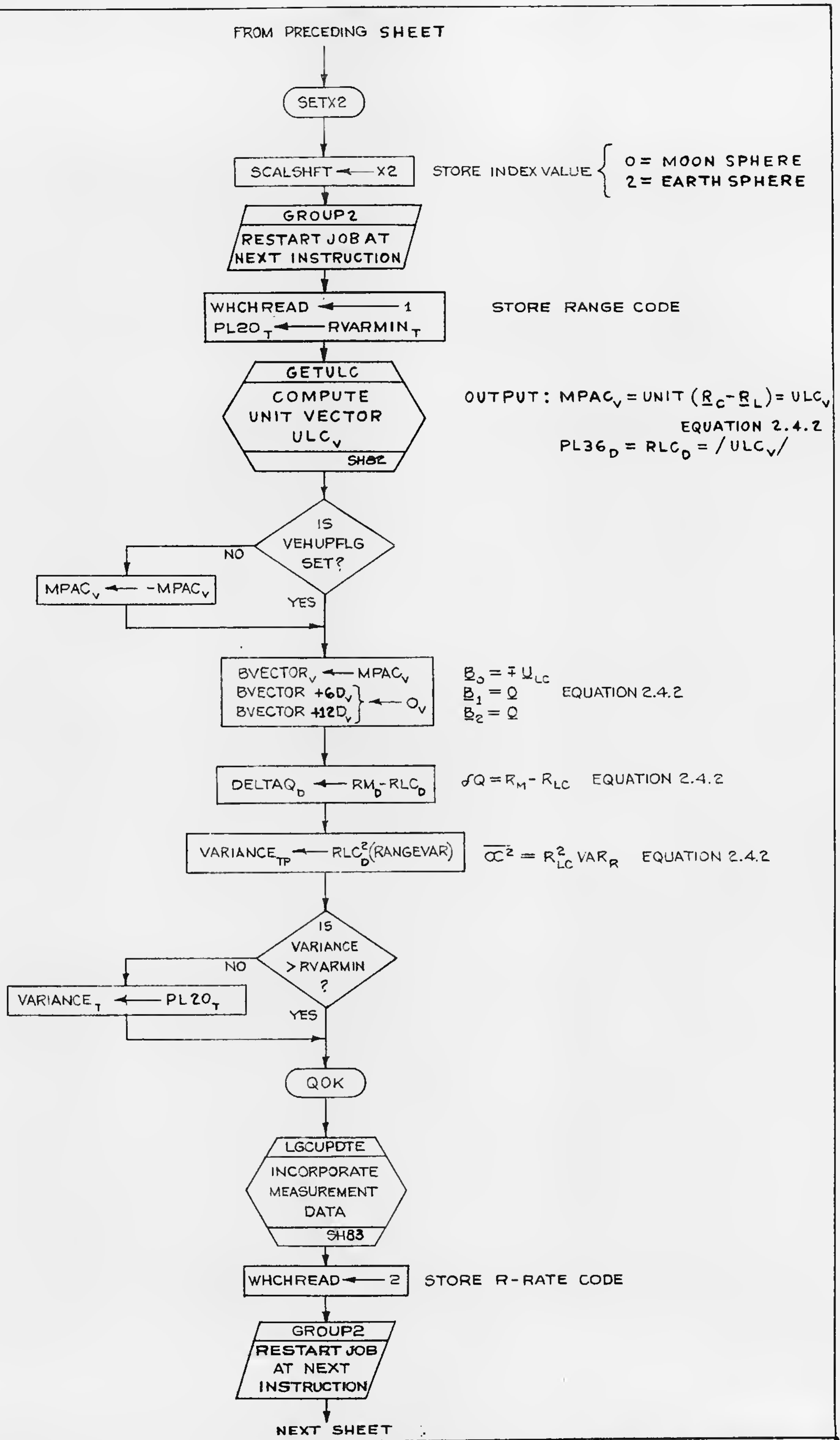
DOCUMENT NO. FC-3600

REV 2

SHEET 72 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 4-4-68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR [signature] 8-16-68	LUMINARY 1D
ANALST	DOCUMENT NO. FC-3600
DOCMR [signature] 5-17-6[illegible]	REV 2
APPR'D [signature] 29 Oct 68	SHEET 73 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION

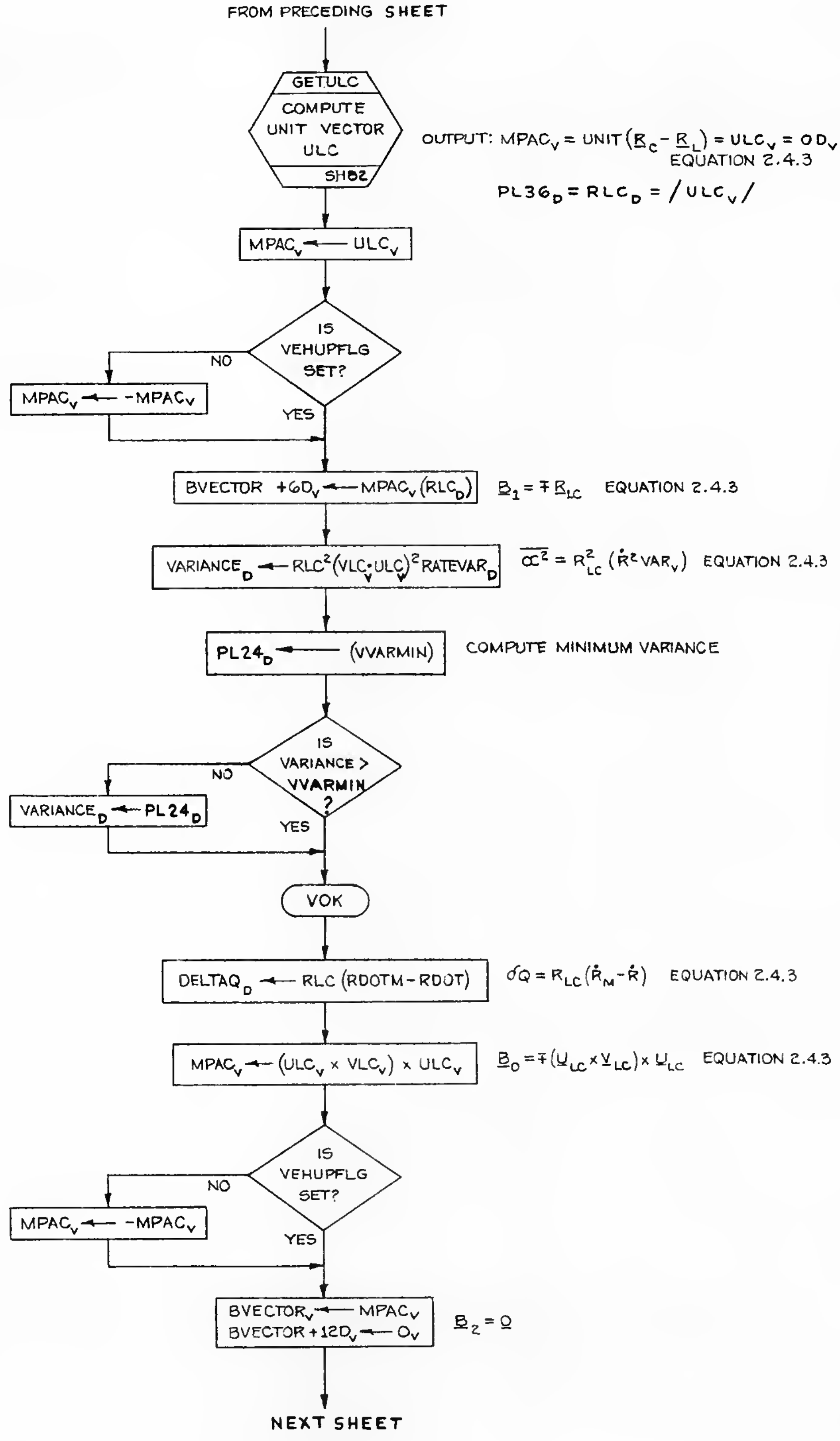
DRAWN	A.C. WILLIAMS	5-17-68
PROGMR	Peter Volante	8-16-68
ANALST		
DOCMR	W. Danforth	5-19-68
APPR'D	John A. Moore	29 Oct 68

LUMINARY 1D

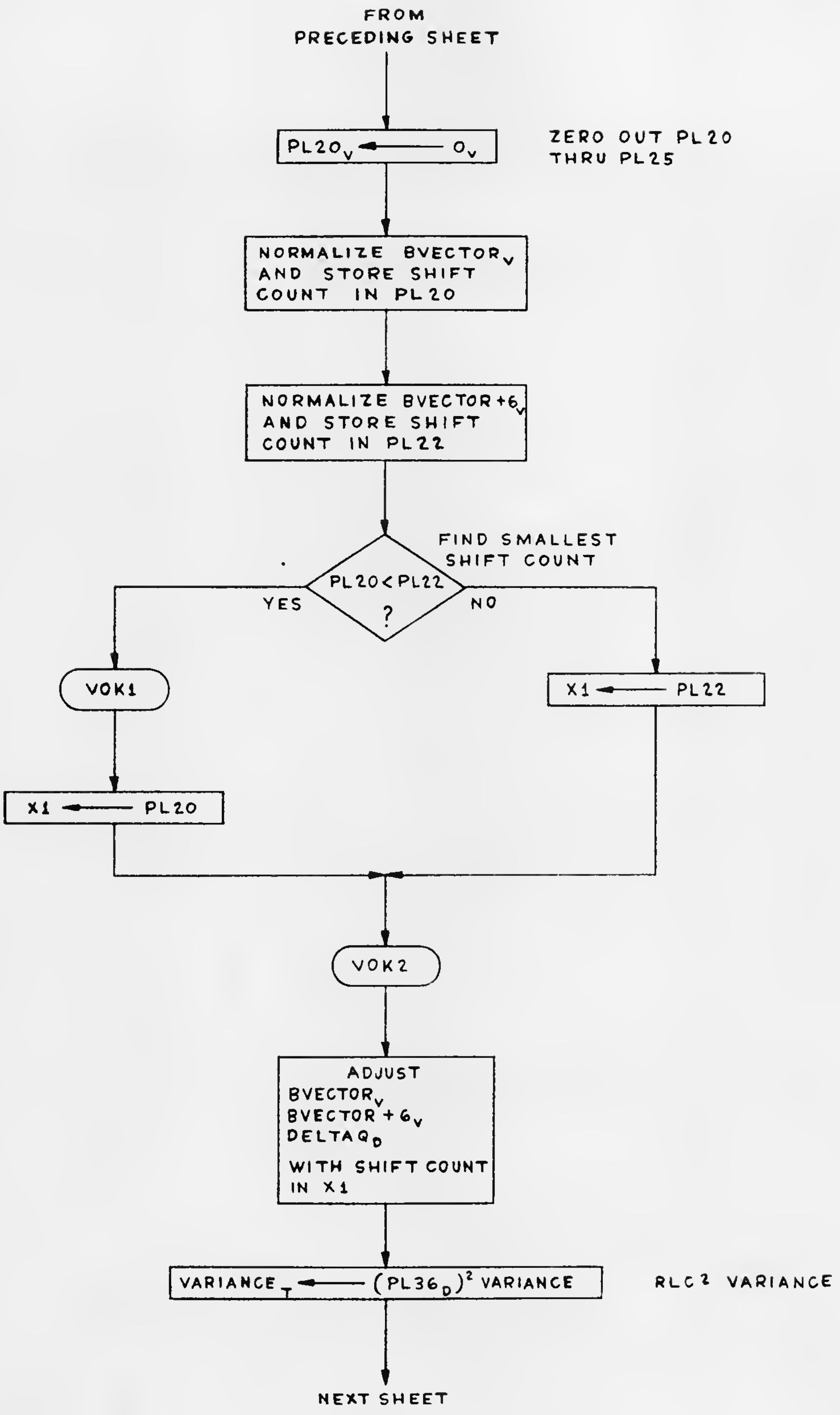
DOCUMENT NO. FC-3600

REV 2

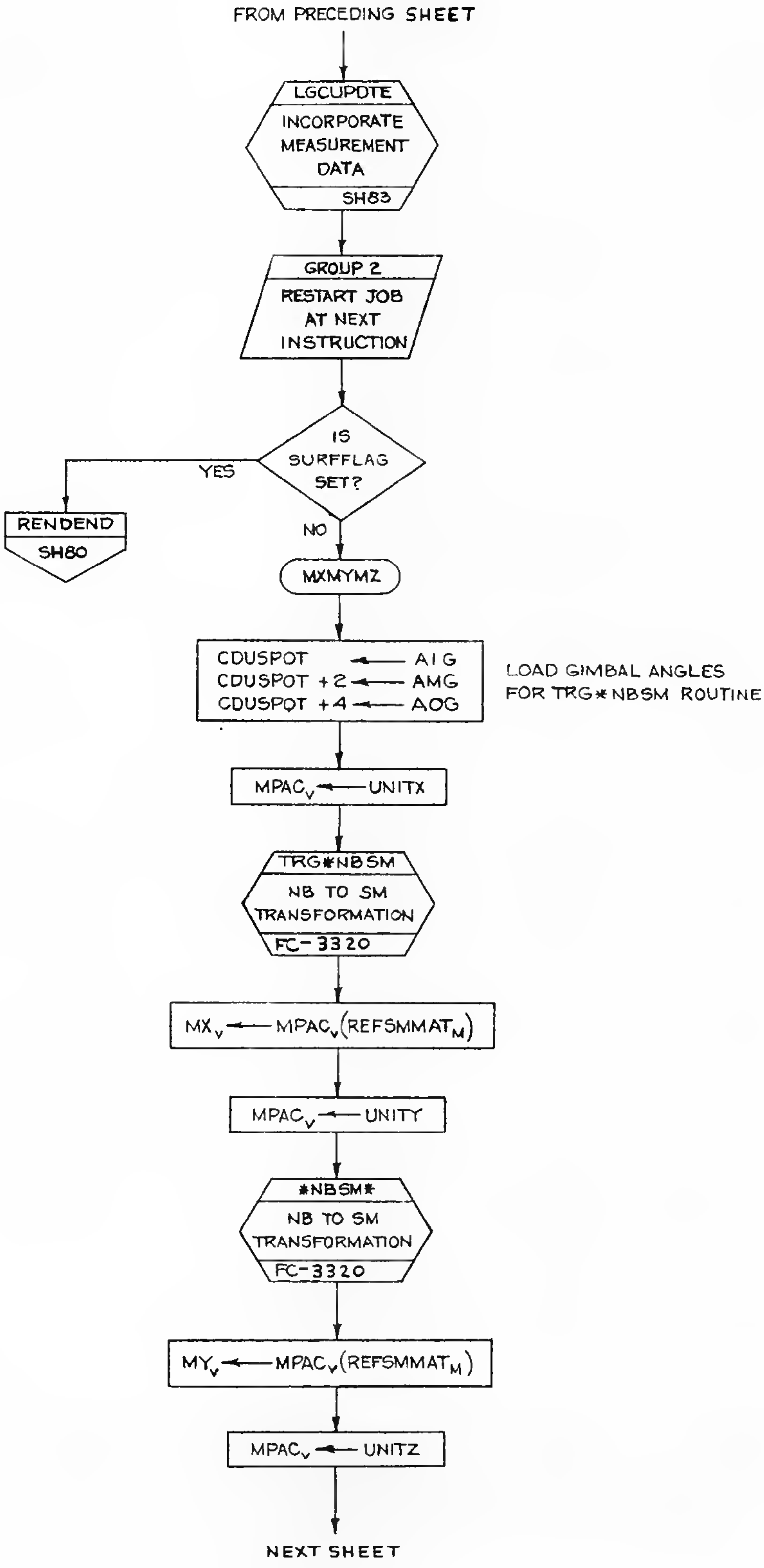
SHEET 74 OF 103



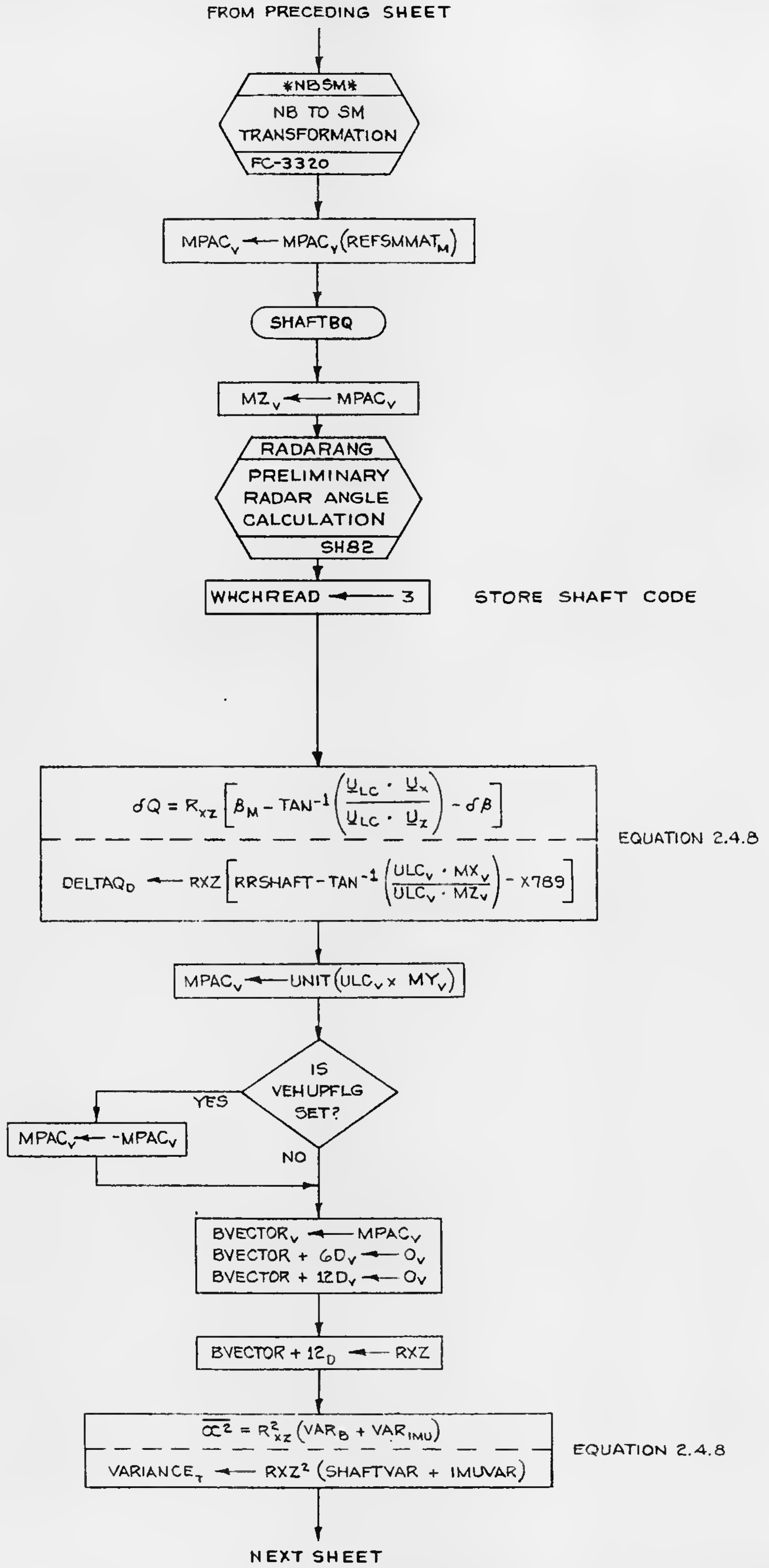
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	A.C.WILLIAMS 4-5-68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGMR	8-16-68	LUMINARY 1D	DOCUMENT NO. FC-3600
ANALST			
DOCMR	5-17-68		
APPR'D	29 Oct 68	REV 2	SHEET 75 OF 103



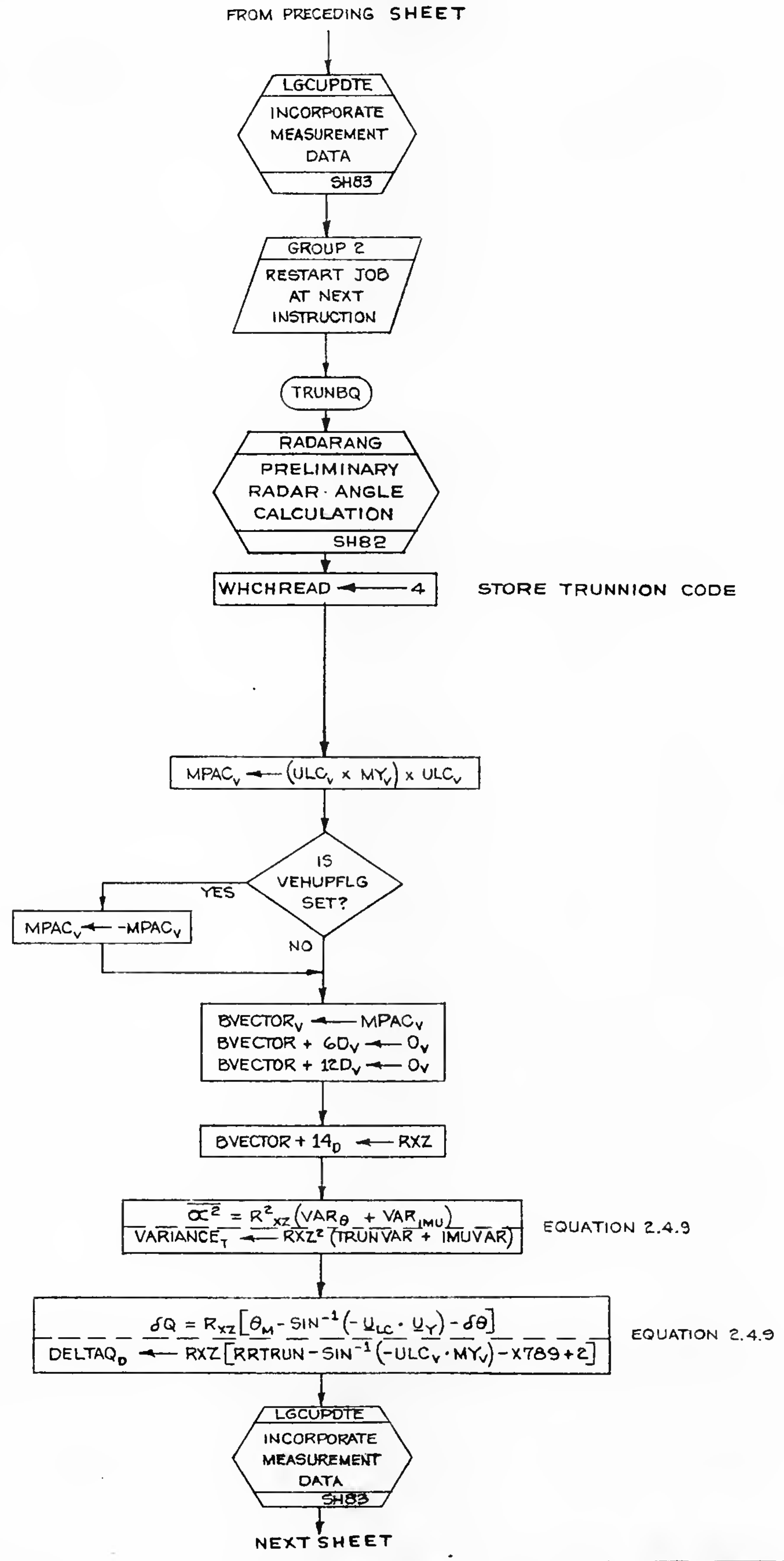
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN G. J. Longille	26MAR69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR S. Volante	10/21/69	LUMINARY 1D
ANALST		DOCUMENT NO. FC-3600
DOCMR W C Dzybich	8-7-69	REV 2
APPR'D R.M. Estes	10/21/69	SHEET 76 OF 103



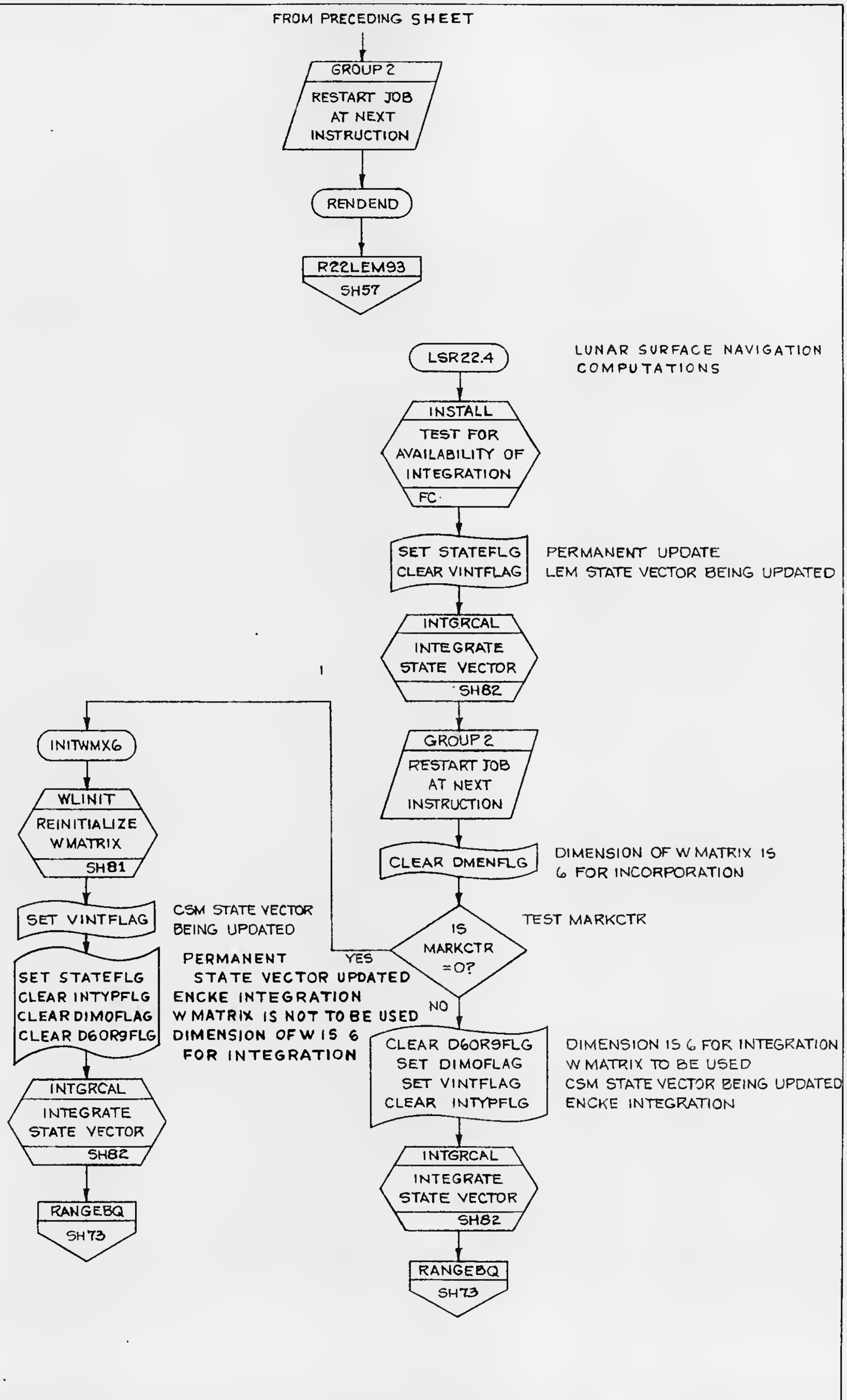
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	4-8-68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR	8-16-68	LUMINARY 1D
ANALYST		DOCUMENT NO. FC-3600
DOCMR	5-17-68	
APPR'D		REV / SHEET 77 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C. WILLIAMS 4-8-68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PROGMR [signature] 8-16-68	LUMINARY 1D
ANALST	DOCUMENT NO. FC-3600
DOCMR W. [signature] 3-17-69	
APPR'D John A. [signature] 29 Oct 68	REV 2 — SHEET 78 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	4-9-68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PROGMR Peter Volante	8-16-68	
ANALST		LUMINARY 1D — DOCUMENT NO. FC-3600
DOCMR M. Diptarti	5-17-68	
APPR'D John A. Moore	29 Oct 68	REV 2 — SHEET 79 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION

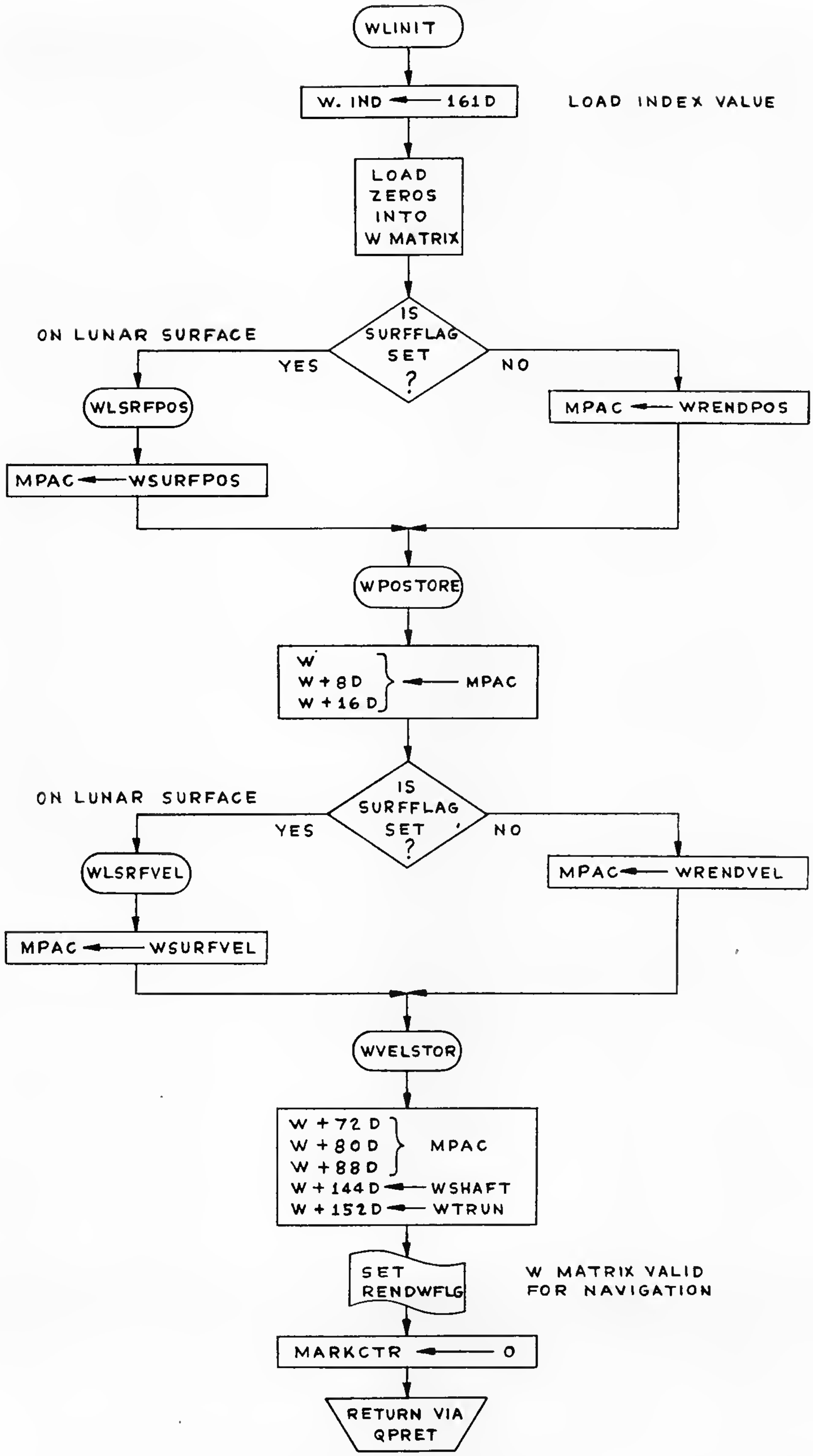
DRAWN A.C.WILLIAMS 4-9-68
PROGMR [illegible] 8-16-68
ANALST
DOCMR [illegible] 5-17-68
APPR'D [illegible] 29Oct68

LUMINARY 1D

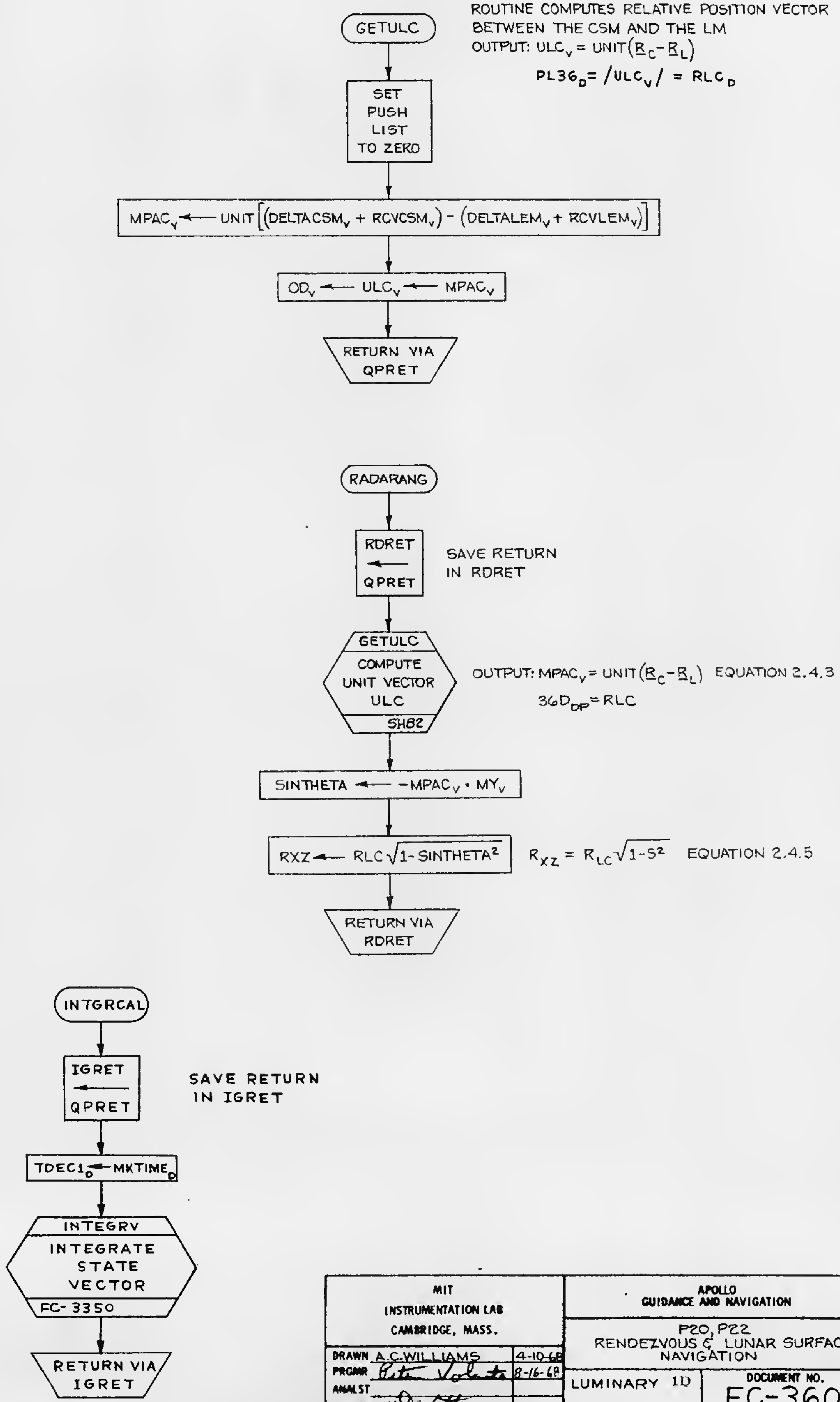
DOCUMENT NO. FC-3600

REV 2

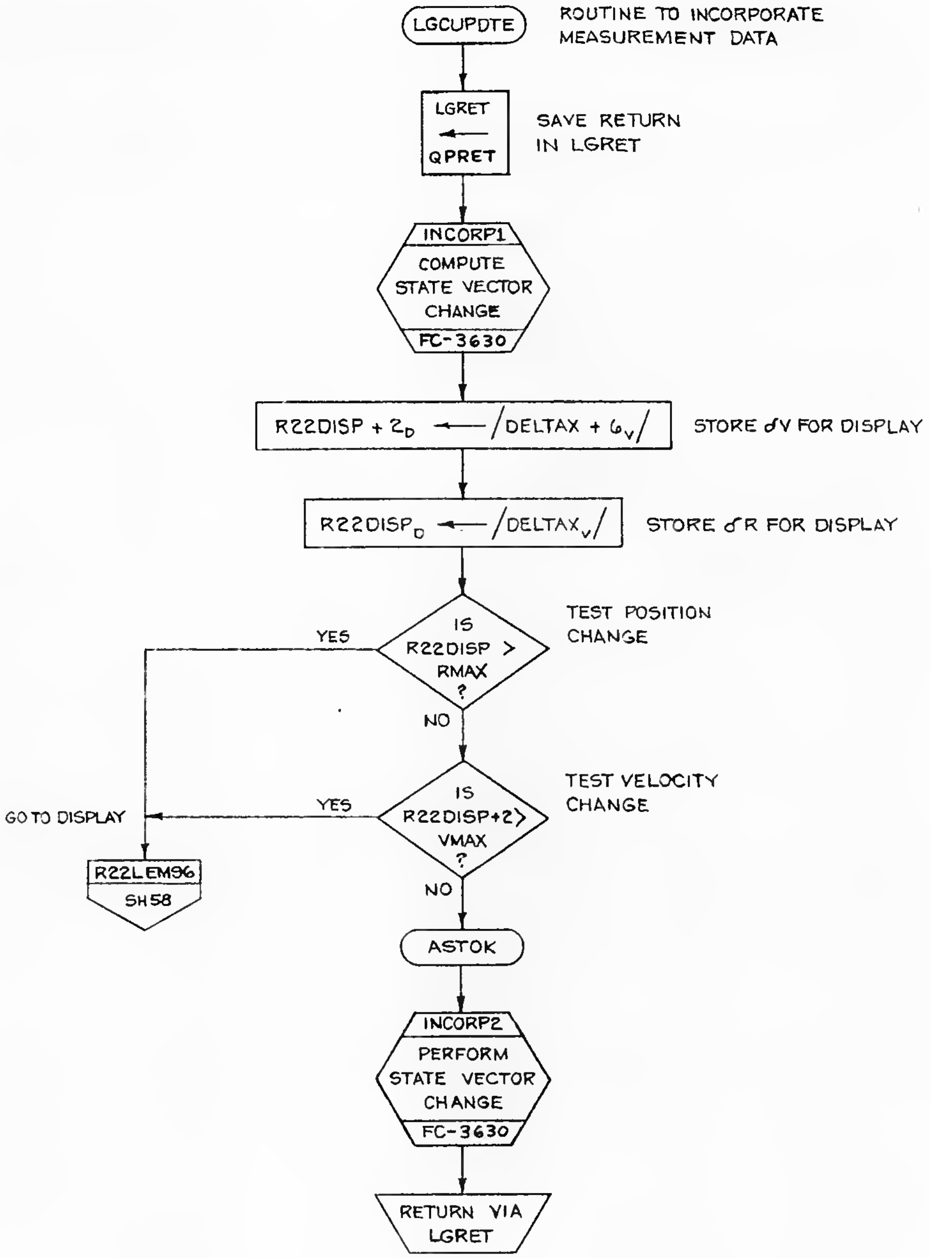
SHEET 80 OF 103



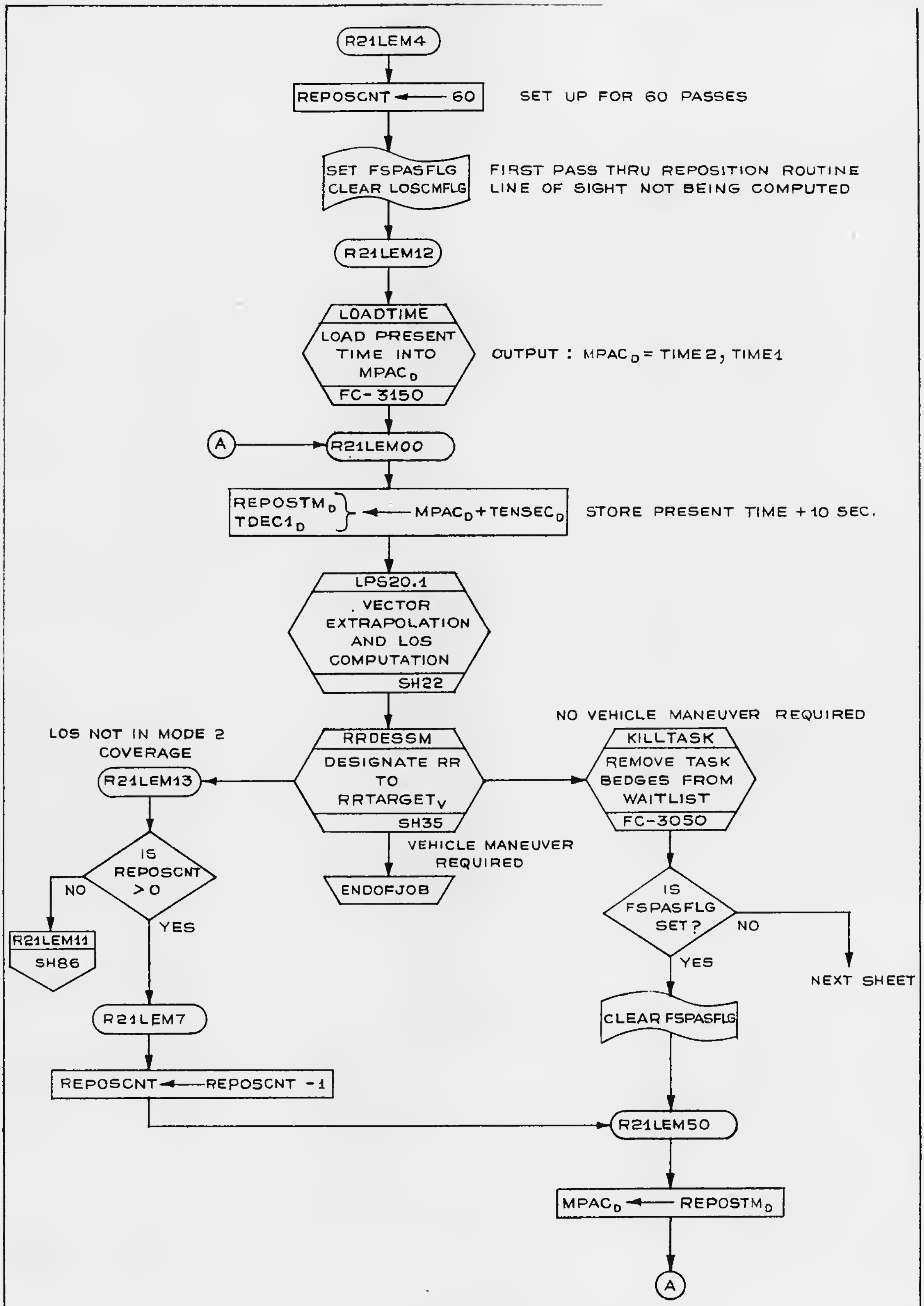
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN	26MAR69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR	10/21/69	LUMINARY 1D — DOCUMENT NO. FC-3600
ANALST		
DOCMR	4-7-69	
APPR'D	10/21/69	REV 2 — SHEET 81 OF 103



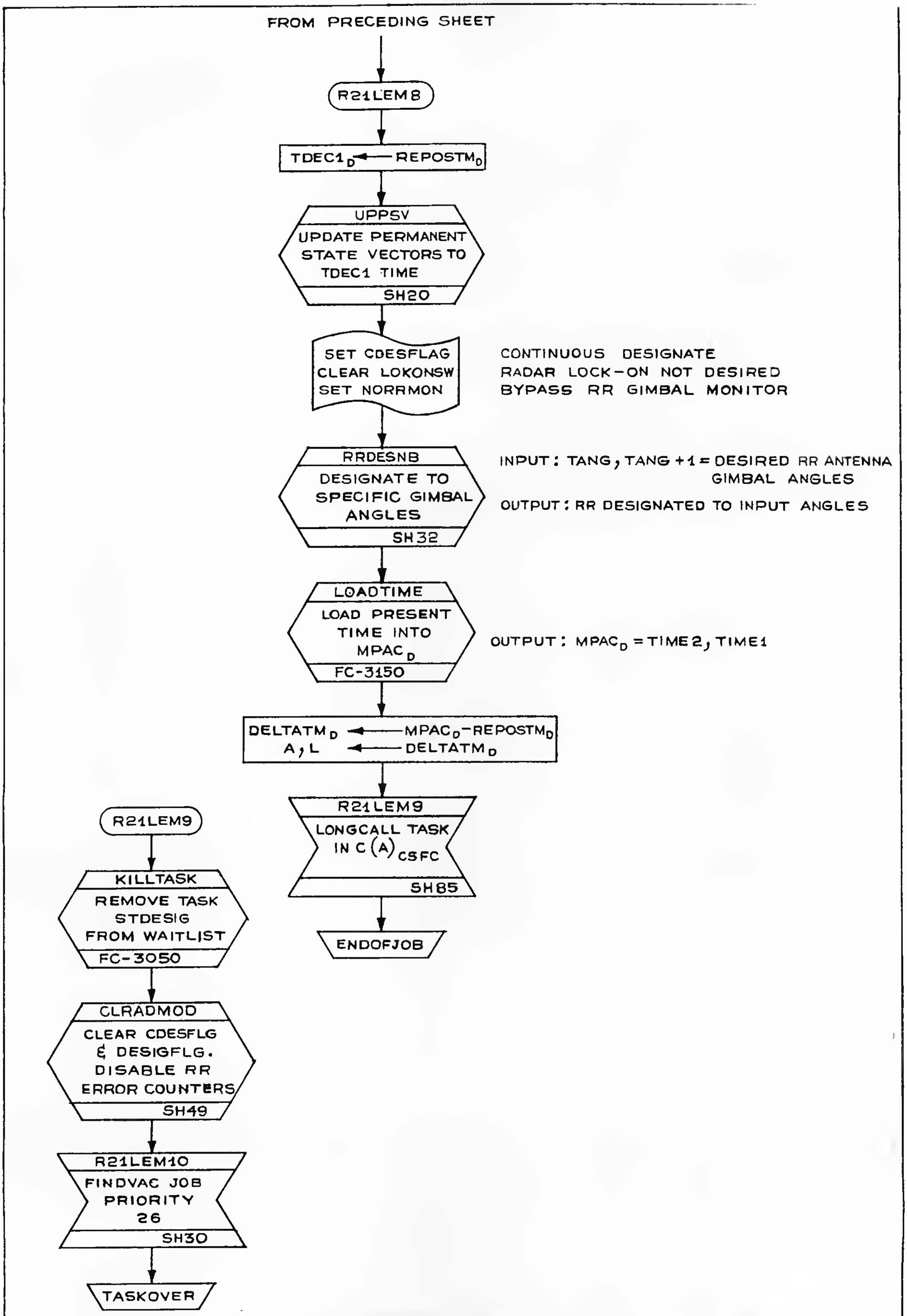
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 4-10-68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR Peter Volante 8-16-68	
ANALST	LUMINARY 1D — DOCUMENT NO. FC-3600
DOCMR W. Dybatt 5-17-6	
APPR'D John A. Moore 22 Oct 68	REV 2 — SHEET 82 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
DRAWN A.C. WILLIAMS	4-10-68	
PRGMR Peter Volante	8-16-68	LUMINARY 1D
ANALST		DOCUMENT NO. FC-3600
DOCMR W. Dagbert	5-17-68	
APPR'D John A. More	29 Oct 68	REV 2 · SHEET 83 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN 20JUNE69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR 10/21/69	LUMINARY 1D
ANALST	DOCUMENT NO. FC-3600
DOCMR 18 JULY 69	REV 2
APPR'D 10/21/69	SHEET 84 OF 103



MIT INSTRUMENTATION LAB
CAMBRIDGE, MASS.

DRAWN	P.M. Dietrich	20 JUNE 69
PROGMR		10/21/69
ANALST		
DOCMR		18 JULY 69
APPR'D		10/21/69

APOLLO GUIDANCE AND NAVIGATION

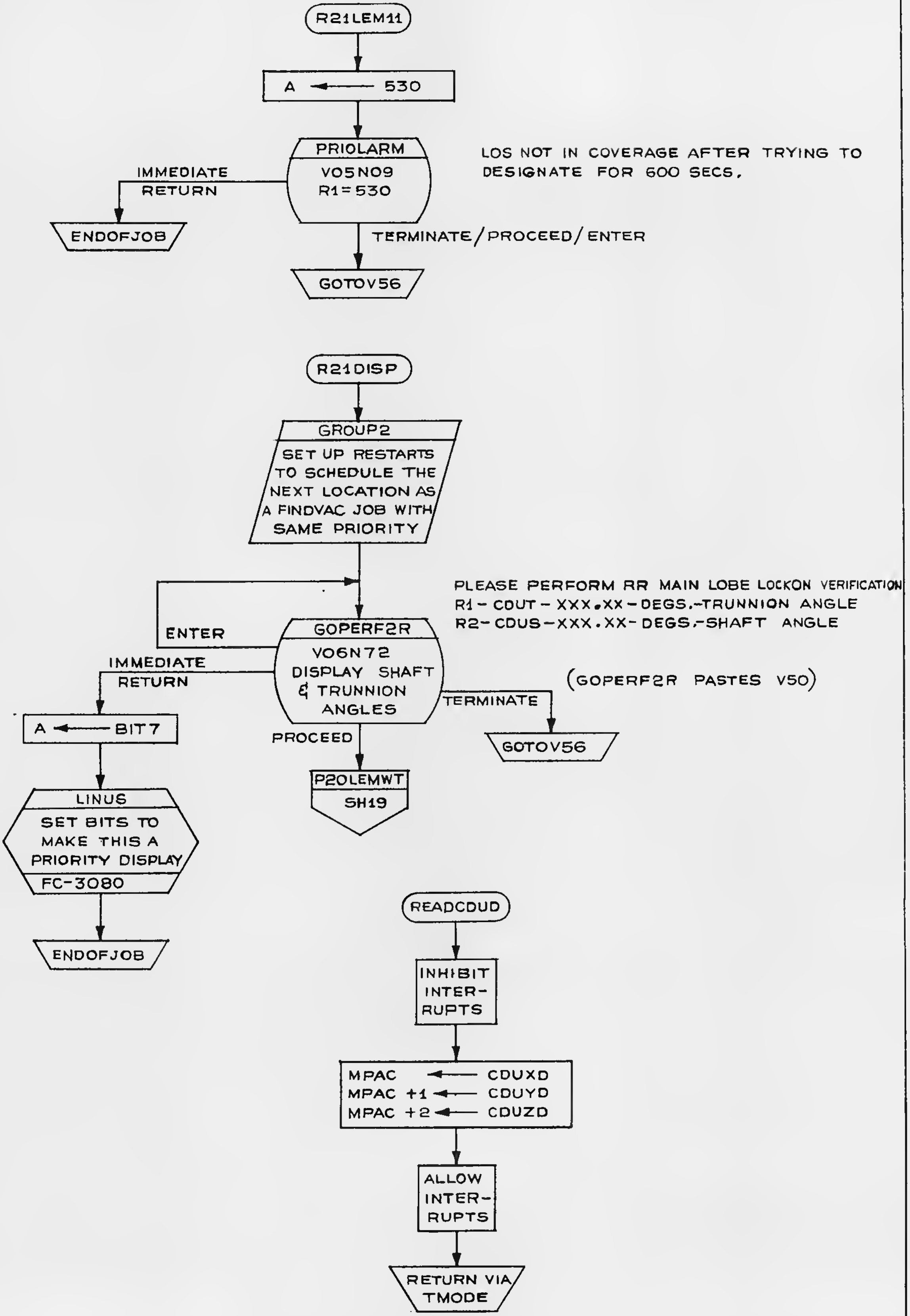
P20, P22
RENDEZVOUS & LUNAR SURFACE NAVIGATION

LUMINARY 1D

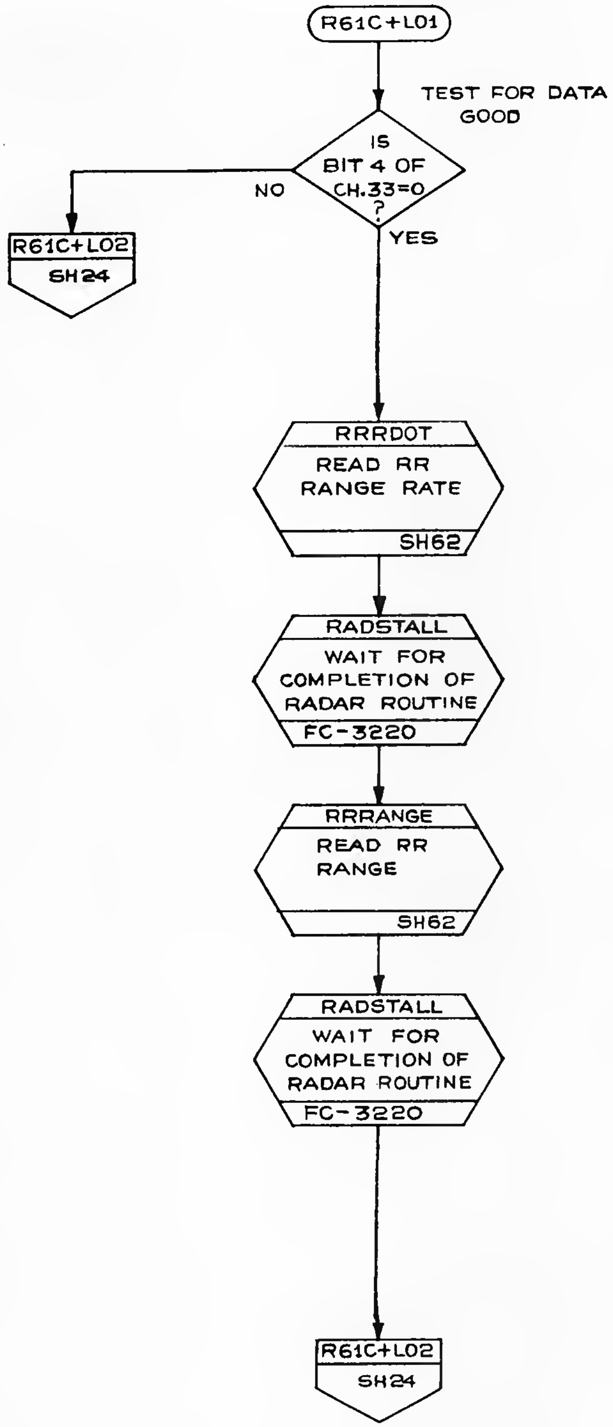
DOCUMENT NO. FC-3600

REV 2

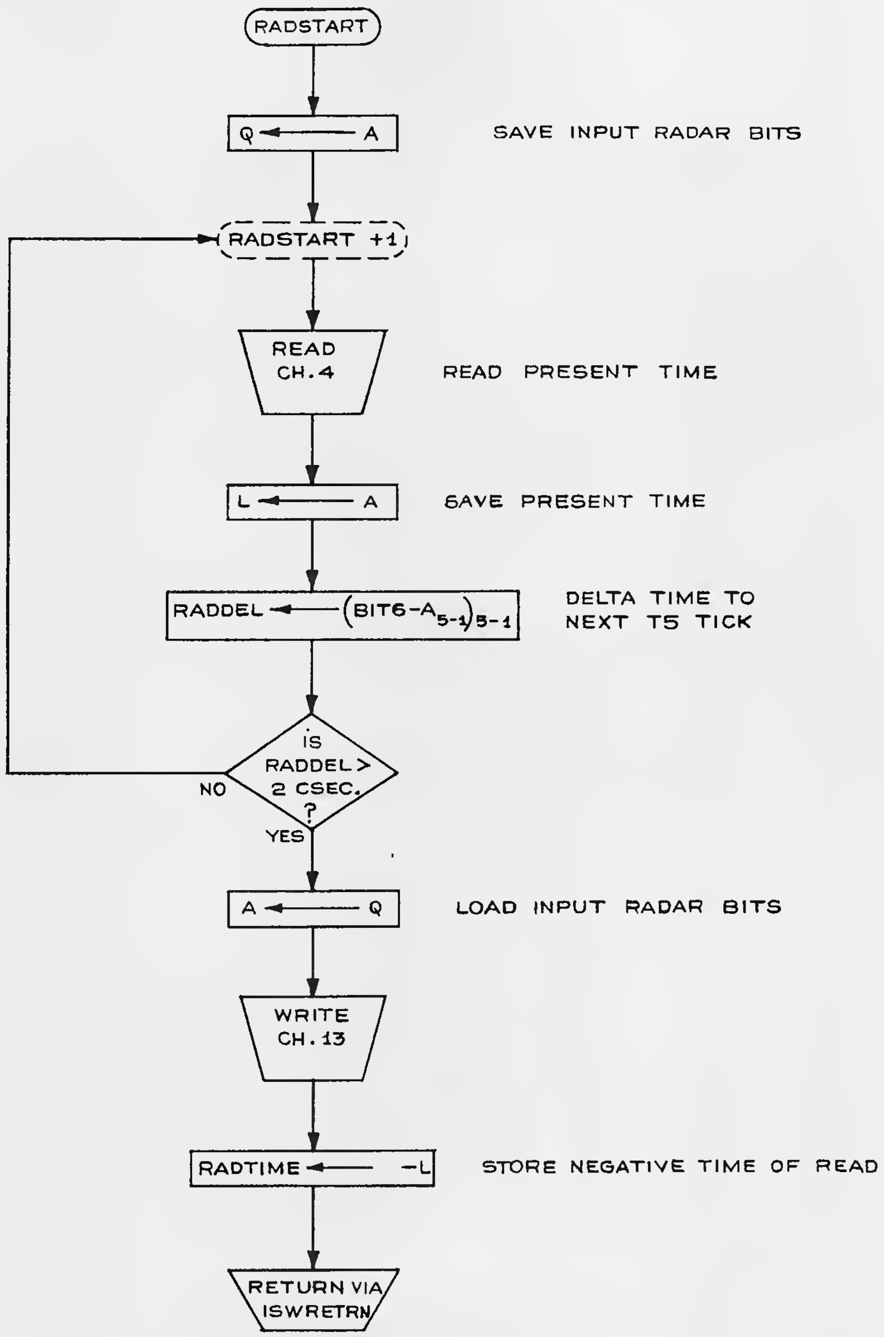
SHEET 85 OF 103



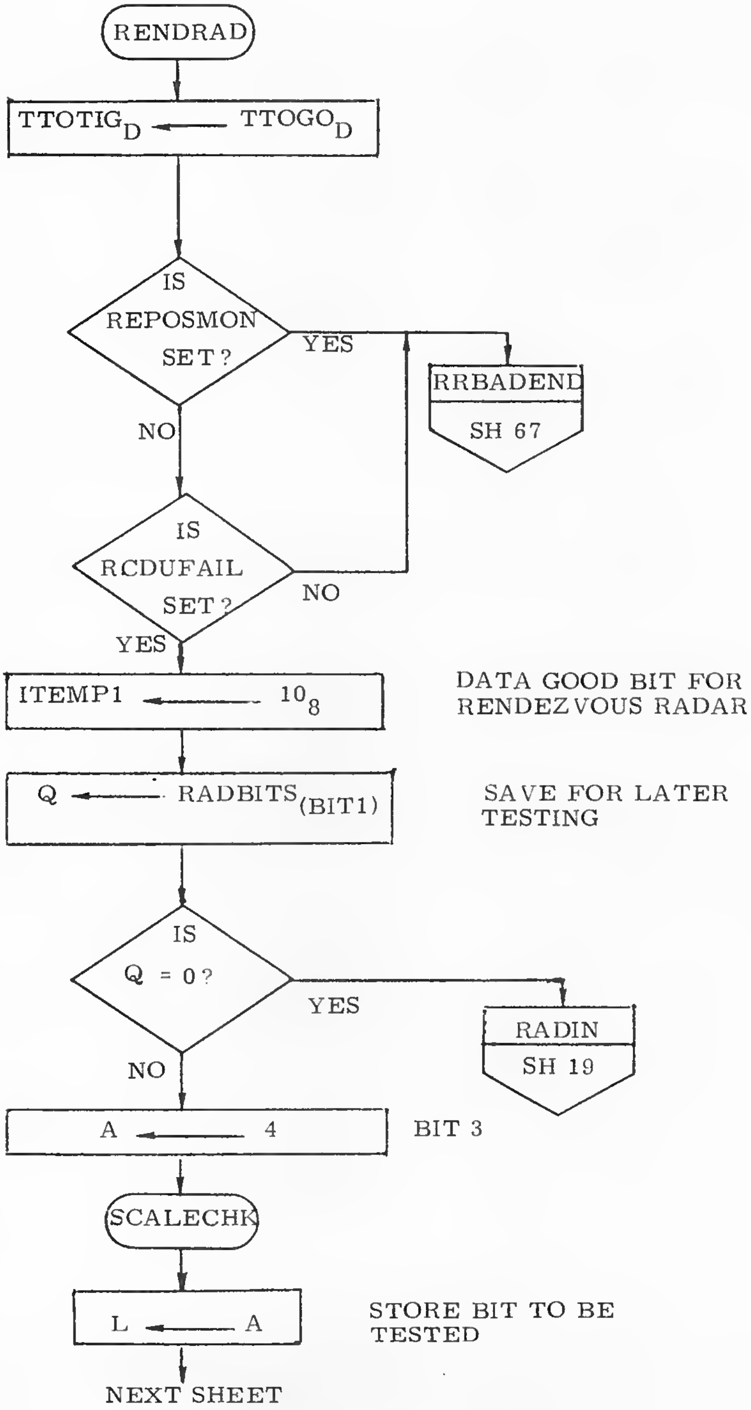
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN	23JUNE69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR	10/21/69	
ANALST		LUMINARY 1D — DOCUMENT NO. FC-3600
DOCMR	10JULY69	
APPR'D	10/21/69	REV. 2 — SHEET 86 OF 103



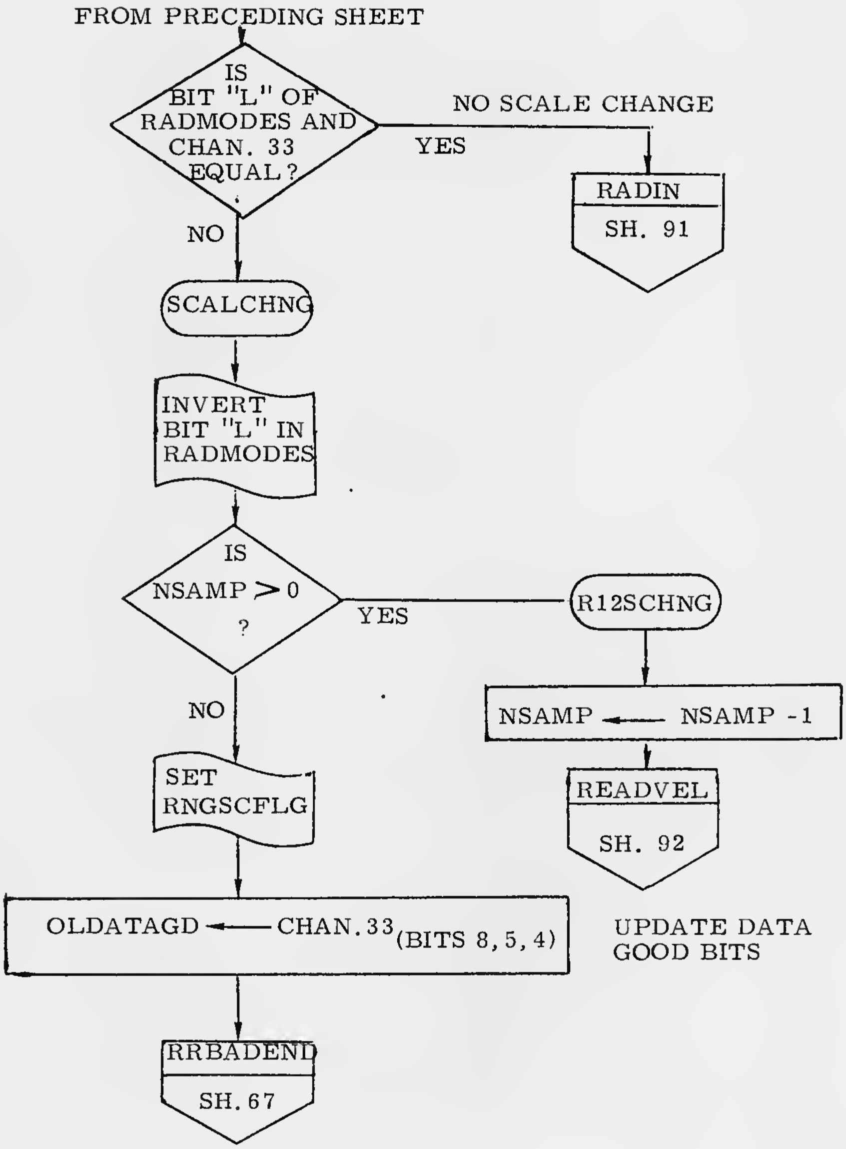
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN P.M. Dietrich	17SEP69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR P. Volante	10/21/69	
ANALST		LUMINARY 1D
DOCMR McDonough	19SEP69	DOCUMENT NO. FC-3600
APPR'D R.M. Estes	10/21/69	REV 2 — SHEET 87 OF 103



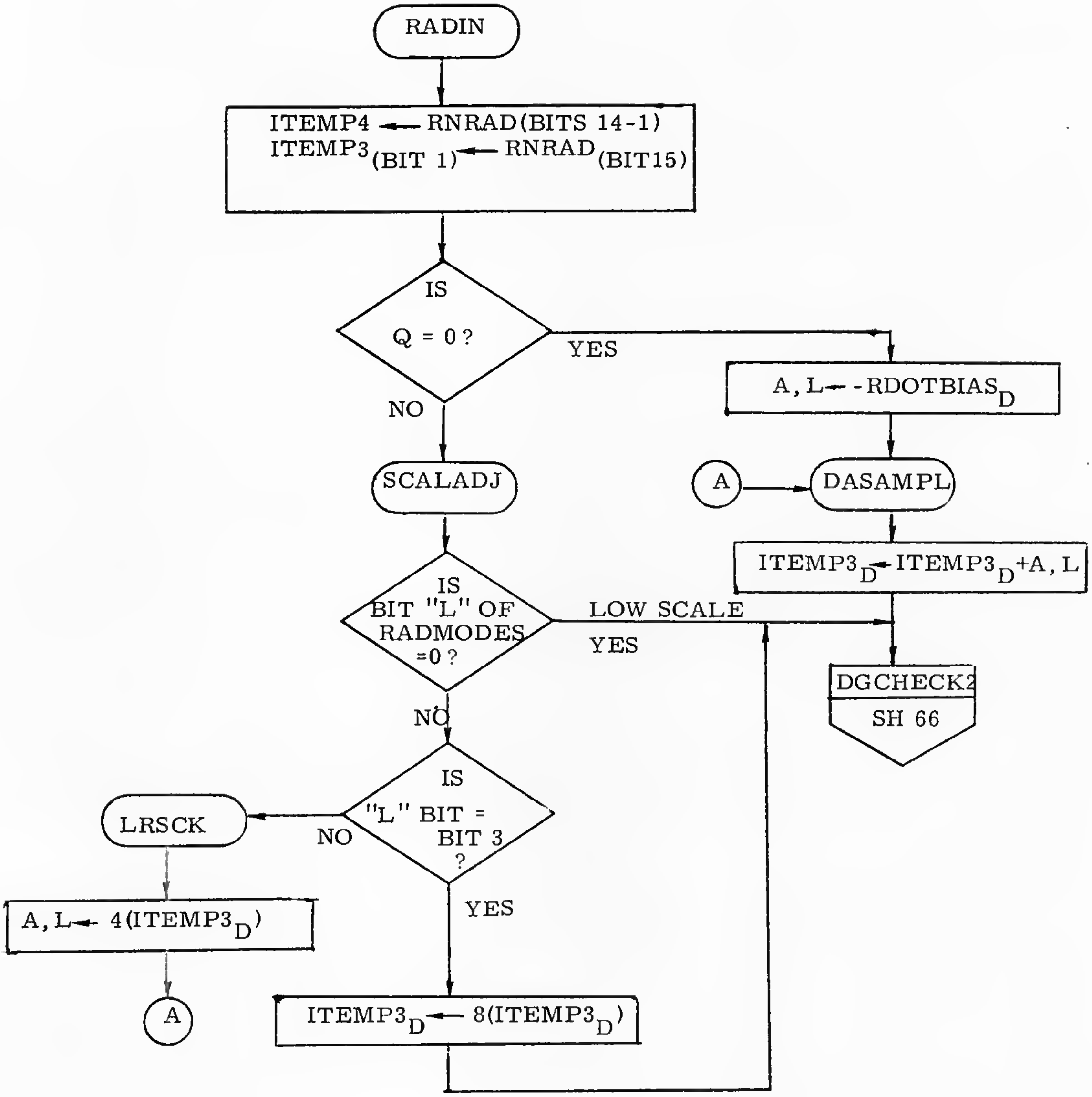
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN	18SEP68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGMR	10/21/69	
ANALST		LUMINARY 1D — DOCUMENT NO. FC-3600
DOCMR	19SEP69	
APPR'D	10/21/69	REV 2. — SHEET 88 OF 103



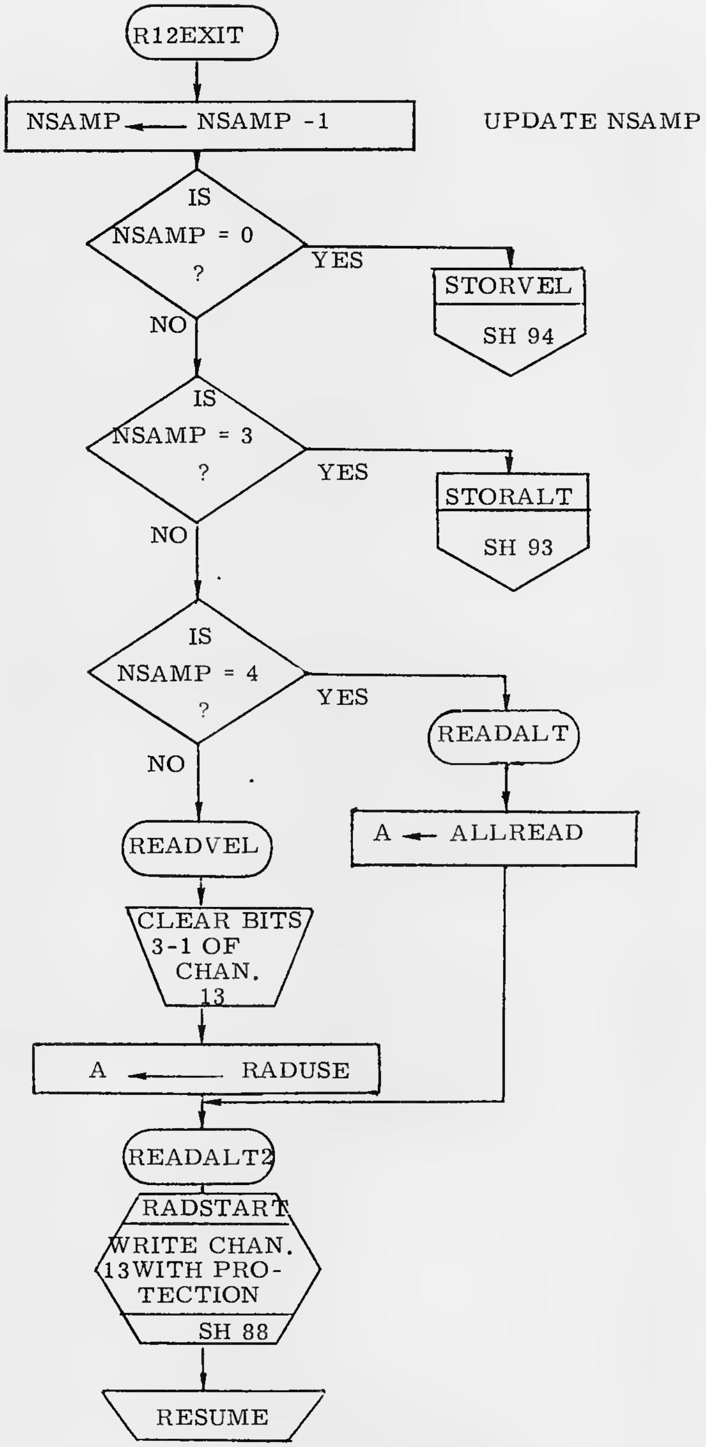
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E. Matta	6/4/70	P20, P22	
PRGMR P. Volante	6/18/70		
ANALST			DOCUMENT NO.
DOCMR M Fitzgerald	6/10/70	LUMINARY 1D	FC-3600
APPR'D R M Estes	6/18/70	REV 2	SHEET 89 OF 103



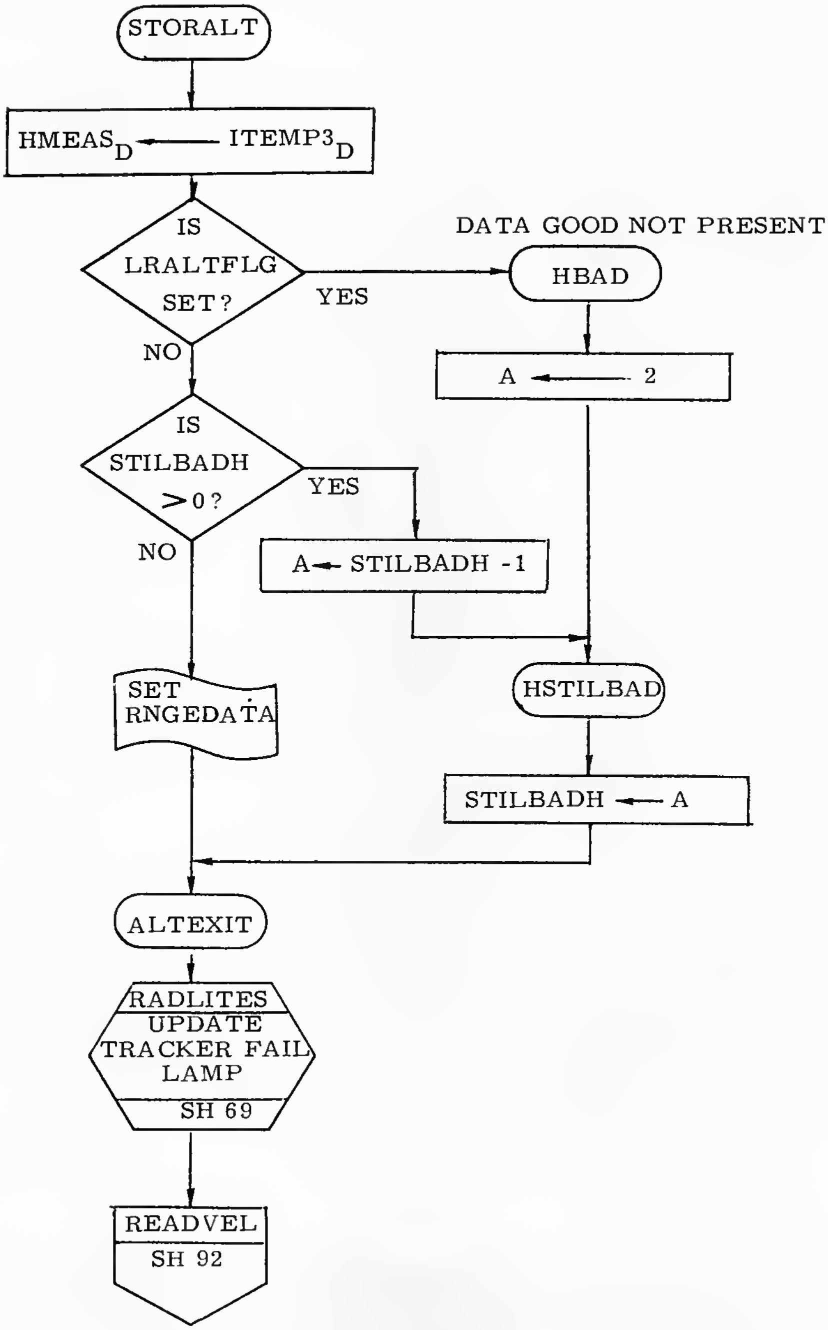
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E. Matta	6/4/70	P20, P22	
PRGMR P. Volante	6/19/70		DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3600
DOCMR	6/10/70		
APPR'D R. McEntee	6/18/70	REV 2	



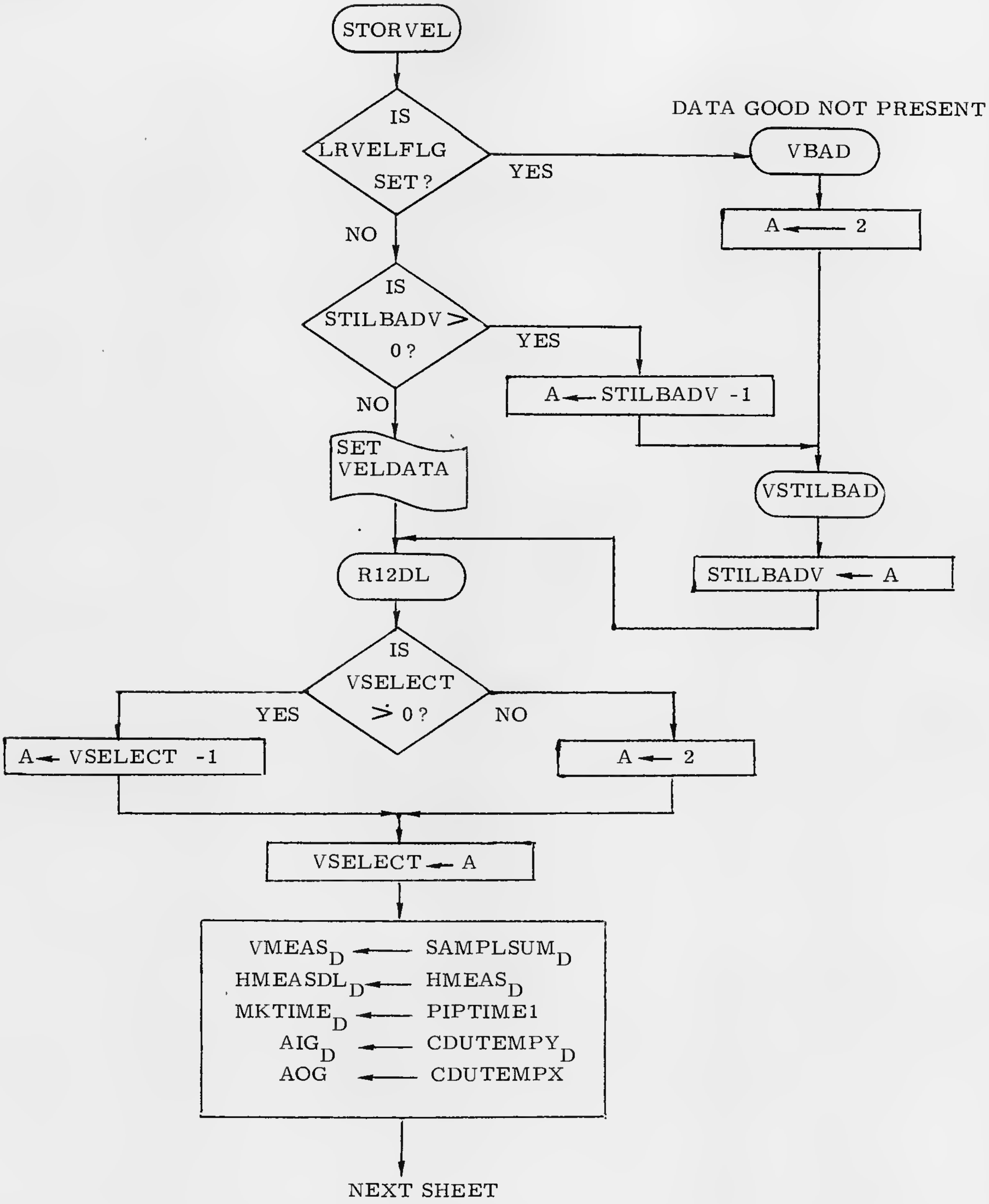
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E. Matis	6/4/70	P20, P22	
PRGMR G. Volante	6/13/70		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3600
DOCMR W. Dunphy	6/9/70		
APPR'D R.M. Enters	6/15/70	REV 2	SHEET 91 OF 103



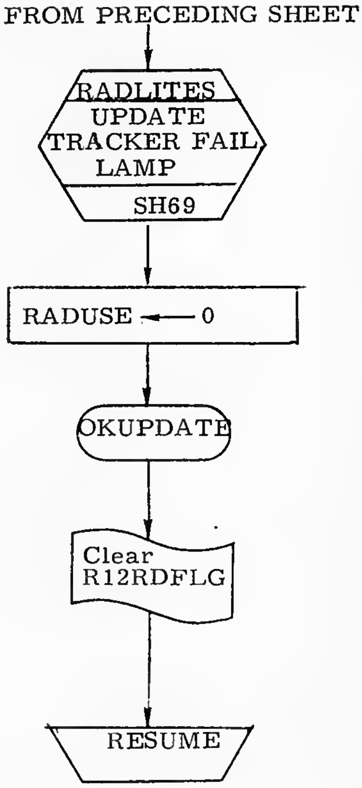
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E Matta	6/4/70	P20, P22	
PRGMR G. Volante	6/18/70		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3600
DOCMR	6/10/70		
APPR'D	6/18/70	REV 2	SHEET 92 OF 103



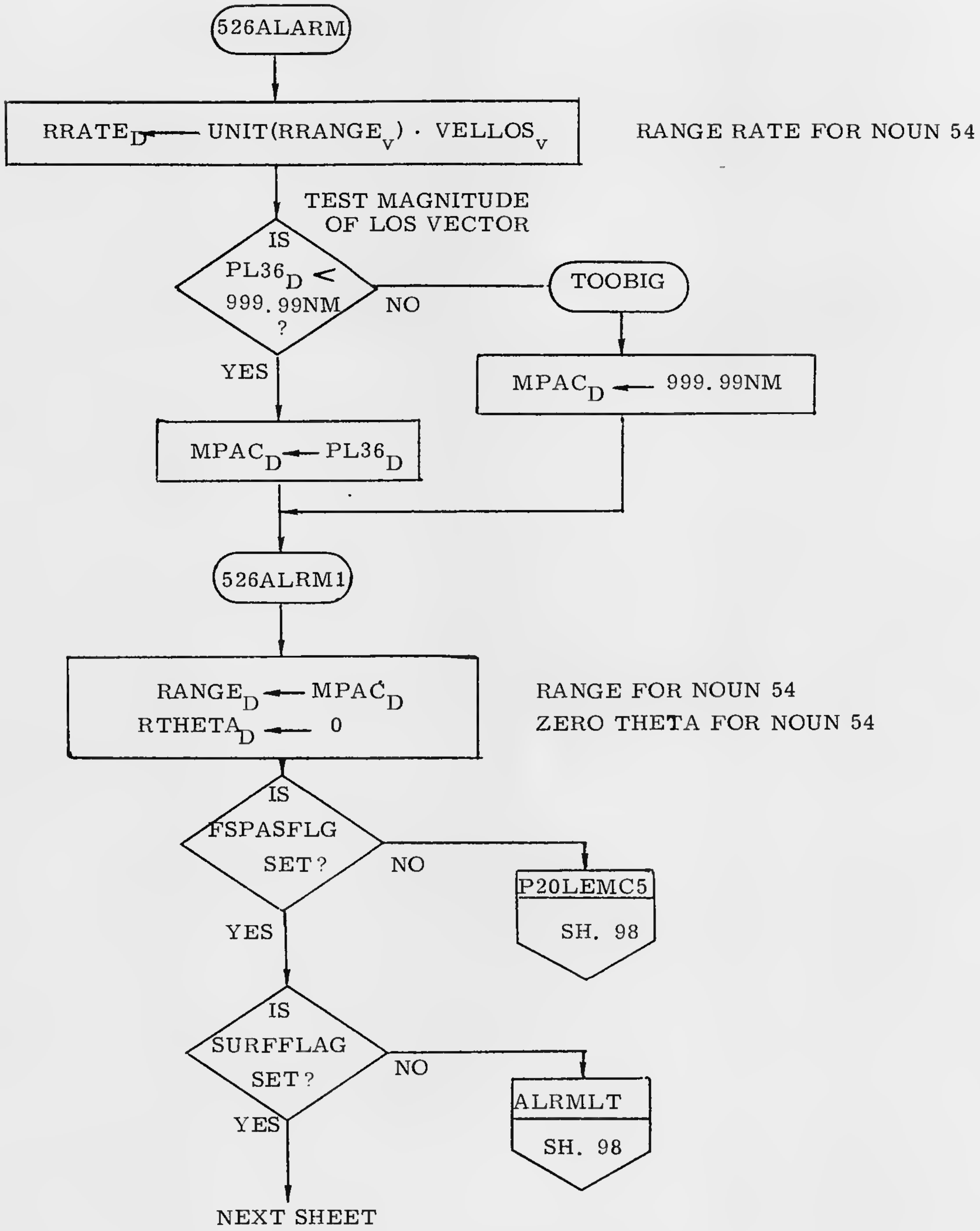
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E. Matta	6/4/70	P20, P22	
PRGMR P. Volante	6/10/70		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3600
DOCMR W. Danforth	6/9/70		
APPR'D R. McCarter	6/18/70	REV 2	SHEET 93 OF 103



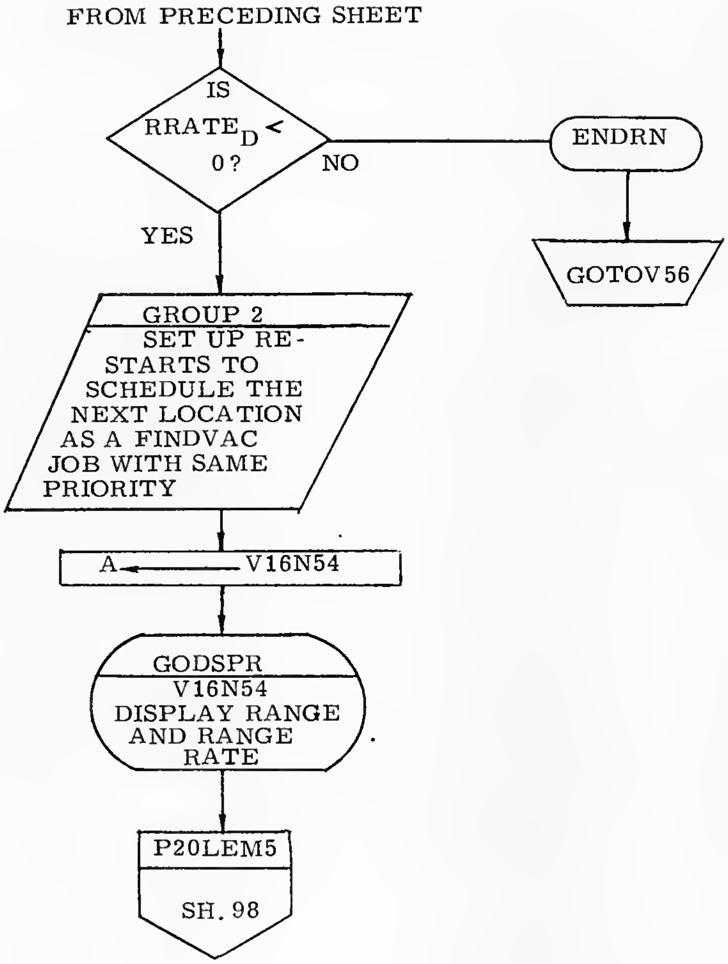
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	6/3/70	P20, P22	
PRGMR	6/19/70		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3600
DOCMR	6/9/70		
APPR'D	6/18/70	REV 2	SHEET 94 OF 103



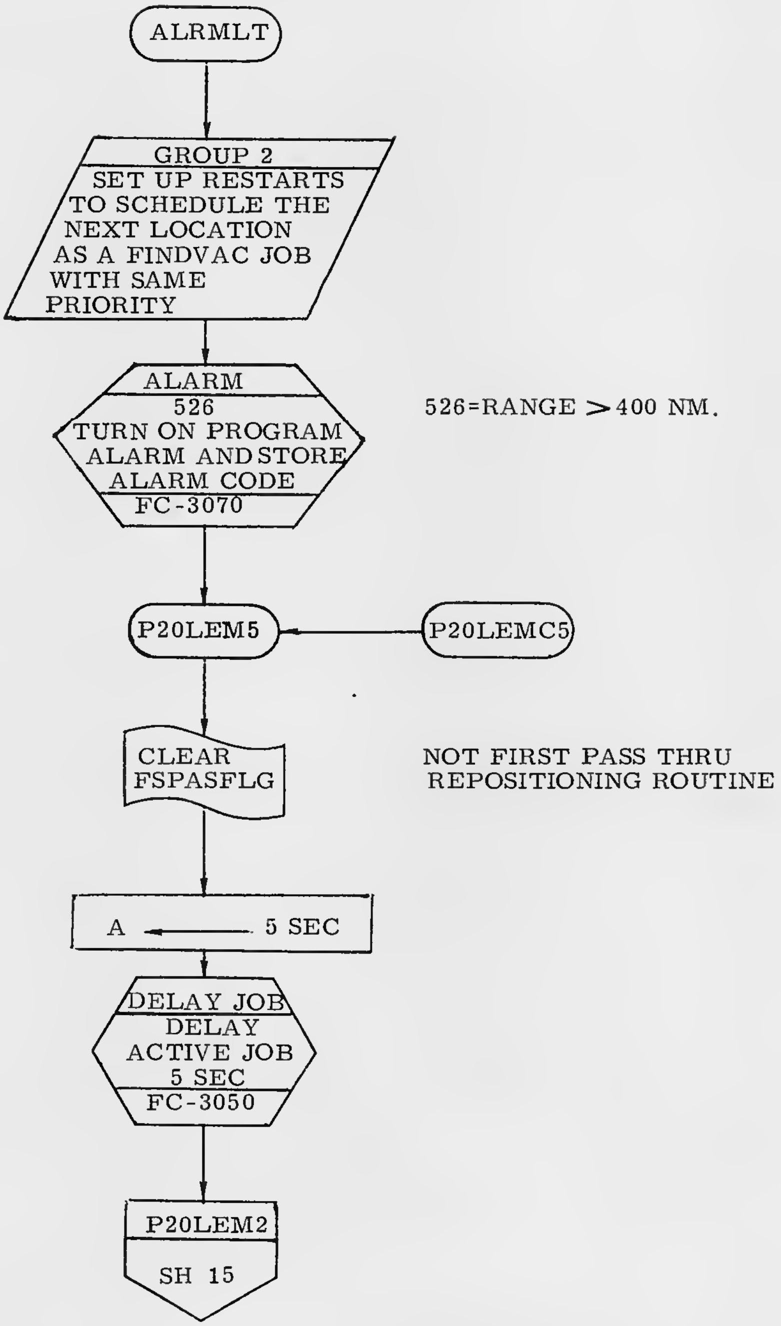
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E Matte	6/3/70	P20, P22	
PRGMR P. Volante	6/18/70		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3600
DOCMR	6/10/70		
APPR'D	6/18/70	REV 2	SHEET 95 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E. Mattos	6/4/70	P20, P22	
PRGMR P. Volante	6/10/70		DOCUMENT NO.
ANALST			
DOCMR W. Forsyth	6/10/70	LUMINARY 1D	FC-3600
APPR'D R. McEntee	6/18/70	REV 2	SHEET 96 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION		
DRAWN	E. Matta	6/4/70	P20, P22	
PRGMR	R. Volante	6/18/70		
ANALST				DOCUMENT NO.
DOCMR	[illegible]	6/10/70	LUMINARY 1D	FC-3600
APPR'D	R. Estes	11/18/70	REV 2	SHEET 97 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E. Matta	6/4/70	P20, P22	
PRGMR P. Volante	6/18/70	LUMINARY 1D	DOCUMENT NO. FC-3600
ANALST			
DOCMR W. Danforth	6/18/70		
APPR'D	6/18/70	REV 2	SHEET 98 OF 103

SUBROUTINES CALLED WHICH ARE
FLOWED ON OTHER FLOW CHARTS

SUBROUTINE NAME	FLOW CHART	DESCRIPTION	WHERE CALLED
ALARM	FC-3070	STORE ALARM CODE AND LITE ALARM LIGHT	SH. 33, 52, 64
ARCTRIG	FC-3310	COMPUTE ANGLE FROM SINE AND COSINE	SH. 8, 37
ATOPCSM	FC-3350	MOVE CSM STATE VECTOR FROM TEMPORARY TO PERMANENT	SH. 14
BALLANGS	FC-3420	COMPUTE LM FDAI BALL DISPLAY ANGLES	SH. 25
BLANKET	FC-3080	BLANK DSKY REGISTER	SH. 7
CDULOGIC	FC-3150	CONVERT 2'S COMPLEMENT ANGLES TO 1'S COMPLEMENT ANGLES	SH. 41, 53
CDUTRIG	FC-3320	COMPUTE SINES AND COSINES OF IMU ANGLES	SH. 35, 40
CDU*SMNB	FC-3320	TRANSFORM VECTOR FROM SM TO NB COORDINATES	SH. 25
CSMCONIC	FC-3350	CSM ORBIT INTEGRATION	SH. 22, 50
DELAYJOB	FC-3050	DELAY ACTIVE JOB	SH. 9, 18
FALTON	FC-3090	TURN ON OPERATOR ERROR LIGHT	SH. 17
FIXDELAY	FC-3040	DELAY ACTIVE TASK	SH. 19, 47
INCORP1	FC-3630	COMPUTE STATE VECTOR DEVIATIONS	SH. 83
INCORP2	FC-3630	INCORPORATE DEVIATIONS INTO ESTIMATED STATE VECTOR	SH. 83
INTEGRV	FC-3350	UPDATE PERMANENT STATE VECTOR	SH. 12, 21
INSTALL	FC-3350	TEST AVAILABILITY OF INTEGRATION	SH. 3, 6, 12, 14, 21
INTWAKE0	FC-3350	RELEASE GRAB OF ORBITAL INTEGRATION	SH. 14
KILLTASK	FC-3050	REMOVE TASK FROM THE WAITLIST	SH 23, 84, 85
LEMCONIC	FC-3350	LM ORBIT INTEGRATION	SH. 22
LOADTIME	FC-3150	LOAD PRESENT TIME INTO $MPAC_D$	SH. 16, 20, 24, 31, 50, 84, 85
MAKECADR	FC-3060	CONSTRUCT CADR OF RETURN ADDRESS	SH. 24
MINIRECT	FC-3350	UPDATE CSM TEMPORARY STATE VECTOR	SH. 14
PR10CHNG	FC-3030	CHANGE PRIORITY OF JOB IN EXECUTION	SH. 3, 17
RADSTALL	FC-3220	WAIT FOR COMPLETION OF RADAR ROUTINE	SH. 30, 31, 59
RESTORDB	FC-3440	SET DEADBAND TO ASTRONAUT SELECTED VALUE	SH. 3, 26
R02BOTH	FC-3220	IMU STATUS CHECK	SH. 15
R60LEM	FC-3420	PERFORM AUTO ATTITUDE MANEUVER	SH. 26
SETMINDB	FC-3440	SET 0.3° RCS DEADBAND	SH. 26
SETRRECR	FC-3210	SET UP RR ERROR COUNTER	SH. 36
STOPRATE	FC-3430	ZERO INPUTS TO AUTOPILOT	SH. 3

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A. J. Fangillo	19 NOV 68	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PROGMR H. Volatt	10/21/69	
ANALST		LUMINARY 1D
DOCMR W C Dewbud	4-7-69	DOCUMENT NO. FC-3600
APPR'D R. M. Evans	10/21/69	REV 2 SHEET 99 OF 103

SUBROUTINES CALLED WHICH ARE FLOWED ON OTHER FLOW CHARTS (CONTINUED)

SUBROUTINE NAME	FLOW CHART	DESCRIPTION	WHERE CALLED
TESTXACT	FC-3100	TEST FOR EXTENDED VERBS OR PRIORITY DISPLAYS ACTIVE	SH. 4, 7
TIMETHET	FC-3360	CALCULATE FLIGHT TIME AND FINAL STATE VECTOR	SH. 14
TRG*NBSM	FC-3320	TRANSFORM FROM NB TO SM COORDINATES	SH. 77
VECPOINT	FC-3420	COMPUTE ANGLES TO POINT VEHICLE	SH. 25
2V1STO2S	FC-3150	CONVERT 1'S COMPLEMENT ANGLES TO 2'S COMPLEMENT ANGLES	SH. 38
NBSM	FC-3320	TRANSFORM FROM NB TO SM COORDINATES	SH. 42
SMNB	FC-3320	TRANSFORM FROM SM TO NB COORDINATES	SH. 35, 41

FLAGS

NAME	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
ACMODFLG FLAG2BIT13	MANUAL ACQUISITION BY RENDEZVOUS RADAR	AUTO ACQUISITION BY RENDEZVOUS RADAR	SH. 17	SH. 15	SH. 18
ANTENFLG FLAG12BIT12	RR ANTENNA IN MODE 2	RR ANTENNA IN MODE 1			SH. 29, 41 30, 45, 46
AUTOMODE FLAG12BIT12	RR NOT IN AUTO MODE	RR IN AUTO MODE			SH. 47, 71
CDESFLAG FLAG12BIT15	CONTINUOUS DESIG-NATE, LGC COMMANDS RR REGARDLESS OF LOCK-ON	LGC CHECKS FOR LOCK-ON WHEN ANTENNA BEING DESIGNATED	SH. 51, 85	SH. 2, 3, 33, 49	SH. 39, 46
DESIGFLG FLAG12BIT10	RR DESIGNATE REQUESTED OR IN PROGRESS	RR DESIGNATE NOT REQUESTED OR IN PROGRESS		SH. 2, 3, 33 40, 43, 49	SH. 39, 46
DIMOFLAG FLAG3BIT1	W-MATRIX IS TO BE USED	W-MATRIX IS NOT TO BE USED	SH. 13, 20, 73, 80	SH. 12, 20, 21, 72, 80	
DMENFLG FLAG5BIT9	DIMENSION OF W IS 9 FOR INCORPORATION	DIMENSION OF W IS 6 FOR INCORPORATION	SH. 72	SH. 80	
D6OR9FLG FLAG3BIT2	DIMENSION OF W IS 9 FOR INTEGRATION	DIMENSION OF W IS 6 FOR INTEGRATION	SH. 13, 20, 73	SH. 12, 20, 21, 72, 80	
IMUSE FLAG0BIT8	IMU IN USE	IMU NOT IN USE		SH. 2	
INTYPFLG FLAG3BIT4	CONIC INTEGRATION	ENCKE INTEGRATION		SH. 12, 20, 21, 73, 80	
LMOONFLG FLAG8BIT11	PERMANENT LM STATE IN LUNAR SPHERE	PERMANENT LM STATE IN EARTH SPHERE			SH. 73
LOKONSW FLAG0BIT5	RADAR LOCK-ON DESIRED	RADAR LOCK-ON NOT DESIRED	SH. 30, 31	SH. 30, 85	SH. 42
LOSCMFLG FLAG2BIT12	LINE OF SIGHT BEING COMPUTED	LINE OF SIGHT NOT BEING COMPUTED	SH. 49	SH. 15, 31, 32, 43, 84	SH. 22, 43
LRVELFLG FLAG12BIT8	LR VELOCITY DATA FAIL	NO LR VELOCITY DATA FAIL		SH. 63	SH. 94

FLAGS (CONTINUED)

NAME	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
NORRMON FLAG5BIT4	BYPASS RR GIMBAL MONITOR	PERFORM RR GIMBAL MONITOR	SH.28, 85	SH.15,28, 31	
NOUPFLAG FLAG1BIT6	NEITHER CSM NOR LM STATE VECTOR MAY BE UPDATED	EITHER STATE VECTOR MAY BE UPDATED	SH.10		SH.56
PDSPFLAG FLAG4BIT12	P20 SETS SO AS TO TURN A NORMAL DISPLAY INTO A PRIORITY DISPLAY IN R60	LEAVE AS NORMAL DISPLAY	SH.26	SH.26	
P25FLAG FLAG0BIT9	P25 OPERATING	P25 NOT OPERATING		SH.2	SH.2, 24
RCDUFAIL FLAG12BIT7	RR CDU FAIL HAS NOT OCCURRED	RR CDU FAIL OCCURRED			SH.66, 68, 71
RCDUOFLG FLAG12BIT13	RR CDU'S BEING ZEROED	RR CDU'S NOT BEING ZEROED			SH.18, 54, 71
REMODFLG FLAG12BIT14	REMODE REQUESTED OR IN PROGRESS	NO REMODE REQUESTED OR IN PROGRESS	SH.33	SH.46	SH.39, 47, 50
RENDWFLG FLAG5BIT1	W-MATRIX VALID FOR NAVIGATION	W-MATRIX INVALID FOR NAVIGATION	SH.81	SH.5, 10	SH.13, 20, 73
REPOSMON FLAG12BIT11	RR REPOSITION IS TAKING PLACE	NO REPOSITION TAKING PLACE			SH.36, 43, 47
RNDVZFLG FLAG0BIT7	P20 RUNNING (RADAR IN USE)	P20 NOT RUNNING	SH.15	SH.2	SH.2, 19, 23, 36, 54
RNGSCFLG FLAG5BIT10	SCALE CHANGE HAS OCCURRED DURING RR READING	NO SCALE CHANGE HAS OCCURRED DURING RR READING	SH.90	SH.59	SH.60
RRNBSW FLAG0BIT6	RADAR TARGET IN NB COORDINATES	RADAR TARGET IN SM COORDINATES	SH.33	SH.23,35	SH.40, 42
RRRSFLAG FLAG12BIT3	RR RANGE READING ON THE HIGH SCALE	RR RANGE READING ON THE LOW SCALE	SH.59	SH.59	
RVSW FLAG7BIT9	DO NOT COMPUTE FINAL STATE VECTOR IN TIME-THETA	COMPUTE FINAL STATE VECTOR IN TIME-THETA		SH.13	
R04FLAG FLAG3BIT9	ALARM 521 SUPPRESSED	ALARM 521 ALLOWED		SH.15	
R61FLAG FLAG1BIT10	RUN R61 LEM	RUN R65 LEM	SH.24	SH.24	SH.27
R77FLAG FLAG5BIT11	R77 IS ON	R77 IS NOT ON			SH.65
SRCHOPTN FLAG2BIT14	RADAR IN AUTOMATIC SEARCH OPTION (R24)	RADAR NOT IN AUTOMATIC SEARCH OPTION	SH.49	SH.15	SH.18, 43, 49
STATEFLG FLAG3BIT5	PERMANENT STATE VECTOR UPDATED	PERMANENT STATE VECTOR NOT UPDATED	SH.20, 72, 73, 80		
SURFFLAG FLAG8BIT8	LM ON LUNAR SURFACE	LM NOT ON LUNAR SURFACE			SH.5, 18, 20, 21 36, 81
TRACKFLG FLAG1BIT5	TRACKING ALLOWED	TRACKING NOT ALLOWED	SH.15	SH.2	SH.2, 17, 24, 54, 55
UPDATFLG FLAG1BIT7	UPDATING BY MARKS ALLOWED	UPDATING BY MARKS NOT ALLOWED	SH.15	SH.2	SH.56
VEHUPFLG FLAG1BIT8	CSM STATE VECTOR BEING UPDATED	LM STATE VECTOR BEING UPDATED	SH.11	SH.11	SH.20, 75, 78, 79

FLAGS (CONTINUED)

NAME	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
VINTFLAG FLAG3BIT3	CSM STATE VECTOR BEING INTEGRATED	LM STATE VECTOR BEING INTEGRATED	SH.20, 21, 72, 80	SH. 12, 20, 72, 73, 80	
V67FLAG FLAG7BIT8	ASTRONAUT OVERWRITE W-MATRIX INITIAL VALUES	ASTRONAUT DOES NOT OVERWRITE W-MATRIX INITIAL VALUES	SH.5	SH.6	SH.5
3AXISFLG FLAG5BIT6	MANEUVER SPECIFIED BY THREE AXIS	MANEUVER SPECIFIED BY ONE		SH.26	

DISPLAYS

VERB-NOUN	TYPE OF DISPLAY	DESCRIPTION OF EACH REGISTER	WHERE EXECUTED
V06N99	FLASHING	R1 - WWPOS - XXX.XX NAUT. MI. - RMS POSITION ERROR R2 - WWVEL - XXX.XX FT/SEC - RMS VELOCITY ERROR	SH. 4
V04N06	FLASHING	R1 - OPTION1 - 00012 - OPTION CODE FOR ASSUMED CSM ORBIT R2 - OPTION2 - 0000X 1 - CSM WILL NOT CHANGE ORBIT 2 - CSM WILL CHANGE ORBIT TO PASS OVER PRESENT LM POSITION	SH. 11
V06N33	FLASHING	R1 XXX. HRS R2 TIG_D - XX. MIN ESTIMATED TIME OF LAUNCH R3 XX.XX SEC	SH. 12
V16N80	PRIORITY FLASHING	R1 - DATAGOOD - XXXXX. - DATA INDICATOR RADAR SEARCH R2 - OMEGAD - XXX.XX DEG. - OMEGA PARAMETERS	SH. 49
V06N05	PRIORITY FLASHING	R1 - DSPTEM1 - XXX.XX DEG. - ANGULAR DIFFERENCE BETWEEN RR AND STATE VECTOR LOS	SH. 55
V06N49	PRIORITY FLASHING	R1 - DSPTEM1 - XXXX.X NAUT. MI. - DELTA R EXCESSIVE R2 - DSPTEM1+2 - XXXX.X FT/SEC - DELTA V UPDATE PAREMETERS R3 - WHCHREAD - XXXXX. - RADAR SOURCE CODE	SH. 58

ALARMS	MEANING	USED
201	SWITCH RR MODE TO AUTOMATIC	SH. 17
205	PERFORM MANUAL ACQUISITION OF RR	SH. 28
501	RADAR ANTENNA OUT OF LIMITS	SH. 28
503	RADAR ANTENNA DESIGNATE FAIL	SH. 30
514	RR GOES OUT OF AUTO MODE WHILE IN USE	SH. 17
520	RADARUPT NOT EXPECTED AT THIS TIME	SH. 64
525	DELTA THETA GREATER THAN 3°	SH. 55
526	RANGE GREATER THAN 400 NAUTICAL MILES	SH. 98
527	VEHICLE MANEUVER REQUIRED	SH. 52

ERASABLE LOCATIONS USED

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
RDOTM	$\dot{R}_M$	RADAR RANGE RATE	METERS/SEC	METERS CSEC	2^7
$TANGNB_D$		RR TRUNNION AND SHAFT ANGLES	DEGREES	REVS	2^0
RRTRUN	θ_M	RADAR TRUNNION ANGLE	DEGREES	REVS	2^0
RRSHAFT	β_M	RADAR SHAFT ANGLE	DEGREES	REVS	2^0
RM	R_M	RADAR RANGE	METERS	METERS	2^{29}
$RRBORSIT_V$	$\underline{r}_{LOS}$	RR LINE OF SIGHT VECTOR	—	—	2^1
$RRTARGET_V$		STATE VECTORS LOS TO CSM	—	—	2^1
$LOSVEL_V$	$\underline{V}_{LC}$	RELATIVE VELOCITY BETWEEN LM AND CSM	METERS/SEC	METERS/CSEC	2^7
$POINTVSM_V$		DIRECTION VECTOR TO CSM	—	—	2^1
$BVECTOR_V$	b_0, b_1, b_2	GEOMETRY VECTORS	SEE TABLE		
$DELTAQ_V$	δQ	MEASURED DEVIATIONS	SEE TABLE		
$VARIANCE_V$	α^2	MEASUREMENT ERROR VARIANCES	SEE TABLE		

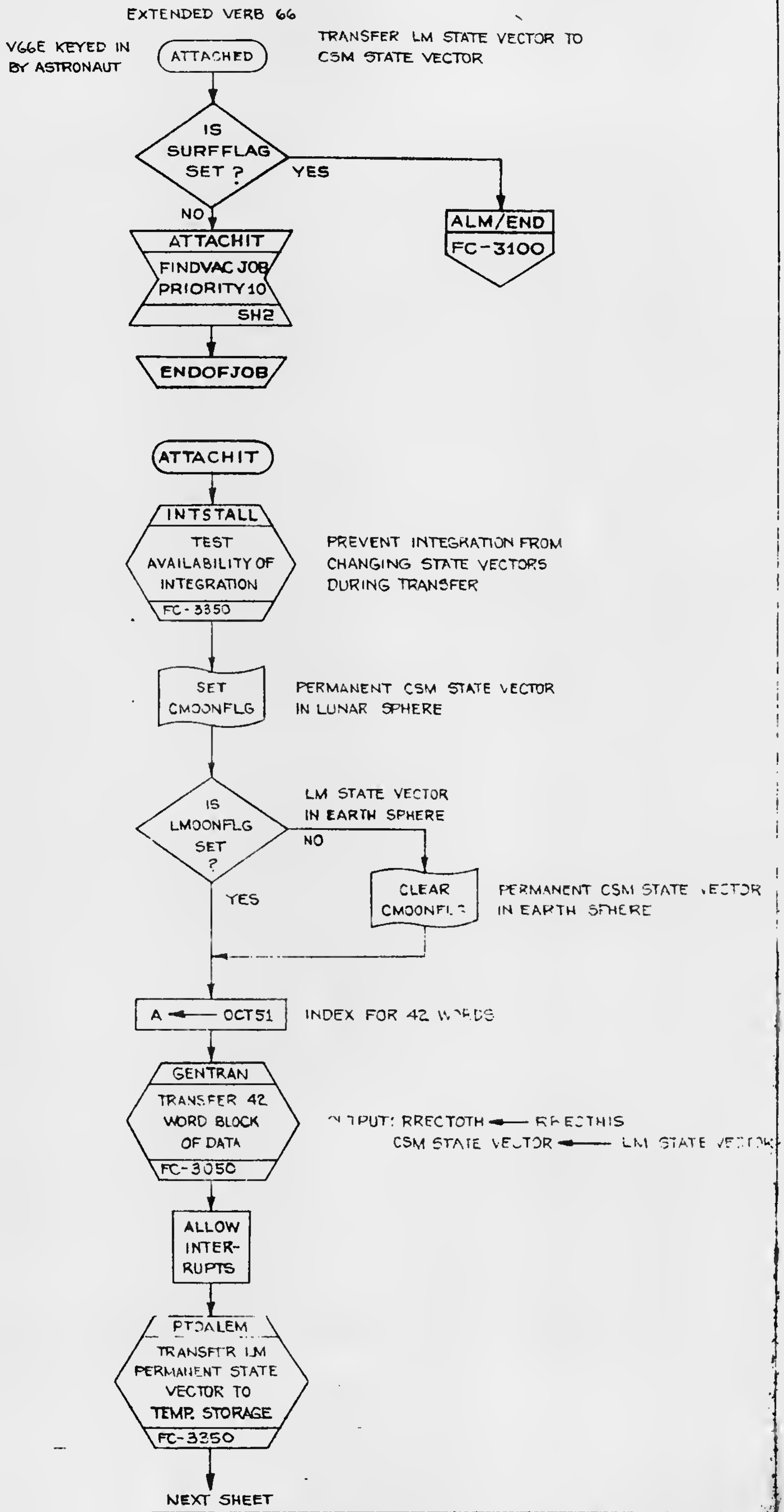
	RANGE				RANGE RATE				SHAFT & TRUNNION			
	EARTH		MOON		EARTH		MOON		EARTH		MOON	
	UNITS	SCALE	UNITS	SCALE	UNITS	SCALE*	UNITS	SCALE*	UNITS	SCALE	UNITS	SCALE
VARIANCE	M^2	2^{40}	M^2	2^{40}	$M^4/CSEC^2$	2^{42}	$M^2/CSEC^2$	2^{42}	M^2	2^{40}	M^2	2^{40}
DELTAQ	M	2^{29}	M	2^{27}	$M^2/CSEC$	2^{30}	$M^2/CSEC$	2^{28}	M	2^{29}	M	2^{27}
BVECTOR $\underline{b}_0$	—	2^1	—	2^1	M/CSEC	2^2	M/CSEC	2^2	—	2^1	—	2^1
$\underline{b}_1$	—	—	—	—	M	2^{21}	M	2^{21}	—	—	—	—
$\underline{b}_2$	—	—	—	—	—	—	—	—	M	2^{25}	M	2^{25}

* Scaling is variable. Depending on magnitude of b_0 and b_1

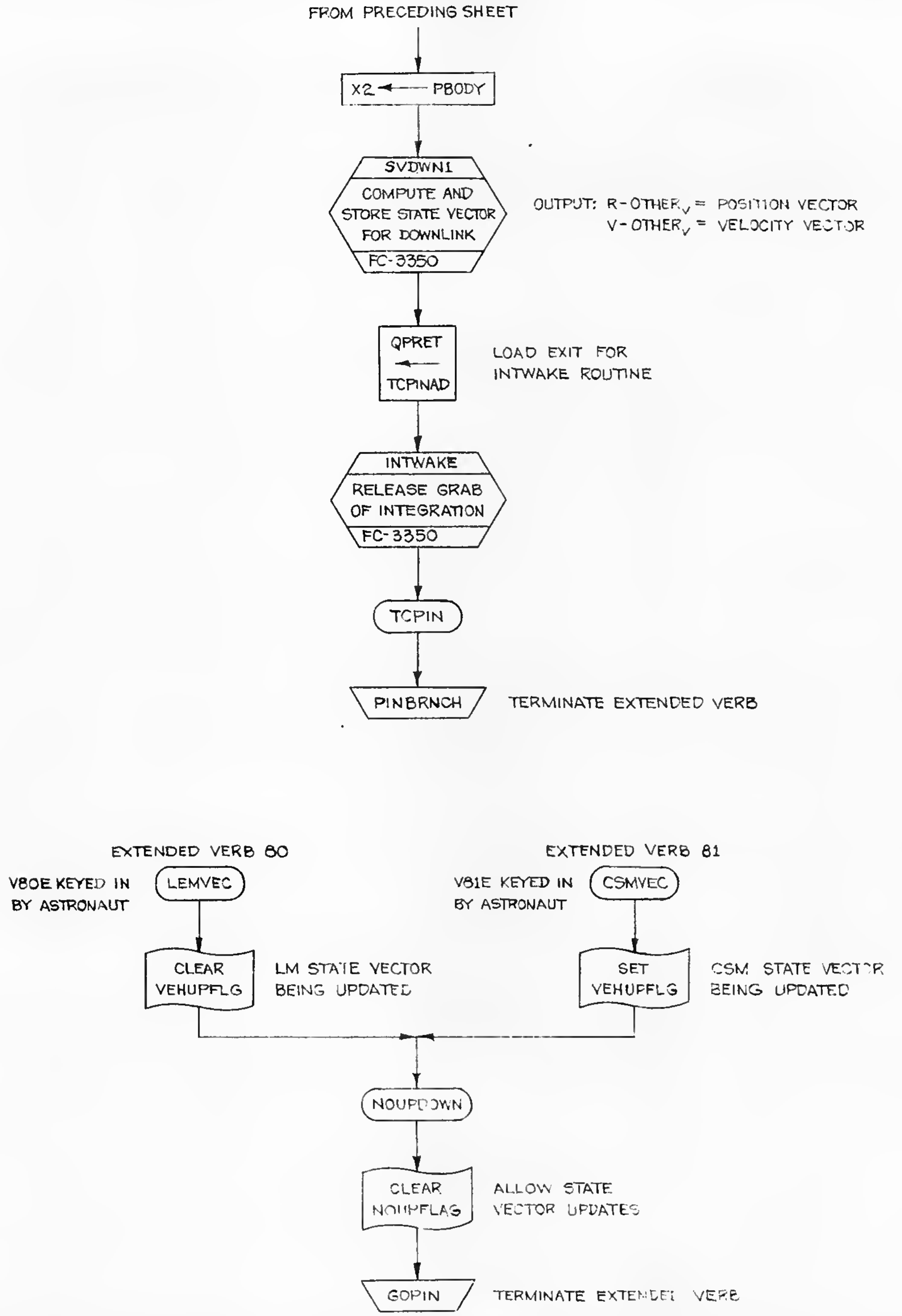
State Vector Extended Verbs

Major Subroutines on This Chart

Extended Verbs		
66	ATTACHED	Sh. 2
80	LEMVEC	Sh. 3
81	CSMVEC	Sh. 3



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS	30MAY69	STATE VECTOR EXTENDED VERBS	
PRGMR *F. Ky...*	20JUNE69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3605
DOCMR *W.C. Dayford*	6JUNE69		
APPR'D *Alex M. Sprant*	20JUNE69	REV 3	SHEET 2 OF 4



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION		
		STATE VECTOR EXTENDED VERBS		
DRAWN A.C.WILLIAMS	2JUNE69			
PRGMR P. Pyle	20JUNE69	LUMINARY 1D	DOCUMENT NO. FC-3605	
ANALST				
DOCMR W C Daykett	4JUNE 69			
APPR'D Alex M. Sorant	20JUNE69	REV 3	SHEET 3	OF 4

SUBROUTINES CALLED WHICH ARE
FLOWED ON OTHER FLOW CHARTS

SUBROUTINE NAME	FLOW CHART	DESCRIPTION	WHERE CALLED
GENTRAN	FC-3050	TRANSFER BLOCK OF WORDS IN STORAGE	SH. 2
INTSTALL	FC-3350	TEST AVAILABILITY OF INTEGRATION, GRAB IF AVAILABLE	SH. 2
INTWAKE	FC-3350	RELEASE GRAB OF INTEGRATION	SH. 3
PTOALEM	FC-3350	TRANSFER LM PERMANENT STATE VECTOR TO TEMPORARY STORAGE	SH. 2
SVDWN1	FC-3350	COMPUTE AND STORE STATE VECTOR FOR DOWNLINK	SH. 3

FLAGS

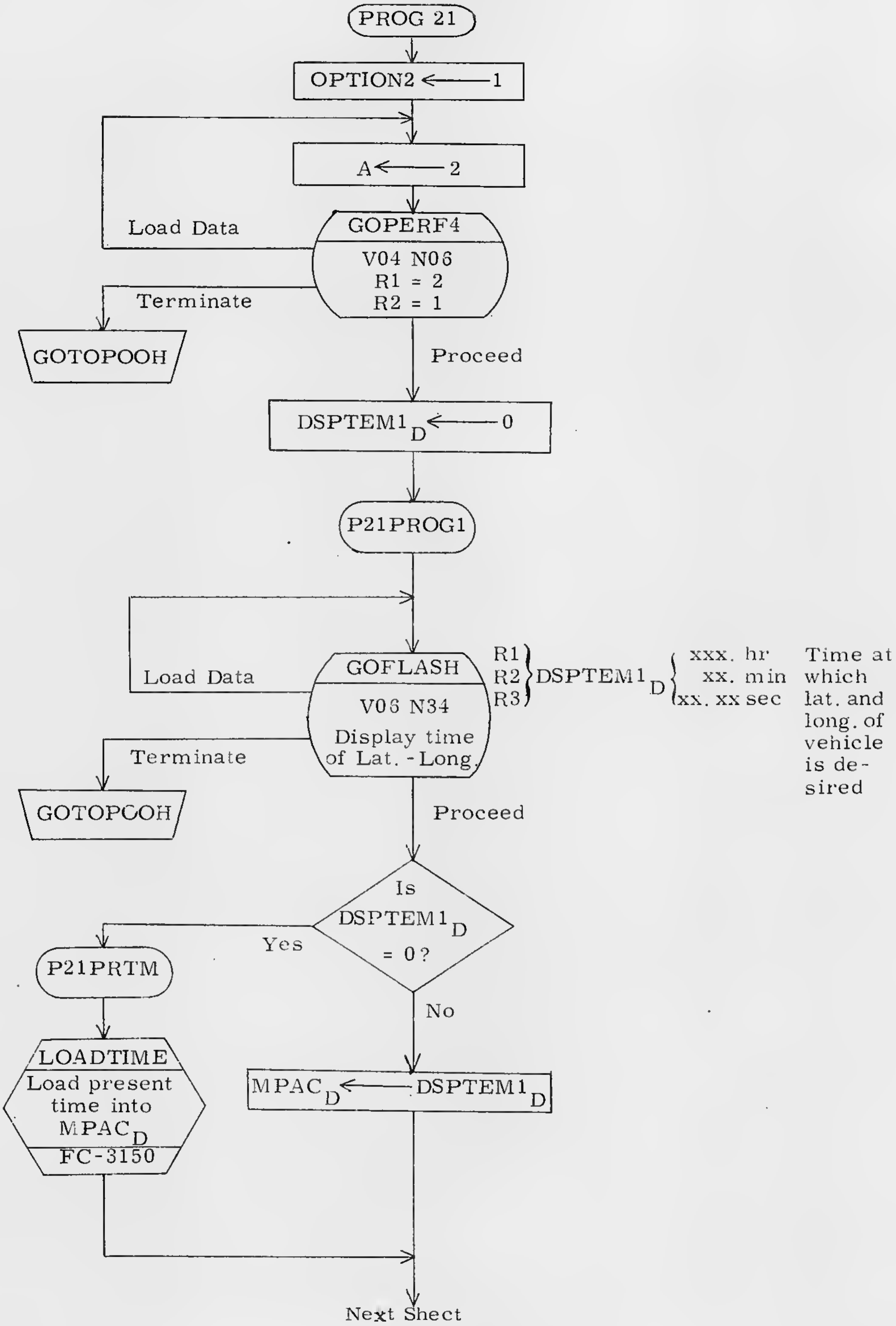
NAME	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
CMOONFLG FLAG8BIT12	PERMANENT CSM STATE VECTOR IN LUNAR SPHERE	PERMANENT CSM STATE VECTOR IN EARTH SPHERE	SH. 2	SH. 2	
LMOONFLG FLAG8BIT11	PERMANET LM STATE VECTOR IN LUNAR SPHERE	PERMANENT LM STATE VECTOR IN EARTH SPHERE			SH. 2
NOUPFLAG FLAG1BIT6	DO NOT ALLOW STATE VECTOR UPDATES	ALLOW STATE VECTOR UPDATES		SH. 3	
VEHUPFLG FLAG1BIT8	CSM STATE VECTOR BEING UPDATED	LM STATE VECTOR BEING UPDATED	SH. 3	SH. 3	

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 6MAY69	STATE VECTOR EXTENDED VERBS
PRGMR P. Kiss 20 June 69	LUMINARY 1D
ANALST	DOCUMENT NO. FC-3605
DOCMR WC Dezhbod 4 June 69	
APPR'D Alida M. Grant 20 June 69	REV 3 SHEET 4 OF 4

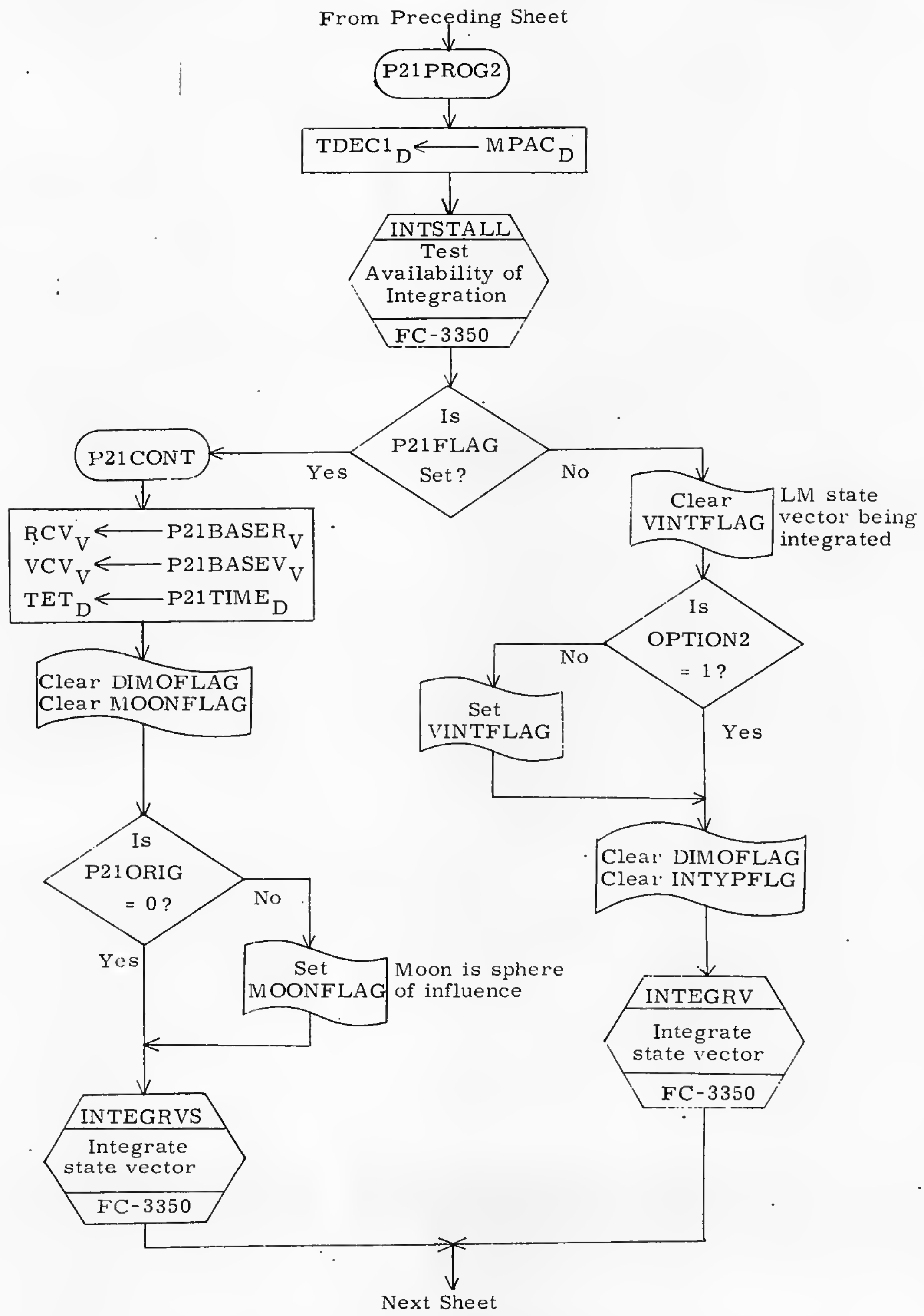
GROUND TRACK DETERMINATION

PROG 21 Sh. 2

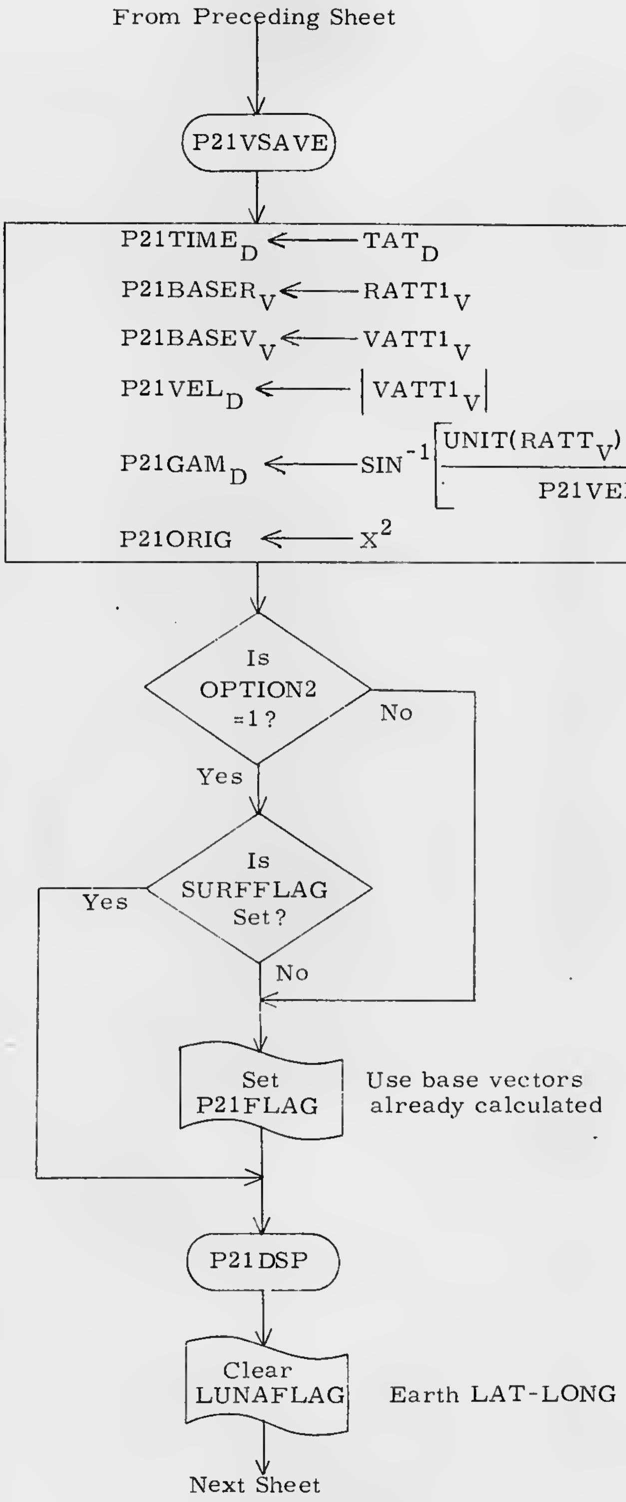
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN J. Flaherty	10/27/69	Ground Track Determination	
PROGMR Bruce J McCoy	10/27/69		
TESTER		LUMINARY 1D	DOCUMENT NO. FC-3610
DESGNR W Danforth	10/27/69		
APPR'D Roberta M. Entes	10/27/69	REV 2	SHEET 1 OF 6



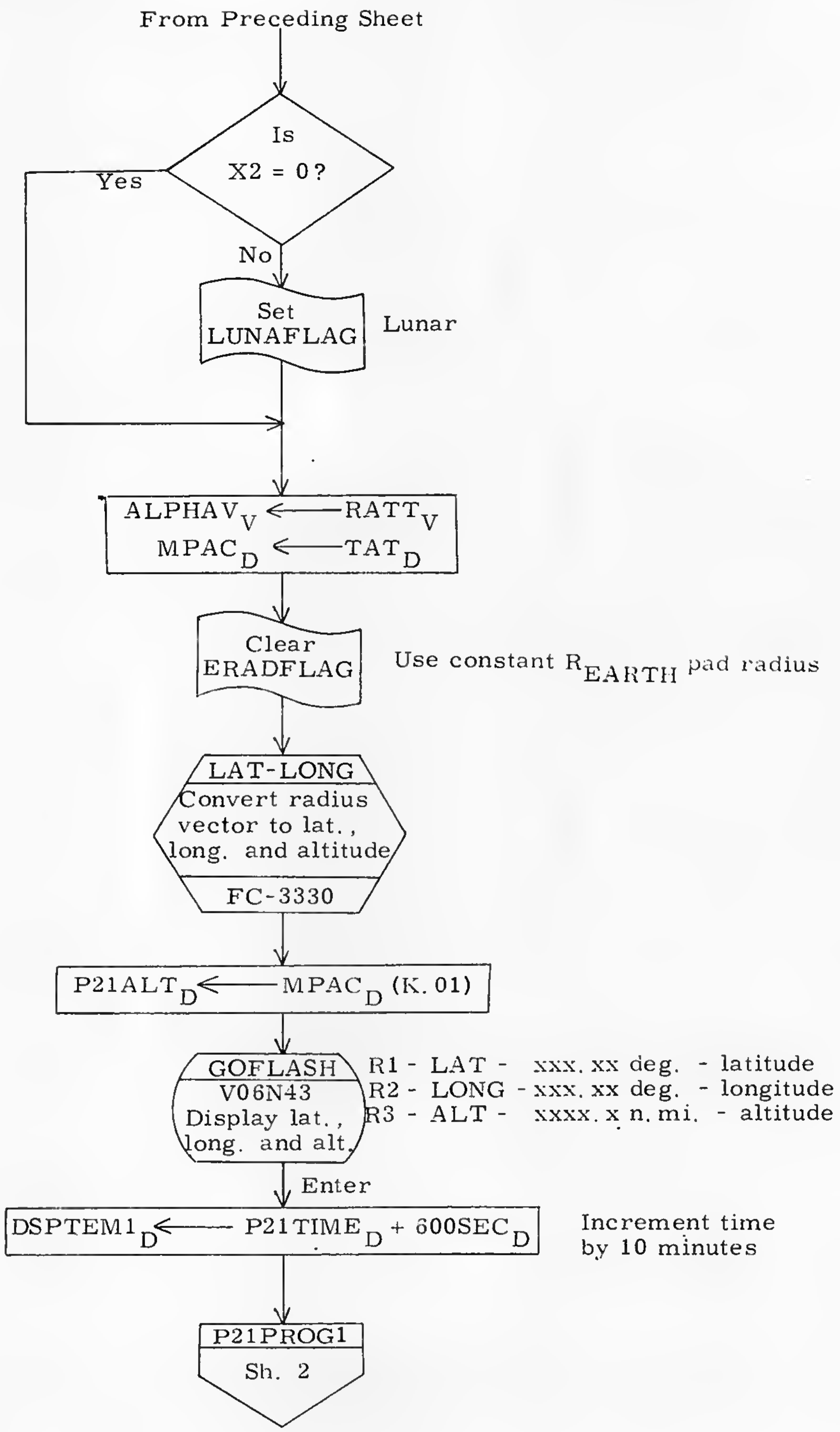
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION
DRAWN	J. Flaherty	10/27/69	Ground Track Determination
PROG'R	Bruce J McCoy	10/27/69	
ANALYST			LUMINARY 1D — DOCUMENT NO. FC-3610
DOC'M'R	W Danforth	10/27/69	
APPR'D	Roberta M. Entes	10/27/69	REV 2 — SHEET 2 OF 6



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN J. Flaherty	10/27/69	Ground Track Determination	
PROGMR Bruce D. McCoy	10/27/69		DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3610
DOCMR W. Doyhorst	10/27/69		
APPR'D Roberta M. Entes	10/27/69	REV 2	SHEET 3 OF 6



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN J. Flaherty	10/27/69	Ground Track Determination	
PROGMR Bruce J. McCoy	10/27/69	LUMINARY 1D	DOCUMENT NO. FC-3610
ANALST			
DOC. MR W. Dogforth	10/27/69		
APPR'D Roberta M. Enter	10/27/69	REV 2	SHEET 4 OF 6



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN J. Flaherty	10/27/69	Ground Track Determination	
PROGMR [illegible signature]	10/27/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3610
DOCMR W Gephart	10/27/69		
APPR'D Roberta M. Entes	10/27/69	REV 2	SHEET 5 OF 6

SUBROUTINES CALLED ON OTHER FLOWCHARTS

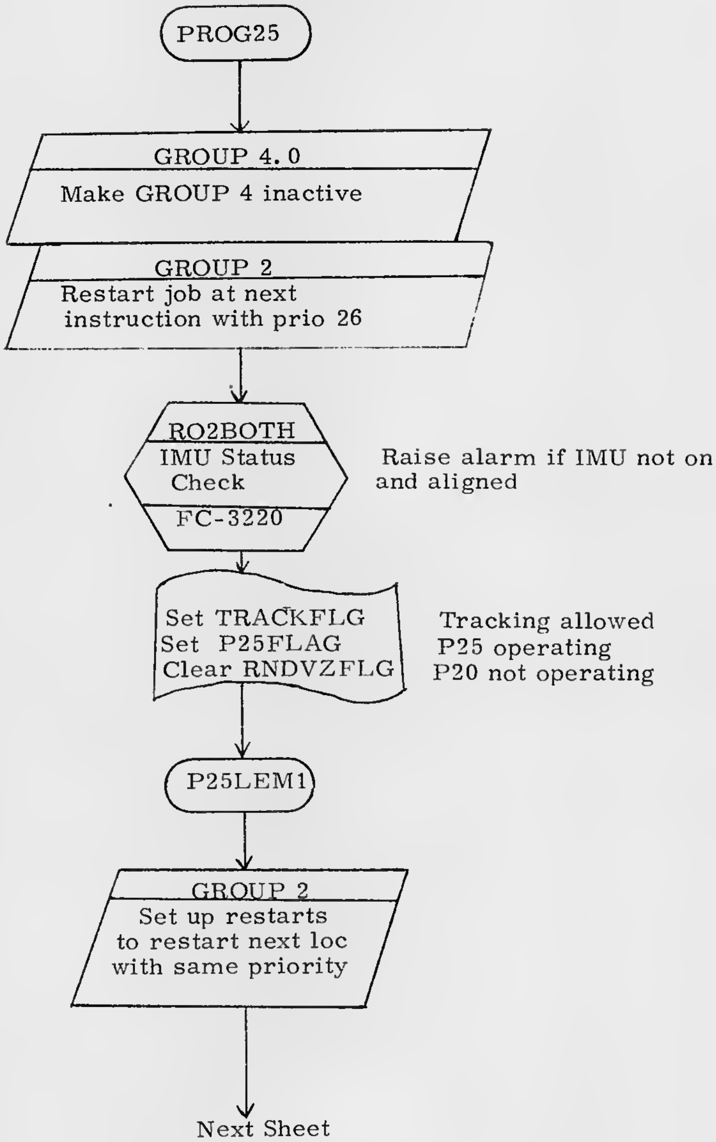
Subroutine	Flowchart	Where Called
LOADTIME	FC-3150	Sh. 2
INSTALL	FC-3350	Sh. 3
INTEGRV	FC-3350	Sh. 3
INTEGRVS	FC-3350	Sh. 3
LAT-LONG	FC-3330	Sh. 5

Flags	Meaning When Set	Meaning When Cleared	Where Set	Where Cleared	Where Tested
DIMOFLAG Flag 3 Bit 1	W Matrix is to be used	W Matrix is not to be used		Sh. 3	
ERADFLAG Flag 1 Bit 13	Compute R_{EARTH} Fischer ellipsoid	Use constant R_{EARTH} pad radius		Sh. 5	
INTYPFLG Flag 3 Bit 4	Conic integration	Encke integration		Sh. 3	
LUNAFLAG Flag 3 Bit 12	Lunar Lat-Long	Earth Lat-Long	Sh. 5	Sh. 4	
MOONFLAG Flag 0 Bit 12	Moon is sphere of influence	Earth if sphere of influence	Sh. 3	Sh. 3	
P21FLAG Flag 0 Bit 11	Use base vectors already calculated	1st pass - calculate base vectors	Sh. 4		Sh. 3
SURFFLAG Flag 8 Bit 8	LM on lunar surface	LM not on lunar surface			Sh. 4
VINTFLAG Flag 3 Bit 3	CSM state vector being integrated	LM state vector being integrated	Sh. 3	Sh. 3	

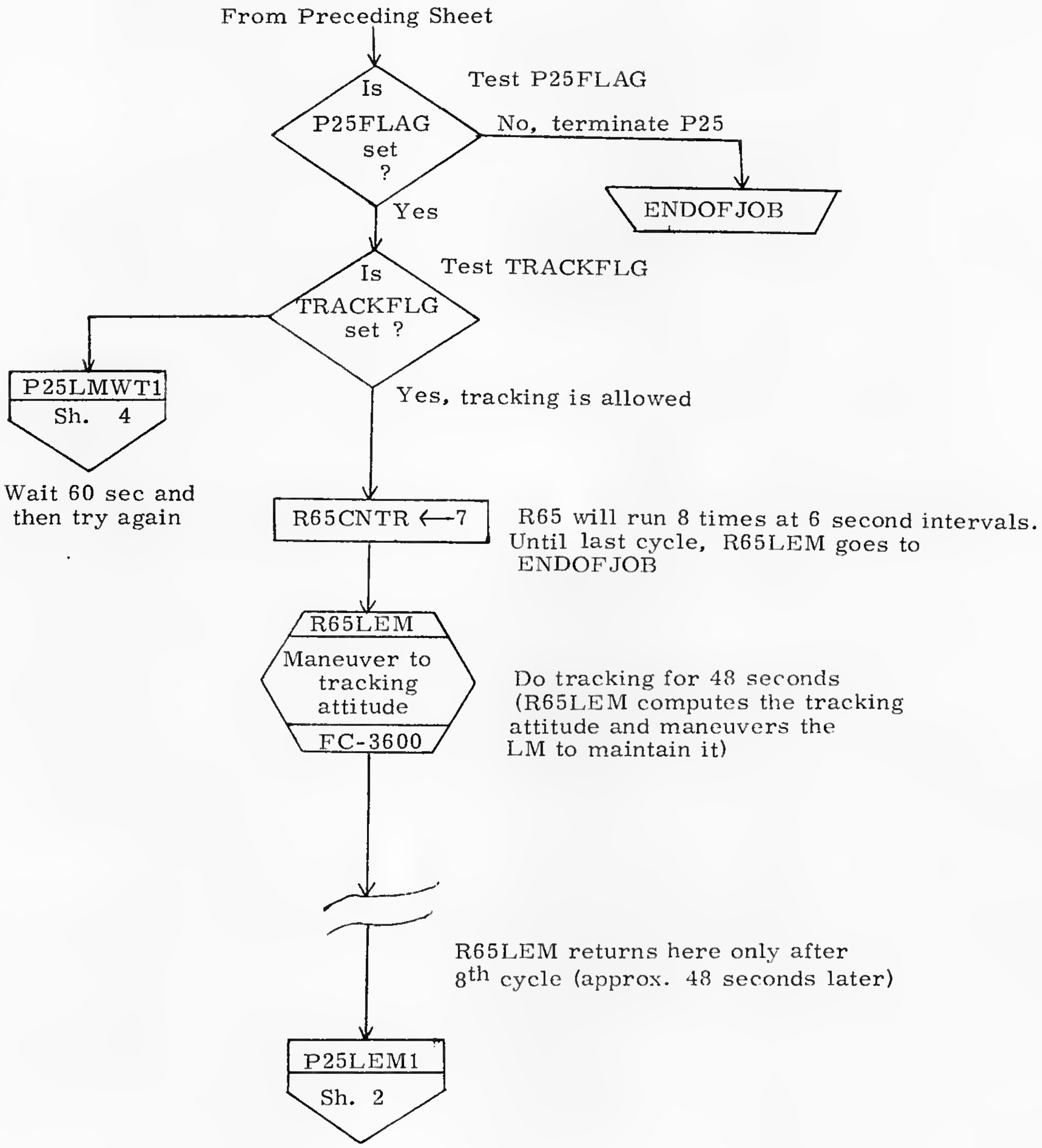
P25 PREFERRED TRACKING ATTITUDE
MAJOR SUBROUTINES ON THIS CHART

PROG25 Sh. 2

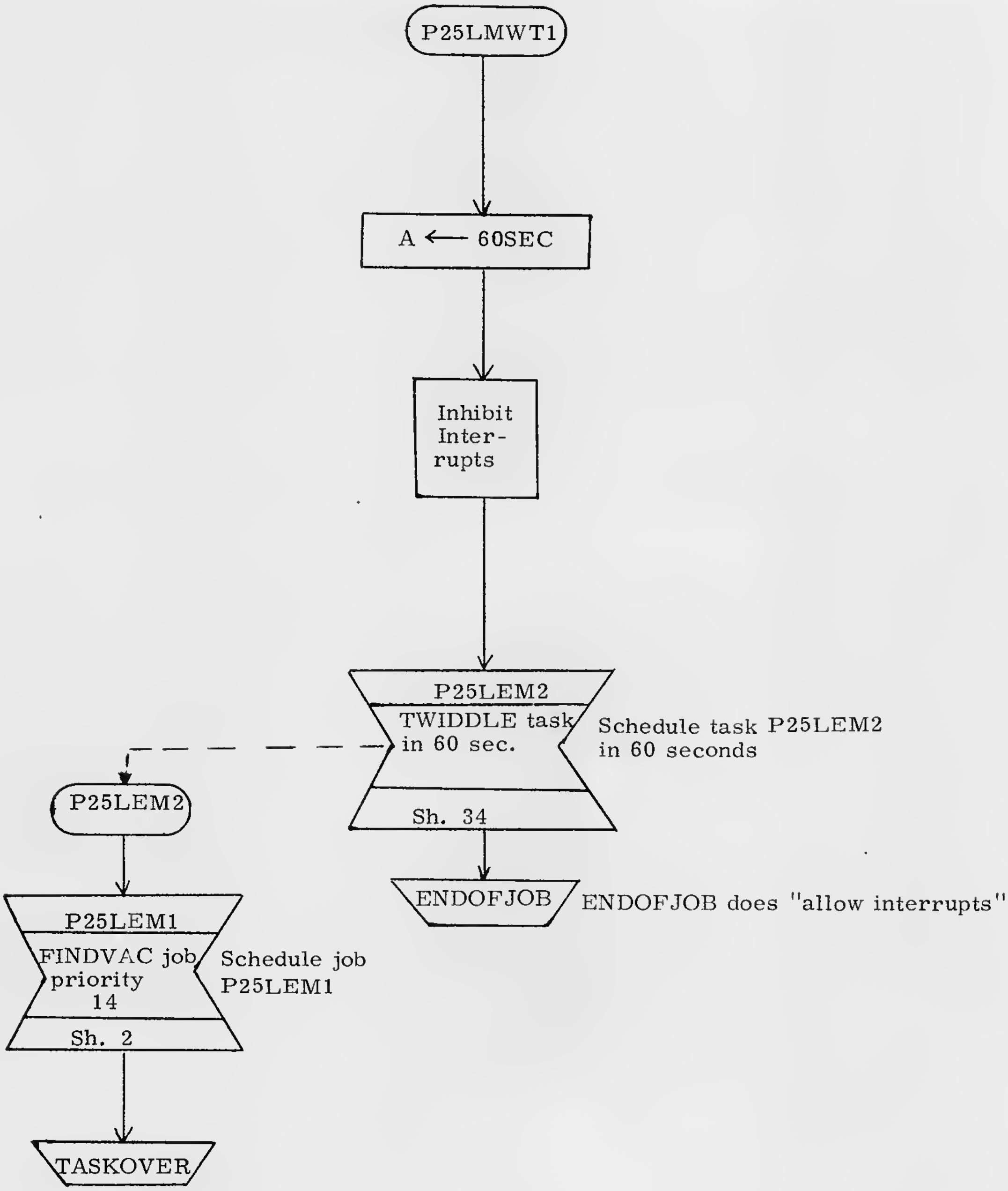
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN [illegible signature]	9/24/69	Preferred Tracking Attitude	
PRGMR P. Volante	10/21/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3620
DOCMR W. Danforth	9/30/69		
APPR'D Roberta M. Estes	10/21/69	REV 3	SHEET 1 OF 5



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	R. Weitch	9/16/69	Preferred Tracking Attitude	
PRGMR	P. Volante	10/21/69	LUMINARY 1D	DOCUMENT NO. FC-3620
ANALST				
DOCMR	W Dayforth	9/30/69		
APPR'D	Roberta M Estes	10/21/69	REV 3	SHEET 2 OF 5



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Leirich	9/12/69	Preferred Tracking Attitude	
PRGMR P. Volante	10/21/69	LUMINARY 1D	DOCUMENT NO. FC-3620
ANALST			
DOCMR W Danforth	9/30/69		
APPR'D Roberto M. Esteves	10/21/69	REV 3	SHEET 3 OF 5



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	9/30/69	Preferred Tracking Attitude	
PRGMR	10/21/69	LUMINARY 1D	DOCUMENT NO. FC-3620
ANALST			
DOCMR	9/30/69		
APPR'D	10/21/69	REV 3	SHEET 4 OF 5

SUBROUTINES

ON OTHER CHARTS

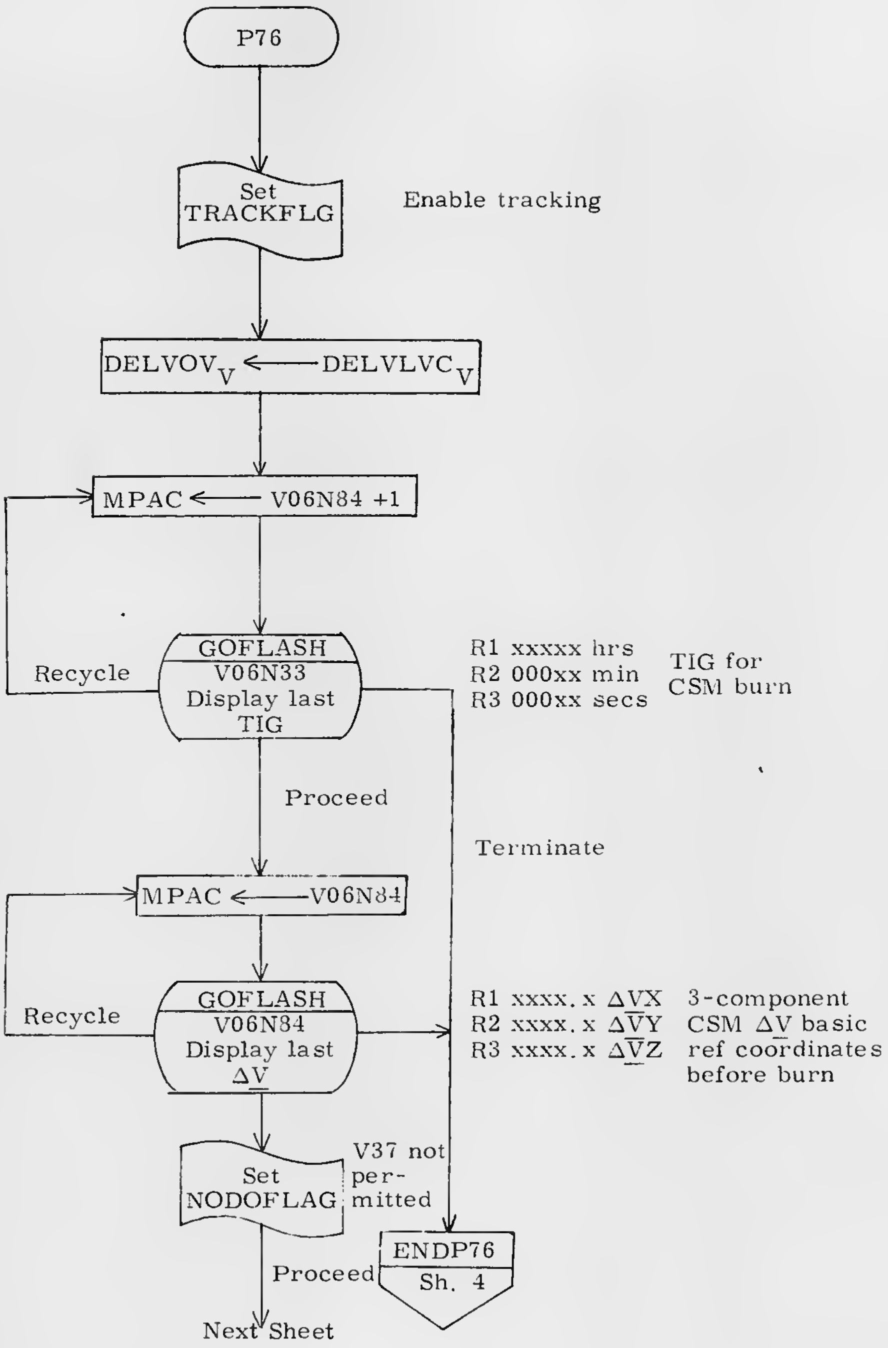
R02BOTH	IMU Status Check
R65LEM	Computes preferred tracking attitude and maneuvers to it.

Flags	Meaning	Set	Cleared	Tested
TRACKFLG	Set - tracking allowed Cleared - tracking not allowed	Sh. 2		Sh. 3
P25FLAG	Set - P25 operating Cleared - P25 not operating	Sh. 2		Sh. 3
RNDVZFLG	Set - P20 running Cleared - P20 not running		Sh. 2	

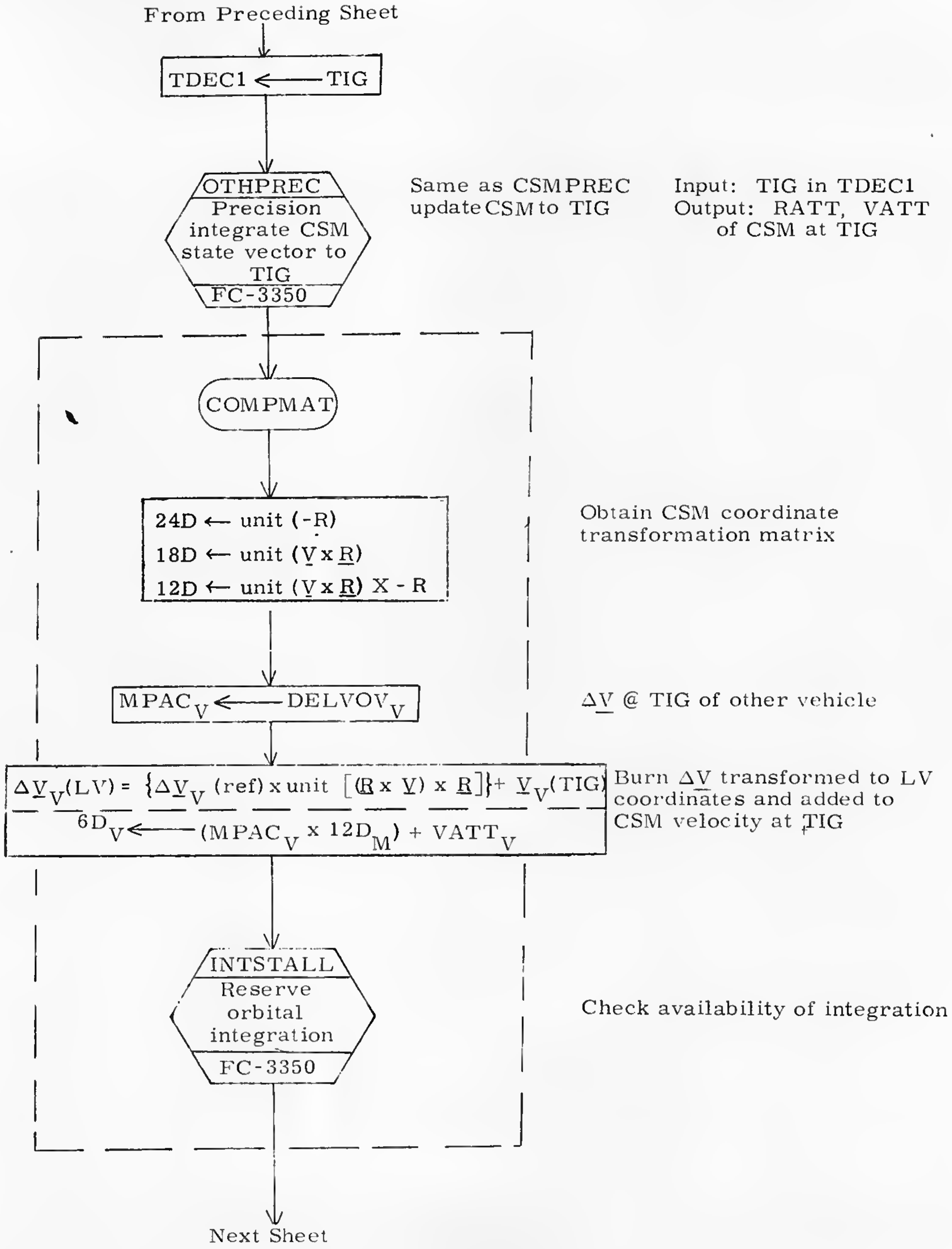
P76 TARGET DELTA VELOCITY

P76 Sh. 2

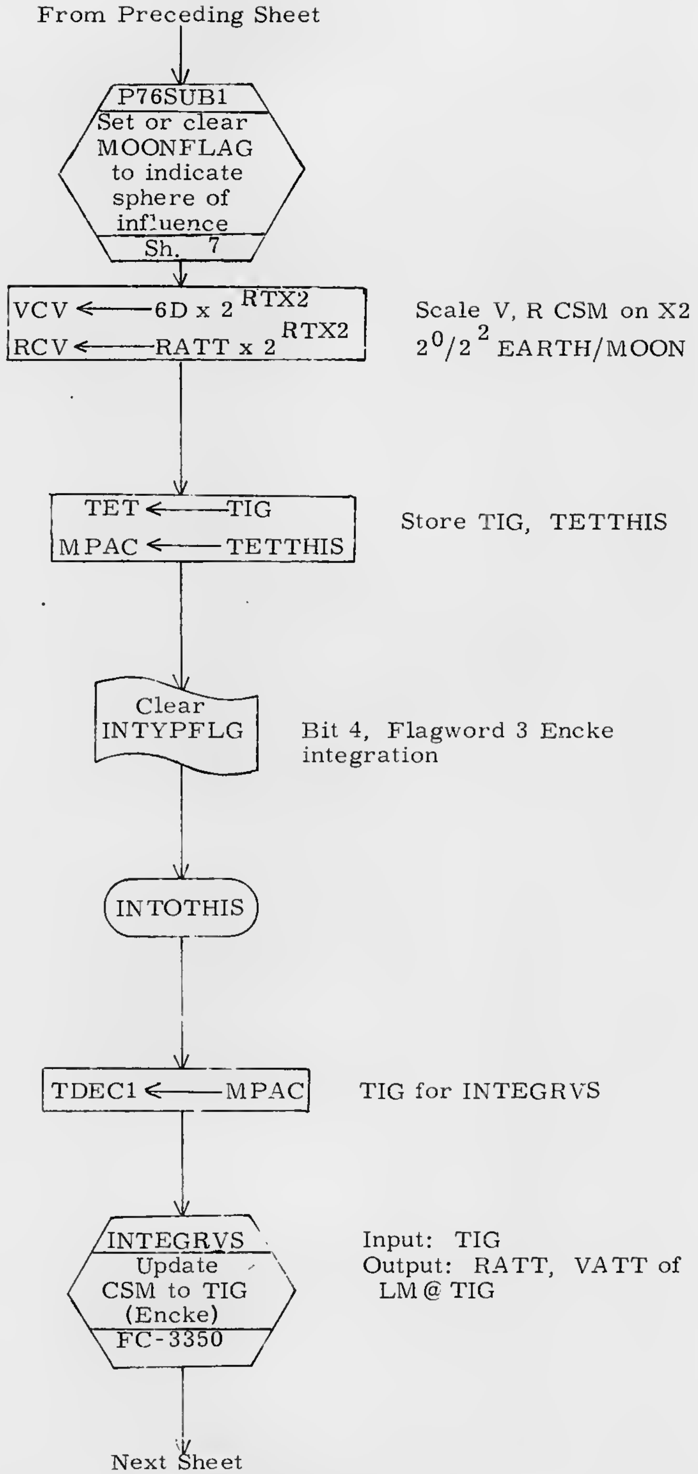
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN I. F. Flaherty	12/8/69	P76 Target Delta V	
PRGMR T. E. Crocker	1/27/70		DOCUMENT NO.
ANALST			
DOCMR Roberta M. Estes	1/27/70	LUMINARY 1D	FC-3640
APPR'D Roberta M. Estes	1/27/70	REV 1	SHEET 1 OF 9



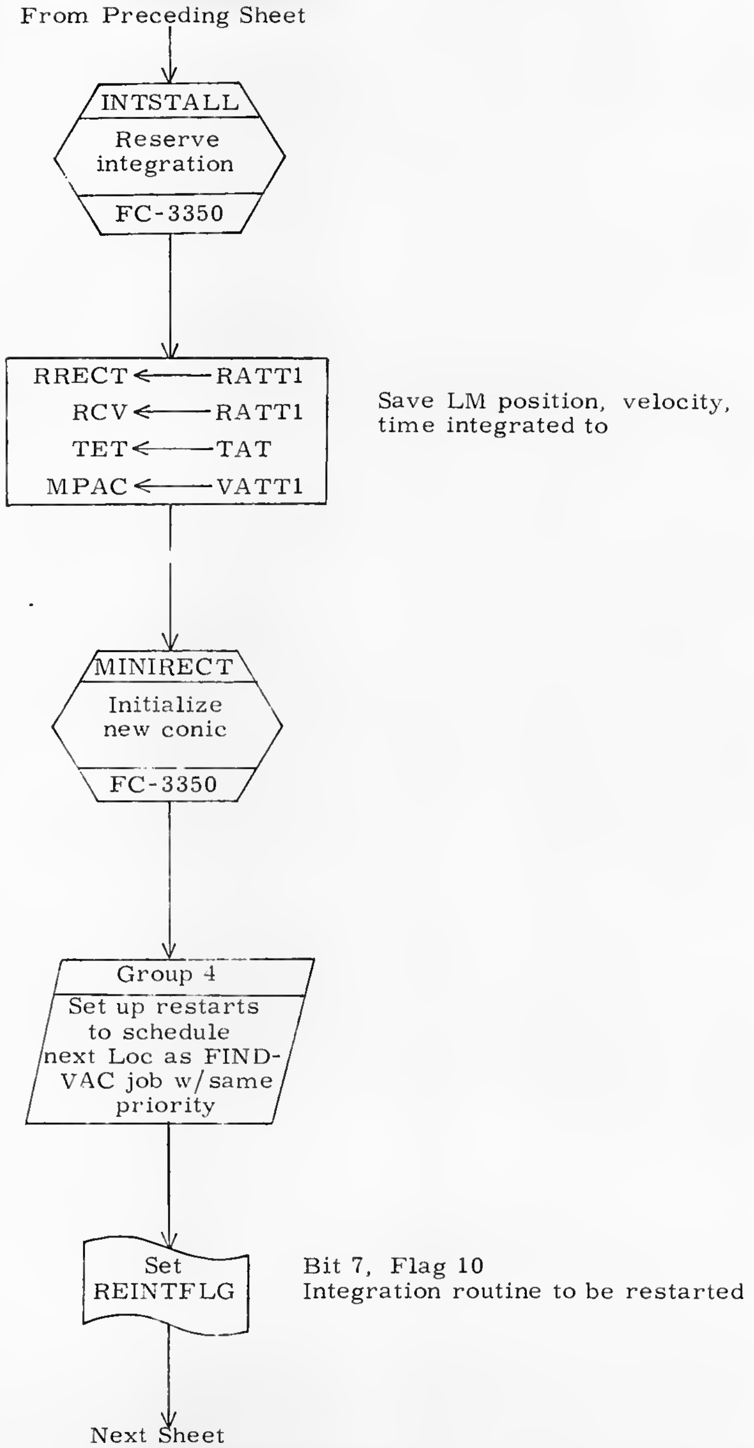
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN J. Flaherty	12/8/69	P76 Target Delta V	
PRGMR T. E. Crocker	1/27/70		
ANALST			DOCUMENT NO.
DOCMR Roberta M Entes	1/27/70	LUMINARY 1D	FC-3640
APPR'D Roberta M Entes	1/27/70	REV 1	SHEET 2 OF 9



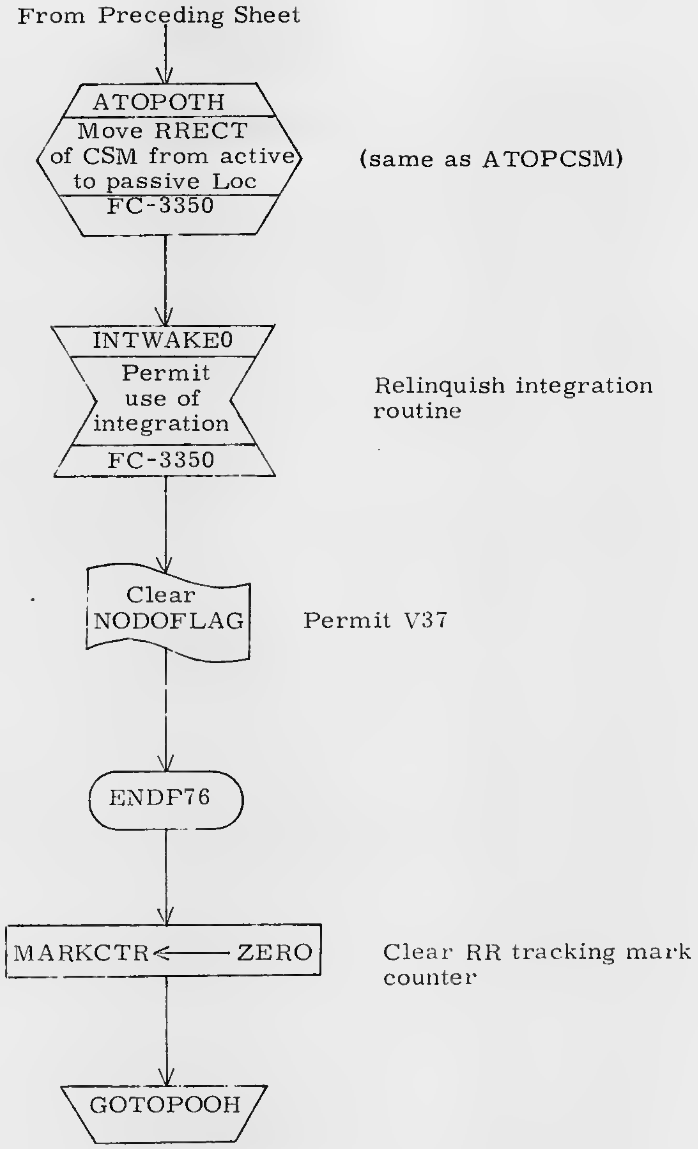
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN J. Flaherty	12/8/69	P76 Target Delta V	
PRGMR T. E. Crocker	1-27-70		DOCUMENT NO.
ANALST			
DOCMR Roberta M. Entes	1/27/70	LUMINARY 1D	FC-3640
APPR'D Roberta M. Entes	1/27/70	REV 1	SHEET 3 OF 9



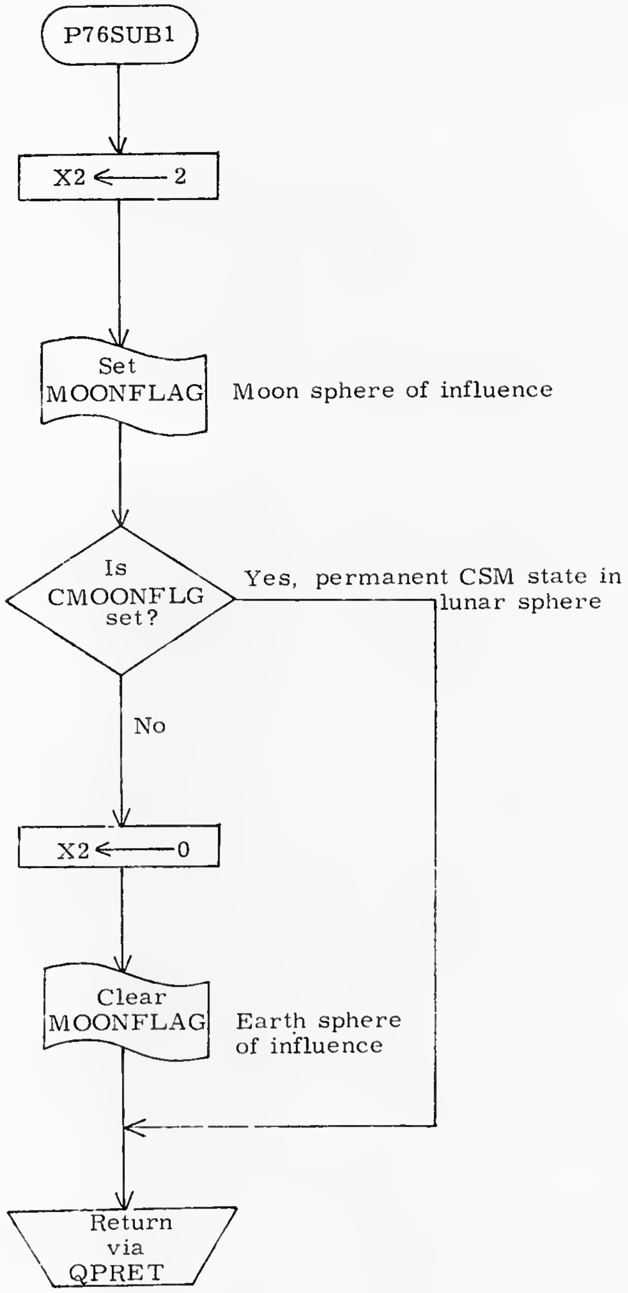
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN T. Flaherty	12/8/69	P76 Target Delta V	
PRGMR T. E. Crocker	1-27-70		DOCUMENT NO.
ANALST			
DOCMR Roberta M Estes	1/27/70	LUMINARY 1D	FC-3640
APPR'D Roberta M Estes	1/27/70	REV 1	SHEET 4 OF 9



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN J. Flaherty	12/8/69	P76 Target Delta V	
PRGMR T.E. Crocker	1-27-70		DOCUMENT NO.
ANALST			
DOCMR Roberta M Estes	1/27/70	LUMINARY 1D	FC-3640
APPR'D Roberta M Estes	1/27/70	REV 1	SHEET 5 OF 9



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN J. Flaherty	12/8/69	P76 Target Delta V	
PRGMR T. E. Crocker	1-27-70		
ANALST			DOCUMENT NO.
DOCMR Roberta M. Eutas	1/27/70	LUMINARY 1D	FC-3640
APPR'D Roberta M. Eutas	1/27/70	REV 1	SHEET 6 OF 9



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN [illegible]	[illegible]	P76 Target Delta V	
PRGMR T. E. Cocker	1-27-70		DOCUMENT NO.
ANALST			
DOCMR Roberta M. Eaton	1/27/70	LUMINARY 1D	FC-3640
APPR'D Roberta M. Eaton	1/27/70	REV 1	SHEET 7 OF 9

SUBROUTINES CALLED

Subroutine Name	Where Flowed	Description	Where called
OTHPREC	3350	(Same as CSMPREC) precision integration of CSM	Sh. 3
INTSTALL	3350	Reserves orbital integration	Sh. 3, 5
INTEGRVS	3350	Enke update of CSM to TIG	Sh. 4
MINIRECT	3350	Initialize new conic	Sh. 5
ATOPOTH	3350	Moves CSM state vector to passive storage loc	Sh. 6
INTWAKE0	3350	Releases integration routines	Sh. 6

FLAGS

Name	Meaning When Set	Meaning When Clear	Where Set	Where Cleared	Where Tested
TRACKFLG	Enable marktaking	Inhibit marktaking	Sh. 2		
MOONFLAG	Moon sphere of influence	Earth sphere of influence	Sh. 7	Sh. 7	
INTYPFLG	Enke integration	Conic integration		Sh. 4	
REINTFLG	Restart integration	Do not restart integration	Sh. 5		
CMOONFLG	Permanent CSM state in lunar sphere	Permanent CSM state in earth sphere			Sh. 7
NODOFLAG	V37 not permitted	V37 permitted	Sh. 2	Sh. 6	

VARIABLE ERASABLE LOCATIONS USED

AGC TAG	GSOP Symbol	Meaning	Engineering Units	AGC Units	AGC Scaling
TDEC1		Storage loc for integration time		csec	2^{28}
TIG		Storage loc for ignition time		csec	2^{28}
DELVOV		ΔV other vehicle (CSM)		m/csec	2^{7}
VCV		Temporary conic velocity		m/csec	2^{7}
RCV		Temporary conic position		m	2^{29}
TET		Temporary time of state vector		csec	2^{28}
TETTHIS		Temporary time of LM state vector		csec	2^{28}
RRECT		Temporary position at RECT time		m	2^{29}
MARKCTR		Mark counter used by R32			2^{0}

DISPLAYS

Verb-Noun	Type of Display	Description of Each Register	Where Executed
V06N84		Display last $\Delta \underline{V}$	Sh. 2
V06N33		Display last TIG	Sh. 2

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN [illegible]	[illegible]	P76 Target Delta V	
PRGMR T. E. Crocker	1-27-70		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3640
DOCMR Roberta M Estes	1/27/70		
APPR'D Roberta M Estes	1/27/70	REV 1	SHEET 9 OF 9

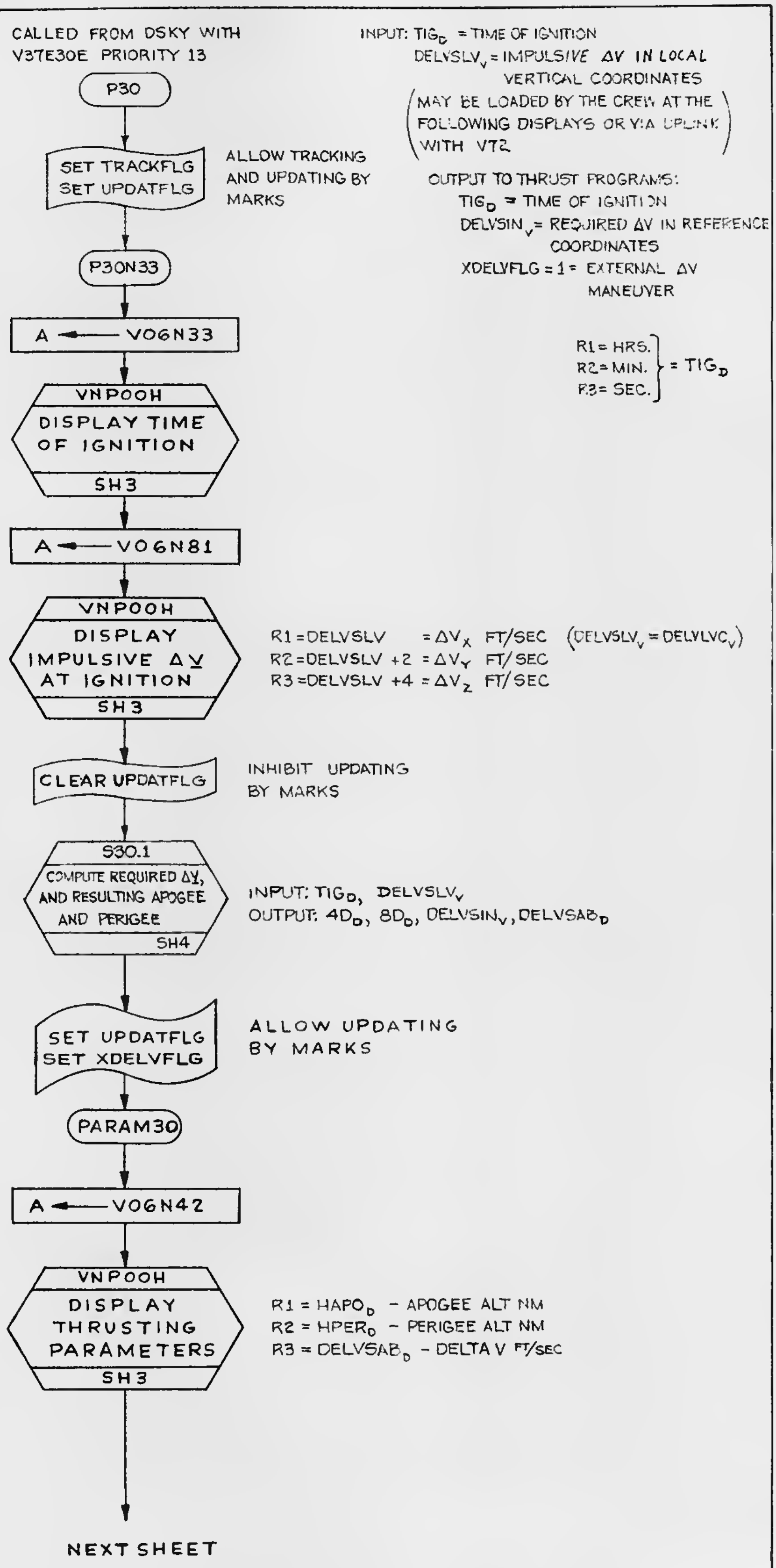
11.0 PRE-THRUST TARGETING PROGRAMS

P30 - EXTERNAL DELTA V

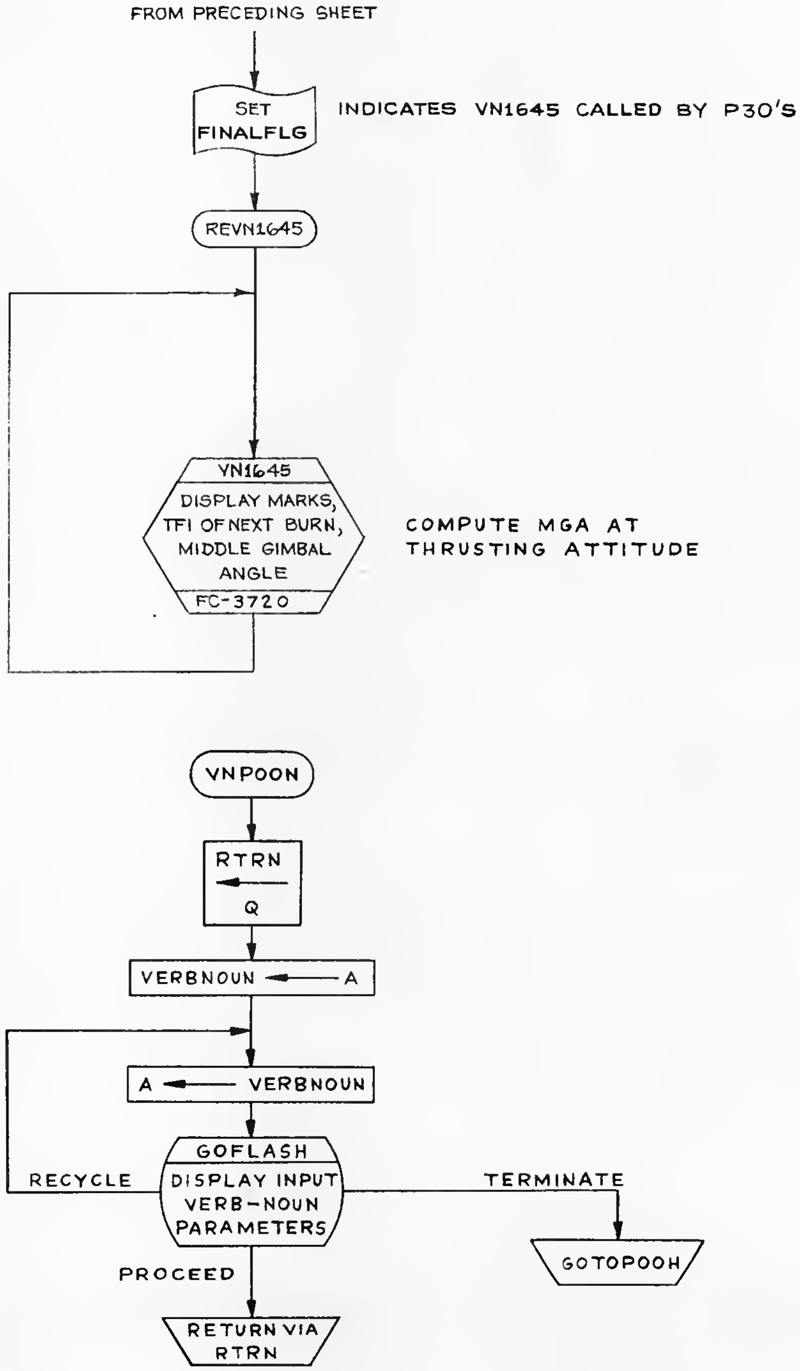
MAJOR SUBROUTINES ON THIS CHART

P30	Sh. 2
S30.1	Sh. 4

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN: L. Gilstrap 9/22/69	P30 EXTERNAL DELTA V
PRGMR	
ANALST Peter J Volante 9/24/69	LUMINARY 1D — DOCUMENT NO. FC-3700
DOCMR WC Doughty 9/26/69	
APPR'D Roberta M Entwistle 9/26/69	REV 3 — SHEET 1 OF 6



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS 4-15-68	P30 EXTERNAL DELTA V	
PRGMR		
ANALST 9 July 68	LUMINARY 1D	DOCUMENT NO. FC-3700
DOCMR 11 July 68		
APPR'D 5-15-68	REV 3	SHEET 2 OF 6



MIT
INSTRUMENTATION LAB
CAMBRIDGE, MASS.

APOLLO
GUIDANCE AND NAVIGATION

P30
EXTERNAL DELTA V

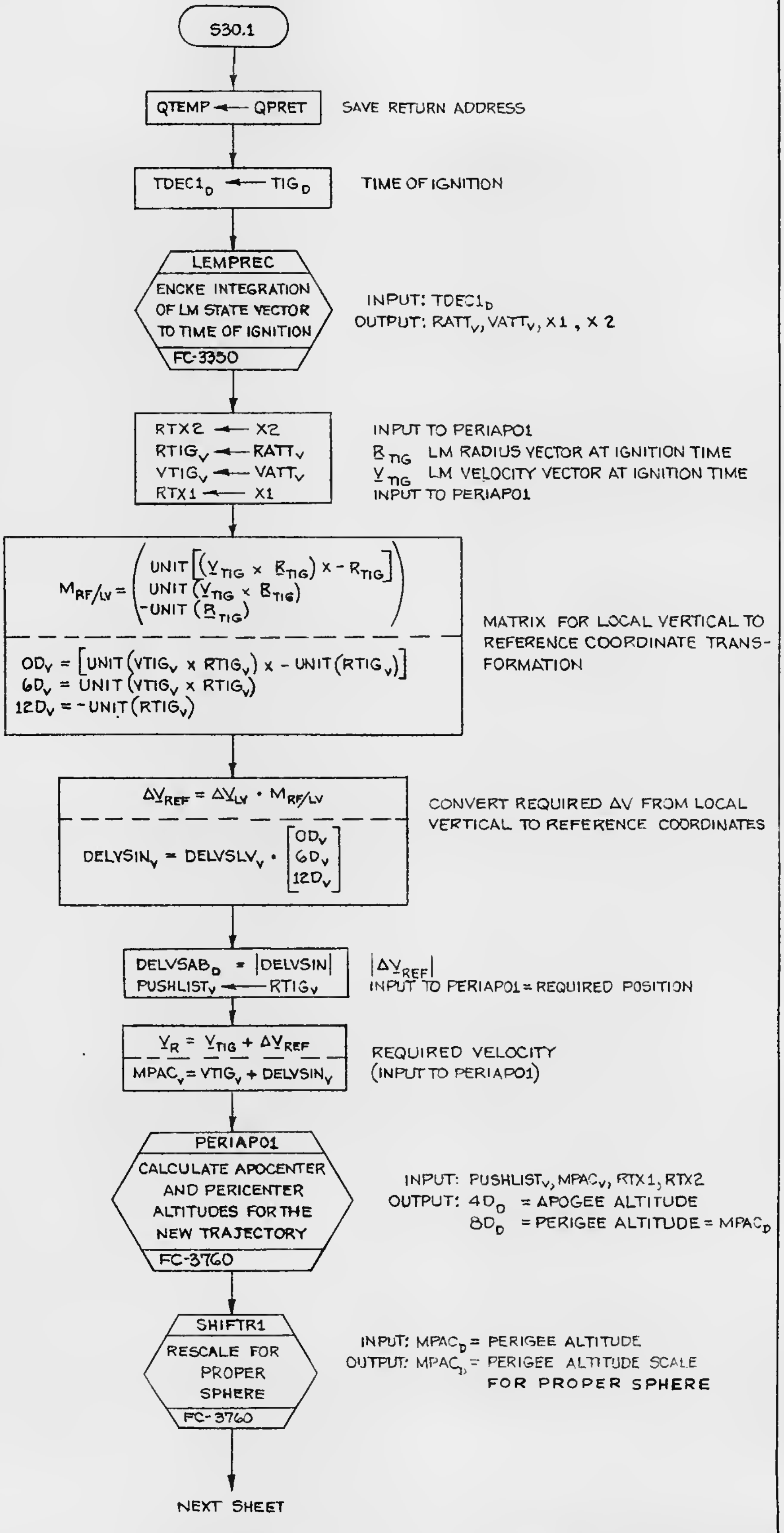
DRAWN	A.C.WILLIAMS	2JUNE69
PRGMR		
ANALST	[illegible]	[illegible]
DOCMR	[illegible]	[illegible]
APPR'D	[illegible]	

LUMINARY 1D

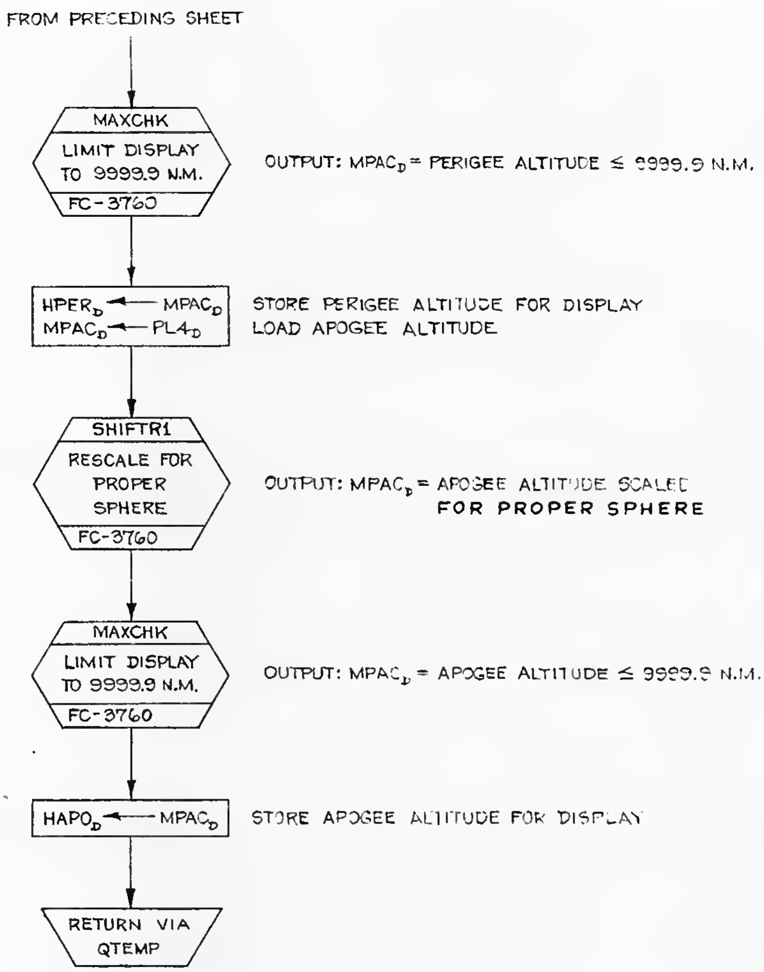
DOCUMENT NO. FC-3700

REV 3

SHEET 3 OF 6



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 4-17-68	P30 EXTERNAL DELTA V
PROGMR R. N. [illegible]	
ANALST [illegible] 9 Jul 69	LUMINARY 1D — DOCUMENT NO. FC-3700
DOCMR [illegible] 11 Jly 69	
APPR'D J. [illegible] 5-15-68	REV 3 — SHEET 4 OF 6



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

P30 EXTERNAL DELTA V

DRAWN A.C.WILLIAMS 3JUNE69
PROGMR
ANALST 9July69
DOCMR 11JLY69
APPR'D

LUMINARY 1D

DOCUMENT NO. FC-3700

REV 3

SHEET 5 OF 6

P30 - EXTERNAL DELTA V

SUBROUTINES ON OTHER CHARTS

PERIAPO1	COMPUTES THE TWO BODY APOCENTER AND PERICENTER ALTITUDES
VN1645	DISPLAY MARKS, TFI OF NEXT BURN, MIDDLE GIMBAL ANGLE
SHFTR1	RESCALE INPUT FOR PROPER SPHERE
MAXCHK	LIMIT INPUT DISPLAY TO 9999.9 N.M.

FLAGS	MEANING		SET	CLEARED	TESTED
TRACKFLG	SET: CLEARED:	TRACKING ALLOWED TRACKING DISALLOWED	SH. 2		
UPDATFLG	SET: CLEARED:	UPDATING VIA MARKS ALLOWED UPDATING VIA MARKS DISALLOWED	SH. 2	SH. 2	
FINALFLG	SET: CLEARED:	LAST PASS THROUGH RENDEZVOUS COMPUTATIONS INTERIM PASS THROUGH RENDEZVOUS COMPUTATIONS	SH. 3		
XDELVFLG	SET: CLEARED:	ΔV LOADED EXTERNALLY (EG. UPLINK) ΔV COMPUTED VIA LAMBERT ROUTINE	SH. 3		

DISPLAYS	MEANING	USED
V06N33	DISPLAY TIME OF IGNITION	SH. 2
V06N81	DISPLAY IMPULSIVE ΔV	SH. 2
V06N42	DISPLAY THRUSTING PARAMETERS	SH. 2
V06N45	DISPLAY MARKS, TIME FROM IGNITION, MIDDLE GIMBAL ANGLE	SH. 3

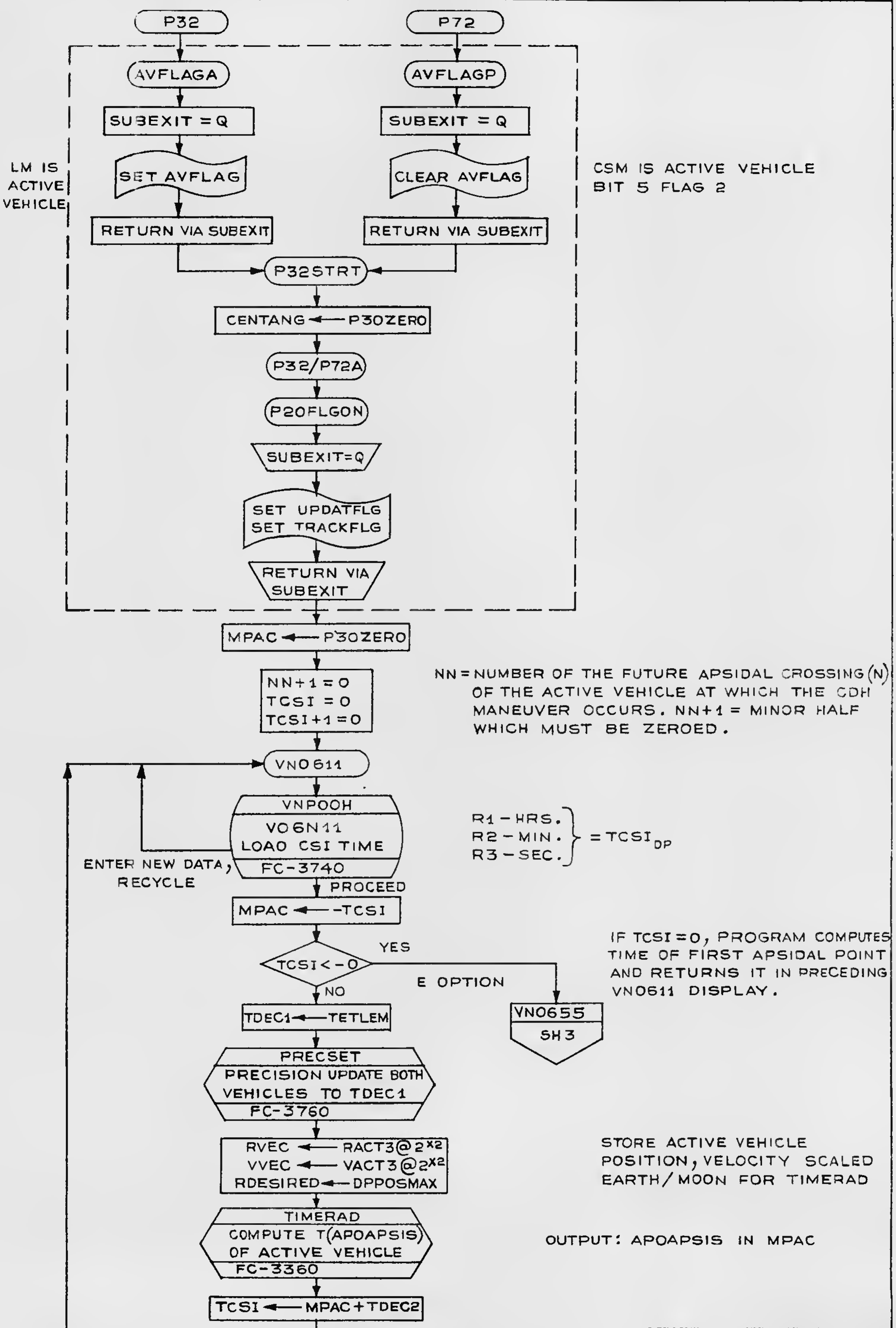
ALARMS

NONE

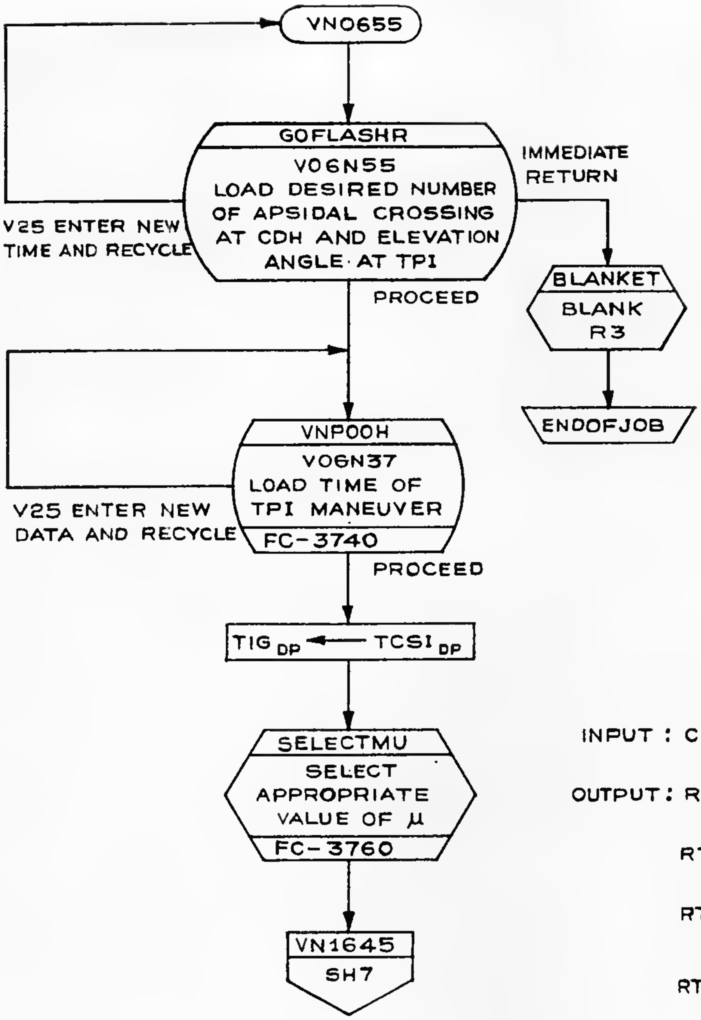
ERASABLES	MEANING	UNITS	SCALING
HAPO	APOGEE ALTITUDE	METERS	B29 (EARTH) B27 (MOON)
HPER	PERIGEE ALTITUDE	METERS	B29 (EARTH) B27 (MOON)
DELVSIN	ΔV OF ACTIVE VEHICLE IN REFERENCE COORDINATES	M/CSC	B7 (EARTH OR MOON)
TIG	TIME OF IGNITION	CENTISECONDS	B28
RVEC	POSITION VECTOR AT IGNITION TIME (INPUT TO PERIAPO)	METERS	B29 (EARTH) B27 (MOON)
RATTℓ	POSITION VECTOR AT IGNITION TIME	METERS	B29
TDEC1	TIME INPUT TO INTEGRATION	CENTISECONDS	B28
RTIG	RADIUS VECTOR AT IGNITION TIME	METERS	B29
VATTℓ	VELOCITY VECTOR AT IGNITION TIME	M/CSC	B7
VTIG	VELOCITY VECTOR AT IGNITION TIME	M/CSC	B7
DELVSLV	ΔV OF ACTIVE VEHICLE IN LOCAL VERTICAL COORDINATES	M/CSC	B7
DELVSAB	ΔV	M/CSC	B7
VVEC	REQUIRED VELOCITY (INPUT TO PERIAPO)	M/CSC	B7 (EARTH) B5 (MOON)
TRKMKCNT	NUMBER OF MARKS SINCE LAST MANEUVER OR INITIATION OF P20		B14
TTOGO	TIME TO GO TILL IGNITION	CENTISECONDS	B28
+MGA	MIDDLE GIMBAL ANGLE	REVOLUTIONS	B0
DISPDEX	SWITCH TO CONTROL THE OPERATION OF CLOKTASK		B14

P32, P72: CO-ELLIPTIC SEQUENCE INITIATION

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN L. J. Laverriere	27 MAY 69	P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
PRGMR [illegible]	9-9-69		
ANALST W. Tempelman	13 June 69	LUMINARY 1D	DOCUMENT NO. FC-3720
DOCMR [illegible]	13 Jun 69		
APPR'D [illegible]	13 JUNE 69	REV 3	SHEET 1 OF 27



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN P.M. Dietz	30 JULY 69	P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION
PRGMR	7-?-69	
ANALST	15 June	
DOCMR	16 Aug	LUMINARY 1D — DOCUMENT NO. FC-3720
APPR'D	9-10-69	REV 3 — SHEET 2 OF 27



R1=NN-NUMBER OF FUTURE APSIDAL CROSSING OF THE ACTIVE VEHICLE AT WHICH THE CONSTANT DIFFERENTIAL ALTITUDE (CDH) MANEUVER OCCURS. (N)

R2=ELEV-DESIRED ANGLE BETWEEN THE LM/CSM LOS AND THE LOCAL HORIZONTAL PLANE OF THE ACTIVE VEHICLE AT TPI. (E)

TPI = TRANSFER PHASE INITIATION

$$\left.\begin{array}{l} R1-\text{HRS.} \\ R2-\text{MIN.} \\ R3-\text{SEC.} \end{array}\right\} TTPI_{DP}$$

$$\text{INPUT : CMOONFLG} \begin{cases} 0 = \text{EARTH} \\ 1 = \text{MOON} \end{cases}$$

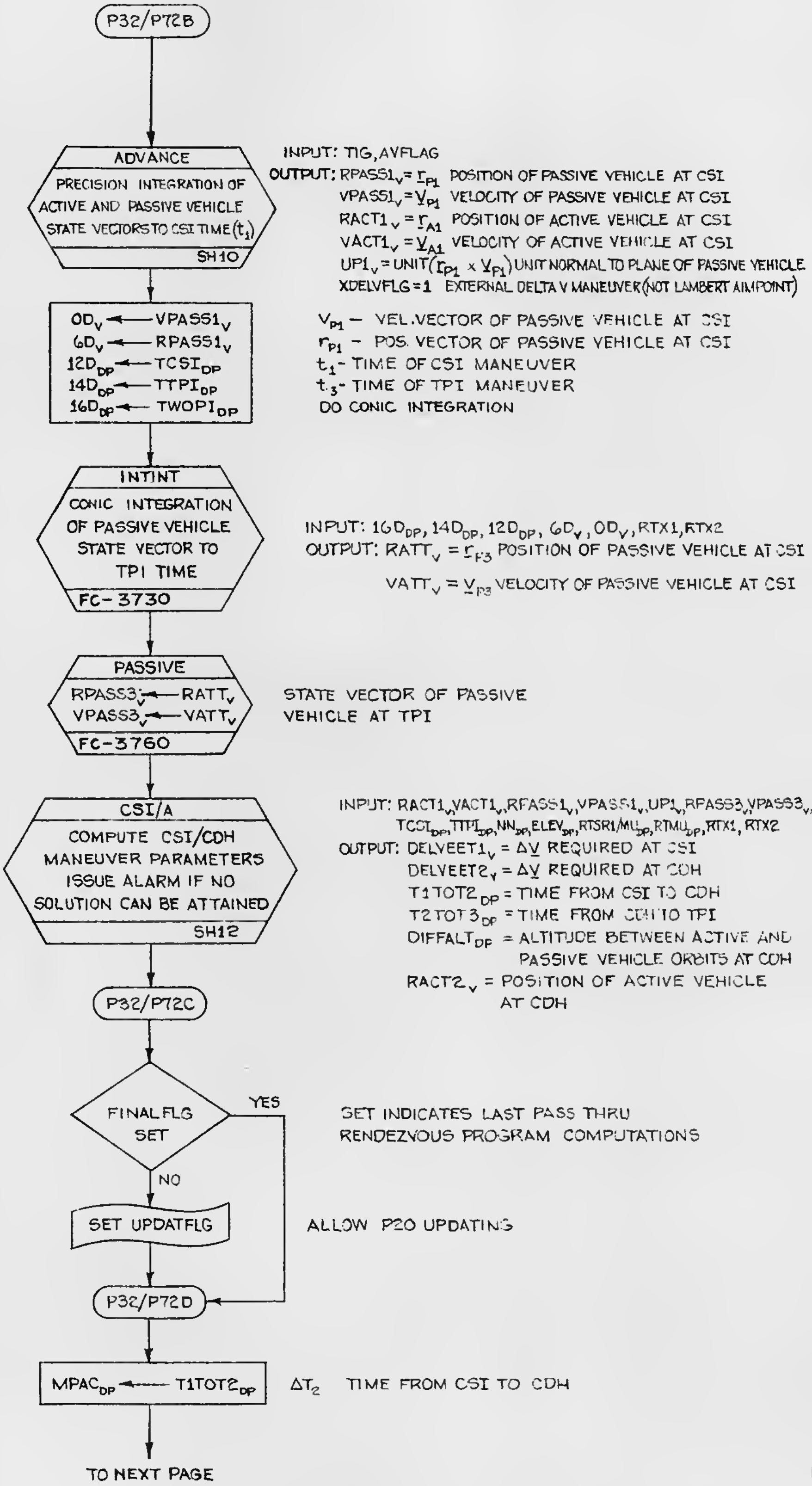
$$\text{OUTPUT: RTSR1/MU}_{DP} = \frac{1}{\sqrt{\mu_e}} \text{ OR } \frac{1}{\sqrt{\mu_m}}$$

$$\text{RTMU}_{DP} = \mu_e \text{ OR } \mu_m$$

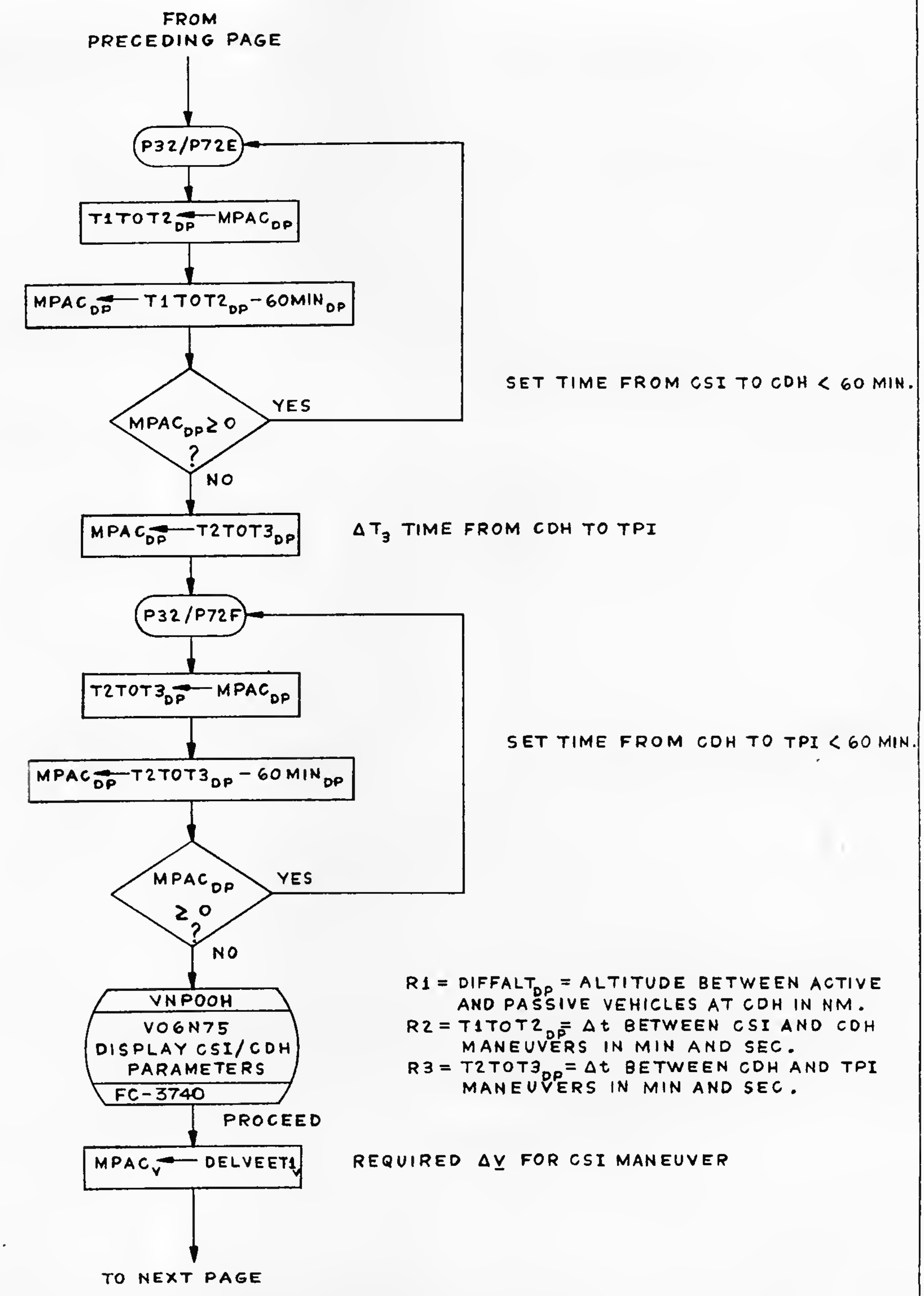
$$\text{RTX1} = \begin{cases} -2 = \text{EARTH} \\ -10 = \text{MOON} \end{cases}$$

$$\text{RTX2} = \begin{cases} 0 = \text{EARTH} \\ 2 = \text{MOON} \end{cases}$$

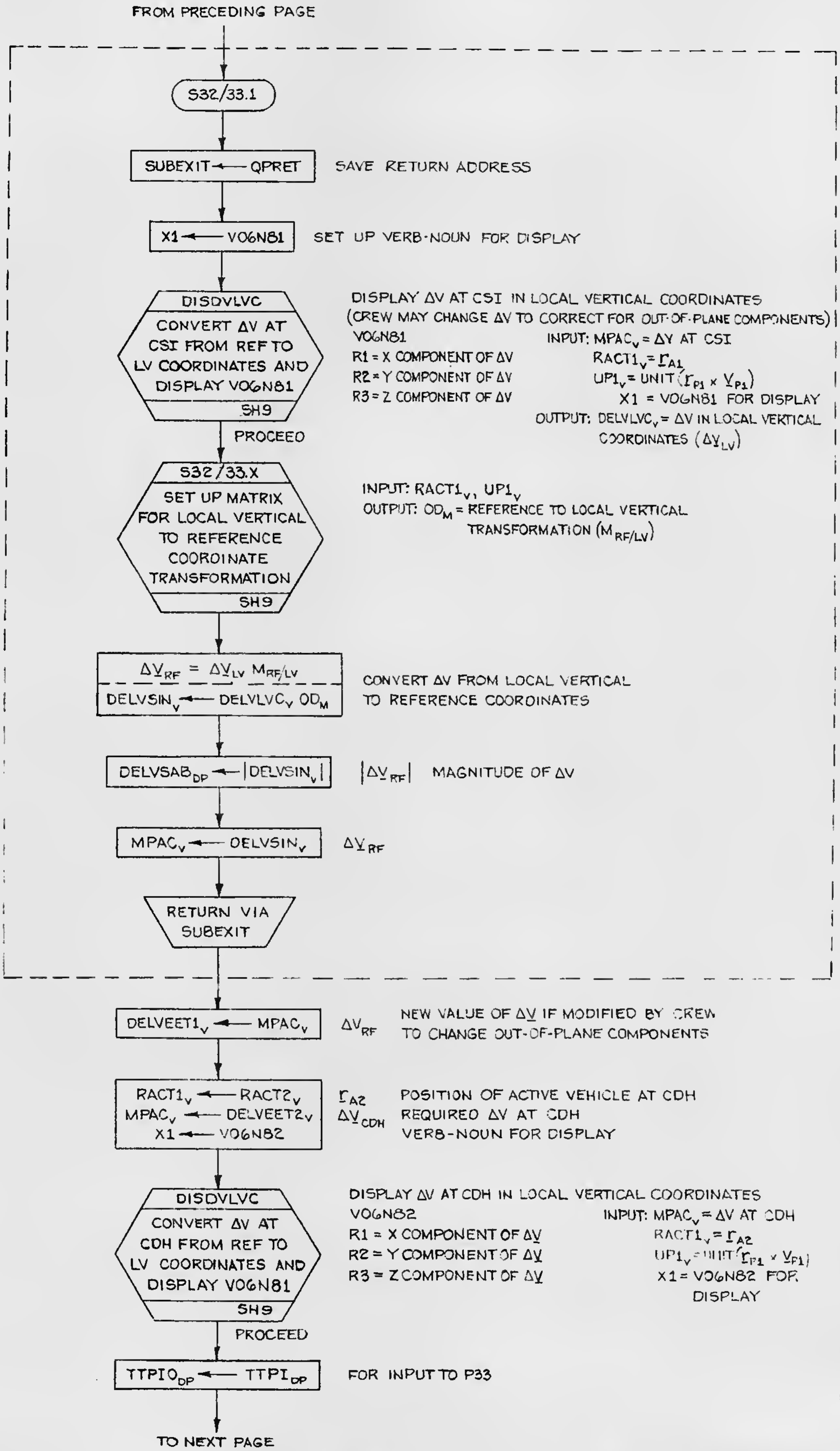
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN P. M. Dickard	30JULY69	P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
PROGMR P. White	9-2-69		DOCUMENT NO.
ANALST W. Tempelman	15 Aug 69	LUMINARY 1D	FC-3720
DOCMR [illegible]	16 Sep 69		
APPR'D Roberta M. Eustis	9-10-69	REV 3	SHEET 3 OF 27



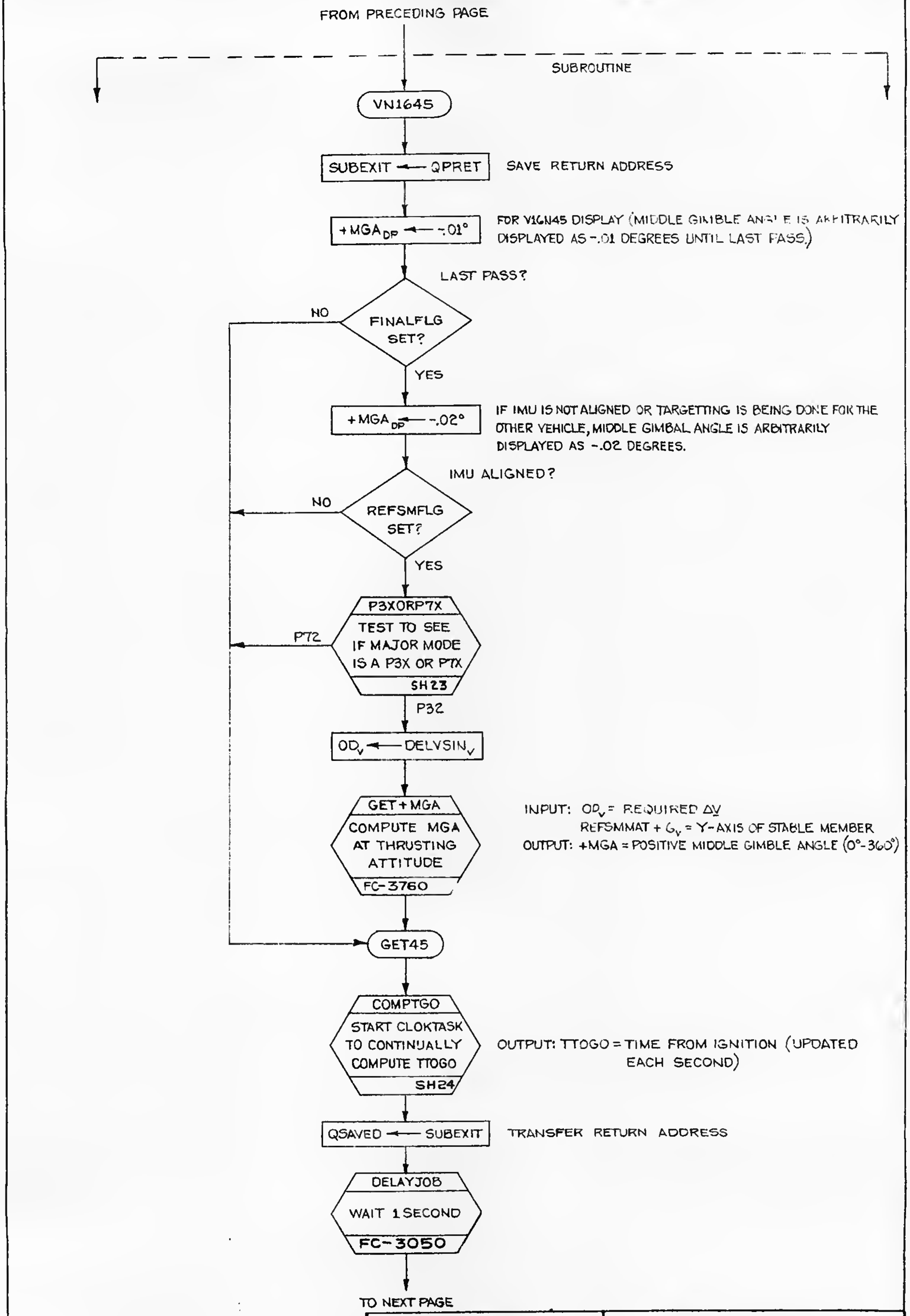
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	4-22-68	P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION
PROGMR [signature]	8-22-68	
ANALST W. Tempelman		LUMINARY 1D — DOCUMENT NO. FC-3720
DOCMR Karl Kull	16 Apr 69	
APPR'D J. Henize	6-2-69	REV 3 — SHEET 4 OF 27



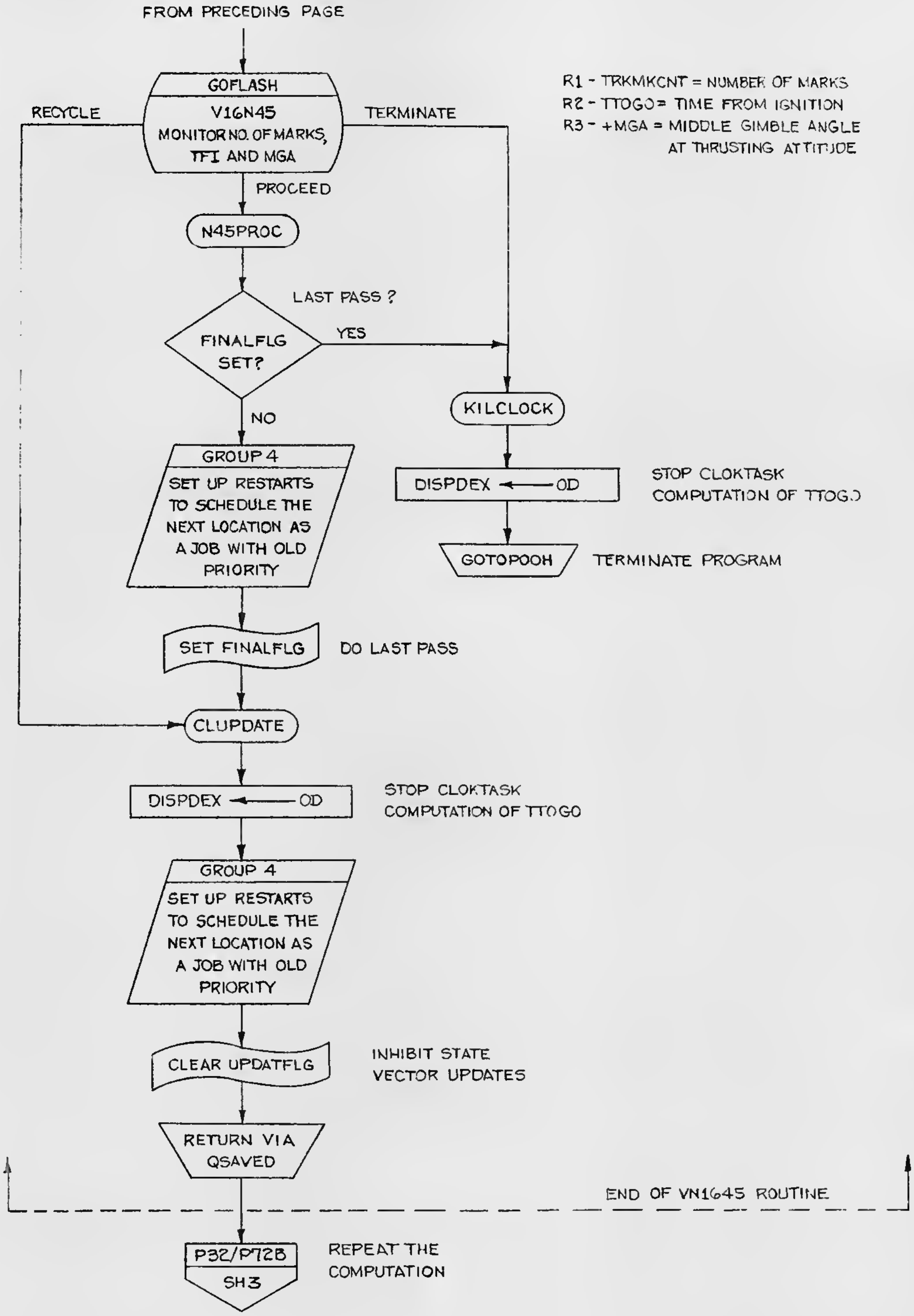
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN A. A. Langille 11 APR 69	P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
PRGMR 11 APR 69		
ANALST 14 Apr 69	LUMINARY 1D	DOCUMENT NO. FC-3720
DOCMR 16 Apr 69		
APPR'D John A. Moore 16 April 69	REV 3	SHEET 5 OF 27



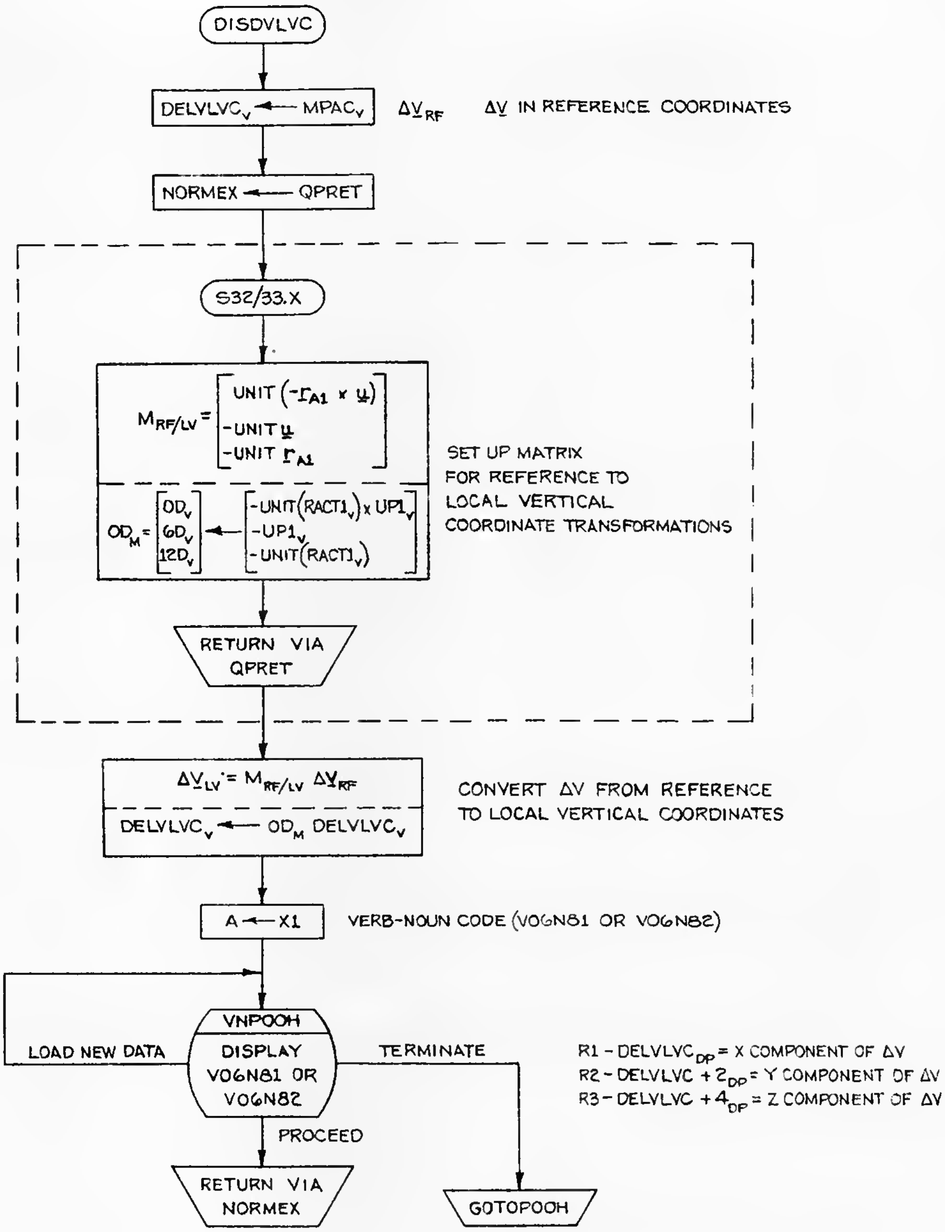
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C. WILLIAMS	4-23-68	P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION
PROGMR Paulete	8-22-68	LUMINARY 1D
ANALST W. Tempelman		DOCUMENT NO. FC-3720
DOCMR [illegible]	6-4-68	REV 3
APPR'D J. Heinje	6-7-68	SHEET 6 OF 27



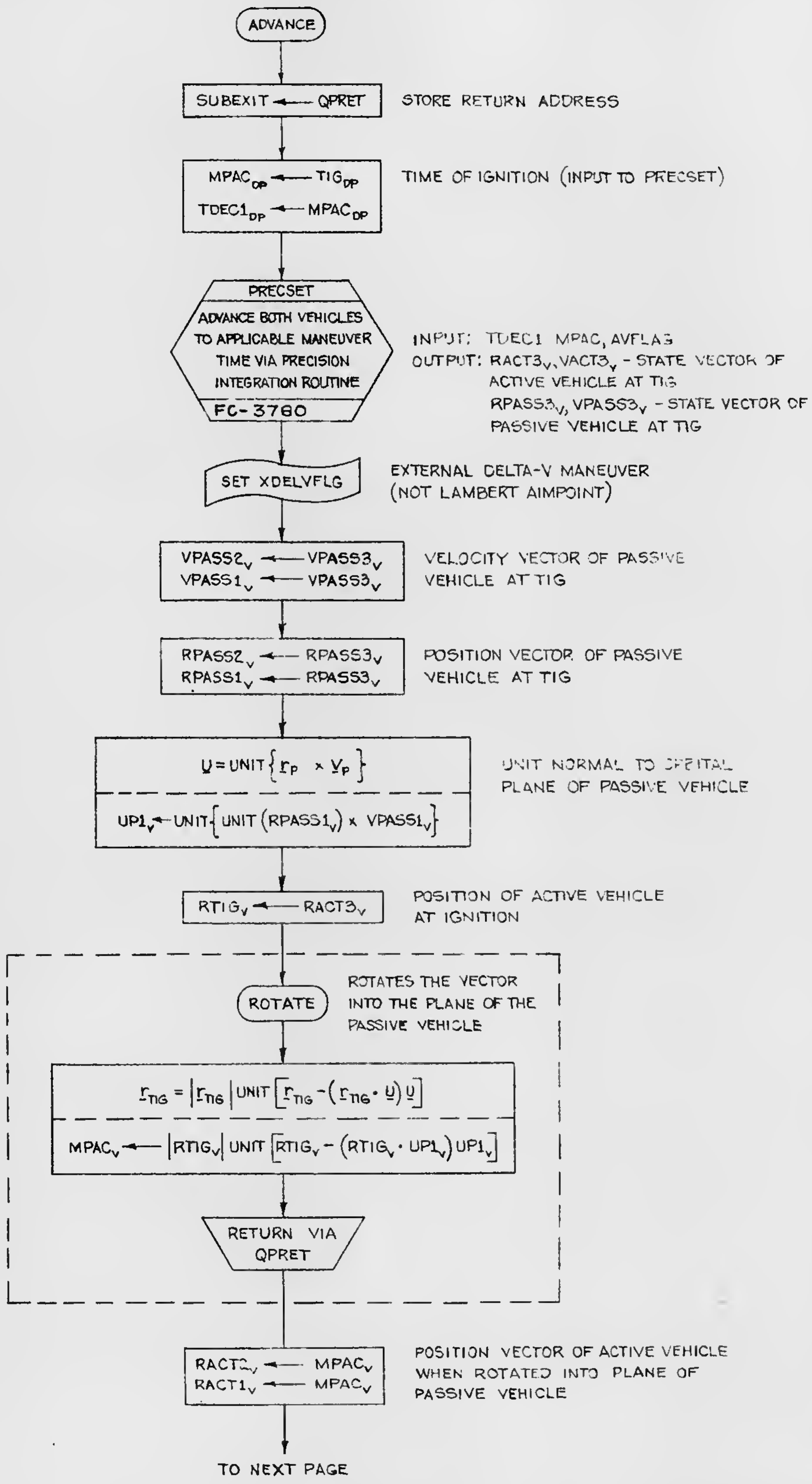
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 4-24-68	P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION
PROGMR 8-22-68	DOCUMENT NO. FC-3720
ANALST	LUMINARY 1D
DOCMR	REV 3
APPR'D 6-7-68	SHEET 7 OF 27



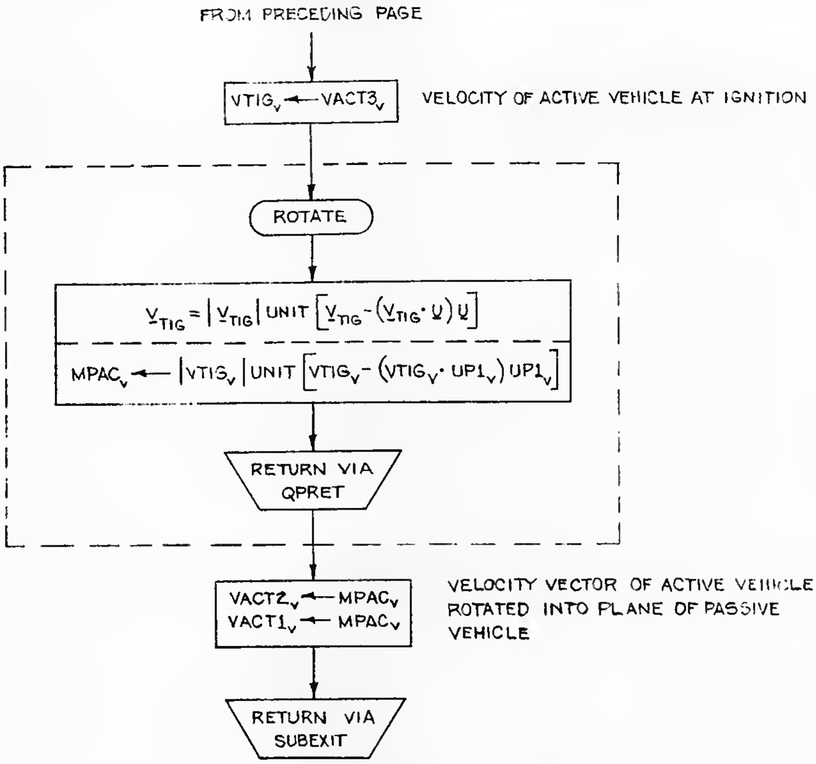
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
DRAWN A.C.WILLIAMS	4-24-68		
PRGMR [illegible]	8-22-68	LUMINARY 1D	DOCUMENT NO. FC-3720
ANALST [illegible]			
DOCMR [illegible]	[illegible]		
APPR'D [illegible]	[illegible]-7-68	REV 3	SHEET 8 OF 27



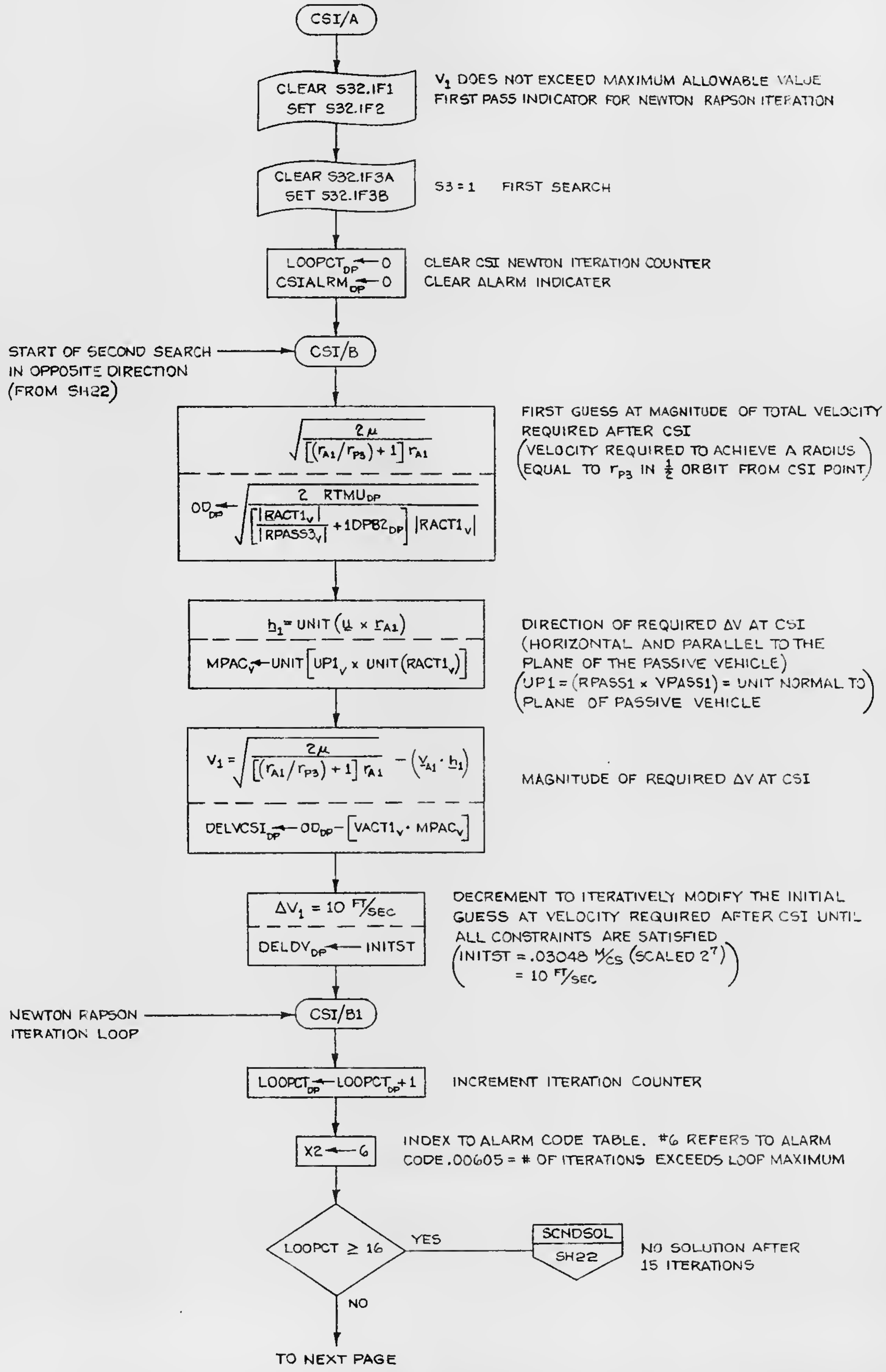
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
DRAWN A.C.WILLIAMS	4-25-68		
PROGMR P. White	8-22-68	LUMINARY 1D	DOCUMENT NO. FC-3720
ANALST			
DOCMR			
APPR'D	6-7-68	REV 3	SHEET 9 OF 27



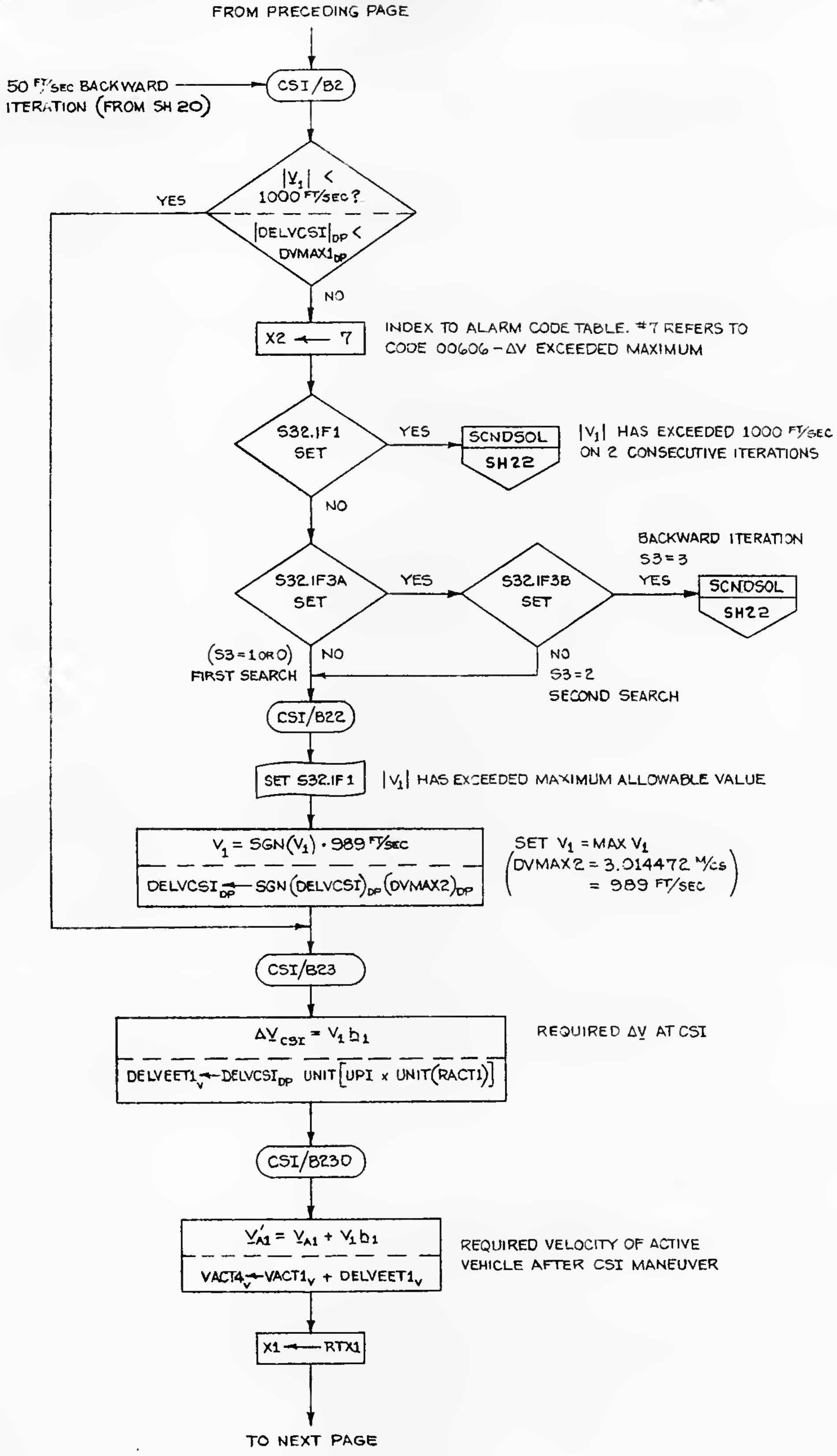
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 5-10-68	P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION
PROGMR P. White 8-22-68	
ANALST W Tempelman	LUMINARY 1D — DOCUMENT NO. FC-3720
DOCMR [illegible]	REV 3
APPR'D J. Hennig 1-7-68	SHEET 10 OF 27



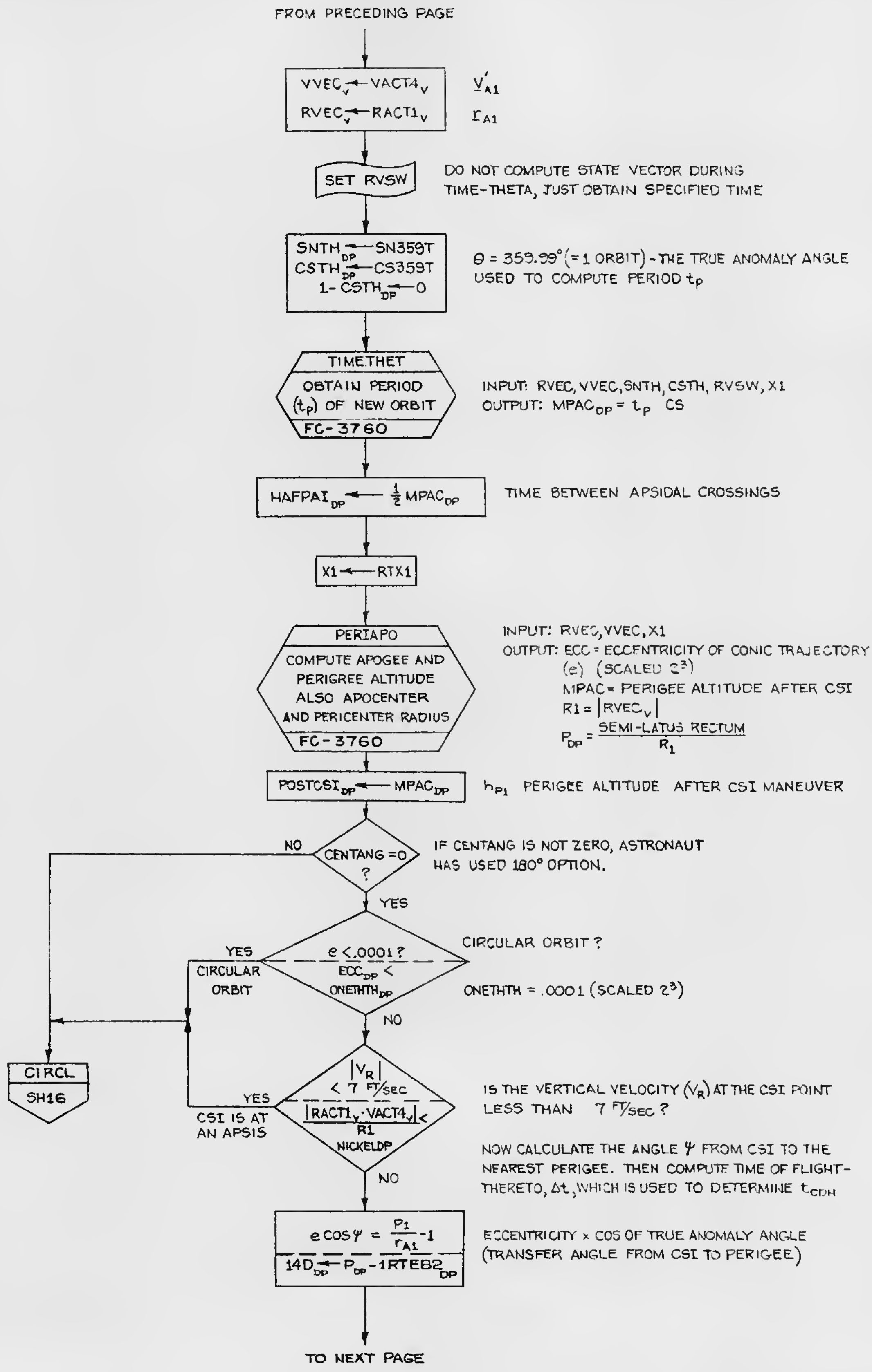
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	A.C. WILLIAMS	6-4-68	P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION
PROGMR	P. White	8-22-68	
ANALST	W. Templeton		LUMINARY 1D · DOCUMENT NO. FC-3720
DOCMR	[illegible]	6-6-68	
APPR'D	J. Heinze	6-7-68	REV 3 · SHEET 11 OF 27



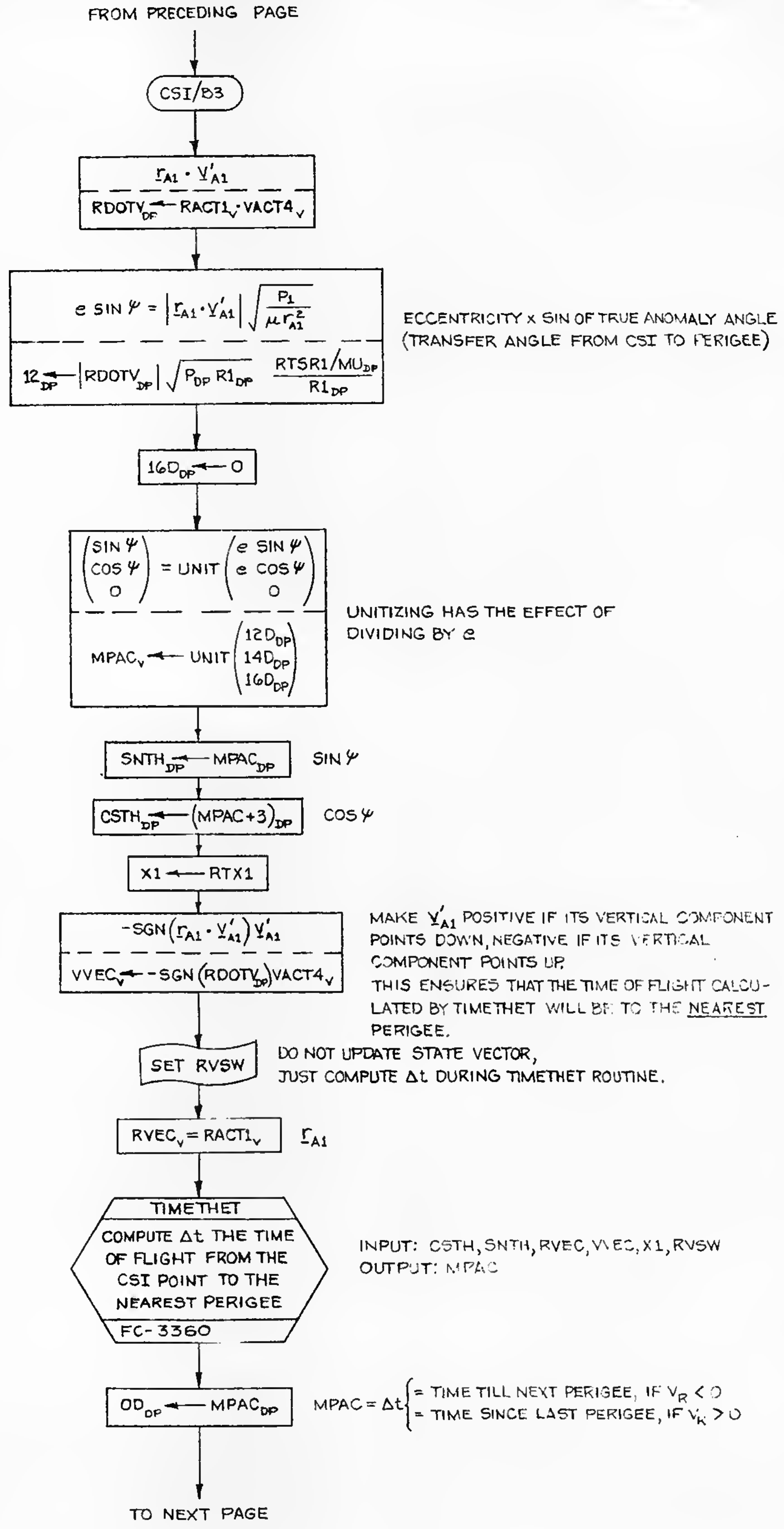
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS 4-25-68	P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
PRGMR P. Volante 8-22-68	LUMINARY 1D	DOCUMENT NO. FC-3720
ANALST W. Tempelman		
DOCMR [illegible] 16 Aug 68		
APPR'D J. Henize 6-7-68	REV 3	SHEET 12 OF 27



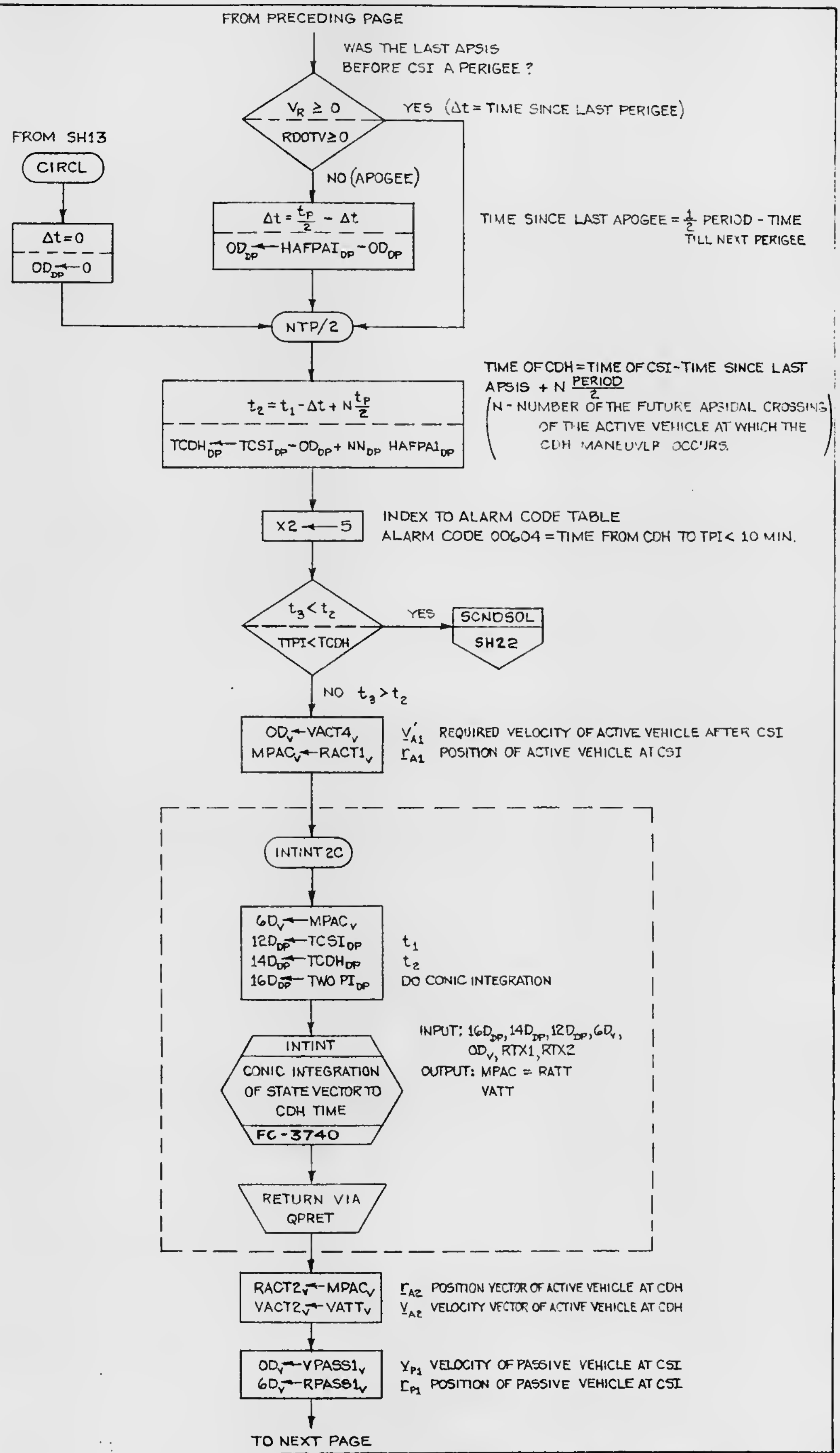
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS 4-26-68	P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
PRGMR P. White 8-22-68	LUMINARY 1D	DOCUMENT NO. FC-3720
ANALST W. [illegible]		
DOCMR [illegible] 11 April 68		
APPR'D J. Hervig 6-7-68	REV 3	SHEET 13 OF 27



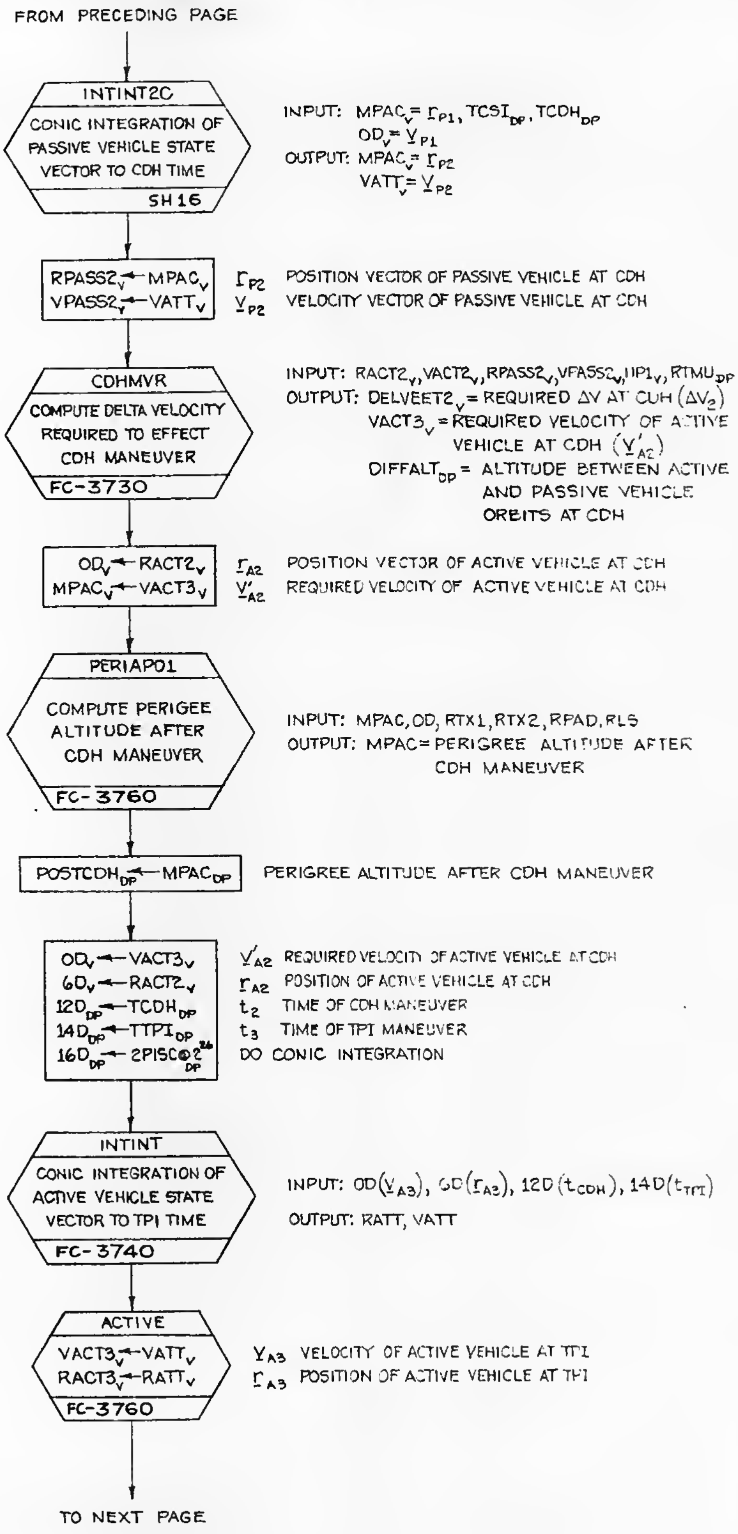
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS	4-29-68	P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
PRGMR P. White	8-22-68	LUMINARY 1D	DOCUMENT NO. FC-3720
ANALST W. Tempelman			
DOCMR [illegible]	[illegible]		
APPR'D J. Hanig	6-7-68	REV 3	SHEET 14 OF 27



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS	4-29-68	P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
PRGMR P.W.White	8-22-68		
ANALST W. Tempelman		LUMINARY 1D	DOCUMENT NO. FC-3720
DOCMR			
APPR'D J. Heinz	6-7-68	REV 3	SHEET 15 OF 27



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P32 AND P72 CO-ELLIPTIC SEQUENCE INIATION	
DRAWN	A.C.WILLIAMS	4-30-68	
PROGMR	R.J. White	8-22-68	LUMINARY 1D
ANALST	W. Tempelman		DOCUMENT NO. FC-3720
DOCMR			
APPR'D	J. Heinz	6-7-68	REV 3 / SHEET 16 OF 27



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
DRAWN A.C.WILLIAMS	5-1-68	LUMINARY 1D	DOCUMENT NO. FC-3720
PRGMR [signature]	8-22-68		
ANALST W. [signature]			
DOCMR [signature]	11-5-68		
APPR'D J. [signature]	6-7-68	REV 3	SHEET 17 OF 27

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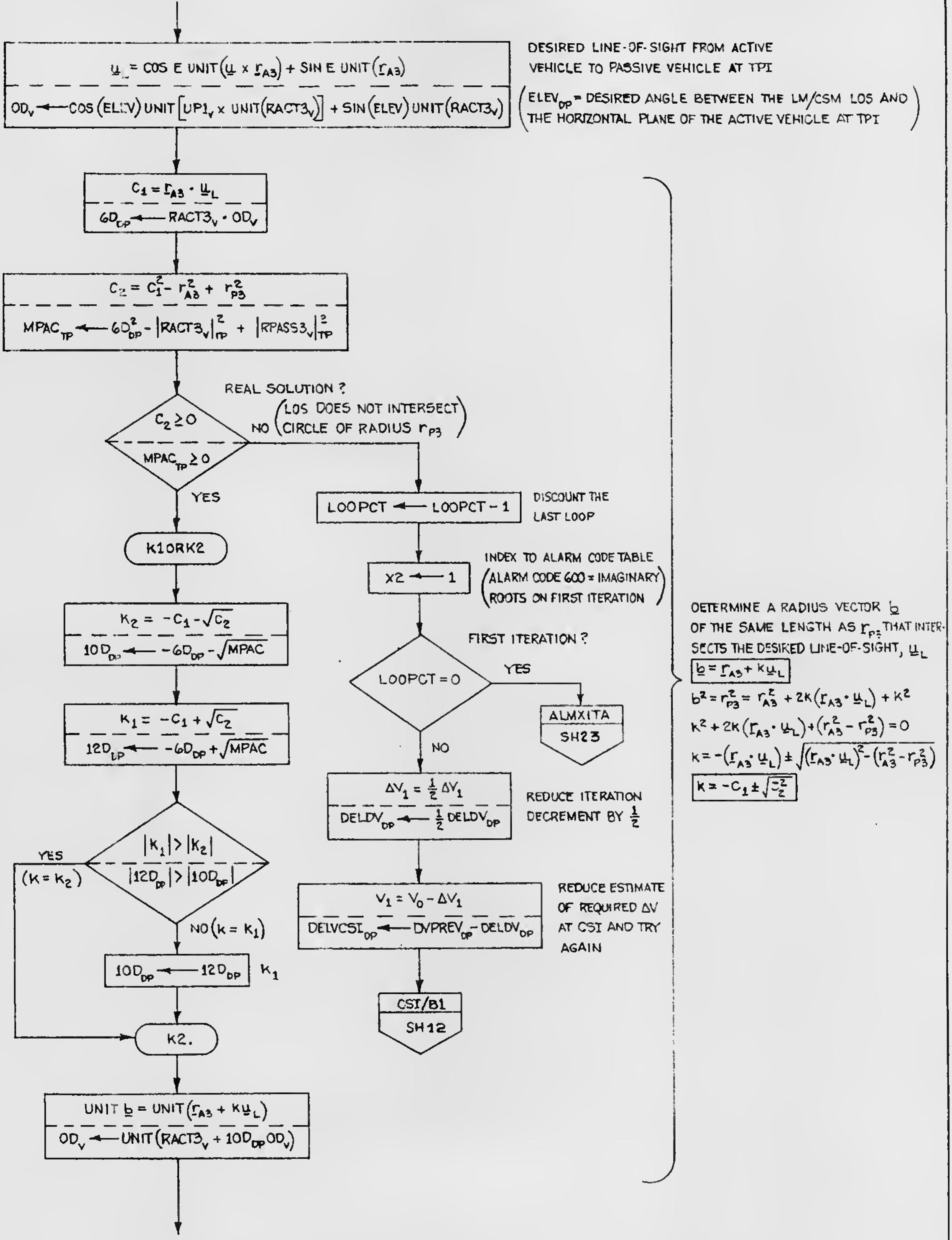
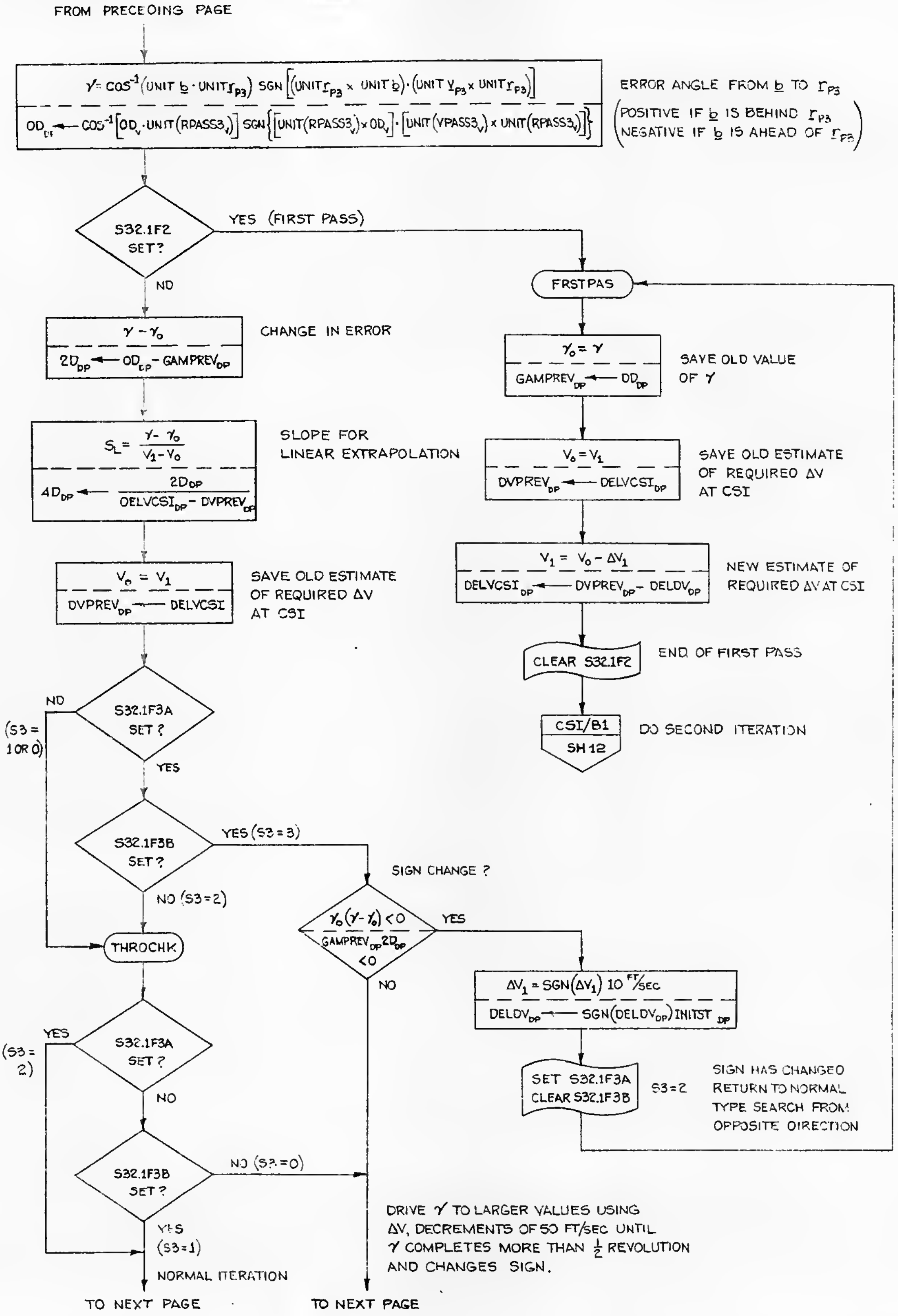
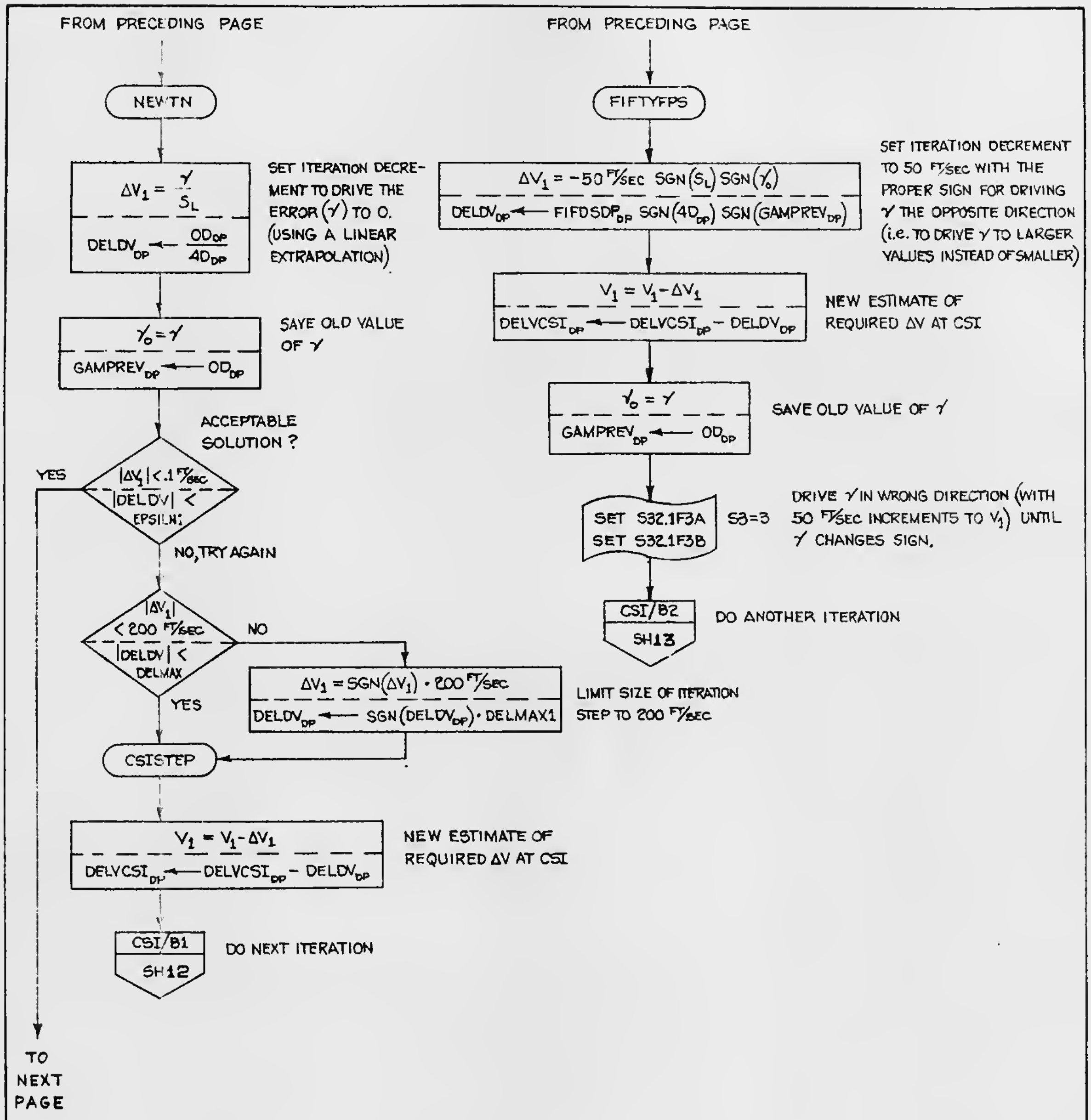


TO NEXT PAGE

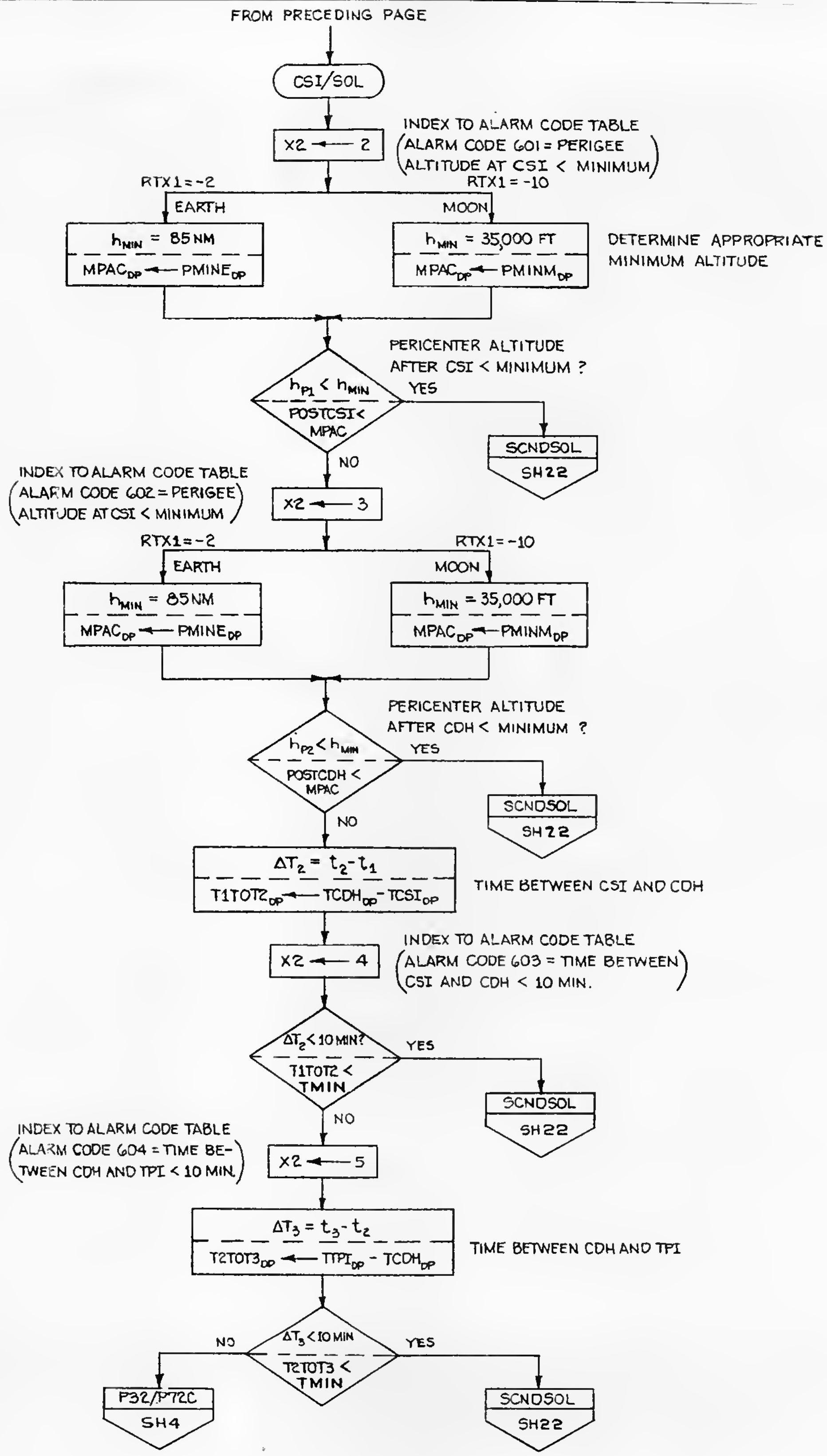
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	5-2-68	P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION
PRGMR	8-22-68	
ANALST		LUMINARY 1D / DOCUMENT NO. FC-3720
DOCMR		
APPR'D	6-2-68	REV 3 / SHEET 18 OF 27



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 5-3-68	P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION
PROGMR P. White 8-22-67	LUMINARY 1D
ANALST N. Tangelmann	DOCUMENT NO. FC-3720
DOCMR 11-6-68	REV 3
APPR'D J. Heng 6-7-68	SHEET 19 OF 27



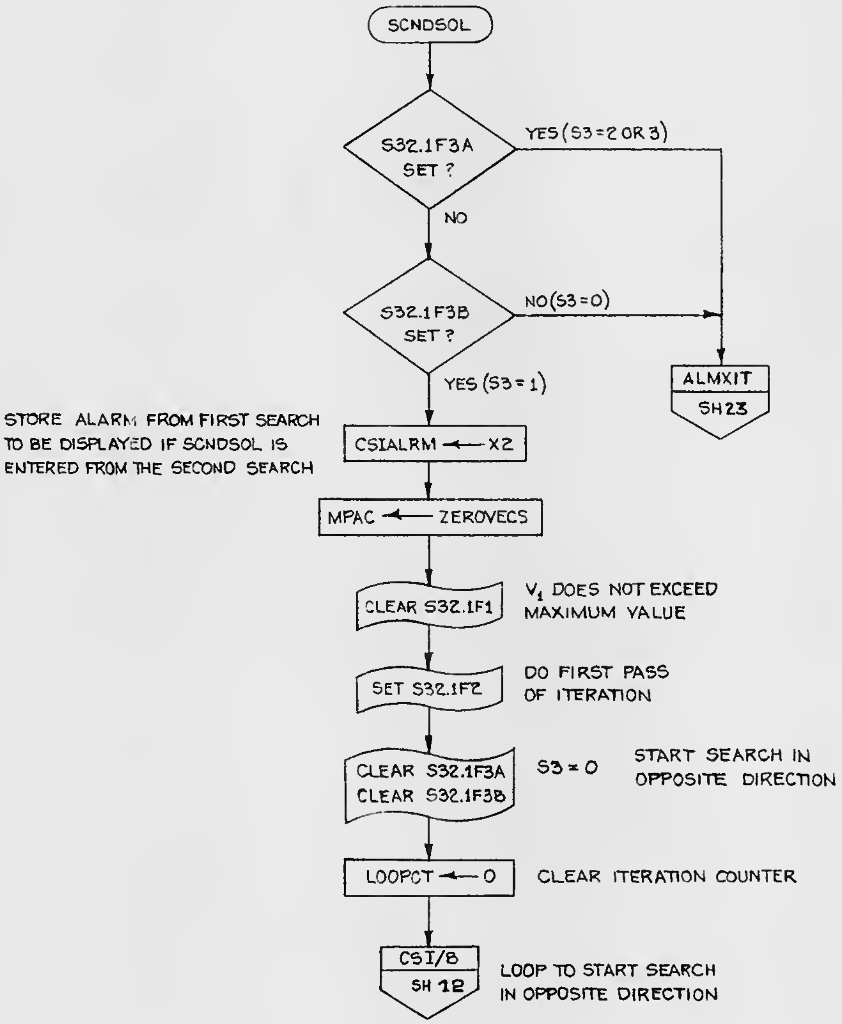
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 5-6-68	P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION
PRGMR P. White 8-22-68	
ANALST W. [illegible]	LUMINARY 1D
DOCMR [illegible] 6-4-68	DOCUMENT NO. FC-3720
APPR'D J. Henig 6-7-68	REV 3 — SHEET 20 OF 27

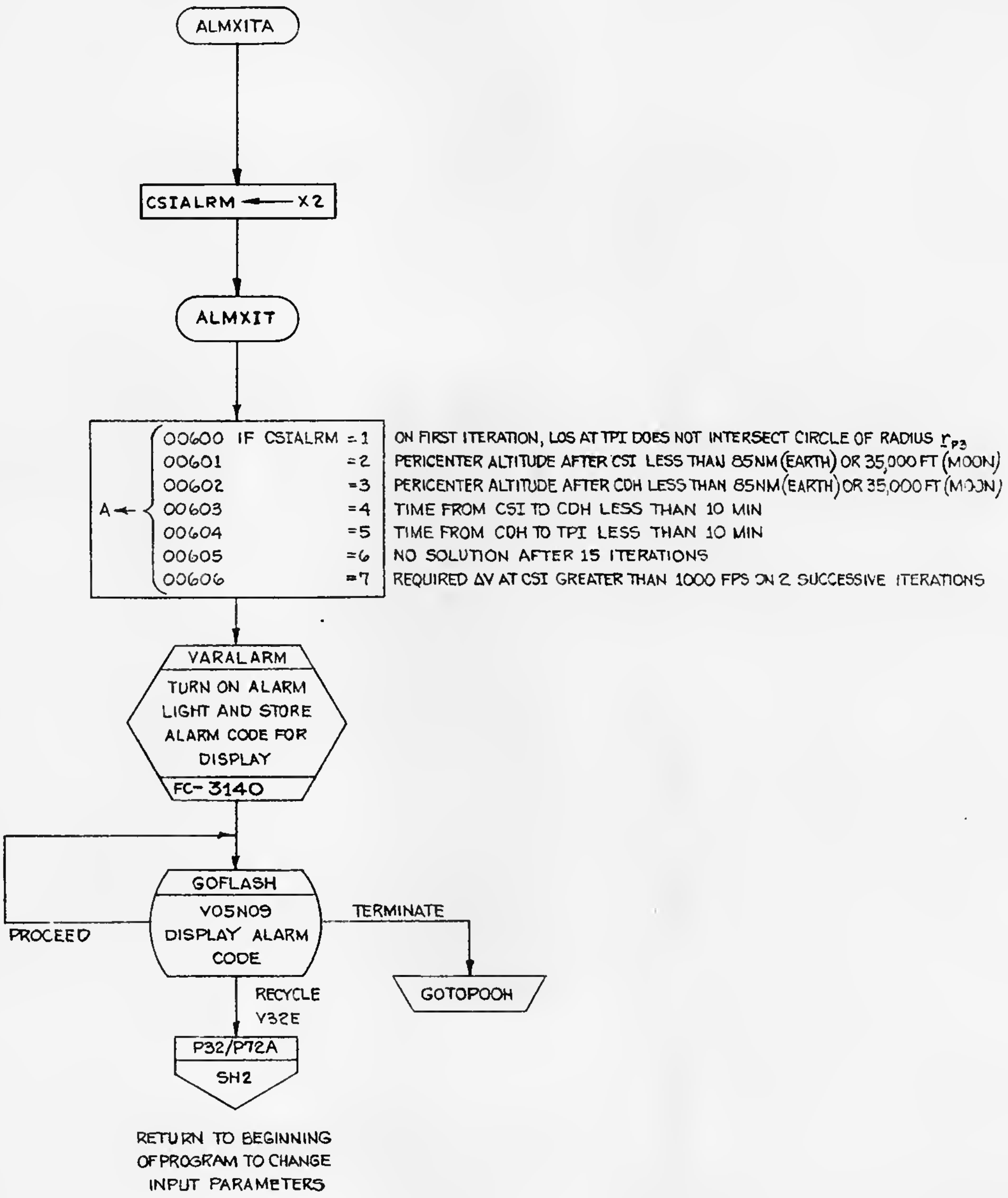


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS 5-6-68	P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
PROGMR [signature] 8-22-68	LUMINARY 1D	DOCUMENT NO. FC-3720
ANALST [signature]		
DOCMR [signature] 11-4-67		
APPR'D [signature] 6-7-68	REV 3	SHEET 21 OF 27

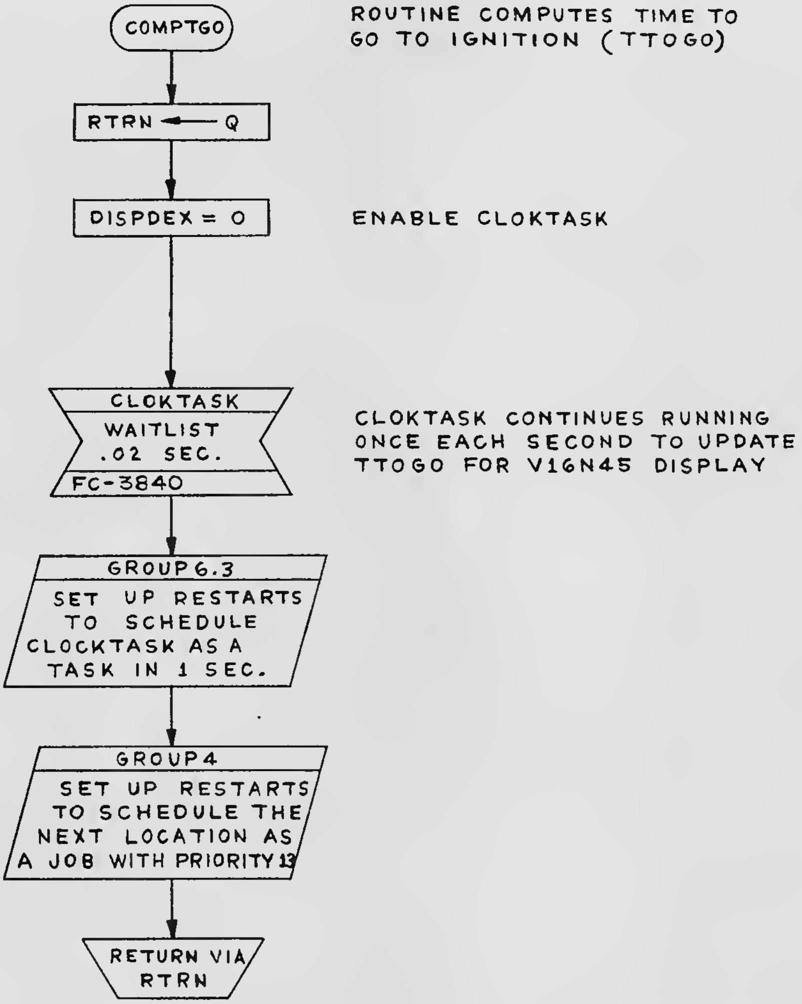
ALARM CONDITIONS THAT CAUSE ENTRY OF SCNDSOL ARE:

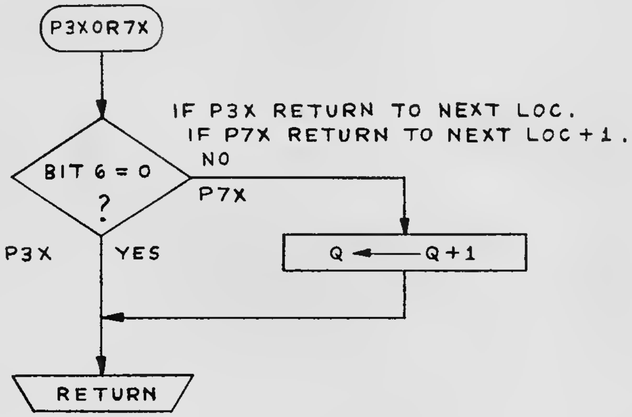
- NO SOLUTION AFTER 15 ITERATIONS
- $V_1 > 1000$ FT/SEC ON 2 SUCCESSIVE ITERATIONS
- $t_3 < t_2$
- $h_{P1} < 85$ NM OR 35,000 FT
- $h_{P2} < 85$ NM OR 35,000 FT
- $\Delta T_2 < 10$ MIN
- $\Delta T_3 < 10$ MIN





MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS 5-7-68	P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
PROGMR P. White 8-22-68		DOCUMENT NO.
ANALST W. Tempelman	LUMINARY 1D	FC-3720
DOCMR [illegible] [illegible]		
APPR'D J. Henize 6-7-68	REV 3	SHEET 23 OF 27





MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION

DRAWN 1 APR 69
PRGMR
ANALST
DOCMR
APPR'D

LUMINARY 1D

DOCUMENT NO. FC-3720

REV 3

SHEET 24 OF 27

P32 - COELLIPTIC SEQUENCE INITIATION

SUBROUTINES	
IN THIS CHART	
AVFLAGA	SETS AVFLAG, UPDATFLG AND TRACKFLG
AVFLAGP	SETS UPDATFLG, TRACKFLG AND CLEARS AVFLAG
S32/33.1	DISPLAY ΔV AT CSI IN LOCAL VERTICAL COORDINATES
DISDVLVC	CONVERT ΔV FROM REFERENCE TO LOCAL VERT COORDS AND DISPLAY
ROTATE	ROTATES VECTOR OF ACTIVE VEHICLE INTO PLANE OF PASSIVE VEHICLE
S32/33.X	COMPUTE MATRIX FOR LOCAL VERT TO REF COORD TRANSFORMATION
PRECSET	ADVANCE BOTH VEHICLES TO APPLICABLE MANEUVER TIME VIA PRECISION INTEGRATION
CSI/A	COMPUTE CSI/CDH MANEUVER PARAMETERS
INTINT2C	PERFORMS HOUSEKEEPING FOR AND CALLS INTEGRATION ROUTINE
VN1645	DISPLAY V16N45
ADVANCE	ACTIVE AND PASSIVE STATE VECTORS TO CSI TIME PRECISION INTEGRATION OF
COMPTGO	COMPUTE TIME TO GO TO IGNITION
P3XORP7X	TEST TO SEE IF CALLING PROGRAM IS P32 OR P72

ON OTHER CHARTS		FLOW CHART NUMBER
SELECTMU	SELECT VALUE ACCORDING TO LUNAR OR EARTH SPHERE OF INFLUENCE	3760
INTINT	PREPARE FOR AND CALL INTEGRATION ROUTINE	3740
GET+MGA	COMPUTE MIDDLE GIMBAL ANGLE AT THRUSTING ATTITUDE	3760
PERIAPO, PERIAPO1	COMPUTE APOGEE AND PERIGEE ALTITUDE	3760
TIMETHET	OBTAIN PERIOD (t_p) OF NEW ORBIT OR Δ BETWEEN 2 POINTS	3360
CDHMVR	COMPUTE CDH MANEUVER PARAMETERS	3730
LEMPREC	UPDATE LM STATE VECTOR TO SPECIFIED TIME VIA PRECISION INTEGRATION	3350
CSMPREC	UPDATE CSM STATE VECTOR TO SPECIFIED TIME VIA PRECISION INTEGRATION	3350

FLAGS	MEANING		SET	CLEARED	TESTED
AVFLAG	SET	LM IS ACTIVE VEHICLE	SH 2	SH 2	
	CLEARED	CSM IS ACTIVE VEHICLE			
UPDATFLG	SET	UPDATING IS ALLOWED	SH 2, SH 4	SH 8	
	CLEARED	TRACKING IS DISALLOWED			
TRACKFLG	SET	TRACKING IS ALLOWED	SH 2		
	CLEARED	TRACKING IS DISALLOWED			
FINALFLG	SET	LAST PASS THRU RENDEZVOUS PROGRAM			
	CLEARED	INTERIM PASS THRU RENDEZVOUS PROGRAM	SH 8		SH 4, SH 7, SH 8
REFSMFLG	SET	REFERENCE MATRIX IS GOOD			SH 7
	CLEARED	REFERENCE MATRIX IS NOT GOOD			
S32.1F1	SET	V_1 EXCEEDS MAXIMUM ALLOWABLE VALUE			
	CLEARED	V_1 DOES NOT EXCEED MAXIMUM ALLOWABLE VALUE	SH 13	SH 12	SH 13
S32.1F2	SET	INDICATES FIRST PASS FOR NEWTON-RHAPSON ITERATION	SH 12,	SH 19	SH 19
	CLEARED	OTHER THAN FIRST PASS			
S32.1F3A, S32.1F3B	=0	START SEARCH IN OPPOSITE DIRECTION	SH 12, 22		SH 19, SH 22
	=1	FIRST SEARCH			
	=2	2ND CYCLE THRU CSI/A AREA	SH 19		
	=3	50 FT/SEC INCREMENTS TO V_1 UNTIL γ CHANGES SIGN	SH 20		
RVSW	SET	JUST COMPUTE Δ FROM TIMETHET ROUTINE			
	CLEARED	COMPUTE Δ AND UPDATE STATE VECTOR DURING TIMETHET	SH 14, SH 15		
XDELVFLG	SET	EXTERNAL ΔV MANEUVER	SH 10		
	CLEARED	LAMBERT AIMPOINT MANEUVER			
CMOONFLG	SET	PERMANENT CSM STATE IN LUNAR SPHERE			
	CLEARED	PERMANENT CSM STATE IN EARTH SPHERE			SH 2

P32 - COELLIPTIC SEQUENCE INITIATION (CONT.)

DISPLAYS	MEANING	USED
V06N11	DISPLAY CSI TIME	SH 2
V06N55	DISPLAY DESIRED NUMBER OF APSIDAL CROSSING AT CDH AND ELEV. ANGLE AT TPI	SH 3
V06N37	DISPLAY TIME OF TPI MANEUVER	SH 3
V16N45	DISPLAY MARKS, TIME FROM IGNITION, MIDDLE GIMBAL ANGLE	SH 8
V06N75	DISPLAY CSI/CDH PARAMETERS	SH 5
V06N81	DISPLAY REQUIRED ΔV FOR CSI	SH 9
V06N82	DISPLAY REQUIRED ΔV FOR CDH	SH 9
V05N09	DISPLAY APPROPRIATE ALARM CODE	SH 23

ALARMS	MEANING	USED
00600	ON FIRST ITERATION, LOS AT TPI DOES NOT INTERSECT CIRCLE OF RADIUS r_{P3}	SH 18
00601	PERICENTER ALTITUDE AFTER TPI LESS THAN 85 NM (EARTH) OR 35,000 FT (MOON)	SH 21
00602	PERICENTER ALTITUDE AFTER CDH LESS THAN 85 NM (EARTH) OR 35,000 FT (MOON)	SH 21
00603	TIME FROM CSI TO CDH LESS THAN 10 MIN	SH 21
00604	TIME FROM CDH TO TPI LESS THAN 10 MIN	SH 16, SH 21
00605	NO SOLUTION AFTER 15 ITERATIONS	SH 12
00606	REQUIRED ΔV AT CSI GREATER THAN 1000 FT/SEC ON 2 SUCCESSIVE ITERATIONS	SH 13

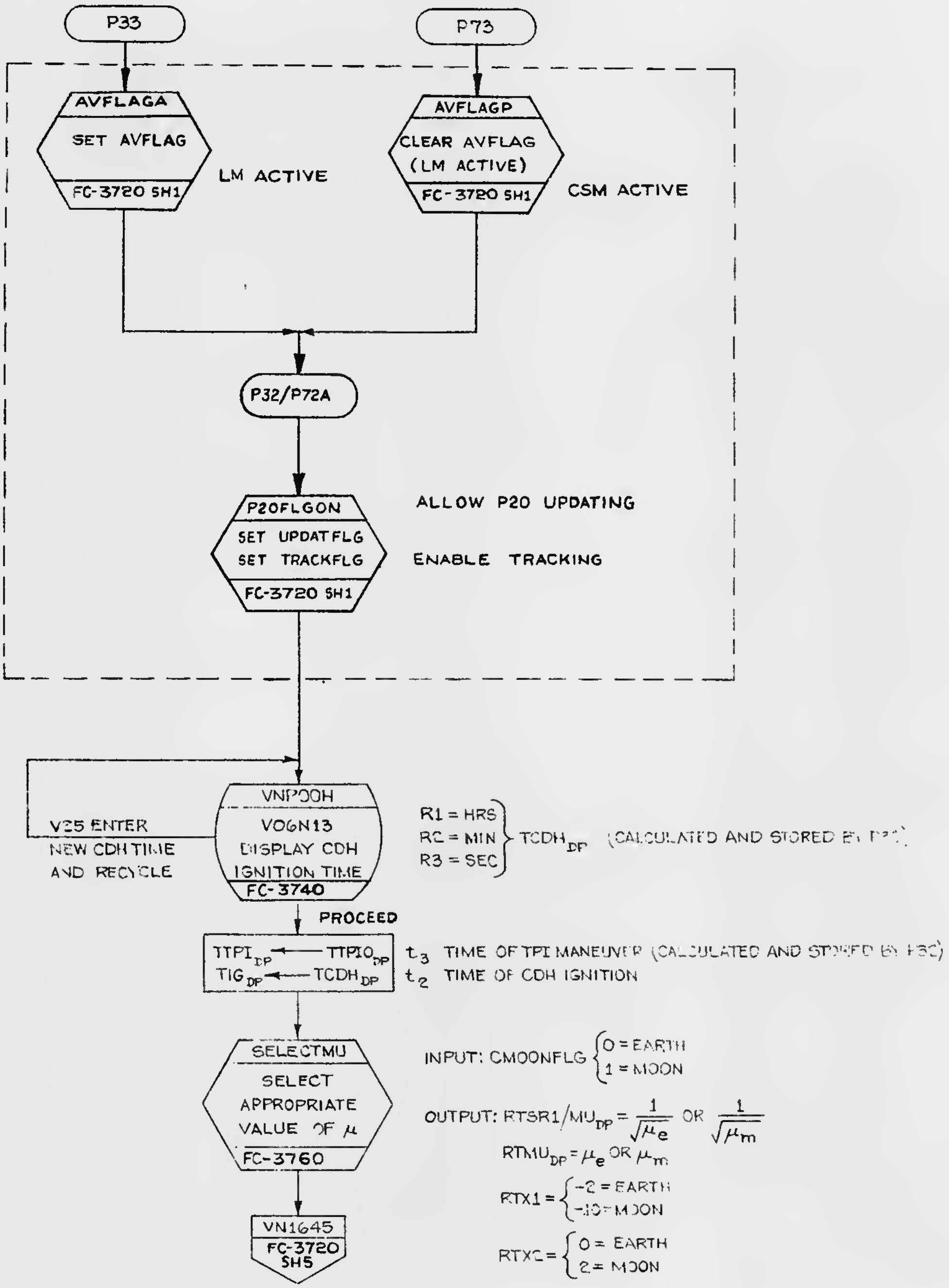
ERASABLES	MEANING	UNITS	SCALING
CSIALRM	ALARM CODE		B28
CSTH	COS OF θ THE TRUE ANOMALY ANGLE	REVOLUTIONS	B1
DELDV	ΔV STORAGE	M/CSEC	B7
DELVEET1	ΔV FOR CSI MANEUVER	M/CSEC	B7
DELVEET2	ΔV FOR CDH MANEUVER	M/CSEC	B7
DELVCSI	ΔV AT CSI	M/CSEC	B7
DELVLVC	ΔV IN LOCAL VERTICAL COORDINATES	M/CSEC	B7
DELVSAB	MAGNITUDE OF ΔV AT CSI		B7
DELVSIN	ΔV AT CSI IN REFERENCE COORDINATES	M/CSEC	B7
DIFFALT	DISTANCE BETWEEN ACTIVE AND PASSIVE VEHICLE ORBITS AT CDH	METERS	B29
DVPREV	PREVIOUS CSI ΔV VALUE	M/CSEC	B7
ECC	ECCENTRICITY		B3
ELEV	DESIRED LOS ANGLE AT TPI	REVOLUTIONS	B1
GAMPREV	PREVIOUS VALUE OF γ, THE ERROR ANGLE FROM b TO r_{P3}	REVOLUTIONS	B0
HAFPA1	TIME BETWEEN APSIDAL CROSSINGS	CENTISECONDS	B28
LOOPCT	ITERATION COUNTER		B28
NN	NUMBER OF APSIDAL CROSSINGS OF ACTIVE VEHICLE		B28
POSTCDH	PERIGEE ALTITUDE AFTER CDH MANEUVER	METERS	B29
POSTCSI	PERIGEE ALTITUDE AFTER CSI MANEUVER	METERS	B29
RACT1	POSITION OF ACTIVE VEHICLE AT CSI TIME	METERS	B29
RACT2	POSITION OF ACTIVE VEHICLE AT CDH TIME	METERS	B29
RACT3	POSITION VECTOR OF ACTIVE VEHICLE AT TPI	METERS	B29
RATT	POSITION VECTOR OUTPUT FROM INTEGRATION	METERS	B29
RDOTV	$\underline{r}_{AI} \cdot \underline{V}'_{AI}$		B36
RPASS1	POSITION VECTOR OF PASSIVE VEHICLE AT CSI TIME	METERS	B29
RPASS2	POSITION VECTOR OF PASSIVE VEHICLE AT CDH	METERS	B29
RPASS3	POSITION VECTOR OF PASSIVE VEHICLE AT TPI	METERS	B29
RTIG	POSITION OF ACTIVE VEHICLE AT CSI BEFORE ROTATION	METERS	B29
RTMU	μ_e OR μ_m	$M^3/CSEC^2$	B36 OR B30
RTSR1/MU	$1/\sqrt{\mu_e}$ OR $1/\sqrt{\mu_m}$	$CSEC/M^{3/2}$	B17 OR B14
RTX1	SHIFT COUNTER; -2 FOR EARTH ORBIT, -10 FOR LUNAR ORBIT		B14
RTX2	SHIFT COUNTER; 0 FOR EARTH ORBIT, 2 FOR LUNAR ORBIT		B14
RVEC	POSITION VECTOR (INPUT TO CONIC ROUTINES)	METERS	B29
SNTH	SINE OF θ THE TRUE ANOMALY ANGLE	REVOLUTIONS	B1
T1TDT2	TIME FROM CSI TO CDH	CENTISECONDS	B28
T2TDT3	TIME FROM CDH TO TPI	CENTISECONDS	B28

ERASABLES	MEANING	UNITS	SCALING
TCDH	TIME OF CDH MANEUVER	CENTISECONDS	B28
TCSI	TIME OF CSI MANEUVER	CENTISECONDS	B28
TIG	TIME OF IGNITION	CENTISECONDS	B28
TTPI	TIME OF TPI MANEUVER	CENTISECONDS	B28
TTPI0	TIME OF TPI MANEUVER FOR P33	CENTISECONDS	B28
UP1	UNIT-NORMAL TO PLANE OF PASSIVE VEHICLE		B1
VACT1	VELOCITY OF ACTIVE VEHICLE AT CSI	M/CSEC	B7
VACT2	VELOCITY VECTOR OF ACTIVE VEHICLE AT CDH	M/CSEC	B7
VACT3	VELOCITY VECTOR OF ACTIVE VEHICLE AT TPI	M/CSEC	B7
VACT4	VELOCITY VECTOR OF ACTIVE VEHICLE AT INTERCEPT	M/CSEC	B7
VATT	VELOCITY VECTOR OUTPUT FROM INTEGRATION	M/CSEC	B7
VPASS1	VELOCITY VECTOR OF PASSIVE VEHICLE AT CSI TIME	M/CSEC	B7
VPASS2	VELOCITY VECTOR OF PASSIVE VEHICLE AT CDH	M/CSEC	B7
VPASS3	VELOCITY VECTOR OF PASSIVE VEHICLE AT TPI	M/CSEC	B7
VVEC	VELOCITY VECTOR (INPUT TO CONIC ROUTINES)	M/CSEC	B7

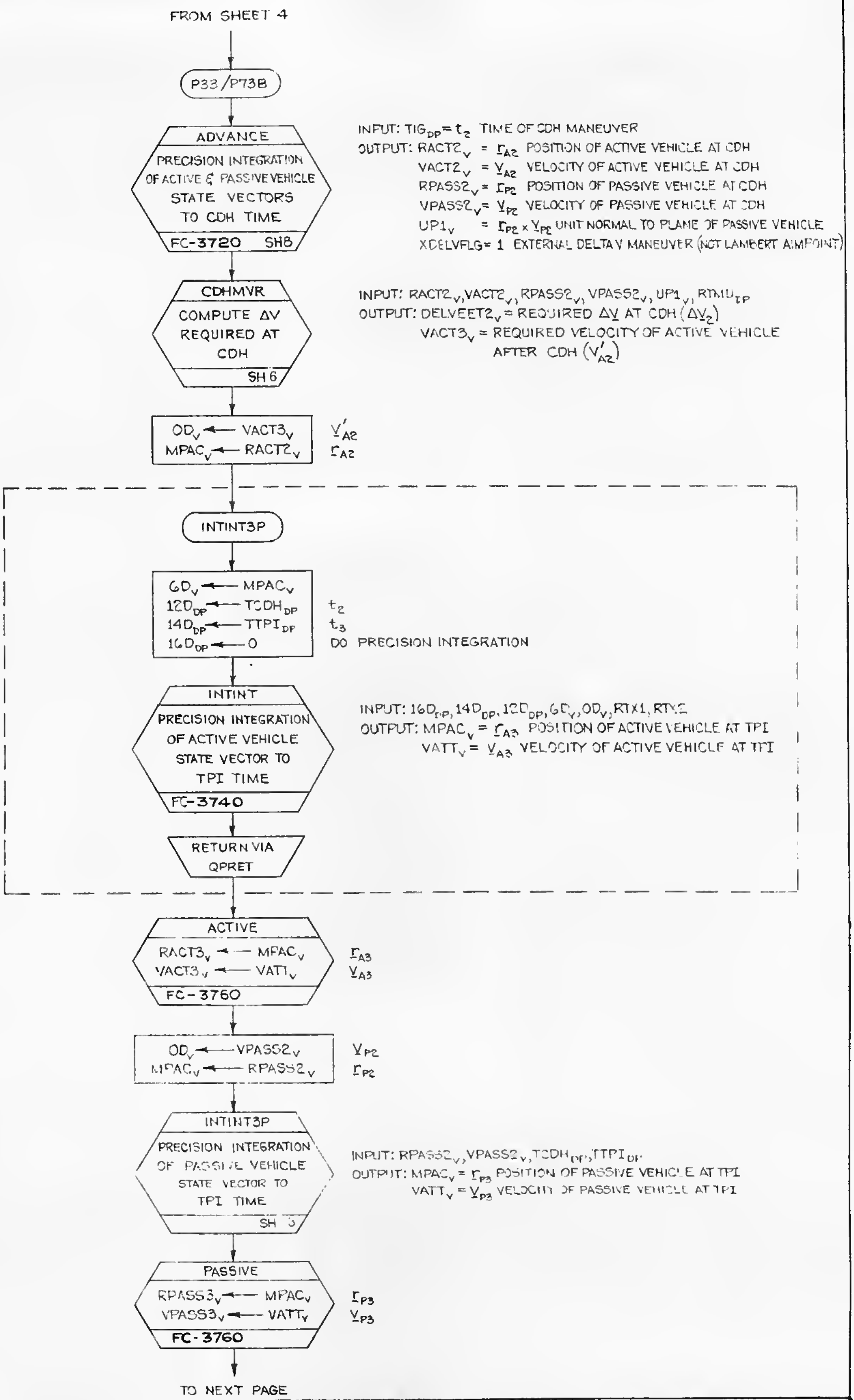
CONSTANTS		VALUE	UNITS	SCALING
MUTABLE	μ_e GRAVITATIONAL CONSTANT OF EARTH	3.986032×10^{10}	$M^3/CSEC^2$	B36
MUTABLE+6	$1/\sqrt{\mu_e}$	$.50087529 \times 10^{-5}$	$CSEC/M^{3/2}$	B17
MUTABLE+8	μ_e GRAVITATIONAL CONSTANT OF MOON	4.902778×10^8	$M^3/CSEC^2$	B30
MUTABLE+14	$1/\sqrt{\mu_m}$	$.45162595 \times 10^{-4}$	$CSEC/M^{3/2}$	B14

P33 and P73

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E. Matta	5/26/70	P33 and P73 Constant Delta Altitude Targetting	
PRGMR P. White			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3730
DOCMR			
APPR'D Roberta M Estes	5/27/70	REV 3	SHEET 1 OF 8



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C. WILLIAMS 6-6-68	P33 AND P73 CONSTANT DELTA ALTITUDE TARGETTING
PRGMR 16-4-69	LUMINARY 1D — DOCUMENT NO. FC-3730
ANALST Wayne Tempelman 6-18-68	
DOCMR 4-16-69	
APPR'D J. Henize 6-18-68	REV 3 — SHEET 2 OF 8



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CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

P33 AND P73
CONSTANT DELTA ALTITUDE TARGETTING

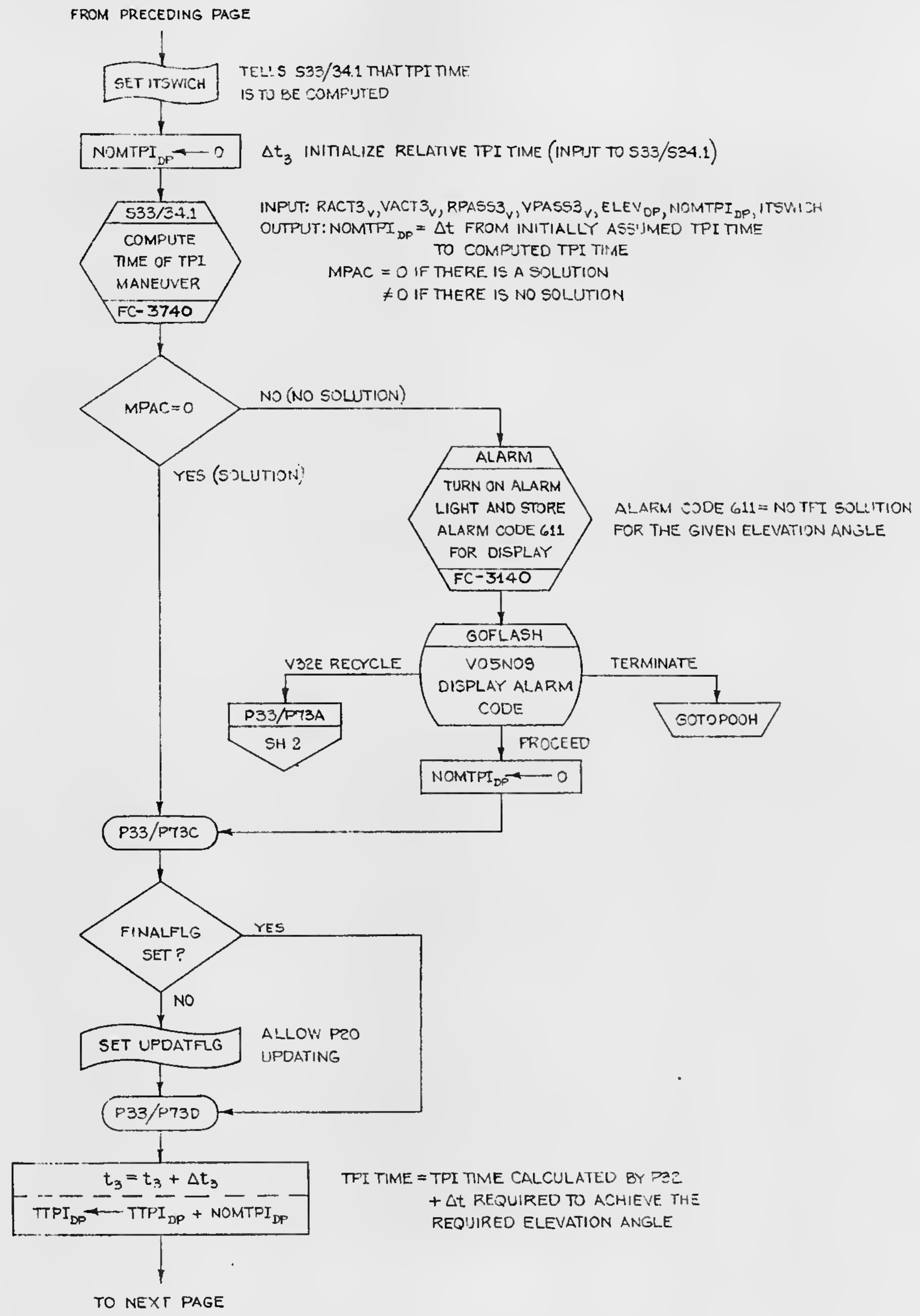
DRAWN	A. C. WILLIAMS	6-7-68
PROGMR	[illegible]	6-4-68
ANALST	Wayne Templeton	6-18-68
DOCMR	[illegible]	4-16-68
APPR'D	J. Henry	6-18-68

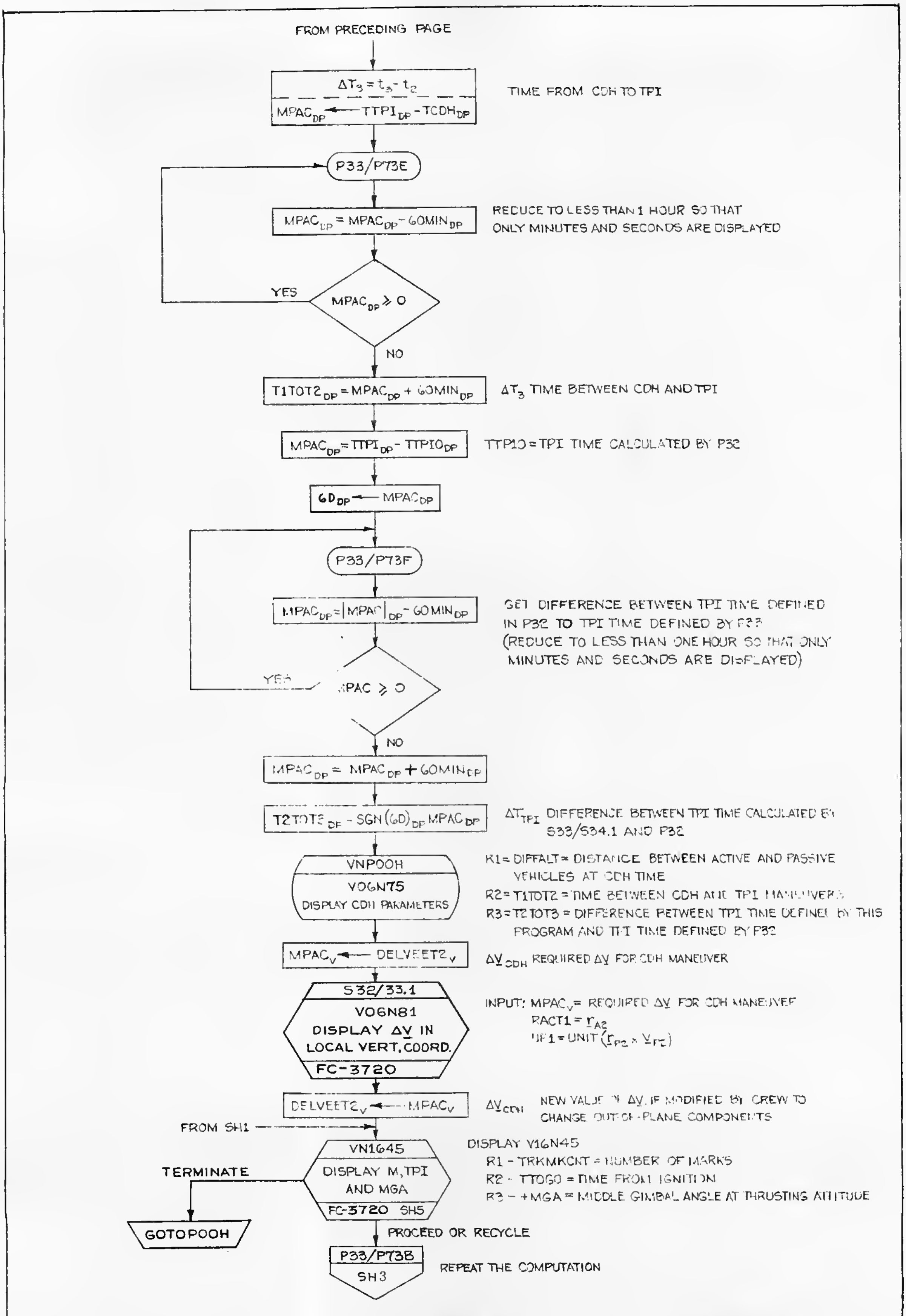
LUMINARY 1D

DOCUMENT NO. FC-3730

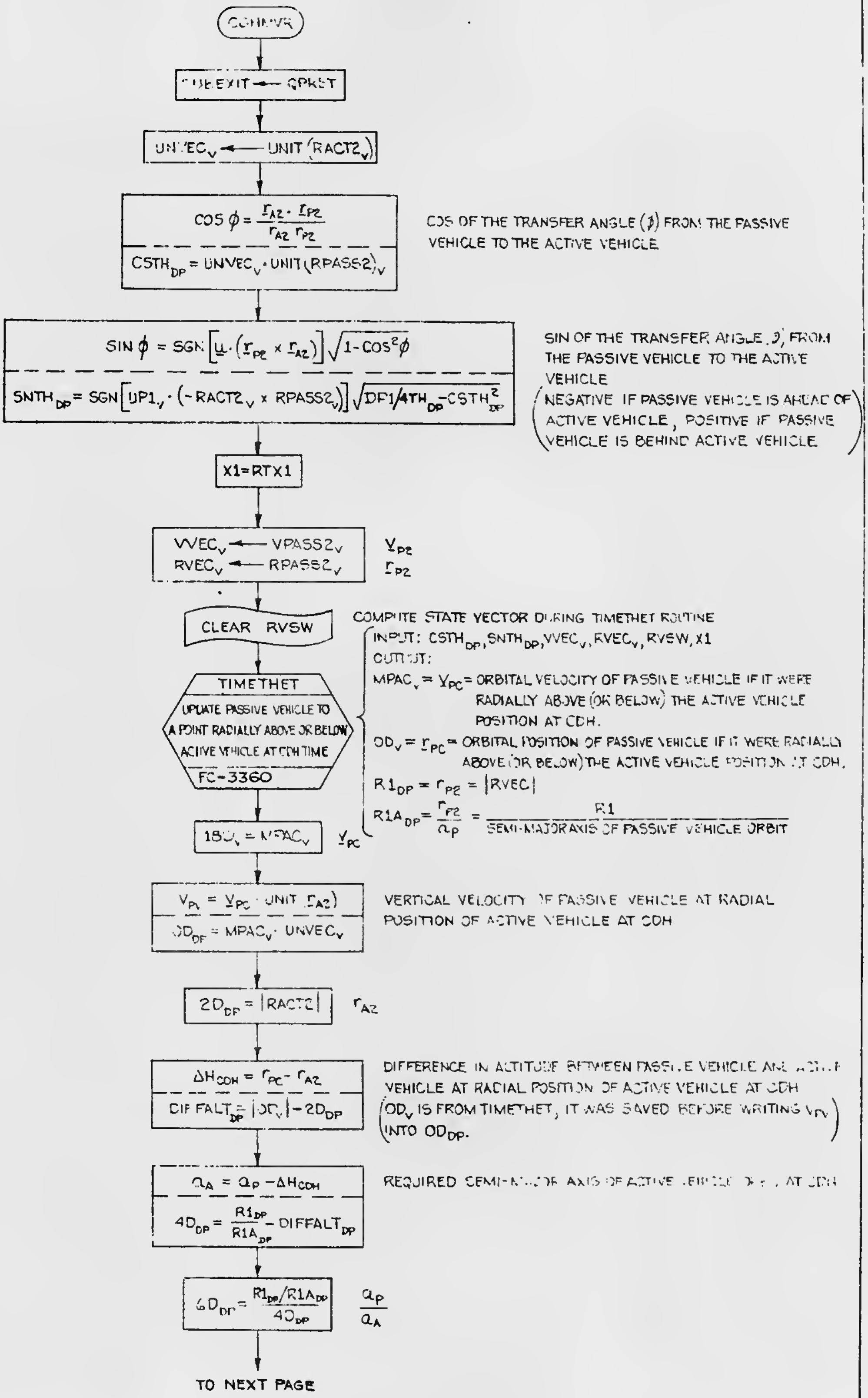
REV 3

SHEET 3 OF 8


FROM PRECEDING PAGE
SET ITSWICH
TELLS S33/34.1 THAT TPI TIME IS TO BE COMPUTED
NOMTPI$_{DP}$ ← 0
Δt_3 INITIALIZE RELATIVE TPI TIME (INPUT TO S33/S34.1)
S33/34.1
COMPUTE TIME OF TPI MANEUVER
FC-3740
INPUT: RACT3$_V$, VACT3$_V$, RPASS3$_V$, VPASS3$_V$, ELEV$_{DP}$, NOMTPI$_{DP}$, ITSWICH
OUTPUT: NOMTPI$_{DP}$ = Δt FROM INITIALLY ASSUMED TPI TIME TO COMPUTED TPI TIME
MPAC = 0 IF THERE IS A SOLUTION
≠ 0 IF THERE IS NO SOLUTION
MPAC=0
NO (NO SOLUTION)
YES (SOLUTION)
ALARM
TURN ON ALARM LIGHT AND STORE ALARM CODE 611 FOR DISPLAY
FC-3140
ALARM CODE 611 = NO TPI SOLUTION FOR THE GIVEN ELEVATION ANGLE
GOFLASH
V05N09 DISPLAY ALARM CODE
V32E RECYCLE
TERMINATE
P33/P73A
SH 2
GOTOPOOH
PROCEED
NOMTPI$_{DP}$ ← 0
P33/P73C
FINALFLG SET?
YES
NO
SET UPDATFLG
ALLOW P20 UPDATING
P33/P73D
$t_3 = t_3 + \Delta t_3$
TTPI$_{DP}$ ← TTPI$_{DP}$ + NOMTPI$_{DP}$
TPI TIME = TPI TIME CALCULATED BY P32 + Δt REQUIRED TO ACHIEVE THE REQUIRED ELEVATION ANGLE
TO NEXT PAGE



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C. WILLIAMS	6-7-68	P33 AND P73 CONSTANT DELTA ALTITUDE TARGETTING
PROGMR [signature]	6-4-68	
ANALST [signature]	6-14-68	LUMINARY 1D — DOCUMENT NO. FC-3730
DOCMR [signature]	4-16-68	
APPR'D J. Henize	6-18-68	REV 3 — SHEET 5 OF 8



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APOLLO
GUIDANCE AND NAVIGATION

P33 AND P73
CONSTANT DELTA ALTITUDE TARGETTING

DRAWN	A.C. WILLIAMS	6-10-68
PRGMR	[illegible]	[illegible]
ANALST	[illegible]	[illegible]
DOCMR	[illegible]	4-6-68
APPR'D	J. Heinz	6-18-68

LUMINARY 1D

DOCUMENT NO. FC-3730

REV 3

SHEET 6 OF 8

FROM PRECEDING PAGE

$$V_{AV} = V_{PV} \left(\frac{a_P}{a_A} \right)^{3/2}$$

$$8D_{DP} = 0D_{DP} (6D)^{3/2}$$

REQUIRED VERTICAL VELOCITY OF ACTIVE VEHICLE AT CDH

$$V_{AH} = \sqrt{\mu \left(\frac{2}{r_{A2}} - \frac{1}{a_A} \right) - V_{AV}^2}$$

$$10D_{DP} = \sqrt{2 \frac{RTMU_{DP}}{2D_{DP}} - \frac{RTMU_{DP}}{4D_{DP}} - 8D_{DP}^2}$$

REQUIRED HORIZONTAL VELOCITY OF ACTIVE VEHICLE AT CDH

$$\underline{V}'_{A2} = V_{AH} \text{ UNIT} \left(\underline{u} \times \underline{r}_{A2} \right) + V_{AV} \text{ UNIT} \left(\underline{r}_{A2} \right)$$

$$VACT3_V = 10D_{DP} \text{ UNIT} \left(UP1_V \times UNVEC_V \right) + 8D_{DP} \text{ UNVEC}_V$$

TOTAL REQUIRED VELOCITY OF ACTIVE VEHICLE AT CDH

$$\Delta \underline{V}_2 = \underline{V}'_{A2} - \underline{V}_{A2}$$

$$DELVEET2_V = VACT3_V - VACT2_V$$

REQUIRED ΔV AT CDH

RETURN VIA SUBEXIT

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	6-11-68	P33 AND P73 CONSTANT DELTA ALTITUDE TARGETTING
PROGMR [illegible]	[illegible]	
ANALST [illegible]	[illegible]	LUMINARY 1D
DOCMR [illegible]	4-16-6[illegible]	DOCUMENT NO. FC-3730
APPR'D J. Haig	6-18-68	REV 3 SHEET 7 OF 8

P33 - CONSTANT DELTA ALTITUDE

SUBROUTINES

IN THIS CHART

P20FLGON	SET TRACKFLG, UPDATFLG
CDHMVR	COMPUTE REQUIRED ΔV FOR CDH MANEUVER

ON OTHER CHARTS

SELECTMU	SELECTS μ ACCORDING TO LUNAR OR EARTH SPHERE OF INFLUENCE
INTINT	PERFORMS HOUSEKEEPING PRIOR TO INTEGRATION CALL
S33/34.1	COMPUTES EITHER E OR TPI TIME
S32/33.1	DISPLAY ΔV IN LOCAL VERT. COORDINATES
VN1645	DISPLAY M, TFI, MGA
TIMETHET	CALCULATES DELTA TIME OF FLIGHT
ACTIVE	ACTIVE VEHICLE POSITION, VELOCITY TO RACT3, VACT3
PASSIVE	PASSIVE VEHICLE POSITION, VELOCITY TO RPASS3, VPASS3

FLAGS	MEANING		SET	CLEARED	TESTED
ITSWICH	SET	TPI TIME TO BE COMPUTED	SH15		
	CLEARED	TPI TIME HAS BEEN COMPUTED			
FINALFLG	SET	LAST PASS THRU RENDEZVOUS PROGRAM			SH15
	CLEARED	INTERIMPASS THRU RENDEZVOUS PROGRAM			
UPDATFLG	SET	UPDATING VIA MARKS ALLOWED	SH15		
	CLEARED	UPDATING VIA MARKS DISALLOWED			
NDELVFLG	SET	EXTERNAL ΔV MANEUVER	SH17		
	CLEARED	LAMBERT AIM POINT MANEUVER			
RVSW	SET	COMPUTE FINAL STATE VECTOR IN TIMETHET IN ADDITION TO Δt		SH16	
	CLEARED	COMPUTE Δt ONLY			
AVFLAG	SET	LM IS ACTIVE VEHICLE	SH12	SH12	
	CLEARED	CSM IS ACTIVE VEHICLE			
TRACKFLG	SET	ENABLE TRACKING	SH12		
	CLEARED				

DISPLAYS	MEANING	USED
V06N13	DISPLAY CDH IGNITION TIME	SH2
V05N11	DISPLAY ALARM CODE 00611	SH4
V06N75	DISPLAY CDH PARAMETERS	SH5
V16N45	DISPLAY M, TFI, MGA	SH5
V06N81	DISPLAY ΔV IN LOCAL VERT. COORDINATES	SH5

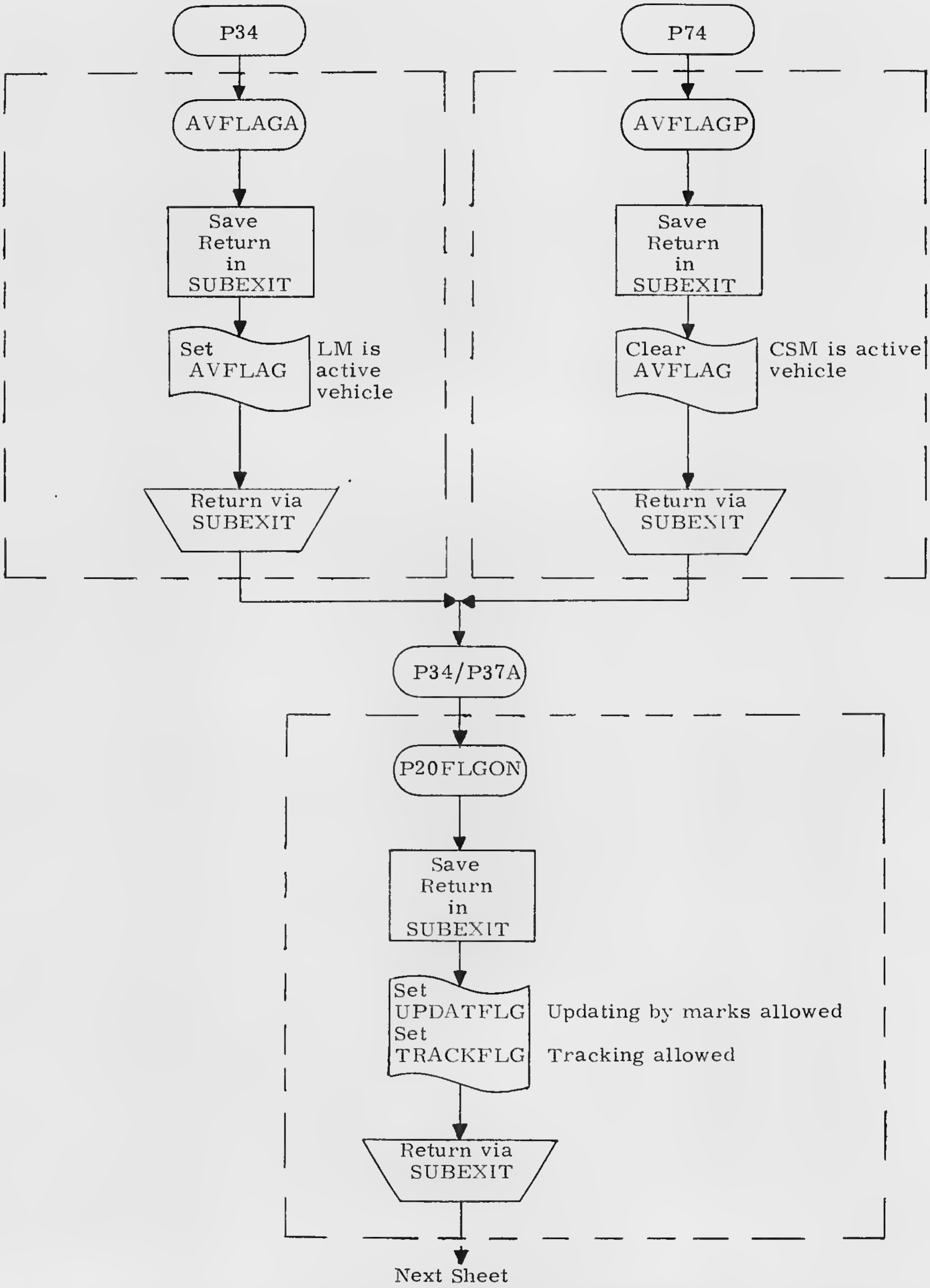
ALARMS	MEANING	USED
00611	NO TPI SOLUTION FOR THE GIVEN ELEVATION ANGLE	SH3

ERASABLES	MEANING	UNITS	SCALING
TTPIO	TIME OF TPI MANEUVER FROM P32	CENTISECS	B28
TTPI	TIME OF TPI MANEUVER	CENTISECS	B28
TIG	TIME OF IGNITION	CENTISECS	B28
TCDH	TIME OF CDH MANEUVER	CENTISECS	B28
VACT3	REQUIRED VELOCITY OF ACTIVE VEHICLE AT CDH	M/CSC	B7
RACT2	ACTIVE VEHICLE POSITION VECTOR AT CDH TIME	METERS	B29
VACT2	VELOCITY VECTOR OF ACTIVE VEHICLE AT CDH	METERS	B29
VPASS2	PASSIVE VEHICLE VELOCITY VECTOR AT CDH TIME	M/CSC	B7
RPASS2	PASSIVE VEHICLE POSITION VECTOR AT CDH TIME	METERS	B29
NOMTPI	Δ FROM NOMINAL TPI TO COMPUTED TPI	CENTISECS	B28
T1TOT2	TIME FROM CDH TO TPI	CENTISECS	B28
T2TOT3	TIME FROM TPI (P32) TO TPI (COMPUTED IN P33)	CENTISECS	B28
DELVEET2	ΔV REQUIRED FOR CDH MANEUVER	M/CSC	B7
UP1	$\underline{r}_{p2} \times \underline{v}_{p2}$ UNIT NORMAL TO PLANE OF PASSIVE VEHICLE		
SNTH	SINE ϕ ANGLE BETWEEN ACTIVE AND PASSIVE VEHICLES AT CDH		B1
CSTH	COS ϕ ANGLE BETWEEN ACTIVE AND PASSIVE VEHICLES AT CDH		B1
RVEC	POSITION VECTOR OUTPUT FROM INTEGRATION	METERS	B29
VVEC	VELOCITY VECTOR OUTPUT FROM INTEGRATION	M/CSC	B7
DIFFALT	DIFFERENCE BETWEEN ACTIVE AND PASSIVE VEHICLES ALTITUDES	METERS	B29

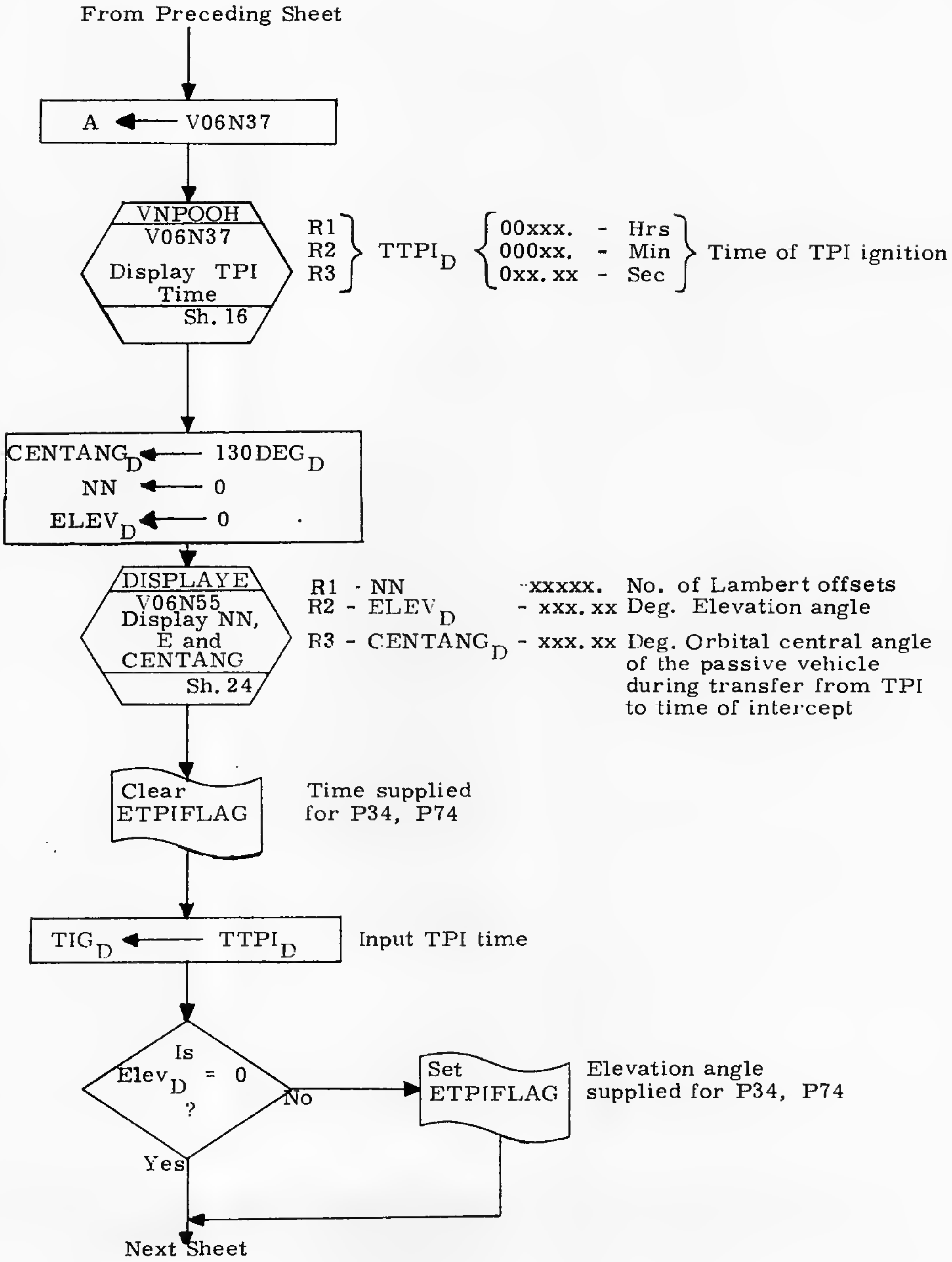
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A. J. Langello	20 AUG 68	P33 AND P73 CONSTANT DELTA ALTITUDE TARGETING
PROGRMR [illegible]	[illegible]	LUMINARY 1D
ANALST W. Templeton	26 Aug 68	DOCUMENT NO. FC-3730
DOCMR [illegible]	4-16-69	REV 3
APPR'D John A. Morse	28 Aug 68	SHEET 8 OF 8

P34, P74: TRANSFER PHASE INITIATION TARGETING

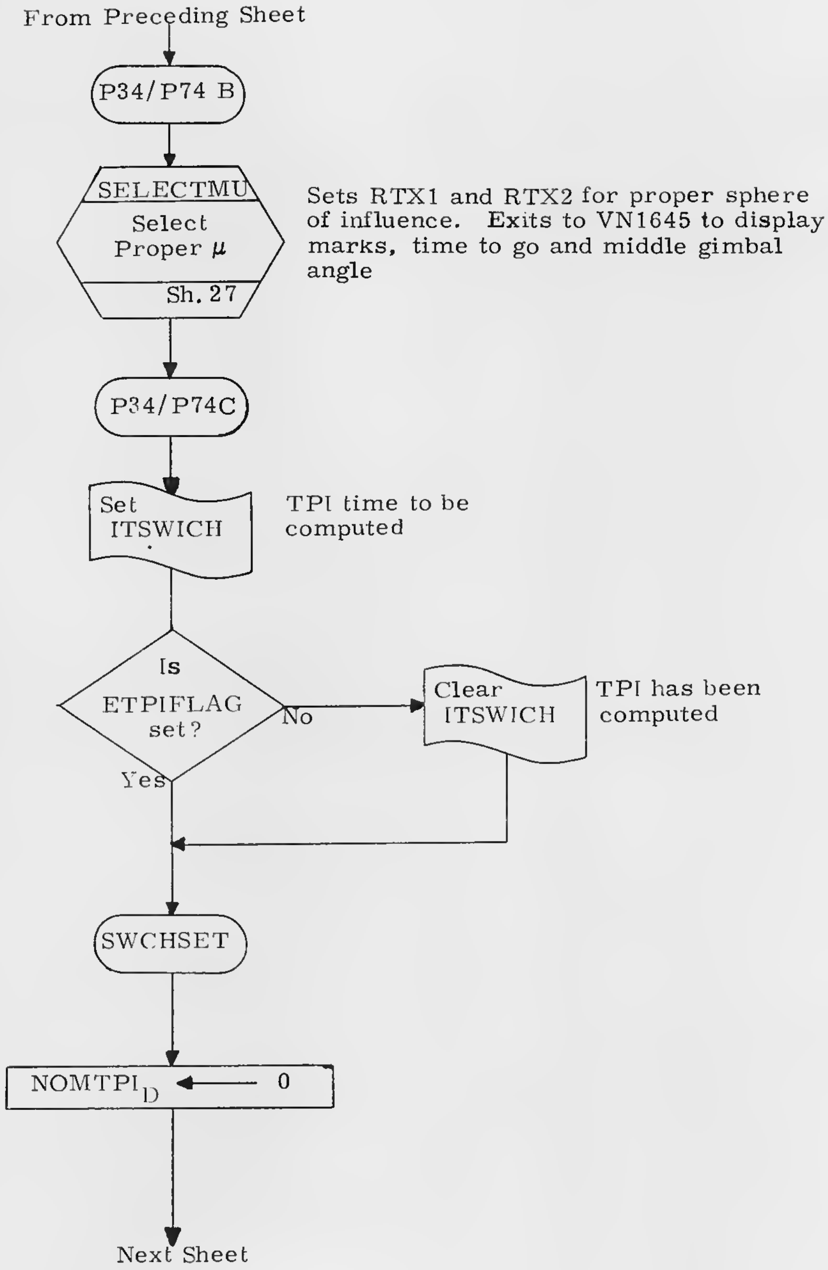
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN [illegible]	12/4/69	P34, P74 Transfer Phase Initiation Targeting	
PRGMR [illegible]	12/11/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3740
DOCMR W Daughter	12/5/69		
APPR'D W Daughter	12/16/69	REV 1	SHEET 1 OF 30

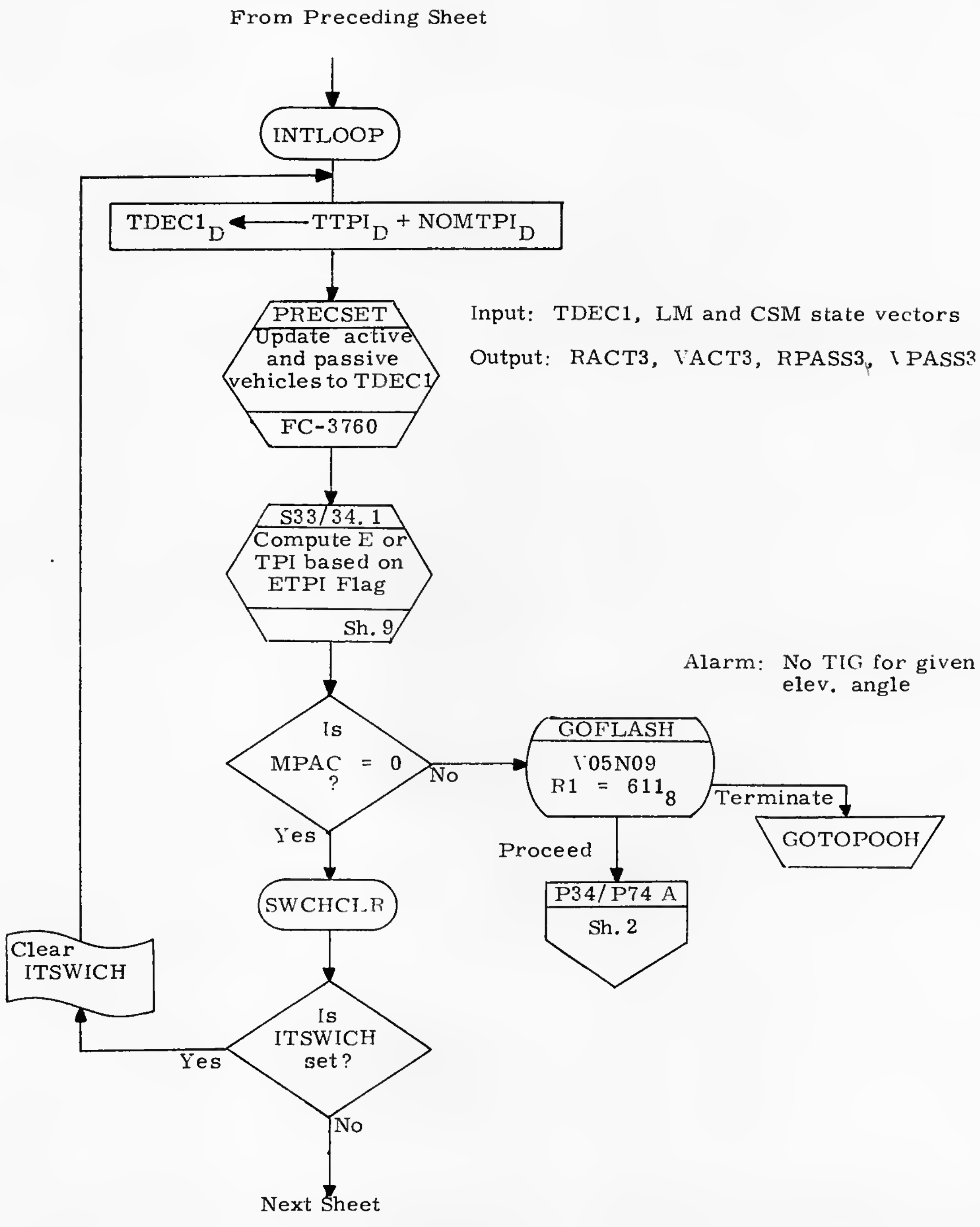


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A. Fucinoi PE	10/14/69	P34, P74 Transfer Phase Initiation Targeting	
PRGMR P. White	12/11/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3740
DOCMR W. Dogharth	12/5/69		
APPR'D W. Dogharth	12/16/69	REV 1	SHEET 2 OF 30

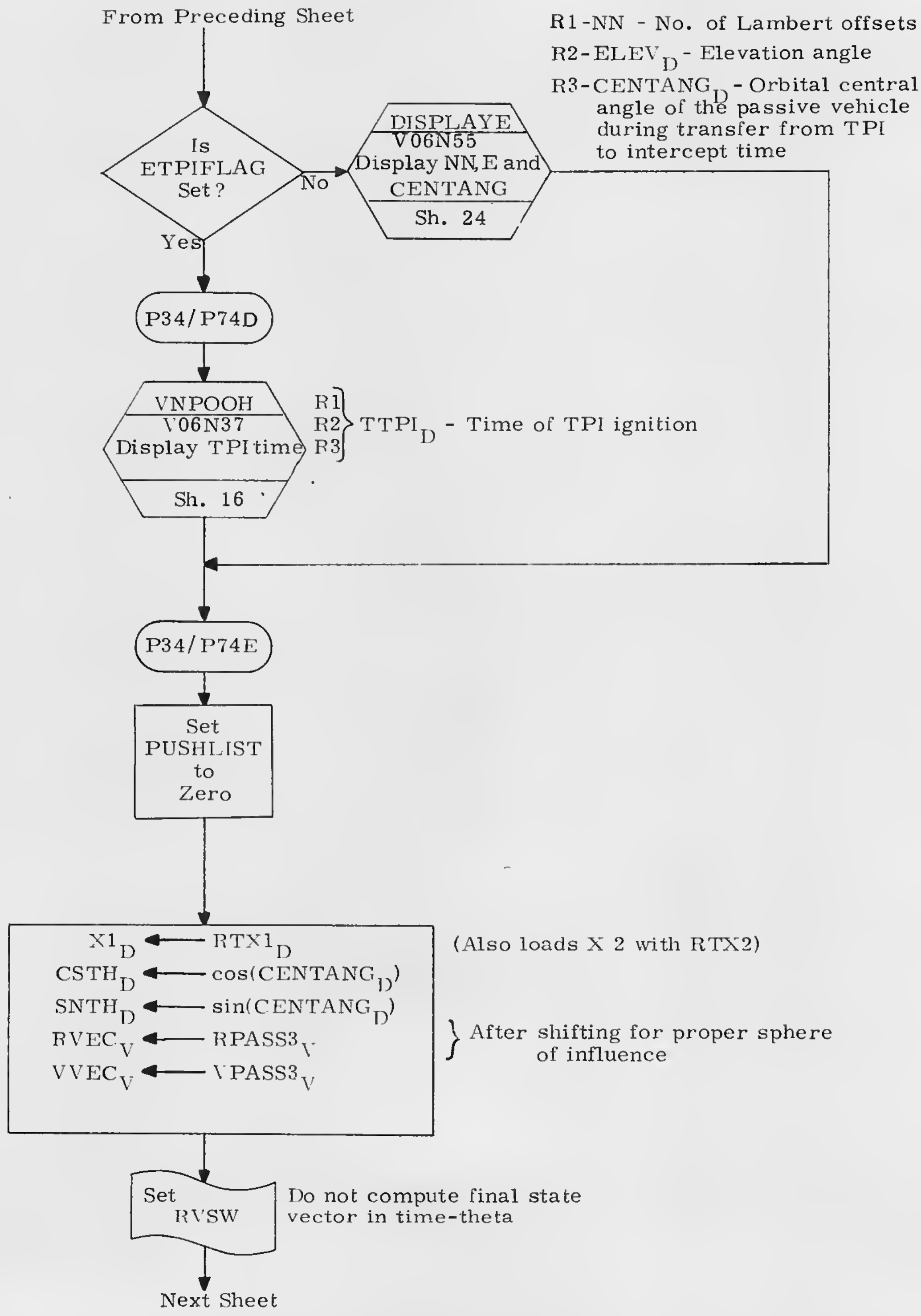


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		P34, P74 Transfer Phase Initiation Targeting	
PRGMR	12/11/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3740
DOCMR	12/5/69		
APPR'D	12/16/69	REV 1	SHEET 3 OF 30

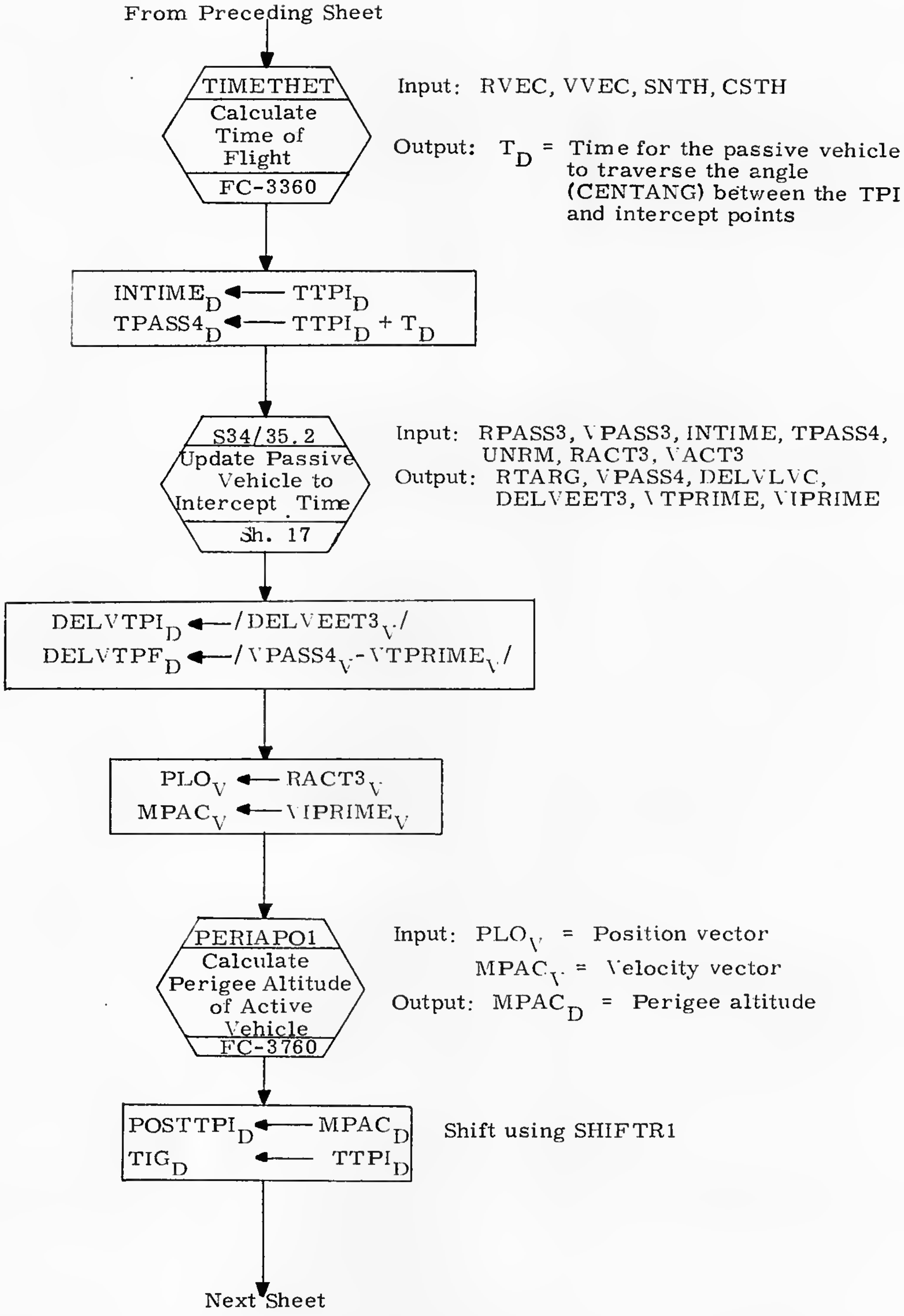

From Preceding Sheet
P34/P74 B
SELECTMU
Select Proper μ
Sh. 27
Sets RTX1 and RTX2 for proper sphere of influence. Exits to VN1645 to display marks, time to go and middle gimbal angle
P34/P74C
Set ITSWICH
TPI time to be computed
Is ETPIFLAG set?
No
Yes
Clear ITSWICH
TPI has been computed
SWCHSET
$NOMTPI_D \leftarrow 0$
Next Sheet



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A. Tucholke	10/14/69	P34, P74 Transfer Phase Initiation Targeting	
PRGMR P. White	12/11/69		DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3740
DOCMR W. Doolittle	12/5/69		
APPR'D W. Doolittle	12/11/69	REV 1	SHEET 5 OF 30

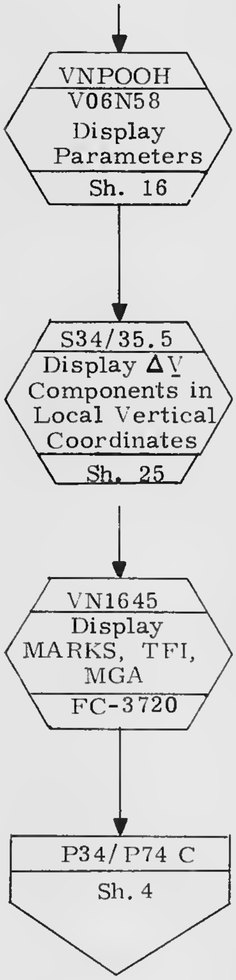


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN [illegible]	10/14/69	P34, P74 Transfer Phase Initiation Targeting	
PRGMR B. White	12/11/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3740
DOCMR W. Danforth	12/5/69		
APPR'D W. Danforth	12/16/69	REV 1	SHEET 6 OF 30



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	10/14/69	P34, P74 Transfer Phase Initiation Targeting	
PRGMR	12/11/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3740
DOCMR	12/5/69		
APPR'D	12/16/69	REV 1	SHEET 7 OF 30

From Preceding Sheet



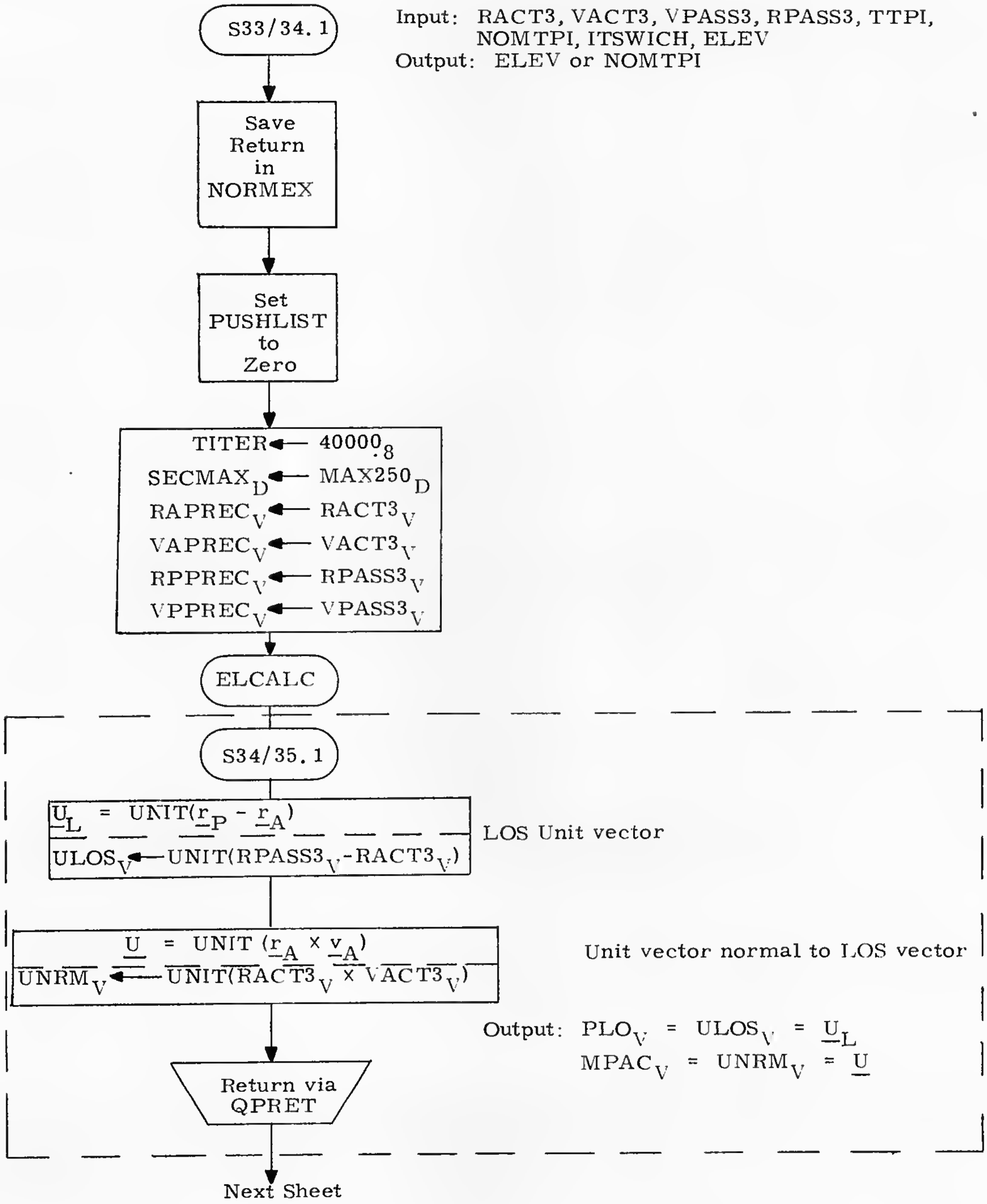
R1 - POSTTPI - Perigee altitude
R2 - DELVTPI - Req. velocity for TPI maneuver
R3 - DELVTPF - Req. velocity for final intercept maneuver

Input: DELVEET3, DELVLVC

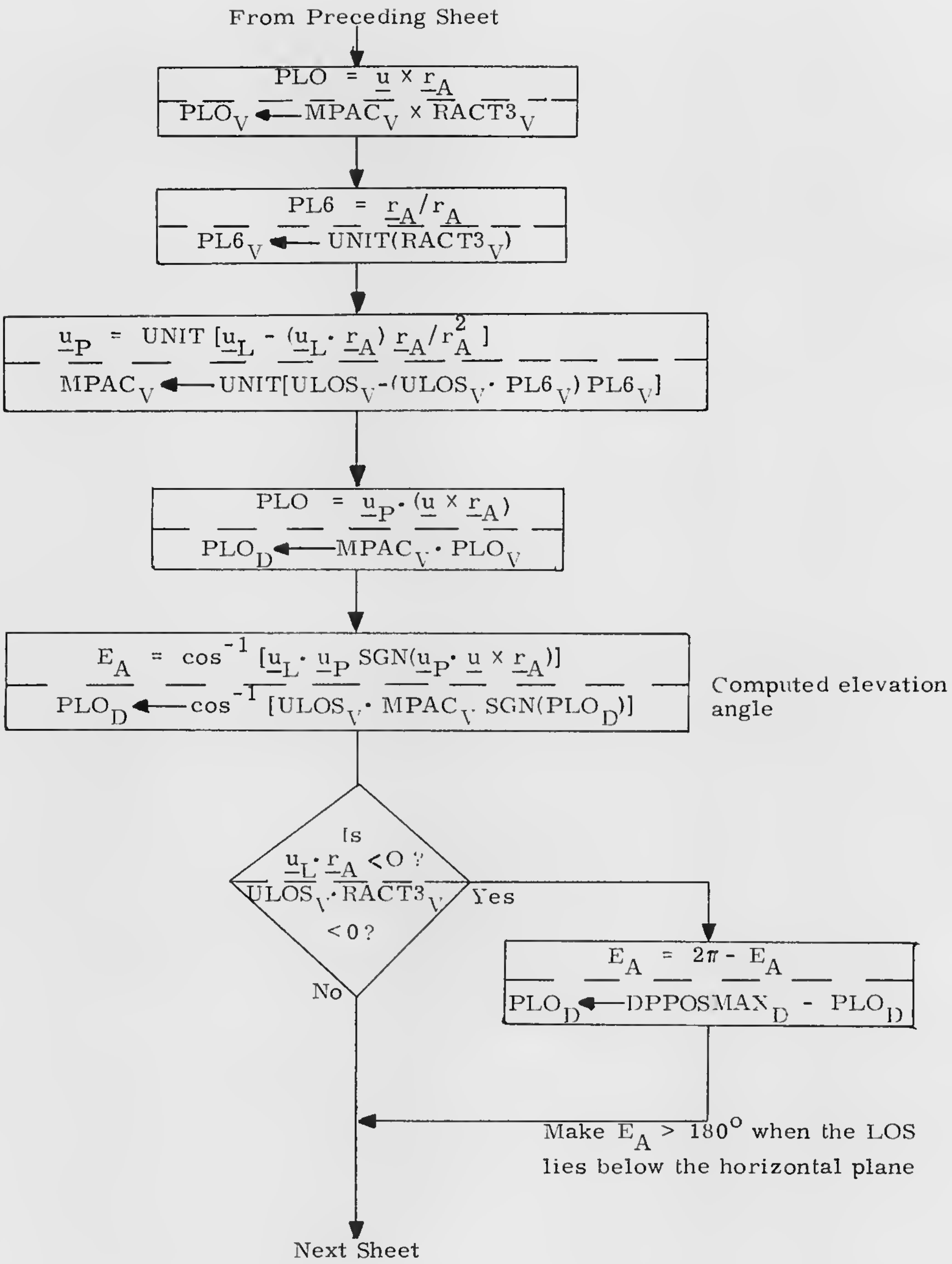
R1 - TRKMKCNT - xxxxx. - no. of marks
R2 - TTOGO - xxBxx - Min/sec - time to/from TPI
R3 - +MGA - xxx.xx - DEG - Middle gimbal angle

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN O. Luckow?	10/14/69	P34, P74 Transfer Phase Initiation Targeting	
PRGMR P. White	12/11/69		DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3740
DOCMR W. Dougherty	12/5/69		
APPR'D W. Dougherty	12/16/69	REV 1	SHEET 8 OF 30

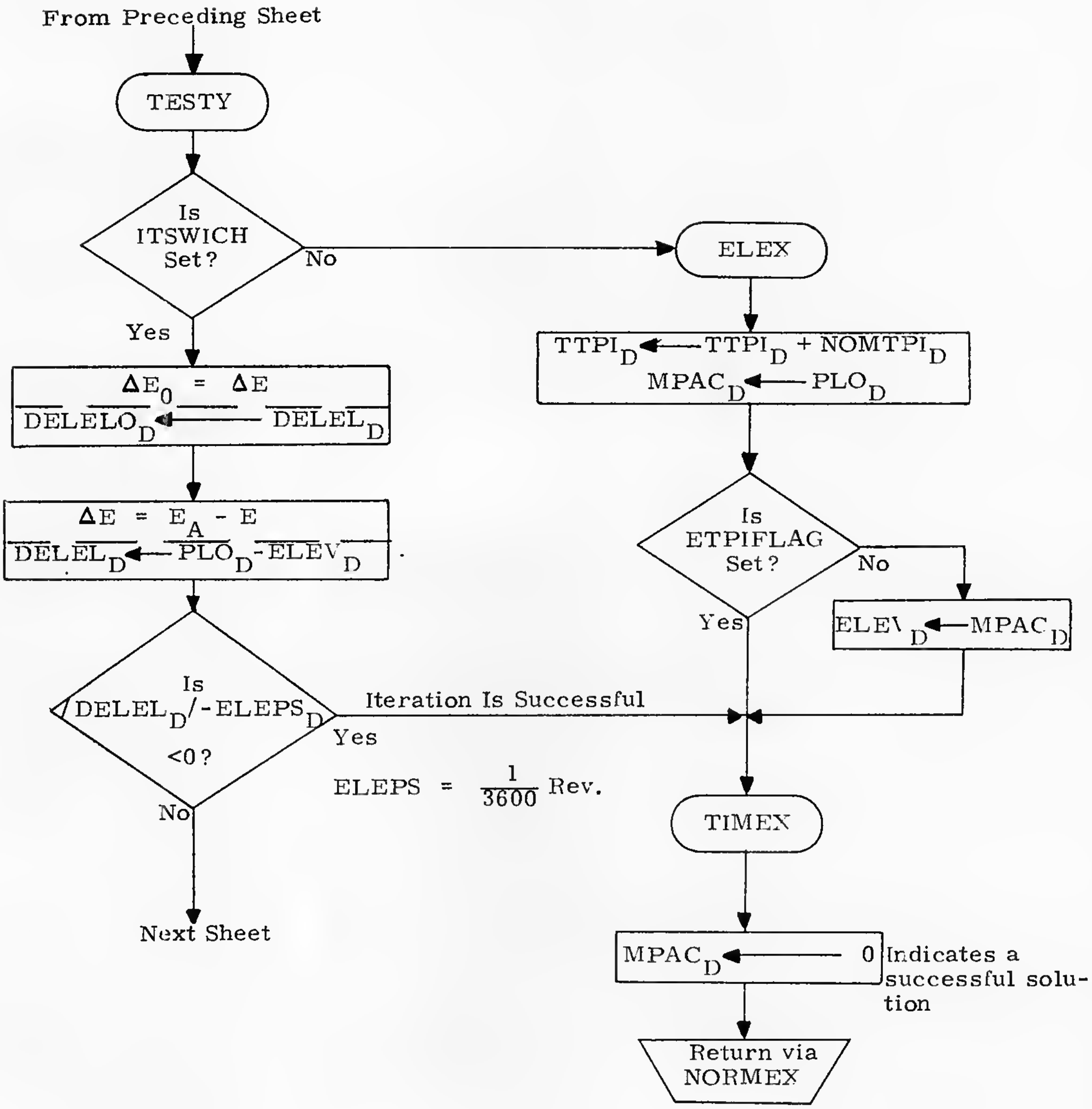
Input: RACT3, VACT3, VPASS3, RPASS3, TTPI, NOMTPI, ITSWICH, ELEV
Output: ELEV or NOMTPI



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A. Tuchol...	10/14/69	P34, P74 Transfer Phase Initiation Targeting	
PRGMR R. White	12/11/69	LUMINARY 1D	DOCUMENT NO. FC-3740
ANALST			
DOCMR W. Danforth	12/5/69		
APPR'D W. Danforth	12/16/69	REV 1	SHEET 9 OF 30



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	[illegible]	[illegible]	P34, P74, Transfer Phase Initiation Targeting	
PRGMR	P J White	12/11/69		
ANALST			LUMINARY 1D	DOCUMENT NO. FC-3740
DOCMR	W Danforth	12/5/69		
APPR'D	W Danforth	12/16/69	REV 1	SHEET 10 OF 30



MIT INSTRUMENTATION LAB
CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

P34, P74 Transfer Phase Initiation Targeting

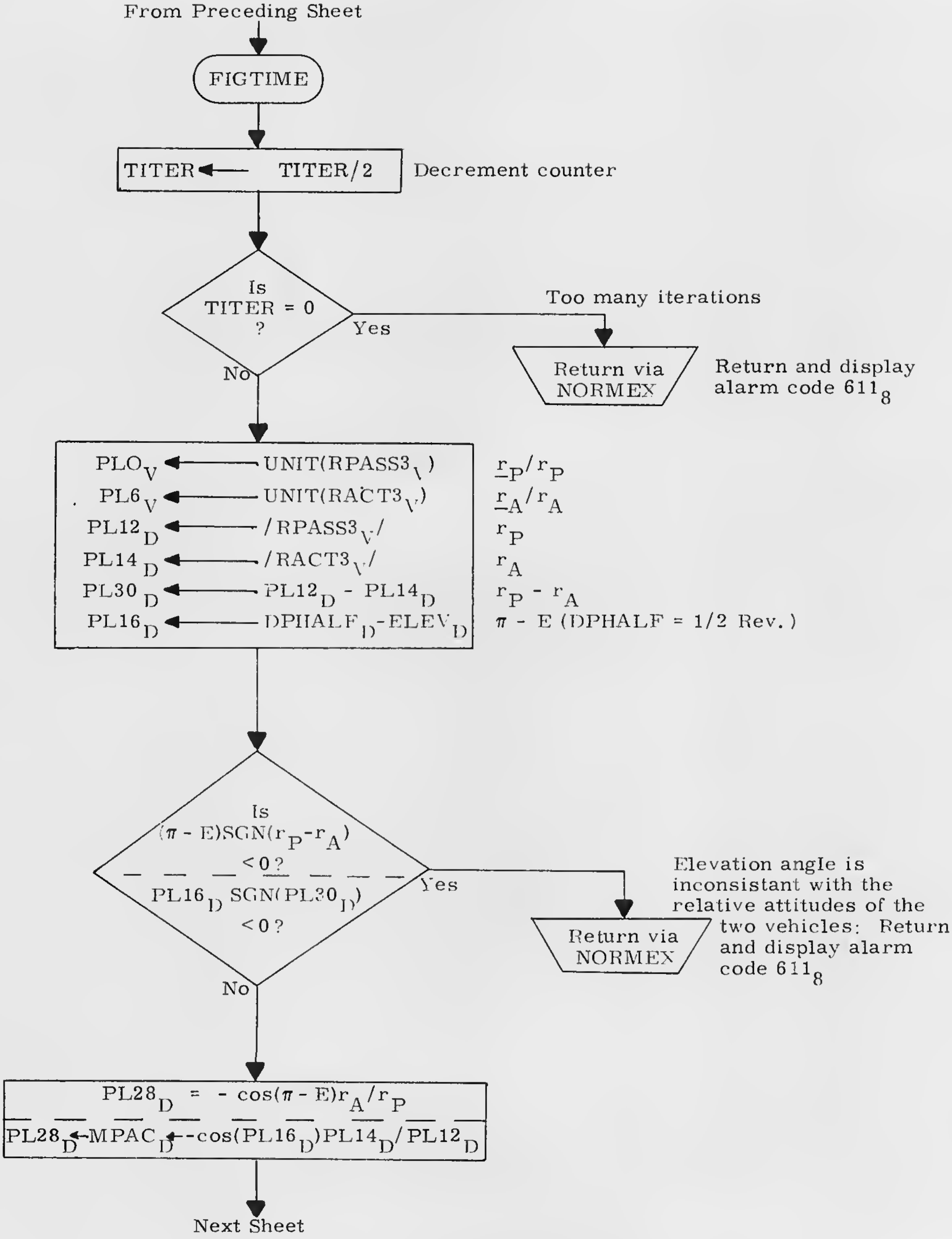
DRAWN	[illegible]	[illegible]
PRGMR	P. White	12/11/69
ANALST		
DOCMR	W Dryburgh	12/5/69
APPR'D	W Dryburgh	12/16/69

LUMINARY 1D

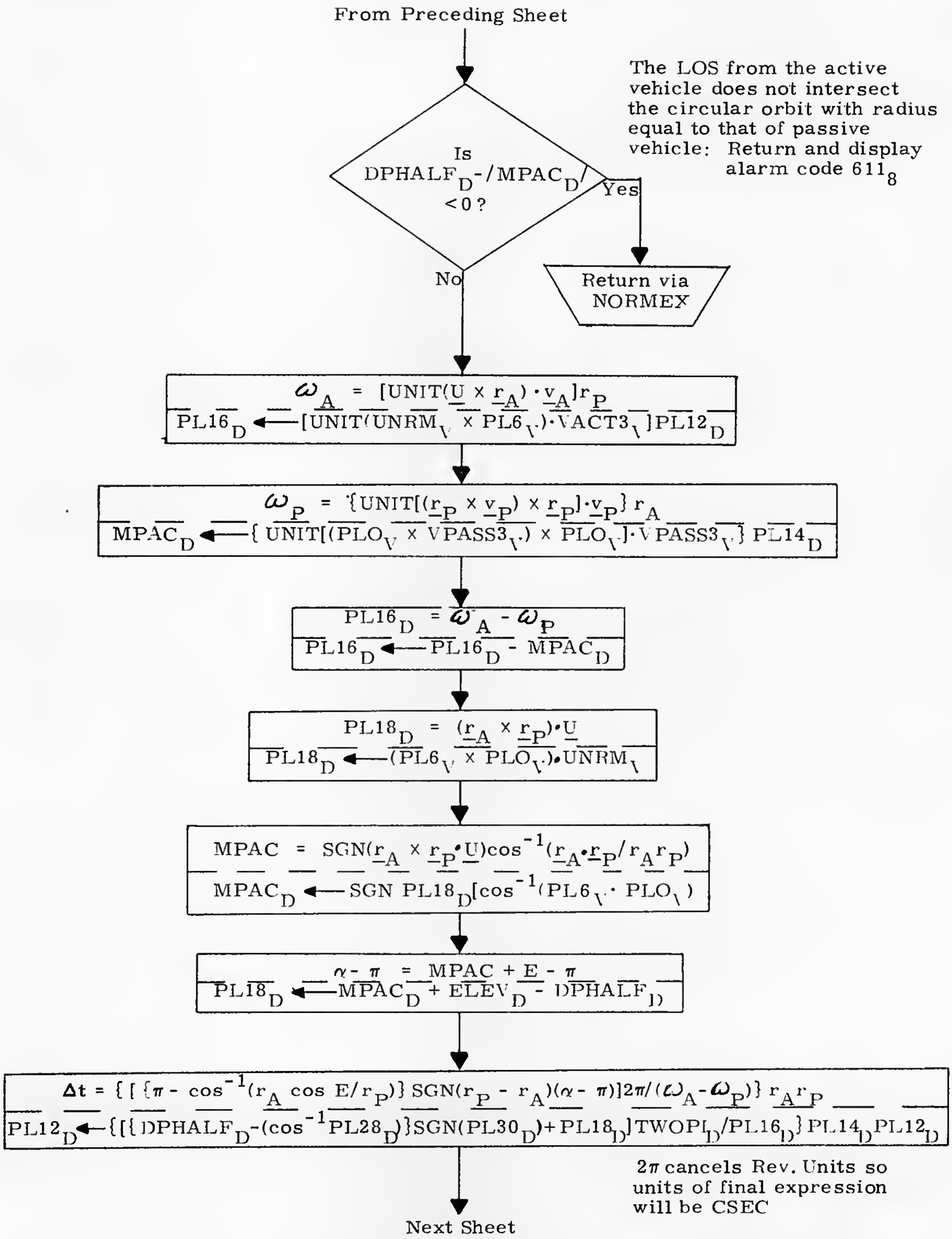
DOCUMENT NO. FC-3740

REV 1

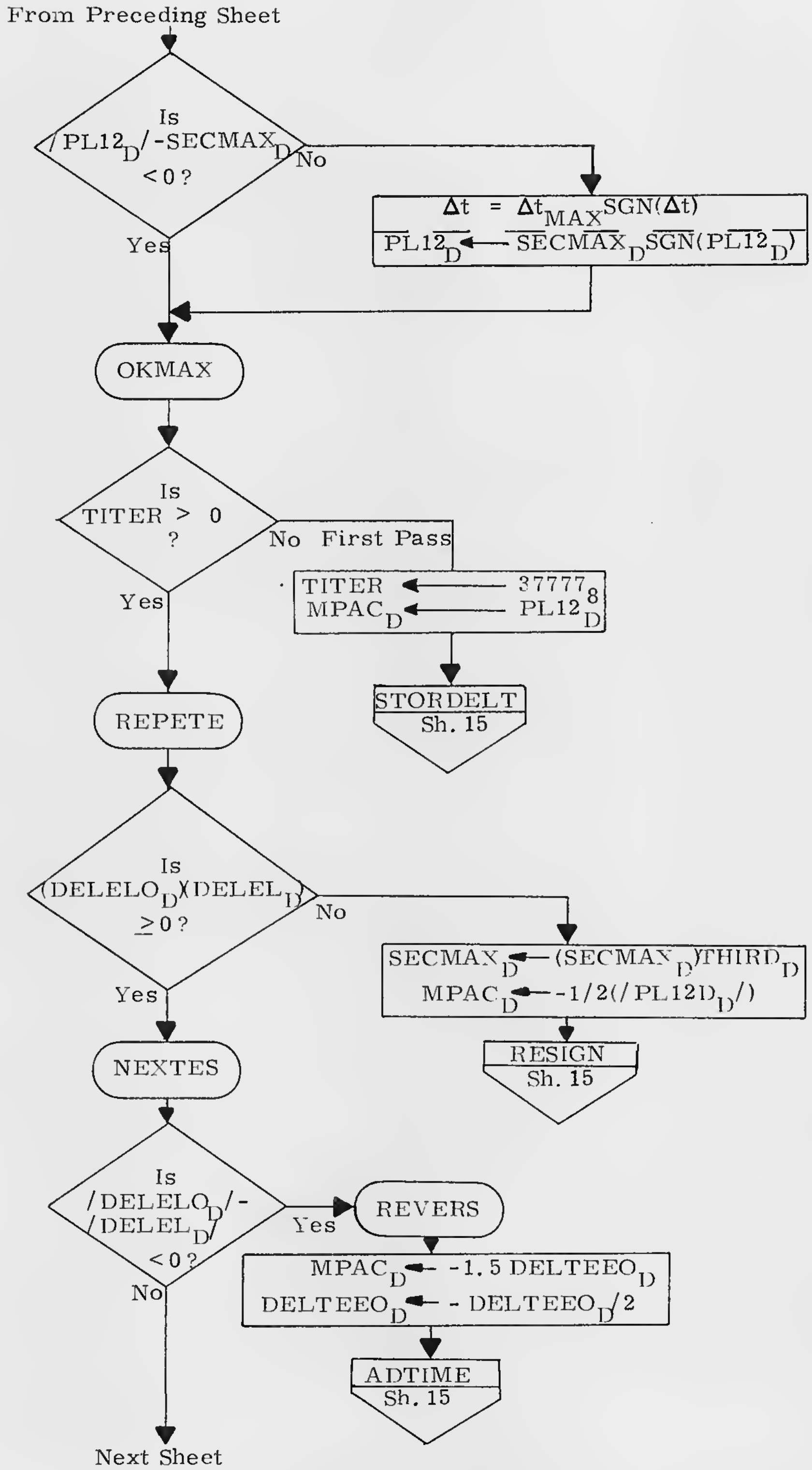
SHEET 11 OF 30



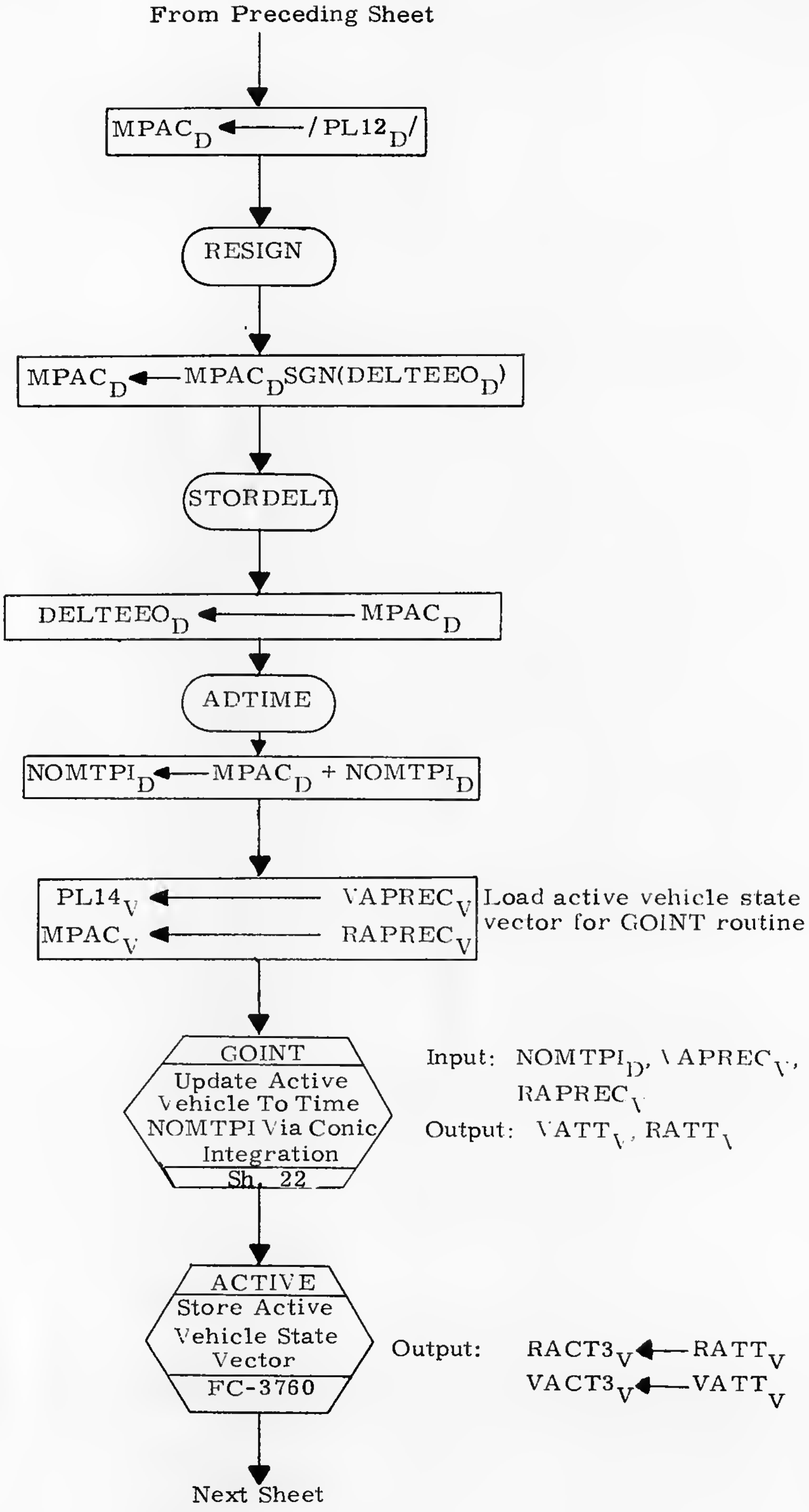
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	O. Tucholke 10/13/69	P34, P74 Transfer Phase Initiation Targeting	
PRGMR	P. White 12/11/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3740
DOCMR	W. Danforth 12/5/69		
APPR'D	W. Danforth 12/16/69	REV 1	SHEET 12 OF 30



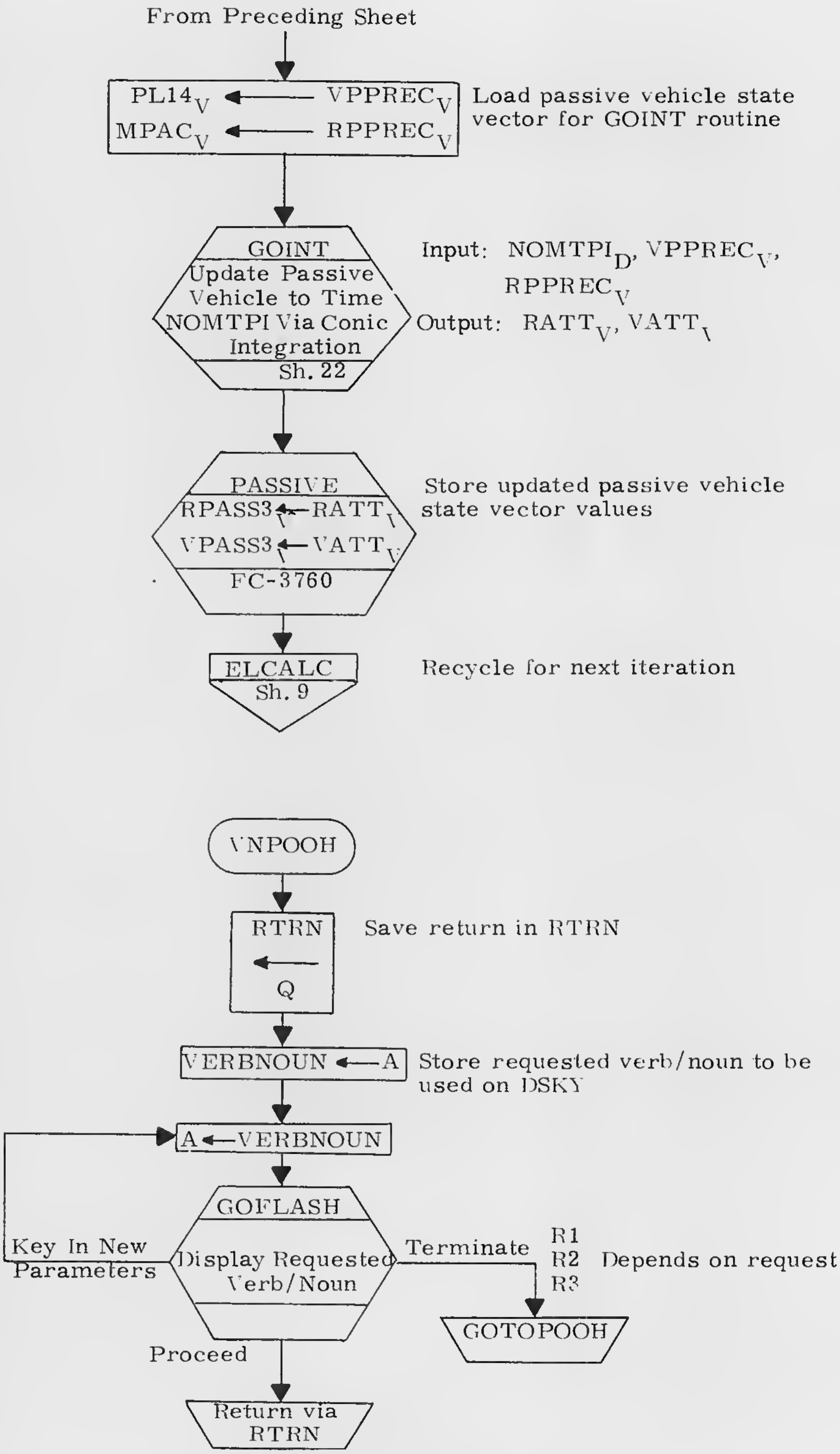
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	O. Tuchcike [?] 10/19/69	P34, P74 Transfer Phase Initiation Targeting	
PRGMR	R. White [?] 12/11/69	LUMINARY 1D	DOCUMENT NO. FC-3740
ANALST			
DOCMR	W. Dayforth [?] 12/5/69		
APPR'D	W. Dayforth [?] 12/16/69	REV 1	SHEET 13 OF 30



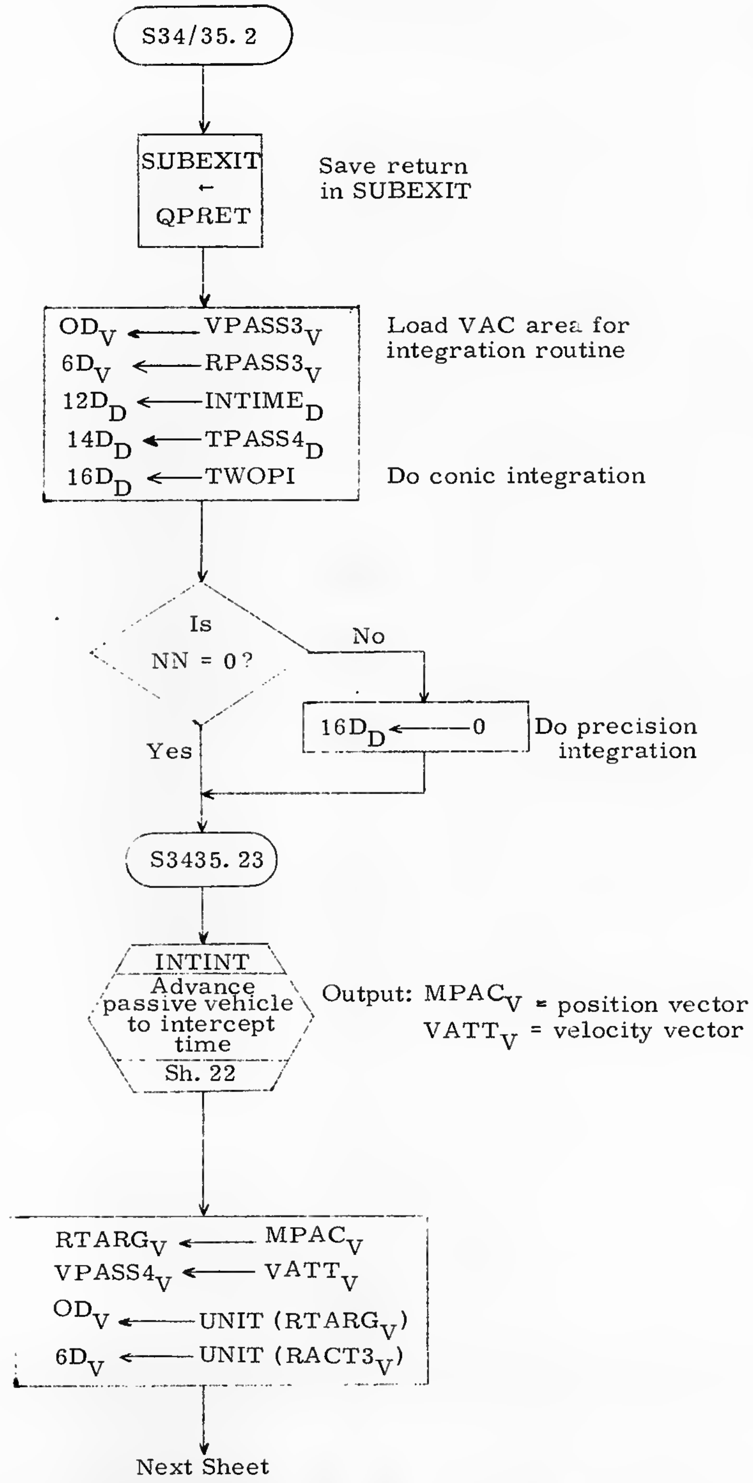
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	A. Tuchokke 10/14/69	P34, P74 Transfer Phase Initiation Targeting	
PRGMR	P. White 12/11/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3740
DOCMR	W. Danforth 12/5/69		
APPR'D	W. Danforth 12/16/69	REV 1	SHEET 14 OF 30



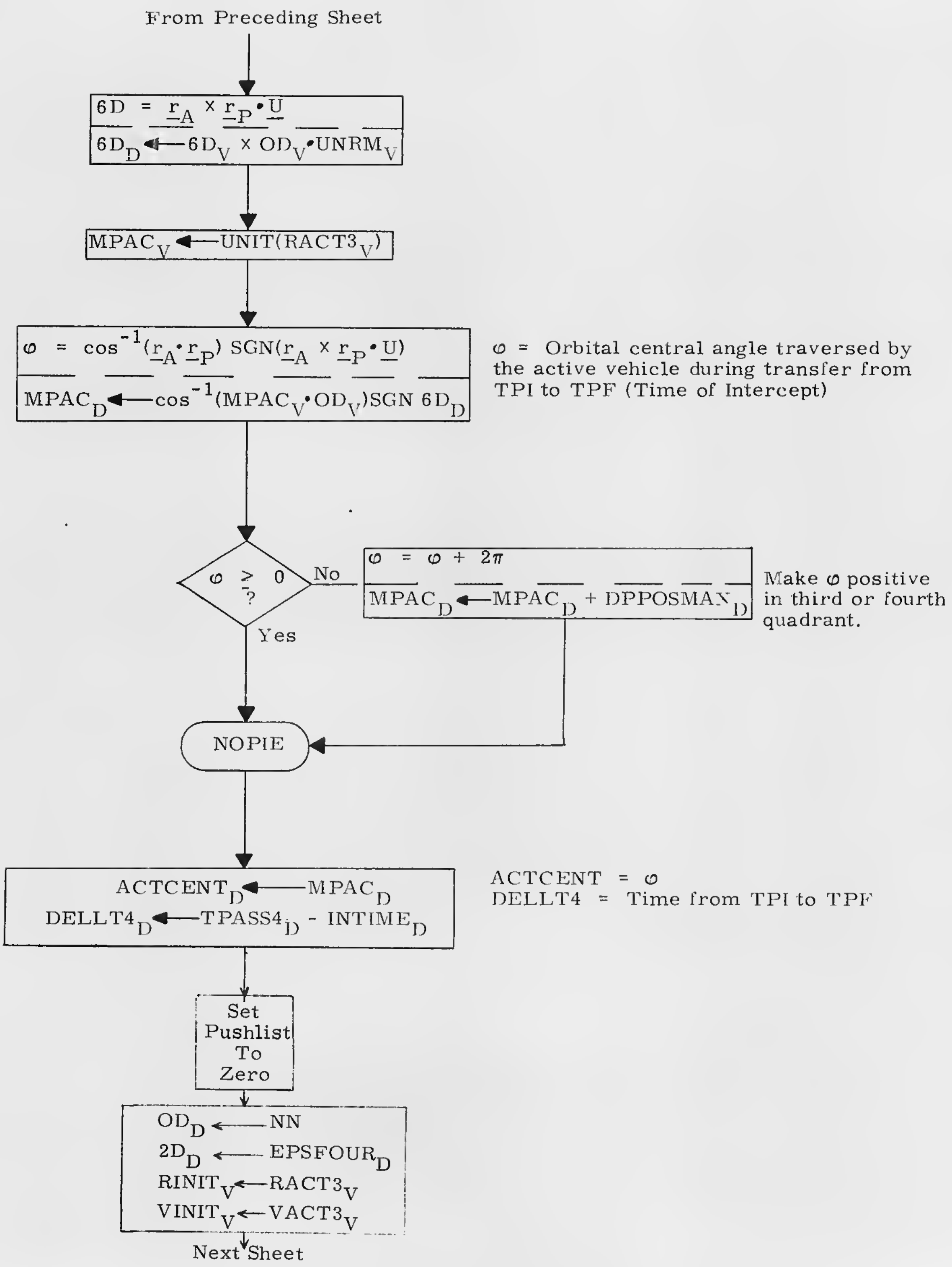
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN O. Tuckoirs	10/14/69	P34, P74 Transfer Phase Initiation Targeting	
PRGMR P. White	12/11/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3740
DOCMR W. Danforth	12/5/69		
APPR'D W. Danforth	12/16/69	REV 1	SHEET 15 OF 30



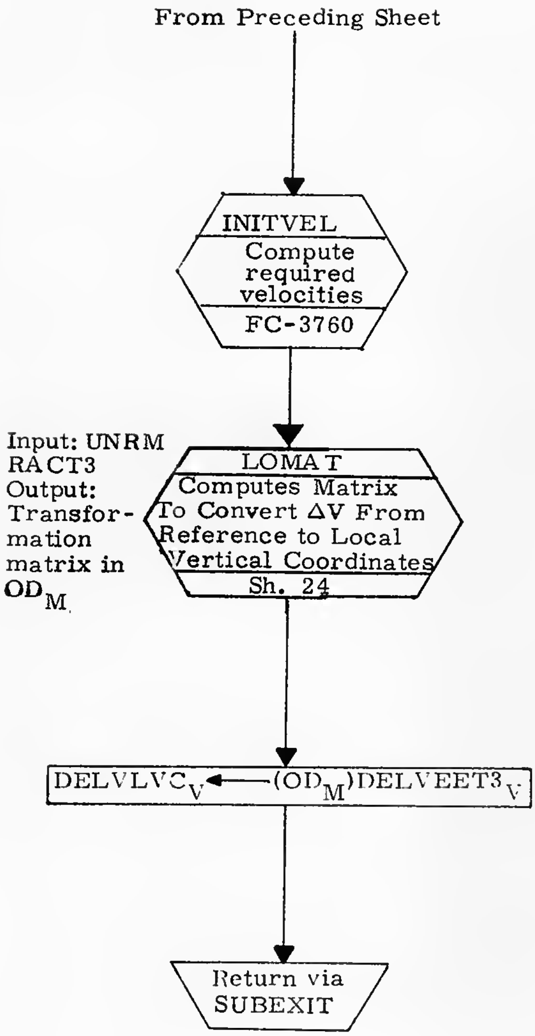
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN O. Tucholke	10/14/69	P34, P74 Transfer Phase Initiation Targeting	
PRGMR P. White	12/11/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3740
DOCMR W. Danforth	12/5/69		
APPR'D W. Danforth	12/16/69	REV 1	SHEET 16 OF 30



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lutkevich	12/2/69	P34, P74, Transfer Phase Initiation Targeting	
PRGMR P. White	12/11/69		DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3740
DOCMR W. Daforth	12/5/69		
APPR'D W. Daforth	12/16/69	REV 1	SHEET 17 OF 28



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A. Luckin[?]	10/14/69	P34, P74 Transfer Phase Initiation Targeting	
PRGMR P. White	12/11/69	LUMINARY 1D	DOCUMENT NO. FC-3740
ANALST			
DOCMR W. Goodwin	12/5/69		
APPR'D W. Goodwin	12/16/69	REV 1	SHEET 18 OF 30

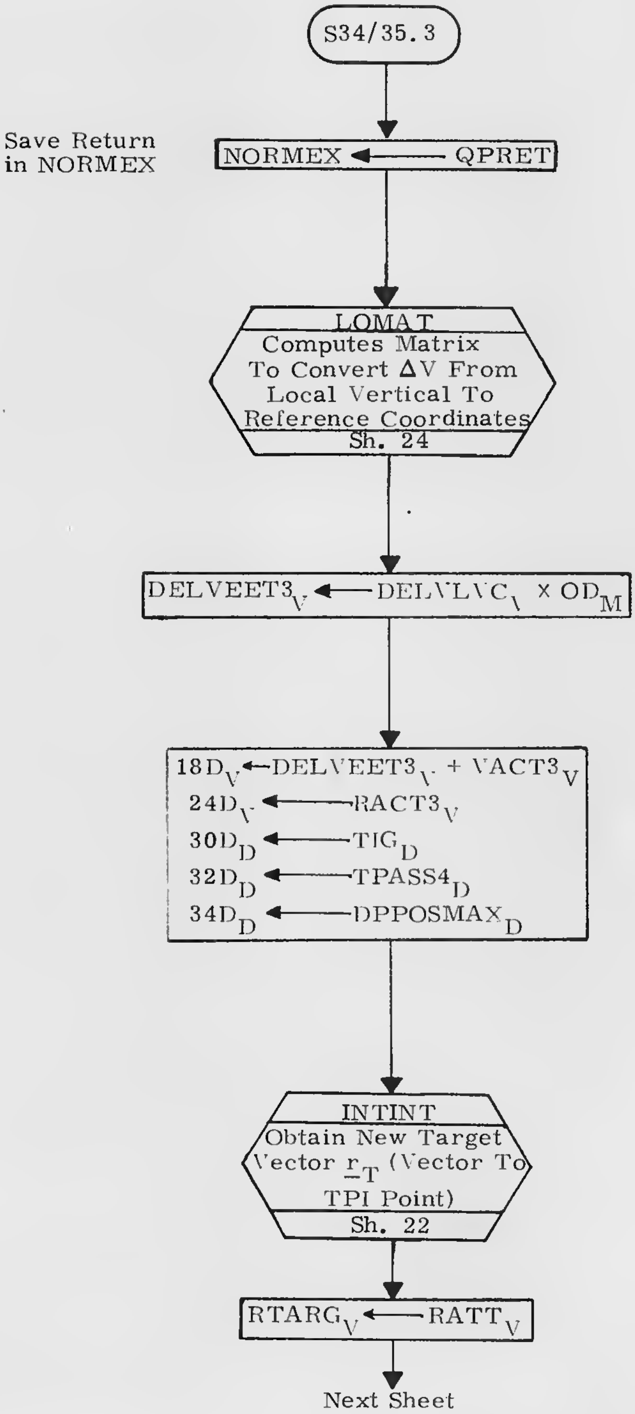


Input: RACT3, VACT3, RTARG, DELLT4, $0D_D$
INTIME, MPAC, X1(= - 2 for earth,
= - 10 for moon orbit)

Output: RTARG(Offset target position vector), VIPRIME(velocity required from TPI point for active vehicle to achieve TPF point), VTPRIME(active vehicle velocity after TPF point), DELVEET3(ΔV for TPI maneuver)

INITVEL computes the required maneuver and delta velocities to transfer the active vehicle from its initial position (TPI) to target position (TPF) in a prescribe time of flight.

$\underline{\Delta V}$ In local vertical coordinates



Calculates line of sight $\Delta\underline{V}$ in reference coordinates at TPI time.
Input: DELVLVC, VACT3, RACT3, TIG, TPASS4, UNRM, ULOS
Output: DVLOS, RTARG

Input: UNRM, RACT3
Output: Transformation matrix in OD_M

Push list counter is 18 upon return from LOMAT
DELVEET3 = $\Delta\underline{V}_{TPI}$ in reference coordinates.
DELVLVC = New $\Delta\underline{V}_{TPI}$ inputted by astronaut overwrite.

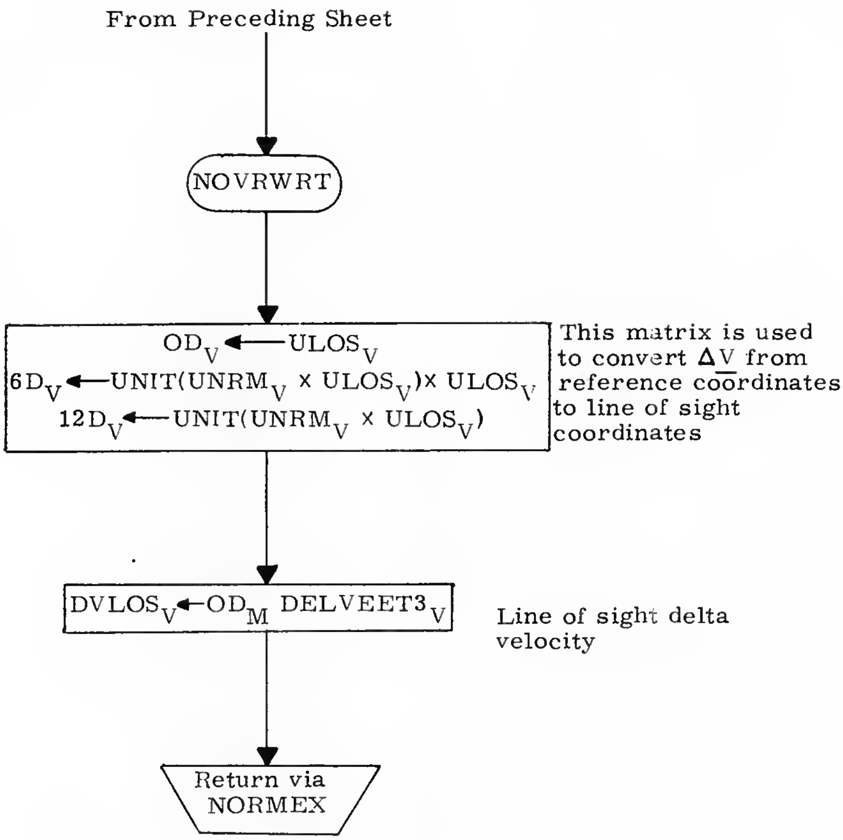
Set up vac area for integration routine

Indicates precision integration

Output: $RATT_V$

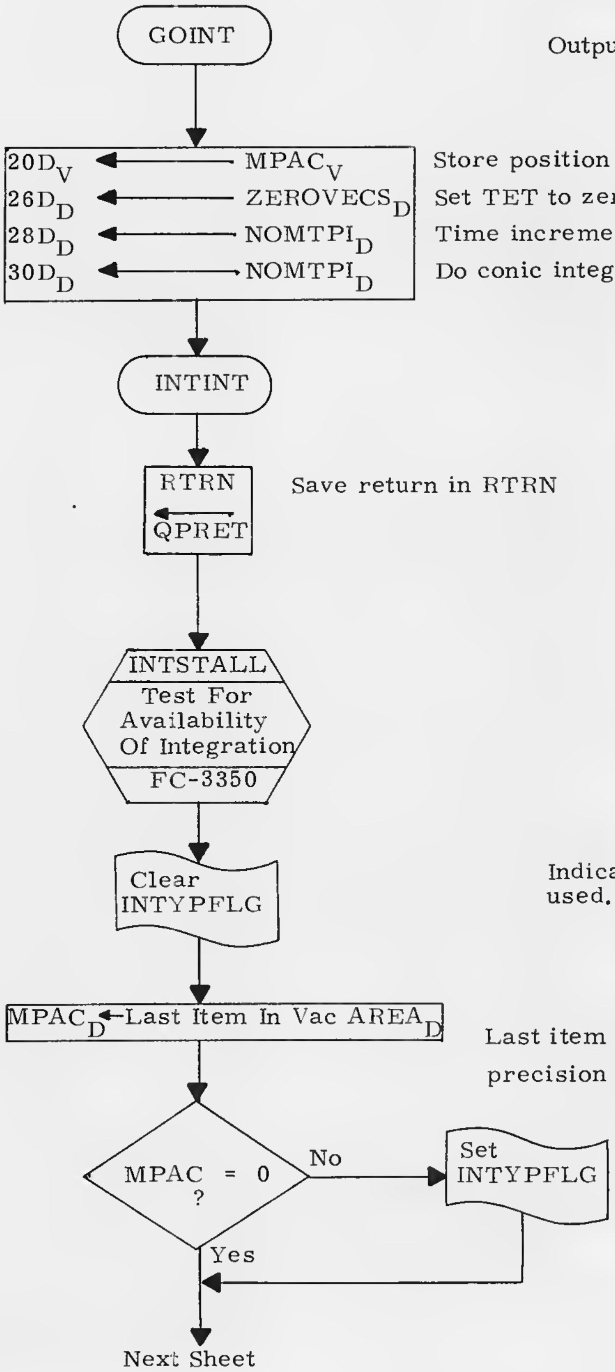
New offset target vector

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A. Luchini	12/14/69	P34, P74 Transfer Phase Initiation Targeting	
PRGMR P. White	12/11/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3740
DOCMR W. Dugbrth	12/5/69		
APPR'D W. Dugbrth	12/16/69	REV 1	SHEET 20 OF 30



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN [illegible]	10/15/69	P34, P74 Transfer Phase Initiation Targeting	
PRGMR P White	12/11/69	LUMINARY 1D	DOCUMENT NO. FC-3740
ANALST			
DOCMR W Dauforth	12/5/69		
APPR'D W Dauforth	12/16/69	REV 1	SHEET 21 OF 30

Routine to prepare user for conic or precision integration.
Input: Velocity vector in push list, $MPAC_V$: Position vector
Output: Updated state vector in $RATT_V$, $VATT_V$



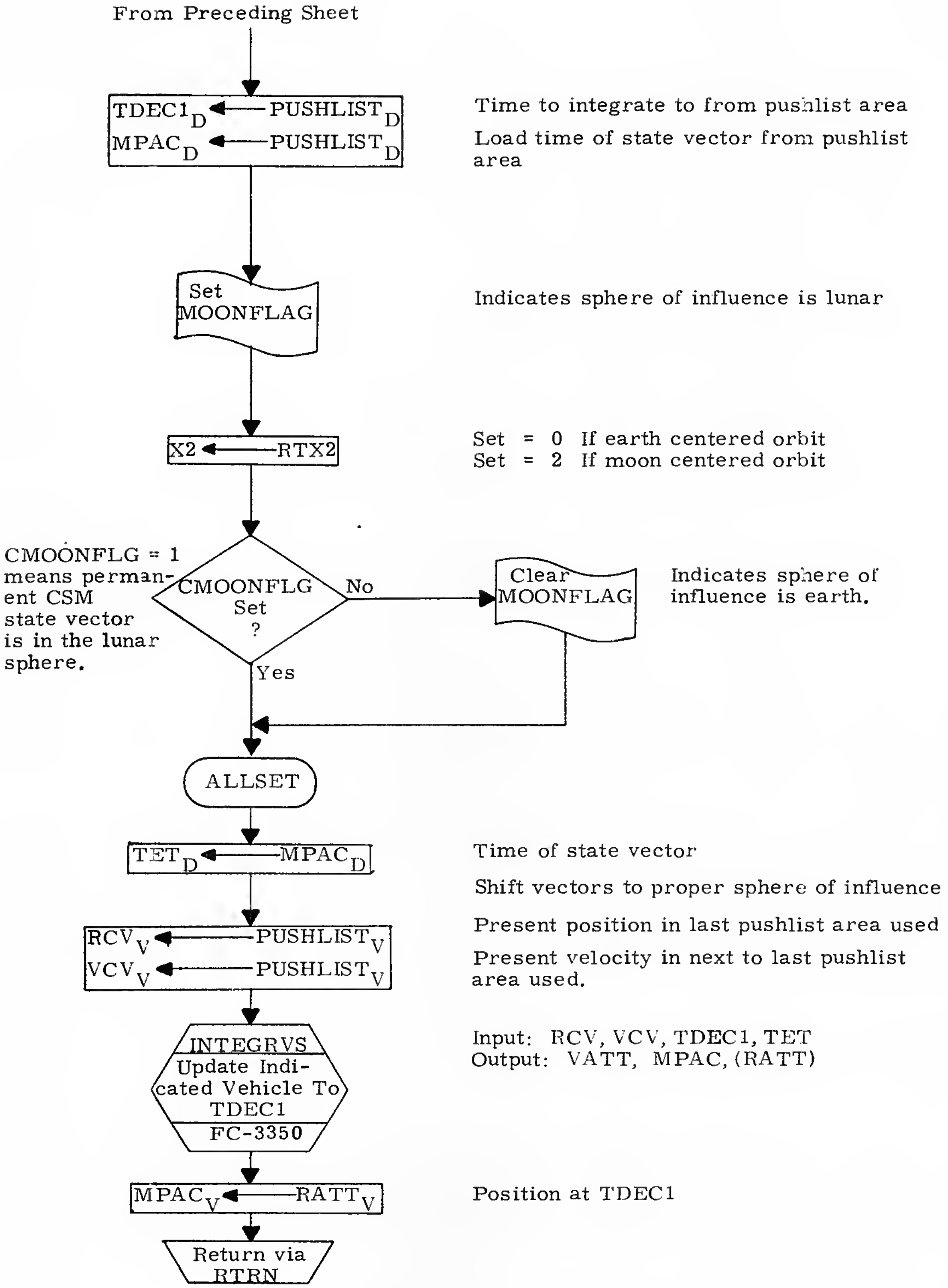
Store position vector
Set TET to zero
Time increment for integration
Do conic integration

Save return in RTRN

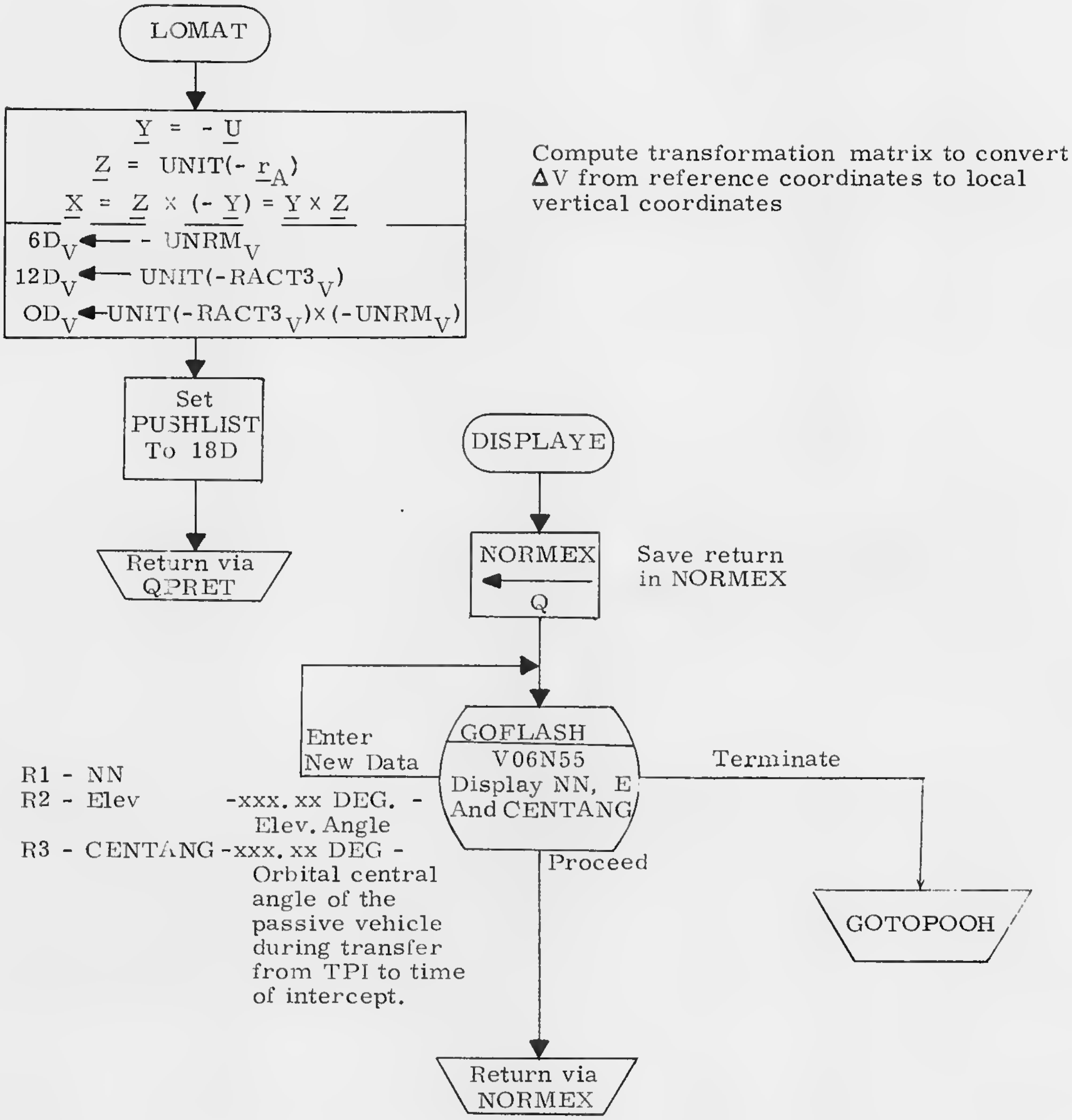
Indicates precision integration is to be used.

Last item set in push list indicates if conic or precision integration should be used.

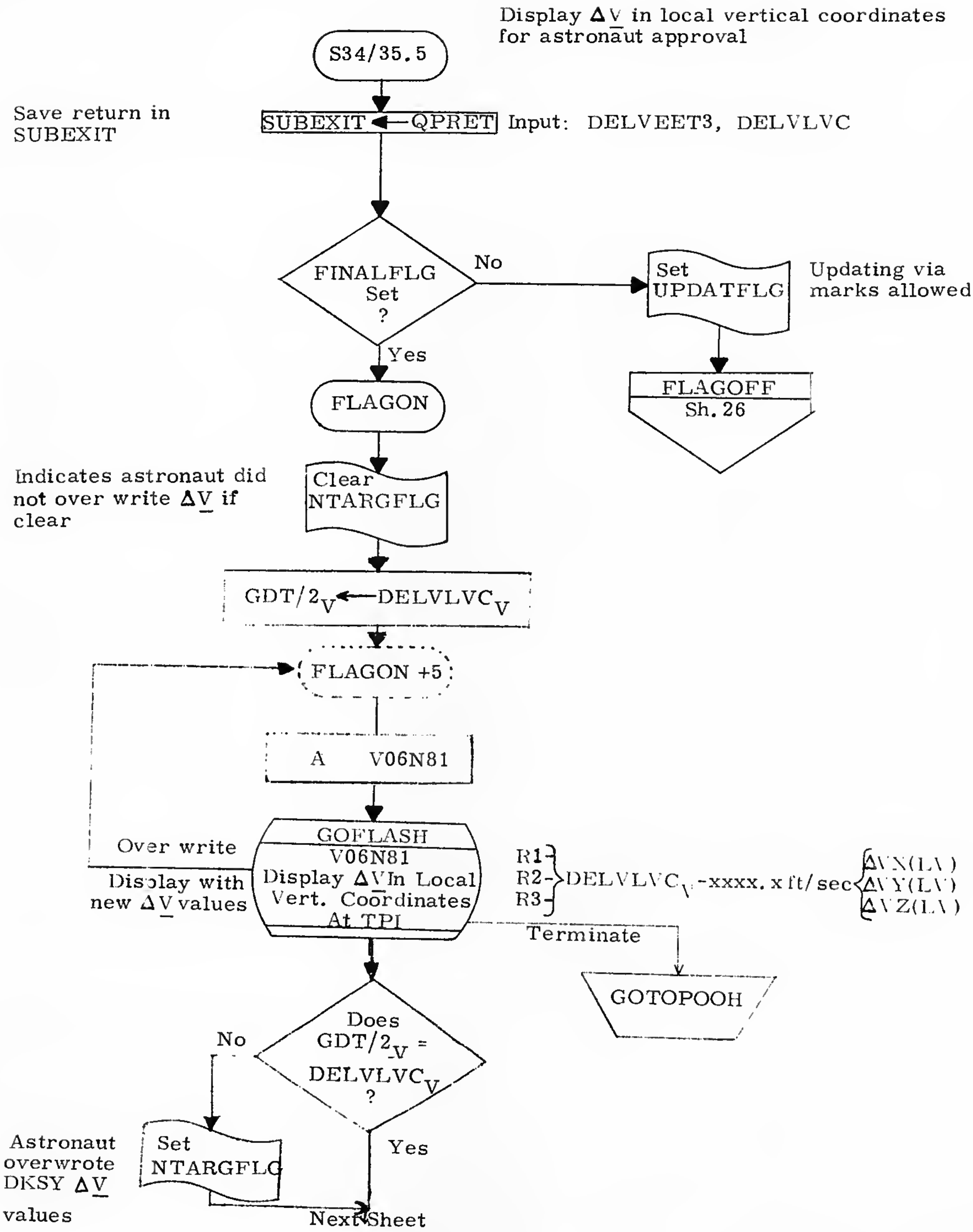
Indicates conic integration is to be used.



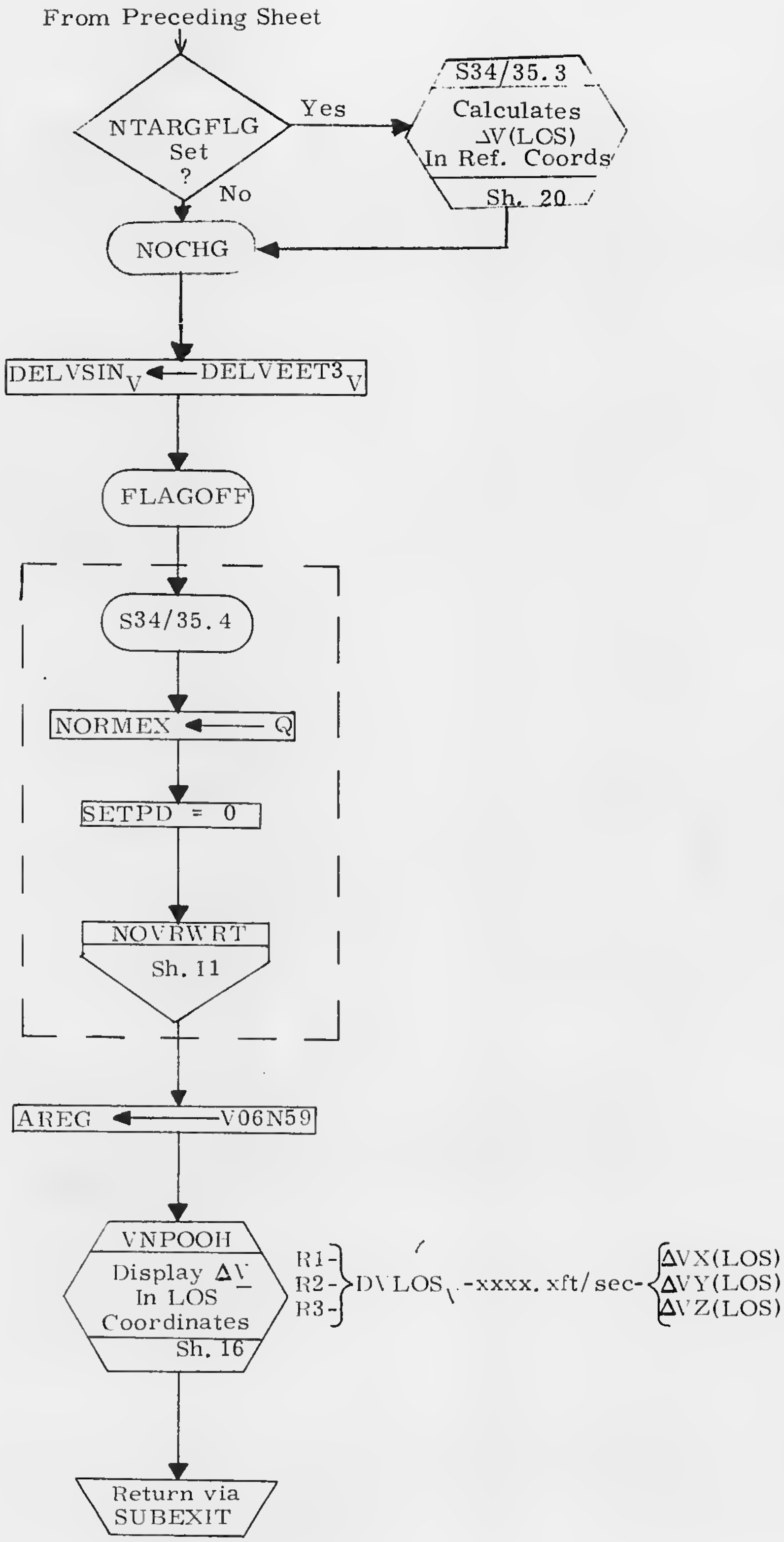
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	A. Tucholke	10/14/69	P34, P74 Transfer Phase Initiation Targeting	
PRGMR	P. White	12/11/69	LUMINARY 1D	DOCUMENT NO. FC-3740
ANALST				
DOCMR	W Dogbrith	12/5/69		
APPR'D	W Dogbrith	12/6/69	REV 1	SHEET 23 OF 30



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Tuchrike	10/14/69	P34, P74 Transfer Phase Initiation Targeting	
PRGMR P. White	12/2/69		DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3740
DOCMR W. Danforth	12/5/69		
APPR'D W. Danforth	12/16/69	REV 1	SHEET 24 OF 30

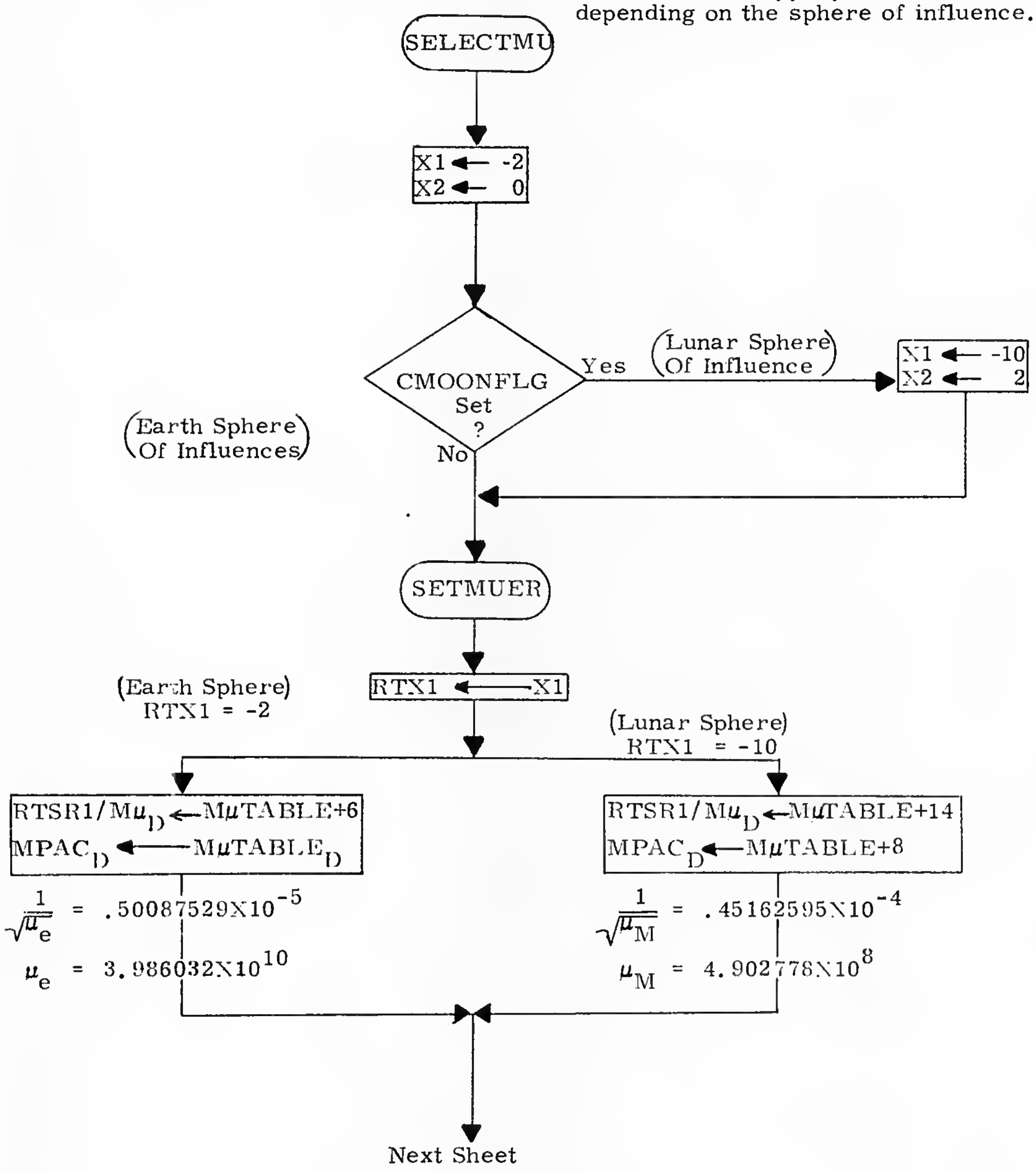


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	[illegible]	12/9/69	P34, P74 Transfer Phase Initiation Targeting	
PRGMR	P Jwhite	12/11/69		
ANALST			LUMINARY 1D	DOCUMENT NO. FC-3740
DOCMR	W Donhart	12/5/69		
APPR'D	W Donhart	12/16/69	REV 1	SHEET 25 OF 30

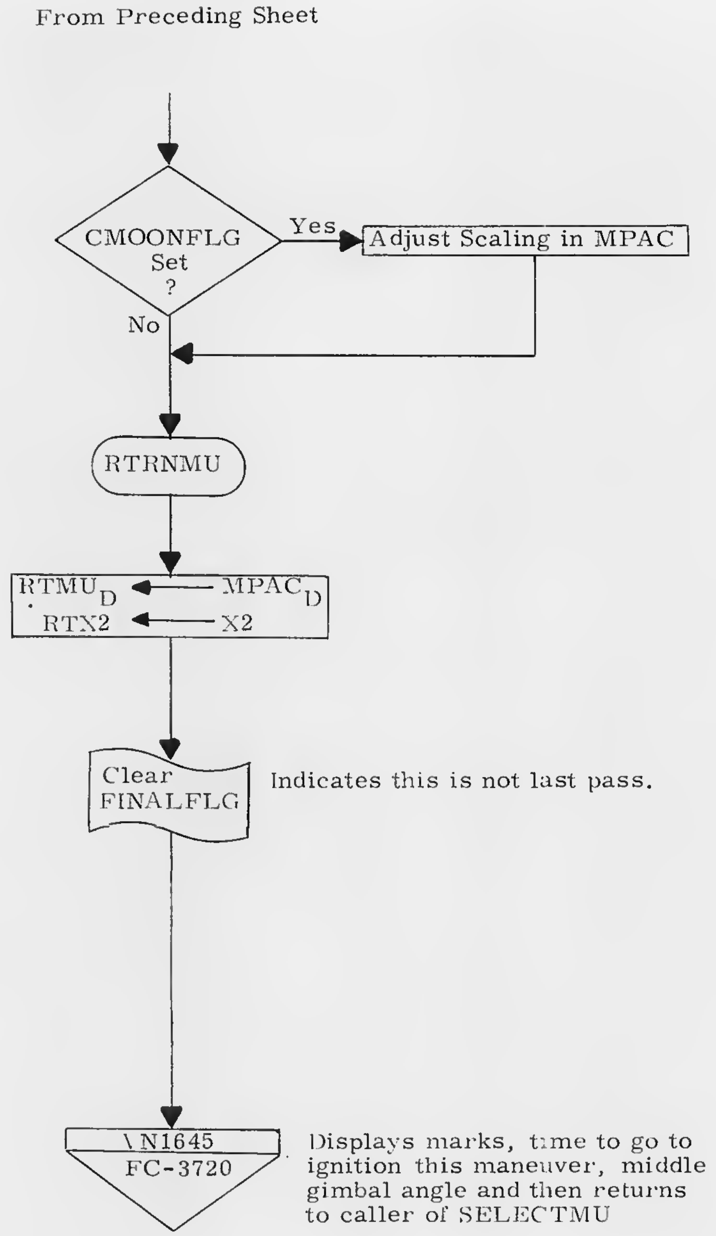


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	P. Tuchol[illegible]	10/15/69	P34, P74 Transfer Phase Initiation Targeting	
PRGMR	P White	12/11/69		
ANALST			LUMINARY 1D	DOCUMENT NO. FC-3740
DOCMR	W Danforth	12/5/69		
APPR'D	W Danforth	12/16/69	REV 1	SHEET 26 OF 30

Calculates the appropriate value of μ depending on the sphere of influence.



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	12/16/69	P34, P74 Transfer Phase Initiation Targeting	
PRGMR	12/11/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3740
DOCMR W Dayforth	12/5/69		
APPR'D W Dayforth	12/16/69	REV 1	SHEET 27 OF 30



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION		
DRAWN	[illegible]	[illegible]	P34, P74 Transfer Phase Initiation Targeting	
PRGMR	P. White	12/11/69		
ANALST			LUMINARY 1D	DOCUMENT NO. FC-3740
DOCMR	W. Danforth	12/5/69		
APPR'D	W. Danforth	12/16/69	REV 1	SHEET 28 OF 30

FLAGS

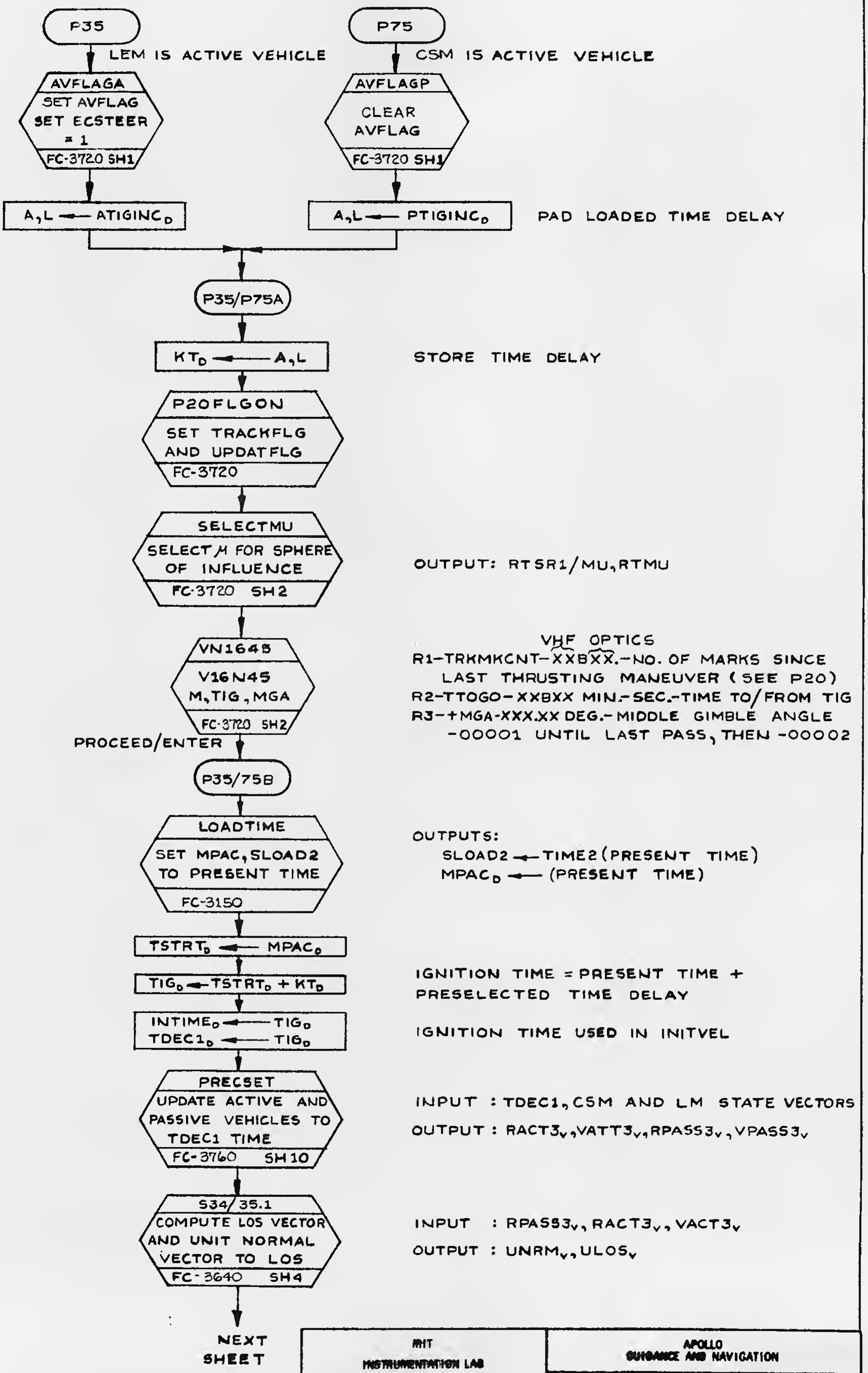
Name	Meaning When Set	Meaning When Cleared	Where Set	Where Cleared	Where Tested
AVFLAG Flag 2 bit 5	LM is active vehicle	CSM is active vehicle	Sh. 2	Sh. 2	
TRACKFLG Flag 1 bit 5	Tracking allowed	Tracking not allowed	Sh. 2,		
UPDATFLG Flag 1 bit 7	Updating by marks allowed	Updating by marks not allowed	Sh. 2, 25		
ETPIFLAG Flag 2 bit 7	Elevation angle supplied for P34, P74	TPI time supplied for P34, P74 to compute elevation	Sh. 3	Sh. 3	Sh. 4, 11
ITSWITCH Flag 7 bit 15	TPI time to be computed	TPI time has been computed	Sh. 4	Sh. 4, 5	Sh. 5, 11
RVSW Flag 7 bit 9	Do not compute final state vector in TIME-THETA	Compute final state vector in TIME-THETA	Sh. 6		
INTYPFLG Flag 3 bit 4	Conic integration	ENCKE integration	Sh. 22	Sh. 22	
MOONFLAG Flag 0 bit 12	Moon is sphere of influence	Earth is sphere of influence	Sh. 23	Sh. 23	
CMOONFLG Flag 8 bit 12	Permanent CSM state in lunar sphere	Permanent CSM state in earth sphere			Sh. 23, 27, 28
FINALFLG Flag 2 bit 6	Last pass thru rendezvous program computations	Interim pass thru rendezvous program computations		Sh. 28	Sh. 25
NTARGFLG Flag 6 bit 3	Astronaut did overwrite delta velocity	Astronaut did not overwrite delta velocity	Sh. 25		Sh. 25
XDELVFLG Flag 2 bit 8	External deltav VG computation	Lambert (aimpoint) VG computation		Sh. 26	

SUBROUTINES CALLED ON OTHER FLOWCHARTS

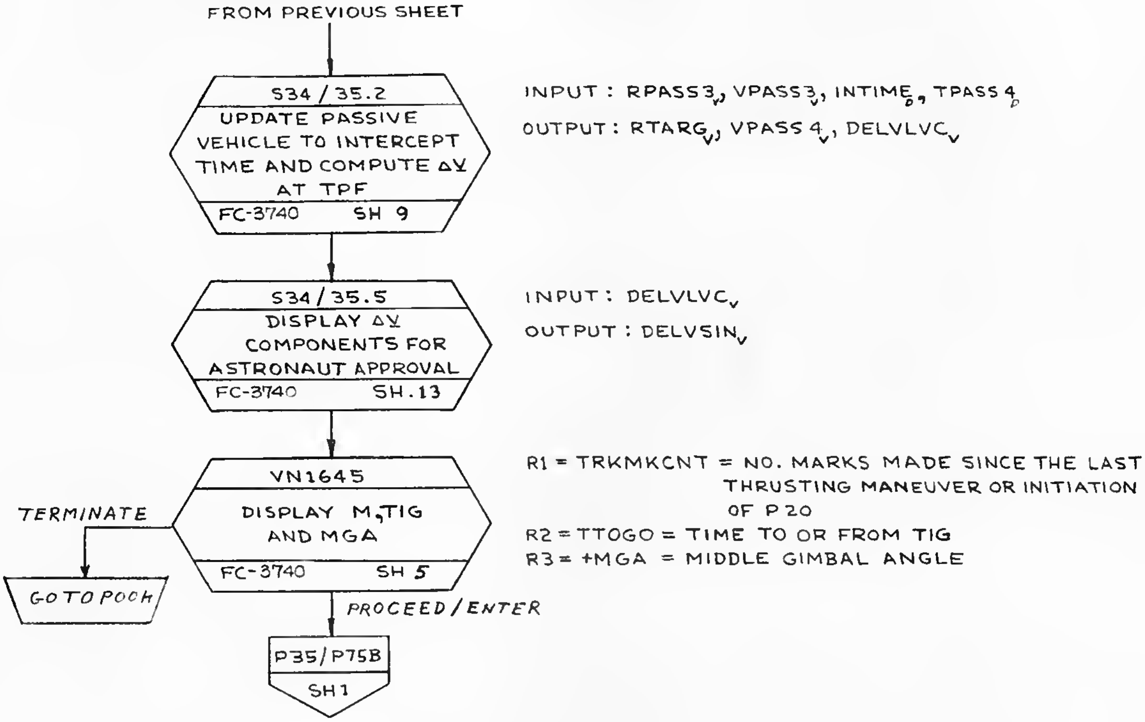
Subroutine	Flowchart	Description	Where Called
PRECSET	FC-3760	Update active and passive vehicles	Sh. 5
TIMETHET	FC-3360	Calculate time of flight	Sh. 7
PERIAPO1	FC-3760	Calculate perigee altitude of active vehicle	Sh. 7
VN1645	FC-3720	Display MARKS, TFI, MGA	Sh. 8
ACTIVE	FC-3760	Store active vehicle state vector	Sh. 15
PASSIVE	FC-3760	Store passive vehicle state vector	Sh. 16
INITVEL	FC-3760	Compute required velocities	Sh. 19
INTSTALL	FC-3350	Test for availability of integration	Sh. 22
INTEGRVS	FC-3350	Update vehicle state vector	Sh. 23
BLANKET	FC-3080	Blank DSKY	Sh. 24

P35, P75 TRANSFER PHASE MIDCOURSE TARGETING

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS	3JUNE69	P35, P37 TRANSFER PHASE MIDCOURSE TARGETING	
PRGMR G. H. Goode	6-4-69		DOCUMENT NO.
ANALST W. Tempelman	6-4-69	LUMINARY 1D	FC-3750
DOCMR Karl Kalk	4 Jun 69		
APPR'D Aleda M. Torak	4JUNE69	REV 2	SHEET 1 OF 4



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN F.D. Lawrence	1 APR 69	P35, P75 TRANSFER PHASE MIDCOURSE TARGETING	
PROGMR J.F. Goode	2 May 69		
ANALST W. Tempelman	4 June 69	LUMINARY 1D	DOCUMENT NO. FC-3750
DOCMR [illegible]	2 May 69		
APPR'D John A. Moore	2 May 69	REV 2	SHEET 2 OF 4



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN 7 Pearson Jr.	28JUNE68	P35, P75 TRANSFER PHASE MIDCOURSE TARGETING	
PRGMR P. Starkite	17JUL68		
ANALST W. Tempelman	20 Sept 68	LUMINARY 1D	DOCUMENT NO. FC-3750
DOCMR W. Gayforth	12JULY68		
APPR'D John A. Moore	25 Sept 68 / 2 May 69	REV 2	SHEET 3 OF 4

P35 TRANSFER PHASE MIDCOURSE

SUBROUTINES

ON OTHER CHARTS

AVFLAGA	SET AVFLAG, SETS ECSTEER = 1
AVFLAGP	CLEAR AVFLAG
LOADTIME	SETS MPAC TO PRESENT TIME
SELECTMU	SELECT μ VALUE ACCORDING TO LUNAR OR EARTH SPHERE OF INFLUENCE
PRECSET	EXECUTES PRECISION UPDATE OF BOTH VEHICLES
S34/35.1	COMPUTE LOS AND UNIT NORMAL VECTORS
S34/35.2	UPDATE PASSIVE VEHICLE TO INTERCEPT TIME
S34/35.5	DISPLAY $\Delta \underline{V}$ COMPONENTS
VN164 S	DISPLAY M, TFI AND MGA
P20FLGON	SET UPDATFLG, TRACKFLG

FLAGS

AVFLAG
TRACKFLG FINALFLG
UPDATFLG AVFLAG

} ALL SET AND CLEARED ON SH1

DISPLAYS

V16N45	R1-TRKMKCNT-XXXXX.-NO OF MARKS	USED
	R2-TTOGO-XXBXX MIN.-SEC.-TIME TO/FROM TIG	SH. 2
	R3-+MGA-XXX.XX DEG. MIDDLE GIMBAL ANGLE	

ALARMS

NONE

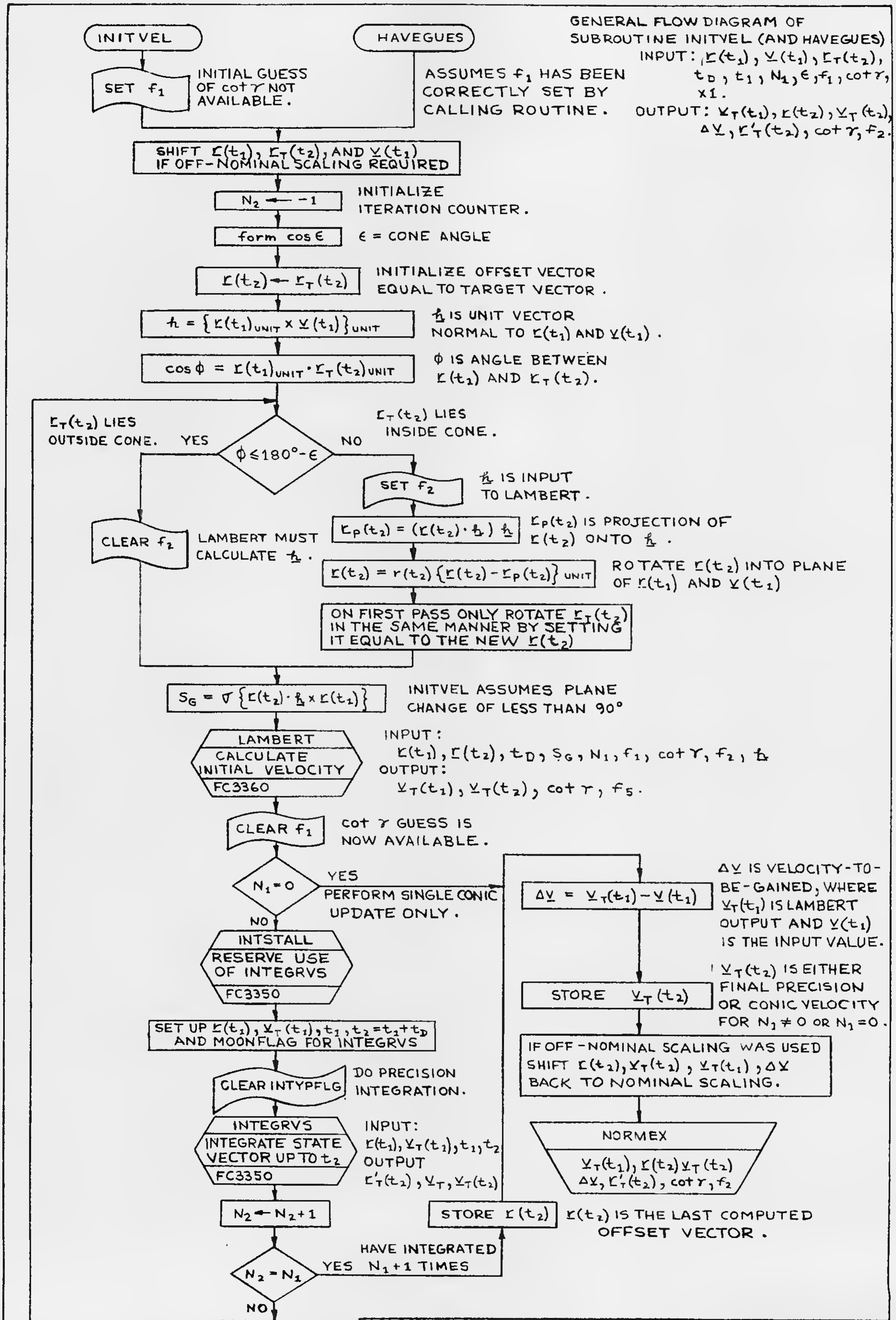
ERASABLES

		UNITS	SCALING
KT	TIMEDELAY STORAGE	CENTISECS	2^{28}
TSTRT	PRESENT TIME STORAGE	CENTISECS	2^{28}
TIG	TIME OF MANEUVER	CENTISECS	2^{28}
ATIGINC	PAD LOADED TIME DELAY FOR P35	CENTISECS	2^{28}
PTIGINC	PAD LOADED TIME DELAY FOR P75	CENTISECS	2^{28}
INTIME	INPUT TIME TO INITVEL	CENTISECS	2^{28}
TDEC1	INPUT TIME TO INTEGRATION	CENTISECS	2^{28}

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN F. Pearson	2JUL68	P35, P75 TRANSFER PHASE MIDCOURSE TARGETING	
PRGMR P. White	19JUL68		
ANALST W. Tempelman	20Sept68	LUMINARY 1D	DOCUMENT NO. FC-3750
DOCMR W. Daggett	12JUL68		
APPR'D John A. Morse	25 Sept. 68 2 May 69	REV 2	SHEET 4 OF 4

COMMON TARGETING SUBROUTINES

MAJOR SUBROUTINES AND EXTERNAL ENTRY POINTS



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN F. Pearson Jr.	27 MAY 68	COMMON TARGETING SUBROUTINES INITVEL, MIDGIM PERIAPO, SELECTMU, PRECSET
PROGRMR P. White	6 SEPT 68	LUMINARY 1D
ANALST		DOCUMENT NO. FC-3760
DOCMGR C. A. Clark	12 JUL 68	
APPR'D John A. Moore	9 Sept 68	REV 3 — SHEET 2 OF 18

INITVEL (AND HAVEGUES)

GIVEN THE INITIAL TIME t_1, THE INITIAL POSITION $\underline{r}(t_1)$, THE FINAL POSITION $\underline{r}_T(t_2)$ AND THE CORRESPONDING TRANSFER TIME t_D, THIS SUBROUTINE CALCULATES THE FOLLOWING VECTORS:

1) THE INITIAL VELOCITY VECTOR $\underline{v}_T(t_1)$ WHICH WILL TAKE ONE IN A PRECISION INTEGRATION FROM $\underline{r}(t_1)$ TO $\underline{r}_T(t_2)$, AND
2) THE FINAL POSITION VECTOR $\underline{r}(t_2)$ WHICH ONE WOULD ARRIVE AT IF ONE USED THE ABOVE INITIAL VELOCITY VECTOR $\underline{v}_T(t_1)$ AND UPDATED USING ONLY A CONIC CALCULATION. THIS VECTOR IS REFERRED TO AS THE OFFSET TARGET VECTOR.

INITVEL IS CALLED BY:
P1Φ (OR P11), CALLIVEL, S4Φ.1, MANUPARM
HAVEGUES IS CALLED BY:
S4Φ.9 .

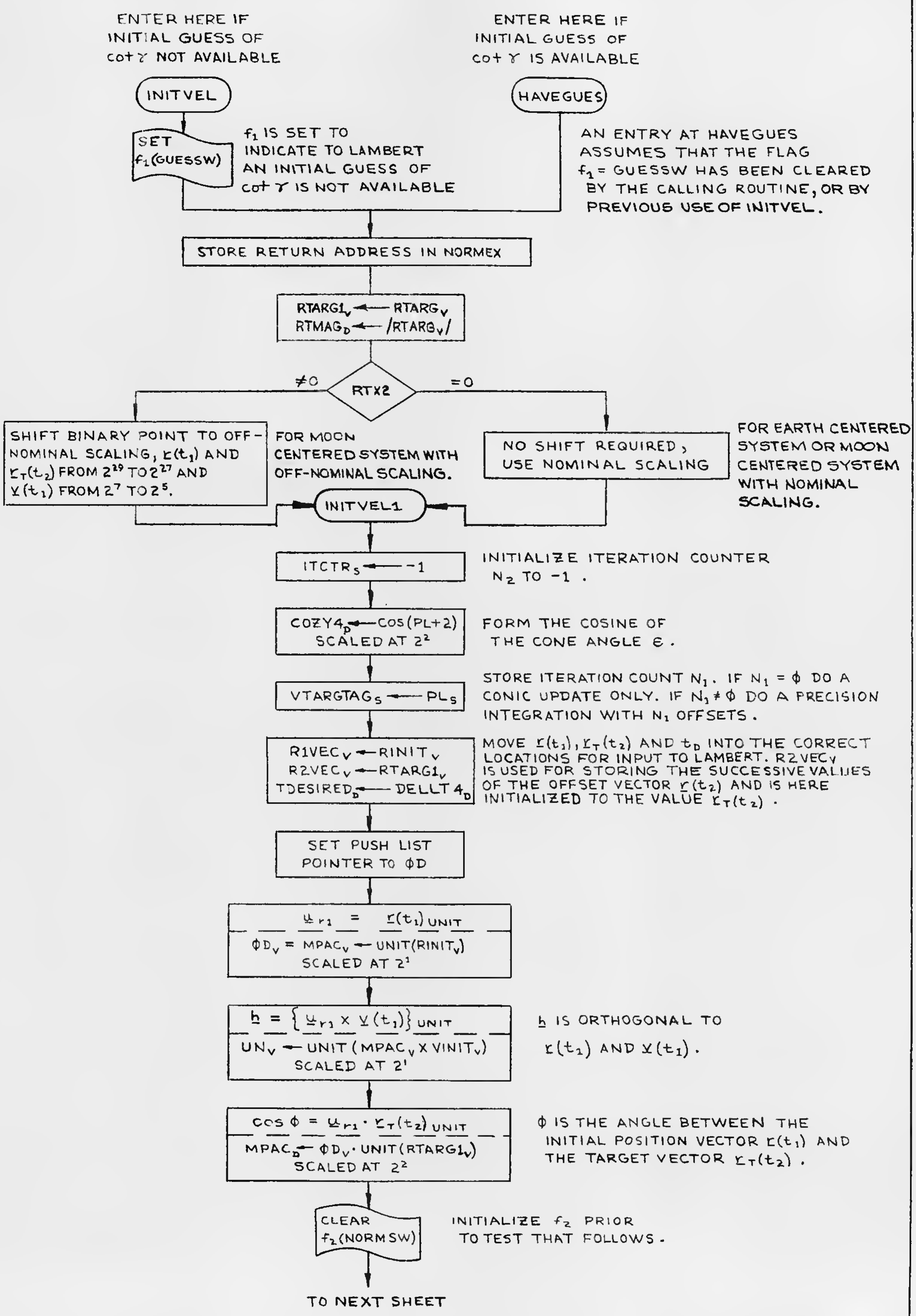
INPUT:

1) $RINIT_V = \underline{r}(t_1)$, INITIAL POSITION VECTOR, IN METERS, AT 2^{29}.
2) $VINIT_V = \underline{v}(t_1)$, INITIAL VELOCITY VECTOR, IN METERS/CSEC, AT 2^7. IT IS USED TO DETERMINE WHETHER THE TRANSFER ANGLE FROM THE INITIAL POSITION VECTOR TO THE TARGET VECTOR IS LESS THAN OR GREATER THAN 180°. IT IS ALSO USED TO SPECIFY THE TRANSFER PLANE IF AND ONLY IF THE TARGET VECTOR LIES WITHIN THE CONE.
3) $RTARG_V = \underline{r}_T(t_2)$, THE TARGET VECTOR, IN METERS, AT 2^{29}. IF $N_1 \neq 0$ IT IS THE TRUE TARGET VECTOR. IF $N_1 = \phi$ IT IS THE OFFSET TARGET VECTOR.
4) DELLT4 $= t_D$, DESIRED TRANSFER TIME FROM $\underline{r}(t_1)$ TO $\underline{r}_T(t_2)$, IN CSEC, AT 2^{28}.
5) INTIME $= t_1$, TIME OF VALIDITY OF $\underline{r}(t_1)$, IN CSEC, AT 2^{28}.
6) $PL_S = N_1$, THE NUMBER OF OFFSETS TO BE USED IN CALCULATING THE OFFSET TARGET VECTOR. IT IS ALSO EQUAL TO THE NUMBER OF ITERATIONS MINUS 1. $N_1 = \phi$ IMPLIES A SINGLE CONIC CALCULATION BUT NO INTEGRATION NOR OFFSET CALCULATION. IN THIS CASE $RTARG_V$ IS ASSUMED TO BE THE OFFSET VECTOR.
7) PL+2 $= \epsilon$, THE CONE ANGLE OF A CONE MEASURED ABOUT $-\underline{r}(t_1)$, IN REVOLUTIONS, AT 2^0.
8) GUESSW $= f_1$, A FLAG, IS CLEAR IF AN INITIAL GUESS OF $\cot\gamma$ IS TO BE INPUT TO LAMBERT, IS SET IF $\cot\gamma$ IS NOT INPUT BUT MUST BE CALCULATED BY LAMBERT.
9) COGA $= \cot\gamma$, THE INITIAL GUESS OF $\cot\gamma$ IF f_1 IS CLEAR.
10) B29FLAG = A FLAG, IS CLEAR IF EARTH IS CENTRAL BODY AND SUBROUTINE SHOULD CALCULATE WITH NOMINAL SCALING, IS SET IF MOON IS CENTRAL BODY AND OFF-NOMINAL SCALING IS REQUIRED.
11) X1 = INDEX REGISTER CONTAINING VALUE USED BY LAMBERT TO SET UP PROPER μ-TABLE, IS -2 FOR EARTH, IS -10D FOR MOON.
12) AVEGFLAG = A FLAG, IF SET $ITERCTR_S$ IS SET EQUAL TO 5, IF CLEAR $ITERCTR_S$ IS SET EQUAL TO 20D.
13) PUSH LIST POINTER IS AT THE GENERAL VALUE PL, WHERE $\phi \leq PL \leq 38D$.

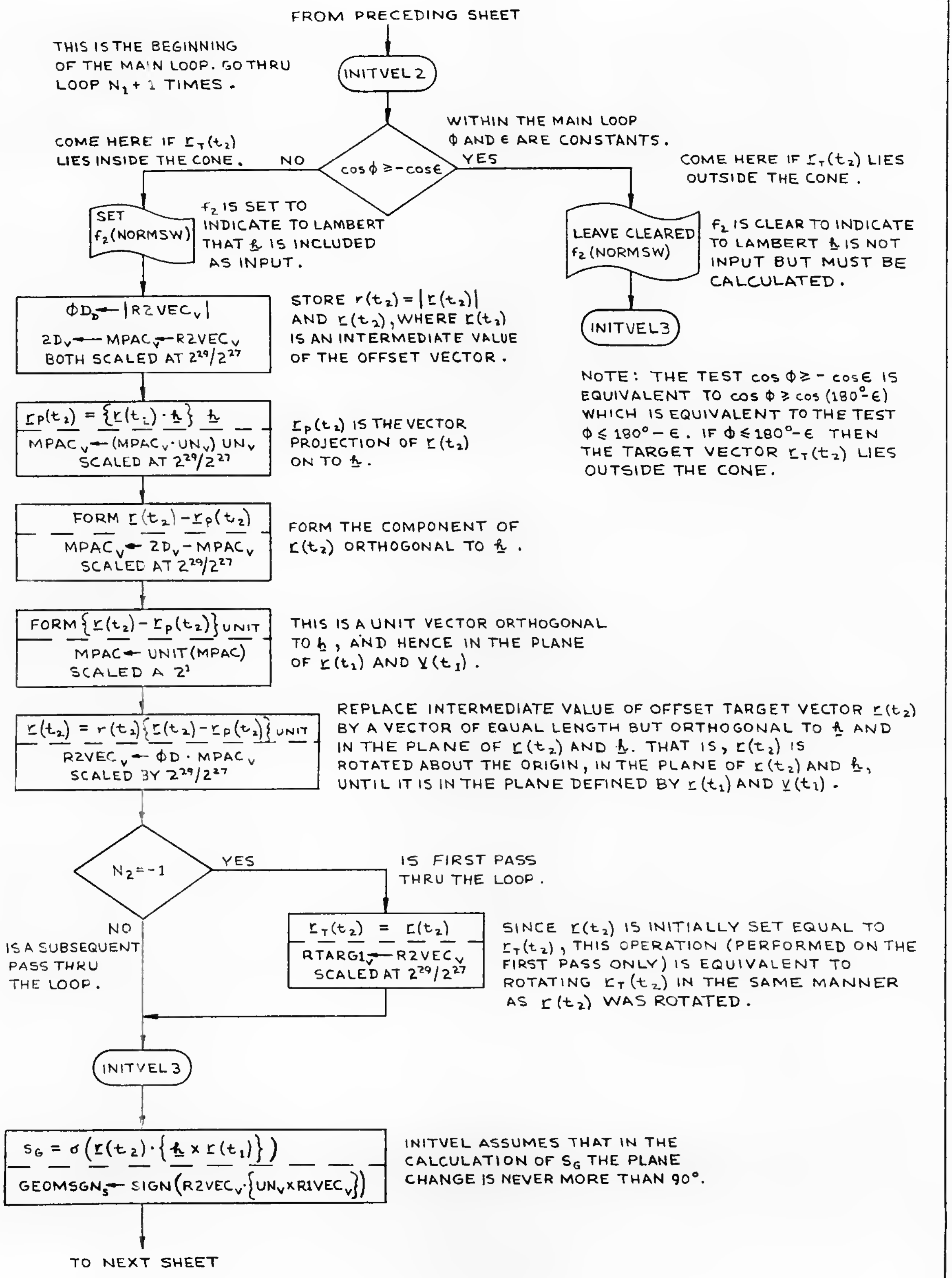
OUTPUT:

1) $VIPRIME_V = \underline{v}_T(t_1)$, THE VELOCITY REQUIRED AT TIME t_1 IN ORDER TO REACH $\underline{r}_T(t_2)$ IN A PRECISION MANNER IN TIME INTERVAL t_D, IN METERS/CSEC, AT 2^7. THIS IS THE FINAL VELOCITY OUTPUT FROM LAMBERT AND IS THE VELOCITY USED IN THE VELOCITY-TO-BE-GAINED EQUATIONS.
2) $RTARG_V = \underline{r}(t_2)$, THE COMPUTED OFFSET TARGET VECTOR, IN METERS, AT 2^{29}.
3) $VTPRIME_V = \underline{v}_T(t_2)$, THE FINAL PRECISION VELOCITY VECTOR RESULTING FROM A PRECISION UPDATE OF THE INITIAL POSITION VECTOR $\underline{r}(t_1)$ AND THE REQUIRED INITIAL VELOCITY VECTOR $\underline{v}_T(t_1)$ IF $N_1 \neq 0$. IT IS THE FINAL CONIC VELOCITY VECTOR RESULTING FROM A CONIC UPDATE OF $\underline{r}(t_1)$ AND $\underline{r}(t_1)$ IF $N_1 = \emptyset$. IT IS IN METERS/CSEC AT 2^7.
4) $DELVEET_V = \Delta\underline{v}$, THE VELOCITY TO BE GAINED, IN METERS/CSEC, AT 2^7.
5) $RATT1_V = \underline{r}'_T(t_2)$, THE POSITION VECTOR RESULTING FROM A PRECISION INTEGRATION FROM $\underline{r}(t_1)$ USING $\underline{v}_T(t_1)$ AS THE INITIAL VELOCITY, IN METERS, AT $2^{29}/2^{27}$.
6) COGA $= \cot\gamma$, COTANGENT OF FLIGHT PATH ANGLE OF THE VECTORS $\underline{r}(t_1)$ AND $\underline{v}_T(t_1)$, MEASURED FROM THE VERTICAL, AT 2^5.
7) NORMSW $= f_2$, A FLAG, IS CLEAR IF THE TARGET VECTOR $\underline{r}_T(t_2)$ LIES OUTSIDE OF THE CONE, IS SET IF $\underline{r}_T(t_2)$ LIES INSIDE THE CONE.
8) $ITERCTR_S$ = ITERATION COUNT USED IN LAMBERT.
9) PUSH LIST POINTER IS AT ΦD.

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN F. Ramson Jr.	10APR68	COMMON TARGETING SUBROUTINES INITVEL, MIDGIM PERIAPC, SELECTMU, PRECSET	
PROGMR P. White	6SEPT68	LUMINARY 1D	DOCUMENT NO. FC-3760
ANALST			
DOCMR G. A. Clark	12JUL68		
APPR'D John A. Morse	9 Sept. 68	REV 3	SHEET 3 OF 18



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN 7 Pearson J. 11APR68	COMMON TARGETING SUBROUTINES INITVEL, MIDGIM PERIAPO, SELECTMU, PRECSET
PROGMR P White 6SEPT68	LUMINARY 1D — DOCUMENT NO. FC-3760
ANALST	
DOCMR L. A. Clark 12JUL68	
APPR'D John A. Morse 9 Sept 68	REV 3 — SHEET 4 OF 18



MIT
INSTRUMENTATION LAB
CAMBRIDGE, MASS.

DRAWN	F. Pearson Jr.	12APR68
PROMR	P.J. White	6SEPT68
ANALST		
DOCMR	G. A. Sclark	12 JUL68
APPR'D	John A. Morse	9 Sept 68

APOLLO
GUIDANCE AND NAVIGATION

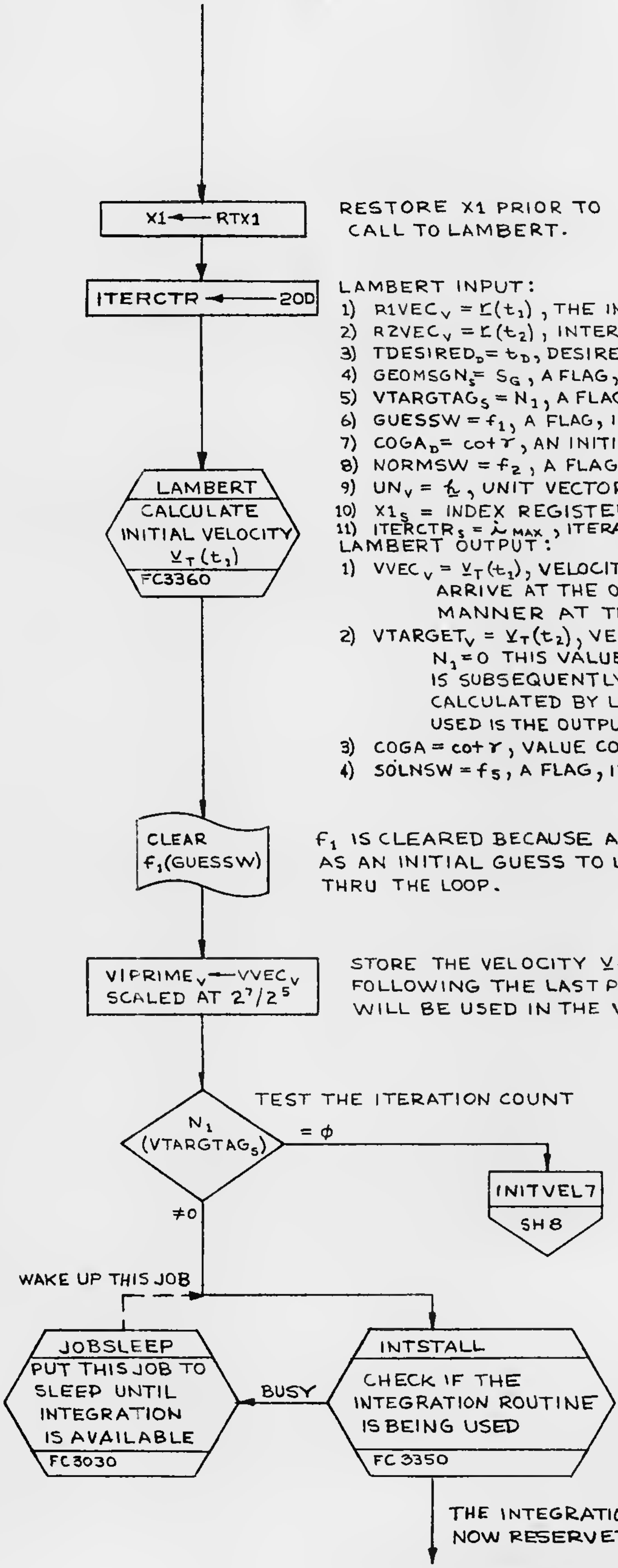
COMMON TARGETING SUBROUTINES
INITVEL, MIDGIM
PERIAPO, SELECTMU, PRECSET
LUMINARY 1D

DOCUMENT NO. FC-3760

REV 3

SHEET 5 OF 18

FROM PRECEDING PAGE



RESTORE X1 PRIOR TO CALL TO LAMBERT.

LAMBERT INPUT:
1) R1VEC$_V$ = $\underline{r}(t_1)$, THE INITIAL POSITION VECTOR.
2) R2VEC$_V$ = $\underline{r}(t_2)$, INTERMEDIATE VALUE OF THE OFFSET VECTOR.
3) TDESIRED$_D$ = t_D, DESIRED TRANSFER TIME.
4) GEOMSGN$_S$ = S_G, A FLAG, IF POSITIVE $\theta \leq 180°$, IF NEGATIVE $\theta > 180°$.
5) VTARGTAG$_S$ = N_1, A FLAG, IF NON-ZERO $\underline{v}_T(t_2)$ IS NOT CALCULATED.
6) GUESSW = f_1, A FLAG, IF SET $\cot\gamma$ IS NOT INPUT.
7) COGA$_D$ = $\cot\gamma$, AN INITIAL GUESS IF f_1 IS CLEAR.
8) NORMSW = f_2, A FLAG, IF CLEAR $\underline{h}$ IS CALCULATED.
9) UN$_V$ = $\underline{h}$, UNIT VECTOR, NORMAL TO $\underline{r}(t_1)$ AND $\underline{v}(t_1)$ IF f_2 SET.
10) X1$_S$ = INDEX REGISTER CONTAINING VALUE TO SELECT μ-TABLE.
11) ITERCTR$_S$ = i_{MAX}, ITERATION COUNTER.

LAMBERT OUTPUT:
1) VVEC$_V$ = $\underline{v}_T(t_1)$, VELOCITY REQUIRED AT TIME t_1 IN ORDER TO ARRIVE AT THE OFFSET POSITION $\underline{r}(t_2)$ IN A CONIC MANNER AT TIME t_2.
2) VTARGET$_V$ = $\underline{v}_T(t_2)$, VELOCITY AT THE OFFSET POSITION. IF $N_1 = 0$ THIS VALUE IS CALCULATED BY LAMBERT AND IS SUBSEQUENTLY USED. IF $N_1 \neq 0$ THIS VALUE IS NOT CALCULATED BY LAMBERT AND THE VALUE SUBSEQUENTLY USED IS THE OUTPUT OF INTEGRVS.
3) COGA = $\cot\gamma$, VALUE CONVERGED TO BY LAMBERT.
4) SOLNSW = f_5, A FLAG, IF CLEAR THE SOLUTION IS VALID.

f_1 IS CLEARED BECAUSE A VALUE OF $\cot\gamma$ IS AVAILABLE NOW AS AN INITIAL GUESS TO LAMBERT ON THE NEXT PASS THRU THE LOOP.

STORE THE VELOCITY $\underline{v}_T(t_1)$ IN ITS OUTPUT LOCATION. FOLLOWING THE LAST PASS THRU THE LOOP THIS VALUE WILL BE USED IN THE VELOCITY-TO-BE-GAINED EQUATION.

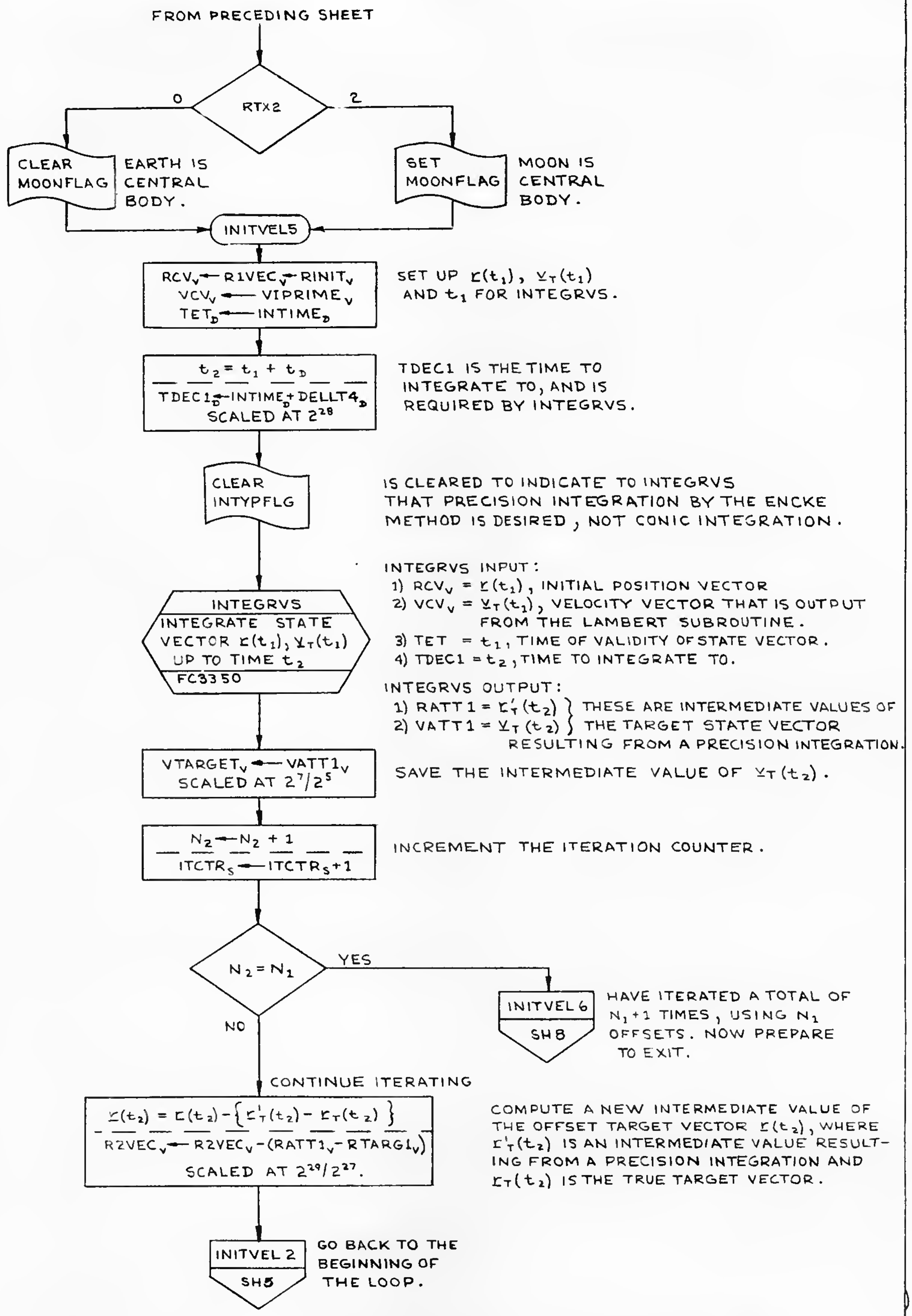
IF THE ITERATION COUNT IS ϕ, THEN PROGRAM PREPARES TO RETURN AFTER A SINGLE CONIC CALCULATION.

IF INTEGRATION ROUTINE IS BEING USED PUT THIS ROUTINE TO SLEEP UNTIL INTEGRATION IS AVAILABLE. IF INTEGRATION ROUTINE IS NOT BEING USED RESERVE ITS USE FOR THIS ROUTINE BY SETTING THE FLAG INTFLAG2.

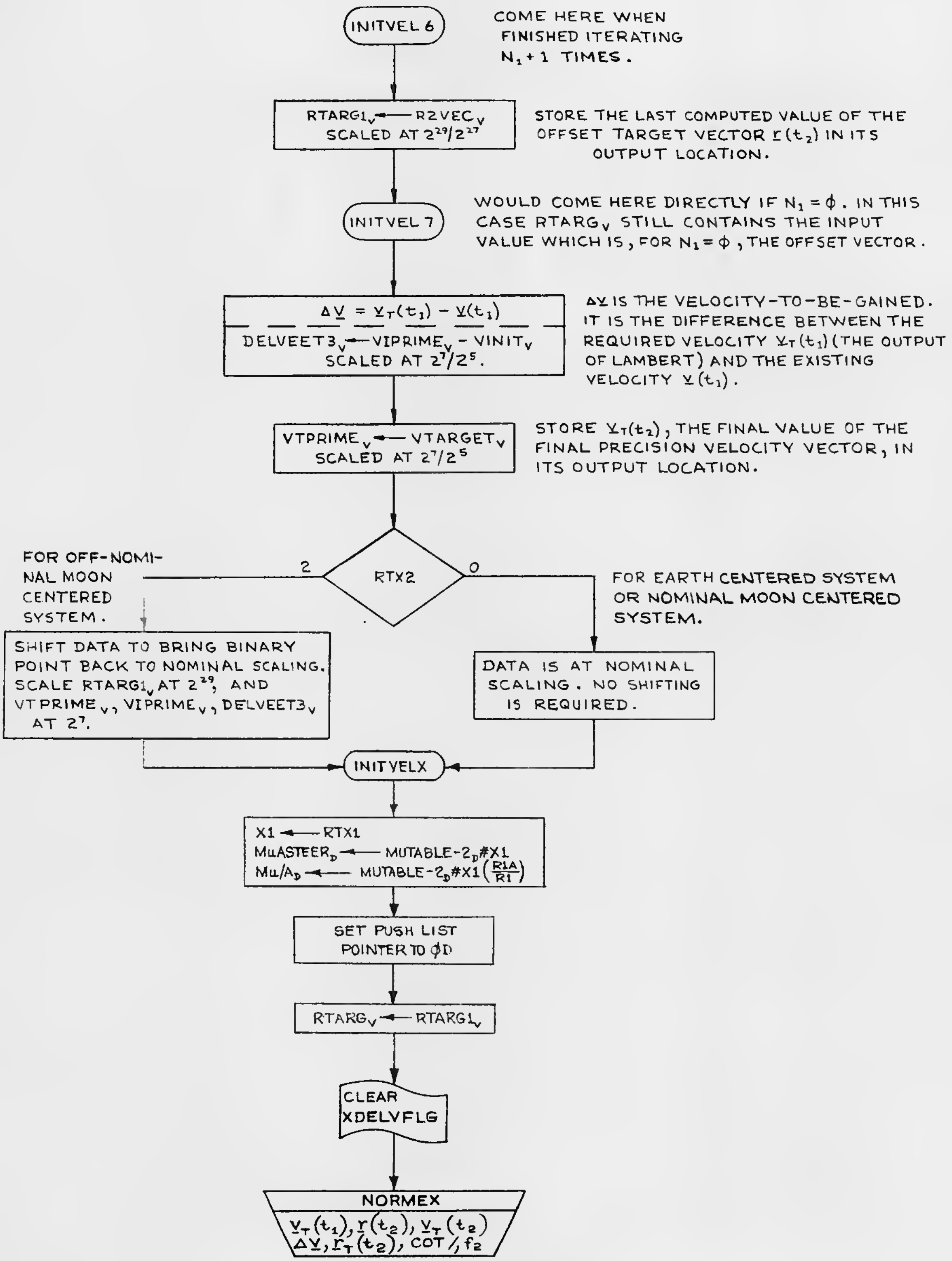
THE INTEGRATION ROUTINE IS NOW RESERVED FOR THIS JOB.

TO NEXT SHEET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN F. Pearson Jr.	15 APR 68	COMMON TARGETING SUBROUTINES INITVEL, MIDGIM PERIAPO, SELECTMU, PRECSET	
PROGMR P. White	6 SEPT 68	LUMINARY 1D	DOCUMENT NO. FC-3760
ANALST			
DOCMR [illegible]	12 JUL 68		
APPR'D John A. Morse	9 Sept. 68	REV 3	SHEET 6 OF 18

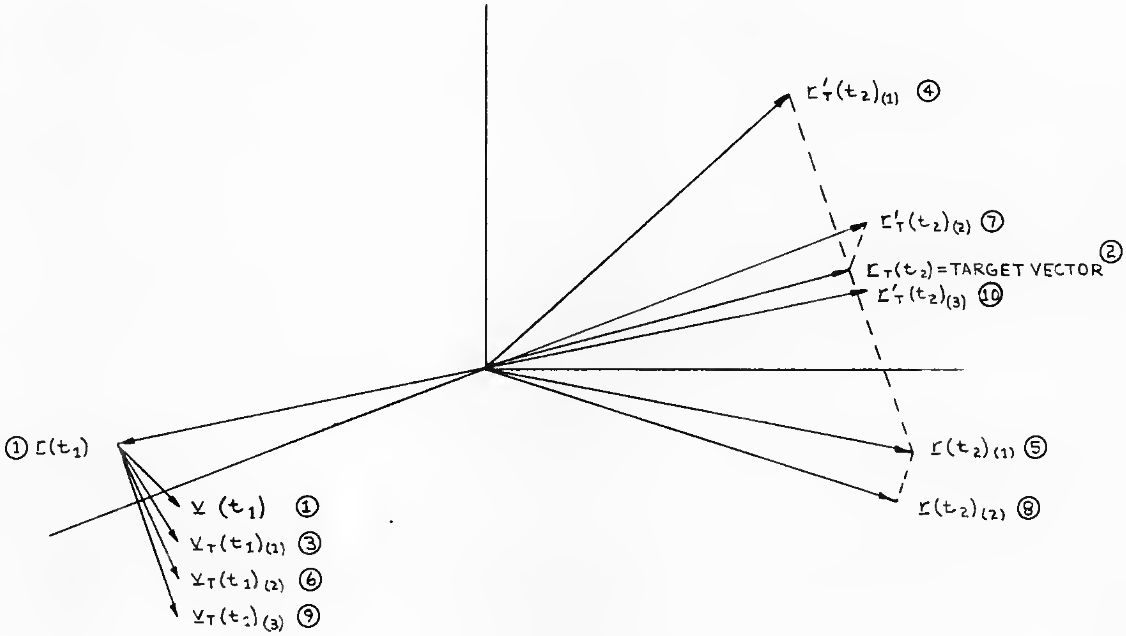


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN F. Pearson J. 15APR68	COMMON TARGETING SUBROUTINES INITVEL, MIDGIM PERIAPO, SELECTMU, PRECSET
PROGMR P. White 6SEPT68	LUMINARY 1D
ANALST	DOCUMENT NO. FC-3760
DOCMR [signature] 12 JUL 68	
APPR'D John A. Moore 9 Sept 68	REV 3 — SHEET 7 OF 18



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN F. Pearson Jr. 16APR68	COMMON TARGETING SUBROUTINES INITVEL, MIDGIM PERIAPO, SELECTMU, PRECSET
PROGMR P. White 6SEPT68	LUMINARY 1D — DOCUMENT NO. FC-3760
ANALST	
DOCMR G. A. Clark 12JUL68	
APPR'D John A. Morse 9Sept.68	REV 3 — SHEET 8 OF 18

THE FOLLOWING IS A GEOMETRICAL REPRESENTATION OF WHAT OCCURS WHEN THREE PASSES ARE MADE THROUGH THE MAIN LOOP IN INITVEL. IT USES 2 OFFSETS AND 3 ITERATIONS ($N_1 = 2$). THE SUBSCRIPTS OF (1), (2) AND (3) FOLLOWING THE VARIABLES REFER TO THE ITERATION NUMBER.



① $\underline{r}(t_1)$ IS THE GIVEN POSITION VECTOR, $\underline{v}(t_1)$ IS THE GIVEN VELOCITY VECTOR.

② $\underline{r}_T(t_2)$ IS THE GIVEN TARGET VECTOR. FOR COMPLETENESS AND CONSISTENCY IN USE OF SUBSCRIPTS THE TARGET VECTOR $\underline{r}_T(t_2)$ CAN BE CONSIDERED TO BE THE ZEROETH OFFSET VECTOR $\underline{r}(t_2)_{(0)}$.

ITERATION 1

③ $\underline{v}_T(t_1)_{(1)}$ IS CALCULATED BY LAMBERT USING $\underline{r}(t_1)$ FROM ① AND $\underline{r}(t_2)_{(0)} = \underline{r}_T(t_2)$ FROM ②.

④ $\underline{r}'_T(t_2)_{(1)}$ IS CALCULATED BY PRECISION INTEGRATION USING $\underline{r}(t_1)$ FROM ① AND $\underline{v}_T(t_1)_{(1)}$ FROM ③.

⑤ $\underline{r}(t_2)_{(1)}$ IS THE OFFSET VECTOR RESULTING FROM SUBTRACTING THE MISS VECTOR BETWEEN $\underline{r}'_T(t_2)_{(1)}$ FROM ④ AND $\underline{r}_T(t_2)$ FROM ② FROM THE OFFSET VECTOR $\underline{r}(t_2)_{(0)} = \underline{r}_T(t_2)$ FROM ②.

ITERATION 2

⑥ $\underline{v}_T(t_1)_{(2)}$ IS CALCULATED BY LAMBERT USING $\underline{r}(t_1)$ FROM ① AND $\underline{r}(t_2)_{(1)}$ FROM ⑤.

⑦ $\underline{r}'_T(t_2)_{(2)}$ IS CALCULATED BY PRECISION INTEGRATION USING $\underline{r}(t_1)$ FROM ① AND $\underline{v}_T(t_1)_{(2)}$ FROM ⑥.

⑧ $\underline{r}(t_2)_{(2)}$ IS THE OFFSET VECTOR RESULTING FROM SUBTRACTING THE MISS VECTOR BETWEEN $\underline{r}'_T(t_2)_{(2)}$ FROM ⑦ AND $\underline{r}_T(t_2)$ FROM ② FROM THE OFFSET VECTOR $\underline{r}(t_2)_{(1)}$ FROM ⑤.

ITERATION 3

⑨ $\underline{v}_T(t_1)_{(3)}$ IS CALCULATED BY LAMBERT USING $\underline{r}(t_1)$ FROM ① AND $\underline{r}(t_2)_{(2)}$ FROM ⑧.

⑩ $\underline{r}'_T(t_2)_{(3)}$ IS CALCULATED BY PRECISION INTEGRATION USING $\underline{r}(t_1)$ FROM ① AND $\underline{v}_T(t_1)_{(3)}$ FROM ⑨.

⑪ THE ROUTINE NOW PREPARES TO EXIT. IT CALCULATES THE VELOCITY-TO-BE-GAINED AS THE DIFFERENCE $\underline{v}_T(t_1)_{(3)} - \underline{v}(t_1)$.

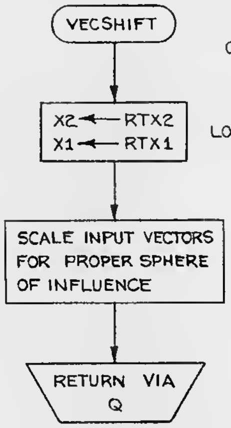
⑫ THERE IS NO CALCULATION OF THE OFFSET VECTOR $\underline{r}(t_2)_{(3)}$ CORRESPONDING TO $\underline{r}'_T(t_2)_{(3)}$.

⑬ THE FINAL OUTPUT VECTORS ARE:

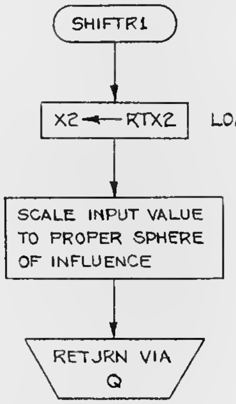
1) $\underline{v}_T(t_1)_{(3)}$ FROM ⑨
2) $\underline{r}(t_2)_{(2)}$ FROM ⑧
3) $\underline{r}'_T(t_2)_{(3)}$ FROM ⑩

PURPOSE: SUBROUTINE TO SCALE INPUT VECTORS TO PROPER SPHERE OF INFLUENCE

INPUT: $MPAC_v$ = INPUT VELOCITY VECTOR
$PLOD_v$ = INPUT POSITION VECTOR
OUTPUT: $MPAC_v$ = VELOCITY VECTOR
$PLOD_v$ = POSITION VECTOR



PURPOSE: SUBROUTINE TO SCALE INPUT DOUBLE PRECISION WORD TO SPHERE VALUE IN INDEX RTX2



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	30MAY69	COMMON TARGETING SUBROUTINES INITVEL, MIDGIM PERIAPO, SELECTMU, PRECSET
PRGMR P.J.White	12 Aug 69	LUMINARY 1D
ANALST		DOCUMENT NO. FC-3760
DOCMR McDogfoot	11 AUG 69	
APPR'D		REV 3 / SHEET 10 OF 18

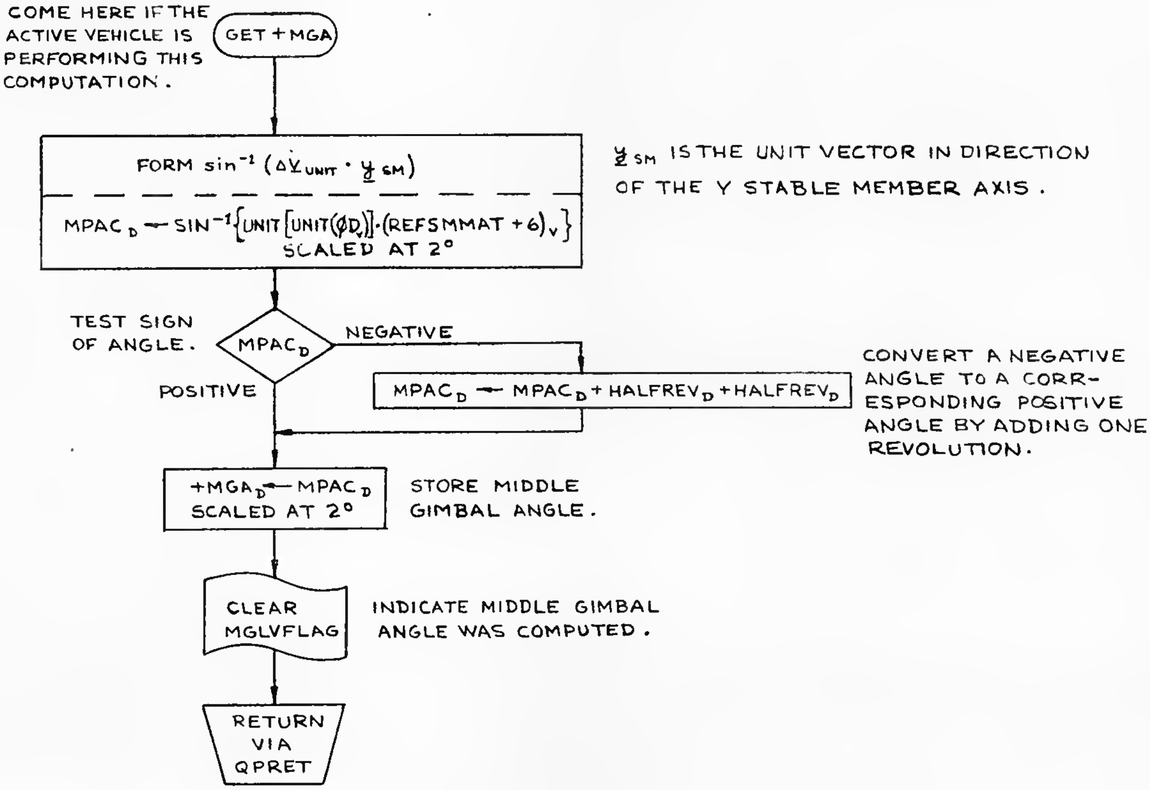
IF THE ACTIVE VEHICLE IS PERFORMING THIS COMPUTATION THIS ROUTINE COMPUTES THE POSITIVE MIDDLE GIMBAL ANGLE FOR THE ACTIVE VEHICLE ASSUMING THE X-AXIS IS ALIGNED WITH THE $\Delta \underline{V}$ IMPULSE THRUST DIRECTION. IF THE PASSIVE VEHICLE IS PERFORMING THIS COMPUTATION THIS ROUTINE TRANSFORMS THE INPUT VELOCITY VECTOR FROM INERTIAL COORDINATES TO LOCAL VERTICAL COORDINATES OF THE ACTIVE VEHICLE.

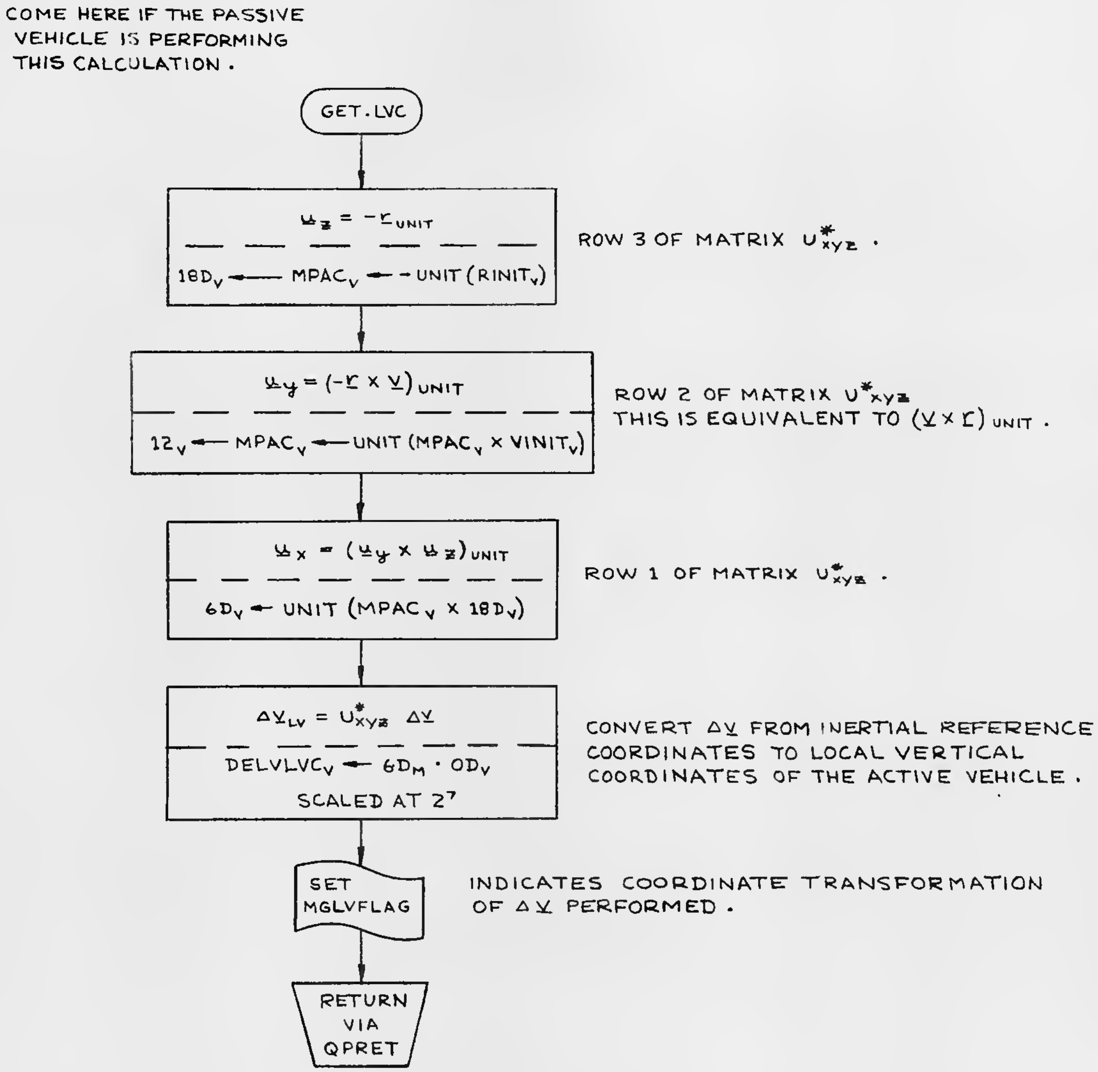
INPUT:

1) $RINIT_V$ = $\underline{r}$, RADIUS VECTOR OF ACTIVE VEHICLE, IN METERS, AT 2^{29}.
2) $VINIT_V$ = $\underline{V}$, VELOCITY VECTOR OF ACTIVE VEHICLE, IN METERS/CSEC AT 2^7.
3) OD_V = $\Delta \underline{V}$, DELTA VELOCITY VECTOR OF ACTIVE VEHICLE IN INERTIAL COORDINATES, IN METERS/CSEC, AT 2^7.

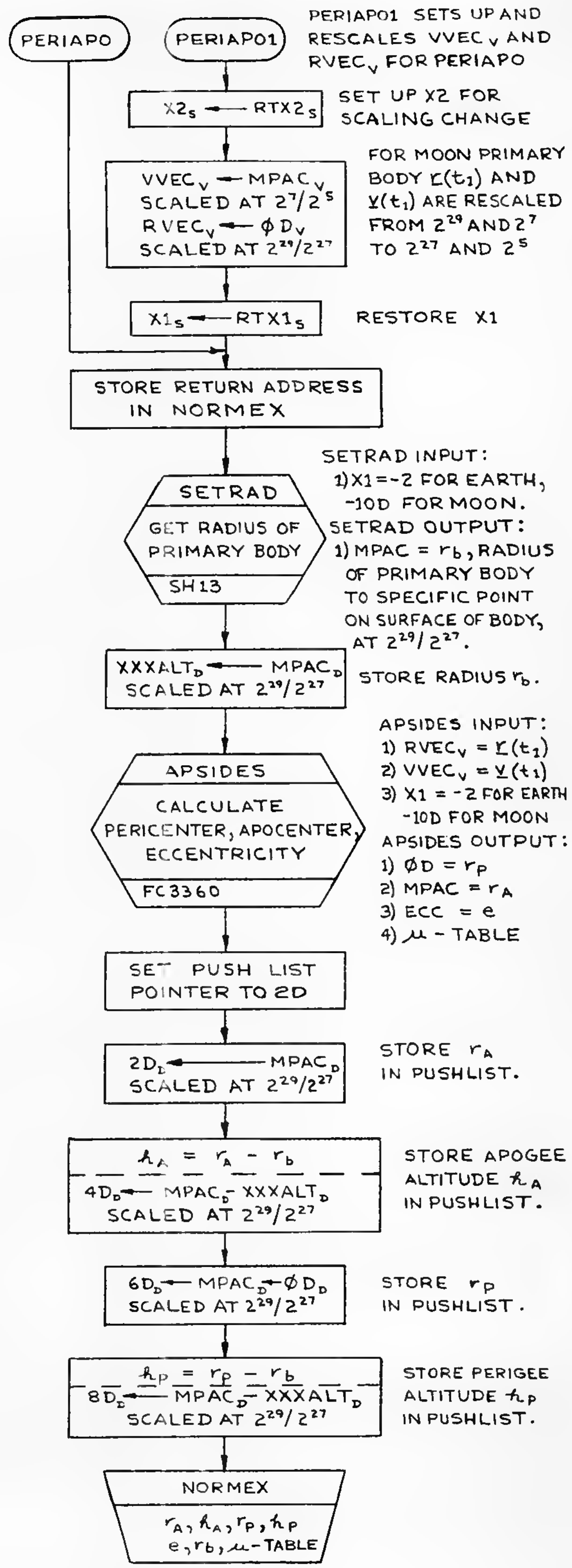
OUTPUT:

1) MGLVFLAG = A FLAG, IS CLEAR IF MIDDLE GIMBAL ANGLE WAS COMPUTED, IS SET IF DELTA VELOCITY VECTOR TRANSFORMED.
2) $+MGA_D$ = MIDDLE GIMBAL ANGLE, IN REVOLUTIONS IN RANGE 0 TO 1, AT 2^0.
3) $DELVLVC_V$ = $\Delta \underline{V}_{LV}$, DELTA VELOCITY VECTOR OF ACTIVE VEHICLE IN LOCAL VERTICAL COORDINATES, IN METERS/CSEC, AT 2^7.





MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN F. Pearson Jr.	24JUN68	COMMON TARGETING SUBROUTINES INITVEL, MIDGIM PERIAPO, SELECTMU, PRECSET
PROGMR P. White	6SEPT68	LUMINARY 1D — DOCUMENT NO. FC-3760
ANALST		
DOCMR G. A. Clark	12AUG68	
APPR'D John A. Morse	9 Sept 68	REV 3 — SHEET 12 OF 18



THIS SUBROUTINE COMPUTES THE TWO BODY APOCENTER AND PERICENTER ALTITUDES, GIVEN (1) THE POSITION AND VELOCITY VECTORS FOR A POINT ON THE TRAJECTORY, AND (2) THE PRIMARY BODY INDICATOR.

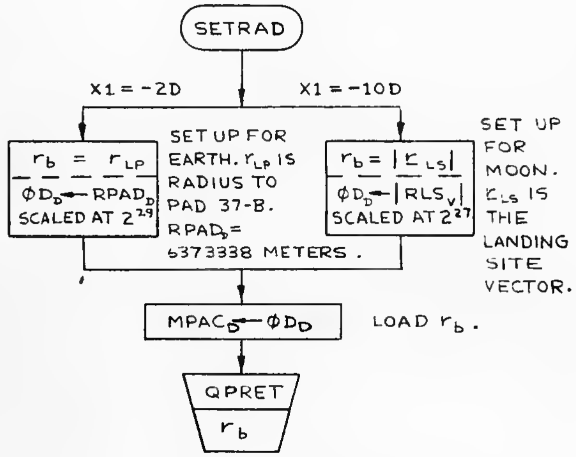
PERIAPO CALLED BY:
S30.1 (IN P30, P37), CSI (IN P32 - P35, P72 - P75), MANUPARM.

PERIAPO1 CALLED BY:
CSI (IN P32 - P35, P72 - P75), P34 - P35, P74 - P75, P38 - P39.

PERIAPO INPUT:
1) $RVEC_V = \underline{r}(t_1)$, POSITION VECTOR TO POINT ON TRAJECTORY, IN METERS, AT $2^{29}/2^{27}$.
2) $VVEC_V = \underline{v}(t_1)$, VELOCITY VECTOR TO POINT ON TRAJECTORY, IN METERS/CSEC AT $2^7/2^5$.
3) $X1_S$ = PRIMARY BODY INDICATOR IN INDEX REGISTER 1, -2 FOR EARTH, -10D FOR MOON.

PERIAPO1 INPUT:
1) $ØD_V = \underline{r}(t_1)$, IN METERS, 2^{29}.
2) $MPAC_V = \underline{v}(t_1)$, IN METERS / CSEC, AT 2^7.
3) $RTX1_S$ = PRIMARY BODY INDICATOR, IS -2 FOR EARTH, -10D FOR MOON.
4) $RTX2_S$ = VALVE USED FOR RESCALING $\underline{r}(t_1)$ AND $\underline{v}(t_1)$ FOR OFF-NOMINAL SCALING, IS 0 FOR EARTH, 2 FOR MOON.

OUTPUT:
1) $2D_D = r_A$, RADIUS OF APOCENTER, IN METERS, AT $2^{29}/2^{27}$.
2) $4D_D = h_A$, APOCENTER ALTITUDE, IN METERS, AT $2^{29}/2^{27}$.
3) $6D_D = r_P$, RADIUS OF PERICENTER, IN METERS, AT $2^{29}/2^{27}$.
4) $8D_D = h_P$, PERICENTER ALTITUDE, IN METERS, AT $2^{29}/2^{27}$.
5) $ECC_D = e$, ECCENTRICITY, AT 2^3.
6) $XXXALT_D = r_b$, RADIUS OF PRIMARY BODY, IN METERS, AT $2^{29}/2^{27}$.
7) μ - TABLE FOR PRIMARY BODY.
8) PUSH LIST POINTER AT 10D.



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN F. Pearson Jr.	21MAY68	COMMON TARGETING SUBROUTINES INITVEL, MIDGIM ~~PERIAPO, SELECTMU, PRECSET~~
PROGR B White	6SEPT68	LUMINARY 1D — DOCUMENT NO. FC-3760
ANALST		
DOCMN G. A. Black	12JUL68	
APPR'D John A. Morse	9Sept68	REV 3 — SHEET 13 OF 18

THIS ROUTINE SETS UP VALUES OF μ AND $1/\sqrt{\mu}$ APPROPRIATE FOR EITHER EARTH OR MOON AS PRIMARY BODY AND DEPENDS ON CONDITION OF CMOONFLG.

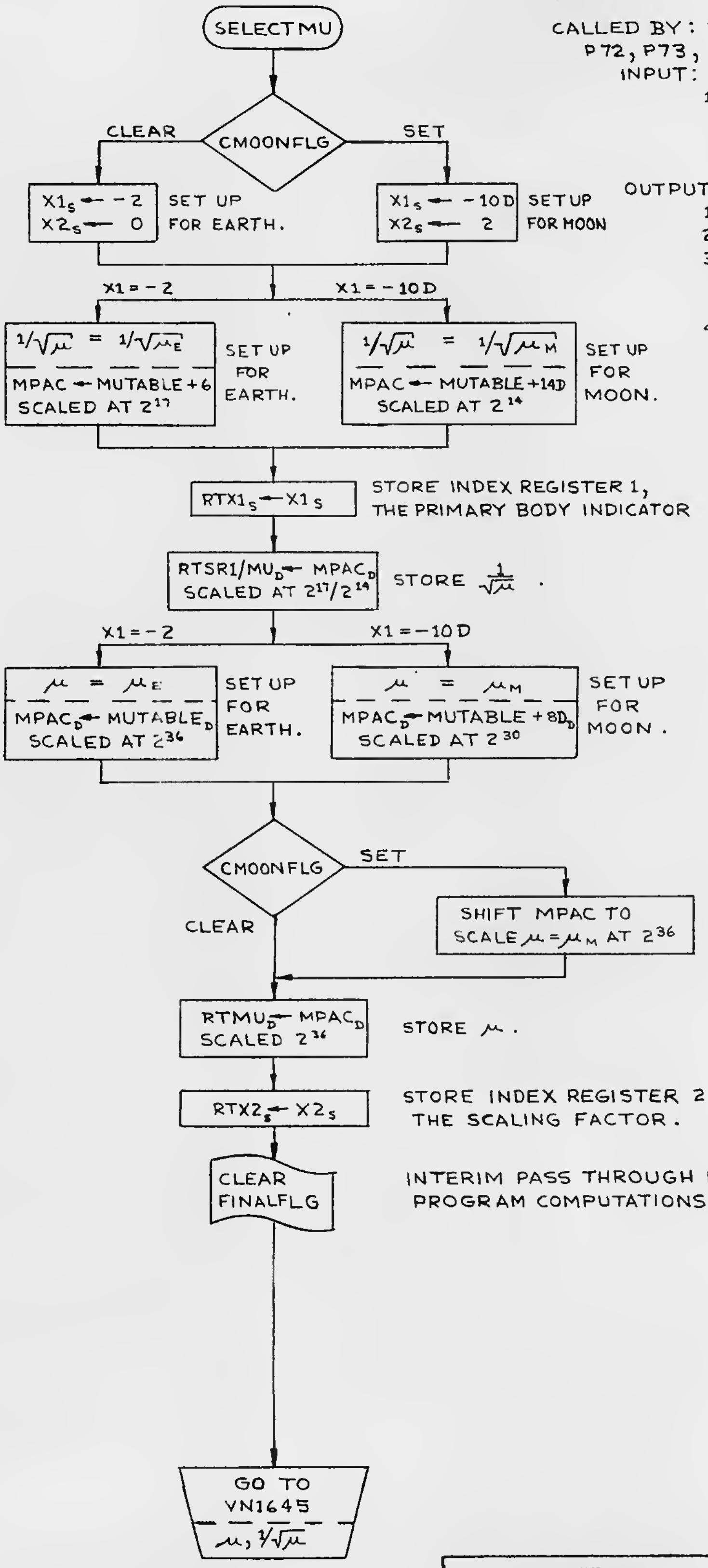
CALLED BY: P32, P33, P34, P35, P38, P39, P72, P73, P74, P75, P78, P79.

INPUT:

1) CMOONFLG = PERMANENT CSM STATE FLAG, IS CLEAR FOR EARTH PRIMARY BODY, IS SET FOR MOON.

OUTPUT:

1) $RTMU_D = \mu$, AT 2^{36}.
2) $RTSR1/MU_D = 1/\sqrt{\mu}$, AT $2^{17}/2^{14}$.
3) $RTX1_S$ = PRIMARY BODY INDICATOR, IS -2 FOR EARTH, -10D FOR MOON.
4) $RTX2_S$ = SCALING FACTOR FOR NOMINAL/OFF-NOMINAL DATA, IS 0 FOR NOMINAL (EARTH), IS 2 FOR OFF-NOMINAL (MOON).



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	F. Peavor Jr.	20 MAY 68	COMMON TARGETING SUBROUTINES INITVEL, MIDGIM PERIAPO, SELECTMU, PRECSET
PRGMR	P. White	6 SEPT 68	LUMINARY 1D — DOCUMENT NO. FC-3760
ANALST			
DOCMR	G. R. Colgate	12 JUL 68	
APPR'D	John A. Moore	9 Sept. 68	REV 3 — SHEET 14 OF 18

THIS ROUTINE PERFORMS A PRECISION UPDATE OF THE ACTIVE AND PASSIVE VEHICLES TO A SPECIFIED TIME.

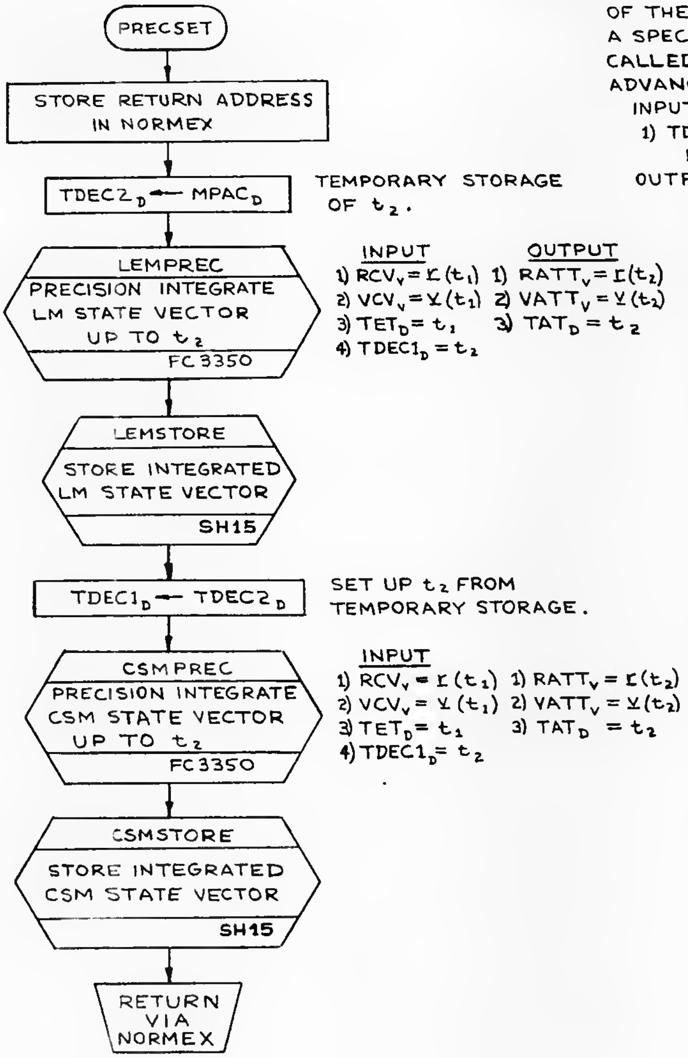
CALLED BY: P34, P35, P39, PREC/TT, ADVANCE

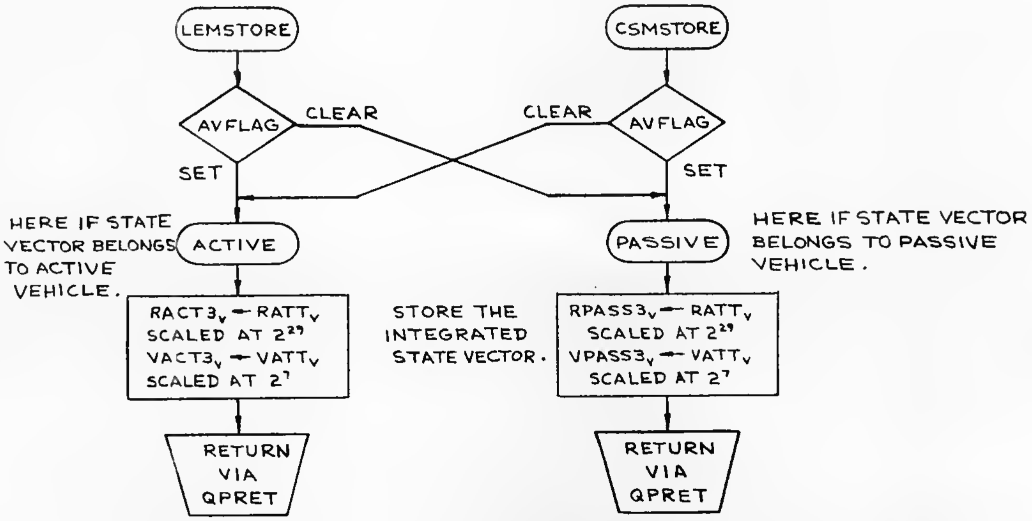
INPUT:

1) $TDEC1_D = MPAC_D = t_2$, TIME TO INTEGRATE TO, IN CSEC AT 2^{28}.

OUTPUT:

1) $RACT3_V = \underline{r}(t_2)$, POSITION VECTOR OF ACTIVE VEHICLE AT t_2, IN METERS, AT 2^{29}.
2) $VACT3_V = \underline{v}(t_2)$, VELOCITY VECTOR OF ACTIVE VEHICLE AT t_2, IN METERS/CSEC, AT 2^7.
3) $RPASS3_V = \underline{r}(t_2)$, POSITION VECTOR OF PASSIVE VEHICLE AT t_2, IN METERS, AT 2^{29}.
4) $VPASS3_V = \underline{v}(t_2)$, VELOCITY VECTOR OF PASSIVE VEHICLE AT t_2, IN METERS/CSEC, AT 2^7.





MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN F. Peavoy Jr. 26JUN68	COMMON TARGETING SUBROUTINES INITVEL, MIDGIM ~~PERIAPO, SELECTMU, PRECSET~~
PRGMR P. White 6SEPT68	LUMINARY 1D — DOCUMENT NO. FC-3760
ANALST	
DOCMR G. P. Colack 12JUL68	
APPR'D John A. Moore 9Sept.68	REV 3 — SHEET 15 OF 18

GENERAL INFORMATION

SUBROUTINES CALLED ON OTHER CHARTS

NAME	FLOW CHART NUMBER	DESCRIPTION	WHERE CALLED
LAMBERT	FC1360	CALCULATE INITIAL AND FINAL VELOCITIES GIVEN THE INITIAL AND FINAL POSITIONS AND TIME	INITVEL (SH 6)
INTSTALL	FC1350	RESERVE INTEGRATION ROUTINE FOR CALLER	INITVEL (SH 6)
INTEGRVS	FC1350	PERFORM PRECISION INTEGRATION ON STATE VECTOR	INITVEL (SH 7)
APSIDES	FC1360	COMPUTE PERICENTER, APOCENTER, ECCENTRICITY	FERIAPO (SH 13)
LEMPREC	FC1350	PERFORM PRECISION INTEGRATION ON LM STATE VECTOR	PRECSET (SH 15)
CSMPREC	FC1350	PERFORM PRECISION INTEGRATION ON CSM STATE VECTOR	PRECSET (SH 15)

FLAGS USED

NAME	MEANING		WHERE SET	WHERE CLEARED	WHERE TESTED
	SET	CLEAR			
MOONFLAG	MOON IS SPHERE OF INFLUENCE	EARTH IS SPHERE OF INFLUENCE	INITVEL (SH 7)	INITVEL (SH 7)	
GUESSW (f_1)	NO STARTING VALUE FOR ITERATION	STARTING VALUE FOR ITERATION EXISTS	INITVEL (SH 4)	INITVEL (SH 6)	
FINALFLG	LAST PASS THROUGH RENDEZVOUS COMPUTATIONS	INTERIM PASS THROUGH RENDEZVOUS COMPUTATIONS		SELECTMU (SH 14)	
AVFLAG	LM IS ACTIVE VEHICLE	CSM IS ACTIVE VEHICLE			PRECSET (SH 15)
INTYPFLG	CONIC INTEGRATION	ENCKE INTEGRATION		INITVEL (SH 7)	
MGLVFLAG	LOCAL VERTICAL COORDINATES COMPUTED	MIDDLE GIMBAL ANGLE COMPUTED	MIDGIM (SH 12)	MIDGIM (SH 11)	
NORMSW (f_2)	UNIT NORMAL INPUT TO LAMBERT	LAMBERT COMPUTES ITS OWN UNIT NORMAL	INITVEL (SH 5)	INITVEL (SH 4)	

AVEGFLAG	AVERAGEG (SERVICER) DESIRED	AVERAGEG (SERVICER) NOT DESIRED			INITVEL (SH 6)
CMOONFLG	CSM STATE VECTOR IN LUNAR SPHERE	CSM STATE VECTOR NOT IN LUNAR SPHERE			SELECTMU (SH 14)
GEOMSGN$_S$ (S_G)	IS PLUS IF TRUE ANOMALY LESS THAN 180^o	IS MINUS IF TRUE ANOMALY GREATER THAN 180^o	INITVEL (SH 5)		
VTARGTAG$_S$	IF NON-ZERO $\underline{v}_T(t_2)$ IS NOT CALCULATED	IF ZERO $\underline{v}_T(t_2)$ IS CALCULATED	INITVEL (SH 4)		INITVEL (SH 6, SH 7)
GUESSW (f_1)	NO STARTING VALUE FOR ITERATION	STARTING VALUE FOR ITERATION EXISTS	INITVEL (SH 4)	INITVEL (SH 6)	

VARIABLES USED (BOTH PUSH LIST AND ERASABLE)

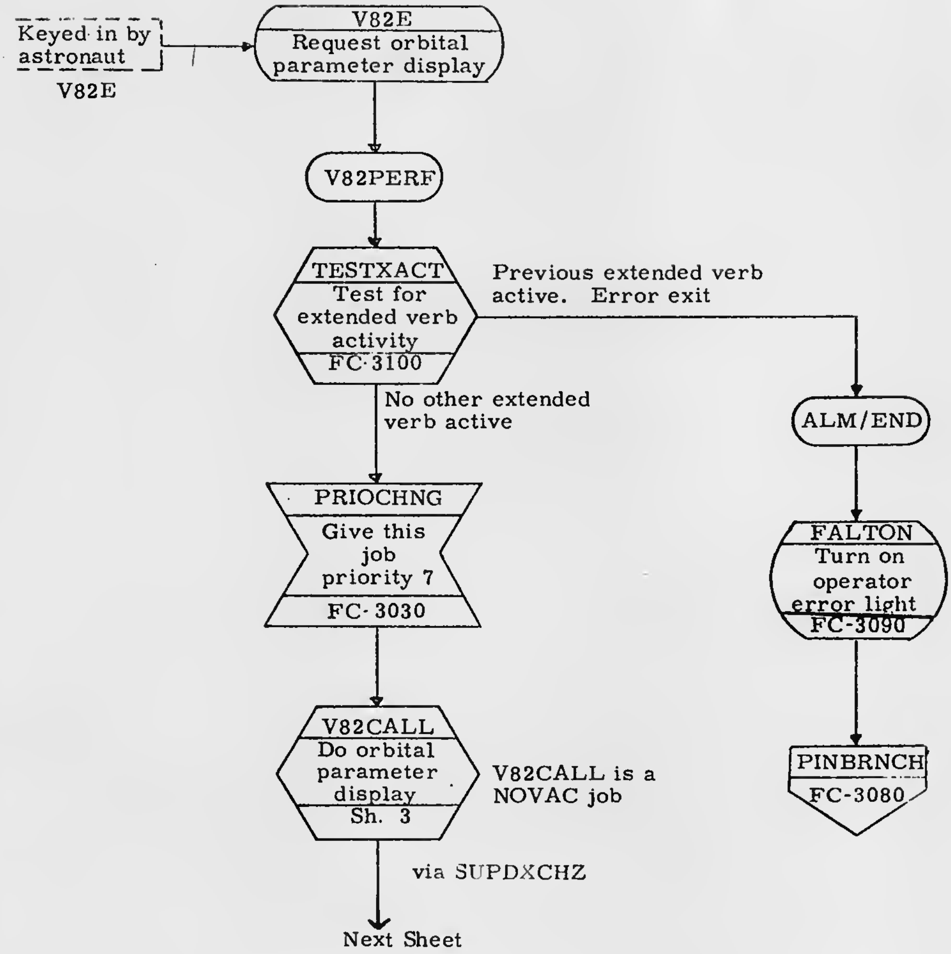
NAME	MEANING	SCALING	LOCATION
ITERCTR$_S$	i_{MAX}, LOOP CONTROL VALUE FOR LAMBERT ROUTINE	2^{14}	22D
TDEC1$_D$	t_2, TIME TO INTEGRATE TO, IN CSEC	2^{28}	32D
TET$_D$	t_1, IN CSEC	2^{28}	E3, 1516
RCV$_V$	$\underline{r}(t_1)$, IN METERS	$2^{29}/2^{27}$	E3, 1534
VCV$_V$	$\underline{v}_T(t_1)$, IN METERS/CSEC	$2^7/2^5$	E3, 1542
RVEC$_V$	$\underline{r}(t)$, POSITION VECTOR, IN METERS	$2^{29}/2^{27}$	E5, 1654
R1VEC$_V$	$\underline{r}(t_1)$, IN METERS	2^{29}	E5, 1654
R2VEC$_V$	$\underline{r}(t_2)$, IN METERS	$2^{29}/2^{27}$	E5, 1662
TDESIRED$_D$	t_D, IN CSEC	2^{28}	E5, 1670
UN$_V$	$\underline{h}$	2^1	E5, 1673
VTARGTAG$_s$	IS THE NUMBER OF OFFSETS USED IN INITVEL ROUTINE	2^{14}	E5, 1701
VTARGET$_v$	$\underline{v}_T(t_2)$	$2^7/2^5$	E5, 1702
VVEC$_v$	$\underline{v}(t)$, VELOCITY VECTOR, IN METERS/CSEC	$2^7/2^5$	E5, 1743
NORMEX$_s$	RETURN ADDRESS OF PERIAPO AND PRECSET		E7, 1450
RTRN$_s$	RETURN ADDRESS OF INITVEL		E7, 1452
TDEC2$_D$	TEMPORARY STORAGE OF TDEC1	2^{28}	E7, 1560
X1INPUT$_s$	TEMPORARY STORAGE OF X1		E7, 1564
ITCTR$_s$	ITERATION COUNTER	2^{14}	E7, 1603
COZY4$_D$	COS (ϵ)	2^2	E7, 1653

CONSTANTS USED

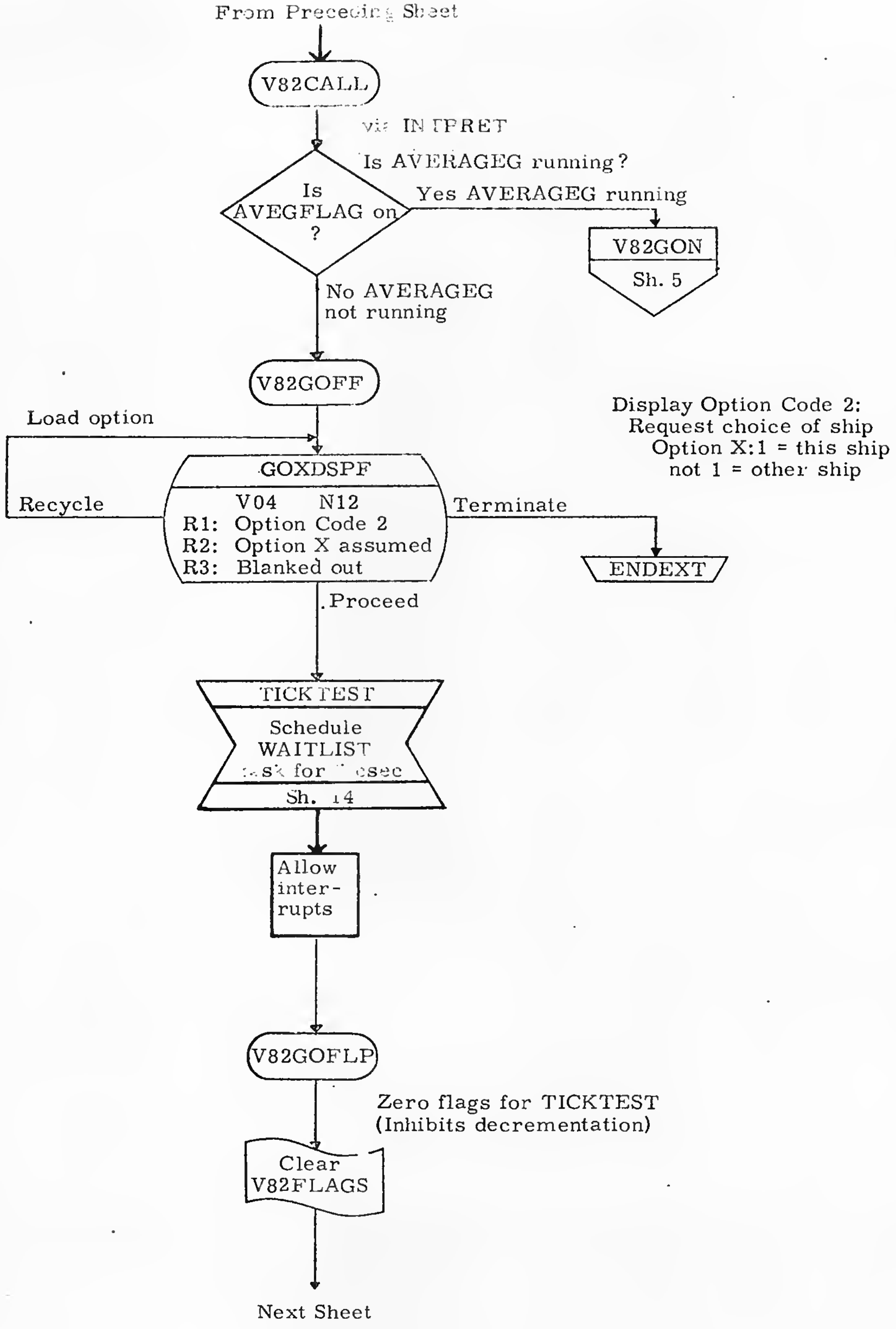
NAME	PHYSICAL MEANING	SCALING	COMPUTER VALUE
$HALFREV_D$	0.5 REVOLUTIONS	2^0	1.0 B-1
$EPSFOUR_D$	15/360 REVOLUTIONS (EQUALS 15^o)	2^0	0.0416666666
$RPAD_D$	STANDARD RADIUS OF PAD 37-B IN METERS, EQUALS 20,909,901.57 FT	2^{29}	6373338 B-29
$MUTABLE_D$	μ_E, IN $M^3/CSEC^2$	2^{36}	3.986032 E10 B-36
MUTABLE + 6D	$1/\sqrt{\mu_E}$ IN $CSEC/M^{3/2}$	2^{-17}	0.50087529 E-5 B17
MUTABLE + $8D_D$	μ_M, IN $M^3/CSEC^2$	2^{30}	4.902778 E8 B-30
MUTABLE + $14D_D$	$1/\sqrt{\mu_M}$, IN $CSEC/M^{3/2}$	2^{-14}	0.45162595 E-4 B14

ORBITAL PARAMETERS DISPLAY

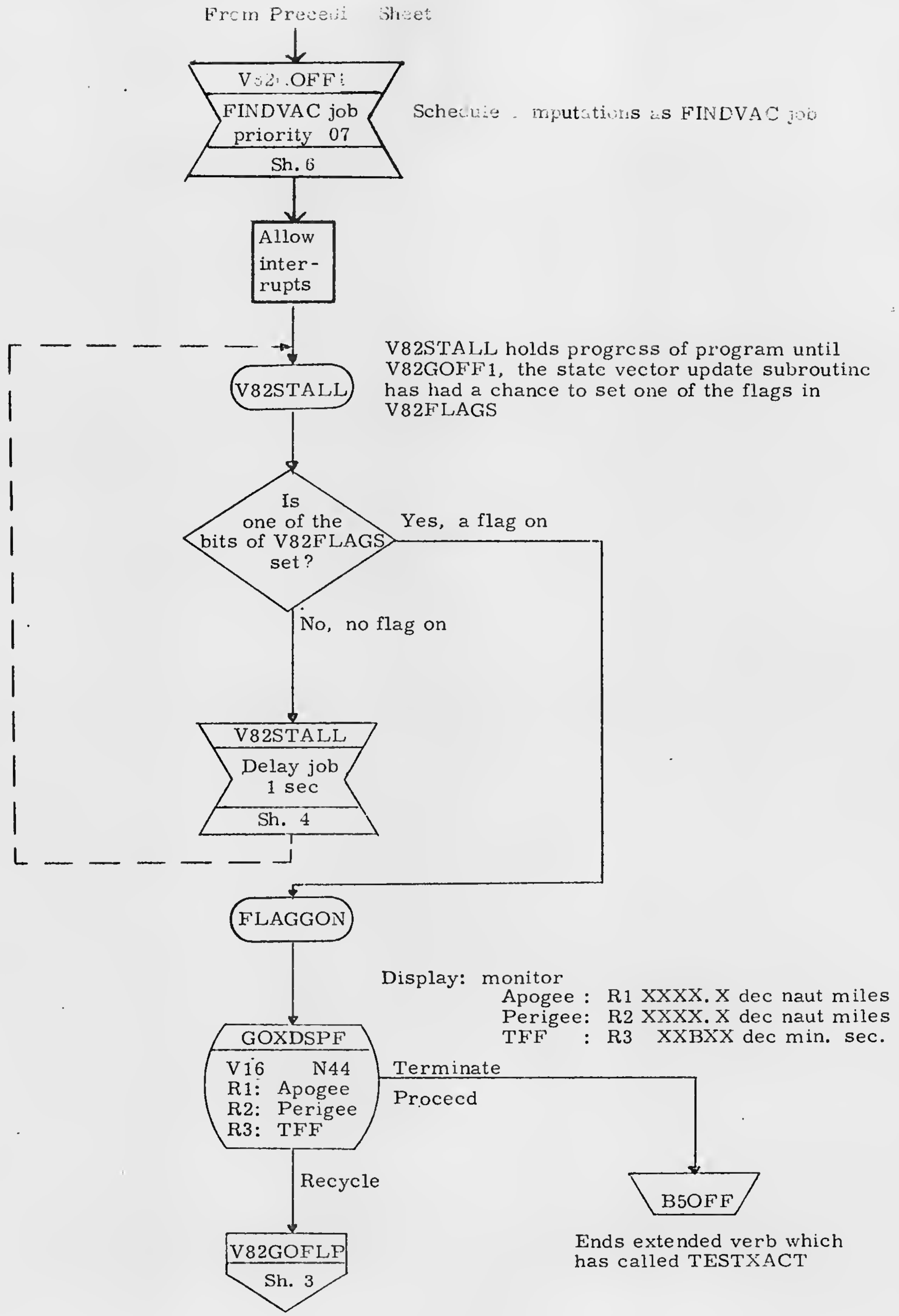
Major Subroutines and External Entry Points:



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN PRGMR ANALST DOCMR APPR'D	Orbital Parameters Display	
	LUMINARY 1D	DOCUMENT NO. FC-3770
	REV 2.	SHEET 2 OF 5



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Orbital Parameters Display	
PRGMR			DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3770
DOCMR			
APPR'D	7/29/69	REV 2	SHEET 3 OF 25



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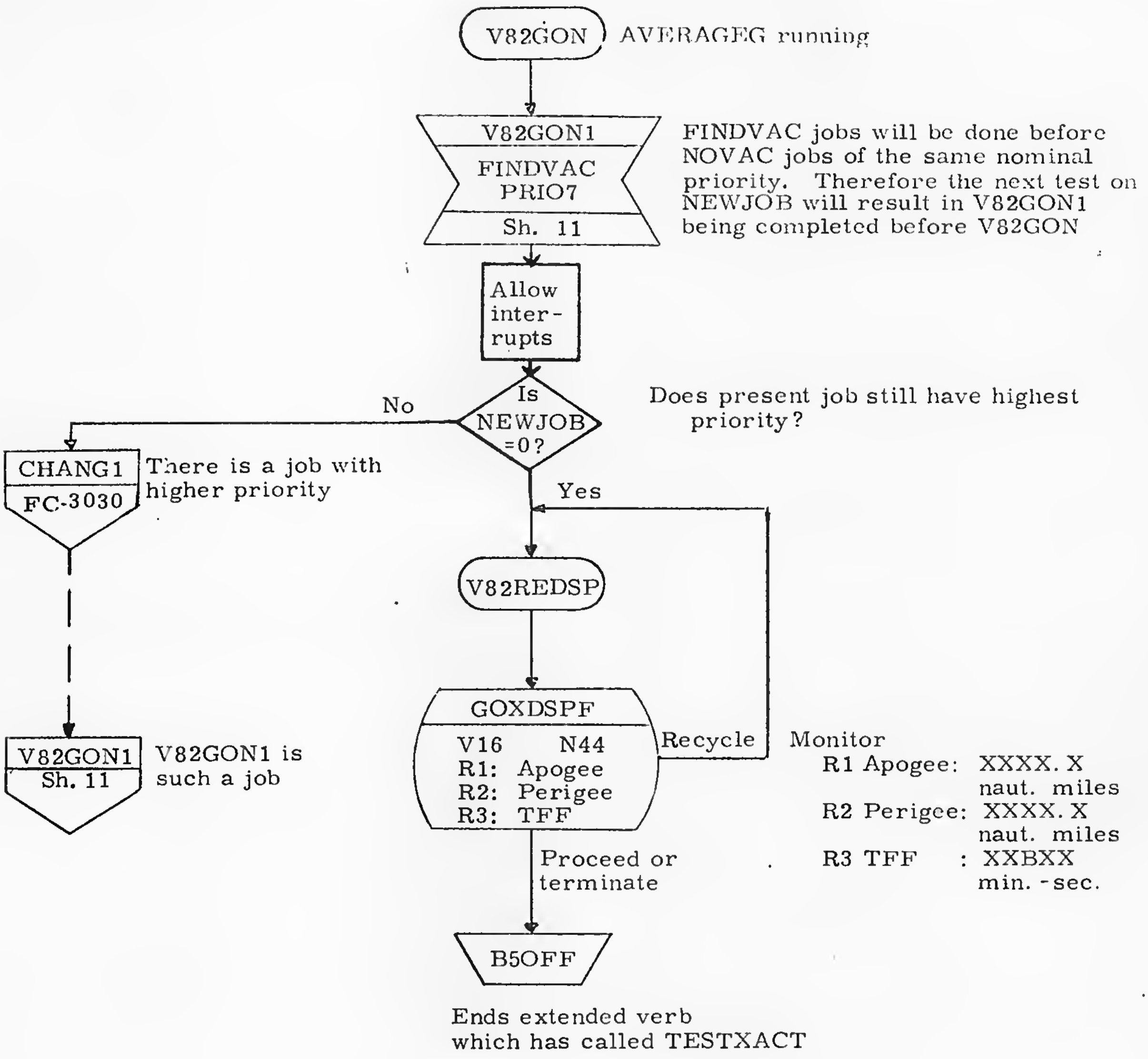
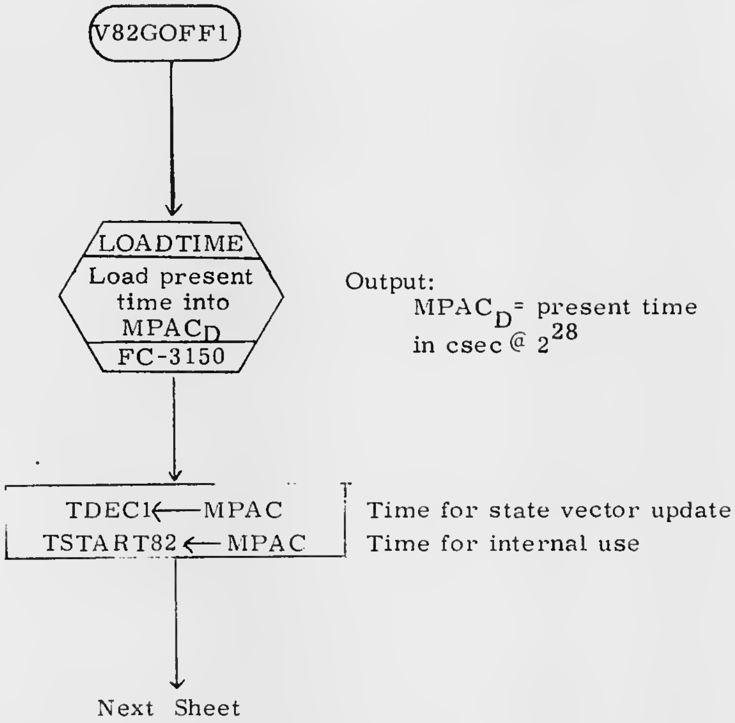
DRAWN	Orbital Parameters Display	
PRGMR	LUMINARY 1D	DOCUMENT NO. FC-3770
ANALST		
DCCMR		
APPR'D	REV 2	SHEET 4 OF 25


V82GON
AVERAGEG running
V82GON1
FINDVAC
PRIO7
Sh. 11
FINDVAC jobs will be done before NOVAC jobs of the same nominal priority. Therefore the next test on NEWJOB will result in V82GON1 being completed before V82GON
Allow inter-rupts
Is NEWJOB =0?
Does present job still have highest priority?
No
Yes
CHANG1
FC-3030
There is a job with higher priority
V82GON1
Sh. 11
V82GON1 is such a job
V82REDSP
GOXDSPF
V16 N44
R1: Apogee
R2: Perigee
R3: TFF
Recycle
Monitor
R1 Apogee: XXXX. X naut. miles
R2 Perigee: XXXX. X naut. miles
R3 TFF : XXBXX min. -sec.
Proceed or terminate
B5OFF
Ends extended verb which has called TESTXACT

V82 scheduled this FINDVAC job of priority 07



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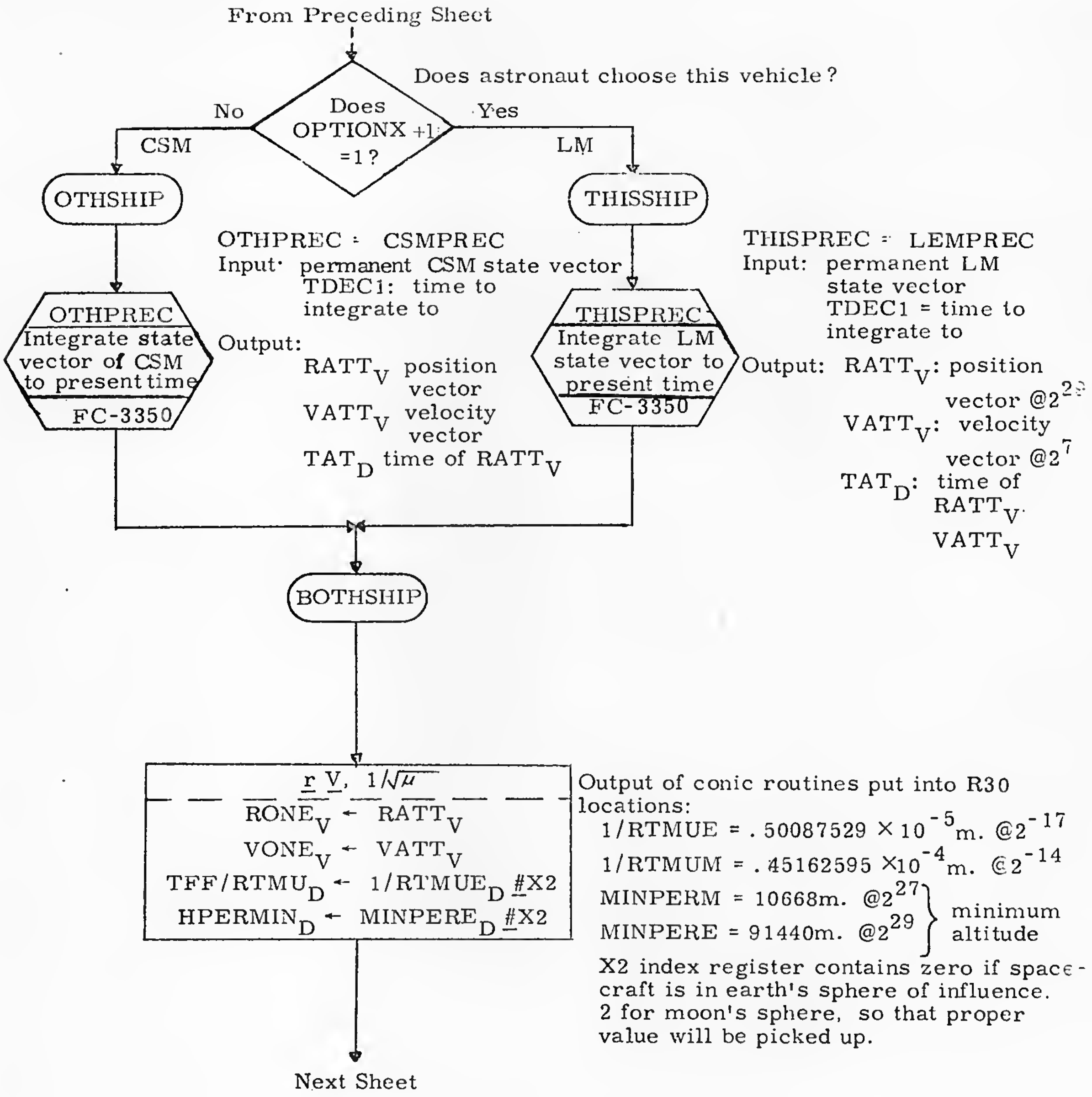
DRAWN O. Bembre	10/20/69	Orbital Parameters Display	
PRGMR T. Crocker	10/30/69	LUMINARY 1D	DOCUMENT NO. FC-3770
ANALST			
DOCMR Roberta M. Entes	10/30/69		
APPR'D Roberta M. Entes	10/30/69	REV 2	SHEET 6 OF 25



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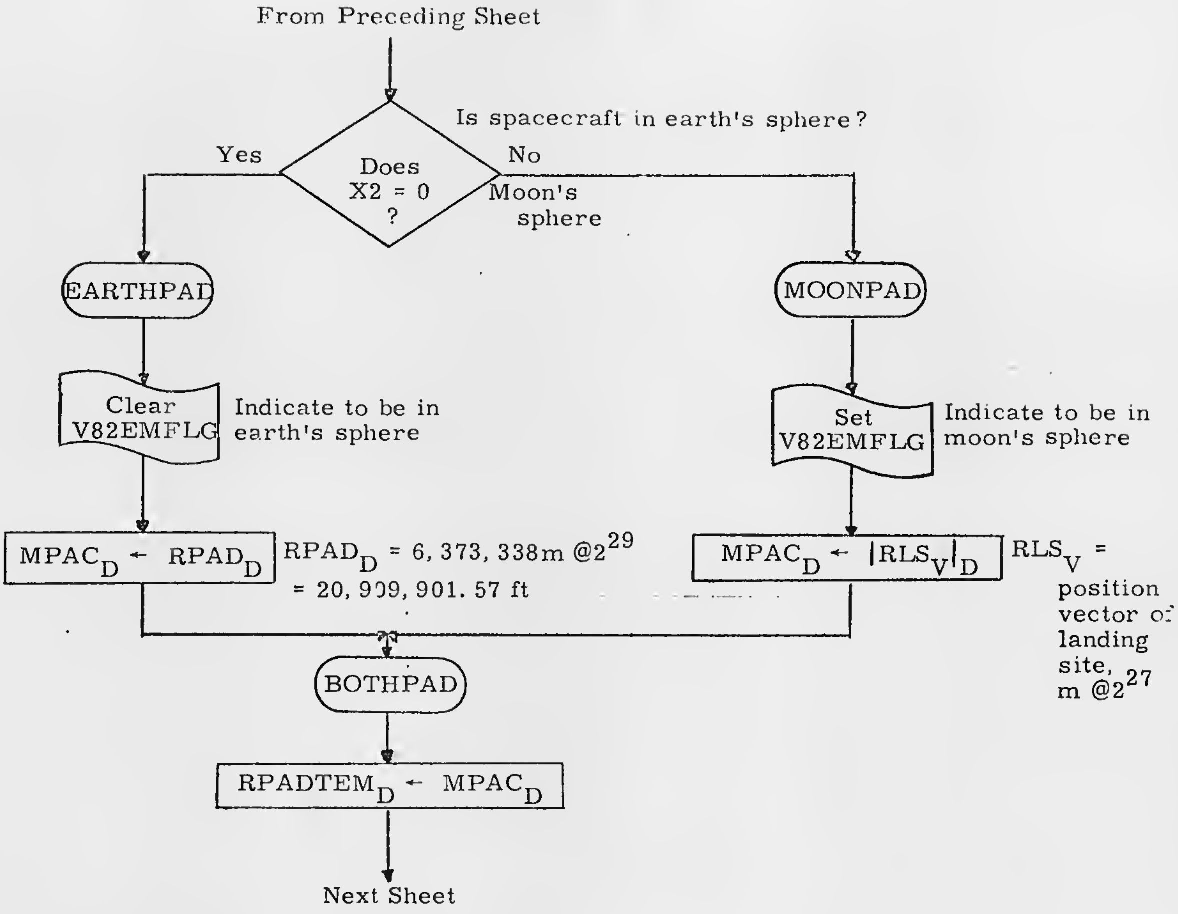
DRAWN		Orbital Parameters Display	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3770
DOCMR			
APPR'D		REV 2	SHEET 7 OF 15



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN	Orbital Parameters Display
PROGMR	
ANALST	LUMINARY 1D — DOCUMENT NO. FC-3770
DOCMR	
APPR'D	REV 2 — SHEET 8 OF 25

From Preceding Sheet

SR30.1
Calculate
$HAPOX_D$, $HPERX_D$
TFF_D, $-TPER_D$
Sh. 15

SR30.1

Input: $RONE_V$ = present position vector: meters @2^{29}

$VONE_V$ = present velocity vector: m/csec @2^{7}

V82EMFLG: Flag on = moon's sphere
Flag off = earth's sphere

$RPADTEM_D$ = radius of pad: meters @2^{29}

Output: $HAPOX_D$ = apogee altitude above pad radius: meters @2^{29}

$HPERX_D$ = perigee altitude above pad radius: meters @2^{29}

TFF_D = time of free fall: csec @ 2^{28}

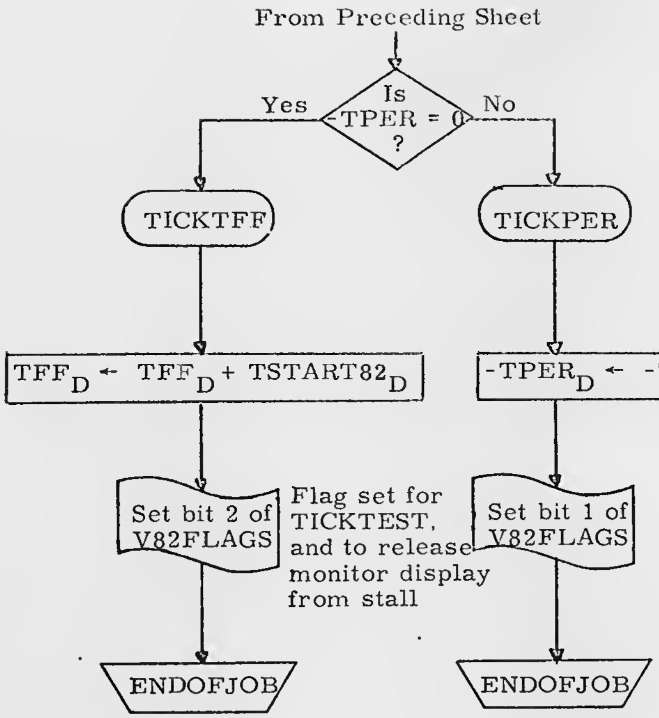
$-TPER_D$ = time to perigee: csec @2^{28}

via LOADTIME (FC-3150)

$TSTART82_D \leftarrow TIME2_D - TSTART82_D$ Time elapsed since TSTART82

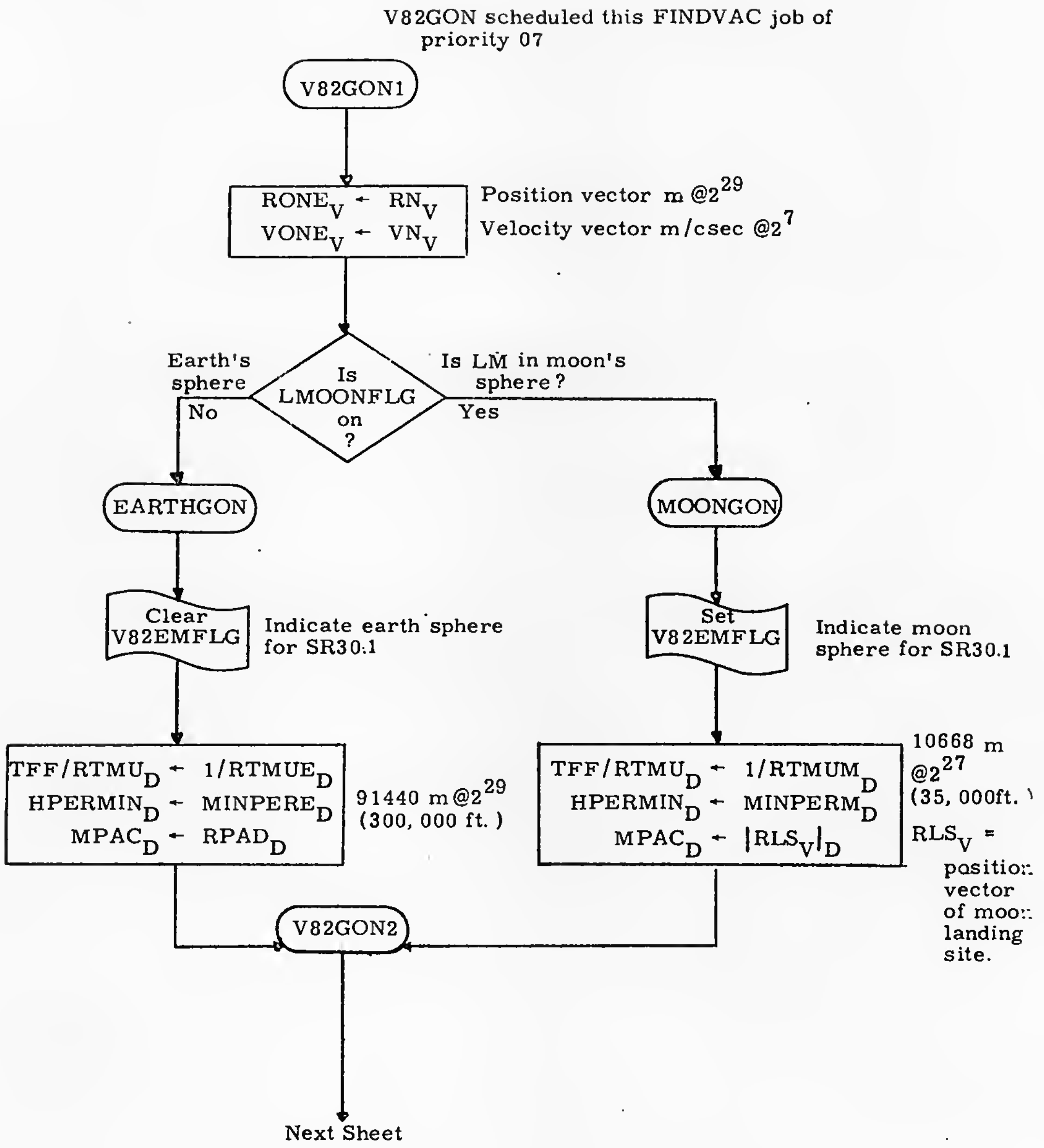
Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN U Burke	1/23/69	Orbital Parameters Display	
PRGMR I. Gocker	10/30/69	LUMINARY 1D	DOCUMENT NO. FC-3770
ANALST			
DOCMR Roberta M. Entes	10/30/69	REV 2	SHEET 9 OF 25
APPR'D Roberta M. Entes	10/30/69		

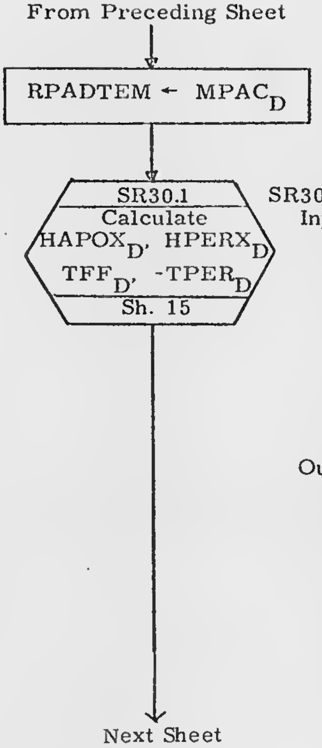


-TPER is set to zero when pericenter is above minimum. If so, TFF will be displayed as 59 min. 59 sec, and -TPER will be decremented. Note, TFF will also be displayed as 59 min. 59 sec when apocenter is below minimum pericenter, but it will then start decrementing, giving meaningless values.

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN	Orbital Parameters Display
PROGMR	LUMINARY 1D — DOCUMENT NO. FC 3770
ANALST	
DOCMR	
APPR'D	REV 2 — SHEET 10 OF 25



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN	Orbital Parameters Display
PRGMR	
ANALST	LUMINARY 1D / DOCUMENT NO. FC 3770
DOCMR	
APPR'D 8/29/69	REV 2 / SHEET 11 OF 25



SR30.1

Input:

- $RONE_V$ = position vector in meters $@2^{29}$
- $VONE_V$ = velocity vector in meters/csec $@2^{7}$
- RPADTEM = pad radius in meters $@2^{29}$
- V82EMFLG on = moon. off = earth

Output:

- $HPERX_D$ perigee height above pad radius $@2^{29}$
- $HAPOX_D$ apogee height above pad radius $@2^{29}$
- $\left.\begin{array}{l} TFF_D \text{ time of freefall} \\ -TPER_D \text{ time to perigee} \end{array}\right\}$ csec $@2^{28}$

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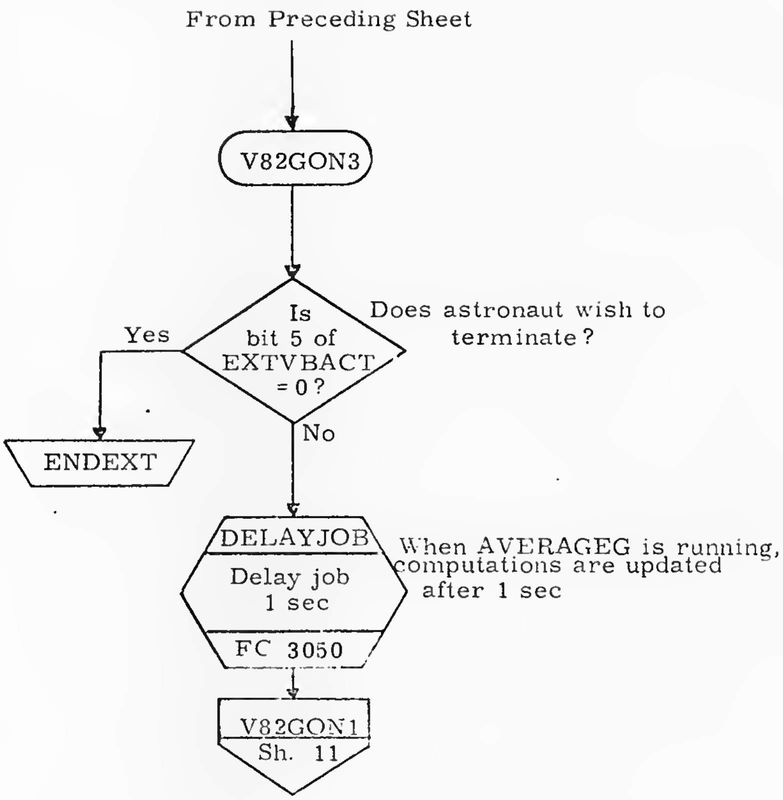
DRAWN D. Rinke	10/7/69	Orbital Parameters Display	
PRGMR T. Crocker	10/30/69		DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3770
DOCMR Roberta M. Enter	10/30/69		
APPR'D Roberta M. Enter	10/30/69	REV 2	SHEET 12 OF 25



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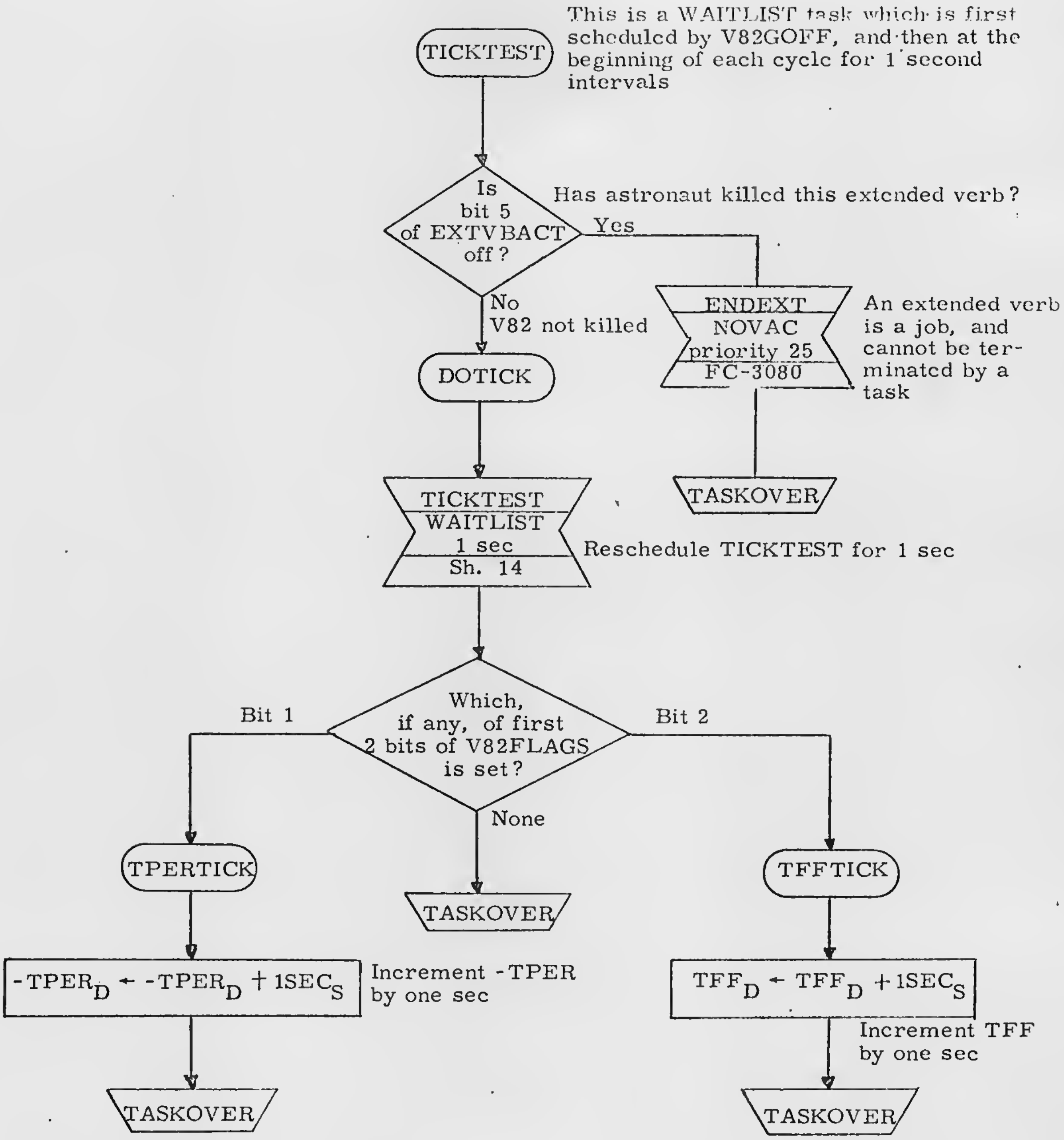
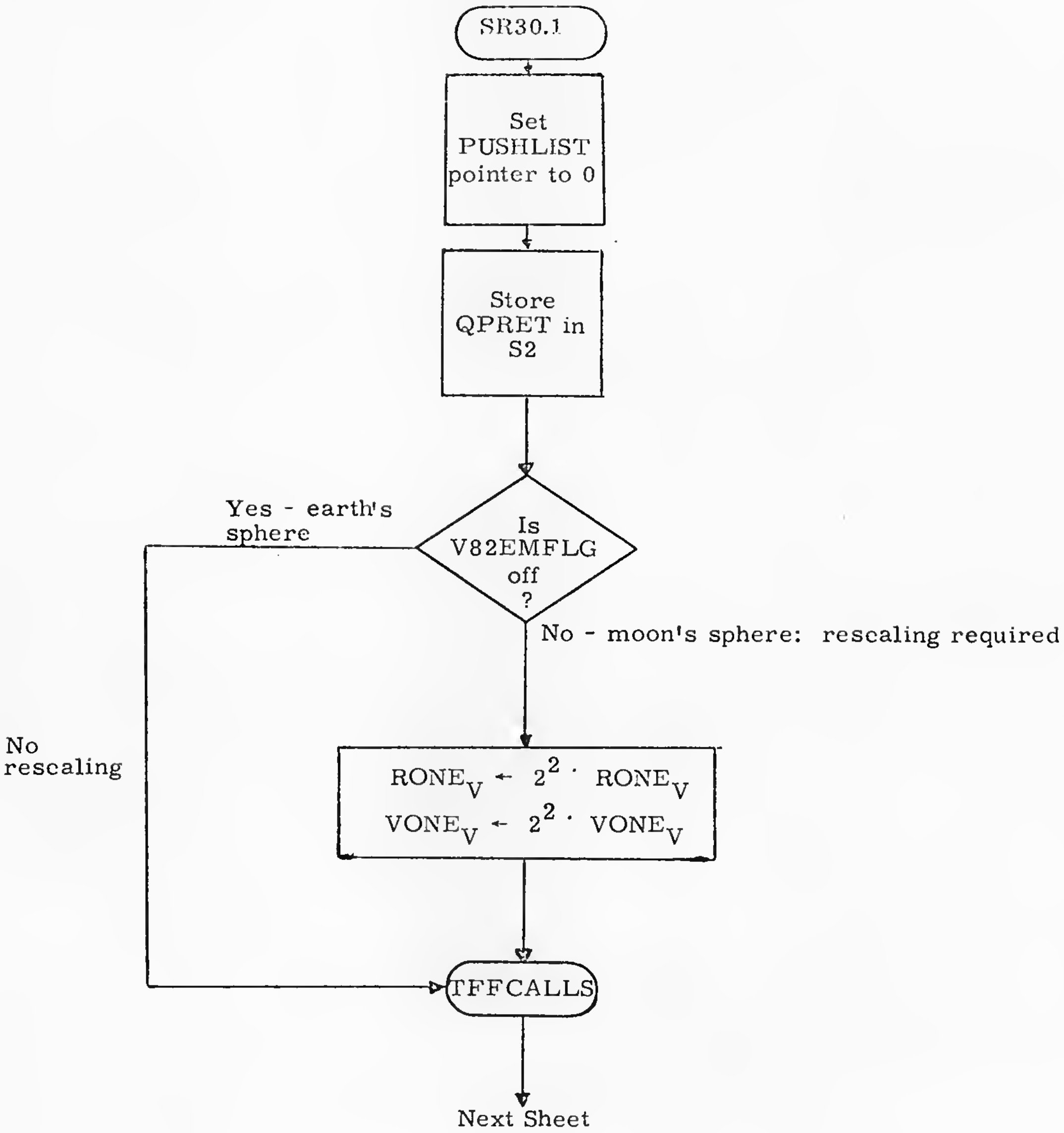
DRAWN B. Burke	10/20/65	Orbital Parameters Display	
PRGMR T. Crocker	10/30/69		DOCUMENT NO.
ANALST			
DOCMR Roberta M. Entes	10/30/69	LUMINARY 1D	FC-3770
APPR'D Roberta M. Entes	10/30/69	REV 2	SHEET 13 OF 25



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN PRGMR ANALST DOCMR APPR'D	Orbital Parameters Display
	LUMINARY 1D — DOCUMENT NO. FC-3770
	REV 2 — SHEET 14 OF 25



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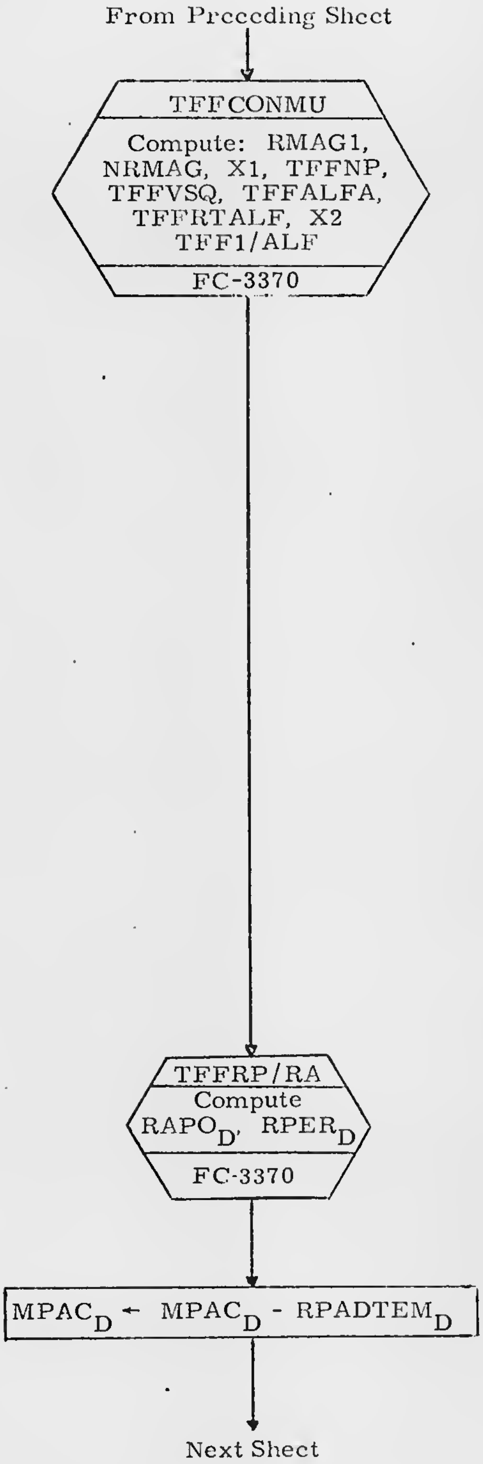
DRAWN	Orbital Parameters Display	
PROGMR		
ANALST	LUMINARY 1D	DOCUMENT NO. FC-3770
DOCMR		
APPR'D	REV 2	SHEET 15 of 25



TFFCONMU:

Input:

$RONE_V$ = position vector in meters E@ 2^{29} M@2^{27}

$VONE_V$ = velocity vector in m/csec E@ 2^7 M@2^5

TFF/RTMU = $1\sqrt{\mu}$ E@2^{-17} M@2^{-14}

Output:

$RMAG1_D$ = radius at time of RONE in meters E@2^{29}, M@2^{27}

$NRMAG_D$ = normalized RMAG, nrom count in X1 meters E@2^{29-NR} M@2^{27-NR}

NR = -X1 = -norm count for NRMAG

$TFFNP_D$: semilatus rectum, weighed by NR: meters E@2^{38-2NR} M@2^{36-2NR}

$TFFVSQ_D$: $\frac{V}{\sqrt{\mu}} \frac{V}{\sqrt{\mu}}$ present velocity, normalized 1/meters E@2^{-20} M@2^{-18}

$TFFALFA_D$: α weighted by NR, in 1/meters E@2^{-26+NR} M@2^{-24+NR}

$TFFRTALF_D$: $\sqrt{\alpha}$ normalized E@2^{-10-NA} M@2^{-9-NA}

X2 = -NA, norm count for $\sqrt{\alpha}$

$TFF1/ALF_D$ = signed, semi-major axis weighted by NA. In meters E@$2^{+22+2NA}$ M@2^{20+2NA}M

$VONE'_V$ = VONE·TFF/RTMU in 1/(M 1/2) @$2^{-10}/2^{-9}$

TFFRP/RA:

Input:

$TFFALFA_D$ = α = (semi-major axis)$^{-1}$ in meters^{-1} @$2^{-26+NR}/2^{-24+NR}$

$TFFNP_D$ = semi-latus rectum in meters @$2^{38-2NR}/2^{36-2NR}$ X1, X2 set by TFFCONMU

Output:

$RPER_D$ = perigee radius in meters @$2^{29}/2^{27}$

$RAPO_D$ = apogee radius in meters @$2^{29}/2^{27}$

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DRAWN [illegible]	Orbital Parameter Display
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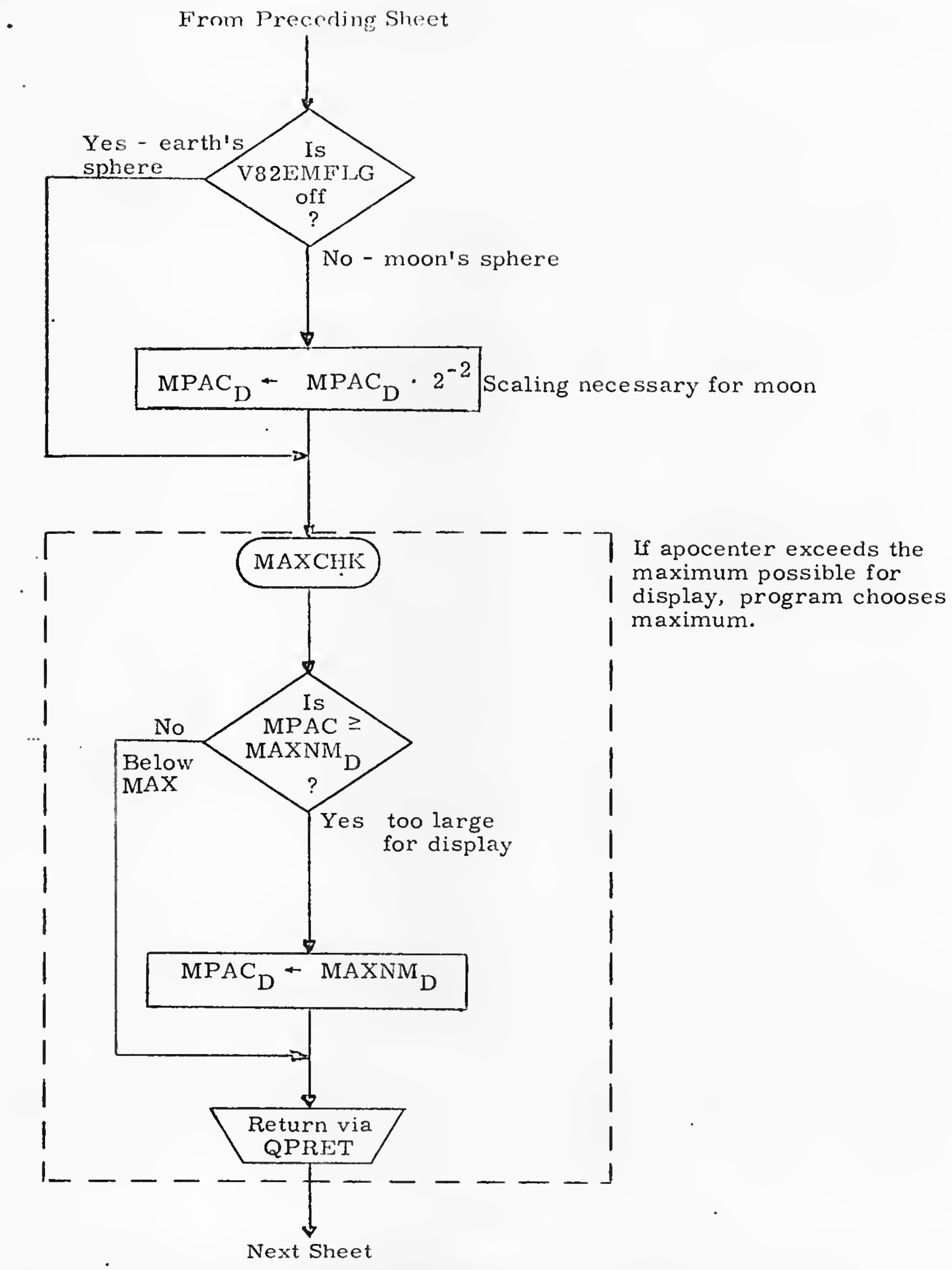
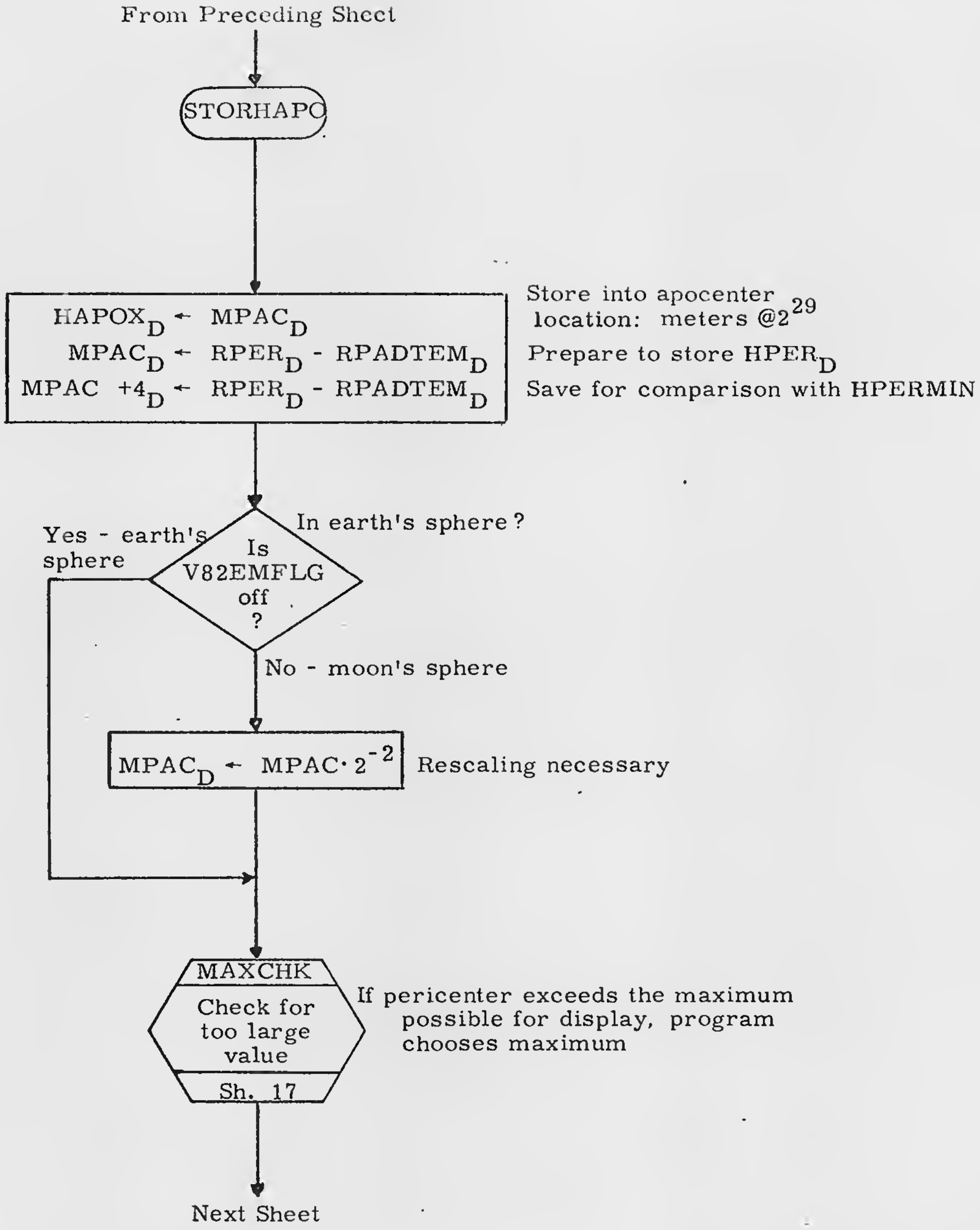
ANALST	
DOCMR [illegible]	
APPR'D [illegible]	REV 2 — SHEET 10 OF 25



From Preceding Sheet
Is V82EMFLG off ?
Yes - earth's sphere
No - moon's sphere
$MPAC_D \leftarrow MPAC_D \cdot 2^{-2}$
Scaling necessary for moon
MAXCHK
If apocenter exceeds the maximum possible for display, program chooses maximum.
Is $MPAC \geq MAXNM_D$?
No
Below MAX
Yes too large for display
$MPAC_D \leftarrow MAXNM_D$
Return via QPRET
Next Sheet



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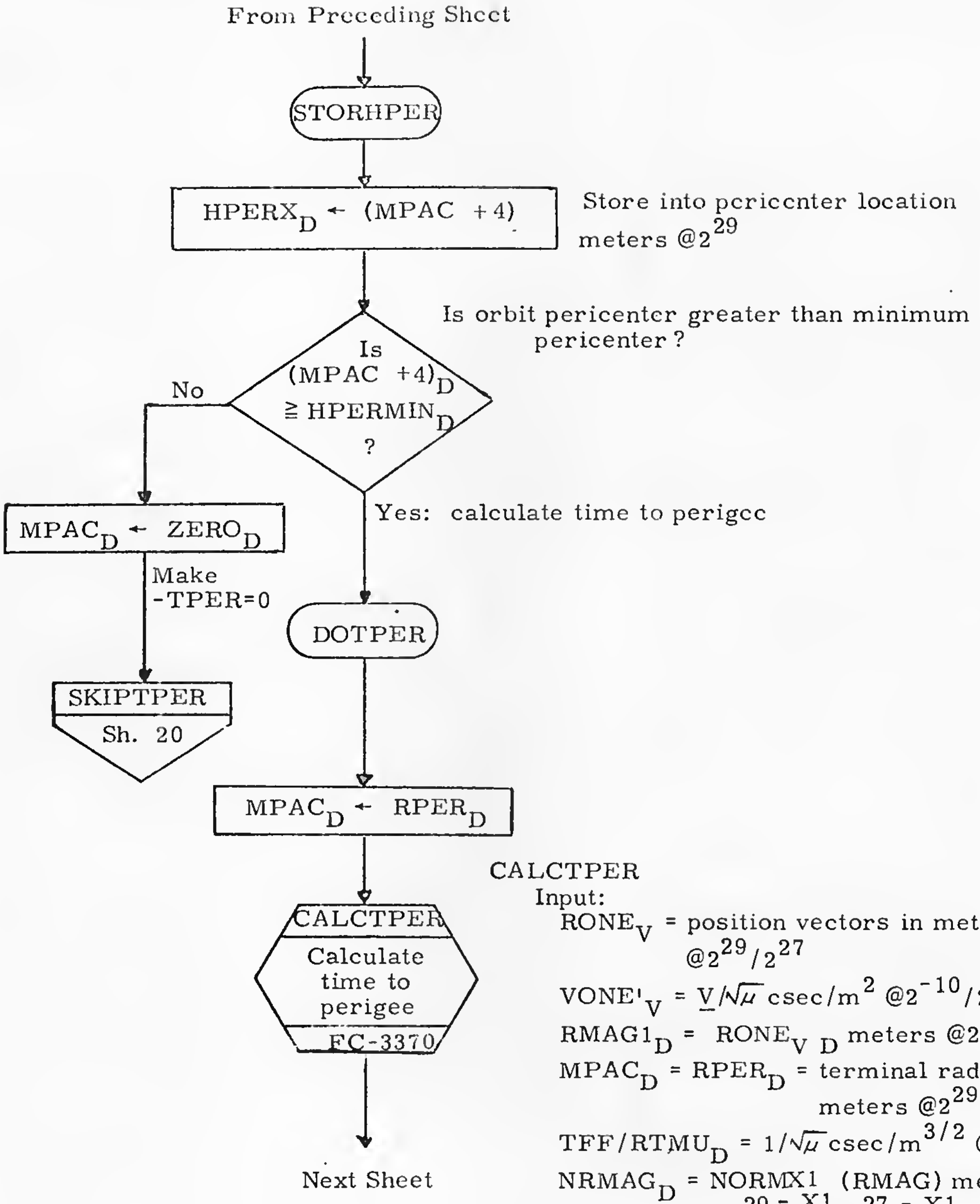
DRAWN [illegible]	Orbital Parameters Display
PROGMR [illegible]	LUMINARY 1D / DOCUMENT NO. FC-3770
ANALST	
DOCMR [illegible]	
APPR'D [illegible]	REV 2 / SHEET 18 OF 25



CALCTPER

Input:

$RONE_V$ = position vectors in meters $@2^{29}/2^{27}$

$VONE'_V = \underline{V}/\sqrt{\mu}$ csec/m^2 $@2^{-10}/2^{-9}$

$RMAG1_D = |RONE_V|_D$ meters $@2^{29}/2^{27}$

$MPAC_D = RPER_D$ = terminal radius length, meters $@2^{29}/2^{27}$

$TFF/RTMU_D = 1/\sqrt{\mu}$ csec/m$^{3/2}$ $@2^{-17}/2^{-14}$

$NRMAG_D$ = NORMX1 (RMAG) meters $@2^{29-X1}/2^{27-X1}$

X1 = Norm factor for RMAG

$TFFNP_D$ = semilatus rectum meters $@2^{38-2X}/2^{36-2X}$

TFFALFA = α meters $@2^{-26+X1}/2^{-24+X1}$

TFFRTALF = $\sqrt{\alpha}$ meters$^{1/2}$ $@2^{10-X2}/2^{9-X2}$

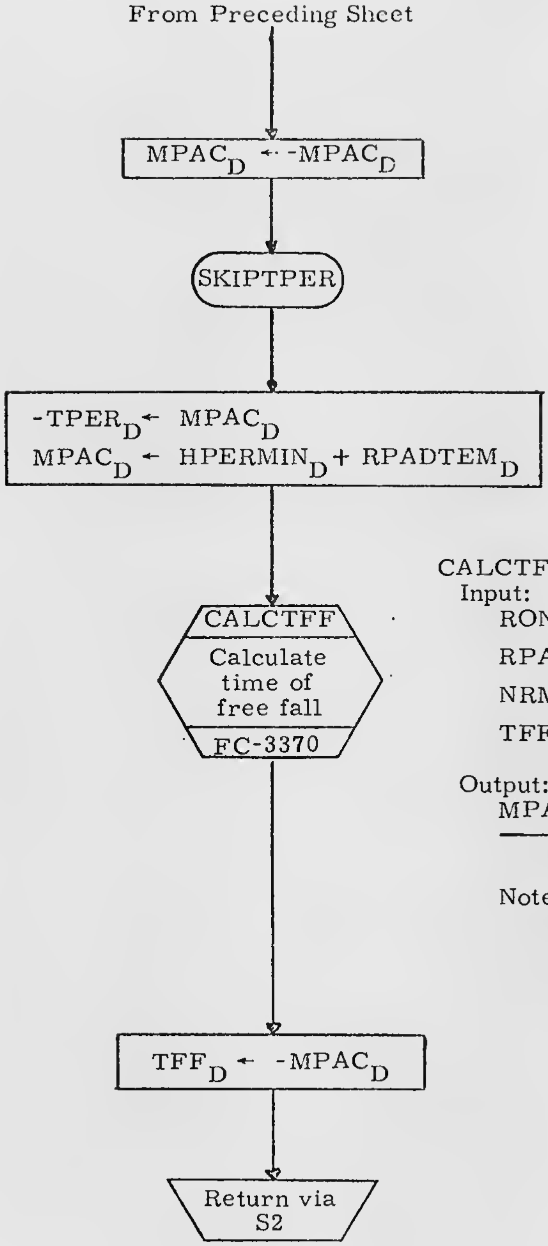
X2 = Norm count for TFFRTALF

TFF1/ALF = signed, semimajor axis, meters $@2^{22-2x2}/2^{20-2x2}$

Output:

$MPAC_D$ = time to perigee in csec $@2^{28}$

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN [illegible]	[illegible]	Orbital Parameters Display	
PRGMR [illegible]	[illegible]		DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3770
DOCMR [illegible]	[illegible]		
APPR'D [illegible]	7/29/[illegible]	REV 2	SHEET 19 OF [illegible]



CALCTFF

Input:

$RONE_V$, $VONE_V$, $RMAG1_D$, MPAC = RPADTEM + HPERMIN, $TFF/RTMU_D$, $NRMAG_D$, X1, $TFFNP_D$, $TFFALFA_D$, $TFFRTALF_D$, X2, TFF1/ALF

Output:

$\underline{MPAC_D}$ = TFF = time of free-fall, in csec @2^{28}

Note:

If the trajectory fails to reach HPERMIN + RPADTEM (300, 000' or 35, 000') then TFF will be displayed as 59B59

DISPLAYS

VERB NOUN	TYPE OF DISPLAY	DESCRIPTION OF EACH REGISTER	WHERE EXECUTED
V04N12	GOXDSPF	R1: Option code 2 R2: Option 1 assumed R3: Blanked out	SH. 3
V16N44	GOXDSPF	R1: XXXX.X naut miles apogee R2: XXXX.X naut miles perigee R3: XXBXX min, sec TFF	SH. 4, 5

FLAGS

NAME	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
AVEGFLAG	AVERAGEG running	AVERAGEG not running			SH. 3
Bit 5 or EXTVBACT	Do not terminate extended verb	Terminate extended verb			SH. 13, 14
LMOONFLG	In moon's sphere	In earth's sphere			SH. 11
V82EMFLG	In moon's sphere	In earth's sphere	SH. 8, 11	SH. 8, 11	SH. 15, 17, 18
Bit 1 of V82FLAGS	TICKPER operating	TICKPER not operating	SH. 10	SH. 4	SH. 4, 14
Bit 2 of V82FLAG	TICKTFF	TICKTFF not operating	SH. 10	SH. 4	SH. 4, 14

SUBROUTINES CALLED WHICH ARE FLOWED ON OTHER FLOW CHARTS

SUBROUTINE NAME	FLOW CHART	DESCRIPTION	WHERE CALLED
CALCTFF	3370	Calculates time of free fall to a particular radius	SH. 20
CALCTPER	3370	Calculates time of free fall to pericenter	SH. 19
DELAYJOB	3050	Delays a job for a particular time period	SH. 13
ENDEXT	3080	Ends an extended verb	SH. 14
FALTON	3090	Turns on operator error light	SH. 2
LOADTIME	3150	Loads present time into $MPAC_D$	SH. 6
OTHPREC	3350	Update LM vector to a particular time	SH. 7
PRIOCHNG	3050	Change calling job's priority	SH. 2
TESTXACT	3100	Test for extended verb activity	SH. 2
TFFCONMU	3370	Computes various parameters used in the TFF routines, and establishes them in the push list area	SH. 16
TFFRP/RA	3370	Calculates perigee and apogee radius for a given conic	SH. 16
THISPREC	3350	Update CSM state vector to a particular time	SH. 7

ERASABLE LOCATIONS USED

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
$-TPER_D$	t_{PER}	Negative of time from pericenter	min/sec	csec	2^{28}
$HAPOX_D$	h_a	Apocenter altitude	feet	meters	$2^{29}/2^{27}$
$HPERMIN_D$		Minimum perigee	feet	meters	$2^{29}/2^{27}$
$HPERX_D$	h_p	Pericenter altitude	feet	meters	$2^{29}/2^{27}$
NEWJOB		Points to coreset of active job of highest priority			
$NRMAG_D$		Normalized RMAG	feet	meters	$2^{27+X1}/2^{24+X1}$
$RAPO_D$		Apogee radius	feet	meters	$2^{29}/2^{27}$
$RATT_V$		Radius vector output of integration	feet	meters	2^{29}
$\|RLS_V\|_D$	r_{LS}	Lunar landing site radius	feet	meters	2^{27}
$RMAG1_D$	r	Magnitude of radius vector	feet	meters	$2^{27}/2^{29}$
RN_V	$\underline{r}$	Radius vector as given by AVERAGEG	feet	meters	2^{29}
$RONE_V$	$\underline{r}$	Radius vector input to integration	feet	meters	$2^{29}/2^{27}$
$RPADTEM_D$		Location for storing pad radius	feet	meters	$2^{29}/2^{27}$

ERASABLE LOCATIONS USED (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
$RPER_D$	r_p	Magnitude of pericenter	feet	meters	$2^{27}/2^{29}$
TFF_D	t_{ff}	Time of free fall to a certain altitude	seconds	csec	2^{28}
$TFF/RTMU_D$	$1/\sqrt{\mu}$	Inverse of the square root of mu	$sec/feet^{3/2}$	$csec/m^{3/2}$	$2^{14}/2^{17}$
$TFFALFA_D$		Inverse of the semimajor axis of a conic	1/feet	1/meters	$2^{-26} - X1/$ $2^{-24} - X1$
$TFFNP_D$	p	Semilatus rectum, normalized	feet	meters	$2^{28} + X1/$ $2^{36} + X1$
$TFFRTALF_D$	$\sqrt{\alpha}$	Square root of alpha	$1/feet^{1/2}$	$1/m^{1/2}$	$2^{-10} - X1/$ $2^{-9} - X1$
$TFFVSQ_D$	$(v')^2$	Velocity/$\sqrt{u}$	$1/feet^{1/2}$	$1/m^{1/2}$	$2^{-20}/2^{-18}$
$TFF1/ALF_D$		Signed, semi-major axis, weighted by X2	feet	meters	$2^{22} - 2 \cdot X2/$ $2^{20} - 2 \cdot X2$
$TIME2_D$		Timing registers	seconds	csec	2^{28}
$TSTART82_D$		Storage for TIME2 input	seconds	csec	2^{28}
$TDEC1_D$		Time to be integrated to	seconds	csec	2^{28}

ERASABLE LOCATIONS USED (CONTINUED)					
AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
$VATT_V$		Velocity output of integration routines	feet/sec	meters/csec	2^7
VN_V		Velocity vector, output of AVERAGEG	feet/sec	m/csec	2^7
$VONE_V$		Velocity vector	feet/sec	m/csec	2^7
$VONE'_V$		VONE/	$feet^{-1/2}$	$m^{-1/2}$	$2^{-10}/2^{-9}$

PROGRAM CONSTANTS					
AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING VALUE AND UNITS	AGC VALUE AND UNITS	AGC SCALING
MAXNM		Maximum display value possible	9999.9 NM	$01065\ 05603_8$	2^0
MINPERE	r_{pMIN}	300, 000 ft reference alt for earth	300, 000 ft	91440 meters	2^{29}
MINPERM	$r_p MIN$	35, 000 ft reference alt for moon	35, 000 ft	1068 meters	2^{27}
RPAD		Standard pad radius	20910922 ft	6373338 meters	2^{29}
1/RTMUE	$1/\sqrt{\mu}_e$	Inverse of the square root of mu for earth	.0008427916 $x10^{-5}$	50087529 $x10^{-5}$	2^{-17}
1/RTMU	$1/\sqrt{\mu}_M$	Inverse of the square root of mu for moon	.007599228 $x10^{-4} sec/ft^{3/2}$	.45162595 $x10^{-4} csec/m^{3/2}$	2^{-14}

R31- RENDEZVOUS PARAMETER DISPLAY

MAJOR SUBROUTINES ON THIS FLOW CHART

EXTENDED VERB 83	V83PERF	REQUEST RENDEZVOUS PARAMETER DISPLAY	SH 2
	R31CALL	SCHEDULE RENDEZVOUS PARAMETER DISPLAY	SH 2

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

DRAWN	F. J. Laverriere	12MAY69
PRGMR	R R Covelli	20JUNE69
ANALST		
DOCMR	W C Wright	19JUNE69
APPR'D	Alida M. Sorant	20JUNE69

R31 - RENDEZVOUS PARAMETER DISPLAY

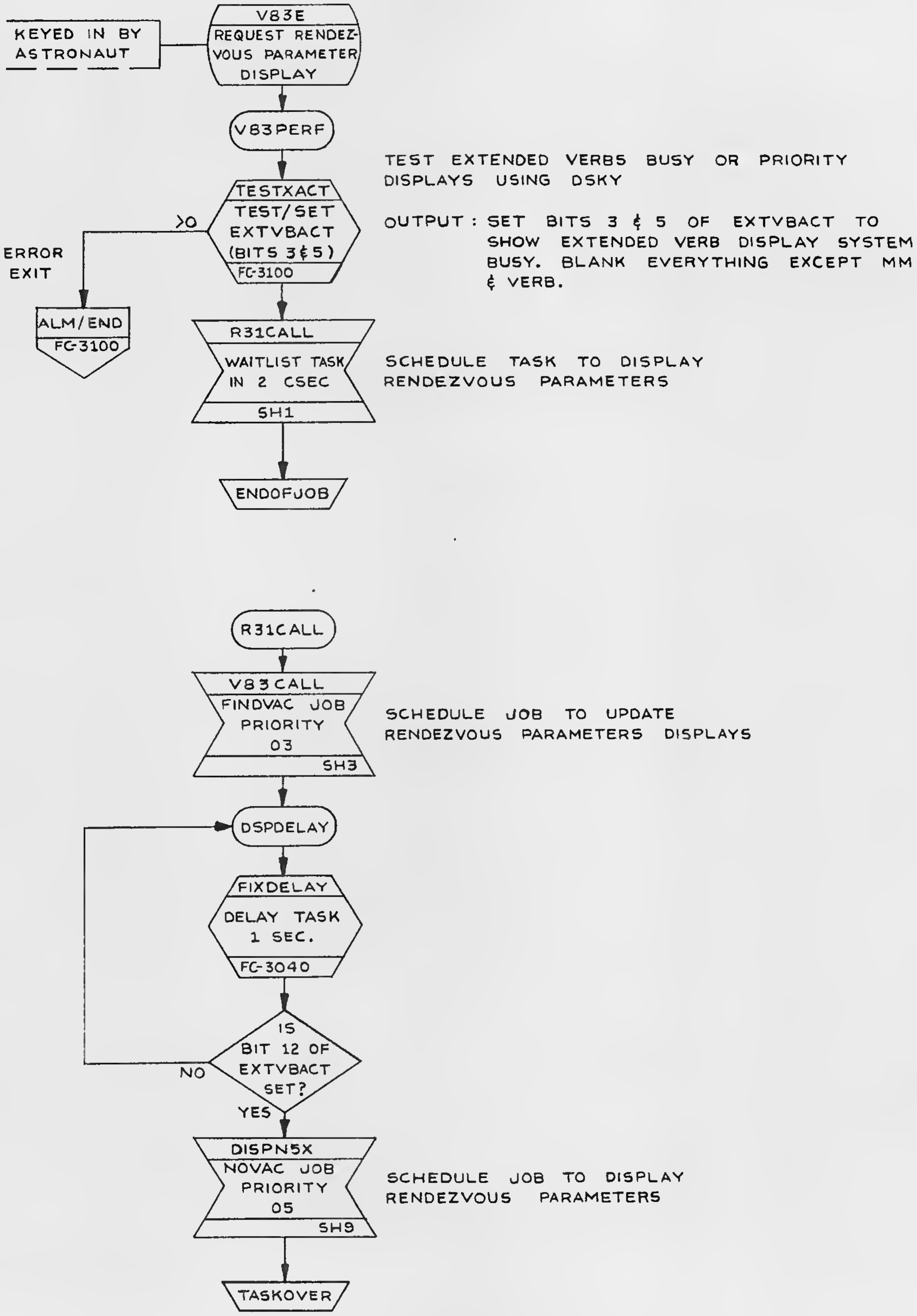
LUMINARY 1D

DOCUMENT NO. FC-3780

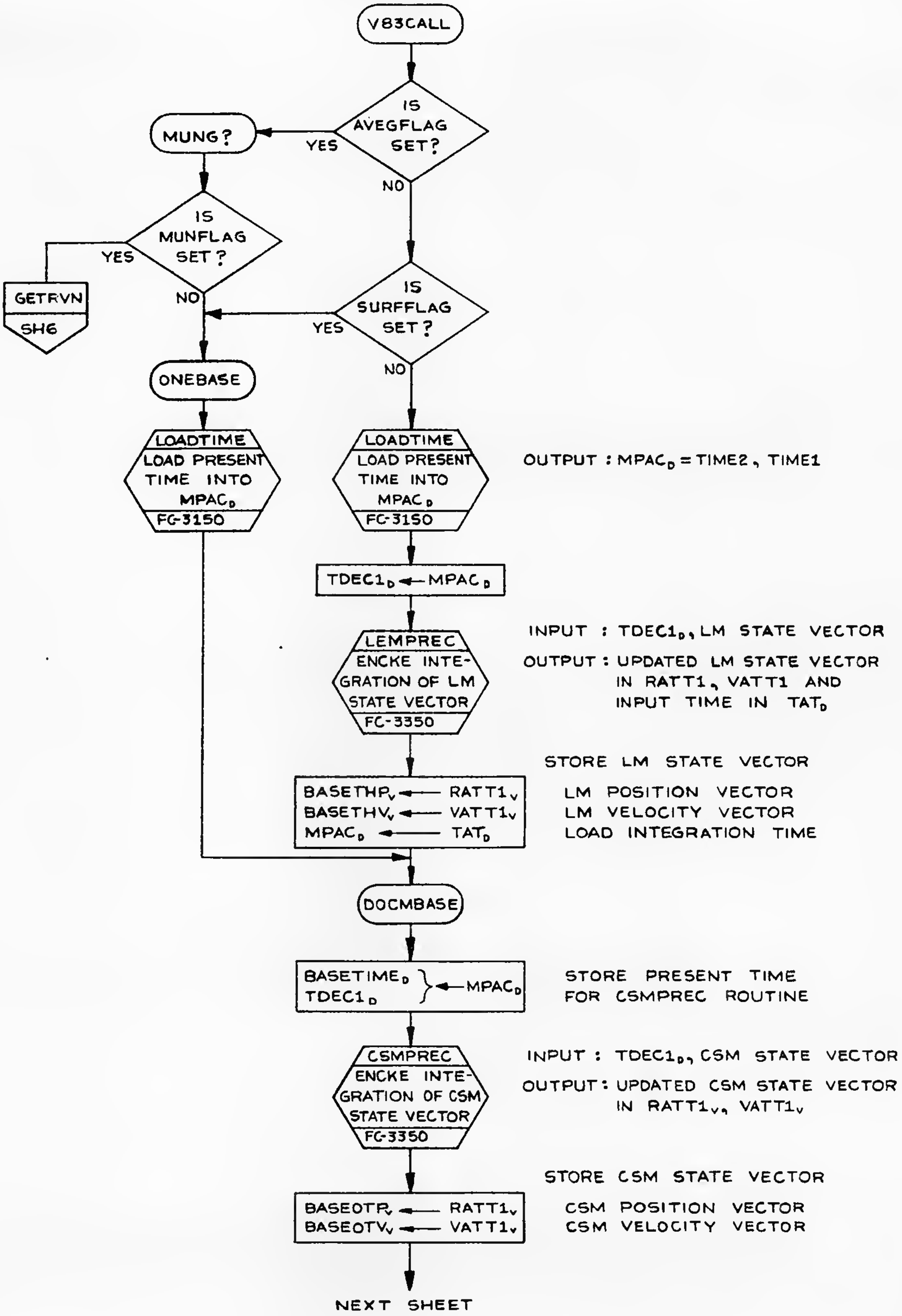
REV 2

SHEET 1 OF 11

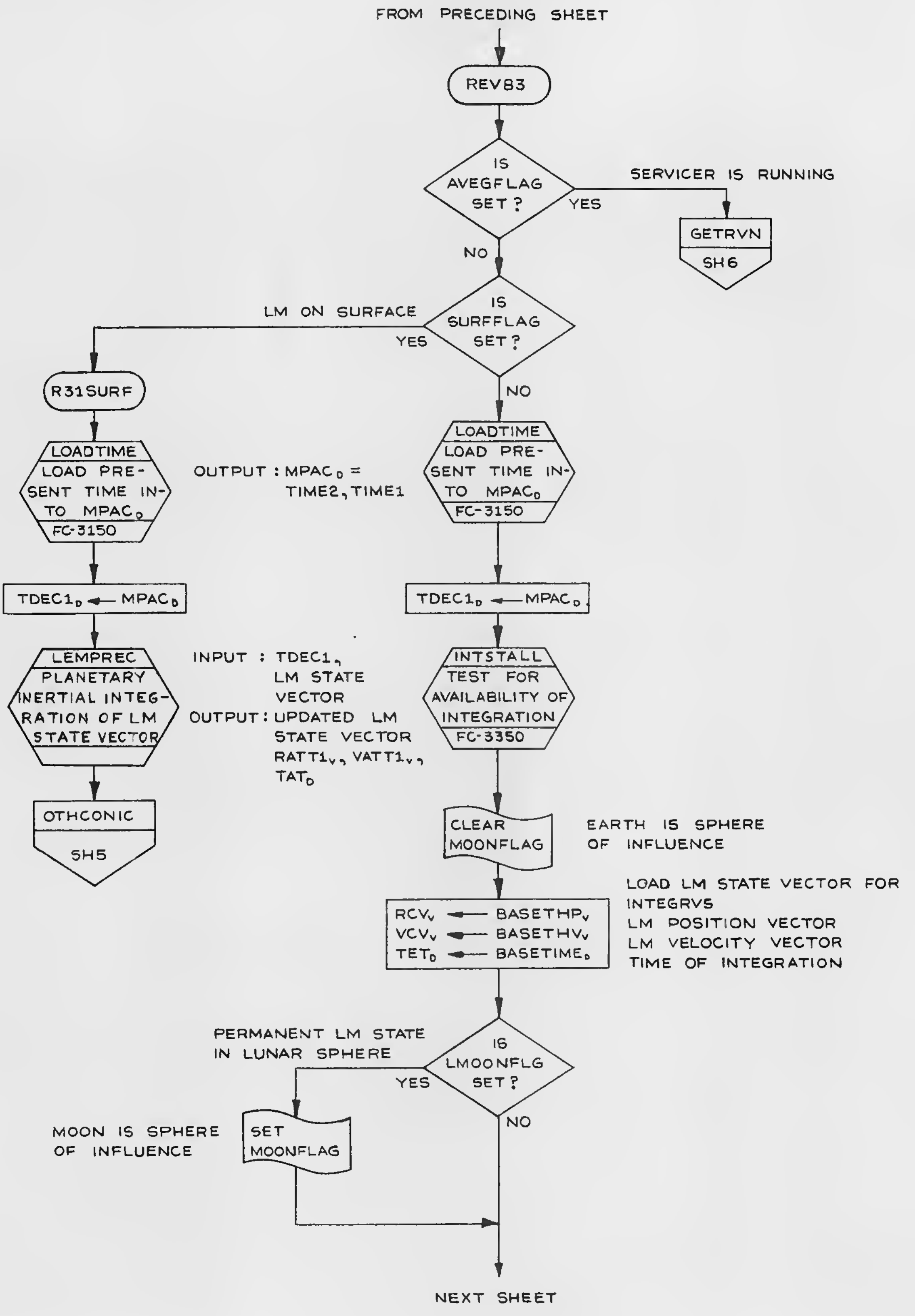
PURPOSE: TO DISPLAY AT ASTRONAUT REQUEST LGC CALCULATED RENDEZVOUS PARAMETERS (RANGE, RANGE RATE, THETA)



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN F.D. LaverRiere 13MAY69	R31 - RENDEZVOUS PARAMETER DISPLAY
PRGMR R.R. Covelli 20JUNE69	
ANALST	LUMINARY 1D — DOCUMENT NO. FC-3780
DOCMR 19JUNE69	
APPR'D Alida M. Grant 20JUNE69	REV 2 — SHEET 2 OF 11



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN [signature] 27MAY69	R31- RENDEZVOUS PARAMETER DISPLAY
PRGMR [signature] 20JUNE69	
ANALST	LUMINARY 1D — DOCUMENT NO. FC-3780
DOCMR [signature] 19JUNE69	
APPR'D [signature]	REV 2 — SHEET 3 OF 11



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

DRAWN	F. D. Lauerriere	28 MAY 69
PRGMR	R. R. Covell	20 JUNE 69
ANALST		
DOCMR	McCoy	19 JUNE 69
APPR'D	Alan M. Sorant	20 JUNE 69

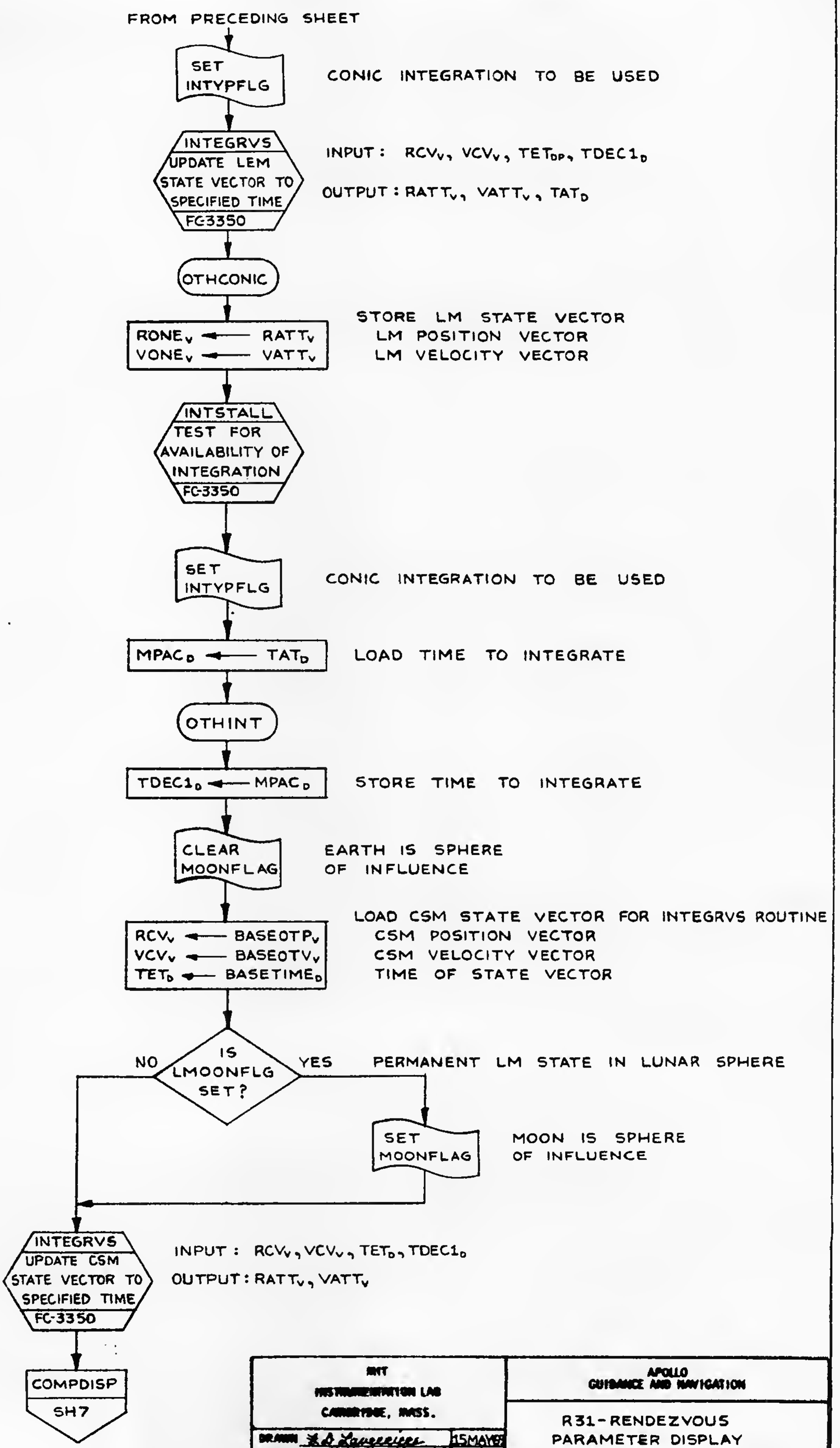
R31- RENDEZVOUS PARAMETER DISPLAY

LUMINARY 1D

DOCUMENT NO. FC-3780

REV 2

SHEET 4 OF 11



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CAMBRIDGE, MASS.

APOLLO
GUIDANCE AND NAVIGATION

R31-RENDEZVOUS
PARAMETER DISPLAY

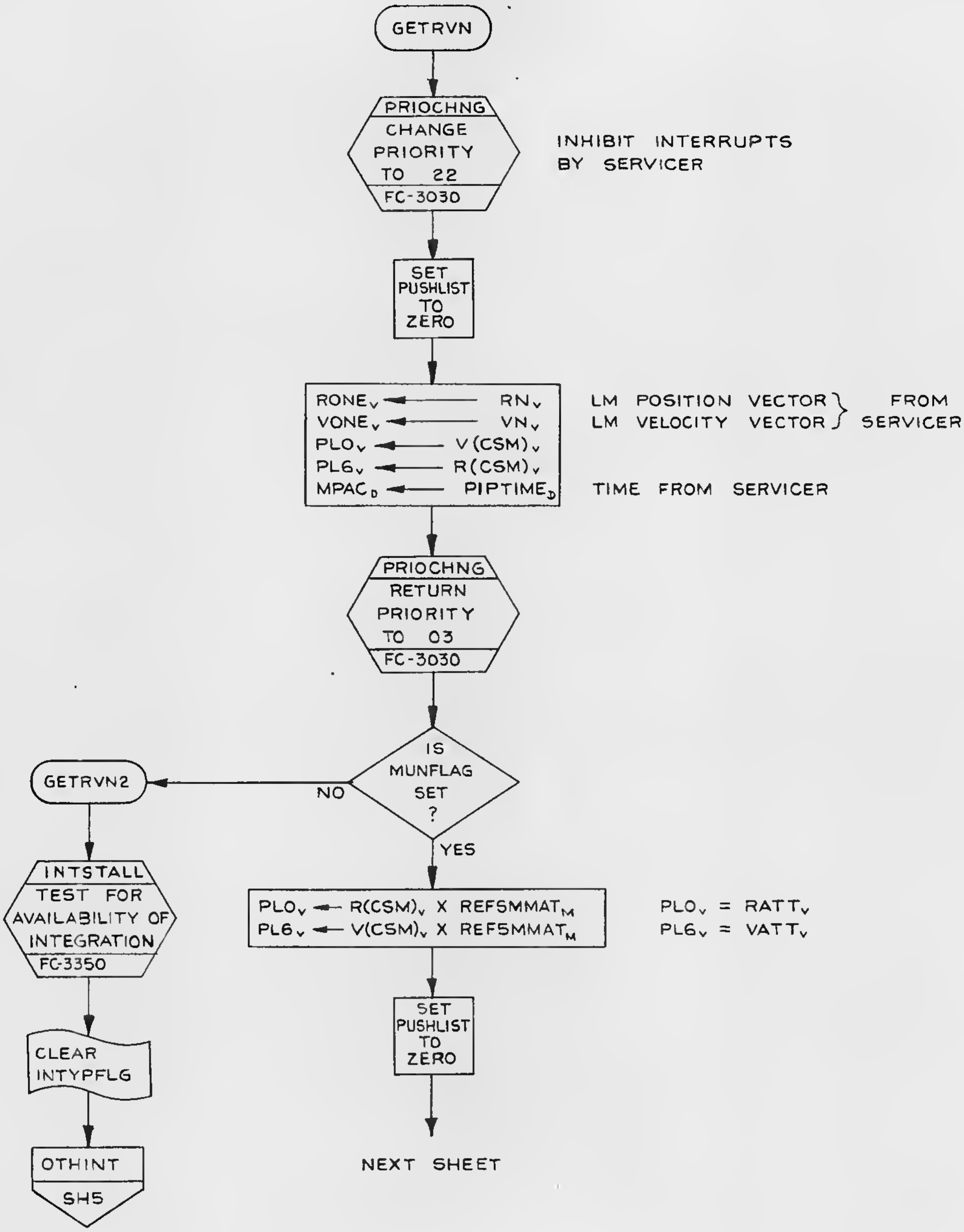
DRAWN	F.D. Laverriere	15MAY69
PRGMR	R.K. Covell	20JUNE69
ANALST		
DOCMR	McDonald	19JUNE69
APPR'D	Allen M. Soreat	20JUNE69

LUMINARY 1D

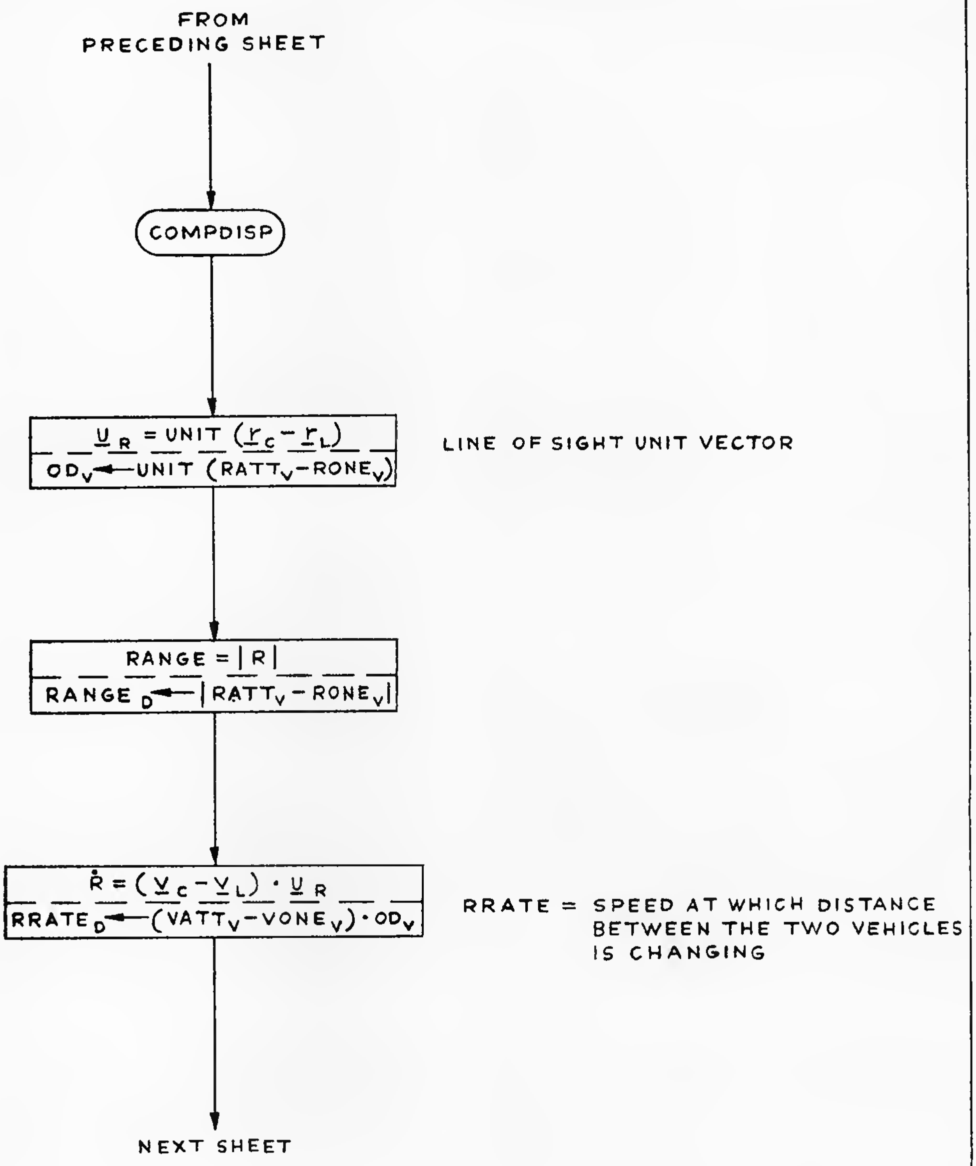
DOCUMENT NO. FC-3780

REV 2

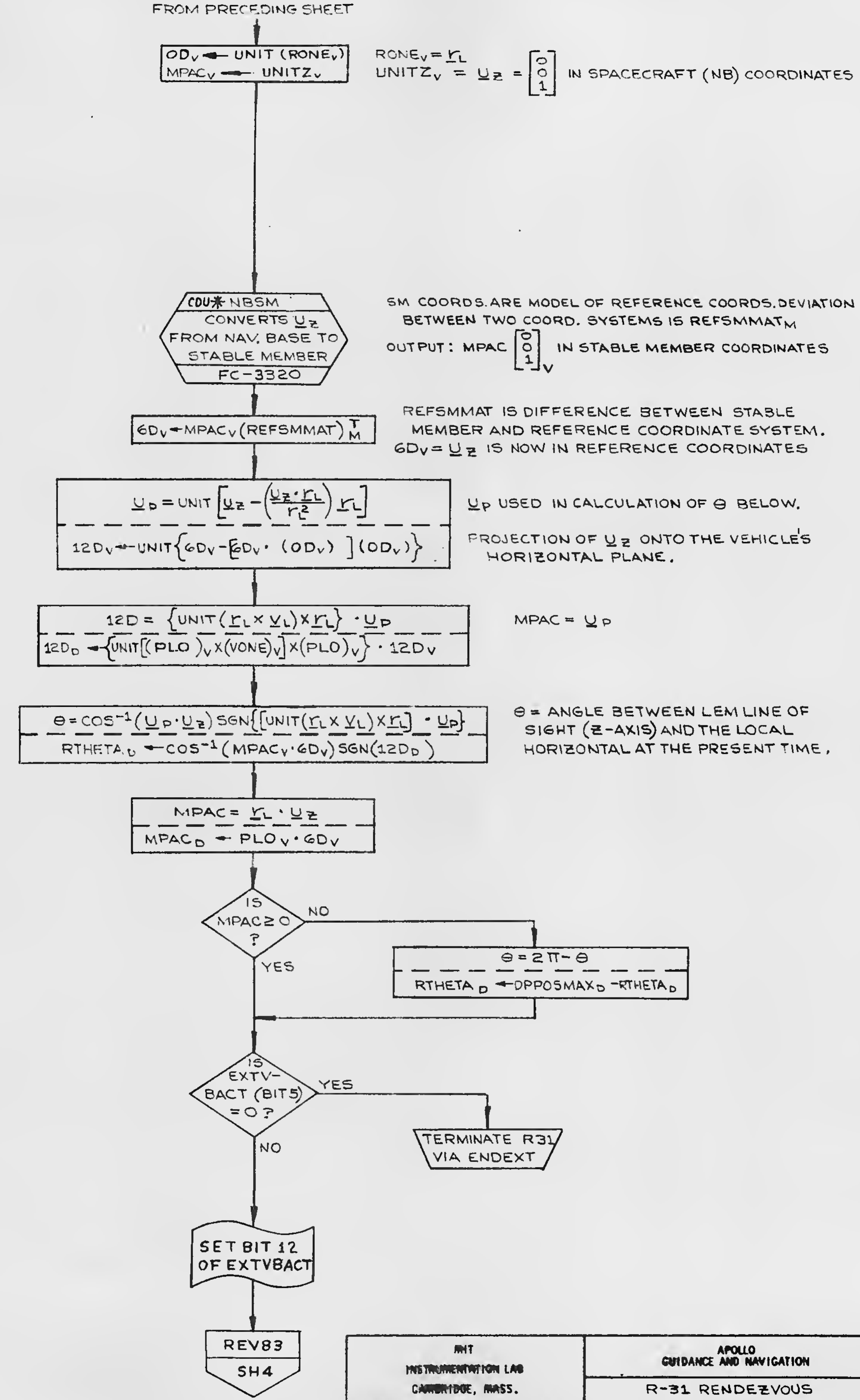
SHEET 5 OF 11



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN 2 JUN 69	R31 – RENDEZVOUS PARAMETER DISPLAY
PRGMR 20 JUNE 69	
ANALST	LUMINARY 1D — DOCUMENT NO. FC-3780
DOCMR	
APPR'D	REV 2 — SHEET 6 OF 11



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	18 JUNE	R31 – RENDEZVOUS PARAMETER DISPLAY	
PROGR	20 JUNE 69	LUMINARY 1D	DOCUMENT NO. FC-3780
ANALST			
DOCMR	19 JUNE 69		
APPR'D	20 JUNE	REV 2	SHEET 7 OF 11



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

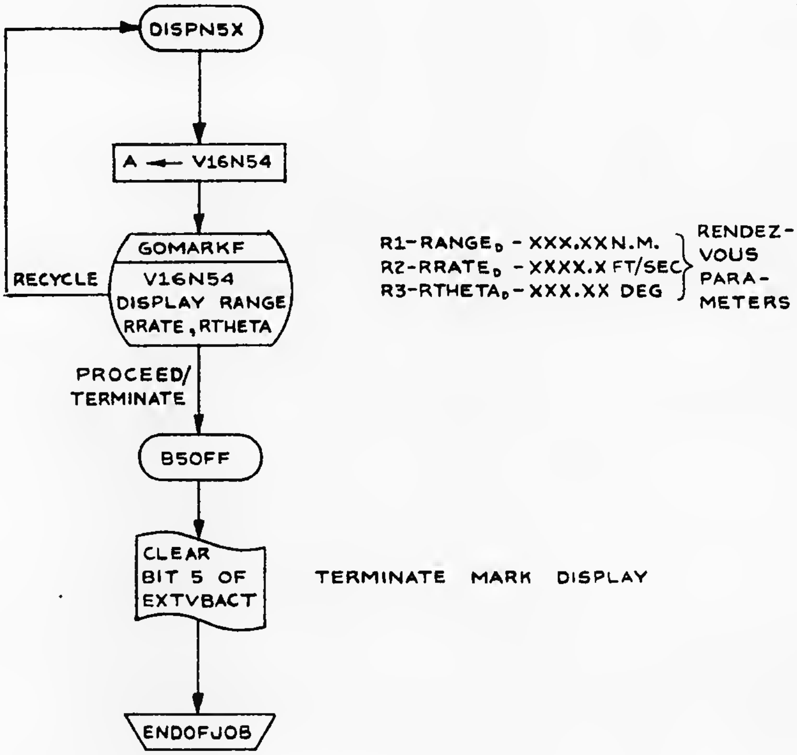
R-31 RENDEZVOUS PARAMETER DISPLAY

DRAWN	J. W. Scott	6 Aug 68
PROGMR		
ANALST		3 Sept 68
DOCMR		26 Aug 6.
APPR'D	John A. Morse	5 Sept 6.

LUMINARY 1D

DOCUMENT NO. FC-3780

REV 2 SHEET 8 OF 11



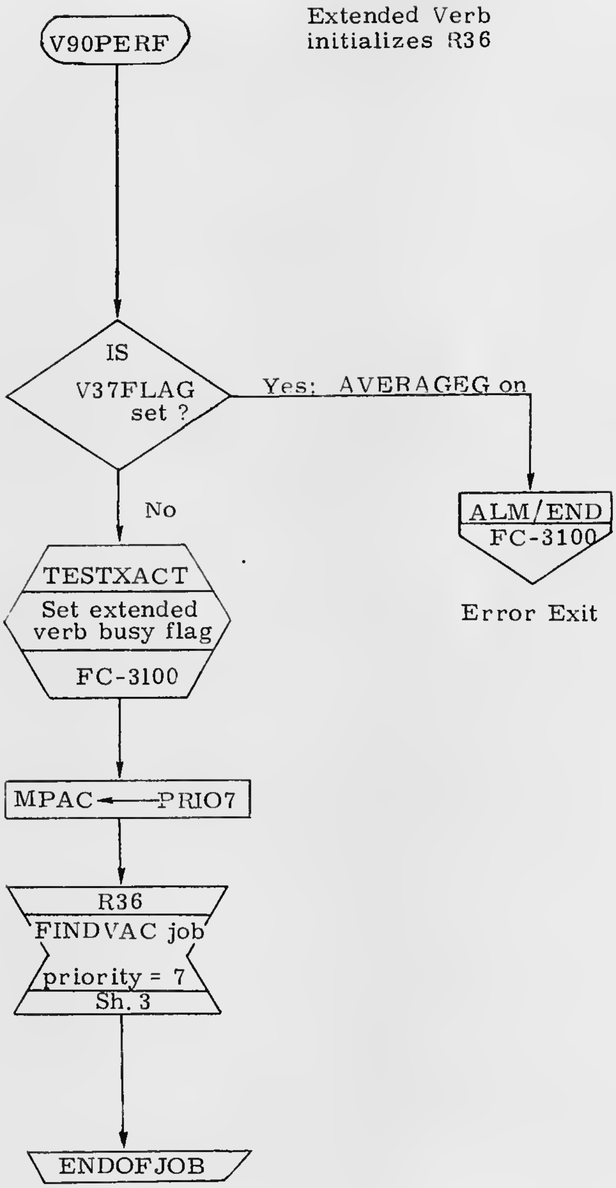
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	15MAY69	R31 - RENDEZVOUS PARAMETER DISPLAY	
PRGMR	20JUNE69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3780
DOCMR	19JUNE69		
APPR'D	20JUNE69	REV 2	SHEET 9 OF 11

ERASABLES (CONTINUED)	MEANING	UNITS	SCALING
VCV_V	VELOCITY VECTOR OF VEHICLE BEING UPDATED VIA INTEGRVS	M/CSEC	2^7
RN_V	POSITION VECTOR OUTPUTTED FROM SERVICER ROUTINE	METERS	2^{29}
VN_V	VELOCITY VECTOR OUTPUTTED FROM SERVICER ROUTINE	M/CSEC	2^7
$PIPTIME_D$	TIME STATE VECTOR UPDATED VIA SERVICER	CENTISECONDS	2^{28}

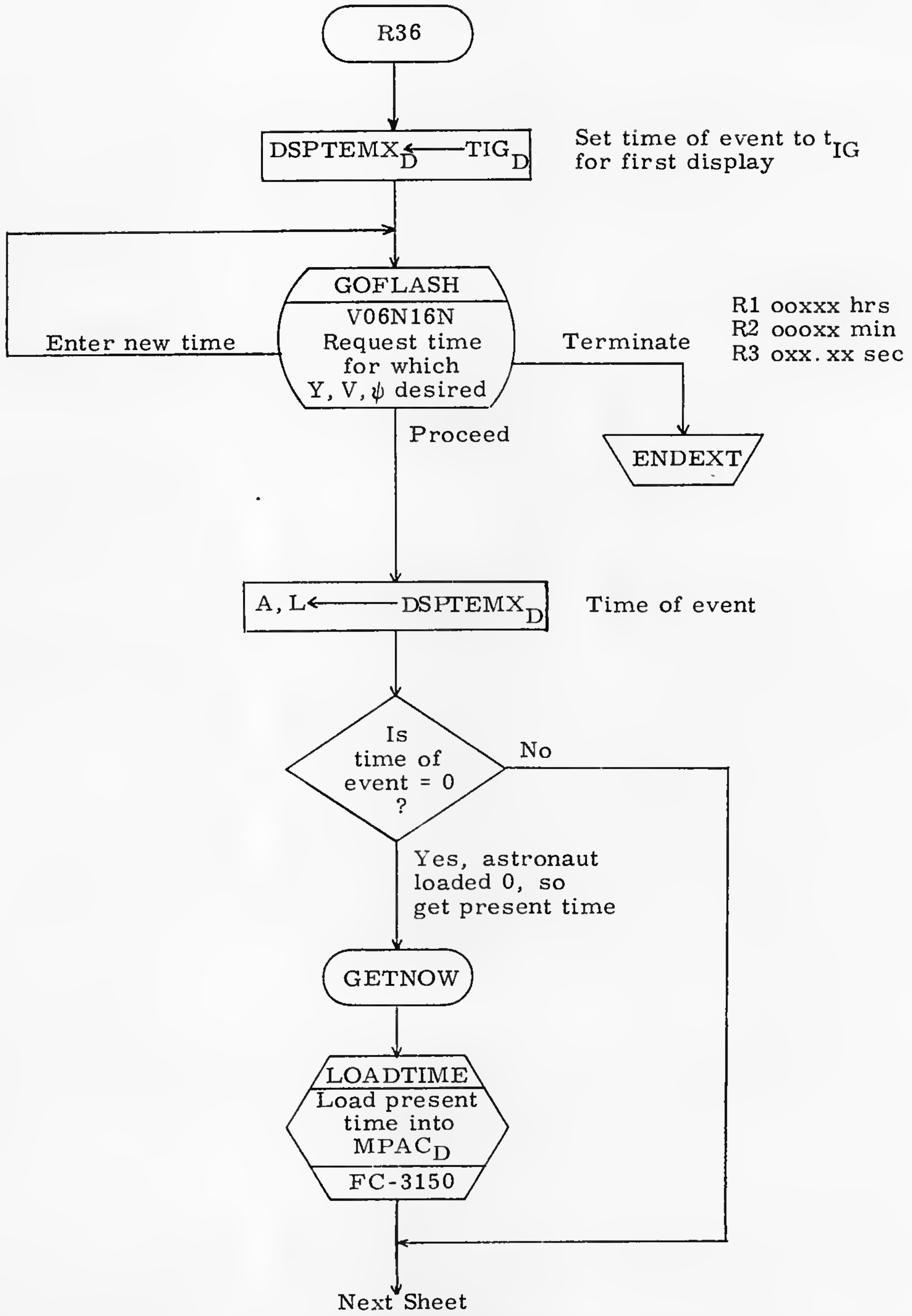
DISPLAYS	MEANING	USED
V16N54	R1 -- $RANGE_D$ -- XXX.XX NAUT. MI. -- DISTANCE BETWEEN VEHICLES R2 -- $RRATE_D$ -- XXX.XX FT/SEC -- ΔVELOCITY BETWEEN VEHICLES R3 -- $RTHETA_D$ -- XXX.XX DEG -- ANGLE BETWEEN LM LOS AND LOCAL HORIZONTAL	SH. 9

R36: OUT-OF-PLANE RENDEZVOUS ROUTINE

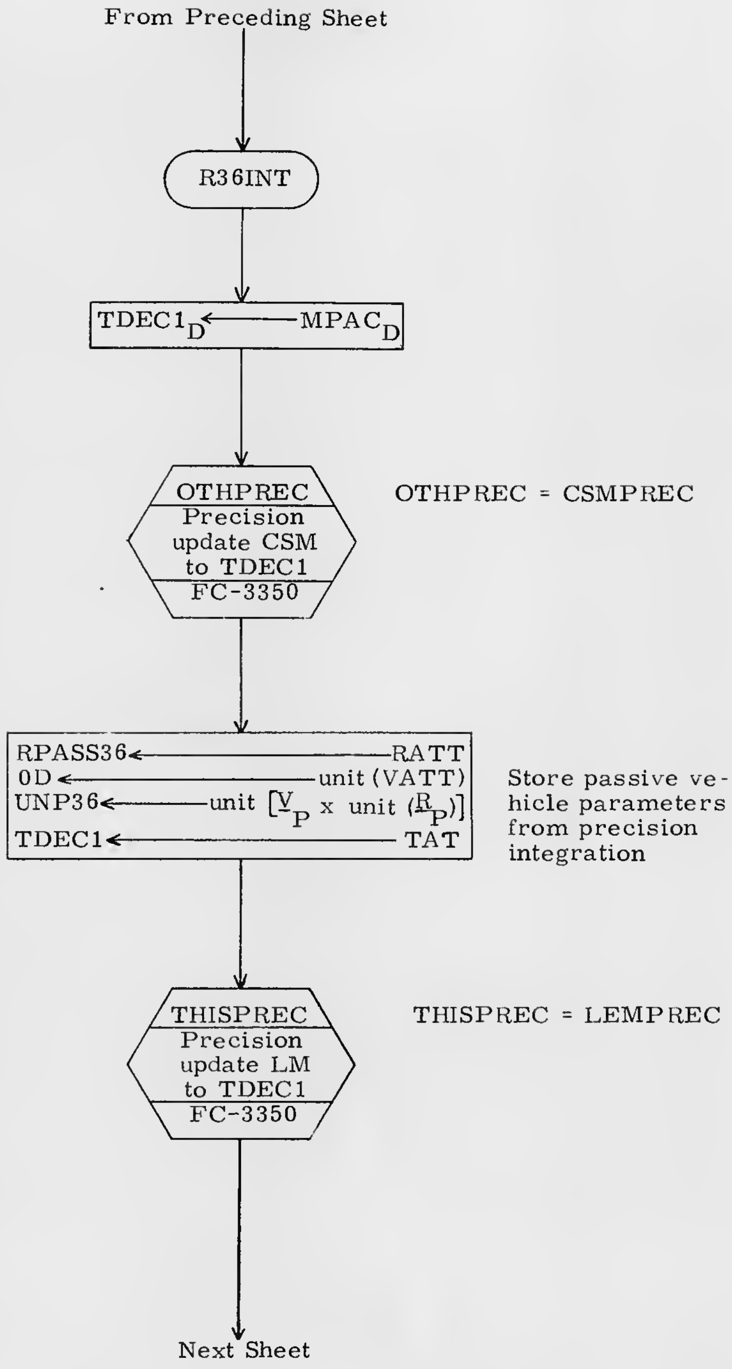
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN L. Duncan	12/4/69	R36: RENDEZVOUS OUT-OF-PLANE DISPLAY	
PRGMR J.E. Crocker	12/11/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3790
DOCMR R.D.W. Estes			
APPR'D W. Danforth	12/16/69	REV 1	SHEET 1 OF 9



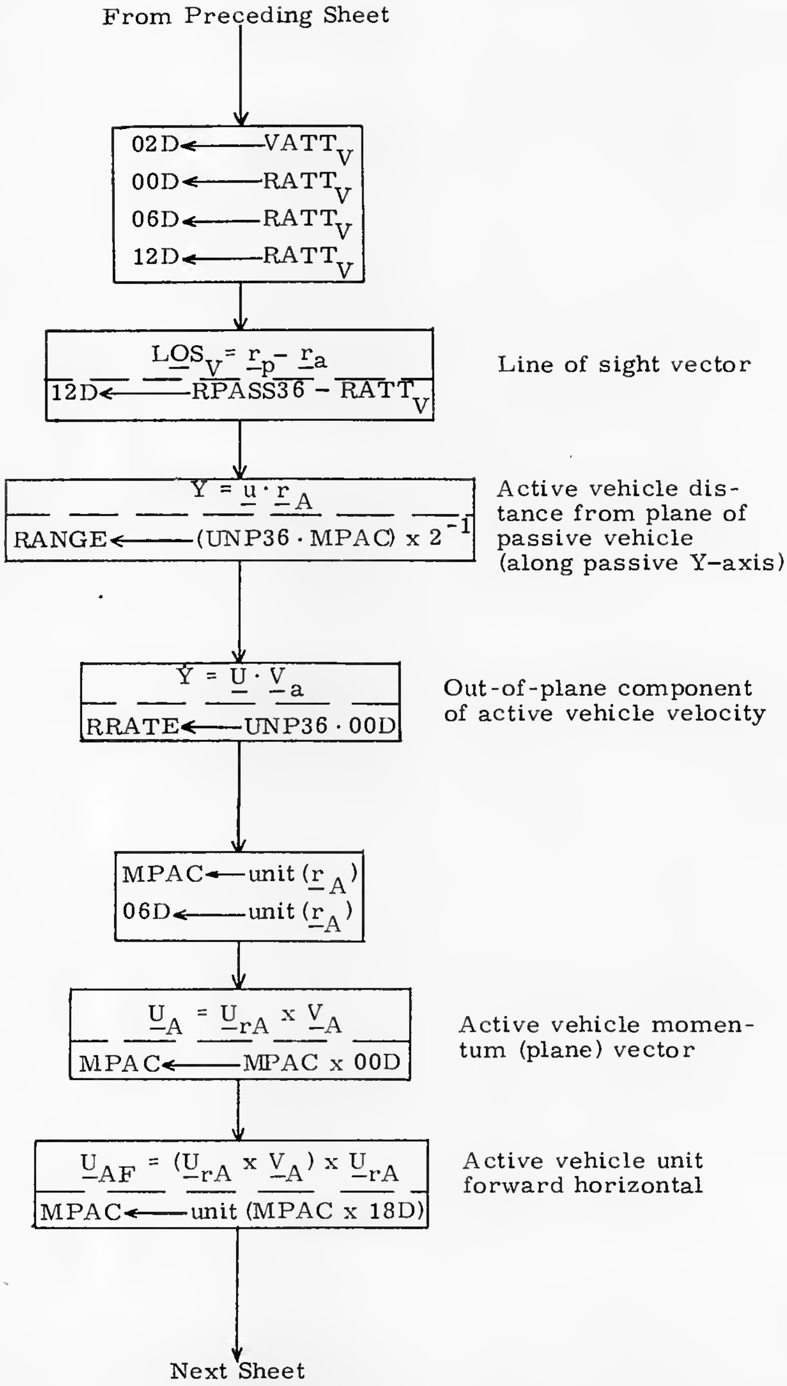
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E. Matta	6/1/70	R36: RENDEZVOUS OUT-OF-PLANE DISPLAY	
PRGMR [illegible]	6/1/70	LUMINARY 1D	DOCUMENT NO. FC-3790
ANALST			
DOCMR [illegible]	6/1/70		
APPR'D [illegible]	6/1/70	REV 1	SHEET 2 OF 9



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN L. Duncan	12/4/69	R36: RENDEZVOUS OUT-OF-PLANE DISPLAY	
PRGMR J. E. Crocker	12/11/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3790
DOCMR R. W. J. Eaton			
APPR'D W. Stoplett	12/16/69	REV 1	SHEET 3 OF 9



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION		
DRAWN L. Duncan	12/4/69	R36: RENDEZVOUS OUT-OF-PLANE DISPLAY		
PRGMR J.E. Crocker	12/11/69	LUMINARY 1D	DOCUMENT NO. FC-3790	
ANALST				
DOCMR RDM Carter				
APPR'D W Danforth	12/16/69	REV 1	SHEET 4 OF 9	



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	L. Duncan	12/4/69	R36: RENDEZVOUS OUT-OF-PLANE DISPLAY	
PRGMR	J.E. Cooker	12/11/69		
ANALST			LUMINARY 1D	DOCUMENT NO. FC-3790
DOCMR	R.M. Eutes			
APPR'D	W. Dughetti	12/16/69	REV 1	SHEET 5 OF 9

From Preceding Sheet

↓

00D ← MPAC
MPAC ← 18D

↓

$\underline{U}_{LI} = \underline{U}_{rA} \times (\underline{U}_L \cdot \underline{r}_A)$
MPAC ← 00D x (12D · 18D)

Unit vertical x $\cos^{-1}$ $(\underline{U}_L \cdot r_A)$ = vertical component of unit LOS

↓

$\text{unit}(\underline{U}_{HL}) = \underline{U}_L - \underline{U}_{rA} \times (\underline{U}_L \cdot \underline{r}_A)$
12D ← unit (12D − MPAC)

Unit horizontal com ponent of LOS = unit LOS = unit vertical component LOS

↓

$\psi = \cos^{-1}(\underline{U}_{AF} - \underline{U}_L)$
RTHETA ← ARCCOS(00D · MPAC)

Psi

↓

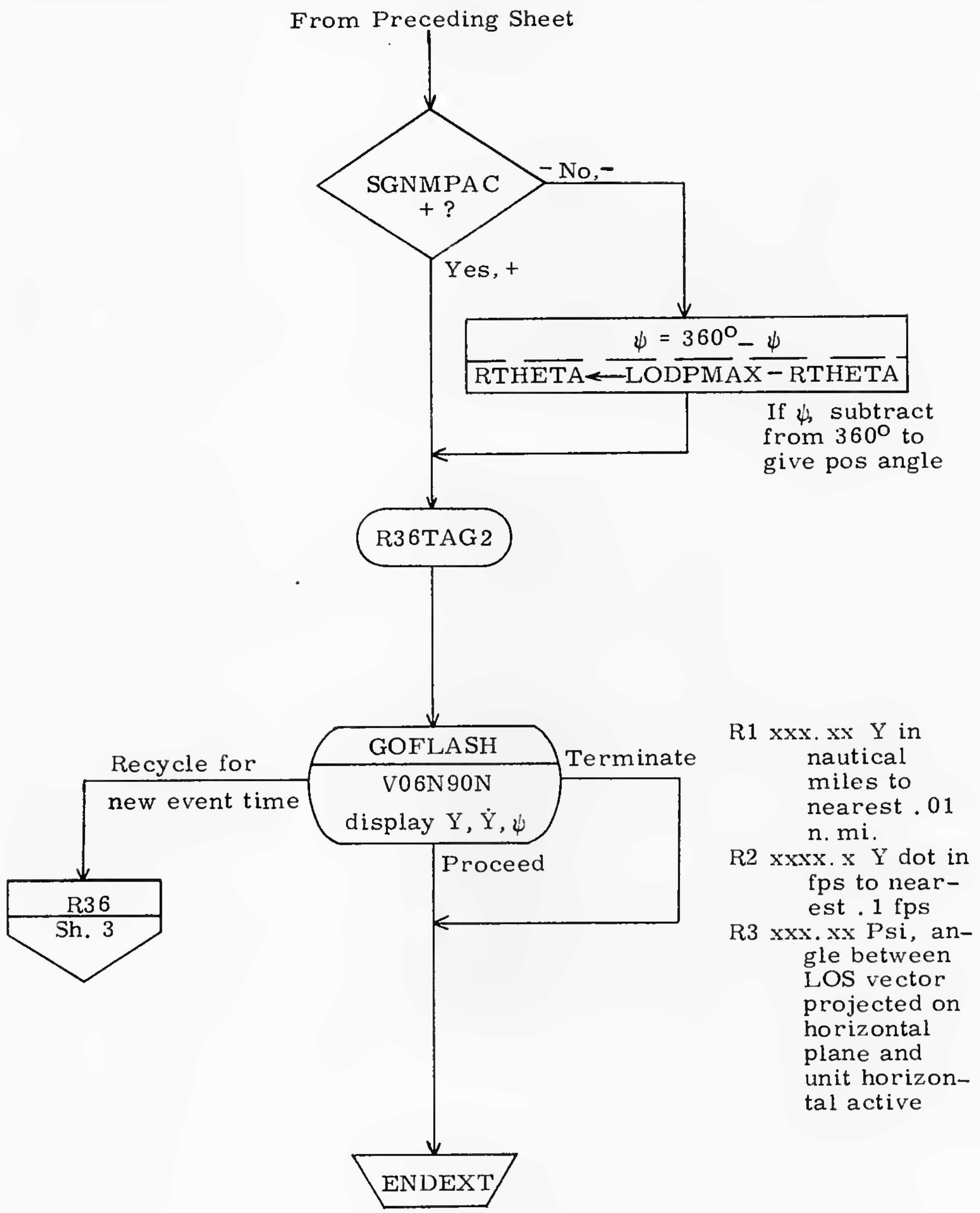
$(\underline{U}_{AF} \times \underline{U}_{HL}) \cdot \underline{r}_A$
MPAC ← (00D x MPAC) · 06D

Unit horizontal of active vehicle crossed into LOS projection on horizontal; result compared with ver tical for sense (par - allel up means pas - sive vehicle is left of active vehicle plane/forward hori - zontal.)

↓

Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN L. Duncan	12/4/69	R36: RENDEZVOUS OUT-OF-PLANE DISPLAY	
PRGMR J. E. Coker	12/11/69	LUMINARY 1D	DOCUMENT NO. FC-3790
ANALST			
DOCMR R M Cutis			
APPR'D W. Dugbith	12/16/69	REV 1	SHEET 6 OF 9



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
			R36: RENDEZVOUS OUT-OF-PLANE DISPLAY	
DRAWN	L. Duncan	12/4/69	LUMINARY 1D	DOCUMENT NO. FC-3790
PRGMR	J.E. Parker	12/11/69		
ANALST				
DOCMR	RMEntes			
APPR'D	W. Dzyndzya	12/16/69	REV 1	SHEET 7 OF 9

SUBROUTINES

ALM/END	FC-3100	Error exit	Sh. 2
LOADTIME	FC-3150	Loads present time into MPAC	Sh. 3
THISPREC	FC-3350	ENKE update of LM	Sh. 4
OTHPREC	FC-3350	ENKE update of CSM	Sh. 4
TESTXACT	FC-3100	Sets extended verb busy flag	Sh. 2

DISPLAYS

V06N16N	Request time for which Y, $\dot{Y}$, ψ desired	Sh. 3
V06N90N	Display Y, $\dot{Y}$ ψ	Sh. 7

FLAGS

Name	Meaning When Set	Meaning When Clear	Where Set	Where Cleared	Where Tested
V37FLAG Flag 7 Bit 6	AVERAGEG (SERVICER) running	AVERAGEG (SERVICER) off			Sh. 2

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E. Matta	6/1/70	R36: RENDEZVOUS OUT-OF-PLANE DISPLAY	
PRGMR P. White	6/1/70		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3790
DOCMR R M Eaton	6/1/70		
APPR'D R M Eaton	6/1/70	REV 1	SHEET 8 OF 9

ERASABLES

		Units	Scaling
DSPTEMX	Display buffer area		2^1
TDEC	Time storage LOS	csec	2^{28}
RPASS36	Storage for passive vehicle position vector	Meters	2^{29}
UNP36	Unit vector of passive vehicle momentum/plane		
RANGE	Y, active vehicle distance from passive vehicle plane	Meters	
RRATE	$\dot{Y}$, active vehicle velocity component normal to passive plane	m/csec	
RTHETA	ψ, angle between active vehicle unit forward horizontal & LOS projected into horizontal plane		

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN L. Duncan	12/4/69	R36: RENDEZVOUS OUT-OF-PLANE DISPLAY	
PRGMR J. E. Crocker	12/11/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3790
DOCMR R M Estes			
APPR'D W. Goforth	12/16/69	REV 1	SHEET 9 OF 9

12.0 THRUST PROGRAMS

P40 DPS THRUST

MAJOR SUBROUTINES AND EXTERNAL ENTRY POINTS

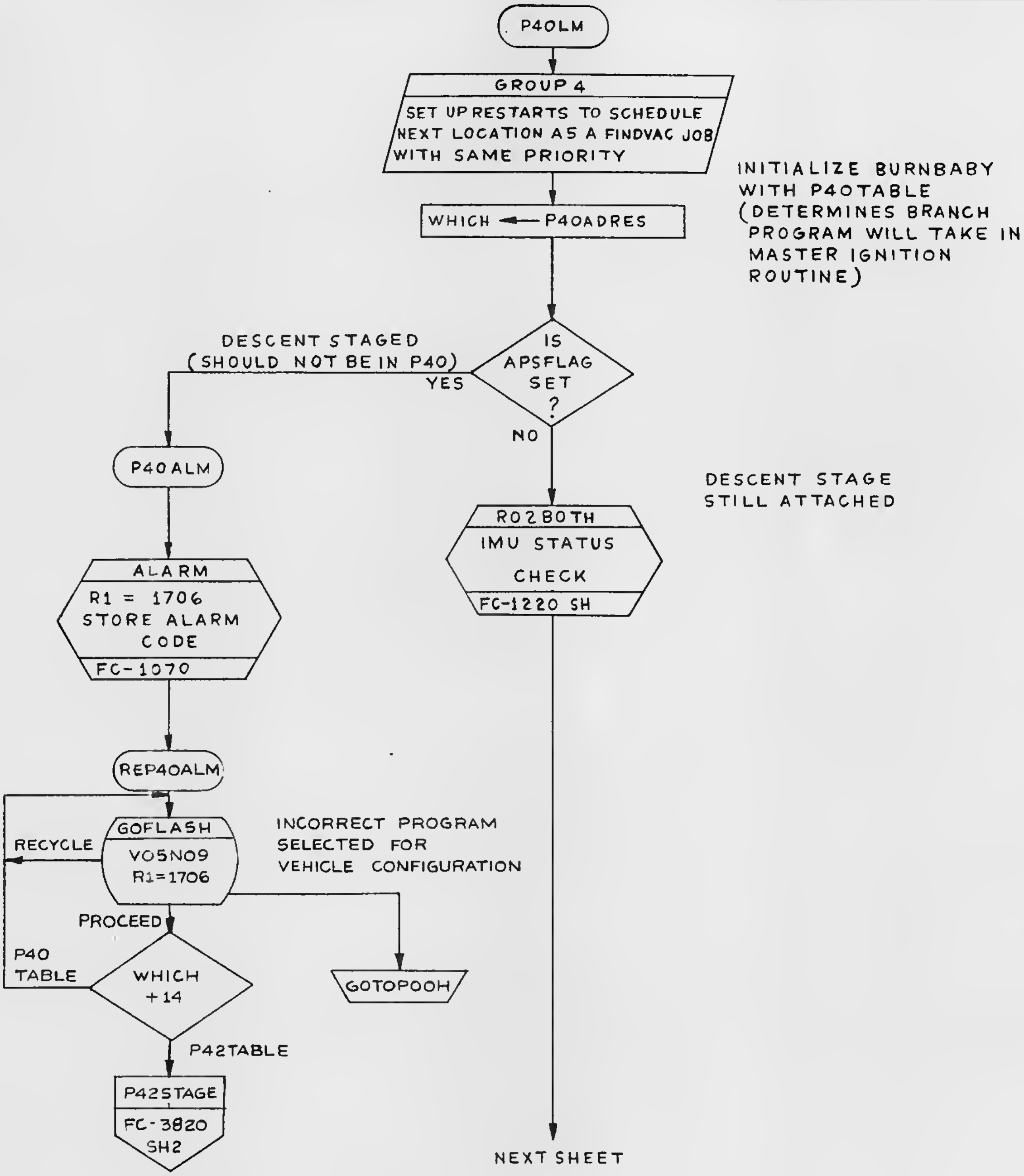
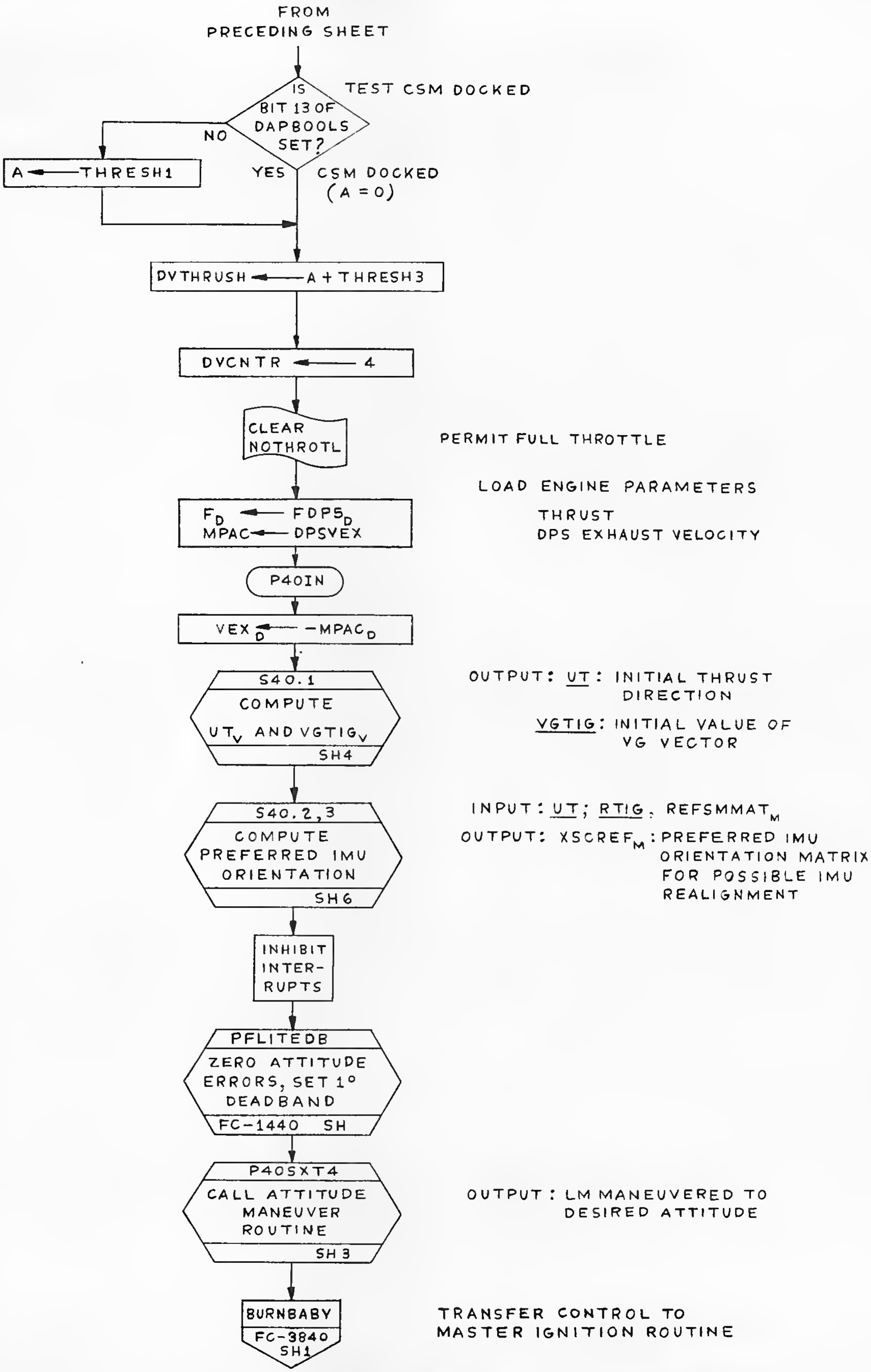


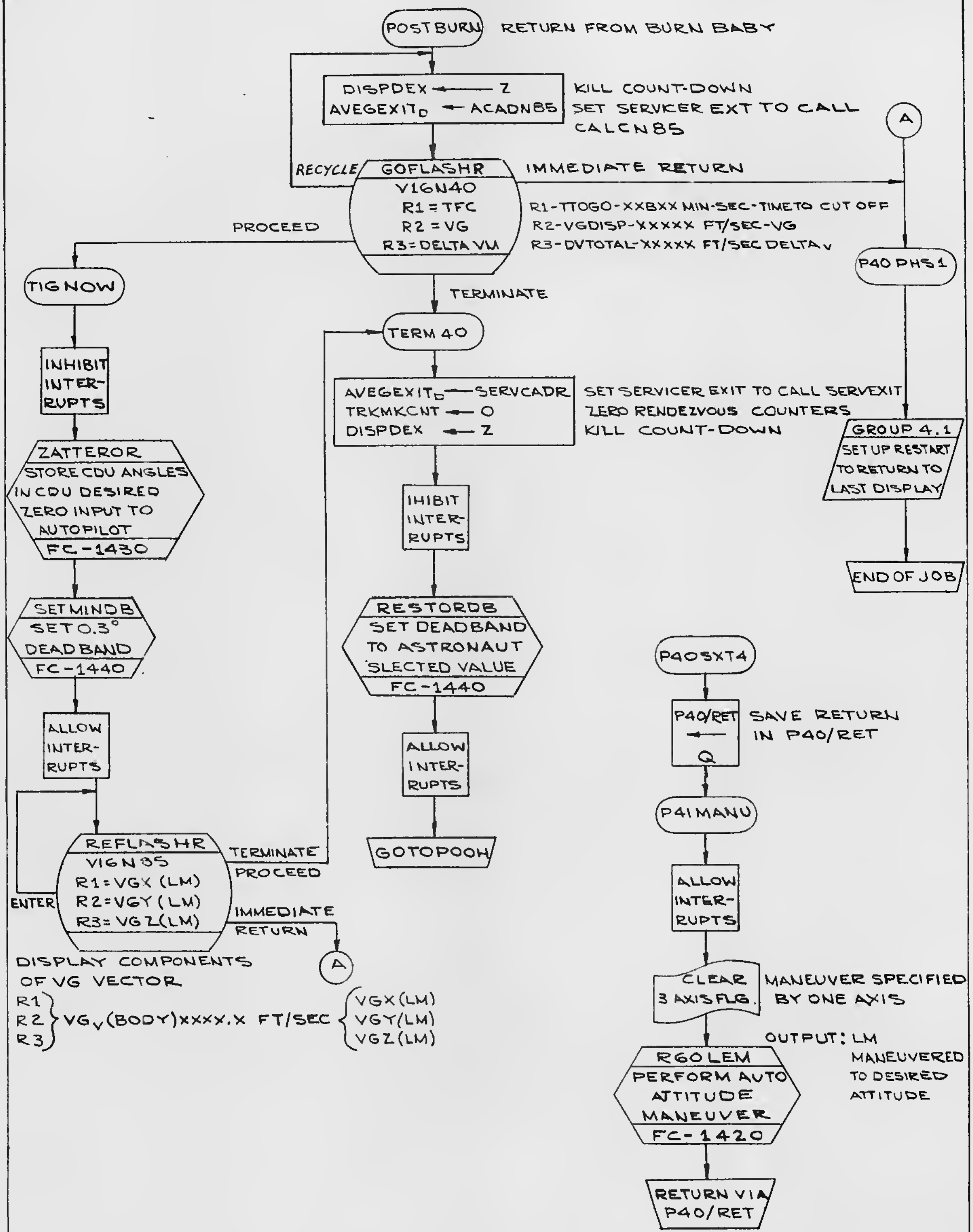
TABLE USED BY MASTER IGNITION ROUTINE — WHICH INDEX

P40TABLE	VN	0640	(0)
	TCF	ULLGNOT	(1)
	TCF	COMFAIL4	(2)
	TCF	GOPOST	(3)
	TCF	TASKOVER	(4)
	TCF	P40SPOT	(5)
	DEC	2240	(6)
	2CADR	STEERING	(7)
	TCF	P40JUNK	(11)
	TCF	WAITABIT	(12)
	TCF	P40IGN	(13)
	TCF	REP40ALM	(14)

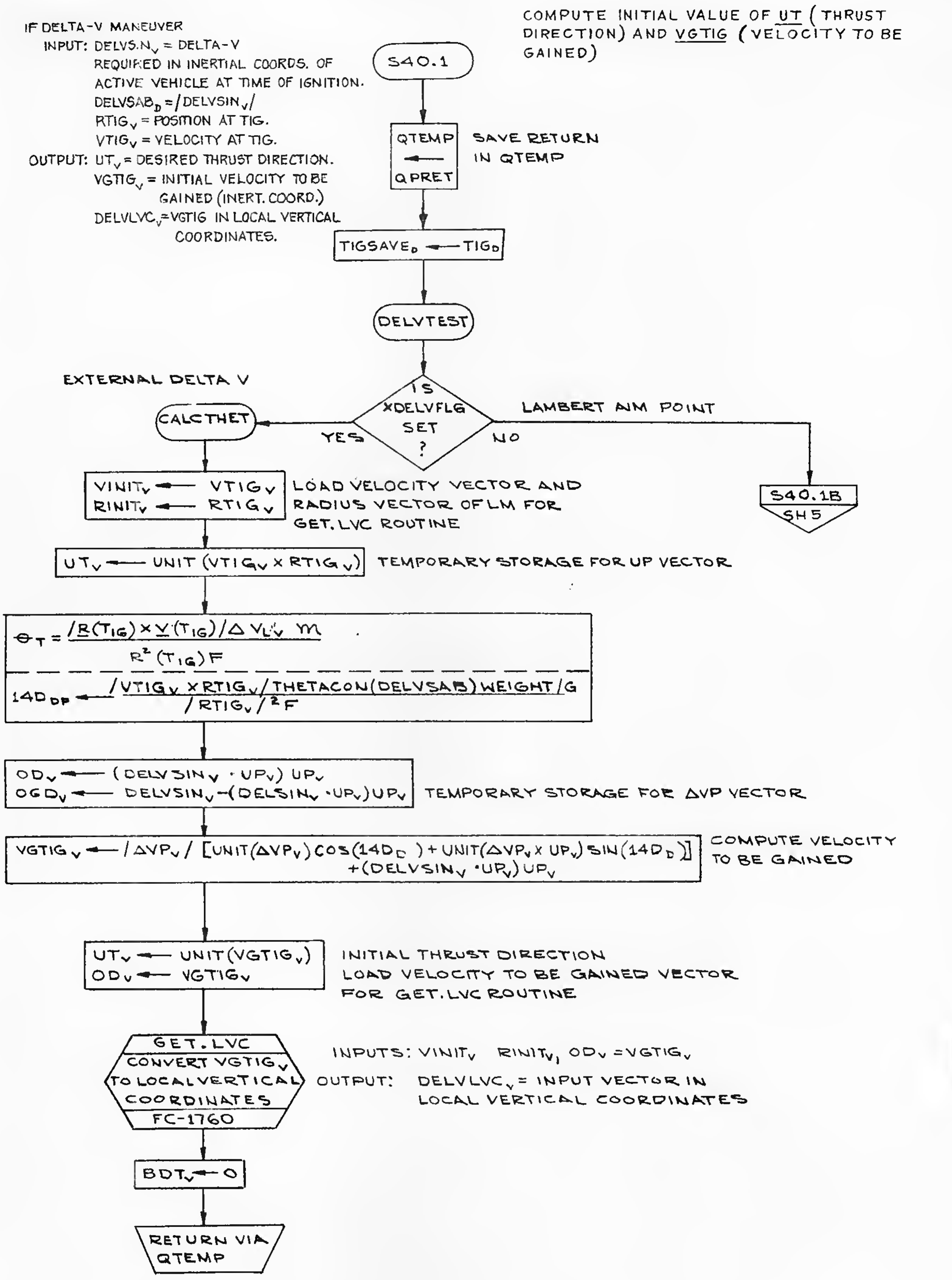
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A. J. Laughlin 29 OCT 68	P40 DPS THRUST
PRGMR [illegible] 31 Oct 68	LUMINARY 1D
ANALST [illegible] 10 Jan 69	DOCUMENT NO. FC-3800
DOCMR [illegible] 31 OCT 68	
APPR'D John A. Moore 24 JAN 69 16 May 69	REV 3 — SHEET 2 OF 9



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN	29OCT68	P40 DPS THRUST
PRGMR	8 Oct 68	
ANALST	10 Jan 69	LUMINARY 1D
DOCMR	31OCT68	DOCUMENT NO. FC-3800
APPR'D John A. Moore	2 JAN 68 16 May 69	REV 3 · SHEET 3 OF 9

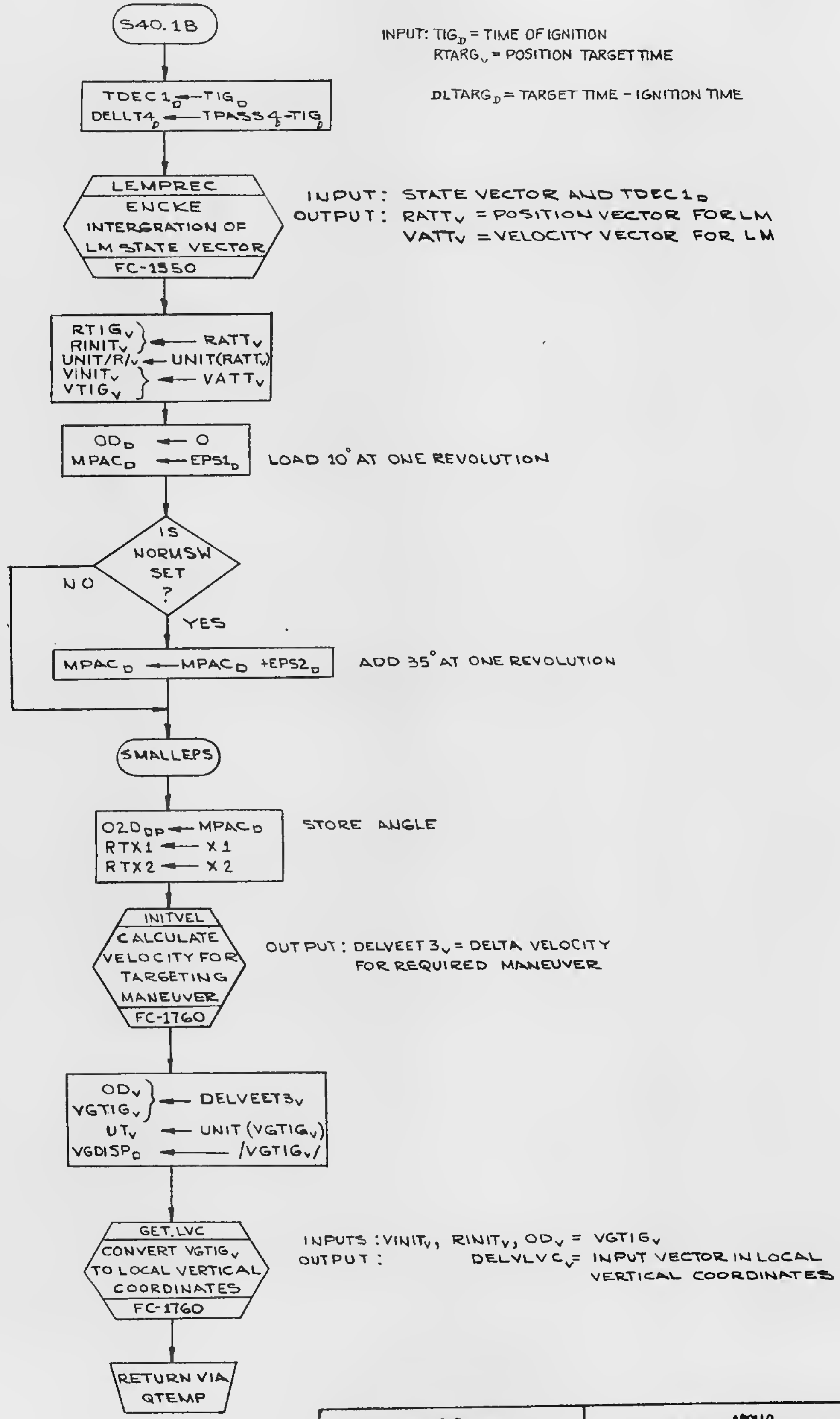


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN W.D. Kueg Jr. 7-26-68	P40 DPS THRUST
PROGMR P. Colley 8-26-68	
ANALST P. Phillips 0 Jan 69	LUMINARY 1D
DOCMR M.C. Danforth 8-5-68	DOCUMENT NO. FC-3800
APPR'D John A. Moss 4 JAN 68 16 May 69	REV 3 SHEET 4 OF 9



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN W. D. Fowell	7-29-68	P40 DPS THRUST	
PRGMR P. Callas	8-26-68	LUMINARY 1D	DOCUMENT NO. FC-3800
ANALST P. Phillips	10 Jan 69		
DOCMR W. C. Doughtie	8-5-68		
APPR'D John A. Moore	24 JAN 68 / 16 May 69	REV 3	SHEET 5 OF 9

LAMBERT AIMPOINT MANEUVER

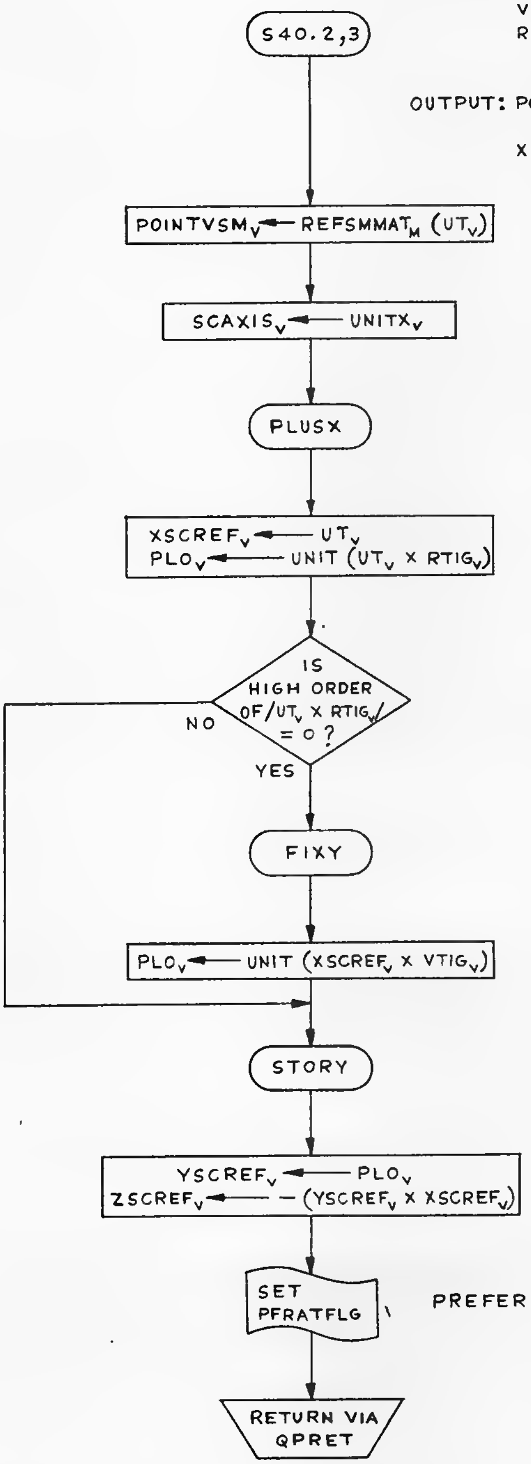


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P40 DPS THRUST	
DRAWN W.D. Knight	3-29-68	LUMINARY 1D	DOCUMENT NO. FC-3800
PROGMR P. Sollen	8-26-68		
ANALST P. Rhiella	10 Jan 69		
DOCMR W.C. Dagnall	8-5-68		
APPR'D John A. Moore	24 JAN 68 / 16 May 69	REV 3	SHEET 6 OF 9

COMPUTE PREFERREO IMU ORIENTATION MATRIX
FOR POSSIBLE IMU REALIGNMENT

INPUT: UT_V = INITIAL THRUST DIRECTION.
$RTIG_V$ = RADIUS VECTOR OF LM.
$VTIG_V$ = VELOCITY VECTOR OF LM.
$REFSMMAT_M$ = TRANSFORMATION MATRIX BETWEEN BRC SYSTEM AND STABLE MEMBER COORDINATE SYSTEM.

OUTPUT: $POINTVSM_V$ = LM THRUST DIRECTION IN SM COOROINATE.
$XSCERF_M$ = PREFERRED IMU ORIENTATION MATRIX.



TRANSFORM THRUST DIRECTION TO SM COODINATES.

PREFERREO ATTITUDE COMPUTED

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN G. J. Longillo 8 MAY 69	P40 DPS THRUST
PRGMR 13 MAY 69	LUMINARY 1D — DOCUMENT NO. FC-3800
ANALST 14 May 69	
DOCMR 13 MAY 69	REV 3 — SHEET 7 OF 9
APPR'D John A. Moore 16 May 69	

SUBROUTINES
IN THIS CHART

P40SXT4	CALL ATTITUDE MANEUVER ROUTINE
S40.1	COMPUTE INITIAL THRUST DIRECTION AND VELOCITY TO BE GAINED
S40.2,3	COMPUTE PREFERRED IMU ORIENTATION

ON OTHER CHARTS

R02 BOTH	IMU STATUS CHECK
ALARM	STORE ALARM CODE
PFLITEDB	ZERO ATTITUDE ERRORS, SET 1° DEADBAND
ZATTEROR	STORE CDU DESIRED, ZERO INPUT TO AUTOPILOT
SETMINDB	SET 0.3° DEADBAND
RESTORDB	SET DEADBAND TO ASTRONUAT SELECTED VALUE
R60LEM	PERFORM AUTO ATTITUDE MANEUVER
GET. LVC	CONVERT INPUT VECTOR TO LOCAL VERTICAL COORDINATES
LEMPREC	ENCKE INTERGRATION OF LM STATE VECTOR
INITVEL	CALCULATE VELOCITY FOR TARGETING MANEUVER

FLAGS	MEANING	SET	CLEARED	TESTED
NOTHROTL	SET - IHIBIT FULL THROTTLE CLEARED - PERMIT FULL THROTTLE		SH 3	
3AXISFLG	SET - MANEUVER SPECIFIED BY THREE AXES CLEARED - MANEUVER SPECIFIED BY ONE AXIS		SH 4	
XDELVFLG	SET - EXTERNAL DELTAV VG COMPUTATION CLEARED - LAMBERT (AIMPOINT) VG COMPUTATION			SH 5
NORMSW	SET - UNIT NORMAL COMPUTED CLEARED - UNIT NORMAL NOT COMPUTED			SH 6
PFRATFLG	SET - PREFERRED ATTITUDE COMPUTED CLEARED - PREFERRED ATTITUDE NOT COMPUTED	SH 7		

DISPLAYS	MEANING	USED
V16N40	R1 - TTOGO - XXBXX MIN-SEC - TIME TO CUTOFF R2 - VGDISP - XXXX.X FT/SEC - VELOCITY TO BE GAINED R3 - D_VTOTAL - XXXX.X FT/SEC - TOTAL DELTA V	SH 4
V16N85	R1, R2, R3 } VG_V (BODY) XXXX.X FT/SEC { VGX (LM), VGY (LM), VGZ (LM) } COMPONENTS OF VG VECTOR	SH 4

ALARMS	MEANING	USED
1706	INCORRECT PROGRAM SELECTED FOR VEHICLE CONFIGURATION	SH 2

ERASABLE	MEANING	UNITS	SCALING
$VINIT_V$	VELOCITY AT TIME OF IGNITION	M/CSC	2^7
$RINIT_V$	POSITION AT TIME OF IGNITION	M	2^{29}
$VGTIG_V$	INITIAL VELOCITY TO BE GAINED	M/CSEC	2^7
UT_V	DESIRED THRUST DIRECTION	UNIT VECTOR	2^1
$XSCREF_V$	WINGS-LEVEL HEAD-UP	UNIT VECTOR	2^1
$YSCREF_V$	LM ORIENTATION IN	UNIT VECTOR	2^1
$ZSCREF_V$	REFERENCE COORDINATES	UNIT VECTOR	2^1
F_D	ENGINE THRUST	M-NEWTONS*	2^7
$TDECAY_D$	ΔT TAIL-OFF TIME TIME OF ENGINE	CSEC	2^{28}

* M-NEWTONS = 10^4 NEWTONS

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN W.D. KNIGHT 7-26-68	P40 DPS THRUST	
PROMR P. Adler 8-26-68	LUMINARY 1D	DOCUMENT NO. FC-3800
ANALST P. Adler 10 Jan 69		
DOCMR W. C. [illegible] 9-5-68		
APPR'D John A. Moore 24 JAN 68	REV 3	SHEET 8 OF 9

FIXED CONSTANTS	MEANING	PHYSICAL VALUE & UNITS	STORED VALUE & UNITS	SCALING
$FDPS_D$	DPS ENGINE THRUST	9712.5 POUNDS	4.319223105 M-NEWTONS*	2^7
$THETA\ CON_D$	$1/\pi$ CONVERSION FACTOR	$1/\pi$ $1/RAD$	.31830989 $1/RAD$	2^8
$TDECAY_D$	DPS ENGINE ΔT TAIL-OFF TIME	0.08 SEC	-8 CSEC	2^{28}

*M-NEWTONS = 10^4 NEWTONS

ADDED FLAG FOR P40 DPS THRUST

FLAG	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
BIT 13 OF DAPBOOLS	CSM DOCKED	CSM IS NOT DOCKED			SH3
APSFLAG	ASCENT STAGE	DESCENT STAGE			SH2

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN W.D. Knight 8-5-68	P40 DPS THRUST	
PROMMR P. Golden 8-26-68		
ANALST P. Kullen 10 Jan 69	LUMINARY 1D	DOCUMENT NO. FC-3800
DOCMR W. C. Dygbith 8-5-68		
APPR'D Edwin A. Moore 24 JAN 68 16 May 69	REV 3	SHEET 9 OF 9

P41 RCS THRUST

MAJOR SUBROUTINES ON THIS CHART

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

DRAWN	D.M. Dietrich	30 MAY 69
PROGMR	P. Adler	17 June 69
ANALST		
DOCMR	W.C. Dayforth	17 JUNE 69
APPR'D	Alvin M. Sloane	17 JUNE 69

APOLLO GUIDANCE AND NAVIGATION

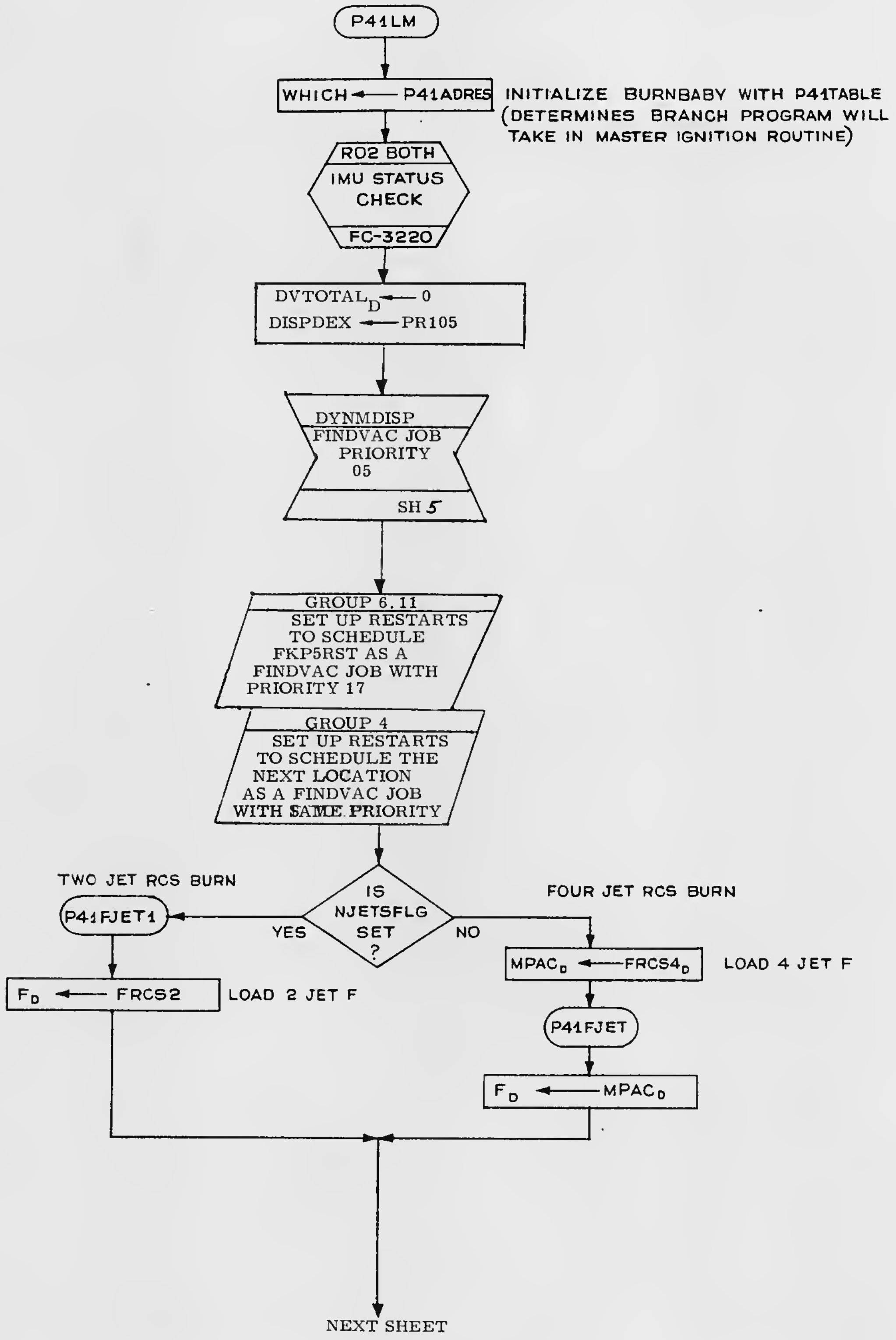
P41 RCS THRUST

LUMINARY 1D

DOCUMENT NO. FC-3810

REV 2

SHEET 1 OF 15



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E. Matta	6/2/70	P41 RCS THRUST	
PRGMR ? Cellen	6/5/70		DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3810
DOCMR W. Danforth	6/5/70		
APPR'D R. M. Eutes	6/6/70	REV 2	SHEET 2 OF 15

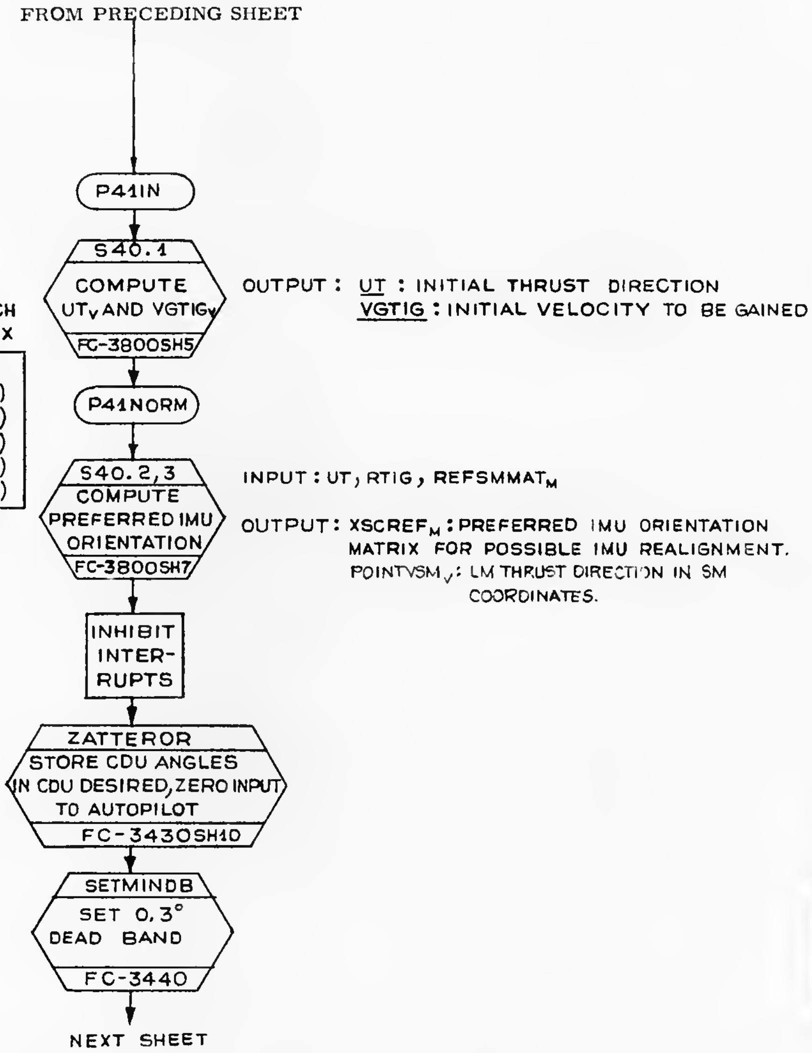
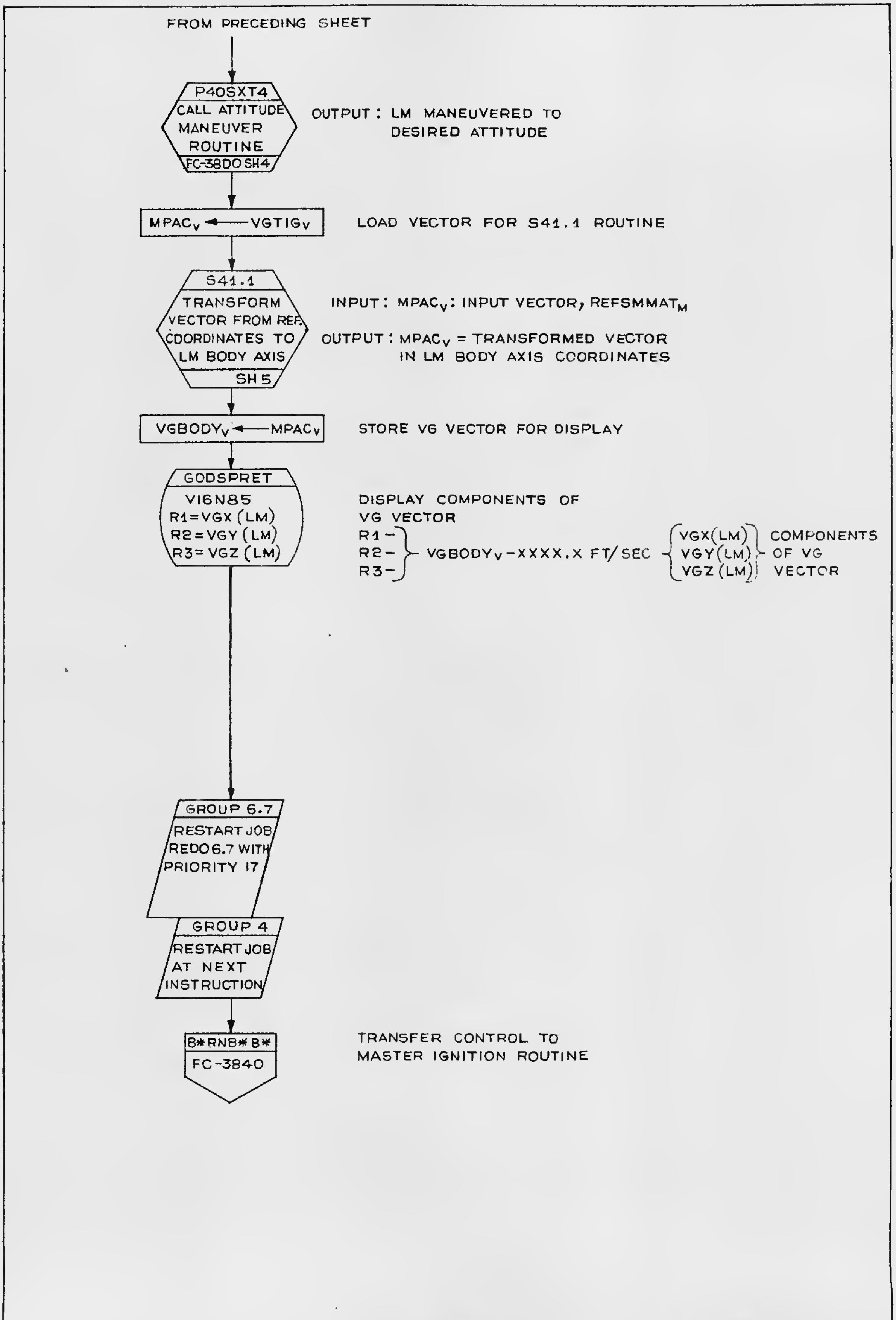


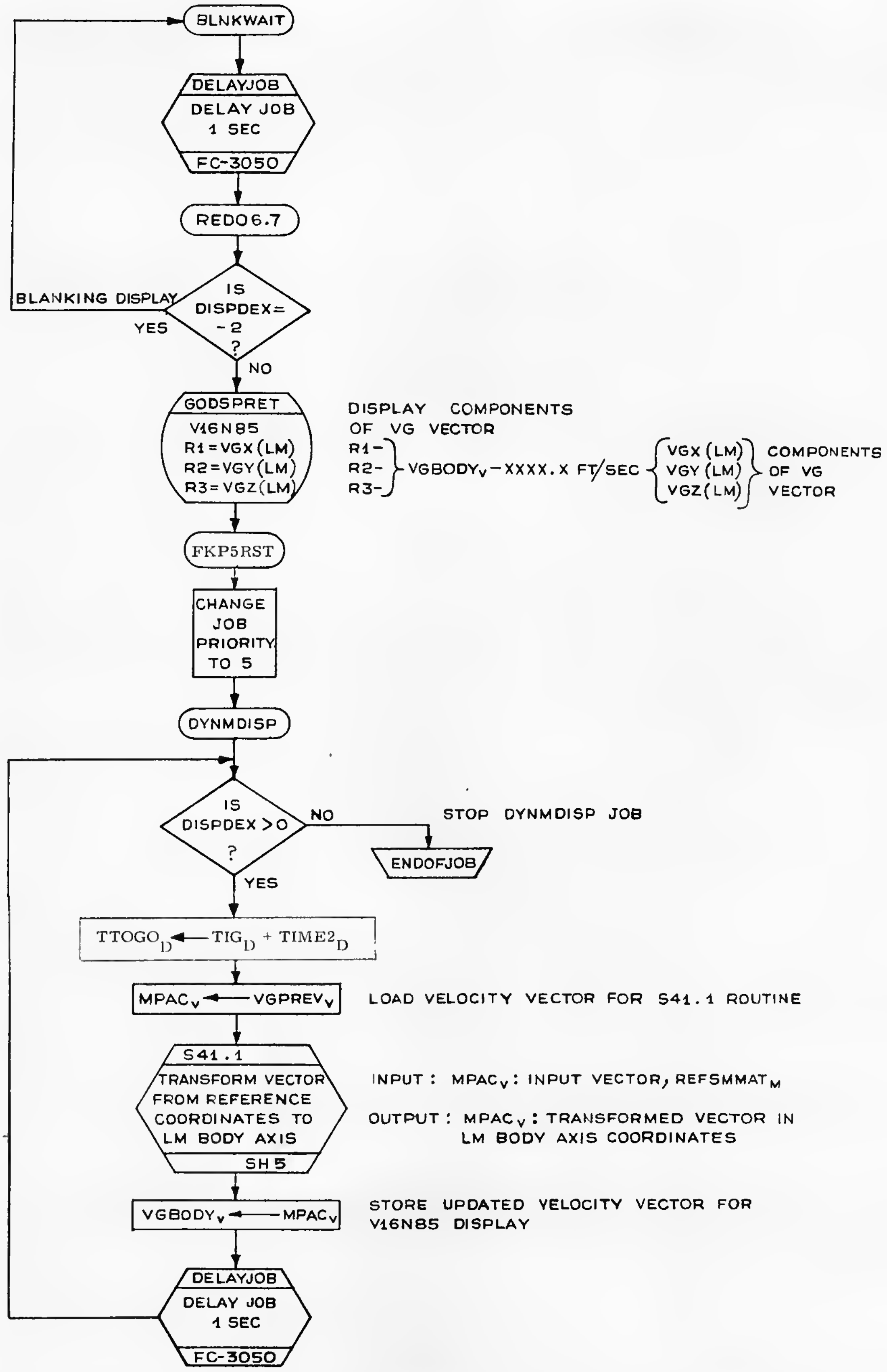
TABLE USED BY MASTER IGNITION ROUTINE

			WHICH INDEX
P41TABLE			
	TCF	P41SPOT	(5)
	DEC	-1	(6)
	2CADR	CALCN85	(7)
	TCF	COMMON	(11)
	TCF	TIGTASK	(12)

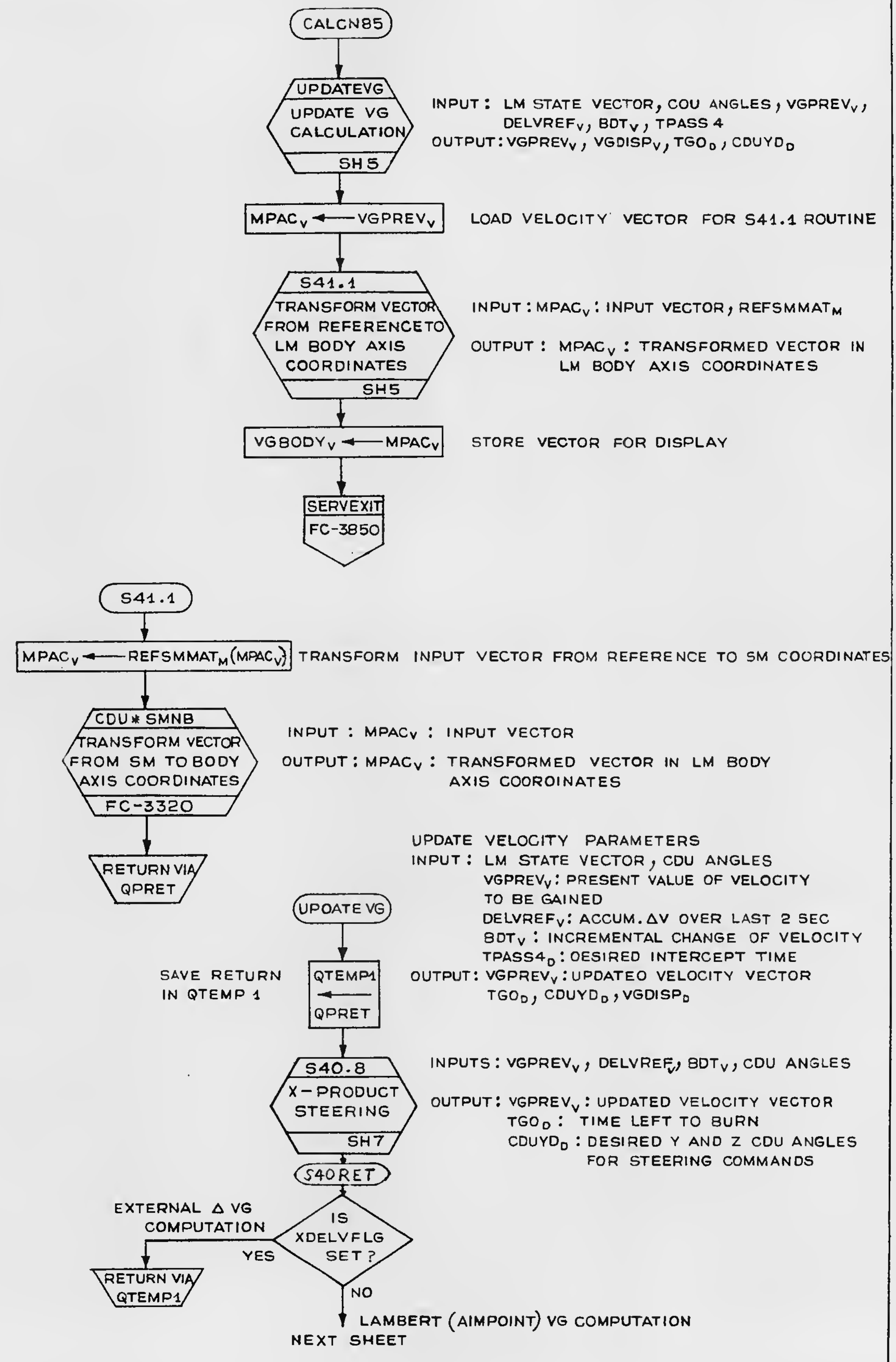
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	30JUL68	P41 RCS THRUST	
PRGMR	8-26-68	LUMINARY 1D	DOCUMENT NO. FC-3810
ANALST	10 Jan 69		
DOCMR	26 Aug		
APPR'D	24 JAN 68	REV 2	SHEET 3 OF 15



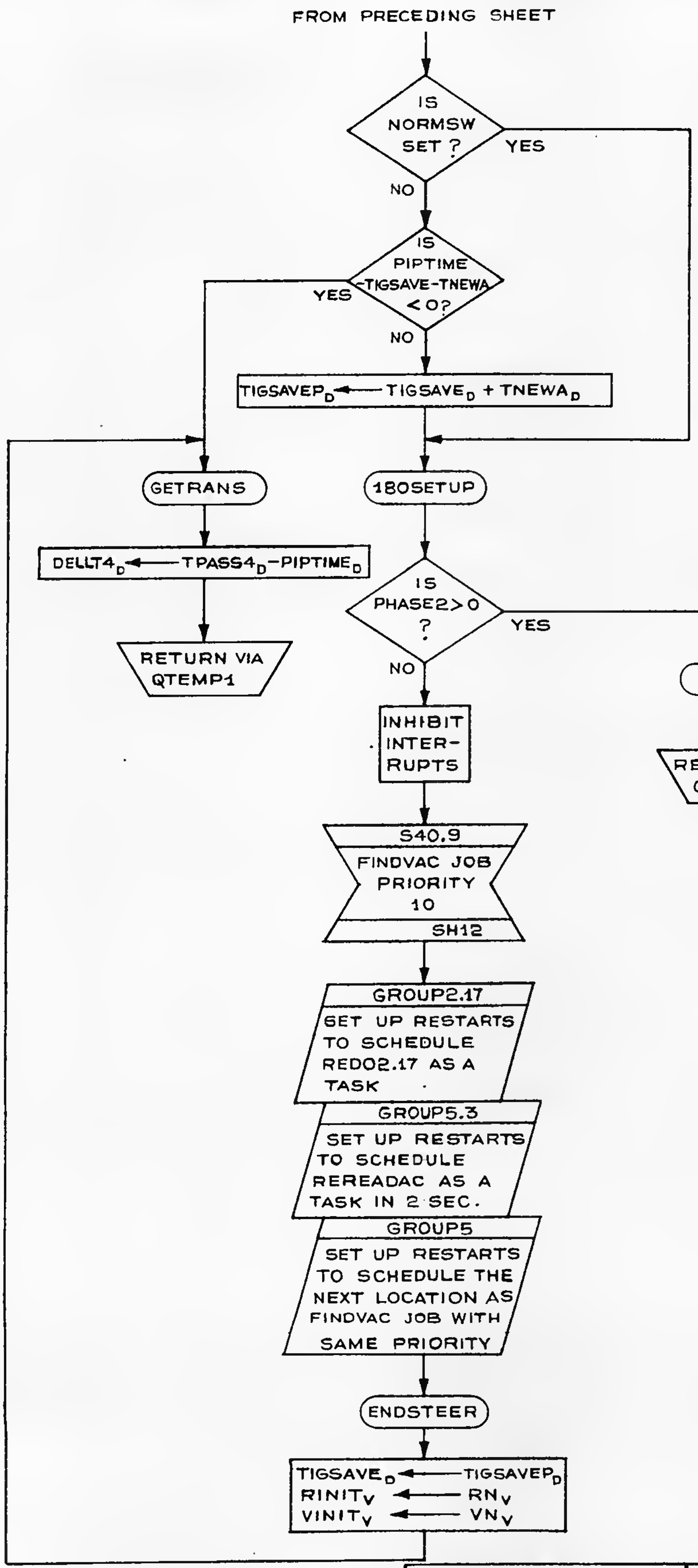
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN L.M. Dietrich	30JUL68	P 41 RCS THRUST	
PROGMR C. Colby	8-26-68		
ANALST P. Phillips	10JAN-69	LUMINARY 1D	DOCUMENT NO. FC-3810
DOCMR W.C. Dogbill	26AUG68		
APPR'D John A. Moore	24 JAN 69	REV 2	SHEET 4 OF 15



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN R.M. Dietz Jr. 30JUL68	P41 RCS THRUST
PRGMR R. Adler 8-26-68	LUMINARY 1D — DOCUMENT NO. FC-3810
ANALST P. Phillips 10Jan69	
DOCMR W. Dvorak 26AUG68	
APPR'D John A. Moore 24JAN69	REV 2 — SHEET 5 OF 15



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN P. M. Dilettri S.	31JUL68	P41 RCS THRUST
PRGMR R. Coller	26Aug68	
ANALST P. Phelan	10Jan69	LUMINARY 1D — DOCUMENT NO. FC-3810
DOCMR W. C. Dingwell	26AUG68	
APPR'D John A. Moore 24	JAN 69	REV 2 — SHEET 6 OF 15



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN J.M. Dietrich 30MAY69	P41 RCS THRUST
PRGMR P. Adler 17June69	
ANALST	LUMINARY 1D
DOCMR McDuffith 17June69	DOCUMENT NO. FC-3810
APPR'D Alida M. Grant 17June69	REV 2 — SHEET 7 OF 15

X-PRODUCT STEERING

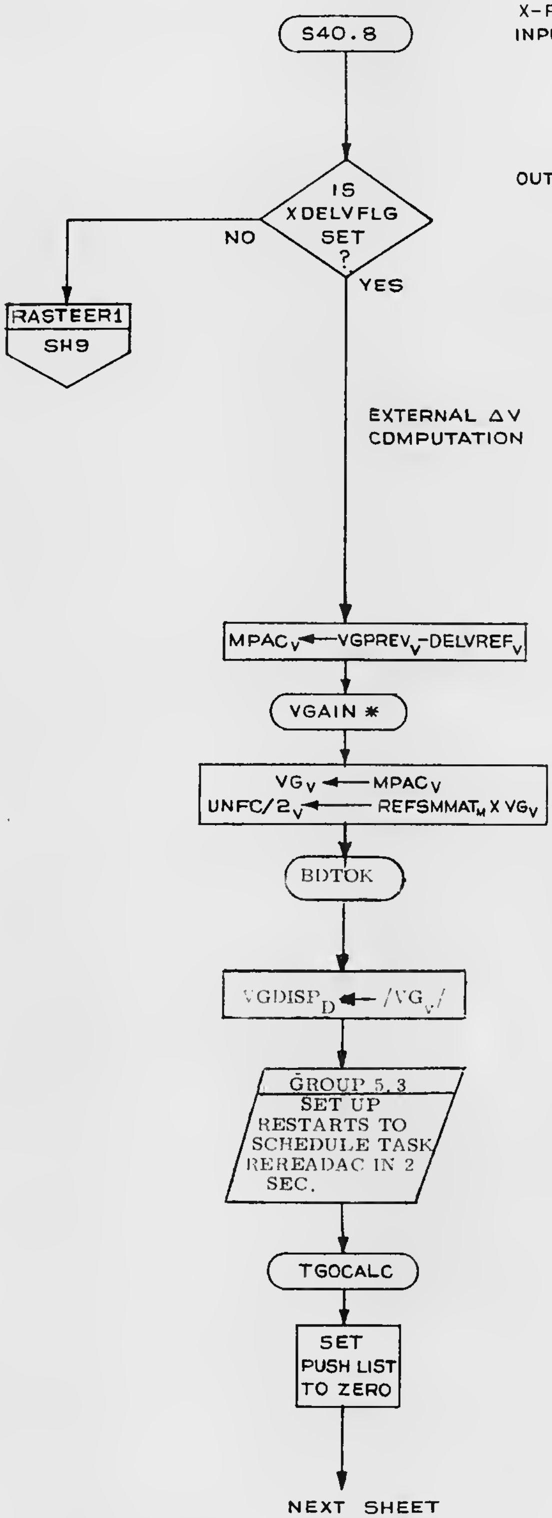
INPUTS : $VGPREV_V$: PRESENT VALUE OF VELOCITY TO BE GAINED VECTOR

$DELVREF_V$: ACCUMULATED ΔV OVER LAST 2 SEC

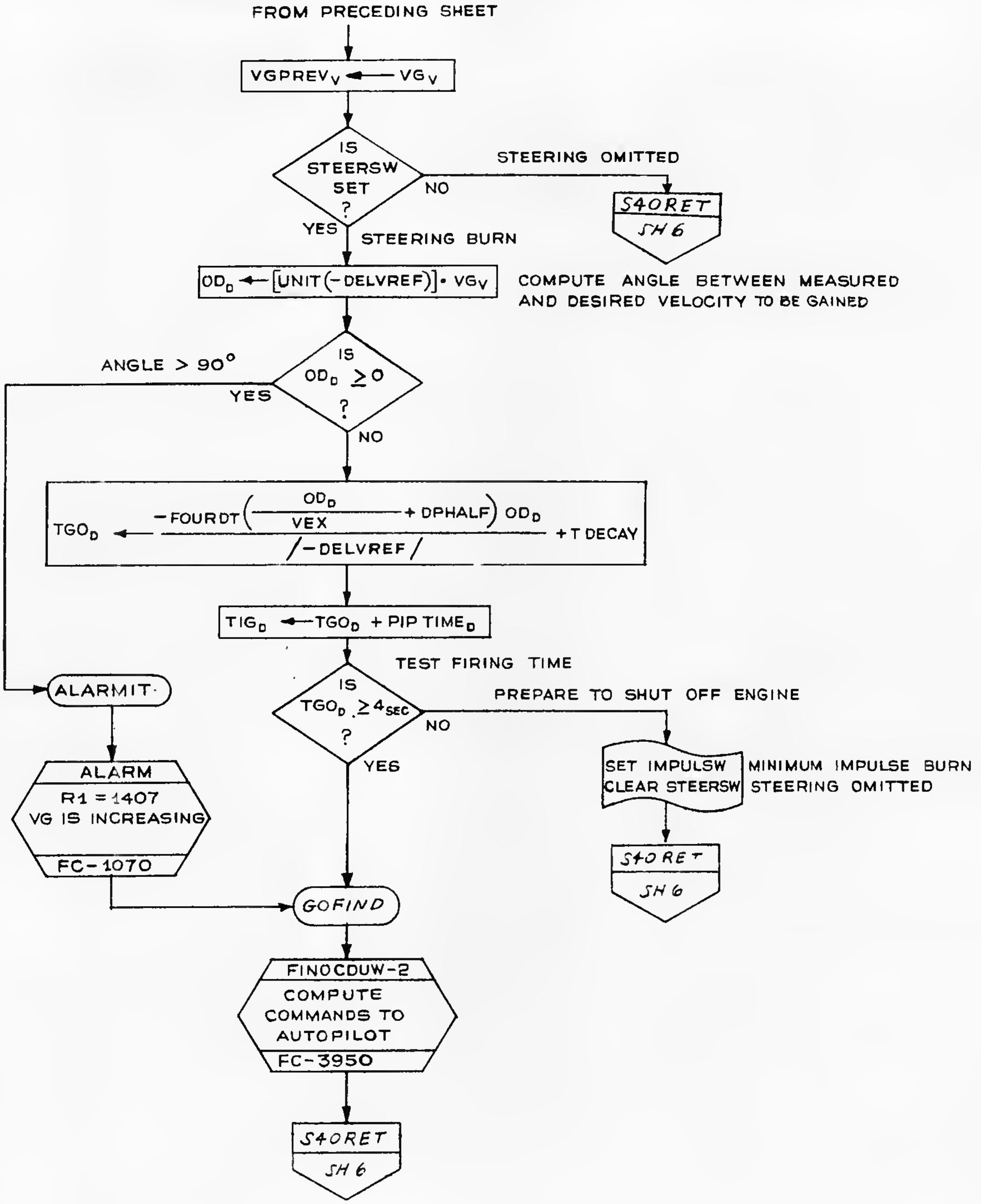
OUTPUT : $VGPREV_V$: UPDATED VALUE OF VELOCITY TO BE GAINED VECTOR

TGO_D : TIME LEFT TO BURN

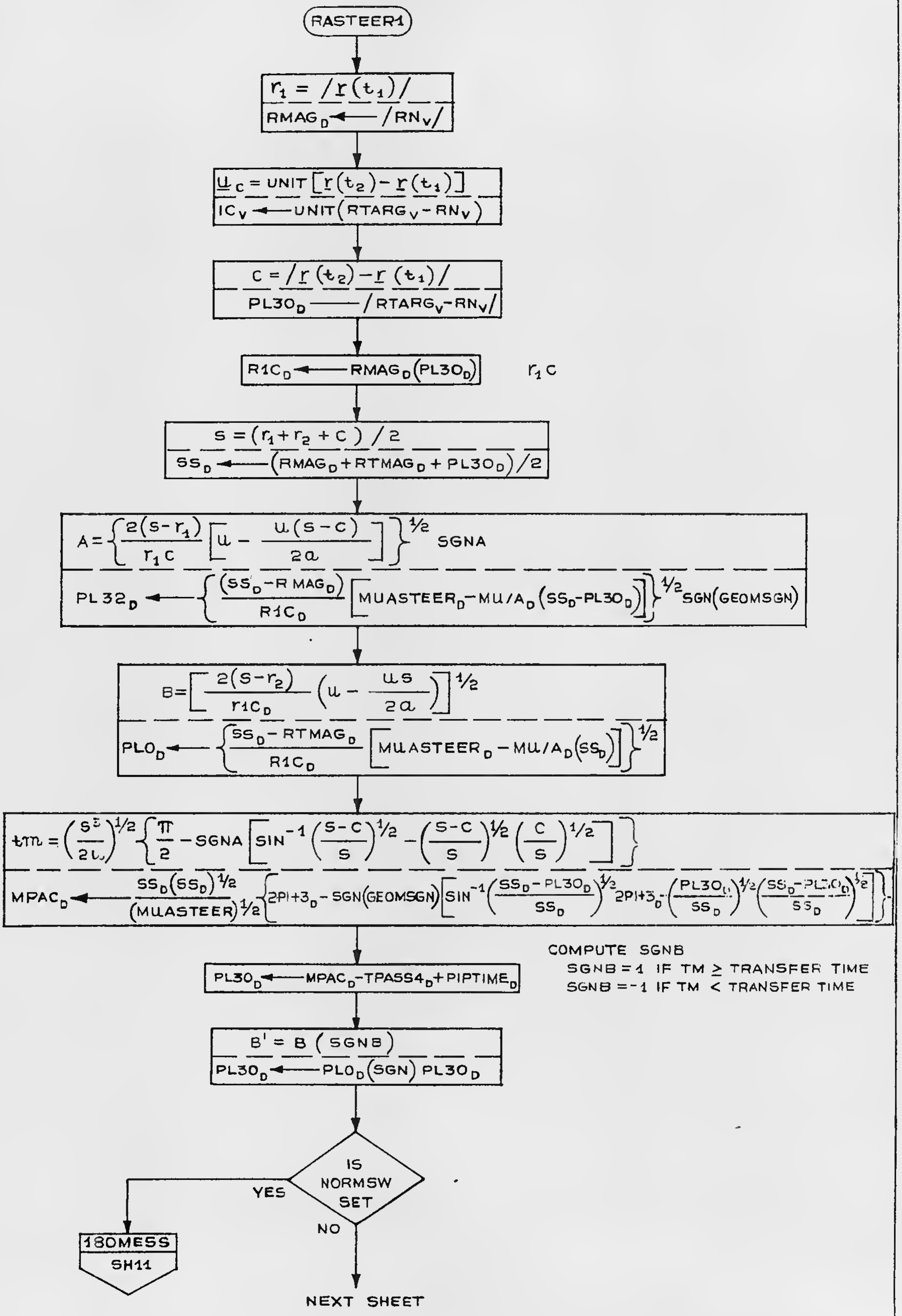
$CDUYD_D$: DESIRED Y & Z CDU ANGLES FOR STEERING COMMANDS



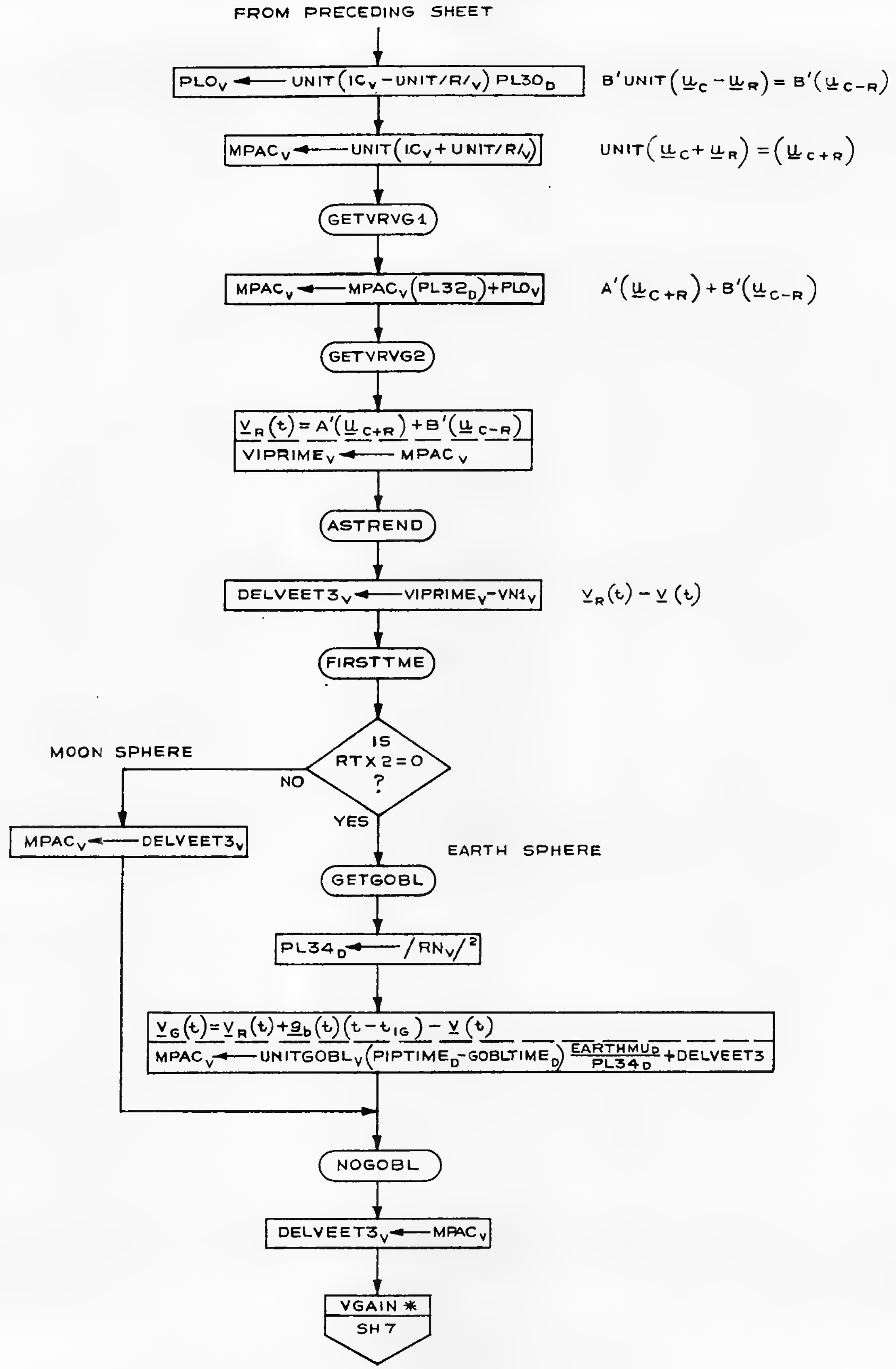
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN P.M. Dietrich	31JUL68	P41 RCS THRUST
PRGMR C. Cutler	8-26-68	
ANALST D. Phillips	10 Jan 69	LUMINARY 1D — DOCUMENT NO. FC-3810
DOCMR W.C. Dagbirth	26AUG68	
APPR'D John A. Morse	24 JAN 69	REV 2 — SHEET 8 OF 15



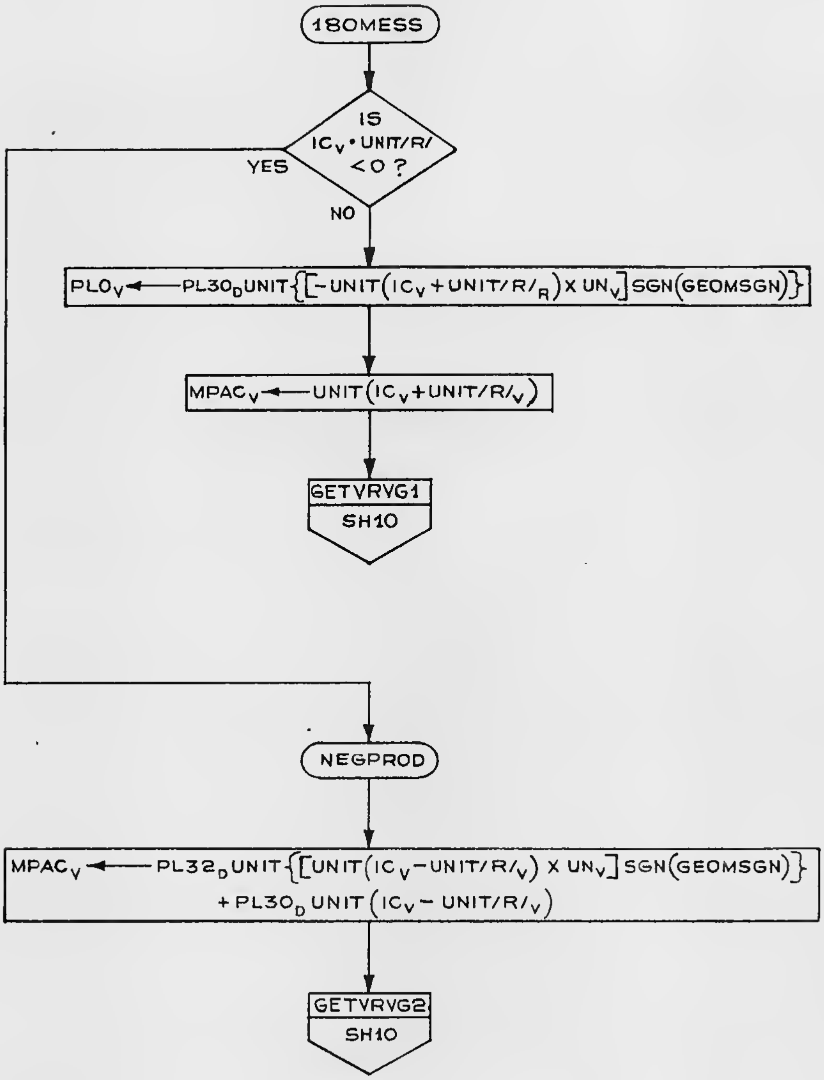
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN P. M. Dietrich 1 AUG 66	P41 RCS THRUST
PRGMR [illegible] 8-26-68	
ANALST P. Phillips 10 Jan 69	LUMINARY 1D — DOCUMENT NO. FC-3810
DOCMR MC [illegible] 26 Nov [illegible]	
APPR'D John A. [illegible] [illegible] JAN 69	REV 2 — SHEET 9 OF 15



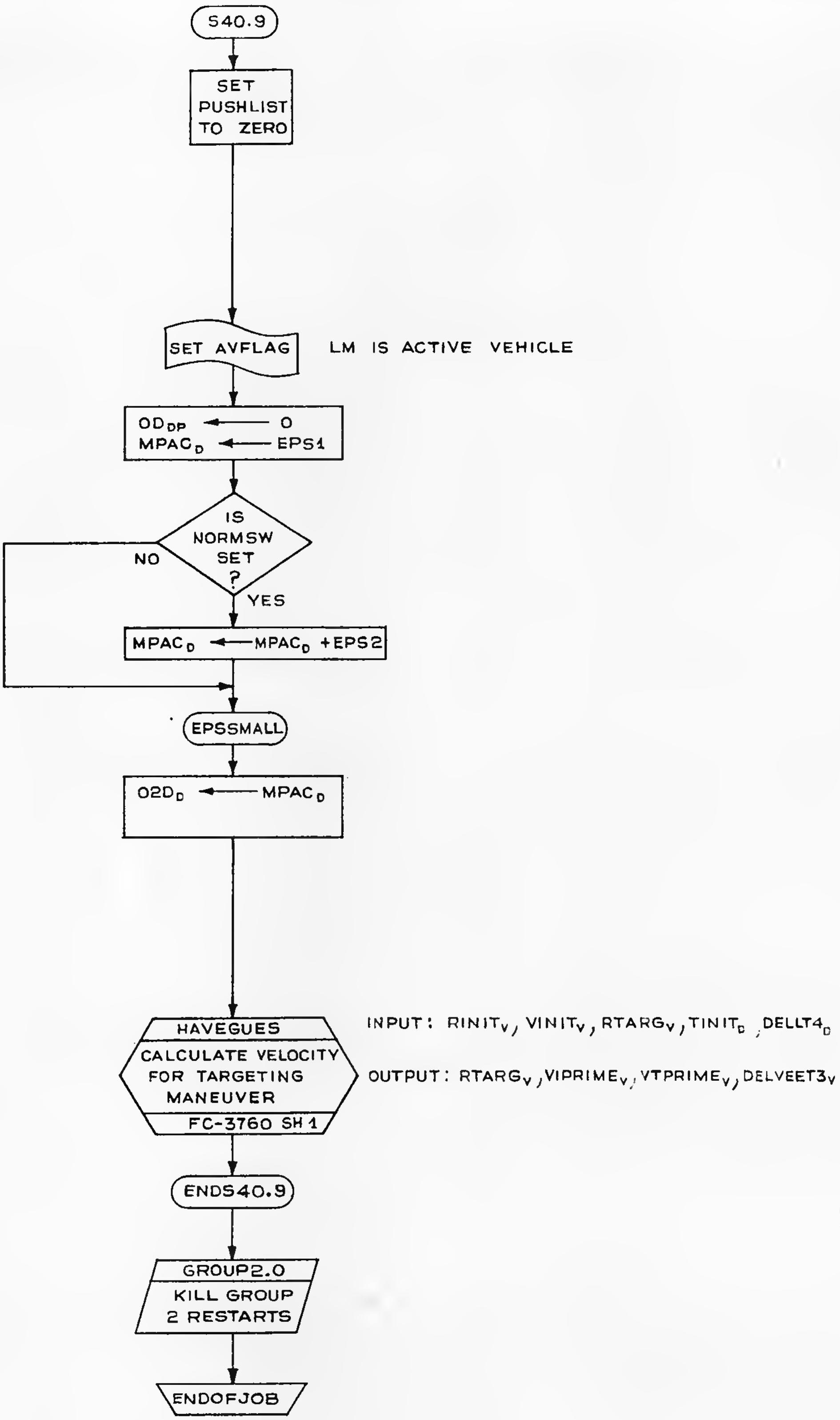
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN D.H. Diestro	2 JUNE 69	P41 RCS THRUST
PRGMR D. Adler	17 June 69	
ANALST		LUMINARY 1D — DOCUMENT NO. FC-3810
DOCMR McFarland	17 JUNE 69	
APPR'D Alida M. Grant	17 JUNE 69	REV 2 — SHEET 10 OF 15



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN 2JUNE69	P41 RCS THRUST	
PROGMR 17June69		
ANALST	LUMINARY 1D	DOCUMENT NO. FC-3810
DOCMR 17JUNE69		
APPR'D 17JUNE69	REV 2	SHEET 11 OF 15



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN P. M. Dietrich	2 JUNE 69	P41 RCS THRUST	
PRGMR P. Adler	17 June 69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3810
DOCMR M C Dougherty	17 JUNE 69		
APPR'D Alex M. Sotant	17 JUNE 69	REV 2	SHEET 12 OF 15



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN D M Dietrich 2 AUG 68	P41 RCS THRUST	
PRGMR 8-26-68		
ANALST P Phillips 10 Aug 69	LUMINARY 1D	DOCUMENT NO. FC-3810
DOCMR WC Danforth 26 AUG		
APPR'D John K Moore	REV 2	SHEET 13 OF 15

SUBROUTINES

ON THIS CHART

S41.1	TRANSFORM VECTOR FROM REF. COORDINATES TO BODY AXIS
CALCN85	CALL VG CALCULATION UPDATE
UPDATEVG	UPDATE VG CALCULATION
S40.8	X-PRODUCT STEERING
S40.9	COMPUTE VELOCITY, VELOCITY-TO-BE-GAINED AND B VECTORS

ON OTHER CHARTS

R02BOTH	IMU STATUS CHECK
S40.1	COMPUTE UT AND VGTIG VECTORS
S40.2,3	COMPUTE PREFERRED IMU ORIENTATION
ZATTEROR	STORE CDU ANGLES IN CDU DESIRED, ZERO INPUT TO AUTOPILOT
SETMINDB	SET 0.3° DEADBAND
P40SXT4	CALL ATTITUDE MANEUVER ROUTINE
DELAYJOB	DELAY SCHEDULED JOB
TMPTOSPT	LOAD CDUS CORRESPONDING TO PIPTIME IN CDUSPOT VECTOR
TRG*SMNB	TRANSFORM FROM SM TO NB COORDINATES
SMNB	TRANSFORM FROM SM TO NB COORDINATES
V1STO2S	CONVERT 1'S COMPLEMENT ANGLES TO 2'S COMPLEMENT ANGLES
ALARM	DISPLAY ALARM CODE
HAVEGUES	CALCULATE VELOCITY FOR TARGETING MANEUVER

FLAGS	MEANING	SET	CLEARED	TESTED
NJETSFLG	SET-TWO JET RCS BURN CLEARED - FOUR JET RCS BURN			SH 2
XDELVFLG	SET-EXTERNAL DELTAV VG COMPUTATION CLEARED - LAMBERT (AIMPOINT) VG COMPUTATION			SH 6,8
STEERSW	SET - STEERING TO BE DONE CLEARED - STEERING OMITTED		SH 9	SH 9
IMPULSW	SET - MINIMUM IMPULSE BURN CLEARED - STEERING BURN	SH 9		
AVFLAG	SET - AVERAGE G (SERVICER) DESIRED CLEARED - AVERAGE G (SERVICER) NOT DESIRED	SH 13		
NORMSW	SET-UNIT NORMAL COMPUTED CLEARED - UNIT NORMAL NOT COMPUTED			SH 7,10,13

DISPLAY	MEANING	USED
V16N85	R1 – VGX(LM), R2 – VGY(LM), R3 – VGZ(LM): VG_V (BODY) XXXX.X FT/SEC, COMPONENTS OF VG VECTOR	SH 4,5

ALARMS	MEANING	USED
1407	VG IS INCREASING	SH 9

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN	P. M. Dietrich	6 AUG 68
PRGMR	[illegible]	8-26-68
ANALST	P Phillips	10 Jan 69
DOCMR	[illegible]	26 [illegible]
APPR'D	John A. Moore	24 JAN 69

P41 RCS THRUST

LUMINARY 1D

DOCUMENT NO. FC-3810

REV 2

ERASABLES	MEANING	UNITS	SCALING
F_D	THRUST FOR ENGINE USED	* M – NEWTONS	2^7
$VGBODY_V$	VELOCITY TO BE GAINED VECTOR (BODY COORDS)	M/CSEC	2^7
VG_V	VELOCITY TO BE GAINED VECTOR	M/CSEC	2^7
$AXID_V$	DESIRED THRUST DIRECTION	UNIT VECTOR	2^1
$VGDISP_D$	MAGNITUDE OF VELOCITY TO BE GAINED VECTOR FOR DISPLAY	M/CSEC	2^7
$VGPREV_V$	VELOCITY TO BE GAINED VECTOR (PREVIOUS)	M/CSEC	2^7
TGO_D	TIME LEFT TO BURN	CSEC	2^{28}
TIG_D	TIME OF IGNITION	CSEC	2^{28}
$AXIS_V$	ACTUAL THRUST DIRECTION	UNIT VECTOR	2^1
$RINIT_V$	ACTIVE VEHICLE RADIUS VECTOR	METERS	2^{29}
$VINIT_V$	ACTIVE VEHICLE VELOCITY VECTOR	M/CSEC	2^7
$TNIT_D$	TIME OF STATE VECTOR	CSEC	2^{28}
$DELLT4_D$	REMAINING TIME TILL INTERCEPT	CSEC	2^{28}
$DELVEET3_V$	VELOCITY TO BE GAINED	M/CSEC	2^7
BDT_V	INCREMENTAL CHANGE OF THE VELOCITY TO BE GAINED VECTOR DUE TO RATE OF CHANGE OF VELOCITY REQUIRED AND GRAVITY VECTOR. THIS IS $\underline{0}_V$ FOR EXTERNAL ΔV.	M/CSEC	2^7

* M-NEWTONS = 10^4 NEWTONS

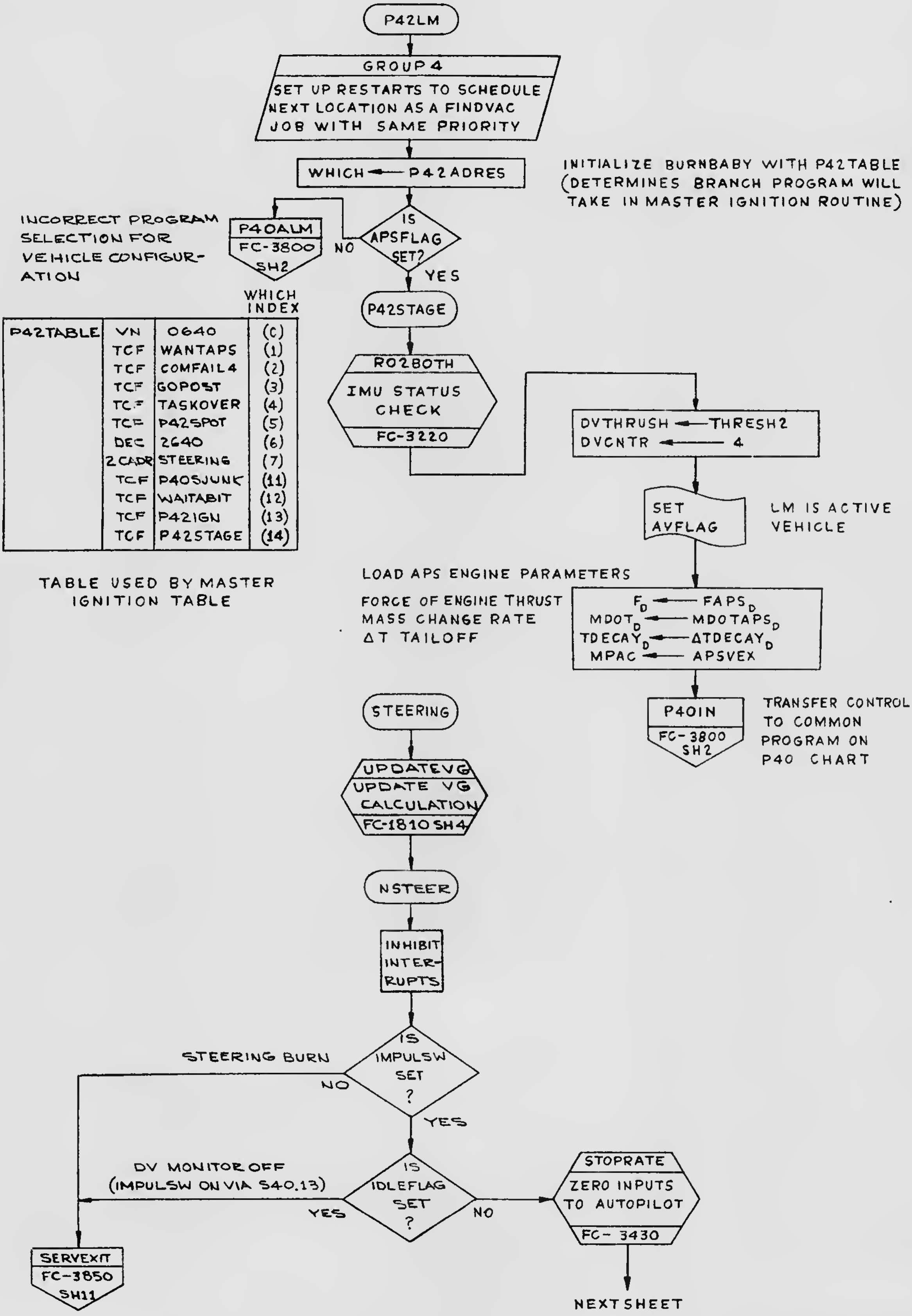
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN R.M. Lietrich 6 AUG 68	P41 RCS THRUST
PRGMR P. Adler 8-26-68	LUMINARY 1D
ANALST P Phillips 10 Jan 69	DOCUMENT NO. FC-3810
DOCMR McDaybrith 26 AUG 68	
APPR'D John A. Moore 24 JAN 69	REV 2 — SHEET 15 OF 15

P42
APS THRUST

MAJOR SUBROUTINES ON THIS CHART

P42LM	APS THRUST PROGRAM	SH 2
STEERING	SERVICER EXIT FOR STEERING BURN	SH 2
GETDT	STORE INPUT A IN TGO + 1	SH 3

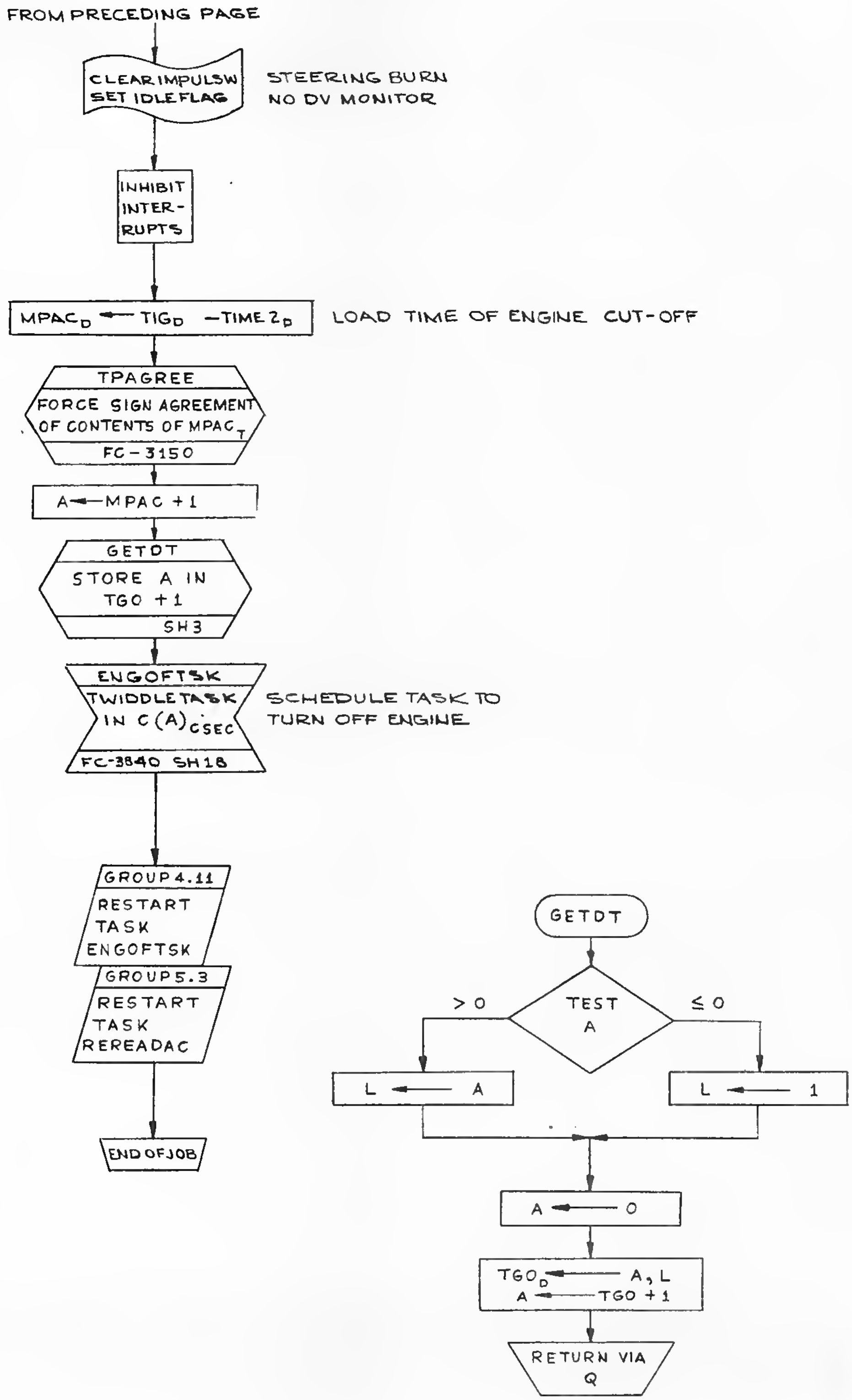
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	8 MAY 69	P42 APS THRUST	
PRGMR	13 MAY 69		
ANALST	16 May 69	LUMINARY 1D	DOCUMENT NO. FC-3820
DOCMR	13 MAY 69		
APPR'D	16 May 69	REV 3	SHEET 1 OF 4



			WHICH INDEX
P42TABLE	VN	0640	(0)
	TCF	WANTAPS	(1)
	TCF	COMFAIL4	(2)
	TCF	GOPOST	(3)
	TCF	TASKOVER	(4)
	TCF	P42SPOT	(5)
	DEC	2640	(6)
	2CADR	STEERING	(7)
	TCF	P40SJUNK	(11)
	TCF	WAITABIT	(12)
	TCF	P42IGN	(13)
	TCF	P42STAGE	(14)

TABLE USED BY MASTER IGNITION TABLE

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN W. D. Knight 7-30-68	P42 APS THRUST
PROGMR 8-28-68	
ANALST 10 Jan 69	LUMINARY 1D
DOCMR 8-28-68	DOCUMENT NO. FC-3820
APPR'D John A. Morse 24 JAN 69	REV 3 — SHEET 2 OF 4



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P42 APS THRUST	
DRAWN	7-29-68	LUMINARY 1D	DOCUMENT NO. FC-3820
PROGMR	9-28-68		
ANALST	10 Jan 69		
DOCMR	8-28-68		
APPR'D	29 JAN 69 / 16 May 69	REV 3	SHEET 3 OF 4

SUBROUTINES

ON THIS CHART

STEERING — SERVICER EXIT FOR STEERING BURN

ON OTHER CHARTS

R02 BOTH — IMU STATUS CHECK

UPDATEVG — UPDATEVG CALCULATION

TPAGREE — FORCE SIGN AGREEMENT OF CONTENTS OF $MPAC_T$

FLAGS	MEANING	SET	CLEARED	TESTED
AVFLAG	SET - LM IS ACTIVE VEHICLE CLEARED - CSM IS ACTIVE VEHICLE	SH 2		
IMPULSW	SET - MINIMUM IMPULSE BURN CLEARED - STEERING BURN		SH 3	SH 2
IDLEFLAG	SET - NO DV MONITOR CLEARED - CONNECT DV MONITOR	SH 3		SH 2

ERASABLE	MEANING	UNITS	SCALING
F	THRUST FOR ENGINE USED	M-NEWTONS*	2^7
MDOT	MASS CHANGE RATE	KG/CSEC	2^3
TDECAY	DELTA-T TAILOFF	CSEC	2^{28}
TGO	TIME OF ENGINE CUT-OFF	CSEC	2^{28}

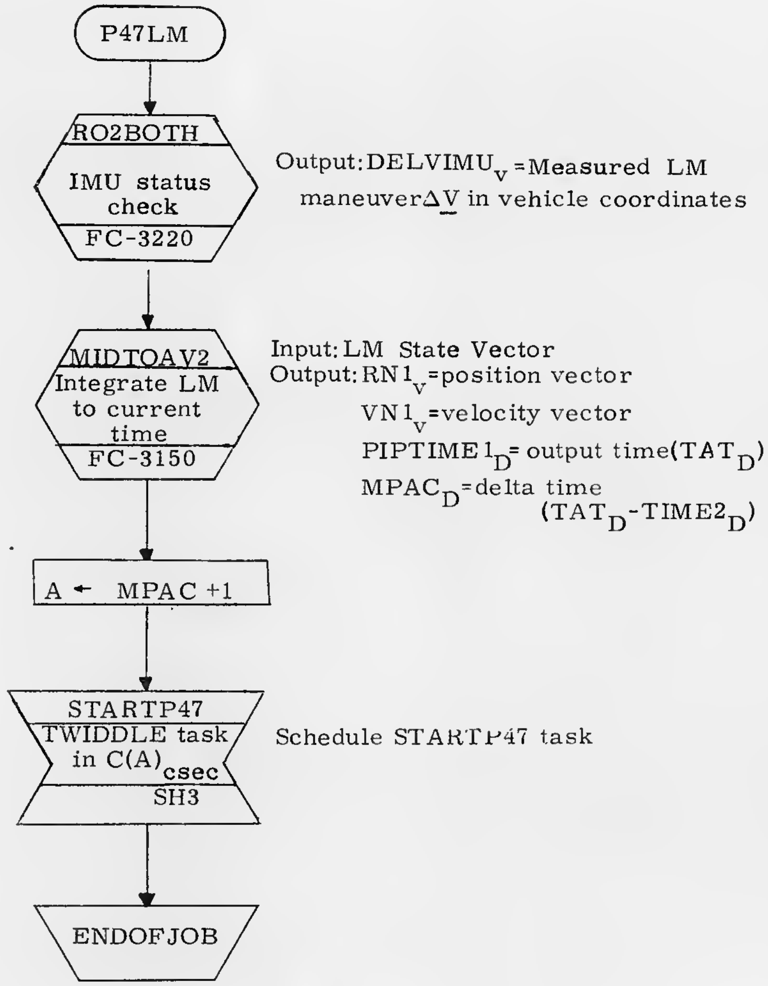
*M-NEWTONS = 10^4 NEWTONS

FIXED CONSTANTS	MEANING	PHYSICAL VALUE & UNITS	STORED VALUE & UNITS	SCALING
$FAPS_D$	APS ENGINE THRUST	3500 POUNDS	1.5568 M-NEWTONS *	2^7
$MDOTAPS_D$	APS ENGINE MASS CHANGE RATE	5.14 KG/SEC	.0513781393 KG/CSEC	2^3
$\Delta TDECAY_D$	APS ENGINE ΔT TAIL-OFF	-0.07 SEC	-7 CSEC	2^{28}

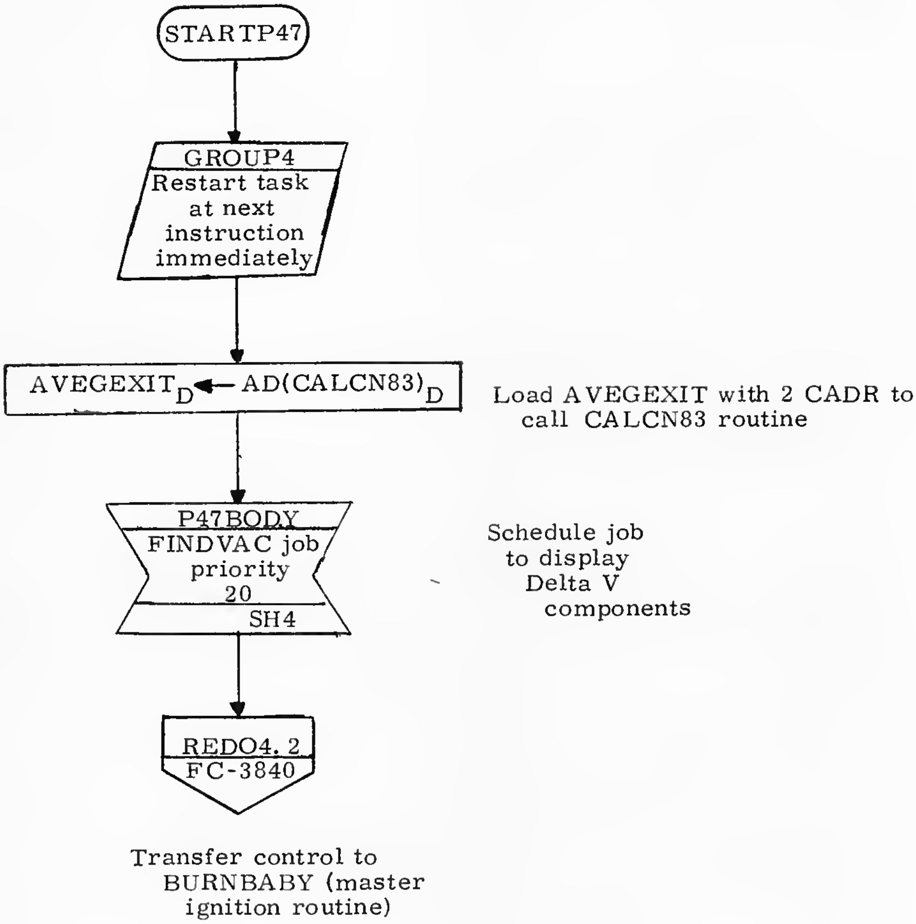
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN W D KNIGHT	1-29-68	P42 APS THRUST
PROGMR P Adler	8-28-68	
ANALST [illegible]	10 Jan 69	LUMINARY 1D — DOCUMENT NO. FC-3820
DOCMR W E [illegible]	8-28-68	
APPR'D John A. Morse 24 JAN 69 16 May 69		REV 3 — SHEET 4 OF 4

P47 THRUST MONITOR

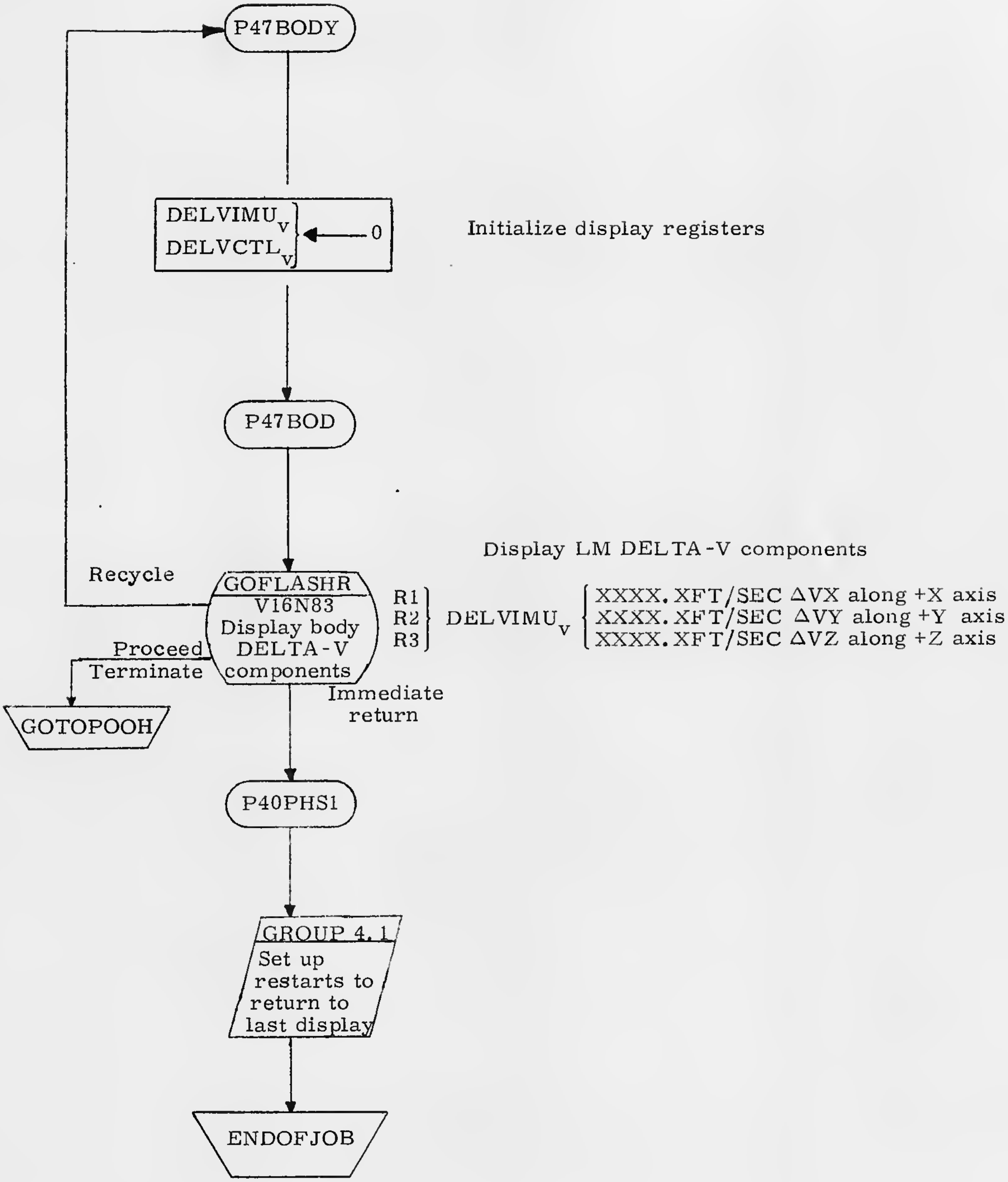
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	J. Cincotta	6 Aug 69	P47 THRUST MONITOR	
PRGMR	P. Adler	14 Aug 69	LUMINARY 1D	DOCUMENT NO. FC-3830
ANALST				
DOCMR	W C Danforth	8 AUG 69		
APPR'D	Alex W. Kosmala	15 AUG 69	REV 3	SHEET 1 OF 5



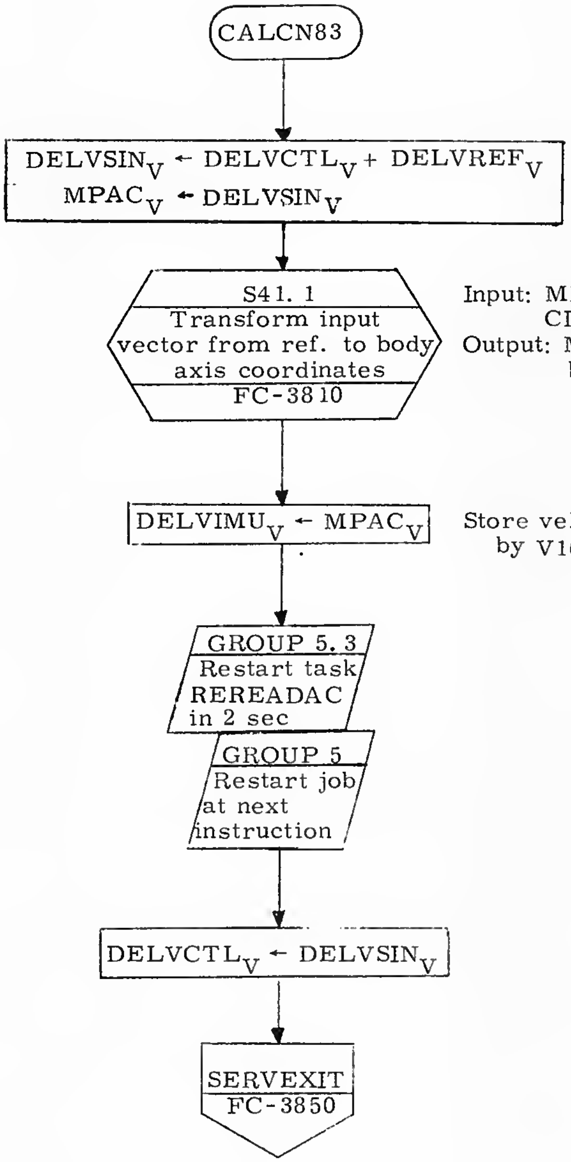
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN [illegible]	8 Aug 69	P47 Thrust Monitor	
PRGMR [illegible]	11 Aug 69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3830
DOCMR W C Danforth	5 Aug 69		
APPR'D [illegible]	15 AUG 69	REV 3	SHEET 2 OF 5



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN J. Cincotta	6Aug69	P47 Thrust Monitor	
PRGMR P. Adler	14Aug69	LUMINARY 1D	DOCUMENT NO. FC-3830
ANALST			
DOCMR W C Danforth	5Aug69		
APPR'D [illegible]	15Aug69	REV 3	SHEET 3 OF 5



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN J. Cuccolla	5 Aug 69	P47 Thrust Monitor	
PRGMR P. Adler	14 Aug 69		
ANALST			DOCUMENT NO.
DOCMR M Colaghith	5 AUG 69	LUMINARY 1D	FC-3830
APPR'D Alexa M. Stout	15 AUG 69	REV 3	SHEET 4 OF 5



$DELVCTL_V$ = LM velocity components in reference coordinates

Input: $MPAC_V$: input vector, REFSMMAT, CDUX, CDUY, CDUZ
Output: $MPAC_V$: transformed vector in body coordinates

Store velocity components for display by V16N83

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN J. Cincotta	6 Aug 67	P47 Thrust Monitor	
PRGMR [illegible]	4 Aug 67		
ANALST			
DOCMR [illegible]	5 AUG 67	LUMINARY 1D	DOCUMENT NO. FC-3830
APPR'D [illegible]	15 AUG 67	REV 3	SHEET 5 OF 5

BURN BABY BURN
(MASTER IGNITION ROUTINE)

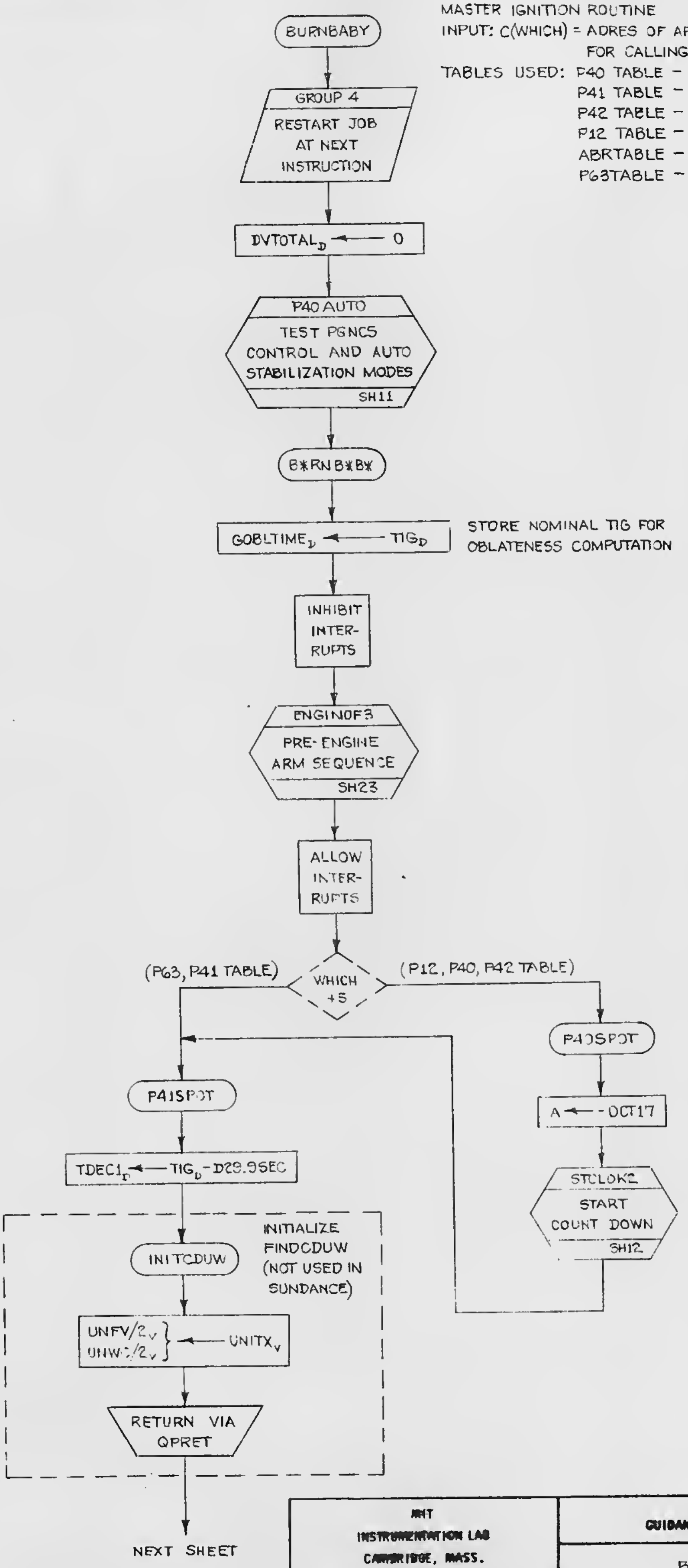
MAJOR SUBROUTINES ON THIS CHART

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN [illegible]	[illegible]	Burn Baby Burn (Master Ignition Routine)	
PRGMR P. Adler	10/9/69	LUMINARY 1D	DOCUMENT NO. FC-3840
ANALST			
DOCMR W C Danforth	10/9/69		
APPR'D Robert M. Este	10/9/69	REV 3	SHEET 1 OF 25

MASTER IGNITION ROUTINE

INPUT: C(WHICH) = ADRES OF APPROPRIATE TABLE FOR CALLING PROGRAM.

TABLES USED: P40 TABLE – DPS THRUST
P41 TABLE – RCS THRUST
P42 TABLE – APS THRUST
P12 TABLE – APS THRUST
ABRTABLE – ABORT
P63TABLE – DPS THRUST



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

DRAWN	A. C. WILLIAMS	5JUNE69
PRGMR	C. Schulenberg	6AUG69
ANALST		
DOCMR	WC Danforth	6AUG69
APPR'D	Alexis W. Lorant	6AUG69

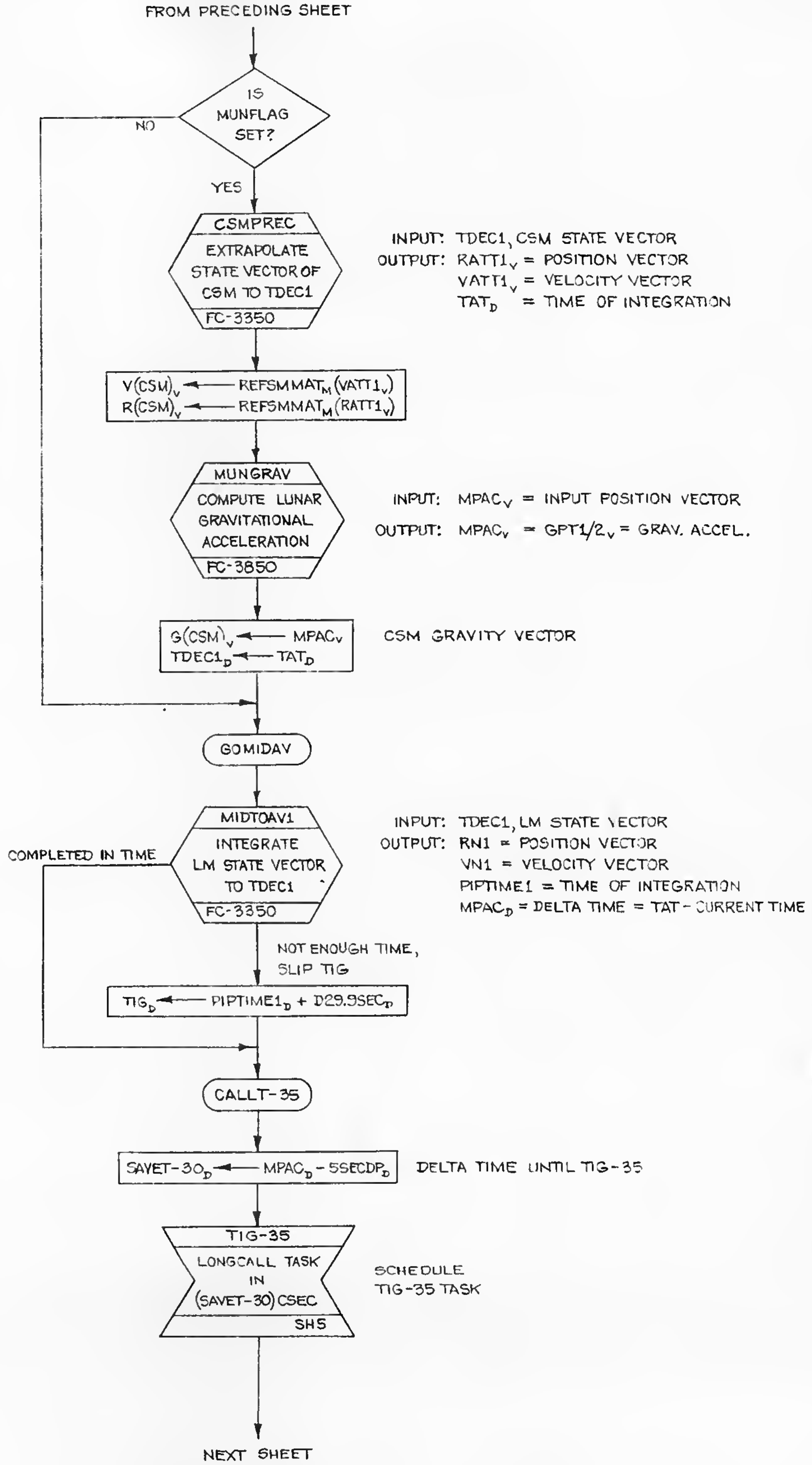
BURN BABY BURN (MASTER IGNITION ROUTINE)

LUMINARY 1D

DOCUMENT NO. FC-3840

REV 3

SHEET 2 OF 25



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

BURN BABY BURN (MASTER IGNITION ROUTINE)

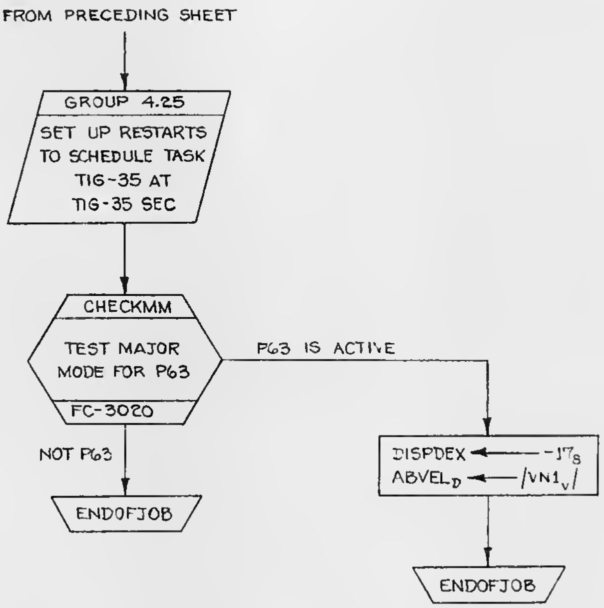
DRAWN	A.C.WILLIAMS	5JUNE69
PRGMR	C. Schulenberg	6 AUG 69
ANALST		
DOCMR	WC Deckert	6 AUG 69
APPR'D	Alex M. Kosmala	6 AUG 69

LUMINARY 1D

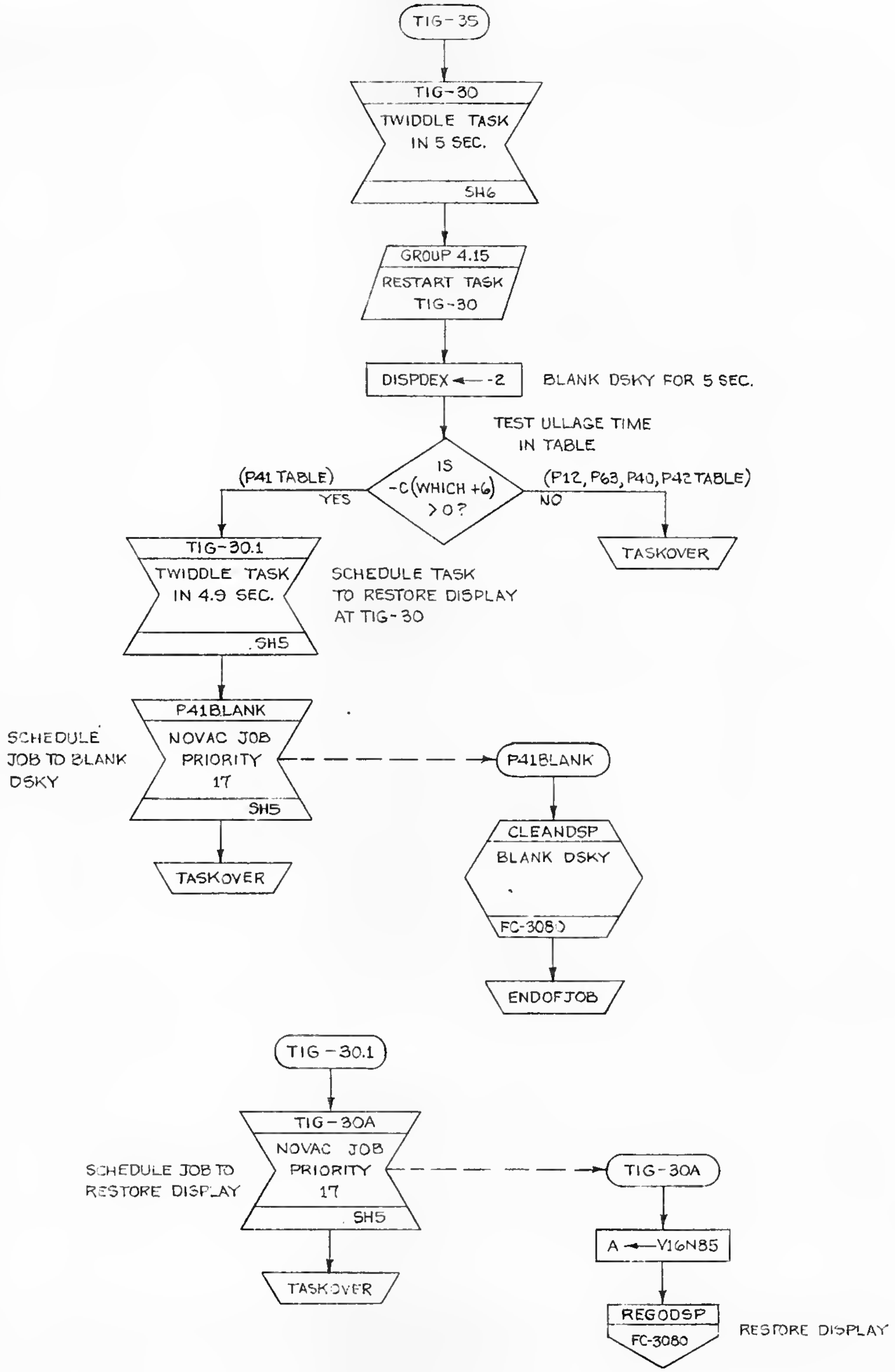
DOCUMENT NO. FC-3840

REV 3

SHEET 3 OF 25



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS	5JUNE69	BURN BABY BURN (MASTER IGNITION ROUTINE)	
PROGMR C. Schulenberg	6AUG69	LUMINARY 1D	DOCUMENT NO. FC-3840
ANALST			
DOCMR [illegible]	6AUG69		
APPR'D [illegible]	6AUG69	REV 3	SHEET 4 OF 25



MIT
INSTRUMENTATION LAB
CAMBRIDGE, MASS.

APOLLO
GUIDANCE AND NAVIGATION

BURN BABY BURN
(MASTER IGNITION ROUTINE)

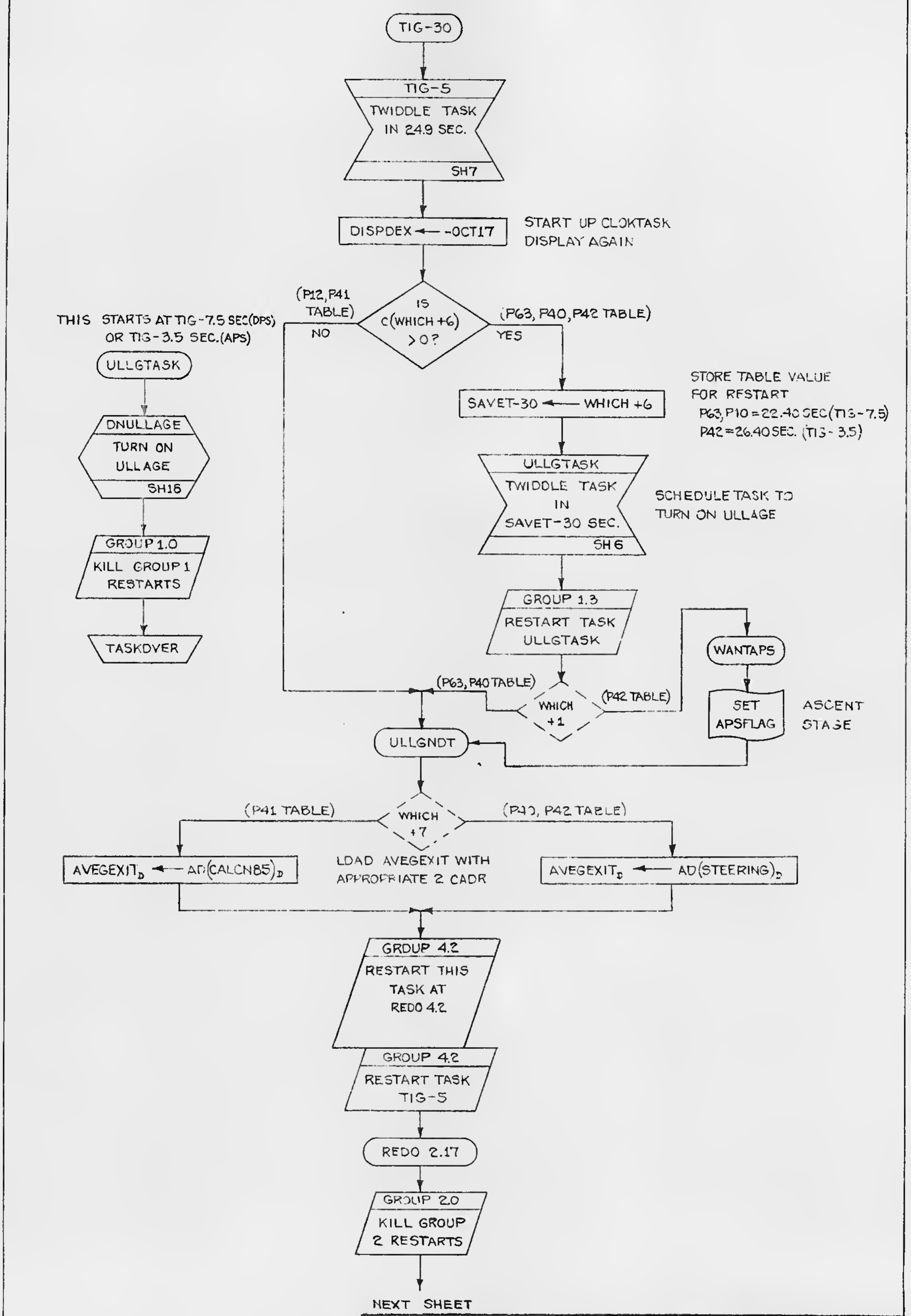
DRAWN	A.C.WILLIAMS	6-20-68
PRGMR	P. Adler	4 Sept 68
ANALST	[illegible]	10 Jan 69
DOCMR	W.C. Daugherty	7-29-68
APPR'D	John A. Moore	29 JAN 69

LUMINARY 1D

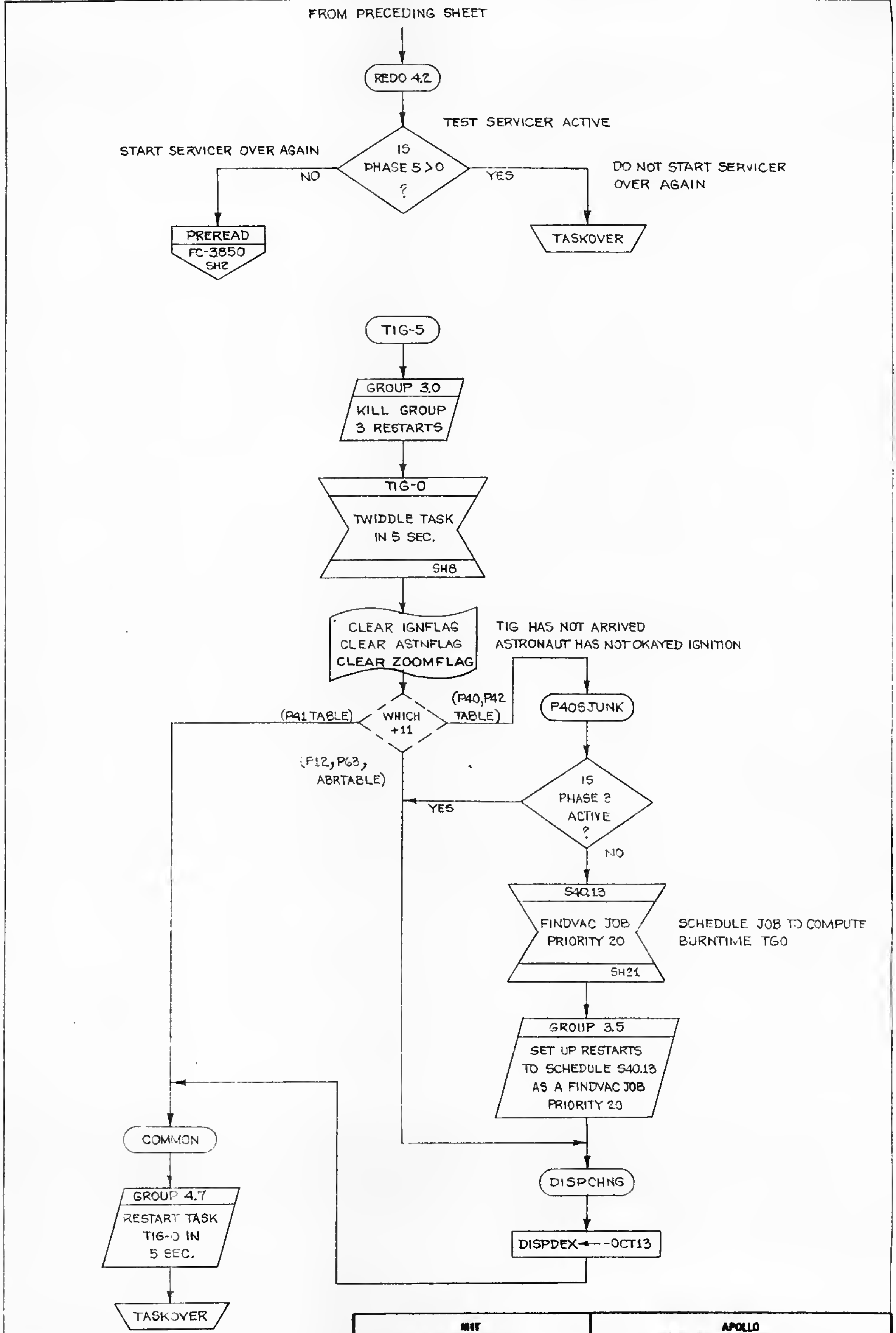
DOCUMENT NO. FC-3840

REV 3

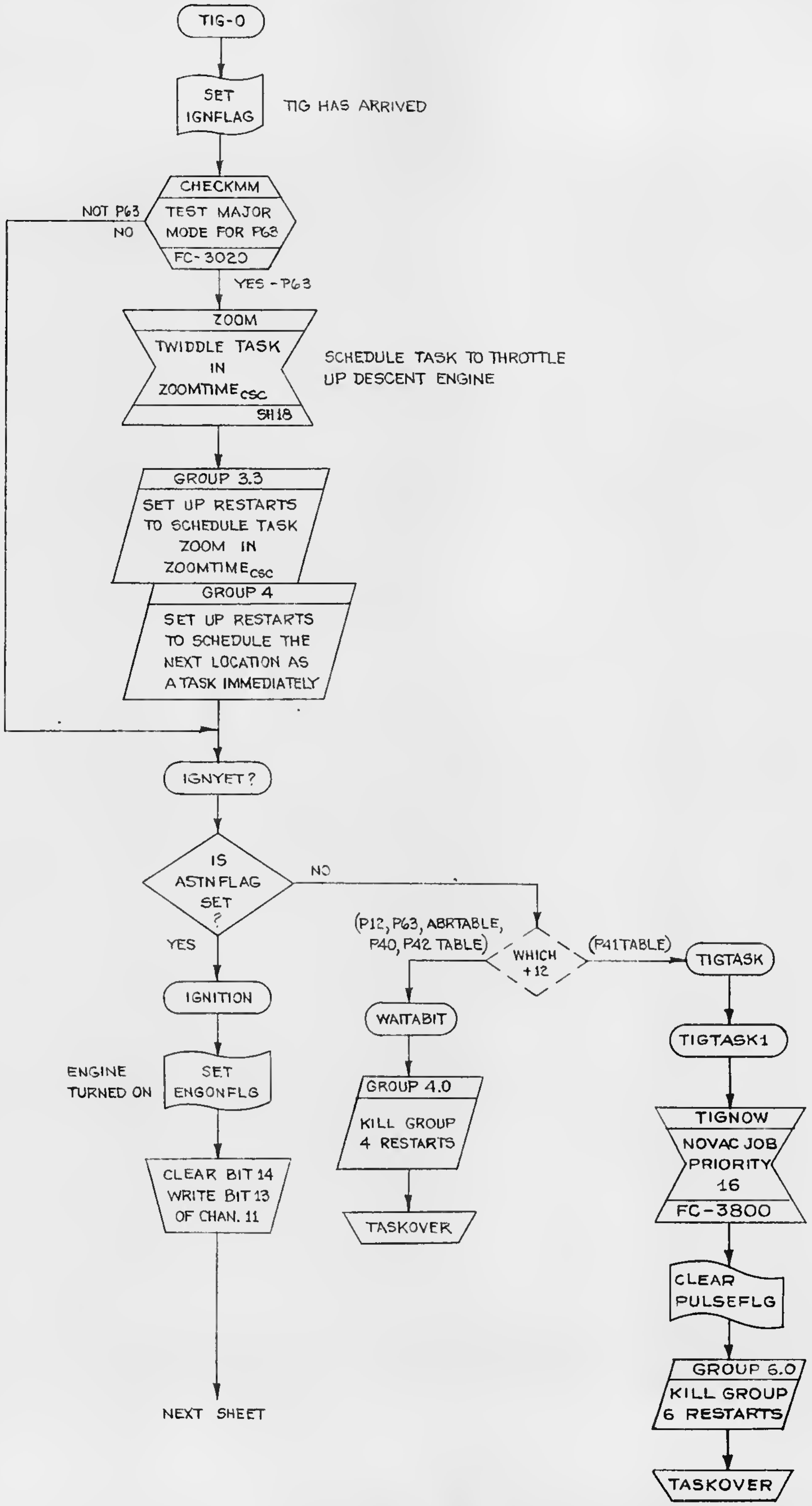
SHEET 5 OF 25



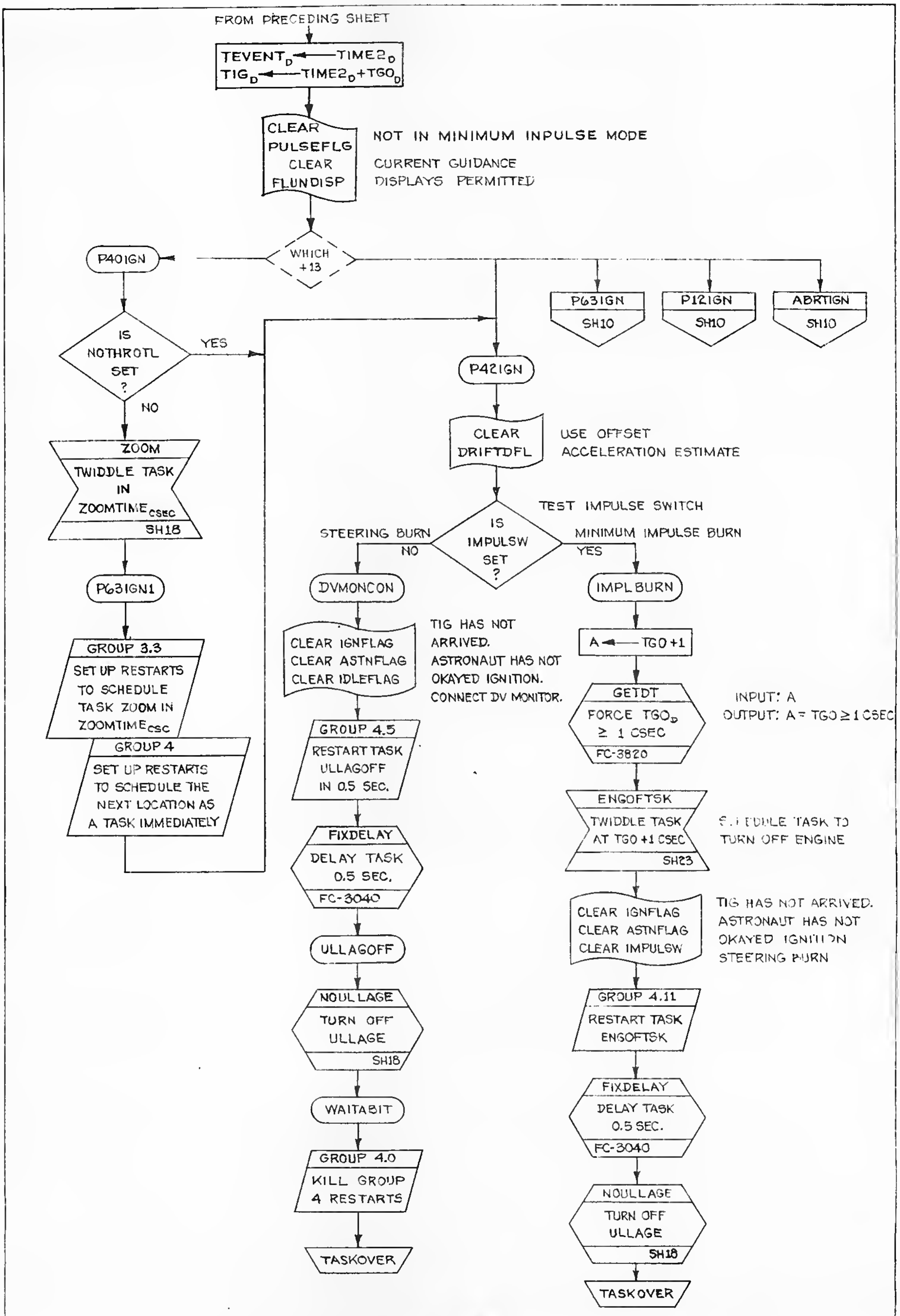
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	6-21-68	BURN BABY BURN (MASTER IGNITION ROUTINE)
PROGRM P. Colley	4 Sept 68	
ANALYST P. Volante	10 Jan 69	LUMINARY 1D — DOCUMENT NO. FC-3840
DOCMR W.C. Dodson	7-29-68	
APPR'D John A. Morse	24 JAN 69	REV 3 — SHEET 6 OF 25



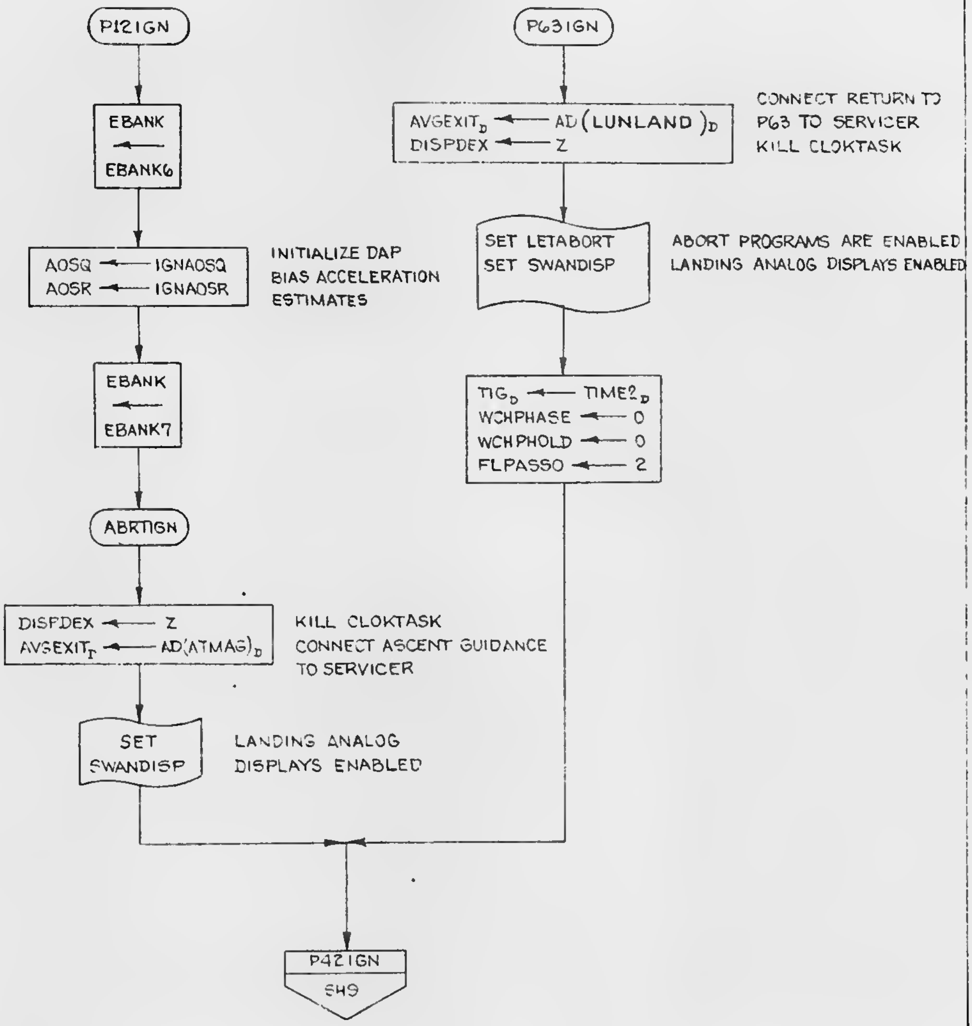
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	6JUNE69	BURN BABY BURN (MASTER IGNITION ROUTINE)
PRGMR C. Schulenberg	6AUG69	LUMINARY 1D — DOCUMENT NO. FC-3840
ANALST		
DOCMR	6AUG69	
APPR'D		REV 3 — SHEET 7 OF 25



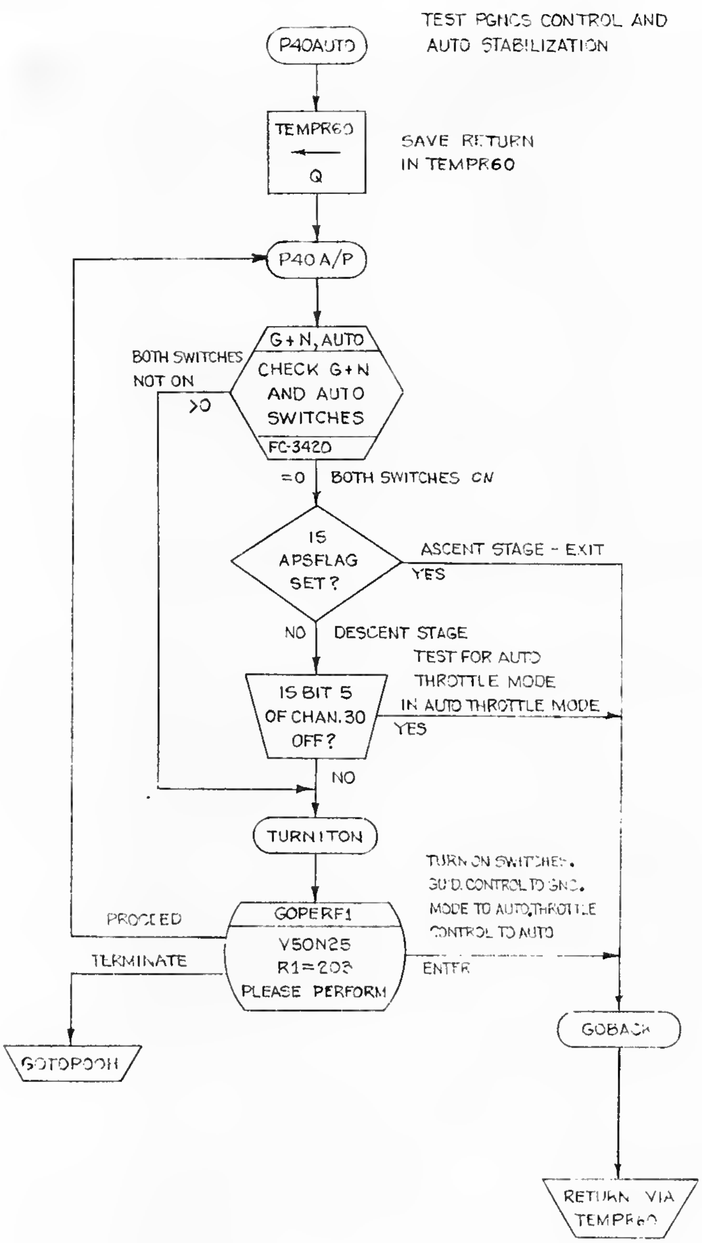
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	9JUNE69	BURN BABY BURN (MASTER IGNITION ROUTINE)
PROGMR C. Schulenberg	6AUG69	LUMINARY 1D — DOCUMENT NO. FC-3840
ANALST		
DOCMR WC Dayforth	6AUG69	
APPR'D [illegible]		REV 3 — SHEET 8 OF 25



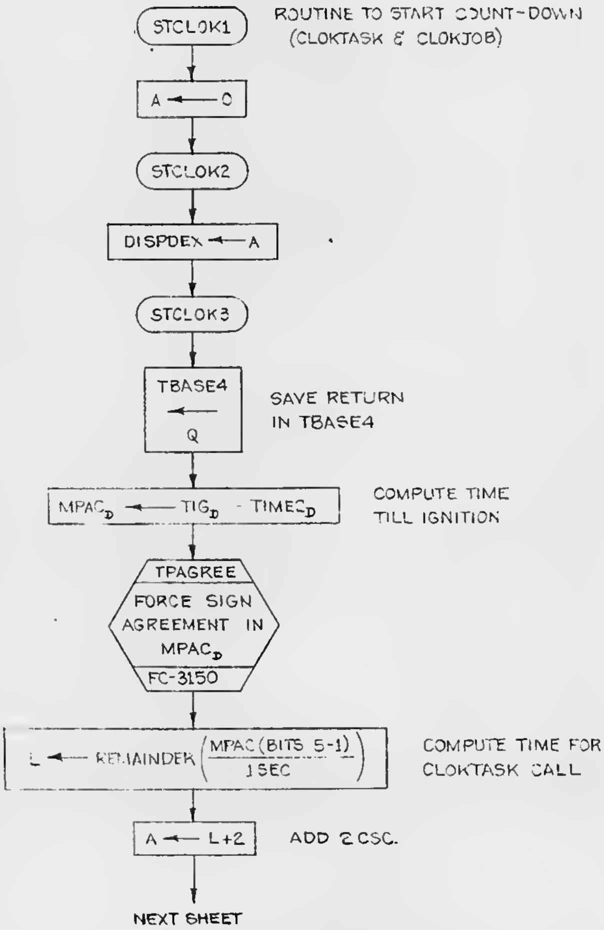
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	10JUN69	BURN BABY BURN (MASTER IGNITION ROUTINE)
PRGMR C. Schulenberg	6AUG69	LUMINARY 1D
ANALST		DOCUMENT NO. FC-3840
DOCMR McDonforth	6AUG69	REV 3
APPR'D [illegible]	6AUG69	SHEET 9 OF 25



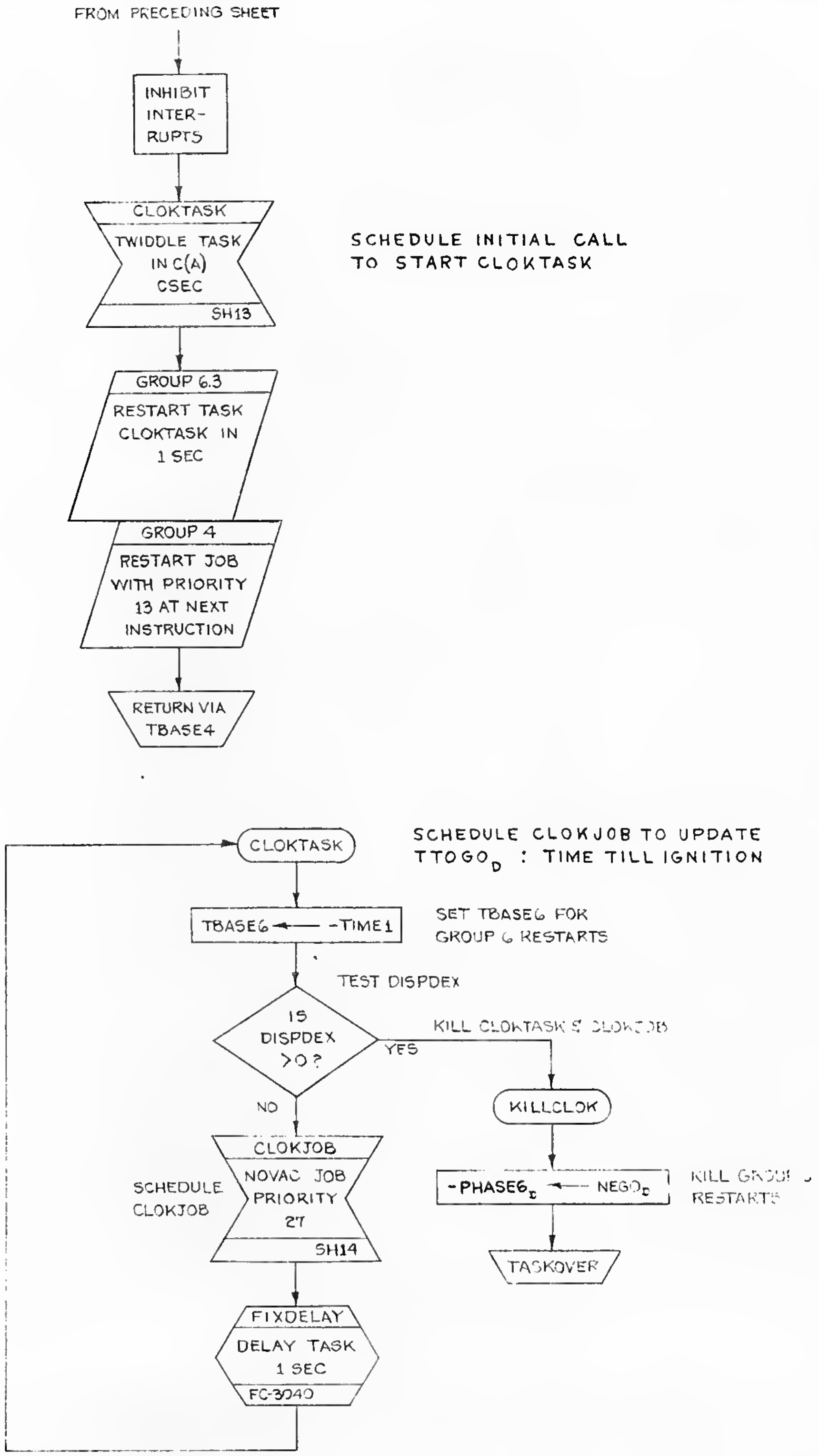
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS	10 JUN 69	BURN BABY BURN (MASTER IGNITION ROUTINE)	
PRGMR C. Schulenberg	6 AUG 69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3840
DOCMR W.C. Danforth	6 AUG 69		
APPRVD [illegible]	6 AUG 69	REV 3	SHEET 10 OF 25



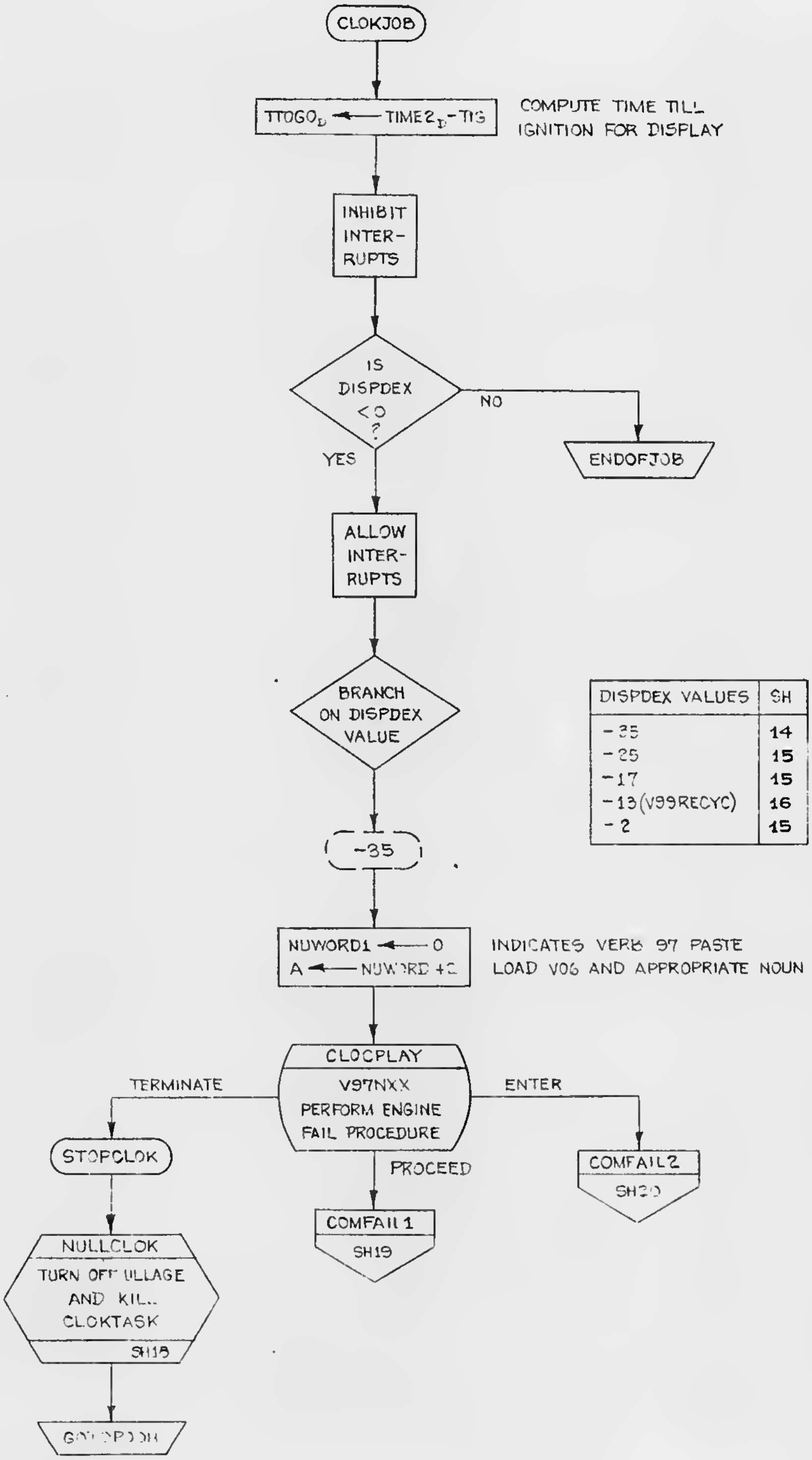
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 6-25-68	BURN BABY BURN (MASTER IGNITION ROUTINE)
PRGMR P. Adler 4 Sept 68	LUMINARY 1D — DOCUMENT NO. FC-3840
ANALST P. Adler 11 Jan 69	
DOCMR W.C. Daughrity 7-29-68	REV 3
APPR'D John R. Moore 24 Jan 69	SHEET 11 OF 25



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 6-27-68	BURN BABY BURN (MASTER IGNITION ROUTINE)
PRGMR 7 Sep 68	LUMINARY 1D
ANALST 11 ... 68	DOCUMENT NO. FC-3840
DOCMR 7-29-68	
APPR'D 24 JAN 69	REV 3 — SHEET 12 OF 25

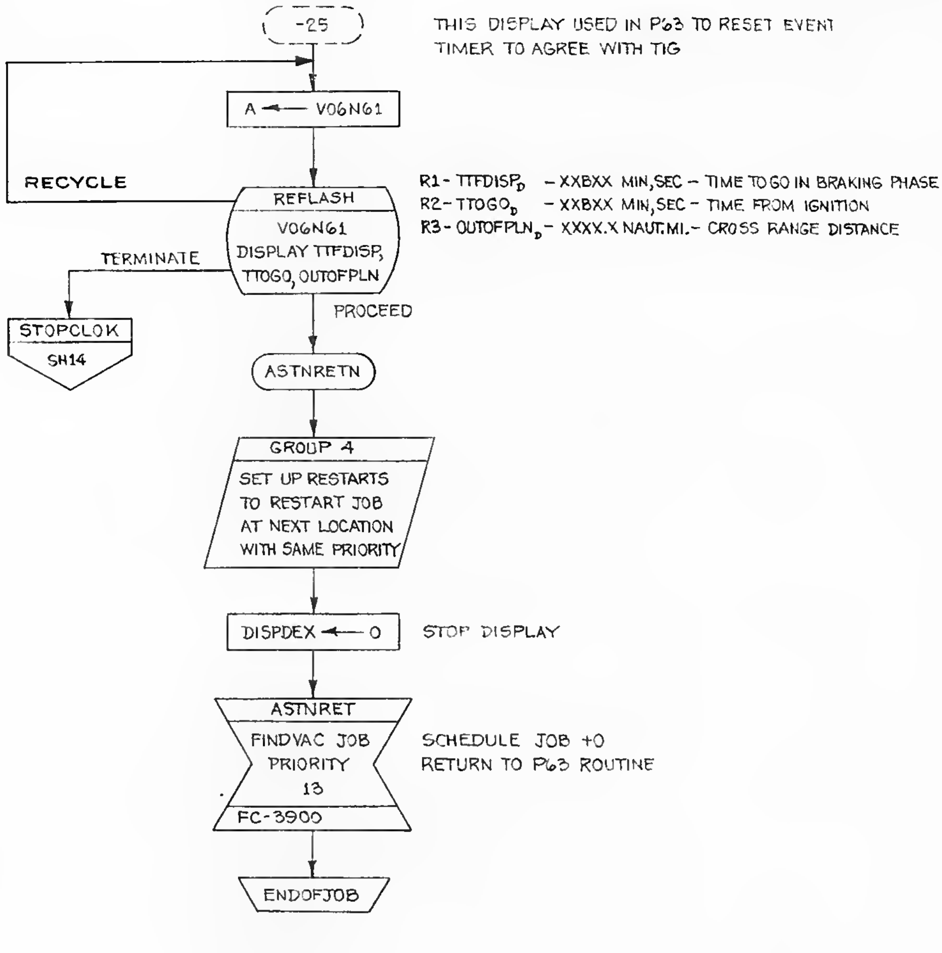


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 6-27-65	BURN BABY BURN (MASTER IGNITION ROUTINE)
PRGMR P Adler 4 Sept 68	
ANALST	LUMINARY 1D — DOCUMENT NO. FC-3840
DOCMR W.C. 7-29-68	
APPR'D John A. More 24 JAN 69	REV 3 — SHEET 13 OF 25

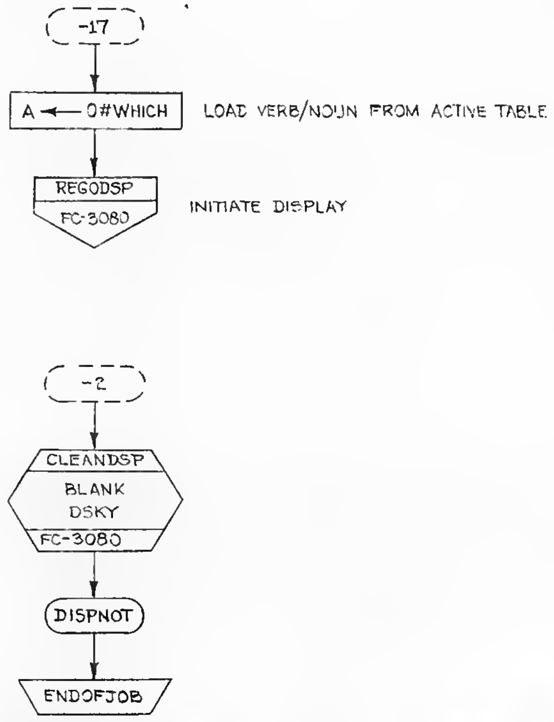


DISPDEX VALUES	SH
−35	14
−25	15
−17	15
−13 (V99RECYC)	16
−2	15

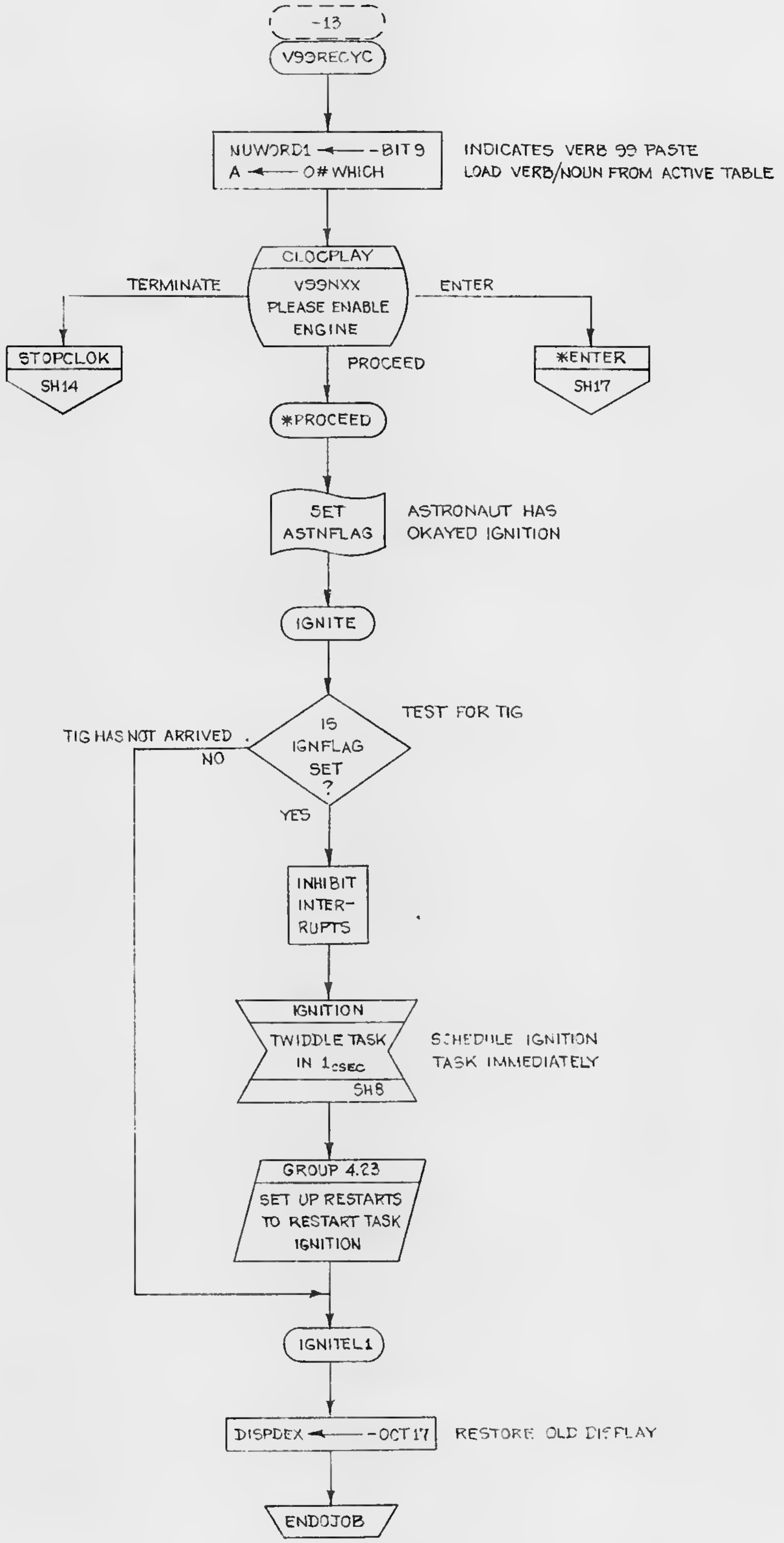
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	11JUN69	BURN BABY BURN (MASTER IGNITION ROUTINE)
PROMR C. Schulenberg	6AUG69	
ANALST		LUMINARY 1D — DOCUMENT NO. FC-3840
DOCMR McDonnell	6AUG69	
APPR'D [signature]	6AUG69	REV 3 — SHEET 14 OF 25



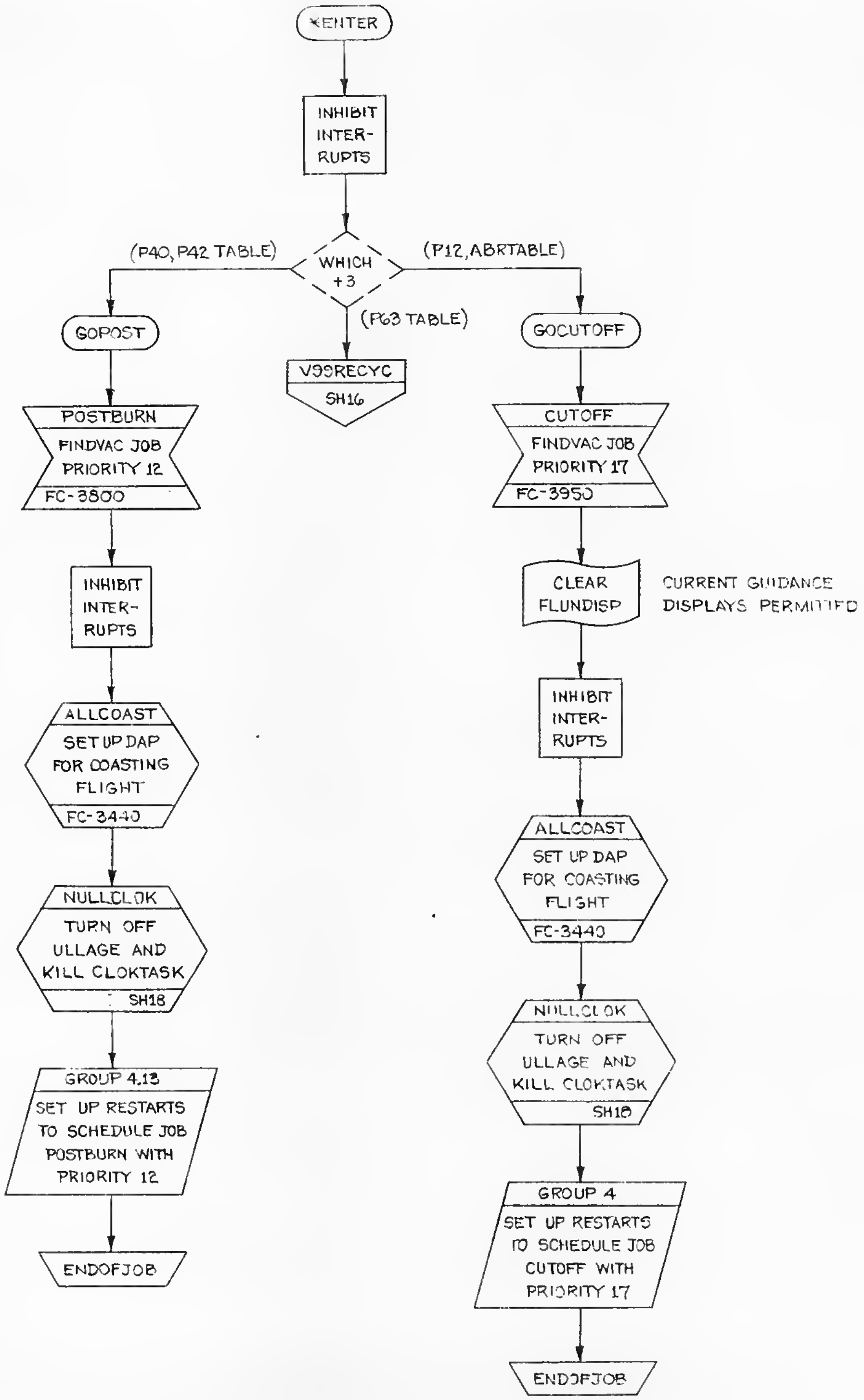
WHICH TABLE	VERB/ NOUN
P12	06 74
P40	06 40
P42	06 40
P63	06 62
ABRTABLE	06 63



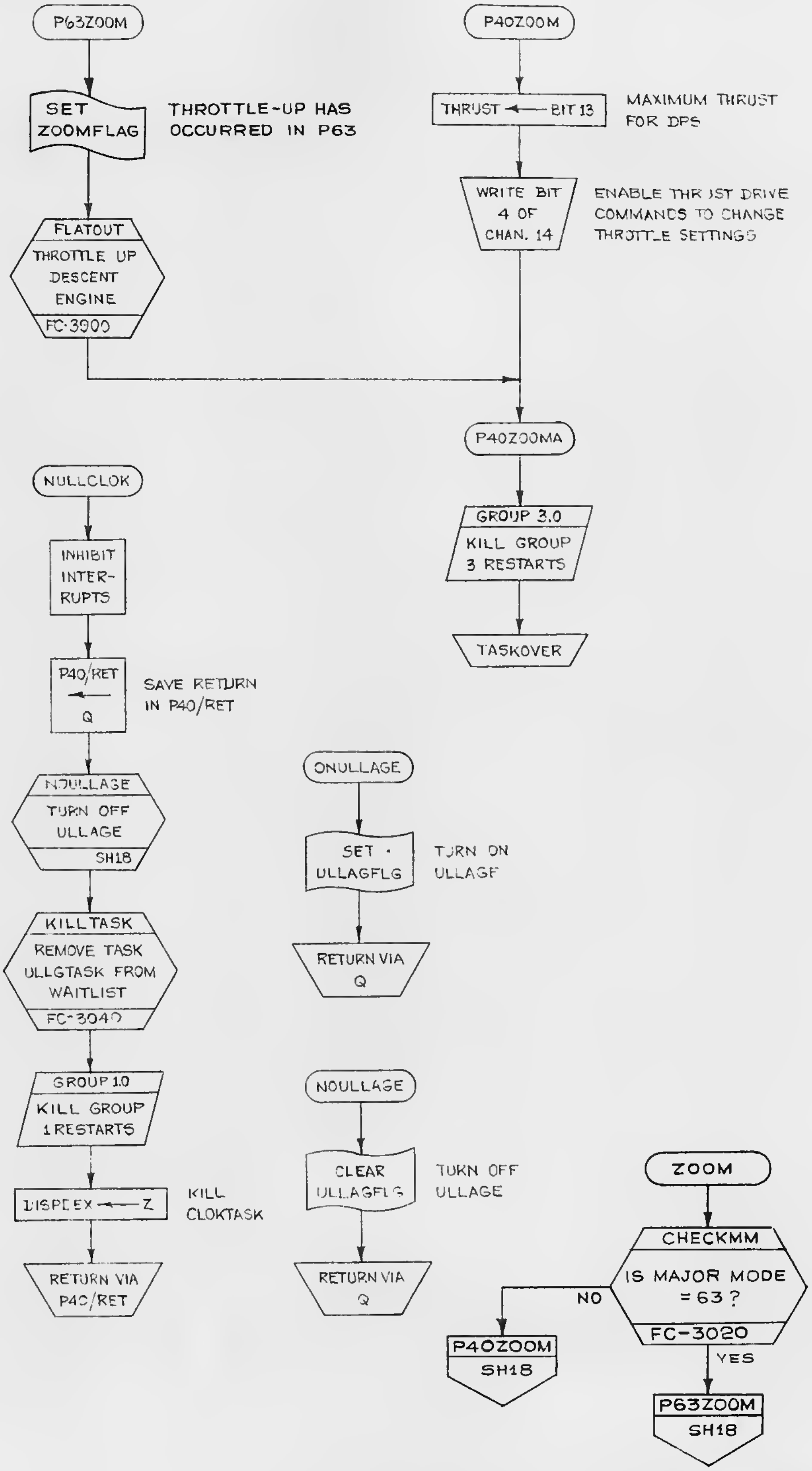
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	11 JUN 69	BURN BABY BURN (MASTER IGNITION ROUTINE)
PRGMR C. Schulenberg	6 AUG 69	LUMINARY 1D — DOCUMENT NO. FC-3840
ANALST		
DOCMR W.C. Danforth	6 AUG 69	
APPR'D [signature]	6 AUG 69	REV 8 — SHEET 15 OF 25



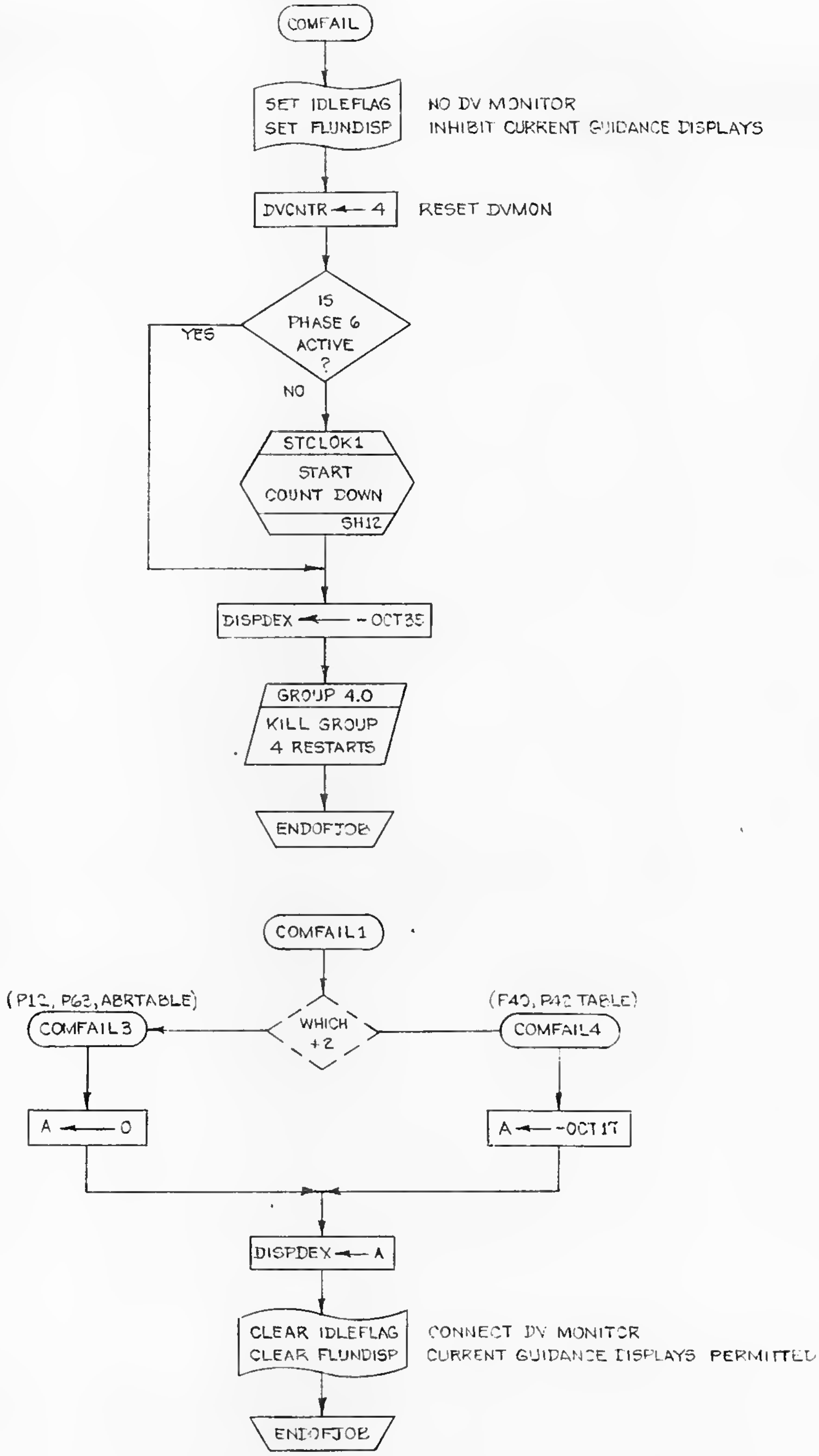
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 12JUN69	BURN BABY BURN (MASTER IGNITION ROUTINE)
PRGMR C. Schulenberg 6AUG69	LUMINARY 1D
ANALST	DOCUMENT NO. FC-3840
DOCMR W.C. Daykatt 6AUG69	
APPR'D [illegible] 6AUG69	REV 3 SHEET 16 OF 25



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	12 JUN 69	BURN BABY BURN (MASTER IGNITION ROUTINE)
PRGMR C. Schulenberg	6 AUG 69	
ANALST		LUMINARY 1D — DOCUMENT NO. FC-3840
DOCMR WC Dagforth	6 AUG 69	
APPR'D	6 AUG 69	REV 3 — SHEET 17 OF 25



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	12JUN69	BURN BABY BURN (MASTER IGNITION ROUTINE)
PRGMR C. Schulenberg	6 AUG 69	
ANALST		LUMINARY 1D — DOCUMENT NO. FC-3840
DOCMR W.C. Dayboth	6 AUG 69	
APPR'D [illegible]		REV 3 — SHEET 18 OF 25



MIT
INSTRUMENTATION LAB
CAMBRIDGE, MASS.

DRAWN	A.C.WILLIAMS	13 JUN 69
PROGMR	C. Schulenberg	6 AUG 69
ANALST		
DOCMR	WC Danforth	6 AUG 69
APPR'D	Alex M. Sorant	6 AUG 69

APOLLO
GUIDANCE AND NAVIGATION

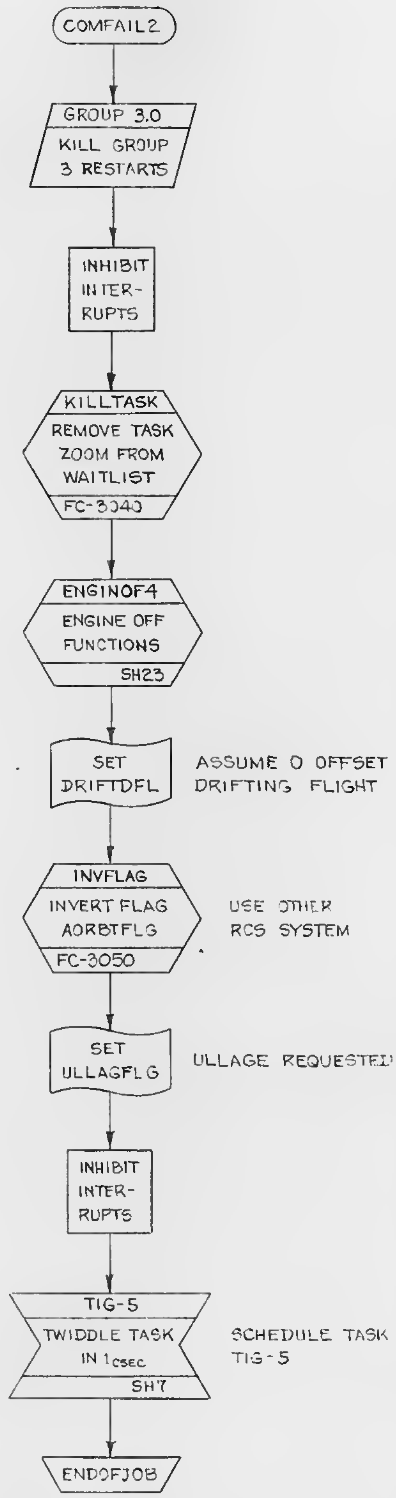
BURN BABY BURN
(MASTER IGNITION ROUTINE)

LUMINARY 1D

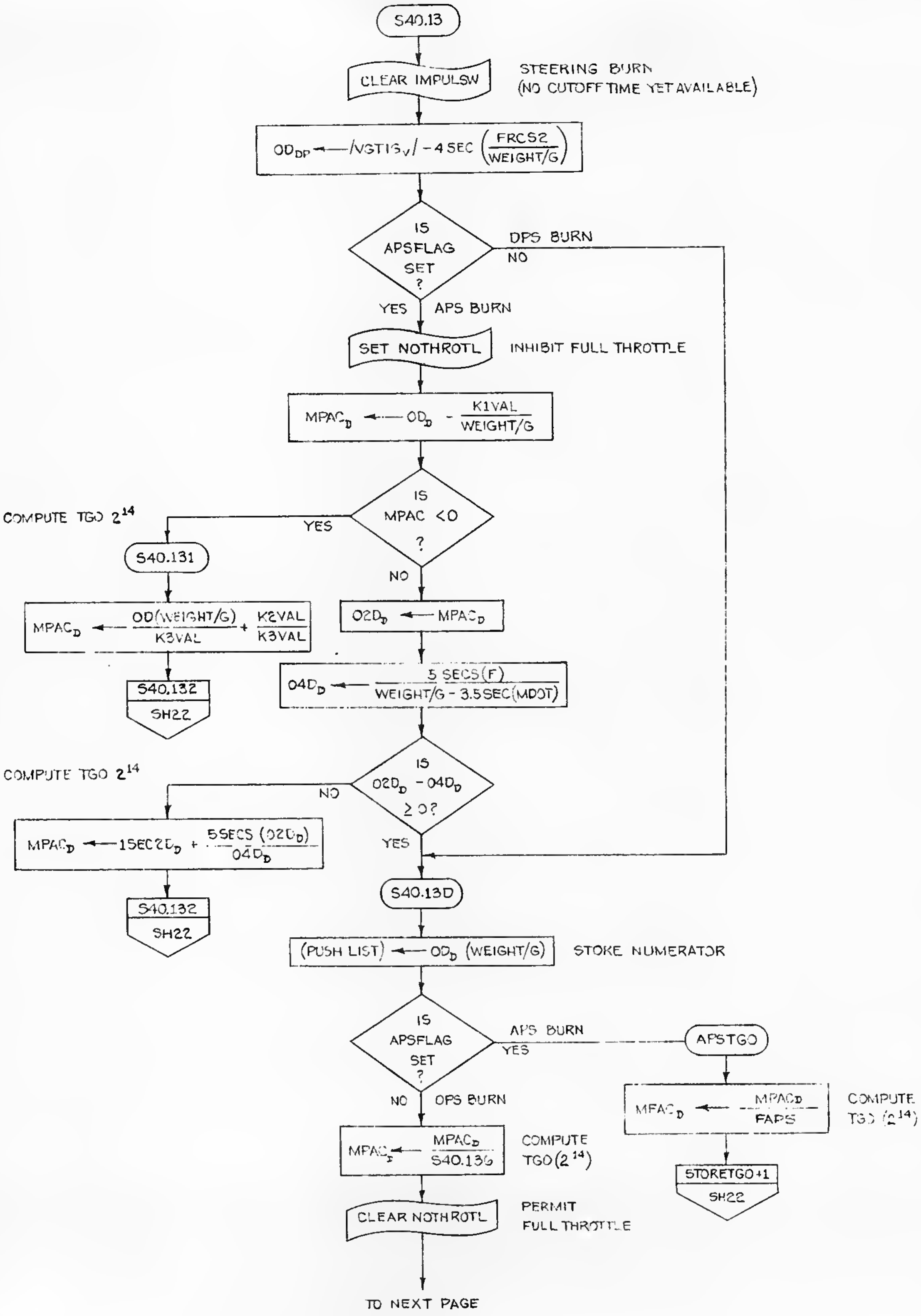
DOCUMENT NO. FC-3840

REV 3

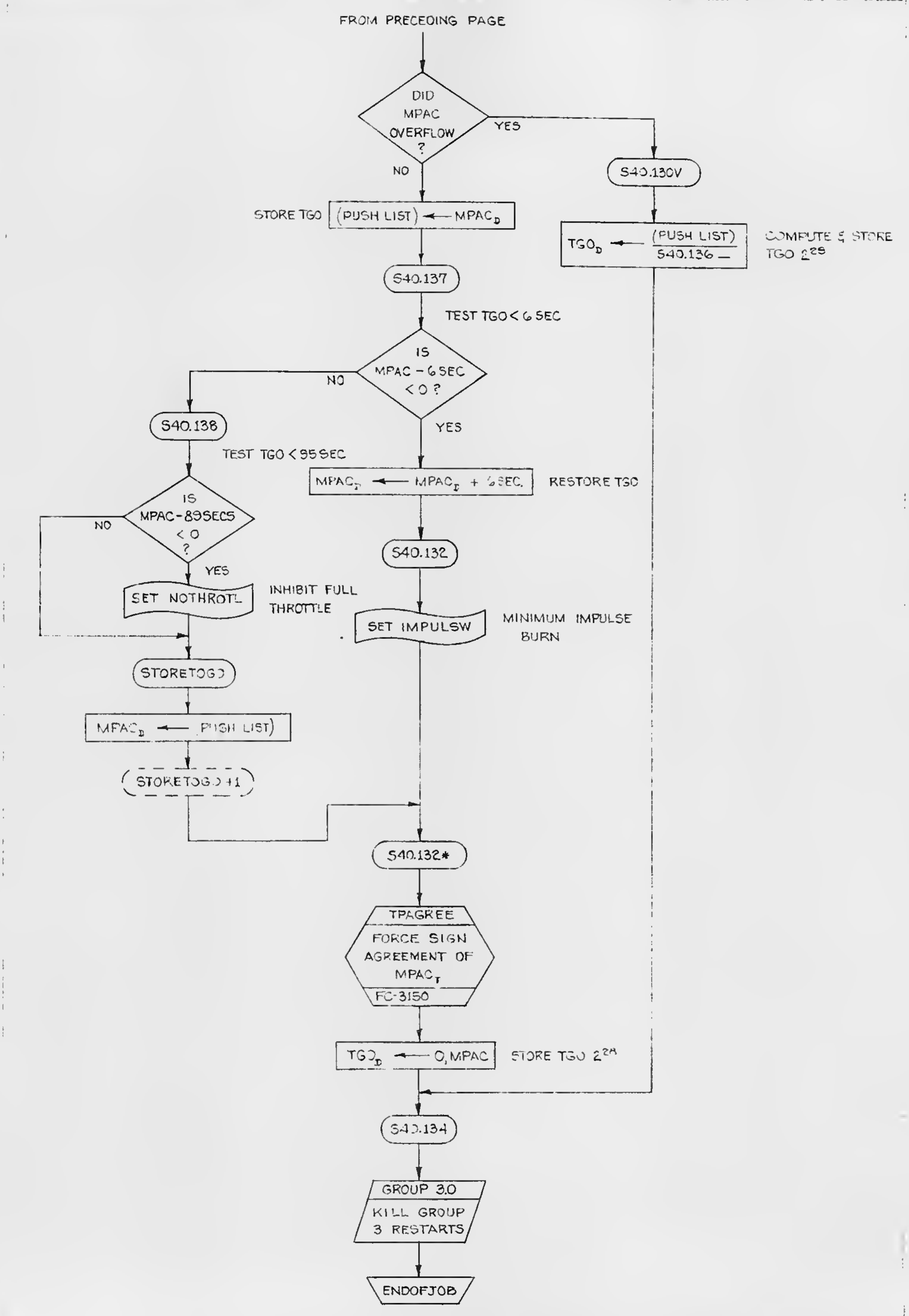
SHEET 19 OF 25



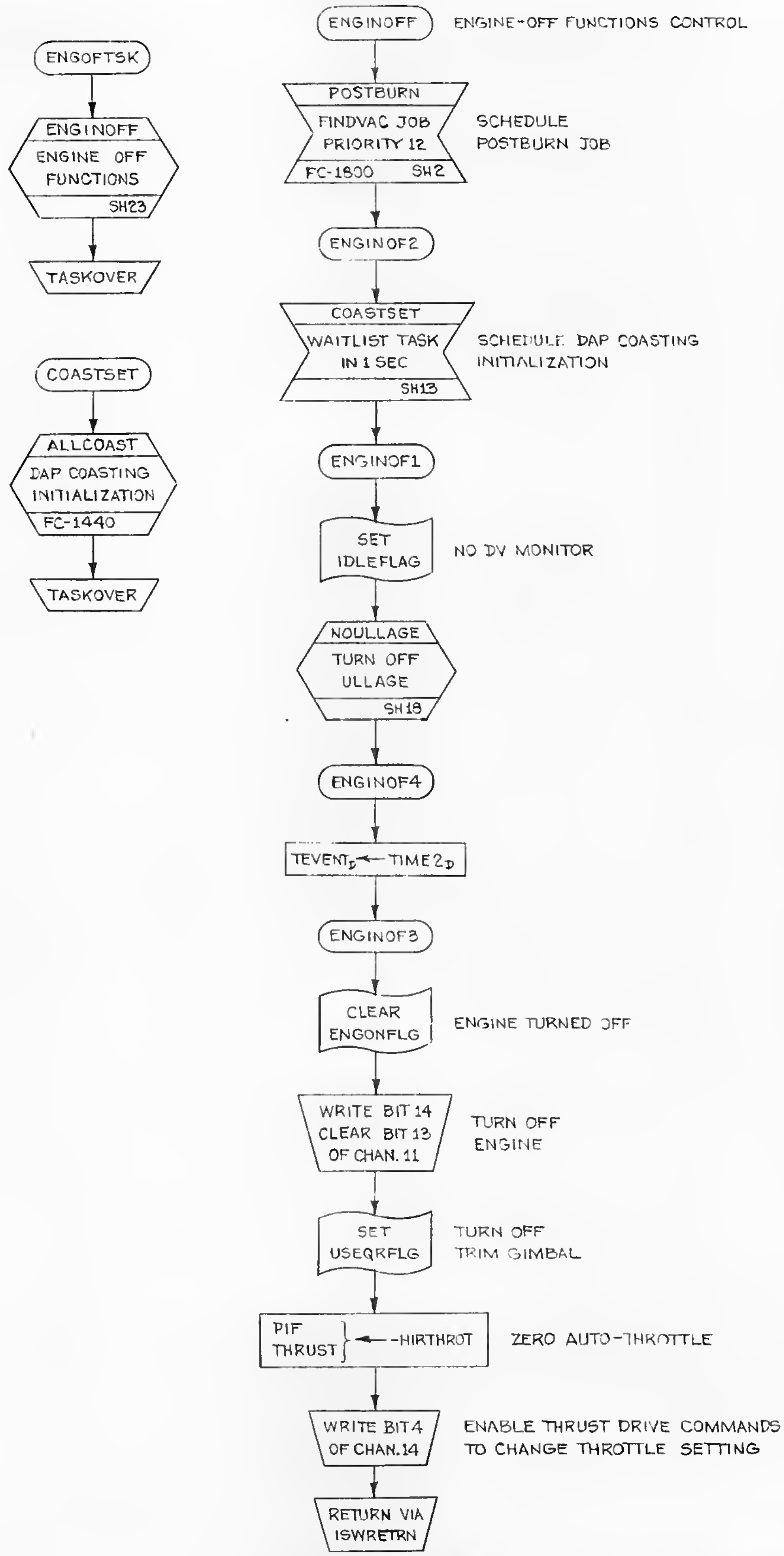
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 13JUN69	BURN BABY BURN (MASTER IGNITION ROUTINE)
PRGMR C. Schulenberg 6 AUG 69	LUMINARY 1D
ANALST	DOCUMENT NO. FC-3840
DOCMR WC Dodrel 6 AUG 69	
APPR'D [illegible]	REV 3 SHEET 20 OF 25



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	A.C.WILLIAMS 6-28-68	BURN BABY BURN (MASTER IGNITION ROUTINE)	
PROGMR	P. Adler 4 Sept 68		
ANALST	P. Volante 11 Jan 69	LUMINARY 1D	DOCUMENT NO. FC-3840
DOCMR	W. C. Dickett 7-29-68		
APPR'D	John A. Moore 24 JAN 69	REV 3	SHEET 21 OF 25



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
	BURN BABY BURN (MASTER IGNITION ROUTINE)
DRAWN A.C.WILLIAMS 7-1-68	
PRGMR [illegible]	LUMINARY 1D
ANALST [illegible] 10 Jan 69	DOCUMENT NO. FC-3840
DOCMR [illegible] 7-29-68	
APPR'D [illegible] 24 JAN 69	REV 3 SHEET 22 OF 25



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS	13JUN69	BURN BABY BURN (MASTER IGNITION ROUTINE)	
PROGMR C. Schulenberg	6AUG69	LUMINARY 1D	DOCUMENT NO. FC-3840
ANALST			
DOCMR McDiarmid	6AUG69		
APPR'D		REV 3	SHEET 23 OF 25

SUBROUTINES CALLED WHICH ARE FLOWED ON OTHER FLOW CHARTS

SUBROUTINE NAME	FLOW CHART	DESCRIPTION	WHERE CALLED
ALLCOAST	FC-3440	SET UP DAP FOR COASTING FLIGHT	SH. 17,23
CHECKMM	FC-3020	TEST MAJOR MODE	SH. 4,8
CLEANDSP	FC-3080	BLANK DSKY	SH. 5,15
CSMPREC	FC-3350	EXTRAPOLATE CSM STATE VECTOR	SH. 3
FIXDELAY	FC-3040	DELAY ACTIVE TASK	SH. 9,13
FLATOUT	FC-3900	THROTTLE UP DESCENT ENGINE	SH. 18
G&N, AUTO	FC-3420	CHECK G&N AND AUTO SWITCHES	SH. 11
INVFLAG	FC-3050	INVERT INPUT FLAG BIT	SH. 20
KILLTASK	FC-3040	REMOVE TASK FROM WAITLIST	SH. 18,20
MIDTOAV1	FC-3350	INTEGRATE LM STATE VECTOR	SH. 3
MUNGRAV	FC-3850	COMPUTE LUNAR GRAVITATIONAL ACCELERATION	SH. 3
TPAGREE	FC-3150	FORCE SIGN AGREEMENT IN $MPAC_T$	SH. 12,22

FLAGS

NAME	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
APSFLAG FL. 10, BIT13	ASCENT STAGE	DESCENT STAGE			SH. 11
ASTNFLAG FL. 7, BIT12	ASTRONAUT HAS OKAYED IGNITION	ASTRONAUT HAS NOT OKAYED IGNITION	SH. 6,16	SH. 7,9	SH. 8
DRIFTDFL FL. 13, BIT8	T3RUPT CALLS GYRO COMPENSATION	T3RUPT DOES NO GYRO COMPENSATION	SH. 20	SH. 9	
ENGONFLG FL. 5, BIT7	ENGINE TURNED ON	ENGINE TURNED OFF	SH. 8	SH. 23	
FLUNDISP FL. 8, BIT10	CURRENT GUIDANCE DISPLAYS INHIBITED	CURRENT GUIDANCE DISPLAYS PERMITTED	SH. 19	SH. 9, 17, 19	
IDLEFLAG FL. 7, BIT7	NO DV MONITOR	CONNECT DV MONITOR	SH. 19	SH. 9, 19	
IGNFLAG FL. 7, BIT13	TIG HAS ARRIVED	TIG HAS NOT ARRIVED	SH. 8	SH. 7,9	SH. 16
IMPULSW FL. 2, BIT9	MINIMUM IMPULSE BURN	STEERING BURN	SH. 22	SH. 9,21	SH. 9
MUNFLAG FL. 6, BIT8	SERVICER CALLS MUNRVG	SERVICER CALLS CALCRVG			SH. 3
NOTHROTL FL. 5, BIT12	INHIBIT FULL THROTTLE	PERMIT FULL THROTTLE	SH. 21,22	SH. 21	SH. 9
ULLAGFLG FL. 13, BIT6	ULLAGE REQUESTED BY MISSION PROGRAM	NO INTERNAL ULLAGE REQUEST	SH. 18,20	SH. 18	
USEQRFLG FL. 13, BIT14	GIMBAL UNUSABLE. USE JETS ONLY	TRIM GIMBAL MAY BE USED	SH. 23		
LETABORT FL. 9, BIT9	ABORT PROGRAMS ARE ENABLED	ABORT PROGRAMS ARE NOT ENABLED	SH. 10		
PULSEFLG FL. 13, BIT15	MINIMUM IMPULSE COMMAND MODE	NOT IN MINIMUM IMPULSE COMMAND MODE		SH. 10	
SWANDISP FL. 7, BIT11	LANDING ANALOG DISPLAYS ENABLED	LANDING ANALOG DISPLAYS SUPPRESSED	SH. 10		

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. D. Hart	17JULY69	BURN BABY BURN (MASTER IGNITION ROUTINE)	
PRGMR C. Schulenberg	6 AUG 69	LUMINARY 1D	DOCUMENT NO. FC-3840
ANALST			
DOCMR W.C. [illegible]	6 AUG 69		
APPR'D [illegible]	6 AUG 69	REV 3	SHEET 24 OF 25

DISPLAYS

V06N40 V99N40	R1 - TTOGO - XXBXX MIN-SEC - TIME TO IGNITION/CUTOFF R2 - VGDISP - XXXX.X FT/SEC-VG R3 - DVTOTAL - XXXX.X FT/SEC - DELTA V	SH. 13

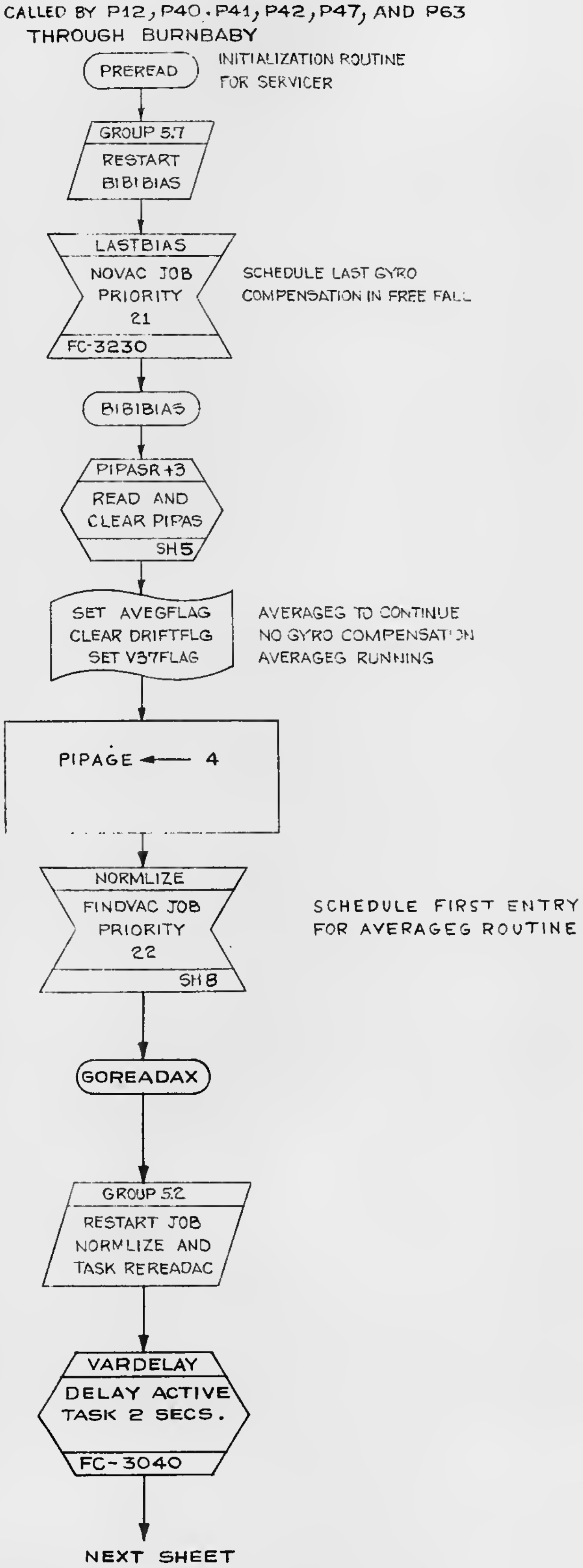
ERASABLE LOCATIONS USED

		UNITS	SCALING
TIG_D	TIME OF ENGINE IGNITION	CSEC	2^{28}
TGO_D	TIME FROM ENGINE CUT-OFF	CSEC	2^{28}
PIF THRUST	} AUTO THROTTLE COMMAND REGISTERS	-	-

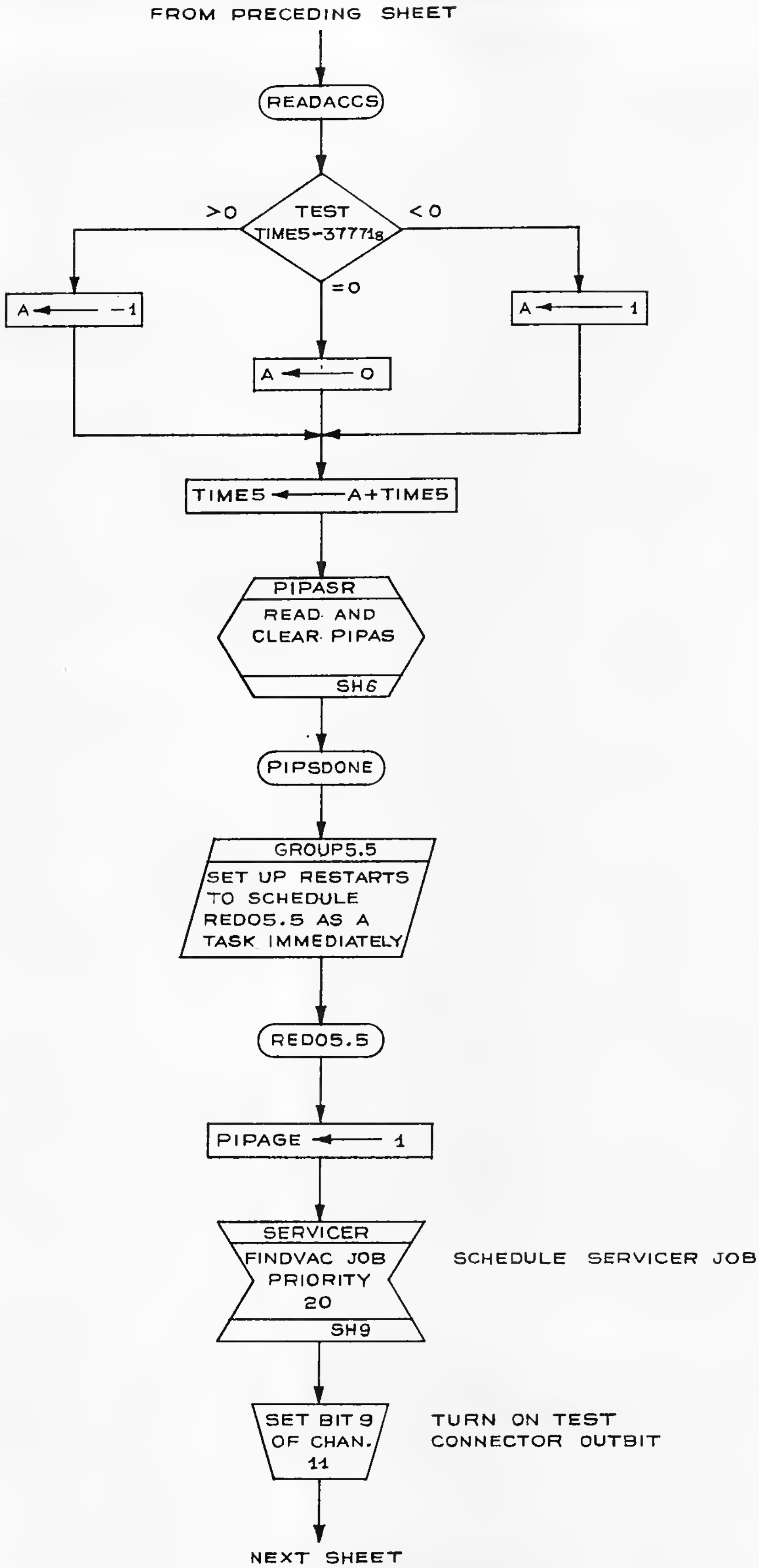
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN R. D. Hart	17 JULY 69	BURN BABY BURN (MASTER IGNITION ROUTINE)
PRGMR C. Schulenberg	6 AUG 69	LUMINARY 1D
ANALST		DOCUMENT NO. FC-3840
DOCMR [illegible]	6 AUG 69	REV 3
APPR'D [illegible]	[illegible] AUG	SHEET 25 OF 25

SERVICER

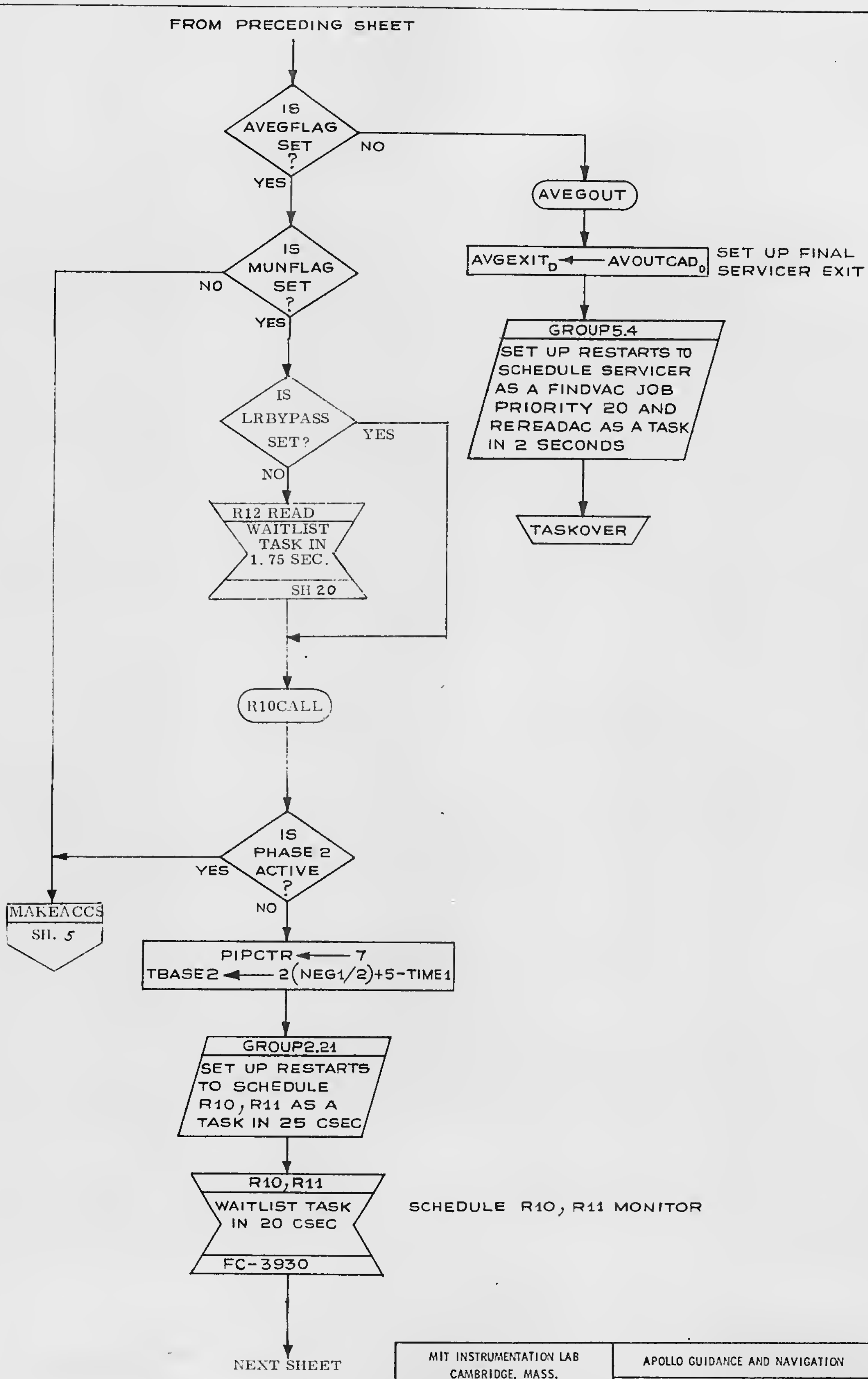
MAJOR SUBROUTINES ON THIS CHART



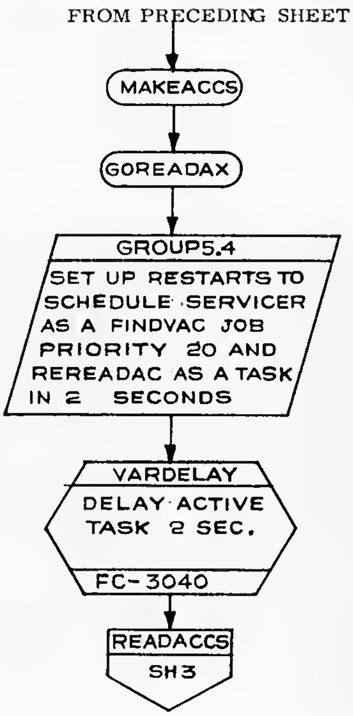
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS 6-11-68	SERVICER	
PRGMR		
ANALST P Phelan Jan 10, 69	LUMINARY 1D	DOCUMENT NO. FC-3850
DOCMR		



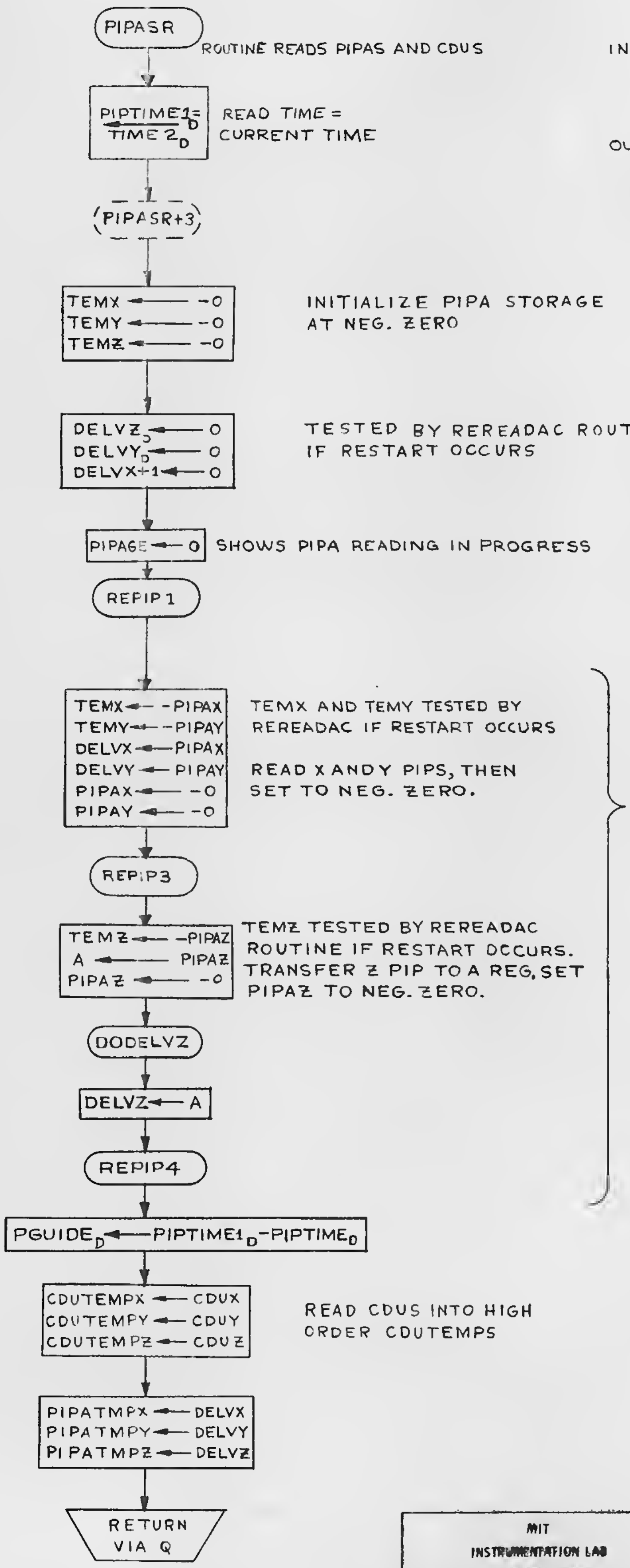
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	14 MAY 69	SERVICER	
PROGMR C. Schulenberg	13 AUG 69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3850
DOCMR	13 AUG 69		
APPR'D	13 AUG 69	REV 3	SHEET 3 OF 22



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		SERVICER	
PRGMR	6/5/70		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3850
DOCMR	6/5/70		
APPR'D		REV 3	SHEET 4 OF 22



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN	15MAY69	SERVICER
PROGMR C. Schulenberg	13 AUG 69	
ANALST		LUMINARY 1D
DOCMR	13 AUG 69	DOCUMENT NO. FC-3850
APPR'D		REV 3 — SHEET 5 OF 22



INPUT
PIPAX, PIPAY, PIPAZ
TIME 2, CDUX, CDUY, CDUZ

OUTPUT
DELVX, DELVY, DELVZ,
CDUTEMPX, CDUTEMPY, CDUTEMPZ
PIPATMPX, PIPATMPY, PIPATMPZ

$$\Delta \underline{V} = \begin{bmatrix} PIPAX \\ PIPAY \\ PIPAZ \end{bmatrix}$$

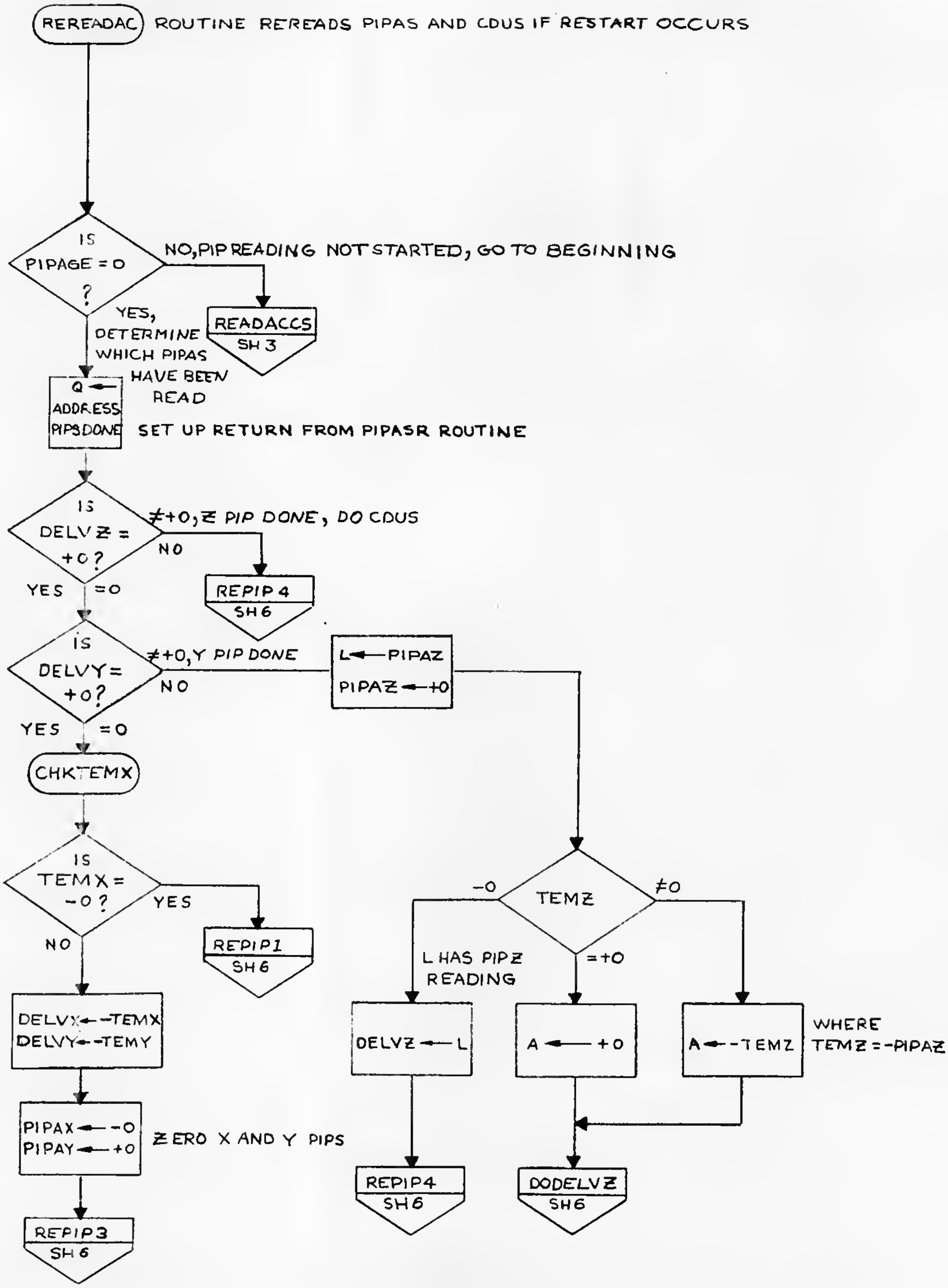
WHERE

$$PIPAX = \int_0^2 \underline{a}_x \, dt$$

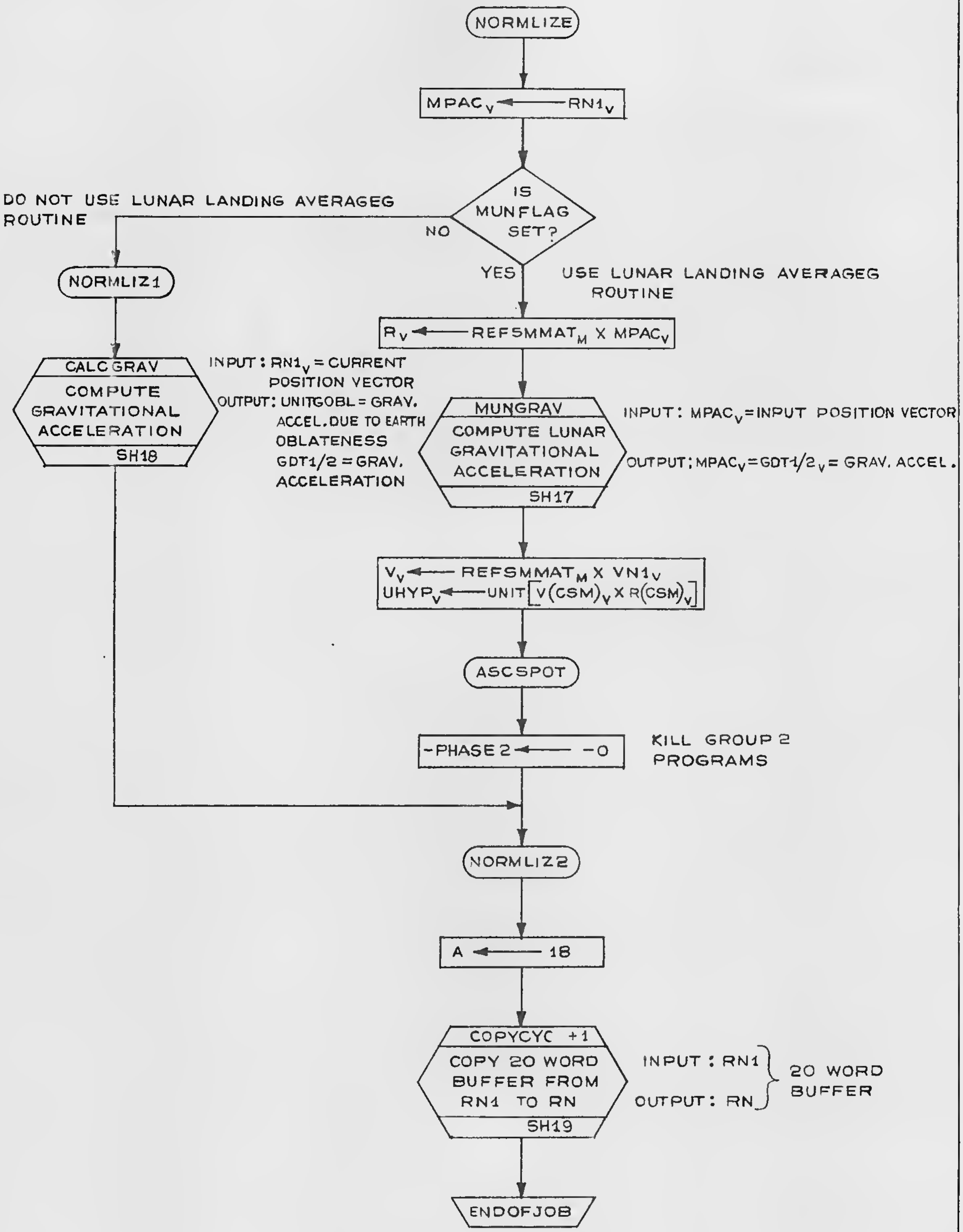
$$PIPAY = \int_0^2 \underline{a}_y \, dt$$

$$PIPAZ \int_0^2 \underline{a}_z \, dt$$

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN [signature] 25 JUL 68	SERVICER	
PROGMR [signature]		
ANALST [signature]	LUMINARY 1D	DOCUMENT NO. FC-3850
DOCMGR [signature]		
APPR'D John A. Morse 24 JAN 69	REV 3	SHEET 6 OF 22

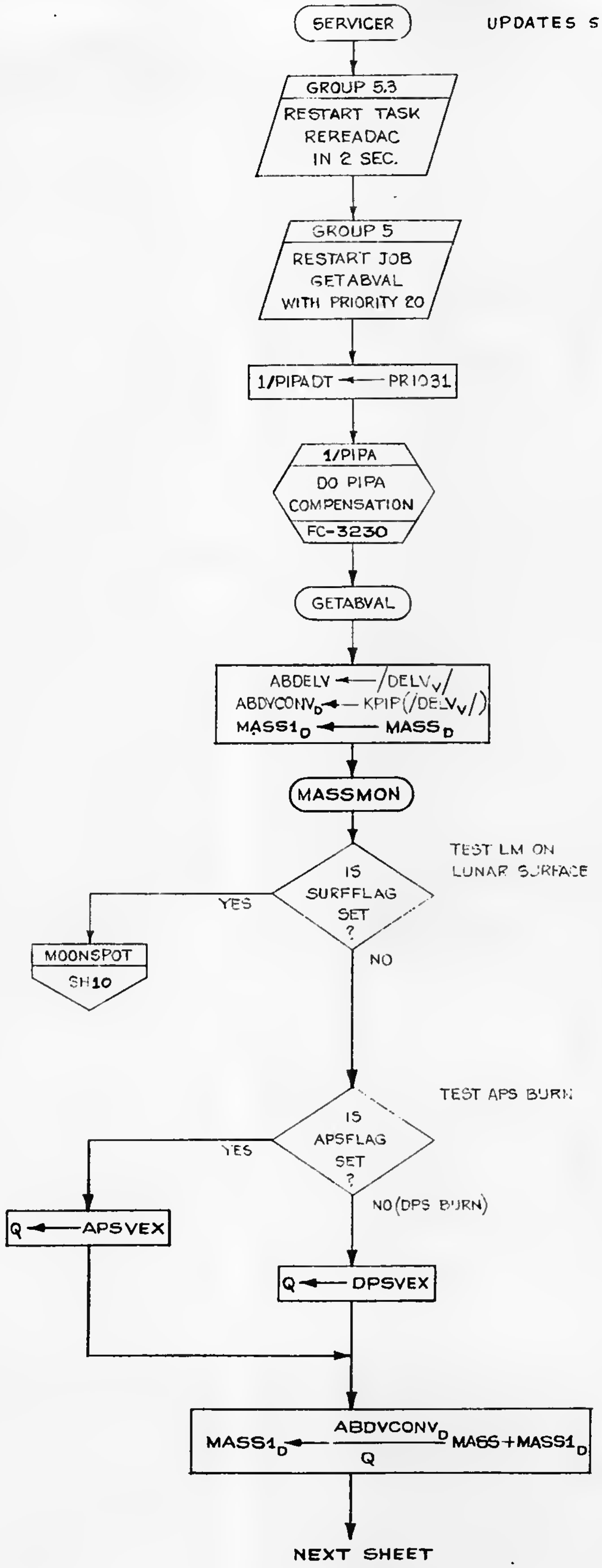


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN 25JUL68	SERVICER
PRGMR 9AUG68	LUMINARY 1D — DOCUMENT NO. FC-3850
ANALST Jan 10, 69	
DOCMR 29JUL68	
APPR'D John A. Morse 24 JAN 69	REV 3 — SHEET 7 OF 22

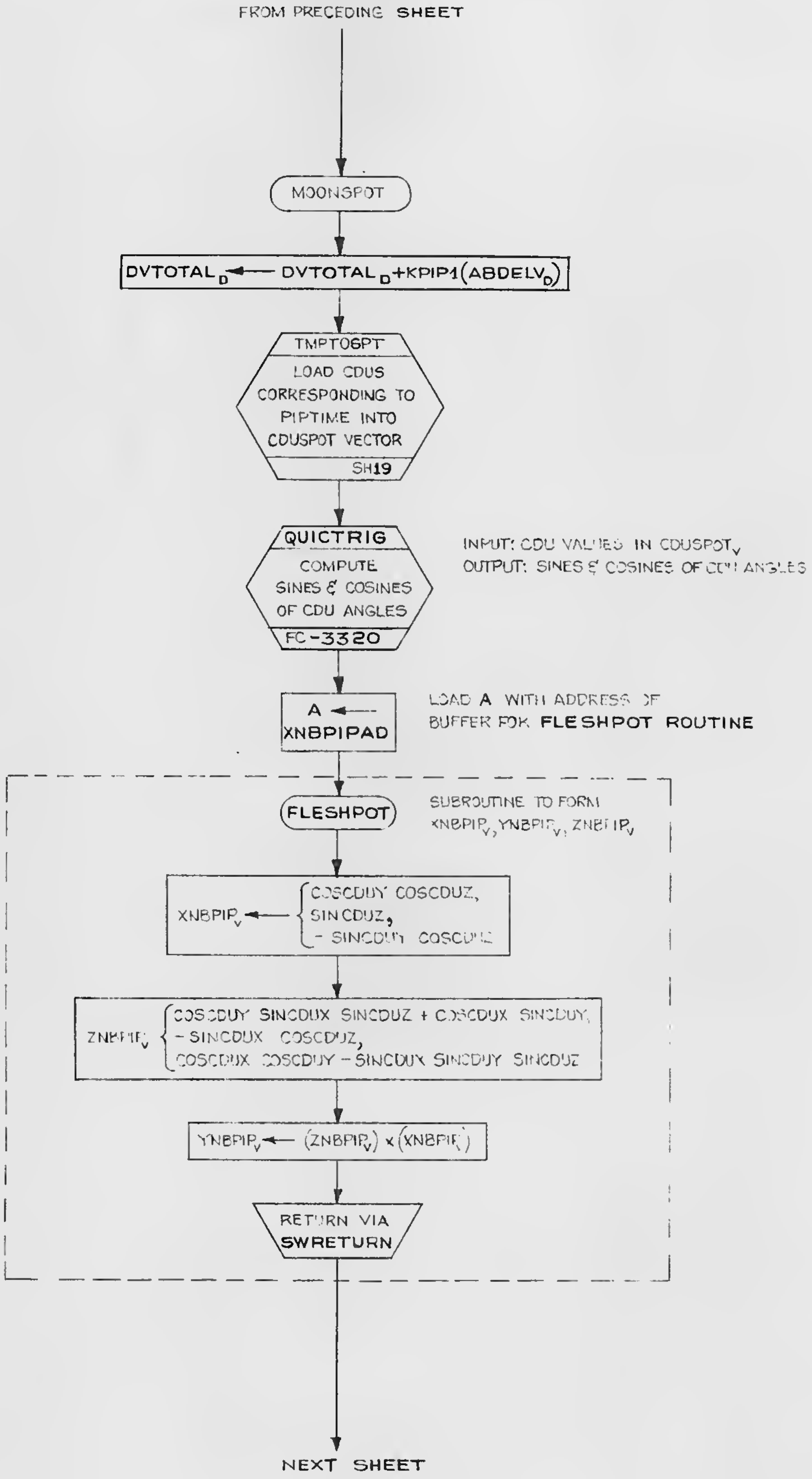


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	21 MAY 69	SERVICER	
PRGMR C. Schulenberg	18 AUG 69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3850
DOCMR	13 AUG 69		
APPR'D		REV 3	SHEET 8 OF 22

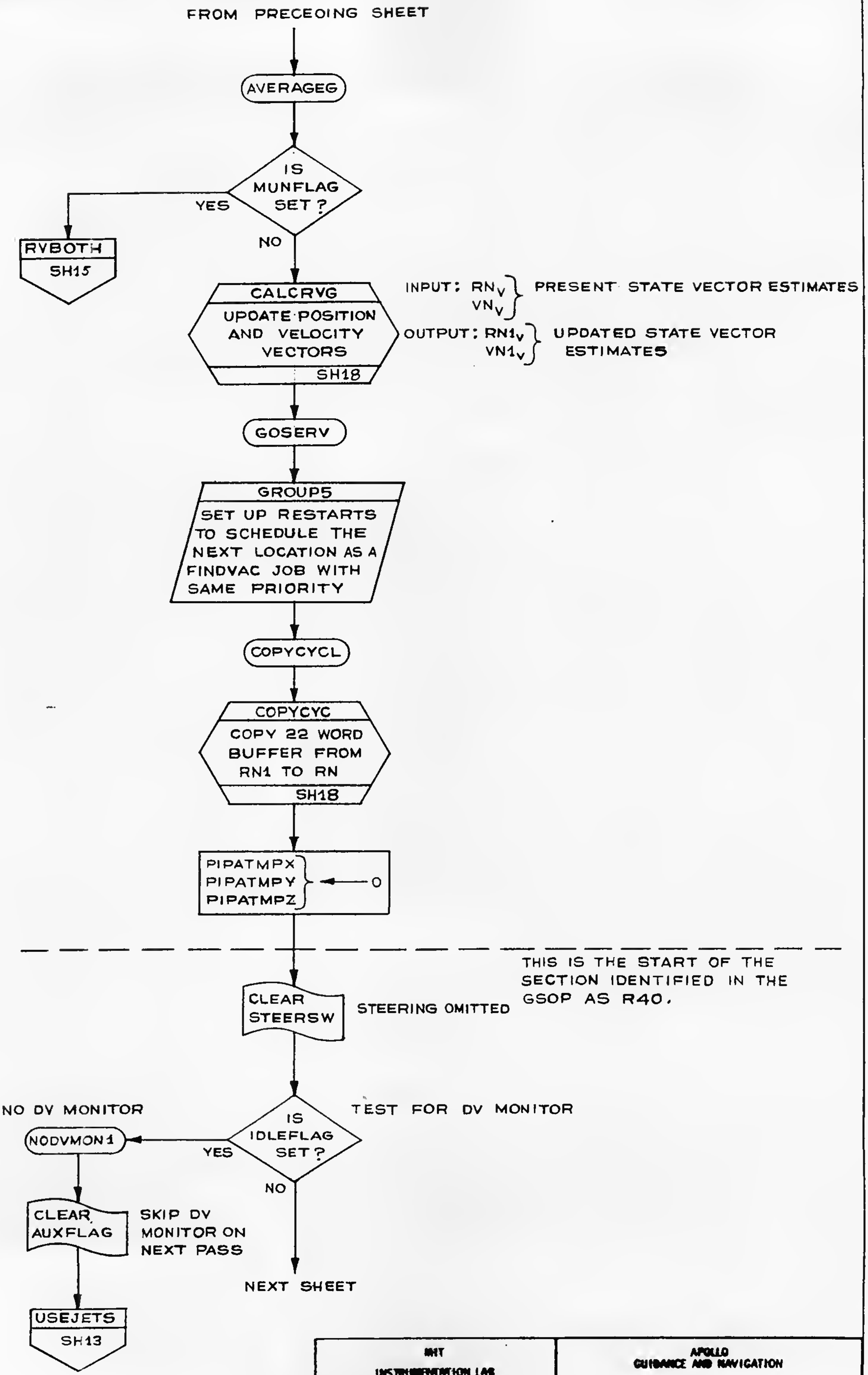
UPDATES STATE VECTOR AND MASS OF LM



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS 6-12-65	SERVICER	
PRGMR R. Covelli 8-7-68	LUMINARY 1D	DOCUMENT NO. FC-3850
ANALST P. Philiu 10/4/69		
DOCMR W. Grantitd 6-24-68		
APPR'D John A. Morse 24 JAN 69	REV 3	SHEET 9 OF 22



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
	SERVICER
DRAWN A.C.WILLIAMS 6-14-68	
PROMR [signature] 8-7-68	LUMINARY 1D
ANALST [signature] 10 Jan 69	DOCUMENT NO. FC-3850
DOCMR [signature] 6-24-68	
APPR'D [signature]	REV 8 — SHEET 10 OF 22



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

DRAWN 21MAY69
PRGMR C. Schulenberg 13 AUG 69
ANALST
DOCMR 13 AUG 69
APPR'D 13 AUG 69

APOLLO GUIDANCE AND NAVIGATION

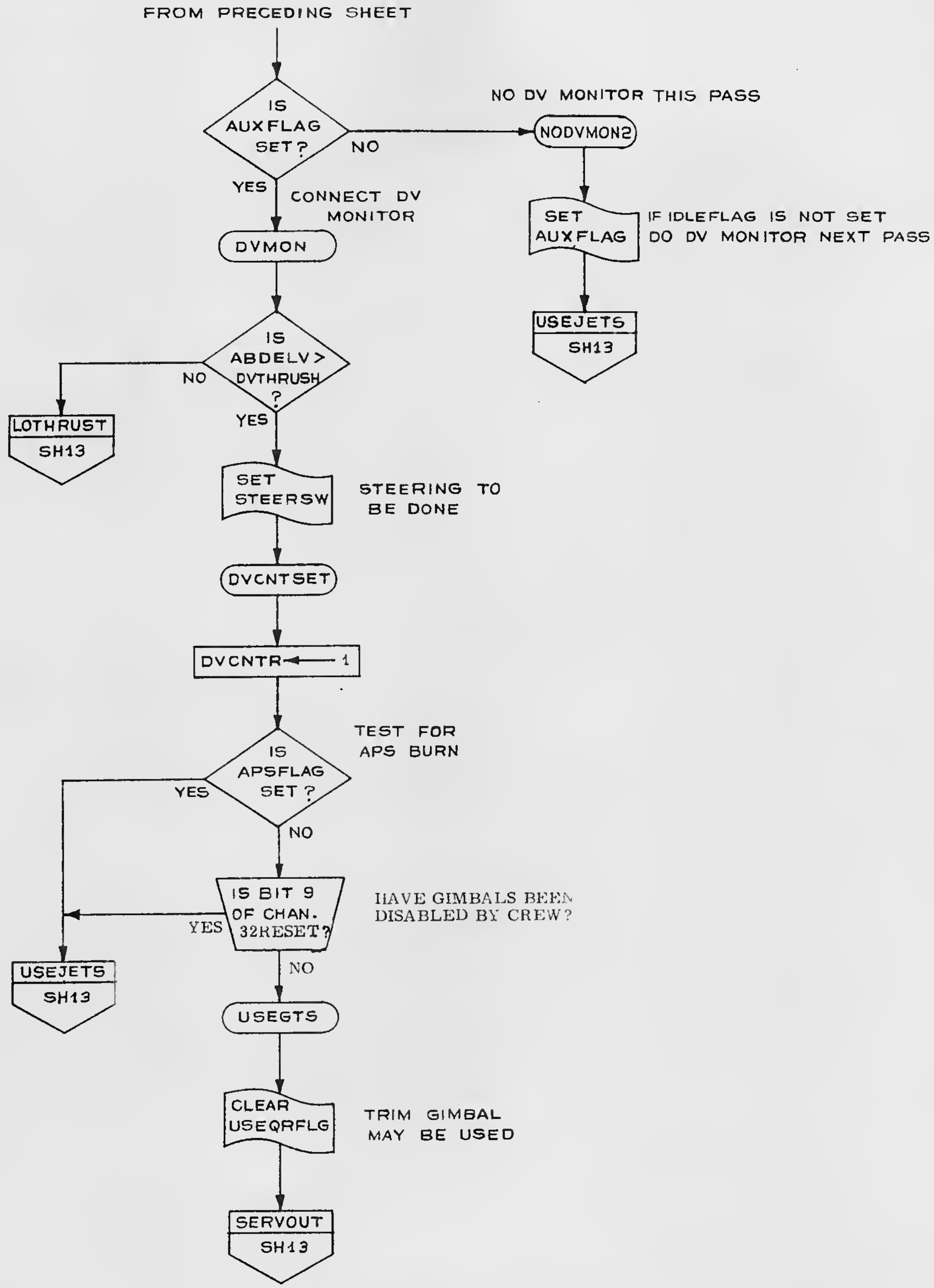
SERVICER

LUMINARY 1D

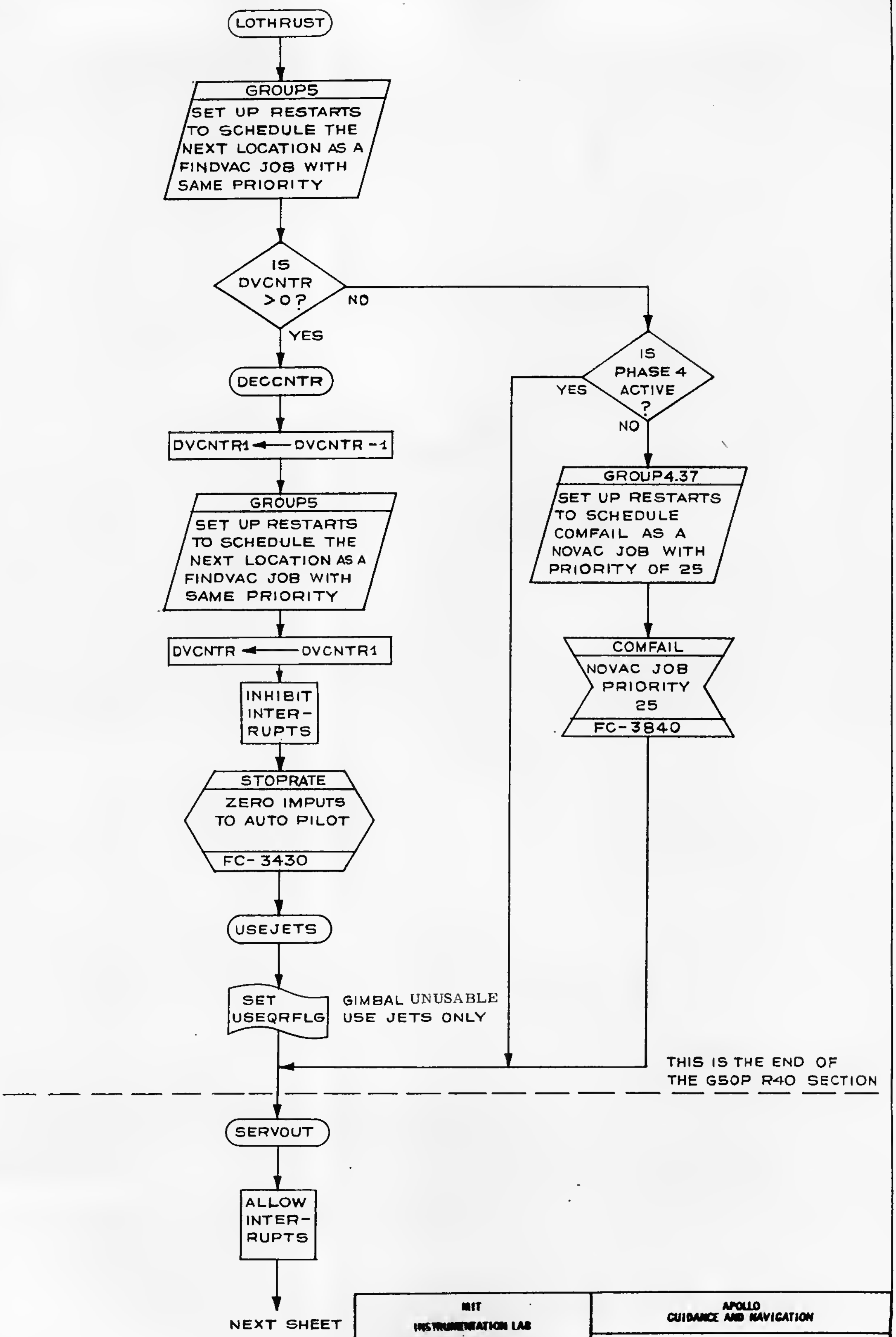
DOCUMENT NO. FC-3850

REV 3

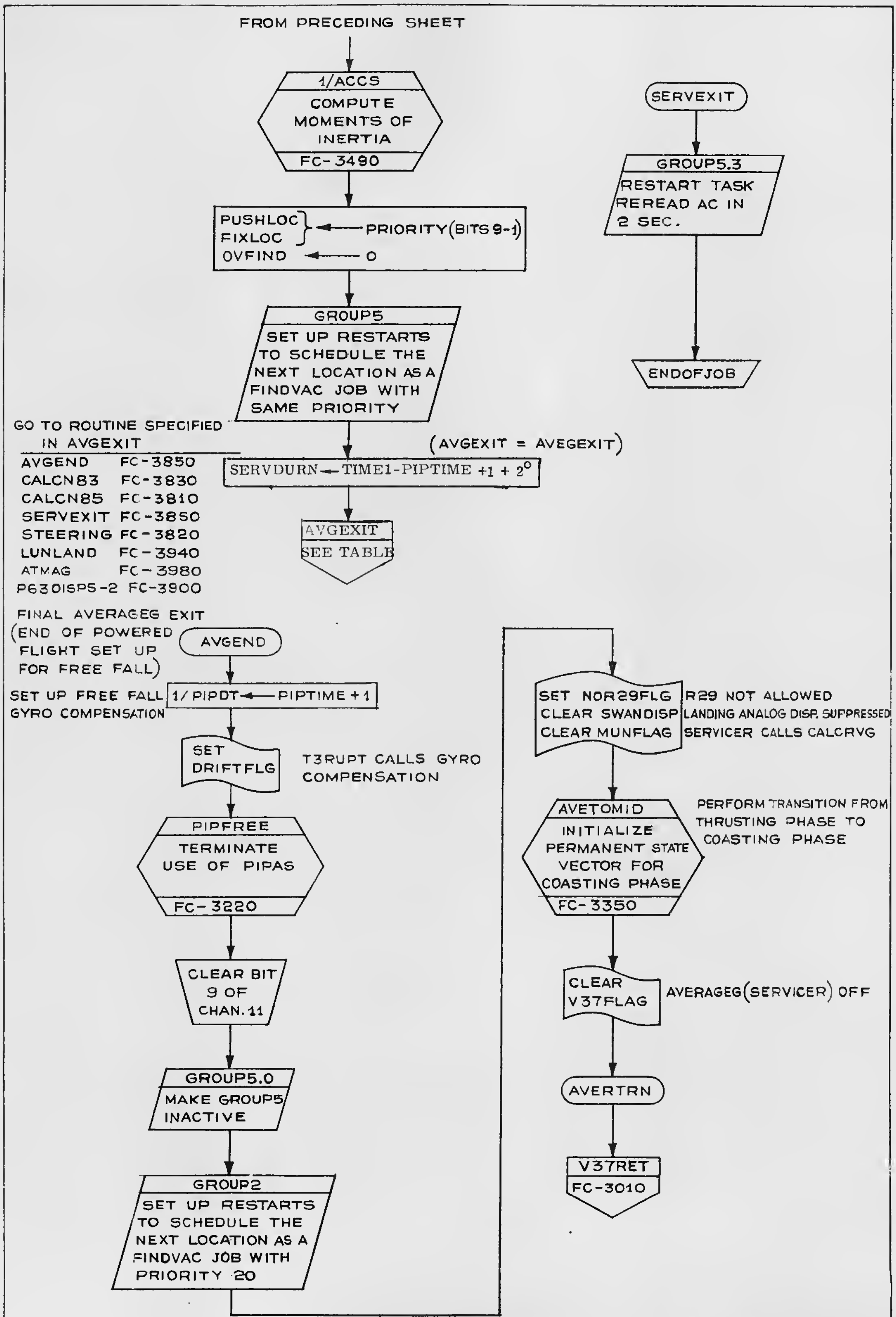
SHEET 11 OF 22



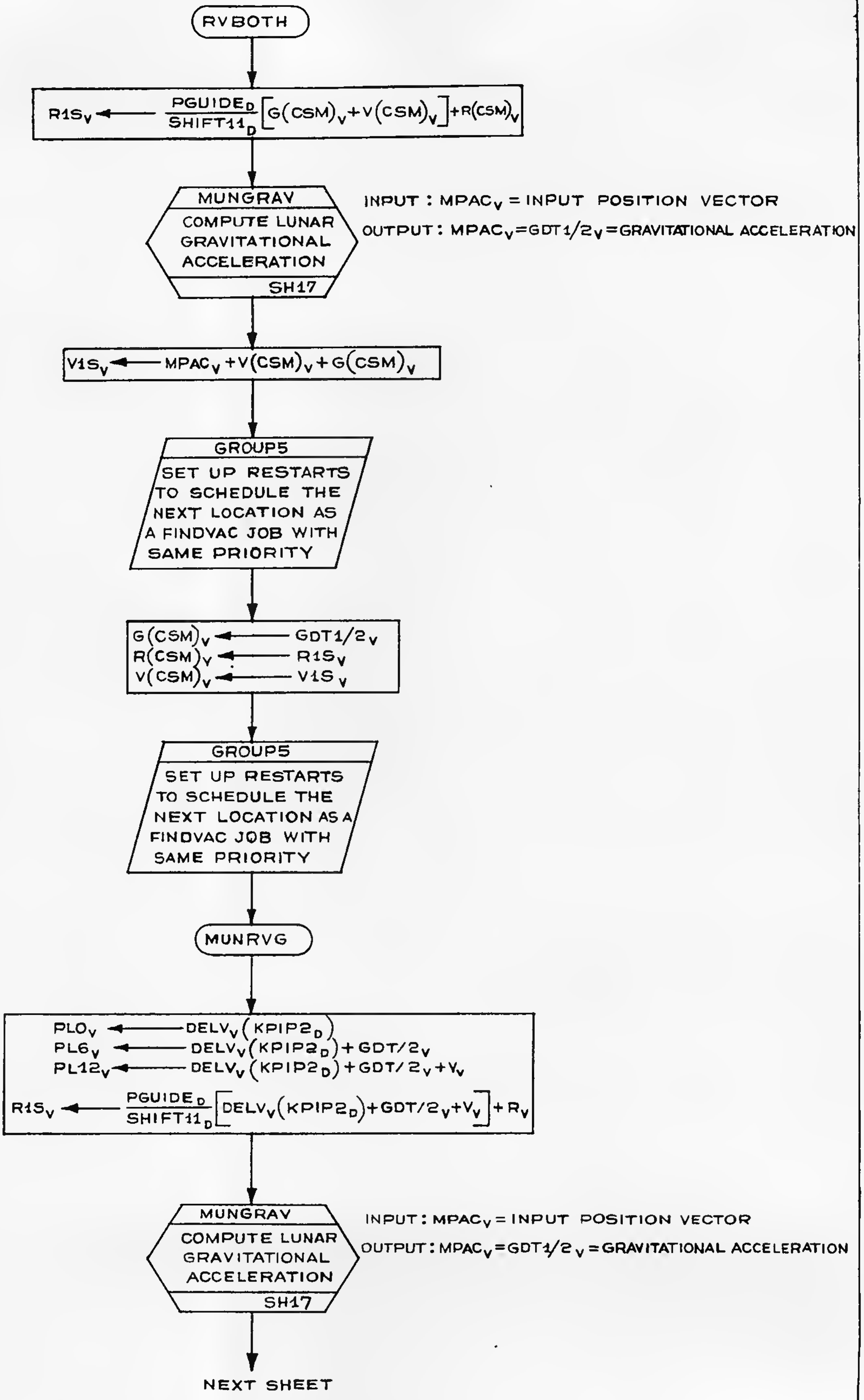
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	22MAY69	SERVICER	
PRGMR C. Schulenberg	13AUG69	LUMINARY 1D	DOCUMENT NO. FC-3850
ANALST			
DOCMR	13AUG69		
APPR'D	13AUG69	REV 3	SHEET 12 OF 22



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN D.M. Dietz 22MAY69	SERVICER
PRGMR C. Schulenberg 18 AUG69	LUMINARY 1D — DOCUMENT NO. FC-3850
ANALST	
DOCMR McDonald 19 AUG 69	REV 3
APPRVD Alvin M. Drant 23 AUG 69	SHEET 13 OF 22



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN P. M. Dietrich 22 MAY 69	SERVICER
PROMR C. Schulenberg 13 AUG 69	LUMINARY 1D
ANALST	DOCUMENT NO. FC-3850
DOCMR W. C. Dieghot 13 AUG 69	REV 3
APPR'D Alex M. ... 13 AUG 69	SHEET 14 OF 22



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN D.M. Dickard	23MAY69	SERVICER
PRGMR C. Schulenberg	13 AUG 69	
ANALST		LUMINARY 1D — DOCUMENT NO. FC-3850
DOCMR W.C. Dodrill	13 AUG 69	
APPR'D Alan Ivy Green	13 AUG 69	REV 3 — SHEET 15 OF 22

FROM PRECEDING SHEET

$V1S_V \leftarrow MPAC_V + PL6_V + PLO_V + V_V$
$ABVEL_D \leftarrow /V1S_V/$
$HDOTDISP_D \leftarrow UNIT/R/_V \cdot V1S_V$
$DELVS_V \leftarrow (R1S_V \times WM_V) \times 4$
$HCALC_D \leftarrow /R1S_V/ - /LAND/_D$

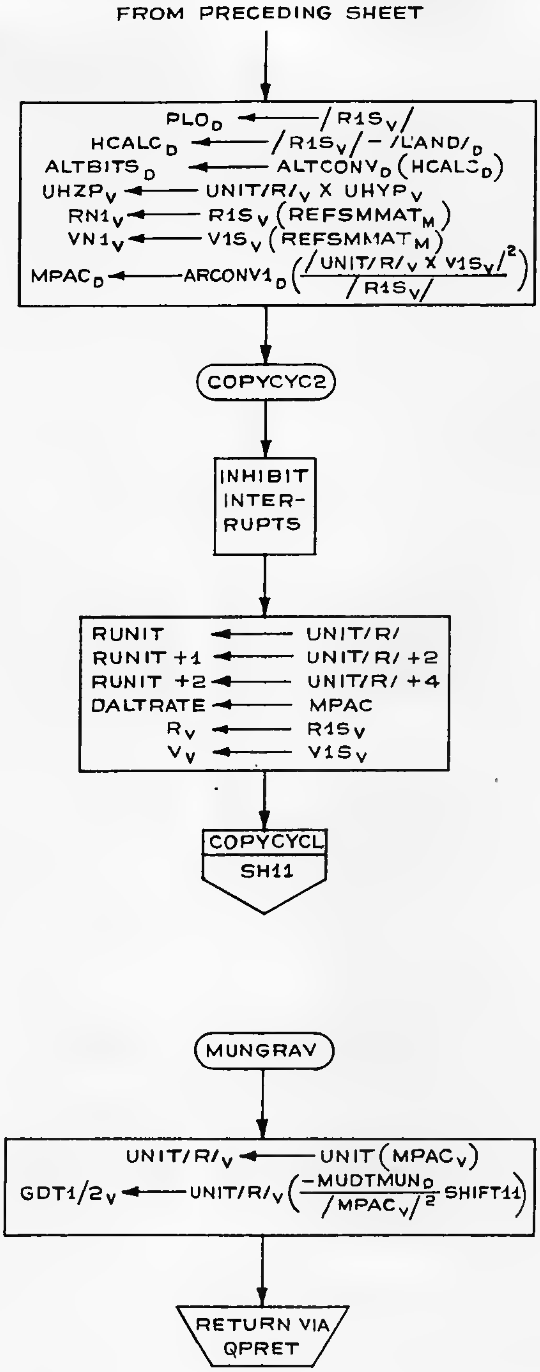
MUNRETRN
R12 – DESCENT STATE VECTOR UPDATE
FC-3935

COPYCYC1

GROUP5
SET UP RESTARTS TO SCHEDULE THE NEXT LOCATION AS A FINDVAC JOB WITH SAME PRIORITY

NEXT SHEET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN P.M. Dietz	23MAY69	SERVICER	
PRGMR C. Schulenberg	13 AUG 69	LUMINARY 1D	DOCUMENT NO. FC-3850
ANALST			
DOCMR MC Danforth	13 AUG 69		
APPR'D Alexa M. Lesant	13 AUG 69	REV 3	SHEET 16 OF [illegible]



MIT
INSTRUMENTATION LAB
CAMBRIDGE, MASS.

DRAWN	P.M. Dietrich	23 MAY 69
PROGMR	C. Schulenberg	13 AUG 69
ANALST		
DOCMR	McDoguitt	13 AUG 69
APPR'D		13 AUG 69

APOLLO
GUIDANCE AND NAVIGATION

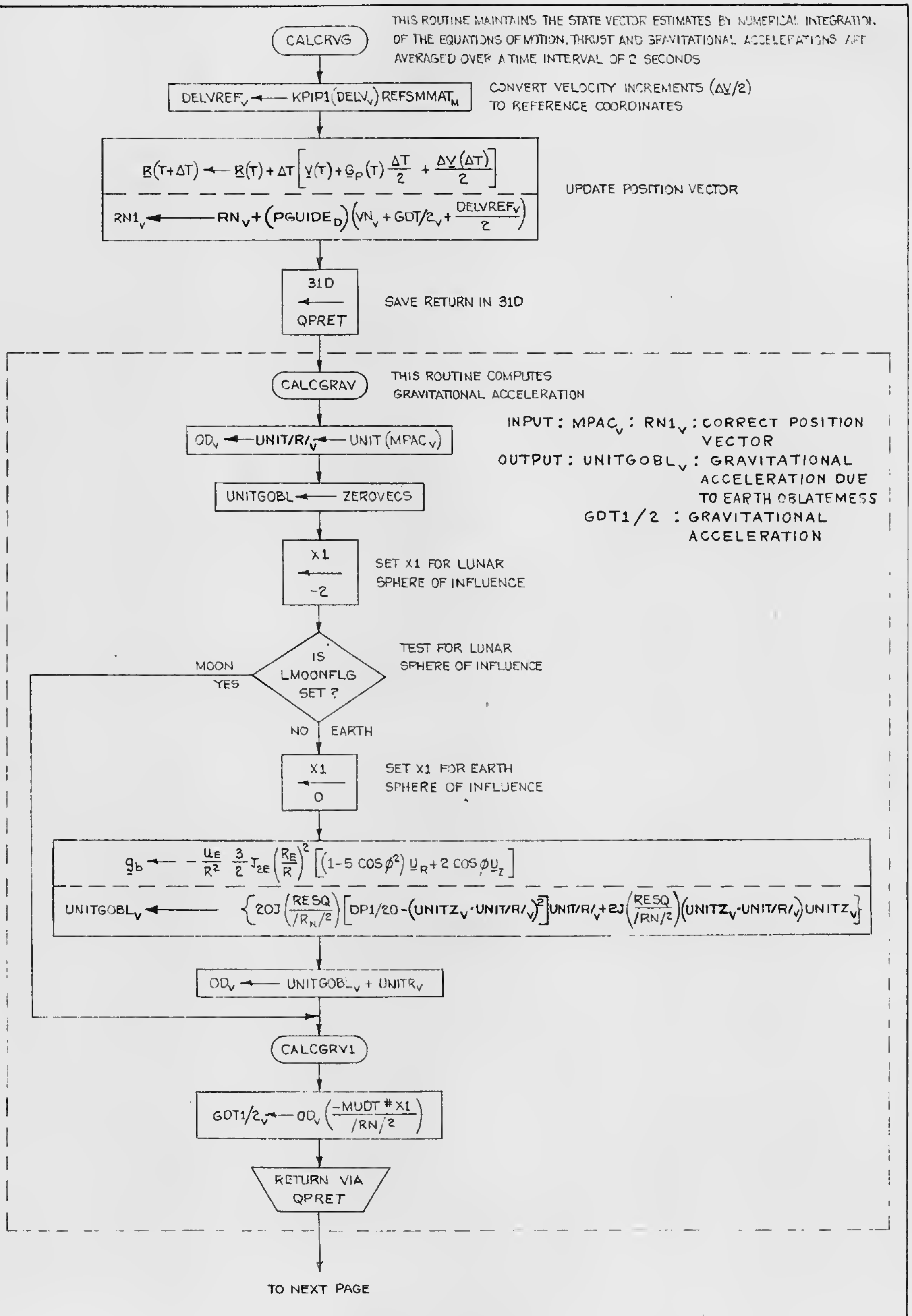
SERVICER

LUMINARY 1D

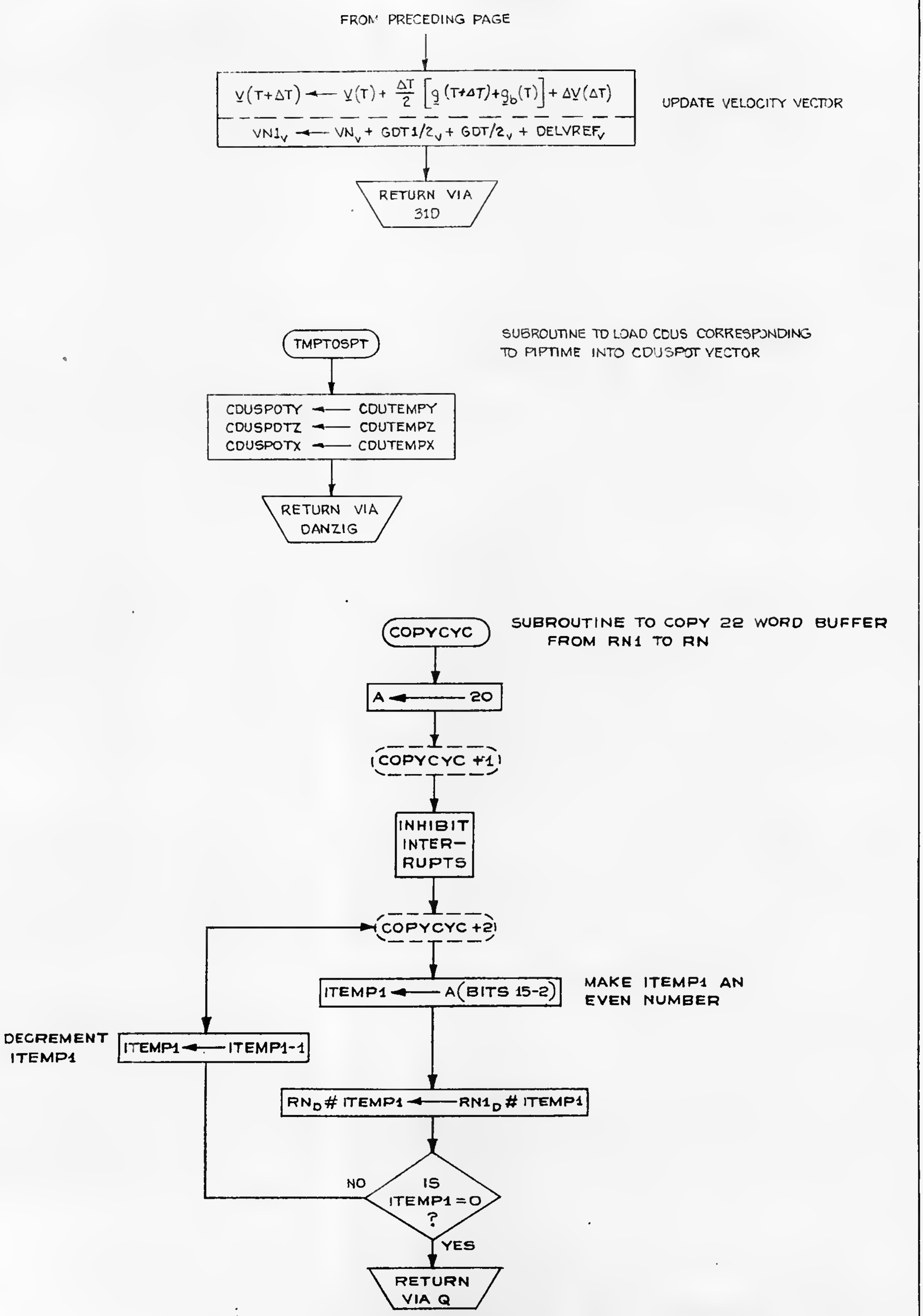
DOCUMENT NO. FC-3850

REV 3

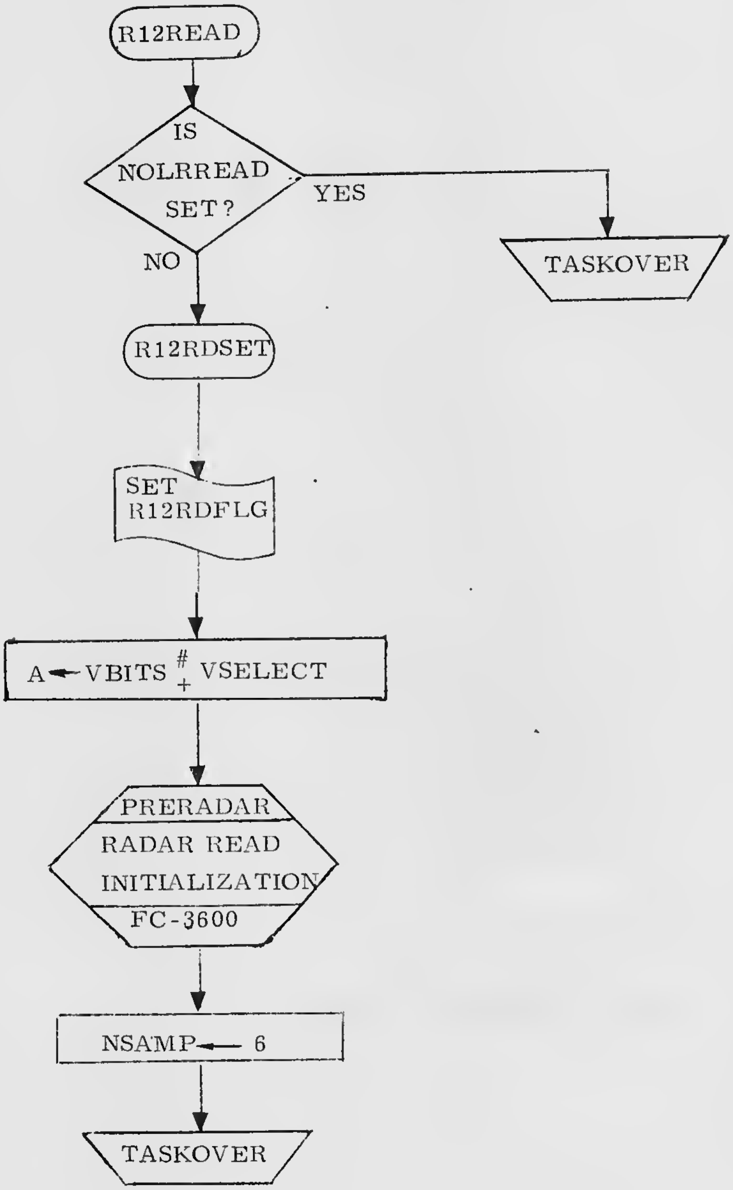
SHEET 17 OF 22



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS	6-18-68	SERVICER	
PROGMR R. Covell	8-7-68		
ANALST P. Phillips	10 Jan 69	LUMINARY 1D	DOCUMENT NO. FC-3850
DOCMR W. Duffith	6-24-68		
APPR'D John A. Moran	24 JAN 69	REV 3	SHEET 18 OF 22



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 6-18-68	SERVICER
PROGMR 8-7-68	
ANALST 10 Jan 69	LUMINARY 1D — DOCUMENT NO. FC-3850
DOCMR 6-24-68	
APPR'D 24 Jan 69	REV 3 — SHEET 19 OF 22



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E. Matta	6/2/70	SERVICER	
PRGMR D. McKay	6/5/70		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3850
DOCMR	6/5/70		
APPR'D	6/10/70	REV 3	SHEET 20 OF 22

SUBROUTINES CALLED WHICH ARE
FLOWED ON OTHER FLOW CHARTS

SUBROUTINE NAME	FLOW CHART	DESCRIPTION	WHERE CALLED
AVETOMID	FC-3350	INITIALIZE PERMANENT STATE VECTOR FOR COASTING PHASE	SH. 14
COMFAIL	FC-3840	THRUST FAIL PROGRAM	SH. 13
LASTBIAS	FC-3230	LAST GYRO COMPENSATION IN FREE FALL	SH. 2
PIPFREE	FC-3220	TERMINATE USE OF PIPAS	SH. 14
PRERADAR	FC-3600	RADAR READ INITIALIZATION	SH. 20
QUICTRIG	FC-3320	COMPUTE SINES AND COSINES OF CDU ANGLES	SH. 10
R10,R11	FC-3930	LANDING RADAR MONITOR	SH. 4
STOPRATE	FC-3430	ZERO INPUTS TO AUTOPILOT	SH. 13
VARDELAY	FC-3040	DELAY ACTIVE TASK	SH. 2, 4
1/ACCS	FC-3490	COMPUTE MOMENTS OF INERTIA	SH. 14
1/PIPA	FC-3230	COMPENSATE PIPAS AND GYROS	SH. 9

ERASABLE LOCATIONS USED

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
$DVTOTAL_D$		ACCUMULATED DELTA-V	FEET/SEC	M/CSEC	2^{-7}
$GDT1/2_V$		GRAVITATIONAL ACCELERATION VECTOR (DELTA TIME)	FEET/SEC	M/CSEC	2^{-7}
$MASS1_D$		VEHICLE MASS	POUNDS	KG	2^{-16}
$PGUIDE_D$		DELTA PIPTIME	SECONDS	CSEC	2^{28}
$RN1_V$		LM POSITION VECTOR	FEET	METERS	2^{-29}
$VN1_V$		LM VELOCITY VECTOR	FEET/SEC	M/CSEC	2^{-7}
$XNBPIP_V$		STABLE MEMBER TO NAVIGATION BASE TRANSFORMATION MATRIX FOR LAST PIP TIME	—	—	2^{-1}
$YNBPIP_V$			—	—	2^{-1}
$ZNBPIP_V$			—	—	2^{-1}

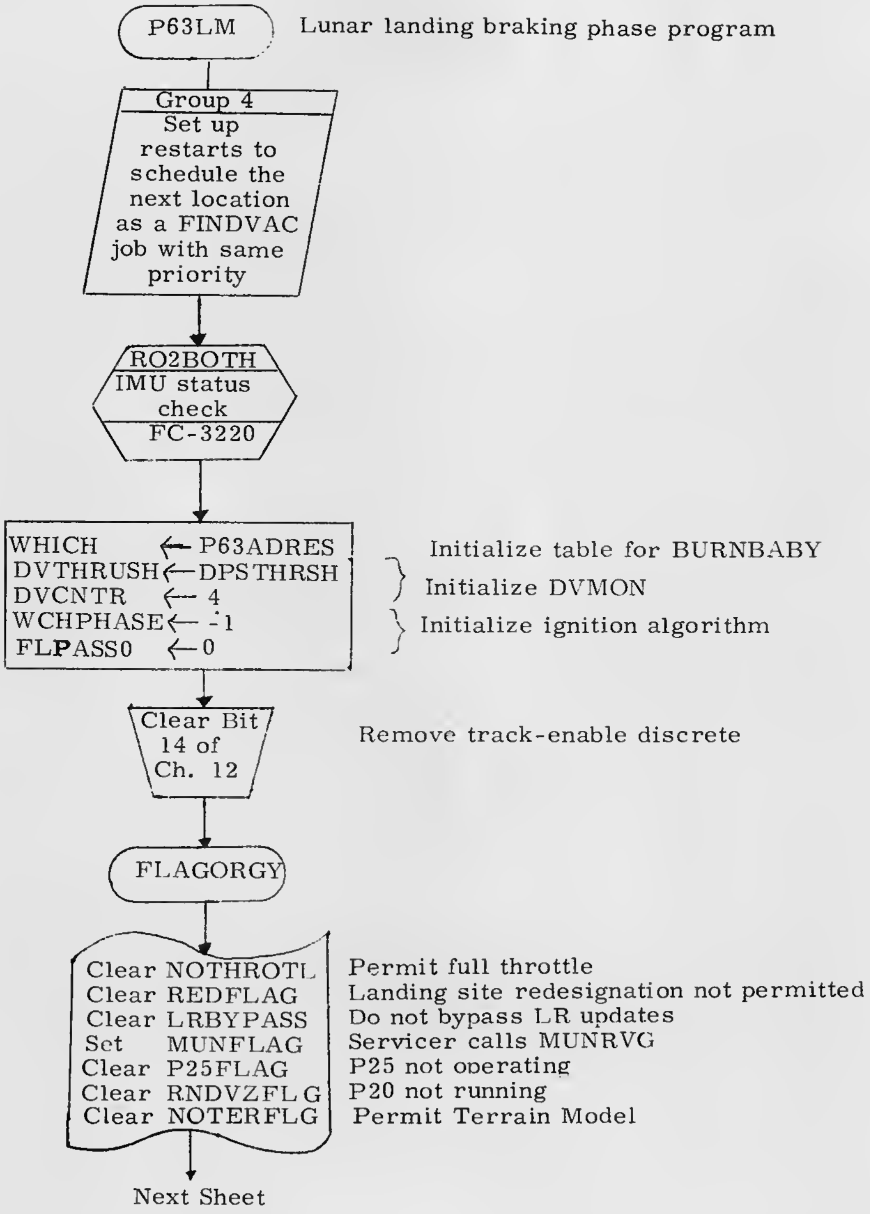
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN R. D. Hart 4 Jun 69	SERVICER
PROGMR C. Schulenberg 1 Aug 69	LUMINARY 1D
ANALST	DOCUMENT NO. FC-3850
DOCMR MC Dybatt 13 Aug 69	REV 3
APPR'D Alex M. Doane 3 Aug 69	SHEET 21 OF 22

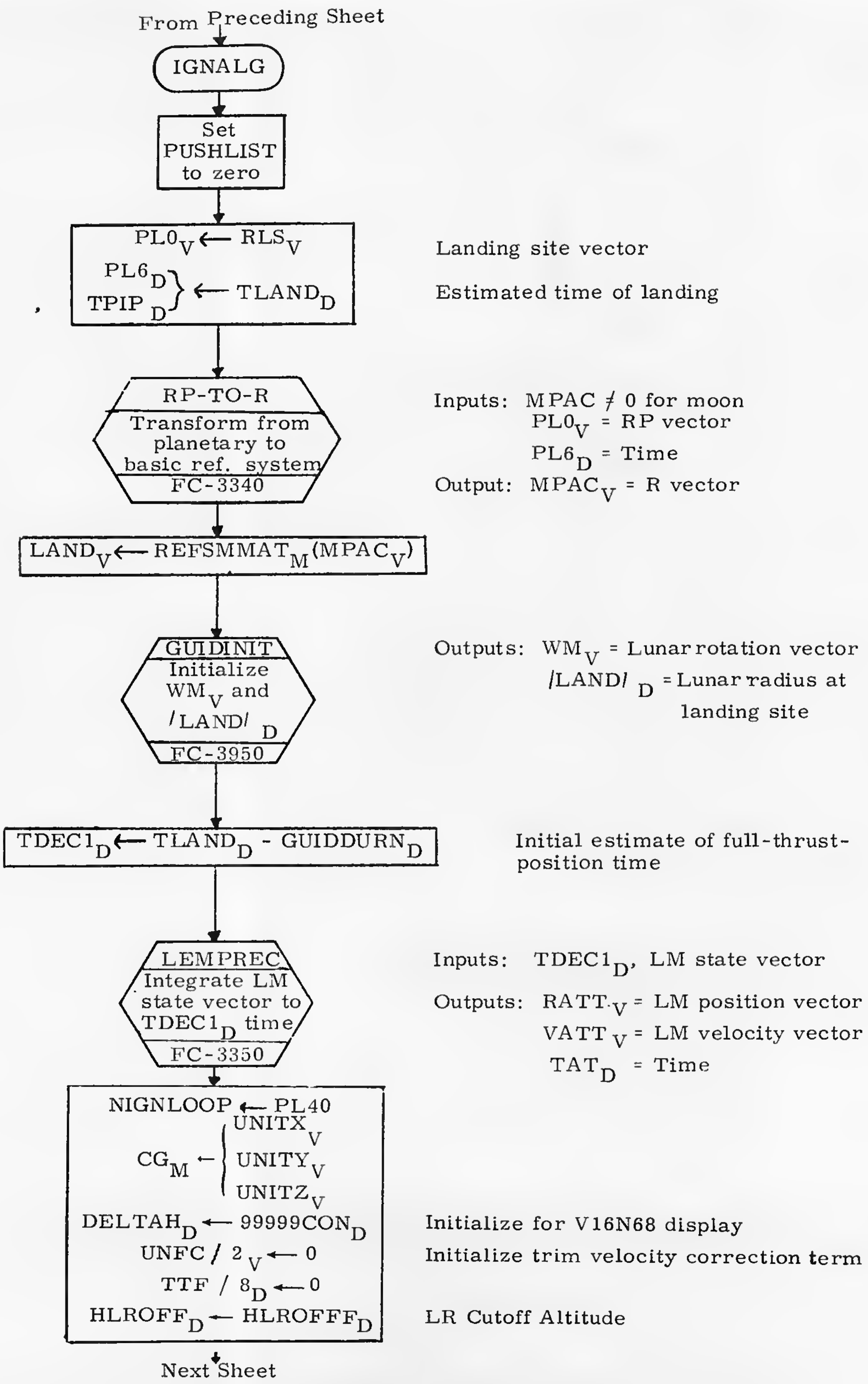
FLAGS

NAME	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
APSFLAG FLAG 10 BIT 13	APS BURN	DPS BURN			SH. 9,12
AUXFLAG FLAG 6 BIT 2	IF IDLEFLAG IS NOT SET, SERVICER WILL DO DVMON ON NEXT PASS	SERVICER WILL SKIP DVMON ON NEXT PASS	SH. 12	SH. 11	SH. 12
AVEGFLAG FLAG 7 BIT 5	AVERAGEG (SERVICER) DESIRED	AVERAGEG (SERVICER) NOT DESIRED	SH. 2		SH. 4
DRIFTFLG FLAG 2 BIT 15	T3RUPT CALL GYRO COMPENSATION	T3RUPT DOES NO GYRO COMPENSATION	SH. 14	SH. 2	
MUNFLAG FLAG 6 BIT 8	USE LUNAR LANDING AVERAGEG	DO NOT USE LUNAR LANDING AVERAGEG		SH. 14	SH. 4, 8, 11
NOR29FLG FLAG 3 BIT 11	R29 NOT ALLOWED	R29 ALLOWED	SH. 14		
STEERSW FLAG 2 BIT 11	STEERING TO BE DONE	STEERING OMITTED	SH. 12	SH. 11	
SURFFLAG FLAG 8 BIT 8	LM ON LUNAR SURFACE	LM NOT ON LUNAR SURFACE			SH. 9
SWANDISP FLAG 7 BIT 11	LANDING ANALOG DISPLAYS ENABLED	LANDING ANALOG DISPLAYS SUPPRESSED		SH. 14	
USEQRFLG FLAG 13 BIT 14	GIMBAL UNUSABLE. USE JETS ONLY	TRIM GIMBAL MAY BE USED	SH. 13	SH. 12	
V37FLAG FLAG 7 BIT 6	AVERAGEG (SERVICER) RUNNING	AVERAGEG (SERVICER) OFF	SH. 2	SH. 14	
LRBYPASS FLAG 11 BIT 15	BYPASS ALL LANDING RADAR UPDATES	DO NOT BYPASS LANDING RADAR UPDATES			SH. 4
NOLRREAD FLAG 11 BIT 10	LANDING RADAR REPOSITIONING	LANDING RADAR NOT REPOSITIONING			SH. 20

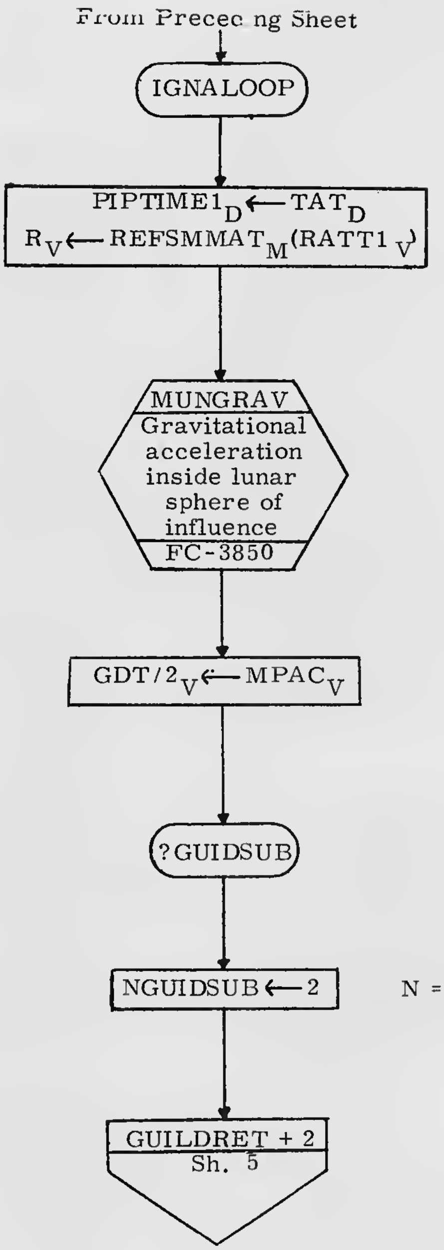
LUNAR LANDING

MAJOR SUBROUTINES ON THIS CHART


P63LM
Lunar landing braking phase program
Group 4
Set up restarts to schedule the next location as a FINDVAC job with same priority
RO2BOTH
IMU status check
FC-3220
WHICH ← P63ADRES
DVTHRUSH ← DPSTHRSH
DVCNTR ← 4
WCHPHASE ← -1
FLPASS0 ← 0
Initialize table for BURNBABY
Initialize DVMON
Initialize ignition algorithm
Clear Bit 14 of Ch. 12
Remove track-enable discrete
FLAGORGY
Clear NOTHROTL
Clear REDFLAG
Clear LRBYPASS
Set MUNFLAG
Clear P25FLAG
Clear RNDVZFLG
Clear NOTERFLG
Permit full throttle
Landing site redesignation not permitted
Do not bypass LR updates
Servicer calls MUNRVG
P25 not operating
P20 not running
Permit Terrain Model
Next Sheet



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	D Lutkewich 9/30/69	Lunar Landing	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR	W Dogbrth 9/30/69		
APPR'D	Robert M Ertes 11/25/69	REV 2	SHEET 3 OF 52



Input: $MPAC_V$ = R vector

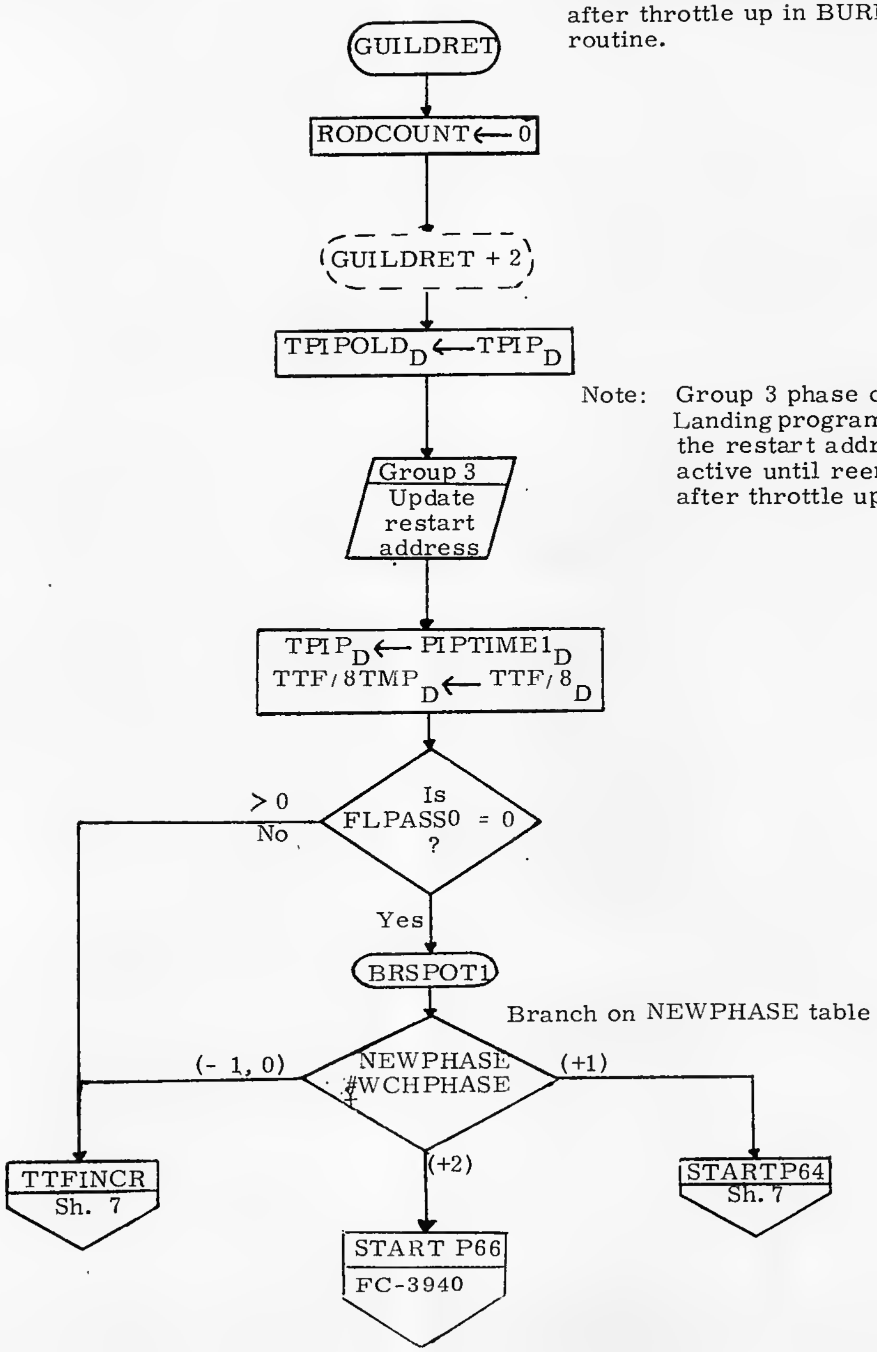
Output: $MPAC_V$ = $GDT1/2_V$

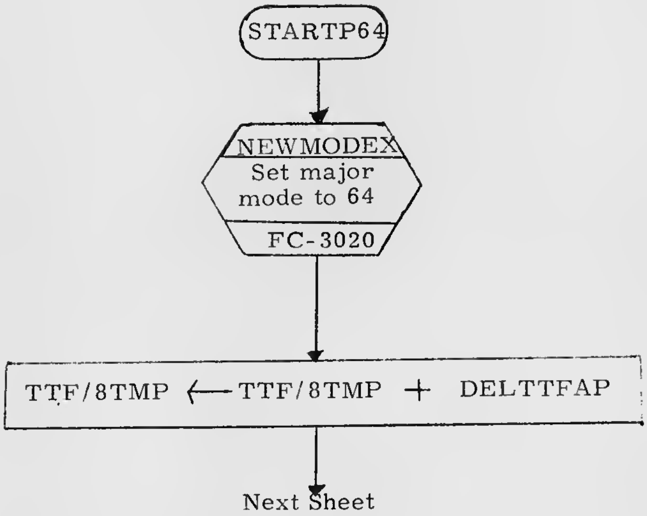
Delivers N passes of quadratic guidance

N = 3

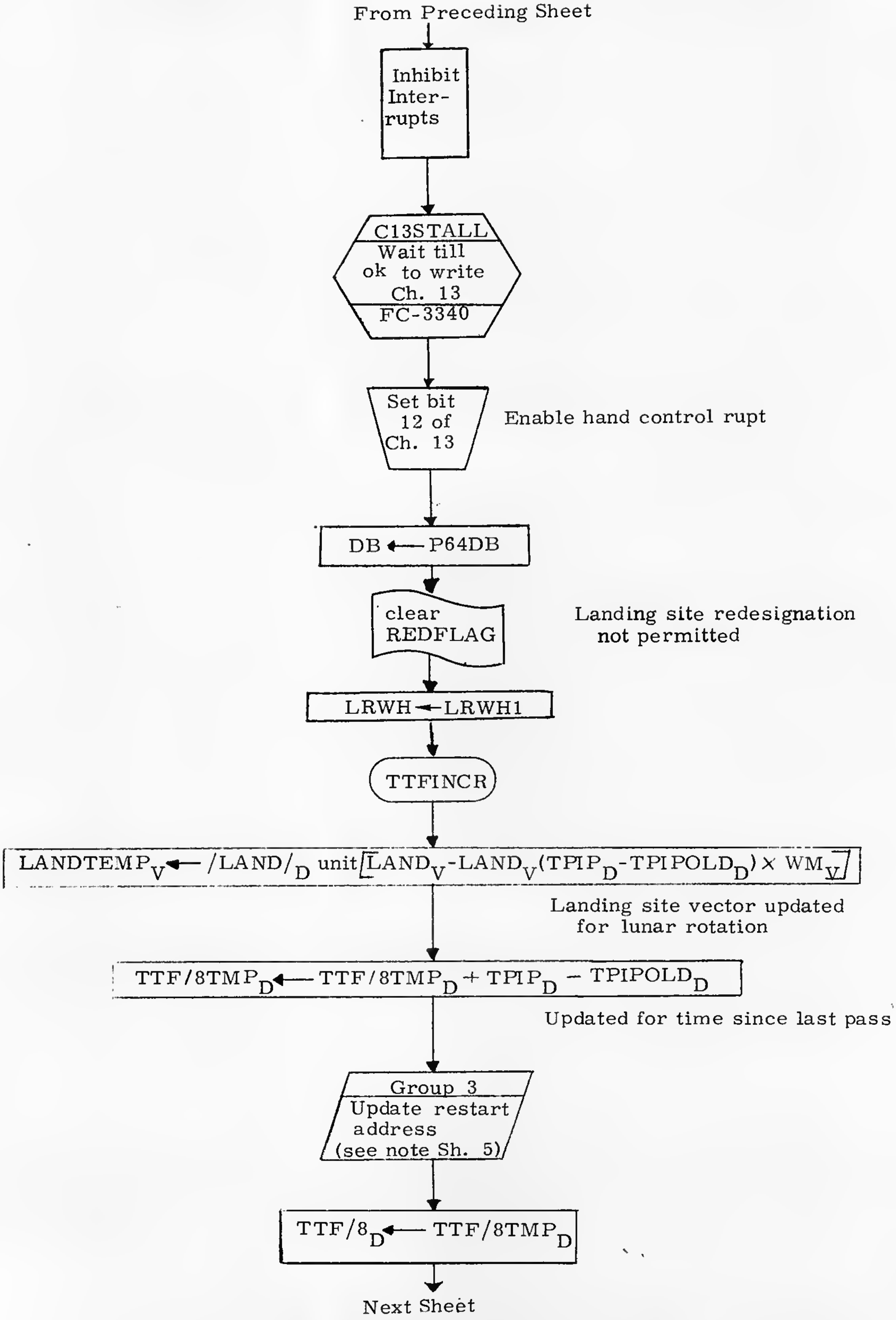
Entry to Guidance from R13 routine called by SERVICER every two seconds after throttle up in BURNBABY routine.

Note: Group 3 phase changes in Lunar Landing program change only the restart address and are not active until reentry to Guidance after throttle up.

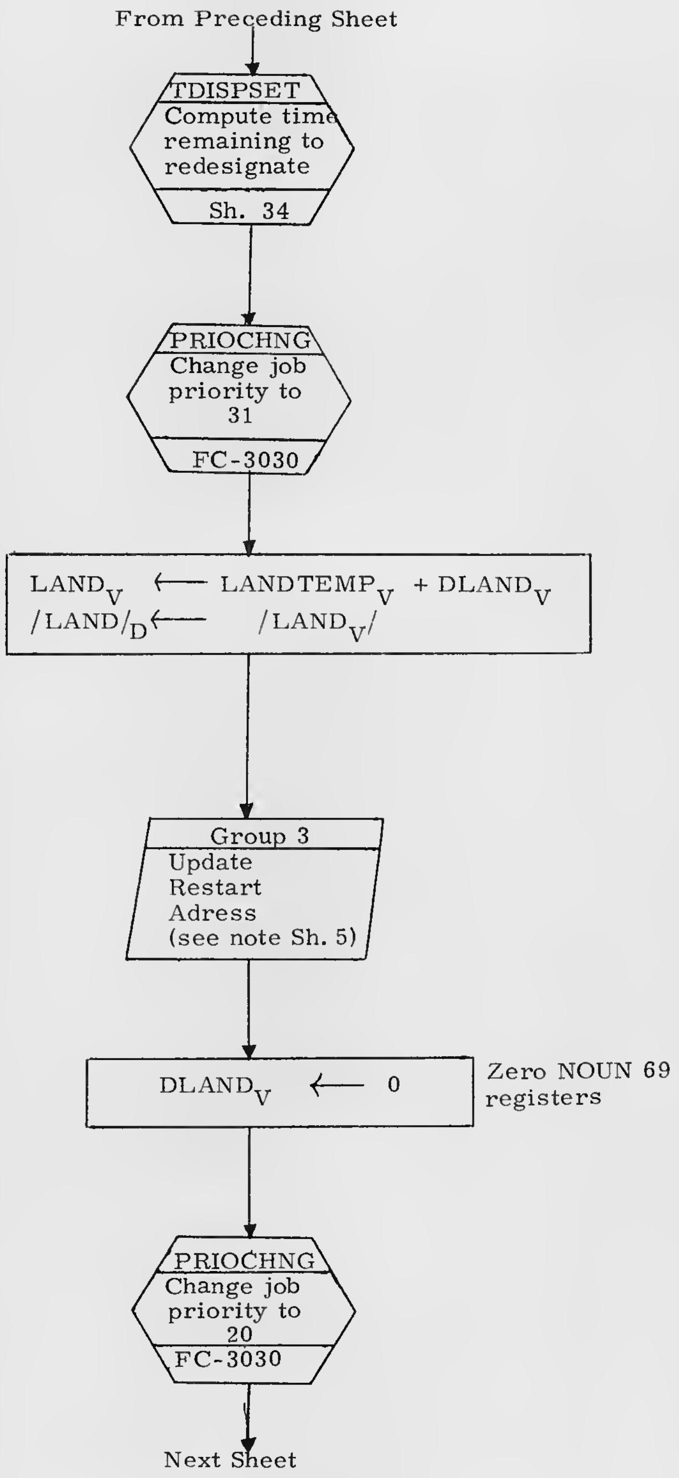


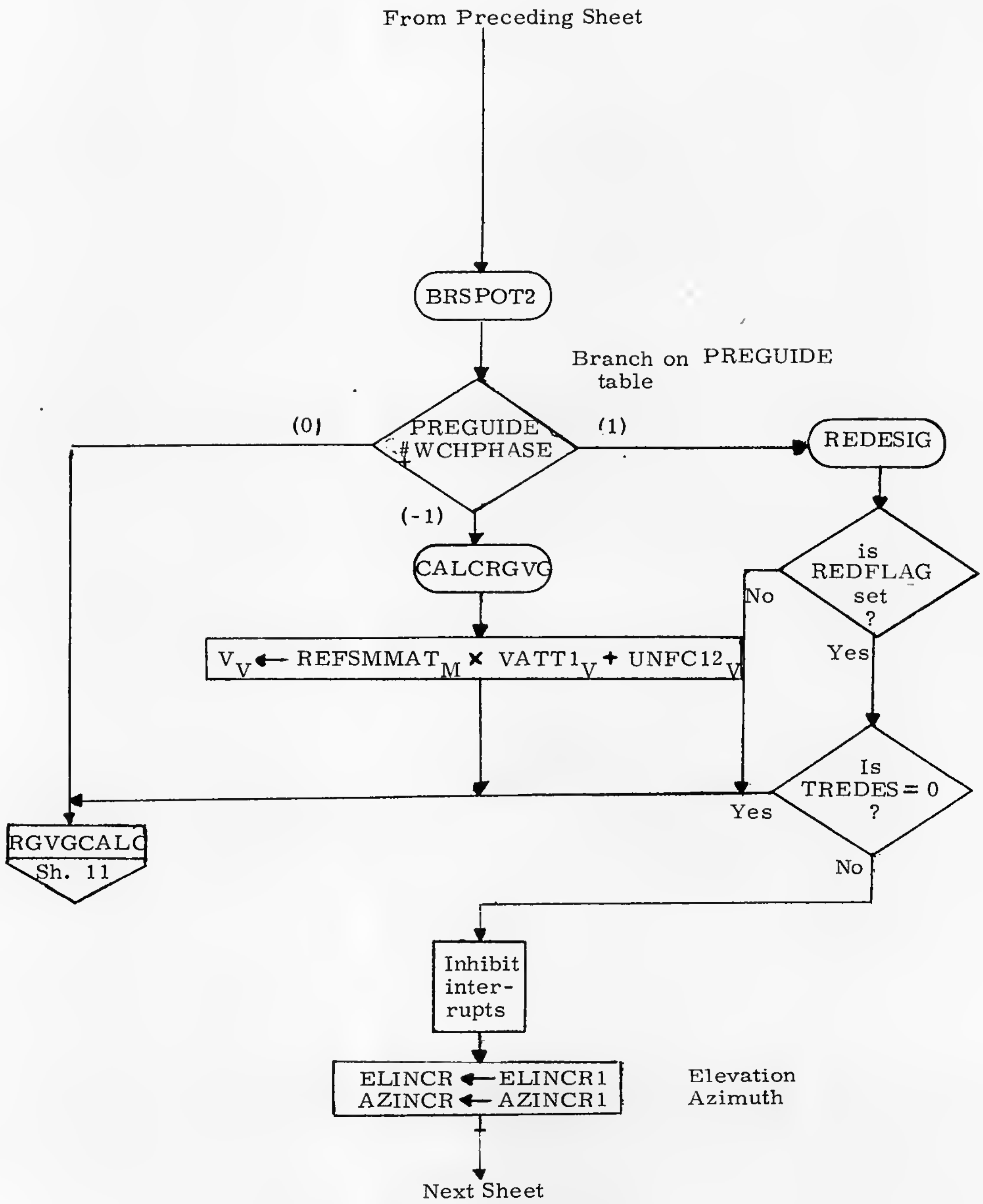


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION		
DRAWN	R Welch	3/5/70	Lunar Landing	
PRGMR				
ANALST			LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR	W Danforth	9/30/69		
APPR'D	Roberto M Estes	11/25/69	REV 2	SHEET 6 OF 52

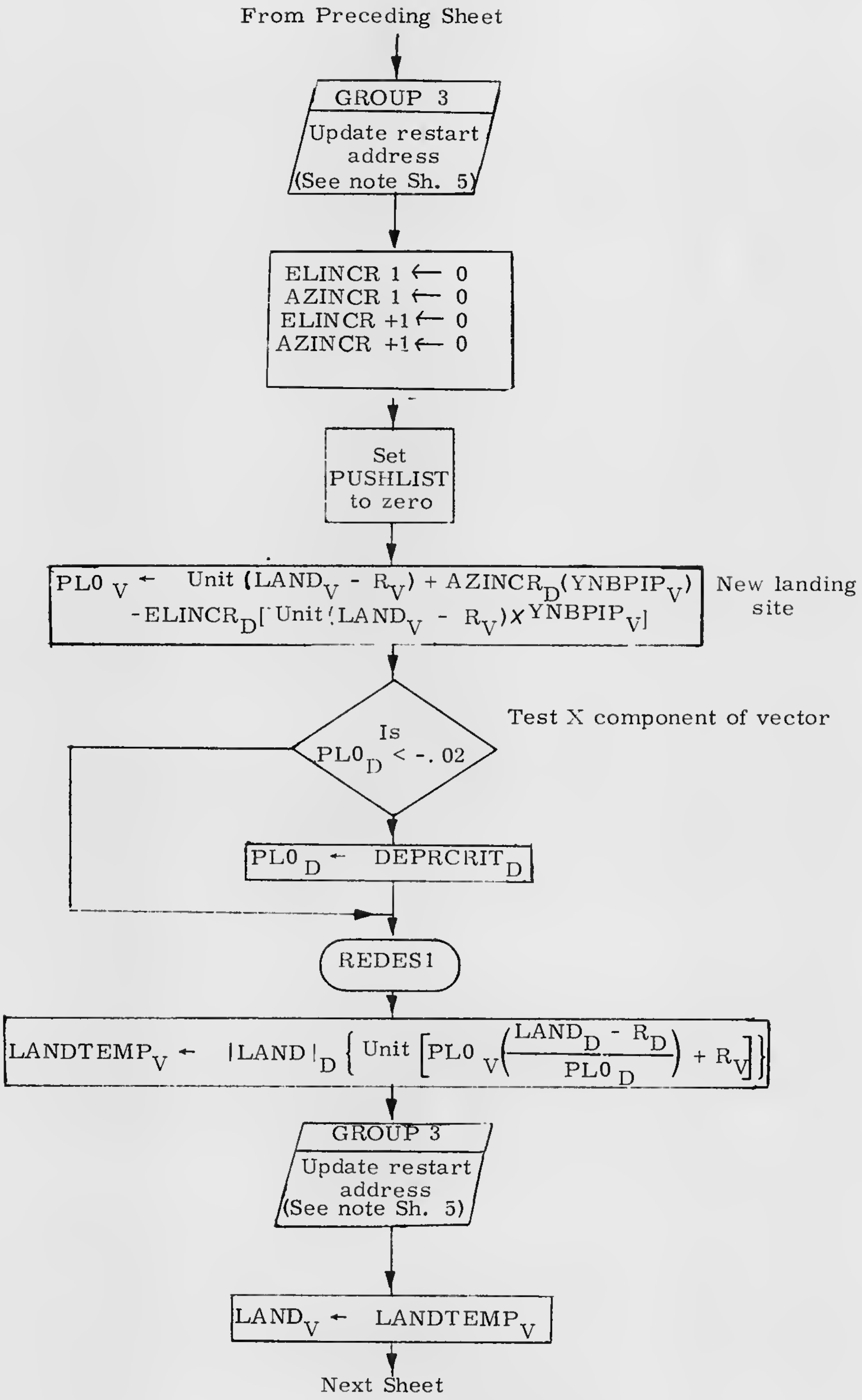


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R Welch	3/5/70	Lunar Landing	
PRGMR			
ANALST		LUMINARY 1 D	DOCUMENT NO. FC-3900
DOCMR W Dogbith	9/30/69		
APPR'D Roberto M Entas	11/25/69	REV 2	SHEET 7 OF 52

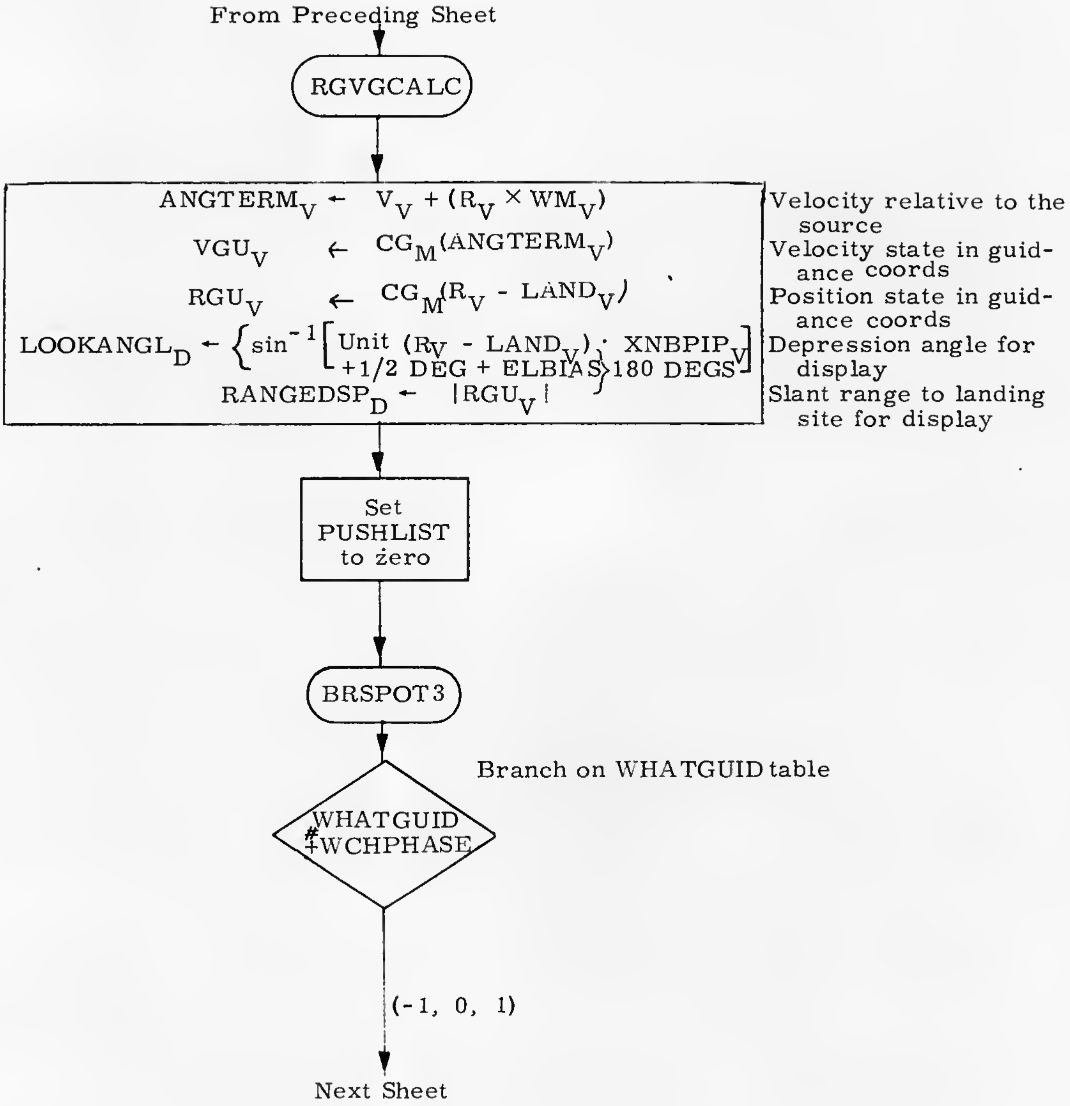

From Preceding Sheet
TDISPSET
Compute time remaining to redesignate
Sh. 34
PRIOCHNG
Change job priority to 31
FC-3030
$LAND_V \leftarrow LANDTEMP_V + DLAND_V$
$/LAND/_D \leftarrow /LAND_V/$
Group 3
Update Restart Adress (see note Sh. 5)
$DLAND_V \leftarrow 0$
Zero NOUN 69 registers
PRIOCHNG
Change job priority to 20
FC-3030
Next Sheet



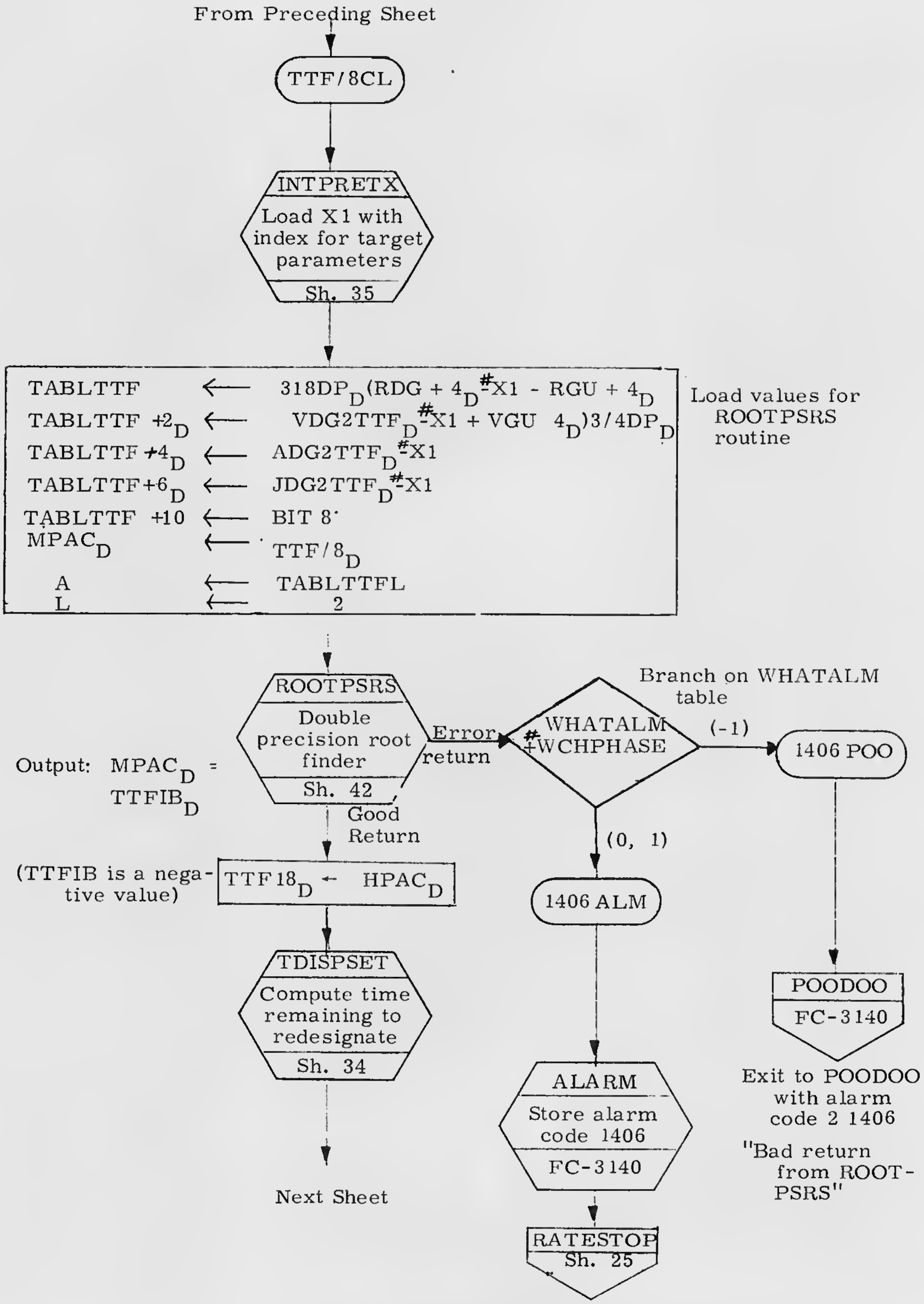
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R Welch	3/5/70	Lunar Landing	
PRGMR		LUMINARY 1 D	DOCUMENT NO. FC-3900
ANALST			
DOCMR W Dayforth	9/30/69		
APPR'D Roberto M Ester	11/25/69	REV 2	SHEET 9 OF 52



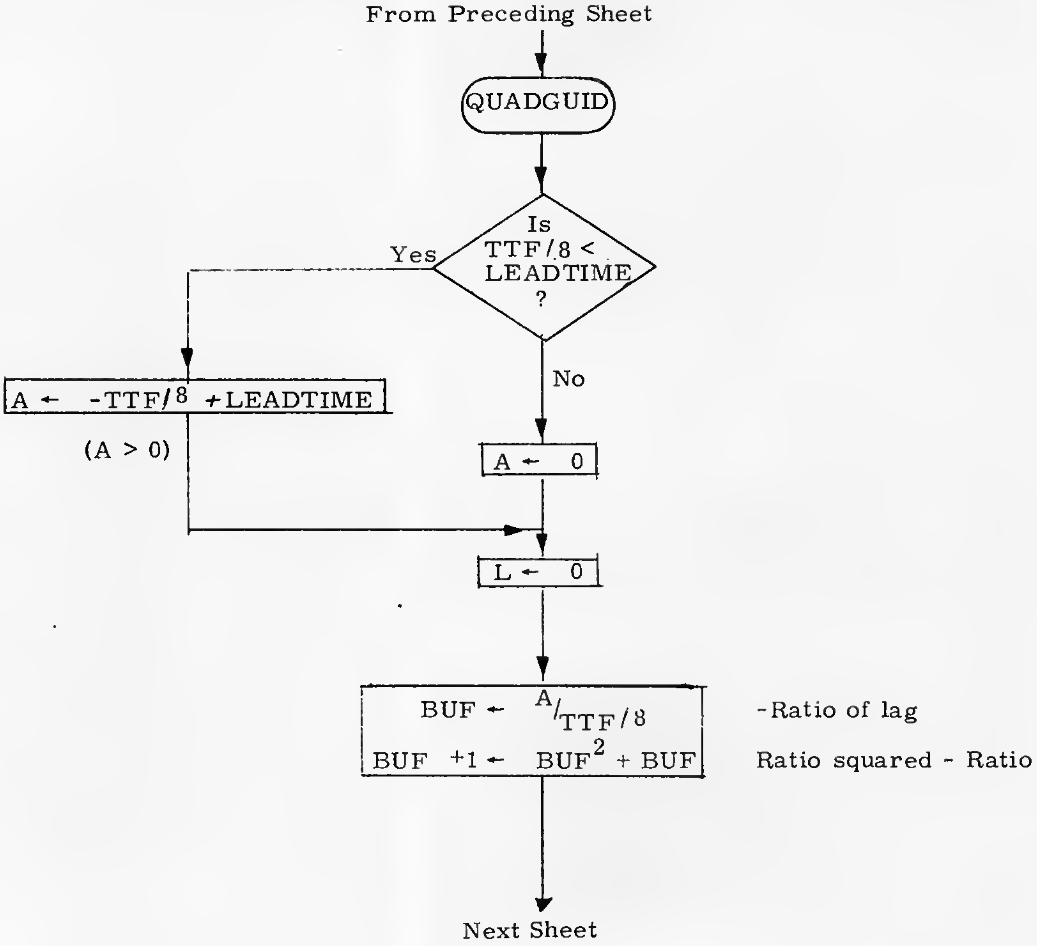
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	R Welch	3/5/70	Lunar Landing	
PRGMR				
ANALST			LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR	W Dayforth	9/30/69		
APPR'D	R M Estes	11/25/67	REV 2	SHEET 10 OF 52



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R Welch	3/5/70	Lunar Landing	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR W Daughtrie	9/30/69		
APPR'D RM Eustis	11/25/69	REV 2	SHEET 11 of 52



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R Welch	3/5/70	Lunar Landing	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR W Dagforth	9/30/69		
APPR'D R M Eates	11/25/69	REV 2	SHEET 12 OF 52



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	R Welch	3/5/72	Lunar Landing	
PRGMR			LUMINARY 1D	DOCUMENT NO. FC-3900
ANALST				
DOCMR	W Danforth	9/30/69		
APPR'D	RMM Eaton	11/25/67	REV 2	SHEET 13 OF 52

From Preceding Sheet

$MPAC \leftarrow 2\ BUF^2 + BUF$
$PL26 \leftarrow 3\ BUF^2 + BUF$
$PL28 \leftarrow 4\ BUF^2 + 3\ BUF$
$PL30 \leftarrow 6\ BUF^2 + 6\ BUF + 1$

} Store in PUSHLIST

INTPRETX
Load X1 with index for target parameters
Sh. 35

$$MPAC_V \leftarrow \left[\frac{PL26_D \dfrac{RDG_V \# X1 - RGU_V}{4(TTF/8_D)} + PL28_D(VDG_V \# X1) + MPAC_D(VGU_V)}{TTF/8_D} \right] 3/4$$
$$+ PL30_D(ADG_V \# X1)$$

AFCCALC1

$$UNFC/2_V \leftarrow MPAC_V \times CG_M - \frac{GDT/2_V}{GSCALE_D}$$

AFCCALC2

$$|AFC|_D \leftarrow |UNFC/2_V|$$

$$MPAC_D \leftarrow \left(\frac{HIGHESTF_D}{MASS_D} \right)^2 - (UNFC/2 + 2_D)^2 - (UNFC/2_D)^2$$

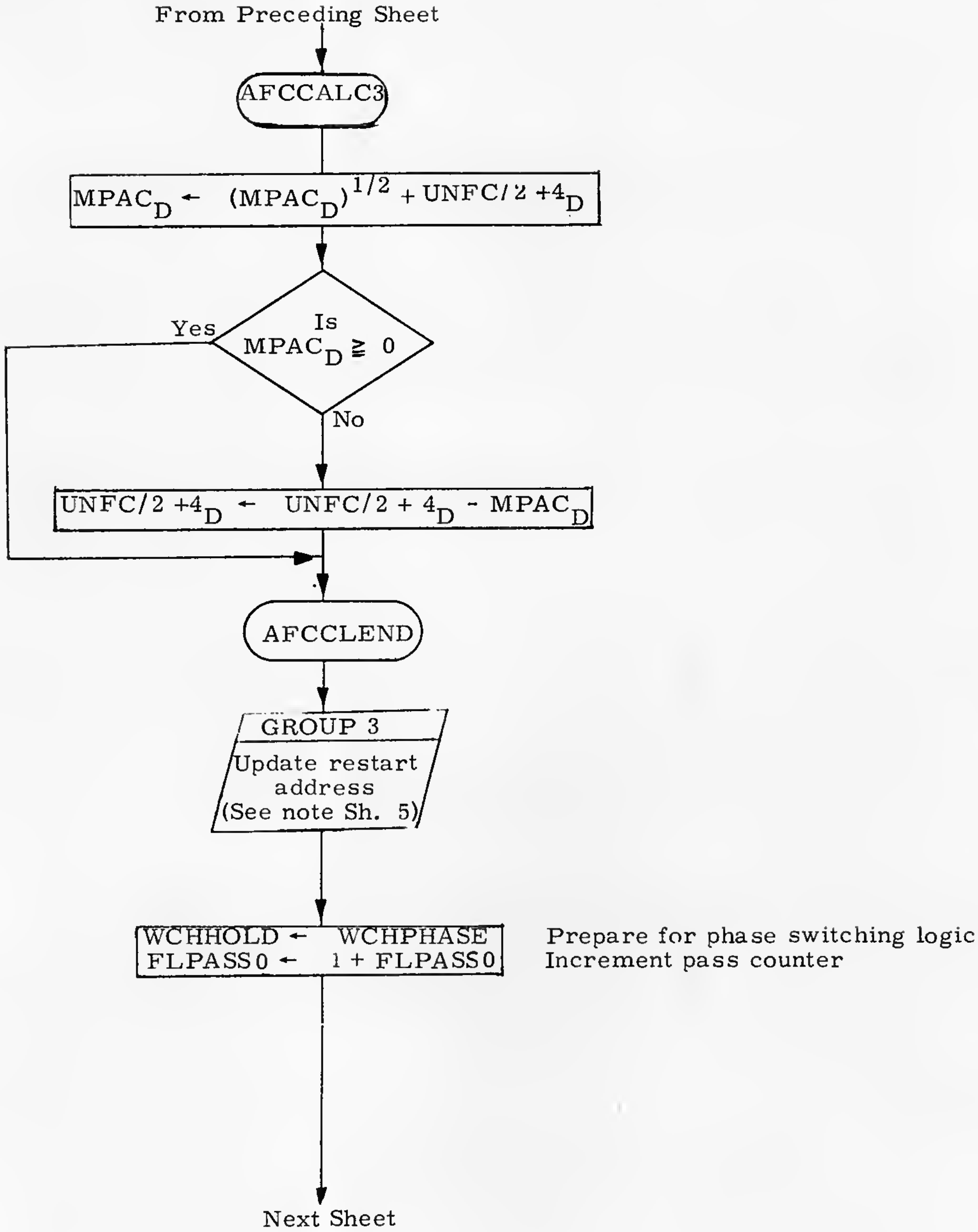
Is $MPAC_D \geq 0$?

No: $MPAC_D \leftarrow 0$

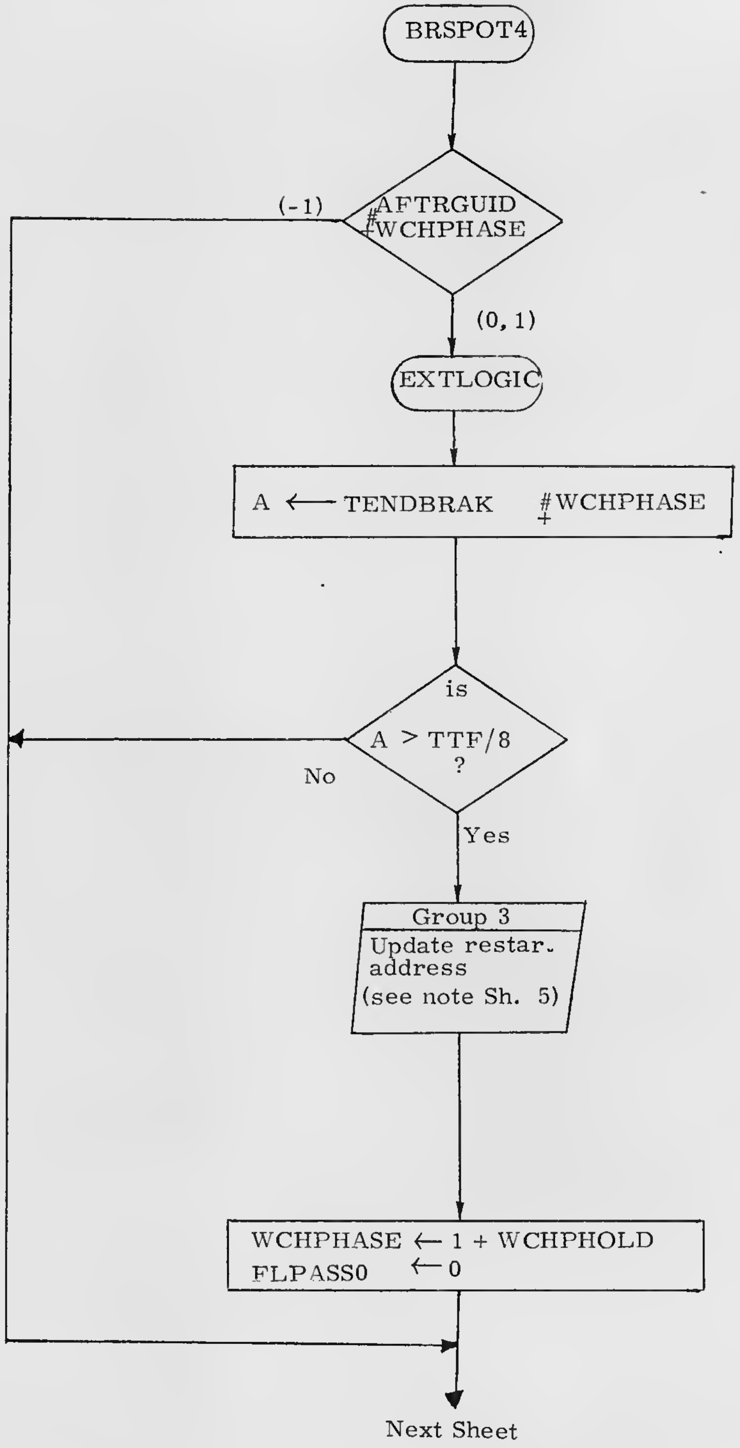
Yes

Next Sheet

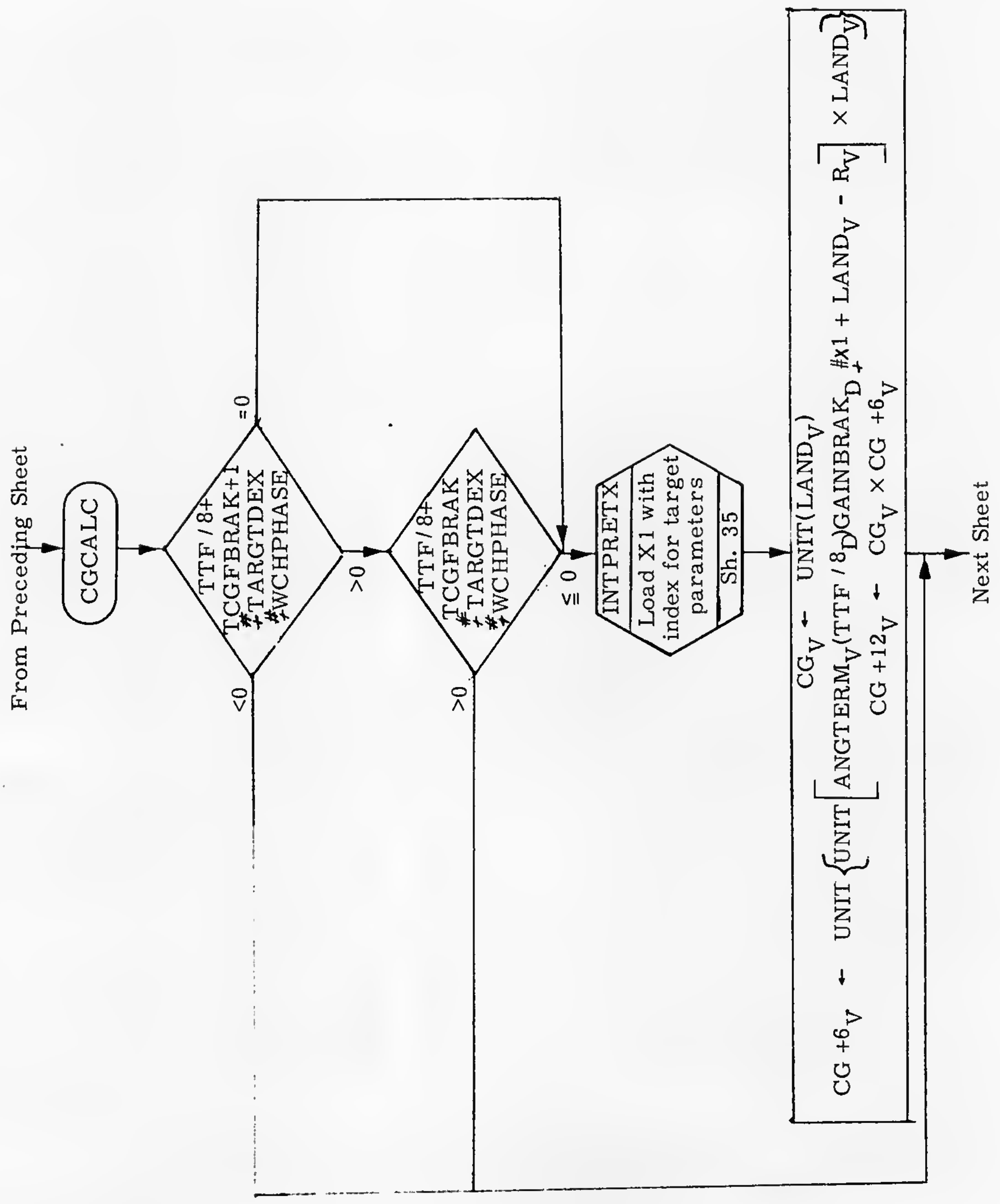
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R Welch	3/5/70	Lunar Landing	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR W Danforth	9/30/69		
APPR'D RM Eaton	11/25/69	REV 2	SHEET 14 OF 52



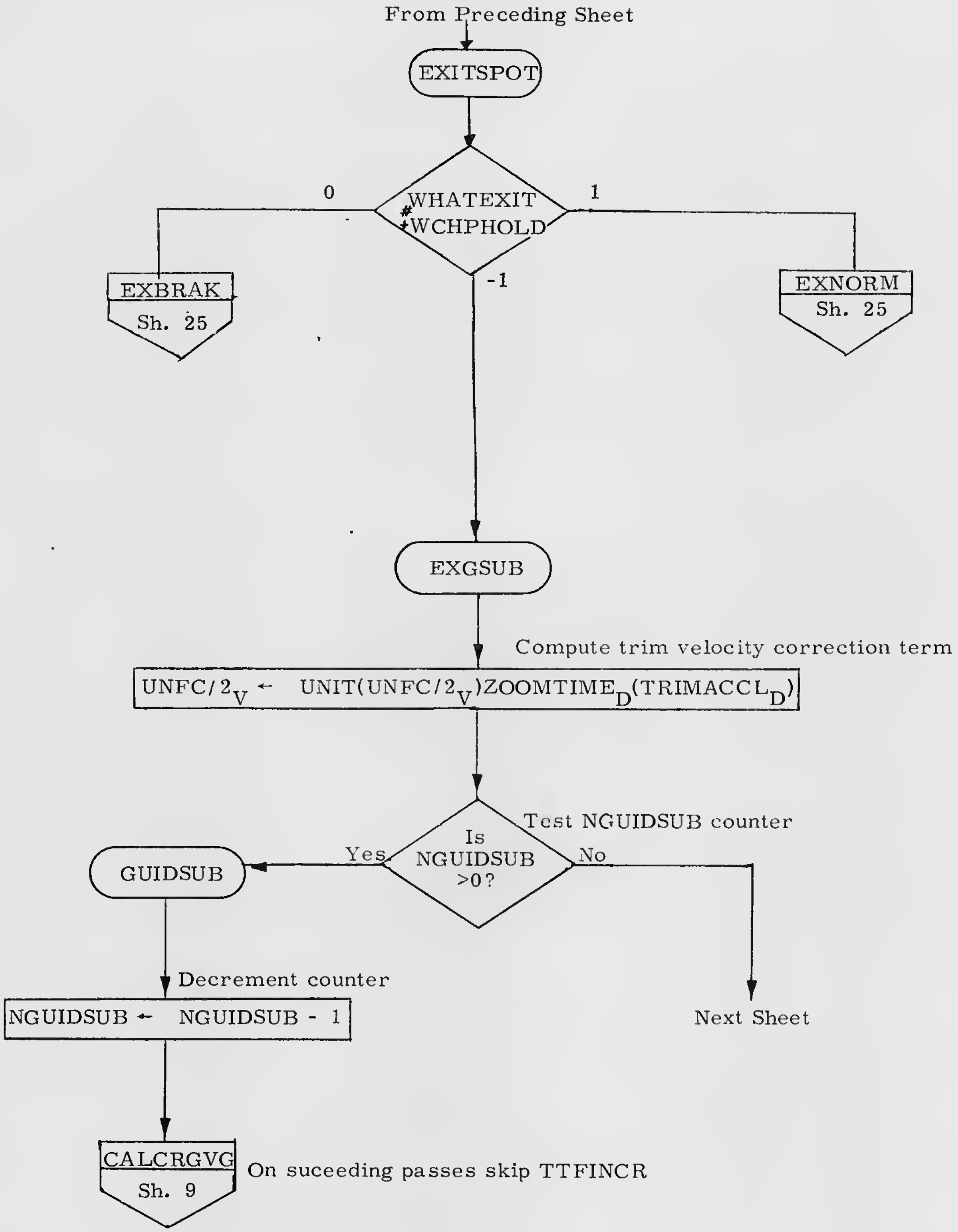
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R Welch	3/5/70	Lunar Landing	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR W Danforth	9/30/69		
APPR'D R M Enter	11/25/69	REV 2	SHEET 15 OF 52



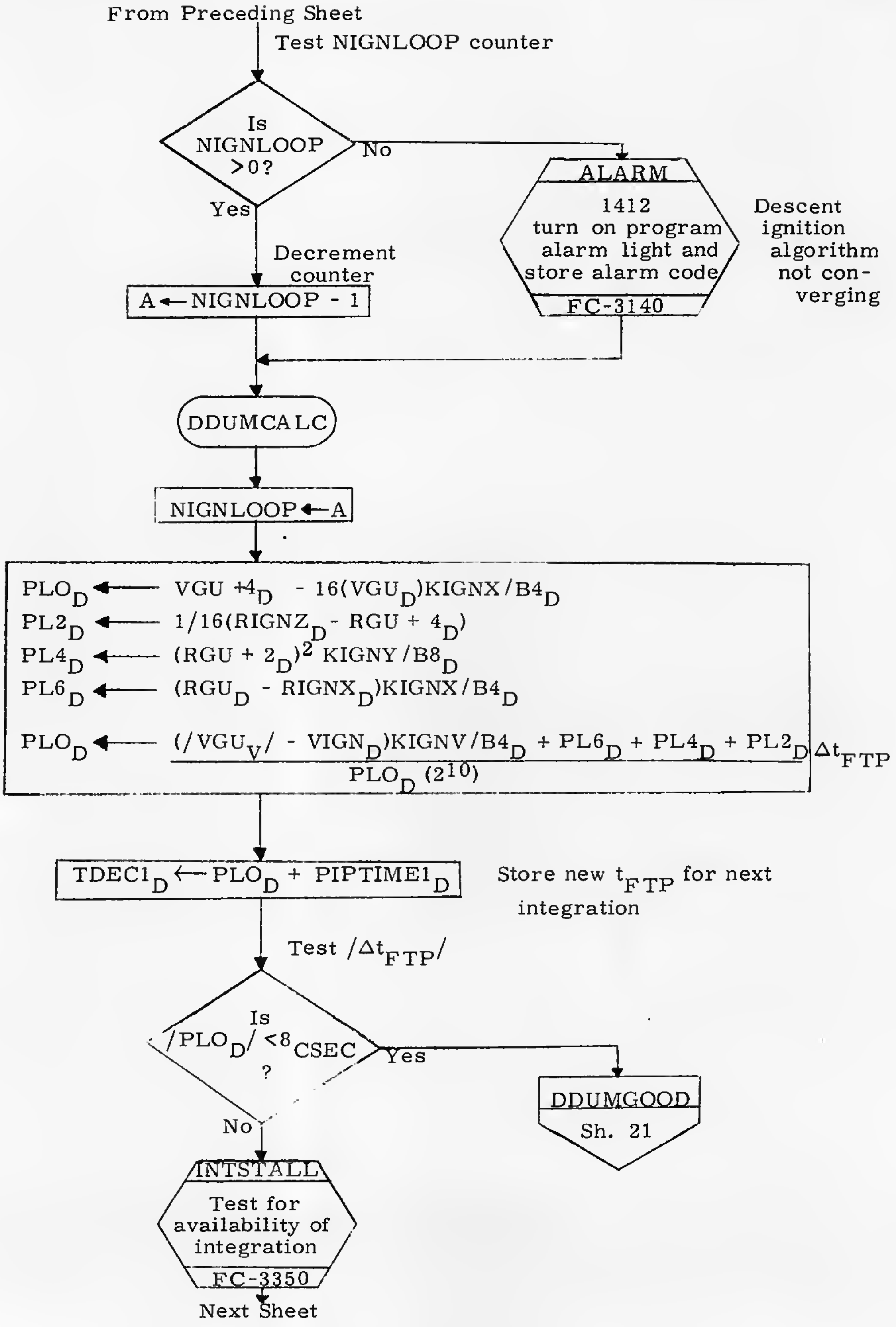
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	K Welch	3/5/70	Lunar Landing	
PRGMR				
ANALST			LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR	W Danforth	9/30/69		
APPR'D	RM Estes	11/25/69	REV 2	SHEET 16 OF 52



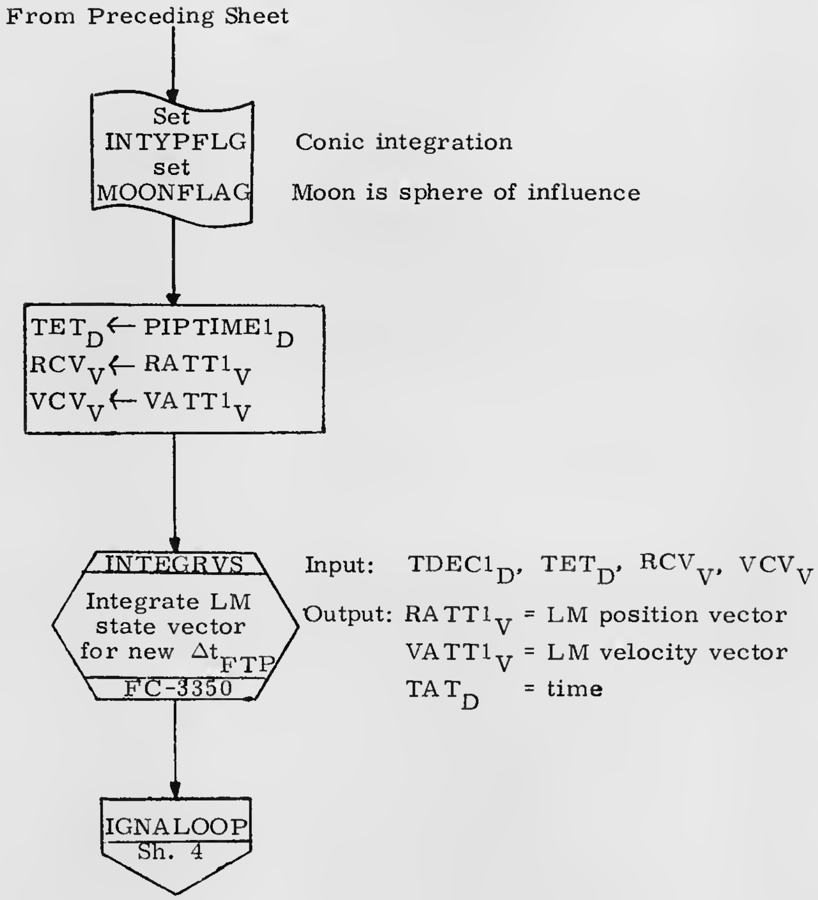
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R Welch	3/5/70	Lunar Landing	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR W Danforth	7/30/69		
APPR'D R M Ents	11/25/67	REV 2	SHEET 17 OF 52



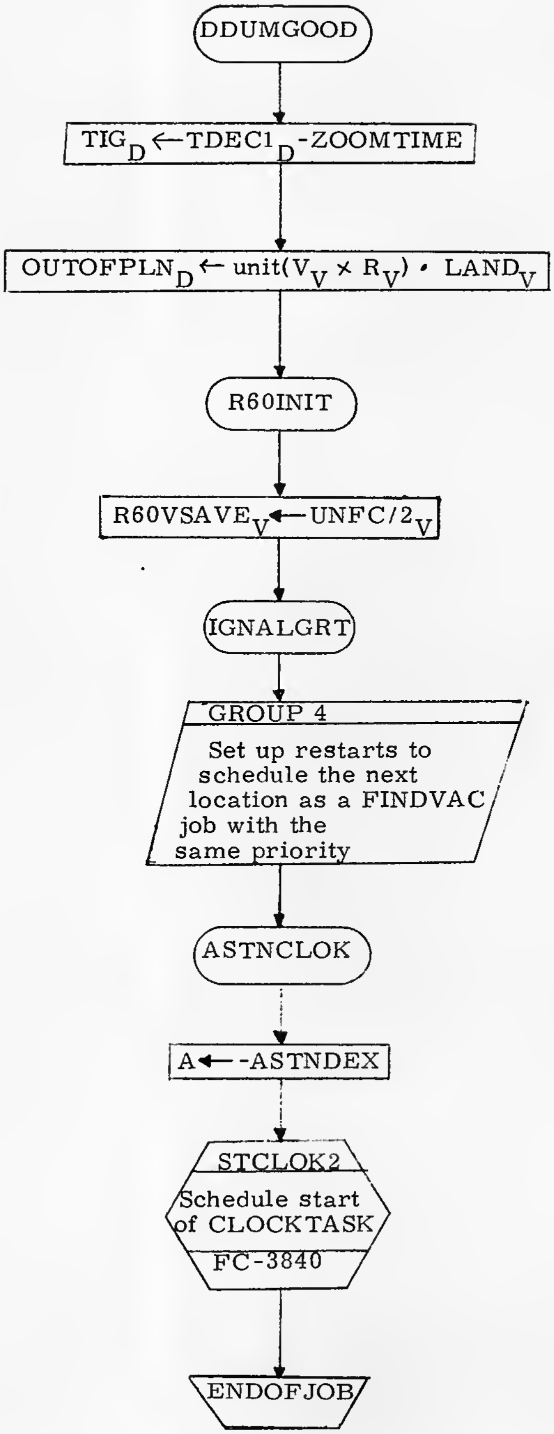
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN K Welch	3/5/70	Lunar Landing	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR W Dogbrith	9/30/69		
APPR'D RMEnt	11/25/69	REV 2	SHEET 18 OF 52



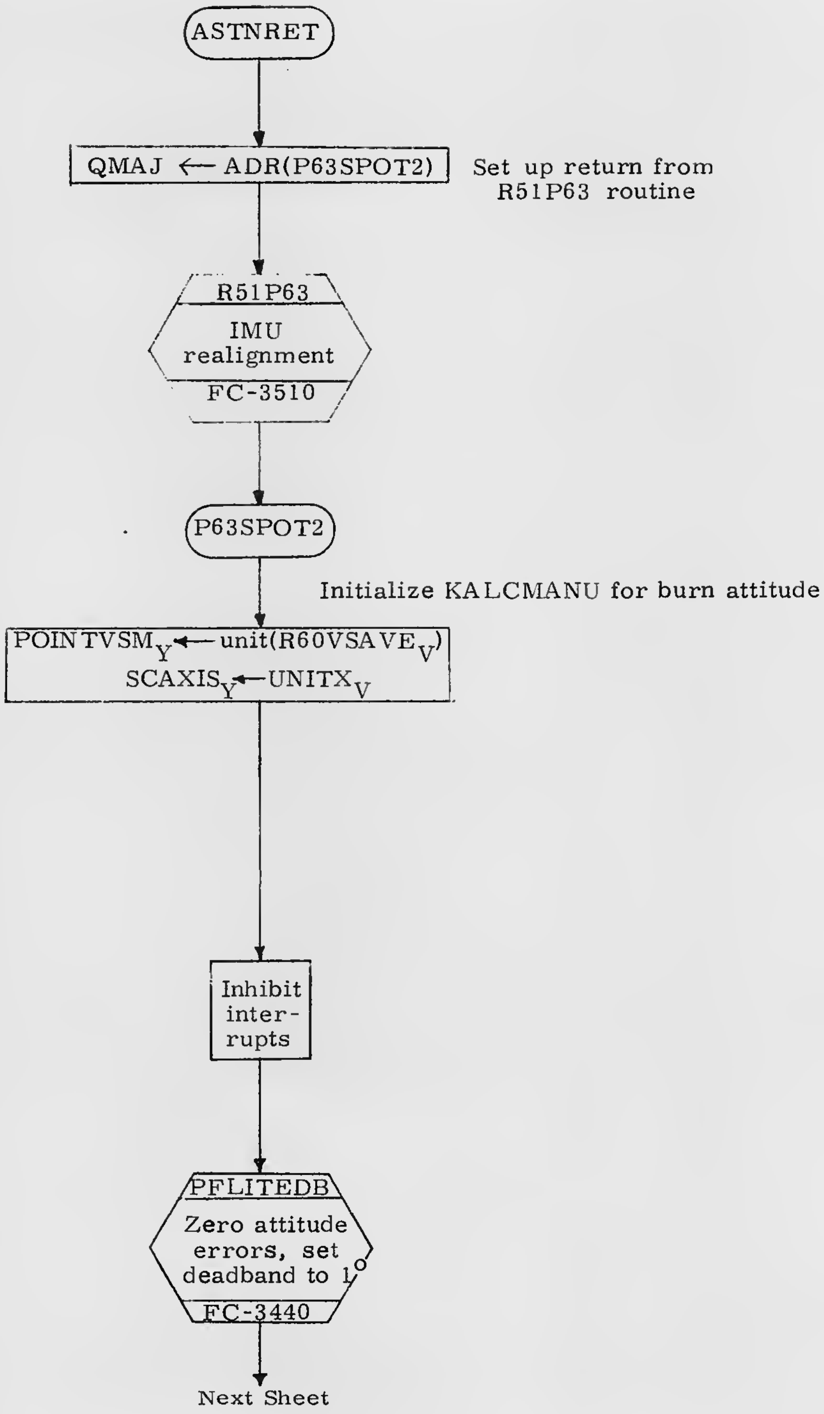
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R Wild	3/5/70	Lunar Landing	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR W Dogbrith	9/30/69		
APPR'D R M Evter	11/25/69	REV 2	SHEET 19 OF 52



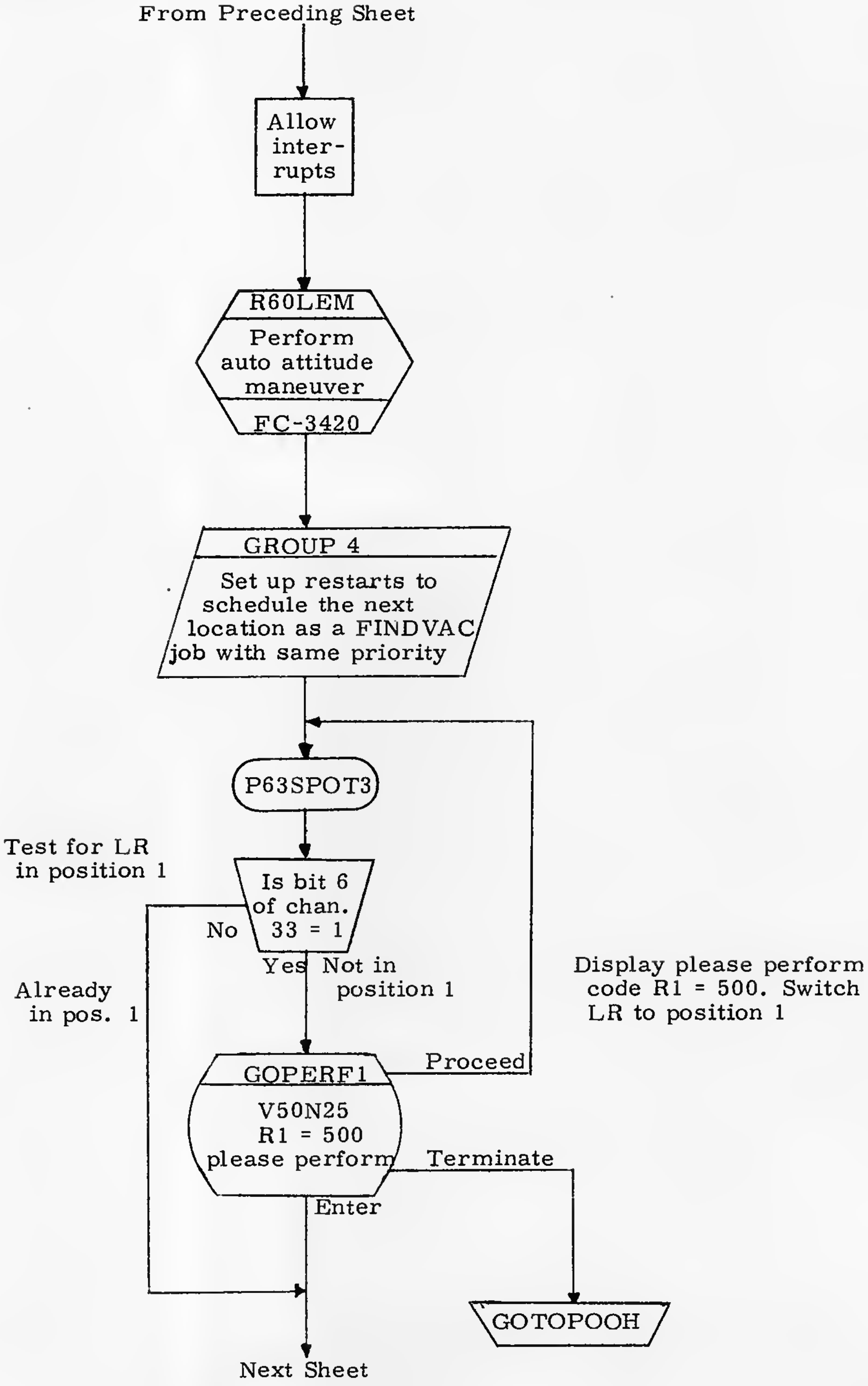
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	R Welch	3/5/70	Lunar Landing	
PRGMR				
ANALST			LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR	W Danforth	9/30/69		
APPR'D	RMEntes	11/25/69	REV 2	SHEET 20 OF 52



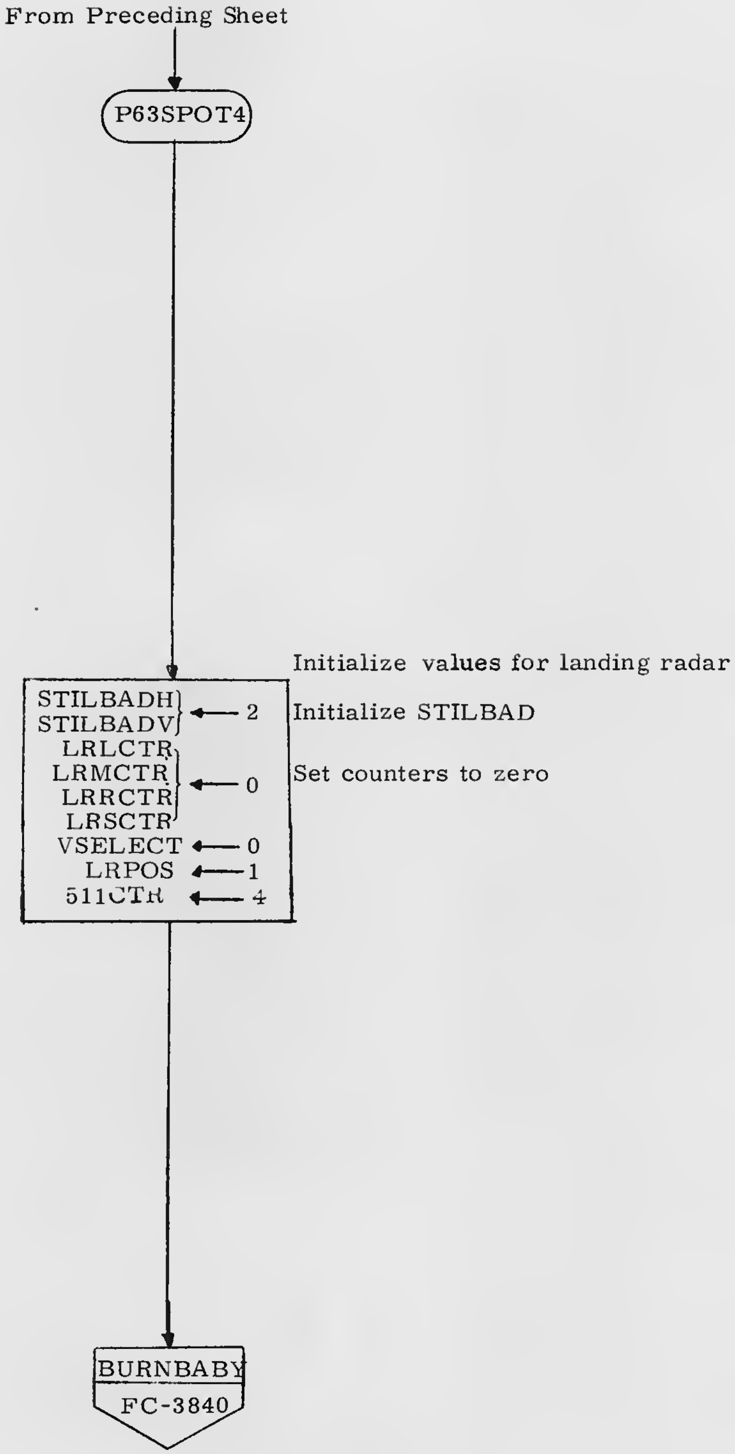
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN RWelch	3/5/70	Lunar Landing	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR	9/30/69		
APPR'D	11/25/69	REV 2	SHEET 21 OF 52



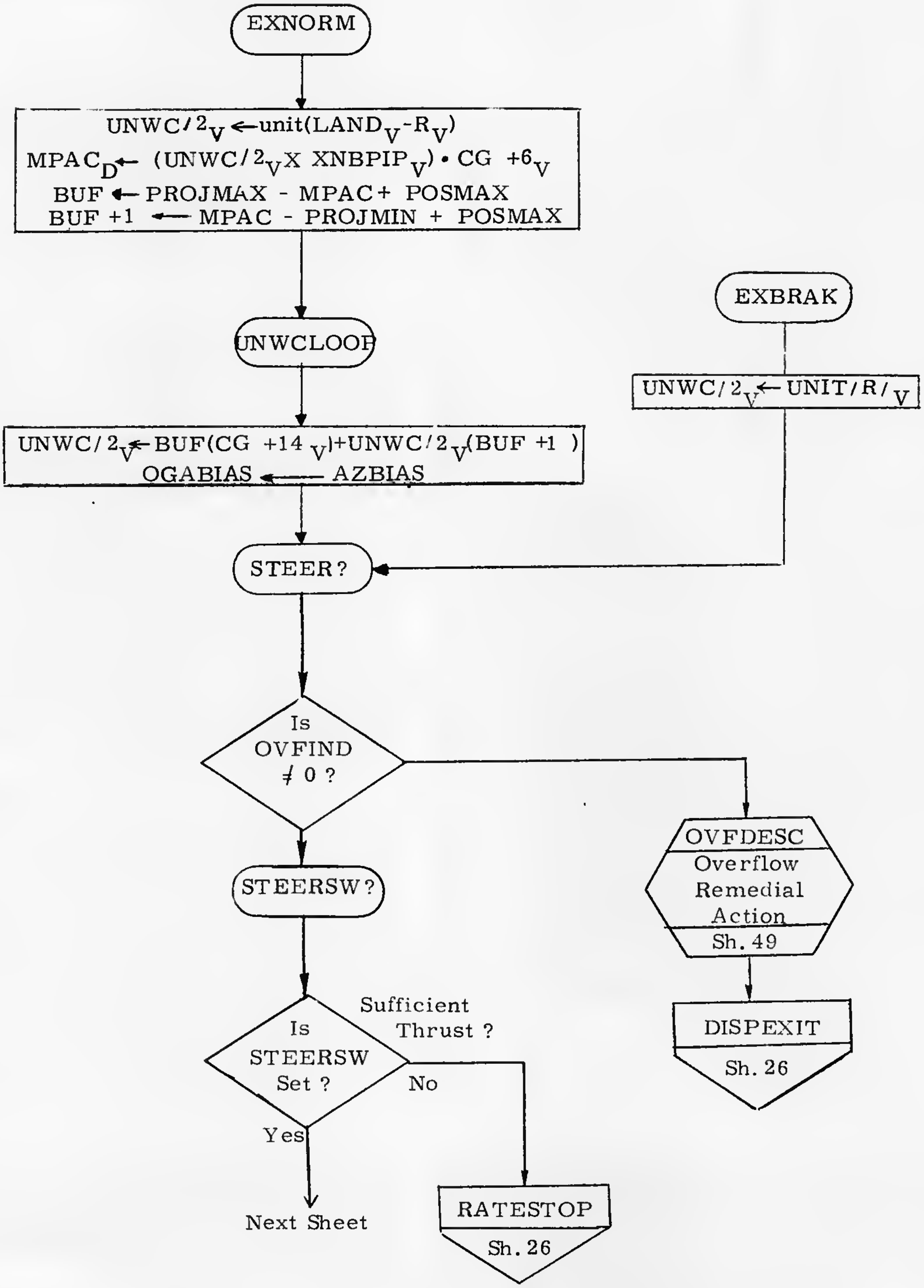
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R Welch	3/5/20	Lunar Landing	
PRGMR		LUMINARY 1D	DOCUMENT NO. FC-3900
ANALST			
DOCMR W Danforth	9/30/69		
APPR'D RMEnter	11/25/69	REV 2	SHEET 22 OF 52



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	R Welch 3/5/70	Lunar Landing	
PRGMR		LUMINARY 1D	DOCUMENT NO. FC-3900
ANALST			
DOCMR	W Dogbritt 9/30/69		
APPR'D	RM Enter 11/25/69	REV 2	SHEET 23 OF 52



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R Welch	3/17/70	Lunar Landing	
PRGMR			
ANALST		LUMINARY 1 D	DOCUMENT NO. FC-3900
DOCMR W Dopbirth	9/30/69		
APPR'D R M Estes	11/25/69	REV 2	SHEET 24 OF 52



MIT INSTRUMENTATION LAB
CAMBRIDGE, MASS.

DRAWN R Welch 3/5/72
PRGMR
ANALST
DOCMR W Dogbrith 9/30/69
APPR'D RM Estes 11/25/69

APOLLO GUIDANCE AND NAVIGATION

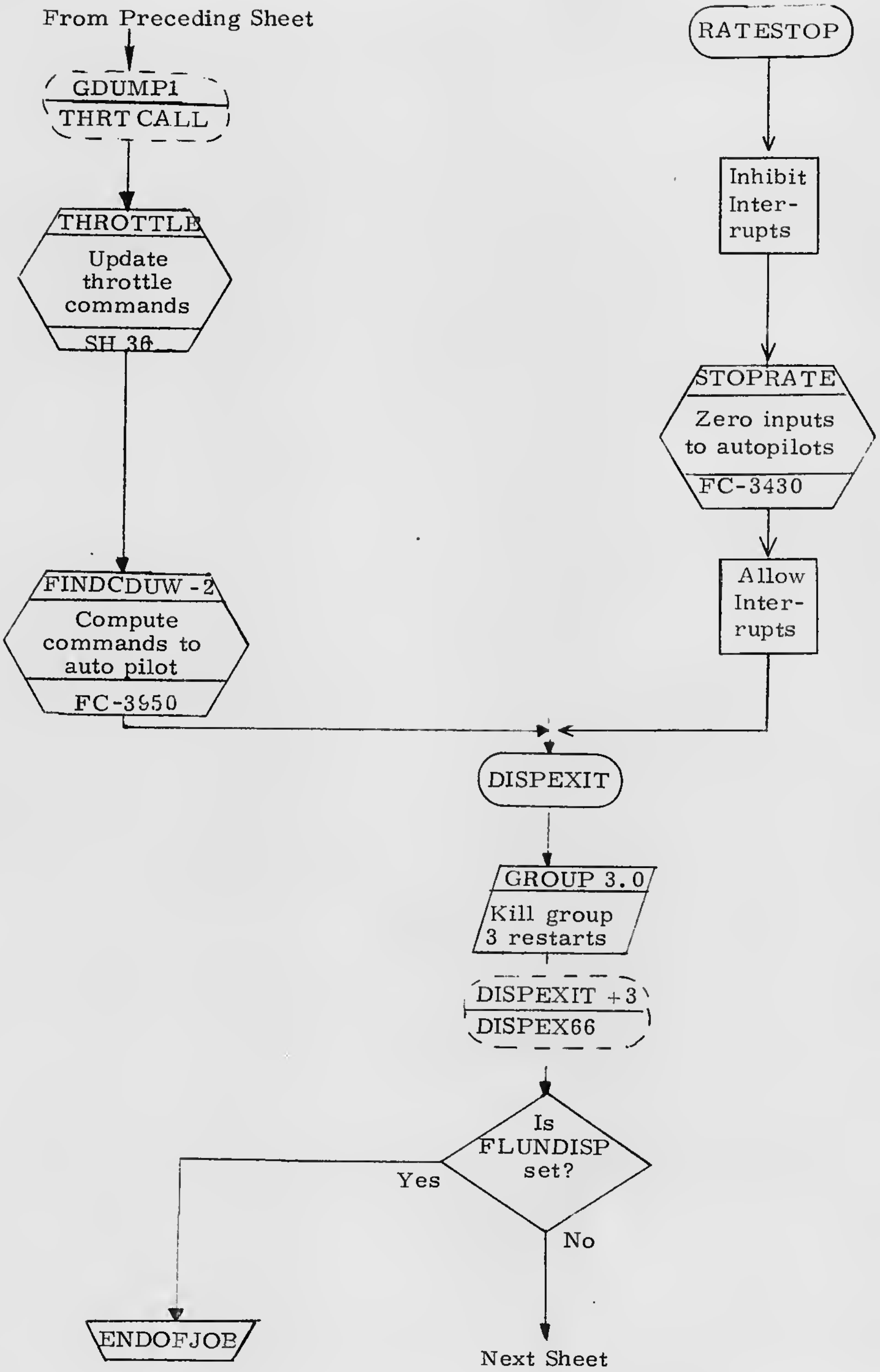
Lunar Landing

LUMINARY 1D

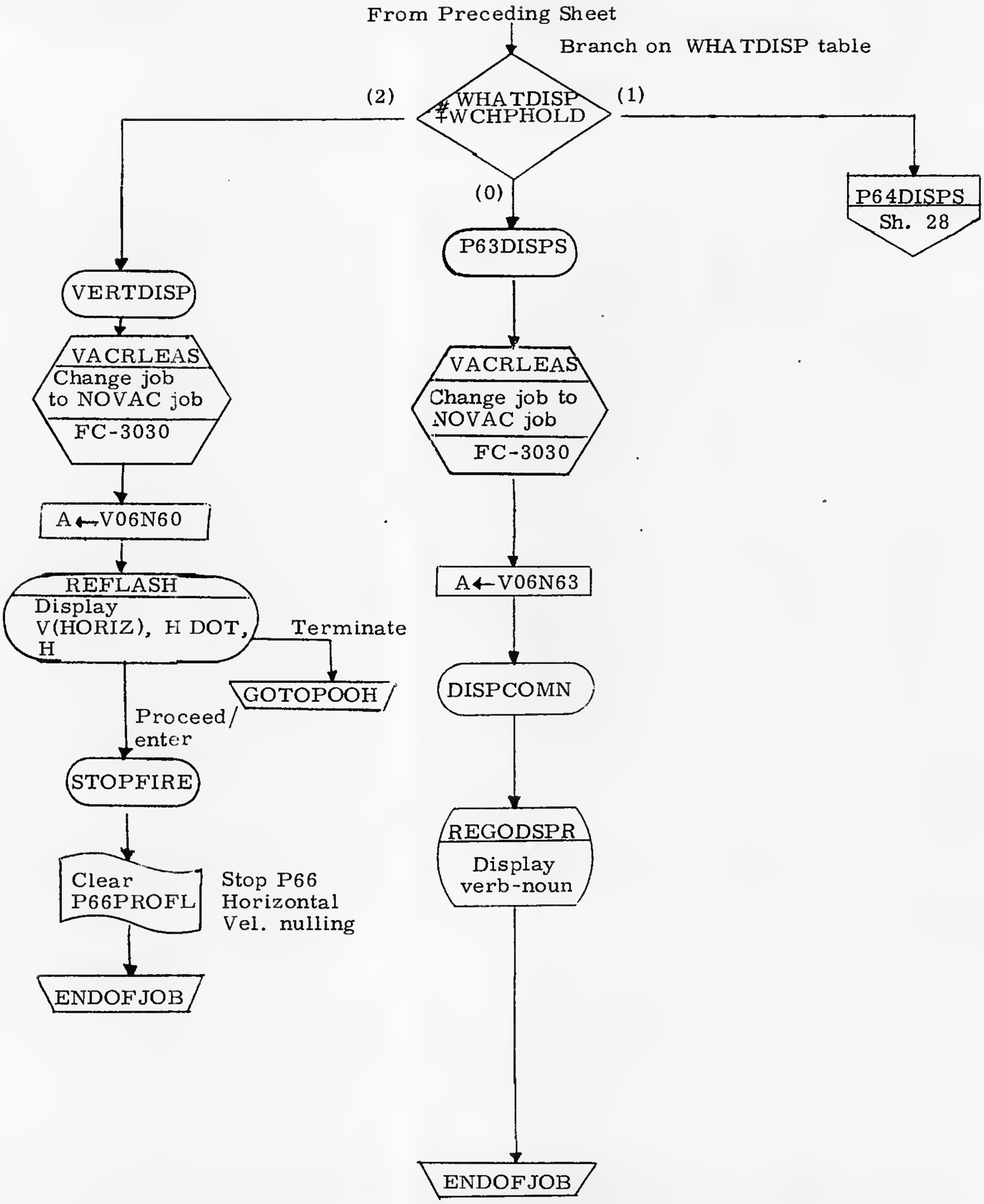
DOCUMENT NO. FC-3900

REV 2

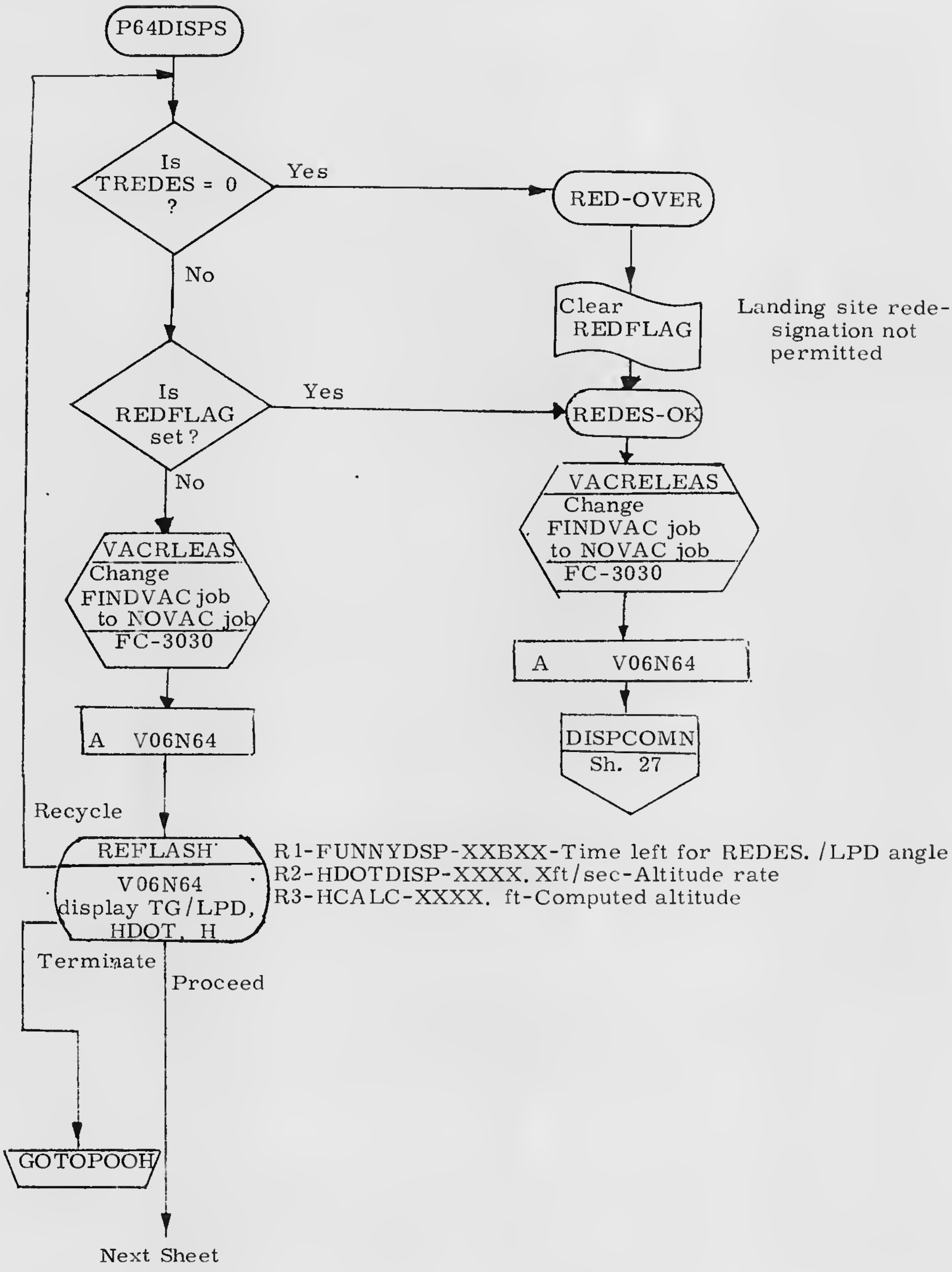
SHEET 25 OF 52



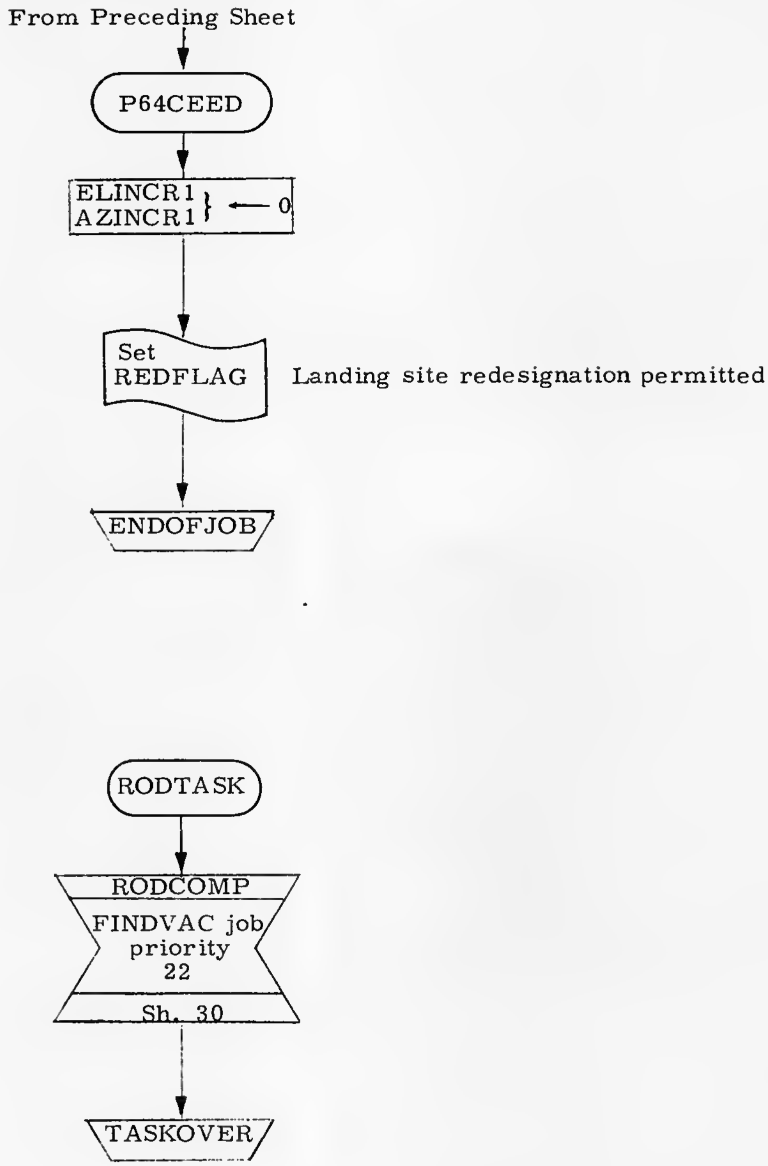
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R Welch	3/5/20	Lunar Landing	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR W Dogbith	9/30/69		
APPR'D R M Eutes	11/25/69	REV 2	SHEET 26 OF 52



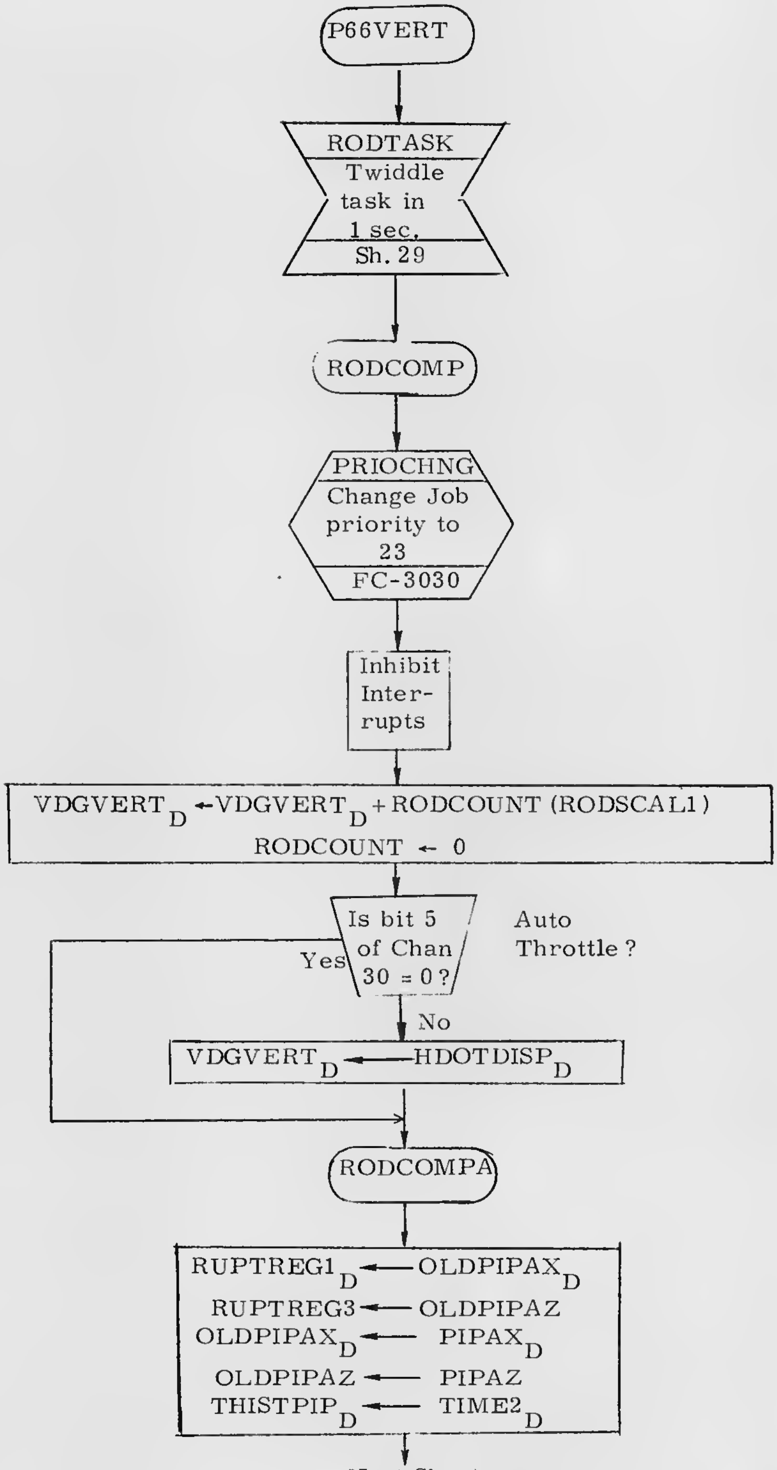
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R Wilck	3/5/70	Lunar Landing	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR W Danforth	9/30/69		
APPR'D R M Eutis	11/25/69	REV 2	SHEET 27 OF 52



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	R Welch	3/15/70	Lunar Landing	
PRGMR				
ANALST			LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR	W Dagforth	9/30/69		
APPR'D	[illegible]	11/25/67	REV 2	SHEET 28 OF 52



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R Welch	3/17/?8	Lunar Landing	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR W Dayforth	9/30/69		
APPR'D R M Easter	11/25/69	REV 2	SHEET 29 OF 52



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Wild	3/5/70	Lunar Landing	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR W Danforth	3/13/70		
APPR'D RM Estes	3/25/70	REV 2	SHEET 30 OF 52

DEIMUBOB
COMPUTE ΔV SINCE PIPTIME
SH35

MPAC $\leftarrow$ OLDPIPAX + PIPATMPX
MPAC +1 $\leftarrow$ 0
MPAC +3 $\leftarrow$ OLDPIPAY + PIPATMPY
MPAC +4 $\leftarrow$ 0
MPAC +5 $\leftarrow$ OLDPIPAZ + PIPATMPZ
MPAC +6 $\leftarrow$ 0

DELVROD $\leftarrow$ TEMX + RUPTREG1 - OLDPIPAX
DELVROD +2 $\leftarrow$ TEMY + RUPTREG2 - OLDPIPAY
DELVROD +4 $\leftarrow$ TEMZ + RUPTREG3 - OLDPIPAZ

TEMX $\leftarrow$ 0
TEMY $\leftarrow$ 0
TEMZ $\leftarrow$ 0

ITRPNT1

$PL0_V \leftarrow MPAC_V(KPIP1_D)$

$PL30_D \leftarrow THISTPIP_D - PIPTIME_D$ — Time since PIPTIME

$$PL6_D \leftarrow \frac{PL30_D}{4SEC(28)}$$

$PL24_V \leftarrow PL0_V + (GPT/2_V - VBIAS_V)PL6_D + V_V$ — Updated velocity

$PL14_V \leftarrow UNIT(R_V)$

$HDOTDISP_D \leftarrow PL14_V \cdot PL24_V$

$HCALC1_D \leftarrow PL30_D(HDOTDISP_D) + |R_V| - |LAND|_D$

$$PL0_V \leftarrow \frac{VDGVERT_D - HDOTDISP_D}{TAUROD_D}$$

$$PL20_D \leftarrow \frac{|GDT/2_V|}{GSCALE_D}$$

$PL0_D \leftarrow PL0_D + PL20_D$

$MPAC_V \leftarrow UNITX_V$

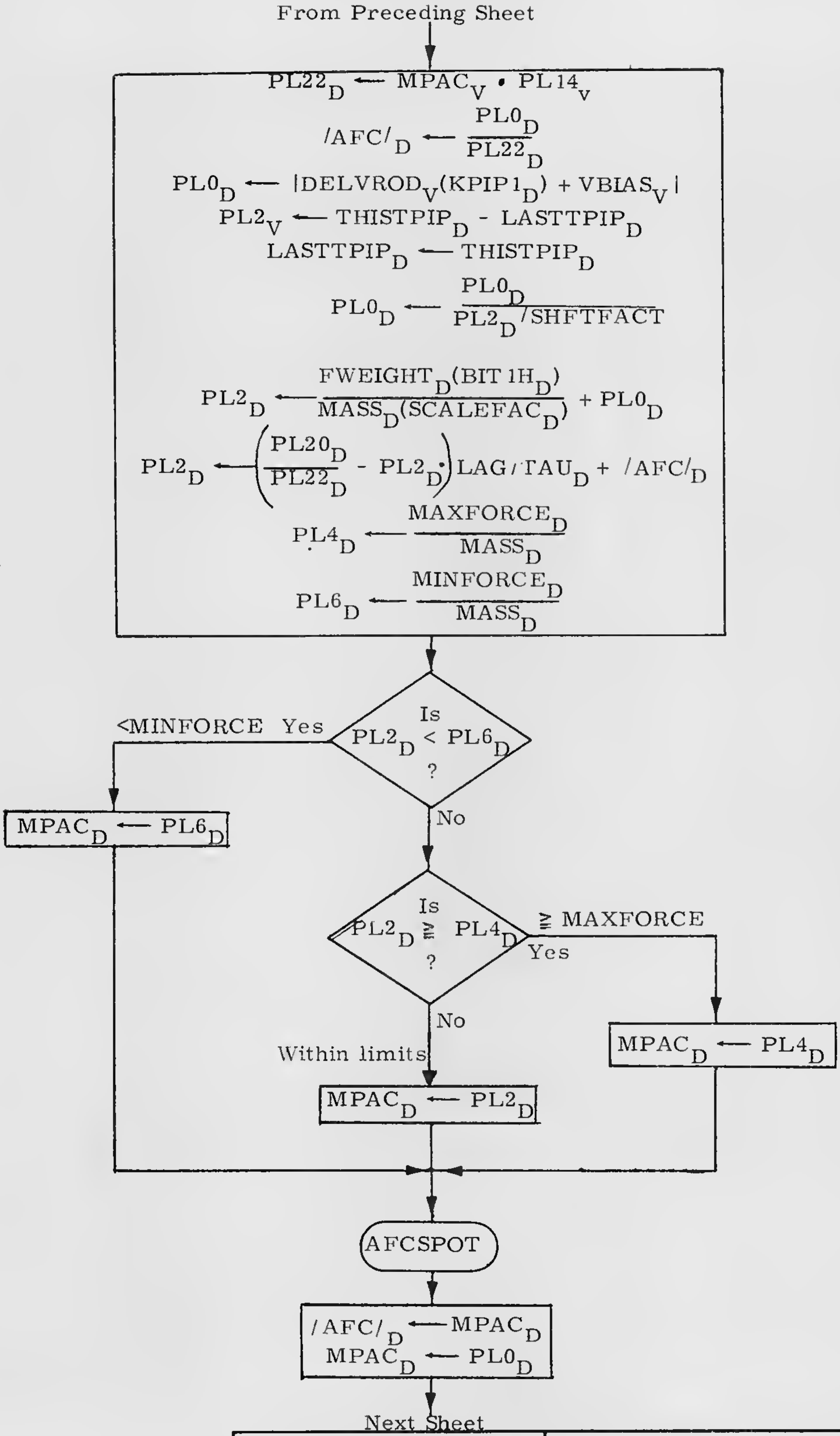
NBSM
Transform input vector from NB to SM coord.
FC-3320

Input: $MPAC_V$ = input vector in NB coordinates

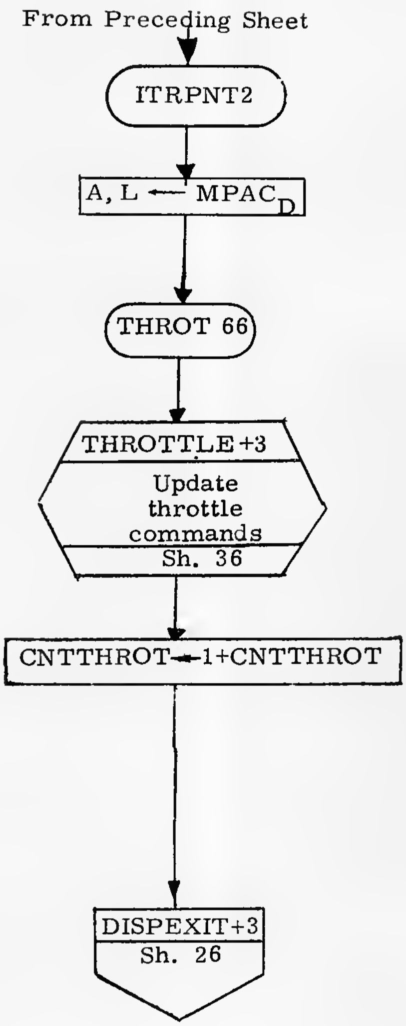
Output: $MPAC_V$ = transformed vector in SM coordinates

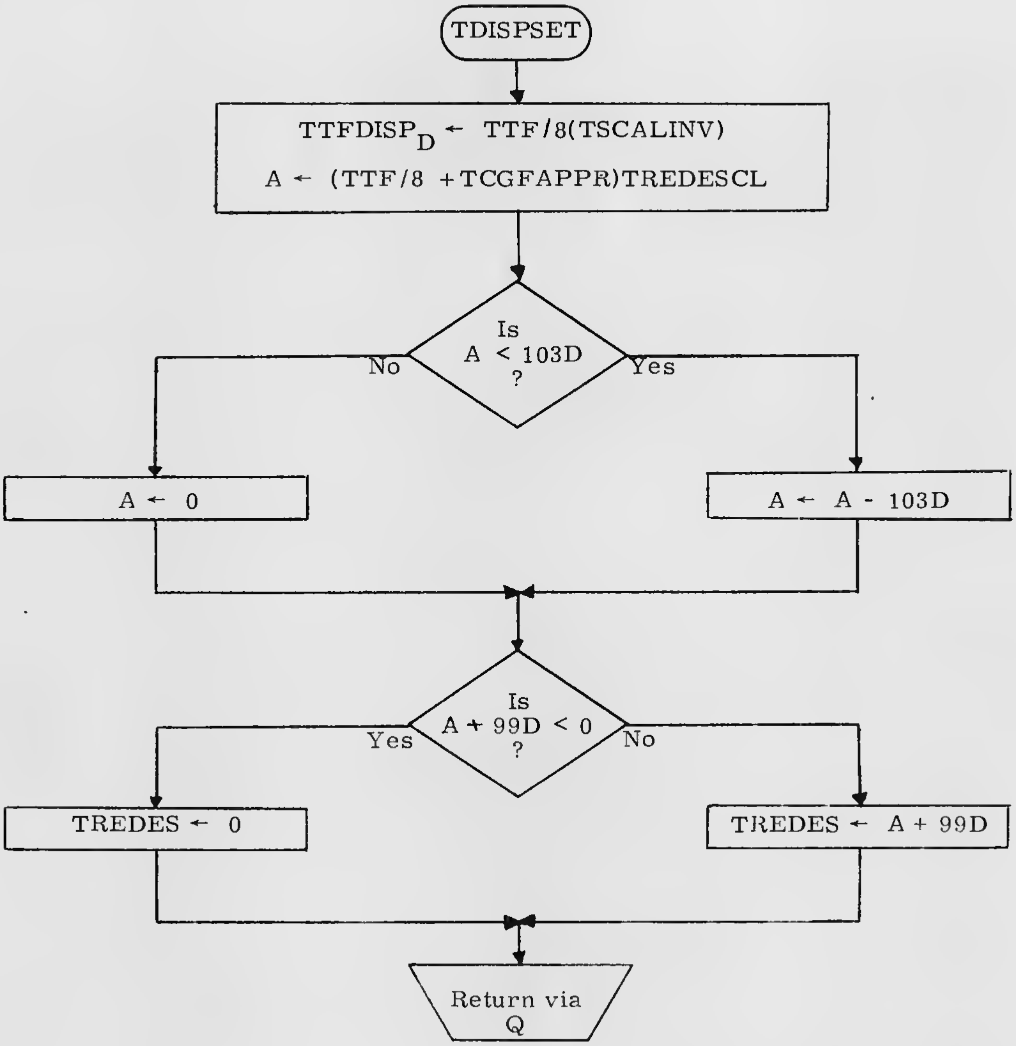
Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R Welch	3/5/70	Lunar Landing	
PRGMR		LUMINARY 1D	DOCUMENT NO. FC-3900
ANALST			
DOCMR W Dybuth	8/30/69		
APPR'D RM Eaton	11/25/69	REV 2	SHEET 31 OF 52

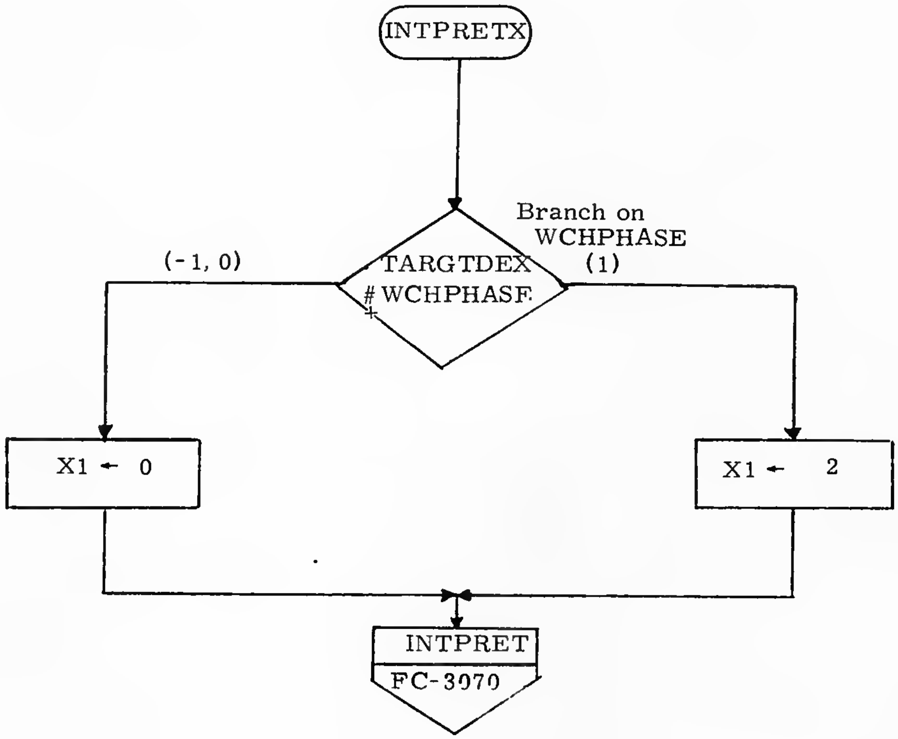


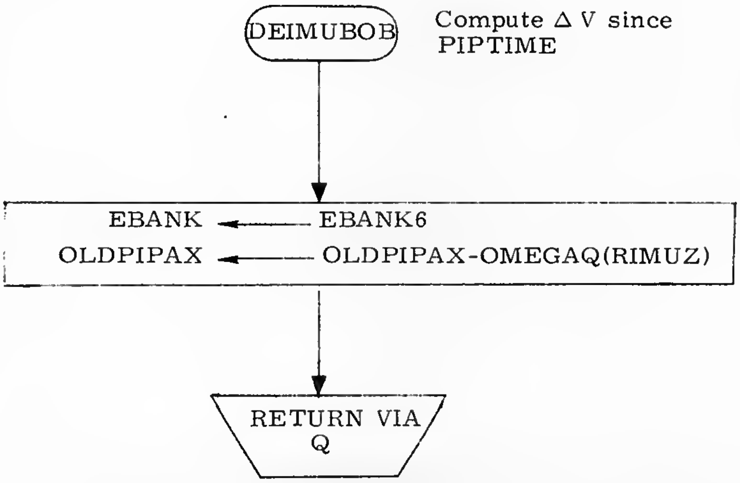
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R Welch	3/5/70	Lunar Landing	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR W Dogbrith	9/30/69		
APPR'D RM Entes	11/25/69	REV 2	SHEET 32 OF 52


From Preceding Sheet
ITRPNT2
A, L ← MPAC$_D$
THROT 66
THROTTLE +3
Update throttle commands
Sh. 36
CNTTHROT ← 1+CNTTHROT
DISPEXIT+3
Sh. 26

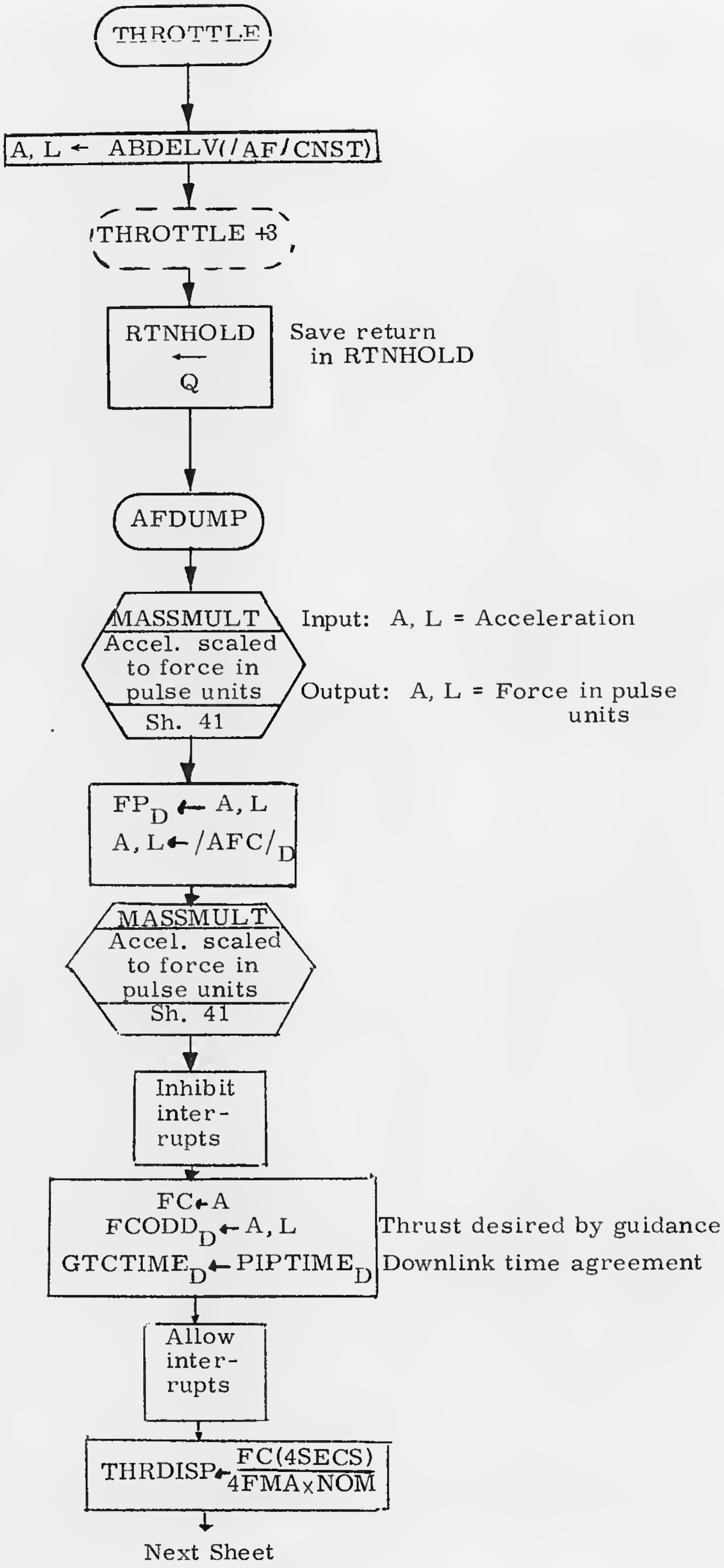


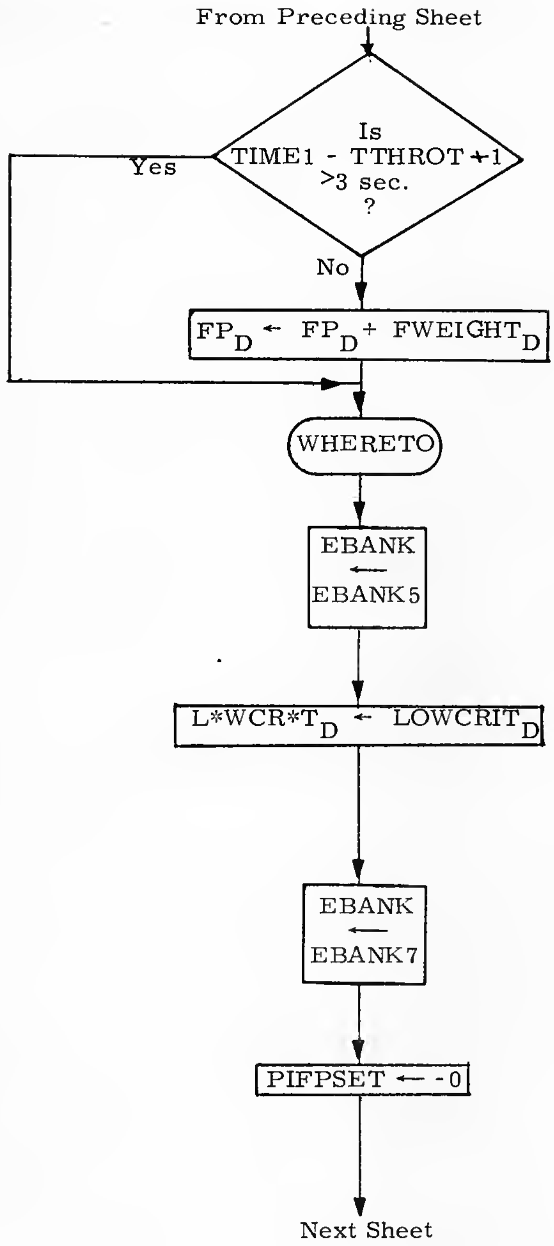
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R Welch	3/5/70	Lunar Landing	
PRGMR			
ANALST		LUMINARY 1 D	DOCUMENT NO. FC-3900
DOCMR W Dugforth	9/30/69		
APPR'D RM Evtas	11/25/69	REV 2	SHEET 34 OF 52

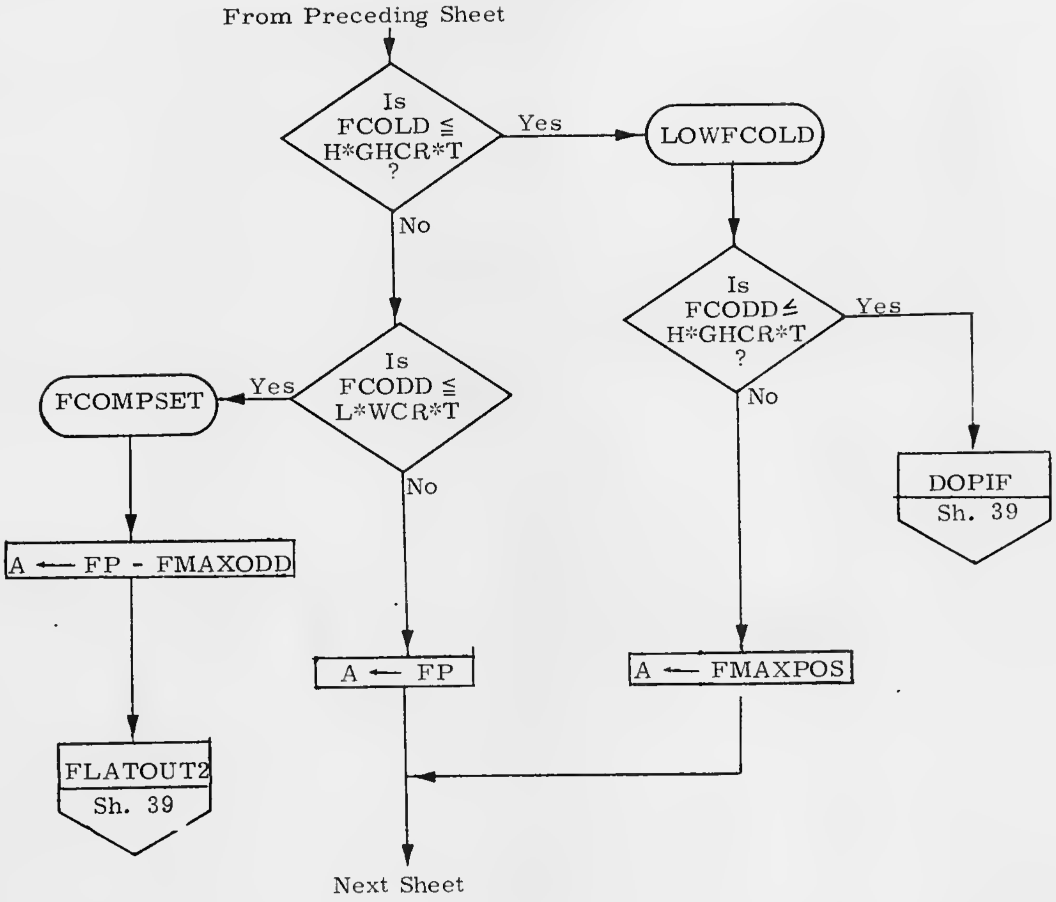




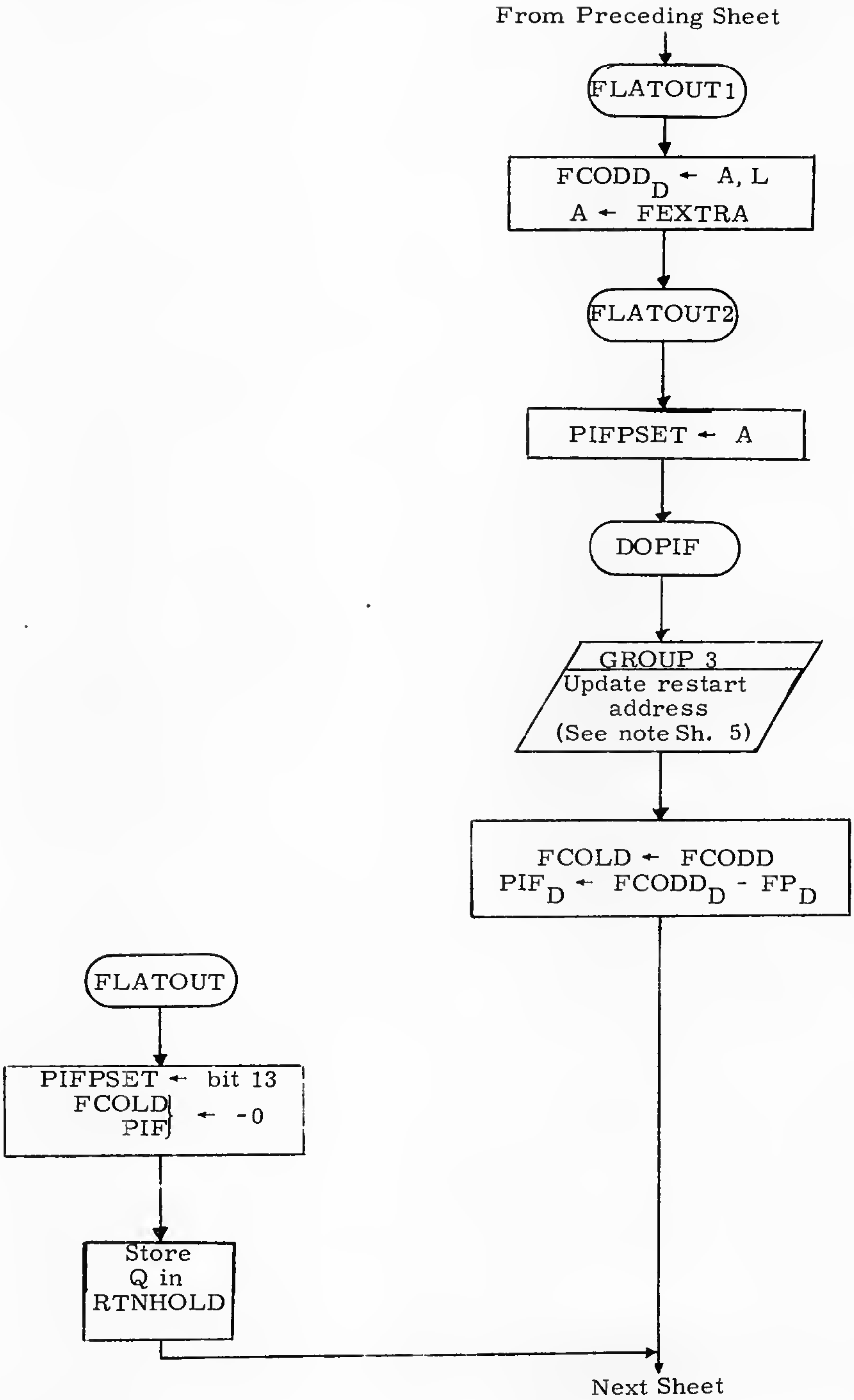
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	R Welch 3/5/70	Lunar Landing	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3000
DOCMR	W Dayhoff 9/30/69		
APPR'D	R M Eastes 11/25/69	REV 2	SHEET 35 OF 52


THROTTLE
A, L ← ABDELV(/AF/CNST)
THROTTLE +3
RTNHOLD ← Q
Save return in RTNHOLD
AFDUMP
MASSMULT
Accel. scaled to force in pulse units
Sh. 41
Input: A, L = Acceleration
Output: A, L = Force in pulse units
FP_D ← A, L
A, L ← $/AFC/_D$
MASSMULT
Accel. scaled to force in pulse units
Sh. 41
Inhibit inter-rupts
FC ← A
$FCODD_D$ ← A, L
$GTCTIME_D$ ← $PIPTIME_D$
Thrust desired by guidance
Downlink time agreement
Allow inter-rupts
THRDISP ← $\frac{FC(4SECS)}{4FMAx NOM}$
Next Sheet

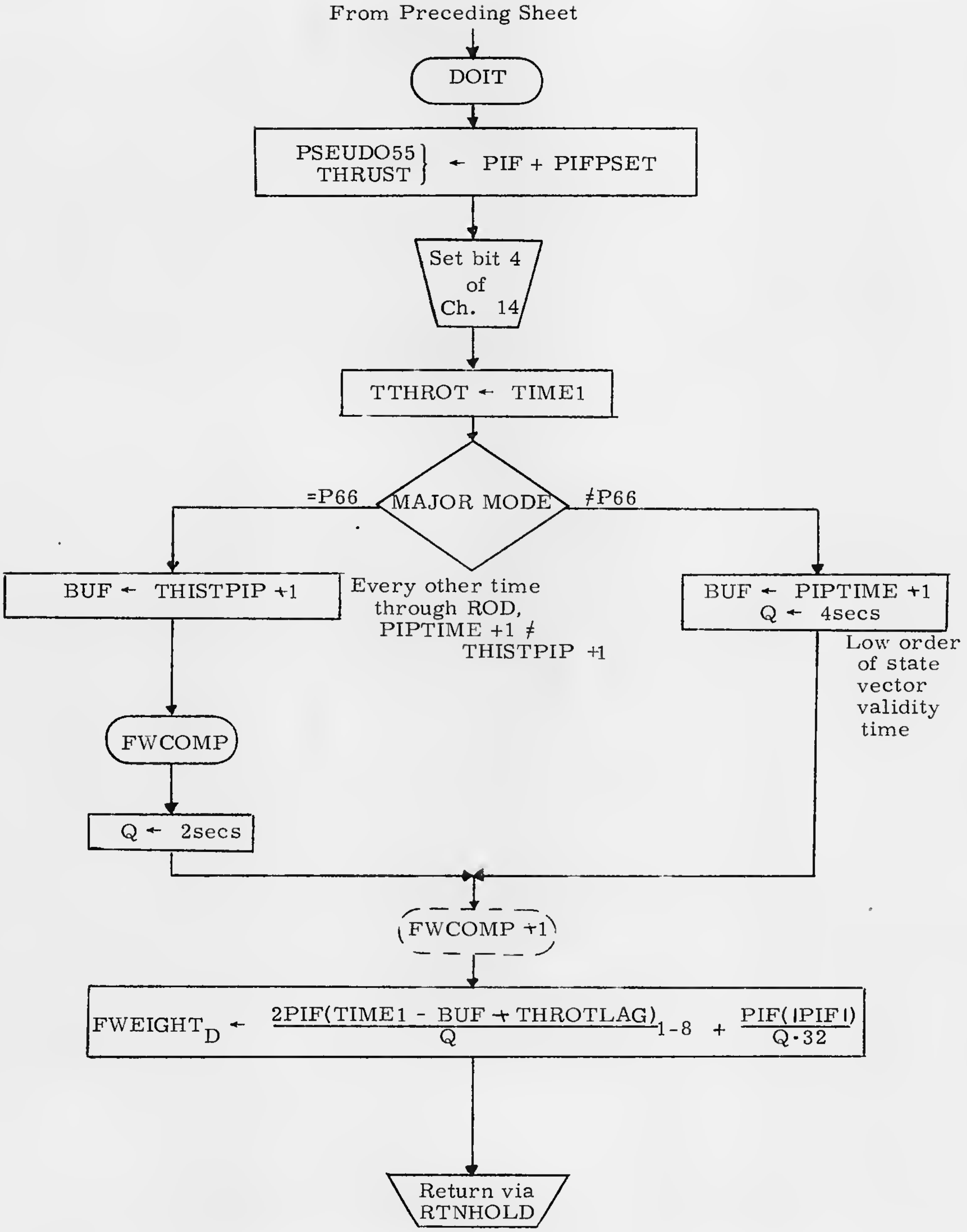

From Preceding Sheet
Is TIME1 - TTHROT +1 >3 sec. ?
Yes
No
$FP_D \leftarrow FP_D + FWEIGHT_D$
WHERETO
EBANK ← EBANK5
$L*WCR*T_D \leftarrow LOWCRIT_D$
EBANK ← EBANK7
PIFPSET ← -0
Next Sheet



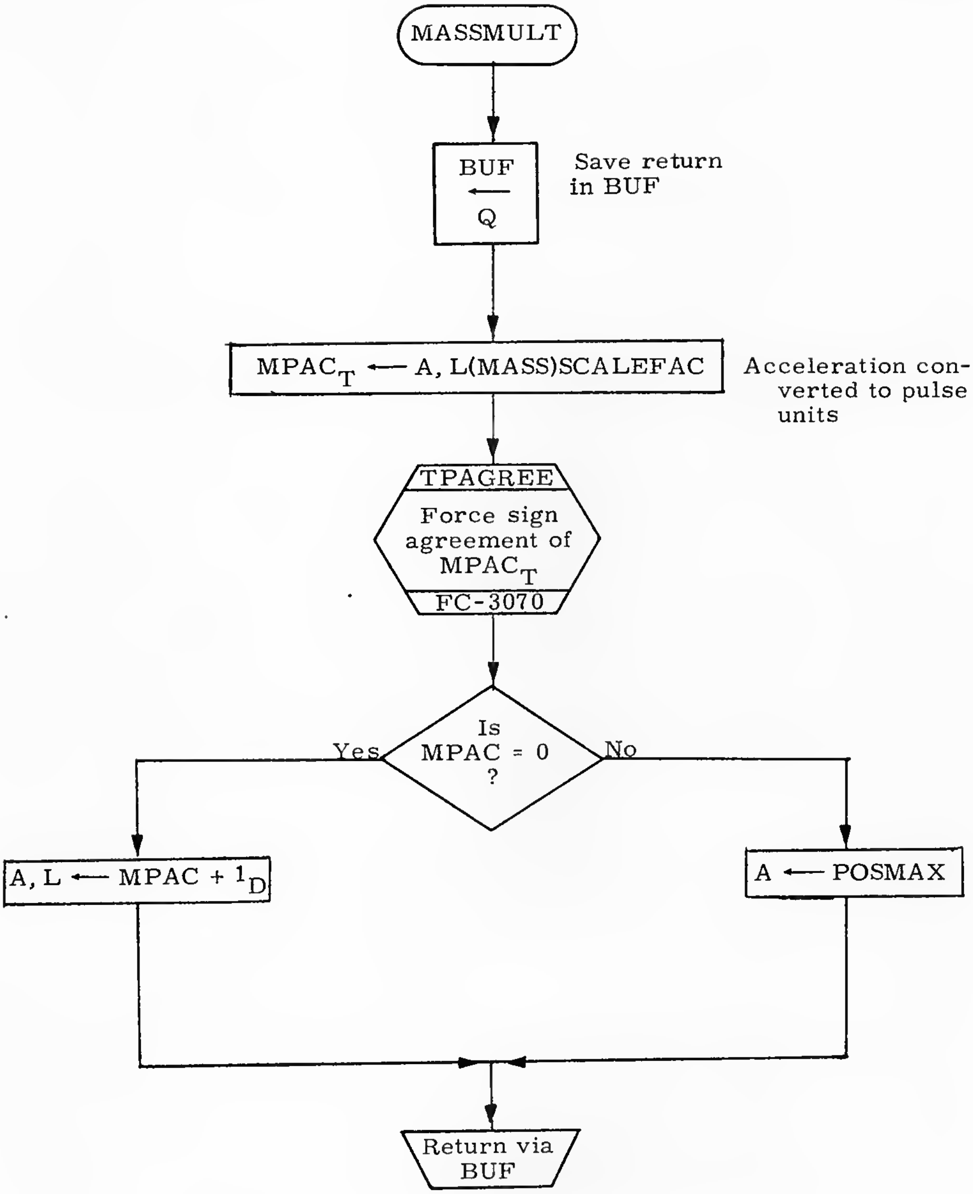
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R Welch	3/5/70	Lunar Landing	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR W Dogbeck	9/30/69		
APPR'D R M Easton	11/25/69	REV 2	SHEET 38 OF 52



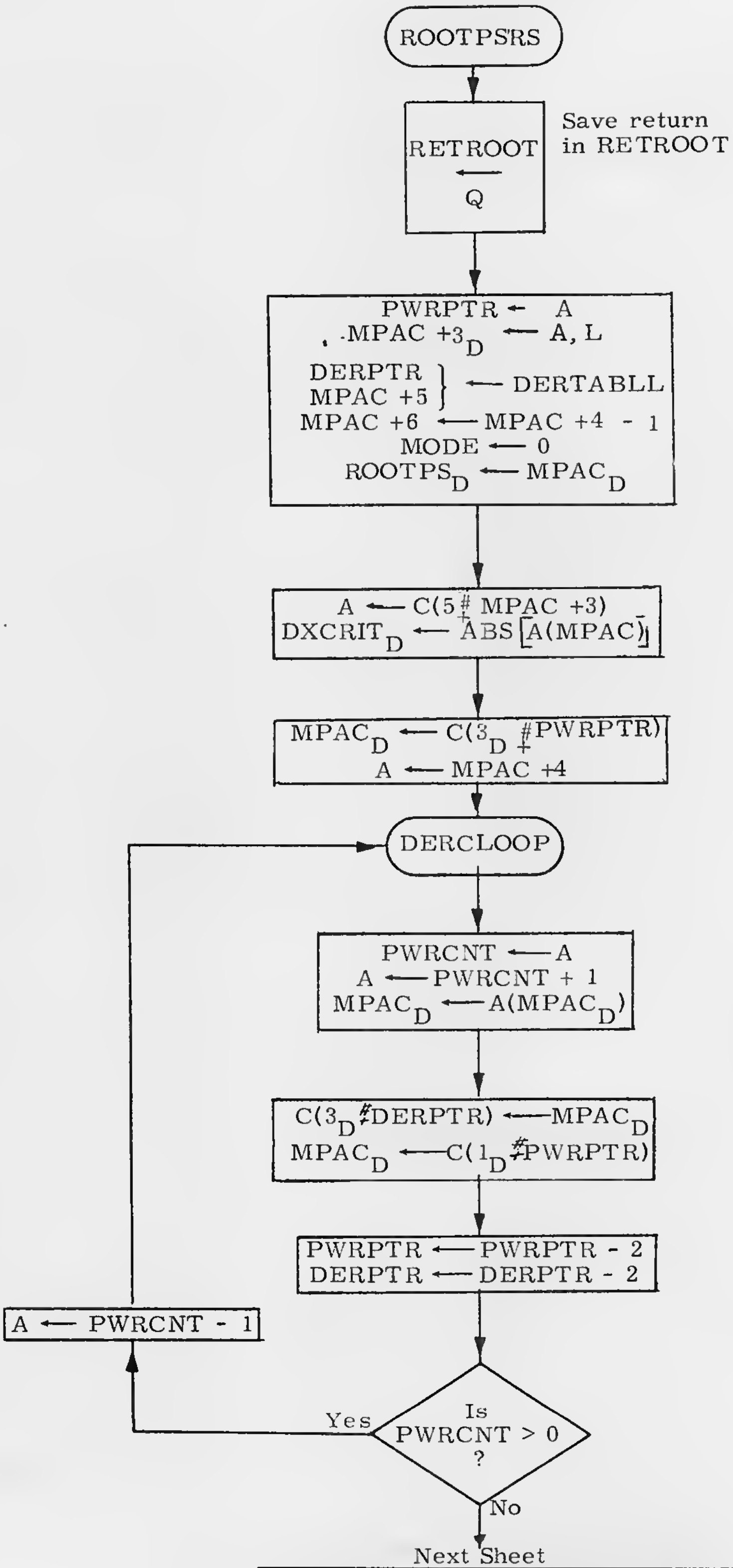
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R Wild	3/5/70	Lunar Landing	
PRGMR		LUMINARY 1D	DOCUMENT NO. FC-3900
ANALST			
DOCMR W Dogbrtd	7/30/69		
APPR'D RMEntex	11/25/69	REV 2	SHEET 39 OF 52



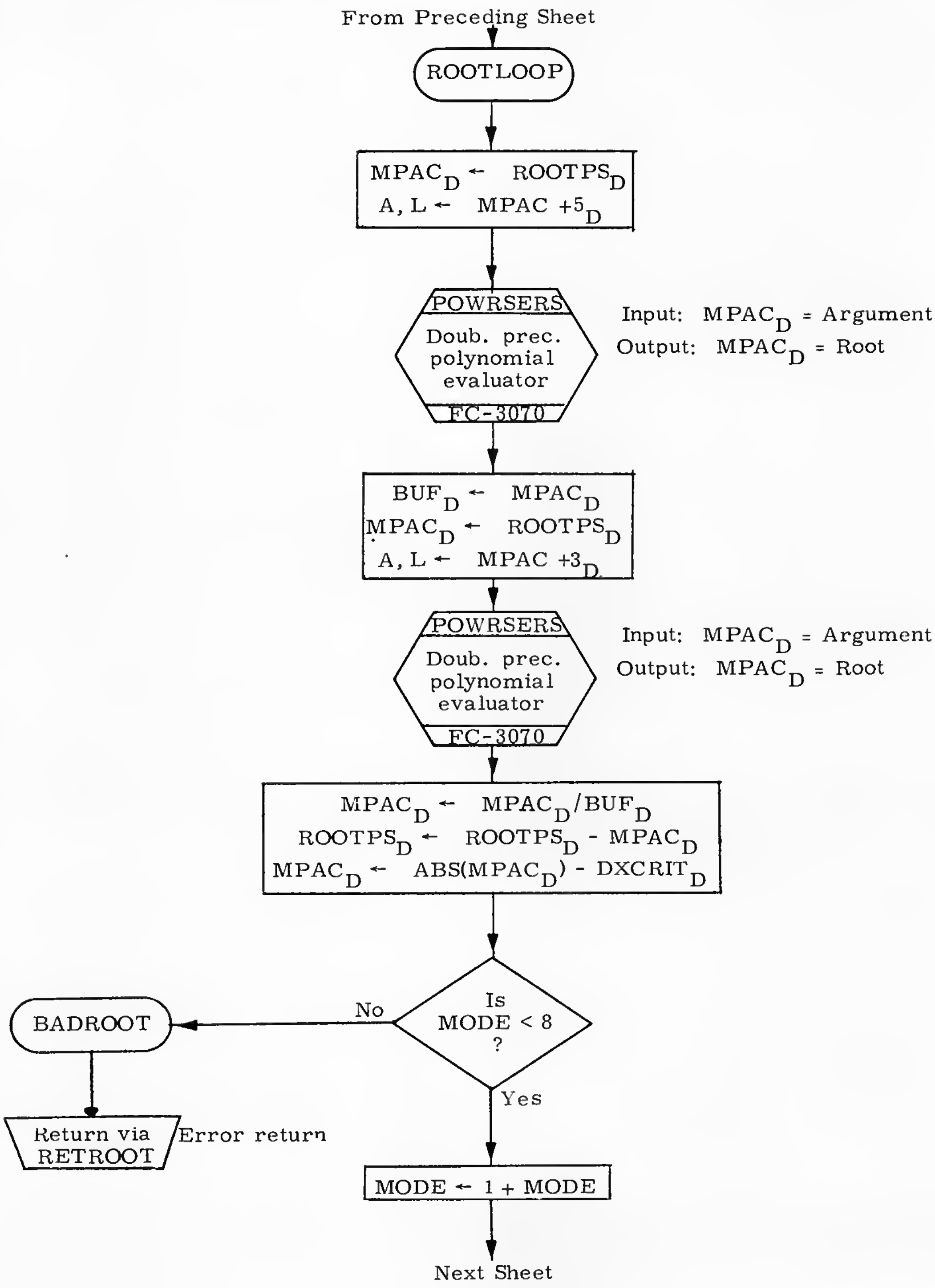
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R Welch	3/5/70	Lunar Landing	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR W Danforth	9/30/69		
APPR'D RM Entas	11/25/69	REV 2	SHEET 40 OF 52



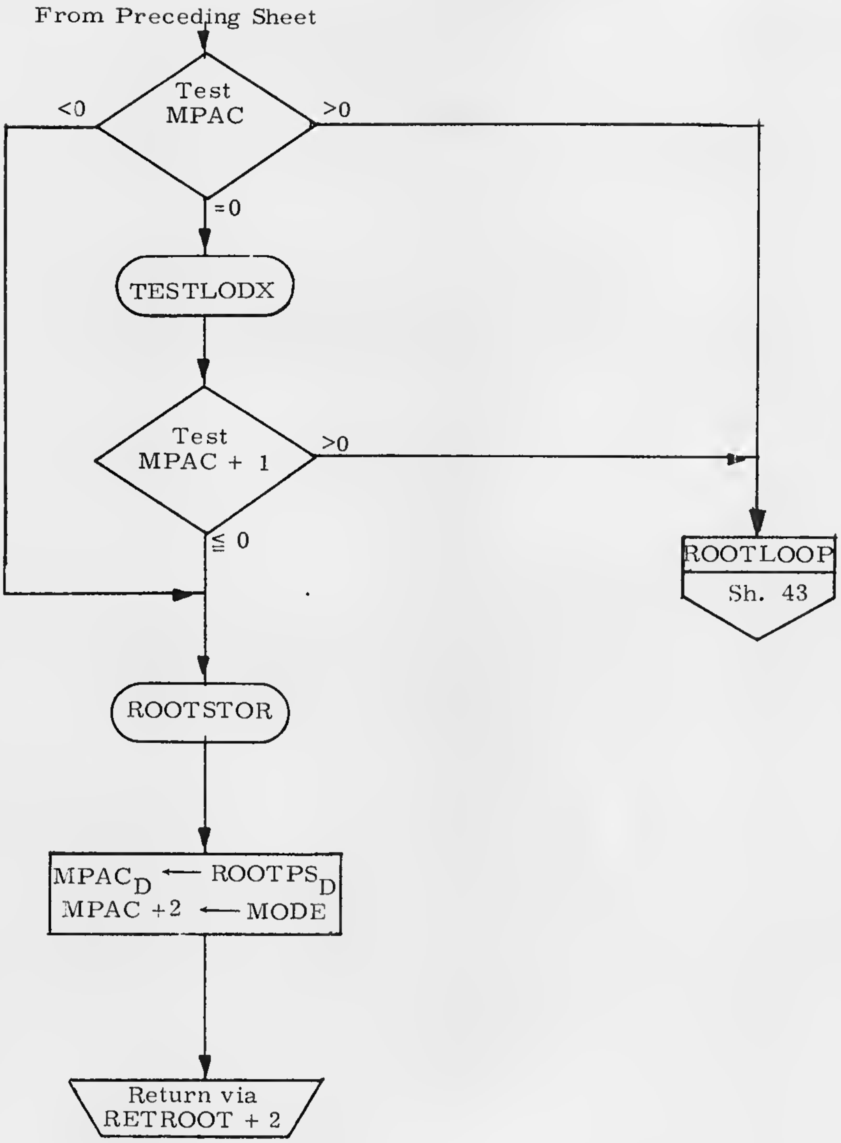
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Welch	3/5/70	Lunar Landing	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR W Dogbeth	2/30/69		
APPR'D RM Eaton	11/25/69	REV 2	SHEET 41 OF 52



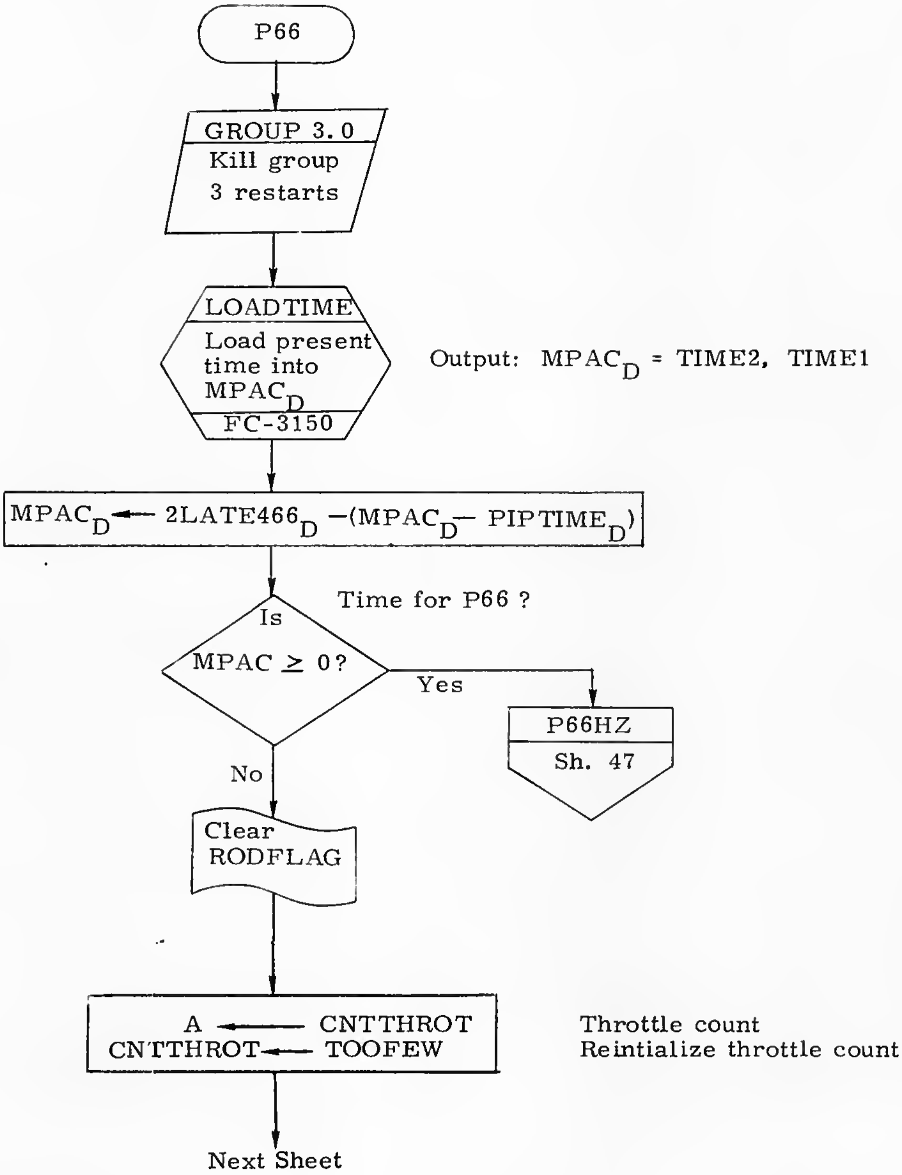
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R Welch	3/5/70	Lunar Landing	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR W Danforth	9/30/69		
APPR'D R M Ertes	11/25/69	REV 2	SHEET 42 OF 52

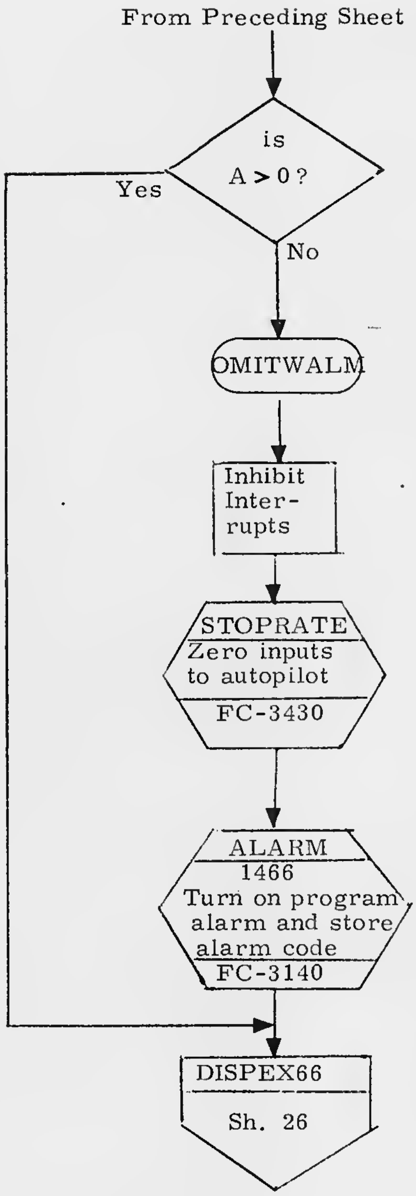


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R Welch	3/5/70	Lunar Landing	
PRGMR		LUMINARY 1D	DOCUMENT NO. FC-3900
ANALST			
DOCMR W C Daugherty	9/30/69		
APPR'D R M Enter	11/25/70	REV 2	SHEET 43 OF 52



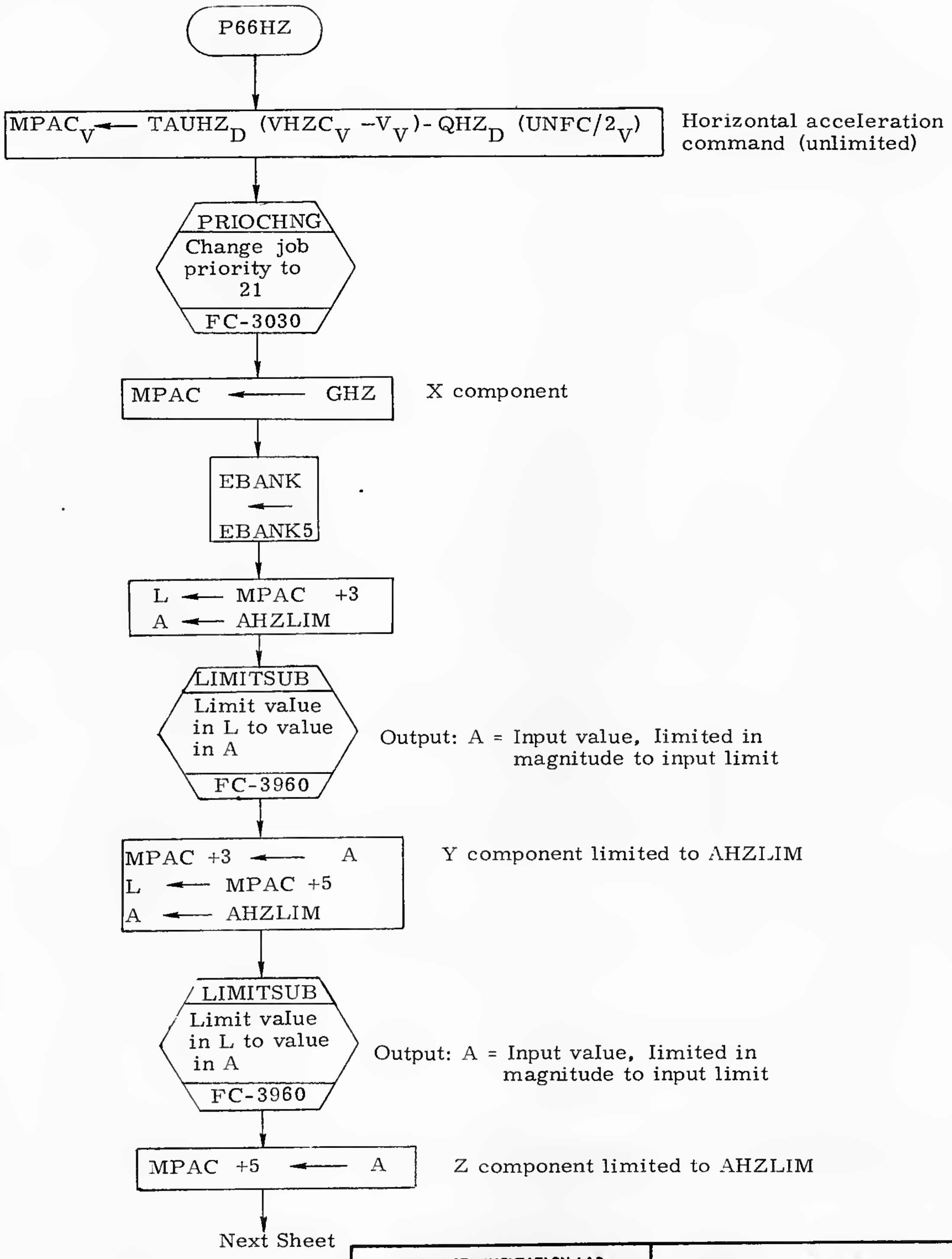
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R Wild	2/5/2?	Lunar Landing	
PRGMR		LUMINARY 1D	DOCUMENT NO. FC-3900
ANALST			
DOCMR W Dowbith	9/30/69		
APPR'D RM Evans	10/25/69	REV 2	SHEET 44 OF 52


P66
GROUP 3.0
Kill group 3 restarts
LOADTIME
Load present time into MPAC_D
FC-3150
Output: MPAC_D = TIME2, TIME1
MPAC_D ← 2LATE466_D −(MPAC_D − PIPTIME_D)
Time for P66 ?
Is MPAC ≥ 0?
Yes
P66HZ
Sh. 47
No
Clear RODFLAG
A ← CNTTHROT
CNTTHROT ← TOOFEW
Throttle count
Reintialize throttle count
Next Sheet

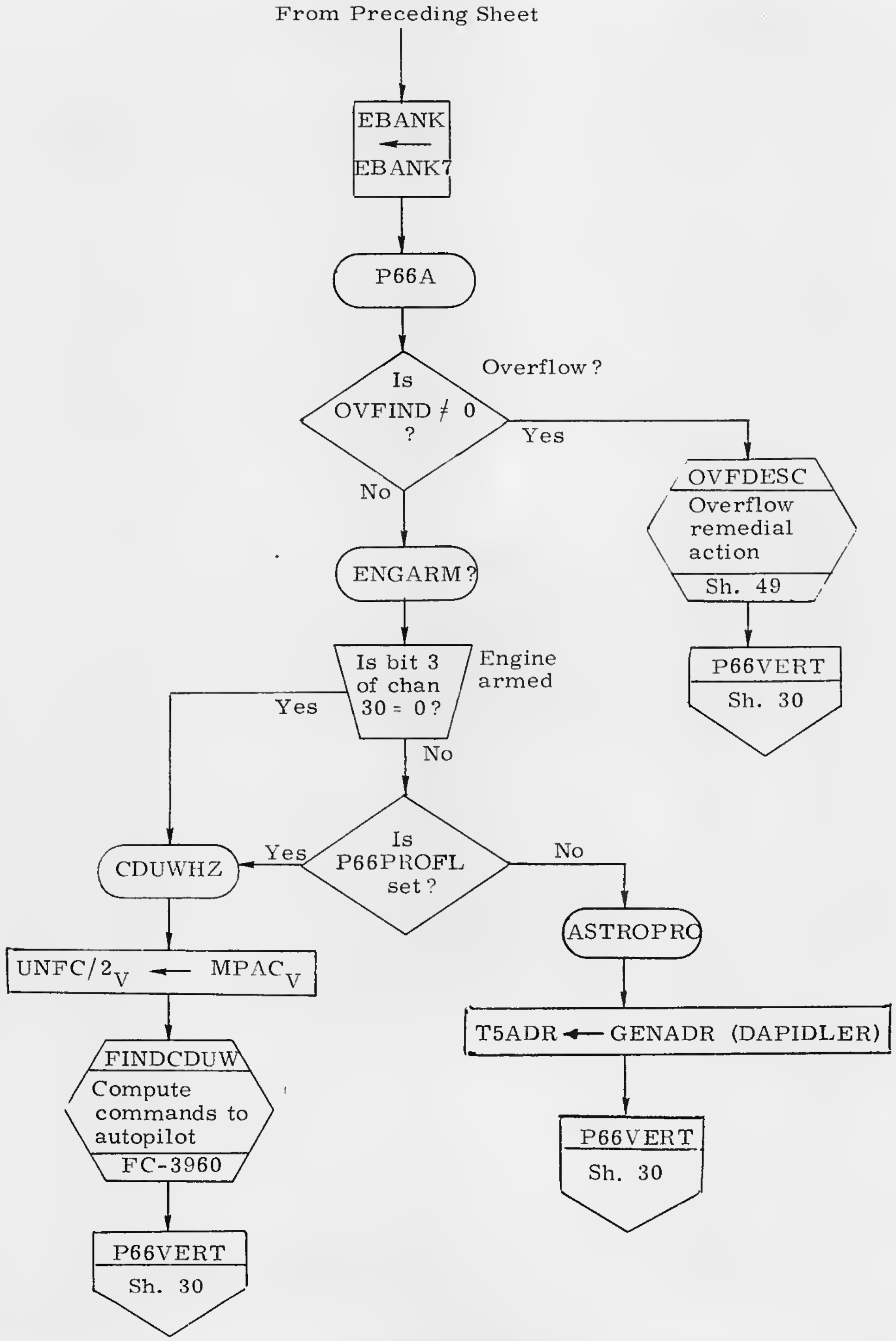


1466=Throttle servicing insufficient

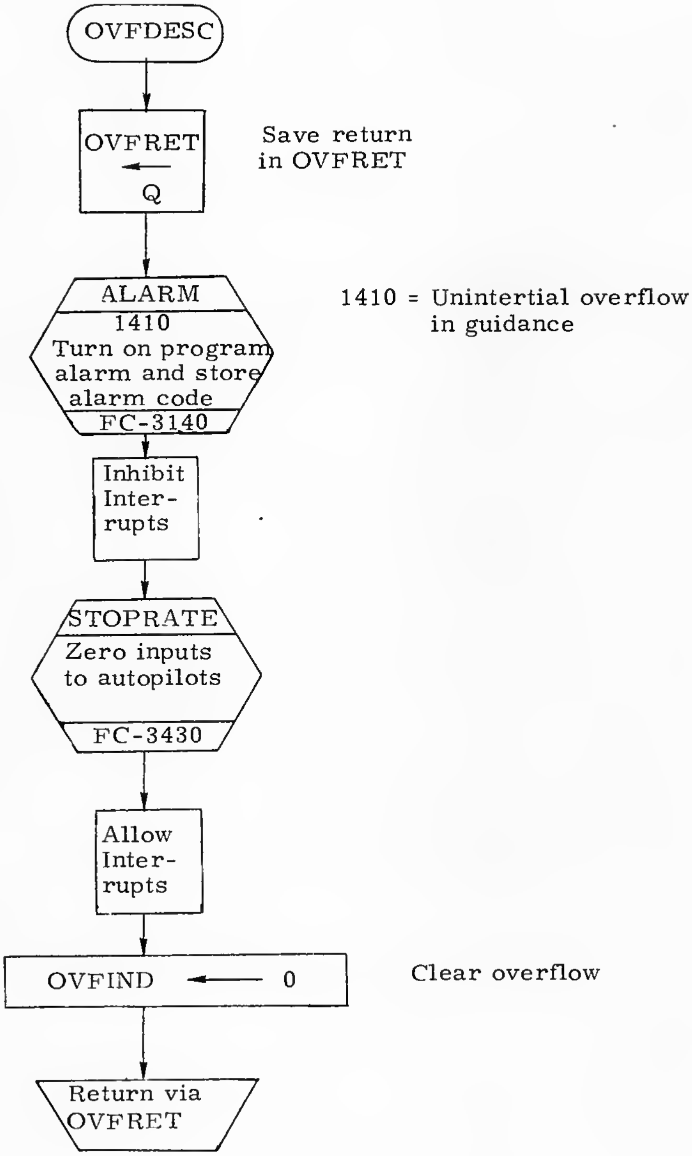
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	E. Matta	5/22/70	Lunar Landing	
PRGMR				
ANALST			LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR	W. Griffith	6/1/70		
APPR'D	R.M. Eaton	6/1/70	REV 2	SHEET 46 OF 52



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Welch	3/5/70	Lunar Landing	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR W Danforth	3/13/70		
APPR'D R M Exler	3/25/70	REV 2	SHEET 47 OF 52



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN *GR Welch*	3/5/70	Lunar Landing
PRGMR		LUMINARY 1D
ANALST		DOCUMENT NO. FC-3900
DOCMR *W. Danforth*	3/13/70	
APPR'D *K M Estes*	3/25/70	REV 2 — SHEET 48 OF 52



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	R. Welch 3/5/70	Lunar Landing	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR	W. Danforth 3/13/70		
APPR'D	R M Eates 3/25/70	REV 2	SHEET 49 OF 52

SUBROUTINES CALLED ON
OTHER FLOWCHARTS

Subroutine	Flowchart	Description	Where Called
RO2BOTH	FC-3220	IMU status check	Sh. 2
RP-TO-R	FC-3340	Transform from planetary to basic reference system	Sh. 3
GUIDINIT	FC-3950	Initialize WM_V and $\lvert LAND \rvert_D$	Sh. 3
LEMPREC	FC-3350	Integrate LM state vector	Sh. 3
MUNGRAV	FC-3850	Compute lunar gravitational acceleration	Sh. 4
NEWMODEX	FC-3020	Set new major mode	Sh. 6
C13STALL	FC-3340	Wait till ok to write ch. 13	Sh. 7
PRIOCHNG	FC-3030	Change job priority	Sh. 8
ALARM	FC-3140	Store alarm code; turn on program alarm light	Sh. 12, 19, 26, 46, 49
INTSTALL	FC-3350	Test availability of integration	Sh. 19
INTEGRVS	FC-3350	Integrate state vector	Sh. 20
STCLOK2	FC-3840	Schedule start of CLOCKTASK	Sh. 21
R51P63	FC-3510	IMU realignment	Sh. 22
PFLITEDB	FC-3440	Zero attitude errors. set deadband to 1°	Sh. 22
R6OLEM	FC-3420	Perform auto attitude maneuver	Sh. 23
VACRLEAS	FC-3030	Change FINDVAC job to NOVAC job	Sh. 27, 28
FINDCDUW	FC-3950	Compute commands to autopilot	Sh. 26, 48
STOPRATE	FC-3430	Zero inputs to autopilot	Sh. 26, 46, 49
PRIOCHNG	FC-3030	Change job priority	Sh. 30, 47
NBSM	FC-3320	Transform vector from NB to SM coordinates	Sh. 31
TPAGREE	FC-3070	Force sign agreement of $MPAC_T$	Sh. 41
POWRSERS	FC-3070	Double precision polynomial evaluator	Sh. 43

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN D Lutkevich	9/30/69	Lunar Landing
PRGMR		
ANALST		LUMINARY 1D — DOCUMENT NO. FC-3900
DOCMR W Danforth	11/25/69	
APPR'D RM Enter	11/25/69	REV 2 — SHEET 50 OF 52

SUBROUTINES CALLED ON
OTHER FLOWCHARTS (CONT.)

Subroutine	Flowchart	Description	Where Called
LOADTIME	FC-3150	Load present time into $MPAC_D$	Sh. 45
LIMITSUB	FC-3960	Limit value in L to value in A	Sh. 47

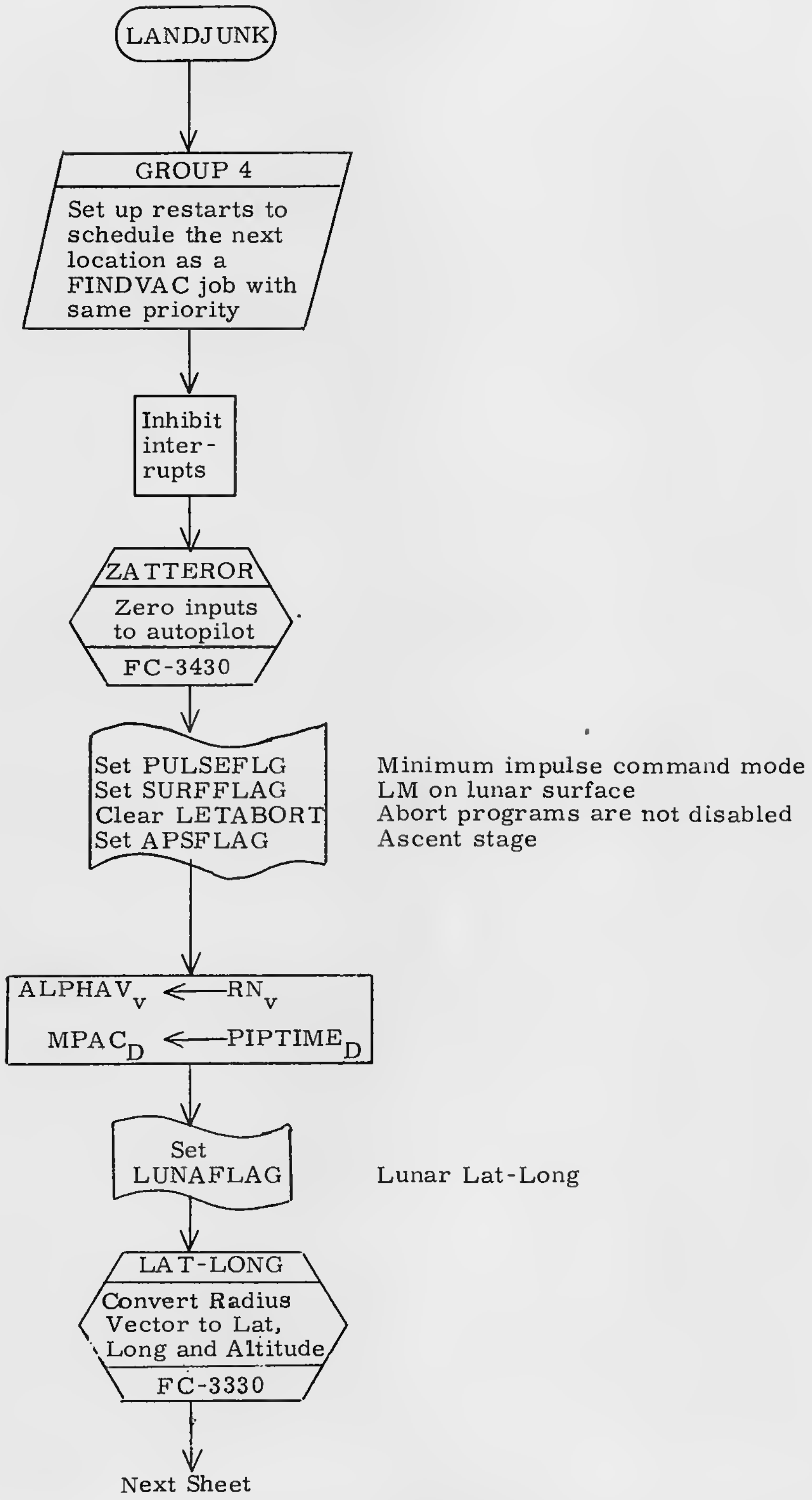
FLAGS

Name	Meaning When Set	Meaning When Clear	Where Set	Where Cleared	Where Tested
NOTHROTL Flag 5 Bit 12	Inhibit full throttle	Permit full throttle		Sh. 2	
REDFLAG Flag 6 Bit 6	Landing site redesignation permitted	Landing site redesignation not permitted	Sh. 29	Sh. 2, 7, 28	Sh. 9, 28
LRBYPASS Flag 11 Bit 15	Bypass all LR updates	Do not bypass LR updates		Sh. 2	
MUNFLAG Flag 6 Bit 8	SERVICER calls MUNRVG	SERVICER calls CALCRVG	Sh. 2		
P25 FLAG Flag 0 Bit 9	P25 operating	P25 not operating		Sh. 2	
RNDVZFLG Flag 0 Bit 7	P20 running	P20 not running		Sh. 2	
NOTERFLG Flag 1 Bit 11	Terrain model inhibited	Terrain model permitted		Sh. 2	
INTYPFLG Flag 3 Bit 4	Conic integration	Encke integration	Sh. 20		
MOONFLAG Flag 0 Bit 12	Moon is sphere of influence	Earth is sphere of influence	Sh. 20		
STEERSW Flag 2 Bit 11	Sufficient thrust is present	Insufficient thrust is present			Sh. 25
FLUNDISP Flag 8 Bit 10	Current guidance displays inhibited	Current guidance displays permitted			Sh. 26
RODFLAG Flag 1 Bit 12	If in P66, normal operation continues	If in P66, reinitialization is performed		Sh. 45	
P66PROFL Flag 0 Bit 1	Continue P66 horizontal vel. nulling	Stop P66 horizontal velocity nulling		Sh. 27	Sh. 48

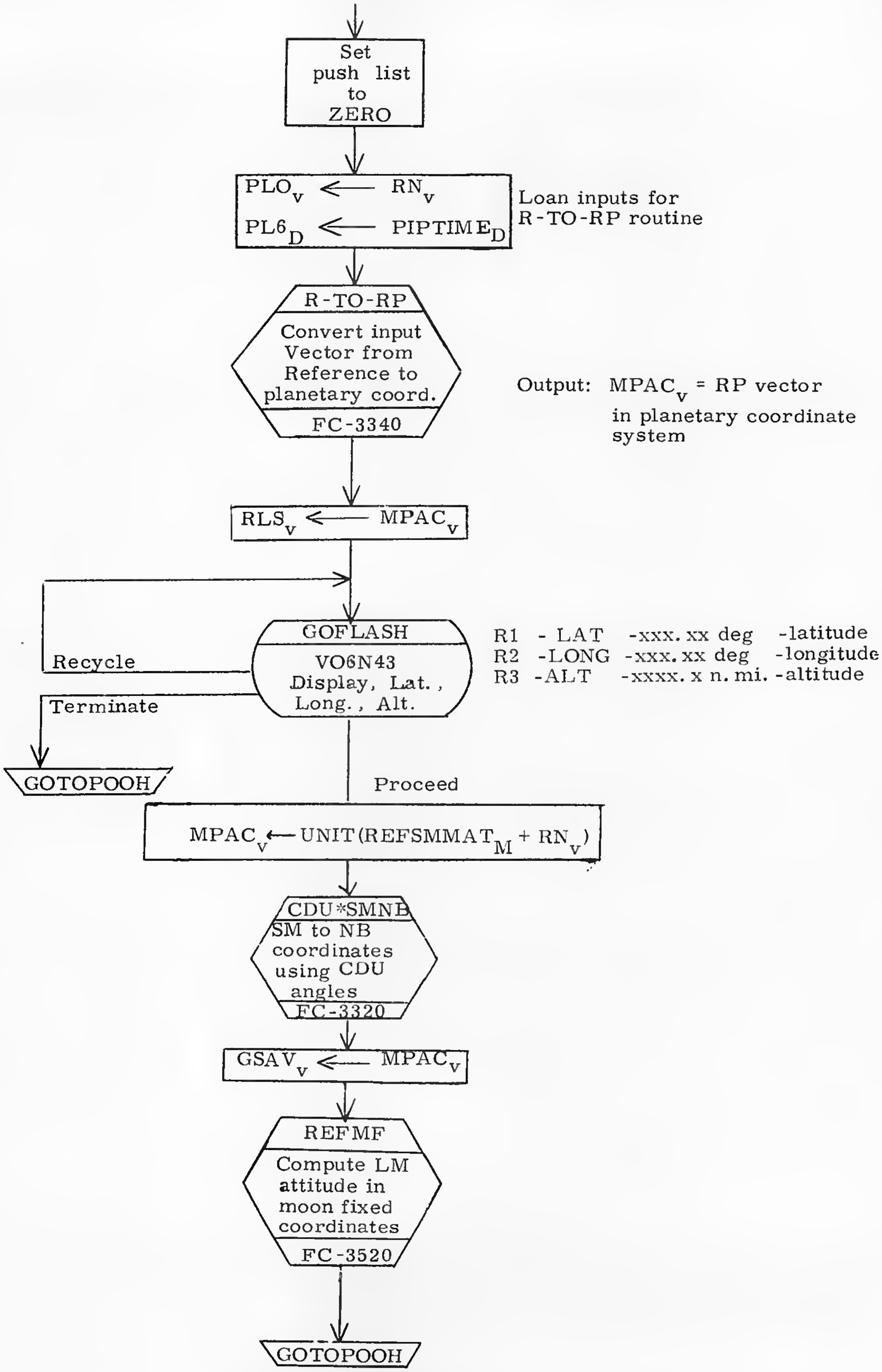
LANDING CONFIRMATION

LANDJUNK Sh. 2

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Landing Confirmation	
PRGMR Frances Kiwen	11/26/69	LUMINARY 1D	DOCUMENT NO. FC-3910
ANALST			
DOCMR W. Danforth	10/21/69		
APPR'D Roberto M. Estes	11/26/69	REV 1	SHEET 1 OF 5



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN [illegible]	[illegible]	Landing Confirmation	
PRGMR Frances Kirwen	11/26/69		DOCUMENT NO.
ANALST		LUMINARY 1D	FC 3910
DOCMR W. Danforth	10/21/69		
APPR'D Roberta M. Eates	11/26/69	REV 1	SHEET 2 OF 5



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN Jo Sullivan	12-15-69	Landing Confirmation	
PRGMR Frances Kirven	11/26/69	LUMINARY 1D	DOCUMENT NO. FC-3910
ANALST			
DOCMR W Danforth	10/21/69		
APPR'D Roberta M. Estes	11/26/69	REV 1	SHEET 3 OF 5

FLAGS

Name	Meaning When Set	Meaning When Cleared	Where Set	Where Cleared	Where Tested
PULSEFLG FLAG 13 BIT 15	Minimum impulse command mode	Not in minimum impulse command mode	Sh. 2		
SURFFLAG FLAG 8 BIT 8	LM on lunar surface	LM not on lunar surface	Sh. 2		
LETABORT FLAG 9 BIT 9	Abort programs are enabled	Abort programs are not enabled		Sh. 2	
APSFLAG FLAG 10 BIT 13	Ascent stage	Descent stage	Sh. 2		
LUNAFLAG FLAG 3 BIT 12	Lunar lat-long	Earth lat-long	Sh. 2		

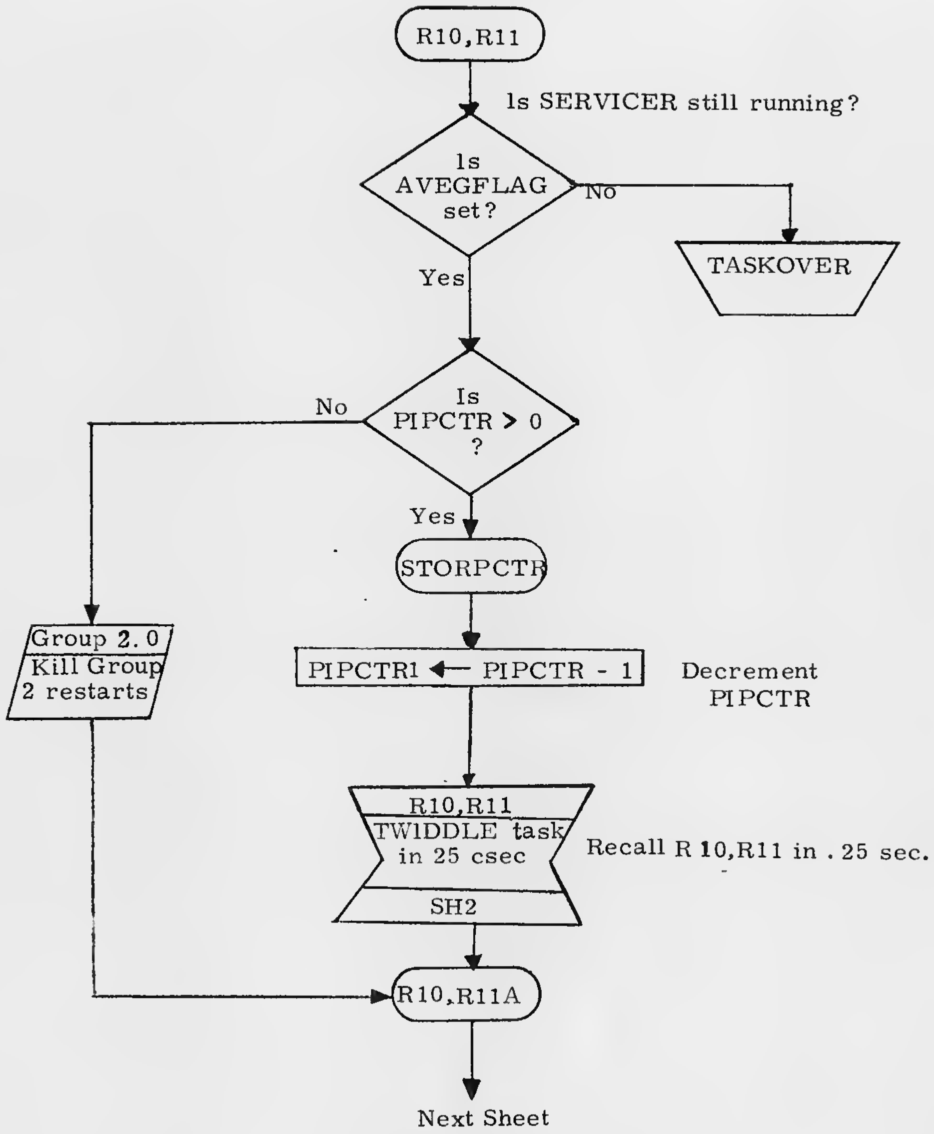
SUBROUTINES CALLED ON OTHER FLOWCHARTS

Subroutine	Flowchart	Description	Where Called
ZATTEROR	FC-3430	Zero inputs to autopilot	Sh. 2
LAT-LONG	FC-3330	Convert radius vector to Lat., Long. and altitude	Sh. 2
R-TO-RP	FC-3340	Convert vector from reference to planetary	Sh. 3
REFMF	FC-3520	Compute LM attitude in moon fixed coordinates	Sh. 3
CDU*SMNB	FC-3320	SM to NB coordinates using CDU angles	Sh. 3

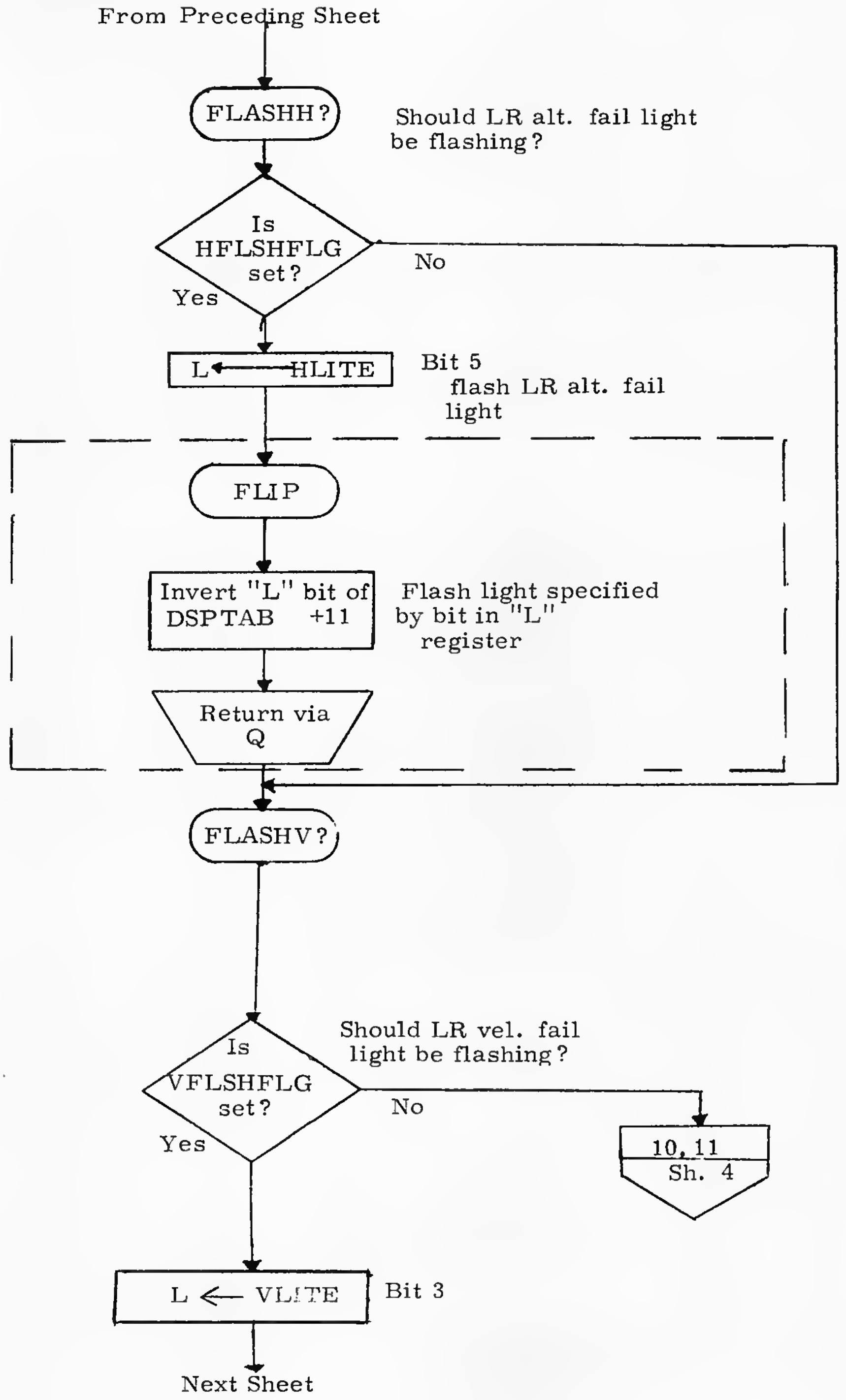
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN [illegible]	[illegible]	Landing Confirmation	
PRGMR Frances Kirwen	10/21/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3910
DOCMR W Danforth	10/21/69		
APPR'D Roberta M. Estes	[illegible]	REV 1	SHEET 5 OF 5

R09, R10, R11

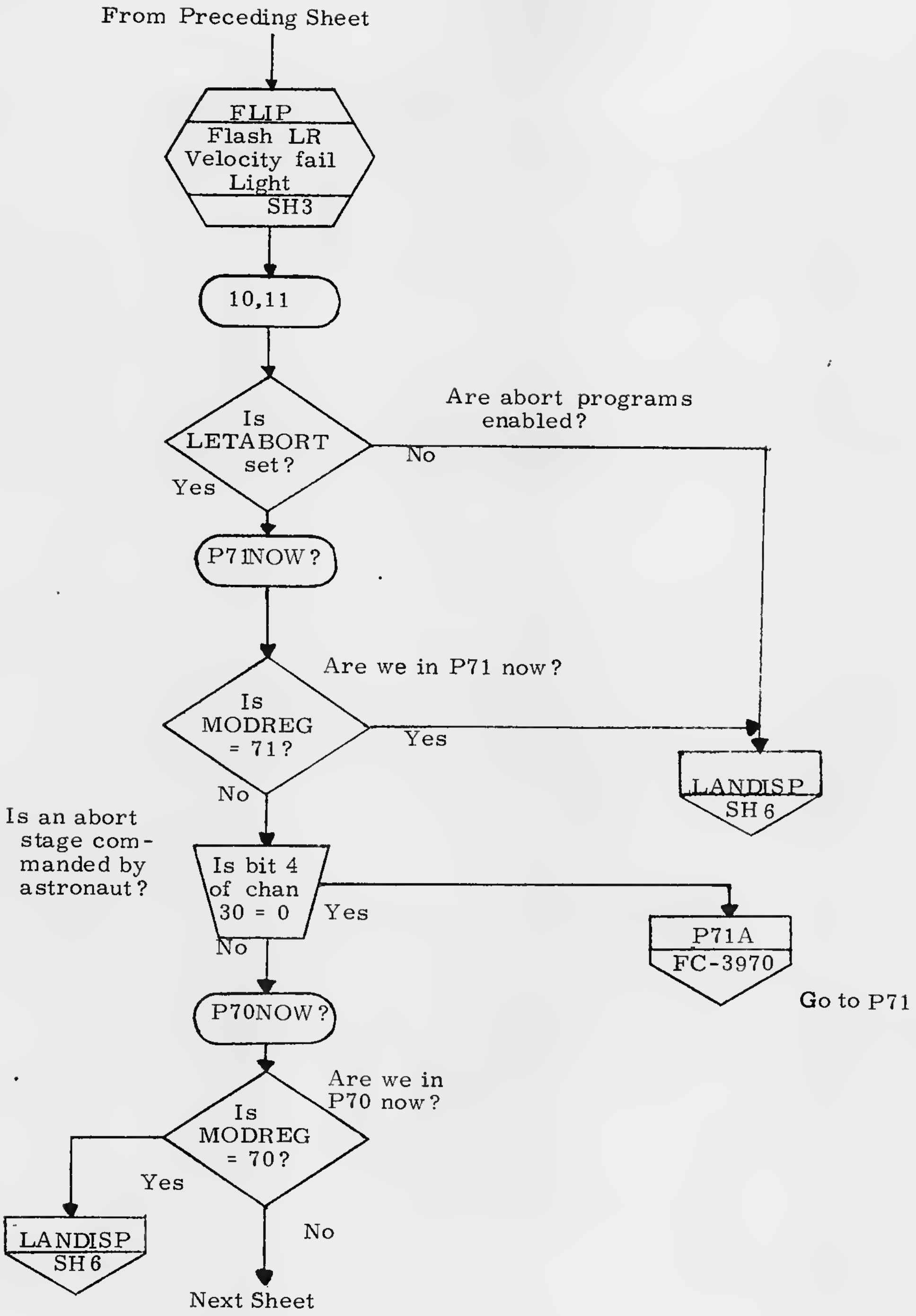
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D Lutkevich	10/29/69	R09, R10, R11	
PRGMR P. Bernikowich	11/25/69	LUMINARY 1D	DOCUMENT NO. FC-3930
ANALST			
DOCMR W Danforth	11/21/69		
APPR'D Roberta M. Sutton	11/25/69	REV 2	SHEET 1 OF 21



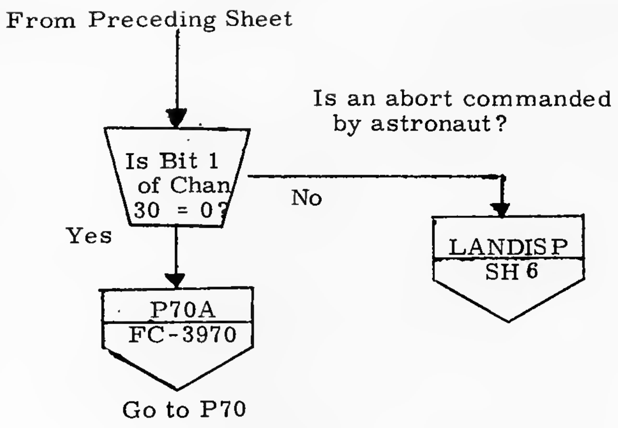
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN	10/29/69	R09, R10, R11
PRGMR	10/29/69	LUMINARY 1D — DOCUMENT NO. FC-3930
ANALST		
DOCMR W Danforth	9/26/69	
APPR'D	10/30/69	REV 2 — SHEET 2 OF 21



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		R09, R10, R11	
PRGMR	10/29/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3930
DOCMR W Danforth	9/26/69		
APPR'D		REV 2	SHEET 3 OF 21



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lutkevich	1/24/69	R09, R10, R11	
PRGMR P. Berurkowich	10/29/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3930
DOCMR W. Danforth	9/26/69		
APPR'D Roberta M. Ente	10/29/69	REV 2	SHEET 4 OF 21



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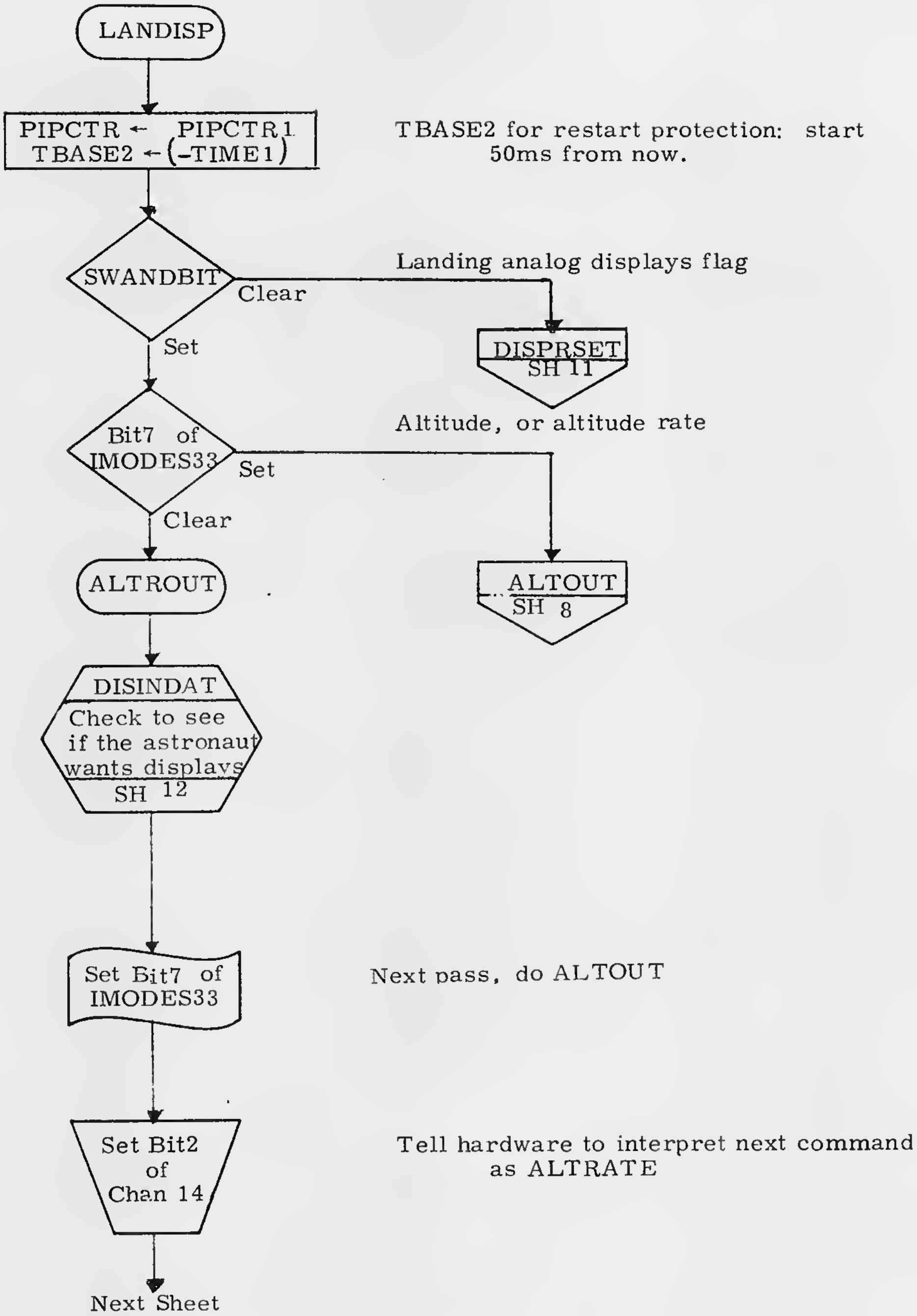
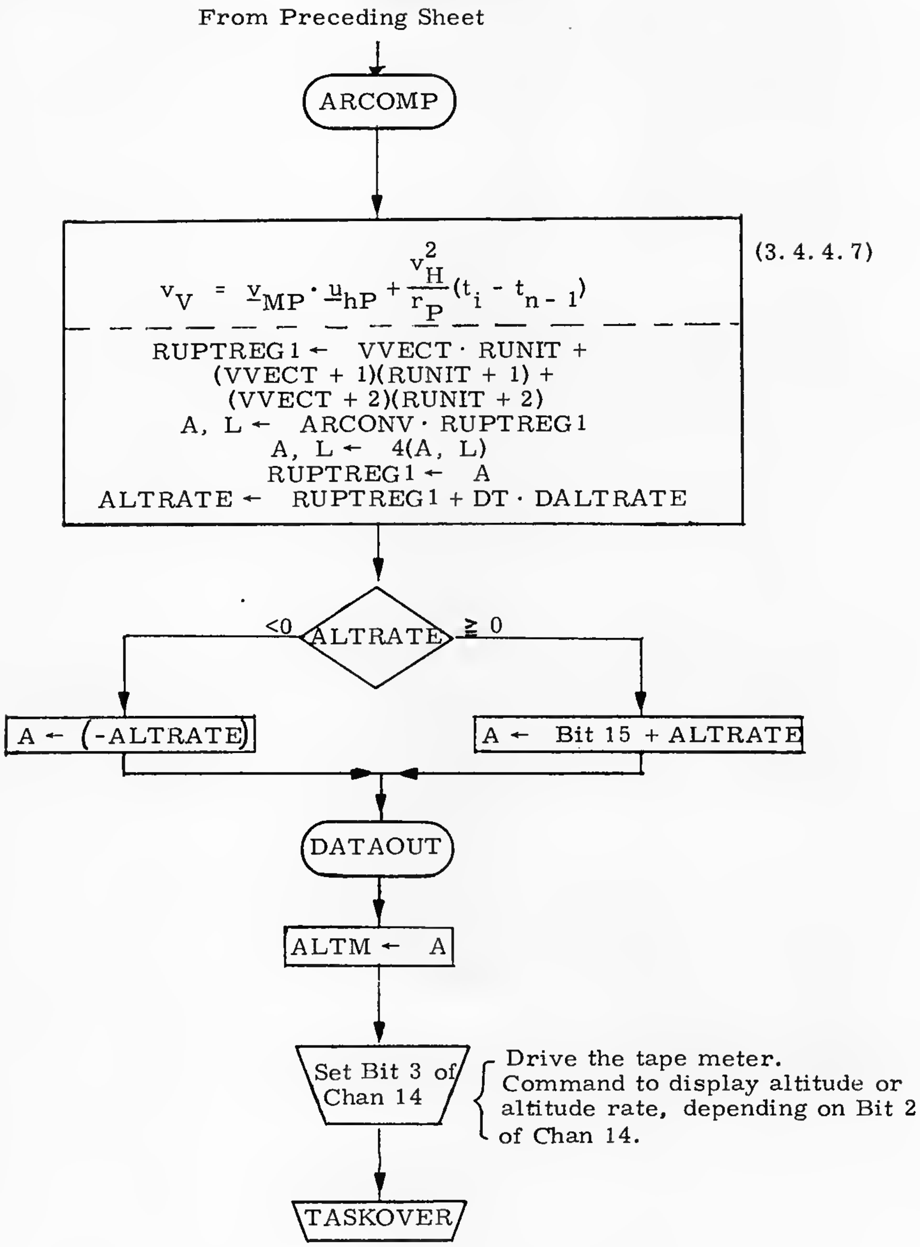
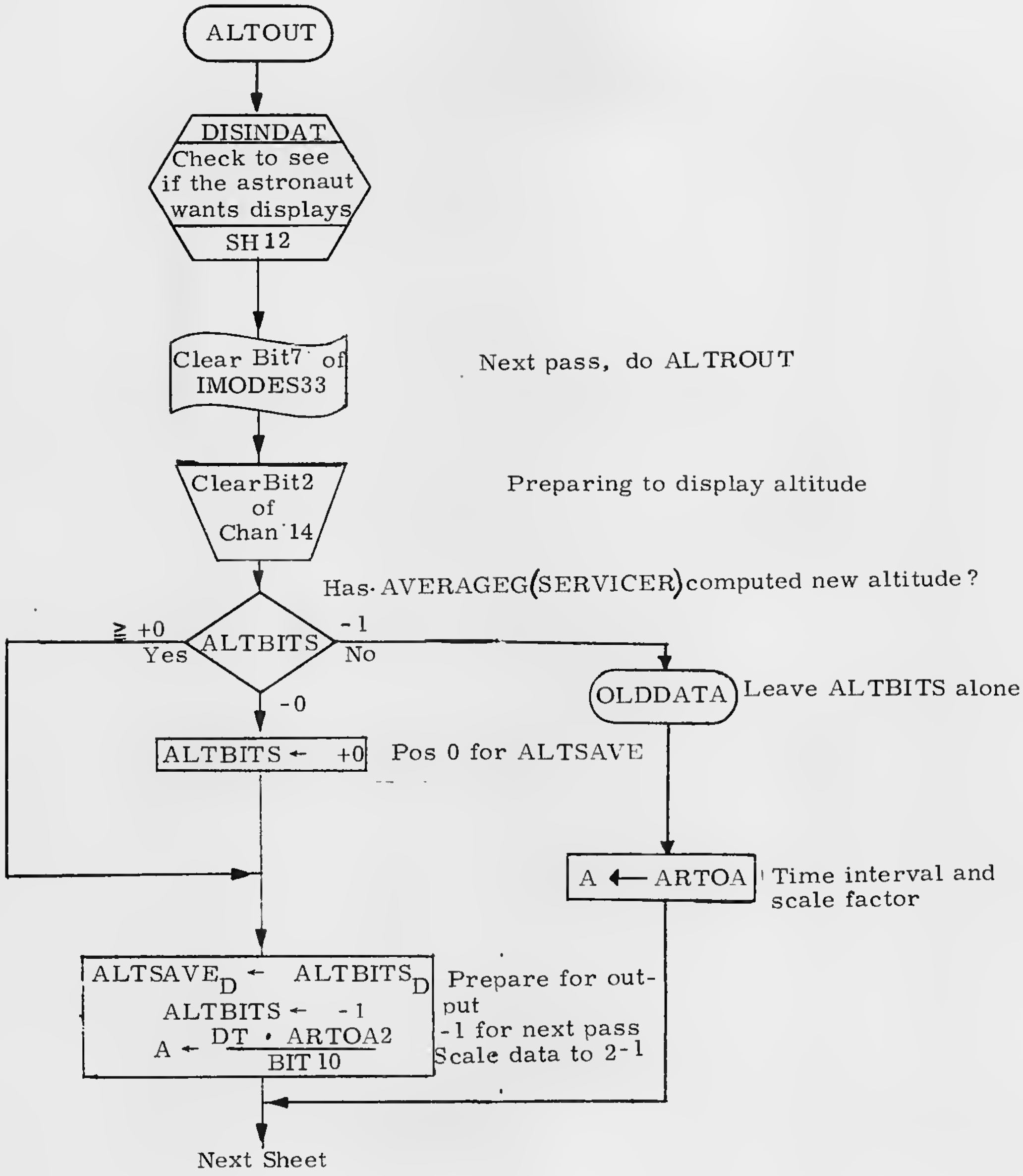
DRAWN [illegible]	9/26/69	R09, R10, R11	
PRGMR [illegible]	10/29/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3930
DOCMR [illegible]	9/26/69		
APPR'D [illegible]	10/30/69	REV 2	SHEET 5 OF 21



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN Ilutkewich	9/14/67	R09, R10, R11	
PRGMR W. Bernikowicz	10/29/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3930
DOCMR W. Danforth	9/26/69		
APPR'D R. M. Evans	10/30/69	REV 2	SHEET 6 OF 21



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN [signature]	9/26/69	R09, R10, R11	
PRGMR [signature]	10/29/69	LUMINARY 1D	DOCUMENT NO. FC-3930
ANALST			
DOCMR W Danforth	9/26/69		
APPR'D [signature]	10/30/69	REV 2	SHEET 7 OF 21



MIT INSTRUMENTATION LAB
CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

R09, R10, R11

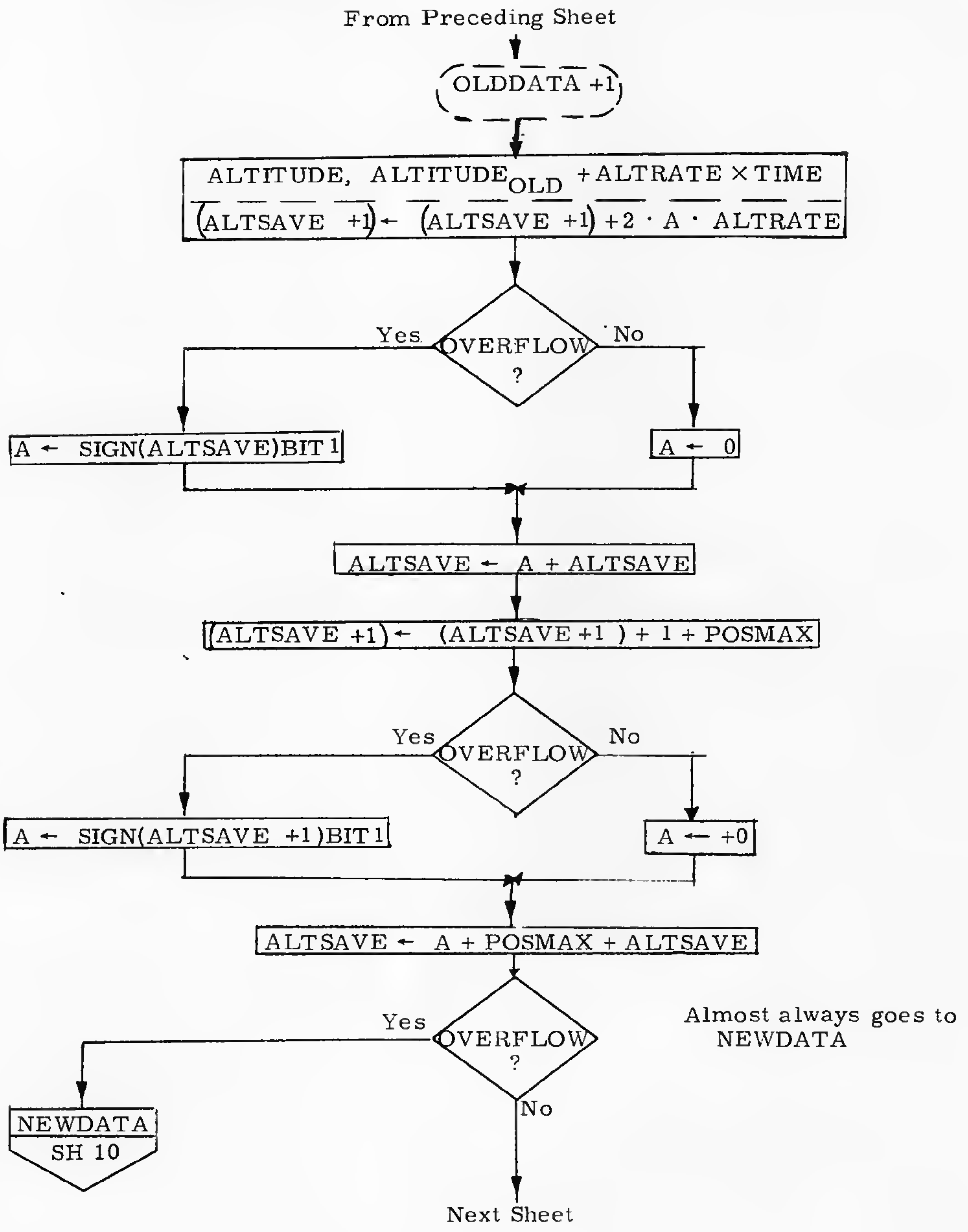
LUMINARY 1D

DOCUMENT NO. FC-3930

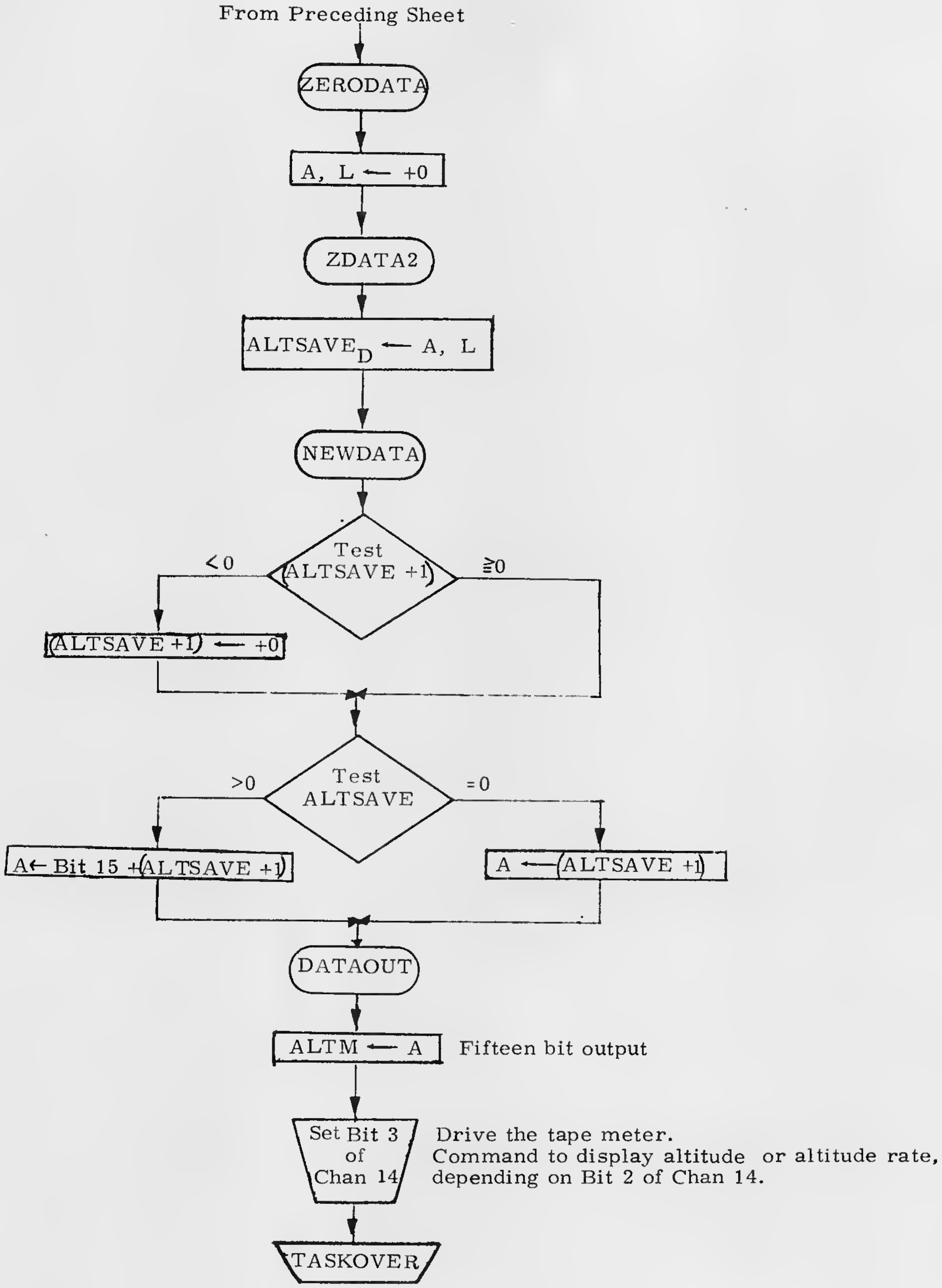
DRAWN 9/26/69
PRGMR 10/29/69
ANALST
DOCMR 9/26/69
APPR'D 10/30/69

REV 2

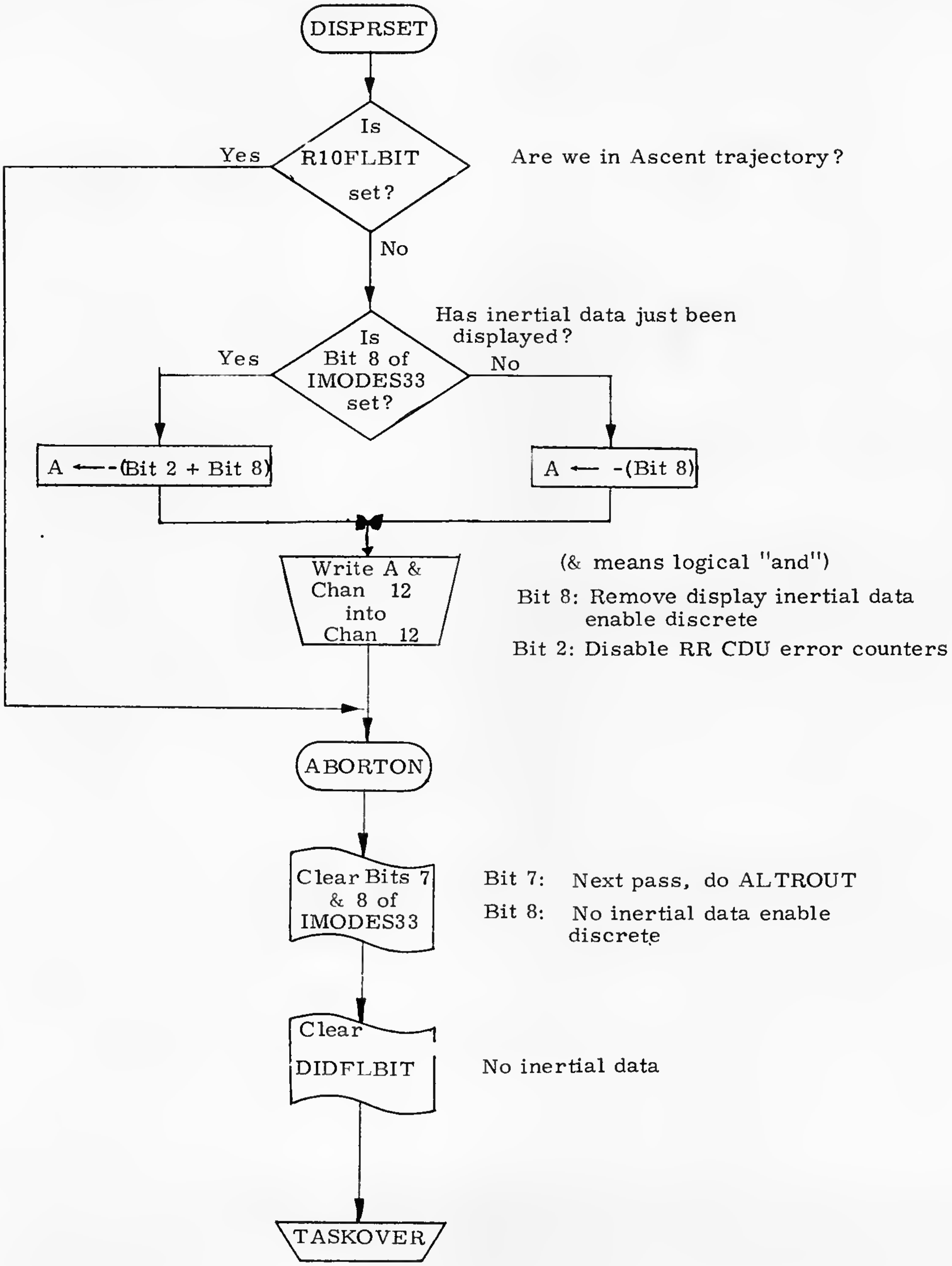
SHEET 8 of 21



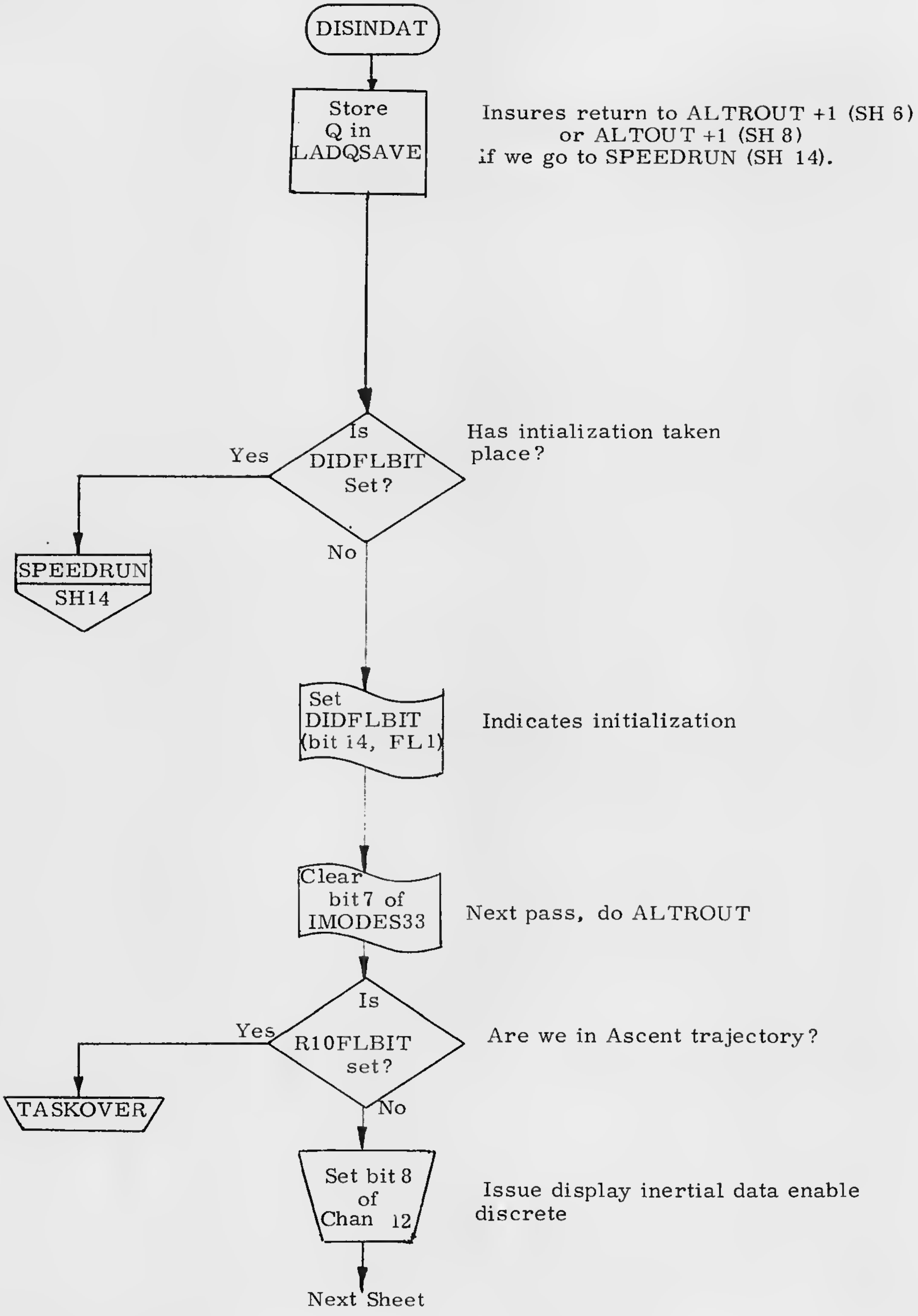
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lutkewich	9/24/69	R09, R10, R11	
PRGMR A. Bernikowicz	10/29/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3930
DOCMR W Dayforth	9/26/69		
APPR'D R. M. Estes	10/30/69	REV 2	SHEET 9 OF 21



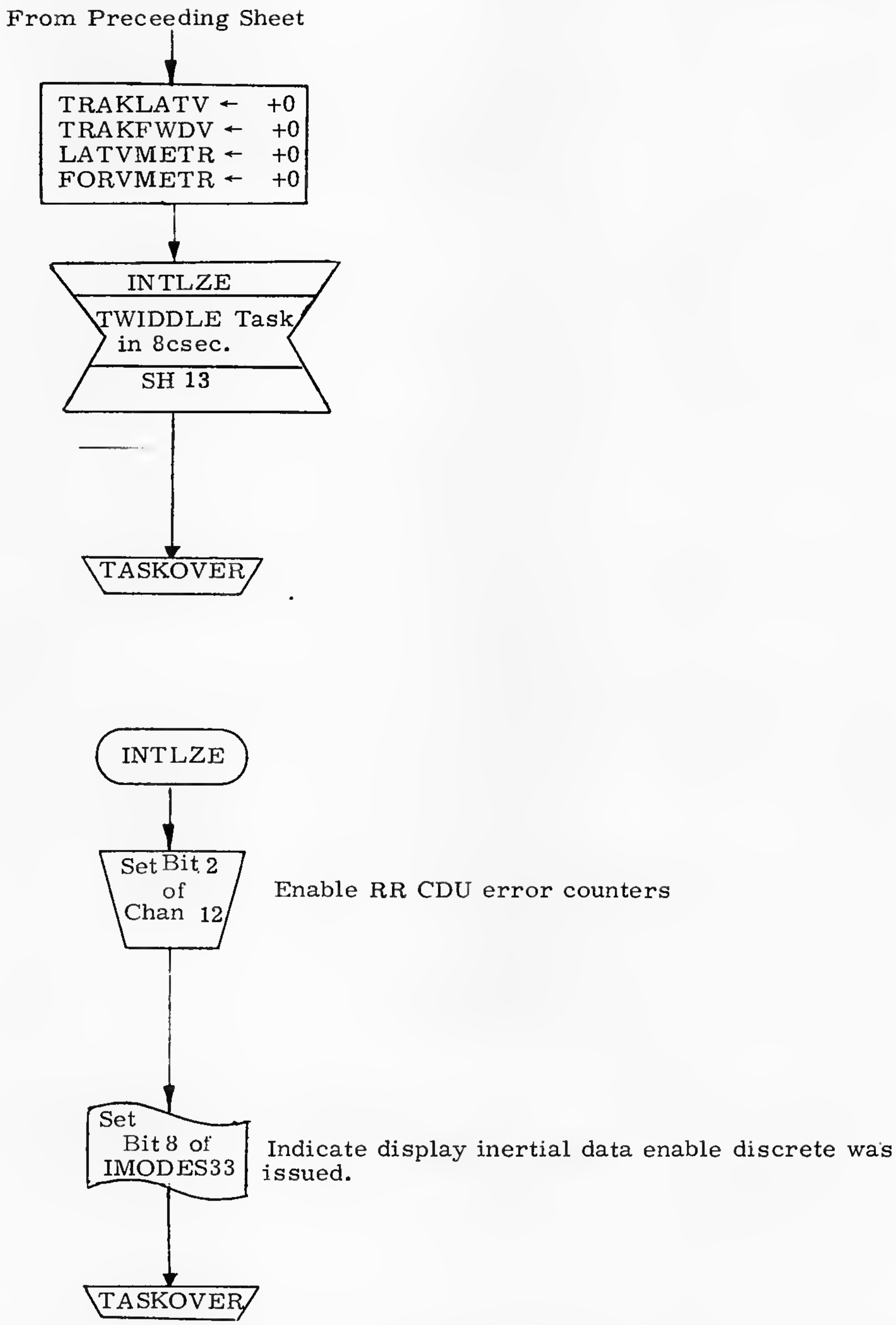
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lutkewich	9/26/69	R09, R10, R11	
PRGMR [illegible]	10/29/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3930
DOCMR W Danforth	9/26/69		
APPR'D R.M. Estes	10/30/69	REV 2	SHEET 10 OF 21



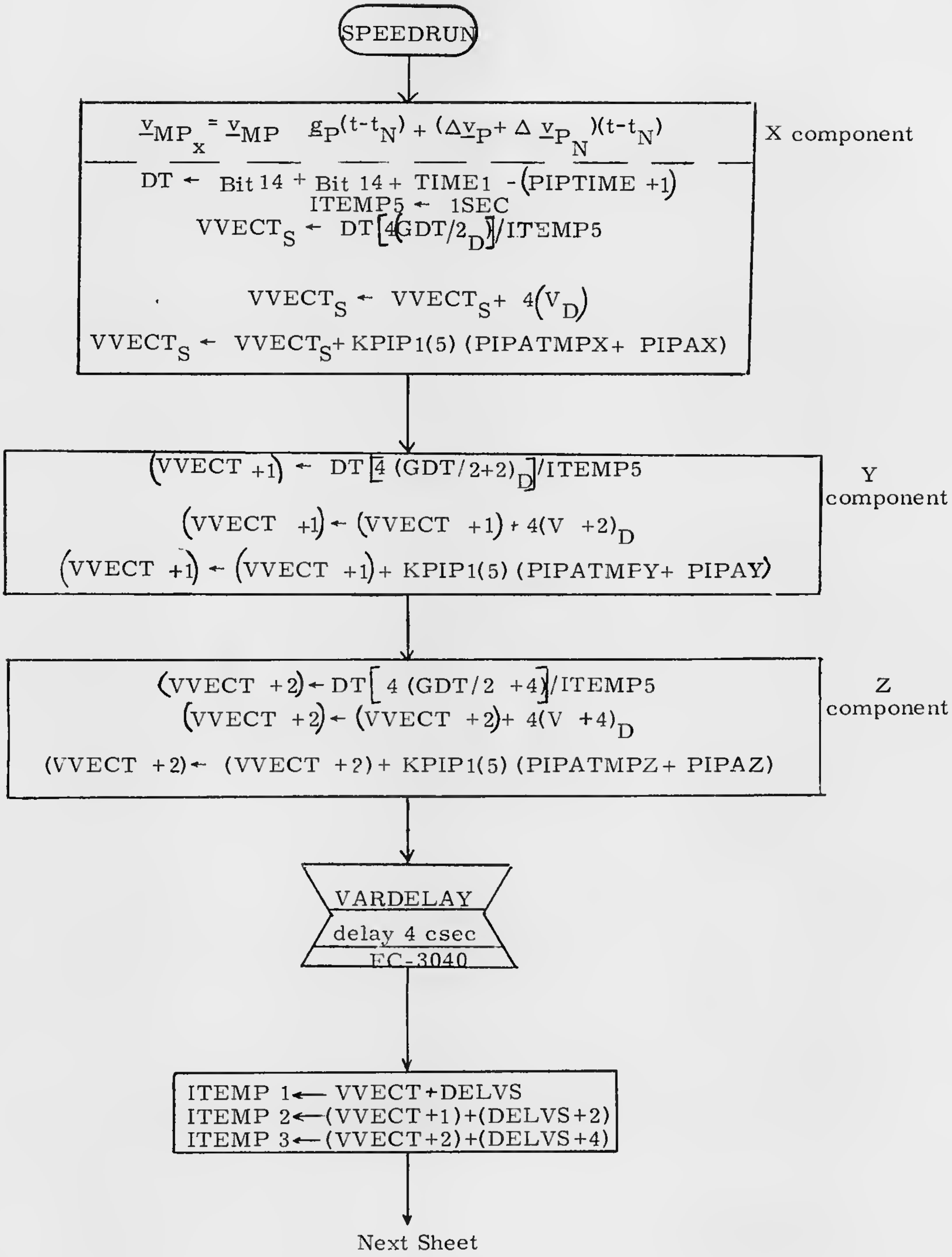
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Zutkevich	9/24/69	R09, R10, R11	
PRGMR D. Berwikowitz	10/29/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3930
DOCMR W. Danforth	9/26/69		
APPR'D R. M. Eaton	10/30/69	REV 2	SHEET 11 OF 21



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	9/24/69	R09, R10, R11	
PRGMR	10/28/69		DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3930
DOCMR	9/26/69		
APPR'D R.M. Eiter	10/30/69	REV 2	SHEET 12 OF 21



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	9/26/69	R09, R10, R11	
PRGMR	10/29/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3930
DOCMR W Dagforth	9/26/69		
APPR'D R M Estes	10/30/69	REV 2	SHEET 13 OF 21


SPEEDRUN
vMPx = vMP gP(t-tN) + (ΔvP + Δ vPN)(t-tN)
X component
DT ← Bit 14 + Bit 14 + TIME1 -(PIPTIME +1)
ITEMP5 ← 1SEC
VVECTS ← DT[4(GDT/2D]/ITEMP5
VVECTS ← VVECTS + 4(VD)
VVECTS ← VVECTS + KPIP1(5) (PIPATMPX + PIPAX)
(VVECT +1) ← DT[4 (GDT/2+2)D]/ITEMP5
(VVECT +1) ← (VVECT +1) + 4(V +2)D
(VVECT +1) ← (VVECT +1) + KPIP1(5) (PIPATMPY + PIPAY)
Y component
(VVECT +2) ← DT[4 (GDT/2 +4)]/ITEMP5
(VVECT +2) ← (VVECT +2) + 4(V +4)D
(VVECT +2) ← (VVECT +2) + KPIP1(5) (PIPATMPZ + PIPAZ)
Z component
VARDELAY
delay 4 csec
FC-3040
ITEMP 1 ← VVECT + DELVS
ITEMP 2 ← (VVECT +1) + (DELVS +2)
ITEMP 3 ← (VVECT +2) + (DELVS +4)
Next Sheet

From Preceding Sheet

$v_{HY} = \underline{v}_{MP} \cdot \underline{u}_{HYP}$

RUPTREG1 ← UHYP (ITEMP1)
RUPTREG1 ← RUPTREG1 + ITEMP2 (UHYP +2)
RUPTREG1 ← RUPTREG1 + ITEMP3 (UHYP +4)
VHY ← 2(RUPTREG1)

Velocity directed along the Y-coordinate

$v_{HZ} = \underline{v}_{MP} \underline{u}_{HZP}$

RUPTREG1 ← UHZP(ITEMP1)
RUPTREG1 ← RUPTREG1+ (UHZP +2)ITEMP2
RUPTREG1 ← RUPTREG1+ (UHZP+4)ITEMP3
VHZ ← 2(RUPTREG1)

Velocity directed along the Z-coordinate

GET22/32

EBANK ← EBANK6
ITEMP3 ← M22
ITEMP4 ← M32
EBANK ← EBANK7

sin(AOG)
cos(AOG) } computed by T4RUPT every 0. 25 sec

LATFWDV

$v_{HL} = v_{HZ} \sin AOG + v_{HY} \cos AOG$

RUPTREG1 ← ITEMP4(VHY)
RUPTREG1 ← RUPTREG1 + ITEMP3(VHZ)
LATVEL ← 2(RUPTREG1) VELCONV

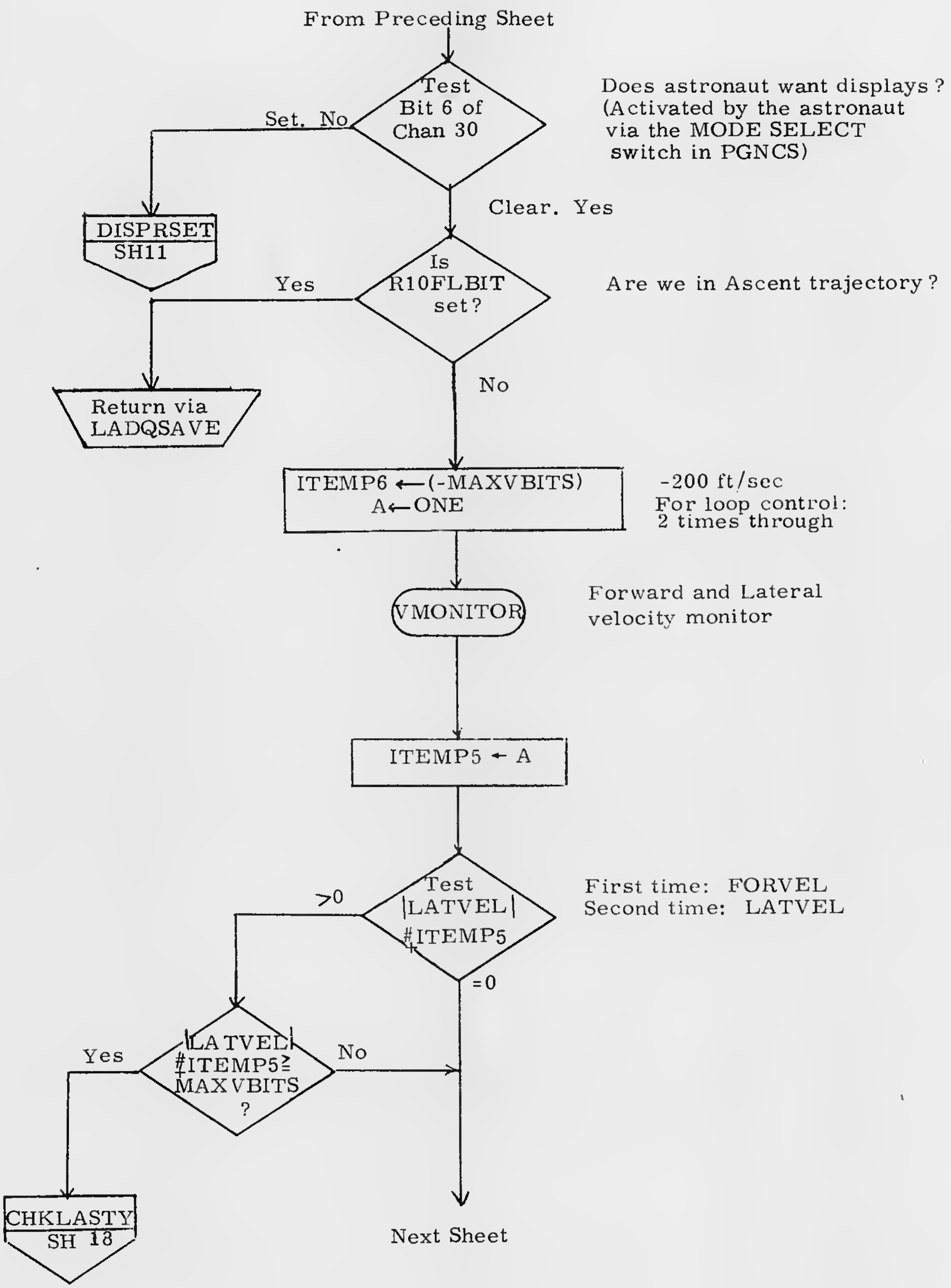
Compute LATVEL

$v_{HF} = v_{HZ} \cos AOG - v_{HY} \sin AOG$

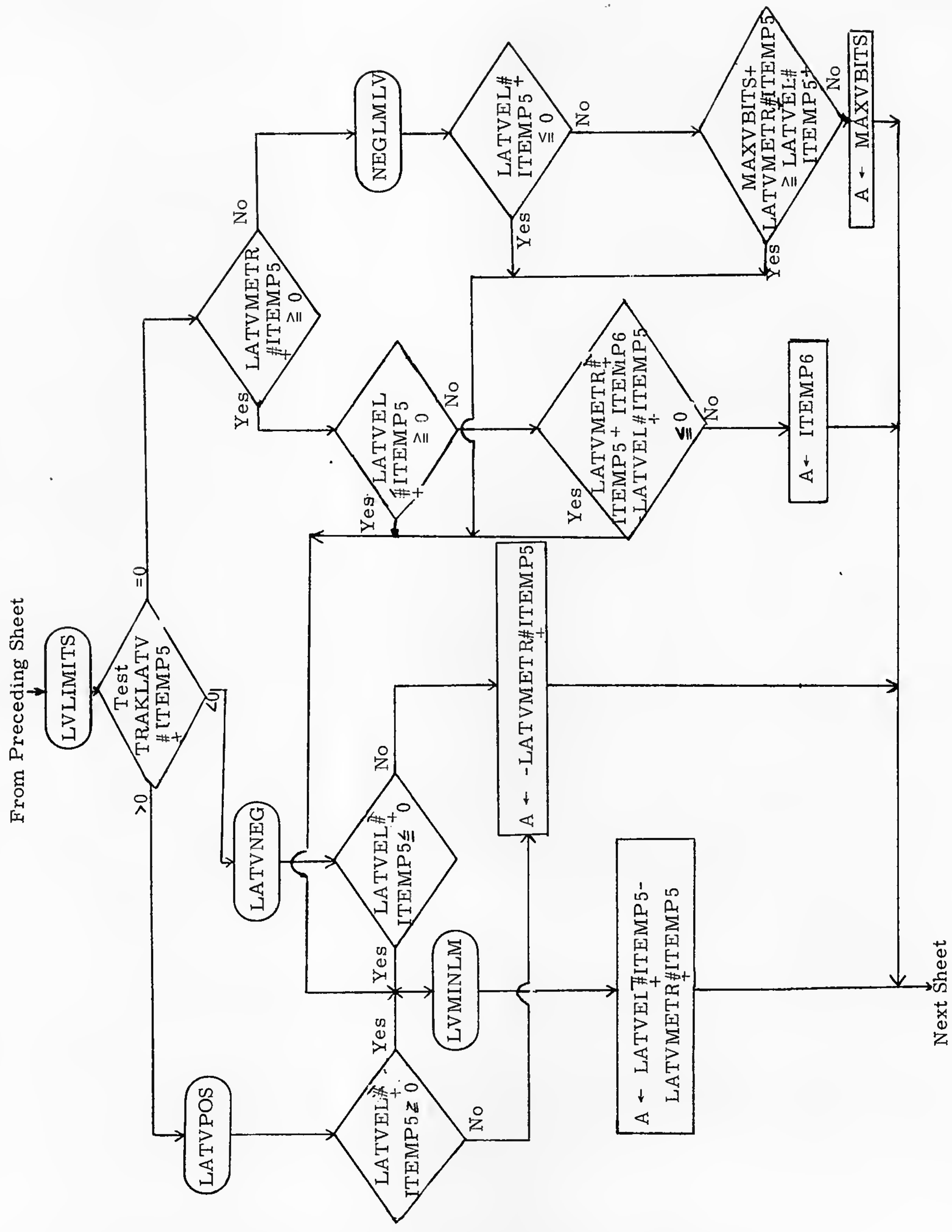
RUPTREG1 ← ITEMP4(VHZ)
RUPTREG1 ← RUPTREG1 - (VHY)ITEMP3
FORVEL ← 2(RUPTREG1) VELCONV

Compute FORVEL

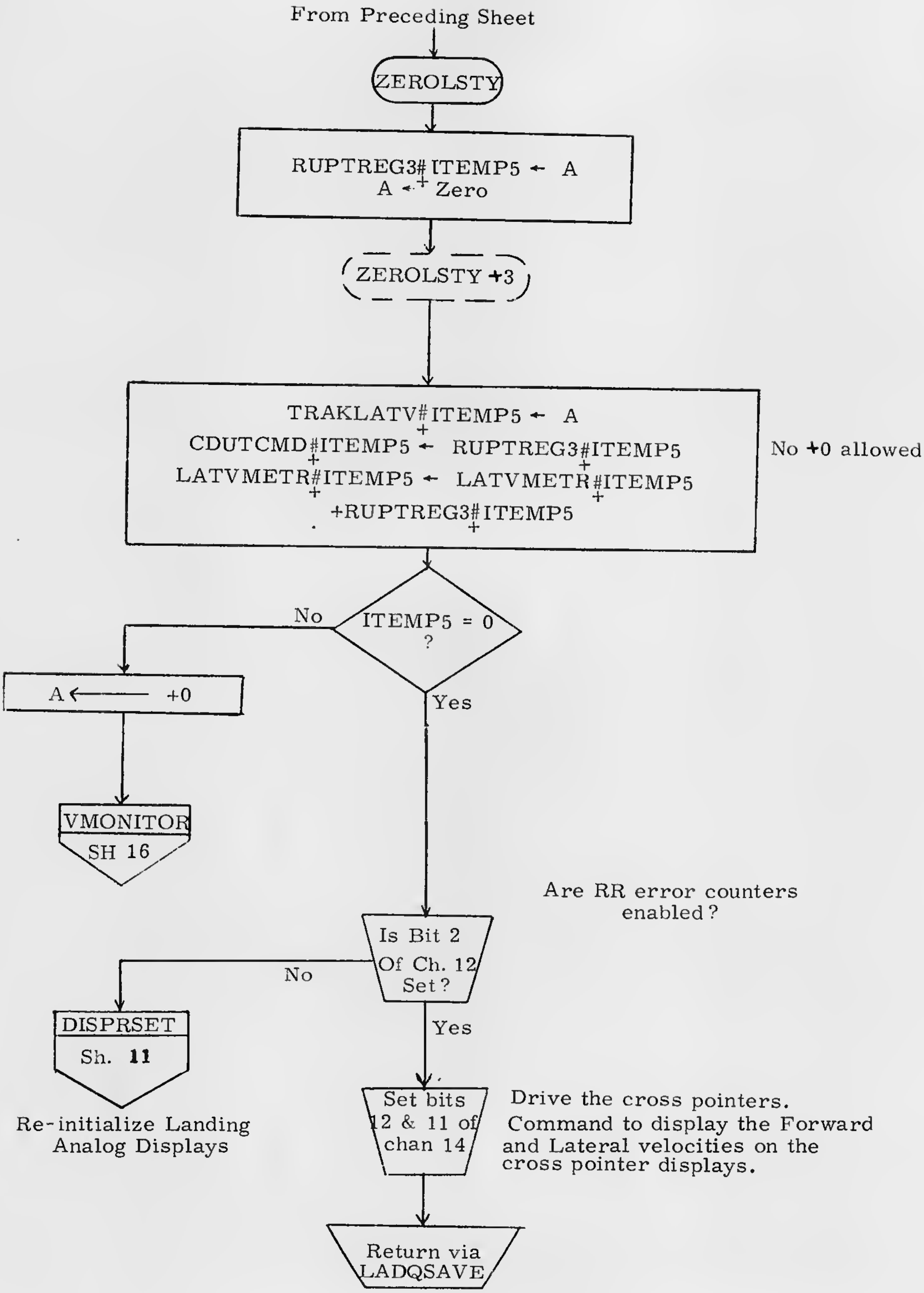
Next Sheet



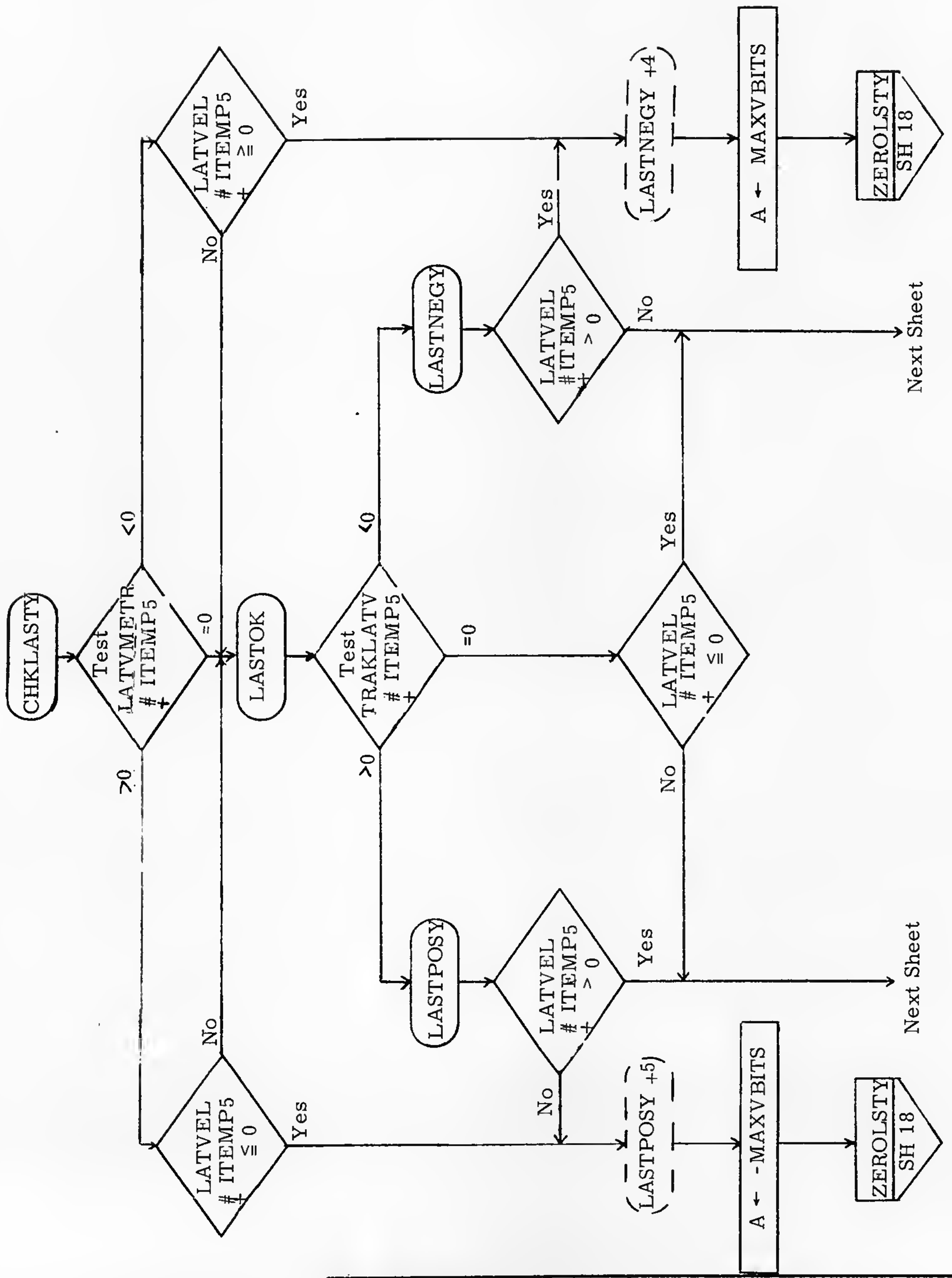
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E. Lulkevich	9/26/69	R09, R10, R11	
PRGMR D. Bernikowich	10/29/69	LUMINARY 1D	DOCUMENT NO. FC 3930
ANALST			
DOCMR W Dayforth	9/26/69		
APPR'D R.M. Eutas	10/30/69	REV 2	SHEET 16 OF 21



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lutkewich	9/26/69	R09, R10, R11	
PRGMR W. Bernikowich	10/29/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3930
DOCMR W Dauforth	9/26/69		
APPR'D R.M. Evtes	10/30/69	REV 2	SHEET 17 of 21



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN D. Lutkewich 9/26/69	R09, R10, R11
PRGMR D. Bernikowich 10/29/69	
ANALST	DOCUMENT NO.
DOCMR W. Dayforth 9/26/69	LUMINARY 1D — FC-3930
APPR'D R. M. Ennis 10/30/69	REV 2 — SHEET 18 OF 21



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
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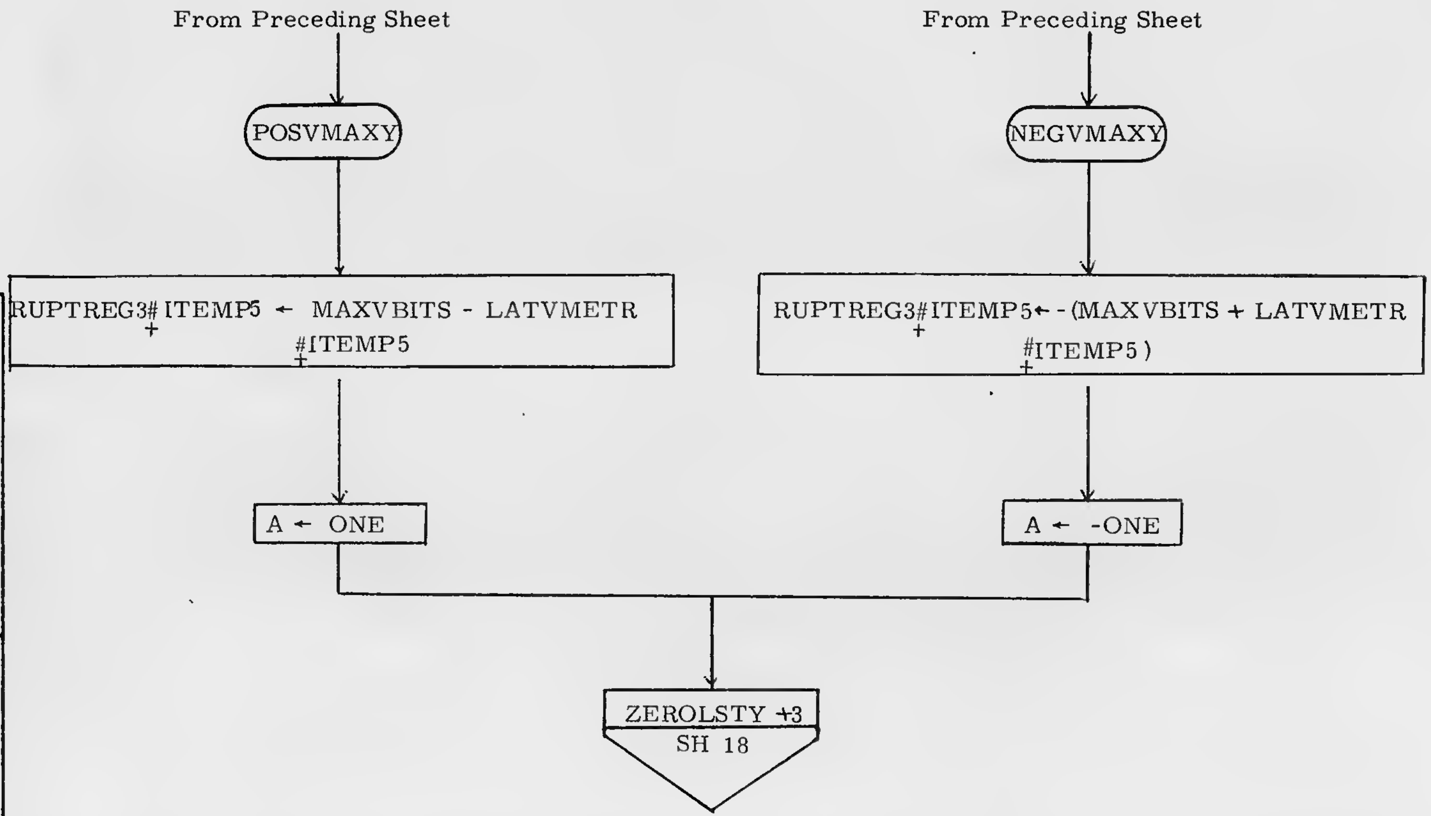
PRGMR D Bernikowich	10/29/69	LUMINARY 1D	DOCUMENT NO. FC-3030
ANALST			
DOCMR W Danforth	9/26/69		
APPR'D R.M. Evans	10/30/69	REV 2	SHEET 19 OF 21



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	9/26/6?	R09, R10, R11	
PRGMR	10/29/69	LUMINARY 1D	DOCUMENT NO. FC-3930
ANALST			
DOCMR	7/26/69		
APPR'D R. M.	10/29/69	REV 2	SHEET 20 OF 21

ROUTINES CALLED ON OTHER FLOWCHARTS

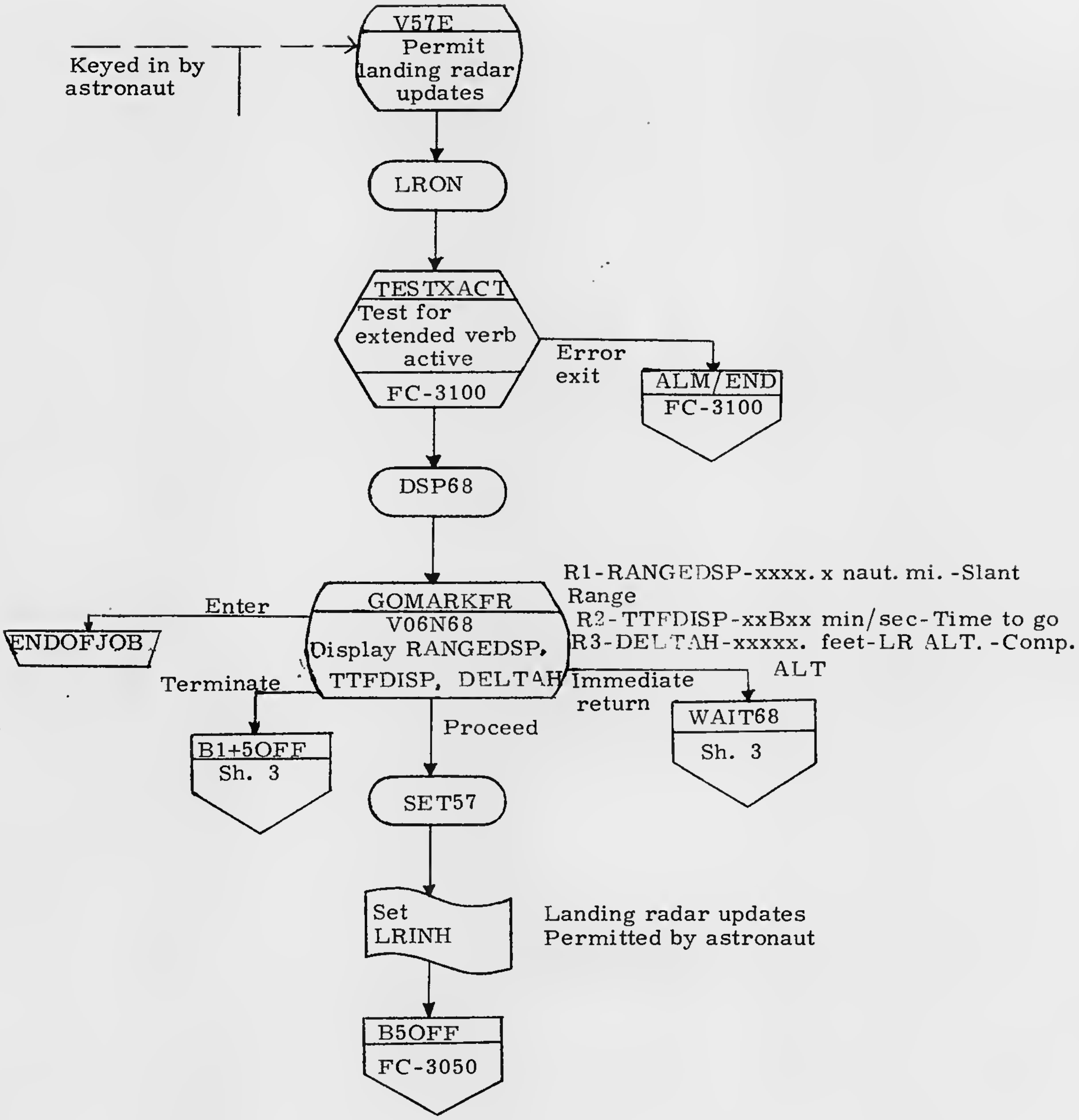
Routine	Flowchart	Description	Where Called
VARDELAY	FC-3040	Wait specified time	Sh. 14
P71A	FC-3970	P71	Sh. 4
P70A	FC-3970	P70	Sh. 5

FLAG

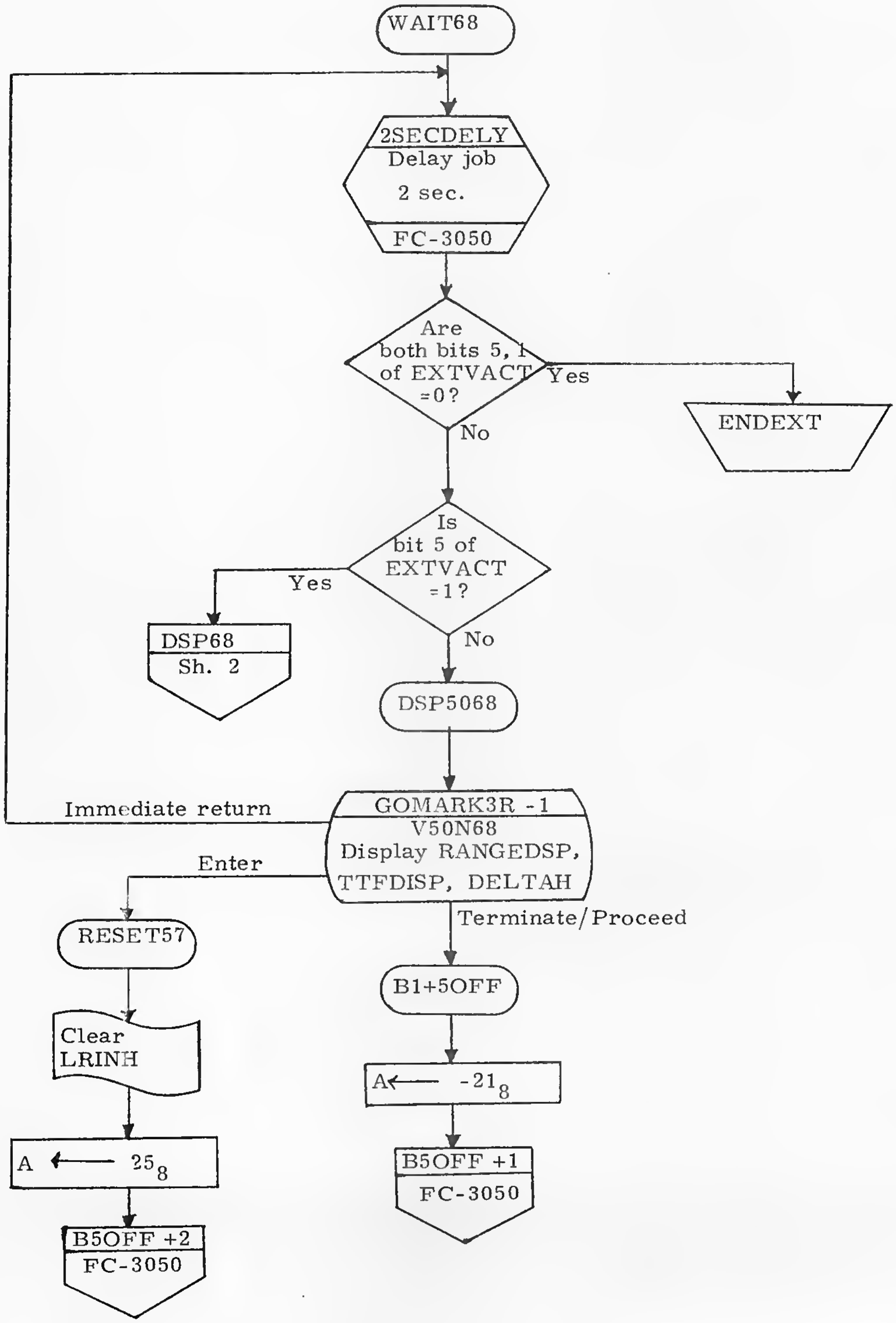
Name	Meaning When Set	Meaning When Cleared	Where Set	Where Cleared	Where Tested
AVEGFLAG Flag 7 Bit 5	AVERAGEG (SERVICER) desired	AVERAGEG (SERVICER) not desired			Sh. 2
HFLSHFLG Flag 11 Bit 1	LR altitude fail lamp should be flashing	LR altitude fail lamp should not be flashing			Sh. 3
VFLSHFLG Flag 11 Bit 2	LR velocity fail lamp should be flashing	LR velocity fail lamp should not be flashing			Sh. 3
LETABORT Flag 9 Bit 9	Abort programs are enabled	Abort programs are not enabled			Sh. 4
R10FLAG Flag 0 Bit 2	R10 outputs data to altitude and altitude rate meters only	Besides output when set, also to forward and lateral velocity crosspointer			Sh. 11 12 16
DIDFLAG	Inertial data is available	Perform data display initialization functions	Sh. 12	Sh. 11	Sh. 12

R12 - DESCENT STATE VECTOR UPDATE

MAJOR SUBROUTINES ON THIS CHART

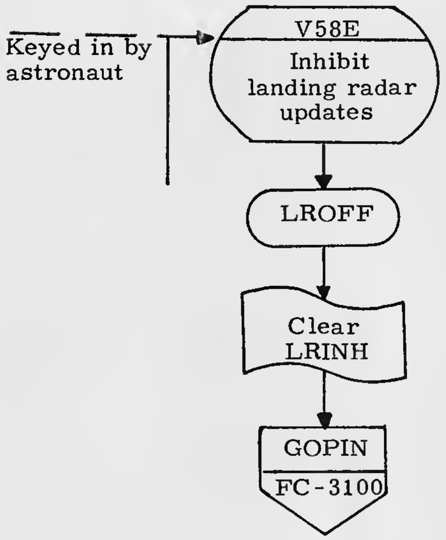


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN G. Welch	9/23/69	R12 - Descent State Vector Update	
PRGMR D. Moore	12/1/69		
ANALST		NUMBER 1D	DOCUMENT NO. FC-3925
DOCMR W. Danforth	10/30/69		
APPR'D Roberta M. Estes	12/1/69	REV 2	SHEET 2 OF 35



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A. Welch	10/23/68	R12 - Descent State Vector Update	
PRGMR D. Moore	12/1/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3935
DOCMR W. Dyforth	10/30/69		
APPR'D Roberta M. Erte	12/1/69	REV 2	SHEET 3 OF 35

EXTENDED VERB 58



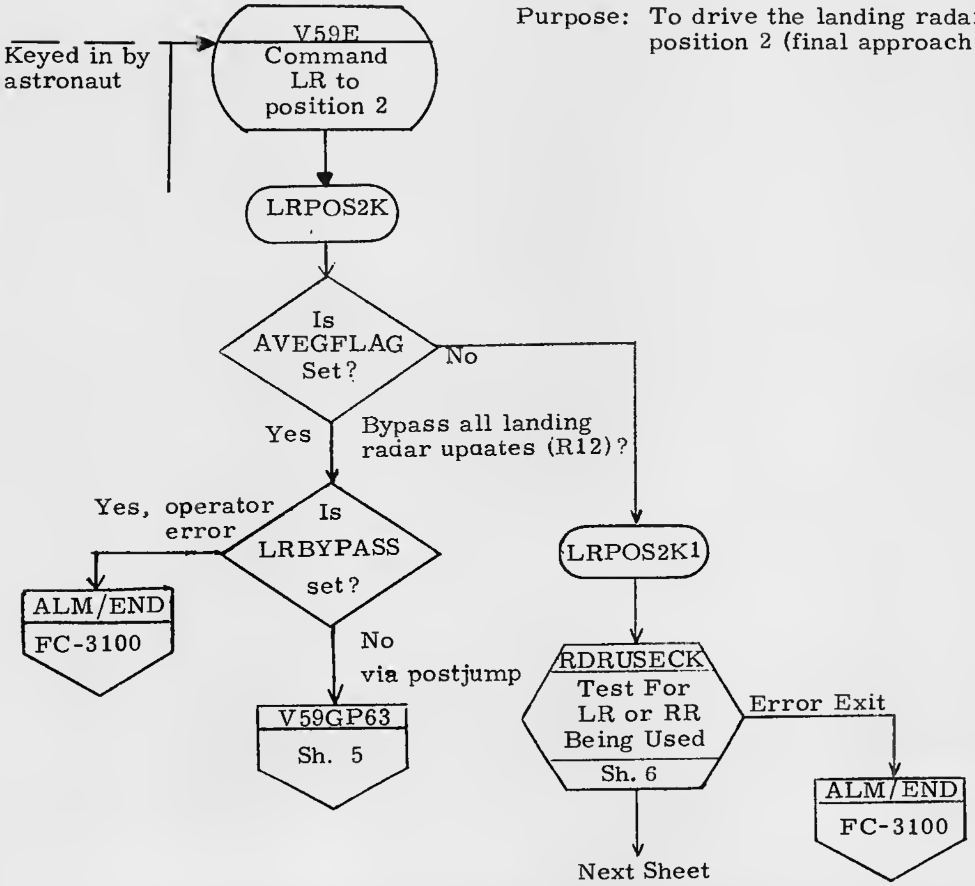
Purpose: To inhibit the incorporation of landing radar data during descent state vector update

Landing radar updates inhibited by astronaut

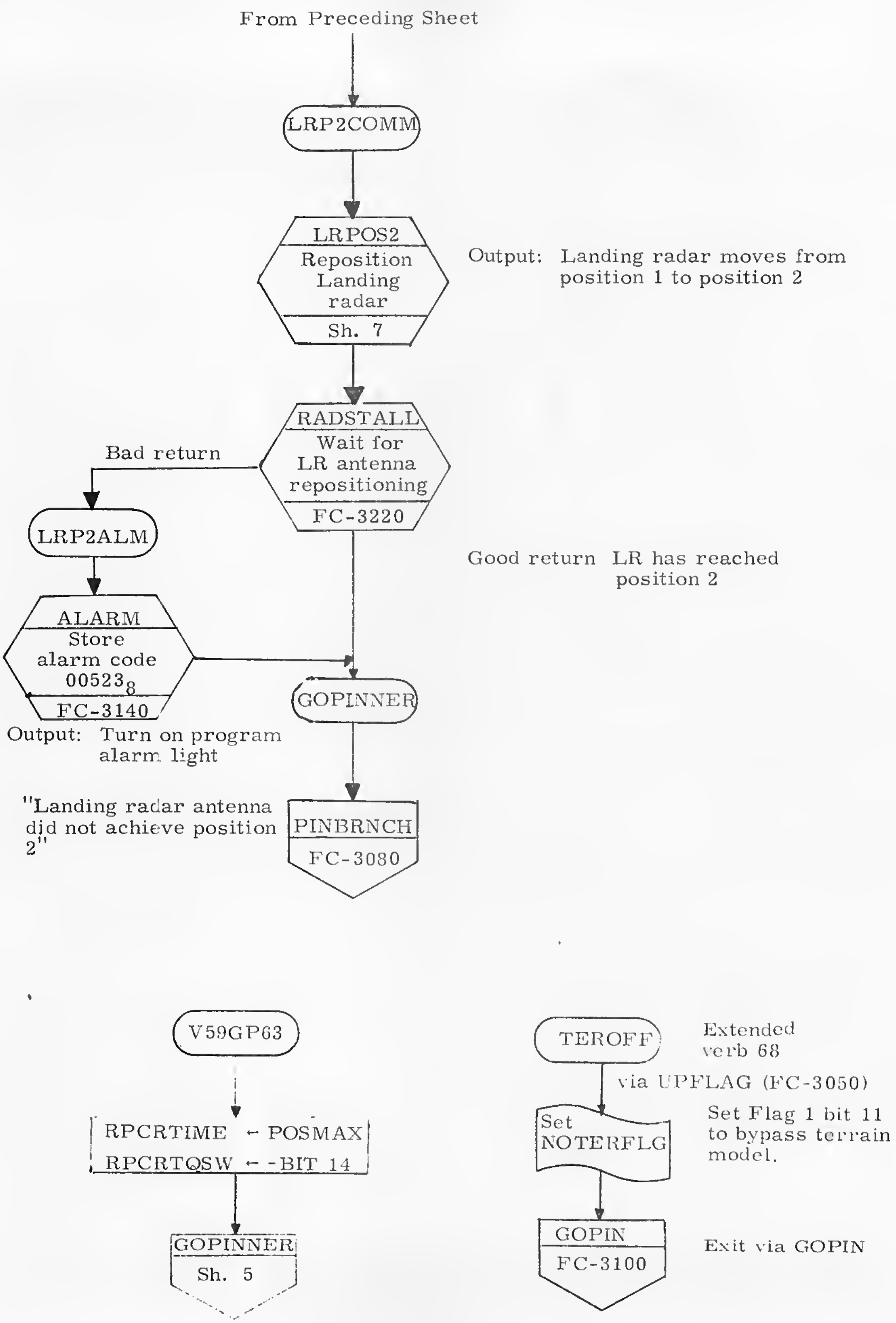
Exit via GOPIN

EXTENDED VERB 59

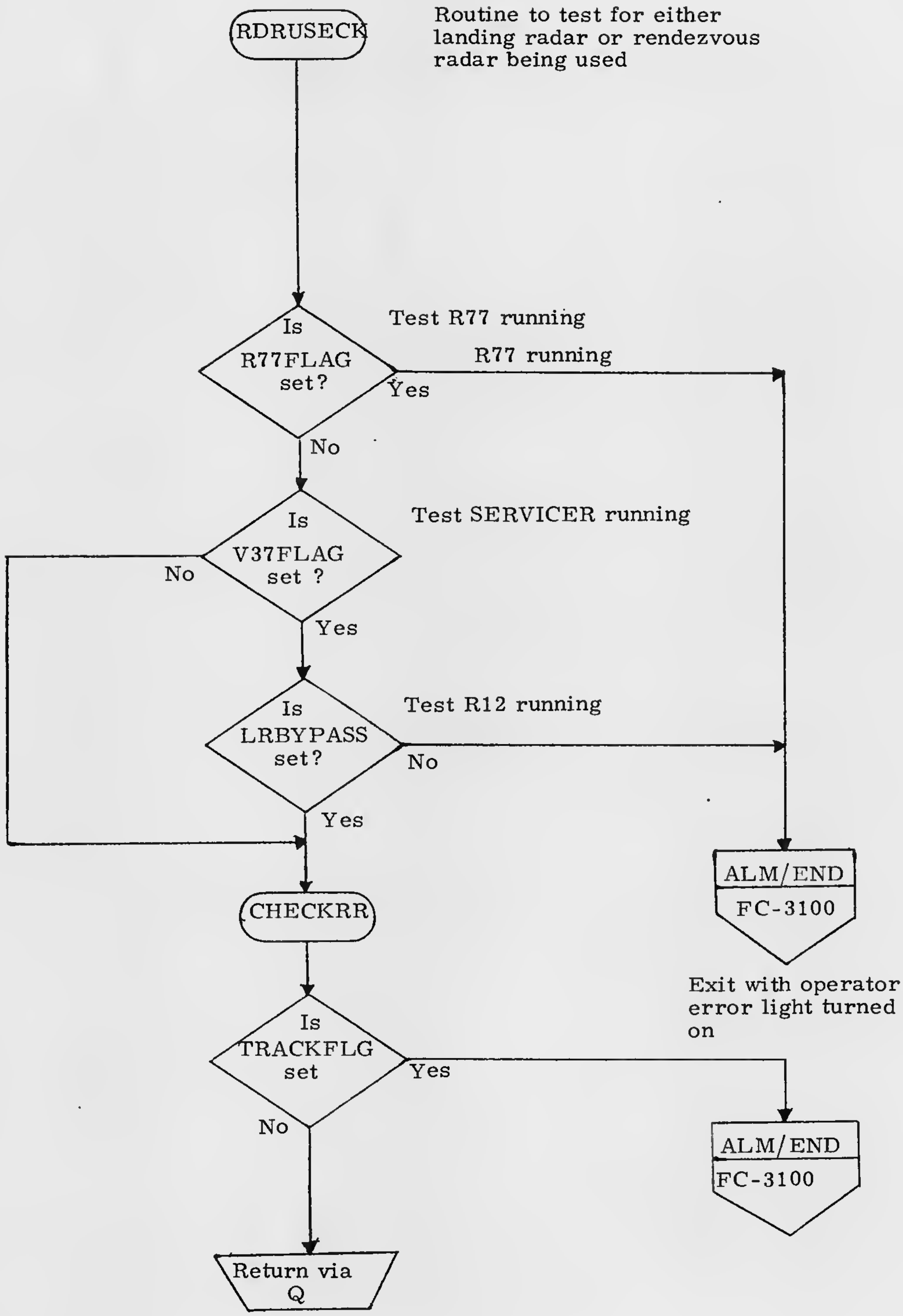
Purpose: To drive the landing radar to position 2 (final approach)



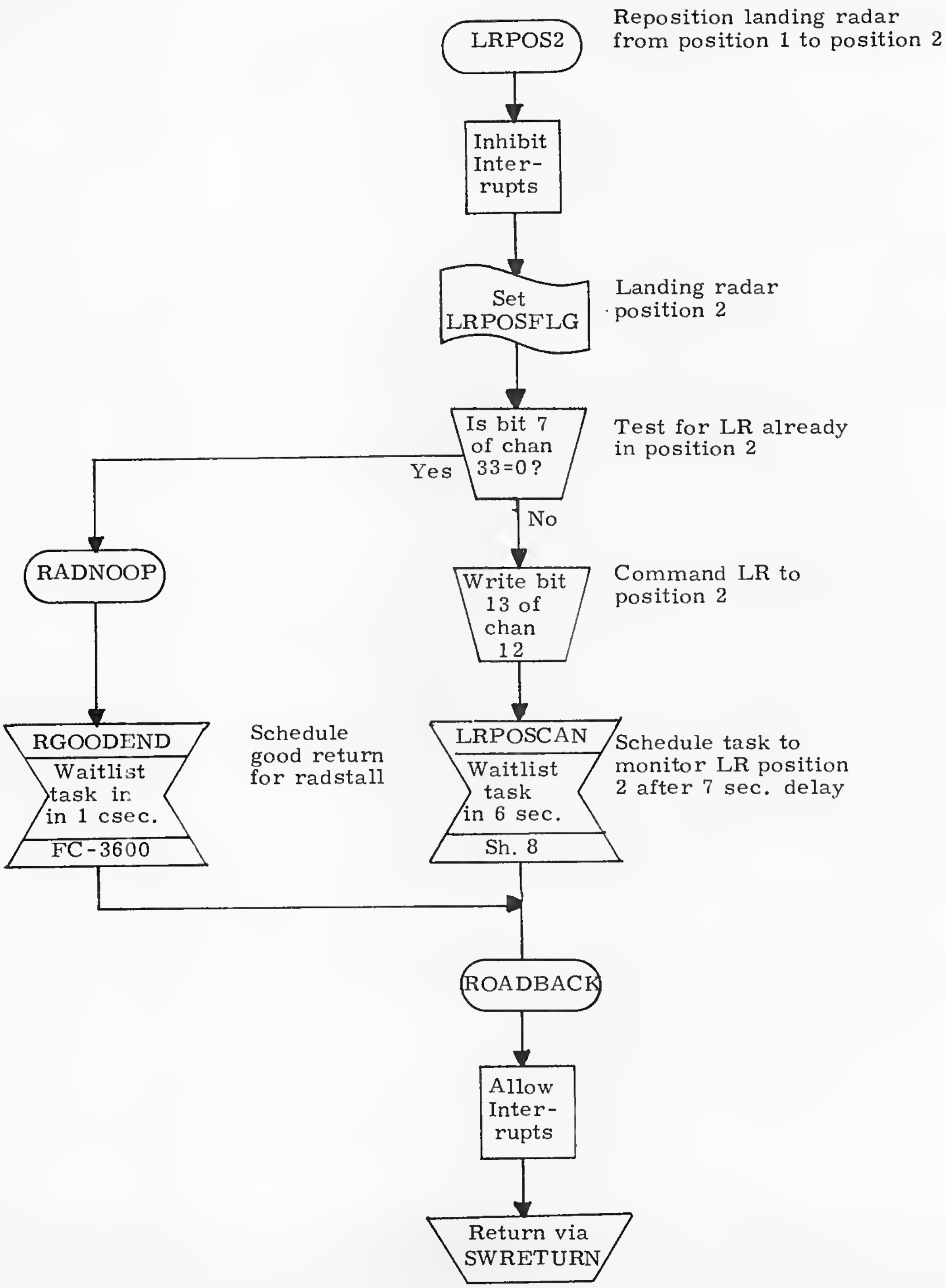
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN R. Welch	12/2/69	R12 - Descent State Vector Update
PRGMR D. Moore	12/1/69	
ANALST		LUMINARY 1D — DOCUMENT NO. FC-3935
DOCMR W Danforth	10/30/69	
APPR'D Roberta M. Eutzer	12/1/69	REV 2 — SHEET 4 OF 35



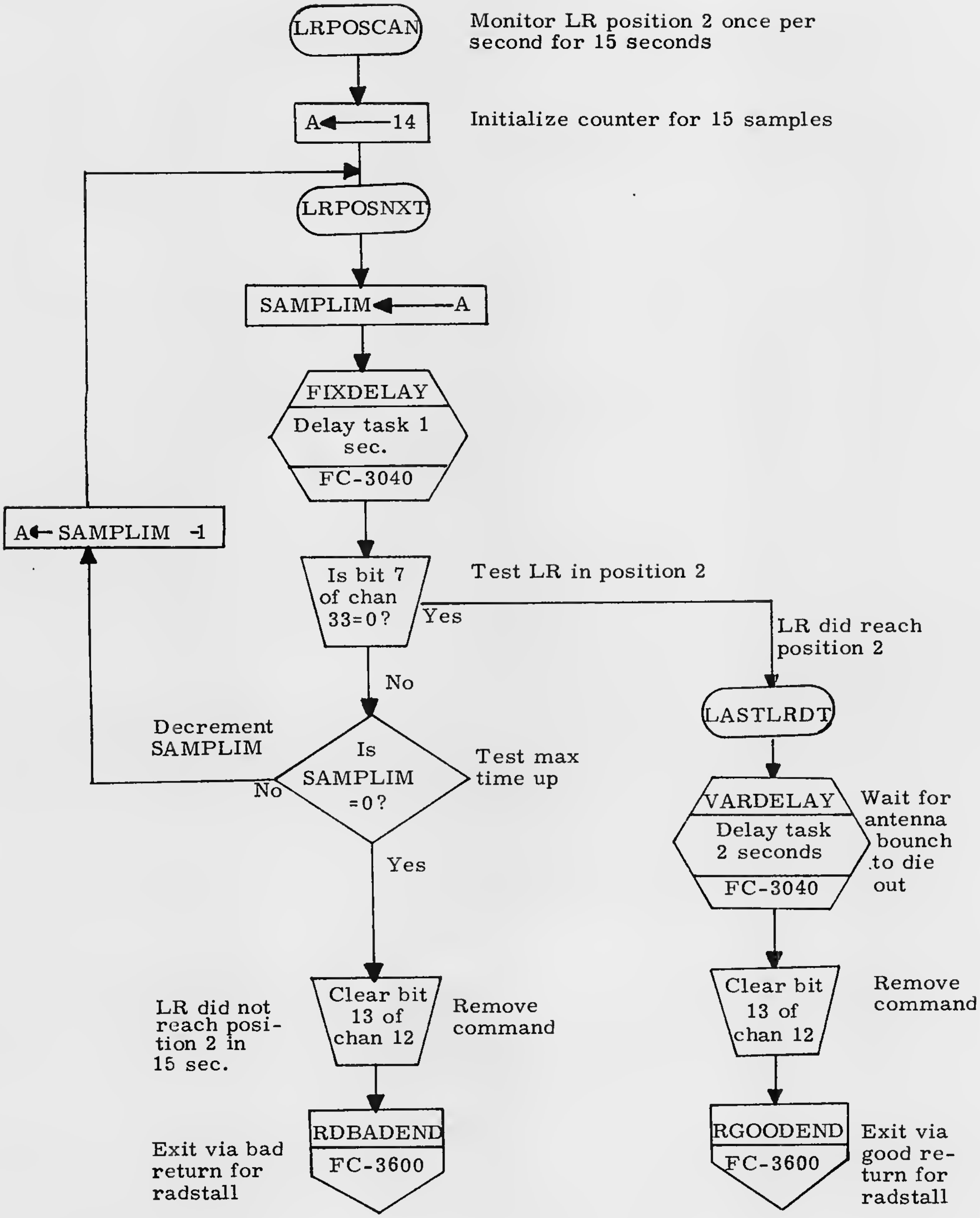
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Welch	10/23/69	R12 - Descent State Vector Update	
PRGMR D. Moore	12/1/69		
ANALST			DOCUMENT NO.
DOCMR W Dayhith	10/30/69	LUMINARY 1D	FC-3935
APPR'D Roberta M. Estes	12/1/69	REV 2	SHEET 5 OF 35



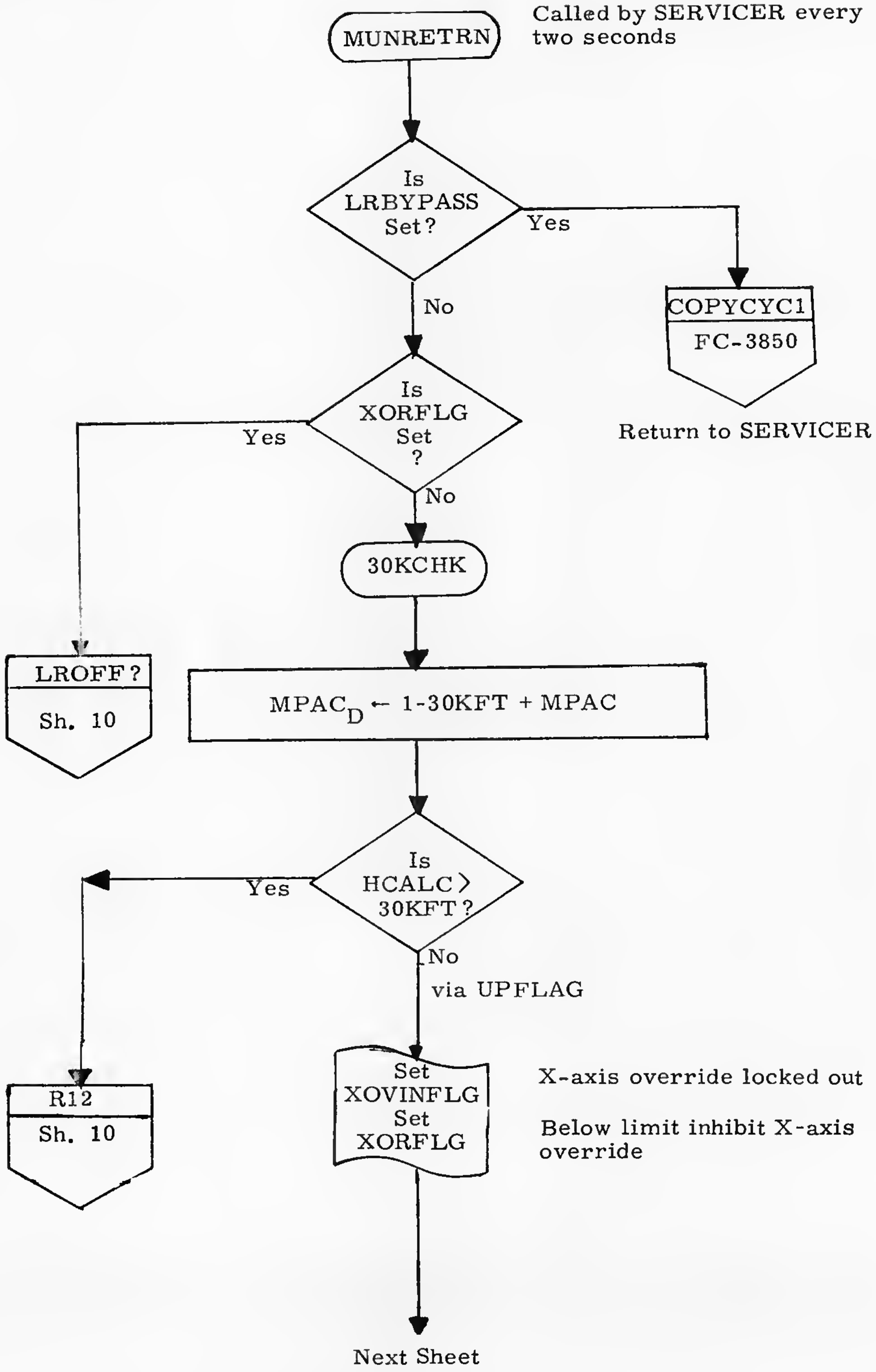
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Welch	10/29/69	R12 - Descent State Vector Update	
PRGMR D. Moore	12/1/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3935
DOCMR W Dysforth	10/30/69		
APPR'D R.M. Estes	12/1/69	REV 2	SHEET 6 OF 35



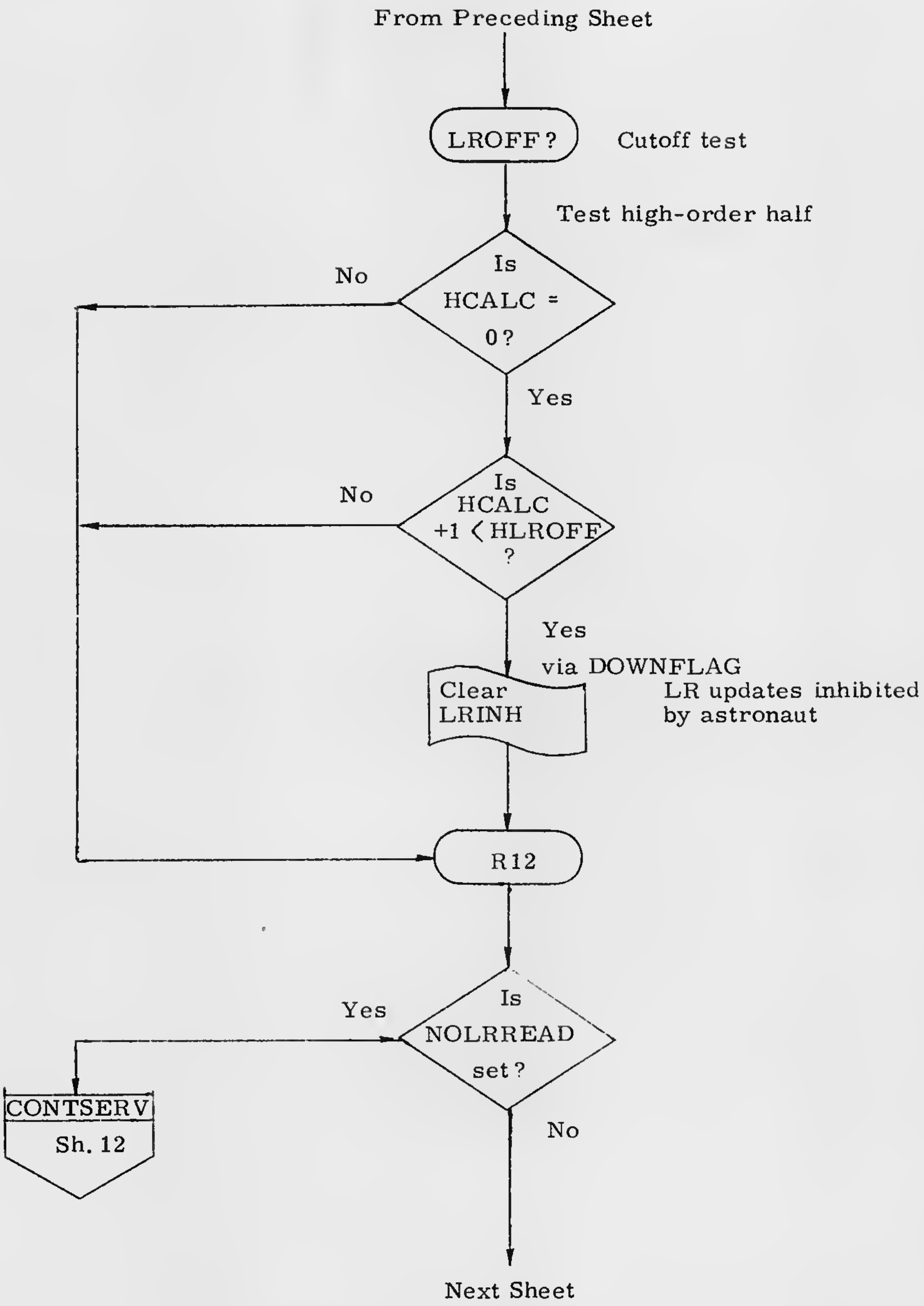
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Welch	10/23/69	R12 - Descent State Vector Update	
PRGMR D. Moore	12/1/69		DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3935
DOCMR W Dugforth	10/30/69		
APPR'D R.M. Ewing	10/1/67	REV 2	SHEET 7 OF 35



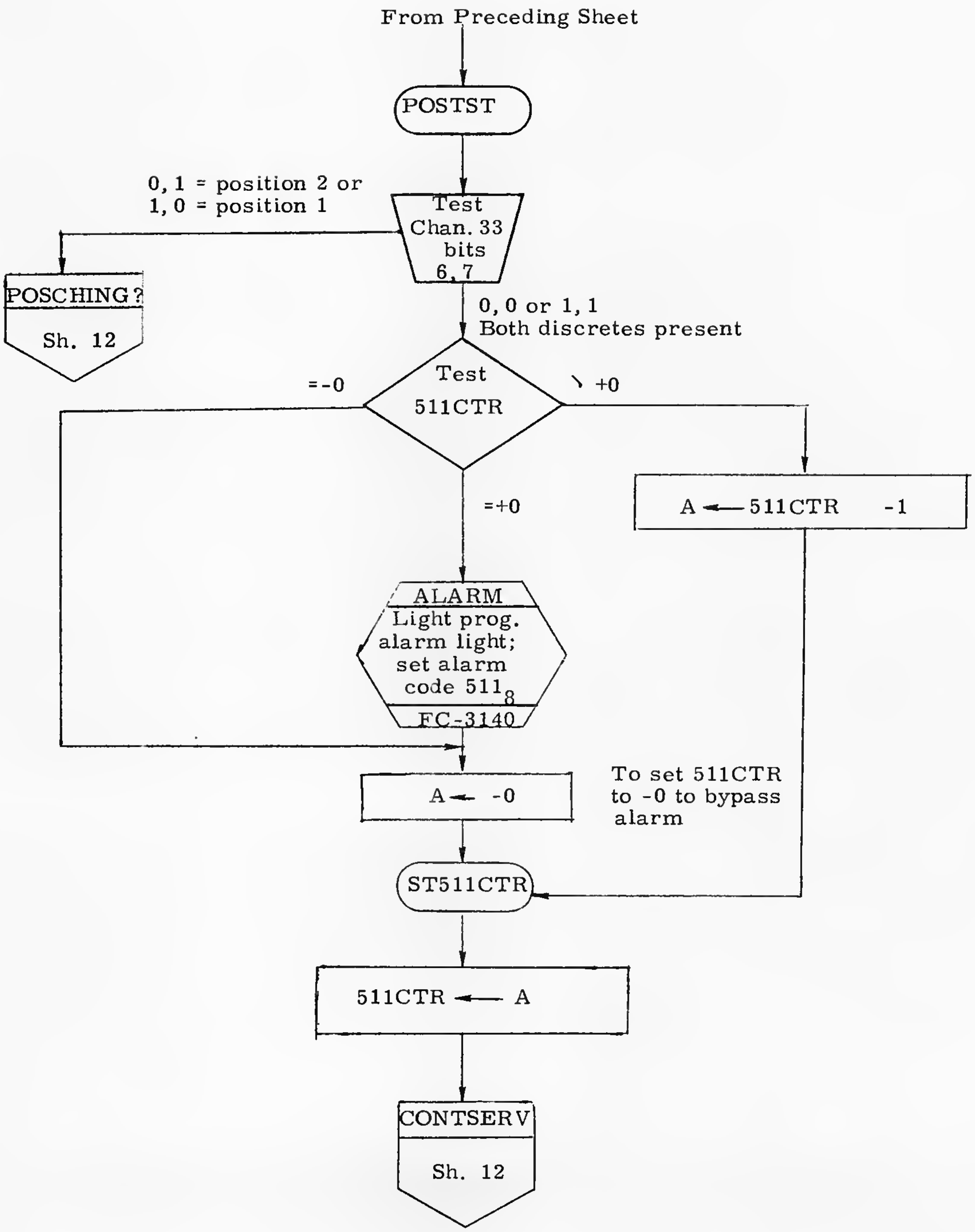
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Welch	11/29/69	R12 - Descent State Vector Update	
PRGMR De Moore	12/1/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3935
DOCMR W Danforth	12/09/69		
APPR'D R.M. Eates	12/1/69	REV 2	SHEET 8 OF 35



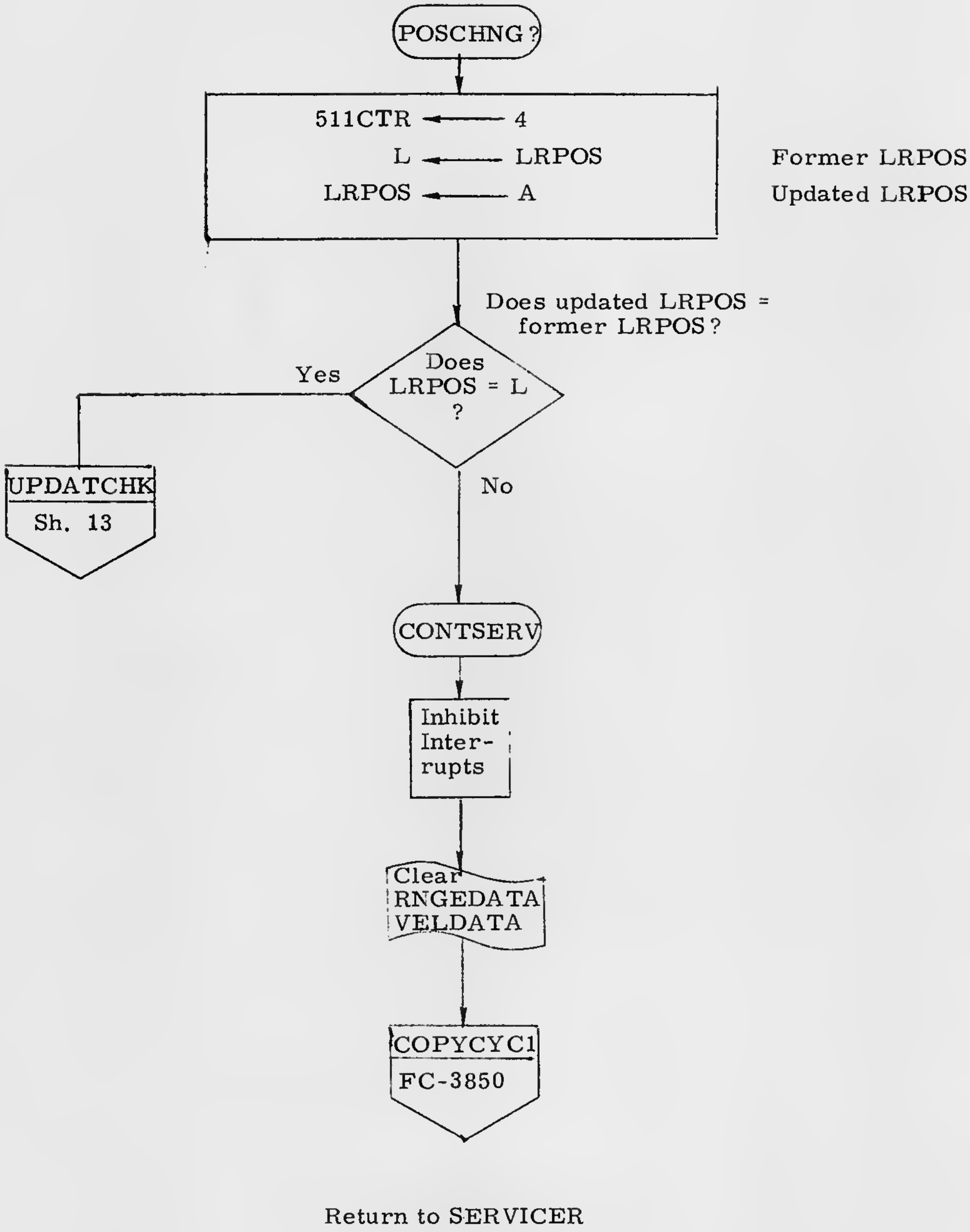
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Welch	10/23/69	R12 - Descent State Vector Update	
PRGMR D. Moore	12/1/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3935
DOCMR W. Danforth	11/24/69		
APPR'D R.M. Eaton	12/1/69	REV 2	SHEET 9 OF 35



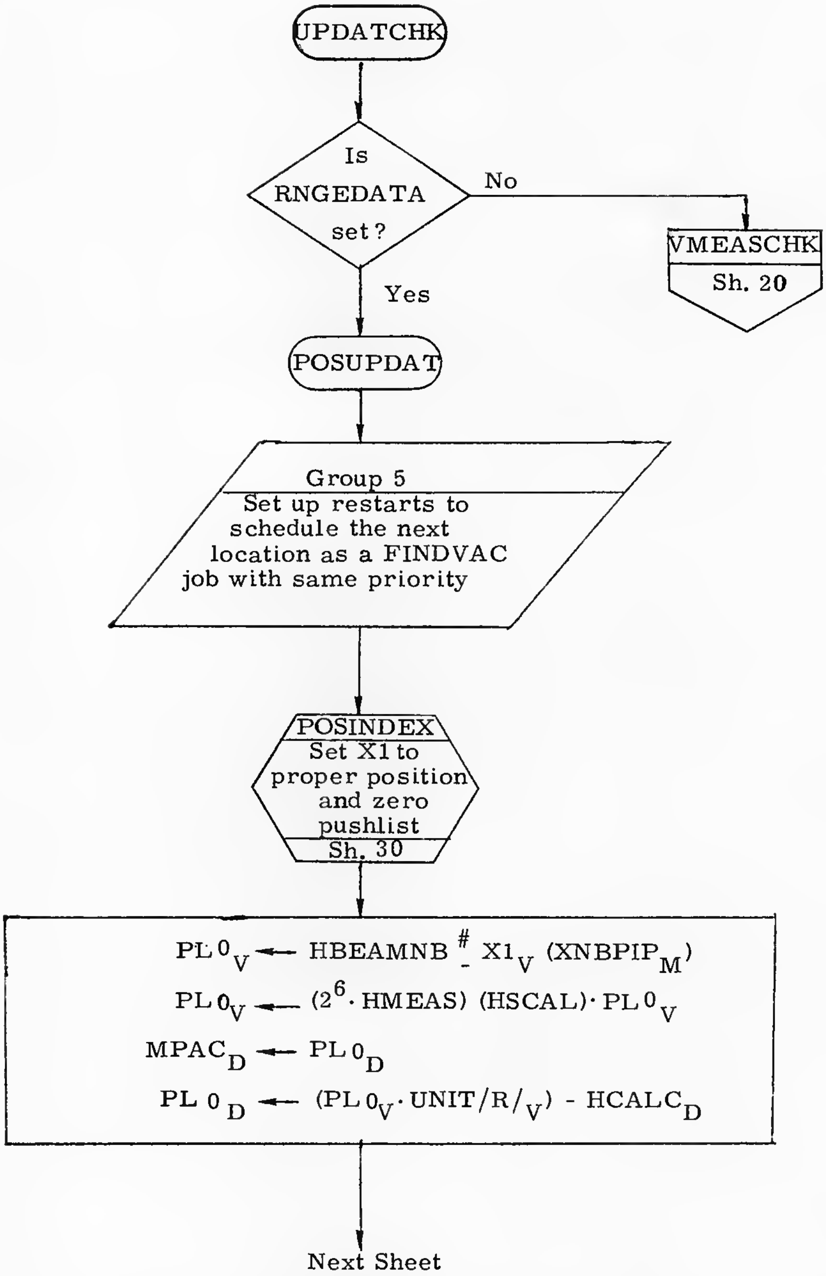
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E. Matta	6/12/70	R12 - Descent State Vector Update	
PRGMR J. Moore	6/12/70		DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3935
DOCMR W. Dootook	6/12/70		
APPR'D R. M. Entes	6/12/70	REV 2	SHEET 10 OF 35



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E. Motta	6/12/70	R12 - Descent State Vector Update	
PRGMR D. Moore	6/17/70		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3935
DOCMR W. Dentzel	6/17/70		
APPR'D R. M. Eaton	6/17/70	REV 2	SHEET 11 OF 35



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E. Matta	6/12/70	R12 - Descent State Vector Update	
PRGMR D Moore	6/17/70		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3935
DOCMR	6/17/70		
APPR'D	6/17/70	REV 2	SHEET 12 OF 35



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION		
DRAWN E. Matta	6/12/70	R12-Descent State Vector Update		
PRGMR D. Moore	6/17/70		DOCUMENT NO.	
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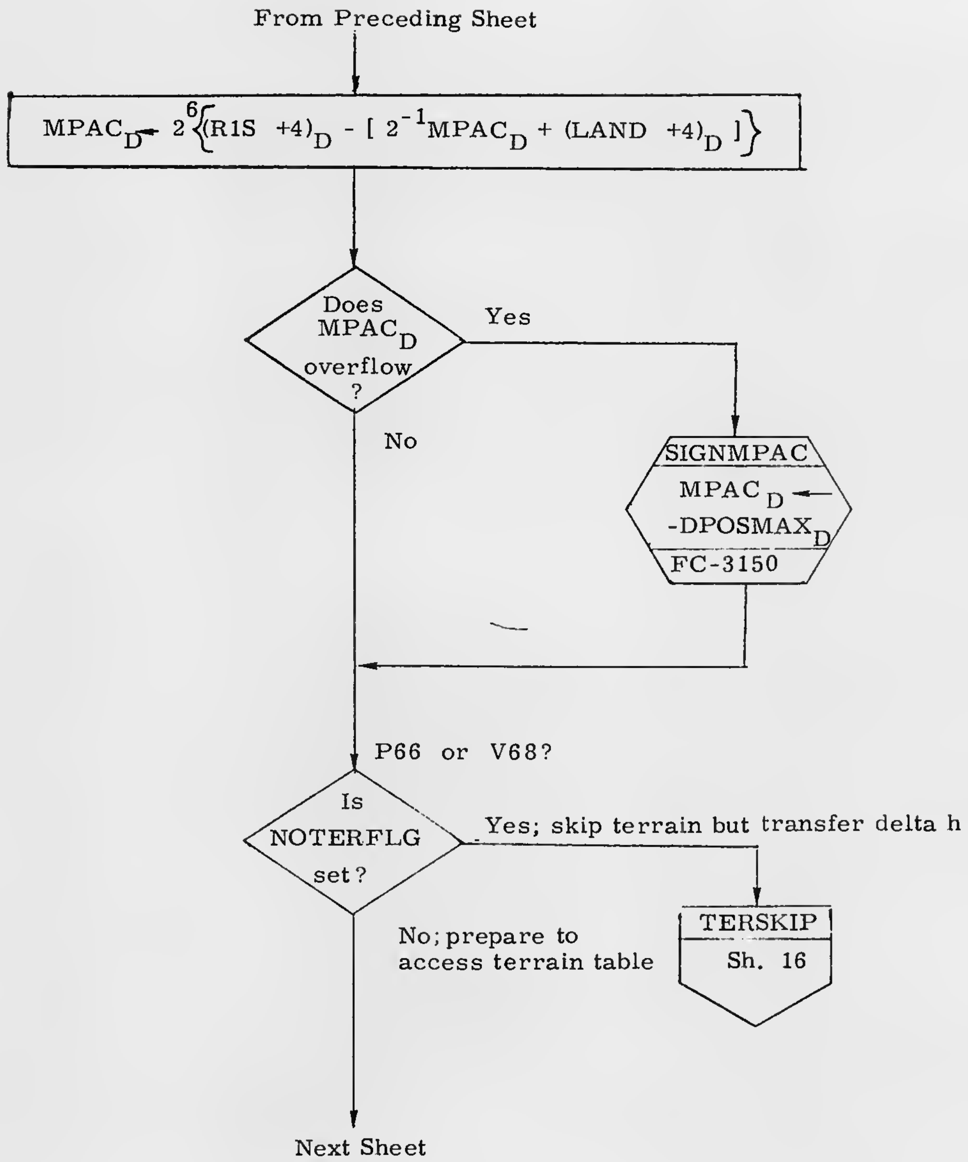
DOCMR	6/17/70			
APPR'D R M Ensten	6/17/70	REV 2		SHEET 13 OF 35



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
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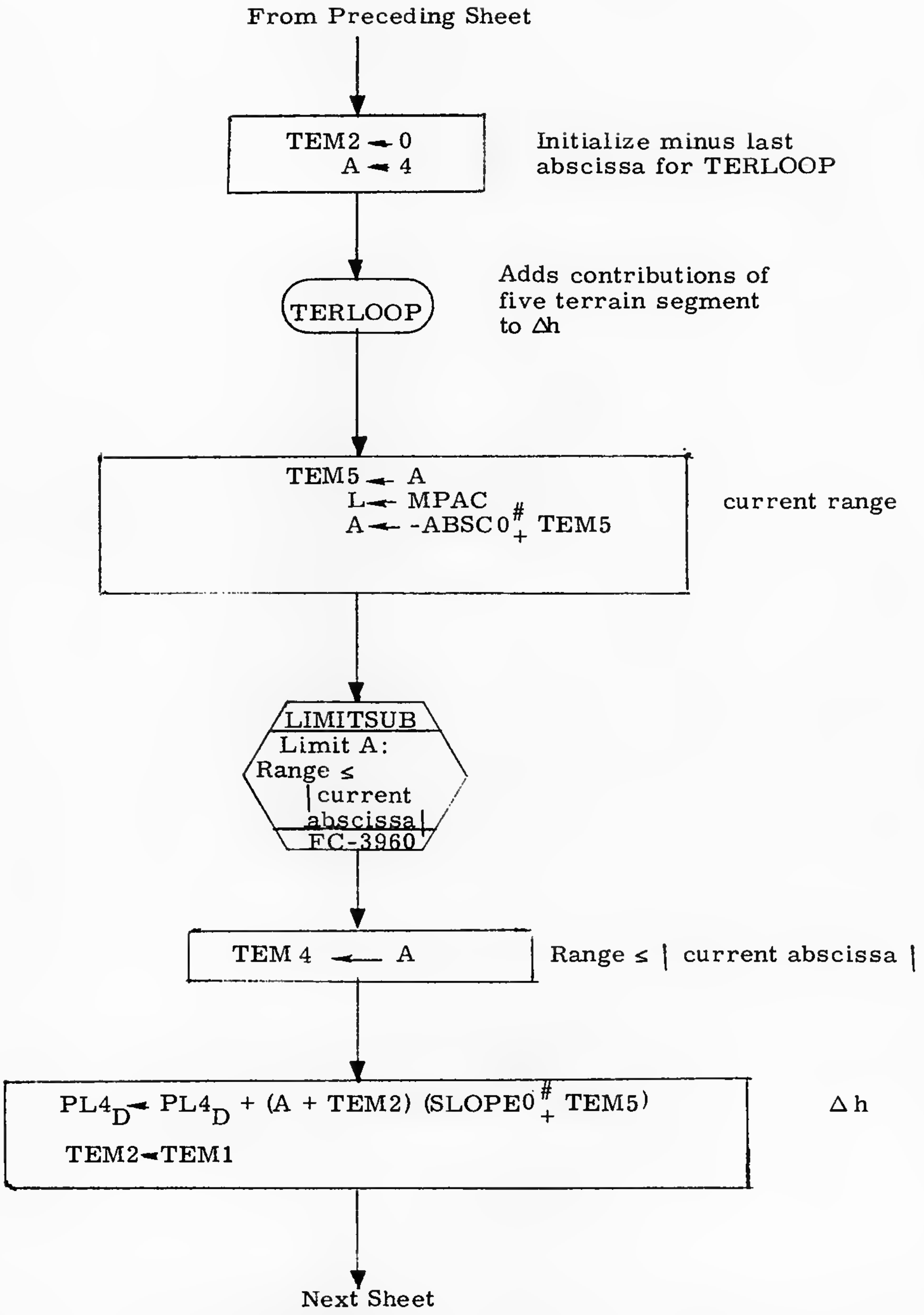
PRGMR A. Moore	6/17/70		DOCUMENT NO.
ANALST			
DOCMR W. Danforth	6/17/70	LUMINARY 1D	FC-3935
APPR'D R. M. Erton	6/17/70	REV 2	SHEET 14 OF 35



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E. Motta	6/12/70	R12 - Descent State Vector Update	
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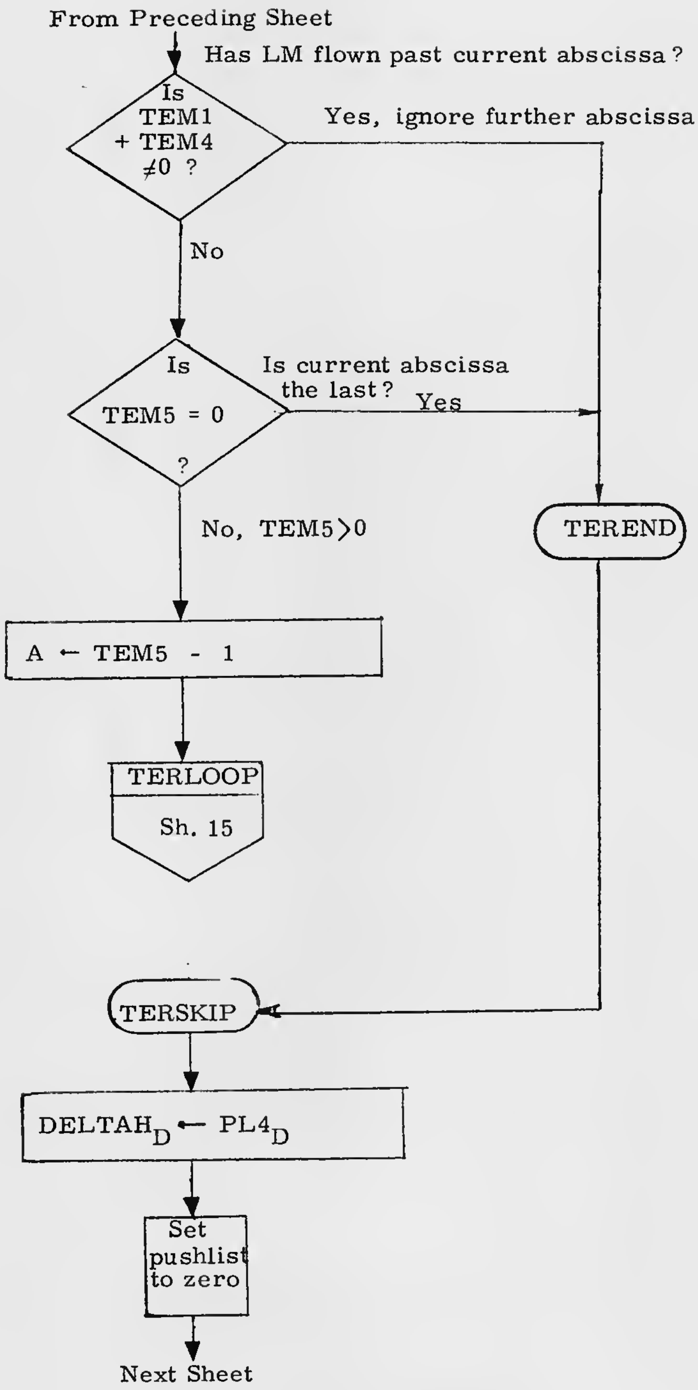
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3935
DOCMR N. Dofstd	6/17/70		
APPR'D R M Estes	6/17/70	REV 2	SHEET 15 OF 35



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
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ANALST			
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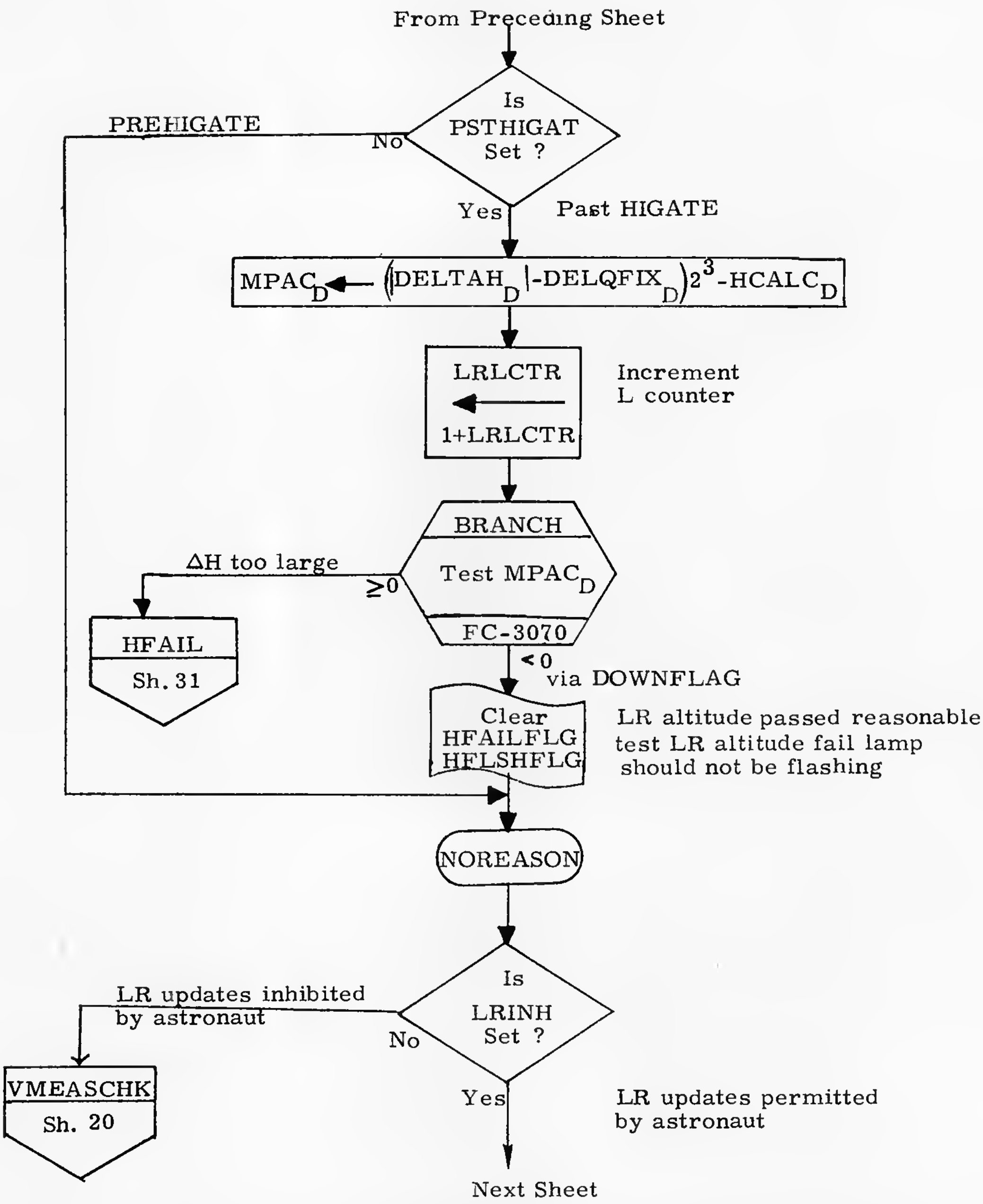
APPR'D [illegible]	6/17/70	REV 2	SHEET 16 OF 35



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	R. Welch 10/29/69	R12 - Descent State Vector Update	
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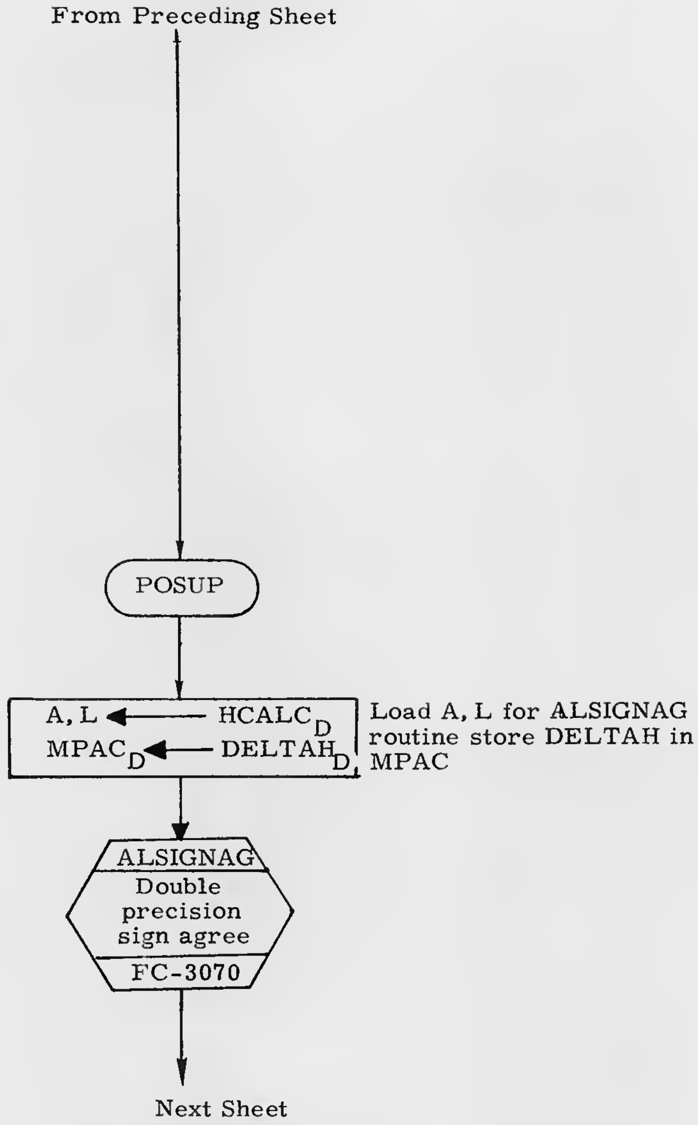
ANALST		LUMINAR 1D	DOCUMENT NO. FC-3935
DOCMR	W. Danforth 10/29/69		
APPR'D	R. M. Estes 12/1/69	REV 2	SHEET 17 OF 35



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
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PRGMR D Moore	3/7/70		
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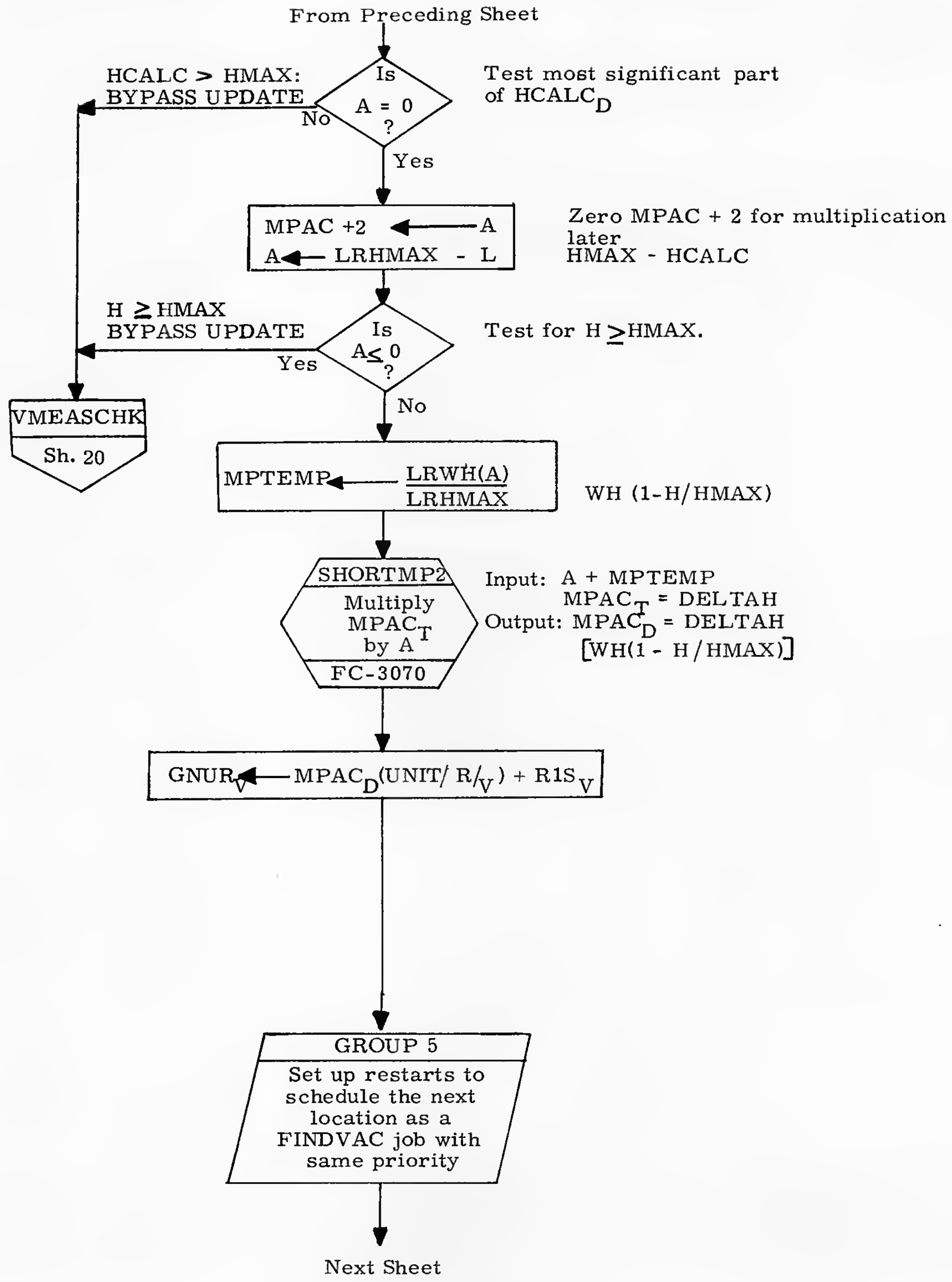
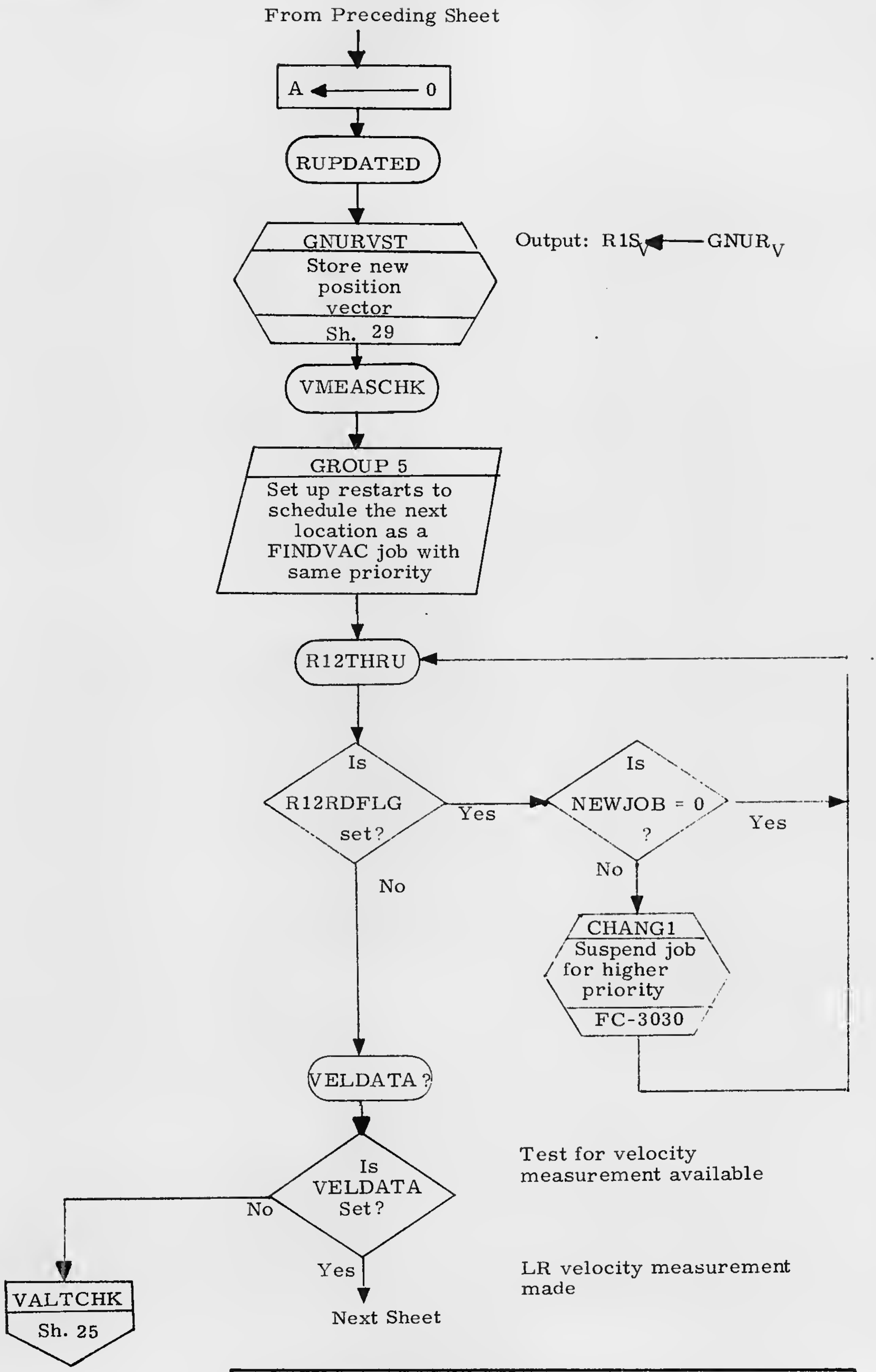
DOCMR W Danforth	3/5/70		
APPR'D RM Estes	3/9/70	REV 2	SHEET 18 OF 35



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Welch	10/23/69	R12 - Descent State Vector Update	
PRGMR D Moore	12/1/69		DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3935
DOCMR W Danforth	10/30/69		
APPR'D R.M. Sute	12/1/69	REV 2	SHEET 19 OF 35



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
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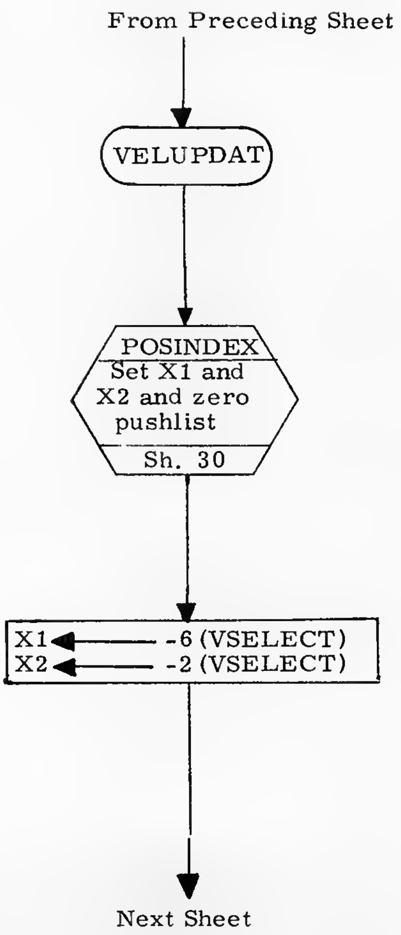
ANALST		LUMINARY 1D	FC 3935
DOCMR [illegible]	6/17/70		
APPR'D [illegible]	6/17/70	REV 2	SHEET 20 OF 35



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN B. Welch	10/23/69	R12 - Descent State Vector Update	
PRGMR D. Moore	12/1/69		DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3935
DOCMR W. Dugforth	10/31/69		
APPR'D R.M. Enter	12/1/69	REV 2	SHEET 21 OF 35

From Preceding Sheet

$MPAC_V \leftarrow (VZBEAMNB_V\#\ X\,1)\ (XNBPIP)$

$PL0_V \leftarrow MPAC_V$

$PL6_D \leftarrow VMEAS_D\ \ (VZSCAL\#\ X2)$

$PL12_V \leftarrow V1S_V + DELVS_V$

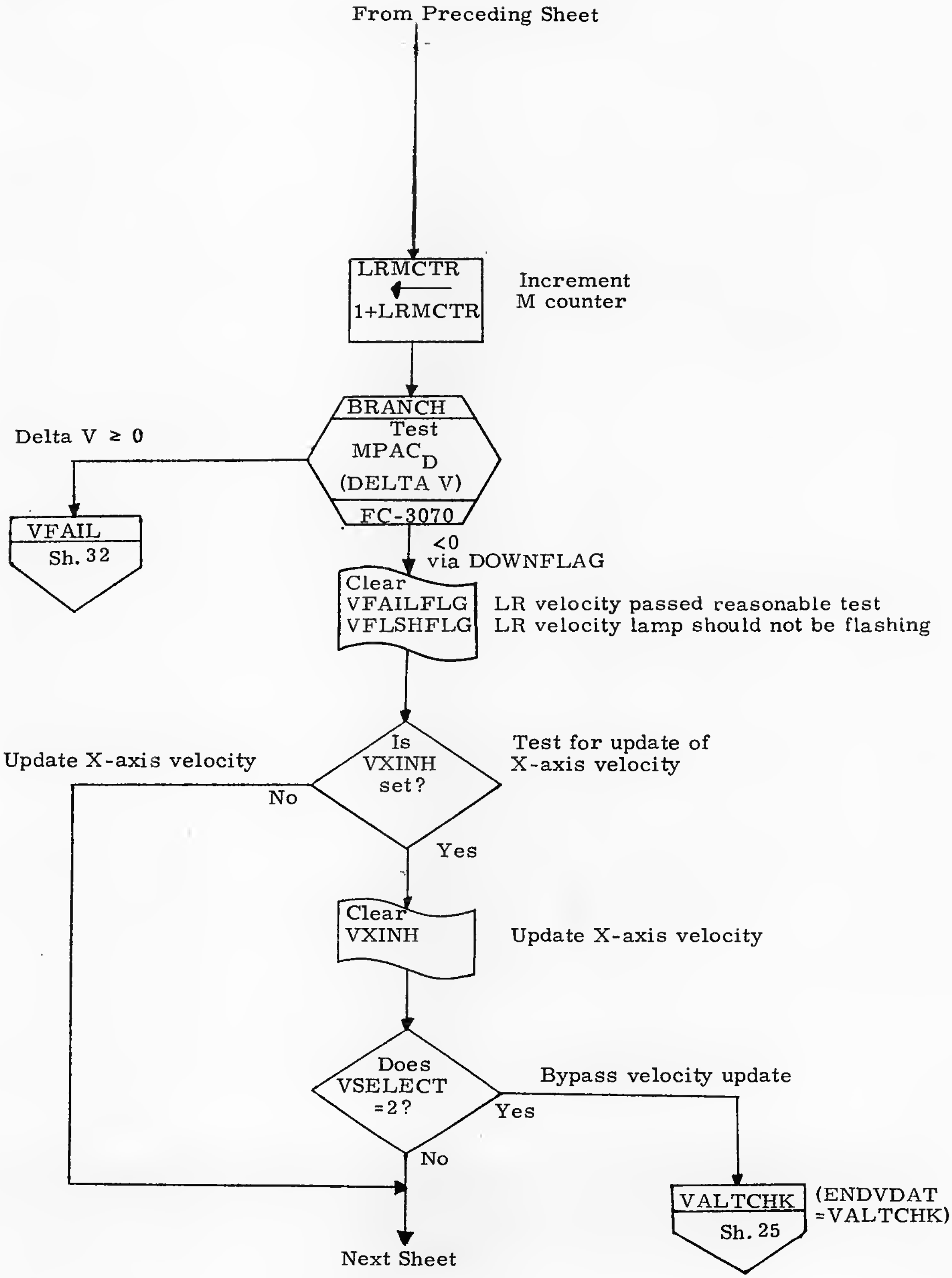
$PL20_V \leftarrow 2^{-3}\,|PL12_V| + VELBIAS_D$

$PL22_D \leftarrow PL20_D - (PL12_V \cdot PL0_V)$

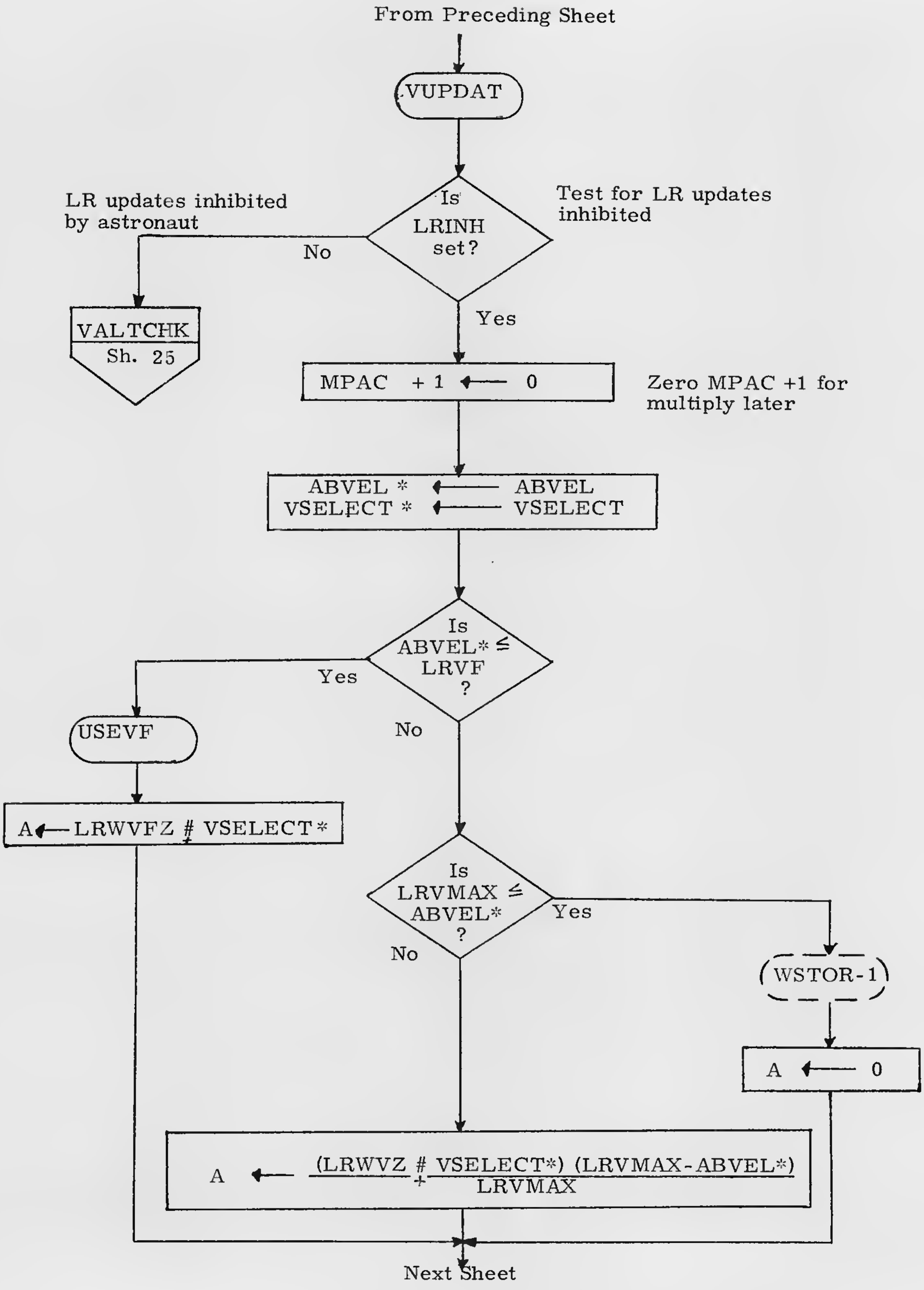
$MPAC_D \leftarrow |PL22_D| - PL20_D$

Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN G. Welch	10/23/69	R12 - Descent State Vector Update	
PRGMR D. Moore	12/1/69		DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3935
DOCMR W. Dayhuff	10/31/69		
APPR'D R. M. Enter	12/1/69	REV 2	SHEET 22 OF 35



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	G. Welch	10/23/69	R12 - Descent State Vector Update	
PRGMR	D Moore	12/1/69		
ANALST			LUMINARY 1D	DOCUMENT NO. FC-3935
DOCMR	W Dayhuff	11/3/69		
APPR'D	R.M. Eaton	12/1/1969	REV 2	SHEET 23 OF 35



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	R. Welch 10/23/69	R12 - Descent State Vector Update	
PRGMR	D Moore 12/1/69		DOCUMENT NO.
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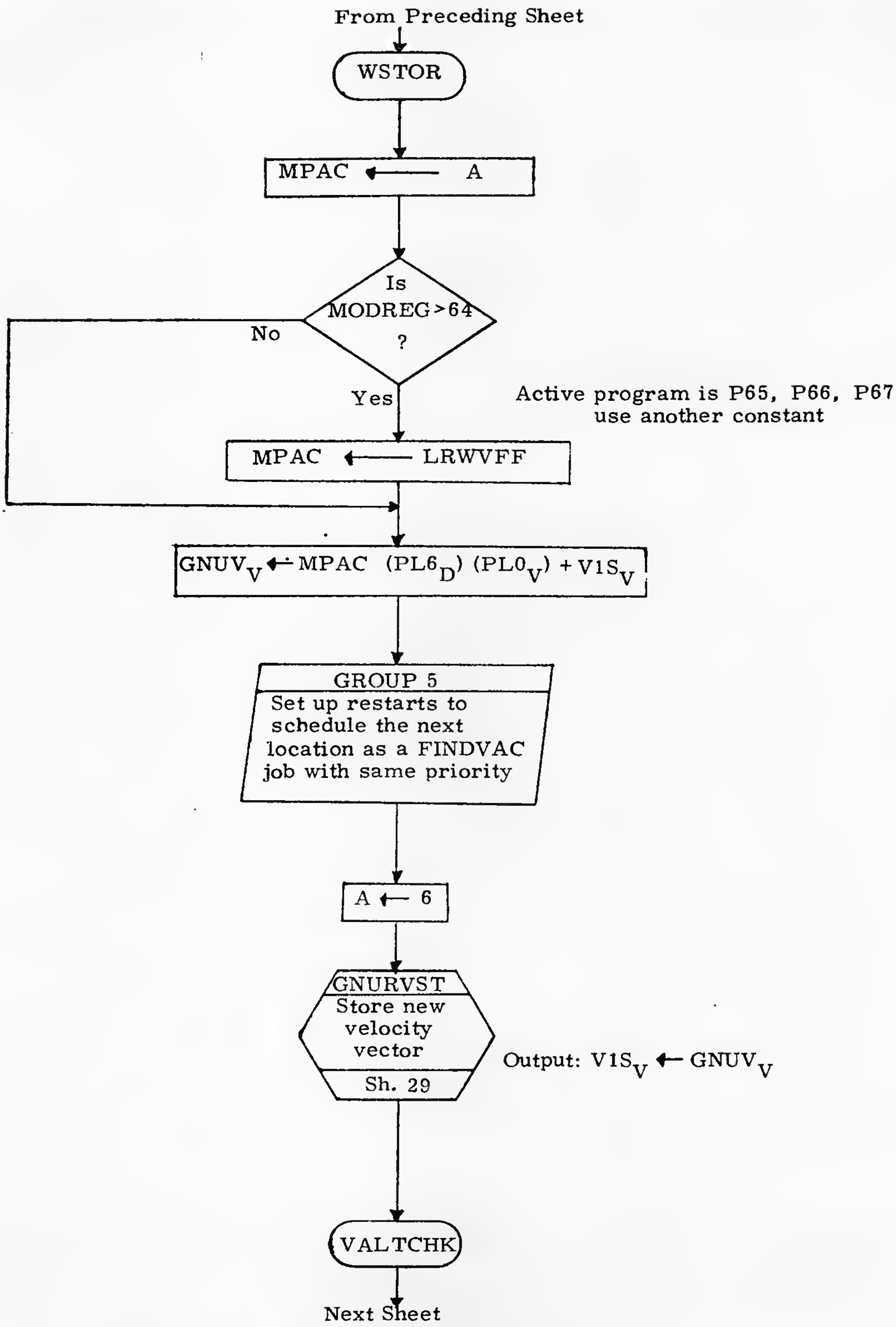
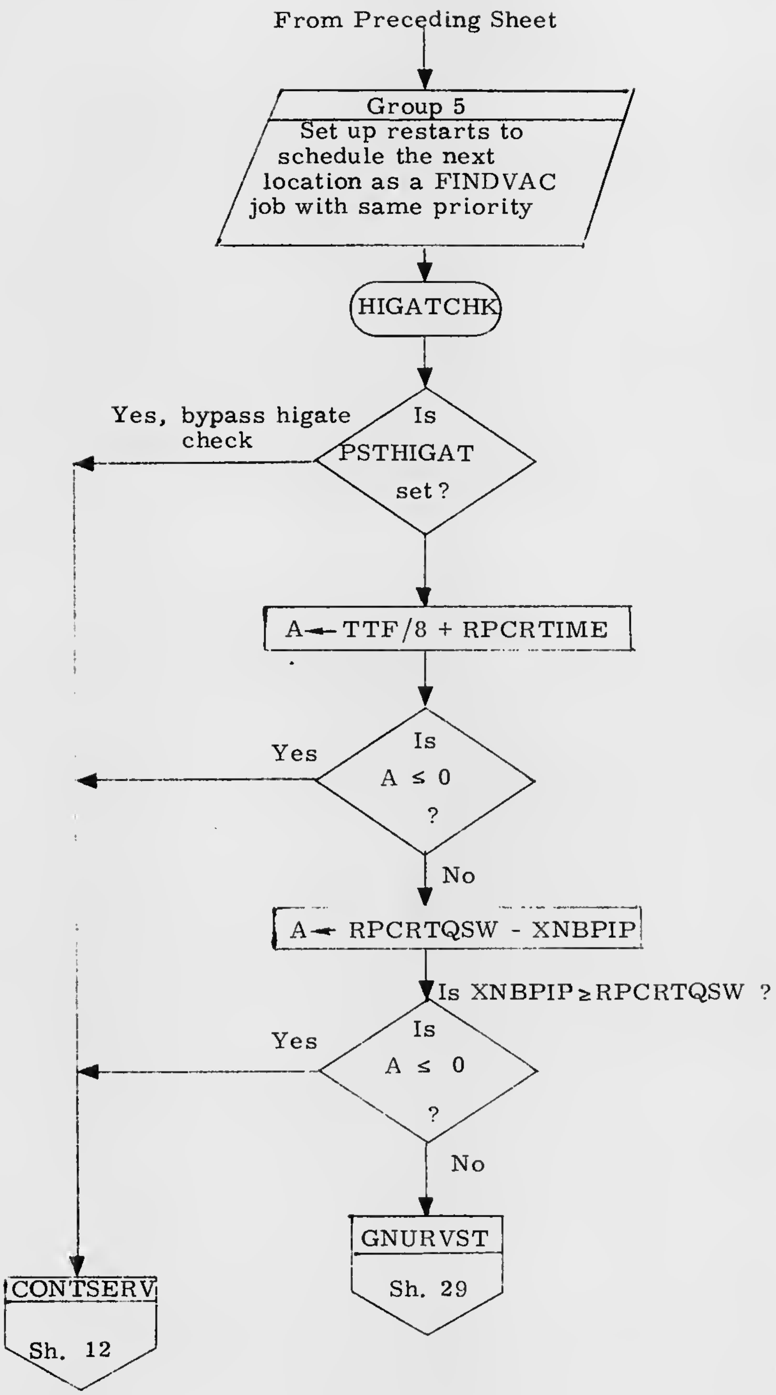
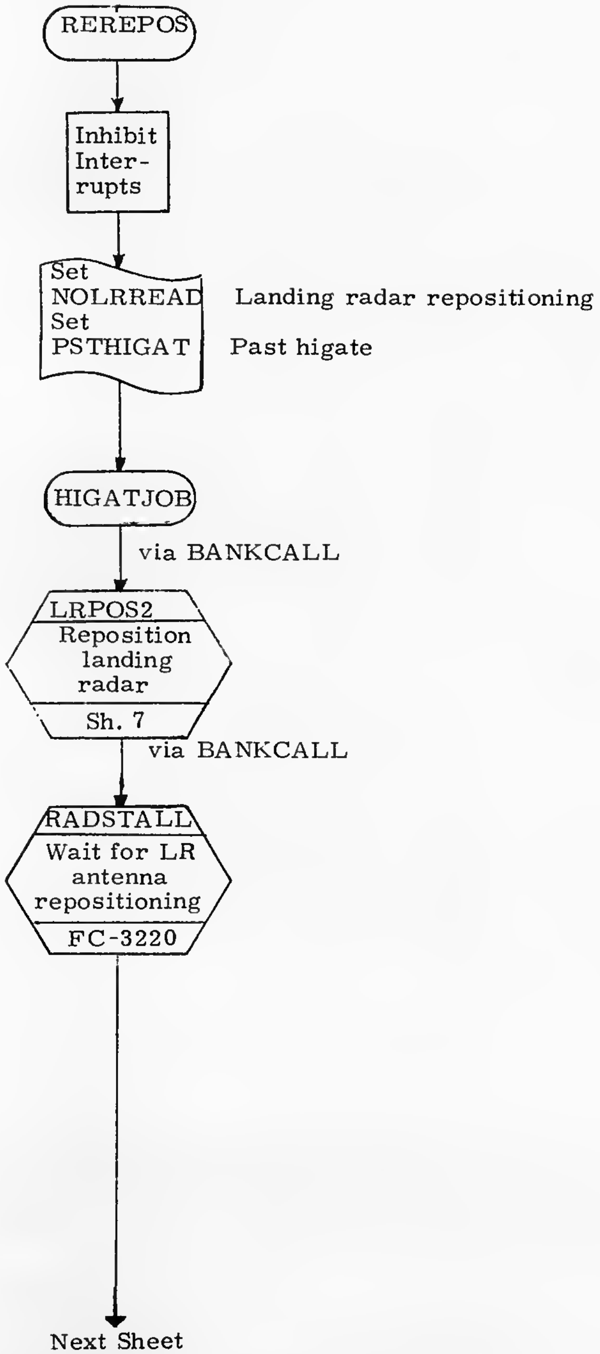
APPR'D	R.M. Enter 12/1/69	REV 2	SHEET 24 OF 35



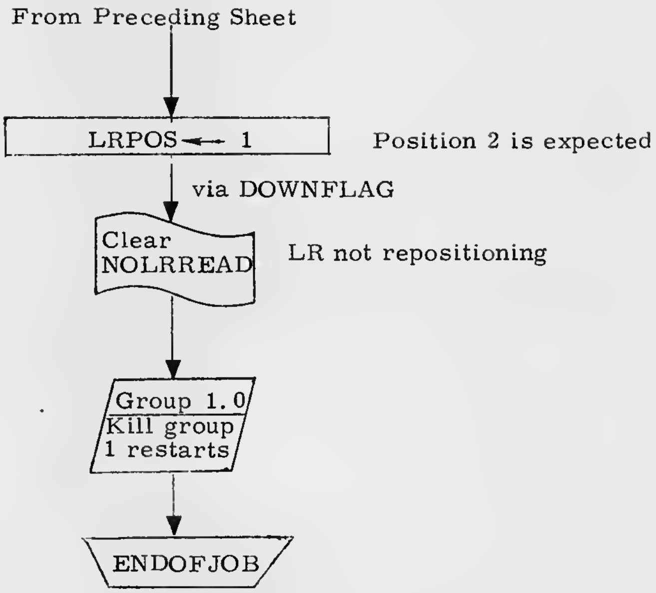
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN	10/23/69	R12 - Descent State Vector Update
PRGMR	12/1/69	
ANALST		LUMINARY 1D — DOCUMENT NO. C-3935
DOCMR	10/30/69	
APPR'D	12/1/69	REV 2 — SHEET 25 OF 35



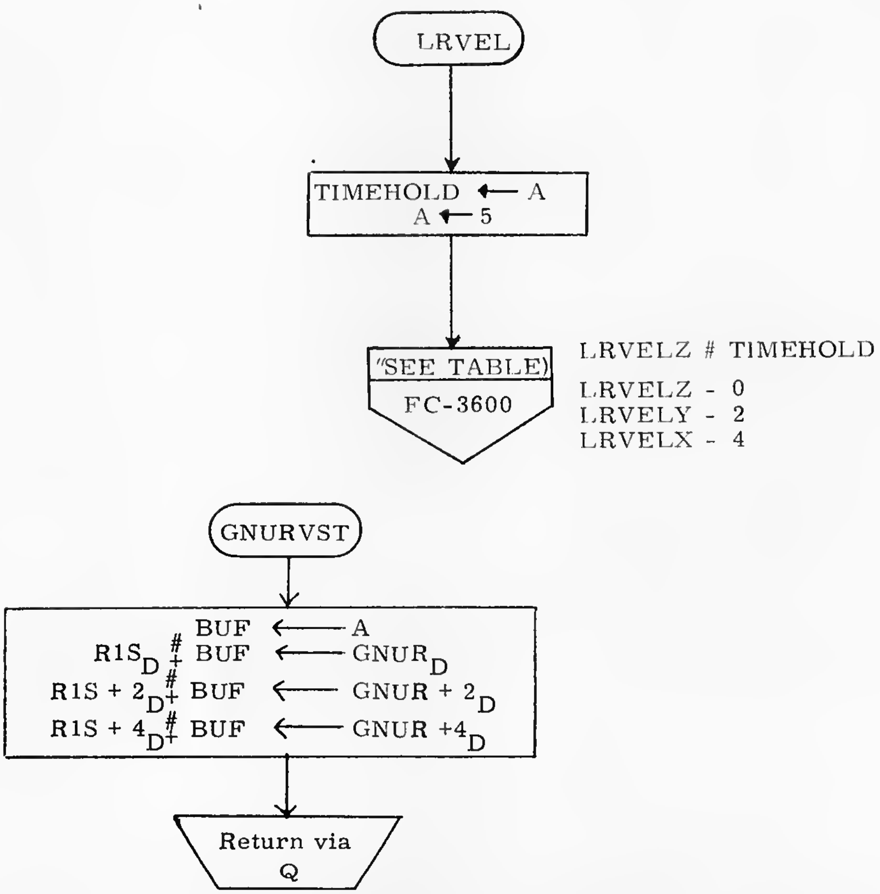
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E. Metts	6/15/70	R12-Descent State Vector Update	
PRGMR H. Moore	6/17/70		DOCUMENT NO.
ANALST			
DOCMR W. Dryfoot	6/17/70	LUMINARY 1D	FC-3935
APPR'D R. McEntee	6/17/70	REV 2	SHEET 26 OF 35

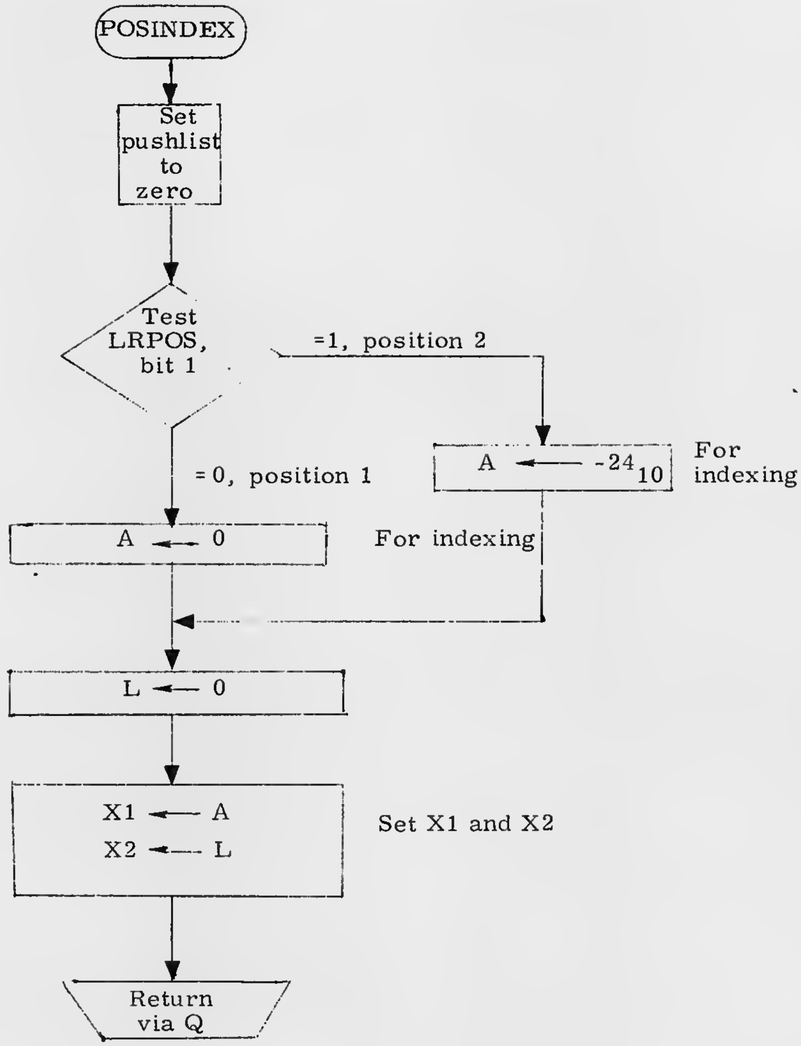


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Walsh	10/23/69	R12 - Descent State Vector Update	
PRGMR D Moore	12/1/69		DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3935
DOCMR W Danforth	10/31/69		
APPR'D RMEnte	12/1/69	REV 2	SHEET 27 OF 35

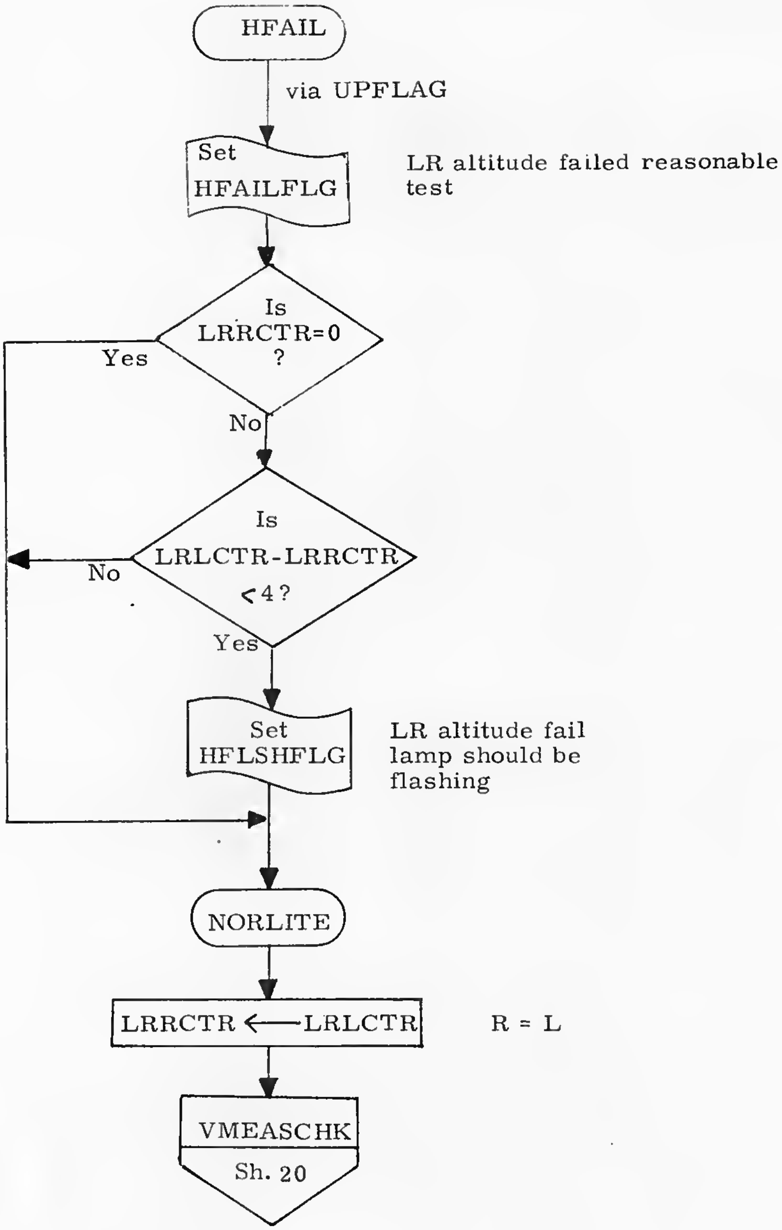


From Preceding Sheet
LRPOS ← 1
Position 2 is expected
via DOWNFLAG
Clear NOLRREAD
LR not repositioning
Group 1.0
Kill group 1 restarts
ENDOFJOB

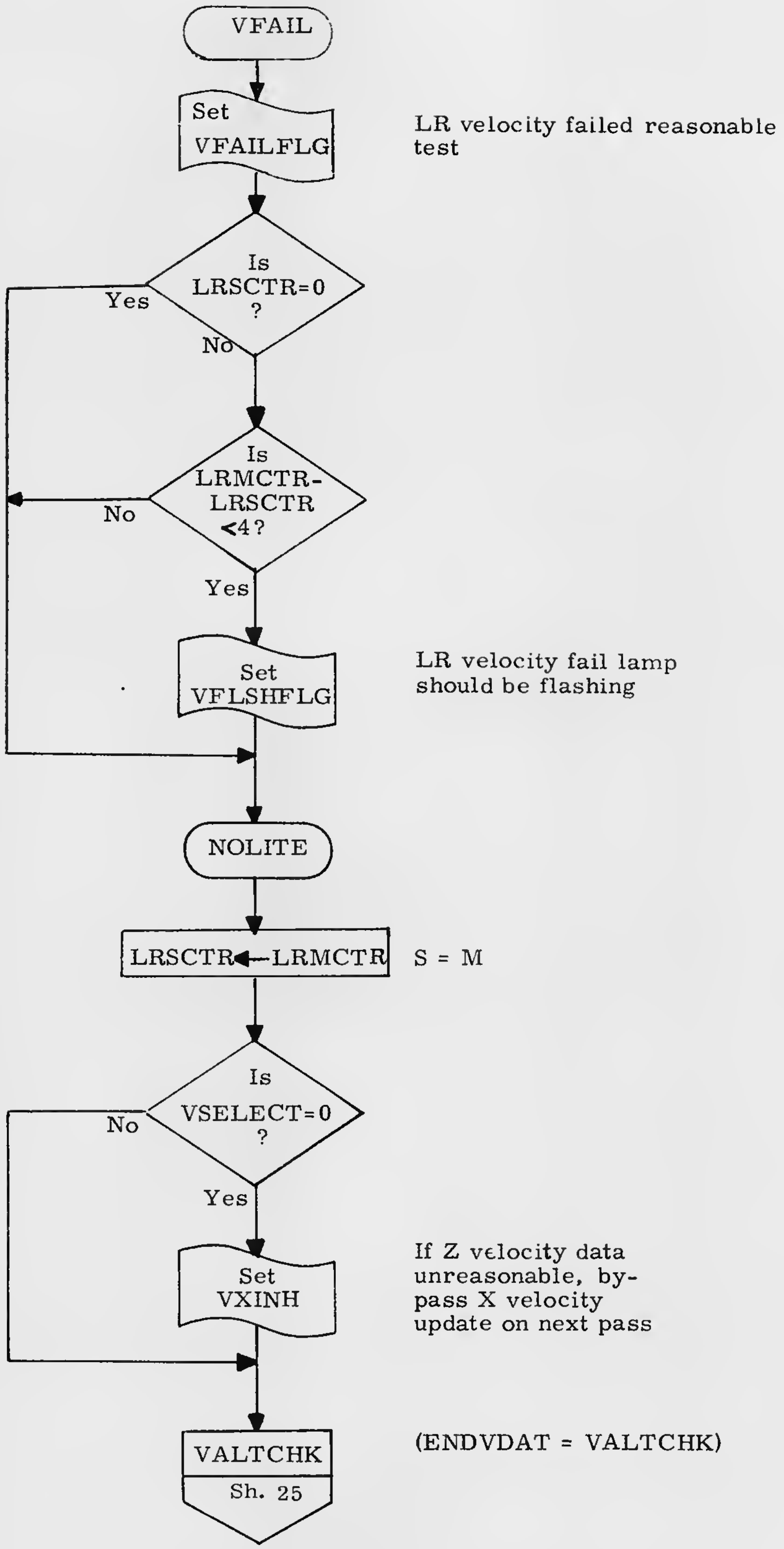

LRVEL
TIMEHOLD ← A
A ← 5
(SEE TABLE)
FC-3600
LRVELZ # TIMEHOLD
LRVELZ - 0
LRVELY - 2
LRVELX - 4
GNURVST
BUF ← A
R1S_D # BUF ← GNUR_D
R1S + 2_D # BUF ← GNUR + 2_D
R1S + 4_D # BUF ← GNUR +4_D
Return via Q



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E. Matta	6/15/70	R12-Descent State Vector Update	
PRGMR P. Moore	6/17/70		DOCUMENT NO.
ANALST			
DOCMR N. Danforth	6/17/70	LUMINARY 1D	FC-3935
APPR'D R.M. Eator	6/17/70	REV 2	SHEET 30 OF 35



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN L. Welch	10/23/69	R12 - Descent State Vector Update	
PRGMR D. Moore	12/1/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3935
DOCMR W. Dapbitt	10/34/69		
APPR'D R M Estes	12/1/69	REV 2	SHEET 31 OF 357



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. L. Welch	10/03/[illegible]	R12 - Descent State Vector Update	
PRGMR D. Moore	12/1/69		DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3935
DOCMR W. [illegible]	11/3/69		
APPR'D RM Evans	12/1/69	REV 2	SHEET 32 OF 35

Subroutine	Flowchart	Description	Where Called
TESTXACT	FC-3100	Test for extended verb active	Sh. 2
2SECDELY	FC-3050	Delay job 2 seconds	Sh. 3
RADSTALL	FC-3220	Wait for end of radar routine	Sh. 5, 27
ALARM	FC-3140	Store alarm code	Sh. 5, 11
FIXDELAY	FC-3040	Delay task 1 second	Sh. 8
VARDELAY	FC-3040	Delay task 2 seconds	Sh. 8
BRANCH	FC-3070	Test $MPAC_D$	Sh. 17, 23
ALSIGNAG	FC-3070	Double precision sign agree	Sh. 18
SHORTMP2	FC-3070	Multiply $MPAC_T$	Sh. 19
RGOODEND	FC-3600	Radar good end	Sh. 7
SIGNMPAC	FC-3150	Sign agreement in MPAC	Sh. 14
LIMITSUB	FC-3960	Limit value in A	Sh. 15
CHANG1	FC-3030	Suspend active job	Sh. 20

FLAGS

Name	Meaning When Set	Meaning When Cleared	Where Set	Where Cleared	Where Tested
LRINH FLAG 11 BIT 8	LR updates permitted by astronaut	LR updates inhibited by astronaut	Sh. 2	Sh. 3, 4, 10	Sh. 17, 24
AVEGFLAG FLAG 7 BIT 5	Averageg (SERVICER) desired	Averageg (SERVICER) not desired			Sh. 4
R77FLAG FLAG 5 BIT 11	R77 is on	R is not on			Sh. 6
V37FLAG FLAG 7 BIT 6	Averageg (SERVICER) running	Averageg (SERVICER) off			Sh. 6
LRBYPASS FLAG 11 BIT 15	Bypass all landing radar updates	Do not bypass landing radar updates			Sh. 4, 6, 9
TRACKFLG FLAG 1 BIT 5	Tracking allowed	Tracking not allowed			Sh. 6
LRPOSFLG FLAG 12 BIT 6	Landing radar position 2	Landing radar position 1	Sh. 7		
XORFLG FLAG 11 BIT 9	Below limit inhibit X-axis override	Above limit do not inhibit	Sh. 9		
XOVINFLG FLAG 13 BIT 9	X-axis override locked out	X-axis override okay	Sh. 9		
NOLRREAD FLAG 11 BIT 10	LR repositioning; bypass update	LR not repositioning	Sh. 27	Sh. 28	Sh. 10
HFAILFLG FLAG 11 BIT 13	LR altitude failed reasonability test	LR altitude passed reasonability test	Sh. 31	Sh. 17	

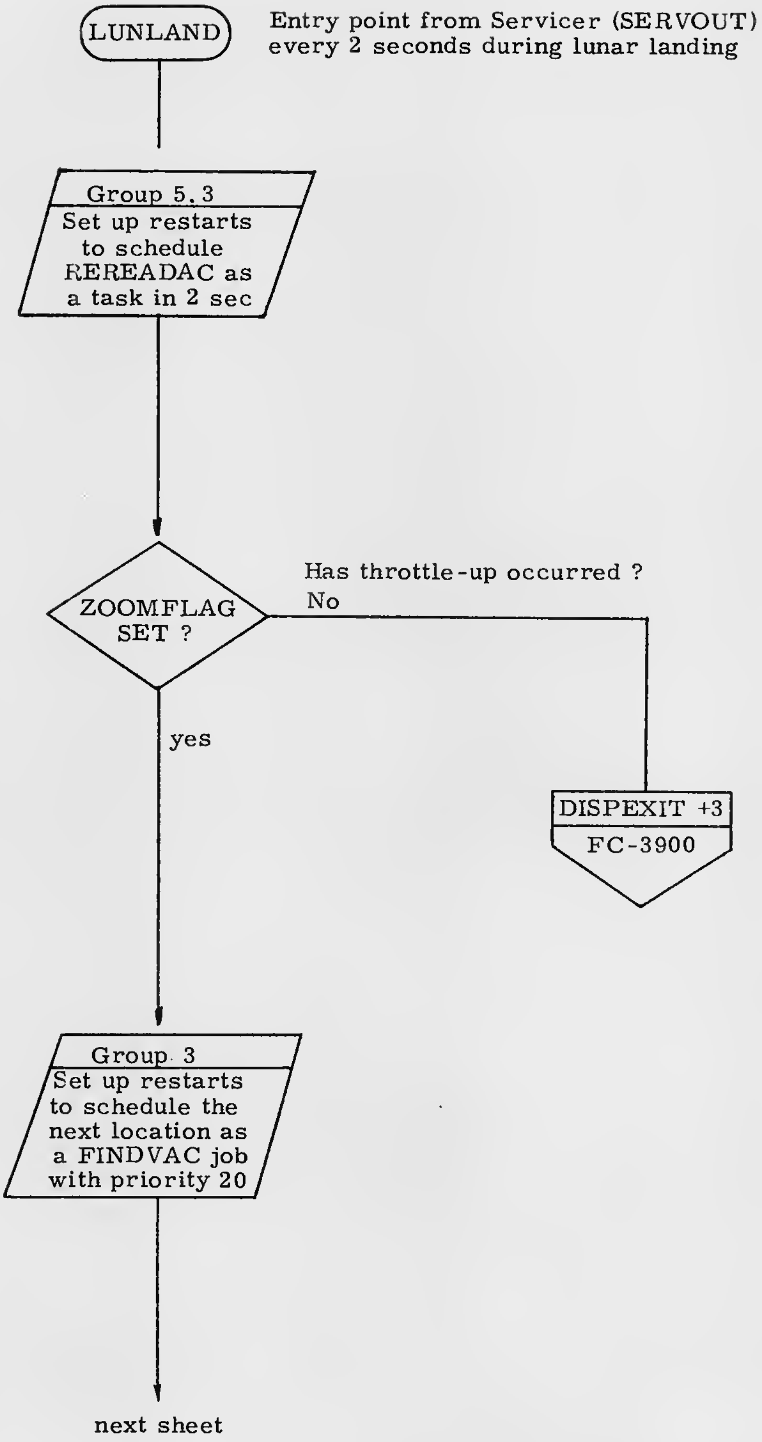
FLAGS (CONTINUED)

Name	Meaning When Set	Meaning When Cleared	Where Set	Where Cleared	Where Tested
R12RDFLG FLAG 11 BIT 3	Wait till all velocity reads done	LR velocity reads done			Sh. 20
PSTHIGAT FLAG 11 BIT 11	Past higate	Pre higate	Sh. 27		
RNGEDATA FLAG 11 BIT 4	LR altitude measurement made	LR altitude measurement not made		Sh. 12	Sh. 13
VELDATA FLAG 11 BIT 7	LR velocity measurement made	LR velocity measurement not made		Sh. 12	Sh. 20
VFAILFLG FLAG 11 BIT 14	LR velocity failed reasonability test	LR velocity passed reasonability test	Sh. 32	Sh. 23	
HFLSHFLG FLAG 11 BIT 1	LR altitude fail lamp should be flashing	LR altitude fail lamp should not be flashing	Sh. 31	Sh. 17	
VXINH FLAG 11 BIT 12	Bypass X velocity update on next pass	Update X-axis velocity	Sh. 32	Sh. 23	Sh. 23
VFLSHFLG FLAG 11 BIT 2	LR velocity fail lamp should be flashing	LR velocity fail lamp should not be flashing	Sh. 32	Sh. 23	
NOTERFLG FLAG 1 BIT 11	Terrain model inhibited	Terrain model permitted	Sh. 5		Sh. 14

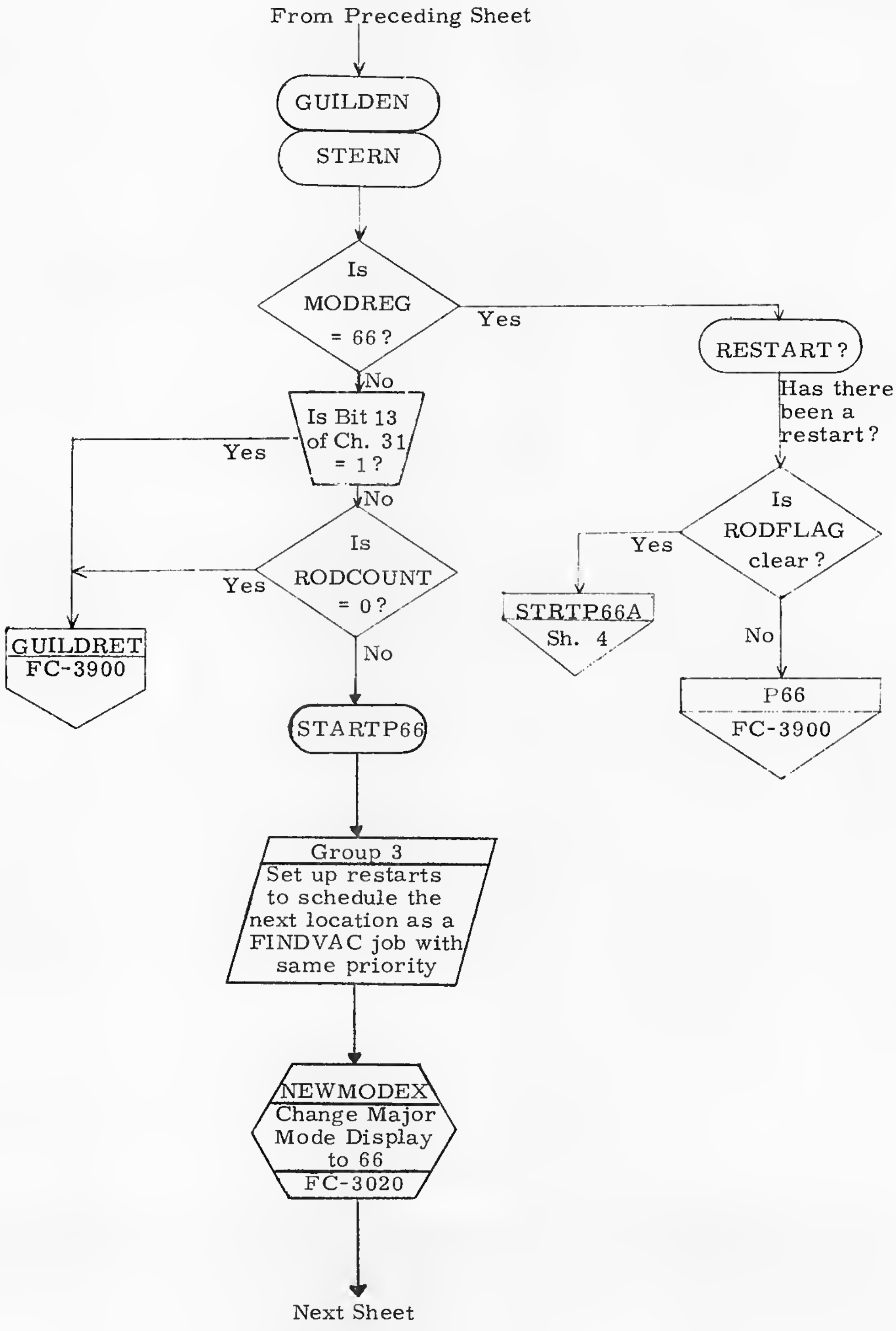
R13 - Landing Auto Modes Monitor

LUNLAND Sh. 2
DESCBITS Sh. 6

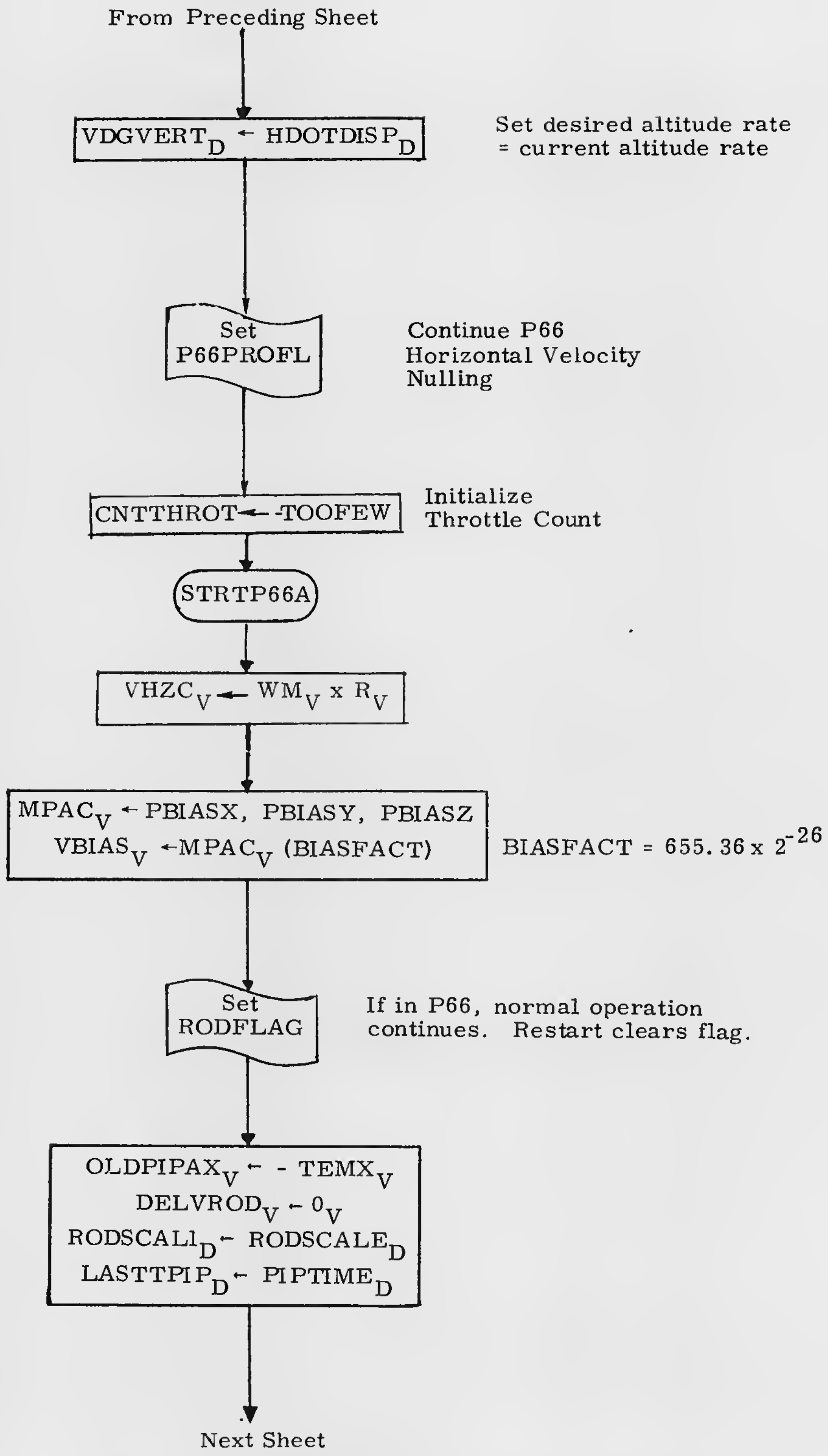
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Welch	12/4/68	Landing Auto Modes Monitor	
PRGMR P. Adler	12/9/69	LUMINARY 1L	DOCUMENT NO. FC-3940
ANALST			
DOCMR W. Danforth	12/5/69		
APPR'D W. Danforth	12/16/69	REV 3	SHEET 1 OF 7



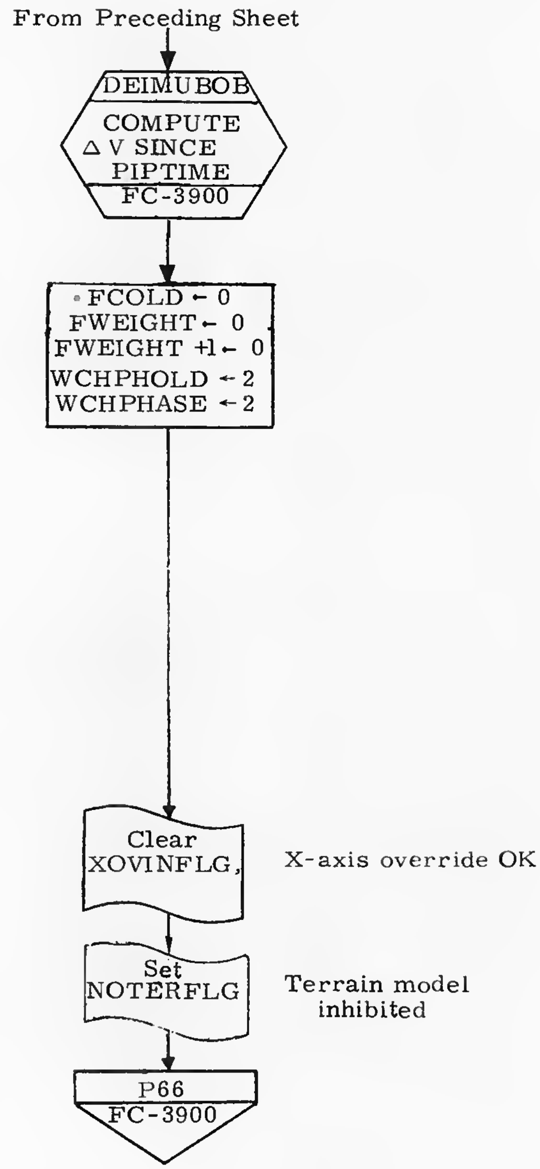
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lutkevich	8-16-69	Landing Auto Modes Monitor	
PRGMR A. Klumpp	20Aug69		DOCUMENT NO.
ANALST			
DOCMR W. C. DANFORTH		LUMINARY 1D	FC-3940
APPR'D Allan M. Sears	20AUG69	REV 3	SHEET 2 OF 7



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN I Goldstone 12/2/69	Landing Auto Modes Monitor
PRGMR P Adler 20AUG69	LUMINARY 1D — DOCUMENT NO. FC-3940
ANALST	
DOCMR MC Dogbeth 4AUG69	
APPR'D Alex M. Sorant 20AUG69	REV 3 — SHEET 3 OF 7

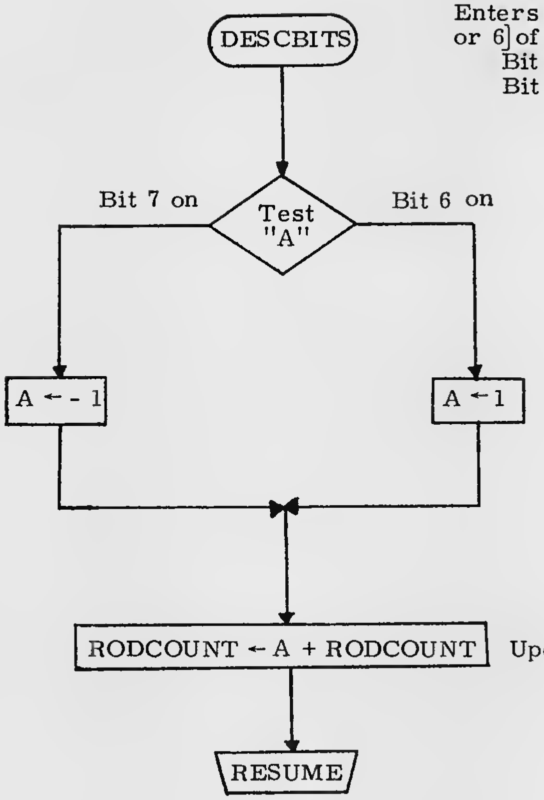


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Landing Auto Modes Monitor	
PRGMR	P. Adler 20Aug69	LUMINARY 1D	DOCUMENT NO. FC-3940
ANALST			
DOCMR	W C Doxbooth 4 AUG 69		
APPR'D	[signature] 20 AUG 69	REV 3	SHEET 4 OF 7



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Landing Auto Modes Monitor	
PRGMR P. Adler	30 Jul 69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3940
DOCMR W C Dughtz	4 AUG 69		
APPR'D	20 AUG 69	REV 3	SHEET 5 OF 7

Subroutine to update RODCOUNT with output from rate of descent switch activated by astronaut
Enters from MARKRUPT with [Bit 7 or 6] of Channel 16 in A.
Bit 7 = - rate increment
Bit 6 = + rate increment



Update RODCOUNT counter

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Landing Auto Modes Monitor	
PRGMR R. Adler	20 Aug 69	LUMINARY 1D	DOCUMENT NO. FC-3940
ANALST			
DOCMR W C Doghett	4 Aug 69		
APPR'D Allan M. Joan	20 Aug 69	REV 3	SHEET 6 OF 7

SUBROUTINES CALLED ON OTHER FLOWCHARTS

Subroutine	Flowchart	Description	Where Called
DISPEXIT	FC-3900	Lunar Landing Entry Point	Sh. 2
GUILDRET	FC-3900	Lunar Landing Entry Point	Sh. 3
VERTGUID	FC-3900	Lunar Landing Entry Point	Sh. 3, 5
NEWMODEX	FC-3020	Change Major Mode Display	Sh. 3

FLAGS

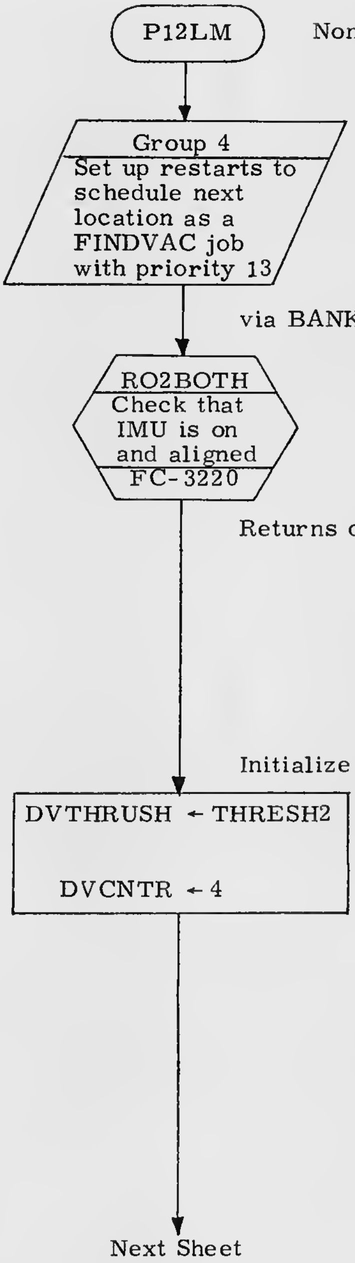
Name	Meaning When Set	Meaning When Cleared	Where Set	Where Cleared	Where Tested
ZOOMFLAG Flag 5, Bit 8	Throttle-up has occured in P63	Throttle-up has not occured in P63			Sh. 2
RODFLAG Flag 1 Bit 12	If in P66, normal operation continues	If in P66 reinitialization is performed	Sh. 4		Sh. 3
XOVINFLG Flag 13 Bit 9	X- axis override locked out	X-axis override permitted		Sh. 5	
REDFLAG Flag 6 Bit 6	Landing site redesignation permitted	Landing site redesignation not permitted		Sh. 5	
P66PROFL Flag 0 Bit 1	Continue P66 horizontal velocity nulling	Stop P66 horizontal velocity nulling	Sh. 4		
NOTERFLG Flag 1 Bit 11	Terrain Model inhibited	Terrain model permitted	Sh. 5		

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN M Connor	12-2-69	Landing Auto Modes Monitor	
PRGMR			
ANALST			DOCUMENT NO.
DOCMR W Dryfoos	12/5/69	LUMINARY 1D	FC-3940
APPR'D Roberto M Eastes	3/9/70	REV 3	SHEET 7 OF 7

P12 - ASCENT GUIDANCE

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		P12-Ascent Guidance	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3950
DOCMR A M SARANT			
APPR'D	6/25/70	REV	SHEET 1 OF 63

Nominal Powered Ascent Program



via BANKCALL

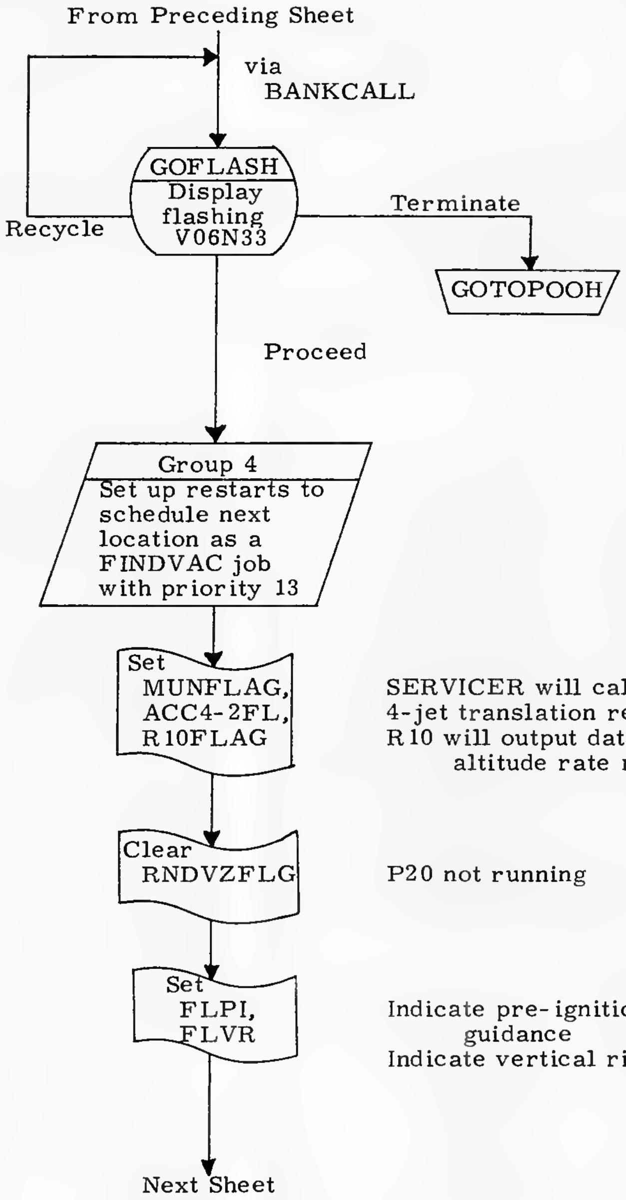
Returns only if IMU is OK; otherwise P12 is terminated

Initialize Δv Monitor parameters:

Set Δv_K = minimum acceptable 2-second Δv to APS value: .0308m/csec @ $10^{-4} \times 14$

Counter N_c @ 2^{14}

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN Marge Emerson		P12-Ascent Guidance	
PRGMR F. J. Bosman			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3950
DOCMR			
APPR'D RDM Estes	6/25/70	REV	SHEET 2 OF 63



Let astronaut verify ignition time (TIG_D):
R1: ooxxx. hrs.
R2: oooxx. min.
R3: oxx.xx sec.

SERVICER will call MUNRVG
4-jet translation requested
R10 will output data to altitude, altitude rate meters only.

P20 not running

Indicate pre-ignition phase of ascent guidance
Indicate vertical rise

From Preceding Sheet

GUIDINIT
Initialize ascent guidance parameters
Sh. 42

Output: $WM_V = \underline{\omega}_M$ = moon rotational velocity in SM coordinates in rad/csec @ 2^{-17}

$/LAND/_D = r_{LS}$ = landing site radius in m @ 2^{24}

Input: $/LAND/_D = r_{LS}$ in m @ 2^{24}

$VRECTCSM_V = \underline{v}_c$ = CSM velocity in reference coords

$RRECTCSM_V = \underline{r}_c$ = CSM position in reference coords

P12INIT
Initialize thrusting and target parameters
Sh. 44

Output: $1/DV3_D$, $1/DV2_D$, $1/DV1_D$

= thrust filter parameters in csec/m @ 2^7

AT_D = a_T in m/csec^2 @ 2^{-9}

$TBUP_D$ = τ in csec @ 2^{17}

TTO_D = $\Delta t_{tail\text{-}off}$ in csec @ 2^{17}

VE_D = v_e in m/csec @ 2^7

RCO_D = R_D in m @ 2^{24}

TXO_D = X-axis override time in csec @ 2^{28}

YCO_D = Y_D in m @ 2^{24}

$YDOTD_D$ = $\dot{Y}_D$ in m/csec @ 2^7

$QAXIS_V$ = $\underline{Q}$ in SM coords @ 2^1

Next Sheet

From Preceding Sheet

P12LMB

$TGO_D \leftarrow (TGO)A_D$

Set t_{GO} = burn time in csec @ 2^{17}

$TDEC1_D \leftarrow TIG_D$

t_{IG} in csec @ 2^{28}

LEMPREC
Integrate state vector to t_1
FC-3350

Input = $TDEC1_D$ = t_1 in csec @ 2^{28}
(= t_{IG} here)
WM_V = $\underline{\omega}_M$ in rad/csec @ 2^{-17}

Output = $RATT_V$ = $\underline{r}(t_1)$ = $\underline{r}(t_{IG})$
in reference coords
in m @ 2^{29}
$VATT_V$ = $\underline{v}(t_1)$ = $\underline{v}(t_{IG})$
in reference coords
in m/csec @ 2^{7}

Convert state vector at t_{IG} to SM coordinates:

$V1S_V \leftarrow 2^1 \cdot REFSMMAT_M \times VATT_V$

$MPAC_V \leftarrow 2^6 \cdot REFSMMAT_M \cdot RATT_V$

$R_V \leftarrow MPAC_V$

$\underline{v}(t_{IG})$ in m/csec @ 2^7

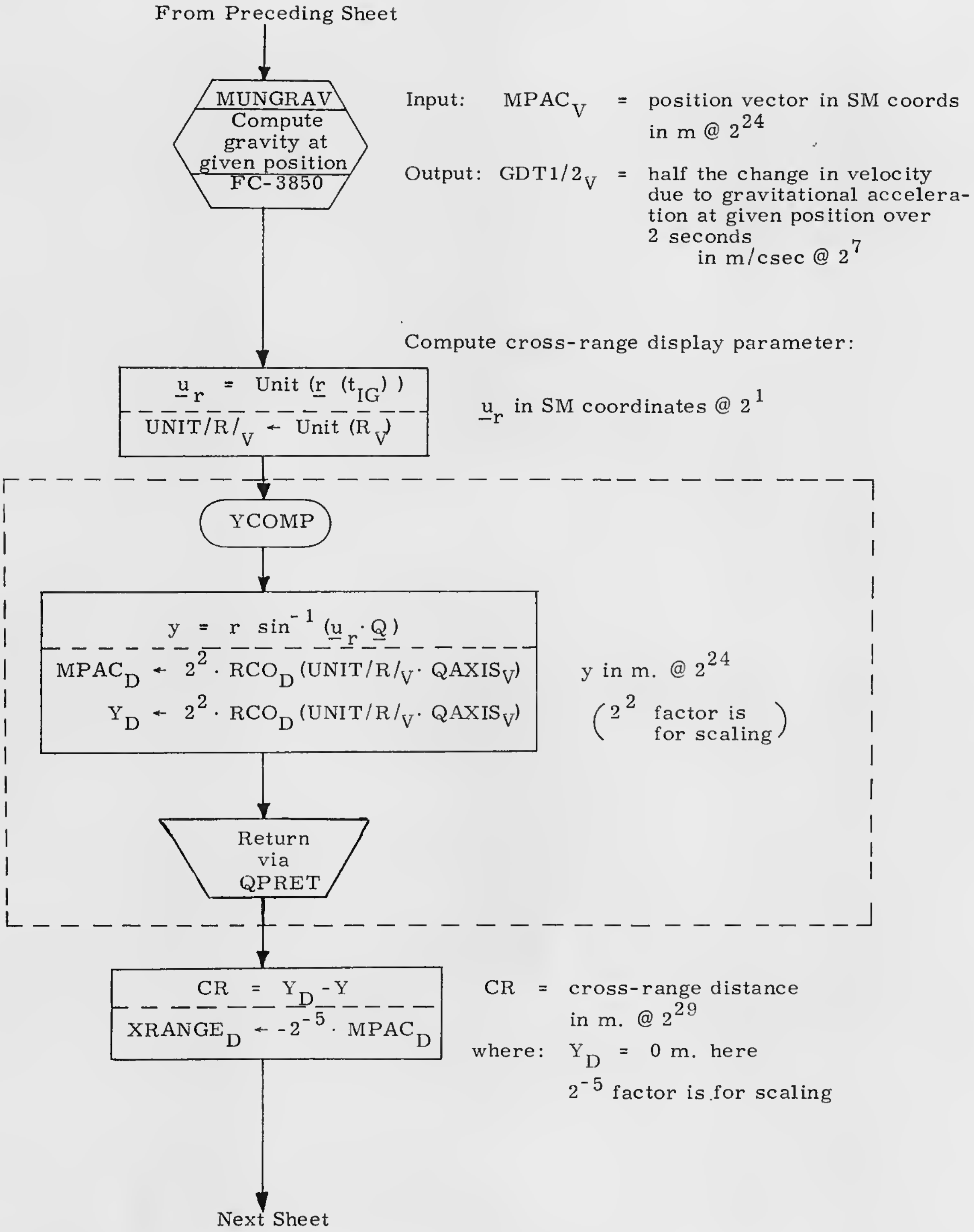
$\underline{r}(t_{IG})$ in m @ 2^{24}

where $REFSMMAT_M$
= reference - SM coordinate transformation matrix @ 2^1

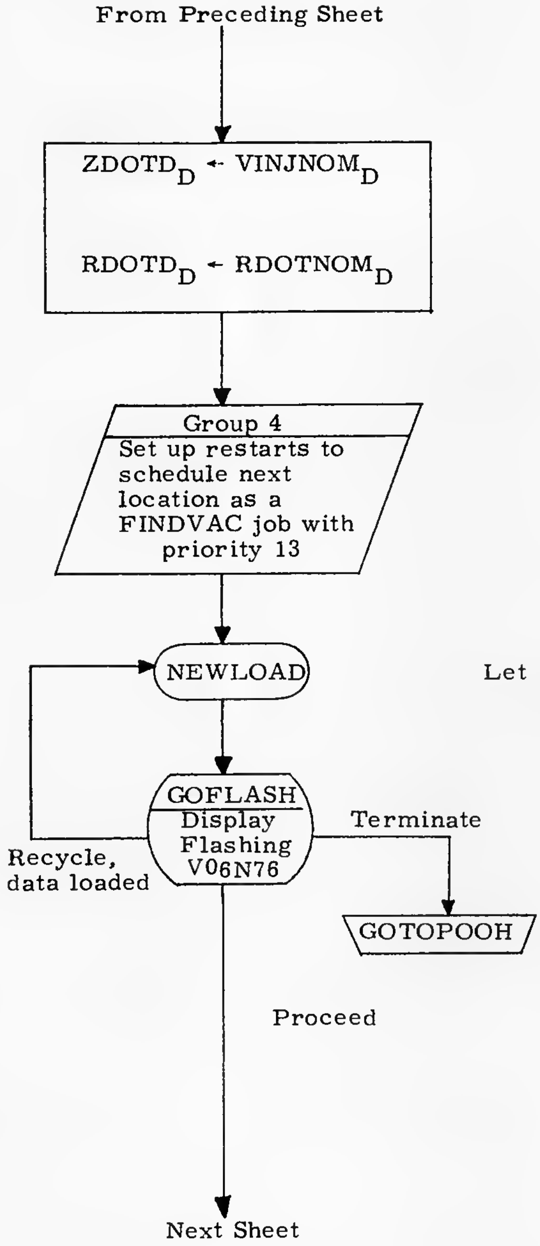
2^1, 2^6 factors are for scaling

Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN [signature]		P12-Ascent Guidance	
PRGMR [signature]			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3950
DOCMR			
APPR'D [signature]	6/15/70	REV	SHEET 5 OF 63



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN Nancy Erickson	P12-Ascent Guidance	
PRGMR J. J. Blyman		
ANALST	LUMINARY 1D	DOCUMENT NO. FC-3950
DOCMR		
APPR'D R. M. Estes 6/25/70	REV	SHEET 6 OF 63



$\dot{Z}_D$ = required injection down-range velocity in m/csec @ 2^7

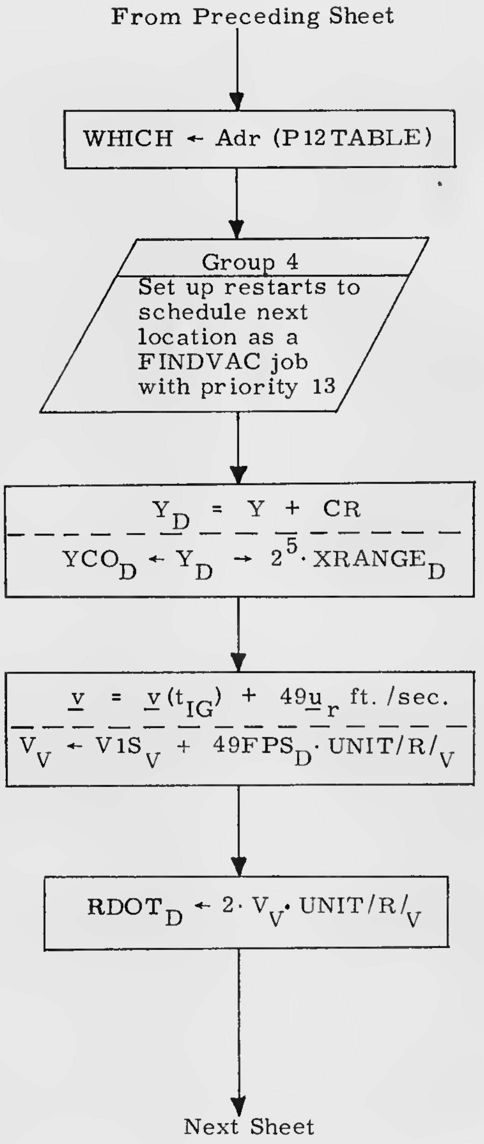
$\dot{R}_D$ = desired injection radial velocity in m/csec @ 2^7

Let astronaut verify target parameters

R1: xxxx. x ft. /sec. $\dot{Z}_D$ ($ZDOTD_D$)

R2: xxxx. x ft. /sec. $\dot{R}_D$ ($RDOTD_D$)

R3: xxxx. x nm. CR ($XRANGE_D$)



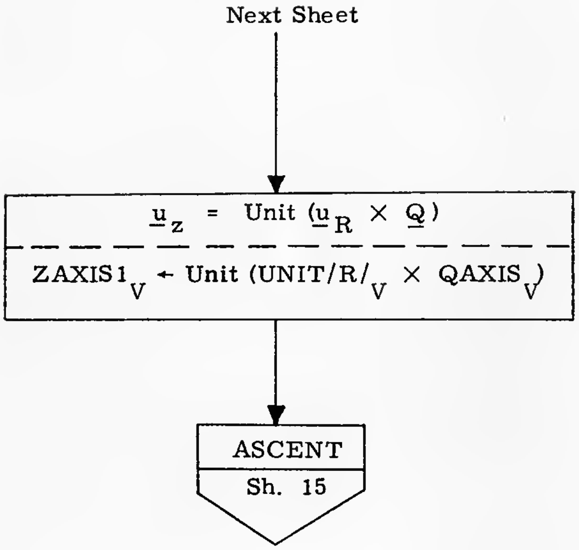
Specify table for BURNBABY

Compute Y_D in m @ 2^{24}

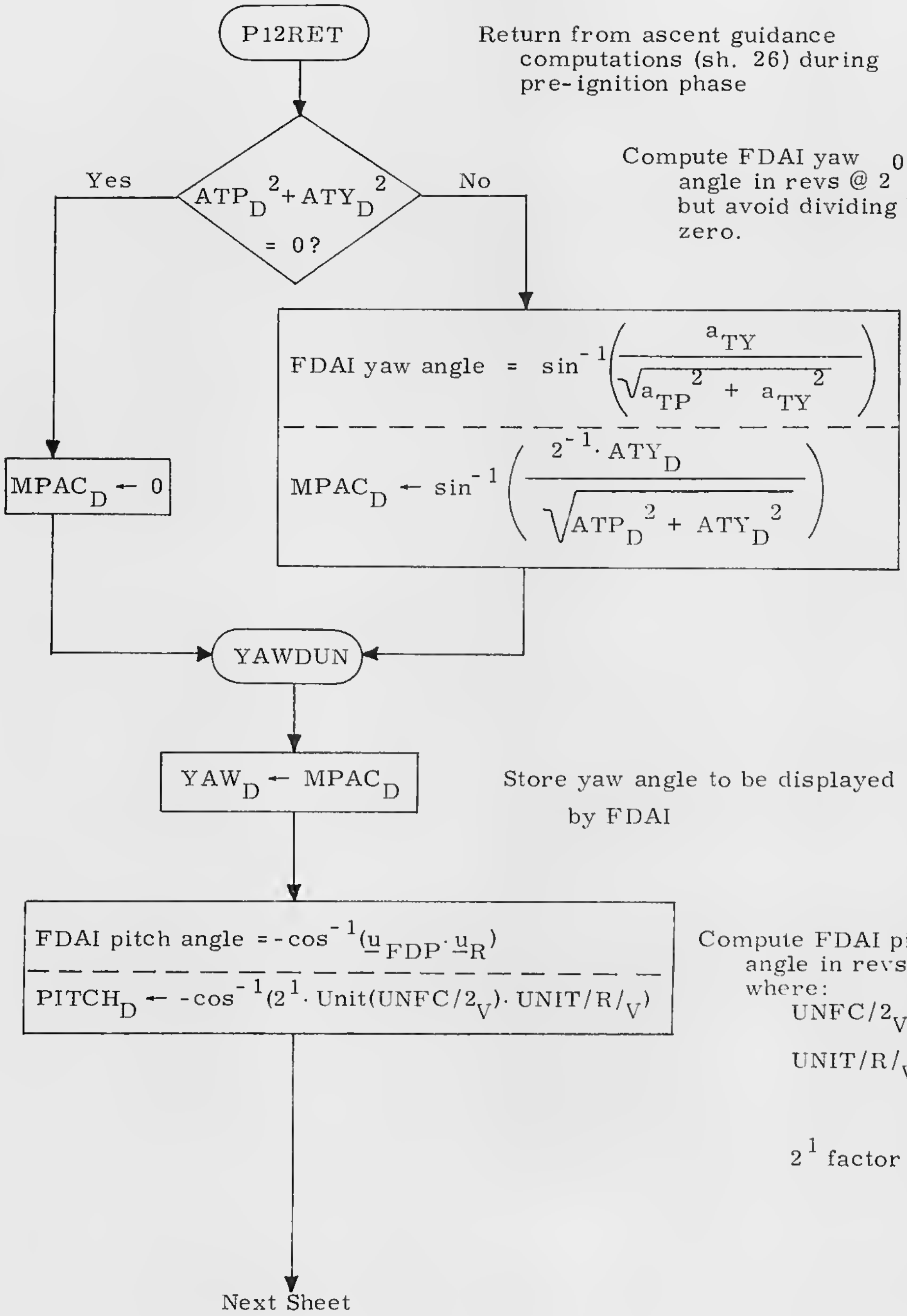
2^5 factor is for scaling

Extrapolate LM velocity through vertical rise phase
$\underline{v}$ in SM coordinates in m/csec @ 2^7

$\dot{R}$ = component of velocity in radial direction in m/csec @ 2^7



Compute Z-axis component of local vertical coordinate system in SM coords @ 2^1



Return from ascent guidance computations (sh. 26) during pre-ignition phase

Compute FDAI yaw angle in revs @ 2^0, but avoid dividing by zero.

$ATY_D = a_{TY}$ @ 2^{-9}

$ATP_D = a_{TP}$ @ 2^{-9}

2^{-1} factor is for scaling

Store yaw angle to be displayed by FDAI

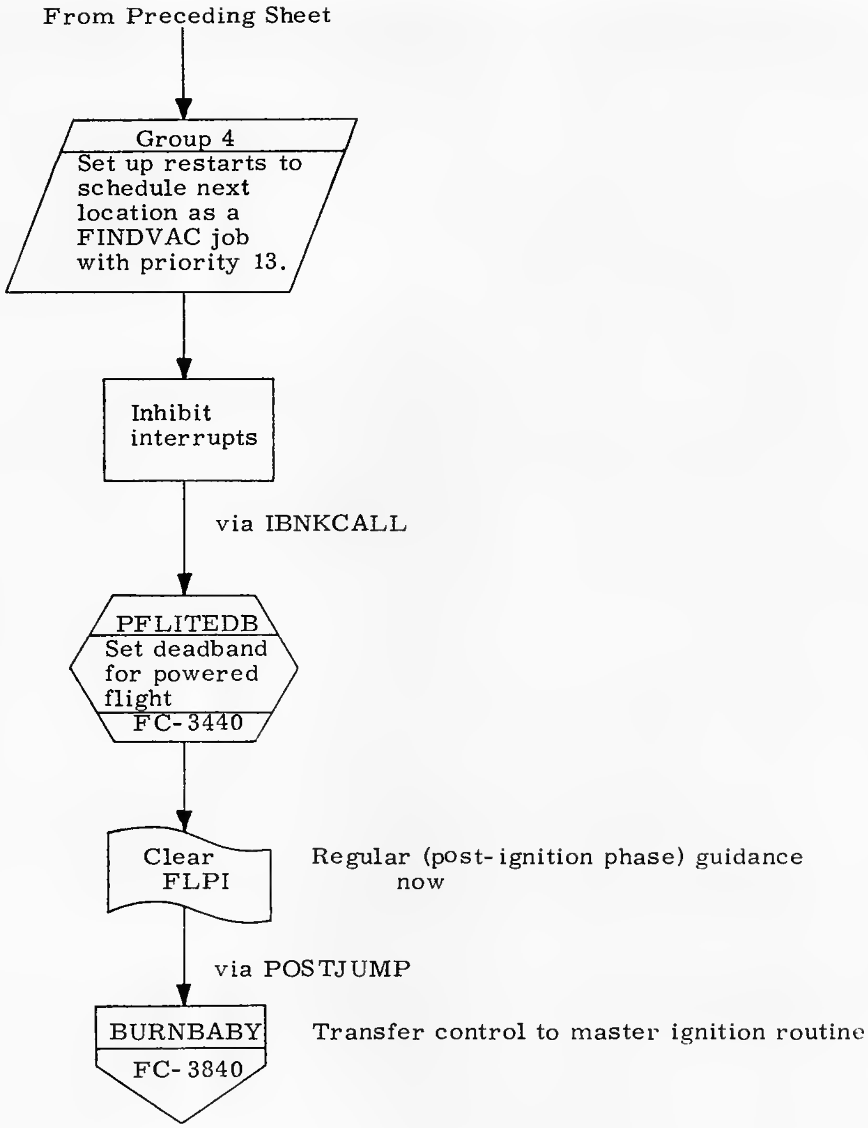
Compute FDAI pitch angle in revs @ 2^0 where:

$UNFC/2_V = \underline{u}_{FDP}$ in SM coords

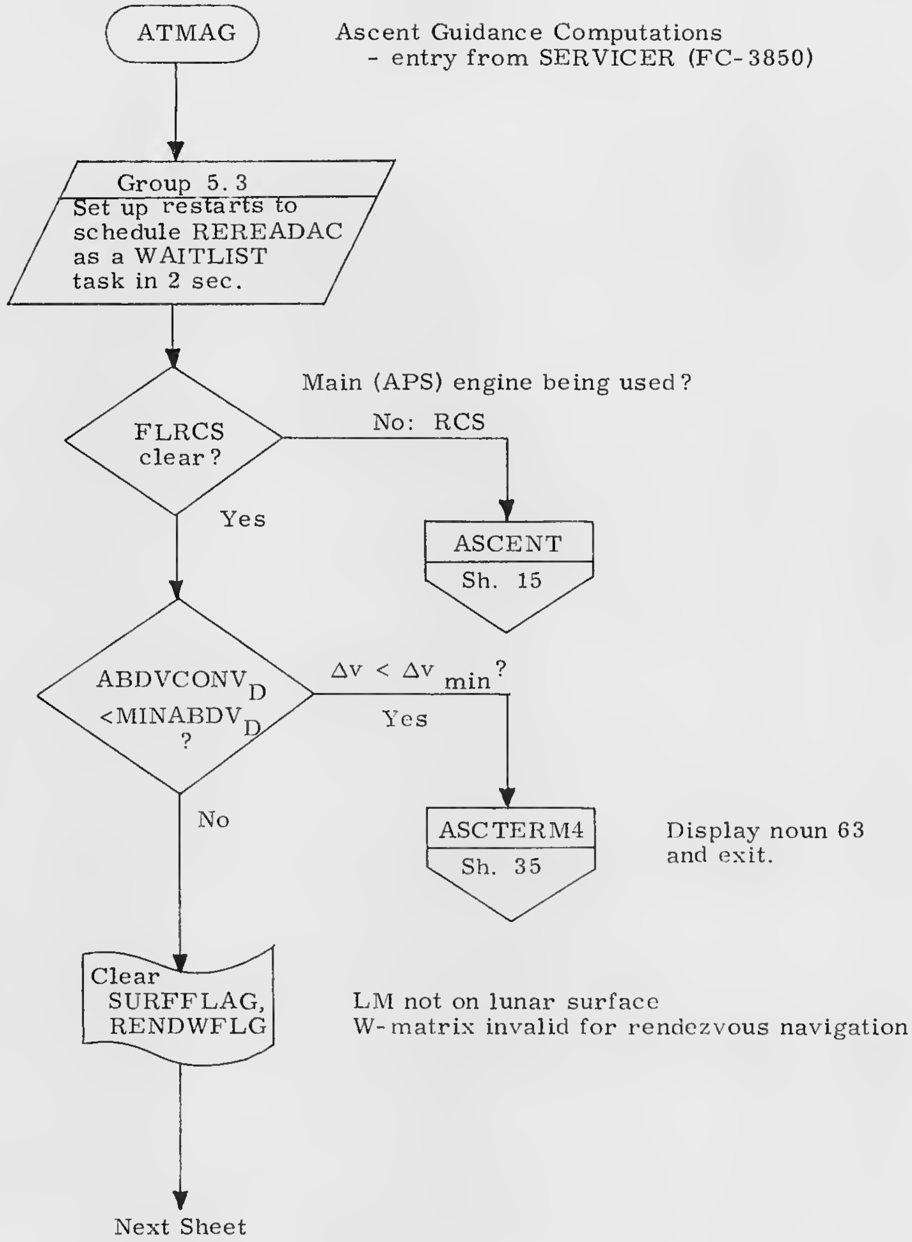
$UNIT/R/_V = \underline{u}_R$ in SM coords @ 2^1

2^1 factor is for scaling

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	Marge Cuckoo (signature)	P12-Ascent Guidance	
PRGMR	(signature)		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3950
DOCMR			
APPR'D	RMM Estes 6/25/70	REV	SHEET 10 OF 63



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN [illegible]		P12-Ascent Guidance	
PRGMR [illegible]		LUMINARY 1D	DOCUMENT NO. FC-3950
ANALST			
DOCMR			
APPR'D R M Estes	6/25/72	REV	SHEET 11 OF 63



ATMAG
Ascent Guidance Computations
- entry from SERVICER (FC-3850)
Group 5.3
Set up restarts to schedule REREADAC as a WAITLIST task in 2 sec.
Main (APS) engine being used?
FLRCS clear?
No: RCS
Yes
ASCENT
Sh. 15
ABDVCONV_D <MINABDV_D ?
Δv < Δv min ?
Yes
No
ASCTERM4
Sh. 35
Display noun 63 and exit.
Clear SURFFLAG, RENDWFLG
LM not on lunar surface
W-matrix invalid for rendezvous navigation
Next Sheet

From Preceding Sheet

$1/DV0_D \leftarrow 1/DV1_D$
$1/DV1_D \leftarrow 1/DV2_D$
$1/DV2_D \leftarrow 1/DV3_D$
$1/DV3_D \leftarrow 2^{-12} \div ABDVCONV_D$

Update thrust filter parameters in csec/m @ 2^7

where: $ABDVCONV_D$ = new Δv increment in m/csec @ 2^5

2^{-12} factor is for scaling

Update τ = mass ÷ mass flow rate ratio

$PL\chi_D \leftarrow 2^4 \cdot 1/2 \left[1/DV0_D + 1/DV1_D + 1/DV2_D + 1/DV3_D \right] \cdot VE_D \cdot 2SEC(9)_D$

Intermediate result: in csec @ 2^{17}

where: VE_D = v_e in m/csec @ 2^7

$2SEC(9)_D$ = $1/4\Delta t$ = $1/4 \cdot 200$ csec @2^7

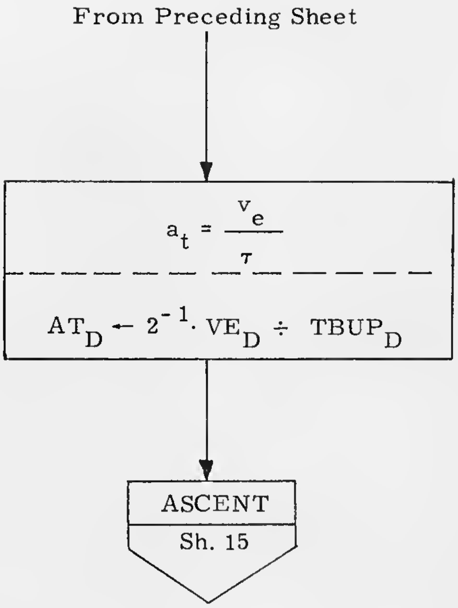
2^4 factor is for scaling

$$\tau = 1/2 \left[1/4 \left(\frac{1}{\Delta v_0} + \frac{1}{\Delta v_1} + \frac{1}{\Delta v_2} + \frac{1}{\Delta v_3} \right) v_e \Delta t + \tau - 3\,\Delta t \right]$$

$TBUP_D \leftarrow PL\chi_D + 1/2\ TBUP_D - 6SEC(18)_D$

τ in csec @ 2^{17}
where $6SEC(18)_D$
= $1/2 \cdot 3\Delta t$
= $1/2 \cdot 3(200$ csec$)$ @2^{17}

Next Sheet



Compute thrust acceleration
a_t in m/csec^2
@ 2^{-9}

where: $VE_D = v_e$ in m/csec @ 2^7

$TBUP_D = \tau$ in csec @ 2^{17}

2^{-1} factor is for scaling

ASCENT

Ascent Guidance Computations - common entry

$/R/MAG_D \leftarrow |R_V|$

R in m @ 2^{24}

$ZDOT_D \leftarrow 2^1(V_V \cdot ZAXIS1_V)$

$\dot{Z} = \underline{v} \cdot \underline{u}_Z$ in m/csec @ 2^7

where: $V_V = \underline{v}$ in SM coords in m/csec @ 2^7

$ZAXIS1_V = \underline{u}_z$ in SM coords @ 2^1

2^1 factor is for scaling

$\underline{u}_y = \underline{u}_z \times \underline{u}_R$

$LAXIS_V \leftarrow 2^1\ (ZAXIS1_V \times UNIT/R/_V)$

$\underline{u}_y$ = Y-axis of local vertical coordinate system in SM coords @ 2^1

where: $ZAXIS1_V = \underline{u}_z$ in SM coords @ 2^1

$UNIT/R/_V = \underline{u}_R$ in SM coords @ 2^1

2^1 factor is for scaling

$YDOT_D \leftarrow 2^1(V_V \cdot LAXIS_V)$

$\dot{Y} = \underline{v} \cdot \underline{u}_y$ in m/csec @ 2^7

where: $V_V = \underline{v}$ in SM coords in m/csec @ 2^7

$LAXIS_V = \underline{u}_y$ in SM coords @ 2^1

2^1 factor is for scaling

Next Sheet

From Preceding Sheet

YCOMP — Compute Y — Sh. 6

Input: $RCO_D = R_D$ in m @ 2^{24}

$UNIT/R/_V = \underline{u}_r$ in SM coords @ 2^1

$QAXIS_V = \underline{Q}$ in SM coords @ 2^1

Output: $Y_D = Y$ in m @ 2^{24}

Compute g_{eff} in m/csec^2 @ 2^{-9}

$$g_{eff} = \frac{|\underline{r} \times \underline{v}|^2}{r^3} + \underline{g} = \frac{|\underline{u}_r \times \underline{v}|^2}{r} + \frac{\underline{u}_r \cdot \underline{g}\,\Delta t}{\Delta t}$$

$$GEFF_D \leftarrow 2^1 \cdot \frac{(UNIT/R/_v \times V_v)^2}{/R/MAG_D} + \frac{UNIT/R/_v \cdot GDT1/2_v}{2\ SEC(18)_D}$$

where:

$UNIT/R/_V = \underline{u}_r$ @ 2^1

$V_V = \underline{v}$ @ 2^7

$/R/MAG_D = r$ @ 2^{24}

$GDT1/2_V = 1/2\ \underline{g}\,\Delta t$ @ 2^7

$= \underline{g}\ \Delta t$ @ 2^8

$2SEC(18)_D = \Delta t$ @ 2^{18}

Is P70 or P71 running?

P7071FLG Set?

No (P12): go to the join above the $DZDOT_D$ box

Yes:

ZDOTDCMP — Compute $\dot{Z}_D$ — Sh. 46

Input: $JPARM_D = 2J$ in m @ 2^{24}

$KPARM_D = 2K$ in m/rev @ 2^{24}

$R_V = R$ in m, in SM coords

$R(CSM)_V = \underline{R}_c$ in m, in SM coords

$WM_V = \underline{\omega}_M$ in rad/csec in SM coords

$RP_D = R_P$ in m @ 2^{24}

Output: $ZDOTD_D = \dot{Z}_D$ in m/csec @ 2^7

$DZDOT_D \leftarrow ZDOTD_D - ZDOT_D$	$\Delta \dot{Z} = \dot{Z}_D - \dot{Z}$
$DYDOT_D \leftarrow YDOTD_D - YDOT_D$	$\Delta \dot{Y} = \dot{Y}_D - \dot{Y}$
$DRDOT_D \leftarrow RDOTD_D - RDOT_D$	$\Delta \dot{R} = \dot{R}_D - \dot{R}$

in m/c sec @ 2^7

Next Sheet

From Preceding Sheet

Compute $\underline{v}_G$ in SM coords in m/csec @ 2^7

$$\underline{v}_G = \Delta\dot{R}\underline{u}_R + \Delta\dot{Y}\underline{u}_Y + \Delta\dot{Z}\underline{u}_Z$$

$$VGVECT_V \leftarrow 2^1 \left[DRDOT_D \cdot UNIT/R/_V + DYDOT_D \cdot LAXIS_V + DZDOT_D \cdot ZAXIS1_V\right]$$

where:
$UNIT/R/_V = \underline{u}_r$
$LAXIS_V = \underline{u}_Y$
$ZAXIS1_V = \underline{u}_Z$
all in SM coords @ 2^1
2^1 factor is for scaling

$$\underline{v}_G = \underline{v}_G - 1/2 t_{go}\, g_{eff}\, \underline{u}_r$$

$$VGVECT_V \leftarrow VGVECT_V - 2^1(TGO_D \cdot GEFF_D \cdot UNIT/R/_V)$$

Adjust $\underline{v}_G$ in SM coords, in m/csec @ 2^7 to account for g_{eff}
where:
$TGO_D = t_{go}$ in csec @ 2^{17}
$GEFF_D = g_{eff}$ in m/csec^2 @ 2^{-9}
$UNIT/R/_V = \underline{u}_r$ in SM coords @ 2^1
2^1 factor is for scaling

Convert $\underline{v}_G$ to body (NB) coords

$$\underline{v}_{GB} = [SMNB]\,\underline{v}_G$$

$$VGBODY_V \leftarrow 2^1 \cdot XNBPIP_M \times VGVECT_V$$

where:
$XNBPIP_M$ = SM - NB coordinate transformation matrix @ 2^1
2^1 factor is for scaling

$$v_g = |\underline{v}_G|$$

$$MPAC_D = |VGVECT_V|$$

FLRCS clear?

Main (APS) engine being used?

Yes → MAINENG Sh. 19

No: RCS → Next Sheet

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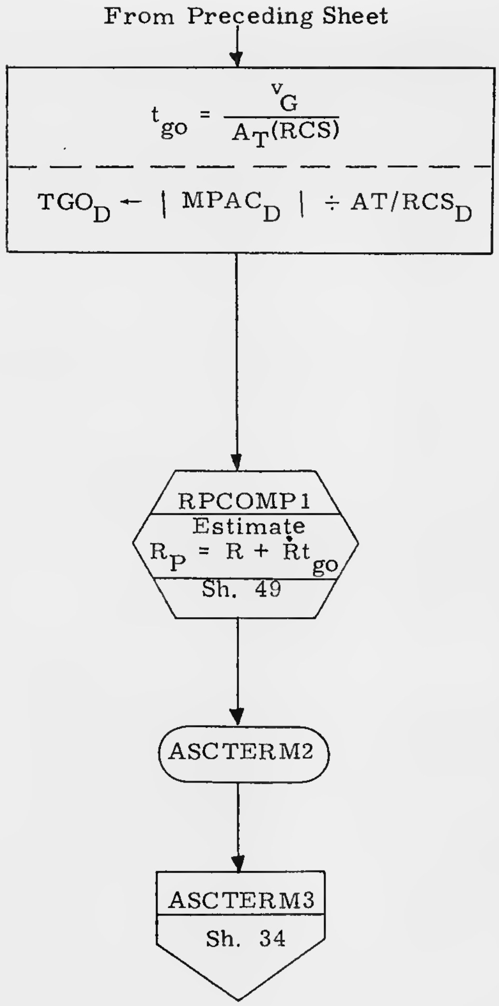
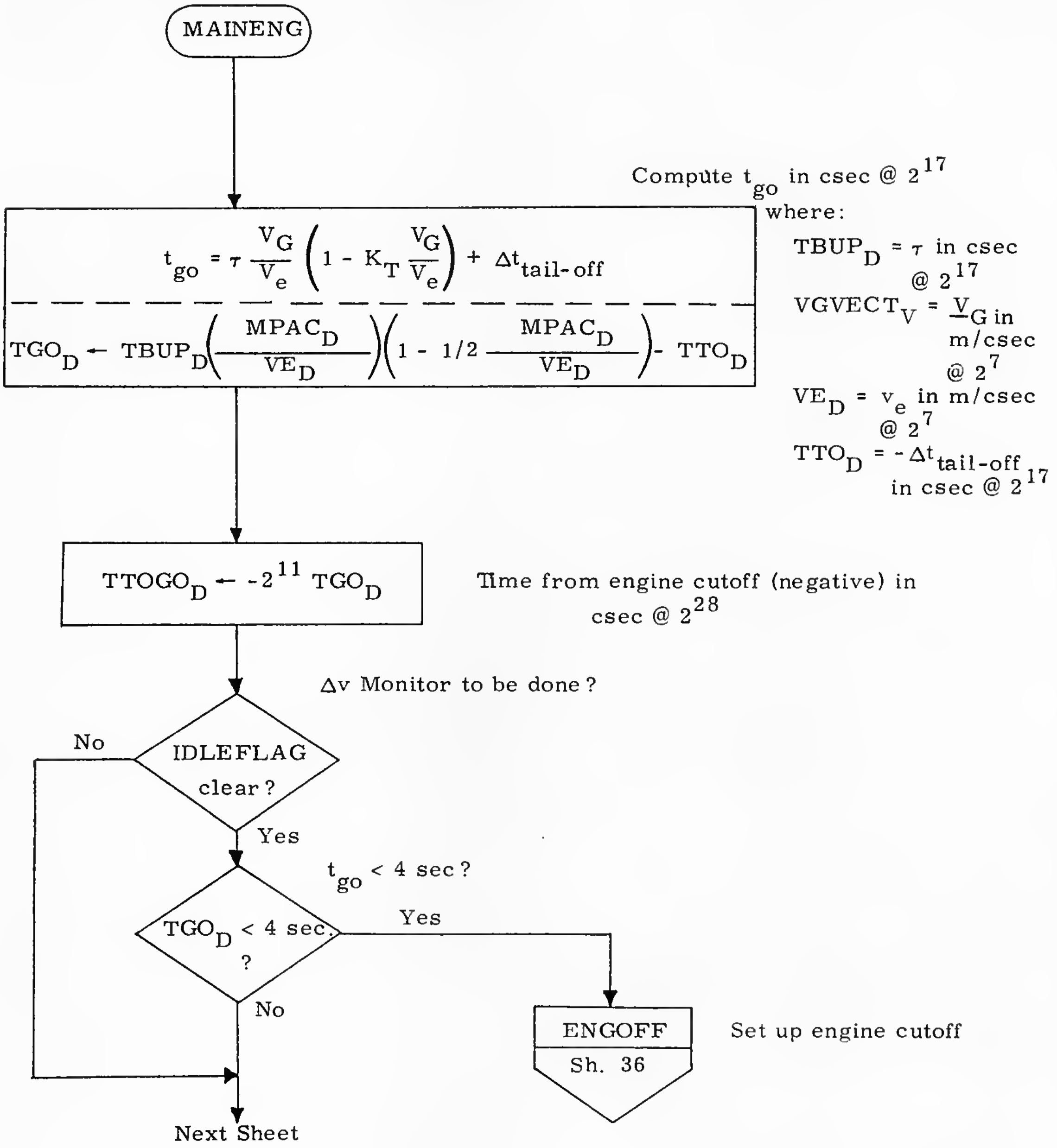
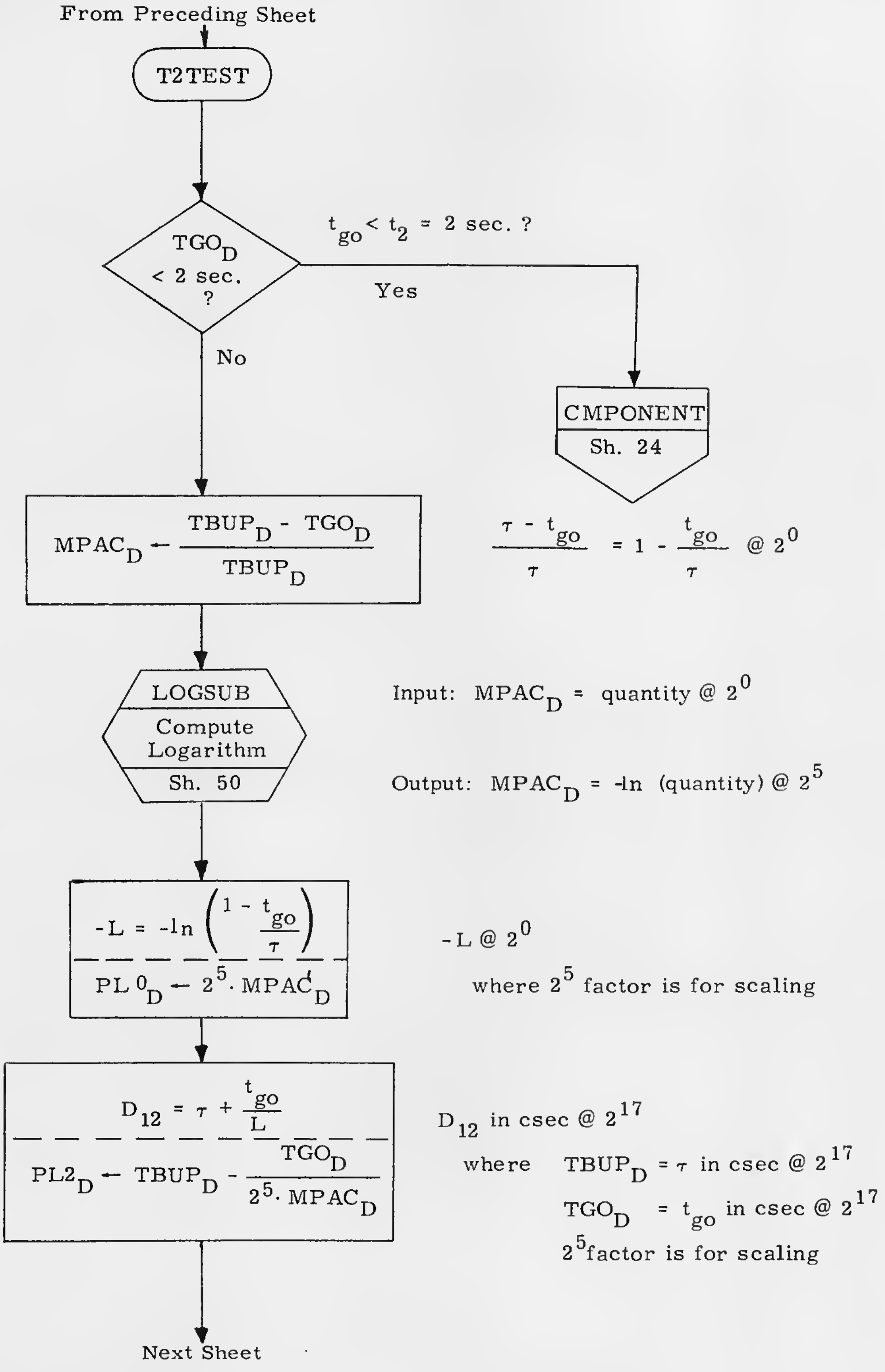


Update t_{go} in csec @ 2^{17}
where:

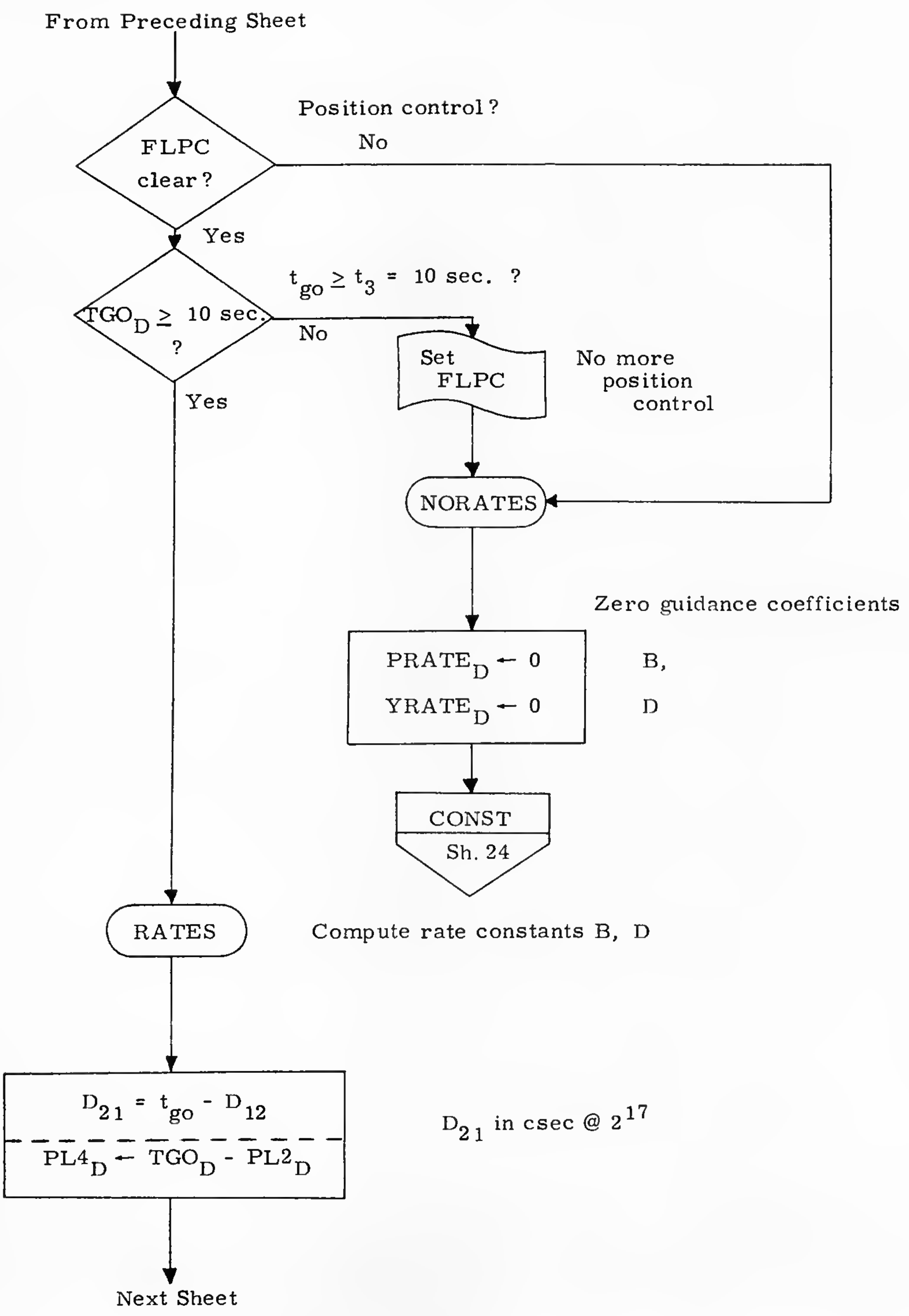
AT/RCS_D
$= A_T(RCS)$
= acceleration of 4 RCS jets in a dry LM
in m/csec^2 @ 2^{-10}

Input: $/R/MAG_D$ = R in m @ 2^{24}
$RDOT_D$ = $\dot{R}$ in m/csec @ 2^7
TGO_D = t_{go} in csec @ 2^{17}
Output: RP_D = R_P in m @ 2^{24}


MAINENG
Compute t_{go} in csec @ 2^{17}
$t_{go} = \tau \frac{V_G}{V_e}\left(1 - K_T \frac{V_G}{V_e}\right) + \Delta t_{tail-off}$
$TGO_D \leftarrow TBUP_D\left(\frac{MPAC_D}{VE_D}\right)\left(1 - 1/2 \frac{MPAC_D}{VE_D}\right) - TTO_D$
where:
$TBUP_D = \tau$ in csec @ 2^{17}
$VGVECT_V = \underline{V}_G$ in m/csec @ 2^7
$VE_D = v_e$ in m/csec @ 2^7
$TTO_D = -\Delta t_{tail-off}$ in csec @ 2^{17}
$TTOGO_D \leftarrow -2^{11}\ TGO_D$
Time from engine cutoff (negative) in csec @ 2^{28}
Δv Monitor to be done?
IDLEFLAG clear?
No
Yes
t_{go} < 4 sec?
TGO_D < 4 sec. ?
Yes
No
ENGOFF
Sh. 36
Set up engine cutoff
Next Sheet



From Preceding Sheet
T2TEST
TGO_D < 2 sec. ?
$t_{go} < t_2 = 2$ sec. ?
Yes
No
CMPONENT
Sh. 24
$MPAC_D \leftarrow \frac{TBUP_D - TGO_D}{TBUP_D}$
$\frac{\tau - t_{go}}{\tau} = 1 - \frac{t_{go}}{\tau}$ @ 2^0
LOGSUB
Compute Logarithm
Sh. 50
Input: $MPAC_D$ = quantity @ 2^0
Output: $MPAC_D$ = -ln (quantity) @ 2^5
$-L = -\ln\left(1 - \frac{t_{go}}{\tau}\right)$
$PL0_D \leftarrow 2^5 \cdot MPAC_D$
$-L$ @ 2^0
where 2^5 factor is for scaling
$D_{12} = \tau + \frac{t_{go}}{L}$
$PL2_D \leftarrow TBUP_D - \frac{TGO_D}{2^5 \cdot MPAC_D}$
D_{12} in csec @ 2^{17}
where $TBUP_D = \tau$ in csec @ 2^{17}
$TGO_D = t_{go}$ in csec @ 2^{17}
2^5 factor is for scaling
Next Sheet



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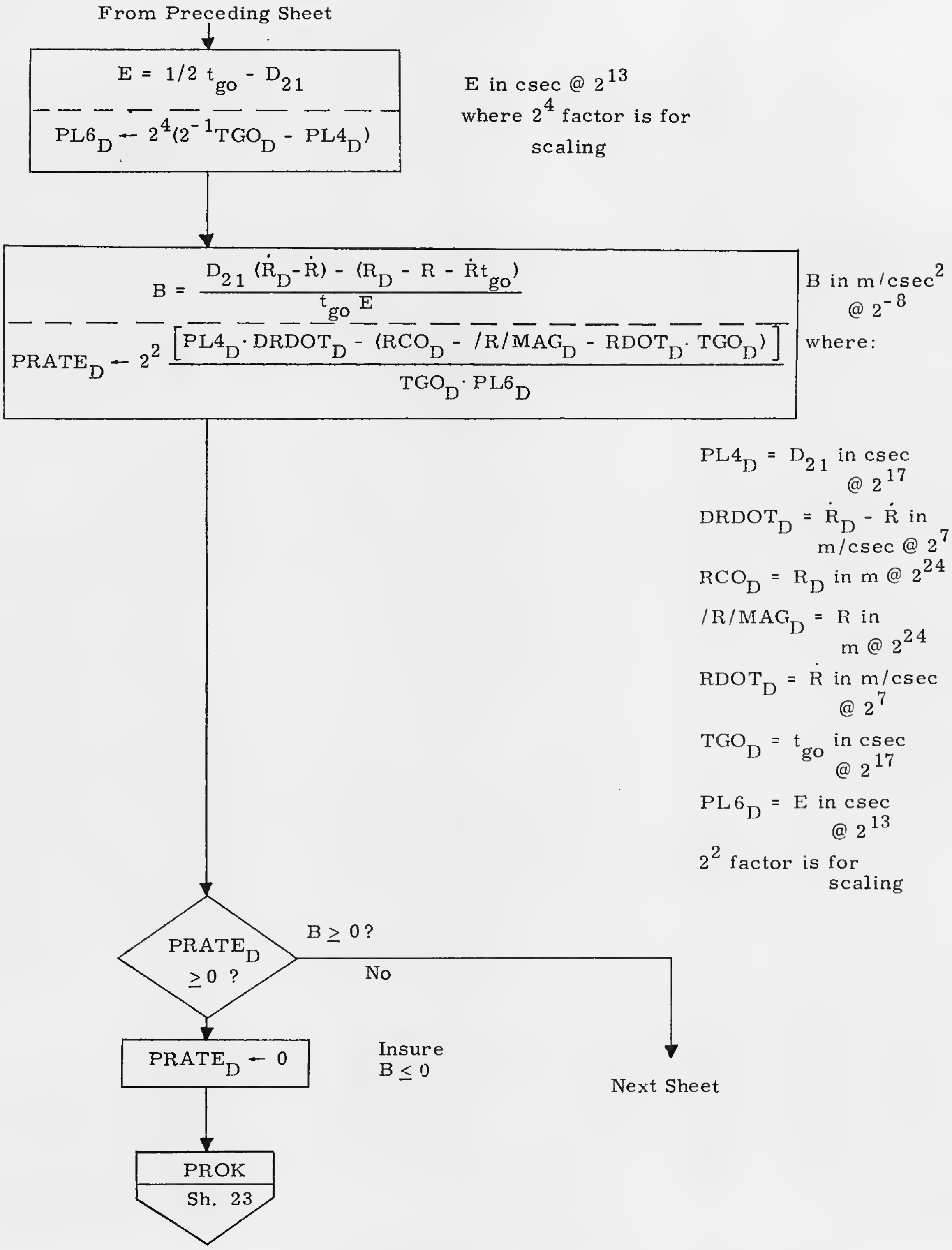

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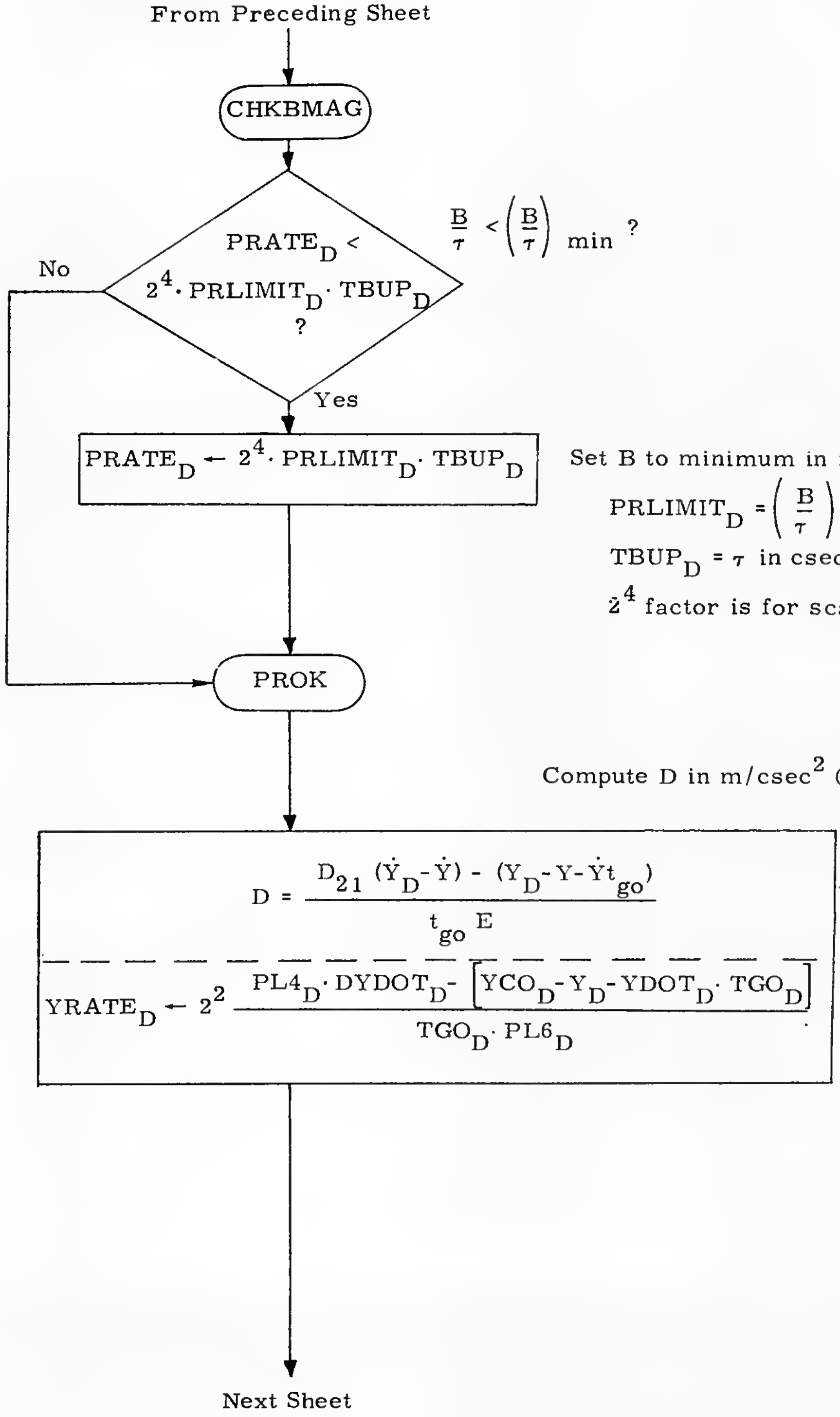

$\frac{B}{\tau} < \left(\frac{B}{\tau}\right)_{min}$?

Set B to minimum in m/csec @ 2^{-8}

$PRLIMIT_D = \left(\frac{B}{\tau}\right)_{min}$ in m/csec^3 @ 2^{-21}

$TBUP_D = \tau$ in csec @ 2^{17}

2^4 factor is for scaling

Compute D in m/csec^2 @ 2^{-8}

where:

$PL4_D = D_{21}$ in csec @ 2^{17}

$DYDOT_D = \dot{Y}_D - \dot{Y}$ in m/csec @ 2^7

$YCO_D = Y_D$ in m @ 2^{24}

$Y_D = Y$ in m @ 2^{24}

$YDOT_D = \dot{Y}$ in m/csec @ 2^7

$TGO_D = t_{go}$ in csec @ 2^{17}

$PL6_D = E$ in csec @ 2^{13}

2^2 factor is for scaling

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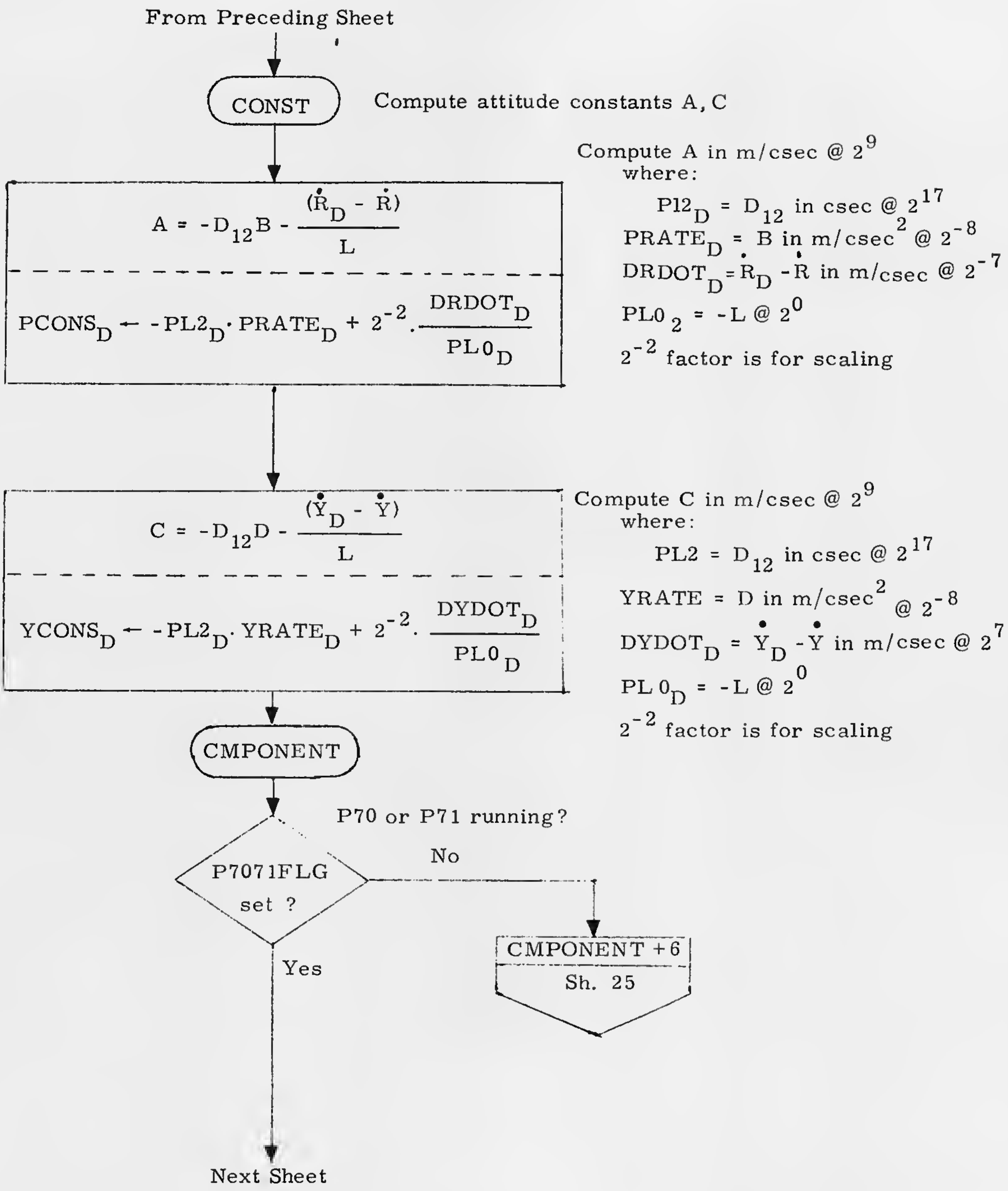

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From Preceding Sheet

RPCOMP2
Compute R_P estimate
Sh. 49

Input: $/R/MAG_D$ = R in m @ 2^{24}
$RDOT_D$ = $\dot{R}$ in m/csec @ 2^7
TGO_D = t_{go} in csec @ 2^{17}
$PCONS_D$ = A in m/csec @ 2^9
$PRATE_D$ = B in m/csec^2 @ 2^{-8}
$TBUP_D$ = τ in csec @ 2^{17}
Output: RP_D = R_P in m @ 2^{24}

CMPONENT +6 — Compute acceleration components

$$a_{TR} = \frac{A + B\Delta t}{\tau} - g_{eff}$$

$$ATR_D \leftarrow 2^1 \frac{PCONS_D + PRATE_D \cdot 100CS_D}{TBUP_D} - GEFF_D$$

a_{TR} in m/csec^2 @ 2^{-9}
where:
$PCONS_D$ = A in m/csec @ 2^9
$PRATE_D$ = B in m/csec^2 @ 2^{-8}
$100CS_D$ = Δt = 100 csec @ 2^{17}
$TBUP_D$ = τ in csec @ 2^{17}
$GEFF_D$ = g_{eff} in m/csec^2 @ 2^{-9}
2^1 factor is for scaling

Next Sheet

From Preceding Sheet

$$a_{TY} = \frac{C + D\Delta t}{\tau}$$

$$ATY_D \leftarrow 2^1 \cdot \frac{YCONS_D + YRATE_D \cdot 100CS_D}{TBUP_D}$$

a_{TY} in m/csec^2 @ 2^{-9}
where:

$YCONS_D$ = C in m/csec @ 2^9
$YRATE_D$ = D in m/csec^2 @ 2^{-8}
$100CS_D$ = Δt = 100 csec @ 2^{17}
$TBUP_D$ = τ in csec @ 2^{17}
2^1 factor is for scaling

$$\underline{a}_H = a_{TY}\underline{u}_Y + a_{TR}\underline{u}_R$$

$$PL0_V \leftarrow 2^1 \cdot [ATY_D \cdot LAXIS_V + ATR_D \cdot UNIT/R/_V]$$

$\underline{a}_H$ in SM coordinates
in m/csec^2 @ 2^{-9}
where
$LAXIS_V$ = $\underline{u}_Y$ in
SM coords @ 2^1
$UNIT/R/_V$ = $\underline{u}_R$ in
SM coords @ 2^1
2^1 factor is for scaling

$PL6_D \leftarrow |PL0_V|$ — a_H @ 2^{-9}

$PL8_D \leftarrow AT_D^2 - |PL0_V|^2$ — $a_T^2 - a_H^2$ @ 2^{-18}

$PL10_D \leftarrow AT_D$ — a_T @ 2^{-9}

Next Sheet

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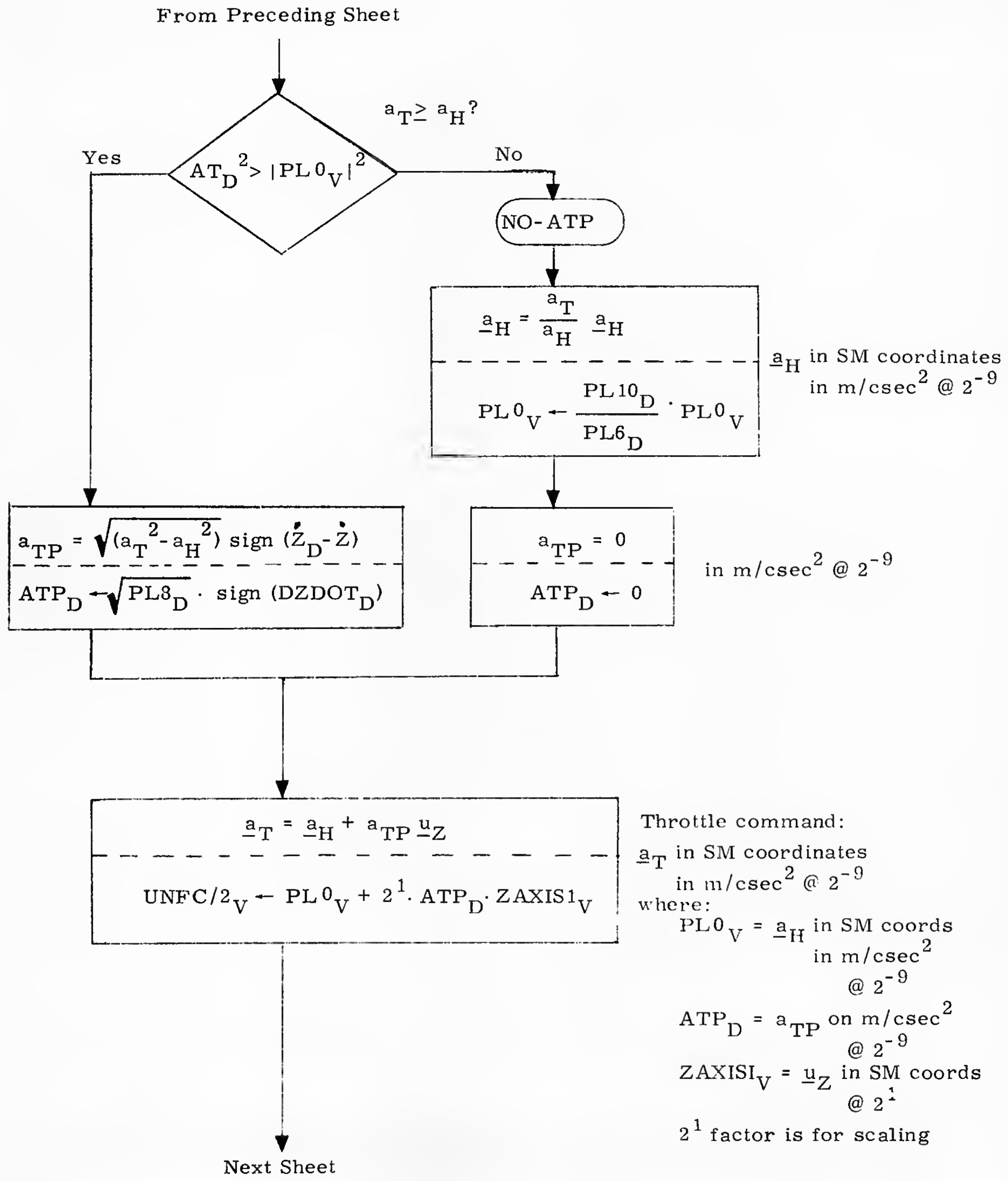

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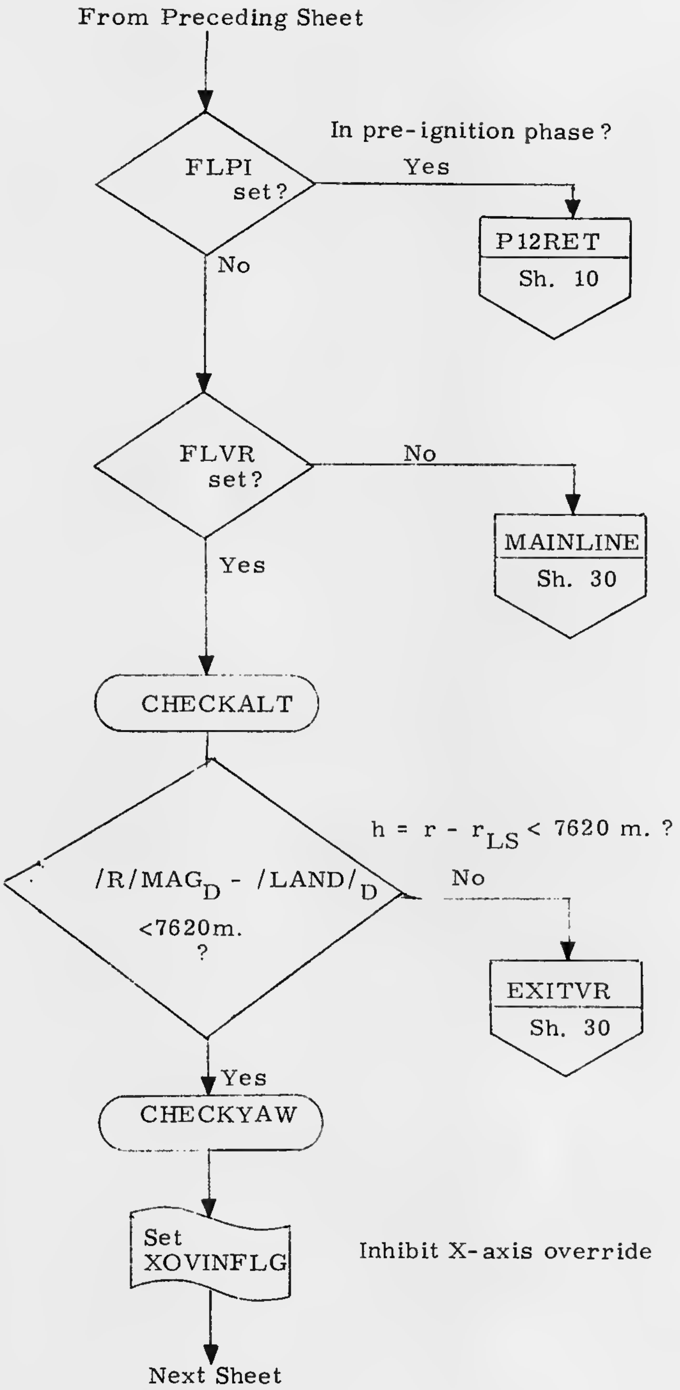

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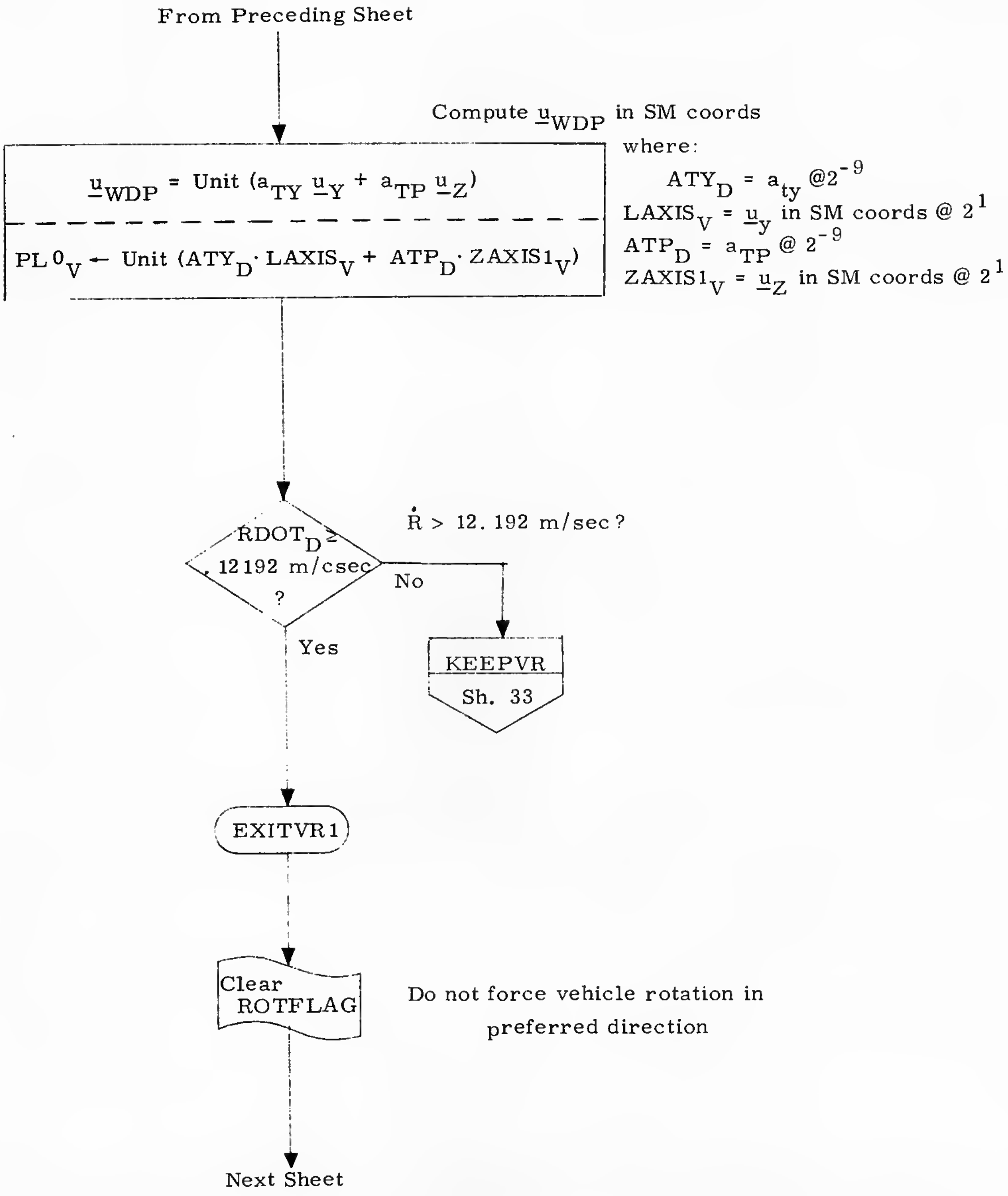

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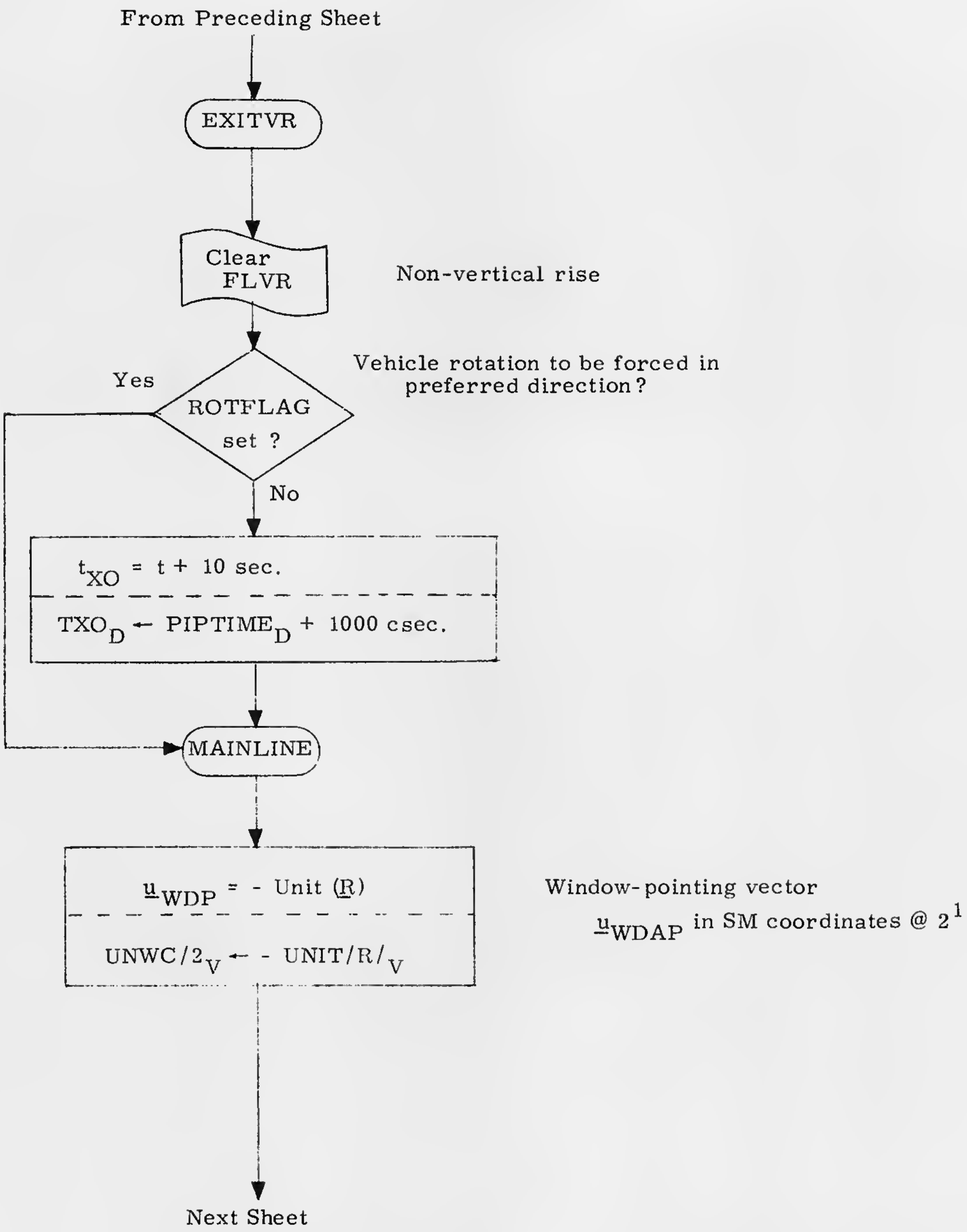

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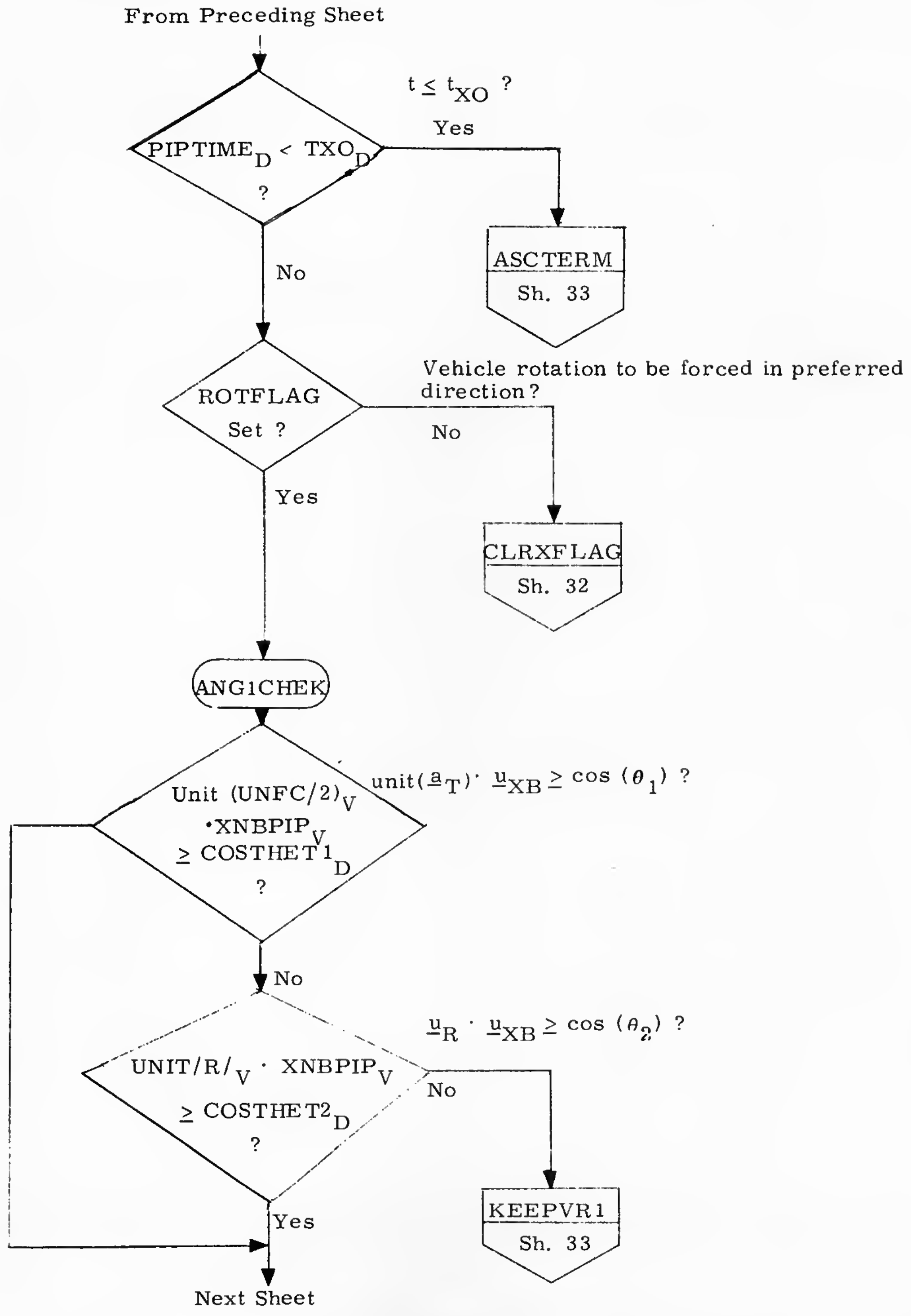

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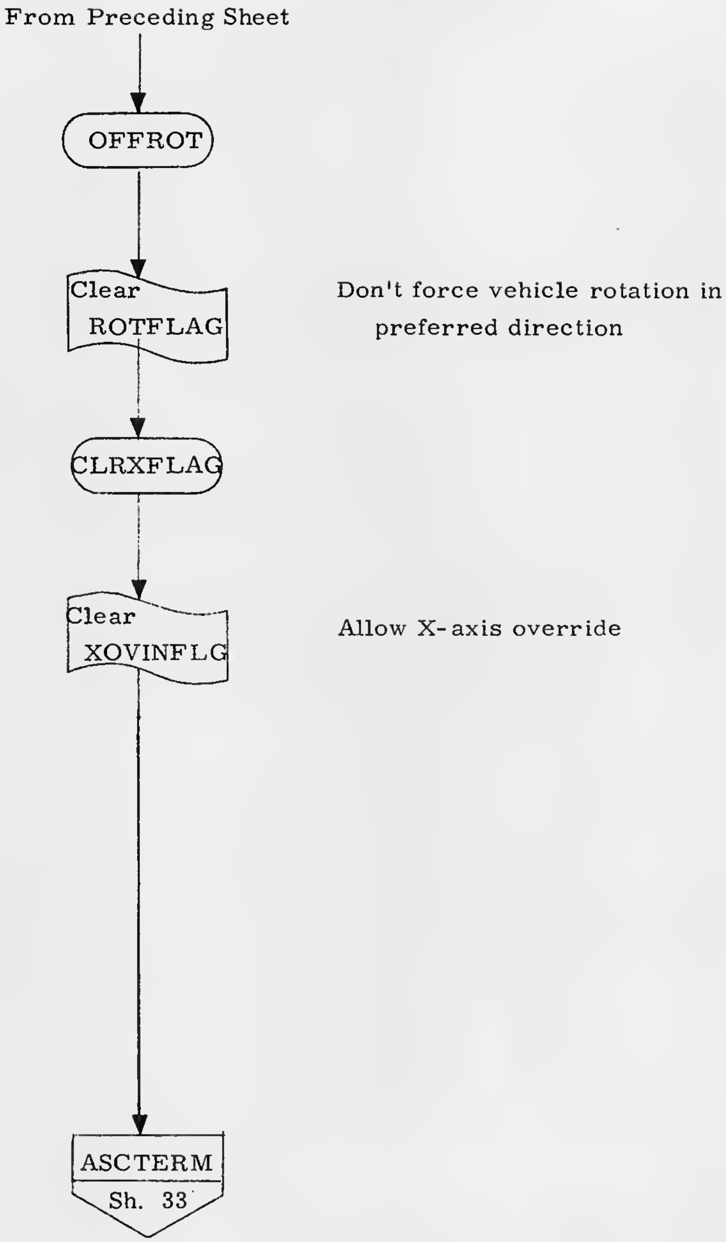

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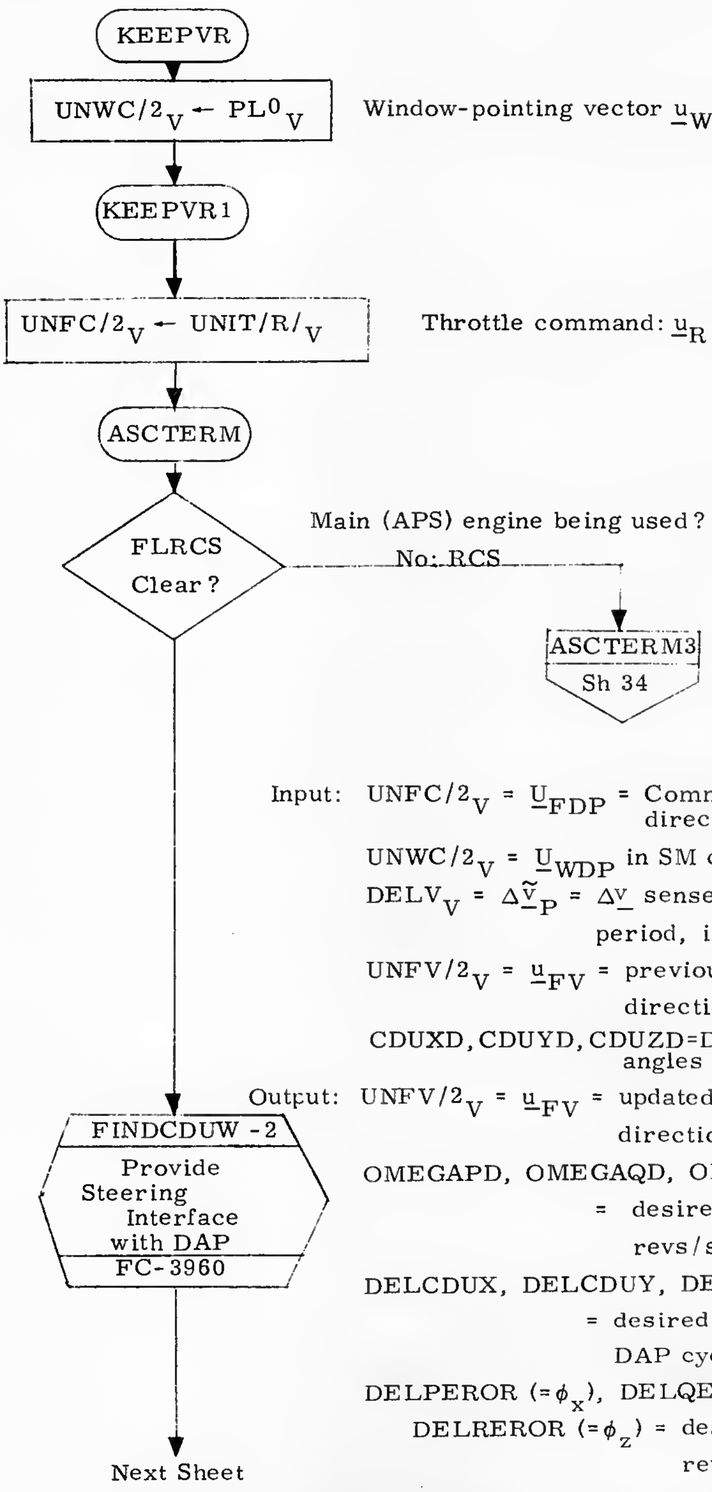


Input: $UNFC/2_V$ = $\underline{U}_{FDP}$ = Commanded thrust direction in SM coords @ 2^1

$UNWC/2_V$ = $\underline{U}_{WDP}$ in SM coordinates @ 2^1

$DELV_V$ = $\Delta\underline{\tilde{v}}_P$ = $\Delta\underline{v}$ sensed in last 2-sec. period, in SM coords

$UNFV/2_V$ = $\underline{u}_{FV}$ = previous measured thrust direction in SM coords @ 2^1

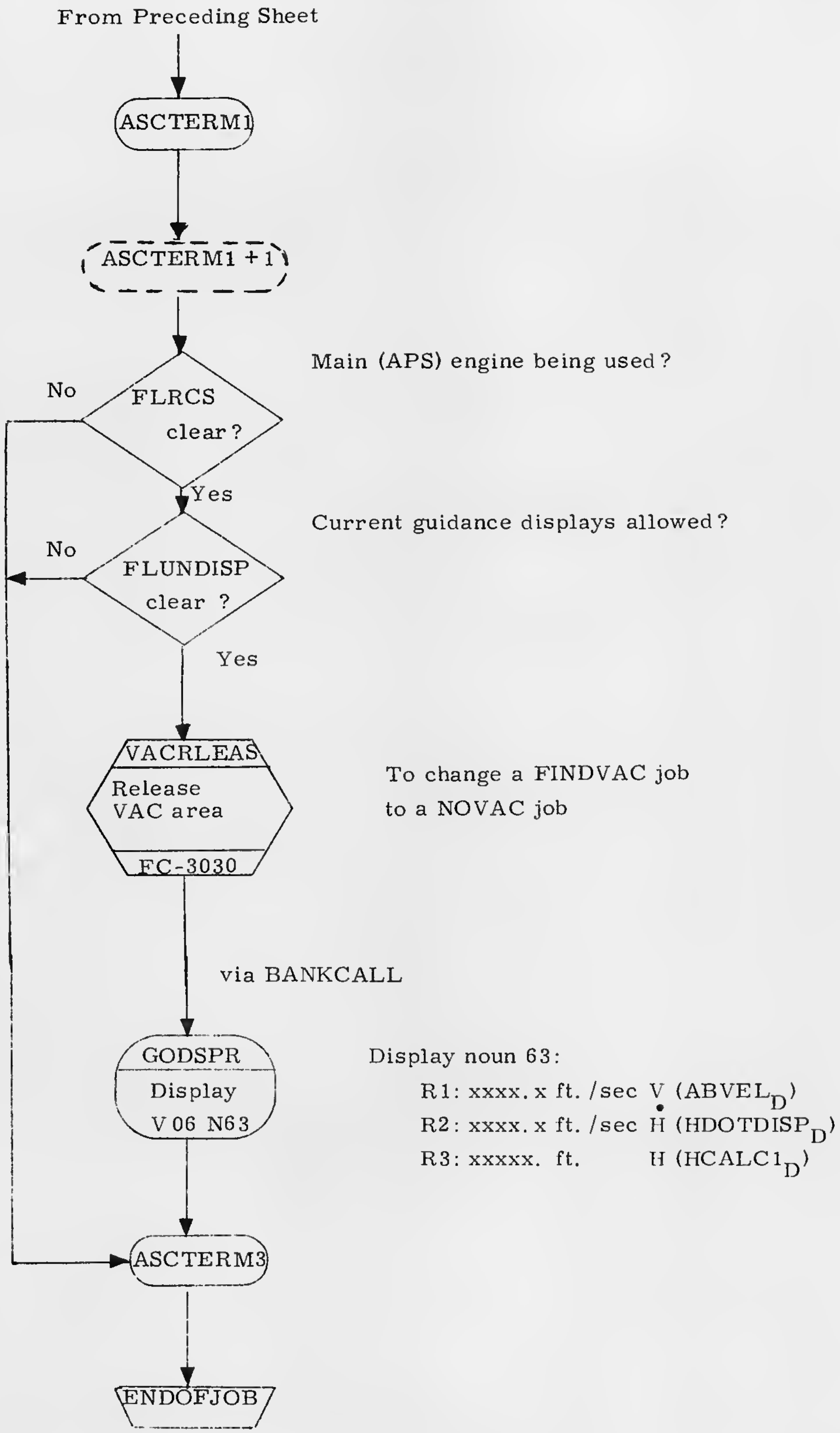
CDUXD, CDUYD, CDUZD=DAP desired IMU gimbal angles in revs @2^{-1}

Output: $UNFV/2_V$ = $\underline{u}_{FV}$ = updated measured thrust direction in SM coords @ 2^1

OMEGAPD, OMEGAQD, OMEGARD = $\underline{\omega}_{DV}$ = desired attitude rates in revs/sec @ 2-3

DELCDUX, DELCDUY, DELCDUZ = δ $\underline{CDU}$ = desired attitude change per DAP cycle, in revs @ 2^{-1}

DELPEROR (=ϕ_x), DELQEROR (=ϕ_y), DELREROR (=ϕ_z) = desired lag angles in revs @ 2^{-1}



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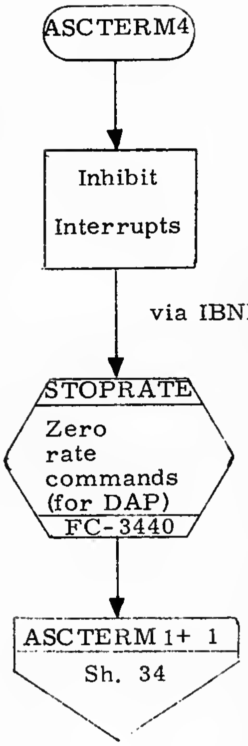

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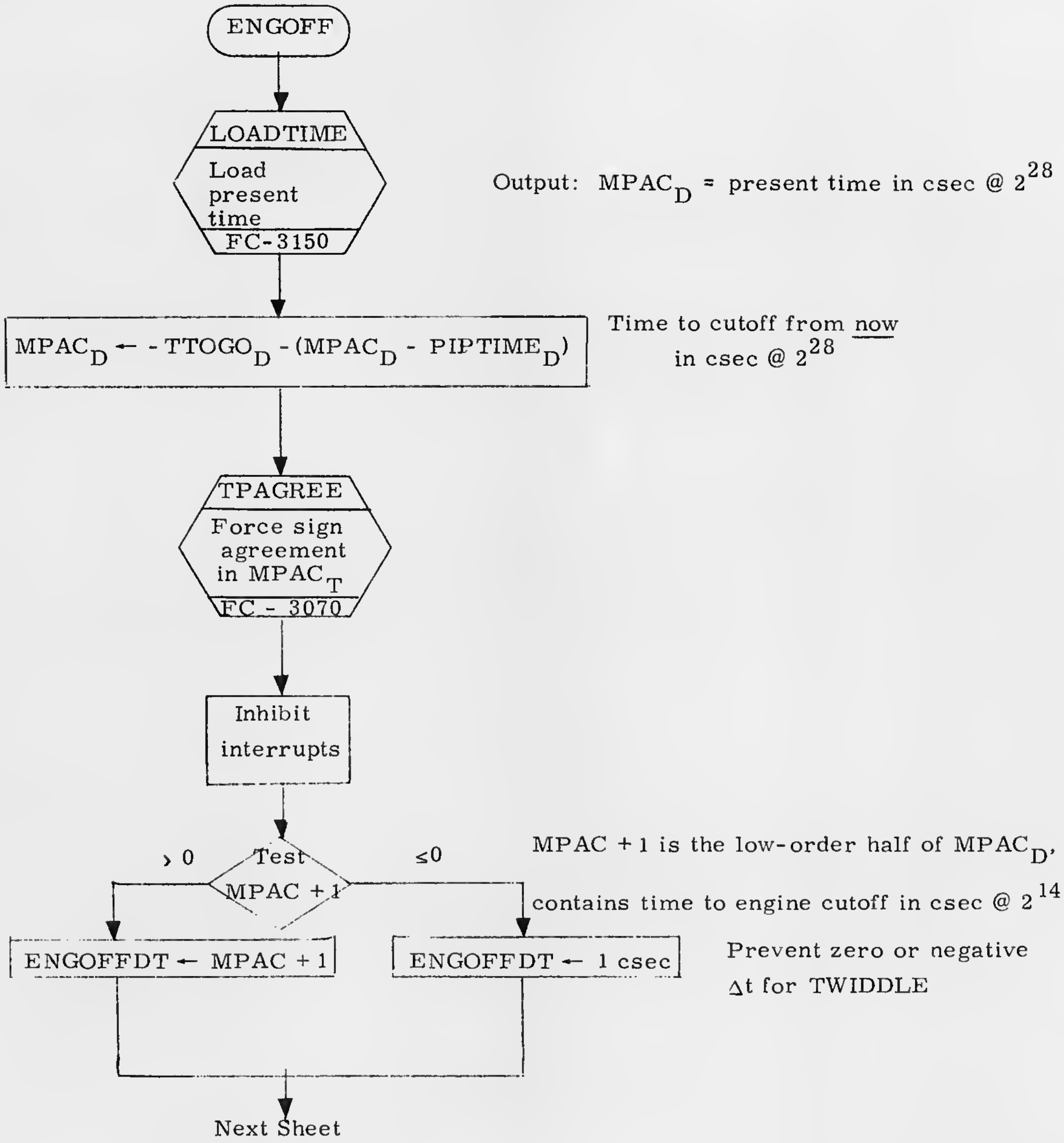

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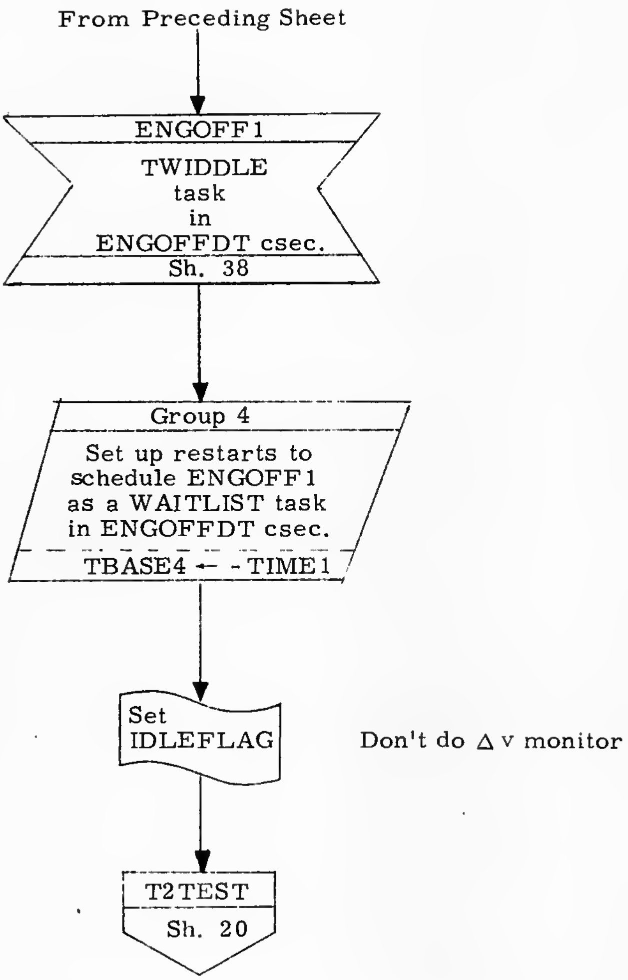

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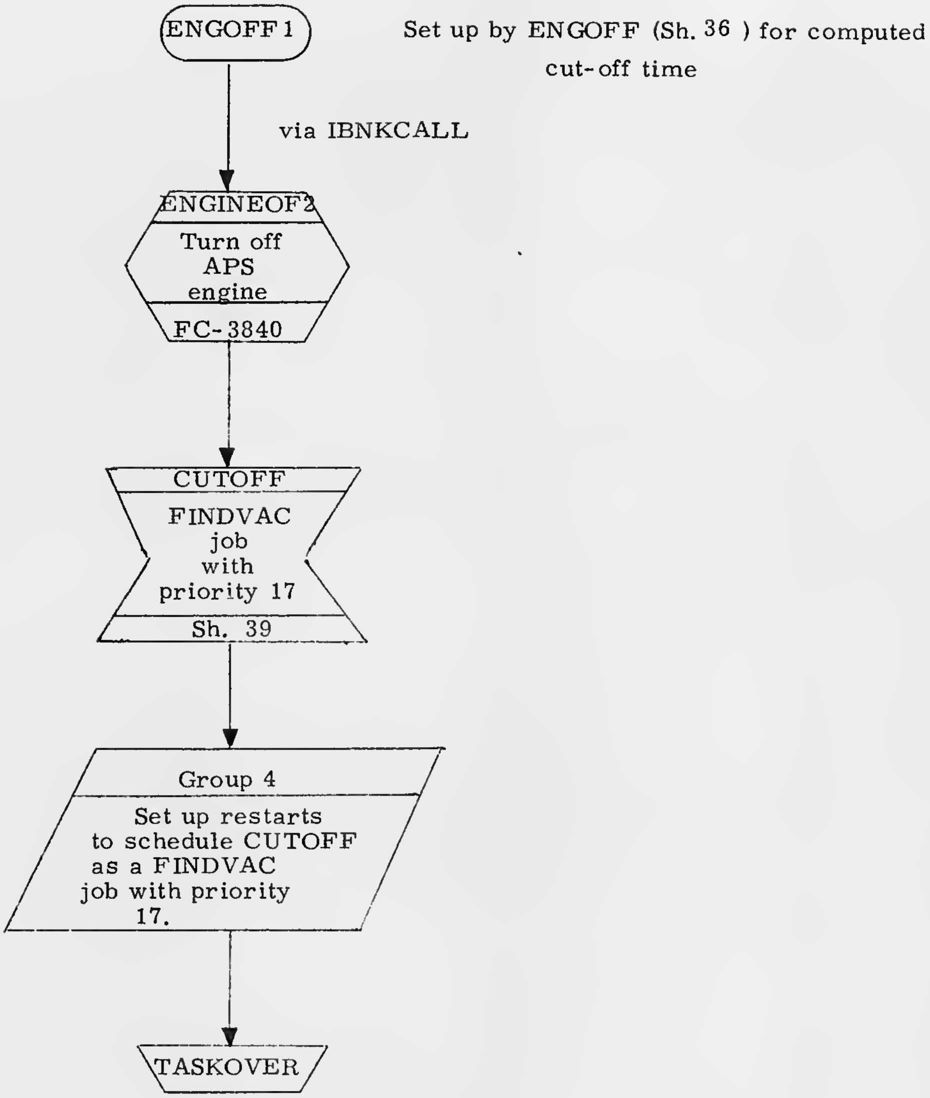

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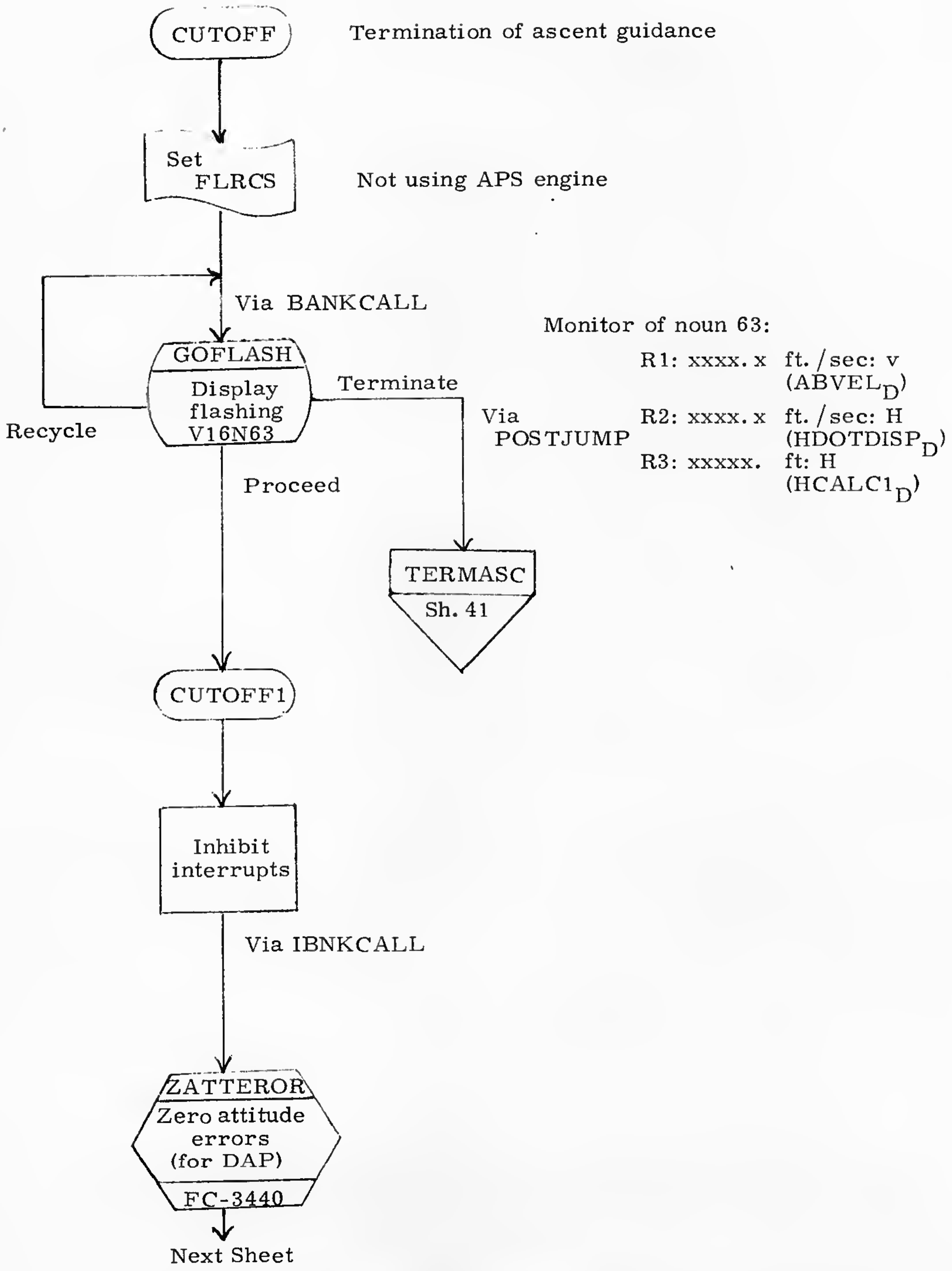

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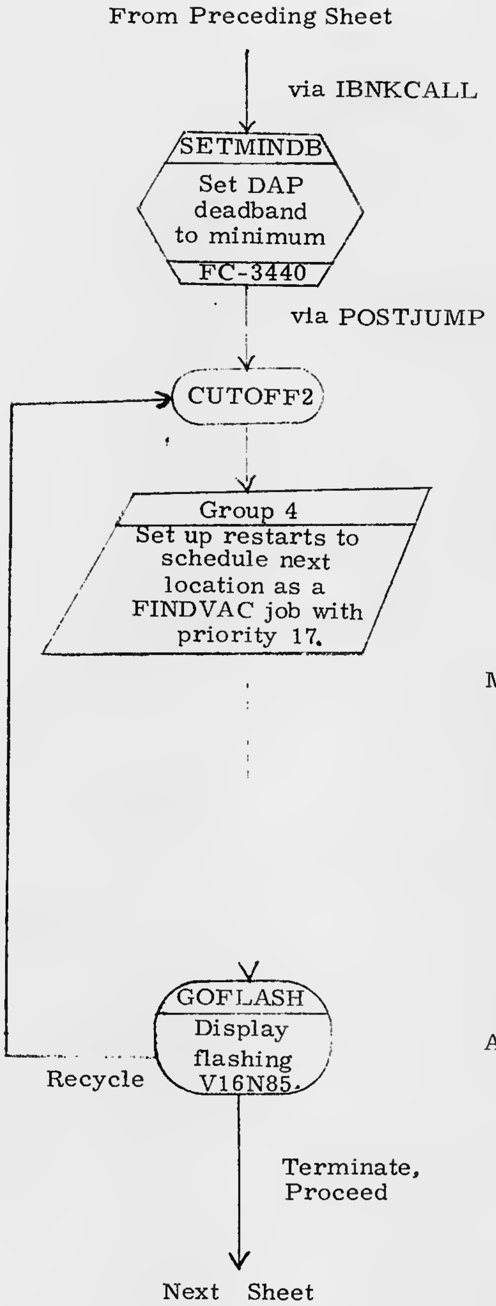

Monitor of noun 85:
R1: xxxx.x ft/sec
R2: xxxx.x ft/sec
R3: xxxx.x ft/sec
} 3 Components of $\underline{v}_G$ in body (NB) coordinates ($VGBODY_V$)

Astronaut may null out remaining $\underline{v}_G$ using hand controls

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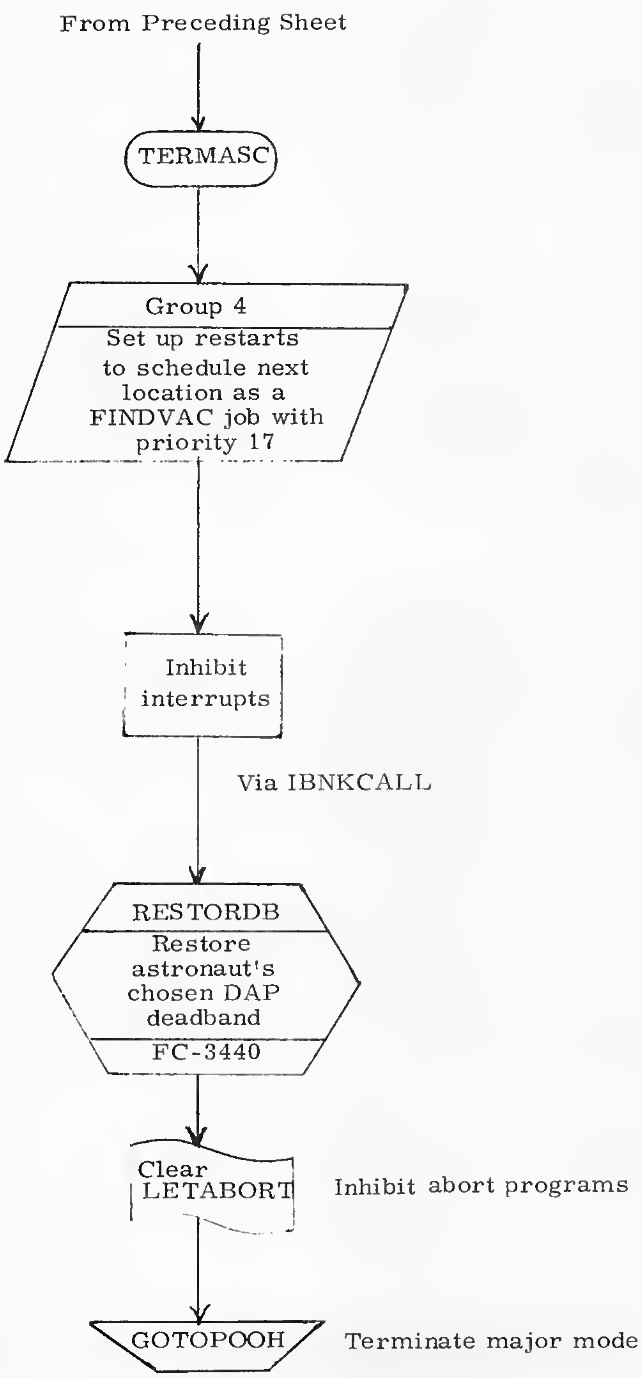
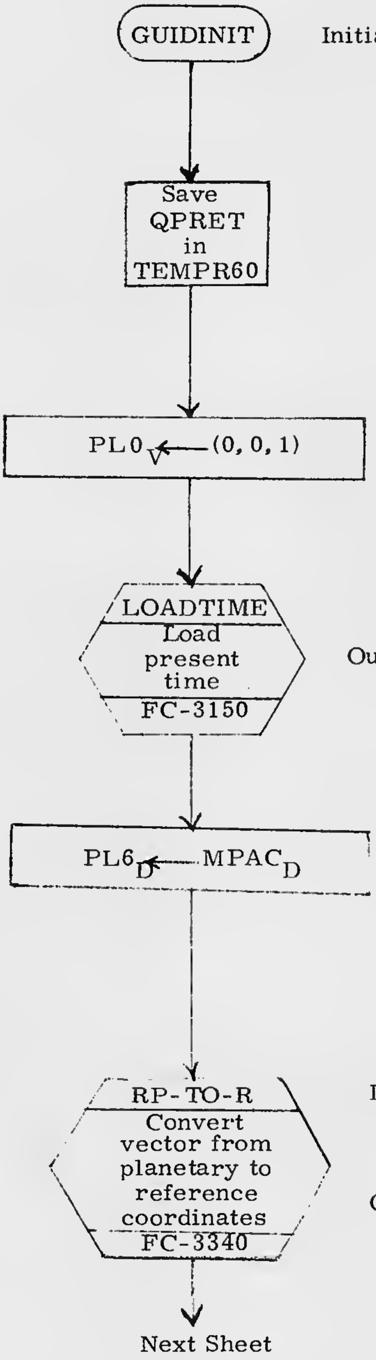
DOCMR			
APPR'D R M Eates	6/25/70	REV	SHEET 40 OF 63



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		P12-Ascent Guidance	
PRGMR		LUMINARY 1D	DOCUMENT NO. FC-3950
ANALST			
DOCMR			
APPR'D	6/25/70	REV	SHEET 41 OF 63



Initialize ascent guidance parameters $\underline{\omega}_M$, r_{LS}

Unit vector @ 2^1

Output: $MPAC_D$ = present time in csec @ 2^{28}

Time in csec @ 2^{28}

Input: $PL0_V$ = vector in planet -fixed coordinates
$PL6_D$ = corresponding time in cscc @ 2^{28}
MPAC $\neq$ 0-indicates moon-fixed coordinates
Output: $MPAC_V$ = given vector in referencc coordinates (same scaling)

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PRGMR *[signature]*		
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DOCMR		
APPR'D *[signature]* 6/25/70	REV	SHEET 42 OF 63

From Preceding Sheet

Compute $\underline{\omega}_M$ = rotational velocity of the moon in SM coordinates in rad/csec $@2^{-17}$

$WM_V \leftarrow MOONRATE_D \times (REFSMMAT_M \times MPAC_V)$

Where:
$MPAC_V$ = moon rotational axis in reference coords $@2^1$

$REFSMMAT_M$ = reference-SM coordinate transformation matrix $@2^1$

$MOONRATE_D$ = moon rotation rate ω_M in rad/csec $@2^{-19}$

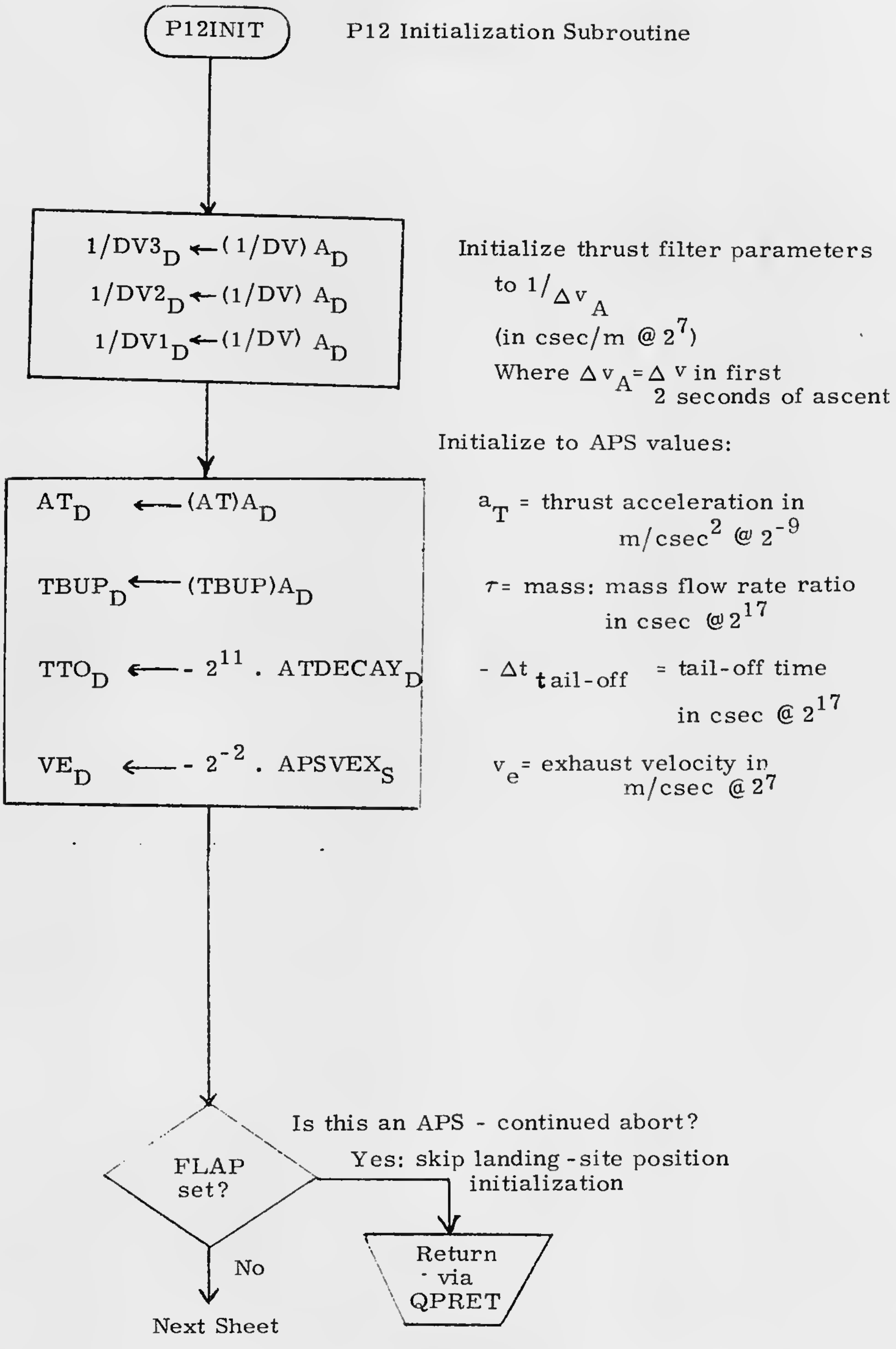
$|LAND|_D \leftarrow 2^3 \cdot |RLS_V|$

Set landing site radius r_{LS} (in m $@2^{24}$)

Where: RLS_V = landing site position vector in m $@2^{27}$

2^3 factor is for scaling

Return via TEMPR60



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DRAWN		P12-Ascent Guidance	
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ANALST		LUMINARY 1D	DOCUMENT NO. FC-3950
DOCMR			
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From Preceding Sheet

COMMINIT — Initialize target parameters

$R_D = r_{LS} + 60,000$ Ft.

$RCO_D \leftarrow /LAND/_D + HINJECT_D$

R_D = desired injection radius in m @ 2^{24}

Where $HINJECT_D$ = 18,288m (≈ 60,000 Ft.) @ 2^{24}

$TXO_D \leftarrow 0$

$YCO_D \leftarrow 0$

$YDOTD_D \leftarrow 0$

Time when X-axis override is allowed in csec @ 2^{28}

Y_D = desired injection cross-range distance in m @ 2^{24}

$\dot{Y}_D$ = desired cross-range velocity in m/csec @ 2^{7}

Compute Q - axis of target coordinate system (in SM coords) @ 2^{1}

$Q = \text{Unit}(\underline{v}_c \times \underline{r}_c)$

$QAXIS_V \leftarrow \text{Unit}[REFSMMAT_M \times (VRECTCSM_V \times RRECTCSM_V)]$

Where:

$VRECTCSM_V = \underline{v}_c$ = CSM velocity in reference coordinates

$RRECTCSM_V = \underline{r}_c$ = CSM position in reference coordinates

$REFSMMAT_M$ = reference - SM coordinate transformation matrix

Return via QPRET

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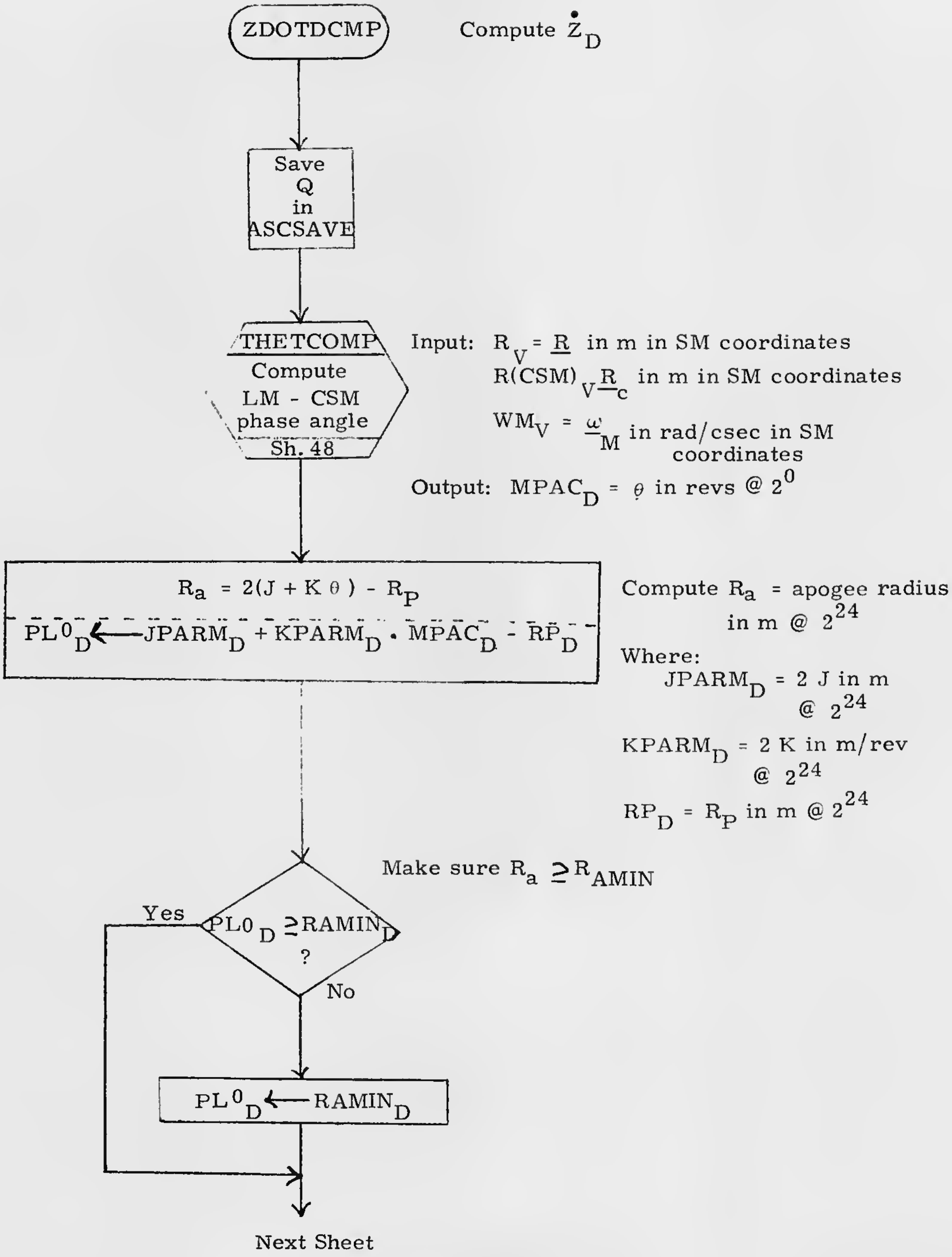

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN	P12-Ascent Guidance
PRGMR	
ANALST	LUMINARY 1D
DOCMR	DOCUMENT NO. FC-3950
APPR'D 6/25/[illegible]	REV
	SHEET 46 OF 63

From Preceding Sheet

$$Z_D = \sqrt{\frac{\mu_M \, R_a}{(J + K\theta) R_P}}$$

$$\text{ZDOTD}_D \leftarrow \sqrt{\frac{\text{MUM}(-37)_D \cdot \text{PL0}_D}{(\text{PL0}_D + \text{RP}_D)\,\text{RP}_D}}$$

Compute $\dot{Z}_D$ in m/csec @ 2^7

Where:

$\text{MUM}(-37)_D = \mu$ in $m^3/csec^2$ @ 2^{37}

$\text{PL0}_D = 2(J + K\theta) - R_P$ in m @ 2^{24}

$\text{RP}_D = R_P$ in m @ 2^{24}

Return via ASCSAVE

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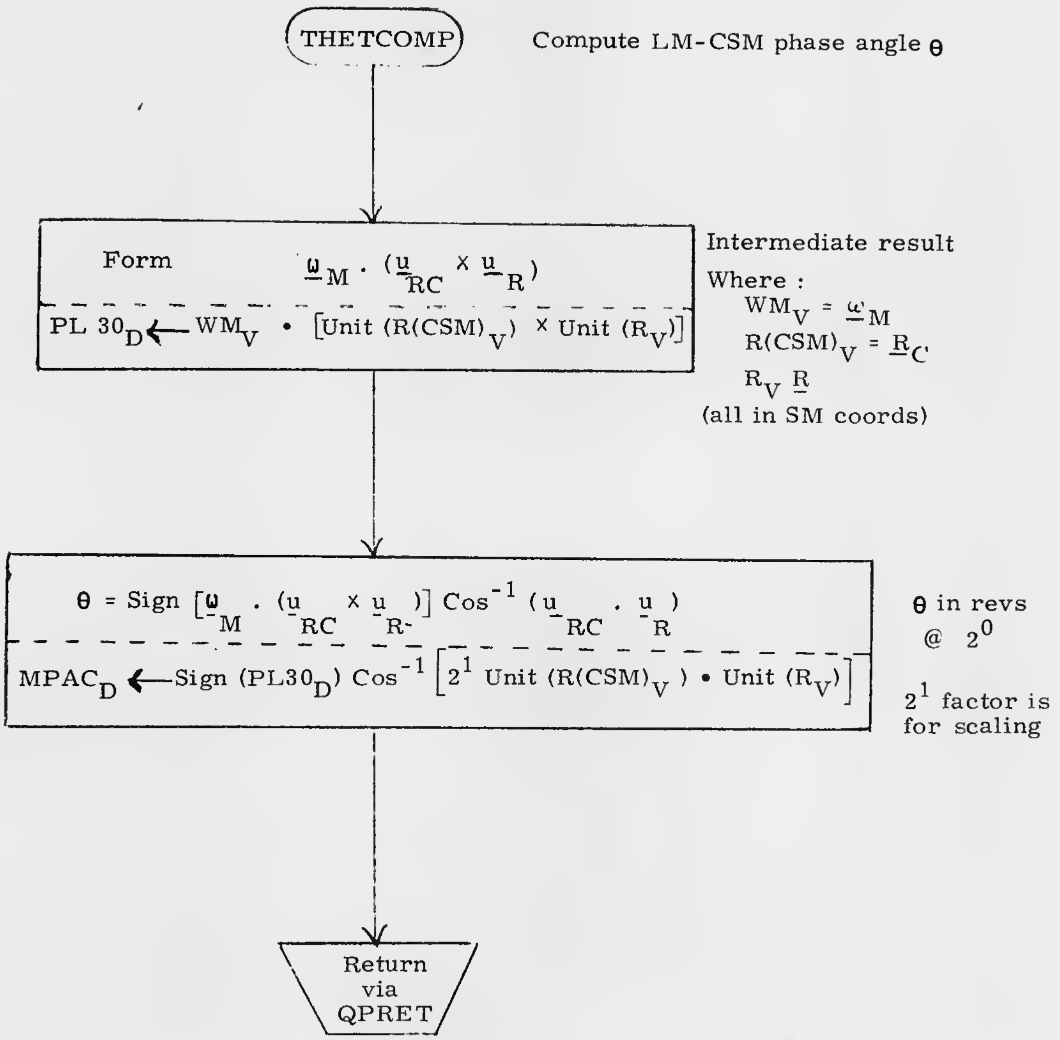
DRAWN *L. Gaudette*		P12-Ascent Guidance	
PRGMR *P. J. Berman*			DOCUMENT NO.
ANALST		LUMINARY 1D	FC 3950
DOCMR			
APPR'D *R. M. Eaton*	6/25/70	REV	SHEET 47 OF 63



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		P12-Ascent Guidance	
PRGMR			DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3950
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RPCOMP1

Entry to compute $R_P = R + Rt_{go}$

$PCONS_D \leftarrow 0$

$PRATE_D \leftarrow 0$

A in m/csec @ 2^9

B in m/csec^2 @ 2^{-8}

RPCOMP2

Entry for long computation of R_P

Compute new R_P (perigee at cutoff) in m @ 2^{24}

$$R_P = R + \dot{R}t_{go} + \frac{A}{2\tau} t_{go}^2 + \frac{B}{6\tau} t_{go}^3$$

$$RP_D \leftarrow /R/MAG_D + RDOT_D\ TGO_D + 2^2 \left[\frac{PCONS_D}{2} + \frac{THIRD_D}{2} \cdot PRATE_D \cdot TGO_D \right] \frac{TGO_D^2}{TBUP_D}$$

Where:

$/R/MAG_D$ = R in m @ 2^{24}

$RDOT_D$ = $\dot{R}$ in m/csec @ 2^7

TGO_D = t_{go} in csec @ 2^{17}

$PCONS_D$ = A in m/csec @ 2^9

$THIRD_D$ = .333333333 @ 2^0

$PRATE_D$ = B in m/csec^2 @ 2^{-8}

$TBUP_D$ = τ in csec @ 2^{17}

2^2 factor is for scaling

Return via QPRET

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PRGMR L.J. Berman			DOCUMENT NO.
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LOGSUB

Compute natural logarithm of quantity $(2^{-n}q)$ in $MPAC_D$ @ 2^0

$MPAC_D \leftarrow 1 - 2^n\, MPAC_D$

$MPAC + 6 \leftarrow -n$

Normalize $MPAC_D$ (to q) and subtract from 1

Save normalization count @ 2^{14}

Input: $MPAC_D = x$ @ 2^0

Coefficients of polynomial:

$C_0 = .0000000060$
$C_1 = -.0312514377$
$C_2 = -.0155686771$
$C_3 = -.0112502068$
$C_4 = -.0018545108$
$C_5 = -.0286607906$
$C_6 = .0385598563$
$C_7 = -.0419361902$

POLY

Compute desired polynomial

FC-3070

Oupput: $MPAC_D = C_0 + C_1 x + C_2 x^2 + C_3 x^3 + C_4 x^4 + C_5 x^5 + C_6 x^6 + C_7 x^7$

here $= \ln(1 - x) = \ln(q)$ @ 2^0

$MPAC + 2 \leftarrow 0$

Zero low-order third of $MPAC_T$ to be used later

$BUF + 1_D \leftarrow MPAC_D$

Save $\ln(q)$ @ 2^0

Next Sheet

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DRAWN Z. Goldbon	P12-Ascent Guidance
PRGMR E. J. Brennan	
ANALST	LUMINARY 1D
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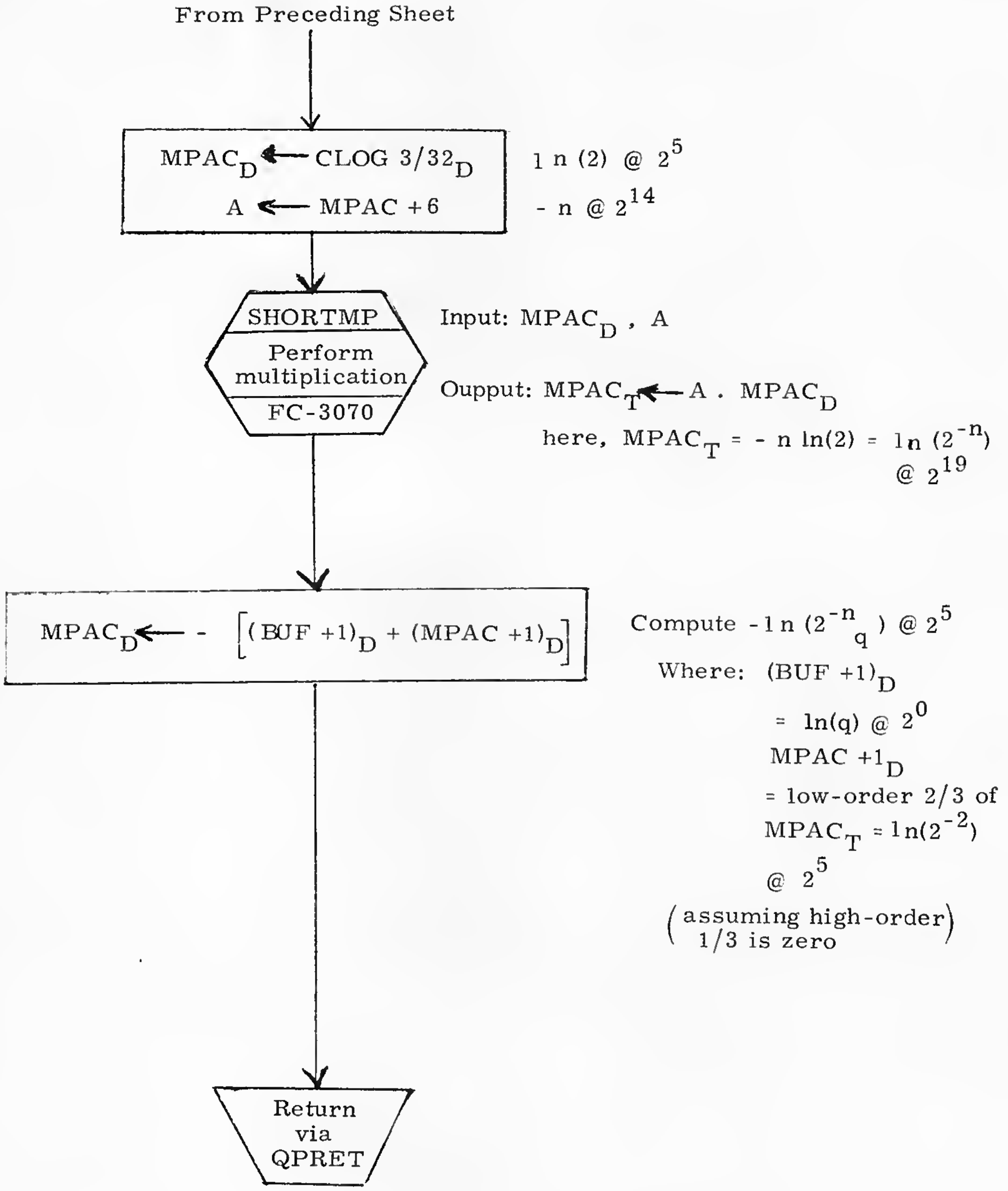

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN	P12-Ascent Guidance	
PRGMR		DOCUMENT NO.
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SUBROUTINES CALLED WHICH ARE FLOWED ON OTHER FLOWCHARTS

Subroutine	Flowchart	Description	Where Called
BURNBABY	FC-3840	Master ignition routine	Sh. 11
CLRADMOD	FC-3600	Initialize RADMODES flags for R29	Sh. 2
ENGINOF2	FC-3840	Turn off APS engine	Sh. 38
FINDCDUW-2	FC-3960	Provide steering interface with DAP	Sh. 33
LEMPREC	FC-3350	Integrate LM state vector to desired time	Sh. 5
LOADTIME	FC-3150	Load present time	Sh. 36, 42
MUNGRAV	FC-3850	Compute gravity at given position	Sh. 6
PFLITEDB	FC-3440	Set deadband for powdered flight (forDAP)	Sh. 11
POLY	FC-3070	Compute desired polynomial	Sh. 50
RESTORDB	FC-3440	Restore astronaut's chosen DAP	Sh. 41
RP-TO-R	FC-3340	Convert vector from planetary to reference coordinates	Sh. 42
R02BOTH	FC-3220	Check that IMU is on and aligned	Sh. 2
SETMINDB	FC-3440	Set DAP deadband to minimum	Sh. 40
SHORTMP	FC-3070	Perform multiplication	Sh. 51
STOPRATE	FC-3440	Zero rate commands (for DAP)	Sh. 35
TPAGREE	FC-3070	Force sign agreement in $MPAC_T$	Sh. 36
VACRLEAS	FC-3030	Release VAC area	Sh. 34
ZATTEROR	FC-3430	Zero attitude errors (for DAP)	Sh. 39

FLAGS

Name	Meaning When Set	Meaning When Clear	Where Set	Where Cleared	Where Tested
ACC4-2FL (bit 11 of FLGWRD13)	Four-jet translation requested	Two-jet translation requested	Sh. 3		
FLAP (bit 8 of FLAGWRD9)	APS-continued abort	Not an APS-continued abort			Sh. 44
FLPC (bit 12 of FLAGWRD8)	No position control	Position control	Sh. 21		Sh. 21
FLPI (bit 11 of FLAGWRD9)	Pre-ignition phase of ascent guidance	Regular (post-ignition) ascent guidance	Sh. 3	Sh. 11	Sh. 28
FLRCS (bit 10 of FLAGWRD9)	RCS injection	APS injection	Sh. 39		Sh. 12, 17, 33, 34
FLUNDISP (bit 10 of FLAGWRD8)	Current guidance displays inhibited	Current guidance displays allowed			Sh. 34
FLVR (bit 14 of FLAGWRD9)	Vertical rise	Non-vertical rise	Sh. 3	Sh. 30	Sh. 28
IDLEFLAG (bit 7 of FLAGWRD7)	No Δ_V Monitor	Connect Δ_V Monitor	Sh. 37		Sh. 19
LETABORT (bit 9 of FLAGWRD9)	Abort programs allowed	Abort programs inhibited		Sh. 41	
MUNFLAG (bit 8 of FLAGWRD6)	Servicer will call MUNRVG	Servicer will call CALCRVG	Sh. 3		
P7071FLG (bit 13 of FLGWRD9)	P70 or P71 is using ascent guidance	P12 is using ascent guidance			Sh. 16, 24, 32

FLAGS (CONTINUED)

Name	Meaning When Set	Meaning When Clear	Where Set	Where Cleared	Where Called
RENDVZFLG (bit 7 of FLAGWRD 0)	P20 running	P20 not running		Sh. 3	
RENDWFLG (bit 1 of FLAGWRD5)	W-matrix valid for rendezvous navigation	W-matrix invalid for rendezvous navigation		Sh. 12	
ROTFLAG (bit 6 of FLAGWRD9)	P70, P71 will force vehicle rotation in preperred direction	Do not force vehicle rotation in preferred direction		Sh. 29, 32	Sh. 30, 31
R10FLAG (bit 2 of FLAGWRD0)	R10 outputs only altitude, altitude rate data	R10 also outputs cross-range data	Sh. 3		
SURFFLAG (bit 8 of FLAGWRD8)	LM on lunar surface	LM not on lunar surface		Sh. 12	
XOVINFLG (bit 9 of FLGWRD13)	X-axis override inhibited	X-axis override allowed	Sh. 28	Sh. 32	

DISPLAYS

Verb-Noun	Type of Display	Description of Registers		Where Called
V06 N33	Flashing	R1: 00xxx. hrs. R2: 000xx. min. R3: 0xx.xx sec. } time of ignition (TIG_D)		Sh. 3
V06N76	Flashing	R1: xxxx.x ft./sec. $\dot{Z}_D$ R2: xxxx.x ft./sec $\dot{R}_D$ R3: xxxx.x nm. CR	($ZDOTD_D$) ($RDOTD_D$) ($XRANGE_D$)	Sh. 7
V06N63	Normal	R1: xxxx.x ft./sec. v R2: xxxx.x ft./sec. $\dot{H}$ R3: xxxxx. ft. H	($ABVEL_D$) ($HDOTDISP_D$) ($HCALC1_D$)	Sh. 34
V16N63	Flashing Monitor	Registers same as V06N63 display above		Sh. 39
V16N85	Flashing Monitor	R1: xxxx.x ft./sec. R2: xxxx.x ft./sec. R3: xxxx.x ft./sec. } $\underline{v}_G$ in body (NB) coordinates ($VGBODY_V$)		Sh. 40

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DRAWN	P12-Ascent Guidance
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ERASABLE LOCATIONS USED

AGC Tag	GSOP Symbol	Meaning	Engineering Units	AGC Units	AGC Scaling
$ABDVCONV_D$	Δv	Magnitude of velocity - change increment	m/sec	m/csec	2^5
$ABVEL_D$	v	Magnitude of velocity, for noun 63 display	m/sec	m/csec	
AT_D	a_T	Thrust acceleration	m/sec^2	m/csec^2	2^{-9}
ATP_D	a_{TP}	Z-axis component of required thrust acceleration	m/sec^2	m/csec^2	2^{-9}
ATR_D	a_{TR}	Radial component of required acceleration	m/sec^2	m/csec^2	2^{-9}
ATY_D	A_{TY}	Cross-range component of required accelaration	m/sec^2	m/csec^2	2^{-9}
CDUXD	CDUXD	DAP desired outer IMU gimbal angle (2's complement)	degrees	revs	2^{-1}
CDUYD	CDUYD	DAP desired inner IMU gimbal angle (2's complement)	degrees	revs	2^{-1}
CDUZD	CDUZD	DAP desired middle IMU gimbal angle (2's complement)	degrees	revs	2^{-1}
DELCDUX	δCDUX	Commanded incremental change (for DAP) in outer IMU gimbal angle (2's complement)	degrees	revs	2^{-1}
DELCDUY	δCDUY	Commanded incremental change (for DAP) in inner IMU gimbal angle (2's complement)	degrees	revs	2^{-1}
DELCDUZ	δCDUZ	Commanded incremental change (for DAP) in middle IMU gimbal angle (2's complement)	degrees	revs	2^{-1}

ERASABLE LOCATIONS USED (CONTINUED)

ABC Tag	GSOP Symbol	Meaning	Engineering Units	AGC Units	AGC Scaling
DELPEROR	Φ_x	Commanded lag angle for outer IMU gimbal angle (for DAP)	degrees	revs	2^{-1}
DELQEROR	Φ_y	Commanded lag angle for inner IMU gimbal angle (for DAP)	degrees	revs	2^{-1}
DELREROR	Φ_z	Commanded lag angle for middle IMU gimbal angle (for DAP)	degrees	revs	2^{-1}
$DELV_V$	$\Delta\tilde{\underline{v}}_p$	Change in velocity sensed during last 2-second period, in SM coords	m/sec	m/csec	
$DRDOT_D$	$\dot{R}_D - \dot{R}$	Difference between desired and actual radial velocities	m/sec	m/csec	2^7
DVCNTR	N_C	Counter indicating 1 + number of cycles before signaling engine failure			2^{14}
DVTHRUSH	Δv_K	Minimum acceptable 2-second velocity change due to thrusting	m/sec	m/csec	$10^{-4} \times 2^{+14}$
$DYDOT_D$	$\dot{Y}_D - \dot{Y}$	Difference between desired and actual cross-range velocities	m/sec	m/csec	2^7
$DZDOT_D$	$\dot{Z}_D - \dot{Z}$	Difference between desired and actual Z-component velocities	m/sec	m/csec	2^7
$GDT1/2_V$	$(1/2)g\Delta t$	Half the change in velocity due to gravitational acceleration over $\Delta t = 2$ seconds	m/sec	m/csec	2^7

ERASABLE LOCATIONS USED (CONTINUED)

AGC Tag	GSOP Symbol	Meaning	Engineering Units	AGC Units	AGC Scaling
$GEFF_D$	g_{eff}	Effective gravitational acceleration	m/sec^2	$m/csec^2$	2^{-9}
$HCALC1_D$	H	Altitude, for noun 63 display	m	m	
$HDOTDISP_D$	$\dot{H}$	Altitude rate, for noun 63 display	m/sec	m/csec	2^7
$JPARM_D$	2J	Parameter in computation of R_a	m	m	2^{24}
$KPARM_D$	2K	Parameter in computation of R_a	m/deg	m/rev	2^{24}
$LAXIS_V$	$\underline{u}_Y$	Y-axis of local vertical coordinate system, in SM coordinates			2^1
OMEGAPD	ω_{DXV}	X - component of commanded attitude rate	deg/sec	revs/sec	2^{-3}
OMEGAQD	ω_{DYV}	Y-component of commanded attitude rate	deg/sec	revs/sec	2^{-3}
OMEGARD	ω_{DZV}	Z- component of commanded attitude rate	deg/sec	revs/sec	2^{-3}
$PCONS_D$	A	First attitude component in required acceleration computation	m/sec	m/csec	2^9
$PIPTIME_D$	t	Time of last accelerometer reading	sec.	csec.	2^{28}
$PITCH_D$		FDAI pitch angle	degrees	revs	2^0
$PRATE_D$	B	First rate component in required acceleration computation	m/sec^2	$m/csec^2$	2^{-8}
$QAXIS_V$	$\underline{Q}$	Q-axis of target coordinate system in SM coordinates			2^1
R_V	$\underline{r}$	Position vector in SM coordinates	m	m	2^{24}
$RATT_V$	$\underline{r}\ (t_1)$	Position at time integrated to, in reference coordinates	m	m	2^{29}

ERASABLE LOCATIONS USED (CONTINUED)

AGC Tag	GSOP Symbol	Meaning	Engineering Units	AGC Units	AGC Scaling
RCO_D	R_D	Desired injection radius	m	m	2^{24}
$RDOT_D$	$\dot{R}$	Radial velocity	m/sec	m/csec	2^7
$RDOTD_D$	$\dot{R}_D$	Desired radial velocity	m/sec	m/csec	2^7
$REFSMMAT_M$	[REFSMMAT]	Transformation matrix between reference and SM coordinate systems			2^1
RLS_V	$\underline{r}_{LS}$	Landing site position vector	m	m	2^{27}
RP_D	R_P	Estimated perigee at cutoff time	m	m	2^{24}
$RRECTCSM_V$	$\underline{r}_C$	CSM position vector in reference coordinates	m	m	
$R(CSM)_V$	$\underline{r}_C$	CSM position vector in SM coordinates	m	m	
$TBUP_D$	τ	Mass to mass flow rate ratio	sec	csec	2^{17}
$TDEC1_D$	t_1	Time to integrate to	sec	csec	2^{28}
TGO_D	t_{go}	Remaining burn time	sec	csec	2^{17}
TIG_D	t_{IG}	Time of ignition	sec	csec	2^{28}
TRKMKCNT		Radar mark counter			2^{14}
TTO_D	$-\Delta t_{tail\text{-}off}$	Tail-off time	sec	csec	2^{17}
$TTOGO_D$		Time from engine cutoff	sec	csec	2^{28}
TXO_D	t_{XO}	Time when X-axis override is allowed	sec	csec	2^{28}
$UNFC/2_V$	$\underline{a}_T$, $\underline{u}_{FV}$	Throttle command (thrust direction) in SM coordinates	m/sec^2	m/csec^2	variable

ERASABLE LOCATIONS USED (CONTINUED)

AGC Tag	GSOP Symbol	Meaning	Engineering Units	AGC Units	AGC Scaling
$UNFV/2_V$	$\underline{u}_{FV}$	Measured thrust direction in SM coordinates			2^1
$UNIT/R/_V$	$\underline{u}_R$	Unit vector in radial direction in SM coordinates			2^1
$UNWC/2_V$	$\underline{u}_{WDP}$	Window-pointing vector in SM coordinates			2^1
V_V	$\underline{v}$	Velocity vector in SM coordinates	m/sec	m/csec	2^7
$VATT_V$	$\underline{v}(t_1)$	Velocity vector at time integrated to, in reference coordinates	m/sec	m/csec	2^7
VE_D	v_e	Exhaust velocity	m/sec	m/csec	2^7
$VGBODY_V$	$\underline{v}_{GB}$	Velocity-to-be-gained in body (NB) coordinates	m/sec	m/csec	2^7
$VGVECT_V$	$\underline{v}_G$	Velocity-to-be-gained in SM coordinates	m/sec	m/csec	2^7
$VRECTCSM_V$	$\underline{v}_C$	CSM velocity vector in reference coordinates	m/sec	m/csec	
$V1S_V$	$\underline{v}\ (t_{IG})$	Velocity at ignition in SM coordinates	m/sec	m/csec	2^7
WHICH		Variable indicating guidance table to be used by master ignition routine			
WM_V	$\underline{\omega}_M$	Moon rotational velocity in SM coordinates	rad/sec	rad/csec	2^{-17}
$XNBPIP_M$ $=\begin{pmatrix} XNBPIP_V \\ YNBPIP_V \\ ZNBPIP_V \end{pmatrix}$	SMNB $=\begin{bmatrix} \underline{u}_{XB} \\ \underline{u}_{YB} \\ \underline{u}_{ZB} \end{bmatrix}$	Transformation matrix between SM and NB coordinate systems			2^1

ERASABLE LOCATIONS USED (CONTINUED)

AGC Tag	GSOP Symbol	Meaning	Engineering Units	AGC Uints	AGC Scaling
$XRANGE_D$	CR	Cross-range translation planned for during burn	m	m	2^{29}
Y_D	Y	Cross-range position	m	m	2^{24}
YAW_D		FDAI yaw angle	degrees	revs	2^{0}
YCO_D	Y_D	Desired cross-range position	m	m	2^{24}
$YCONS_D$	C	Second attitude component in required acceleration computation	m/sec	m/csec	2^{9}
$YDOT_D$	$\dot{Y}$	Cross-range velocity	m/sec	m/csec	2^{7}
$YDOTD_D$	$\dot{Y}_D$	Desired cross-range velocity	m/sec	m/csec	2^{7}
$YRATE_D$	D	Second rate component in required acceleration computation	m/sec^2	m/csec^2	2^{-8}
$ZAXIS1_V$	$\underline{u}_Z$	Z-component of local vertical coordinate system in SM coordinates			2^{1}
$ZDOT_D$	$\dot{Z}$	Down-range velocity	m/sec	m/csec	2^{7}
$ZDOTD_D$	$\dot{Z}_D$	Desired down-range velocity	m/sec	m/csec	2^{7}
$/LAND/_D$	r_{LS}	Landing site radius	m	m	2^{24}
$/R/MAG_D$	R	Position radius	m	m	2^{24}
$1/DV0_D$	$\frac{1}{\Delta v_0}$	First $1/\Delta v$ thrust filter parameter	sec/m	csec/m	2^{7}
$1/DV1_D$	$1/\Delta v_1$	Second $1/\Delta v$ thrust filter parameter	sec/m	csec/m	2^{7}
$1/DV2_D$	$1/\Delta v_2$	Third $1/\Delta v$ thrust filter parameter	sec/m	csec/m	2^{7}
$1/DV3_D$	$1/\Delta v_3$	Fourth $1/\Delta v$ thrust filter parameter	sec/m	csec/m	2^{7}

AGC Tag	GSOP Symbol	Meaning	Engineering Value & Units	AGC Value & Units	AGC Scaling
$APSVEX_S$	$-v_e$ (APS)	Negative of exhaust velocity for APS engine	-3030 m/sec	-30.30 m/csec	2^5
$ATDECAY_D$	$\Delta t_{tail-off}$(APS)	Negative of tail-off time for APS engine	-.10 sec	-10 csec	2^{28}
AT/RCS_D	A_T (RCS)	Acceleration of 4 RCS jets in a dry LM	.785 m/sec^2	.0000785 m/csec^2	2^{-10}
$CLOG2/32_D$	ln (2)	Natural logarithm of 2	.0216608494 X 2^5	.0216608494 X 2^5	2^5
$MINABDV_D$	Δv_{min}	Minimum velocity change	3.56 m/sec	.0356 m/csec	2^5
$MOONRATE_D$	ωM	Moon rotational rate	.26616994890062991 X 10^{-5} rad/sec	.26616994890062991 X 10^{-7} rad/csec	2^{-19}
$MUM(-37)_D$	μm	Lunar gravitational constant	4.902778X10^{10} m^3/sec^2	4.902778 X 10^8 m^3/csec^2	2^{37}
$PRLIMIT_D$	$\frac{B}{\tau}$ min	Minimum (maximum magnitude) B/τ	-63900. X 2^{-21} m/sec^3	-.0639 X 2^{-21} m/csec^3	2^{-21}
$RDOTNOM_D$	$\dot{R}_D$ (nom)	Initial value of desired radial velocity	5.9436 m/sec	.059436 m/csec	2^7

CONSTANTS (CONTINUED)

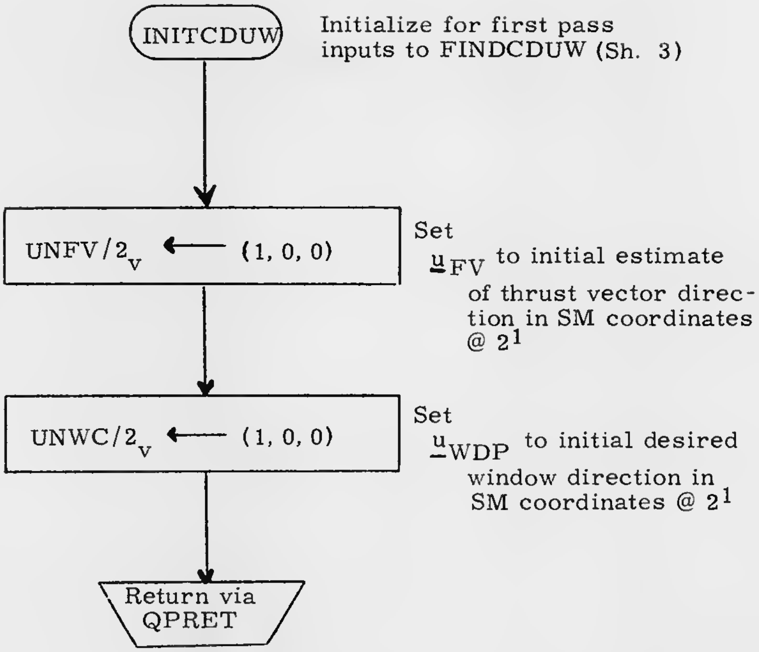
AGC Tag	GSOP Symbol	Meaning	Engineering Value & Units	AGC Value & Units	AGC Scaling
THRESH2	Δv_K (APS)	Minimum acceptable 2-second Δv for APS thrusting	3.08 m/sec	.0308 m/csec	$10^{-4} \times 2^{+14}$
$\mathrm{VINJNOM}_D$	$\dot{Z}_D$ (nom)	Initial value of desired down-range velocity	1679.24 m/sec	16.7924 m/csec	2^7
$\mathrm{(AT)A}_D$	a_T(APS)	Initial APS thrust acceleration	3.2883 m/sec^2	.00032883 $m/csec^2$	2^{-9}
$\mathrm{(TBUP)A}_D$	τ (APS)	Initial mass: mass flow rate ratio for APS thrust	919.02 sec.	91902 csec.	2^{17}
$\mathrm{(TGO)A}_D$	t_{go}(APS)	Nominal total burn time for APS maneuver	370 sec	37000 csec	2^{17}
$\mathrm{(1/DV)A}_D$	$1/\Delta v_A$	Inverse of Δ v acquired during first two seconds of ascent	.152 sec/m	15.2 csec/m	2^7
$\mathrm{49FPS}_D$	$\dot{R}_D$ (tipover)	Expected radial velocity at tipover	14.9352 m/sec	.149352 m/csec	2^6

PAD - LOADS

AGC Tag	GSOP Symbol	Meaning	Engineering Units	AGC Units	AGC Scaling
$COSTHET1_D$	$\cos(\theta_1)$	Cosine of cone angle θ_1 for aborts			2^2
$COSTHET2_D$	$\cos(\theta_2)$	Cosine of cone angle θ_2 for aborts			2^2
$RAMIN_D$	R_{AMIN}	Minimum apogee radius R_a	m	m	2^{24}

FINDCDUW:

Guidance - DAP Interface



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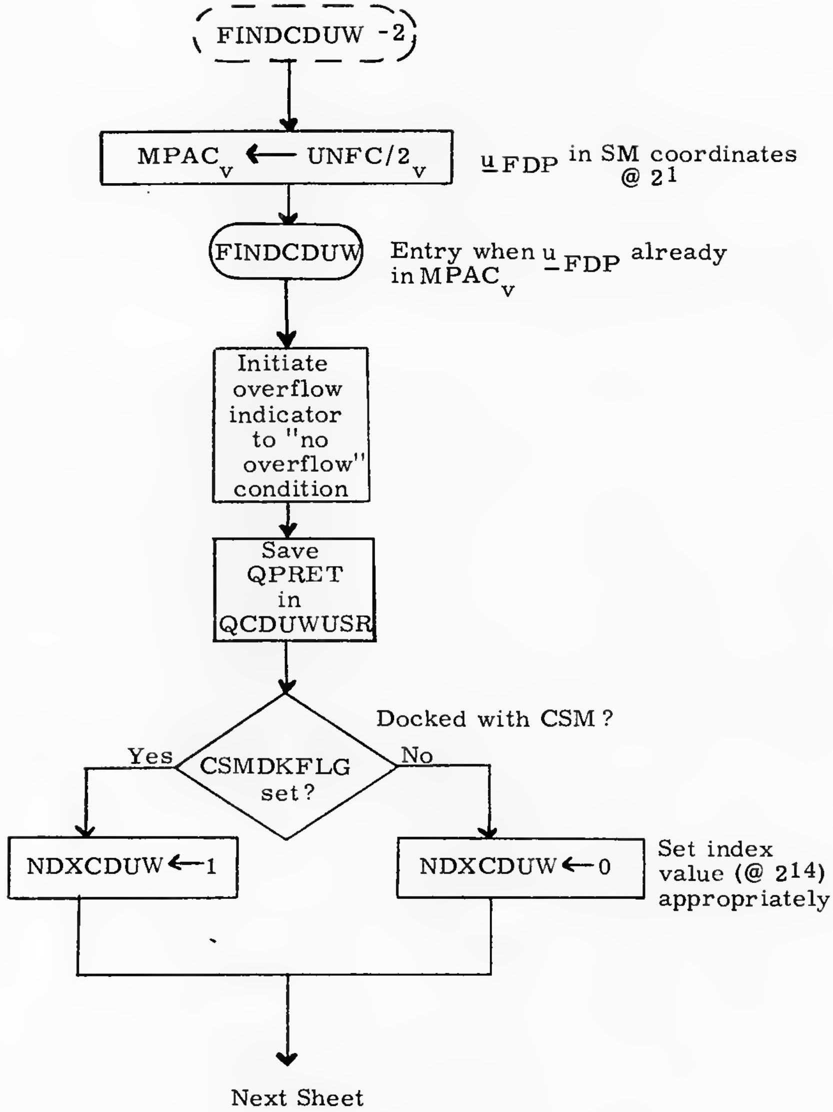

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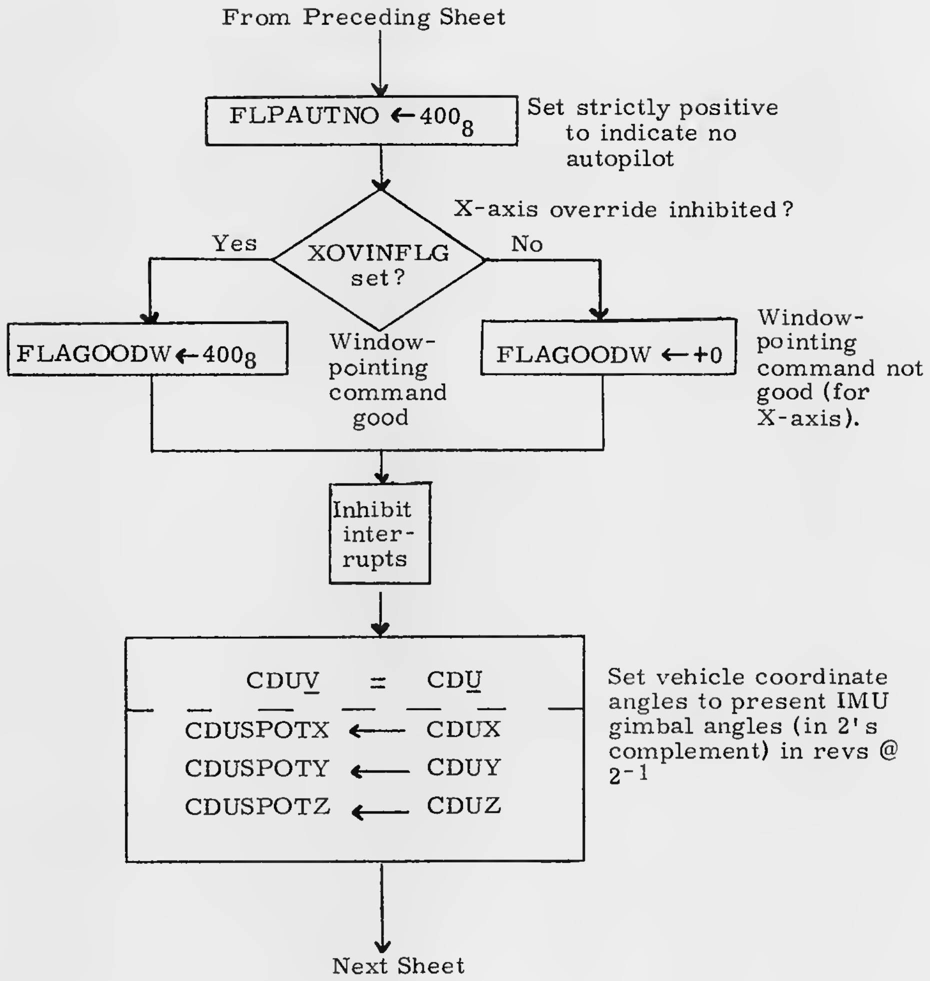

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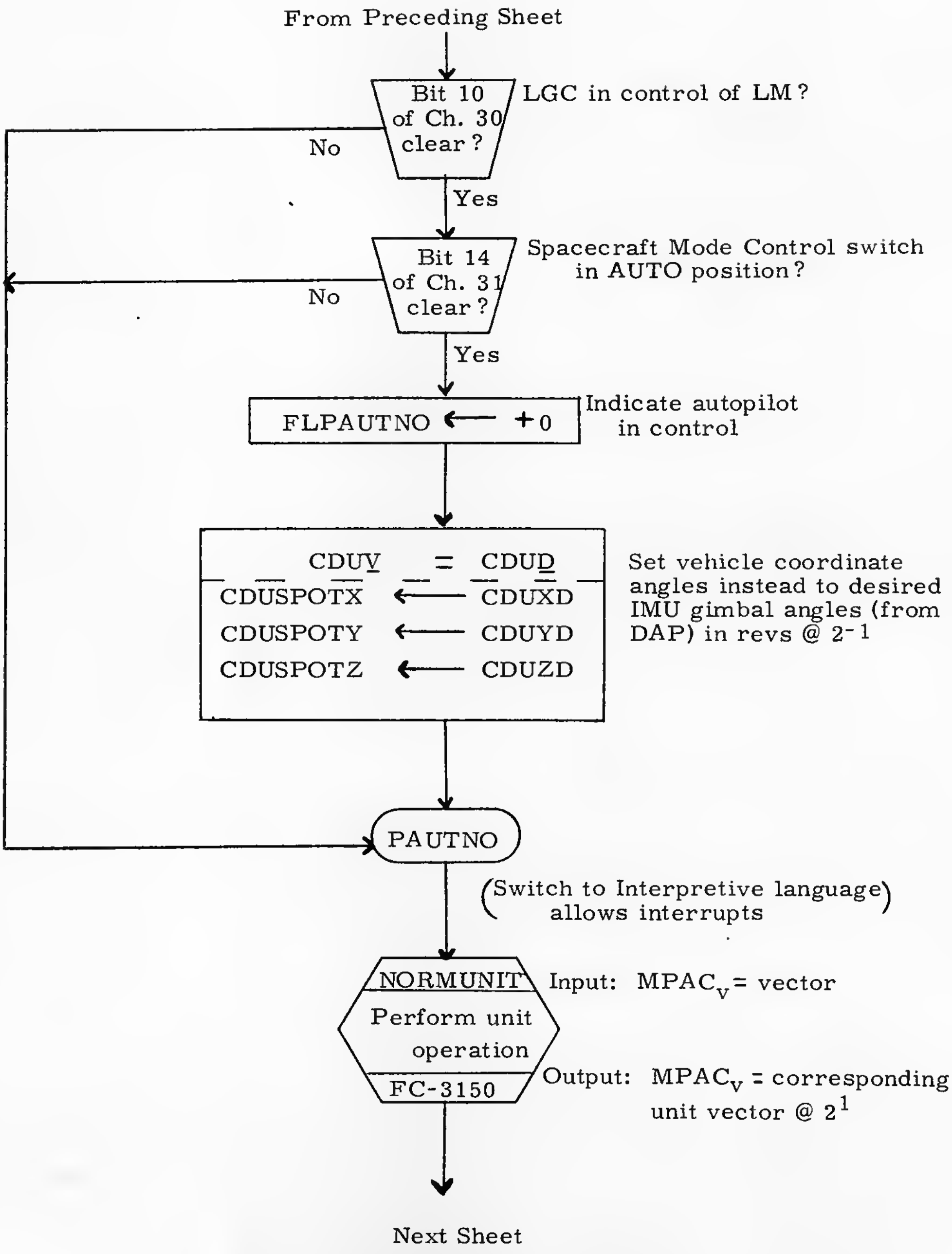

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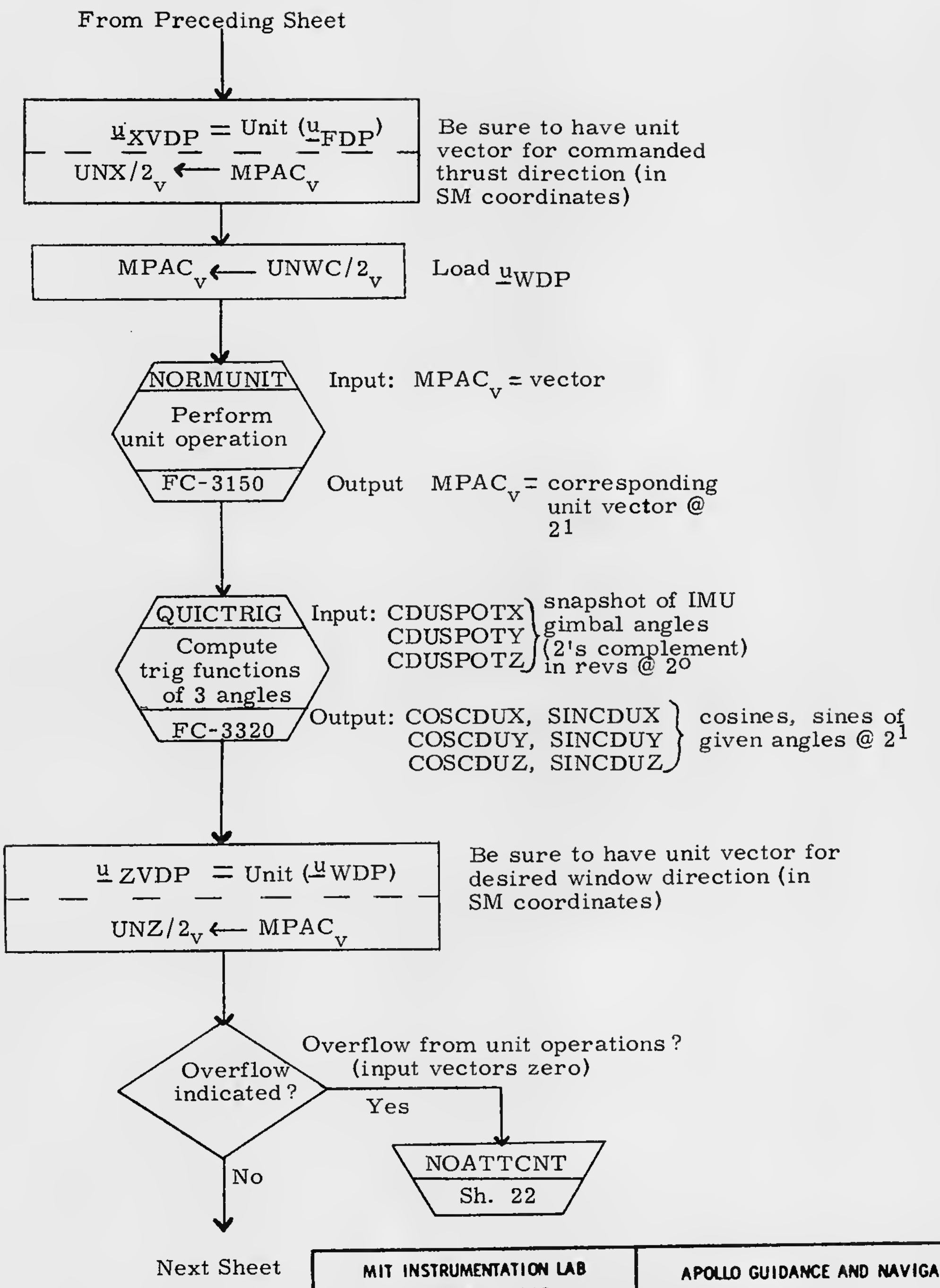

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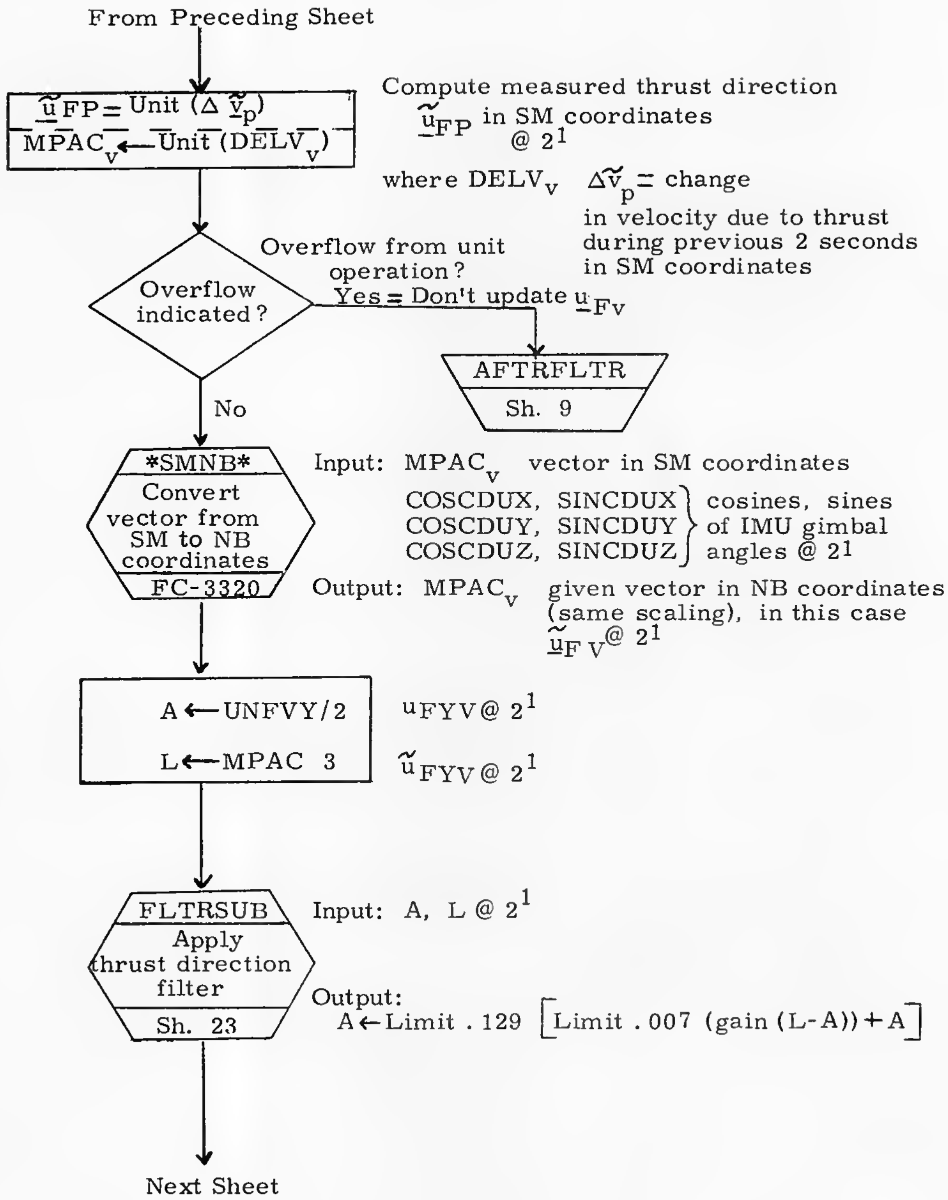

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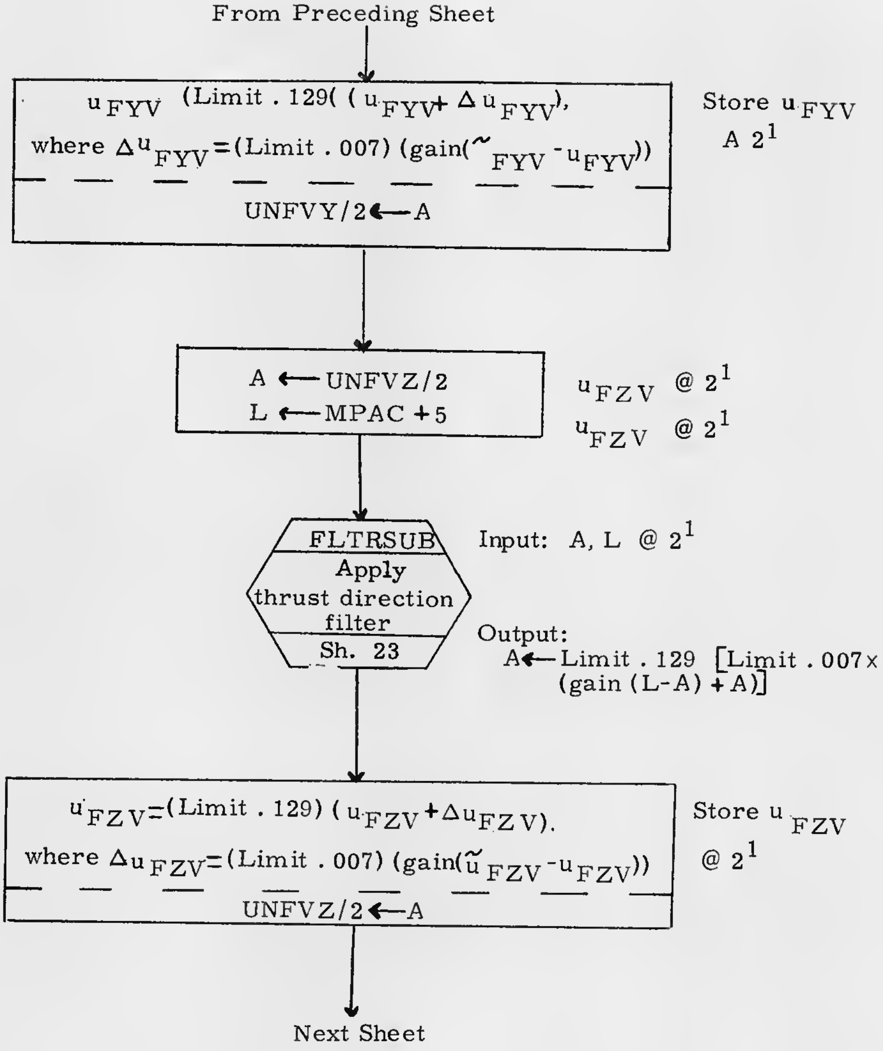

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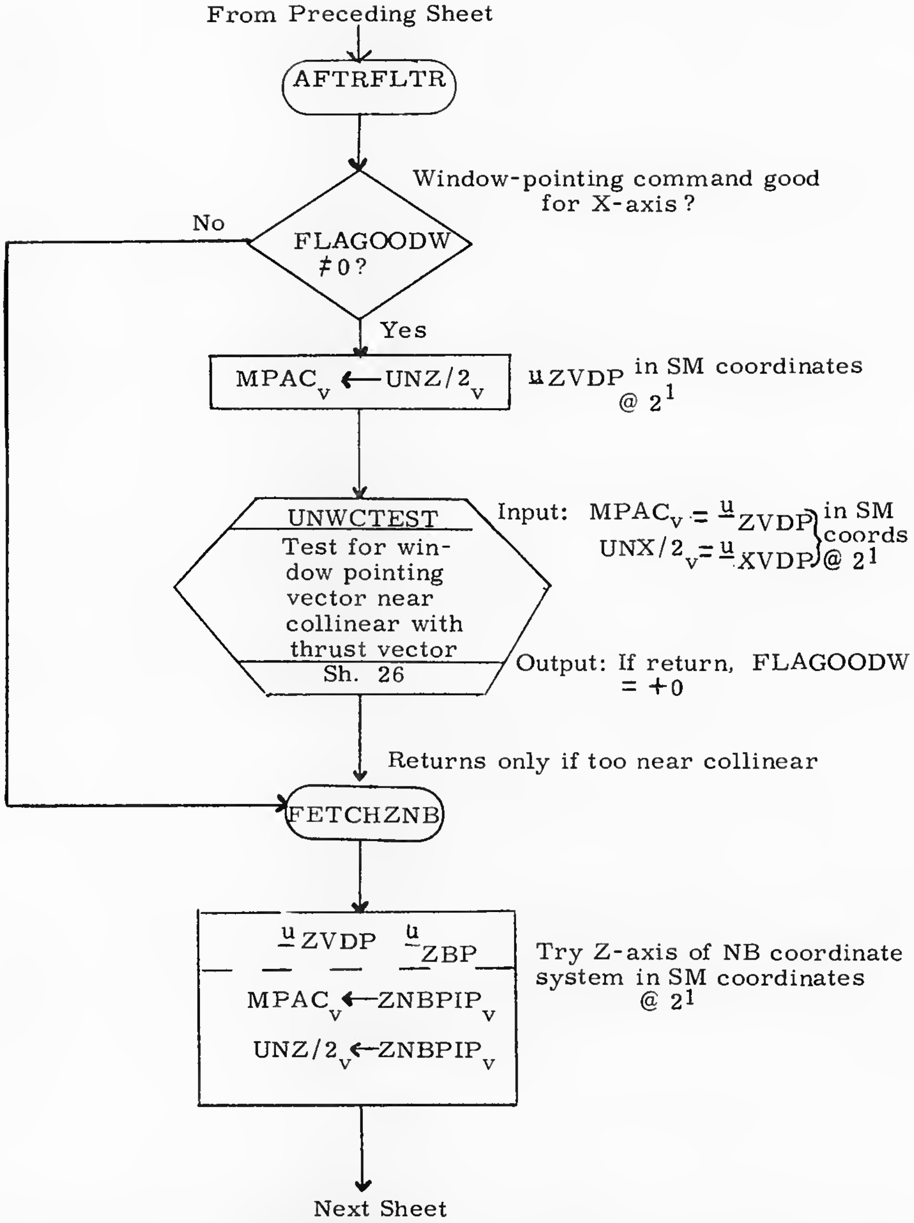

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From Preceding Sheet

UNWCTEST
Test for window pointing vector near collinear with thrust vector
Sh. 26

Input: $MPAC_v = \underline{u}_{ZVDP}$, $UNX/2_v = \underline{u}_{XVDP}$ in SM coords @ 2^1

Output: If return, FLAGOODW = +0

Returns only if too near collinear

$\underline{u}_{ZVDP} = -\underline{u}_{XBP}$
$UNZ/2_v \leftarrow -XNBPIP$

Use -X-axis of NB coordinate system in SM coordinates @ 2^1

DCMCL

UNWCTEST returns here if angle OK

Compute commanded vehicle axes (initial iteration)

$\underline{u}_{YVDP} = \text{Unit}\,(\underline{u}_{ZVDP} \times \underline{u}_{XVDP})$
$PL\phi_v \leftarrow \text{Unit}\,(UNZ/2_v \times UNX/2_v)$

$\underline{u}_{YVDP}$ in SM coordinates @ 2^1

$-\underline{u}_{ZVDP} = \underline{u}_{YVDP} \times \underline{u}_{XVDP}$
$UNZ/2_v \leftarrow 2^1(PL\phi_v \times UNX/2_v$

$\underline{u}_{ZVDP}$ in SM coordinates @ 2^1
2^1 factor is for scaling

Next Sheet

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From Preceding Sheet.

Correct X-axis for thrust offset

$\underline{u}_{XVDP} = \text{Unit}\,(\underline{u}_{XVDP} - u_{FYV}\,\underline{u}_{YVDP} - u_{FZV}\,\underline{u}_{ZVDP}$

$UNX/2_v \leftarrow \text{Unit}\,(UNX/2_v - 2^1 \cdot UNFVY/2_D \cdot PLX_v + 2^1 \cdot UNFVZ/2_D \cdot UNZ/2_v$

$\underline{u}_{XVDP}$ in SM coords @ 2^1

2^1 factors are for scaling

Compute commanded vehicle axes (final iteration)

$\underline{u}_{YVDP} = \underline{u}_{XVDP} \times -\underline{u}_{ZVDP}$

$UNY/2_v \leftarrow 2^1 \cdot (UNX/2_v \times UNZ/2_v)$

$\underline{u}_{YVDP}$ in SM coordinates @ 2^1 where 2^1 factor is for scaling

$u_{ZVDP} = -(\underline{u}_{YVDP} \times \underline{u}_{XDP})$

$UNZ/2_V \leftarrow -2^1 \cdot (UNY/2_V \times UNX/2_V)$

$\underline{u}_{ZVDP}$ in SM coordinates @ 2^1 where 2^1 factor is for scaling

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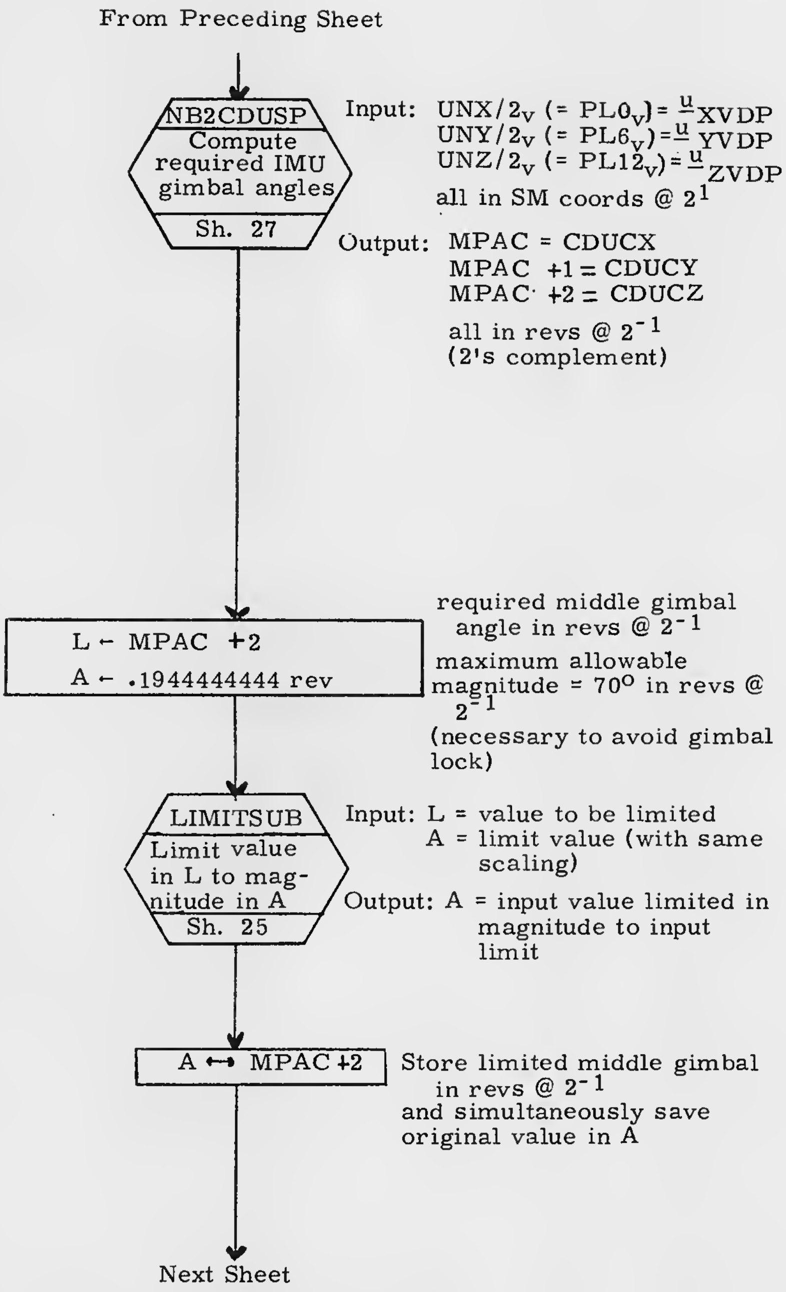

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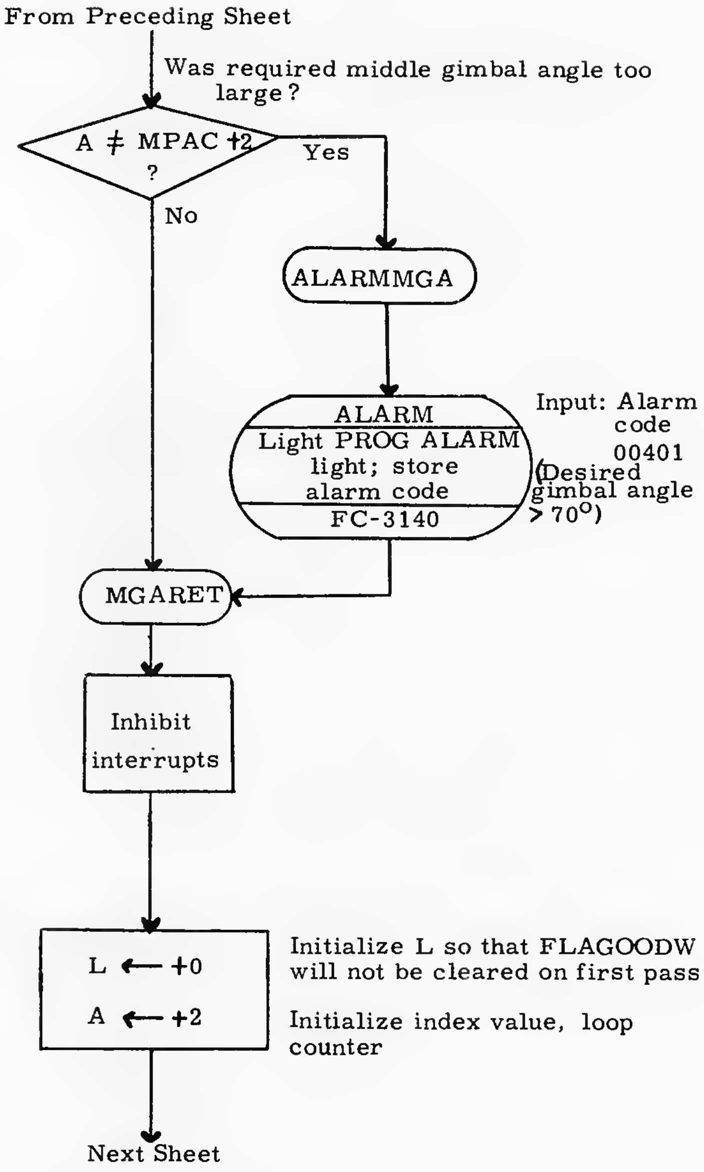

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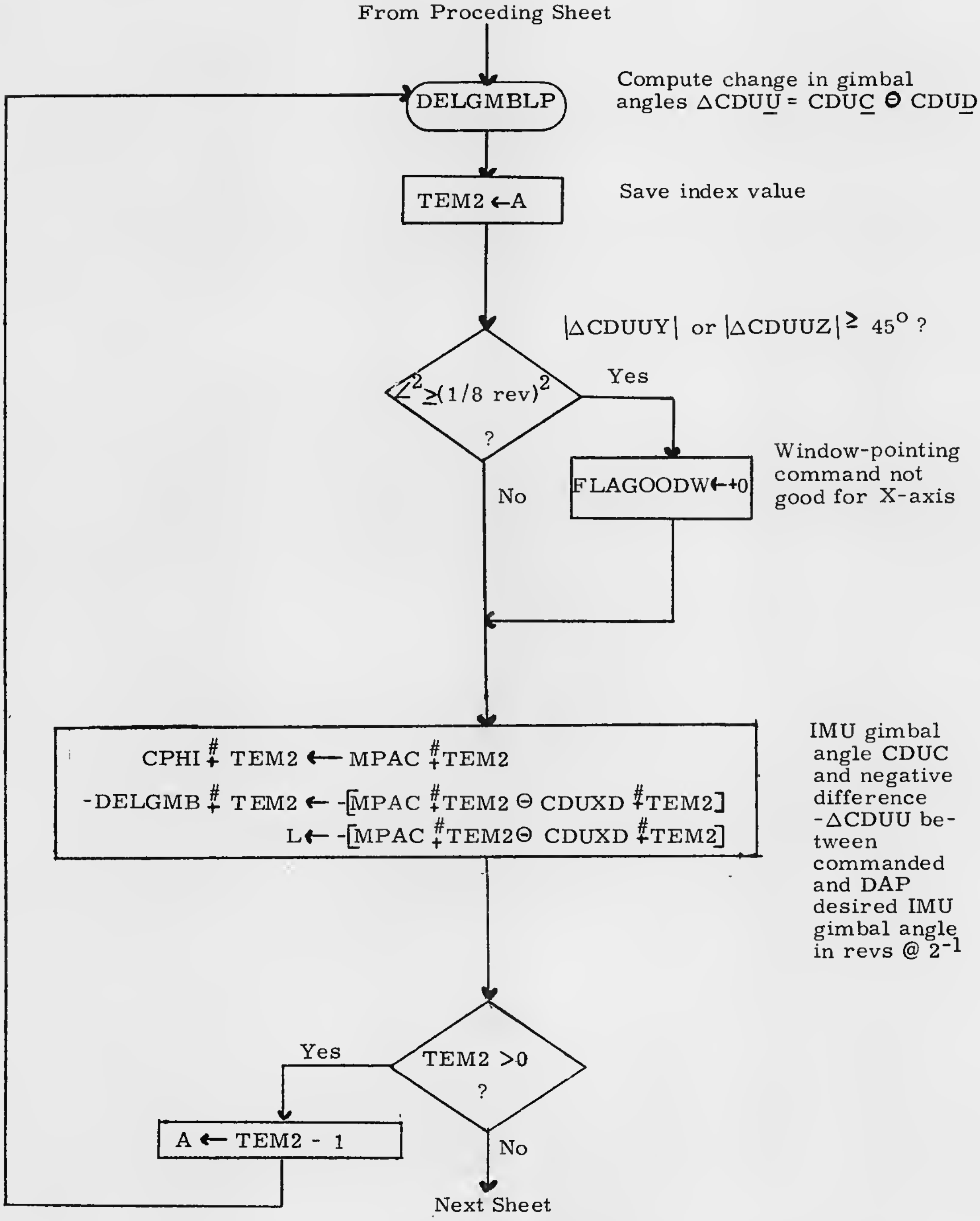

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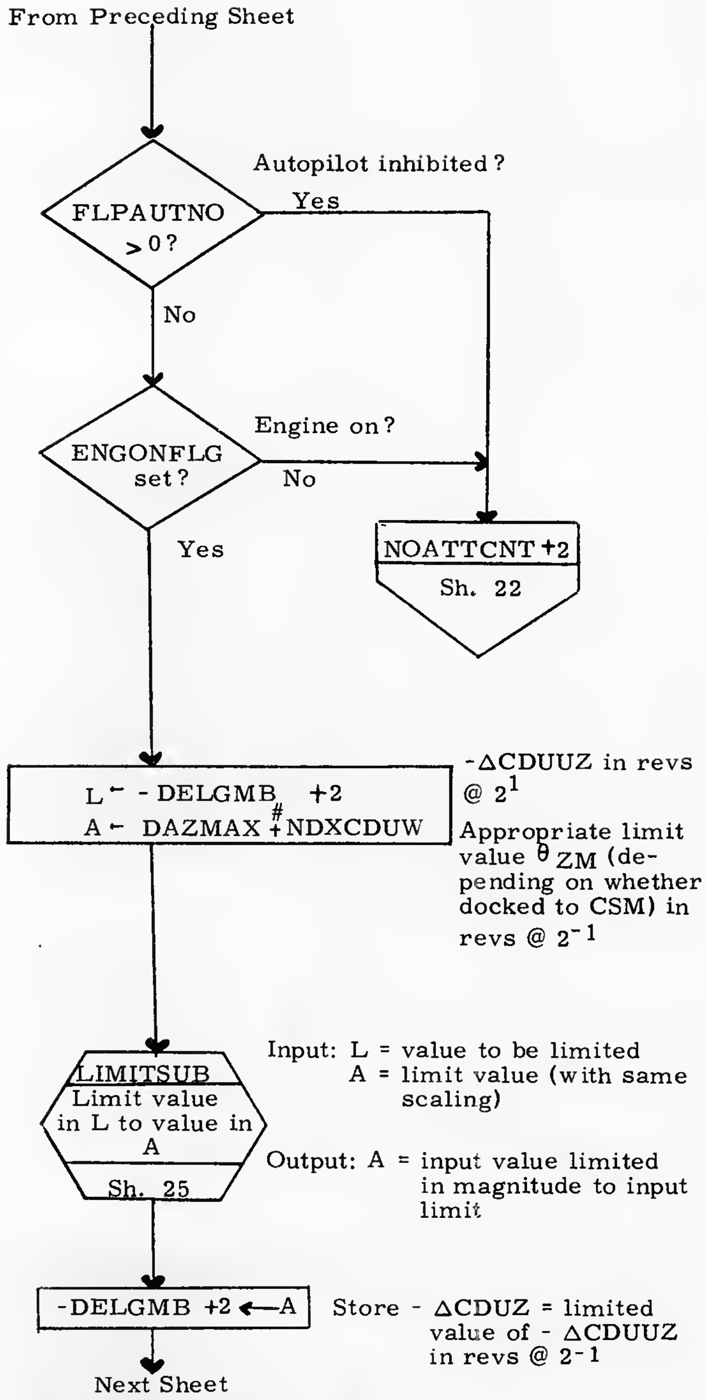

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From Preceding Sheet

L ← (-DELGMB +1) • COSCDUZ

A ← (DAY/2 MAX $\overset{\#}{+}$NDXCDUW

-ΔCDUUY• COS (CDUDZ) in revs @ 2^0

Appropriate limit value θ_{YM} (depending on whether docked to CSM) in revs @ 2

LIMITSUB

Limit value in L to value in A

Sh. 25

Input: L = value to be limited
A = limit value (same scaling)

Output: A = input value limited in magnitude to input limit

A ← A ÷ COSCDUZ

Obtain -ΔCDUY = limited value of $\frac{-\Delta CDUUY \cdot COS(CDUDZ)}{COS(CDUDZ)}$ in revs @ 2^{-1}

A ↔ -DELGMB +1

Store -ΔCDUY and simultaneously save original -ΔCDUUY in revs @ 2^{-1}

L ← -2^1 • A • SINCDUZ ⊖ -DELGMB

A ← DAXMAX $\overset{\#}{+}$ NDXCDUW

ACDUUX ⊖ −ΔCDUUY • SIN (CDUDZ) in revs @ 2^{-1} (2^1 factor is for scaling)

Appropriate limit value θ_{XM} (depending on whether docked to CSM) in revs @ 2^{-1}

Next Sheet

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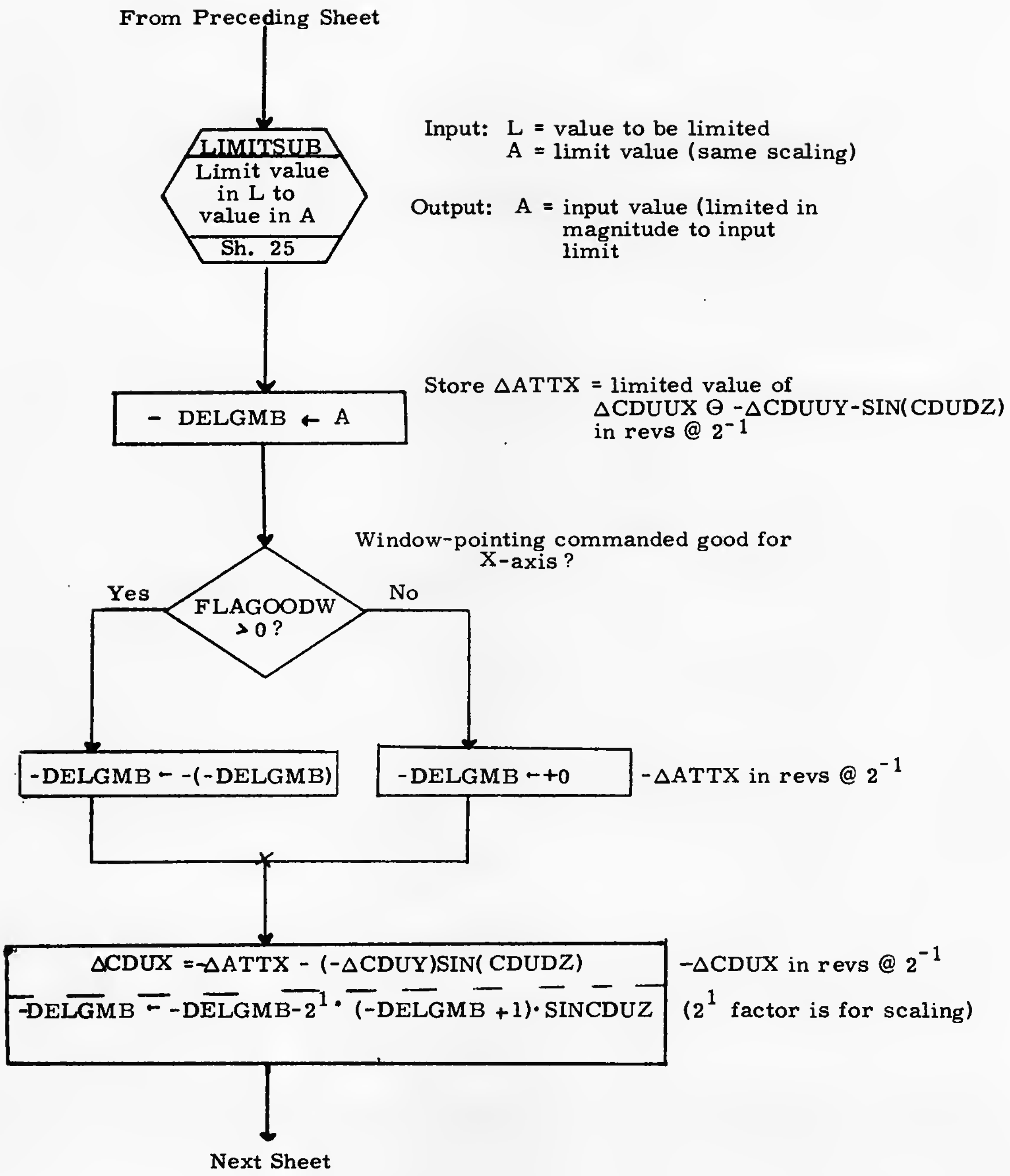

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DOCMR	
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From Preceding Sheet

Compute commanded attitude rates in revs/sec @ 2^{-3}

$\omega_{DXV} = [\Delta CDUX + \Delta CDUY \sin(CDUDZ)] \div 2$ sec

OMEGAPD ← $[-2^2(-DELGMB) - 2^3(-DELGMB + 1)SINCDUZ] \div 2$ sec

2^2, 2^3 factors are for scaling

$\omega_{DYV} = [\Delta CDUY \cos(CDUDZ) \cos(CDUDX) + \Delta CDUZ \sin(CDUDX)] \div 2$ sec

OMEGAQD ← $[-2^4(-DELGMB + 1)COSCDUZ\ COSCDUX - 2^3(-DELGMB + 2)SINCDUX] \div 2$ sec

2^3, 2^4 factors are for scaling

$\omega_{DZV} = [-\Delta CDUY \cos(CDUDZ) \sin(CDUDX) + \Delta CDUZ \cos(CDUDX)] \div 2$ sec

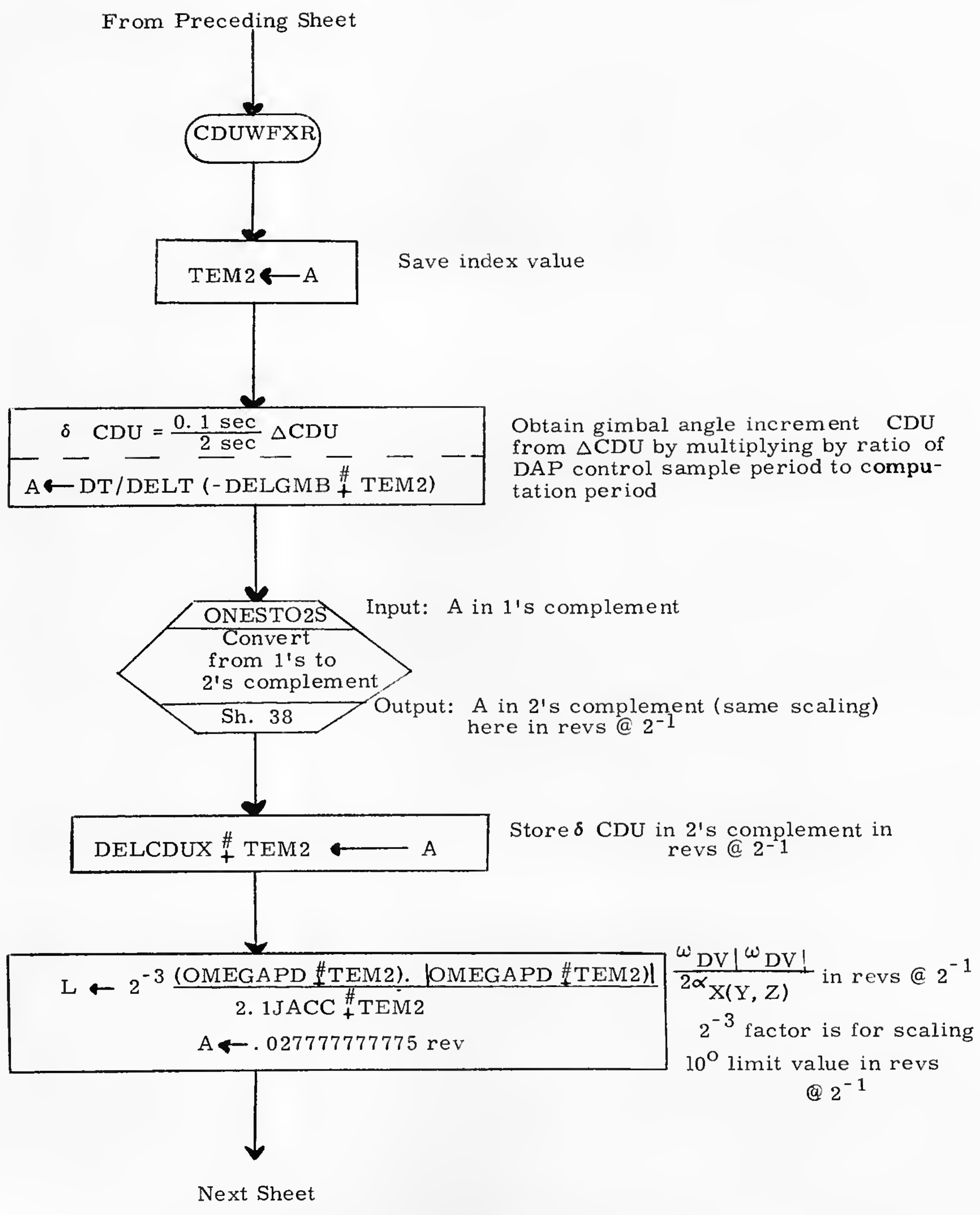
OMEGARD ← $[2^4(-DELGMB + 1)COSCDUZ \cdot SINCDUX - 2^3(-DELGMB + 2)COSCDUX)] \div 2$ sec

2^3, 2^4 factors are for scaling

A ← +2

Initialize index value, loop counter

Next Sheet



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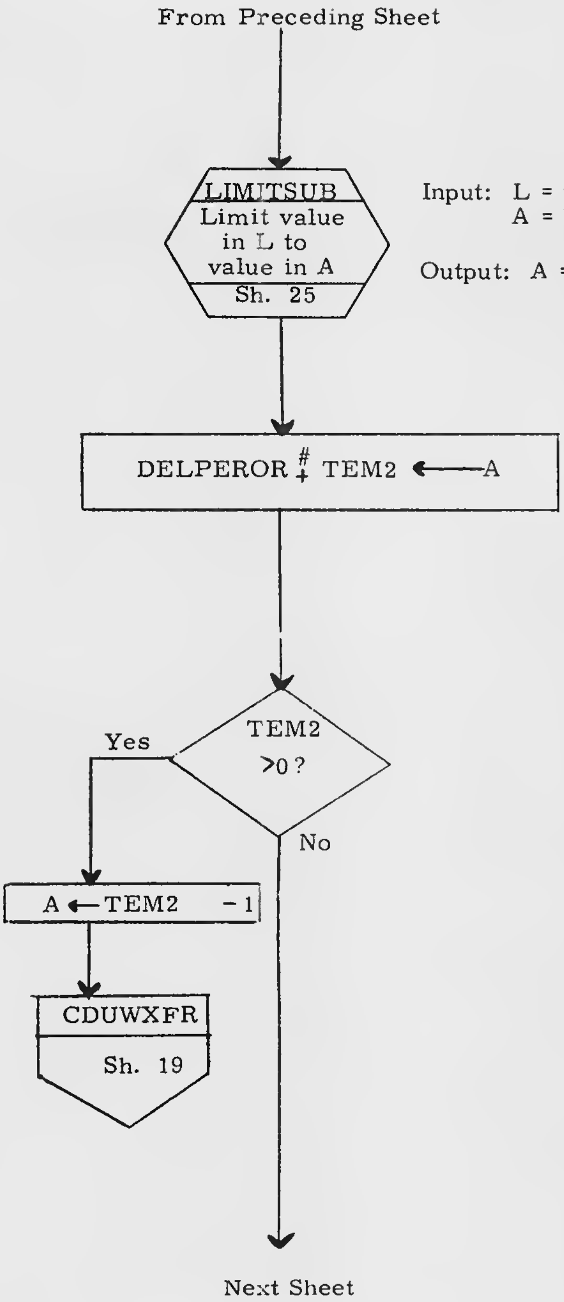

Input: L = value to be limited
A = limit value (same scaling)

Output: A = input value limited in magnitude to input limit

Store $\phi_{X(Y,Z)}$ = limited value of $\frac{\omega_{DV}|\omega_{DV}|}{2\alpha_{X(Y,Z)}}$ in revs @ 2^{-1}

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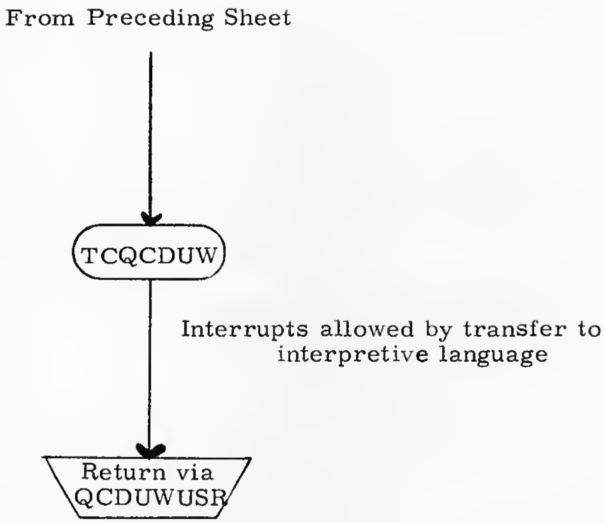

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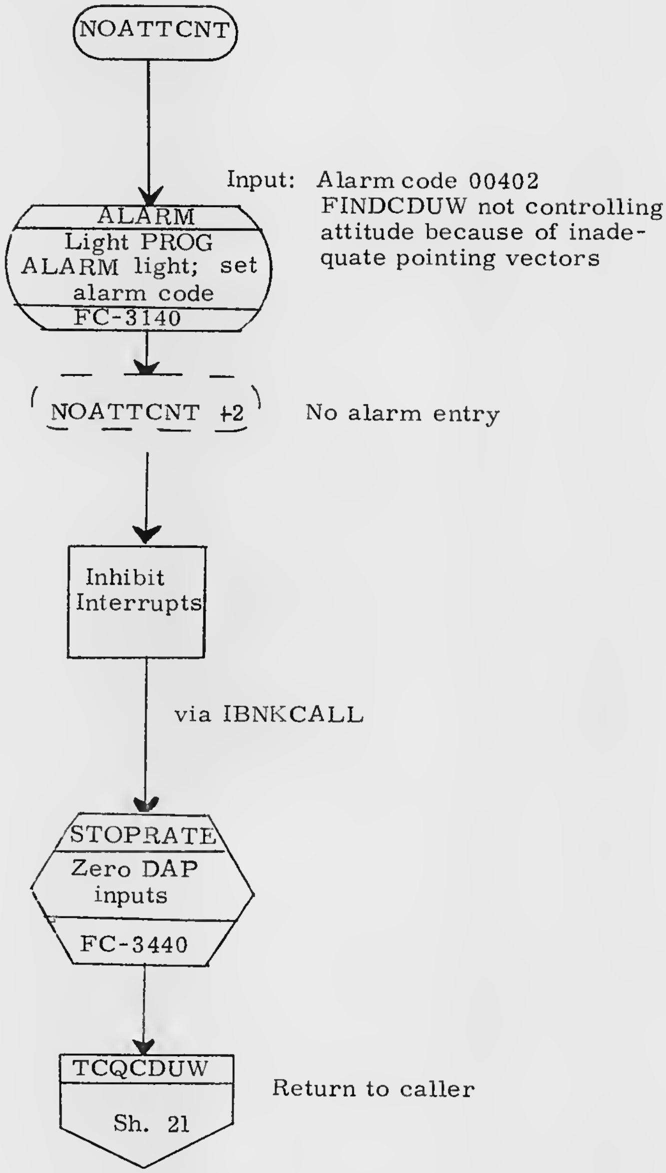

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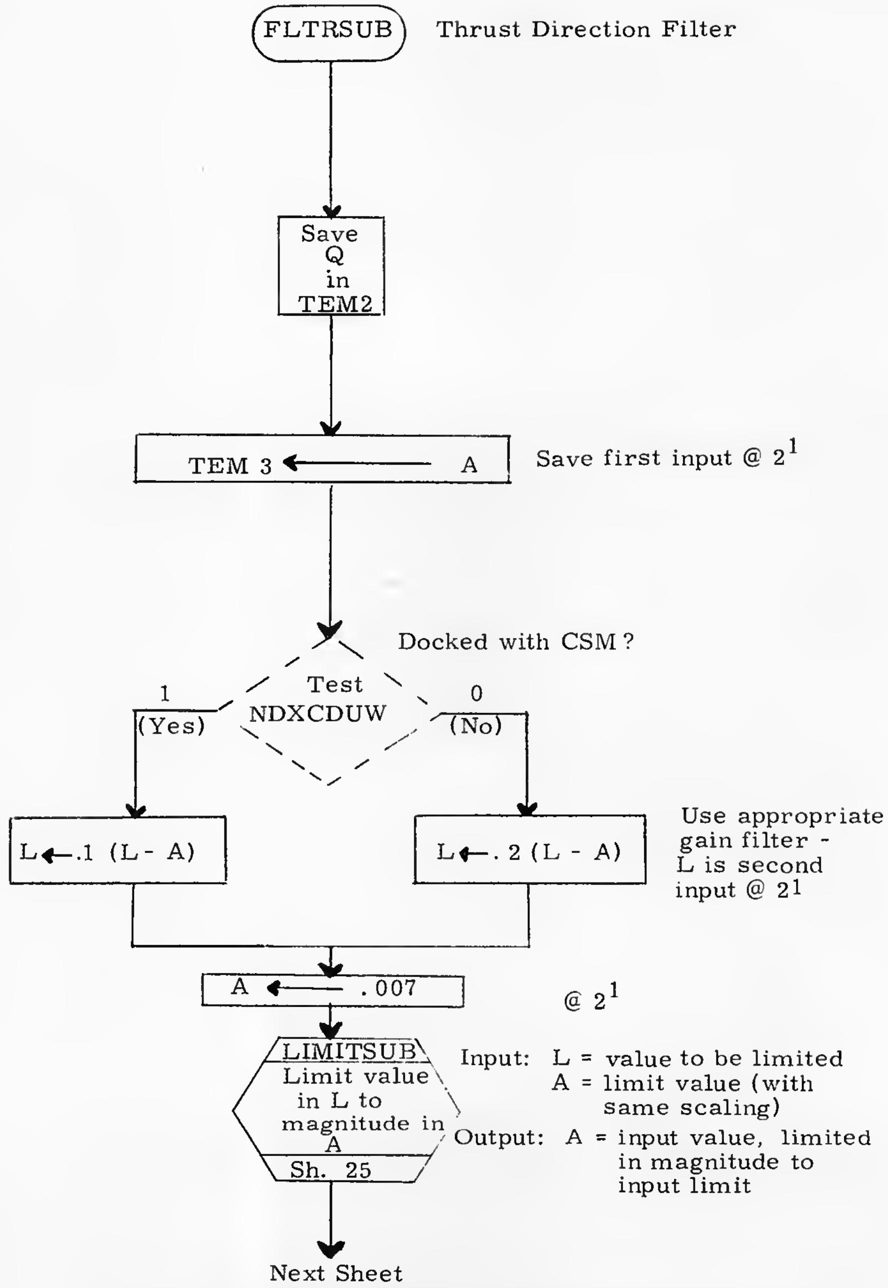

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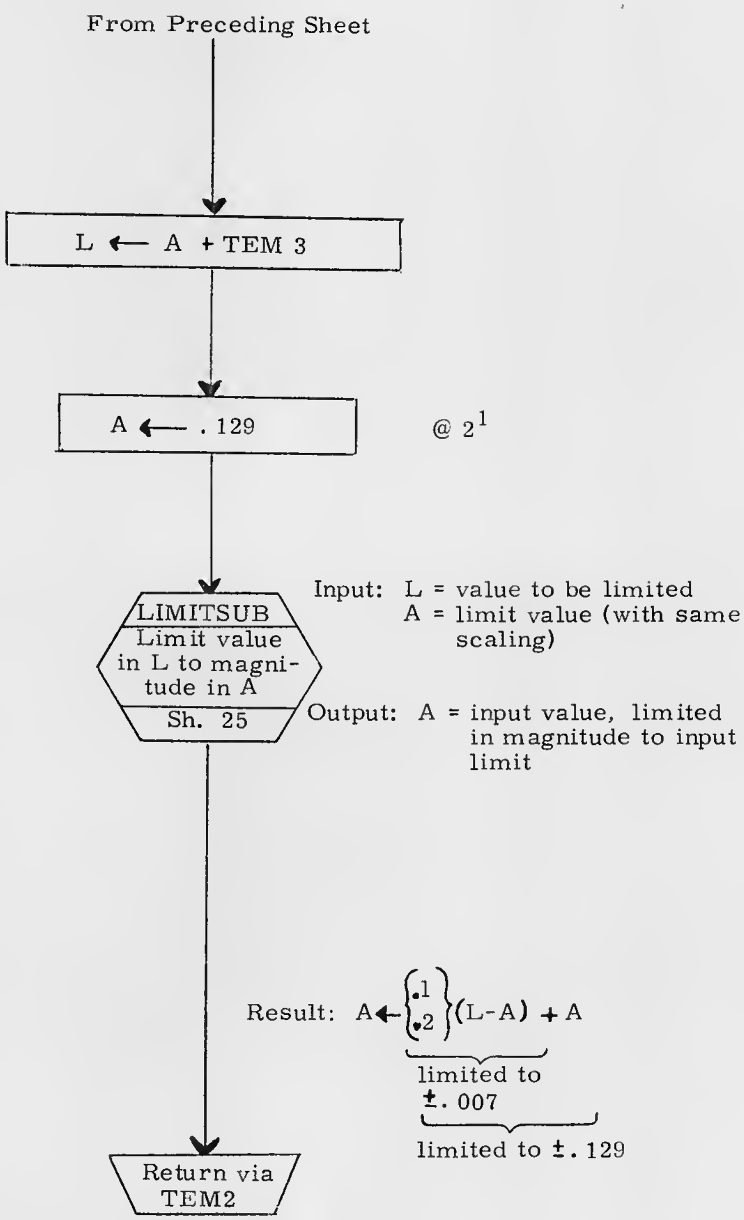

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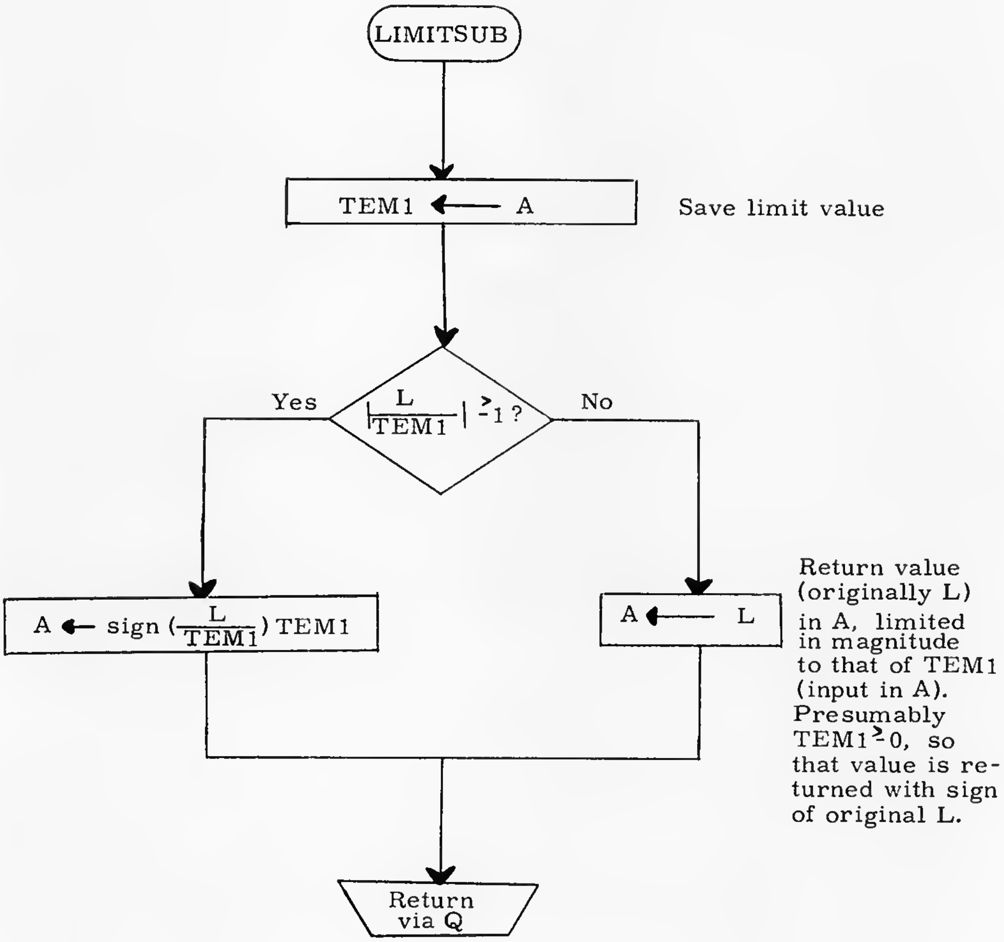

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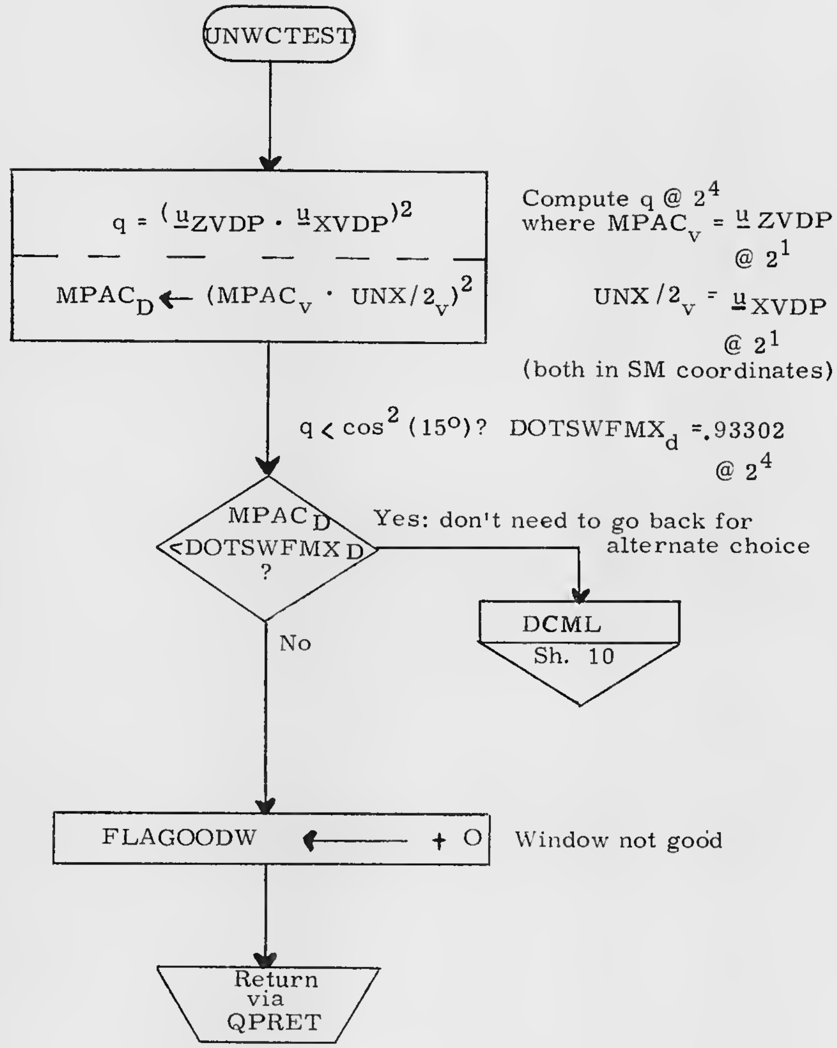

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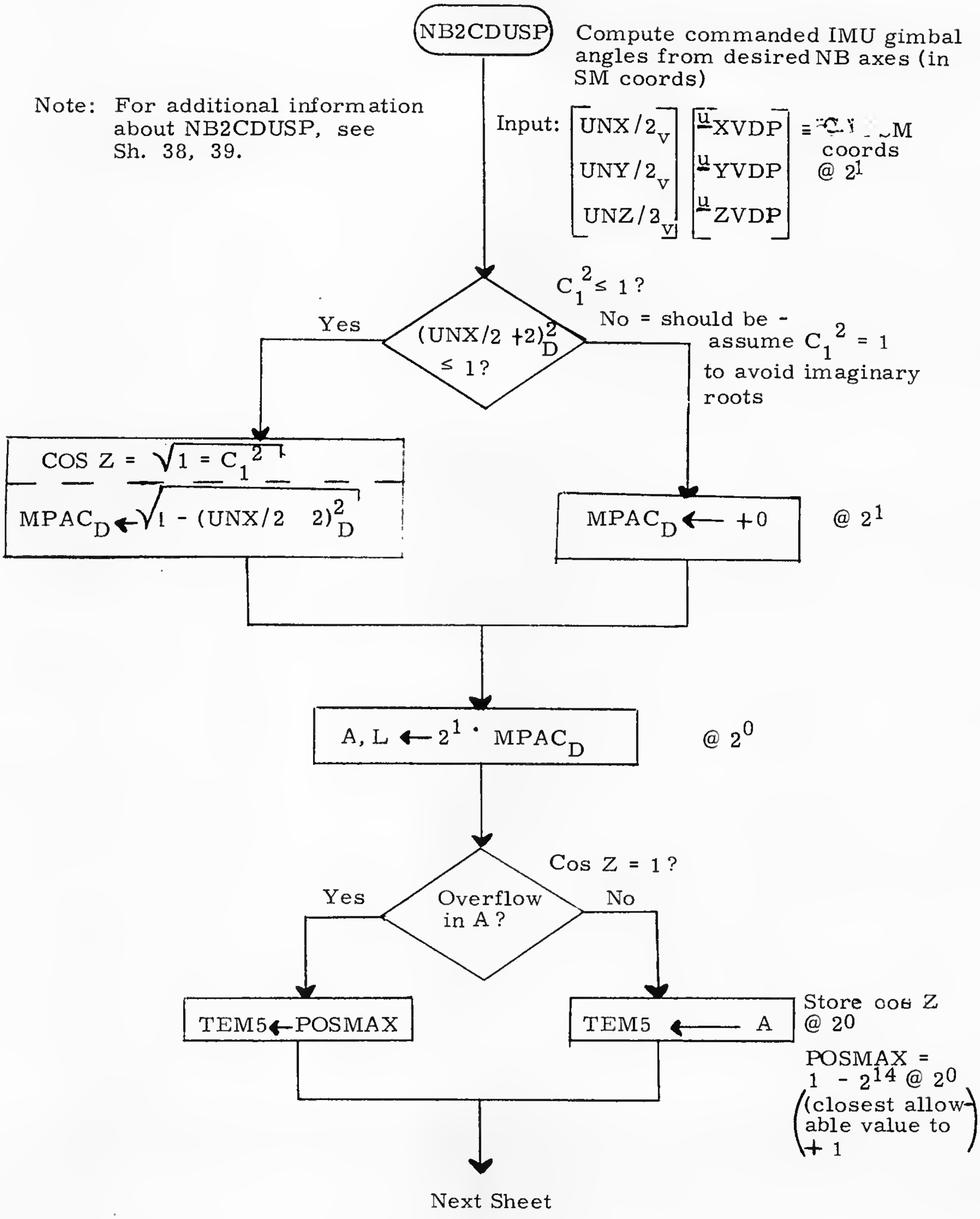

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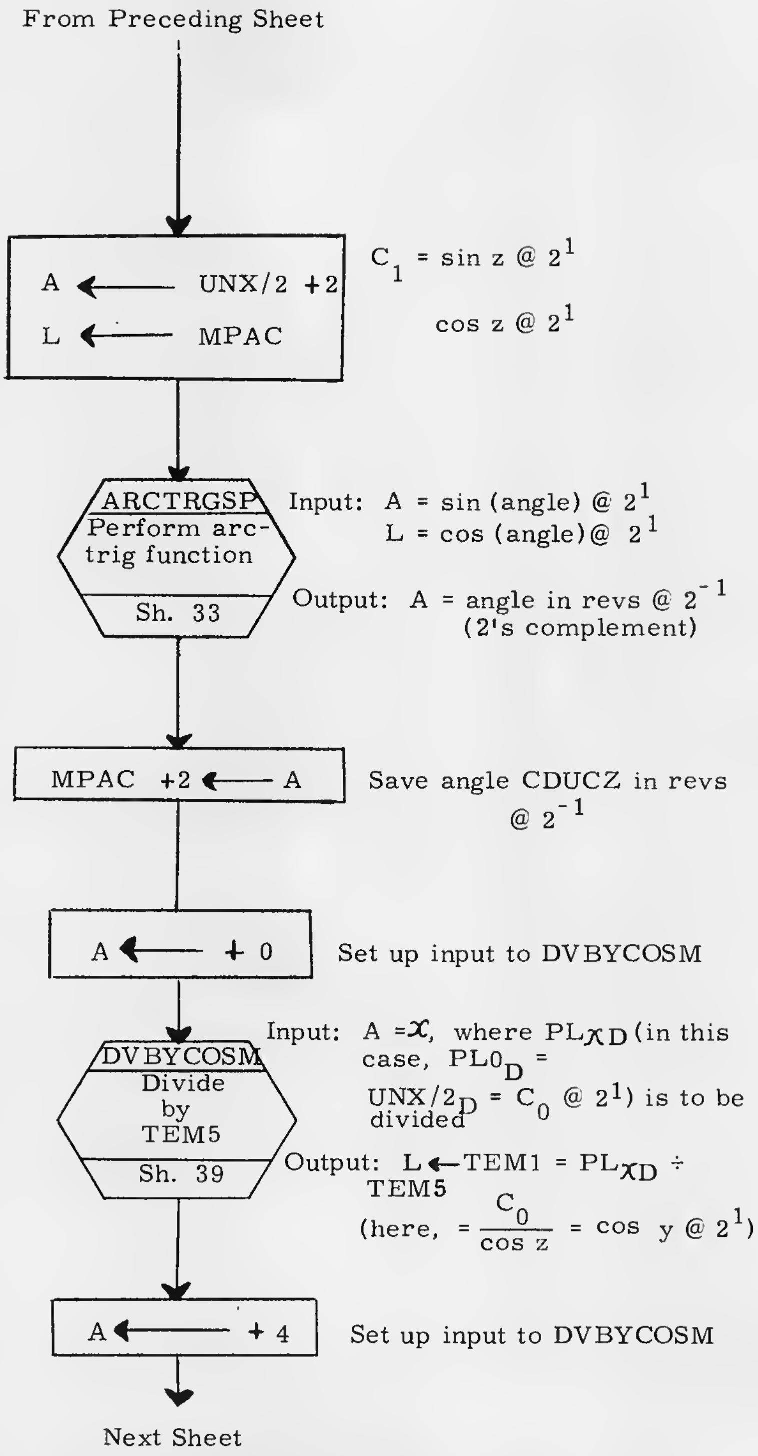

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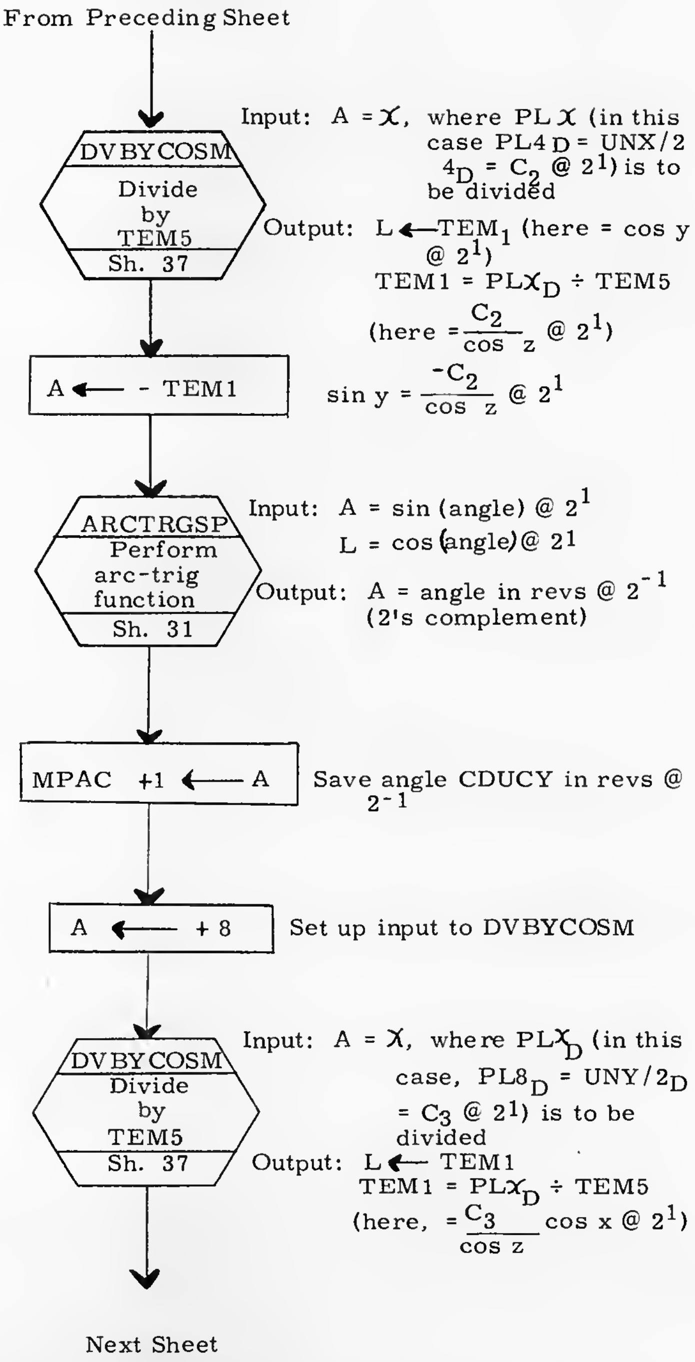

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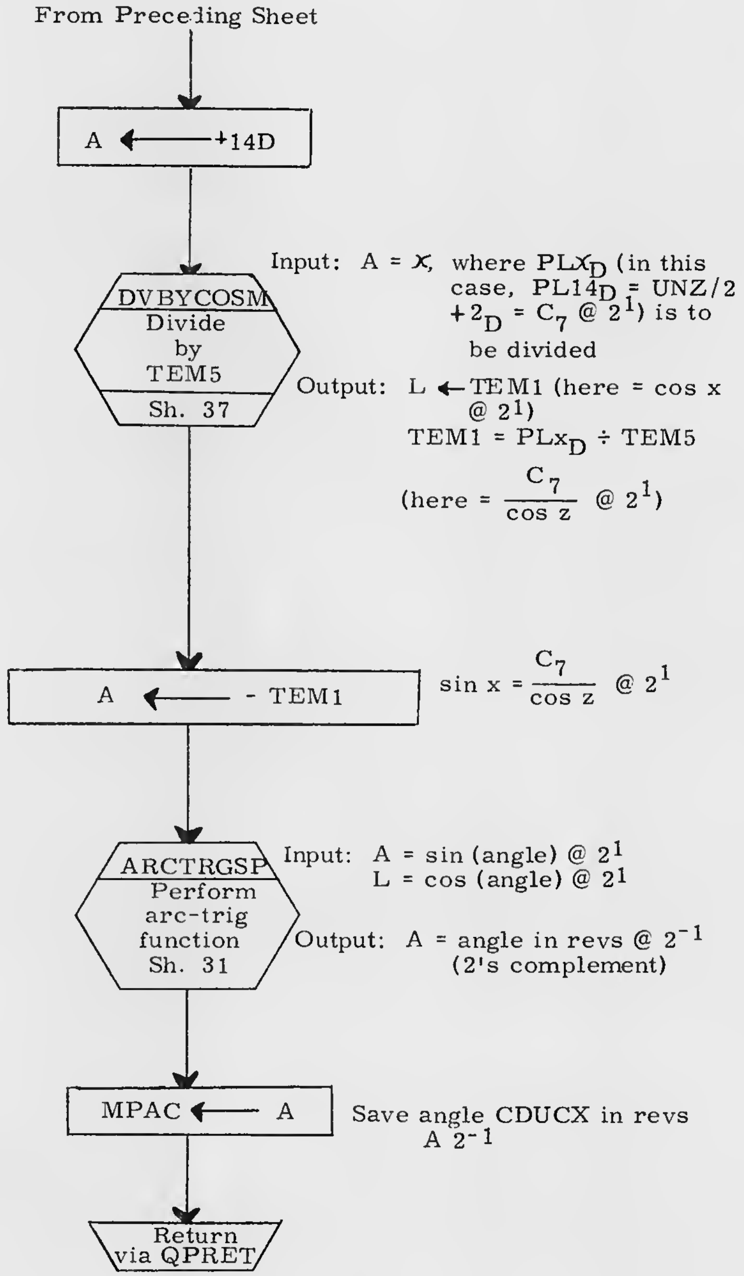
ANALST			
DOCMR		LUMINARY 1D	FC-3960
APPR'D Roberta M. Estes	10/20/69	REV	SHEET 29 OF 44



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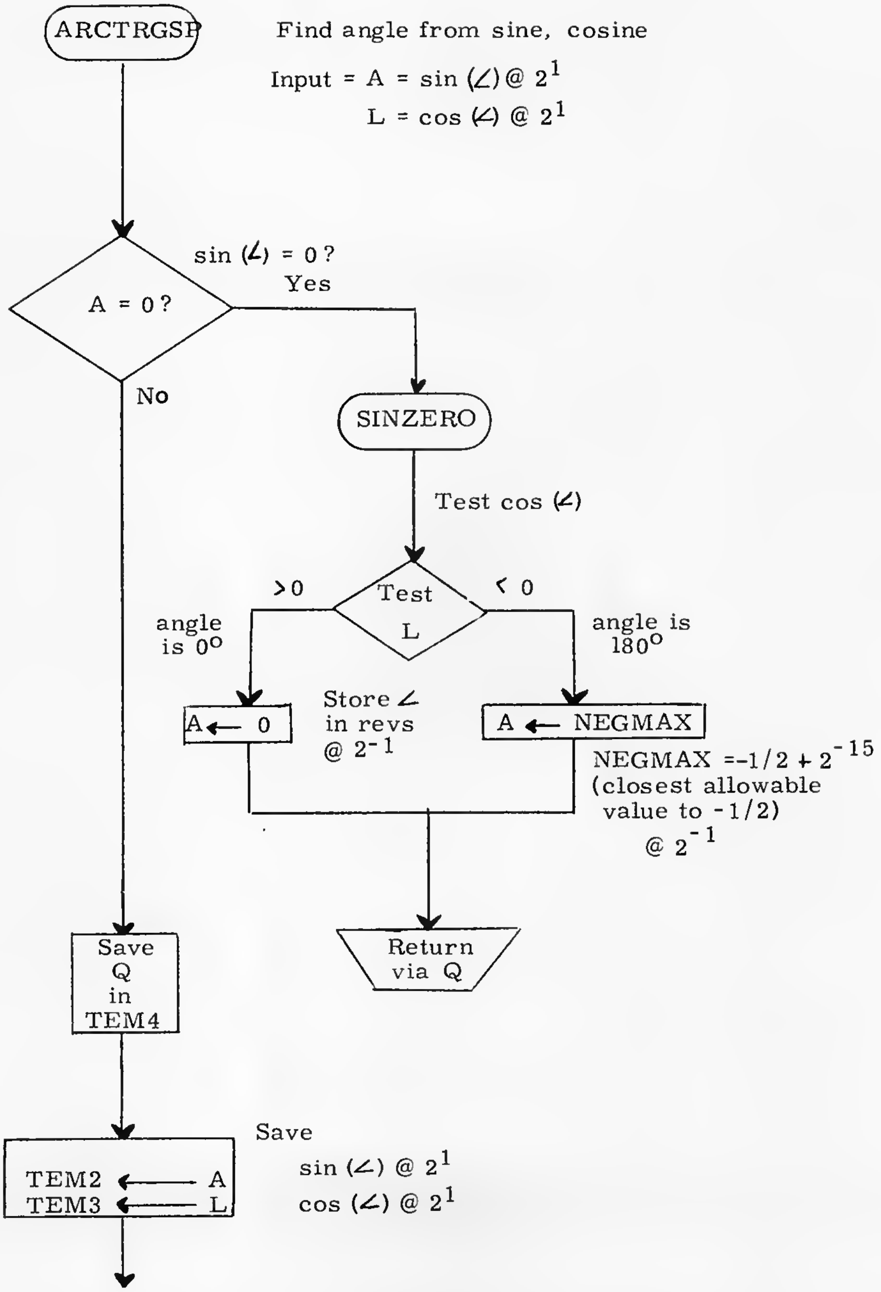

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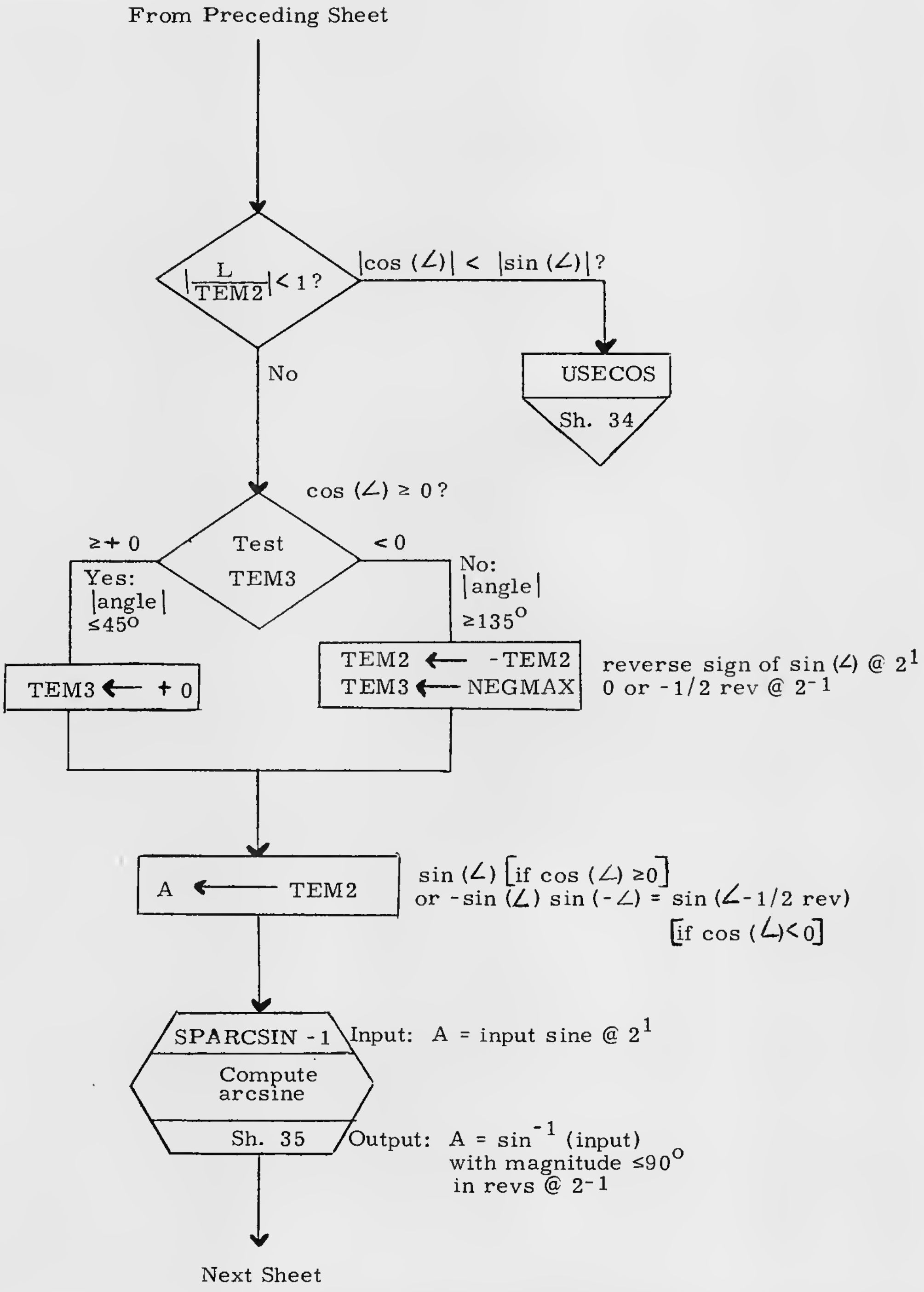
APPR'D Roberta M. Estes	10/20/69	REV	SHEET 31 OF 44



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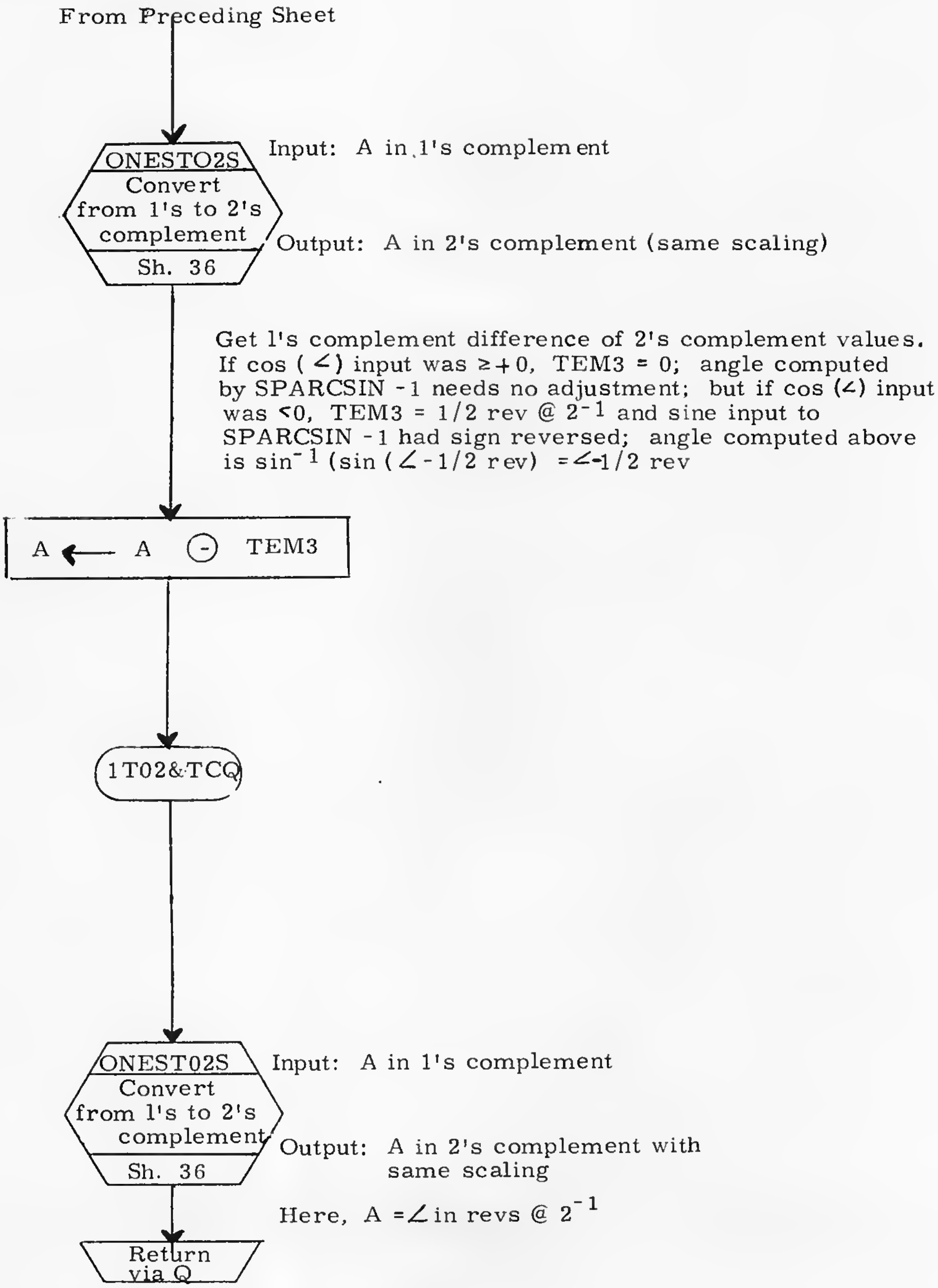

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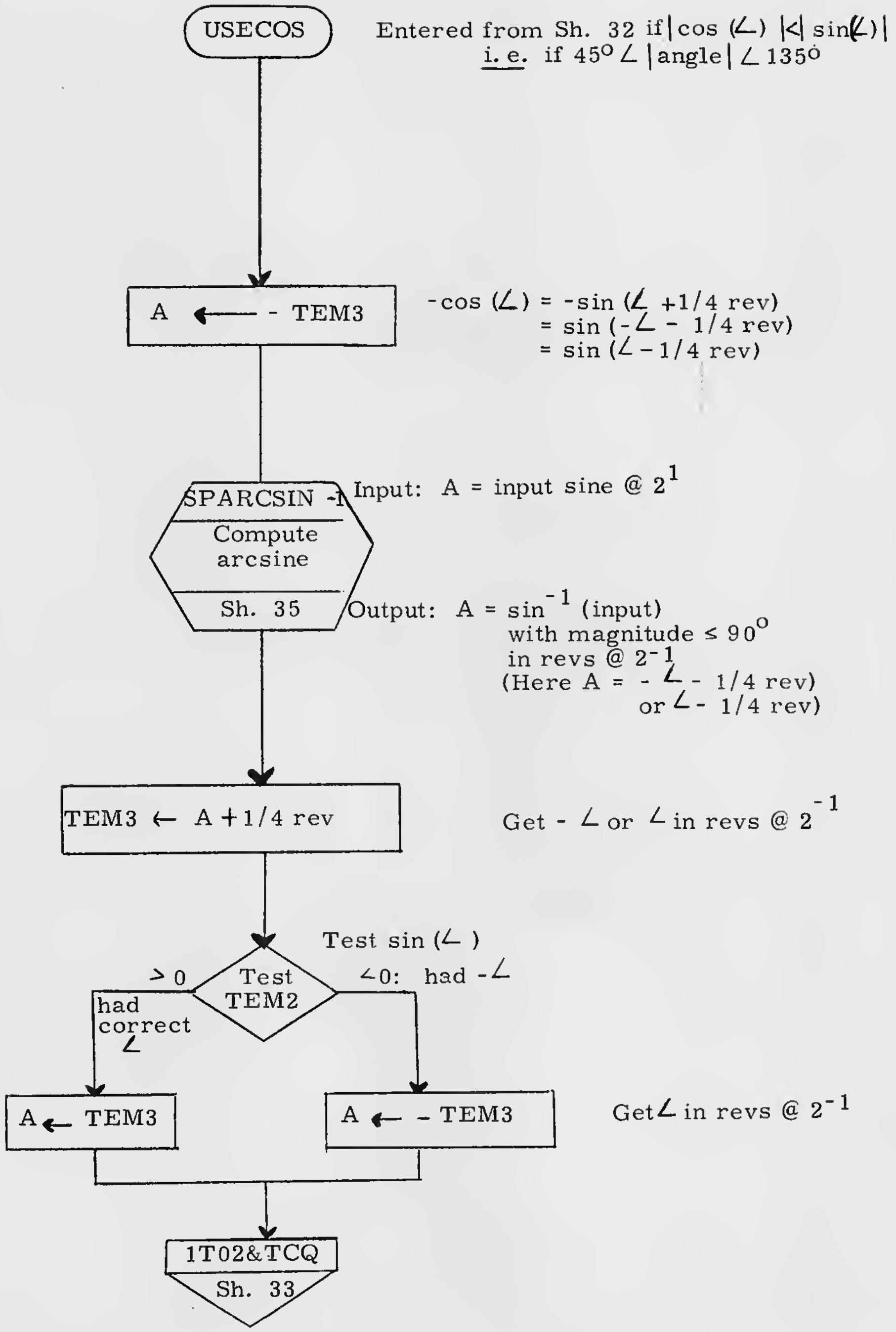

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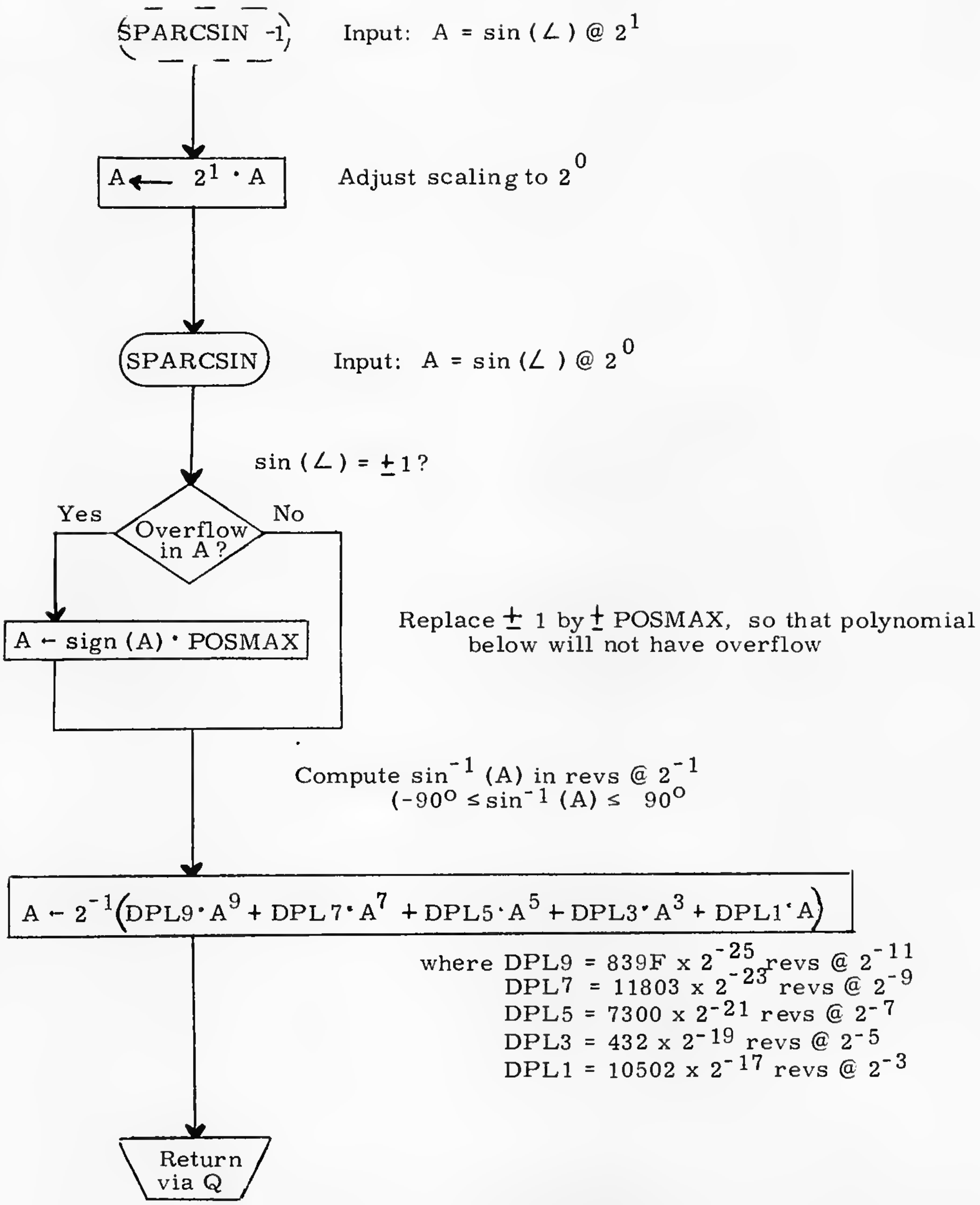

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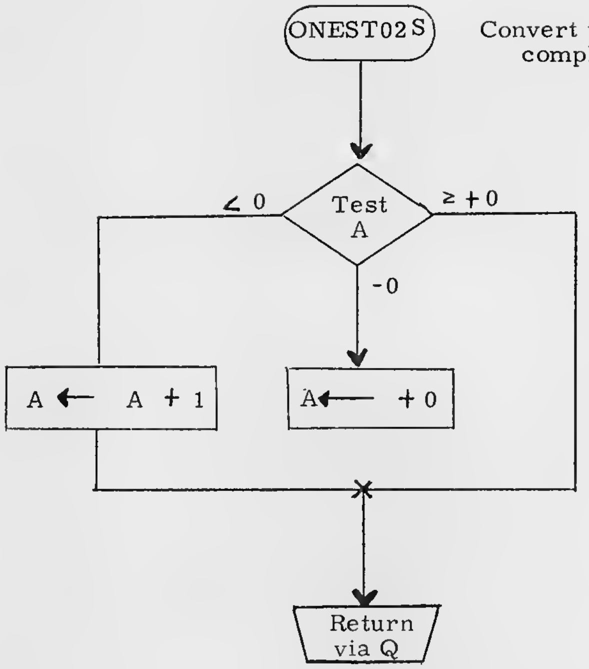
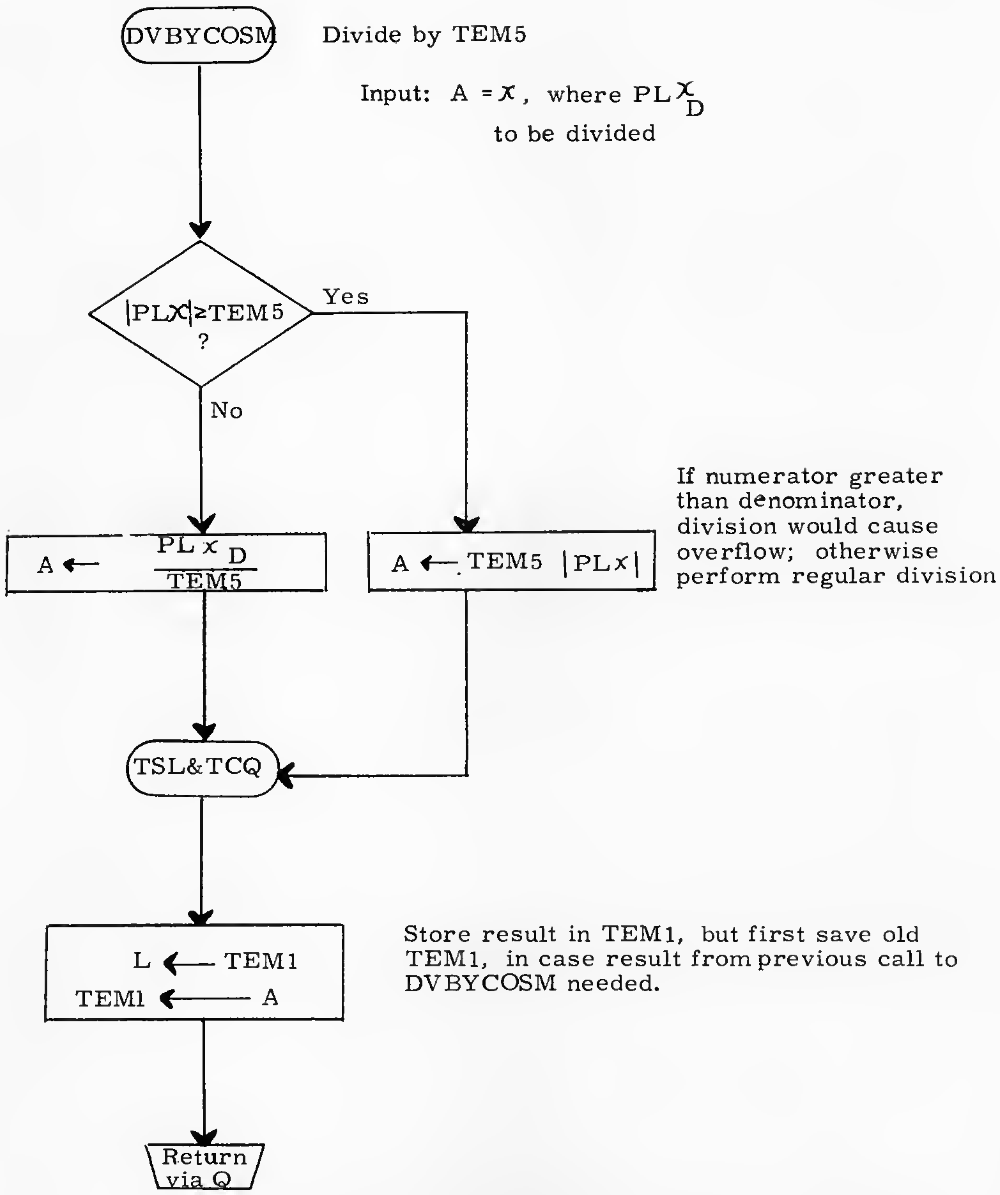


Convert value from 1's to 2's complement notation

Add one low-order bit to negative numbers



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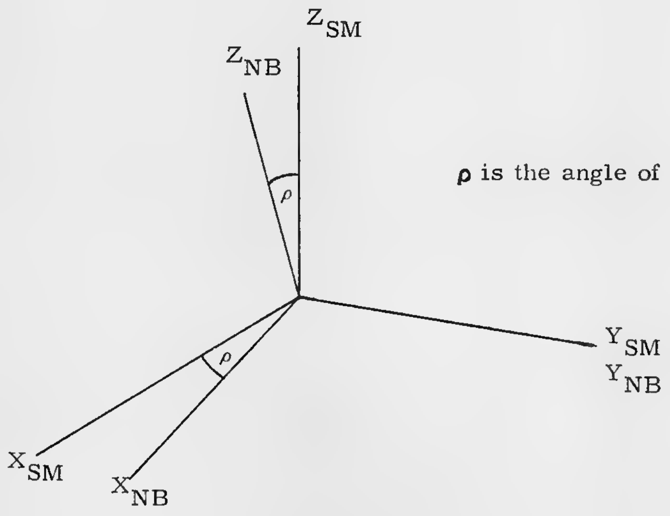
ADDITIONAL INFORMATION ABOUT NB2CDUSP (Nav Base To CDU, Single Precision)

It may help to understand this subroutine by working backwards through the logic. The end result desired is the set of three angles through which the spacecraft is to be rotated.

One of these will rotate about the "Y" axis in a manner somewhat like this:



ρ is the angle of rotation.

Note that the NB axes X_{NB} and Z_{NB} have already been rotated through the desired angle, ρ .

To translate the NB axes into stable member coordinates, one must multiply the identity matrix, which, of course, transforms SM axes to SM coordinates, by this matrix,

$$\left[D \right] = \begin{bmatrix} \cos\rho & 0 & -\sin\rho \\ 0 & 1 & 0 \\ \sin\rho & 0 & \cos\rho \end{bmatrix}$$

, where the rows are unit vectors, parallel to the X_{NB}, Y_{NB} and Z_{NB} axes, expressed in stable member coordinates.

In the same manner, rotation about the X and Z axes will produce the following matrices, in order:

$$[A] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\tau & \sin\tau \\ 0 & -\sin\tau & \cos\tau \end{bmatrix} \quad \text{and} \quad [B] = \begin{bmatrix} \cos\sigma & \sin\sigma & 0 \\ -\sin\sigma & \cos\sigma & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Multiplication of the identity matrix, [I] by the X transformation matrix [A] by the Z and Y transformation matrices, [B] and [D] in this fashion:

$[I] \times [A] \times [B] \times [D]$, yields this matrix:

$$[C] = \begin{bmatrix} \cos\sigma\cos\rho & \sin\sigma & -\sin\rho\cos\tau \\ -\cos\tau\sin\sigma\cos\rho + \sin\tau\sin\rho & \cos\tau\cos\tau & \cos\rho\sin\tau + \sin\rho\cos\tau\sin\sigma \\ \cos\rho\sin\tau\sin\sigma + \cos\tau\sin\rho & -\sin\tau\cos\tau & \cos\tau\cos\rho - \sin\tau\sin\sigma\sin\rho \end{bmatrix}$$

where τ, ρ, and σ are the angles of rotation about the X, Y, and Z axes, respectively.

This matrix is in the push list when NB2CDUSP is called. With the matrix elements C_0, C_1, C_2, C_4 and C_7, located in the push list at $PL0_D$, $PL2_D$, $PL4_D$, $PL8_D$, and and $PL14_D$, one can easily compute the required angles.

Subroutines Called Which Appear on Other Flowcharts

Subroutine	Flowchart	Description	Where Called
ALARM	FC-3140	Light PROG ALARM Light; set alarm code	Sh. 13, 22
NORMUNIT	FC-3150	Perform unit operation	Sh. 5, 6
QUICKTRIG	FC-3320	Compute trig functions of 3 angles	Sh. 6
STOPRATE	FC-3440	Zero DAP inputs	Sh. 22
SMNB	FC-3320	Convert vector from SM to NB coordinates	Sh. 7

Flags

Flag	Meaning When Set	Meaning When Clear	Where Set	Where Cleared	Where Tested
CSMDKFLG (bit 13 of FLGWRD 13)	LM docked with CSM	LM not docked with CSM			Sh. 3
ENGONFLG (bit 7 of FLAGWRDS)	Engine on	Engine off			Sh. 15
XOVINFLG (bit 9 of FLAGWRD 13)	X-axis override inhibited	X-axis override allowed			Sh. 4

Channel Bits

Channel Bit	Meaning When Set	Meaning When Clear	Where Set	Where Cleared	Where Tested
Channel 30 bit 10	AGS has control of spacecraft	LGC has control of spacecraft			Sh. 5
Channel 31 bit 14	Spacecraft Mode Control switch not in AUTO position	Spacecraft Mode Control switch in AUTO position			Sh. 5

Displays

Verb-Noun	Type of Display	Description of Registers	Where Called
	Alarm	PROG ALARM light on; no effect on R1, R2, R3	Sh. 13, 22

Erasable Locations Used

AGC Tag	GSOP Symbol	Meaning	Engineering Unit	AGC Units	Scaling
CDUSPOTX	CDUXV	Snapshot of IMU outer gimbal angle (2's complement)	degrees	revs	2^{-1}
CDUSPOTY	CDUYV	Snapshot of IMU inner gimbal angle (2 's complement)	degrees	revs	2^{-1}
CDUSPOTZ	CDUDZ	Snapshot of IMU middle gimbal (2's complement)	degrees	revs	2^{-1}
CDUX	CDUX	Outer IMU gimbal angle (2's complement)	degrees	revs	2^{-1}
CDUXD	CDUXD	DAP desired outer IMU gimbal angle (2's complement	degrees	revs	2^{-1}
CDUY	CDUY	Inner IMU gimbal angle (2's complement)	degrees	revs	2^{-1}
CDUYD	CDUYD	DAP desired inner IMU gimbal (2's complement)	degrees	revs	2^{-1}
CDUZ	CDUZ	Middle IMU gimbal angle (2's complement	degrees	revs	2^{-1}
CDUZD	CDUDZ	DAP desired middle gimbal angle (2's complement)	degrees	revs	2^{-1}
COSCDUX	COS (CDUX)	Cosine of CDUSPOTX (above)			2^{1}
COSCDUY	COS (CDUY)	Cosine of CDUSPOTY (above)			2^{1}
COSCDUZ	COS (CDUZ)	Cosine of CDUSPOTZ (above)			2^{1}
CPHI	CDUXC	Commanded IMU outer gimbal angle (2's complement)	degrees	revs	2^{-1}
CPHI +1	CDUYC	Commanded IMU inner gimbal angle (2's complement)	degrees	revs	2^{-1}
CPHI +2	CDUZC	Commanded IMU middle gimbal angle (2's complement)	degrees	revs	2^{-1}

Erasable Locations Used (Continued)

AGC Tag	GSOP Symbol	Meaning	Engineering Units	AGC Units	AGC Scaling
DELCDUX	$\delta CDUX$	Commanded incremental change (for DAP) in outer IMU gimbal angle (2's complement)	degrees	revs	2^{-1}
DELCDUX 1	$\delta CDUY$	Commanded incremental change (for DAP) in inner IMU gimbal angle (2's complement)	degrees	revs	2^{-1}
DELCDUX 2	$\delta CDUZ$	Commanded incremental change (for DAP) in middle IMU gimbal angle (2's complement)	degrees	revs	2^{-1}
DELPEROR	ϕ_X	Commanded lag angle for IMU outer gimbal (for DAP)	degrees	revs	2^{-1}
DELPEROR 1	ϕ_Y	Commanded lag angle for IMU inner gimbal (for DAP)	degrees	revs	2^{-1}
DELPEROR 2	ϕ	Commanded lag angle for IMU middle gimbal (for DAP)	degrees	revs	2^{-1}
DELV	$\Delta\tilde{\underline{V}}_P$	Change in velocity due to previous 2 seconds of thrust, in SM coordinates	m/sec	m/sec	
FLAGOODW		Indicates whether or not window pointing command is good for X-axis, by value > 0, +0 respectively			
FLPAUTNO		Indicates whether or not autopilot is in control, by value +0, >0 respectively			
NDXCDUW		Index value corresponding to whether or not LM is docked to CSM, by value of 1, +0 respectively			2^{14}
OMEGAPD	ω_{DXV}	X-component of commanded attitude rate	deg/sec	revs/sec	2^{-3}
OMEGAQD	ω_{DYV}	Y-component of commanded attitude rate	deg/sec	revs/sec	2^{-3}
OMEGARD	ω_{DY_V}	Z-component of commanded attitude rate	deg/sec	revs/sec	2^{-3}

Erasable Locations Used (Continued)

AGC Tag	GSOP Symbol	Meaning	Engineering Units	AGC Units	AGC Scaling
SINCDUX	SIN(CDUX)	Sine of CDUSPOTX (above)			2^1
SINCDUY	SIN(CDUY)	Sine of CDUSPOTY (above)			2^1
SINCDUZ	SIN(CDUZ)	Sine of CDUSPOTZ (above)			2^1
$UNFC/2_V$	$\underline{u}FDP$	Commanded direction in SM coordinates			Variable
$UNFV/2_V$ $\begin{pmatrix} UNFV/2_D \\ UNFY/2_D \\ UNFZ/2_D \end{pmatrix}$	$\underline{u}_{FV}$	Measured thrust direction in SM coordinates			2^1
$UNWC/2_V$	$\underline{u}WDP$	Window-pointing direction command, in SM coordinates			2^1
UNX/2V $= PL0_V$	$\underline{u}XVDP$	Commanded vehicle (NB) Y-axis, in SM coordinates			2^1
$UNY/2_V$ $= PL6_V$	$\underline{u}YVDP$	Commanded vehicle (NB) Y-axis, in SM coordinates			2^1
$UNZ/2_V$ $= PL12_V$	$\underline{u}ZVDP$	Commanded vehicle (NB) Z-axis, in SM coordinates			2^1
-DELGMB	-ΔCDUUX or -ΔATTX or -ΔCDUX	One of several stages in computation of the negative commanded outer IMU gimbal angle change	degrees	revs	2^{-1}
-DELGMB + 1	-ΔCDUUY or -ΔCDUY	Preliminary or final negative commanded inner IMU gimbal angle change	degrees	revs	2^{-1}
-DELGMB + 2	-ΔCDUUZ or -ΔCDUZ	Preliminary or final negative commanded middle IMU gimbal angle change	degrees	revs	2^{-1}

Constants

AGC Tag	GSOP Symbol	Meaning	Engineering Value & Units	AGC Value & Units	AGC Scaling
DAXMAX = DAZMAX	θ_{XM}, θ_{ZM}	Maximum magnitude for commanded IMU outer, middle gimbal change (for LM not docked with CSM)	20 degrees	.055555555555 rev	2^{-1}
DAXMAX +1 = DAZMAX +1	θ_{XM}, θ_{ZM}	Maximum magnitude for commanded IMU outer, middle gimbal angle change (for LM docked with CSM)	2 degrees	.0055555555555 rev	2^{-1}
DAY/2MAX	θ_{YM}	Maximum magnitude for command IMU inner gimbal angle change (for LM not docked with CSM)	20 degrees	.05555555555 rev	2^{0}
DAY/2MAX +1	θ_{YM}	Maximum magnitude for commanded IMU inner gimbal angle change (for LM docked with CSM)	2 degrecs	.0055555555	2^{0}
DT/DELT	$\frac{0.1 \text{ sec}}{2 \text{ sec}}$	Ratio of DAP control sample period to computation period	.05	.05	2^{0}

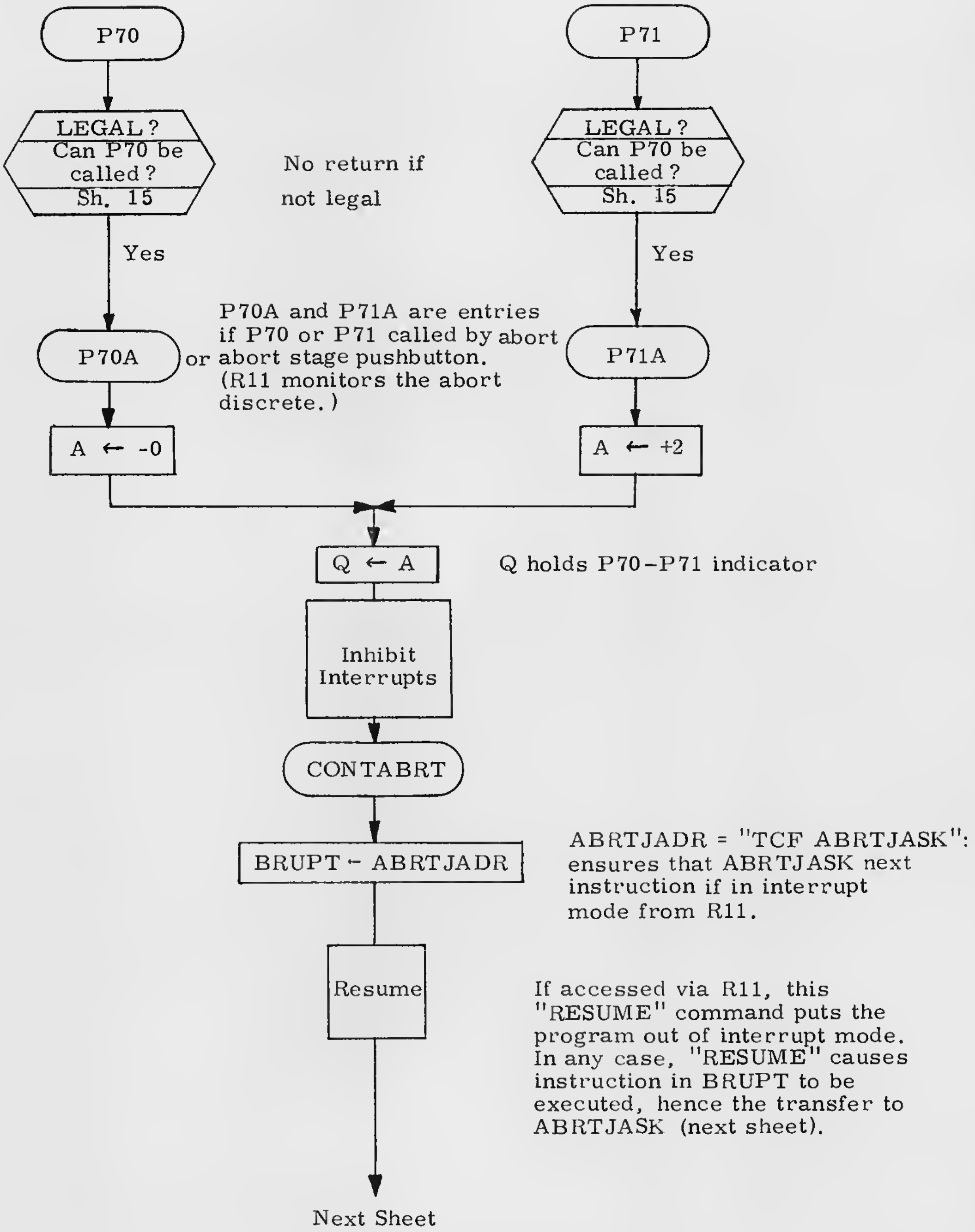
Pad-Loads

AGC Tag	GSOP Symbol	Meaning	Engineering Units	AGC Units	AGC Scaling
1JACC	α_X	Acceleration due to 2-jet torquing around X-axis	deg/sec^2	revs/sec^2	2^{-2}
1JACC +1	α_Y	Acceleration due to 2-jet torquing around Y-axis	deg 1 sec^2	revs/sec^2	2^{-2}
1JACC +2	α_Z	Acceleration due to 2-jet torquing around Z-axis	deg/sec^2	revs/sec^2	2^{-2}

P70 – P71 Abort Programs

External Entry Points:

P70	Keyed in by astronaut:	DPS	Sh. 2
P70A	Entered from R 11:	DPS	Sh. 2
P71	Keyed in by astronaut:	APS	Sh. 2
P71A	Entered from R 11:	APS	Sh. 2
TGOCOMP	Compute t_{go}		Sh. 7
LEGAL?	Determine whether selected major mode is allowed at this time		Sh. 15
THROTUP	Command maximum DPS engine throttle position		Sh. 16



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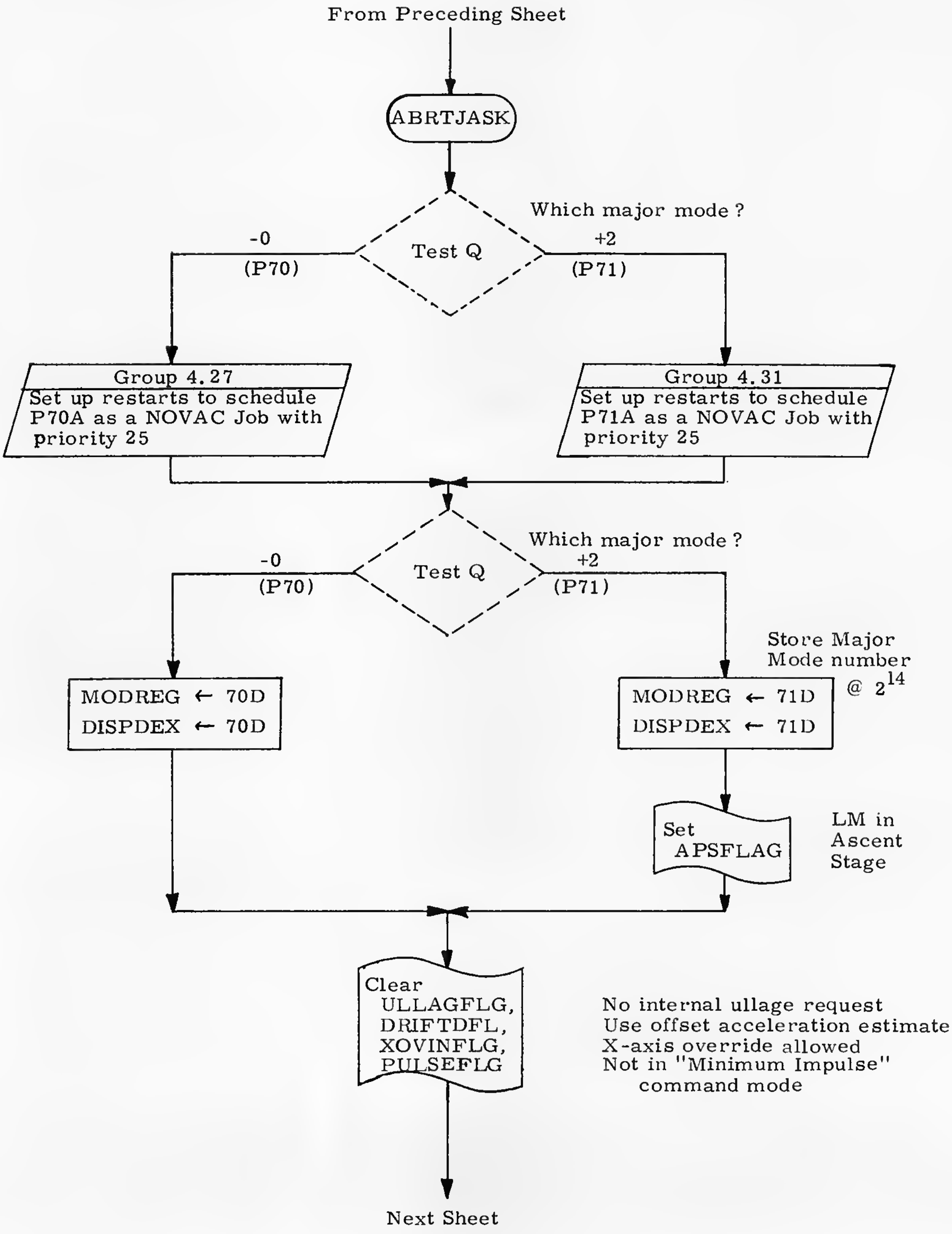
DOCMR A. M. Sarant	7/23/69		
APPR'D Alek M. Sarant	7/25/69	REV 3	SHEET 2 OF 25



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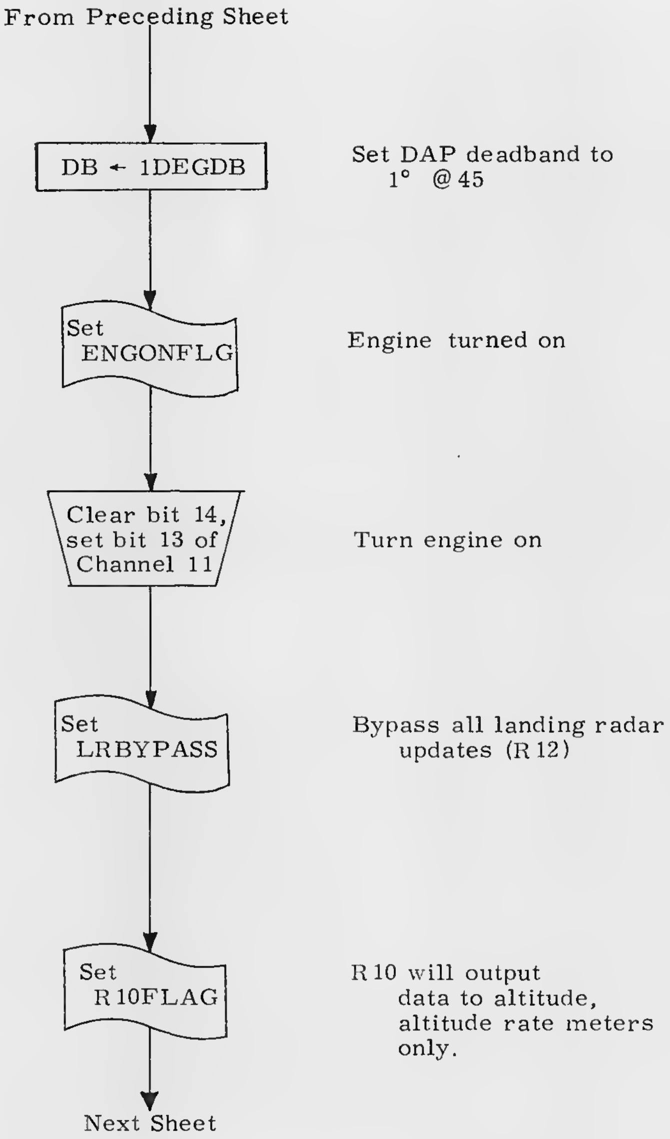

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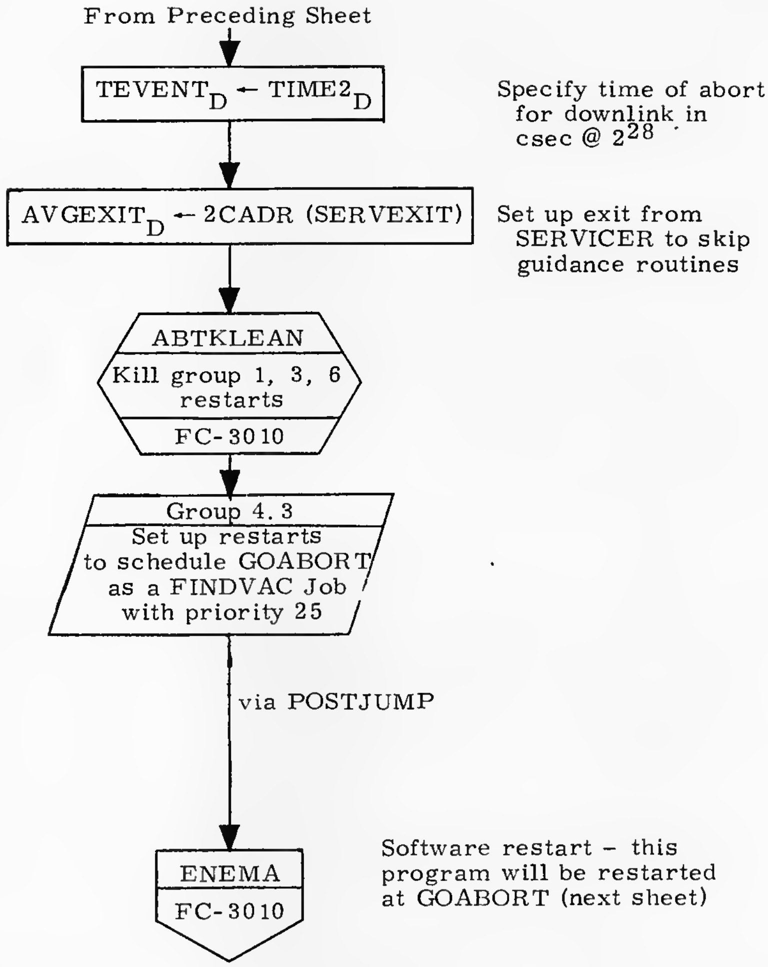

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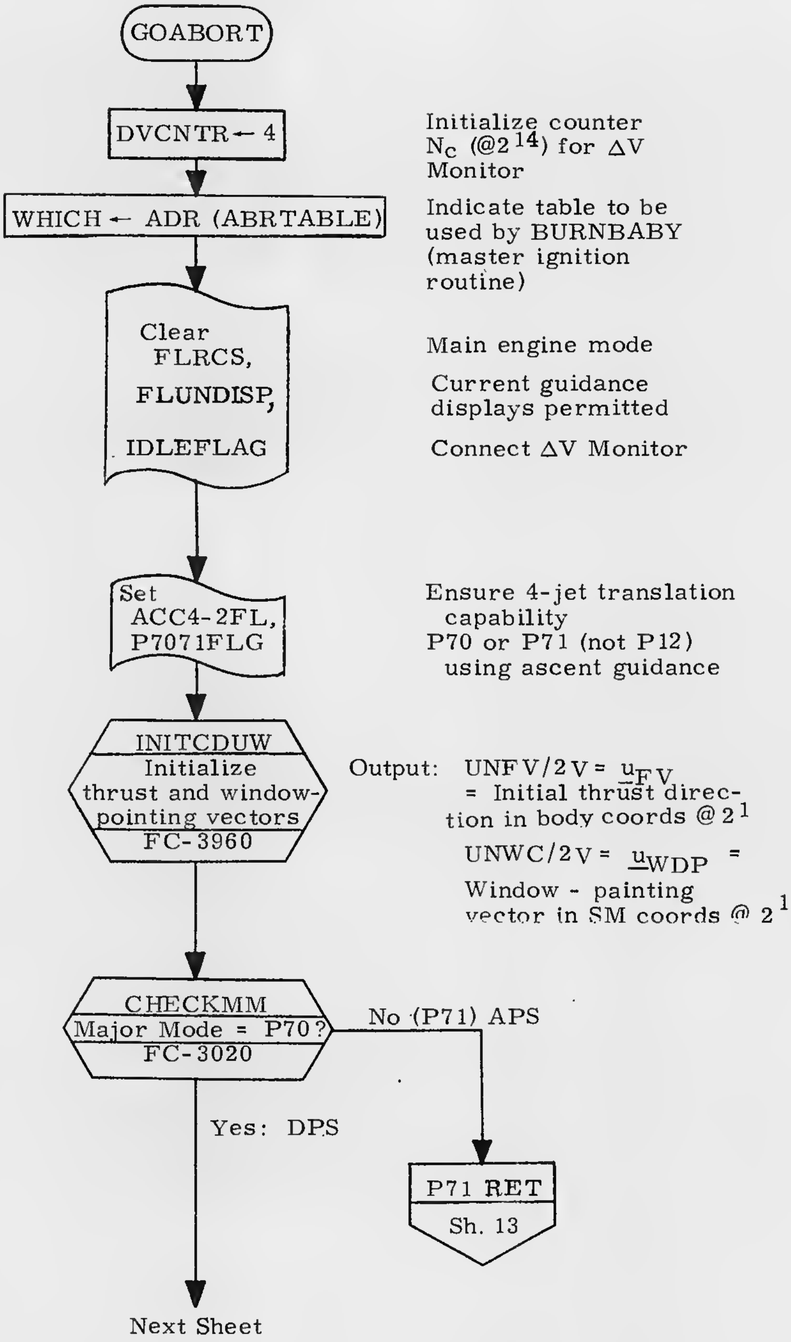

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From Preceding Sheet

P70INIT

TGOCOMP

LOADTIME
Load present time
FC-3150

$MPAC_D \leftarrow TIME2_D$ = Present time in csec @ 2^{28}

$TGO_D \leftarrow 2^{11} \cdot (MPAC_D - TIG_D)$

Compute t_{go} = time from ignition in csec @ 2^{17}.
2^{11} factor is for scaling.

Return via
QPRET

$\tau = \frac{m}{\dot{m}}$

$TBUP_D \leftarrow \frac{MASS_D}{2^4 \cdot MDOTDPS_D}$

Compute τ in csec @ 2^{17}
where:
$MASS_D$ = mass in kg @ 2^{16}
$MDOTDPS_D = \dot{m}_{DPS}$
= mass decrementation rate for DPS thrust
= .148 kg/csec @ 2^3

2^4 factor is for scaling.

$^1/_{\Delta v_1} = {}^1/_{\Delta v_2} = {}^1/_{\Delta v_3} = {}^1/_{\Delta v_{IG}} = \frac{m}{\dot{m} V_e \Delta t}$

$MPAC_D \leftarrow \frac{MASS_D}{K(1/DV)_D \cdot 2}$

$1/DV1_D \leftarrow MPAC_D$

$1/DV2_D \leftarrow MPAC_D$

$1/DV3_D \leftarrow MPAC_D$

Initialize
$^1/_{\Delta v}$ parameters in csec/m @ 2^7
Where:
$MASS_D$ = mass in kg @ 2^{16}

$K(1/DV)_D = \dot{m} V_e \, (\Delta t/2)$
in $\frac{kg - m}{csec}$ @ 2^9

Next Sheet

From Preceding Sheet

$$a_T = \frac{1/\Delta t}{1/\Delta v_{IG}}$$

$$AT_D \leftarrow \frac{K(AT)_D}{MPAC_D}$$

Compute thrust acceleration in $m/csec^2$ @ 2^{-9}

where:

$K(AT)_D = 1/\Delta t$ in $csec^{-1}$ @ 2^{-2}

$$TTO_D \leftarrow 100PCTTO_D$$

Set $\Delta t_{tail\text{-}off}$ in csec @ 2^{17}

where:

$100PCTTO_D = \Delta t_{tail\text{-}off}$ (DPS) in csec @ 2^{17}

$$VE_D \leftarrow -2^{-2} \cdot DPSVEX$$

Set V_e = Exhaust velocity in m/csec @ 2^7

where:

$DPSVEX = -V_e$ (DPS) = in m/csec @ 2^5

2^{-2} factor is for scaling.

COMMINIT

Initialize target parameters R_D, Y_D, $\dot{R}_D$, $\dot{Y}_D$

FC-3950

Input: $/LAND/_D = r_{LS}$ in m @ 2^{24}

$VRECTCSM_V = \underline{v}_c$ in reference coords

$RRECTCSM_V = \underline{r}_c$ in reference coords

Output: $RCO_D = R_D$ in m @ 2^{24}

$YCO_D = Y_D$ in m @ 2^{24}

$YDOTD_D = \dot{Y}_D$ in m/csec @ 2^7

$TXO_D = t_{xo}$ in csec @ 2^{28}

$QAXIS_V = \underline{Q}$ @ 2^1

Next Sheet

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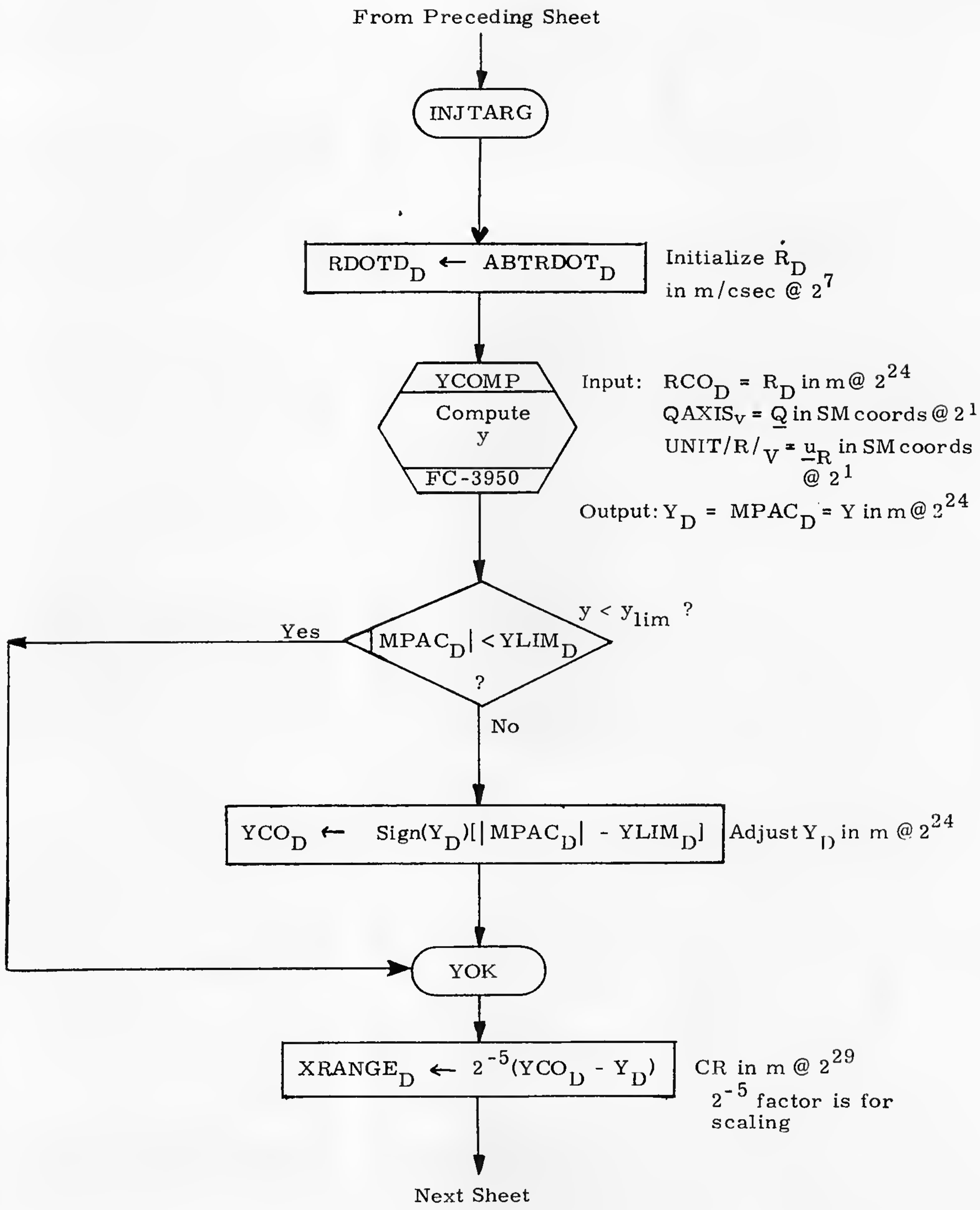
APPR'D	7/25/69	REV 3	SHEET 8 OF 25



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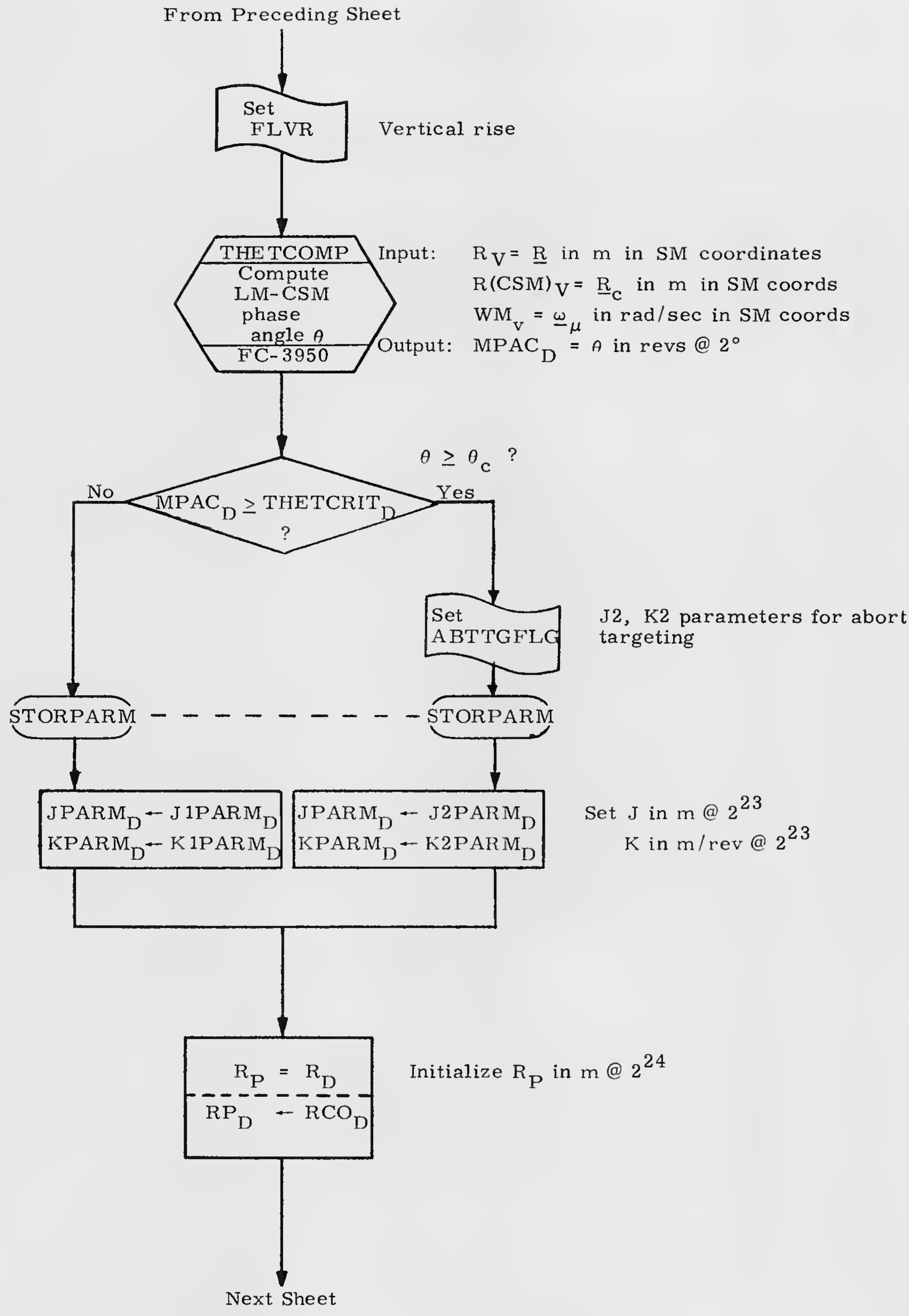
DOCMR A. M. Sozant	7/23/69	
APPR'D Alesa M. Sozant	7/25/69	REV 3 — SHEET 9 OF 25



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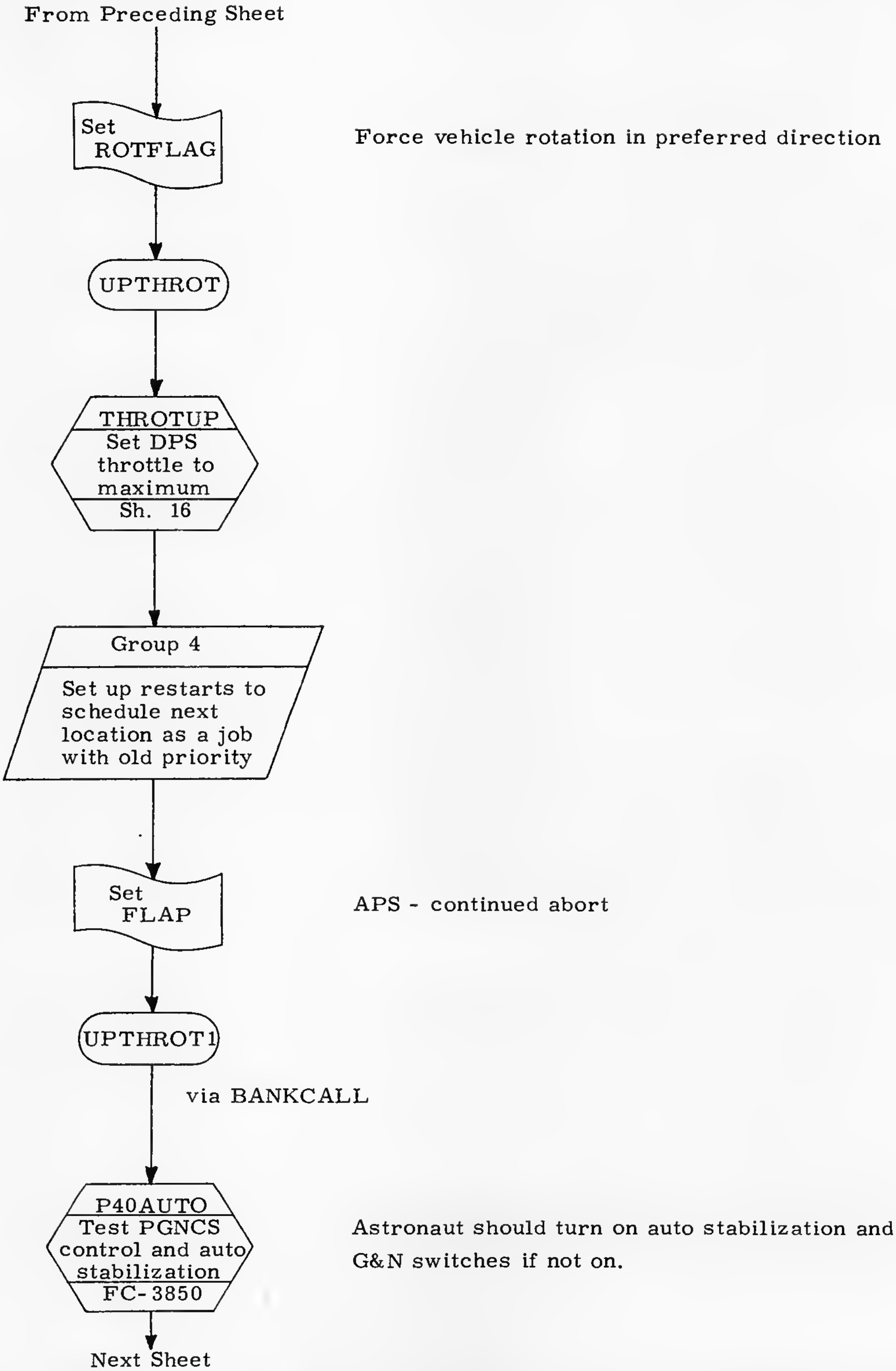

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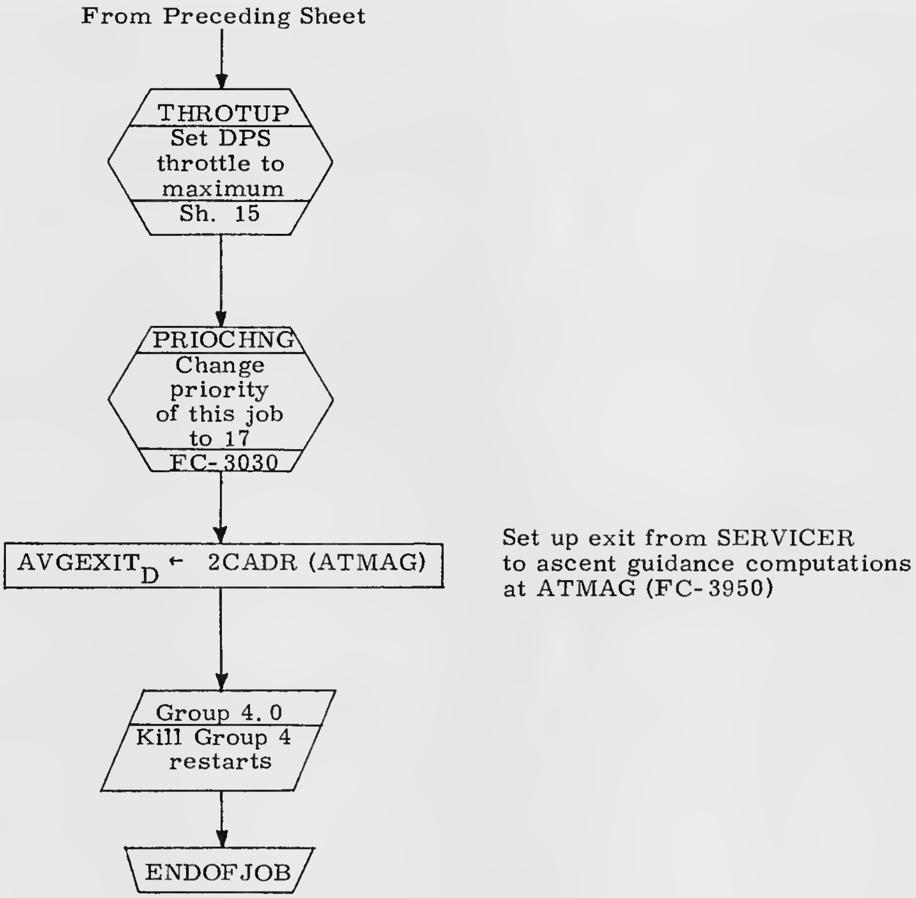
DOCMR				
APPR'D	Robert M. Eaton	10/16/69	REV 3	SHEET 11 OF 25



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. L. Welch	10/6/69	Abort Programs	
PRGMR L J Berman	10-16-69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3970
DOCMR			
APPR'D Roberto M. Estes	10/16/69	REV 3	SHEET 12 OF 25

P71RET

Clear LETABORT

Abort programs not allowed

DVTHRUSH ← THRESH2

Set Δv = minimum acceptable 2-second Δv to APS value in m/csec @ $10^{-4} \times 2^{14}$

P12INIT
Initialize thrusting and target parameters for ascent
FC-3950

Input: $/LAND/_D$ = r_{LS} in m @ 2^{24}
$VRECTCSM_V$ = $\underline{v}_c$ = CSM velocity in reference coords
$RRECTCSM_V$ = $\underline{r}_c$ = CSM position in reference coords

Output: $1/DV3_D$, $1/DV2_D$, $1/DV1_D$ = thrust filter parameters in csec/m @ 2^7
AT_D = a_T in m/csec^2 @ 2^{-9}
$TBUP_D$ = t in csec @ 2^{17}
TTO_D = $\Delta t_{tail\text{-}off}$ in csec @ 2^{17}
VE_D = v_e in m/csec @ 2^7
RCO_D = R_D in m @ 2^{24}
TXO_D = X-axis override time in csec @ 2^{28}
YCO_D = Y_D in m @ 2^{24}
$YDOTD_D$ = $\dot{y}_D$ in m/csec @ 2^7
$QAXIS_V$ = $\underline{Q}$ in SM coords @ 2^1

Is FLAP set ?

Is this APS continued abort after DPS staging?

Yes → OLDTIME Sh. 14

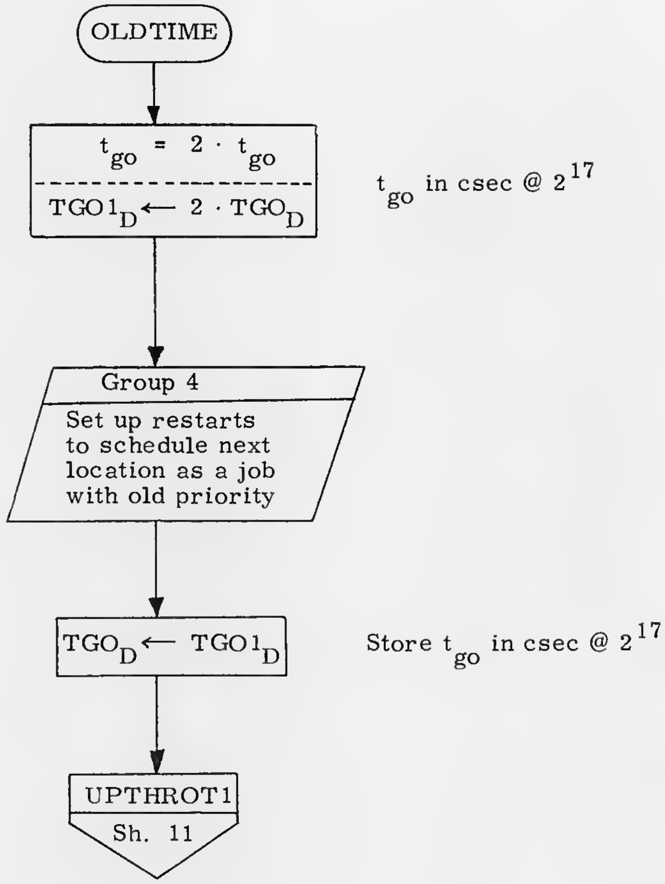
No ↓

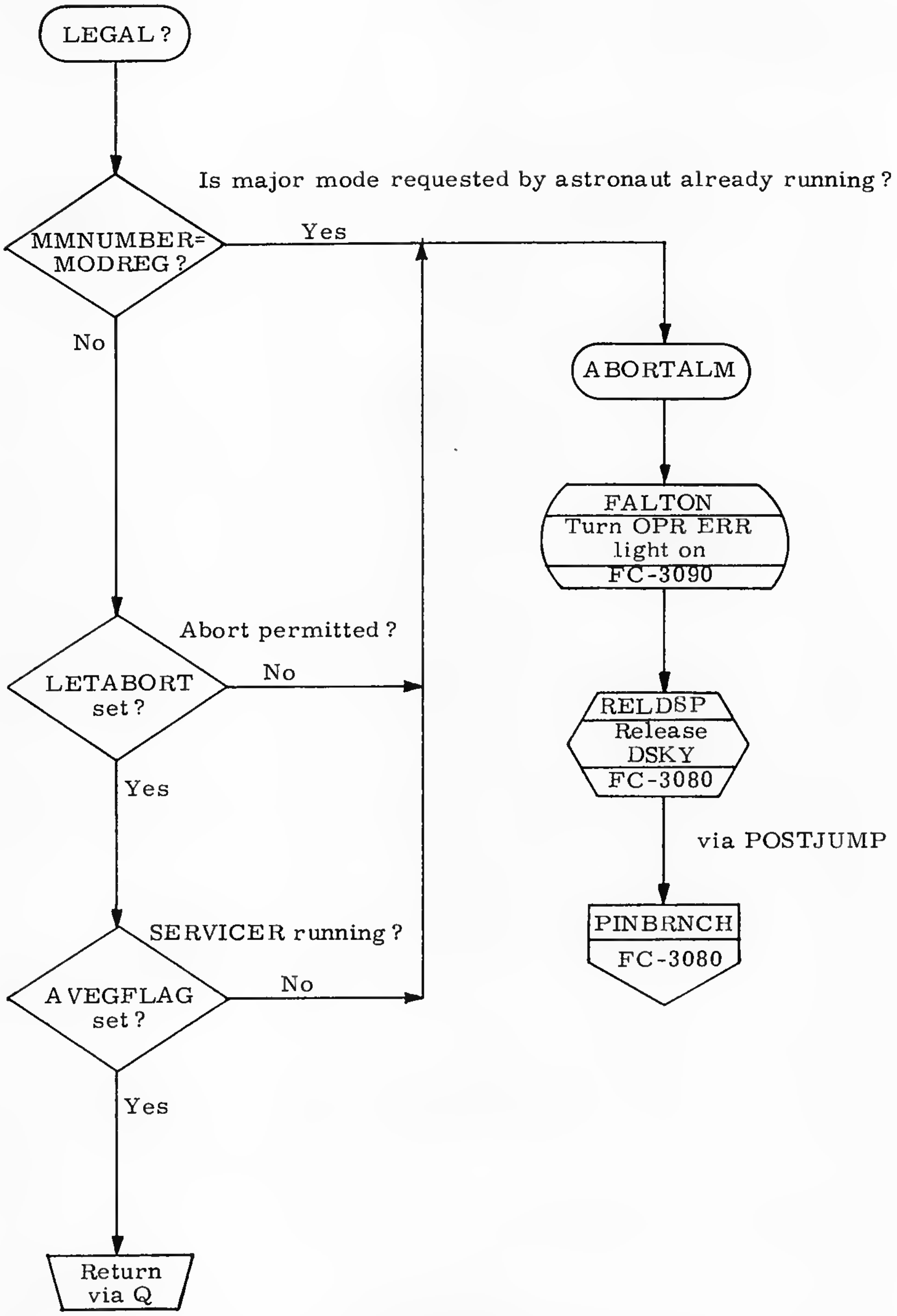
TGOCOMP
Compute time from ignition
Sh. 7

Output: TGO_D = t_{go} in csec @ 2^{17}

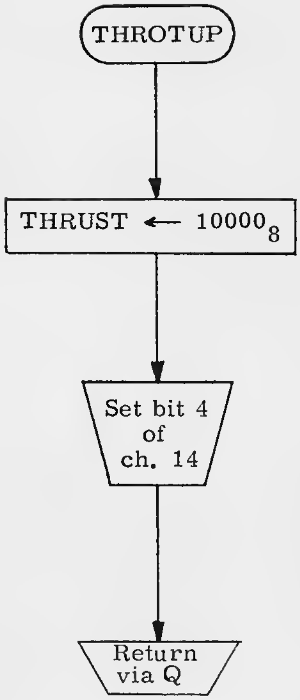
INJTARG Sh. 9

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Welch	10/6/69	Abort Programs	
PRGMR L J Berman	10-16-69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3970
DOCMR			
APPR'D Roberta M. Estes	10/16/69	REV 3	SHEET 13 OF 25


OLDTIME
$t_{go} = 2 \cdot t_{go}$
$TGO1_D \leftarrow 2 \cdot TGO_D$
t_{go} in csec @ 2^{17}
Group 4
Set up restarts to schedule next location as a job with old priority
$TGO_D \leftarrow TGO1_D$
Store t_{go} in csec @ 2^{17}
UPTHROT1
Sh. 11



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	R. D. Kerr	7/23/69	Abort Programs	
PRGMR	L. J. Berman	7/25/69		
ANALST	L. J. Berman	7/25/69	LUMINARY 1D	DOCUMENT NO. FC-3970
DOCMR	A. M. Sorant	7/23/69		
APPR'D	Alicia M. Sorant	7/25/69	REV 3	SHEET 15 OF 25



Store descent engine throttle command (maximum)

Cause output pulses to be sent from THRUST for use in controlling position of descent engine throttle

SUBROUTINES CALLED WHICH ARE
FLOWED ON OTHER FLOW CHARTS

Subroutine Name	Flow Chart	Description	Where Called
ABTKLEAN	FC-3010	Kill group 1, 3, 6 restarts	Sh. 5
CHECKMM	FC-3020	Check major mode	Sh. 6
COMMINIT	FC-3950	Initialize some target parameters for ascent guidance	Sh. 8
ENEMA	FC-3010	Perform software restart	Sh. 5
FALTON	FC-3090	Turn on OPR ERR light	Sh. 15
INITCDUW	FC-3960	Initialize thrust and window pointing vectors	Sh. 6
LOADTIME	FC-3150	Load present time	Sh. 7
PINBRNCH	FC-3080	Terminate DSKY operation	Sh. 15
PRIOCHNG	FC-3030	Change priority of current job	Sh. 12
P12INIT	FC-3950	Initialize ascent guidance and targeting parameters	Sh. 13
P40AUTO	FC-3850	Test PGNCS control and auto stabilization discretes	Sh. 11
RELDSP	FC-3080	Release DSKY	Sh. 15
YCOMP	FC-3950	Compute cross-range distance Y	Sh. 9

DISPLAYS

Type		Description of Registers	Where Called
Operator Error		OPR ERR light on; no effect on R1, R2, R3	Sh. 15

FLAGS

Flag	Meaning When Set	Meaning When Clear	Where Set	Where Cleared	Where Tested
ABTTGFLG (bit 7 of flagword 9)	J2, K2 parameters used for abort targeting	J1, K1 parameters used for abort targeting	Sh. 10		
ACC4-2FL (bit 11 of flagword 13)	4-jet translation requested	2 - jet translation requested	Sh. 6		
APSFLAG (bit 13 of flagword 10)	LM in Ascent Stage	LM in Descent Stage	Sh. 3		
AVEGFLAG (bit 5 of flagword7)	SERVICER is running	SERVICER is not running			Sh. 15
DRIFTDFL (bit 8 of flagword13)	Assume zero offset drifting flight	Use offset acceleration estimate		Sh. 3	
ENGONFLG (bit 7 of flagword 5)	Engine is on	Engine is off	Sh. 4		
FLAP (bit 8 of flagword 9)	APS - continued abort	Not an APS- continued abort	Sh. 11		Sh. 13
FLRCS (bit 10 of flagword 9)	RCS injection	APS injection		Sh. 6	
FLUNDISP (bit 10 of flagword 8)	Current guidance displays inhibited	Current guidance displays allowed.		Sh. 6	

FLAGS (CONTINUED)

Flag	Meaning When Set	Meaning When Clear	Where Set	Where Cleared	Where Tested
FLVR (bit 14 of flagword 9)	Vertical rise	Non - vertical rise	Sh. 10		
IDLEFLAG (bit 7 of flagword 7)	No Δ V Monitor	Connect Δ V Monitor		Sh. 6	
LETABORT (bit 9 of flagword 9)	Abort programs allowed	Abort programs inhibited		Sh. 13	Sh. 15
LRBYPASS (bit 15 of flagword 11)	Bypass all landing radar updates	Don't bypass landing radar updates	Sh. 4		
PULSEFLG (bit 15 of flagword 13)	In "Minimum Impulse" command mode	Not in "Minimum Impulse" command mode		Sh. 3	
P7OP71FLG (bit 13 of flagword 9)	P70 or P71 using ascent guidance	P12 using ascent guidance	Sh. 6		
R10FLAG (bit 2 of flagword)	R10 outputs altitude, altitude rate data only	R10 also outputs cross - range data	Sh. 4		
ULLAGFLG (bit 6 of flagword 13)	Ullage requested by program	No internal ullage request		Sh. 3	
XOVINFLG (bit 9 of flagword 13)	X-axis override inhibited	X - axis override allowed		Sh. 3	

CHANNEL BITS

Channel Bit	Effect When Set	Effect When Clear	Where Set	Where Cleared	Where Tested
Ch. 11 bit 14	Engine - off signal present	No engine - off signal present		Sh. 4	
Ch. 11 bit 13	Engine - on signal present	No engine - on signal present	Sh. 4		
Ch. 14 bit 4	Command from THRUST sent to DPS engine throttle	Command from THRUST not sent	Sh. 16		

ERASABLE LOCATIONS USED

AGC Tag	GSOP Symbol	Meaning	Engineering Units	AGC Units	AGC Scaling
AT_D	a_T	Thrust acceleration	m/sec^2	$m/csec^2$	2^{-9}
$AVGEXIT_D$		Pointer containing address of exit from SERVICER (FC-3850).			
BRUPT		Register used to save contents hardware B register during interrupt mode; the instruction contained in BRUPT is executed immediately upon leaving interrupt mode (by RESUME instructions).			
DB		Attitude deadband, for DAP	deg	deg	45
DISPDEX		Major mode number, for display interface routines			2^{14}
DVCNTR	N_c	Counter indicating 1 + number of cycles before signaling engine failure			2^{14}
DVTHRUSH	ΔV_K	Minimum acceptable 2-second Δ V	m/sec	m/csec	$10^{-4} x 2^{+14}$
$JPARM_D$	J	Parameter used in computation of R_a (apogee radius)	m	m	2^{23}
$KPARM_D$	K	Parameter used in computation of R_a (apogee radius)	m/deg	m/rev	2^{23}
$MASS_D$	m	Mass of vehicle	K_g	K_g	2^{16}
MMNUMBER		Major mode number selected by astronaut			2^{14}
MODREG		Number of major mode in progress			2^{14}
$QAXIS_V$	$\underset{\sim}{Q}$	Q - axis of target coordinate system, in SM coordinates			2^{1}

ERASABLE LOCATIONS USED (CONTINUED)

AGC Tag	GSOP Symbol	Meaning	Engineering Units	AGC Units	AGC Scaling
R_V	$\underline{r}$	Position vector in SM coords	m	m	2^{24}
RCO_D	$\underline{R}_D$	Desired injection radius	m	m	2^{24}
$RDOTD_D$	$\dot{\underline{R}}_D$	Desired radial velocity	m/sec	m/csec	2^{7}
RP_D	R_P	Estimated perigee at cutoff time	m	m	2^{24}
$RRECTCSM_V$	$\underline{r}_c$	CSM position vector in reference coordinates	m	m	
$R(CSM)_V$	$\underline{r}_c$	CSM position vector in SM coordinates	m	m	
$TEVENT_D$	t_{EVENT}	Time of relevant event, for downlink	sec	csec	2^{28}
THRUST		Commanded DPS engine throttle position			
TIG_D	t_{IG}	Time of ignition	sec	scec	2^{28}
$TIME2_D$	t	Present time	sec	csec	2^{28}
TXO_D	t_{XO}	Time when X - axis override is allowed	sec	csec	2^{28}
$UNIT/R/_V$	$\underline{u}_R$	Radial direction, in SM coordinates			2^{1}
$VRECTCSM_V$	$\underline{v}_C$	CSM velocity vector, in reference coordinates	m/sec	m/csec	
WHICH		Variable address of table to be used by master ignition routine			
WM_V	$\underline{\omega}_M$	Moon rotational velocity in SM coordinates	rad/sec	rad/csec	2^{-17}

ERASABLE LOCATIONS USED (CONTINUED)

AGC Tag	GSOP Symbol	Meaning	Engineering Units	AGC Units	AGC Scaling
$XRANGE_D$	CR	Cross - range position error	m	m	2^{29}
Y_D	Y	Cross - range position	m	m	2^{24}
YCO_D	Y_D	Desired cross - range position	m	m	2^{24}
$YDOTD_D$	Y_D	Desired cross - range velocity	m/sec	m/csec	2^{7}
$/LAND/_D$	r_{LS}	Landing site radius	m	m	2^{24}
$1/DV1_D$	$\frac{1}{\Delta v_1}$	Second $1/\Delta v$ thrust filter parameter	sec/m	csec/m	2^{7}
$1/DV2_D$	$\frac{1}{\Delta v_2}$	Third $1/\Delta v$ thrust filter parameter	sec/m	csec/m	2^{7}
$1/DV3_D$	$\frac{1}{\Delta v_3}$	Fourth $1/\Delta v$ thrust filter parameter	sec/m	csec/m	2^{7}

CONSTANTS

AGC Tag	GSOP Symbol	Meaning	Engineering Value & Units	AGC Value & Units	AGC Scaling
DPSVEX	$-V_e$ (DPS)	Negative of DPS exhaust velocity	-2955.8886 m/sec	-29.558886 m/csec	2^5
$K(AT)_D$	$1/\Delta t$	Inverse of Δt = 2 seconds	$.5\ sec^{-1}$	$.005\ csec^{-1}$	2^{-2}
$K(1/DV)_D$	$\dot{m}V_e \left(\frac{\Delta t}{2}\right)$	Constant ($\dot{m}V_e$. 1 sec) used in computation of initial $1/\Delta v$ parameters	43670 kg-m/sec	436.7 kg-m/csec	2^9 2^9
$MDOTDPS_D$	$\dot{m}_{DPS}$	Rate of mass loss during DPS burn	14.8 kg/sec	.148 kg/csec	2^3
THRESH2	Δv_K (APS)	Minimum acceptable 2-second Δv during APS burn	3.08 m/sec	.0308 m/csec	10^{-4}x2 +14
$100PCTTO_D$	$\Delta t_{tail-off}$ (DPS)	DPS tail-off time (from 100 % thrust)	.38 sec	38 csec	2^{17}

PAD LOADS

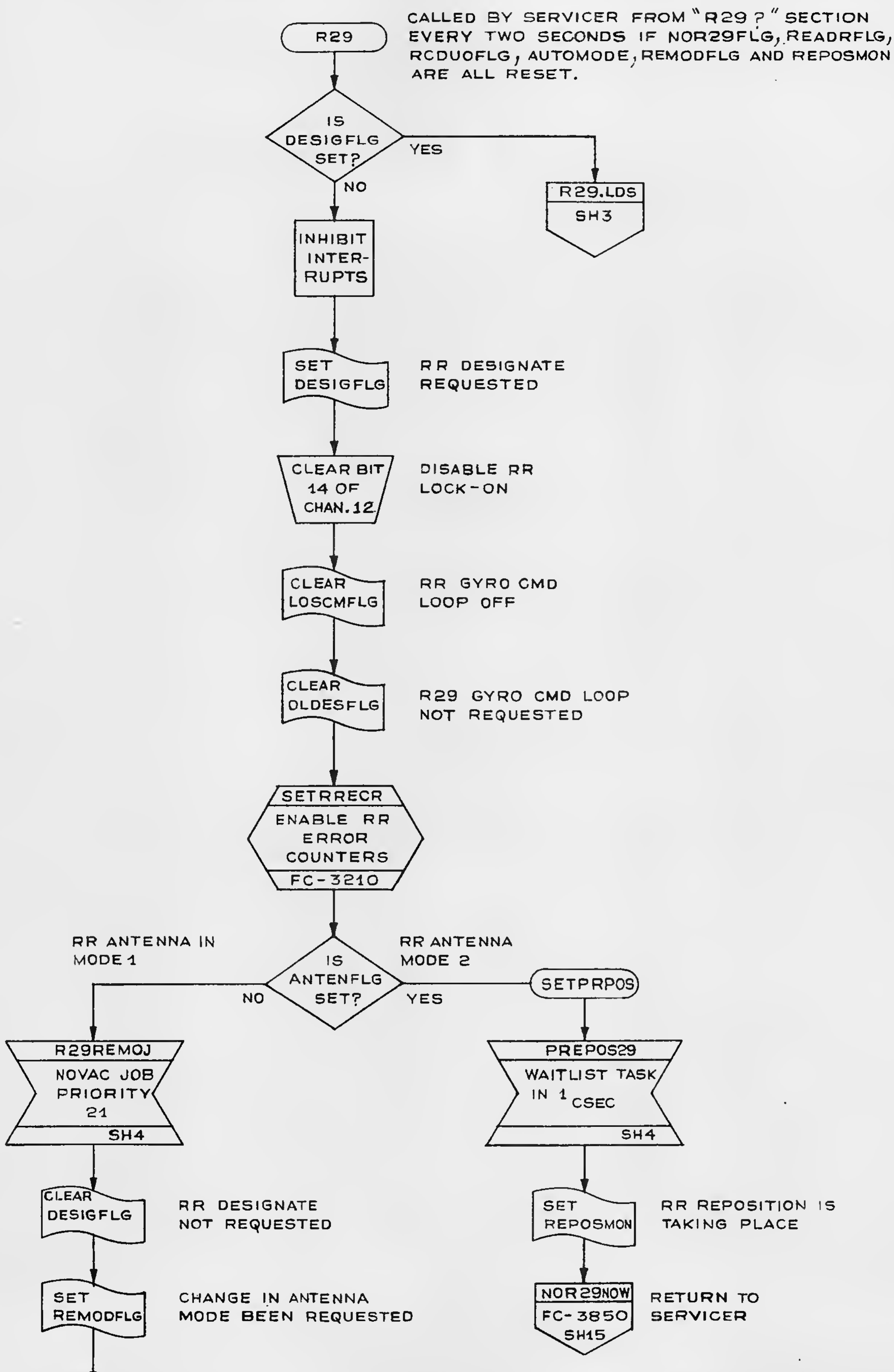
AGC Tag	GSOP Symbol	Meaning	Engineering Unit	AGC Unit	AGC Scaling
$ABTRDOT_D$	$\dot{R}_D$ (abort)	Desired radial velocity for abort	in/sec	in/csec	2^7
$J1PARM_D$	J1	Value for $JPARM_D$ (sec above) when LM-CSM phase angle is less then critical angle	m	m	2^{23}
$J2PARM_D$	J2	Value for $JPARM_D$ (see above) when LM-CSM phase angle is greater than or equal to critical angle	m	m	2^{23}
$K1PARM_D$	K1	Value for $KPARM_D$ (see above) when LM-CSM phase angle is less than critical angle	m/deg	m/rev	2^{23}
$K2PARM_D$	K2	Value for $KPARM_D$ (see above) when LM-CSM phase angle is greater than or equal to critical angle	m/deg	m/rev	2^{23}
$THETCRIT_D$	θ_c	Critical angle for choice of J, K . parameter values	deg	revs	2^0
$YLIM_D$	Y_{lim}	Magnitude of cross-range position necessary to require adjustment of desired cross-range position	m	m	2^{24}

R29 - POWERED FLIGHT RR DESIGNATE

MAJOR SUBROUTINES ON THIS CHART

R29	Sh. 2

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	7/30/68	R29-Powered Flight RR Designate	
PRGMR	10/9/69	LUMINARY 1D	DOCUMENT NO. FC-3930
ANALST			
DOCMR	10/1/69		
APPR'D	10/9/69	REV 3	SHEET 1 OF 14



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

R29-POWERED FLIGHT RR DESIGNATE

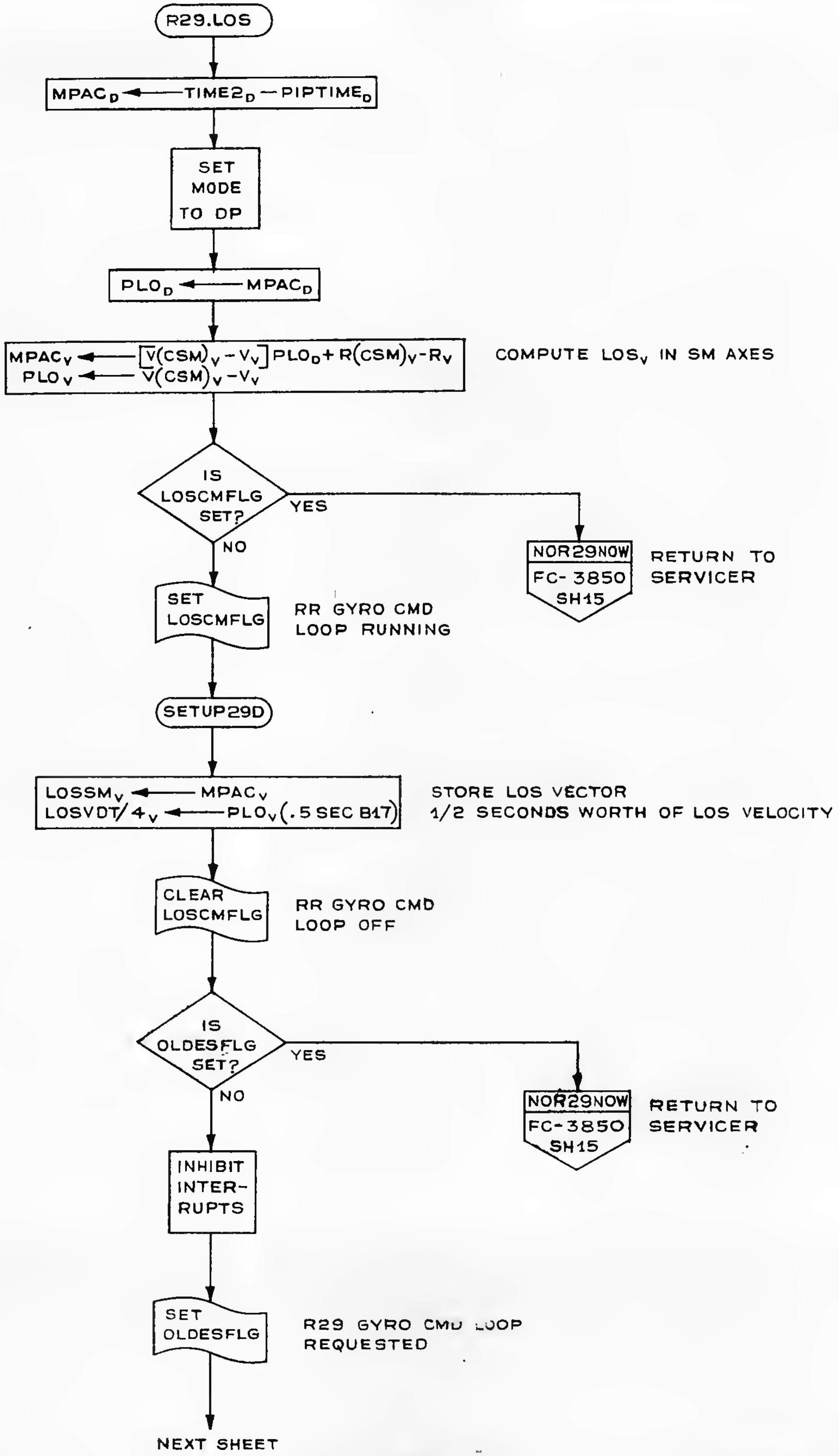
DRAWN	D.M. Dietro	23DEC68
PRGMR	Hugh Blair-Smith	22MAY69
ANALST		
DOCMR	M. Daghost	21MAY69
APPR'D	Aleta M. Swart	22MAY69

LUMINARY 1D

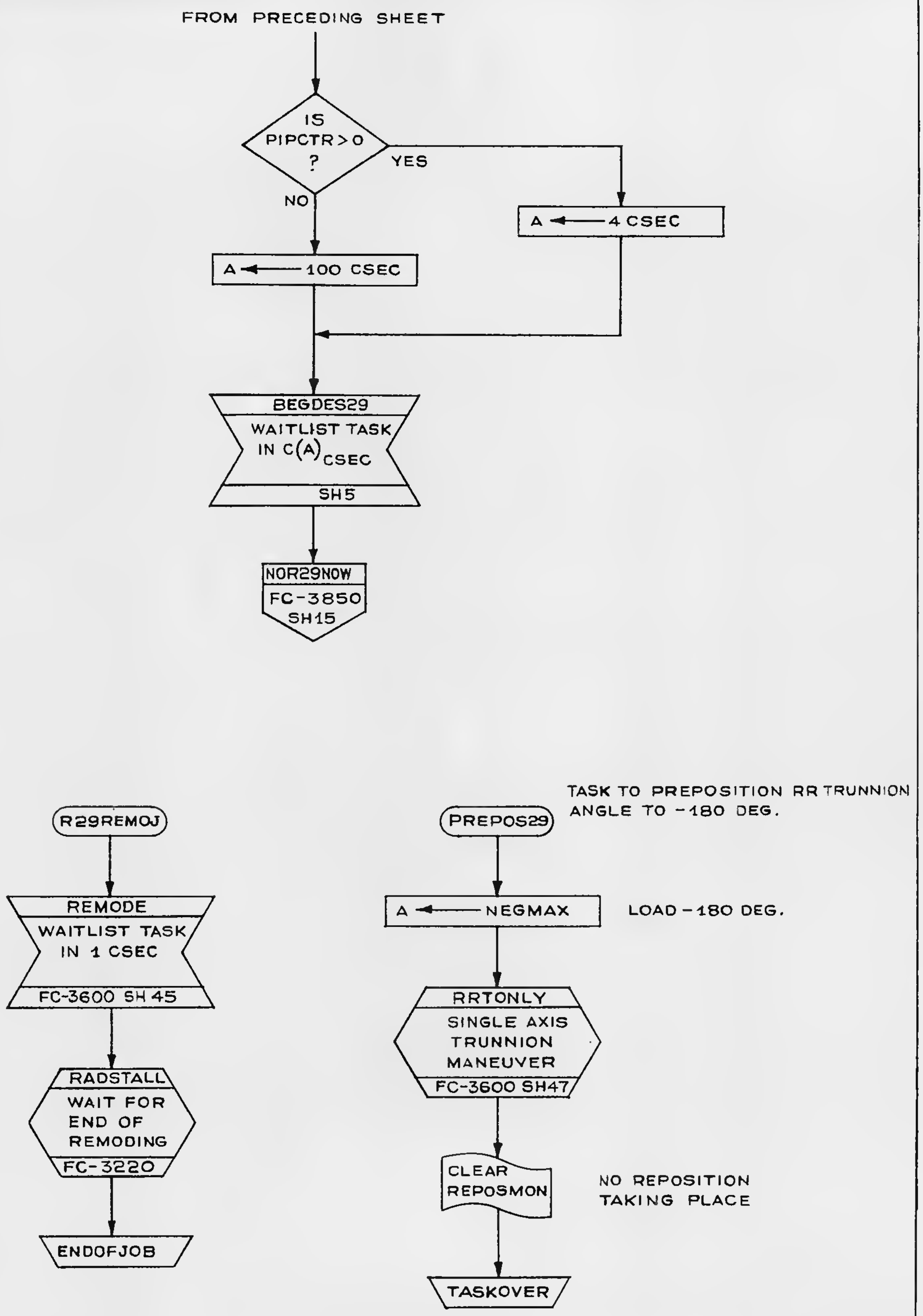
DOCUMENT NO. FC-3980

REV 3

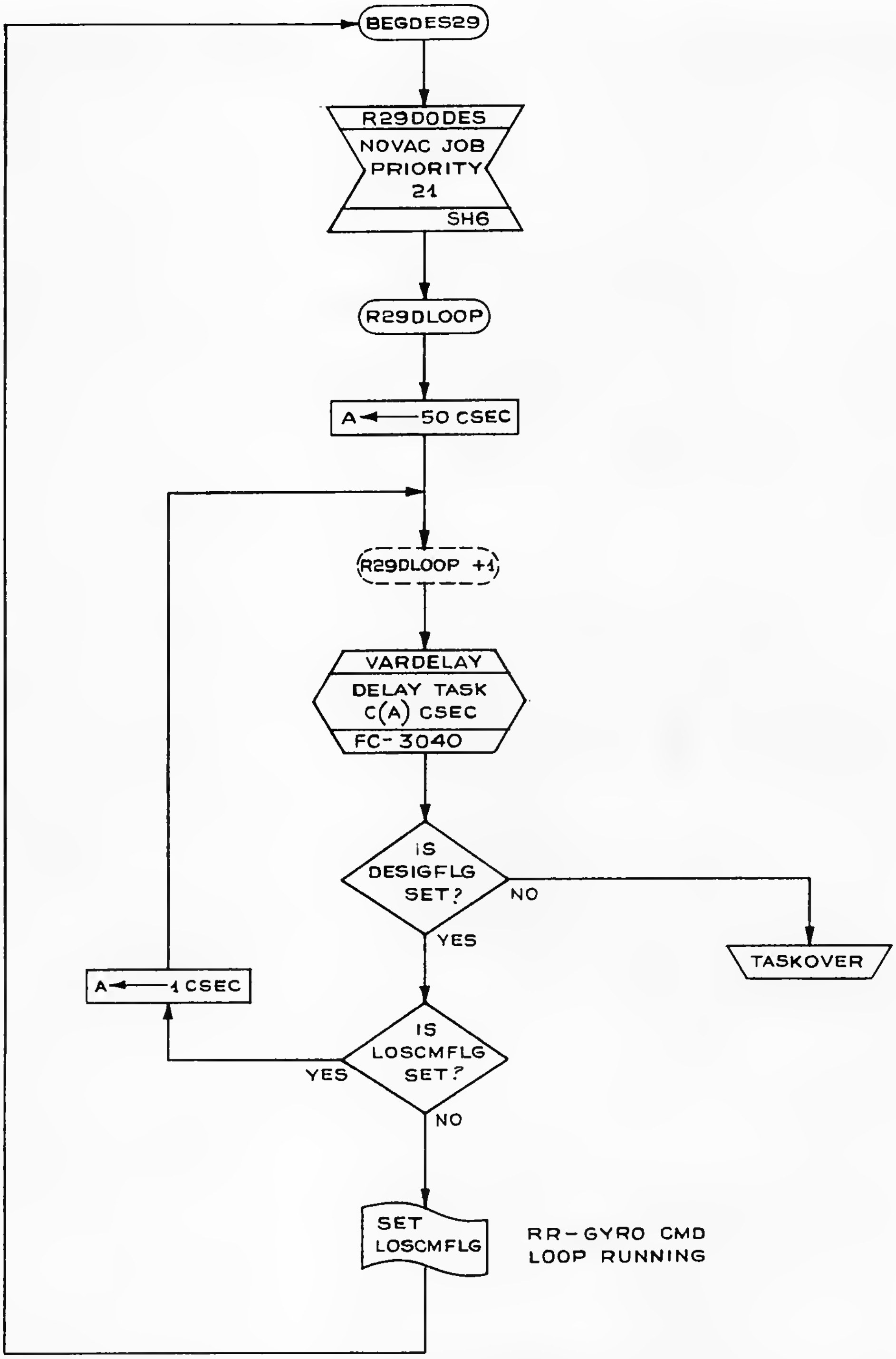
SHEET 2 OF 14



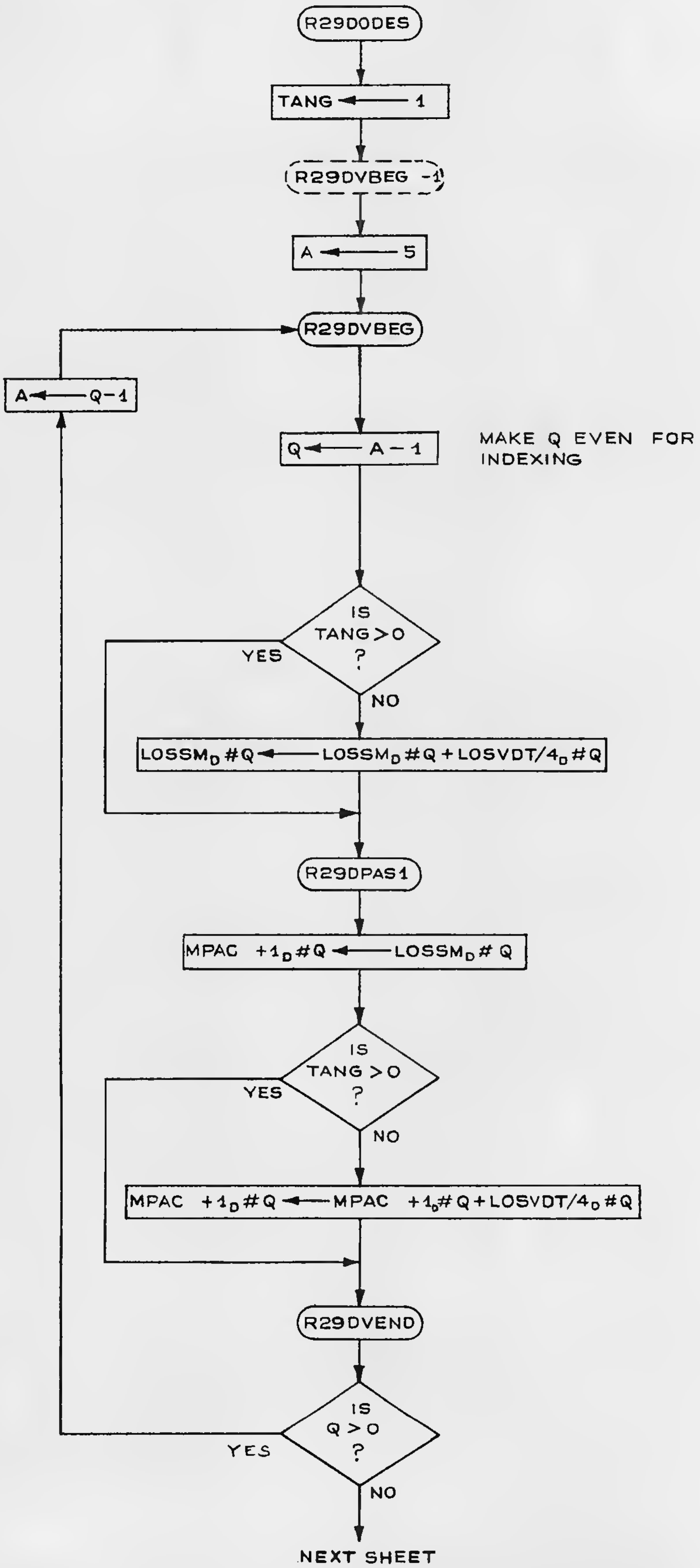
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN [illegible]	23DEC68	R29—POWERED FLIGHT RR DESIGNATE	
PRGMR [illegible]	22MAY69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3980
DOCMR [illegible]	21MAY69		
APPR'D [illegible]	22MAY69	REV	SHEET 3 OF 14



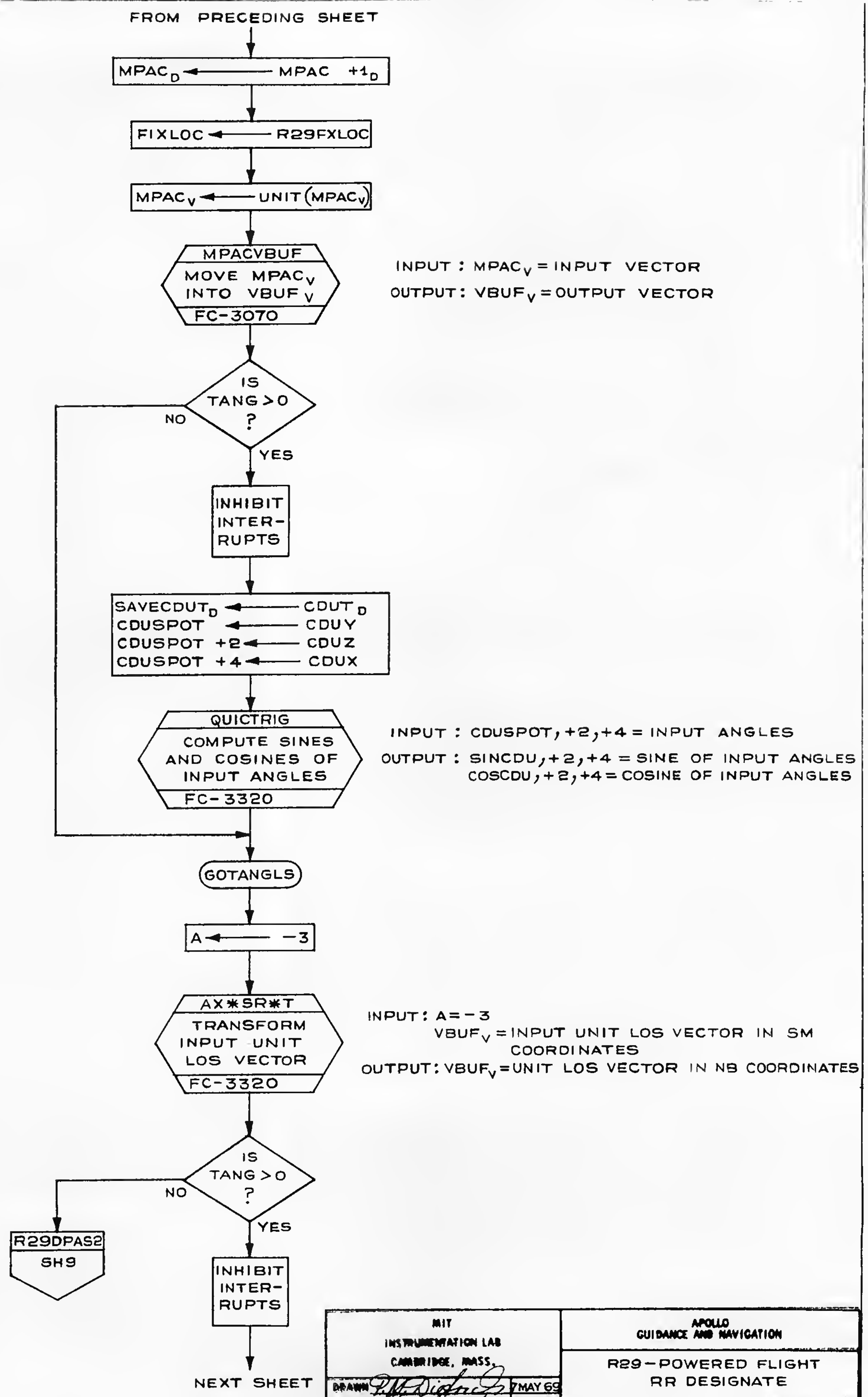
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN 26DEC68	R29 - POWERED FLIGHT RR DESIGNATE
PRGMR 22MAY69	LUMINARY 1D
ANALST	DOCUMENT NO. FC-3980
DOCMR 21MAY69	
APPR'D 22MAY69	REV 3 · SHEET 4 OF 14



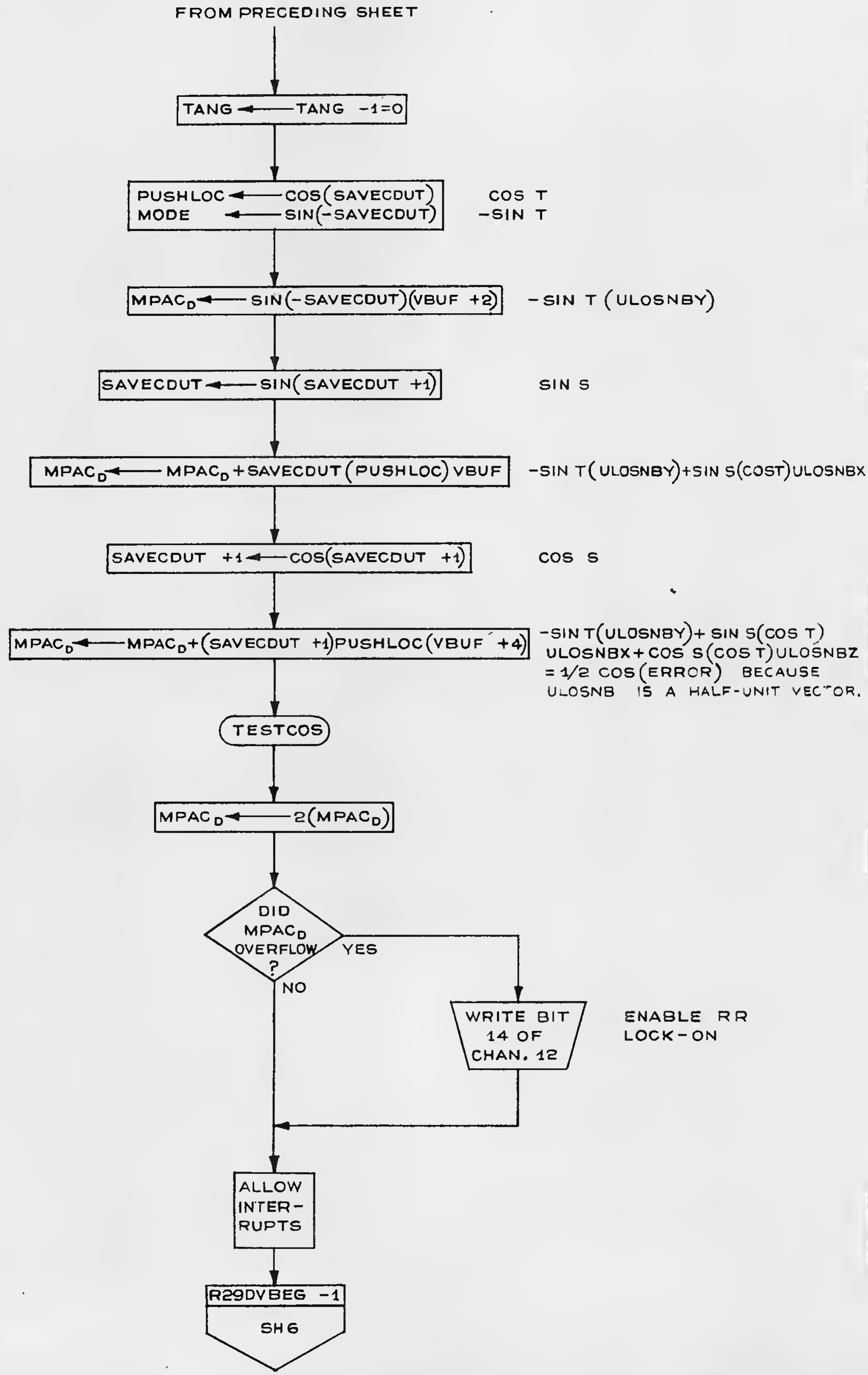
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN 26DEC68	R29-POWERED FLIGHT RR DESIGNATE	
PROGMR 22MAY69	LUMINARY 1D	DOCUMENT NO. FC-3980
ANALST		
DOCMNR 21MAY69		
APPR'D 22MAY69	REV 3	SHEET 5 OF 14



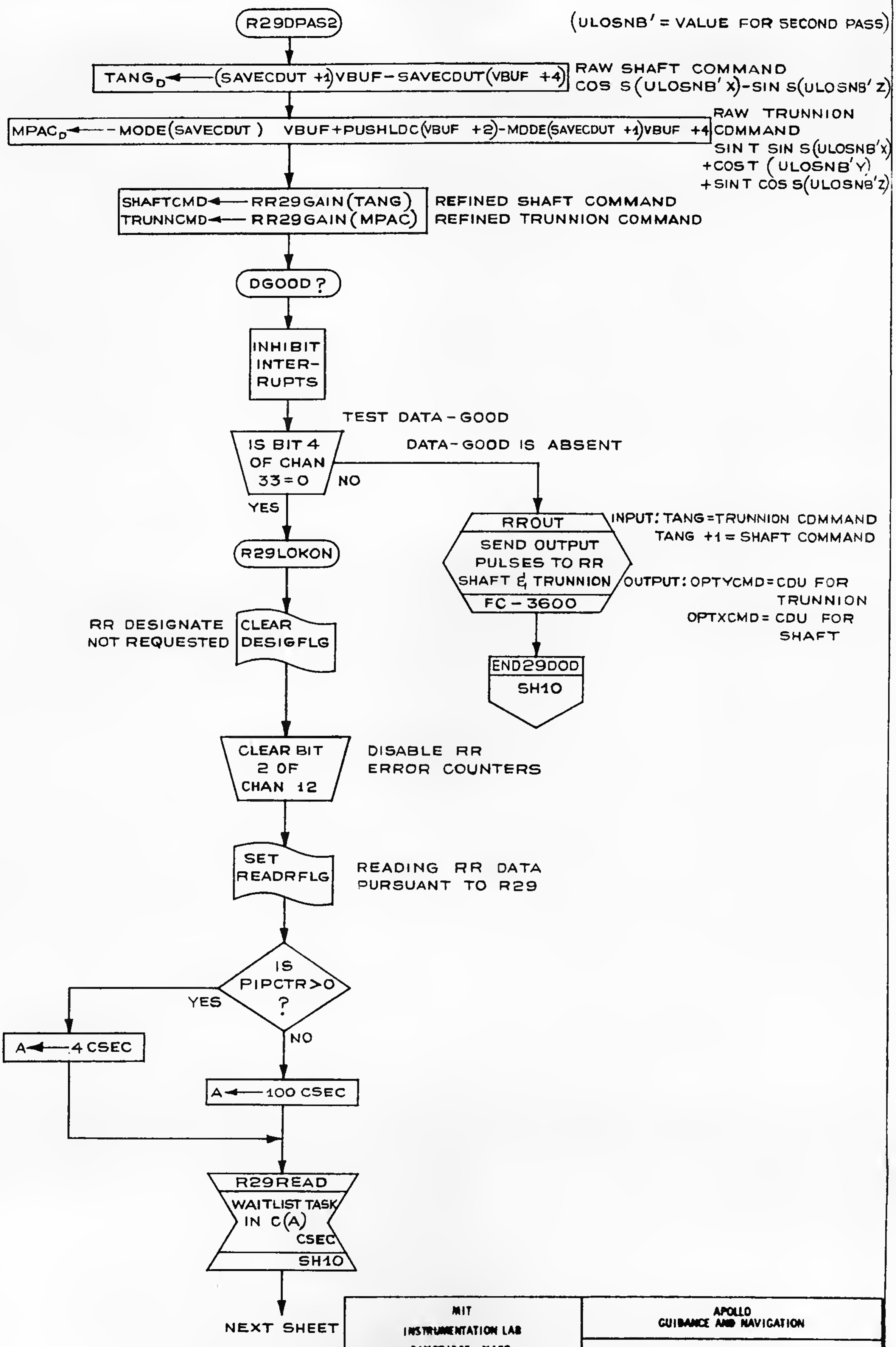
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN P. M. Dietrich	27DEC68	R29–POWERED FLIGHT RR DESIGNATE
PRGMR Hugh Blair-Smith	22 MAY 69	LUMINARY 1D
ANALST		DOCUMENT NO. FC-3980
DOCMR W. E. Englund	21 MAY 69	
APPR'D Alexa W. Sozent	22 MAY 69	REV 3 — SHEET 6 OF 14



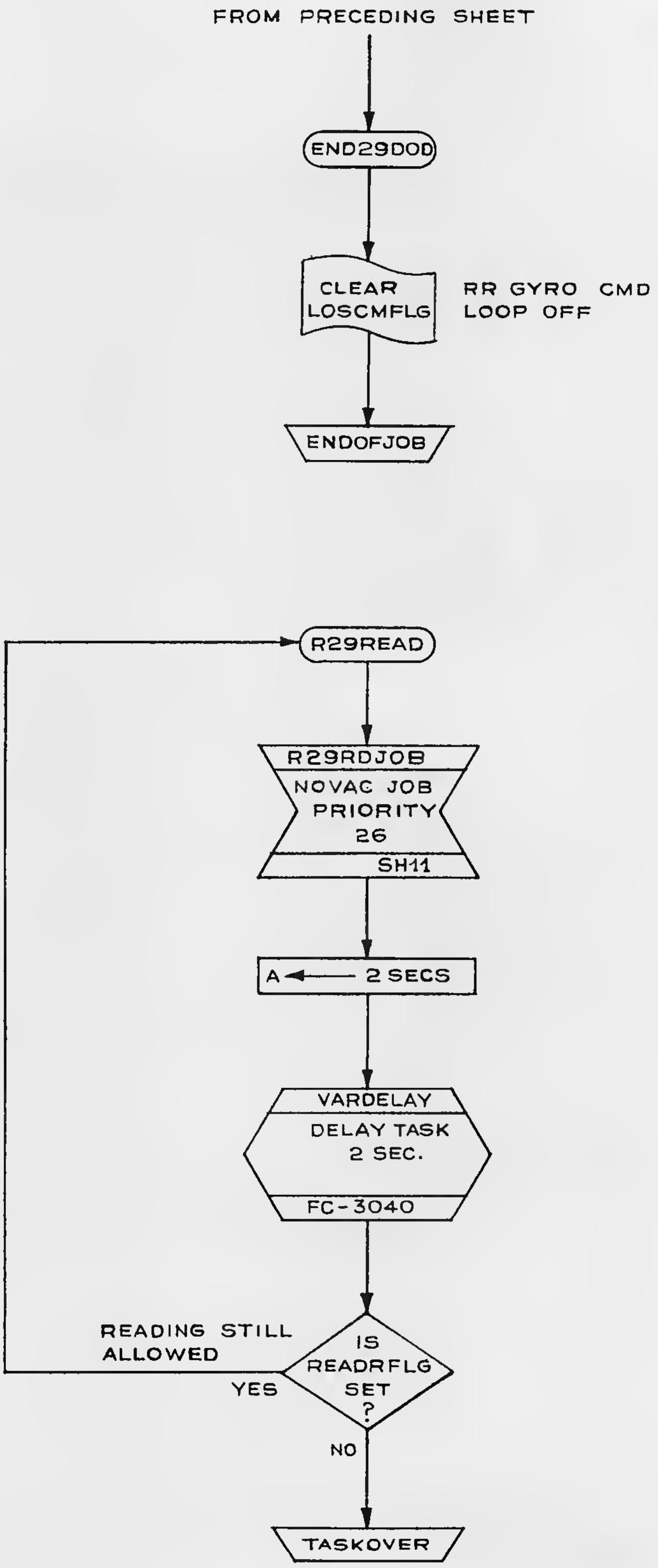
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN P. M. Dickson 7 MAY 69	R29—POWERED FLIGHT RR DESIGNATE
PROGMR 22 MAY 69	LUMINARY 1D
ANALYST	DOCUMENT NO. FC-3980
DOCMR 21 MAY 69	
APPR'D	REV 3 SHEET 7 OF 14



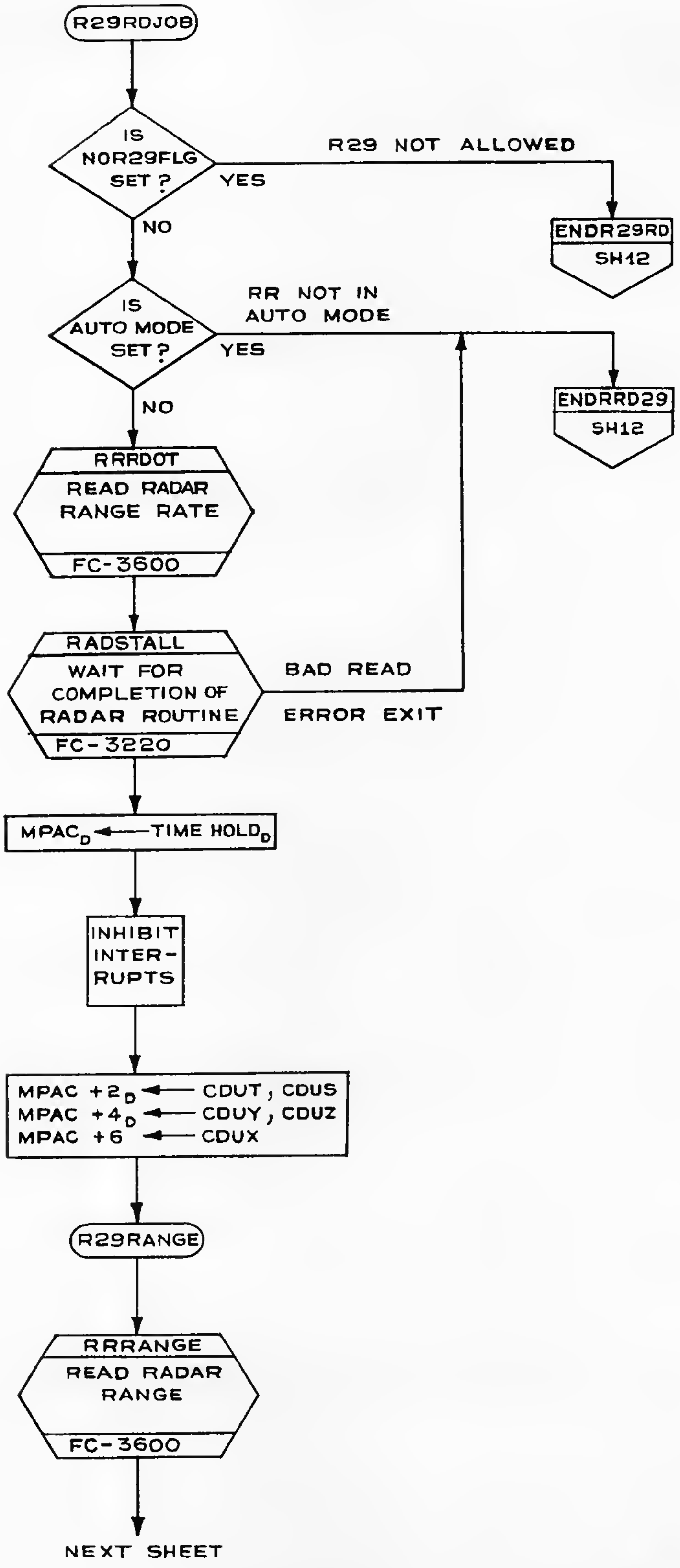
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D.M. Dieffie	22APR69	R29 − POWERED FLIGHT RR DESIGNATE	
PRGMR Hugh Blair-Smith	22MAY69	LUMINARY 1D	DOCUMENT NO. FC-3980
ANALST			
DOCMR	21MAY69		
APPR'D	22MAY69	REV 3	SHEET 8 OF 14



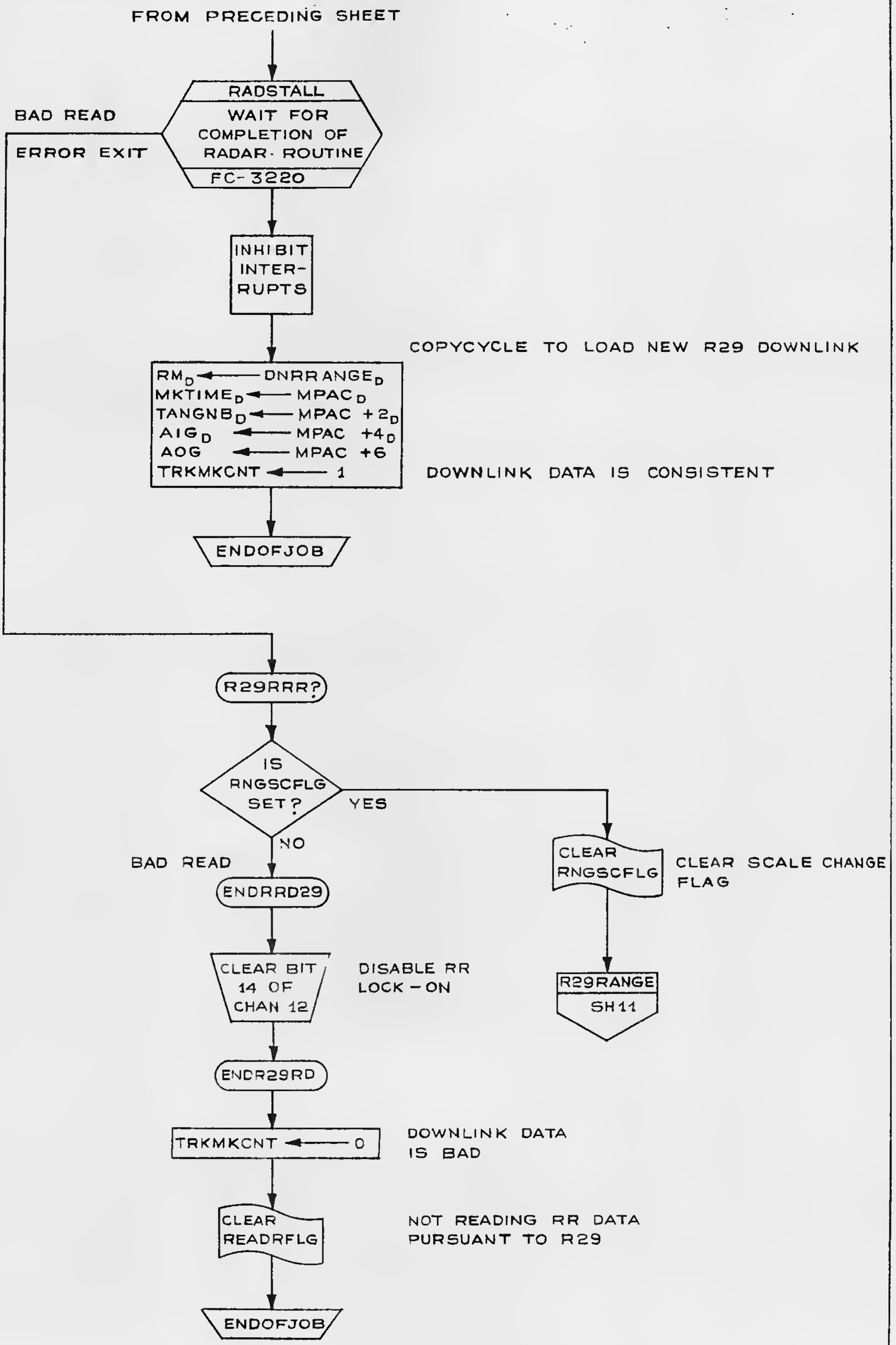
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN D.M. Diedrich 22APR69	R29 - POWERED FLIGHT RR DESIGNATE
PRGMR Hugh Blair-Smith 29May69	
ANALST	LUMINARY 1D
DOCMR McDonald 31MAY69	DOCUMENT NO. FC-3980
APPR'D Saul M. Swanson	
REV 3	SHEET 9 OF 14



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN [illegible] 22APR69 PRGMR [illegible] 22MAY69 ANALST DOCMR [illegible] 21MAY69 APPR'D [illegible] 22MAY69	R29-POWERED FLIGHT RR DESIGNATE
LUMINARY 1D	DOCUMENT NO. FC-3980
REV 3	SHEET 10 OF 14



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN 23APR69 PRGMR 22 MAY 69 ANALST DOCMR 31 MAY 69 APPR'D	R29—POWERED FLIGHT RR DESIGNATE
LUMINARY 1D	DOCUMENT NO. FC-3980
REV 3	SHEET 11 OF 14



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN P.M. Dietz Jr. 23APR69	R29—POWERED FLIGHT RR DESIGNATE
PRGMR Hugh Blair-Smith 22 MAY 69	
ANALST	LUMINARY 1D
DOCMR W. Dietrich 21 MAY 69	DOCUMENT NO. FC-3980
APPR'D Allan M. Saunt 22 MAY 69	REV 3

ERASABLE LOCATIONS USED					
AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
$LOSSM_V$	$\underline{r}_{LOS}$	LINE OF SIGHT VECTOR	METERS	METERS	2^{24}
$LOSVDT/4_V$		1/2 SECONDS WORTH OF LOS VELOCITY (I.E., Δ LOS)	METERS/SEC	METERS CSEC	2^{24}
TANG	C_T	RR TRUNNION COMMAND		BITS	2^0
TANG+1	C_S	RR SHAFT COMMAND		BITS	2^0

SUBROUTINES CALLED WHICH ARE FLOWED ON OTHER FLOW CHARTS			
SUBROUTINE NAME	FLOW CHART	DESCRIPTION	WHERE CALLED
AX*SR*T	FC-3320	TRANSFORM INPUT UNIT VECTOR FROM SM TO NB COORDINATES	SH. 7
MPACVBUF	FC-3070	STORE VECTOR IN MPAC INTO VBUF	SH. 7
QUICTRIG	FC-3320	COMPUTE SINES AND COSINES OF INPUT ANGLES	SH. 7
RADSTALL	FC-3220	WAIT FOR COMPLETION OF RADAR ROUTINE	SH. 4, 11, 12
RROUT	FC-3600	SEND OUTPUT PULSES TO RR SHAFT AND TRUNNION	SH. 9
RRRANGE	FC-3600	READ RADAR RANGE	SH. 11
RRRDOT	FC-3600	READ RADAR RANGE RATE	SH. 11
RRTONLY	FC-3600	SINGLE AXIS TRUNNION MANEUVER	SH. 4
SETRRECR	FC-3210	ENABLE RR ERROR COUNTERS	SH. 2
VARDELAY	FC-3040	DELAY ACTIVE TASK TIME IN A	SH. 5, 10

FLAGS					
NAME	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
ANTENFLG FLAG 12 BIT 12	RR ANTENNA IS IN MODE 2	RR ANTENNA IS IN MODE 1			SH. 2
AUTOMODE FLAG 12 BIT 2	RR NOT IN AUTO MODE	RR IN AUTO MODE			SH. 11
DESIGFLG FLAG 12 BIT 10	RR DESIGNATE REQUESTED	RR DESIGNATE NOT REQUESTED	SH. 2	SH. 2,9	SH. 2,5
LOSCMFLG FLAG 2 BIT 12	RR GYRO CMD LOOP RUNNING	RR GYRO CMD LOOP OFF	SH. 3,5	SH. 2,3,10	SH. 3,5
NOR29FLG FLAG 3 BIT 11	R29 NOT ALLOWED	R29 ALLOWED			SH. 11
OLDESFLG FLAG 0 BIT 1	R29 GYRO CMD LOOP REQUESTED	R29 GYRO CMD LOOP NOT REQUESTED	SH. 3	SH. 2	SH. 3
READRFLG FLAG 3 BIT 9	READING RR DATA PURSUANT TO R29	NOT READING RR DATA PURSUANT TO R29		SH. 12	SH. 10
REMODFLG FLAG 12 BIT 14	CHANGE IN ANTENNA MODE HAS BEEN REQUESTED	NO REMODE REQUESTED	SH. 2		
REPOSMON FLAG 12 BIT 11	RR REPOSITION IS TAKING PLACE	NO REPOSITION TAKING PLACE	SH. 2	SH. 4	
RNGSCFLG FLAG 5 BIT 10	SCALE CHANGE HAS OCCURRED DURING RR READING	NO SCALE CHANGE HAS OCCURRED DURING RR READING		SH. 12	SH. 12

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN P.M. Dietrich	23APR69	R29-POWERED FLIGHT RR DESIGNATE	
PROGRM Hugh Blair-Smith	22 MAY 69	LUMINARY 1D	DOCUMENT NO. FC-3980
ANALST			
DOCMN M. Dotson	21 MAY 69		
APPR'D Aleta M. Grant	22MAY69	REV 3	SHEET 14 OF 14

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Major entries

Each major entry is followed by (1) the number and name of the flowchart in which it is flowed, (2) the word ENTRY, and (3) the sheet on which the entry begins.

Example: KEYRUPT1 FC-3110 Keyrupt and Uprupt ENTRY 4

This means that KEYRUPT1 is flowed in FC-3110, Keyrupt and Uprupt, starting on sheet 4.

Subroutines

The name of each subroutine called in one flowchart and flowed in another is followed by (1) the number and name of the flowchart in which it is called, (2) the word CALLED, and (3) the sheet(s) on which it is called.

Example: AXISGEN FC-3520 P57 CALLED 35, 40

This means that AXISGEN is a subroutine called on sheets 35 and 40 of FC-3520, P57, and flowed in some other flowchart.

Flag bits

The name of each flag bit is followed by the number and name of the flowchart in which the flag is set, cleared, or tested. The letters S, C, and T and the numbers following them indicate on which sheet(s) the flag is set, cleared, or tested.

Example: AVFLAG FC-3720 P32/P72 (CSI) S-2 C-2

This means that AVFLAG is set on sheet 2 and cleared on sheet 2 of FC-3720, P32/P72 (CSI).

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1/PIPA	FC-3230	ENTRY 2		
1/PIPA	FC-3520	CALLED 18		
1/PIPA	FC-3850	CALLED 9		
1STOTWOS	FC-3440	ENTRY 35		
1STO2S	FC-3150	ENTRY 4		
1STO2S	FC-3520	CALLED 30		
1TO2SUB	FC-3150	ENTRY 8		
2SECDELY	FC-3935	CALLED 3		
2V1STO2S	FC-3150	ENTRY 7		
2V1STO2S	FC-3600	CALLED 38		
3AXISFLG	FC-3400		C-4	
3AXISFLG	FC-3420		C-2	T-2
3AXISFLG	FC-3510		C-43	
3AXISFLG	FC-3600		C-26	
3AXISFLG	FC-3800		C-4	
360SW	FC-3360	S-31	C-27	T-29

Internal Distribution List

LUMINARY 1D

Group 23A	S. MacDougall	DL7-205	(15)
	Berberian Brand Gustafson Higgins Kachmar Klumpp	Kriegsman Levine (4) Muller Pu Reber Robertson	
Group 23B	J. Flaherty	DL7-238A	(4)
	Berman Eyles	McCoy Moore	
Group 23B	J. Kaloostian	DL7-221L	(5)
	Bernikowich Dunbar Ostanek	Volante White	
Group 23B	D. Lutkevich	DL7-236H	(15)
	Daniel Klawsnik Nayar	Reed (10) Smith	
Group 23P	M. Rash	DL7-203	(4)
	Battin Cherry	Copps Larson	
Group 23B	C. Taylor	DL7-221L	(9)
	Barnert Covelli Densmore Engel Gilson	Hamilton Millard Rosenburg Rye	
Group 33	J. Hargrove	DL7-111	(4)
	Drane Glick	Johnson Mimno	
Group 23H	R. Shane	DL7-272	(3)
	Cogliano Kossuth	O'Connor	
Group 23C	J. Whittemore	DL11-102	(3)
	Kalan Mabeck	Weissman	

Group 23D	S. Beaulieu	DL7-209	(1)
	Nevins		
Group 23P	H. O'Sullivan	DL7-266	(2)
	Greene	Stubbs	
Group 23D	S. Beaulieu	DL7-332A	(8)
	Dunbar Groome Johnson Metzinger	Olsson Schroeder Schulte Watson	
Group 23S	P. Amsler	DL7-240	(8)
	Adams Canepa Felleman Johnston	McOuat Werner White	
Group 23T	D. Farrell	DL7-144B	(8)
	Edmonds Grace Kido Lawrence	Lones Megna Sheridan St. Amand	
Group 23N	G. Grover	DL11-201	(4)
	Blanchard Johnson	Ogletree Tanner	
Group 23P	E. Johnson	DL7-248	(4)
	Hoag Larson	Ragan Stameris	
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CSDL Technical Documentation Center			(2)

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