

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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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 ID
(Rev. 173)
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MIT

CAMBRIDGE, MASSACHUSETTS, 02139

**CHARLES STARK DRAPER
LABORATORY**

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The publication of this report does not constitute approval by the National Aeronautics and Space Administration of the findings or the conclusions contained therein. It is published only for the exchange and stimulation of ideas.

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

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

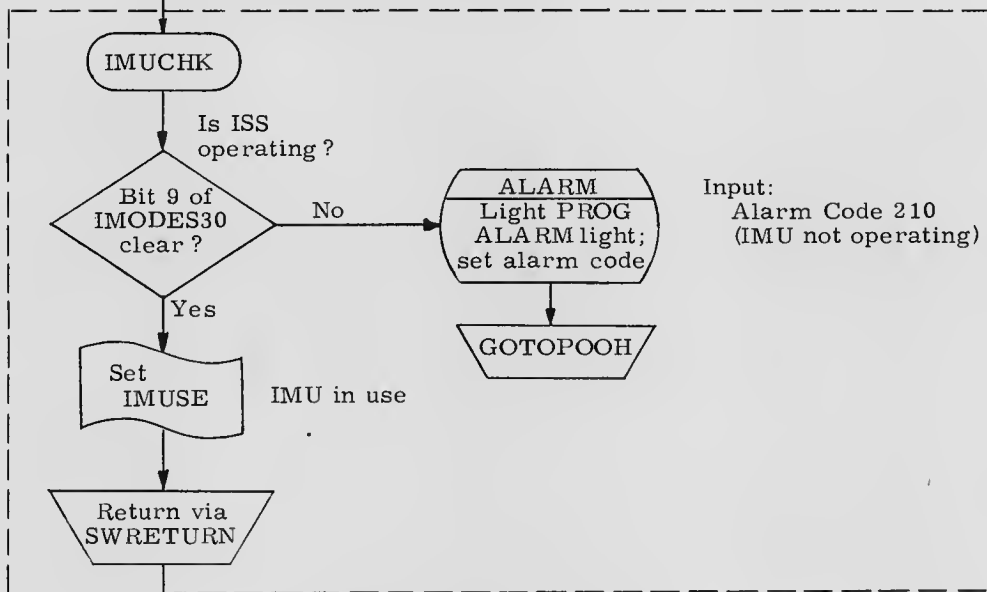
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>L. Goldstone</i>	<i>3/27/69</i>	P51 IMU Orientation Determination	
PRGMR <i>D. Millard</i>	<i>9/15/69</i>	LUMINARY	DOCUMENT NO.
ANALST		1D	FC-3500
DOCMR		REV ²	SHEET 1 OF 24
APPR'D <i>Robert M. Estes</i>	<i>9-9-69</i>		

P51

Selected by astronaut via DSKY by V37E51E

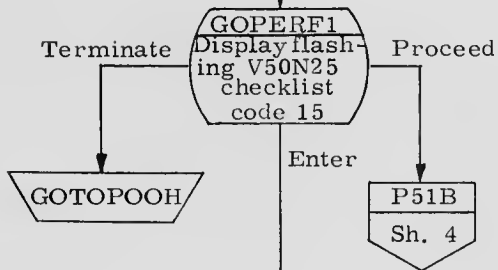
Determine the inertial orientation of the IMU using sightings on two celestial bodies with the AOT or a backup optical system. The program may only be performed while the LM is in flight.

Via BANKCALL



Input:
Alarm Code 210
(IMU not operating)

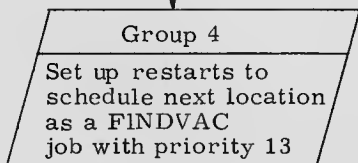
P51 +2



Please perform celestial body acquisition

- R1 - 00015
- R2 - blank
- R3 - blank

Skip coarse alignment



Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Lutz</i> 8/27/69		P51 IMU Orientation Determination	
PRGMR <i>D. Mullis</i> 7/5/69	ANALST	LUMINARY ID	DOCUMENT NO. FC-3500
DOCMR	APPR'D <i>Robert M. Entes</i> 9-9-69	REV 2	SHEET 2 OF 24

From Preceding Sheet

THETAD ← 0
 THETAD +1 ← 0
 THETAD +2 ← 0

Zero the desired gimbal angles

GODSPRET
 Display
 V06N22

Display Noun 22: desired CDU angles

R1 = 000.00 deg (THETAD)
 R2 = 000.00 deg (THETAD +1)
 R3 = 000.00 deg (THETAD +2)

P51 +18D

GODSPRET
 Display
 V41N22

Now display V41:
 coarse align CDU's

COARSE
 Coarse align
 IMU
 Sh. 9

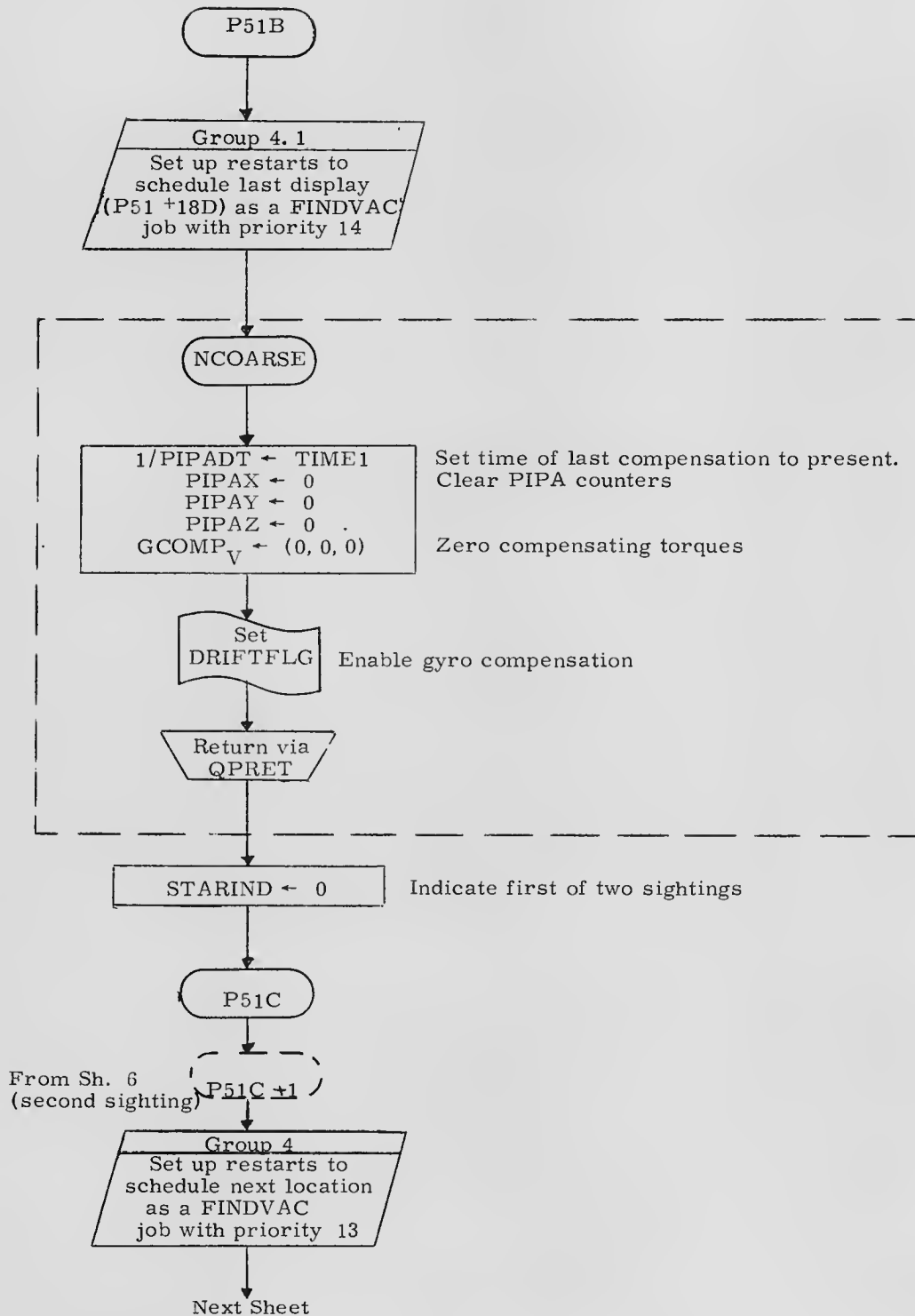
Coarse align and return to fine align mode
 Input:

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

Group 4
 Set up restarts to
 schedule next location
 as a FINDVAC
 job with priority 13

P51 +2
 Sh. 2

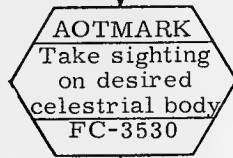
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Lutkenich</i> 8/27/69		P51 IMU Orientation Determination	
PRGMR <i>W. Dallas</i> 9/5/69	LUMINARY 1D	DOCUMENT NO. FC-3500	
ANALST			
DOCMR			
APPR'D <i>Robert M. Estes</i> 9-9-69	REV 2	SHEET 3 OF 24	



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>J. Cinotta</i> 8-27-69	P51 IMU Orientation Determination	
PRGMR	<i>J. P. Mullins</i> 9/5/69	LUMINARY	DOCUMENT NO.
ANALST		1D	FC-3500
DOCMR		REV 2	SHEET 4 OF 24
APPR'D	<i>Robert M. Eade</i> 9-9-69		

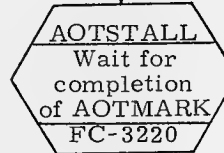
From Preceding Sheet

Via BANKCALL

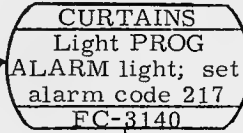


Output:

AOTCODE = AOT position code and star code from N71 display
 $STARSAV2_V = (STARAD + 6)_V = LOS$ to celestial body in SM coords @ 2^1
 $TSIGHT_D =$ time of sighting in csec @ 2^{28}

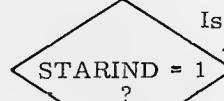


Bad return



Indicate bad return from stall routine

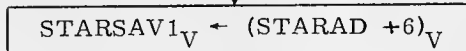
Normal return



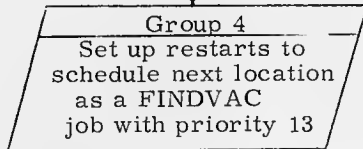
Is this the first or second sighting?

Yes - second sighting

No - first sighting

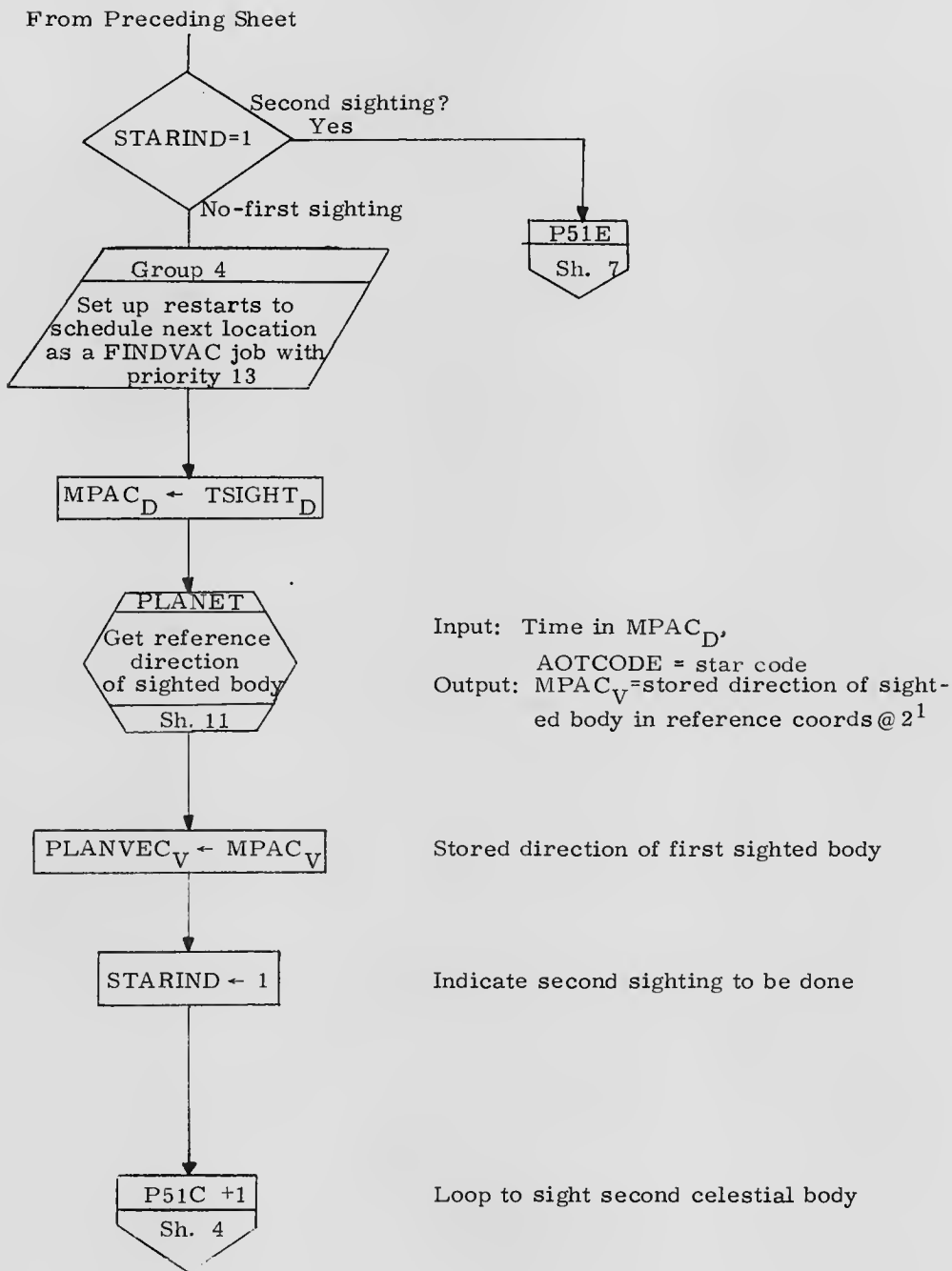


Observed direction of sighted body in SM coords @ 2^1

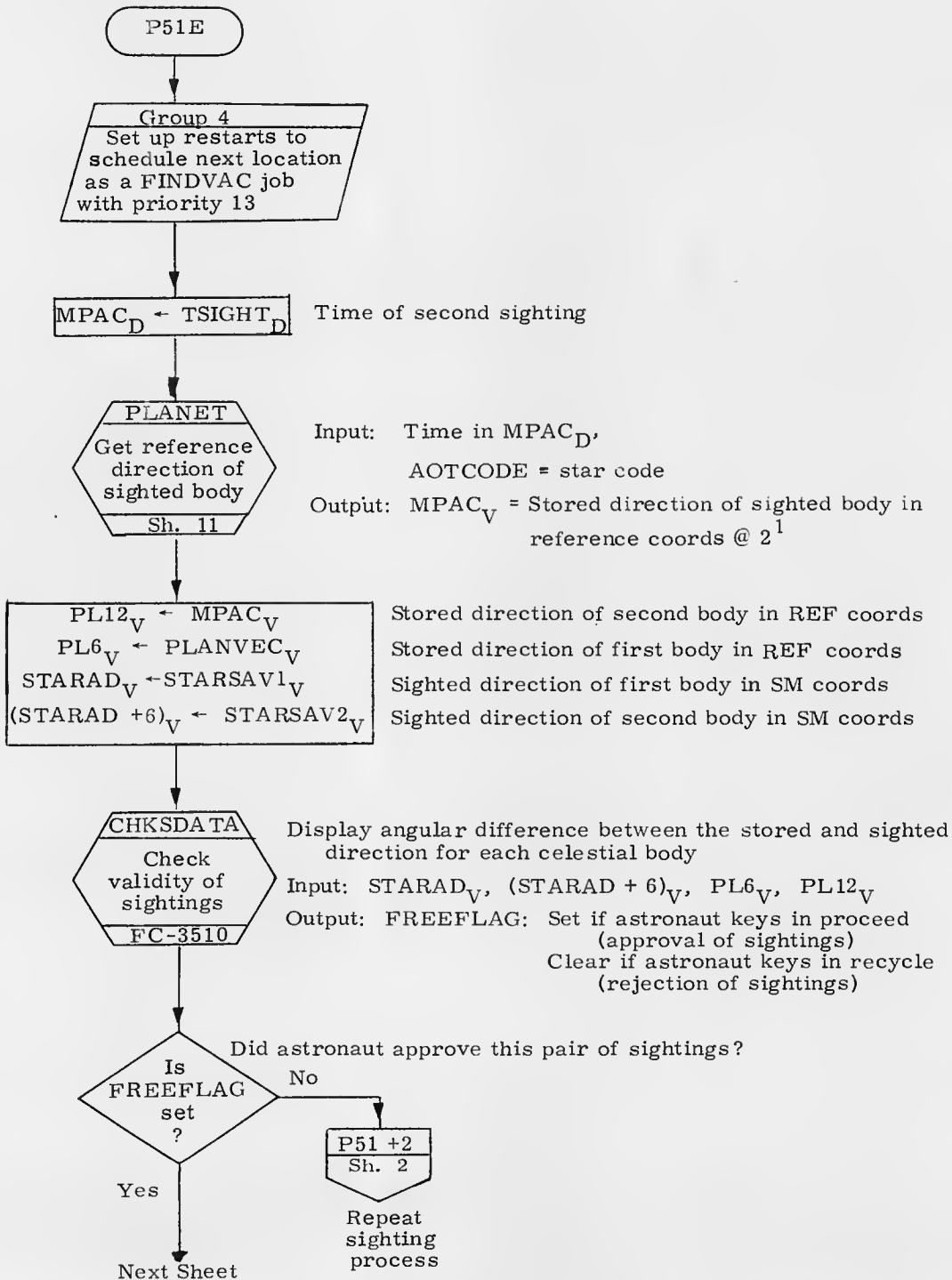


Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN: J. C. Coyote 5-21-69		P51 IMU Orientation Determination	
PRGMR: J. M. Miller 9/5/69	ANALST:	LUMINARY ID	DOCUMENT NO. FC-3500
DOCMR:	APPR'D: Roberto M. Euter 9-9-69	REV 2	SHEET 5 OF 24



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. G. ...</i> 8-27-69		P51 IMU Orientation Determination	
PRGMR <i>R. Miller</i> 9/5/69	ANALST	LUMINARY 1D	DOCUMENT NO. FC-3500
DOCMR	APPR'D <i>Robert M. ...</i> 9-9-69	REV 2	SHEET 6 OF 24



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Luthers</i>	<i>9/27/69</i>	P51 IMU Orientation Determination	
PRGMR <i>D. Mallard</i>	<i>9/16/69</i>	LUMINARY	DOCUMENT NO.
ANALST		1D	FC-3500
DOCMR			
APPR'D <i>Robert M. Ester</i>	<i>9-9-69</i>	REV 2	SHEET 7 OF 24

From Preceding Sheet

P51G

AXISGEN
Compute
transformation
matrix
FC-3310

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 REFERENCE and SM coordinate systems

X1 ← -ECADR(XDC)
X2 ← -ECADR(REFSMMAT)

Prepare inputs to MATMOVE

MATMOVE
Move
matrix
data
FC-3510

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

Result: REFSMMAT_M ← XDC_M

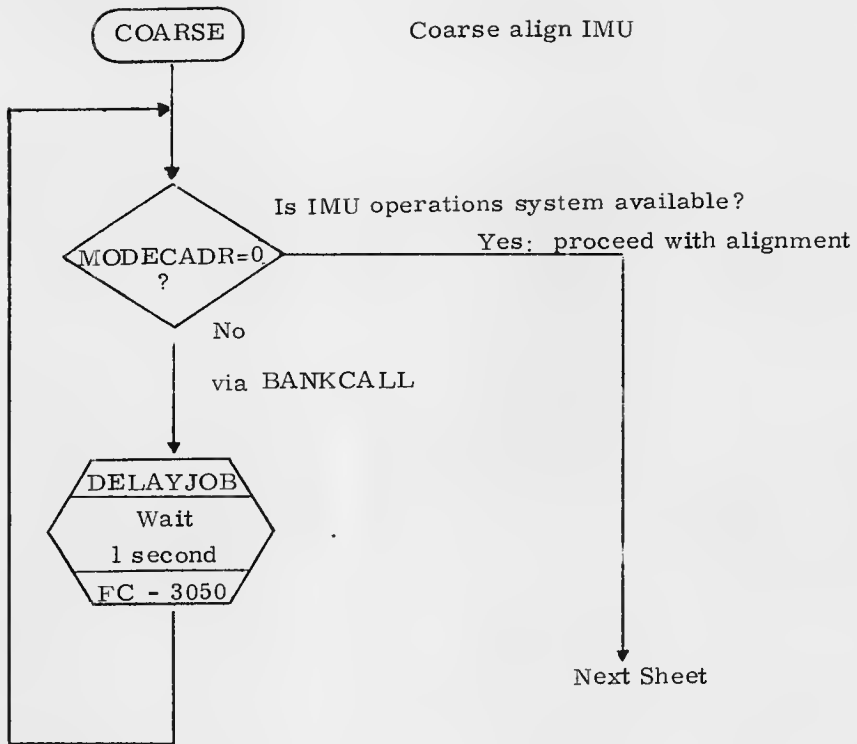
Set
REFSMFLG

REFSMMA T is valid

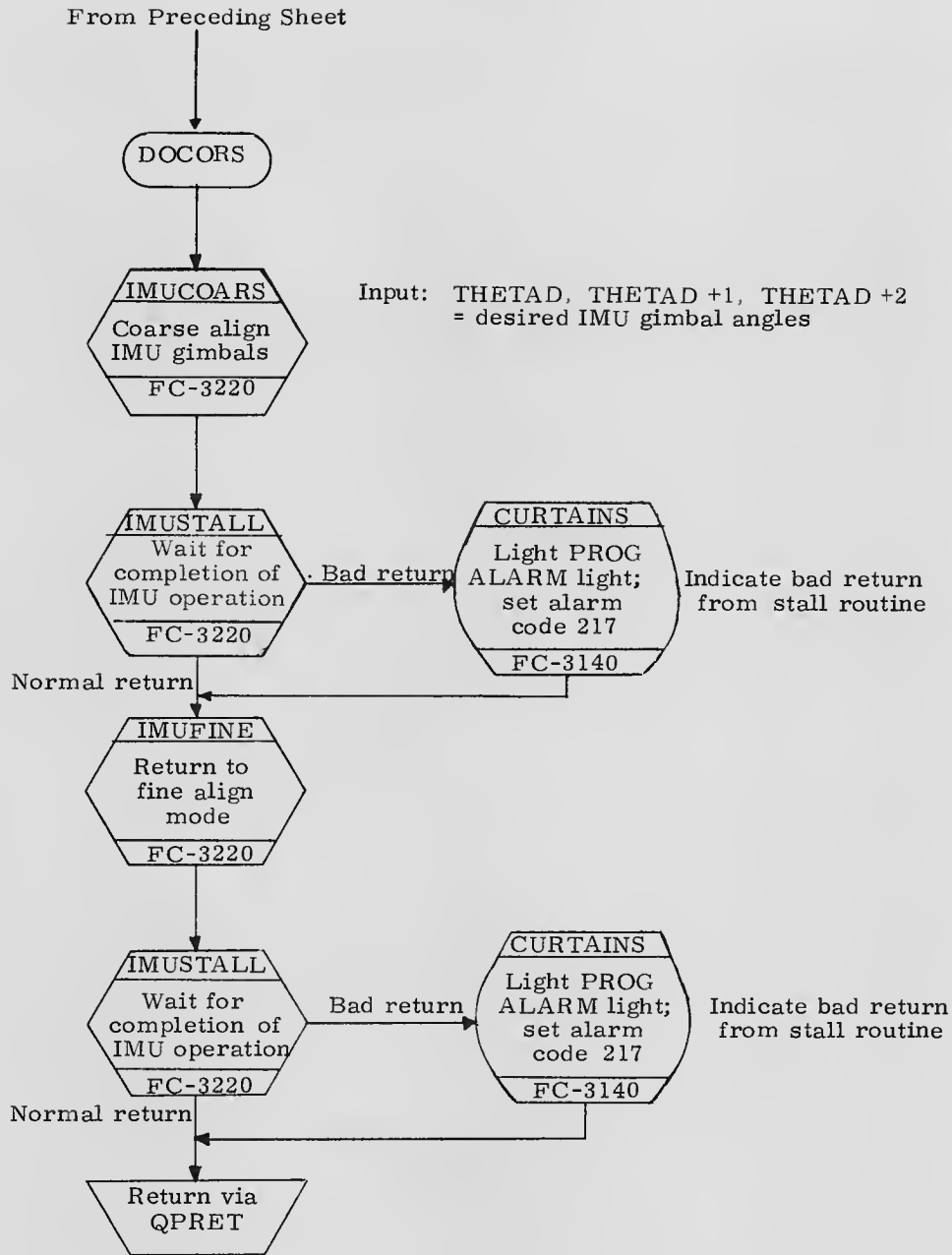
GOTOPOOH

Terminate program

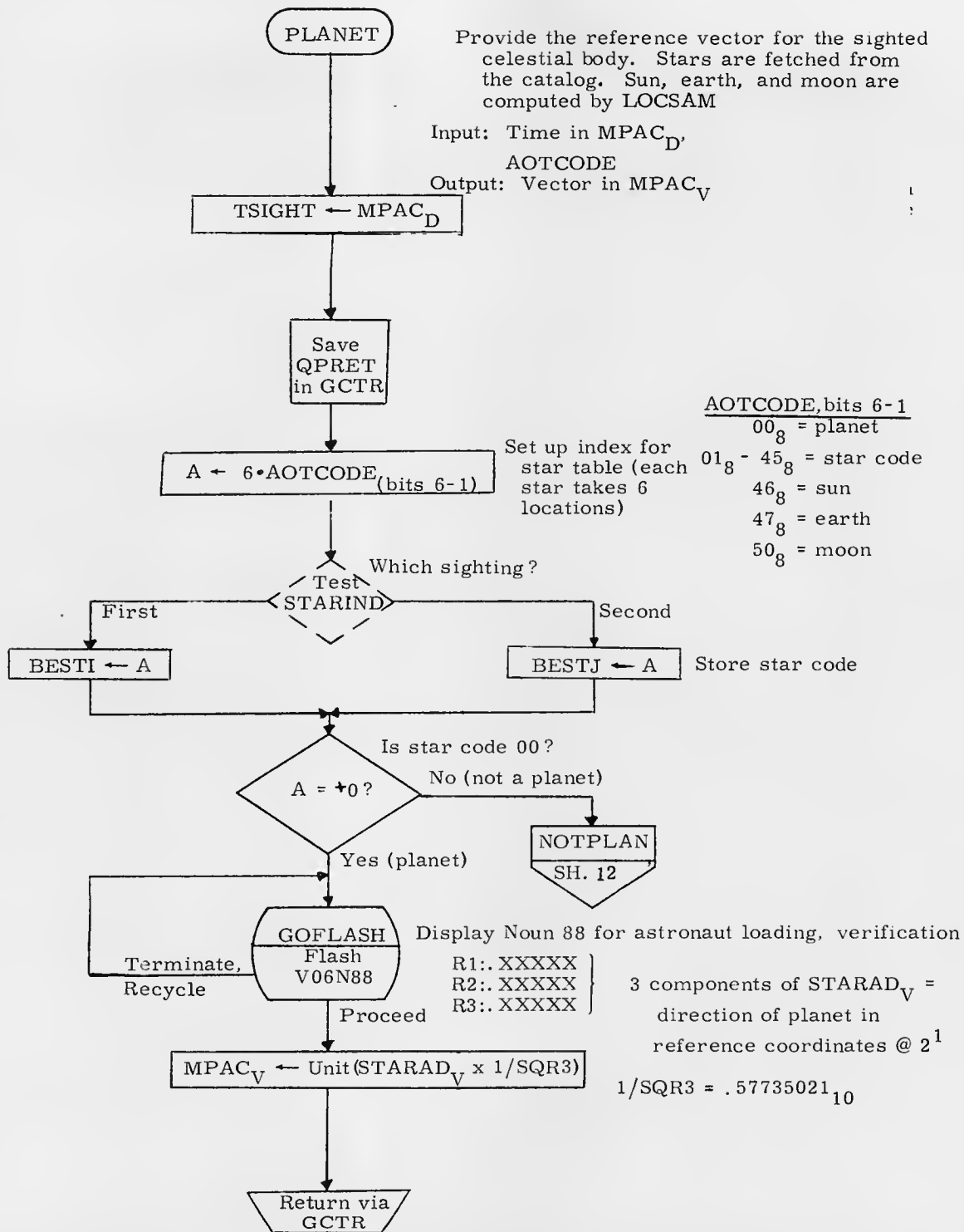
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Lutzovich</i> 8/27/68		P51 IMU Orientation Determination	
PRGMR <i>R. J. Miller</i> 9/5/68	ANALST	LUMINARY 1D	DOCUMENT NO. FC-3500
DOCMR	APPR'D <i>Robert M. Ester</i> 9-9-69	REV 2	SHEET 8 OF 24



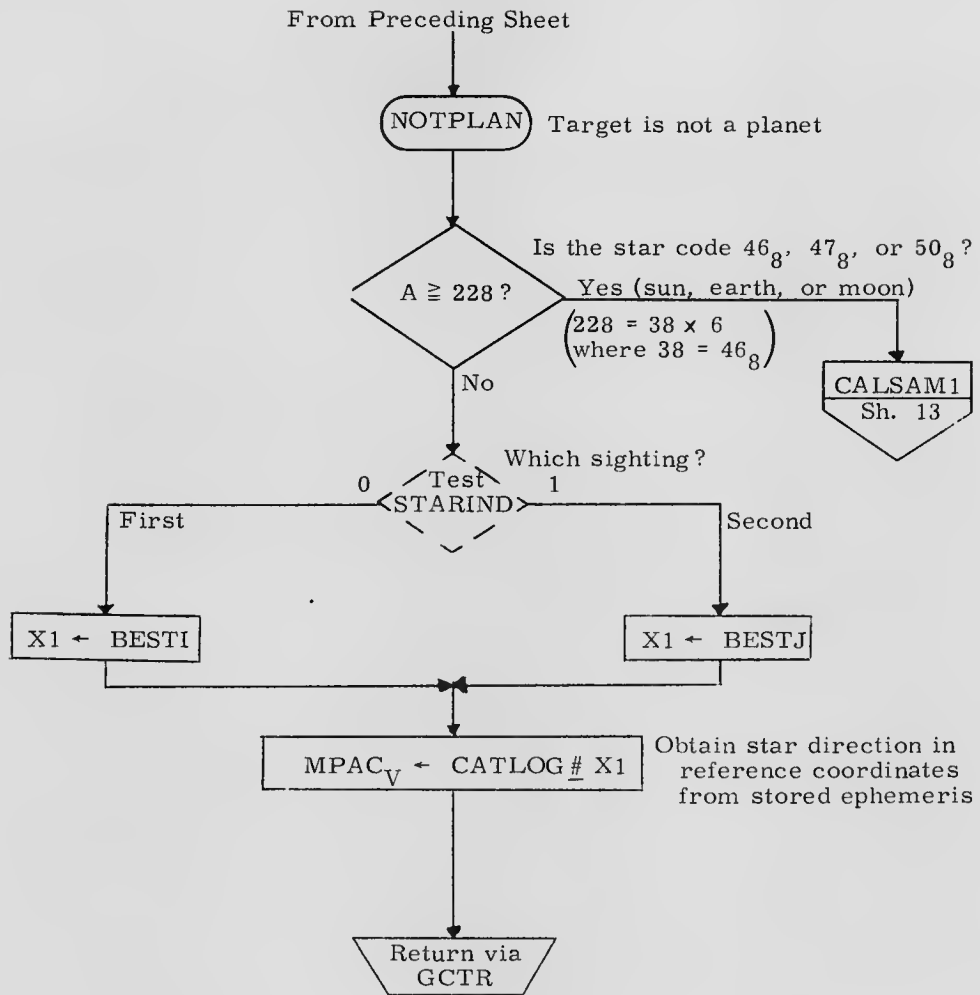
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>L. Goldstone</i> 8/27/69		P51 IMU Orientation Determination	
PRGMR <i>R. M. Ester</i> 9/5/69		DOCUMENT NO.	FC-3500
ANALST		LUMINARY 1D	
DOCMR		REV 2	SHEET 9 OF 24
APPR'D <i>Robert M. Ester</i> 9-9-69			



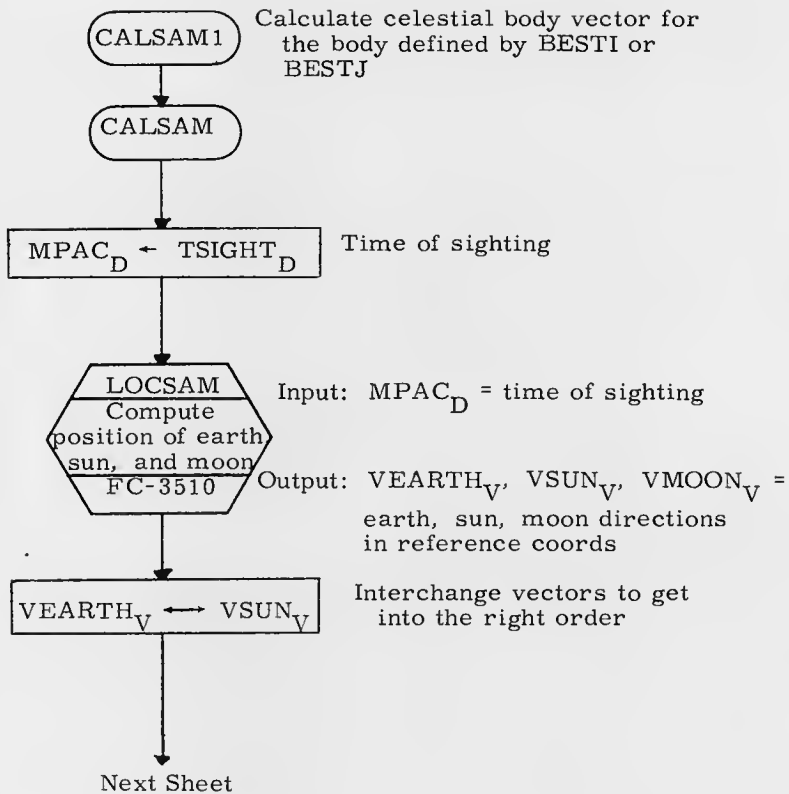
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DRAWN <i>S. Luthersick</i>	<i>8/25/69</i>	P51 IMU Orientation Determination	
PRGMR <i>S. Miller</i>	<i>9/5/69</i>	LUMINARY 1D	DOCUMENT NO. FC-3500
ANALST			
DOCMR			
APPR'D <i>Robert M. Estlin</i>	<i>9-9-69</i>	REV 2	SHEET 10 OF 24



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. C. ...</i> 8-27-67		P51 IMU Orientation Determination	
PRGMR <i>R. P. ...</i> 9/5/67		LUMINARY	DOCUMENT NO.
ANALST		1D	FC-3500
DOCMR		REV 2	SHEET 11 OF 24
APPR'D <i>Robert M. ...</i> 9-9-67			



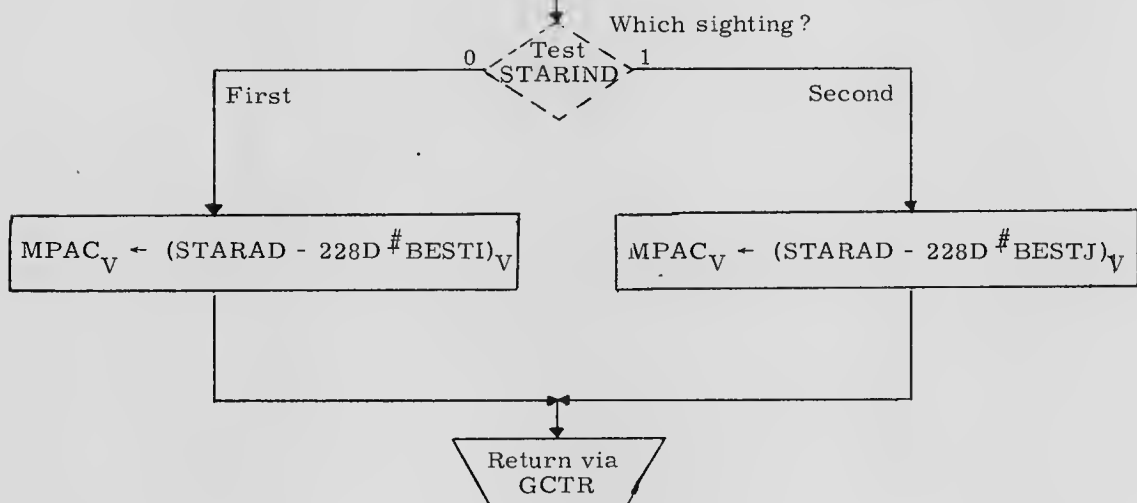
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>J. Conner</i> 8/27/69	P51 IMU Orientation Determination	
PRGMR	<i>J. Conner</i> 9/5/69	LUMINARY 1D	DOCUMENT NO. FC-3500
ANALST			
DOCMR			
APPR'D	<i>Robert M. Ester</i> 9-9-69	REV 2	SHEET 12 OF 24



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN: <i>J. Cipriotti</i>		P51 IMU Orientation Determination	
PRGMR: <i>St. Mallard</i>	<i>8-27-69</i>	LUMINARY 1D	DOCUMENT NO. FC-3500
ANALST			
DOCMR			
APPR'D: <i>Robert M. Estlin</i>	<i>9-9-69</i>	REV 2	SHEET 13 OF 24

From Preceding Sheet

Load
 $STARAD_V = VEARTH_V$
 = sun direction
 or $(STARAD + 6)_V = VSUN_V$
 = earth direction
 or $(STARAD + 12)_V = VMOON_V$
 = moon direction in
 reference coordinates
 @2¹



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DRAWN <i>J. Conolly</i>	<i>8-27-69</i>	P51 IMU Orientation Determination	
PRGMR <i>R. M. East</i>	<i>9/5/69</i>	LUMINARY 1D	DOCUMENT NO. FC-3500
ANALST			
DOCMR			
APPR'D <i>Robert M. East</i>	<i>9-9-69</i>	REV 2	SHEET 14 OF 24

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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DRAWN <i>D. Lytkovick</i> 8/27/69		P51 IMU Orientation Determination	
PRGMR <i>D. Millard</i> 9/6/69		LUMINARY ID	DOCUMENT NO.
ANALST _____			FC-3500
DOCMR _____		REV 2	SHEET 15 OF 24
APPR'D <i>Robert M. Eichen</i> 9-7-69			

DISPLAYS

VERB-NOUN	TYPE OF DISPLAY	DESCRIPTION OF EACH REGISTER	WHERE EXECUTED
V06N22	ALARM	PROG ALARM LIGHT ON; NO EFFECT ON R1, R2, R3	SH. 2, 5, 10
V41N22	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
V06N88	FLASHING	V41: COARSE ALIGN IMU'S R1, R2, R3 AS IN V06N22 ABOVE R1: .XXXXXX } R2: .XXXXXX } 3 COMPONENTS OF DIRECTION R3: .XXXXXX } OF PLANET IN REFERENCE COORDINATES @21	SH. 3 SH. 11

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>L. J. J. J.</i>	<i>8/27/69</i>	P51 IMU Orientation Determination	
PRGMR <i>J. S. Miller</i>	<i>9/15/69</i>	LUMINARY 1D	DOCUMENT NO. FC-3500
ANALST			
DOCMR			
APPR'D <i>Robert M. Egan</i>	<i>9-9-69</i>	REV 2	SHEET 1 ⁶ OF 24

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 X STAR CODE FOR FIRST STAR SIGHTED (USED AS INDEX VALUE)			2^{14}
BESTJ		6 X 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 ΔV IN SM COORDS	M/SEC	M/CSEC	.000585 $\times 2^{14}$
PIPAY		Y-COMPONENT OF SENSED ΔV IN SM COORDS	M/SEC	M/CSEC	.000585 $\times 2^{14}$
PIPAZ		Z-COMPONENT OF SENSED ΔV 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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>L. Galambos</i>	<i>8/22/69</i>	P51 IMU Orientation Determination	
PRGMR <i>R. Ballard</i>	<i>9/5/69</i>	LUMINARY ID	DOCUMENT NO. FC-3500
ANALST			
DOCMR			
APPR'D <i>Robert M. Euter</i>	<i>9-9-69</i>	REV 2	SHEET 17 OF 24

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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>L. J. Johnson</i>	<i>8/7/69</i>	P51 IMU Orientation Determination	
PRGMR <i>R. J. Hillard</i>	<i>9/15/69</i>	LUMINARY 1D	DOCUMENT NO. FC-3500
ANALST			
DOCMR			
APPR'D <i>Robert M. Ester</i>	<i>9-9-69</i>	REV 2	SHEET 18 OF 24

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}

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>L. Addatore</i>	<i>8/27/69</i>	P51 IMU Orientation Determination	
PRGMR <i>D. Ballard</i>	<i>7/15/69</i>	LUMINARY 1D	DOCUMENT NO. FC-3500
ANALST			
DOCMR			
APPR'D <i>Robert M. Ester</i>	<i>9-9-69</i>	REV 2	SHEET 19 OF 24

PROGRAM CONSTANTS

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING AND AGC VALUE	AGC SCALING
CATALOG -6		DIRECTION OF STAR 1 (α ANDROMEDAE (ALPHERATZ)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.8748658918 \\ +.0260879174 \\ +.48386621670 \end{pmatrix}$	2 ¹
CATALOG -12D		DIRECTION OF STAR 2 (β CETI (DIPHA)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.9342640400 \\ +.1735073142 \\ -.3115219339 \end{pmatrix}$	2 ¹
CATALOG -18D		DIRECTION OF STAR 3 (γ CASSIOPEIAE (NAVI)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.4775639450 \\ +.1166004340 \\ +.8708254803 \end{pmatrix}$	2 ¹
CATALOG -24D		DIRECTION OF STAR 4 (α ERIDANI (ACHERNAR)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.4917678276 \\ +.2204887125 \\ -.8423473935 \end{pmatrix}$	2 ¹
CATALOG -30D		DIRECTION OF STAR 5 (α URSAE MINORIS (POLARIS)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.0130968840 \\ +.0078062795 \\ +.9998837600 \end{pmatrix}$	2 ¹
CATALOG -36D		DIRECTION OF STAR 6 (θ ERIDANI (ACAMAR)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.5450107404 \\ +.5314955466 \\ -.6484410356 \end{pmatrix}$	2 ¹
CATALOG -42D		DIRECTION OF STAR 7 (α CETI (MENKAR)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.7032235469 \\ +.7075846047 \\ +.0692868685 \end{pmatrix}$	2 ¹
CATALOG -48D		DIRECTION OF STAR 8 (=10 _g) (α PERSEI (MIRFAK)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.4105636020 \\ +.4988110001 \\ +.7632988371 \end{pmatrix}$	2 ¹
CATALOG -54D		DIRECTION OF STAR 9 (=11 _g) (α TAURI (ALDEBARAN)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.3507315038 \\ +.8926333307 \\ +.2831839492 \end{pmatrix}$	2 ¹

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DRAWN <i>L. Galstone</i>	<i>8/27/69</i>	P51 IMU Orientation Determination	
PRGMR <i>J.M. Nelson</i>	<i>7/15/69</i>	LUMINARY	DOCUMENT NO. FC-3500
ANALST		1D	
DOCMR			
APPR'D <i>Roberto M. Ester</i>	<i>9-9-69</i>	REV 2	SHEET 20 OF 24

PROGRAM CONSTANTS (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING AND AGC VALUE	AGC SCALING
CATALOG -60D		DIRECTION OF STAR 10D (=12 ₈) (β ORIONIS (RIGEL)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.2011399589 \\ +.9690337941 \\ -.1432348512 \end{pmatrix}$	2 ¹
CATALOG -66D		DIRECTION OF STAR 11D (=13 ₈) (α AURIGAE (CAPELLA)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.1371725575 \\ +.6813721061 \\ +.7189685267 \end{pmatrix}$	2 ¹
CATALOG -72D		DIRECTION OF STAR 12D (=14 ₈) (α CARINAE (CANOPUS)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.0614937230 \\ +.6031563286 \\ -.7952489957 \end{pmatrix}$	2 ¹
CATALOG -78D		DIRECTION OF STAR 13D (=15 ₈) (α CANIS MAJORIS (SIRIUS)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.1820751783 \\ +.9404899869 \\ -.2869271926 \end{pmatrix}$	2 ¹
CATALOG -84D		DIRECTION OF STAR 14D (=16 ₈) (α_2 CANIS MINORIS (PROCYON)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.4118589524 \\ +.9065485360 \\ +.0924226975 \end{pmatrix}$	2 ¹
CATALOG -90D		DIRECTION OF STAR 15D (=17 ₈) (γ VELOSUM (REGOR)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.3612508532 \\ +.5747270840 \\ -.7342932655 \end{pmatrix}$	2 ¹
CATALOG -96D		DIRECTION OF STAR 16D (=20 ₈) (γ URSAE MAJORIS (DNOCES)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.4657947941 \\ +.4774785033 \\ +.7450164351 \end{pmatrix}$	2 ¹
CATALOG -102D		DIRECTION OF STAR 17D (=21 ₈) (α HYDRAE (ALPHARD)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.7742591356 \\ +.6152504197 \\ -.1482894839 \end{pmatrix}$	2 ¹
CATALOG -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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DRAWN <i>D. L. Litchfield</i>	<i>8/27/69</i>	P51 IMU Orientation Determination	
PRGMR <i>D. L. Litchfield</i>	<i>7/31/69</i>	LUMINARY 1D	DOCUMENT NO. FC-3500
ANALST			
DOCMR			
APPR'D <i>Robert M. Estlin</i>	<i>9-9-69</i>	REV 2	SHEET 21 OF 24

PROGRAM CONSTANTS (CONTINUED)

ASG TAG	GSOP SYMBOL	MEANING	ENGINEERING AND AGC VALUE	AGC SCALING
CATALOG - 114D		DIRECTION OF STAR 19D (=23 ₈) (β LEONIS (DENEbola)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.9656605484 \\ +.0525933156 \\ +.2544280809 \end{pmatrix}$	2 ¹
CATALOG - 120D		DIRECTION OF STAR 20D (=24 ₈) (γ CORVI (GIENAH)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.9525211695 \\ -.0593434796 \\ -.2986331746 \end{pmatrix}$	2 ¹
CATALOG - 126D		DIRECTION OF STAR 21D (=25 ₈) (α CRUCIS (ACRUX)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.4523440203 \\ -.0493710140 \\ -.8904759346 \end{pmatrix}$	2 ¹
CATALOG - 132D		DIRECTION OF STAR 22D (=26 ₈) (α VIRGINIS (SPICA)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.9170097662 \\ -.3502146628 \\ -.1908999176 \end{pmatrix}$	2 ¹
CATALOG - 138D		DIRECTION OF STAR 23D (=27 ₈) (η URSAE MAJORIS (ALKAID)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.5812035376 \\ -.2909171294 \\ +.7599800468 \end{pmatrix}$	2 ¹
CATALOG - 144D		DIRECTION OF STAR 24D (=30 ₈) (θ CENTAURI (MENKENT)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.6898393233 \\ -.4182330640 \\ -.5909338474 \end{pmatrix}$	2 ¹
CATALOG - 150D		DIRECTION OF STAR 25D (=31 ₈) (α BOOTIS (ARCTURUS)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.7861763936 \\ -.5217996305 \\ +.3311371675 \end{pmatrix}$	2 ¹
CATALOG - 156D		DIRECTION OF STAR 26D (=32 ₈) (α CORONAE BOREALIS (ALPHECCA)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.5326876930 \\ -.7160644554 \\ +.4511047742 \end{pmatrix}$	2 ¹
CATALOG - 162D		DIRECTION OF STAR 27D (=33 ₈) (α SCORPII (ANTARES)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.3516499609 \\ -.8240752703 \\ -.4441196390 \end{pmatrix}$	2 ¹

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DRAWN <i>L. Galantone</i>	<i>8/27/69</i>	P51 IMU Orientation Determination	
PRGMR <i>J. Millard</i>	<i>7/15/69</i>	LUMINARY ID	DOCUMENT NO. FC-3500
ANALST			
DOCMR			
APPR'D <i>Robert M. Ester</i>	<i>9-9-69</i>	REV 2	SHEET 22 OF 24

PROGRAM CONSTANTS (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING AND AGC VALUE	AGC SCALING
CATALOG - 168D		DIRECTION OF STAR 28D (=34 _g) (α TRIANGULI AUSTR. (ATRIA)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.1146237858 \\ -.3399692557 \\ -.9334250333 \end{pmatrix}$	2 ¹
CATALOG - 174D		DIRECTION OF STAR 29D (=35 _g) (α OPHIUCHI (RASALHAGUE)) IN REFERENCE COORDINATES	$\begin{pmatrix} -.1124304773 \\ -.9694934200 \\ +.2178116072 \end{pmatrix}$	2 ¹
CATALOG - 180D		DIRECTION OF STAR 30D (=36 _g) (α LYRAE (VEGA)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.1217293692 \\ -.7702732847 \\ +.6259880410 \end{pmatrix}$	2 ¹
CATALOG - 186D		DIRECTION OF STAR 31D (=37 _g) (α SAGITTARI (NUNKI)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.2069525789 \\ -.8719885748 \\ -.4436288486 \end{pmatrix}$	2 ¹
CATALOG - 192D		DIRECTION OF STAR 32D (=40 _g) (α AQUILAE (ALTAIR)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.4537196908 \\ -.8779508801 \\ +.1527766153 \end{pmatrix}$	2 ¹
CATALOG - 198D		DIRECTION OF STAR 33D (=41 _g) (β CAPRICORNI (DABIH)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.5520184464 \\ -.7933187400 \\ -.2567508745 \end{pmatrix}$	2 ¹
CATALOG - 204D		DIRECTION OF STAR 34D (=42 _g) (α PAVONIS (PEACOCK)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.3201817378 \\ -.4436021946 \\ -.8370786986 \end{pmatrix}$	2 ¹
CATALOG - 210D		DIRECTION OF STAR 35D (=43 _g) (α CYGNI (DENEVB)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.4541086270 \\ -.5392368197 \\ +.7092312789 \end{pmatrix}$	2 ¹
CATALOG - 216D		DIRECTION OF STAR 36D (=44 _g) (ϵ PEGASI (ENIF)) IN REFERENCE COORDINATES	$\begin{pmatrix} +.8139832631 \\ -.5557243189 \\ +.1091204557 \end{pmatrix}$	2 ¹

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DRAWN <i>[Signature]</i>	<i>[Date]</i>	P51 IMU Orientation Determination	
PRGMR <i>[Signature]</i>	<i>[Date]</i>	LUMINARY ID	DOCUMENT NO. FC-3500
ANALST			
DOCMR			
APPR'D <i>[Signature]</i>	<i>[Date]</i>	REV 2	SHEET 23 OF 24

PROGRAM CONSTANTS (CONTINUED)

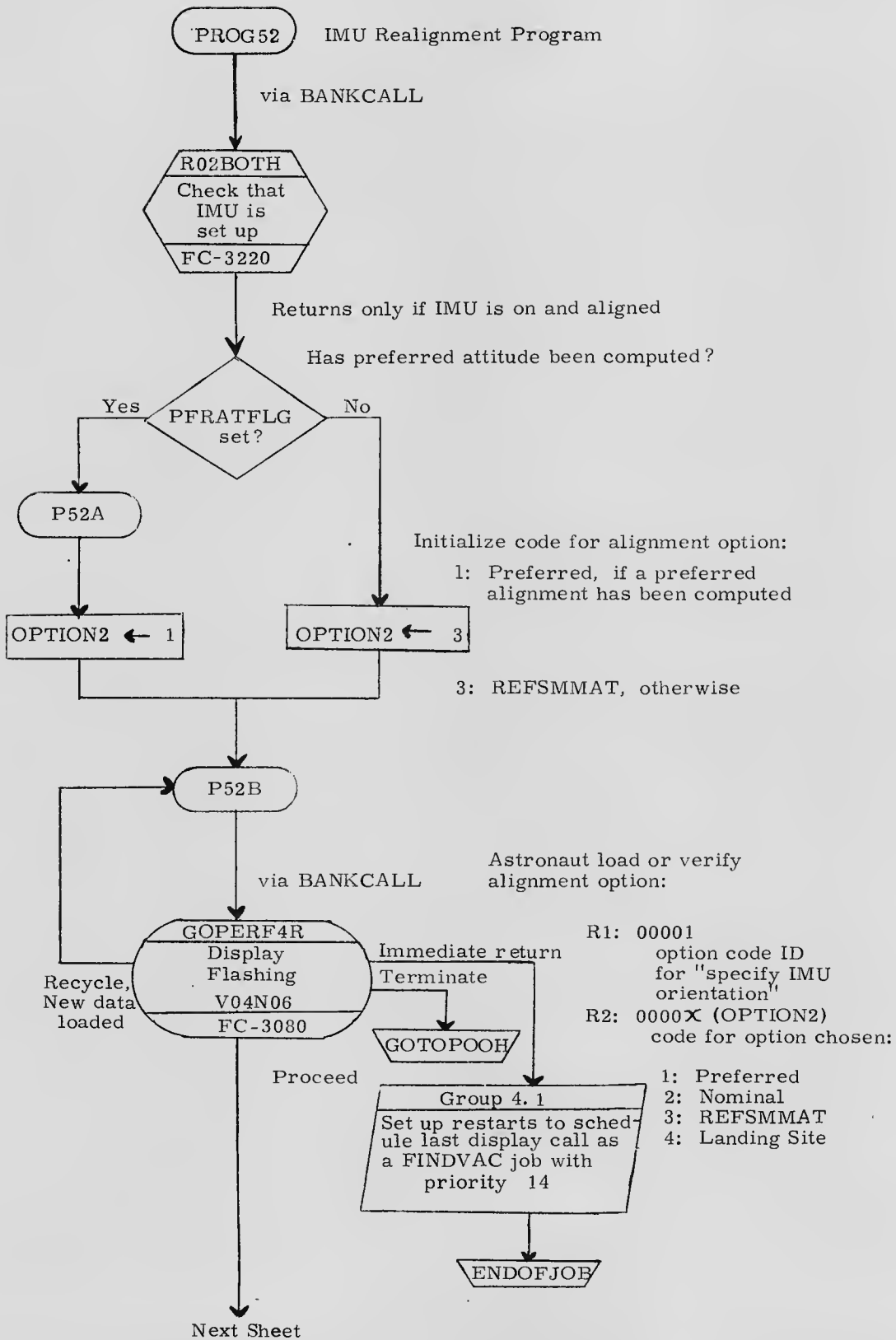
AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING AND AGC VALUE	AGC SCALING
CATALOG -222D		DIRECTION OF STAR 37D (=45g) (α PISCIS AUSTR. (FORMALHAUT)) IN REFERENCE COORDINATES	(+.8342971408) (-.2392481515) (-.4966976975)	2 ¹

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>L. Goldstone</i>	<i>8/27/69</i>	P51 IMU Orientation Determination	
PRGMR <i>D. Mallard</i>	<i>9/13/69</i>	LUMINARY 1D	DOCUMENT NO. FC-3500
ANALST			
DOCMR			
APPR'D <i>Robert M. Evers</i>	<i>9-9-69</i>	REV 2	SHEET 24 OF 24

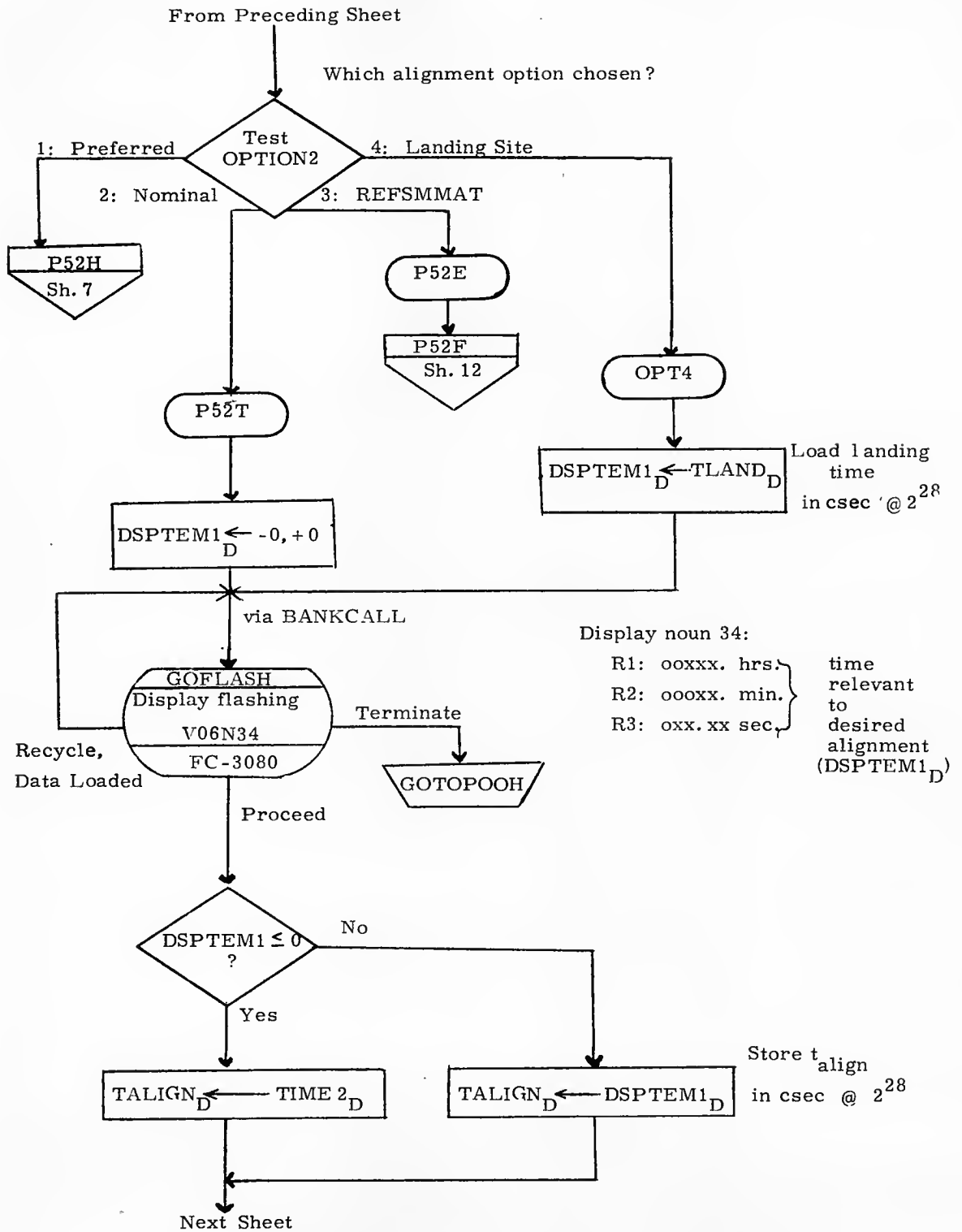
P52: IMU REALIGNMENT PROGRAM

PROG52	Sh. 2
LSORIENT	Sh. 6
RDCDUS	Sh. 9
S52.3	Sh. 13
N89DISP	Sh. 14
S52.2	Sh. 17
GYCOARS	Sh. 19
R51	Sh. 22
LOCSAM	Sh. 30
OCCOS	Sh. 31
PICAPAR =R56	Sh. 34
OCCULT	Sh. 41
R52	Sh. 42
CHKSDATA =R54	Sh. 46
R55	Sh. 48
MA TMOVE	Sh. 50

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>J. J. ...</i>	P52	
PROGR	<i>J. J. ...</i>		
APPROV	<i>J. J. ...</i>		
DATE	<i>3/6/70</i>	LUMINARY 1D	DOCUMENT NO. FC-3510
APPROV	<i>Robert M. Estes</i>	REV 1	SECRET 1 OF 55

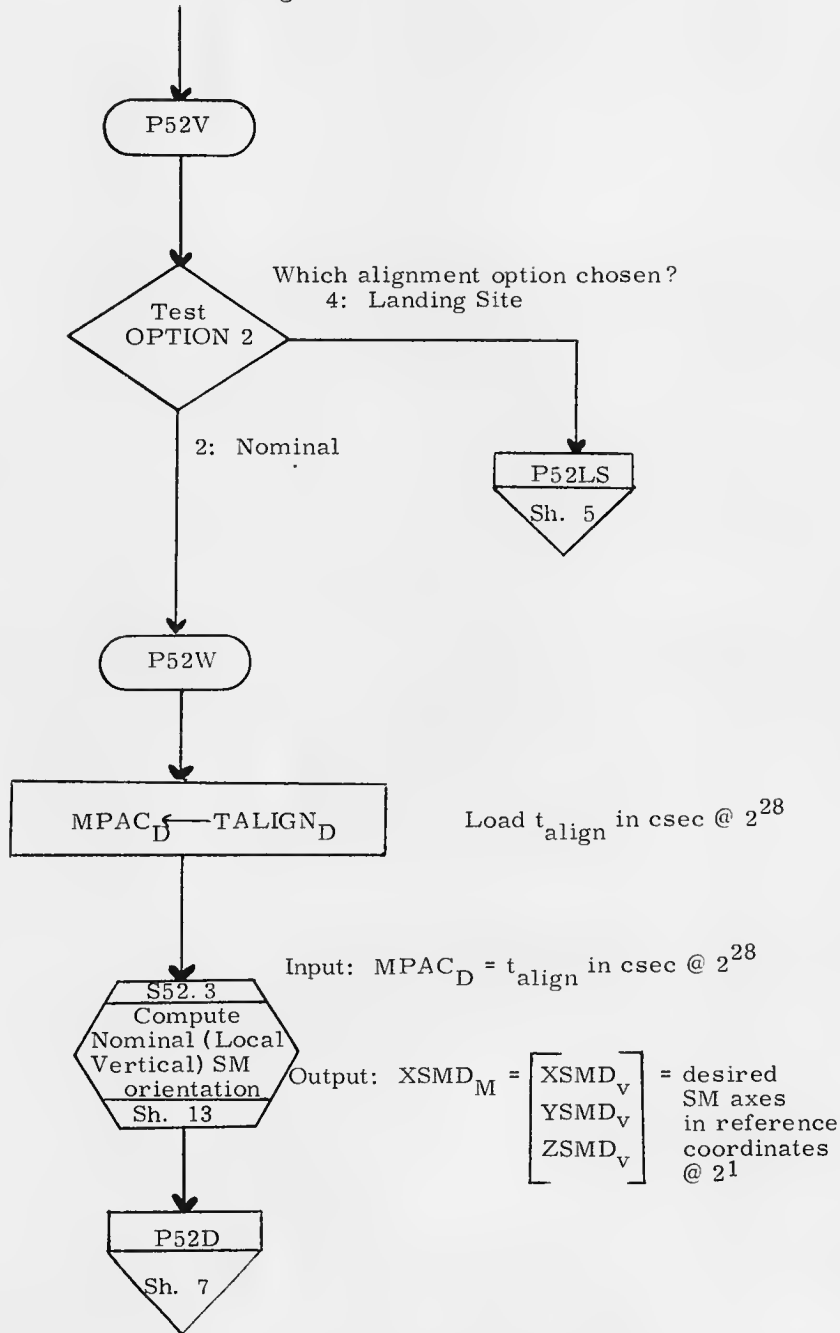


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>Chinnister</i>	<i>10/9/69</i>	P52	
PRGMR		LUMINARY ID	DOCUMENT NO. FC-3510
ANALST		REV 1	SHEET 2 OF 55
DOCMR			
APPR'D <i>Robert McEntire</i>	<i>3/6/70</i>		

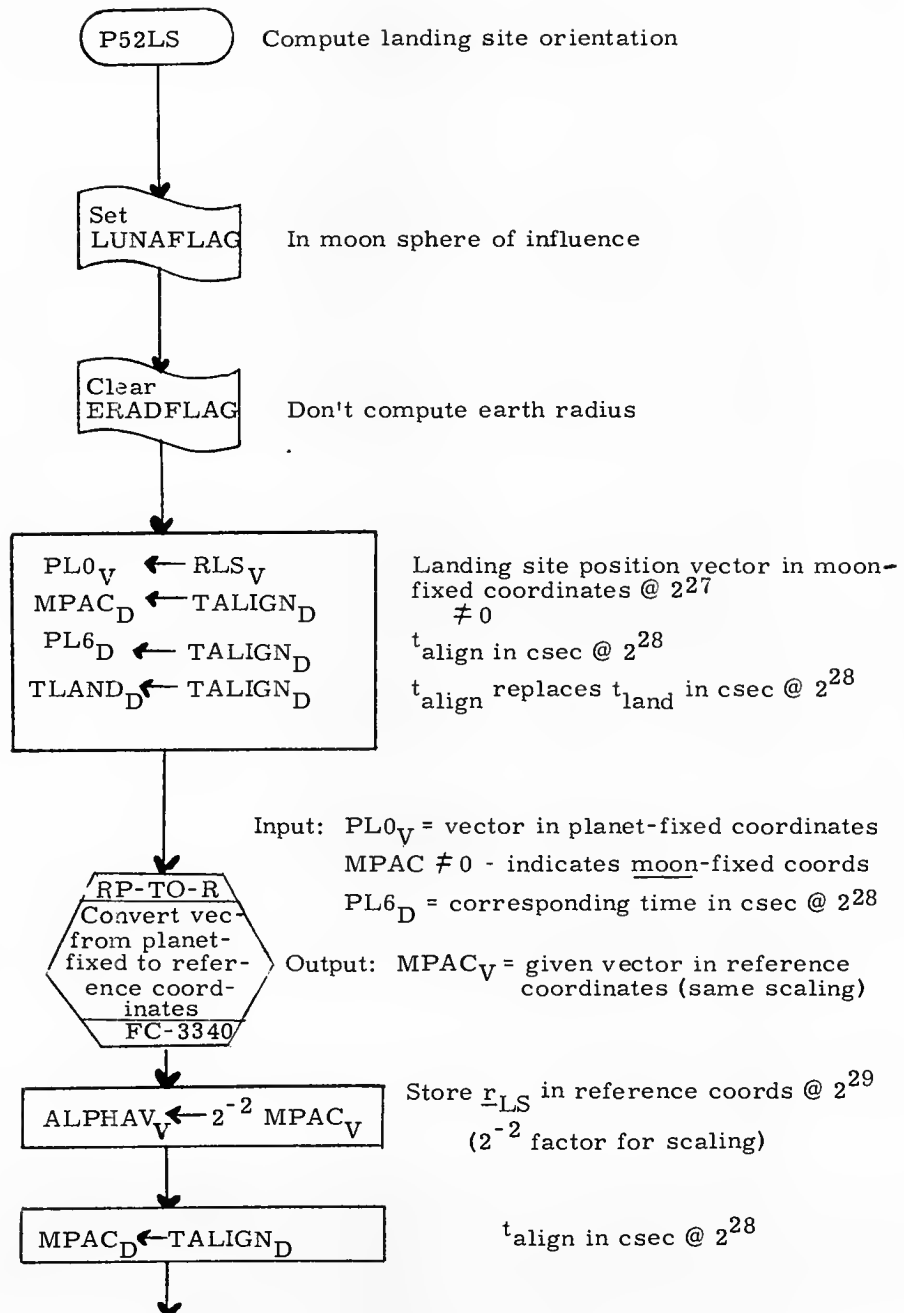


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>James R. ...</i> 10/1/67		P52	
PRGMR		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3510
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APPR'D <i>Robert M. ...</i> 2/4/70			

From Preceding Sheet

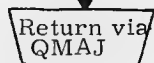
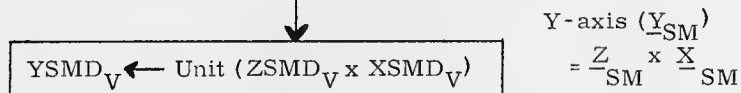
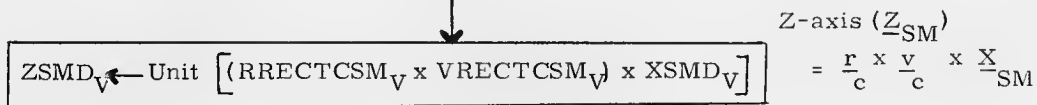
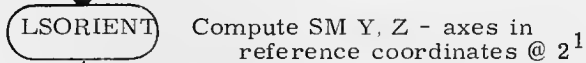
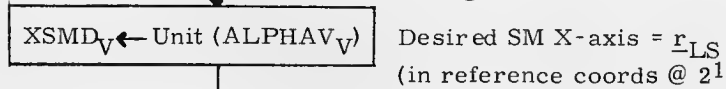
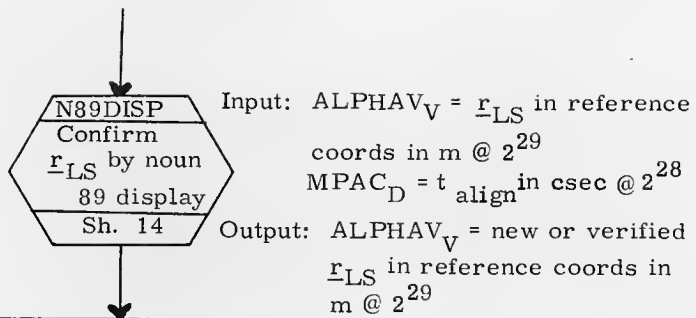


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DRAWN <i>[Signature]</i>	<i>10/1/67</i>	P52	
PRGMR		DOCUMENT NO.	
ANALST		LUMINARY ID	FC-3510
DOCMR		REV 1	SHEET 4 OF 55
APPR'D <i>[Signature]</i>	<i>3/6/70</i>		



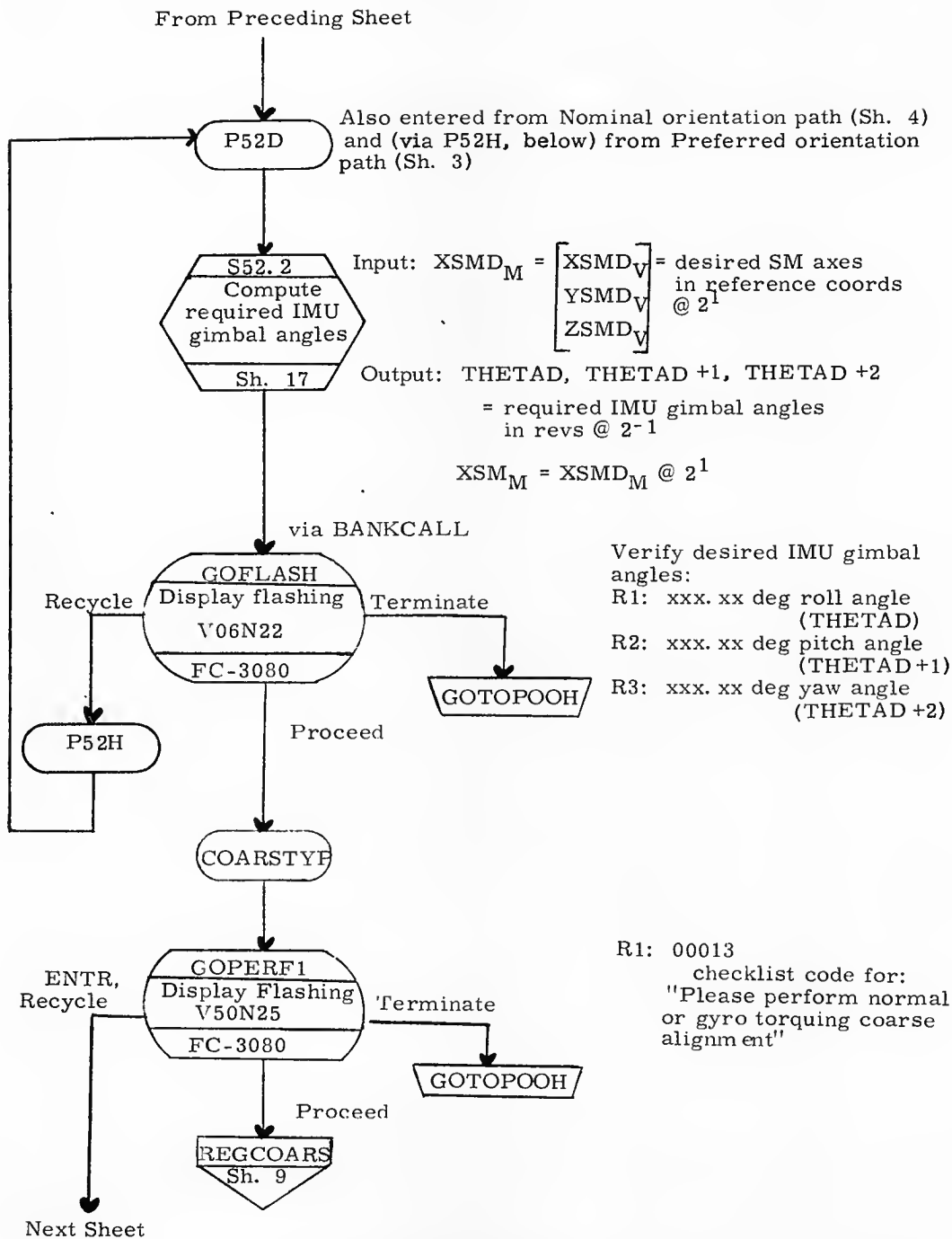
Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. ...</i> 11/64		P52	
PRGMR		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3510
DOCMR		REV 1	SHEET 5 OF 55
APPR'D <i>R. ...</i> 3/6/70			



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MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>Robert M. Evers</i>	<i>4/9/68</i>	P52	
PRGMR		LUMINARY 1 D	DOCUMENT NO.
ANALST			FC-3510
DOCMR		REV 1	SHEET 6 OF 55
APPR'D <i>Robert M. Evers</i>	<i>3/6/70</i>		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i>	<i>[Signature]</i> 10/6/69	P52	
PREPDR		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3510
DOCMR		REV 1	SHEET 7 OF 55
APPR'D <i>[Signature]</i>	5/17/70		

From Preceding Sheet

Convert desired SM axes
from reference to SM
(present) coordinates
@ 21

$$\begin{aligned} XDC_V &\leftarrow \text{Unit (REFSMMAT}_M \times XSMD_V) \\ YDC_V &\leftarrow \text{Unit (REFSMMAT}_M \times YSMD_V) \\ ZDC_V &\leftarrow \text{Unit (REFSMMAT}_M \times ZSMD_V) \end{aligned}$$

GYCOARS
Gyro torquing
coarse
alignment
Sh. 19

Input: $XDC_M = \begin{bmatrix} XDC_V \\ YDC_V \\ ZDC_V \end{bmatrix}$ = desired SM
axes relative
to present
SM coordinates
@ 21

$XSMD_M = \begin{bmatrix} XSMD_V \\ YSMD_V \\ ZSMD_V \end{bmatrix}$ = desired SM
axes in
reference
coordinates
@ 21

P52OUT
Sh. 12

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>Amistaw</i> 10/1/69		P52	
PRGMR			DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3510
DOCMR		REV 1	SHEET 8 OF 55
APPR'D <i>Robert M. Euter</i> 3/6/70			

REGCOARS

Regular coarse alignment path

CAL53A

Input: $XSM_{M} = \begin{bmatrix} XSM_{V} \\ YSM_{V} \\ ZSM_{V} \end{bmatrix} = \text{desired SM axes in reference coords @ } 2^1$

S52.2
Compute required IMU gimbals angles
Sh. 17

Output: THETAD, THETAD +1, THETAD +2
= required IMU gimbals angles in revs @ 2^{-1}
 $XSM_{M} = XSM_{M}$

RDCDUS

Inhibit Inter-rupts

PL1 ← CDUX
PL2 ← CDUY
PL3 ← CDUZ

Present IMU gimbals angles (2's complement) in revs @ 2^{-1}

Allow inter-rupts

Return via DANZIG

Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>Rossiter</i> 10/4/69		P52	
PRGMR			DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3510
DOCMR		REV 1	SHEET 9 OF 55
APPR'D <i>Rossiter</i> 12/6/70			

From Preceding Sheet

$X1 \leftarrow 3$

Initialize index register

CALOOP

$PL4 \leftarrow |2^{-1} \cdot PL(4 \# X1) - 2^{-1}(\text{THETAD} + 3 \# X1)|$

Difference between actual and required IMU gimbal angle in revs @ 20
(2^{-1} factors for scaling)

Change big enough to bother with?
 $1^\circ \leq PL4 \leq 359^\circ$
? Yes: do coarse alignment

No: check next angle

Any angles left to check?
 $X1 \geq 1$
? No

Yes

$X1 \leftarrow X1 - 1$

FINEONLY
Sh. 11

Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>Chen</i>	<i>3/4/70</i>	P52	
PRGMR		DOCUMENT NO.	
ANALST		LUMINAR V 1D	FC-3510
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APPR'D <i>R. M. E.</i>	<i>3/6/70</i>		

From Preceding Sheet

GROUP 4
Set up restarts to schedule next location as a FINDVAC job with priority 13

COARFINE

Input: THETAD, THETAD +1, THETAD +2
= desired IMU gimbal angles (2's complement) in revs @ 2⁻¹

COARSE
Coarse align IMU
FC-3500

NCOARSE
Re-initiate gyro compensation
FC-3500

FINEONLY

X1 ← -Adr (XSM)
X2 ← -Adr (REFSMMAT)

Set inputs to MATMOVE

MATMOVE
Move matrix
Sh. 50

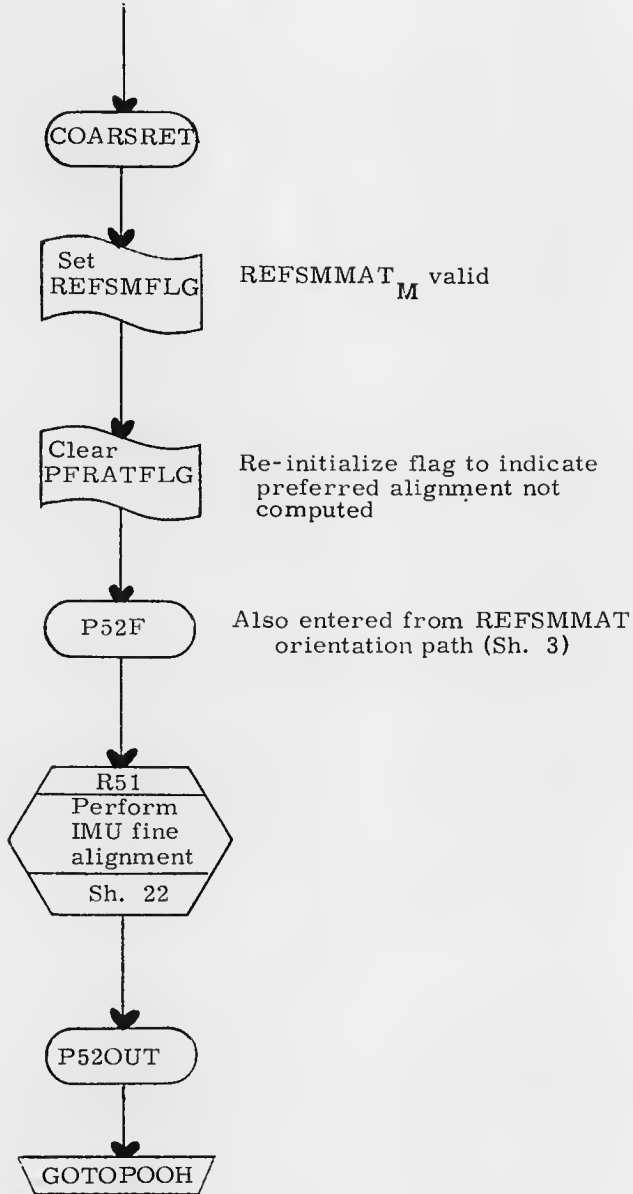
Input: X1 = -Adr (matrix to be moved)
X2 = -Adr (matrix to be stored into)

Result: $REFSMMAT_M \leftarrow XSM_M$

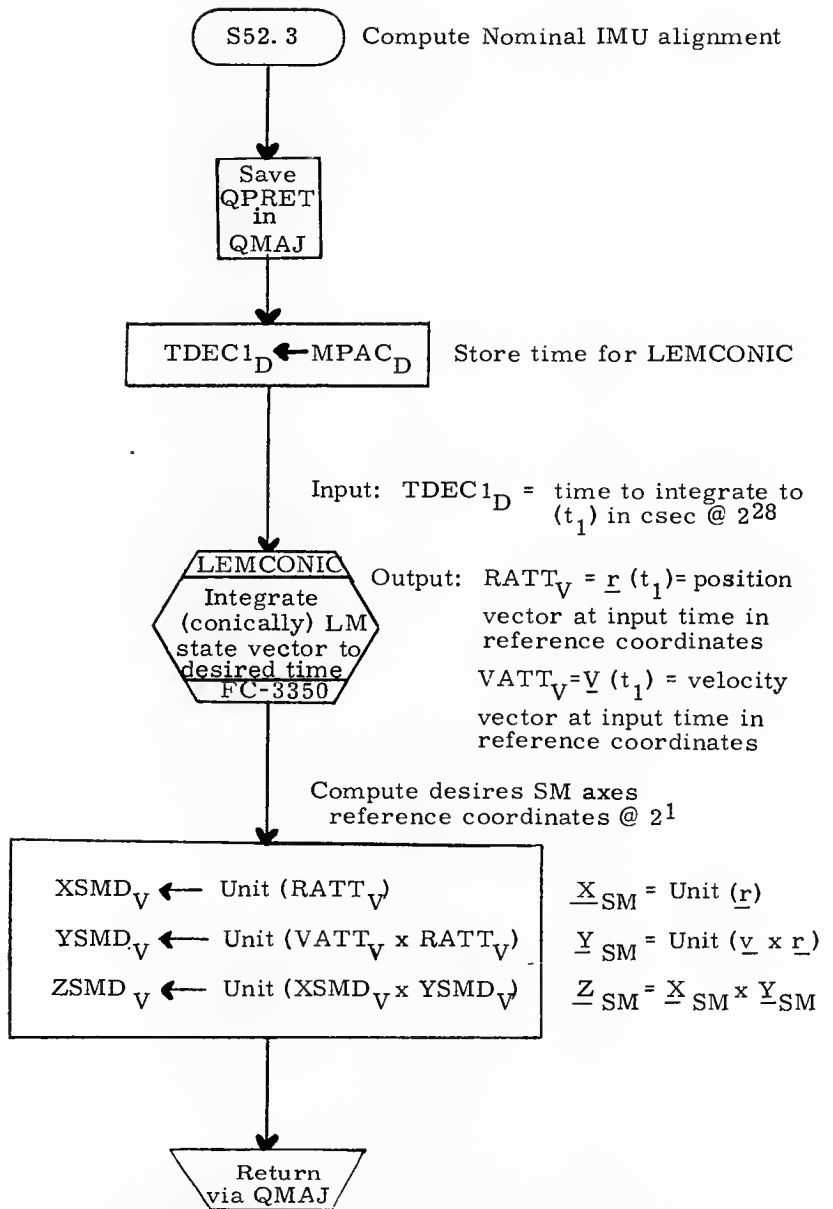
Next Sheet

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DRAWN <i>[Signature]</i> 10/26/70		P52	
PRGMR		DOCUMENT NO.	
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MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>Johnston</i>		P52	
PRGMR		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3510
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APPR'D <i>Robert M. Estes</i>	<i>12/6/70</i>		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i> 11/23/61		P52	
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ANALST			FC-3510
DOCMR		REV 1	SHEET 13 OF 55
APPR'D <i>[Signature]</i> 2/4/70			

N89DISP

Confirm r_{LS} by noun 89 display

Save
QPRET
in
QMAJ

$(GDT/2 + 4)_D \leftarrow MPAC_D$

Save t_{align} in csec @ 2^{28}

LAT-LONG
Compute lati-
tude, longitude,
altitude
FC-3330

Input: $ALPHAV_V$ = position vector
in m in reference coords
@ 2^{29}
 $MPAC_D$ = corresponding
time in csec @ 2^{28}

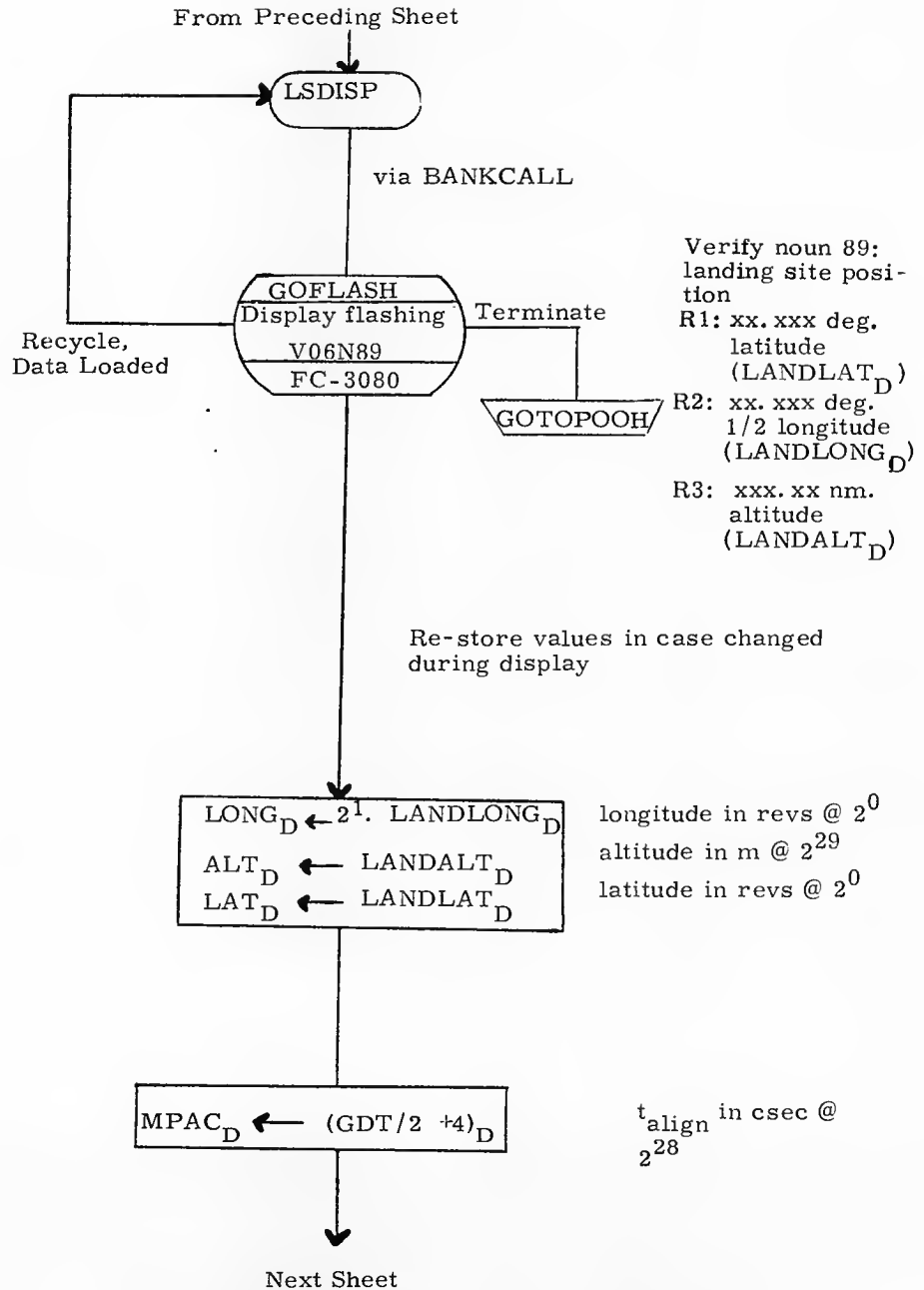
Output: LAT_D = latitude of given
position in revs @ 2^0
 $LONG_D$ = longitude of
given position in revs @
 2^0
 ALT_D = altitude of given
position in m @ 2^{29}

$LANDLONG_D \leftarrow 2^{-1} LONG_D$
 $LANDALT_D \leftarrow ALT_D$
 $LANDLAT_D \leftarrow LAT_D$

1/2 of longitude in
revs @ 2^0
altitude in m @ 2^{29}
latitude in revs @ 2^0

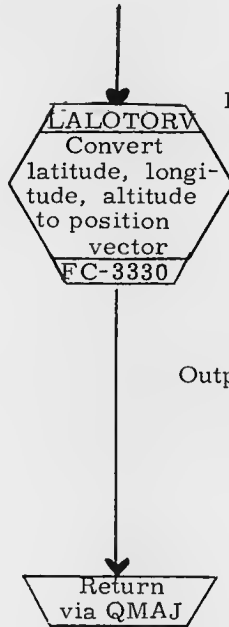
Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. McIntire</i> 10/2/69		P52	
PRGMR		DOCUMENT NO.	
ANALST		LUMINARY ID	FC-3510
DOCMR		REV 1	SHEET 14 OF 55
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ANALST			
DOCMR			
APPR'D <i>[Signature]</i>	<i>[Date]</i>	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: $ALPHA_{V_V}$ = position vector in m. in reference coords @ 2^{29}

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
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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 } sines, cosine
SINCDUY, COSCDUY } of IMU gimbal
SINCDUZ, COSCDUZ } angles @ 2¹

CALCSMSC
Compute NB axes in SM coordinates
FC-3320

Input: SINCDUX, COSCDUX } sines, cosines
SINCDUY, COSCDUY } of IMU gimbal
SINCDUZ, COSCDUZ } angles @ 2¹

Output: $XNB_M = \begin{bmatrix} XNB_V \\ YNB_V \\ ZNB_V \end{bmatrix}$ = NB axes in SM (present) coordinates @ 2¹

S52. 2A

$XNB_V \leftarrow \text{Unit}(XNB_V \times \text{REFSMMAT}_M)$
 $YNB_V \leftarrow \text{Unit}(YNB_V \times \text{REFSMMAT}_M)$
 $ZNB_V \leftarrow \text{Unit}(ZNB_V \times \text{REFSMMAT}_M)$

Convert NB axes from SM to reference coords @ 2¹

Next Sheet

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From Preceding Sheet

S52. 2. 1

X1 ← - Adr (XSMD)
X2 ← - Adr (XSM)

Set inputs to MATMOVE

MATMOVE
Move
matrix

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

Sh. 50

Result: $XSM_M \leftarrow XSMD_M$

CALCGA
Compute
desired IMU
gimbal
angles
FC-3310

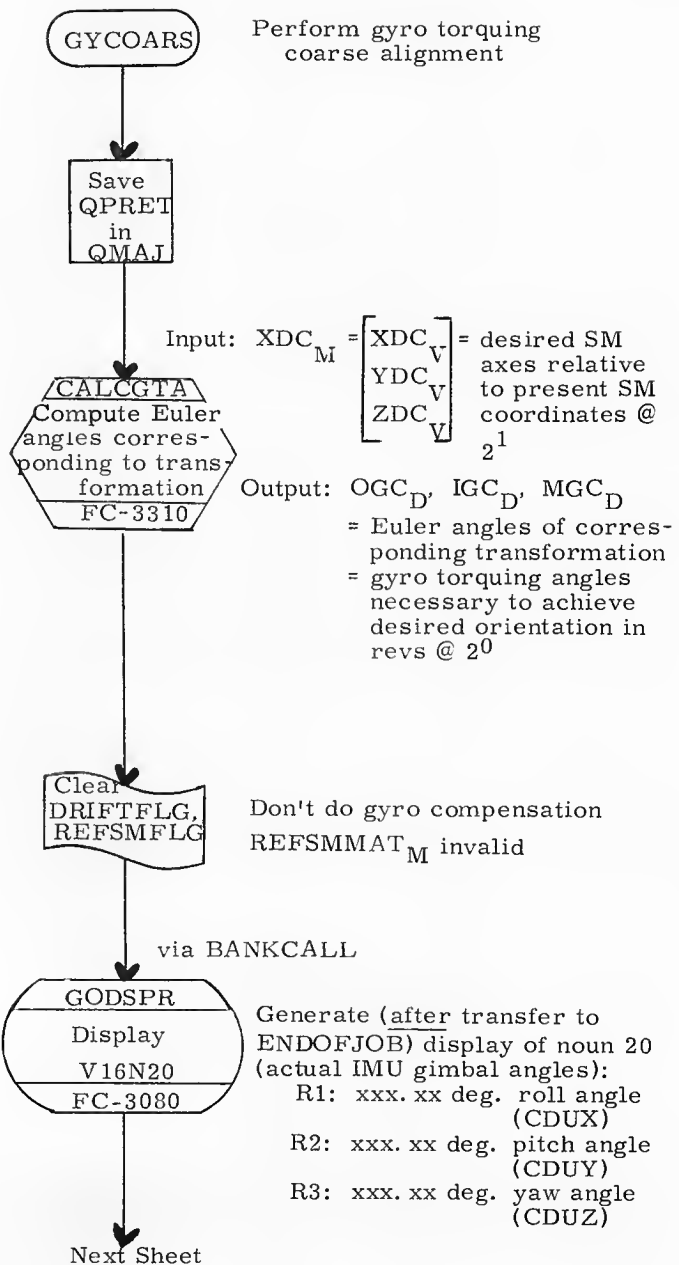
Input: XNB_M = NB axes in reference coordinates
@ 2^1

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}

Return
via QMJ

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DOCMR _____			
APPR'D <i>Robert M. Estes</i> 3/6/70	REV 1	SHEET 18 OF 55	



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DRAWN <i>Johnston</i> 10/14/69		P52	
PRGMR		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3510
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APPR'D <i>Robert M. Estes</i> 3/4/70			

From Preceding Sheet

A ← ECADR (OGC)

Load input to IMUPULSE

via BANKCALL

IMUPULSE
Torque
IMU gimbal
gyros
FC-3220

Input: A = ECADR (X), where
 $X_D [= OGC_D]$, $(X+2)_D [= IGC_D]$,
 $(X+4)_D [= MGC_D]$ contain
 gyro torquing angles
 in revs @ 20

via BANKCALL

IMUSTALL
Wait until
IMU operation
complete
FC-3220

Bad return

CURTAINS
Light PROG ALARM
light; set alarm
code 217
FC-3140

Indicate bad
return from
stall routine

Normal
return

Group 4
Set up restarts to
schedule next loca-
tion as a FINDVAC
job with priority 13

X1 ← - Adr (XSMD)
X2 ← - Adr (REFSMMAT)

Set inputs to MATMOVE

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APPR'D <i>Robert M. Enter</i> 3/6/70	REV 1	SHEET 20 OF 55	

From Preceding Sheet



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

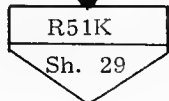
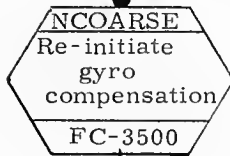
Result: $REFSMMAT_M \leftarrow XSMD_M$



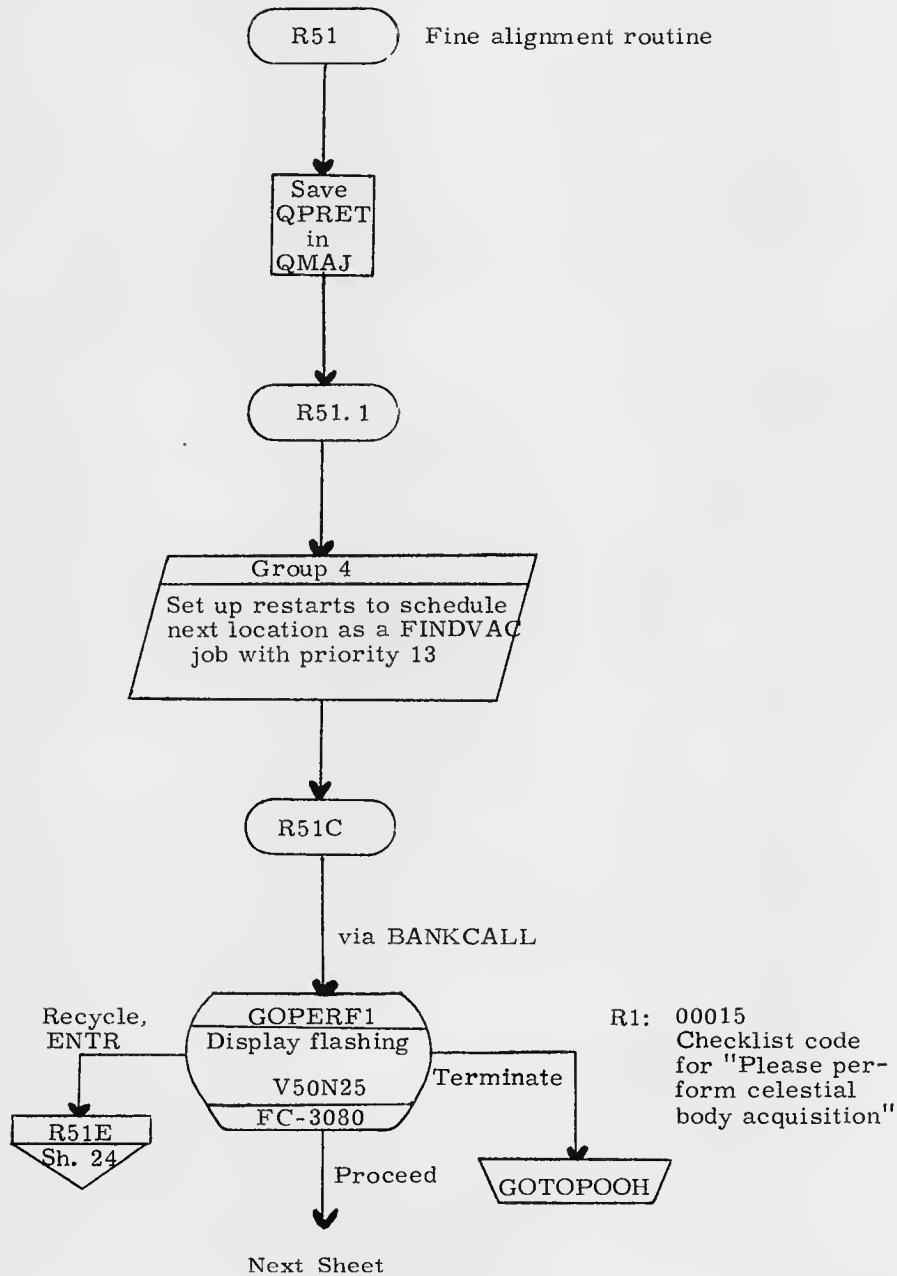
Re-initialize flag to indicate preferred alignment not computed



$REFSMMAT_M$ valid

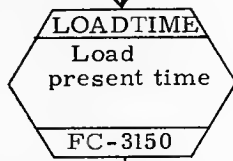


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>Robert M. Eater</i>	<i>3/6/70</i>	P52	
PRGMR		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3510
DOCMR		REV 1	SHEET 21 OF 55
APPR'D <i>Robert M. Eater</i>	<i>3/6/70</i>		

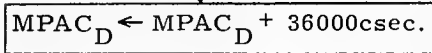


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>Samuel...</i> <i>11/15/67</i>		P52	
PRGMR		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3510
DOCMR		REV 1	SHEET 22 OF 55
APPR'D <i>Robert M. Ester</i> <i>3/6/70</i>			

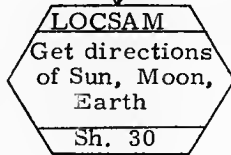
From Preceding Sheet



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



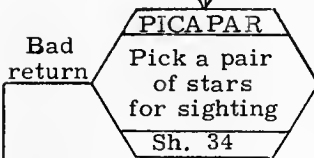
Estimate 6 min. from now to sighting



Input: $MPAC_D = t_{\text{sight}}$ in csec @ 2^{28}

Output: $VSUN_V = u_S$ direction of sun
 $VEARTH_V = u_E$ direction of earth
 $VMOON_V = u_M$ direction of moon
 all in reference coords @ 2^1
 $CSUN_D = \text{cosine of angle of occultation of Sun}$
 $CEARTH_D = \text{cosine of angle of occultation of Earth}$
 $CMOON_D = \text{cosine of angle of occultation of Moon}$
 all @ 2^2

via BANKCALL



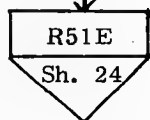
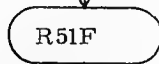
Input: $VEARTH_V, VSUN_V, VMOON_V$
 = directions (from LM) of Earth, Sun, Moon, in reference coordinates @ 2^1
 $CEARTH_D, CSUN_D, CMOON_D$
 = cosines of angles of occultation of Earth, Sun, Moon @ 2^2

Output: $BESTI, BESTJ = \text{indexes to reference directions of stars found}$

Bad return

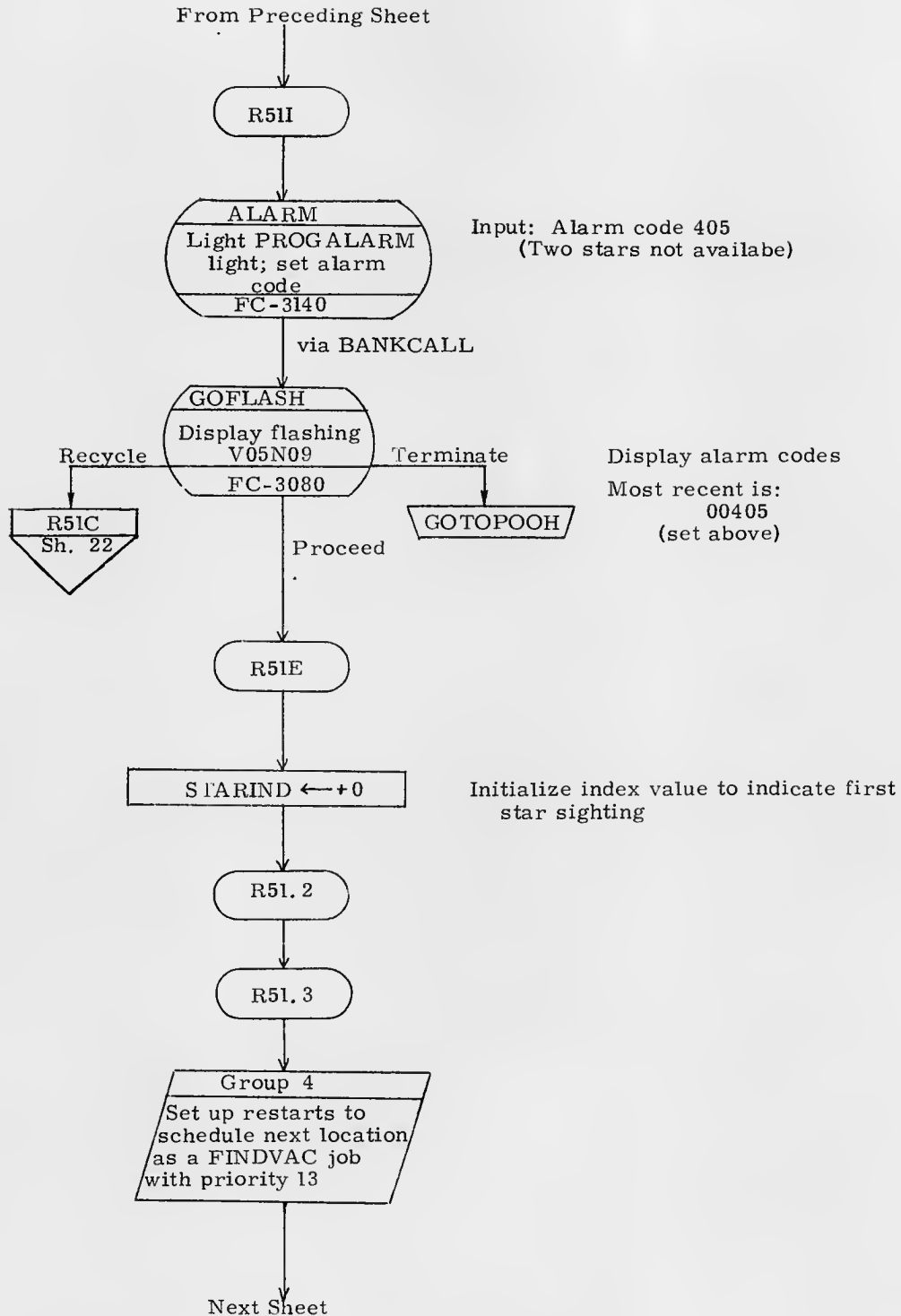
No star pair found

Normal return



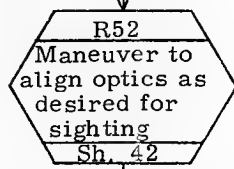
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DRAWN <i>[Signature]</i> 10/29/68		P52	
PRGMR		LUMINARY 1D	DOCUMENT NO.
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DRAWN <i>D. Lutkench</i> 10/19/69		P52	
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ANALST			FC-3510
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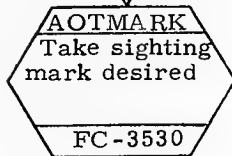
From Preceding Sheet



Input: STARIND = index to which star sighting
BESTI or BESTJ = corresponding star index value

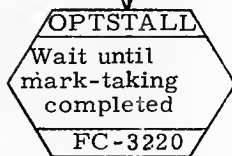
Output: STARCODE = codes for AOT position detent and sighted body

via BANKCALL

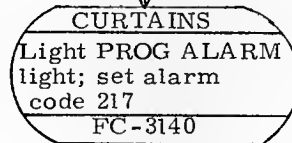


Input: STARCODE (=AOTCODE)

Output: STARS_V2_V = (STARAD + 6)_V¹ = line-of-sight to star sighted, in SM coords @ 2¹
TSIGHT_D = time of sighting in csec @ 2²⁸

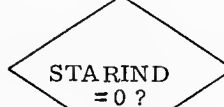


Bad return

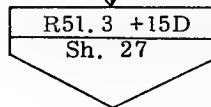


Indicate bad return from stall routine

Normal return



First star sighting?
No: second



Yes

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DRAWN <i>J. Lutterbeck 10/29/69</i>		P52	
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From Preceding Sheet

R51.4

STARSAVI_V ← (STARAD + 6)_V

Save line-of-sight to first star in SM
coords @ 2¹

MPAC_D ← TSIGHT_D

t_{sight} in case @ 2²⁸

PLANET
Provide refer-
ence direction
for star sighter
FC-3500

Input: MPAC_D = time of sighting in csec @ 2²⁸
STARCODE = star code

Output: MPAC_V = reference vector for sighted star @ 2¹

PLANVEC_V ← MPAC_V

Save reference vector for first star @ 2¹

STARIND ← -1

Set index value to indicate second star sighting

R51.3
Sh. 24

Go back to do second star sighting

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(R51.3 +15D)

STARSAV2_V ← (STARAD +6)_V

Line of sight to second star sighted in SM coords @ 2¹

Group 4
Set up restarts to schedule next location as a FINDVAC job with priority 13.

MPAC_D ← TSIGHT_D

t_{sight} in csec @ 2²⁸

PLANET
Provide reference direction for sighted star
FC-3500

Input: MPAC_D = time of sighting in csec @ 2²⁸
STARCODE = star code

Output: MPAC_V = reference vector for sighted star @ 2¹

(STARAD +6)_V ← Unit (REFSMMAT_M × MPAC_V)
STARAD_V ← Unit (REFSMMAT_M × PLANVEC_V)

Second star direction

First star direction
Both from stored reference vectors in SM coords @ 2¹

PL6_V ← STARSAV1_V
PL12_V ← STARSAV2_V

First star direction

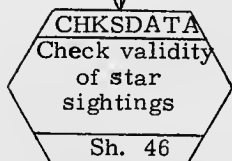
Second star direction

Both from star sightings in SM coords @ 2¹

Next Sheet

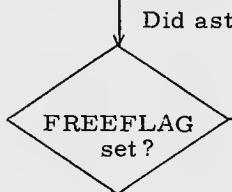
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>Lathewil 10/29/69</i>	P52	
PRGMR			
ANALST		DOCUMENT NO.	
DCCMR		LUMINARY 1D.	FC-3510
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From Preceding Sheet



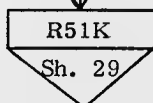
Input: $STARAD_V, (STARAD + 6)_V$
 = 2 star vectors from reference list
 $PL6_V, PL12_V$
 = same 2 star vectors from star sightings

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

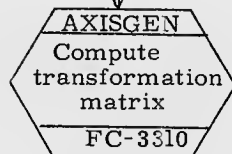


Did astronaut key in "Proceed"?

No

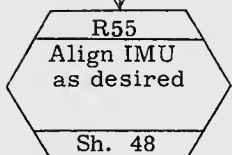


Yes



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

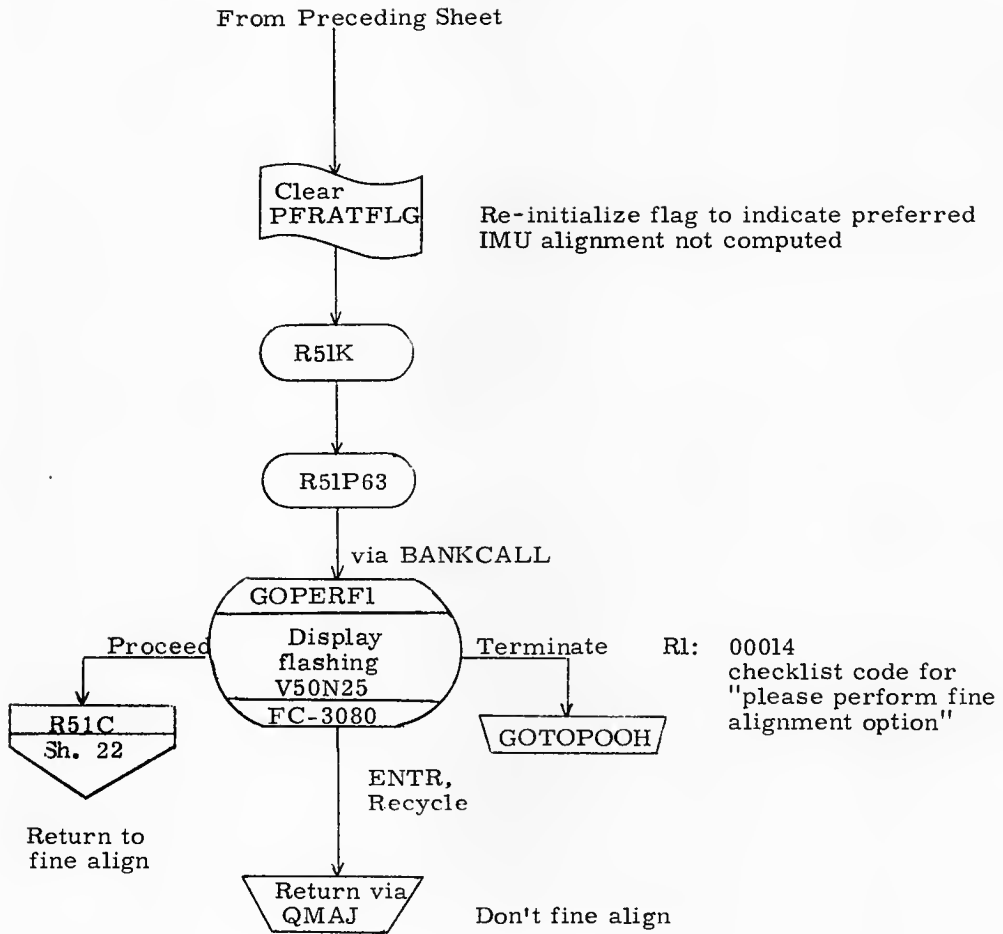
Output: $XDC_M = \begin{bmatrix} XDC_V \\ YDC_V \\ ZDC_V \end{bmatrix} = STARAD_M$
 = transformation matrix giving desired SM axes in terms of present ones. @ 2^1



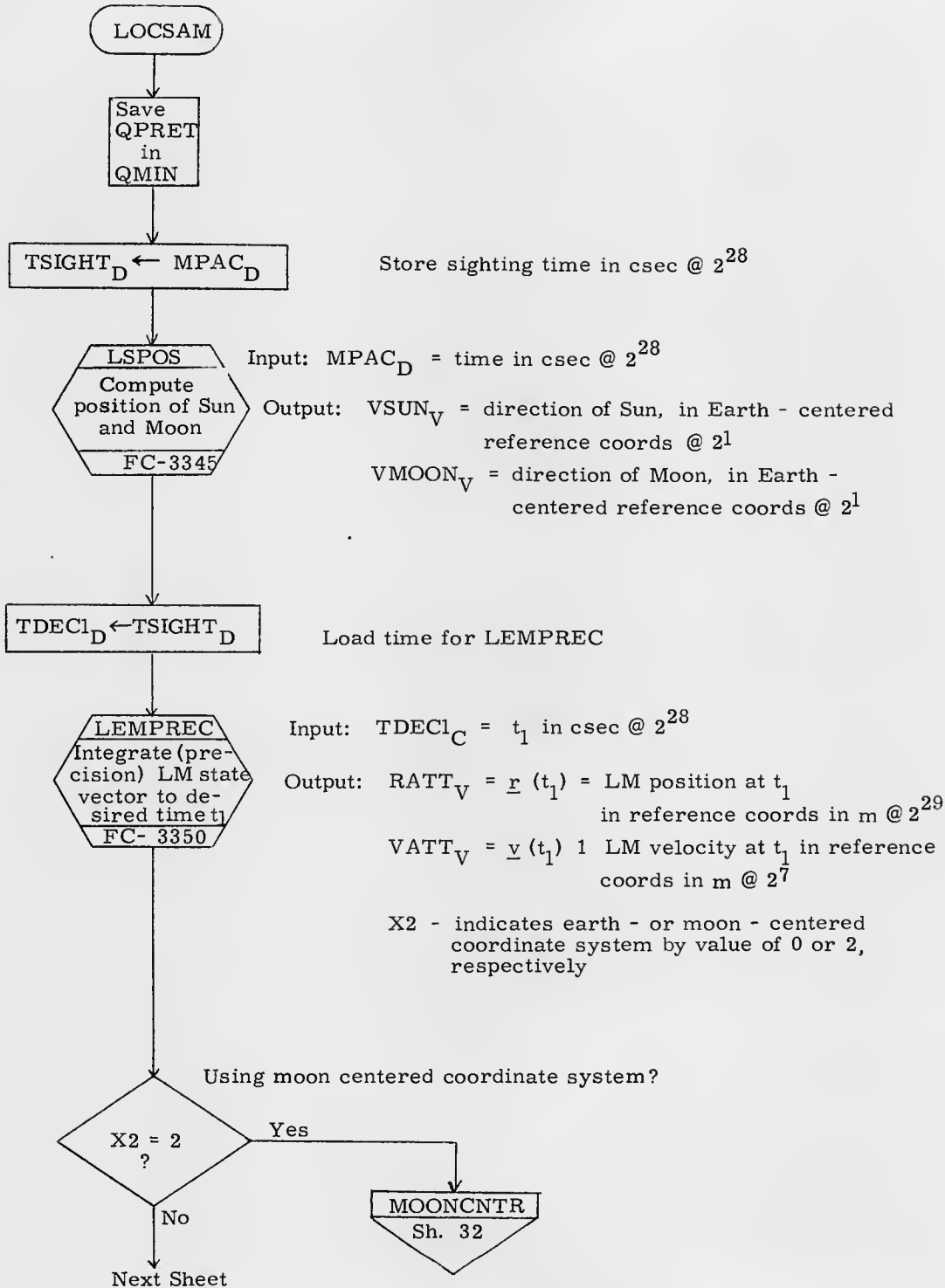
Input: $XDC_M = \begin{bmatrix} XDC_V \\ YDC_V \\ ZDC_V \end{bmatrix}$ = desired SM axes relative to present SM coords @ 2^1

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DOCMR			
APPR'D <i>Robert M. Eide 2/6/70</i>	REV 1	SHEET 29 OF 55	



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DRAWN <i>D. Autbeluck 10/9/69</i>		P52	
PKGMAR		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3510
DOCMR			
APPR'D <i>R. S. ...</i>	3/6/70	REV 1	SHEET 30 OF 55

From Preceding Sheet

EARTCNTR

$$\underline{u}_M = \text{Unit} (R_{EM} \cdot \underline{u}_{EM} - \underline{R}_L)$$

$$\text{VMOON}_V \leftarrow \text{Unit} (2^1 \cdot \text{RSUBEM}_D \cdot \text{VMOON}_V - \text{RATT}_V)$$

Compute direction of Moon relative to LM in reference coords @ 2¹

where
 RSUBEM_D = mean distance from Earth to Moon
 = 384402000 m. @ 2²⁹
 2¹ factor is for scaling

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

$$\text{VEARTH}_V \leftarrow -\text{Unit} (\text{RATT}_V)$$

Direction of Earth relative to LM in reference coords @ 2¹

$$\text{PL } 36_D \leftarrow |\text{RATT}_V|$$

$$\text{MPAC}_D \leftarrow \text{RSUBEM}_D$$

Distance between Earth and LM in m @ 2²⁹

r_E = Earth equatorial radius
 = 6378166 m. @ 2²⁹

OCCOS

Compute cosine of angle of occultation (@ 2²)

$$\text{MPAC}_D \leftarrow 2^{-1} \cos \left[5^\circ + \sin^{-1} \left(\frac{\text{MPAC}_D}{2 \cdot \text{PL } 36_D} \right) \right]$$

2⁻¹ factor is for scaling

Return via QPRET

$$\text{CEARTH}_D \leftarrow \text{MPAC}_D$$

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

cos (angle of occultation of Earth) @ 2²

@ 2²

ENDSAM
Sh. 33

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. L. ... 1/4/68</i>		P52	
PRGMR		LUMINARY 1D	DOCUMENT NO.
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DOCMR			
APPR'D <i>Roberta M. ... 3/6/70</i>		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 @ 2¹ where ROE_D = ρ_E = ratio of Earth-Sun distance to Earth-Moon distance = .00257125 @ 2⁰

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

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

Direction of Earth relative to LM in Moon-centered reference coords @ 2¹

where RSUBEM_D = R_{EM} = mean distance from Earth to Moon = 384402000 m. @ 2²⁹

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

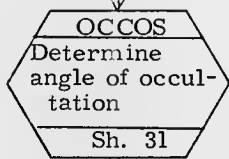
$$VMOON_V \leftarrow - \text{Unit} (RATT_V)$$

Direction of Moon relative to LM in Moon-reference coords @ 2¹

$$PL36_D \leftarrow |RATT_V|$$

$$MPAC_D \leftarrow RSUBEM_D$$

Distance between Moon and LM in m @ 2²⁹
r_M = Moon equatorial radius = 1738090 m. @ 2²⁹



Input: PL36_D = distance to body in m @ 2²⁹
MPAC_D = radius of body in m @ 2²⁹
Output: MPAC_D = cosine of angle of occultation @ 2²

$$CMOON_D \leftarrow MPAC_D$$

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

Cos (angle of occultation of Moon) @ 2² @ 2²

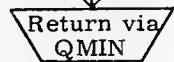
Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Zickmund 10/9/69</i>		P52	
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ANALST			
DOCMR			
APPR'D <i>Robert M. Estab</i>	<i>3/6/70</i>	REV 1	SHEET 32 OF 55

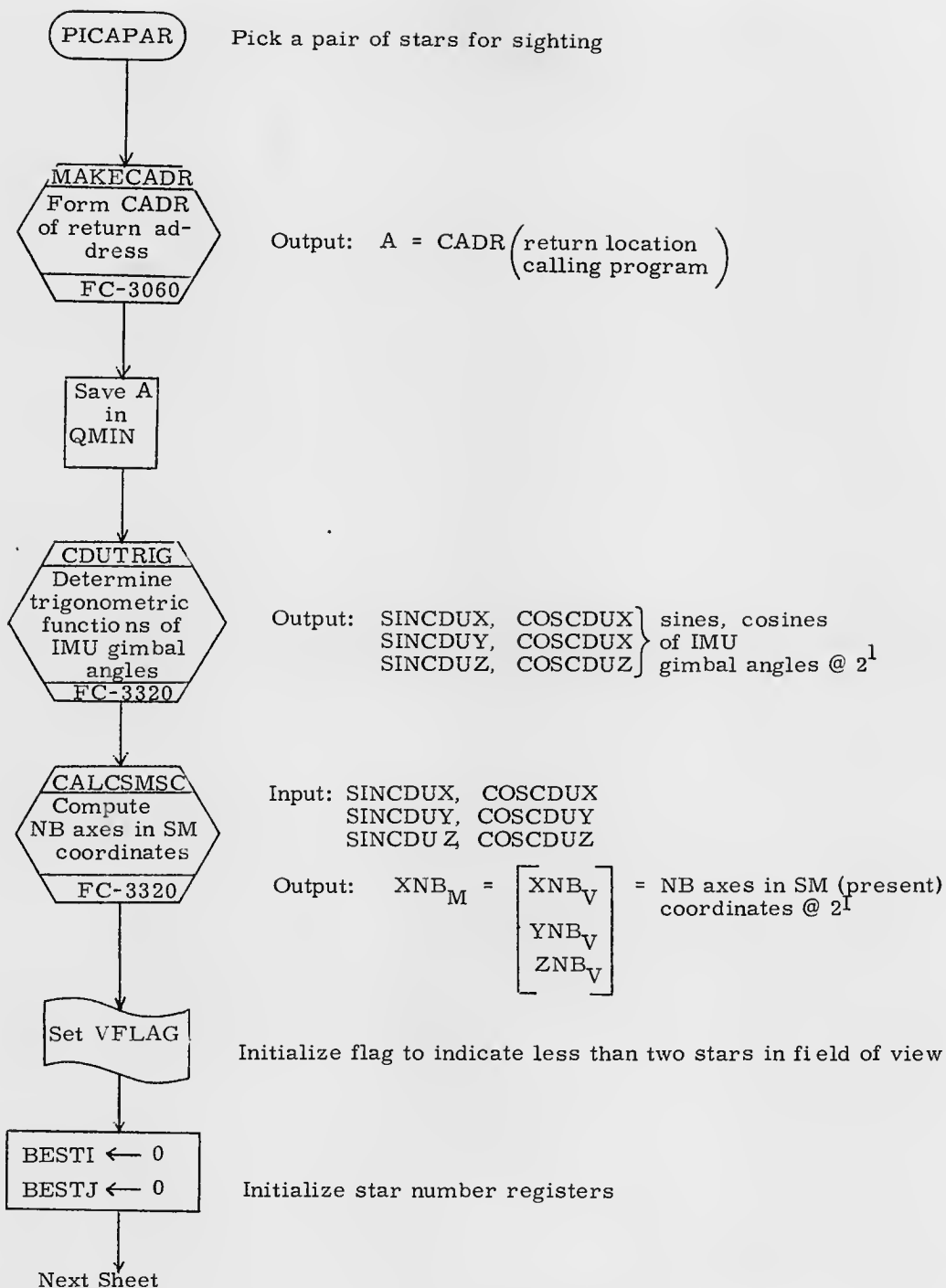
From Preceding Sheet



$CSUN_D \longleftarrow \cos(60^\circ) @ 2^2$



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APPR'D <i>Robert M. Ester</i>	<i>3/6/70</i>		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. Lytkend, 10/9/69</i>		P52	
PRGMR		LUMINARY 1D	DOCUMENT NO.
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DOCMR		REV 1	SHEET 34 of 55
APPR'D <i>Robert M. Eddy</i>	<i>2/6/70</i>		

From Preceding Sheet

$SAX_V \leftarrow \text{Unit} \left[\left(\frac{1}{2} XNB_V + \frac{1}{2} ZNB_V \right) \times \text{REFSMMAT}_M \right]$

Compute shaft axis
in reference coordi-
nates @ 2^1

$X1 \leftarrow 228D$ Initialize index register

PIC1 Find star (in reference table)
within 50° of AOT shaft axis

$X1 > 6$?

No

PICEND
Sh. 40

$X1 \leftarrow X1 - 6$

PIC2

$(\text{CATLOG}\#-X1) SAX_V \geq \cos(50^\circ)$?
Star in AOT field of view ?

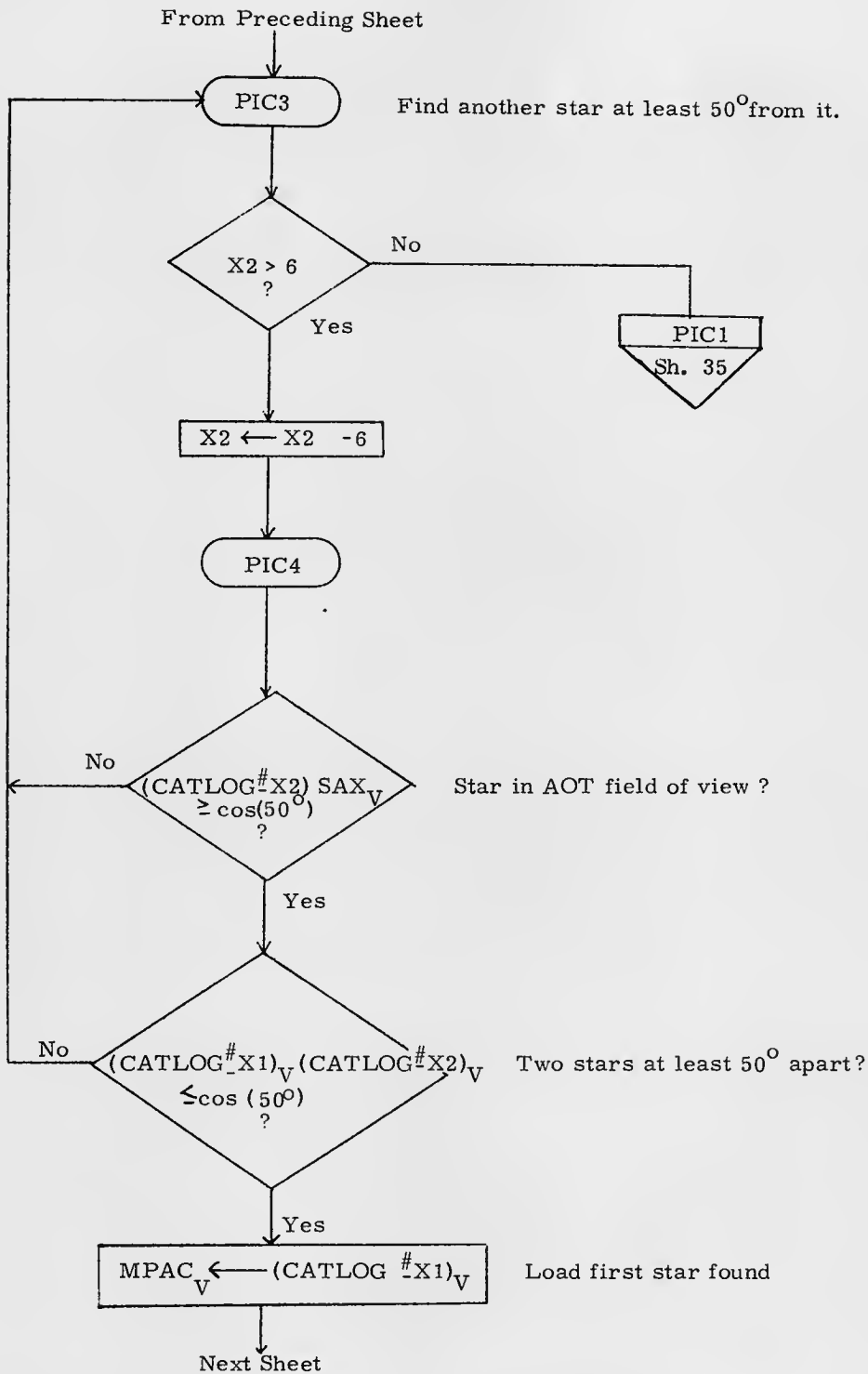
No

Yes

$X2 \leftarrow X1$ Initialize other index register to index of star found

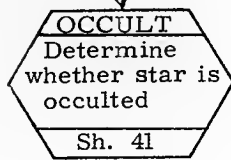
Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. Suterich 10/9/69</i>		P52	
PRGMR		DOCUMENT NO.	
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DOCMR		REV 1	SHEET 35 OF 55
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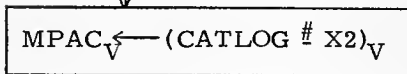
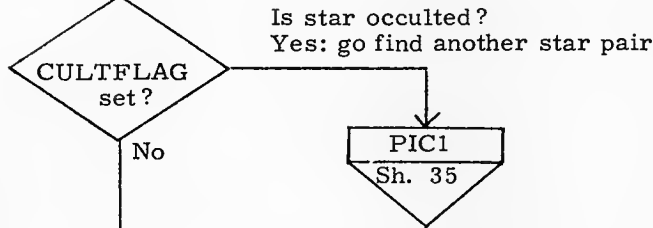
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>G. L. ... 11/67</i>		P52	
PRGMR		LUMINARY 10	DOCUMENT NO.
ANALST			FC-3510
DOCMR		REV 1	SHEET 36 OF 55
APPR'D <i>Robert M. ...</i>	<i>3/6/70</i>		

From Preceding Sheet

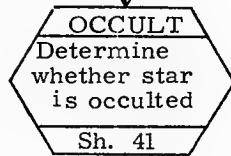


Input: $MPAC_V$ = star direction in reference coordinates @ 2^1
 $VEARTH_V$, $VSUN_V$, $VMOON_V$ = directions of Earth, Sun, Moon in reference coords @ 2^1
 $CEARTH_D$, $CSUN_D$, $CMOON_D$ = cosines of angles of occultation of Earth, Sun, Moon @ 2^2

Output: CULTFLAG - indicating whether star is occulted

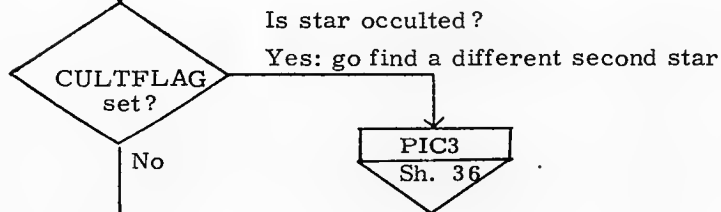


Load second star found



Input: $MPAC_V$ = star direction in reference coordinates @ 2^1
 $VEARTH_V$, $VSUN_V$, $VMOON_V$ = directions of Earth, Sun, Moon in reference coordinates @ 2^1
 $CEARTH_D$, $CSUN_D$, $CMOON_D$ = cosines of angles of occultation of Earth, Sun, Moon @ 2^2

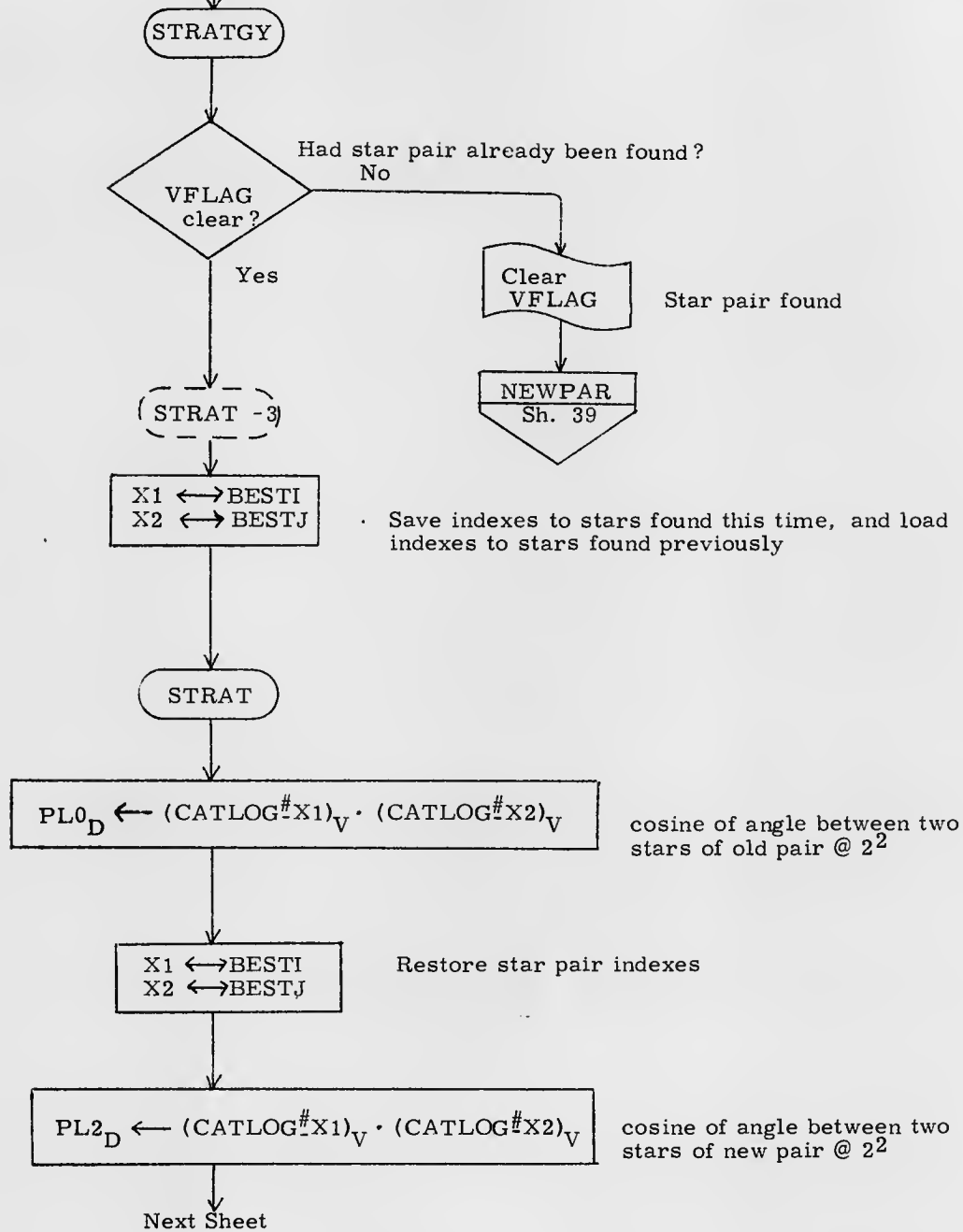
Output: CULTFLAG - indicating whether star is occulted



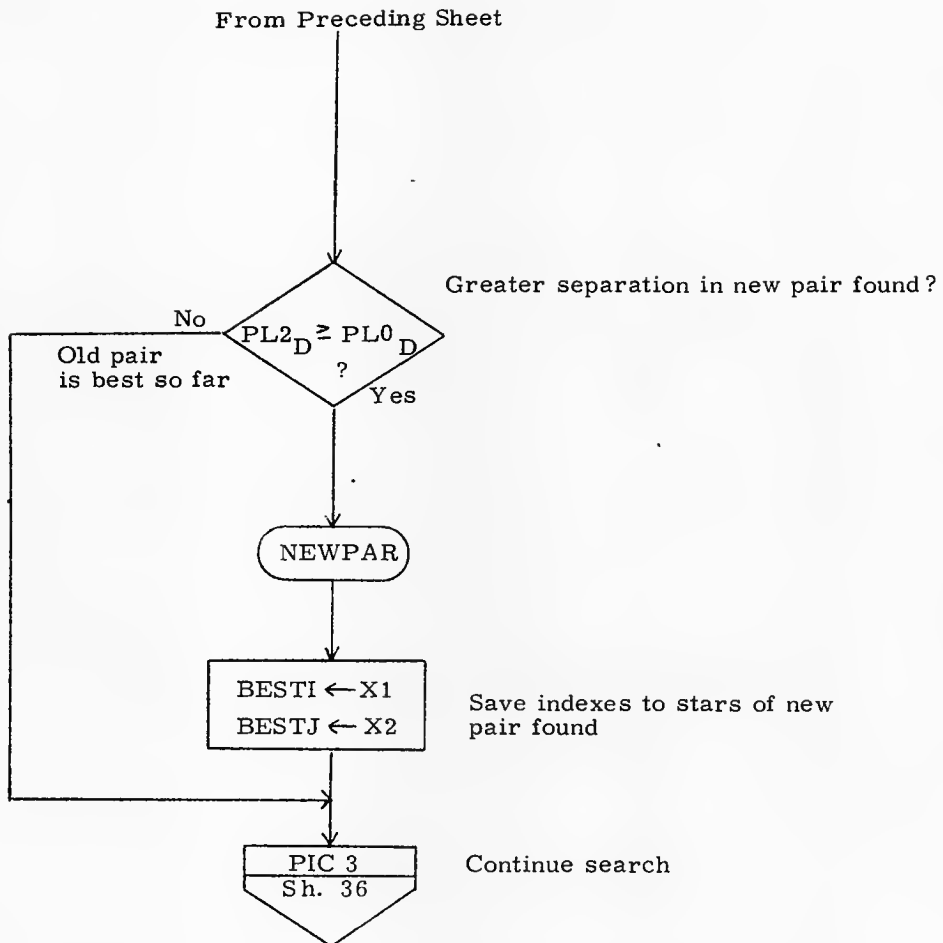
Next Sheet

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DRAWN <i>D. Luttwich 10/9/69</i>		P52	
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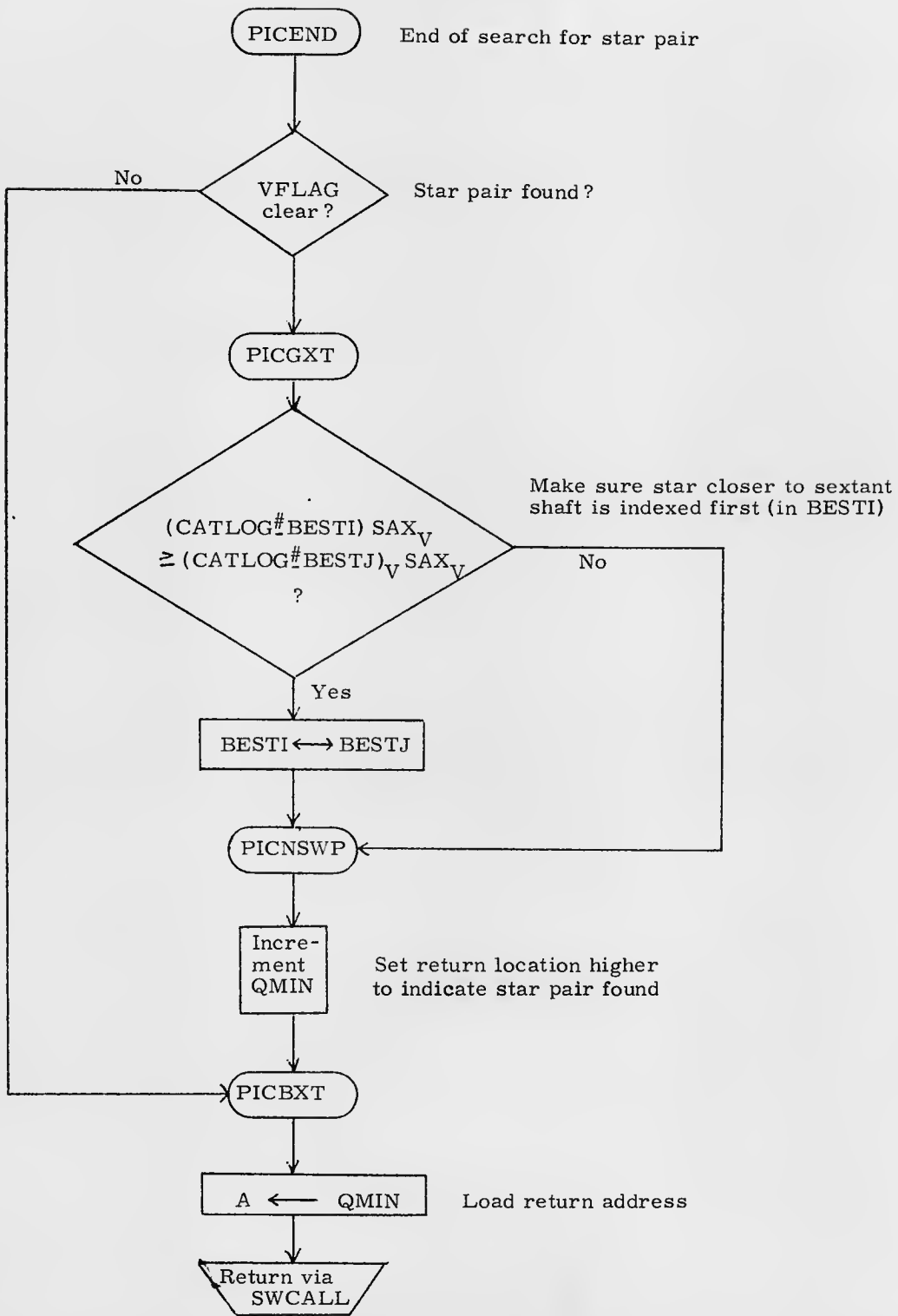
From Preceding Sheet



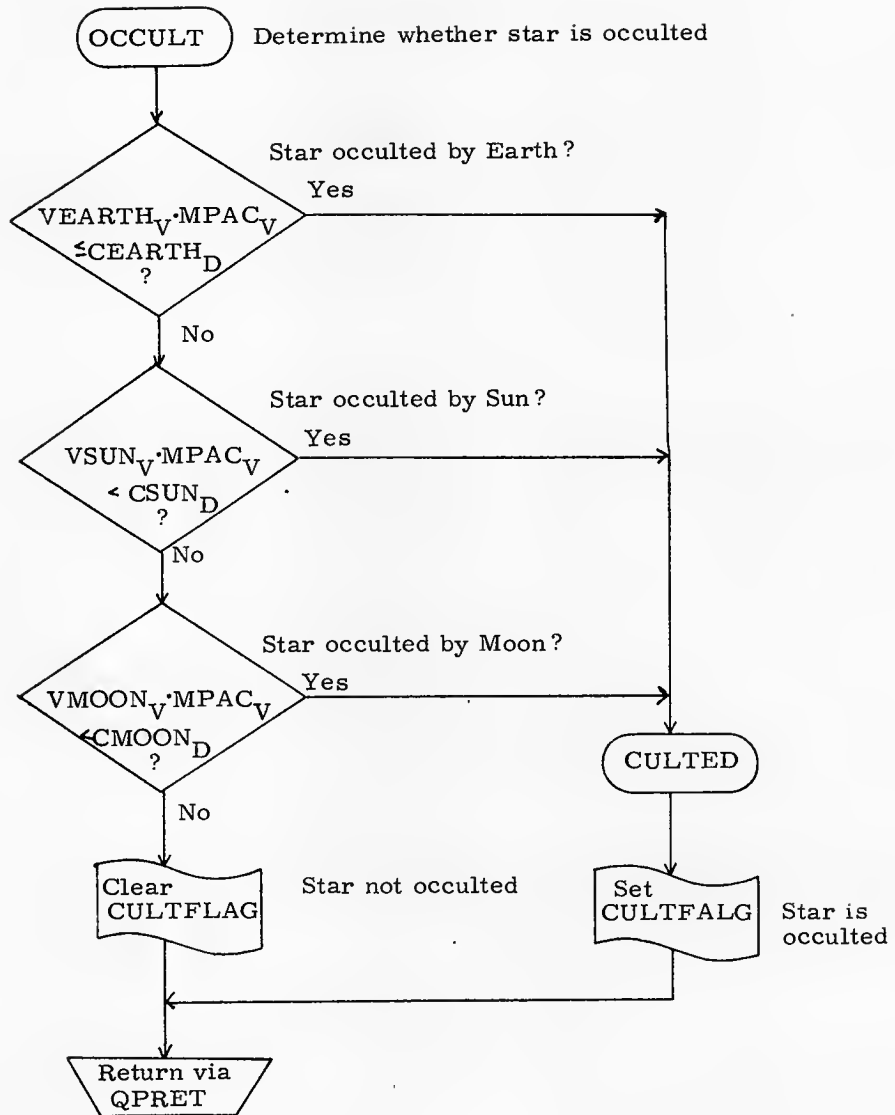
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Littered</i> 11/9/69		P52	
PRGMR		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3510
DOCMR		REV 1	SHEET 38 OF 55
APPR'D <i>Robert M. Eder</i>	3/6/70		



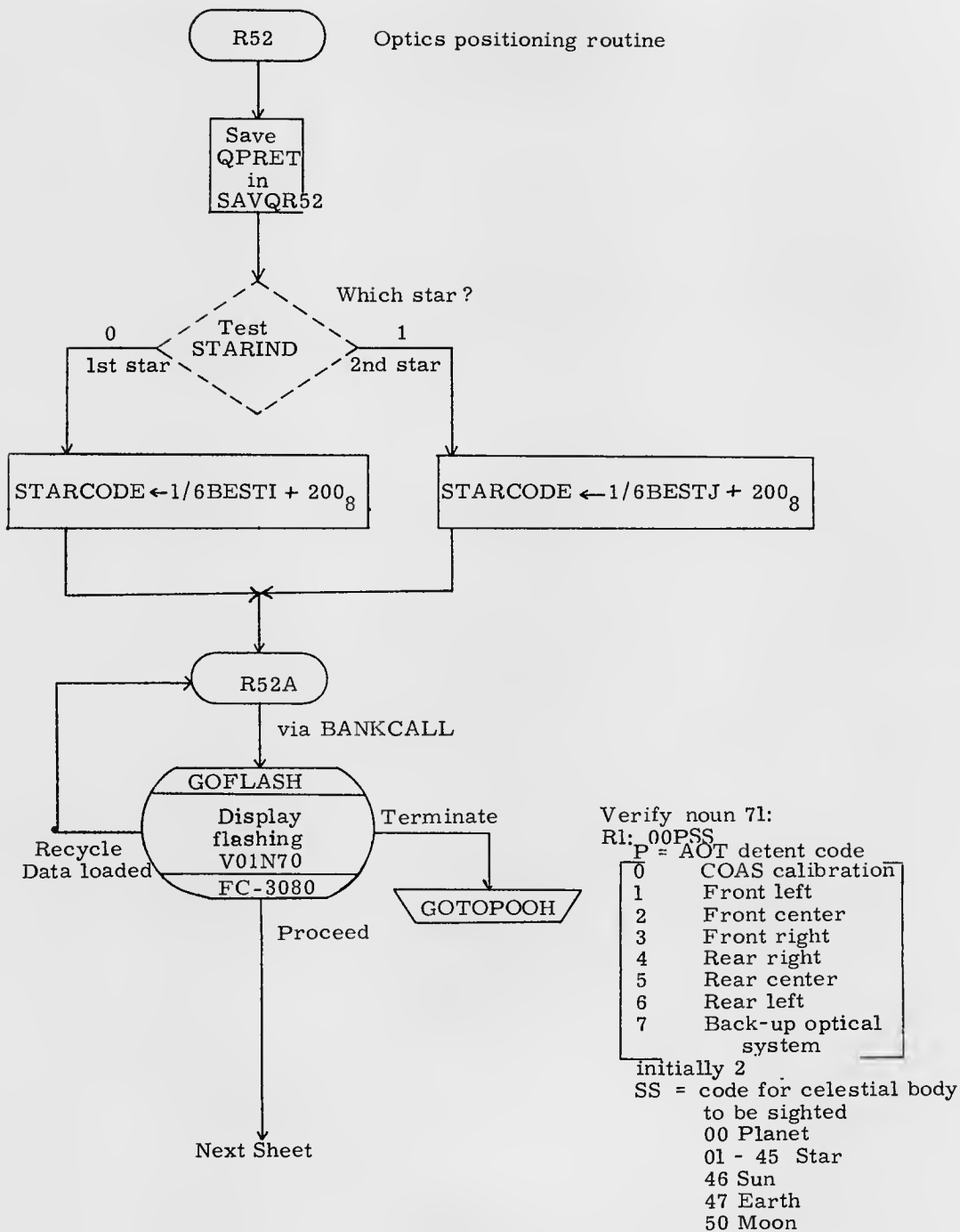
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Lutkenich 4/9/69</i>		P52	
PRGMR		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3510
DOCMR		REV 1	SHEET 39 OF 55
APPR'D <i>Robert M. Estes</i>	<i>3/6/70</i>		



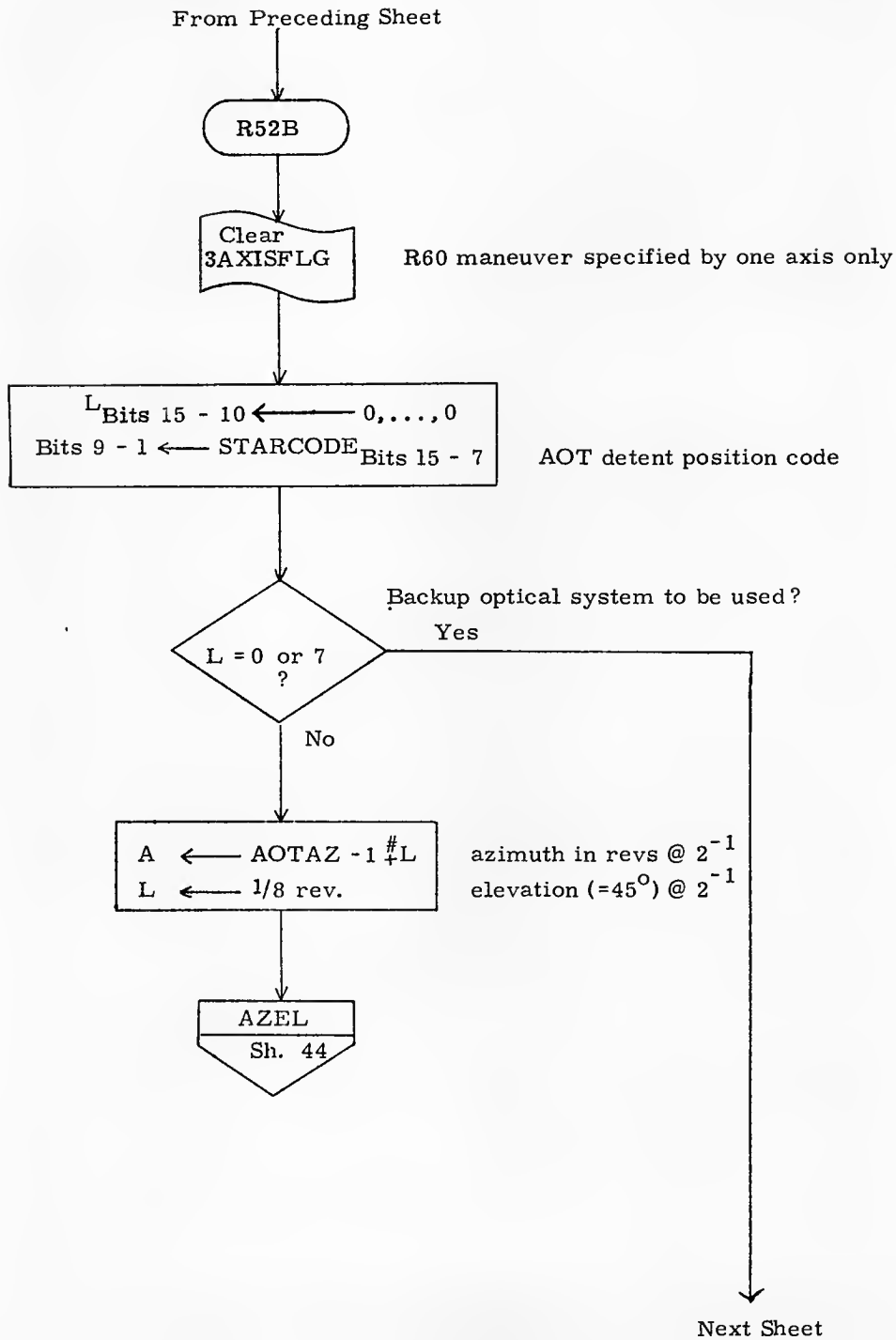
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. S. ... 1/19/69</i>		P52	
PRGMR		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3510
DOCMR		REV 1	SHEET 40 OF 55
APPR'D <i>Robert M. ... 13/6/70</i>			



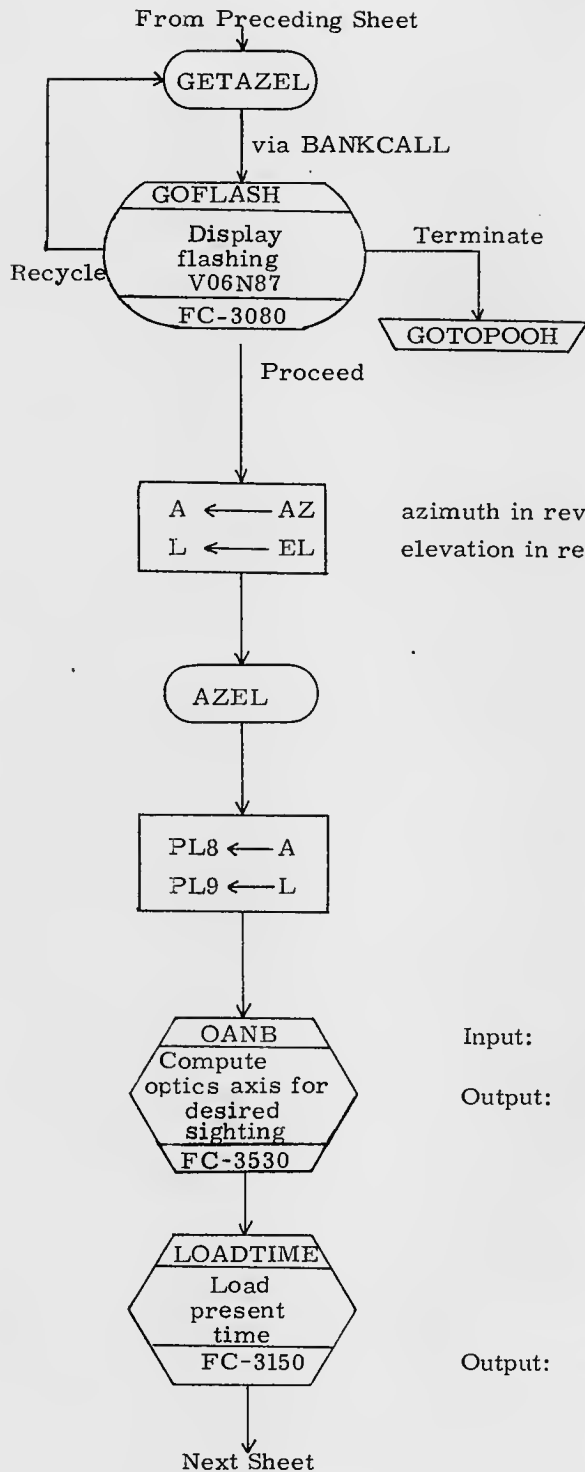
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Lutkenel 10/9/69</i>		P52	
PRGMR		LUMINARY 1D	DOCUMENT NO. FC-3510
ANALST			
DOCMR			
APPR'D <i>Robert M. Estes</i>	12/6/70	REV 1	SHEET 41 OF 55



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



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DRAWN <i>D. Littlewood 1/6/69</i>		P52	
PRGMR		LUMINARY 1D	DOCUMENT NO. FC-3510
ANALST			
DOCMR			
APPR'D <i>Roberta McEwen 3/6/70</i>		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}

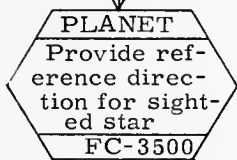
Input: PL8 = azimuth in revs @ 2^{-1}
PL9 = elevation in revs @ 2^{-1}

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

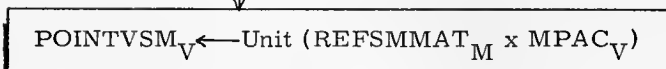
Output: MPAC_D = present time in csec @ 2^{28}

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DRAWN <i>D. Lockwood</i>	<i>10/9/69</i>	P52	
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ANALST			
DOCMR			
APPR'D <i>Robert M. Evers</i>	<i>3/6/70</i>	REV 1	SHEET 44 OF 55

From Preceding Sheet

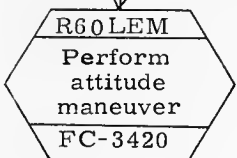


Input: MPAC_D = sighting time in csec @ 2²⁸
STARCODE = star code
Output: MPAC_V = reference vector for sighted star

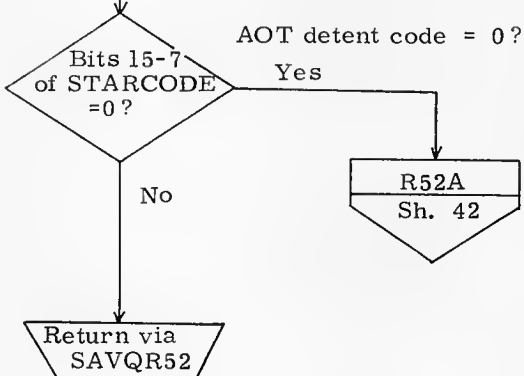


Convert vector to SM coords @ 2¹

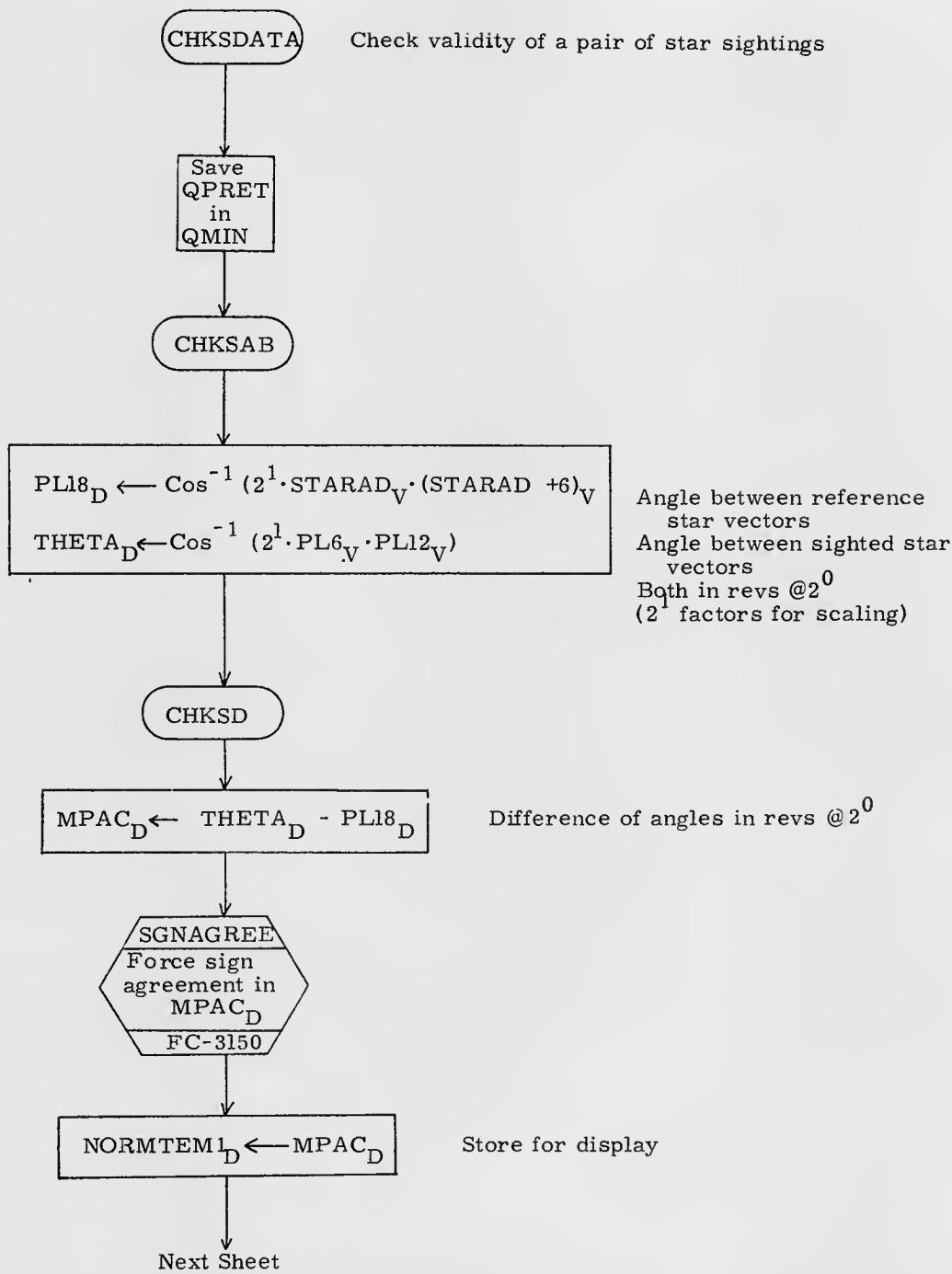
via BANKCALL



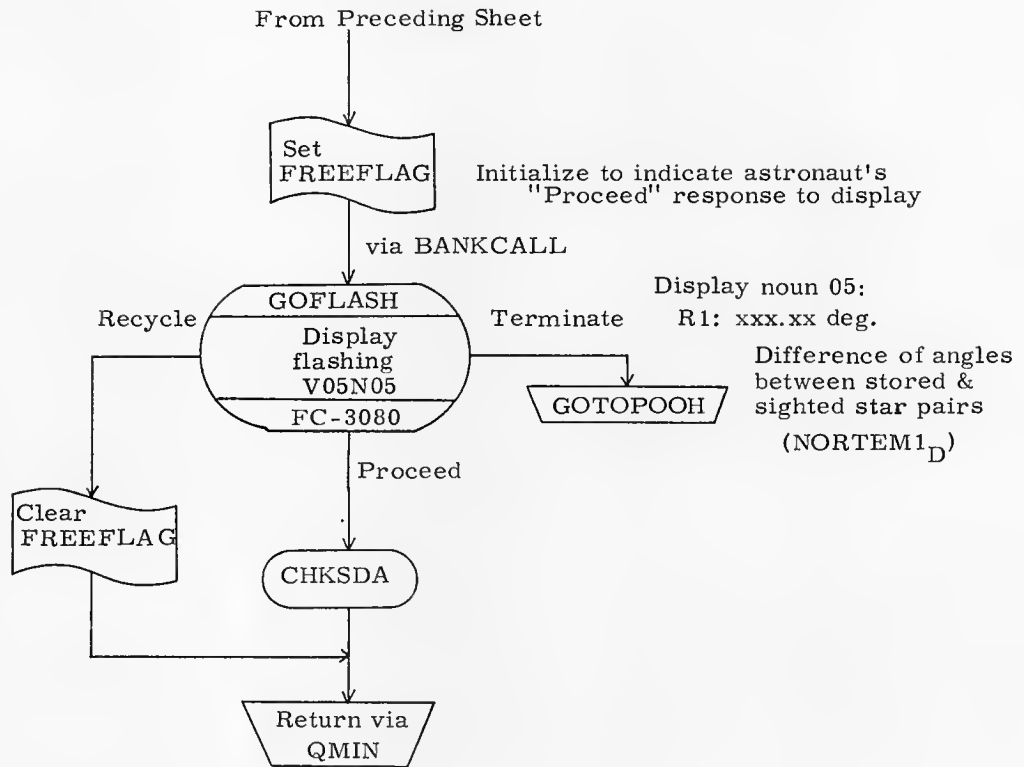
Input: SCAXIS_V = axis of spacecraft to be aligned in NB coords @ 2¹
POINTVSM_V = axis to align with in SM coords @ 2¹
3AXISFLG - clear to indicate 1-axis alignment



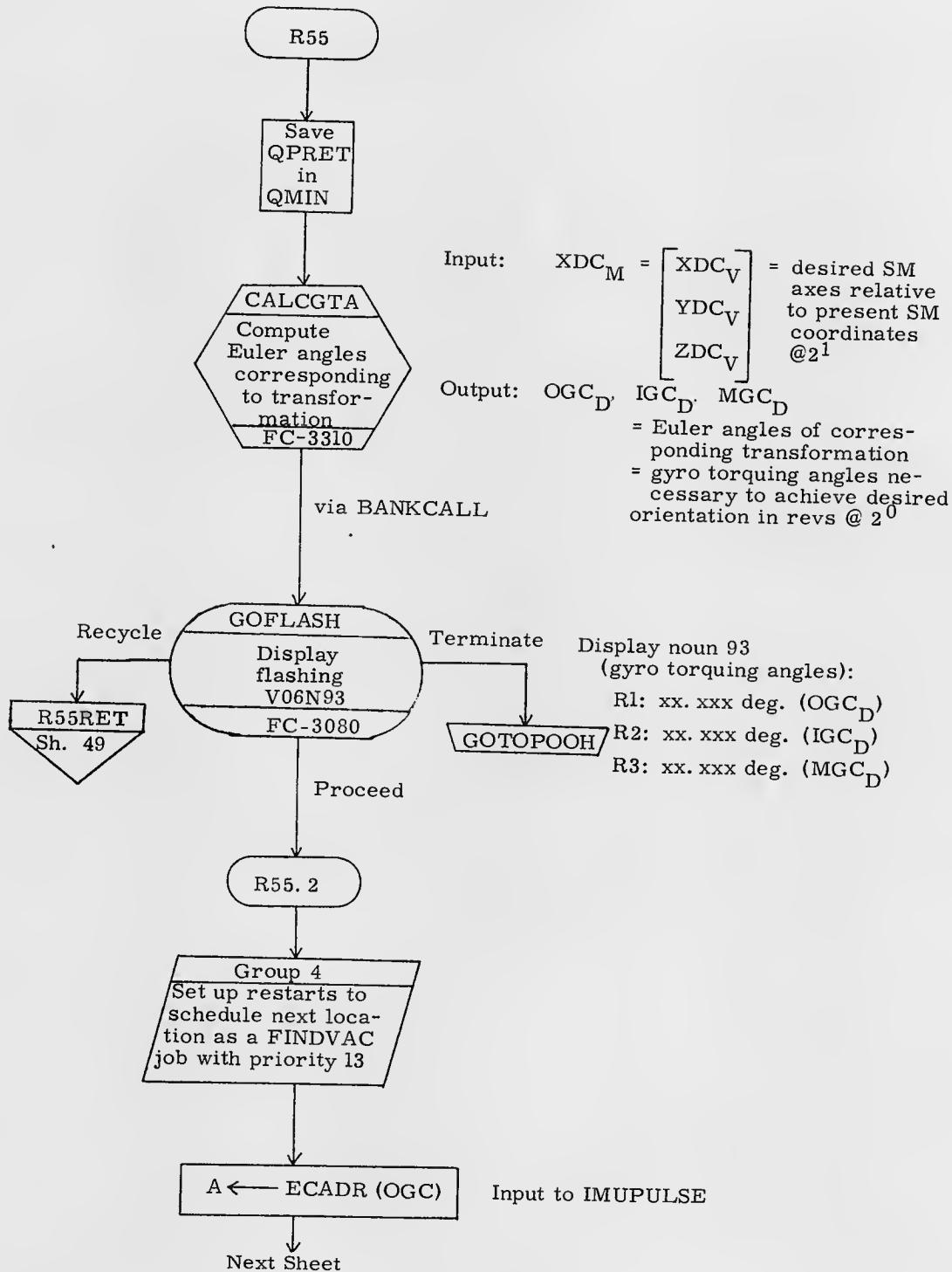
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. L. Lutenich</i> 10/9/69		P52	
PRGMR		LUMINARY 1D	DOCUMENT NO. FC-3510
ANALST			
DOCMR			
APPR'D <i>Robert M. Egan</i> 3/6/70		REV 1	SHEET 45 OF 55



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DRAWN <i>R. Lutkenich</i>	<i>12/9/69</i>	P52	
PRGMR		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3510
DOCMR		REV 1	SHEET 46 OF 55
APPR'D <i>Robert M. Estes</i>	<i>3/6/70</i>		



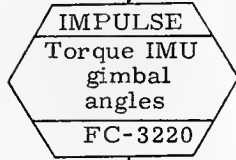
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Litten</i> 12/9/68		P52	
PRGMR		LUMINARY ID	DOCUMENT NO.
ANALST			FC-3510
DOCMR		REV 1	SHEET 47 OF 55
APPR'D <i>Robert M. Owen</i>	3/6/70		



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DRAWN <i>Robert M. Estes</i> 11/9/69		P52	
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From Preceding Sheet

via BANKCALL



Input: $A = ECADR(\mathcal{L})$, where \mathcal{L}_D $[=OGC_D]$, $(\mathcal{L} + 2)_D$
 $[=IGC_D]$, $(\mathcal{L} + 4)_D$ $[=MGC_D]$ contain gyro
torquing angles in revs @ 2^0

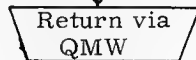
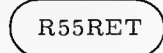
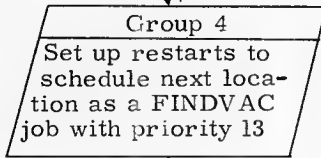
via BANKCALL



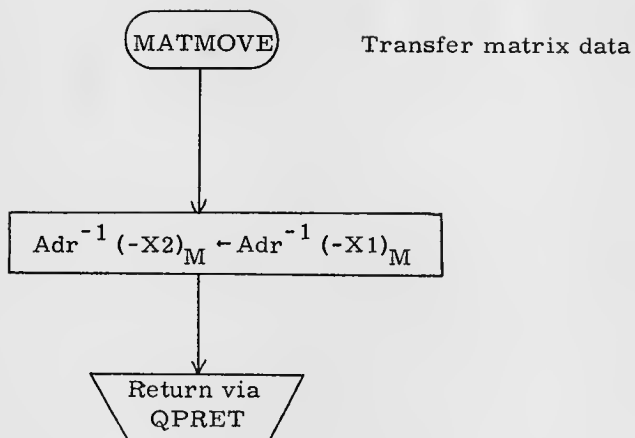
Bad return



Indicate bad return from
stall routine



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DRAWN <i>D. Subkovich</i> 10/9/69		P52	
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ANALST			FC-3510
DOCMR		REV 1	SHEET 49 OF 55
APPR'D <i>Robert M. Edwards</i> 3/6/70			



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DRAWN	<i>R. L. Smith</i>		P52
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3510
DOCMR			
APPR'D	<i>Robert M. Eden</i>	REV 1	SHEET 50 OF 55
	3/6/70		

EXTERNAL ROUTINES CALLED

<u>Routine</u>	<u>Flowchart</u>	<u>Where Called</u>
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

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DRAWN <i>D. Lutenich 1/9/69</i>		P52	
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ANALST			FC-3510
DOCMR			
APPR'D <i>Robert M. Estes 3/6/70</i>		REV 1	SHEET 51 OF 55

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	

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DRAWN <i>D. Lutenich 11/9/69</i>		P52	
PACKED		LUMINARY 1D	DOCUMENT NO. FC-3510
ANALYST			
DESIGN		REV 1	SHEET 52 OF 55
APPROV <i>Robert M. Estes 3/16/70</i>			

DISPLAYS

<u>Verb-Noun</u>	<u>Type of Display</u>	<u>Where Called</u>
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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>L. L. L...</i>	<i>10/9/69</i>	P52	
PROMR		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3510
DESGR			
APPR'D <i>Robert M. ...</i>	<i>3/4/70</i>	REV 1	SHEET 53 OF 55

ERASABLE LOCATIONS USED

ALPHAV _V	OGC _D	THETAD +2			
ALT _D	OPTION2 _D	TIME2 _D			
AOTCODE (=STARCODE)	POINTVSM _V	TLAND _D			
AZ	RATT _V	TSIGHT _D			
BESTI	REFSMMAT _M	VATT _V			
BESTJ	RLS _V	VEARTH _V			
CDUX	RRECTCSM _V	VMOON _V			
CDUY	SAX _V	VRECTCSM _V			
CDUZ	SCAXIS _V	VSUN _V			
CEARTH _D	SINCDUX	XDC _M = <table border="1" style="display: inline-table; vertical-align: middle;"><tr><td>XDC_V</td></tr><tr><td>YDC_V</td></tr><tr><td>ZDC_V</td></tr></table>	XDC _V	YDC _V	ZDC _V
XDC _V					
YDC _V					
ZDC _V					
CMOON _D	SINCDUY	XNB _M = <table border="1" style="display: inline-table; vertical-align: middle;"><tr><td>XNB_V</td></tr><tr><td>YNB_V</td></tr><tr><td>ZNB_V</td></tr></table>	XNB _V	YNB _V	ZNB _V
XNB _V					
YNB _V					
ZNB _V					
COSCDUX	SINCDUZ	XSM _M = <table border="1" style="display: inline-table; vertical-align: middle;"><tr><td>XSM_V</td></tr><tr><td>YSM_V</td></tr><tr><td>ZSM_V</td></tr></table>	XSM _V	YSM _V	ZSM _V
XSM _V					
YSM _V					
ZSM _V					
COSCDUY	STARAD _V	XSMD _M = <table border="1" style="display: inline-table; vertical-align: middle;"><tr><td>XSMD_V</td></tr><tr><td>YSMD_V</td></tr><tr><td>ZSMD_V</td></tr></table>	XSMD _V	YSMD _V	ZSMD _V
XSMD _V					
YSMD _V					
ZSMD _V					
COSCDUZ	(STARAD +6) _V				
CSUN _D	STARCODE				
EL	(= AOTCODE)				
IGC _D	STARIND				
LANDALT _D	STARSAV1 _V				
LANDLAT _D	STARSAV2 _V				
LANDLONG _D	TALIGN _D				
LAT _D	TDEC1 _D				
LONG _D	THETAD				
MGC _D	THETAD +1				

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Sullivan</i> 1/9/69		P52	
PROJECT		LUMINARY 1D	DOCUMENT NO.
ANALYST			FC-3510
DESIGNER			
APPROVED <i>Robert M. Ester</i> 3/6/70	REV 1	SHEET 54 OF 55	

CONSTANTS

(CATLOG -6)_V

(CATLOG -12D)_V

·
·
·

(CATLOG -216D)_V

(CATLOG -222D)_V

ROE_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

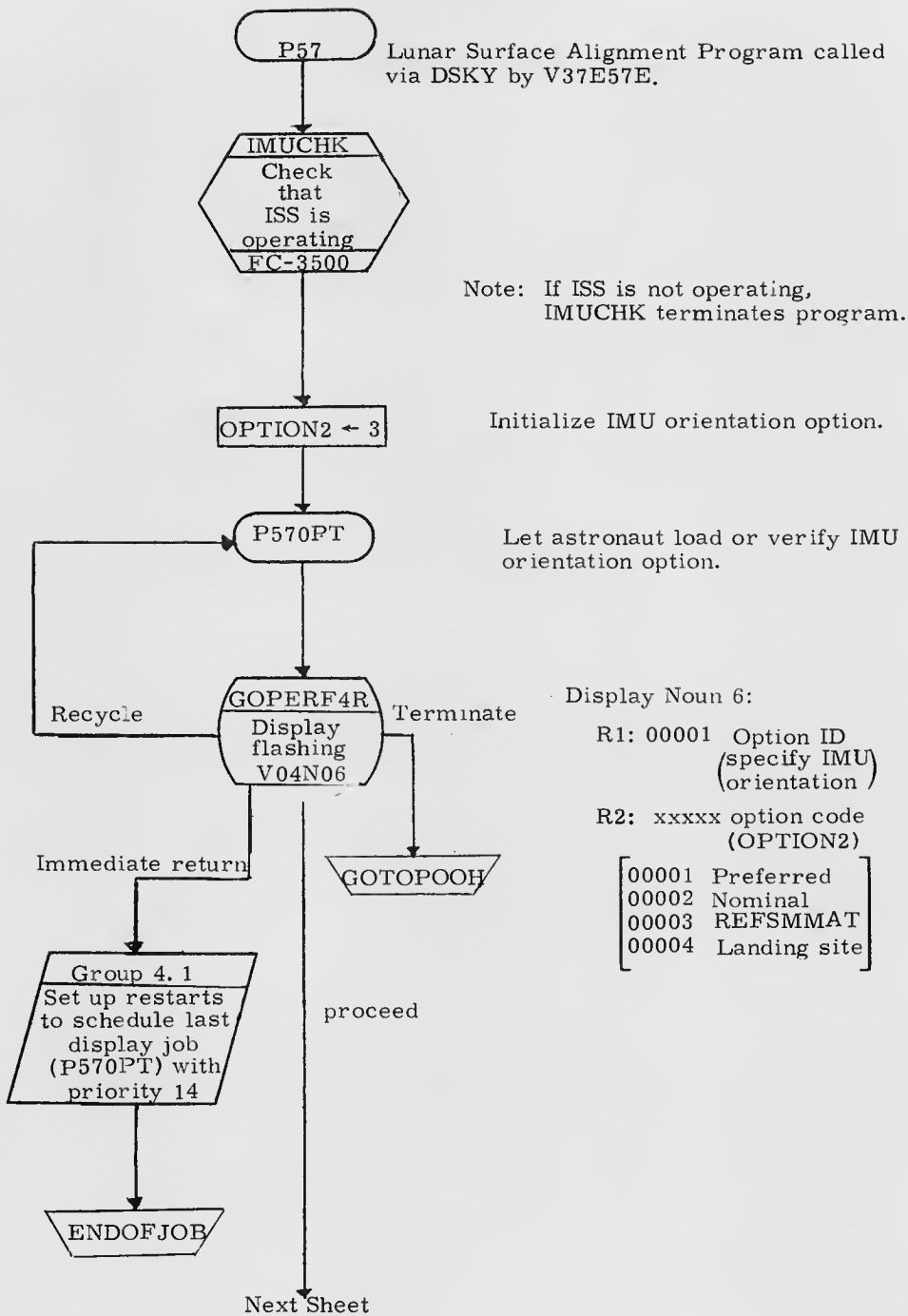
AOTEL +5

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>E. J. ...</i>		P52
PROGR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3510
OCCHR			
APPR'D	<i>Robert M. ...</i>	3/6/70 REV 1	SHEET 55 OF 55

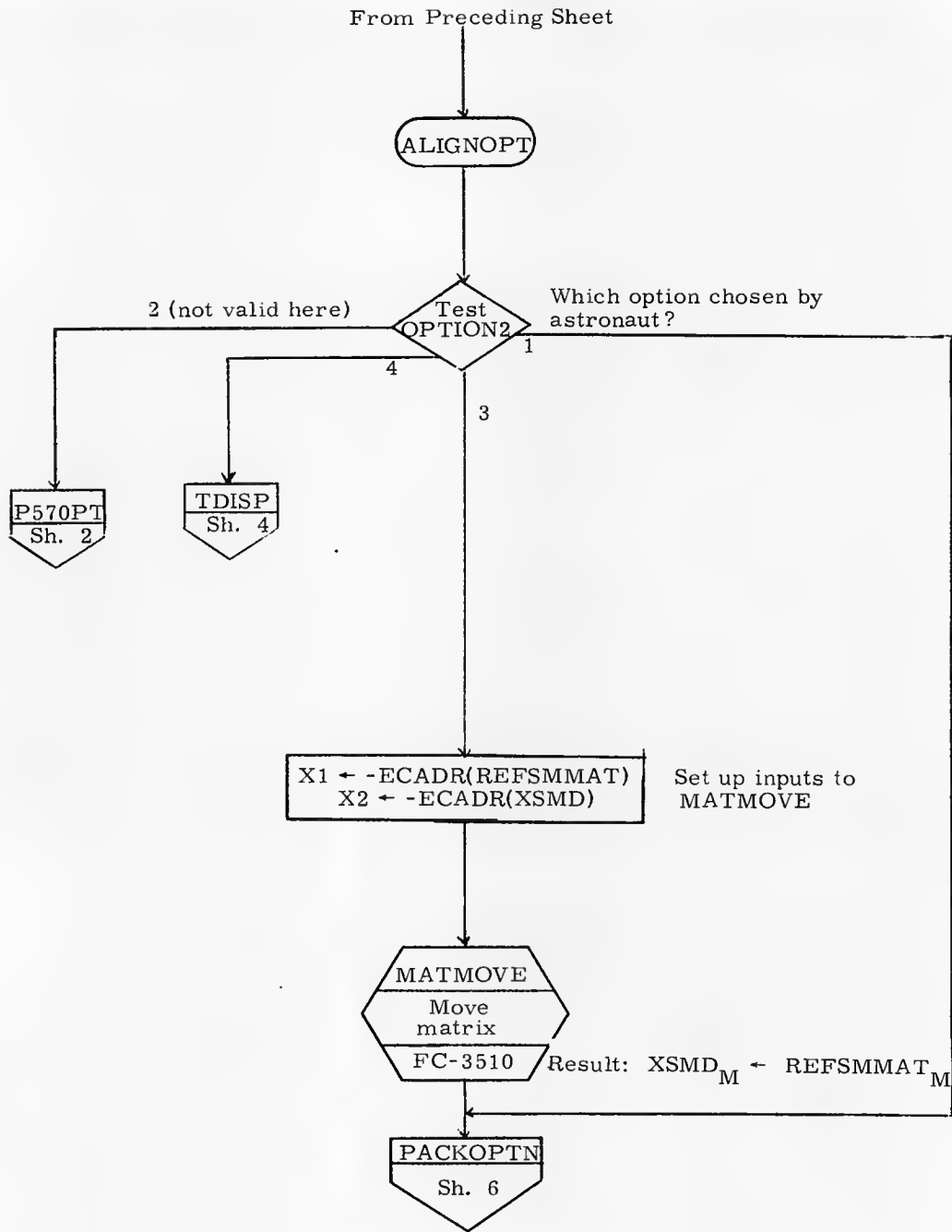
P57: Lunar Surface Alignment Program

P57	IMU alignment program - to be done on lunar surface	Sh. 2
GVDETER	Determine direction of lunar gravitation	Sh. 11
P57OPT0	Alignment Mode 0 sequence (get reference vectors: Y, Z NB axes)	Sh. 21
P57OPT1	Alignment Mode 1 sequence (get reference vectors: gravity direction, Z NB axis)	Sh. 23
P57OPT3	Alignment Mode 3 sequence (get reference vectors: gravity direction, 1 sighted star direction)	Sh. 24
P57OPT2	Alignment Mode 2 sequence (get reference vectors: 2 sighted star directions)	Sh. 25
R59	Star sighting routine	Sh. 25
SURFLINE	Compute lunar surface alignment angles (using 2 reference vectors)	Sh. 34
COATRIM	Coarse align IMU	Sh. 37
GYROTRIM	Compute angles for fine alignment	Sh. 39
JUSTTRIM	Fine align IMU	Sh. 41
SURFDISP	Do display to request performance of fine alignment (2nd attempt) option	Sh. 42
REFMF	Determine LM attitude in moon-fixed coordinates	Sh. 46
MFREF	Convert 2 reference vectors from moon-fixed to reference coordinates	Sh. 48

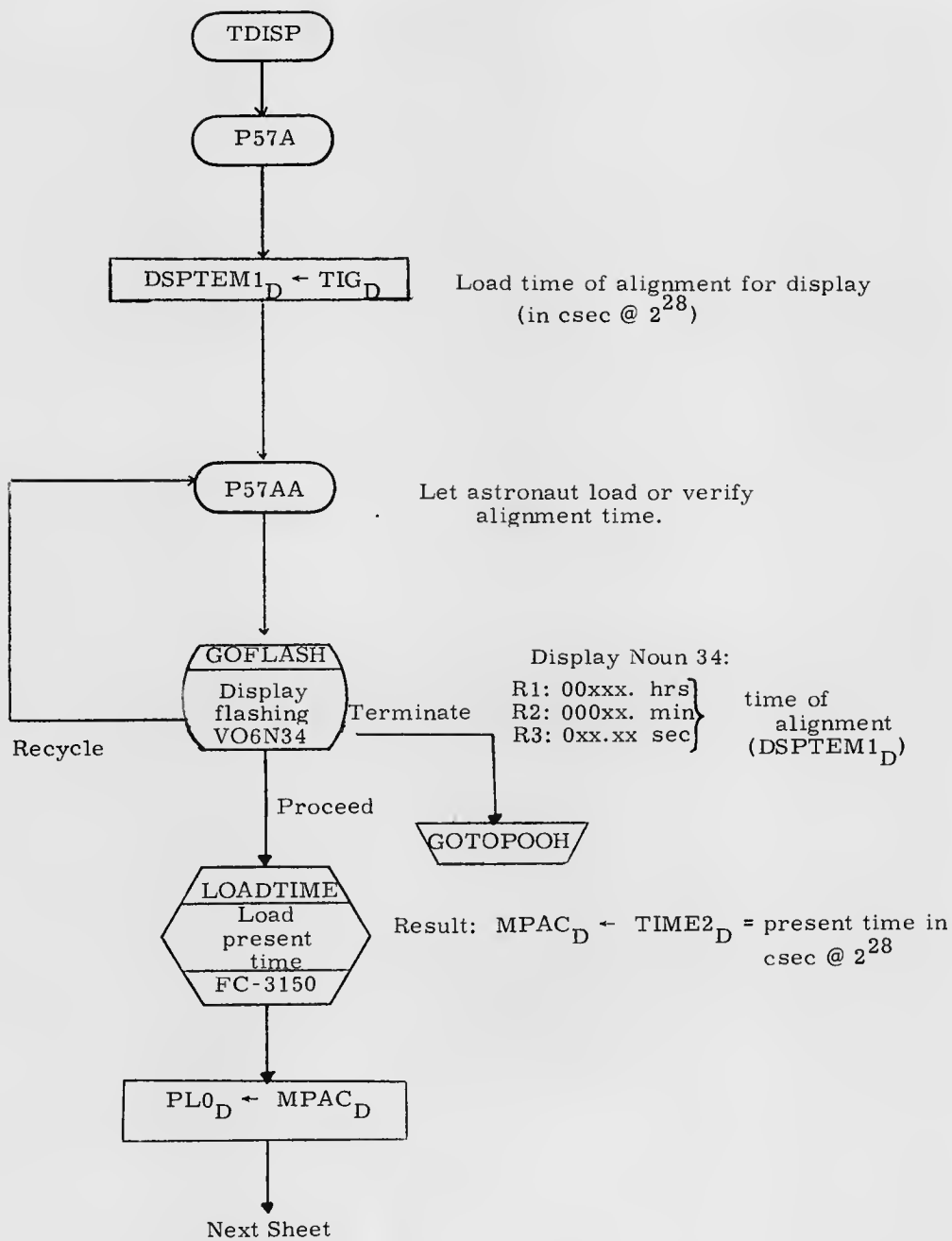
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. Cincotta</i>		P57	
PRGMR <i>J. Millard</i>		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3520
DOCMR <i>Alan M. Brant</i>		REV 2	SHEET 1 OF 65
APPR'D <i>W. Sorant</i>			



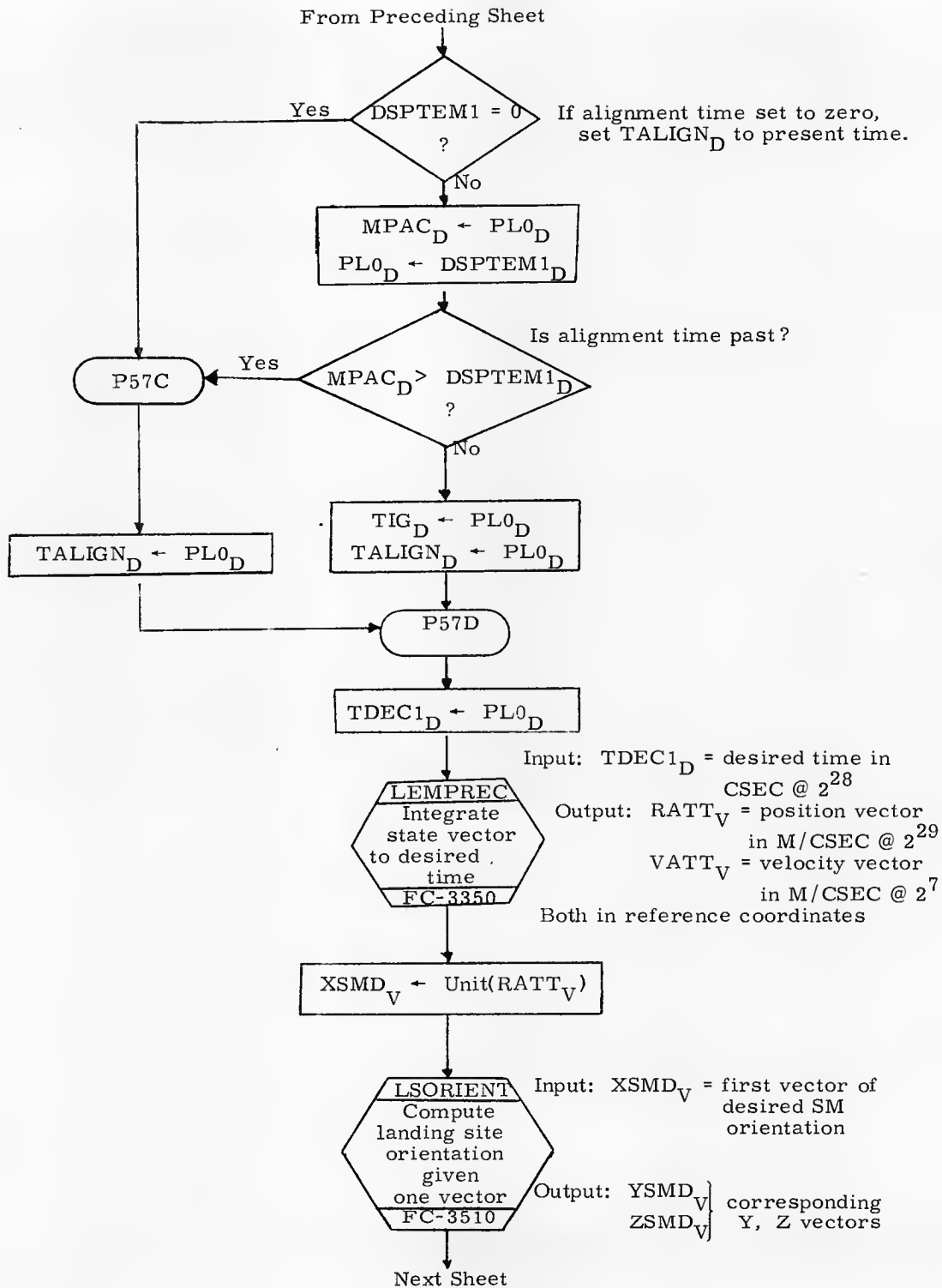
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. Conner</i>		P57	
PRGMR <i>Donald Hillard</i>		DOCUMENT NO.	
ANALST		LUMINARY ID	FC-3520
DOCMR <i>A.M. Sorant</i>		REV 2	
APPR'D <i>A.M. Sorant</i>		SHEET 2 OF 65	



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN: <i>J. C. ...</i>		P57	
PRGMR: <i>K. Muller</i>	<i>8/29/69</i>	LUMINARY 1D	DOCUMENT NO.
ANALST:			FC-3520
DOCMR: <i>G. W. ...</i>	<i>8/29/69</i>	REV 2	SHEET 3 OF 65
APPR'D: <i>[Signature]</i>	<i>8/29/69</i>		

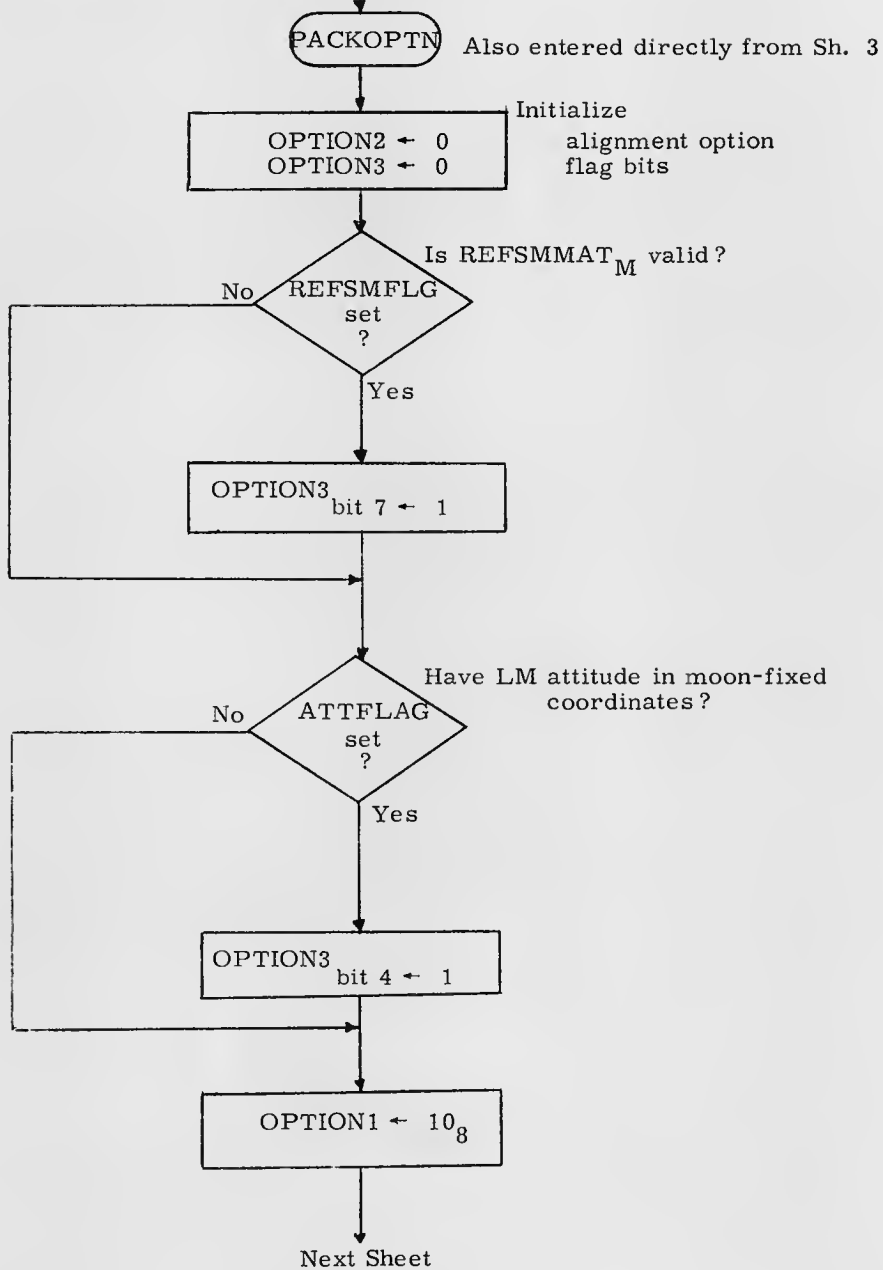


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>J. Conolly</i>	P57	
PRGMR	<i>J. Mullard</i>	DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3520
DOCMR	<i>A. M. Grant</i>	REV 2	SHEET 4 OF 65
APPR'D	<i>A. M. Grant</i>		

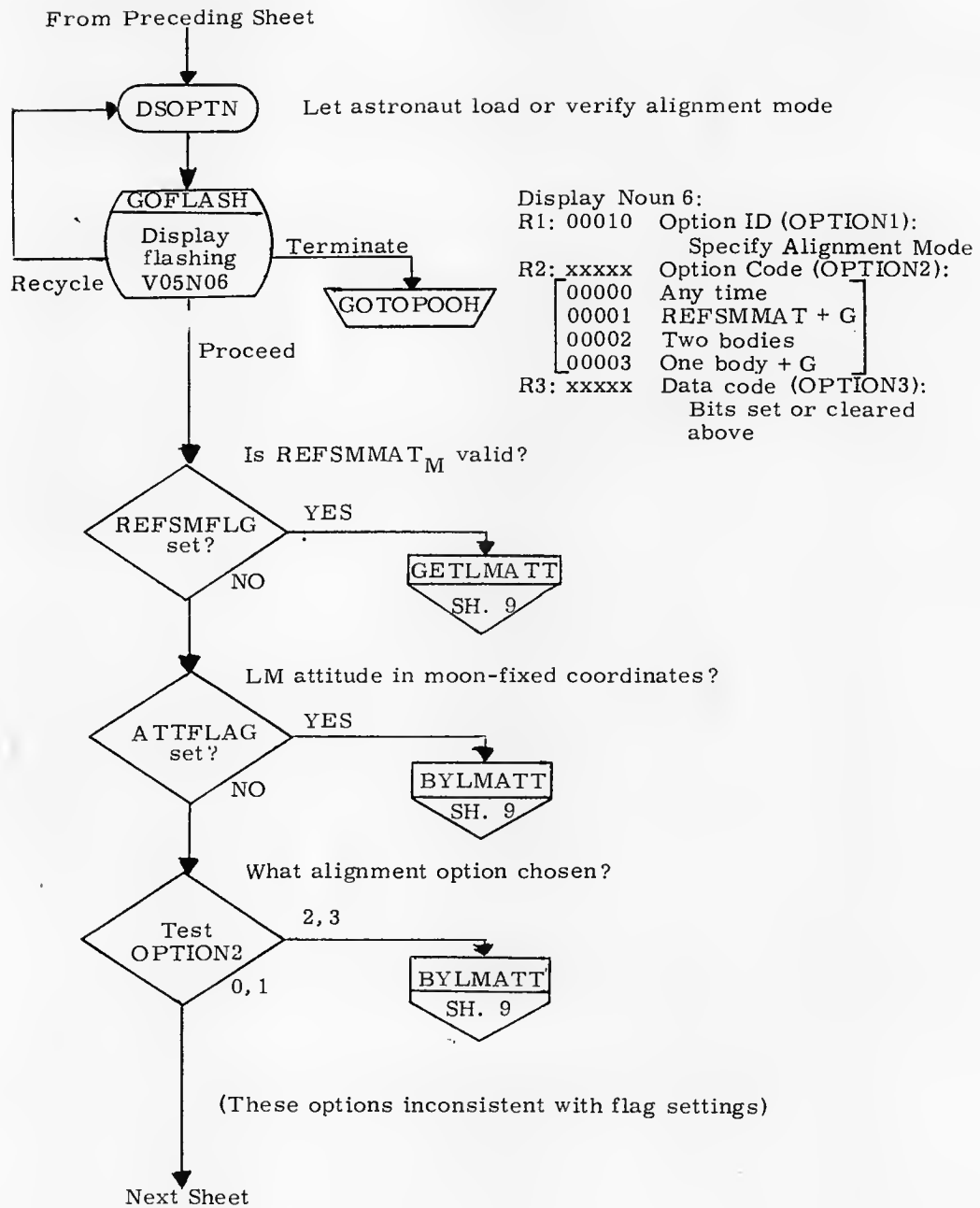


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P57	
DRAWN <i>J.C. Cicotta</i>	<i>1-30-69</i>	DOCUMENT NO.	
PRGMR <i>D. Millard</i>	<i>8/24/69</i>	LUMINARY 1D	FC-3520
ANALST		REV 2	SHEET 5 OF 65
DOCMR <i>A.M. Grant</i>	<i>8/29/69</i>		
APPR'D <i>A.M. Grant</i>	<i>8/29/69</i>		

From Preceding Sheet



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. C. ...</i> 7-21-69		P57	
PRGMR <i>D. ...</i> 8/29/69		DOCUMENT NO.	
ANALST		LUMINARY ID	FC -3520
DOCMR <i>Albert M. ...</i> 8/10/69		REV 2	SHEET 6 OF 65
APPR'D <i>...</i> 8/10/69			



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		P57	
DRAWN		LUMINARY 1D	DOCUMENT NO. FC-3520
PRGMR	<i>P. Muller</i> 8/22/69		
ANALST		REV 2	SHEET 7 OF 65
DOCMR	<i>A.M. Stewart</i> 8/28/69		
APPR'D	<i>A.M. Stewart</i> 8/29/69		

From Preceding Sheet



INPUT: Alarm code
701

(Illegal
option code
selected)

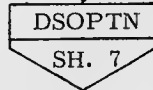


Display Noun 9:
Alarm Codes

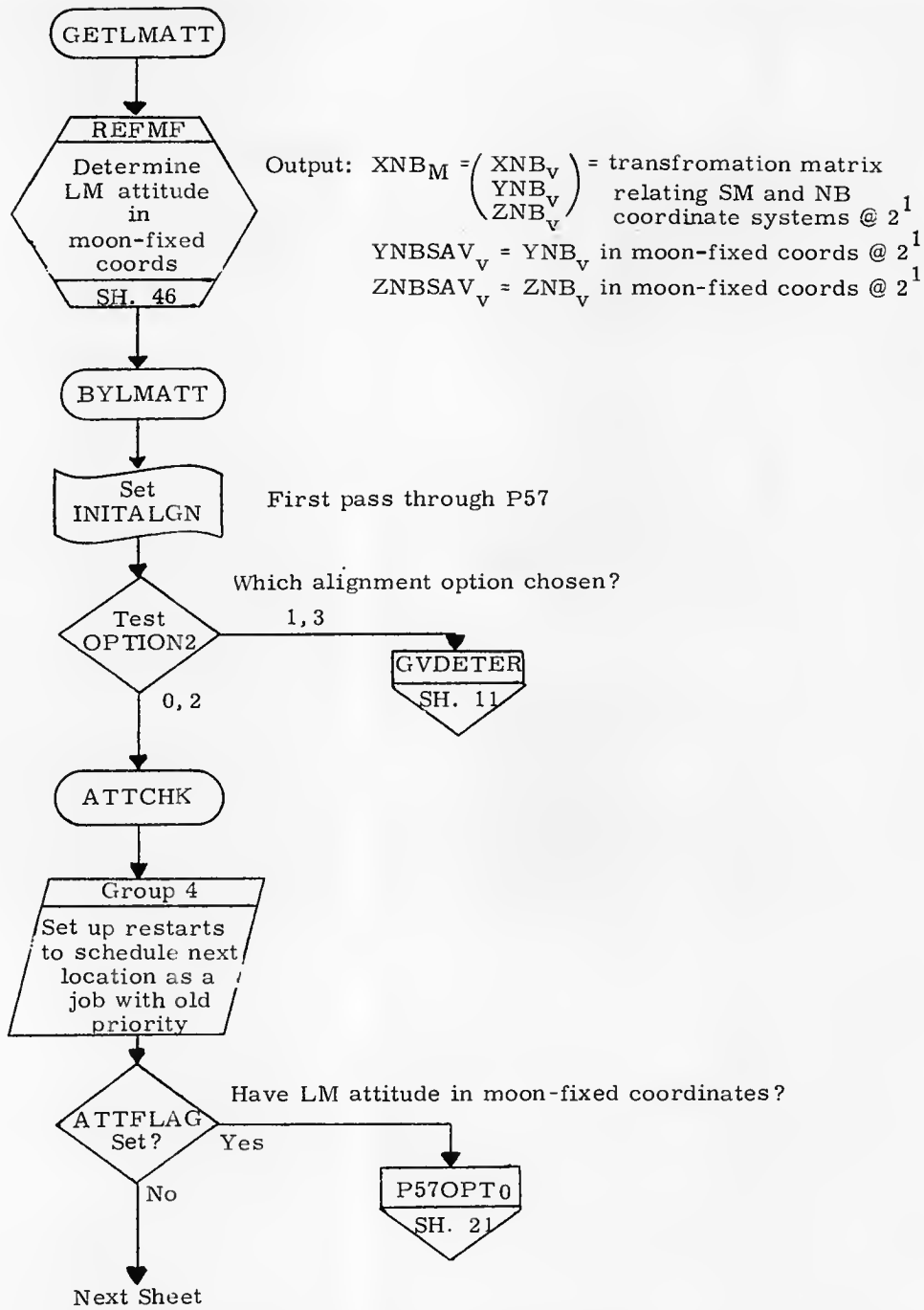
Terminate



Recycle,
Proceed

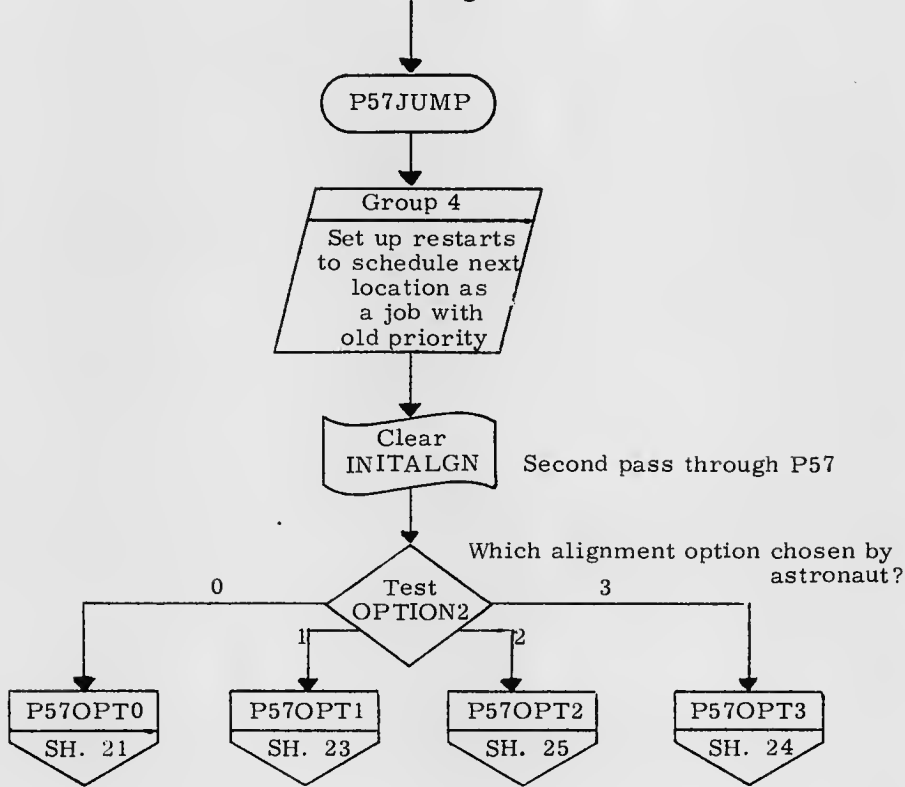


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P57	
DRAWN		LUMINARY ID	DOCUMENT NO.
PRGMR	<i>A. Hillard</i> 8/29/69		FC-3520
ANALST		REV 2	SHEET 8 OF 65
DOCMR	<i>A.M. Sorian</i> 8/29/69		
APPR'D	<i>A.M. Sorian</i> 8/29/69		

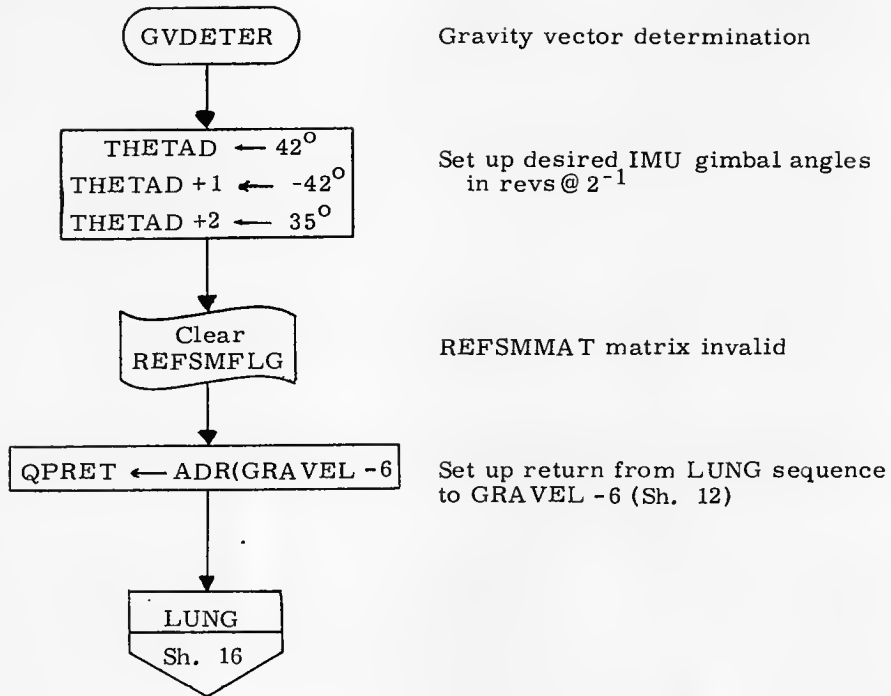


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P57	
DRAWN	<i>J. Muller</i>		
PRGMR	<i>J. Muller</i>		
ANALST			DOCUMENT NO.
DOCMR	<i>A.M. Smart</i>	LUMINARY ID	FC-3520
APPR'D	<i>A.M. Smart</i>	REV 2	SHEET 9 OF 65

From Preceding Sheet



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P57	
DRAWN			
PRGMR	<i>J. Hillard</i>	<i>9/28/69</i>	DOCUMENT NO.
ANALST			FC-3520
DOCMR	<i>U. M. Sorant</i>	<i>8/28/69</i>	LUMINARY 1D
APPR'D	<i>U. M. Sorant</i>	<i>8/28/69</i>	REV 2
			SHEET 10 OF 65



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P57	
DRAWN	<i>[Signature]</i>		
PRGMR	<i>[Signature]</i>		
ANALST			DOCUMENT NO.
DOCMR	<i>[Signature]</i>	LUMINARY 1D	FC-3520
APPR'D	<i>[Signature]</i>	REV 2	SHEET 11 OF 65

(GRAVEL - 6)

X1 ← 18D
X2 ← -6D

Initialize iteration registers

GRAVEL

MPAC_V ← (XUNIT - 6 #X2)_V

MPAC_V ← $\begin{cases} XUNIT_V = (1, 0, 0) @ 2^1 \\ YUNIT_V = (0, 1, 0) @ 2^1 \\ ZUNIT_V = (0, 0, 1) @ 2^1 \end{cases}$

NBSM
Convert vector
from
NB to SM
coords
FC-3320

Input: MPAC_V in NB coordinates

Output: MPAC_V = Same vector in SM coordinates

(XNB + 18D #X1)_V ← MPAC_V

$\left. \begin{matrix} XNB_V \\ YNB_V \\ ZNB_V \end{matrix} \right\} \leftarrow MPAC_V$

(XSM + 18D #X1)_V ← (STAR + 6 #X2)_D · STAR_V + 2² - (XUNIT - 6 #X2)_V

$XSM_V \leftarrow STAR_D \cdot STAR_V \cdot 2^2 - XUNIT_V$
 $YSM_V \leftarrow (STAR + 2)_D \cdot STAR_V \cdot 2^2 - YUNIT_V$
 $ZSM_V \leftarrow (STAR + 4)_D \cdot STAR_V \cdot 2^2 - ZUNIT_V$
2¹ factor is for scaling

X2 ← X2 + 2

Yes
X1 > 6
?

X1 ← X1 - 6

Next Sheet

Have obtained

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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P57	
DRAWN <i>J. Conner</i>	7-31-69		
PRGMR <i>J. Conner</i>	8/25/69		
ANALST		DOCUMENT NO.	FC-3520
DOCMR <i>J. Conner</i>	8/29/69	LUMINARY 1D	
APPR'D <i>J. Conner</i>	8/29/69	PREV 2	SHEET 12 OF 65

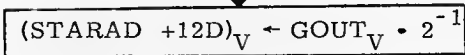
From Preceding Sheet

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

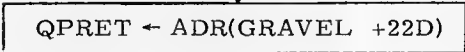
$\begin{pmatrix} XSM_V \\ YSM_V \\ ZSM_V \end{pmatrix}$ Giving desired SM orientation relative to present SM coordinates



Output: THETAD, THETAD +1, THETAD +2
= IMU gimbal angles necessary to achieve desired orientation in revs @ 2¹



Save value from first call to LUNG



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



Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. C. ...</i> 7/31/69		P57	
PRGMR <i>D. ...</i> 8/29/69		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3520
DOCMR <i>am ...</i> 8/29/69		REV 2	SHEET 13 OF 65
APPR'D <i>am ...</i> 8/29/69			

From Preceding Sheet

(GRAVEL +22D)

$$\text{STARSAV1}_V \leftarrow \text{Unit}(\text{GOUT}_V \cdot 2^{-1} + (\text{STARAD} + 12\text{D})_V)$$

Add old and new values of gravitational direction in NB coords @ 2²

$$\text{DSPTEM1}_D \leftarrow \cos^{-1}(2 \cdot \text{STARSAV1}_V \cdot \text{GSAV}_V)$$

Clear FREEFLAG

Initialize for "Proceed" case

GOFLASH
Display flashing V06N04

Display Noun 4:

R1: XXX.XX deg

gravity error angle (DSPTEM1)

Recycle

Terminate

Proceed

Indicate "Recycle"

Set FREEFLAG

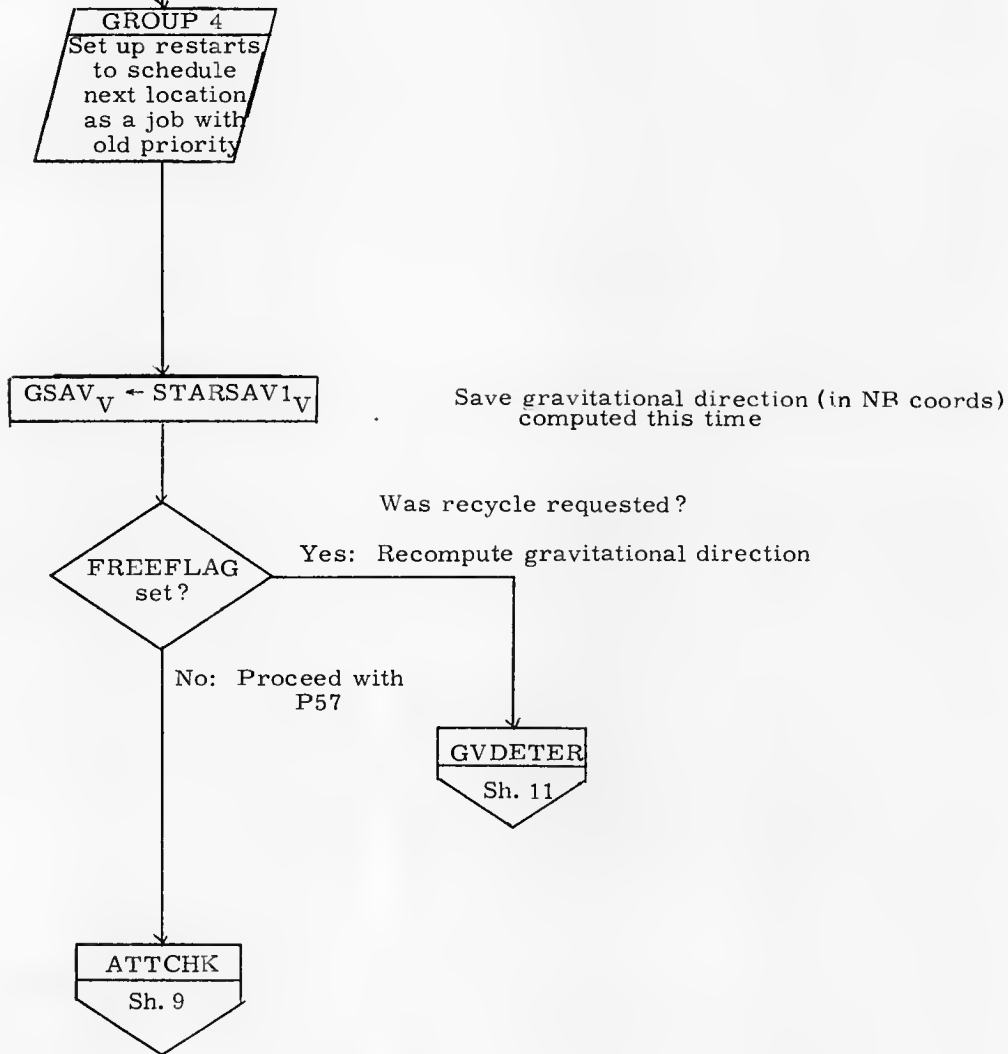
GOTOPOOH

PROGRAV

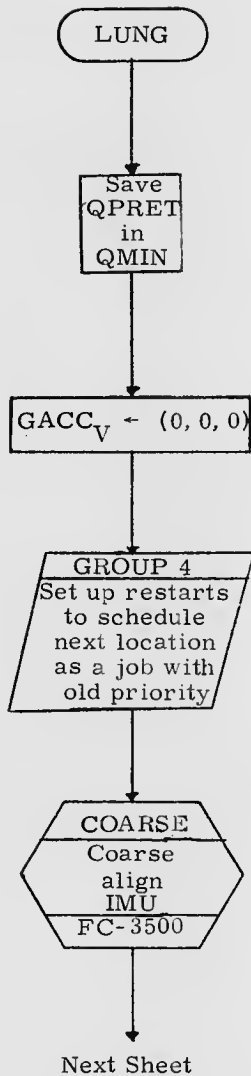
Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J.C. McClellan</i>	1-31-69	P57	
PRGMR <i>J.C. McClellan</i>	8/29/69	DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3520
DOCMR <i>A.M. Grant</i>	8/29/69	REV 2	SHEET 14 OF 65
APPR'D <i>A.M. Grant</i>	8/29/69		

From Preceding Sheet



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>J.C. Pirella</i> 7-31-67	P57	
PRGMR	<i>D. Muller</i> 8/29/67	LUMINARY 1D	DOCUMENT NO. FC-3520
ANALST			
DOCMR	<i>A.M. Sorant</i> 8/29/67		
APPR'D	<i>A.M. Sorant</i> 8/29/67	REV 2	SHEET 15 OF 65

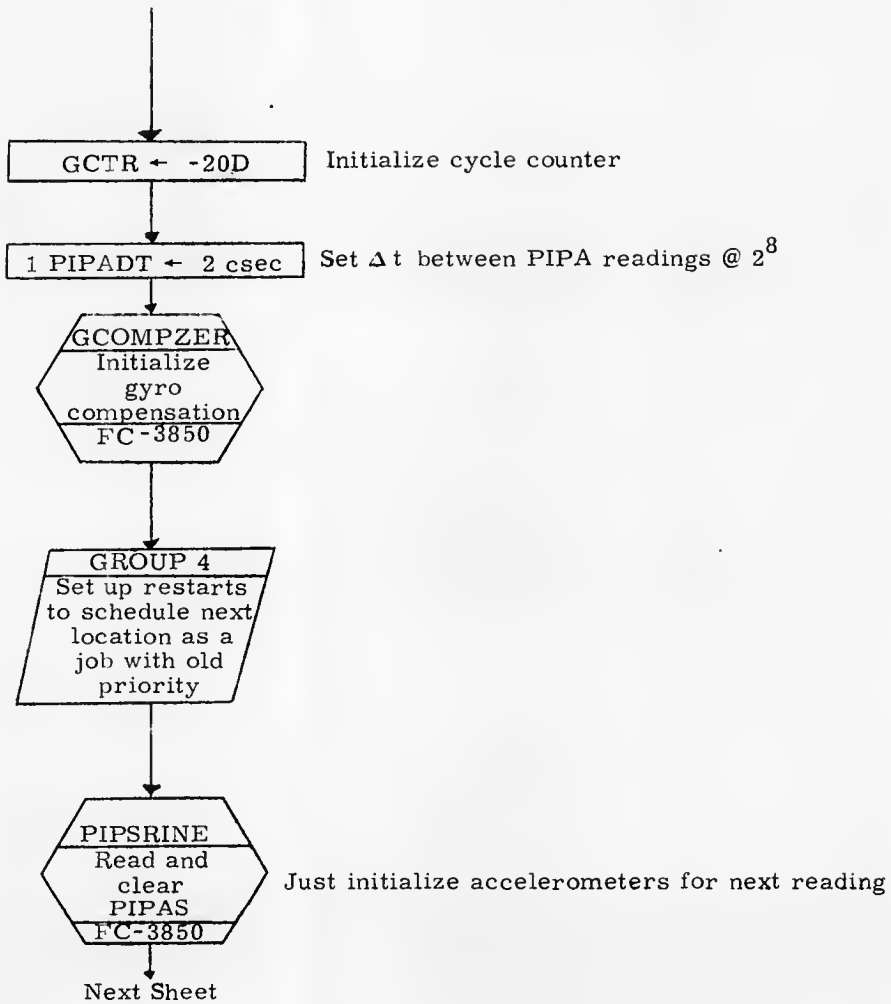


Initialize ΔV accumulation

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

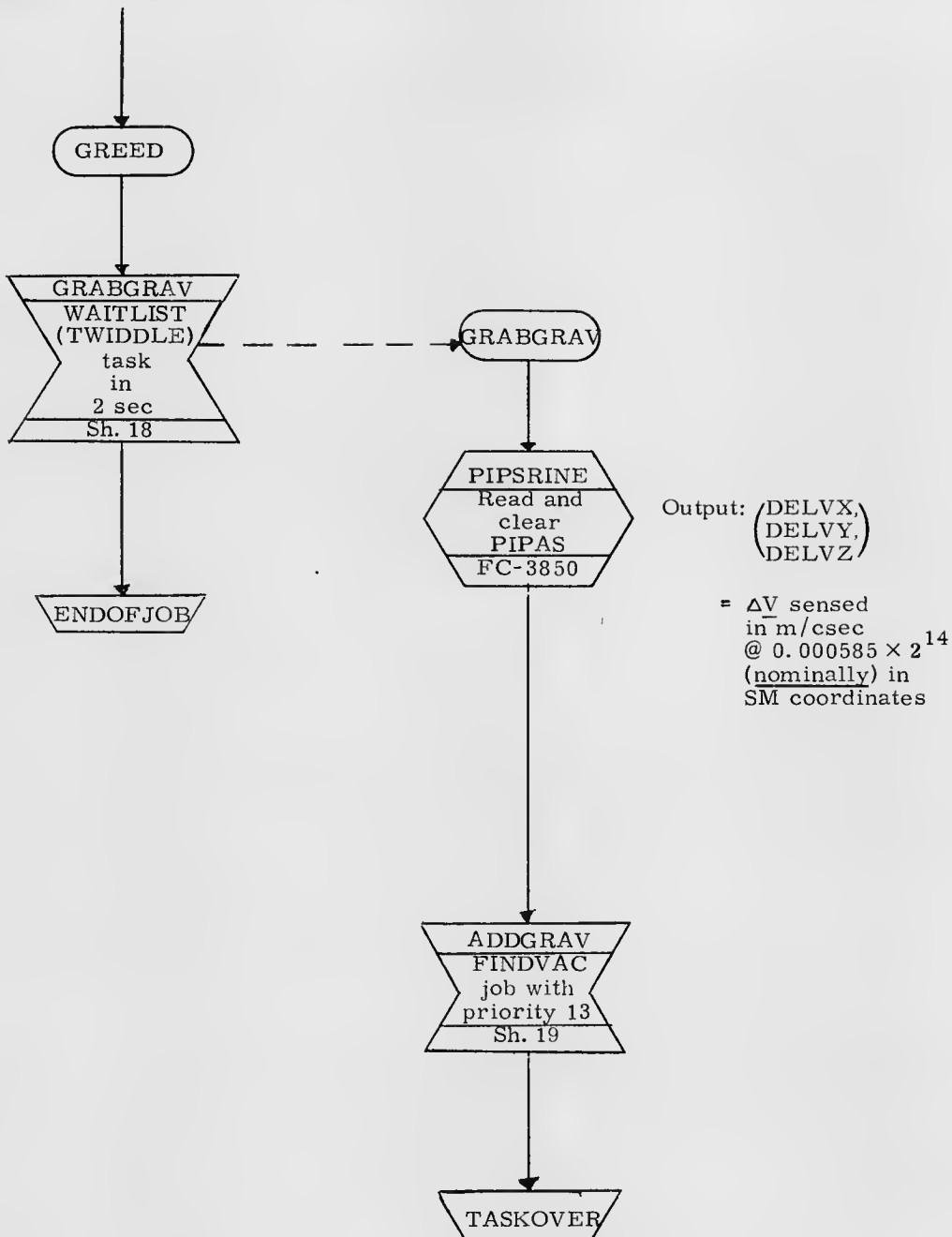
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P57	
DRAWN	<i>J. Coxall</i> 7-31-68	LUMINARY 1D	DOCUMENT NO.
PRGMR	<i>D. Muller</i> 8/29/68		FC-3520
ANALST			
DOCMR	<i>A.M. Sorant</i> 8/29/68		
APPR'D	<i>A.M. Sorant</i> 8/29/68	REV 2	SHEET 16 OF 65

From Preceding Sheet

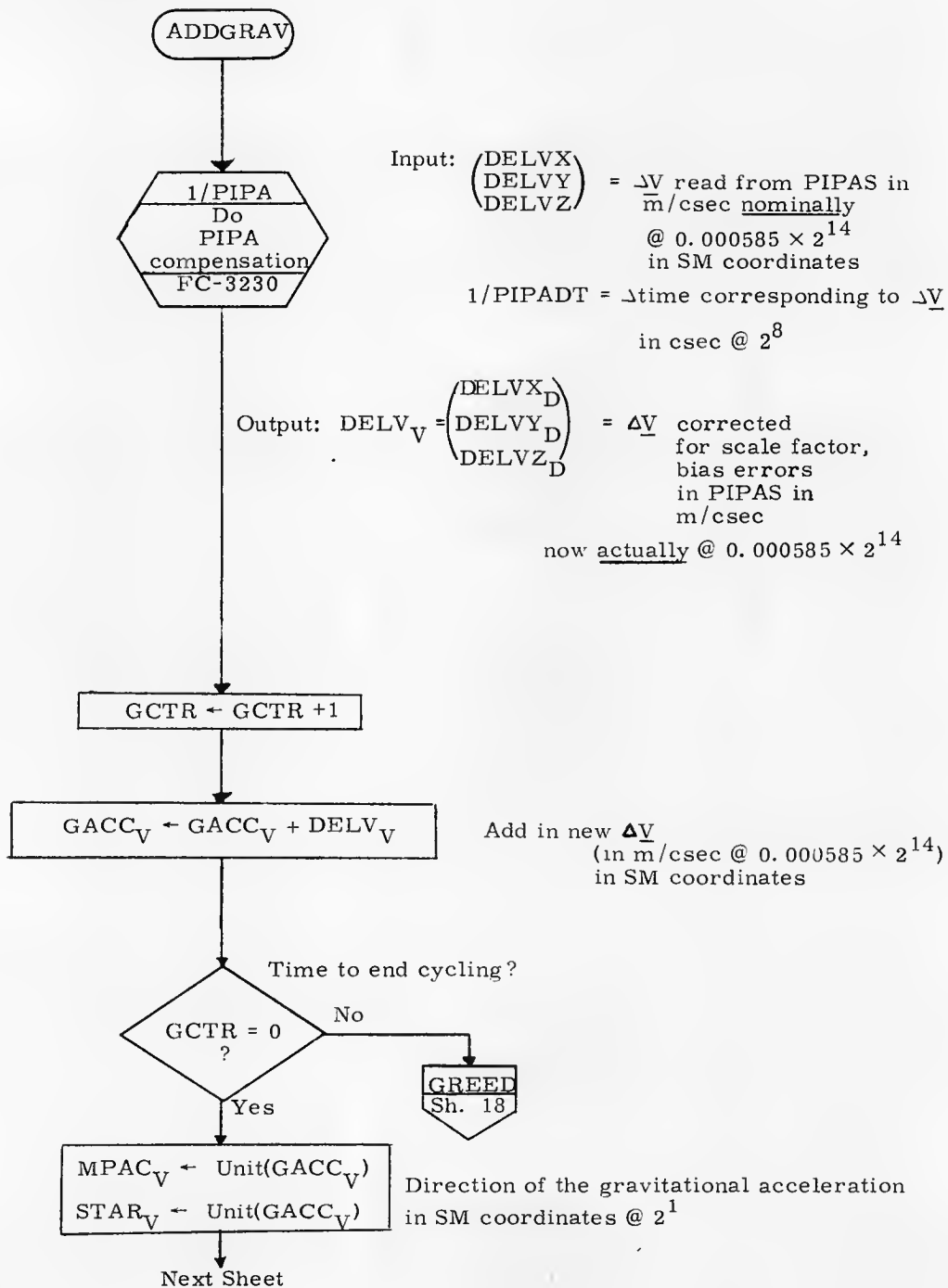


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. Ciccotta</i>		P57	
PRGMR <i>J. Ciccotta</i>	7-3-69	DOCUMENT NO.	
ANALST	8/19/69	LUMINARY 1D	FC-3520
DOCMR <i>Amstrong</i>	8/19/69	REV 2	SHEET 17 OF 65
APPR'D <i>Amstrong</i>	8/22/69		

From Preceding Sheet

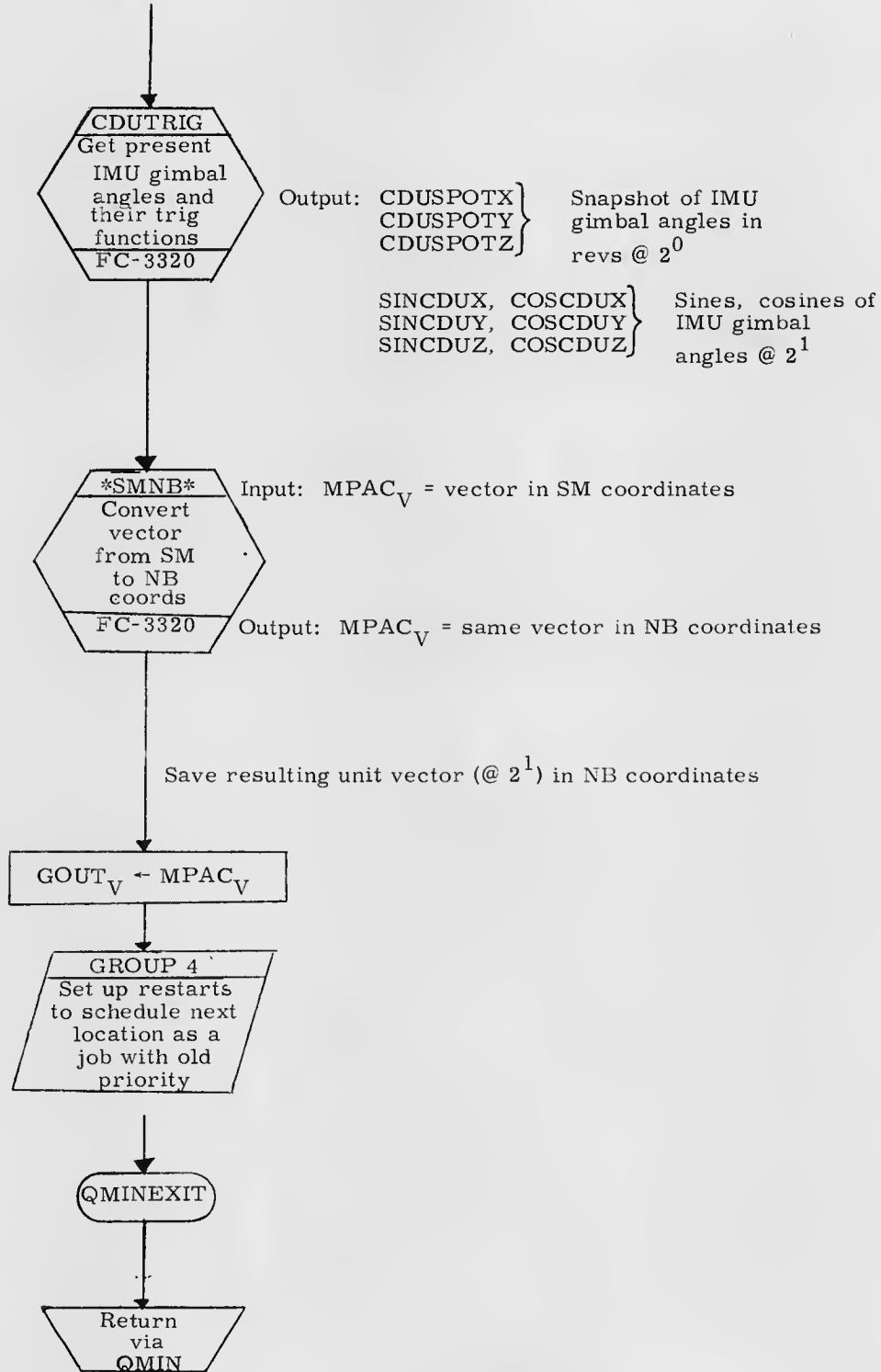


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P57	
DRAWN	<i>J. C. ...</i>	<i>1-31-69</i>	
PRGMR	<i>J. C. ...</i>	<i>9/25/69</i>	
ANALST			DOCUMENT NO.
DOCMR	<i>AM ...</i>	<i>8/29/69</i>	LUMINARY 1D FC-3520
APPR'D	<i>AM ...</i>	<i>8/29/69</i>	REV 2 SHEET 18 OF 65



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>J. C. ...</i>	7-31-69	P57
PRGMR	<i>D. ...</i>	8/25/69	
ANALST			DOCUMENT NO. FC-3520
DOCMR	<i>Ann Sorant</i>	8/29/69	LUMINARY 1D
APPR'D	<i>Ann Sorant</i>	8/29/69	REV 2
			SHEET 19 OF 65

From Preceding Sheet



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. Cincotta</i> 7-31-69		P57	
PRGMR <i>D. Miller</i> 8/29/69		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3520
DOCMR <i>AMC Sorant</i> 8/29/69		REV 2	SHEET 20 OF 65
APPR'D <i>AMC Sorant</i> 8/29/69			

P57OPT0

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

$VEC1_V \leftarrow YNBSA_V$
 $VEC2_V \leftarrow ZNBSA_V$

CDUTRIG
Get present
IMU gimbal
angles and
their trig
functions
FC-3320

Output: $CDUSPOTX$ } Snapshot of IMU
 $CDUSPOTY$ } gimbal angles in
 $CDUSPOTZ$ } in revs @ 2^0
 $SINCDUX, COSCDUX$ } Sines, cosines
 $SINCDUY, COSCDUY$ } of IMU gimbal
 $SINCDUZ, COSCDUZ$ } angles @ 2^1

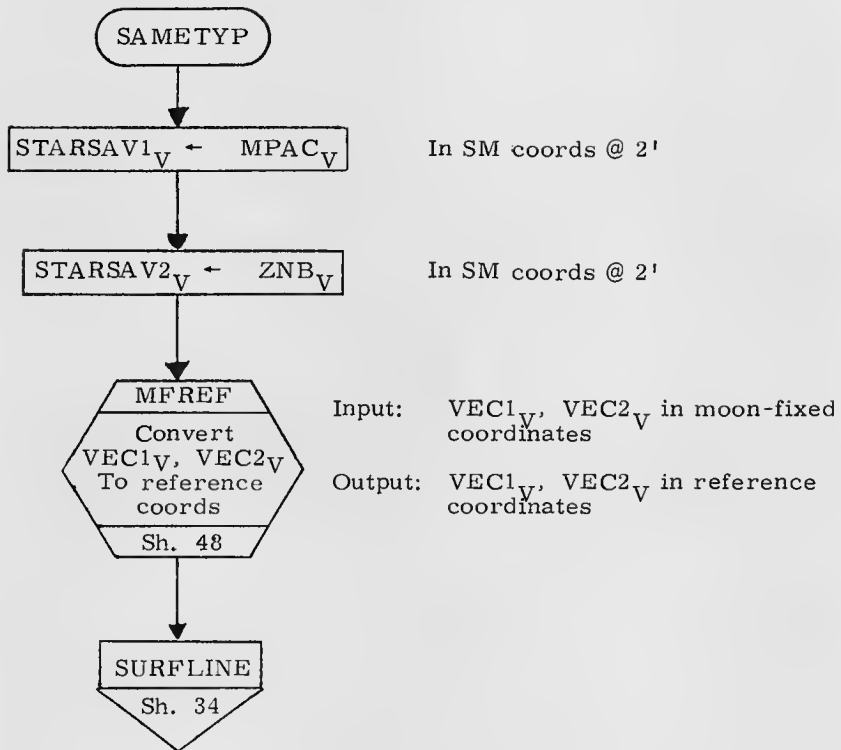
CALCSMSC
Compute
SM-NB
transformation
matrix
FC-3320

Input: $SINCDUX, COSCDUX$ } TRIG functions
 $SINCDUY, COSCDUY$ } of present IMU
 $SINCDUZ, COSCDUZ$ } 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

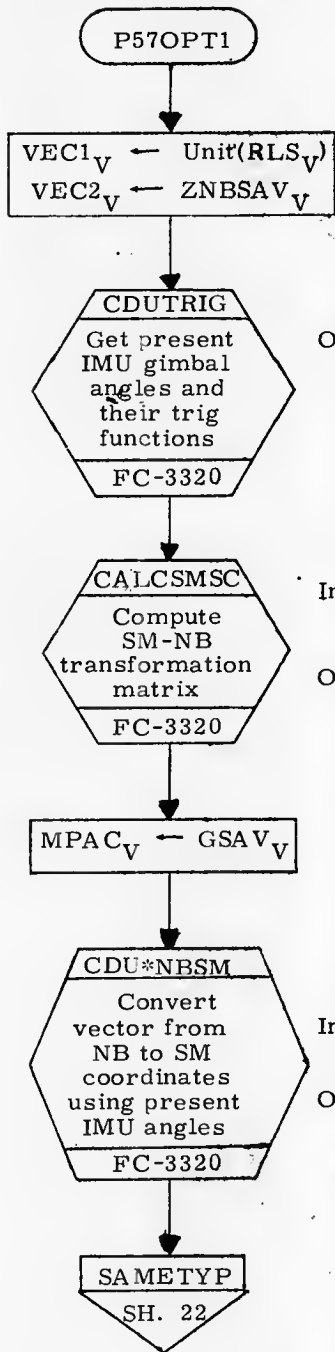
$MPAC_V \leftarrow YNB_V$

Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P57	
DRAWN	<i>[Signature]</i>		
PRGMR	<i>[Signature]</i> 8/29/69		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3520
DOCMR	<i>[Signature]</i> 8/29/69		
APPR'D	<i>[Signature]</i> 8/29/69	REV 2	SHEET 21 OF 65



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P57	
DRAWN	<i>[Signature]</i>	LUMINARY 1D	DOCUMENT NO.
PRGMR	<i>[Signature]</i> 8/29/69		FC-3520
ANALST			
DOCMR	<i>[Signature]</i> 8/29/69		
APPR'D	<i>[Signature]</i> 8/29/69	REV 2	SHEET 22 OF 65



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

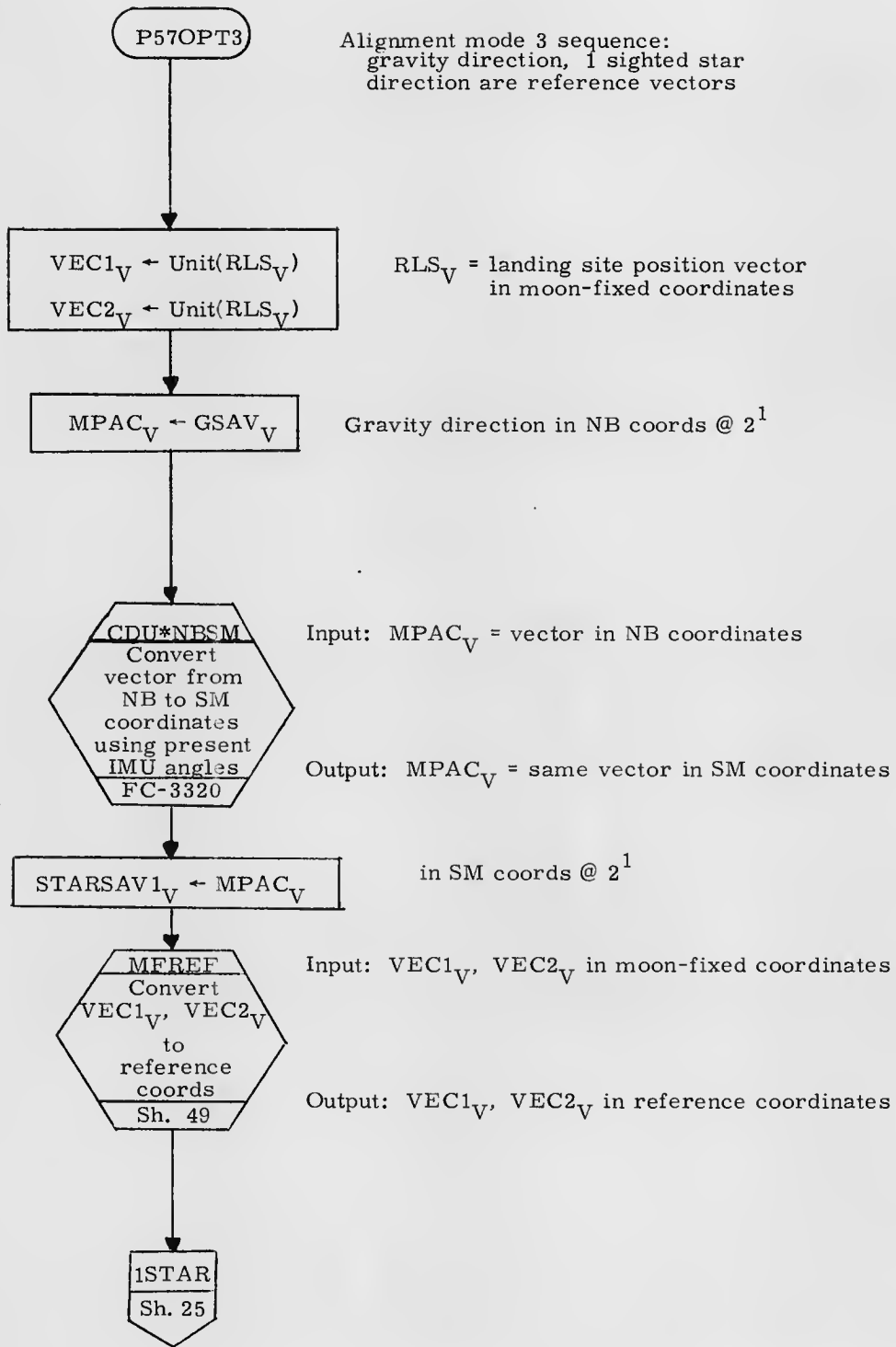
RLS_V = Landing site position in moon-fixed coordinates

Output: $\left. \begin{matrix} CDUSPOTX \\ CDUSPOTY \\ CDUSPOTZ \end{matrix} \right\}$ Snapshot of IMU gimbal angles in revs @ 2^0
 $\left. \begin{matrix} SINCDUX, COSCDUX \\ SINCDUY, COSCDUY \\ SINCDUZ, COSCDUZ \end{matrix} \right\}$ Sines, cosines of IMU gimbal angles @ 2^1

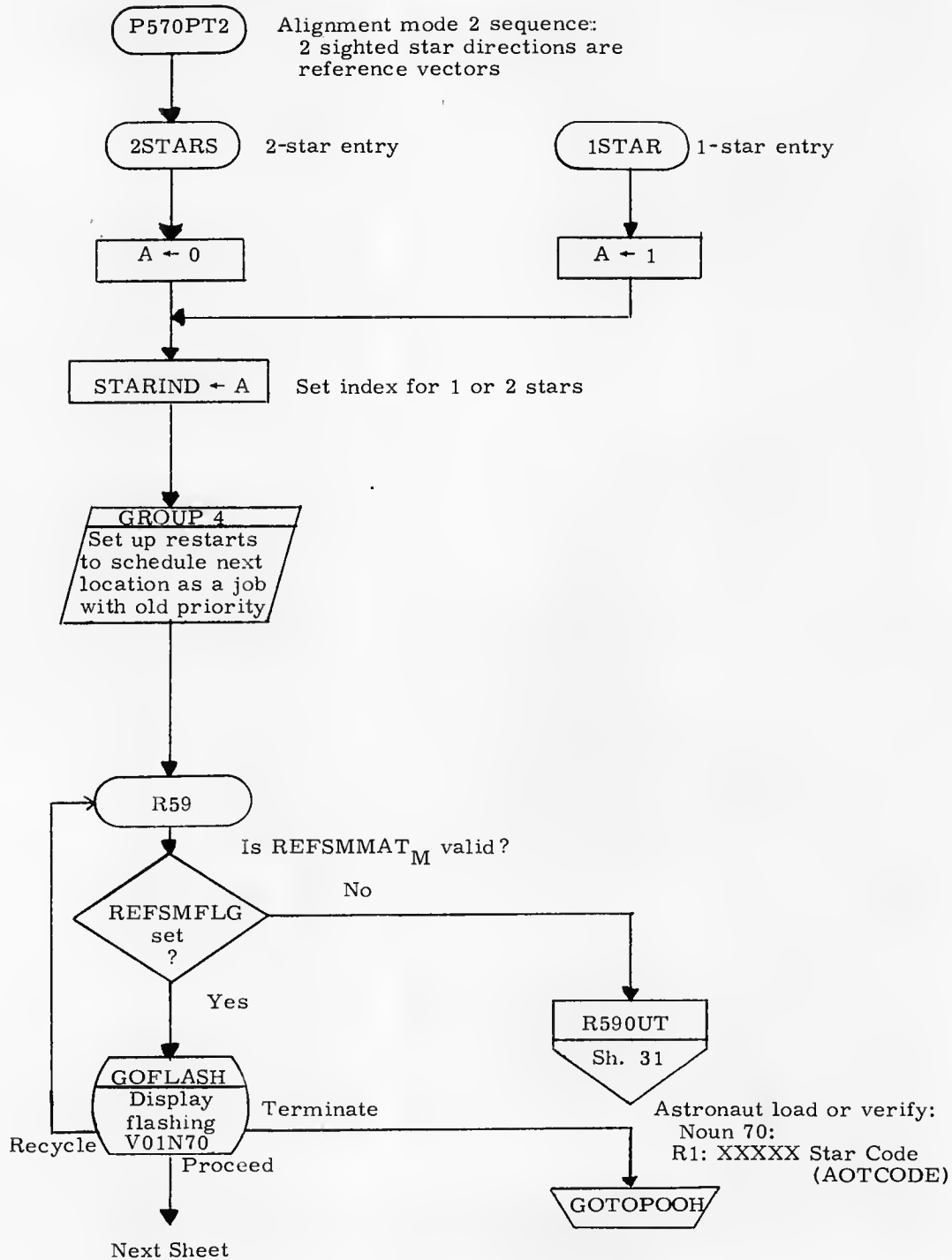
Input: $\begin{matrix} SINCDUX, COSCDUX \\ SINCDUY, COSCDUY \\ SINCDUZ, COSCDUZ \end{matrix}$
 Output: $XNB_M = \begin{pmatrix} XNB_V \\ YNB_V \\ ZNB_V \end{pmatrix}$ = Transformation matrix relating SM and NB coordinate systems @ 2^1

Input: $MPAC_V$ = vector in NB coordinates
 Output: $MPAC_V$ = same vector in SM coordinates

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

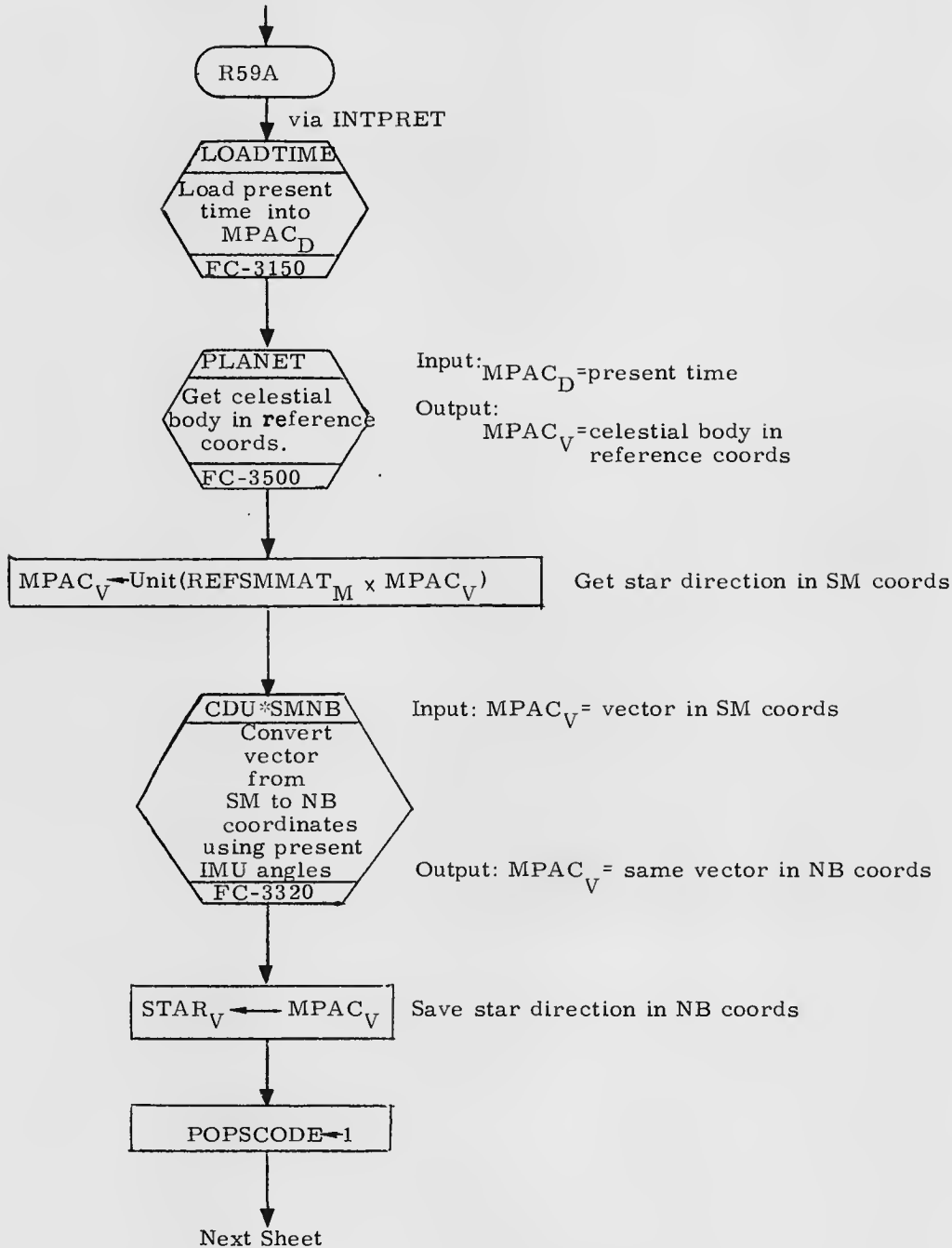


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P57	
DRAWN <i>J. Coxello</i>	<i>8-4-69</i>	LUMINARY ID	DOCUMENT NO. FC-3520
PRGMR <i>A. Muller</i>	<i>8/29/69</i>		
ANALST			
DOCMR <i>A. Messant</i>	<i>8/29/69</i>	REV 2	SHEET 24 OF 65
APPR'D <i>A. Messant</i>	<i>8/29/69</i>		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	J. Concetta	P57	
PRGMR	J. Concetta	LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3520
DOCMR	WMSorant	REV 2	SHEET 25 OF 65
APPR'D	WMSorant		

From Preceding Sheet



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

From Preceding Sheet

INCAZ

$QMIN \leftarrow AOTAZ - 1 \frac{\#}{\#} POSCODE$

$PL8 \leftarrow AOTAZ - 1 \frac{\#}{\#} POSCODE$
 $PL9 \leftarrow \frac{1}{8} rev$

Set inputs to OANB
AZIMUTH
elevation = 45°

OANB
Compute
optic axis
for desired
sighting
FC-3530

Input: $PL8 = \text{azimuth angle @ } 2^{-1}$
 $PL9 = \text{elevation angle @ } 2^{-1}$

Output: $SCAXIS_V = \text{optics axis in NB coords @ } 2^1$

Get angle between star direction and optics sighting
sighting direction ($@ 2^0$)

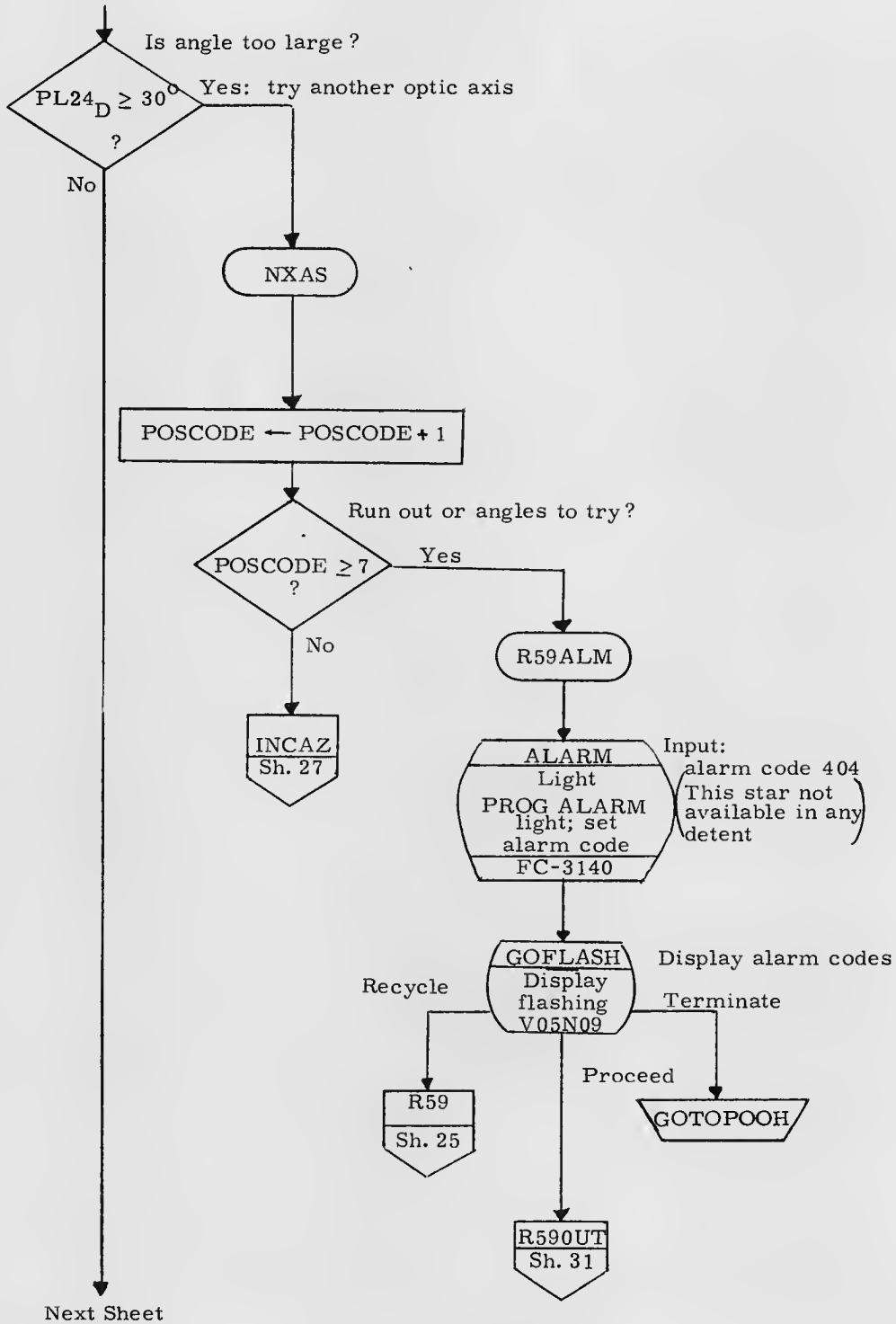
$PL24_D \leftarrow \cos^{-1}(STAR_V \cdot SCAXIS_V \cdot 2^1)$

2^1 factor is for scaling

Next Sheet

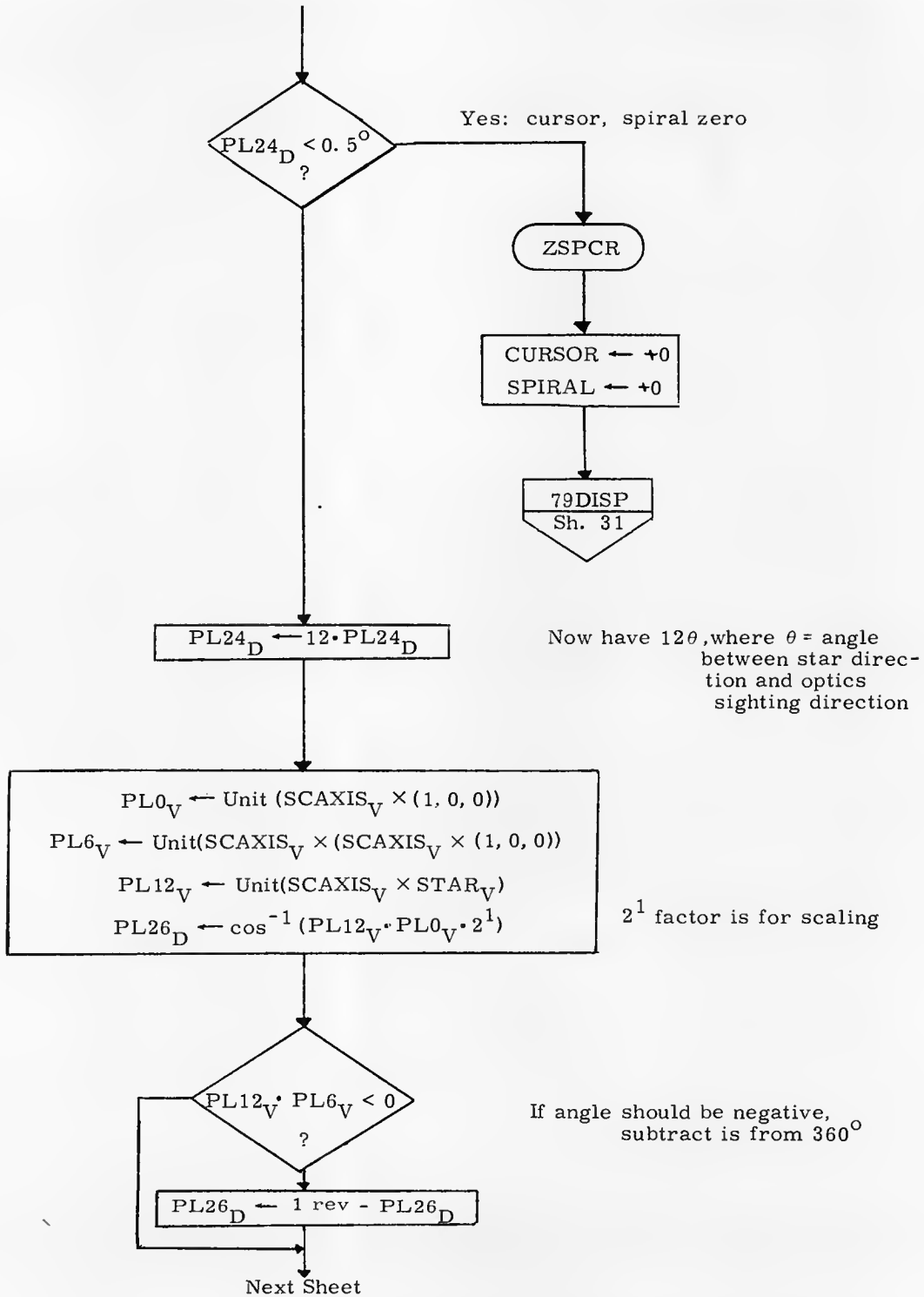
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P57	
DRAWN <i>J. Fucillo</i>	<i>8-1-69</i>	LUMINARY 1D	DOCUMENT NO.
PRGMR <i>J. Fucillo</i>	<i>8/29/69</i>		FC-3520
ANALST			
DOCMR <i>A. M. Sant</i>	<i>8/29/69</i>	REV 2	SHEET 27 OF 65
APPR'D <i>A. M. Sant</i>	<i>8/29/69</i>		

From Preceding Sheet



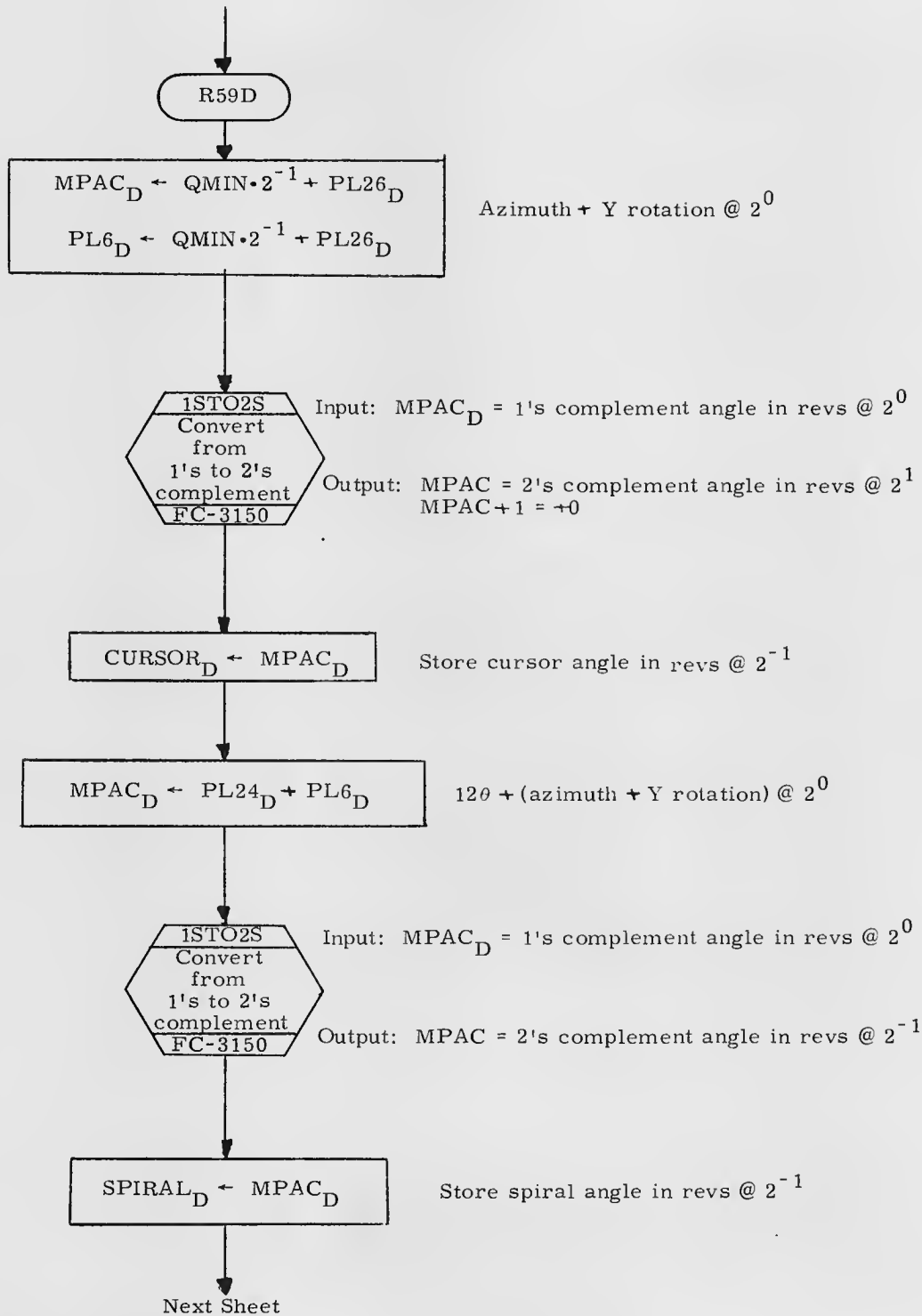
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. Concetta</i> 8-1-65		P57	
PRGMR <i>A. Phelan</i> 8/2/65		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3520
DOCMR <i>AMC</i> 8/19/65		REV 2	SHEET 28 OF 65
APPR'D <i>AMC</i> 8/29/65			

From Preceding Sheet

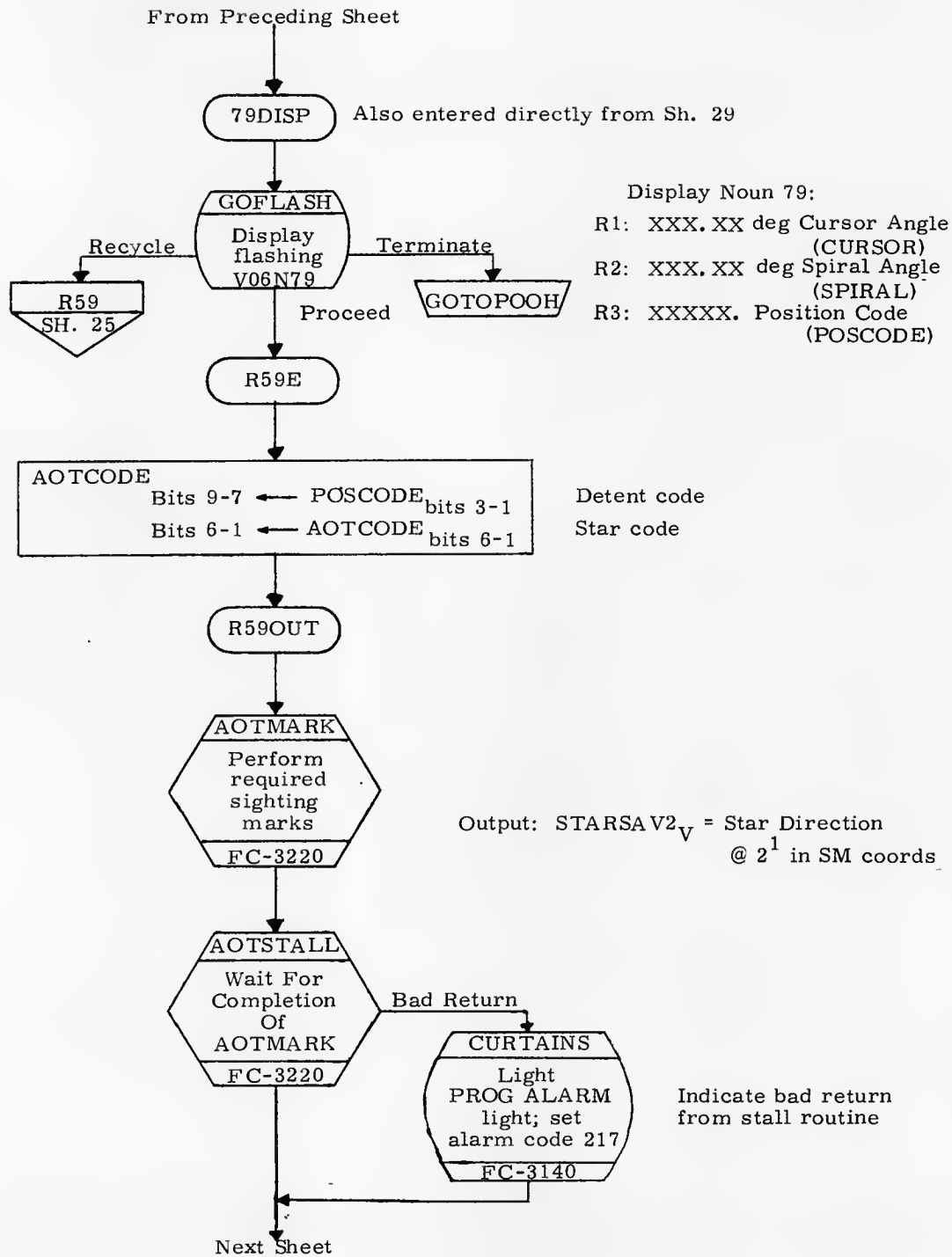


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i>		P57	
PRGMR <i>[Signature]</i>	<i>[Date]</i>	LUMINARY 1D	DOCUMENT NO. FC-3520
ANALST	<i>[Date]</i>	REV 2	SHEET 29 OF 65
DOCMR <i>[Signature]</i>	<i>[Date]</i>		
APPR'D <i>[Signature]</i>	<i>[Date]</i>		

From Preceding Sheet

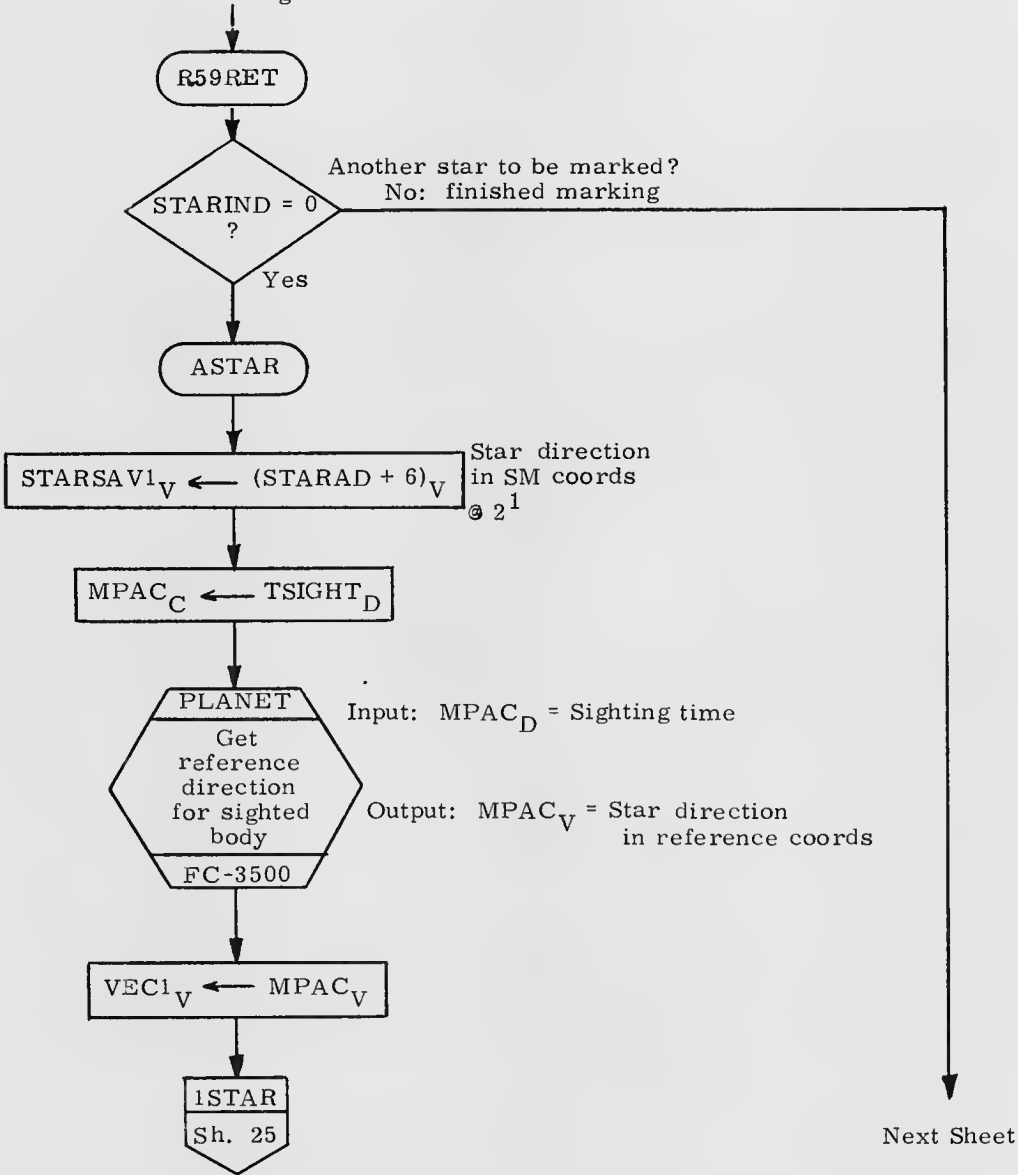


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. Cocetta</i> 8-1-68		P57	
PRGMR <i>J. Miller</i> 8/29/68			DOCUMENT NO. FC-3520
ANALST		LUMINARY 1D	
DOCMR <i>A. M. Smart</i> 8/29/68			
APPR'D <i>A. M. Smart</i> 8/29/68		REV 2	SHEET 30 OF 65



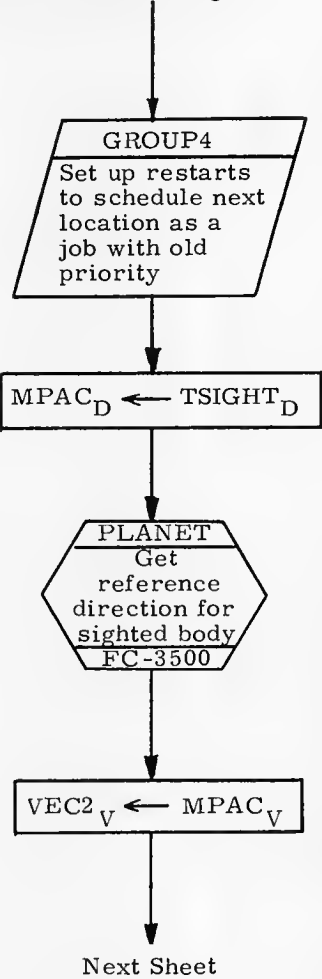
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P57	
DRAWN	<i>J. Mullard</i>		
PRGMR	<i>J. Mullard</i>		
ANALST	<i>J. Mullard</i>		
DOCMR	<i>R.M. Sout</i>	LUMINARY 1D	DOCUMENT NO. FC-3520
APPR'D	<i>R.M. Sout</i>	R.V. 2	SHEET 31 OF 65

From Preceding Sheet



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>H. E. Hart</i> 7-20-68		P57	
PRGMR <i>J. P. Holland</i> 8/29/68		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3520
DOCMR <i>A. M. S. ...</i> 8/29/68		REV 2	SHEET 32 OF 65
APPR'D <i>A. M. S. ...</i> 8/29/68			

From Preceding Sheet

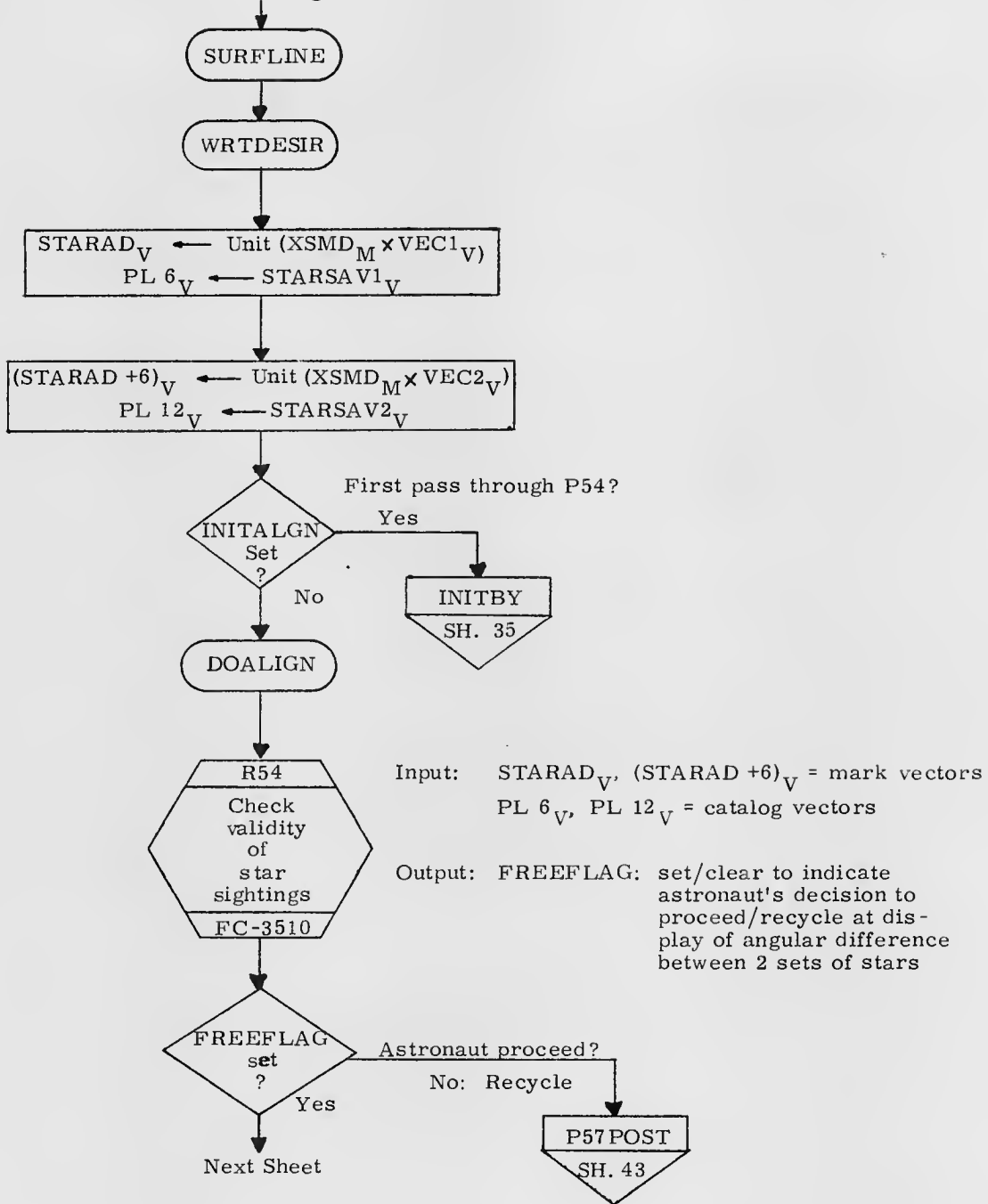


Input: $MPAC_D$ = Sighting time

Output: $MPAC_V$ = Star direction
in reference coords

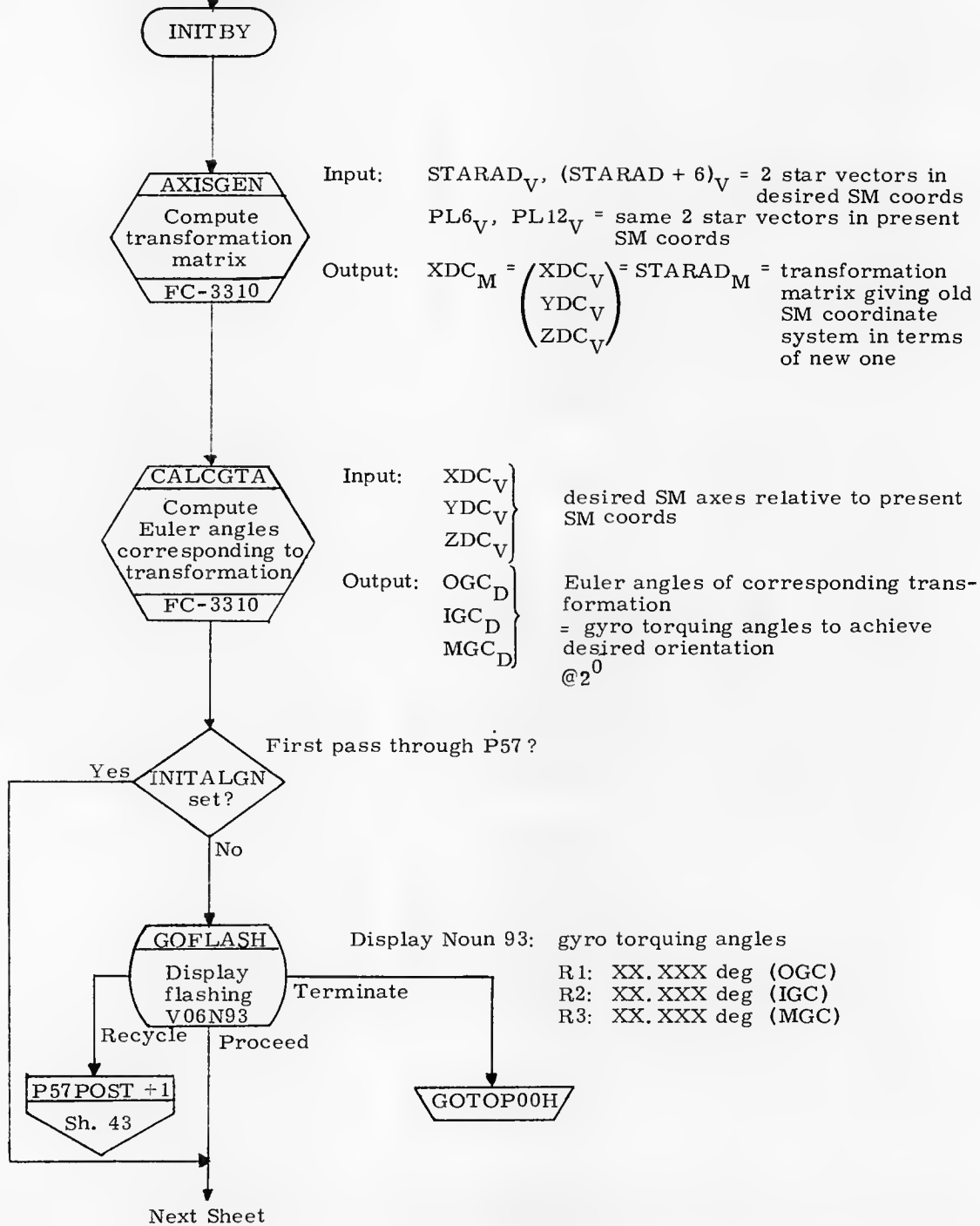
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. P. Hart</i>		P57	
PRGMR <i>D. P. Mullard</i>	<i>8/19/68</i>	DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3520
DOCMR <i>A. M. Sorant</i>	<i>8/19/68</i>	REV 2	SHEET 33 OF 65
APPR'D <i>A. M. Sorant</i>	<i>8/29/68</i>		

From Preceding Sheet

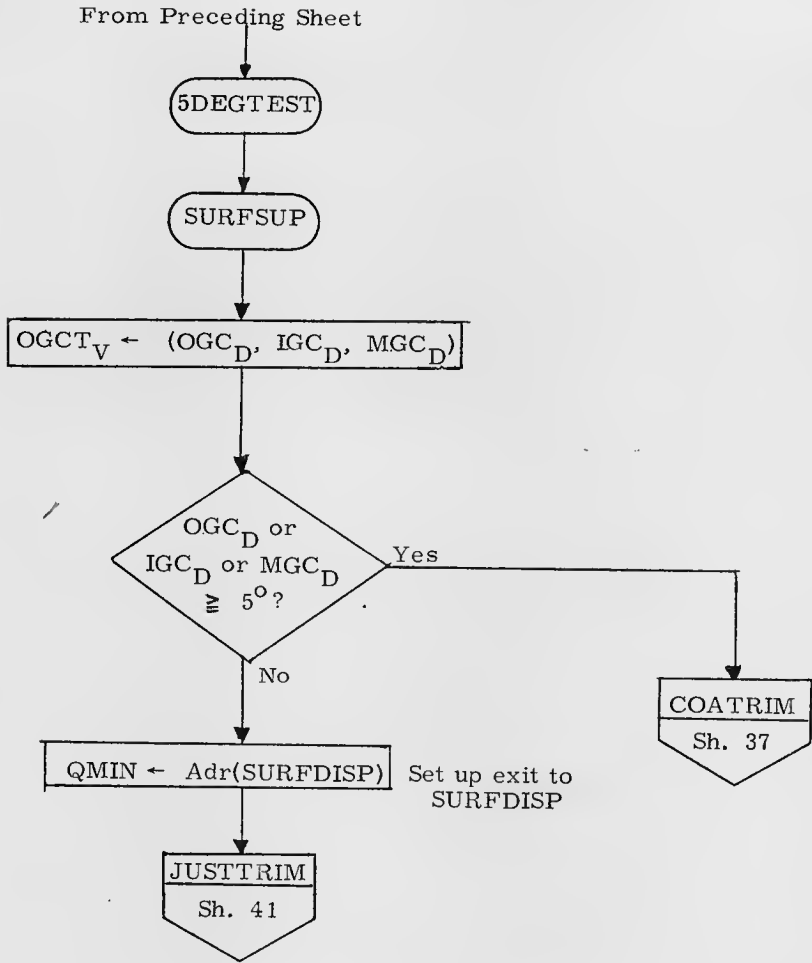


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>S. Paley</i>		P57	
PRGMR <i>S. Paley</i>	<i>8/29/69</i>	LUMINARY 1D	DOCUMENT NO. FC-3520
ANALST <i>A.M. Grant</i>	<i>8/29/69</i>		
DOCMR <i>A.M. Grant</i>	<i>8/29/69</i>	REV 2	SHEET 34 OF 65
APPR'D <i>A.M. Grant</i>	<i>8/29/69</i>		

From Preceding Sheet



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P57	
DRAWN <i>J.H. Connors</i>		LUMINARY 1D	DOCUMENT NO.
PRGMR <i>R.P. Hallard</i>	<i>8/23/69</i>		FC-3520
ANALST			
DOCMR <i>G.M. Sarant</i>	<i>8/23/69</i>		
APPR'D <i>G.M. Sarant</i>	<i>8/23/69</i>	REV 2	SHEET 35 OF 65



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i>		P57	
PRGMR <i>[Signature]</i>	<i>[Signature]</i>	LUMINARY 1D	DOCUMENT NO. FC-3520
ANALST	<i>[Signature]</i>		
DOCMR <i>[Signature]</i>	<i>[Signature]</i>	REV 2	SHEET 36 OF 65
APPR'D <i>[Signature]</i>	<i>[Signature]</i>		

COATRIM

X1 ← - ECADR(XDC)
X2 ← - ECADR(XSM)

Set up inputs to MATMOVE

MATMOVE
Move matrix
FC-3510

Result: $XSM_M \leftarrow XDC_M$

CDUTRIG
Get present IMU gimbal angles and their trig functions
FC-3320

Output: $\left. \begin{array}{l} CDUSPOTX \\ CDUSPOTY \\ CDUSPOTZ \end{array} \right\}$ Snapshot of IMU gimbal angles in revs @ 2^0
 $\left. \begin{array}{l} SINCDUX, COSCDUX \\ SINCDUY, COSCDUY \\ SINCDUZ, COSCOUZ \end{array} \right\}$ Sines, cosines of IMU gimbal, angles @ 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

CALCGA
Compute driving angles needed to align IMU
FC-3310

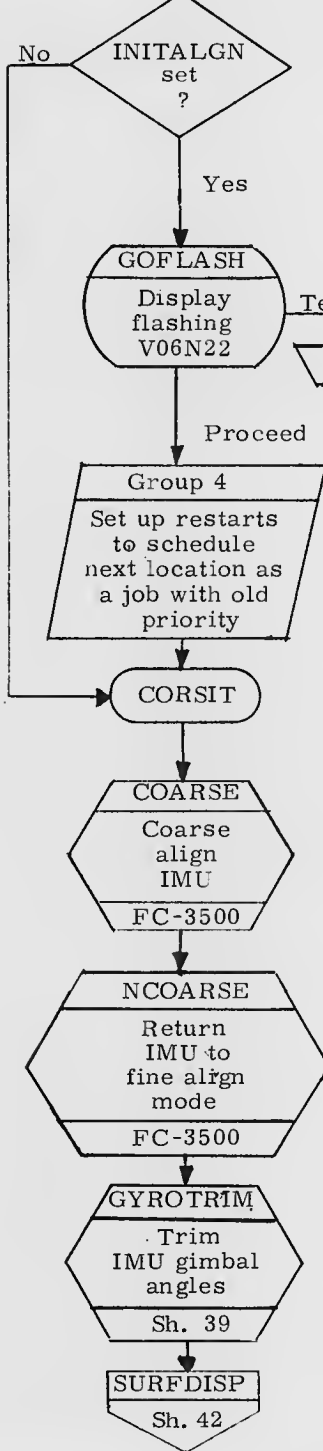
Input: XNB_M relating NB and present SM coordinate systems
 XSM_M relating desired SM orientation and present SM coordinate system

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

Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i>		P57	
PRGMR <i>[Signature]</i>	8/29/68	LUMINARY 1D	DOCUMENT NO. FC-3520
ANALST <i>[Signature]</i>	8/29/68	REV 2	SHEET 37 OF 65
DOCMR <i>[Signature]</i>	8/29/68		
APPR'D <i>[Signature]</i>	8/29/68		

From Preceding Sheet



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 <i>R.S. Connel</i>		P57	
PRGMR <i>D. McLeod</i>	<i>8/29/69</i>	DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3520
DOCMR <i>AM Sorant</i>	<i>8/29/69</i>	REV 2	
APPR'G <i>AM Sorant</i>	<i>8/29/69</i>	SHEET 38 OF 65	

GYROTRIM

Save
QPRET
in
QMIN

CDUSPOTY ← THETAD +1
CDUSPOTZ ← THETAD +2
CDUSPOTX ← THETAD

MPAC_V ← (1, 0, 0)

TRG*NBSM
Convert
vector
from NB to SM
coordinates
using given
IMU angles
FC-3320

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 } sines, cosines of
SINCOUY, COSCDUY } IMU gimbal
SINCDUZ, COSCDUZ } angles given @ 2¹

STARAD_V ← MPAC_V

Save vector in SM coordinates

MPAC_V ← (0, 1, 0)

NBSM
Convert
vector from
NB to SM
coordinates
using trig
functions of
IMU angles
FC-3320

Input: MPAC_V = vector in NB coordinates
SINCDUX, COSCDUX } Trig functions
SINCDUY, COSCDUY } of IMU gimbal
SINCDUZ, COSCDUZ } @ 2¹

Output: MPAC_V = given vector in SM coords

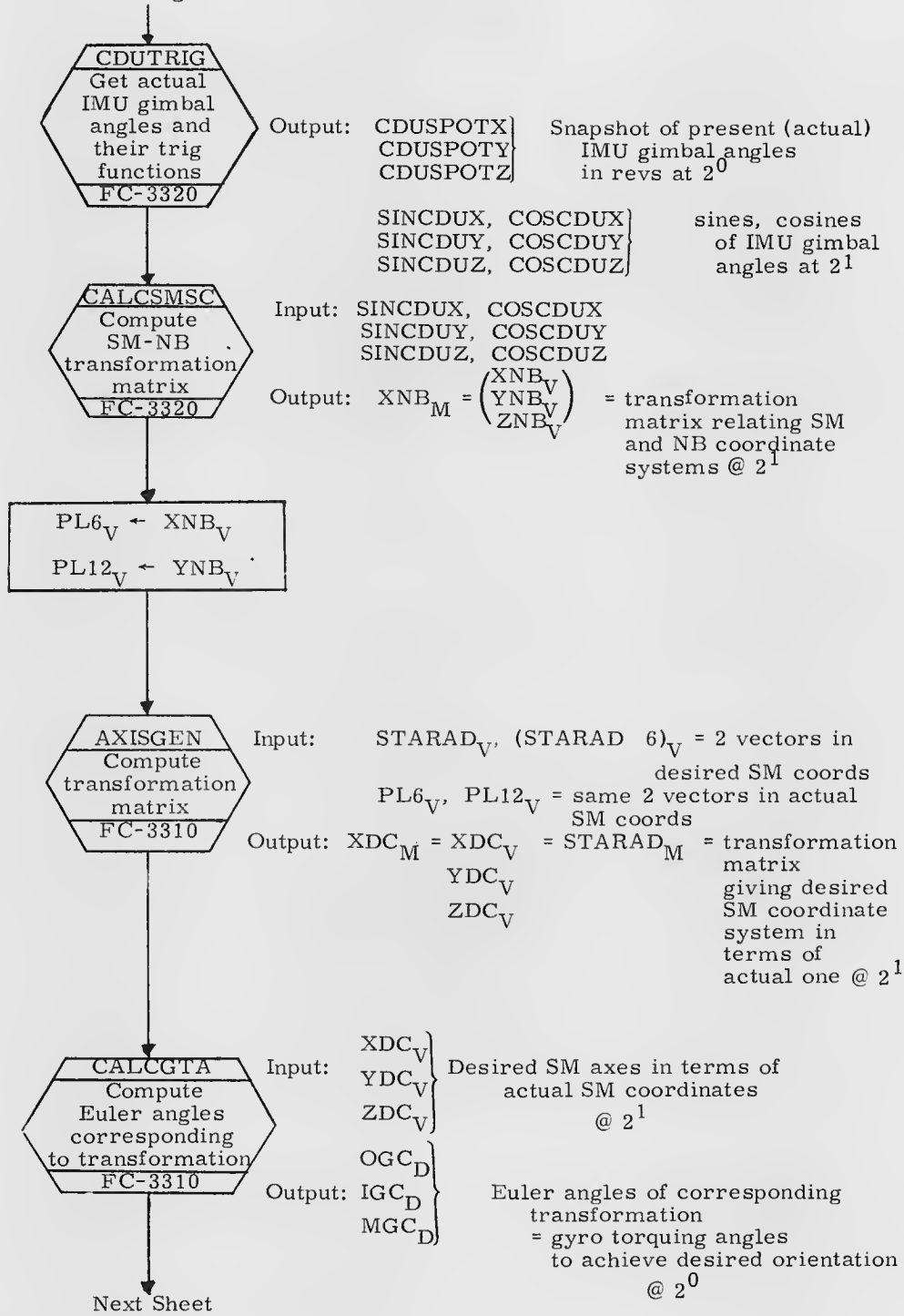
(STARAD +6)_V ← MPAC_V

Save vector in SM coordinates

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MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P57	
DRAWN <i>J. Cicciolla</i>	<i>8-1-69</i>	LUMINARY 1D	DOCUMENT NO.
PRGMR <i>A. Ballard</i>	<i>8/29/69</i>		FC-3520
ANALST		REV 2	SHEET 39 OF 65
DOCMR <i>AM Spant</i>	<i>8/29/69</i>		
APPR'D <i>AM Spant</i>	<i>8/29/69</i>		

From Preceding Sheet



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. Coxotta</i>	8-16-69	P57	
PRGMR <i>D. M. ...</i>	8/29/69	DOCUMENT NO.	
ANALST		LUMINARY 1 D	FC-3520
DOCMR <i>AM ...</i>	8/29/69	REV 2	SHEET 40 OF 65
APPR'D <i>AM ...</i>	8/29/69		

from preceding sheet

JUSTTRIM

A ECADR(OGC)

IMUPULSE
Torque
gyros to
align IMU
FC-3220

Input: A = ECADR (α)
Where gyro torquing angles are at
 $\alpha_D, (\alpha + 2)_D, (\alpha + 4)_D$
(i.e. at OGC_D, IGC_D, MGC_D)

IMUSTALL
Wait for
completion
of IMU
operation
FC-3220

Bad return

Normal
return

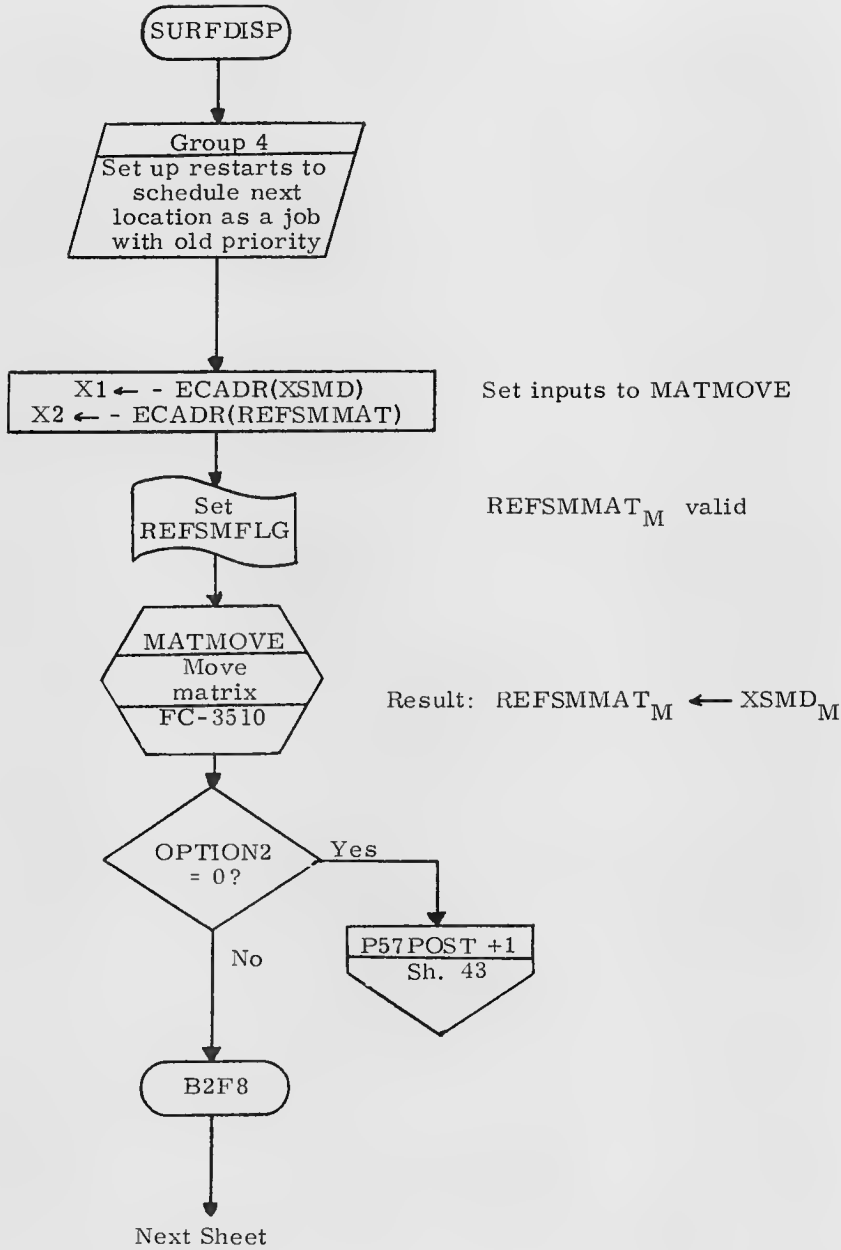
CURTAINS
Light PROG
ALARM light;
set alarm
code 217
FC-3140

Indicate bad return from
stall routine

QMINEXIT

Return
via QMIN

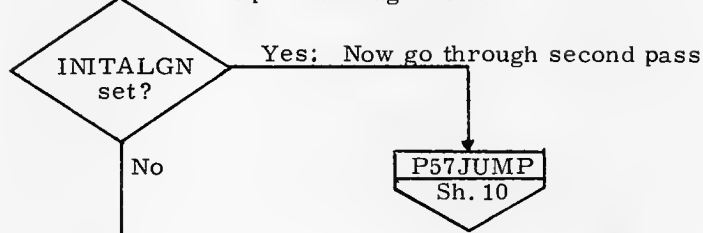
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Lutzke</i> 8/24/69		P57	
PRGMR <i>D. M. ...</i> 8/19/69		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3520
DOCMR <i>A. M. ...</i> 8/29/69		REV 2	SHEET 41 OF 65
APPR'D <i>A. M. ...</i> 8/29/69			



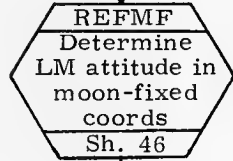
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		P57	
PRGMR	<i>[Signature]</i>	DOCUMENT NO.	
ANALST	<i>[Signature]</i>	LUMINARY 1D	FC-3520
DOCMR	<i>[Signature]</i>	REV 2	
APPR'D	<i>[Signature]</i>	SHEET 42 OF 65	

From Preceding Sheet

First pass through P57?



P57JUMP
Sh. 10



Output: $XNB_M = \begin{pmatrix} XNB_V \\ YNB_V \\ ZNB_V \end{pmatrix}$ = Transformation matrix relating SM and NB coordinate systems @ 2¹

YNBSAV_V = YNB_V in moon-fixed coords

ZNBSAV_V = ZNB_V in moon-fixed coords

P57POST

P57POST +1

Proceed:
Do fine alignment

Terminate



P57JUMP
Sh. 10

GOTOPOOH

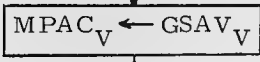
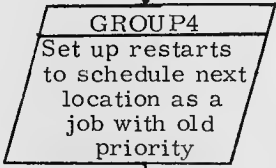
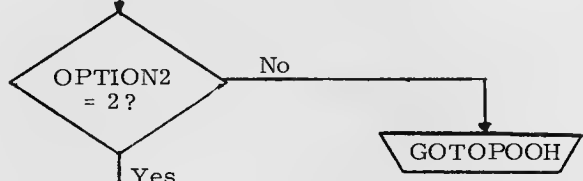
ENTR,
Recycle:
Don't do fine alignment

Next Sheet

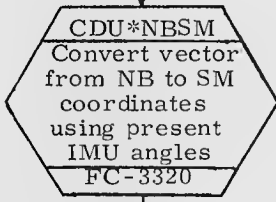
R1: 00014
Astronaut: Please perform fine alignment option

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		P57	
PRGMR	<i>J. E. Miller</i>	LUMINARY 1D	DOCUMENT NO. FC-3520
ANALST	<i>J. E. Miller</i>	REV 2	SHEET 43 OF 65
DOCMR	<i>Allen Grant 8/29/69</i>		
APPR'D	<i>Allen Grant 8/29/69</i>		

From Preceding Sheet



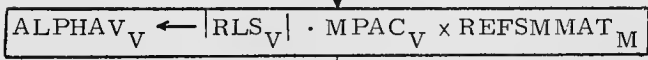
Load gravitational direction in NB coords 2^1



Input: $MPAC_V$ = vector in NB coordinates
Output: $MPAC_V$ = same vector in SM coords



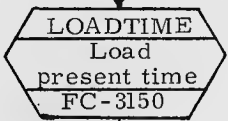
Want lunar latitude, longitude



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



Assume constant earth radius

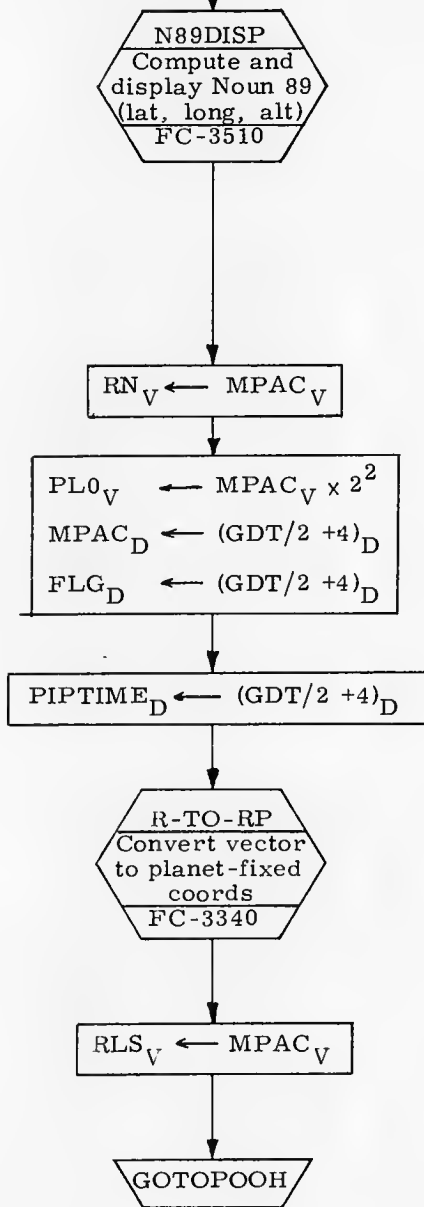


Result: $MPAC_D \leftarrow TIME2_D$ = present time in csec @ 2^{28}

Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P57	
DRAWN		LUMINARY ID	DOCUMENT NO.
PRGMR	<i>D. M. S. Grant</i> 8/29/69		FC-3520
ANALST			
DOCMR	<i>D. M. S. Grant</i> 8/29/69		
APPR'D	<i>D. M. S. Grant</i> 8/29/69	REV 2	SHEET 44 OF 65

From Preceding Sheet



Input: $ALPHA V_V$ = 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}

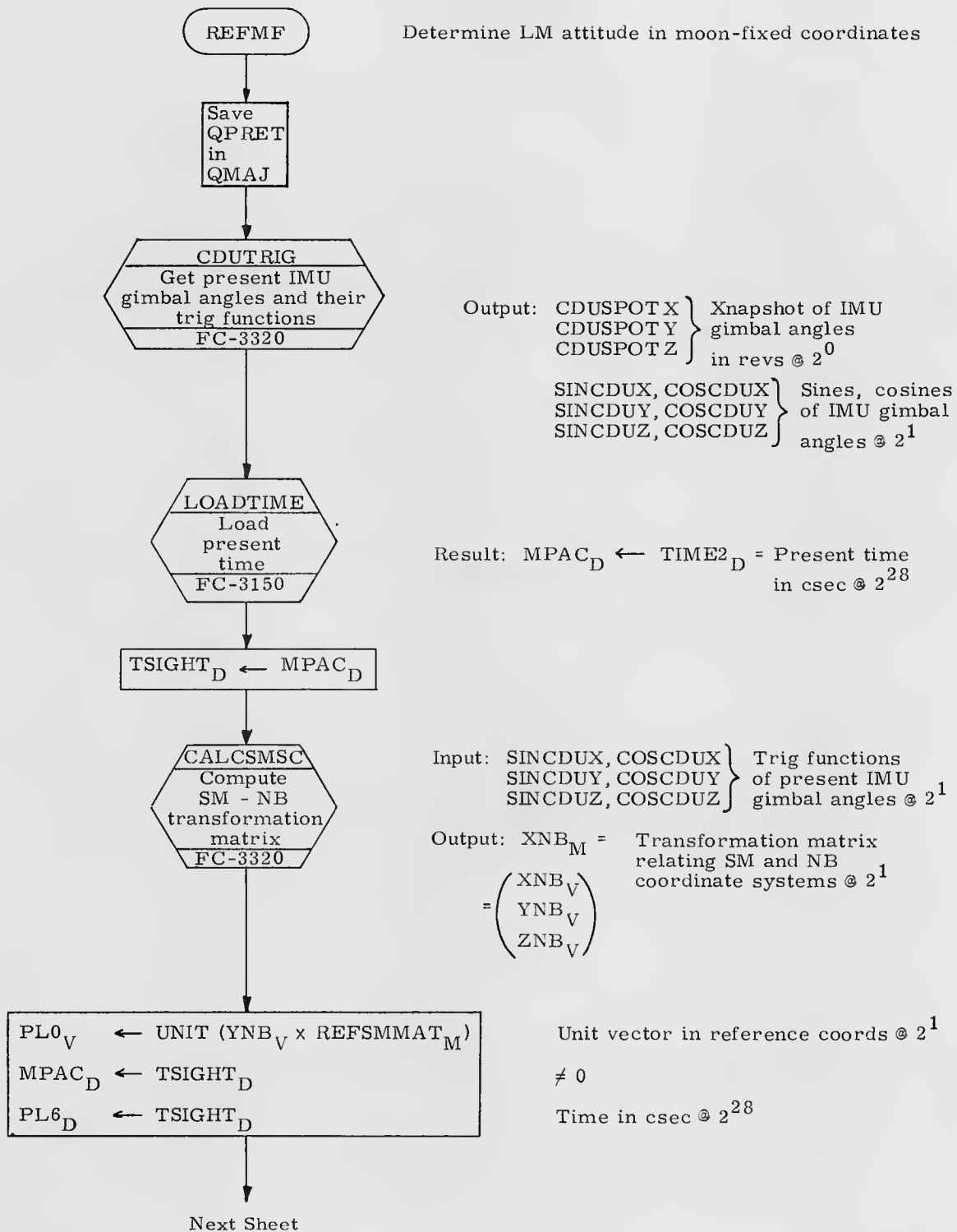
$MPAC \neq 0$ -- indicates moon-fixed coordinates desired

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

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

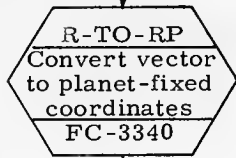
Terminate major mode P57

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. E. Hart</i>	7-25-69	P57	
PRGMR <i>D. Mullard</i>	8/2/69	LUMINARY 1D	DOCUMENT NO. FC-3520
ANALST			
DOCMR <i>Am Spant</i>	8/29/69	REV 2	SHEET 45 OF 65
APPR'D <i>Am Spant</i>	8/29/69		



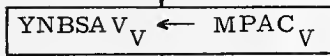
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>F. P. Hart</i>	7-28-69	P57	
PRGMR <i>D. Mulford</i>	8/23/69	LUMINARY 1D	DOCUMENT NO. FC-3520
ANALST <i>A.M. Sorant</i>	8/29/69		REV 2
DOCMR <i>A.M. Sorant</i>	8/29/69		
APPR'D <i>A.M. Sorant</i>	8/29/69		

From Preceding Sheet

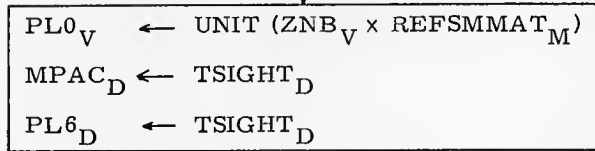


Input: $PL0_V$ = Vector in reference coordinates
 $PL6_D$ = Corresponding time in csec @ 2^{28}
 $MPAC \neq 0$ -- indicates moon-fixed coordinates desired

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



Save resulting unit vector @ 2^1

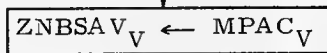


Unit vector in reference coords @ $2^1 \neq 0$
 Time in csec @ 2^{28}

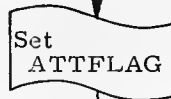


Input: $PL0_V$ = Vector in reference coordinates
 $PL6_D$ = Corresponding time in csec @ 2^{28}
 $MPAC \neq 0$ -- indicate moon-fixed coordinates desired

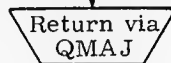
Output: $MPAC_V$ = Given vector in moon-fixed coordinates (same scaling)



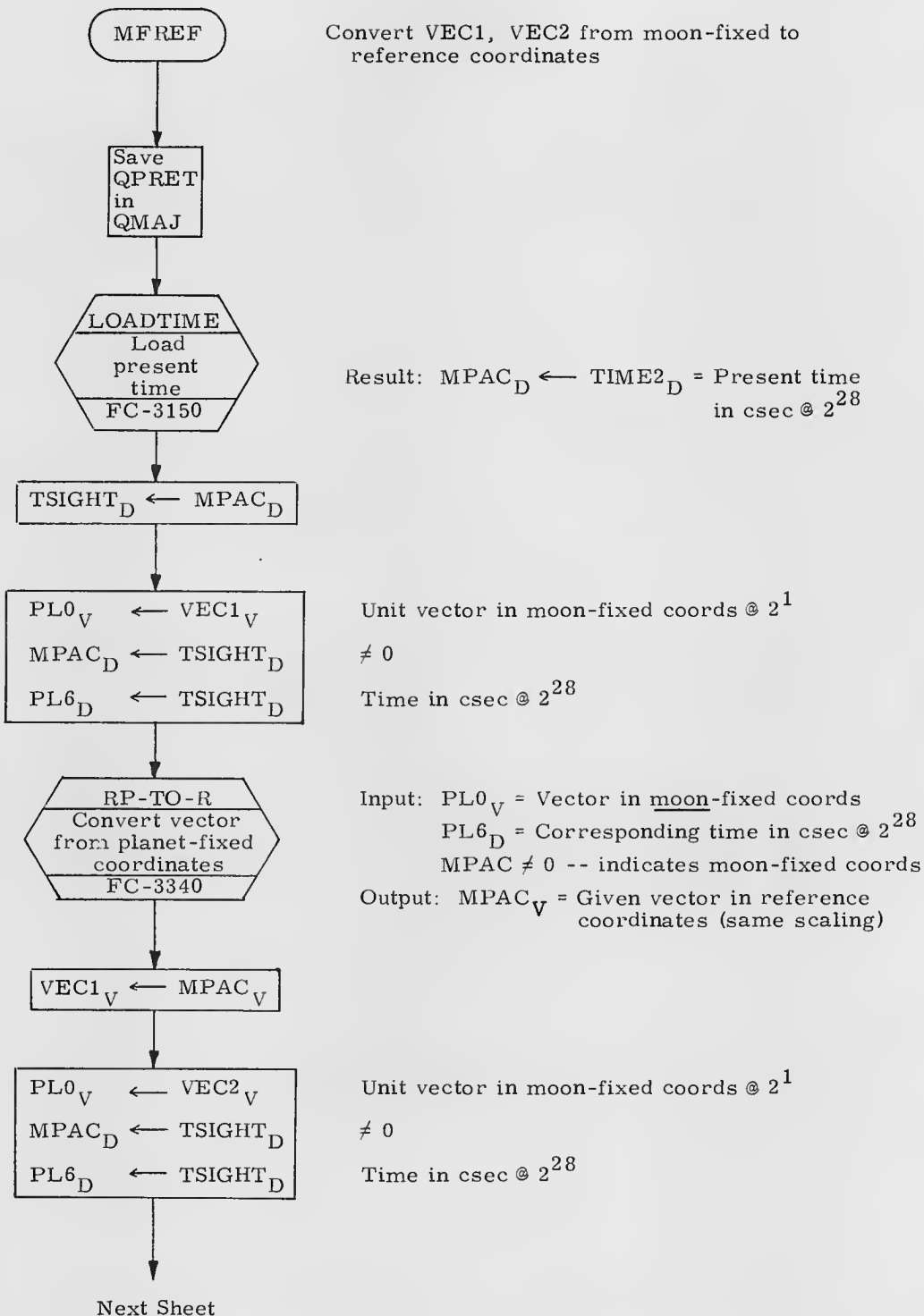
Save resulting unit vector @ 2^1



Have LM attitude in moon-fixed coordinates

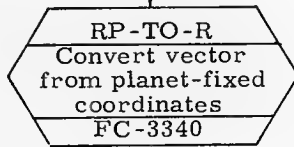


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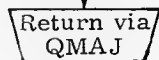
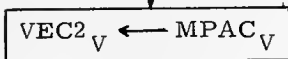
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DRAWN <i>R. J. West</i>	<i>2/28/69</i>	P57	
PRGMR <i>R. J. West</i>	<i>8/29/69</i>	DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3520
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From Preceding Sheet



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)



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ANALST		LUMINARY 1D	DOCUMENT NO.
DOCMR	<i>A. M. Stewart</i> 8/29/65		FC-3520
APPR'D	<i>A. M. Stewart</i> 8/29/65	REV 2	SHEET 49 OF 65

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

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ANALST	<i>P. Mullard</i>		
DOCMR	<i>A. M. S. Grant</i>	LUMINARY 1D	SHEET 50 of 65
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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

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ANALST			FC-3520
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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
ISTO2S	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

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PRGMR <i>R. P. Hart</i>	<i>8/29/68</i>		
ANALST		LUMINARY 1D	DOCUMENT NO.
DOCMR <i>Amesbury 8/29/68</i>			FC-3520
APPR'D <i>Amesbury 8/29/68</i>		REV 2	SHEET 52 OF 65

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	
FREFFLAG 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

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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
V05N09	Alarm	PROG ALARM light on; no change to registers R1, R2, R3	Sh. 8, 28 31, 41
V06N04	Flashing	R1: xxxxx } Alarm codes R2: xxxxx } R3: xxxxx }	Sh. 8, 28
V01N70	Flashing	R1: xxx. xx deg Gravity error angle	Sh. 14
V06N79	Flashing	R1: xxxxx Star code (AOTCODE)	Sh. 25
V06N93	Flashing	R1: xxx. xx deg Cursor angle (CURSOR) R2: xxx. xx deg Spiral angle (SPIRAL) R3: xxxxx. Position code (POSCODE)	Sh. 31
V06N22	Flashing	R1: xx. xxx deg (OGC) R2: xx. xxx deg (IGC) R3: xx. xxx deg (MGC) } Gyro torquing angles 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)	Sh. 35 Sh. 38

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DRAWN <i>R.D. Hart</i>	5-2-69	P57	
PRGMR <i>R.D. Hart</i>	8/23/69	DOCUMENT NO.	
ANALST		LUMINARY ID	FC-3520
DOCMR <i>Am. Smart</i>	8/29/69	REV 2	SHEET 54 OF 65
APPR'D <i>Am. Smart</i>	8/29/69		

DISPLAYS

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

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PRGMR <i>R. Mullard</i>	<i>8/29/69</i>		FC-3520
ANALST			
DOCMR <i>A.M. Grant</i>	<i>8/29/69</i>		
APPR'D <i>A.M. Grant</i>	<i>8/29/69</i>	REV 2	SHEE. 55 OF 65

ERASABLE LOCATIONS USED

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
ALPHAV		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}

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DOCMR <i>A.M. Smart</i>	<i>8/29/69</i>	REV 2	SHEET 56 of 65
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ERASABLE LOCATIONS USED (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
DELV _V (DELVX _D) (DELVY _D) (DELVZ _D)	$\Delta \underline{v}$	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 ALPHA V _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

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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, 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 choice 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	r(t ₁)	Position vector (in reference coordinates) at time specified by TDEC1 _D (below)	m	m	2 ²⁹

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PRGMR <i>D. Miller</i>	<i>4/29/69</i>	LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3520
DOCMR <i>A. M. Spang</i>	<i>8/29/69</i>	REV 2	SHEE. 53 OF 65
APPR'D <i>A. M. Spang</i>	<i>8/29/69</i>		

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	r _{-LS}	Landing site position vector in moon-fixed coordinates	m	m	2 ⁷ 2
RNV	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

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DRAWN <i>R.P. Hard</i>	8-7-69	P57	
PRGMR <i>R.P. Ballard</i>	4/29/69	DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3520
DOCMR <i>A.M. Sorant</i>	8/29/69	SHEET 59 of 65	
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ERASABLE LOCATIONS USED (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
STARIND		Index used to distinguish between two star sightings			
STARSA V1 V		First of 2 reference vectors in SM coordinates			2 ¹
STARSA V2 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

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ANALST			
DOCMR	<i>C. M. Spont</i>	LUMINARY 1D	DOCUMENT NO. FC-3520
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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

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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

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PROGRAM CONSTANTS

AGC TAG	MEANING	ENGINEERING AND AGC VALUE	AGC SCALING
CATLOG -6	Direction of star 1 (α Andromedae (Alpheratz)) in Reference coords	+ .8748658918 + .0360879174 + .4836621670	2 ¹
CATLOG -12D	Direction of star 2 (β Ceti (Diphda)) in Reference coords	+ .9342640100 + .1735673142 - .3115219339	2 ¹
CATLOG -18D	Direction of star 3 (γ Cassiopeiae (Navi)) in Reference coords	+ .4775639450 + .1166001340 + .8708254803	2 ¹
CATLOG -24D	Direction of star 4 (α Eridani (Achernar)) in Reference coords	+ .4917678276 + .2204887125 - .8423473935	2 ¹
CATLOG -30D	Direction of star 5 (α Ursae Minoris (Polaris)) in Reference coords	+ .0130968640 + .0078062795 + .9998837600	2 ¹
CATLOG -36D	Direction of star 6 (θ Eridani (Achernar)) in Reference coords	+ .5450107404 + .5314955466 - .6484410355	2 ¹
CATLOG -42D	Direction of star 7 (α Ceti (Menkar)) in Reference coords	+ .7032235469 + .7075846047 + .0692868665	2 ¹
CATLOG -48D	Direction of star 8 (=10 ₈) (α Persel (Mirfak)) in Reference coords	+ .4105636020 + .4988110001 + .7632988371	2 ¹
CATLOG -54D	Direction of star 9 (=11 ₈) (α Tamri (Aldohama)) in Reference coords	+ .3507315036 + .9926832207 + .2831839492	2 ¹
CATLOG -60D	Direction of star 10D (=12 ₈) (β Orionis (Rigel)) in Reference coords	+ .2011399589 + .9690337941 - .1432348512	2 ¹
CATLOG -66D	Direction of star 11D (=13 ₈) (α Aurigae (Capella)) in Reference coords	+ .1371725573 + .6813721061 + .7189685267	2 ¹
CATLOG -72D	Direction of star 12D (=14 ₈) (α Carinae (Canopus)) in Reference coords	- .0614937230 + .6031563285 - .7952489957	2 ¹
CATLOG -78D	Direction of star 13D (=15 ₈) (α Canis Majoris (Sirius)) in Reference coords	- .1820751783 + .9404899869 - .2869271926	2 ¹
CATLOG -84D	Direction of star 14D (=16 ₈) (α_2 Canis Minoris (Procyon)) in Reference coords	- .4118585524 + .9065485360 + .0924226975	2 ¹
CATLOG -90D	Direction of star 15D (=17 ₈) (γ Velorum (Regor)) in Reference coords	- .3612508532 + .5747270840 - .7342932655	2 ¹
CATLOG -96D	Direction of star 16D (=20 ₈) (γ Ursae Majoris (Dnoces)) in Reference coords	- .4557947941 + .4774785033 + .7450184351	2 ¹
CATLOG -102D	Direction of star 17D (=21 ₈) (α Hydrae (Alphard)) in Reference coords	- .7742591356 + .6152504197 - .1482893839	2 ¹
CATLOG -108D	Direction of star 18D (=22 ₈) (α Leonis (Regulus)) in Reference coords	- .8603205210 + .4636213089 + .2098647835	2 ¹

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PRGMR <i>[Signature]</i>	8/25/69		DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3520
DOCMR <i>[Signature]</i>	8/29/69		
APPR'D <i>[Signature]</i>	8/29/69	REV 2	SHEET 63 OF 65

PROGRAM CONSTANTS (CONTINUED)

AGC TAG	MEANING	ENGINEERING AND AGC VALUE	AGC SCALING
CATLOG -114D	Direction of star 19D (=23 _g) (β Leonis (Denebola)) in Reference coords	(-.9656605484) (+.0525933156) (+.2544260899)	2 ¹
CATLOG -120D	Direction of star 20D (=24 _g) (γ Corvi (Gienah)) in Reference coords	(-.9525211695) (-.0593434796) (-.2986331746)	2 ¹
CATLOG -126D	Direction of star 21D (=25 _g) (α Crucis (Acrux)) in Reference coords	(-.4523440203) (-.0493710140) (-.8904759346)	2 ¹
CATLOG -132D	Direction of star 22D (=26 _g) (α Virginis (Spica)) in Reference coords	(-.9170097662) (-.3502146628) (-.1903999176)	2 ¹
CATLOG -138D	Direction of star 23D (=27 _g) (γ Ursae Majoris (Alkaid)) in Reference coords	(-.5813035376) (-.2909171294) (+.7599300468)	2 ¹
CATLOG -144D	Direction of star 24D (=30 _g) (θ Centauri (Menkent)) in Reference coords	(-.6898393233) (-.4182330640) (-.5903338474)	2 ¹
CATLOG -150D	Direction of star 25D (=31 _g) (α Bootis (Arcturus)) in Reference coords	(-.7801763036) (-.5217996305) (+.3311371675)	2 ¹
CATLOG -156D	Direction of star (=32 _g) (α Coroneae Borealis (Alphecca)) in Reference coords	(-.5325876930) (-.7160644554) (+.4511047742)	2 ¹
CATLOG -162D	Direction of star 27D (=33 _g) (α Scorpii (Antares)) in Reference coords	(+.3516499609) (-.8240702100) (-.4441196390)	2 ¹
CATLOG -168D	Direction of star 28D (=34 _g) (α Trianguli Austr. (Atria)) in Reference coords	(-.1143237858) (-.3399602557) (-.9354250333)	2 ¹
CATLOG -174D	Direction of star 29D (=35 _g) (α Ophiuchi (Rasalhague)) in Reference coords	(-.1124301773) (-.9694934200) (+.2178116072)	2 ¹
CATLOG -180D	Direction of star 30D (=36 _g) (α Lyrae (Vega)) in Reference coords	(+.1217293692) (-.7702732347) (+.6259880410)	2 ¹
CATLOG -186D	Direction of star 31D (=37 _g) (α Sagittarii (Nunki)) in Reference coords	(+.2069325789) (-.8713885748) (+.4435288496)	2 ¹
CATLOG -192D	Direction of star 32D (=40 _g) (α Aquilae (Altair)) in Reference coords	(+.4537196908) (-.8779508801) (+.1527766153)	2 ¹
CATLOG -198D	Direction of star 33D (41 _g) (β Capricorni (Dabih)) in Reference coords	(+.5520184464) (-.7933187400) (-.2567508745)	2 ¹
CATLOG -204D	Direction of star 34D (=42 _g) (α Pavonis (Peacock)) in Reference coords	(+.3261317378) (-.4436021946) (-.8370786936)	2 ¹
CATLOG -210D	Direction of star 35D (=43 _g) (α Cygni (Deneb)) in Reference coords	(+.4541036270) (-.5892369197) (+.7022312739)	2 ¹
CATLOG -216D	Direction of star 36D (=44 _g) (α Pegasi (Enif)) in Reference coords	(+.8138832631) (-.5557243189) (+.1691204557)	2 ¹

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Belmont</i>		P57	
PRGMR <i>R. M. Bell</i>	<i>8/29/69</i>	DOCUMENT NO.	
ANALST		LUMINARY ID	FC-3520
DOCMR <i>Am. Grant</i>	<i>8/29/69</i>	REV 2	SHEET 64 OF 65
APPR'D <i>Am. Grant</i>	<i>8/29/69</i>		

PROGRAM CONSTANTS (CONTINUED)

AGC TAG	MEANING	ENGINEERING AND AGC VALUE	AGC SCALING
CATLOG -222D	Direction of star 37D (=45 ₀) (α Piscis Austr. (Formalhaut)) in Reference coords	(1.8342971408 - .2392481515 - .4966976975)	2 ¹

PAD LOADS

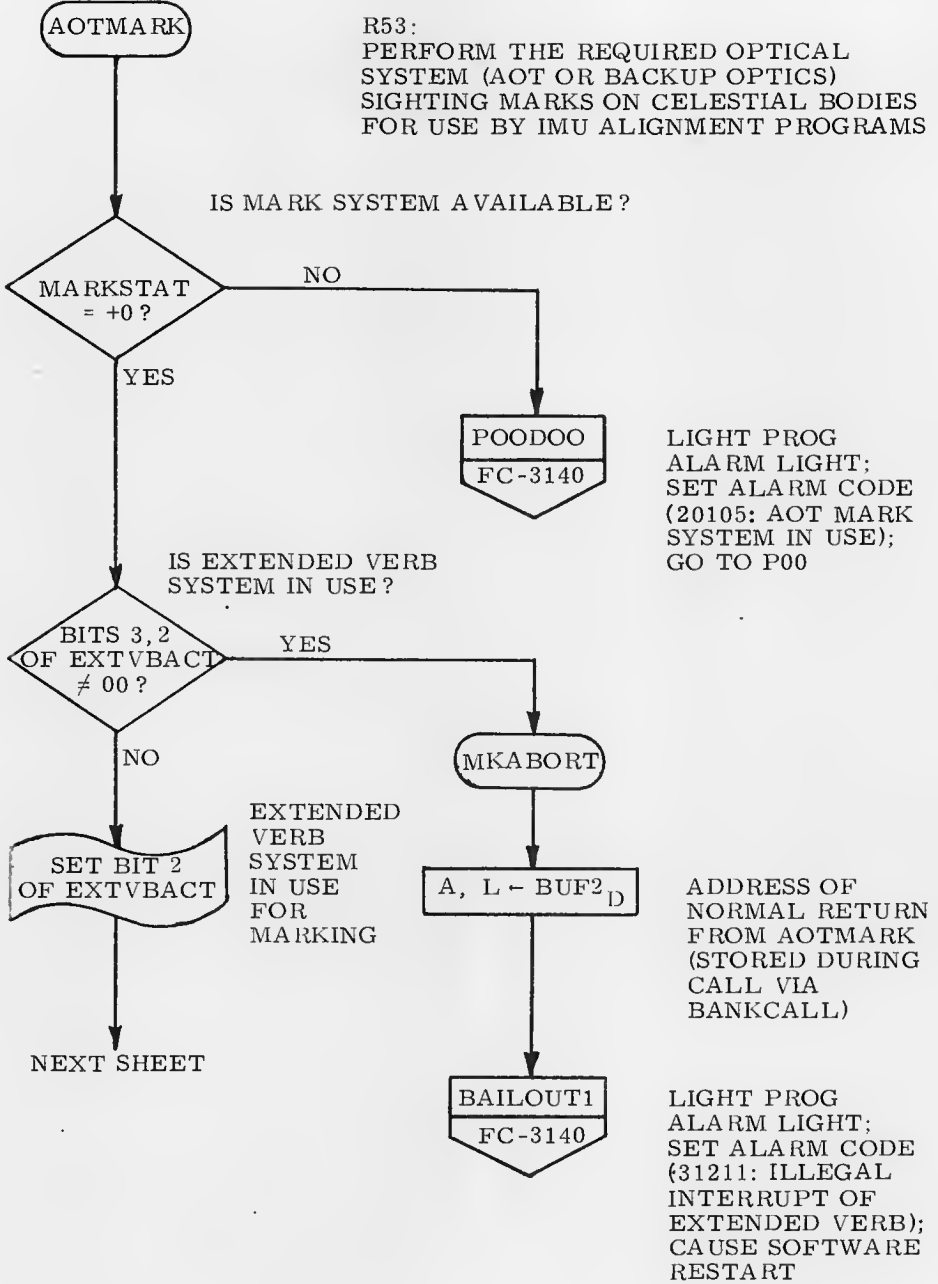
AGC TAG	GSOP TAG	MEANING	ENGINEERING VALUE AND UNITS	AGC VALUE AND UNITS	AGC SCALING	OCTAL VALUE
AOTAZ, . . AOTAZ +5		Azimuth angles corresponding to 6 AOT detent positions	degrees	revs	2 ⁻¹	

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>B. P. Hart</i>	<i>8-2-67</i>	P57	
PRGMR <i>B. P. Hart</i>	<i>8/29/67</i>	DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3520
DOCMR <i>A. M. Grant</i>	<i>8/29/67</i>	REV 2	SHEET 65 OF 65
APPR'D <i>A. M. Grant</i>	<i>8/29/67</i>		

MARK TAKING ROUTINES

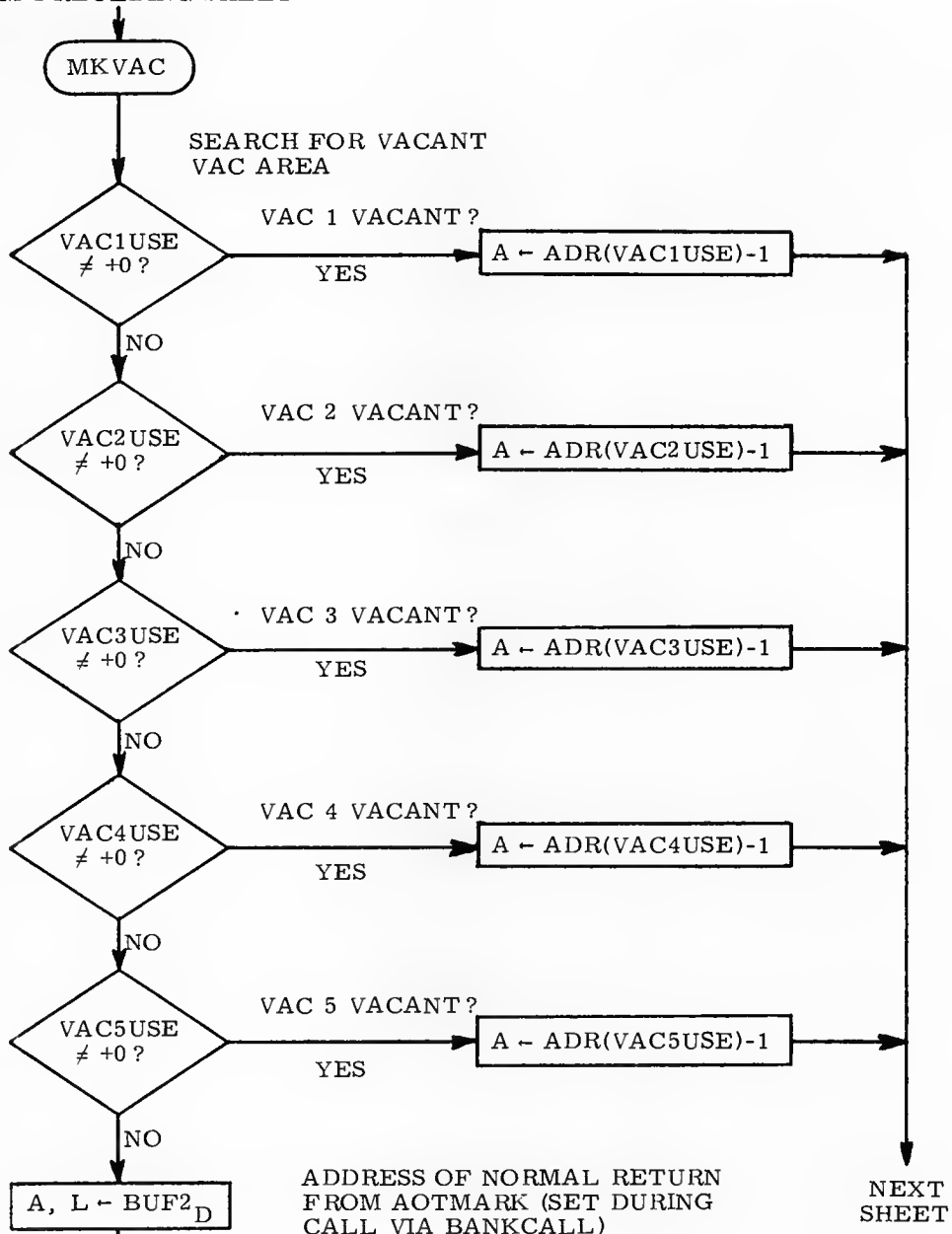
AOTMARK	(R53) SET UP DESIRED SIGHTING MARKS	SH. 2
GETDAT	GET DATA ON DESIRED MARK(S) AND SET UP MARKING	SH. 5
PASTIT	REQUEST MARK VIA DISPLAY	SH. 9
AVESTAR	AVERAGE IN MARK VECTOR	SH. 11
MKRELEAS	RELEASE MARK SYSTEM	SH. 14
MARKRUPT	(R57) STORE MARK DATA - AT TIME OF MARK	SH. 18
XMKRUPT	ENTERED FROM MARKRUPT WHEN X-AXIS MARK TAKEN	SH. 21
YMKRUPT	ENTERED FROM MARKRUPT WHEN Y-AXIS MARK TAKEN	SH. 21
MARKTYPE	DETERMINE WHETHER IN FLIGHT OR ON LUNAR SURFACE	SH. 21
MKREJ	ENTERED FROM MARKRUPT WHEN MARK REJECT BUTTON PRESSED	SH. 25
REMARK	RETURN TO ALLOW ANOTHER MARK	SH. 27
SURFJOB	ON-SURFACE ENTRY TO REMARK	SH. 27
CHANGEVB	SET UP MARK DISPLAY	SH. 28
OANB	COMPUTE OPTICS AXIS FOR DESIRED SIGHTING	SH. 31

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Lukovich</i> 7/69		Mark Taking Routines	
PRGMR <i>D. Willard</i> 11/69		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3530
DOCMR <i>Robert M. Estes</i> 11/20/69		REV . 3	SHEET 1 OF 45
APPR'D <i>Robert M. Estes</i> 11/20/69			



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>D. Lutzkiel</i>	Mark Taking Routines	
PRGMR	<i>D. M. Soren</i>	Luminary 1D	DOCUMENT NO. FC-3530
ANALST			
DOCMR	<i>A. M. Soren</i>		
APPR'D	<i>A. M. Soren</i>	REV 3	SHEET 2 OF 45

FROM PRECEDING SHEET



ADDRESS OF NORMAL RETURN
FROM AOTMARK (SET DURING
CALL VIA BANKCALL)

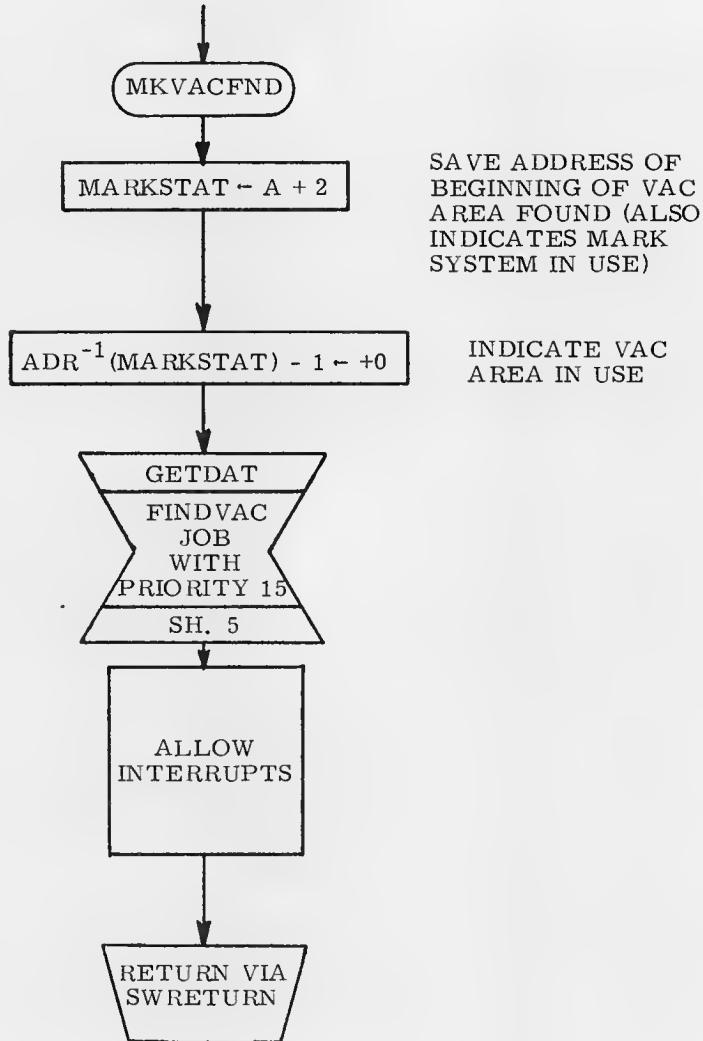
NEXT
SHEET

LIGHT PROG
ALARM LIGHT;
STORE
ALARM
CODE (31207:
NO VAC AREA
AVAILABLE
FOR MARKS);
CAUSE SOFTWARE
RESTART

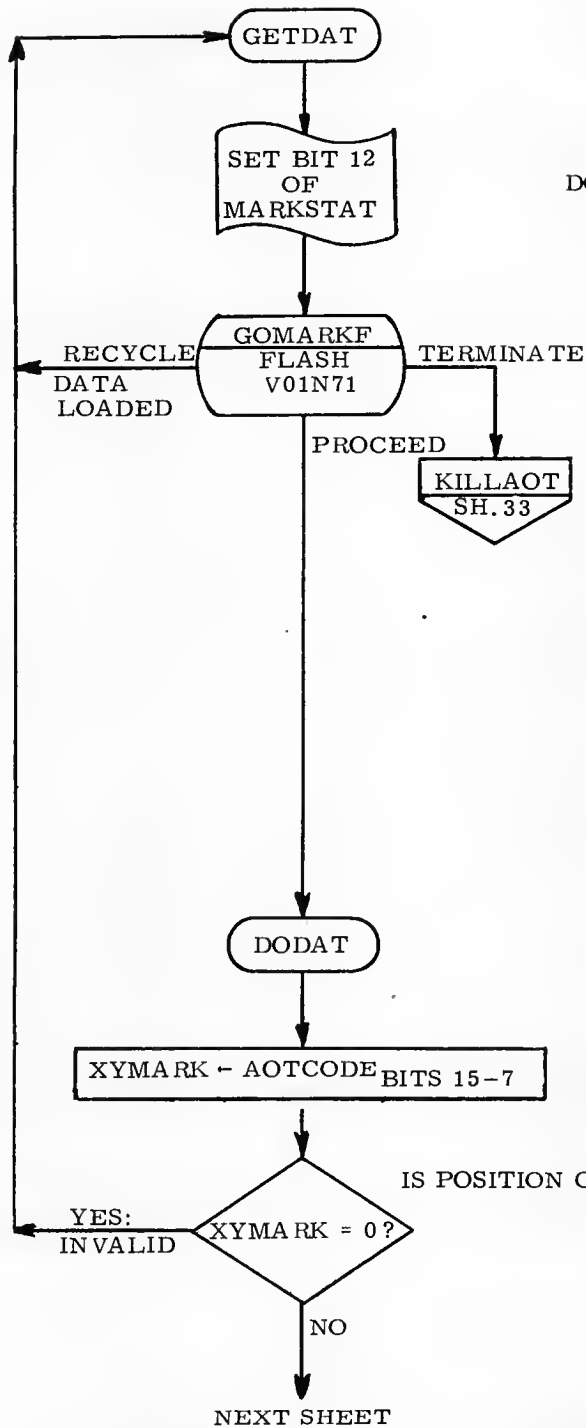
BAILOUT1
FC-3140

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

FROM PRECEDING SHEET



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>D. Lusk</i> 7/69	Mark Taking Routines	
PRGMR	<i>D. Lusk</i> 7/69		
ANALST		Luminary 1D	DOCUMENT NO. FC-3530
DOCMR	<i>A. M. Sorant</i> 7/25/69	REV 3	SHEET 4 OF 45
APPR'D	<i>A. M. Sorant</i> 7/25/69		



DON'T ACCEPT MARKS YET

DISPLAY (FOR LOADING OR VERIFICATION) NOUN 71:

R1: 00 PSS (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?

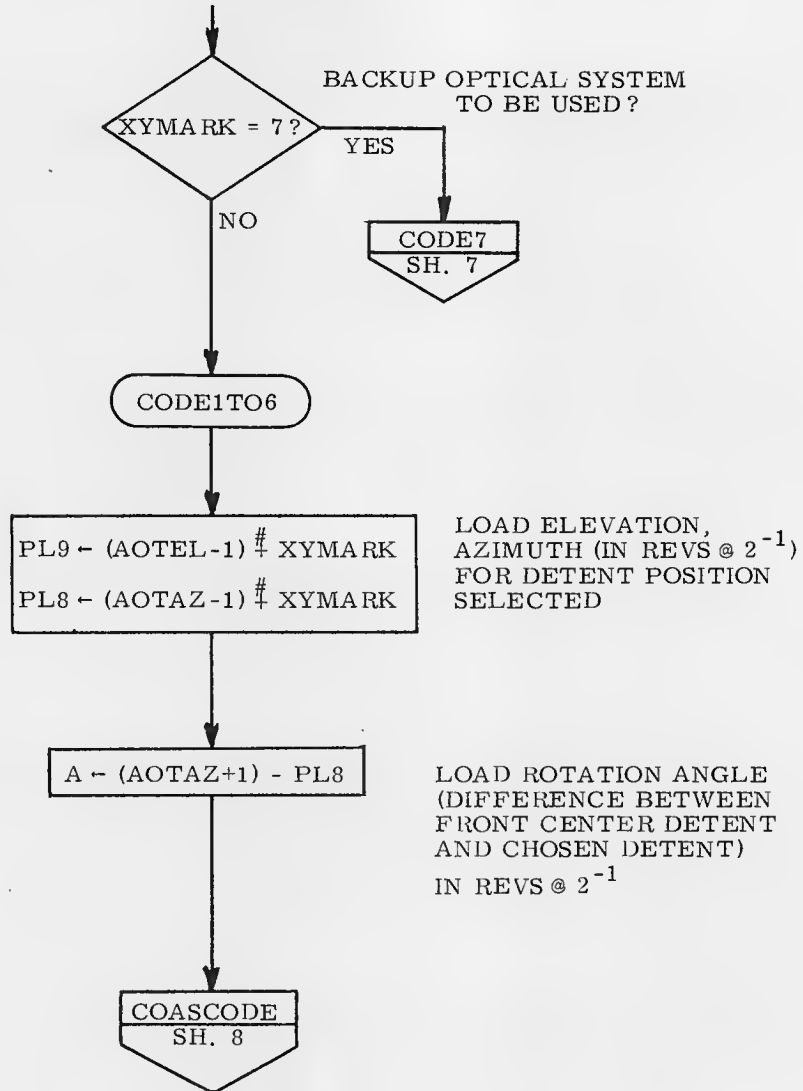
YES: INVALID

NO

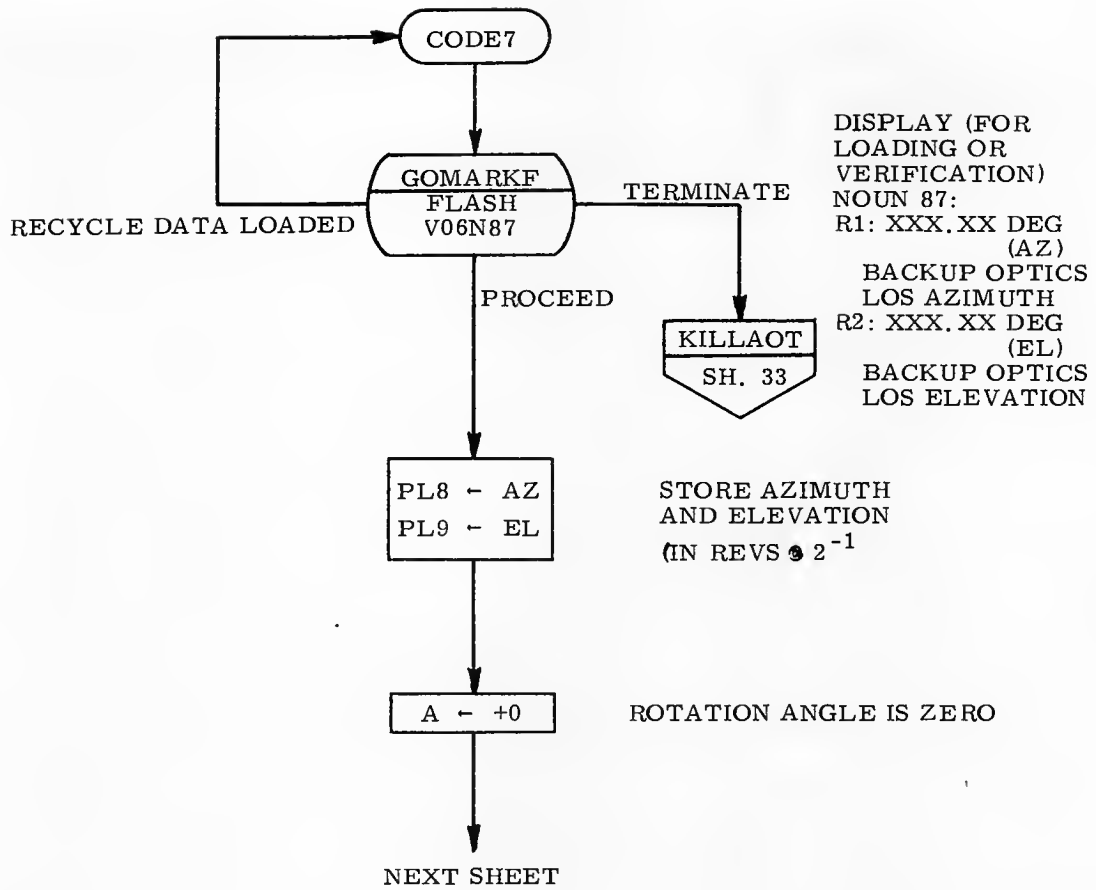
NEXT SHEET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. G. ...</i>	<i>9/69</i>	Mark Taking Routines	
PRGMR <i>J. ...</i>	<i>7/69</i>	Luminary 1D	DOCUMENT NO. FC-3530
ANALST			
DOCMR <i>Ally ...</i>	<i>9/25/69</i>	REV 3	SHEET 5 OF 15
APPR'D <i>Ally ...</i>	<i>7/25/69</i>		

FROM PRECEDING SHEET



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. S. ...</i> 7/69	PRGMR <i>D. M. ...</i> 7/69	Mark Taking Routines	
ANALST	DOCMR <i>Alfred M. ...</i> 7/25/69	Luminary 1D	DOCUMENT NO. FC-3530
APPR'D <i>Alfred M. ...</i> 7/25/69	REV 3	SHEET 6 OF 13	



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

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 @ 2¹
PL24_V = X-PLANE PROJECTION
OF SCAXIS_V IN NB
COORDS @ 2¹
PL18_V = Y-PLANE PROJECTION
SCAXIS_V IN NB COORDS
@ 2¹

PL12_V ← COS(PL10 × 2⁻¹) · PL18_V - SIN(PL10 × 2⁻¹) · PL24_V
PL18_V ← SIN(PL10 × 2⁻¹) · PL18_V + COS(PL10 × 2⁻¹) · PL24_V

TAKE ROTATION INTO ACCOUNT
Y-MARK PLANE
VECTOR IN NB
COORDS @ 2²
X-MARK PLANE
VECTOR IN NB
COORDS @ 2²
(2⁻¹ FACTORS FOR
SCALING)

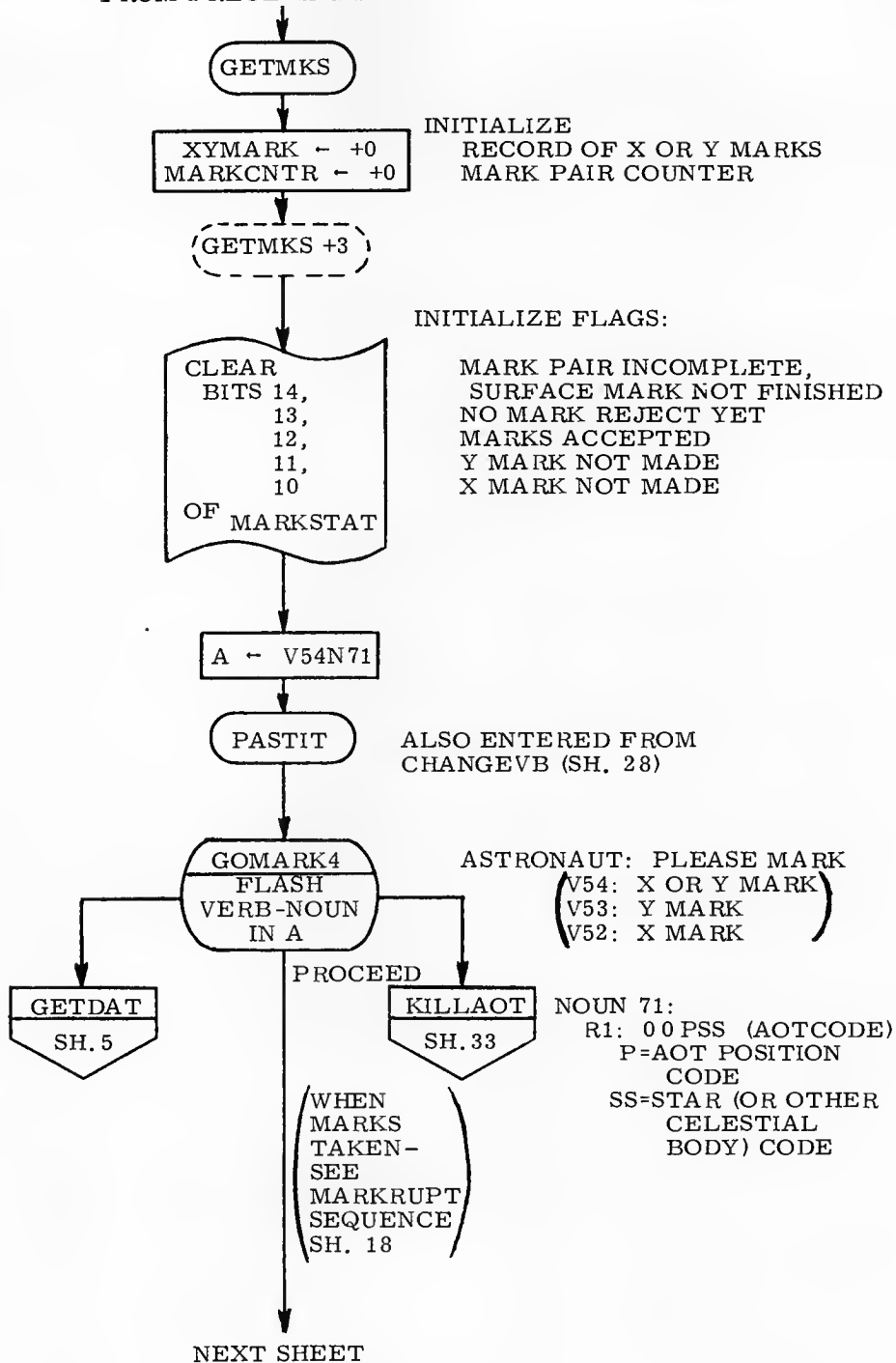
(STARAD +6)_V ← (0, 0, 0)

INITIALIZE AVERAGE LOS VECTOR

NEXT SHEET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>D. Lytkov</i> 7/19	Marking Routines	
PRGMR	<i>D. Lytkov</i> 7/67	DOCUMENT NO.	
ANALST		Luminary 1D	FC-2520
DOCMR	<i>Alvin J. Smith</i> 7/25/67	REV 3	SHEET 8 OF 15
APPR'D	<i>Alvin J. Smith</i> 7/25/67		

FROM PRECEDING SHEET



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

FROM PRECEDING SHEET

MARKCHEX

ALSO ENTERED FROM
DSP V6N79 (SH. 29)

SET
BIT 12 OF
MARKSTAT

DON'T ACCEPT ANY MORE MARKS

XYMARK ← MARKSTAT BITS 9-1

SAVE MARK VAC
AREA ADDRESS

MKDEX ← +0

INITIALIZE NUMBER OF
MARK PAIRS PROCESSED

IS LAST SIGHTING PAIR COMPLETE?

BITS 11, 10
OF MARKSTAT
BOTH SET
?

NO

YES

OTHER PAIR(S)
COMPLETE?

TEST
MARKCNTR

>0
(YES)

+0
(NO)

DISCOUNT
INCOMPLETE
PAIR

MARKCNTR ← MARKCNTR - 1

ALARM
LIGHT PROG
ALARM LIGHT;
SET ALARM
CODE
FC-3140

INPUT=
ALARM
CODE 111
(MARK
MISSING)

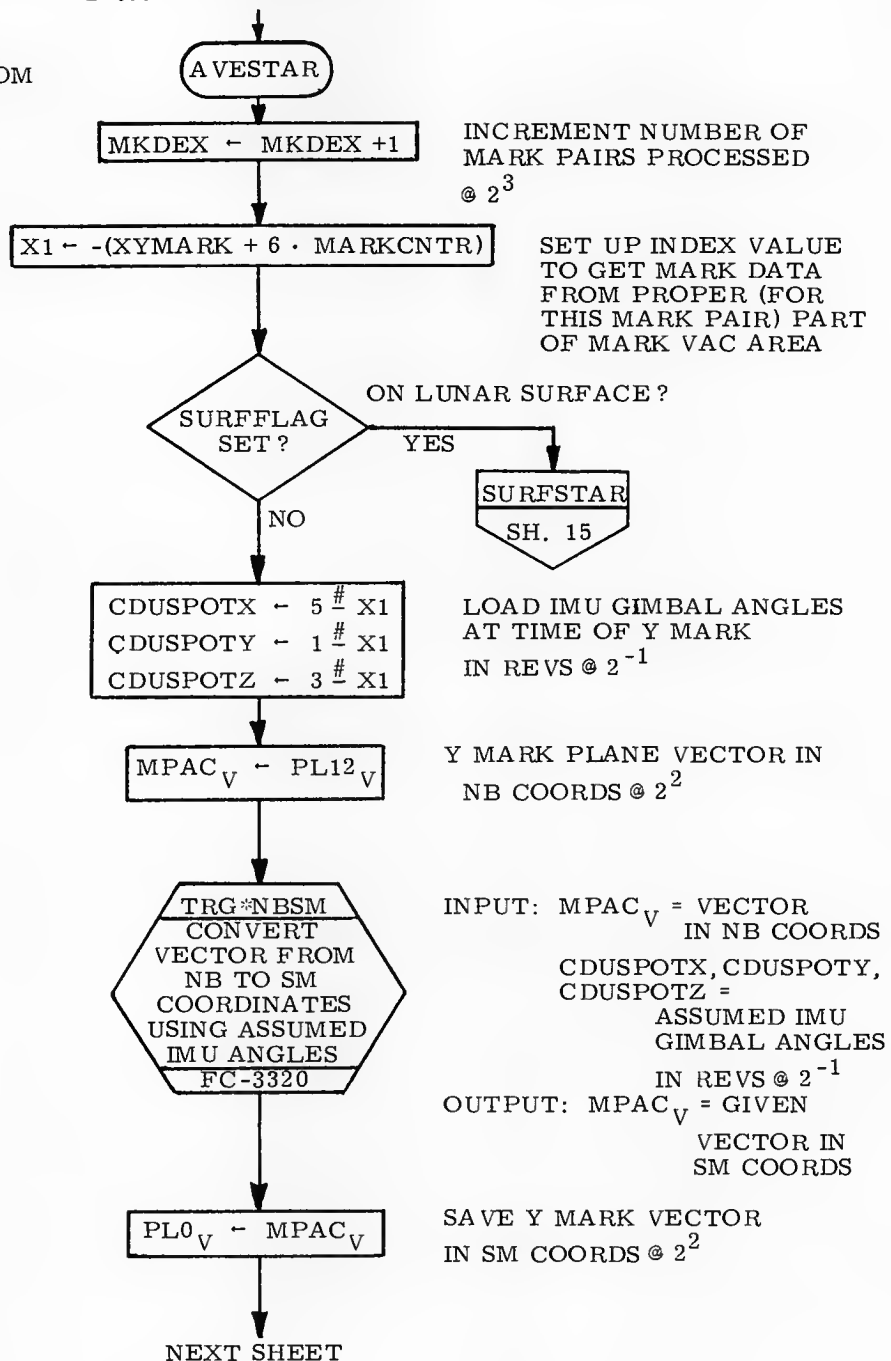
GETMKS
SH. 9

NEXT SHEET

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

FROM PRECEDING SHEET

ALSO ENTERED FROM
AVEIT (SH. 13)



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

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 @ 2²

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 @ 2²)

PL24_V ← UNIT(MPAC_V × PL0_V)

LOS FOR THIS MARK PAIR:
 UNIT (X_{MP(SM)}} × Y_{MP(SM)}}) @ 2¹

NEXT SHEET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>D. Lutz</i>	7/69	Mark Taking Routines	
PRGMR	<i>D. Lutz</i>	7/69		
ANALST			Luminary 1D	DOCUMENT NO. FC-3530
DOCMR	<i>A. M. Sorant</i>	7/25/69		
APPR'D	<i>A. M. Sorant</i>	7/25/69	REV 3	SHEET 12 OF 45

FROM PRECEDING SHEET

AVEIT

ALSO ENTERED FROM SURFSTAR (SH. 11)

AVERAGE IN LOS VECTOR
(FROM NEW MARK PAIR)
IN SM COORDS @ 2¹

$$(\text{STARAD} + 6)_V \leftarrow \left(\frac{\text{MKDEX} - 1 \times 2^{-3}}{\text{MKDEX}} \right) \cdot (\text{STARAD} + 6)_V + \left(\frac{\text{PL24}_V \times 2^{-3}}{\text{MKDEX}} \right)$$

$$\text{STARSAV2}_V \leftarrow \left(\frac{\text{MKDEX} - 1 \times 2^{-3}}{\text{MKDEX}} \right) \cdot (\text{STARAD} + 6)_V + \left(\frac{\text{PL24}_V \times 2^{-3}}{\text{MKDEX}} \right)$$

WHERE:
 (STARAD + 6)_V = LOS VECTOR AVERAGE SO FAR IN SM COORDS @ 2¹
 PL24_V = NEW LOS VECTOR IN SM COORDS @ 2¹
 MKDEX = NUMBER OF MARK PAIRS PROCESSED SO FAR @ 2³
 2⁻³ FACTORS ARE FOR SCALING

TEST MARKCNTR

MORE MARK PAIRS TO BE PROCESSED?

>0 (YES)

+0 (NO)

MARKCNTR ← MARKCNTR - 1

ENDMARKS

AVESTAR
SH. 11

INHIBIT INTERRUPTS

MKRELEAS
WAITLIST
TASK
IN
.05 SEC
SH. 14

ENDMARK
FC-3080

TERMINATE DISPLAY
INTERFACE FOR MARKING

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Lutz</i>	<i>7/69</i>	Mark Taking Routines	
PRGMR <i>D. Lutz</i>	<i>7/69</i>	DOCUMENT NO.	
ANALST		Luminary 1D	FC-3530
DOCMR <i>A. M. Spant</i>	<i>7/25/69</i>	REV 3	SHEET 13 OF 45
APPR <i>A. M. Spant</i>	<i>7/25/69</i>		

MKRELEAS

$ADR^{-1} [(MARKSTAT_{BITS\ 9-1}) - 1] \leftarrow (MARKSTAT_{BITS\ 9-1}) - 1$
 $MARKSTAT \leftarrow +0$

FREE VAC
 AREA USED
 FOR MARKS

 MARK SYSTEM
 AVAILABLE

A ← 1

VIA IBNKCALL

GOODEND
 FC-3220

TERMINATE AOTMARK
 SEQUENCE

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

SURFSTAR

ENTERED FROM AVESTAR (SH. 11) IF ON LUNAR SURFACE

CDUSPOTX ← 4 # X1
CDUSPOTY ← 0 # X1
CDUSPOTZ ← 2 # X1

LOAD IMU GIMBAL ANGLES AT TIME OF MARK
IN REVS @ 2⁻¹

MPAC ← 1 # X1

LOAD CURSOR ANGLE IN REVS @ 2⁻¹

CDULOGIC
CONVERT
ANGLE FROM
2'S TO 1'S
COMPLEMENT
FC-3150

INPUT: MPAC = 2'S COMPLEMENT ANGLE
IN REVS @ 2⁻¹

OUTPUT: MPAC_D = 1'S COMPLEMENT ANGLE
IN REVS @ 2⁰

PL24_D ← MPAC_D

CURSOR ANGLE IN REVS @ 2⁰

CURSOR ANGLE ZERO?
MPAC_D = 0 ?

YES

YZCHK

SPIRAL ANGLE ALSO ZERO?

3 # X1 = 0 ?

YES

YSZERO

MPAC_V ← SCAXIS_V

OPTICS AXIS IN
NB COORDS @ 2¹

JUSTOA
SH. 17

NO

NO

MPAC_D ← PL24_D

NEXT SHEET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. J. Russell</i>	7/69	Mark Taking Routines	
PRGMR <i>D. Hallard</i>	7/69	Luminary 1D	DOCUMENT NO. FC-3530
ANALST			
DOCMR <i>A. M. Grant</i>	7/25/69	REV 3	SHEET 15 OF 45
APPR'D <i>A. M. Grant</i>	7/25/69		

FROM PRECEDING SHEET

JUSTZY

$$PL0_V \leftarrow \text{UNIT}[\text{UNIT}(\text{COS}(MPAC_D) \cdot PL12_V - \text{SIN}(MPAC_D) \cdot PL18_V) \times SCAXIS_V]$$

$$MPAC \leftarrow 3 \# X1$$

LOAD SPIRAL ANGLE IN REVS @ 2^{-1}

CDULOGIC
CONVERT
ANGLE FROM
2'S TO 1'S
COMPLEMENT
FC-3150

INPUT: MPAC = 2'S COMPLEMENT

ANGLE IN REVS @ 2^{-1}

OUTPUT: MPAC_D = 1'S COMPLEMENT

ANGLE IN REVS @ 2^0

$$PL26_D \leftarrow \frac{1}{12} (1 + MPAC_D - PL24_D)$$

SEPARATION ANGLE IN
REVS @ 2^0

$$= \frac{1}{12} (360^\circ + \text{SPIRAL } \angle - \text{CURSOR } \angle)$$

NEXT SHEET

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

FROM PRECEDING SHEET

$$MPAC_V = 2^1 \cdot [\cos(PL26_D) \cdot SCAXIS_V + \sin(PL26_D) \cdot PL0_V]$$

JUSTOA

$$MPAC_V = \text{UNIT}(MPAC_V)$$

STAR LOS VECTOR IN NB COORDS @ 2¹

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

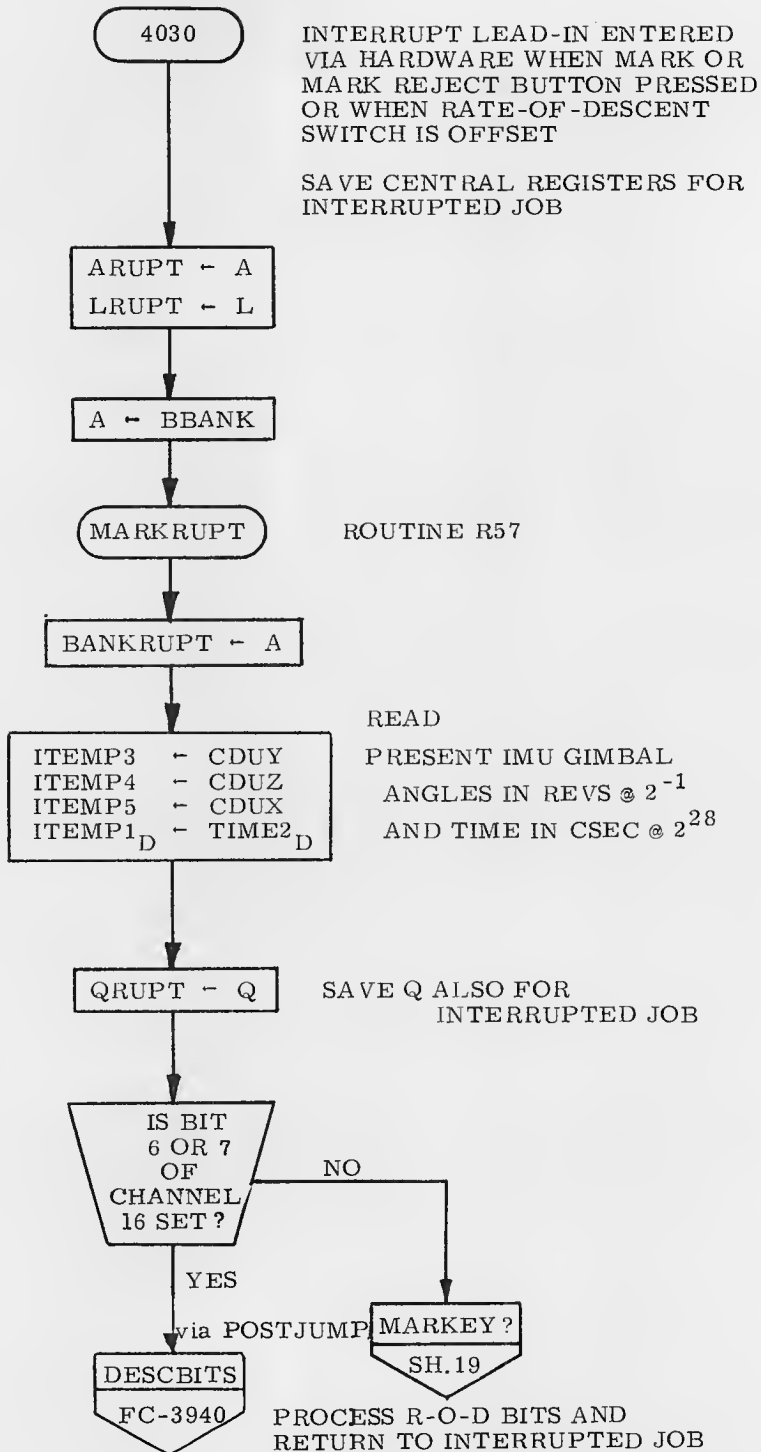
$$PL24_V = MPAC_V$$

LOS VECTOR IN SM COORDS @ 2¹

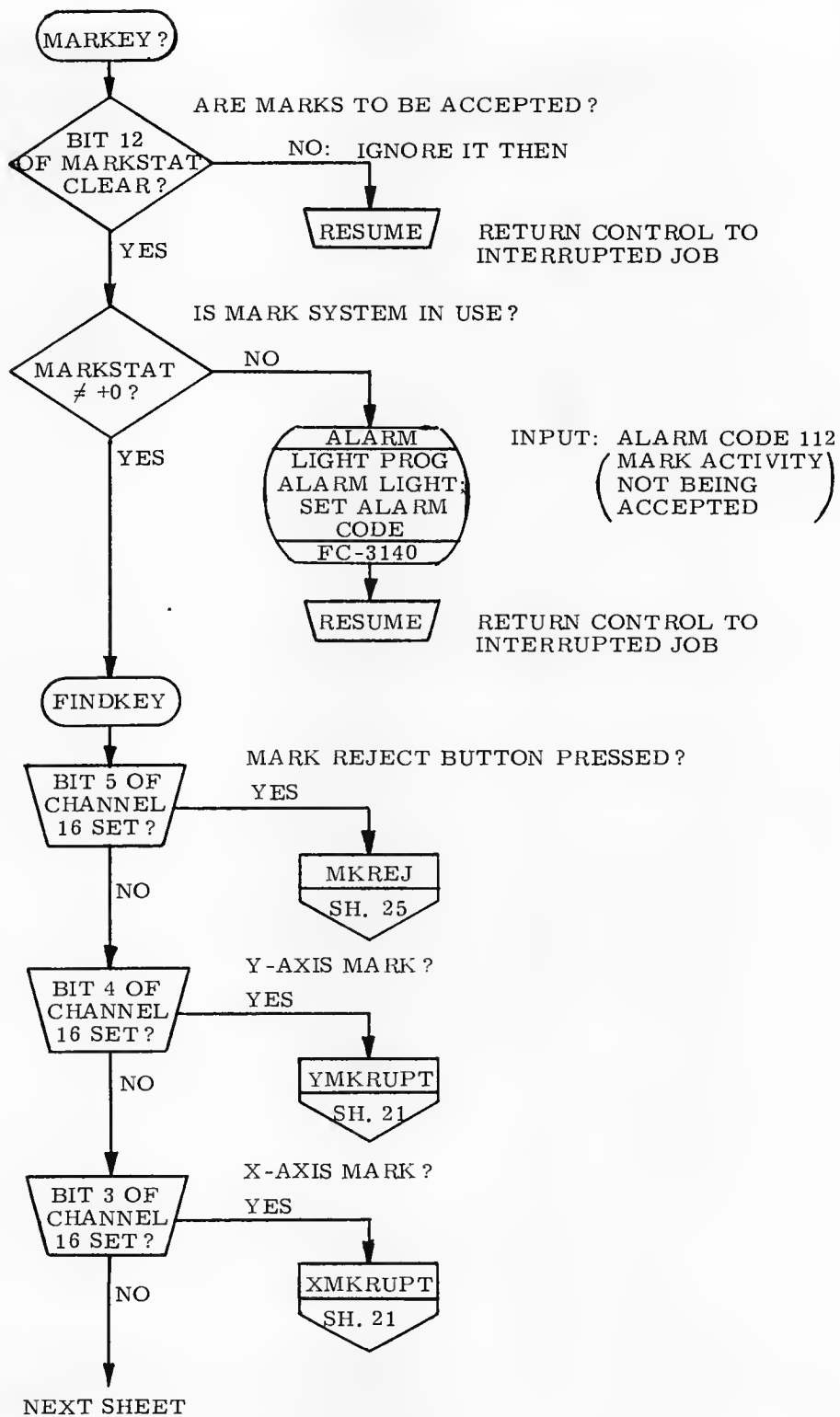
$$= \cos(\text{SEP } \angle) \underline{u}_O + (\cos(\text{CURSOR } \angle) \underline{Y}_{MP} - \sin(\text{CURSOR } \angle) \underline{X}_{MP}) \times \underline{u}_O$$

AVEIT
 SH. 13

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. L. R. 7/69</i>	7/69	Mark Taking Routines	
PRGMR <i>P. M. 7/69</i>	7/69	Luminary 1D	DOCUMENT NO. FC-3530
ANALST			
DOCMR <i>A. M. Grant 7/25/69</i>	7/25/69	REV 3	SHEET 17 OF 45
APPR'D <i>A. M. Grant 7/25/69</i>	7/25/69		

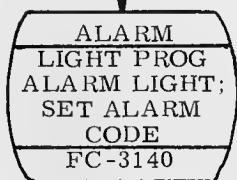


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Buttkumil</i>	<i>4/69</i>	Mark Taking Routines	
PRGMR <i>D. Miller</i>	<i>7/69</i>	DOCUMENT NO.	
ANALST		Luminary 1D	FC-3530
DOCMR <i>A. M. Soant</i>	<i>7/25/69</i>	REV 3	SHEET 18 OF 45
APPR'D <i>A. M. Soant</i>	<i>7/25/69</i>		

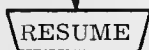


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Lutz</i>	<i>7/69</i>	Mark Taking Routines	
PRGMR <i>J. Muller</i>	<i>7/69</i>	DOCUMENT NO.	
ANALST		Luminary 1D	FC-3530
DOCMR <i>A. M. Grant</i>	<i>7/25/69</i>	REV 3	SHEET 19 OF 45
APPR'D <i>A. M. Grant</i>	<i>7/25/69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

FROM PRECEDING SHEET

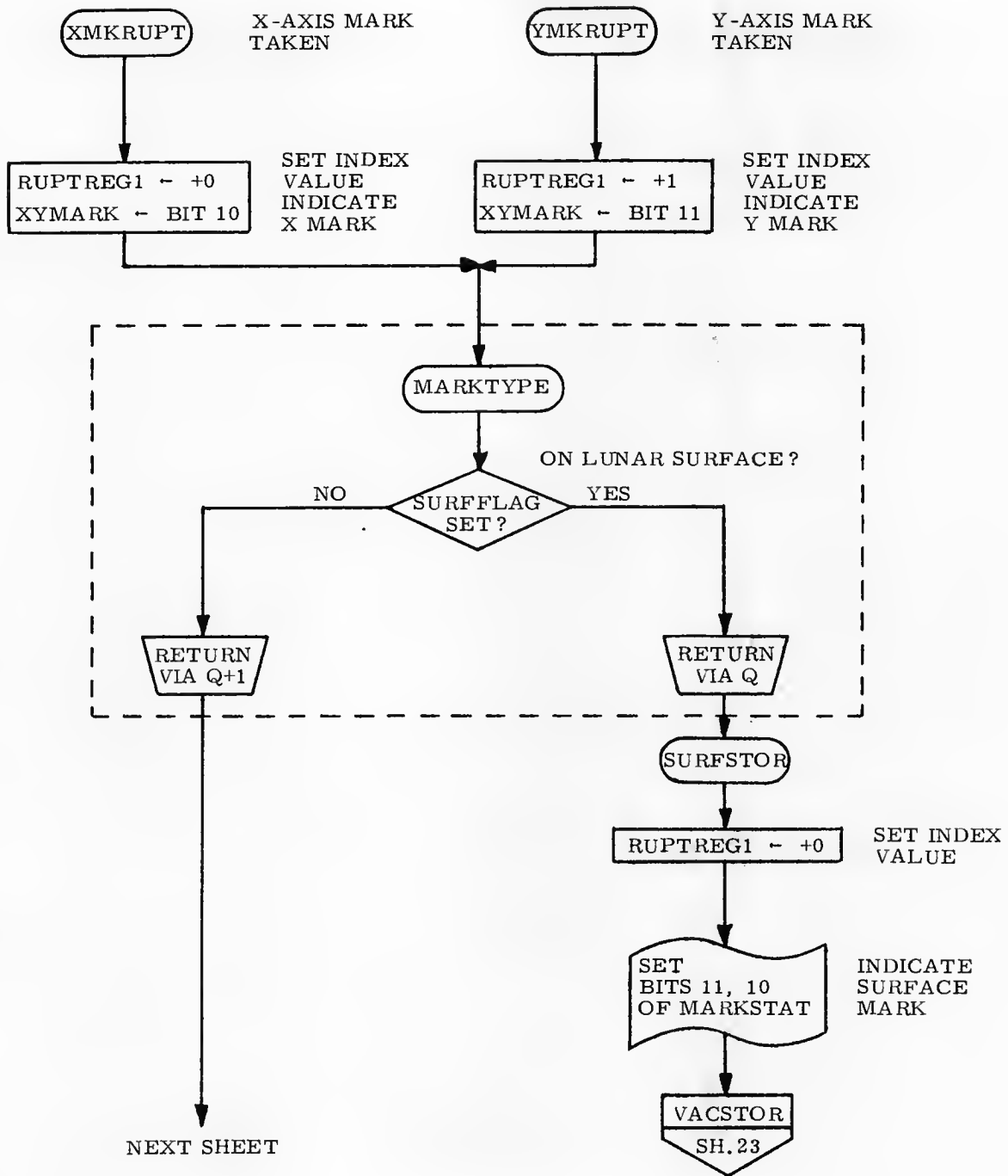


INPUT:
ALARM CODE 113
(NO INBITS IN CHANNEL 16)

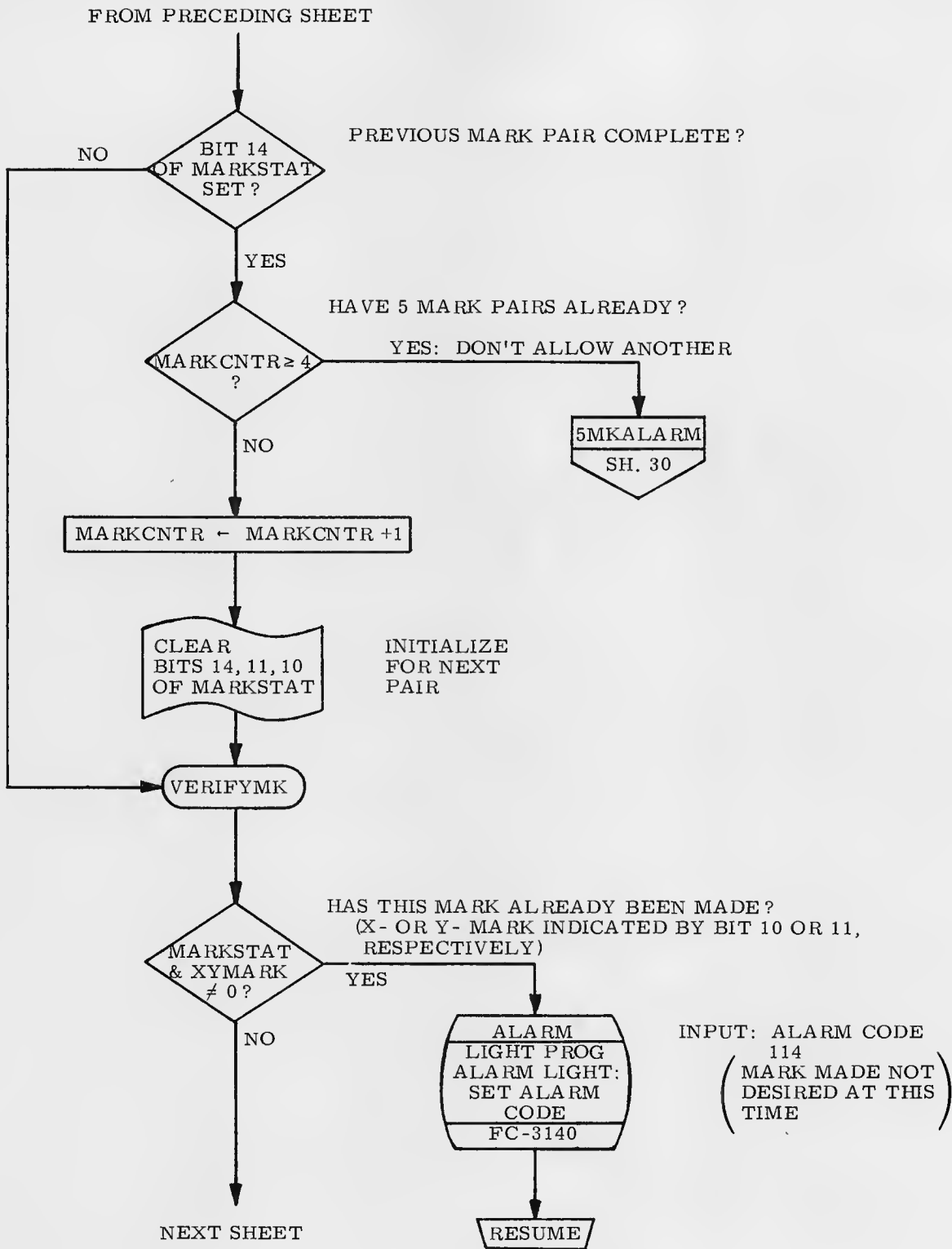


RETURN CONTROL TO INTERRUPTED JOB

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Sullivan</i> 7/16/69		Mark Taking Routines	
PRGMR <i>D. Sullivan</i> 7/16/69			DOCUMENT NO.
ANALST		Luminary 1D	FC-3530
DOCMR <i>A. M. Sorant</i> 7/15/69		REV 3	SHEET 20 OF 45
APPR'D <i>A. M. Sorant</i> 7/15/69			



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Lutterwick</i> 7/16/69	PRGMR <i>J. Mulford</i> 7/16/69	Mark Taking Routines	
ANALST	DOCMR <i>W. M. Grant</i> 7/23/69	Luminary 1D	DOCUMENT NO. FC-3530
APPR'D <i>W. M. Grant</i> 7/23/69	REV 3	SHEET 21 OF 45	



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

FROM PRECEDING SHEET

VACSTOR

RUPTREG2 ← MARKSTAT BITS 9-1

GET MARK VAC AREA ADDRESS

TSIGHT_D ← ITEMP1_D

STORE TIME OF MARK
(IN CSEC @ 2²⁸)

RUPTREG1 ← RUPTREG1 + 6 · MARKCNTR + RUPTREG2
MKDEX ← RUPTREG1 + 6 · MARKCNTR + RUPTREG2

SET UP INDEX VALUES TO POINT TO PROPER (FOR THIS MARK) PART OF MARK VAC AREA

4 # RUPTREG1 ← ITEMP5
0 # RUPTREG1 ← ITEMP3
2 # RUPTREG1 ← ITEMP4

STORE X, Y, Z IMU GIMBAL ANGLES AT TIME OF MARK IN APPROPRIATE PART OF MARK VAC AREA

MARKTYPE
DETERMINE WHETHER ON LUNAR SURFACE
SH. 21

ON LUNAR SURFACE

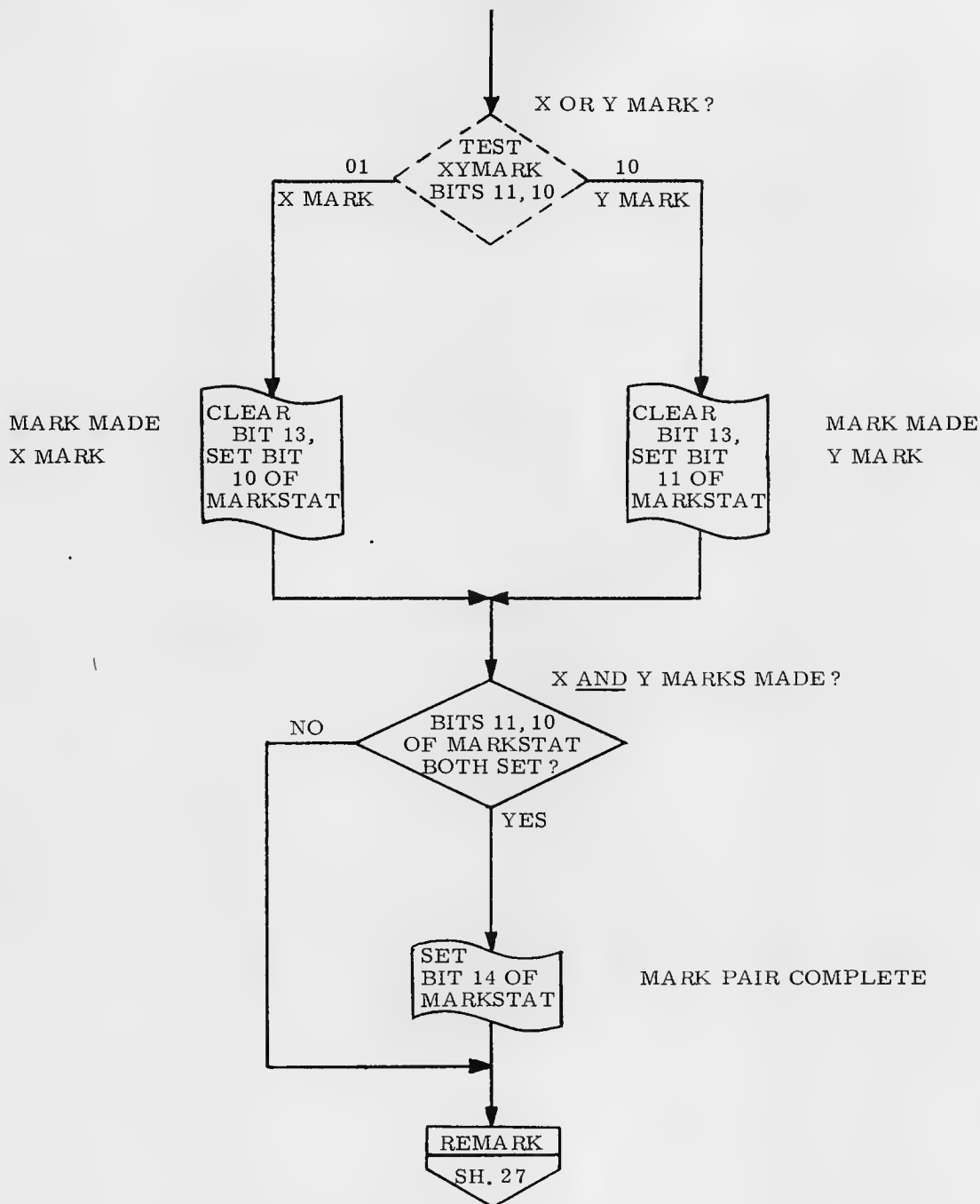
NOT ON LUNAR SURFACE

SURFJOB
SH. 27

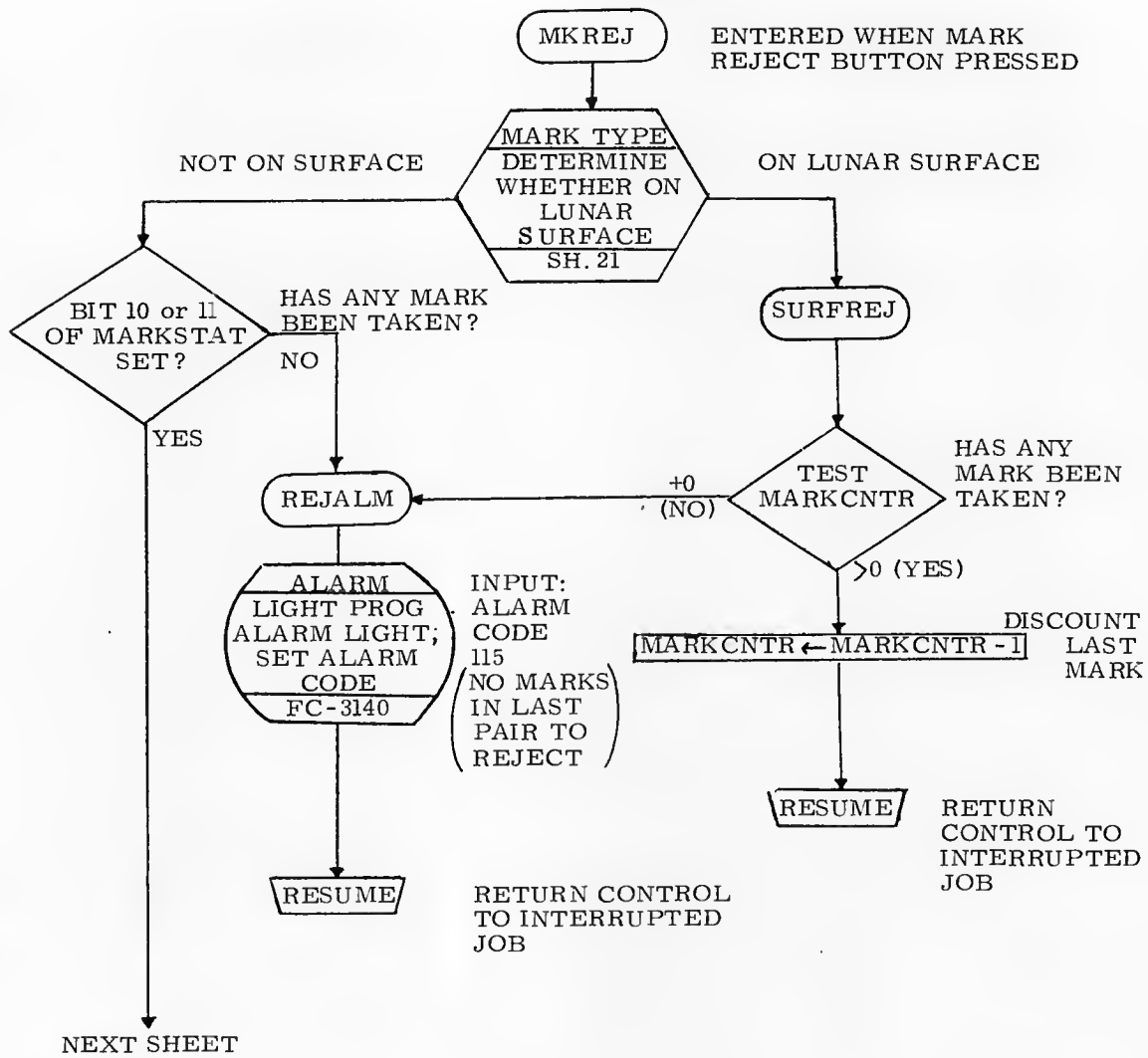
NEXT SHEET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>S. L. Kovich</i> 7/69		Mark Taking Routines	
PRGMR <i>F. Mulholland</i> 7/69			DOCUMENT NO. FC-3530
ANALST		Luminary 1D	
DOCMR <i>A. M. Sorant</i> 7/25/69			
APPR <i>A. M. Sorant</i> 7/25/69	REV 3	SHEET 23 OF 45	

FROM PRECEDING SHEET

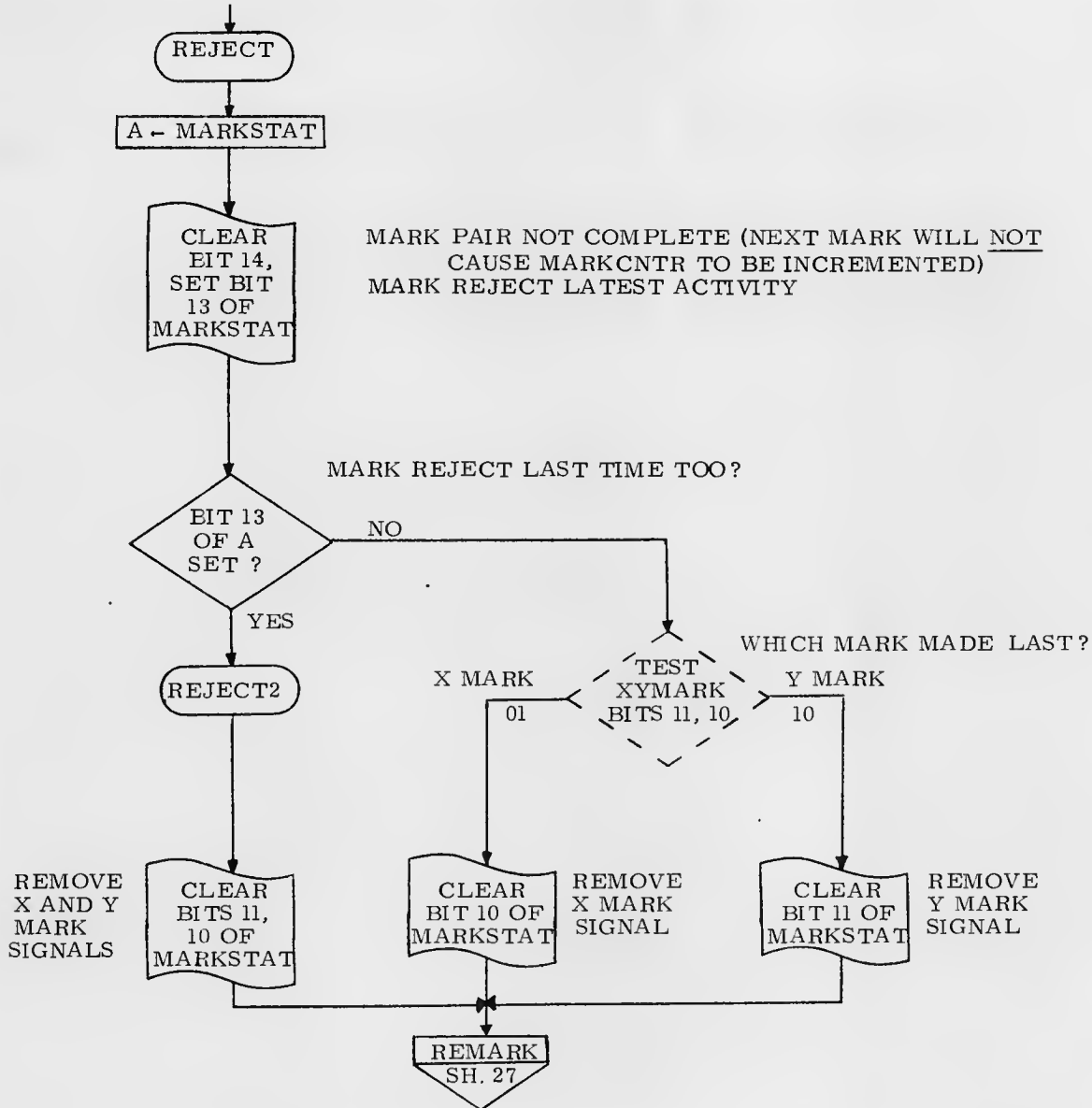


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Lutterbach</i> 7/69	7/69	Mark Taking Routines	
PRGMR <i>D. Mulford</i>	7/69	Luminary ID	DOCUMENT NO. FC-3530
ANALST			
DOCMR <i>A.M. Sorant</i> 7/25/69	7/25/69	REV 3	SHEET 24 OF 45
APPR'D <i>A.M. Sorant</i>	7/25/69		

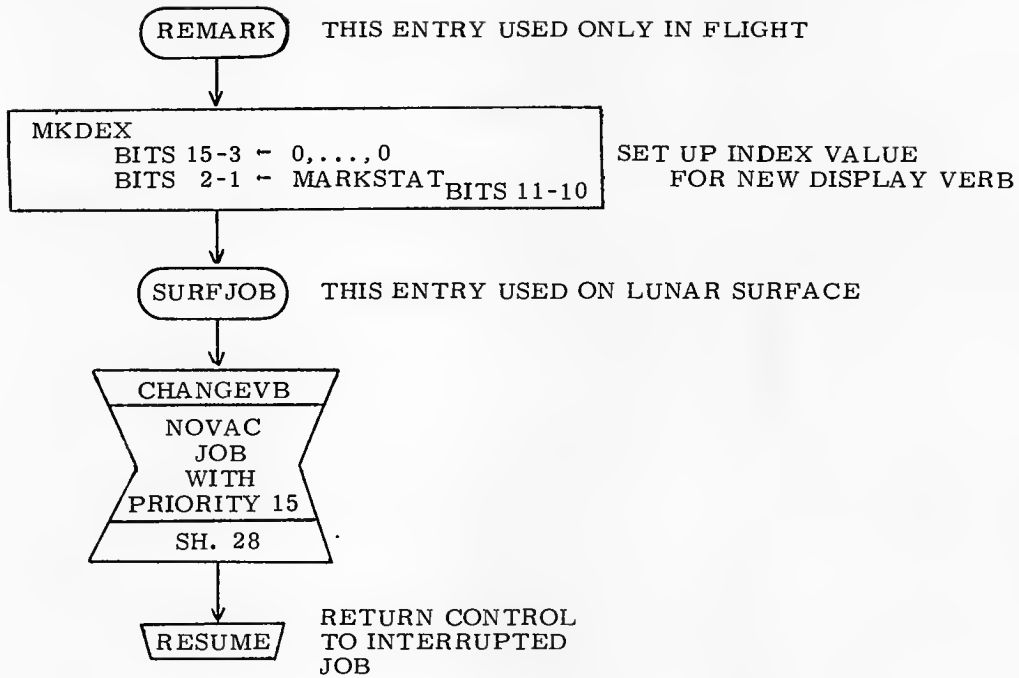


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. J. Szwed</i> 7/69		Mark Taking Routines	
PRGMR <i>F. M. Lewis</i> 7/69		DOCUMENT NO.	
ANALST		Luminary 1D	FC-3530
DOCMR <i>A. M. Szwed</i> 7/25/69		REV 3	
APPR'D <i>A. M. Szwed</i> 7/25/69		SHEET 25 OF 45	

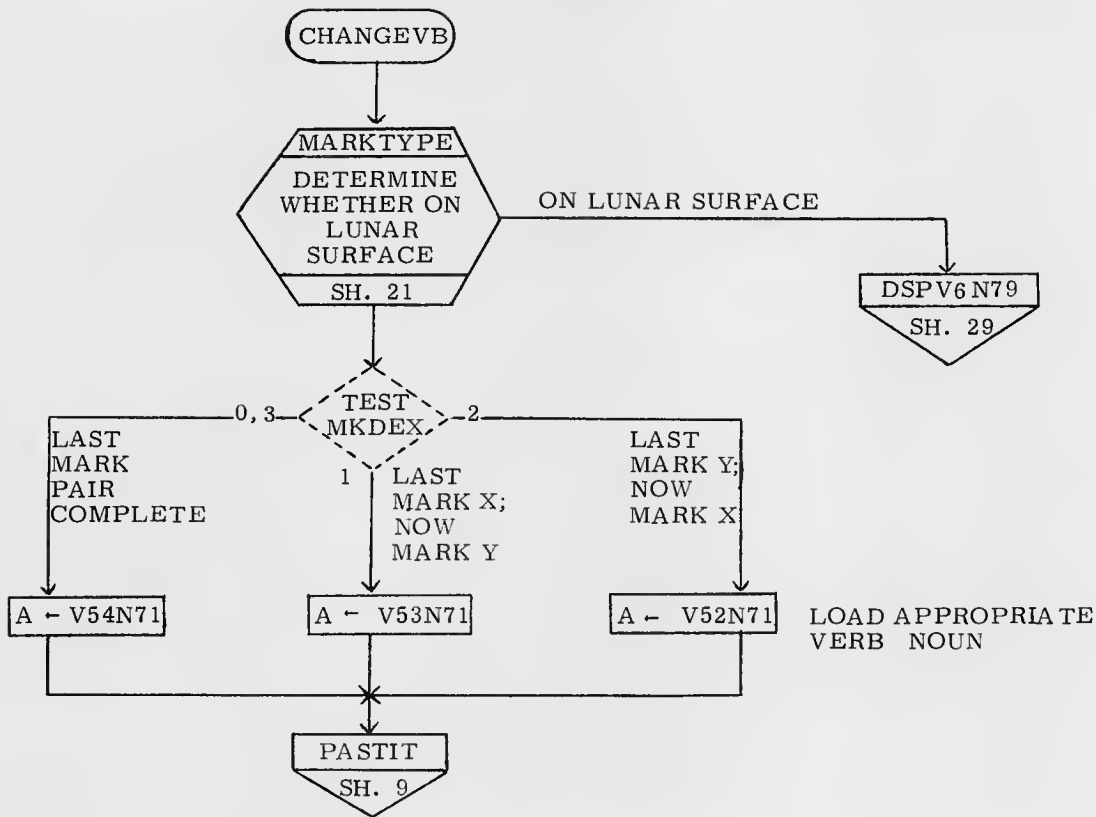
FROM PRECEDING SHEET



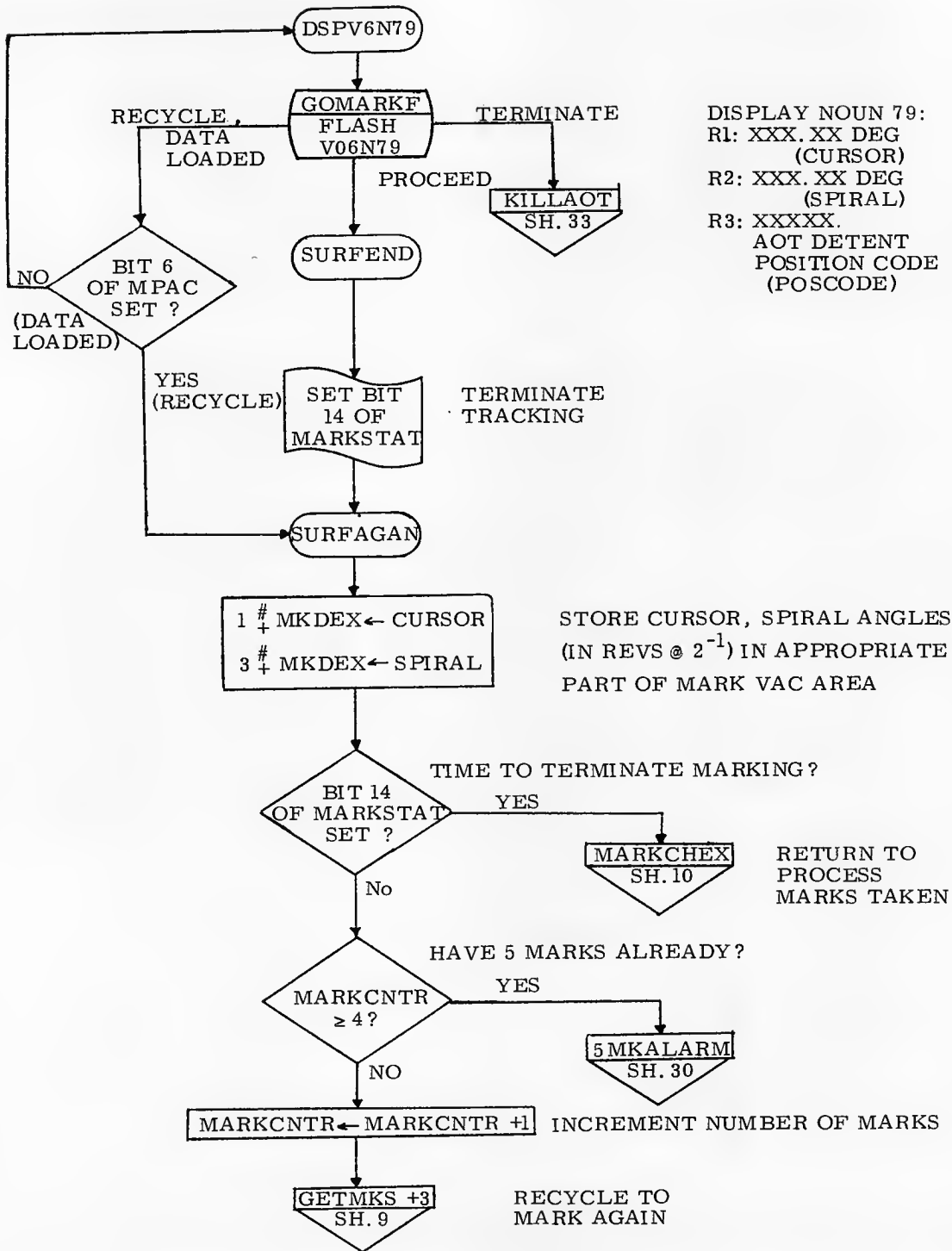
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Lutterwick</i> 7/19	PRGMR <i>D. Mallow</i> 7/69	Mark Taking Routines	
ANALST	DOCMR <i>A. M. Grant</i> 7/25/69	Luminary 1D	DOCUMENT NO. FC-3530
APPR'D <i>A. M. Grant</i> 7/25/69	REV 3	SHEET 26 OF 45	



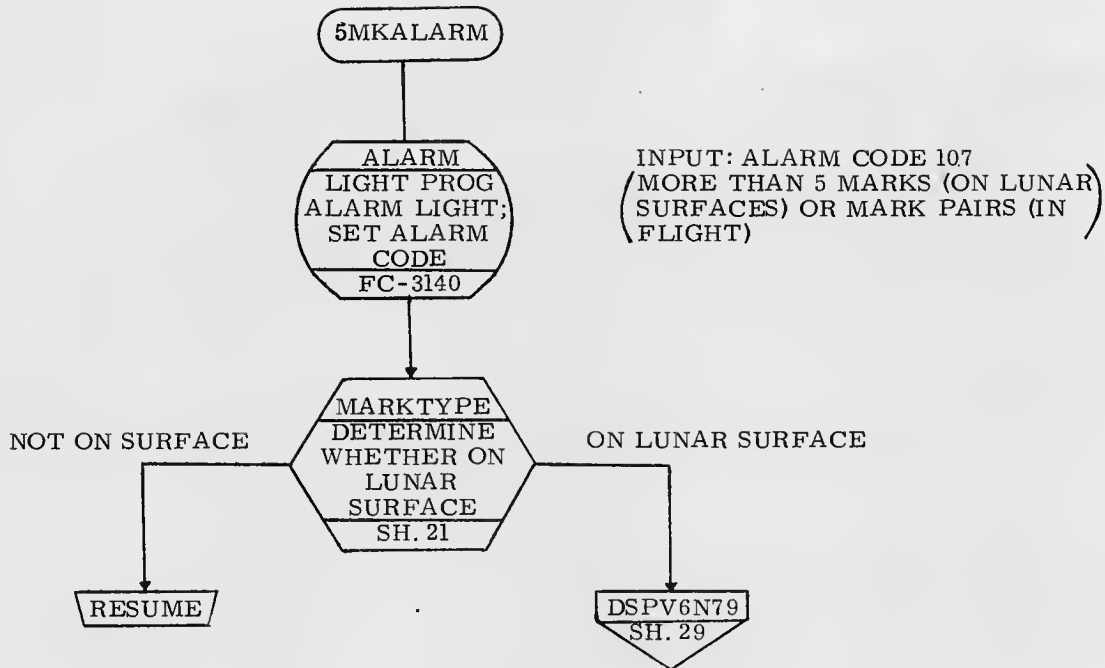
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Lutz</i>	<i>7/69</i>	Mark Taking Routines	
PRGMR <i>L. Muller</i>	<i>7/69</i>	Luminary 1D	DOCUMENT NO. FC-3530
ANALST <i>A. M. Grant</i>	<i>7/25/68</i>	REV 3	SHEET 27 OF 45
APPR'D <i>A. M. Grant</i>	<i>7/25/68</i>		



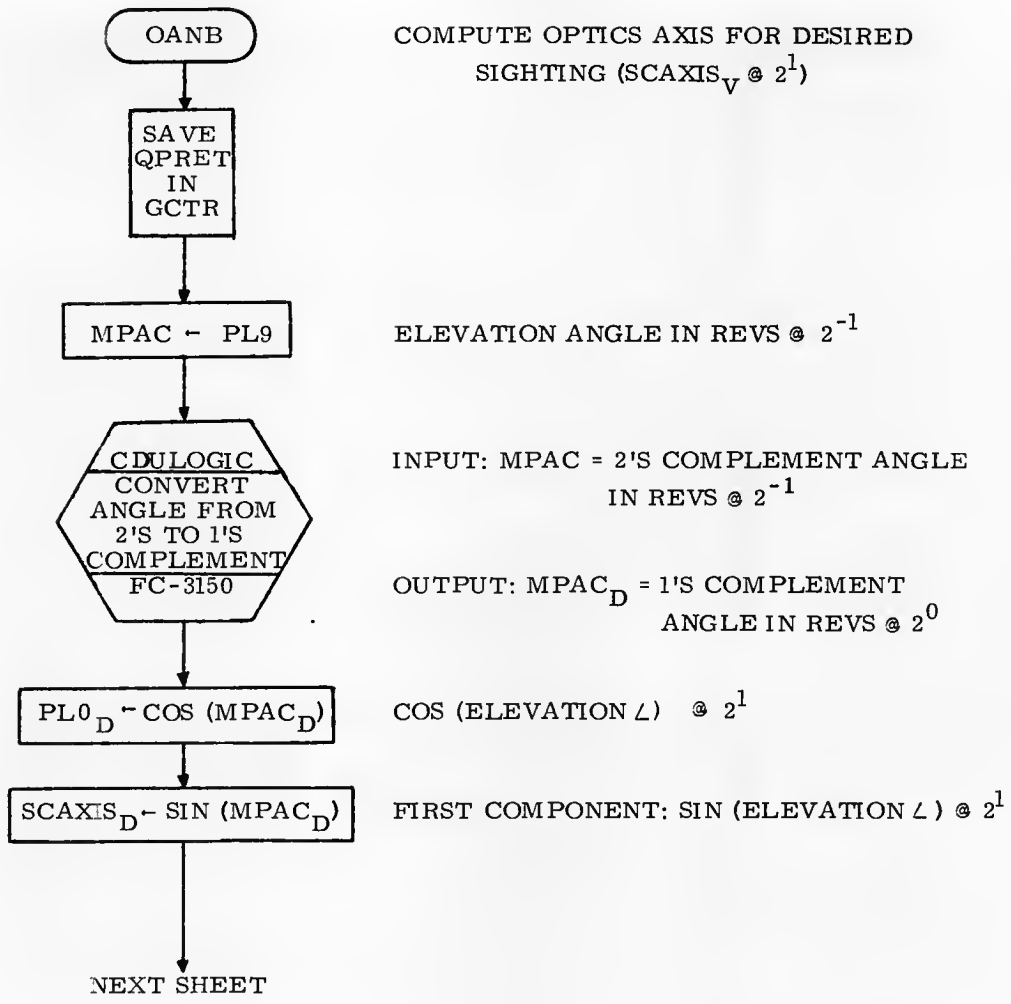
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. Lutzke</i>	<i>7/69</i>	Mark Taking Routines	
PRGMR <i>J. Mullard</i>	<i>7/69</i>	Luminary 1D	DOCUMENT NO. FC-3530
ANALST			
DOCMR <i>A. M. Siant</i>	<i>7/25/68</i>	REV 3	SHEET 28 OF 45
APPR'D <i>A. M. Siant</i>	<i>5/23/69</i>		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. M. Sorant</i>	7/25/69	Mark Taking Routines	
PRGMR <i>A. M. Sorant</i>	7/69	Luminary 1D	DOCUMENT NO.
ANALST			FC-3530
DOCMR <i>A. M. Sorant</i>	7/25/69	REV 3	SHEET 29 OF 45
APPR'D <i>A. M. Sorant</i>	7/25/69		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>J. S. Quinn</i> 7/69	Mark Taking Routines	
PRGMR	<i>J. S. Quinn</i> 7/69	Luminary 1D	DOCUMENT NO. FC-3530
ANALST			
DOCMR	<i>A. M. Grant</i> 7/25/69	REV 3	SHEET 30 OF 45
APPR'D	<i>A. M. Grant</i> 7/25/69		



COMPUTE OPTICS AXIS FOR DESIRED SIGHTING (SCAXIS_V @ 2¹)

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 @ 2⁰

COS (ELEVATION ∠) @ 2¹

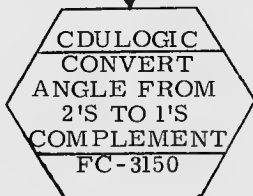
FIRST COMPONENT: SIN (ELEVATION ∠) @ 2¹

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Sullivan 7/69</i>		Mark Taking Routines	
PRGMR <i>J. Mulland 7/69</i>			DOCUMENT NO. FC-3530
ANALST		Luminary 1D	
DOCMR <i>Alvin M. Grant 7/25/69</i>			
APPR'D <i>Alvin M. Grant 7/25/69</i>		REV 3	SHEET 31 OF 45

FROM PRECEDING SHEET

MPAC ← PL8

AZIMUTH 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

PL18_V ← [+0, COS(MPAC_D), - SIN(MPAC_D)]

Y-PLANE PROJECTION OF OPTICS AXIS

[0, COS(AZIMUTH \angle), - SIN(AZIMUTH \angle)] @ 2^1

(SCAXIS +2)_D ← COS(MPAC_D) · SIN(MPAC_D) · 2¹

SECOND COMPONENT:

COS(AZIMUTH \angle) SIN(AZIMUTH \angle) @ 2^1 . 2¹ FACTOR IS FOR SCALING

(SCAXIS +4)_D ← COS(MPAC_D) · PL0_D · 2¹

THIRD COMPONENT:

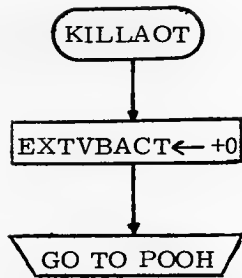
COS AZIMUTH \angle) SIN(ELEVATION \angle) @ 2^1 . 2¹ FACTOR IS FOR SCALING

PL24_V ← UNIT(PL18_V × SCAXIS_V)

X-PLANE PROJECTION OF OPTICS AXIS @ 2^1

RETURN VIA GCTR

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



TERMINATE PROGRAM

ALLOW EXTENDED VERB ACTIVITY

TERMINATE MAJOR MODE

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. L. ...</i>	<i>7/69</i>	Mark Taking Routines	
PRGMR <i>D. ...</i>	<i>7/69</i>	Luminary 1D	DOCUMENT NO.
ANALST			FC-3530
DOCMR <i>Alvin M. ...</i>	<i>7/23/69</i>	REV 3	SHEET 33 OF 45
APPR'D <i>A. M. ...</i>	<i>7/23/69</i>		

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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Lutz</i>	<i>2/19</i>	Mark Taking Routines	
PRGMR <i>J. Holland</i>	<i>7/67</i>	DOCUMENT NO.	
ANALST		Luminary 1D	FC-3530
DOCMR <i>Alvin T. Grant</i>	<i>7/25/69</i>	REV 3	SHEET 34 OF 45
APPR'D <i>A. M. Grant</i>	<i>7/25/69</i>		

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 EXTENDED VERB		SH. 33	SH. 2
EXTVBACT BIT 2	EXTENDED VERB SYSTEM IN USE FOR MARKING	EXTENDED VERB SYSTEM NOT IN USE FOR MARKING	SH. 2	SH. 33	SH. 2
MARKSTAT BIT 14	IF IN FLIGHT: MARK PAIR COMPLETE IN ON LUNAR SURFACE: MARKING TO BE TERMINATED	IF IN FLIGHT: MARK PAIR INCOMPLETE IF ON LUNAR SURFACE: MARKING NOT TO BE TERMINATED	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 ACCEPTED	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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Lutz</i> 7/69		Mark Taking Routines	
PRGMR <i>D. Mullard</i> 7/69		DOCUMENT NO.	
ANALST		Luminary 1D	FC-3530
DOCMR <i>A. M. Sorant</i> 7/25/69		REV 3	
APPR'D <i>A. M. Sorant</i> 7/25/69		SHEET 35 OF 45	

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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Sutherland</i> 7/69	PRGMR <i>M. Ballard</i> 7/69	Mark Taking Routines	
ANALST	DOCMR <i>Alchaly Soward</i> 7/25/69	Luminary 1D	DOCUMENT NO. FC-3530
APPR'D <i>A. M. Soward</i> 7/25/69	REV 3	SHEET 36 OF 45	

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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Spitznagel</i> 7/69	Mark Taking Routines		
PRGMR <i>E. Mallard</i> 7/69	Luminary 1D		DOCUMENT NO.
ANALST			FC-3530
DOCMR <i>Alfred M. Sorenson</i> 7/25/69	REV 3		SHEET 37 OF 45
APPR'D <i>A. M. Sorenson</i> 7/25/69			

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 BANK-CALL)			
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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. Lutzpfordt</i>	<i>7/69</i>	Mark Taking Routines	
PRGMR <i>J. Mullard</i>	<i>7/69</i>	Luminary 1D	DOCUMENT NO. FC-3530
ANALST			
DOCMR <i>Alex M. Sorant</i>	<i>7/25/69</i>	REV 3	SHEET 38 OF 45
APPR'D <i>A. M. Sorant</i>	<i>7/25/69</i>		

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}
ITEMP _{1D}		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}

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Sullivan</i> 7/69		Mark Taking Routines	
PRGMR <i>J. Mulvaney</i> 7/69		Luminary 1D	DOCUMENT NO. FC-3530
ANALST			
DOCMR <i>Alex M. Sorant</i> 7/25/69			
APPR'D <i>A. M. Sorant</i> 7/25/69	REV 3	SHEET 39 OF 45	

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			

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. J. Grant</i> 7/69		Mark Taking Routines	
PRGMR <i>D. J. Grant</i> 7/69		Luminary 1D	DOCUMENT NO.
ANALST			FC-3530
DOCMR <i>A. M. Grant</i> 7/25/69		REV 3	SHEET 40 OF 45
APPR'D <i>A. M. Grant</i> 7/25/69			

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			

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. L. ...</i>		Mark Taking Routines	
PRGMR <i>L. ...</i>		Luminary 1D	DOCUMENT NO.
ANALST			FC-3530
DOCMR <i>Alexander Grant 7/23/69</i>		REV 3	SHEET 41 OF 45
APPR'D <i>A. M. Grant 7/23/69</i>			

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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. J. Smith</i>	<i>7/69</i>	Mark Taking Routines	
PRGMR <i>D. J. Smith</i>	<i>7/69</i>	Luminary 1D	DOCUMENT NO. FC-3530
ANALST			
DOCMR <i>W. J. Smith</i>	<i>7/25/69</i>		
APPR'D <i>W. J. Smith</i>	<i>7/25/69</i>	REV 3	SHEET 42 OF 45

PROGRAM CONSTANTS

AGC TAG	MEANING	ENGINEERING AND AGC VALUE	AGC SCALING
CATLOG -6	Direction of star 1 (α Andromedae (Alpheratz)) in Reference coords	(+.8748658918) (+.0260879174) (+.4836621670)	2 ¹
CATLOG -12D	Direction of star 2 (β Ceti (Diphda)) in Reference coords	(+.9342640400) (+.1735073142) (-.3115219339)	2 ¹
CATLOG -18D	Direction of star 3 (γ Cassiopeiae (Navi)) in Reference coords	(+.4775639450) (+.1166004340) (+.8708254803)	2 ¹
CATLOG -24D	Direction of star 4 (α Eridani (Achernar)) in Reference coords	(+.4917678276) (+.2204887125) (-.8423473935)	2 ¹
CATLOG -30D	Direction of star 5 (α Ursae Minoris (Polaris)) in Reference coords	(+.0130968840) (+.0078062795) (+.9998837600)	2 ¹
CATLOG -36D	Direction of star 6 (θ Eridani (Acamar)) in Reference coords	(+.5450107404) (+.5314955466) (-.6484410356)	2 ¹
CATLOG -42D	Direction of star 7 (α Ceti (Menkar)) in Reference coords	(+.7032235469) (+.7075846047) (+.0692868685)	2 ¹
CATLOG -48D	Direction of star 8 (=10 ₈) (α Persei (Mirfak)) in Reference coords	(+.4105636020) (+.4988110001) (+.7632988371)	2 ¹
CATLOG -54D	Direction of star 9 (=11 ₈) (α Tauri (Aldebaran)) in Reference coords	(+.3507315038) (+.8926333307) (+.2831839492)	2 ¹
CATLOG -60D	Direction of star 10D (=12 ₈) (β Orionis (Rigel)) in Reference coords	(+.2011399589) (+.9690337941) (-.1432348512)	2 ¹
CATLOG -66D	Direction of star 11D (=13 ₈) (α Aurigae (Capella)) in Reference coords	(+.1371725575) (+.6813721061) (+.7189685267)	2 ¹
CATLOG -72D	Direction of star 12D (=14 ₈) (α Carinae (Canopus)) in Reference coords	(-.0614937230) (+.6031563286) (-.7952489957)	2 ¹
CATLOG -78D	Direction of star 13D (=15 ₈) (α Canis Majoris (Sirius)) in Reference coords	(-.1820751783) (+.9404899869) (-.2869271926)	2 ¹
CATLOG -84D	Direction of star 14D (=16 ₈) (α_2 Canis Minoris (Procyon)) in Reference coords	(-.4118589524) (+.9065485360) (+.0924226975)	2 ¹
CATLOG -90D	Direction of star 15D (=17 ₈) (γ Velorum (Regor)) in Reference coords	(-.3612508532) (+.5747270840) (-.7342932655)	2 ¹
CATLOG -96D	Direction of star 16D (=20 ₈) (γ Ursae Majoris (Dnoces)) in Reference coords	(-.4357947941) (+.4774785033) (+.7450164351)	2 ¹
CATLOG -102D	Direction of star 17D (=21 ₈) (α Hydrae (Alphard)) in Reference coords	(-.7742591356) (+.6152504197) (-.1482892839)	2 ¹
CATLOG -108D	Direction of star 18D (=22 ₈) (α Leonis (Regulus)) in Reference coords	(-.8608205219) (+.4636213989) (+.2098647835)	2 ¹

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Sullivan</i> 7/69	PRGMR <i>D. Sullivan</i> 7/69	Mark Taking Routines	
ANALST	DOCMR <i>Alex M. Sorant</i> 7/25/69	Luminary 1D	DOCUMENT NO. FC-3530
APPR'D <i>A. M. Sorant</i> 7/25/69	REV 3	SHEET 43 OF 45	

PROGRAM CONSTANTS (CONTINUED)

AGC TAG	MEANING	ENGINEERING AND AGC VALUE	AGC SCALING
CATALOG -114D	Direction of star 19D (=23 ₈) (β Leonis (Denebola)) in Reference coords	(-.9656605484 +.0525933156 +.2544280809)	2 ¹
CATALOG -120D	Direction of star 20D (=24 ₈) (γ Corvi (Gienah)) in Reference coords	(-.9525211695 -.0593434796 -.2986331746)	2 ¹
CATALOG -126D	Direction of star 21D (=25 ₈) (α Crucis (Acrux)) in Reference coords	(-.4523440203 -.0493710140 -.8904759346)	2 ¹
CATALOG -132D	Direction of star 22D (=26 ₈) (α Virginis (Spica)) in Reference coords	(-.9170097662 -.3502146628 -.1908999176)	2 ¹
CATALOG -138D	Direction of star 23D (=27 ₈) (γ Ursae Majoris (Alkaid)) in Reference coords	(-.5812035376 -.2909171294 +.7599800468)	2 ¹
CATALOG -144D	Direction of star 24D (=30 ₈) (θ Centauri (Menkent)) in Reference coords	(-.6898393233 -.4182330640 -.5909338474)	2 ¹
CATALOG -150D	Direction of star 25D (=31 ₈) (α Bootis (Arcturus)) in Reference coords	(-.7861763936 -.5217996305 +.3311371675)	2 ¹
CATALOG -156D	Direction of star (=32 ₈) (α Coronae Borealis (Alphecca)) in Reference coords	(-.5326876930 -.7160644554 +.4511047742)	2 ¹
CATALOG -162D	Direction of star 27D (=33 ₈) (α Scorpii (Antares)) in Reference coords	(-.3516499609 -.8240752703 -.4441196390)	2 ¹
CATALOG -168D	Direction of star 28D (=34 ₈) (α Trianguli Austr. (Atria)) in Reference coords	(-.1146237858 -.3399692557 -.9334250333)	2 ¹
CATALOG -174D	Direction of star 29D (=35 ₈) (α Ophiuchi (Rasalhague)) in Reference coords	(-.1124304773 -.9694934200 +.2178116072)	2 ¹
CATALOG -180D	Direction of star 30D (=36 ₈) (α Lyrae (Vega)) in Reference coords	(+.1217293692 -.7702732847 +.6259880410)	2 ¹
CATALOG -186D	Direction of star 31D (=37 ₈) (σ Sagittarii (Nunki)) in Reference coords	(+.2069525789 -.8719885748 -.4436288486)	2 ¹
CATALOG -192D	Direction of star 32D (=40 ₈) (α Aquilae (Altair)) in Reference coords	(+.4537196908 -.8779508801 +.1527766153)	2 ¹
CATALOG -198D	Direction of star 33D (41 ₈) (β Capricorni (Dabih)) in Reference coords	(+.5520184464 -.7933187400 -.2567508745)	2 ¹
CATALOG -204D	Direction of star 34D (=42 ₈) (α Pavonis (Peacock)) in Reference coords	(+.3201817378 -.4436021946 -.8370786986)	2 ¹
CATALOG -210D	Direction of star 35D (=43 ₈) (α Cygni (Deneb)) in Reference coords	(+.4541086270 -.5392368197 +.7092312789)	2 ¹
CATALOG -216D	Direction of star 36D (=44 ₈) (ε Pegasi (Enif)) in Reference coords	(+.8139832631 -.5557243189 +.1691204557)	2 ¹

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Lutz</i> 7/69	PRGMR <i>D. Lutz</i> 7/69	Mark Taking Routines	
ANALST	DOCMR <i>A. M. Saut</i> 7/23/69	Luminary 1D	DOCUMENT NO. FC-3530
APPR'D <i>A. M. Saut</i> 7/23/69	REV 3	SHEET 44 OF 45	

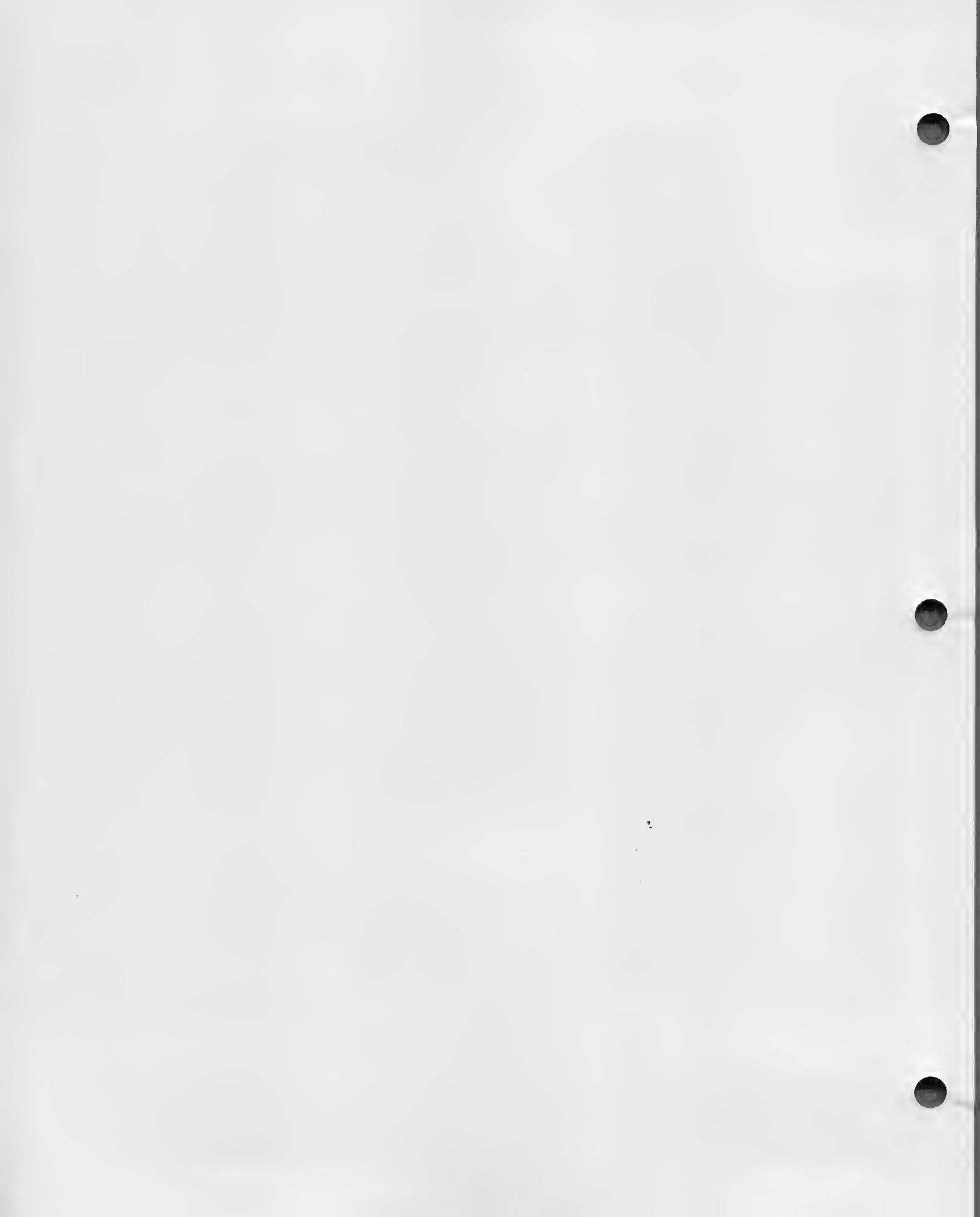
PROGRAM CONSTANTS (CONTINUED)

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

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



10.0 NAVIGATION PROGRAMS



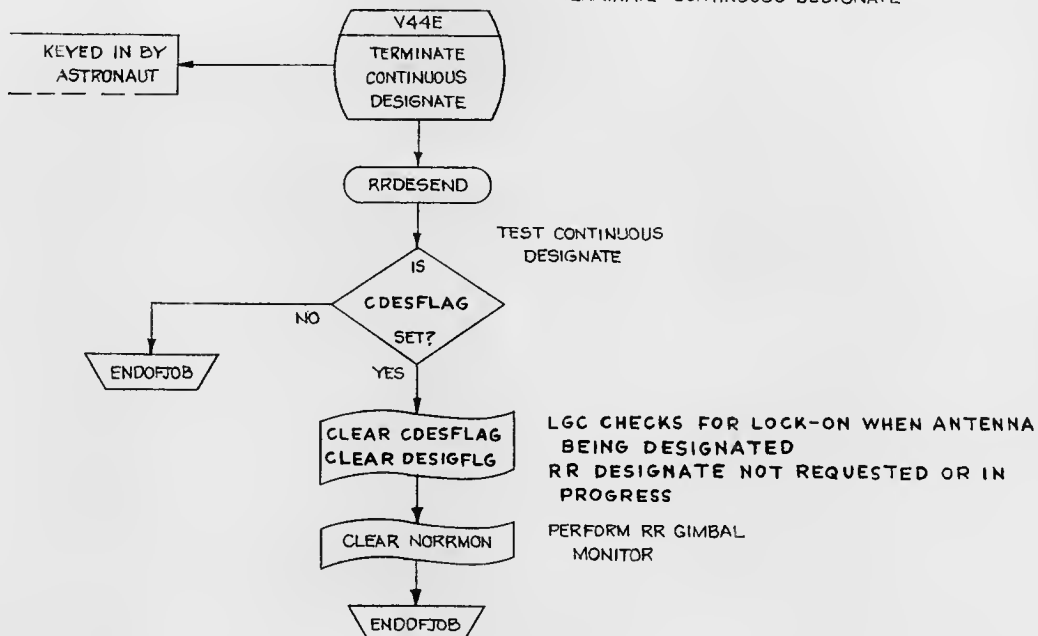
P20, P22 RENDEZVOUS AND LUNAR SURFACE NAVIGATION

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
RRONLY	SINGLE AXIS RR SHAFT MANEUVER	47
RRONLY	SINGLE AXIS RR TRUNNION MANEUVER	47
RRROUT	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 <i>L. G. ...</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE	
PRGMR <i>G. Volante</i>	<i>12/8/69</i>	DOCUMENT NO. FC-3600	
ANALST		LUMINARY 1D	
DOCMR <i>W. ...</i>	<i>12/8/69</i>		
APPR'D <i>Robert M. ...</i>		REV 2	SHEET 1 OF 103

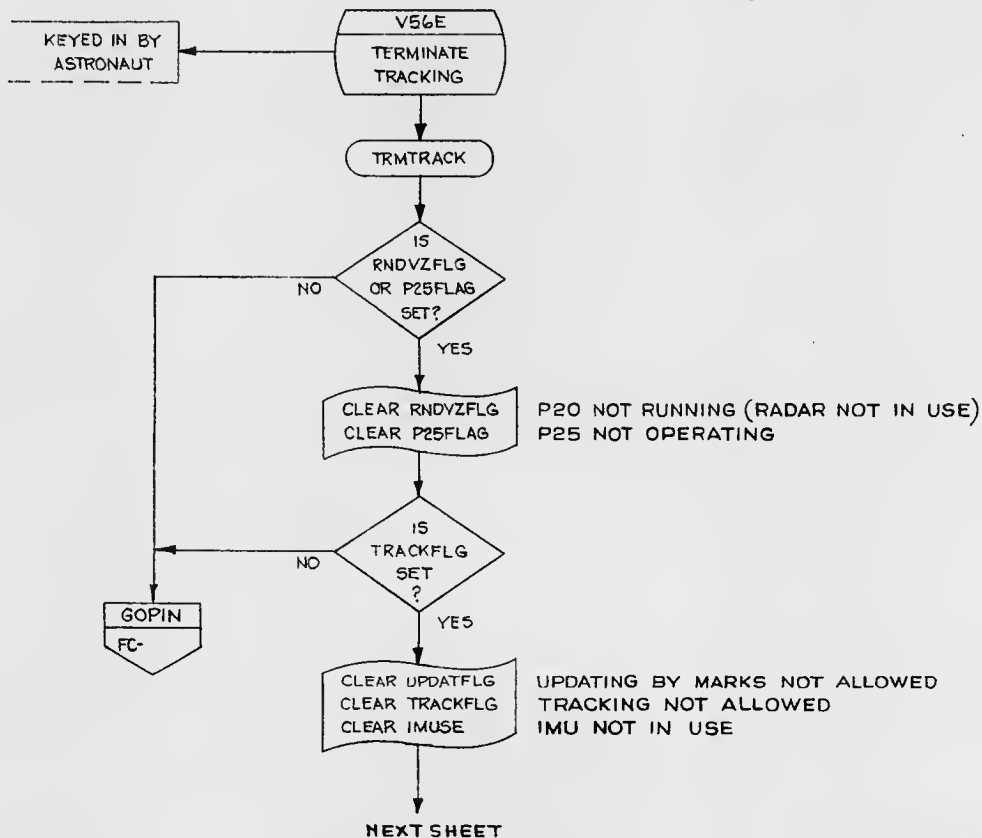
EXTENDED VERB 44

TERMINATE CONTINUOUS DESIGNATE



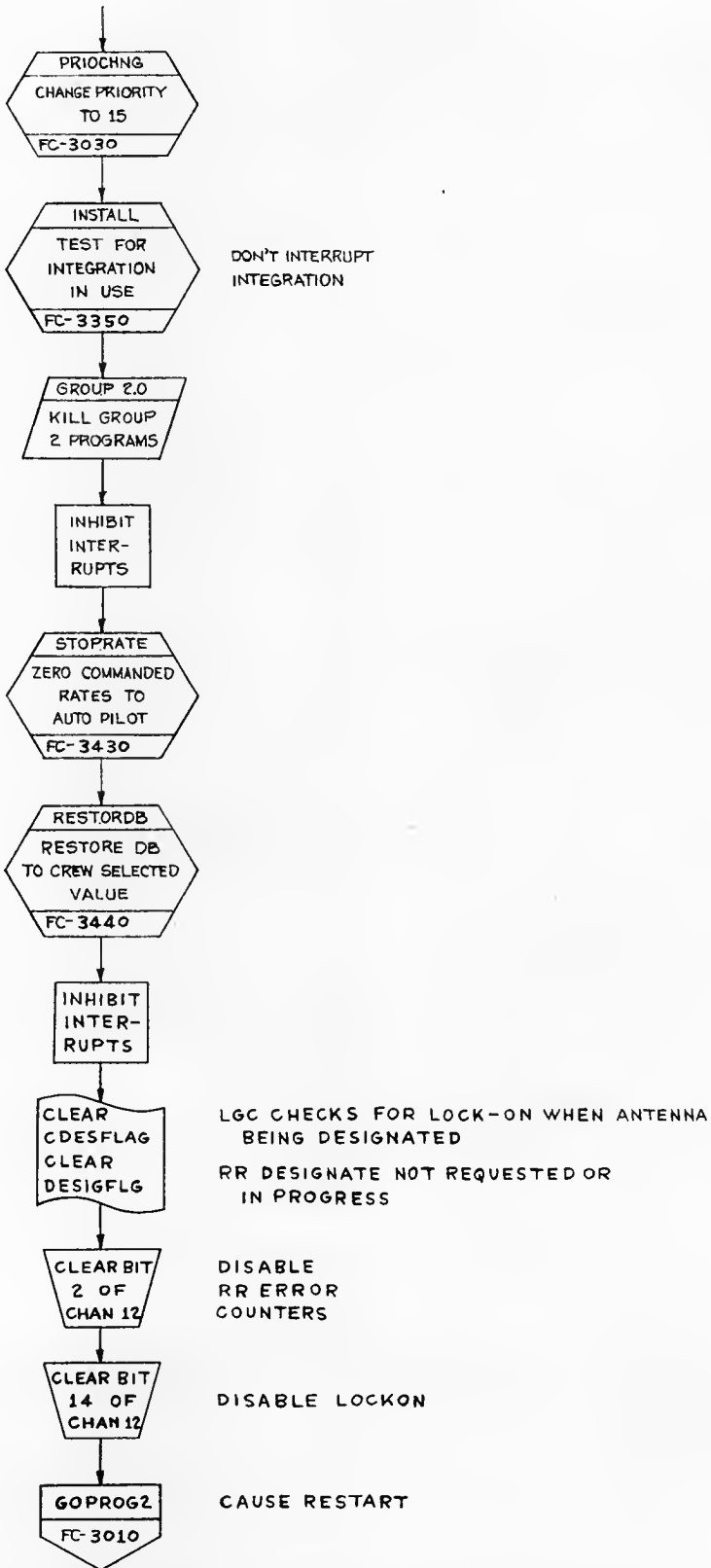
EXTENDED VERB 56

TERMINATE TRACKING



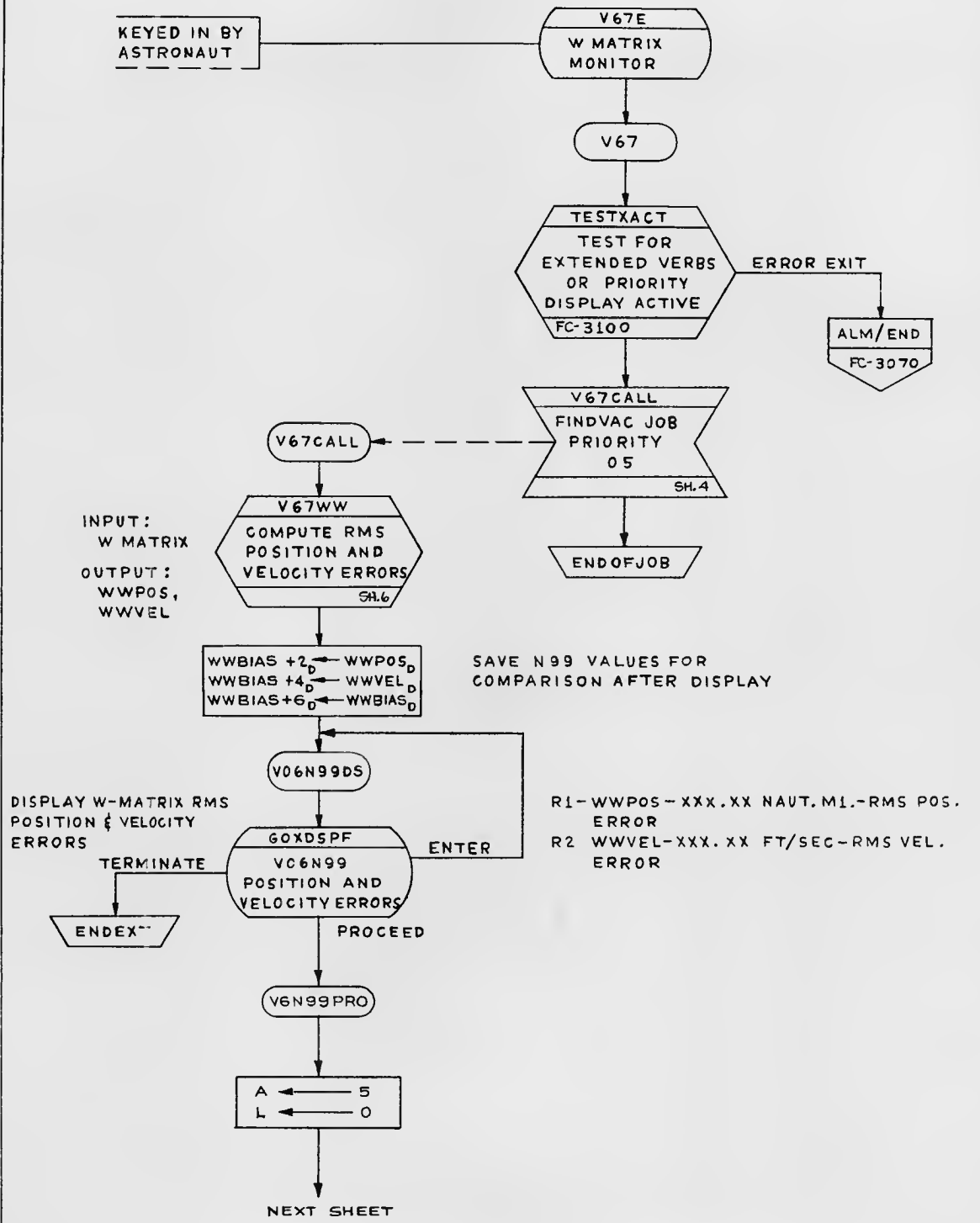
INT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS 5-28-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROJNR Peter Volante 8-16-68		LUMINARY ID	DOCUMENT NO.
ANALST [Signature] 6-3			FC-3600
DOCNR [Signature]		SHEET 2 OF 103	
APPR'D John A. Moore 29 Oct 68		RES	

FROM PRECEDING SHEET



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS 5-28-68 PROGRAM Peter Volante 8-16-68 ANALYST DESIGNER W. G. Griffith 6-5-68 APPROVED John A. Moore 8-20-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
		LUMINARY ID	DOCUMENT NO. FC-3600
		SHEET 3 OF 103	

EXTENDED VERB 67



INPUT:
W MATRIX
OUTPUT:
WWPOS,
WWVEL

SAVE N99 VALUES FOR
COMPARISON AFTER DISPLAY

DISPLAY W-MATRIX RMS
POSITION & VELOCITY
ERRORS

R1 - WWPOS - XXX.XX NAUT. MI. - RMS POS.
ERROR
R2 - WWVEL - XXX.XX FT/SEC - RMS VEL.
ERROR

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. J. Loville</i> 4 MAR 69		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGR <i>P. North</i> 10/21/69		LUMINARY 1D	DOCUMENT NO. FC-3600
ANALST			
DOCNR <i>W.C. Dwyer</i> 4-7-69			
APPR'D <i>Robert M. Estess</i> 10/21/69		REV 2	SHEET 4 OF 103

FROM PRECEDING SHEET

N99LOOP

LOOP TO COMPARE N99 VALUES BEFORE AND AFTER DISPLAY

$$L \leftarrow \sum_{Q=0}^3 WWPOS+4\#Q - WWPOS \# Q$$

IS
L = 0
?

SET
V67FLAG

V06N9933

IS
V67FLAG
SET?

ENDEXT

PL0_D ← WWPOS_D
PL2_D ← WWVEL_D
PL4_D ← WWBIAS_D

IS
SURFFLAG
SET?

V67SURF

WRENDPOS ← PL0
WRENDVEL ← PL2

WSURFPOS ← PL0
WSURFVEL ← PL2

V67CLRF

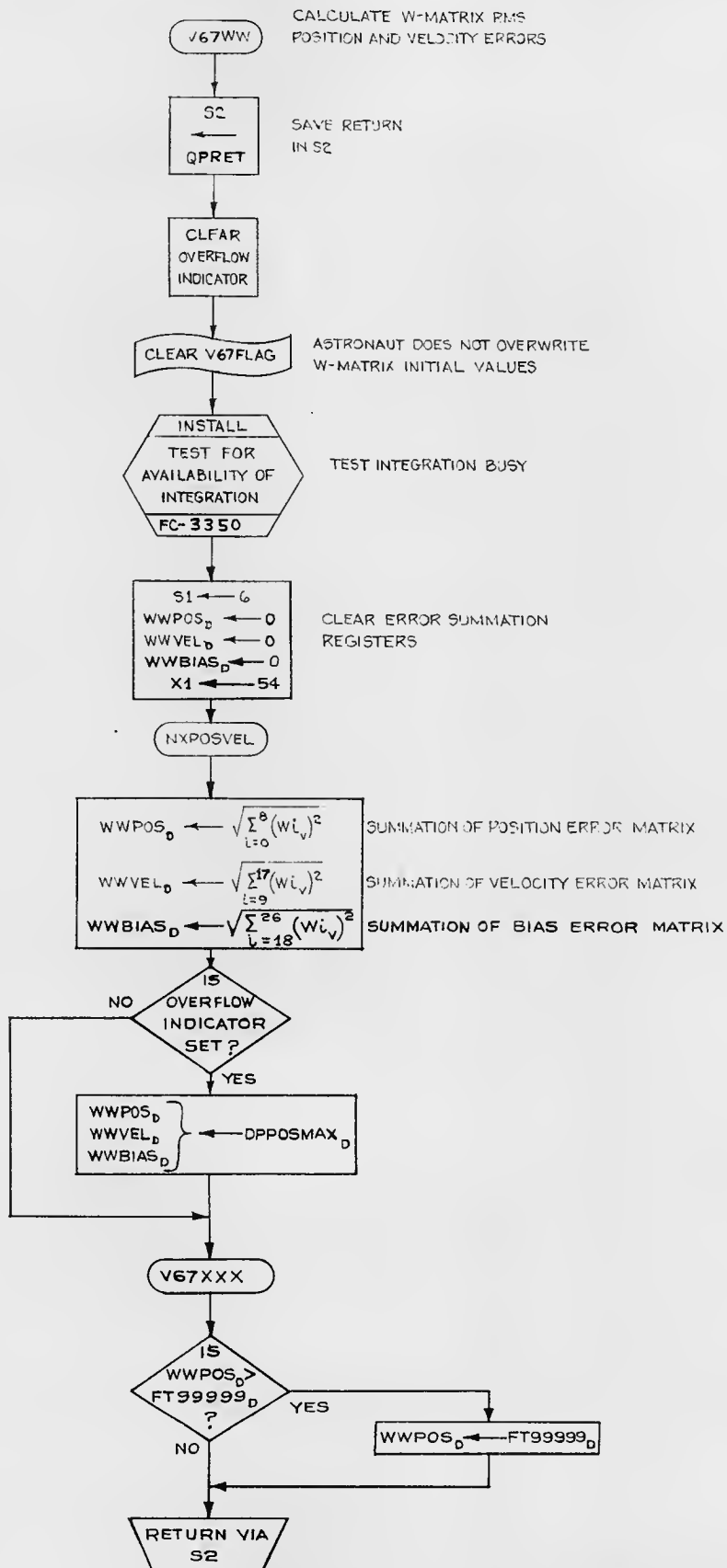
WTRUN }
WSHAFT } ← PL4

CLEAR
RENDWFLG

W-MATRIX INVALID
FOR RENDEZVOUS
NAVIGATION

ENDEXT

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>G. J. Langille</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAM <i>F. V. ...</i>	4-MAR-69 10/21/69	LUMINARY 1 st	DOCUMENT NO. FC-3600
ANALYST <i>W. C. ...</i>	11-7-69	REV 2	SHEET 5 OF 103
APPROVED <i>...</i>	10/21/69		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS 6-26-68		P20 P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGR P-2-V-6 8-16-68	ANALYST	LUMINARY ID	DOCUMENT NO.
DOCMR M.C. [Signature] 6-28-68			FC-3600
APPR'D John A. Moore 8 Oct 68	REV 2	SHEET 6 OF 103	

EXTENDED VERB 95 : DISPLAY RR LOS AZIMUTH AND ELEVATION

PURPOSE: GIVEN THE RR ANTENNA TRUNNION AND SHAFT ANGLES COMPUTE AND DISPLAY AZIMUTH AND ELEVATION.

INPUT: $GDUT_D$ = RR TRUNNION & SHAFT ANGLES.

OUTPUT: $RR-AZ_D$ = ANGLE BETWEEN THE LOS AND THE X-Z NB PLANE.

$RR-ELEV_D$ = ANGLE BETWEEN +Z NB AND PROJECTION OF LOS INTO X-Z PLANE.



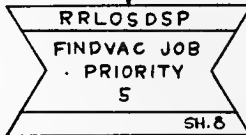
PREVIOUS EXTENDED VERB OR PRIORITY DISPLAY BUSY

ERROR EXIT

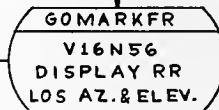
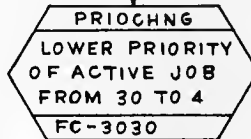


INPUT: EXTVBACT

OUTPUT: BITS 3 & 5 OF EXTVBACT SET TO INDICATE EXTENDED VERB ACTIVE



SCHEDULE JOB TO COMPUTE LOS AZIMUTH AND ELEVATION ANGLES



DISPLAY RR LOS AZIMUTH & ELEVATION

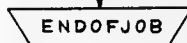
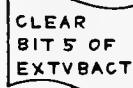
R1-RR-AZ - XXX.XX DEG.- LOS AZIMUTH ANGLE.
R2-RR-ELEV-XXX.XX DEG.- LOS ELEVATION ANGLE.

IMMEDIATE RETURN

TERMINATE/ PROCEED/ ENTER



TERMINATE RRLOSDSP ROUTINE



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>G. J. Longville</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAM <i>G. J. Longville</i>	5 MAR 69 10/21/69	LUMINARY 1 D	DOCUMENT NO. FC-3600
ANALYST			
DOCNR <i>FC-3600</i>	4-7-69		
APPR'D <i>Robert M. Egan</i>	10/21/69	REV 2	SHEET 7 OF 10

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

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

LOAD RR TRUNNION & SHAFT ANGLES FOR RRNB ROUTINE

INPUT: $TANGNB_D$ = RR TRUNNION & SHAFT CDU ANGLES.
 OUTPUT: $PL32_V$ }
 $MPAC_V$ } 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: $THETA_D$ }
 $MPAC_D$ } ANGLE THETA IN REV.
 ($-0.5 \leq \theta \leq 0.5$)

IS THETA ≥ 0 ?
 YES
 NO
 ANGLE IS NEGATIVE: MAKE IT POSITIVE

INSURE DISPLAY OF 0-360 DEG. ABOUT +Y

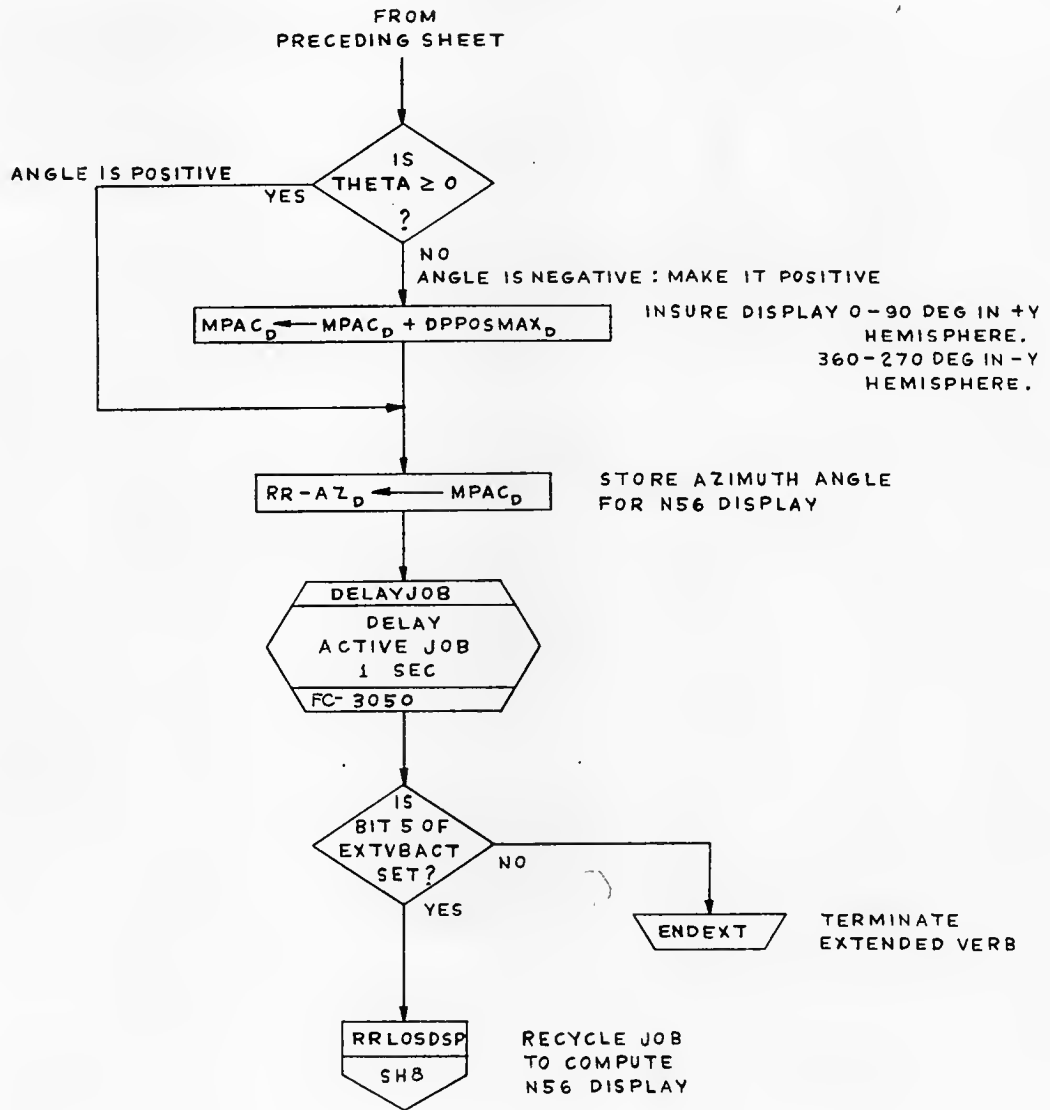
STORE ELEVATION ANGLE FOR N56 DISPLAY

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: $THETA_D$ }
 $MPAC_D$ } = ANGLE THETA IN REV.
 ($-0.5 \leq \theta \leq 0.5$)

NEXT SHEET

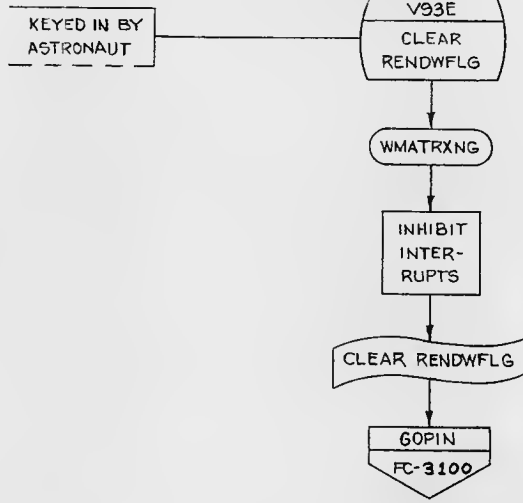
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. J. Fungillo</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRCNR <i>J. V. Valdes</i>	5 MAR 69	LUMINARY 1D	DOCUMENT NO. FC-3600
ANALST	10/21/69		
DOCMR <i>W. E. Douglas</i>	4-7-69	REV 2	SHEET 8 OF 103
APPR'D <i>Roberto M. Eder</i>	10/24/67		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>a. J. Loville</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGMR <i>J. T. ...</i>	SMAR69 10/21/69	LUMINARY 1D	DOCUMENT NO. FC-3600
ANALST	4-1-68	REV 2	SHEET 9 OF 103
DOCNR <i>no date</i>	4-1-68		
APPR'D <i>Robert M. ...</i>	10/21/69		

EXTENDED VERB 93

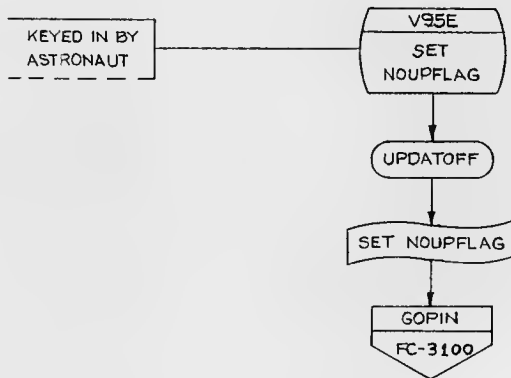
CLEAR RENDWFLG



W MATRIX INVALID FOR RENDEZVOUS NAVIGATION

EXTENDED VERB 95

NO STATE VECTOR UPDATE ALLOWED



NEITHER CSM NOR LEM STATE VECTOR MAY BE UPDATED

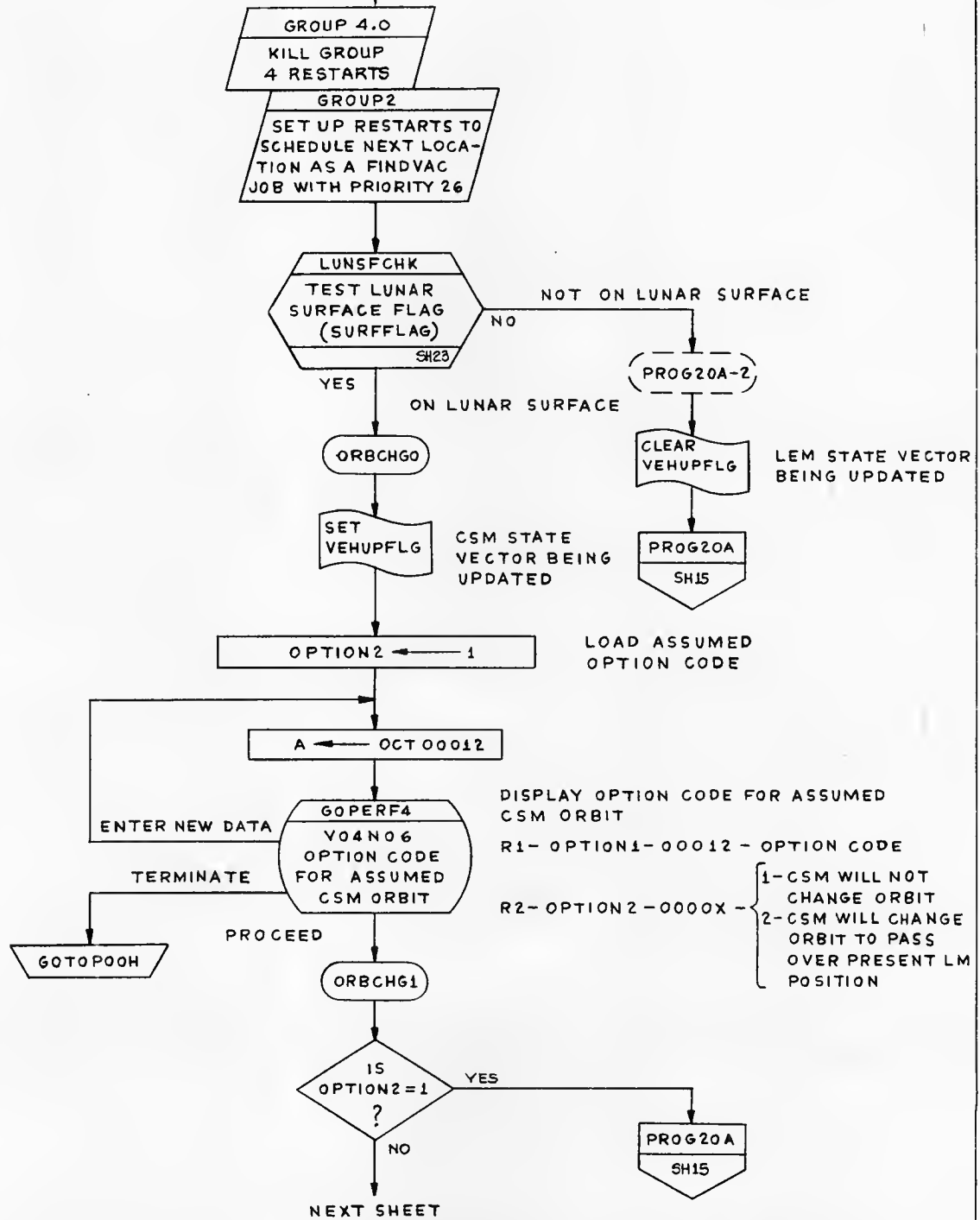
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
DRAWN	A.C. WILLIAMS	5-29-68	
PRGRM	<i>Peter Volante</i>	8-16-68	
ANALST			LUMINARY 1D
DOCNR	<i>M. G. Smith</i>	6-5-68	DOCUMENT NO. FC-3600
APPRD	<i>John A. Mann</i>	9-0-68	REV 2
			SHEET 10 OF 103

RENDEZVOUS
NAVIGATION

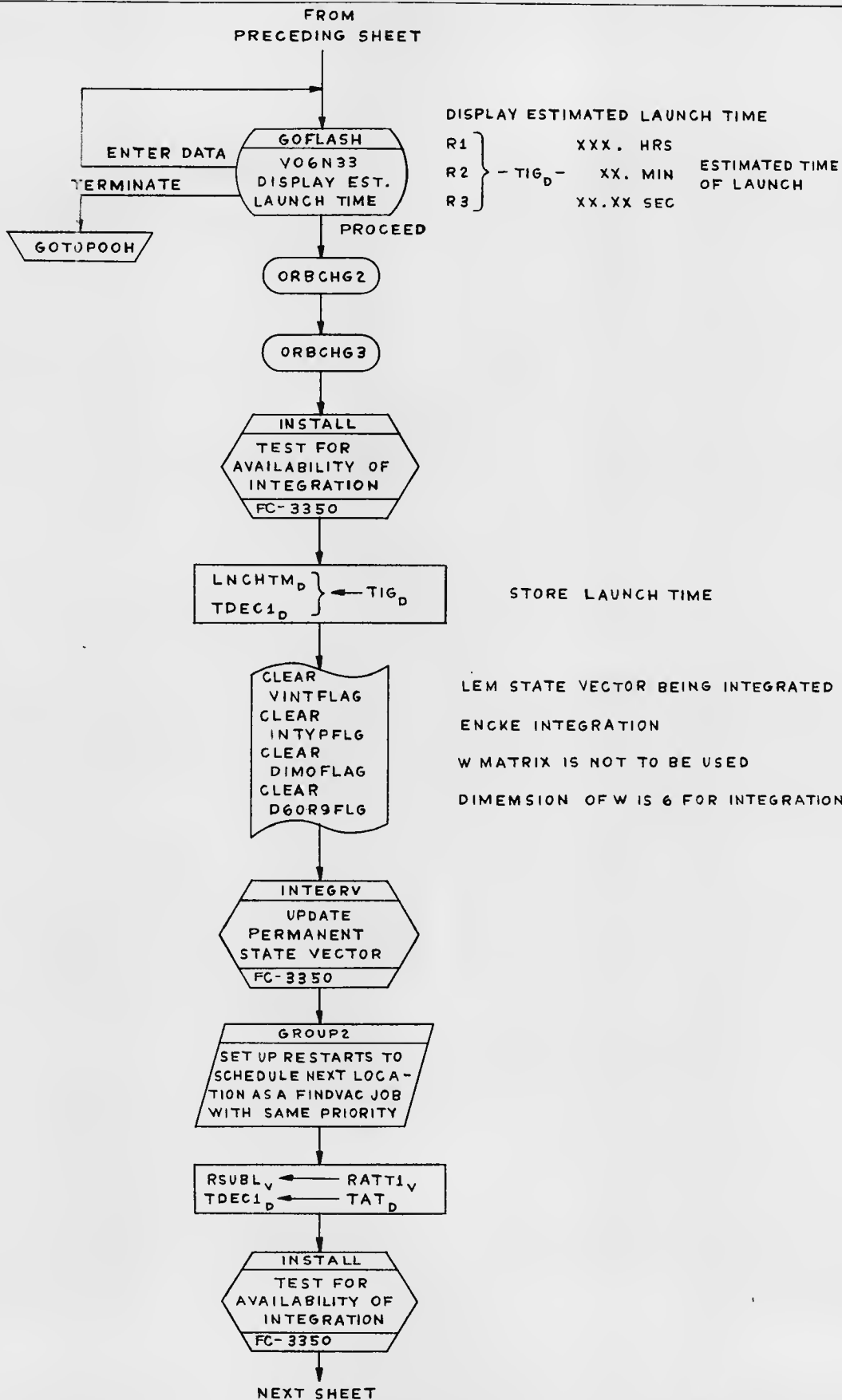
PROG20

PROG22

LUNAR SURFACE
NAVIGATION



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. J. Farnelle</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGMR <i>P. V. ...</i>	6 MAR 69	LUMINARY 1D	DOCUMENT NO. FC-3600
ANALST	10/21/69	REV 2	SHEET 11 OF 103
DOCNR <i>MC ...</i>	4-7-69		
APPR'D <i>...</i>	10/21/69		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>G. J. Amello</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGMR <i>F. J. V. L. 26</i>		LUMINARY 1D	
ANALST		DOCUMENT NO. FC-3600	
DOCNR <i>W. C. ...</i>		REV 2	
APPRD <i>Rub...</i>		SHEET 12 OF 103.	

FROM
PRECEDING SHEET

SET
VINTFLAG
CLEAR
INTYPFLG
CLEAR
DIMOFLAG

C5M STATE VECTOR BEING INTEGRATED
ENCKE INTEGRATION
W MATRIX IS NOT TO BE USED

IS
RENDWFLG
SET
?

NO
YES

SET
DIMOFLAG
SET
D6OR9FLG

W MATRIX IS TO BE USED
DIMENSION OF W IS 9 FOR INTEGRATION

NOMATX

INTEGRV
UPDATE
PERMANENT
STATE VECTOR
FC-3350

GROUP2
SET UP RESTARTS TO
SCHEDULE NEXT LOCA-
TION AS A FINDVAC JOB
WITH SAME PRIORITY

VSUBC_v ← VATT1_v
RSUBC_v ← RATT1_v
PL20D_v ← UNIT (RSUBC_v X VSUBC_v)
JCSM_v ← UNIT (RSUBC_v X PL20D_v)
CSTH_D ← UNIT (RSUBC_v) · UCSM_v
SNTH_D ← $\sqrt{ONEB-2_D - (CSTH_D)^2}$

NORMAL TO PRESENT C5M ORBITAL PLANE
} INPUT VALUES FOR TIME-THETA ROUTINE

RVEC_v ← RSUBC_v
VVEC_v ← -VSUBC_v

LOAD INPUT FOR
TIME-THETA ROUTINE

CLEAR
RVSW

COMPUTE FINAL STATE VECTOR
IN TIME-THETA ROUTINE

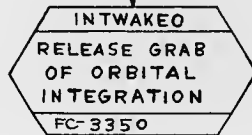
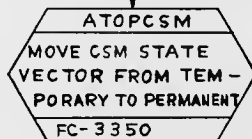
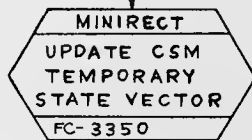
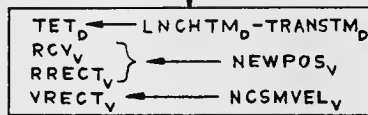
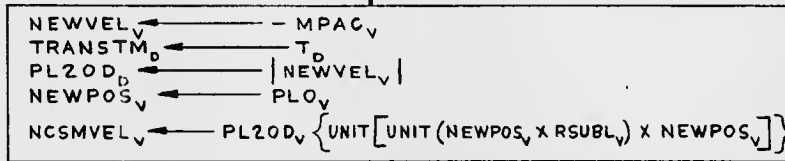
NEXT SHEET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. J. Langille</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGMR <i>R. J. Langille</i>	6 MAR 69 10/21/69	LUMINARY ID	DOCUMENT NO. FC-3600
ANALST			
DOCNR <i>W. C. Dyer</i>	47-69		
APPR'D <i>Robert M. ...</i>	10/21/69	REV 2	SHEET 13 OF 103

FROM
PRECEDING SHEET



INPUT: $RVEC_V, VVEC_V$ = INITIAL SPACECRAFT VALUES
 $CSTH_D, SNTH_D$ = ANGLE OF MANEUVER
OUTPUT: T_D = TRANSFER TIME
 PLQ_V = FINAL POSITION VECTOR
 $MPAC_V$ = FINAL VELOCITY VECTOR



NEXT SHEET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>G. J. Langille</i>		7MAR69	P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION
PRGRM <i>J. W. Smith</i>		10/21/69	LUMINARY 1D
ANALST			DOCUMENT NO. FC-3600
DOCMR <i>McDonnell</i>		4-9-69	
APPR'D <i>Robert M. Eason</i>		10/21/69	REV 2
			SHEET 14 OF 103

FROM
PRECEDING SHEET

PROG 20A

R02BOTH

IMU
STATUS
CHECK

FC-3220

SET
UPDATFLG
SET
TRACKFLG
SET
RNDVZFLG

UPDATING BY MARKS ALLOWED

TRACKING ALLOWED

P20 / P22 RUNNING (RADAR IN USE)

CLEAR
R04FLAG
CLEAR
NORRMON
CLEAR
SRCHOPTN
CLEAR
ACMODFLG
CLEAR
LOSCMFLG

R77 REQUESTED

PERFORM RR GIMBAL MONITOR

RADAR NOT IN SEARCH OPTION

AUTO ACQUISITION BY RENDEZVOUS RADAR

LINE OF SIGHT NOT BEING COMPUTED

~~CLRADMOM~~
REMOVE
DESIGNATE
REQUESTS
SH49

SET
FSPASFLG

FIRST PASS THRU
REPOSITION ROUTINE

P20LEM1

GROUP2

RESTART JOB
AT NEXT
INSTRUCTION

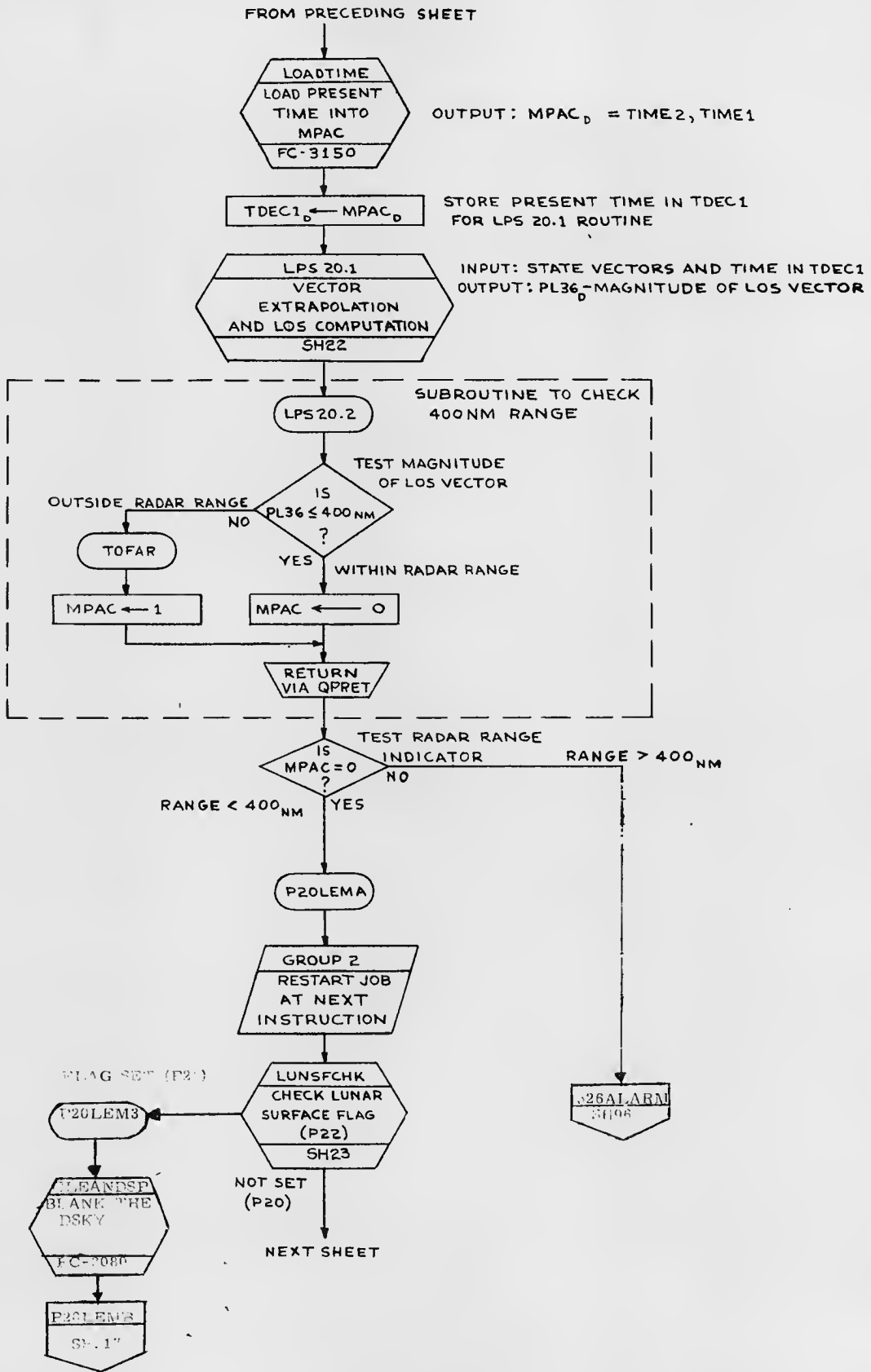
MARKCTR ← 0

ZERO RENDEZVOUS TRACKING
MARK COUNTER

P20LEM2

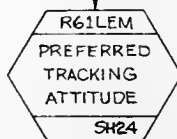
NEXT SHEET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>G. J. Langille</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGMR <i>J. W. Smith</i>	7 MAR 68 10/21/69	LUMINARY 1D	DOCUMENT NO. FC-3600
ANALST			
DOCMR <i>W. C. Dwyer</i>	4-7-69		
APPR'D <i>R. M. ...</i>	10/21/69	REV 2	SHEET 15 OF 108

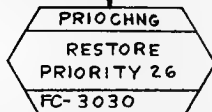
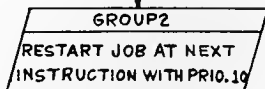
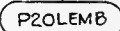


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
DRAWN <i>F. Reason Jr</i>	9 JAN 68	LUMINARY 1D	DOCUMENT NO.
PROGR <i>Pete Volante</i>	10/21/67		FC-3600
ANALYST		REV 2	SHEET 16 OF 103
DOCNR <i>W. D. Griffith Jr</i>	17 MAY 68		
APPR'D <i>John A. Moore</i>	29 OCT 68		

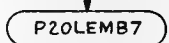
FROM PRECEDING SHEET



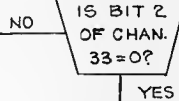
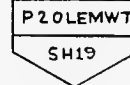
INPUT: LOS VECTOR
OUTPUT: MANEUVER TO PREFERRED TRACKING ATTITUDE



NO

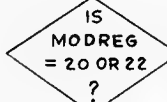
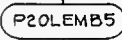


TEST RR AUTO MODE DISCRETE PRESENT

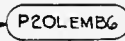


NO

NEXT SHEET



P20 OR P22 OPERATING

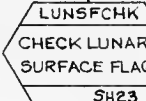
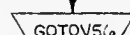


REQUEST SELECTION OF AUTO MODE



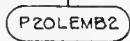
PROCEED

TERMINATE

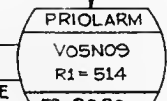


FLAG SET (P22)

NOT SET (P20)

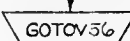


PROCEED/ENTER

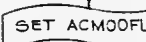
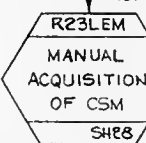
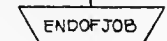


RR OUT OF AUTO MODE WHILE IN USE

TERMINATE



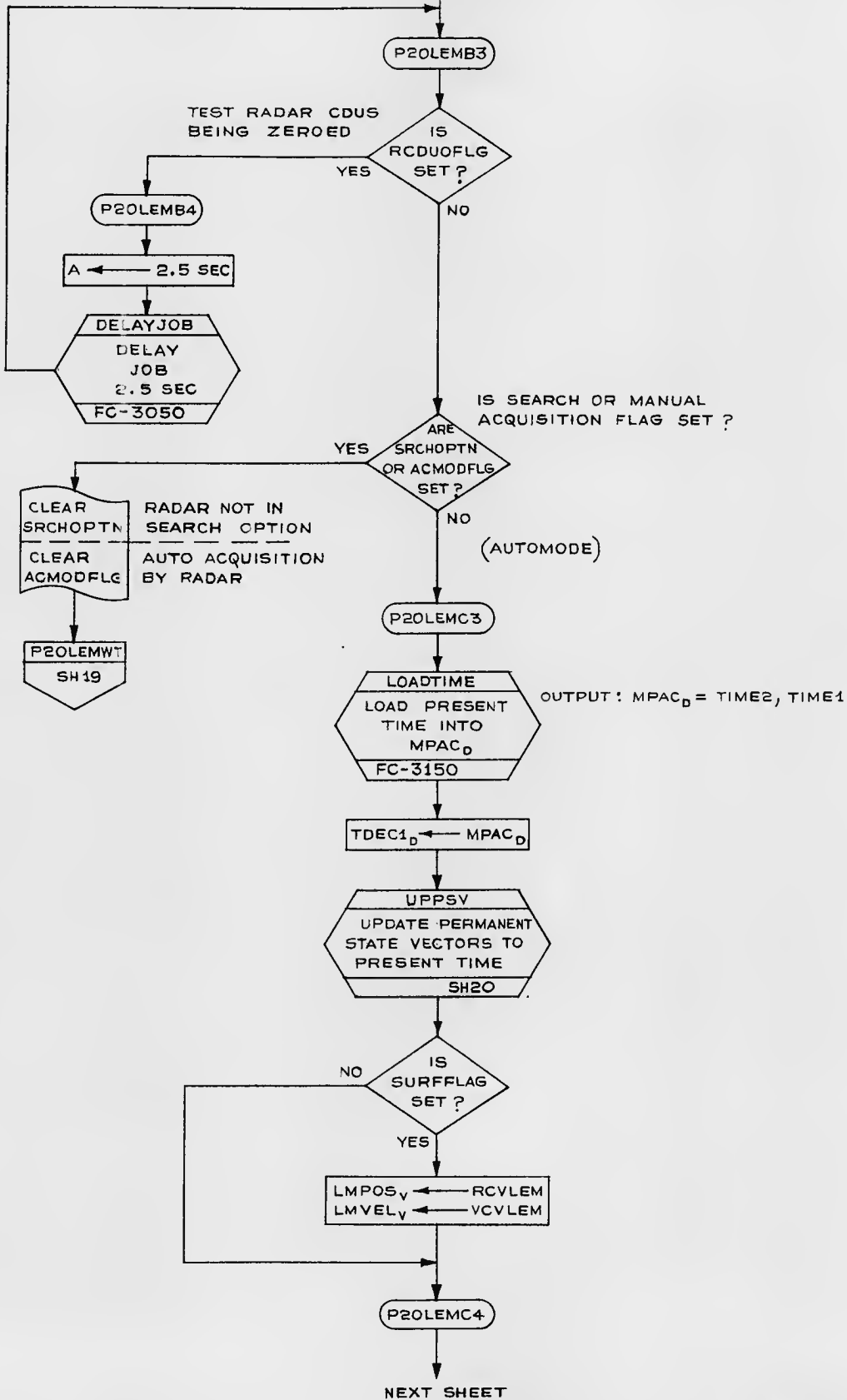
IMMEDIATE RETURN



MANUAL ACQUISITION BY RADAR

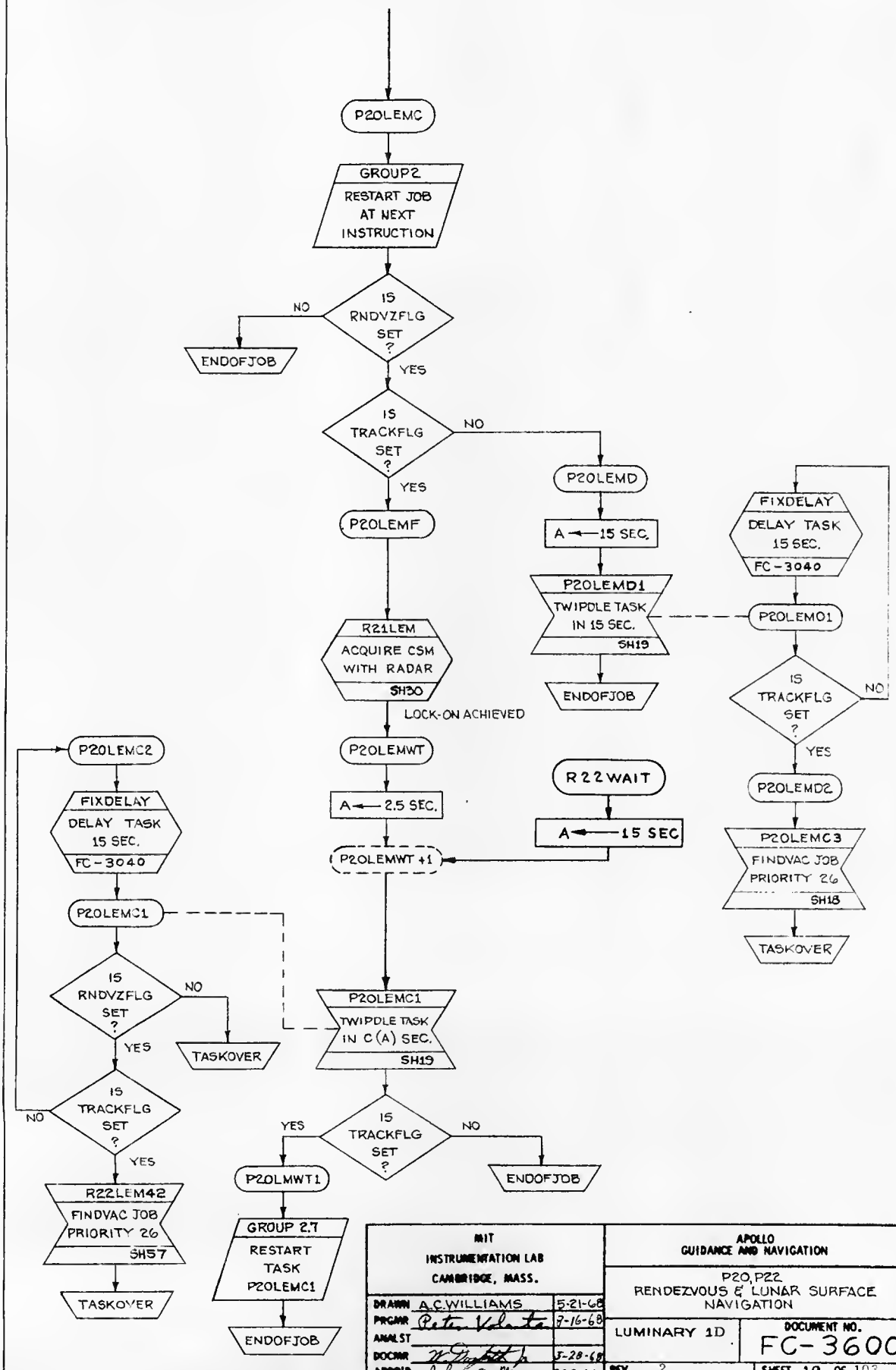
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN: A.C. WILLIAMS 5-20-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAM: Peter Volante 8-16-68		DOCUMENT NO.	
ANALYST:		LUMINARY I.D.	
DOCARR: [Signature] 5-28-68		FC-3600	
APPROB: John A. Moore 8-20-68		REV 2	
		SHEET 17 OF 103	

FROM PRECEDING SHEET

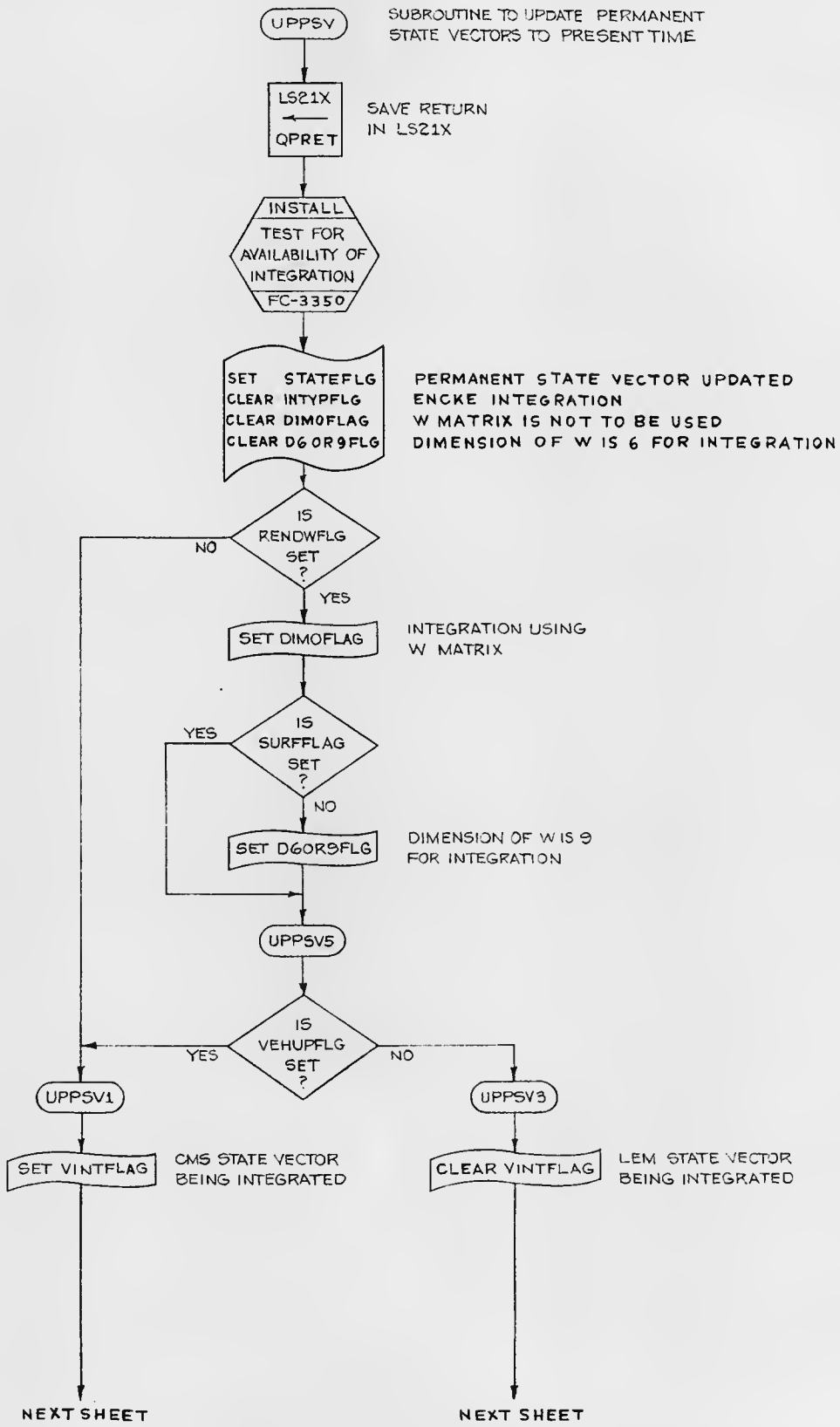


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>P.M. Smith</i>		P20, P22	
PROGRAM <i>Guidance</i>		RENDEZVOUS & LUNAR SURFACE NAVIGATION	
ANALYST		LUMINARY 1 D	DOCUMENT NO.
DOCTR <i>Mc Donnell</i>		FC-3600	
APPR'D <i>W.M. Kelly</i>		REV 2	SHEET 18 OF 103

FROM
PRECEDING SHEET



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS 5-21-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGRM Peter Volante 7-16-68		LUMINARY 1D	
ANALST		DOCUMENT NO. FC-3600	
DOCMR John A. Moore 5-28-68		REV 2	
APPR'D John A. Moore 29 Oct 68		SHEET 19 OF 103	



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
DRAWN	A.C. WILLIAMS	4-1-68	DOCUMENT NO. FC-3600
PCWR	<i>Peter Volante</i>	8-16-68	
ANALYST			LUMINARY 1D
DOCWR	<i>John A. Moore</i>	5-17-68	REV 2
APPR'D	<i>John A. Moore</i>	29 Oct 68	SHEET 20 OF 103

FROM PRECEDING SHEET

FROM PRECEDING SHEET

INTEGRV
UPDATE
PERMANENT
STATE VECTOR
FC-3350

GROUP 2
RESTART JOB
AT NEXT
INSTRUCTION

INSTALL
TEST FOR
AVAILABILITY OF
INTEGRATION
FC-3350

$MPAC_D \leftarrow TETCSM_D$

LOAD TIME FOR
LEM INTEGRATION

CLEAR VINTFLAG

LEM STATE VECTOR
BEING INTEGRATED

INTEGRV
UPDATE
PERMANENT
STATE VECTOR
FC-3350

GROUP 2
RESTART JOB
AT NEXT
INSTRUCTION

INSTALL
TEST FOR
AVAILABILITY OF
INTEGRATION
FC-3350

SET VINTFLAG

CSM STATE VECTOR
BEING INTEGRATED

$MPAC_D \leftarrow TETLEM_D$

LOAD TIME FOR
CSM INTEGRATION

UPPSV4

INTEGRATE OTHER VEHICLE
WITHOUT W MATRIX

SET STATEFLG
CLEAR INTYPFLG
CLEAR DIMOFLAG
CLEAR D6OR9FL6

PERMANENT STATE VECTOR UPDATED
ENCKE INTEGRATION
W MATRIX IS NOT TO BE USED
DIMENSION OF W IS 6 FOR INTEGRATION

$TDEC1_D \leftarrow MPAC_D$

INTEGRV
UPDATE
PERMANENT
STATE VECTOR
FC-3350

IS
SURFFLAG
SET?

YES

$LMPOS_V \leftarrow RCVLEM_V$
 $LMVEL_V \leftarrow VCVLEM_V$

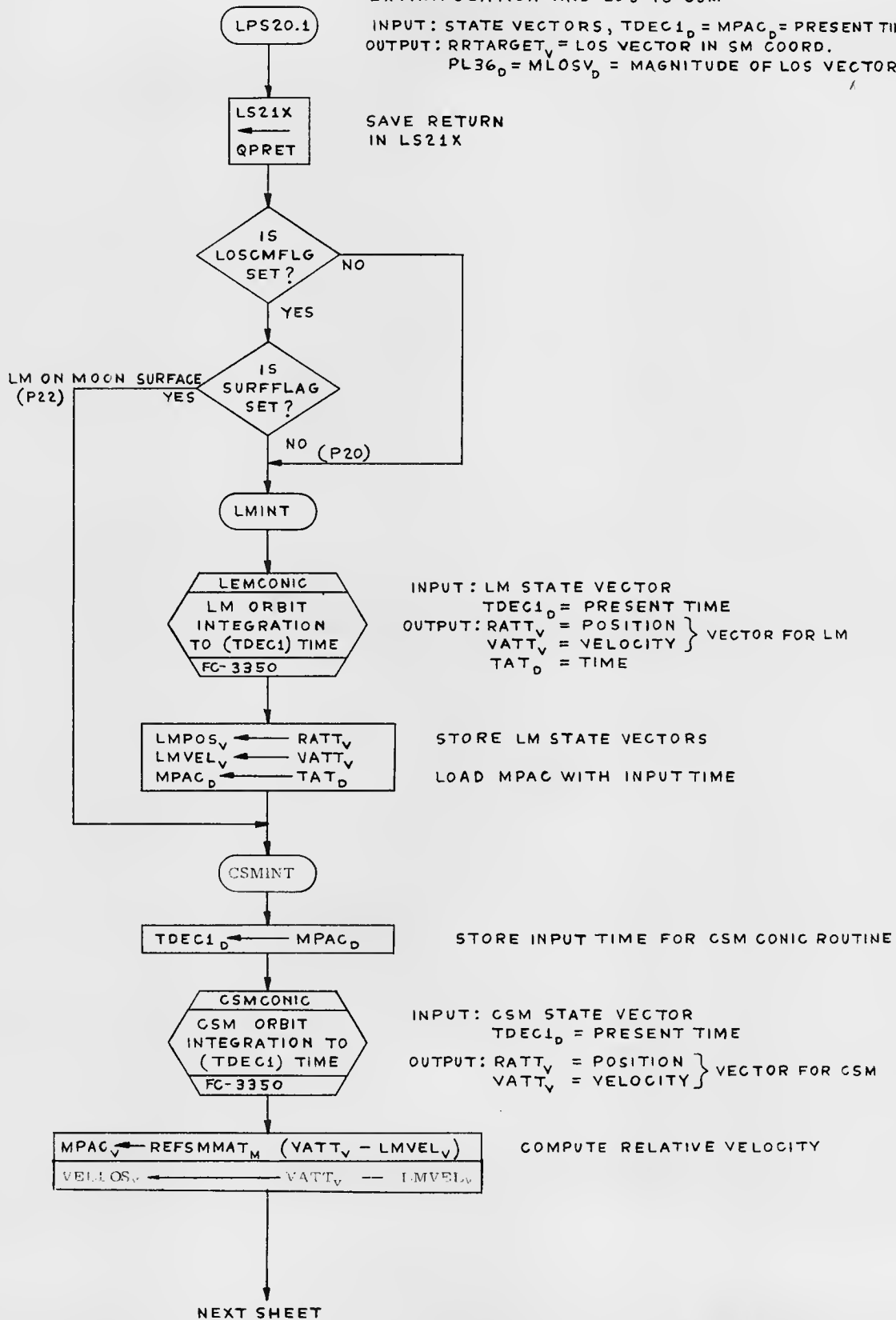
RETURN VIA
LS21X

P2OLEMC4
SH18

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS 4-1-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGRM <i>P20 Vols 1-8</i>	4-1-68	LUMINARY 1-D	DOCUMENT NO.
ANALST			FC-3600
DOCTR <i>W. DeGroot</i>	5-17-66		
APPR'D <i>John A. Moore</i>	29 Oct 68	REV	SHEET 21 OF 103

SUBROUTINE TO COMPUTE VECTOR
EXTRAPOLATION AND LOS TO CSM

INPUT: STATE VECTORS, $TDEC1_D = MPAC_D =$ PRESENT TIME
OUTPUT: $RRTARGET_V =$ LOS VECTOR IN SM COORD.
 $PL36_D = MLOS_V =$ MAGNITUDE OF LOS VECTOR



SAVE RETURN
IN LS21X

INPUT: LM STATE VECTOR
 $TDEC1_D =$ PRESENT TIME
OUTPUT: $RATT_V =$ POSITION } VECTOR FOR LM
 $VATT_V =$ VELOCITY }
 $TAT_D =$ TIME

STORE LM STATE VECTORS
LOAD MPAC WITH INPUT TIME

STORE INPUT TIME FOR CSM CONIC ROUTINE

INPUT: CSM STATE VECTOR
 $TDEC1_D =$ PRESENT TIME
OUTPUT: $RATT_V =$ POSITION } VECTOR FOR CSM
 $VATT_V =$ VELOCITY }

COMPUTE RELATIVE VELOCITY

NEXT SHEET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
DRAWN <i>G. J. Langille</i>	11MARS	LUMINARY 1D	DOCUMENT NO. FC-3600
PRGRM <i>F. W. ...</i>	10/01/69		
ANALST			
DOCMR <i>M. ...</i>	4-7-69		
APPR'D <i>W. ...</i>	10/21/69	REV 2	SHEET 22 OF 103

FROM PRECEDING SHEET

KILLTASK
REMOVE TASK
DESLOOP+2 FROM
WAITLIST
FC-3050

KILL THE TASK WHICH CALLS
DODES ROUTINE (STORING INTO
ERASEABLES DODES USES)

LOSVEL_v ← MPAC_v
MPAC_v ← RATT_v - LMPOS_v
RRANGE_v ← MPAC_v

STORE RELATIVE VELOCITY
COMPUTE RELATIVE POSITION (LOS_v)

NOTSHIFT

TEST RANGE LIMIT
IS RANGE > 400NM ?

526ALARM
SHIG

RRTARGET_v ← REFSMMAT_M [UNIT(MPAC_v)]
MLOS_v ← PL36_D

CONVERT LOS TO SM COORD.
STORE MAGNITUDE OF LOS_v

CLEAR
RRNBSW

RADAR TARGET IN SM COORDINATES

RETURN VIA
LS21X

LUNSFCHK

SUBROUTINE TO TEST
LUNAR SURFACE FLAG (SURFLAG)

CALLING SEQUENCE
L+0 - TC LUNSFCHK
L+1 - LEM ON SURFACE (P22)
L+2 - LEM NOT ON SURFACE (P20)

(P22) YES
LEM ON SURFACE
IS SURFFLAG SET ?

(P20) NO
LEM NOT ON SURFACE

Q ←
1 + Q

INCREMENT
Q

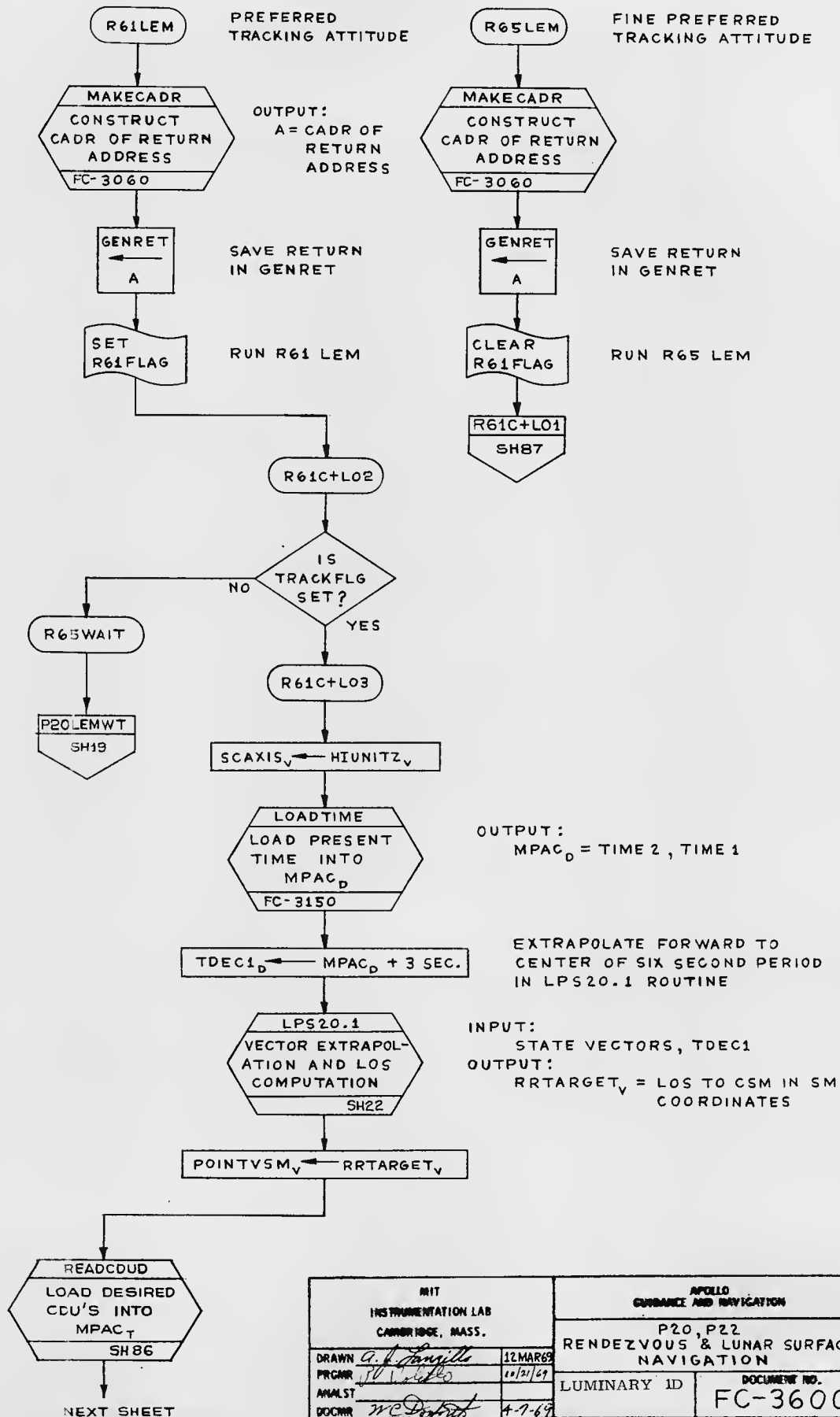
RETURN
TO L+1

RETURN VIA
Q

RETURN VIA
Q

RETURN TO
L+2

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. J. Langella</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAM <i>A. J. Langella</i>	11MARG	LUMINARY 1D	DOCUMENT NO. FC-3600
ANALYST <i>A. J. Langella</i>	10/21/69	REV 2	SHEET 23 OF 103
DOCTR <i>A. J. Langella</i>	4-7-69		
APPR'D <i>A. M. S. ...</i>	10/21/69		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>G. J. Angille</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGRM <i>JV 1.2.68</i>	12 MAR 68	LUMINARY ID	DOCUMENT NO. FC-3600
ANALST	10/21/67	APPR'D <i>W. M. East</i>	REV 2
DOCHR	4-7-69	SHEET 24 OF 103	
APPR'D <i>W. M. East</i>	12/21/67		

FROM
PRECEDING SHEET

VECPNT1
COMPUTE DESIRED
ANGLES TO POINT
VEHICLE
FC-3420

INPUT: SCAXIS_v = SPECIFIED S/C AXIS TO BE
MANEUVERED
POINTVSM_v = DIRECTION OF FINAL ATTITUDE
OUTPUT: MPAC_T = DESIRED 3 GIMBAL ANGLES

CPHI_T ← MPAC_T

GROUP 2
SET UP RESTARTS TO
SCHEDULE NEXT LOC-
ATION AS A FINDVAC
JOB WITH SAME PRIORITY

IS
TRACKFLG
SET?

NO
R65WAIT
SH24

YES
G+N,AUTO
CHECK G+N
AND AUTO
SWITCHES
FC-3420

BOTH SWITCHES NOT SET

>0

R61C+L04

BALLANGS
COMPUTE LM
FDAI BALL
OISPLAY ANGLES
FC-3420

INPUT: CPHI, CTHETA,
CPSI
OUTPUT: FDAIX, FDAIY,
FOAIZ

R61C+L06
SH 27

+0

MPAC_v ← RRTARGET_v

COU*SMNB
TRANSFORM VECTOR
FROM SM TO NB
COORDINATES
FC-3320

INPUT: MPAC_v = INPUT VECTOR COU ANGLES
OUTPUT: MPAC_v = TRANSFORMED VECTOR

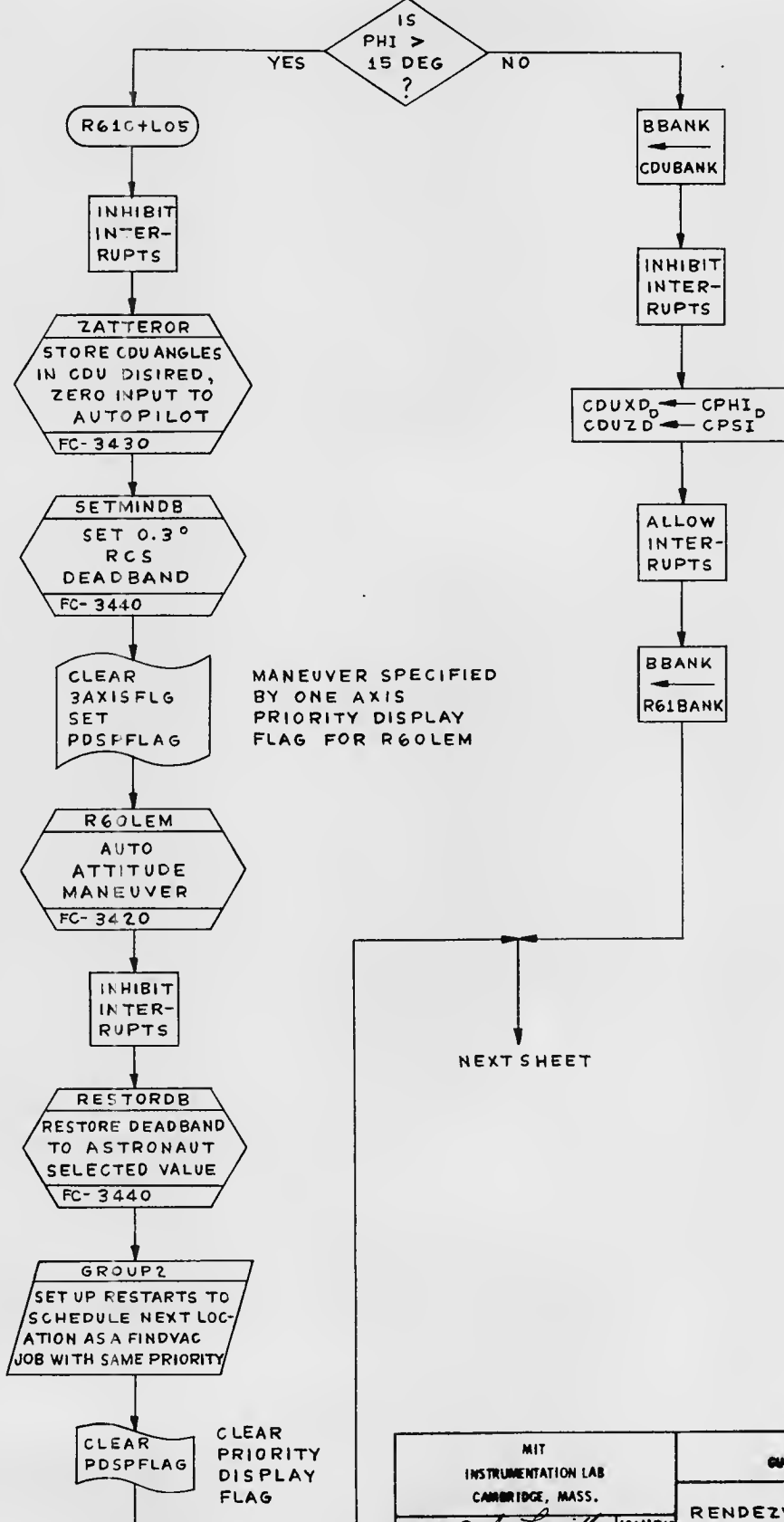
MPAC_D ← MPAC+5_D-COS15DEG_D

MPAC+5_D = PHI = Z-COMPONENT OF LOS

NEXT SHEET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>G. J. Saville</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAM <i>J. V. Santos</i>	12MAR69	LUMINARY 1D	DOCUMENT NO. FC-3600
ANALYST	10/21/69	REV 2	SHEET 25 OF 103
DOCNR <i>M. D. Bryant</i>	4-9-69		
APPR'D <i>S. M. Fuster</i>	10/21/69		

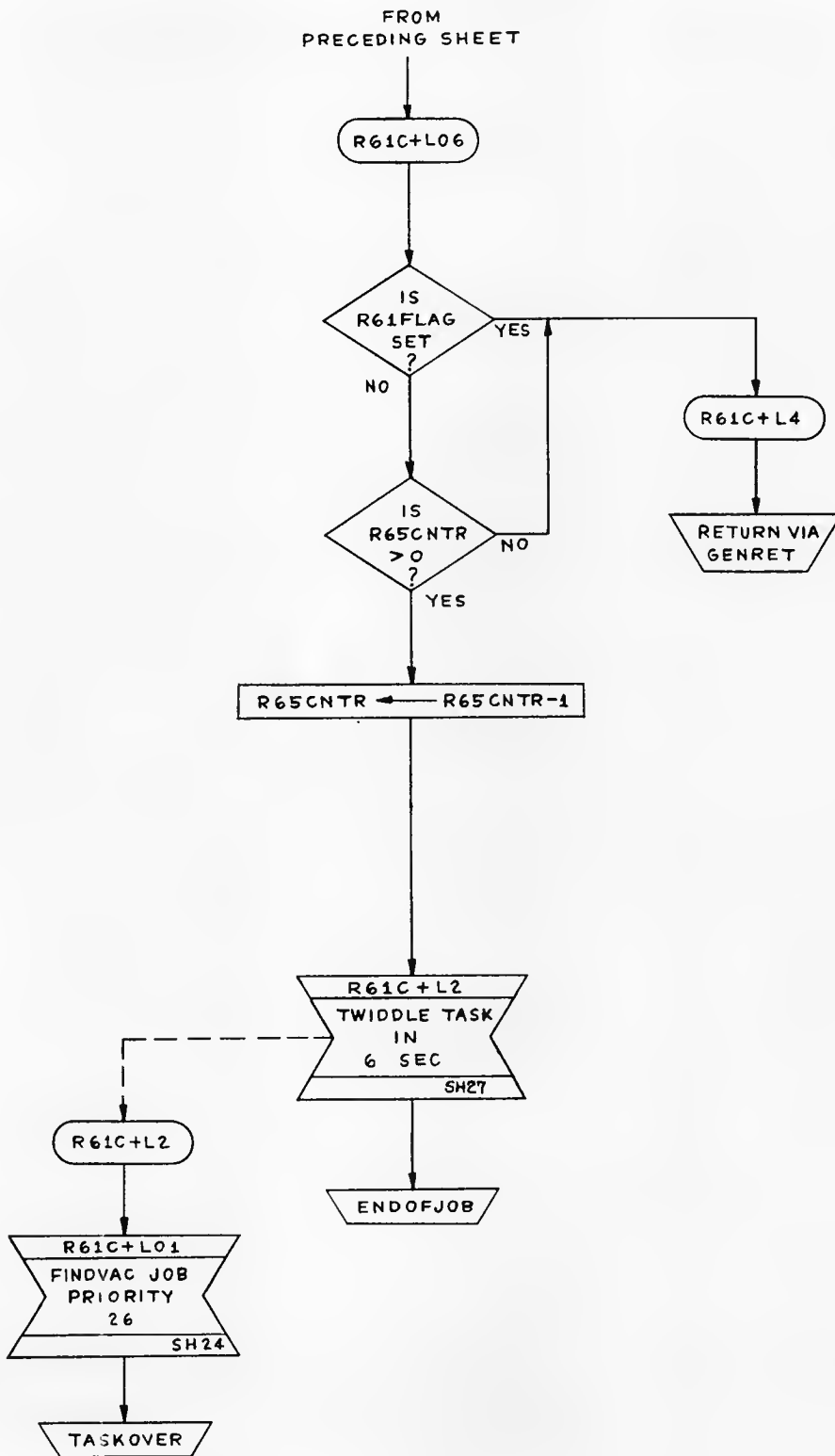
FROM
PRECEDING SHEET



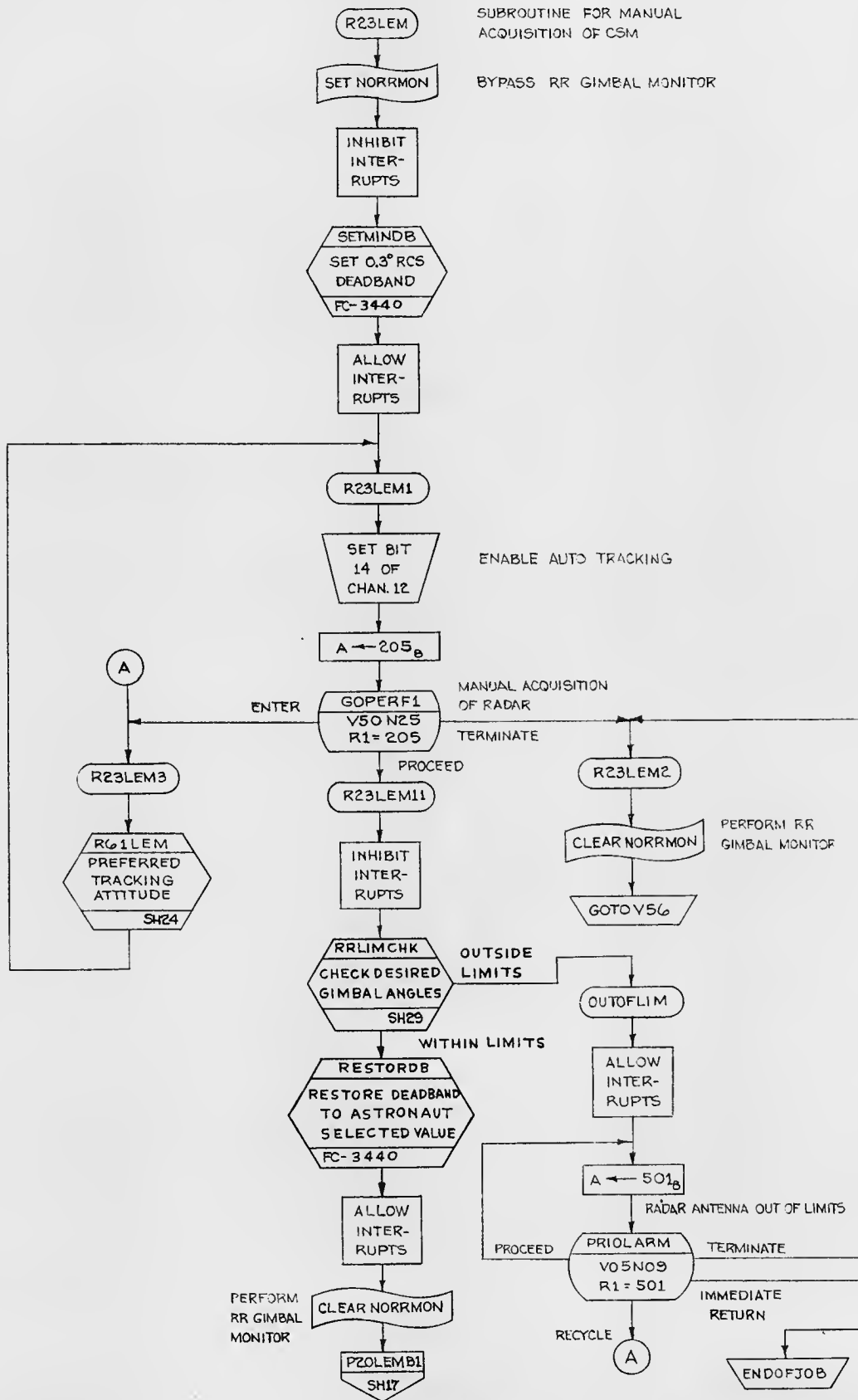
MANEUVER SPECIFIED
BY ONE AXIS
PRIORITY DISPLAY
FLAG FOR R60LEM

NEXT SHEET

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



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. J. Langille</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAM	<i>P. J. ...</i>	12 MAR 69	DOCUMENT NO.
ANALYST		10/21/69	LUMINARY 1D
DOCNR	<i>mc ...</i>	4-7-69	FC-3600
APPROV	<i>R. M. ...</i>	10/21/69	REV 2
			SHEET 27 OF 103



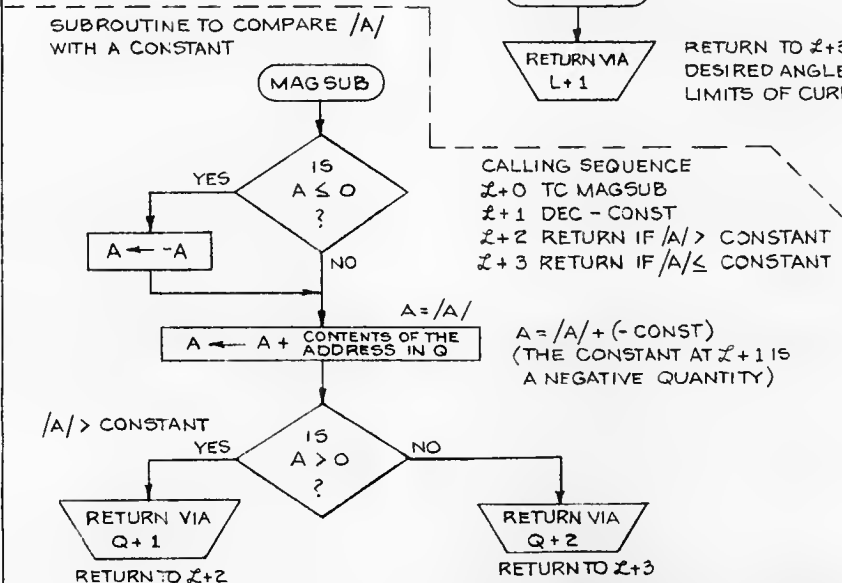
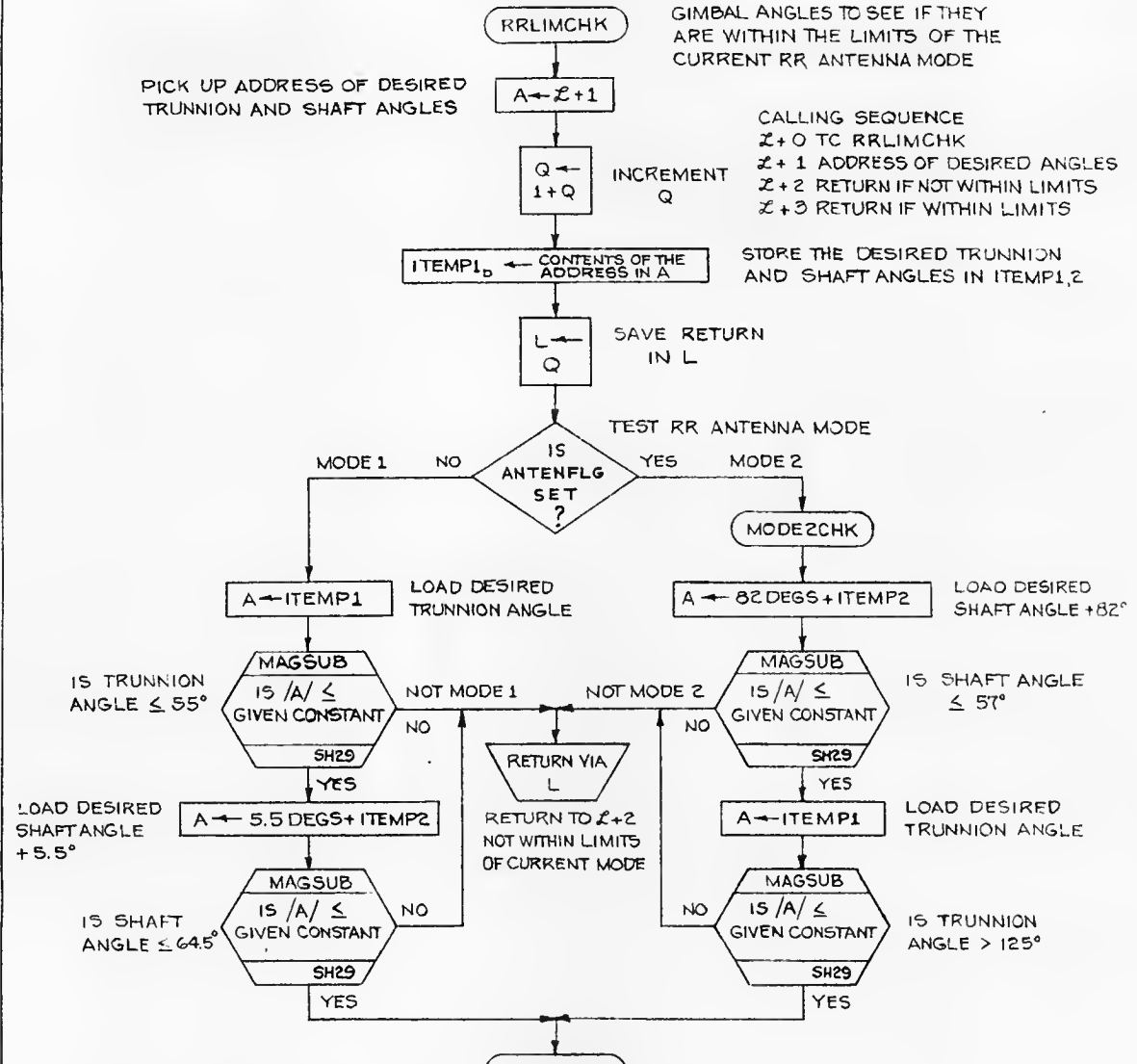
SUBROUTINE FOR MANUAL ACQUISITION OF CSM
BYPASS RR GIMBAL MONITOR

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS 5-24-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGR Peter Volpe 8-16-68	ANALYST	LUMINARY 1D	DOCUMENT NO. FC-3600
DOCWR McHugh 5-28-68	APPR'D John A. Moore 8-28-68	REV 2	SHEET 28 OF 103

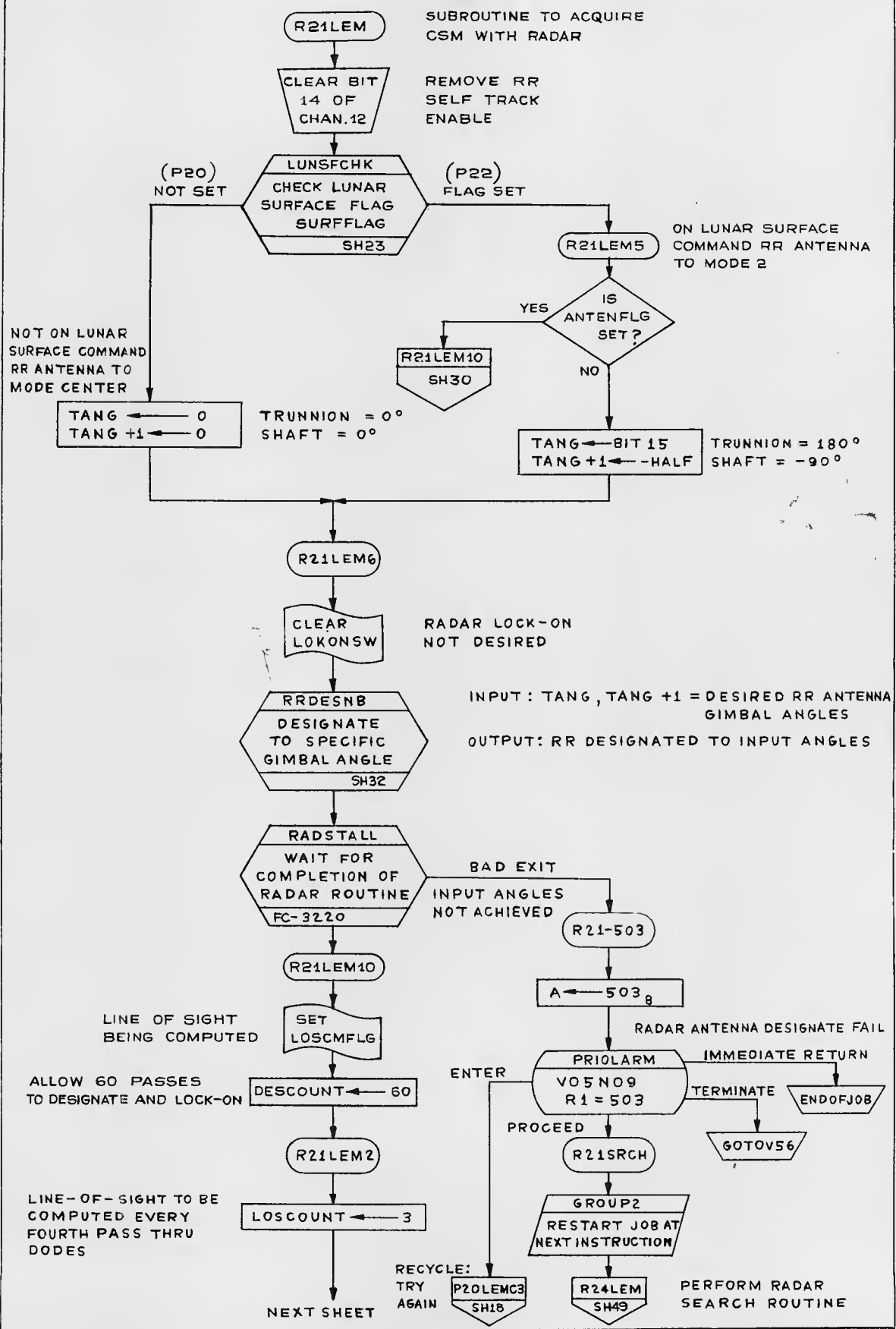
SUBROUTINE TO CHECK DESIRED GIMBAL ANGLES TO SEE IF THEY ARE WITHIN THE LIMITS OF THE CURRENT RR ANTENNA MODE

PICK UP ADDRESS OF DESIRED TRUNNION AND SHAFT ANGLES

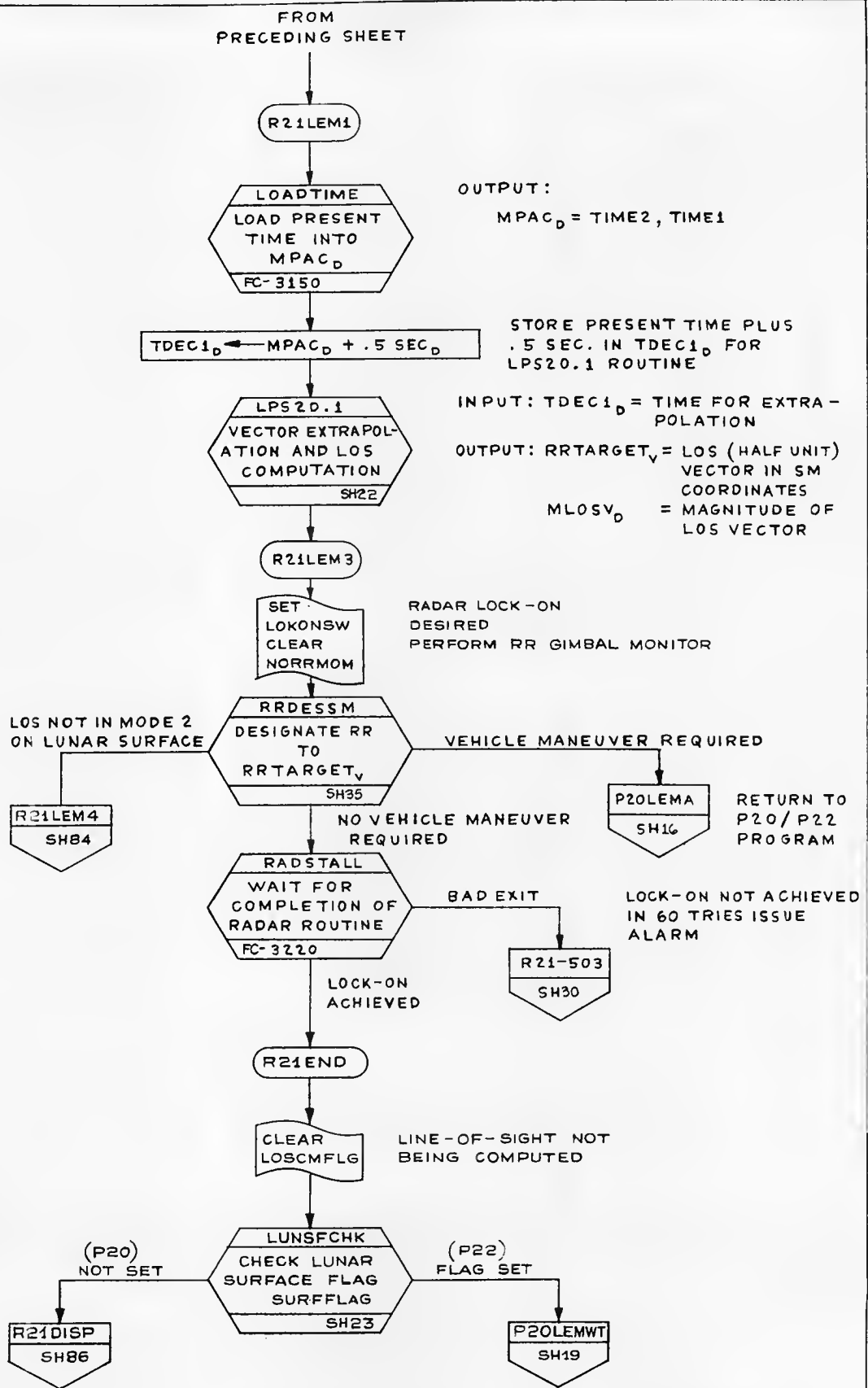
CALLING SEQUENCE
 $Z+0$ TC RRLIMCHK
 $Z+1$ ADDRESS OF DESIRED ANGLES
 $Z+2$ RETURN IF NOT WITHIN LIMITS
 $Z+3$ RETURN IF WITHIN LIMITS



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

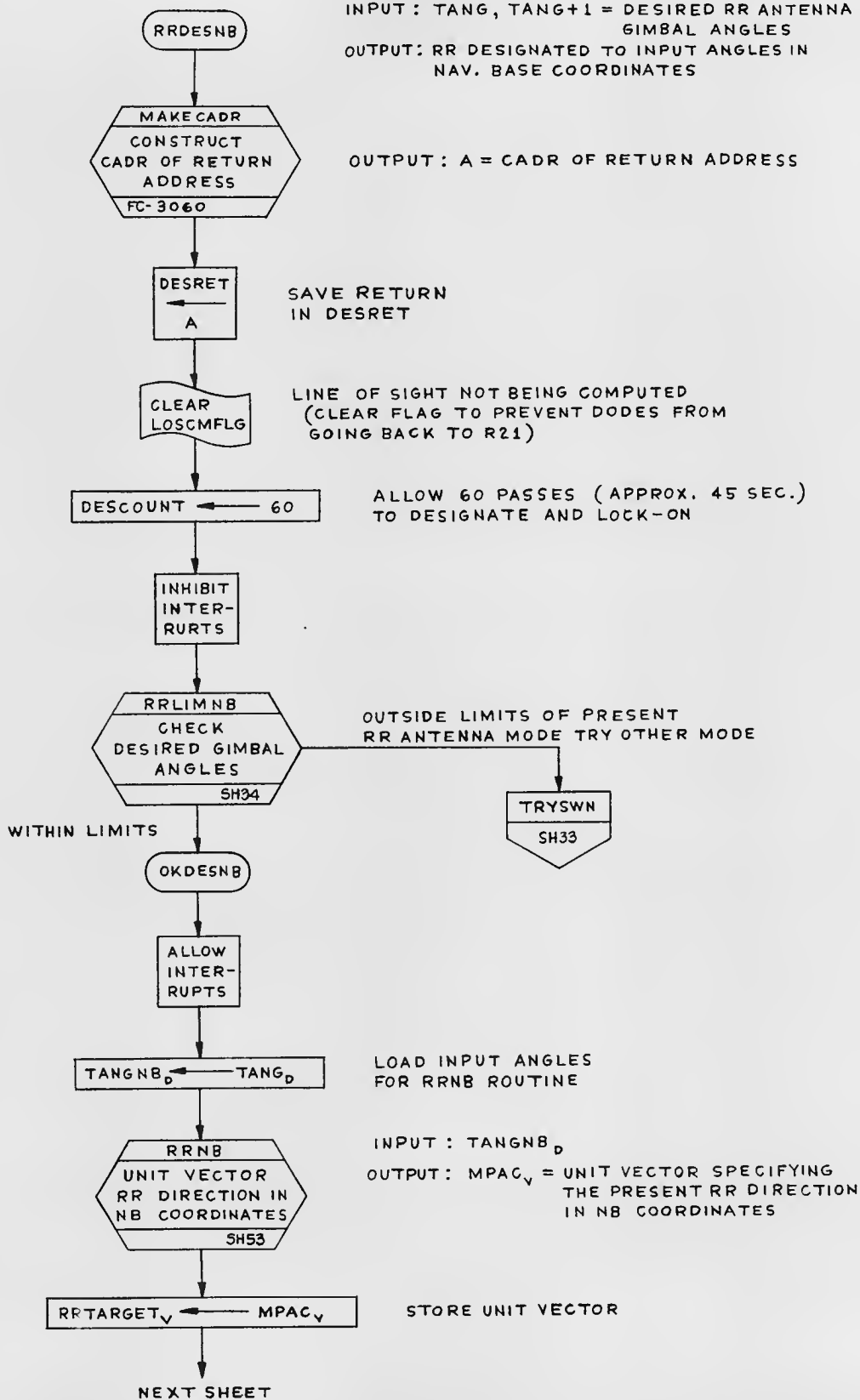


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN: <i>A. J. Langille</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGR: <i>J. L. ...</i>		DOCUMENT NO. FC-3600	
ANALYST: <i>W. C. ...</i>		LUMINARY 1D	
DOCNR: <i>...</i>		REV 2	
APPR'D: <i>...</i>		SHEET 30 OF 103	



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. J. Fungillo</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAM	<i>J. J. Volpe</i>	13MARG	DOCUMENT NO.
ANALYST		10/21/69	LUMINARY 1D
DOCNR	<i>MC Doherty</i>	4-7-67	FC-3600
APPR'D	<i>J. M. ...</i>	10/21/69	REV 2 SHEET 31 OF 103

SUBROUTINE TO DESIGNATE RR TO SPECIFIC
 GIMBAL ANGLES IN NAV. BASE COORDINATES
 INPUT: TANG, TANG+1 = DESIRED RR ANTENNA
 GIMBAL ANGLES
 OUTPUT: RR DESIGNATED TO INPUT ANGLES IN
 NAV. BASE COORDINATES



OUTPUT: A = CADR OF RETURN ADDRESS

SAVE RETURN
IN DESRET

LINE OF SIGHT NOT BEING COMPUTED
(CLEAR FLAG TO PREVENT DODES FROM
GOING BACK TO R21)

ALLOW 60 PASSES (APPROX. 45 SEC.)
TO DESIGNATE AND LOCK-ON

OUTSIDE LIMITS OF PRESENT
RR ANTENNA MODE TRY OTHER MODE

WITHIN LIMITS

LOAD INPUT ANGLES
FOR RRNB ROUTINE

INPUT: TANGNB_D
 OUTPUT: MPAC_V = UNIT VECTOR SPECIFYING
 THE PRESENT RR DIRECTION
 IN NB COORDINATES

STORE UNIT VECTOR

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
DRAWN <i>A. J. Smith</i>	14 MAR 69	LUMINARY 1D	DOCUMENT NO. FC-3600
PROGRAM <i>S. V. 4-50</i>	10/21/69		
ANALYST <i>W. E. Gault</i>	4-7-69		
APPR'D <i>R. M. Gault</i>	10/21/69	REV 2	SHEET 32 OF 103

FROM
PRECEDING SHEET

SET
RRNBSW

RADAR TARGET IN
NB COORDINATES

INHIBIT
INTER-
RUPTS

STARTDES+1
SH36

EXIT TO STARTDES ROUTINE

TRYSWN

RMODINV
INVERT RR
ANTENNA MODE
(ANTENFLG)
SH46

RRLIMNB
CHECK
DESIRED GIMBAL
ANGLES
SH34

OUTSIDE LIMITS OF
BOTH ANTENNA MODES

WITHIN LIMITS
OF OTHER MODE

RMODINV
INVERT RR
ANTENNA MODE
(ANTENFLG)
SH46

RETURN MODE
FLAG TO
ORIGINAL
STATE

NODESNB

RMODINV
INVERT RR
ANTENNA MODE
(ANTENFLG)
SH46

SET
REMODEFLG

REMODE REQUESTED
OR IN PROGRESS

ALARM
"502"
BAD RADAR GIMBAL
ANGLE INPUT
FC-3070

OUTPUT: STORE ALARM
CODE AND LITE
ALARM LIGHT

OKDESNB
SH32

CLRADMOD

REMOVE DESIGNATE REQUESTS

INHIBIT
INTER-
RUPTS

CLEAR
CDESFLAG
CLEAR
DESIGFLG

LGC CHECKS FOR LOCK-ON
WHEN ANTENNA BEING
DESIGNATED
RR DESIGNATE NOT REQUESTED
OR IN PROGRESS

CLEAR BIT
2 OF
CHAN 12

DISABLE
RR ERROR
COUNTERS

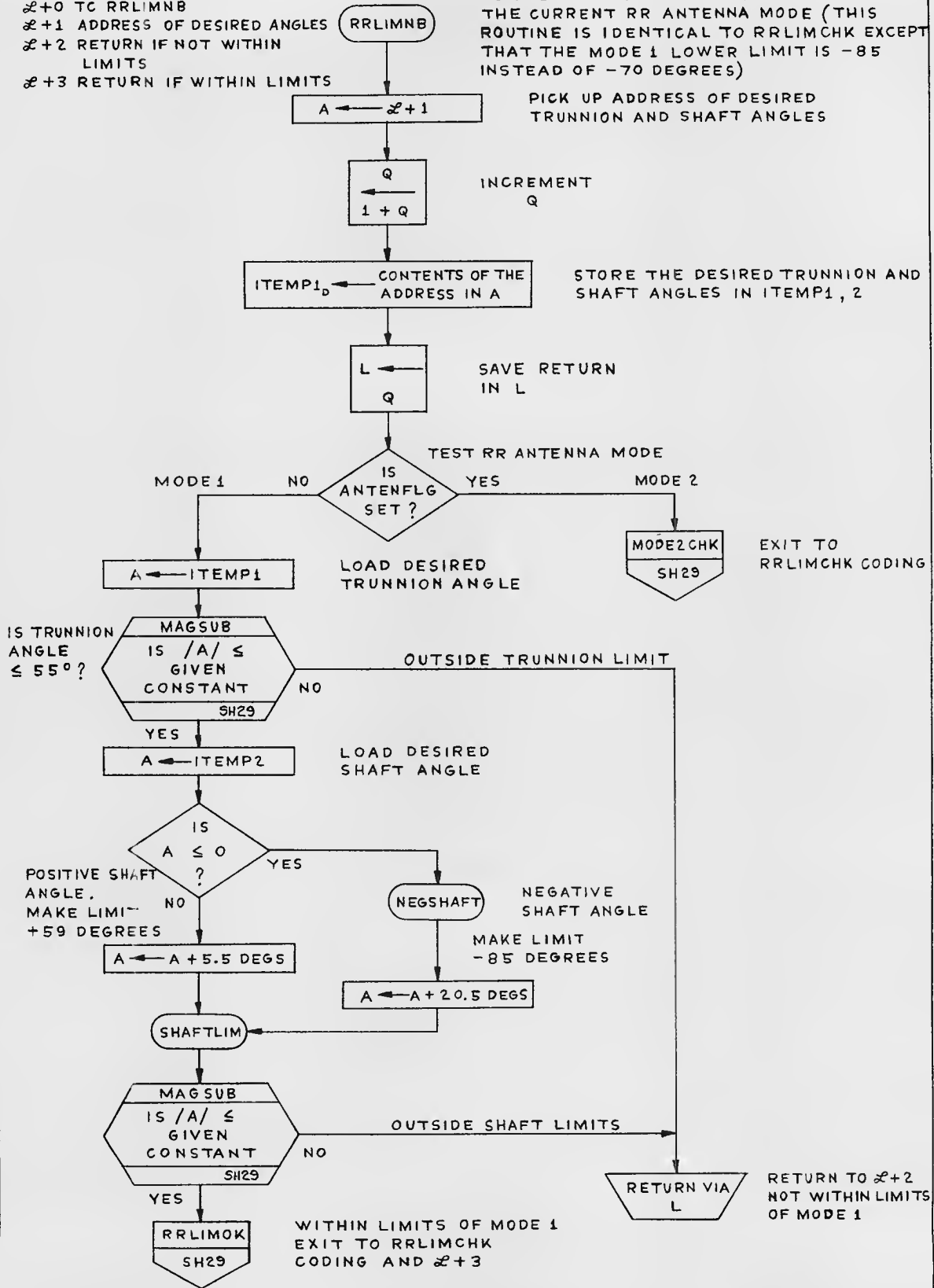
ENDOFJOB

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>G. J. Langille</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRM <i>G. J. Langille</i>	DATE <i>10/21/67</i>	LUMINARY ID:	DOCUMENT NO. FC-3600
ANALST <i>W. E. Dyer</i>	DATE <i>1-7-67</i>	APPR'D <i>R. M. Egan</i>	SHEET 33 OF 103
DOCTR <i>W. E. Dyer</i>	DATE <i>10/21/67</i>	REV 2	

CALLING SEQUENCE:

- ℓ+0 TC RRLIMNB
- ℓ+1 ADDRESS OF DESIRED ANGLES
- ℓ+2 RETURN IF NOT WITHIN LIMITS
- ℓ+3 RETURN IF WITHIN LIMITS

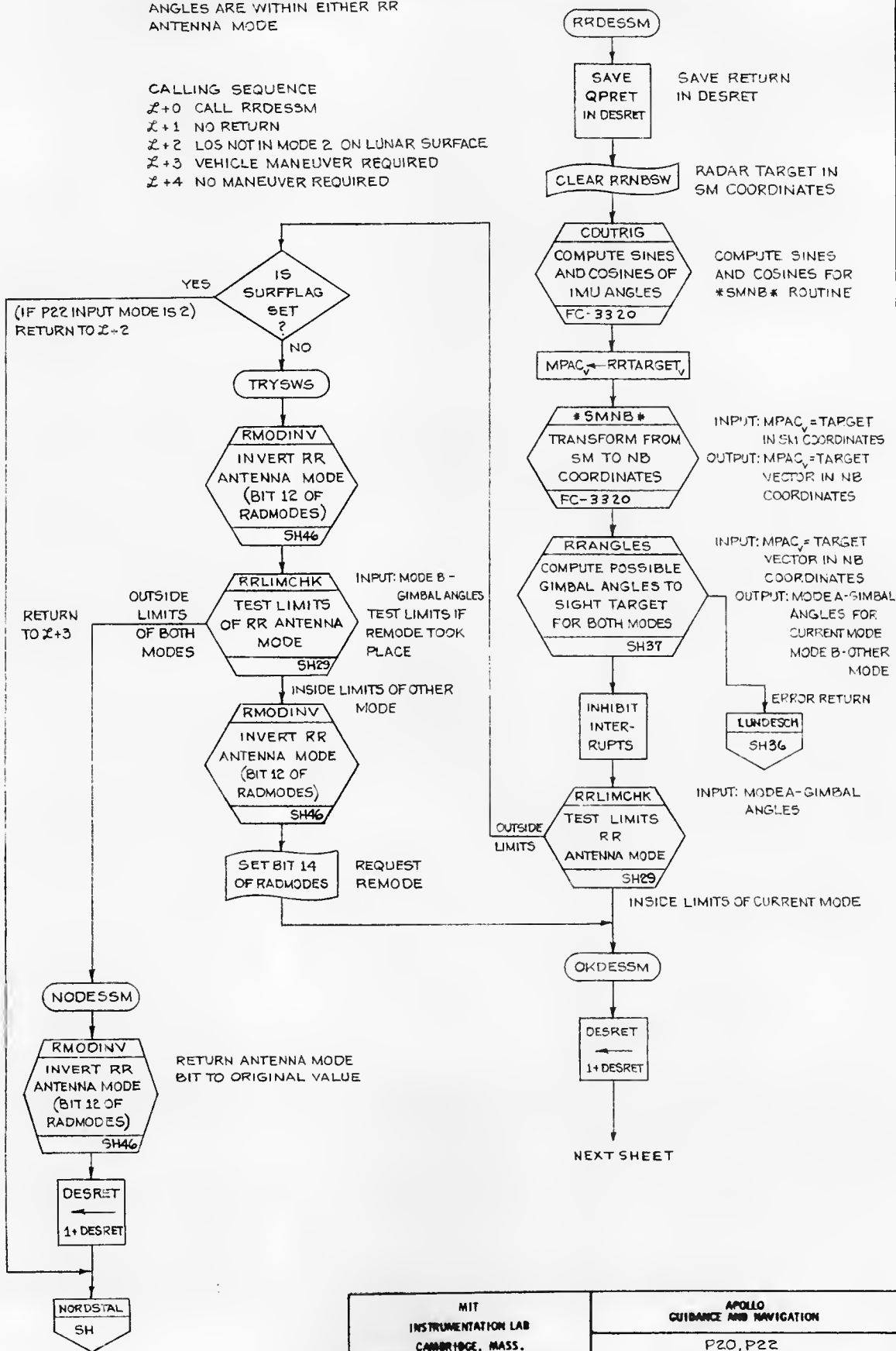
SUBROUTINE TO CHECK DESIRED GIMBAL ANGLES TO SEE IF THEY ARE WITHIN THE LIMITS OF THE CURRENT RR ANTENNA MODE (THIS ROUTINE IS IDENTICAL TO RRLIMCHK EXCEPT THAT THE MODE 1 LOWER LIMIT IS -85 INSTEAD OF -70 DEGREES)



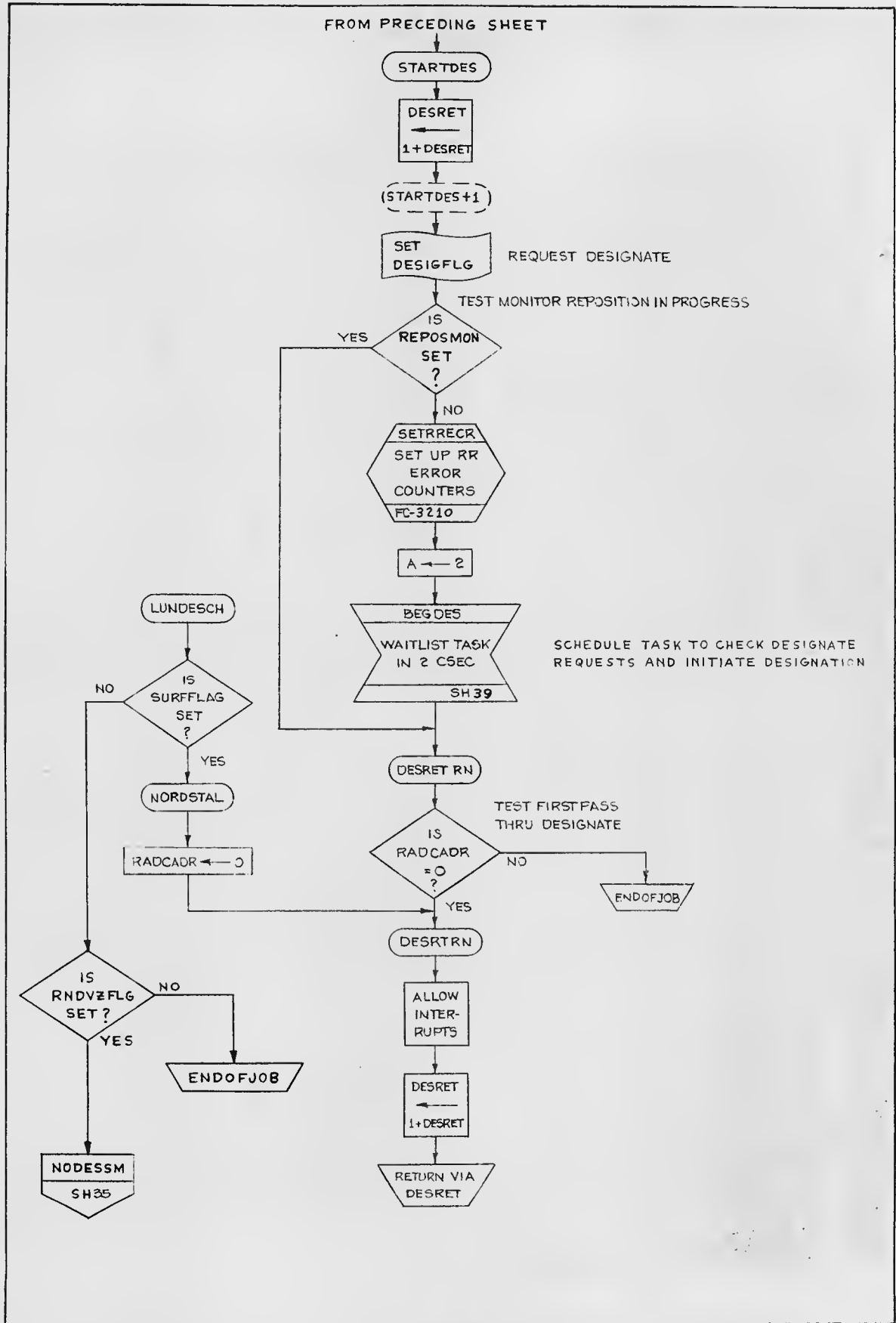
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. J. Longella</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRCNR <i>D. W. ...</i>	14 MAR 68	LUMINARY 1D	DOCUMENT NO. FC-3600
ANALST	10/21/69	REV 2	SHEET 34 OF 103
DOCMR <i>W. E. ...</i>	4-7-69		
APPR'D <i>D. M. ...</i>	10/21/69		

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

CALLING SEQUENCE
 L+0 CALL RRDESSM
 L+1 NO RETURN
 L+2 LOS NOT IN MODE 2 ON LUNAR SURFACE
 L+3 VEHICLE MANEUVER REQUIRED
 L+4 NO MANEUVER REQUIRED

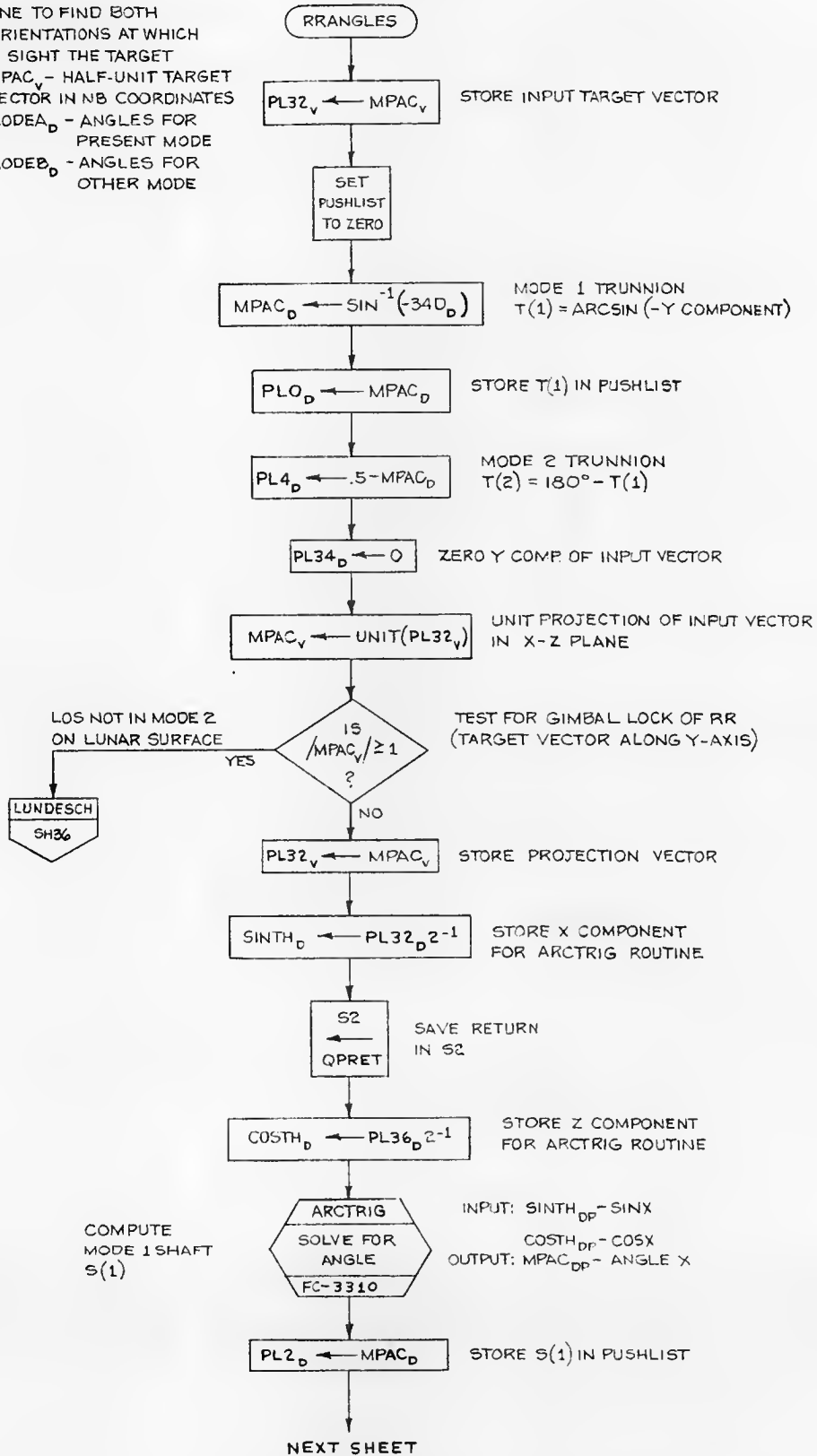


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A.C. Williams</i> 3-8-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGR <i>John Volante</i> 10/21/69	ANALST	LUMINARY 1D	DOCUMENT NO. FC-3600
DGCNR <i>W. D. ...</i> 5-17-69	APPR'D <i>John A. ...</i> 10/21/68	REV 2	SHEET 35 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
DRAWN	A.C. WILLIAMS	3-11-68	
PROGR	<i>G. A. Williams</i>	10/21/67	
APPROV			LUMINARY ID
DOCUM	<i>J. A. Moore</i>	5-17-60	DOCUMENT NO.
APPROV	<i>John A. Moore</i>	29 Oct 68	FC-3600
		REV 2	SHEET 36 OF 103

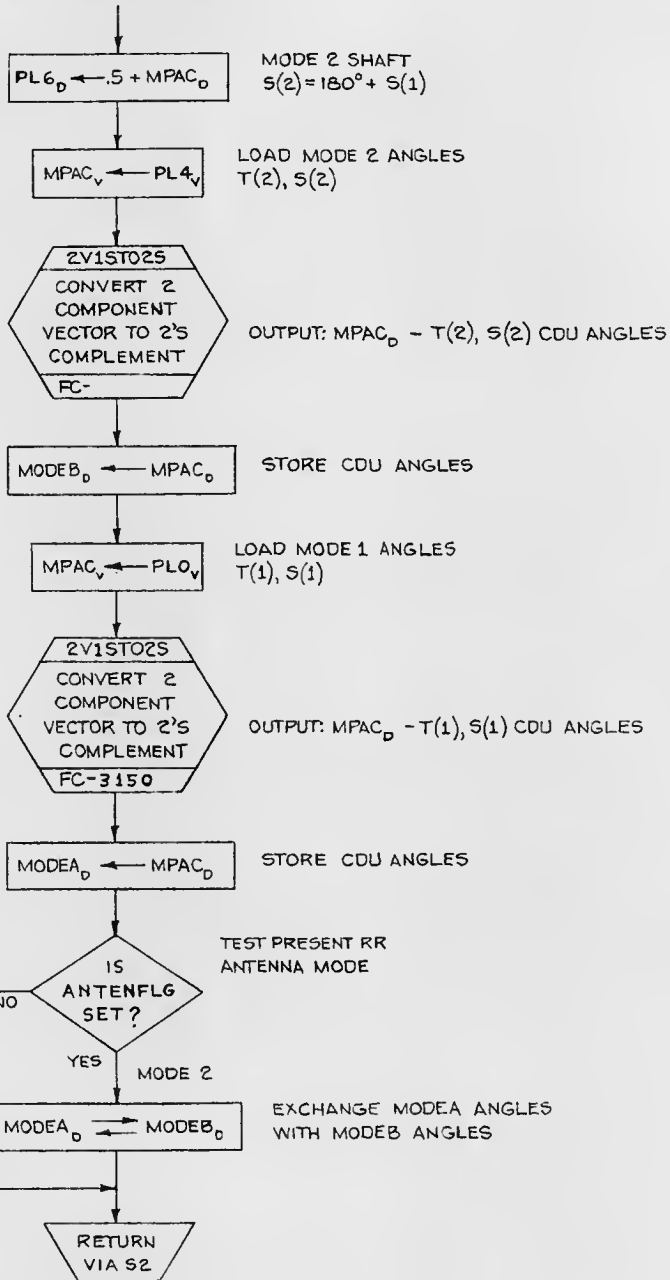
SUBROUTINE TO FIND BOTH
 RR GIMBAL ORIENTATIONS AT WHICH
 RR MIGHT SIGHT THE TARGET
 INPUT: MPAC_v - HALF-UNIT TARGET
 VECTOR IN NB COORDINATES
 OUTPUT: MODEA_D - ANGLES FOR
 PRESENT MODE
 MODEB_D - ANGLES FOR
 OTHER MODE



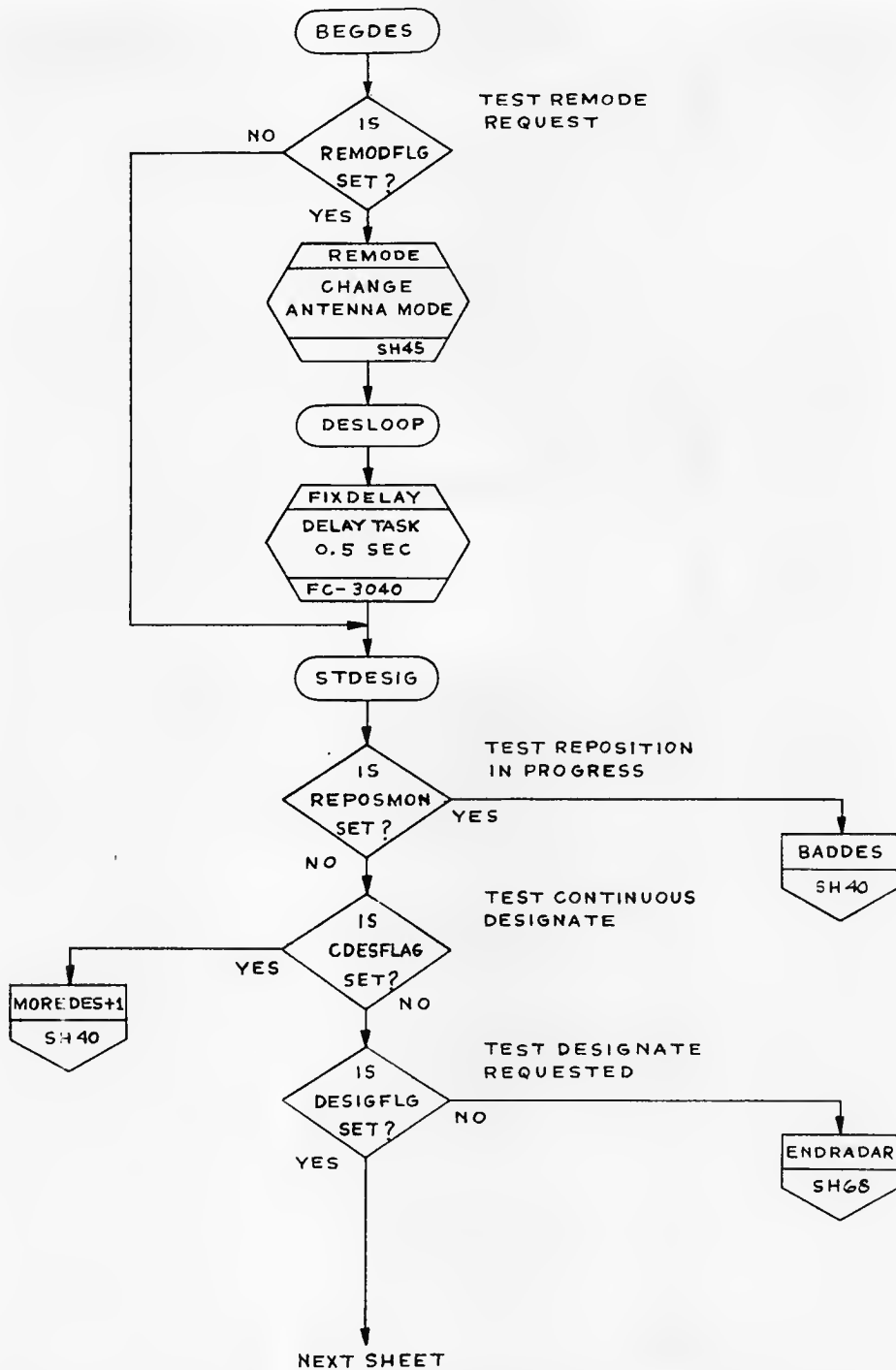
COMPUTE
 MODE 1 SHAFT
 S(1)

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	ANALST	LUMINARY 1D	DOCUMENT NO. FC-3600
DOCMR W. G. Gault 5-17-68	APPR'D John A. Moore 8-9-68	REV 2	SHEET 37 OF 103

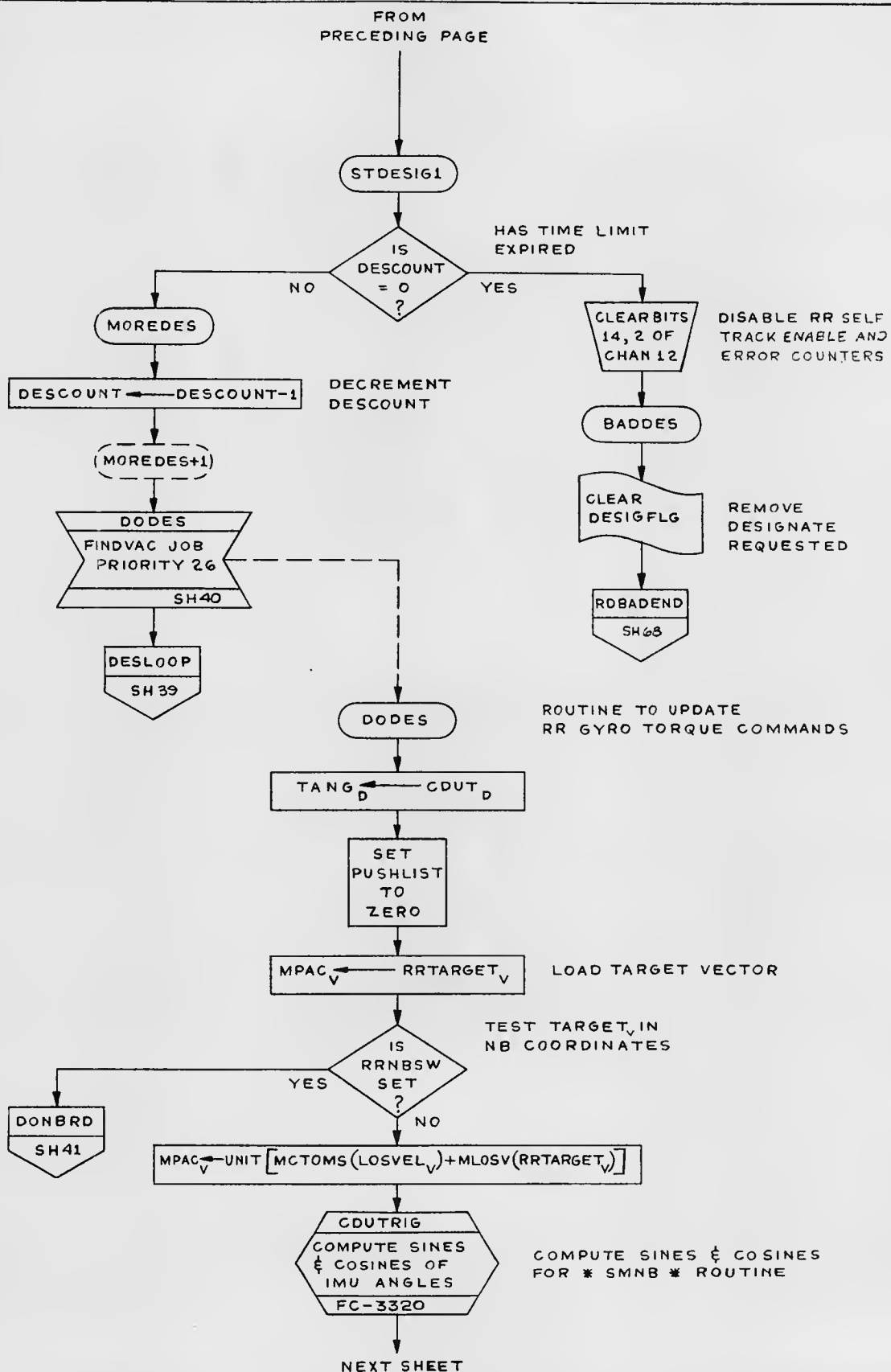
FROM PRECEDING SHEET



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO ORBITANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS 4-2-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAM Peter Volante 8-16-68	ANALYST	LUMINARY 1D	DOCUMENT NO.
DOCWR Mr. DeLoach 5-17-68	APPR'D John A. Moran 29 Oct 68		FC-3600
		REV 2	SHEET 38 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGRM <i>[Signature]</i>	12 MAR 68	LUMINARY ID	DOCUMENT NO.
ANALST	16 AUG 68		FC-3600
DOCNR <i>[Signature]</i>	17 MAY 68		
APPR'D <i>[Signature]</i>	25 OCT 68	REV 2	SHEET 39 OF 103

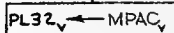
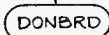


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. J. Janylla</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGMR <i>W. J. Volz</i>	12 MAR 68	LUMINARY ID:	DOCUMENT NO.
ANALST	16 AUG 68		FC-3600
DOCHR <i>W. J. Volz</i>	19 MAY 68	REV 2	SHEET 40 OF 103
APPR'D <i>John A. Thorne</i>	29 OCT 68		

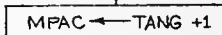
FROM PRECEDING SHEET



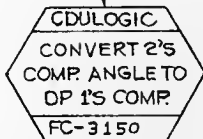
INPUT: MPAC_v - TARGET_v IN SM COORDINATES
 OUTPUT: MPAC_v - TARGET_v IN NB COORDINATES



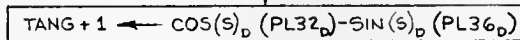
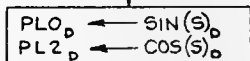
STORE LOS TARGET_v



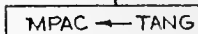
LOAD SHAFT CDU ANGLE (S)



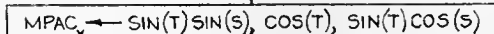
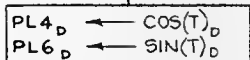
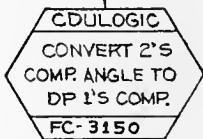
INPUT: MPAC - 2'S COMPLEMENT ANGLE
 OUTPUT: MPAC_D - 1'S COMPLEMENT ANGLE



SHAFT COMMAND = TARGET_v · [COS(S), 0, -SIN(S)]



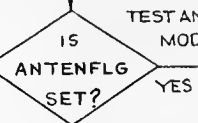
LOAD TRUNNION CDU ANGLE (T)



U_v



TRUNNION COMMAND = -(U_v · TARGET_v)

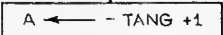
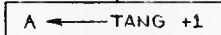


TEST ANTENNA MODE

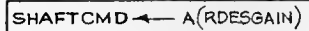
NO

MODE 2

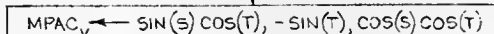
YES



REVERSE SHAFT POLARITY



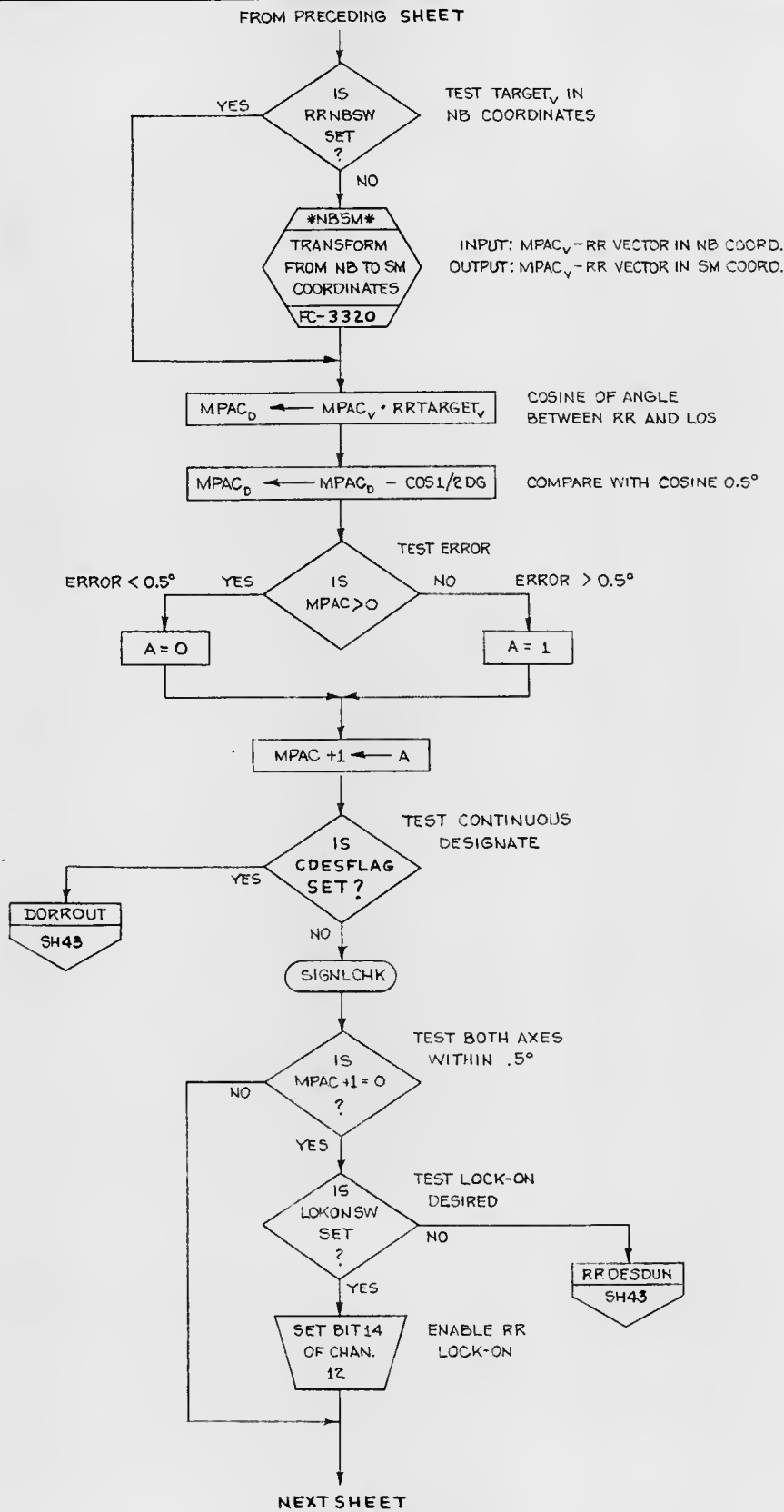
SHAFT COMMAND



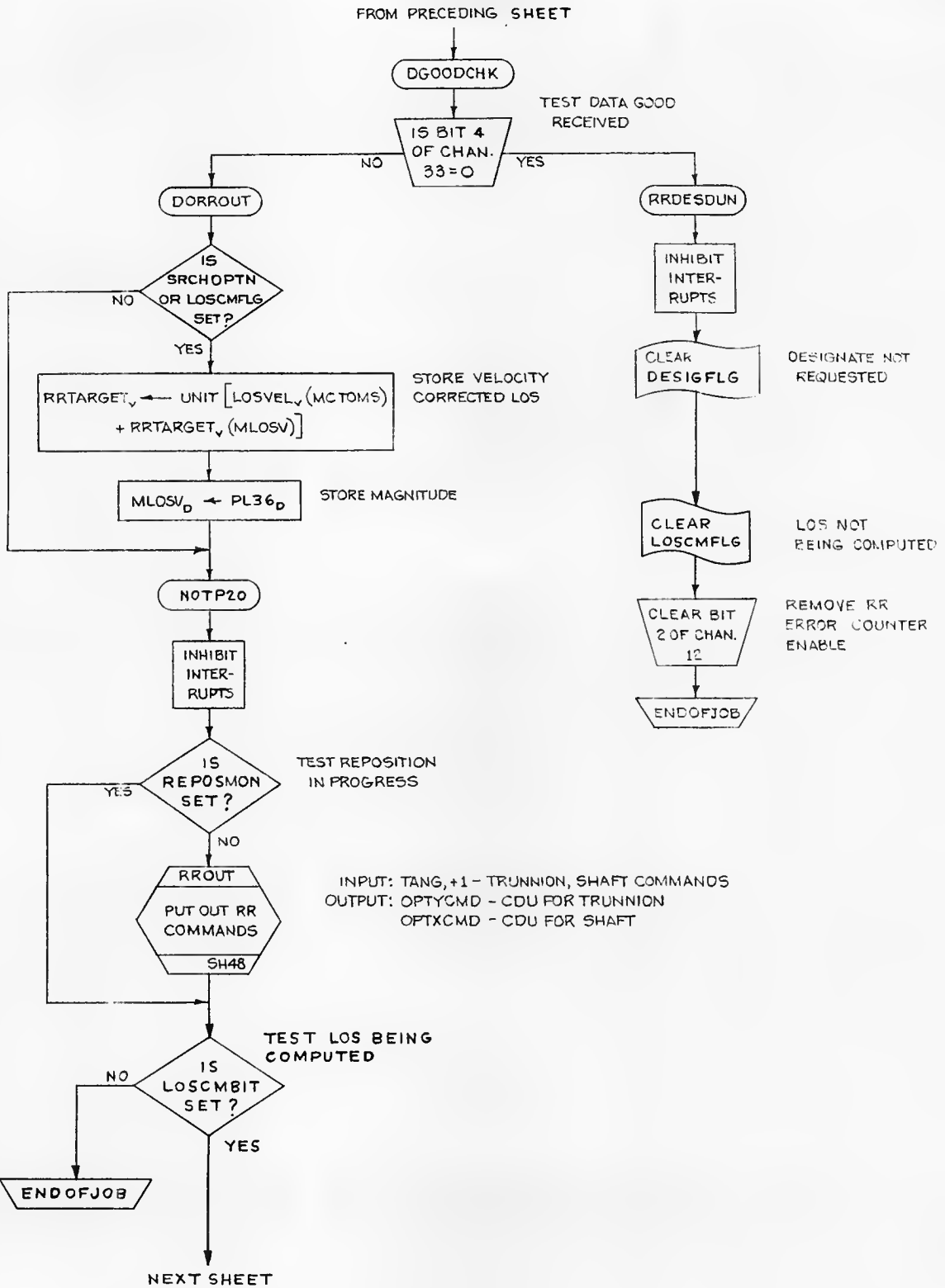
RR LOS VECTOR

NEXT SHEET

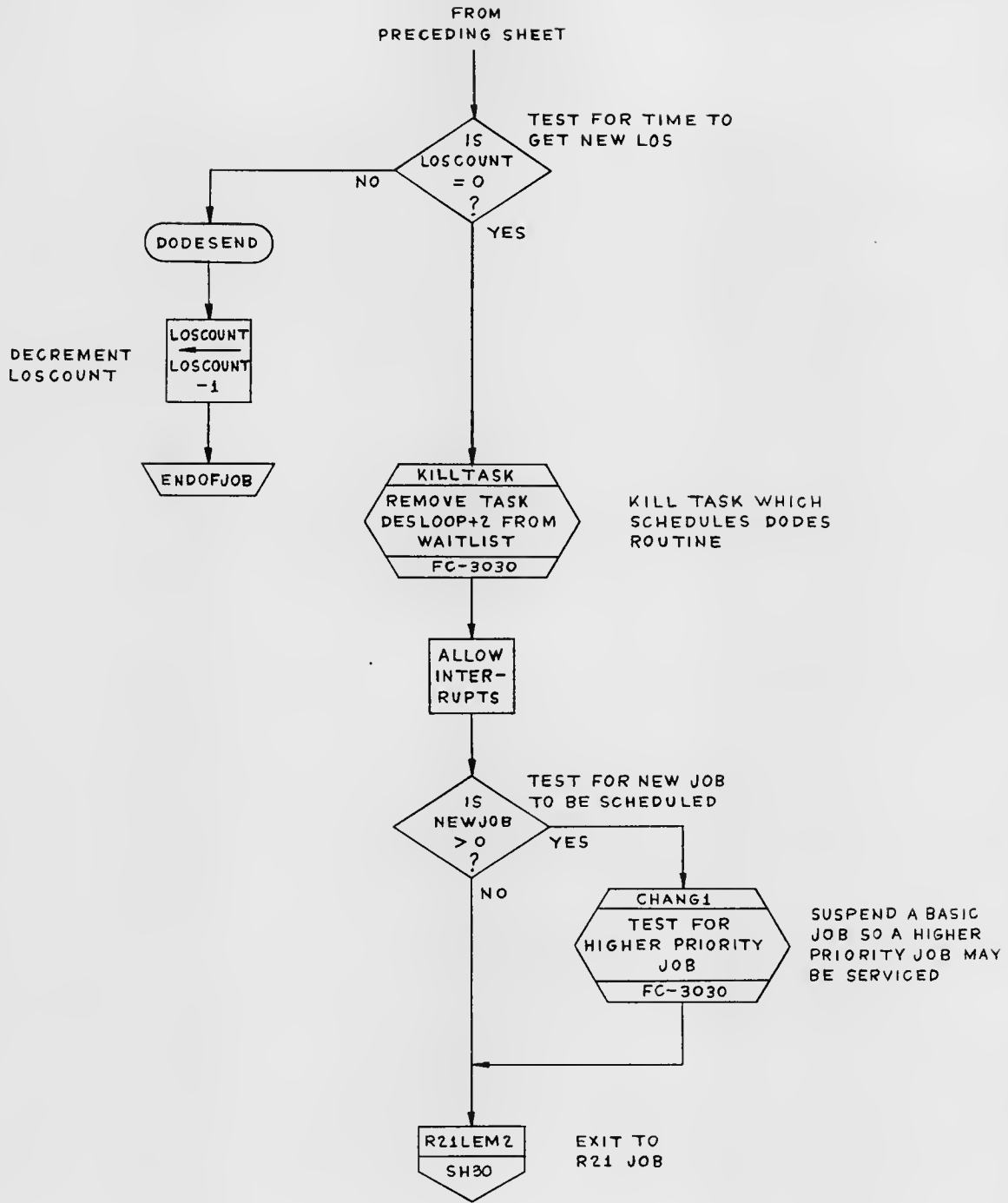
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS 2-12-69		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAM Peter Volante 8-16-69		DOCUMENT NO.	
ANALYST		LUMINARY 1D	
DOCWR M. G. ... 5-17-69		FC-3600	
APPR'D John A. ... 2-20-69		REV 2	
		SHEET 41 OF 103	



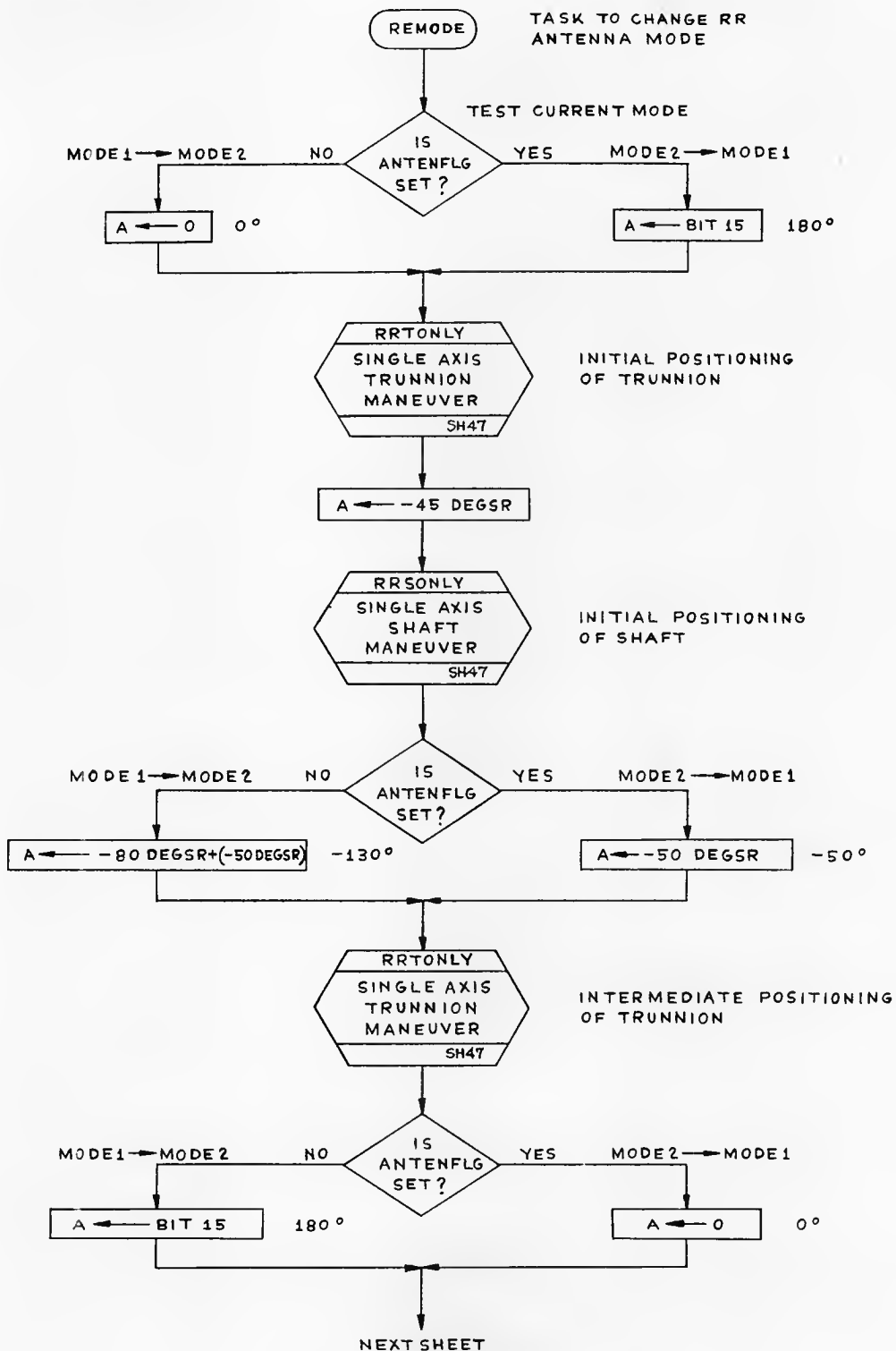
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS 5-24-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAMMER Peter V. ... 8-16-68	ANALYST	LUMINARY 1D	DOCUMENT NO. FC-3600
DOCWR	APPR'D	REV 2	SHEET 42 OF 103



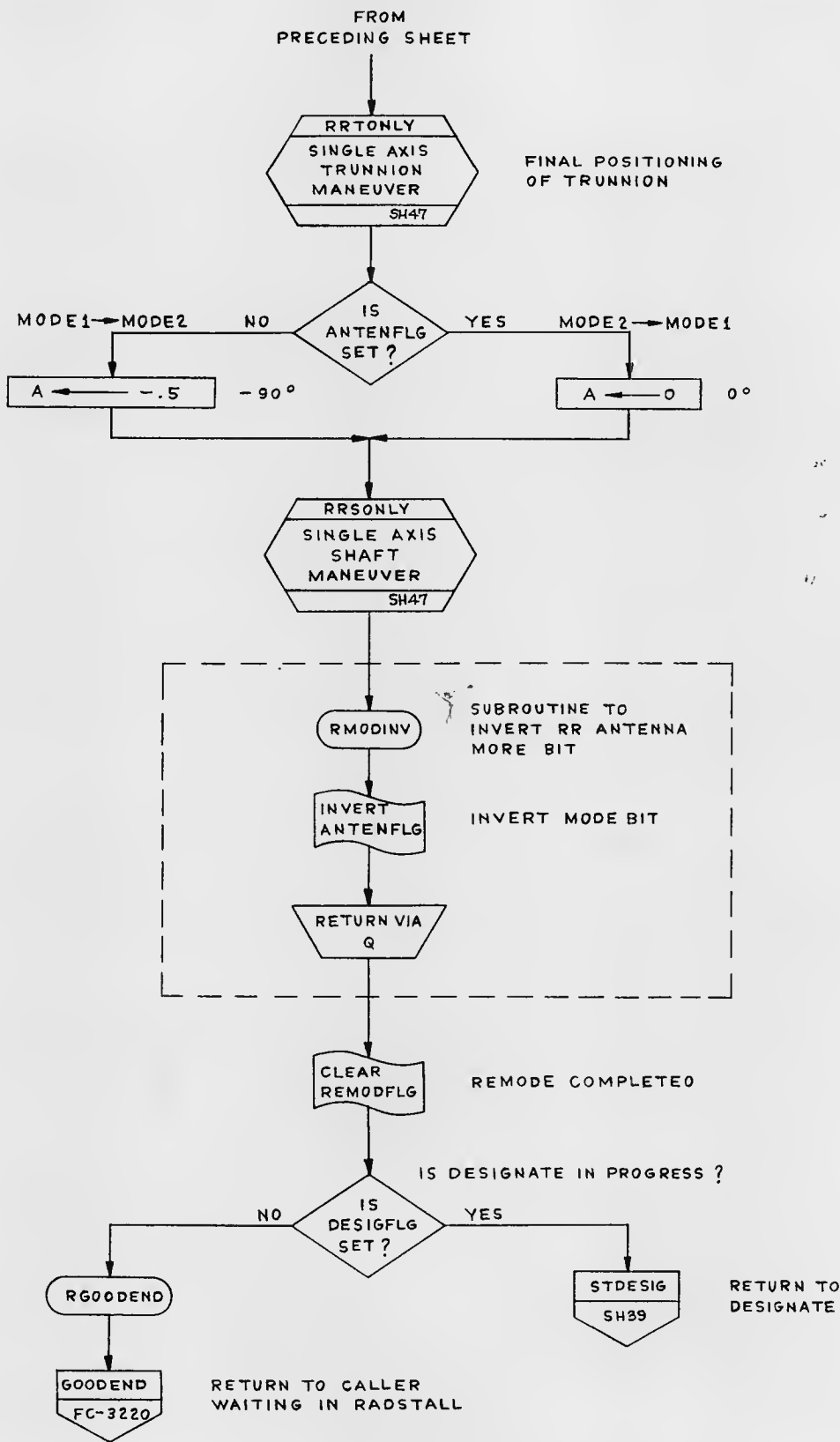
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS 3-14-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAMMER Peter Volante 8-16-68	ANALYST	LUMINARY ID:	DOCUMENT NO. FC-3600
DOCWR John A. Moore 5-17-68	APPR'D John A. Moore 29 Oct 68	REV 2.	SHEET 43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



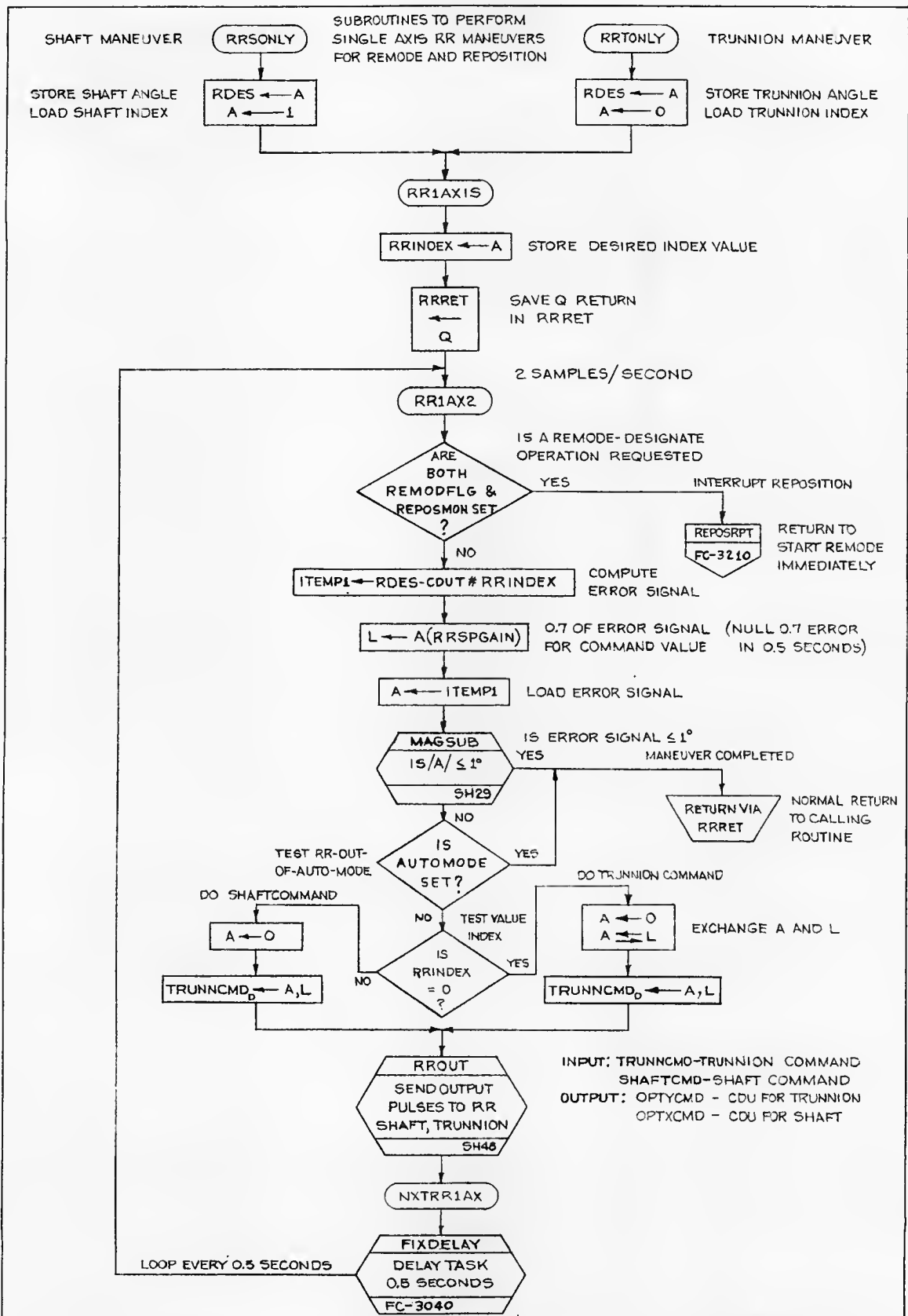
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. J. ...</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRM <i>J. ...</i>	18MAR69	LUMINARY 1D	DOCUMENT NO.
ANALST	10/21/69	FC-3600	
DOCNR <i>...</i>	4-7-69	REV 2	SHEET 44 OF 103
APPR'D <i>...</i>	10/21/69		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. J. Langille</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGMR <i>J. J. ...</i>	19 MAR 69	LUMINARY ID	DOCUMENT NO.
ANALST <i>W. C. ...</i>	10/21/69		FC-3600
DOCMR <i>W. C. ...</i>	4-7-69	REV 2	SHEET 45 OF 103
APPR'D <i>R. M. ...</i>	10/21/69		



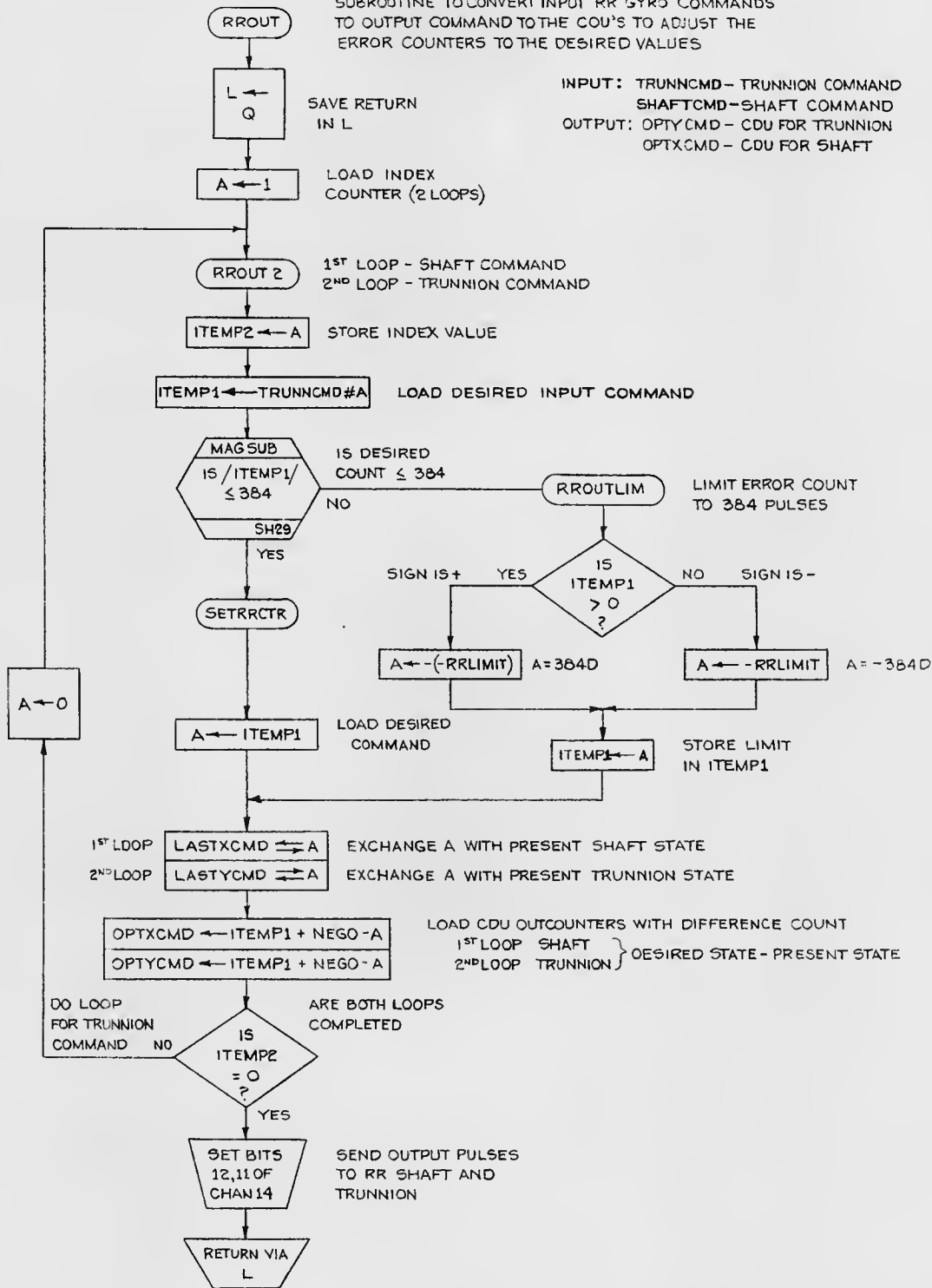
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. J. Sanzella</i> 19 MAR 69		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAM <i>R. J. Volante</i> 10/21/69	ANALYST	LUMINARY 1D	DOCUMENT NO.
BOGMR <i>J. C. England</i> 4-7-69	APPR'D <i>R. M. England</i> 10/21/69	REV 2	FC-3600
			SHEET 46 OF 103



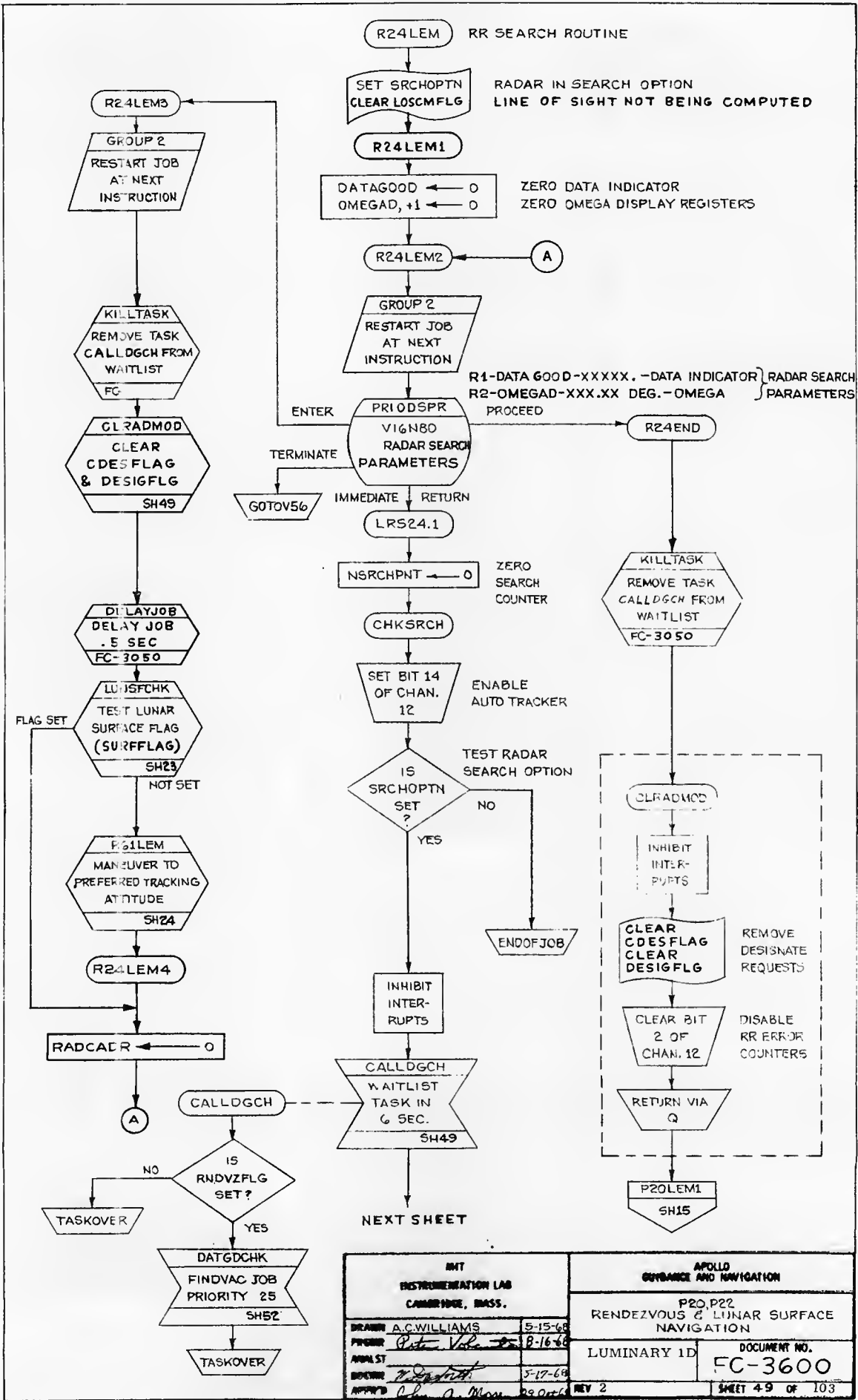
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
DRAWN	A.C. WILLIAMS	3-6-68	LUMINARY ID
PROGR	<i>Robert Volante</i>	8-16-68	
ANALYST			DOCUMENT NO. FC-3600
DESIGN	<i>W. D. ...</i>	5-17-68	
APPROV	<i>John A. ...</i>	29 Oct 68	REV 2
			SHEET 47 OF 103

SUBROUTINE TO CONVERT INPUT RR GYRO COMMANDS TO OUTPUT COMMAND TO THE COU'S TO ADJUST THE ERROR COUNTERS TO THE DESIRED VALUES

INPUT: TRUNNCMD - TRUNNION COMMAND
 SHAFTCMD - SHAFT COMMAND
 OUTPUT: OPTXCMD - CDU FOR TRUNNION
 OPTXCMD - CDU FOR SHAFT

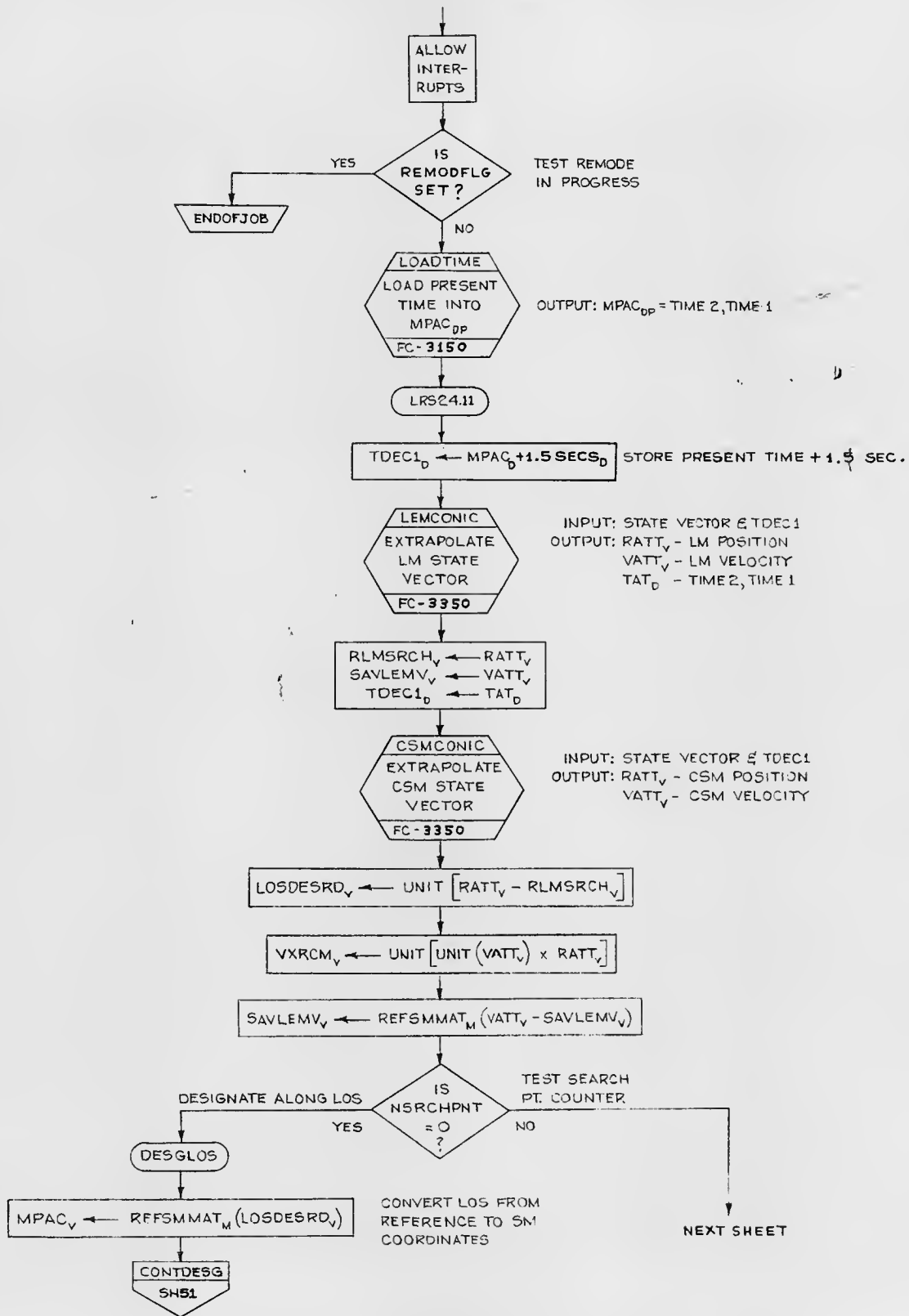


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <u>A.C. WILLIAMS</u> 3-7-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAMMER <u>John A. Williams</u> 8-16-68		LUMINARY ID}	DOCUMENT NO.
ANALYST			FC-3600
DOCTR <u>John A. Williams</u> 5-17-68		REV 2	SHEET 48 OF 103
APPROV <u>John A. Williams</u> 2-25-68			

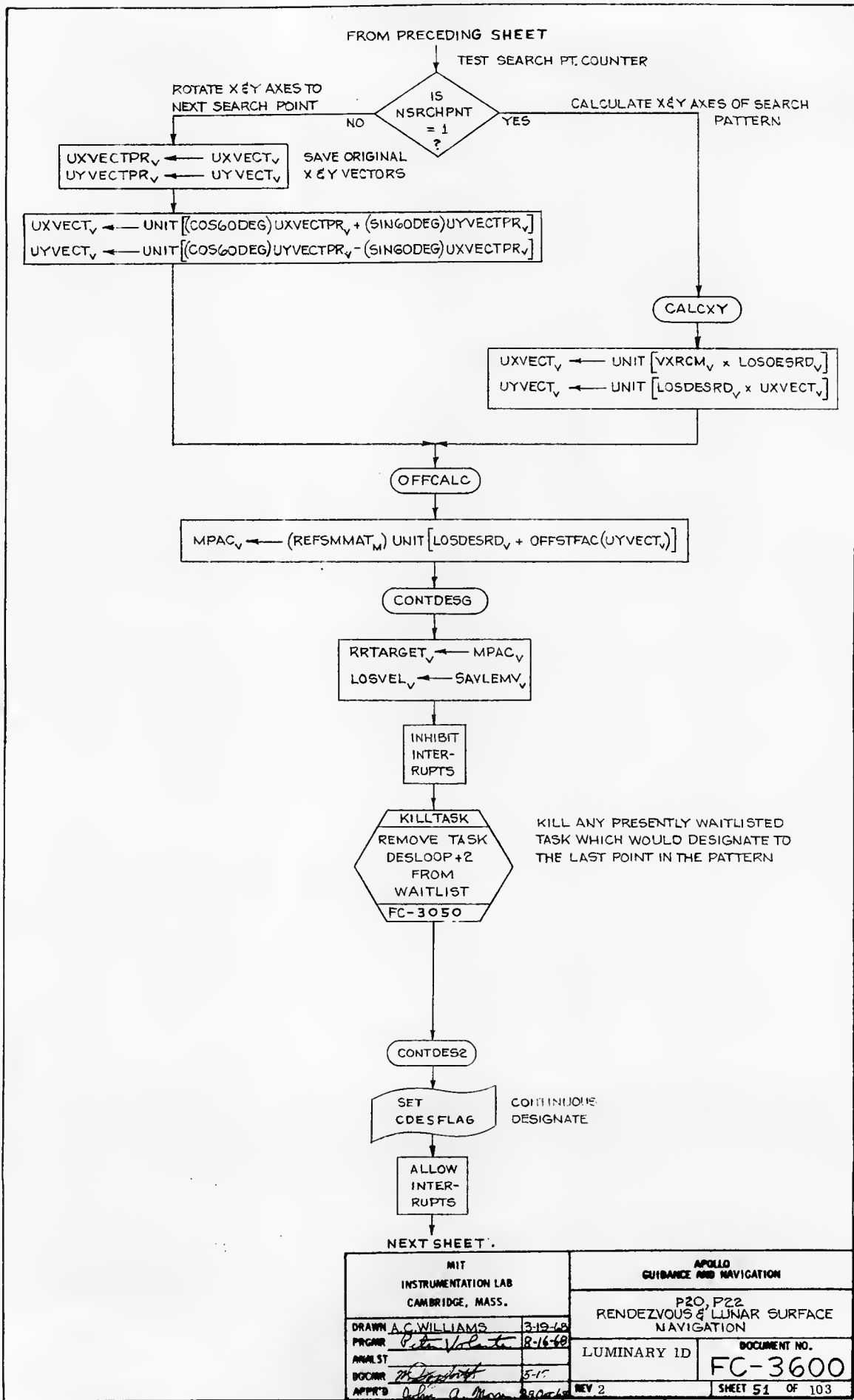


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN: A.C. WILLIAMS 5-15-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PLOTTED: Peter Vohr 8-16-68		LUMINARY ID:	
ANALYST:		DOCUMENT NO. FC-3600	
DESIGNER:		REV 2	
APPROVED: John A. Moore 29 Oct 68		SHEET 49 OF 103	

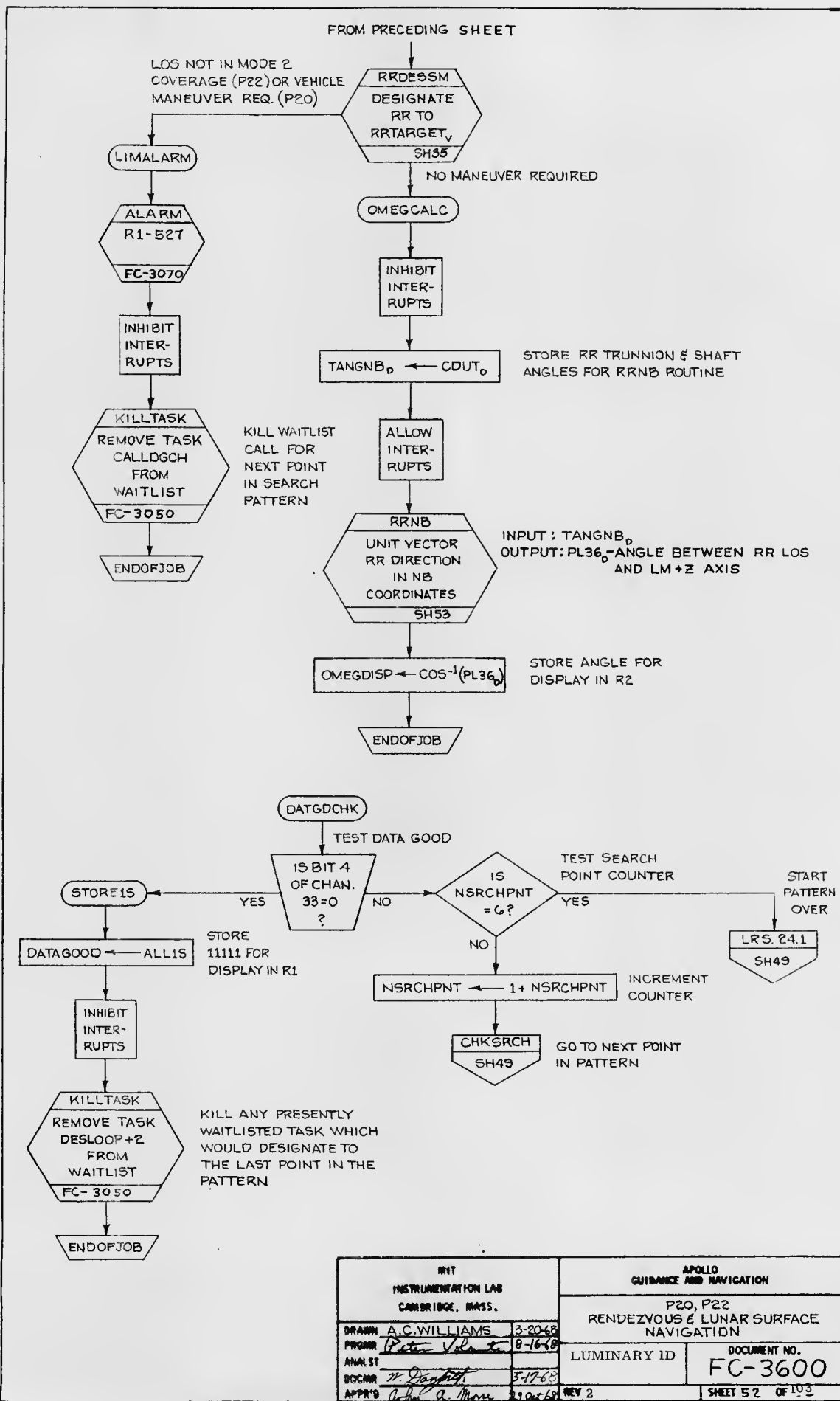
FROM PRECEDING SHEET



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS 5-15-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAM Peter Volante 8-16-68	ANALYST	ILLUMINARY ID	DOCUMENT NO. FC-3600
DOCWR J. G. ... 5-17-68	APPR'D John A. ... 8-9-68	REV 2	SHEET 50 OF 103



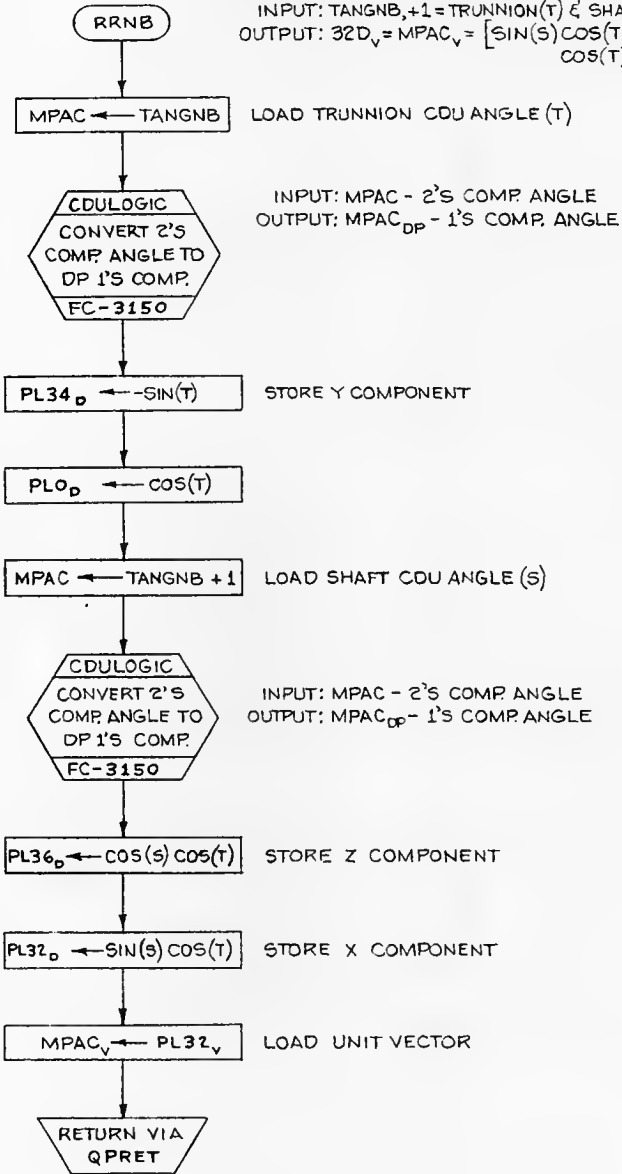
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS 3-19-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGR Peter Volante 8-16-68	ANALYST	LUMINARY ID	DOCUMENT NO.
DOCTR	5-17		FC-3600
APPR'D John A. Moore 8-20-68	REV 2	SHEET 51 OF 103	



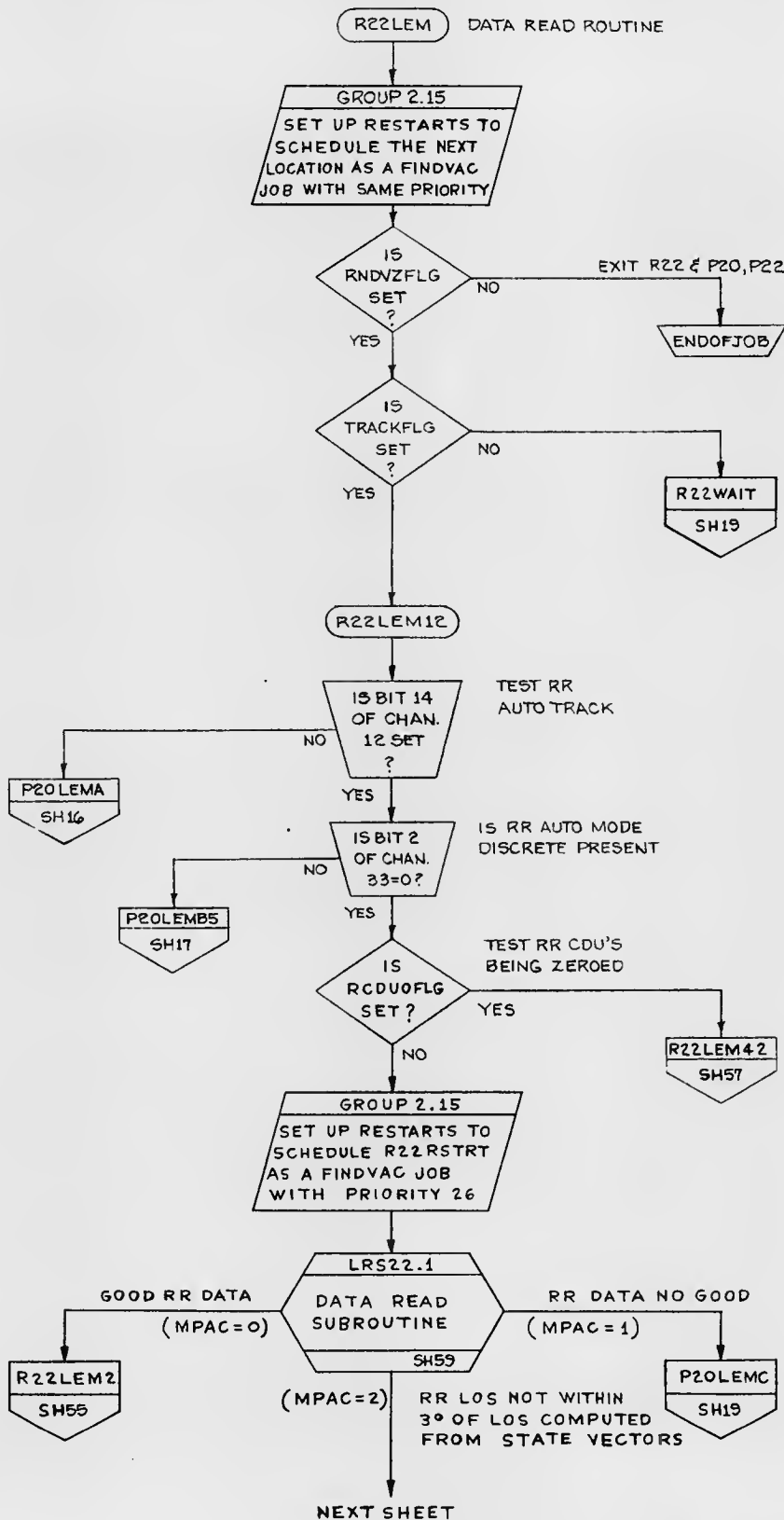
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS 3-20-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAM Peter Volante 8-16-68	ANALYST	LUMINARY ID	DOCUMENT NO. FC-3600
DOCNR W. J. ... 5-17-68	APPR'D John A. ... 2-9-68	REV 2	SHEET 52 OF 103

ROUTINE TO OBTAIN A UNIT VECTOR
SPECIFYING THE PRESENT RR DIRECTION
IN NB COORDINATES

INPUT: TANGNB,+1 = TRUNNION(T) & SHAFT(S) CDU ANGLES
OUTPUT: $32D_v = MPAC_v = [\sin(s)\cos(t), -\sin(t), \cos(s)\cos(t)]$

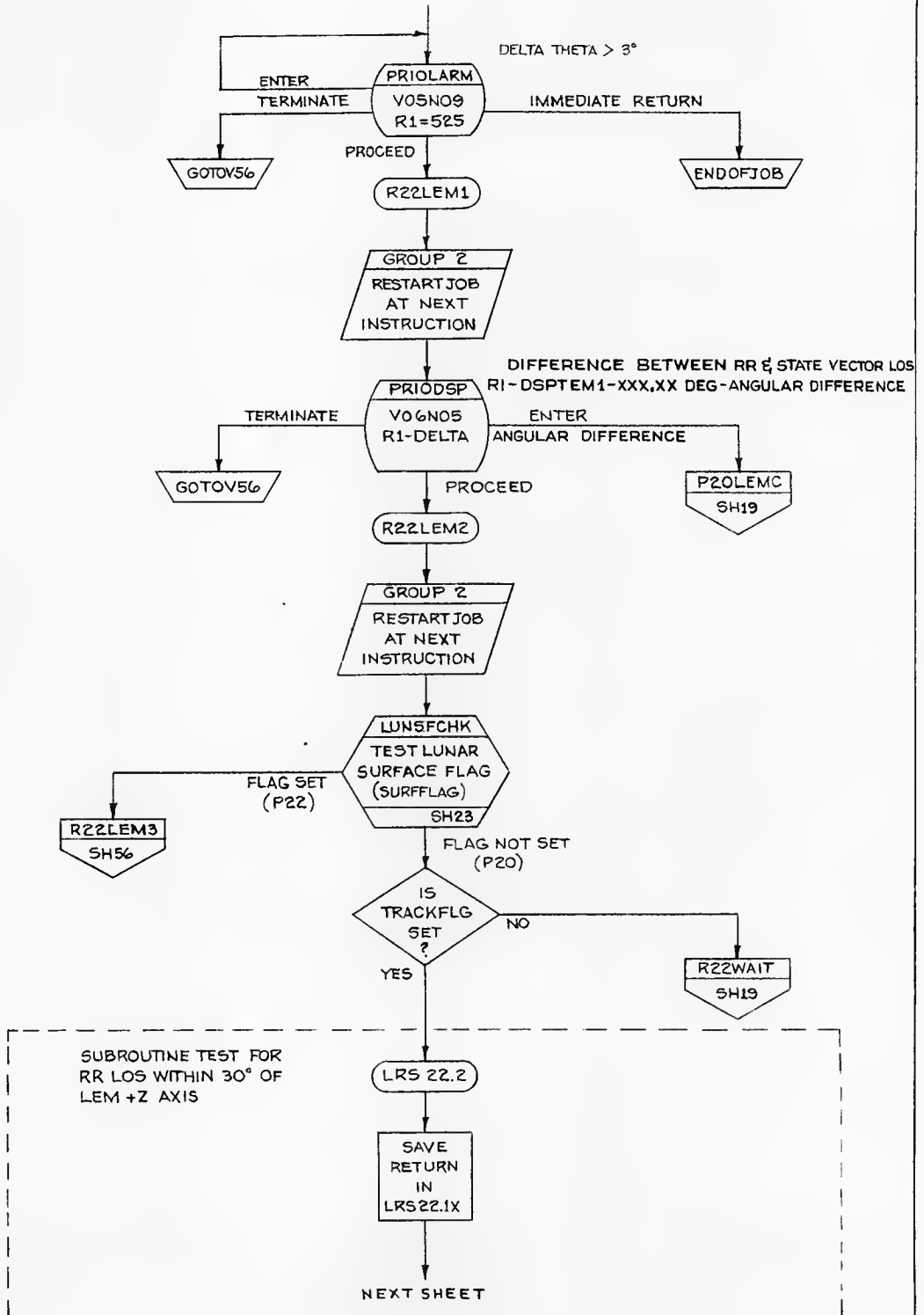


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
DRAWN	A.C. WILLIAMS	3-20-68	
PROMOTED	<i>Robert Volante</i>	8-16-68	
ANALYST			LUMINARY ID
DOCNR	<i>FC-3600</i>	5-17-68	DOCUMENT NO. FC-3600
APPR'D	<i>John A. Moore</i>	29 Oct 68	REV 2
			SHEET 53 OF 103



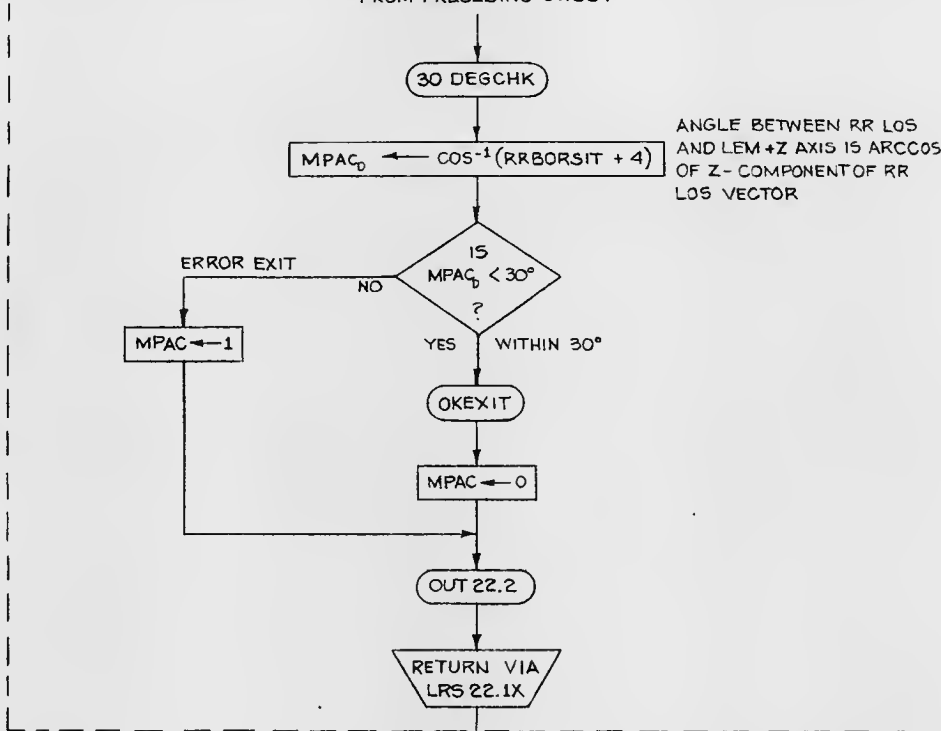
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
DRAWN	A.C. WILLIAMS	2-25-68	LUMINARY 1D
PRGRM	<i>John A. Williams</i>	8-16-68	
ANALST			DOCUMENT NO. FC-3600
DOCMR	<i>W. J. ...</i>	5-17-68	
APPR'D	<i>John A. Williams</i>	8-20-68	REV 2
			SHEET 54 OF 103

FROM PRECEDING SHEET

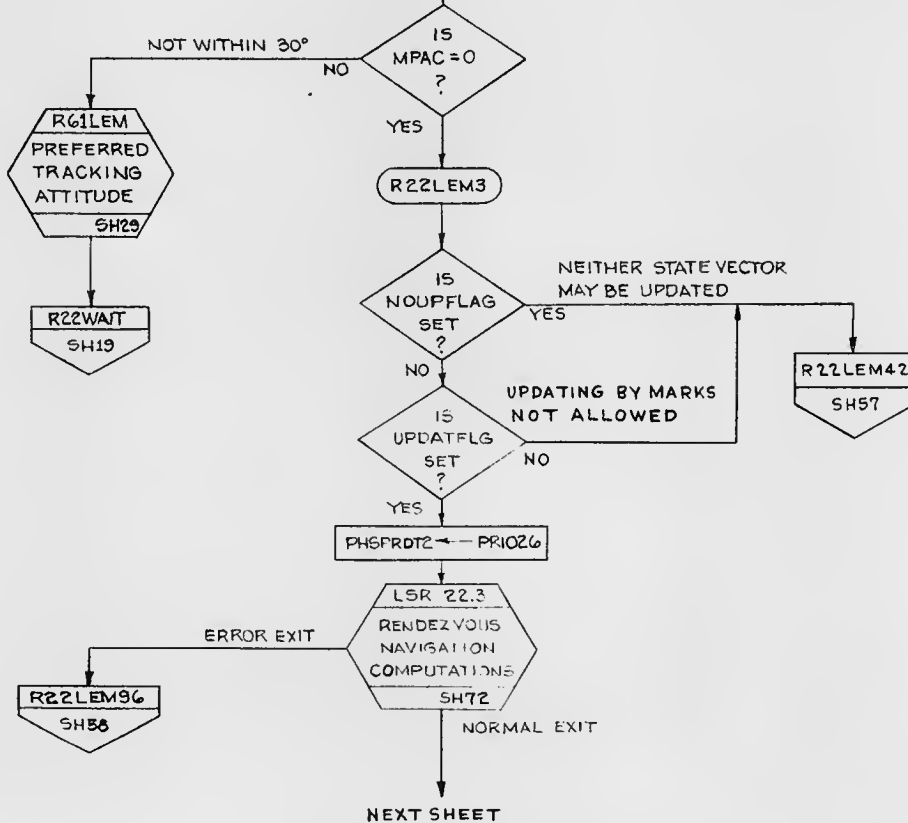


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS 3-25-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGRM P. de Valera	8-16-68	LUMINARY ID	DOCUMENT NO. FC-3600
ANALST			
DOCNR H. Dugbill	5-17-68		
APPR'G John A. Moore	8-30-68	REV 2	SHEET 55 OF 103

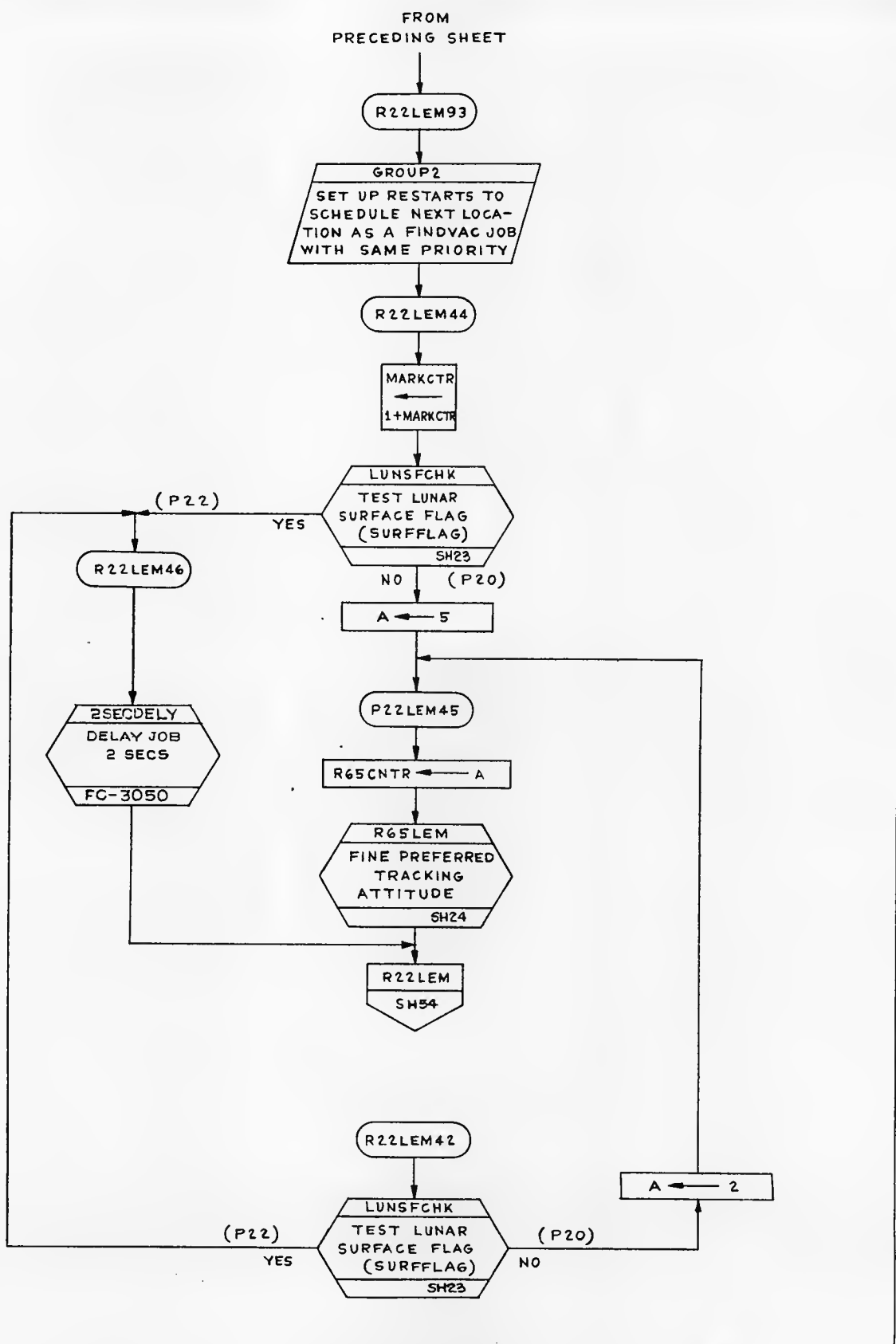
FROM PRECEDING SHEET



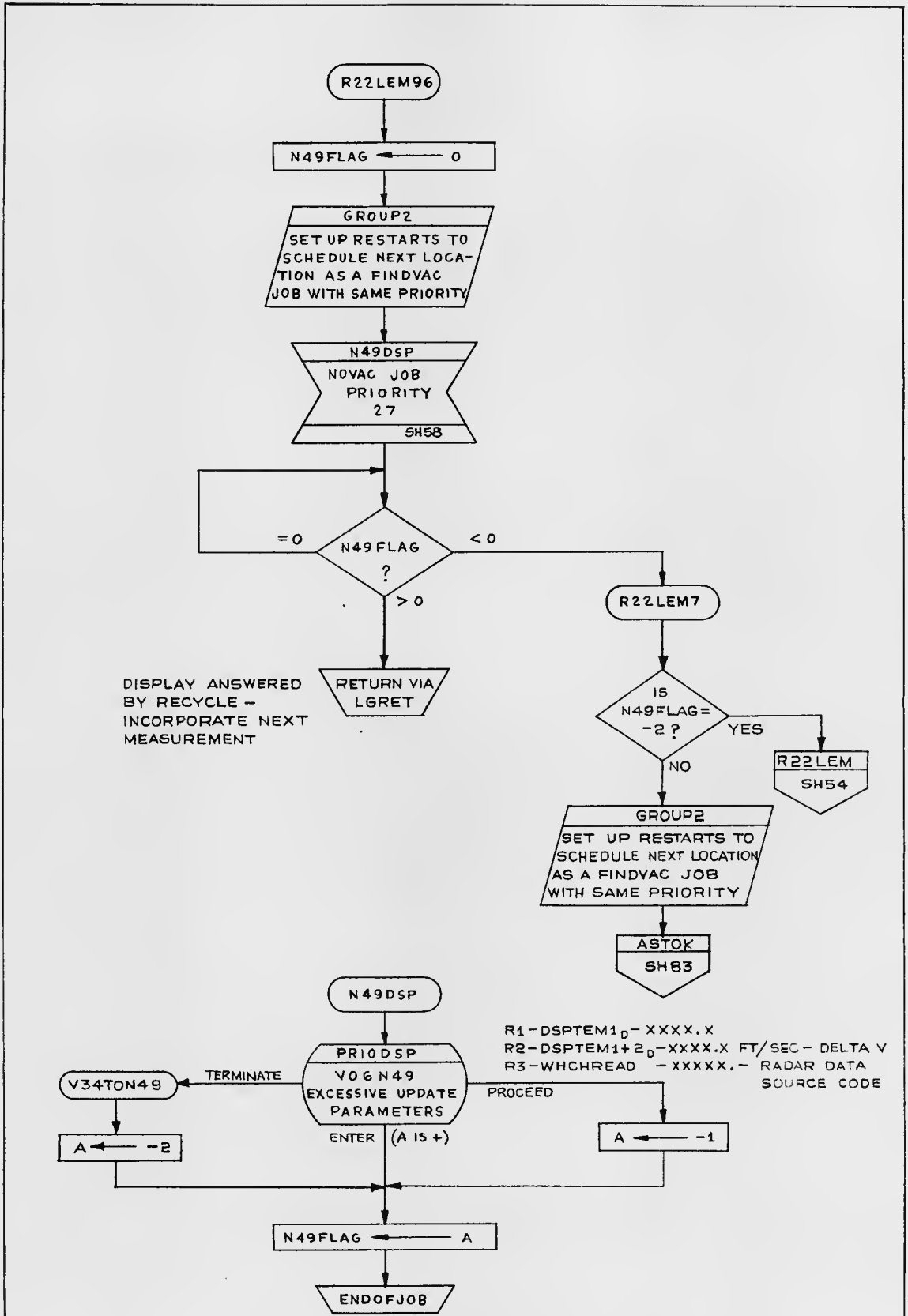
ANGLE BETWEEN RR LOS AND LEM+Z AXIS IS ARCCOS OF Z-COMPONENT OF RR LOS VECTOR



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS 3-26-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAM	<i>Barton V. ...</i> 10/21/69	LUMINARY ID	DOCUMENT NO.
ANALYST	<i>W. ...</i> 5-17-68		FC-3600
DOCK	<i>John R. ...</i> 29 Oct 68	REV 2	SHEET 56 OF 103



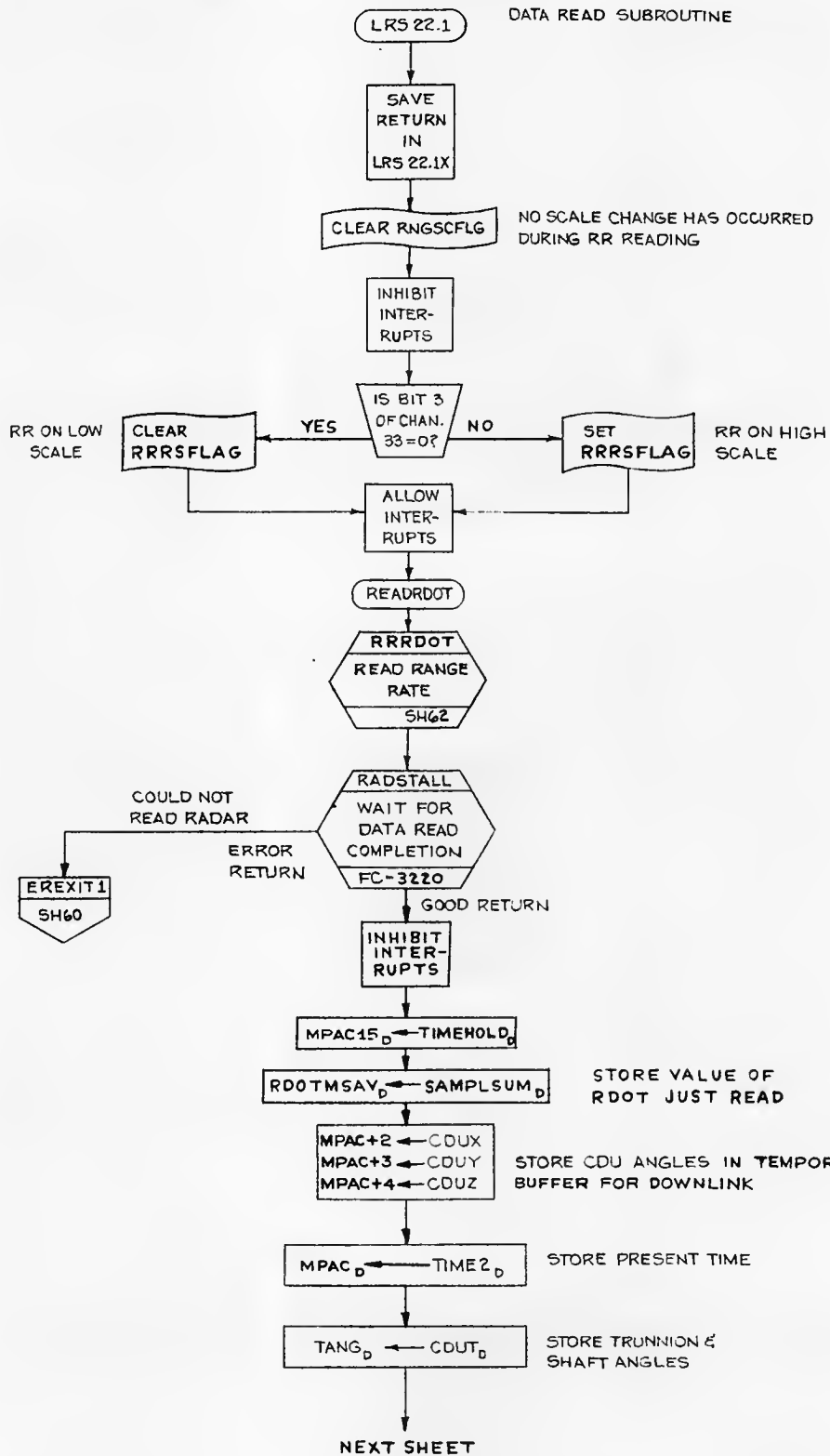
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
DRAWN <i>G. J. ...</i>	20MAR69	LUMINARY ID	DOCUMENT NO. FC-3600
PROGR <i>P. J. ...</i>	10/1/69		
ANALST <i>...</i>			
DOCTR <i>...</i>	4-7-69		
APPR'D <i>...</i>	10/23/69	REV 2	SHEET 57 OF 103



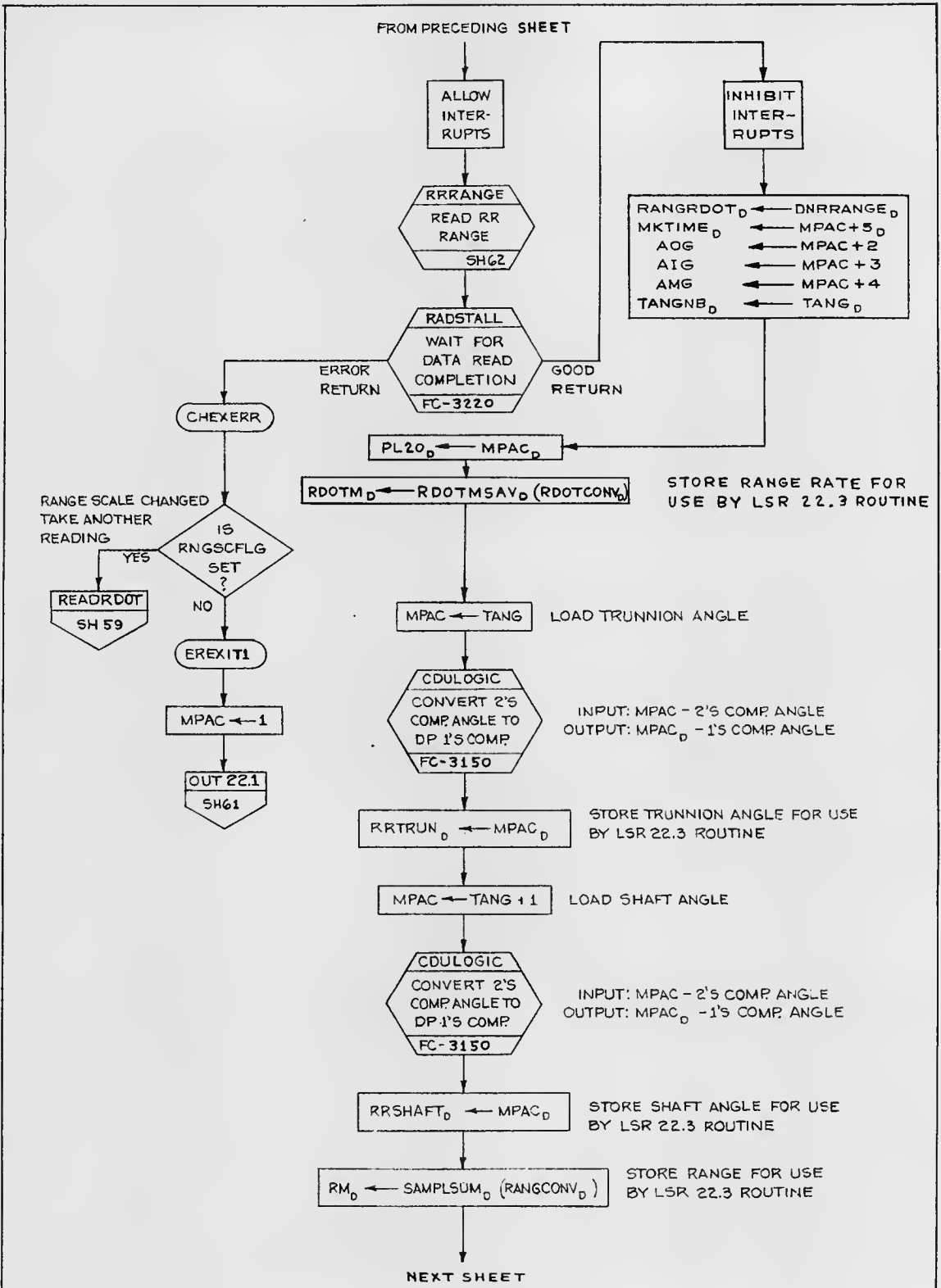
DISPLAY ANSWERED
BY RECYCLE -
INCORPORATE NEXT
MEASUREMENT

R1 - DSPTEM1_D - XXXX.X
R2 - DSPTEM1+2_D - XXXX.X FT/SEC - DELTA V
R3 - WHCHREAD - XXXXX. - RADAR DATA
SOURCE CODE

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>G. A. Langille</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAM	<i>G. A. Langille</i>	21MAY69	DOCUMENT NO.
ANALYST	<i>G. A. Langille</i>	10/21/67	FC-3600
DOCK	<i>W. C. Douglas</i>	4-7-69	LUMINARY ID
APPRO'D <i>G. M. Sullivan</i>	10/21/67	REV 2	SHEET 58 OF 103

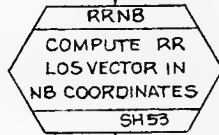


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
DRAWN	A.C. WILLIAMS	5-12-68	LUMINARY ID
PROGR	<i>P. to Val. to</i>	8-16-68	
ANALST			DOCUMENT NO. FC-3600
DOCWR	<i>W. D. ...</i>	3-17-68	
APPR'D	<i>John A. ...</i>	8-20-68	REV 2
			SHEET 59 OF 103

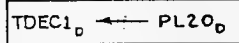
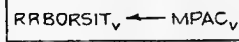


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS 3-27-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAM Peter Volante 8-16-68	ANALYST	LUMINARY ID	DOCUMENT NO.
DOCWR M. [Signature] 5-17-68	APPR'D John A. Moore 8-20-68	REV 2	FC-3600
			SHEET 60 OF 103

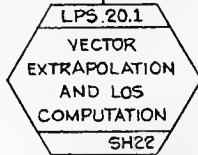
FROM PRECEDING SHEET



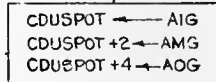
OUTPUT: $MPAC_v = RR$ LOS VECTOR



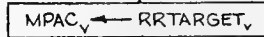
STORE PRESENT TIME IN $TDEC1_{DP}$ FOR LPS 20.1 ROUTINE



INPUT: STATE VECTORS AND $TDEC1$
OUTPUT: $RRTARGET_v = LOS$ TO CSM

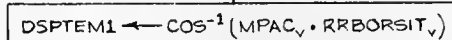


LOAD IMU ANGLES FOR
TRG*SMNB ROUTINE



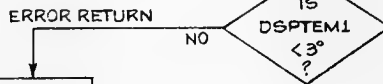
ROTATE LOS AT MARK TIME FROM
SM TO NB COORDINATES

OUTPUT: $MPAC_v = LOS_v$ IN NB COORDINATES



STORE ANGLE BETWEEN LOS
OF STATE VECTORS & RR LOS

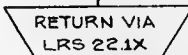
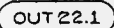
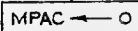
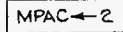
TEST ANGLE



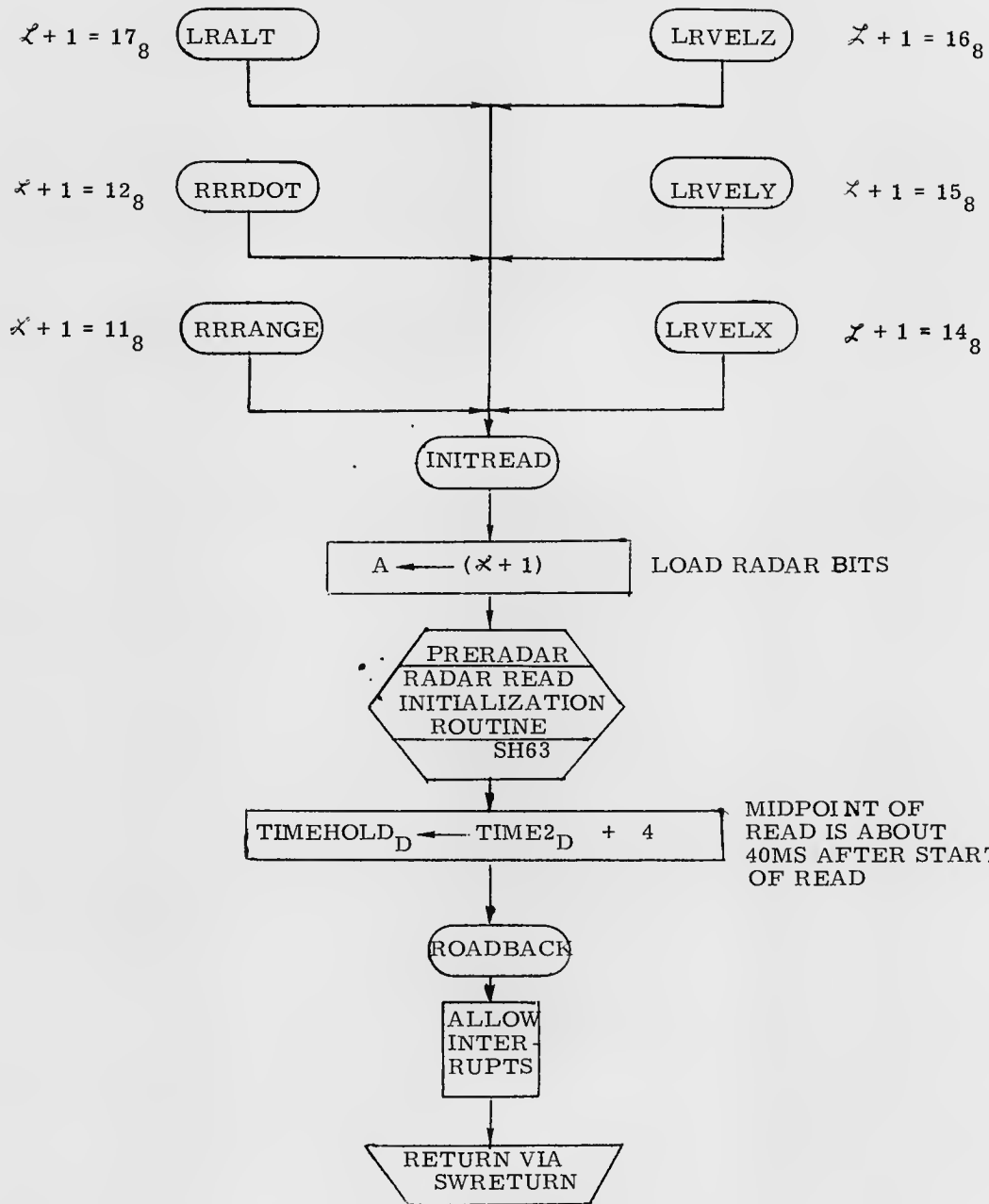
ERROR RETURN

NO

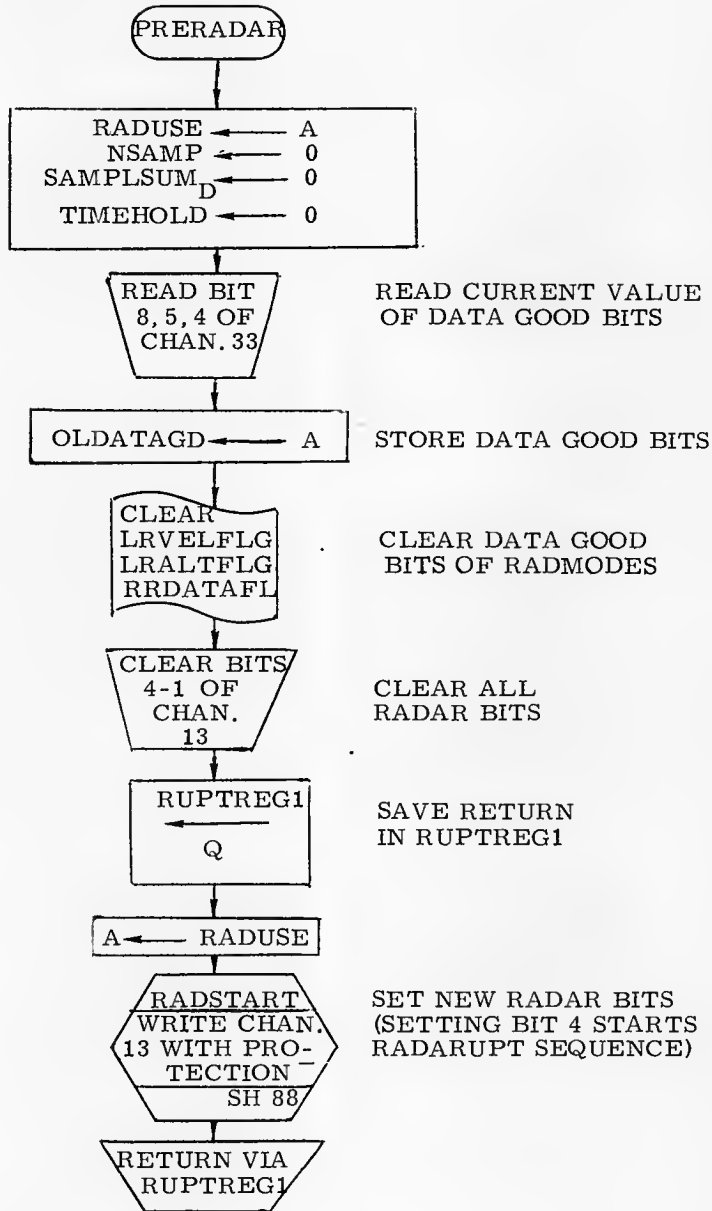
YES



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS 3-28-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGR <i>Peter Vela</i> 8-16-68	ANALST	LUMINARY ID	DOCUMENT NO.
DOGRW <i>J. D. Griffith</i> 5-17-68	APPR'D <i>John R. Moore</i> 4-30-68		FC-3600
REV 2		SHEET 61 OF 108	



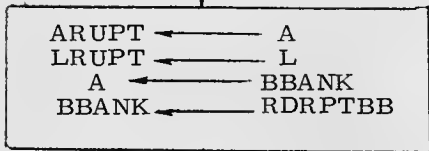
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>E. Motta</i>	6/3/70	P20, P22	
PRGMR	<i>P. Volante</i>	6/14/70		
ANALST			LUMINARY 1D	DOCUMENT NO.
DOCMR	<i>M. DeBartolo</i>	6/9/70		FC-3600
APPR'D	<i>J. M. ...</i>	6/18/70	REV 2	SHEET 62 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>E. meta</i> 6/3/70	P20, P22	
PRGMR	<i>P. Volante</i> 6/19/70	LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3600
DOCMR	<i>M. DeForest</i> 6/14/70	REV 2	SHEET 63 OF 103
APPR'D	<i>R. M. Enten</i> 6/16/70		

4044

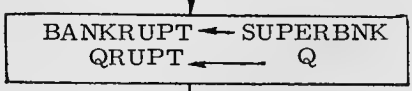
RADAR RUPT



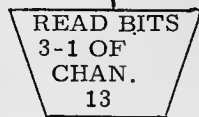
SAVE VALUES FOR RETURN TO INTERRUPTED PROGRAM

LOAD BBANK FOR RADAREAD ROUTINE

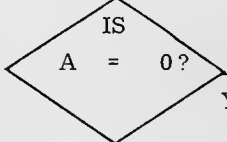
RADAREAD



SAVE VALUE FOR RETURN VIA TASKOVER

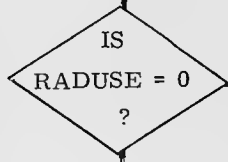
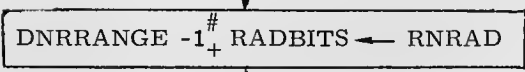


READ RADAR BITS



YES

NO

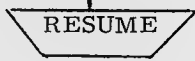
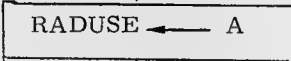


YES

NO

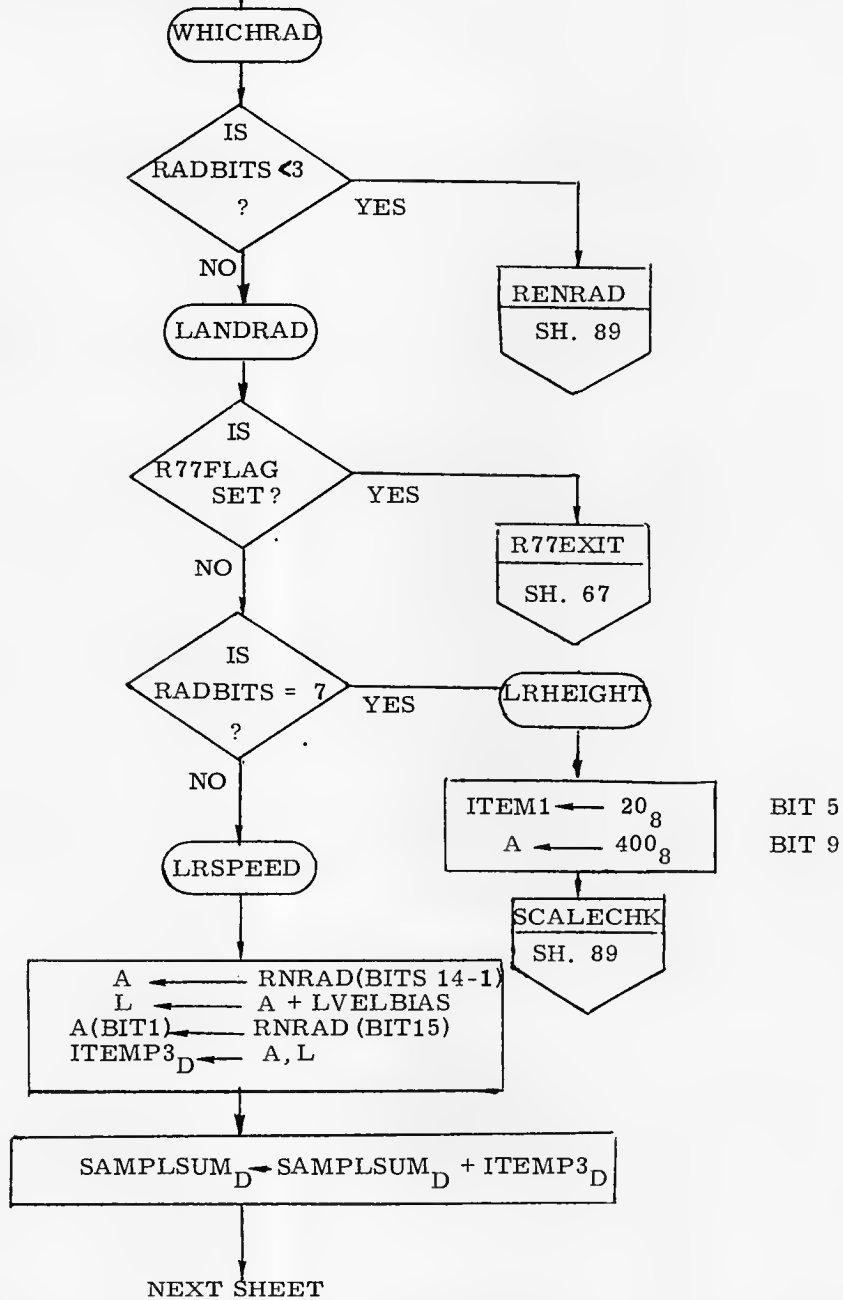
NEXT SHEET

BADRUPT

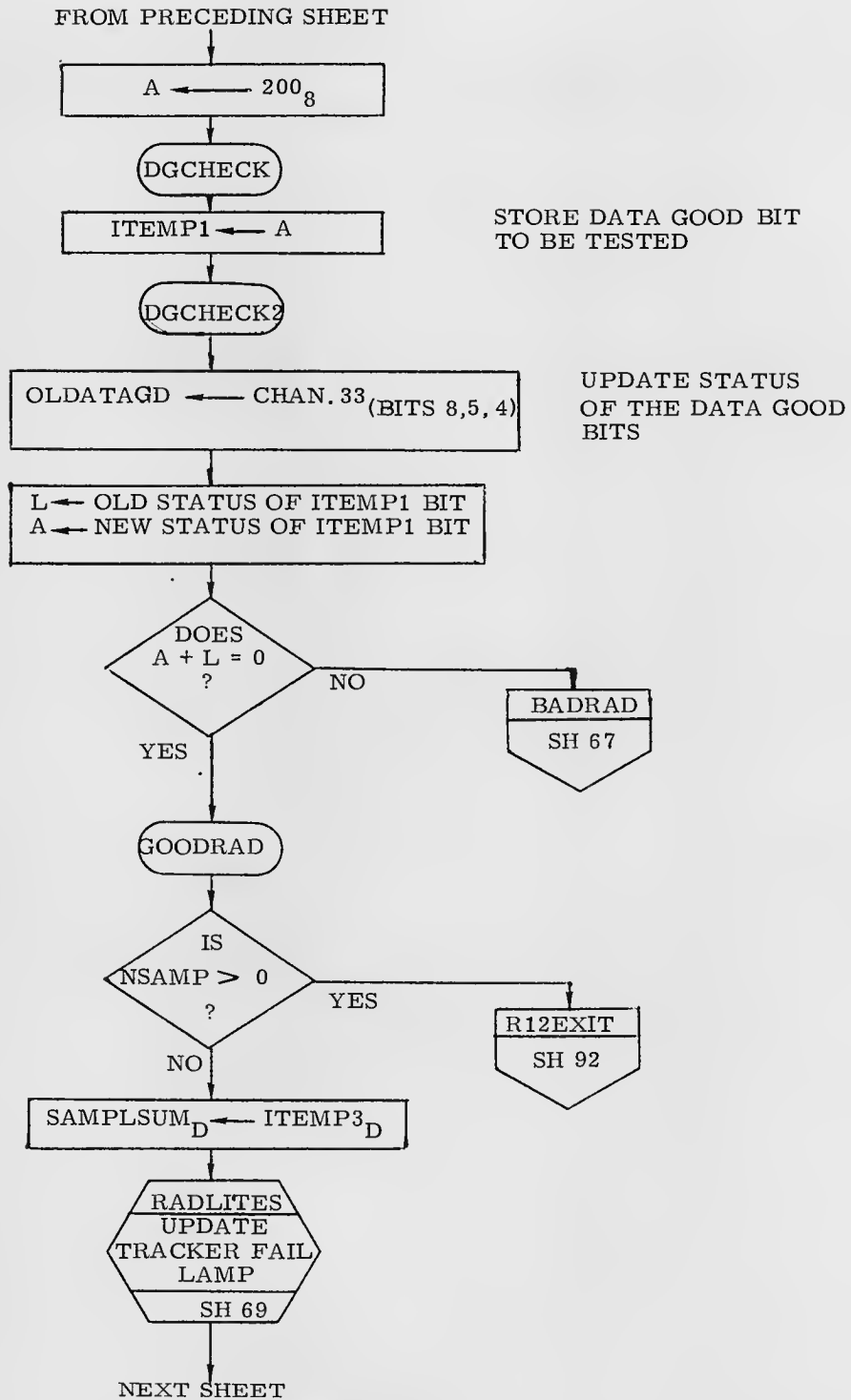


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>E. Motta</i>	6/5/70	P20, P22	
PRGMR <i>B. Volante</i>	6/10/70	LUMINARY 1D	DOCUMENT NO.
ANALST <i>M. J. ...</i>	6/10/70		FC-3600
DOCMR <i>M. J. ...</i>	6/10/70	REV 2	SHEET 64 OF 103

FROM PRECEDING SHEET

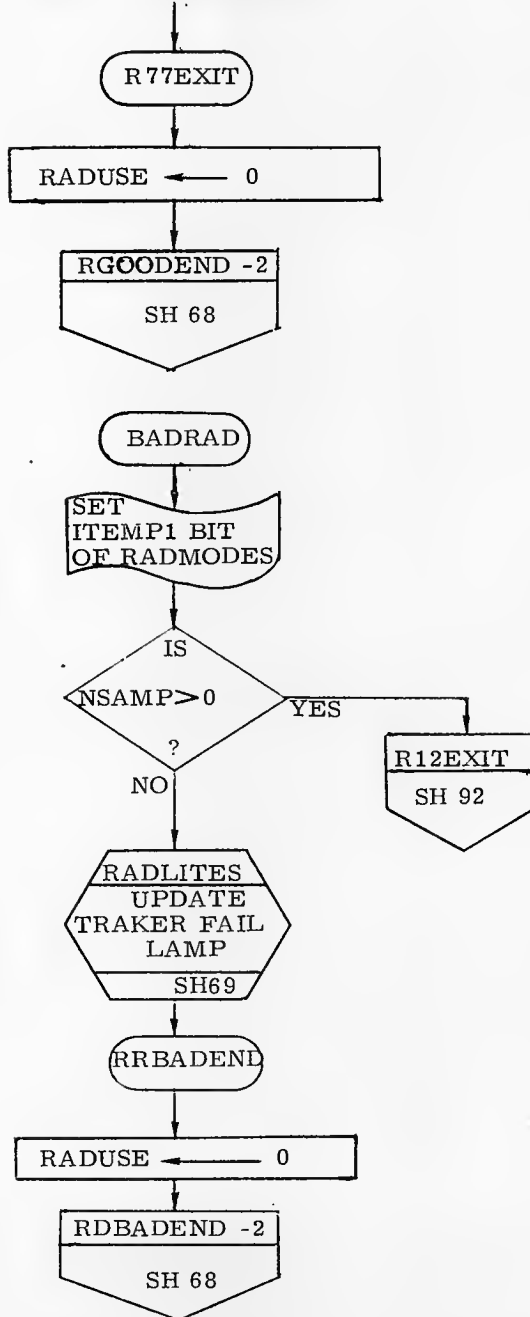


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P20, P22	
DRAWN	<i>E. Mathe</i>	<i>6/3/70</i>	LUMINARY 1D
PRGMR	<i>P. Volante</i>	<i>6/18/70</i>	
ANALST			DOCUMENT NO.
DOCMR	<i>W. D. ...</i>	<i>6/20/70</i>	FC- 3600
APPR'D	<i>R.M. ...</i>	<i>6/18/70</i>	REV 2
			SHEET 65 OF 103



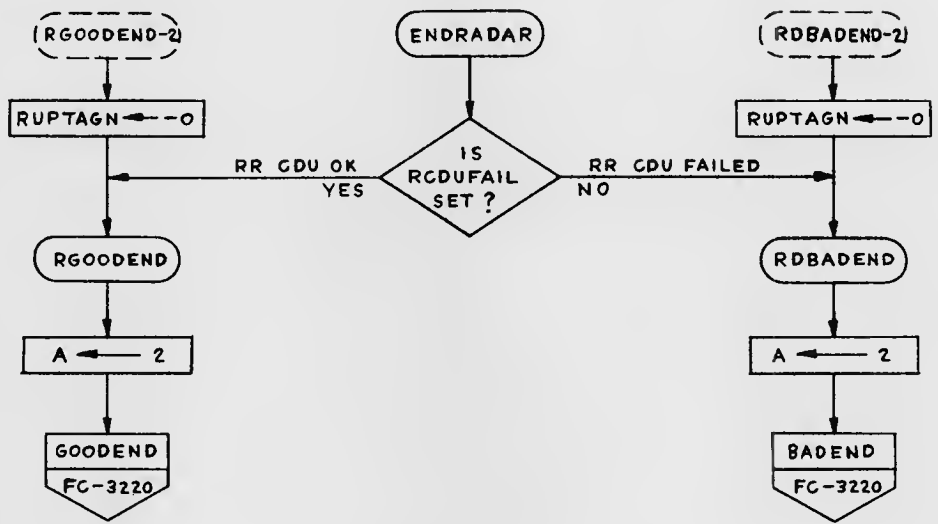
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>E. Metz</i>	P20, P22	
PRGMR	<i>P. Volante</i>	DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3600
DOCMR	<i>W. DeWitt</i>	REV 2	SHEET 66 OF 103
APPR'D	<i>RME</i>		

FROM PRECEDING SHEET

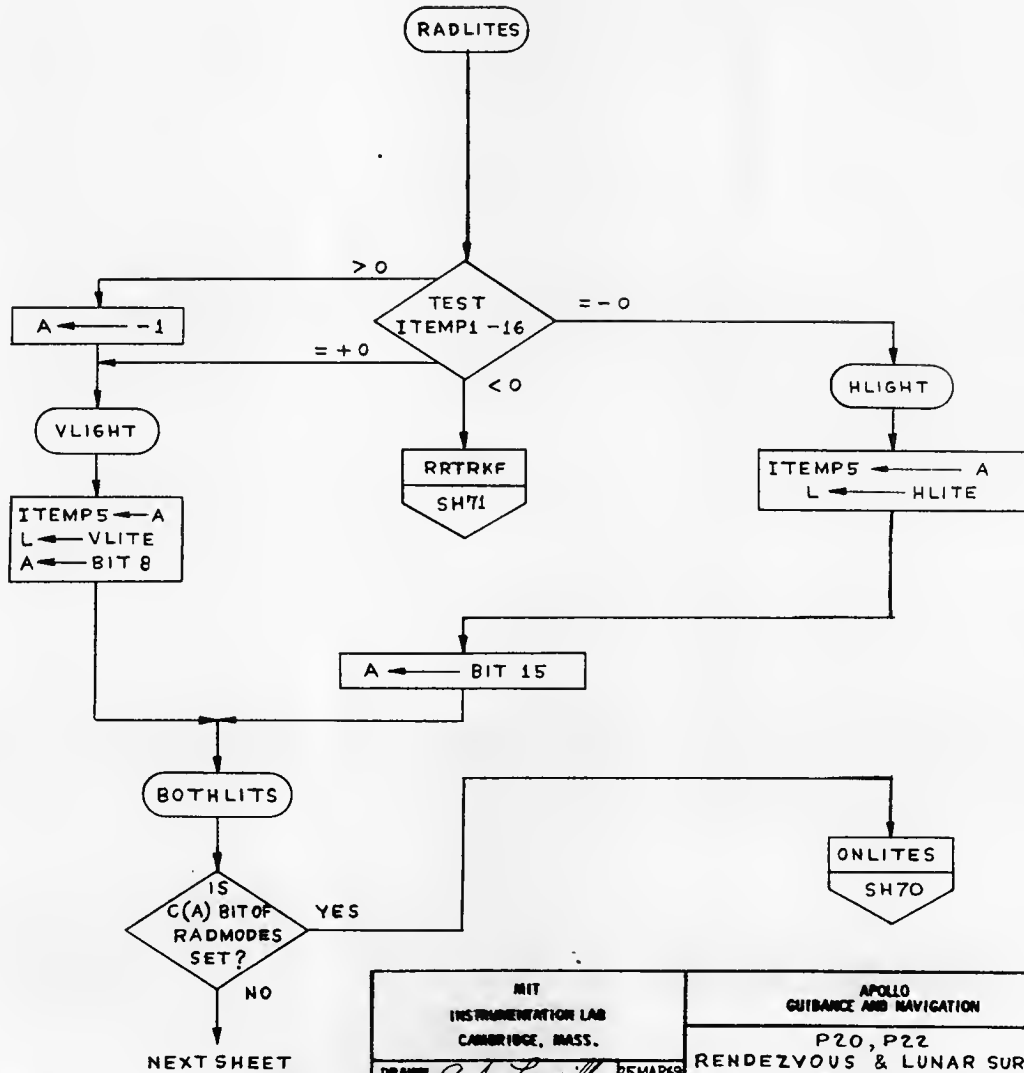


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>E. Matto</i> 6/11/70		P20, P22	
PRGMR <i>P. Volante</i> 6/18/70		DOCUMENT NO.	
ANALST <i>W. D. ...</i> 6/10/70		LUMINARY 1D	FC-3600
DOCMR <i>R. D. ...</i> 6/18/70		REV 2	SHEET 67 OF 103
APPR'D <i>R. D. ...</i> 6/18/70			

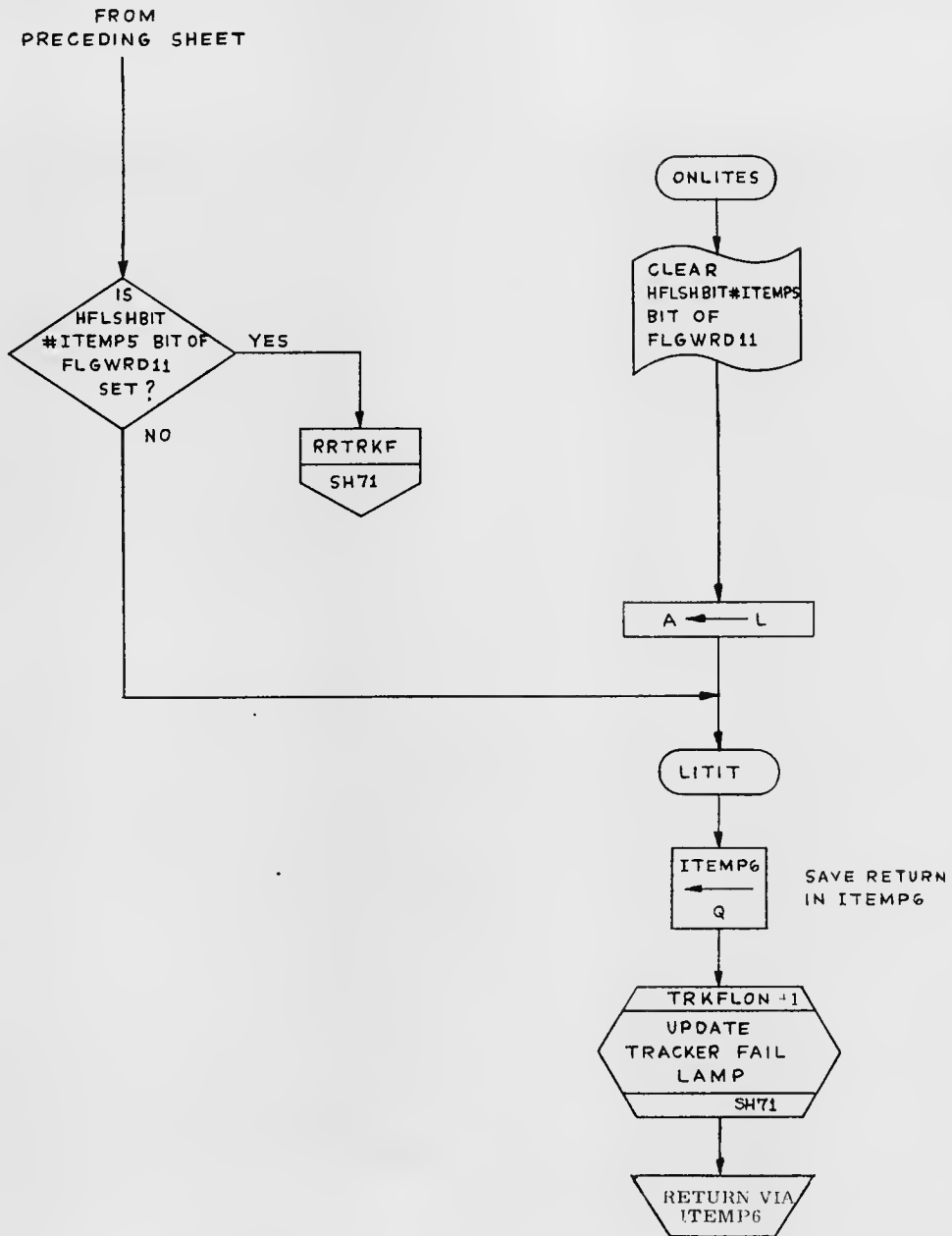
ROUTINES TO TERMINATE RR OPERATIONS



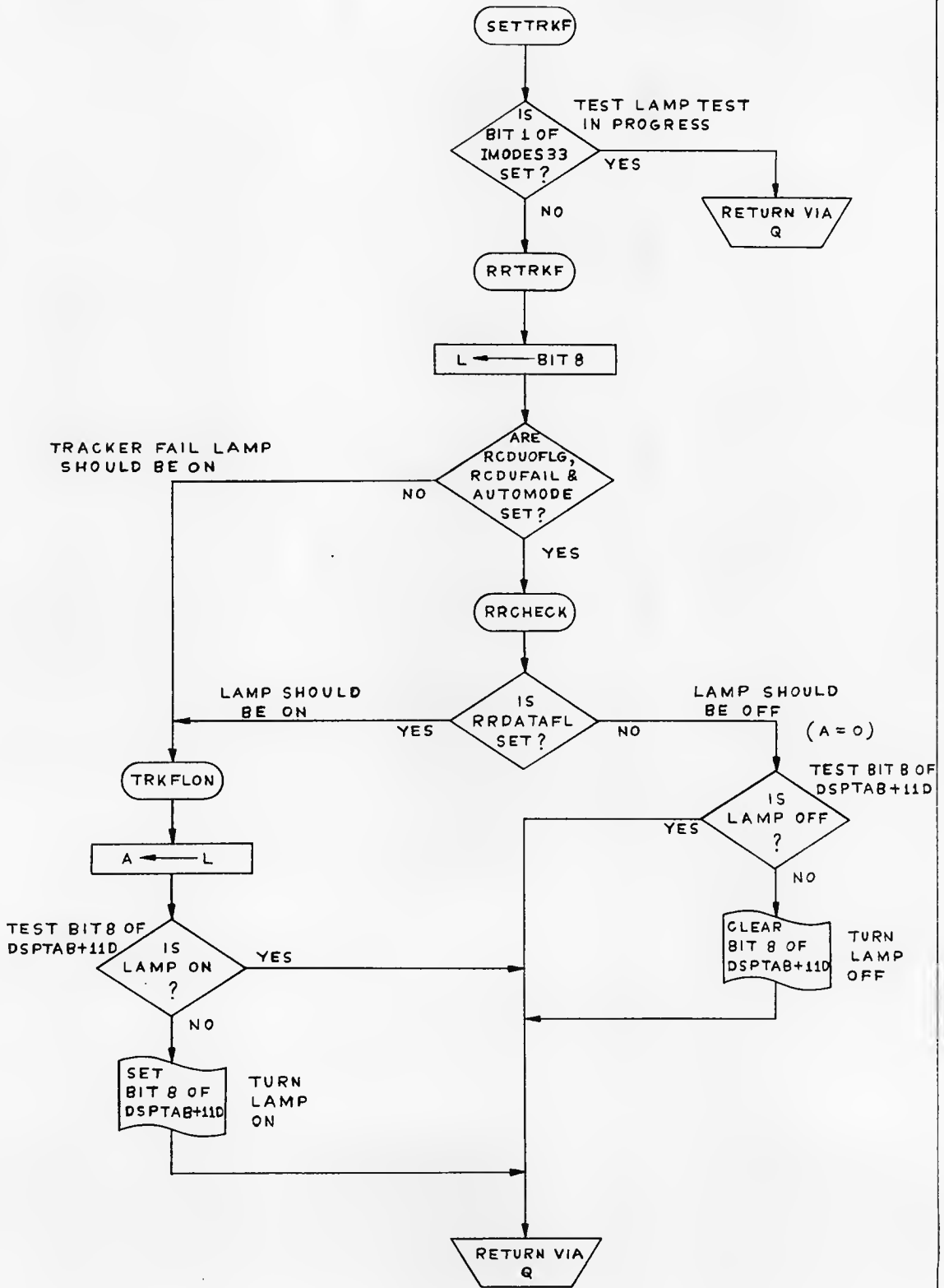
SGT INSTRUMENTATION LAB CAMDEN, NJ.		AFPLS GUIDANCE AND NAVIGATION	
DRAWN <i>R. D. Smith</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
CHECKED <i>R. D. Smith</i>		LUMINARY ID	DOCUMENT NO. FC-3600
DATE <i>10/21/69</i>			
APPROVED <i>R. D. Smith</i>		SHEET 66 OF 108	



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
DRAWN <i>J. J. Long</i>	25 MAR 69	LUMINARY ID	DOCUMENT NO. FC-3600
PRGRM <i>P. J. Long</i>	10/21/69		
ANALYST			
DOCNR <i>77-01-100</i>	2-7-69		
APPR'D <i>B. M. ...</i>	12/21/69	REV 2	SHEET 69 OF 103

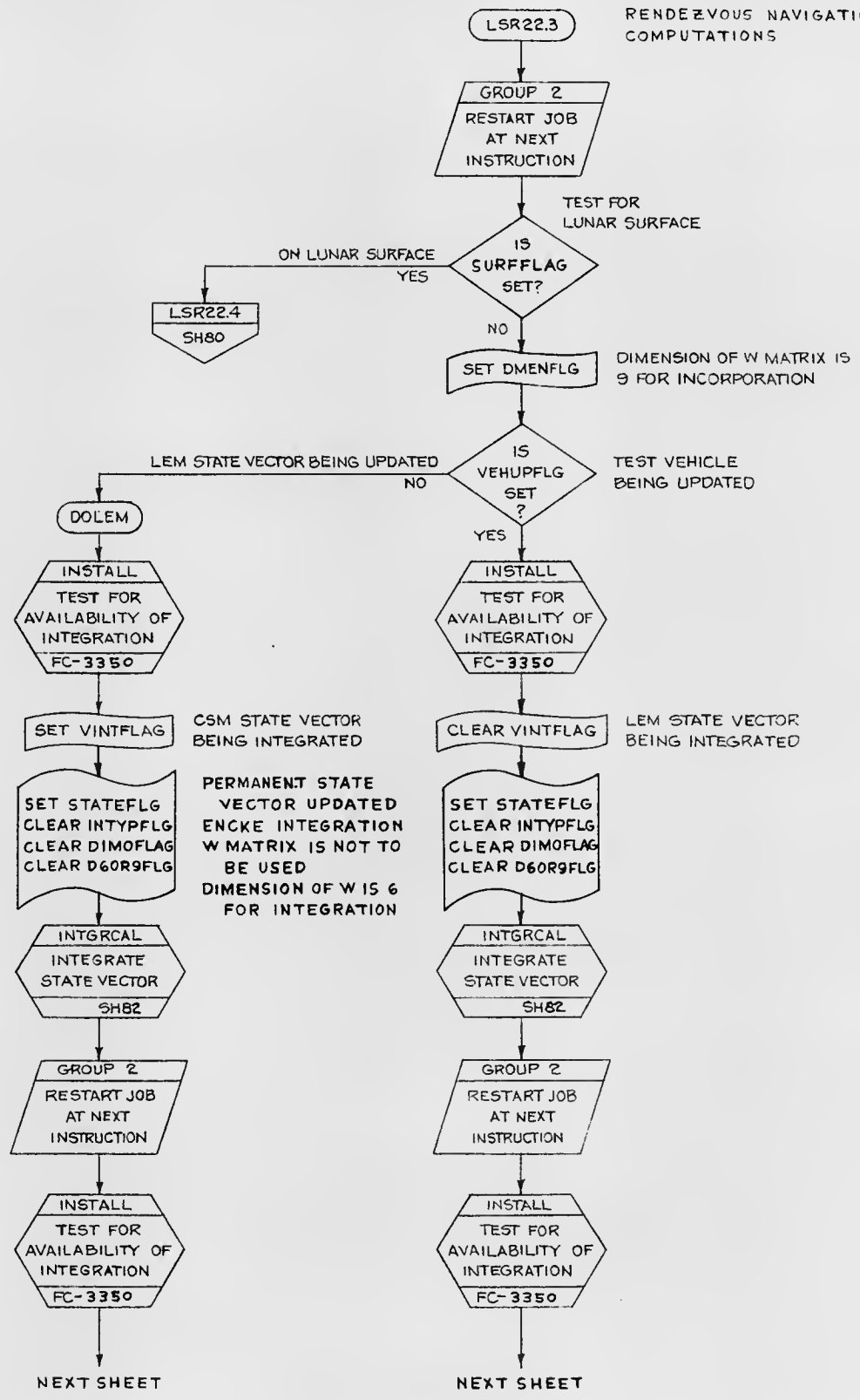


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>G. J. Angello</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAM <i>70 Vol 3</i>	REVISOR <i>25MAR69</i>	LUMINARY ID	DOCUMENT NO.
ANALYST	<i>10/21/69</i>		FC-3600
DOCNR <i>W.C. Pugh</i>	<i>4-7-69</i>		
APPR'D <i>R. M. Euter</i>	<i>10/21/69</i>	REV 2	SHEET 70 OF 103

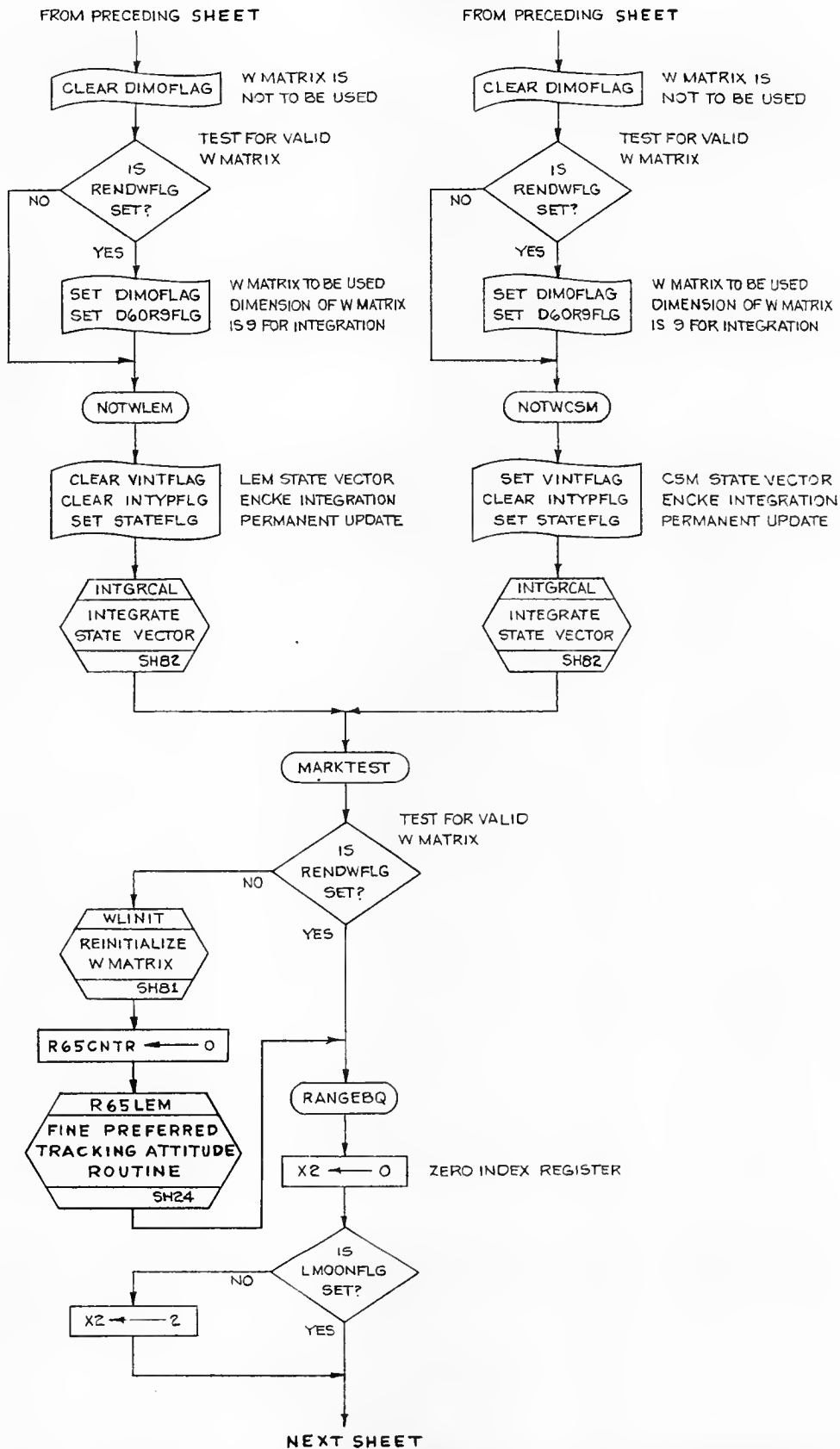


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>G. J. Langella</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGR <i>3-10-69</i>	REMARKS <i>25 MAR 69</i>	LUMINARY 11D	DOCUMENT NO.
ANMLST			FC-3600
DOCKR <i>W. C. ...</i>	<i>4-7-69</i>		
APPR'D <i>R. M. ...</i>	<i>10/21/69</i>	REV 2	SHEET 71 OF 103

RENDEZVOUS NAVIGATION
COMPUTATIONS



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS 4-4-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAM Peter Williams	10/21/69	LUMINARY ID	DOCUMENT NO.
ANALYST			FC-3600
DESIGNER M. D. Smith	5-17-64	REV 2	SHEET 72 OF 103
APPROVER John A. Moran	29 Oct 64		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS 4-4-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAM <i>P. Williams</i> 8-16-68	ANALYST	LUMINARY ID	DOCUMENT NO. FC-3600
DOCTR <i>W. D. Smith</i> 5-17-68	APPROV <i>John A. Moore</i> 8-9-68	REV 2	SHEET 73 OF 103

FROM PRECEDING SHEET

SETX2

SCALSHFT ← X2

STORE INDEX VALUE { 0 = MOON SPHERE
2 = EARTH SPHERE

GROUP2
RESTART JOB AT
NEXT INSTRUCTION

WHCHREAD ← 1
PL20_T ← RVARMIN_T

STORE RANGE CODE

GETULC
COMPUTE
UNIT VECTOR
ULC_V
SH82

OUTPUT: MPAC_V = UNIT (R_C - R_L) = ULC_V
EQUATION 2.4.2
PL36_D = RLC_D = /ULC_V/

IS
VEHUPFLG
SET?

NO
MPAC_V ← -MPAC_V

YES

BVECTOR_V ← MPAC_V
BVECTOR +6D_V } ← Q_V
BVECTOR +12D_V }

B₀ = 7 U_{LC}
B₁ = 0
B₂ = 0
EQUATION 2.4.2

DELTAQ_D ← RM_D - RLC_D

ΔQ = R_M - R_{LC} EQUATION 2.4.2

VARIANCE_{TP} ← RLC_D² (RANGEVAR)

σ² = R_{LC}² VAR_R EQUATION 2.4.2

IS
VARIANCE
> RVARMIN
?

NO
VARIANCE_T ← PL20_T

YES

QOK

LGCUPDTE
INCORPORATE
MEASUREMENT
DATA
SH83

WHCHREAD ← 2

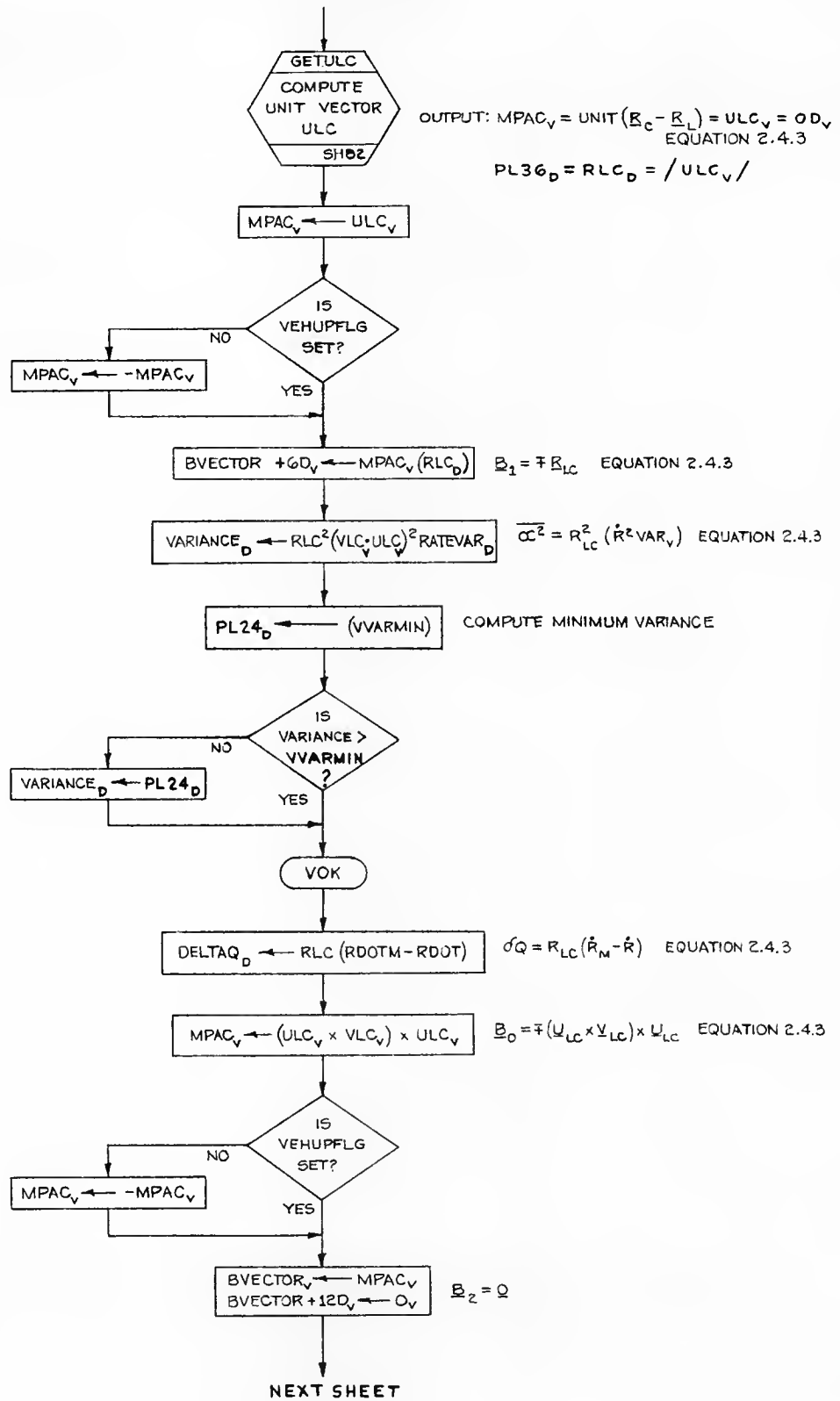
STORE R-RATE CODE

GROUP2
RESTART JOB
AT NEXT
INSTRUCTION

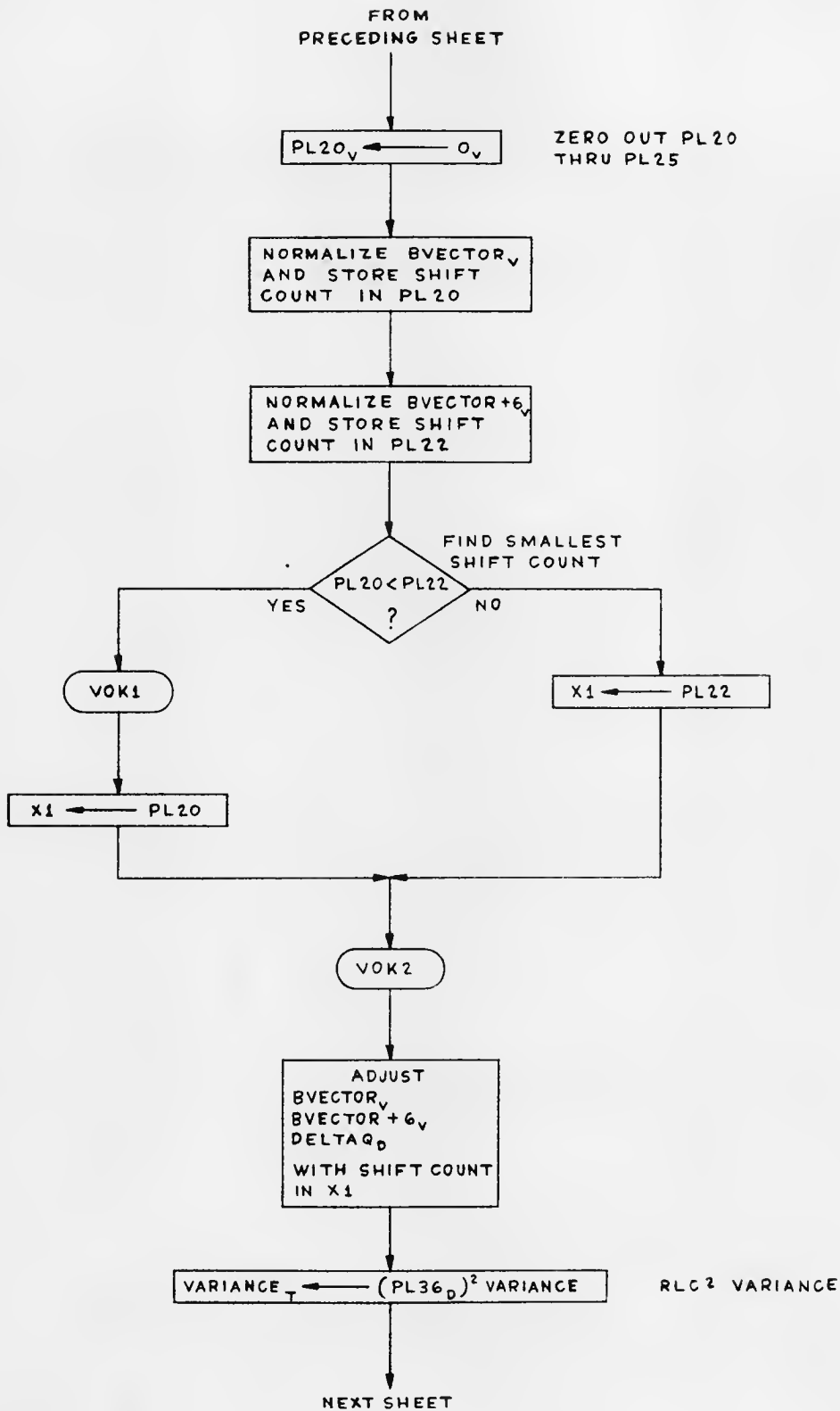
NEXT SHEET

MHT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS 5-17-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGR <i>Delta Vector</i>	5-16-68	LUMINARY ID	DOCUMENT NO.
ANALST			FC-3600
DOCR <i>[Signature]</i>	5-19-68	REV 2	SHEET 74 OF 103
APPR <i>John A. Moore</i>	29 Oct 68		

FROM PRECEDING SHEET

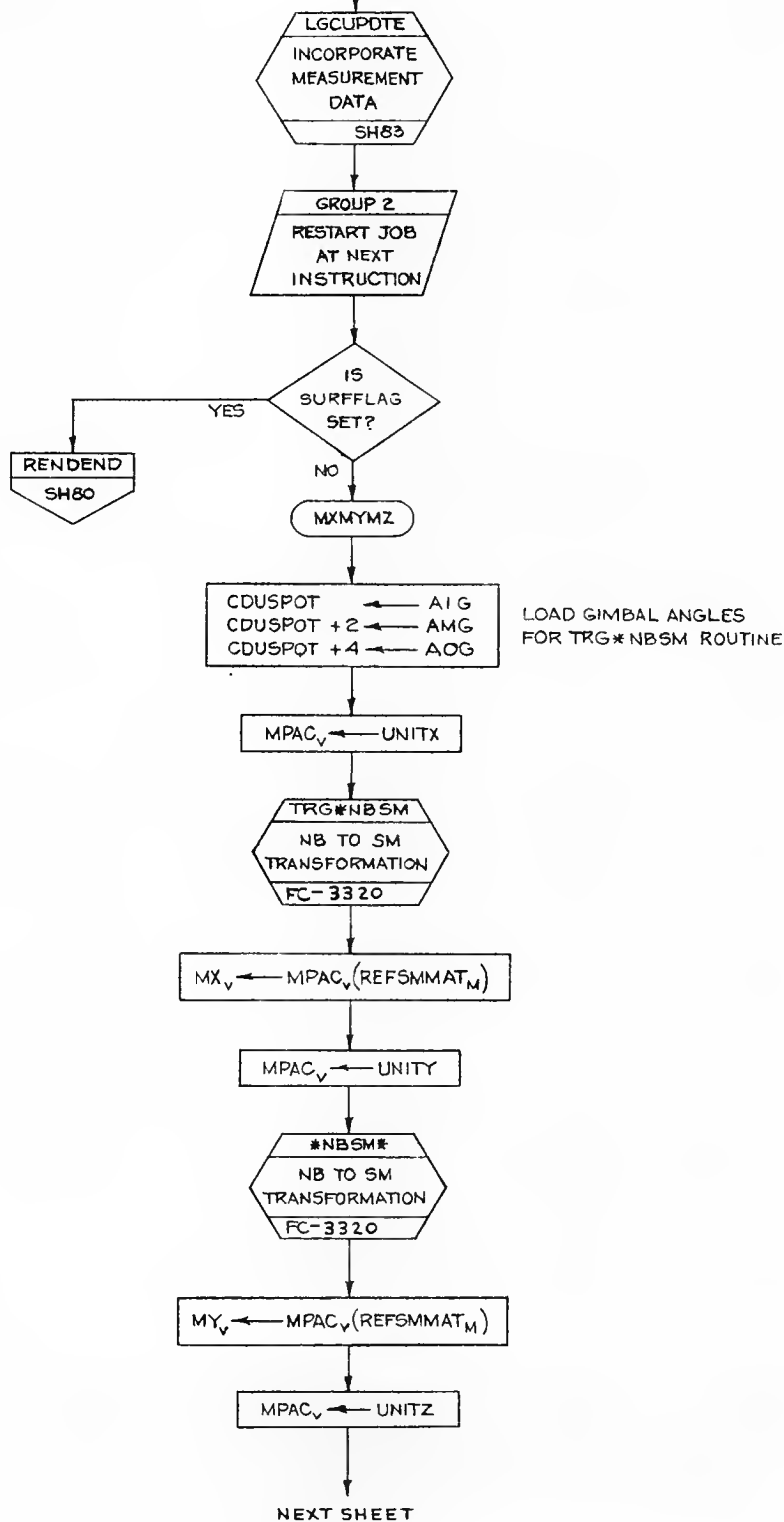


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
DRAWN	A.C. WILLIAMS	4-5-68	
PRGRM	<i>Pluto Vector</i>	8-16-68	
ANALST			
DOCMR	<i>M. J. ...</i>	5-17-68	
APPR'D	<i>John G. Moore</i>	29 Oct 68	
		LUMINARY ID	DOCUMENT NO. FC-3600
		REV 2	SHEET 75 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>G. J. Longino</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAM <i>V. J. ...</i>	DATE <i>10/21/69</i>	LUMINARY ID	DOCUMENT NO.
ANALYST			FC-3600
DOCTOR <i>J. P. ...</i>	DATE <i>8-7-68</i>	REV 2	SHEET 76 OF 103
APPROV <i>R. M. ...</i>	DATE <i>10/21/69</i>		

FROM PRECEDING SHEET



LOAD GIMBAL ANGLES
FOR TRG*NBSM ROUTINE

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
DRAWN	A.C. WILLIAMS	4-8-68	DOCUMENT NO. FC-3600
PRODR	<i>[Signature]</i>	8-16-68	
ANALST	<i>[Signature]</i>		LUMINARY ID
DOCWR	<i>[Signature]</i>	5-17-68	
APPR'D	<i>[Signature]</i>	8-20-68	SHEET 77 OF 108

FROM PRECEDING SHEET

#NB5M*
NB TO SM
TRANSFORMATION
FC-3320

$MPAC_v \leftarrow MPAC_v(REFSMMAT_M)$

SHAFTBQ

$MZ_v \leftarrow MPAC_v$

RADARANG
PRELIMINARY
RADAR ANGLE
CALCULATION
SH82

WHCHREAD \leftarrow 3

STORE SHAFT CODE

$$\sigma Q = R_{xz} \left[\beta_M - \tan^{-1} \left(\frac{U_{Lc} \cdot U_x}{U_{Lc} \cdot U_z} \right) - \sigma \beta \right]$$

$$\text{DELTAQ}_D \leftarrow RXZ \left[\text{RRSHAFT} - \tan^{-1} \left(\frac{ULC_v \cdot MX_v}{ULC_v \cdot MZ_v} \right) - X789 \right]$$

EQUATION 2.4.8

$MPAC_v \leftarrow \text{UNIT}(ULC_v \times MY_v)$

IS
VEHUPFLG
SET?

YES

$MPAC_v \leftarrow -MPAC_v$

NO

$BVECTOR_v \leftarrow MPAC_v$
 $BVECTOR + 6D_v \leftarrow O_v$
 $BVECTOR + 12D_v \leftarrow O_v$

$BVECTOR + 12D \leftarrow RXZ$

$$\sigma^2 = R_{xz}^2 (\text{VAR}_B + \text{VAR}_{IMU})$$

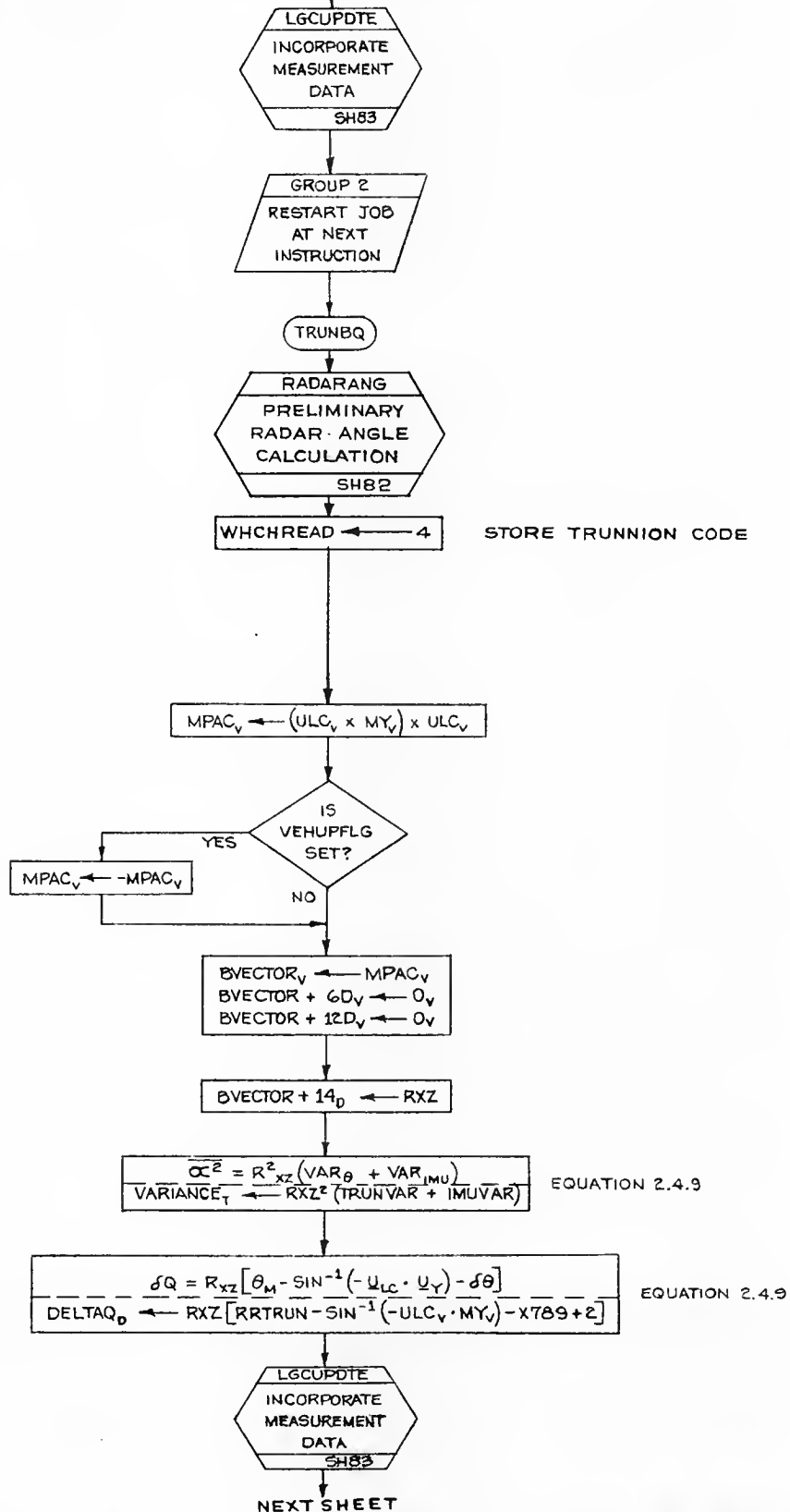
$$\text{VARIANCE}_T \leftarrow RXZ^2 (\text{SHAFTVAR} + \text{IMUVAR})$$

EQUATION 2.4.8

NEXT SHEET

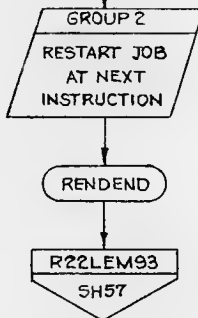
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS 4-8-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRM <i>Ref. V.L. Jr.</i>	8-16-68	LUMINARY 1D	DOCUMENT NO. FC-3600
ANALYST <i>W. S. ...</i>	3-17-69	REV 2	SHEET 78 OF 109
APPR'D <i>John A. Moore</i>	29 Oct 68		

FROM PRECEDING SHEET



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS 4-9-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGR Peter Volante 8-16-68		LUMINARY ID	DOCUMENT NO.
ANALYST			FC-3600
DOCWR [Signature] 5-17-68		REV 2	SHEET 79 OF 103
APPR'D John A. Mason 2-9-69			

FROM PRECEDING SHEET

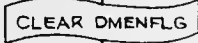
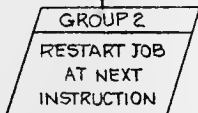
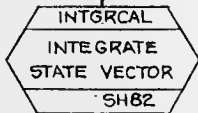


LUNAR SURFACE NAVIGATION COMPUTATIONS

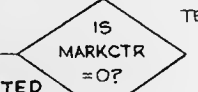
LSR22.4



PERMANENT UPDATE
LEM STATE VECTOR BEING UPDATED

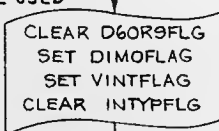


DIMENSION OF W MATRIX IS 6 FOR INCORPORATION

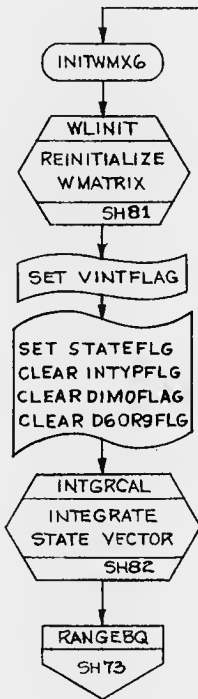
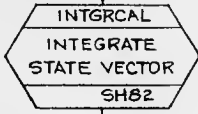


TEST MARKCTR

YES
PERMANENT STATE VECTOR UPDATED
ENCKE INTEGRATION
W MATRIX IS NOT TO BE USED
DIMENSION OF W IS 6 FOR INTEGRATION



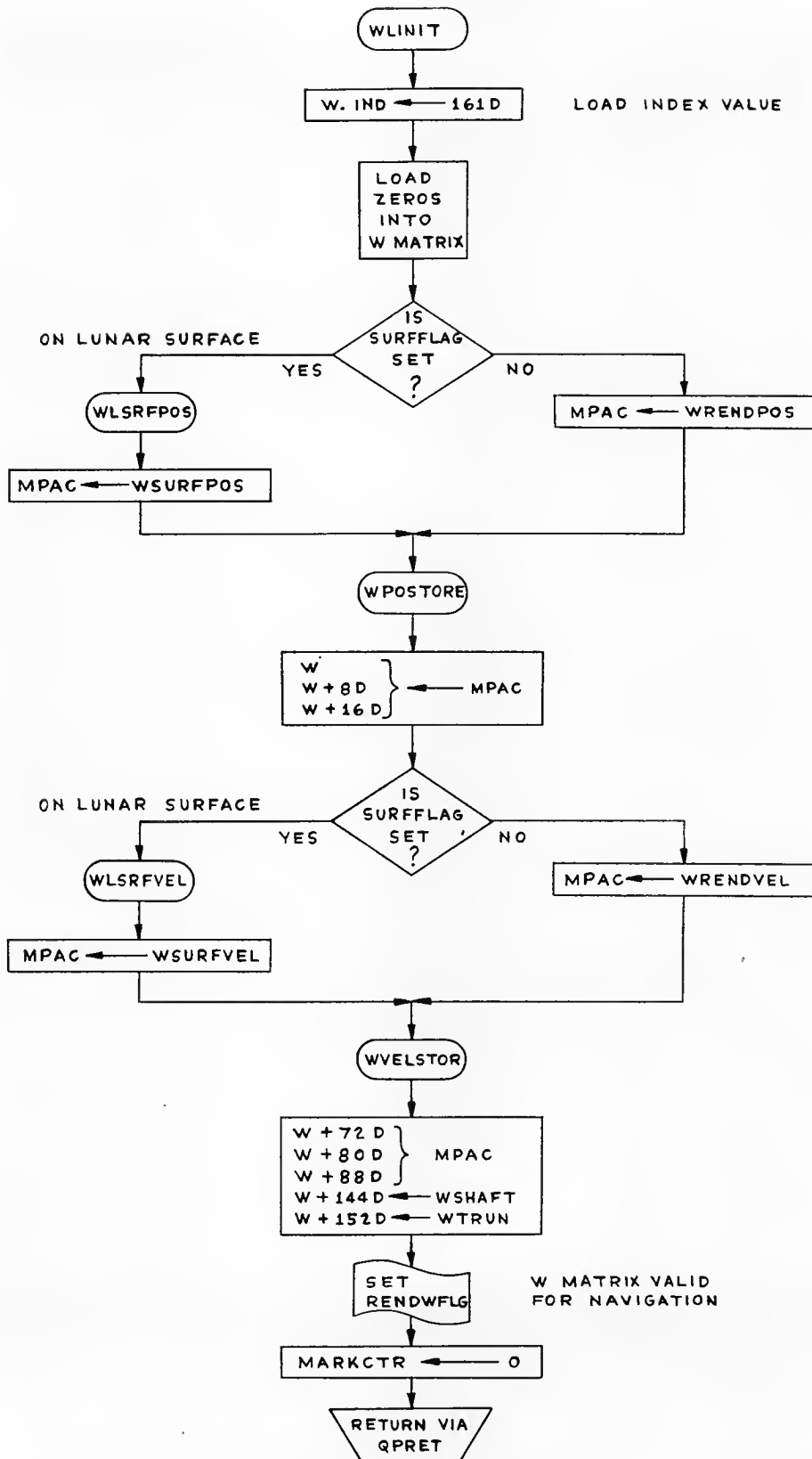
DIMENSION IS 6 FOR INTEGRATION
W MATRIX TO BE USED
CSM STATE VECTOR BEING UPDATED
ENCKE INTEGRATION



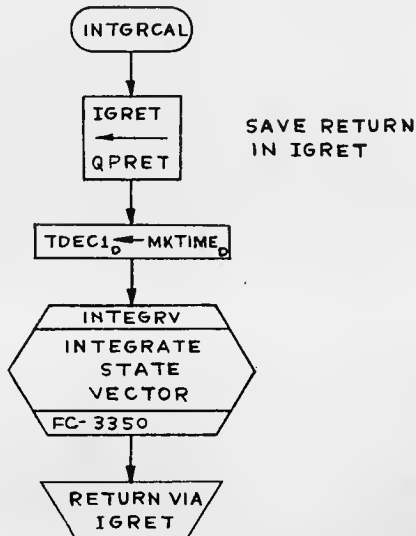
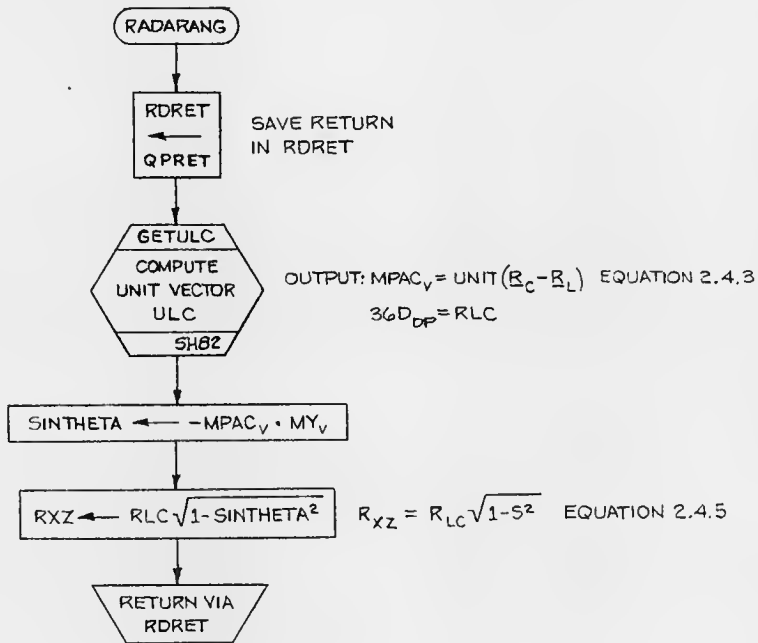
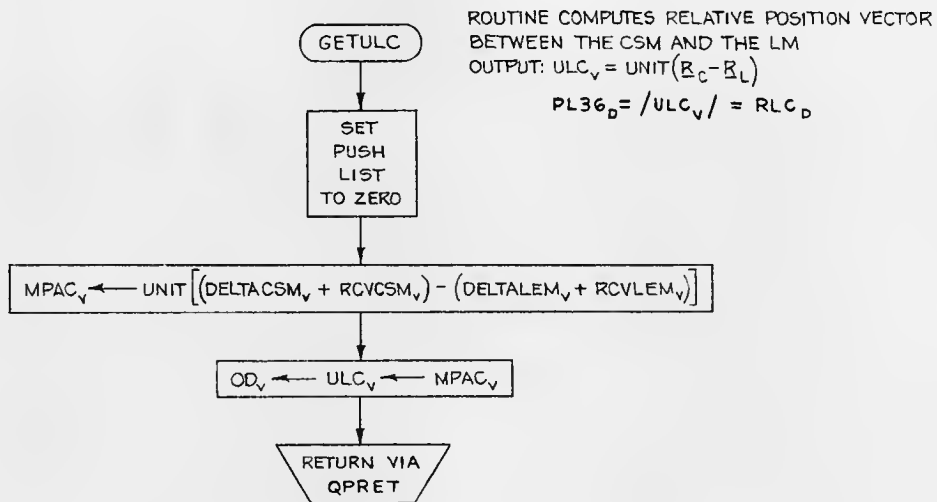
CSM STATE VECTOR BEING UPDATED

PERMANENT STATE VECTOR UPDATED
ENCKE INTEGRATION
W MATRIX IS NOT TO BE USED
DIMENSION OF W IS 6 FOR INTEGRATION

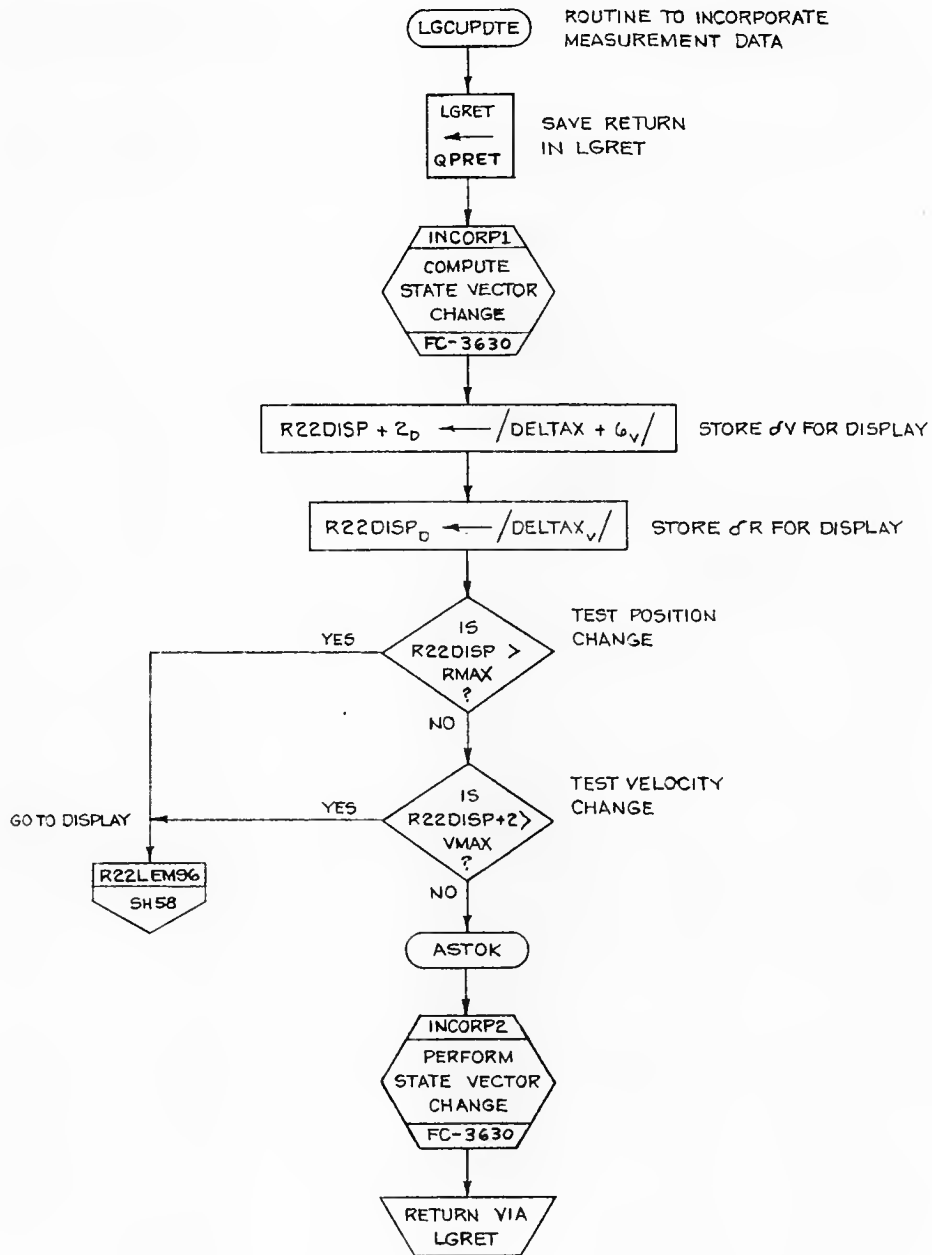
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS 4-9-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGR P. Val. 8-16-68	ANALYST	LUMINARY ID	DOCUMENT NO.
DOCTR 5-17-68	APPR'D John A. Moore 12 Oct 68		FC-3600
		REV 2	SHEET 80 OF 103



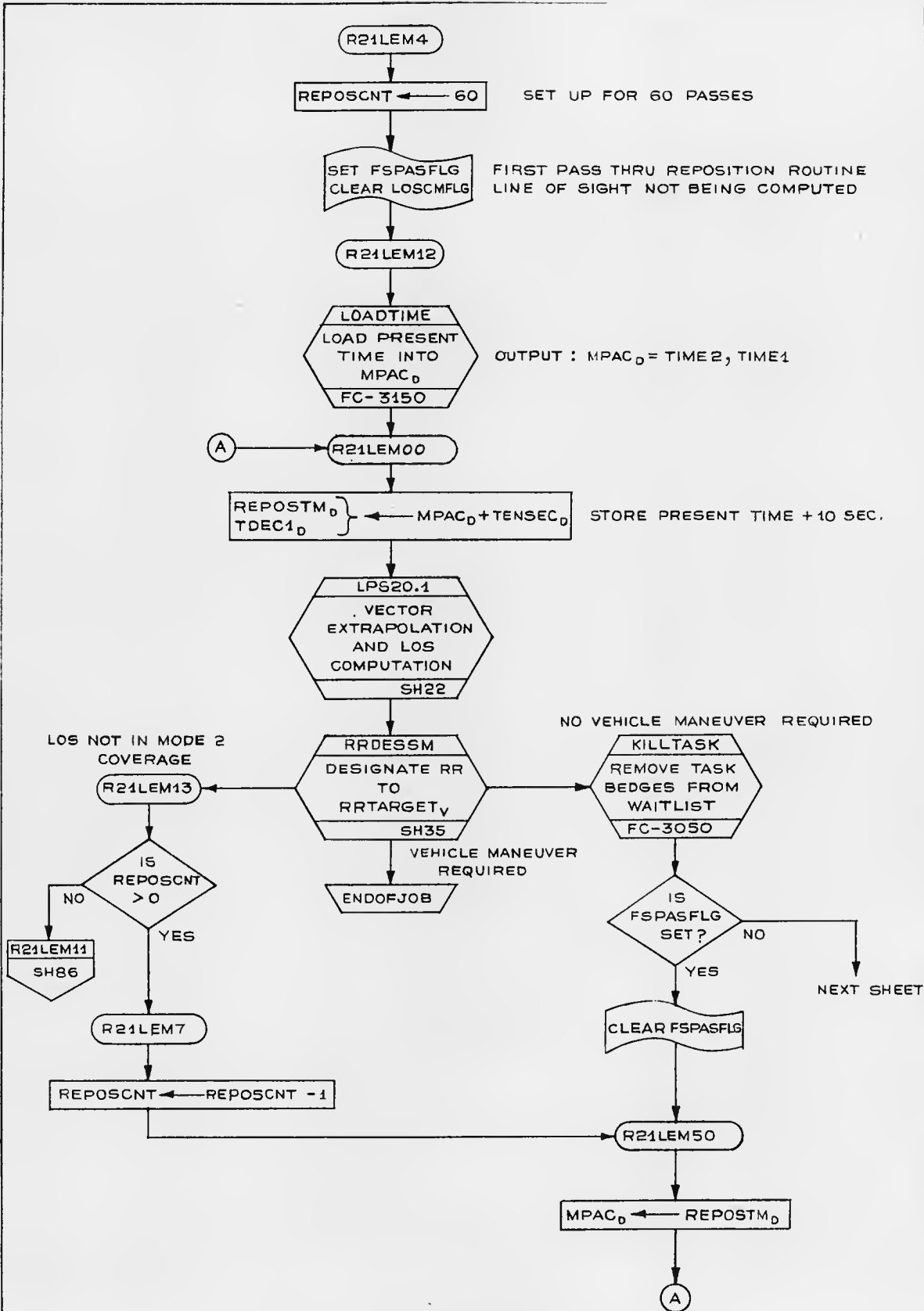
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>G. J. Santillo</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGRM <i>Variable</i>	26MARG9 10/21/69	LUMINARY ID	DOCUMENT NO. FC-3600
ANALST	9-7-69	REV 2	SHEET 81 OF 103
APPR'D <i>H. M. Egan</i>	10/21/69		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS 4-10-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAM Peter Volante 8-16-68	ANALYST	LUMINARY ID	DOCUMENT NO.
DOCNR 74-20-68-1 5-17-68	APPR'D John A. Manu 12 Oct 68	REV 2	FC-3600
			SHEET 82 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS 4-10-68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGR Peter Volante 8-16-68		LUMINARY ID	DOCUMENT NO.
ANPLST			FC-3600
DOCNR W. D. ... 5-17-68		REV 2	SHEET 83 OF 103
APP'D John A. ... 29 Oct 68			



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D.M. ...</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAM <i>C. ...</i>	20 JUNE 69	LUMINARY 11D	DOCUMENT NO. FC-3600
ANALYST	18 JULY 69	REV 2	SHEET 84 OF 103
DOCKED <i>...</i>			
APPROVED <i>R. ...</i>			

FROM PRECEDING SHEET

R21LEM8

TDEC1_D ← REPOSTM_D

UPPSV
UPDATE PERMANENT
STATE VECTORS TO
TDEC1 TIME
SH20

SET CDESFLAG
CLEAR LOKONSW
SET NORRMON

CONTINUOUS DESIGNATE
RADAR LOCK-ON NOT DESIRED
BYPASS RR GIMBAL MONITOR

RRDESNB
DESIGNATE TO
SPECIFIC GIMBAL
ANGLES
SH32

INPUT: TANG, TANG + 1 = DESIRED RR ANTENNA
GIMBAL ANGLES
OUTPUT: RR DESIGNATED TO INPUT ANGLES

LOADTIME
LOAD PRESENT
TIME INTO
MPAC_D
FC-3150

OUTPUT: MPAC_D = TIME2, TIME1

DELTATM_D ← MPAC_D - REPOSTM_D
A, L ← DELTATM_D

R21LEM9

KILLTASK
REMOVE TASK
STDESIG
FROM WAITLIST
FC-3050

CLRADM
CLEAR CDESFLG
& DESIGFLG.
DISABLE RR
ERROR COUNTERS
SH49

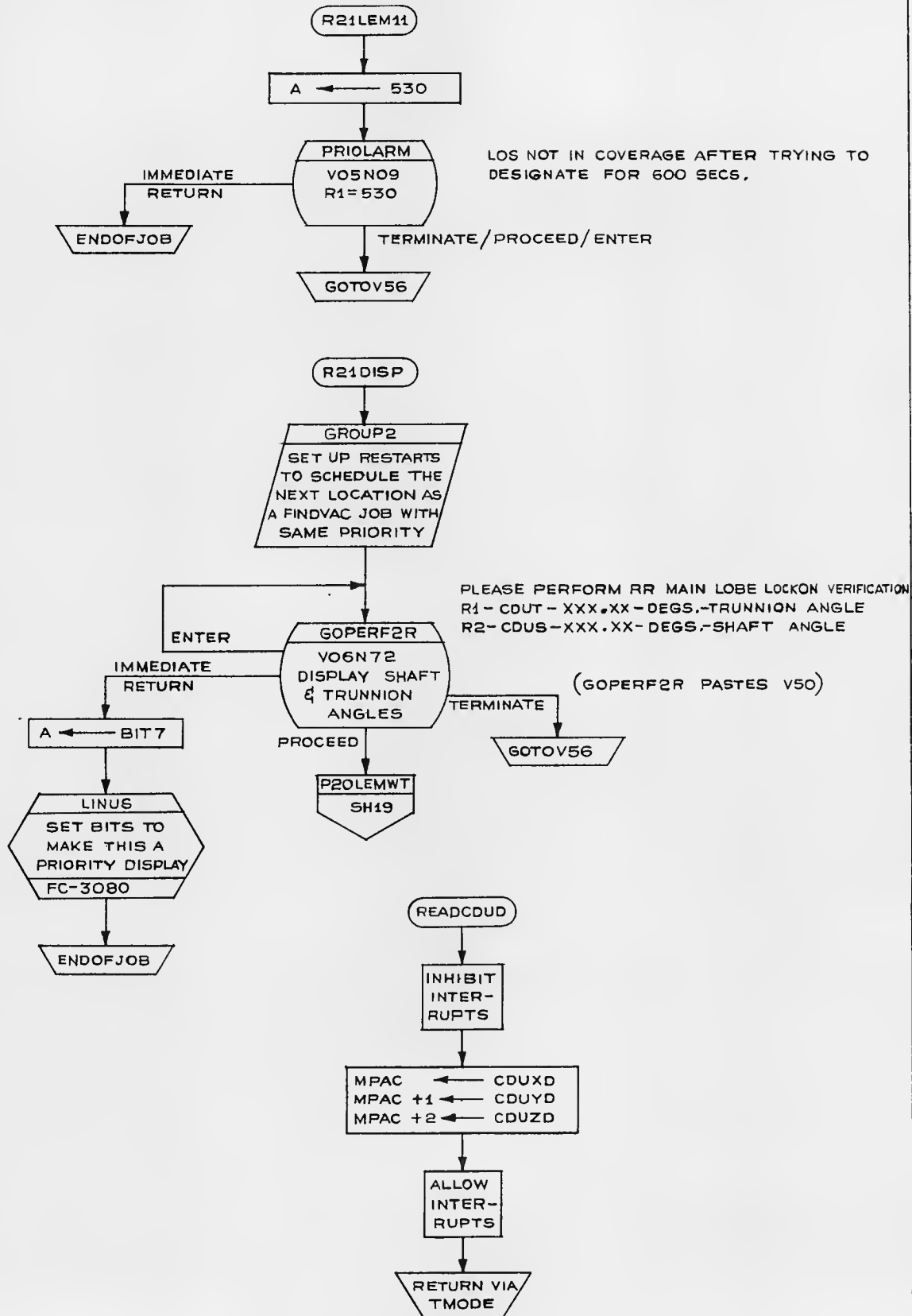
R21LEM10
FINDVAC JOB
PRIORITY
26
SH30

TASKOVER

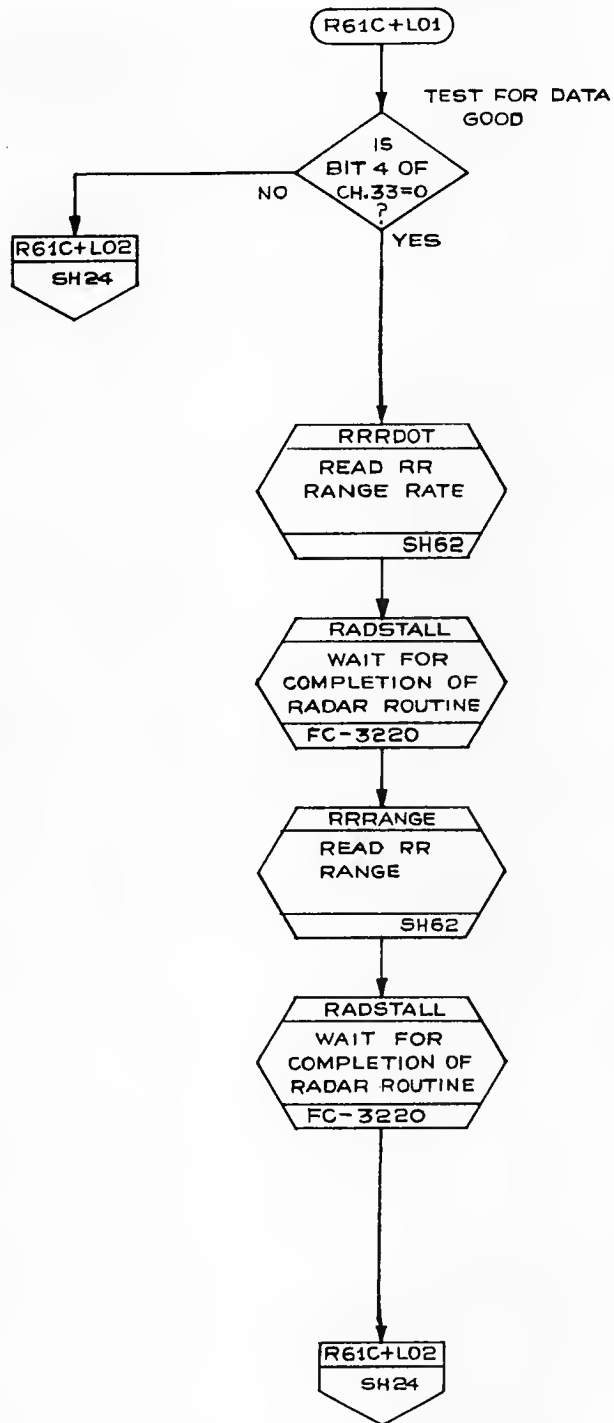
R21LEM9
LONGCALL TASK
IN C(A) CSFC
SH85

ENDOFJOB

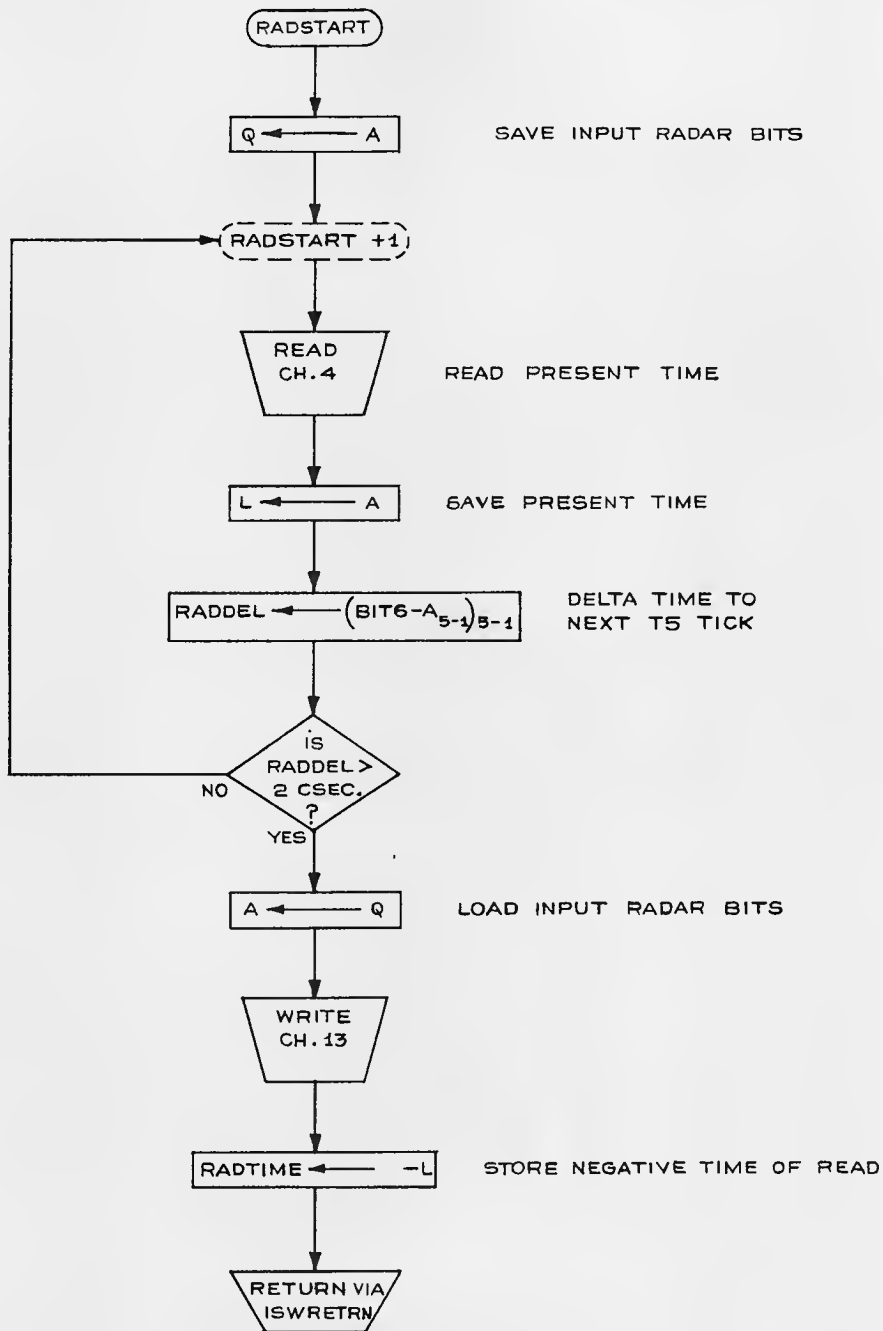
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>DM O'Leary</i>		P20, P22	
PROGRAM <i>P. Volcan 360</i>		RENDEZVOUS & LUNAR SURFACE NAVIGATION	
ANALYST	DATE <i>10/21/69</i>	LUMINARY ID	DOCUMENT NO.
DOCNR <i>W.P. D'Amico</i>	<i>10/21/69</i>		FC-3600
APPR'D <i>R.M. Egan</i>	<i>10/21/69</i>	REV 2	SHEET 85 OF 103



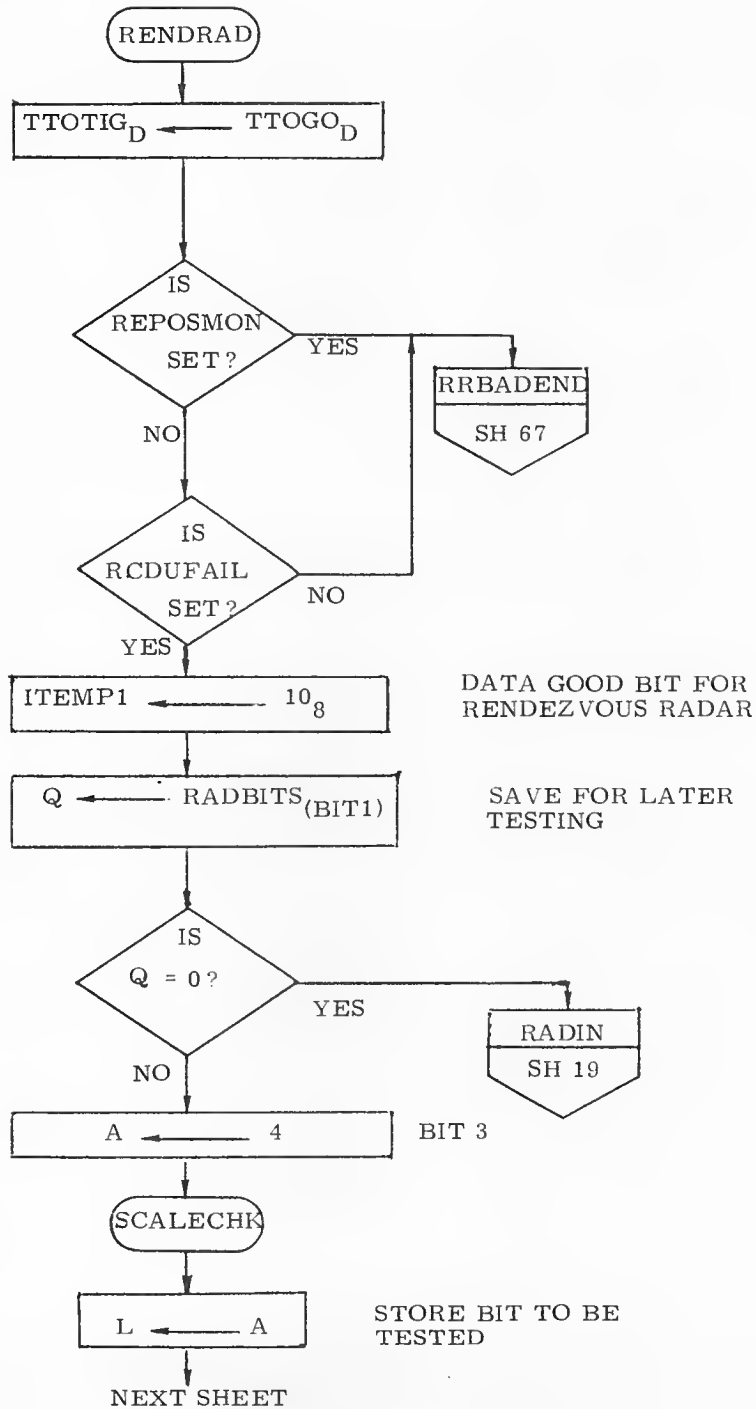
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>P.M. Dyer</i>		P20, P22	
PROGRM <i>P. K. ...</i>		RENDEZVOUS & LUNAR SURFACE NAVIGATION	
ANALYST <i>P.M. Dyer</i>		DOCUMENT NO.	
DOCNR <i>FC-3600</i>		LUMINARY ID	
APPR'D <i>P.M. Dyer</i>		FC-3600	
23JUN69 10/21/69 10/21/69		REV. 2	
		SHEET 86 OF 103	



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>P.M. Dietrich</i>		P20, P22	
PROGR <i>P. Valente</i>		RENDEZVOUS & LUNAR SURFACE NAVIGATION	
ANALST		DOCUMENT NO.	
DOCR <i>McDonald</i>		LUMINARY 1D	FC-3600
APPR'D <i>R. M. E. S. S.</i>		REV 2	SHEET 87 OF 103

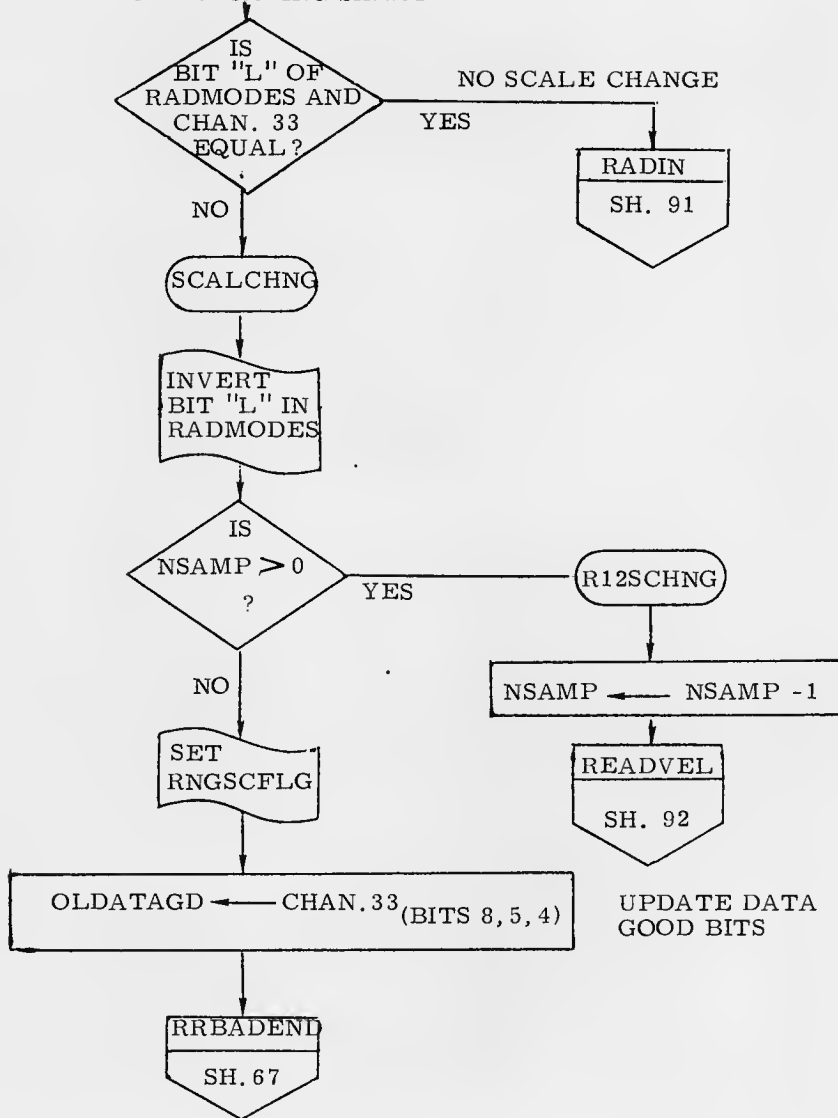


INT INSTRUMENTATION LAB CAMBRIDGE, MASS		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>P.M. Dietrich</i> 18 SEP 68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAM <i>B. Volante</i> 10/21/69		DOCUMENT NO.	
REQUEST		LUMINARY 1D	
DESIGN <i>J.C. England</i> 19 SEP 68		FC-3600	
APPROV <i>R. M. ...</i> 10/21/69		REV 2. SHEET 88 OF 103	

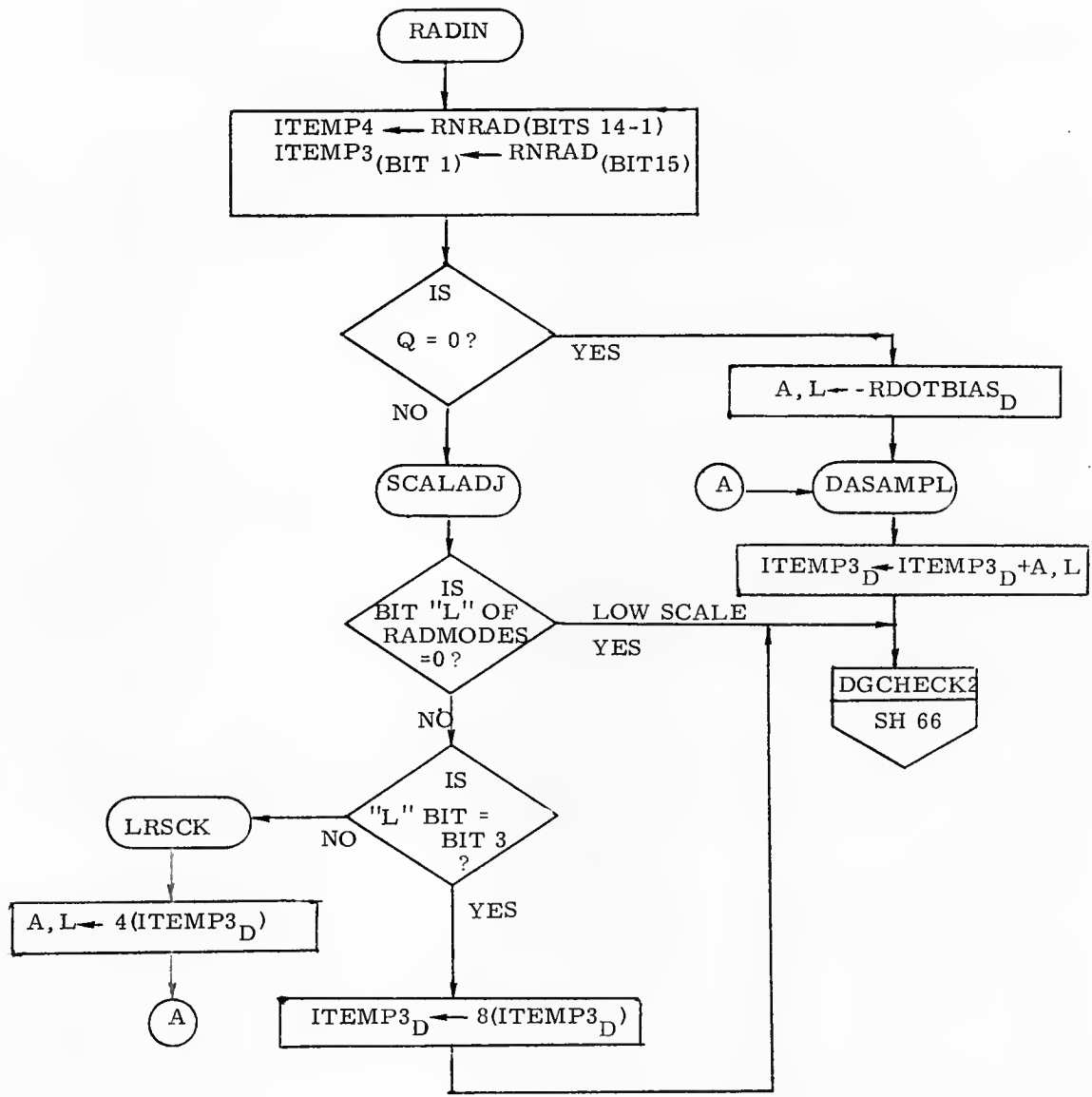


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>E. Matka</i>	6/14/70	P20, P22
PRGMR	<i>P. Volante</i>	6/18/70	DOCUMENT NO.
ANALST			LUMINARY 1D FC-3600
DOCMR	<i>M. G. ...</i>	6/14/70	REV 2
APPR'D	<i>R. M. ...</i>	6/18/70	SHEET 89 OF 103

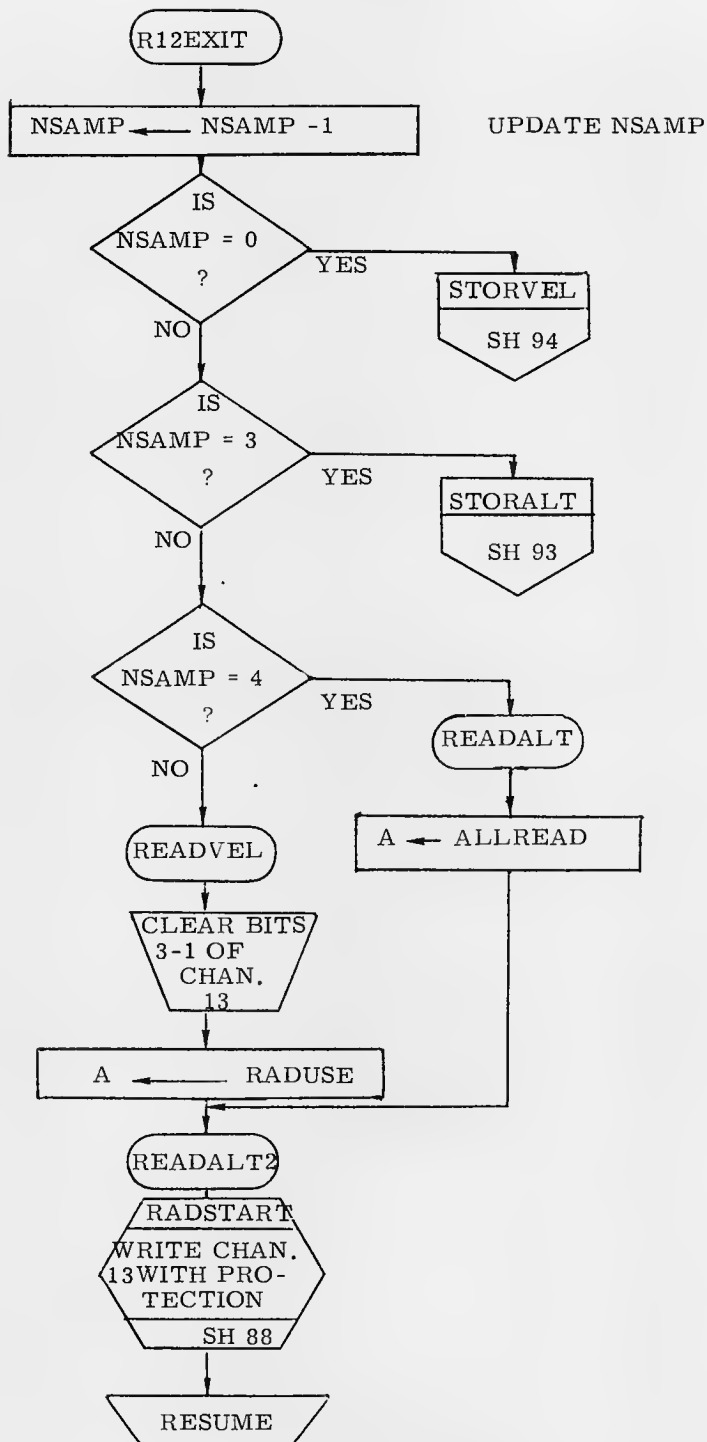
FROM PRECEDING SHEET



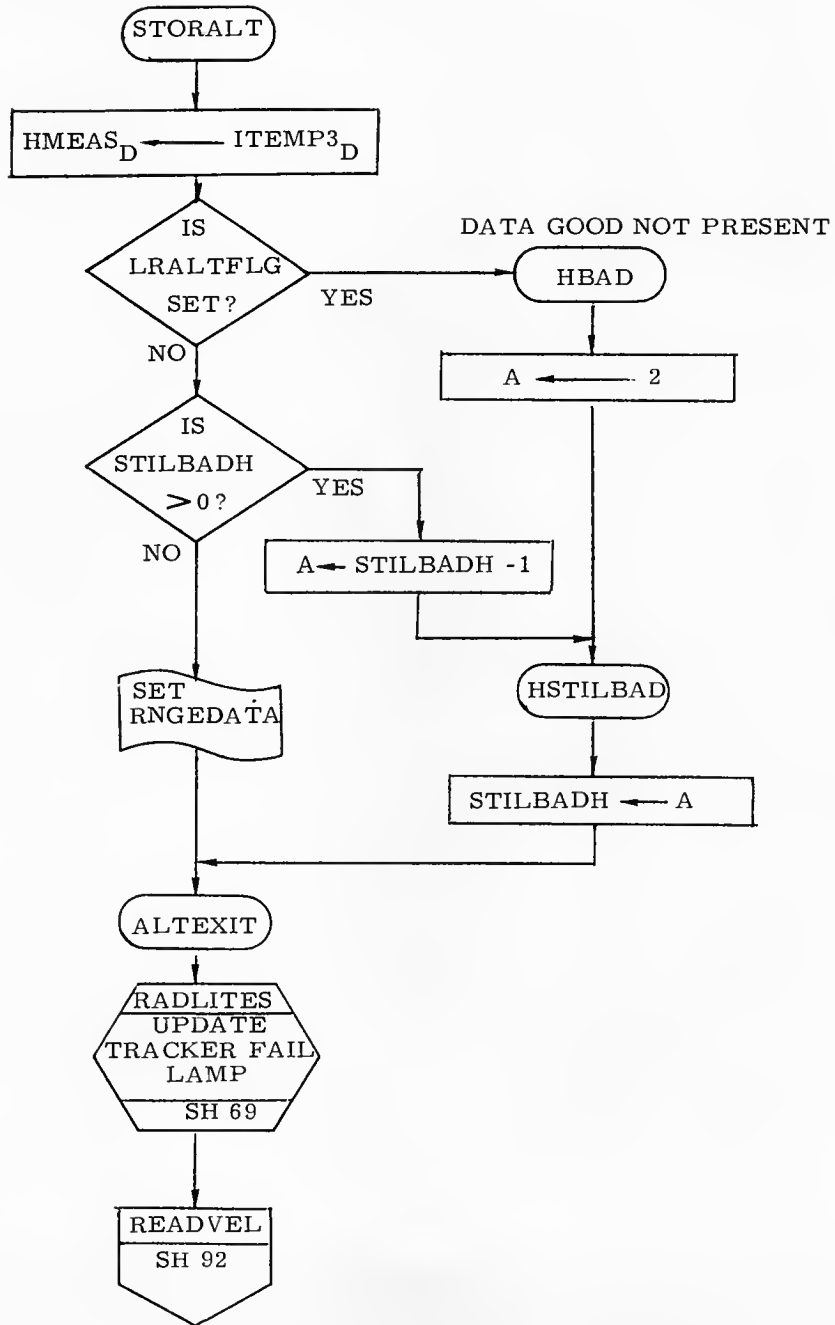
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>E. Mather</i>	<i>2/7/70</i>	P20, P22
PRGMR	<i>P. Volante</i>	<i>6/19/70</i>	DOCUMENT NO.
ANALST			FC-3600
DOCMR	<i>W. P. ...</i>	<i>6/10/71</i>	LUMINARY 1D
APPR'D	<i>R. M. ...</i>	<i>6/18/70</i>	REV 2
			SHEET 90 OF 103



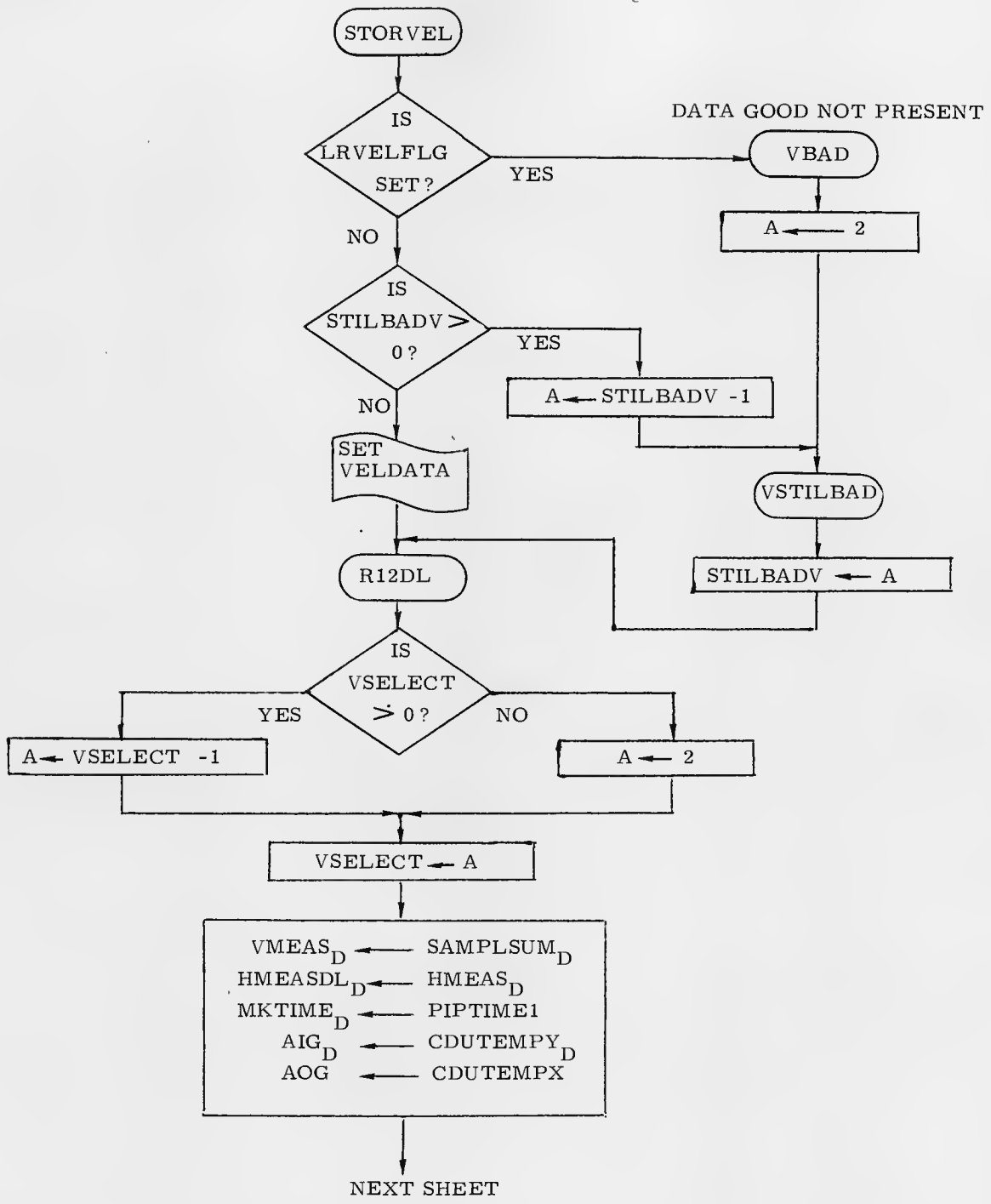
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P20, P22	
DRAWN	<i>E. Matia</i>	6/4/70	
PRGMR	<i>G. Volante</i>	6/19/70	
ANALST			
DOCMR	<i>M. G. ...</i>	6/9/70	
APPR'D	<i>R. M. ...</i>	6/18/70	
		REV 2	DOCUMENT NO. FC-3600
			SHEET 91 OF 103



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P20, P22	
DRAWN	<i>E. Matto</i> 6/14/70	LUMINARY 1D	DOCUMENT NO.
PRGMR	<i>G. Volante</i> 6/18/70		FC-3600
ANALST		REV 2	SHEET 92 OF 103
DOCMR	<i>M. G. ...</i> 6/18/70		
APPR'D	<i>R.M. ...</i> 6/18/70		

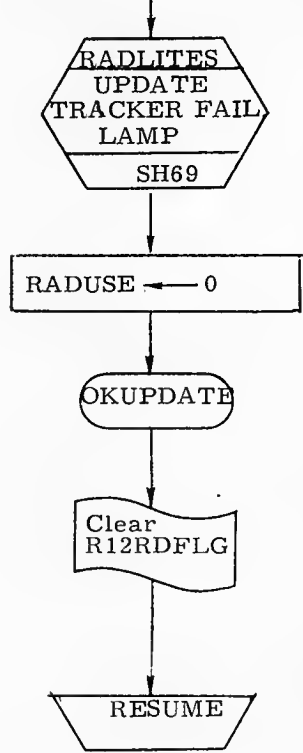


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>E. Mata</i> 6/4/70	P20, P22	
PRGMR	<i>P. J. ...</i> 6/19/70	LUMINARY 1D	DOCUMENT NO. FC-3600
ANALST			
DOCMR	<i>W. ...</i> 6/9/70	REV 2	SHEET 93 OF 103
APPR'D	<i>R.M.G. ...</i> 6/18/70		

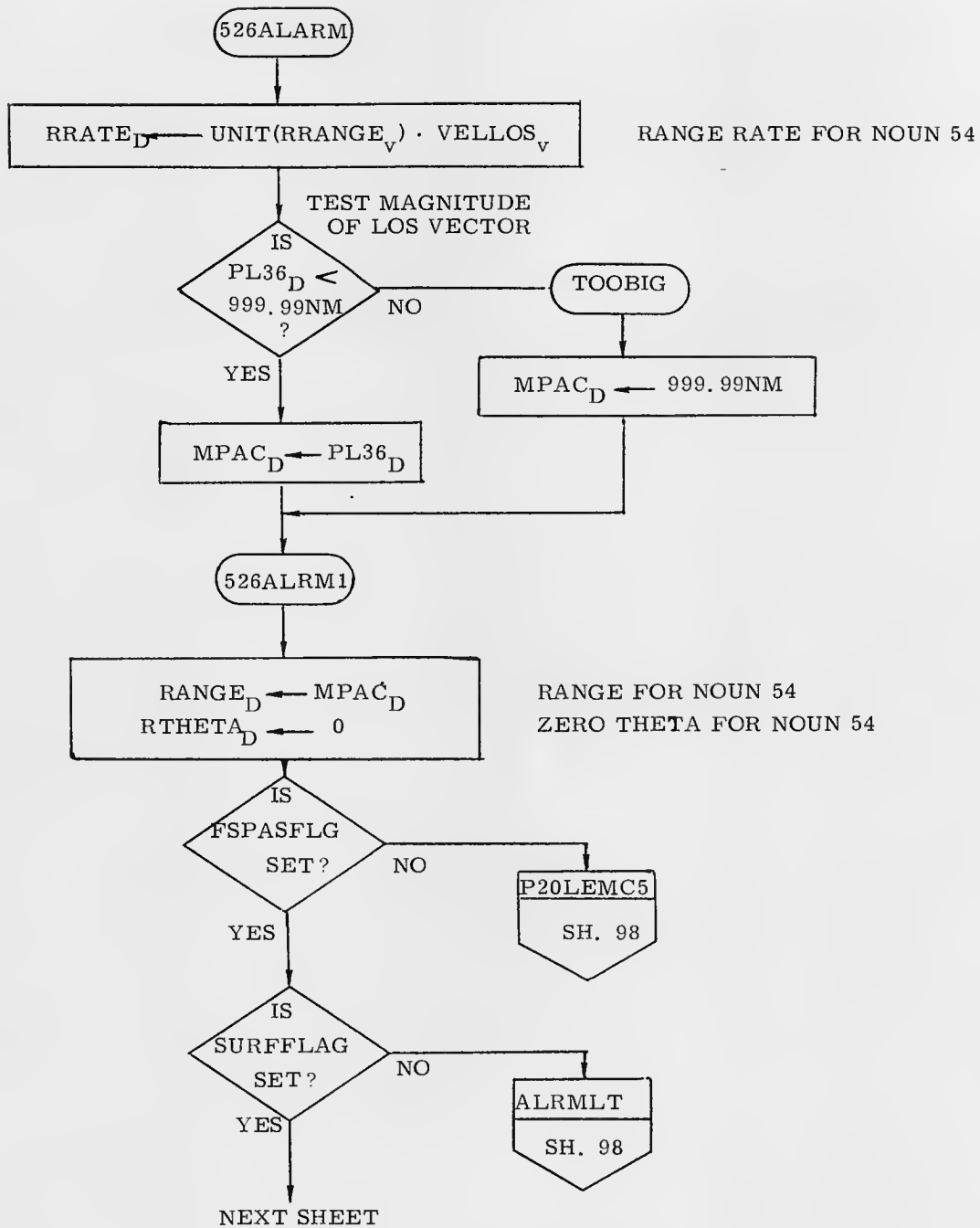


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P20, P22	
DRAWN	<i>E. Metz</i> 6/15/70	LUMINARY 1D	DOCUMENT NO.
PRGMR	<i>P. Valente</i> 6/19/70		FC-3600
ANALST		REV	2
DOCMR	<i>W. D. ...</i> 6/19/70	SHEET 94 OF 103	
APPR'D	<i>R. M. ...</i> 6/18/70		

FROM PRECEDING SHEET

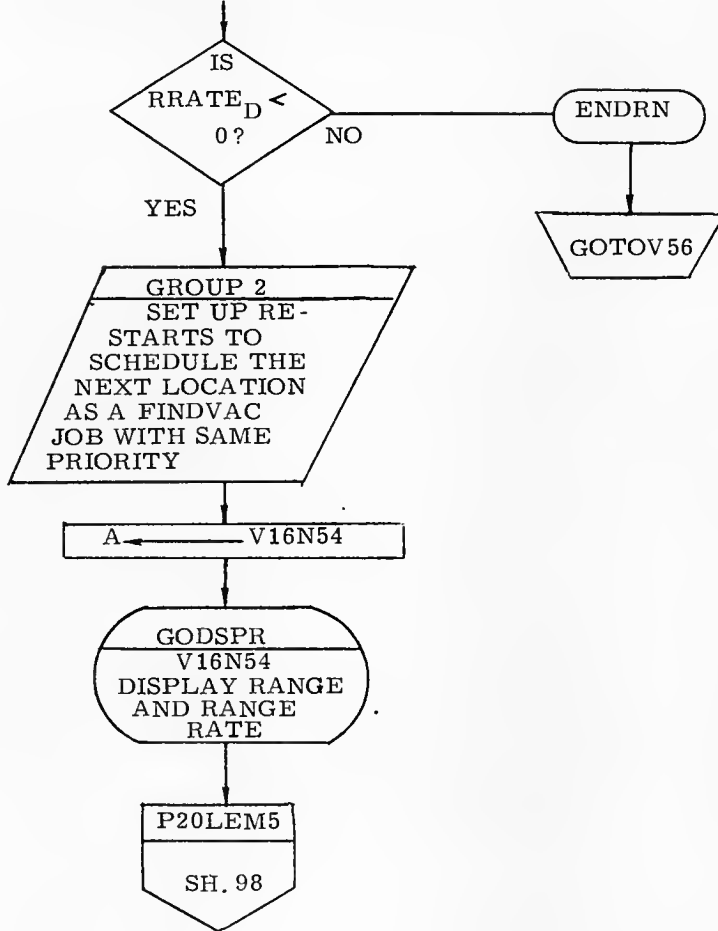


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>E. Metz</i>	6/3/70	P20, P22
PRGMR	<i>P. Volante</i>	6/18/70	
ANALST			LUMINARY 1D
DOCMR	<i>m. [unclear]</i>	6/10/70	DOCUMENT NO. FC-3600
APPR'D	<i>Jim E. [unclear]</i>	6/15/70	REV 2 SHEET 95 OF 103

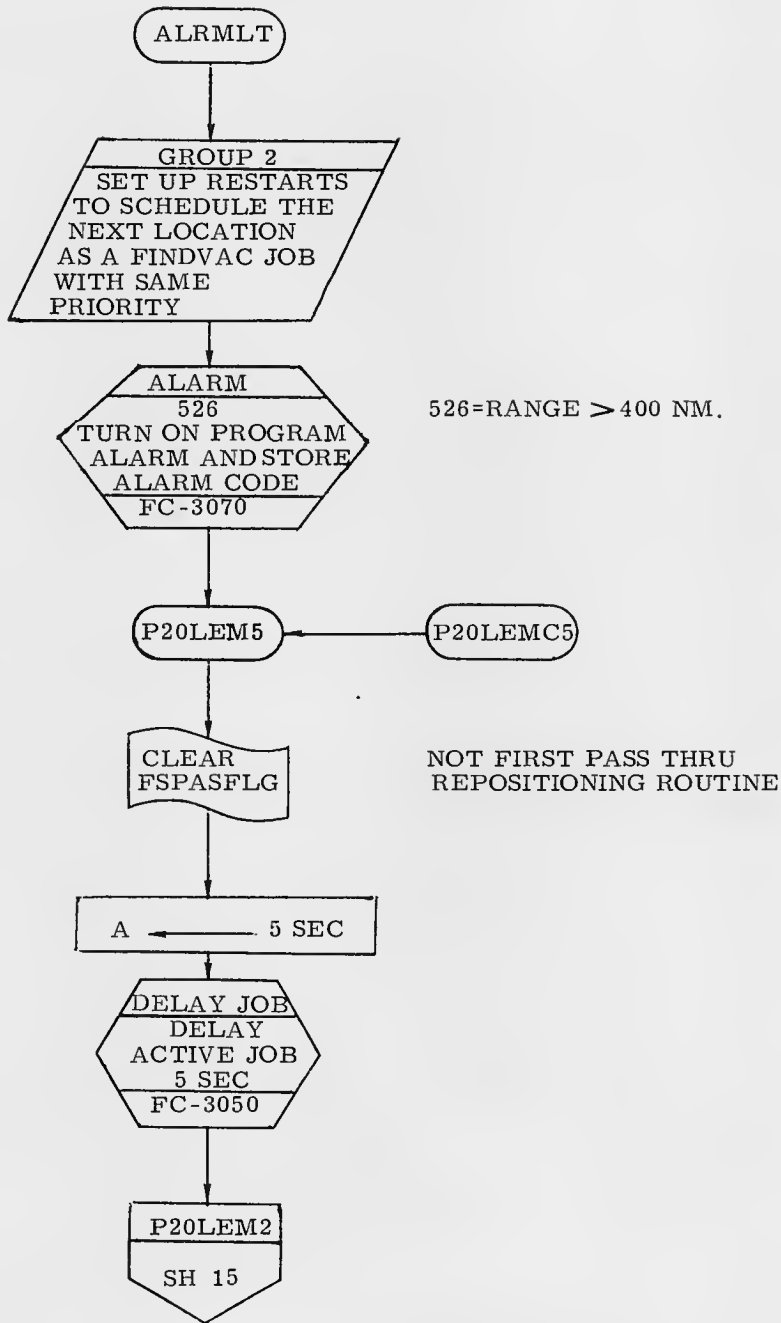


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>E. Martin</i> 6/12/70	P20, P22	
PRGMR	<i>P. J. ...</i> 6/18/70	DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3600
DOCMR	<i>W. ...</i> 6/18/70	REV 2	SHEET 96 OF 103
APPR'D	<i>R. ...</i> 6/18/70		

FROM PRECEDING SHEET



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>E. Matka</i> 6/4/70	P20, P22	
PRGMR	<i>G. Volante</i> 6/18/70	DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3600
DOCMR	<i>W. G. Smith</i> 6/10/70	REV 2	SHEET 97 OF 103
APPR'D	<i>R. M. Estes</i> 6/18/70		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>E. Matka</i> 6/11/70	P20, P22	
PRGMR	<i>P. Volants</i> 6/18/70	LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3600
DOCMR	<i>M. D. ...</i> 6/14/70	REV 2	SHEET 98 OF 103
APPR'D	<i>R. M. ...</i> 6/18/70		

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

AIRT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. J. Langille</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
FROM <i>W. J. White</i>		LUMINARY ID	
ANALYST		DOCUMENT NO. FC-3600	
DOCNR <i>W. C. DeGard</i>		REV 2	
APPR'D <i>R. M. Evers</i>		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
VECPPOINT	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 DESIGNATE, 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
DIMOFFLAG 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. 53	SH. 94

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
DRAWN <i>A. J. Long</i>	12 NOV 68	LUMINARY ID	DOCUMENT NO. FC-3600
PRGRM <i>W. G. ...</i>	10/21/69		
ANALST <i>W. G. ...</i>	4-7-69		
DOCMR <i>R. M. ...</i>	10/21/69	REV 2	SHEET 100 OF 103

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 FLAG4BIT2	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
REPOSOMN 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	
RVS 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
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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>G. J. Langille</i>		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PROGRAM	<i>G. J. Langille</i>	19 NOV 68	
ANALYST	<i>G. J. Langille</i>	10/21/69	
DOCTR	<i>M. C. Dwyer</i>	8-7-69	
APPR'D	<i>R. D. ...</i>	10/21/69	
LUMINARY 1D		REV 2	DOCUMENT NO. FC-3600
			SHEET 101 OF 103

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 R3 - WIICHEAD - XXXXX. - RADAR SOURCE CODE PARAMETERS	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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>G. J. Langille</i> 19 NOV 68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PCHKR <i>P. J. ...</i> 10/21/69		LUMINARY 1D	
ANALST		DOCUMENT NO. FC-3600	
DOCKR <i>...</i> 4-7-65		REV 2	
APPR'D <i>R. ...</i> 10/21/69		SHEET 102 OF 103	

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	$\underline{\delta Q}$	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 _{b₀}	—	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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>G. J. ...</i> 19 NOV 68		P20, P22 RENDEZVOUS & LUNAR SURFACE NAVIGATION	
PRGRM <i>P. J. ...</i> 1/21/69		LUMINARY 1-D	
ANALST		DOCUMENT NO. FC-3600	
DOCNR <i>77C ...</i> 4-7-65		REV 2	
APPR'D <i>P. M. ...</i> 10/20/68		SHEET 103 OF 103	

State Vector Extended Verbs
Major Subroutines on This Chart

Extended
Verbs

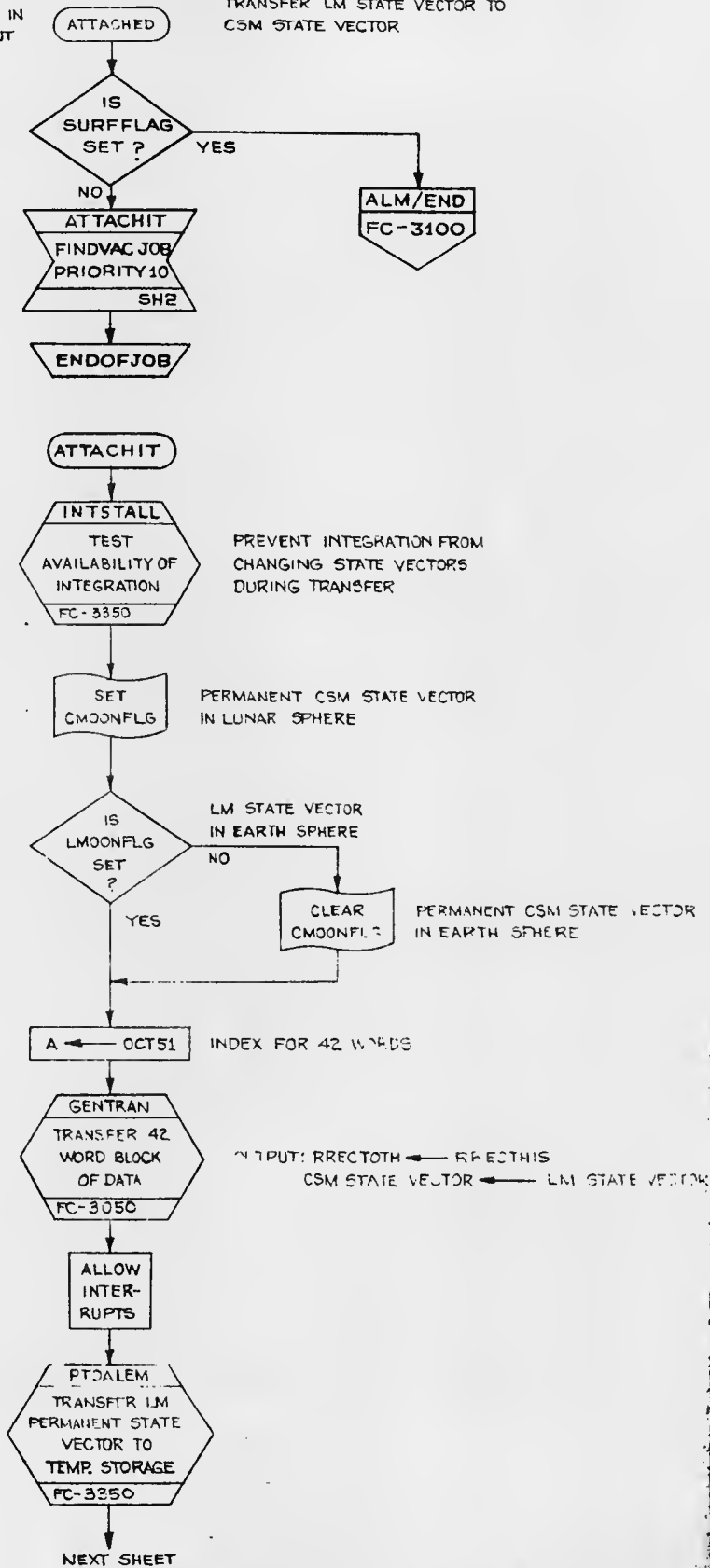
66	ATTACHED	Sh. 2
80	LEMVEC	Sh. 3
81	CSMVEC	Sh. 3

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>L. Galanter</i>	STATE VECTOR EXTENDED VERBS	
PRGMR		LUMINARY 1D	DOCUMENT NO. FC-3605
ANALST	<i>P. Rye</i>		
DOCMR	<i>M. E. Ent...</i>	REV 3	SHEET 1 OF 4

EXTENDED VERB 66

V666 KEYPED IN BY ASTRONAUT

TRANSFER LM STATE VECTOR TO CSM STATE VECTOR



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS		STATE VECTOR EXTENDED VERBS	
PROGRAM P.Ky2	30MAY63	LUMINARY ID	DOCUMENT NO. FC-3605
ANALYST	20JUN63		
DOCOR J.C. DeLoach	6JUN63		
APPROV Alex M. Spang	REV 3		SHEET 2 OF 4

FROM PRECEDING SHEET

X2 ← PBODY

SVDWNI
COMPUTE AND
STORE STATE VECTOR
FOR DOWNLINK
FC-3350

OUTPUT: R-OTHER_v = POSITION VECTOR
V-OTHER_v = VELOCITY VECTOR

QPRET
←
TCPINAD

LOAD EXIT FOR
INTWAKE ROUTINE

INTWAKE
RELEASE GRAB
OF INTEGRATION
FC-3350

TCPIN

PINBRNCH

TERMINATE EXTENDED VERB

EXTENDED VERB 80

V80E KEYED IN
BY ASTRONAUT

LEMVEC

CLEAR
VEHUPFLG

LM STATE VECTOR
BEING UPDATED

EXTENDED VERB 81

V81E KEYED IN
BY ASTRONAUT

CSMVEC

SET
VEHUPFLG

CSM STATE VECTOR
BEING UPDATED

NOUPDOWN

CLEAR
NOUPFLAG

ALLOW STATE
VECTOR UPDATES

GOPIN

TERMINATE EXTENDED VERB

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS		STATE VECTOR EXTENDED VERBS	
PROGRAM P.Fy 2	20 JUNE 67	LUMINARY 1D	DOCUMENT NO.
ANALYST			FC-3605
DOCMR J.C. Doughty	4 JUNE 67		
APPR'D <i>[Signature]</i>	20 JUNE 67	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	SII, 2
INTSTALL	FC-3350	TEST AVAILABILITY OF INTEGRATION, GRAB IF AVAILABLE	SII, 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	SII, 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	PERMANENT LM STATE VECTOR IN LUNAR SPHERE	PERMANENT LM STATE VECTOR IN EARTH SPHERE			SII, 2
NOUPFLAG FLAG1BIT6	DO NOT ALLOW STATE VECTOR UPDATES	ALLOW STATE VECTOR UPDATES		SII, 3	
VEHUPFLG FLAG1BIT8	CSM STATE VECTOR BEING UPDATED	LM STATE VECTOR BEING UPDATED	SII, 3	SII, 3	

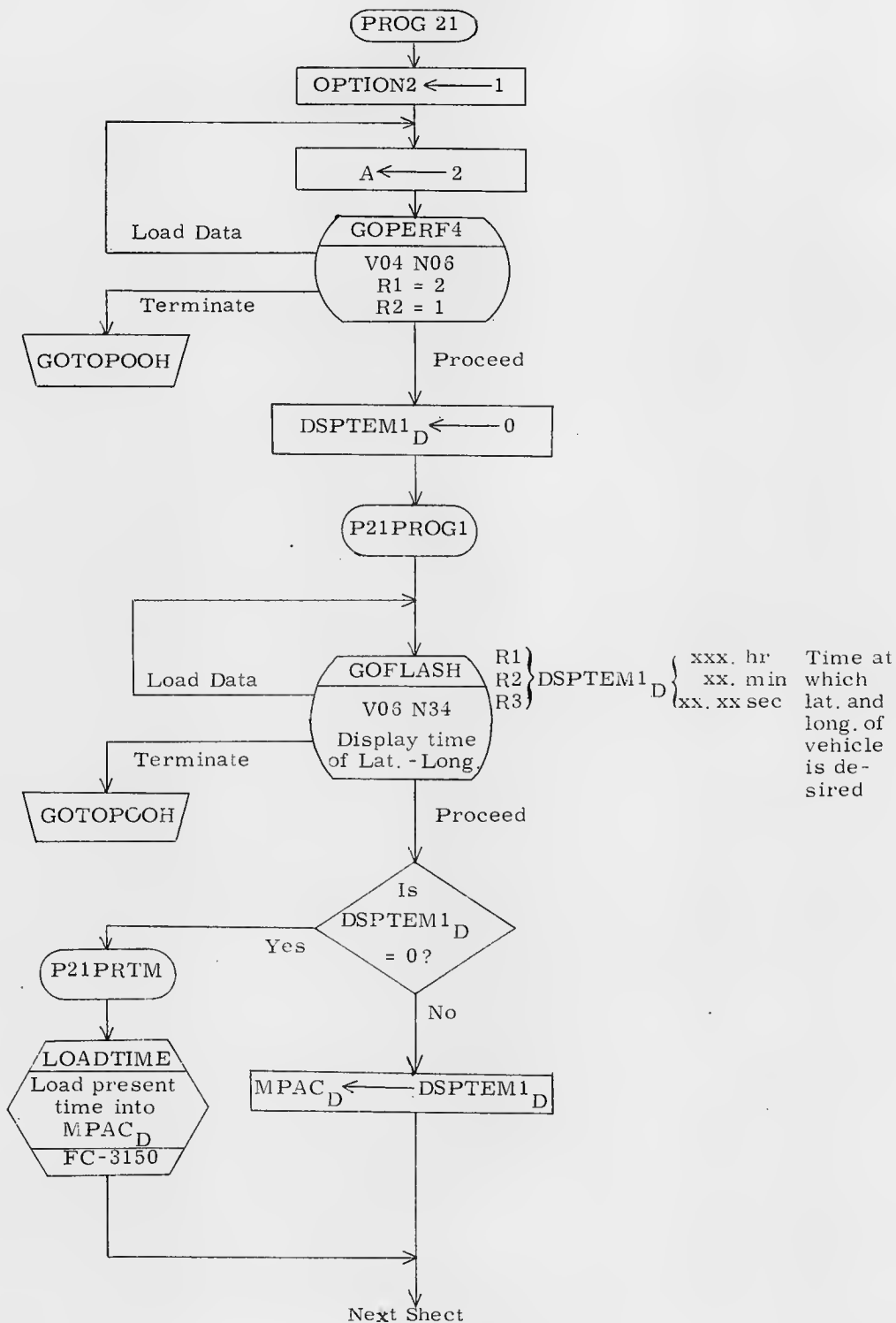
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		STATE VECTOR EXTENDED VERBS	
DRAWN A.C. WILLIAMS	6 MAY 68		
PROGRAM P. King	20 JUN 68		
ANALYST		LUMINARY 1D	DOCUMENT NO.
DOCNR MC-1000	4-JUNE 67		FC-3605
APPR'D B.L. de G. Grant	REV 3		SHEET 4 OF 4

GROUND TRACK DETERMINATION

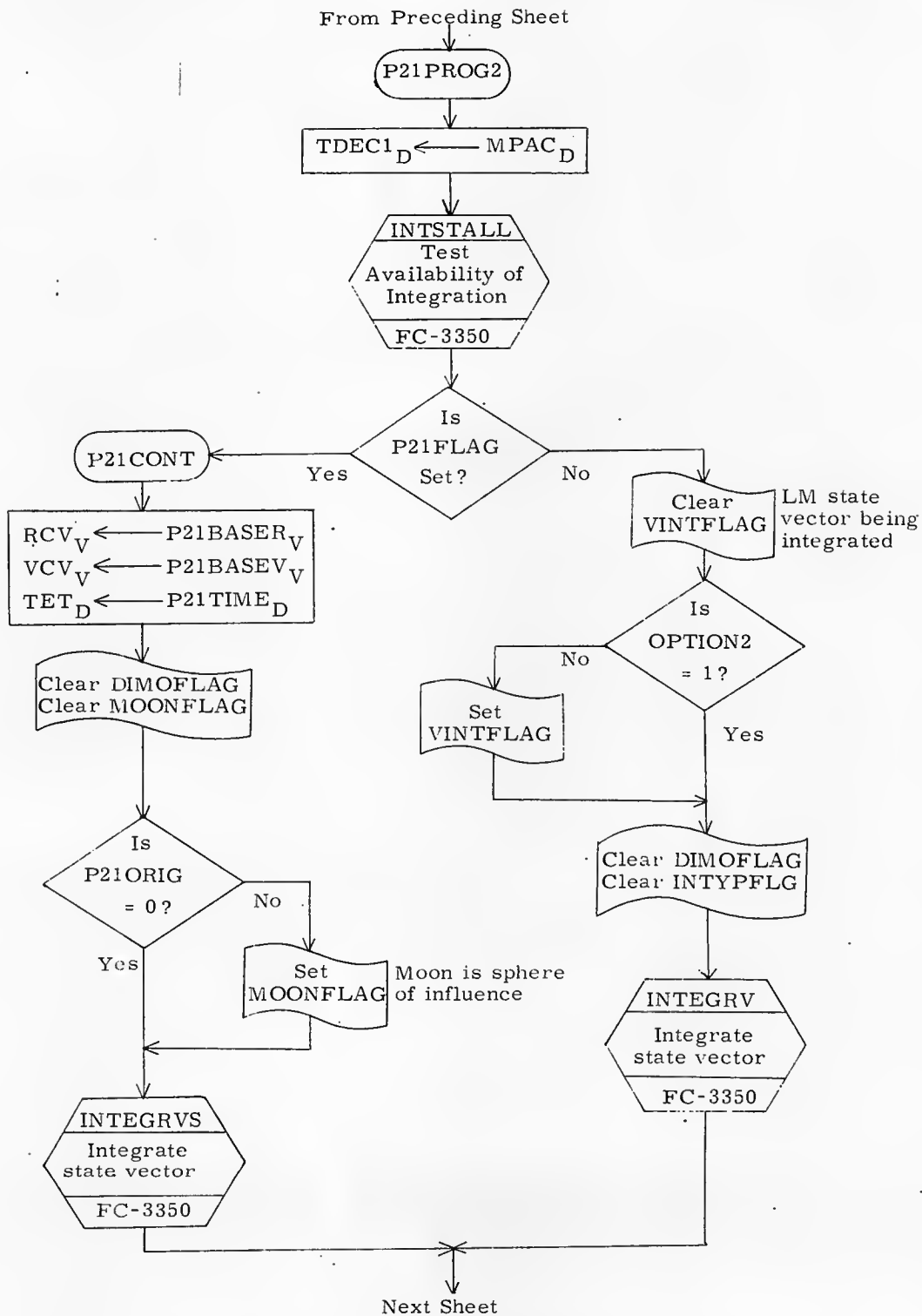
PROG 21

Sh. 2

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		Ground Track Determination	
DRAWN <i>J. Flaherty</i>	<i>10/27/69</i>		
PROGR <i>Bruce M. Key</i>	<i>10/27/69</i>		
INDST		LUMINARY 1D	DOCUMENT NO. FC-3610
DCWR <i>W. Doughty</i>	<i>10/27/69</i>		
APPR <i>Robert M. Estes</i>	<i>10/27/69</i>	REV 2	SHEET 1 OF 6



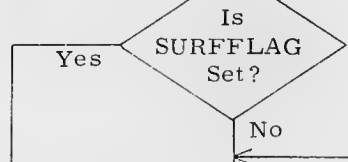
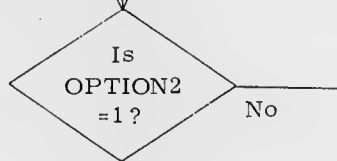
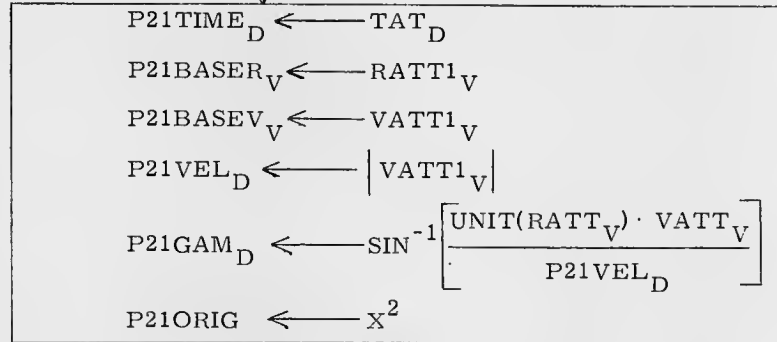
MIT INSTRUMENTATION LAB. CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. Flaherty</i> 10/27/69		Ground Track Determination	
PROJECT <i>Bruce McCoy</i> 10/27/69		DOCUMENT NO.	
ANALYST		LUMINARY 1D	FC-3610
CHECKED <i>W. Douglas</i> 10/27/69		REV 2	
APPROVED <i>Robert M. Swain</i> 10/27/69		SHEET 2 OF 6	



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	J. Elabarchy	10/27/69	Ground Track Determination
PROGR	Russell McLaughlin	10/27/69	
ANALST			DOCUMENT NO. FC-3610
OCORR	M. Douglas	10/27/69	
APPR'D	Robert M. Estlin	10/27/69	LUMINARY 1D
			REV 2
			SHEET 3 OF 6

From Preceding Sheet

P21VSAVE



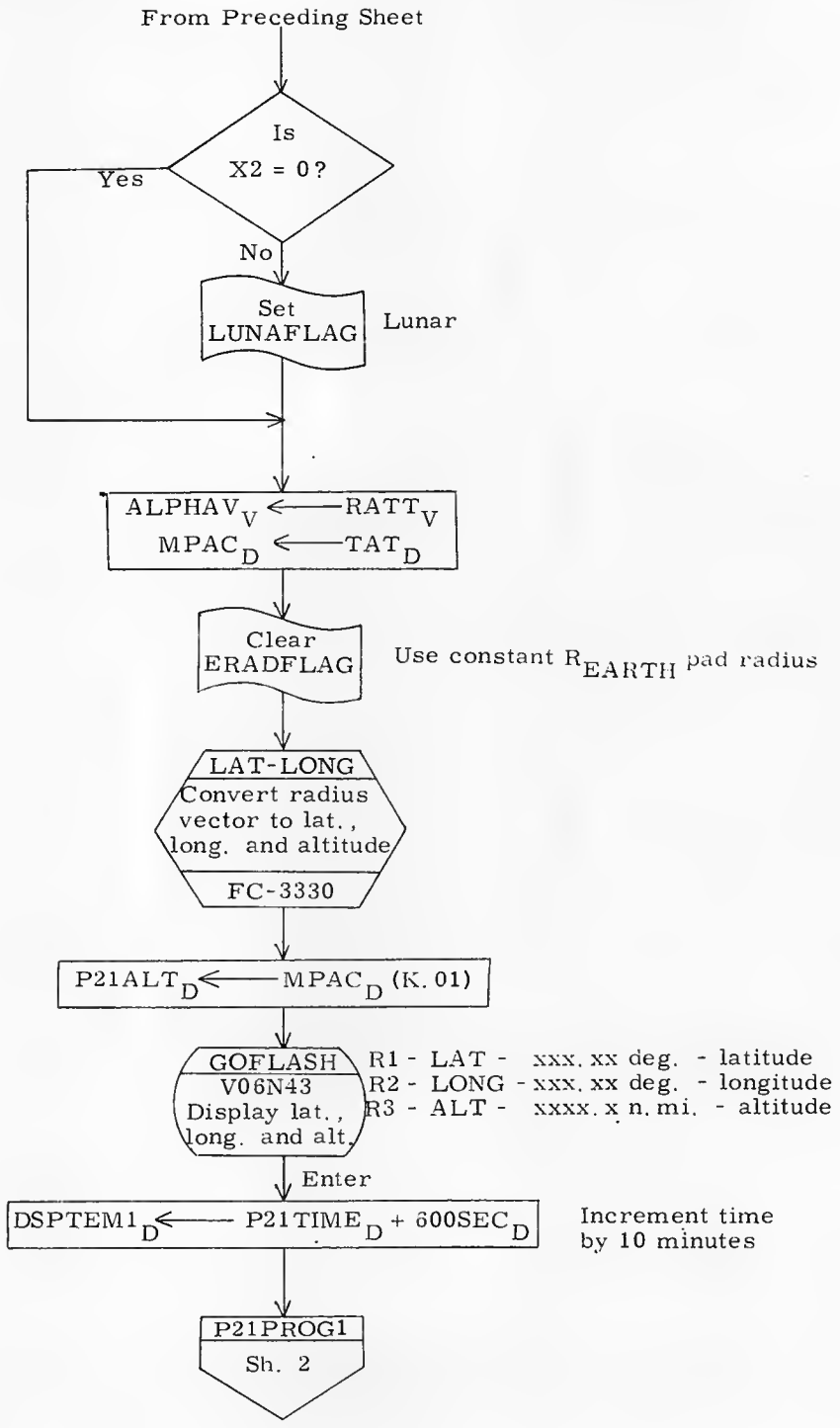
Set P21FLAG Use base vectors already calculated

P21DSP

Clear LUNAFLAG Earth LAT-LONG

Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		Ground Track Determination	
DRAWN <i>J. Flaherty</i>	<i>10/27/69</i>	LUMINARY 1D	DOCUMENT NO. FC-3610
PROGRAMMER <i>Bruce A. Kelley</i>	<i>10/27/69</i>		
ANALYST			
DOCTR <i>W. DeGroot</i>	<i>10/27/69</i>		
APPROV <i>Robert M. Estes</i>	<i>10/27/69</i>	REV 2	SHEET 4 OF 6



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. Flaherty</i> 10/27/69		Ground Track Determination	
PROGR <i>James McLaughlin</i> 10/27/69		LUMINARY 1D	DOCUMENT NO. FC-3610
ANALYST <i>J.</i>			REV 2
DCOMR <i>W. Engle</i> 10/27/69			
APPROV <i>Robert M. Estes</i> 10/27/69			

SUBROUTINES CALLED ON OTHER FLOWCHARTS

<u>Subroutine</u>	<u>Flowchart</u>	<u>Where Called</u>
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
DIMOF 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 3 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

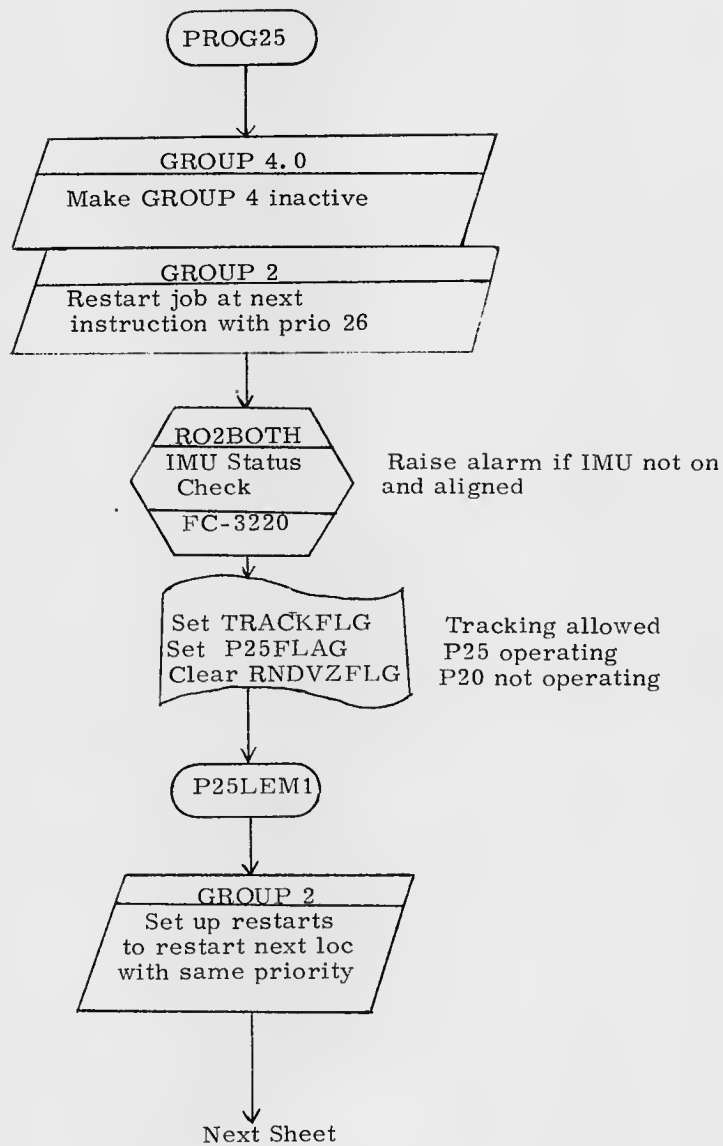
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. Flaherty</i> 10/27/69		Ground Track Determination	
PROGR <i>Bruce McCloy</i> 10/27/69	LIST <i>J.</i>	LUMINARY 1D	DOCUMENT NO. FC-3610
DCOMR <i>W. Dwyer</i> 10/27/69	APPROD <i>Robert M. Carter</i> 10/27/69		REV 2

P25 PREFERRED TRACKING ATTITUDE
 MAJOR SUBROUTINES ON THIS CHART

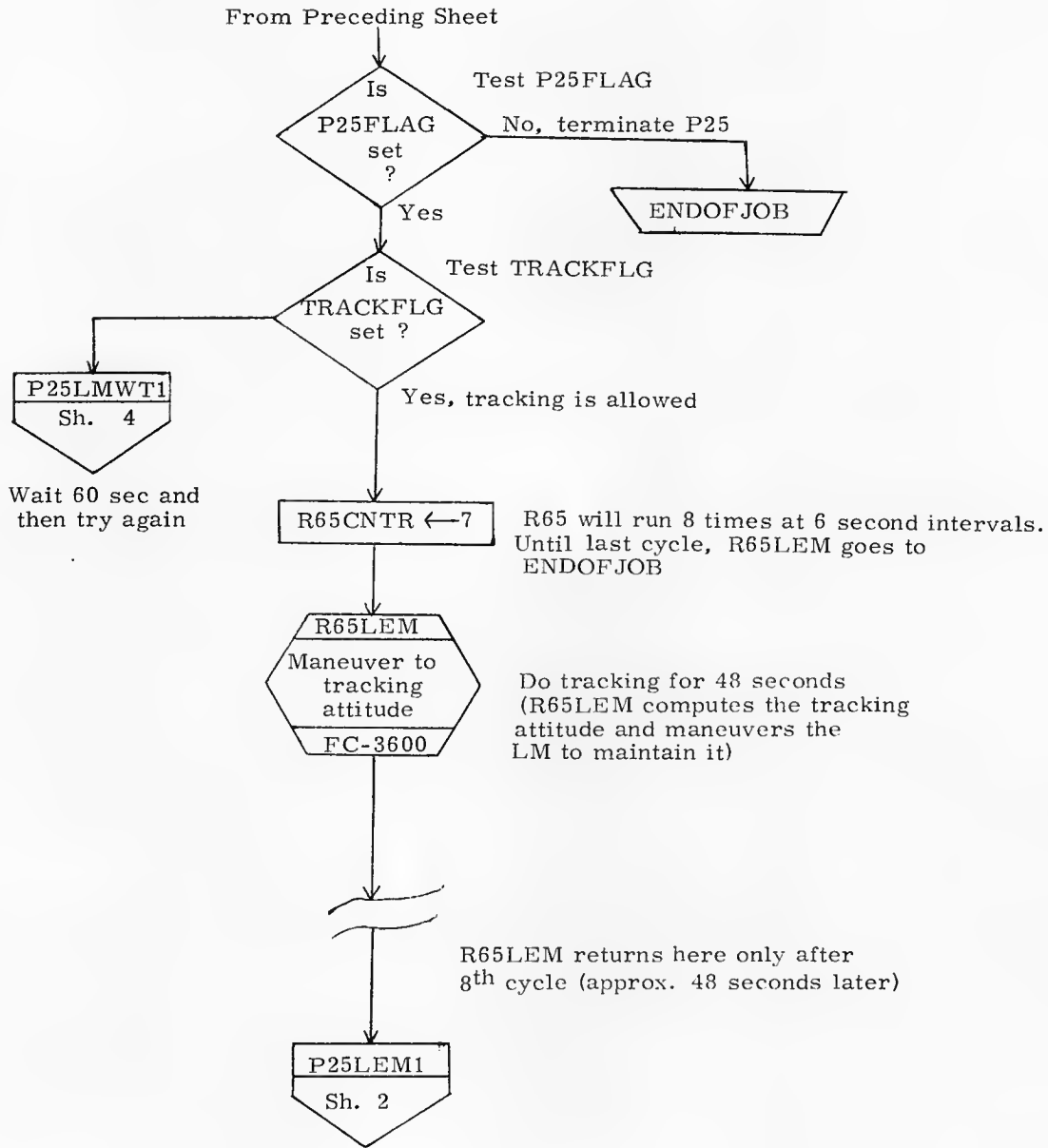
PROG25

Sh. 2

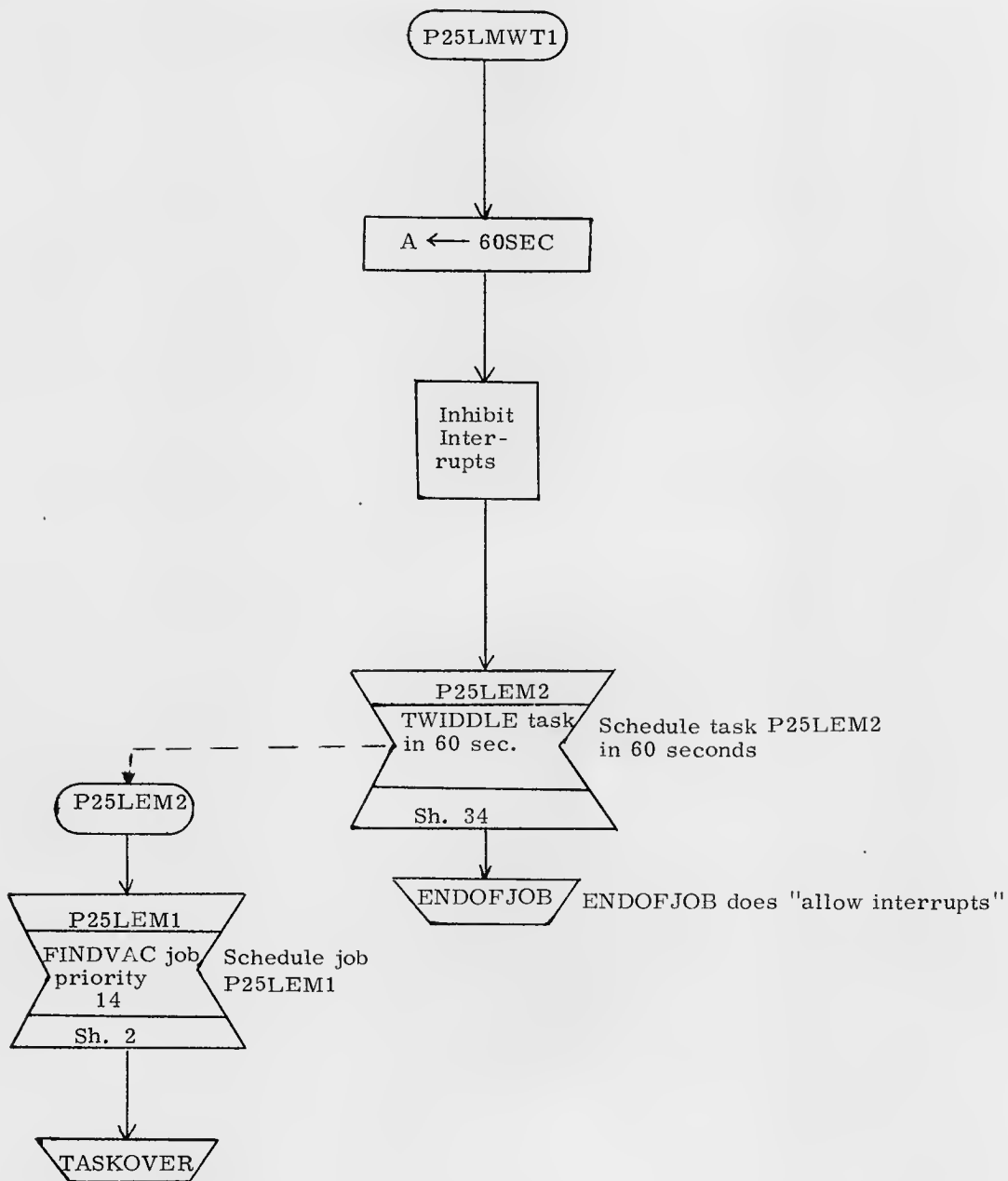
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>P. L. ...</i> 9/14/69		Preferred Tracking Attitude	
PRGMR <i>P. Volante</i> 10/21/69		LUMINARY 1D	DOCUMENT NO. FC-3620
ANALST			
DOCMR <i>W. Dayforth</i> 9/30/69			
APPR'D <i>Robert M. Ester</i> 10/21/69		REV 3	SHEET 1 OF 5



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>P. Volante</i>	9/22/69	Preferred Tracking Attitude	
PRGMR <i>P. Volante</i>	10/21/69	LUMINARY 1D	DOCUMENT NO. FC-3620
ANALST			
DOCMR <i>W. Siefert</i>	7/30/69		
APPR'D <i>Robert M. Estes</i>	10/21/69	REV 3	SHEET 2 OF 5



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. V. Volante</i>	<i>9/13/67</i>	Preferred Tracking Attitude	
PRGMR <i>C. Volante</i>	<i>10/21/69</i>	LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3620
DOCMR <i>W. D. Sanford</i>	<i>9/30/67</i>		
APPR'D <i>R. V. Volante</i>	<i>M. E. E. J. 10/21/69</i>	REV 3	SHEET 3 OF 5



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>Robert M. Estes</i> 9/22/68	Preferred Tracking Attitude	
PRGMR	<i>G. Veloso</i> 10/21/69	LUMINARY ID	DOCUMENT NO.
ANALST			FC-3620
DOCMR	<i>W. D. Griffith</i> 7/30/69		
APPR'D	<i>Robert M. Estes</i> 10/21/69	REV 3	SHEET 4 OF 5

SUBROUTINES
ON OTHER CHARTS
R02BOTH
R65LEM

IMU Status Check

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	

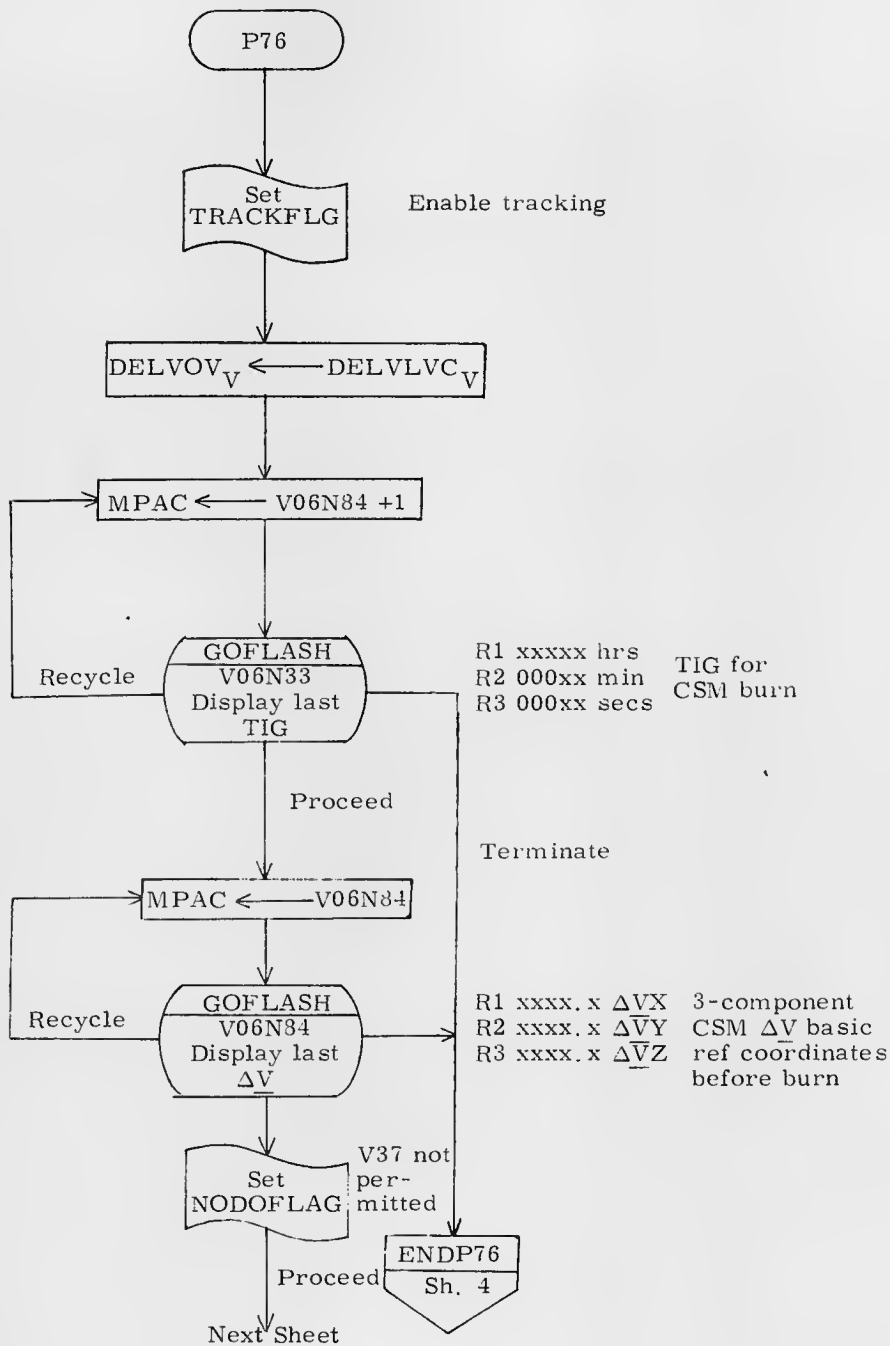
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>P. Volante</i>	<i>9/24/69</i>	Preferred Tracking Attitude	
PRGMR <i>P. Volante</i>	<i>10/21/69</i>	LUMINARY 1D	DOCUMENT NO. FC-3620
ANALST			
DOCMR <i>W. Douglas</i>	<i>9/30/69</i>		
APPR'D <i>R. F. ...</i>	<i>10/21/69</i>	REV 3	SHEET 5 OF 5

P76 TARGET DELTA VELOCITY

P76

Sh. 2

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P76 Target Delta V	
DRAWN <i>J. Flaherty</i>	<i>10/8/69</i>		DOCUMENT NO.
PRGMR <i>T.E. Crocker</i>	<i>1/27/70</i>		
ANALST			
DOCMR <i>Robert M. Estes</i>	<i>1/27/70</i>	LUMINARY 1D	FC-3640
APPR'D <i>Robert M. Estes</i>	<i>1/27/70</i>	REV 1	SHEET 1 OF 9



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. Flaherty</i>		P76 Target Delta V	
PRGMR <i>T. E. Coaker</i>		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3640
DOCMR <i>Robert M. Estes</i>		REV 1	SHEET 2 OF 9
APPR'D <i>Robert M. Estes</i>			

From Preceding Sheet

TDEC1 ← TIG

OTHPREC
Precision
integrate CSM
state vector to
TIG
FC-3350

Same as CSMPREC
update CSM to TIG

Input: TIG in TDEC1
Output: RATT, VATT
of CSM at TIG

COMPMAT

24D ← unit (-R)
18D ← unit (V x R)
12D ← unit (V x R) X - R

Obtain CSM coordinate
transformation matrix

MPAC_V ← DELVOV_V

ΔV @ TIG of other vehicle

$$\Delta V_V(LV) = \left\{ \Delta V_V(\text{ref}) \times \text{unit} \left[(R \times V) \times R \right] \right\} + V_V(\text{TIG})$$

$${}^6D_V \leftarrow (MPAC_V \times 12D_M) + VATT_V$$

Burn ΔV transformed to LV
coordinates and added to
CSM velocity at TIG

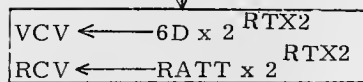
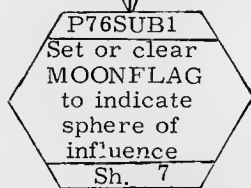
INTSTALL
Reserve
orbital
integration
FC-3350

Check availability of integration

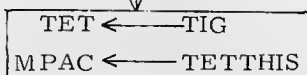
Next Sheet

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

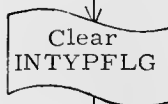
From Preceding Sheet



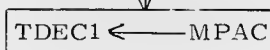
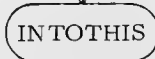
Scale V, R CSM on X2
 $2^0/2^2$ EARTH/MOON



Store TIG, TETTHIS



Bit 4, Flagword 3 Encke integration



TIG for INTEGRVS

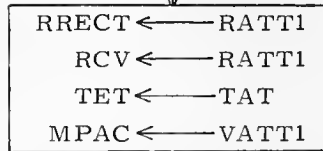
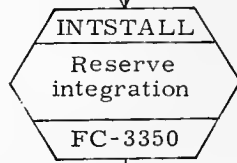


Input: TIG
 Output: RATT, VATT of LM @ TIG

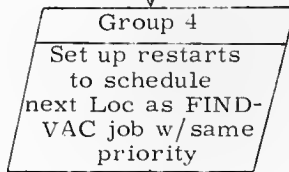
Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. Flaherty</i> 10/8/69		P76 Target Delta V	
PRGMR <i>T. E. Crocker</i> 1-27-70		DOCUMENT NO.	
ANALST		LUMINARY ID	FC-3640
DOCMR <i>Robert M. Estes</i> 11/27/70		REV 1	SHEET 4 OF 9
APPR'D <i>Robert M. Estes</i> 11/27/70			

From Preceding Sheet



Save LM position, velocity,
time integrated to

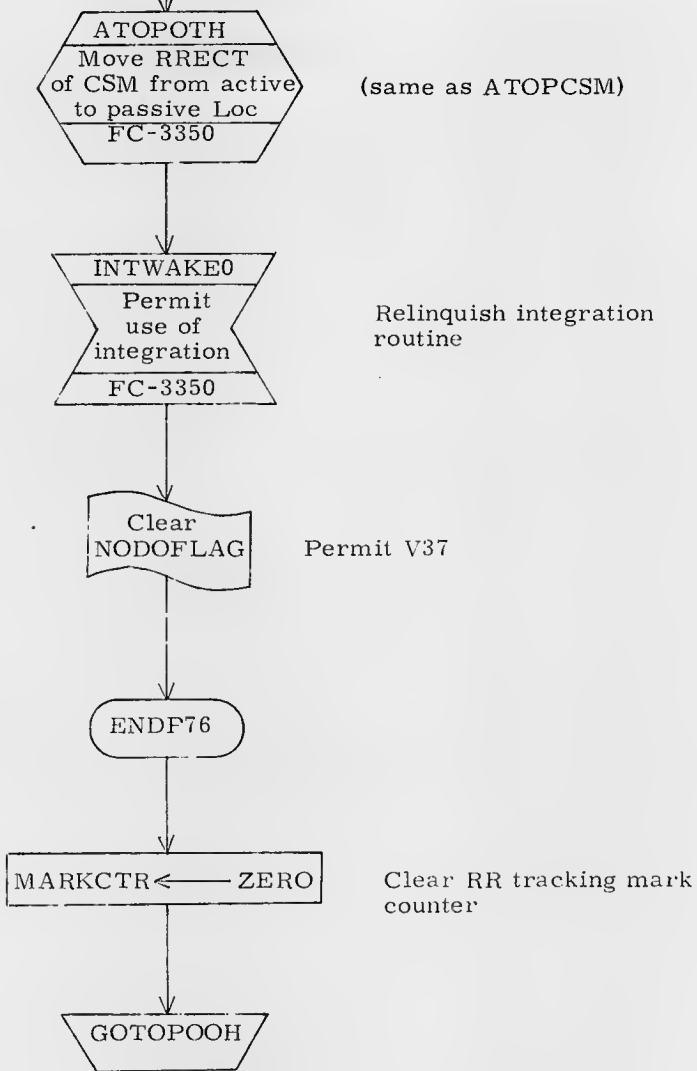


Bit 7, Flag 10
Integration routine to be restarted

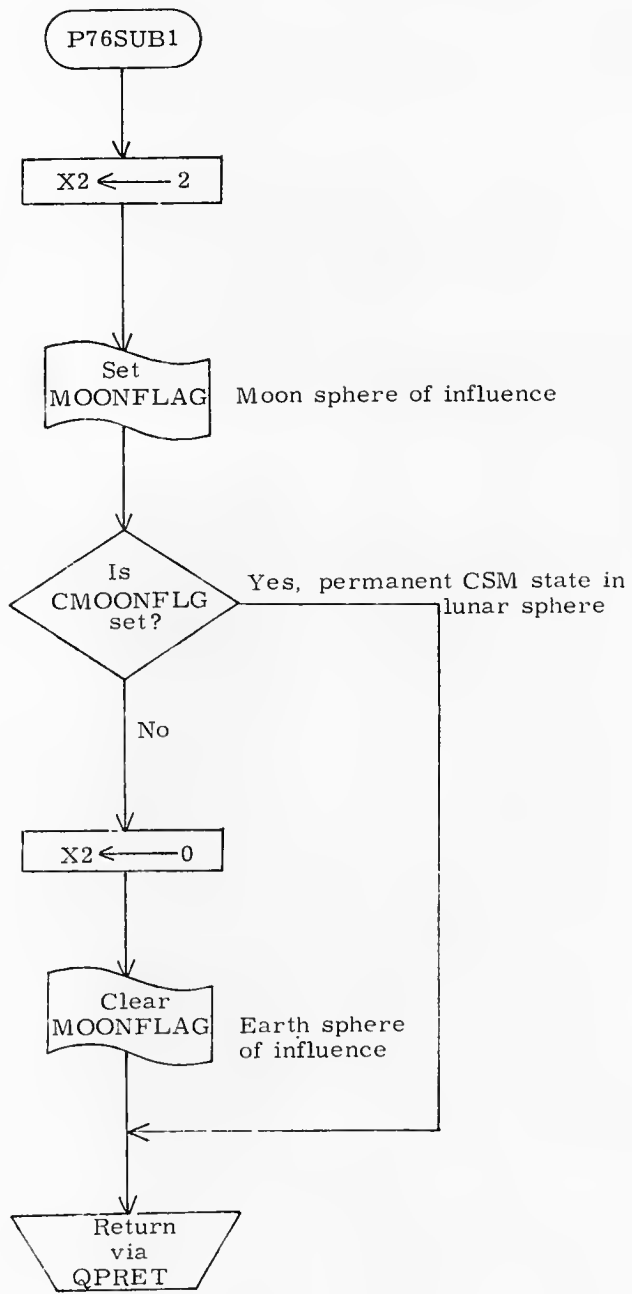
Next Sheet

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

From Preceding Sheet



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		LUMINARY 1D	FC-3640
DOCMR	Robert M. Estes 1/27/70	REV 1	SHEET 6 OF 9
APPR'D	Robert M. Estes 1/27/70		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P76 Target Delta V	
DRAWN <i>R. Wick</i>	<i>12/1/68</i>		
PRGMR <i>T. E. Coker</i>	<i>1-27-70</i>	DOCUMENT NO.	
ANALST		FC-3640	
DOCMR <i>Robert M. Ertel</i>	<i>1/27/70</i>	LUMINARY 1D	
APPR'D <i>Robert M. Ertel</i>	<i>1/27/70</i>	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	

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P76 Target Delta V	
DRAWN <i>T. E. Cooley</i>	<i>1/27/70</i>		DOCUMENT NO.
PRGMR <i>T. E. Cooley</i>	<i>1-22-70</i>		FC-3640
ANALST		LUMINARY 1D	
DOCMR <i>Roberto M. Estes</i>	<i>1/27/70</i>	REV 1	SHEET 8 OF 9
APPR'D <i>Roberto M. Estes</i>	<i>1/27/70</i>		

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 ΔV	Sh. 2
V06N33		Display last TIG	Sh. 2

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>(Signature)</i>		P76 Target Delta V	
PRGMR <i>T. E. Coche</i>	<i>1-27-70</i>	LUMINARY 1D	DOCUMENT NO. FC-3640
ANALST			
DOCMR <i>Robert M. Estes</i>	<i>1/27/70</i>	REV 1	SHEET 9 OF 9
APPR'D <i>Robert M. Estes</i>	<i>1/27/70</i>		



11.0 PRE-THRUST TARGETING PROGRAMS

P30 - EXTERNAL DELTA V
 MAJOR SUBROUTINES ON THIS CHART

P30 Sh. 2
 S30.1 Sh. 4

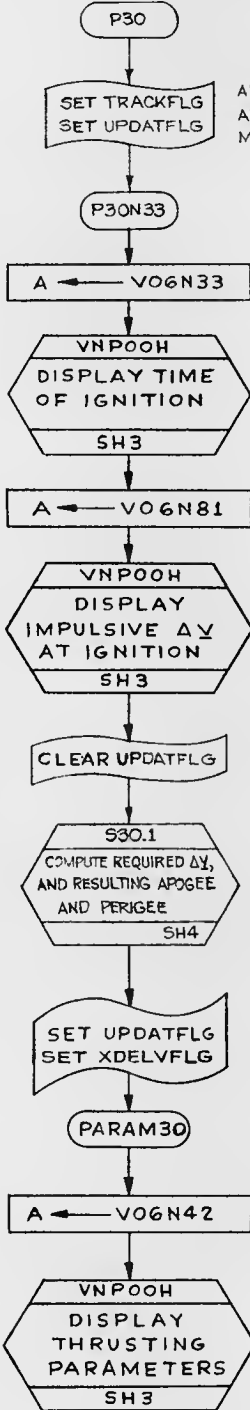
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>L. Gilbertson</i> 9/2/69		P30 EXTERNAL DELTA V	
PRGMR		LUMINARY 1D	DOCUMENT NO. FC-3700
ANALST <i>Peter J. Hillier</i>	9/16/69		
DOCMR <i>W.C. Hughes</i>	9/26/69		
APPR'D <i>Robert M. Estes</i>	9/26/69	REV 3	SHEET 1 OF 6

CALLED FROM DSKY WITH
V3TE30E PRIORITY 13

INPUT: TIG_D = TIME OF IGNITION
 $DELVSLV_V$ = IMPULSIVE ΔV IN LOCAL
VERTICAL COORDINATES
(MAY BE LOADED BY THE CREW AT THE
FOLLOWING DISPLAYS OR VIA UPLINK
WITH VT2)

OUTPUT TO THRUST PROGRAMS:
 TIG_D = TIME OF IGNITION
 $DELVSIN_V$ = REQUIRED ΔV IN REFERENCE
COORDINATES
 $XDELVFLG = 1$ = EXTERNAL ΔV
MANEUVER

$R1 = \text{HRS.}$
 $R2 = \text{MIN.}$
 $R3 = \text{SEC.}$ } = TIG_D



ALLOW TRACKING
AND UPDATING BY
MARKS

INHIBIT UPDATING
BY MARKS

INPUT: TIG_D , $DELVSLV_V$
OUTPUT: $4D_D$, $8D_D$, $DELVSIN_V$, $DELVSAB_D$

ALLOW UPDATING
BY MARKS

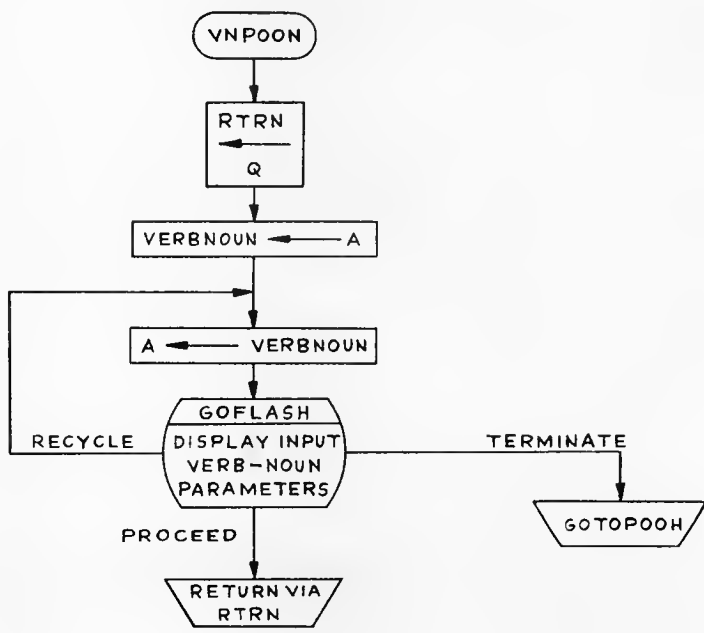
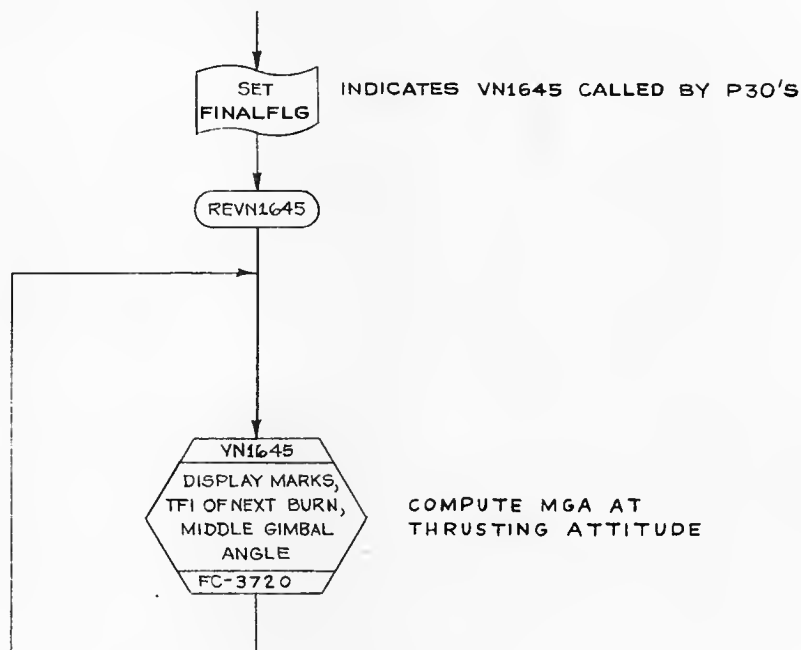
$R1 = DELVSLV = \Delta V_x$ FT/SEC ($DELVSLV_V = DELVLVC_V$)
 $R2 = DELVSLV + 2 = \Delta V_y$ FT/SEC
 $R3 = DELVSLV + 4 = \Delta V_z$ FT/SEC

$R1 = HAPO_D$ - APOGEE ALT NM
 $R2 = HPER_D$ - PERIGEE ALT NM
 $R3 = DELVSAB_D$ - DELTA V FT/SEC

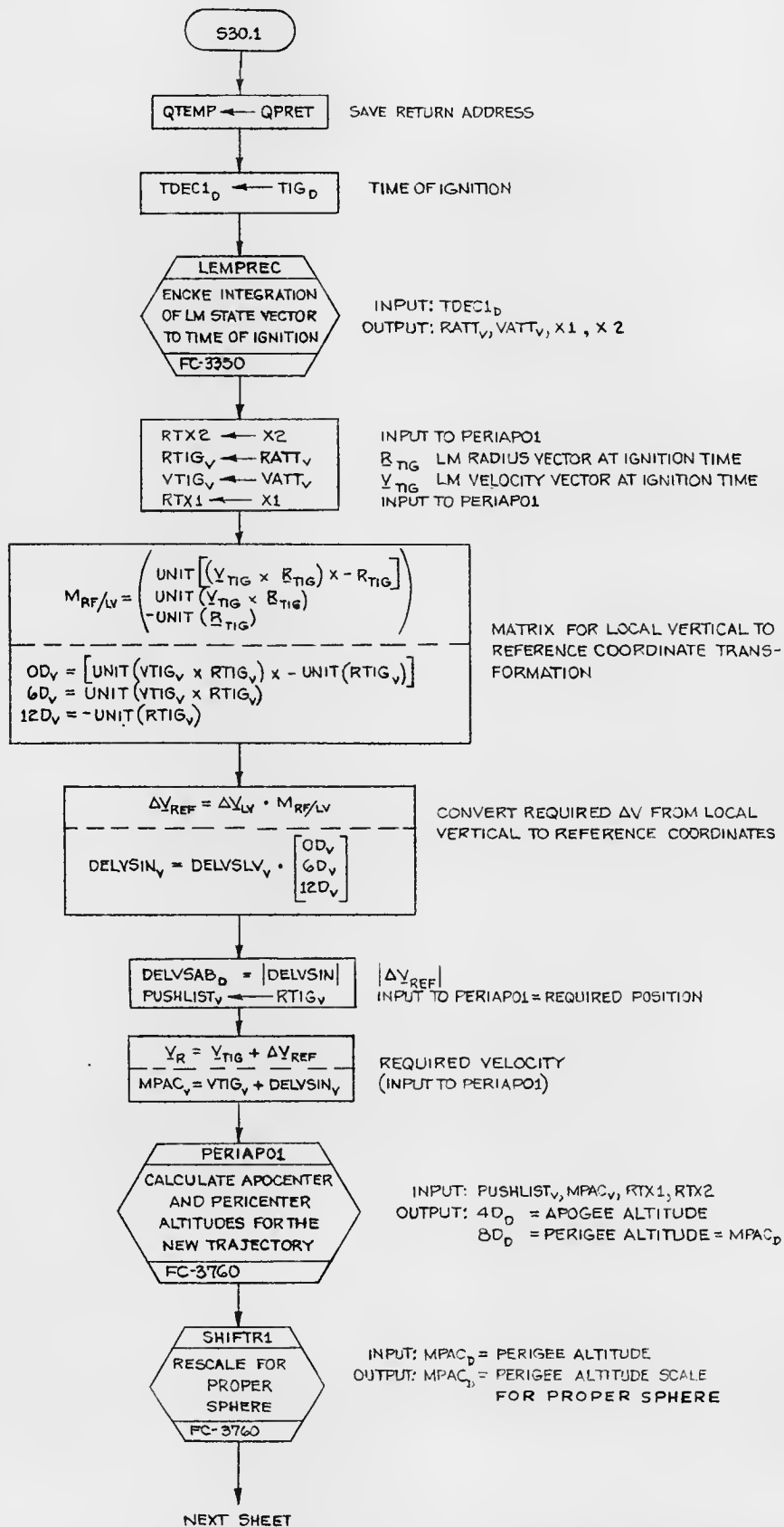
NEXT SHEET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P30 EXTERNAL DELTA V	
DRAWN A.C. WILLIAMS	4-15-68	DOCUMENT NO. FC-3700	
PROGRAM <i>[Signature]</i>	<i>[Signature]</i>	LUMINARY ID	SHEET 2 OF 6
ANALYST <i>[Signature]</i>	<i>[Signature]</i>	REV 3	
APPROV <i>[Signature]</i>	5-15-68		

FROM PRECEDING SHEET

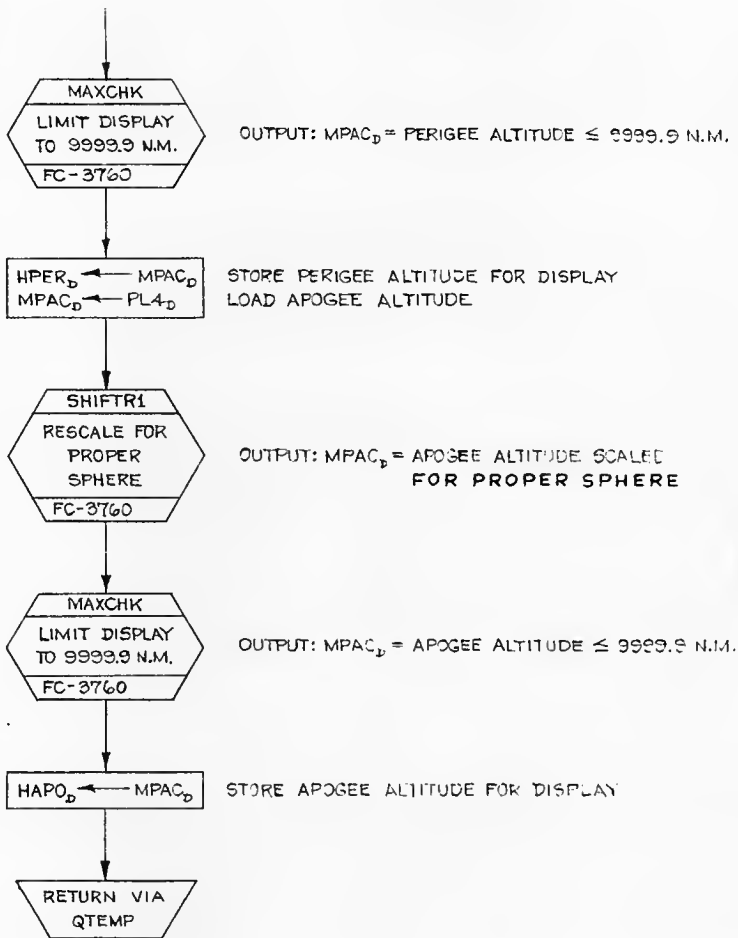


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS		P30 EXTERNAL DELTA V	
PROGRAM		DOCUMENT NO.	
ANALYST <i>Robert Hall</i>		FC-3700	
DOCMR <i>McG...</i>		LUMINARY ID	
APPR'D <i>...</i>		REV 3	
		SHEET 3 OF 6	



RMT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P30 EXTERNAL DELTA V	
DRAWN A.C.WILLIAMS	4-17-68	DOCUMENT NO. FC-3700	
PROGR		LUMINARY 1D	REV 3
ANALST			
DOCMR		SHEET 4 OF 6	
APPR'B			

FROM PRECEDING SHEET



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS		P30 EXTERNAL DELTA V	
PROGR	3JUN65	LUMINARY 1D	DOCUMENT NO. FC-3700
ANLST			REV 3
DOCHR			
APPR'D			

P30 - EXTERNAL DELTA V

SUBROUTINES ON OTHER CHARTS

PERIAP01	COMPUTES THE TWO BODY APOCENTER AND PERICENTER ALTITUDES
VN1645	DISPLAY MARKS, TFI OF NEXT BURN, MIDDLE GIMBAL ANGLE
SIHFTRI	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 PERIAP0)	METERS	B29 (EARTH) B27 (MOON)
RATTI	POSITION VECTOR AT IGNITION TIME	METERS	B29
TDEC1	TIME INPUT TO INTEGRATION	CENTISECONDS	B28
RTIG	RADIUS VECTOR AT IGNITION TIME	METERS	B29
VATTI	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 PERIAP0)	M/CSC	B7 (EARTH) B5 (MOON)
TRKMKCN7	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
DISPDEN	SWITCH TO CONTROL THE OPERATION OF CLOKTASK		B14

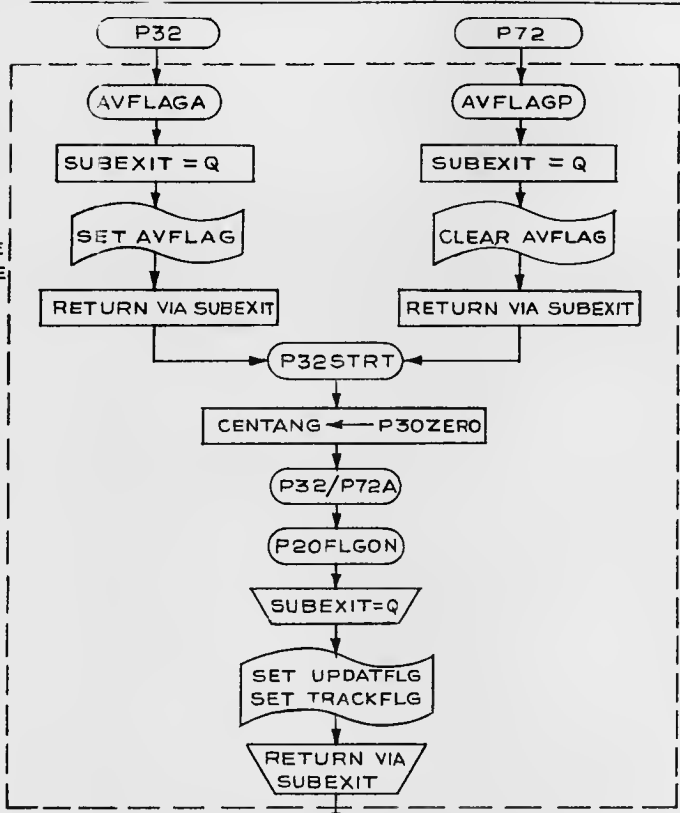
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i>		P30 - EXTERNAL DELTA V	
ANALYST <i>[Signature]</i>		DOCUMENT NO. FC-3700	
APPR'D <i>[Signature]</i>		LUMINARY ID	REV 3
		SHEET 6 OF 6	

P32, P72: CO-ELLIPTIC SEQUENCE INITIATION

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>L. J. D'Amore</i>		P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
FROM <i>FC-3720</i>	27 MAY 68	LUMINARY 1D	DOCUMENT NO.
ANALYST <i>W. Tempelman</i>	15 JUN 68		FC-3720
DOOR <i>Paul Chubb</i>	15 JUN 68	REV 3	SHEET 1 OF 27
APPR'D <i>Alfred M. Swartz</i>	15 JUN 68		

LM IS ACTIVE VEHICLE

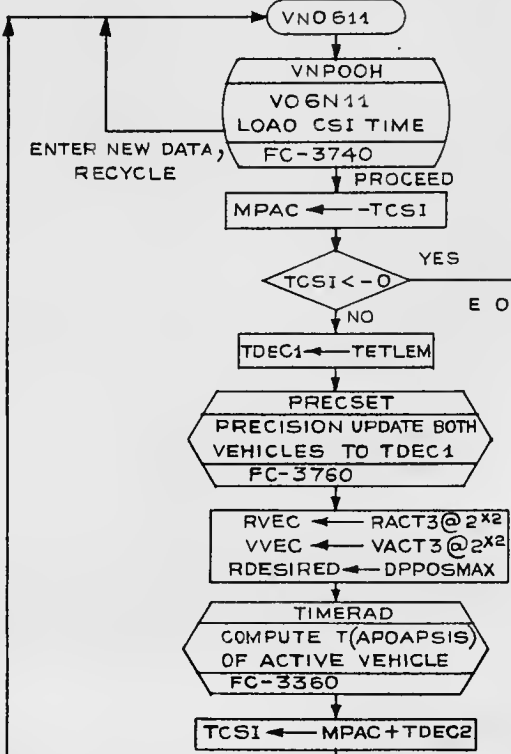
CSM IS ACTIVE VEHICLE BIT 5 FLAG 2



MPAC ← P30ZERO

NN+1 = 0
TCSI = 0
TCSI+1 = 0

NN = NUMBER OF THE FUTURE APSIDAL CROSSING (N) OF THE ACTIVE VEHICLE AT WHICH THE CDH MANEUVER OCCURS. NN+1 = MINOR HALF WHICH MUST BE ZEROED.



R1 - HRS.
R2 - MIN.
R3 - SEC. } = TCSI_{DP}

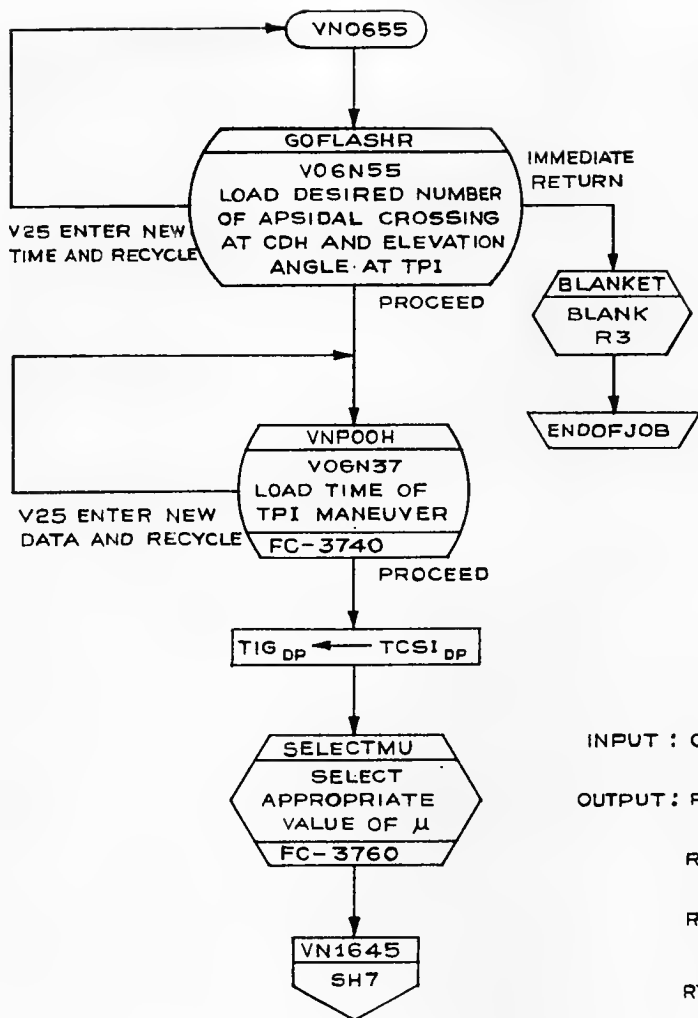
IF TCSI = 0, PROGRAM COMPUTES TIME OF FIRST APSIDAL POINT AND RETURNS IT IN PRECEDING VNO611 DISPLAY.

STORE ACTIVE VEHICLE POSITION, VELOCITY SCALED EARTH/MOON FOR TIMERAD

OUTPUT: APOAPSIS IN MPAC

REENTER AT VNO611 WITH CALCULATED CSI TIME

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i>		P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
PROGR <i>[Signature]</i>	BOJUNY6	DOCUMENT NO.	FC-3720
ANALST <i>[Signature]</i>	1-1-69	LUMINARY 1D	REV 3
DOORR <i>[Signature]</i>	11 Aug 69	SHEET 2 OF 27	
APPR'D <i>[Signature]</i>	17-10-69		



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
 R1 - HRS. } TTPI_{DP}
 R2 - MIN. }
 R3 - SEC. }

INPUT : CMOONFLG { 0 = EARTH
 1 = MOON

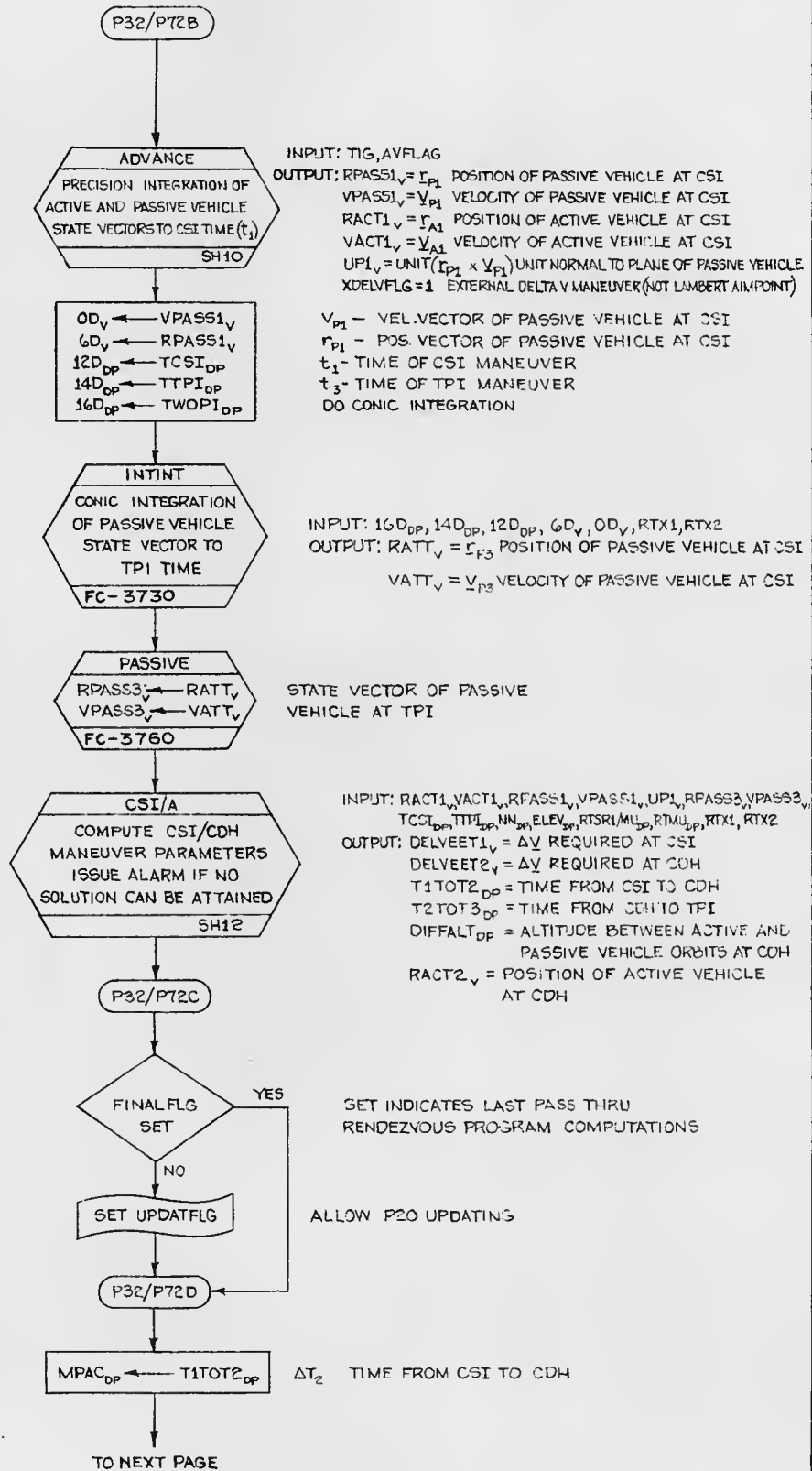
OUTPUT : $RTSR1/\mu_{DP} = \frac{1}{\sqrt{\mu_e}}$ OR $\frac{1}{\sqrt{\mu_m}}$

$RTM_{DP} = \mu_e$ OR μ_m

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

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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>P.M. Diederich</i>		P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
PROGRAM <i>P32</i>	30 JULY 68	DOCUMENT NO.	
ANALYST <i>H. Scarpelone</i>	7-2-69	LUMINARY 1D	FC-3720
DOCARR <i>H. Scarpelone</i>	15 JUN 68	REV 3	SHEET 3 OF 27
APPR'D <i>P.M. Diederich</i>	16 NOV 68		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
DRAWN	A.C. WILLIAMS	4-22-68	DOCUMENT NO. FC-3720
PROWR	<i>M. S. Williams</i>	8-22-68	
ANALST	<i>M. S. Williams</i>	16 Apr 69	
DOCNR	<i>Final Draft</i>	6-7-68	
APPR'D	<i>J. H. Hwang</i>	REV 3	SHEET 4 OF 27

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P32/P72E

$T1TOT2_{DP} \leftarrow MPAC_{DP}$

$MPAC_{DP} \leftarrow T1TOT2_{DP} - 60MIN_{DP}$

MPAC_{DP} ≥ 0 ?

YES

SET TIME FROM GSI TO CDH < 60 MIN.

NO

$MPAC_{DP} \leftarrow T2TOT3_{DP}$

ΔT_3 TIME FROM CDH TO TPI

P32/P72F

$T2TOT3_{DP} \leftarrow MPAC_{DP}$

$MPAC_{DP} \leftarrow T2TOT3_{DP} - 60MIN_{DP}$

MPAC_{DP} ≥ 0 ?

YES

SET TIME FROM CDH TO TPI < 60 MIN.

NO

VNPOOH
VOGN75
DISPLAY GSI/CDH
PARAMETERS
FC-3740

PROCEED

$MPAC_V \leftarrow DELVEET_V$

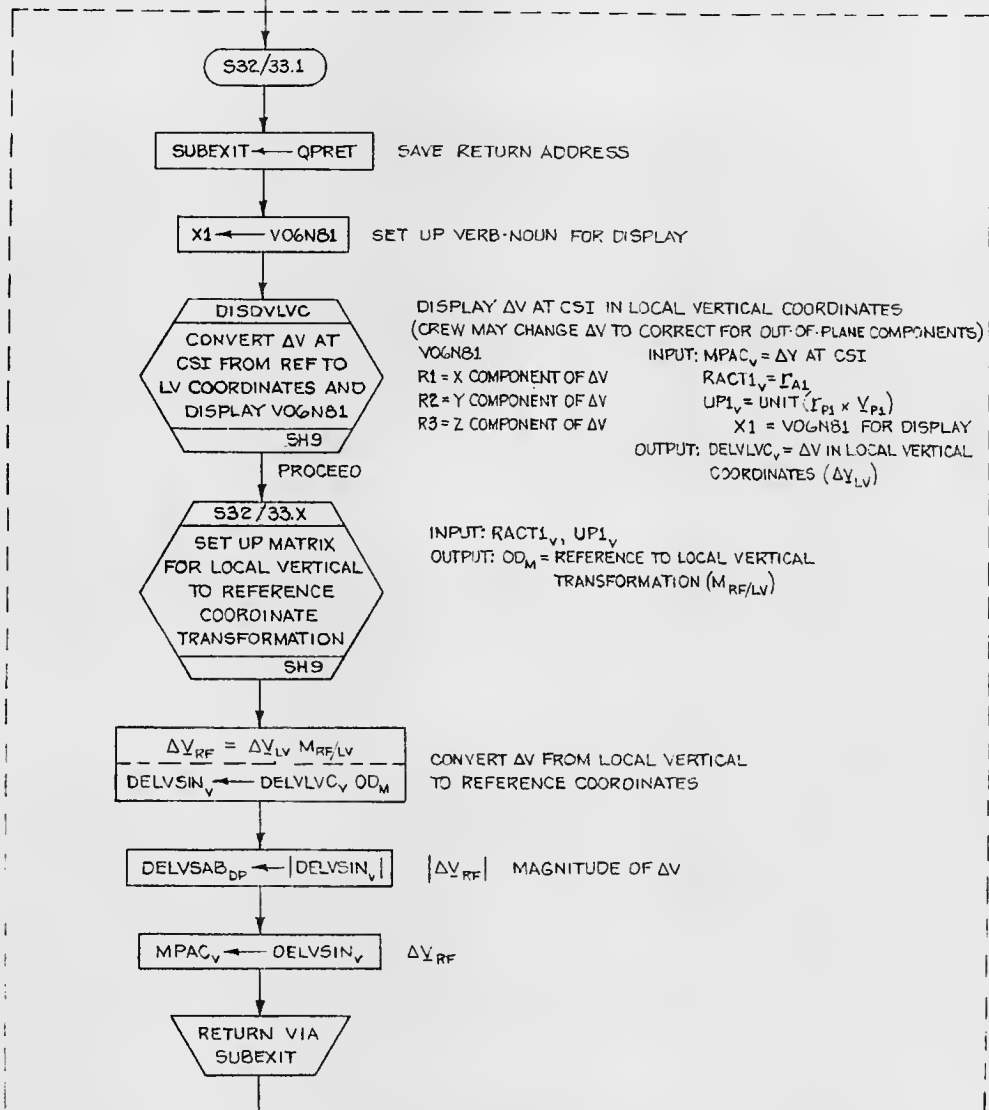
REQUIRED ΔV FOR GSI MANEUVER

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R1 = DIFFALT_{DP} = ALTITUDE BETWEEN ACTIVE AND PASSIVE VEHICLES AT CDH IN NM.
R2 = $T1TOT2_{DP}$ = Δt BETWEEN GSI AND CDH MANEUVERS IN MIN AND SEC.
R3 = $T2TOT3_{DP}$ = Δt BETWEEN CDH AND TPI MANEUVERS IN MIN AND SEC.

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. J. Angillo</i>		P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
PROGRAMMER <i>A. J. Angillo</i>	SIAPROB	DOCUMENT NO.	FC-3720
ANALYST <i>A. J. Angillo</i>	SIAPROB	LUMINARY ID	
DOCTR <i>A. J. Angillo</i>	SIAPROB	REV 3	SHEET 5 OF 27
APPR'D <i>John A. Moore</i>	10/1/69		

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DISPLAY ΔV AT CSI IN LOCAL VERTICAL COORDINATES (CREW MAY CHANGE ΔV TO CORRECT FOR OUT-OF-PLANE COMPONENTS)
 VO6N81 INPUT: MPAC_v = ΔV AT CSI
 R1 = X COMPONENT OF ΔV RACT1_v = Γ_{A1}
 R2 = Y COMPONENT OF ΔV UP1_v = UNIT(Γ_{P1} × Y_{P1})
 R3 = Z COMPONENT OF ΔV X1 = VO6N81 FOR DISPLAY
 OUTPUT: DELVLVC_v = ΔV IN LOCAL VERTICAL COORDINATES (ΔV_{LV})

INPUT: RACT1_v, UP1_v
 OUTPUT: OD_M = REFERENCE TO LOCAL VERTICAL TRANSFORMATION (M_{REF/LV})

CONVERT ΔV FROM LOCAL VERTICAL TO REFERENCE COORDINATES

|ΔV_{RF}| MAGNITUDE OF ΔV

ΔV_{RF}

DELVEET1_v ← MPAC_v ΔV_{RF} NEW VALUE OF ΔV IF MODIFIED BY CREW TO CHANGE OUT-OF-PLANE COMPONENTS

RACT1_v ← RACT2_v Γ_{A2} POSITION OF ACTIVE VEHICLE AT CDH
 MPAC_v ← DELVEET2_v ΔV_{CDH} REQUIRED ΔV AT CDH
 X1 ← VO6N82 VERB-NOUN FOR DISPLAY

DISDLVLC
 CONVERT ΔV AT CDH FROM REF TO LV COORDINATES AND DISPLAY VO6N81
 SH9
 INPUT: MPAC_v = ΔV AT CDH
 R1 = X COMPONENT OF ΔV RACT1_v = Γ_{A2}
 R2 = Y COMPONENT OF ΔV UP1_v = UNIT(Γ_{P1} × Y_{P1})
 R3 = Z COMPONENT OF ΔV X1 = VO6N82 FOR DISPLAY

TTPIO_{DP} ← TTPI_{DP} FOR INPUT TO P33

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MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS		P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
PROWR <i>Pauline</i>	4-23-68	LUMINARY ID	DOCUMENT NO.
ANALST <i>W. Tompkins</i>	8-22-68		FC-3720
DOCMR <i>John J. ...</i>	6-7-68	REV 3	SHEET 6 OF 27

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SUBROUTINE

VN1645

SUBEXIT ← QPRET SAVE RETURN ADDRESS

+MGA_{DP} ← -.01° FOR VIGN45 DISPLAY (MIDDLE GIMBLE ANGLE IS ARBITRARILY DISPLAYED AS -.01 DEGREES UNTIL LAST PASS)

LAST PASS?

NO
FINALFLG SET?

YES

+MGA_{DP} ← -.02° IF IMU IS NOT ALIGNED OR TARGETTING IS BEING DONE FOR THE OTHER VEHICLE, MIDDLE GIMBAL ANGLE IS ARBITRARILY DISPLAYED AS -.02 DEGREES.

IMU ALIGNED?

NO
REFSMFLG SET?

YES

PT2
P3XORP7X
TEST TO SEE IF MAJOR MODE IS A P3X OR PTX
SH23

P32

OD_v ← DELVSIN_v

INPUT: OD_v = REQUIRED ΔV
REFSMMAT + G_v = Y-AXIS OF STABLE MEMBER
OUTPUT: +MGA = POSITIVE MIDDLE GIMBLE ANGLE (0°-360°)

GET+MGA
COMPUTE MGA AT THRUSTING ATTITUDE
FC-3760

GET45

OUTPUT: TTOGO = TIME FROM IGNITION (UPDATED EACH SECOND)

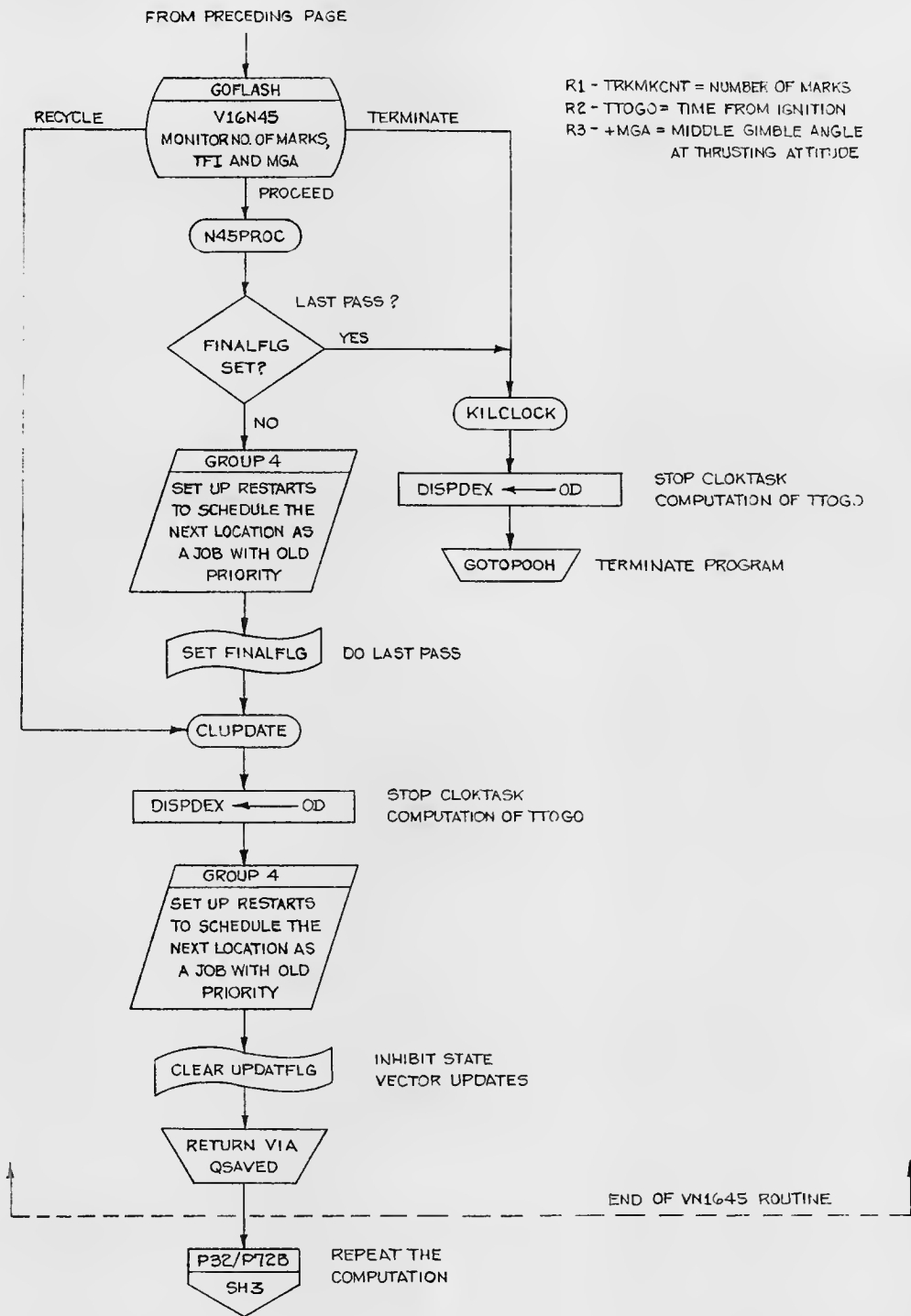
COMPTGO
START CLOKTASK TO CONTINUALLY COMPUTE TTOGO
SH24

QSAVED ← SUBEXIT TRANSFER RETURN ADDRESS

DELAYJOB
WAIT 1 SECOND
FC-3050

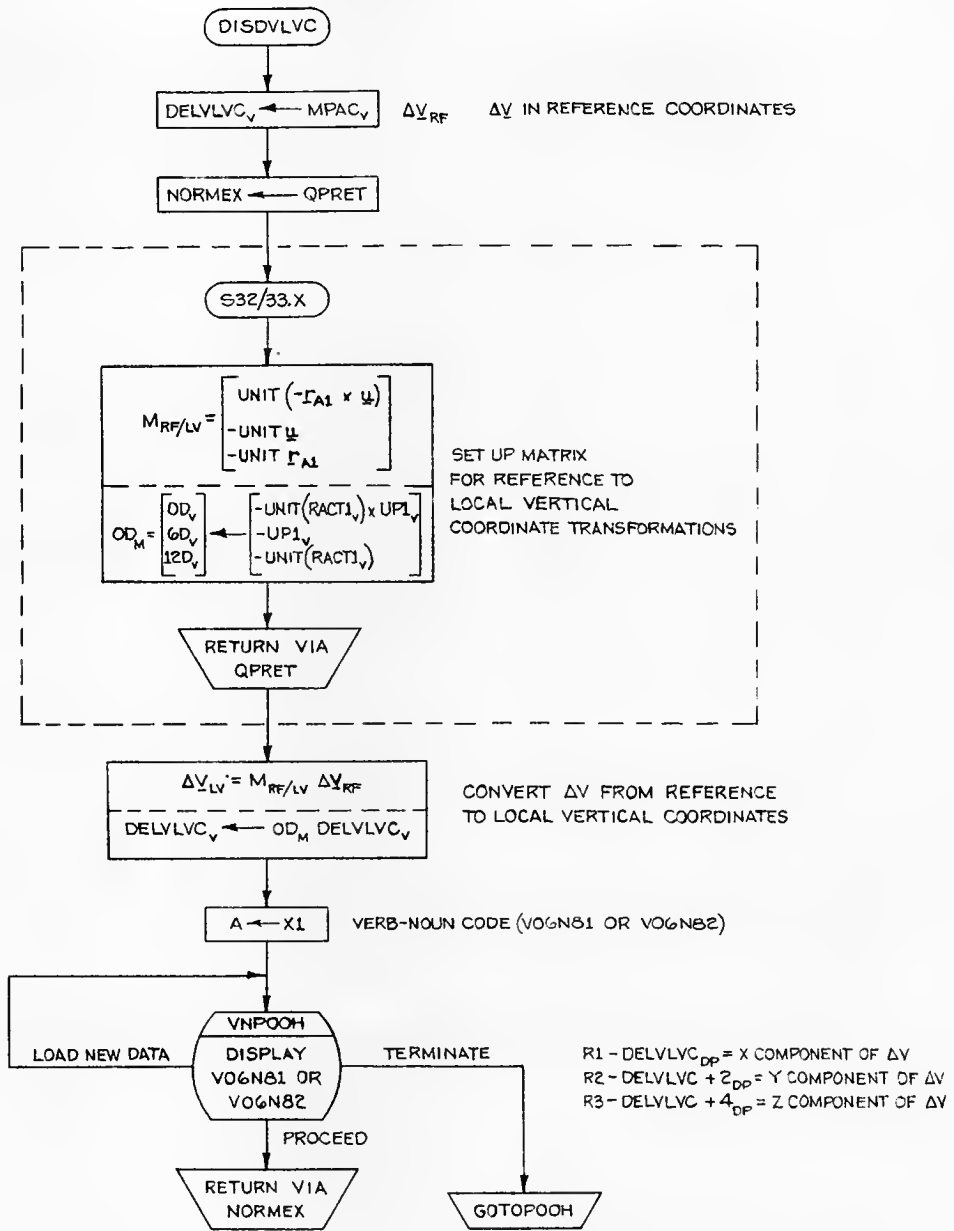
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MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS 4-24-68		P32 AND PT2 CO-ELLIPTIC SEQUENCE INITIATION	
PROGRAM P32/PT2	8-22-68	LUMINARY 1D	DOCUMENT NO. FC-3720
ANALYST W. Thompson	6-7-68		
DOCMR		REV 3	SHEET 7 OF 27

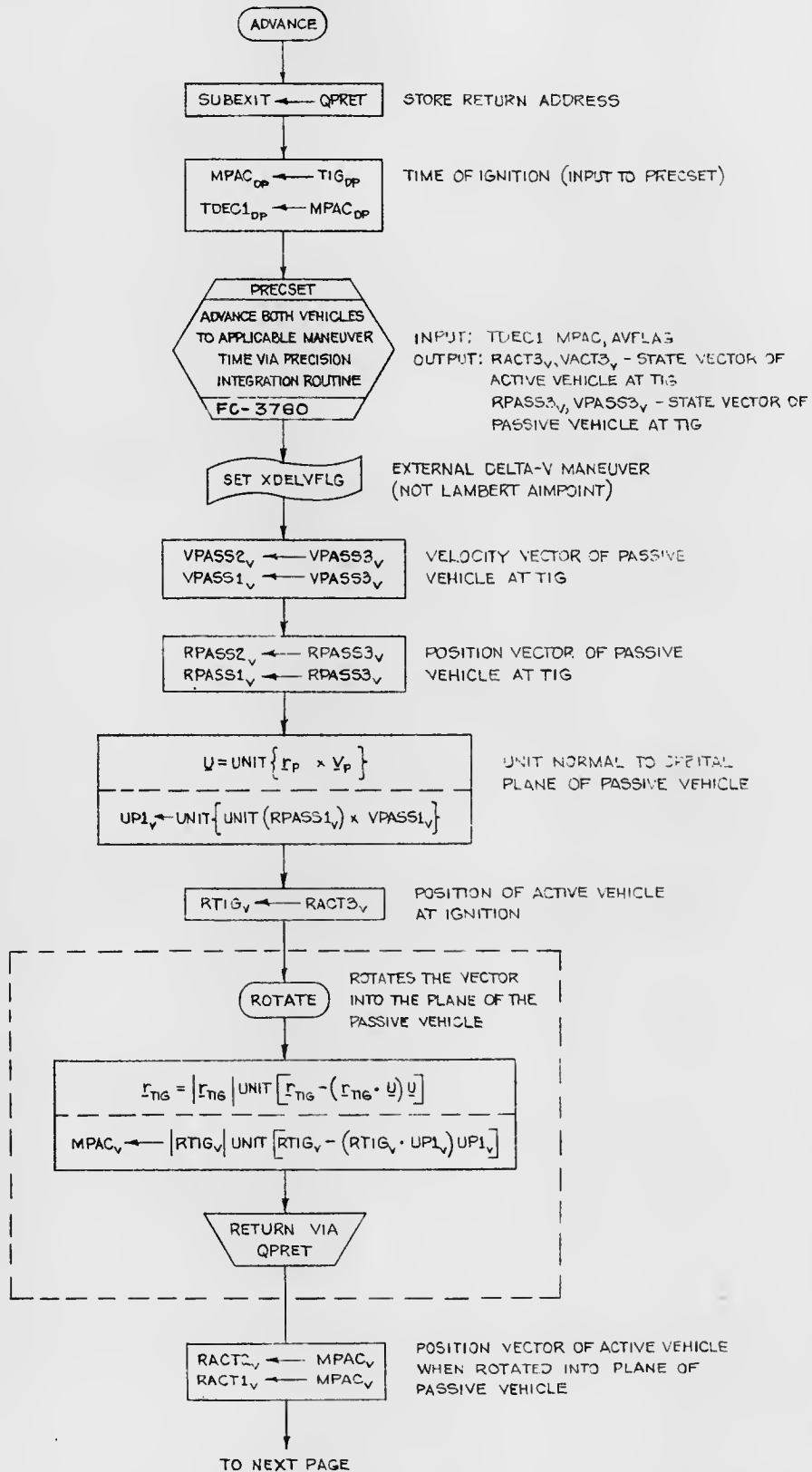


R1 - TRKMKCNT = NUMBER OF MARKS
 R2 - TTOGO = TIME FROM IGNITION
 R3 - +MGA = MIDDLE GIMBLE ANGLE
 AT THRUSTING ATTITUDE

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
BRAWN	A.C.WILLIAMS	4-24-68	DOCUMENT NO. FC-3720
PRGWR	<i>Prohata</i>	8-22-68	
ANALST	<i>H. Tempelmeier</i>		LUMINARY 1D
DOCWR	<i>Heave / Thibault</i>	16 April 69	
APPR'D	<i>J. Heave</i>	6-7-68	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 PROWR <i>P. White</i> ANALST <i>W. Tompkins</i> DOCWR <i>John Kelly</i> APPR'D <i>John Kelly</i>	4-25-68 8-22-68 11-12-68 6-2-68	LUMINARY 1D REV 3	DOCUMENT NO. FC-3720 SHEET 9 OF 27



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS		P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
PROGRAM	5-10-68	DOCUMENT NO.	
ANALYST	8-22-68	LUMINARY 1D	FC-3720
DOCMR	6-14-68	REV 3	SHEET 10 OF 27
APPR'D	6-7-68		

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$VTIG_V \leftarrow VACT3_V$

VELOCITY OF ACTIVE VEHICLE AT IGNITION

ROTATE

$$V_{TIG} = |V_{TIG}| \text{ UNIT } [V_{TIG} - (V_{TIG} \cdot U) U]$$

$$MPAC_V \leftarrow |VTIG_V| \text{ UNIT } [VTIG_V - (VTIG_V \cdot UP1_V) UP1_V]$$

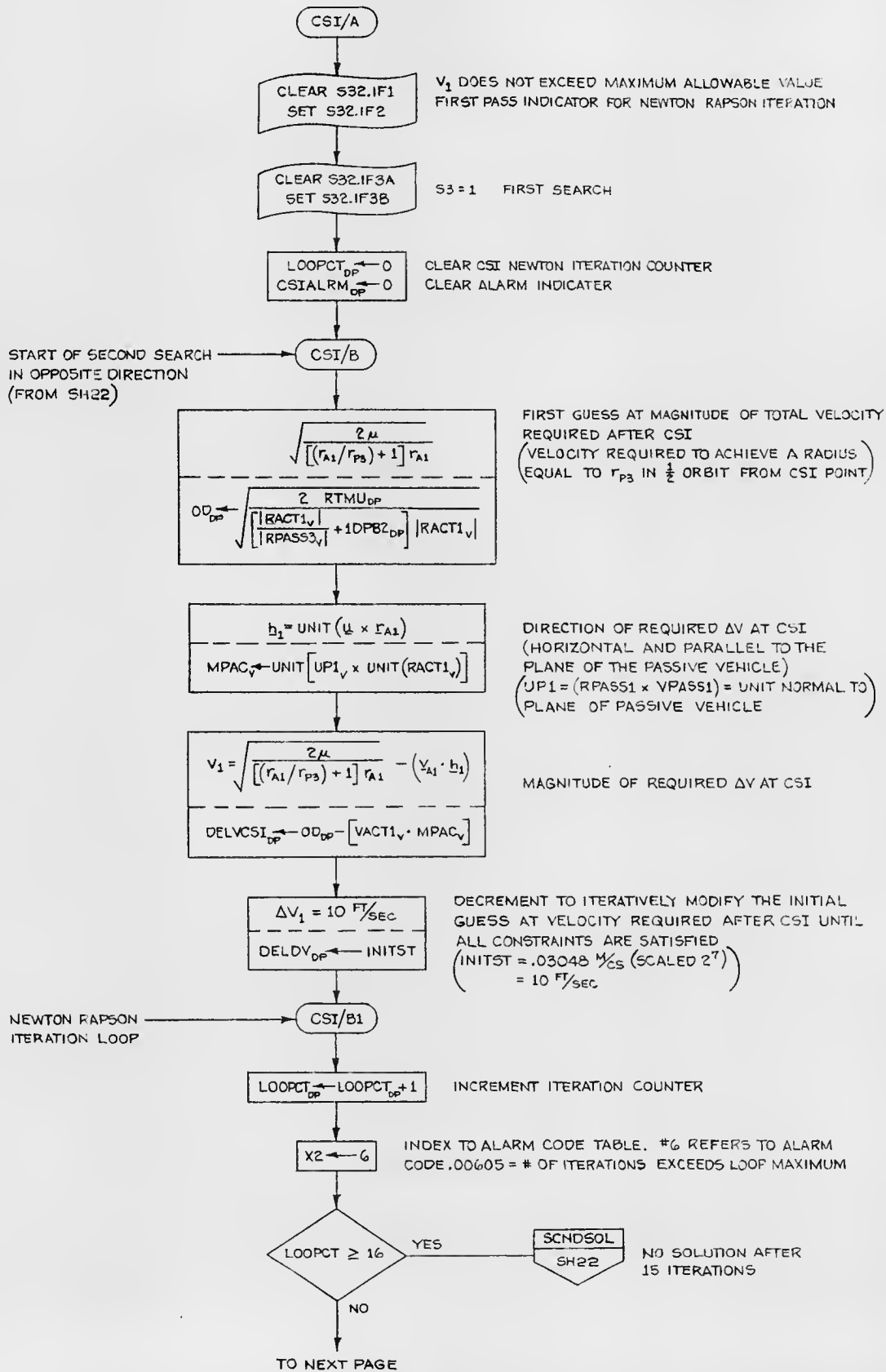
RETURN VIA
QPRET

$VACT2_V \leftarrow MPAC_V$
 $VACT1_V \leftarrow MPAC_V$

VELOCITY VECTOR OF ACTIVE VEHICLE
ROTATED INTO PLANE OF PASSIVE
VEHICLE

RETURN VIA
SUBEXIT

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
DRAWN	A.C. WILLIAMS	6-4-68	DOCUMENT NO. FC-3720
PROWR	<i>Prostate</i>	8-22-68	
ANALST	<i>H. J. Thompson</i>		LUMINARY 1D
DOCAR	<i>Robert Shultz</i>	14 April 69	REV 3
APPR'D	<i>J. H. Hays</i>	6-7-68	SHEET 11 OF 27



RRT INSTRUMENTATION LAB CARBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS		P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
PROGRAM <i>Ed Williams</i>		DOCUMENT NO. FC-3720	
ANALYST <i>Ed Williams</i>		LUMINARY 1D	
DDCMR <i>Ed Williams</i>		REV 3	
APPR'D <i>Ed Williams</i>		SHEET 12 OF 27	

50 FT/SEC BACKWARD
ITERATION (FROM SH 20)

CSI/B2

YES
 $|V_1| < 1000 \text{ FT/SEC?}$
 $|DELVC SI|_{DP} < DVMAX1_{DP}$

NO

X2 ← 7

INDEX TO ALARM CODE TABLE. *7 REFERS TO
CODE 00606 - ΔV EXCEEDED MAXIMUM

S32.IF1
SET

YES

SCNDSOL
SH22

$|V_1|$ HAS EXCEEDED 1000 FT/SEC
ON 2 CONSECUTIVE ITERATIONS

NO

S32.IF3A
SET

YES

S32.IF3B
SET

BACKWARD ITERATION

S3=3

YES

SCNDSOL
SH22

(S3=1 OR 0)
FIRST SEARCH

NO

S3=2
SECOND SEARCH

CSI/B22

SET S32.IF1

$|V_1|$ HAS EXCEEDED MAXIMUM ALLOWABLE VALUE

$V_1 = \text{SGN}(V_1) \cdot 989 \text{ FT/SEC}$
 $DELVC SI_{DP} \leftarrow \text{SGN}(DELVC SI_{DP}) (DVMAX2)_{DP}$

SET $V_1 = \text{MAX } V_1$
 $(DVMAX2 = 3.014472 \text{ M/GS})$
 $= 989 \text{ FT/SEC}$

CSI/B23

$\Delta V_{CSX} = V_1 b_1$
 $DELVEET1_V \leftarrow DELVC SI_{DP} \text{ UNIT}[UPI \times \text{UNIT}(RACT1)]$

REQUIRED ΔV AT CSI

CSI/B23D

$V_{A1}' = V_{A1} + V_1 b_1$
 $VACT4_V \leftarrow VACT1_V + DELVEET1_V$

REQUIRED VELOCITY OF ACTIVE
VEHICLE AFTER CSI MANEUVER

X1 ← RTX1

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		P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
DRAWN A.C. WILLIAMS	4-26-68	LUMINARY 1D	DOCUMENT NO. FC-3720
PRGMR <i>P. White</i>	8-22-68		
ANALST <i>John Thomas</i>		REV 3	SHEET 13 OF 27
DOCMR <i>John Thomas</i>	4-26-68		
APPR'D <i>J. Thomas</i>	4-26-68		

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$$\begin{aligned} V_{VEC} &\leftarrow V_{ACT4} \cdot V_{A1} \\ R_{VEC} &\leftarrow R_{ACT1} \cdot R_{A1} \end{aligned}$$

SET RVSW DO NOT COMPUTE STATE VECTOR DURING TIME-THETA, JUST OBTAIN SPECIFIED TIME

$$\begin{aligned} SN_{TH} &\leftarrow SN359T \\ CS_{TH} &\leftarrow CS359T \\ 1 - CS_{TH} &\leftarrow 0 \end{aligned}$$

$\theta = 359.99^\circ (= 1 \text{ ORBIT})$ - THE TRUE ANOMALY ANGLE USED TO COMPUTE PERIOD t_p

TIMETHET
OBTAIN PERIOD (t_p) OF NEW ORBIT
FC-3760

INPUT: $R_{VEC}, V_{VEC}, SN_{TH}, CS_{TH}, RVSW, X1$
OUTPUT: $MPAC_{DP} = t_p \cdot CS$

$$HAFPAI_{DP} \leftarrow \frac{1}{2} MPAC_{DP}$$

TIME BETWEEN APSIDAL CROSSINGS

$$X1 \leftarrow RTX1$$

PERIAPO
COMPUTE APOGEE AND PERIGEE ALTITUDE ALSO APOCENTER AND PERICENTER RADIUS
FC-3760

INPUT: $R_{VEC}, V_{VEC}, X1$
OUTPUT: $ECC =$ ECCENTRICITY OF CONIC TRAJECTORY (e) (SCALED 2^3)
 $MPAC =$ PERIGEE ALTITUDE AFTER CSI
 $R1 = |R_{VEC}|$
 $P_{DP} = \frac{\text{SEMI-LATUS RECTUM}}{R1}$

$$POSTCSI_{DP} \leftarrow MPAC_{DP}$$

h_{P1} PERIGEE ALTITUDE AFTER CSI MANEUVER

CENTANG = 0 ? IF CENTANG IS NOT ZERO, ASTRONAUT HAS USED 180° OPTION.

$e < .0001$?
 $ECC_{DP} < ONETHH_{DP}$
CIRCULAR ORBIT ?
ONETHH = .0001 (SCALED 2^3)

$|V_R| < 7 \text{ FT/SEC}$
 $\frac{|R_{ACT1} \cdot V_{ACT4}|}{R1} <$
IS THE VERTICAL VELOCITY (V_R) AT THE CSI POINT LESS THAN 7 FT/SEC ?

NICKELDP
NOW CALCULATE THE ANGLE ψ FROM CSI TO THE NEAREST PERIGEE. THEN COMPUTE TIME OF FLIGHT-THERETO, Δt , WHICH IS USED TO DETERMINE t_{CDH}

$$e \cos \psi = \frac{P1}{R_{A1}} - 1$$

$$14D_{DP} \leftarrow P_{DP} - 1 - RTEB2_{DP}$$

ECCENTRICITY x COS OF TRUE ANOMALY ANGLE (TRANSFER ANGLE FROM CSI TO PERIGEE)

TO NEXT PAGE

CIRCL
SH16

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
DRAWN	A.C.WILLIAMS	4-29-68	DOCUMENT NO. FC-3720
PROGRAM	<i>P. Williams</i>	8-27-68	
ANALYST	<i>W. Williams</i>		LUMINARY 1D
DOCK	<i>W. Williams</i>		
APPR'D	<i>J. Young</i>	6-7-68	REV 3
			SHEET 14 OF 27

FROM PRECEDING PAGE

CSI/B3

$$\frac{\Gamma_{A1} \cdot Y'_{A1}}{RDOTV_{DP} \leftarrow RACT1_V \cdot VACT4_V}$$

$$e \sin \psi = \left| \frac{\Gamma_{A1} \cdot Y'_{A1}}{RDOTV_{DP}} \right| \sqrt{\frac{P_1}{\mu \Gamma_{A1}^2}}$$

$$12_{DP} \leftarrow \left| RDOTV_{DP} \right| \sqrt{P_{DP} R1_{DP}} \frac{RTSR1/MU_{DP}}{R1_{DP}}$$

ECCENTRICITY x SIN OF TRUE ANOMALY ANGLE
(TRANSFER ANGLE FROM CSI TO PERIGEE)

16D_{DP} ← 0

$$\begin{pmatrix} \sin \psi \\ \cos \psi \\ 0 \end{pmatrix} = \text{UNIT} \begin{pmatrix} e \sin \psi \\ e \cos \psi \\ 0 \end{pmatrix}$$

$$MPAC_V \leftarrow \text{UNIT} \begin{pmatrix} 12D_{DP} \\ 14D_{DP} \\ 16D_{DP} \end{pmatrix}$$

UNITIZING HAS THE EFFECT OF
DIVIDING BY e

SNTH_{DP} ← MPAC_{DP} SIN ψ

CSTH_{DP} ← (MPAC+3)_{DP} COS ψ

X1 ← RTX1

$$-SGN(\Gamma_{A1} \cdot Y'_{A1}) Y'_{A1}$$

$$VVEC_V \leftarrow -SGN(RDOTV_{DP}) VACT4_V$$

MAKE Y'_{A1} POSITIVE IF ITS VERTICAL COMPONENT
POINTS DOWN, NEGATIVE IF ITS VERTICAL
COMPONENT POINTS UP.
THIS ENSURES THAT THE TIME OF FLIGHT CALCULATED
BY TIMETHET WILL BE TO THE NEAREST
PERIGEE.

SET RVSW DO NOT UPDATE STATE VECTOR,
JUST COMPUTE Δt DURING TIMETHET ROUTINE.

RVEC_V = RACT1_V Γ_{A1}

TIMETHET
COMPUTE Δt THE TIME
OF FLIGHT FROM THE
CSI POINT TO THE
NEAREST PERIGEE
FC-3360

INPUT: CSTH, SNTH, RVEC, VVEC, X1, RVSW
OUTPUT: MPAC

OD_{DP} ← MPAC_{DP} MPAC = Δt { = TIME TILL NEXT PERIGEE, IF V_R < 0
= TIME SINCE LAST PERIGEE, IF V_R > 0

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MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
DRAWN A.C.WILLIAMS	4-29-68	LUMINARY 1D	DOCUMENT NO. FC-3720
PRGRM <i>Powhite</i>	8-22-68		
ANALST <i>H. Longman</i>		REV 3	SHEET 15 OF 27
DOCNR <i>FC-3720</i>	11-11-67		
APPR'D <i>J. Hoyle</i>	6-7-68		

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WAS THE LAST APSIS BEFORE CSI A PERIGEE?

$V_R \geq 0$
 $RDOTV \geq 0$

YES ($\Delta t = \text{TIME SINCE LAST PERIGEE}$)

NO (APOGEE)

FROM SH13

CIRCL

$\Delta t = 0$

$OD_{DP} \leftarrow 0$

$\Delta t = \frac{t_P}{2} - \Delta t$
 $OD_{DP} \leftarrow HAFPAL_{DP} - OD_{DP}$

TIME SINCE LAST APOGEE = $\frac{1}{2}$ PERIOD - TIME TILL NEXT PERIGEE

$NTP/2$

$t_2 = t_1 - \Delta t + N \frac{t_P}{2}$
 $TCDH_{DP} \leftarrow TCSI_{DP} - OD_{DP} + NN_{DP} HAFPAL_{DP}$

TIME OF CDH = TIME OF CSI - TIME SINCE LAST APSIS + $N \frac{\text{PERIOD}}{2}$
 (N = NUMBER OF THE FUTURE APSIDAL CROSSING OF THE ACTIVE VEHICLE AT WHICH THE CDH MANEUVER OCCURS.)

$X2 \leftarrow 5$

INDEX TO ALARM CODE TABLE
 ALARM CODE 00604 = TIME FROM CDH TO TPI < 10 MIN.

$t_3 < t_2$

YES

SCNDSOL

SH22

$TPI < TCDH$

NO $t_3 > t_2$

$OD_V \leftarrow VACTA_V$
 $MPAC_V \leftarrow RACT1_V$

V_{A1} REQUIRED VELOCITY OF ACTIVE VEHICLE AFTER CSI
 Γ_{A1} POSITION OF ACTIVE VEHICLE AT CSI

INTINT 2C

$6D_V \leftarrow MPAC_V$
 $12D_{DP} \leftarrow TCSI_{DP}$
 $14D_{DP} \leftarrow TCDH_{DP}$
 $16D_{DP} \leftarrow TWO PI_{DP}$

t_1
 t_2
 DO CONIC INTEGRATION

INTINT
 CONIC INTEGRATION OF STATE VECTOR TO CDH TIME
 FC-3740

INPUT: $16D_{DP}, 14D_{DP}, 12D_{DP}, 6D_V,$
 $OD_V, RTX1, RTX2$
 OUTPUT: $MPAC = RATT$
 $VATT$

RETURN VIA QPRET

$RACT2_V \leftarrow MPAC_V$
 $VACT2_V \leftarrow VATT_V$

Γ_{A2} POSITION VECTOR OF ACTIVE VEHICLE AT CDH
 V_{A2} VELOCITY VECTOR OF ACTIVE VEHICLE AT CDH

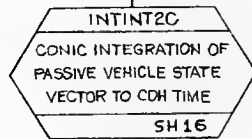
$OD_V \leftarrow VPASS1_V$
 $6D_V \leftarrow RPASS1_V$

V_{P1} VELOCITY OF PASSIVE VEHICLE AT CSI
 Γ_{P1} POSITION OF PASSIVE VEHICLE AT CSI

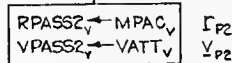
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MNT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P32 AND P72 CO-ELLIPTIC SEQUENCE INIATION	
DRAWN A.C.WILLIAMS	4-30-68	LUMINARY 1D	DOCUMENT NO. FC-3720
FWWR <i>[Signature]</i>	8-22-68		
ANALST <i>[Signature]</i>	<i>[Signature]</i>	REV 3	SHEET 16 OF 27
DOCHR <i>[Signature]</i>	4-7-68		

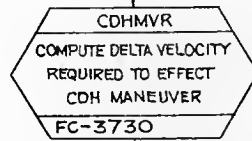
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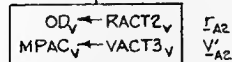
INPUT: $MPAC_V = \Gamma_{P1}$, $TCSI_{DP}$, $TCDH_{DP}$
 $OD_V = \gamma_{P1}$
 OUTPUT: $MPAC_V = \Gamma_{P2}$
 $VATT_V = \gamma_{P2}$



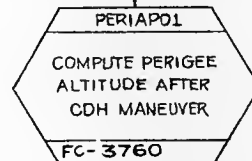
Γ_{P2} POSITION VECTOR OF PASSIVE VEHICLE AT CDH
 γ_{P2} VELOCITY VECTOR OF PASSIVE VEHICLE AT CDH



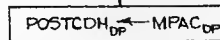
INPUT: $RACT2_V$, $VACT2_V$, $RPASS2_V$, $VPASS2_V$, HPI_V , $RTMU_{DP}$
 OUTPUT: $DELVEET2_V =$ REQUIRED ΔV AT CUH (ΔV_2)
 $VACT3_V =$ REQUIRED VELOCITY OF ACTIVE VEHICLE AT CDH (γ'_{A2})
 $DIFFALT_{DP} =$ ALTITUDE BETWEEN ACTIVE AND PASSIVE VEHICLE ORBITS AT CDH



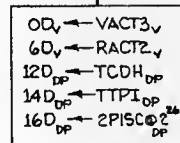
Γ_{A2} POSITION VECTOR OF ACTIVE VEHICLE AT CDH
 γ'_{A2} REQUIRED VELOCITY OF ACTIVE VEHICLE AT CDH



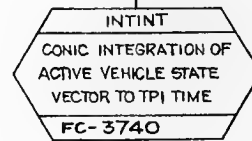
INPUT: $MPAC$, OD , $RTX1$, $RTX2$, $RPAD$, RLS
 OUTPUT: $MPAC =$ PERIGEE ALTITUDE AFTER CDH MANEUVER



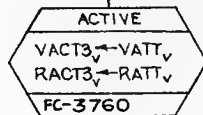
PERIGEE ALTITUDE AFTER CDH MANEUVER



γ'_{A2} REQUIRED VELOCITY OF ACTIVE VEHICLE AT CDH
 Γ_{A2} POSITION OF ACTIVE VEHICLE AT CDH
 t_2 TIME OF CDH MANEUVER
 t_3 TIME OF TPI MANEUVER
 DO CONIC INTEGRATION



INPUT: $OD(\gamma_{A3})$, $GD(\Gamma_{A2})$, $12D(t_{CDH})$, $14D(t_{TPI})$
 OUTPUT: $RATT$, $VATT$



γ_{A3} VELOCITY OF ACTIVE VEHICLE AT TPI
 Γ_{A3} POSITION OF ACTIVE VEHICLE AT TPI

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DRAWN	A.C. WILLIAMS	5-1-68	
PROGR	<i>Boyle</i>	8-22-68	
ANALST	<i>M. Longman</i>		LUMINARY 1D
DOCTR	<i>John A. Chalk</i>	11-11-67	DOCUMENT NO. FC-3720
APPR'D	<i>J. Heagy</i>	6-9-68	REV 3
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$$\underline{u}_L = \cos E \text{ UNIT}(\underline{u} \times r_{A3}) + \sin E \text{ UNIT}(r_{A3})$$

$$OD_v \leftarrow \cos(ELEV) \text{ UNIT}[UP_{1v} \times \text{UNIT}(RACT3_v)] + \sin(ELEV) \text{ UNIT}(RACT3_v)$$

DESIRED LINE-OF-SIGHT FROM ACTIVE VEHICLE TO PASSIVE VEHICLE AT TPI
 (ELEV_{DP} = DESIRED ANGLE BETWEEN THE LM/CSM LOS AND THE HORIZONTAL PLANE OF THE ACTIVE VEHICLE AT TPI)

$$C_1 = r_{A3} \cdot \underline{u}_L$$

$$GD_{EP} \leftarrow RACT3_v \cdot OD_v$$

$$C_2 = C_1^2 - r_{A3}^2 + r_{P3}^2$$

$$MPAC_{TP} \leftarrow GD_{DP}^2 - |RACT3_v|_{TP}^2 + |RPASS3_v|_{TP}^2$$

REAL SOLUTION?
 YES $C_2 \geq 0$
 NO (LOS DOES NOT INTERSECT) $C_2 < 0$
 NO (CIRCLE OF RADIUS r_{P3})

LOOPCT \leftarrow LOOPCT - 1
 DISCOUNT THE LAST LOOP

X2 \leftarrow 1
 INDEX TO ALARM CODE TABLE
 (ALARM CODE 600 = IMAGINARY ROOTS ON FIRST ITERATION)

FIRST ITERATION?
 YES LOOPCT = 0
 NO

DETERMINE A RADIUS VECTOR b OF THE SAME LENGTH AS r_{P3} THAT INTERSECTS THE DESIRED LINE-OF-SIGHT, \underline{u}_L
 $b = r_{A3} + k \underline{u}_L$
 $b^2 = r_{P3}^2 = r_{A3}^2 + 2k(r_{A3} \cdot \underline{u}_L) + k^2$
 $k^2 + 2k(r_{A3} \cdot \underline{u}_L) + (r_{A3}^2 - r_{P3}^2) = 0$
 $k = -(r_{A3} \cdot \underline{u}_L) \pm \sqrt{(r_{A3} \cdot \underline{u}_L)^2 - (r_{A3}^2 - r_{P3}^2)}$
 $k = -C_1 \pm \sqrt{-C_2}$

$\Delta V_1 = \frac{1}{2} \Delta V_0$
 $DELVDV_{DP} \leftarrow \frac{1}{2} DELVDV_{DP}$
 REDUCE ITERATION DECREMENT BY $\frac{1}{2}$

$V_1 = V_0 - \Delta V_1$
 $DELVCST_{DP} \leftarrow DV_{PREV_{DP}} - DELVDV_{DP}$
 REDUCE ESTIMATE OF REQUIRED ΔV AT CSI AND TRY AGAIN

CSI/B1
 SH12

YES
 K1ORR2
 $k_2 = -C_1 - \sqrt{-C_2}$
 $10D_{DP} \leftarrow -GD_{DP} - \sqrt{MPAC}$
 $k_1 = -C_1 + \sqrt{-C_2}$
 $12D_{DP} \leftarrow -GD_{DP} + \sqrt{MPAC}$

YES $|k_1| > |k_2|$
 YES $|12D_{DP}| > |10D_{DP}|$
 NO $(k = k_1)$
 $10D_{DP} \leftarrow 12D_{DP} \quad k_1$

K2.
 $\text{UNIT } b = \text{UNIT}(r_{A3} + k \underline{u}_L)$
 $OD_v \leftarrow \text{UNIT}(RACT3_v + 10D_{DP} OD_v)$

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DRAWN A.C.WILLIAMS		P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
PROGRAM P32/P72	5-2-65	DOCUMENT NO.	
ANALYST W. Langlois	8-22-65	LUMINARY 1D	FC-3720
DOCTR. J. H. ...	4 April 67	REV 3	SHEET 18 OF 27
APPR'D J. H. ...	6-7-68		

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$$\gamma = \cos^{-1}(\text{UNIT } b \cdot \text{UNIT } \Gamma_{P3}) \text{ SGN} \left[(\text{UNIT } \Gamma_{P3} \times \text{UNIT } b) \cdot (\text{UNIT } V_{P3} \times \text{UNIT } \Gamma_{P3}) \right]$$

$$OD_{L1} \leftarrow \cos^{-1} \left[OD_V \cdot \text{UNIT}(RPASS3_V) \right] \text{ SGN} \left[\left[\text{UNIT}(RPASS3_V) \times OD_V \right] \cdot \left[\text{UNIT}(VPASS3_V) \times \text{UNIT}(RPASS3_V) \right] \right]$$

ERROR ANGLE FROM b TO Γ_{P3}
 (POSITIVE IF b IS BEHIND Γ_{P3})
 (NEGATIVE IF b IS AHEAD OF Γ_{P3})

S32.1F2 SET? YES (FIRST PASS)

CHANGE IN ERROR

$$\gamma - \gamma_0$$

$$2D_{DP} \leftarrow OD_{EP} - \text{GAMPREV}_{DP}$$

SLOPE FOR LINEAR EXTRAPOLATION

$$S_L = \frac{\gamma - \gamma_0}{V_1 - V_0}$$

$$4D_{DP} \leftarrow \frac{2D_{DP}}{DELVCSTI_{DP} - DVPREV_{DP}}$$

SAVE OLD ESTIMATE OF REQUIRED ΔV AT CSI

$$V_0 = V_1$$

$$DVPREV_{DP} \leftarrow DELVCSTI$$

FRSTPAS

SAVE OLD VALUE OF γ

$$\gamma_0 = \gamma$$

$$\text{GAMPREV}_{DP} \leftarrow OD_{DP}$$

SAVE OLD ESTIMATE OF REQUIRED ΔV AT CSI

$$V_0 = V_1$$

$$DVPREV_{DP} \leftarrow DELVCSTI_{DP}$$

NEW ESTIMATE OF REQUIRED ΔV AT CSI

$$V_1 = V_0 - \Delta V_1$$

$$DELVCSTI_{DP} \leftarrow DVPREV_{DP} - DELDV_{DP}$$

CLEAR S32.1F2 END OF FIRST PASS

CSI/B1 DO SECOND ITERATION
 SH 12

(S3 = 1 OR 0) S32.1F3A SET?

S32.1F3B SET? YES (S3 = 3)

S32.1F3B SET? NO (S3 = 2)

THROCHK

(S3 = 2) S32.1F3A SET?

S32.1F3B SET? YES (S3 = 1)

S32.1F3B SET? NO (S3 = 0)

TO NEXT PAGE

SIGN CHANGE?

$$\frac{\gamma_0(\gamma - \gamma_0)}{\text{GAMPREV}_{DP} 2D_{DP}} < 0$$

YES

$$\Delta V_1 = \text{SGN}(\Delta V_1) 10 \text{ FT/SEC}$$

$$DELVDV_{DP} \leftarrow \text{SGN}(DELVDV_{DP}) \text{ INITST}_{DP}$$

SET S32.1F3A CLEAR S32.1F3B S3 = 2
 SIGN HAS CHANGED RETURN TO NORMAL TYPE SEARCH FROM OPPOSITE DIRECTION

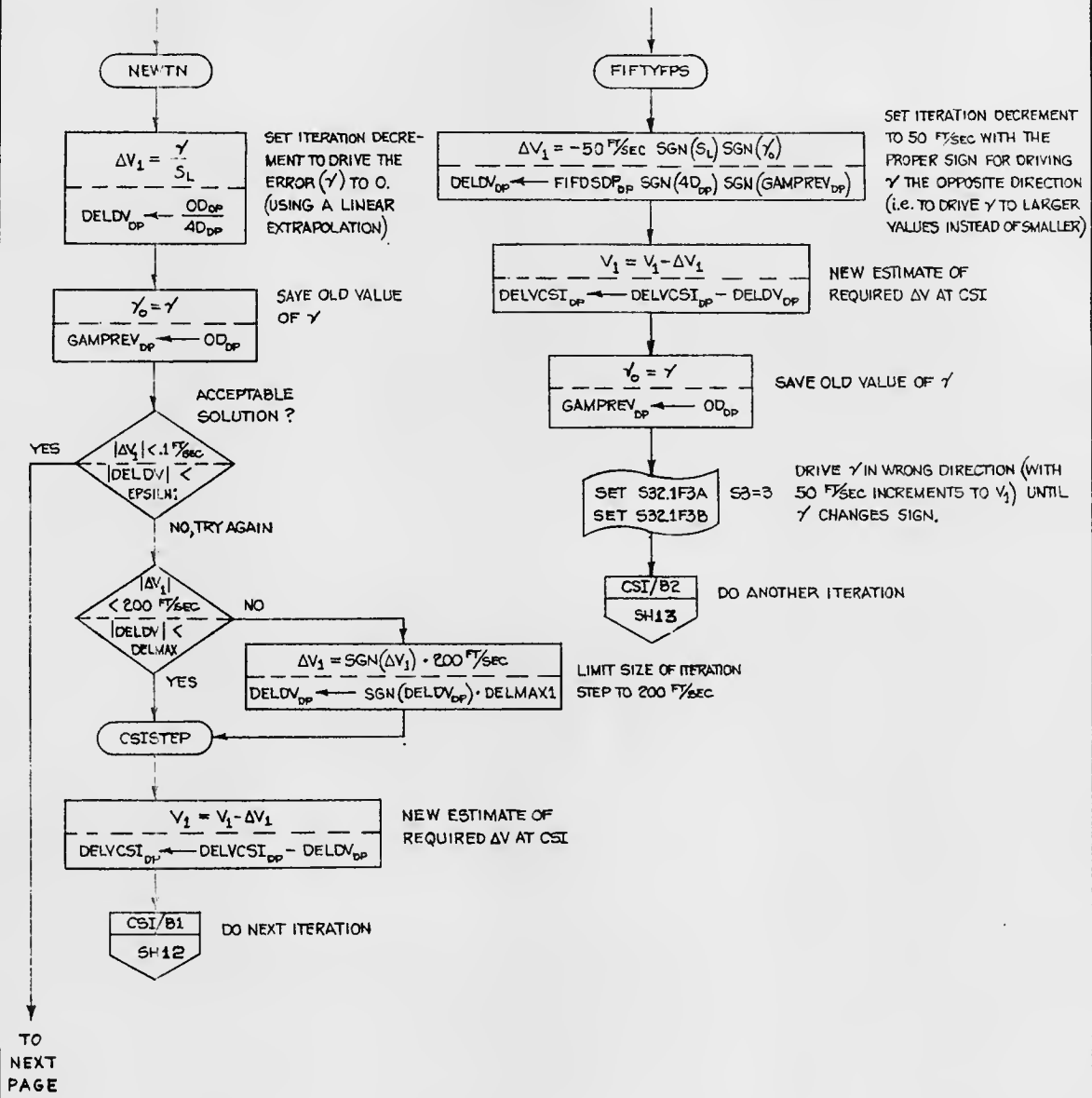
DRIVE γ TO LARGER VALUES USING ΔV DECREMENTS OF 50 FT/SEC UNTIL γ COMPLETES MORE THAN $\frac{1}{2}$ REVOLUTION AND CHANGES SIGN.

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MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
DRAWN A.C.WILLIAMS PROJEN P. Williams ANALYST P. Williams DOCUM P. Williams APPR'D J. Henry	5-3-68 2-22-68 1-16-68 1-7-68	LUMINARY ID	DOCUMENT NO. FC-3720
		REV 3	SHEET 19 OF 27

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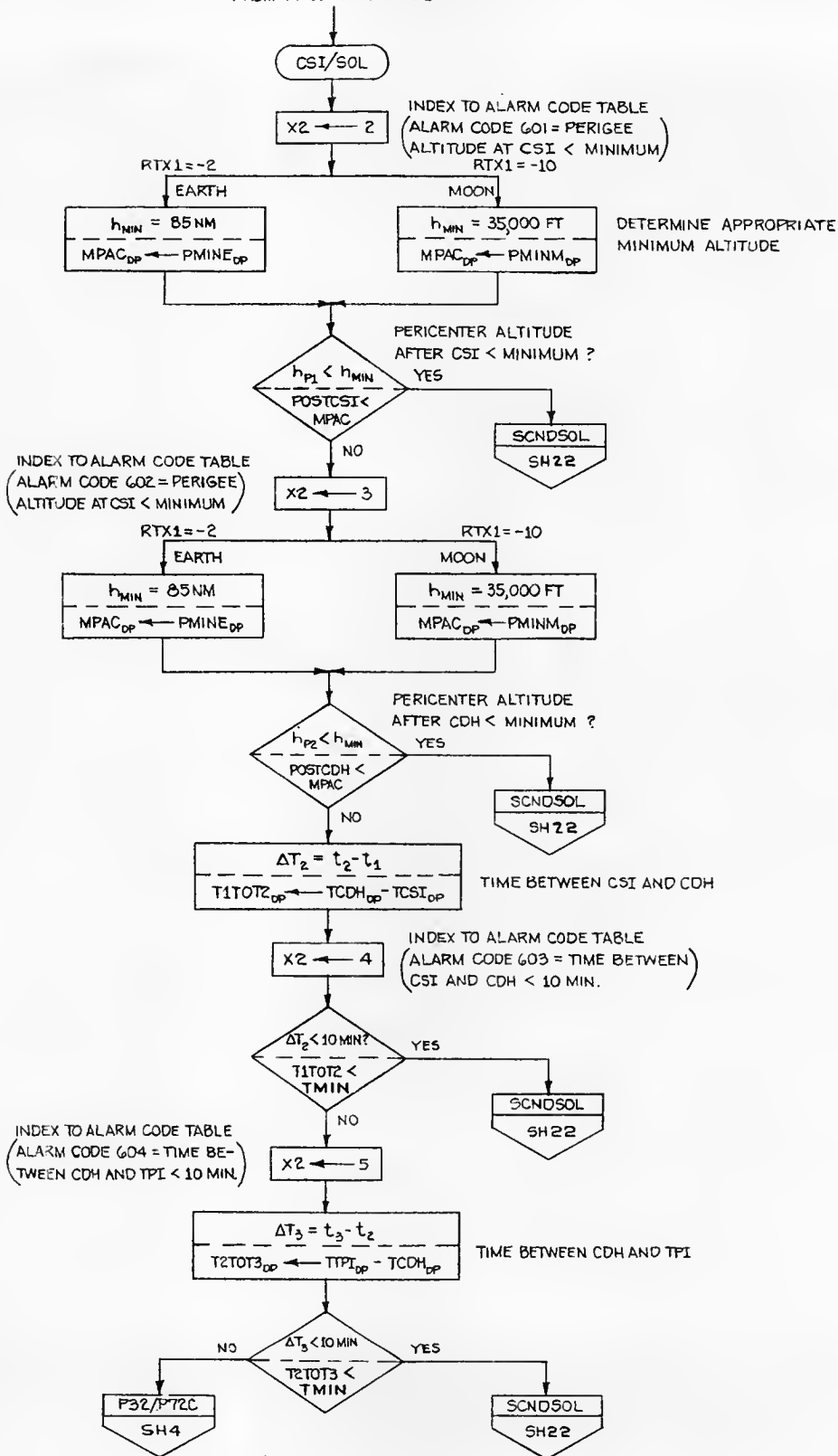
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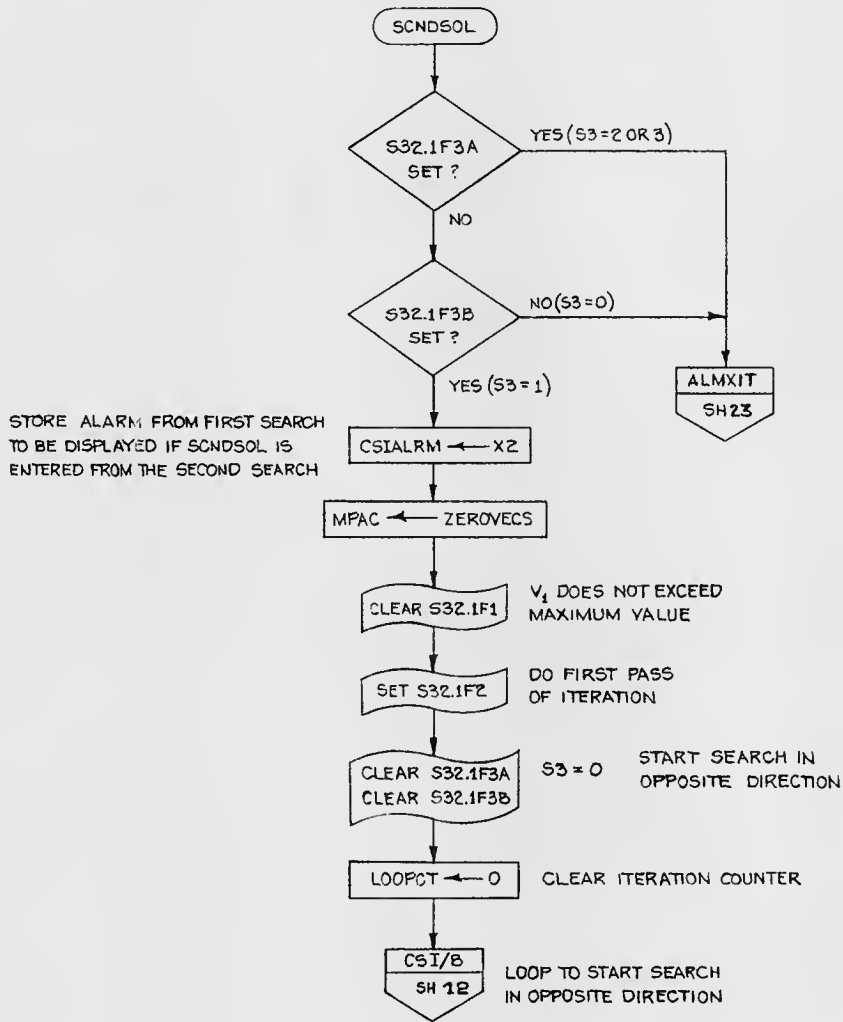
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
DRAWN	A.C.WILLIAMS	5-6-68	DOCUMENT NO. FC-3720
FIGURE	P. White	8-22-68	
ANALYST	W. Longman		
DOCNR	FC-3720	4-2-69	
APPR'D	J. King	6-9-68	
		LUMINARY 1D	REV 3
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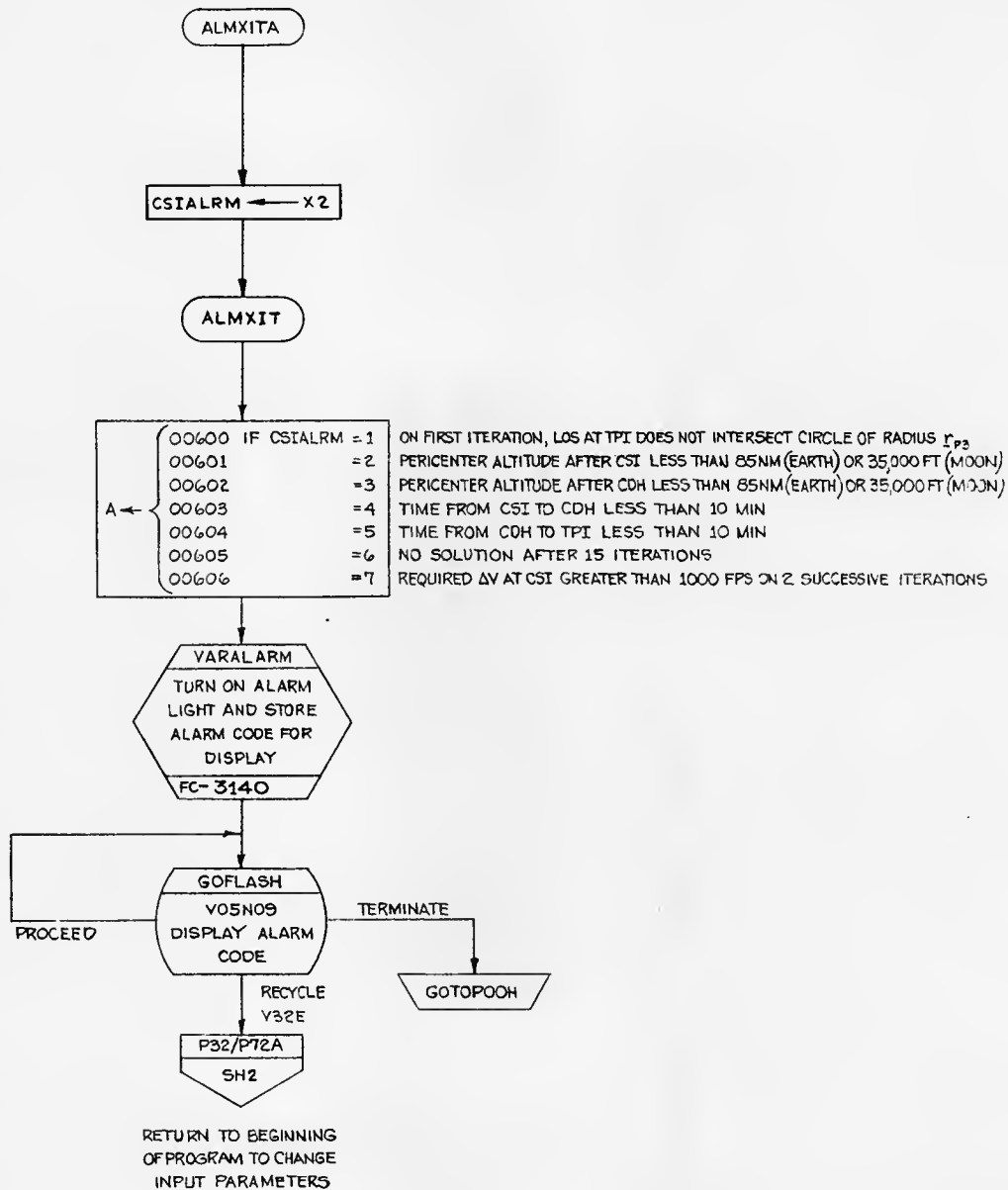


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
DRAWN	A.C. WILLIAMS	5-6-68	
CHKD	<i>[Signature]</i>	8-22-68	
ANALYST	<i>[Signature]</i>		
DOCNR	<i>[Signature]</i>		
APPR'D	<i>[Signature]</i>	6-7-68	
		LUMINARY 1D	DOCUMENT NO. FC-3720
		REV 3	SHEET 21 OF 27

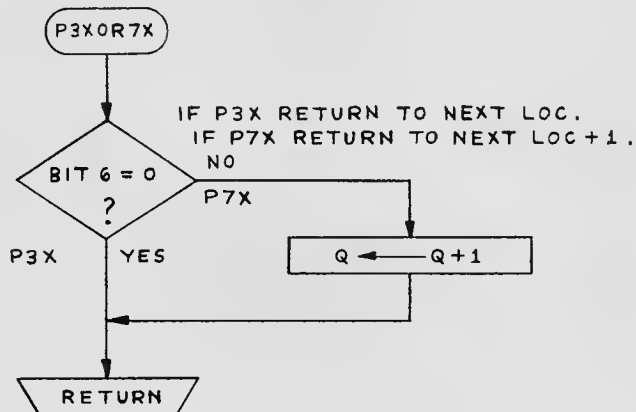
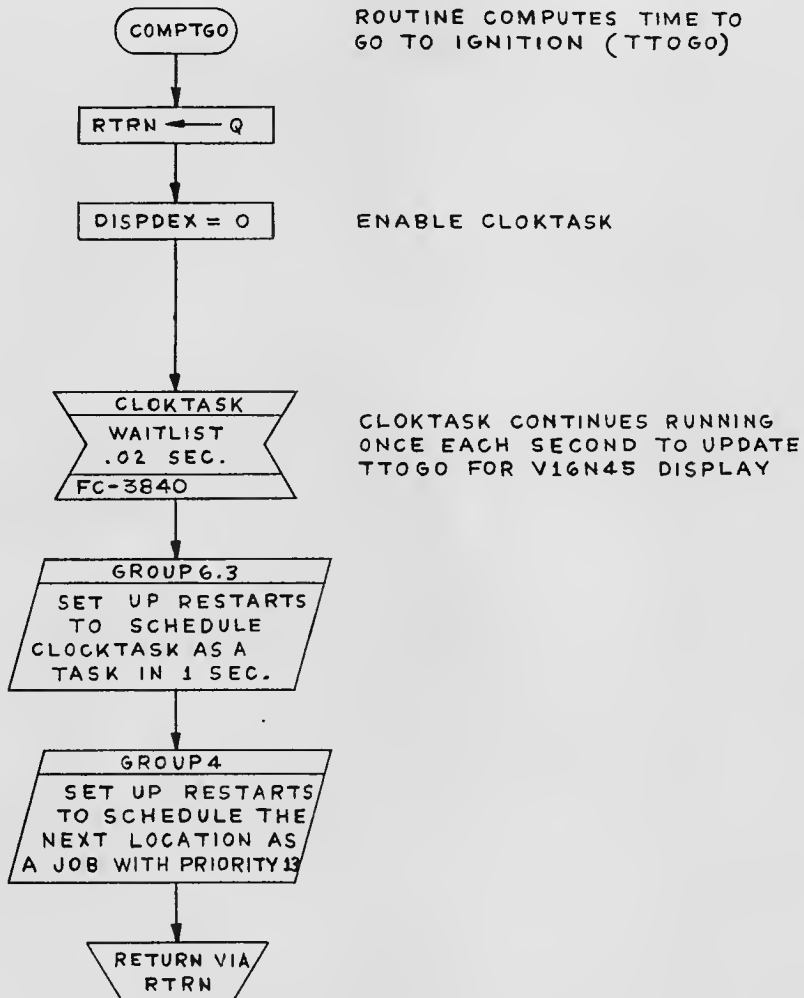
ALARM CONDITIONS THAT CAUSE ENTRY OF SCNDSOL ARE:
 NO SOLUTION AFTER 15 ITERATIONS
 $V_1 > 1000$ FT/SEC ON 2 SUCCESSIVE ITERATIONS
 $t_3 < t_2$
 $h_{P1} < 85$ NM OR 35,000 FT
 $h_{P2} < 85$ NM OR 35,000 FT
 $\Delta T_2 < 10$ MIN
 $\Delta T_3 < 10$ MIN



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P32 AND P72 CO-ELLIPTIC SEQUENCE INIATION	
DRAWN A.G.WILLIAMS	5-6-68	LUMINARY 1D	DOCUMENT NO. FC-3720
PROGRAM <i>[Signature]</i>	8-22-68		REV 3
ANALYST <i>[Signature]</i>			SHEET 22 OF 27
DOCNR <i>[Signature]</i>			
APPR'D <i>[Signature]</i>	6-7-68		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
DRAWN	A.C.WILLIAMS	5-7-68	
PROGR	<i>P. DeWalt</i>	8-22-68	
ANALYST	<i>W. Tompkins</i>		
DOCNR	<i>Therese L. Shull</i>	11-11-68	
APPR'D	<i>J. Henige</i>	6-2-68	
		LUMINARY 1D	DOCUMENT NO. FC-3720
		REV 3	SHEET 23 OF 27



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P32 AND P72 CO-ELLIPTIC SEQUENCE INITIATION	
DRAWN <i>C. J. Langille</i>	1 APR 65	LUMINARY 1D	DOCUMENT NO. FC-3720
PROGR <i>C. J. Langille</i>	1 APR 65		
ANALYST <i>H. Ferguson</i>	1 APR 65		
DOCNR <i>FC-3720</i>	1 APR 65		
APPR'D <i>John C. Moran</i>	1 APR 65	REV 3	SHEET 24 OF 27

SUBROUTINES

IN THIS CHART

AVFLAGA
AVFLAGP
S32/33.1
DISDVLVC
ROTATE
S32/33.X
PRECSET
CSI/A
INTINT2C
VN1645
ADVANCE

COMPTGO
P3XORP7X

SETS AVFLAG, UPDATFLG AND TRACKFLG
SETS UPDATFLG, TRACKFLG AND CLEARS AVFLAG
DISPLAY ΔV AT CSI IN LOCAL VERTICAL COORDINATES
CONVERT ΔV FROM REFERENCE TO LOCAL VERT COORDS AND DISPLAY
ROTATES VECTOR OF ACTIVE VEHICLE INTO PLANE OF PASSIVE VEHICLE
COMPUTE MATRIX FOR LOCAL VERT TO REF COORD TRANSFORMATION
ADVANCE BOTH VEHICLES TO APPLICABLE MANEUVER TIME VIA PRECISION INTEGRATION
COMPUTE CSI/CDH MANEUVER PARAMETERS
PERFORMS HOUSEKEEPING FOR AND CALLS INTEGRATION ROUTINE
DISPLAY V16N45
ACTIVE AND PASSIVE STATE VECTORS TO CSI TIME PRECISION
INTEGRATION OF
COMPUTE TIME TO GO TO IGNITION
TEST TO SEE IF CALLING PROGRAM IS P32 OR P72

ON OTHER CHARTS

FLOW CHART
NUMBER

SELECTMU

INTINT
GET+MGA
PERIAP0
PERIAP01
TIMETHET
CDHMVR
LEMPREC
CSMPREC

SELECT VALUE ACCORDING TO LUNAR OR EARTH SPHERE OF INFLUENCE 3760
PREPARE FOR AND CALL INTEGRATION ROUTINE 3740
COMPUTE MIDDLE GIMBAL ANGLE AT THRUSTING ATTITUDE 3760
COMPUTE APOGEE AND PERIGEE ALTITUDE 3760

OBTAIN PERIOD (t_p) OF NEW ORBIT OR Δ BETWEEN 2 POINTS 3360
COMPUTE CDH MANEUVER PARAMETERS 3730
UPDATE LM STATE VECTOR TO SPECIFIED TIME VIA PRECISION INTEGRATION 3350
UPDATE CSM STATE VECTOR TO SPECIFIED TIME VIA PRECISION INTEGRATION 3350

FLAGS	MEANING	SET	CLEARED	TESTED
AVFLAG	SET LM IS ACTIVE VEHICLE	SH 2	SII 2	
UPDATFLG	CLEARED CSM IS ACTIVE VEHICLE			
TRACKFLG	SET UPDATING IS ALLOWED	SH 2, SH 4	SH 8	
FINALFLG	CLEARED TRACKING IS DISALLOWED	SH 2		
	SET TRACKING IS ALLOWED			
	CLEARED TRACKING IS DISALLOWED			
	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	SII 12	SII 13
S32.1F2	SET INDICATES FIRST PASS FOR NEWTON-RHAPSON ITERATION	SH 12,	SII 19	SH 19
	CLEARED OTHER THAN FIRST PASS			
	=0 START SEARCH IN OPPOSITE DIRECTION	SH 12, 22		SH 19, SH 22
S32.1F3A	=1 FIRST SEARCH			
S32.1F3B	=2 2ND CYCLE THRU CSI/A AREA	SH 19		
	=3 50 FT/SEC INCREMENTS TO V_1	SH 20		
RVS	UNTIL γ CHANGES SIGN			
	SET JUST COMPUTE Δ FROM TIMETHET ROUTINE			
	CLEARED COMPUTE Δ AND UPDATE STATE VECTOR DURING TIMETHET	SH 14, SH 15		
NDELVFLG	SET EXTERNAL ΔV MANEUVER	SH 10		
CMOONFLG	CLEARED LAMBERT AIMPOINT MANEUVER			
	SET PERMANENT CSM STATE IN LUNAR SPHERE			
	CLEARED PERMANENT CSM STATE IN EARTH SPHERE			SH 2

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P32 AND P72 COELLIPTIC SEQUENCE INITIATION	
DRAWN <i>A. J. Angelle</i>		LUMINARY 1D	DOCUMENT NO.
PERCER <i>Richard Smith</i>	8-22-68		FC-3720
ANALYST <i>W. J. Angelle</i>	8-22-68		
DOCTR <i>John A. Morse</i>	10/6/68		
APPROB <i>John A. Morse</i>	08 AUG 68	REV 3.	SHEET 25 OF 27

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
CSALRM	ALARM CODE		B28
CSTH	COS OF θ THE TRUE ANOMALY ANGLE	REVOLUTIONS	B1
DEL DV	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
HAFPAI	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	$\frac{r_{AI}}{r_{PI}} \cdot \frac{V_{AI}}{V_{PI}}$		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	$1/\sqrt{\mu_c}$ 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

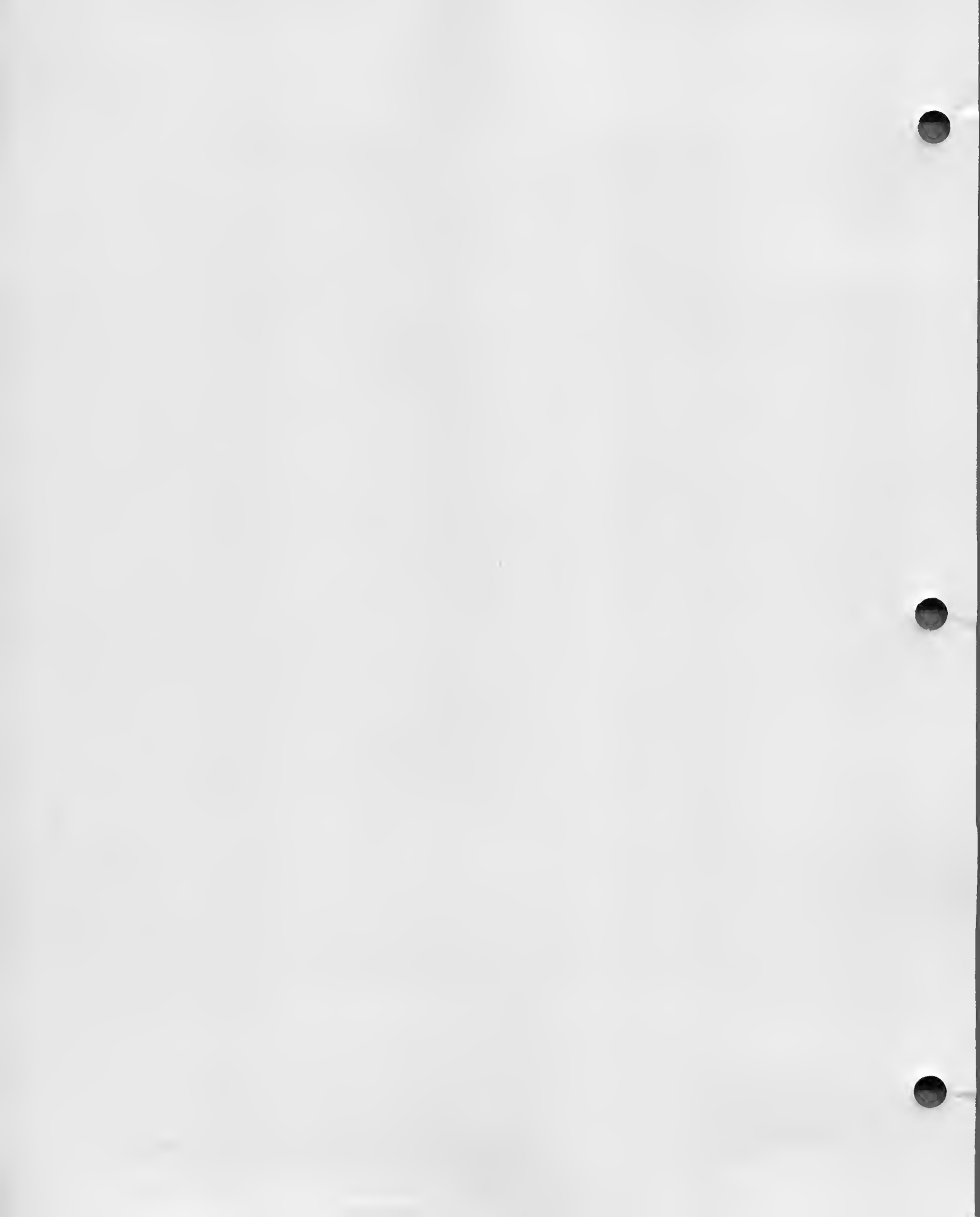
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P32 AND P72 COELLIPTIC SEQUENCE INITIATION	
DRAWN <i>A. J. Langille</i>		LUMINARY 1D	DOCUMENT NO.
PROGR <i>W. J. Langille</i>			FC-3720
ANALST <i>W. J. Langille</i>			
DOCR <i>W. J. Langille</i>			
APPR'D <i>W. J. Langille</i>		REV 3	SHEET 26 OF 27

P32 - COELLIPTIC SEQUENCE INITIATION

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
UPI	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_m 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

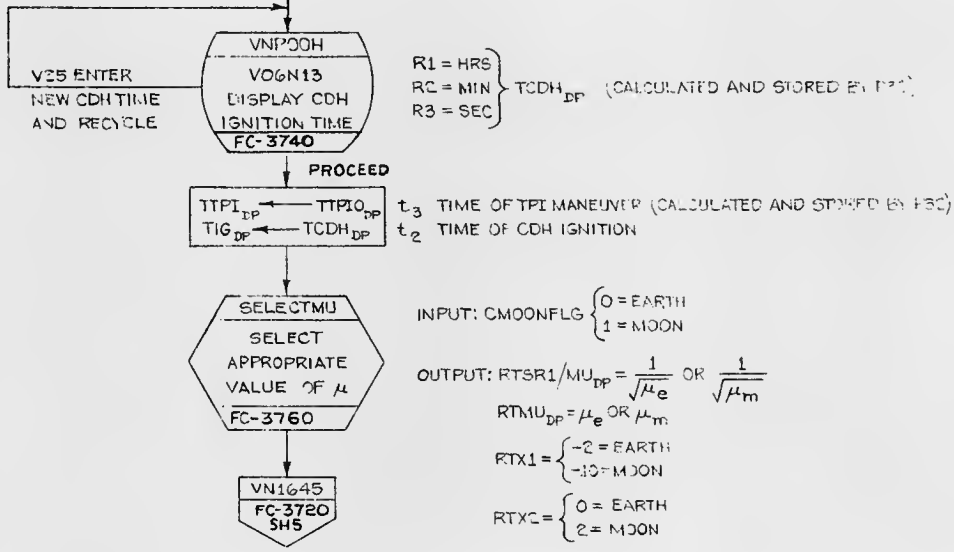
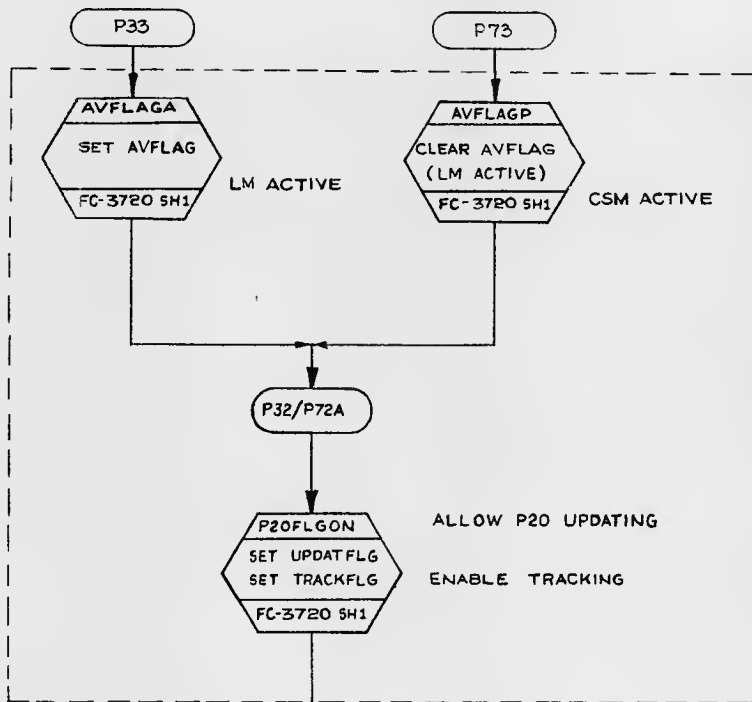
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>G. J. Longley</i>		P32 AND P72 COELLIPTIC SEQUENCE INITIATION	
PROWR <i>Kathleen J. Roberts</i>	8-22-68	LUMINARY 1D	DOCUMENT NO.
ANALYST <i>M. Longley</i>	8-23-68		FC-3720
DOCWR <i>John V. Hill</i>	<i>U. Hill</i>		
APPR'D <i>John A. Moran</i>	28 AUG 68	REV 3	SHEET 27 OF 27



P33 and P73

P33 SH. 2
 P73 SH. 2
 INTINT3P SH. 3
 CDHM VR SH. 6

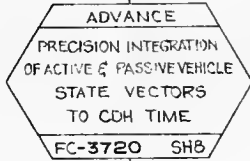
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P33 and P73	
DRAWN <i>E. Matta</i>	<i>5/36/70</i>	Constant Delta Altitude Targetting	
PRGMR <i>F. White</i>		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3730
DOCMR		REV 3	SHEET 1 OF 8
APPR'D <i>Robert M. Estes</i>	<i>5/27/70</i>		



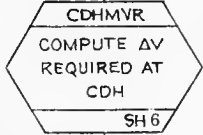
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P33 AND P73 CONSTANT DELTA ALTITUDE TARGETTING	
BRAWN A.C. WILLIAMS	6-6-68	LUMINARY 1D	DOCUMENT NO.
PRGRM <i>Will Williams</i>	16-9-69		FC-3730
ANALST <i>Wayne Tompkins</i>	6-11-68	REV 3	SHEET 2 OF 8
DOCWR <i>Wayne Tompkins</i>	4-16-69		
APPR'D <i>J. Hoyle</i>	6-18-68		

FROM SHEET 4

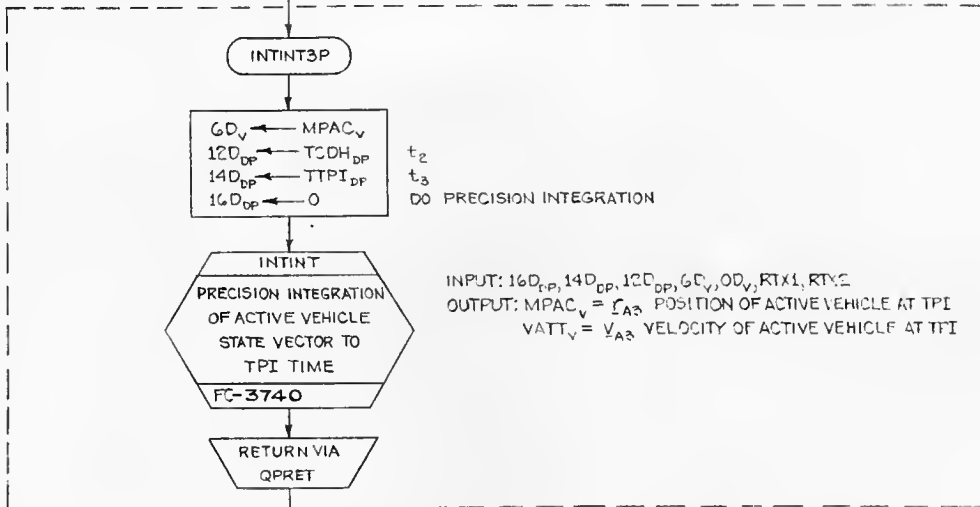
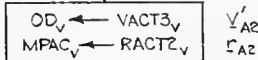
P33/P73B



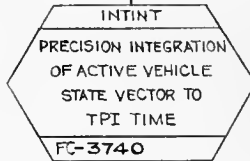
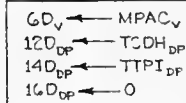
INPUT: $TIG_{DP} = t_2$ TIME OF CDH MANEUVER
 OUTPUT: $R_{ACT2}_V = \Gamma_{A2}$ POSITION OF ACTIVE VEHICLE AT CDH
 $V_{ACT2}_V = Y_{A2}$ VELOCITY OF ACTIVE VEHICLE AT CDH
 $R_{PASS2}_V = \Gamma_{P2}$ POSITION OF PASSIVE VEHICLE AT CDH
 $V_{PASS2}_V = Y_{P2}$ VELOCITY OF PASSIVE VEHICLE AT CDH
 $UP_{1V} = \Gamma_{P2} \times Y_{PC}$ UNIT NORMAL TO PLANE OF PASSIVE VEHICLE
 $XDELV_{LG} = 1$ EXTERNAL DELTA V MANEUVER (NOT LAMBERT AIMPOINT)



INPUT: $R_{ACT2}_V, V_{ACT2}_V, R_{PASS2}_V, V_{PASS2}_V, UP_{1V}, RTMU_{TP}$
 OUTPUT: $DELVEET_{2V} =$ REQUIRED ΔV AT CDH (ΔV_2)
 $V_{ACT3}_V =$ REQUIRED VELOCITY OF ACTIVE VEHICLE AFTER CDH (V'_{A2})

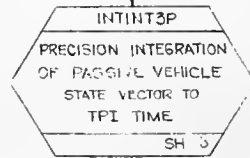
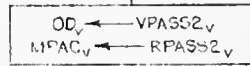
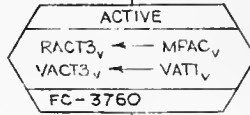


INTINT3P

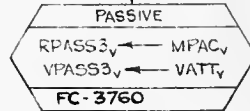


INPUT: $16D_{DP}, 14D_{DP}, 12D_{DP}, 6D_V, OD_V, RTX_1, RTX_2$
 OUTPUT: $MPAC_V = \Gamma_{A3}$ POSITION OF ACTIVE VEHICLE AT TPI
 $V_{ACT}_V = Y_{A3}$ VELOCITY OF ACTIVE VEHICLE AT TPI

RETURN VIA QPRET



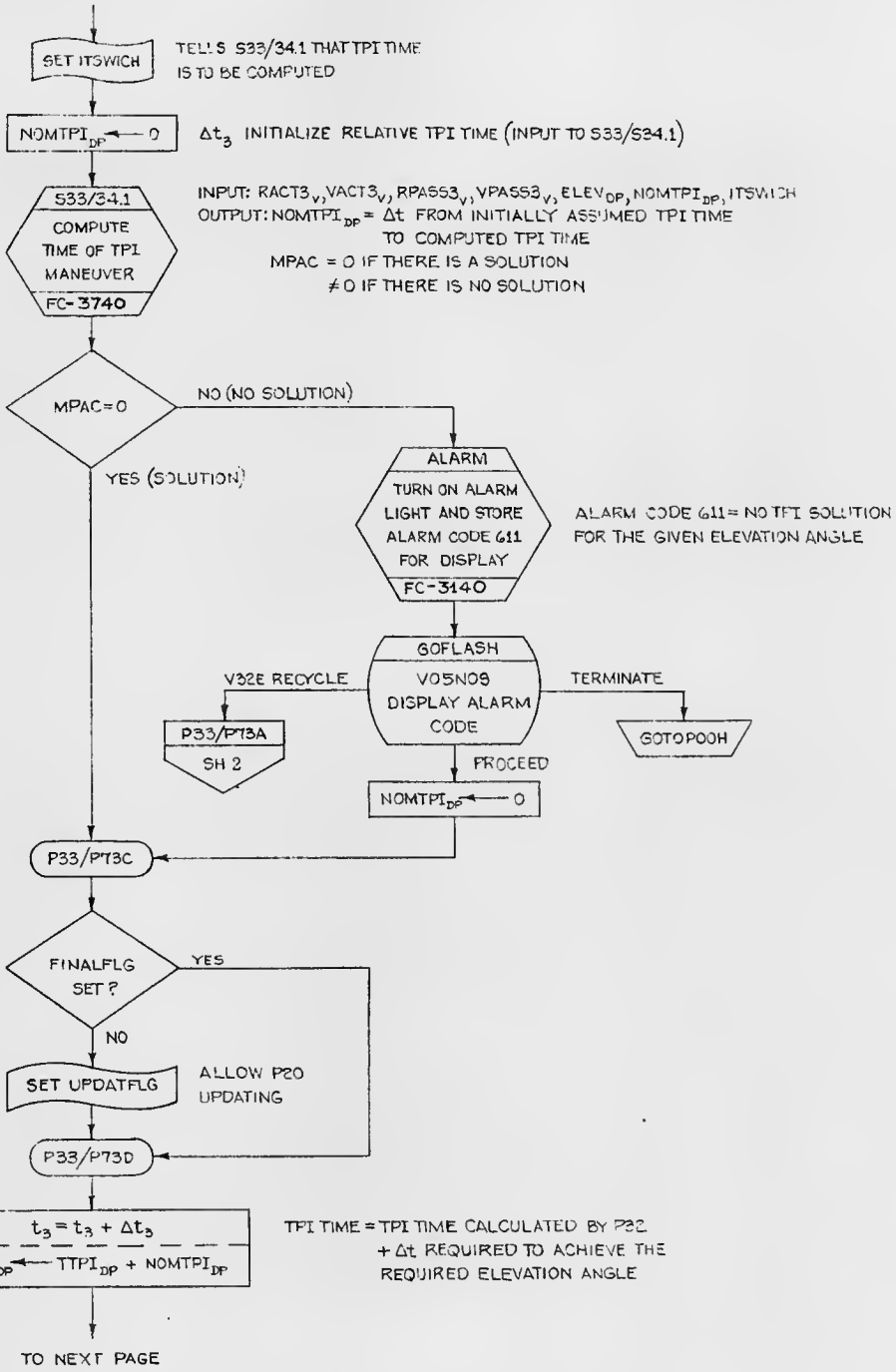
INPUT: $R_{PASS2}_V, V_{PASS2}_V, TCDH_{TP}, TTPI_{DP}$
 OUTPUT: $MPAC_V = \Gamma_{P3}$ POSITION OF PASSIVE VEHICLE AT TPI
 $V_{ACT}_V = Y_{P3}$ VELOCITY OF PASSIVE VEHICLE AT TPI



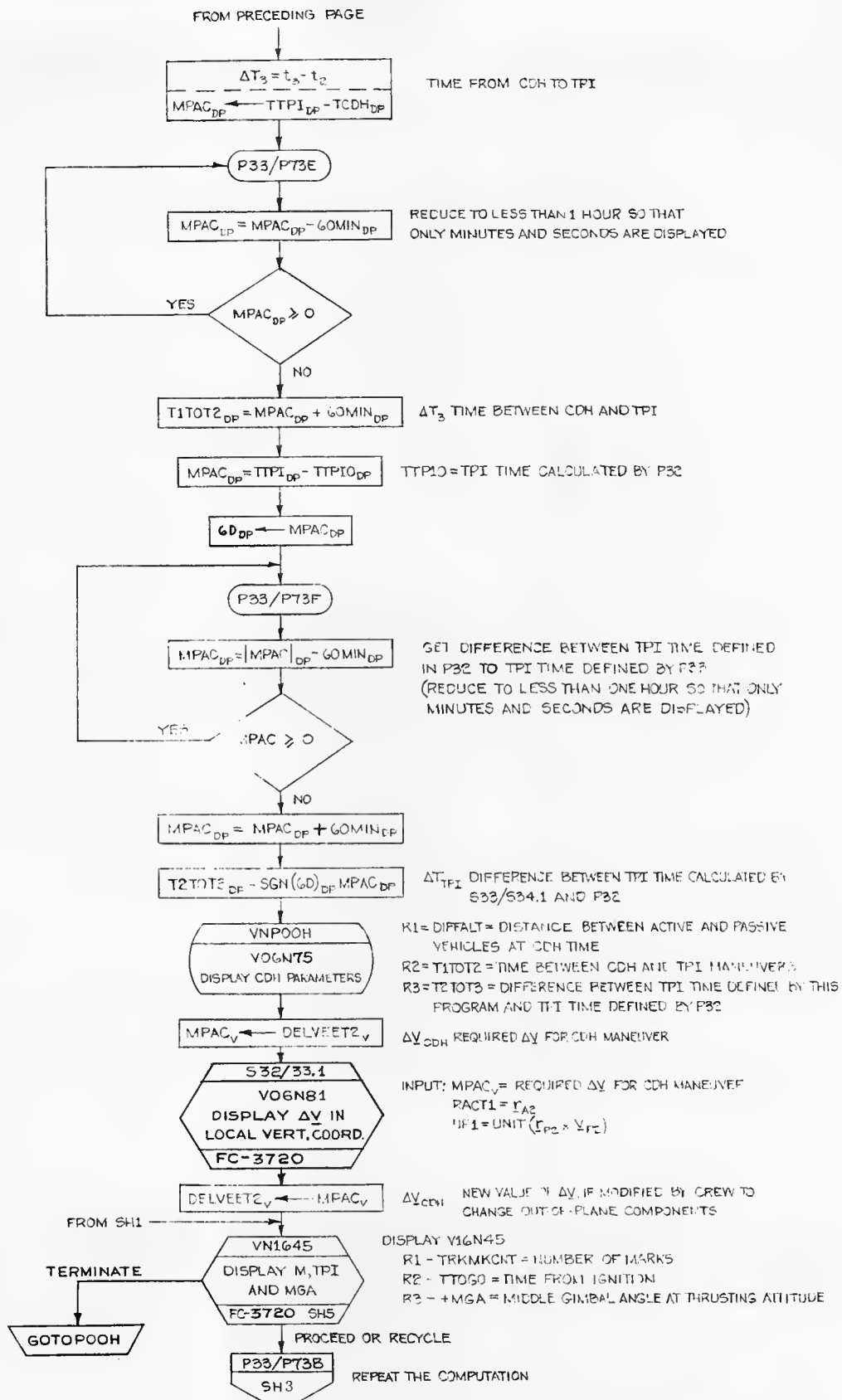
TO NEXT PAGE

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P33 AND P73 CONSTANT DELTA ALTITUDE TARGETING	
DRAWN A. CAVILLIAMS	6-7-68	LUMINARY ID	DOCUMENT NO. FC-3730
PROGR <i>[Signature]</i>	6-9-68		
ANALST <i>[Signature]</i>	6-11-68	REV 3	SHEET 3 OF 8
APPR'D <i>[Signature]</i>	6-18-68		

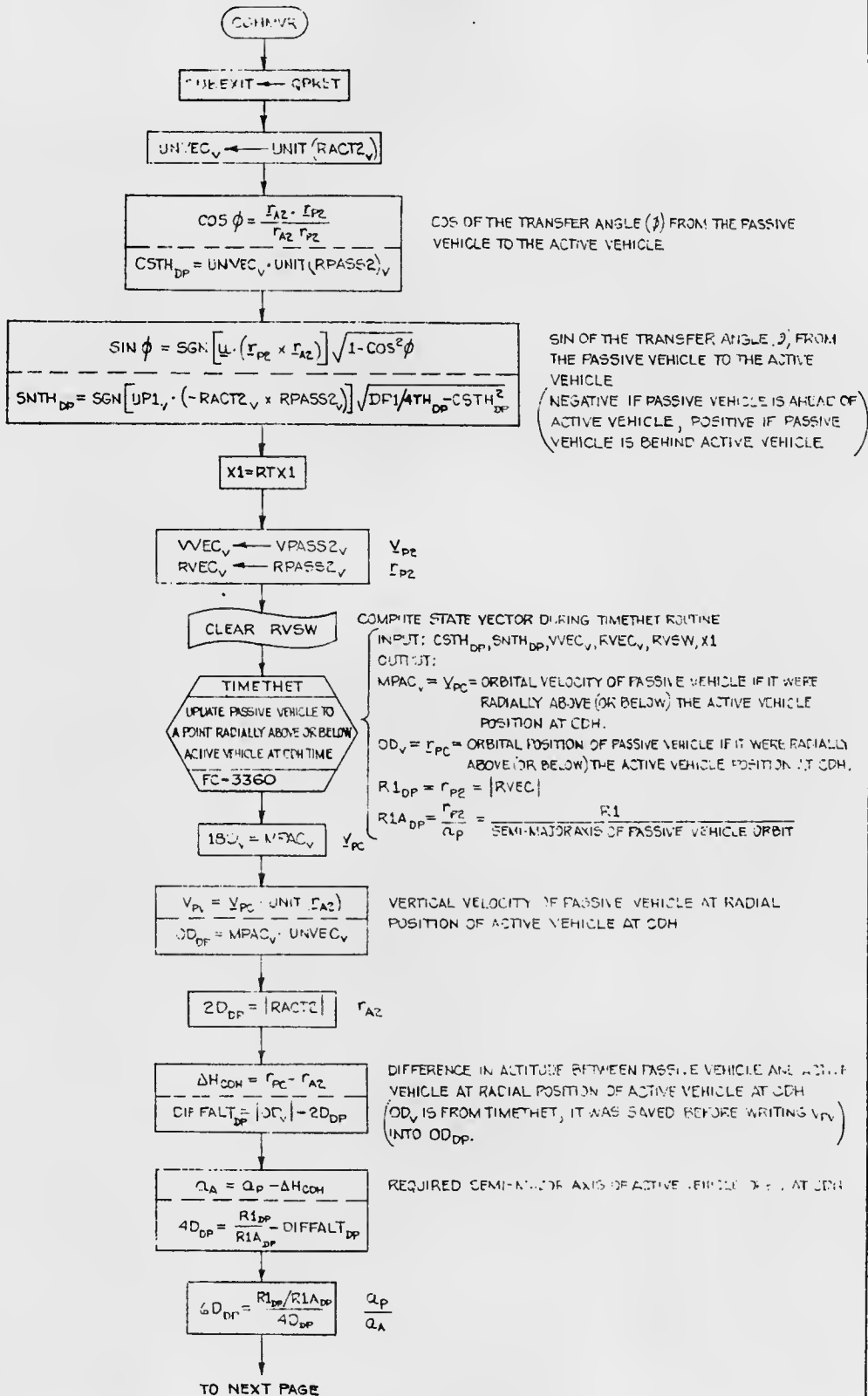
FROM PRECEDING PAGE



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P33 AND P73 CONSTANT DELTA ALTITUDE TARGETTING	
DRAWN <i>A.C. Williams</i>	6-7-68	DOCUMENT NO. FC-3730	
PROGR <i>Williams</i>	1-4-69		
ANALST <i>James Thompson</i>	4-12-68	LUMINARY 1 D	
DOCOR <i>Robert Fuller</i>	4-16-68	REV 3	SHEET 4 OF 8
APPR'D <i>J. Frazier</i>	6-18-68		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION		
		P33 AND P73 CONSTANT DELTA ALTITUDE TARGETING		
DRAWN A.C. WILLIAMS	6-7-68	LUMINARY 1D	DOCUMENT NO. FC-3730	
PROWR <i>[Signature]</i>	6-4-68		REV 3	SHEET 5 OF 8
ANALST <i>[Signature]</i>	6-11-68			
DOCWR <i>[Signature]</i>	4-16-68			
APPR'D <i>[Signature]</i>	6-18-68			



RMT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P33 AND P73 CONSTANT DELTA ALTITUDE TARGETING	
DRAWN A.C. WILLIAMS PROGMR ANALST DOCWR APPR'D	6-10-68 6-11-68 6-11-68 6-11-68 6-11-68	LUMINARY 1D	DOCUMENT NO. FC-3730
		REV 3	SHEET 6 OF 8

FROM PRECEDING PAGE

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

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

REQUIRED VERTICAL VELOCITY OF ACTIVE VEHICLE AT CDH

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

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

REQUIRED HORIZONTAL VELOCITY OF ACTIVE VEHICLE AT CDH

$$V'_{A2} = V_{AH} \text{ UNIT}(\underline{L} \times \Gamma_{A2}) + V_{AV} \text{ UNIT}(\Gamma_{A2})$$

$$\text{VACT3}_V = 10D_{DF} \text{ UNIT}(U_{PV} \times \text{UNVEC}_V) + 8D_{DF} \text{ UNVEC}_V$$

TOTAL REQUIRED VELOCITY OF ACTIVE VEHICLE AT CDH

$$\Delta V_2 = V'_{A2} - V_{A2}$$

$$\text{DELVEET2}_V = \text{VACT3}_V - \text{VACT2}_V$$

REQUIRED ΔV AT CDH

RETURN VIA SUBEXIT

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P33 AND P73 CONSTANT DELTA ALTITUDE TARGETTING	
DRAWN A.C. WILLIAMS	6-11-68	LUMINARY 1D	DOCUMENT NO.
PROGR <i>[Signature]</i>	6-9-68		FC-3730
ANALST <i>[Signature]</i>	6-11-68	REV 3	SHEET 7 OF 8
DOCMR <i>[Signature]</i>	4-16-68		
APPR'D <i>[Signature]</i>	6-18-68		

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
 TIMEHET CALCULATES DELTA TIME OF FLIGHT
 ACTIVE ACTIVE VEHICLE POSITION, VELOCITY TO RACT3, VACT3
 PASSIVE PASSIVE VEHICLE POSITION, VELOCITY TO RPASS3, VPASS3

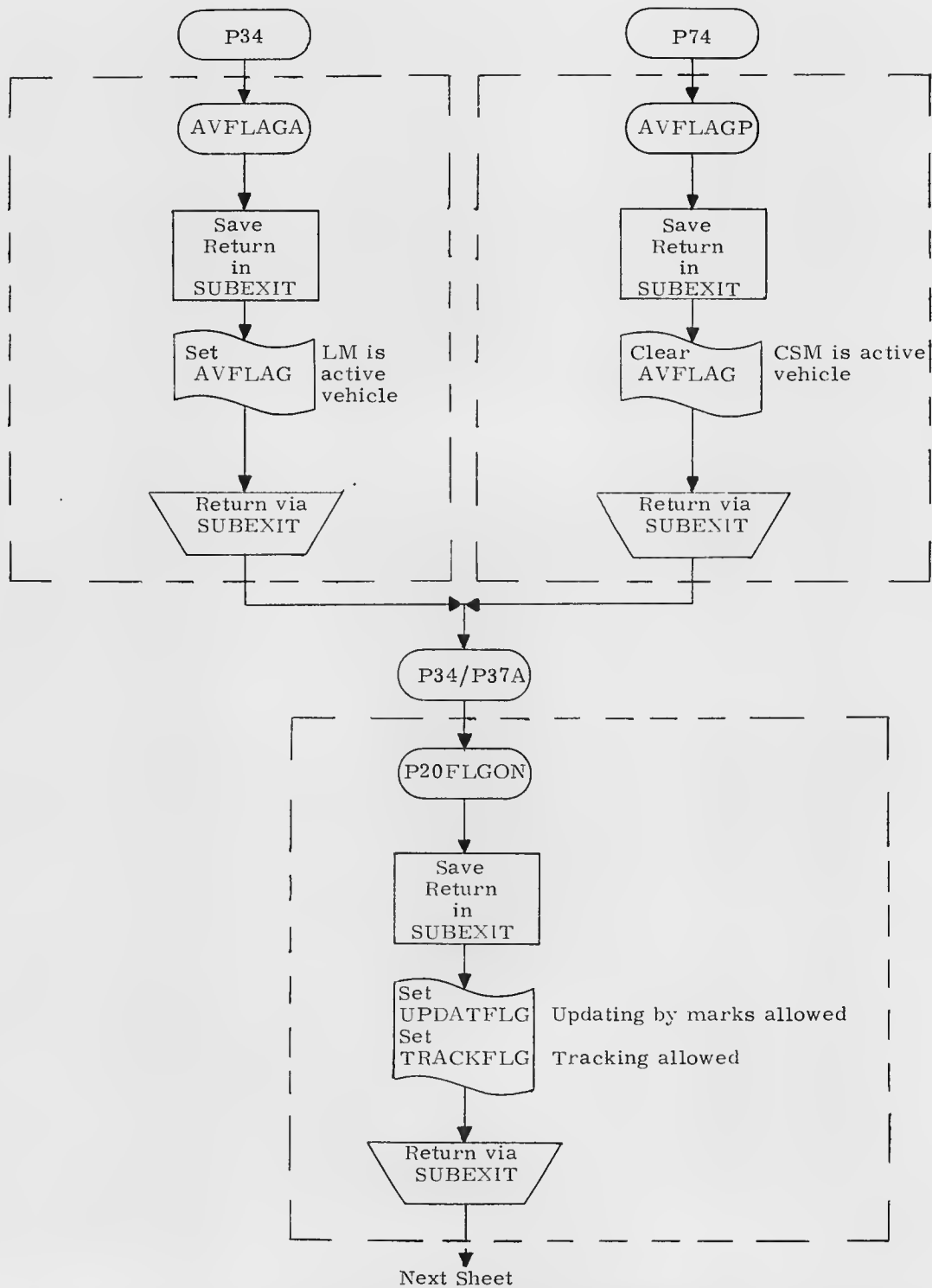
FLAGS	MEANING	SET	CLEARED	TESTED
ITSWICH	SET TPI TIME TO BE COMPUTED	SH15		
FINALFLG	CLEARED TPI TIME HAS BEEN COMPUTED			SH15
UPDATFLG	SET LAST PASS THRU RENDEZVOUS PROGRAM			
	CLEARED INTERIMPASS THRU RENDEZVOUS PROGRAM			
NDLVFLG	SET UPDATING VIA MARKS ALLOWED	SH15		
	CLEARED UPDATING VIA MARKS DISALLOWED			
RVSW	SET EXTERNAL ΔV MANEUVER	SH17		
	CLEARED LAMBERT AIM POINT MANEUVER			
AVFLAG	SET COMPUTE FINAL STATE VECTOR IN TIMEHET IN ADDITION TO Δt		SH16	
	CLEARED COMPUTE Δt ONLY			
TRACKFLG	SET LM IS ACTIVE VEHICLE	SH12	SH12	
	CLEARED CSM IS ACTIVE VEHICLE			
	SET ENABLE TRACKING	SH12		
DISPLAYS	CLEARED MEANING		USED	
V06N13	DISPLAY CDH IGNITION TIME		SH12	
V05N11	DISPLAY ALARM CODE 00611		SH4	
V06N75	DISPLAY CDH PARAMETERS		SH5	
V16N45	DISPLAY M, TFI, MGA		SH16	
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	
TPIO	TIME OF TPI MANEUVER FROM P32	CENTISECS	B28	
TTPI	TIME OF TPI MANEUVER	CENTISECS	B28	
FIG	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	$\hat{r}_{p2} \times \hat{v}_{p2}$ 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	
		P33 AND P73	
		CONSTANT DELTA ALTITUDE TARGETING	
DRAWN <i>G. J. Langille</i>	2.0 AUG 65		
PROGRAM <i>(Signature)</i>	1.29-1.5		
ANALYST <i>(Signature)</i>	1.16-1.9	LUMINARY 1D	DOCUMENT NO.
DOCWR <i>(Signature)</i>			FC-3730
APPR'D <i>(Signature)</i>	25 Aug 65	REV 3	SHEET 8 OF 8

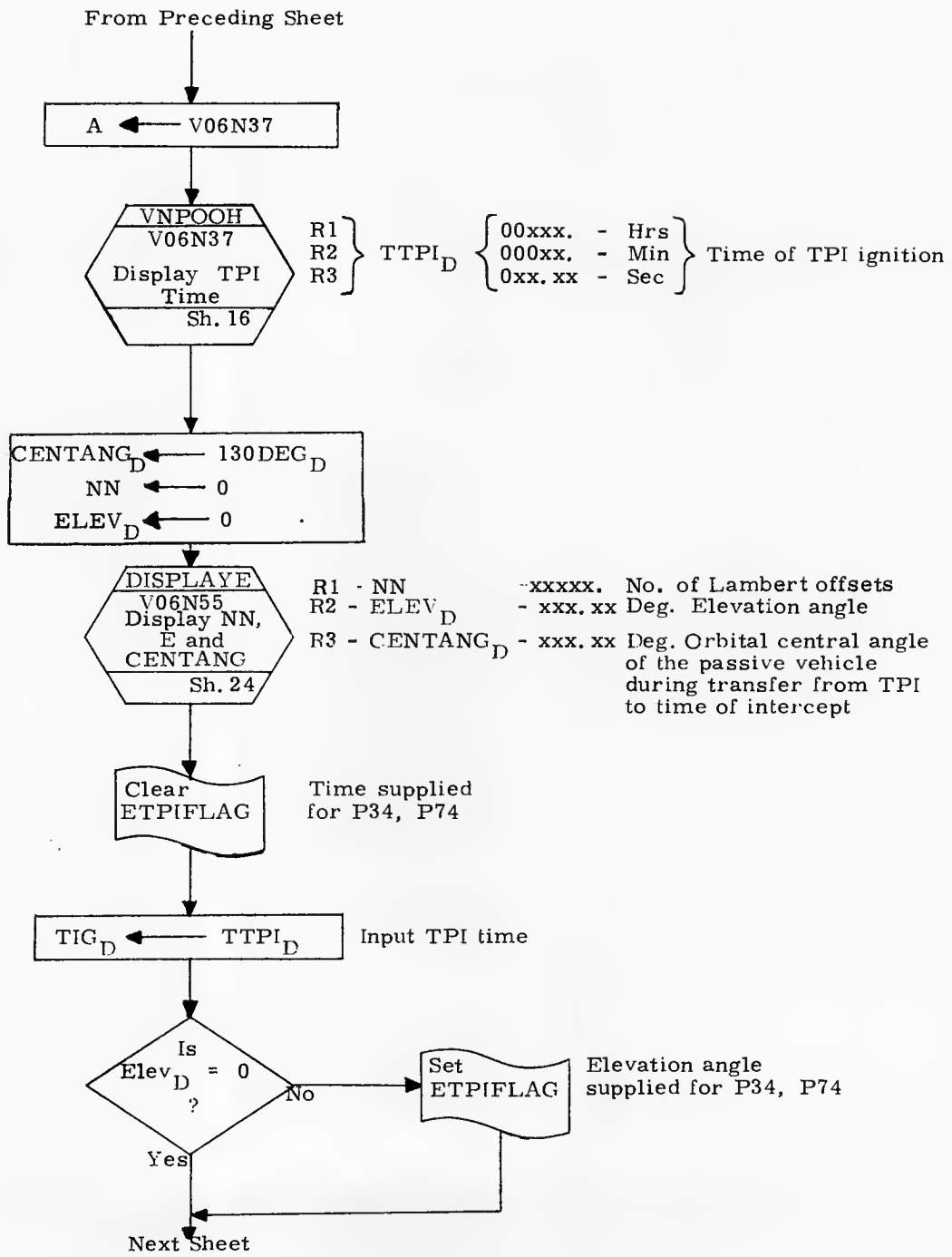
P34, P74: TRANSFER PHASE INITIATION TARGETING

P34	Sh. 2
P74	Sh. 2
S33/34.1	Sh. 9
VNPOOH	Sh. 16
S34/35.2	Sh. 17

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. Luciani</i>		P34, P74 Transfer Phase Initiation Targeting	
PRGMR <i>H. Roberts</i>	<i>12/11/69</i>	LUMINARY 1D	DOCUMENT NO. FC-3740
ANALST			
DOCMR <i>M. Danforth</i>	<i>12/15/69</i>	REV 1	SHEET 1 OF 30
APPR'D <i>M. Danforth</i>	<i>12/16/69</i>		

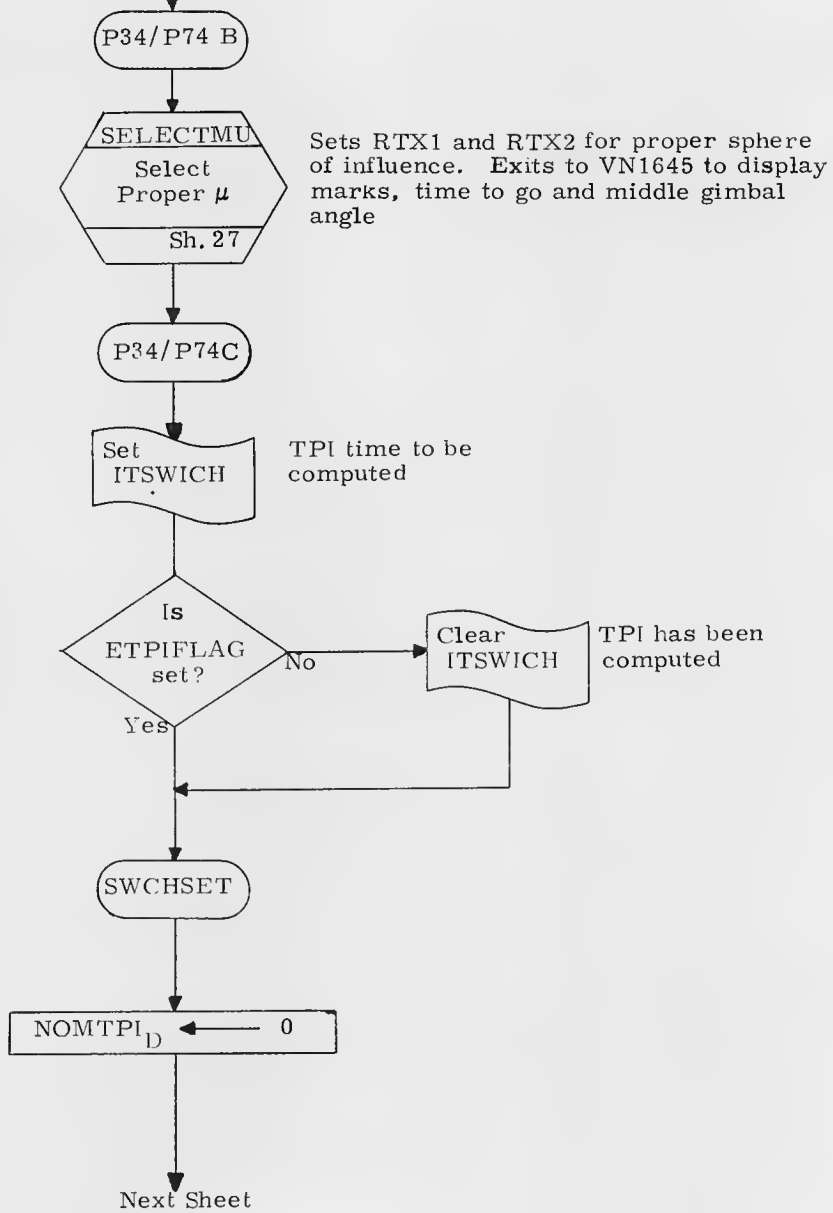


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. Luciani PE</i> 10/14/69		P34, P74 Transfer Phase Initiation Targeting	
PRGMR <i>P. White</i>	12/11/69	LUMINARY 1D	DOCUMENT NO. FC-3740
ANALST			
DOCMR <i>M. D. Smith</i>	12/5/69	REV 1	SHEET 2 OF 30
APPR'D <i>M. D. Smith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



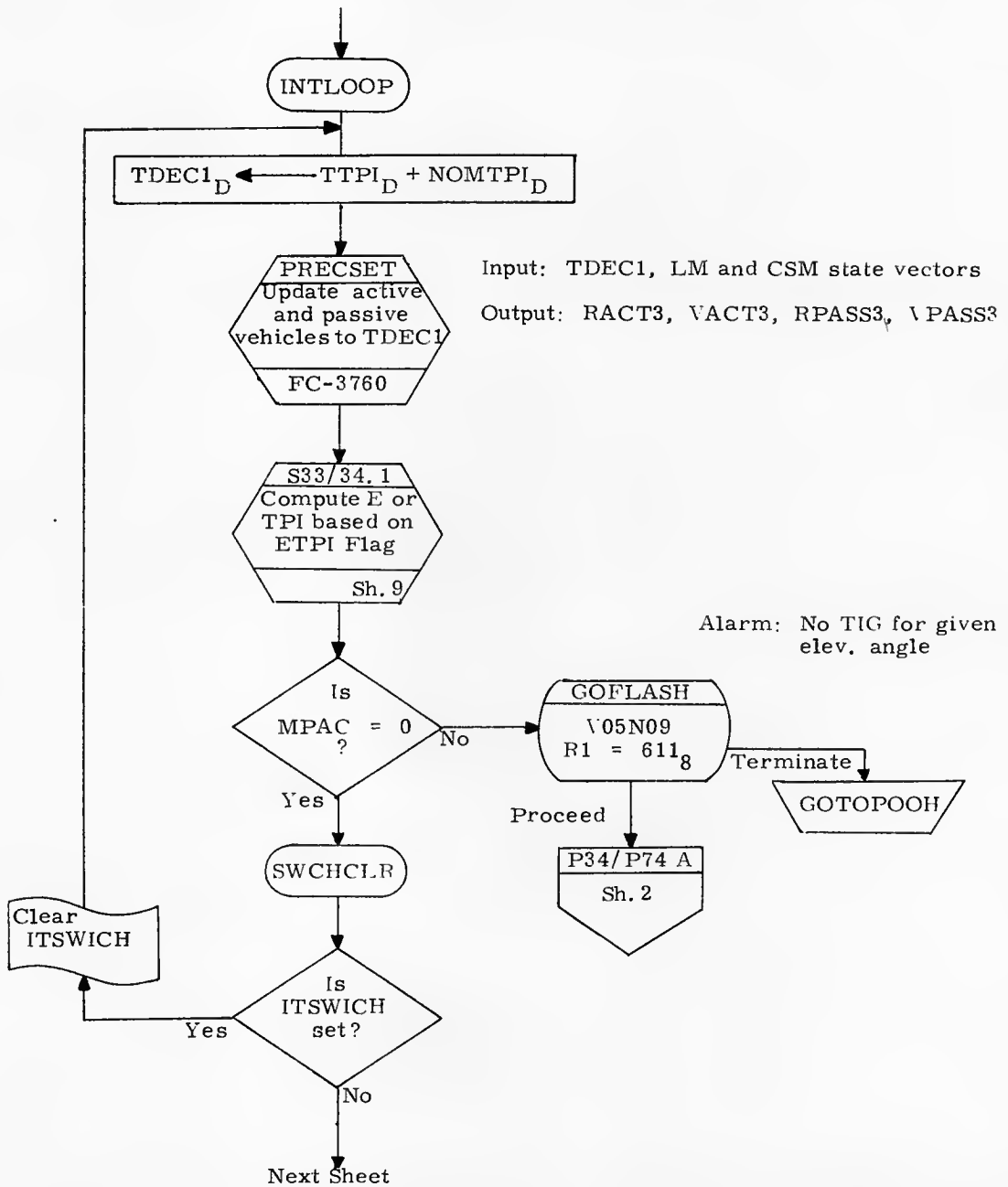
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
			P34, P74 Transfer Phase Initiation Targeting	
DRAWN	<i>O. Guichard</i>	<i>12/14/69</i>	LUMINARY 1D	DOCUMENT NO.
PRGMR	<i>P. Smith</i>	<i>12/11/69</i>		FC-3740
ANALST			REV 1	SHEET 3 OF 30
DOCMR	<i>M. D. Smith</i>	<i>12/5/69</i>		
APPR'D	<i>M. D. Smith</i>	<i>12/14/69</i>		

From Preceding Sheet



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>Q. Suckale</i> 12/14/69		P34, P74 Transfer Phase Initiation Targeting	
PRGMR <i>P. White</i> 12/11/69		LUMINARY 1D	DOCUMENT NO. FC-3740
ANALST			
DOCMR <i>W. Suckale</i> 12/15/69		REV 1	SHEET 4 OF 30
APPR'D <i>W. Suckale</i> 12/16/69			

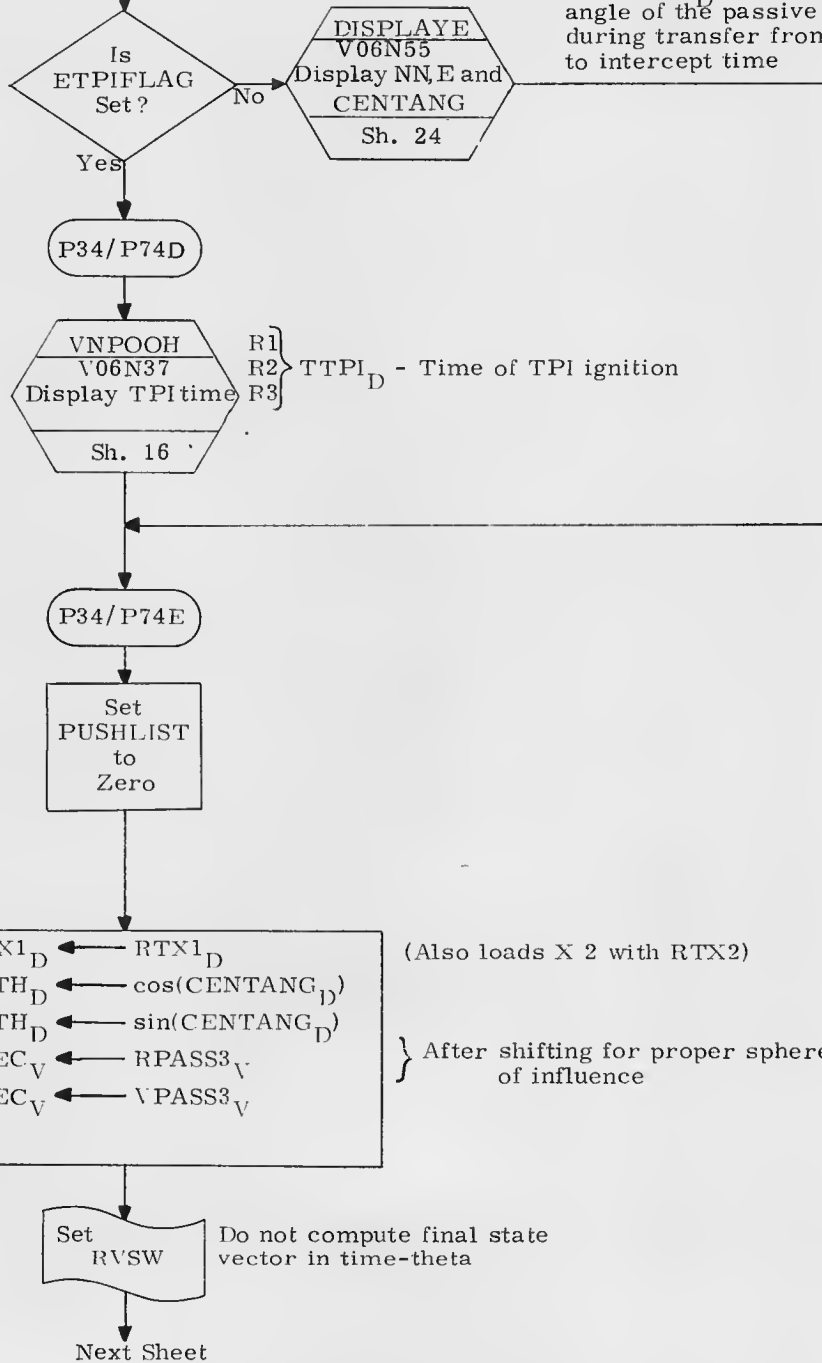
From Preceding Sheet



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

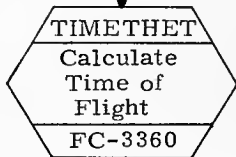
From Preceding Sheet

R1-NN - No. of Lambert offsets
 R2-ELEV_D - Elevation angle
 R3-CENTANG_D - Orbital central angle of the passive vehicle during transfer from TPI to intercept time



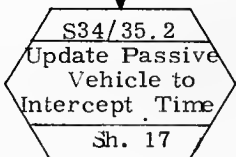
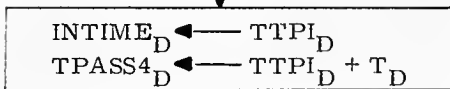
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. Lucifora</i>	<i>10/14/69</i>	P34, P74 Transfer Phase Initiation Targeting	
PRGMR <i>P. White</i>	<i>12/11/69</i>	LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3740
DOCMR <i>W. D. Smith</i>	<i>12/5/69</i>	REV 1	SHEET 6 OF 30
APPR'D <i>W. D. Smith</i>	<i>12/16/69</i>		

From Preceding Sheet

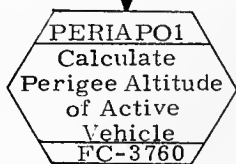
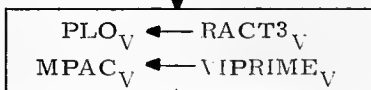
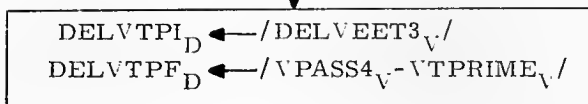


Input: RVEC, VVEC, SNTH, CSTH

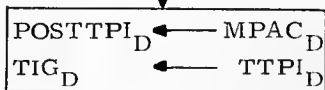
Output: T_D = Time for the passive vehicle to traverse the angle (CENTANG) between the TPI and intercept points



Input: RPASS3, VPASS3, INTIME, TPASS4, UNRM, RACT3, VACT3
Output: RTARG, VPASS4, DELVLVC, DELVEET3, VTPRIME, VIPRIME



Input: PLO_V = Position vector
 $MPAC_V$ = Velocity vector
Output: $MPAC_D$ = Perigee altitude

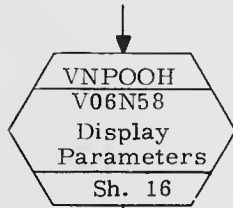


Shift using SHIFTR1

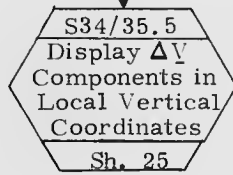
Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
			P34, P74 Transfer Phase Initiation Targeting	
DRAWN	<i>D. Tucker</i>	<i>12/14/69</i>	LUMINARY 1D	DOCUMENT NO.
PRGMR	<i>R. White</i>	<i>12/14/69</i>		FC-3740
ANALST			REV 1	SHEET 7 OF 30
DOCMR	<i>W. Dwyer</i>	<i>12/15/69</i>		
APPR'D	<i>W. Dwyer</i>	<i>12/16/69</i>		

From Preceding Sheet



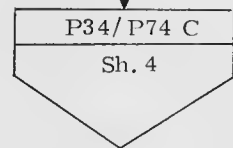
R1 - POSTTPI - Perigee altitude
 R2 - DELVTPI - Req. velocity for TPI maneuver
 R3 - DELVTPF - Req. velocity for final intercept maneuver



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 <i>O. Luchak</i> 10/14/69		P34, P74 Transfer Phase Initiation Targeting	
PRGMR <i>R. White</i> 12/11/69		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3740
DOCMR <i>W. Daghith</i> 12/5/69		REV 1	SHEET 8 OF 30
APPR'D <i>W. Daghith</i> 12/16/69			

S33/34.1

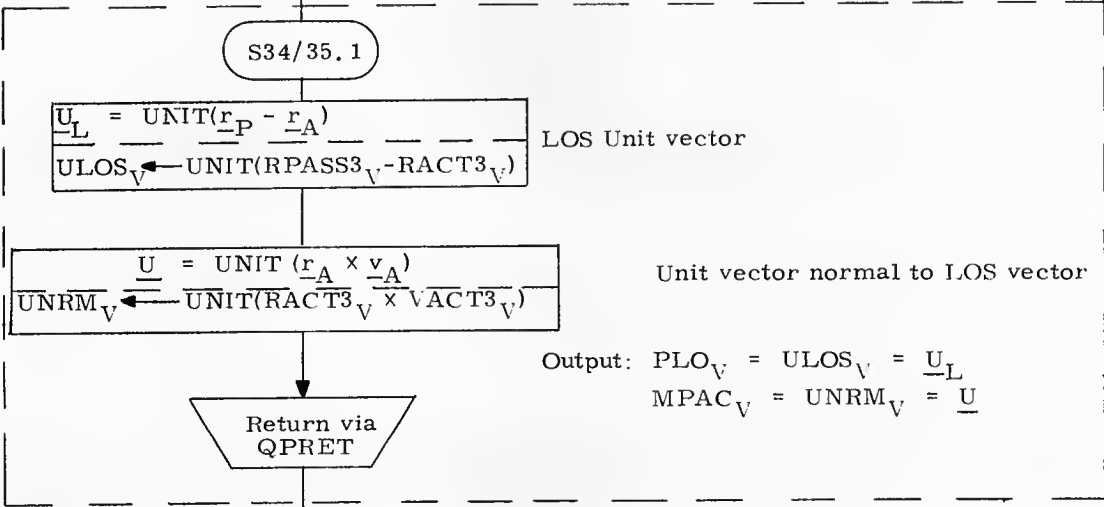
Input: RACT3, VACT3, VPASS3, RPASS3, TTPI,
NOMTPI, ITSWICH, ELEV
Output: ELEV or NOMTPI

Save
Return
in
NORMEX

Set
PUSHLIST
to
Zero

TITER ← 40000.8
SECMA_D ← MAX250_D
RAPREC_V ← RACT3_V
VAPREC_V ← VACT3_V
RPPREC_V ← RPASS3_V
VPPREC_V ← VPASS3_V

ELCALC



Next Sheet

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

From Preceding Sheet

$$\begin{aligned} \text{PLO} &= \underline{u} \times \underline{r}_A \\ \text{PLO}_V &\leftarrow \text{MPAC}_V \times \text{RACT3}_V \end{aligned}$$

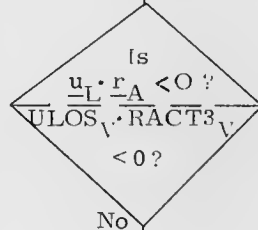
$$\begin{aligned} \text{PL6} &= \underline{r}_A / \underline{r}_A \\ \text{PL6}_V &\leftarrow \text{UNIT}(\text{RACT3}_V) \end{aligned}$$

$$\begin{aligned} \underline{u}_P &= \text{UNIT} [\underline{u}_L - (\underline{u}_L \cdot \underline{r}_A) \underline{r}_A / r_A^2] \\ \text{MPAC}_V &\leftarrow \text{UNIT} [\text{ULOS}_V - (\text{ULOS}_V \cdot \text{PL6}_V) \text{PL6}_V] \end{aligned}$$

$$\begin{aligned} \text{PLO} &= \underline{u}_P \cdot (\underline{u} \times \underline{r}_A) \\ \text{PLO}_D &\leftarrow \text{MPAC}_V \cdot \text{PLO}_V \end{aligned}$$

$$\begin{aligned} E_A &= \cos^{-1} [\underline{u}_L \cdot \underline{u}_P \text{SGN}(\underline{u}_P \cdot \underline{u} \times \underline{r}_A)] \\ \text{PLO}_D &\leftarrow \cos^{-1} [\text{ULOS}_V \cdot \text{MPAC}_V \text{SGN}(\text{PLO}_D)] \end{aligned}$$

Computed elevation angle



Yes

$$\begin{aligned} E_A &= 2\pi - E_A \\ \text{PLO}_D &\leftarrow \text{DPPOS} \text{MAN}_D - \text{PLO}_D \end{aligned}$$

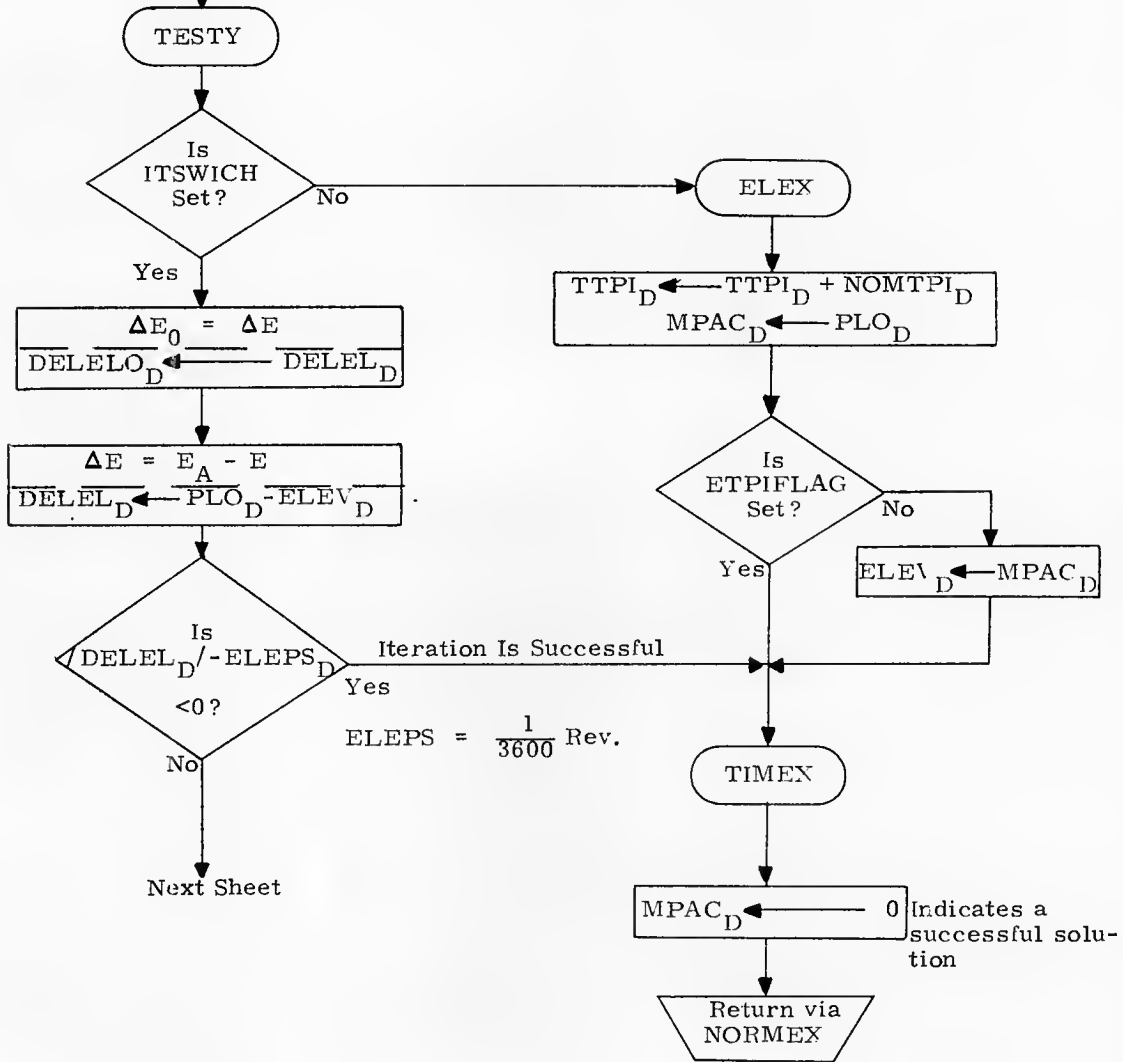
No

Make $E_A > 180^\circ$ when the LOS lies below the horizontal plane

Next Sheet

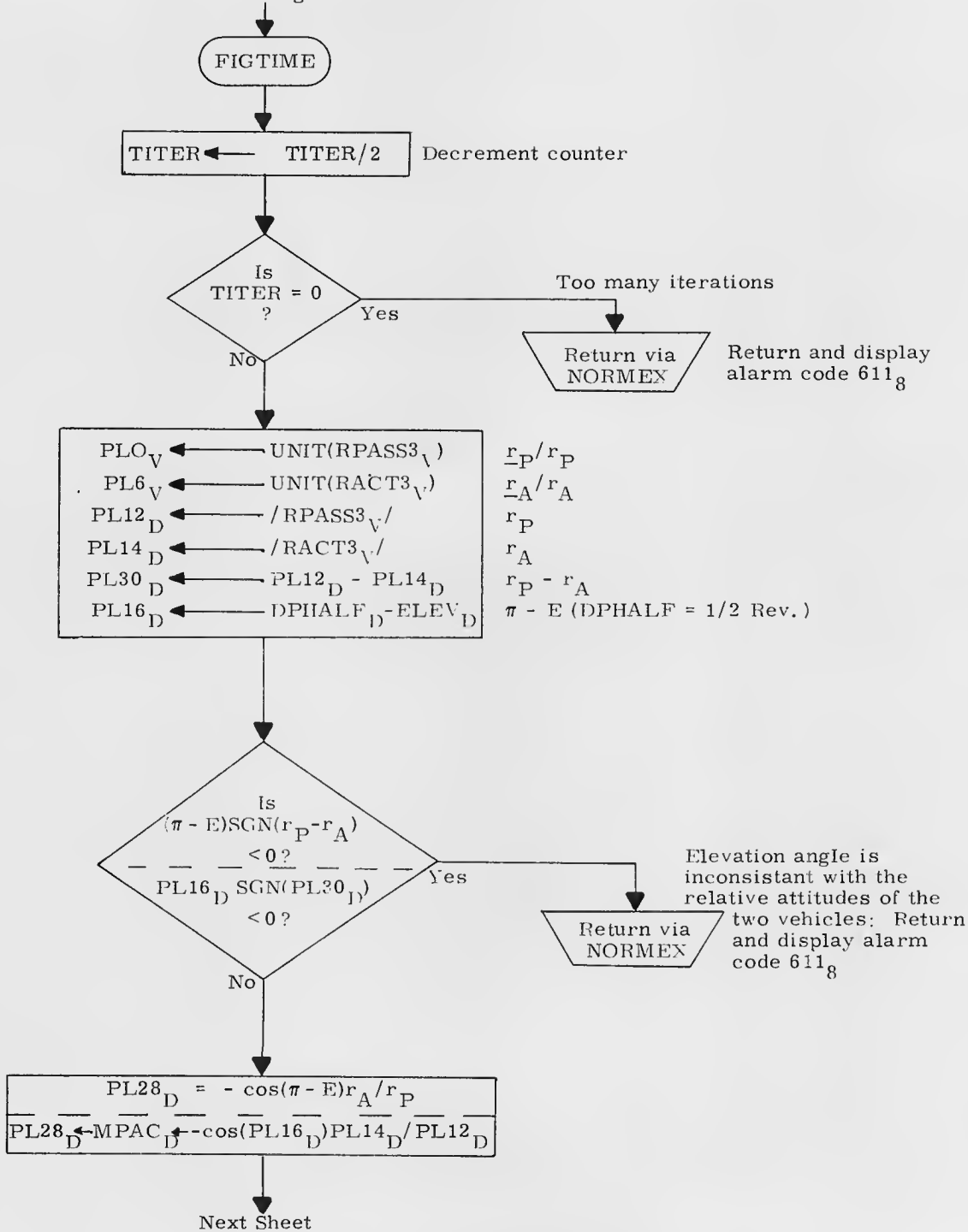
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i>		P34, P74, Transfer Phase Initiation Targeting	
PRGMR <i>[Signature]</i>	<i>[Date]</i>	LUMINARY 1D	DOCUMENT NO. FC-3740
ANALST <i>[Signature]</i>	<i>[Date]</i>		REV 1
DOCMR <i>[Signature]</i>	<i>[Date]</i>	SHEET 10 of 30	
APPR'D <i>[Signature]</i>	<i>[Date]</i>		

From Preceding Sheet



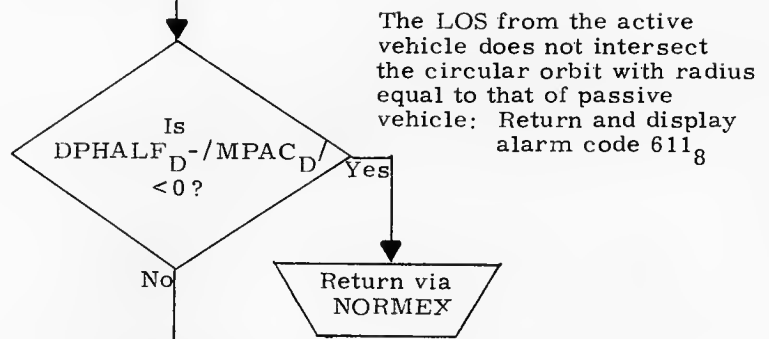
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>[Signature]</i>	P34, P74 Transfer Phase Initiation Targeting	
PRGMR	<i>[Signature]</i>		DOCUMENT NO.
ANALST	<i>[Signature]</i>	LUMINARY 1D	FC-3740
DOCMR	<i>[Signature]</i>	REV 1	SHEET 11 OF 30
APPR'D	<i>[Signature]</i>		

From Preceding Sheet



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>D. Schubert</i>	P34, P74 Transfer Phase Initiation Targeting	
PRGMR	<i>P. White</i>	LUMINARY ID	DOCUMENT NO.
ANALST			FC-3740
DOCMR	<i>W. DeGroot</i>	REV 1	SHEET 12 OF 30
APPR'D	<i>W. DeGroot</i>		

From Preceding Sheet



$$\overline{PL16}_D \leftarrow \frac{\omega_A = [\text{UNIT}(U \times r_A) \cdot v_A] r_P}{[\text{UNIT}(\text{UNRM}_V \times \text{PL6}_V) \cdot \text{VACT3}_V] \text{PL12}_D}$$

$$\overline{MPAC}_D \leftarrow \frac{\omega_P = \{ \text{UNIT}[(r_P \times v_P) \times r_P] \cdot v_P \} r_A}{\{ \text{UNIT}[(\text{PLO}_V \times \text{VPASS3}_V) \times \text{PLO}_V] \cdot \text{VPASS3}_V \} \text{PL14}_D}$$

$$\overline{PL16}_D = \overline{\omega}_A - \overline{\omega}_P$$

$$\overline{PL16}_D \leftarrow \overline{PL16}_D - \overline{MPAC}_D$$

$$\overline{PL18}_D = \frac{(r_A \times r_P) \cdot U}{(\text{PL6}_V \times \text{PLO}_V) \cdot \text{UNRM}_V}$$

$$\overline{MPAC} = \text{SGN}(r_A \times r_P \cdot U) \cos^{-1}(r_A \cdot r_P / r_A r_P)$$

$$\overline{MPAC}_D \leftarrow \text{SGN} \overline{PL18}_D [\cos^{-1}(\text{PL6}_V \cdot \text{PLO}_V)]$$

$$\overline{PL18}_D \leftarrow \frac{\alpha - \pi = \overline{MPAC} + E - \pi}{\overline{MPAC}_D + \overline{ELEV}_D - \overline{DPHALF}_D}$$

$$\overline{PL12}_D \leftarrow \{ [\{ \pi - \cos^{-1}(r_A \cos E / r_P) \} \text{SGN}(r_P - r_A) (\alpha - \pi)] 2\pi / (\omega_A - \omega_P) \} r_A r_P$$

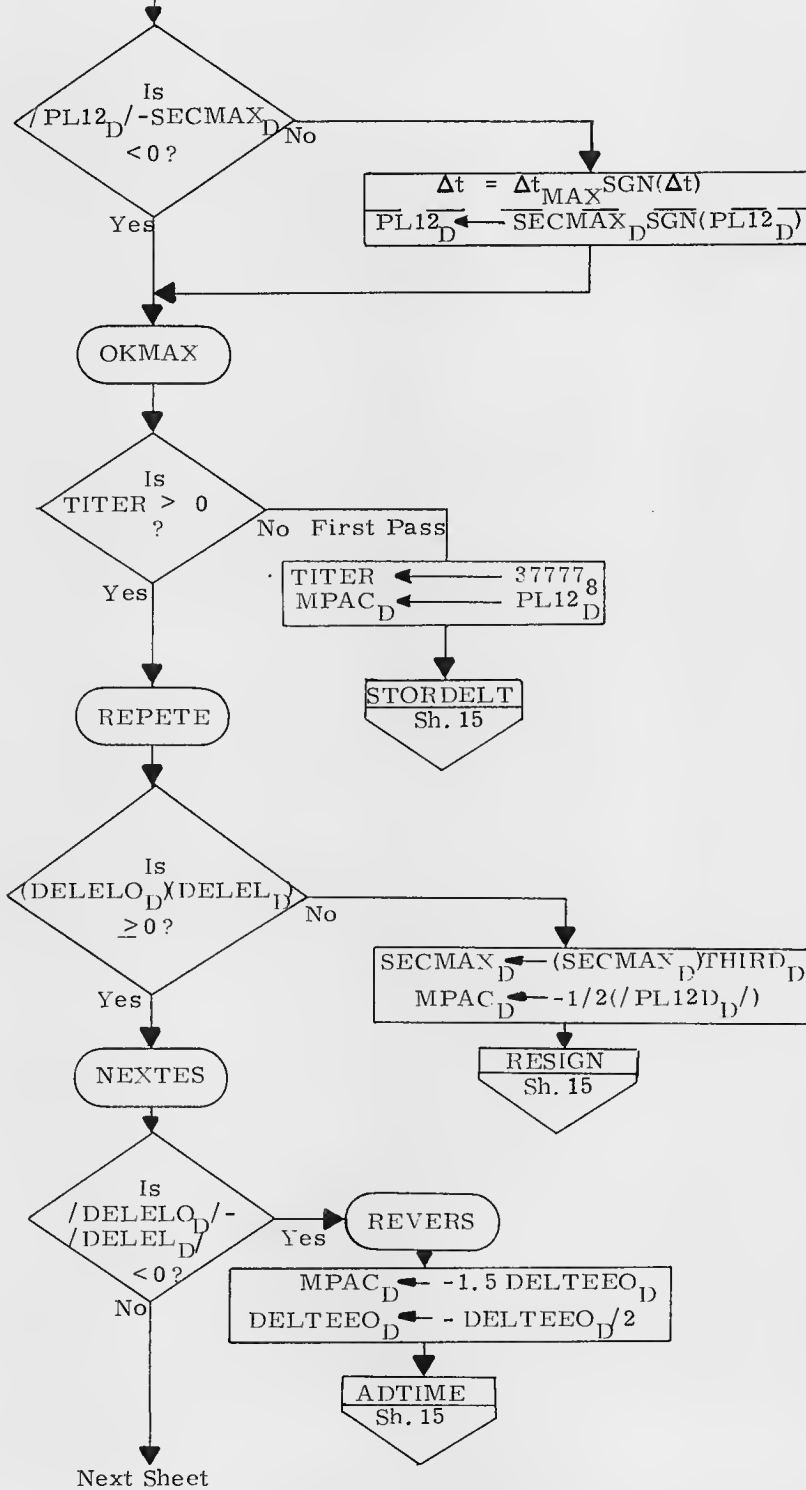
$$\overline{PL12}_D \leftarrow \{ [\{ \overline{DPHALF}_D - (\cos^{-1} \text{PL28}_D) \} \text{SGN}(\text{PL30}_D) + \overline{PL18}_D] \text{TWOPL}_D / \overline{PL16}_D \} \overline{PL14}_D \overline{PL12}_D$$

2π cancels Rev. Units so units of final expression will be CSEC

Next Sheet

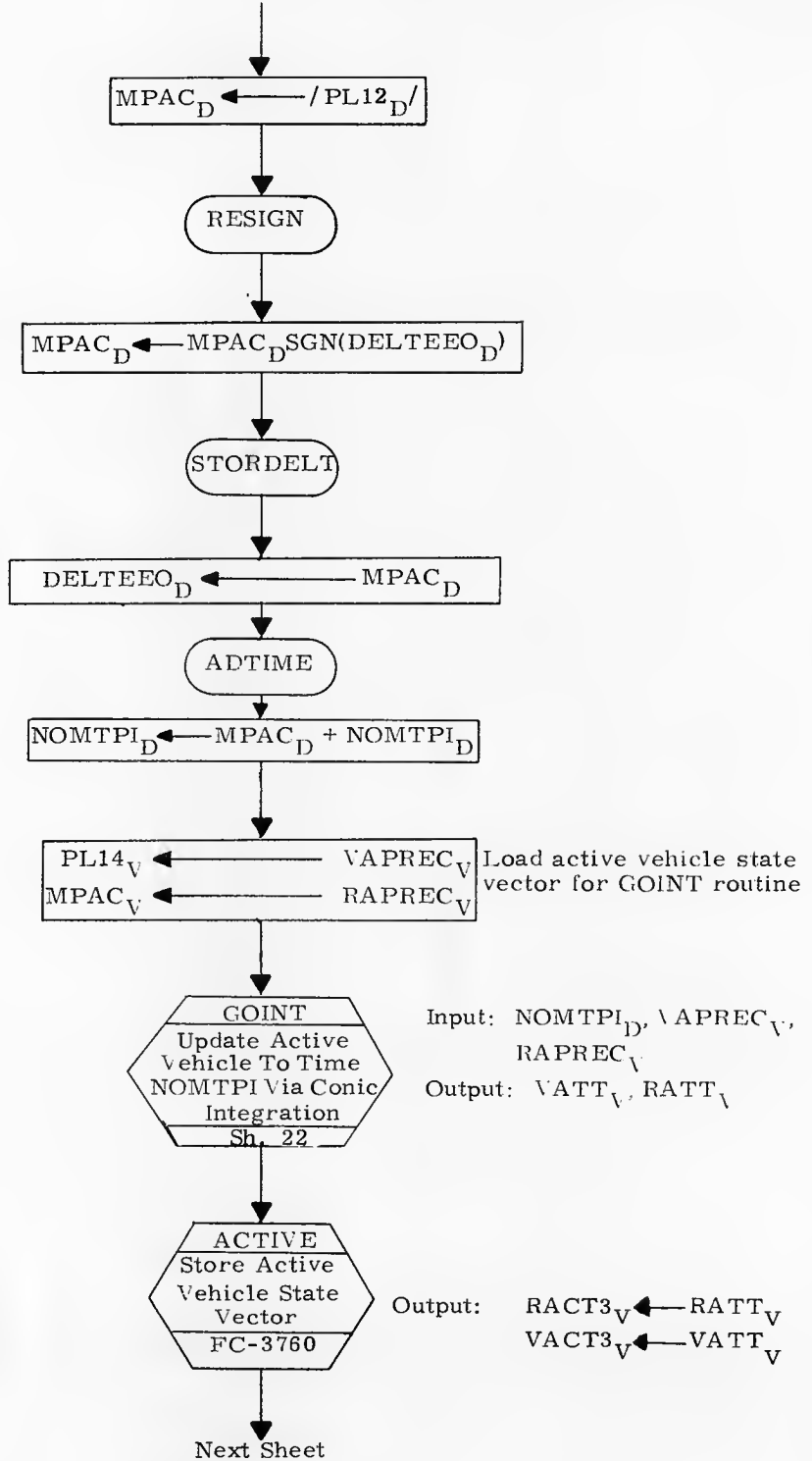
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Fuchs</i> 12/11/69		P34, P74 Transfer Phase Initiation Targeting	
PRGMR <i>White</i> 12/11/69		LUMINARY ID	DOCUMENT NO.
ANALST			FC-3740
DOCMR <i>White</i> 12/15/69		REV 1	SHEET 13 OF 30
APPR'D <i>White</i> 12/16/69			

From Preceding Sheet

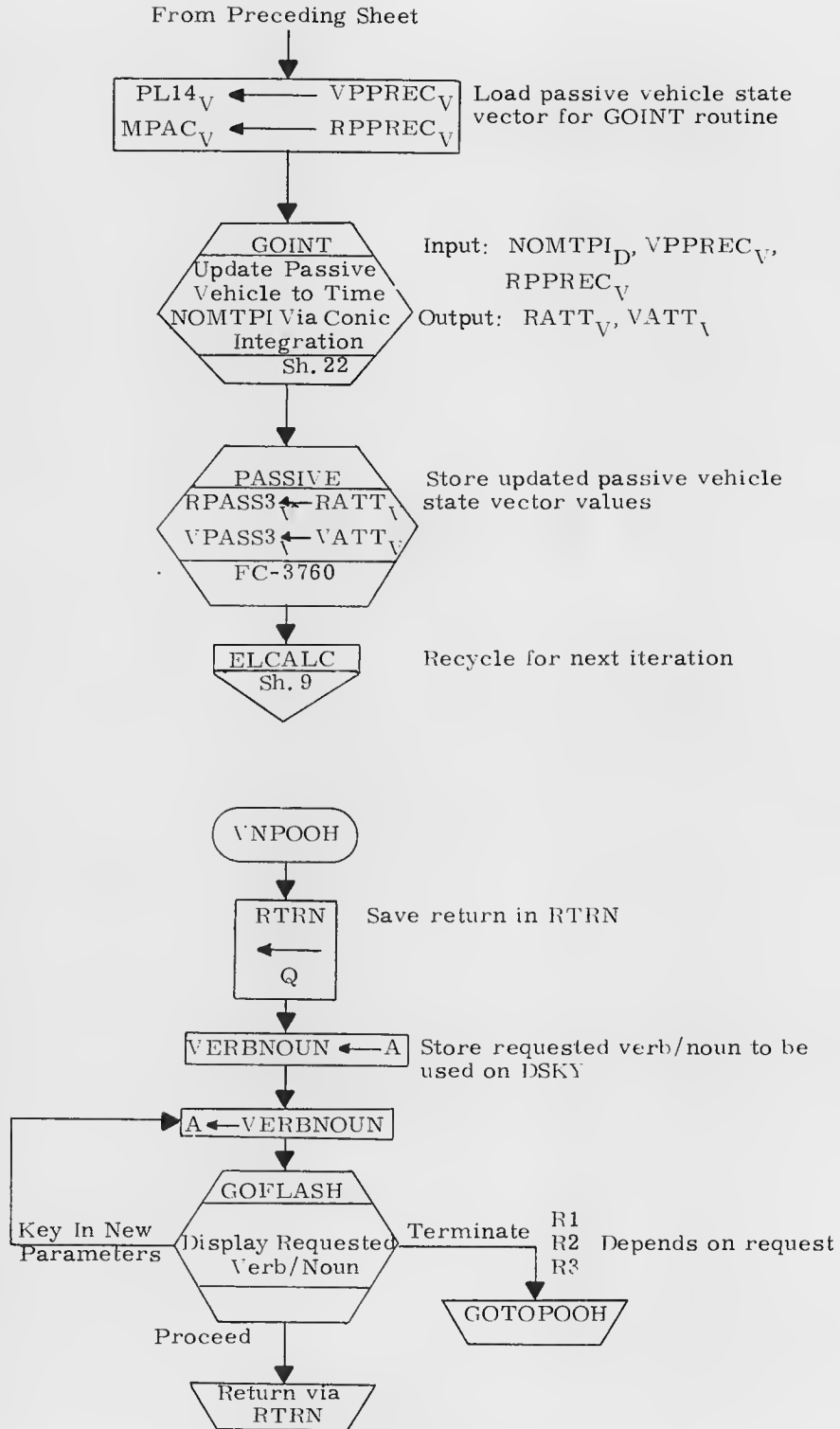


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. G. ...</i> 10/14/69		P34, P74 Transfer Phase Initiation Targeting	
PRGMR <i>P. ...</i> 12/11/69		LUMINARY ID	DOCUMENT NO.
ANALST <i>...</i>			FC-3740
DOCMR <i>...</i> 12/5/69		REV 1	SHEET 14 OF 30
APPR'D <i>...</i>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

From Preceding Sheet



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



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>O. Juchacz</i> 12/14/69	P34, P74 Transfer Phase Initiation Targeting	
PRGMR	<i>Appel</i> 12/11/69	LUMINARY ID	DOCUMENT NO.
ANALST			FC-3740
DOCMR	<i>M. D. ...</i> 12/15/69	REV 1	SHEET 16 OF 30
APPR'D	<i>M. D. ...</i> 12/16/69		

S34/35. 2

SUBEXIT
←
QPRET

Save return
in SUBEXIT

$OD_V \leftarrow VPASS3_V$
 $6D_V \leftarrow RPASS3_V$
 $12D_D \leftarrow INTIME_D$
 $14D_D \leftarrow TPASS4_D$
 $16D_D \leftarrow TWOPI$

Load VAC area for
integration routine

Do conic integration

Is
NN = 0 ?

No

$16D_D \leftarrow 0$

Do precision
integration

Yes

S3435. 23

INTINT
Advance
passive vehicle
to intercept
time
Sh. 22

Output: $MPAC_V$ = position vector
 $VATT_V$ = velocity vector

$RTARG_V \leftarrow MPAC_V$
 $VPASS4_V \leftarrow VATT_V$
 $OD_V \leftarrow UNIT(RTARG_V)$
 $6D_V \leftarrow UNIT(RACT3_V)$

Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. J. ...</i> 12/9/69		P34, P74, Transfer Phase Initiation Targeting	
PRGMR <i>P. White</i> 12/11/69	ANALST	LUMINARY ID	DOCUMENT NO.
DOCMR <i>W. ...</i> 12/5/69	APPR'D <i>W. ...</i> 12/11/69		FC-3740
		REV 1	SHEET 17 OF 28

From Preceding Sheet

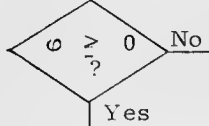
$$6D = \frac{r_A \times r_P \cdot U}{6D_V \times OD_V \cdot UNRM_V}$$

$$MPAC_V \leftarrow UNIT(RACT3_V)$$

$$\phi = \cos^{-1}(\frac{r_A \cdot r_P}{r_A \cdot r_P}) \text{SGN}(r_A \times r_P \cdot U)$$

$$MPAC_D \leftarrow \cos^{-1}(MPAC_V \cdot OD_V) \text{SGN } 6D_D$$

ϕ = Orbital central angle traversed by the active vehicle during transfer from TPI to TPF (Time of Intercept)



$$\phi = \phi + 2\pi$$

$$MPAC_D \leftarrow MPAC_D + DPPOSMA_X_D$$

Make ϕ positive in third or fourth quadrant.

NOPIE

$$ACTCENT_D \leftarrow MPAC_D$$

$$DELLT4_D \leftarrow TPASS4_D - INTIME_D$$

ACTCENT = ϕ
 DELLT4 = Time from TPI to TPF

Set Pushlist To Zero

$$OD_D \leftarrow NN$$

$$2D_D \leftarrow EPSFOUR_D$$

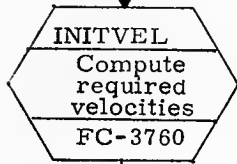
$$RINIT_V \leftarrow RACT3_V$$

$$VINIT_V \leftarrow VACT3_V$$

Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>N. G. ...</i>	P34, P74 Transfer Phase Initiation Targeting	
PRGMR	<i>P. White</i>	LUMINARY ID	DOCUMENT NO. FC-3740
ANALST			
DOCMR	<i>N. G. ...</i>	REV 1	SHEET 18 OF 30
APPR'D	<i>N. G. ...</i>		

From Preceding Sheet

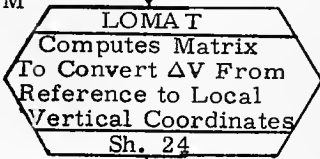


Input: RACT3, VACT3, RTARG, DELLT4, OD_D , INTIME, MPAC, X1(= - 2 for earth, = - 10 for moon orbit)

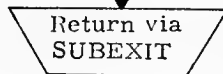
Output: RTARG(Offset target position vector), VIPRIME(velocity required from TPI point for active vehicle to achieve TPF point), VTPRIME(active vehicle velocity after TPF point), DELVEET3(ΔV for TPI maneuver)

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.

Input: UNRM
RACT3
Output: Transformation matrix in OD_M

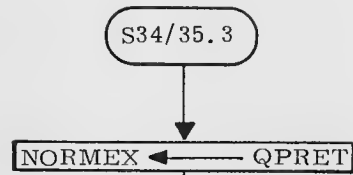


DELVLVC ← $(OD_M) DELVEET3 \Delta V$ In local vertical coordinates



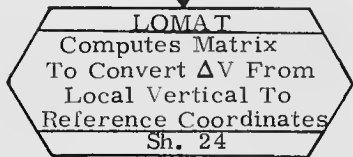
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>A. Luchko</i>	P34, P74 Transfer Phase Initiation Targeting	
PRGMR	<i>P. P. White</i>	LUMINARY ID	DOCUMENT NO.
ANALST			FC-3740
DOCMR	<i>W. DeGroot</i>	REV 1	SHEET 19 OF 30
APPR'D	<i>W. DeGroot</i>		

Save Return
in NORMEX



Calculates line of sight ΔV in
reference coordinates at TPI time.

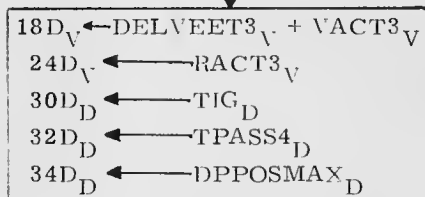
Input: DELVLVC, VACT3,
RACT3, TIG, TPASS4,
UNRM, ULOS
Output: DVLOS, RTARG



Input: UNRM, RACT3
Output: Transformation matrix
in OD_M

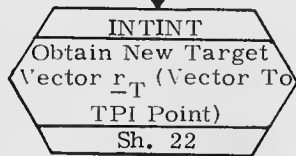


Push list counter is 18 upon
return from LOMAT
 $DELVEET3 = \Delta V_{TPI}$ in reference
coordinates.
 $DELVLVC = \text{New } \Delta V_{TPI}$ inputted by
astronaut overwrite.

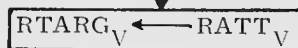


Set up vac area for integration
routine

Indicates precision integration



Output: $RATT_V$



New offset target vector

Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>N. Luchini</i> 12/11/69		P34, P74 Transfer Phase Initiation Targeting	
PRGMR <i>P. White</i>	12/11/69	LUMINARY ID	DOCUMENT NO.
ANALST			FC-3740
DOCMR <i>N. Luchini</i>	12/15/69	REV 1	SHEET 20 OF 30
APPR'D <i>N. Luchini</i>	12/16/69		

From Preceding Sheet

NOVRWRT

$$\begin{aligned} OD_V &\leftarrow ULOS_V \\ 6D_V &\leftarrow UNIT(UNRM_V \times ULOS_V) \times ULOS_V \\ 12D_V &\leftarrow UNIT(UNRM_V \times ULOS_V) \end{aligned}$$

This matrix is used to convert ΔV from reference coordinates to line of sight coordinates

$$DVLOS_V \leftarrow OD_M \text{ DELVEET3}_V$$

Line of sight delta velocity

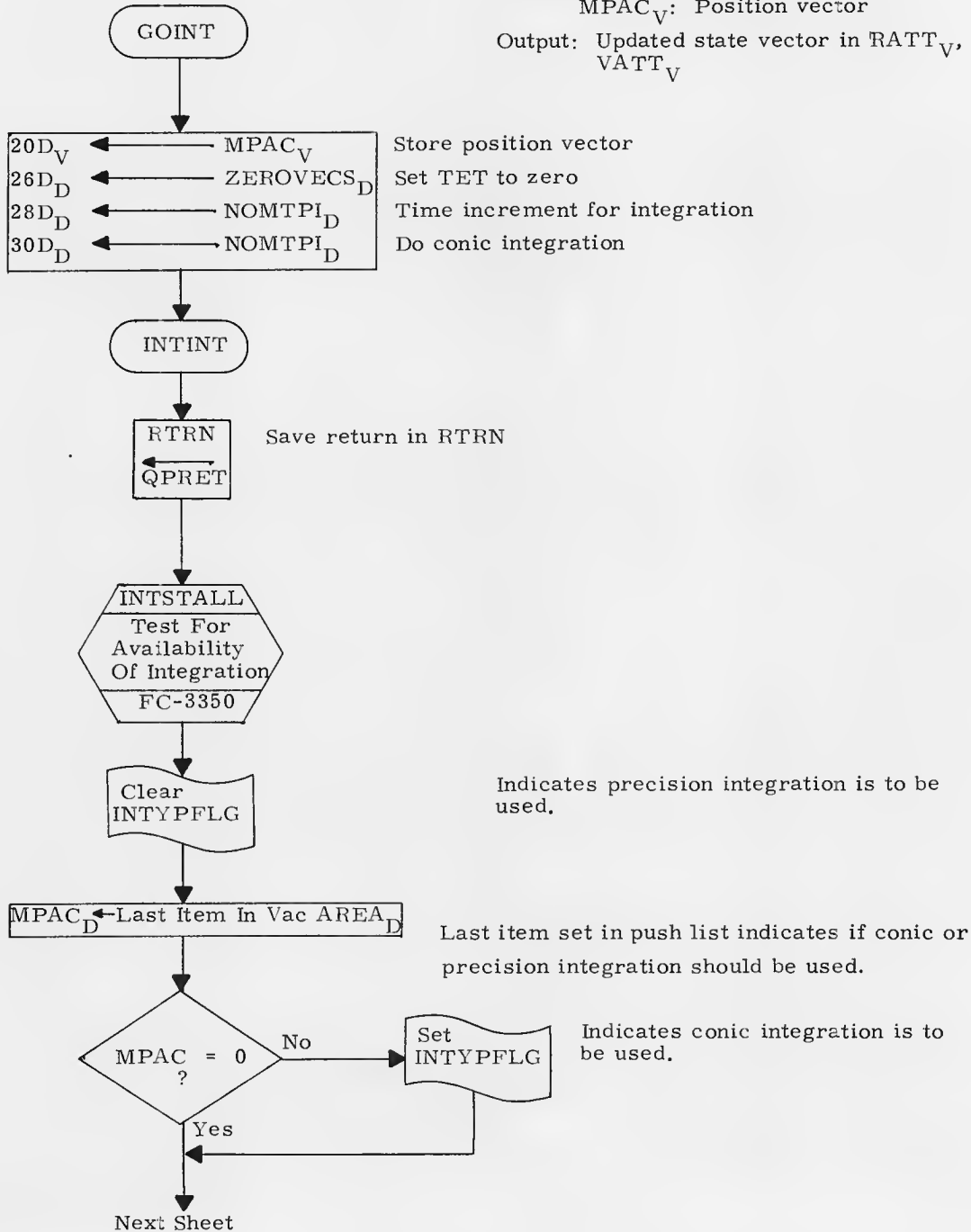
Return via
NORMEX

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>P. White</i> 10/15/69	P34, P74 Transfer Phase Initiation Targeting	
PRGMR	<i>P. White</i> 12/11/69	LUMINARY ID	DOCUMENT NO.
ANALST			FC-3740
DOCMR	<i>W. DeBitch</i> 12/6/69	REV 1	SHEET 21 OF 30
APPR'D	<i>W. DeBitch</i> 12/16/69		

Routine to prepare user for conic or precision integration.

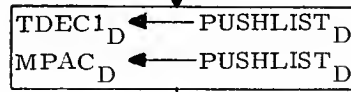
Input: Velocity vector in push list,
MPAC_V: Position vector

Output: Updated state vector in RATT_V,
VATT_V



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. S. White</i> 12/14/69		P34, P74 Transfer Phase Initiation Targeting	
PRGMR <i>D. S. White</i>	12/11/69	LUMINARY 1D	DOCUMENT NO. FC-3740
ANALST			
DOCMR <i>D. S. White</i>	12/17/69	REV 1	SHEET 22 OF 30
APPR'D <i>D. S. White</i>	12/16/69		

From Preceding Sheet



Time to integrate to from pushlist area
Load time of state vector from pushlist area

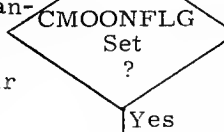


Indicates sphere of influence is lunar



Set = 0 If earth centered orbit
Set = 2 If moon centered orbit

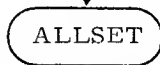
CMOONFLG = 1 means permanent CSM state vector is in the lunar sphere.



No
Yes

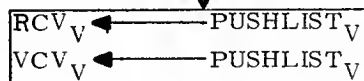


Indicates sphere of influence is earth.



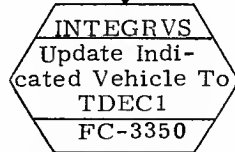
Time of state vector

Shift vectors to proper sphere of influence

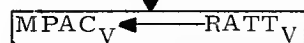


Present position in last pushlist area used

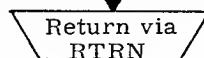
Present velocity in next to last pushlist area used.



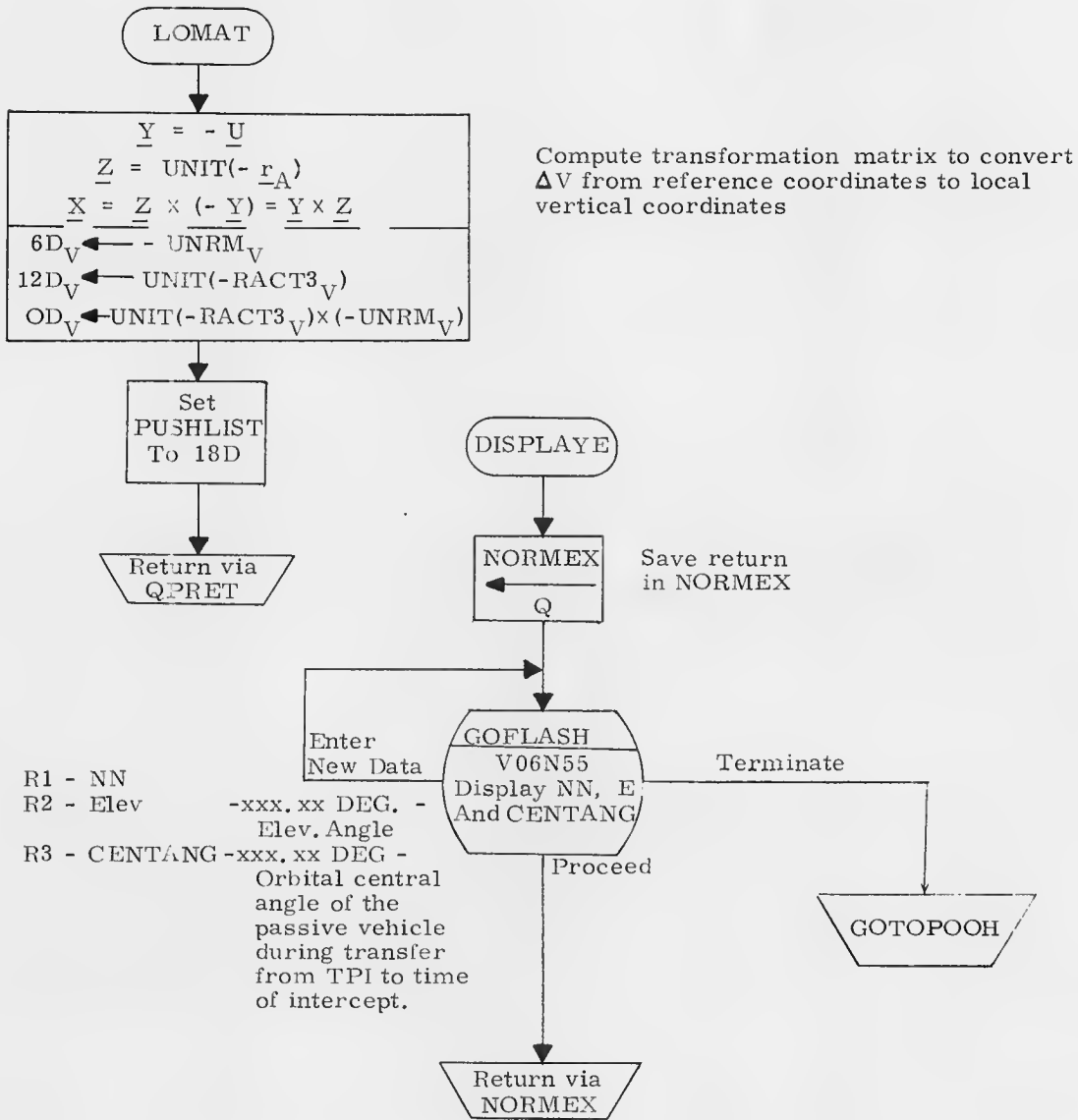
Input: RCV, VCV, TDEC1, TET
Output: VATT, MPAC, (RATT)



Position at TDEC1



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>A. Tscholke</i> 12/14/69	P34, P74 Transfer Phase Initiation Targeting	
PRGMR	<i>R. White</i> 12/11/69	LUMINARY ID	DOCUMENT NO.
ANALST			FC-3740
DOCMR	<i>W. D. Smith</i> 12/5/69	REV 1	
APPR'D	<i>W. D. Smith</i> 12/6/69		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P34, P74 Transfer Phase Initiation Targeting	
DRAWN	<i>D. Luhrs</i>	10/14/69	DOCUMENT NO. FC-3740
PRGMR	<i>R. White</i>	12/14/69	
ANALST			LUMINARY 1D REV 1
DOCMR	<i>W. Dwyer</i>	12/15/69	
APPR'D	<i>W. Dwyer</i>	12/16/69	
			SHEET 24 OF 30

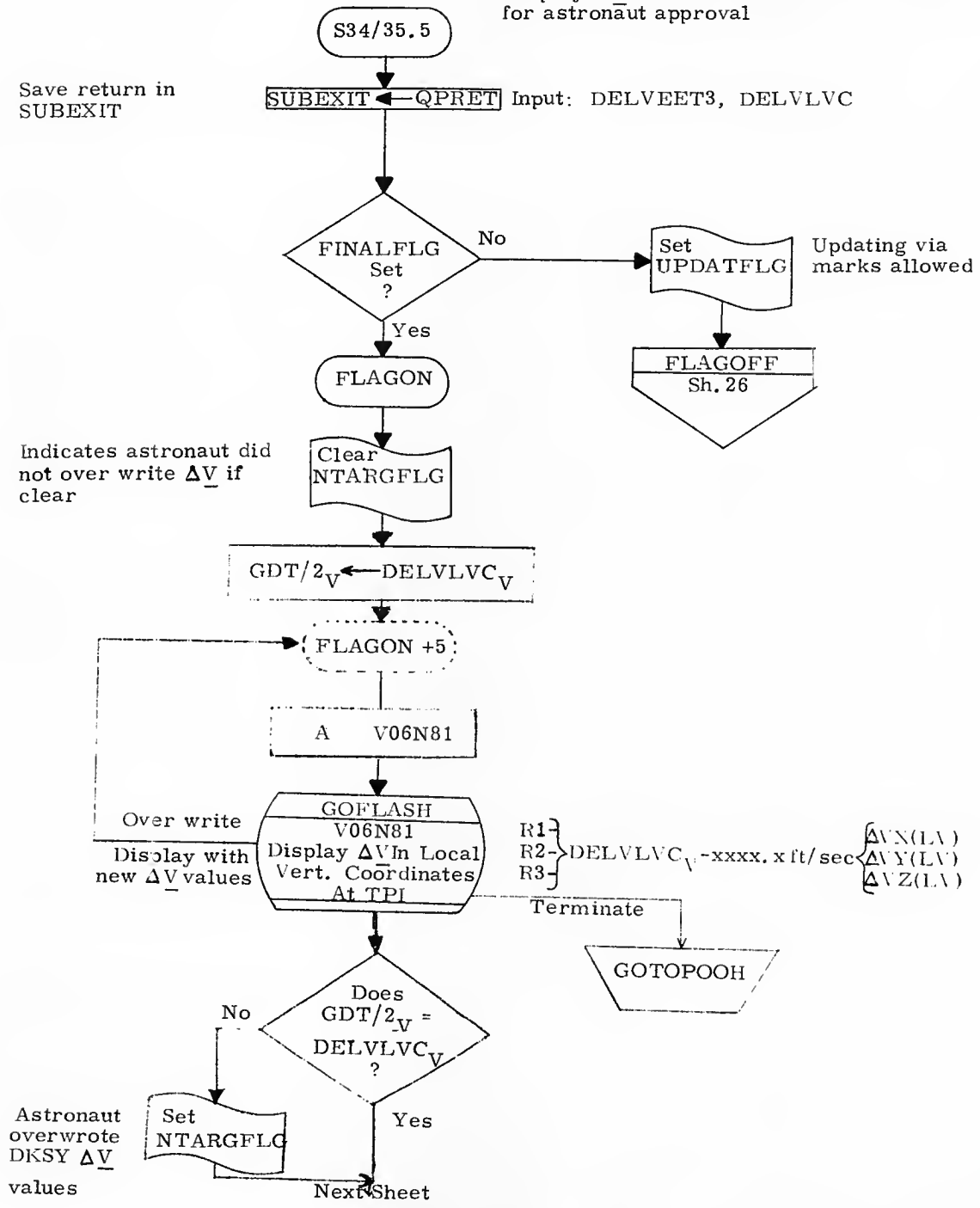
Display ΔV in local vertical coordinates for astronaut approval

Save return in SUBEXIT

SUBEXIT ← QPRET Input: DELVEET3, DELVLVC

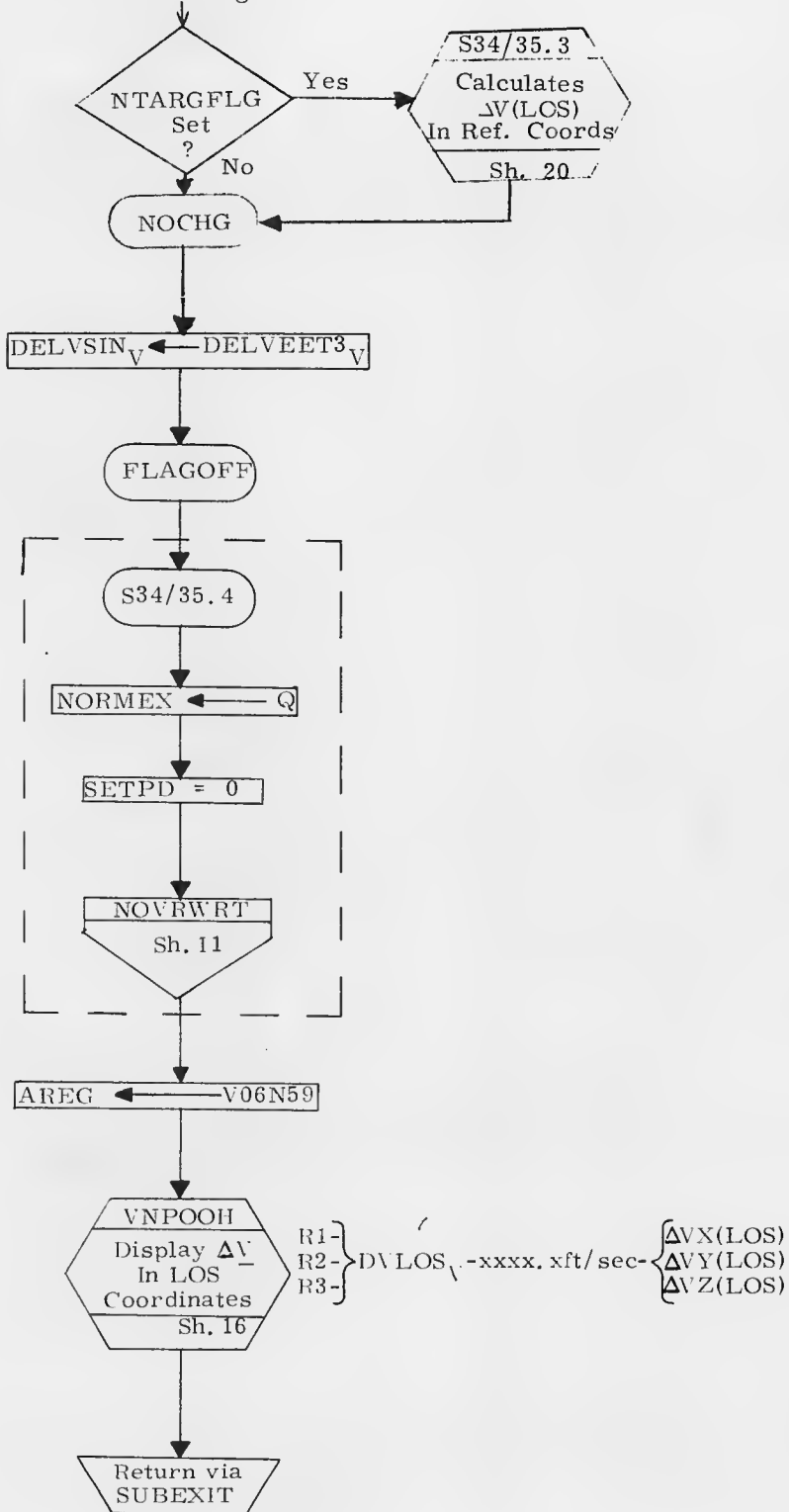
Indicates astronaut did not over write ΔV if clear

Updating via marks allowed



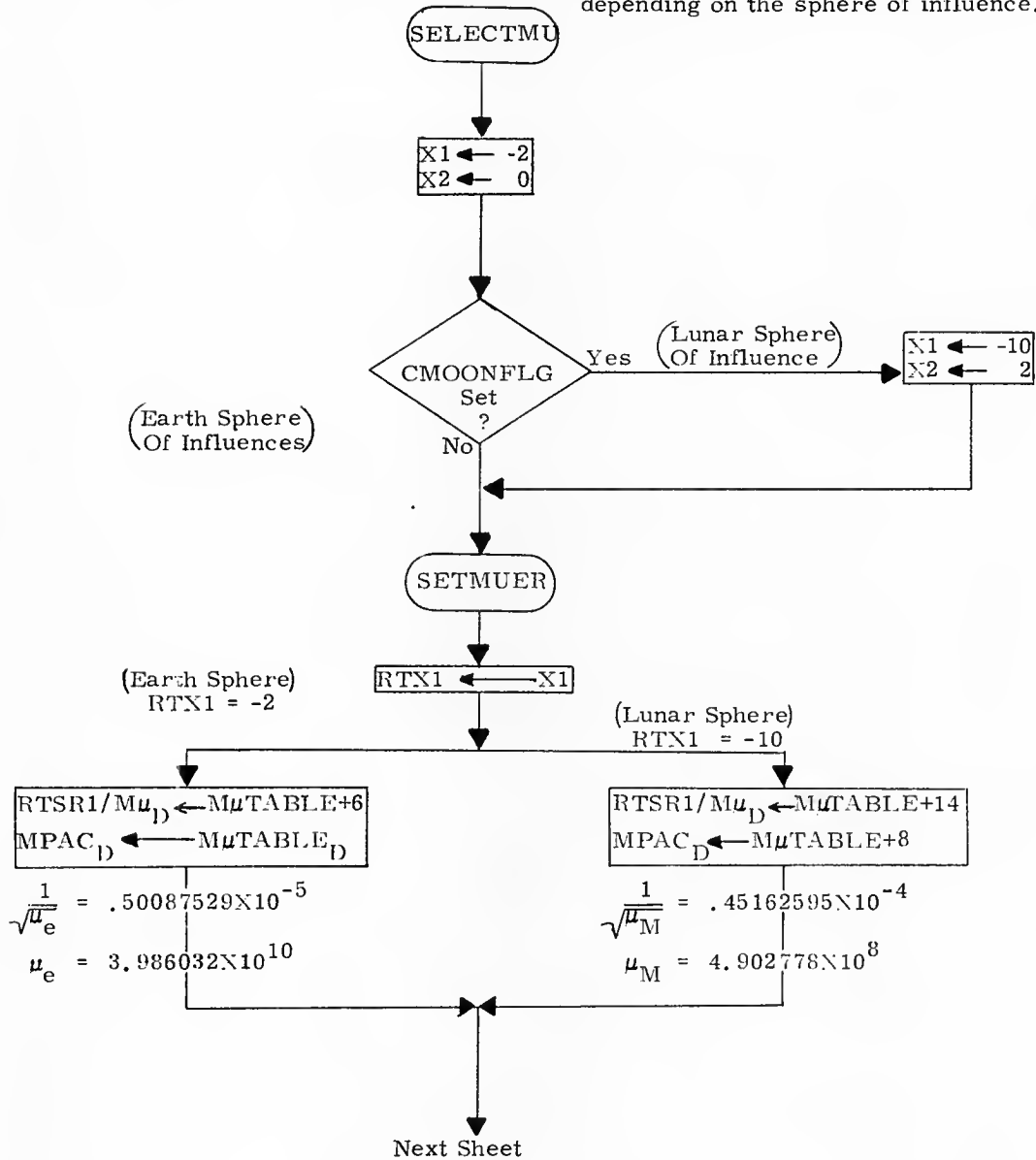
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>W. D. ...</i>	<i>12/18/69</i>	P34, P74 Transfer Phase Initiation Targeting	
PRGMR	<i>P. White</i>	<i>12/11/69</i>	LUMINARY ID	DOCUMENT NO.
ANALST				FC-3740
DOCMR	<i>W. D. ...</i>	<i>11/5/69</i>	REV 1	SHEET 25 OF 30
APPR'D	<i>W. D. ...</i>	<i>12/16/69</i>		

From Preceding Sheet



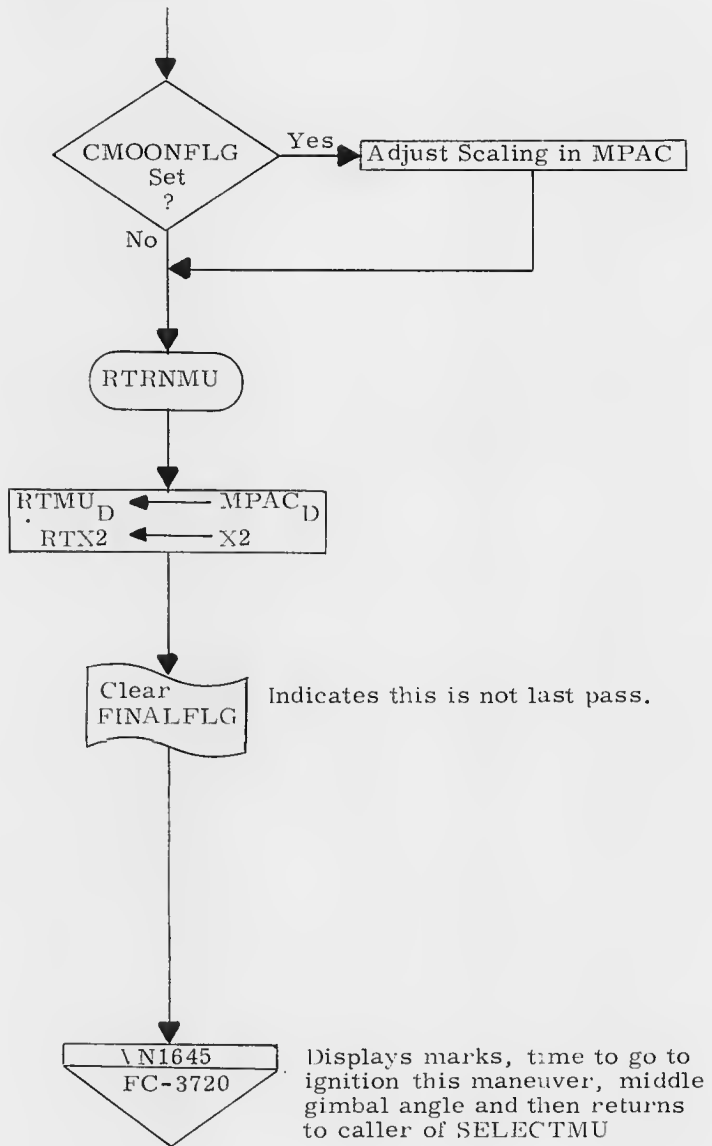
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. Luchinsky</i> 12/15/69		P34, P74 Transfer Phase Initiation Targeting	
PRGMR <i>P. P. White</i>	12/11/69	LUMINARY ID	DOCUMENT NO. FC-3740
ANALST <i>W. D. Griffith</i>	12/15/69	REV 1	SHEET 26 OF 30
DOCMR <i>W. D. Griffith</i>	12/15/69		
APPR'D <i>W. D. Griffith</i>	12/16/69		

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



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

From Preceding Sheet



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P34, P74 Transfer Phase Initiation Targeting	
DRAWN	<i>[Signature]</i>		
PRGMR	<i>[Signature]</i>		
ANALST		LUMINARY 1 D	DOCUMENT NO. FC-3740
DOCMR	<i>[Signature]</i>		
APPR'D	<i>[Signature]</i>	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	

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. Tschalke</i> 12/14/69		P34, P74 Transfer Phase Initiation Targeting	
PRGMR <i>P. White</i> 12/11/69		DOCUMENT NO.	
ANALST		LUMINARY 1 D	
DOCMR <i>W. D. Smith</i> 12/15/69		FC-3740	
APPR'D <i>W. D. Smith</i> 12/16/69		REV 1	
		SHEET 29 OF 30	

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

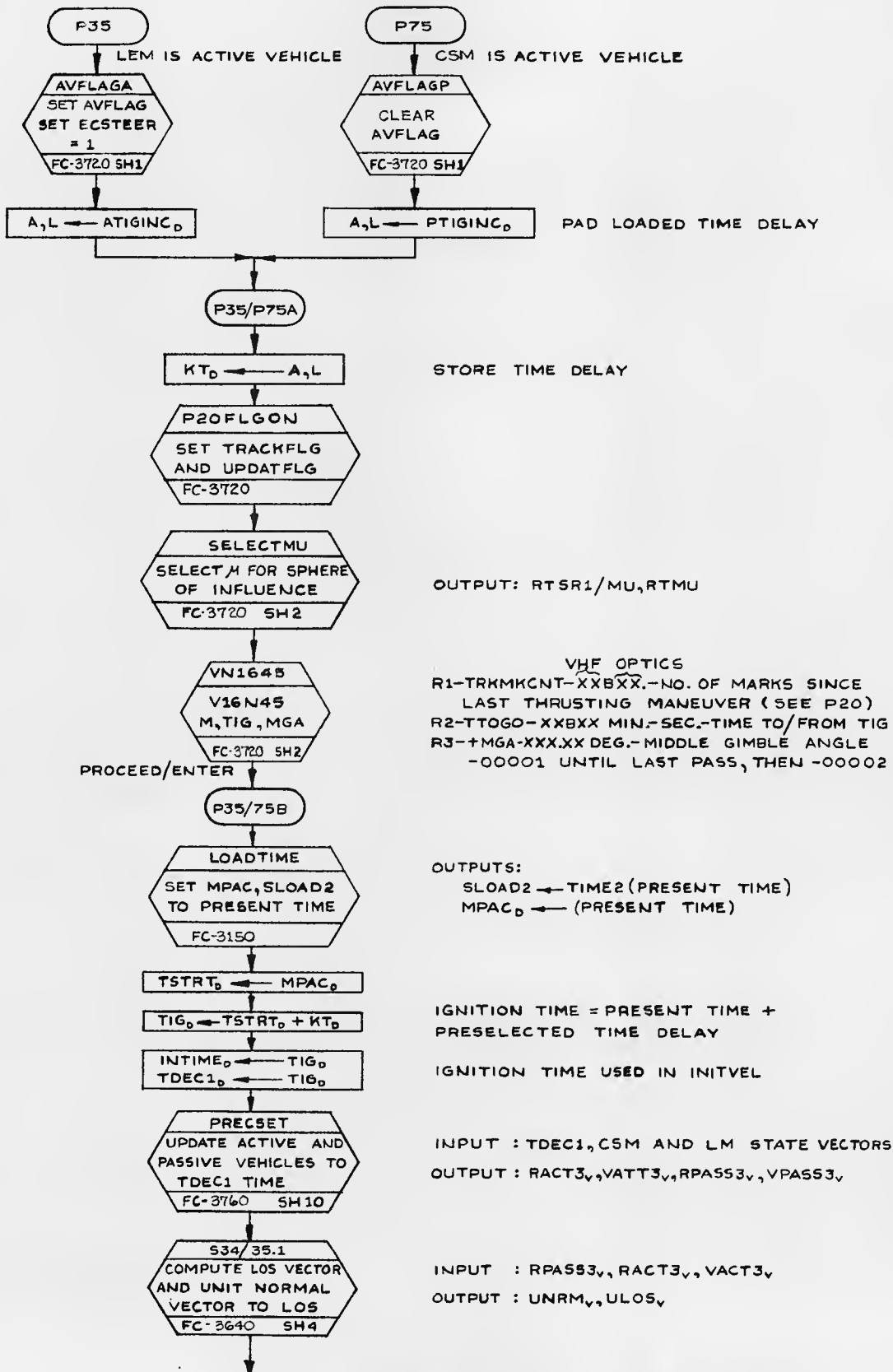
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>G. Tschalke</i> 12/14/69		P34, P74 Transfer Phase Initiation Targeting	
PRGMR <i>R. White</i> 12/11/69	ANALST	LUMINARY 1D	DOCUMENT NO.
DOCMR <i>W. Daghith</i> 12/5/69	APPR'D <i>W. Daghith</i> 12/16/69		FC-3740
REV 1		SHEET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

P35, P75 TRANSFER PHASE MIDCOURSE TARGETING

P35 Sh. 2

P75 Sh. 2

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS		P35, P37 TRANSFER PHASE MIDCOURSE TARGETING	
PRGRM <i>G. H. Hood</i>	6-4-69	LUMINARY 1D	DOCUMENT NO. FC-3750
ANALYST <i>W. Thompson</i>	6-4-69		
DOCNR <i>Final 1/2/69</i>	4 Jun 69	APPR'D <i>Alfred M. Sorant</i>	
APPR'D <i>Alfred M. Sorant</i>		REV 2	SHEET 1 OF 4



STORE TIME DELAY

OUTPUT: RTSR1/MU,RTMU

VHF OPTICS
 R1-TRKMKCNT-XXBXX.-NO. OF MARKS SINCE
 LAST THRUSTING MANEUVER (SEE P20)
 R2-TTGO-XXBXX MIN.-SEC.-TIME TO/FROM TIG
 R3-+MGA-XXX.XX DEG.-MIDDLE GIMBLE ANGLE
 -00001 UNTIL LAST PASS, THEN -00002

OUTPUTS:
 SLOAD2 ← TIME2 (PRESENT TIME)
 MPAC_D ← (PRESENT TIME)

IGNITION TIME = PRESENT TIME +
 PRESELECTED TIME DELAY

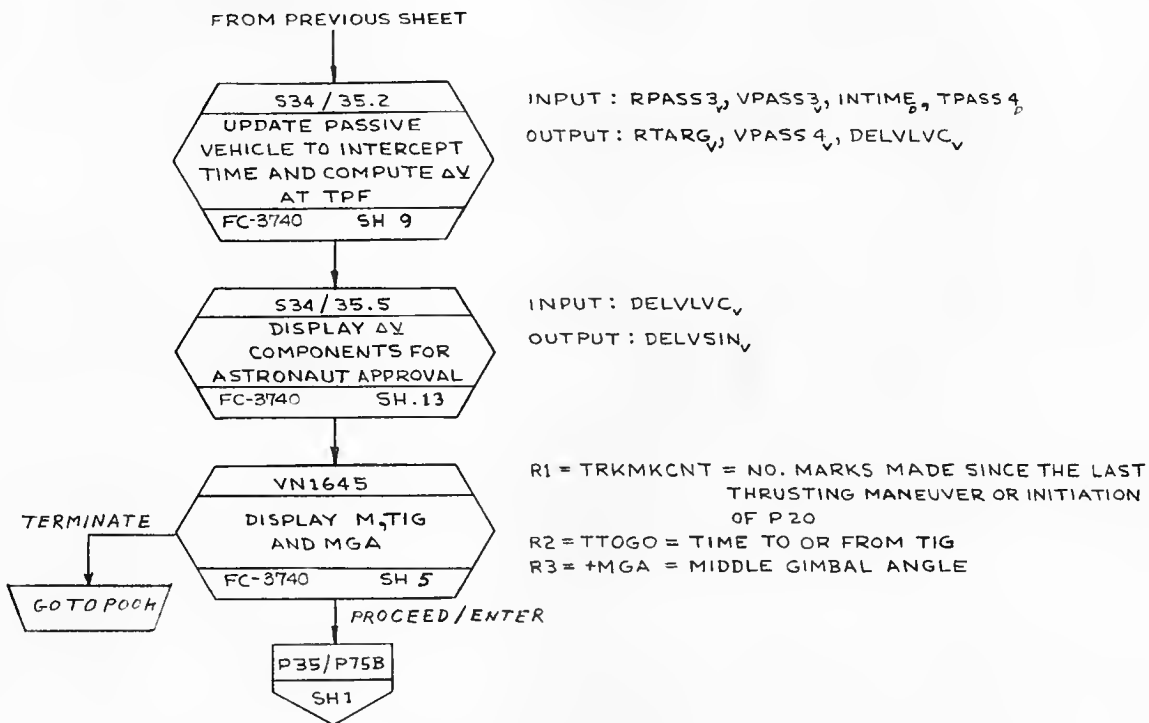
IGNITION TIME USED IN INITVEL

INPUT : TDEC1, CSM AND LM STATE VECTORS
 OUTPUT : RACT3_v, VATT3_v, RPASS3_v, VPASS3_v

INPUT : RPASS3_v, RACT3_v, VACT3_v
 OUTPUT : UNRM_v, ULOS_v

NEXT SHEET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>F. D. Swerdlow</i>		3 APR 69	
PROGRAMMER <i>J. F. Jordan</i>		2 MAR 69	
ANALYST <i>H. Thompson</i>		14 JUNE 69	
DOCNR <i>17000-1-01-01</i>		2 MAY 69	
APPR <i>John A. Moore</i>		2 MAY 69	
		LUMINARY 1D	DOCUMENT NO. FC-3750
		REV 2	SHEET 2 OF 4



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P35, P75 TRANSFER PHASE MIDCOURSE TARGETING	
DRAWN <i>F. Pomeroy</i>	28JUN68	LUMINARY 1D	DOCUMENT NO. FC-3750
PRGRM <i>P. White</i>	17JUL68		
ANALST <i>R. J. ...</i>	20 Sep 68	REV 2	SHEET 3 OF 4
DOCMR <i>W. ...</i>	12JUL68		
APPR'D <i>John A. ...</i>	25 Sept 68		
	2 May 69		

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 ΔV COMPONENTS
VN164 5	DISPLAY M, TFI AND MGA
P20FLGON	SET UPDATFLG, TRACKFLG

FLAGS

AVFLAG		} ALL SET AND CLEARED ON SH1
TRACKFLG	FINALFLG	
UPDATFLG	AVFLAG	

DISPLAYS

R1-TRKMKCNT-XXXXX.-NO OF MARKS	USED
V16N45 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 ^{2.8}
TSTRT	PRESENT TIME STORAGE	CENTISECS	2 ^{2.8}
TIG	TIME OF MANEUVER	CENTISECS	2 ^{2.8}
ATIGINC	PAD LOADED TIME DELAY FOR P35	CENTISECS	2 ^{2.8}
PTIGINC	PAD LOADED TIME DELAY FOR P75	CENTISECS	2 ^{2.8}
INTIME	INPUT TIME TO INITVEL	CENTISECS	2 ^{2.8}
TDEC 1	INPUT TIME TO INTEGRATION	CENTISECS	2 ^{2.8}

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P35, P75 TRANSFER PHASE MIDCOURSE TARGETING	
DRAWN <i>F. Pearson</i>	2 JUL 68	LUMINARY 1D	DOCUMENT NO. FC-3750
PROGR <i>F. White</i>	19 JUL 68		
ANALYST <i>W. J. ...</i>	20 Sept 68	REV 2	SHEET 4 OF 4
DOCNR <i>W. J. ...</i>	12 JUL 68		
APPR'D <i>John A. Morse</i>	26 Sept 68		
		2 May 69	

COMMON TARGETING SUBROUTINES

MAJOR SUBROUTINES AND EXTERNAL ENTRY POINTS

INITVEL	Sh. 4
HAVEGUES	Sh. 4
VECSHIFT	Sh. 10
SHIFTR1	Sh. 10
GET+MGA	Sh. 11
GET. LVC	Sh. 12
PERIAPO	Sh. 13
PERIAPO1	Sh. 13
SELECTMU	Sh. 14
PRECSET	Sh. 15
LEMSTORE	Sh. 15
CSMSTORE	Sh. 15

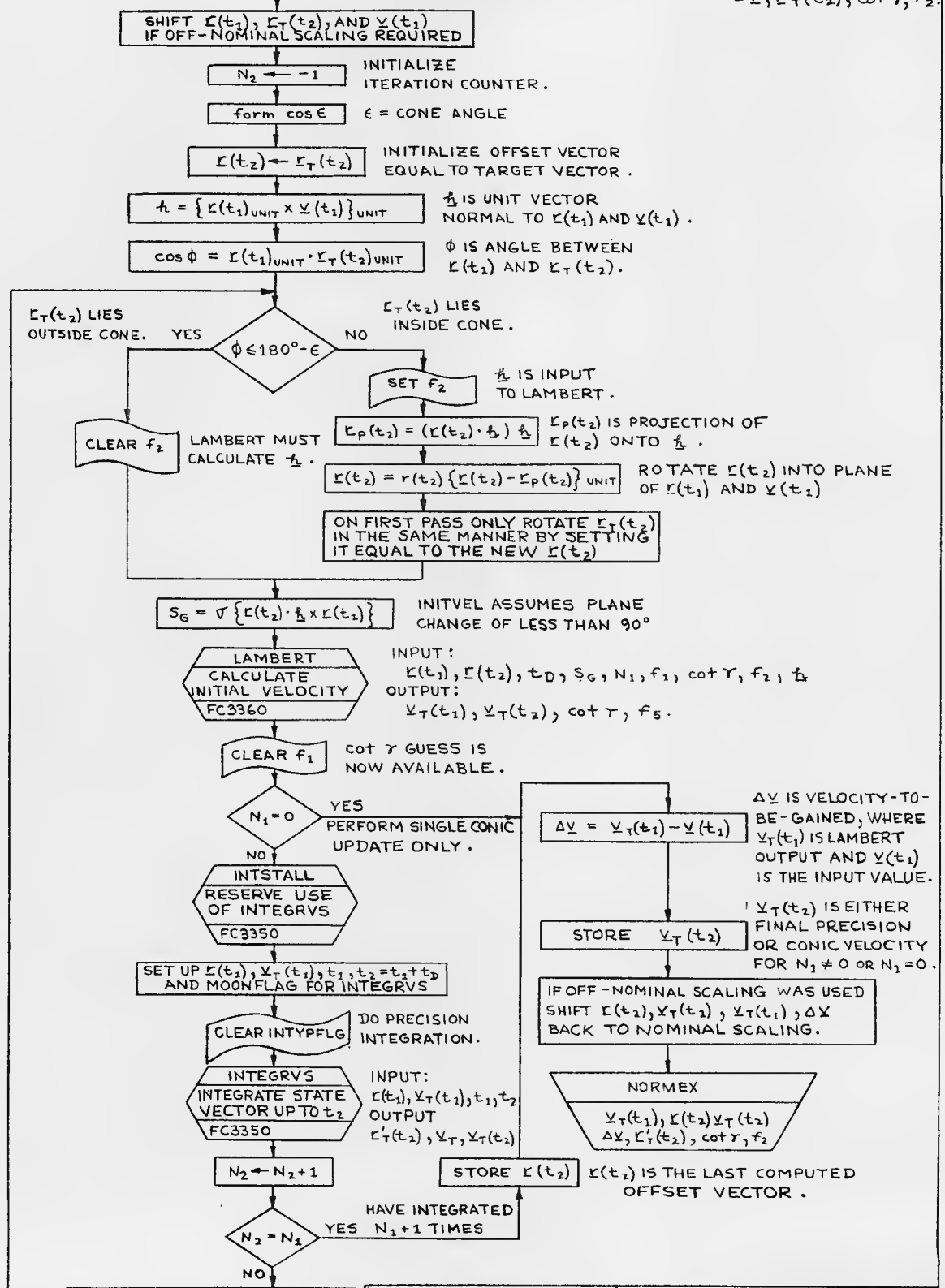
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>L. Delintore</i>		Common Targeting Subroutines	
PRGMR <i>W. Delintore</i>		INITVEL, MIDGM	
ANALST		PERIAPO, SELECTMU, PRECSET	
DOCMR <i>W. Delintore</i>		LUMINARY 1D	DOCUMENT NO. FC-3760
APPR'D <i>Robert M. Estes</i>		REV 3	SHEET 1 OF 18

GENERAL FLOW DIAGRAM OF SUBROUTINE INITVEL (AND HAVEGUES)

INITVEL
 SET f_1 INITIAL GUESS OF $\cot \gamma$ NOT AVAILABLE.

HAVEGUES
 ASSUMES f_1 HAS BEEN CORRECTLY SET BY CALLING ROUTINE.

INPUT: $\mathbf{r}(t_1), \mathbf{v}(t_1), \mathbf{r}(t_2), t_D, t_1, N_2, \epsilon, f_1, \cot \gamma, \times 1$.
 OUTPUT: $\mathbf{v}_T(t_1), \mathbf{r}(t_2), \mathbf{v}_T(t_2), \Delta \mathbf{v}, \mathbf{r}'(t_2), \cot \gamma, f_2$.



AFPT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>F. DeWitt</i>	27 MAY 66	COMMON TARGETING SUBROUTINES INITVEL, MIDGIM	
PROGRAM <i>P. B. White</i>	6 SEP 66	PERIARO, SELECTMU, PRECSET	
ANALYST <i>L. O. Clark</i>	12 JUL 66	LUMINARY ID	DOCUMENT NO. FC-3760
APPROV <i>John A. More</i>	7 Sept 66	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:

P10 (OR P11), CALLVEL, S40.1, MANUPARM

HAVEGUES IS CALLED BY:

S40.9.

INPUT:

- 1) RINIT_v = $\underline{r}(t_1)$, INITIAL POSITION VECTOR, IN METERS, AT 2²⁹.
- 2) VINIT_v = $\underline{v}(t_1)$, INITIAL VELOCITY VECTOR, IN METERS/CSEC, AT 2⁷. 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 2²⁹. IF $N_1 \neq 0$ IT IS THE TRUE TARGET VECTOR. IF $N_1 = 0$ 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 2²⁸.
- 5) INTIME = t_1 , TIME OF VALIDITY OF $\underline{r}(t_1)$, IN CSEC, AT 2²⁸.
- 6) PL₅ = 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. $N_1 = 0$ 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 = ϵ , THE CONE ANGLE OF A CONE MEASURED ABOUT $-\underline{r}(t_1)$, IN REVOLUTIONS, AT 2⁰.
- 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 ITERCTR₅ IS SET EQUAL TO 5, IF CLEAR ITERCTR₅ IS SET EQUAL TO 20D.
- 13) PUSH LIST POINTER IS AT THE GENERAL VALUE PL, WHERE $0 \leq PL \leq 38D$.

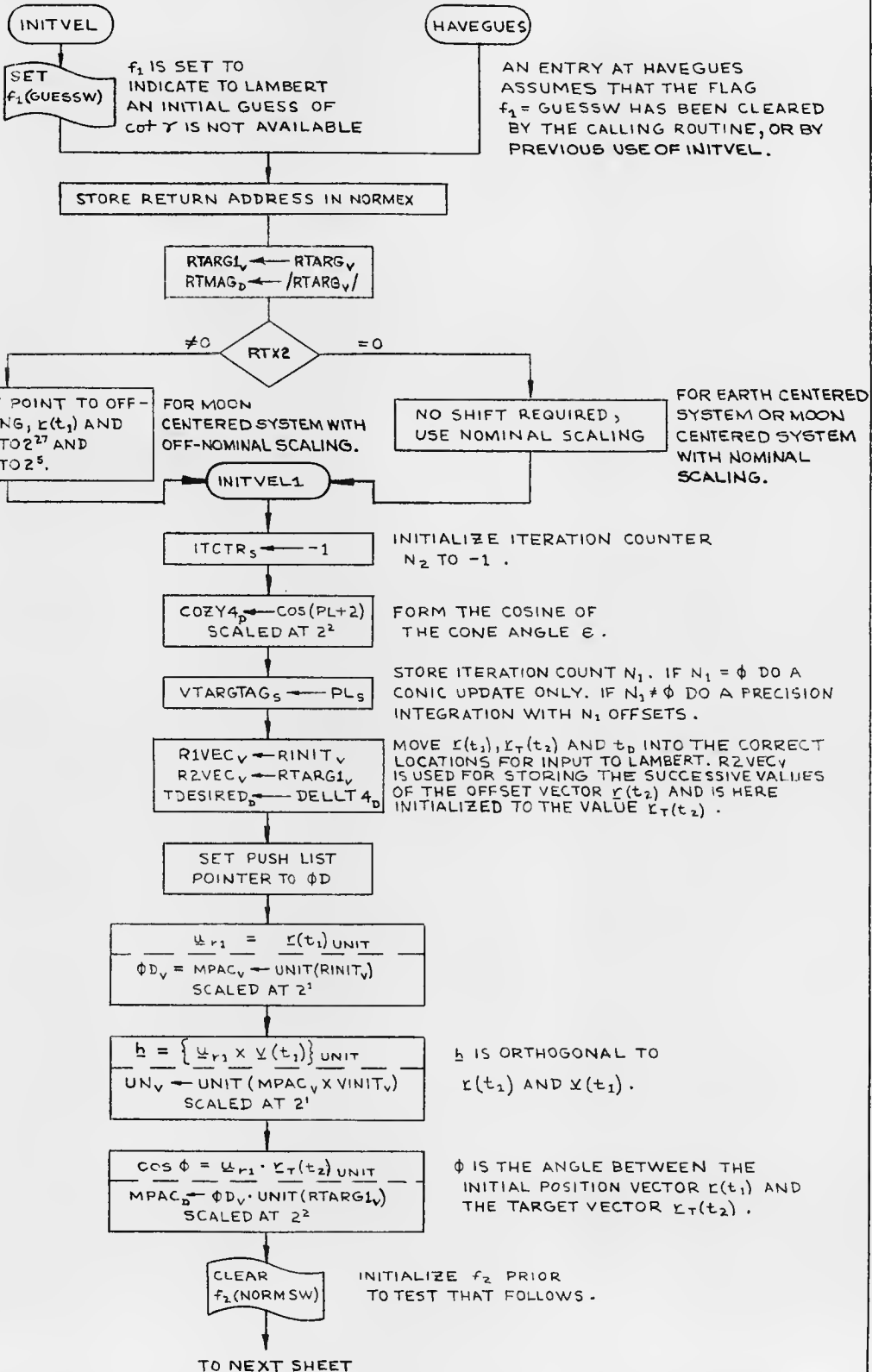
OUTPUT:

- 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 2⁷. 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 2²⁹.
- 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 $\underline{v}_T(t_1)$ IF $N_1 = 0$. IT IS IN METERS/CSEC AT 2⁷.
- 4) DELVEET_v = $\Delta \underline{v}$, THE VELOCITY TO BE GAINED, IN METERS/CSEC, AT 2⁷.
- 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 2²⁹/2²⁷.
- 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 2⁵.
- 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) ITERCTR₅ = ITERATION COUNT USED IN LAMBERT.
- 9) PUSH LIST POINTER IS AT 0D.

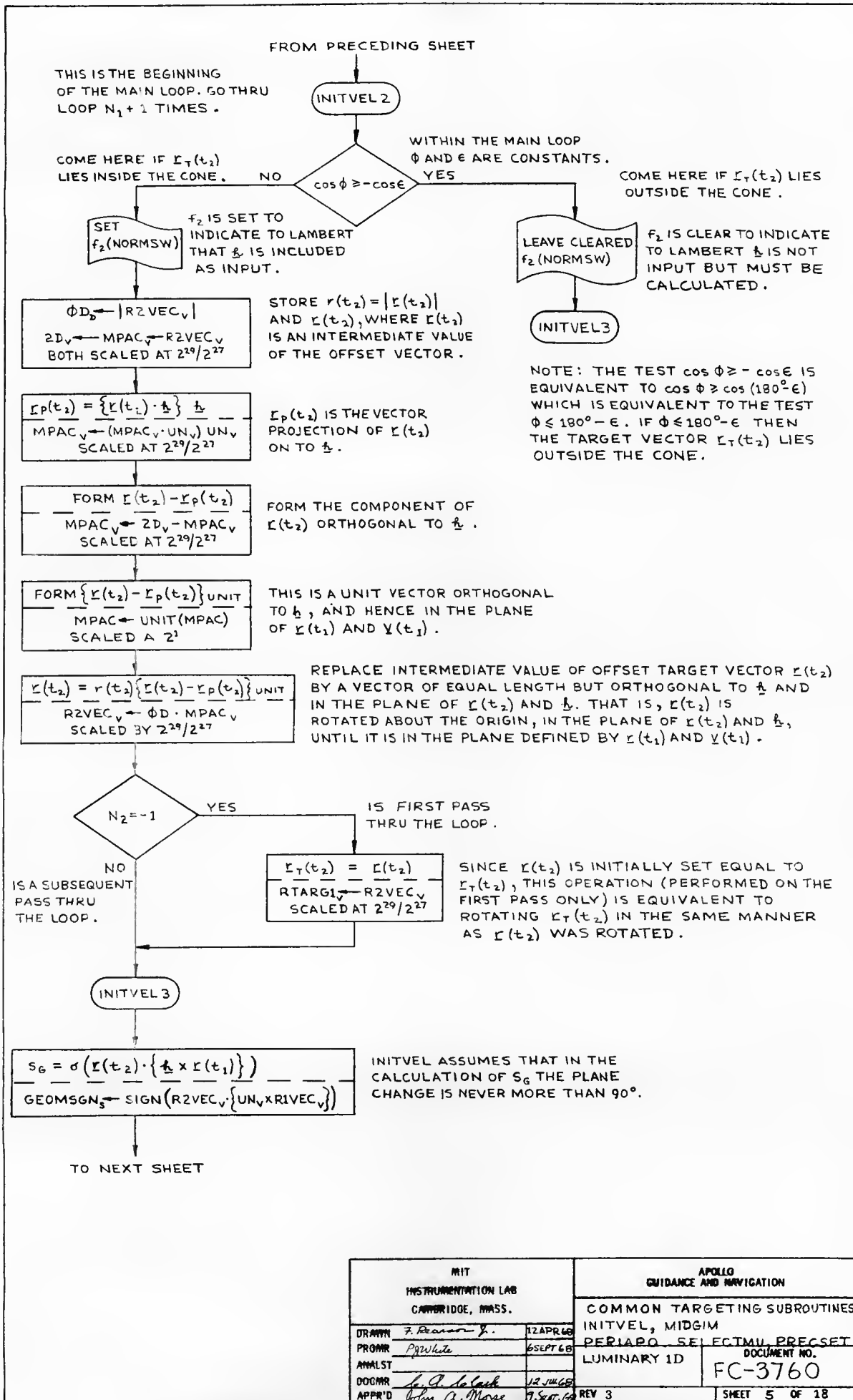
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>F. Ransom Jr.</i>		COMMON TARGETING SUBROUTINES	
PROGRAM <i>P. White</i>		INITVEL, MDSIM	
ANALYST		PERIAPC, SELECTION, PRECSET	
DOCWR <i>G. J. LaSalle</i>		LUMINARY 1D	
APPR'D <i>John A. Moore</i>		DOCUMENT NO. FC-3760	
10 APR 68		REV 3	
6 SEPT 68		SHEET 3 OF 18	
13 JUL 68			
9 SEPT 68			

ENTER HERE IF
INITIAL GUESS OF
CO+Y NOT AVAILABLE

ENTER HERE IF
INITIAL GUESS OF
CO+Y IS AVAILABLE



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN 7 Reason 2		COMMON TARGETING SUBROUTINES	
PROGR P. White		INITVEL, MIDGIM	
ANALST		PERIAPC, SELECTMU, PRECSET	
DOCNR		LUMINARY ID	
APPRD John A. Morse		DOCUMENT NO. FC-3760	
11 APR 68		REV 3	
6 SEPT 68		SHEET 4 OF 18	
12 JUL 68			
9 SEPT 68			



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>F. Pearson Jr.</i>		12 APR 68	
PROGR <i>PgWhite</i>		6 SEPT 68	
ANALST		PERIAPD SELECTMU PRECSET	
DOCNR <i>L. P. deLoach</i>		LUMINARY ID	
APPR'D <i>John A. Morse</i>		DOCUMENT NO. FC-3760	
		REV 3	
		SHEET 5 OF 18	

FROM PRECEDING PAGE

X1 ← RTX1

RESTORE X1 PRIOR TO CALL TO LAMBERT.

ITERCTR ← 200

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_v = t_D , DESIRED TRANSFER TIME.
- 4) GEOMSGN_v = S_G , A FLAG, IF POSITIVE $\theta \leq 180^\circ$; IF NEGATIVE $\theta > 180^\circ$.
- 5) VTARGETAG_v = 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_v = $\cot \gamma$, AN INITIAL GUESS IF f_1 IS CLEAR.
- 8) NORMSW = f_2 , A FLAG, IF CLEAR \underline{u} IS CALCULATED.
- 9) UN_v = \underline{u} , UNIT VECTOR, NORMAL TO $\underline{r}(t_1)$ AND $\underline{v}(t_1)$ IF f_2 SET.
- 10) X1_v = INDEX REGISTER CONTAINING VALUE TO SELECT μ -TABLE.
- 11) ITERCTR_v = μ_{MAX} , ITERATION COUNTER.

LAMBERT
CALCULATE
INITIAL VELOCITY
 $\underline{v}_T(t_1)$
FC3360

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 INTEGRV5.
- 3) COGA = $\cot \gamma$, VALUE CONVERGED TO BY LAMBERT.
- 4) SOLNSW = f_5 , A FLAG, IF CLEAR THE SOLUTION IS VALID.

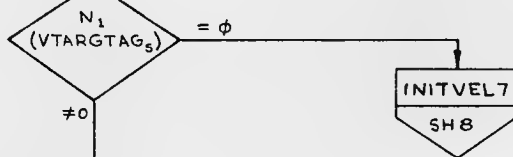
CLEAR
 f_1 (GUESSW)

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.

VIPRIME_v ← VVEC_v
SCALED AT $2^7/2^5$

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.

TEST THE ITERATION COUNT



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

WAKE UP THIS JOB

JOBSLEEP
PUT THIS JOB TO SLEEP UNTIL INTEGRATION IS AVAILABLE
FC3030

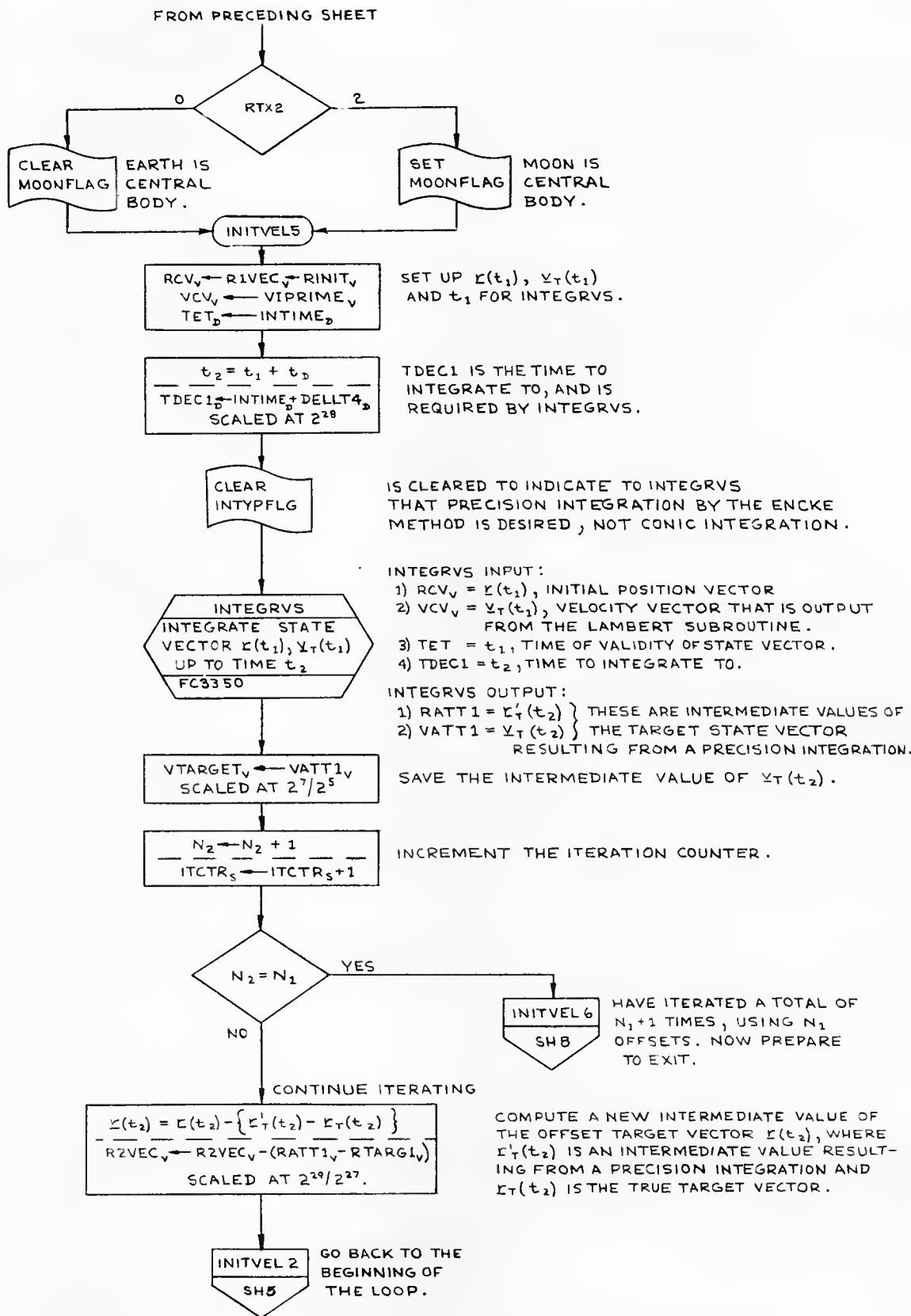
INTSTALL
CHECK IF THE INTEGRATION ROUTINE IS BEING USED
FC3350

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 INTFLAG 2.

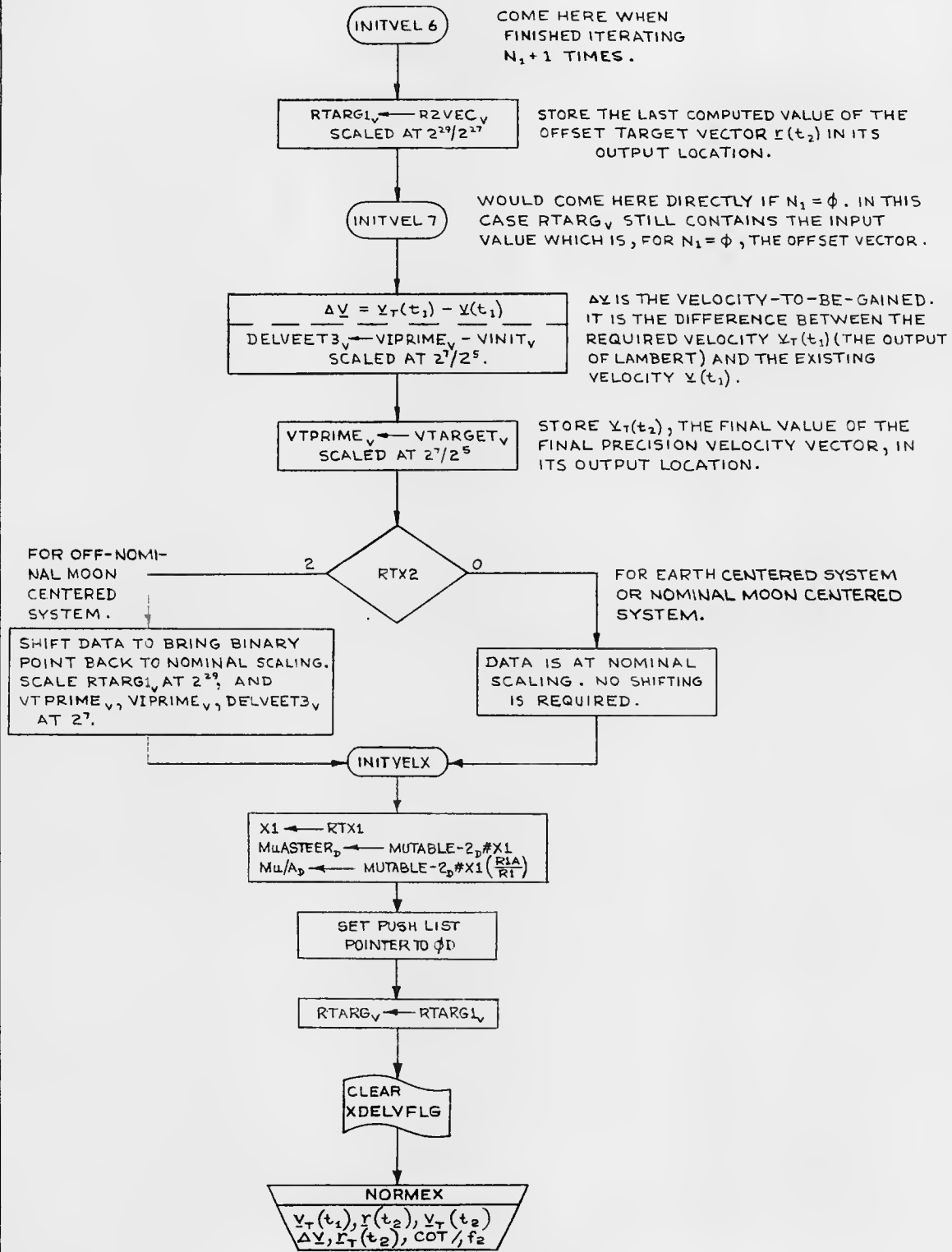
THE INTEGRATION ROUTINE IS NOW RESERVED FOR THIS JOB.

TO NEXT SHEET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>F. Pearson</i>		COMMON TARGETING SUBROUTINES	
PROGR <i>R. White</i>		INITVEL, MIDGIM	
ANALST		PERIAPD SELECTM PRECSET	
DOCMR		LUMINARY ID	
APPR'D <i>John A. Morse</i>		DOCUMENT NO. FC-3760	
15 APR 68		REV 3	
6 SEPT 68		SHEET 6 OF 18	
7 SEPT 68			



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>F. Pearson</i>		COMMON TARGETING SUBROUTINES	
PROWR <i>P. White</i>		INITVEL, MIDGIM	
ANALST		PERIAPD, SELECTMU, PRECSET	
DOCMR <i>J. A. Black</i>		LUMINARY 1D	
APPR'D <i>John A. Mose</i>		DOCUMENT NO. FC-3760	
REV 3		SHEET 7 OF 18	



COME HERE WHEN FINISHED ITERATING $N_1 + 1$ TIMES.

STORE THE LAST COMPUTED VALUE OF THE OFFSET TARGET VECTOR $r(t_2)$ IN ITS OUTPUT LOCATION.

WOULD COME HERE DIRECTLY IF $N_1 = \phi$. IN THIS CASE $RTARGv$ STILL CONTAINS THE INPUT VALUE WHICH IS, FOR $N_1 = \phi$, THE OFFSET VECTOR.

Δv IS THE VELOCITY-TO-BE-GAINED. IT IS THE DIFFERENCE BETWEEN THE REQUIRED VELOCITY $v_T(t_2)$ (THE OUTPUT OF LAMBERT) AND THE EXISTING VELOCITY $v(t_1)$.

STORE $v_T(t_2)$, THE FINAL VALUE OF THE FINAL PRECISION VELOCITY VECTOR, IN ITS OUTPUT LOCATION.

FOR OFF-NOMINAL MOON CENTERED SYSTEM.

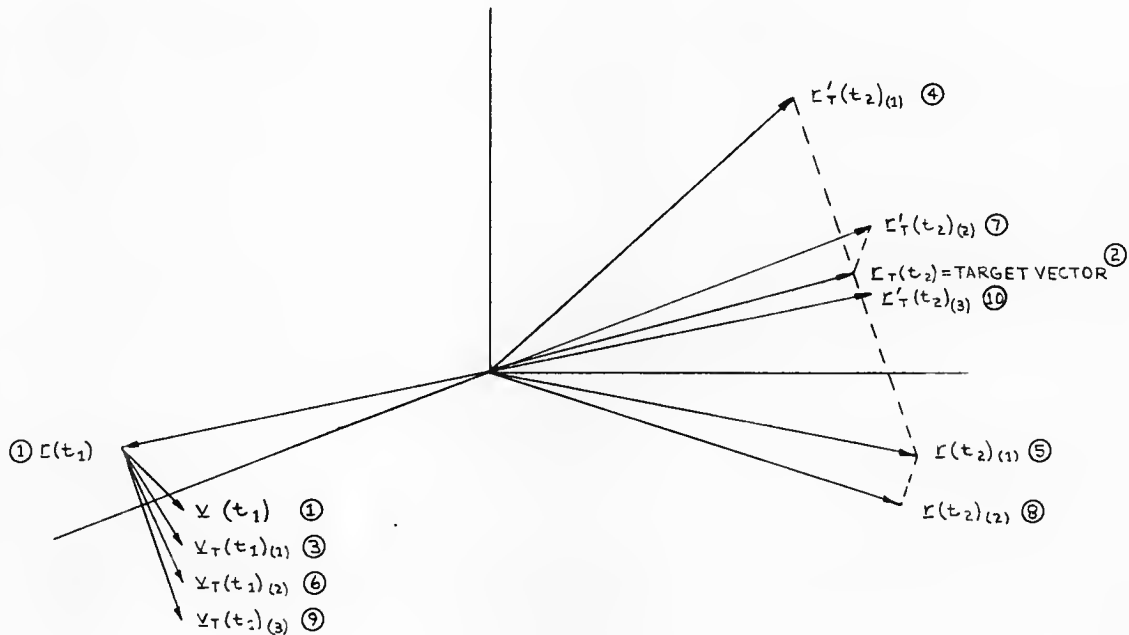
FOR EARTH CENTERED SYSTEM OR NOMINAL MOON CENTERED SYSTEM.

SHIFT DATA TO BRING BINARY POINT BACK TO NOMINAL SCALING. SCALE $RTARG1v$ AT 2^{29} , AND $VTPRIMEv$, $VIPRIMEv$, $DELVEET3v$ AT 2^7 .

DATA IS AT NOMINAL SCALING. NO SHIFTING IS REQUIRED.

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>F. Keason</i>		16 APR 68	COMMON TARGETING SUBROUTINES
PROGRAM <i>Ppplhite</i>		6 SEP 68	INITVEL, MIDGIM
ANALYST			PERIAPD, SELECTMU, PRECSET
DOCWR <i>G. A. LaGrish</i>		12 JUL 68	LUMINARY ID
APPROV <i>John A. Moore</i>		9 SEP 68	DOCUMENT NO. FC-3760
		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.

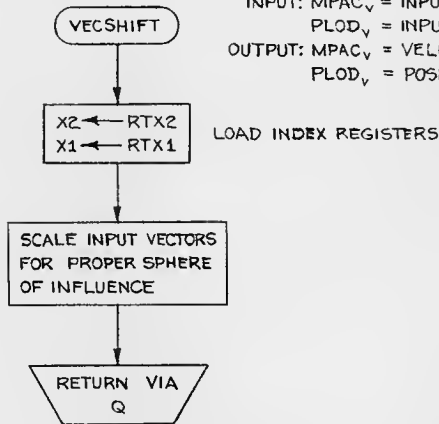


- ① $\Sigma(t_1)$ IS THE GIVEN POSITION VECTOR, $\Psi(t_1)$ IS THE GIVEN VELOCITY VECTOR.
 ② $\Sigma_T(t_2)$ IS THE GIVEN TARGET VECTOR. FOR COMPLETENESS AND CONSISTENCY IN USE OF SUBSCRIPTS THE TARGET VECTOR $\Sigma_T(t_2)$ CAN BE CONSIDERED TO BE THE ZEROETH OFFSET VECTOR $\Sigma(t_2)_{(0)}$.
- ITERATION 1 {
 ③ $\Psi_T(t_1)_{(1)}$ IS CALCULATED BY LAMBERT USING $\Sigma(t_1)$ FROM ① AND $\Sigma(t_2)_{(0)} = \Sigma_T(t_2)$ FROM ②.
 ④ $\Sigma'_T(t_2)_{(1)}$ IS CALCULATED BY PRECISION INTEGRATION USING $\Sigma(t_1)$ FROM ① AND $\Psi_T(t_1)_{(1)}$ FROM ③.
 ⑤ $\Sigma(t_2)_{(1)}$ IS THE OFFSET VECTOR RESULTING FROM SUBTRACTING THE MISS VECTOR BETWEEN $\Sigma'_T(t_2)_{(1)}$ FROM ④ AND $\Sigma_T(t_2)$ FROM ② FROM THE OFFSET VECTOR $\Sigma(t_2)_{(0)} = \Sigma_T(t_2)$ FROM ②.
- ITERATION 2 {
 ⑥ $\Psi_T(t_1)_{(2)}$ IS CALCULATED BY LAMBERT USING $\Sigma(t_1)$ FROM ① AND $\Sigma(t_2)_{(1)}$ FROM ⑤.
 ⑦ $\Sigma'_T(t_2)_{(2)}$ IS CALCULATED BY PRECISION INTEGRATION USING $\Sigma(t_1)$ FROM ① AND $\Psi_T(t_1)_{(2)}$ FROM ⑥.
 ⑧ $\Sigma(t_2)_{(2)}$ IS THE OFFSET VECTOR RESULTING FROM SUBTRACTING THE MISS VECTOR BETWEEN $\Sigma'_T(t_2)_{(2)}$ FROM ⑦ AND $\Sigma_T(t_2)$ FROM ② FROM THE OFFSET VECTOR $\Sigma(t_2)_{(1)}$ FROM ⑤.
- ITERATION 3 {
 ⑨ $\Psi_T(t_1)_{(3)}$ IS CALCULATED BY LAMBERT USING $\Sigma(t_1)$ FROM ① AND $\Sigma(t_2)_{(2)}$ FROM ⑧.
 ⑩ $\Sigma'_T(t_2)_{(3)}$ IS CALCULATED BY PRECISION INTEGRATION USING $\Sigma(t_1)$ FROM ① AND $\Psi_T(t_1)_{(3)}$ FROM ⑨.
 ⑪ THE ROUTINE NOW PREPARES TO EXIT. IT CALCULATES THE VELOCITY-TO-BE-GAINED AS THE DIFFERENCE $\Psi_T(t_1)_{(3)} - \Psi(t_1)$.
 ⑫ THERE IS NO CALCULATION OF THE OFFSET VECTOR $\Sigma(t_2)_{(3)}$ CORRESPONDING TO $\Sigma'_T(t_2)_{(3)}$.
 ⑬ THE FINAL OUTPUT VECTORS ARE:
 1) $\Psi_T(t_1)_{(3)}$ FROM ⑨
 2) $\Sigma(t_2)_{(2)}$ FROM ⑧
 3) $\Sigma'_T(t_2)_{(3)}$ FROM ⑩

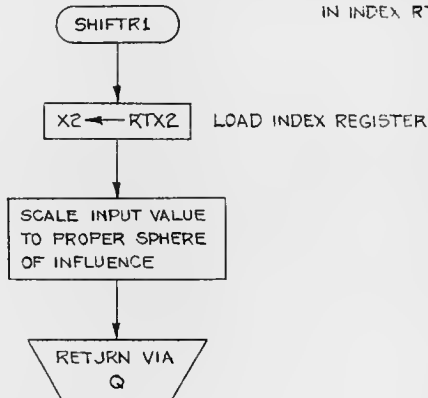
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>F. Reason 2-</i>		COMMON TARGETING SUBROUTINES	
PROGRAM <i>White</i>		INITVEL, MIGDIM	
APPROVED		PERIAPD, SELECTMUL, PRECGET	
DOCNR		LUMINAR: ID	
APPR'D <i>John A. Moran</i>		DOCUMENT NO. FC-3760	
12 APR 68		REV 3	
12 AUG 69		SHEET 9 OF 18	
12 JUL 68			
7 SEPT 67			

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		COMMON TARGETING SUBROUTINES	
PRGRM P. White	30 MAY 69	INITVEL, MIDGIM PERIAPO, SELECTMU, PRECSET	
ANALYST	22 Aug 69	LUMINARY ID	DOCUMENT NO.
DOCNR MC [Signature]	11 AUG 69		FC-3760
APPRD [Signature]		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 ΔV 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.

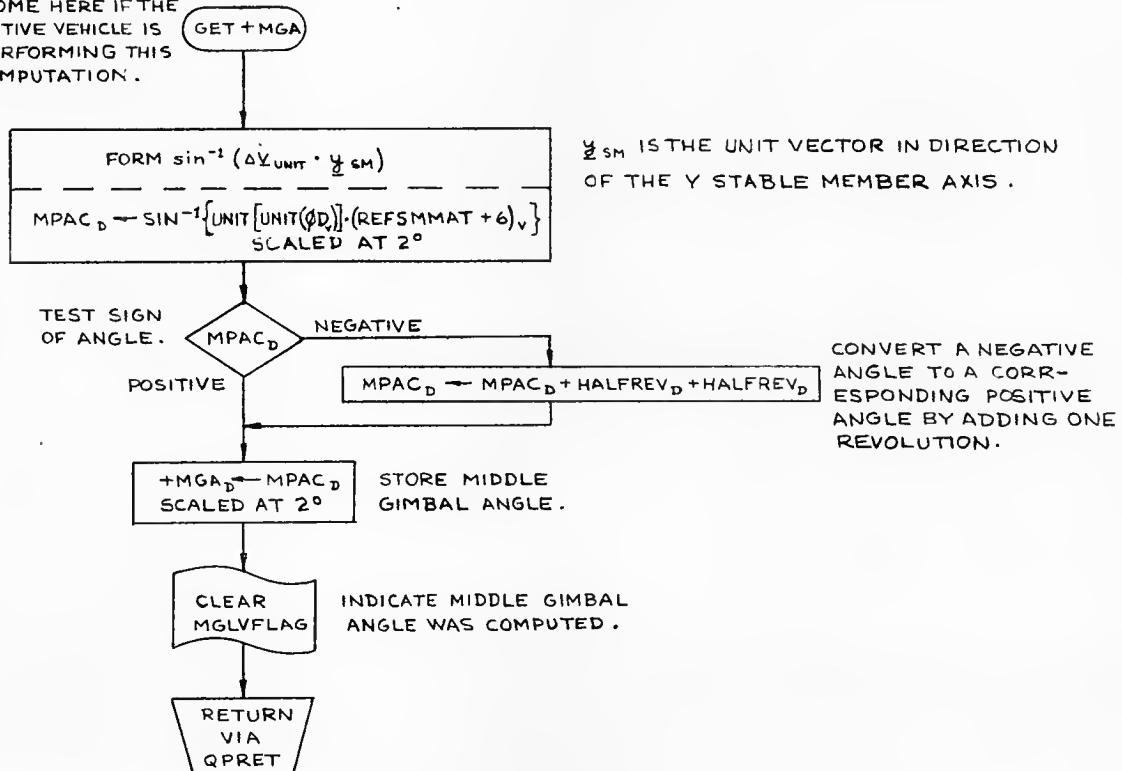
INPUT :

- 1) $R_{INIT_V} = r$, RADIUS VECTOR OF ACTIVE VEHICLE, IN METERS, AT 2^{29} .
- 2) $V_{INIT_V} = v$, VELOCITY VECTOR OF ACTIVE VEHICLE, IN METERS/CSEC AT 2^7 .
- 3) $OD_V = \Delta v$, DELTA VELOCITY VECTOR OF ACTIVE VEHICLE IN INERTIAL COORDINATES, IN METERS/CSEC, AT 2^7 .

OUTPUT :

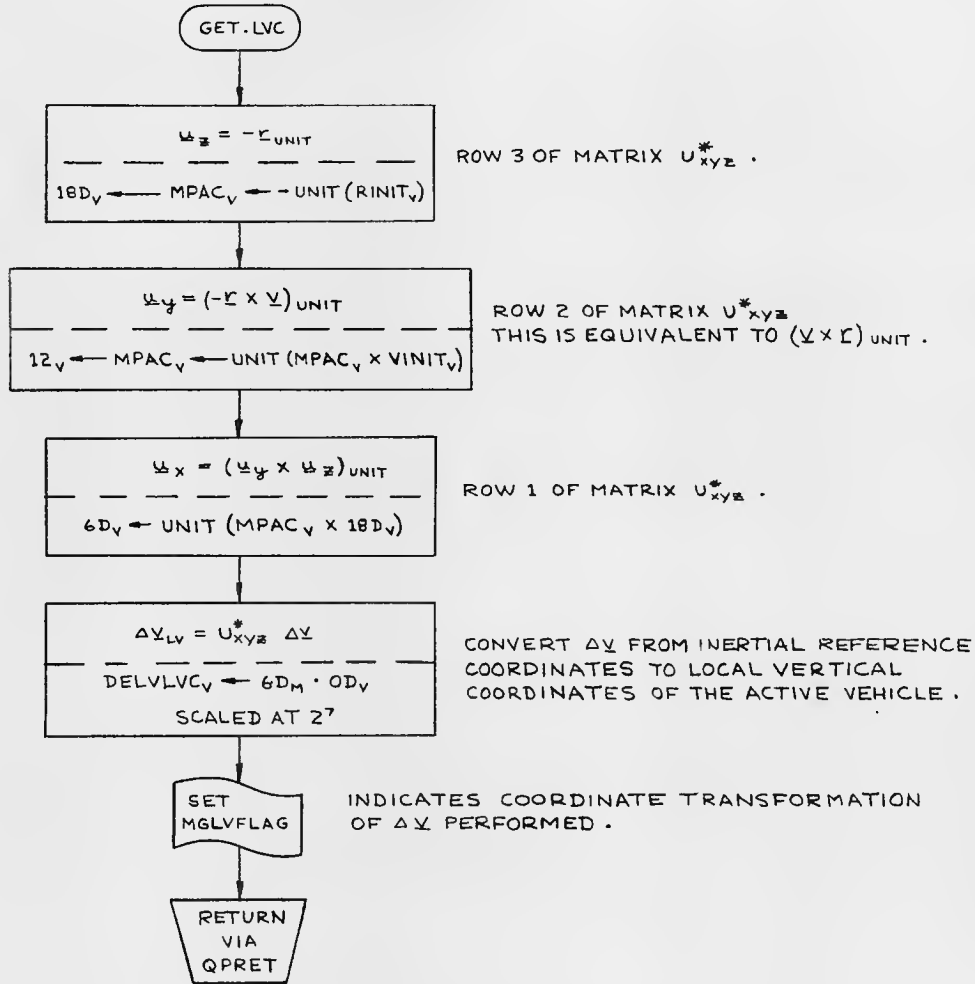
- 1) MGLVFLAG = A FLAG, IS CLEAR IF MIDDLE GIMBAL ANGLE WAS COMPUTED, IS SET IF DELTA VELOCITY VECTOR TRANSFORMED.
- 2) $+MGA_D$ = MIDDLE GIMBAL ANGLE, IN REVOLUTIONS IN RANGE 0 TO 1, AT 2^0 .
- 3) $DELVLVC_V = \Delta v_{LV}$, DELTA VELOCITY VECTOR OF ACTIVE VEHICLE IN LOCAL VERTICAL COORDINATES, IN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

COME HERE IF THE ACTIVE VEHICLE IS PERFORMING THIS COMPUTATION.

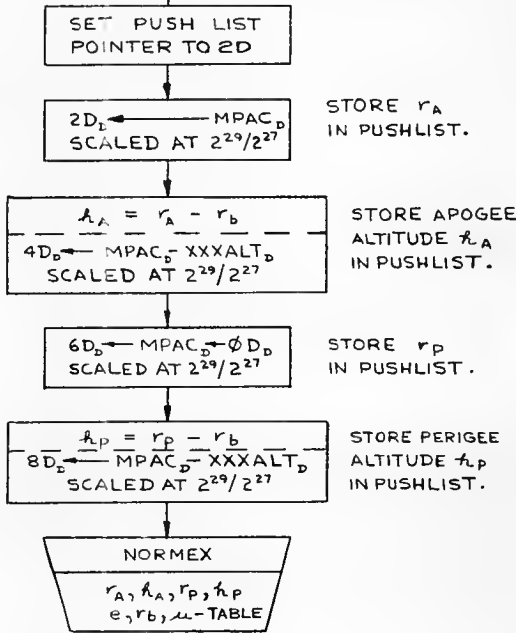
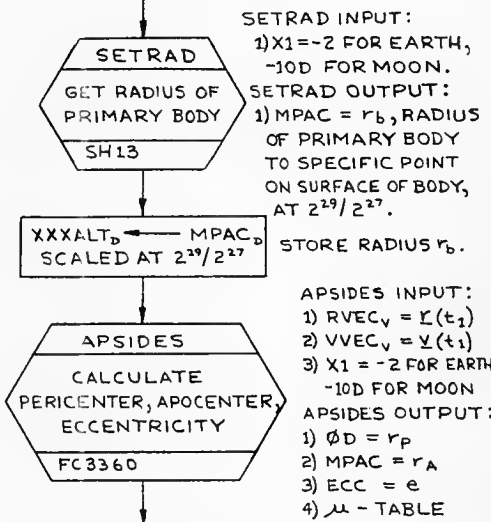
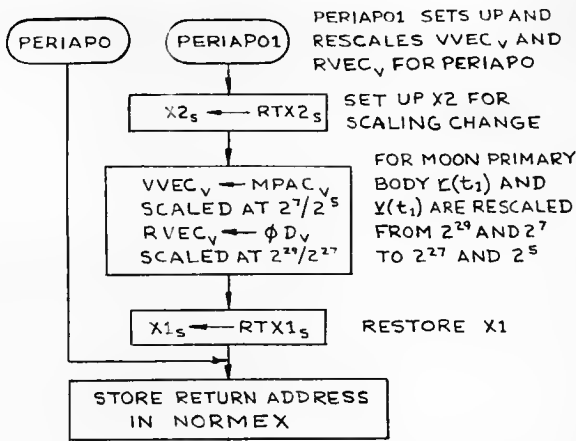


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>F. Pearson 2</i>	23 JUN 68	COMMON TARGETING SUBROUTINES INITVEL, MIDGIM	
PROGRAM <i>P. White</i>	6 SEPT 68	PERIAPD, SELECTMIL, PRESET LUMINARY 1D	
ANALYST		DOCUMENT NO. FC-3760	
DESIGN <i>L. A. DeFuria</i>	12 JUL 68	REV 3	
APPR'D <i>John A. Moore</i>	17 SEPT 68	SHEET 11 OF 18	

COME HERE IF THE PASSIVE
VEHICLE IS PERFORMING
THIS CALCULATION .



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>F. Reason 2-</i>	24JUN68	COMMON TARGETING SUBROUTINES INITVEL, MIDGIM	
PROWR <i>P. White</i>	6SEPT68	PERIARO, SELECTMU, PRECSET DOCUMENT NO.	
ANALST		LUMINARY ID	FC-3760
DOCTR <i>J. A. G. G.</i>	12JUN68		
APPR'D <i>John A. Morse</i>	21SEP68	REV 3	SHEET 12 OF 15



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:

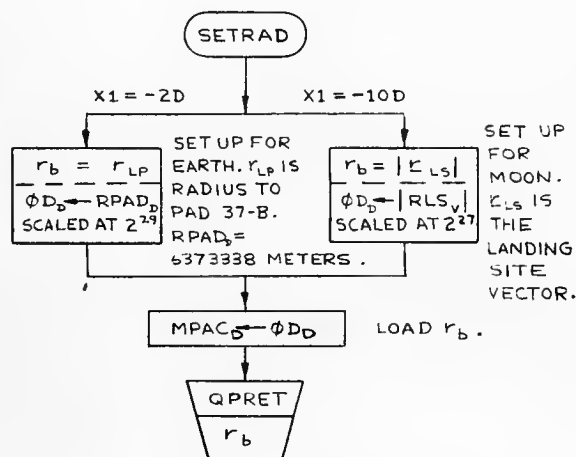
- $R_{VECV} = \mathcal{Y}(t_1)$, POSITION VECTOR TO POINT ON TRAJECTORY, IN METERS, AT $2^{29}/2^{27}$.
- $V_{VECV} = \mathcal{Y}(t_1)$, VELOCITY VECTOR TO POINT ON TRAJECTORY, IN METERS/CSEC AT $2^7/2^5$.
- $X1_s$ = PRIMARY BODY INDICATOR IN INDEX REGISTER 1, -2 FOR EARTH, $-10D$ FOR MOON.

PERIAPO1 INPUT:

- $\phi D_v = \mathcal{L}(t_1)$, IN METERS, 2^{29} .
- $MPAC_v = \mathcal{Y}(t_1)$, IN METERS/CSEC, AT 2^7 .
- $RTX1_s$ = PRIMARY BODY INDICATOR, $15 - 2$ FOR EARTH, $-10D$ FOR MOON.
- $RTX2_s$ = VALVE USED FOR RESCALING $\mathcal{Y}(t_1)$ AND $\mathcal{Y}(t_1)$ FOR OFF-NOMINAL SCALING, 150 FOR EARTH, 2 FOR MOON.

OUTPUT:

- $2D_D = r_A$, RADIUS OF APOCENTER, IN METERS, AT $2^{29}/2^{27}$.
- $4D_D = \mathcal{L}_A$, APOCENTER ALTITUDE, IN METERS, AT $2^{29}/2^{27}$.
- $6D_D = r_p$, RADIUS OF PERICENTER, IN METERS, AT $2^{29}/2^{27}$.
- $8D_D = \mathcal{L}_p$, PERICENTER ALTITUDE, IN METERS, AT $2^{29}/2^{27}$.
- $ECC_D = e$, ECCENTRICITY, AT 2^3 .
- $XXXALT_D = r_b$, RADIUS OF PRIMARY BODY, IN METERS, AT $2^{29}/2^{27}$.
- μ - TABLE FOR PRIMARY BODY.
- PUSH LIST POINTER AT $10D$.



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>F. Pearson Jr.</i>		COMMON TARGETING SUBROUTINES	
PROGRAM <i>Chute</i>		INITVEL, MIDGIM	
ANALYST		PERIAPO, SELECT MULTIPRESET	
DOCWR <i>J. A. Blak</i>		LUMINARY ID	
APPR'D <i>John A. Morse</i>		FC-3760	
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.

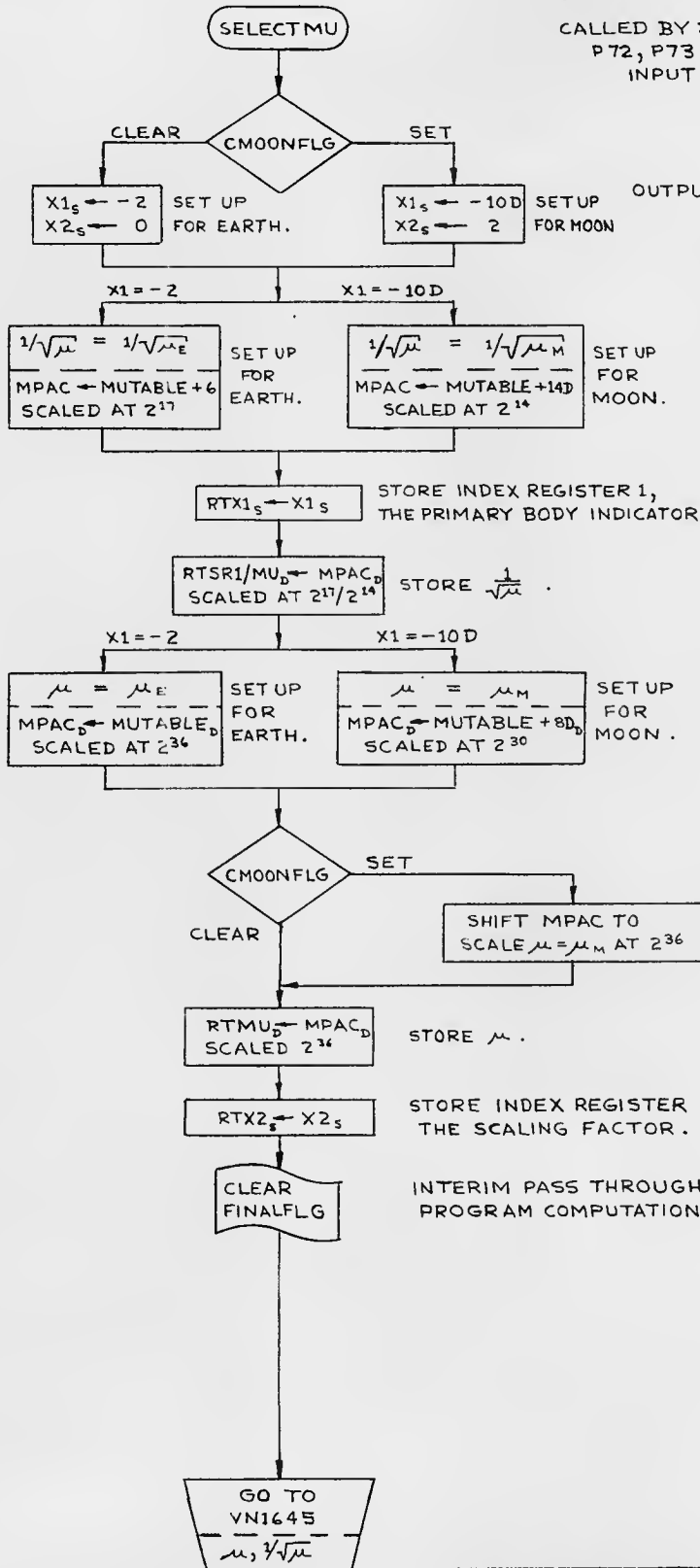
CALLED BY: P32, P33, P34, P35, P38, P39, P72, P73, P74, P75, P78, P79.

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. Pearson	20 MAY 68	COMMON TARGETING SUBROUTINES INITVEL, MIDGIM PERIAPO, SELECTMU, PRECSET	
PROGRAM: P. White	15 SEP 68	LUMINARY ID	DOCUMENT NO.
ANALYST:			FC-3760
DOCWR: J. P. Lohr	12 JUL 68	REV 3	SHEET 14 OF 18
APPR'D: John A. Mose	7 Sept 68		

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 T_0 , IN CSEC AT 2^{28} .

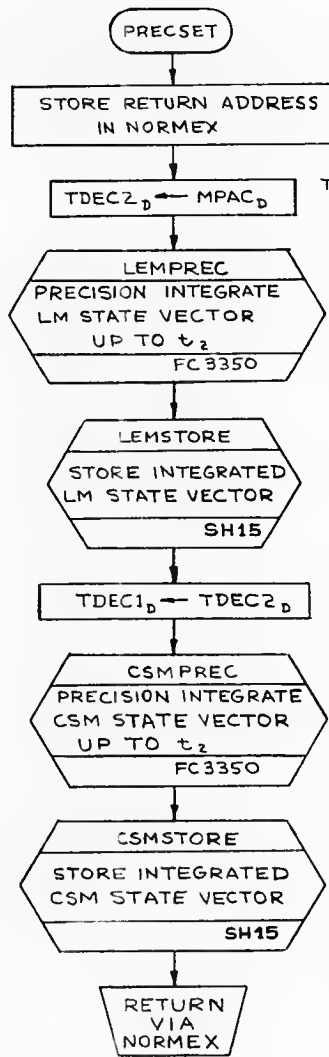
OUTPUT:

1) $RACT3_V = \mathcal{L}(t_2)$, POSITION VECTOR OF ACTIVE VEHICLE AT t_2 , IN METERS, AT 2^{29} .

2) $VACT3_V = \mathcal{V}(t_2)$, VELOCITY VECTOR OF ACTIVE VEHICLE AT t_2 , IN METERS/CSEC, AT 2^7 .

3) $RPASS3_V = \mathcal{L}(t_2)$, POSITION VECTOR OF PASSIVE VEHICLE AT t_2 , IN METERS, AT 2^{29} .

4) $VPASS3_V = \mathcal{V}(t_2)$, VELOCITY VECTOR OF PASSIVE VEHICLE AT t_2 , IN METERS/CSEC, AT 2^7 .



TEMPORARY STORAGE OF t_2 .

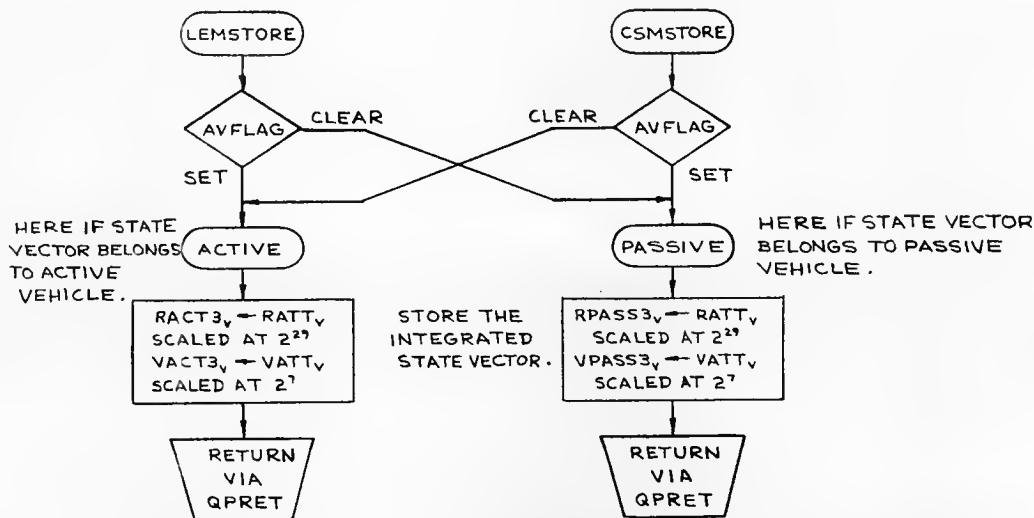
INPUT
 1) $RCV_V = \mathcal{L}(t_1)$
 2) $VCV_V = \mathcal{V}(t_1)$
 3) $TET_D = t_1$
 4) $TDEC1_D = t_2$

OUTPUT
 1) $RATT_V = \mathcal{L}(t_2)$
 2) $VATT_V = \mathcal{V}(t_2)$
 3) $TAT_D = t_2$

SET UP t_2 FROM TEMPORARY STORAGE.

INPUT
 1) $RCV_V = \mathcal{L}(t_1)$
 2) $VCV_V = \mathcal{V}(t_1)$
 3) $TET_D = t_1$
 4) $TDEC1_D = t_2$

OUTPUT
 1) $RATT_V = \mathcal{L}(t_2)$
 2) $VATT_V = \mathcal{V}(t_2)$
 3) $TAT_D = t_2$



HERE IF STATE VECTOR BELONGS TO ACTIVE VEHICLE.

STORE THE INTEGRATED STATE VECTOR.

HERE IF STATE VECTOR BELONGS TO PASSIVE VEHICLE.

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>F. Beaman</i>		COMMON TARGETING SUBROUTINES INITVEL, MIDGIM	
PROGRAM <i>P. White</i>		PERIAPD, SELECTM, PRECSET DOCUMENT NO.	
ANALYST		LUMINARY ID	
DOCNR <i>by P. L. Lask</i>		FC-3760	
APP'D <i>John A. Mince</i>		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	FERIAP0 (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)	

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. J. Langille</i>		COMMON TARGETING SUBROUTINES	
PROGRAM <i>P. J. White</i>		INITVEL, MIDGIM	
ANALYST		PERIAP0, SELECTMU, PRECSET	
DOCWR <i>L. A. Black</i>		LUMINARY ID	
APPR'D <i>John A. Moore</i>		DOCUMENT NO. FC-3760	
REV 3		SHEET 16 OF 18	

AVEGFLAG	AVERAGEG (SERV-ICER) DESIRED	AVERAGEG (SERV-ICER) 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°	IS MINUS IF TRUE ANOMALY GREATER THAN 180°	INITVEL (SH 5)		
VTARGETAG _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	h	2^1	E5, 1673
VTARGETAG _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
XIINPUT _S	TEMPORARY STORAGE OF X1		E7, 1564
ITCTR _S	ITERATION COUNTER	2^{14}	E7, 1603
COZY4 _D	$\cos(\epsilon)$	2^2	E7, 1653

INT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. J. Langille</i> PROWR <i>A. J. Langille</i> ANALST DOCWR <i>R. P. Blank</i> APPR'D <i>John A. Moran</i>	11JUL68 12JUN69 12JUN68 15JUL68	COMMON TARGETING SUBROUTINES INITVEL, MIDGIM PERIAPO, SELECTMU, PRECSET LUMINAR: 1D	DOCUMENT NO. FC-3760 REV 3
			SHEET 17 OF 18

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°)	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

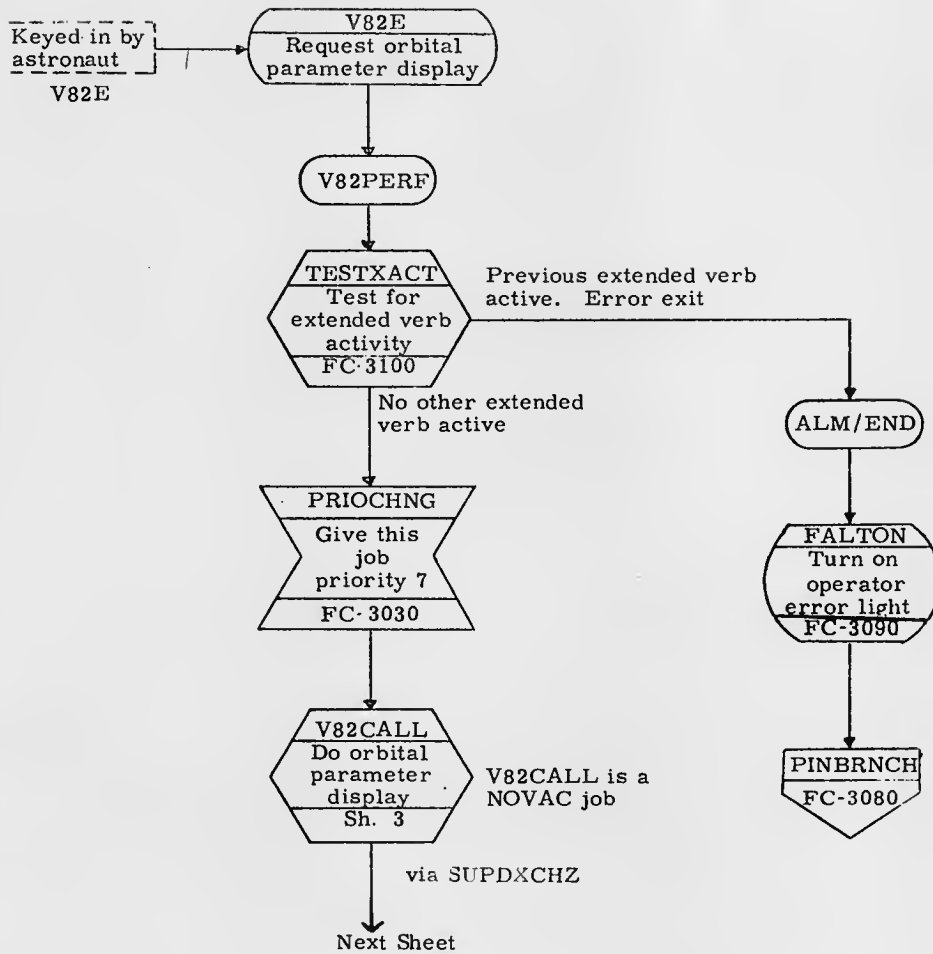
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>G. J. Langille</i>		COMMON TARGETING SUBROUTINES	
PROWR <i>W. G. Lutz</i>		INITVEL, MIDGIM	
ANALST		PERIADO, SELECTMU, PRECSET	
DOCTR <i>G. J. Langille</i>		LUMINARY ID	DOCUMENT NO.
APPR'D <i>John A. Moore</i>			FC-3760
11 JUL 68		REV 3	SHEET 18 OF 18

ORBITAL PARAMETERS DISPLAY

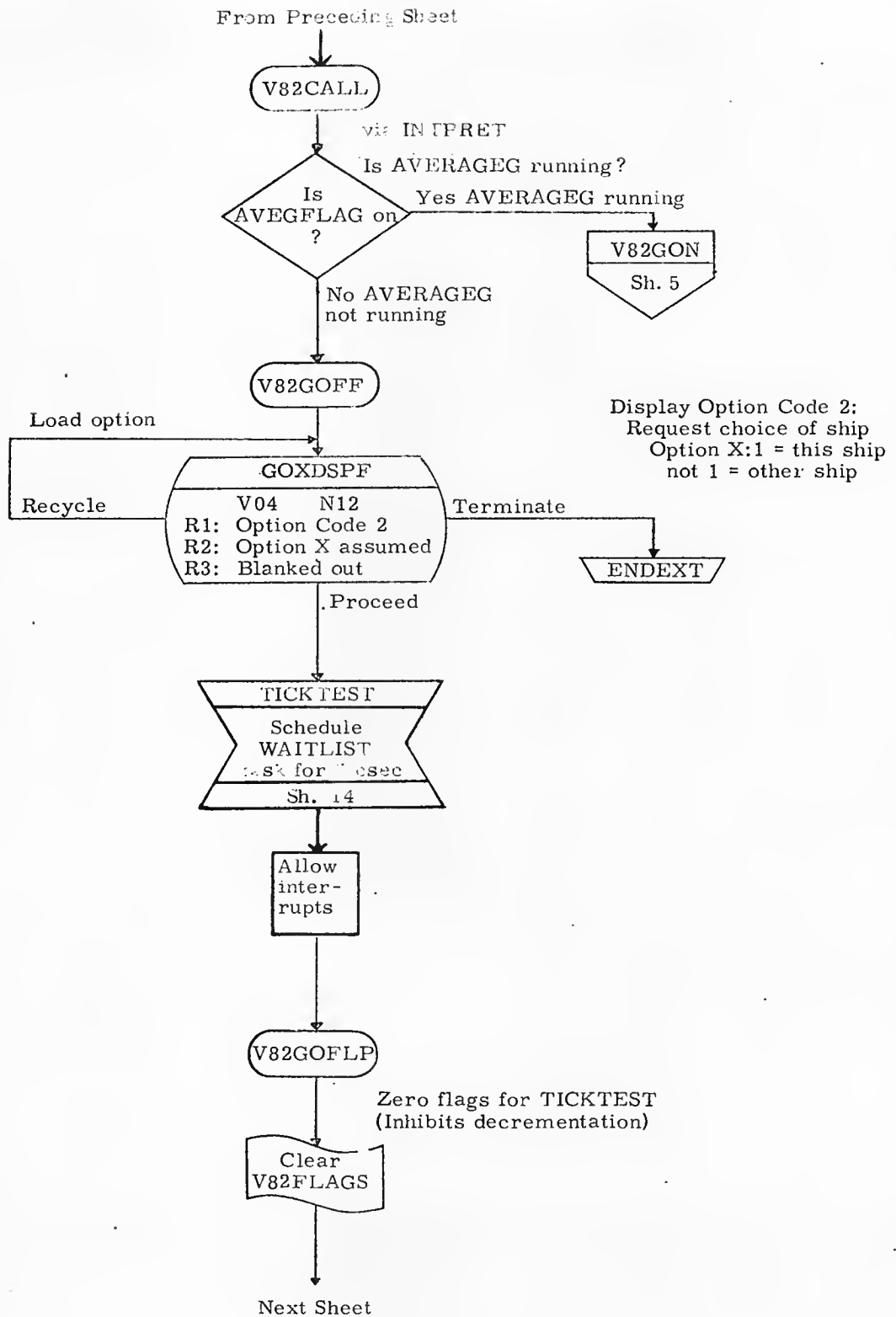
Major Subroutines and External Entry Points:

V82PERF	Sh. 2
V82CALL	Sh. 3
TICKTEST	Sh. 14
SR30.1	Sh. 15

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>G. Burke</i>	<i>10/10/69</i>	Orbital Parameters Display	
PRGMR <i>T.E. Crocker</i>	<i>10/20/69</i>	LUMINARY 1D	DOCUMENT NO. FC-3770
ANALST			
DOCMR <i>Robert M. Estes</i>	<i>10/30/69</i>	REV 2	SHEET 1 OF 25
APPR'D <i>Robert M. Estes</i>	<i>10/30/69</i>		

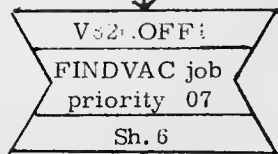


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>E. Carr</i>	<i>2-5-67</i>	Orbital Parameters Display	
PRGMR <i>T. G. G.</i>	<i>2-2-67</i>		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3770
DOCMR <i>T. G. G.</i>	<i>2-2-67</i>		
APPR'D <i>W. S. G.</i>	<i>2-2-67</i>	REV 2.	SHEET 2 OF 5



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>S. C. Smith</i>	Orbital Parameters Display	
PRCMR	<i>T. G. ...</i>	DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3770
DOCNR		REV 2	SHEET 3 OF 25
APPR'D	<i>W. S. ...</i>		

From Precedi Sheet



Schedule computations as FINDVAC job

Allow
inter-
rupts

V82STALL

V82STALL holds progress of program until V82GOFF1, the state vector update subroutine has had a chance to set one of the flags in V82FLAGS

Is
one of the
bits of V82FLAGS
set?

Yes, a flag on

No, no flag on

V82STALL

Delay job
1 sec

Sh. 4

FLAGGON

Display: monitor

Apogee : R1 XXXX.X dec naut miles

Perigee: R2 XXXX.X dec naut miles

TFF : R3 XXBXX dec min. sec.

GOXDSPF

V16 N44
R1: Apogee
R2: Perigee
R3: TFF

Terminate

Proceed

Recycle

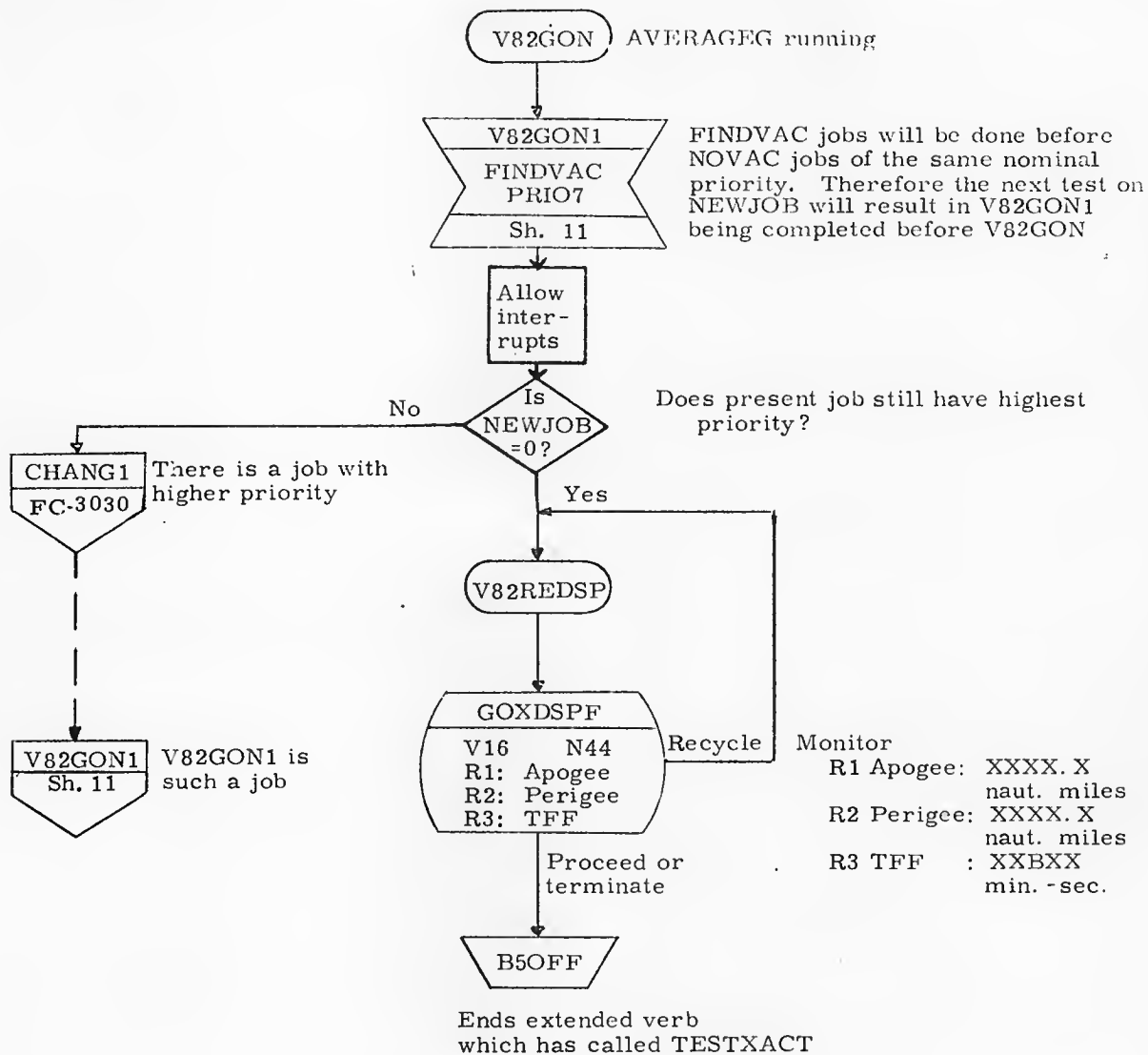
V82GOFLP

Sh. 3

B5OFF

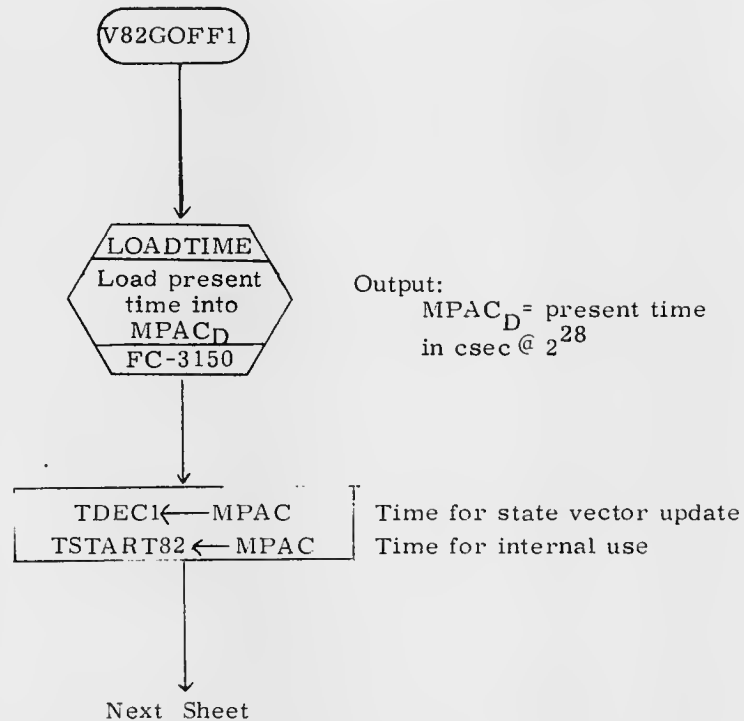
Ends extended verb which
has called TESTXACT

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Orbital Parameters Display	
PRGMR	ANALST	LUMINARY 1D	DOCUMENT NO. FC-3770
DCCMR	APPR'D	REV 2	SHEET 4 OF 25

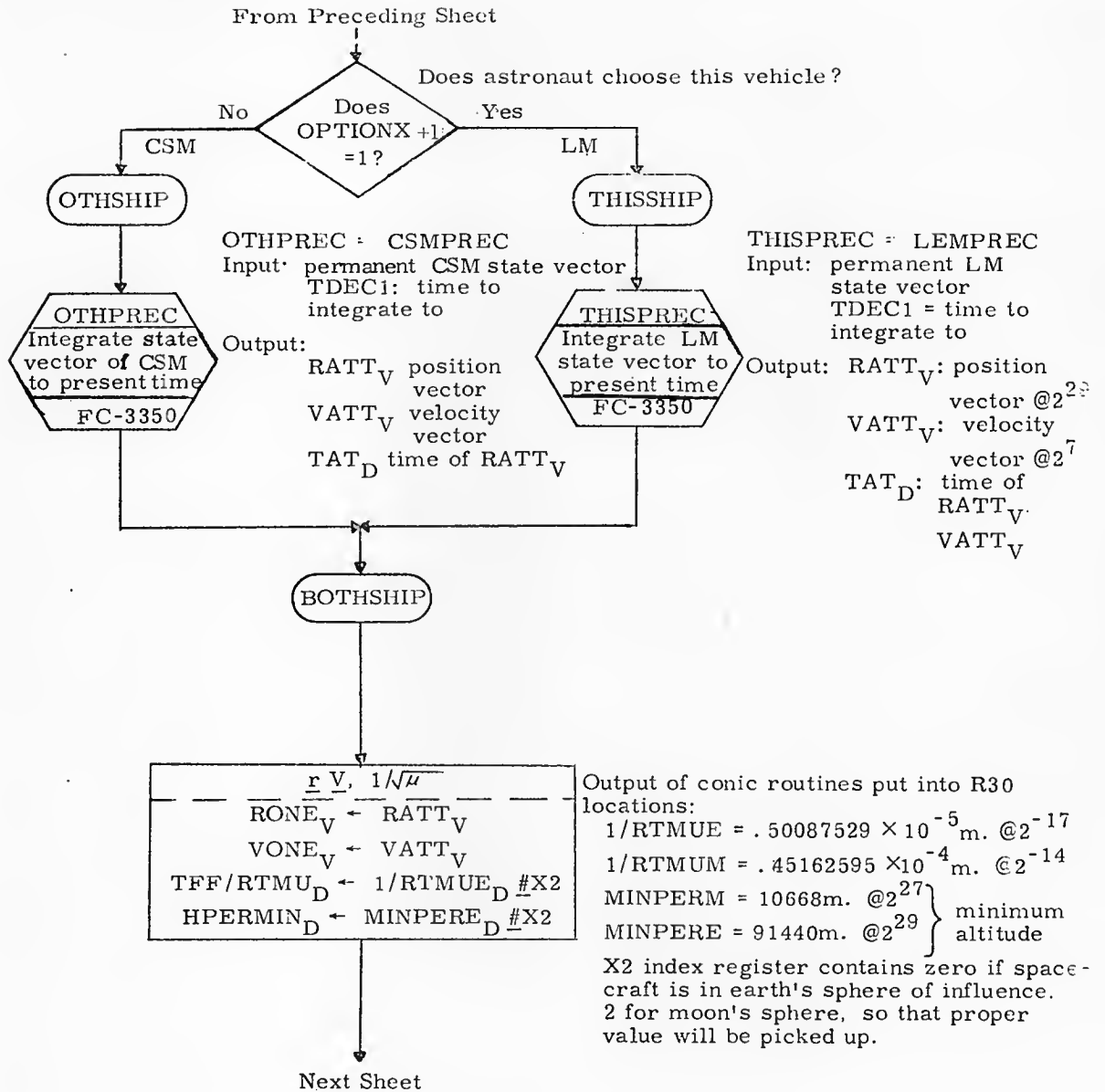


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>S. C. ...</i>	<i>...</i>	Orbital Parameters Display	
PRGMR <i>...</i>	<i>...</i>	DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3770
DOCMR <i>...</i>	<i>...</i>	REV 2	SHEET 5 OF 25
APPR'D <i>...</i>	<i>...</i>		

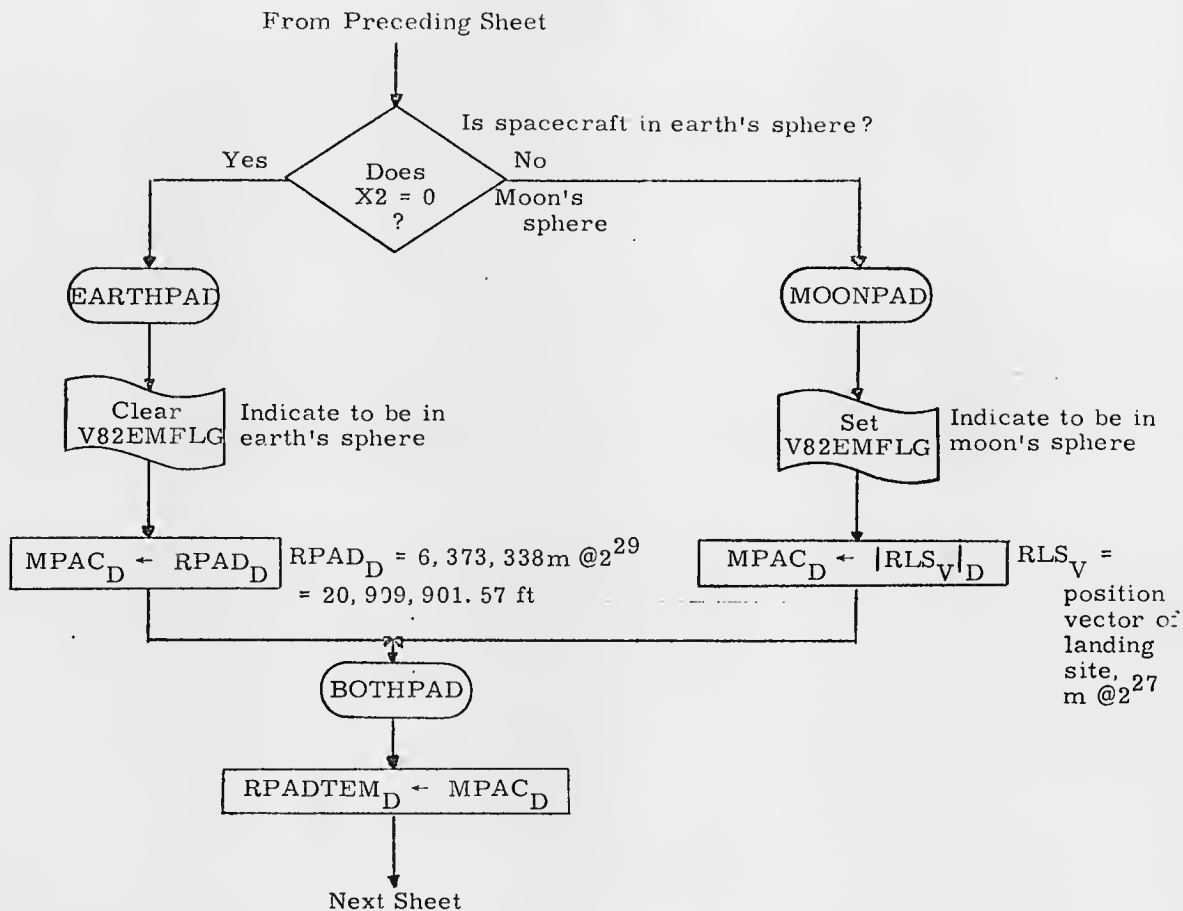
V82 scheduled this FINDVAC job of priority 07



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>G. Bevilacqua</i>	<i>10/27/69</i>	Orbital Parameters Display	
PRGMR	<i>T. Cocker</i>	<i>10/30/69</i>	LUMINARY 1D	DOCUMENT NO.
ANALST				FC-3770
DOCMR	<i>Robert M. Entes</i>	<i>10/30/69</i>	REV 2.	SHEET 6 OF 25
APPR'D	<i>Robert M. Entes</i>	<i>10/30/69</i>		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Orbital Parameters Display	
PRGMR		LUMINARY 1D	DOCUMENT NO. FC-3770
ANALST			
DOCMR		REV 2	SHEET 7 OF 15
APPR'D			



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>[Signature]</i>	Orbital Parameters Display	
PROGR	<i>[Signature]</i>	LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3770
DOCMR	<i>[Signature]</i>	REV 2	SHEET 8 OF 25
APPR'D	<i>[Signature]</i>		

From Preceding Sheet

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

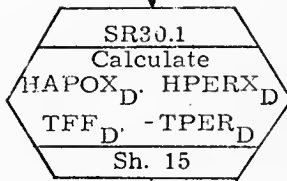
$RPADTEM_D$ = radius of pad: meters
@ 2^{29}

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}



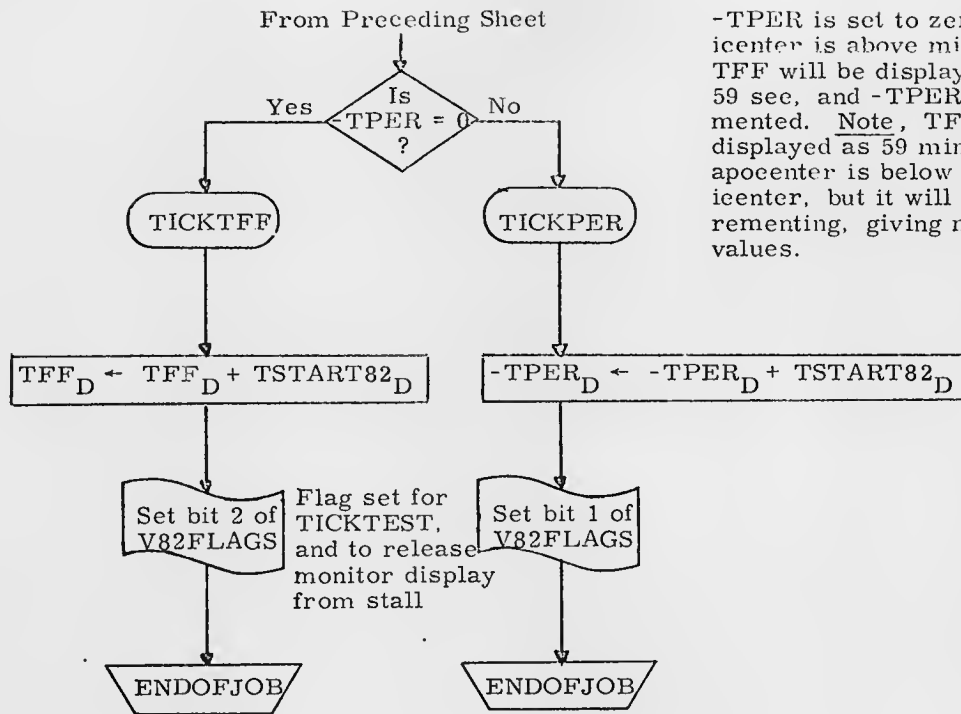
via LOADTIME (FC-3150)

$TSTART82_D \leftarrow TIME2_D - TSTART82_D$

Time elapsed since TSTART82

Next Sheet

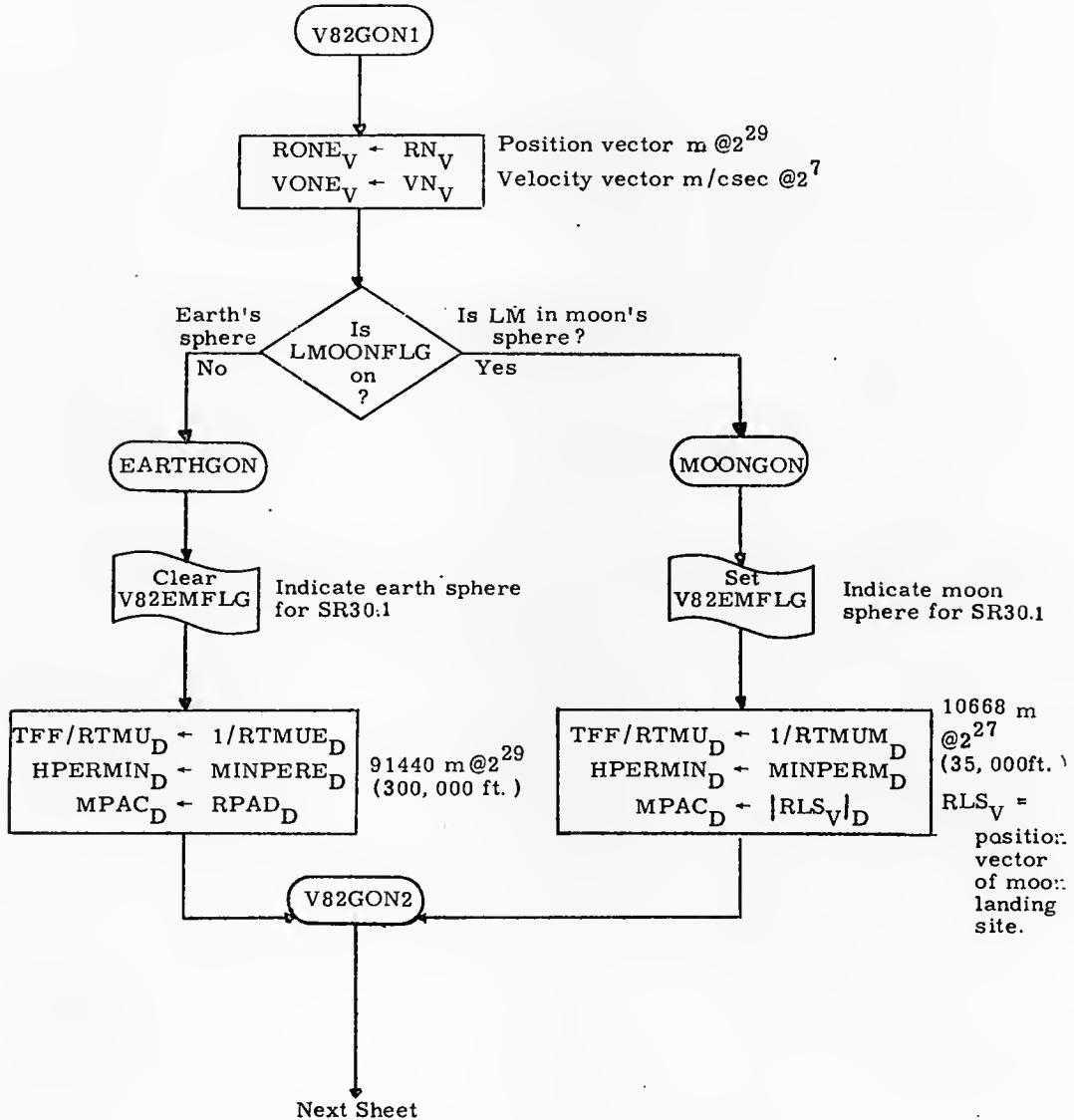
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. Burke</i>		Orbital Parameters Display	
PRGMR <i>I. Crocker</i>		DOCUMENT NO.	
ANALST		LUMINARY 1 D	FC-3770
DOCMR <i>Robert M. Estes</i>		REV 2	
APPR'D <i>Robert M. Estes</i>		SHEET 9 OF 25	



-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	<i>J. C. ...</i>	Orbital Parameters Display	
PRGMR	<i>J. C. ...</i>	LUMINARY1D	DOCUMENT NO. FC 3770
ANALST			
DOCMR		REV 2	SHEET 10 OF 25
APPR'D	<i>McNaut</i>		

V82GON scheduled this FINDVAC job of priority 07



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J.C. Smith</i>		Orbital Parameters Display	
PRGMR <i>T. Smith</i>		DOCUMENT NO. FC 3770	
ANALST		LUMINARY 1D	
DOCMR <i>...</i>		REV 2	
APPR'D <i>...</i>		SHEET 11 OF 25	

From Preceding Sheet

RPADTEM ← MPAC_D

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

SR30.1

Input:

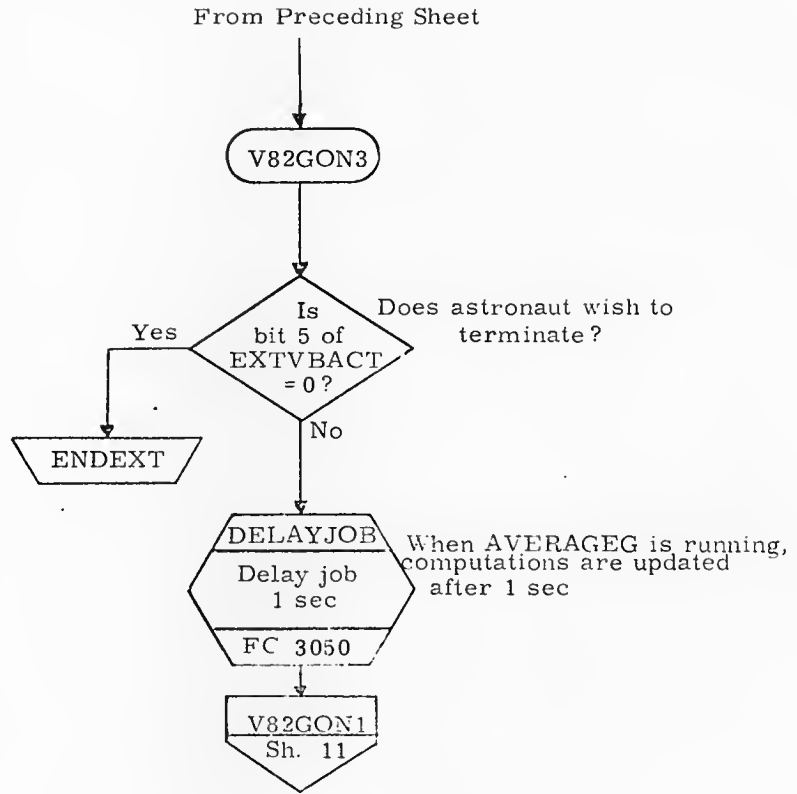
RONE_V = position vector in
meters @2²⁹
VONE_V = velocity vector in
meters/csec @2⁷
RPADTEM = pad radius in
meters @2²⁹
V82EMFLG on = moon.
off = earth

Output:

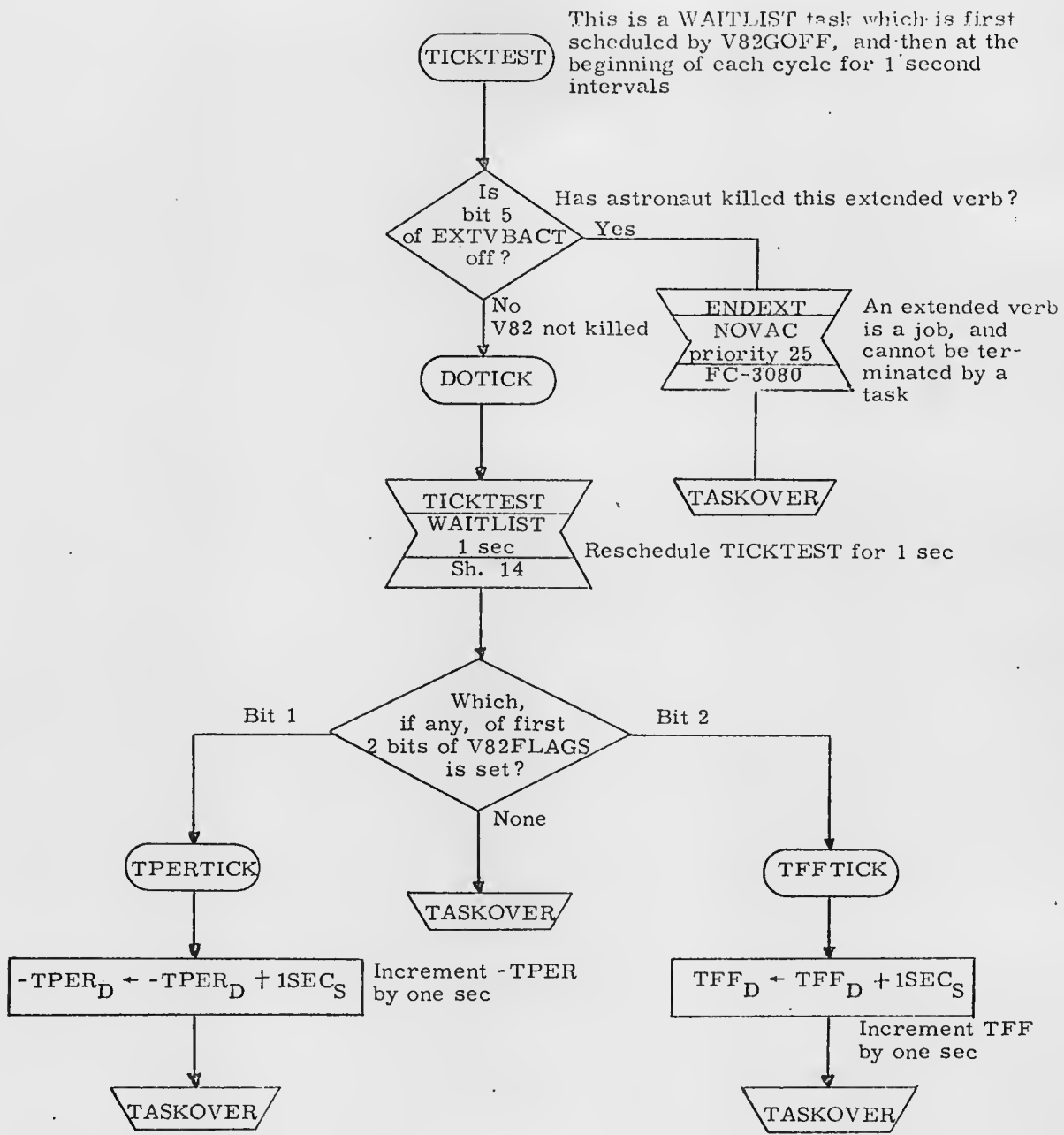
HPERX_D perigee height above
pad radius @2²⁹
HAPOX_D apogee height above
pad radius @2²⁹
TFF_D time of freefall } csec
-TPER_D time to perigee } @2²⁸

Next Sheet

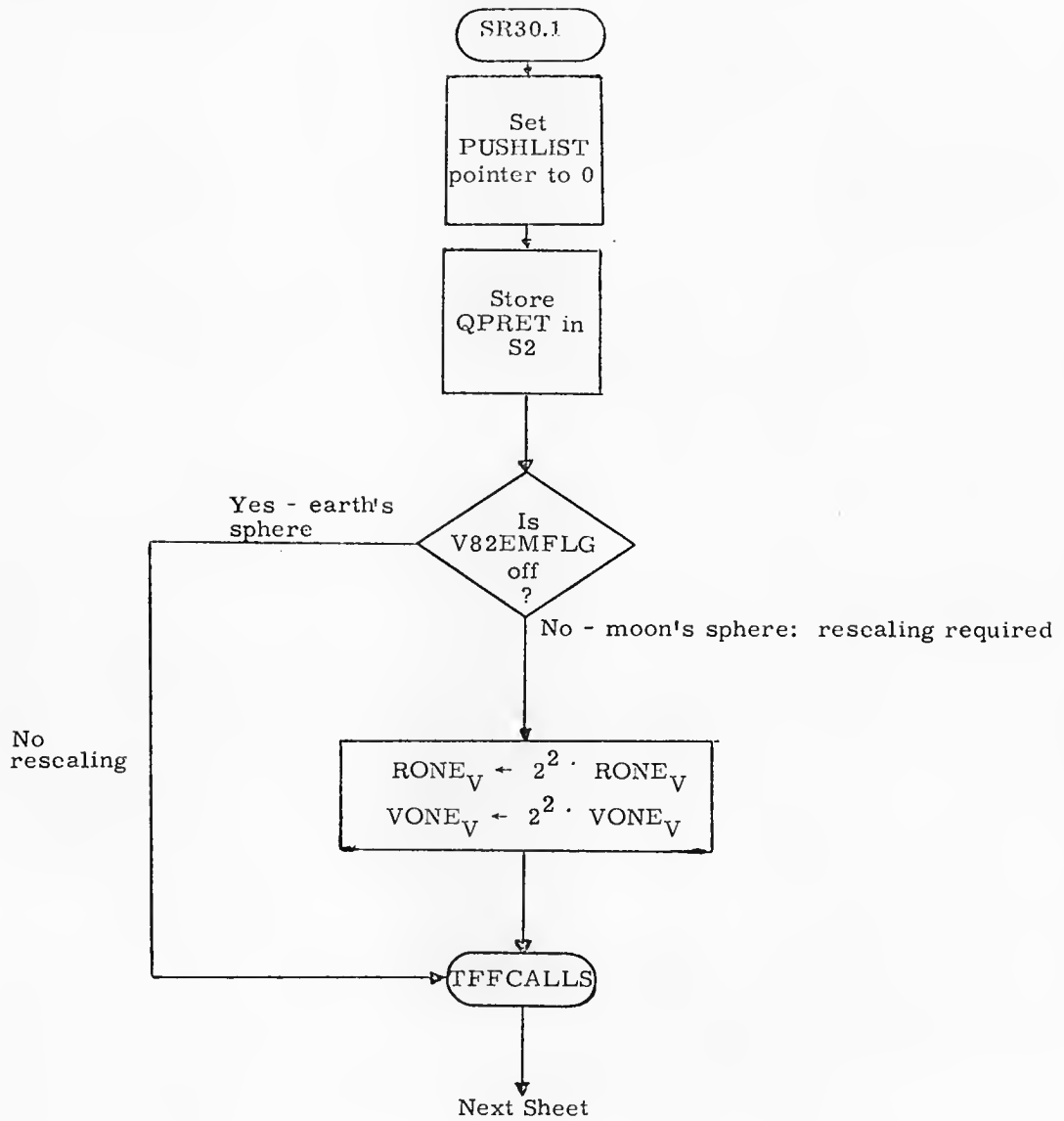
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		Orbital Parameters Display	
DRAWN <i>D. Burke</i>	<i>10/22/67</i>		
PRGMR <i>T. Cochran</i>	<i>10/30/67</i>		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3770
DOCMR <i>Robert M. Entel</i>	<i>10/30/67</i>	REV 2	SHEET 12 OF 25
APPR'D <i>Robert M. Entel</i>	<i>10/30/67</i>		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>G. Burke</i>	<i>10/20/69</i>	Orbital Parameters Display
PRGMR	<i>J. Crocker</i>	<i>10/30/69</i>	DOCUMENT NO.
ANALST			LUMINARY 1D FC-3770
DCGR	<i>Roberto M. Entes</i>	<i>10/30/69</i>	REV 2
APPR'D	<i>Roberto M. Entes</i>	<i>10/30/69</i>	SHEET 13 OF 25

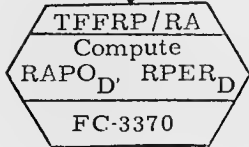
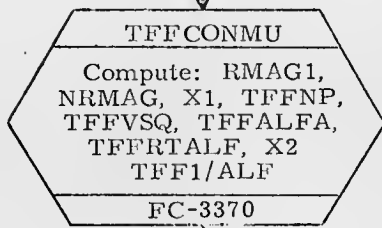


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>C. G. ...</i>	Orbital Parameters Display	
PROGR	<i>...</i>	LUMINARY 1D	DOCUMENT NO. FC-3770
ANLST	<i>...</i>		
DCCMR	<i>...</i>		
APPR'D	<i>C. G. ...</i>	REV 2	SHEET 11 OF 25



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN: <i>J. C. ...</i>	DATE: <i>...</i>	Orbital Parameters Display	
PROGR: <i>T. ...</i>	REV: <i>...</i>	LUMINARY 1D	DOCUMENT NO.
ANALST: <i>...</i>	DATE: <i>...</i>		FC-3770
DCCMR: <i>...</i>	DATE: <i>...</i>	REV: 2	SHEET 15 OF 25
APPR'D: <i>...</i>	DATE: <i>...</i>		

From Preceding Sheet



Next Sheet

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 $RMAG$, norm 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 $E@2^{38-2NR} M@2^{36-2NR}$

$TFFVSQ_D$: $\frac{V}{\sqrt{\mu}}$ 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 $E@2^{+22+2NA} M@2^{20+2NA} M$

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

TFFRP/RA:

Input:

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

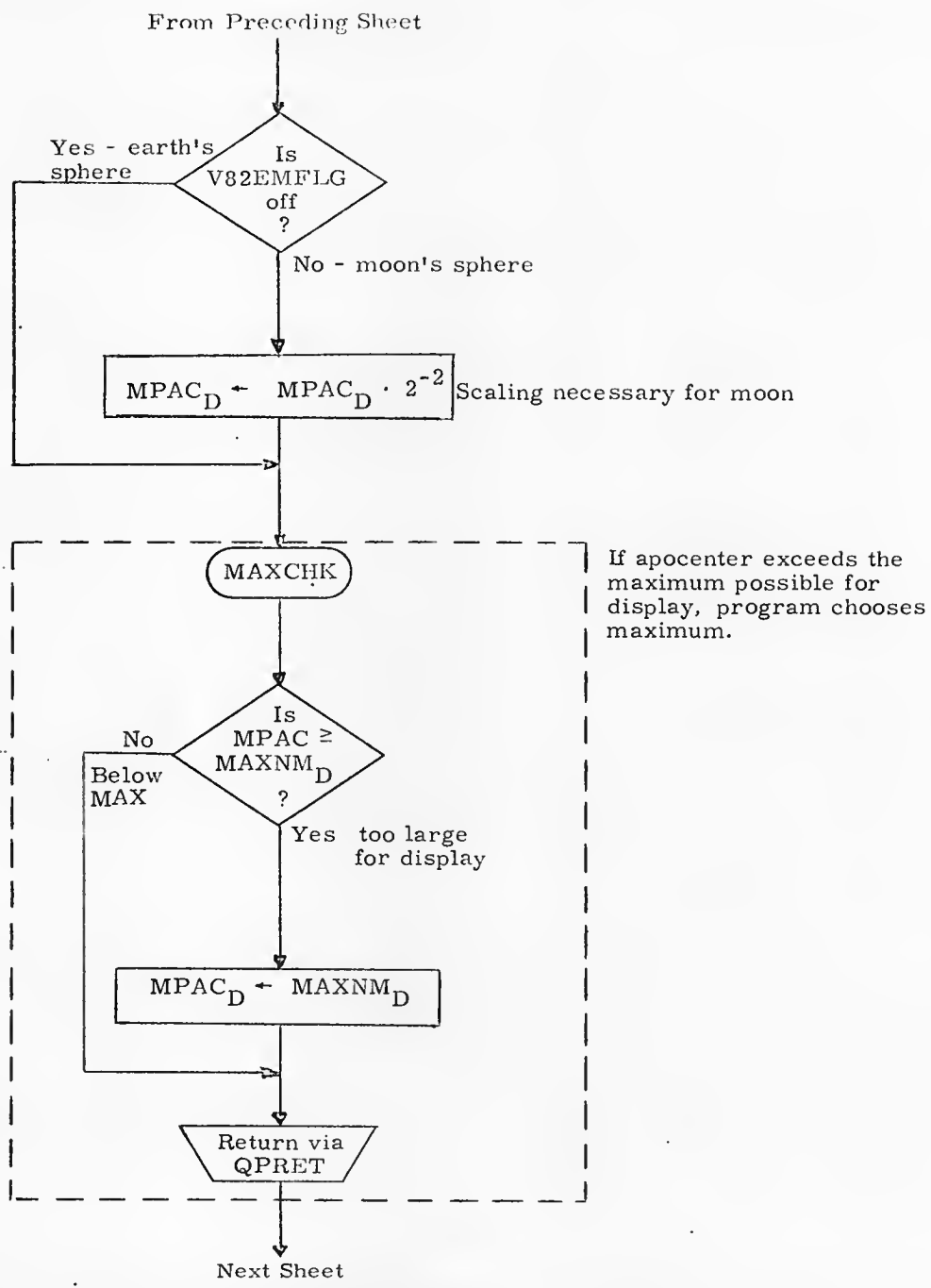
$TFFNP_D$ = semi-latus rectum in meters $@2^{38-2NR}/2^{36-2NR} X1, X2$ set by TFFCONMU

Output:

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

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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. C. ...</i>	DATE	Orbital Parameter Display	
PRGMR <i>J. C. ...</i>	DATE	LUMINARY 1D	DOCUMENT NO.
ANLST			FC-3770
DOCMR		REV 2	SHEET 10 OF 25
APPR'D <i>William ...</i>			



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Orbital Parameters Display	
PROGR		DOCUMENT NO.	
ANALST		LUMINARY 1 D,	FC-3770
DOCMR		2	SHEET 17 OF 25
APPR'D			

From Preceding Sheet

STORHAPC

$HAPOX_D \leftarrow MPAC_D$
 $MPAC_D \leftarrow RPER_D - RPADETEM_D$
 $MPAC +4_D \leftarrow RPER_D - RPADETEM_D$

Store into apocenter location: meters @2²⁹
Prepare to store HPER_D
Save for comparison with HPERMIN

In earth's sphere?
Is V82EMFLG off?
Yes - earth's sphere
No - moon's sphere

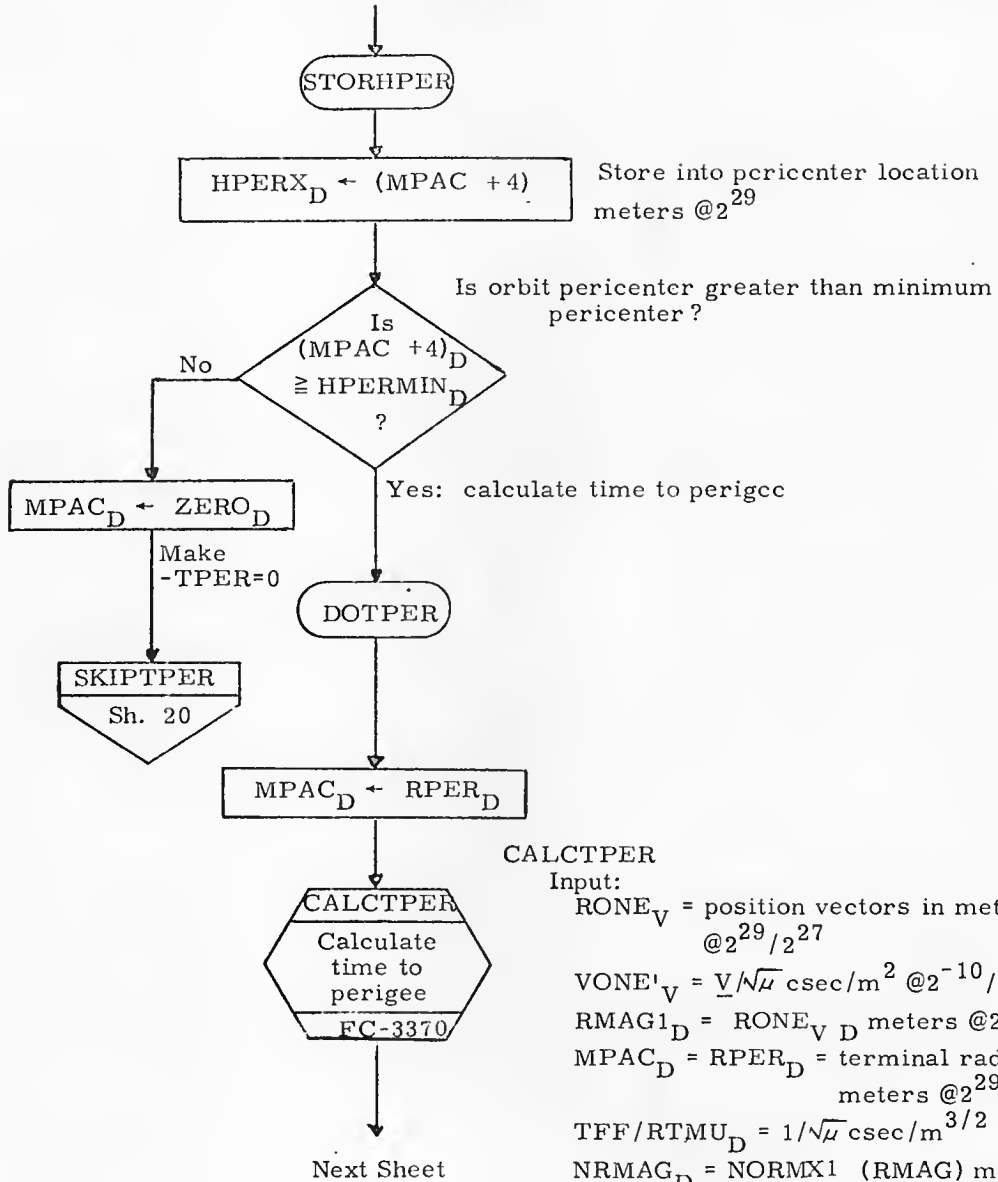
$MPAC_D \leftarrow MPAC \cdot 2^{-2}$ Rescaling necessary

MAXCHK
Check for too large value
If pericenter exceeds the maximum possible for display, program chooses maximum
Sh. 17

Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i>		Orbital Parameters Display	
PROGR <i>[Signature]</i>		LUMINARY 1D	DOCUMENT NO. FC-3770
ANALST <i>[Signature]</i>		REV 2	SHEET 18 OF 25
DOCMR <i>[Signature]</i>			
APPR'D <i>[Signature]</i>			

From Preceding Sheet



Store into pericenter location meters @ 2^{29}

Is orbit pericenter greater than minimum pericenter?

Yes: calculate time to perigee

CALCTPER

Input:

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

$VONE_V = \frac{V}{\sqrt{\mu}}$ csec/m² @ $2^{-10}/2^{-9}$

$RMAG_D = RONE_V$ 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 @ $2^{38} - 2X/2^{36} - 2X$

$TFFALFA = \alpha$ 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		Orbital Parameters Display	
PRGMR			DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3770
DOCMR		REV 2	SHEET 1 of 5
APPR'D			

From Preceding Sheet

$MPAC_D \leftarrow -MPAC_D$

SKIPTPER

$-TPER_D \leftarrow MPAC_D$
 $MPAC_D \leftarrow HPERMIN_D + RPADTEM_D$

CALCTFF
Calculate
time of
free fall
FC-3370

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:

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

Note:

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

$TFF_D \leftarrow -MPAC_D$

Return via
S2

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i>	DATE <i>[Date]</i>	Orbital Parameters Display	
PRGMR <i>[Signature]</i>	DATE <i>[Date]</i>	DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3770
DOCMR		REV 2	SHEET 2 OF 2
APPR'D <i>[Signature]</i>			

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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Orbital Parameters Display	
PRGR		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3770
DOCR		2	SHEET 21 OF 25
APPROV	<i>[Signature]</i>		

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
EINDEX	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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>C. Beuba</i>	<i>11/20/69</i>	Orbital Parameters Display
PRGMR	<i>L. Crocker</i>	<i>10/30/69</i>	
ANALST			DOCUMENT NO.
DOCMR	<i>Roberta M. Entz</i>	<i>10/30/69</i>	LUMINARY 1D
APPR'D	<i>Roberta M. Entz</i>	<i>10/30/69</i>	REV 2
			FC-3770
			SECRET 22 OF 25

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
RMAG _D	r	Magnitude of radius vector	feet	meters	2 ²⁷ /2 ²⁹
RNV	r _̄	Radius vector as given by AVERAGE	feet	meters	2 ²⁹
RONE _V	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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Orbital Parameters Display	
PRGMR		DOCUMENT NO.	
ANALST		LUMINARY 1D FC-3770	
DOCMR		RE. 2 SHEET 23 OF 25	
APPR'D	<i>[Signature]</i>		

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/√μ	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 - X ₁ / 2 ⁻²⁴ - X ₁
TFFNP _D	p	Semilatus rectum, normalized	feet	meters	2 ²⁸ + X ₁ / 2 ³⁶ + X ₁
TFFRTALF _D	√α	Square root of alpha	1/feet ^{1/2}	1/m ^{1/2}	2 ⁻¹⁰ - X ₁ / 2 ⁻⁹ - X ₁
TFFVQS _D	(v') ²	Velocity/√u	1/feet ^{1/2}	1/m ^{1/2}	2 ⁻²⁰ /2 ⁻¹⁸
TFFI/ALF _D		Signed, semi-major axis, weighted by X ₂	feet	meters	2 ²² - 2 · X ₂ / 2 ²⁰ - 2 · X ₂
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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Orbital Parameters Display	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3770
DCMR			
APPR'D	<i>[Signature]</i>	REV 2	SHEET 24 OF 25

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 _p MIN	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}

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Orbital Parameters Display	
PRGRM		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3770
DOCHR		REV: 2	SHEET 25 OF 25
APPR'D:	<i>[Signature]</i>		

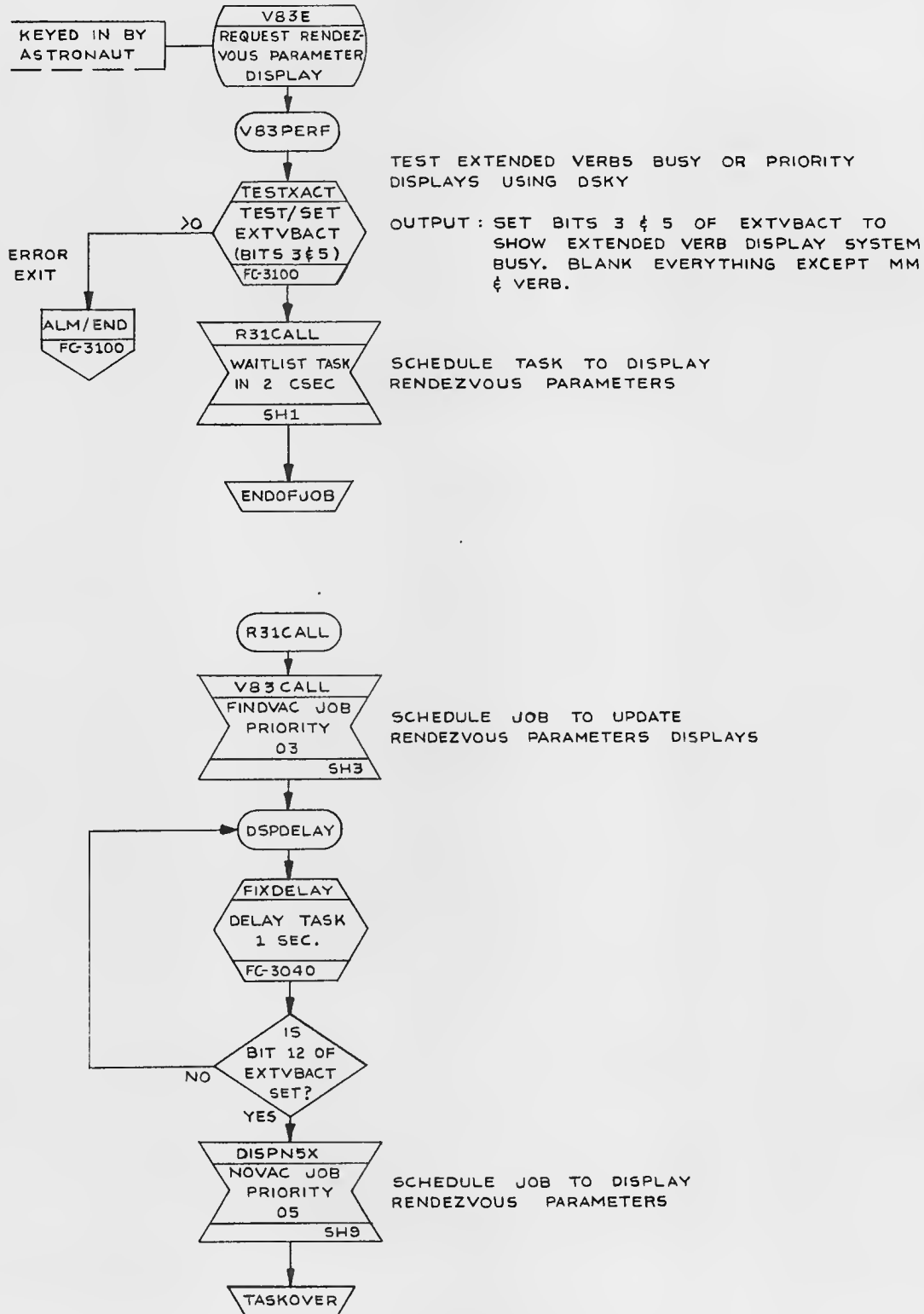
R31 - RENDEZVOUS PARAMETER DISPLAY

MAJOR SUBROUTINES ON THIS FLOW CHART

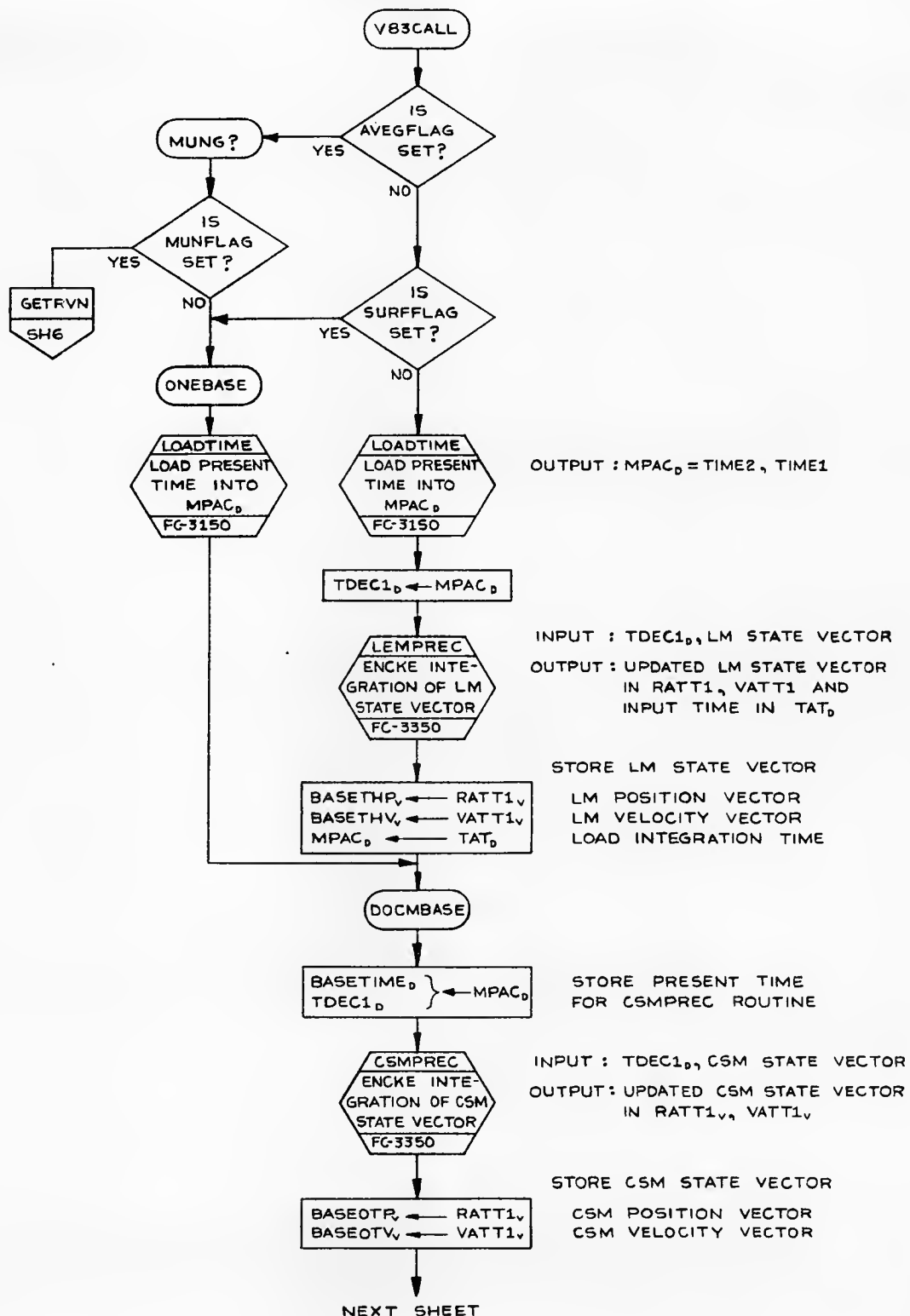
EXTENDED	V83PERF	REQUEST RENDEZVOUS PARAMETER DISPLAY	SH 2
VERB 83	R31CALL	SCHEDULE RENDEZVOUS PARAMETER DISPLAY	SH 2

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		R31 - RENDEZVOUS PARAMETER DISPLAY	
DRAWN <i>F. D. GARDNER</i> PRGMR <i>R. R. Covert</i> ANALST DOCNR <i>W. D. [Signature]</i> APPR'D <i>Richard M. Spang</i>	12 MAY 68 20 JUNE 69 19 JUNE 69 20 JUNE 69	LUMINARY ID	DOCUMENT NO. FC-3780
		REV 2	SHEET 1 OF 11

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

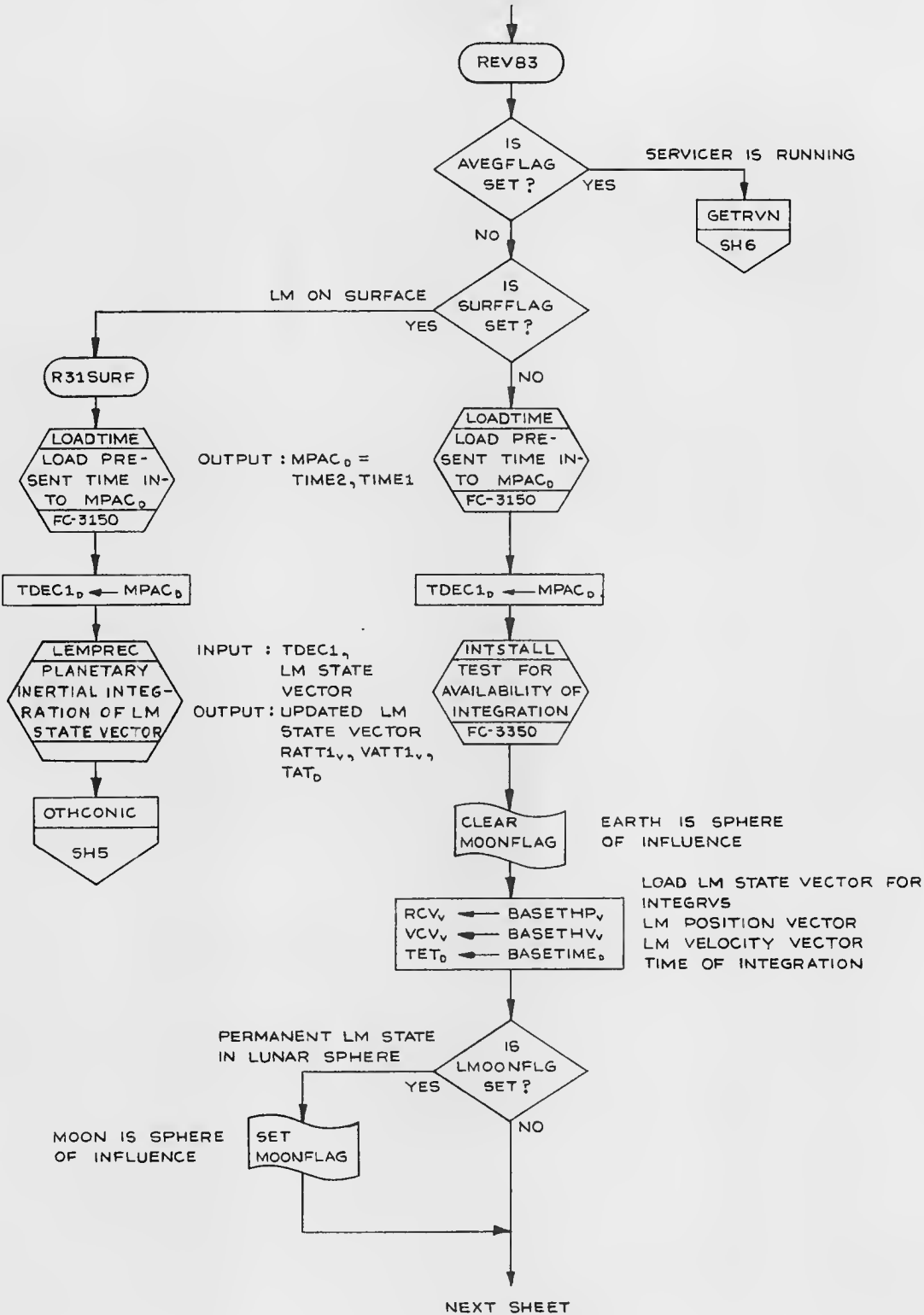


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. J. Sauer</i>		13 MAY 66	
PRGRM <i>R. R. Coelli</i>		20 JUNE 67	
APPLST		LUMINARY ID	DOCUMENT NO. FC-3780
DOCHR <i>FC-3780</i>		19 JUNE 69	
APPR'D <i>W. M. Stewart</i>		REV 2	SHEET 2 OF 11



INT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J.R. Powell</i> 27 MAY 69 PROGRAM <i>R.R. Powell</i> 20 JUN 69 ANALYST DOCNR <i>FC-3780</i> 20 JUN 69 APPR'D <i>R.R. Powell</i> 20 JUN 69		R31- RENDEZVOUS PARAMETER DISPLAY	
		LUMINARY ID	DOCUMENT NO. FC-3780
		REV 2	SHEET 3 OF 11

FROM PRECEDING SHEET



INT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		R31- RENDEZVOUS PARAMETER DISPLAY	
DRAWN <i>F. A. Fournier</i> PRGMR <i>R. R. Coelli</i> ANALST DOCMR <i>M. D. Smith</i> APPR'D <i>M. D. Smith</i>	28 MAY 69 20 JUNE 69 4 JUNE 69 20 JUNE 69	LUMINARY ID	DOCUMENT NO. FC-3780
		REV 2	SHEET 4 OF 11

FROM PRECEDING SHEET

SET
INTYPFLG

CONIC INTEGRATION TO BE USED

INTEGRVS
UPDATE LEM
STATE VECTOR TO
SPECIFIED TIME
FC3350

INPUT: RCV_v , VCV_v , TET_{op} , $TDEC1_D$

OUTPUT: $RATT_v$, $VATT_v$, TAT_D

OTHCONIC

$RONE_v \leftarrow RATT_v$
 $VONE_v \leftarrow VATT_v$

STORE LM STATE VECTOR
LM POSITION VECTOR
LM VELOCITY VECTOR

INSTALL
TEST FOR
AVAILABILITY OF
INTEGRATION
FC3350

SET
INTYPFLG

CONIC INTEGRATION TO BE USED

$MPAC_D \leftarrow TAT_D$

LOAD TIME TO INTEGRATE

OTHINT

$TDEC1_D \leftarrow MPAC_D$

STORE TIME TO INTEGRATE

CLEAR
MOONFLAG

EARTH IS SPHERE
OF INFLUENCE

$RCV_v \leftarrow BASEOP_v$
 $VCV_v \leftarrow BASEOTV_v$
 $TET_D \leftarrow BASETIME_D$

LOAD CSM STATE VECTOR FOR INTEGRVS ROUTINE
CSM POSITION VECTOR
CSM VELOCITY VECTOR
TIME OF STATE VECTOR

NO
IS
LMOONFLG
SET?
YES

PERMANENT LM STATE IN LUNAR SPHERE

SET
MOONFLAG

MOON IS SPHERE
OF INFLUENCE

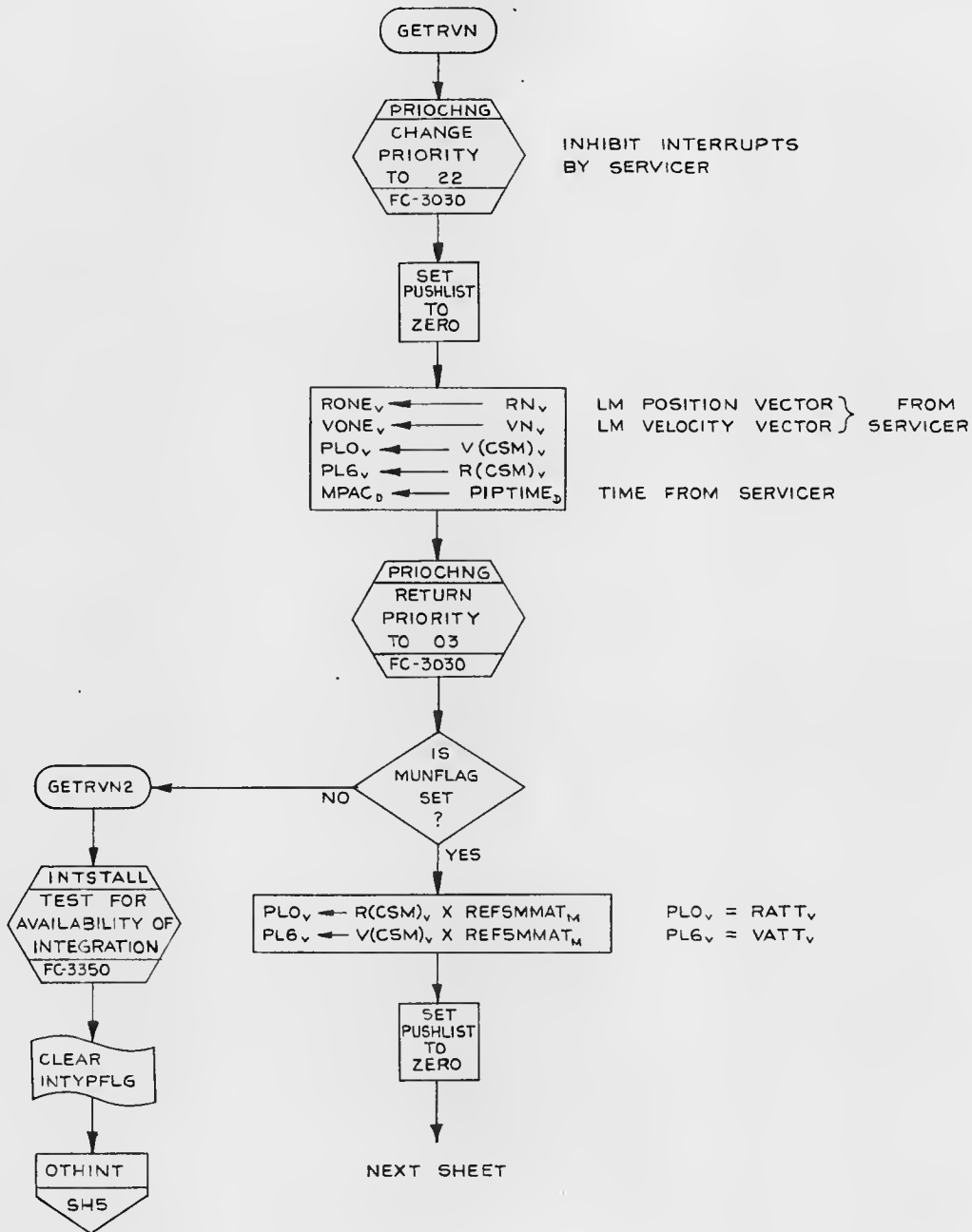
INTEGRVS
UPDATE CSM
STATE VECTOR TO
SPECIFIED TIME
FC-3350

INPUT: RCV_v , VCV_v , TET_D , $TDEC1_D$

OUTPUT: $RATT_v$, $VATT_v$

COMPDISP
SH7

INT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. A. Gausser</i> CHECKED <i>R. R. Beck</i> ANALYST DOCNR APPR		15MAY 69 20 JUN 69 LUMINARY 1D DOCUMENT NO. FC-3780	
REV 2		SHEET 5 OF 11	



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>St A. Gervais</i>		R31 - RENDEZVOUS PARAMETER DISPLAY	
PROGRAM <i>R. K. Coelli</i>	2 JUN 69	LUMINARY ID	DOCUMENT NO. FC-3780
APPROVAL <i>[Signature]</i>	20 JUL 69	REV 2	SHEET 6 OF 11
APPROVAL <i>[Signature]</i>	2 JUN 69		

FROM
PRECEDING SHEET

COMPDISP

$$\frac{\underline{U}_R = \text{UNIT}(\underline{r}_C - \underline{r}_L)}{\text{OD}_V \leftarrow \text{UNIT}(\text{RATT}_V - \text{RONE}_V)}$$

LINE OF SIGHT UNIT VECTOR

$$\frac{\text{RANGE} = |R|}{\text{RANGE}_D \leftarrow |\text{RATT}_V - \text{RONE}_V|}$$

$$\frac{\dot{R} = (\underline{v}_C - \underline{v}_L) \cdot \underline{U}_R}{\text{RRATE}_D \leftarrow (\text{VATT}_V - \text{VONE}_V) \cdot \text{OD}_V}$$

RRATE = SPEED AT WHICH DISTANCE
BETWEEN THE TWO VEHICLES
IS CHANGING

NEXT SHEET

AFT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		R31 - RENDEZVOUS PARAMETER DISPLAY	
DRAWN <i>A. J. ...</i>	18 JUNE 67	LUMINARY ID	DOCUMENT NO. FC-3780
FROM <i>A. J. ...</i>	20 JUNE 67		
ANALYST			
DOCKING <i>...</i>	19 JUNE 67		
APPRO'D <i>...</i>		REV 2	SHEET 7 OF 11

FROM PRECEDING SHEET

$OD_V \leftarrow \text{UNIT}(RONE_V)$
 $MPAC_V \leftarrow \text{UNIT}Z_V$

$RONE_V = r_L$
 $\text{UNIT}Z_V = \underline{U}_Z = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$ IN SPACECRAFT (NB) COORDINATES

CDU* NBSM
 CONVERTS \underline{U}_Z
 FROM NAV. BASE TO
 STABLE MEMBER
 FC-3320

SM COORDS. ARE MODEL OF REFERENCE COORDS. DEVIATION
 BETWEEN TWO COORD. SYSTEMS IS REFSMMAT_M
 OUTPUT: $MPAC \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}_V$ IN STABLE MEMBER COORDINATES

$GD_V \leftarrow MPAC_V (REFSMMAT)_M^T$

REFSMMAT IS DIFFERENCE BETWEEN STABLE
 MEMBER AND REFERENCE COORDINATE SYSTEM.
 $GD_V = \underline{U}_Z$ IS NOW IN REFERENCE COORDINATES

$\underline{U}_D = \text{UNIT} \left[\underline{U}_Z - \left(\frac{\underline{U}_Z \cdot r_L}{r_L^2} \right) r_L \right]$
 $12D_V \leftarrow \text{UNIT} \{ GD_V - [GD_V \cdot (OD_V)] (OD_V) \}$

\underline{U}_D USED IN CALCULATION OF Θ BELOW.
 PROJECTION OF \underline{U}_Z ONTO THE VEHICLE'S
 HORIZONTAL PLANE.

$12D = \left\{ \text{UNIT}(r_L \times \underline{V}_L) \times r_L \right\} \cdot \underline{U}_D$
 $12D_D \leftarrow \left\{ \text{UNIT}[(PLO)_V \times (VONE)_V] \times (PLO)_V \right\} \cdot 12D_V$

$MPAC = \underline{U}_D$

$\Theta = \cos^{-1}(\underline{U}_D \cdot \underline{U}_Z) \text{SGN} \left\{ \left[\text{UNIT}(r_L \times \underline{V}_L) \times r_L \right] \cdot \underline{U}_D \right\}$
 $R\Theta_{D_D} \leftarrow \cos^{-1}(MPAC_V \cdot GD_V) \text{SGN}(12D_D)$

$\Theta =$ ANGLE BETWEEN LEM LINE OF
 SIGHT (Z-AXIS) AND THE LOCAL
 HORIZONTAL AT THE PRESENT TIME,

$MPAC = r_L \cdot \underline{U}_Z$
 $MPAC_D \leftarrow (PLO)_V \cdot GD_V$

IS
 $MPAC \geq 0$
 ?

NO

YES

$\Theta = 2\pi - \Theta$
 $R\Theta_{D_D} \leftarrow \text{DPOS} \text{MAX}_D - R\Theta_{D_D}$

IS
 EXT
 V-
 BACT (BIT5)
 = 0?

YES

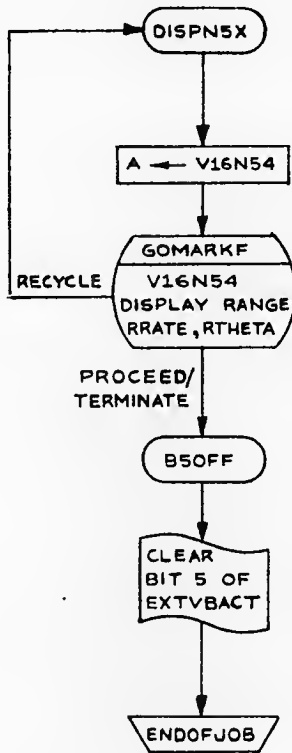
NO

TERMINATE R31
 VIA ENDEXT

SET BIT 12
 OF EXT
 VBACT

REV83
 SH4

INT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		R-31 RENDEZVOUS PARAMETER DISPLAY	
DRAWN <i>J.W. J... 6/26/68</i> PRGRM <i>...</i> ANALST <i>...</i> DOCMR <i>...</i> APPR'D <i>John A. Morse 15 Sept 68</i>	REV 2	LUMINARY ID	DOCUMENT NO. FC-3780
			SHEET 8 OF 11



R1-RANGE₀ - XXX.XXXN.M. } RENDEZ-
 R2-RRATE₀ - XXXX.X FT/SEC } VOUS
 R3-RTHETA₀ - XXX.XX DEG } PARA-
 METERS

TERMINATE MARK DISPLAY

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		R31 - RENDEZVOUS PARAMETER DISPLAY	
DRAWN <i>Ed. [unclear]</i> CHECKED <i>A. R. [unclear]</i> APPROVED <i>[unclear]</i> DATE <i>20 June 69</i>	DESIGNED <i>[unclear]</i> DATE <i>[unclear]</i>	LUMINARY ID	DOCUMENT NO. FC-3780
APPROVED <i>[unclear]</i>		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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>V. J. Hart</i>		R-31 RENDEZVOUS PARAMETER DISPLAY	
PRGMR <i>R. R. Cook</i>	DATE <i>20 Jun 69</i>	LUMINARY ID	DOCUMENT NO. FC-3780
ANALYST			
DOCNR <i>FC-3780</i>	DATE <i>19 Jun 69</i>		
APPR'D <i>W. H. M. Strain</i>	DATE <i>20 Jun 69</i>	REV 2	SHEET 11 OF 11

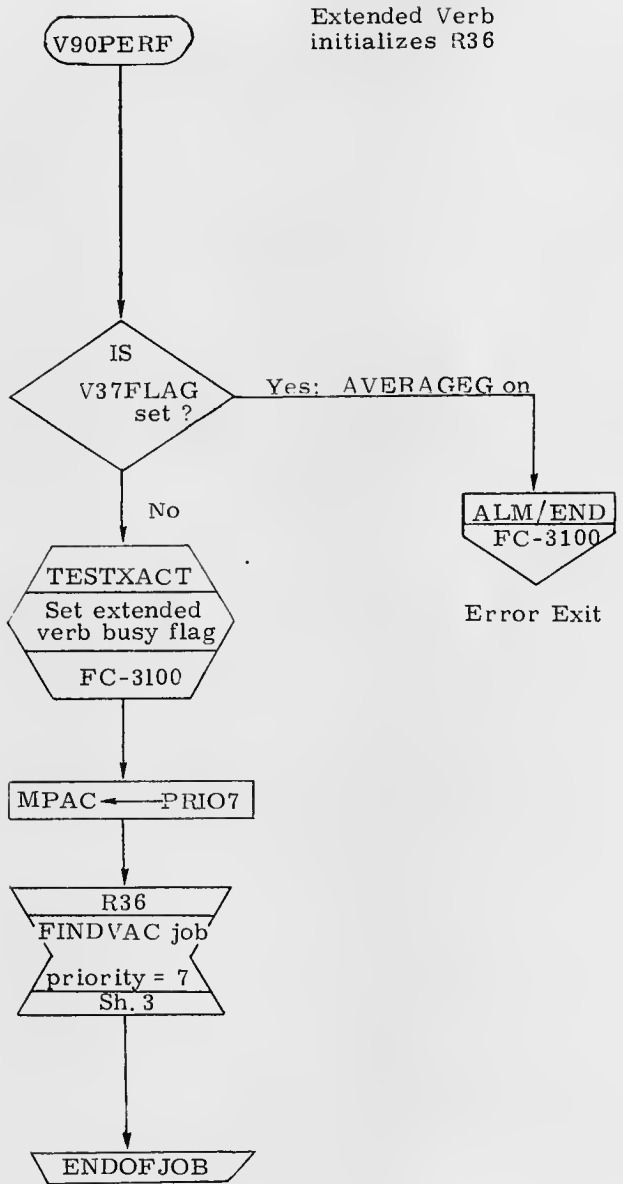


R36: OUT-OF-PLANE RENDEZVOUS ROUTINE

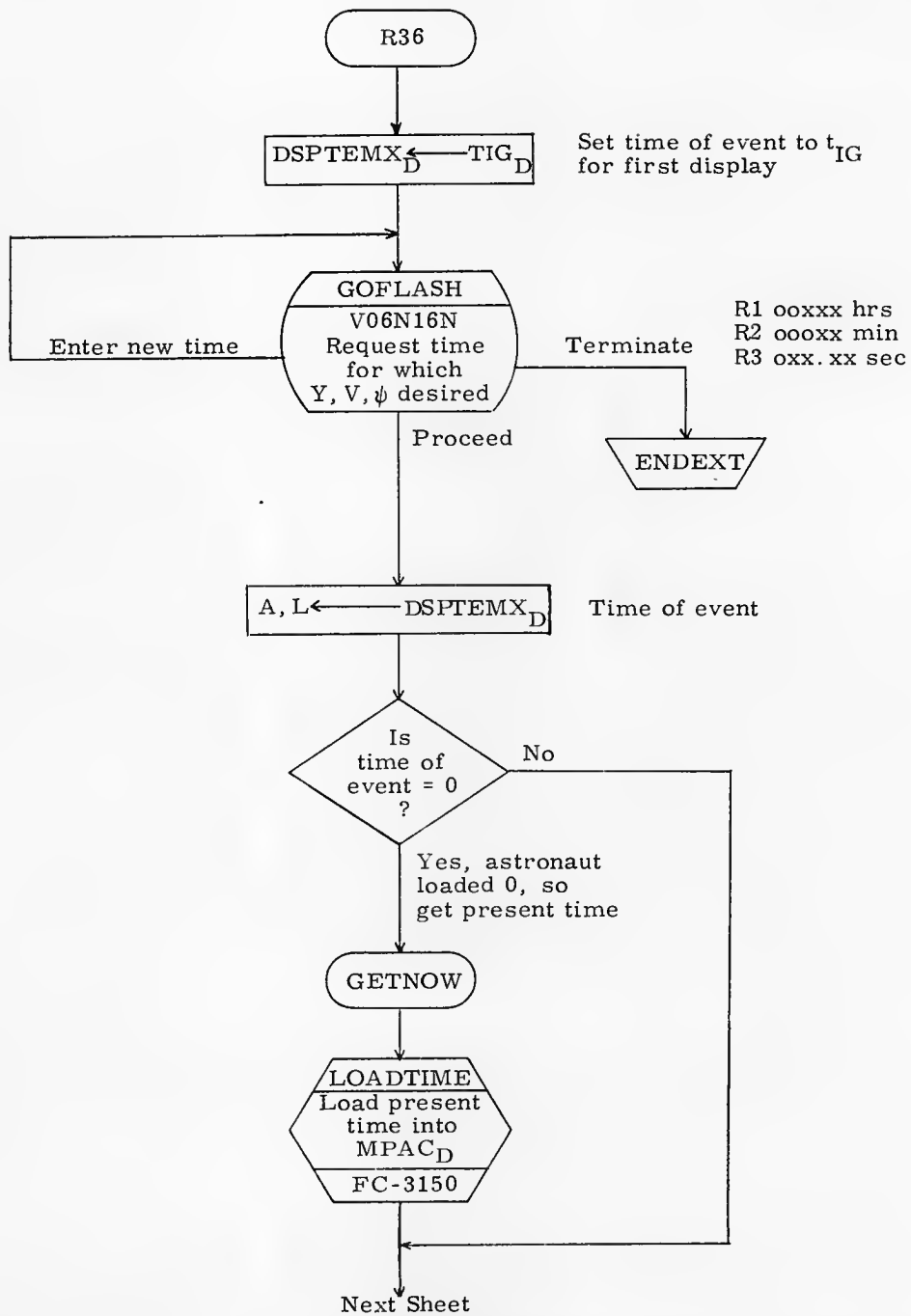
V90PERF Sh. 2

R36 Sh. 3

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>L. Duncan</i>	<i>12/4/69</i>	R36: RENDEZVOUS OUT- OF-PLANE DISPLAY	
PRGMR <i>J.E. Crocker</i>	<i>12/11/69</i>	LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3790
DOCMR <i>R.D.M. Easter</i>		REV 1	SHEET 1 OF 9
APPR'D <i>W. Dyer</i>	<i>12/14/69</i>		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
			R36: RENDEZVOUS OUT- OF-PLANE DISPLAY	
DRAWN	<i>P. Matto</i>	<i>6/1/70</i>	LUMINARY 1D	DOCUMENT NO.
PRGMR	<i>P. Matto</i>	<i>6/1/70</i>		FC-3790
ANALST			REV 1	SHEET 2 OF 9
DOCMR	<i>RME</i>	<i>6/1/70</i>		
APPR'D	<i>RME</i>	<i>6/1/70</i>		



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

From Preceding Sheet

R36INT

TDEC1_D ← MPAC_D

OTHPREC
Precision
update CSM
to TDEC1
FC-3350

OTHPREC = CSMPREC

RPASS36 ← RATT
OD ← unit (VATT)
UNP36 ← unit [V_P x unit (R_P)]
TDEC1 ← TAT

Store passive ve-
hicle parameters
from precision
integration

THISPREC
Precision
update LM
to TDEC1
FC-3350

THISPREC = LEMPREC

Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>L. Duncan</i>	<i>12/4/69</i>	R36: RENDEZVOUS OUT- OF-PLANE DISPLAY	
PRGMR <i>J. E. Cooper</i>	<i>12/11/69</i>	LUMINARY 1D	DOCUMENT NO. FC-3790
ANALST			
DOCMR <i>R.M. Ginter</i>			
APPR'D <i>W. D. Ginter</i>	<i>12/18/69</i>	REV 1	SHEET 4 OF 9

From Preceding Sheet

$$\begin{aligned} 02D &\leftarrow VATT_V \\ 00D &\leftarrow RATT_V \\ 06D &\leftarrow RATT_V \\ 12D &\leftarrow RATT_V \end{aligned}$$

$$\frac{LOS_V = r_p - r_a}{12D \leftarrow RPASS36 - RATT_V}$$

Line of sight vector

$$\frac{Y = u \cdot r_A}{RANGE \leftarrow (UNP36 \cdot MPAC) \times 2^{-1}}$$

Active vehicle distance from plane of passive vehicle (along passive Y-axis)

$$\frac{\dot{Y} = \underline{U} \cdot \underline{V}_a}{RRATE \leftarrow UNP36 \cdot 00D}$$

Out-of-plane component of active vehicle velocity

$$\begin{aligned} MPAC &\leftarrow \text{unit}(r_A) \\ 06D &\leftarrow \text{unit}(r_A) \end{aligned}$$

$$\frac{\underline{U}_A = \underline{U}_{rA} \times \underline{V}_A}{MPAC \leftarrow MPAC \times 00D}$$

Active vehicle momentum (plane) vector

$$\frac{\underline{U}_{AF} = (\underline{U}_{rA} \times \underline{V}_A) \times \underline{U}_{rA}}{MPAC \leftarrow \text{unit}(MPAC \times 18D)}$$

Active vehicle unit forward horizontal

Next Sheet

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

From Preceding Sheet

$$\begin{array}{l} 00D \leftarrow \text{MPAC} \\ \text{MPAC} \leftarrow 18D \end{array}$$

$$\frac{\underline{U}_{LI} = \underline{U}_{rA} \times (\underline{U}_L \cdot \underline{r}_A)}{\text{MPAC} \leftarrow 00D \times (12D \cdot 18D)}$$

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

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

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

$$\frac{\psi = \cos^{-1}(\underline{U}_{AF} \cdot \underline{U}_L)}{\text{RTHETA} \leftarrow \text{ARCCOS}(00D \cdot \text{MPAC})}$$

Psi

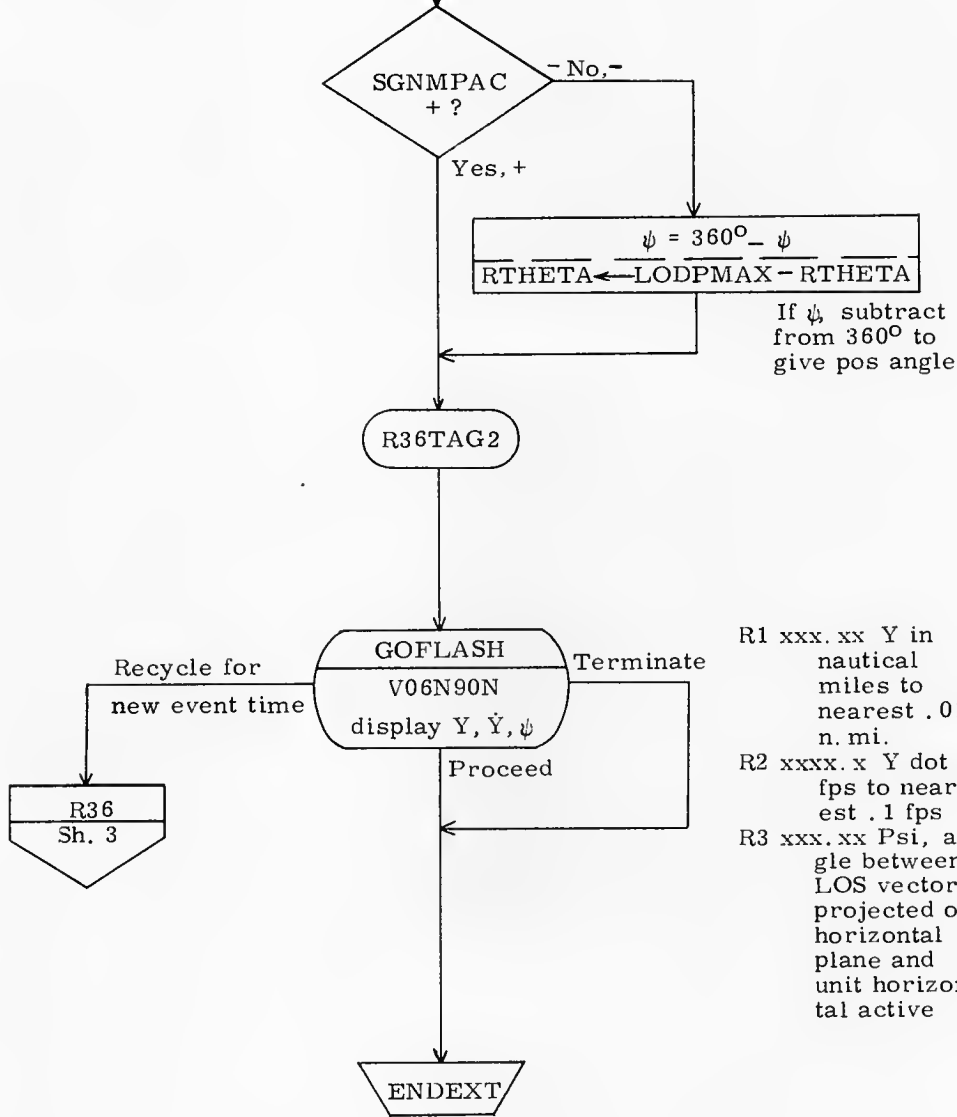
$$\frac{(\underline{U}_{AF} \times \underline{U}_{HL}) \cdot \underline{r}_A}{\text{MPAC} \leftarrow (00D \times \text{MPAC}) \cdot 06D}$$

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 <i>L. Duncan</i>	<i>12/4/69</i>	R36: RENDEZVOUS OUT- OF-PLANE DISPLAY	
PRGMR <i>J.E. Coker</i>	<i>12/11/69</i>	LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3790
DOCMR <i>R.M. Carter</i>		REV 1	SHEET 6 OF 9
APPR'D <i>W. Boylston</i>	<i>12/16/69</i>		

From Preceding Sheet



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>L. Duncan</i> 12/14/69			R36: RENDEZ VOUS OUT-OF-PLANE DISPLAY	
PRGMR <i>J.E. Parker</i> 12/11/69			LUMINARY 1D:	DOCUMENT NO.
ANALST				FC-3790
DOCMR <i>R.M. Estes</i>			REV 1	SHEET 7 OF 9
APPR'D <i>M. Bryant</i> 12/16/69				

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

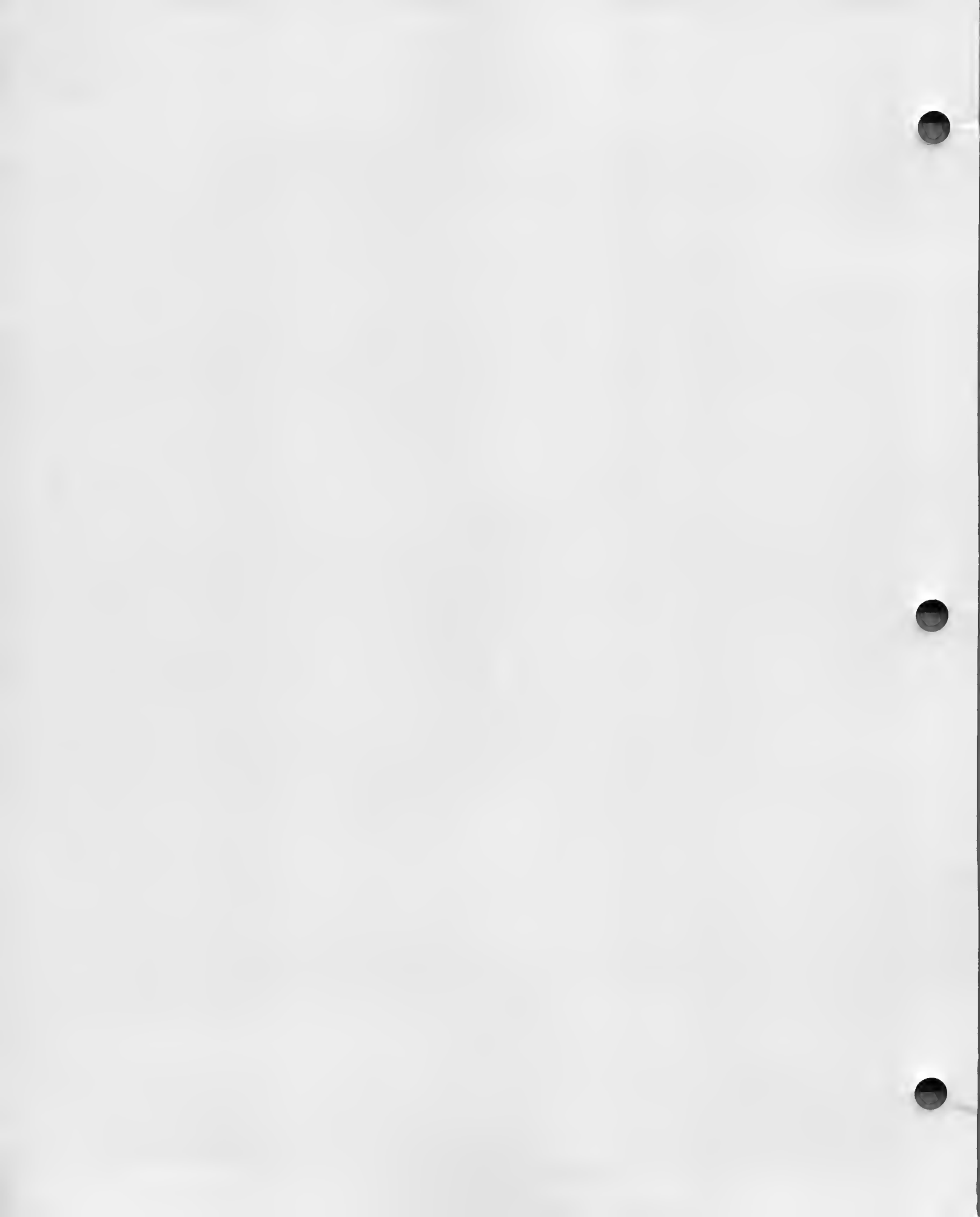
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>E. Thatta</i>	<i>6/1/70</i>	R36: RENDEZVOUS OUT- OF-PLANE DISPLAY	
PRGMR <i>P. P. White</i>	<i>6/1/70</i>		DOCUMENT NO. FC-3790
ANALST		LUMINARY 1D	
DOCMR <i>R. M. Estes</i>	<i>6/1/70</i>	REV 1	SHEET 8 OF 9
APPR'D <i>R.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

ERASABLES

		Units	Scaling
DSPTMX	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 for- ward horizontal & LOS projected into horizontal plane		

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>L. Dunagan</i> 12/4/69	R36: RENDEZVOUS OUT- OF-PLANE DISPLAY	
PRGMR	<i>J. E. Cocker</i> 12/11/69	LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3790
DOCMR	<i>R. M. E. [unclear]</i>	REV 1	SHEET 9 OF 9
APPR'D	<i>W. Griffith</i> 12/16/69		

12.0 THRUST PROGRAMS

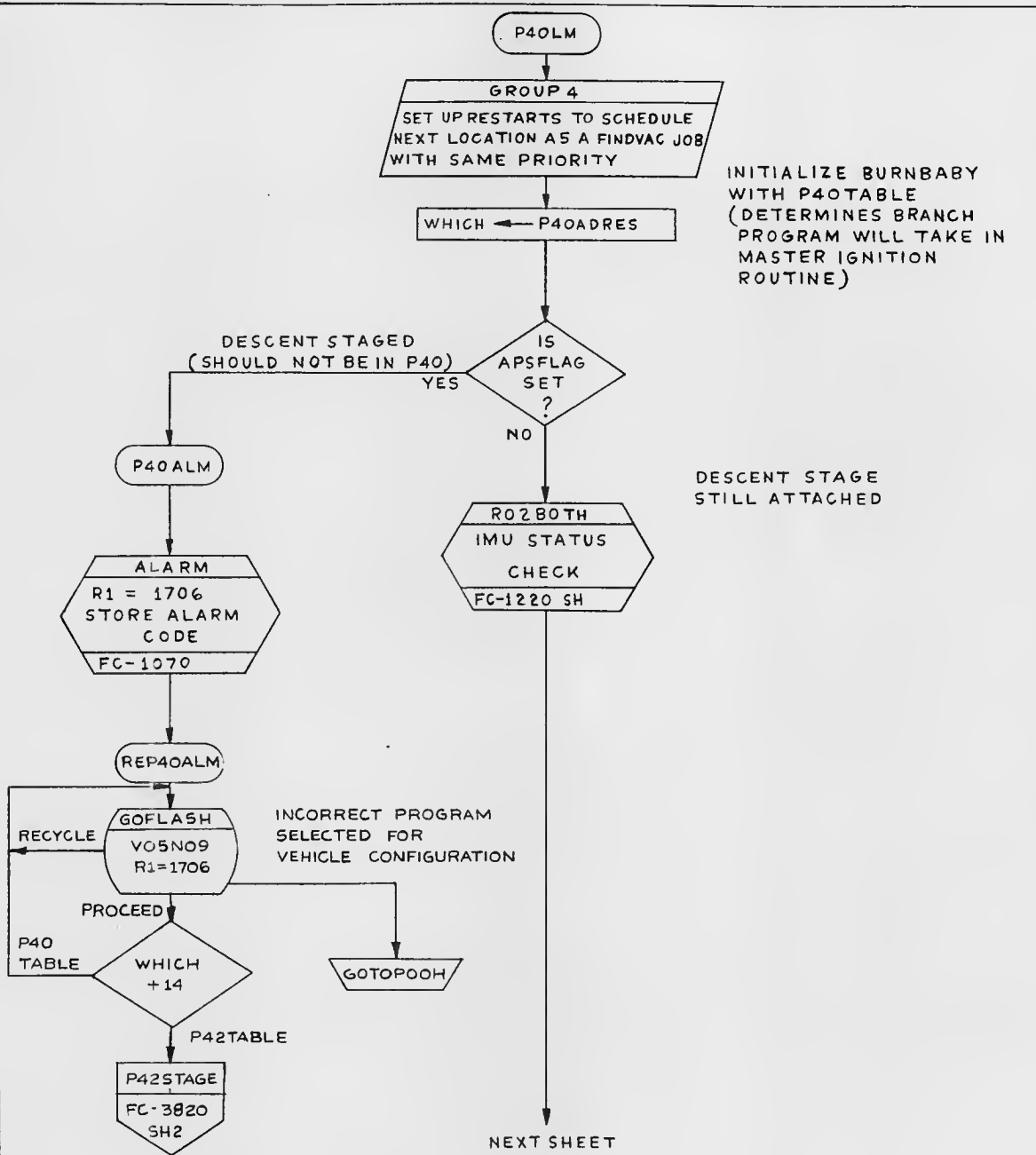


P40 DPS THRUST

MAJOR SUBROUTINES AND EXTERNAL ENTRY POINTS

P40LM	P40 DPS THRUST PROGRAM	SH. 2
P40SXT4	CALL ATTITUDE MANEUVER ROUTINE	SH. 4
S40.1	COMPUTE INITIAL THRUST DIRECTION AND VELOCITY TO BE GAINED	SH. 5
S40.2,3	COMPUTE PREFERRED IMU ORIENTATION	SH. 7

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i>		P40 DPS THRUST	
PRGRM <i>[Signature]</i>	EMAY65	LUMINARY ID	DOCUMENT NO. FC-3800
ANALST <i>[Signature]</i>	10/14/65		
DOCMR <i>[Signature]</i>	10/14/67	REV 2	SHEET 1 OF 9
APPR'D <i>[Signature]</i>	10/14/65		



INITIALIZE BURNBABY WITH P40TABLE (DETERMINES BRANCH PROGRAM WILL TAKE IN MASTER IGNITION ROUTINE)

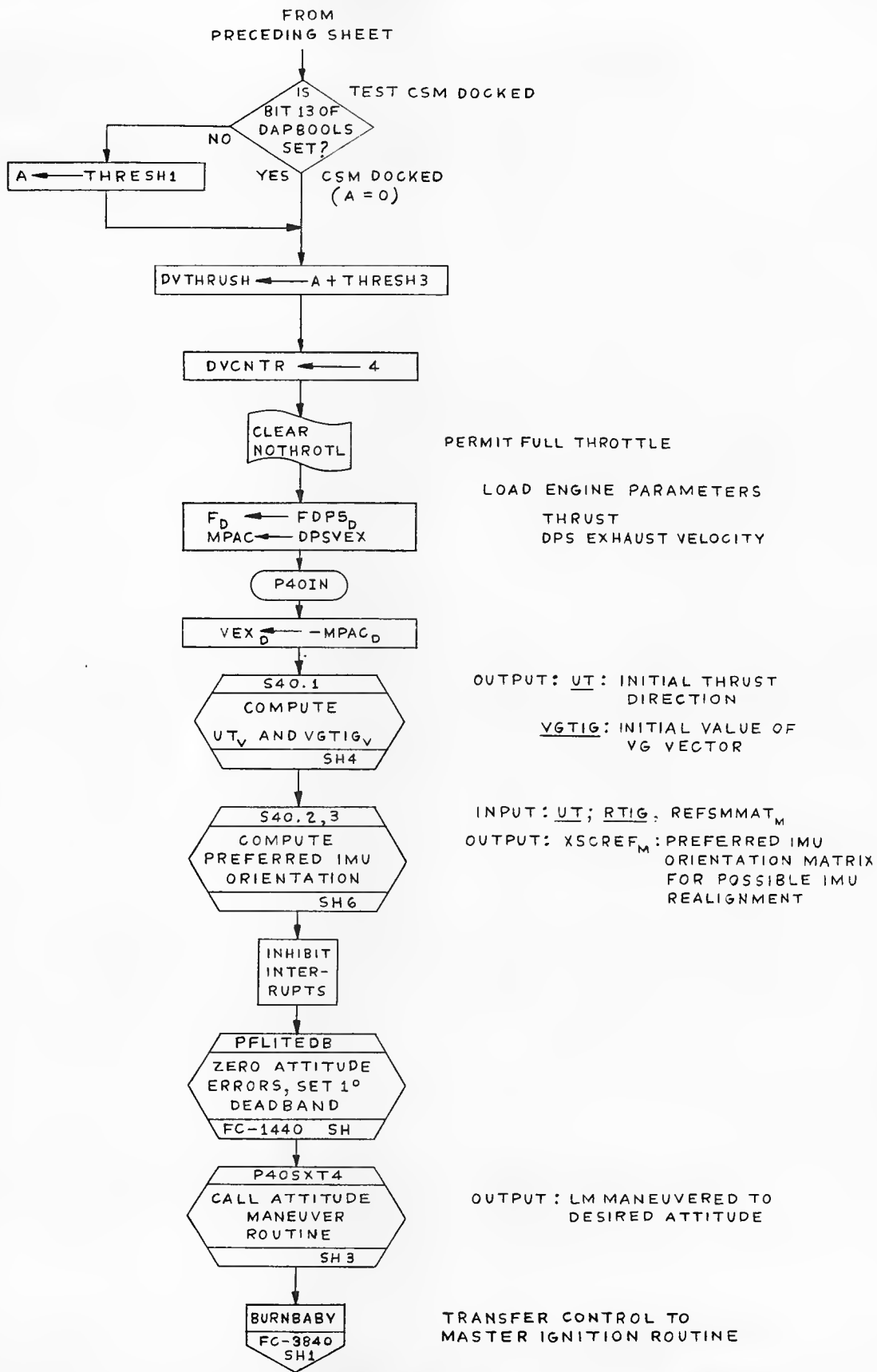
DESCENT STAGE STILL ATTACHED

TABLE USED BY MASTER IGNITION ROUTINE WHICH INDEX

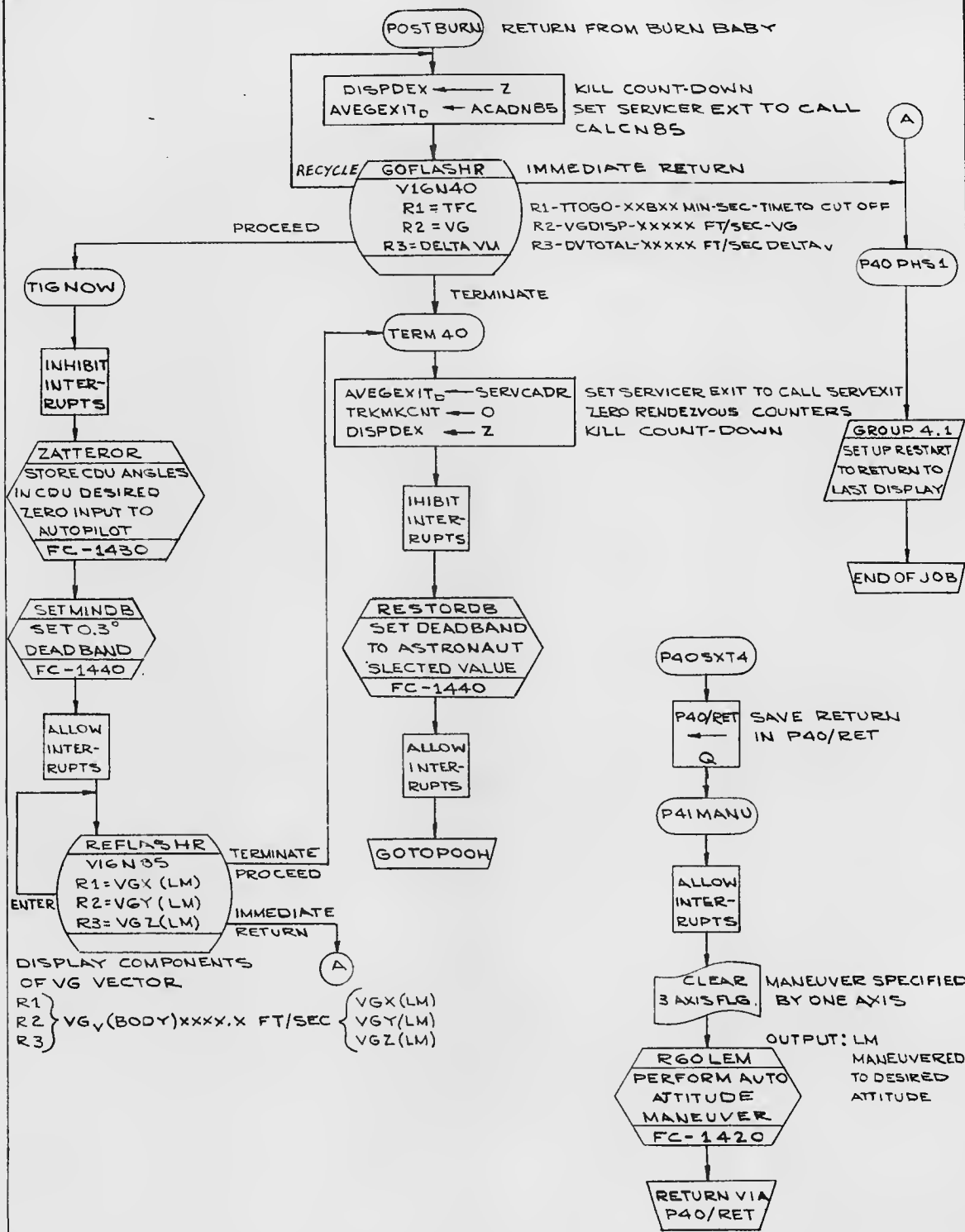
P40TABLE	VN	0640	(0)
	TCF	ULLGNOT	(1)
	TCF	COMFAIL4	(2)
	TCF	GOPOST	(3)
	TCF	TASKOVER	(4)
	TCF	P40SPOT	(5)
	DEC	2240	(6)
	2CADR	STEERING	(7)
	TCF	P40JUNK	(11)
	TCF	WAITABIT	(12)
	TCF	P40IGN	(13)
	TCF	REP40ALM	(14)

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>C. J. Langille</i>		P40 DPS THRUST	
PROGRAM <i>John A. Moore</i>		LUMINARY ID	
ANALYST <i>John A. Moore</i>		DOCUMENT NO. FC-3800	
DOCKED <i>John A. Moore</i>		REV 3	
APPR'D <i>John A. Moore</i>		SHEET 2 OF 9	

16 May 69



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. J. Langille</i> 29 OCT 68		P40 DPS THRUST	
PROGRAM <i>A. J. Langille</i> 31 Oct 68	APPROVED <i>A. J. Langille</i> 10 Nov 68	LUMINARY ID	DOCUMENT NO.
DOCWR <i>A. J. Langille</i> 31 OCT 68	APPR'D <i>John A. Moore</i> 24 Jan 69	REV 3	FC-3800
		SHEET 3 OF 9	



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P40 DPS THRUST	
DRAWN <i>W.D. King</i>	7-26-68	LUMINARY.1D	DOCUMENT NO. FC-3800
PROWR <i>A. Colby</i>	8-26-68		
ANALST <i>P. Phillip</i>	10-16-68		
DOCWR <i>W.C. [unclear]</i>	11-5-68		
APPR'D <i>John A. [unclear]</i>	14-11-68	REV 3	SHEET 4 OF 9

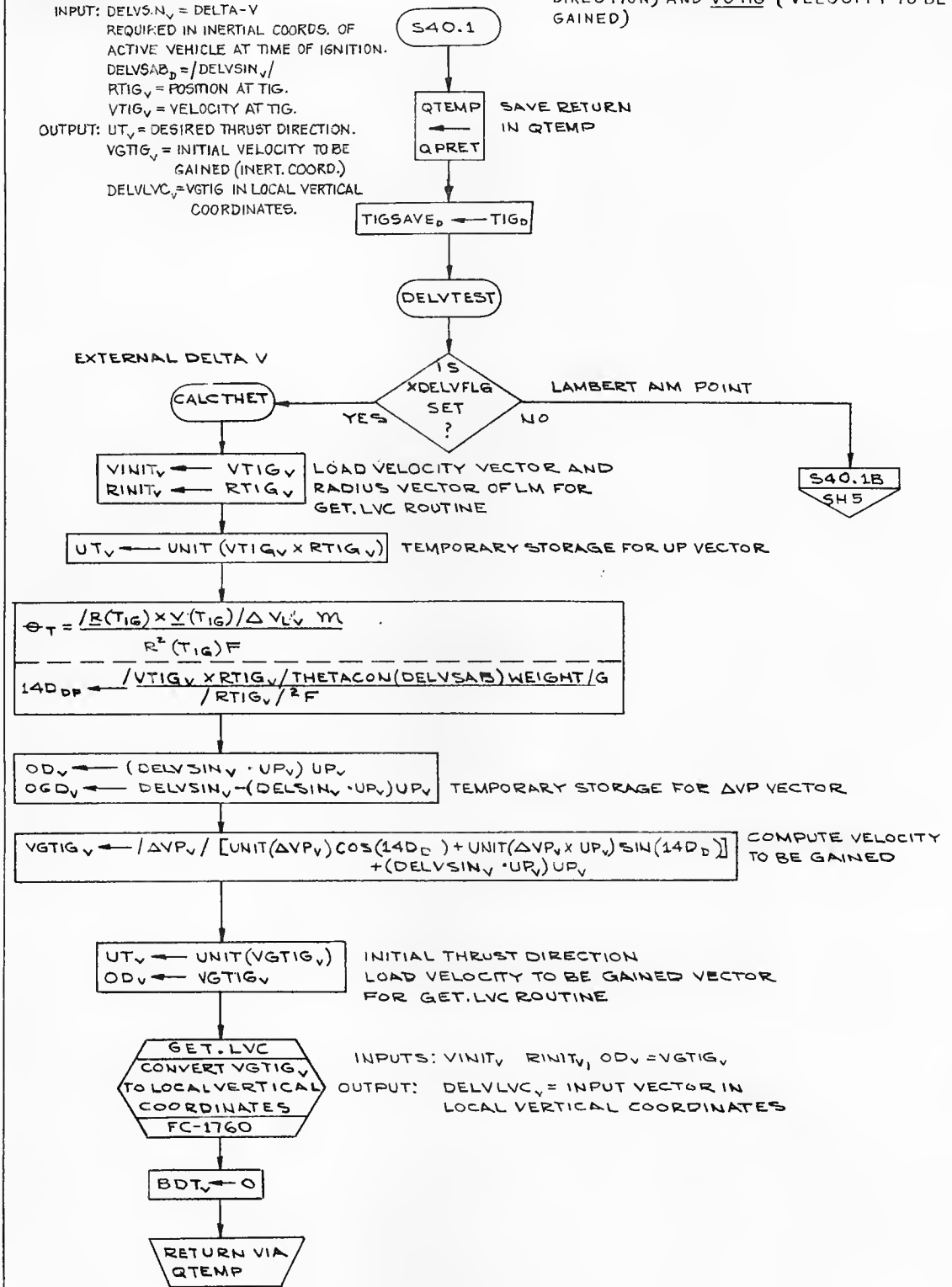
16 May 69

IF DELTA-V MANEUVER

INPUT: DELVS.N_v = DELTA-V
 REQUIRED IN INERTIAL COORDS. OF
 ACTIVE VEHICLE AT TIME OF IGNITION.
 DELVSA_b = /DELVSIN_v/
 RTIG_v = POSMON AT TIG.
 VTIG_v = VELOCITY AT TIG.

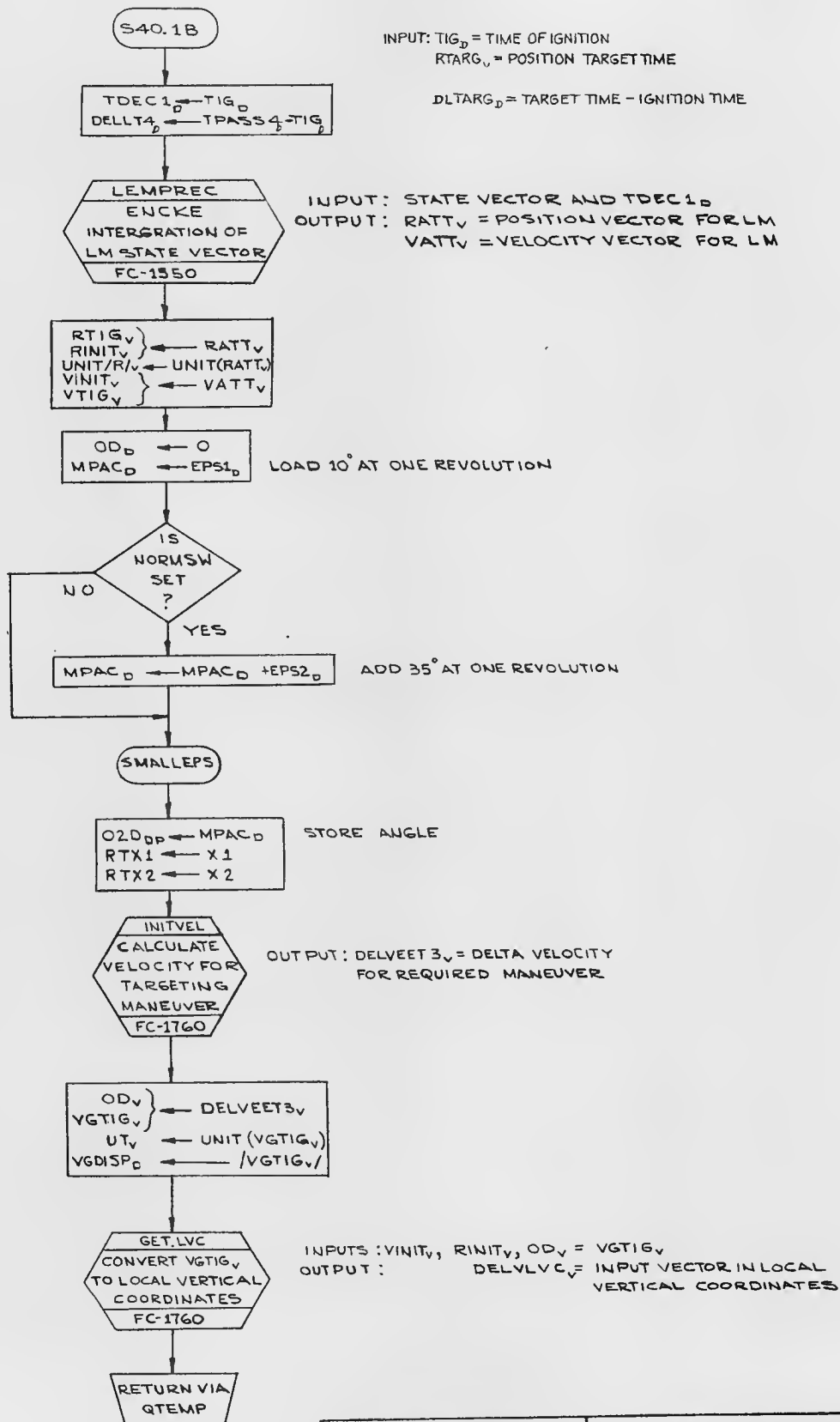
OUTPUT: UT_v = DESIRED THRUST DIRECTION.
 VGTIG_v = INITIAL VELOCITY TO BE
 GAINED (INERT. COORD.)
 DELVLVC_v = VGTIG_v IN LOCAL VERTICAL
 COORDINATES.

COMPUTE INITIAL VALUE OF UT (THRUST
 DIRECTION) AND VGTIG (VELOCITY TO BE
 GAINED)



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P40 DPS THRUST	
DRAWN <i>W. J. ...</i>	7-29-68	LUMINARY ID	DOCUMENT NO.
PROGR <i>P. ...</i>	8-26-68		FC-3800
ANALST <i>P. ...</i>	10 Jan 69		
DOCMR <i>M. C. ...</i>	8-5-68		
APPR'D <i>John ...</i>	16 May 69	REV 3	SHEET 5 OF 9

LAMBERT AIMPOINT MANEUVER

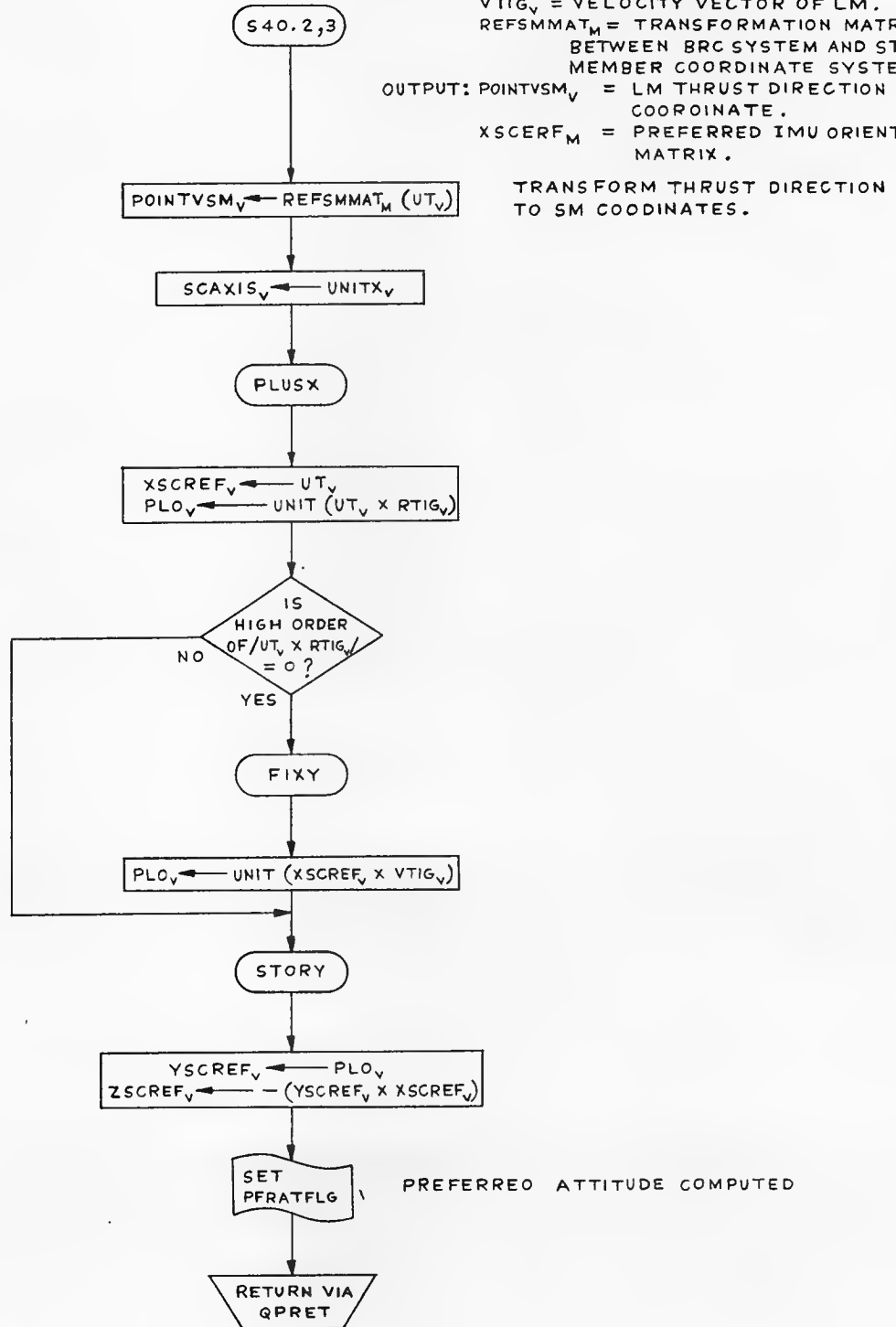


RIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P40 DPS THRUST	
DRAWN <i>[Signature]</i> PROWR <i>[Signature]</i> ANALST <i>[Signature]</i> DOCWR <i>[Signature]</i> APPR'D <i>[Signature]</i>	7-29-68 8-26-68 10/26/68 8-5-68 28 JAN 69	LUMINARY 1 D REV 3	DOCUMENT NO. FC-3800 SHEET 6 OF 9

16 May 69

COMPUTE PREFERRED 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.
 $REFSMAT_M$ = TRANSFORMATION MATRIX
 BETWEEN BRC SYSTEM AND STABLE
 MEMBER COORDINATE SYSTEM.
 OUTPUT: $POINTVSM_V$ = LM THRUST DIRECTION IN SM
 COORDINATE.
 $XSCREF_M$ = PREFERRED IMU ORIENTATION
 MATRIX.



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. J. Longella</i>		P40 DPS THRUST	
PROGRM <i>[Signature]</i>		LUMINARY ID	
ANALYST <i>[Signature]</i>		DOCUMENT NO. FC-3800	
DOCMR <i>[Signature]</i>		REV 3	
APPR'D <i>[Signature]</i>		SHEET 7 OF 9	

SUBROUTINES

IN THIS CHART

P40 SXT4

S40.1

S40.2,3

CALL ATTITUDE MANEUVER ROUTINE

COMPUTE INITIAL THRUST DIRECTION AND VELOCITY TO BE GAINED

COMPUTE PREFERRED IMU ORIENTATION

ON OTHER CHARTS

R02 BOTH

ALARM

PFLITE DB

ZATTEROR

SET MINDB

RESTORDB

R60LEM

GET. LVC

LEMPREC

INITVEL

IMU STATUS CHECK

STORE ALARM CODE

ZERO ATTITUDE ERRORS, SET 1° DEADBAND

STORE CDU DESIRED, ZERO INPUT TO AUTOPILOT

SET 0.3° DEADBAND

SET DEADBAND TO ASTRONAUT SELECTED VALUE

PERFORM AUTO ATTITUDE MANEUVER

CONVERT INPUT VECTOR TO LOCAL VERTICAL COORDINATES

ENCKE INTEGRATION OF LM STATE VECTOR

CALCULATE VELOCITY FOR TARGETING MANEUVER

FLAGS	MEANING	SET	CLEARED	TESTED
NOTHROTL	SET - INHIBIT 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 DELTA V G 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 - T TO GO - XXBXX MIN-SEC-TIME TO CUTOFF R2 - VG DISP - XXXX.X FT/SEC-VELOCITY TO BE GAINED R3 - DV TOTAL - XXXX.X FT/SEC-TOTAL DELTA V	SH 4
V16N85	R1 } R2 } VG _V (BODY) XXXX.X FT/SEC { VGX(LM) R3 } { VGY(LM) } COMPONENTS OF { VGZ(LM) } 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
VG TIG _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 } LM ORIENTATION IN } REFERENCE COORDINATES	UNIT VECTOR	2 ¹
YSCREF _V		UNIT VECTOR	2 ¹
ZSCREF _V		UNIT VECTOR	2 ¹
F _D	ENGINE THRUST	M-NEWTONS	2 ⁷
TDECAY _D	ATTAIL-OFF TIME TIME OF ENGINE	CSEC	2 ²⁸

* M-NEWTONS = 10⁴ NEWTONS

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P40 DPS THRUST	
DRAWN	W.D. EDGENT	7-24-68	LUMINARY ID
PROWR	J. Kelly	8-26-68	
ANALST	W. C. ...	10/2/68	DOCUMENT NO. FC-3800
DOCTR	W. C. ...	9-5-68	
APPR'D	Jim A. ...	24 Nov 68	REV 3
			SHEET 8 OF 9

FIXED CONSTANTS	MEANING	PHYSICAL VALUE F UNITS	STORED VALUE F UNITS	SCALING
FDPSE	DPS ENGINE THRUST	9712.5 POUNDS	4.319223105 M-NEWTONS*	27
THETA CON _D	$\frac{1}{\pi}$ CONVERSION FACTOR	$\frac{1}{\pi}$ $\frac{1}{\text{RAD}}$.31830989 $\frac{1}{\text{RAD}}$	28
TDECAY _D	DPS ENGINE AT TAIL-OFF TIME	0.08 SEC	-8 CSEC	228

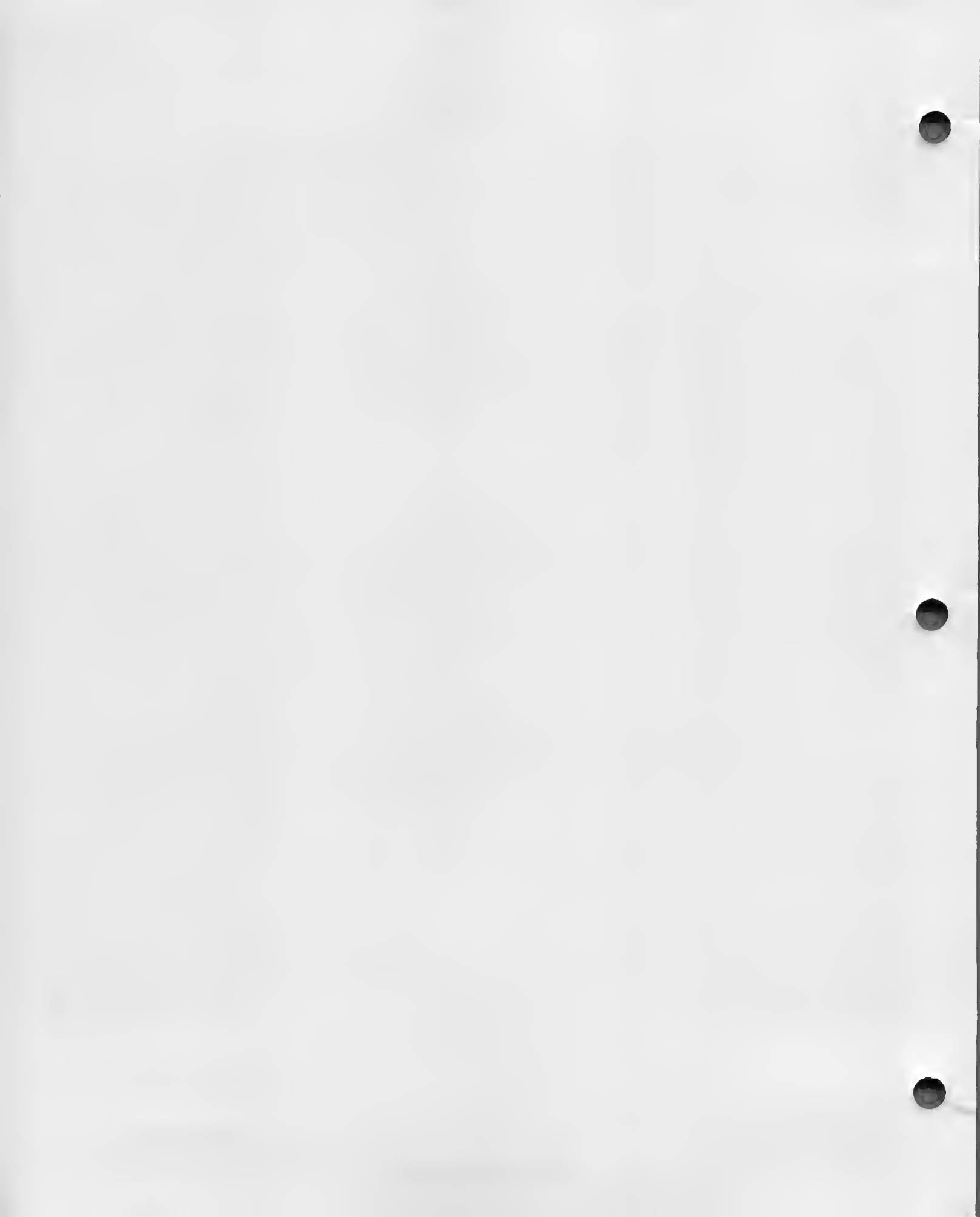
*M-NEWTONS = 10⁴ NEWTONS

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	
		P40 DPS THRUST	
DRAWN	<i>W.D. Knight</i>	8-5-68	LUMINARY ID
PROGR	<i>P. Sullivan</i>	8-26-68	
ANALST	<i>P. Sullivan</i>	8-26-68	DOCUMENT NO. FC-3800
DOGRM	<i>W.C. Knight</i>	8-5-68	
APPR'D	<i>John A. Thomas</i>	24 MAY 69	REV 3
			SHEET 9 OF 9

16 May 69

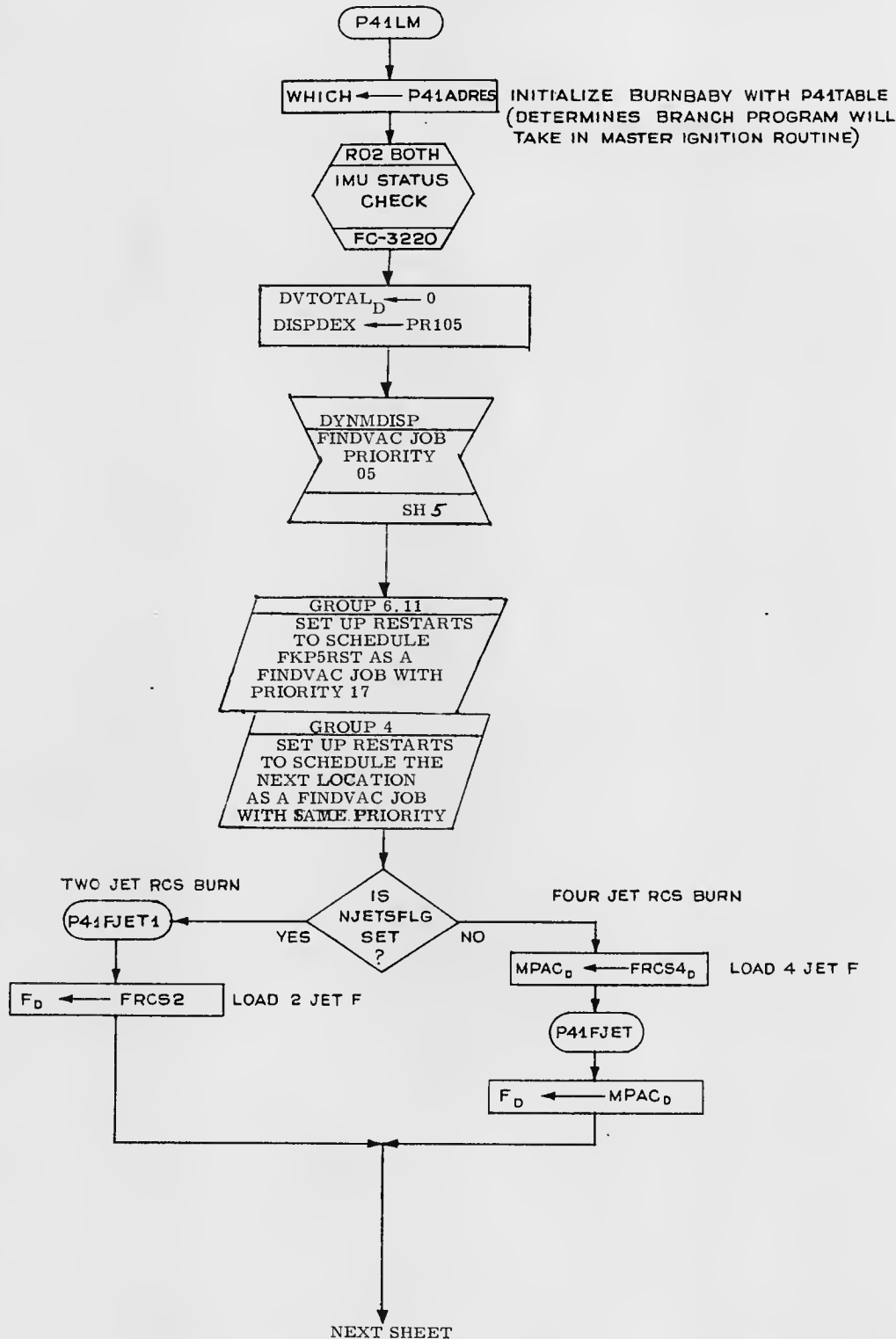


P41 RCS THRUST

MAJOR SUBROUTINES ON THIS CHART

P41LM	P41 RCS THRUST PROGRAM	SH2
CALCN85	CALL VG CALCULATION	SH6
S41.1	TRANSFORM VECTOR FROM REF. COORD TO BODY AXIS	SH6
UPDATEVG	UPDATE VG CALCULATION	SH6

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P41 RCS THRUST	
DRAWN <i>W. M. Dietrich</i>	BY <i>ROMAYGE</i>	LUMINARY ID	DOCUMENT NO.
PROGR <i>W. M. Dietrich</i>	<i>17 JUNE 69</i>		FC-3810
ANALYST			
DOCMR <i>W. M. Dietrich</i>	<i>17 JUNE 69</i>		
APPR'D <i>W. M. Dietrich</i>	<i>17 JUNE 69</i>	REV 2.	SHEET 1 OF 15



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>E. Motta</i> 6/2/70		P41 RCS THRUST	
PRGMR <i>P. Allen</i> 6/5/70		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3810
DOCMR <i>R. D. Smith</i> 6/5/70		REV 2	SHEET 2 OF 15
APPR'D <i>R. W. Euter</i> 6/16/70			

FROM PRECEDING SHEET

P41IN

S40.1

COMPUTE
UT_v AND VGTIG_v
FC-3800SH5

OUTPUT : UT : INITIAL THRUST DIRECTION
VGTIG : INITIAL VELOCITY TO BE GAINED

TABLE USED BY MASTER WHICH
IGNITION ROUTINE INDEX

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

P41NORM

S40.2,3
COMPUTE
PREFERRED IMU
ORIENTATION
FC-3800SH7

INPUT : UT, RTIG, REFSMMAT_M

OUTPUT : XSCREF_M : PREFERRED IMU ORIENTATION
MATRIX FOR POSSIBLE IMU REALIGNMENT.
POINTVSM_v : LM THRUST DIRECTION IN SM
COORDINATES.

INHIBIT
INTER-
RUPTS

ZATTEROR
STORE CDU ANGLES
IN CDU DESIRED, ZERO INPUT
TO AUTOPILOT
FC-3430SH10

SETMINDB

SET 0.3°
DEAD BAND
FC-3440

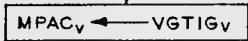
NEXT SHEET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>P. M. Dietrich</i>	80JUL68	P41 RCS THRUST	
PROGR <i>Galley</i>	8-16-68		
ANALST <i>P. Hillen</i>	10 Jan 69	LUMINARY 1D	DOCUMENT NO. FC-3810
DOORR <i>W. C. Dugan</i>	26 Apr 69	REV 2	SHEET 3 OF 15
APPR <i>John A. Moore</i>	24 JUN 68		

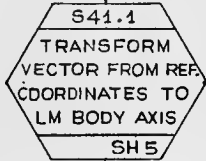
FROM PRECEDING SHEET



OUTPUT: LM MANEUVERED TO DESIRED ATTITUDE

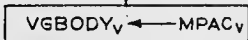


LOAD VECTOR FOR S41.1 ROUTINE

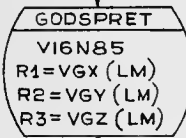


INPUT: MPAC_V; INPUT VECTOR, REFSMMAT_M

OUTPUT: MPAC_V = TRANSFORMED VECTOR IN LM BODY AXIS COORDINATES

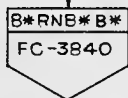
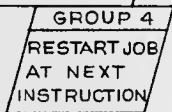
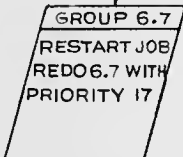


STORE VG VECTOR FOR DISPLAY



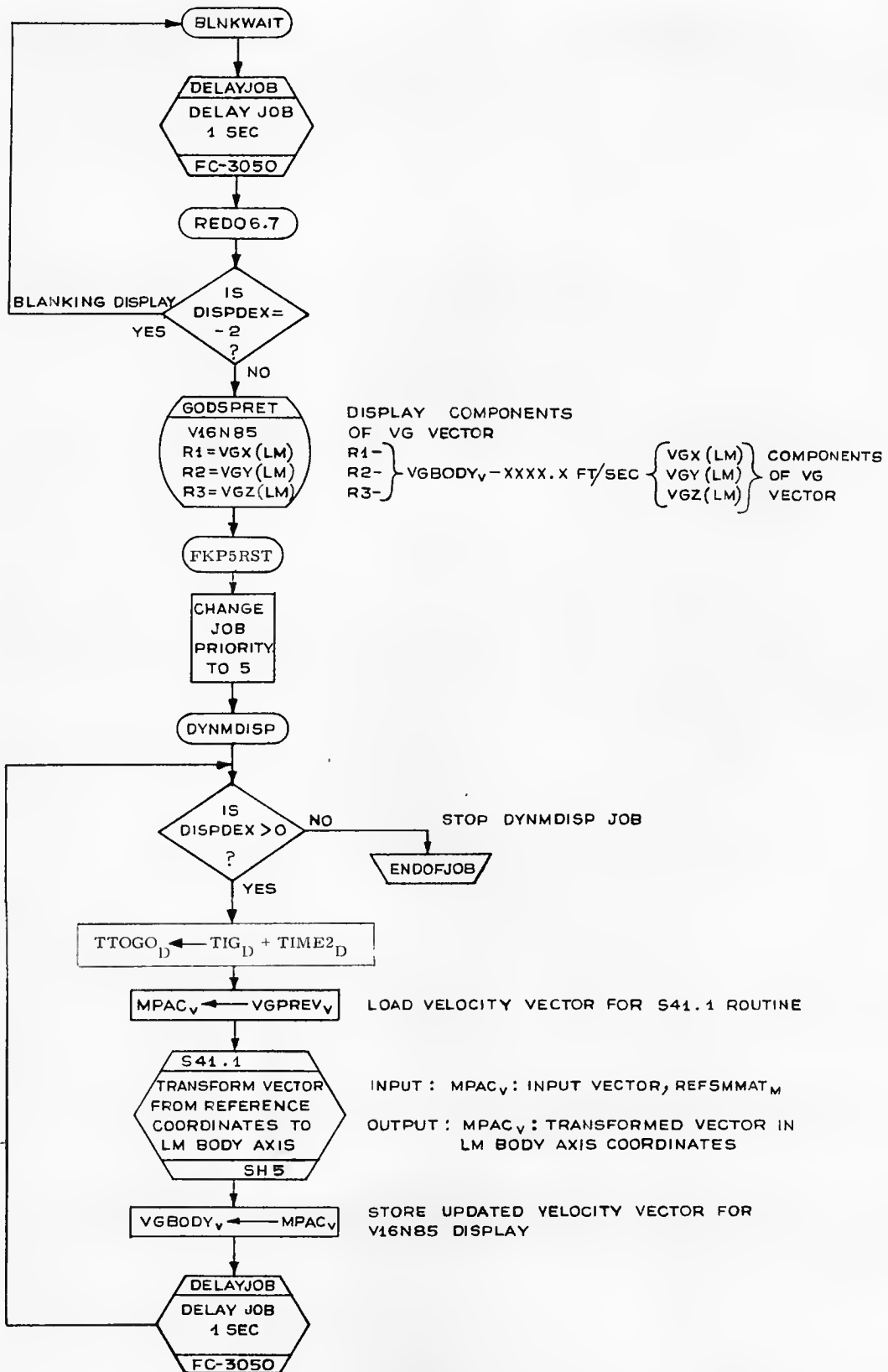
DISPLAY COMPONENTS OF VG VECTOR

R1 - } VGBODY_V - XXXX.X FT/SEC { VGX(LM) COMPONENTS
 R2 - } { VGY(LM) OF VG
 R3 - } { VGZ(LM) VECTOR



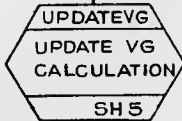
TRANSFER CONTROL TO MASTER IGNITION ROUTINE

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P 41 RCS THRUST	
DRAWN <i>P. M. Dietrich</i>	30JUL68	LUMINARY ID	DOCUMENT NO. FC-3810
PROGR <i>P. Fuller</i>	8-26-68		
ANALST <i>P. Fuller</i>	10JAN-69	SHEET 4 OF 15	
DOCNR <i>mc [signature]</i>	26AUG 68		
APPR'D <i>John A. More</i>	24 JAN 69	REV 2	

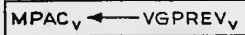


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P 41 RCS THRUST	
DRAWN <i>P.M. Dietrich</i>	BOJUL68	LUMINARY ID	DOCUMENT NO. FC-3810
PROGRAM <i>P. Phillips</i>	26A468		
ANALYST <i>P. Phillips</i>	26A468		
DOCNR <i>77C-3810</i>	26A468		
APPR'D <i>John A. Moore</i>	26A468	REV 2	SHEET 5 OF 15

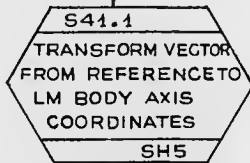
CALGN85



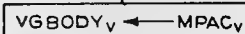
INPUT : LM STATE VECTOR, CDU ANGLES, VGPREV_v,
DELVREF_v, BDT_v, TPASS 4
OUTPUT: VGPREV_v, VGDISP_v, TGO_D, CDUY_D



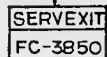
LOAD VELOCITY VECTOR FOR S41.1 ROUTINE



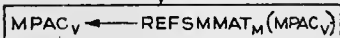
INPUT : MPAC_v : INPUT VECTOR, REFSMMAT_M
OUTPUT : MPAC_v : TRANSFORMED VECTOR IN
LM BODY AXIS COORDINATES



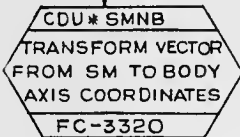
STORE VECTOR FOR DISPLAY



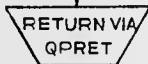
S41.1



TRANSFORM INPUT VECTOR FROM REFERENCE TO SM COORDINATES



INPUT : MPAC_v : INPUT VECTOR
OUTPUT : MPAC_v : TRANSFORMED VECTOR IN LM BODY
AXIS COORDINATES

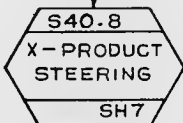


UPDATE VELOCITY PARAMETERS
INPUT : LM STATE VECTOR, CDU ANGLES
VGPREV_v : PRESENT VALUE OF VELOCITY
TO BE GAINED
DELVREF_v : ACCUM. ΔV OVER LAST 2 SEC
BDT_v : INCREMENTAL CHANGE OF VELOCITY
TPASS4_D : DESIRED INTERCEPT TIME
OUTPUT: VGPREV_v : UPDATED VELOCITY VECTOR
TGO_D, CDUY_D, VGDISP_D

UPOATE VG

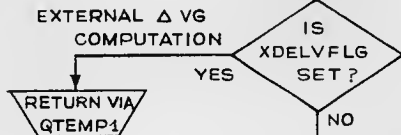


SAVE RETURN
IN QTEMP 1



INPUTS : VGPREV_v, DELVREF_v, BDT_v, CDU ANGLES
OUTPUT: VGPREV_v : UPDATED VELOCITY VECTOR
TGO_D : TIME LEFT TO BURN
CDUY_D : DESIRED Y AND Z CDU ANGLES
FOR STEERING COMMANDS

S40RET



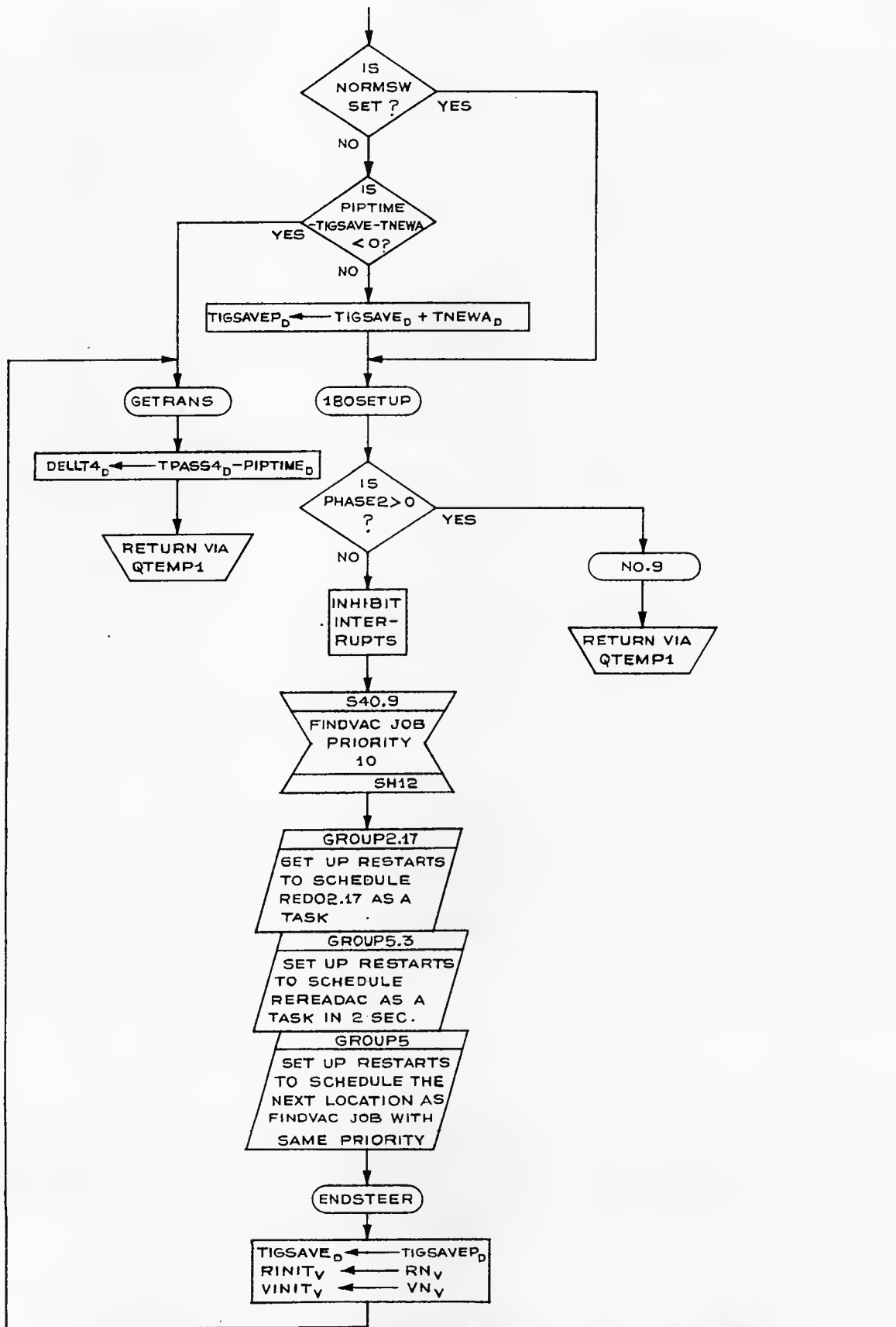
EXTERNAL Δ VG
COMPUTATION
YES



NO
LAMBERT (AIMPOINT) VG COMPUTATION
NEXT SHEET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P41 RCS THRUST	
DRAWN <i>P.M. Dutton</i>	SIJULES	LUMINARY ID	DOCUMENT NO. FC-3810
PRGRM <i>P. Collins</i>	26 AUG 68		
ANALST <i>P. Phillips</i>	10 20 68	REV 2	SHEET 6 OF 15
DOCNR <i>W.C. 26011</i>	26 AUG 68		
APPR'D <i>John A. Moore</i>	24 JAN 69		

FROM PRECEDING SHEET



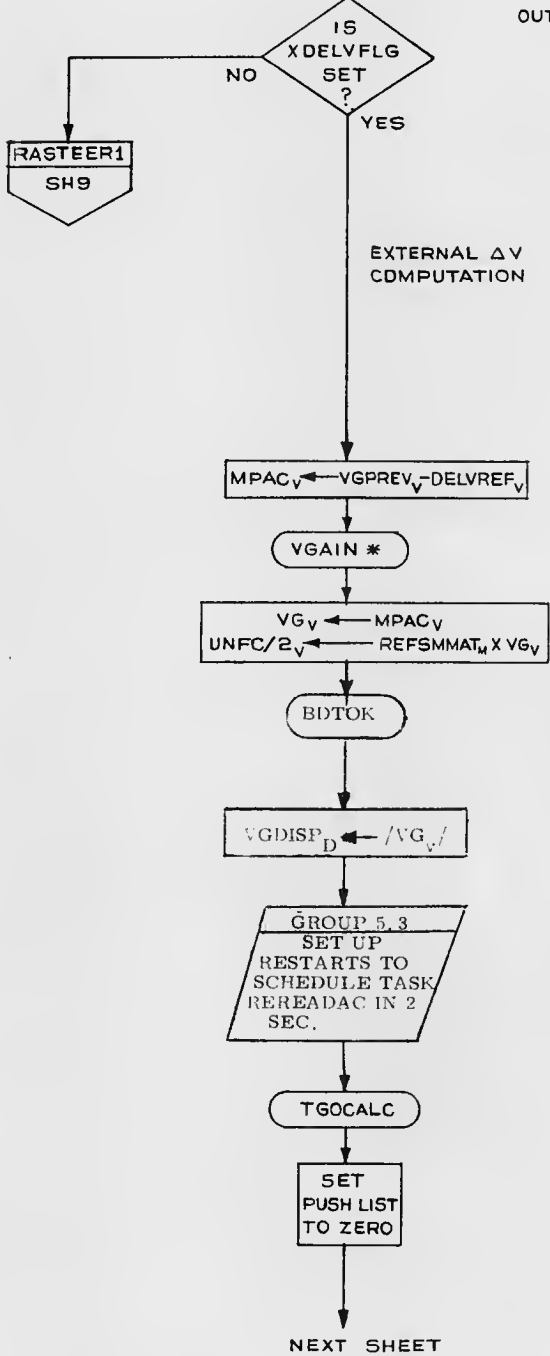
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN: <i>P.M. DiDazio</i>		P41 RCS THRUST	
PROGRAM: <i>DiDazio</i>	DATE: <i>7 June 67</i>	LUMINARY ID	DOCUMENT NO.
ANALYST: <i>McQuinn</i>	DATE: <i>19 June 67</i>		FC-3810
DOCNO: <i>FC-3810</i>	REV: <i>2</i>		SHEET 7 OF 15

S40.8

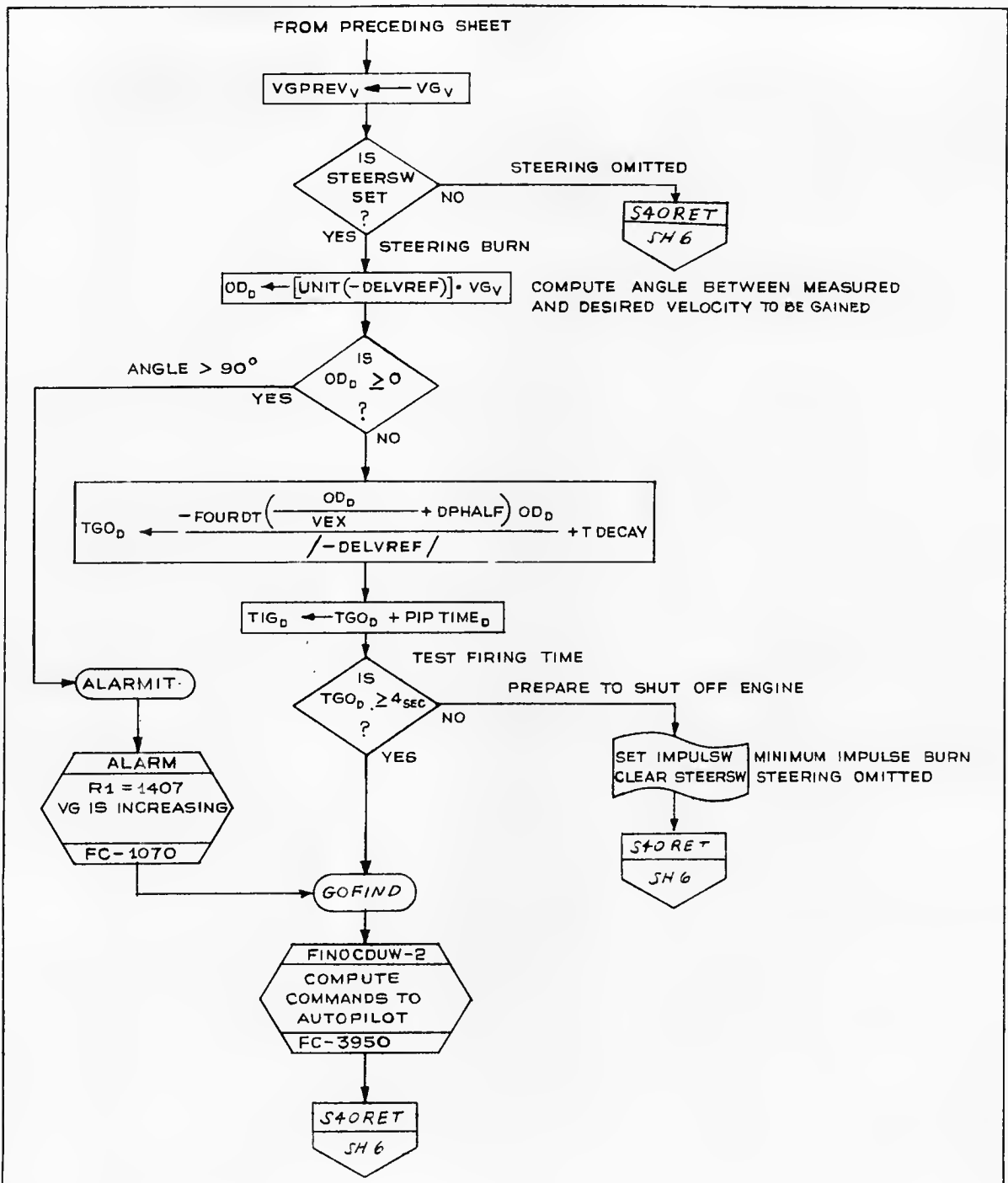
X-PRODUCT STEERING

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	
		P41 RCS THRUST	
DRAWN <i>P. M. Dietrich</i>	31 JUL 68	LUMINARY 1D	DOCUMENT NO. FC-3810
PRGWR <i>P. M. Dietrich</i>	8-26-68		
ANALST <i>P. Phyllis</i>	10 Jan 69	REV 2	SHEET 8 OF 15
DOCWR <i>P. Phyllis</i>	26 APR 68		
APPR'D <i>John A. Morse</i>	24 JAN 69		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P41 RCS THRUST	
DRAWN <i>P. M. ...</i>	1 AUG 68	LUMINARY ID	DOCUMENT NO. FC-3810
PRGWR <i>D. ...</i>	8-26-68		
ANALST <i>D. ...</i>	10/26/69	REV 2	SHEET 9 OF 15
DOCWR <i>FC ...</i>	26 AUG 69		
APPR'D <i>John A. Moore</i>	APRIL 69		

RASTEER1

$$r_1 = /r(t_1)/$$
$$RMAG_D \leftarrow /RN_V/$$

$$u_c = \text{UNIT} [r(t_2) - r(t_1)]$$
$$IC_V \leftarrow \text{UNIT} (RTARG_V - RN_V)$$

$$c = /r(t_2) - r(t_1)/$$
$$PL30_D \leftarrow /RTARG_V - RN_V/$$

$$R1C_D \leftarrow RMAG_D (PL30_D) \quad r_1 C$$

$$s = (r_1 + r_2 + c) / 2$$
$$SS_D \leftarrow (RMAG_D + RTMAG_D + PL30_D) / 2$$

$$A = \left\{ \frac{2(s-r_1)}{r_1 c} \left[u - \frac{u(s-c)}{2a} \right] \right\}^{1/2} \text{SGNA}$$
$$PL32_D \leftarrow \left\{ \frac{(SS_D - RMAG_D)}{R1C_D} \left[\text{MUASTEER}_D - \text{MU}/A_D (SS_D - PL30_D) \right] \right\}^{1/2} \text{SGN}(\text{GEOMSGN})$$

$$B = \left[\frac{2(s-r_2)}{r_1 c} \left(u - \frac{us}{2a} \right) \right]^{1/2}$$
$$PLO_D \leftarrow \left\{ \frac{SS_D - RTMAG_D}{R1C_D} \left[\text{MUASTEER}_D - \text{MU}/A_D (SS_D) \right] \right\}^{1/2}$$

$$t_{\pi} = \left(\frac{s^3}{2L} \right)^{1/2} \left\{ \frac{\pi}{2} - \text{SGNA} \left[\sin^{-1} \left(\frac{s-c}{s} \right)^{1/2} - \left(\frac{s-c}{s} \right)^{1/2} \left(\frac{c}{s} \right)^{1/2} \right] \right\}$$
$$\text{MPAC}_D \leftarrow \frac{SS_D (SS_D)^{1/2}}{(\text{MUASTEER})^{1/2}} \left\{ 2\pi + 3_D - \text{SGN}(\text{GEOMSGN}) \left[\sin^{-1} \left(\frac{SS_D - PL30_D}{SS_D} \right)^{1/2} 2\pi + 3_D - \left(\frac{PL30_D}{SS_D} \right)^{1/2} \left(\frac{SS_D - PL30_D}{SS_D} \right)^{1/2} \right] \right\}$$

COMPUTE SGNB
SGNB = 1 IF TM ≥ TRANSFER TIME
SGNB = -1 IF TM < TRANSFER TIME

$$PL30_D \leftarrow \text{MPAC}_D - \text{TPASS}_D + \text{PIPTIME}_D$$

$$B' = B (\text{SGNB})$$
$$PL30_D \leftarrow PLO_D (\text{SGN}) PL30_D$$

IS
NORMSW
SET

YES

NO

180MESS
SH11

NEXT SHEET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>W. D. ...</i> 2 JUNE 65		P41 RCS THRUST	
PROGR <i>H. Adles</i>	<i>7/1/65</i>	LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3810
DOCMR <i>MC ...</i>	<i>17 JUNE 65</i>	REV 2	SHEET 10 OF 15
APPR'D <i>Allen W. Smart</i>	<i>7/1/65</i>		

FROM PRECEDING SHEET

$$PLO_V \leftarrow UNIT(IC_V - UNIT/R/V) PL30_D$$

$$B'UNIT(\underline{U}_C - \underline{U}_R) = B'(\underline{U}_{C-R})$$

$$MPAC_V \leftarrow UNIT(IC_V + UNIT/R/V)$$

$$UNIT(\underline{U}_C + \underline{U}_R) = (\underline{U}_{C+R})$$

GETVRVG1

$$MPAC_V \leftarrow MPAC_V(PL32_D) + PLO_V$$

$$A'(\underline{U}_{C+R}) + B'(\underline{U}_{C-R})$$

GETVRVG2

$$\underline{V}_R(t) = A'(\underline{U}_{C+R}) + B'(\underline{U}_{C-R})$$

$$VIPRIME_V \leftarrow MPAC_V$$

ASTREND

$$DELVEET3_V \leftarrow VIPRIME_V - VN1_V$$

$$\underline{V}_R(t) - \underline{V}(t)$$

FIRSTTME

MOON SPHERE

IS
RTX2=0
?

NO

$$MPAC_V \leftarrow DELVEET3_V$$

EARTH SPHERE

GETGOBL

$$PL34_D \leftarrow /RN_V^2$$

$$\underline{V}_G(t) = \underline{V}_R(t) + \underline{g}_b(t)(t - t_{IG}) - \underline{V}(t)$$

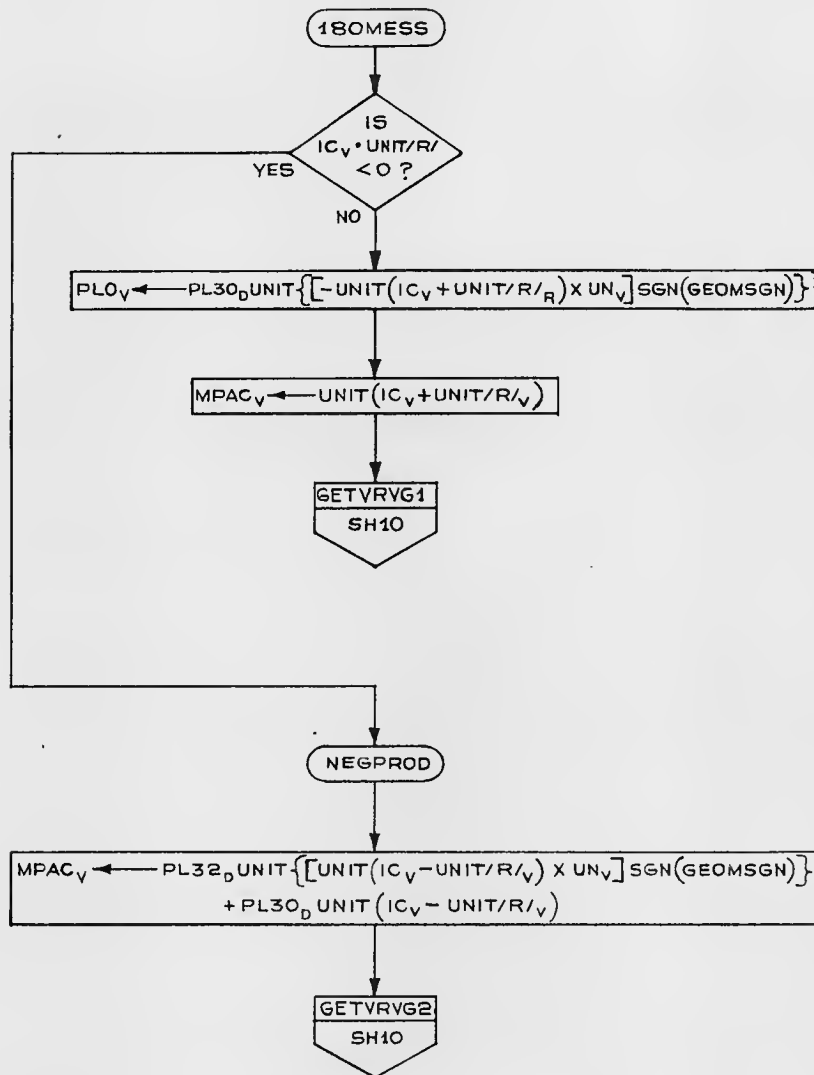
$$MPAC_V \leftarrow UNITGOBL_V(PIPTIME_D - GOBLTIME_D) \frac{EARTH\mu_D}{PL34_D} + DELVEET3_V$$

NOGOBL

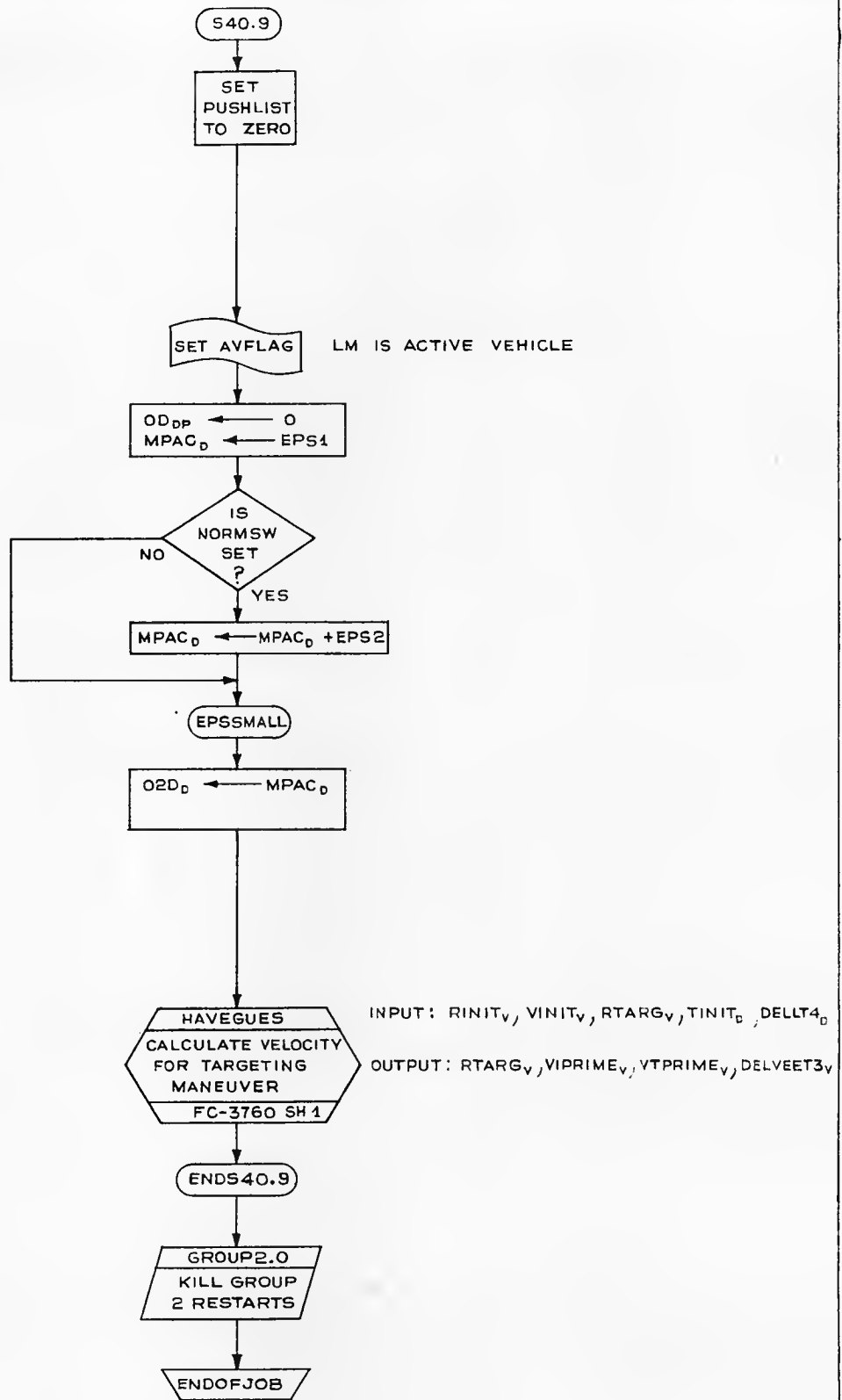
$$DELVEET3_V \leftarrow MPAC_V$$

VGAIN *
SH 7

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i>		P41 RCS THRUST	
PROGRAM <i>[Signature]</i>	JUNE 69	LUMINARY ID	DOCUMENT NO. FC-3810
ANALYST	JUNE 67		
DOOR <i>[Signature]</i>	JUNE 69	REV 2	SHEET 11 OF 15
APPROV. <i>[Signature]</i>	JUNE 69		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>P. M. Decker</i>		P41 RCS THRUST	
PROGRAM <i>P. Collier</i>	JUNE 68	LUMINARY ID	DOCUMENT NO.
ANALYST	7/20/68		FC-3810
DOCNR <i>FC-3810</i>	JUNE 69	REV 2	SHEET 12 OF 15
APPR'D <i>Allen M. Sorani</i>	JUNE 68		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P41 RCS THRUST	
DRAWN <i>D.M. Dietrich</i>	2 AUG 68	LUMINARY ID	DOCUMENT NO. FC-3810
PROGRAM <i>P. Phillips</i>	2 AUG 68		
ANALYST <i>P. Phillips</i>	10 AUG 68	REV 2	SHEET 13 OF 15
DOCWR <i>MC Phillips</i>	2 AUG 68		
APPR'D <i>John R. Man...</i>	2 AUG 68		

SUBROUTINES

ON THIS CHART

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

ON OTHER CHARTS

- RO2BOTH 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
- V1ST02S 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
V16NB5	R1- } $V_{GV}(\text{BODY})$ XXXX.X FT/SEC { VGX(LM) R2- } { VGY(LM) R3- } { VGZ(LM)	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 <i>P. M. Dietrich</i>		P41 RCS THRUST	
PROGRAM <i>P. Phillips</i>	SAUGSE <i>8-24-68</i>	LUMINARY ID	DOCUMENT NO. FC-3810
ANALYST <i>P. Phillips</i>	<i>10 Jan 69</i>		
DOCNR <i>MC-200-100</i>	<i>26 Nov 68</i>	REV 2	SHEET 14 OF 15
APPR'D <i>John A. Moran</i>	<i>29 Nov 69</i>		

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
DELT4 _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 <u>Q_V</u> FOR EXTERNAL ΔV.	M/CSEC	2 ⁷

* M - NEWTONS = 10⁴ NEWTONS

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P41 RCS THRUST	
DRAWN <i>D.M. Dietrich</i>	6AUG 68	LUMINARY 1D	DOCUMENT NO. FC-3810
PRGMR <i>P. Keller</i>	8-26-68		
ANALST <i>P. Phelan</i>	10 Jan 69	REV 2	SHEET 15 OF 15
DOCMR <i>M. D. Smith</i>	26 AUG 68		
APPR'D <i>John R. Moore</i>	24 MAR 69		

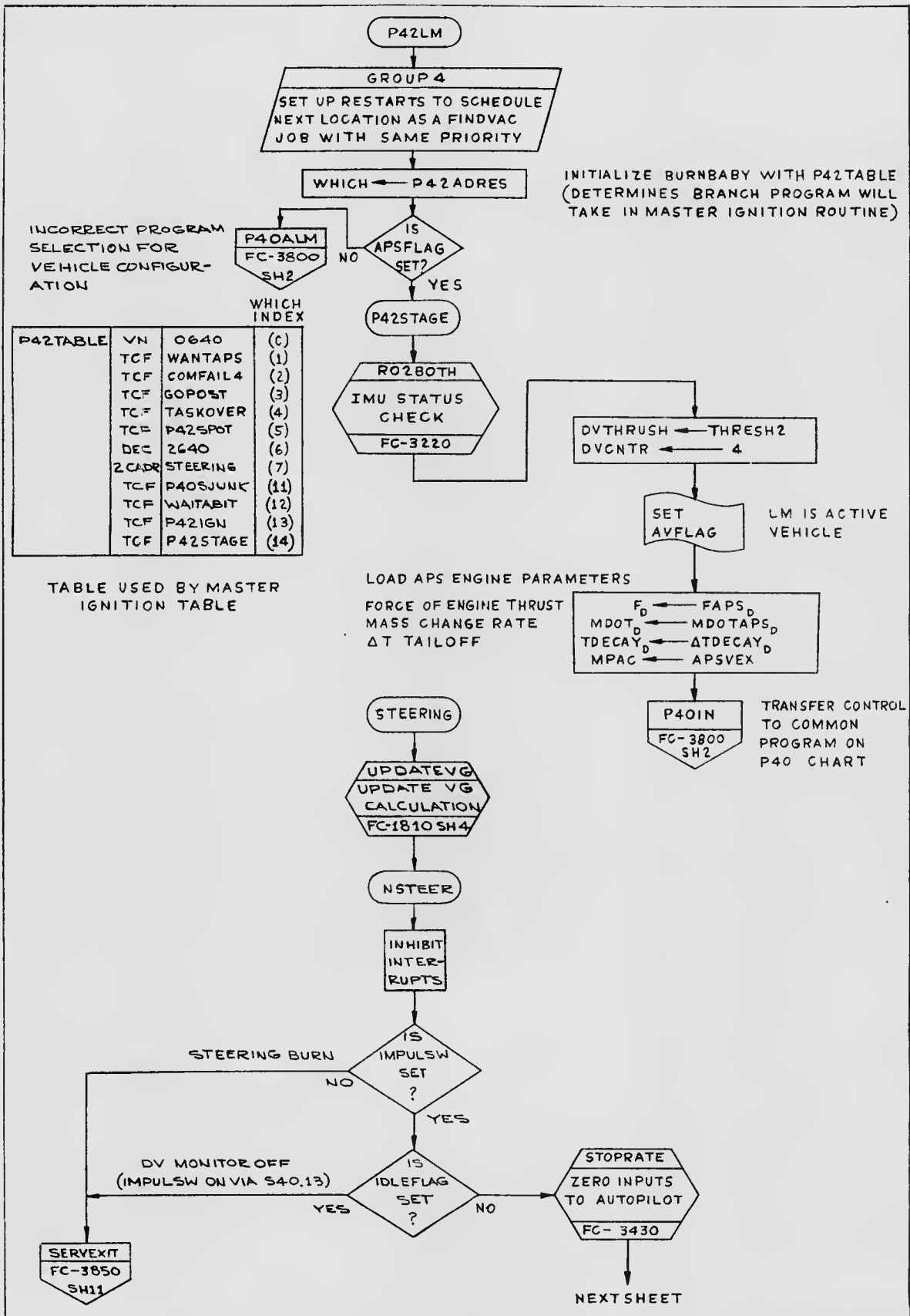


P42
 APS THRUST

MAJOR SUBROUTINES ON THIS CHART

P42LM	APS THRUST PROGRAM	SH2
STEERING	SERVICER EXIT FOR STEERING BURN	SH2
GETDT	STORE INPUT A IN TGO +1	SH3

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P42 APS THRUST	
DRAWN <i>J. J. ...</i>	8 MAY 69	LUMINARY ID	DOCUMENT NO. FC-3820
PRGMR <i>W. J. ...</i>	7 MAY 69		
ANALST <i>W. J. ...</i>	16 MAY 69		
DOCMR <i>W. J. ...</i>	18 MAY 69		
APPR'D <i>John B. Moore</i>	16 May 69	REV 3	SHEET 1 OF 4



INCORRECT PROGRAM SELECTION FOR VEHICLE CONFIGURATION

INITIALIZE BURNBABY WITH P42TABLE (DETERMINES BRANCH PROGRAM WILL TAKE IN MASTER IGNITION ROUTINE)

P42TABLE	VN	WHICH INDEX
	0640	(C)
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

LOAD APS ENGINE PARAMETERS
FORCE OF ENGINE THRUST
MASS CHANGE RATE
ΔT TAILOFF

LM IS ACTIVE VEHICLE

TRANSFER CONTROL TO COMMON PROGRAM ON P40 CHART

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P42 APS THRUST	
DRAWN <i>W.D. King</i>	7-30-68	LUMINARY ID	DOCUMENT NO. FC-3820
CHKD BY <i>P. G. Miller</i>	8-28-68		
DOCWR <i>M.C. Smith</i>	8-28-68	REV 3	SHEET 2 OF 4
APPR'D <i>John B. Moore</i>		11. Mar. 1968	

FROM PRECEDING PAGE

CLEAR IMPULSW
SET IDLEFLAG STEERING BURN
NO DV MONITOR

INHIBIT
INTER-
RUPTS

$MPAC_D \leftarrow TIG_D - TIME_2_D$ LOAD TIME OF ENGINE CUT-OFF

TPAGREE
FORCE SIGN AGREEMENT
OF CONTENTS OF $MPAC_T$
FC-3150

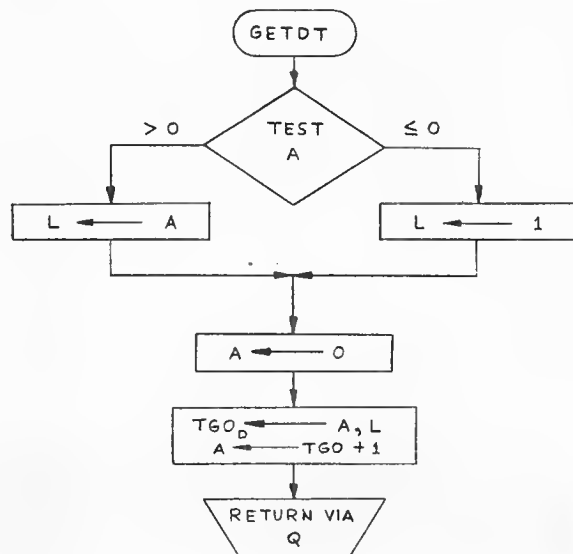
$A \leftarrow MPAC + 1$

GETDT
STORE A IN
 $TGO + 1$
SH3

ENGOFTSK
TWIDDLETASK SCHEDULE TASK TO
IN $C(A)CSEC$ TURN OFF ENGINE
FC-3840 SH18

GROUP 4.11
RESTART
TASK
ENGOFTSK
GROUP 5.3
RESTART
TASK
REREADAC

END OF JOB



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P4-2 APS THRUST	
DRAWN <i>W.D. Knight</i>	T-29-68	LUMINARY 1D	DOCUMENT NO. FC-3820
PROGR <i>D. Gully</i>	8-28-68		
ANALST <i>T. Sullivan</i>	10/2/68	REV 3	SHEET 3 OF 4
DOCNR <i>W.C. Knight</i>	8-28-68		
APPR'D <i>John A. Moore</i>	24 JAN 69 16 May 69		

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 MPACT

FLAGS	MEANING	SET	CLEARED	TESTED
AVFLAG	SET - LM IS ACTIVE VEHICLE CLEARED - CSM IS ACTIVE VEHICLE	SH2		
IMPULSW	SET - MINIMUM IMPULSE BURN CLEARED - STEERING BURN		SH3	SH2
IDLEFLAG	SET - NO DV MONITOR CLEARED - CONNECT DV MONITOR	SH3		SH2

ERASABLE	MEANING	UNITS	SCALING	*M-NEWTONS=10 ⁴ NEWTONS
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	

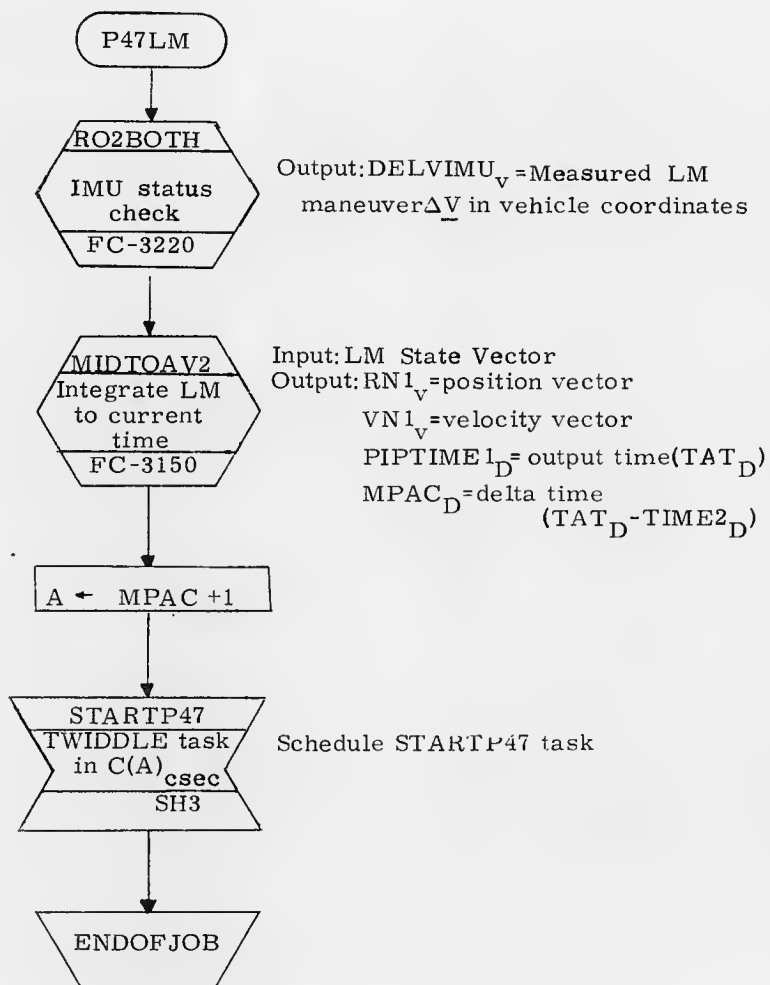
FIXED CONSTANTS	MEANING	PHYSICAL VALUE STORED VALUE		
		UNITS	UNITS	SCALING
FAPS _D	APS ENGINE THRUST	3500 POUNDS	1.5568 M-NEWTONS *	2 ⁷
MDOTAPS _D	APS ENGINE MASS CHANGE RATE	5.14 KG/SEC	.0513781393 KG/CSEC	2 ³
ATDECAY _D	APS ENGINE ΔT TAIL-OFF	-0.07 SEC	-7 CSEC	2 ²⁸

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P42 APS THRUST	
DRAWN W. DEWIGHT	1-29-68	LUMINARY ID	DOCUMENT NO.
PROGR J. Geller	8-28-68		FC-3820
ANALST J. Geller	11-26-68	REV 3	SHEET 4 OF 4
DOCTR W. C. Engsted	8-28-68		
APPR'D John H. Morse	24 JAN 69		

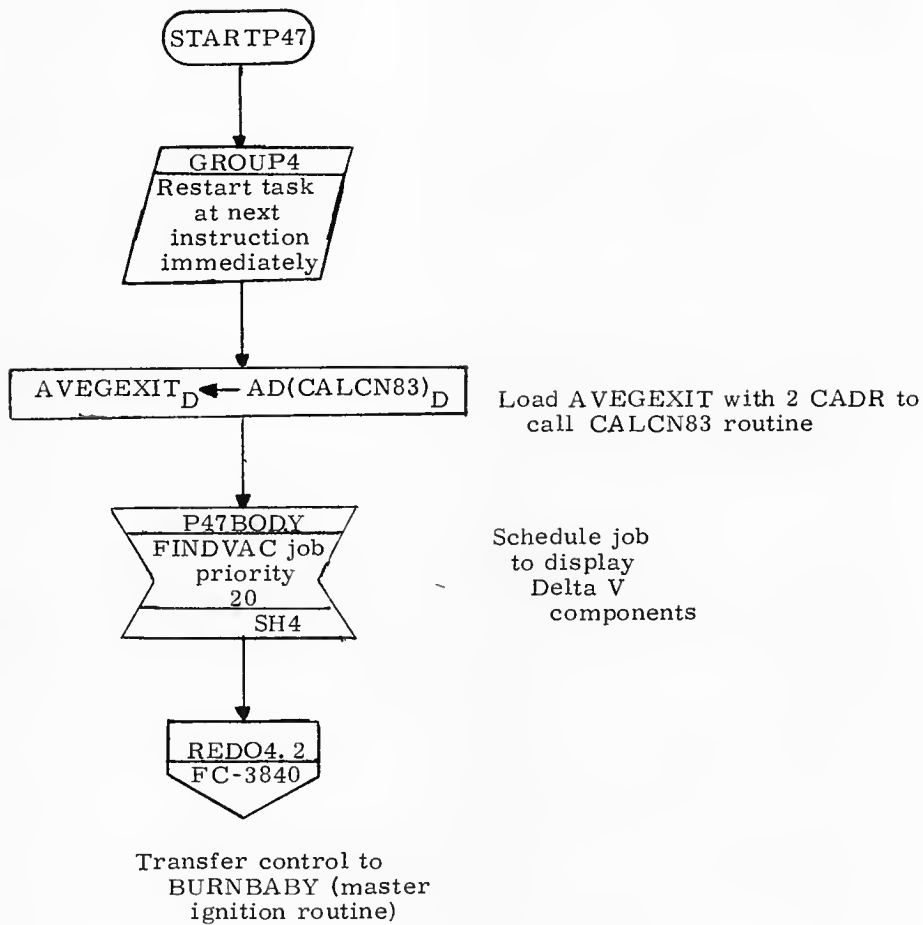
P47 THRUST MONITOR

P47LM SH. 2
 CALCN83 SH. 5

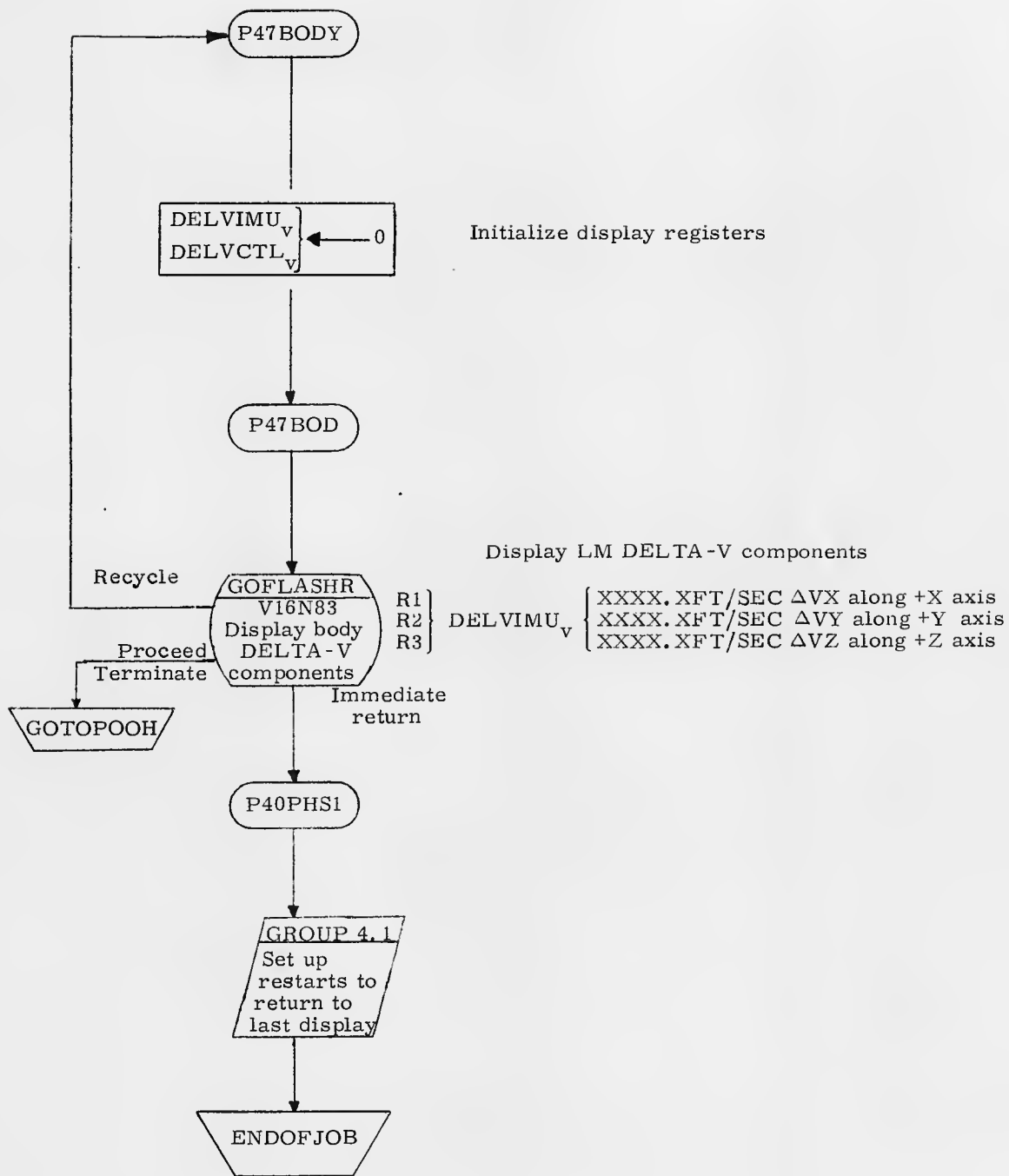
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. Conolly</i>		P47 THRUST MONITOR	
PRGMR <i>P. Allen</i>		DOCUMENT NO. FC-3830	
ANALST		LUMINARY ID	
DOCMR <i>W.C. Danforth</i>		REV 3	
APPR'D <i>W.C. Danforth</i>		SHEET 1 OF 5	



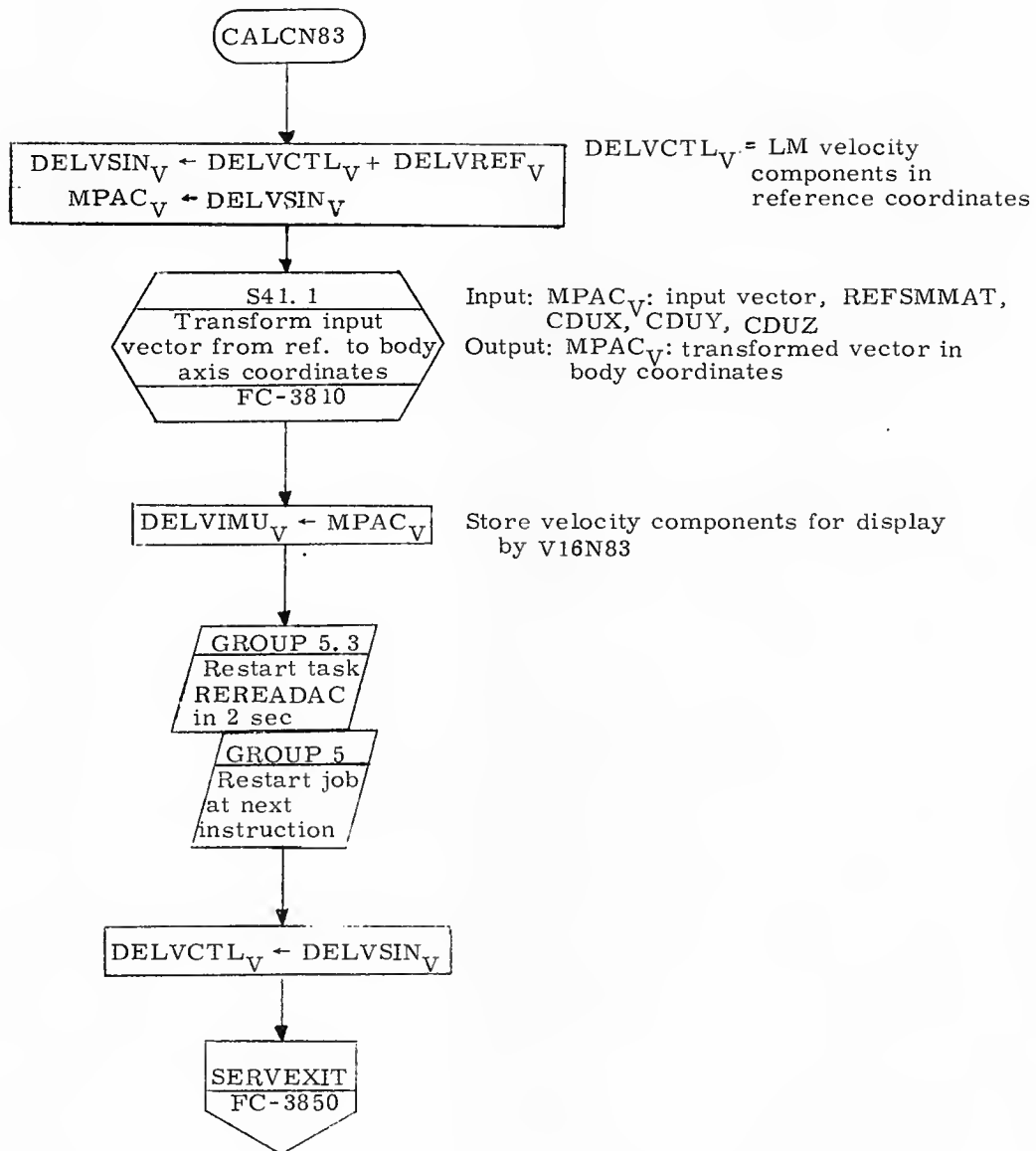
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. J. ...</i>	<i>...</i>	P47 Thrust Monitor	
PRGMR <i>...</i>	<i>...</i>		DOCUMENT NO. FC-3830
ANALST		LUMINARY 1D	
DOCMR <i>W. C. Danforth</i>	<i>5A1568</i>	REV 3	SHEET 2 OF 5
APPR'D <i>...</i>	<i>15 AUG 66</i>		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. Conceller</i>		P47 Thrust Monitor	
PRGMR <i>P. Gullen</i>	<i>5 Aug 69</i>	LUMINARY 1D	DOCUMENT NO. FC-3830
ANALST			
DOCMR <i>W.C. Douglas</i>	<i>5 AUG 69</i>	REV 3	SHEET 3 OF 5
APPR'D <i>W.C. Douglas</i>	<i>5 AUG 69</i>		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. Conolly</i>		P47 Thrust Monitor	
PRGMR <i>P. Keller</i>	<i>14 Aug 69</i>	DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3830
DOCMR <i>J. Conolly</i>	<i>5 AUG 69</i>	REV 3	SHEET 4 OF 5
APPR'D <i>Alexander J. ...</i>	<i>5 AUG 69</i>		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. Sincilla</i> 6 Aug 69		P47 Thrust Monitor	
PRGMR <i>P. Adley</i>	<i>MA 0667</i>	LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3830
DOCMR <i>W.C. DeGroot</i>	<i>5 AUG 69</i>	REV 3	SHEET 5 OF 5
APPR <i>W.C. DeGroot</i>	<i>5 AUG 69</i>		



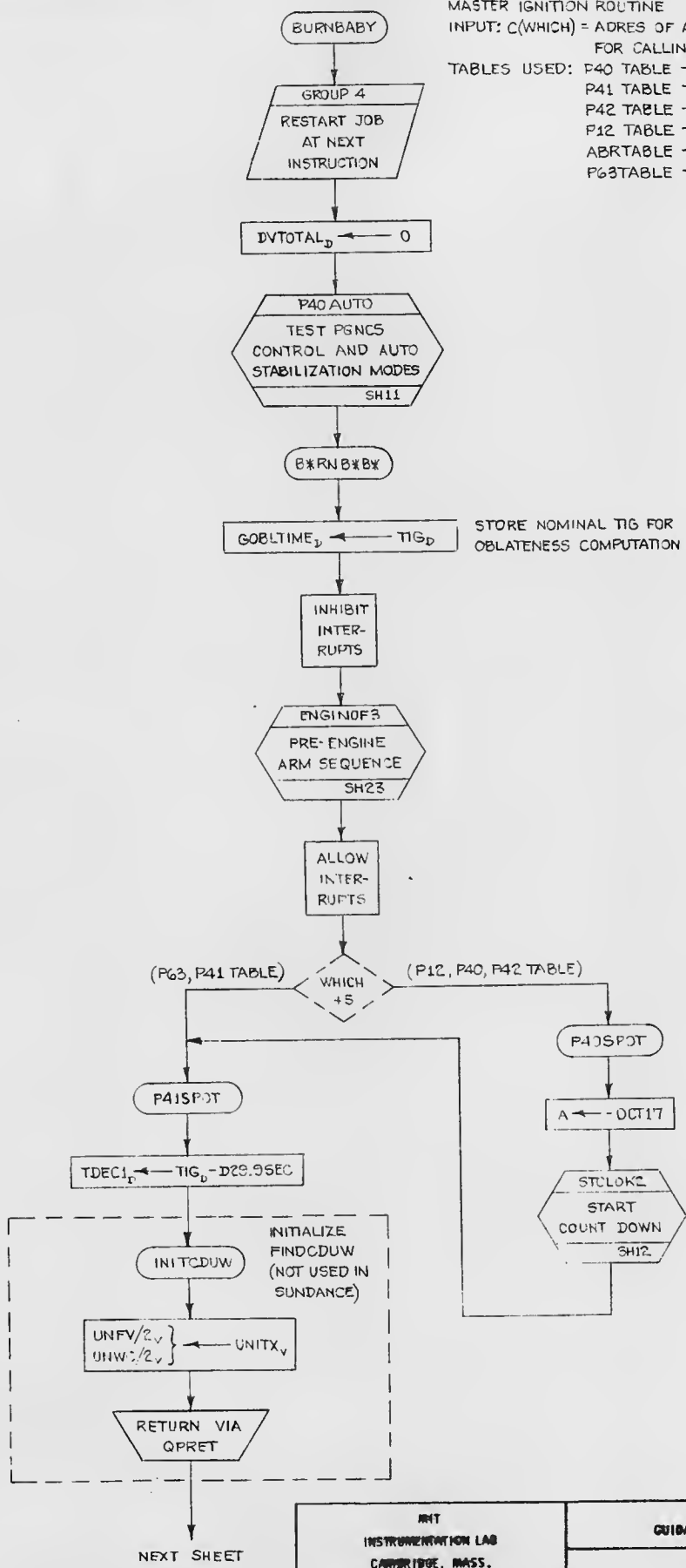
BURN BABY BURN
(MASTER IGNITION ROUTINE)

MAJOR SUBROUTINES ON THIS CHART

BURNBABY	Sh. 2
ENGINOF2	Sh. 13
P40AUTO	Sh. 11
STCLOK1	Sh. 12

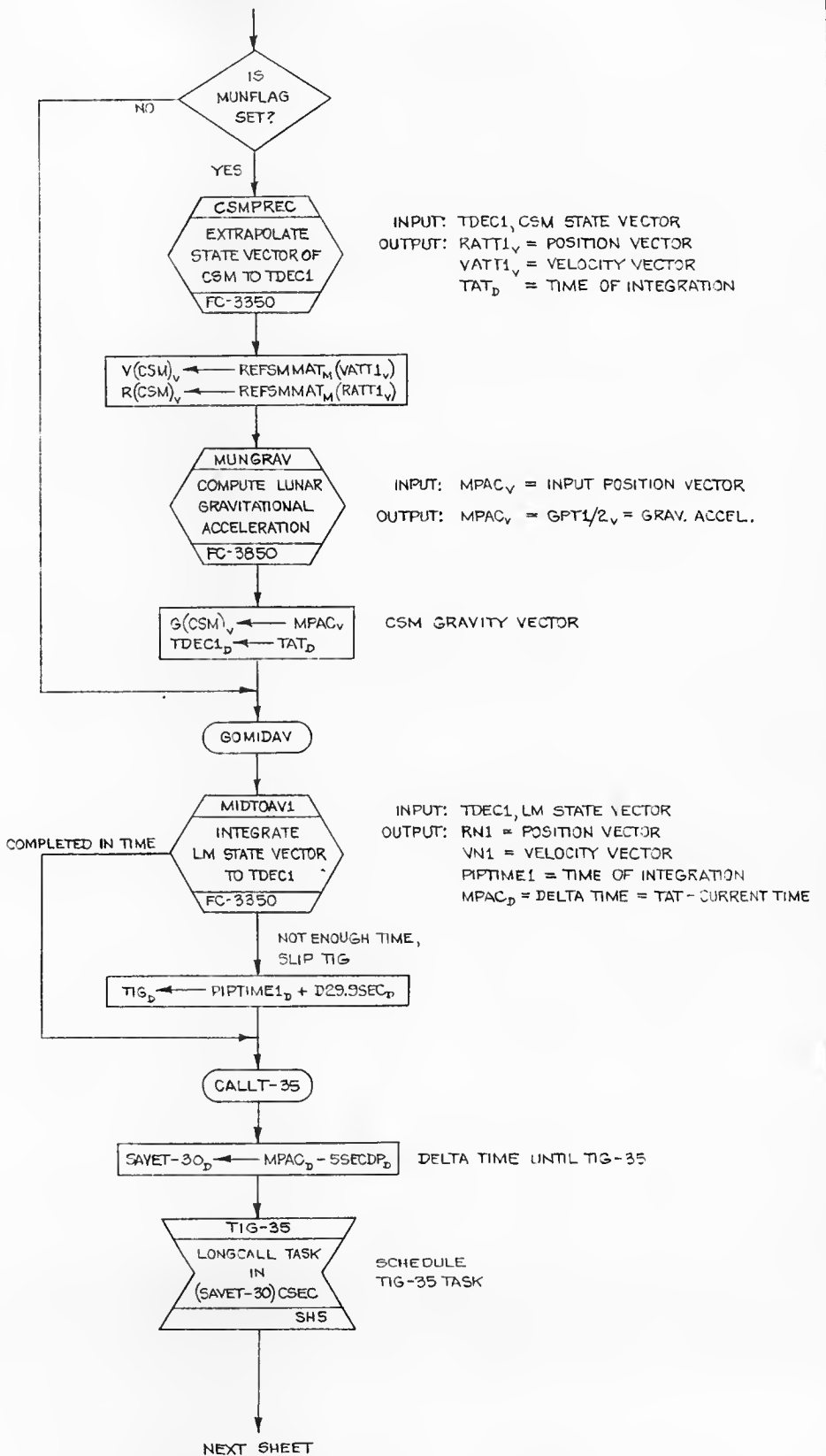
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>K. J. ...</i>		Burn Baby Burn (Master Ignition Routine)	
PRGMR <i>K. J. ...</i>	<i>6/2/69</i>	LUMINARY ID	DOCUMENT NO.
ANALST	<i>10/1/69</i>		FC-3840
DOCMR <i>J. E. ...</i>	<i>10/1/69</i>	REV 3	SHEET 1 OF 25
APPR'D <i>Robert M. ...</i>	<i>10/1/69</i>		

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



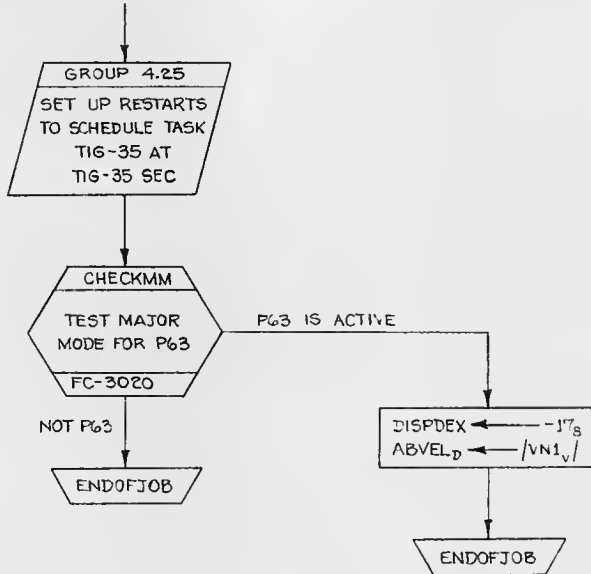
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS		BURN BABY BURN (MASTER IGNITION ROUTINE)	
PROGR C. Schulerberg	5JUNE69	LUMINARY ID	DOCUMENT NO.
ANALST	6AUG69		FC-3840
DOCMR W.C. DeLoach	6AUG69	REV 3	SHEET 2 OF 25
APPR'D <i>Alvin H. Grant</i>	6AUG69		

FROM PRECEDING SHEET

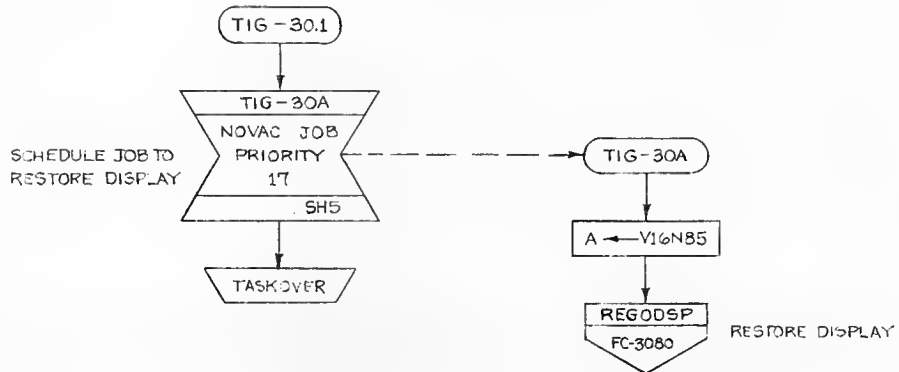
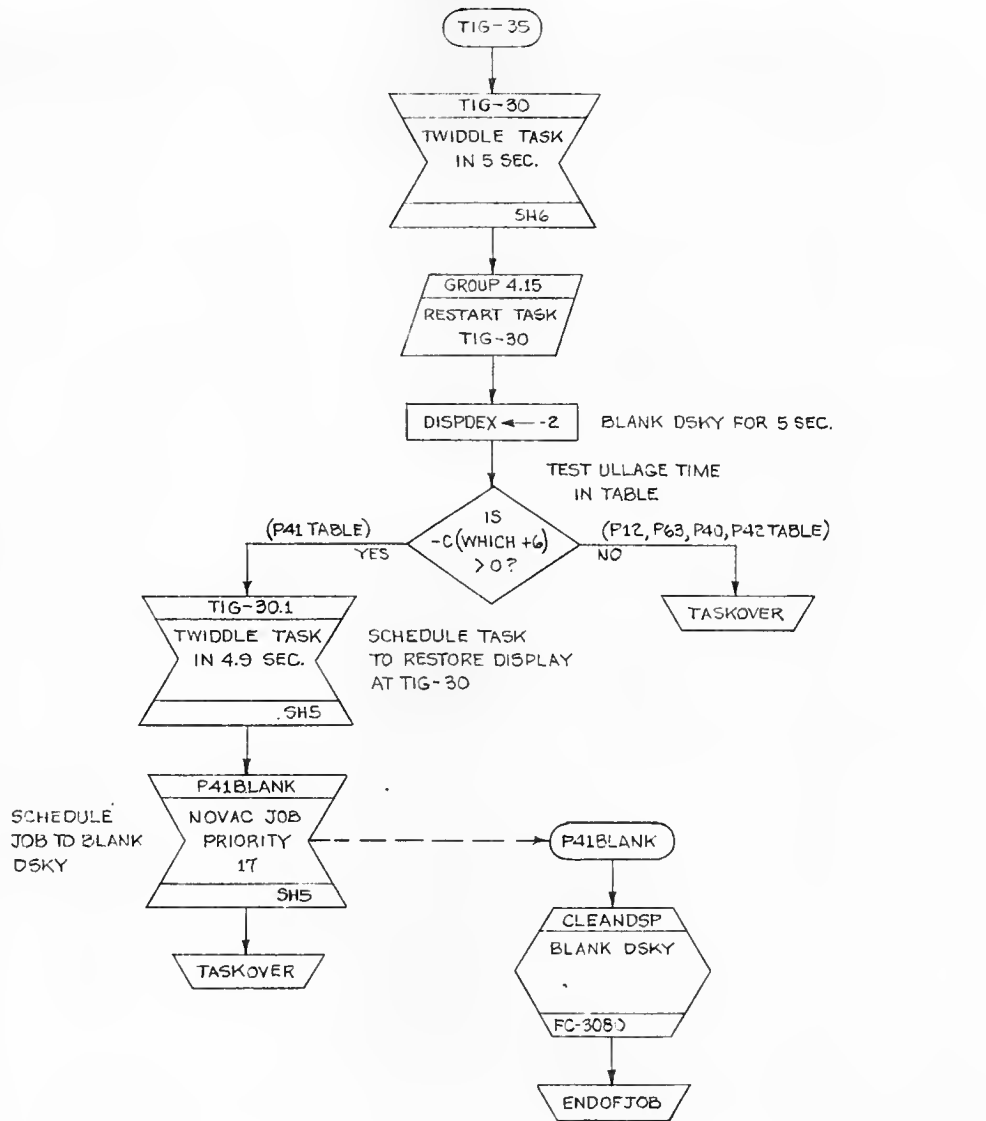


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS	5 JUNE 69	BURN BABY BURN (MASTER IGNITION ROUTINE)	
PRGRM C. Schulenberg	6 AUG 69	LUMINARY ID	DOCUMENT NO.
ANALST			FC-3840
DOCRN MC Decker	6 AUG 69		
APPR'D [Signature]	REV 3		SHEET 3 OF 25

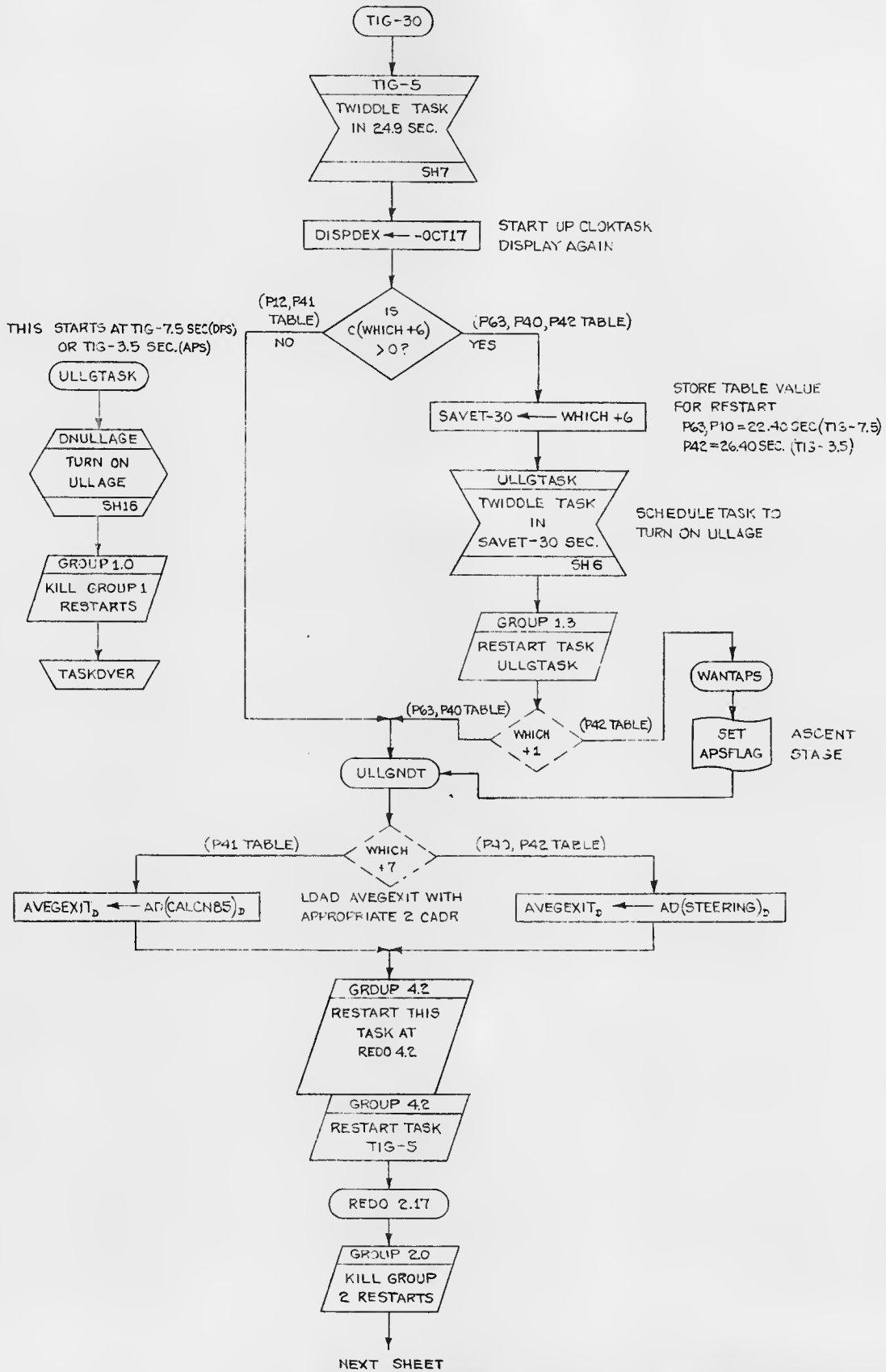
FROM PRECEDING SHEET



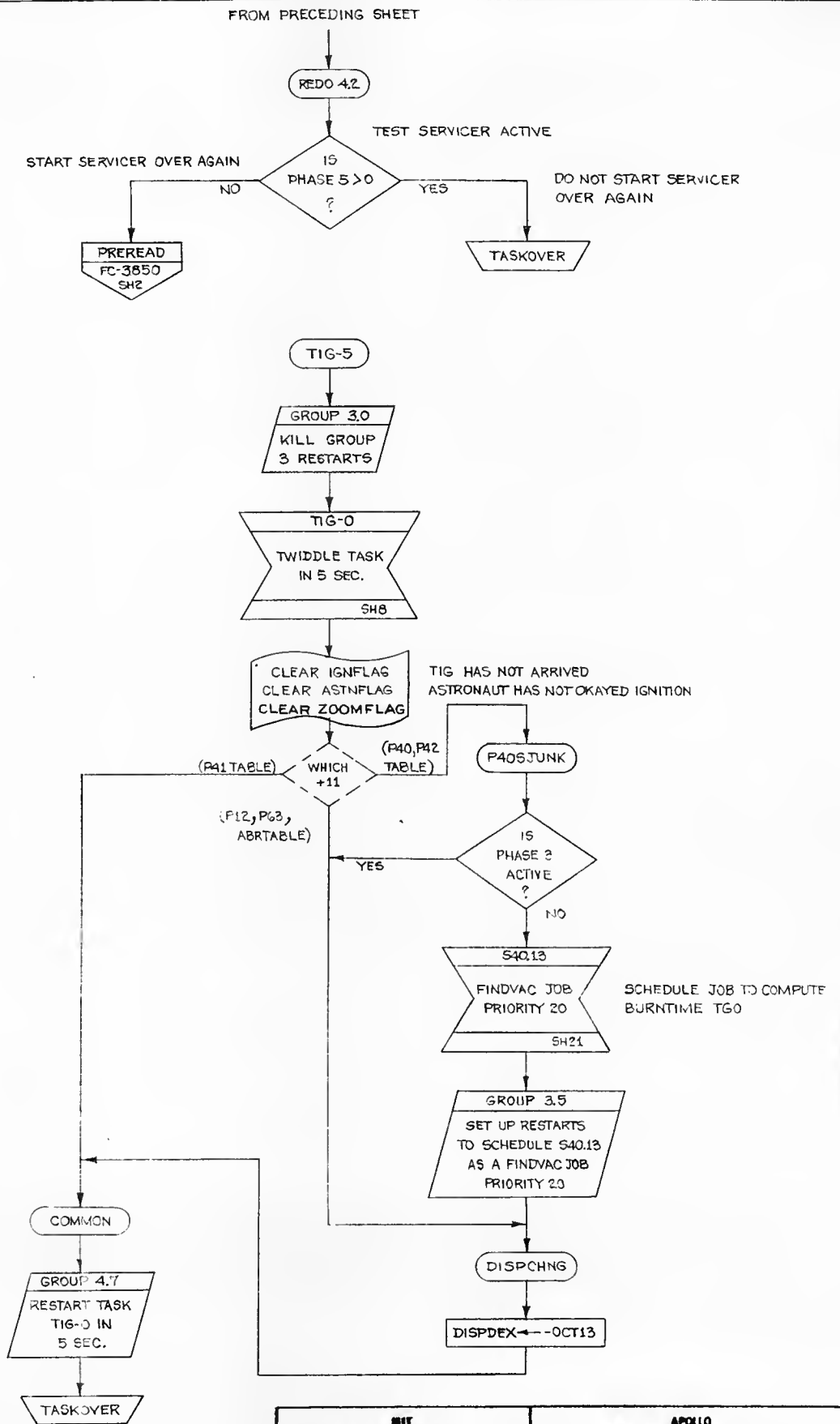
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <u>A.C. WILLIAMS</u>		BURN BABY BURN (MASTER IGNITION ROUTINE)	
PROWR <u>C. Schulenberg</u>	5JUN65	LUMINARY ID	DOCUMENT NO.
ANALST	6 AUG 67		FC-3840
DOCMR <u>McDonnell</u>	6 AUG 67		
APPR'D <u>Robert J. ...</u>	REV 3		SHEET 4 OF 25



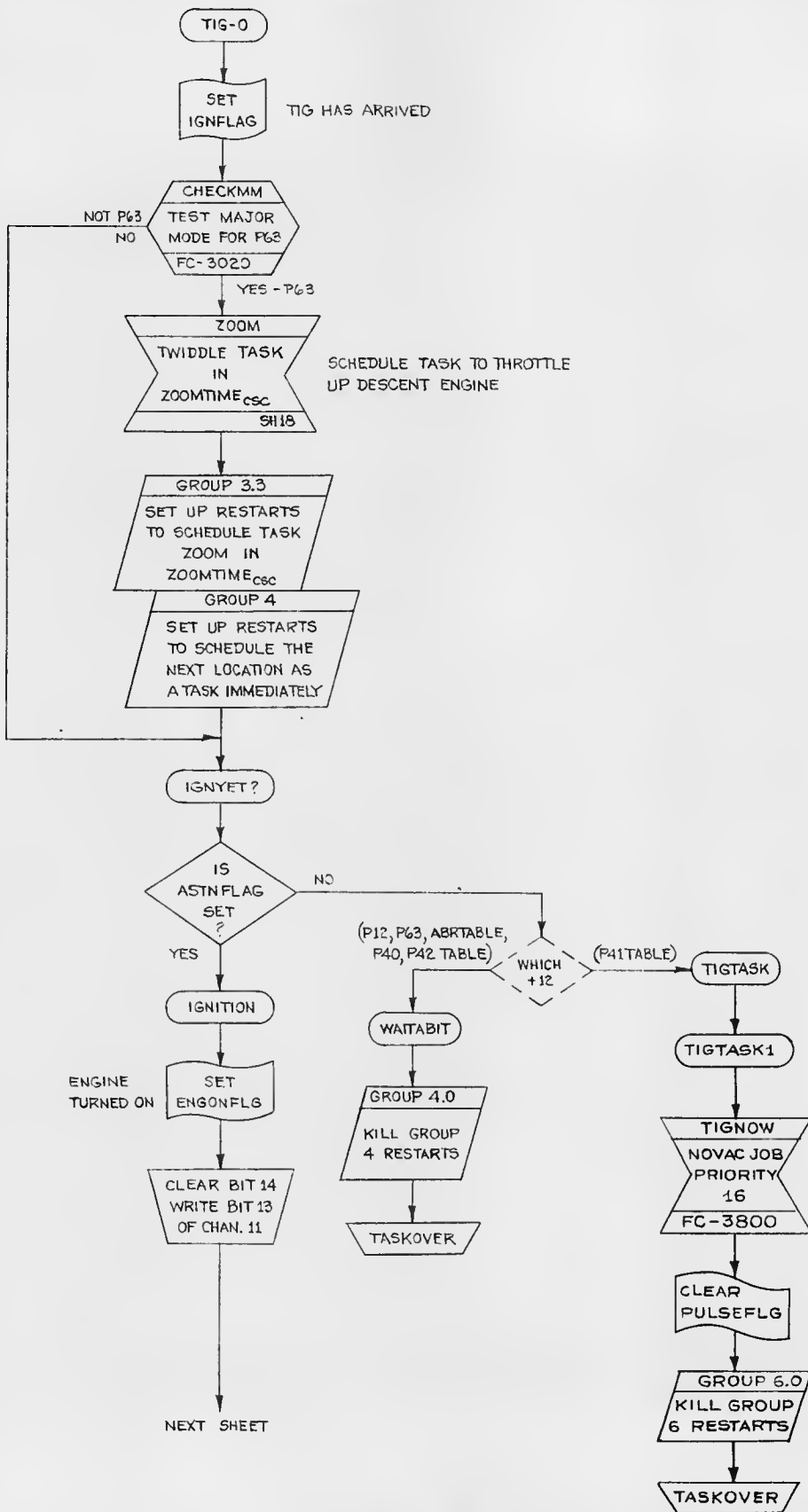
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		BURN BABY BURN (MASTER IGNITION ROUTINE)	
DRAWN	A.C. WILLIAMS	6-20-68	LUMINARY ID
PRGRM	<i>P. Carter</i>	<i>6/20/68</i>	
ANALST	<i>W. Williams</i>	<i>10/26/68</i>	DOCUMENT NO. FC-3840
DOCNR	<i>W.C. Williams</i>	<i>7-29-68</i>	
APPR'D	<i>John A. Williams</i>	<i>29 JAN 69</i>	REV 3
			SHEET 5 OF 25



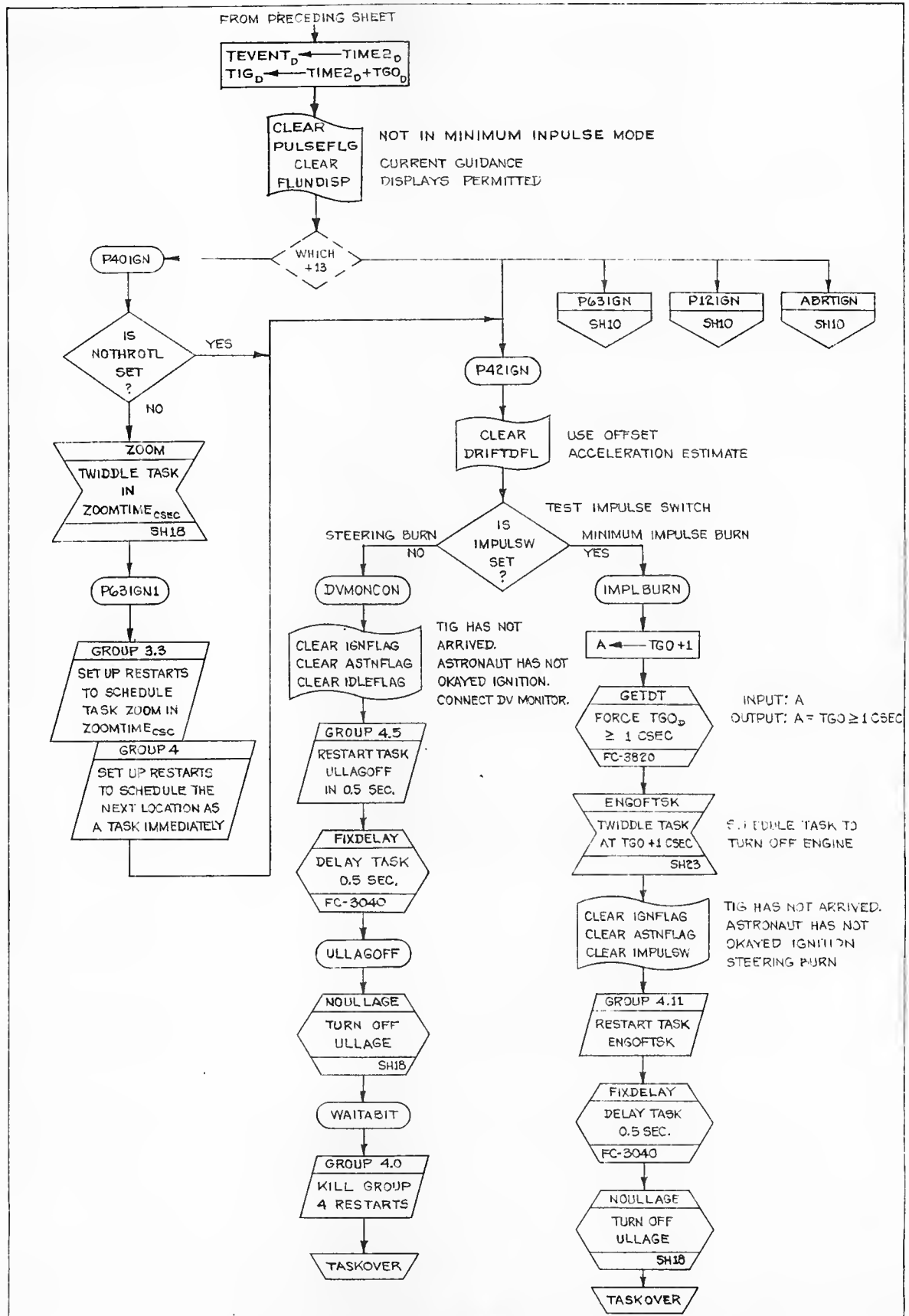
MFT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS		BURN BABY BURN (MASTER IGNITION ROUTINE)	
PROGRAM	6-21-68	LUMINARY ID	DOCUMENT NO.
ANALYST	7-29-68		FC-3840
DOCNR	7-29-68	REV 3	SHEET 6 OF 25
APPR'D	John A. Moore 24 JAN 69		



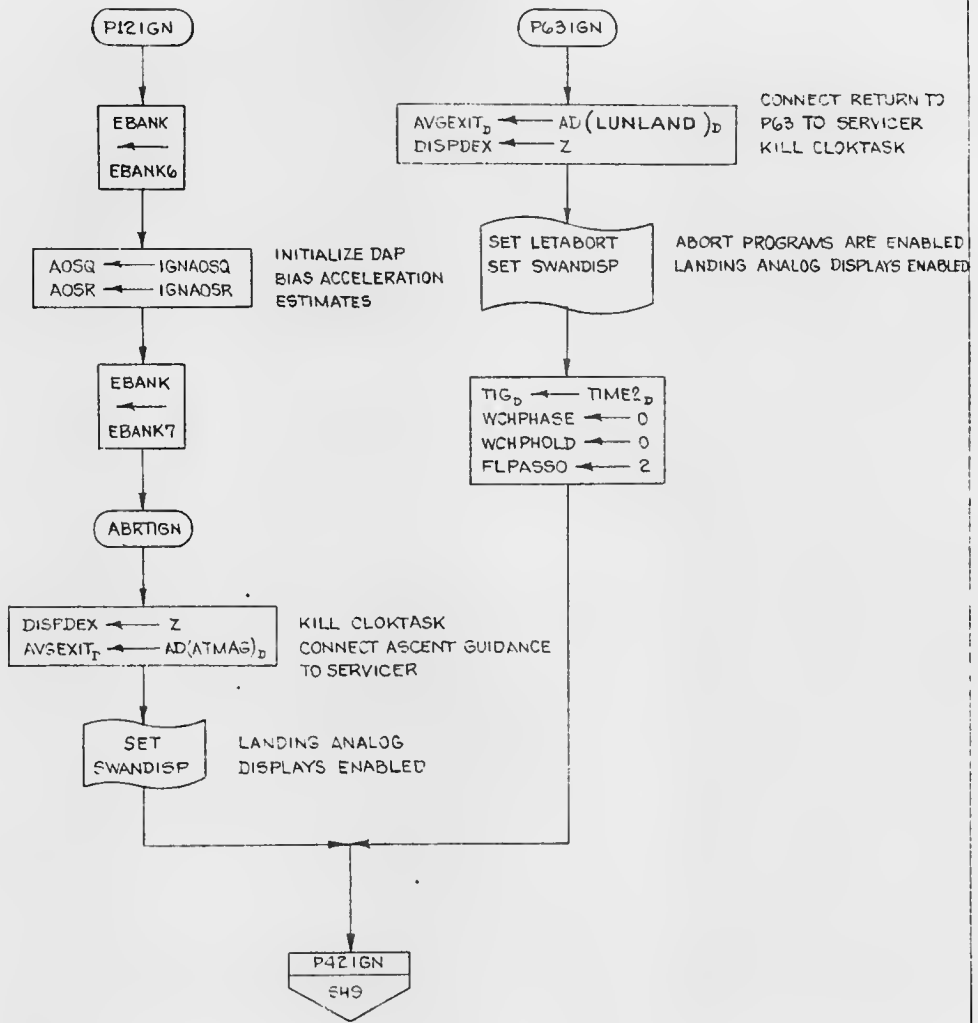
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS		6 JUNE 69	
PRGRM C. Schulenberg		6 AUG 69	
ANALST		LUMINARY 1D	
DOCNR McC... ..		6 AUG 69	
APPRD		REV 3	
		DOCUMENT NO. FC-3840	
		SHEET 7 OF 25	



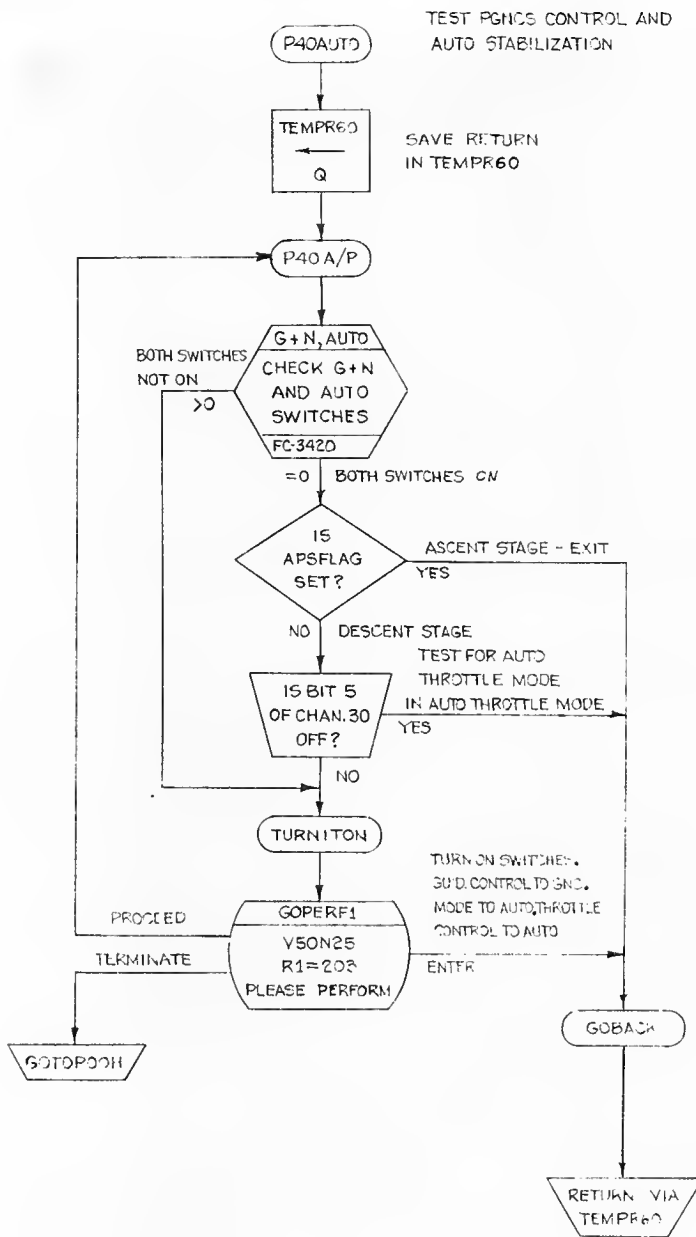
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A. C. WILLIAMS 9JUN69		BURN BABY BURN (MASTER IGNITION ROUTINE)	
PROGRAM C. Schulenberg 6AUG69	ANALYST	LUMINARY 1D	DOCUMENT NO. FC-3840
DOCTR MC Danforth 6AUG69	APPR' B. C. ...	REV 3	SHEET 8 OF 25



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS		BURN BABY BURN (MASTER IGNITION ROUTINE)	
PROGRAM C. Schulenberg	10JUN69 6AUG69	LUMINARY ID	DOCUMENT NO. FC-3840
ANALYST		REV 3	SHEET 9 OF 25
DOCNR MC-2141	6 AUG 69		
APPROV			



INT INSTRUMENTATION LAB CARBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS 10 JUN 69		BURN BABY BURN (MASTER IGNITION ROUTINE)	
FROM C. Schulenberg 6 AUG 69		LUMINARY 1D	DOCUMENT NO. FC-384
ANALYST MC Donnell 6 AUG 69			
APPROVED [Signature] 6 AUG 69		REV 3	SHEET 10 OF 25



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
BURN BABY BURN (MASTER IGNITION ROUTINE)			
DRAWN A.C. WILLIAMS	6-25-68	LUMINARY ID	DOCUMENT NO.
PROGRAM <i>P. Colley</i>	15 Sept 68		FC-3840
ANALYST <i>P. C. Williams</i>	11 Nov 68	REV 3	SHEET 11 OF 25
DOCNR <i>FC-3840</i>	7-27-68		
APPROV <i>John A. Moore</i>	22 Nov 69		

STCLOK1 ROUTINE TO START COUNT-DOWN
(CLOKTASK & CLOKJOB)

A ← 0

STCLOK2

DISPDEX ← A

STCLOK3

TBASE4
←
Q

SAVE RETURN
IN TBASE4

MPAC_D ← TIG_D - TIME_C_D

COMPUTE TIME
TILL IGNITION

TPAGREE
FORCE SIGN
AGREEMENT IN
MPAC_D
FC-3150

L ← REMAINDER (MPAC (BITS 5-1) / 1 SEC)

COMPUTE TIME FOR
CLOKTASK CALL

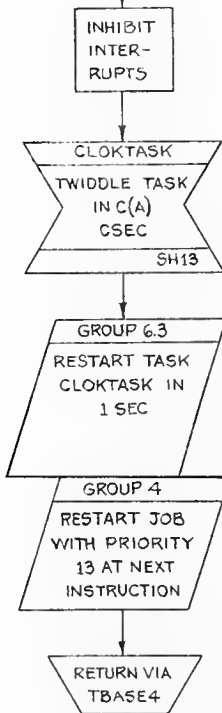
A ← L+2

ADD 2 CSC.

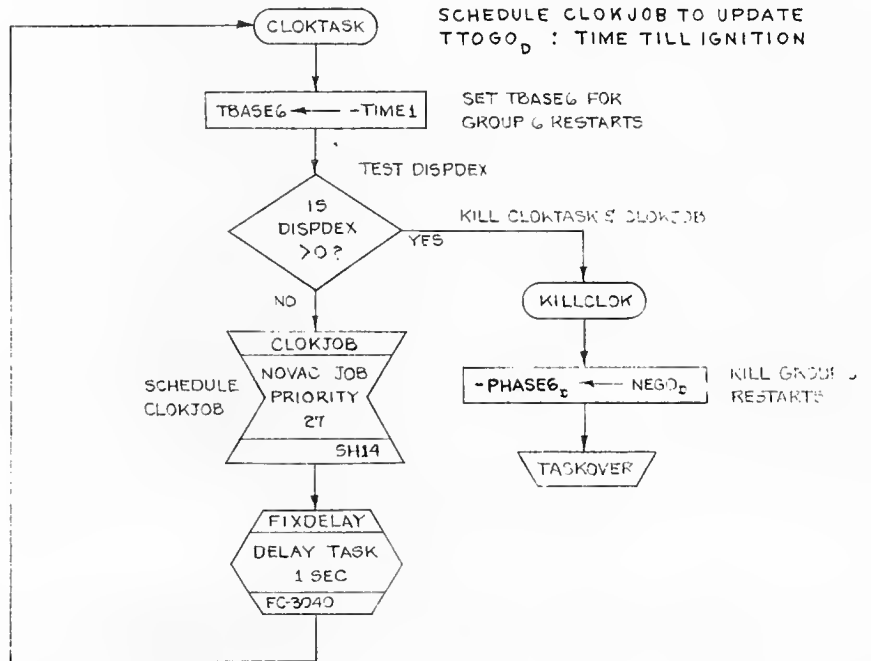
NEXT SHEET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS		BURN BABY BURN (MASTER IGNITION ROUTINE)	
PRGMR P. Collier	6-27-68	LUMINARY ID	DOCUMENT NO. FC-3840
ANALYST P. Williams	12/24/68		
DOCMR W. C. ...	9-29-68	REV 3	SHEET 12 OF 25
APPR'D John A. Moore	11/16/69		

FROM PRECEDING SHEET

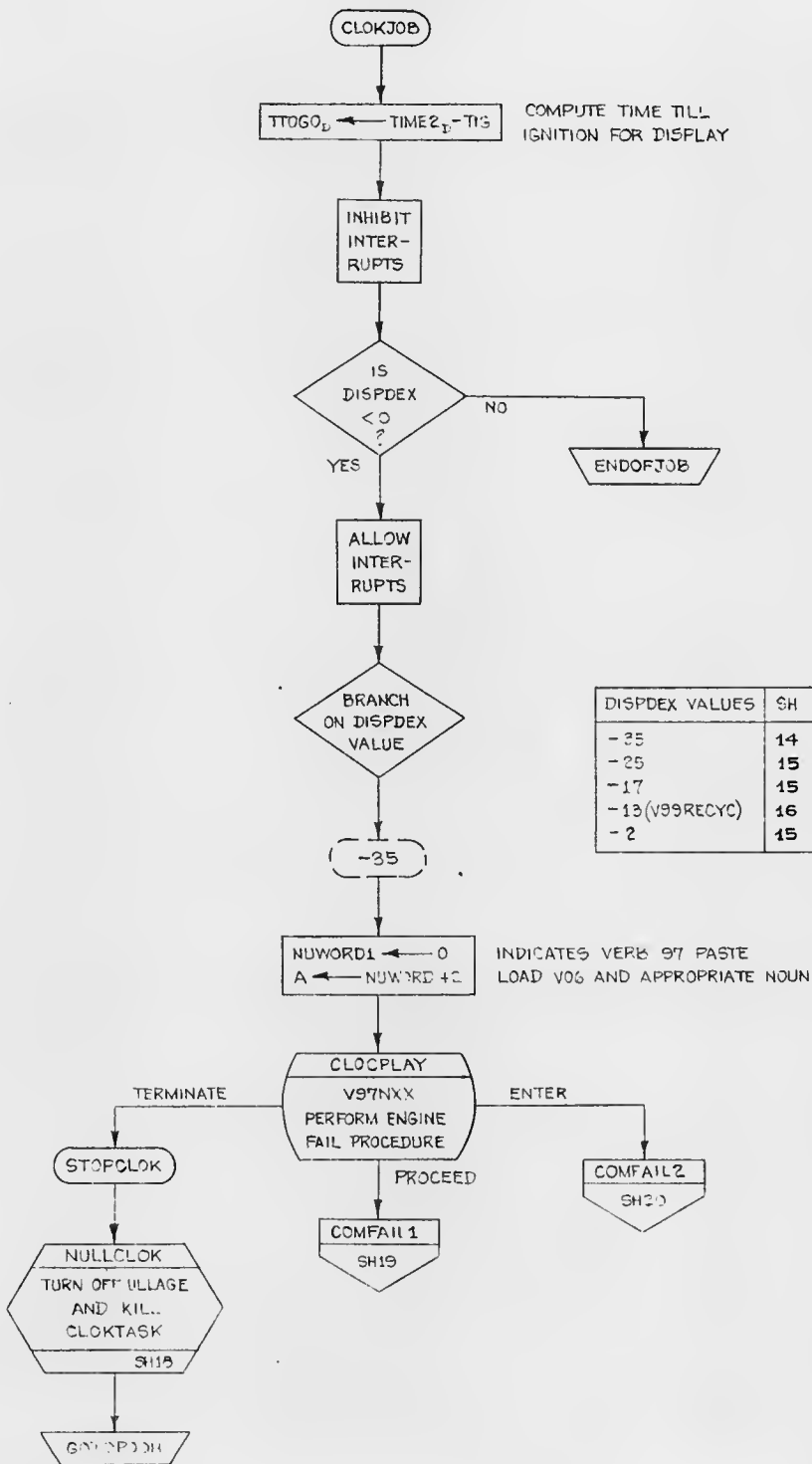


SCHEDULE INITIAL CALL TO START CLOKTASK

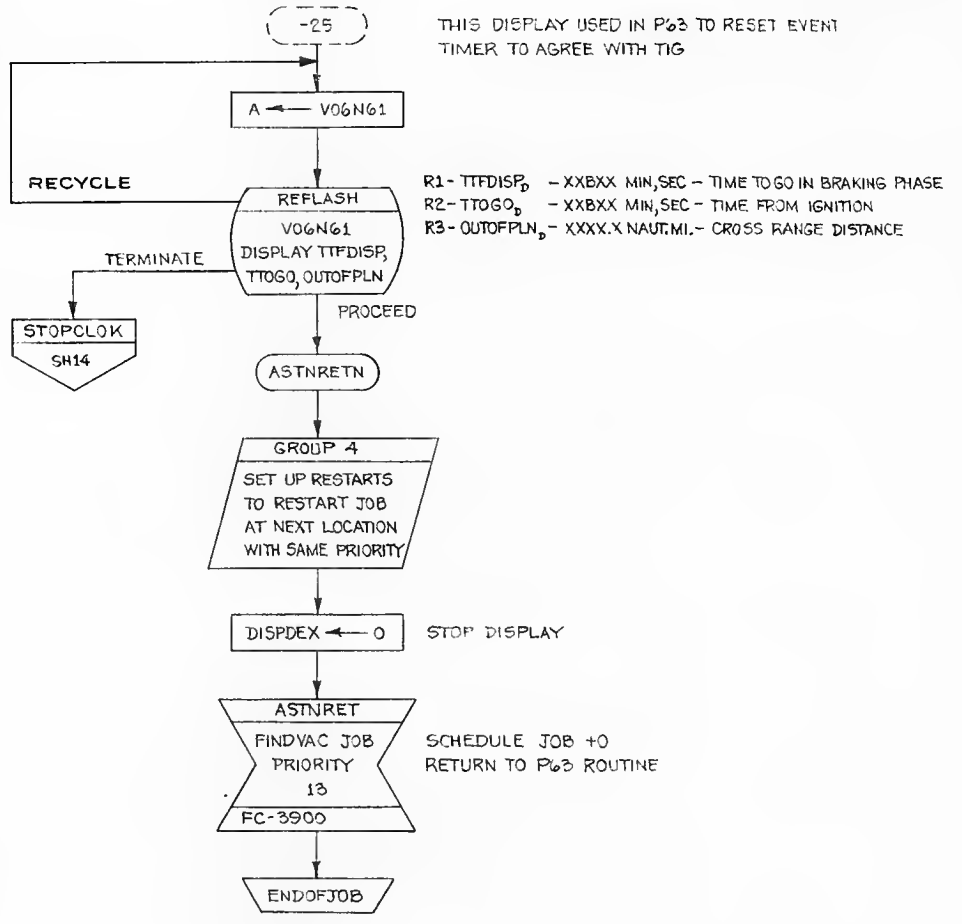


SCHEDULE CLOKJOB TO UPDATE TTOGO_D : TIME TILL IGNITION

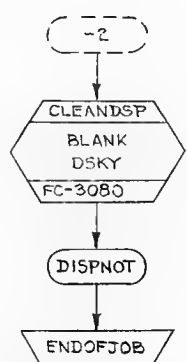
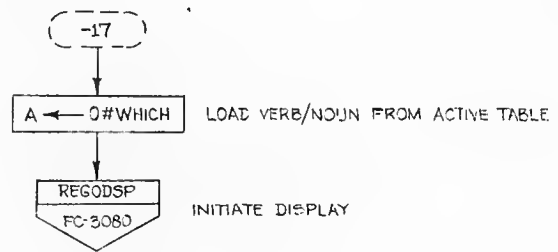
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRWNR	A.C. WILLIAMS	BURN BABY BURN (MASTER IGNITION ROUTINE)	
PRGWR	<i>B. Collins</i>	LUMINARY ID	DOCUMENT NO.
ANLST	<i>P. MacLellan</i>		FC-3840
DOCWR	<i>W. C. Dwyer</i>	REV 3	SHEET 13 OF 25
APPR'D	<i>John A. Moran</i> 24 JUN 69		



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

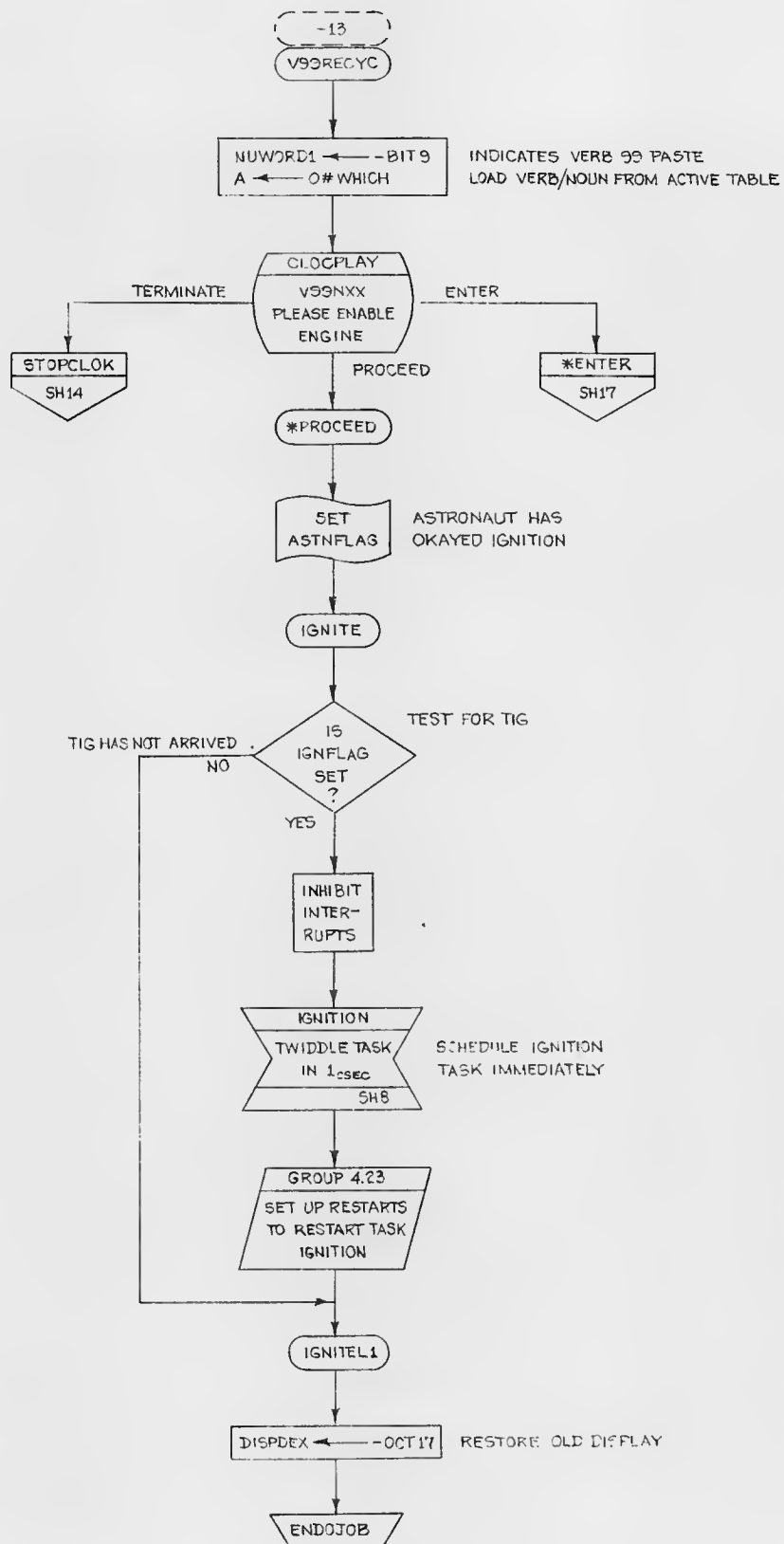


WHICH TABLE	VERB/ NOUN
P12	06 74
P43	06 40
P42	06 40
P63	06 62
ABRTABLE	06 63

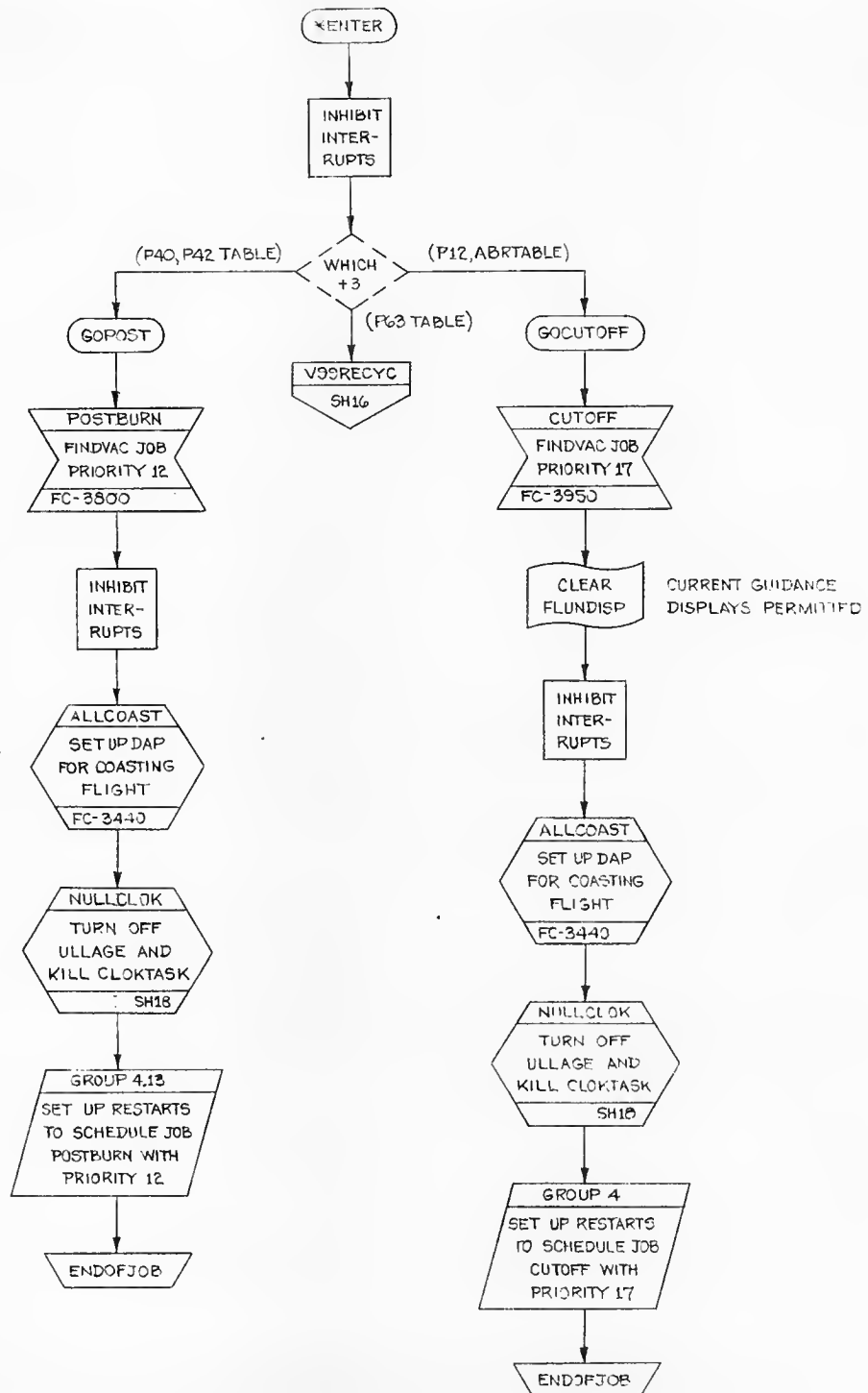


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	A.C. WILLIAMS	11JUN69	BURN BABY BURN (MASTER IGNITION ROUTINE)
PROGRAM	C. Schultenberg	6 AUG 69	
ANALYST			LUMINARY ID
DOCNR	mc [signature]	6 AUG 69	DOCUMENT NO. FC-3840
APPR'D	[signature]	6 AUG 69	REV B

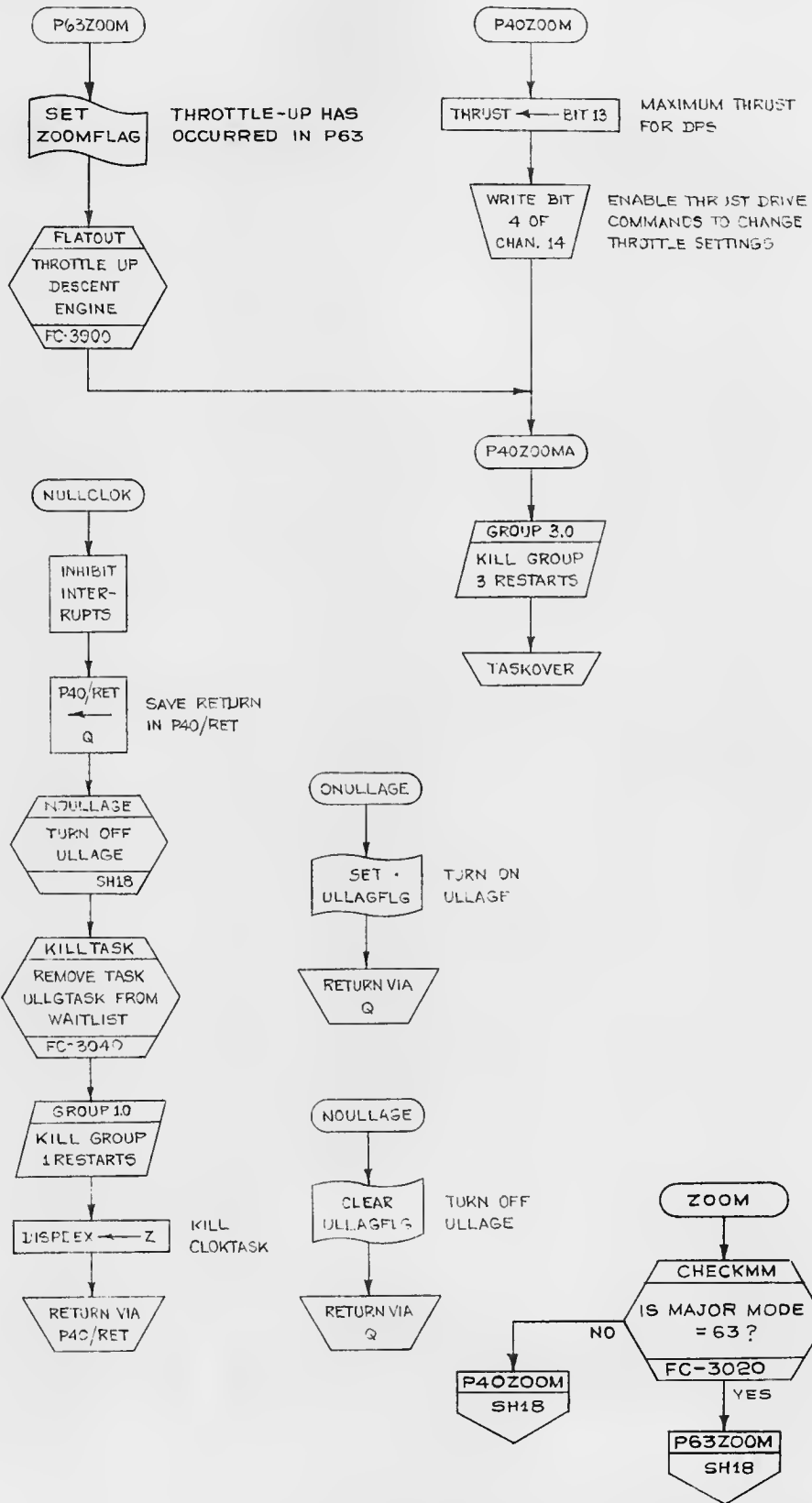
SHEET 15 OF 25



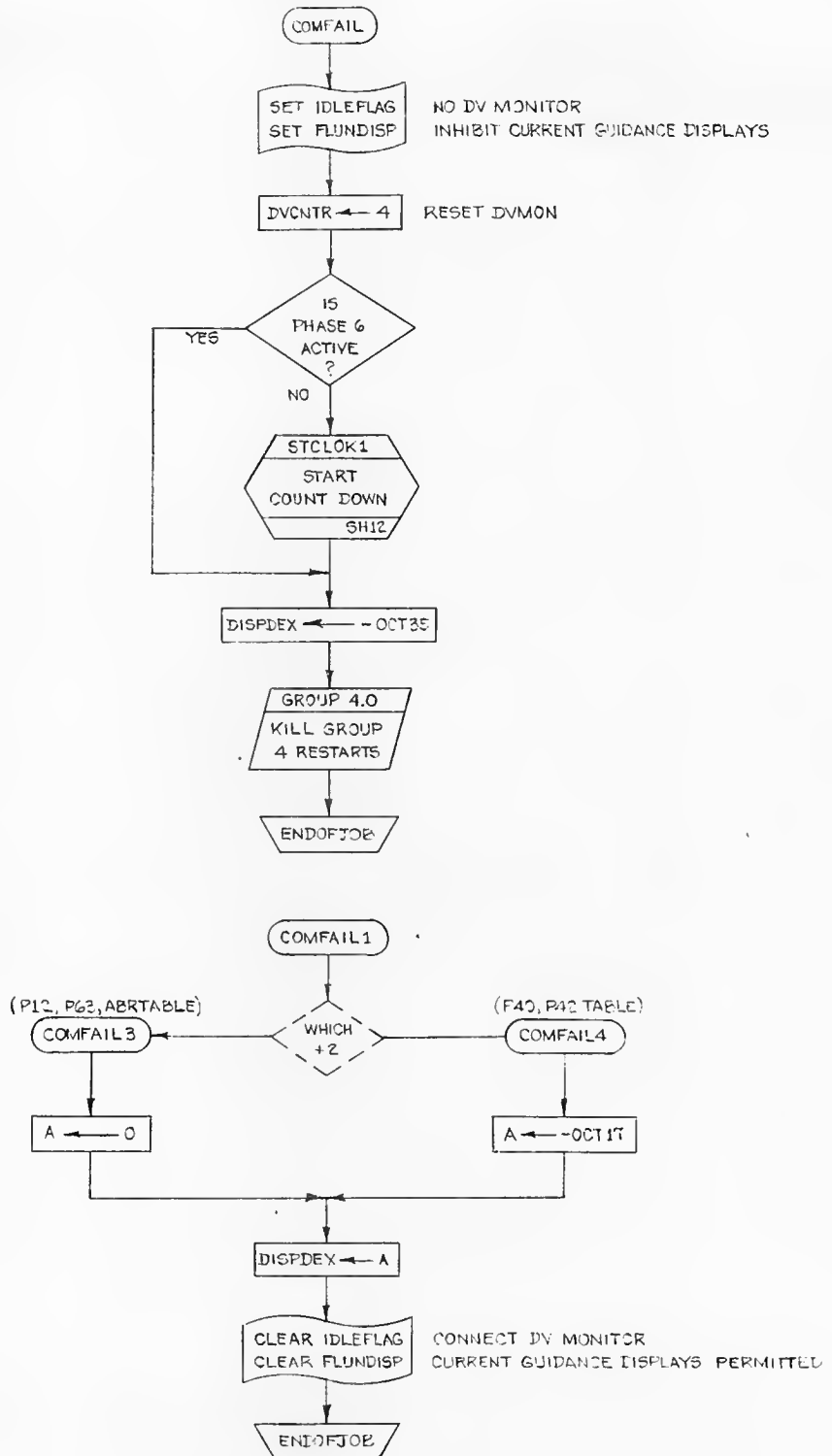
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS		BURN BABY BURN (MASTER IGNITION ROUTINE)	
PROGRAM C. Schulenberg	32 JUN 69	LUMINARY 1D	DOCUMENT NO. FC-3840
ANALYST	6 AUG 69	REV 3	SHEET 16 OF 25
DOCNO J.C. Dignard	6 AUG 69		
APPR'D <i>[Signature]</i>			



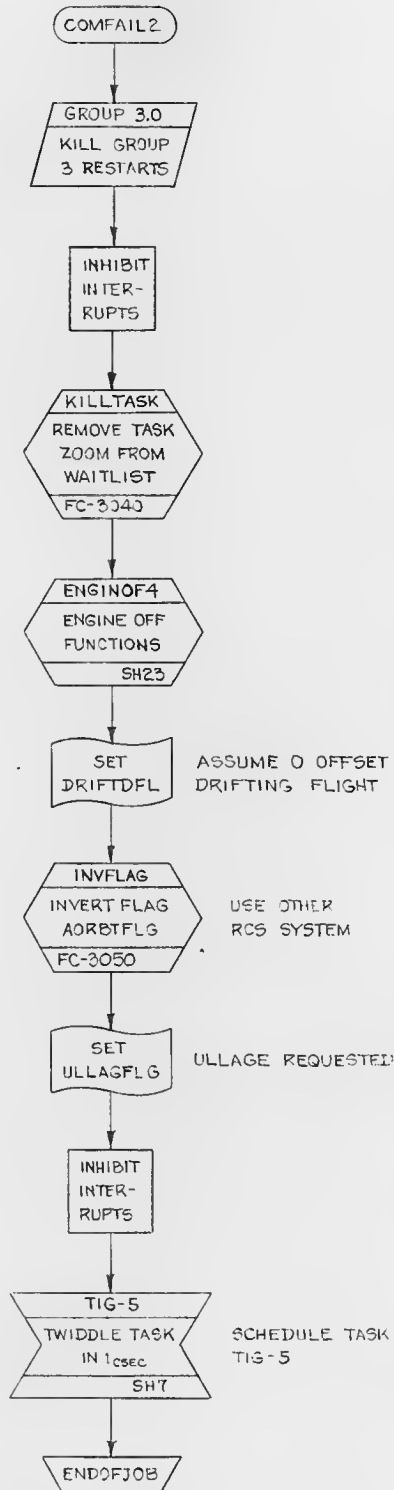
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS 12JUN69		BURN BABY BURN (MASTER IGNITION ROUTINE)	
PROGRAM C.Schulenberg 6 AUG 69	ANALYST	LUMINARY ID	DOCUMENT NO. FC-3840
DOCMR McDebrath 6 AUG 69	APPR'D A.C.Williams 6 AUG 69	REV 3	SHEET 17 OF 25



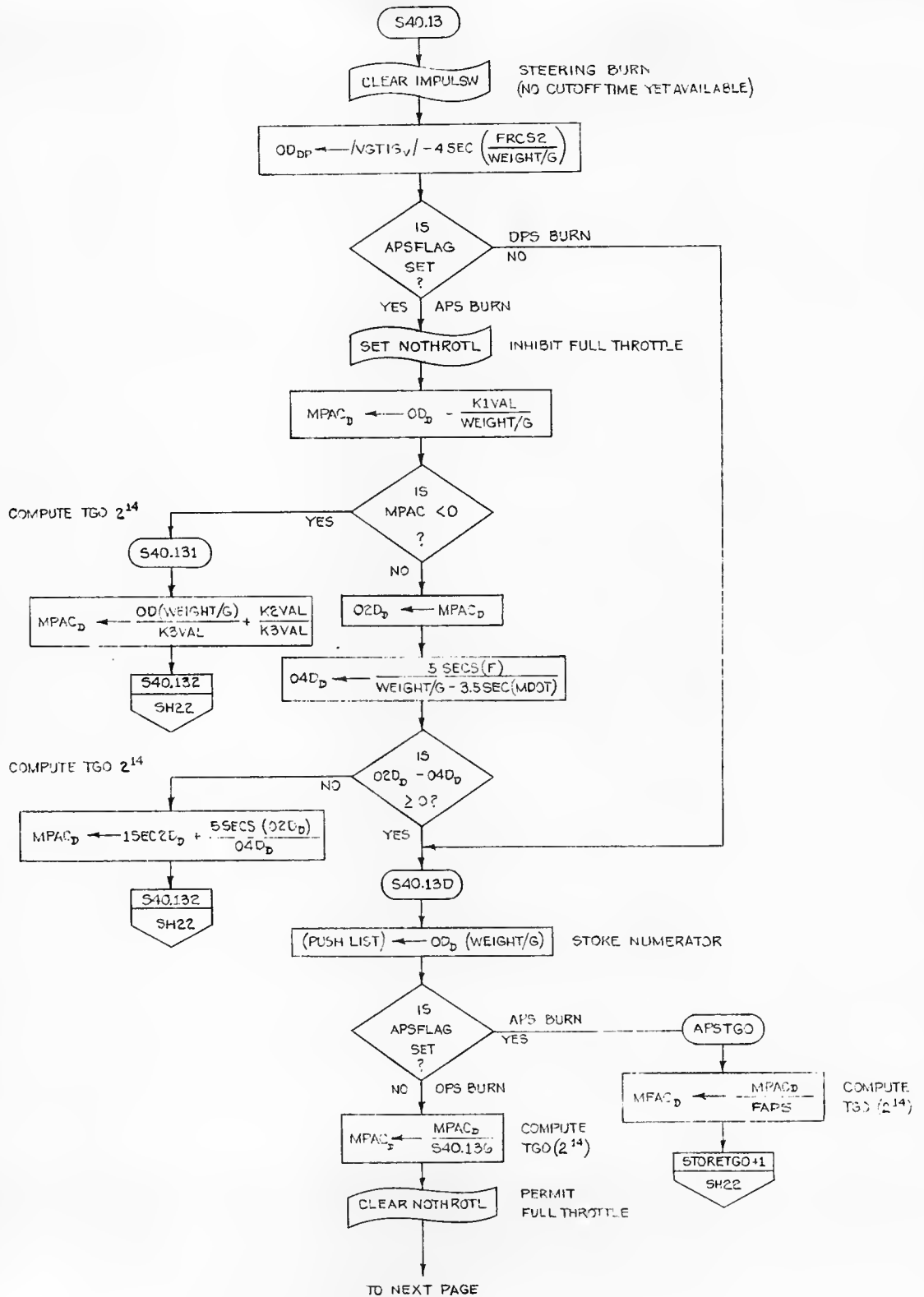
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS 12JUN69		BURN BABY BURN (MASTER IGNITION ROUTINE)	
PROGRAM C. Schulenberg 6 AUG 69		LUMINARY 1D	DOCUMENT NO.
ANALYST		FC-3840	
DOCWR McDaniel 6 AUG 69		REV 3	SHEET 15 OF 25
APPR'D [Signature]			



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS		13 JUN 69	
PRGRM C. Schulenberg		6 AUG 69	
ANALST		LUMINARY 1D	
DOCNR WC Duguid		DOCUMENT NO. FC-3840	
APPR'D <i>Alfred M. Smart</i>		REV 3	
		SHEET 19 OF 25	

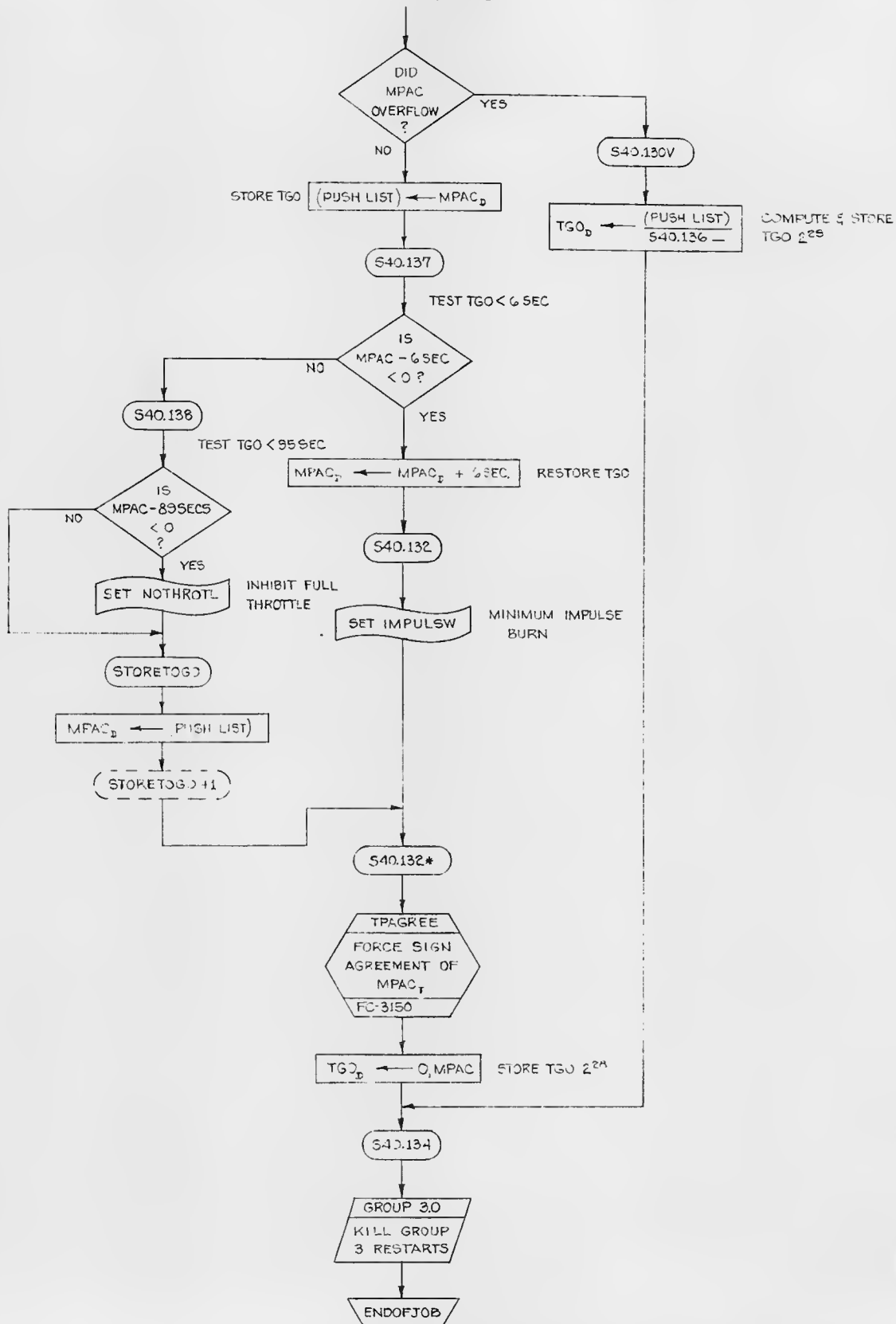


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS 13JUN69		BURN BABY BURN (MASTER IGNITION ROUTINE)	
PROGRAM C. Schulenberg 16 AUG 69	ANALYST	LUMINARY ID	DOCUMENT NO. FC-3840
DOCWR McDiarmid 16 AUG 69	APPR'D <i>William P. ...</i>	REV 3	SHEET 20 OF 25

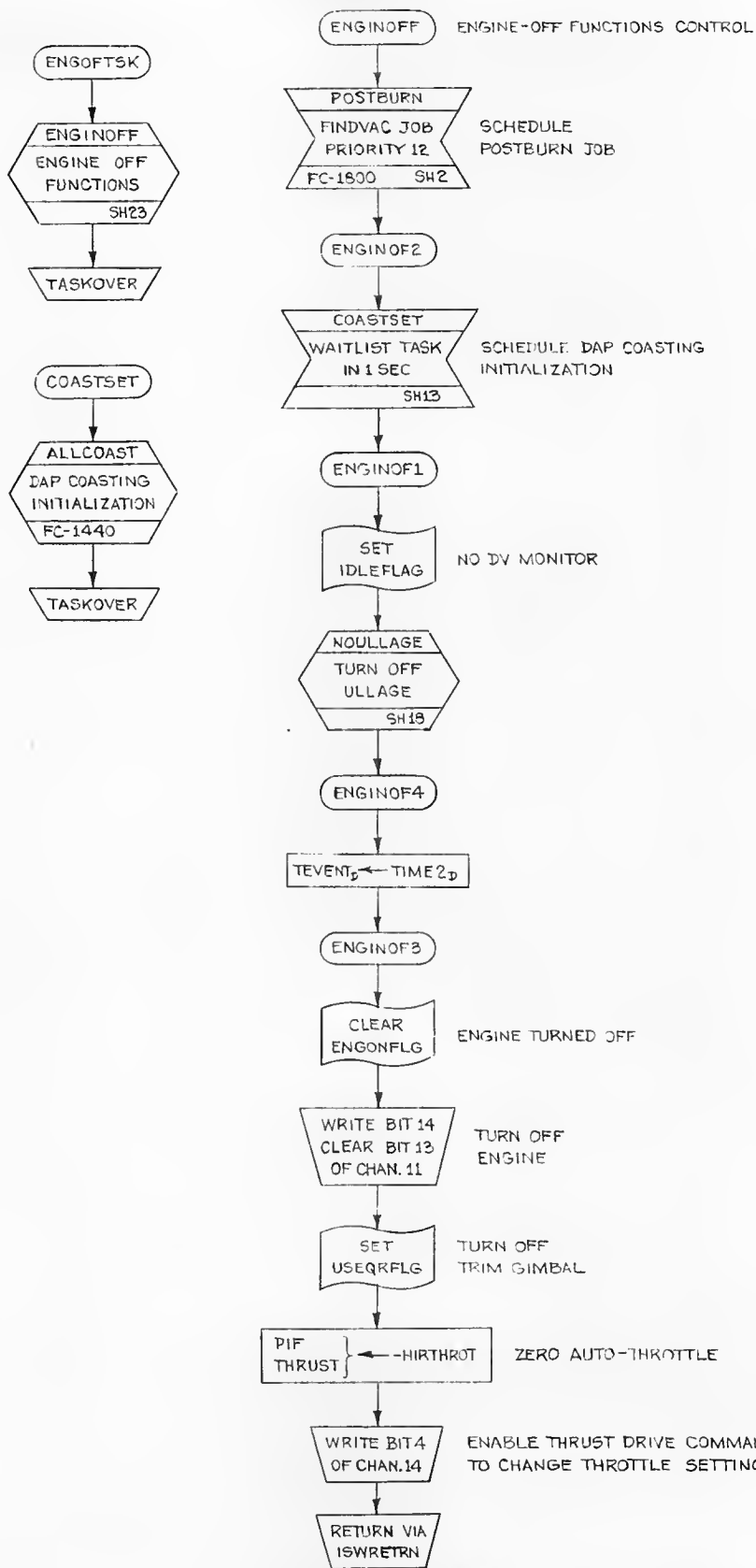


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS 6-28-68		BURN BABY BURN (MASTER IGNITION ROUTINE)	
PROGRAM P. Waller 9 Sept 68	ANALYST P. Waller 11/16/68	LUMINARY ID	DOCUMENT NO. FC-3840
DOCNR 77-C-10000-1-29-68	APPR'D John A. Moore 12/14/68	REV 3	SHEET 21 OF 25

FROM PRECEDING PAGE



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS 7-1-68 PROGRAM <i>P. Collier</i> 7-1-68 ANALYST <i>P. Phillips</i> 7-29-68 DESIGNER <i>John A. Moore</i> 7-29-68 APPROVED <i>John A. Moore</i> 24/10/68		BURN BARY BURN (MASTER IGNITION ROUTINE)	
LUMINARY ID		DOCUMENT NO. FC-3840	
REV 3		SHEET 22 OF 25	



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS		BURN BABY BURN (MASTER IGNITION ROUTINE)	
PROGRAM C. Schulenberg	6 AUG 69	LUMINARY ID	DOCUMENT NO.
ANALYST			FC-3840
DOOR MC	6 AUG 69	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
APFLAG 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	
		BURN BABY BURN (MASTER IGNITION ROUTINE)	
DRAWN <i>E. D. New</i>	17 JULY 68	LUMINARY ID	DOCUMENT NO. FC-3840
PRGMR <i>C. Schusterberg</i>	6 AUG 69		
ANALST			
DOCMR <i>W. C. England</i>	6 AUG 69		
APPR'D <i>Ally</i>	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	
		BURN BABY BURN (MASTER IGNITION ROUTINE)	
DRAWN <i>R. D. Hunt</i>	27 JULY 69	LUMINARY ID	DOCUMENT NO.
PRGRM <i>C. Schulenberg</i>	6 AUG 69		FC-3840
ANALST			
DOCMR <i>J. C. Dyer</i>	6 APR 69		
APPRD <i>Alvin K. ...</i>	10 AUG 69	REV 3	SHEET 25 OF 25

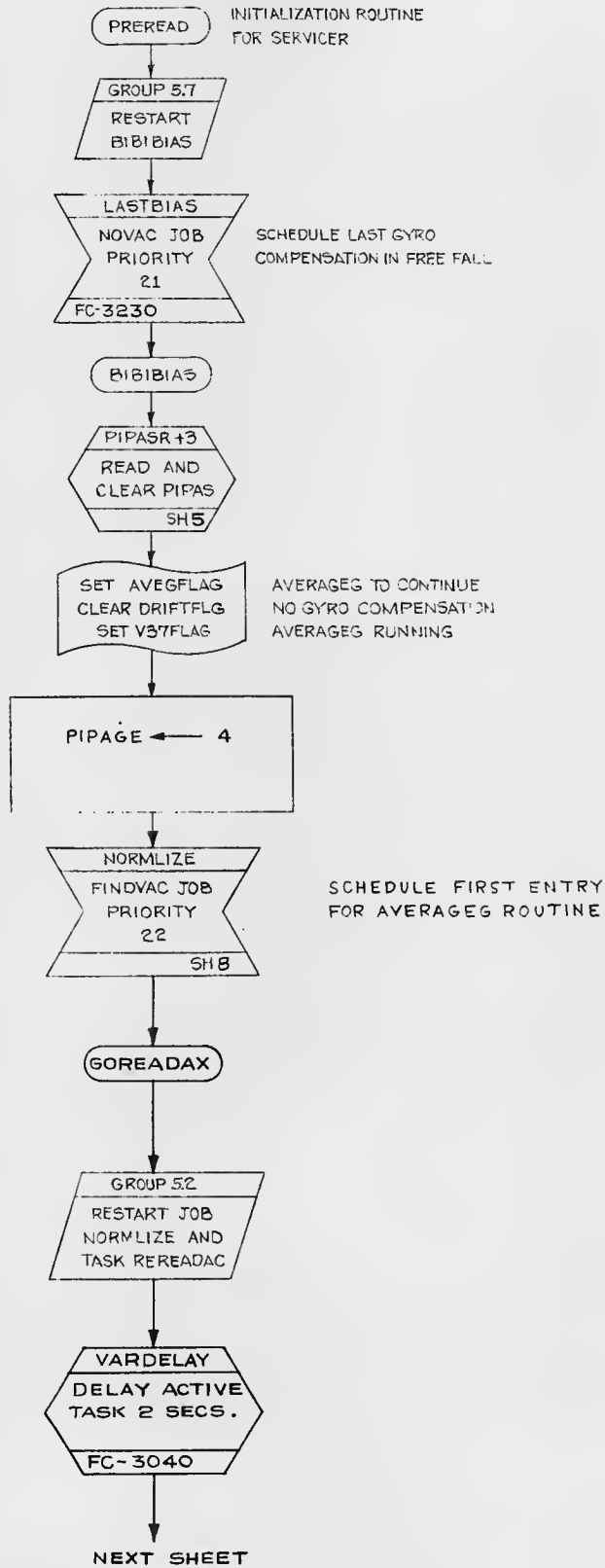
SERVICER

MAJOR SUBROUTINES ON THIS CHART

PREREAD	Sh. 2
PIPASR, PIPASR + 3	Sh. 6
SERVICER	Sh. 9
CALCRVG	Sh. 18
CALCGRAV	Sh. 18
COPYCYC	Sh. 19

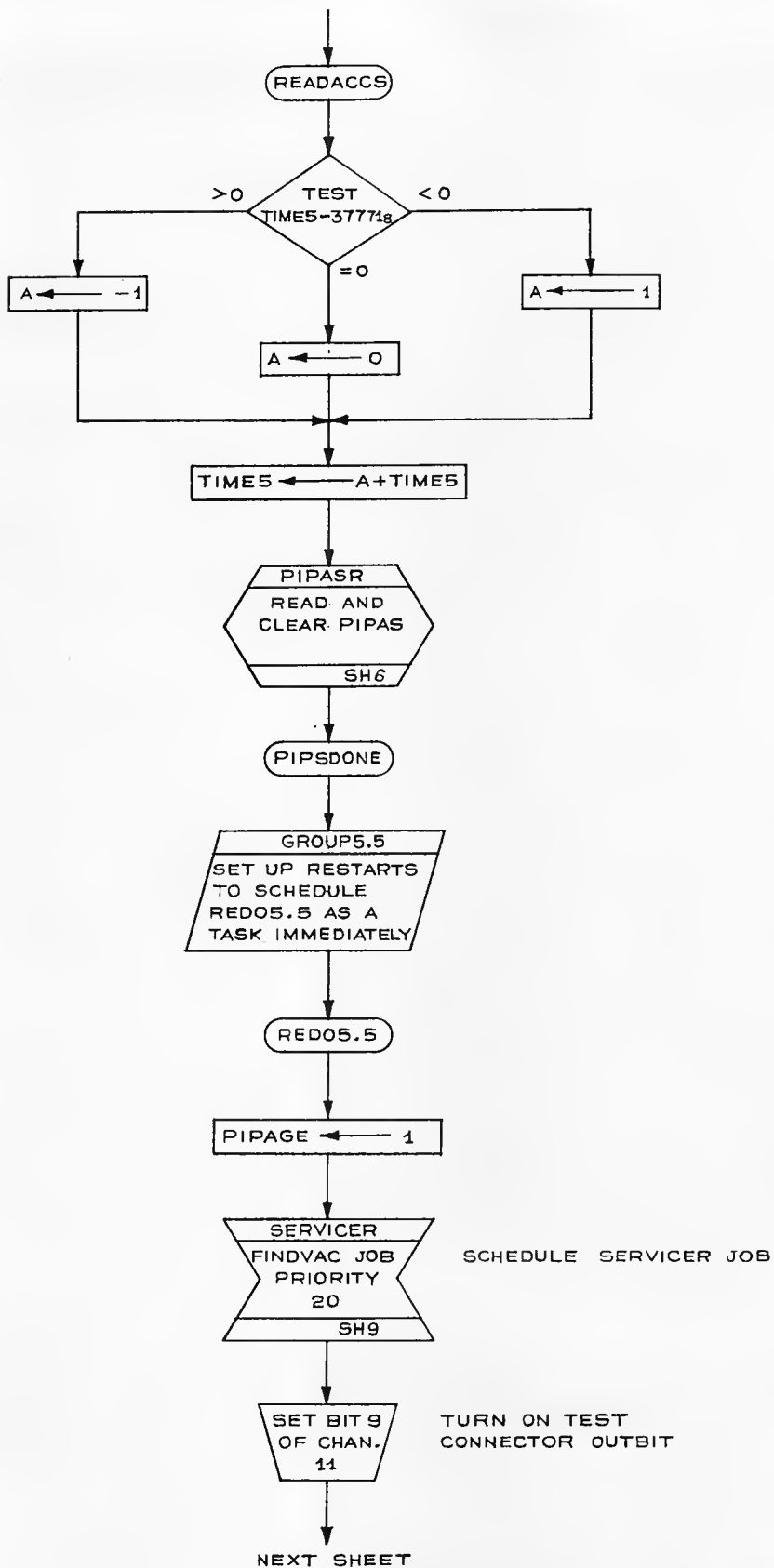
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. Helander</i> 4/24/69		SERVICER	
PRGMR <i>Bruce McKay</i> 4/14/69	ANALST <i>McDonough</i> 9/16/69	LUMINARY 1D	DOCUMENT NO. PC-3850
DOCMR <i>McDonough</i> 9/16/69	APPR'D <i>Robert M. Egan</i> 9-16-69	REV 3	SHEET 1 OF 22

CALLED BY P12, P40, P41, P42, P47, AND P63
THROUGH BURNBABY



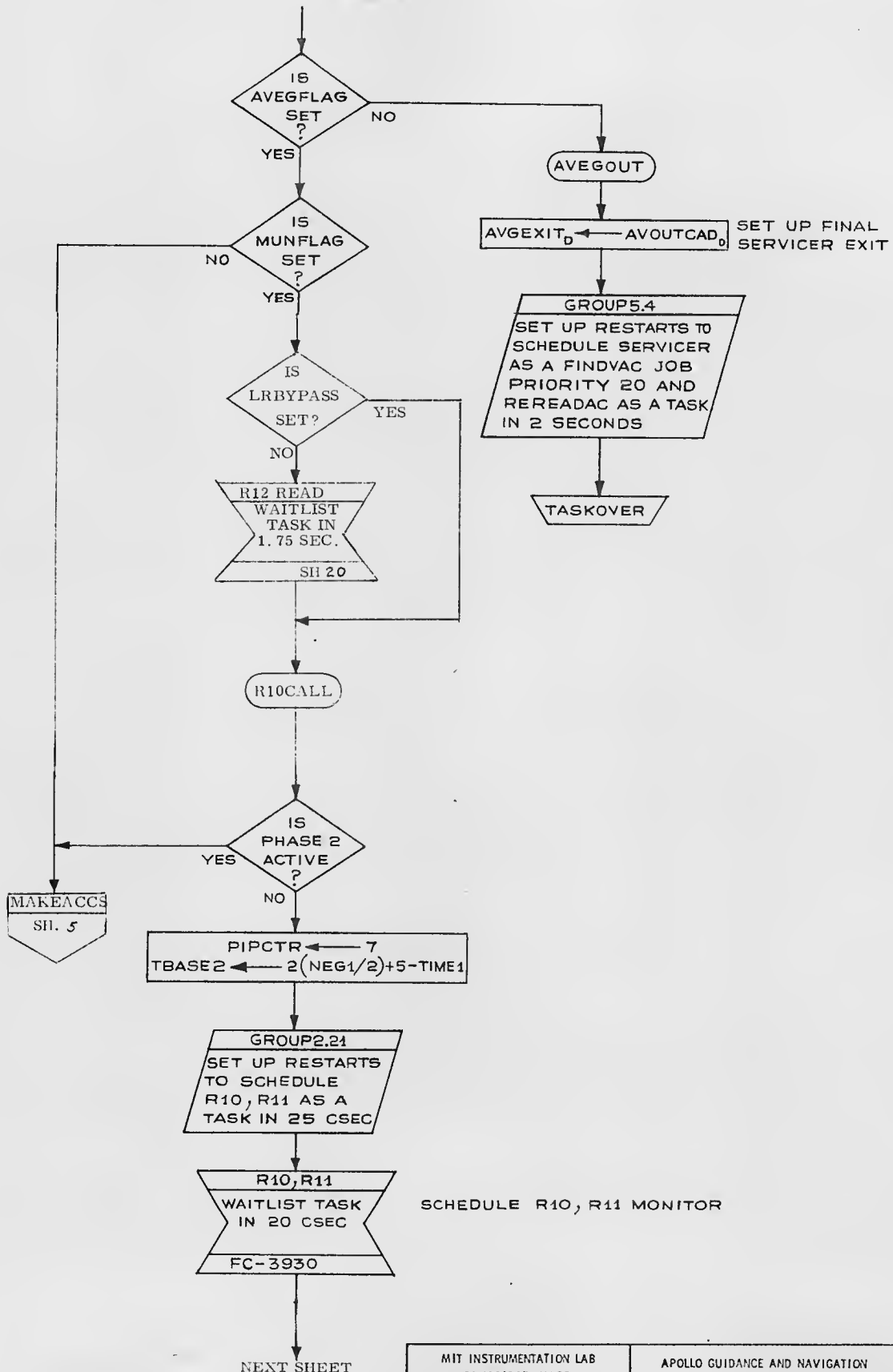
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		SERVICER	
DRAWN A.C. WILLIAMS	6-11-68	LUMINARY ID	DOCUMENT NO. FC-3850
PROGRAM <i>P. Phillips</i>			
ANALYST <i>P. Phillips</i>	Aug 18, 69		
DOCNR <i>M. G. Smith</i>			

FROM PRECEDING SHEET



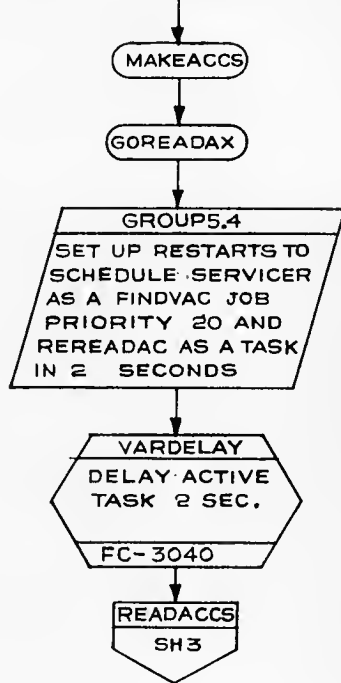
RMT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>P.M. Dietrich</i>		SERVICER	
PROGR <i>C. Schultenberg</i>	LAMAY 69 13 AUG 69	LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3850
DOCNR <i>W.C. Duff</i>	13 AUG 69	REV 3	SHEET 3 OF 24
APPR'D <i>Alexander Sorant</i>	13 AUG 69		

FROM PRECEDING SHEET



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i>		SERVICER	
PRGMR <i>[Signature]</i>	<i>[Date]</i>	LUMINARY 1D	DOCUMENT NO.
ANALST <i>[Signature]</i>	<i>[Date]</i>		FC-3850
DOCMR <i>[Signature]</i>	<i>[Date]</i>	REV 3	SHEET 4 OF 22
APPR'D <i>[Signature]</i>	<i>[Date]</i>		

FROM PRECEDING SHEET



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>P.H. Dittus</i> 15 MAY 68		SERVICER	
PROGR <i>C. Schulenberg</i> 13 AUG 67	ANAL ST	LUMINARY ID	DOCUMENT NO.
DOCMR <i>W.C. Dittus</i> 13 AUG 68	APPR'D <i>W.C. Dittus</i> 30 AUG 68		FC-3850
		REV 3	SHEET 5 OF 22

PIPASR

ROUTINE READS PIPAS AND CDUS

INPUT

PIPAX, PIPAY, PIPAZ
TIME Z, CDUX, CDUY, CDUZ

OUTPUT

DELVX, DELVY, DELVZ,
CDUTEMPX, CDUTEMPY, CDUTEMPZ
PIPATMPX, PIPATMPY, PIPATMPZ

PIPTIME1 ← TIME 2₀

READ TIME =
CURRENT TIME

(PIPASR+3)

TEMX ← -0
TEMY ← -0
TEMZ ← -0

INITIALIZE PIPA STORAGE
AT NEG. ZERO

DELVZ ← 0
DELVY ← 0
DELVX+1 ← 0

TESTED BY REREADAC ROUTINE
IF RESTART OCCURS

PIPAGE ← 0

SHOWS PIPA READING IN PROGRESS

REPIP1

TEMX ← -PIPAX
TEMY ← -PIPAY
DELVX ← PIPAX
DELVY ← PIPAY
PIPAX ← -0
PIPAY ← -0

TEMX AND TEMY TESTED BY
REREADAC IF RESTART OCCURS

READ X AND Y PIPS, THEN
SET TO NEG. ZERO.

$$\Delta \underline{V} = \begin{bmatrix} \text{PIPAX} \\ \text{PIPAY} \\ \text{PIPAZ} \end{bmatrix}$$

REPIP3

TEMZ ← -PIPAZ
A ← PIPAZ
PIPAZ ← -0

TEMZ TESTED BY REREADAC
ROUTINE IF RESTART OCCURS.
TRANSFER Z PIP TO A REG, SET
PIPAZ TO NEG. ZERO.

WHERE

$$\text{PIPAX} = \int_0^z a_x dt$$
$$\text{PIPAY} = \int_0^z a_y dt$$
$$\text{PIPAZ} = \int_0^z a_z dt$$

DODELVZ

DELVZ ← A

REPIP4

PGUIDE_D ← PIPTIME1_D - PIPTIME₀

CDUTEMPX ← CDUX
CDUTEMPY ← CDUY
CDUTEMPZ ← CDUZ

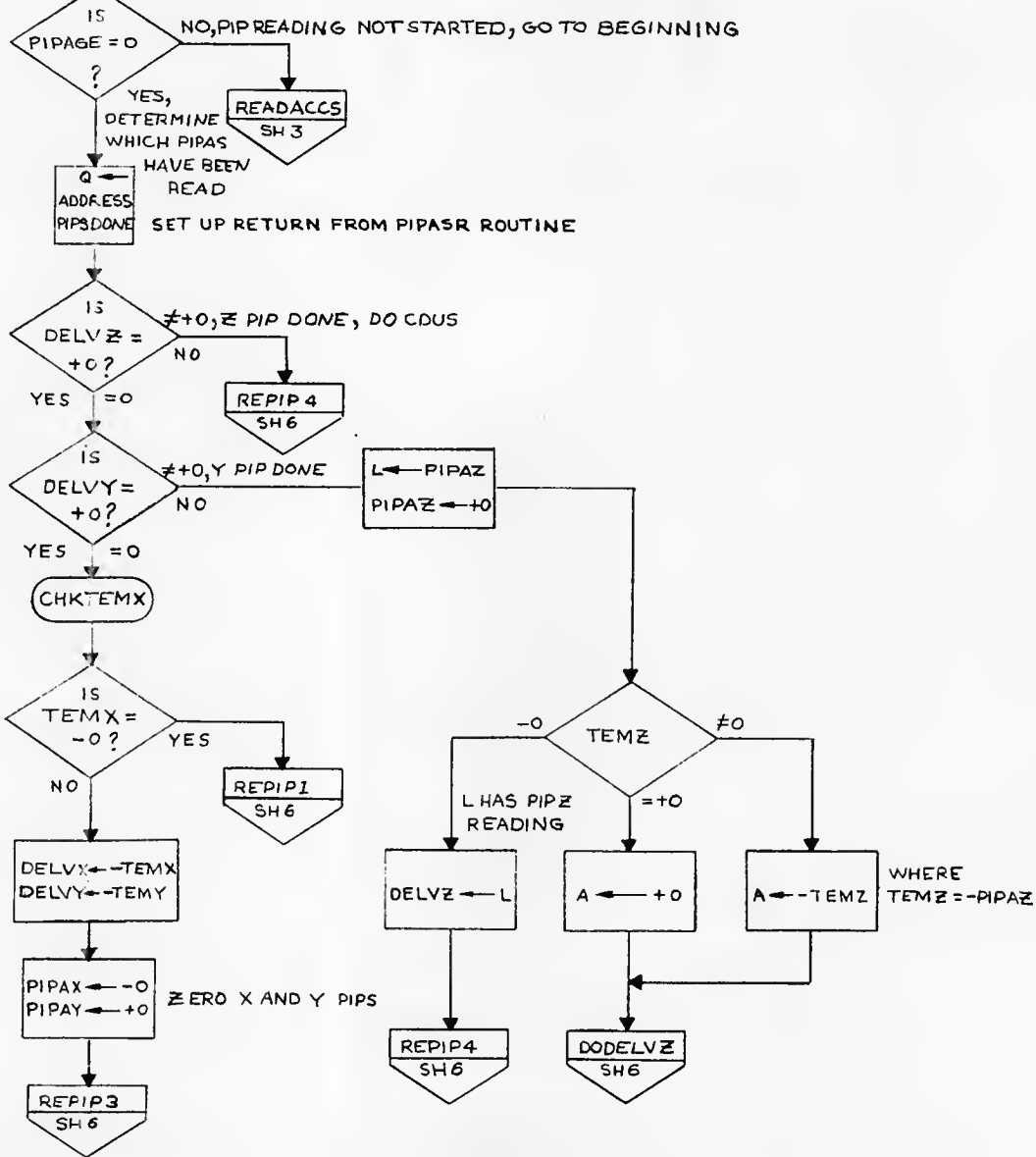
READ CDUS INTO HIGH
ORDER CDUTEMPS

PIPATMPX ← DELVX
PIPATMPY ← DELVY
PIPATMPZ ← DELVZ

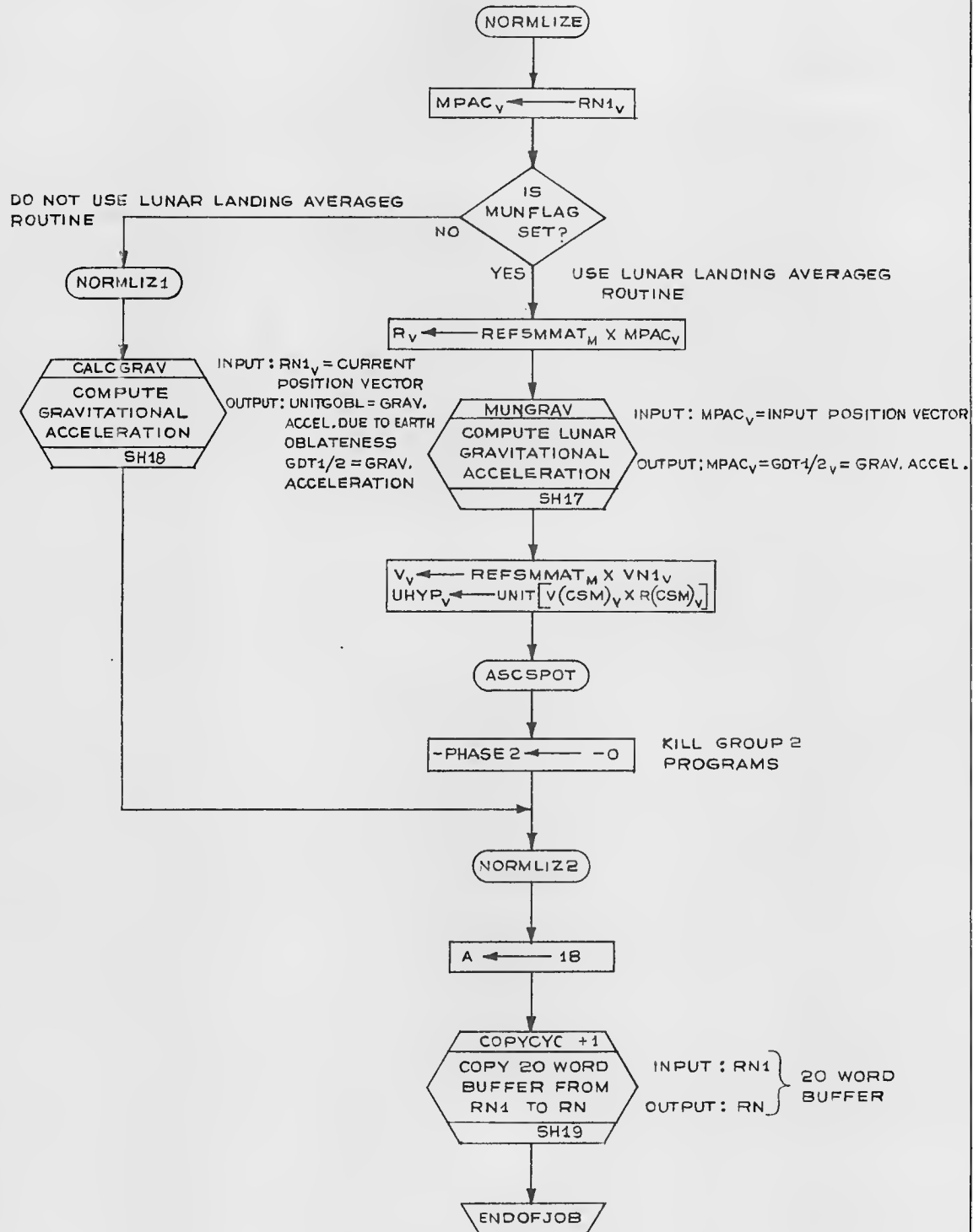
RETURN
VIA Q

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		SERVICER	
DRAWN <i>C. J. Smith</i>	25 JUL 68	LUMINARY ID	DOCUMENT NO. FC-3850
PROGRM <i>J. R. Smith</i>			
ANALST <i>J. R. Smith</i>			
DOGRM <i>J. R. Smith</i>			
APPR'D <i>John A. Murn</i>	24 JAN 69	REV 3	SHEET 6 OF 22

REREADAC ROUTINE REREADS PIPAS AND CDUS IF RESTART OCCURS



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		SERVICER	
DRAWN <i>G. J. ...</i>	25 JUL 68	LUMINARY ID	DOCUMENT NO. FC-3850
PRGMR <i>R. P. ...</i>	7 AUG 68		
ANALST <i>P. ...</i>	20 JUL 68	REV 3	SHEET 1 OF 22
DOCHR <i>M. C. ...</i>	27 JUL 68		
APPR'D <i>John A. ...</i>	24 JUL 69		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		SERVICER	
DRAWN <i>D.M. Dietrich</i>	21 MAY 68	LUMINARY ID	DOCUMENT NO.
PRGRM <i>C. Schulenberg</i>	18 AUG 69		FC-3850
ANALST			
DOCNR <i>MC-100</i>	13 AUG 69		
APPR'D <i>William W. Strand</i>	GA 1003	REV 3	SHEET 8 OF 22

SERVICER

UPDATES STATE VECTOR AND MASS OF LM

GROUP 5.3
RESTART TASK
REREADAC
IN 2 SEC.

GROUP 5
RESTART JOB
GETABVAL
WITH PRIORITY 20

1/PIPADT ← PRI031

1/PIPA
DO PIPA
COMPENSATION
FC-3230

GETABVAL

$ABDELV \leftarrow \frac{DELV_v}{Q}$
 $ABDVCONV_D \leftarrow KPIP(\frac{DELV_v}{Q})$
 $MASS1_D \leftarrow MASS_D$

MASSMON

IS
SURFFLAG
SET?

TEST LM ON
LUNAR SURFACE

YES

MOONSPOT
SH10

NO

TEST APS BURN

IS
APSFLAG
SET?

YES

Q ← APSVEX

NO (DPS BURN)

Q ← DPSVEX

$MASS1_D \leftarrow \frac{ABDVCONV_D}{Q} \cdot MASS + MASS1_D$

NEXT SHEET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		SERVICER	
DRAWN A.C. WILLIAMS	6-12-65	LUMINARY ID	DOCUMENT NO.
PROGRM P. Cavella	8-7-68		FC-3850
ANALST W. Phillips	10/6-69	REV 3	SHEET 9 OF 22
DOCMR W. Phillips	6-24-68		
APPR'D John A. Moore	24 JAN 69		

FROM PRECEDING SHEET

MOONSPOT

$$DVTOTAL_D \leftarrow DVTOTAL_D + KPIP1(ABDELV_D)$$

TMPT06PT
LOAD CDUS
CORRESPONDING TO
PIPTIME INTO
CDUSPOT VECTOR
SH19

QUICTRIG
COMPUTE
SINES & COSINES
OF CDU ANGLES
FC-3320

INPUT: CDU VALUES IN CDUSPOT_V
OUTPUT: SINES & COSINES OF CDU ANGLES

A ←
XNBPIPAD

LOAD A WITH ADDRESS OF
BUFFER FOR FLESHPOT ROUTINE

FLESHPOT

SUBROUTINE TO FORM
XNBPIP_V, YNBPIP_V, ZNBPIP_V

XNBPIP_V ← $\begin{cases} \text{COSCDUY} \text{ COSCDUZ}, \\ \text{SINCDUZ}, \\ - \text{SINCDUY} \text{ COSCDUX} \end{cases}$

ZNBPIP_V ← $\begin{cases} \text{COSCDUY} \text{ SINCDUX} \text{ SINCDUZ} + \text{COSCDUX} \text{ SINCDUY}, \\ - \text{SINCDUX} \text{ COSCDUZ}, \\ \text{COSCDUX} \text{ COSCDUY} - \text{SINCDUX} \text{ SINCDUY} \text{ SINCDUZ} \end{cases}$

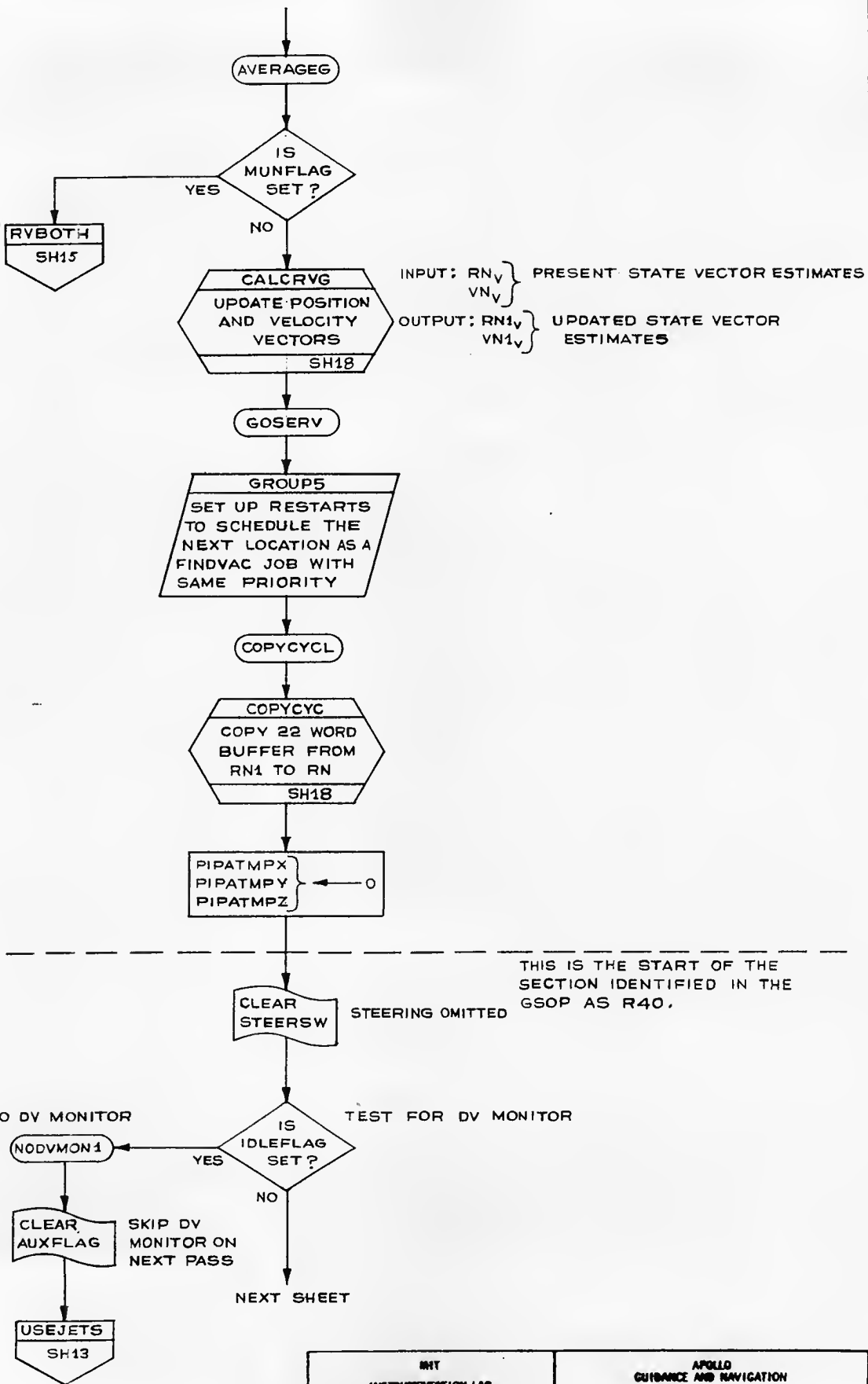
YNBPIP_V ← $(ZNBPIP_V) \times (XNBPIP_V)$

RETURN VIA
SWRETURN

NEXT SHEET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		SERVICER	
DRAWN A.C. WILLIAMS	6-14-68	LUMINARY ID	DOCUMENT NO. FC-3850
PROMR <i>[Signature]</i>	8-7-68		
ANALST <i>[Signature]</i>	10-24-68	SHEET 10 OF 22	
DOCNR <i>[Signature]</i>	6-24-66		
APPR'D <i>[Signature]</i>	10-11-68	REV	

FROM PRECEIOING SHEET



THIS IS THE START OF THE SECTION IDENTIFIED IN THE GSOP AS R40.

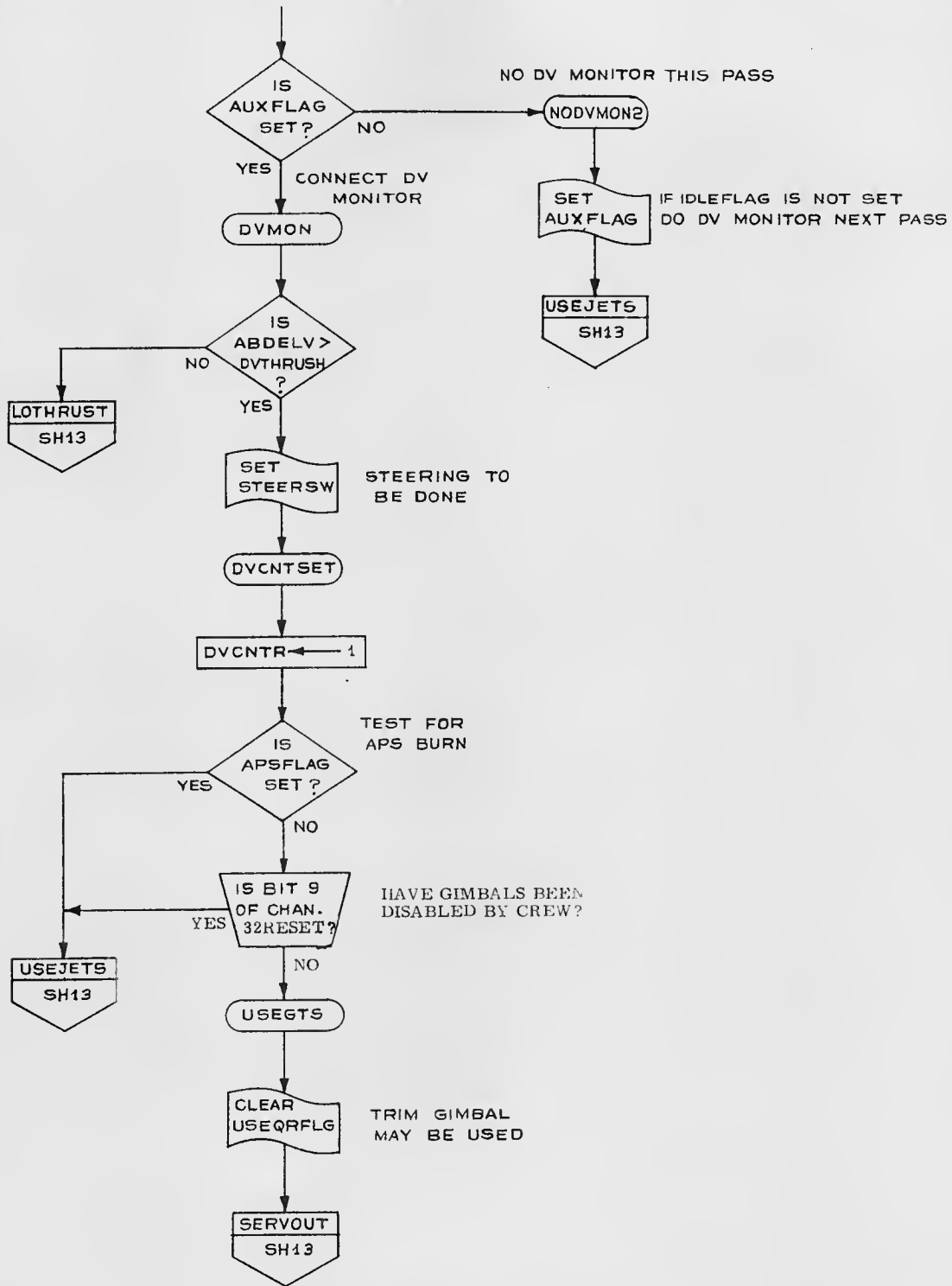
STEERING OMITTED

TEST FOR DV MONITOR

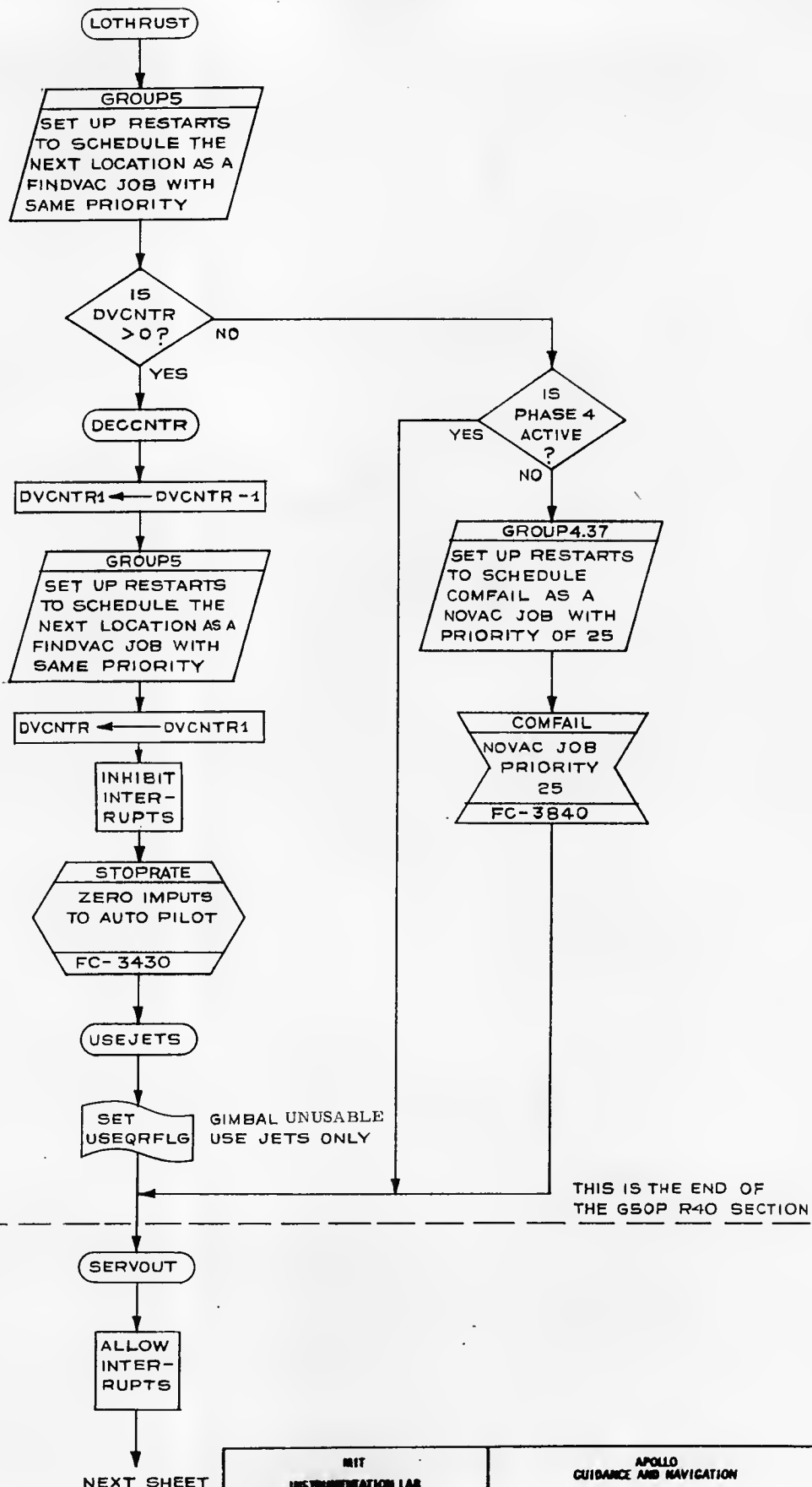
SKIP DV MONITOR ON NEXT PASS

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>P. M. Nielsen</i> 21 MAY 68		SERVICER	
PROGRM <i>A. Schultenberg</i> 13 AUG 67	ANALST	LUMINARY 1D	DOCUMENT NO.
DOCNR <i>WP Design</i> 13 AUG 67	APPR'D <i>W. J. Sandberg</i> 13 AUG 68	REV 3	FC-3850
			SHEET 11 OF 22

FROM PRECEDING SHEET



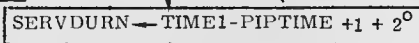
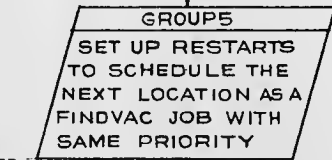
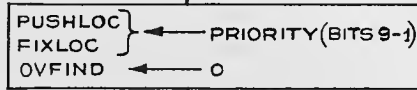
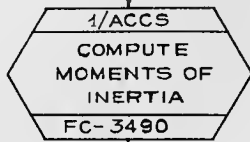
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		SERVICER	
DRAWN <i>P.M. Dietrich</i>	22 MAY 68	LUMINARY ID	DOCUMENT NO.
PRGRM <i>C. Schulenberg</i>	13 AUG 69		FC-3850
ANALST			
DOCTR <i>MC Dietrich</i>	13 AUG 69		
APPR'D <i>Alena 44</i>	13 AUG 69	REV 3	SHEET 12 OF 22



NEXT SHEET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN: <i>P.M. Dietrich</i>		SERVICER	
PROGRAM: <i>C. Schulenberg</i>	DATE: <i>18 AUG 69</i>	LUMINARY 1D	DOCUMENT NO. FC-3850
ANALYST:			
DOCWR: <i>W.C. Doyle</i>	DATE: <i>18 AUG 69</i>		
APPROVED: <i>Alley</i>	REV: <i>3</i>		SHEET 13 OF 22

FROM PRECEDING SHEET



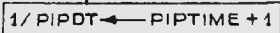
GO TO ROUTINE SPECIFIED IN AVGEXIT

(AVGEXIT = AVEGEXIT)

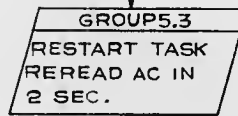
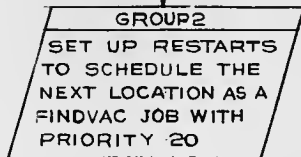
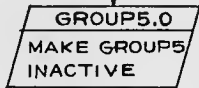
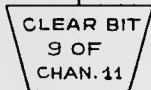
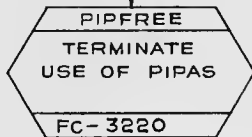
AVGENG	FC-3850
CALCN83	FC-3830
CALCN85	FC-3810
SERVEXIT	FC-3850
STEERING	FC-3820
LUNLAND	FC-3940
ATMAG	FC-3980
P63016PS-2	FC-3900

FINAL AVERAGE EXIT (END OF POWERED FLIGHT SET UP FOR FREE FALL)

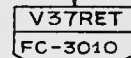
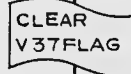
SET UP FREE FALL GYRO COMPENSATION



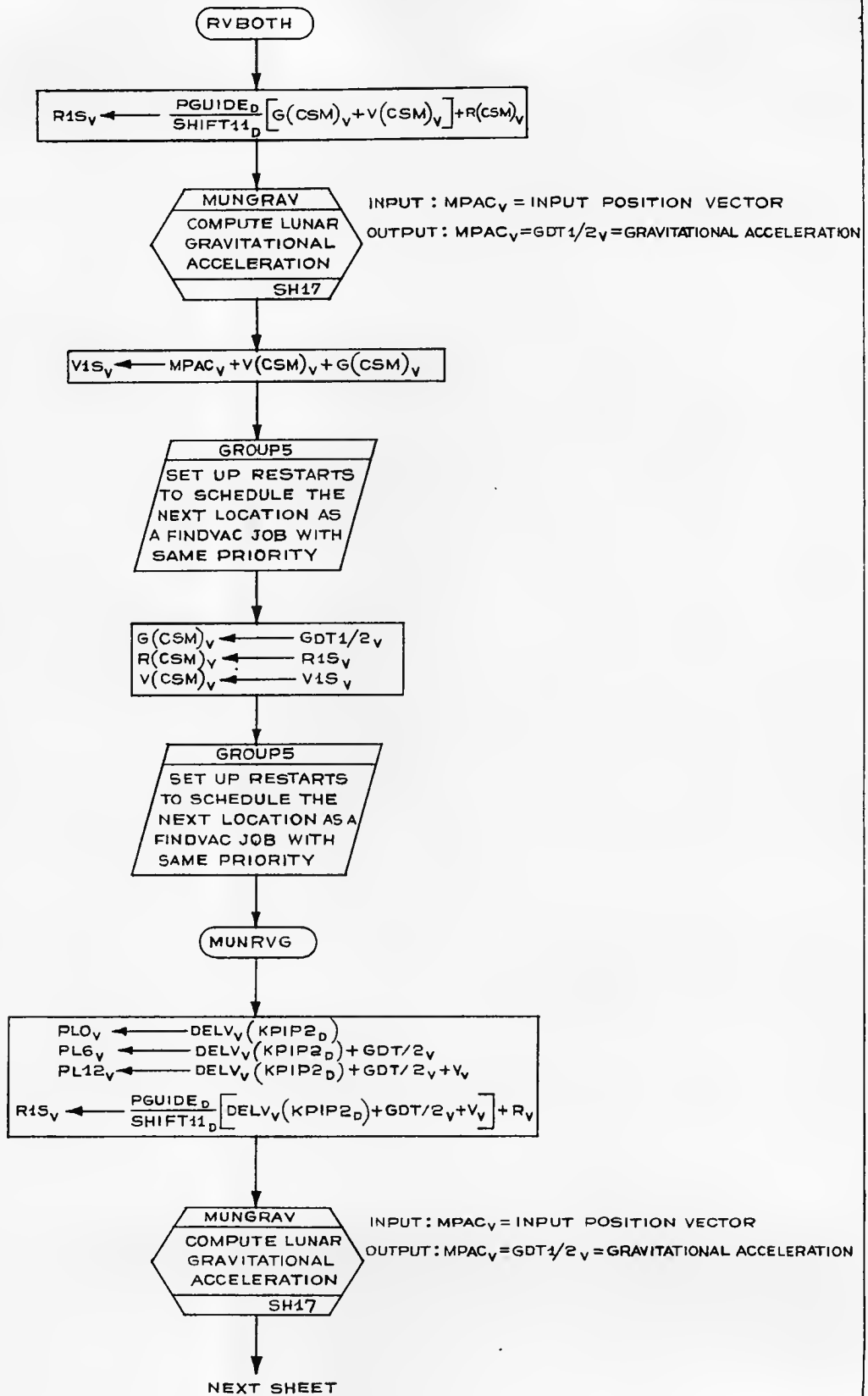
T3RUPT CALLS GYRO COMPENSATION



PERFORM TRANSITION FROM THRUSTING PHASE TO COASTING PHASE



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>P.M. Dietrich</i> 22 MAY 68		SERVICER	
PROGR <i>C. Schulenberg</i> 13 AUG 68		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3850
DOCMR <i>W.D. Dugan</i> 13 NOV 69		SHEET 14 OF 22	REV 3
APPRD <i>Alvin M. ...</i> 13 NOV 69			



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS		APOLLO GUIDANCE AND NAVIGATION	
		SERVICER	
DRAWN	PROGRAM	ANALYST	DOCUMENT NO.
<i>DM. Diab...</i>	<i>C. Schulenberg</i>	<i>W.C. ...</i>	FC-3850
DOCNR	APPROV	LUMINARY ID	SHEET 15 OF 22
<i>W.C. ...</i>	<i>W.C. ...</i>		REV 3

FROM PRECEDING SHEET

$$\begin{aligned} V1S_V &\leftarrow MPAC_V + PL6_V + PLO_V + V_V \\ ABVEL_D &\leftarrow /V1S_V/ \\ HDOTDISP_D &\leftarrow UNIT/R_V \cdot V1S_V \\ DELVS_V &\leftarrow (R1S_V \times WM_V) \times 4 \\ HCALC_D &\leftarrow /R1S_V/ - /LAND/D \end{aligned}$$

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	
		SERVICER	
DRAWN <i>P. M. D. J.</i>	23 MAY 69	LUMINARY 1D	DOCUMENT NO. FC-3850
PROGR <i>C. Schulenberg</i>	13 AUG 69		
ANALST			
DOCMR <i>W. C. D. J.</i>	13 AUG 69		
APPRD <i>Alvin M. ...</i>	13 AUG 69	REV 3	SHEET 18 OF 22

FROM PRECEDING SHEET

$PLO_D \leftarrow /R1S_V/$
 $HCALC_D \leftarrow /R1S_V/-/LAND/D$
 $ALTBITS_D \leftarrow ALTCONV_D(HCALC_D)$
 $UHZP_V \leftarrow UNIT/R_V \times UHYP_V$
 $RN1_V \leftarrow R1S_V(REFSMMAT_M)$
 $VN1_V \leftarrow V1S_V(REFSMMAT_M)$
 $MPAC_D \leftarrow ARCONV1_D \left(\frac{/UNIT/R_V \times V1S_V/}{/R1S_V/} \right)^2$

COPYCYC2

INHIBIT
INTER-
RUPTS

$RUNIT \leftarrow UNIT/R/$
 $RUNIT + 1 \leftarrow UNIT/R/ + 2$
 $RUNIT + 2 \leftarrow UNIT/R/ + 4$
 $DALTRATE \leftarrow MPAC$
 $R_V \leftarrow R1S_V$
 $V_V \leftarrow V1S_V$

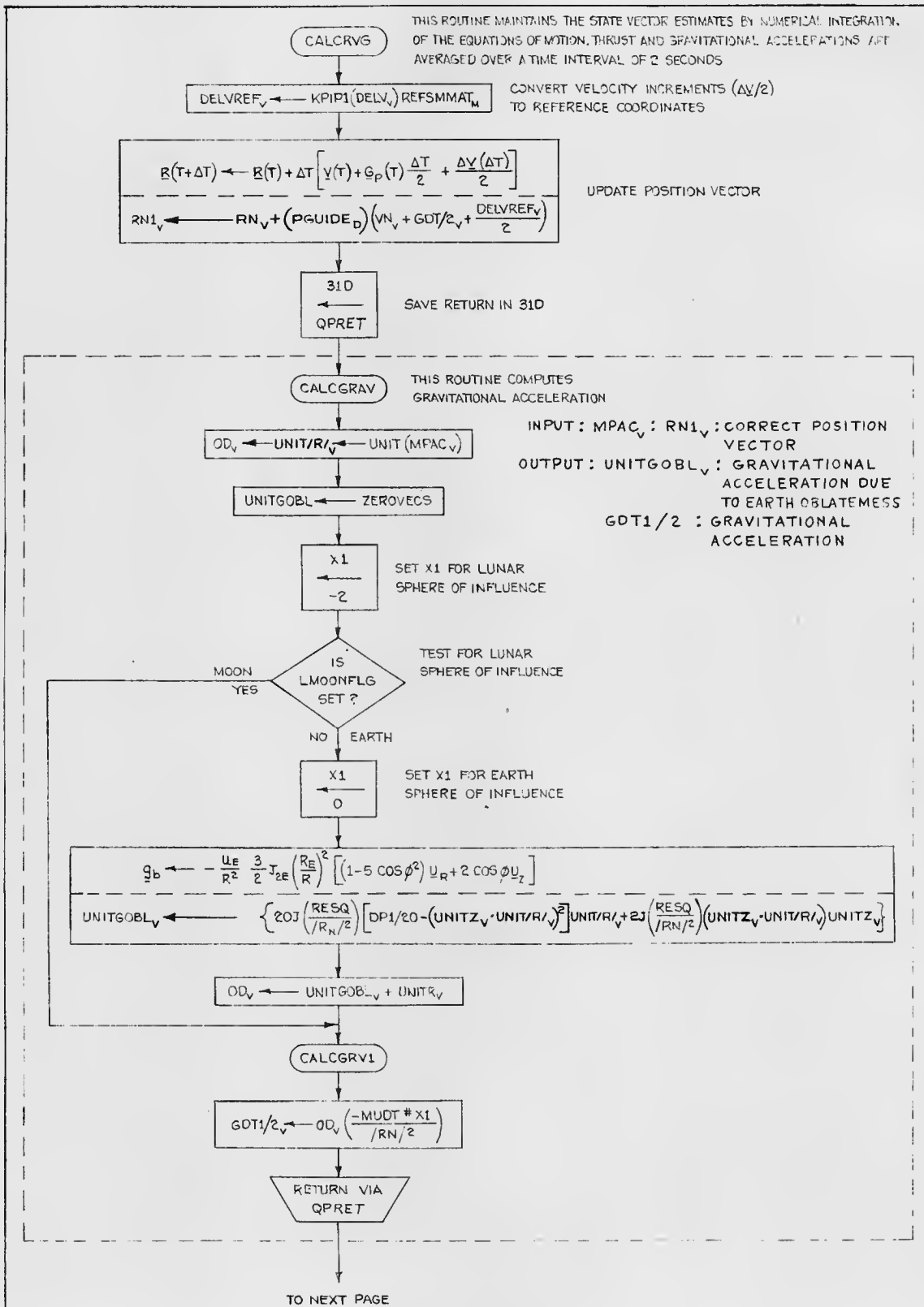
COPYCYCL
SH11

MUNGRAV

$UNIT/R_V \leftarrow UNIT(MPAC_V)$
 $GDT1/2_V \leftarrow UNIT/R_V \left(\frac{-MUDTMUN_D}{/MPAC_V/} SHIFT11 \right)$

RETURN VIA
QPRET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		SERVICER	
DRAWN <i>D.M. Smith</i>	23 MAY 65	LUMINARY 1D	DOCUMENT NO. FC-3850
PROGRAM <i>C. Schulenberg</i>	13 AUG 67		
ANALYST			
DOCWR <i>W.C. Douglas</i>	13 AUG 67		
APPR <i>W.C. Douglas</i>		REV 3	SHEET 17 OF 22



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		SERVICER	
DRAWN A.C.WILLIAMS	6-18-68	LUMINARY 1D	DOCUMENT NO. FC-3850
PROGRAM R. Correll	8-7-68		
ANALYST P. Williams	10/24/68		
DOCNR M. D. ...	6-24-68		
APPR'D John A. Moran	24 JAN 69	REV 3	SHEET 18 OF 22

FROM PRECEDING PAGE

$$\begin{aligned} \underline{v}(T+\Delta T) &\leftarrow \underline{v}(T) + \frac{\Delta T}{2} [g(T+\Delta T) + g_b(T)] + \Delta \underline{v}(\Delta T) \\ VN1_v &\leftarrow VN_v + GDT1/2_v + GDT/2_v + DELVREF_v \end{aligned}$$

UPDATE VELOCITY VECTOR

RETURN VIA
31D

TMPTOSPT

SUBROUTINE TO LOAD CDUS CORRESPONDING
TO FIPTIME INTO CDUSPOT VECTOR

$$\begin{aligned} CDUSPOTY &\leftarrow CDUTEMPY \\ CDUSPOTZ &\leftarrow CDUTEMPZ \\ CDUSPOTX &\leftarrow CDUTEMPX \end{aligned}$$

RETURN VIA
DANZIG

COPYCYC

SUBROUTINE TO COPY 22 WORD BUFFER
FROM RN1 TO RN

A ← 20

(COPYCYC + 1)

INHIBIT
INTER-
RUPTS

(COPYCYC + 2)

ITEMP1 ← A(BITS 15-2)

MAKE ITEMP1 AN
EVEN NUMBER

DECREMENT
ITEMP1

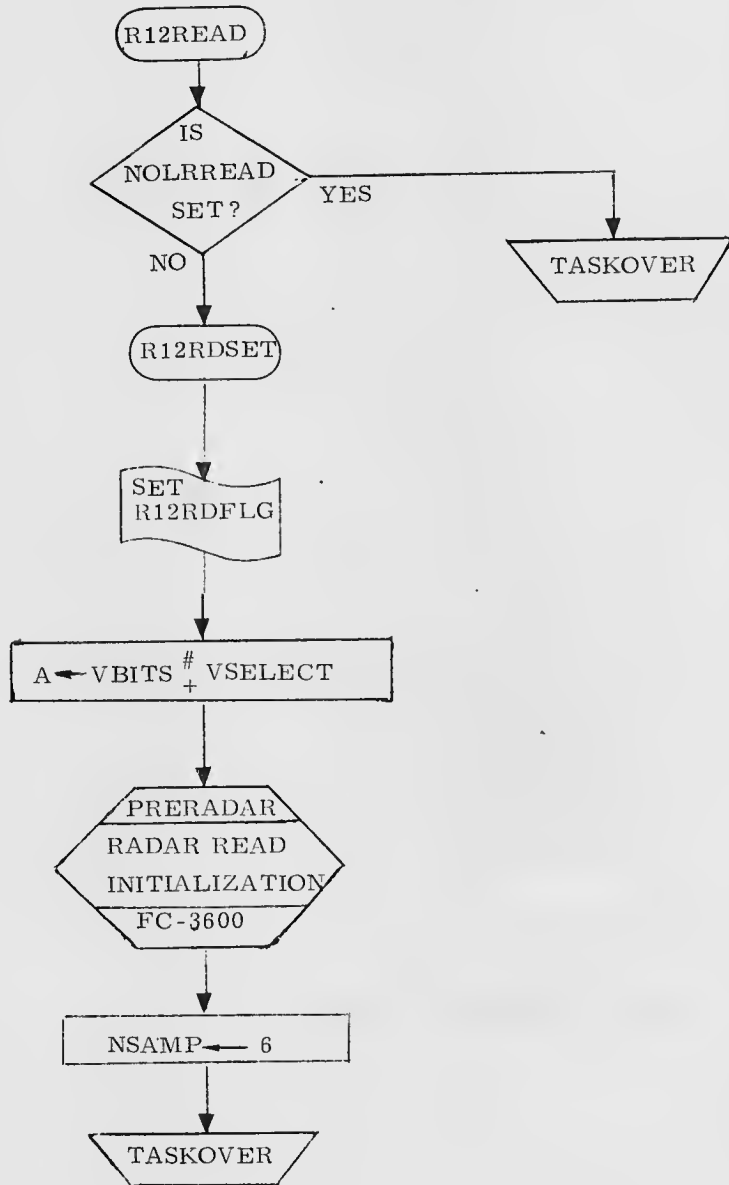
ITEMP1 ← ITEMP1-1

RN_D# ITEMP1 ← RN1_D# ITEMP1

IS
ITEMP1 = 0
?

RETURN
VIA Q

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		SERVICER	
DRAWN	A.C. WILLIAMS	6-18-68	LUMINARY 1D
PROWR	<i>R. Conell</i>	8-7-68	
ANALST	<i>R. Conell</i>	11-20-68	
DOCMR	<i>M. J. Smith</i>	6-24-68	
APPR'D	<i>John A. Moore</i>	24/11/68	REV 3
			DOCUMENT NO. FC-3850
			SHEET 19 OF 22



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>E. Matta</i>	<i>8/2/70</i>	SERVICER	
PRGMR <i>D. M. King</i>	<i>6/7/70</i>	LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3850
DOCMR <i>M. D. ...</i>	<i>6/5/70</i>	REV 3	SHEET 20 OF 22
APPR'D <i>G. M. ...</i>	<i>6/10/70</i>		

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 ⁻²⁰
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	
SERVICER			
DRAWN <i>R. H. Hart</i>	4 Feb 69	LUMINARY ID	DOCUMENT NO. FC-3850
PROGR <i>C. Schulenberg</i>	14 Feb 69		
ANALST			
DOCR <i>MC</i>	19 Nov 69		
APPR <i>W. J. ...</i>	19 Nov 69	REV 3	SHEET 21 OF 22

FLAGS

NAME	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
APSF 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
AVERFLAG FLAG 7 BIT 5	AVERAGEG (SERVICER) DESIRED	AVERAGEG (SERVICER) NOT DESIRED	SH. 2		SH. 4
DRIFTFLAG 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
NO129FLG 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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
SERVICER			
DESIGNED <i>L. R. Shick</i>	11/24/69	LUMINARY 1D	DOCUMENT NO. FC-3850
PROGRAMMED <i>P. Schulenberg</i>	13 AUG 69		
APPROVED <i>me [signature]</i>	13 AUG 69	REV 3	SHEET 22 OF 22

LUNAR LANDING

MAJOR SUBROUTINES ON THIS CHART

P63LM	LUNAR LANDING BRAKING PHASE	SH 2
GUILDRET	GUIDANCE ENTRY FROM R13 ROUTINE	SH 5
P63DISPS	P63 DISPLAY ROUTINE ENTRY	SH 27
FLATOUT	FULL THROTTLE ON DPS ENGINE	SH 39
P66		SH 45

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		Lunar Landing	
DRAWN	<i>J. Sullivan</i> 11/24/69	LUMINARY 1D	DOCUMENT NO.
PRGMR	<i>[Signature]</i> 11-25-69		FC-3900
ANALST			
DOCMR	<i>W. Danforth</i> 7/30/69		
APPR'D	<i>Robert M. Foster</i> 11/25/69	REV 2	SHEET 1 OF 52

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 ← DPS THRS
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 <i>D. L. ...</i> 9/20/68		Lunar Landing	
PRGMR		LUMINARY 1D	DOCUMENT NO. FC-3900
ANALST			
DOCMR <i>W. ...</i>	9/30/69		
APPR'D <i>Robert M. ...</i>	11/25/69	REV 2	SHEET 2 OF 52

From Preceding Sheet

IGNALG

Set
PUSHLIST
to zero

$PL0_V \leftarrow RLS_V$
 $PL6_D \leftarrow TLAND_D$
 $TPIP_D \leftarrow TLAND_D$

Landing site vector
 Estimated time of landing

RP-TO-R
 Transform from
 planetary to
 basic ref. system
 FC-3340

Inputs: MPAC \neq 0 for moon
 $PL0_V = RP$ vector
 $PL6_D = Time$
 Output: MPAC $_V = R$ vector

$LAND_V \leftarrow REFSMMAT_M(MPAC_V)$

GUIDINIT
 Initialize
 WM_V and
 $/LAND/ _D$
 FC-3950

Outputs: $WM_V = Lunar$ rotation vector
 $/LAND/ _D = Lunar$ radius at
 landing site

$TDEC1_D \leftarrow TLAND_D - GUIDDURN_D$

Initial estimate of full-thrust-
 position time

LEMPREC
 Integrate LM
 state vector to
 $TDEC1_D$ time
 FC-3350

Inputs: $TDEC1_D$, LM state vector
 Outputs: $RATT_V = LM$ position vector
 $VATT_V = LM$ velocity vector
 $TAT_D = Time$

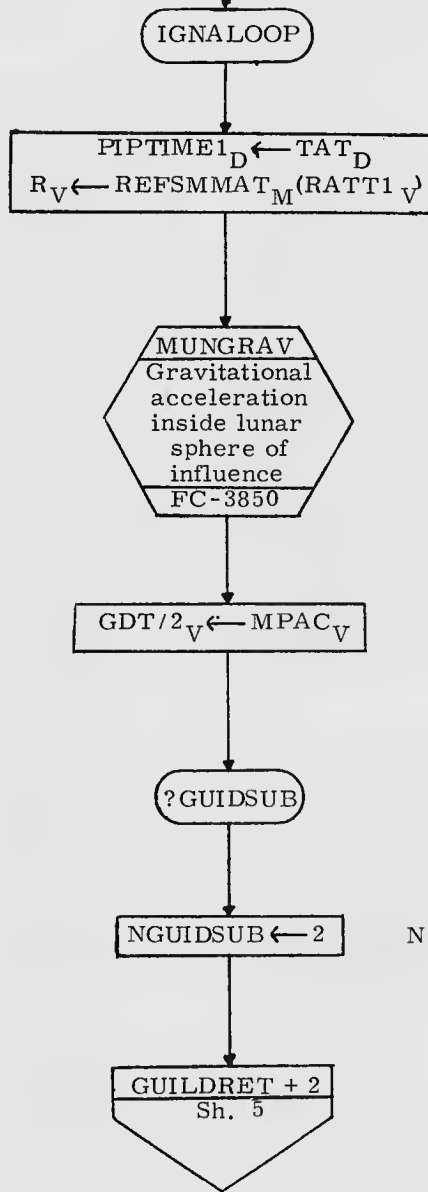
$NIGNLOOP \leftarrow PL40$
 $UNITX_V$
 $CG_M \leftarrow \begin{cases} UNITY_V \\ UNITZ_V \end{cases}$
 $DELTAH_D \leftarrow 99999CON_D$
 $UNFC / 2_V \leftarrow 0$
 $TTF / 8_D \leftarrow 0$
 $HLROFF_D \leftarrow HLROFFD_D$

Initialize for V16N68 display
 Initialize trim velocity correction term
 LR Cutoff Altitude

Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Lutz</i>	<i>9/22/69</i>	Lunar Landing	
PRGMR		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3900
DOCMR <i>M. Smith</i>	<i>9/30/69</i>	REV 2	SHEET 3 OF 52
APPR'D <i>R. E. Smith</i>	<i>11/25/69</i>		

From Preceding Sheet



Input: $MPAC_V = R$ vector

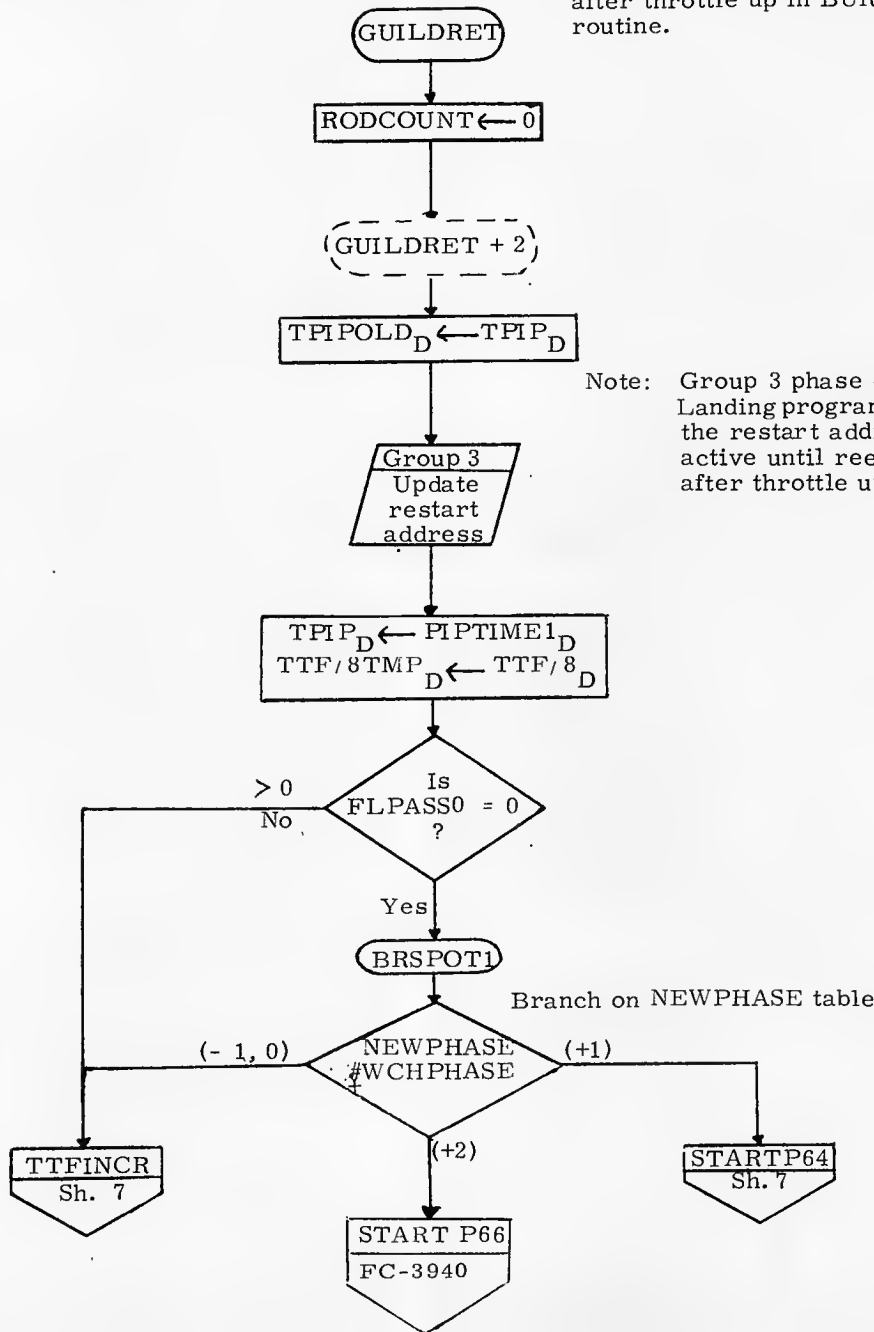
Output: $MPAC_V = GDT1/2_V$

Delivers N passes of quadratic guidance

N = 3

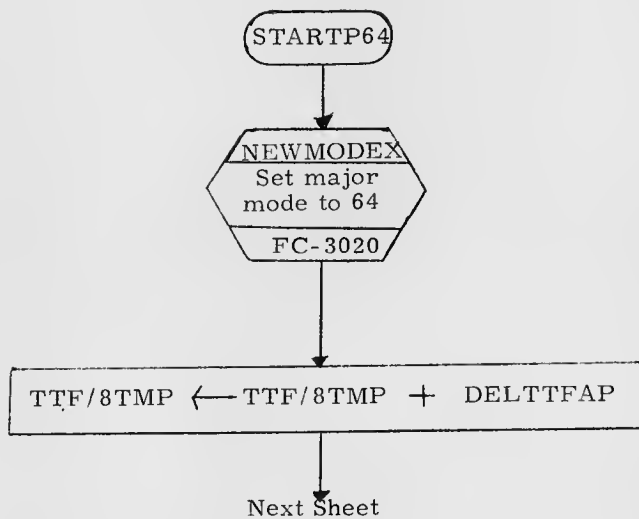
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Fullbrook</i> 7/3/69		Lunar Landing	
PRGMR		LUMINARY 1 D	DOCUMENT NO. FC-3900
ANALST			
DOCMR	<i>W. Doughty</i> 9/30/69		
APPR'D	<i>Robert M. Evans</i> 11/25/69	REV 2	SHEET 4 OF 52

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 <i>R. Wuch</i> 3/5/70		Lunar Landing	
PRGMR		LUMINARY 1D	DOCUMENT NO. FC-3900
ANALST			
DOCMR <i>M. D. Smith</i> 7/30/69		REV 2	SHEET 5 of 52
APPR'D <i>R. Roberts</i> ME 11/25/69			



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Welch</i> 3/5/70		Lunar Landing	
PRGMR		LUMINARY 1D	DOCUMENT NO. FC-3900
ANALST			
DOCMR <i>W. Doughty</i>	9/30/69		
APPR'D <i>Robert M. Ester</i>	11/25/69	REV 2	SHEET 6 OF 52

From Preceding Sheet

Inhibit Inter-rupts

C13STALL
Wait till ok to write Ch. 13
FC-3340

Set bit 12 of Ch. 13

Enable hand control rupt

DB ← P64DB

clear REDFLAG

Landing site redesignation not permitted

LRWH ← LRWH1

TTFINCR

$LANDTEMP_V \leftarrow /LAND/D \text{ unit} [LAND_V - LAND_V(TPIP_D - TPIPOLD_D) \times WM_V]$

Landing site vector updated for lunar rotation

$TTF/8TMP_D \leftarrow TTF/8TMP_D + TPIP_D - TPIPOLD_D$

Updated for time since last pass

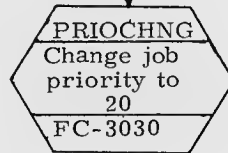
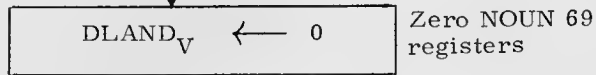
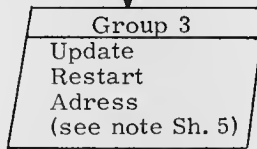
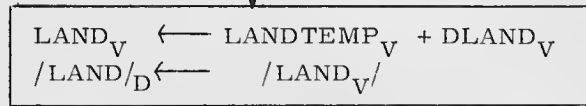
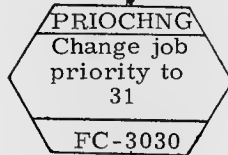
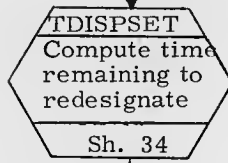
Group 3
Update restart address
(see note Sh. 5)

$TTF/8_D \leftarrow TTF/8TMP_D$

Next Sheet

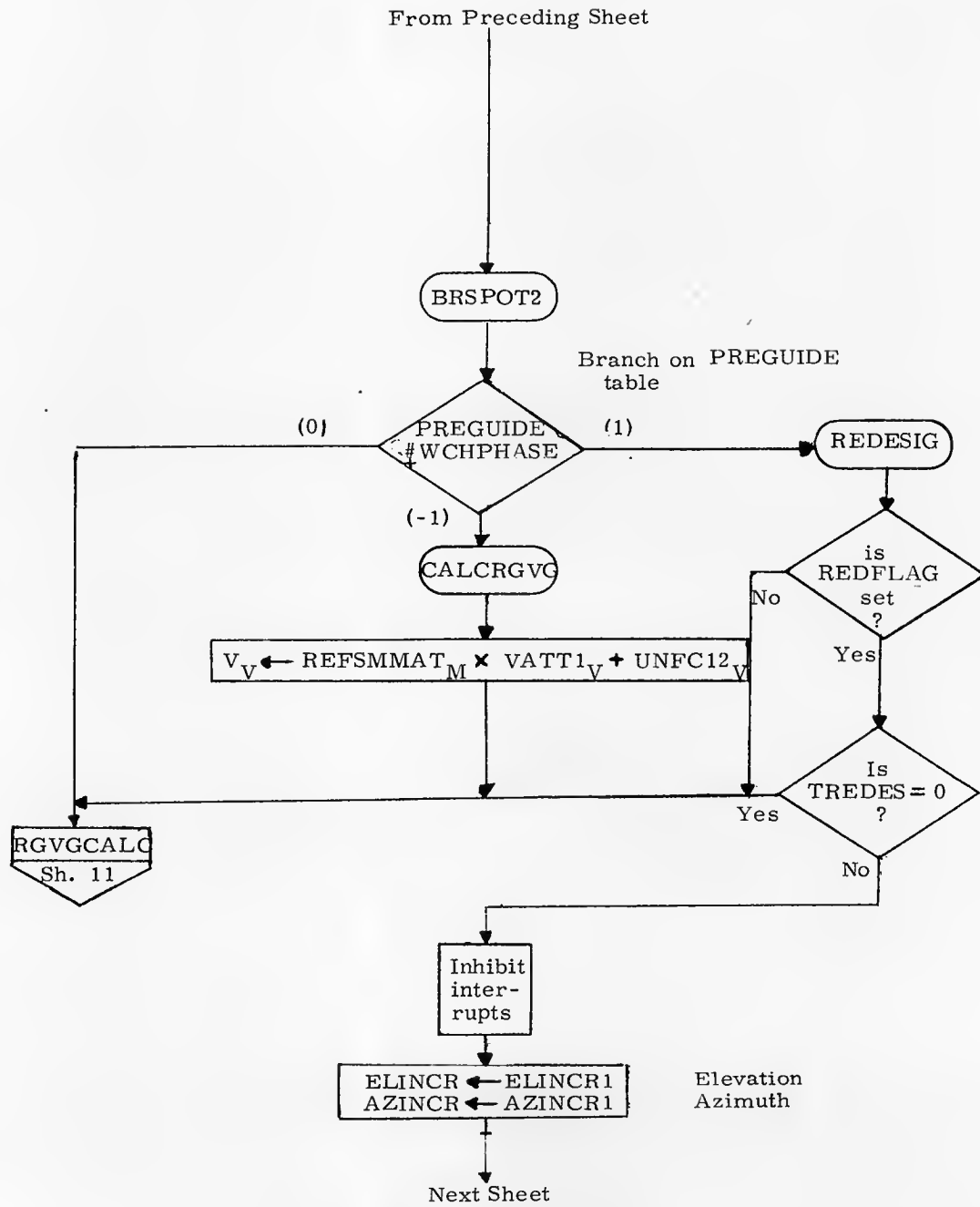
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Welch</i> 3/5/69		Lunar Landing	
PRGMR		LUMINARY 1 D	DOCUMENT NO.
ANALST			FC-3900
DOCMR	<i>W. D. Smith</i> 9/30/69	REV 2	SHEET 7 OF 52
APPR'D <i>Robert M. Evans</i>	11/25/69		

From Preceding Sheet



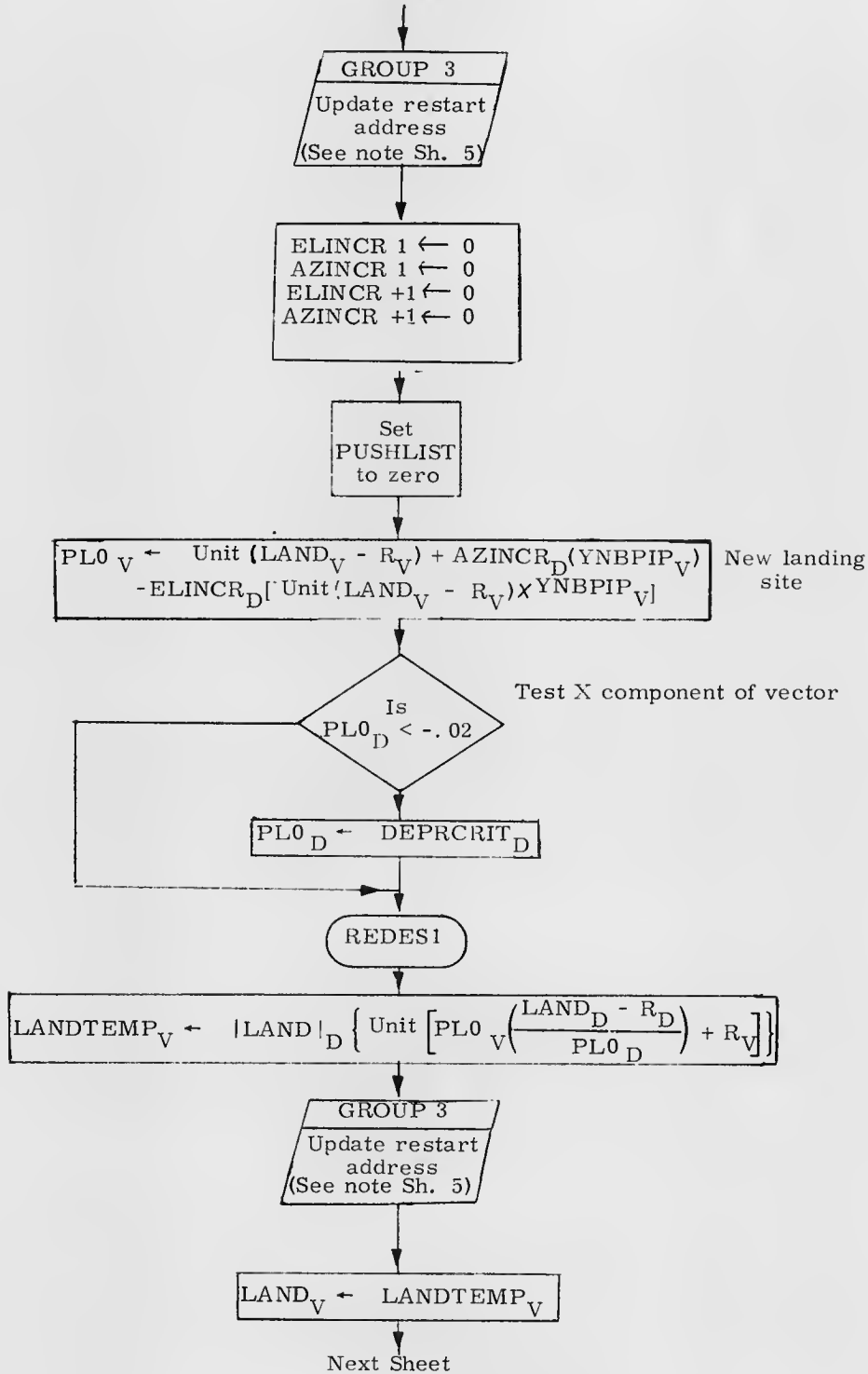
Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Welch</i>	<i>3/5/70</i>	Lunar Landing	
PRGMR		LUMINARY 1 D	DOCUMENT NO.
ANALST			FC-3900
DOCMR <i>M. Sponholz</i>	<i>9/30/69</i>	REV 2	SHEET 8 OF 52
APPR'D <i>Robert M. Foster</i>	<i>11/25/69</i>		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Welch</i> 3/5/69		Lunar Landing	
PRGMR		LUMINARY 1 D	DOCUMENT NO. FC-3900
ANALST			
DOCMR	<i>R. Daghouth</i> 9/30/69		
APPR'D	<i>Robert M. Foster</i> 11/25/69	REV 2	SHEET 9 OF 52

From Preceding Sheet



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>R. Welch</i>	Lunar Landing	
PRGMR		LUMINARY 1D	DOCUMENT NO. FC-3900
ANALST			
DOCMR	<i>W. Douglas</i>		
APPR'D	<i>R. M. Egan</i>	REV 2	SHEET 10 OF 52

From Preceding Sheet

RGVGCALC

$$\begin{aligned} \text{ANGTERM}_V &\leftarrow V_V + (R_V \times \text{WM}_V) \\ \text{VGU}_V &\leftarrow \text{CG}_M(\text{ANGTERM}_V) \\ \text{RGU}_V &\leftarrow \text{CG}_M(R_V - \text{LAND}_V) \\ \text{LOOKANGL}_D &\leftarrow \left\{ \sin^{-1} \left[\text{Unit} (R_V - \text{LAND}_V); \text{XNBPIP}_V \right] \right. \\ &\quad \left. + 1/2 \text{ DEG} + \text{ELBIAS} \right\} 180 \text{ DEGS} \\ \text{RANGEDSP}_D &\leftarrow |\text{RGU}_V| \end{aligned}$$

Velocity relative to the source
Velocity state in guidance coords
Position state in guidance coords
Depression angle for display
Slant range to landing site for display

Set
PUSHLIST
to zero

BRSPOT 3

Branch on WHATGUID table

WHATGUID

WCHPHASE

(-1, 0, 1)

Next Sheet

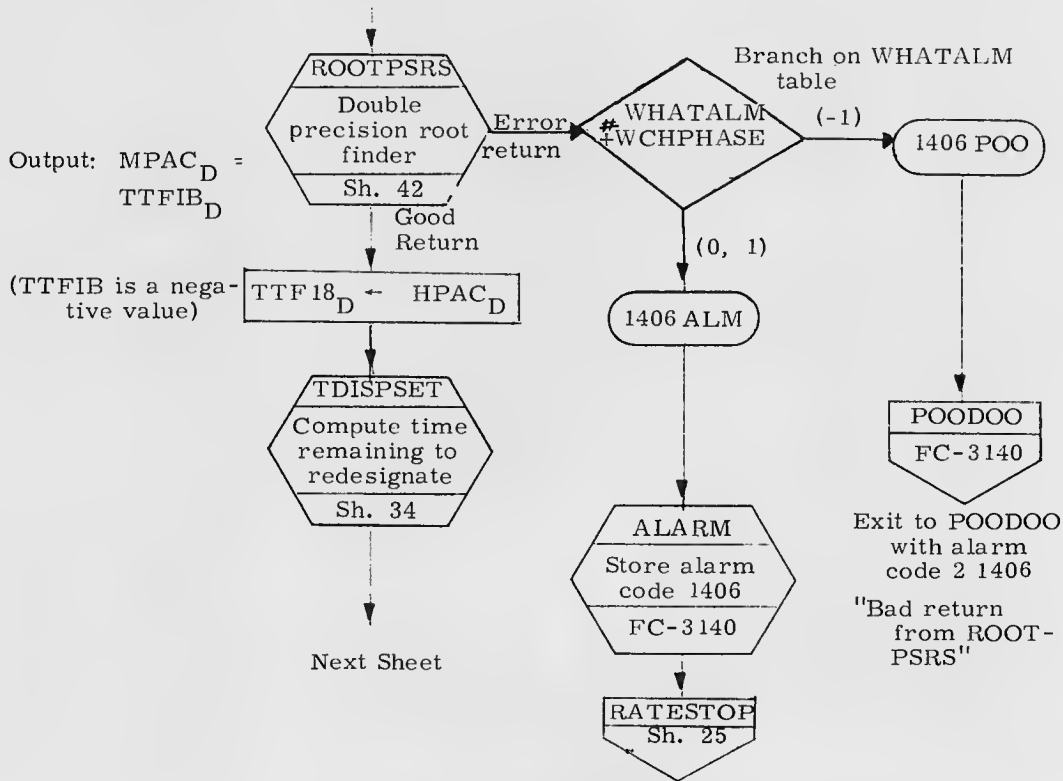
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Welch</i> 3/5/72		Lunar Landing	
PRGMR		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3900
DOCMR <i>R. Daghfah</i>	9/30/69	REV 2	SHEET 11 of 52
APPR'D <i>R.M. Egan</i>	11/25/69		

From Preceding Sheet

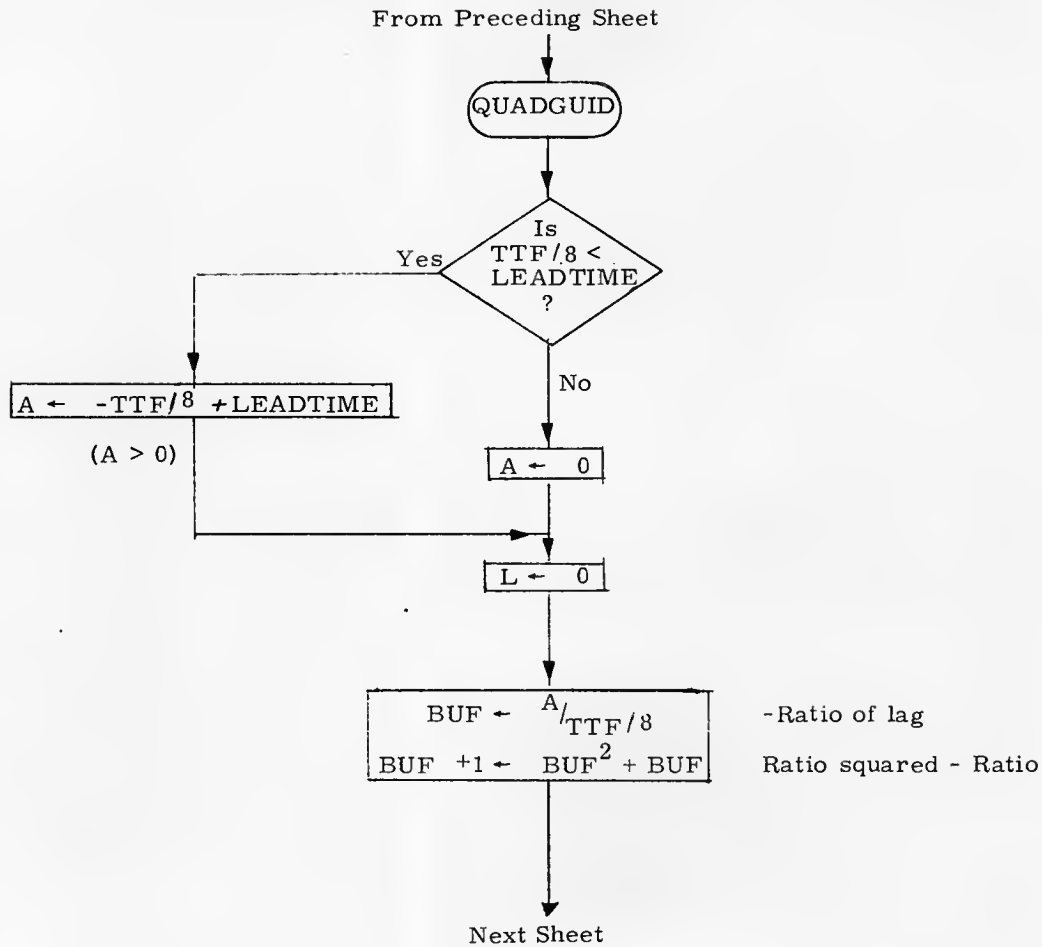
TTF/8CL

INTPRETX
Load X1 with index for target parameters
Sh. 35

TABLTTF	←	$318DP_D (RDG + 4_D \cdot X1 - RGU + 4_D)$	Load values for ROOTPSRS routine
TABLTTF +2 _D	←	$VDG2TTF_D \cdot X1 + VGU \cdot 4_D) / 3 / 4DP_D$	
TABLTTF +4 _D	←	$ADG2TTF_D \cdot X1$	
TABLTTF +6 _D	←	$JDG2TTF_D \cdot X1$	
TABLTTF +10	←	BIT 8	
MPAC _D	←	TTF/8 _D	
A	←	TABLTTFL	
L	←	2	



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R Welch</i> 3/5/69		Lunar Landing	
PRGMR		LUMINARY 1 D	DOCUMENT NO.
ANALST			FC-3900
DOCMR <i>W Duglith</i>	7/30/69	REV 2	SHEET 12 OF 52
APPR'D <i>R M E...</i>	11/25/69		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Welch</i> 3/5/69		Lunar Landing	
PRGMR		LUMINARY 1 D	DOCUMENT NO.
ANALST			FC-3900
DOCMR <i>W. Dayforth</i>	9/30/69		
APPR'D <i>R. Y. E. ...</i>	11/6/67	REV 2	SHEET 13 OF 52

From Preceding Sheet

MPAC ← 2 BUF ² + BUF	} Store in PUSHLIST
PL26 ← 3 BUF ² + BUF	
PL28 ← 4 BUF ² + 3 BUF	
PL30 ← 6 BUF ² + 6 BUF + 1	

INTPRETX
Load X1 with index for target parameters
Sh. 35

$$MPAC_V \leftarrow \left[\frac{PL26_D \frac{RDG_V^{\#X1} - RGU_V}{4(TTF/8_D)} + PL28_D (VDG_V^{\#X1}) + MPAC_D (VGU_V)}{TTF/8_D} \right]^{3/4} + PL30_D (ADG_V^{\#X1})$$

AFCCALC1

$$UNFC/2_V \leftarrow MPAC_V \times CG_M - \frac{GDT/2_V}{GSCALE_D}$$

AFCCALC2

$$|AFC|_D \leftarrow |UNFC/2_V|$$

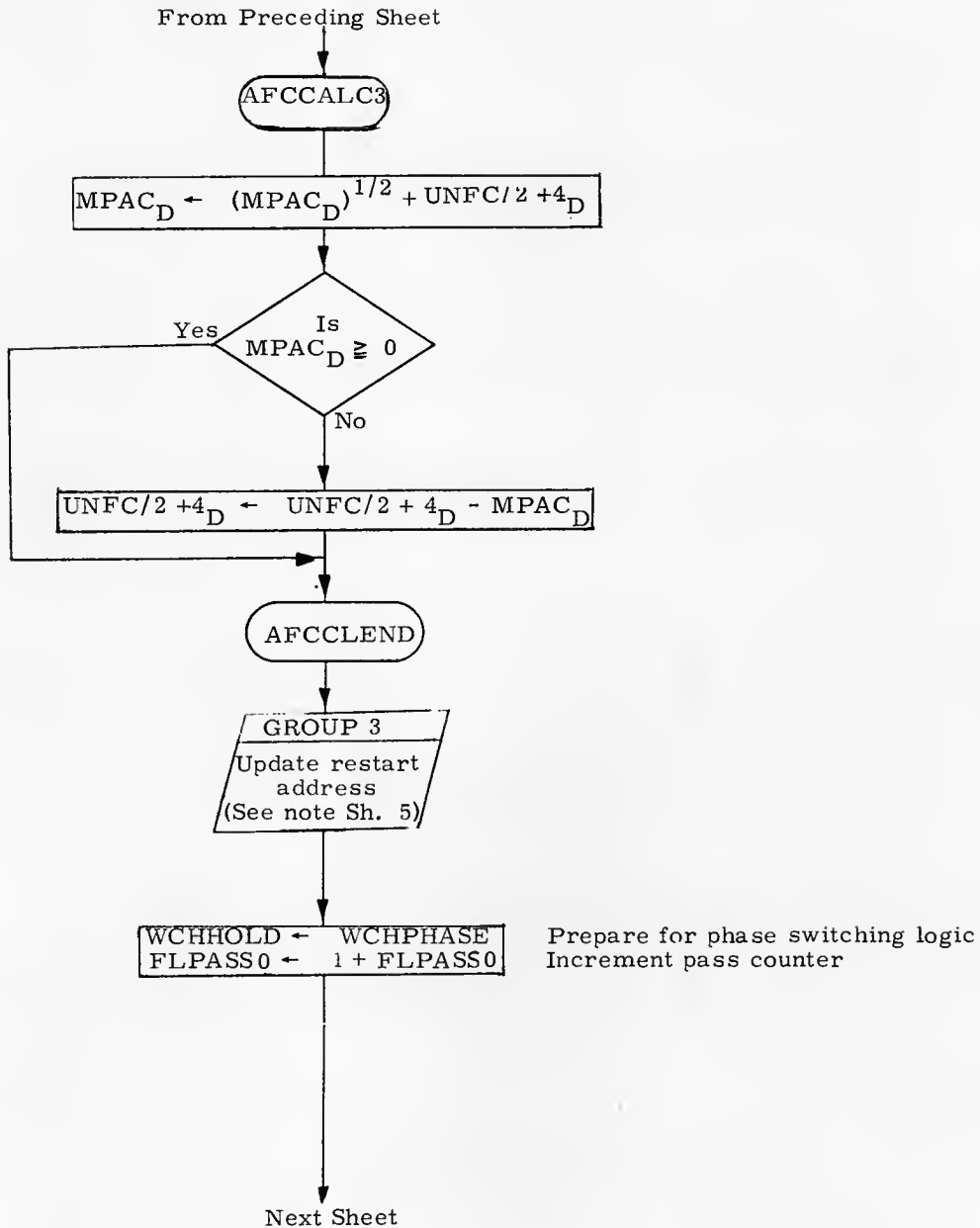
$$MPAC_D \leftarrow \left(\frac{HIGHESTF_D}{MASS_D} \right)^2 - (UNFC/2 + 2_D)^2 - (UNFC/2_D)^2$$

Is MPAC_D ≥ 0 ?

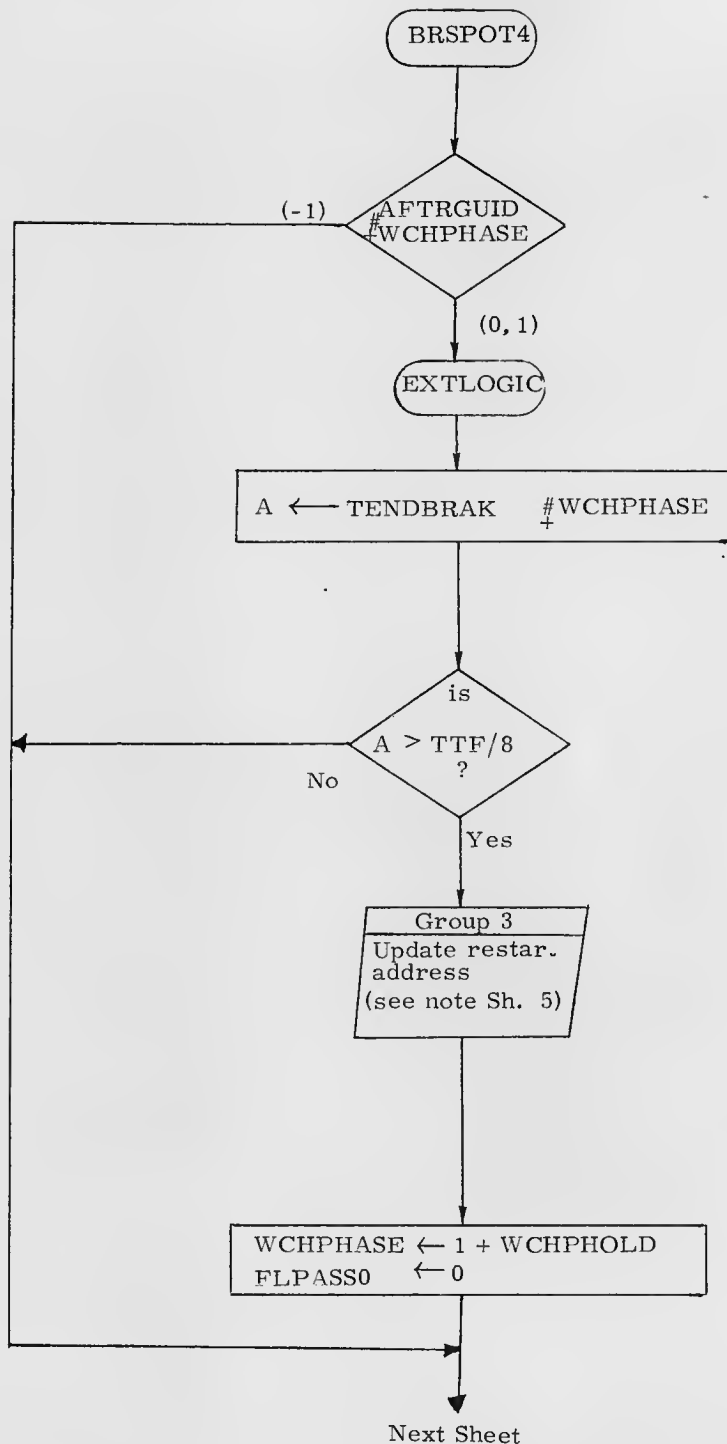
No → MPAC_D ← 0

Yes →

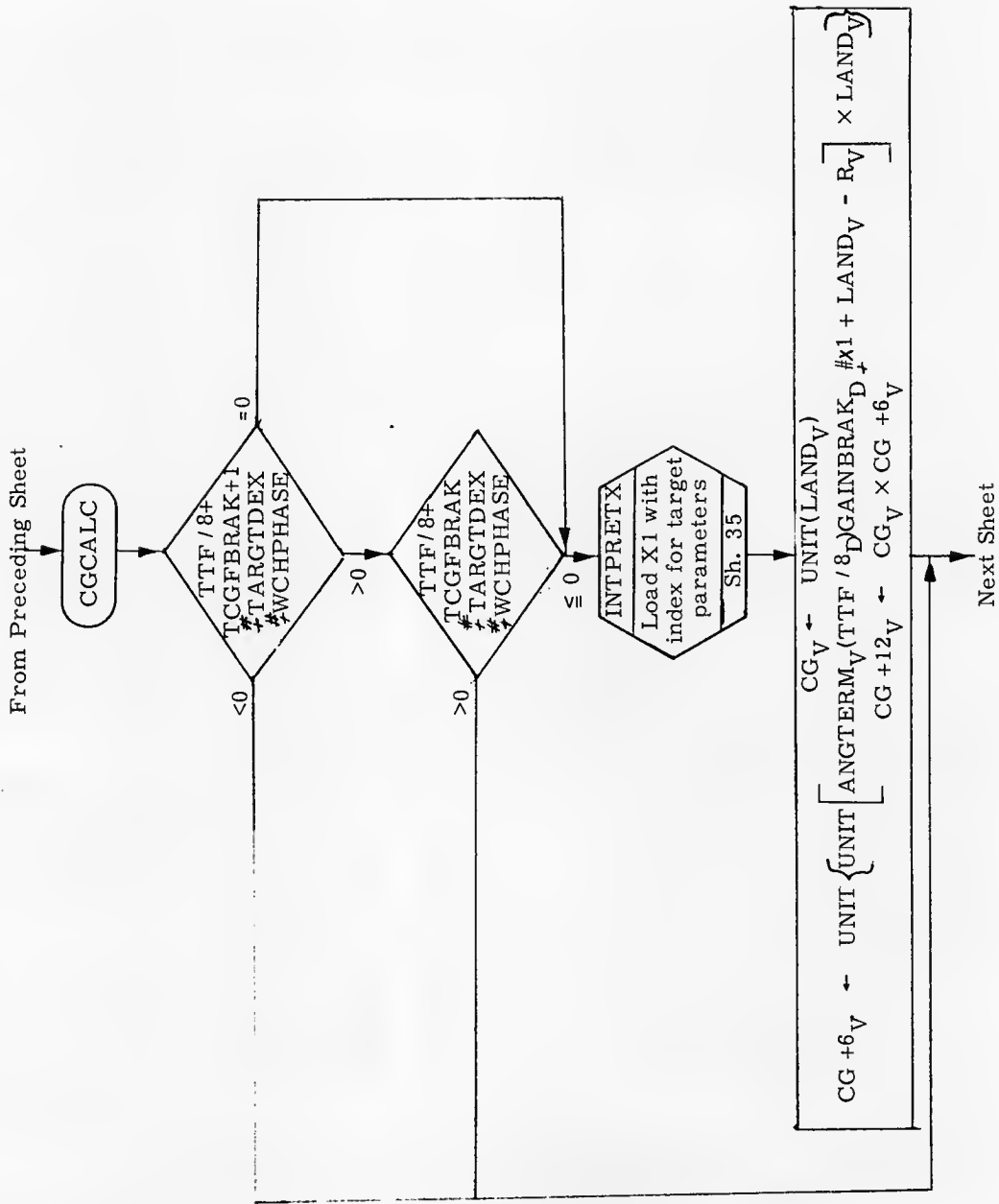
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R Welch</i>	3/5/70	Lunar Landing	
PRGMR		LUMINARY 1'D	DOCUMENT NO. FC-3900
ANALST			
DOCMR <i>W Dagbith</i>	7/2/69	REV 2	SHEET 14 OF 52
APPR'D <i>R M Evans</i>	11/25/69		



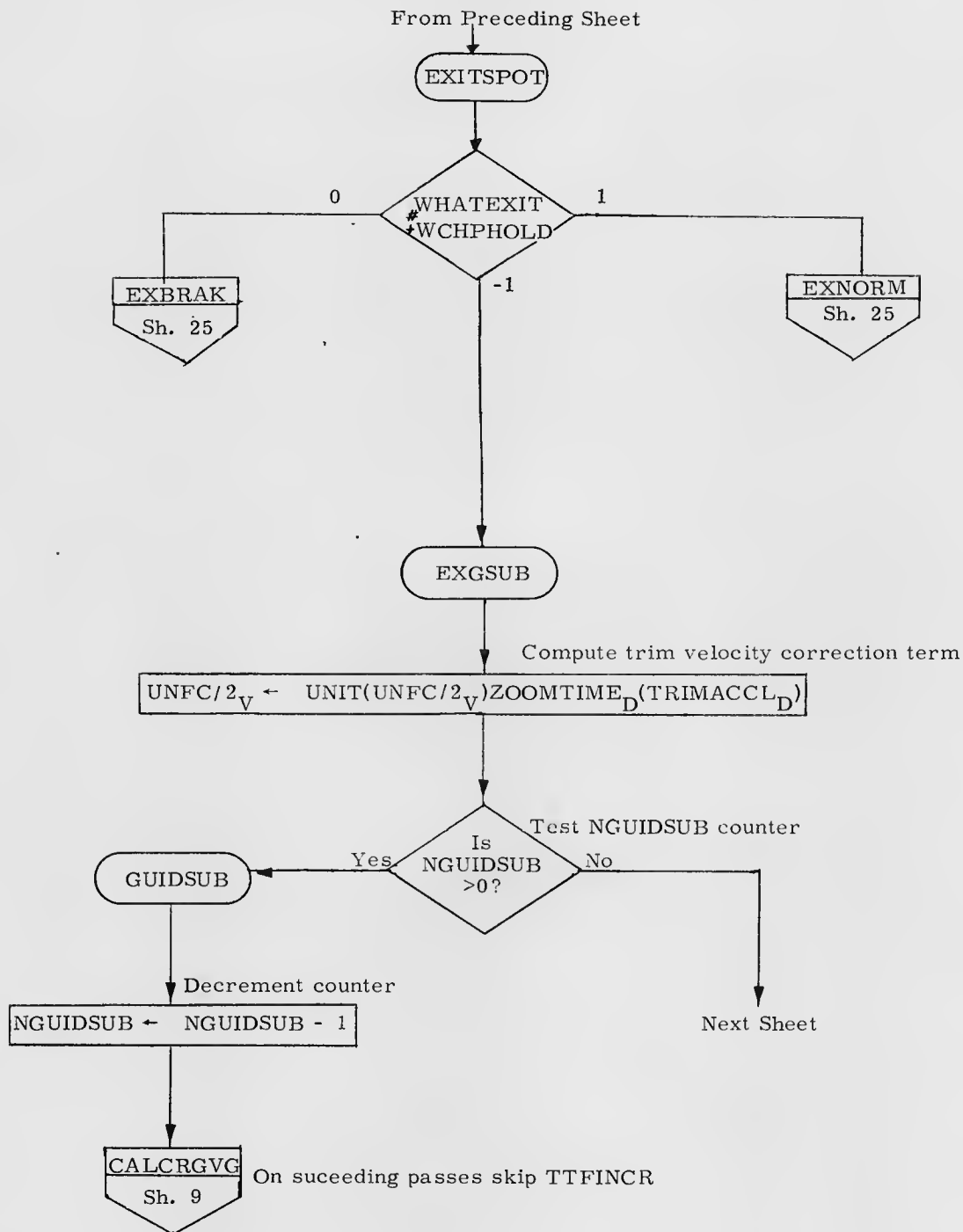
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		Lunar Landing	
DRAWN <i>R Welch</i>	<i>3/5/70</i>	LUMINARY 1 D	DOCUMENT NO.
PRGMR			FC-3900
ANALST		REV 2	SHEET 15 OF 52
DOCMR <i>W Dargatzis</i>	<i>7/30/69</i>		
APPR'D <i>R M Entes</i>	<i>11/25/69</i>		



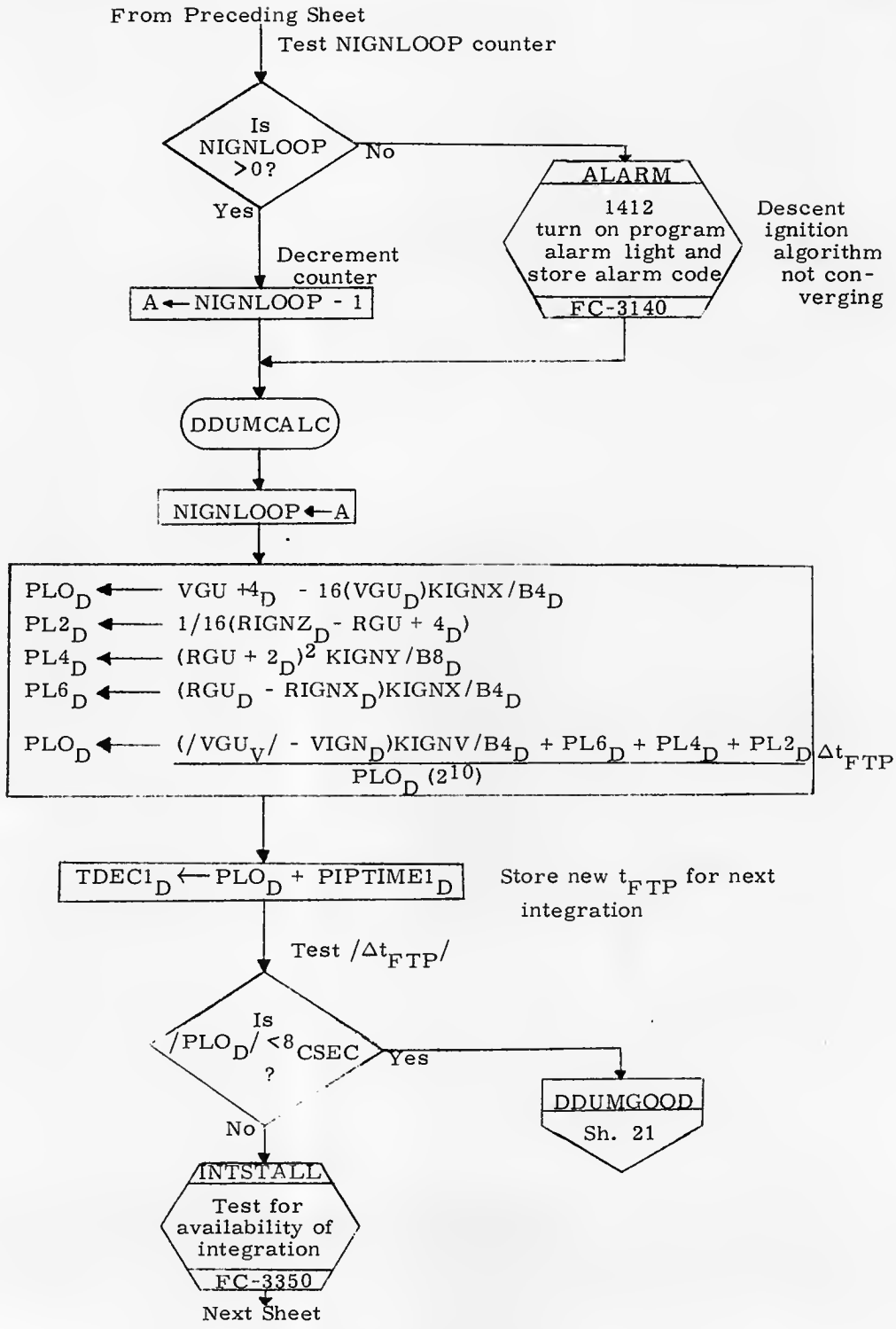
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		Lunar Landing	
DRAWN	<i>R. Welch</i>	<i>3/5/70</i>	LUMINARY 1 D
PRGMR			DOCUMENT NO.
ANALST			FC-3900
DOCMR	<i>W. Danforth</i>	<i>9/30/69</i>	REV 2
APPR'D	<i>R.M. Ewing</i>	<i>11/5/69</i>	SHEET 16 OF 52



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>R. Welch</i>	<i>2/5/70</i>	Lunar Landing
PRGMR			
ANALST			LUMINARY 1 D
DOCMR	<i>W. Donahue</i>	<i>7/24/69</i>	DOCUMENT NO. FC-3900
APPR'D	<i>R.M. Evers</i>	<i>11/25/67</i>	REV 2
			SHEET 17 OF 52



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		Lunar Landing	
DRAWN <i>K. Welch</i> 3/5/70		LUMINARY 1D	DOCUMENT NO. FC-3900
PRGMR			
ANALST			
DOCMR <i>W. Doghith</i> 9/29/69			
APPR'D <i>R. M. E. ...</i> 11/25/69		REV 2	SHEET 18 OF 52



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R Wild</i> 3/5/69		Lunar Landing	
PRGMR		LUMINARY 1-D	DOCUMENT NO. FC-3900
ANALST			
DOCMR <i>W Dreyfus</i> 2/29/69		REV 2	SHEET 19 OF 52
APPR'D RYM <i>Enter</i> 11/25/69			

From Preceding Sheet

Set
INTYPFLG
set
MOONFLAG

Conic integration
Moon is sphere of influence

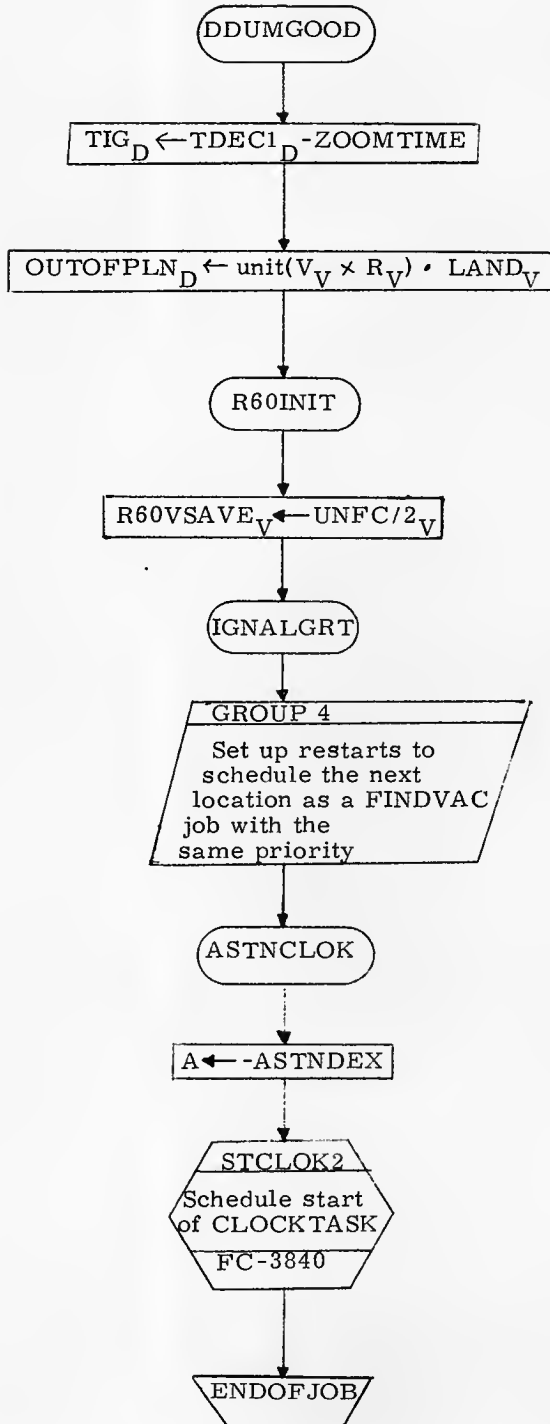
$TET_D \leftarrow PIPTIME1_D$
 $RCV_V \leftarrow RATT1_V$
 $VCV_V \leftarrow VATT1_V$

INTEGRVS
Integrate LM
state vector
for new Δt_{FTP}
FC-3350

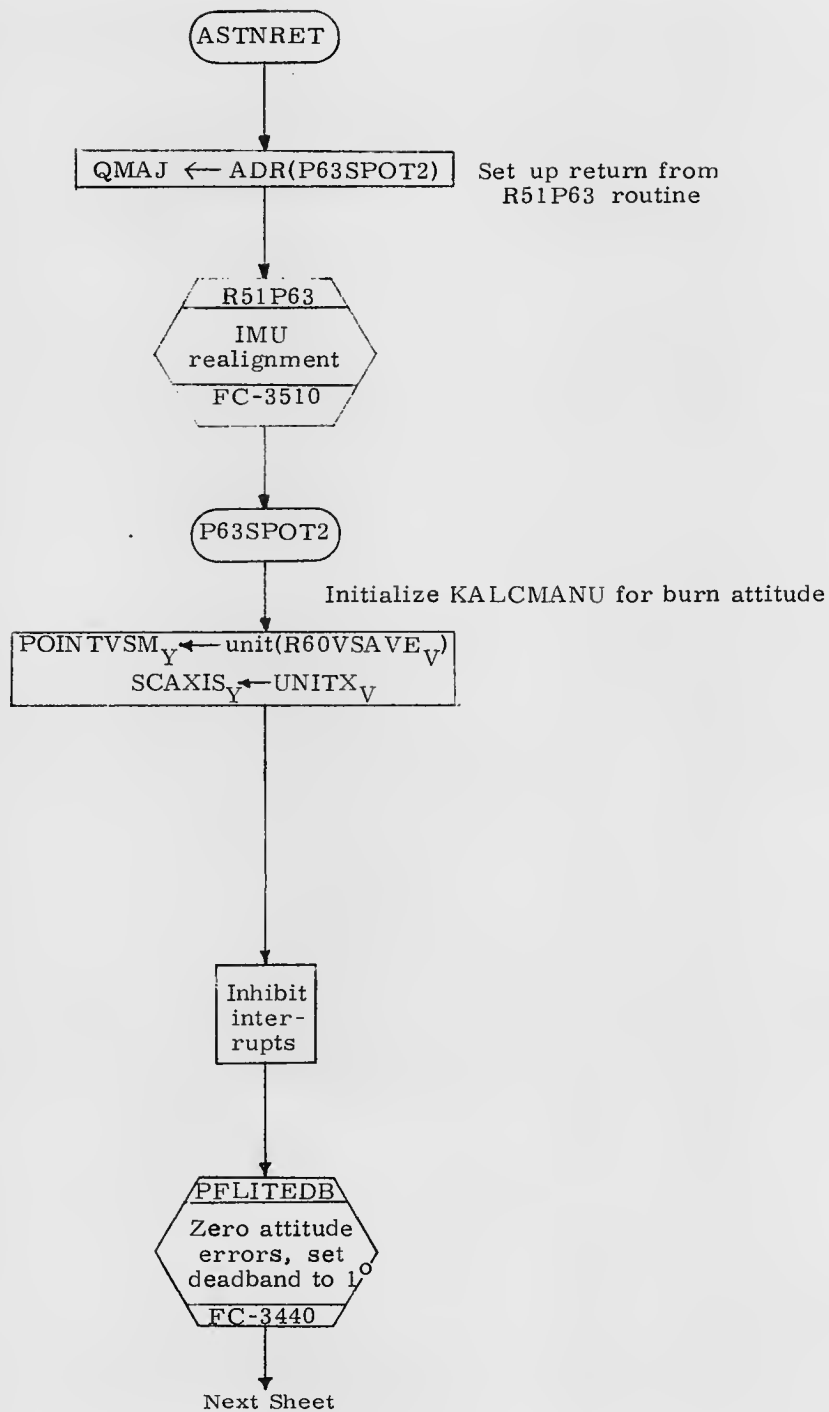
Input: $TDEC1_D$, TET_D , RCV_V , VCV_V
Output: $RATT1_V$ = LM position vector
 $VATT1_V$ = LM velocity vector
 TAT_D = time

IGNALOOP
Sh. 4

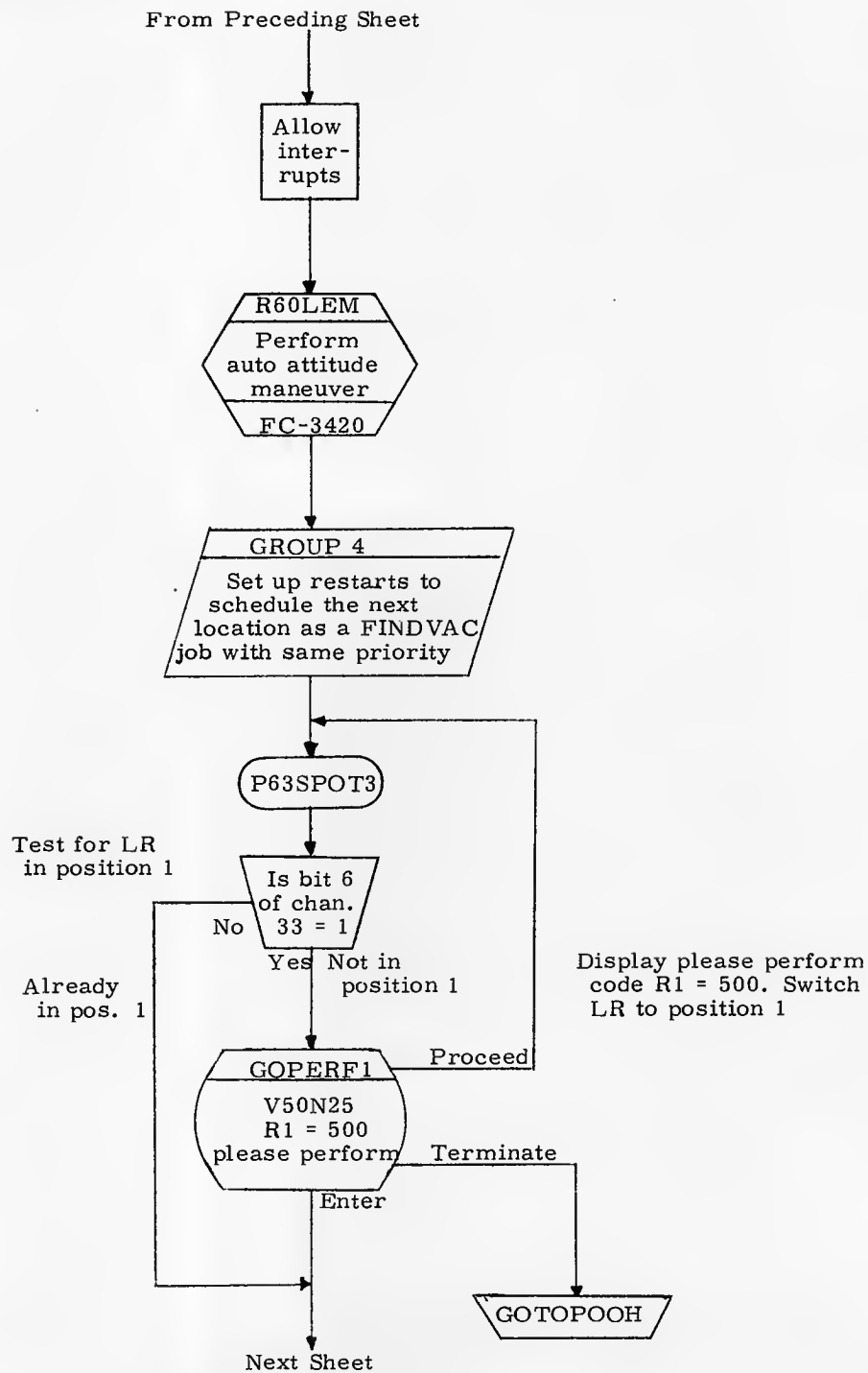
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Welch</i>	<i>2/5/70</i>	Lunar Landing	
PRGMR		LUMINARY ID	DOCUMENT NO. FC-3900
ANALST			
DOCMR <i>W. Doynt</i>	<i>2/24/69</i>		
APPR'D <i>R.M. Entes</i>	<i>11/25/69</i>	REV 2	SHEET 20 OF 52



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		Lunar Landing	
DRAWN	<i>R. Welch</i> 3/5/69	LUMINARY 1D	DOCUMENT NO. FC-3900
PRGMR			
ANALST			
DOCMR	<i>W. English</i> 9/29/69		
APPR'D	<i>R. M. ...</i> 11/25/69	REV 2	SHEET 21 OF 52



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R Welch</i> 3/5/69		Lunar Landing	
PRGMR		LUMINARY 1D	DOCUMENT NO. FC-3900
ANALST			
DOCMR <i>J. Dougherty</i>	9/29/69		
APPR'D <i>R.M. Estes</i>	11/25/69	REV 2	SHEET 22 OF 52



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Welch</i> 3/5/70		Lunar Landing	
PRGMR		LUMINARY 1D	DOCUMENT NO. FC-3900
ANALST			
DOCMR <i>R. Welch</i> 8/20/69			
APPR'D <i>R. Welch</i> 11/25/69		REV 2	SHEET 23 OF 52

From Preceding Sheet

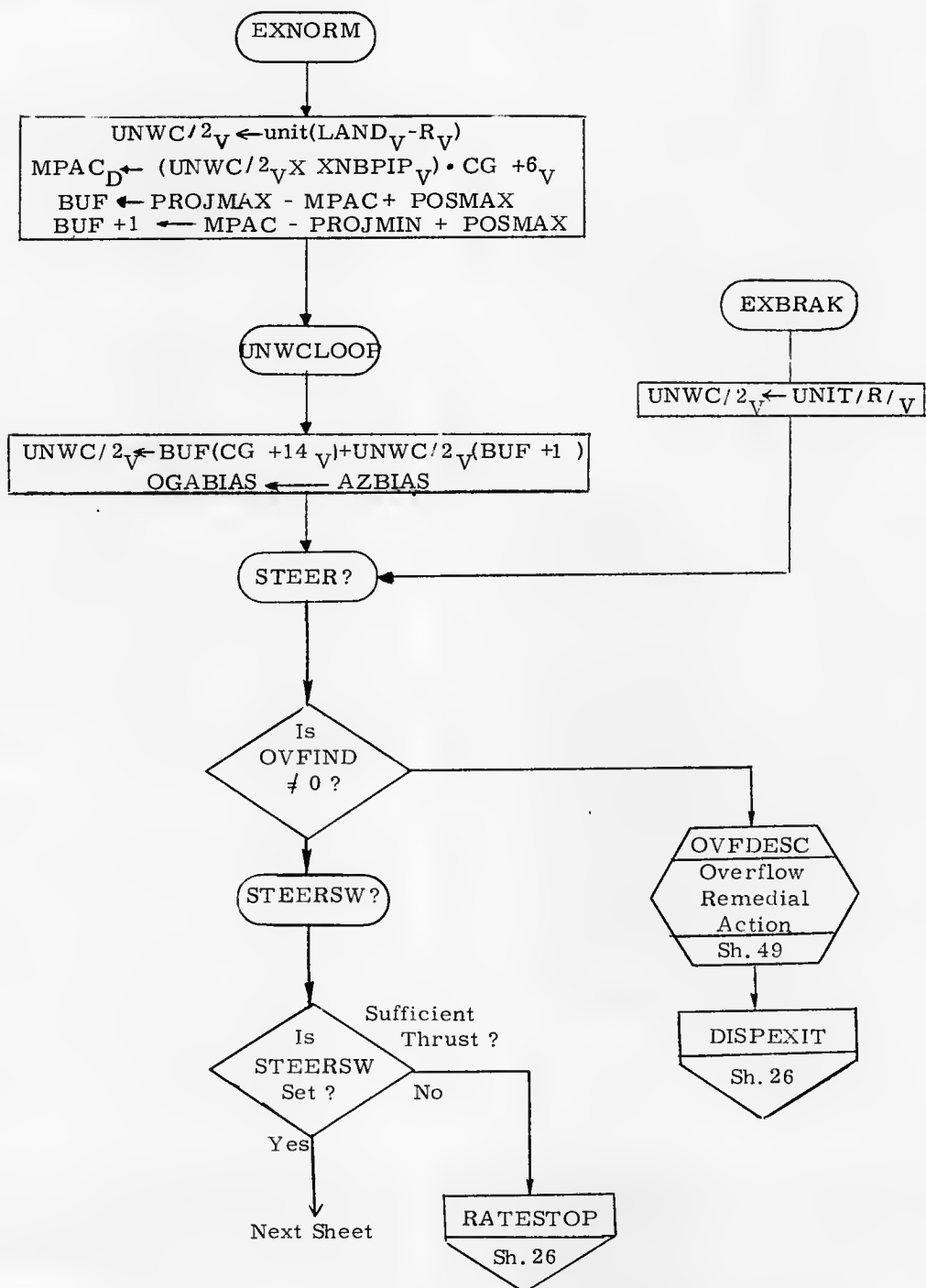
P63SPOT4

Initialize values for landing radar

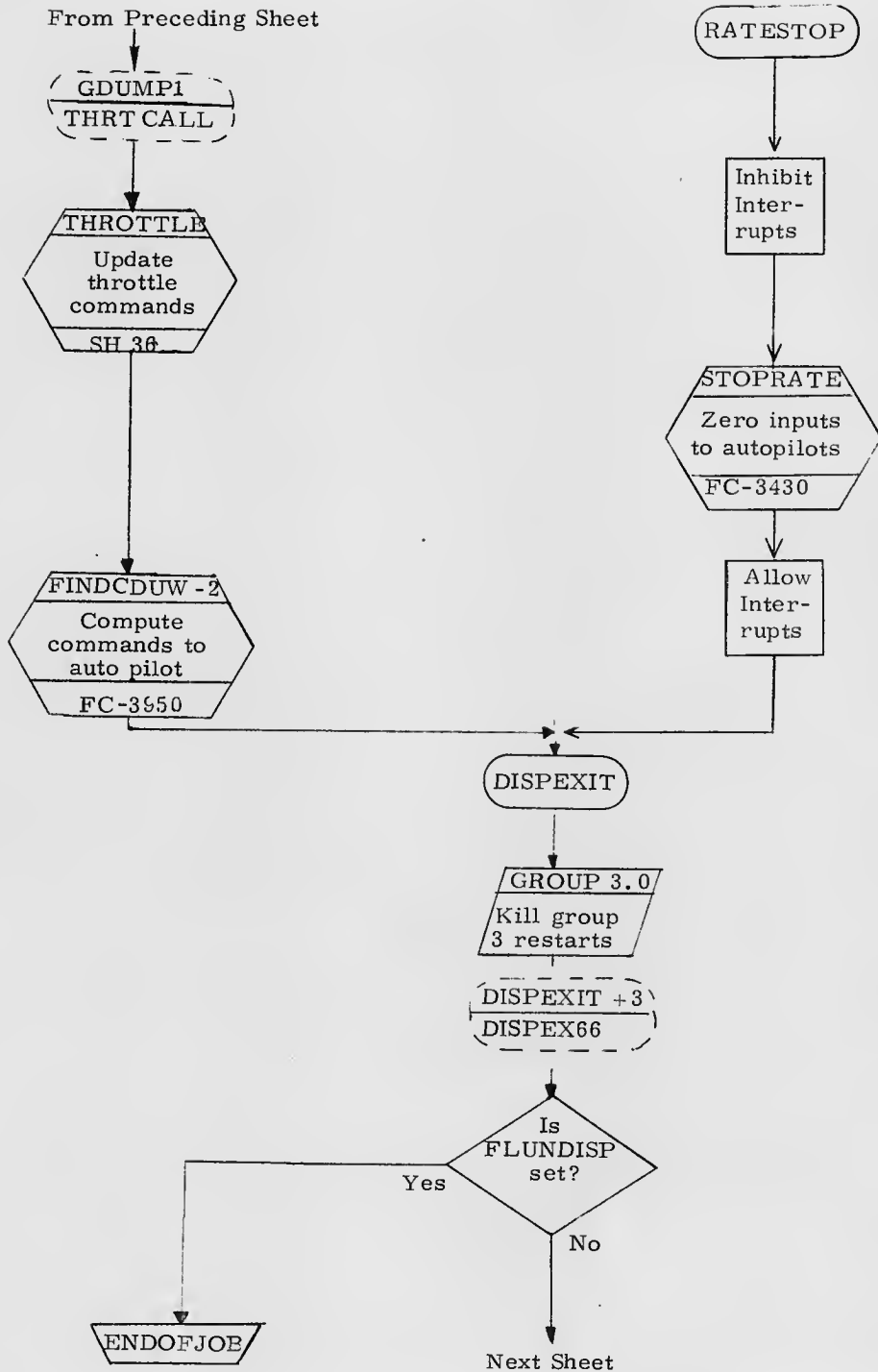
STILBADH	← 2	Initialize STILBAD
STILBADV		
LRLCTR		
LRMCTR	← 0	Set counters to zero
LRRCTR		
LRSCTR		
VSELECT	← 0	
LRPOS	← 1	
511CTR	← 4	

BURNBABY
FC-3840

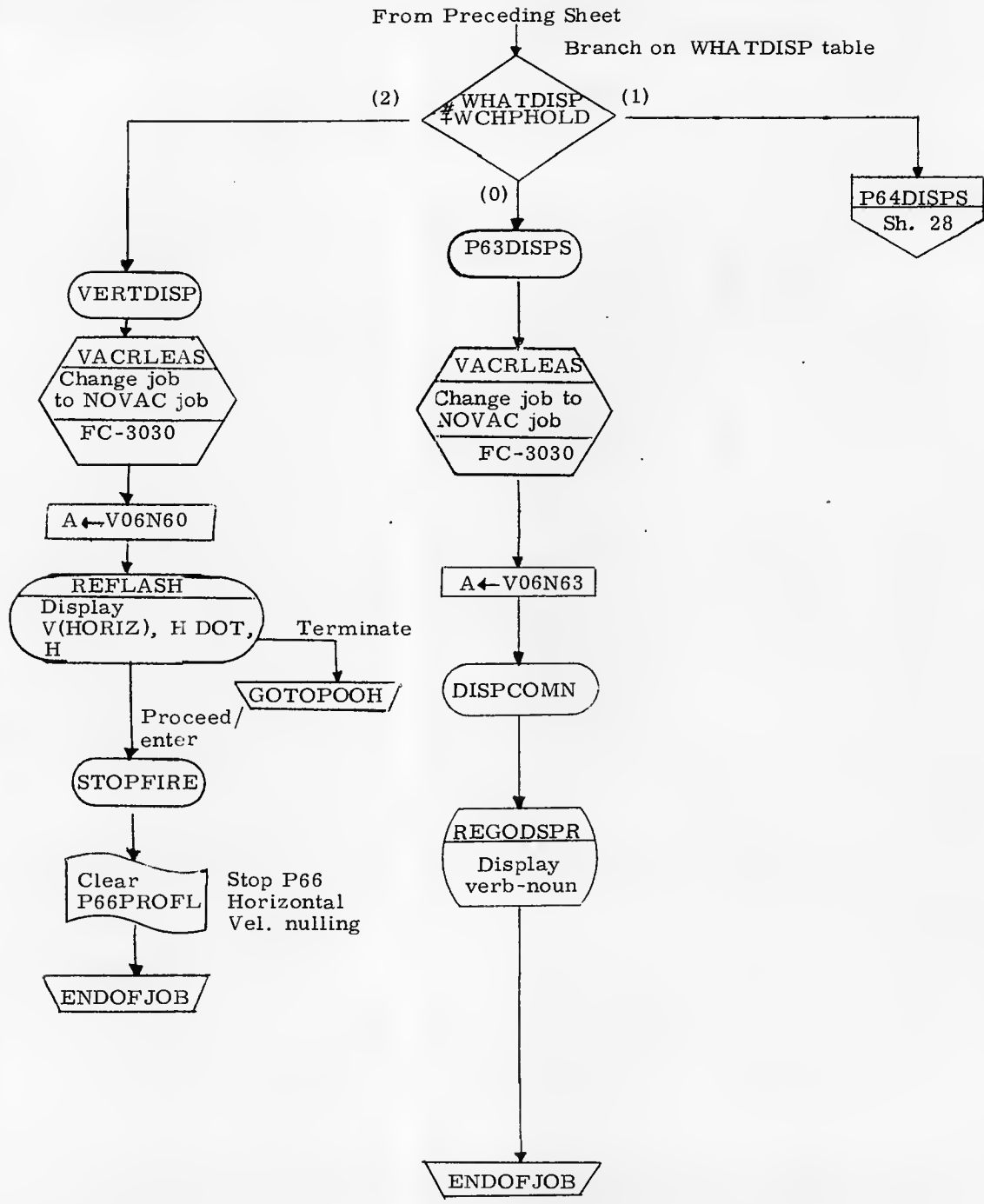
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Welch</i>	<i>1/17/69</i>	Lunar Landing	
PRGMR		LUMINARY 1 D	DOCUMENT NO.
ANALST			FC-3900
DOCMR <i>W. Dyer</i>	<i>9/30/69</i>	REV 2	
APPR'D <i>R.M. Euter</i>	<i>11/25/69</i>		SHEET 24 OF 52



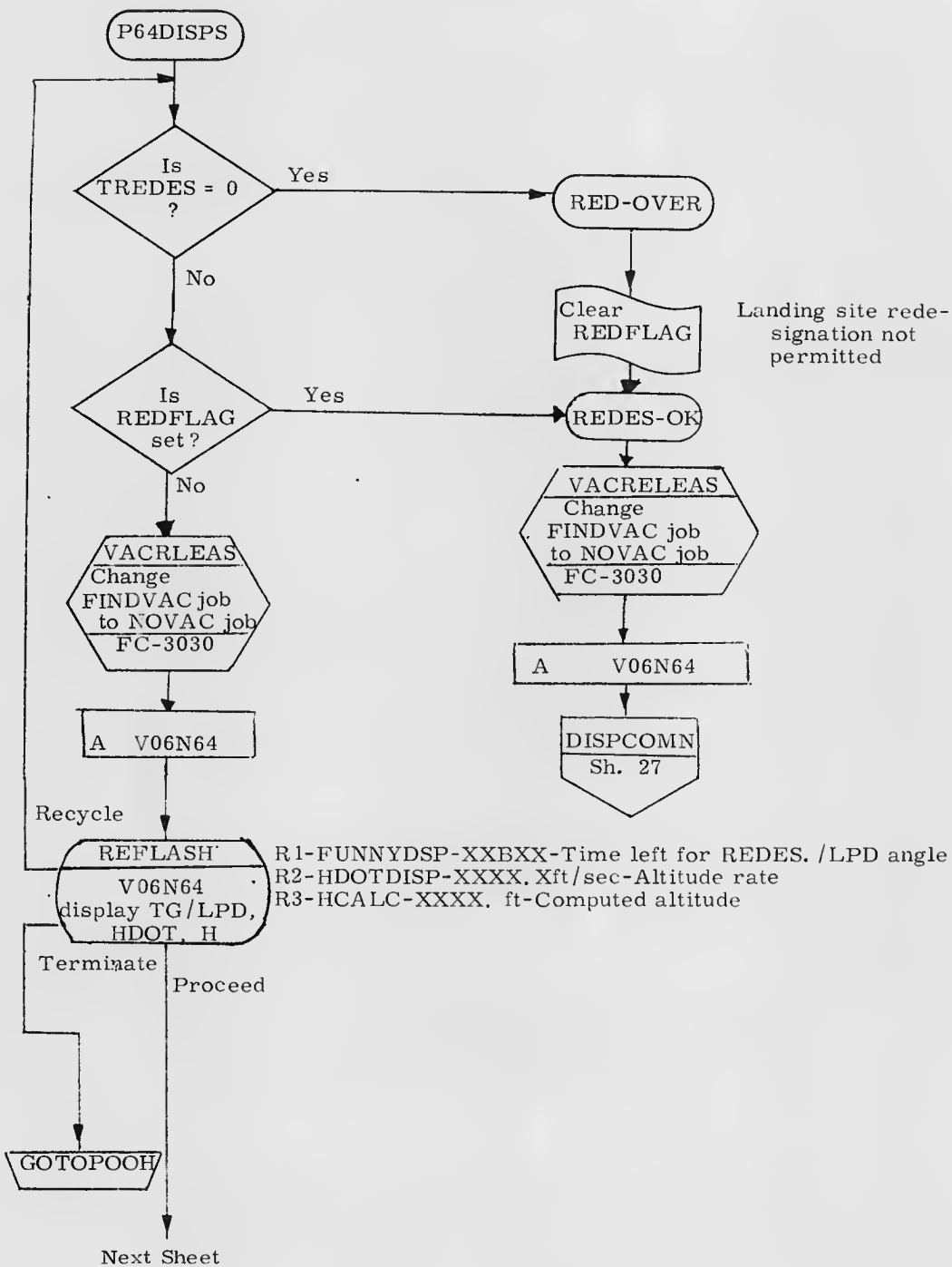
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		Lunar Landing	
DRAWN	<i>R. Walsh</i>	3/1/72	
PRGMR			
ANALST			
DOCMR	<i>R. Dornith</i>	9/30/69	LUMINARY 1D
APPR'D	<i>R.M. Evans</i>	11/25/69	REV 2
			DOCUMENT NO. FC-3900
			SHEET 25 OF 52



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Welch</i> 3/5/70		Lunar Landing	
PRGMR		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3900
DOCMR <i>W. Doughty</i>	9/24/69	REV 2	SHEET 26 OF 52
APPR'D <i>R. M. Evans</i>	11/25/67		

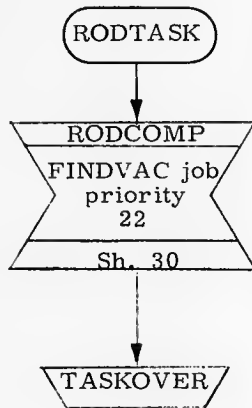
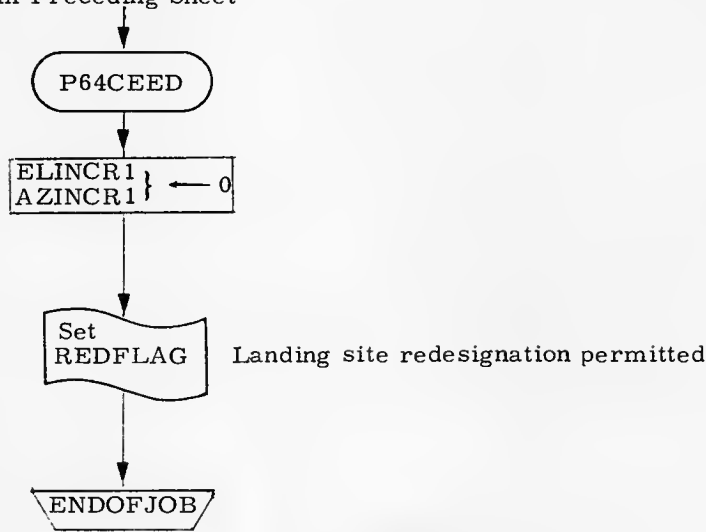


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		Lunar Landing	
DRAWN	<i>R. Wilek</i> 5/5/70	LUMINARY 1 D	DOCUMENT NO.
PRGMR			FC-3900
ANALST		REV 2	SHEET 27 of 52
DOCMR	<i>W. Danforth</i> 9/30/69		
APPR'D	<i>R. M. Easton</i> 11/25/69		

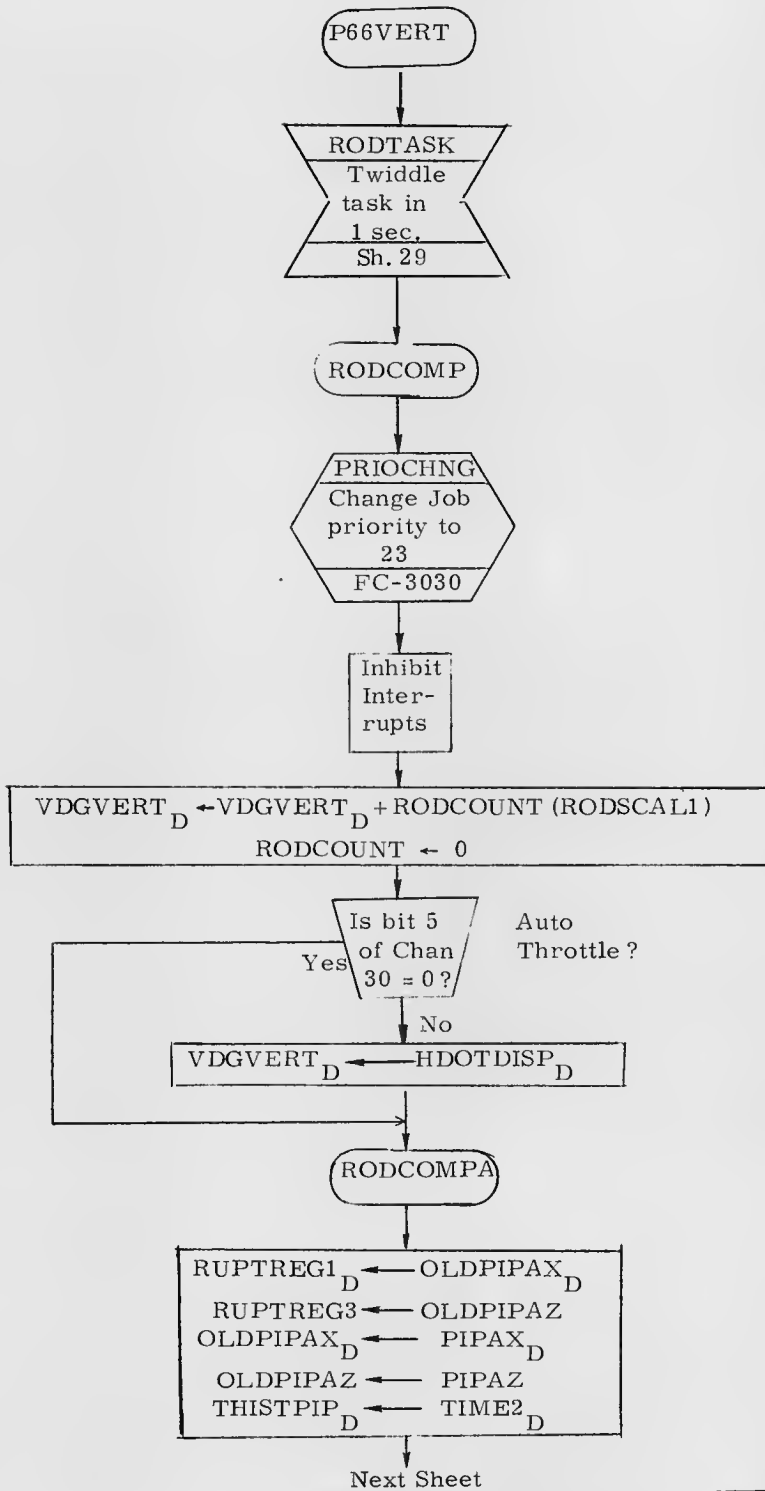


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R Welch</i> 3/5/70		Lunar Landing	
PRGMR		LUMINARY 1D	DOCUMENT NO. FC-3900
ANALST			
DOCMR <i>W. D. Smith</i> 9/29/69			
APPR'D <i>RMM Entas</i> 11/25/67	REV 2	SHEET 28 OF 52	

From Preceding Sheet



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Welch</i> 2/17/69		Lunar Landing	
PRGMR		LUMINARY 1-D	DOCUMENT NO.
ANALST			FC-3900
DOCMR <i>W. Dwyer</i>	9/30/69	REV 2	SHEET 29 OF 52
APPR'D <i>R.M. Easton</i>	11/25/69		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		Lunar Landing	
DRAWN	<i>K. Welch</i> 3/5/70	LUMINARY 1D	DOCUMENT NO.
PRGMR			FC-3900
ANALST			
DOCMR	<i>W. Dayforth</i> 3/19/70		
APPR'D	<i>R.M. Estes</i> 3/25/70	REV 2	SHEET 30 OF 52

DEIMUBOB
 COMPUTE
 Δ V SINCE
 PIPTIME
 SH35

MPAC ← OLDPIPAX + PIPATMPX
 MPAC +1 ← 0
 MPAC +3 ← OLDPIPAY + PIPATMPY
 MPAC +4 ← 0
 MPAC +5 ← OLDPIPAZ + PIPATMPZ
 MPAC +6 ← 0

DELVROD ← TEMX + RUPTREG1 - OLDPIPAX
 DELVROD +2 ← TEMY + RUPTREG2 - OLDPIPAY
 DELVROD +4 ← TEMZ + RUPTREG3 - OLDPIPAZ

TEMX ← 0
 TEMY ← 0
 TEMZ ← 0

ITRPNT 1

$PL0_V \leftarrow MPAC_V (KPIP1_D)$
 $PL30_D \leftarrow THISTPIP_D - PIPTIME_D$
 $PL6_D \leftarrow \frac{PL30_D}{4SEC(28)}$
 $PL24_V \leftarrow PL0_V + (GPT/2_V - VBIAS_V)PL6_D + V_V$
 $PL14_V \leftarrow UNIT(R_V)$
 $HDOTDISP_D \leftarrow PL14_V \cdot PL24_V$
 $HCALC1_D \leftarrow PL30_D(HDOTDISP_D) + |R_V| - |LAND|_D$
 $PL0_V \leftarrow \frac{VDGVERT_D - HDOTDISP_D}{TAUROD_D}$
 $PL20_D \leftarrow \frac{|GDT/2_V|}{GSCALE_D}$
 $PL0_D \leftarrow PL0_D + PL20_D$

Time since
 PIPTIME

 Updated ve-
 locity

MPAC_V ← UNITX_V

NBSM
 Transform input
 vector from NB
 to SM coord.
 FC-3320

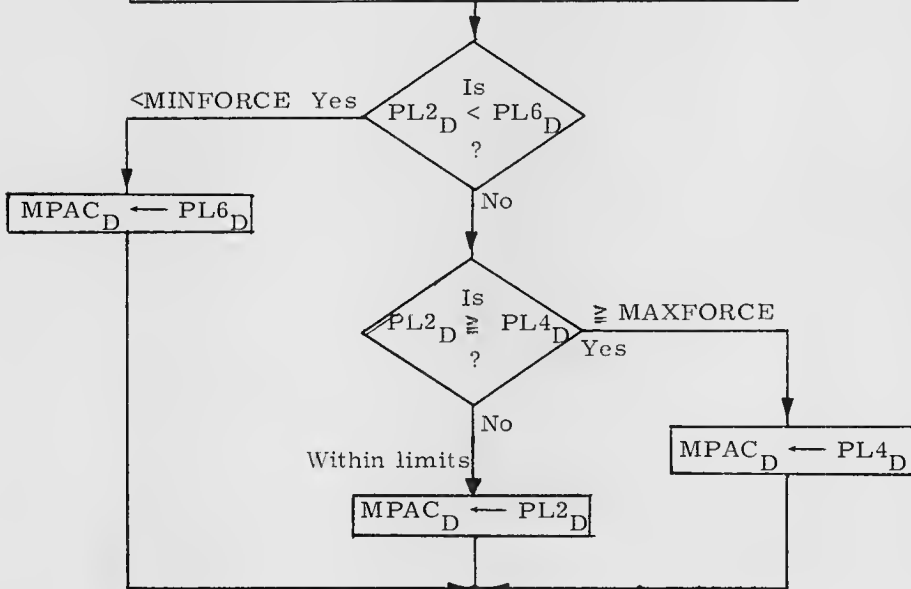
Input: MPAC_V = input vector
 in NB coord-
 inates
 Output: MPAC_V = transformed
 vector in
 SM coord-
 inates

Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Welch</i> 8/15/69		Lunar Landing	
PRGMR		LUMINARY 1 D	DOCUMENT NO.
ANALST			FC-3900
DOCMR <i>W. Dwyer</i>	8/24/69	REV 2	SHEET 31 OF 52
APPR'D BY <i>E. ...</i>	11/25/69		

From Preceding Sheet

$$\begin{aligned}
 PL22_D &\leftarrow MPAC_V \cdot PL14_V \\
 /AFC/D &\leftarrow \frac{PL0_D}{PL22_D} \\
 PL0_D &\leftarrow |DELVR0D_V(KPIP1_D) + VBIAS_V| \\
 PL2_V &\leftarrow THISTPIP_D - LASTTPIP_D \\
 LASTTPIP_D &\leftarrow THISTPIP_D \\
 PL0_D &\leftarrow \frac{PL0_D}{PL2_D / SHFTFACT} \\
 PL2_D &\leftarrow \frac{FWIGHT_D (BIT 1H_D)}{MASS_D (SCALEFAC_D)} + PL0_D \\
 PL2_D &\leftarrow \left(\frac{PL20_D}{PL22_D} - PL2_D \right) LAG / \tau_{D} + /AFC/D \\
 PL4_D &\leftarrow \frac{MAXFORCE_D}{MASS_D} \\
 PL6_D &\leftarrow \frac{MINFORCE_D}{MASS_D}
 \end{aligned}$$



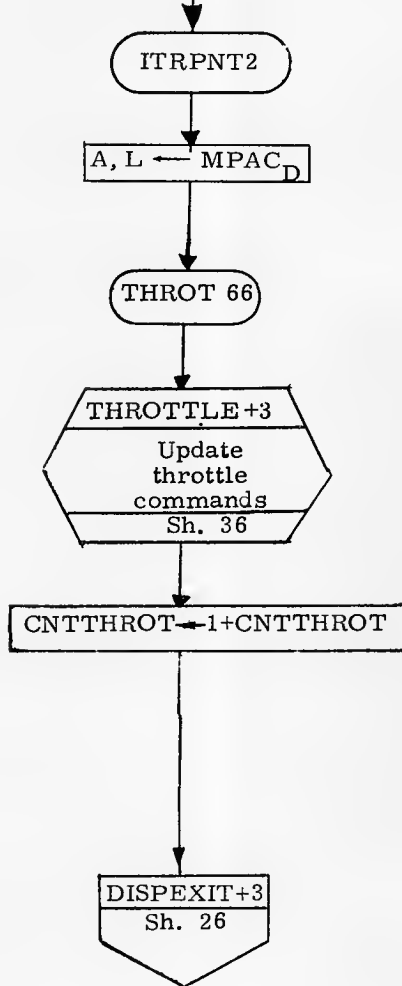
AFCSPOT

$$\begin{aligned}
 /AFC/D &\leftarrow MPAC_D \\
 MPAC_D &\leftarrow PL0_D
 \end{aligned}$$

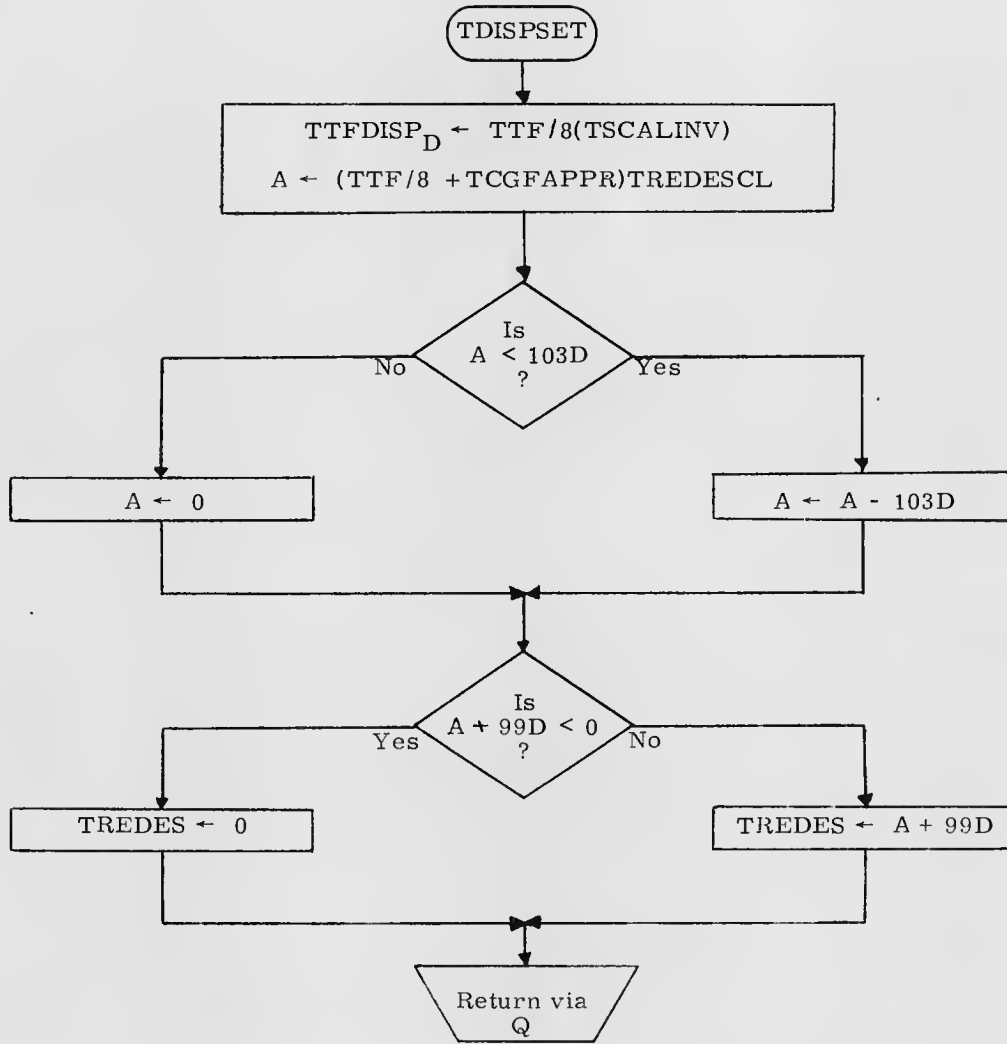
Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Welch</i> 3/5/70		Lunar Landing	
PRGMR		LUMINARY 1D	DOCUMENT NO. FC-3900
ANALST		REV 2	SHEET 32 OF 52
DOCMR <i>W. English</i> 9/30/69			
APPR'D <i>R.M. Evers</i> 11/25/69			

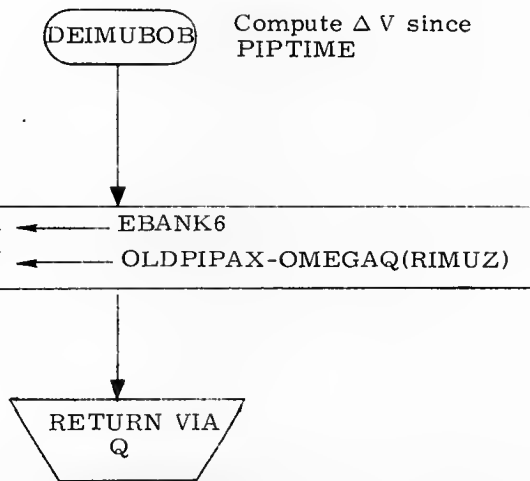
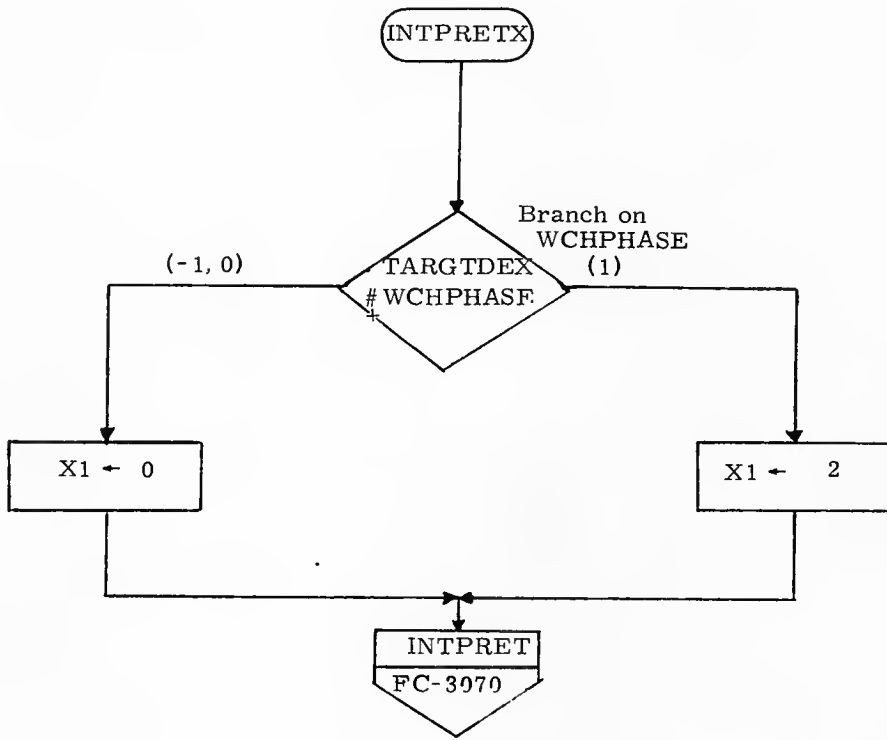
From Preceding Sheet



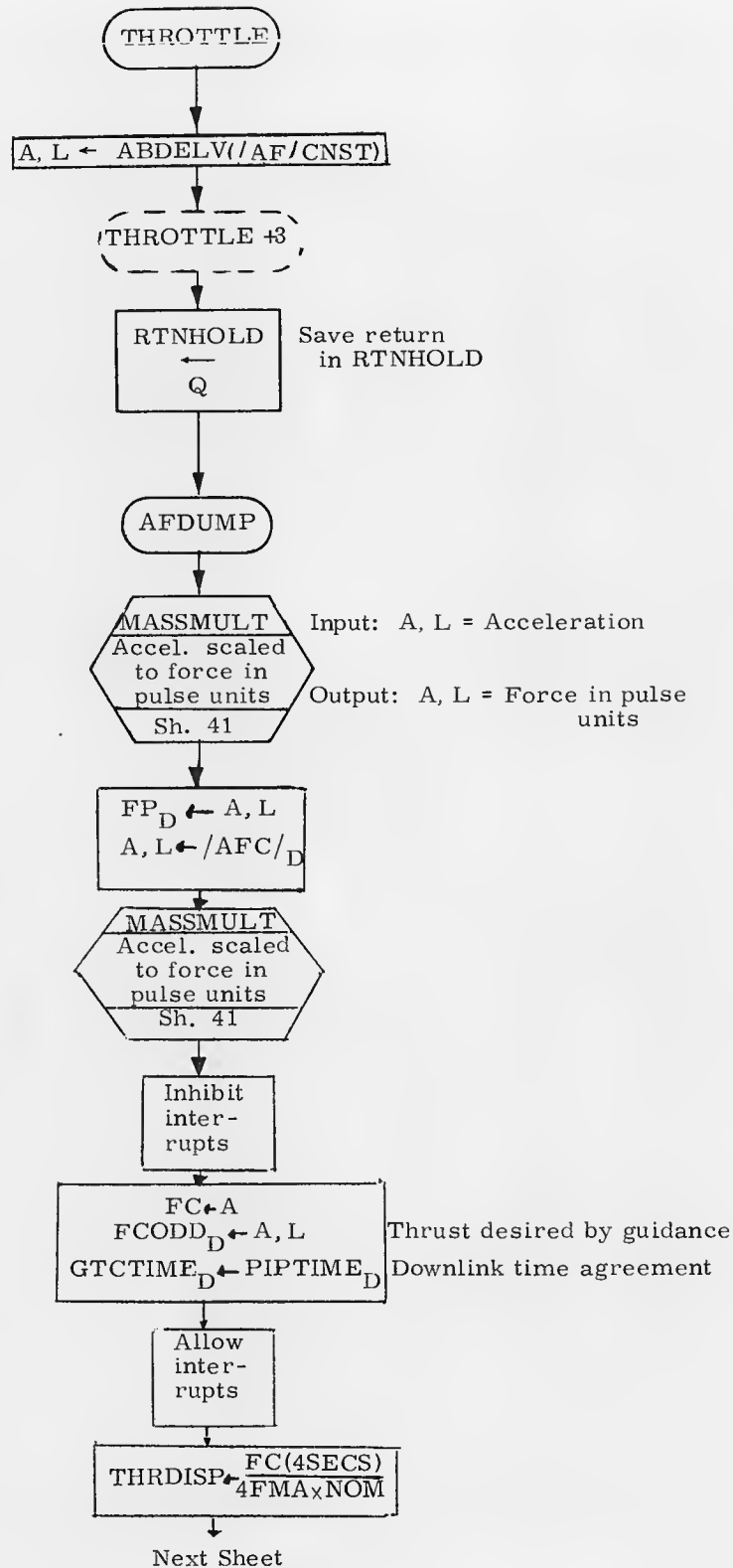
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Welch</i> 2/1/70		Lunar Landing	
PRGMR		LUMINARY 1D	DOCUMENT NO. FC-3900
ANALST			
DOCMR <i>W. Donahue</i>	9/30/69	REV 2	SHEET 33 OF 52
APPR'D <i>R.M. Carter</i>	11/25/69		



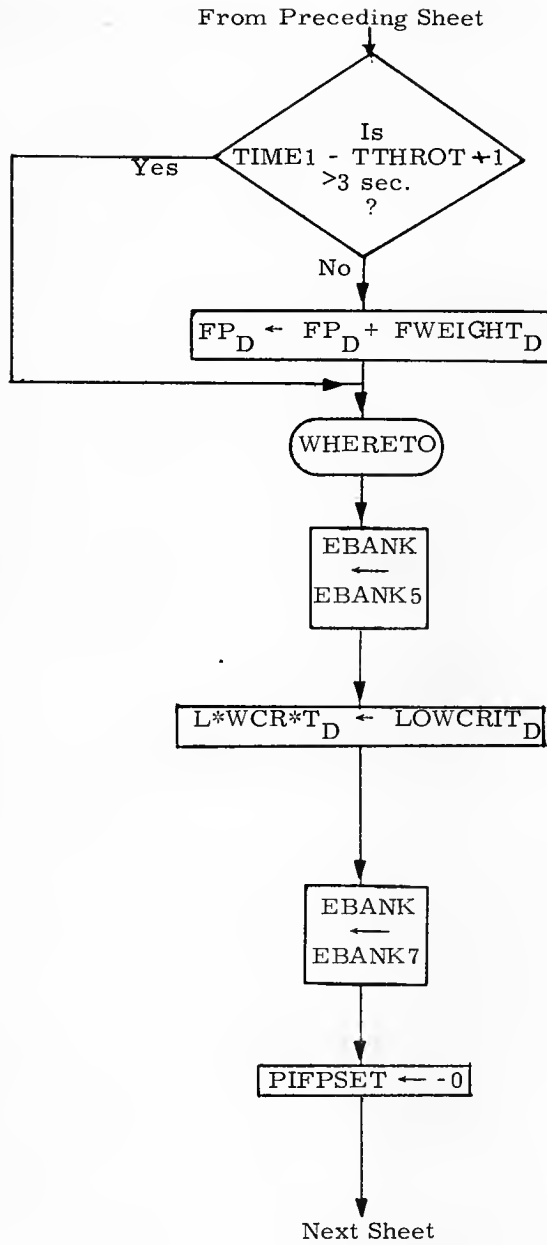
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Wallis</i>	<i>3/17/70</i>	Lunar Landing	
PRGMR		LUMINARY 1 D	DOCUMENT NO. FC-3900
ANALST			
DOCMR <i>W. Diefert</i>	<i>8/30/69</i>	REV 2	SHEET 34 OF 52
APPR'D <i>R.M. Evers</i>	<i>11/65/69</i>		



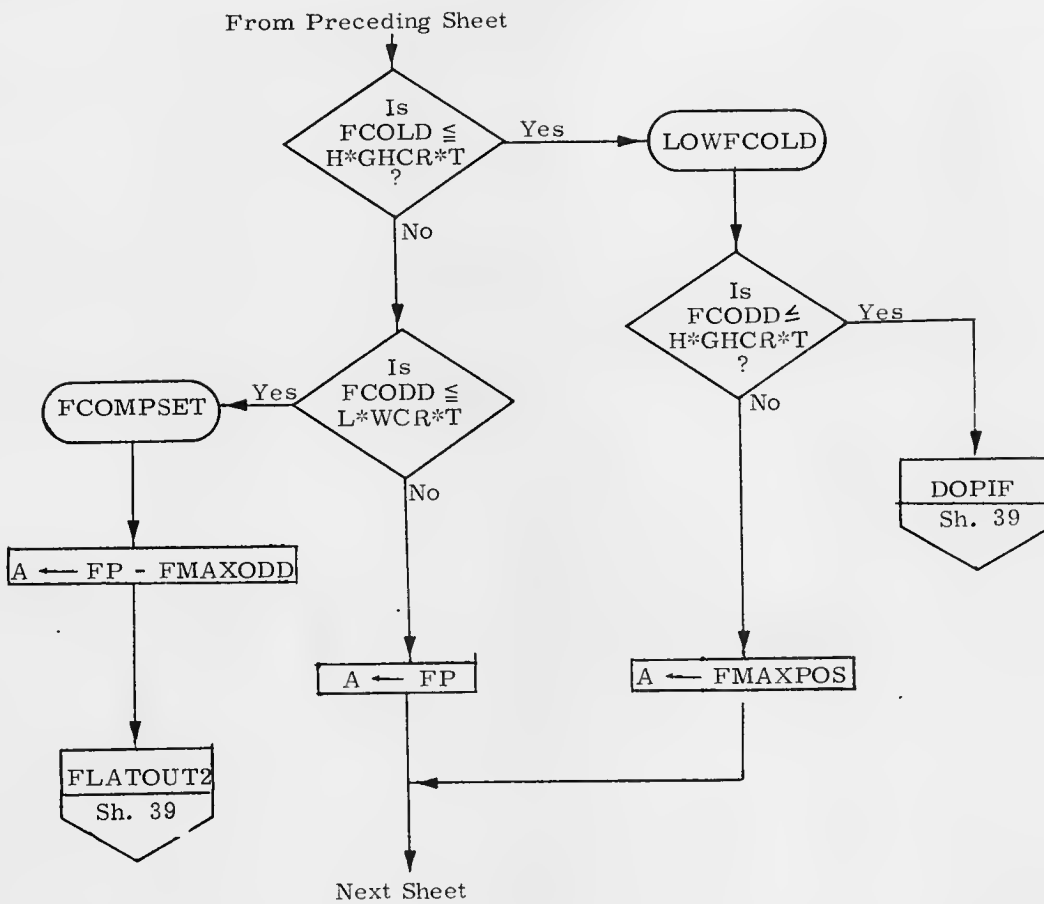
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		Lunar Landing	
DRAWN	<i>R. Welch</i> 3/5/70	LUMINARY 1D	DOCUMENT NO. FC-3900
PRGMR			
ANALST			
DOCMR	<i>W. English</i> 9/24/69		
APPR'D	<i>R.M. English</i> 11/25/69	REV 2	SHEET 35 OF 52



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Welch</i> 4/27/70		Lunar Landing	
PRGMR		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3900
DOCMR <i>W. Danforth</i>	9/30/69	REV 2	SHEET 36 OF 52
APPR'D <i>R.M. Estes</i>	11/25/69		

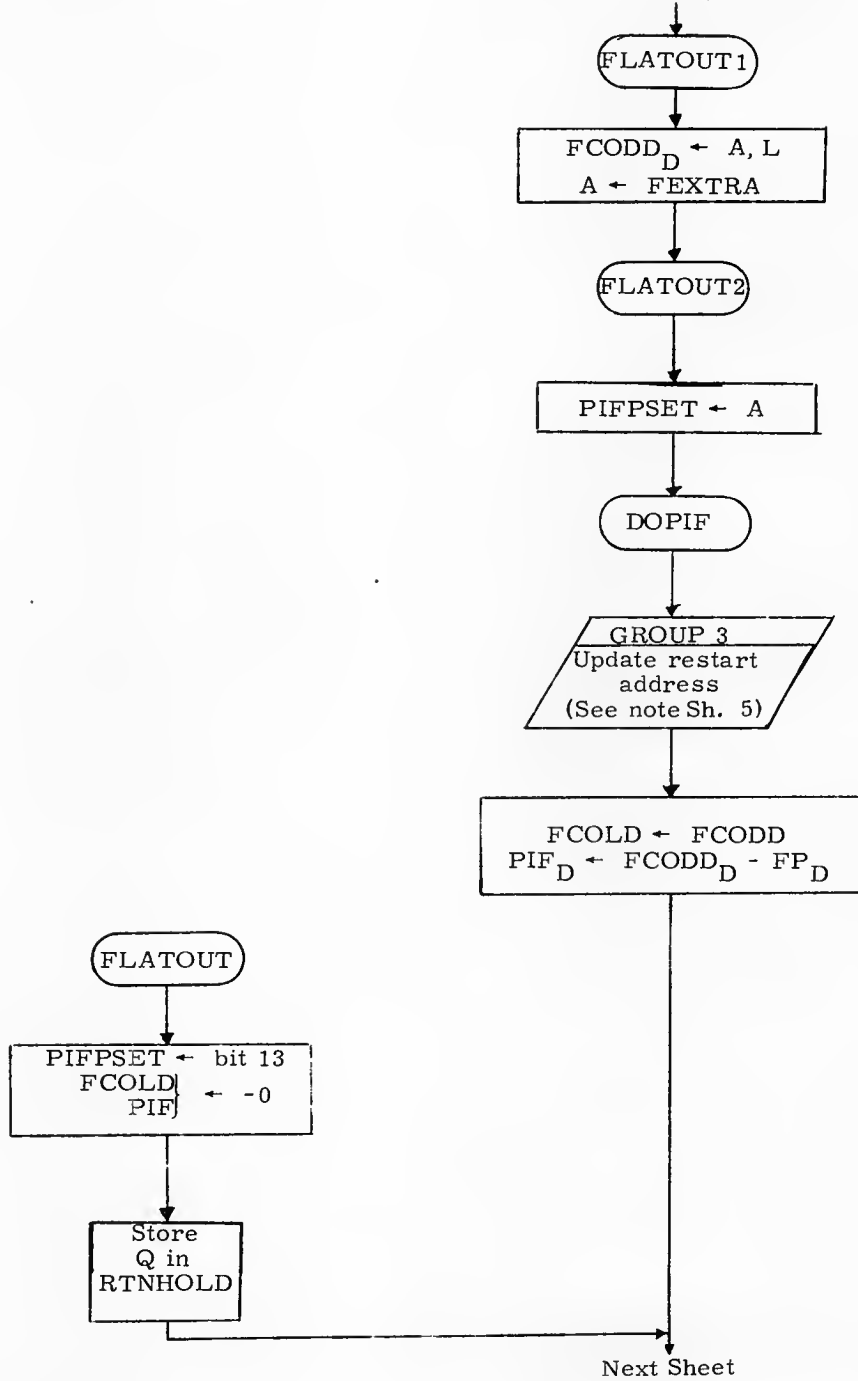


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		Lunar Landing	
DRAWN	<i>R Walsh</i> 3/2/70		
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3900
DOCMR	<i>W Doughty</i> 9/30/69		
APPR'D	<i>R M Estes</i> 11/25/69	REV 2	SHEET 37 OF 52



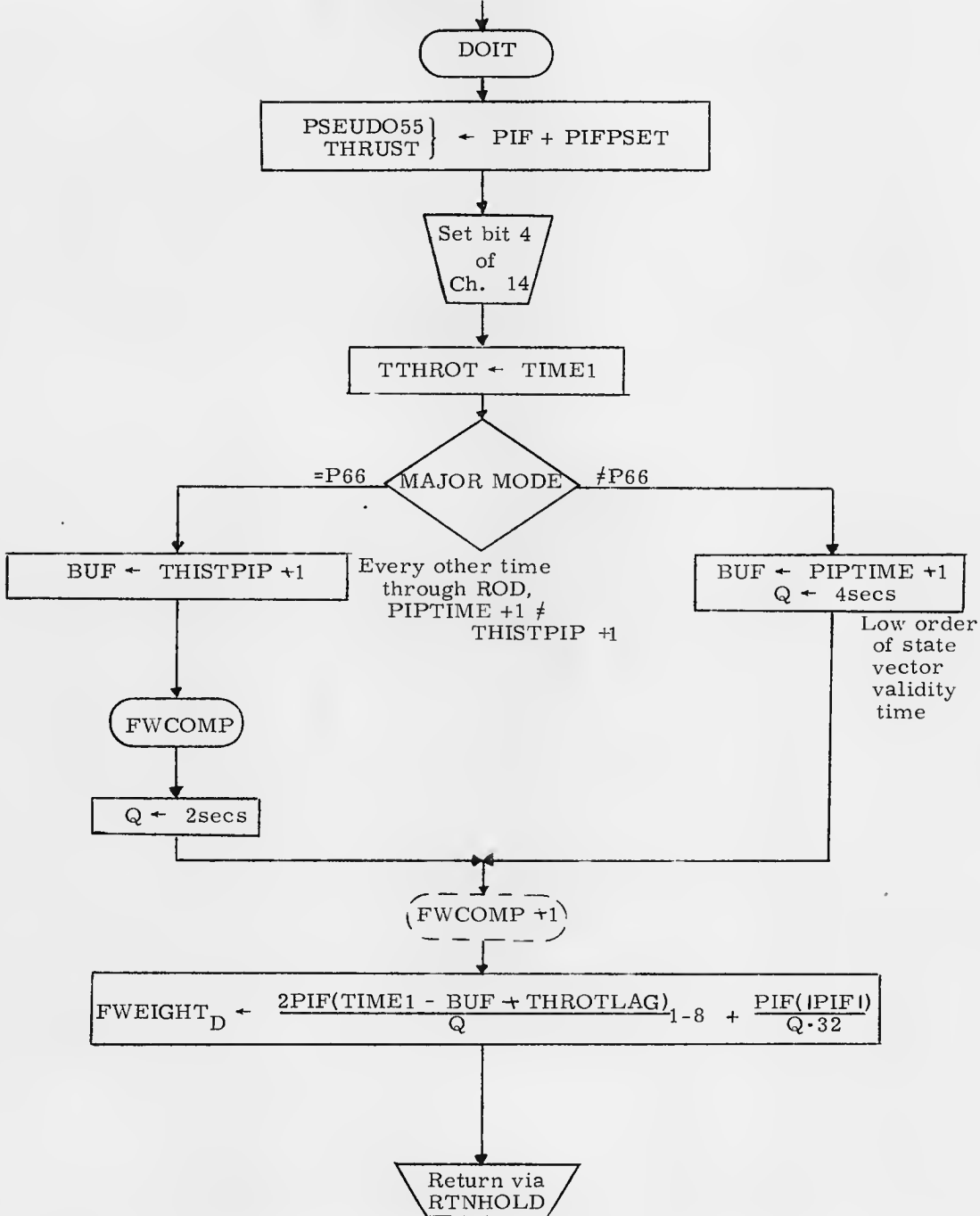
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>R. Welch</i> 3/5/70	Lunar Landing	
PRGMR		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3900
DOCMR	<i>R. Dugan</i> 9/30/69	REV 2	SHEET 38 of 52
APPR'D	<i>R. M. Estlin</i> 11/25/69		

From Preceding Sheet

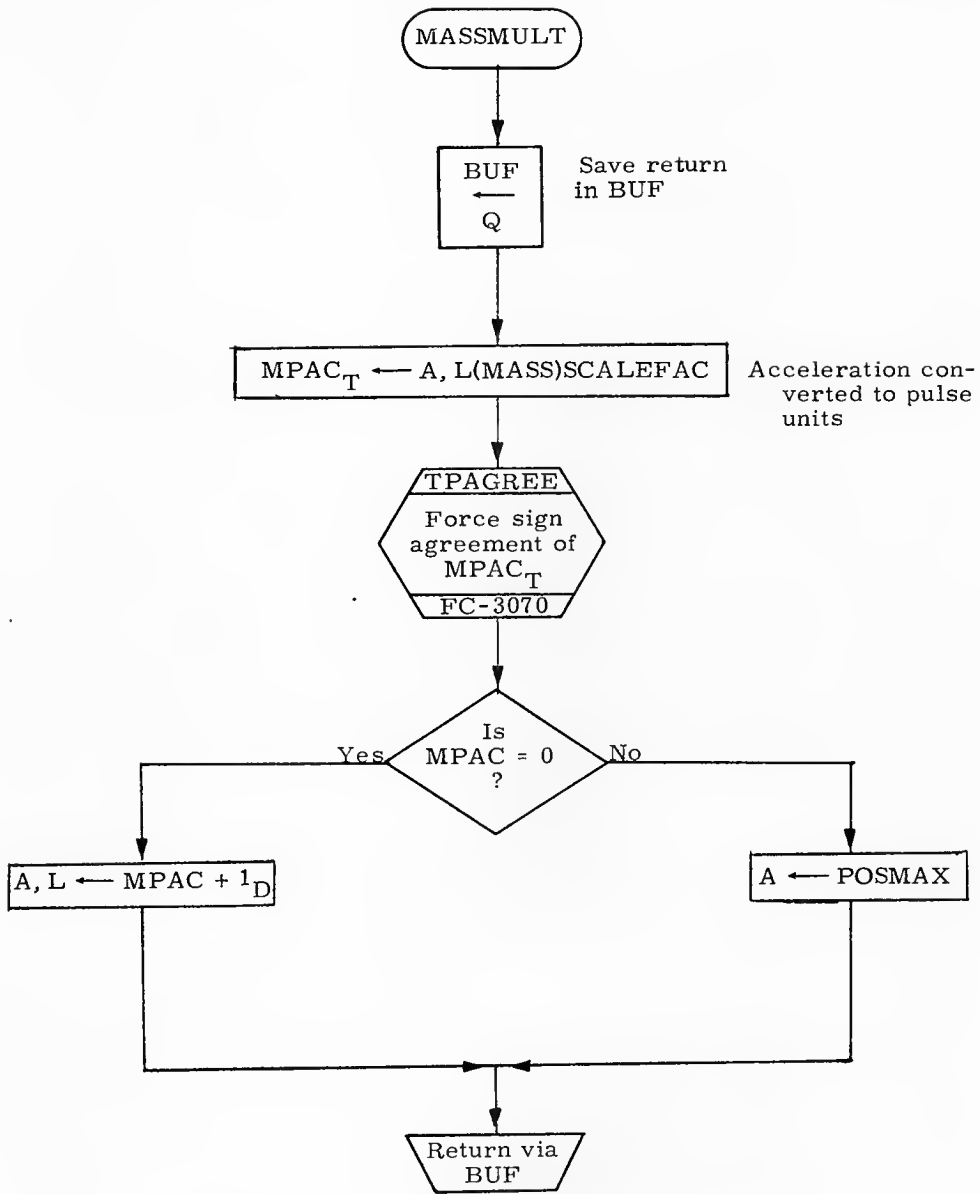


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Wildch</i> 3/17/70		Lunar Landing	
PRGMR		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3900
DOCMR <i>W. Doyl</i>	7/3/69	REV 2	SHEET 390F 52
APPR'D <i>R.M. F...</i>	11/25/69		

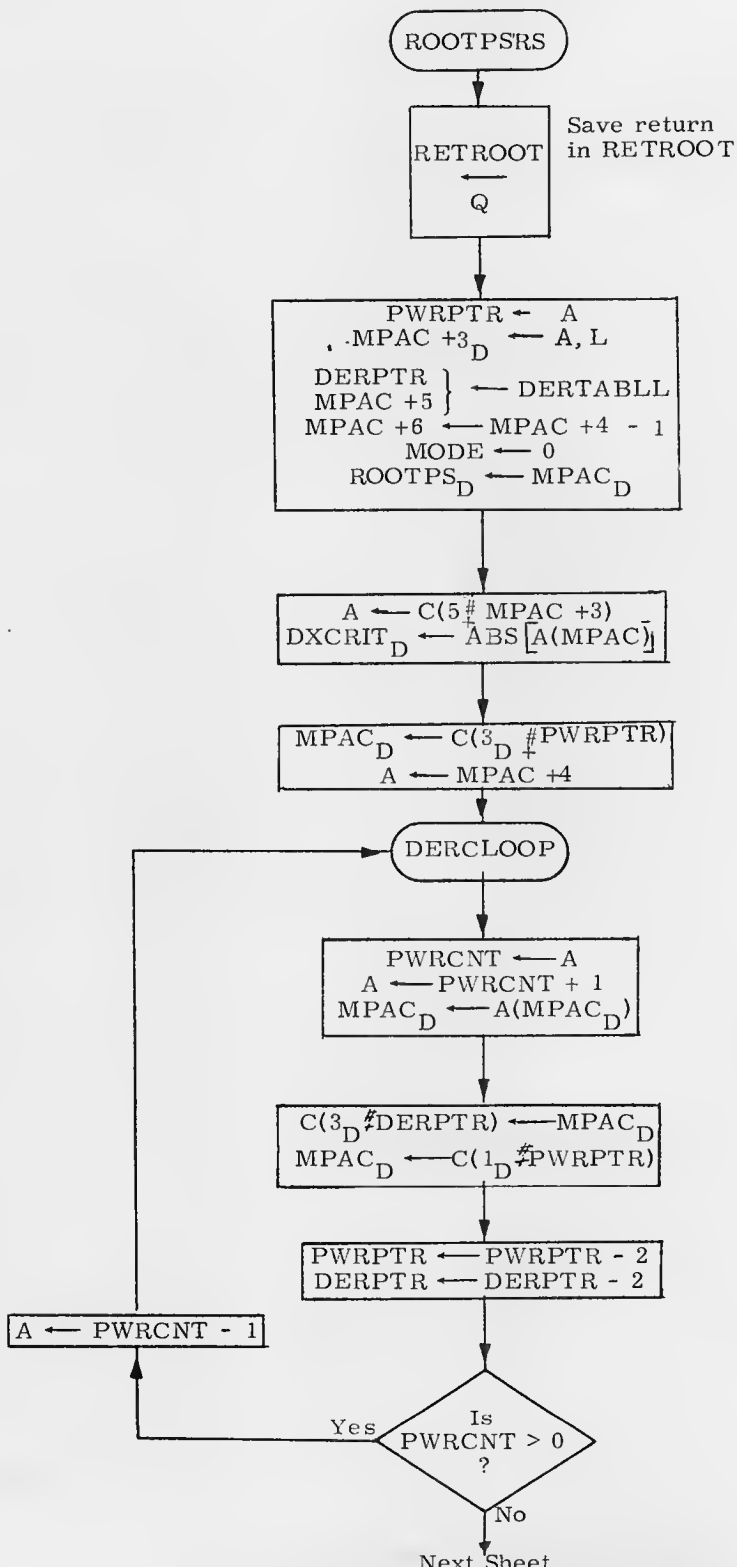
From Preceding Sheet



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>R. Weld</i> 3/5/70	Lunar Landing	
PRGMR		LUMINARY 1 D	DOCUMENT NO.
ANALST			FC-3900
DOCMR	<i>W. Dwyer</i> 7/31/69	REV 2	SHEET 40 of 52
APPR'D	<i>R.M. Estes</i> 11/25/69		

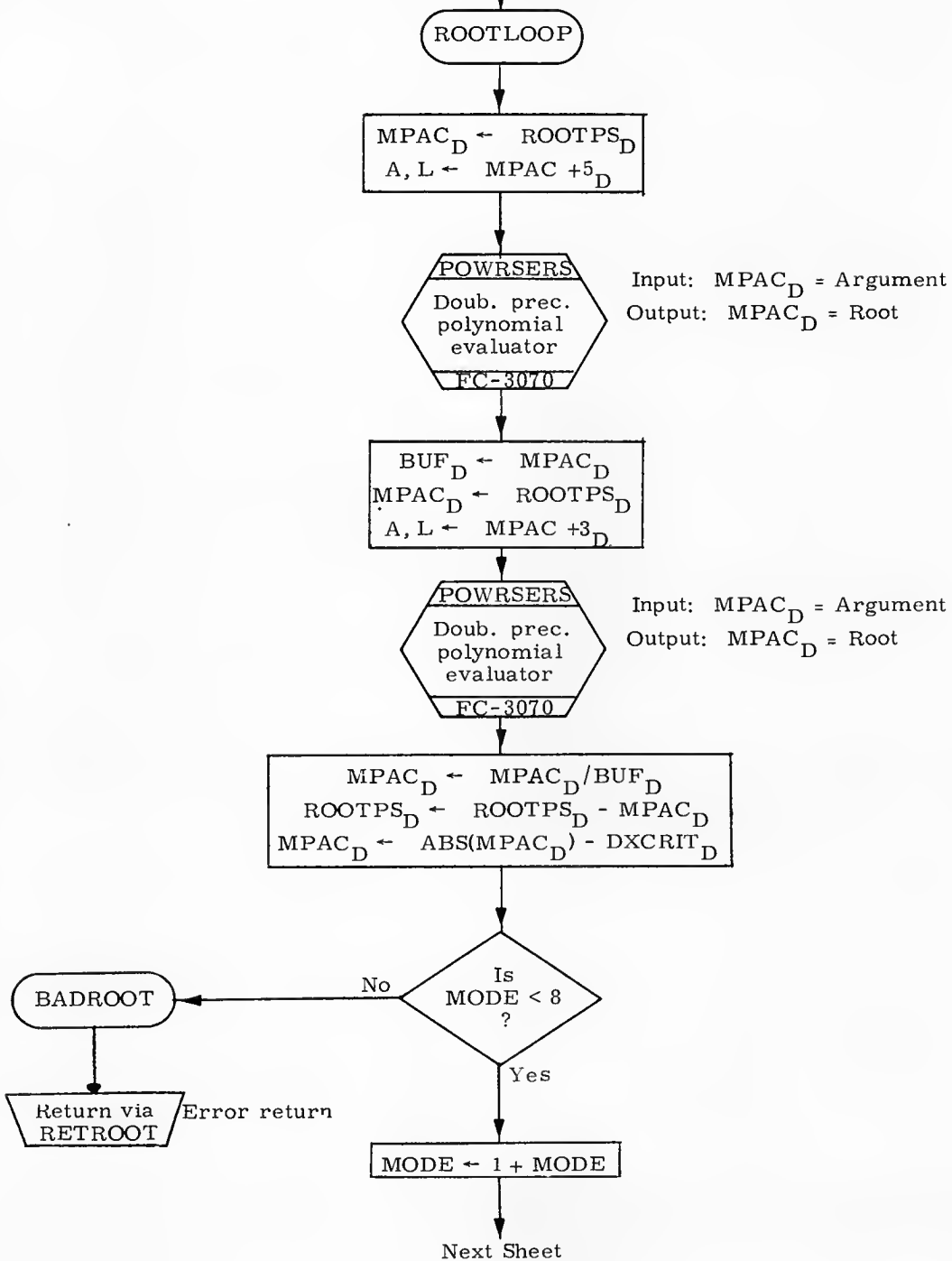


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Welch</i> 3/5/70		Lunar Landing	
PRGMR		LUMINARY-1D	DOCUMENT NO.
ANALST			FC-3900
DOCMR	<i>W. Dougherty</i> 3/24/69	REV 2	SHEET 41 OF 52
APPR'D	<i>R.M. Evans</i> 11/25/67		

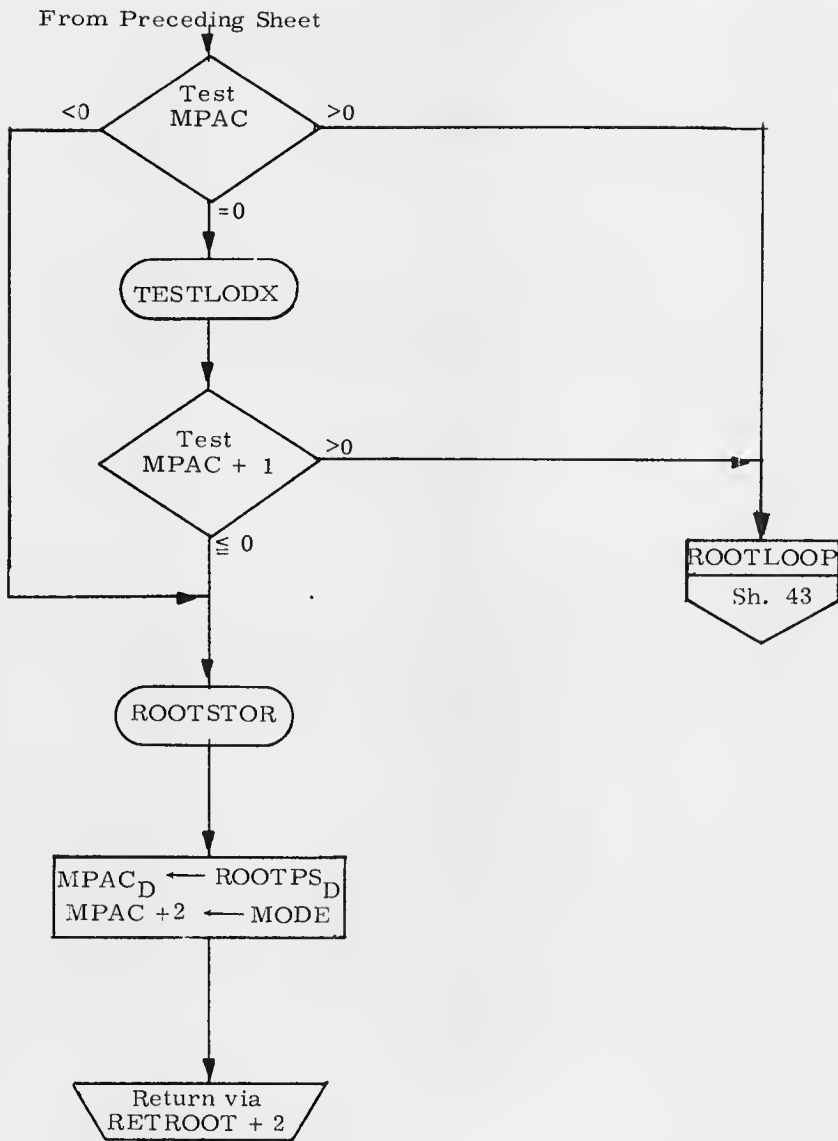


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Welch</i> 3/5/70		Lunar Landing	
PRGMR		LUMINARY 1 D	DOCUMENT NO.
ANALST			FC-3900
DOCMR <i>W. Danforth</i> 7/30/69		REV 2	SHEET 42 OF 52
APPR'D <i>R.M. Estes</i> 11/25/69			

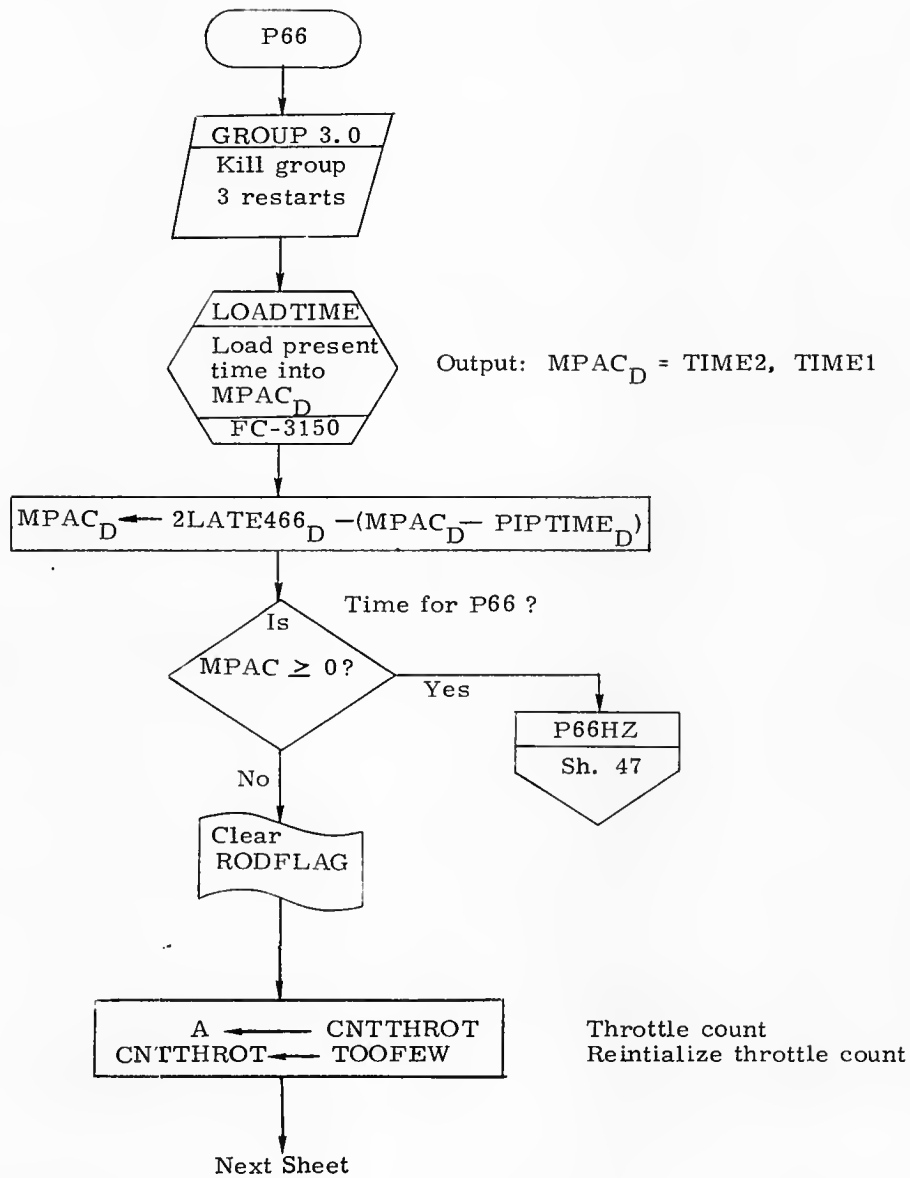
From Preceding Sheet



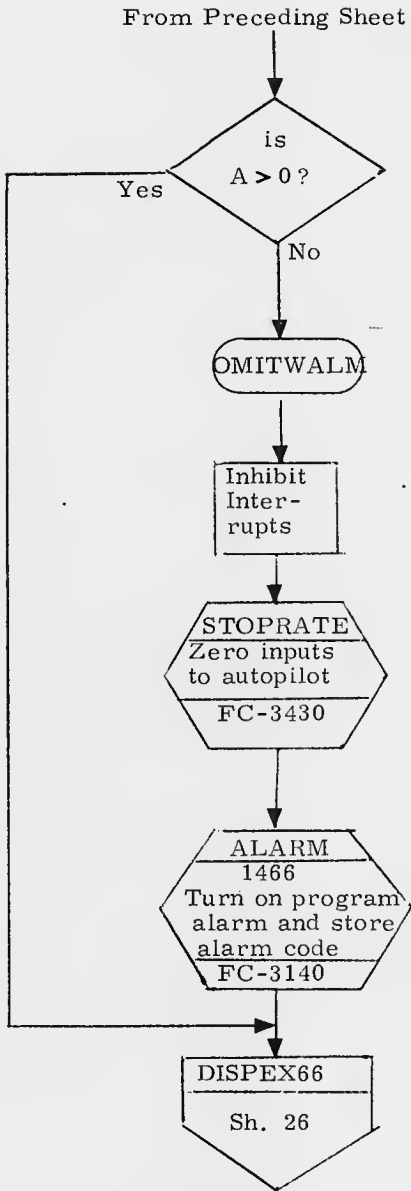
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>R. W. White</i>	Lunar Landing	
PRGMR		LUMINARY 1D	DOCUMENT NO. FC-3900
ANALST			
DOCMR	<i>W. C. Dwyer</i>	REV 2	SHEET 43 OF 52
APPR'D	<i>R. M. Egan</i>		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Welch</i> 2/5/69		Lunar Landing	
PRGMR		LUMINARY 1D	DOCUMENT NO. FC-3900
ANALST			
DOCMR	<i>W. Donath</i> 7/29/69	REV 2	SHEET 44 OF 52
APPR'D	<i>R. M. Euter</i> 8/25/69		

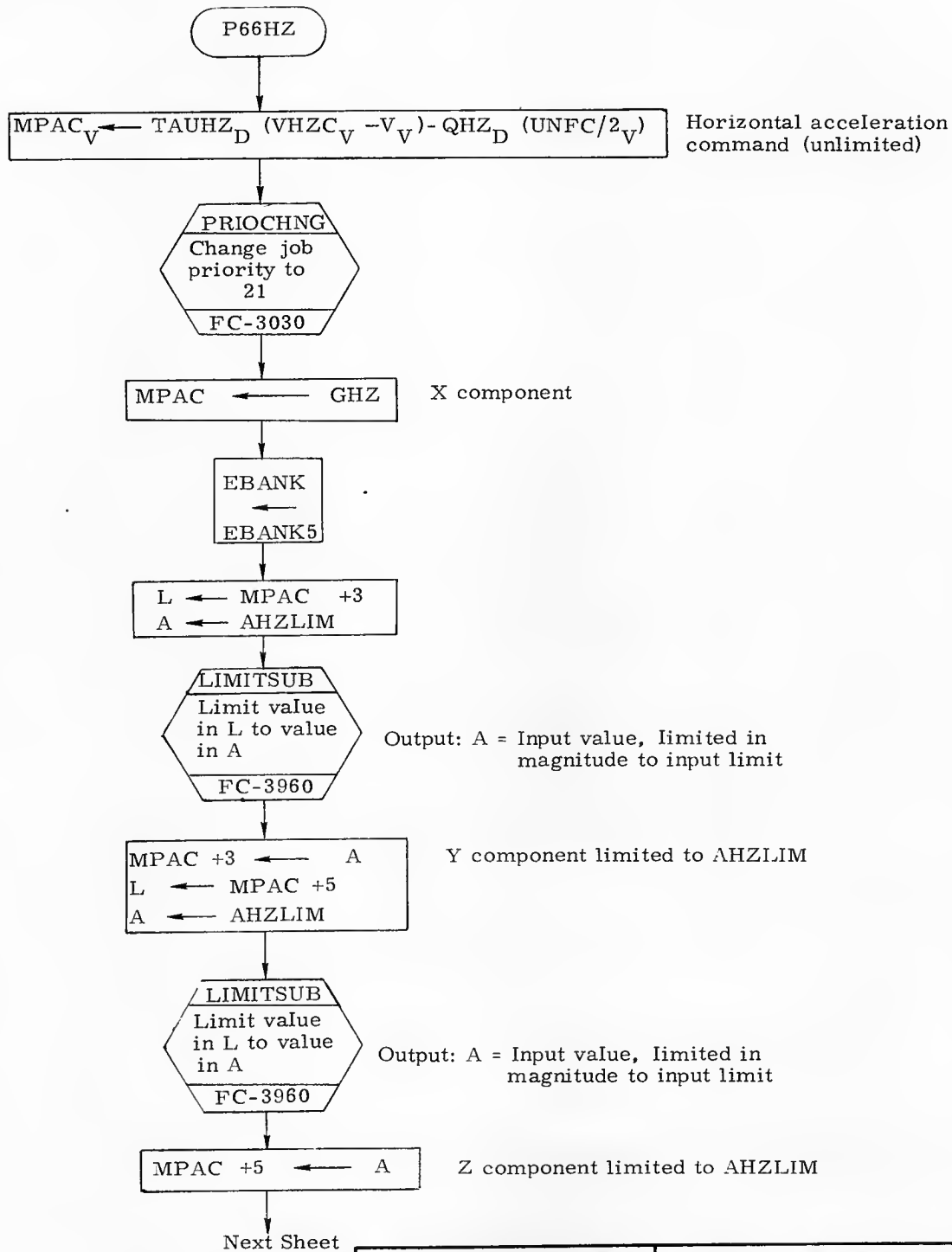


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. Welke</i> 3/5/70		Lunar Landing	
PRGMR		LUMINARY 1 D	DOCUMENT NO. FC-3900
ANALST			
DOCMR <i>W. Dapkin</i>	3/13/70	REV 2	SHEET 45 OF 52
APPR'D <i>R.M. Eyles</i>	3/25/70		



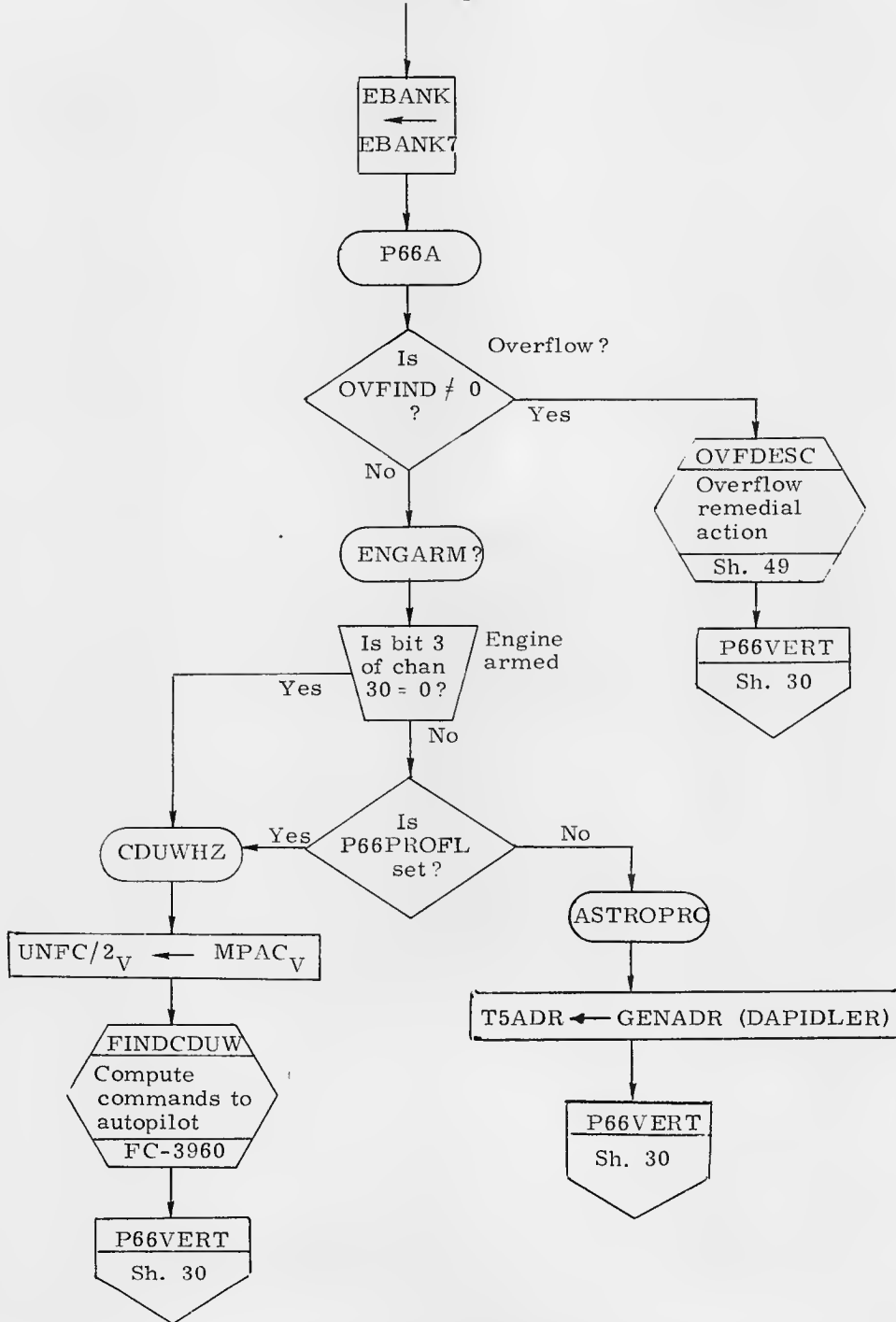
1466=Throttle servicing insufficient

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>E. Matta</i>		Lunar Landing	
PRGMR	<i>5/22/70</i>	DOCUMENT NO. FC-3900	
ANALST		LUMINARY 1D	
DOCMR <i>W. J. ...</i>	<i>6/1/70</i>		
APPR'D <i>R. J. ...</i>	<i>6/1/70</i>	REV 2	SHEET 46 OF 52

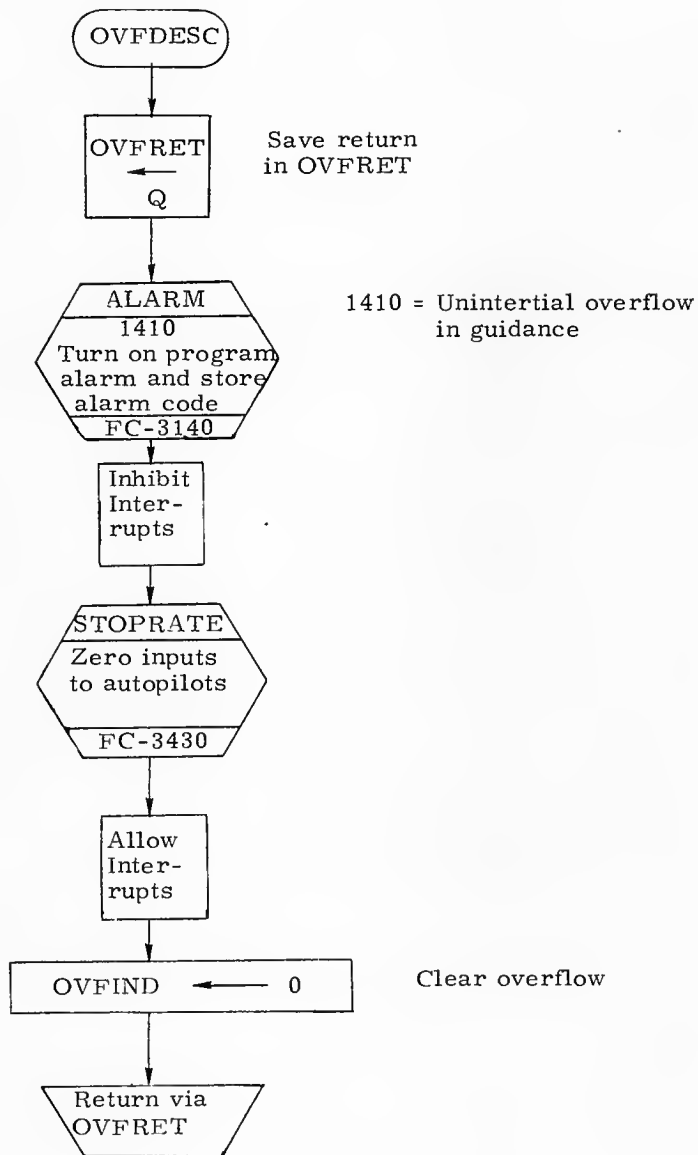


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		Lunar Landing	
DRAWN	<i>A. Welchs</i> 3/15/70	LUMINARY 1D	DOCUMENT NO.
PRGMR			FC-3900
ANALST			
DOCMR	<i>W. D. ...</i> 3/19/70		
APPR'D	<i>R.M. Euler</i> 3/25/70	REV 2	SHEET 47 OF 52

From Preceding Sheet



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		Lunar Landing	
DRAWN <i>Ar. Wolcott</i>	<i>3/15/70</i>	LUMINARY 1 D	DOCUMENT NO. FC-3900
PRGMR			
ANALST			
DOCMR <i>W. Dayford</i>	<i>3/13/70</i>		
APPR'D <i>R.M. Eason</i>	<i>3/25/70</i>	REV 2	SHEET 48 OF 52



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>C. Welsh</i>	Lunar Landing	
PRGMR			
ANALST		LUMINARY 1D	DOCUMENT NO.
DOCMR	<i>W. Donnelly</i>		FC-3900
APPR'D	<i>R.M. ...</i>	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 $ LAND _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
STCLOK 2	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	<i>D. Lutkewich</i>	<i>7/20/69</i>	Lunar Landing
PRGMR			
ANALST			DOCUMENT NO.
DOCMR	<i>W. Dornath</i>	<i>11/25/69</i>	LUMINARY 1D
APPR'D	<i>R.M. Entes</i>	<i>11/25/69</i>	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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		Lunar Landing	
DRAWN	<i>G. Walch</i> 3/5/70	LUMINARY 1D	DOCUMENT NO.
PRGMR			FC-3900
ANALST			
DOCMR	<i>W. Dwyer</i> 3/13/70		
APPR'D	<i>R. M. Eades</i> 3/25/70	REV 2	SHEET 51 OF 52

FLAGS

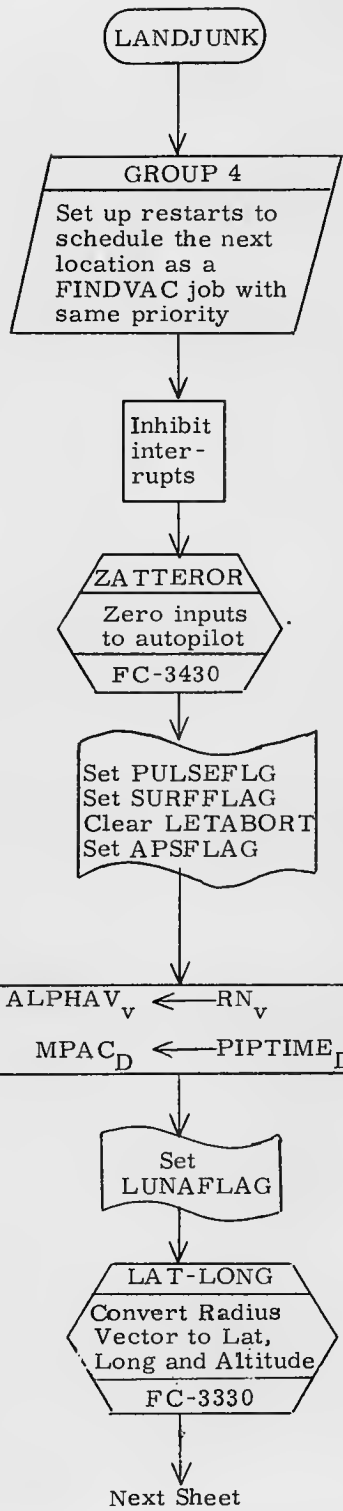
Name	Meaning When Set	Meaning When Clear	Where Set	Where Cleared	Where Tested
NOTHROTL Flag 5 Bit 12	Inhibit full throttle	Permit full throttle		Sh. 2	
REDFLAG Flag 6 Bit 6	Landing site re-designation permitted	Landing site re-designation not permitted	Sh. 29	Sh. 2, 7, 28	Sh. 9, 28
LRBYPASS Flag 11 Bit 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	
RNDVZ FLG 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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Sackman</i> 9/24/69		Lunar Landing	
PRGMR		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3900
DOCMR <i>W. Dornith</i>	11/25/69	REV 2	
APPR'D <i>R.M. Evers</i>	11/25/69	SHEET 52 OF 52	

LANDING CONFIRMATION

LANDJUNK Sh. 2

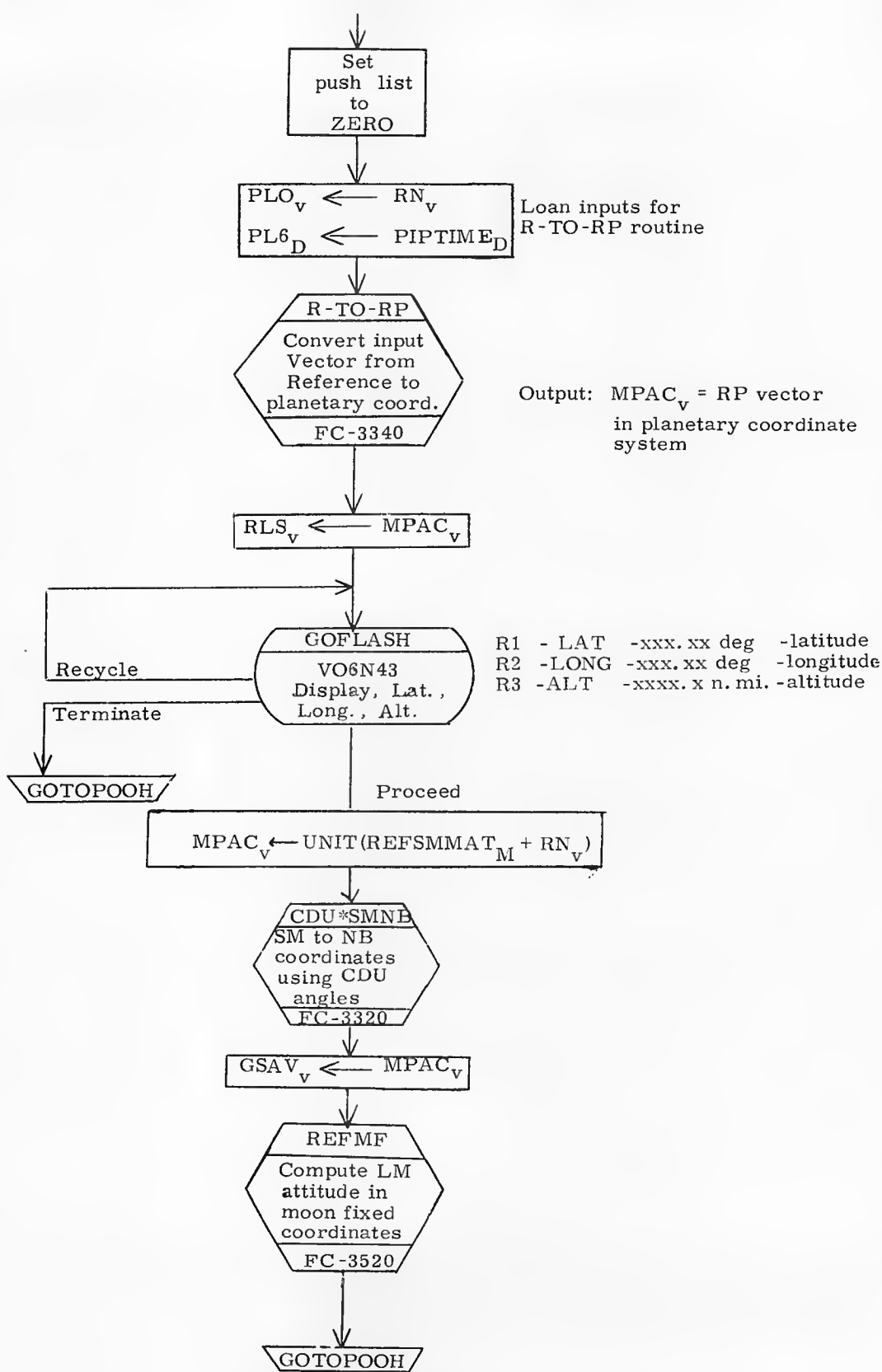
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>Gene Sullivan</i>	<i>02/15/69</i>	Landing Confirmation	
PRGMR <i>Frances Kerven</i>	<i>11/24/69</i>	LUMINARY 1D	DOCUMENT NO. FC-3910
ANALST			
DOCMR <i>W. Danforth</i>	<i>11/21/69</i>	REV 1	SHEET 1 OF 5
APPR'D <i>Roberto M. Entes</i>	<i>11/26/69</i>		



Minimum impulse command mode
LM on lunar surface
Abort programs are not disabled
Ascent stage

Lunar Lat-Long

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>Francis Riven</i> 11/24/69		Landing Confirmation	
PRGMR <i>Francis Riven</i>	11/24/69	LUMINARY 1D	DOCUMENT NO.
ANALST			FC 3910
DOCMR <i>W. Doughty</i>	11/24/69	REV 1	SHEET 2 OF 5
APPR'D <i>Robert M. Estes</i>	11/24/69		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>John Sullivan</i> 10/15/69		Landing Confirmation	
PRGMR <i>Frances Rivens</i> 11/24/69		LUMINARY 1D	DOCUMENT NO. FC-3910
ANALST			
DOCMR <i>W. Danforth</i> 11/21/69		REV 1	SHEET 3 OF 5
APPR'D <i>Robert M. Estes</i> 11/26/69			

FLAGS

Name	Meaning When Set	Meaning When Cleared	Where Set	Where Cleared	Where Tested
PULSEFLAG 13 BIT 15	Minimum impulse command mode	Not in minimum impulse command mode	Sh. 2		
SURFLAG 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 10 BIT 13	Ascent stage	Descent stage	Sh. 2		
LUNAFFLAG 3 BIT 12	Lunar lat-long	Earth lat-long	Sh. 2		

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>ess. J. Williams</i>		Landing Confirmation	
PRGMR <i>Frances Bowen</i>	<i>11/24/69</i>	LUMINARY ID	DOCUMENT NO. FC-3910
ANALST			
DOCMR <i>W. D. Smith</i>	<i>10/21/69</i>		
APPR'D <i>Roberta M. Carter</i>	<i>11/24/69</i>	REV 1	SHEET 4 OF 5

SUBROUTINES CALLED ON OTHER FLOWCHARTS

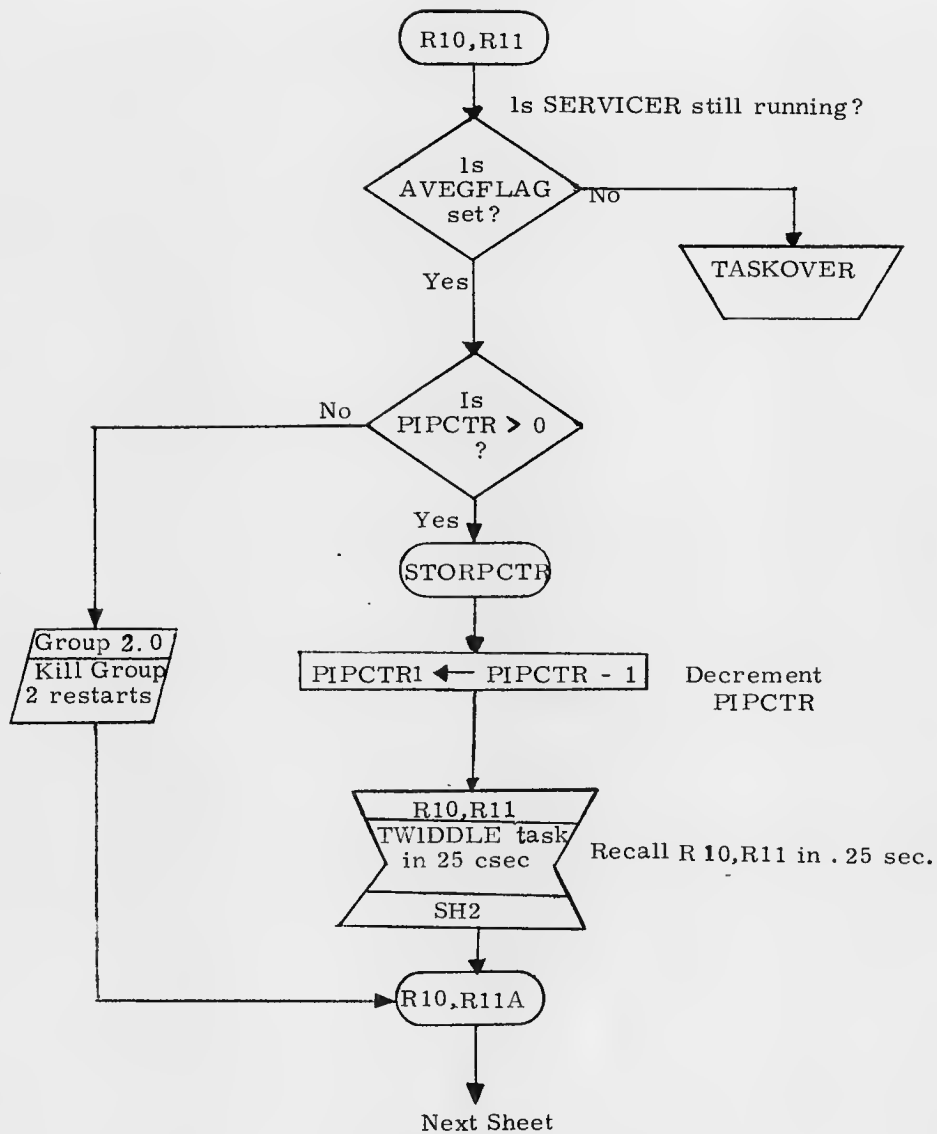
Subroutine	Flowchart	Description	Where Called
ZATTEROR	FC-3430	Zero inputs to autopilot	Sh. 2
LAT-LONG	FC-3330	Convert radius vector to Lat., Long. and altitude	Sh. 2
R-TO-RP	FC-3340	Convert vector from reference to planetary	Sh. 3
REFMF	FC-3520	Compute LM attitude in moon fixed coordinates	Sh. 3
CDU*SMNB	FC-3320	SM to NB coordinates using CDU angles	Sh. 3

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>in silhouette</i>	<i>10/21/69</i>	Landing Confirmation	
PRGMR <i>Francesa Riven</i>	<i>10/21/69</i>	LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3910
DOCMR <i>W. Duffield</i>	<i>10/21/69</i>		
APPR'D <i>Robert M. Evers</i>	<i>10/21/69</i>	REV 1	SHEET 5 OF 5

R09, R10, R11

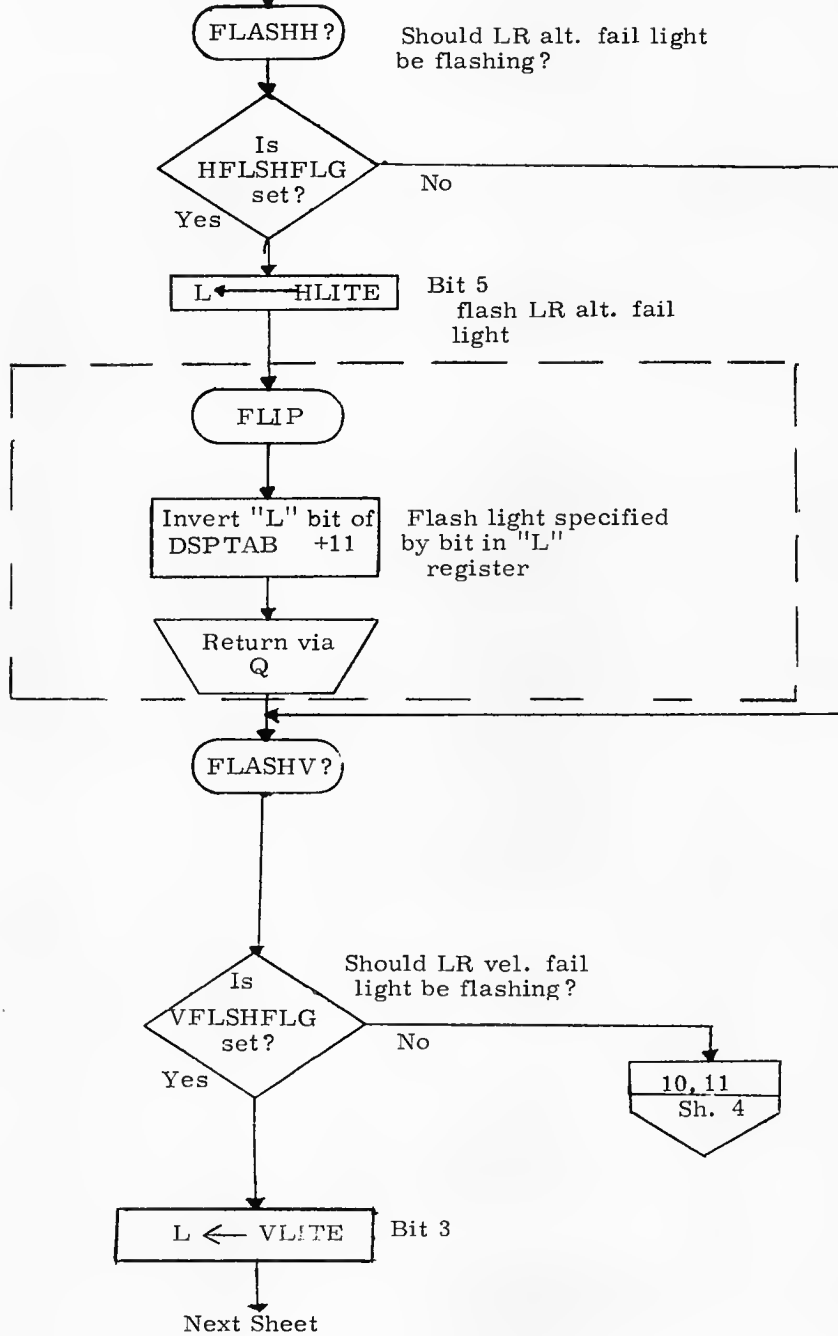
R10, R11	Sh. 2
FLIP	Sh. 3
10, 11	Sh. 4
LANDISP	Sh. 6

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Zick</i>	<i>10/29/69</i>	R09, R10, R11	
PRGMR <i>R.P. Bernick</i>	<i>11/25/69</i>		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3930
DOCMR <i>H. Dwyer</i>	<i>11/21/69</i>		
APPR'D <i>Robert M. Sita</i>	<i>11/25/69</i>	REV 2	SHEET 1 OF 21

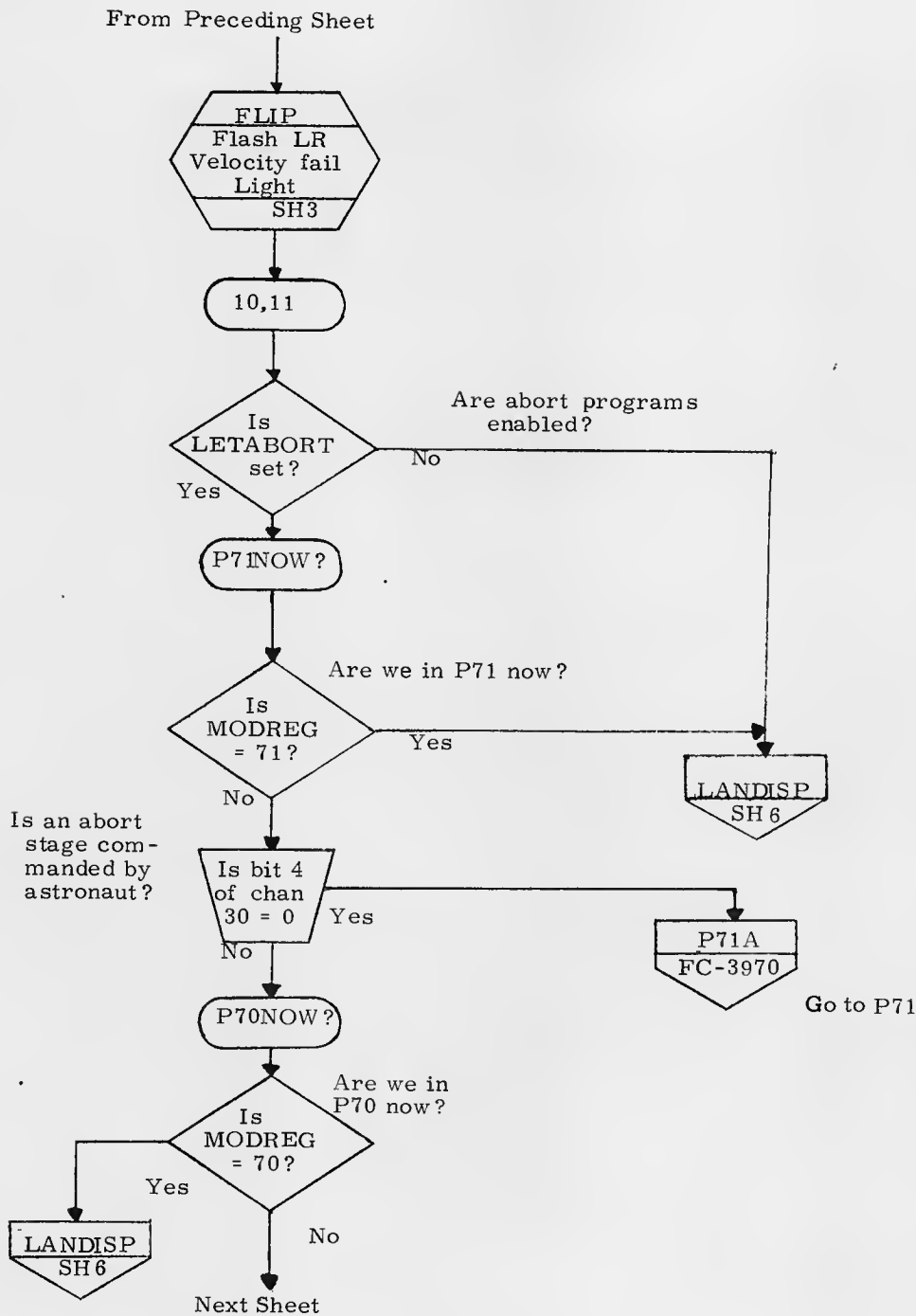


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. J. Danforth</i> 10/29/69		R09, R10, R11	
PRGMR <i>A. Bernikowicz</i> 10/29/69		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3930
DOCMR <i>W. Danforth</i> 9/26/69		REV 2	SHEET 2 OF 21
APPR'D <i>Robert M. Pitzer</i> 10/31/69			

From Preceding Sheet

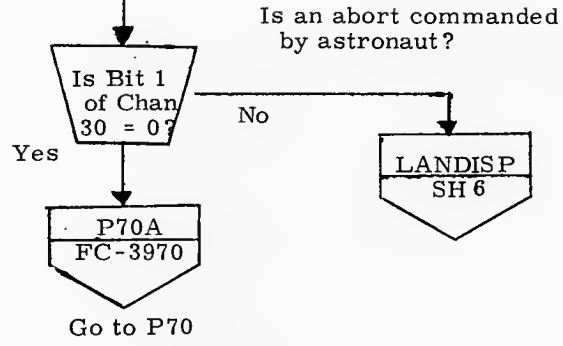


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. Lubbe</i> 7/26/69		R09, R10, R11	
PRGMR <i>D. Bernick</i> 10/29/69		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3930
DOCMR <i>W. Danforth</i> 7/26/69		REV 2	SHEET 3 OF 21
APPR'D <i>Robert M. Evers</i> 10/29/69			

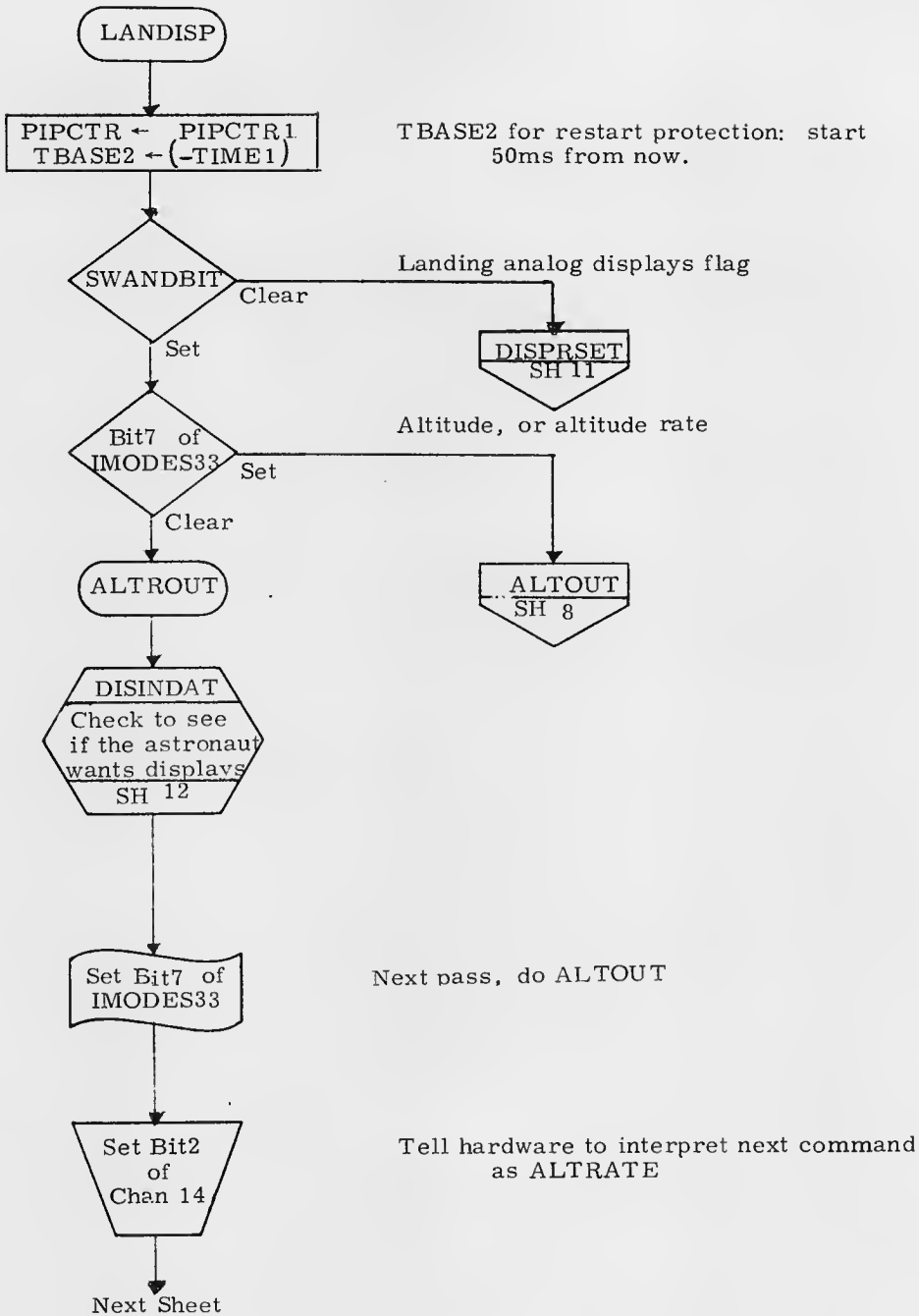


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>Aditkovich</i> 9/24/69		R09, R10, R11	
PRGMR <i>P. Beukovich</i> 10/29/69		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3930
DOCMR <i>H. Dargatzis</i> 7/26/69		REV 2	SHEET 4 OF 21
APPR'D <i>Roberta M. Entel</i> 10/28/69			

From Preceding Sheet



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. L. Lusk</i> 9/26/69		R09, R10, R11	
PRGMR <i>D. Bernier</i> 10/29/69		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3930
DOCMR <i>W. D. Griffith</i> 9/26/69		REV 2	SHEET 5 of 21
APPR'D <i>Robert M. Foster</i> 10/29/69			



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>John Good</i> 7/24/69		R09, R10, R11	
PRGMR <i>D. Bernikowicz</i> 10/29/69		DOCUMENT NO. FC-3930	
ANALST		LUMINARY 1D	
DOCMR <i>W. D. Guth</i> 9/26/69		REV 2	SHEET 6 OF 21
APPR'D <i>M. S. ...</i> 10/20/69			

From Preceding Sheet

ARCOMP

(3.4.4.7)

$$v_V = v_{MP} \cdot \frac{v_H}{r_P} + \frac{v_H^2}{r_P} (t_i - t_{n-1})$$

RUPTREG1 ← VVECT · RUNIT +
 (VVECT + 1)(RUNIT + 1) +
 (VVECT + 2)(RUNIT + 2)
 A, L ← ARCONV · RUPTREG1
 A, L ← 4(A, L)
 RUPTREG1 ← A
 ALTRATE ← RUPTREG1 + DT · DALTRATE

< 0 ALTRATE ≥ 0

A ← (-ALTRATE)

A ← Bit 15 + ALTRATE

DATAOUT

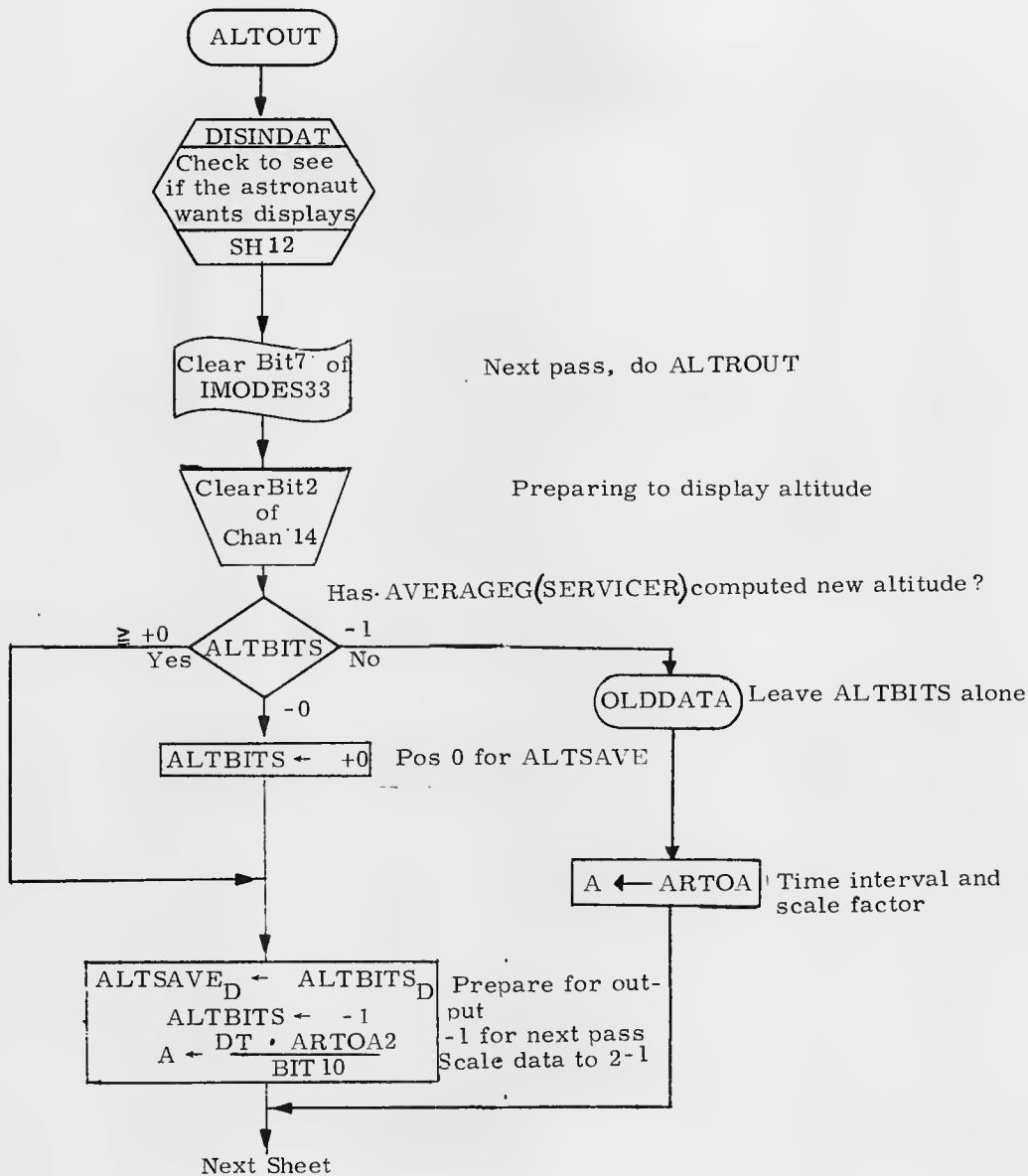
ALTM ← A

Set Bit 3 of Chan 14

Drive the tape meter.
Command to display altitude or altitude rate, depending on Bit 2 of Chan 14.

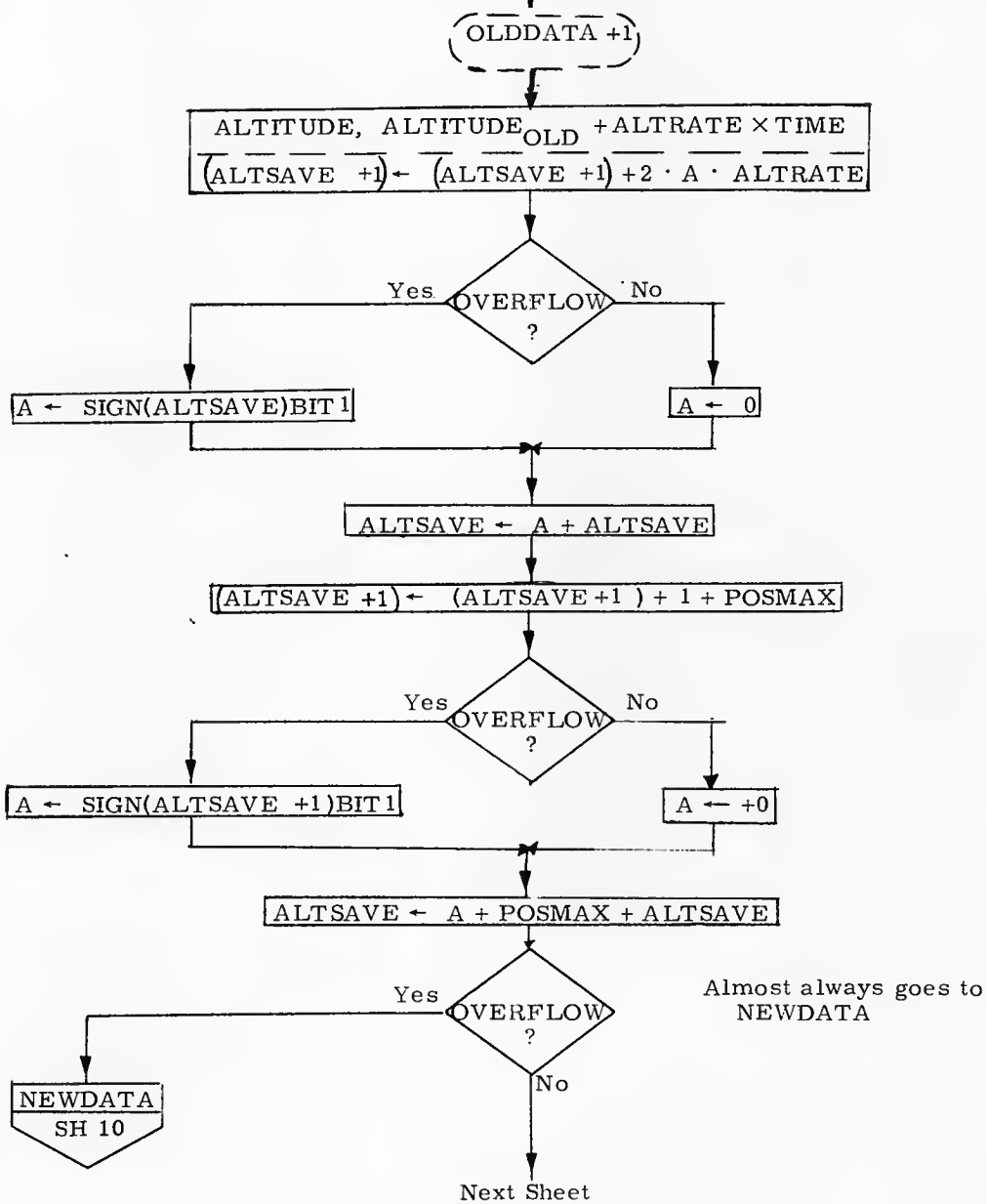
TASKOVER

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. Littlewood</i>	<i>9/26/67</i>	R09, R10, R11	
PRGMR <i>R. Benicovich</i>	<i>10/29/67</i>	LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3930
DOCMR <i>W. Dwyer</i>	<i>9/26/67</i>	REV 2	SHEET 7 OF 21
APPR'D <i>R. W. Smith</i>	<i>10/29/67</i>		



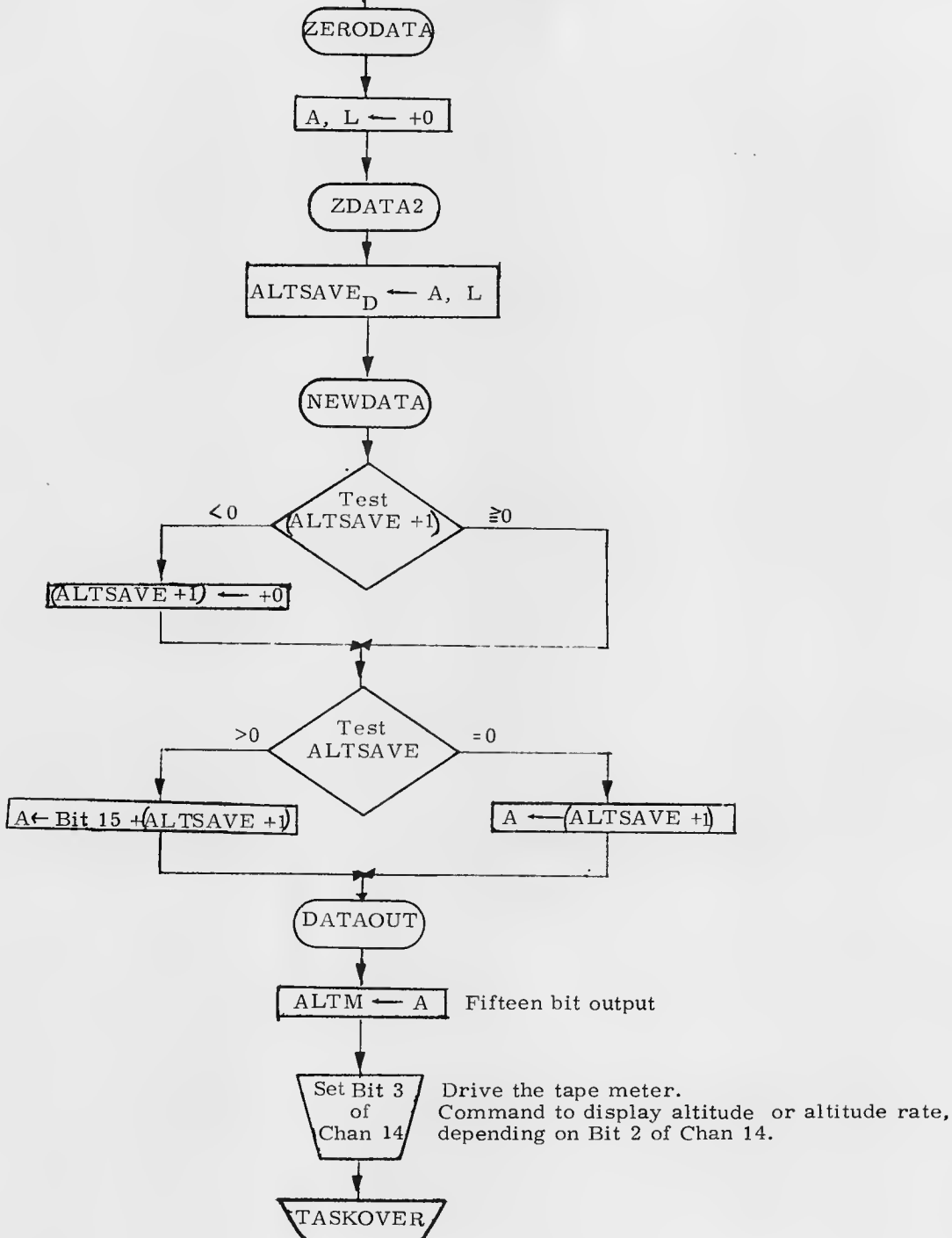
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>E. L. ...</i> 1/26/69		R09, R10, R11	
PRGMR <i>D. Bernikovich</i> 10/29/69		LUMINARY ID	DOCUMENT NO. FC-3930
ANALST		REV 2	SHEET 8 ~ 21
DOCMR <i>H. ...</i> 9/26/69			
APPR'D <i>R.M. ...</i> 10/29/69			

From Preceding Sheet

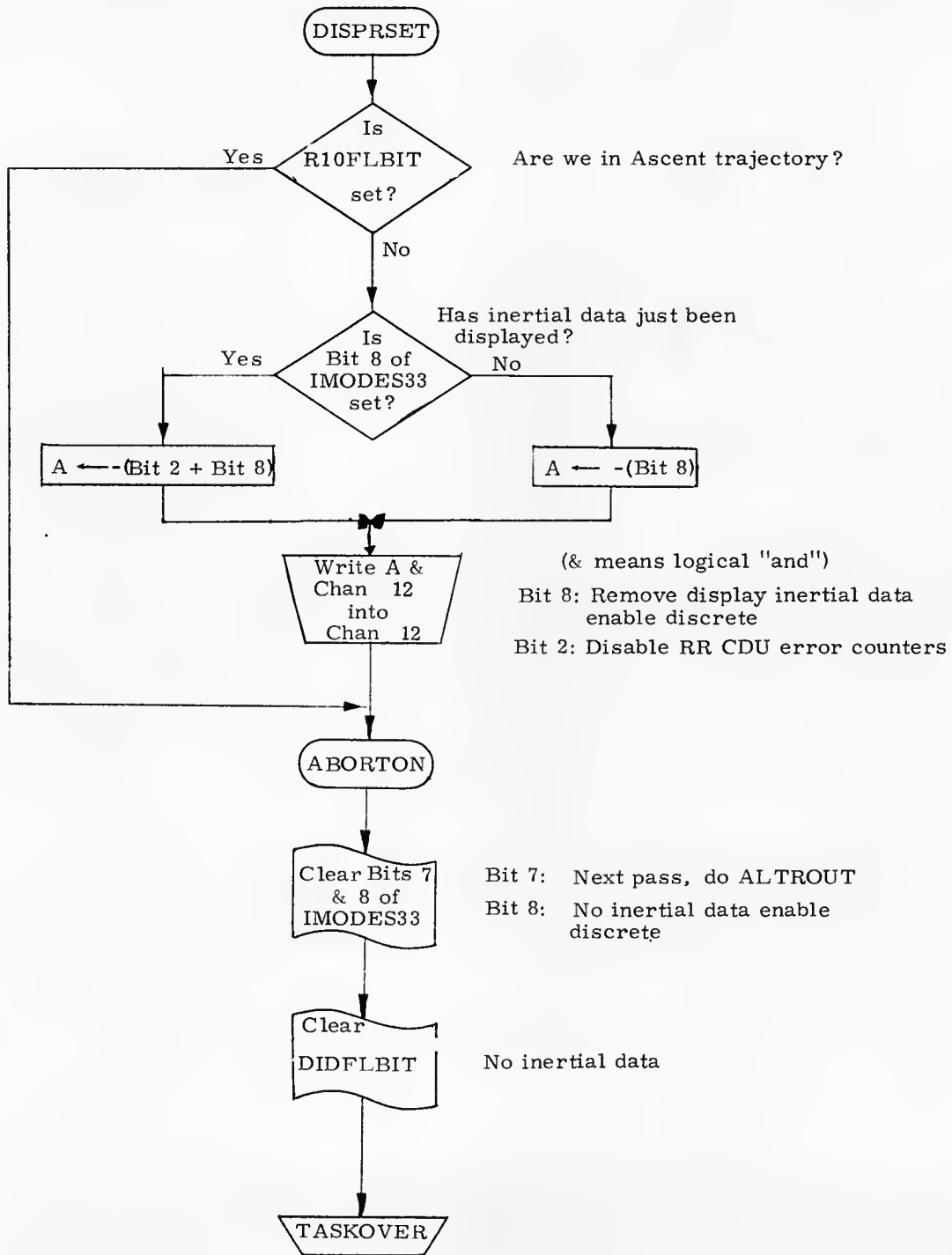


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. J. Beard</i> 9/24/69		R09, R10, R11	
PRGMR <i>Ed Bernikowicz</i> 10/29/69		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3930
DOCMR <i>W. English</i> 9/26/69		REV 2	SHEET 9 of 21
APPR'DR <i>M. Estes</i> 10/20/69			

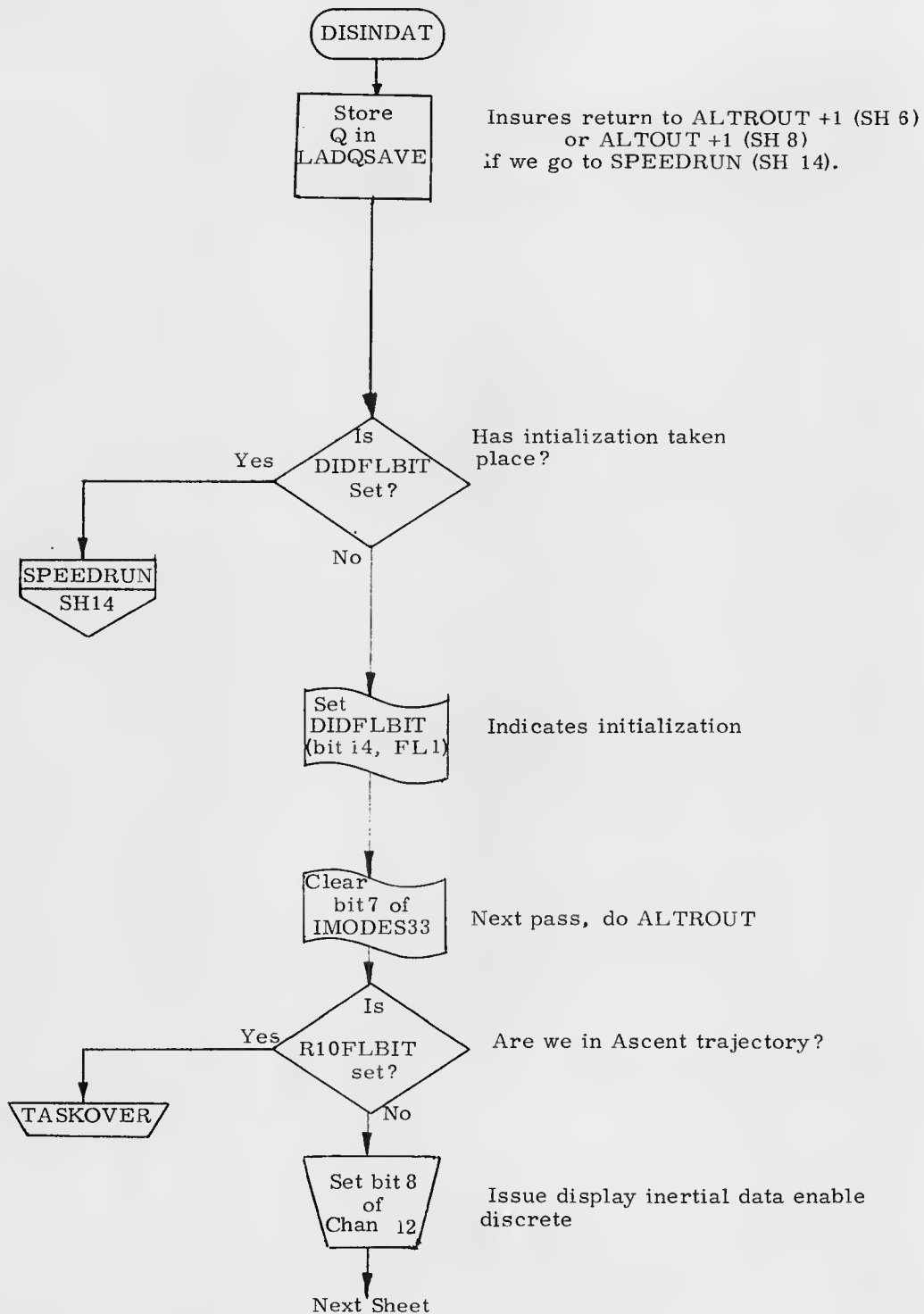
From Preceding Sheet



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. J. ...</i>		R09, R10, R11	
PRGMR <i>A. B. ...</i> 10/29/69		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3930
DOCMR <i>W. ...</i> 9/26/69		REV 2	
APPR'DR. <i>M. ...</i> 10/30/69		SHEET 10 OF 21	



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. J. ...</i>	<i>9/24/69</i>	R09, R10, R11	
PRGMR <i>D. Ben ...</i>	<i>10/29/69</i>	LUMINARY 1D	DOCUMENT NO. FC-3930
ANALST		REV 2	SHEET 11 OF 21
DOCMR <i>W. ...</i>	<i>9/26/69</i>		
APPR'DR <i>...</i>	<i>10/29/69</i>		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. L. ...</i> 7/26/69		R09, R10, R11	
PRGMR <i>A. Bernick</i> 10/29/69		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3930
DOCMR <i>M. DeGroot</i> 7/26/69		REV 2	
APPR'D <i>R.M. ...</i> 10/29/69		SHEET 12 OF 21	

From Preceding Sheet

```

TRAKLATV ← +0
TRAKFWDV ← +0
LATVMETR ← +0
FORVMETR ← +0
    
```

INTLZE
 TWIDDLE Task
 in 8csec.
 SH 13

TASKOVER

INTLZE

Set Bit 2
 of
 Chan 12

Enable RR CDU error counters

Set
 Bit 8 of
 IMODES33

Indicate display inertial data enable discrete was issued.

TASKOVER

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. J. ...</i>		R09, R10, R11	
PRGMR <i>D. J. ...</i>		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3930
DOCMR <i>W. ...</i>		REV 2	SHEET 13 OF 21
APPR'D <i>R. M. Estes</i>			

SPEEDRUN

$$\frac{v_{MP_x}}{DT} = \frac{v_{MP}}{DT} \left[g_P(t-t_N) + (\Delta v_P + \Delta v_{P_N})(t-t_N) \right] \quad \text{X component}$$

$$DT \leftarrow \text{Bit 14} + \text{Bit 14} + \text{TIME1} - (\text{PIPTIME} + 1)$$

$$\text{ITEMP5} \leftarrow 1\text{SEC}$$

$$\text{VVECT}_S \leftarrow DT \left[\frac{4(\text{GDT}/2)_D}{\text{ITEMP5}} \right]$$

$$\text{VVECT}_S \leftarrow \text{VVECT}_S + 4(V_D)$$

$$\text{VVECT}_S \leftarrow \text{VVECT}_S + \text{KPIP1}(5) (\text{PIPATMPX} + \text{PIPAX})$$

$$(\text{VVECT} + 1) \leftarrow DT \left[\frac{4(\text{GDT}/2+2)_D}{\text{ITEMP5}} \right]$$

$$(\text{VVECT} + 1) \leftarrow (\text{VVECT} + 1) + 4(V + 2)_D$$

$$(\text{VVECT} + 1) \leftarrow (\text{VVECT} + 1) + \text{KPIP1}(5) (\text{PIPATMPY} + \text{PIPAY})$$

Y component

$$(\text{VVECT} + 2) \leftarrow DT \left[\frac{4(\text{GDT}/2 + 4)}{\text{ITEMP5}} \right]$$

$$(\text{VVECT} + 2) \leftarrow (\text{VVECT} + 2) + 4(V + 4)_D$$

$$(\text{VVECT} + 2) \leftarrow (\text{VVECT} + 2) + \text{KPIP1}(5) (\text{PIPATMPZ} + \text{PIPAZ})$$

Z component

VARDELAY
delay 4 csec
FC-3040

$$\text{ITEMP 1} \leftarrow \text{VVECT} + \text{DELVS}$$

$$\text{ITEMP 2} \leftarrow (\text{VVECT} + 1) + (\text{DELVS} + 2)$$

$$\text{ITEMP 3} \leftarrow (\text{VVECT} + 2) + (\text{DELVS} + 4)$$

Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Sullivan</i>	<i>4/26/69</i>	R09, R10, R11	
PRGMR <i>D. Bernhardt</i>	<i>4/24/69</i>	LUMINARY 1D	DOCUMENT NO. FC-3930
ANALST			
DOCMR <i>W. Dugforth</i>	<i>7/26/69</i>	REV 2	SHEET 14 of 21
APPR'D <i>R. M. Foster</i>	<i>10/30/69</i>		

From Preceding Sheet

$$v_{HY} = v_{MP} \cdot u_{HYP}$$

 RUPTREG1 ← UHYP (ITEMP1)
 RUPTREG1 ← RUPTREG1 + ITEMP2 (UHYP +2)
 RUPTREG1 ← RUPTREG1 + ITEMP3 (UHYP +4)
 VH Y ← 2(RUPTREG1)

Velocity directed along the Y-coordinate

$$v_{HZ} = v_{MP} \cdot u_{HZP}$$

 RUPTREG1 ← UHZP (ITEMP1)
 RUPTREG1 ← RUPTREG1 + (UHZP +2)ITEMP2
 RUPTREG1 ← RUPTREG1 + (UHZP +4)ITEMP3
 VH Z ← 2(RUPTREG1)

Velocity directed along the Z-coordinate

GET22/32

EBANK ← EBANK6
 ITEMP3 ← M22
 ITEMP4 ← M32
 EBANK ← EBANK7

$\left. \begin{matrix} \sin(AOG) \\ \cos(AOG) \end{matrix} \right\}$ 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

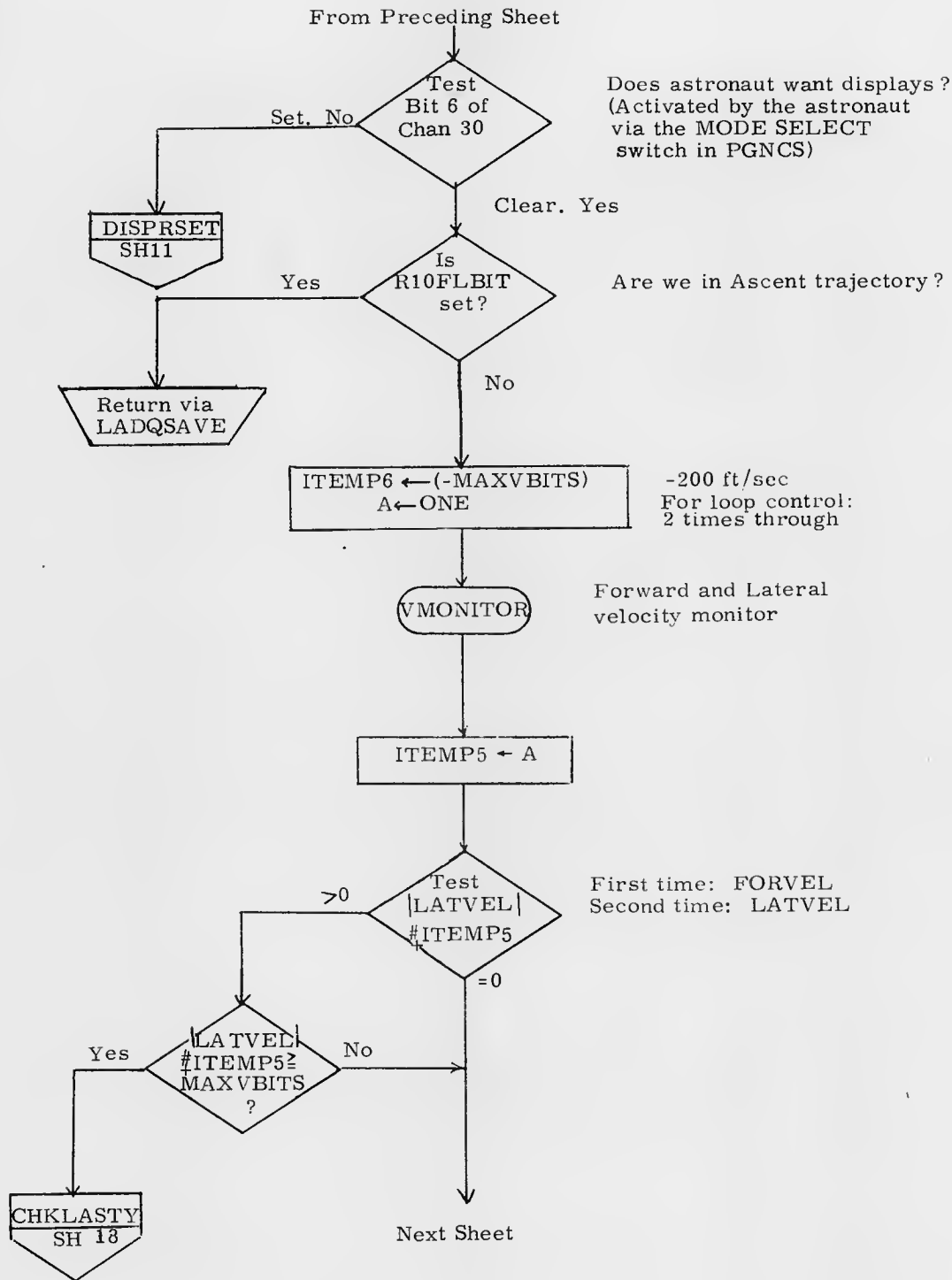
$$v_{HF} = v_{HZ} \cos AOG - v_{HY} \sin AOG$$

 RUPTREG1 ← ITEMP4 (VHZ)
 RUPTREG1 ← RUPTREG1 - (VHY)ITEMP3
 FORVEL ← 2(RUPTREG1) VELCONV

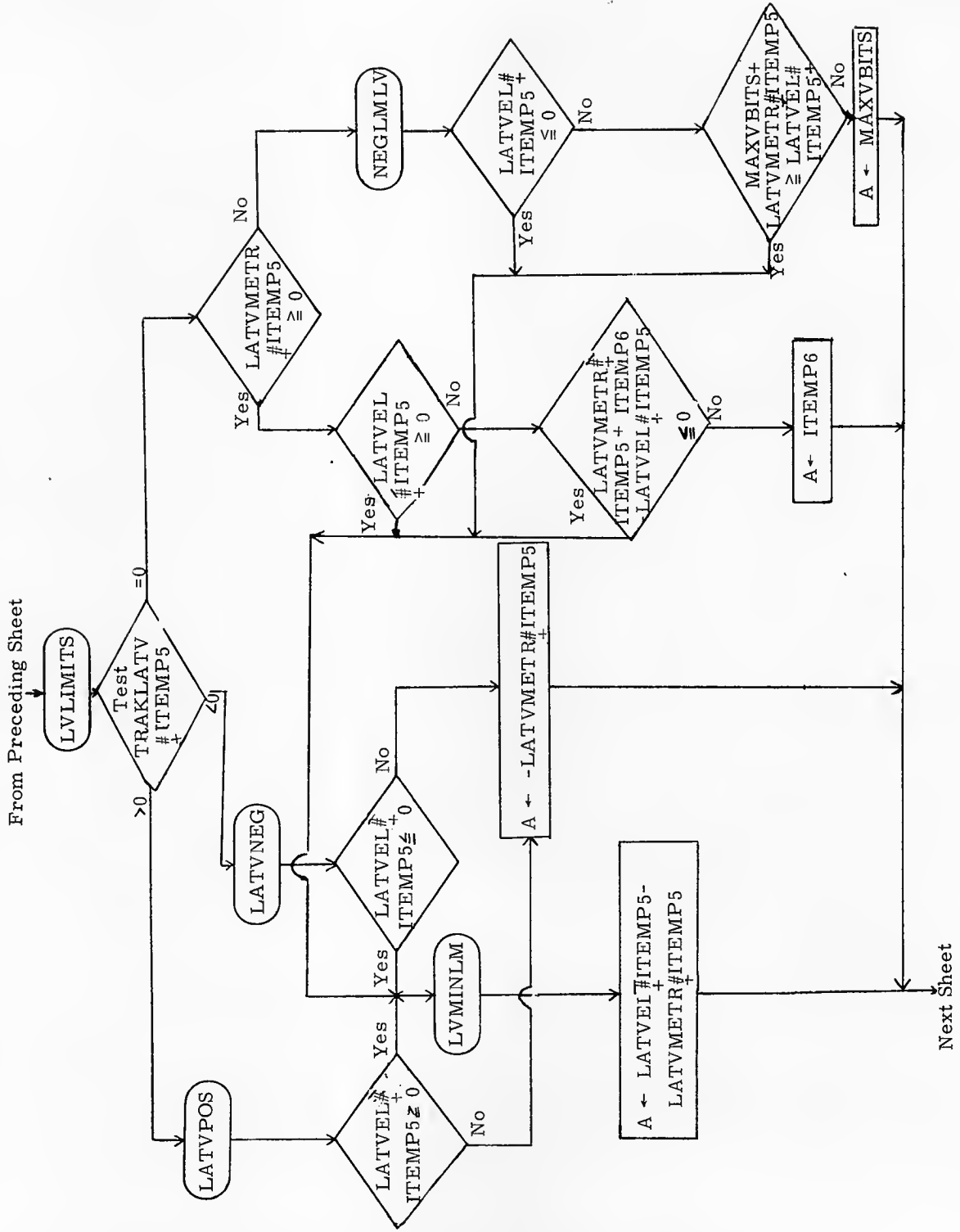
Compute FORVEL

Next Sheet

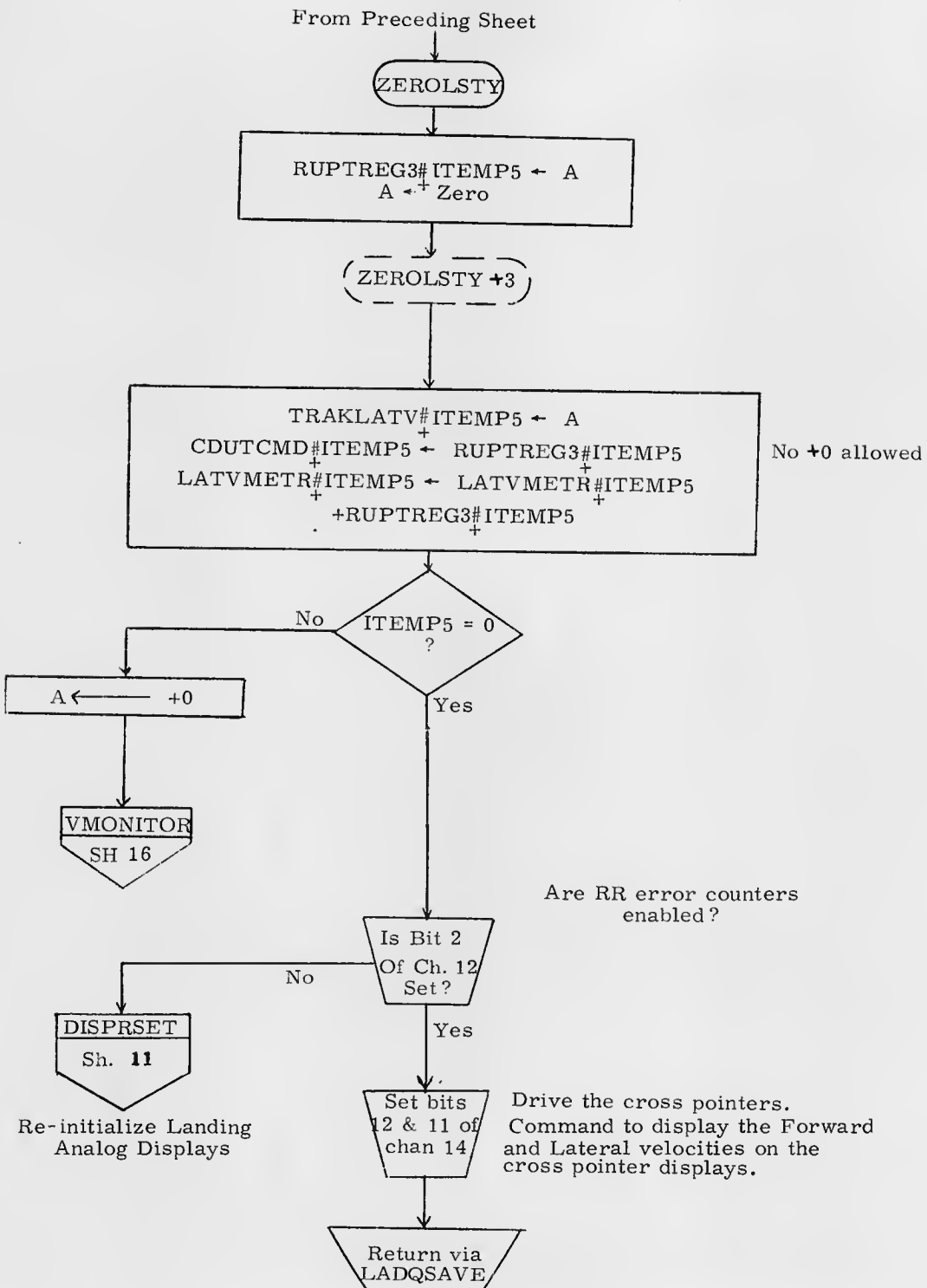
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>E. Lutkenfeld</i>	<i>7/24/68</i>	R09, R10, R11	
PRGMR <i>Del Bernikovich</i>	<i>10/29/69</i>	LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3930
DOCMR <i>W. Dyer</i>	<i>3/26/69</i>	REV 2	SHEET 15 OF 21
APPR'D <i>R.M. Foster</i>	<i>10/30/69</i>		



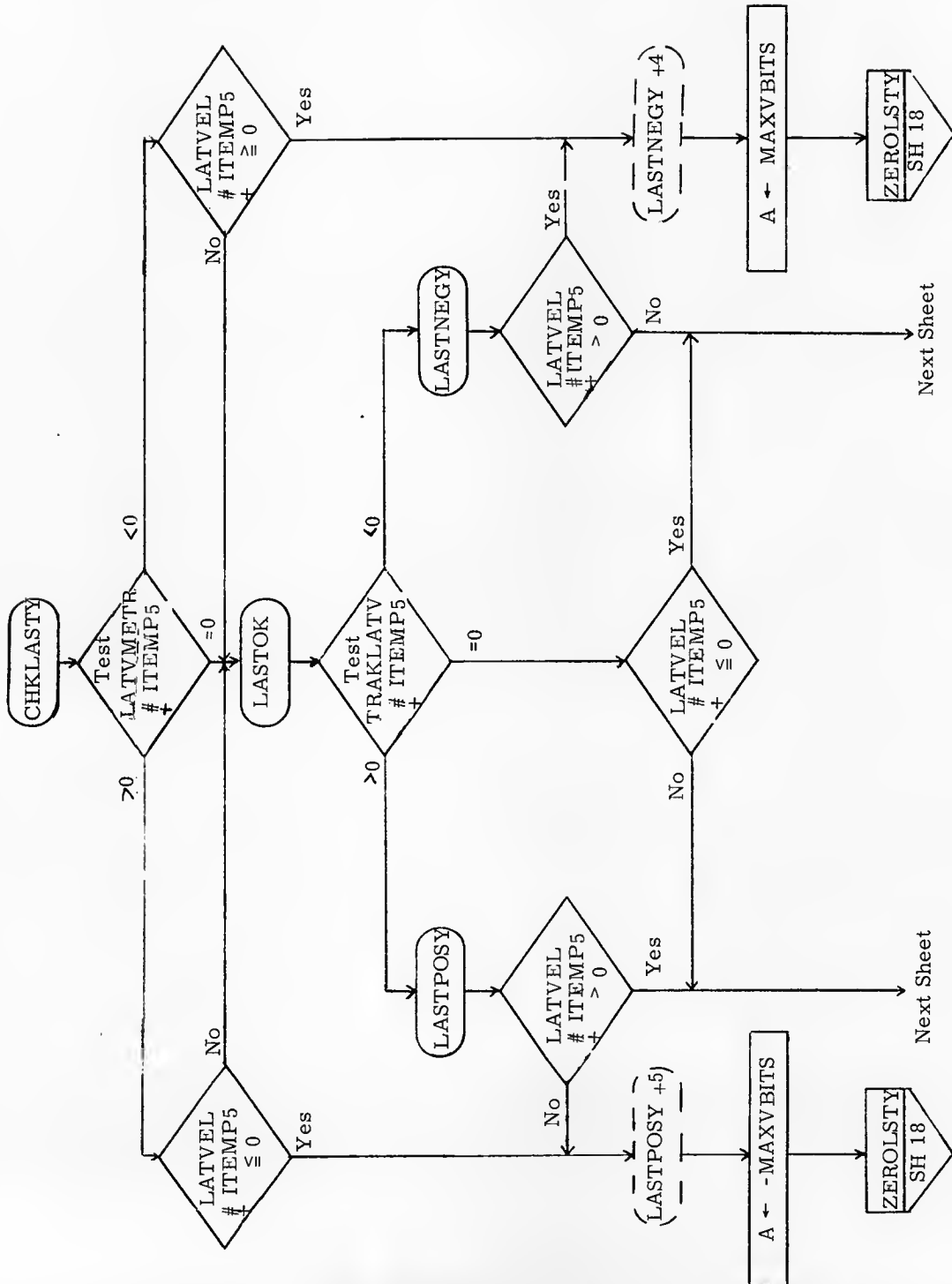
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>E. F. Lutterbach</i> 9/26/69		R09, R10, R11	
PRGMR <i>D. P. Benikovich</i> 10/29/69		LUMINARY 1D	DOCUMENT NO.
ANALST			FC 3930
DOCMR <i>W. D. Griffith</i> 9/26/69		REV 2	SHEET 16 OF 21
APPR'D <i>R. M. Estes</i> 10/30/69			



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i>	<i>[Date]</i>	R09, R10, R11	
PRGMR <i>[Signature]</i>	<i>[Date]</i>	LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3930
DOCMR <i>[Signature]</i>	<i>[Date]</i>	REV 2	SHEET 17 of 21
APPR'D <i>[Signature]</i>	<i>[Date]</i>		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. L. Kunkel</i> 7/24/69		R09, R10, R11	
PRGMR <i>D. Bernhardt</i> 10/29/69		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3930
DOCMR <i>M. Dayforth</i> 8/26/69		REV 2	SHEET 18 OF 21
APPR'D <i>R. M. Evers</i> 10/30/69			



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. S. ...</i> 7/26/69		R09, R10, R11	
PRGMR <i>R. B. ...</i> 7/29/69		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3030
DOCMR <i>M. D. ...</i> 7/26/69	APPR'D <i>R. M. ...</i> 7/27/69	REV 2	SHEET 19 OF 21

From Preceding Sheet

NEGVMAXY

RUPTRREG3#ITEMP5 ← - (MAXVBITS + LATVMETR
#ITEMP5)

A ← - ONE

From Preceding Sheet

POSVMAXY

RUPTRREG3#ITEMP5 ← MAXVBITS - LATVMETR
#ITEMP5

A ← ONE

ZEROLSTY +3
SH 18

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. M. Swice</i> 7/26/69		R09, R10, R11	
PRGMR <i>R. M. Swice</i> 10/23/69		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3930
DOCMR <i>R. M. Swice</i> 7/26/69		REV 2	SHEET 20 OF 21
APPR'D <i>R. M. Swice</i> 10/23/69			

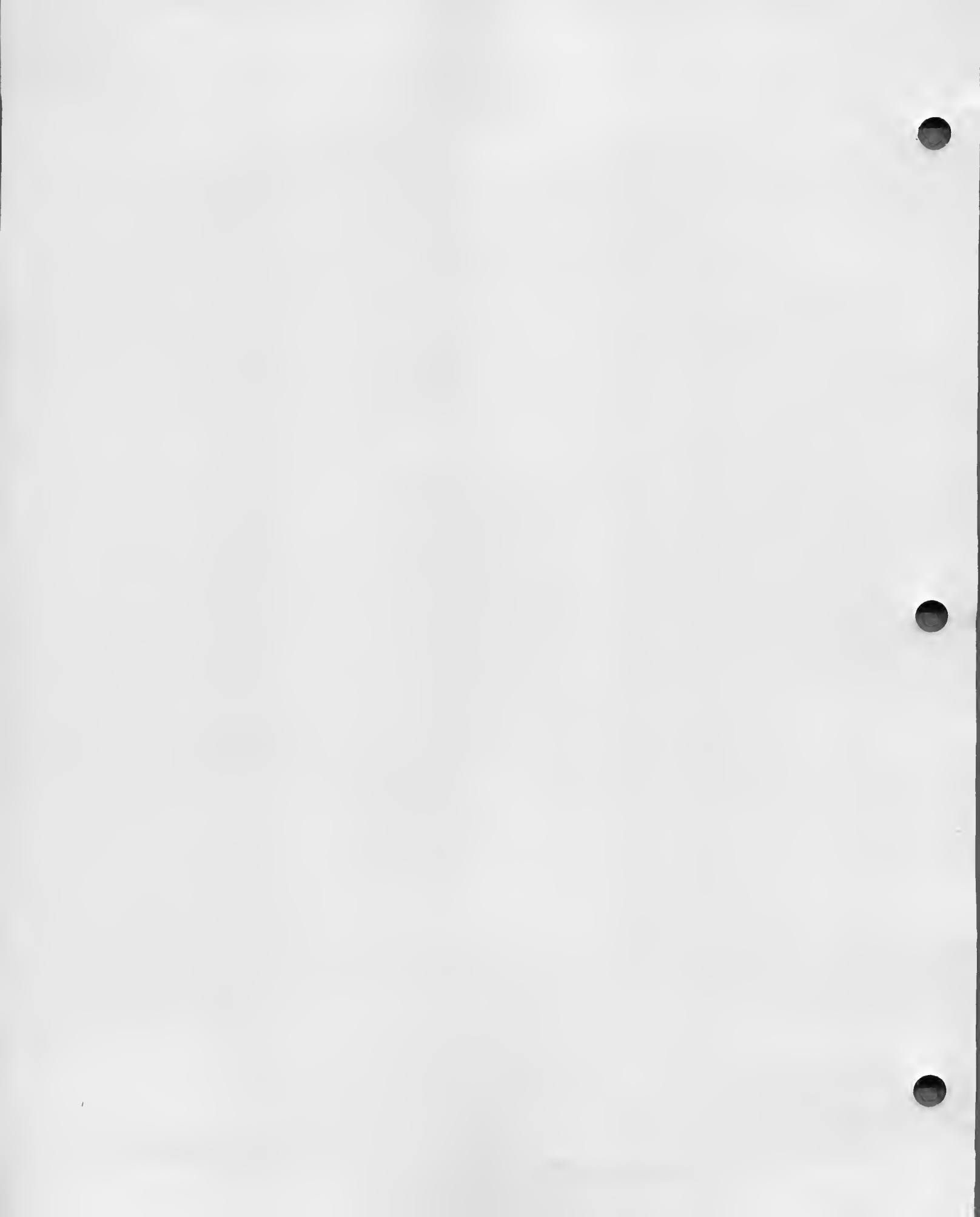
ROUTINES CALLED ON OTHER FLOWCHARTS

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

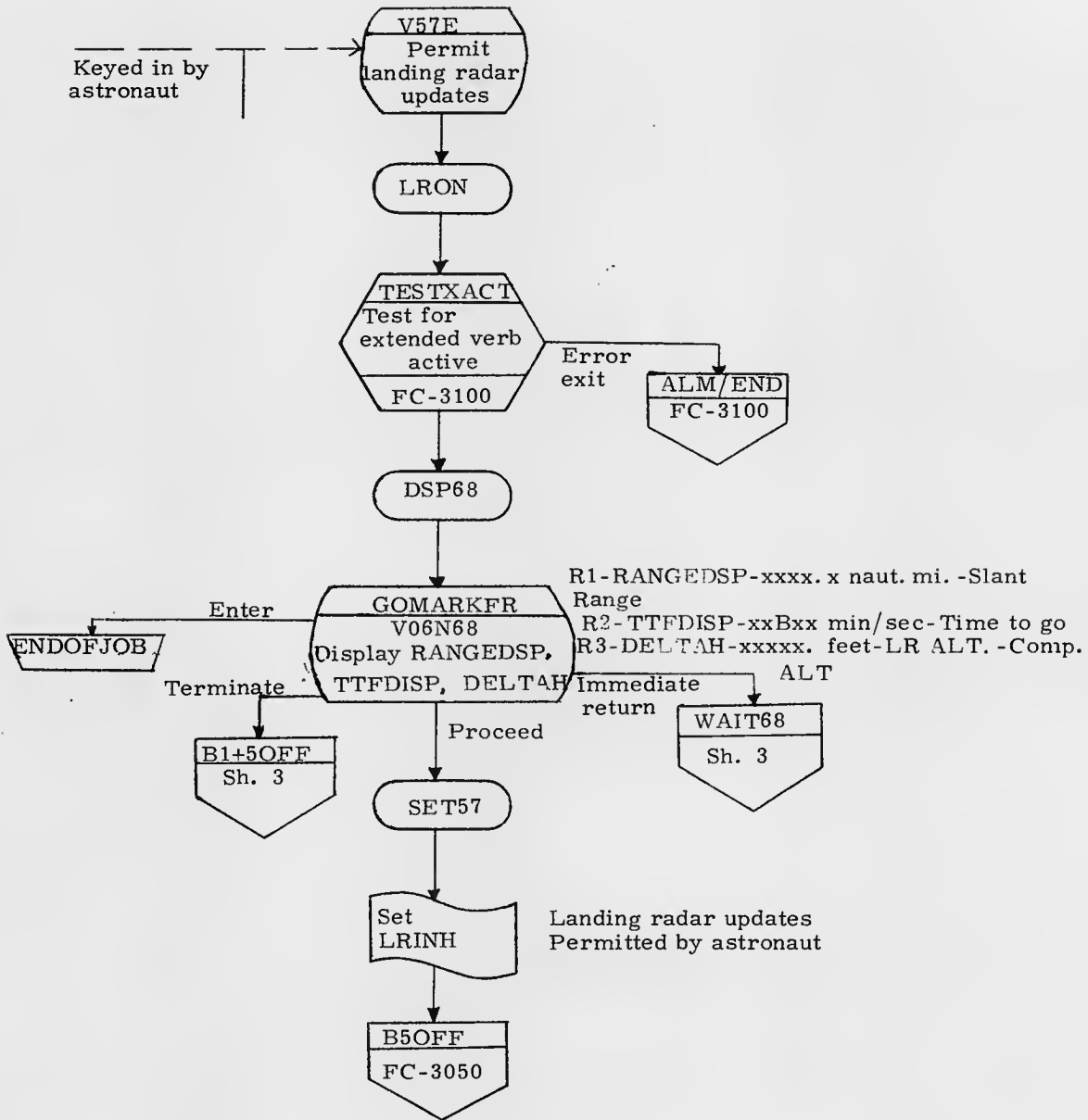
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D. Swuka</i> 10/20/69		R09, R10, R11	
PRGMR <i>Bob Brumby</i> 11/25/69		LUMINARY 1D	DOCUMENT NO. FC-3930
ANALST			
DOCMR <i>R. M. Egan</i> 10/30/69		REV 2	SHEET 21 OF 21
APPR'D <i>R. M. Egan</i> 10/30/69			



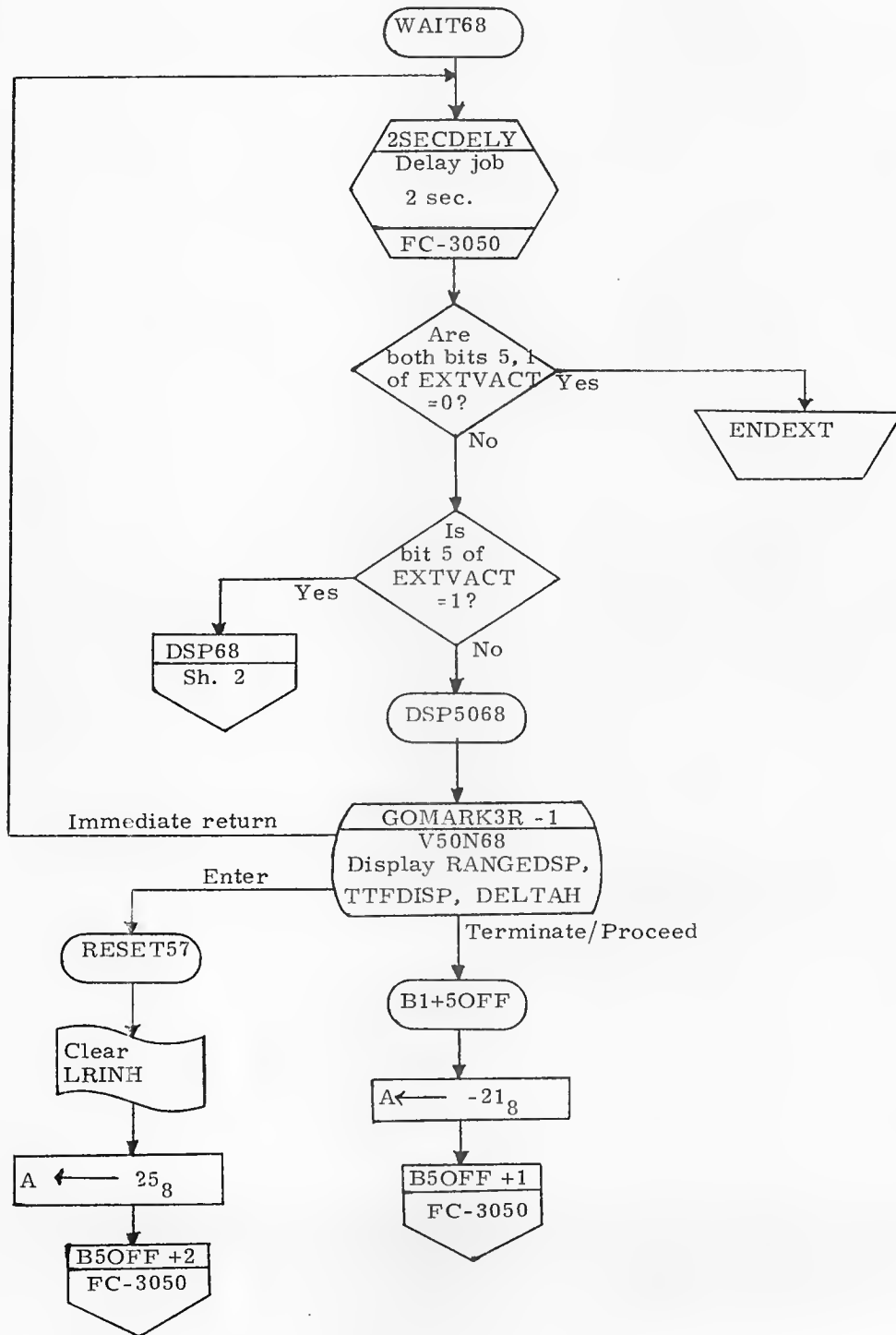
R12 - DESCENT STATE VECTOR UPDATE
 MAJOR SUBROUTINES ON THIS CHART

VERB57	Sh. 2
VERB58	Sh. 4
VERB59	Sh. 4
TEROFF (VB68)	Sh. 5
RDRUSECK	Sh. 6
LRPOS2	Sh. 7
MUNRETRN	Sh. 9

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Welch</i>		R12 - Descent State Vector Update	
PRGMR <i>D. Moore</i>			
ANALST		LUMINARY 1D	DOCUMENT NO.
DOCMR <i>W. Griffith</i>			FC-3935
APPR'D <i>Robert M. Suter</i>		REV 2	SHEET 1 OF 35

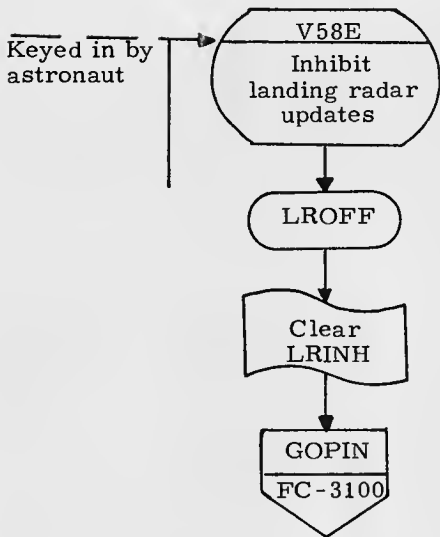


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>G. Wolch</i>	<i>9/23/69</i>	R12 - Descent State Vector Update	
PRGMR <i>D. Mene</i>	<i>12/1/69</i>	DOCUMENT NO.	FC-3050
ANALST		UMI. 2 1D	
DOCMR <i>W. Langwith</i>	<i>10/30/69</i>	REV 2	SHEET 2 OF 35
APPR'D <i>Robert M. Estes</i>	<i>12/1/69</i>		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>A. Wieland</i>	R12 - Descent State Vector Update	
PRGMR	<i>D. Moore</i>	LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3935
DOCMR	<i>W. Dykstra</i>	REV 2	SHEET 3 OF 35
APPR'D	<i>Robert M. Estlin</i>		

EXTENDED VERB 58

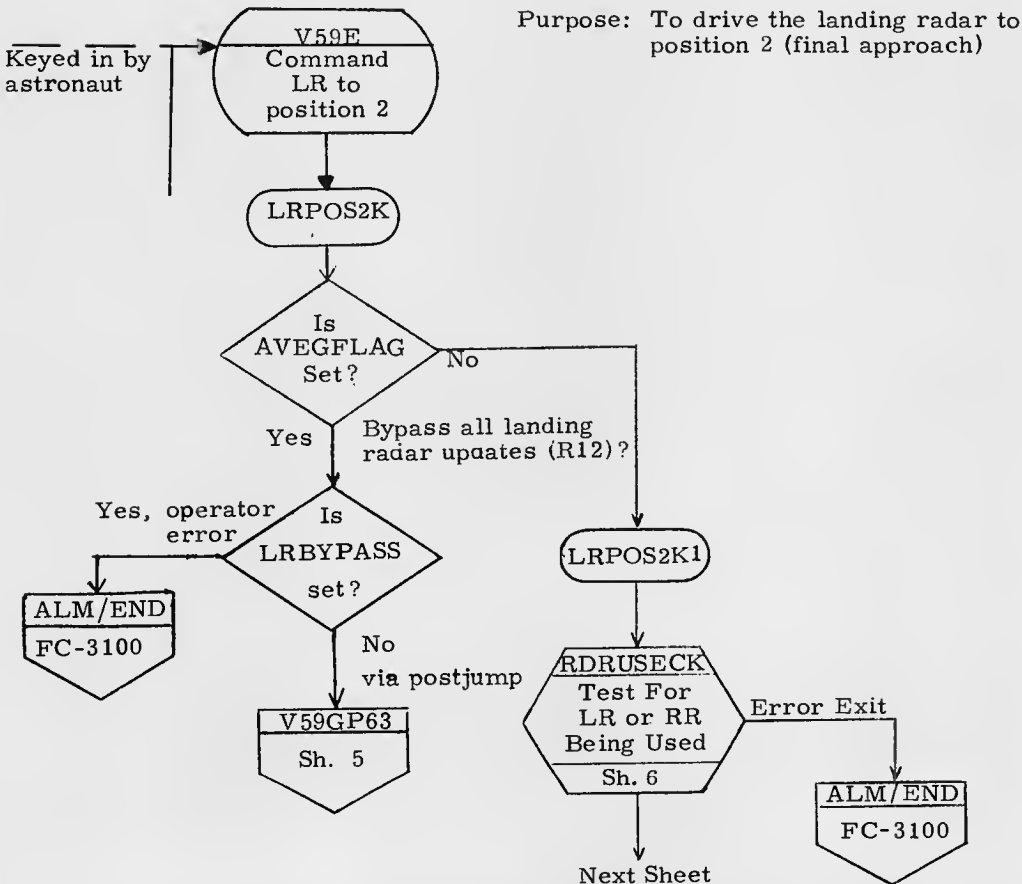


Purpose: To inhibit the incorporation of landing radar data during descent state vector update

Landing radar updates inhibited by astronaut

Exit via GOPIN

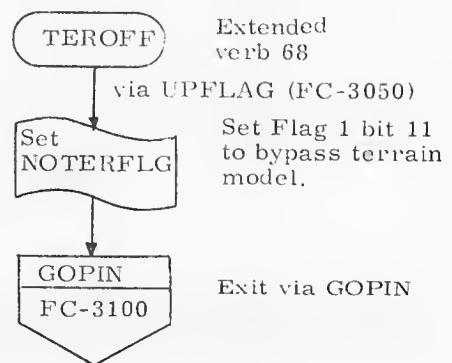
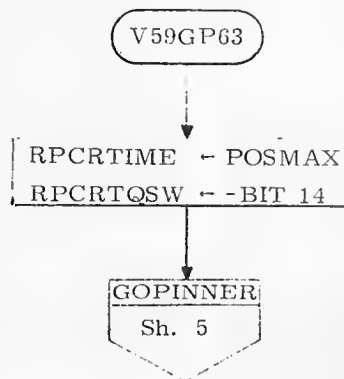
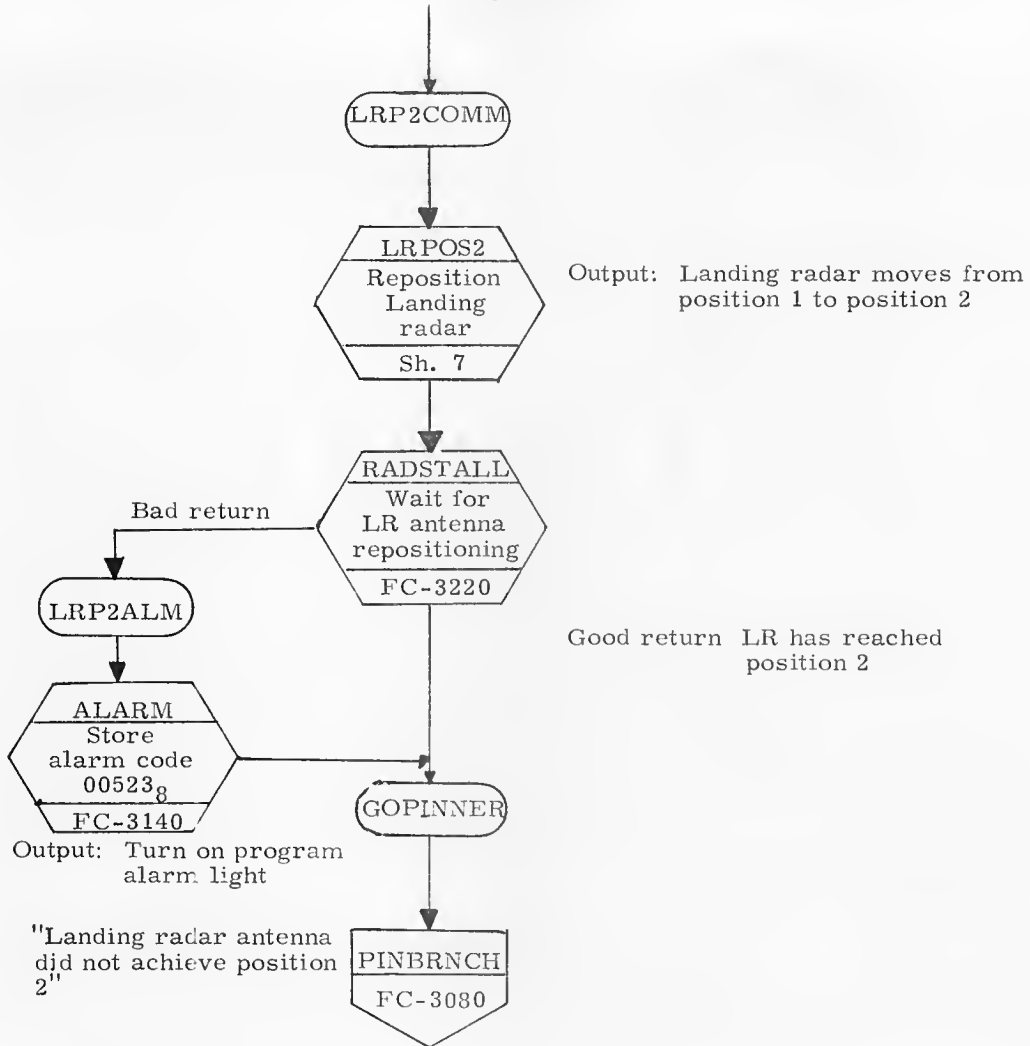
EXTENDED VERB 59



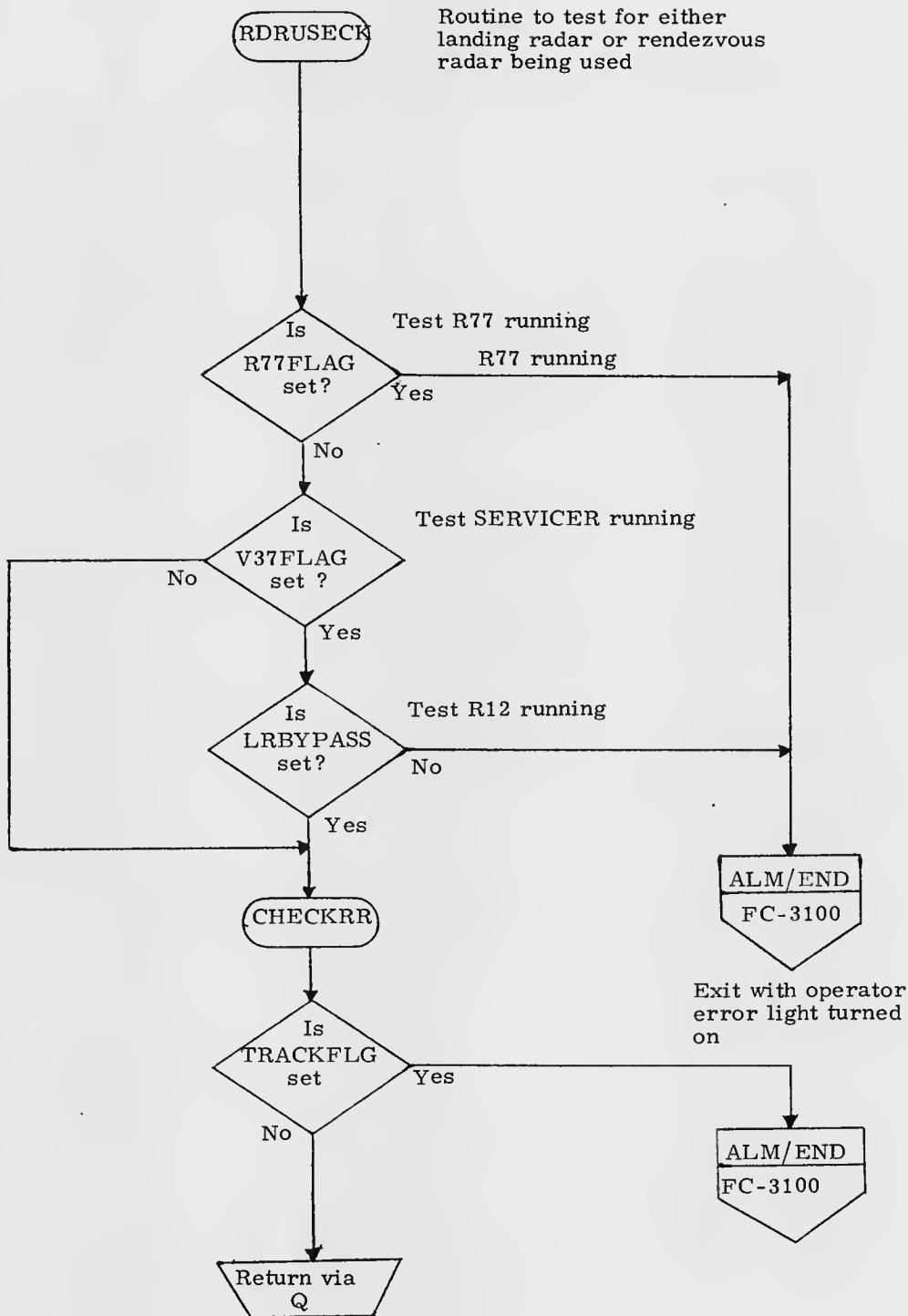
Purpose: To drive the landing radar to position 2 (final approach)

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. Welch</i>		R12 - Descent State Vector Update	
PRGMR <i>D. Moore</i>		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3935
DOCMR <i>H. Deafith</i>		REV 2	SHEET 4 OF 35
APPR'D <i>Robert M. Enten</i>			

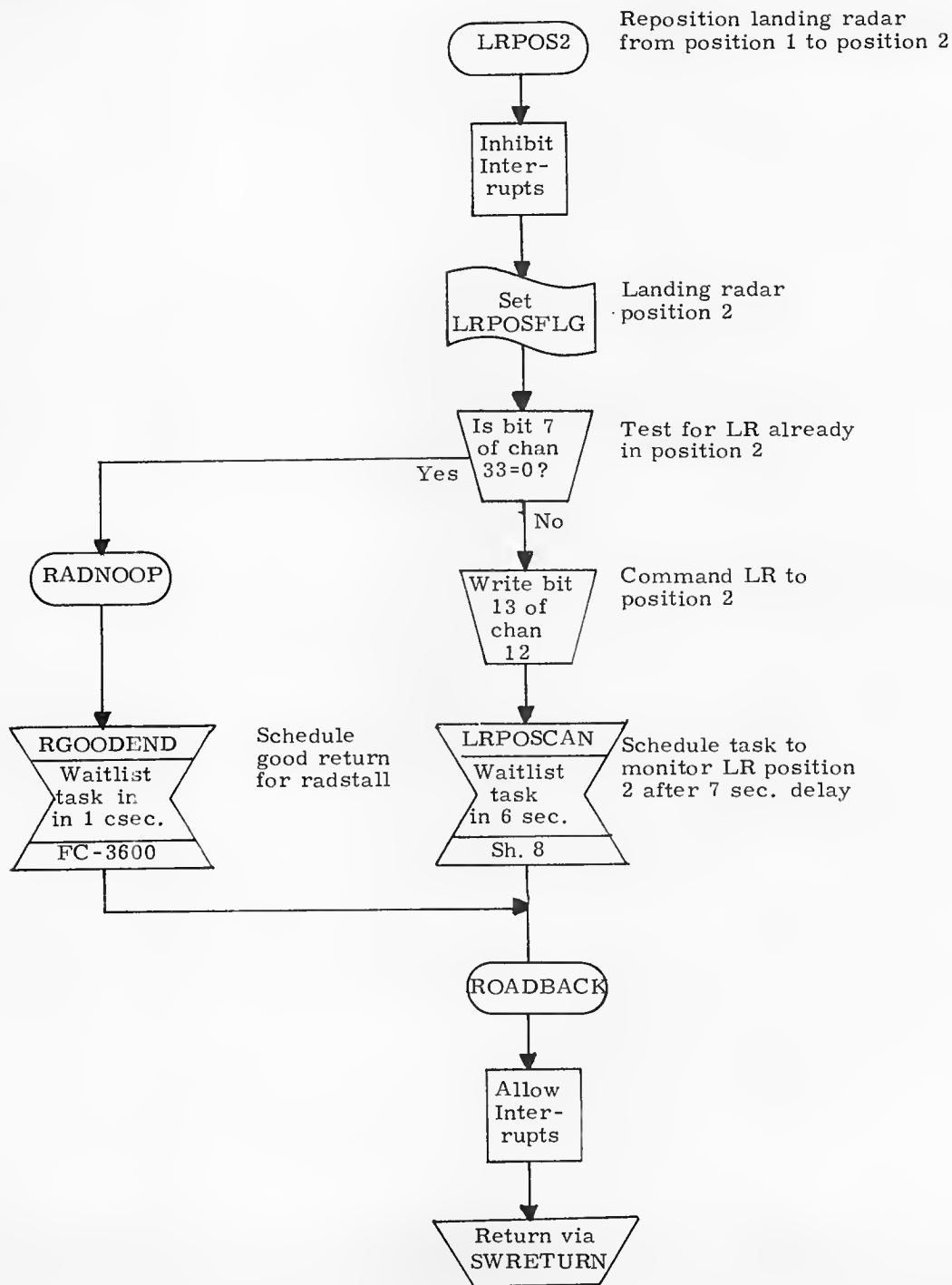
From Preceding Sheet



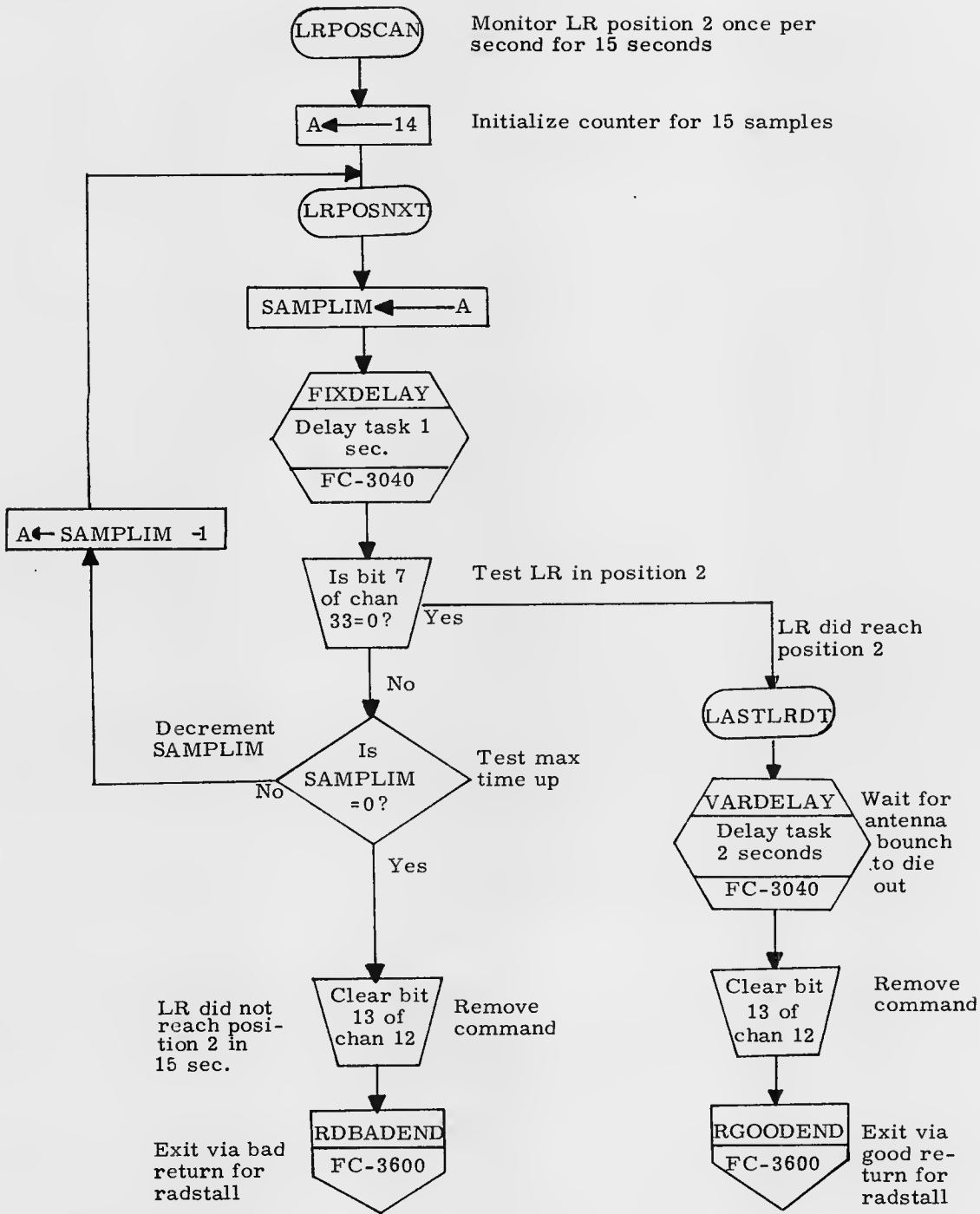
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>A. Welch</i>	<i>11/29/69</i>	R12 - Descent State Vector Update
PRGMR	<i>D. Moore</i>	<i>12/1/69</i>	DOCUMENT NO.
ANALST			LUMINARY 1D FC-3935
DOCMR	<i>W. Dwyer</i>	<i>10/30/69</i>	REV 2
APPR'D	<i>R. ...</i>	<i>12/1/69</i>	SHEET 5 OF 35



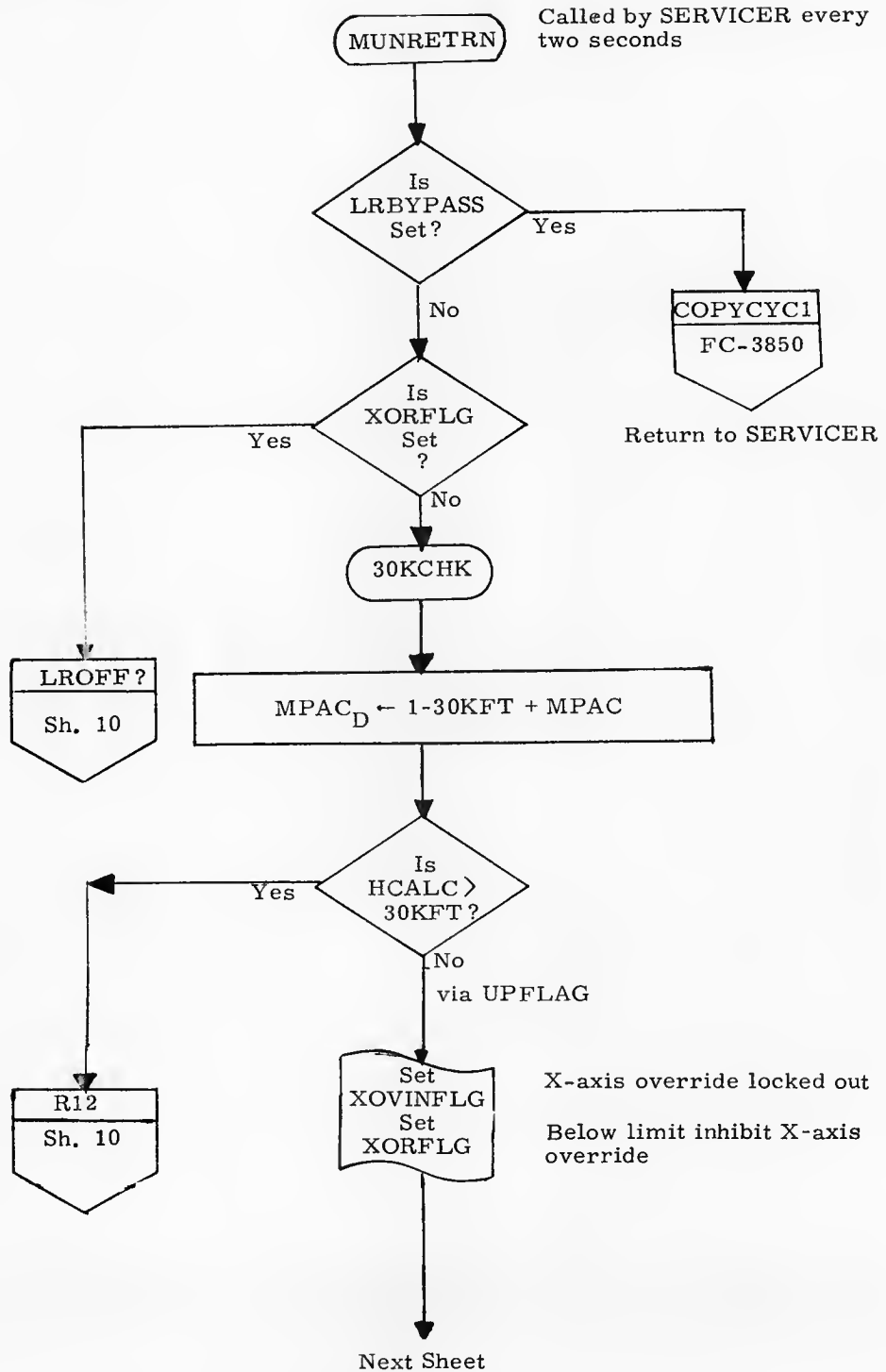
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		R12 - Descent State Vector Update	
DRAWN <i>A. W. White</i>	<i>10/24/69</i>	LUMINARY 1D	DOCUMENT NO.
PRGMR <i>D. Moore</i>	<i>12/1/69</i>		FC-3935
ANALST		REV 2	SHEET 6 OF 35
DOCMR <i>W. English</i>	<i>1/29/69</i>		
APPR'D <i>R. M. Estes</i>	<i>12/1/69</i>		



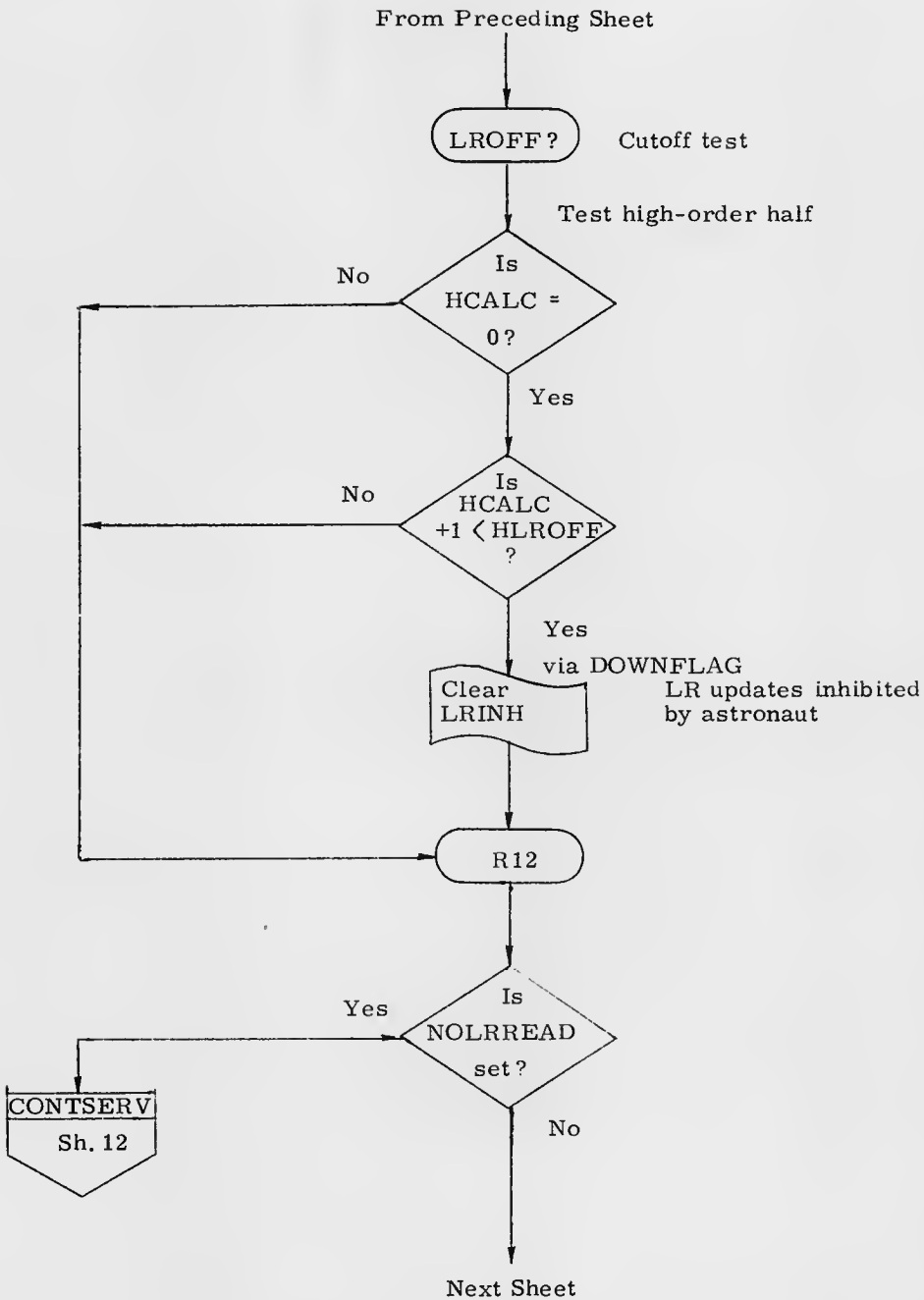
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. Welch</i> 12/1/69		R12 - Descent State Vector Update	
PRGMR <i>R. More</i> 12/1/69		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3935
DOCMR <i>W. DeGhith</i> 12/1/69		REV 2	SHEET 7 OF 35
APPR'D <i>R.M. Evers</i> 12/1/69			



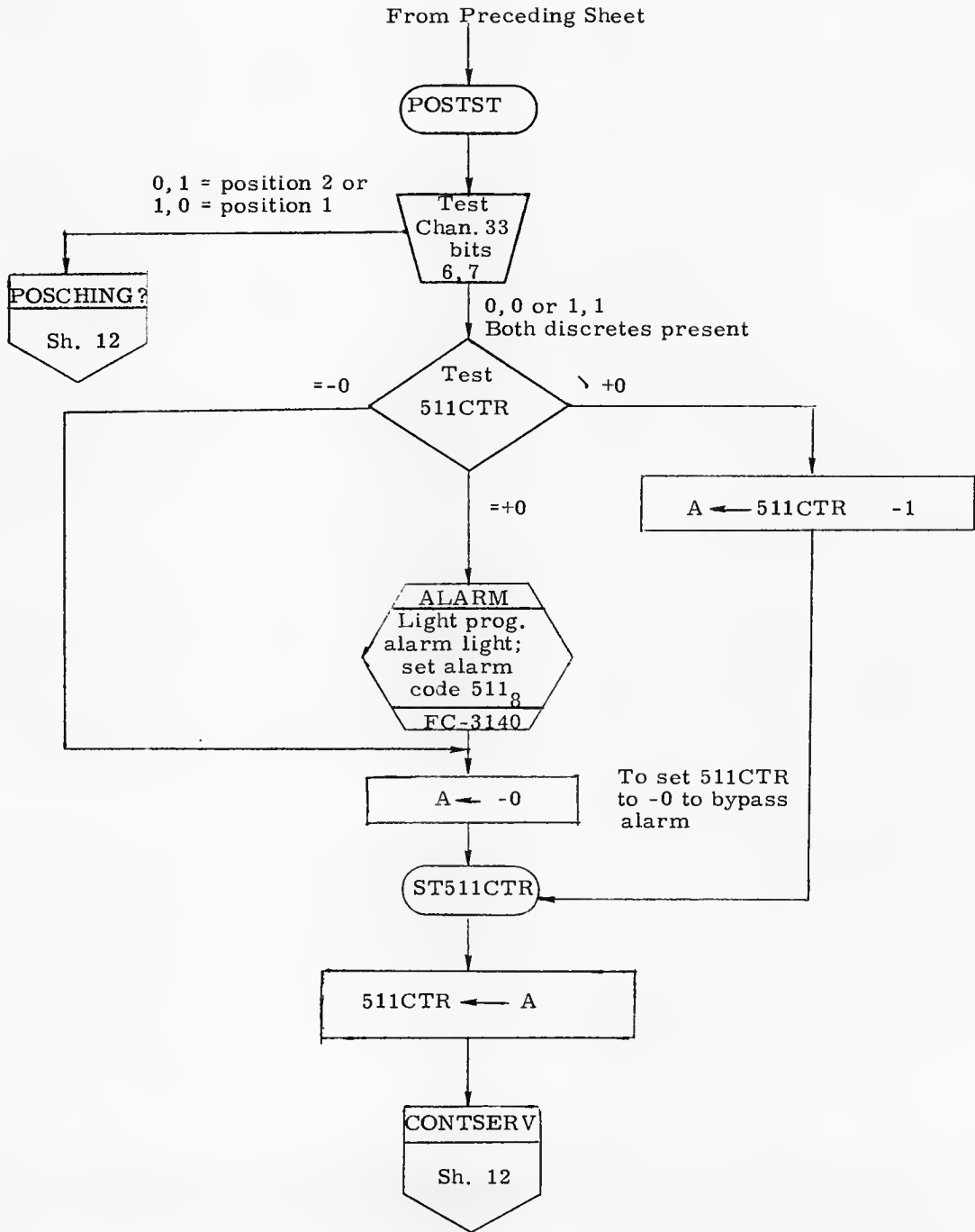
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. Lelach</i> 12/29/69		R12 - Descent State Vector Update	
PRGMR <i>W. Moore</i> 1/16/69		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3935
DOCMR <i>W. Moore</i> 1/20/69		REV 2	
APPR'D <i>R.M. F...</i> 1/21/69		SHEET 8 OF 35	



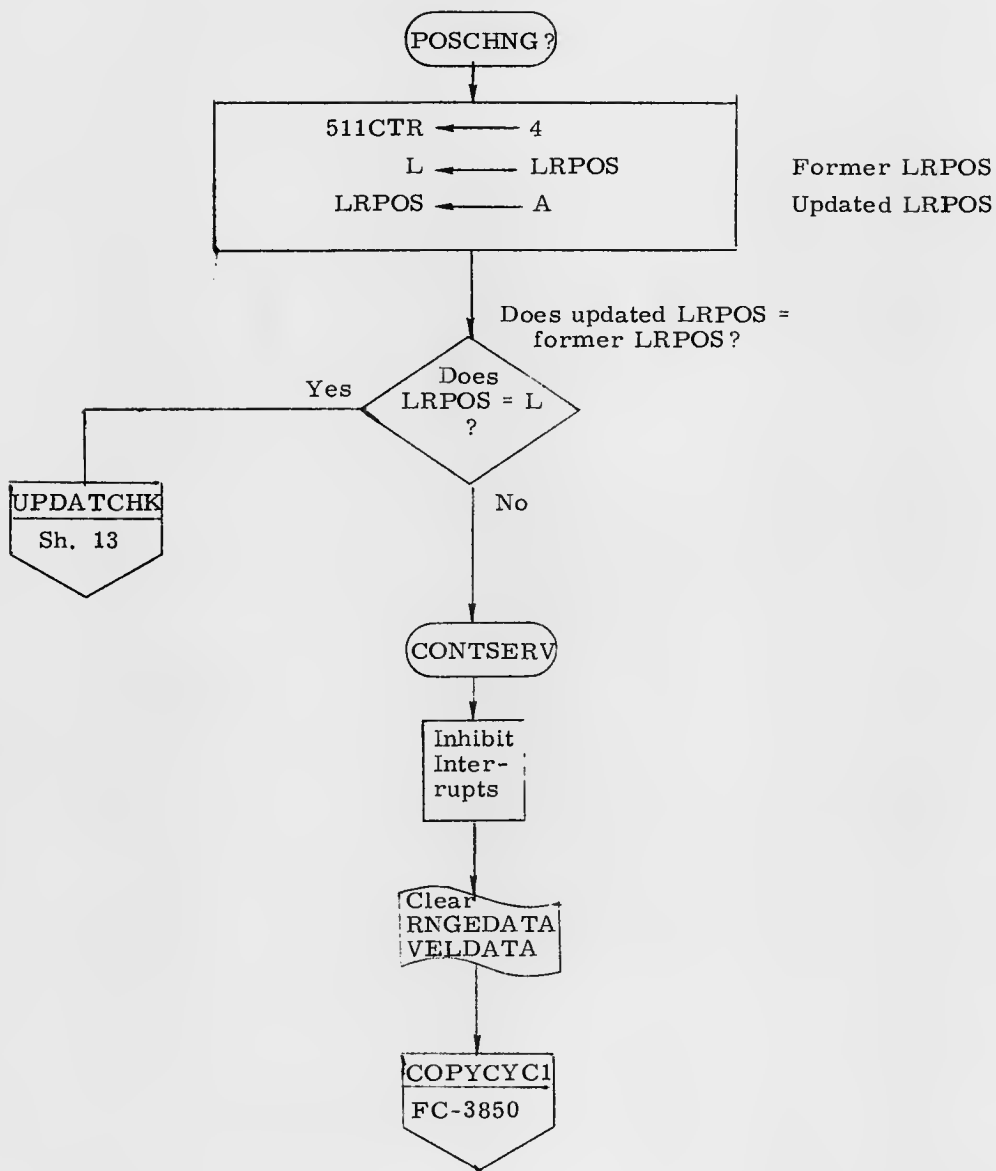
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>A. Delab</i>	R12 - Descent State Vector Update	
PRGMR	<i>R. Moore</i>		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3935
DOCMR	<i>M. Dwyer</i>	REV 2	SHEET 9 OF 35
APPR'D	<i>R. M. Easton</i>		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		R12 - Descent State Vector Update	
DRAWN	<i>E. Mathe</i>	<i>6/12/70</i>	DOCUMENT NO.
PRGMR	<i>J. Moore</i>	<i>6/17/70</i>	LUMINARY 1D
ANALST			FC-3935
DOCMR	<i>M. D. ...</i>	<i>6/15/70</i>	REV 2
APPR'D	<i>Rm Entes</i>	<i>6/11/70</i>	SHEET 10 OF 35

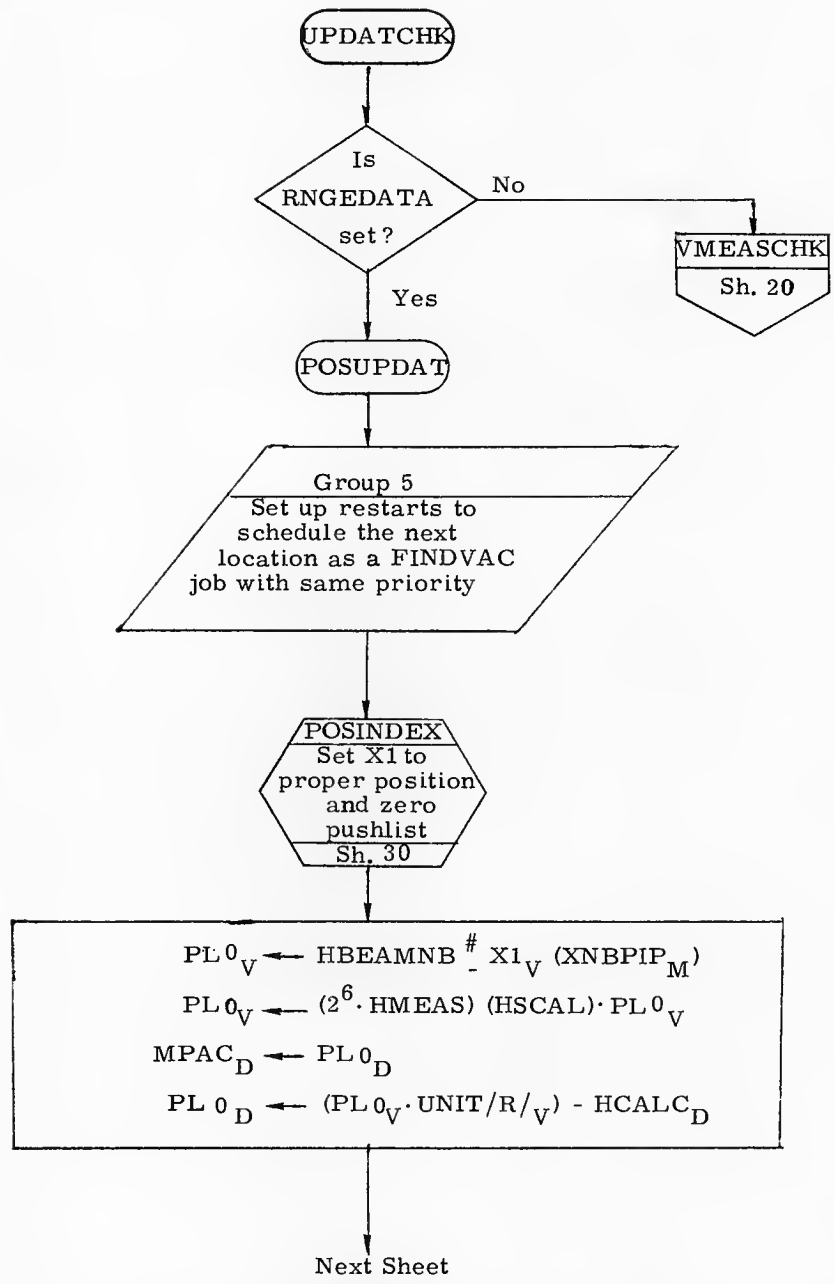


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>E. Matla</i> 6/12/70	R12 - Descent State Vector Update	
PRGMR	<i>D. Stone</i> 6/19/70	LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3935
DOCMR	<i>W. [unclear]</i> 6/17/70	REV 2	SHEET 11 OF 35
APPR'D	<i>R. [unclear]</i> 6/17/70		

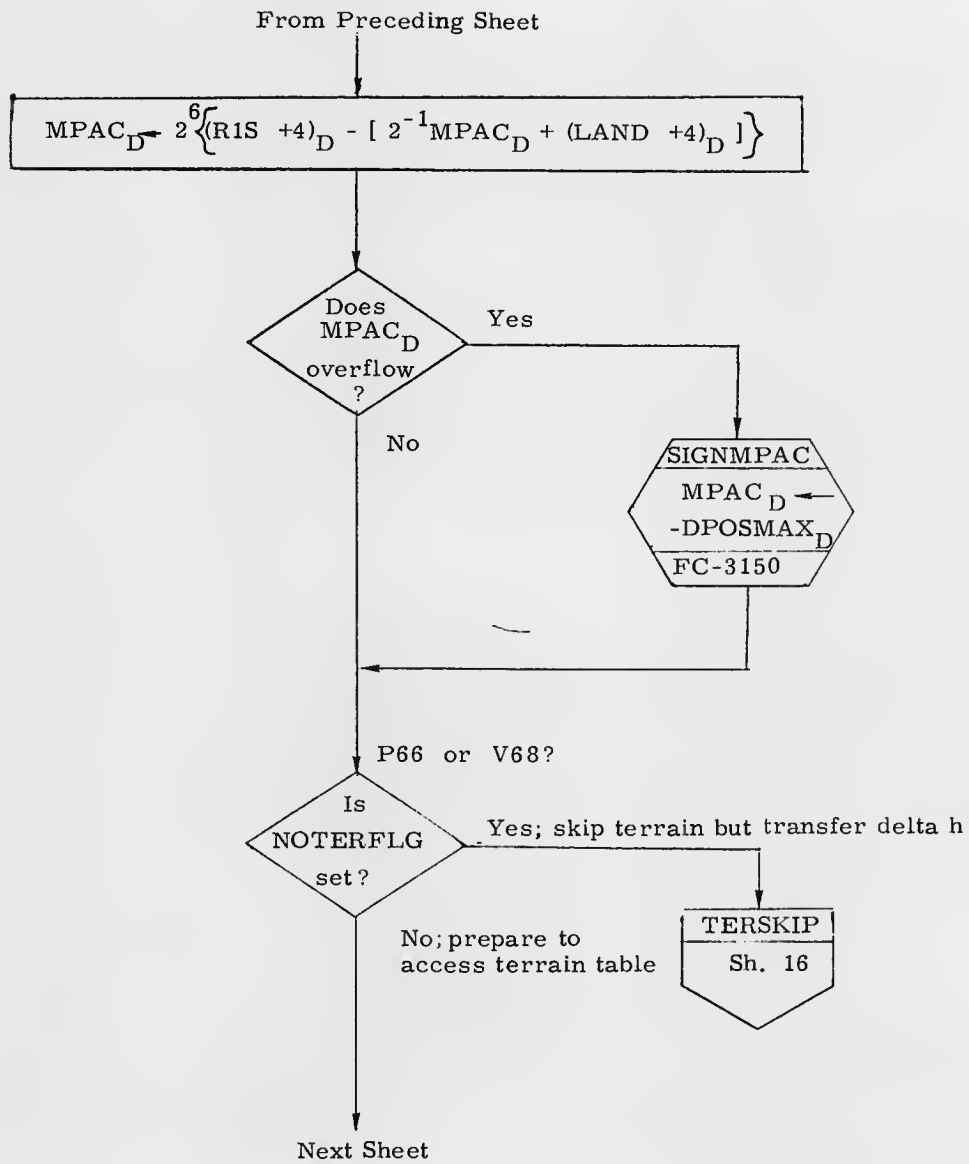


Return to SERVICER

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		R12 - Descent State Vector Update	
DRAWN	<i>E. Mitter</i>	6/12/70	DOCUMENT NO. FC-3935
PRGMR	<i>D. Moore</i>	6/17/70	
ANALST			LUMINARY 1D
DOCMR	<i>W. D. ...</i>	6/17/70	
APPR'D	<i>R. M. ...</i>	6/17/70	REV 2
			SHEET 12 OF 35



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>E. Mattia</i>		R12-Descent State Vector Update	
PRGMR <i>A. Nicolini</i>		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3935
DOCMR <i>M. DeLuca</i>		REV 2	SHEET 13 OF 35
APPR'D <i>R. M. Estu</i>			



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
			R12 - Descent State Vector Update	
DRAWN	<i>E. Matra</i>	<i>6/12/70</i>	LUMINARY ID	DOCUMENT NO.
PRGMR	<i>R. Moore</i>	<i>6/17/70</i>		FC-3935
ANALST			REV 2	SHEET 14 OF 35
DOCMR	<i>W. D. Smith</i>	<i>6/17/70</i>		
APPR'D	<i>R. M. E. [unclear]</i>	<i>6/17/70</i>		

From Preceding Sheet

TEM2 ← 0
A ← 4

Initialize minus last
abscissa for TERLOOP

TERLOOP

Adds contributions of
five terrain segment
to Δh

TEM5 ← A
L ← MPAC
A ← -ABSC0 + TEM5

current range

LIMITSUB
Limit A:
Range ≤
| current
abscissa |
FC-3960

TEM4 ← A

Range ≤ | current abscissa |

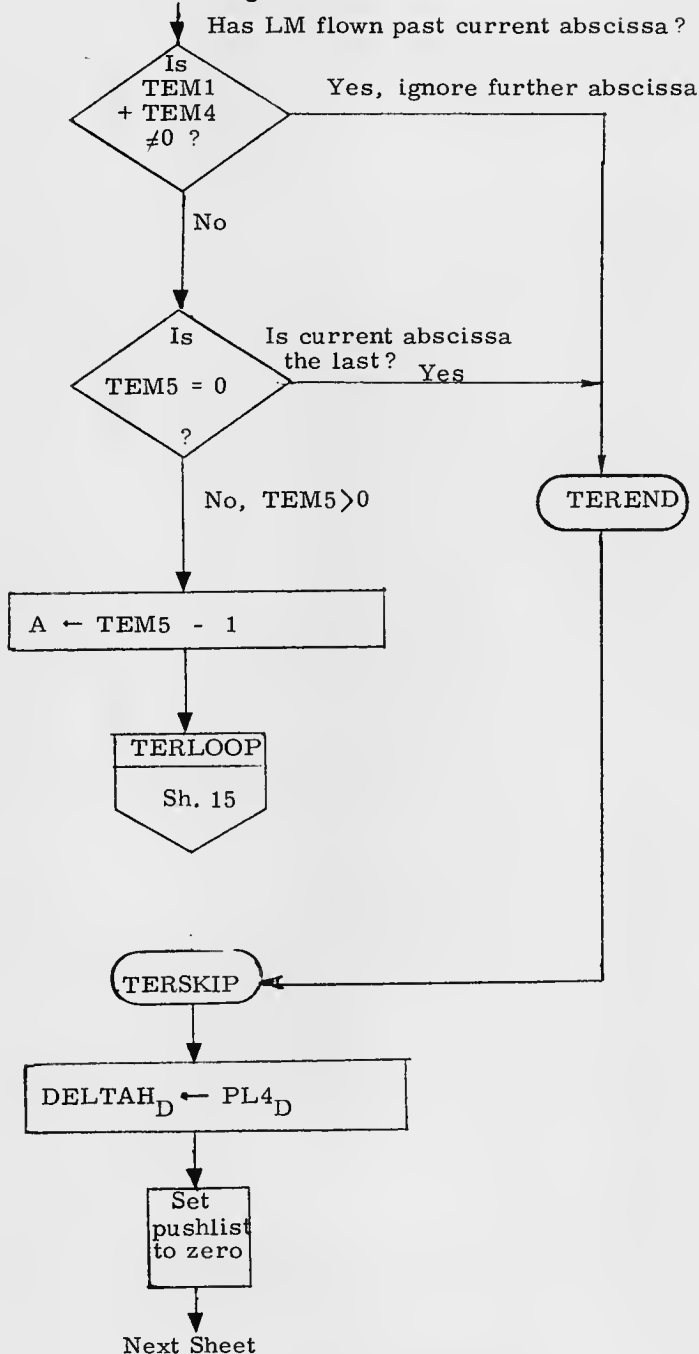
$PL4_D \leftarrow PL4_D + (A + TEM2) (SLOPE0 + TEM5)$
TEM2 ← TEM1

Δh

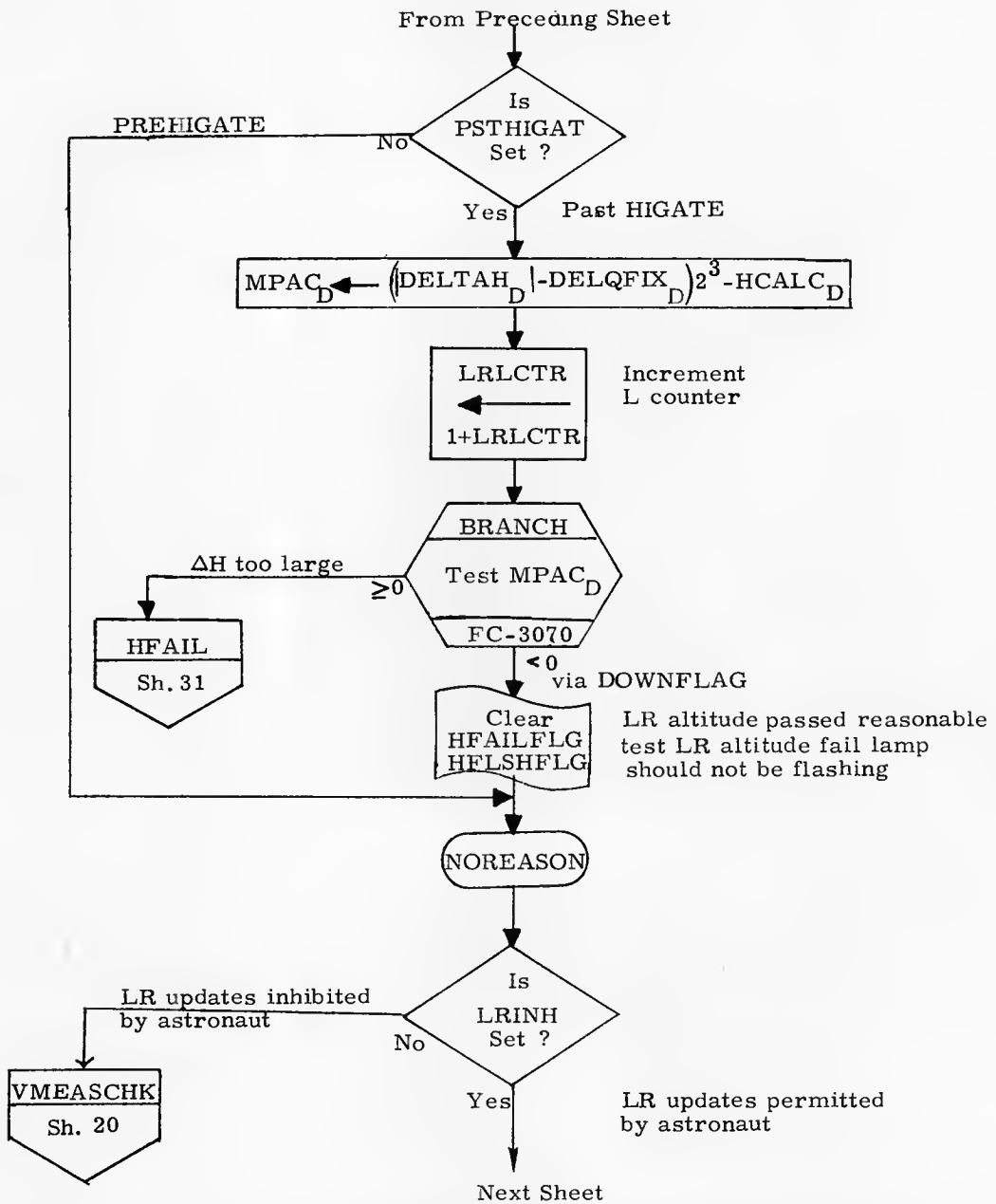
Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>E. Mathe</i> 6/17/70	R12 - Descent State Vector Update	
PRGMR	<i>D. Rose</i> 6/17/70	LUMINARY 1D	DOCUMENT NO. FC-3935
ANALST			
DOCMR	<i>W. Probst</i> 6/17/70	REV 2	SHEET 15 OF 35
APPR'D	<i>R.M. Easton</i> 6/17/70		

From Preceding Sheet

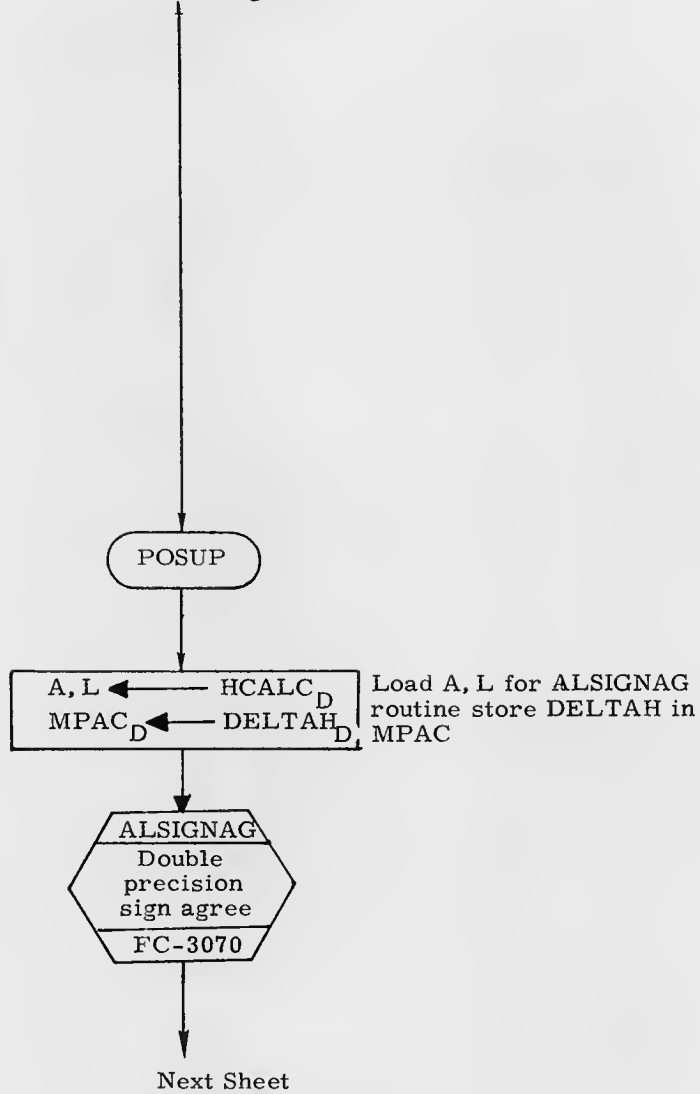


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		R12 - Descent State Vector Update	
DRAWN	<i>E. Matto</i>	<i>6/12/70</i>	LUMINARY 1D
PRGMR	<i>D. Moore</i>	<i>6/17/70</i>	
ANALST			DOCUMENT NO. FC-3935
DOCMR	<i>no D. Matto</i>	<i>6/17/70</i>	REV 2
APPR'D	<i>R. Moore</i>	<i>6/17/70</i>	
			SHEET 16 OF 35

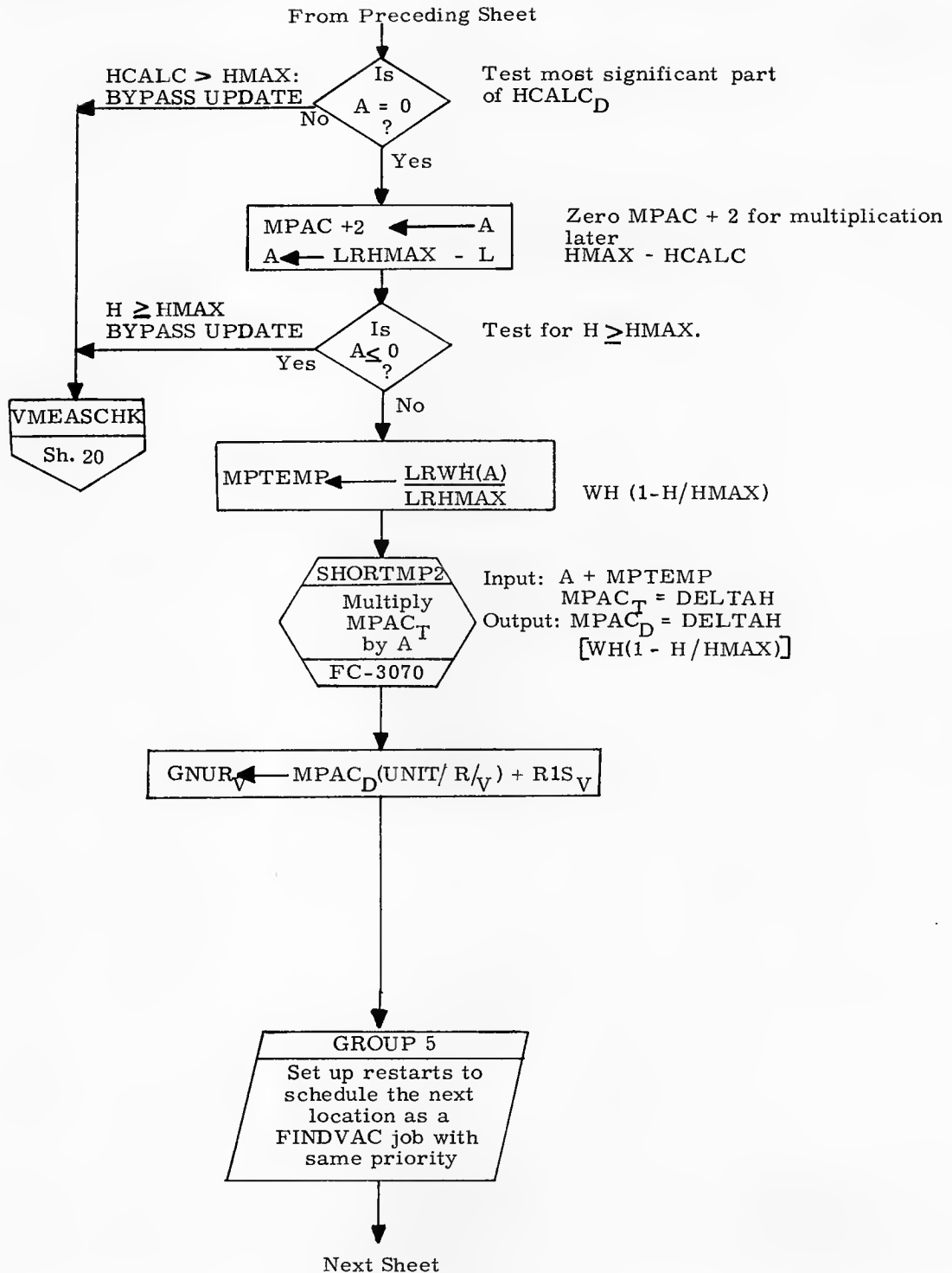


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>R. Welch</i> 12/29/69	R12 - Descent State Vector Update	
PRGMR	<i>R. Moore</i> 1/1/69	UMINAR, 1D	DOCUMENT NO. C-3935
ANALST			
DOCMR	<i>R. DeGroot</i> 10/29/69	REV 2	SHEET 17 OF 35
APPR'D	<i>R. Y. Evans</i> 12/1/69		

From Preceding Sheet

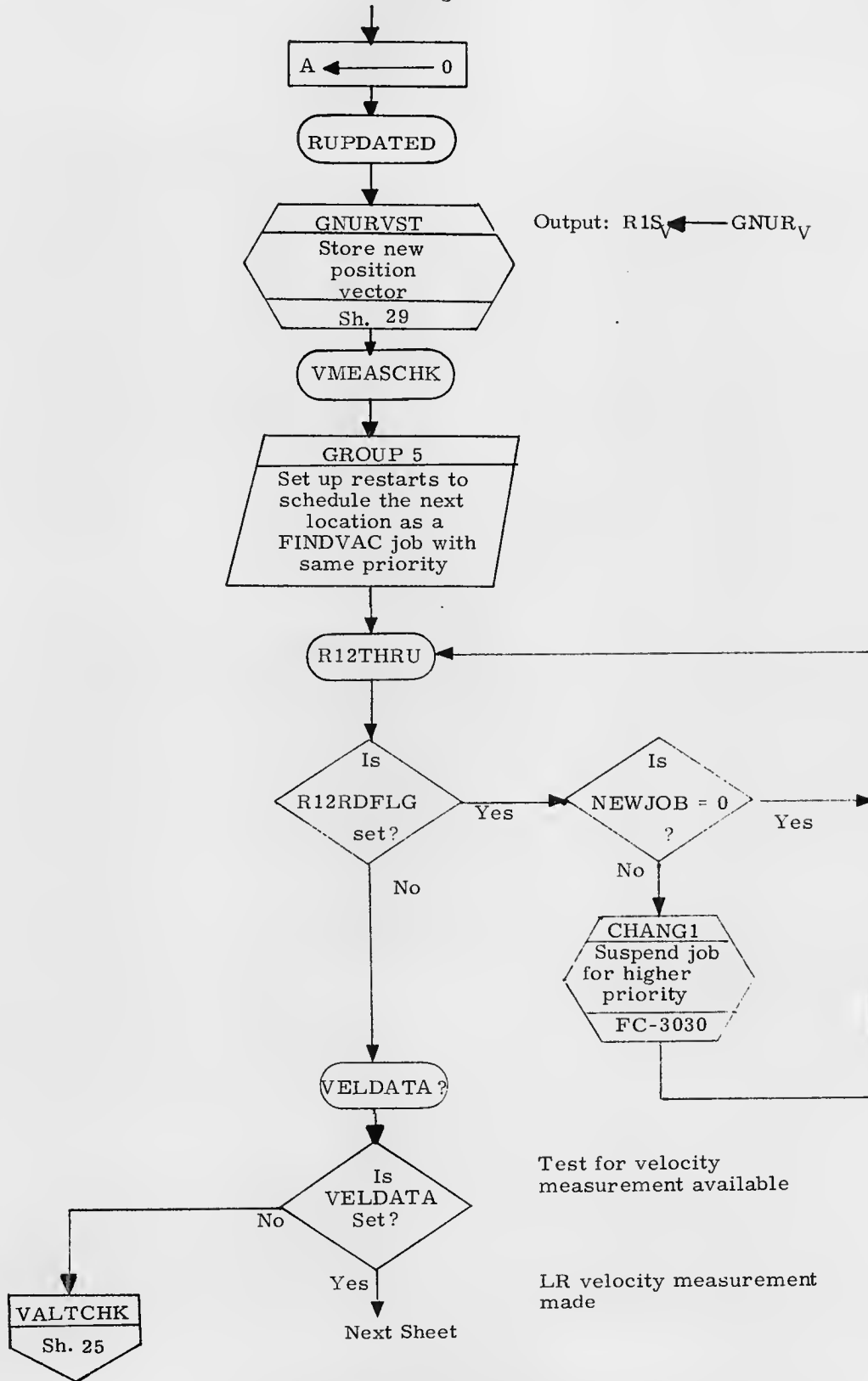


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		R12 - Descent State Vector Update	
PRGMR	<i>D Moore</i> 3/9/70	LUMINARY 1D	DOCUMENT NO.
ANALST	<i>D Moore</i> 3/9/70		FC-3935
DOCMR	<i>W Doughty</i> 3/5/70	REV 2	SHEET 18 OF 35
APPR'D	<i>R M Easter</i> 3/9/70		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Wolch</i> 12/23/69		R12 - Descent State Vector Update	
PRGMR <i>D. Moore</i> 12/1/69		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3935
DOCMR <i>W. DeLoach</i> 1/5/69		REV 2	
APPR'D <i>R.M. Ester</i> 12/1/69		SHEET 19 OF 35	

From Preceding Sheet



Test for velocity measurement available

LR velocity measurement made

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
			R12 - Descent State Vector Update	
DRAWN	<i>E. Matta</i>	6/12/70	DOCUMENT NO.	
PRGMR	<i>P. J. ...</i>	6/17/70	FC 3935	
ANALST			LUMINARY 1D	
DOCMR	<i>M. ...</i>	6/17/70	REV 2	SHEET 20 OF 35
APPR'D	<i>R. ...</i>	6/17/70		

From Preceding Sheet

VELUPDAT

POSINDEX
Set X1 and
X2 and zero
pushlist
Sh. 30

X1 ← -6 (VSELECT)
X2 ← -2 (VSELECT)

Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Welch</i> 12/29/69		R12 - Descent State Vector Update	
PRGMR <i>D. Stone</i> 12/1/69		DOCUMENT NO.	
ANALST		ADMIN OR: 1D	PC-3935
DOCMR <i>W. Baylath</i> 12/5/69		REV 2	SHEET 21 OF 35
APPR'D <i>R.M. Stone</i> 12/1/69			

From Preceding Sheet

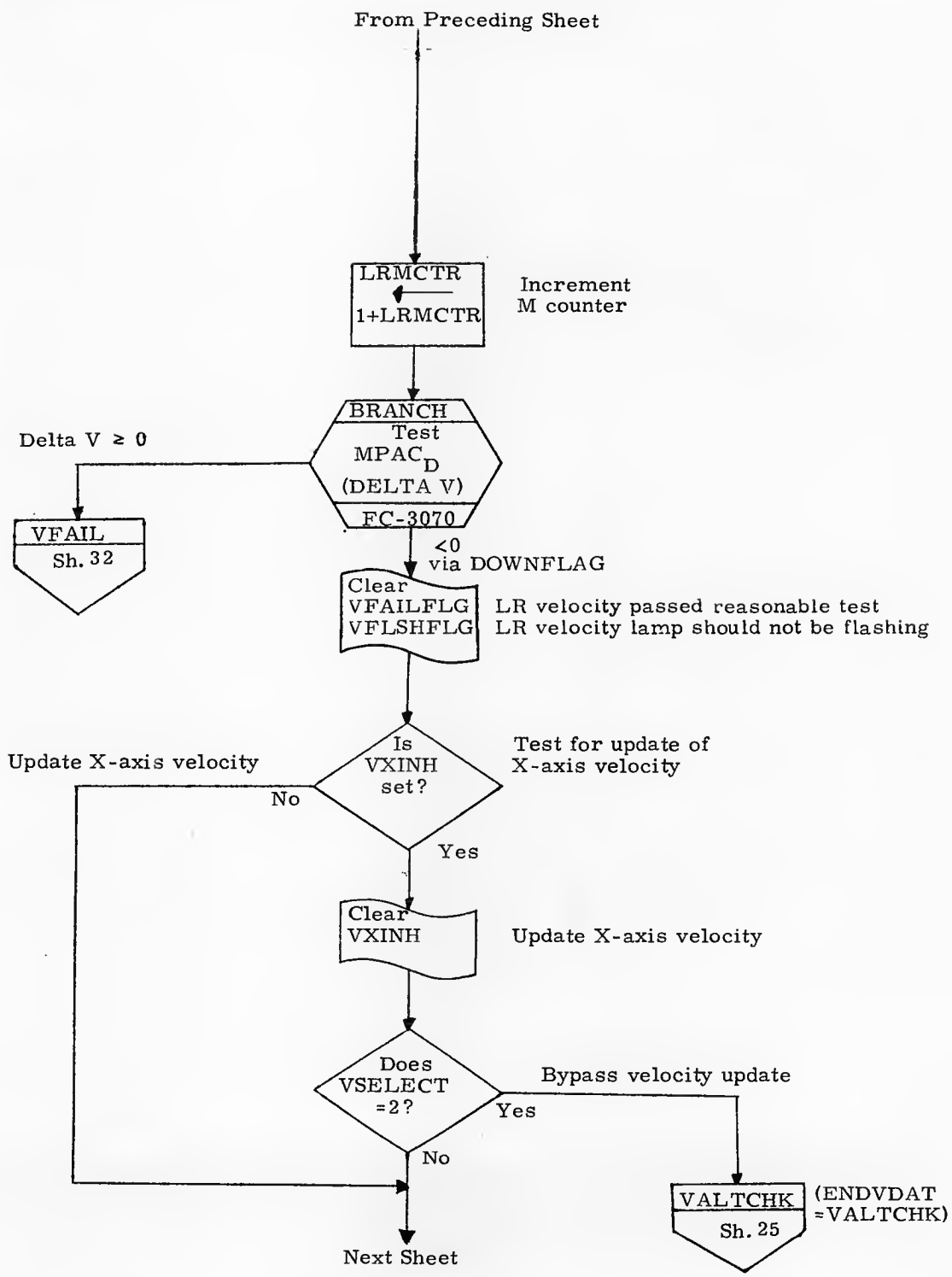
$$\text{MPAC}_V \leftarrow \text{VZBEAMNB}_V \times 1 \text{ (XNBPIP)}$$

$$\begin{aligned} \text{PL0}_V &\leftarrow \text{MPAC}_V \\ \text{PL6}_D &\leftarrow \text{VMEAS}_D \text{ (VZSCAL}_\# \times 2) \end{aligned}$$

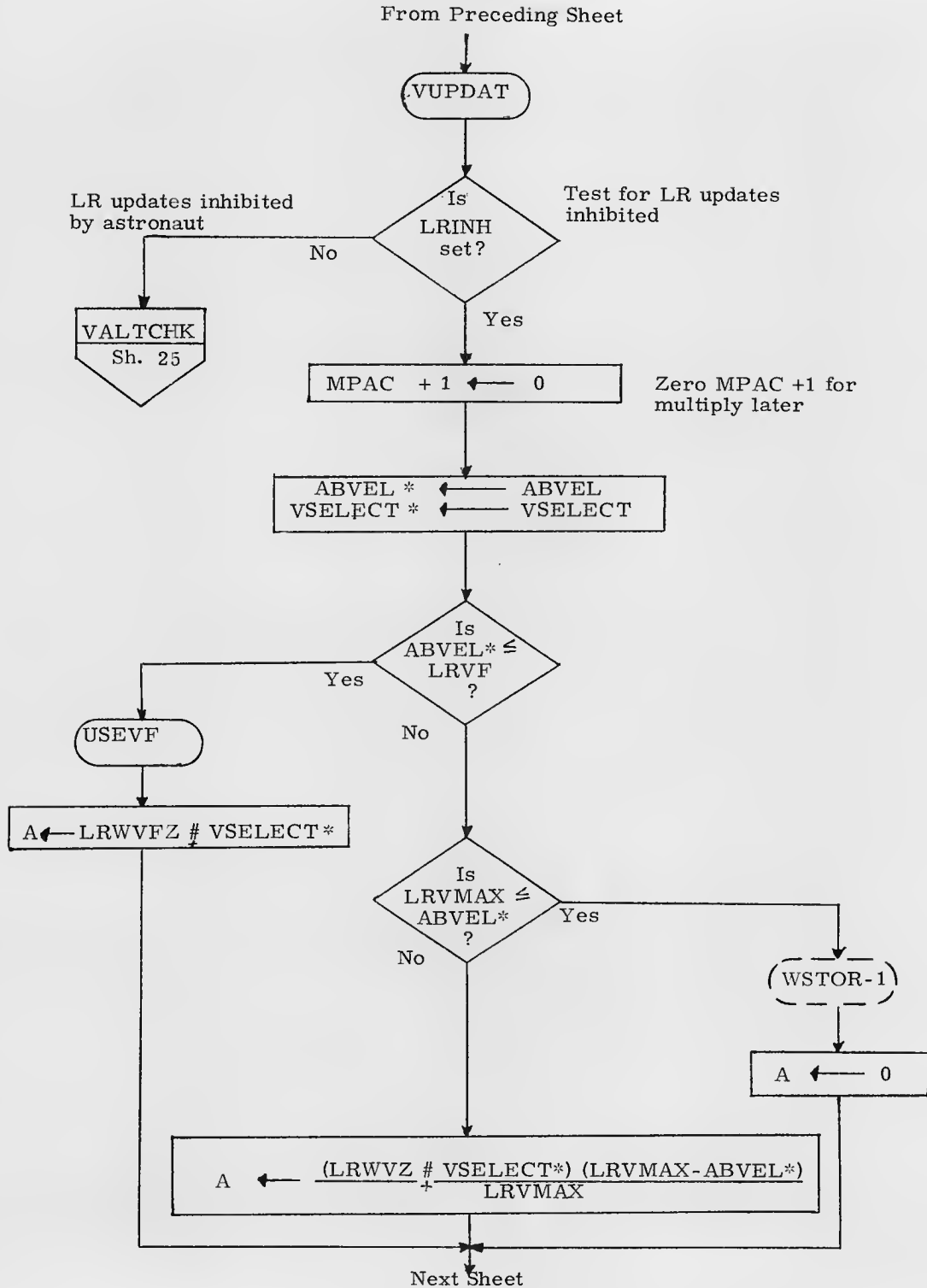
$$\begin{aligned} \text{PL12}_V &\leftarrow \text{VIS}_V + \text{DELVS}_V \\ \text{PL20}_V &\leftarrow 2^{-3} |\text{PL12}_V| + \text{VELBIAS}_D \\ \text{PL22}_D &\leftarrow \text{PL20}_D - (\text{PL12}_V \cdot \text{PL0}_V) \\ \text{MPAC}_D &\leftarrow |\text{PL22}_D| - \text{PL20}_D \end{aligned}$$

Next Sheet

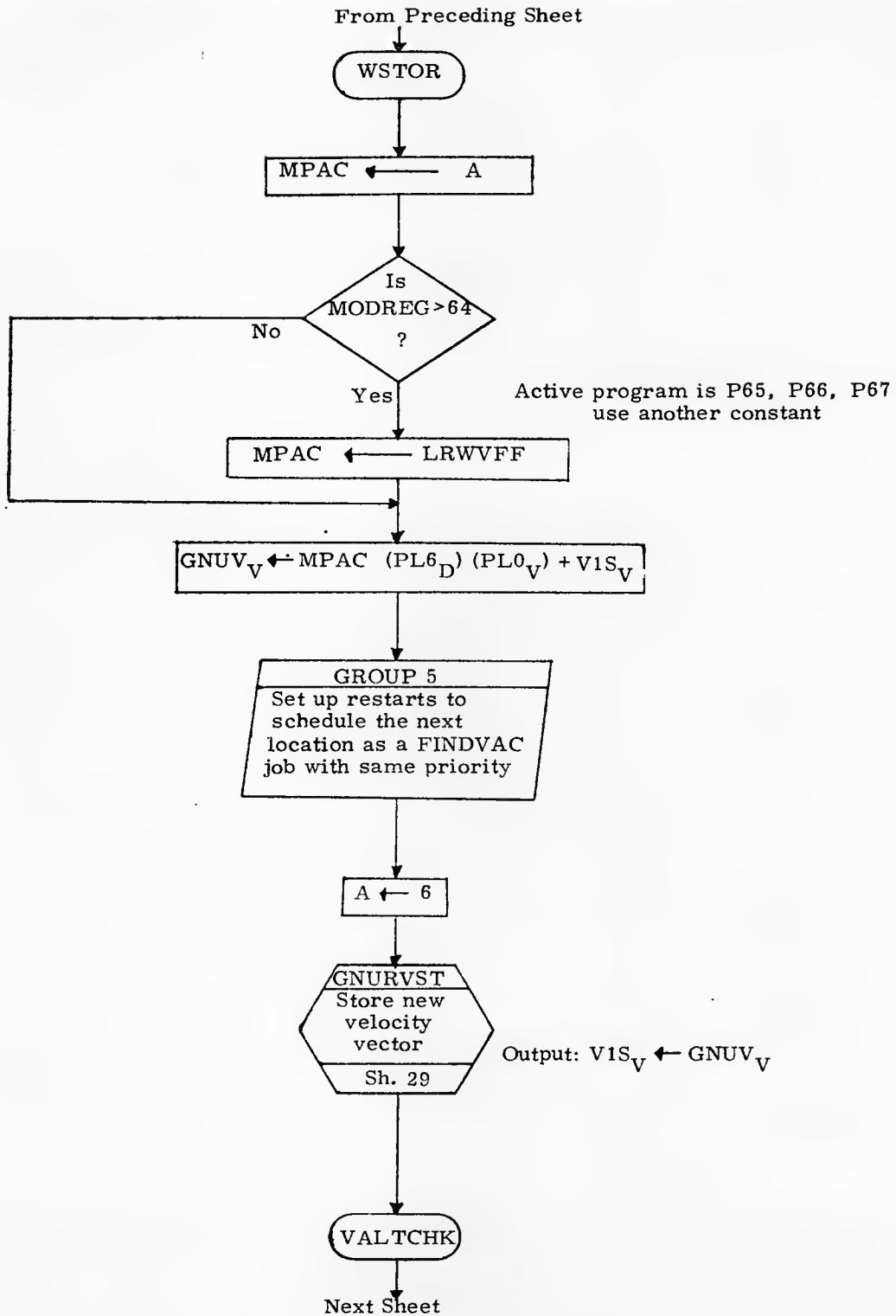
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>G. Welch</i> 12/1/69		R12 - Descent State Vector Update	
PRGMR <i>D. Moore</i> 12/1/69	ANALST	LUMINARY 1D	DOCUMENT NO.
DOCMR <i>W. Dwyer</i> 12/1/69	APPR'D <i>R. M. Epton</i> 12/1/69		FC-3935
REV 2		SHEET 22 OF 35	



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i>		R12 - Descent State Vector Update	
PRGMR <i>[Signature]</i>	<i>[Date]</i>	DOCUMENT NO.	
ANALST	<i>[Date]</i>	LUMINARY 1D	FC-3935
DOCMR <i>[Signature]</i>	<i>[Date]</i>	REV 2	SHEET 23 OF 35
APPR'D <i>[Signature]</i>	<i>[Date]</i>		

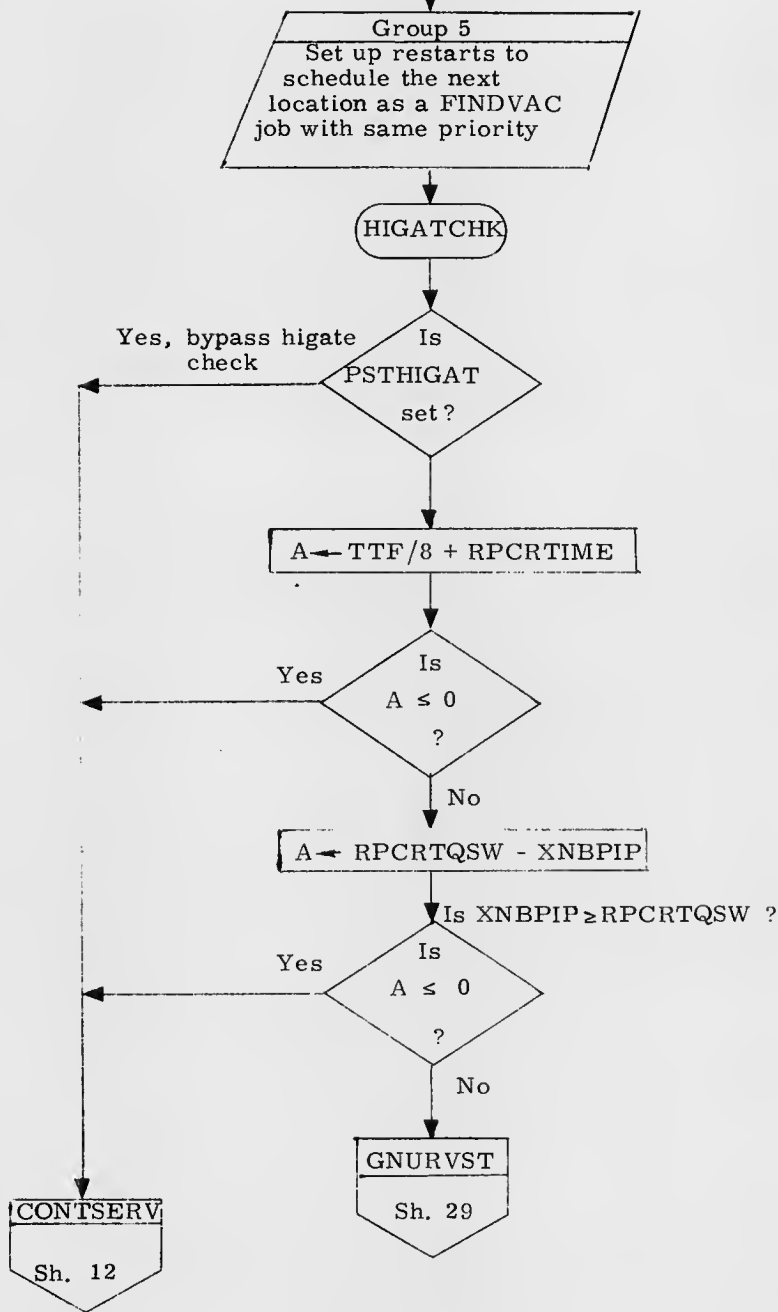


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. Welch</i>		R12 - Descent State Vector Update	
PRGMR <i>D. Moore</i>	<i>10/29/69</i>	DOCUMENT NO.	
ANALST	<i>12/1/69</i>	LUMINARY 1D	FC-3935
DOCMR <i>W. Dwyer</i>	<i>10/29/69</i>	REV 2	SHEET 24 OF 35
APPR'D <i>R.M. Carter</i>	<i>12/1/69</i>		

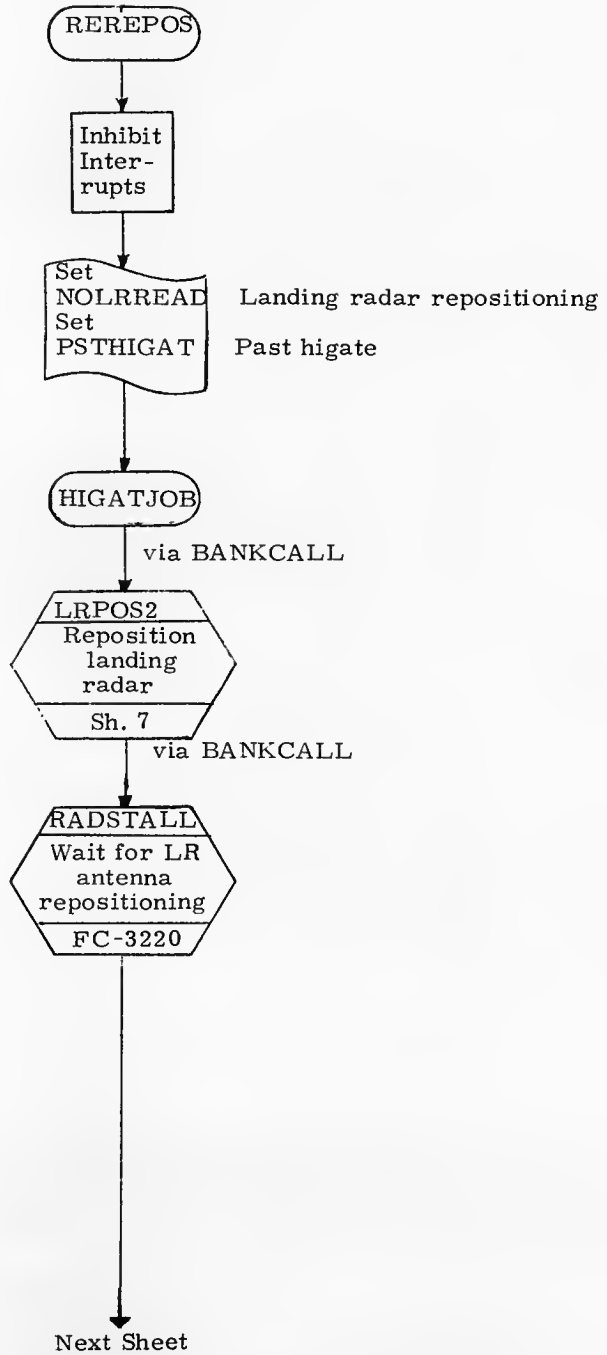


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. L. Smith</i> 10/29/69		R12 - Descent State Vector Update	
PRGMR <i>R. Moore</i> 12/1/69		LUMINARY 1D	DOCUMENT NO. i C-3935
ANALST			
DOCMR <i>R. L. Smith</i> 10/29/69		REV 2	SHEET 25 OF 35
APPR'D <i>R. M. E. Smith</i> 12/1/69			

From Preceding Sheet

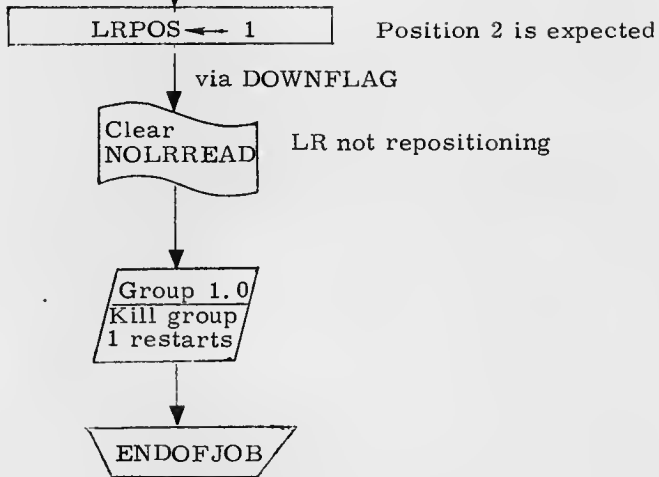


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>E. Matti</i>	6/15/70	R12-Descent State Vector Update	
PRGMR	<i>J. Moore</i>	6/17/70	LUMINARY 1D	DOCUMENT NO.
ANALST				FC-3935
DOCMR	<i>N. DeGroot</i>	6/17/70	REV 2	SHEET 26 OF 35
APPR'D	<i>R. E. ...</i>	6/17/70		

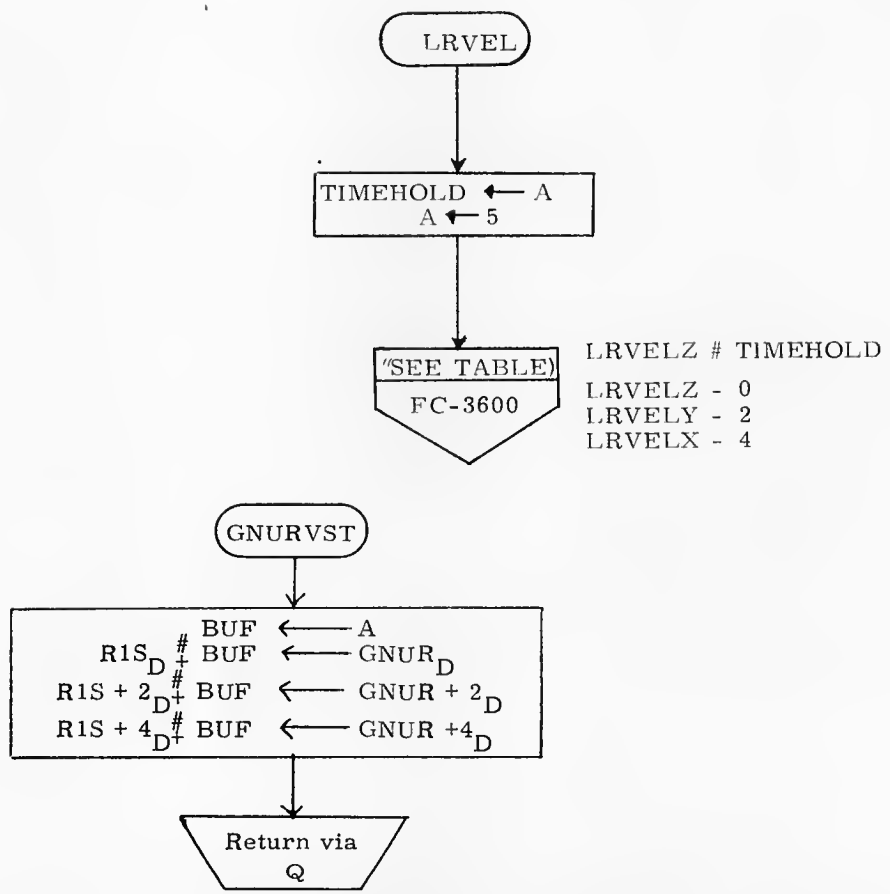


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>B. L. Dale</i>	<i>12/23/69</i>	R12 - Descent State Vector Update	
PRGMR <i>D. Moore</i>	<i>12/1/69</i>	LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3935
DOCMR <i>M. England</i>	<i>12/2/69</i>	REV 2	SHEET 27 OF 35
APPR'D <i>ROM Entes</i>	<i>12/1/69</i>		

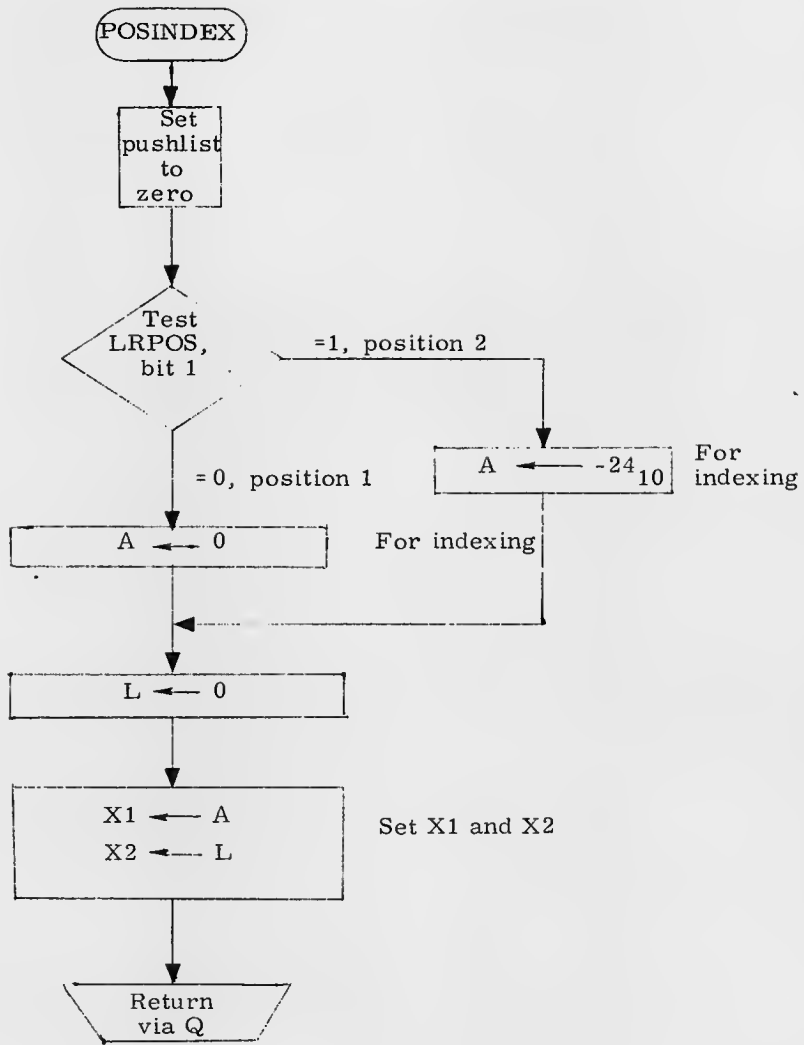
From Preceding Sheet



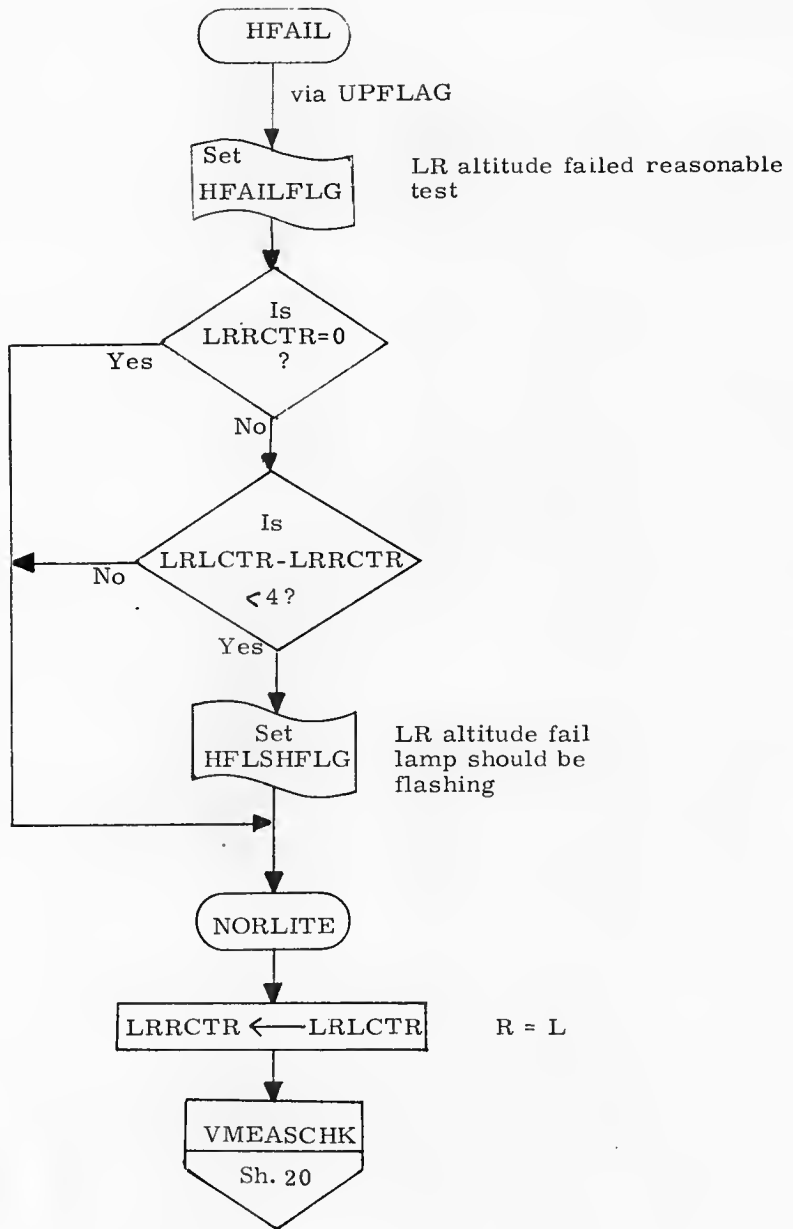
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>E. Matte</i> 6/15/70	R12-Descent State Vector Update	
PRGMR	<i>D. Moore</i> 6/17/70		DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3935
DOCMR	<i>W. DeForest</i> 6/17/70	REV 2	SHEET 28 OF 35
APPR'D	<i>R.M. Eason</i> 4/17/71		



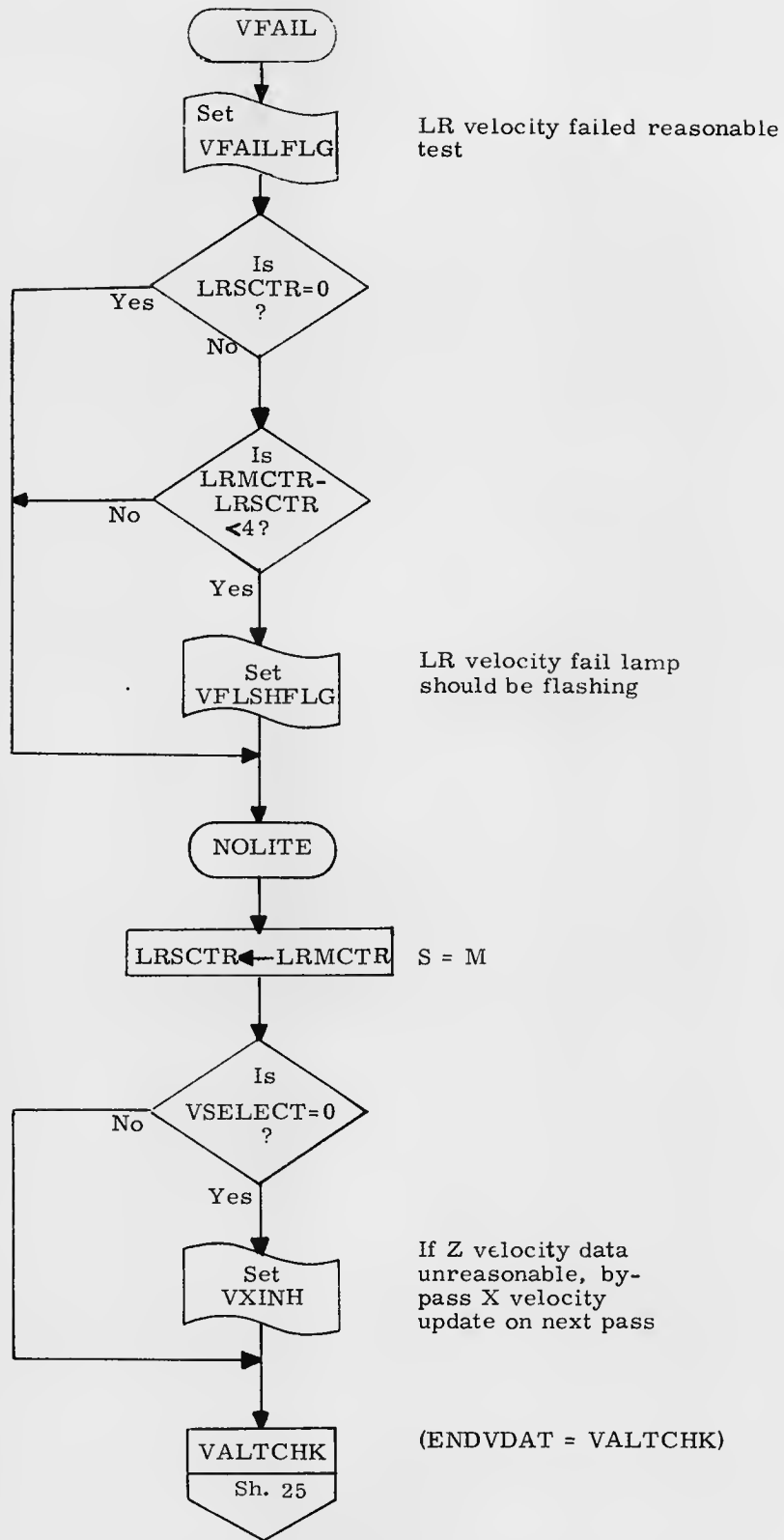
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. Welch</i>	<i>10/23/69</i>	R12 - Descent State Vector Update	
PRGMR <i>D. Moore</i>	<i>12/1/69</i>	LUMINARY 1D	DOCUMENT NO. FC-3935
ANALST			
DOCMR <i>M. Daybath</i>	<i>10/30/69</i>	REV 2	SHEET 29 OF 35
APPR'D <i>RME</i>	<i>12/1/69</i>		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
			R12-Descent State Vector Update	
DRAWN	<i>E. Mitter</i>	4/15/70	LUMINARY 1D	DOCUMENT NO.
PRGMR	<i>R. Moore</i>	6/17/70		FC-3935
ANALST			REV 2	SHEET 30 OF 35
DOCMR	<i>W. Anderson</i>	6/17/70		
APPR'D	<i>R. M. E. ...</i>	6/17/70		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>P. Welch</i> 11/18/69		R12 - Descent State Vector Update	
PRGMR <i>Osborne</i> 12/1/69	ANALST	LUMINARY 1D	DOCUMENT NO. GC-3935
DOCMR <i>M. Daphith</i> 10/30/69	APPR'D <i>Rim E. ...</i> 12/1/69	REV 2	SHEET 3 OF 35



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>R. Wolach</i>	<i>12/23/69</i>	R12 - Descent State Vector Update
PRGMR	<i>R. Moore</i>	<i>12/1/69</i>	DOCUMENT NO.
ANALST			FC-3935
DOCMR	<i>R. Moore</i>	<i>12/3/69</i>	LUMINARY 1D
APPR'D	<i>R.M. Evers</i>	<i>12/1/69</i>	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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D</i>		R12 - Descent State Vector Update	
PRGMR <i>D Moore</i>	12/1/69	LUMINARY 1D	DOCUMENT NO. FC-3935
ANALST			
DOCMR <i>W Dayforth</i>	11/25/69		
APPR'D <i>R M Evers</i>	12/1/69	REV 2	SHEET 33 OF 35

FLAGS

Name	Meaning When Sct	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	Average (SERVICER) desired	Average (SERVICER) not desired			Sh. 4
R77FLAG FLAG 5 BIT 11	R77 is on	R is not on			Sh. 6
V37FLAG FLAG 7 BIT 6	Average (SERVICER) running	Average (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
HFMAILFLG FLAG 11 BIT 13	LR altitude failed reasonability test	LR altitude passed reasonability test	Sh. 31	Sh. 17	

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		R12 - Descent State Vector Update	
PRGMR	<i>D Moore</i>	12/1/69	
ANALST			
DOCMR	<i>W Doughty</i>	11/25/69	LUMINARY 1D
APPR'D	<i>R M Estes</i>	12/1/69	REV 2
			DOCUMENT NO. FC-3935
			SHEET 34 OF 35

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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		R12 - Descent State Vector Update	
PRGMR	<i>D Moore</i>	12/1/69	
ANALST			
DOCMR	<i>W. Daghouth</i>	11/25/69	LUMINARY 1D
APPR'D	<i>RDM Euston</i>	12/1/69	DOCUMENT NO. FC-3935
		REV 2	SHEET 35 OF 35

R13 - Landing Auto Modes Monitor

LUNLAND Sh. 2
DESCBITS Sh. 6

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>G. Welch</i>	<i>12/4/69</i>	Landing Auto Modes Monitor	
PRGMR <i>P. Allen</i>	<i>12/9/69</i>	LUMINARY 1L	DOCUMENT NO.
ANALST			FC-3940
DOCMR <i>W. Donahue</i>	<i>12/15/69</i>	REV 3	SHEET 1 OF 7
APPR'D <i>W. Donahue</i>	<i>12/16/69</i>		

LUNLAND

Entry point from Servicer (SERVOUT)
every 2 seconds during lunar landing

Group 5.3
Set up restarts
to schedule
REREADAC as
a task in 2 sec

ZOOMFLAG
SET ?

Has throttle-up occurred ?
No

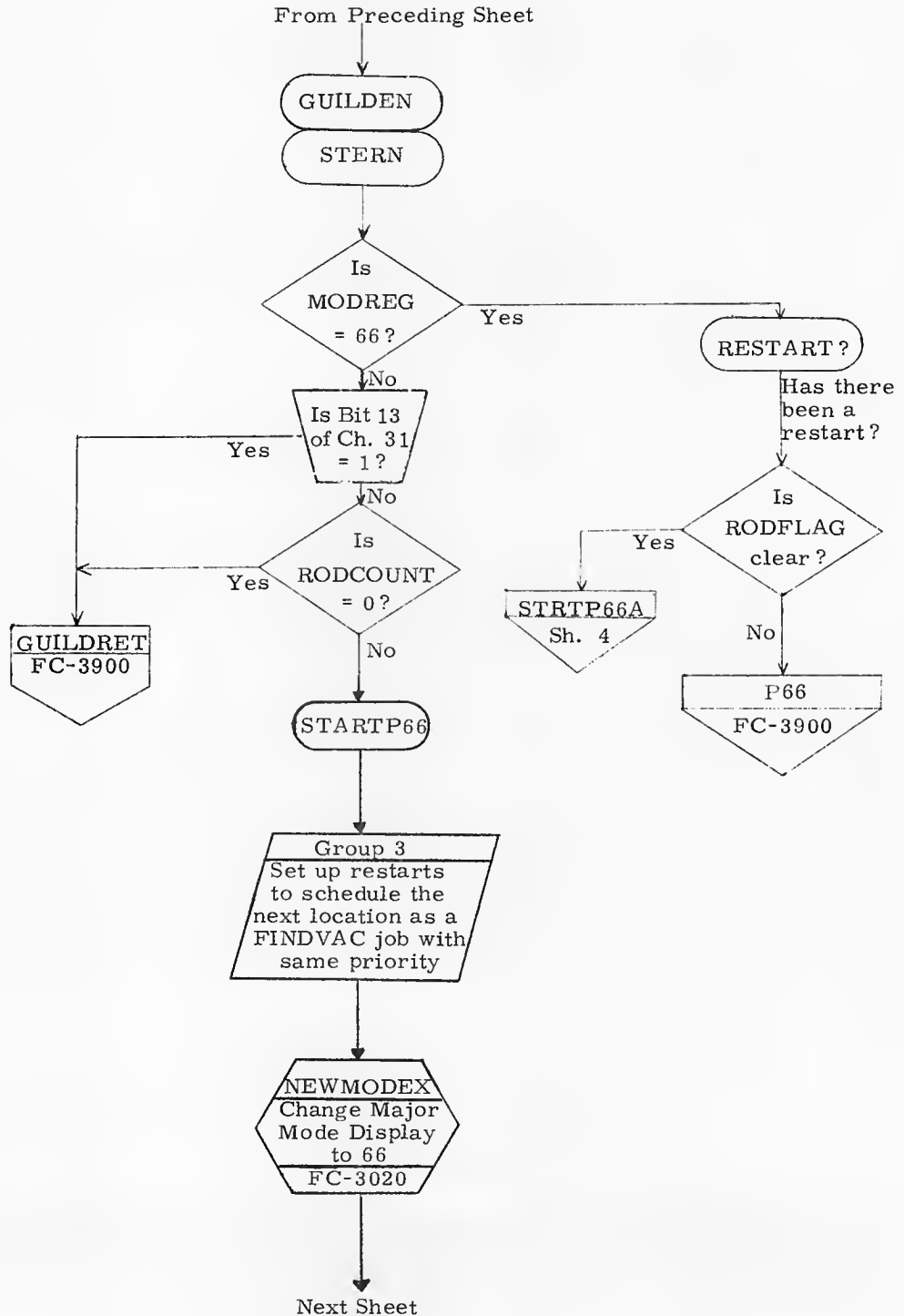
yes

DISPEXIT +3
FC-3900

Group 3
Set up restarts
to schedule the
next location as
a FINDVAC job
with priority 20

next sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. Lutkenich</i> 8-14-69		Landing Auto Modes Monitor	
PRGMR <i>A. Cohen</i> 8/16/69		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3940
DOCMR W. C. DANFORTH		REV 3	SHEET 2 OF 7
APPR'D <i>Alexander M. Spang</i> 8/20/69			



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>L. Holdstone</i>	<i>12/2/69</i>	Landing Auto Modes Monitor	
PRGMR <i>P. Keller</i>	<i>20 AUG 69</i>	LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3940
DOCMR <i>W.C. Day</i>	<i>1 AUG 69</i>	REV 3	SHEET 3 OF 7
APPR'D <i>Allen M. Sorant</i>	<i>20 AUG 69</i>		

From Preceding Sheet

$VDGVERT_D \leftarrow HDOTDISP_D$

Set desired altitude rate = current altitude rate

Set
P66PROFL

Continue P66
Horizontal Velocity
Nulling

$CNTTHROT \leftarrow -TOOFEW$

Initialize
Throttle Count

STRTP66A

$VHZC_V \leftarrow WM_V \times R_V$

$MPAC_V \leftarrow PBIASX, PBIASZ$
 $VBIAS_V \leftarrow MPAC_V (BIASFACT)$

$BIASFACT = 655.36 \times 2^{-26}$

Set
RODFLAG

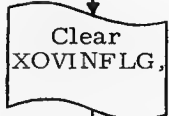
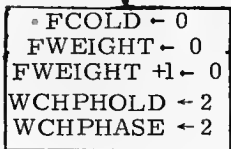
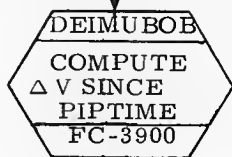
If in P66, normal operation
continues. Restart clears flag.

$OLDPIPAX_V \leftarrow -TEMX_V$
 $DELVRD_V \leftarrow 0_V$
 $RODSCALI_D \leftarrow RODSCALE_D$
 $LASTTPIP_D \leftarrow PIPTIME_D$

Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Landing Auto Modes Monitor	
PRGMR	<i>P. Collins</i> 20 AUG 69	LUMINARY 1D	DOCUMENT NO. FC-3940
ANALST			
DOCMR	<i>W.C. Duffell</i> 4 AUG 69		
APPR'D	<i>Allen By</i> 20 AUG 69	REV 3	SHEET 4 OF 7

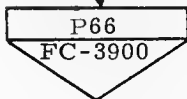
From Preceding Sheet



X-axis override OK

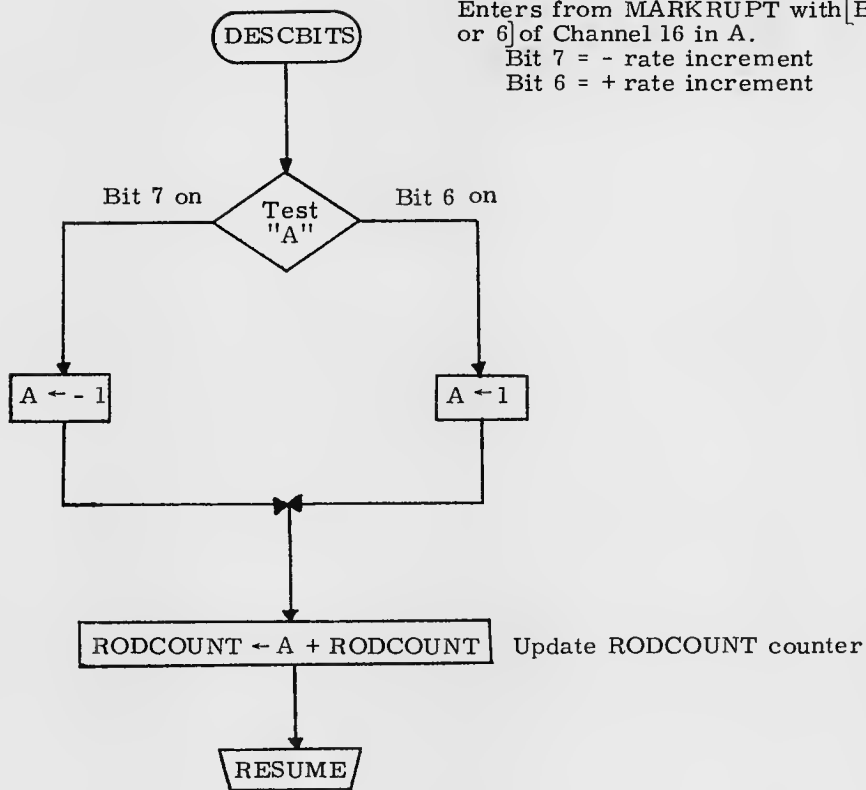


Terrain model inhibited



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Landing Auto Modes Monitor	
PRGMR	<i>P. Adcox</i>		DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3940
DOCMR	<i>H.C. Dyer</i>		
APPR'D	<i>W. J. ...</i>	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



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN _____		Landing Auto Modes Monitor	
PRGMR <i>R Keller</i>	<i>20 Aug 68</i>	DOCUMENT NO.	
ANALST _____	_____	LUMINARY 1D	FC-3940
DOCMR <i>H C Dykstra</i>	<i>4 Nov 69</i>	REV 3	
APPR'D <i>Allen M. ...</i>	<i>20 Aug 68</i>	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

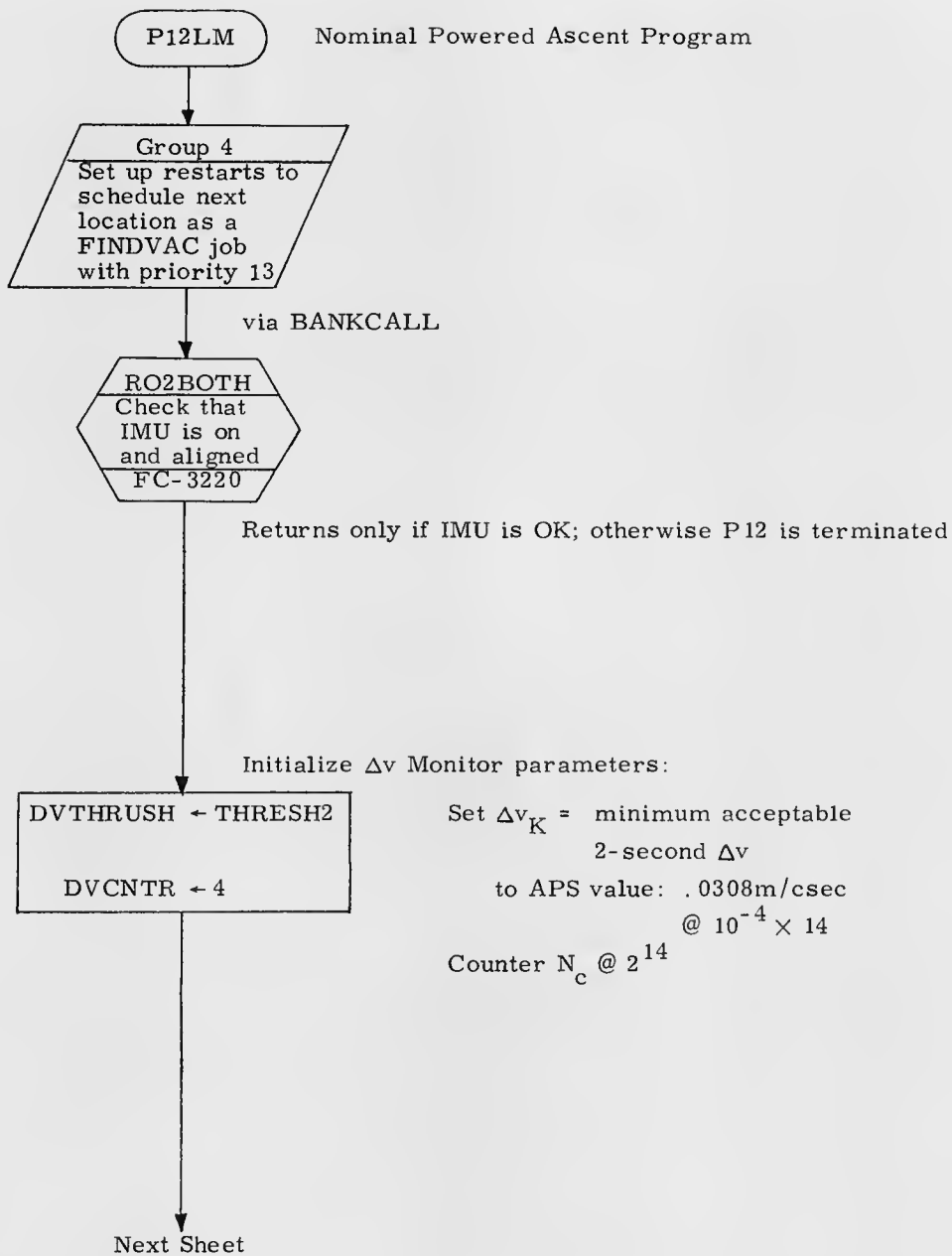
Name	Meaning When Set	Meaning When Cleared	Where Set	Where Cleared	Where Tested
ZOOMFLAG Flag 5, Bit 8	Throttle-up has occurred in P63	Throttle-up has not occurred in P63			Sh. 2
RODFLAG Flag 1 Bit 12	If in P66, normal operation continues	If in P66 reinitialization is performed	Sh. 4		Sh. 3
XOVINFLG 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 <i>M. Connor</i>	<i>12/2/69</i>	Landing Auto Modes Monitor	
PRGMR _____			DOCUMENT NO.
ANALST _____		LUMINARY 1D	FC-3940
DOCMR <i>W. DeWitt</i>	<i>12/15/69</i>	REV 3	SHEET 7 OF 7
APPR'D <i>Robert M. E. ...</i>	<i>3/9/70</i>		

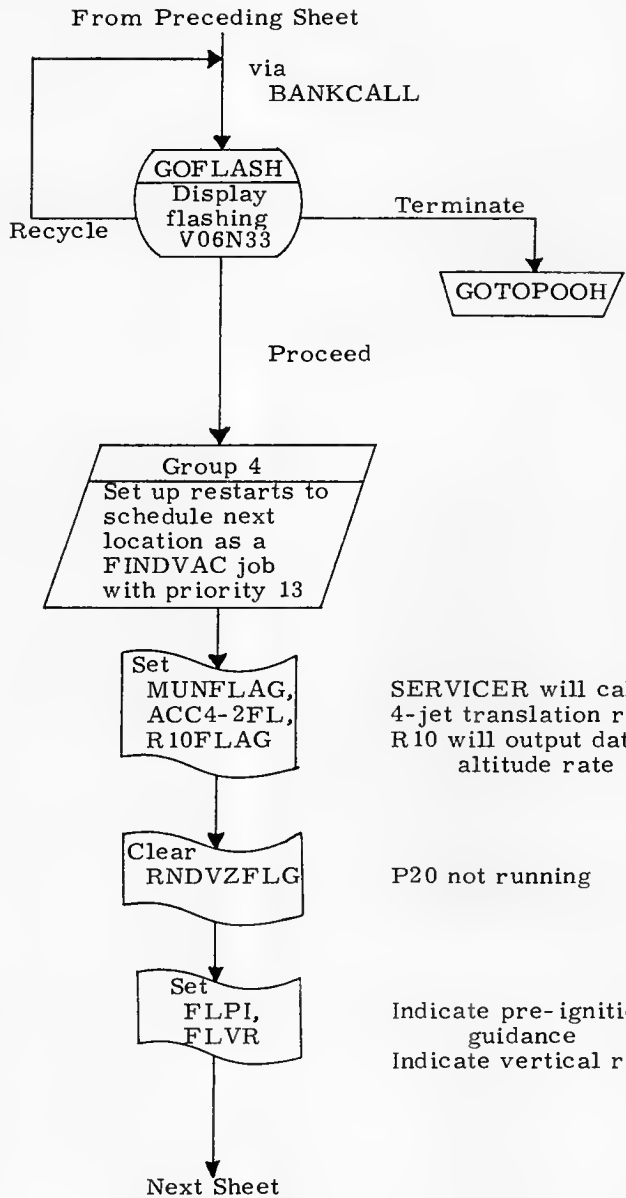
P12 - ASCENT GUIDANCE

P12LM	Sh. 2
YCOMP	Sh. 6
P12RET	Sh. 10
ATMAG	Sh. 12
ASCENT	Sh. 15
ENGOFF	Sh. 36
ENGOFF 1	Sh. 38
CUTOFF	Sh. 39
GUIDINIT	Sh. 42
P12INIT	Sh. 44
COMMINIT	Sh. 45
ZDOTDCMP	Sh. 46
THETCOMP	Sh. 48
RPCOMP1	Sh. 49
RPCOMP2	Sh. 49
LOGSUB	Sh. 50

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i>		P12-Ascent Guidance	
PRGMR <i>[Signature]</i>		LUMINARY 1D	DOCUMENT NO. FC-3950
ANALST			
DOCMR <i>[Signature]</i>			
APPR'D <i>[Signature]</i>	6/25/70	REV	SHEET 1 OF 63



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i>		P12-Ascent Guidance	
PRGMR <i>[Signature]</i>		LUMINARY 1D	DOCUMENT NO. FC-3950
ANALST			
DOCMR			
APPR'D <i>[Signature]</i>	6/25/70	REV	SHEET 2 OF 63



Let astronaut verify ignition time (TIG_D):
 R1: ooxxx. hrs.
 R2: ooxxx. 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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i>		P12-Ascent Guidance	
PRGMR <i>[Signature]</i>		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3800
DOCMR		REV	
APPR'D <i>[Signature]</i>	6/25/70		SHEET 3 OF 63

From Preceding Sheet



Output: $WM_V = \omega_M =$ 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}
 $VRECTCSM_V = v_c =$ CSM velocity in reference coords
 $RRECTCSM_V = r_c =$ 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/csec² @ 2^{-9}
 $TBUP_D = \tau$ in csec @ 2^{17}
 $TTO_D = \Delta t_{tail-off}$ 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
 $QAXIS_V = Q$ in SM coords @ 2^1

Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i>		P12-Ascent Guidance	
PRGMR <i>[Signature]</i>		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3950
DOCMR			
APPR'D <i>[Signature]</i>	6/25/70	REV	SHEET 4 OF 63

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)

$WM_V = \omega_M$ 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:

$VIS_V \leftarrow 2^1 \cdot REFSMMAT_M \times VATT_V$
 $MPAC_V \leftarrow 2^6 \cdot REFSMMAT_M \cdot RATT_V$
 $R_V \leftarrow MPAC_V$

$\underline{v}(t_{IG})$ in m/csec @ 2^7

$\underline{r}(t_{IG})$ in m @ 2^{24}

where $REFSMMAT_M$

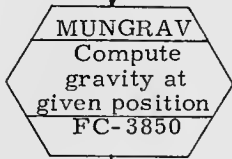
= reference - SM
coordinate
transformation
matrix @ 2^1

$2^1, 2^6$ factors are
for scaling

Next Sheet

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PRGMR <i>J. D. ...</i>		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3950
DOCMR			
APPR'D <i>R.M. ...</i>	6/25/70	REV	SHEET 5 OF 63

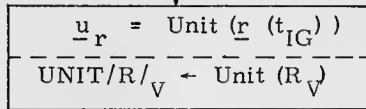
From Preceding Sheet



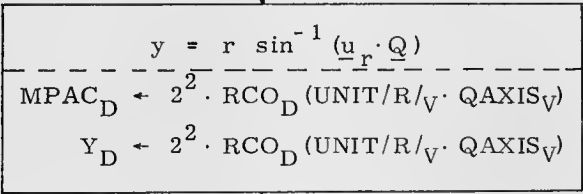
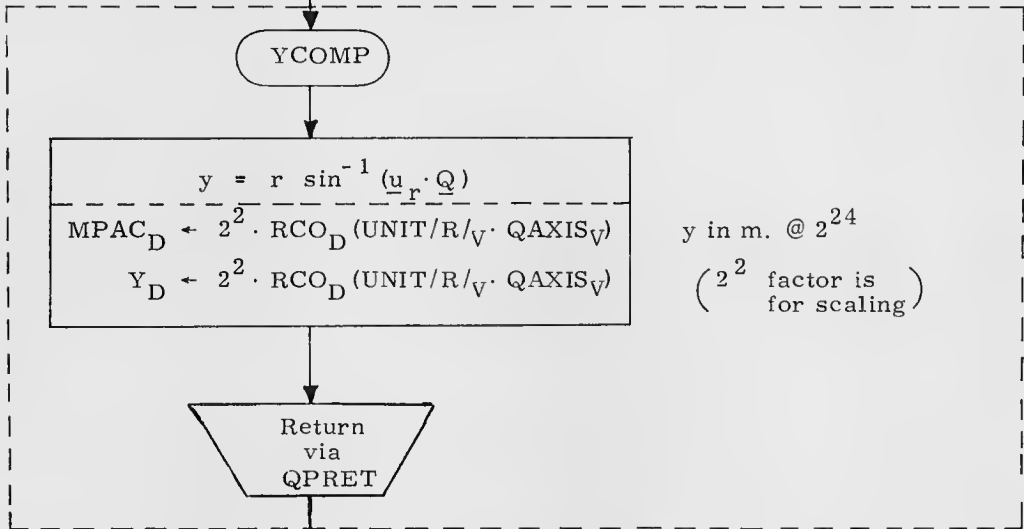
Input: MPAC_V = position vector in SM coords in m @ 2²⁴

Output: GDT1/2_V = half the change in velocity due to gravitational acceleration at given position over 2 seconds in m/csec @ 2⁷

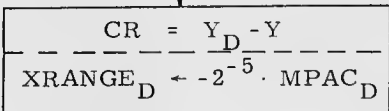
Compute cross-range display parameter:



\underline{u}_r in SM coordinates @ 2¹



y in m. @ 2²⁴
(2² factor is for scaling)



CR = cross-range distance in m. @ 2²⁹
where: Y_D = 0 m. here
2⁻⁵ factor is for scaling

Next Sheet

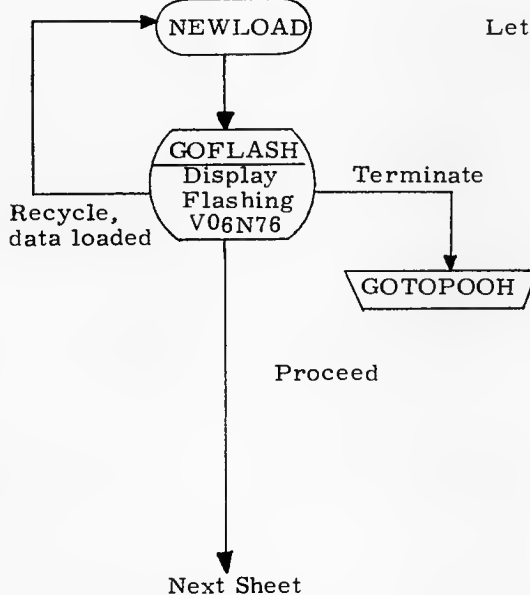
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DRAWN <i>M. J. ...</i>		P12-Ascent Guidance	
PRGMR <i>J. ...</i>		LUMINARY 1D	DOCUMENT NO. FC-3950
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APPR'D <i>R.M. Estes</i>	10/25/68	REV	SHEET 6 OF 63

From Preceding Sheet

ZDOTD_D ← VINJNOM_D
 RDOTD_D ← RDOTNOM_D

\dot{Z}_D = required injection
 down-range velocity
 in m/csec @ 2⁷
 \dot{R}_D = desired injection
 radial velocity
 in m/csec @ 2⁷

Group 4
 Set up restarts to
 schedule next
 location as a
 FINDVAC job with
 priority 13



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)

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PRGMR <i>J. Beaman</i>		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3950
DOCMR		REV	
APPR'D <i>R.M. Eaten</i>	6/25/70		SHEET 7 OF 63

From Preceding Sheet

WHICH ← Adr (P12 TABLE)

Specify table
for BURNBABY

Group 4
Set up restarts to
schedule next
location as a
FINDVAC job
with priority 13

$$Y_D = Y + CR$$

$$YCO_D + Y_D \rightarrow 2^5 \cdot XRANGE_D$$

Compute Y_D in m @ 2^{24}
 2^5 factor is for
scaling

$$\underline{v} = \underline{v}(t_{IG}) + 49\underline{u}_r \text{ ft./sec.}$$

$$\underline{V}_V + V1S_V + 49FPS_D \cdot \text{UNIT}/R/V$$

Extrapolate LM velocity
through vertical rise
phase
 \underline{v} in SM coordinates
in m/csec @ 2^7

$$RDOT_D \leftarrow 2 \cdot \underline{V}_V \cdot \text{UNIT}/R/V$$

\dot{R} = component of
velocity in
radial direction
in m/csec @ 2^7

Next Sheet

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DOCMR			
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$$\underline{u}_z = \text{Unit}(\underline{u}_R \times \underline{Q})$$

$$\text{ZAXIS1}_V \leftarrow \text{Unit}(\text{UNIT/R}_V \times \text{QAXIS}_V)$$

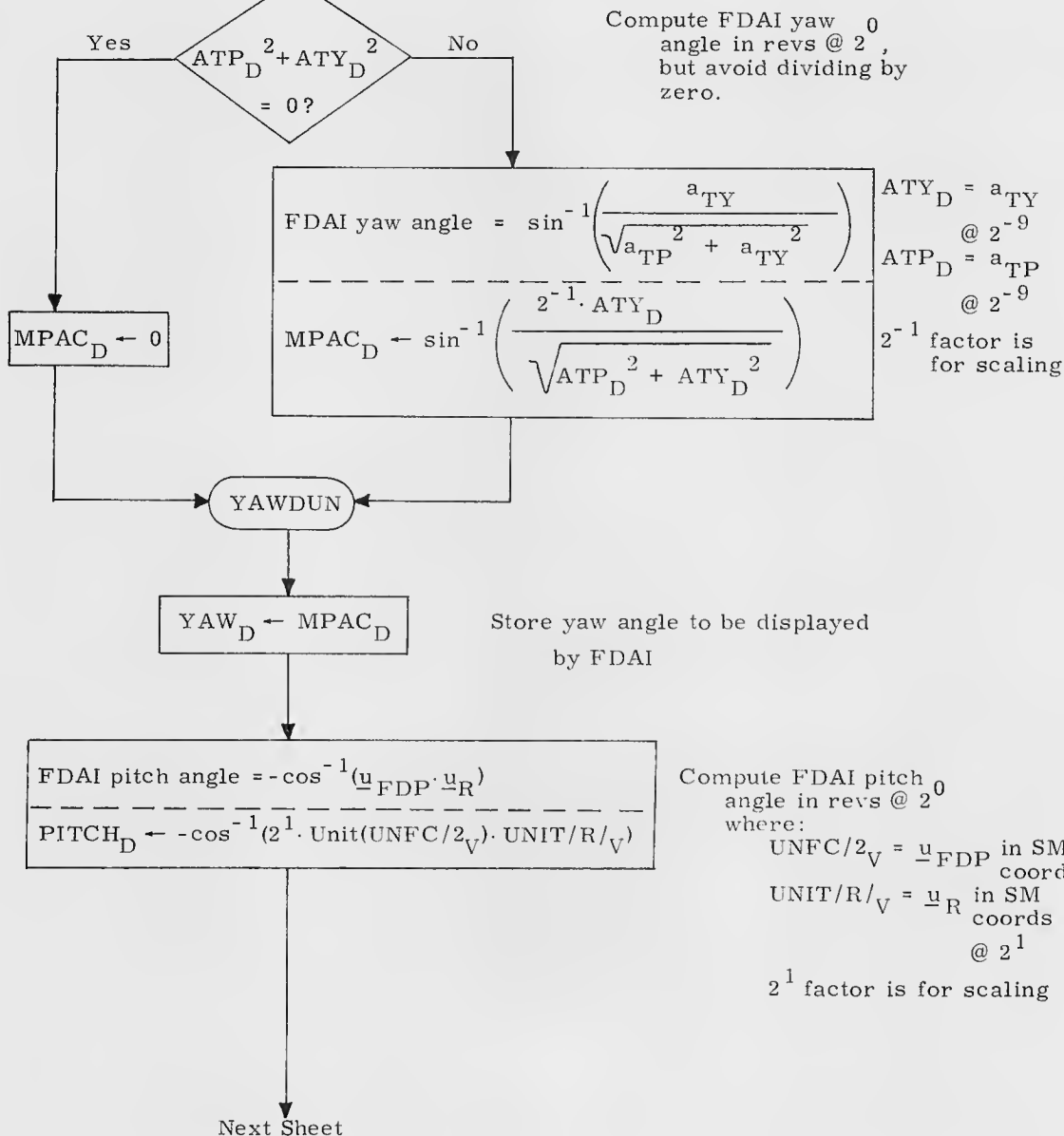
Compute Z-axis
component of
local vertical
coordinate system
in SM coords @ 2¹

ASCENT
Sh. 15

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PRGMR <i>J. German</i>		LUMINARY 1D	DOCUMENT NO. FC-3950
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DOCMR			
APPR'D <i>R.M. Estes</i>	6/25/70	REV	SHEET 9 OF 63

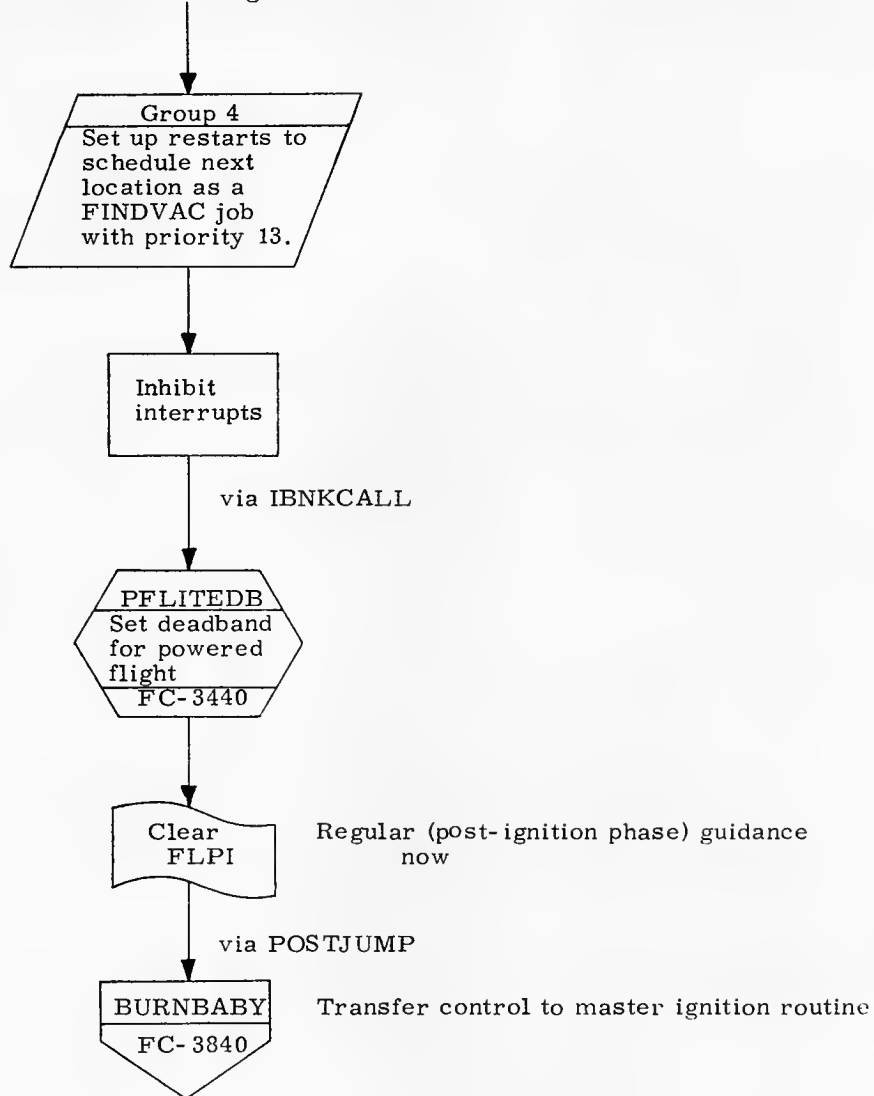
P12RET

Return from ascent guidance computations (sh. 26) during pre-ignition phase



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From Preceding Sheet



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DRAWN <i>Mary Ann</i>		P12-Ascent Guidance	
PRGMR <i>J. J. ...</i>		LUMINARY 1D	DOCUMENT NO. FC-3950
ANALST			
DOCMR			
APPR'D <i>R. M. ...</i>	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

ASCENT
Sh. 15

Yes

ABDVCONV_D
< MINABDV_D
?

$\Delta v < \Delta v_{min}$?

Yes

ASCTERM4
Sh. 35

Display noun 63
and exit.

No

Clear
SURFFLAG,
RENDWFLG

LM not on lunar surface
W-matrix invalid for rendezvous navigation

Next Sheet

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PRGMR <i>J. ...</i>		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3950
DOCMR		REV	
APPR'D <i>R.M. ...</i>	6/25/70	SHEET 12 OF 63	

From Preceding Sheet

$$\begin{aligned} 1/DV^0_D &\leftarrow 1/DV^1_D \\ 1/DV^1_D &\leftarrow 1/DV^2_D \\ 1/DV^2_D &\leftarrow 1/DV^3_D \\ 1/DV^3_D &\leftarrow 2^{-12} \div ABDVCONV_D \end{aligned}$$

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

$$PLX_D \leftarrow 2^4 \cdot 1/2 \left[1/DV^0_D + 1/DV^1_D + 1/DV^2_D + 1/DV^3_D \right] \cdot VE_D \cdot 2SEC(9)_D$$

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

$$\tau = 1/2 \left[1/4 \left(\frac{1}{\Delta v_0} + \frac{1}{\Delta v_1} + \frac{1}{\Delta v_2} + \frac{1}{\Delta v_3} \right) v_e \Delta t + \tau - 3 \Delta t \right]$$

$$TBUP_D \leftarrow PLX_D + 1/2 TBUP_D - 65EC(18)_D$$

τ in csec @ 2^{17}
where $65EC(18)_D$
= $1/2 \cdot 3 \Delta t$
= $1/2 \cdot 3(200)$ csec
@ 2^{17}

Next Sheet

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		P12-Ascent Guidance	
DRAWN <i>Mary Beth</i>		LUMINARY 1D	DOCUMENT NO.
PRGMR <i>J. J. ...</i>			FC-3950
ANALST			
DOCMR			
APPR'D <i>R.M. ...</i>	6/25/70	REV	SHEET 13 OF 63

From Preceding Sheet

$$a_t = \frac{v_e}{\tau}$$

$$AT_D \leftarrow 2^{-1} \cdot VE_D \div TBUP_D$$

Compute thrust acceleration

$$a_t \text{ in m/csec}^2$$
$$\text{@ } 2^{-9}$$

where: $VE_D = v_e$ in m/csec @ 2^7

$TBUP_D = \tau$ in csec @ 2^{17}

2^{-1} factor is for scaling

ASCENT
Sh. 15

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ASCENT

Ascent Guidance Computations
- common entry

$$/R/MAG_D \leftarrow |R_V|$$

R in m @ 2²⁴

$$ZDOT_D \leftarrow 2^1 (V_V \cdot ZAXIS1_V)$$

$\dot{Z} = \underline{v} \cdot \underline{u}_Z$ in m/csec @ 2⁷
 where: $V_V = \underline{v}$ in SM coords
 in m/csec @ 2⁷
 $ZAXIS1_V = \underline{u}_Z$ in SM coords
 @ 2¹
 2¹ 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 @ 2¹
 where: $ZAXIS1_V = \underline{u}_z$ in SM
 coords @ 2¹
 $UNIT/R_V = \underline{u}_R$ in
 SM coords @ 2¹
 2¹ factor is for scaling

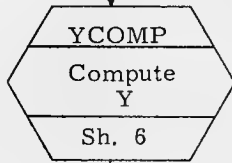
$$YDOT_D \leftarrow 2^1 (V_V \cdot LAXIS_V)$$

$\dot{Y} = \underline{v} \cdot \underline{u}_y$ in m/csec @ 2⁷
 where: $V_V = \underline{v}$ in SM coords
 in m/csec @ 2⁷
 $LAXIS_V = \underline{u}_y$ in SM coords @ 2¹
 2¹ factor is for scaling

Next Sheet

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DRAWN <i>Allegretti</i>		P12-Ascent Guidance	
PRGMR <i>Allegretti</i>		LUMINARY 1D	DOCUMENT NO. FC-3950
ANALST			
DOCMR		REV	SHEET 15 OF 63
APPR'D <i>RMM/Enter</i>	<i>6/25/70</i>		

From Preceding Sheet



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/csec² @ 2^{-9}

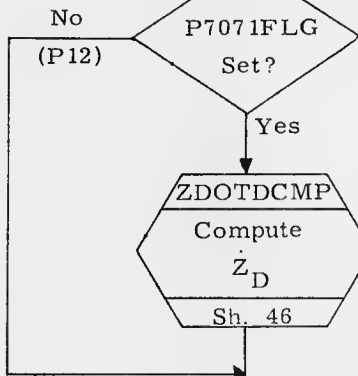
$$g_{eff} = \frac{|r \times v|^2}{r^3} + g = \frac{|\underline{u}_r \times \underline{v}|^2}{r} + \frac{\underline{u}_r \cdot \underline{g} \Delta t}{\Delta t}$$

$$GEFF_D \leftarrow 2^1 \cdot \frac{(UNIT/R/V \times V_V)^2}{/R/MAG_D} + \frac{UNIT/R/V \cdot GDT1/2_V}{2 SEC(18)_D}$$

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?



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

$$DZDOT_D \leftarrow ZDOTD_D - ZDOT_D$$

$$DYDOT_D \leftarrow YDOTD_D - YDOT_D$$

$$DRDOT_D \leftarrow RDOTD_D - RDOT_D$$

$$\left. \begin{aligned} \Delta \dot{Z} &= \dot{Z}_D - \dot{Z} \\ \Delta \dot{Y} &= \dot{Y}_D - \dot{Y} \\ \Delta \dot{R} &= \dot{R}_D - \dot{R} \end{aligned} \right\} \begin{array}{l} \text{in m/c sec} \\ @ 2^7 \end{array}$$

Next Sheet

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APPR'D <i>[Signature]</i>	<i>[Signature]</i>		

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

$$\underline{v}_G = \underline{v}_G - 1/2t_{go} g_{eff} \underline{u}_r$$

$$VGVECT_V \leftarrow VGVECT_V - 2^1 (TGO_D \cdot GEFF_D \cdot UNIT/R/V)$$

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/csec² @ 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

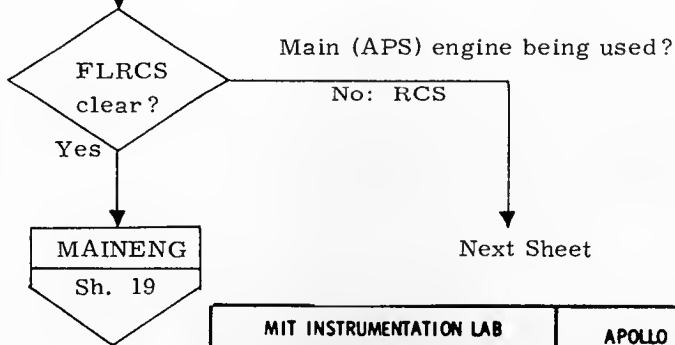
$$\underline{v}_{GB} = [SMNB] \underline{v}_G$$

$$VGBODY_V \leftarrow 2^1 \cdot XNBPIP_M \times VGVECT_V$$

where:
 $XNBPIP_M =$ SM - NB coordinate transformation matrix @ 2^1
 2^1 factor is for scaling

$$v_g = |\underline{v}_G|$$

$$MPAC_D = |VGVECT_V|$$



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From Preceding Sheet

$$t_{go} = \frac{v_G}{A_T(RCS)}$$

$$TGO_D \leftarrow |MPAC_D| \div AT/RCS_D$$

Update t_{go} in csec @ 2^{17}

where:

$$AT/RCS_D = A_T(RCS)$$

= acceleration of 4 RCS jets in a dry LM
in $m/csec^2 @ 2^{-10}$

RPCOMP1
Estimate
 $R_P = R + \dot{R}t_{go}$
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}

Output: $RP_D = R_P$ in $m @ 2^{24}$

ASCTERM2

ASCTERM3

Sh. 34

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		P12-Ascent Guidance	
DRAWN <i>M. J. ...</i>		LUMINARY ID	DOCUMENT NO. FC-3950
PRGMR <i>A. J. ...</i>			
ANALST			
DOCMR			
APPR'D <i>R.M. Enter</i>	6/25/70	REV	SHEET 18 OF 63

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}
 $VGVECT_V = \frac{V_G}{V_e}$ 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?

No
 IDLEFLAG clear?

Yes
 $t_{go} < 4$ sec?

Yes
 $TGO_D < 4$ sec?

ENG OFF
 Sh. 36

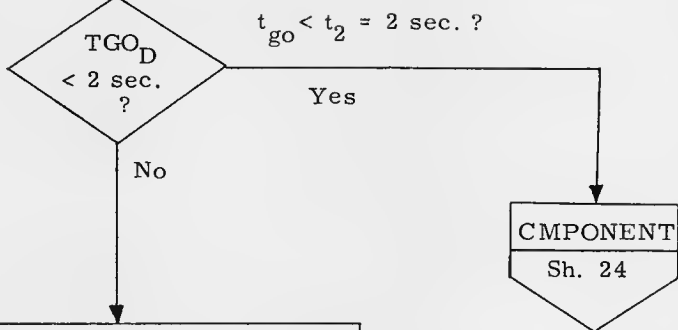
Set up engine cutoff

Next Sheet

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From Preceding Sheet

T2TEST



$t_{go} < t_2 = 2 \text{ sec. ?}$

Yes

No

COMPONENT
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: $MPAC_D = \text{quantity} @ 2^0$

Output: $MPAC_D = -\ln(\text{quantity}) @ 2^5$

$$\frac{-L = -\ln\left(1 - \frac{t_{go}}{\tau}\right)}{PL0_D \leftarrow 2^5 \cdot MPAC_D}$$

$-L @ 2^0$
where 2^5 factor is for scaling

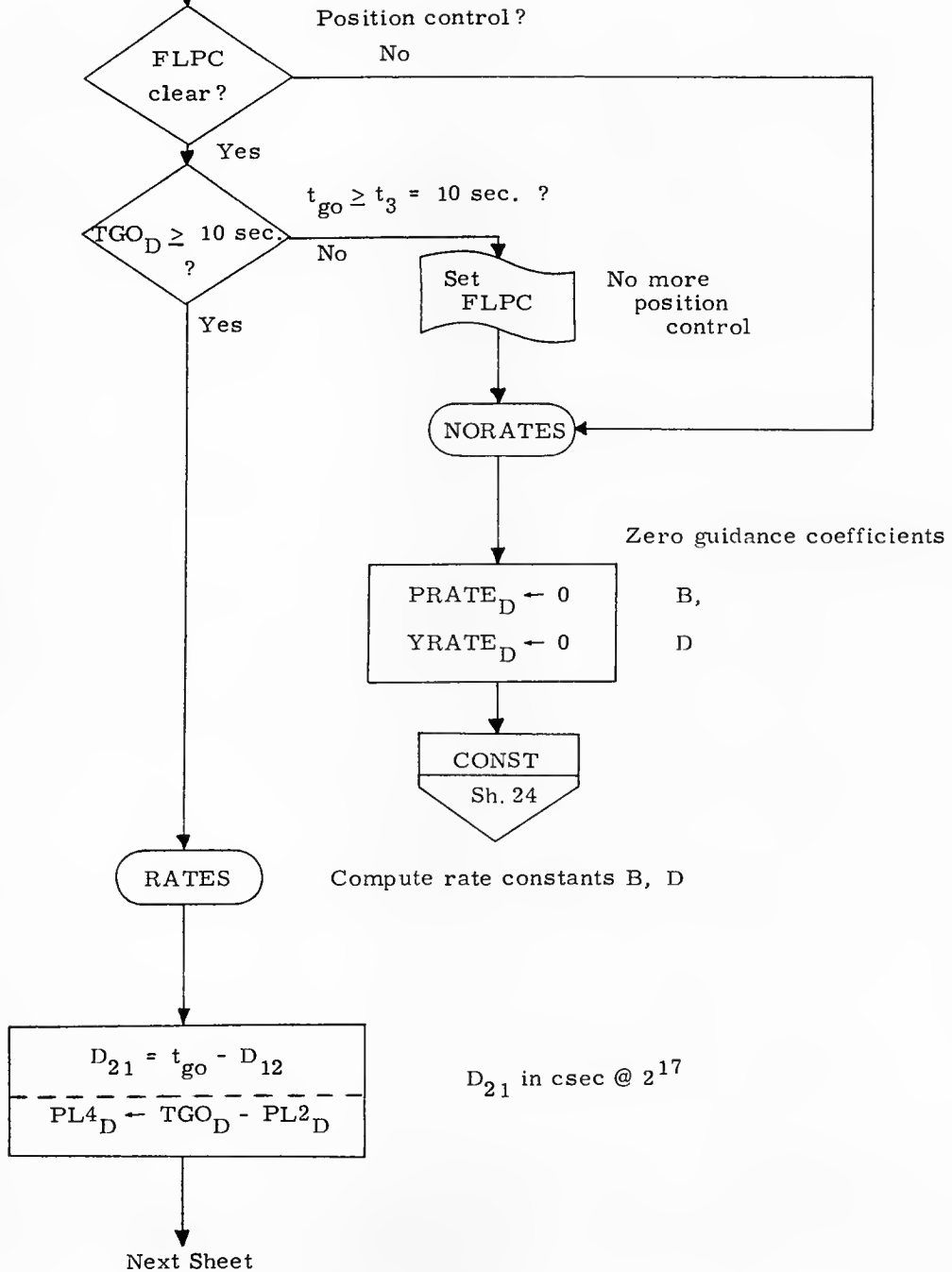
$$\frac{D_{12} = \tau + \frac{t_{go}}{L}}{PL2_D \leftarrow TBUP_D - \frac{TGO_D}{2^5 \cdot MPAC_D}}$$

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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DRAWN <i>[Signature]</i>		P12-Ascent Guidance	
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DRAWN <i>Alfred Chiswick</i>		P12-Ascent Guidance	
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ANALST			
DOCMR			
APPR'D <i>R.M. Eitan</i>	6/25/70	REV	SHEET 21 OF 63

From Preceding Sheet

$$E = 1/2 t_{go} - D_{21}$$

$$PL6_D \leftarrow 2^4 (2^{-1} TGO_D - PL4_D)$$

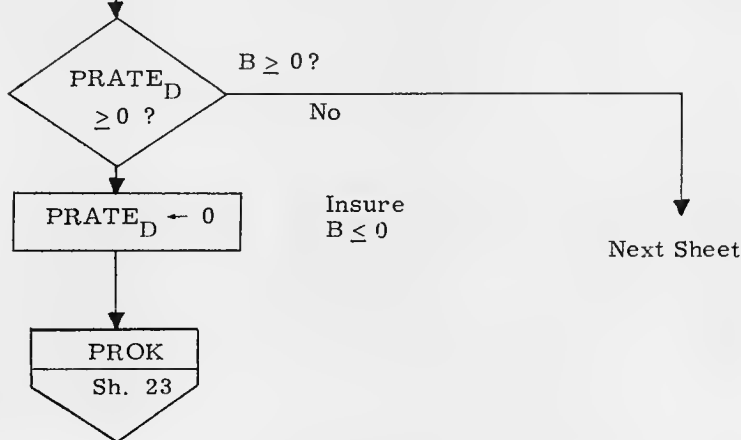
E in csec @ 2^{13}
 where 2^4 factor is for
 scaling

$$B = \frac{D_{21} (\dot{R}_D - \dot{R}) - (R_D - R - \dot{R} t_{go})}{t_{go} E}$$

$$PRATE_D \leftarrow 2^2 \left[\frac{PL4_D \cdot DRDOT_D - (RCO_D - /R/MAG_D - RDOT_D \cdot TGO_D)}{TGO_D \cdot PL6_D} \right]$$

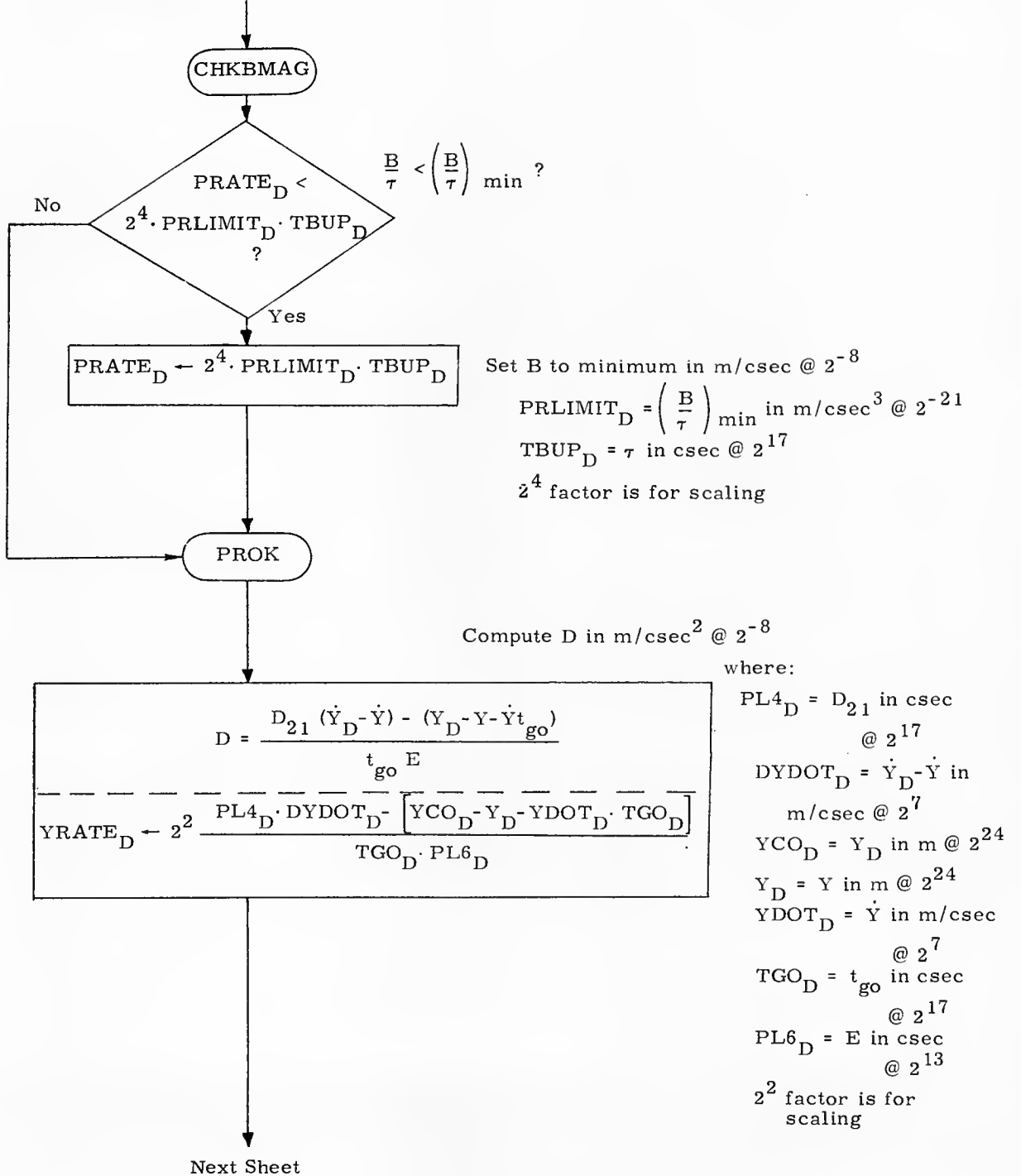
B in m/csec²
 @ 2^{-8}
 where:

- $PL4_D = D_{21}$ in csec @ 2^{17}
- $DRDOT_D = \dot{R}_D - \dot{R}$ in m/csec @ 2^7
- $RCO_D = R_D$ in m @ 2^{24}
- $/R/MAG_D = R$ in m @ 2^{24}
- $RDOT_D = \dot{R}$ in m/csec @ 2^7
- $TGO_D = t_{go}$ in csec @ 2^{17}
- $PL6_D = E$ in csec @ 2^{13}
- 2^2 factor is for scaling



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From Preceding Sheet

CONST

Compute attitude constants A, C

$$A = -D_{12}B - \frac{(\dot{R}_D - \dot{R})}{L}$$

$$PCONS_D \leftarrow -PL2_D \cdot PRATE_D + 2^{-2} \cdot \frac{DRDOT_D}{PL0_D}$$

Compute A in m/csec @ 2^9
where:

$$PL2_D = D_{12} \text{ in csec @ } 2^{17}$$

$$PRATE_D = B \text{ in m/csec}^2 \text{ @ } 2^{-8}$$

$$DRDOT_D = \dot{R}_D - \dot{R} \text{ in m/csec @ } 2^{-7}$$

$$PL0_D = -L \text{ @ } 2^0$$

2^{-2} factor is for scaling

$$C = -D_{12}D - \frac{(\dot{Y}_D - \dot{Y})}{L}$$

$$YCONS_D \leftarrow -PL2_D \cdot YRATE_D + 2^{-2} \cdot \frac{DYDOT_D}{PL0_D}$$

Compute C in m/csec @ 2^9
where:

$$PL2 = D_{12} \text{ in csec @ } 2^{17}$$

$$YRATE = D \text{ in m/csec}^2 \text{ @ } 2^{-8}$$

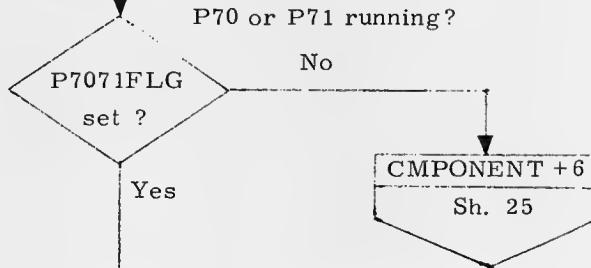
$$DYDOT_D = \dot{Y}_D - \dot{Y} \text{ in m/csec @ } 2^7$$

$$PL0_D = -L \text{ @ } 2^0$$

2^{-2} factor is for scaling

COMPONENT

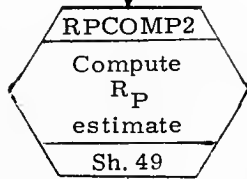
P70 or P71 running?



Next Sheet

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Input: $/R/MAG_D = R$ in m @ 2^{24}
 $RDOT_D = R$ 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/csec² @ 2^{-8}
 $TBUP_D = \tau$ in csec @ 2^{17}
 Output: $RP_D = R_P$ in m @ 2^{24}

(COMPONENT +6)

Compute acceleration components

$$a_{TR} = \frac{A + B \Delta t}{\tau} - g_{eff}$$

$$ATR_D \leftarrow 2^1 \frac{PCONS_D + PRATE_D \cdot 100CS_D}{TBUP_D} - GEF D$$

a_{TR} in m/csec² @ 2^{-9}

where:

$PCONS_D = A$ in m/csec @ 2^9
 $PRATE_D = B$ in m/csec² @ 2^{-8}
 $100CS_D = \Delta t = 100$ csec @ 2^{17}
 $TBUP_D = \tau$ in csec @ 2^{17}
 $GEFF_D = g_{eff}$ in m/csec² @ 2^{-9}
 2^1 factor is for scaling

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$$a_{TY} = \frac{C + D\Delta t}{\tau}$$

$$ATY_D \leftarrow 2^1 \cdot \frac{YCONS_D + YRATE_D \cdot 100CS_D}{TBUP_D}$$

a_{TY} in m/csec² @ 2⁻⁹

where:

$YCONS_D = C$ in m/csec @ 2⁹

$YRATE_D = D$ in m/csec² @ 2⁻⁸

$100CS_D = \Delta t = 100$ csec @ 2¹⁷

$TBUP_D = \tau$ in csec @ 2¹⁷

2¹ 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/csec² @ 2⁻⁹

where

$LAXIS_V = \underline{u}_Y$ in

SM coords @ 2¹

$UNIT/R/V = \underline{u}_R$ in

SM coords @ 2¹

2¹ factor is for scaling

$$PL6_D \leftarrow |PL0_V|$$

$$PL8_D \leftarrow AT_D^2 - |PL0_V|^2$$

$$PL10_D \leftarrow AT_D$$

a_H @ 2⁻⁹

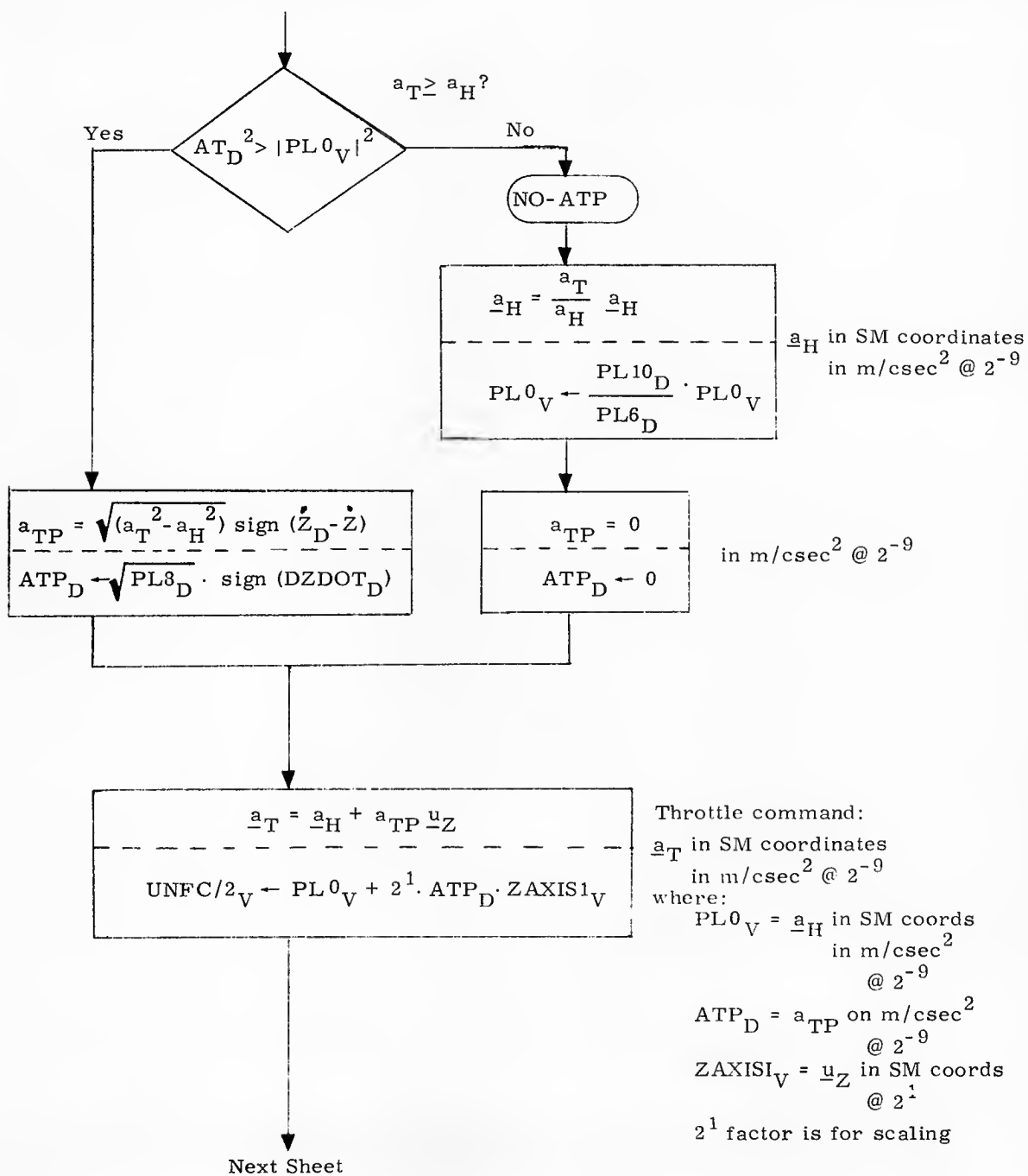
$a_T^2 - a_H^2$ @ 2⁻¹⁸

a_T @ 2⁻⁹

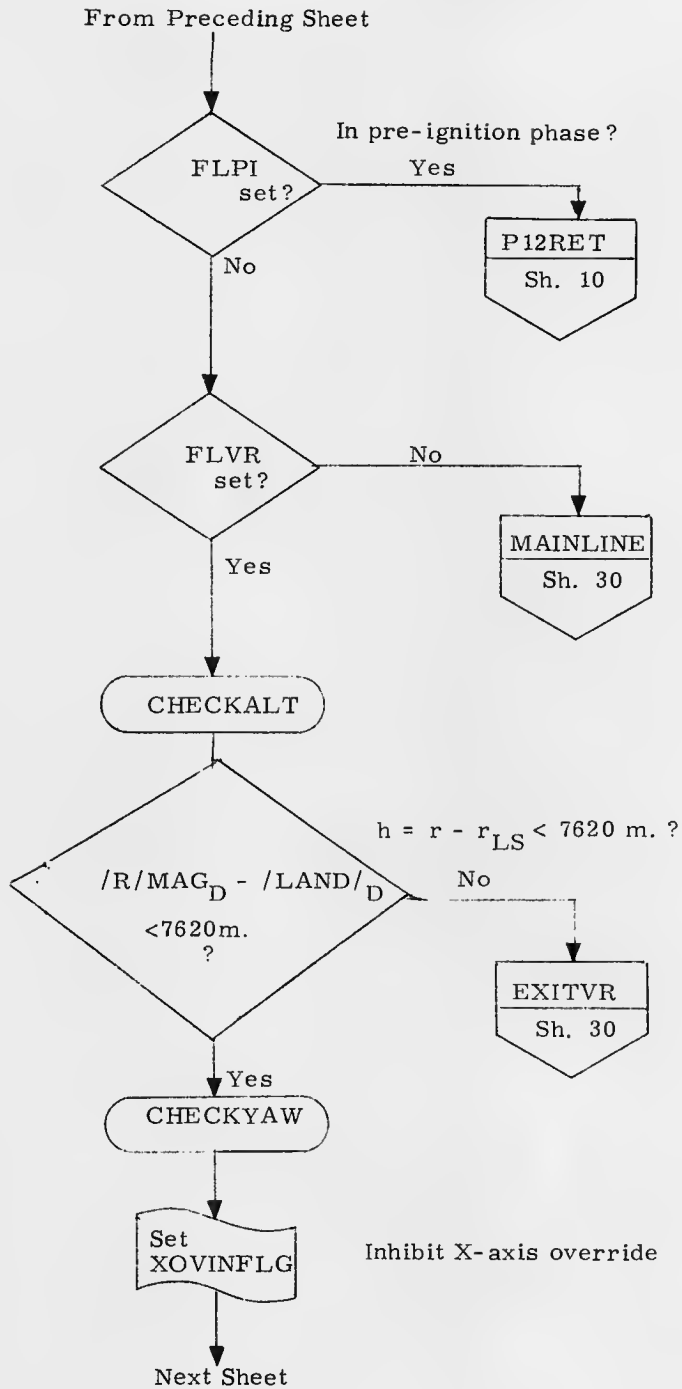
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PRGMR <i>J. German</i>		LUMINARY 1D	DOCUMENT NO. FC-3950
ANALST			
DOCMR			
APPR'D <i>RM E. Matto</i>	<i>10/25/70</i>	REV	SHEET 27 OF 63



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PRGMR	<i>J. Williams</i>	LUMINARY 1D	DOCUMENT NO.
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Compute \underline{u}_{WDP} in SM coords

$$\underline{u}_{WDP} = \text{Unit} (a_{TY} \underline{u}_Y + a_{TP} \underline{u}_Z)$$

$$PL^0_V \leftarrow \text{Unit} (ATY_D \cdot LAXIS_V + ATP_D \cdot ZAXIS1_V)$$

where:
 $ATY_D = a_{ty} @ 2^{-9}$
 $LAXIS_V = \underline{u}_y$ in SM coords @ 2^1
 $ATP_D = a_{tp} @ 2^{-9}$
 $ZAXIS1_V = \underline{u}_z$ in SM coords @ 2^1

$\dot{R}_{DOT_D} > 12.192 \text{ m/csec} ?$

$\dot{R} > 12.192 \text{ m/sec} ?$

No

Yes

KEEPVVR
Sh. 33

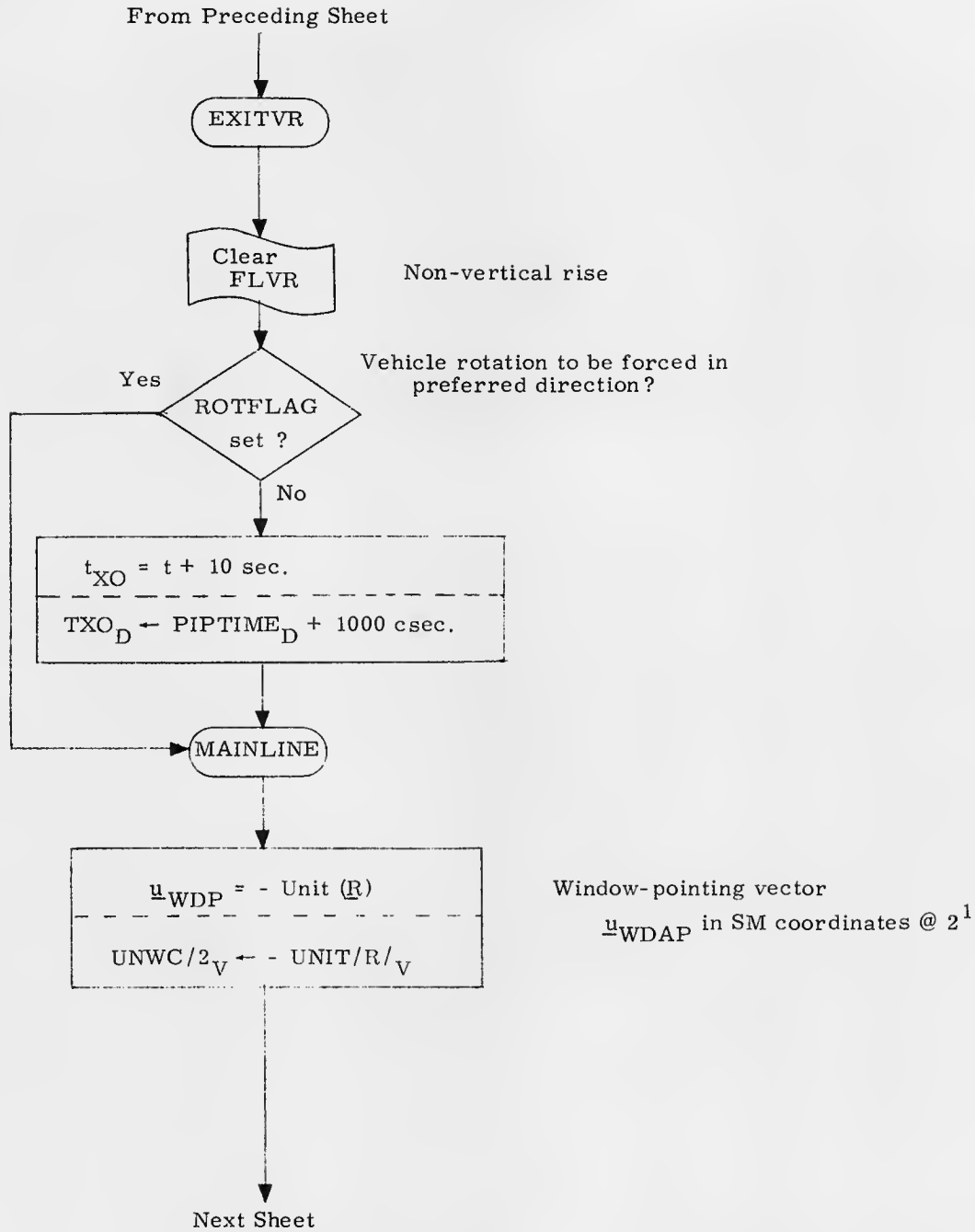
EXITVVR1

Clear ROTFLAG

Do not force vehicle rotation in preferred direction

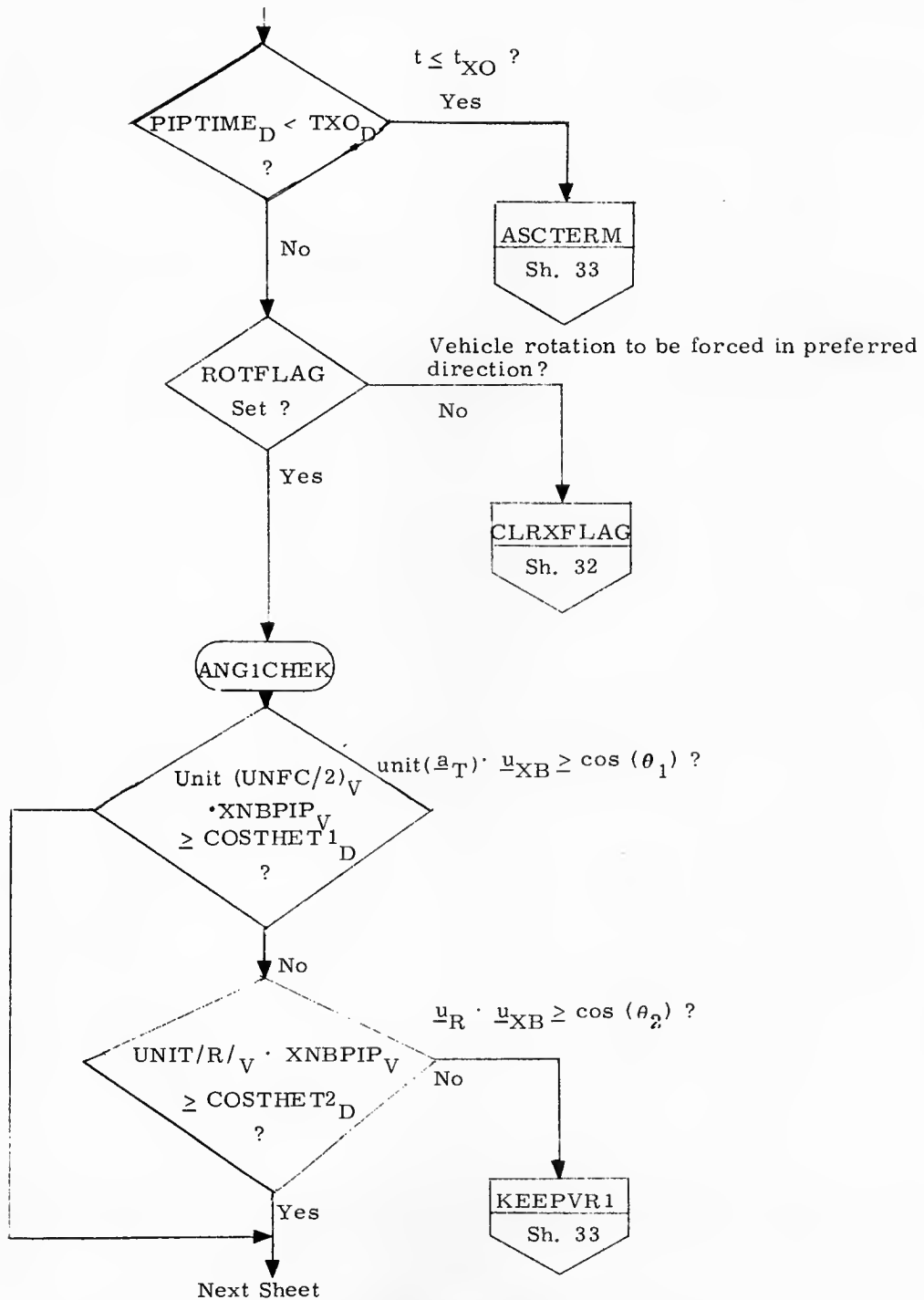
Next Sheet

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DRAWN <i>E. Matta</i>		P12-Ascent Guidance	
PRGMR <i>F. J. German</i>		DOCUMENT NO.	
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APPR'D <i>R. D. E. Enter</i>	6/25/70	SHEET 31 OF 63	

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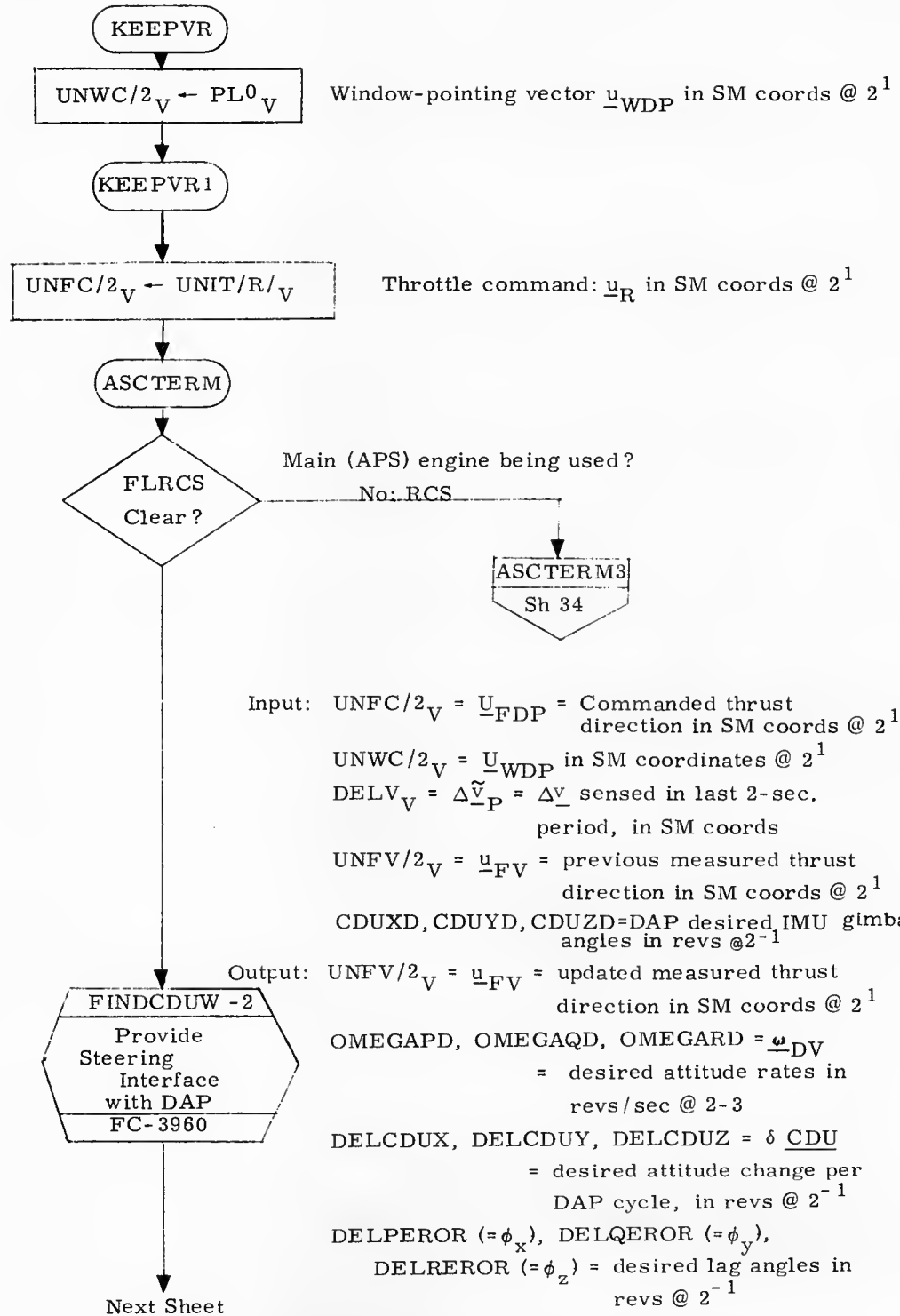


Don't force vehicle rotation in preferred direction

Allow X-axis override

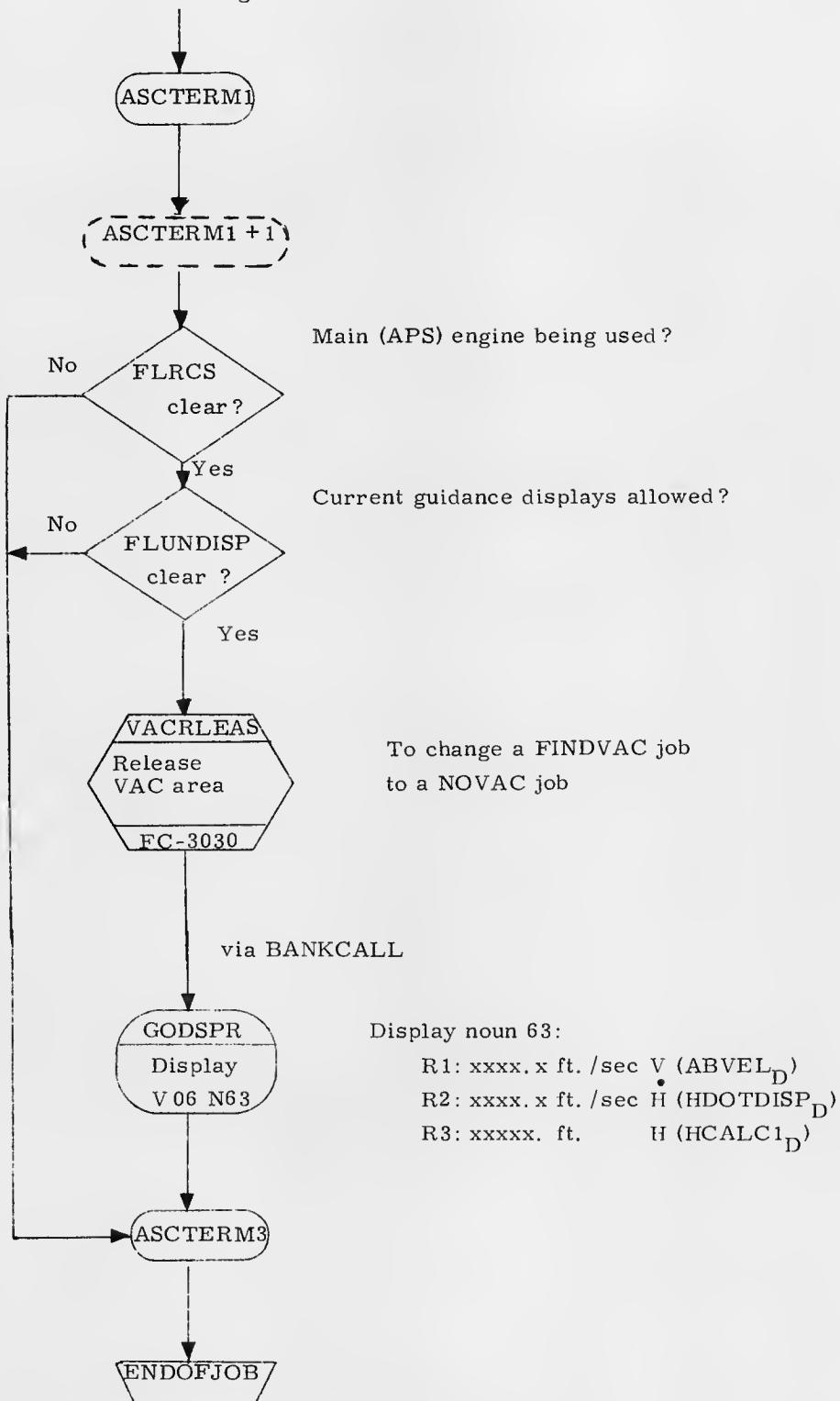
ASCTERM
Sh. 33

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PRGMR	<i>F. Swann</i>	DOCUMENT NO.	
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APPR'D	<i>R. M. Estes</i>	<i>6/25/68</i>	

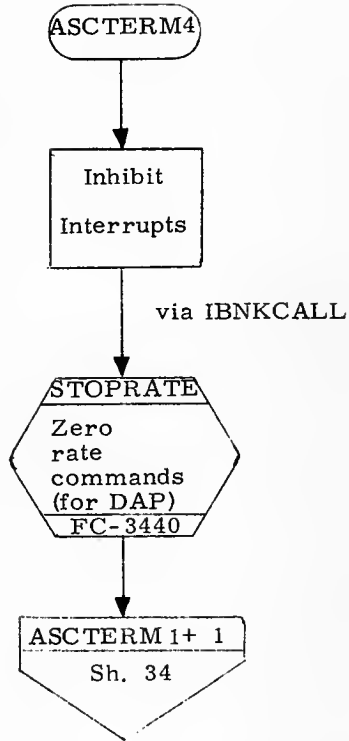


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DRAWN <i>E. Matto</i>		P12-Ascent Guidance	
PRGMR <i>J. Williams</i>		DOCUMENT NO.	
ANALST		LUMINARY ID	FC-3950
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APPR'D <i>R.M. Euter</i>		6/25/70	

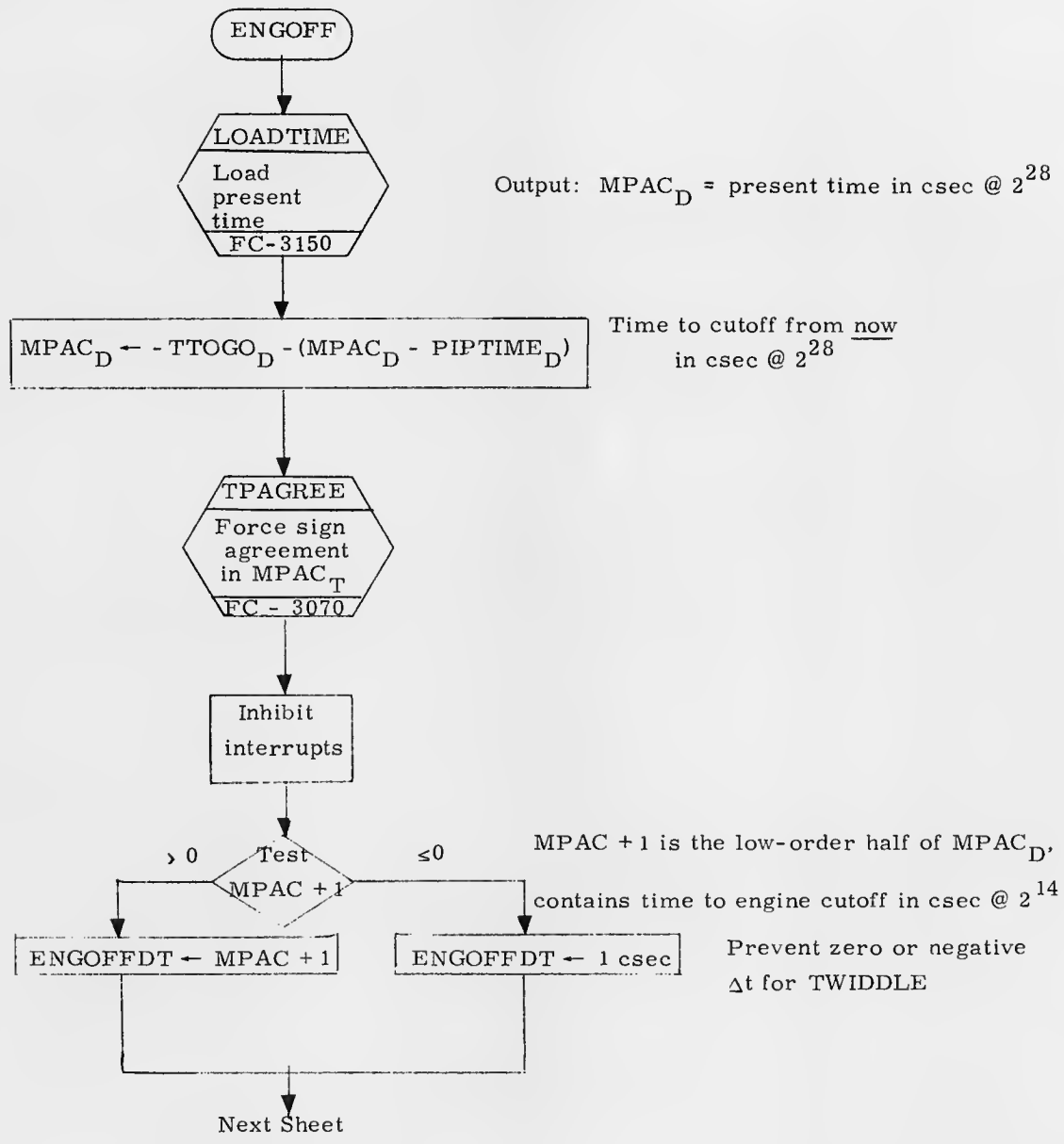
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DRAWN <i>E. Matka</i>		P12-Ascent Guidance	
PRGMR <i>J. Johnson</i>		DOCUMENT NO.	
ANALST		LUMINARY ID	FC-3950
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APPR'D <i>RMM Entes</i>		6/25/69	

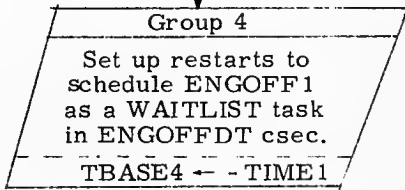
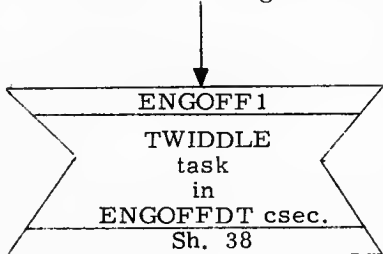


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		P12-Ascent Guidance	
DRAWN <i>E. Matto</i>		LUMINARY 1D	DOCUMENT NO.
PRGMR <i>P.J. German</i>			FC-3950
ANALST			
DOCMR			
APPR'D <i>RIM Estes</i>	<i>6/25/70</i>	REV	SHEET 35 OF 63

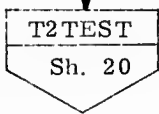


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PRGMR <i>J. Bernier</i>		LUMINARY 1D	DOCUMENT NO.
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APPR'D <i>RME</i>			

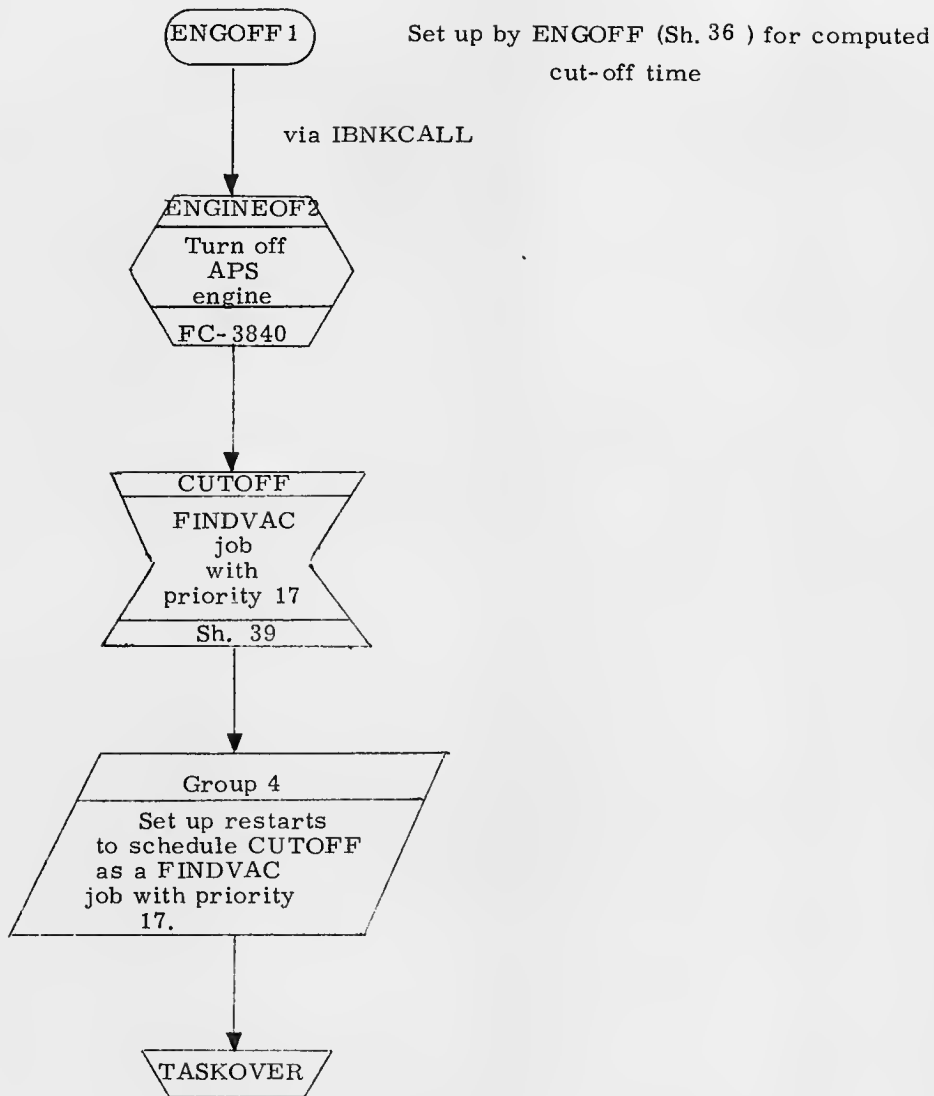
From Preceding Sheet



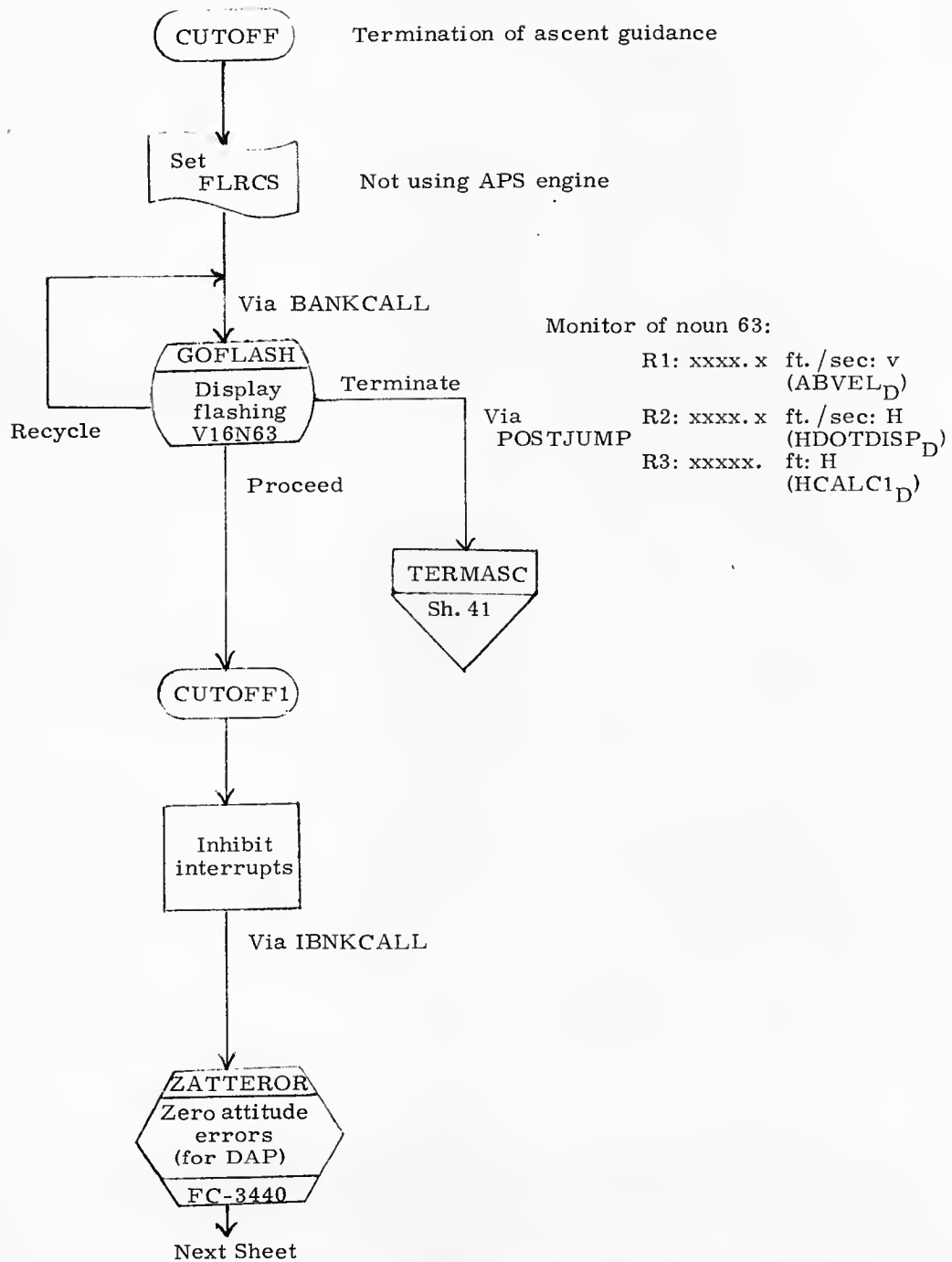
Don't do Δv monitor



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		P12-Ascent Guidance	
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ANALST			
DOCMR			
APPR'D	<i>R. M. Eitan</i>	6/25/70	REV SHEET 37 OF 63

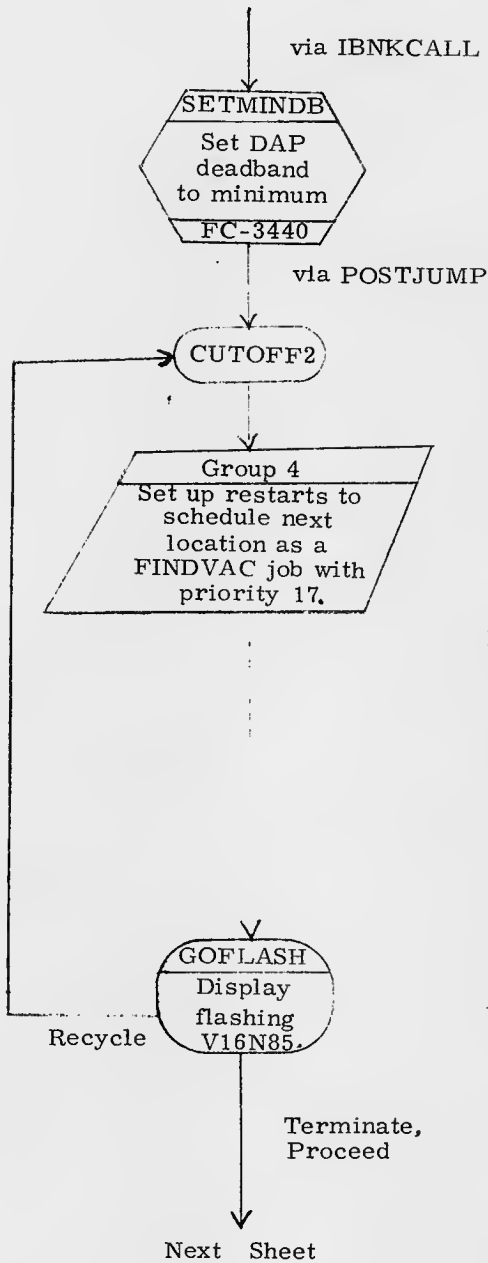


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PRGMR <i>J. Brennan</i>		LUMINARY 1D	DOCUMENT NO.
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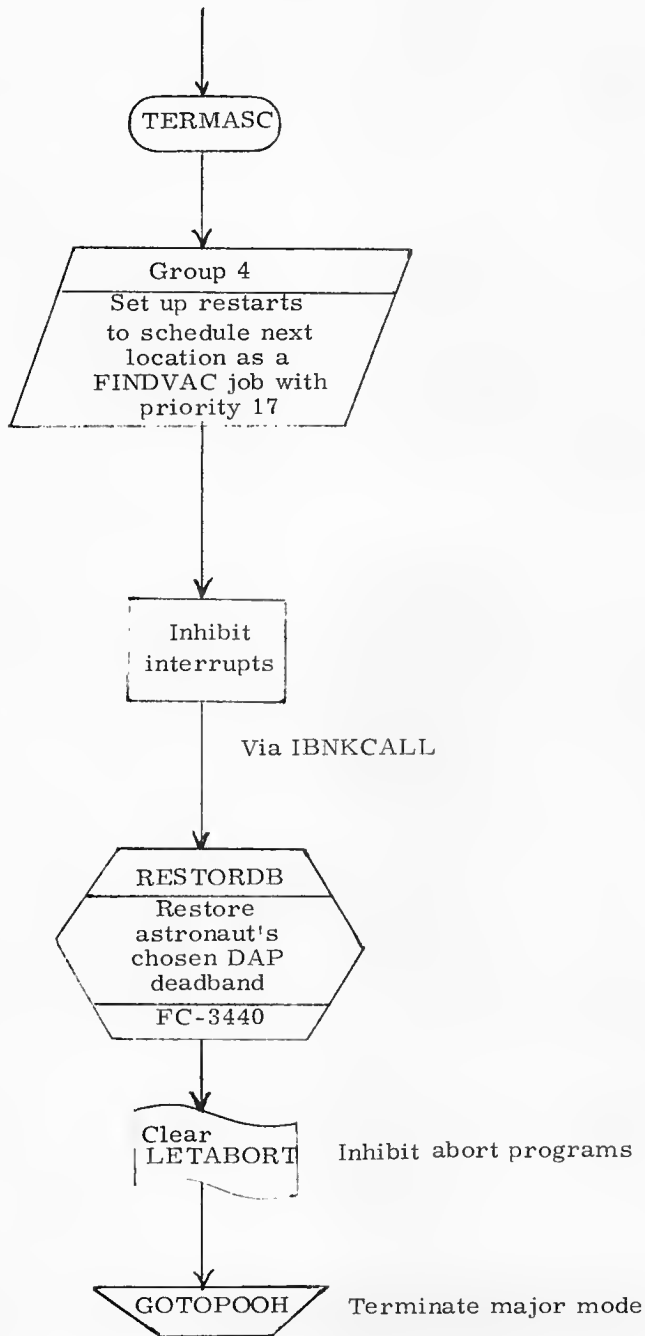


Monitor of noun 85:
 R1: xxxx. x ft/sec }
 R2: xxxx. x ft/sec } Components of v_G in body (NB)
 R3: xxxx. x ft/sec } coordinates (VG BODY v)

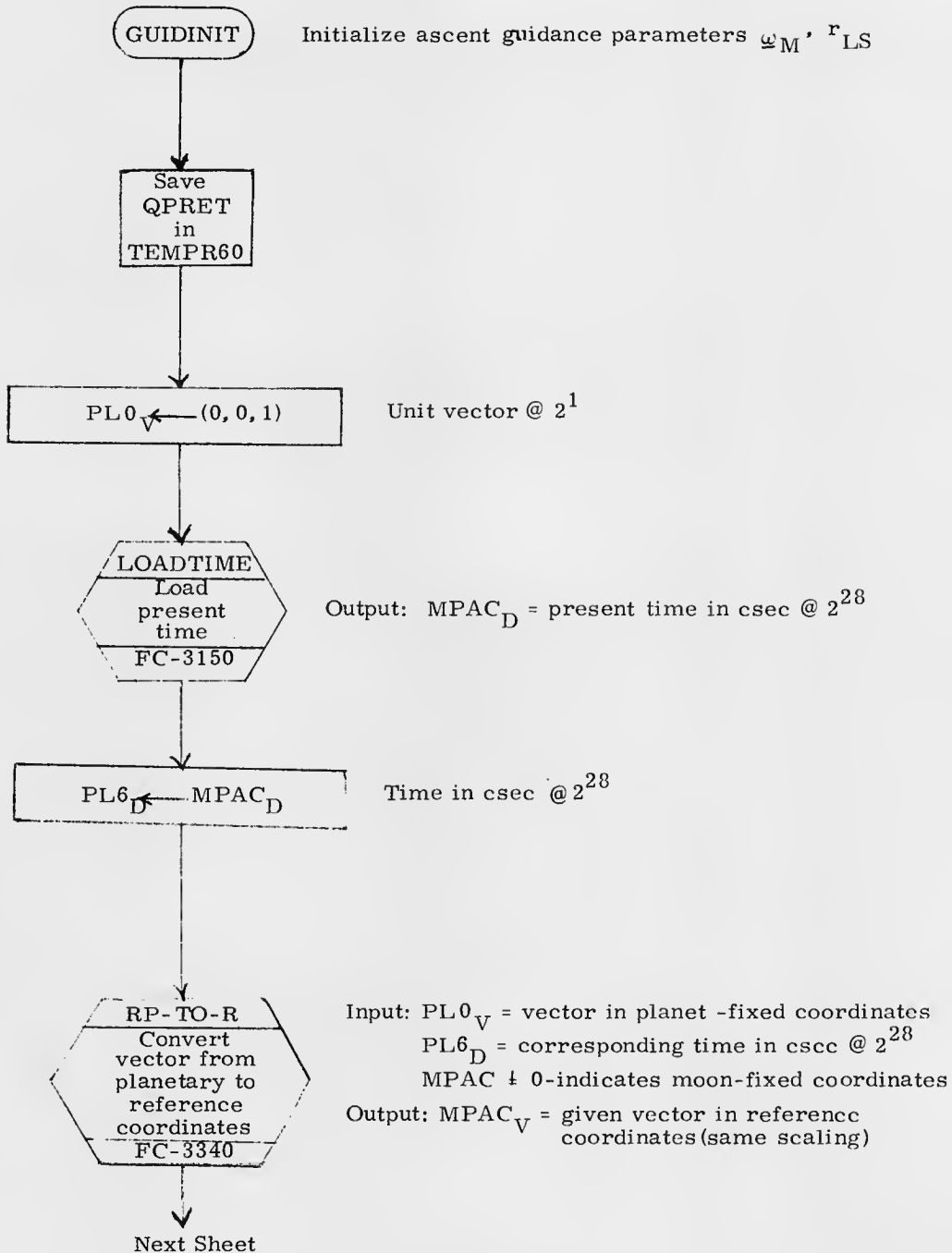
Astronaut may null out remaining v_G using hand controls

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From Preceding Sheet

Compute ω_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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P12INIT

P12 Initialization Subroutine

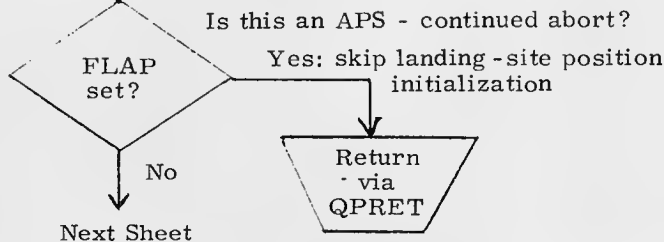
$1/DV^3_D \leftarrow (1/DV) A_D$
 $1/DV^2_D \leftarrow (1/DV) A_D$
 $1/DV^1_D \leftarrow (1/DV) A_D$

Initialize thrust filter parameters
to $1/\Delta v_A$
(in csec/m @ 2^7)
Where $\Delta v_A = \Delta v$ in first
2 seconds of ascent

$AT_D \leftarrow (AT)A_D$
 $TBUP_D \leftarrow (TBUP)A_D$
 $TTO_D \leftarrow - 2^{11} \cdot ATDECAY_D$
 $VE_D \leftarrow - 2^{-2} \cdot APSVEX_S$

Initialize to APS values:

a_T = thrust acceleration in
m/csec² @ 2^{-9}
 τ = mass: mass flow rate ratio
in csec @ 2^{17}
 $\Delta t_{tail-off}$ = tail-off time
in csec @ 2^{17}
 v_e = exhaust velocity in
m/csec @ 2^7



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APPR'D <i>W. M. ...</i>	6/15/60	REV	SHEET 44 OF 63

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COMMIT

Initialize target parameters

$$R_D = r_{LS} + 60,000 \text{ Ft.}$$

$$RCO_D \leftarrow /LAND/D + HINJECT_D$$

R_D = desired injection radius in $m @ 2^{24}$
 Where $HINJECT_D = 18,288m$
 ($\approx 60,000 \text{ Ft.}$)
 $@ 2^{24}$

$$TXO_D \leftarrow 0$$

$$YCO_D \leftarrow 0$$

$$YDOTD \leftarrow 0$$

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) $@ 2^1$

$$Q = \text{Unit} \left(\frac{v_c}{c} \times \frac{r_c}{c} \right)$$

$$Q\text{AXIS}_V \leftarrow \text{Unit} [\text{REFSMMAT}_M \times (\text{VRECTCSM}_V \times \text{RRECTCSM}_V)]$$

Where:
 $\text{VRECTCSM}_V = \frac{v}{c} = \text{CSM velocity in reference coordinates}$
 $\text{RRECTCSM}_V = \frac{r}{c} = \text{CSM position in reference coordinates}$
 $\text{REFSMMAT}_M = \text{reference - SM coordinate transformation matrix}$

Return via QPRET

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ZDOTDCMP

Compute \dot{Z}_D

Save
Q
in
ASCSAVE

THETCOMP
Compute
LM - CSM
phase angle
Sh. 48

Input: $R_V = R$ in m in SM coordinates
 $R(CSM)_V = R_c$ in m in SM coordinates
 $WM_V = \frac{\omega}{M}$ in rad/csec in SM coordinates

Output: $MPAC_D = \theta$ in revs @ 2^0

$R_a = 2(J + K \theta) - R_P$
 $PL^0_D \leftarrow JPARM_D + KPARM_D \cdot MPAC_D - RP_D$

Compute R_a = apogee radius
in m @ 2^{24}

Where:
 $JPARM_D = 2 J$ in m @ 2^{24}
 $KPARM_D = 2 K$ in m/rev @ 2^{24}
 $RP_D = R_P$ in m @ 2^{24}

Make sure $R_a \geq R_{AMIN}$

Yes
 $PL^0_D \geq RAMIN_D$?
 No

$PL^0_D \leftarrow RAMIN_D$

Next Sheet

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From Preceding Sheet

$$Z_D = \sqrt{\frac{\mu_M R_a}{(J + K \theta) R_P}}$$

$$ZDOTD_D = \sqrt{\frac{MUM(-37)_D \cdot PL0_D}{(PL0_D + RP_D) RP_D}}$$

Compute \dot{Z}_D in m/csec @ 2^7

Where:

$$MUM(-37)_D = \mu \text{ in } m^3/csec^2 @ 2^{37}$$

$$PL0_D = 2(J + K \theta) - R_P \text{ in } m @ 2^{24}$$

$$RP_D = R_P \text{ in } m @ 2^{24}$$

Return via
ASCSAVE

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THETCOMP

Compute LM-CSM phase angle θ

Form $\underline{u}_M \cdot (\underline{u}_{RC} \times \underline{u}_R)$
 PL 30_D ← $WM_V \cdot [\text{Unit}(R(\text{CSM})_V) \times \text{Unit}(R_V)]$

Intermediate result

Where :

$WM_V = \frac{\omega_M}{R_C}$
 $R(\text{CSM})_V = \frac{R_C}{R_V}$
 (all in SM coords)

$\theta = \text{Sign} [\underline{u}_M \cdot (\underline{u}_{RC} \times \underline{u}_R)] \text{Cos}^{-1} (\underline{u}_{RC} \cdot \underline{u}_R)$
 MPAC_D ← $\text{Sign}(PL30_D) \text{Cos}^{-1} [2^1 \text{Unit}(R(\text{CSM})_V) \cdot \text{Unit}(R_V)]$

θ in revs
 @ 2^0

2^1 factor is
 for scaling

Return
 via
 QPRET

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RPCOMP1

Entry to compute $R_P = R + R t_{go}$

PCONS_D ← 0
PRATE_D ← 0

A in m/csec @ 2⁹

B in m/csec² @ 2⁻⁸

RPCOMP2

Entry for long computation of R_P

Compute new R_P (perigee at cutoff)

in m @ 2²⁴

$$R_P = R + \dot{R} t_{go} + \frac{A}{2\tau} t_{go}^2 + \frac{B}{6\tau} t_{go}^3$$

$$RP_D \leftarrow /R/MAG_D + RDOT_D TGO_D + 2^2 \left[\frac{PCONS_D}{2} + \frac{THIRD_D}{2} \cdot PRATE_D \cdot TGO_D \right] \frac{TGO_D^2}{TBUP_D}$$

Where:

$/R/MAG_D = R$ in m @ 2²⁴

$RDOT_D = \dot{R}$ in m/csec @ 2⁷

$TGO_D = t_{go}$ in csec @ 2¹⁷

$PCONS_D = A$ in m/csec @ 2⁹

$THIRD_D = .333333333$ @ 2⁰

$PRATE_D = B$ in m/csec² @ 2⁻⁸

$TBUP_D = \tau$ in csec @ 2¹⁷

2² factor is for scaling

Return
via
QPRET

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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

Output: $MPAC_D = C_0 + C_1 x + C_2 x^2 + C_3 x^3 + C_4 x^4 + C_5 x^5 + C_6 x^6 + C_7 x^7$
here = $\ln(1 - x) = \ln(q) @ 2^0$

$MPAC +2 \leftarrow 0$

Zero low-order third of $MPAC_T$ to be
used later

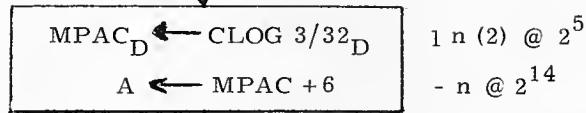
$BUF +1_D \leftarrow MPAC_D$

Save $\ln(q) @ 2^0$

Next Sheet

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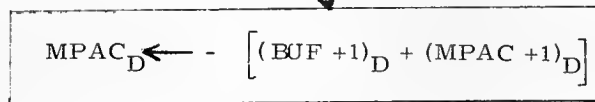
From Preceding Sheet



Input: $MPAC_D$, A

Output: $MPAC_T \leftarrow A \cdot MPAC_D$

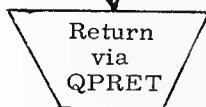
here, $MPAC_T = -n \ln(2) = 1n\ (2^{-n})$
 $@\ 2^{19}$



Compute $-1n\ (2^{-n})\ @\ 2^5$

Where: $(BUF + 1)_D$
 $= \ln(q)\ @\ 2^0$
 $MPAC + 1_D$
 $= \text{low-order } 2/3 \text{ of } MPAC_T = 1n(2^{-2})$
 $@\ 2^5$

(assuming high-order
 $1/3$ is zero)



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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

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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 Δv Monitor	Connect Δv 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

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FLAGS (CONTINUED)

Name	Meaning When Set	Meaning When Clear	Where Set	Where Cleared	Where Called
RENDVZFLG (bit 7 of FLAGWRD0)	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 preferred 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 FLAGWRD13)	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. } time of R2: 000xx. min. } ignition R3: 0xx.xx sec. } (TIG _D)	Sh. 3
V06N76	Flashing	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)	Sh. 7
V06N63	Normal	R1: xxxx.x ft./sec. } v (ABVEL _D) R2: xxxx.x ft./sec. } \dot{H} (HDOTDISP _D) R3: xxxxx. ft. } H (HCALC _D)	Sh. 34
V16N63	Flashing Monitor	Registers same as V06N63 display above	Sh. 39
V16N85	Flashing Monitor	R1: xxxx.x ft./sec. } $v - G$ in body (NB) R2: xxxx.x ft./sec. } coordinates R3: xxxx.x ft./sec. } (VGBODY _V)	Sh. 40

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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 acceleration	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	δ CDUX	Commanded incremental change (for DAP) in outer IMU gimbal angle (2's complement)	degrees	revs	2^{-1}
DELCDUY	δ CDUY	Commanded incremental change (for DAP) in inner IMU gimbal angle (2's complement)	degrees	revs	2^{-1}
DELCDUZ	δ CDUZ	Commanded incremental change (for DAP) in middle IMU gimbal angle (2's complement)	degrees	revs	2^{-1}

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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	$\Delta \tilde{v}_p$	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

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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	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

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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	$\frac{r}{r}_{LS}$	Landing site position vector	m	m	2 ²⁷
RP _D	R _P	Estimated perigee at cutoff time	m	m	2 ²⁴
RRECTCSM _V	$\frac{r}{r}_C$	CSM position vector in reference coordinates	m	m	
R(CSM) _V	$\frac{r}{r}_C$	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	$-\Delta t_{\text{tail-off}}$	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	$\frac{a}{a}_T$, $\frac{u}{u}_{FV}$	Throttle command (thrust direction) in SM coordinates	m/sec ²	m/csec ²	variable

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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
\underline{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
VGBO _{DY} _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	
VIS _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	SMNB	Transformation matrix between SM and NB coordinate systems			2 ¹
	$= \begin{pmatrix} \text{XNBPIP}_V \\ \text{YNBPIP}_V \\ \text{ZNBPIP}_V \end{pmatrix} = \begin{bmatrix} u_{XB} \\ u_{YB} \\ u_{ZB} \end{bmatrix}$				

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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	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/Δv thrust filter parameter	sec/m	csec/m	2 ⁷
1/DV1 _D	1/Δv ₁	Second 1/Δv thrust filter parameter	sec/m	csec/m	2 ⁷
1/DV2 _D	1/Δv ₂	Third 1/Δv thrust filter parameter	sec/m	csec/m	2 ⁷
1/DV3 _D	1/Δv ₃	Fourth 1/Δv thrust filter parameter	sec/m	csec/m	2 ⁷

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APPR'D <i>[Signature]</i>	4/25/70		

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	$\Delta t_{\text{tail-off}}$ (APS)	Negative of tail-off time for APS engine	-.10 sec	-.10 csec	2^8
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	ω_M	Moon rotational rate	.26616994890062991 X 10 ⁻⁵ rad/sec	.26616994890062991 X 10 ⁻⁷ rad/csec	2^{-19}
MUM(-37) _D	μ_m	Lunar gravitational constant	4.902778 X 10 ¹⁰ m ³ /sec ²	4.902778 X 10 ⁸ m ³ /csec ²	2^{37}
PRLIMIT _D	$\frac{B}{7}$ min	Minimum (maximum magnitude) B/7	-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

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DRAWN	<i>L. J. ...</i>	P12-Ascent Guidance	
PRGMR	<i>J. ...</i>	LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3950
DOCMR		REV	SHEET 61 OF 63
APPR'D	<i>RME</i>	6/28/70	

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	$10^{-4} \times 2^{+14}$
VINJNOM _D	\dot{z}_D (nom)	Initial value of desired down-range velocity	1679.24 m/sec	16.7924 m/csec	2^7
(AT)A _D	a_T (APS)	Initial APS thrust acceleration	3.2883 m/sec ²	.00032883 m/csec ²	2^{-9}
(TBUP)A _D	τ (APS)	Initial mass: mass flow rate ratio for APS thrust	919.02 sec.	91902 csec.	2^{17}
(TGO)A _D	t_{go} (APS)	Nominal total burn time for APS maneuver	370 sec	37000 csec	2^{17}
(1/DV)A _D	$1/\Delta v_A$	Inverse of Δv acquired during first two seconds of ascent	.152 sec/m	15.2 csec/m	2^7
49FPS _D	\dot{R}_D (tipover)	Expected radial velocity at tipover	14.9352 m/sec	.149352 m/csec	2^6

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PRGMR <i>[Signature]</i>		LUMINARY 1D	DOCUMENT NO. FC-3950
ANALST <i>[Signature]</i>			
DOCMR			
APPR'D <i>[Signature]</i>	4/25/70	REV	SHEET 620F63

PAD - LOADS

AGC Tag	GSOP Symbol	Meaning	Engineering Units	AGC Units	AGC Scaling
COSTHET1 _D	cos (θ_1)	Cosine of cone angle θ_1 for aborts			2^2
COSTHET2 _D	cos (θ_2)	Cosine of cone angle θ_2 for aborts			2^2
RAMIN _D	R _{AMIN}	Minimum apogee radius R _a	m	m	2^{24}

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DRAWN <i>L. Robinson</i>		P12-Ascent Guidance	
PRGMR <i>J. Beaman</i>		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3950
DOCMR		REV	SHEET 63 OF 63
APPR'D <i>R.M. Estes</i>	<i>6/25/72</i>		

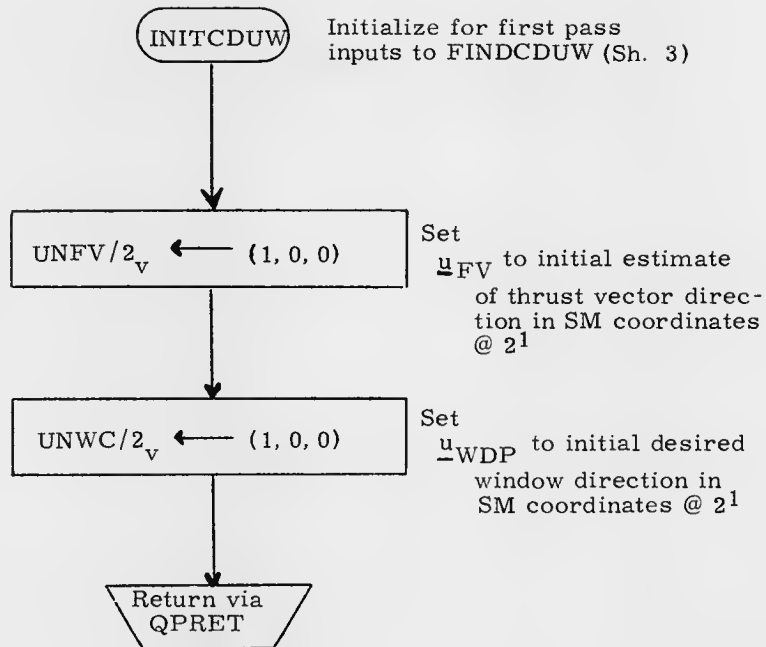


FINDCDUW:

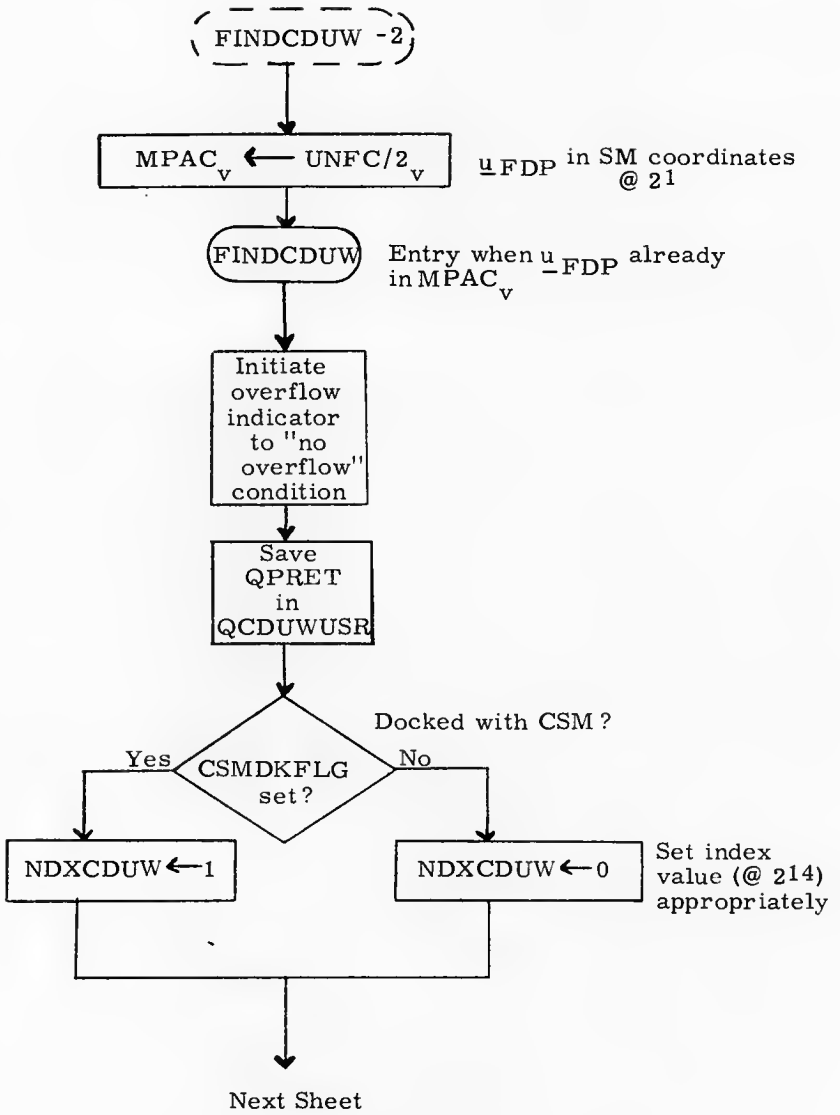
Guidance - DAP Interface

INITCDUW	Sh. 2
FINDCDUW -2	Sh. 3
FINDCDUW	Sh. 3
FLTRSUB	Sh. 23
LIMITSUB	Sh. 25
UNWCTEST	Sh. 26
NB2CDUSP	Sh. 27
ARCTRGSP	Sh. 31
SPARCSIN -1	Sh. 35
SPARCSIN	Sh. 35
ONESTO2S	Sh. 36
DVBYCOSM	Sh. 37

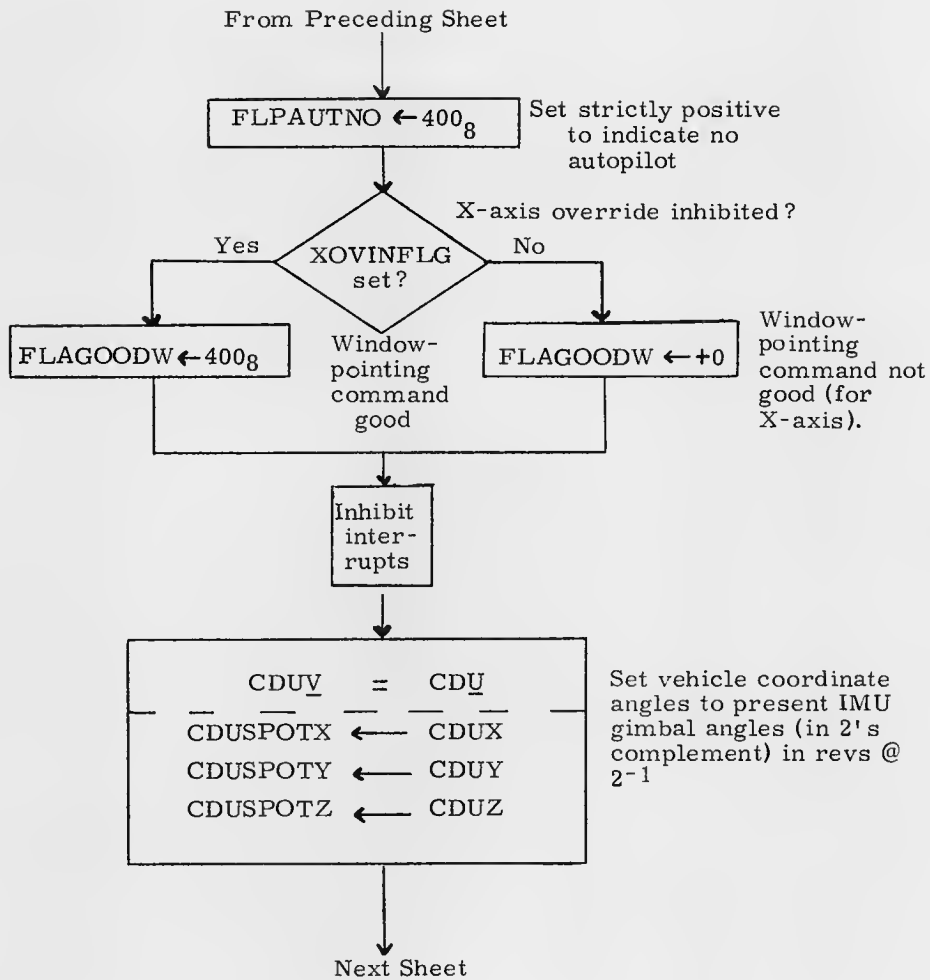
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>Jeanistaw</i> <i>1/4/69</i>		FINDCDUW: Guidance - DAP Interface	
PRGMR		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3960
DOCMR		REV	SHEET 1 OF 44
APPR'D <i>Robert M. Eder</i> <i>1/20/69</i>			



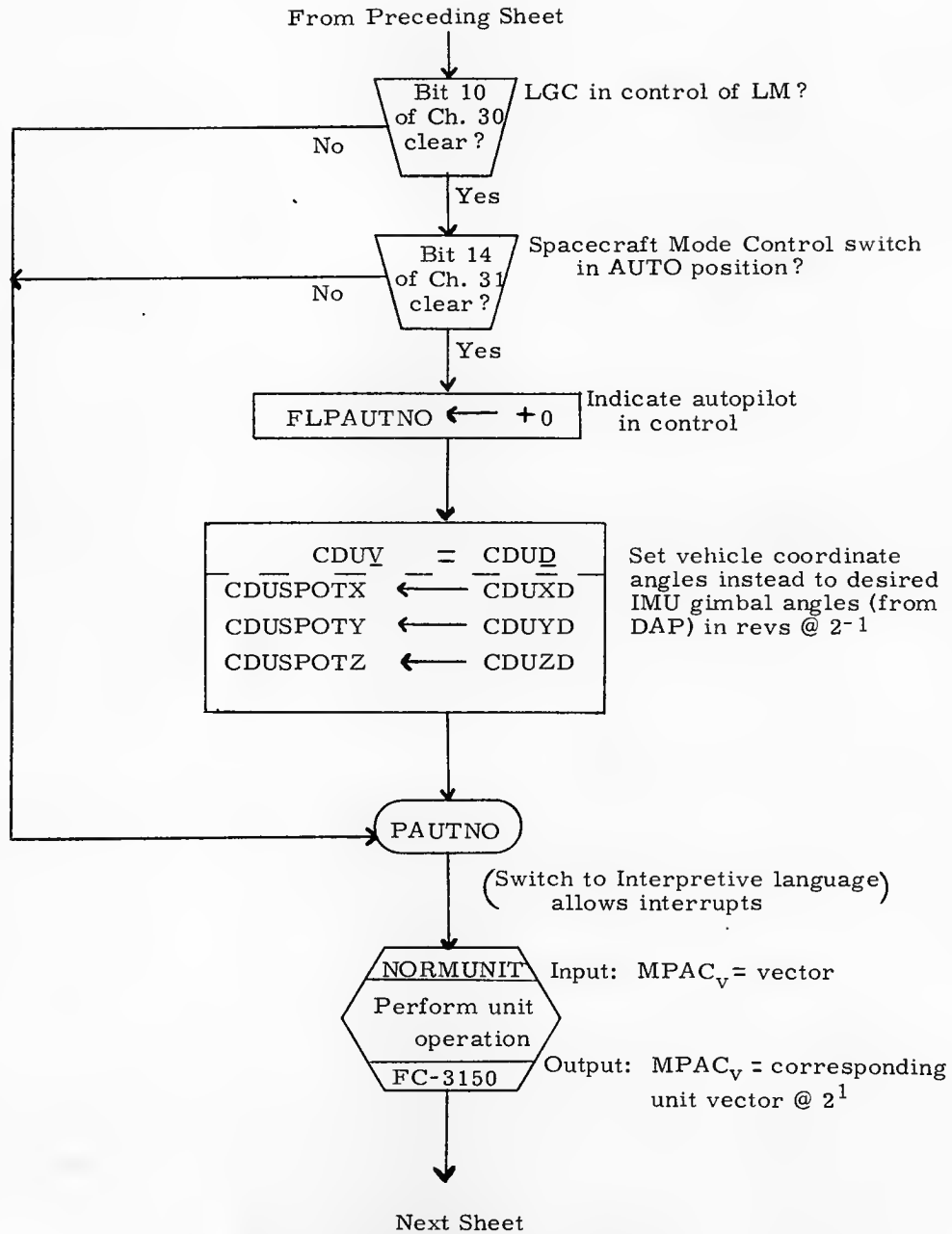
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i>	<i>8/10/69</i>	FINDCDUW: Guidance - DAP Interface	
PRGMR		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3960
DOCMR		REV	SHEET 2 OF 44
APPR'D <i>[Signature]</i>	<i>10/20/69</i>		



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DRAWN <i>Rosenblum</i>	<i>9/16/69</i>	FINDCDUW: Guidance - DAP Interface	
PRGMR		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3960
DOCMR		REV	SHEET 3 OF 44
APPR'D <i>Rosenblum</i>	<i>10/20/69</i>		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. M. Stewart</i>	<i>9/16/69</i>	FINDCDUW: Guidance - DAP Interface	
PRGMR		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3960
DOCMR		REV	SHEET 4 OF 44
APPR'D <i>Roberto M. Escobedo</i>	<i>10/24/69</i>		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>W. Stewart</i> 4/4/69		FINDCDUW: Guidance - DAP Interface	
PRGR		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3960
DOCMR		REV	SHEET 5 OF 44
APPR'D <i>Robert M. Eustel</i> 10/20/69			

From Preceding Sheet

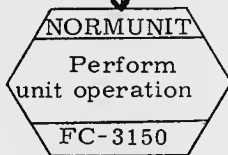
$$\underline{u}_{XVDP} = \text{Unit}(\underline{u}_{FDP})$$

$$\underline{UNX}/2_v \leftarrow \underline{MPAC}_v$$

Be sure to have unit vector for commanded thrust direction (in SM coordinates)

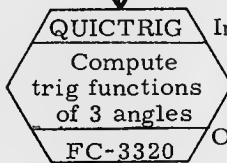
$$\underline{MPAC}_v \leftarrow \underline{UNWC}/2_v$$

Load \underline{u}_{WDP}



Input: $\underline{MPAC}_v = \text{vector}$

Output: $\underline{MPAC}_v = \text{corresponding unit vector @ } 2^1$



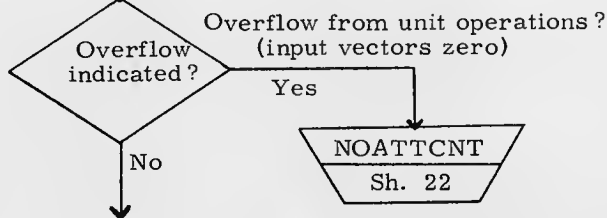
Input: $\left. \begin{array}{l} \text{CDUSPOTX} \\ \text{CDUSPOTY} \\ \text{CDUSPOTZ} \end{array} \right\} \begin{array}{l} \text{snapshot of IMU} \\ \text{gimbal angles} \\ \text{(2's complement)} \\ \text{in revs @ } 2^0 \end{array}$

Output: $\left. \begin{array}{l} \text{COSCDUX, SINCDUX} \\ \text{COSCDUY, SINCDUY} \\ \text{COSCDUZ, SINCDUZ} \end{array} \right\} \begin{array}{l} \text{cosines, sines of} \\ \text{given angles @ } 2^1 \end{array}$

$$\underline{u}_{ZVDP} = \text{Unit}(\underline{u}_{WDP})$$

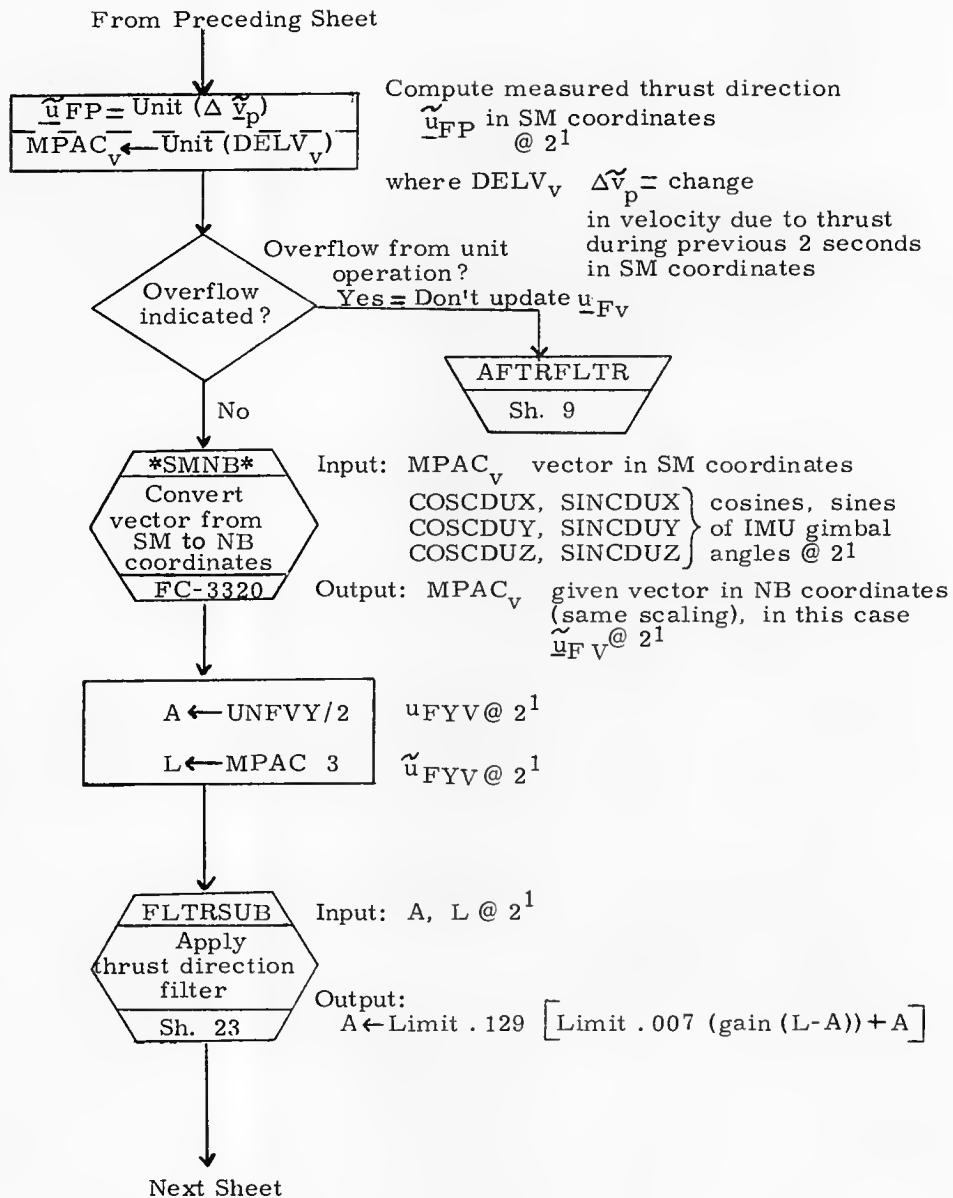
$$\underline{UNZ}/2_v \leftarrow \underline{MPAC}_v$$

Be sure to have unit vector for desired window direction (in SM coordinates)



Next Sheet

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DRAWN <i>John A. Taylor</i> 7/16/69		FINDCDUW: Guidance - DAP Interface	
PRGMR		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3960
DOCMR		REV	SHEET 6 OF 44
APPR'D <i>Robert M. Estes</i> 10/20/69			



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>Amistone</i>	1/16/69	FINDCDUW: Guidance - DAP Interface	
PRGMR		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3960
DOCMR			
APPR'D <i>Robert M. Estes</i>	10/20/69	REV	SHEET 7 OF 44

From Preceding Sheet

$u_{FYV} = (\text{Limit} . 129) (u_{FYV} + \Delta u_{FYV}),$
 where $\Delta u_{FYV} = (\text{Limit} . 007) (\text{gain}(\tilde{u}_{FYV} - u_{FYV}))$

 $UNFVY/2 \leftarrow A$

Store u_{FYV}
A 2^1

$A \leftarrow UNFVZ/2$
 $L \leftarrow MPAC + 5$

$u_{FZV} @ 2^1$
 $u_{FZV} @ 2^1$

FLTRSUB
 Apply
 thrust direction
 filter
 Sh. 23

Input: A, L @ 2^1

Output:
 $A \leftarrow \text{Limit} . 129 [\text{Limit} . 007 \times (\text{gain} (L-A) + A)]$

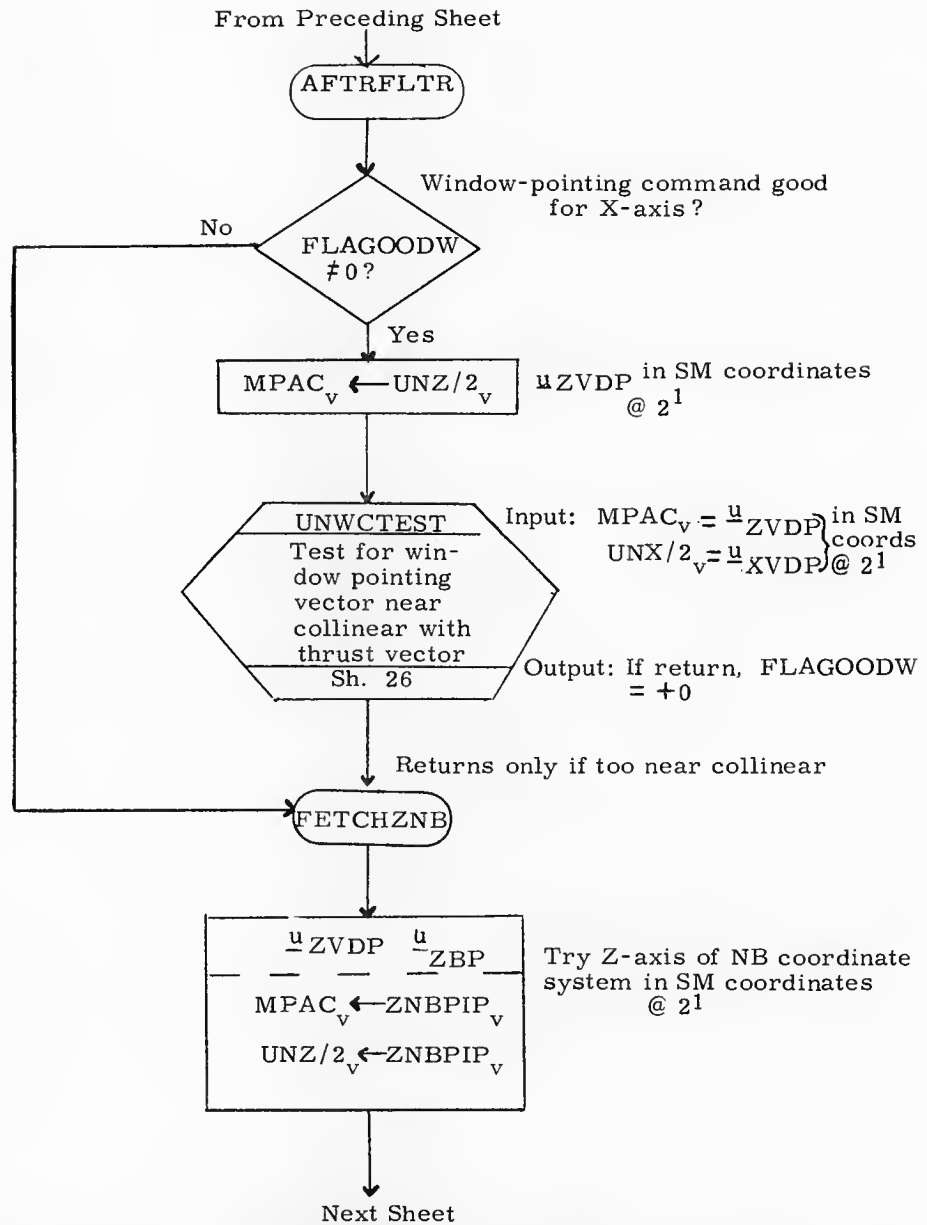
$u_{FZV} = (\text{Limit} . 129) (u_{FZV} + \Delta u_{FZV}),$
 where $\Delta u_{FZV} = (\text{Limit} . 007) (\text{gain}(\tilde{u}_{FZV} - u_{FZV}))$

 $UNFVZ/2 \leftarrow A$

Store u_{FZV}
@ 2^1

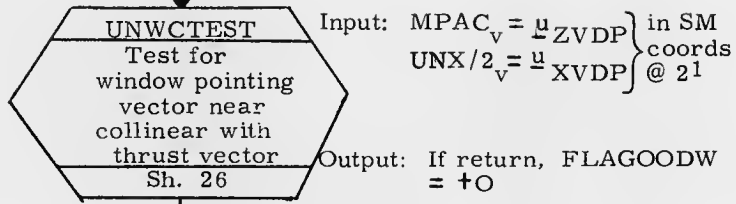
Next Sheet

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DRAWN <i>Signature</i> 1/17/69	PRGMR	FINDCDUW: Guidance - DAP Interface	
ANALST	DOCMR	LUMINARY 1D	DOCUMENT NO. FC-3960
APPR'D <i>Signature</i> 1/20/69	REV	SHEET 8 OF 44	

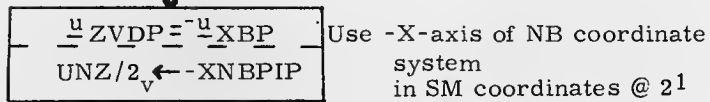


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DRAWN <i>J. Minnister</i>	<i>10/14/69</i>	FINDCDUW: Guidance - DAP Interface	
PRGMR		DOCUMENT NO.	
ANALST		LUMINARY 1D FC-3960	
DOCMR		REV	SHEET 9 OF 44
APPR'D <i>Robert M. Suter</i>	<i>10/20/69</i>		

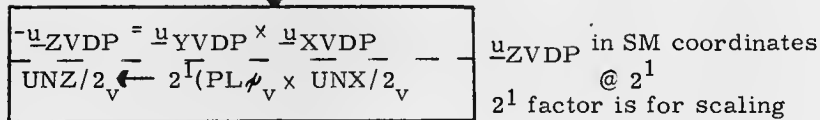
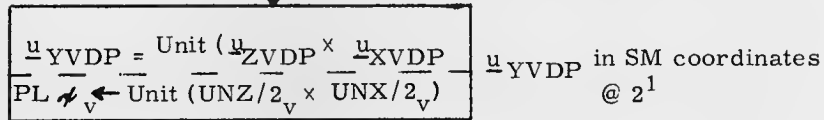
From Preceding Sheet



Returns only if too near collinear



Compute commanded vehicle axes (initial iteration)



Next Sheet

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PRGMR			DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3960
DOCMR		REV	SHEET 10 OF 44
APPR'D <i>[Signature]</i>	<i>[Date]</i>		

From Preceding Sheet.

Correct X-axis for thrust offset

$$\underline{u}_{XVDP} = \text{Unit} \left(\underline{u}_{XVDP} - \underline{u}_{FYV} \frac{\underline{u}_{YVDP}}{\underline{u}_{FZV}} \frac{\underline{u}_{ZVDP}}{\underline{u}_{XVDP}} \right)$$

$$\underline{UNX}/2_v - \text{Unit} \left(\underline{UNX}/2_v - 2^1 \cdot \underline{UNFVY}/2_D \cdot \underline{PLX}_v + 2^1 \cdot \underline{UNFVZ}/2_D \cdot \underline{UNZ}/2_v \right)$$

\underline{u}_{XVDP}
in SM
coords
@ 2^1
 2^1 fac-
tors are
for scaling

Compute commanded vehicle axes
(final iteration)

$$\underline{u}_{YVDP} = \frac{\underline{u}_{XVDP} \times \underline{u}_{ZVDP}}{\underline{UNY}/2_v - 2^1 \cdot (\underline{UNX}/2_v \times \underline{UNZ}/2_v)}$$

\underline{u}_{YVDP} in SM coordinates @ 2^1
where 2^1 factor is for scaling

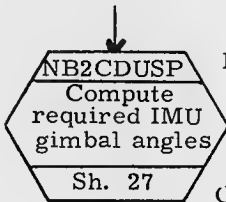
$$\underline{u}_{ZVDP} = -\frac{(\underline{u}_{YVDP} \times \underline{u}_{XVDP})}{\underline{UNZ}/2_v - 2^1 \cdot (\underline{UNY}/2_v \times \underline{UNX}/2_v)}$$

\underline{u}_{ZVDP} in SM coordinates @ 2^1
where 2^1 factor is for scaling

Next Sheet

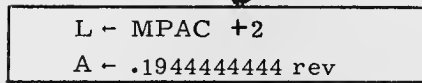
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i> 11/67		FINDCDUW: Guidance - DAP Interface	
PRGMR		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3960
DOCMR		REV	SHEET 11 OF 44
APPR'D <i>[Signature]</i> 10/20/69			

From Preceding Sheet

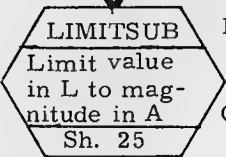


Input: $UNX/2_v (= PL0_v) = \frac{u}{2} XVDP$
 $UNY/2_v (= PL6_v) = \frac{u}{2} YVDP$
 $UNZ/2_v (= PL12_v) = \frac{u}{2} ZVDP$
 all in SM coords @ 2^1

Output: MPAC = CDUCX
 MPAC +1 = CDUCY
 MPAC +2 = CDUCZ
 all in revs @ 2^{-1}
 (2's complement)



required middle gimbal angle in revs @ 2^{-1}
 maximum allowable magnitude = 70° in revs @ 2^{-1}
 (necessary to avoid gimbal lock)



Input: L = value to be limited
 A = limit value (with same scaling)

Output: A = input value limited in magnitude to input limit

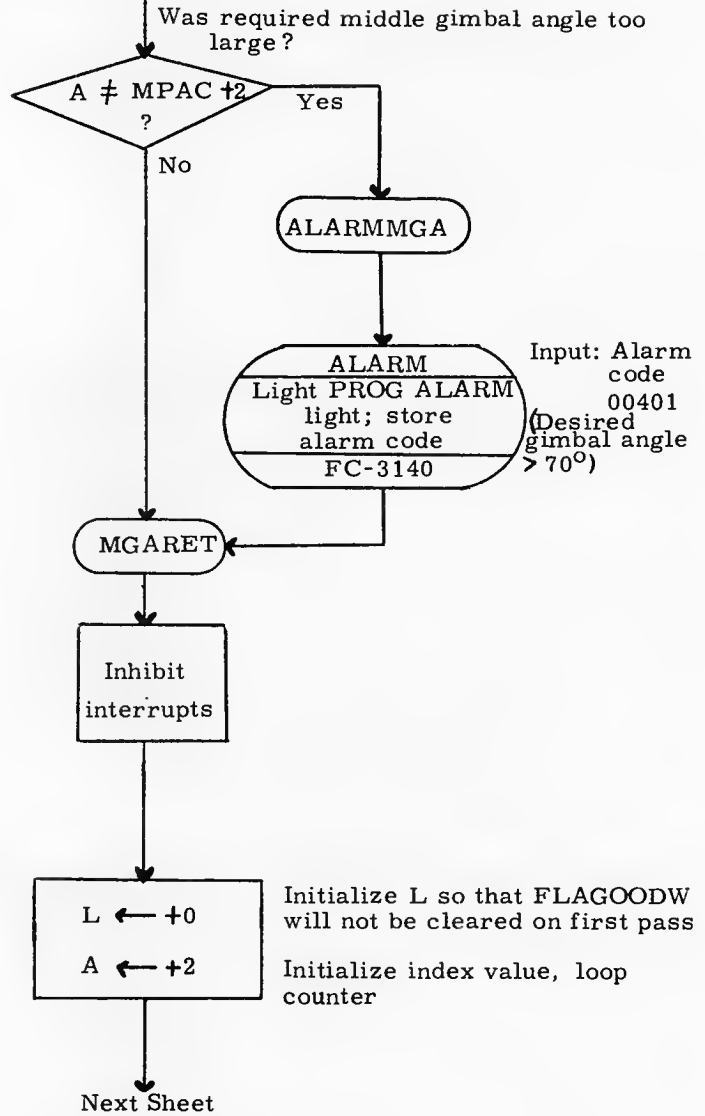


Store limited middle gimbal in revs @ 2^{-1} and simultaneously save original value in A

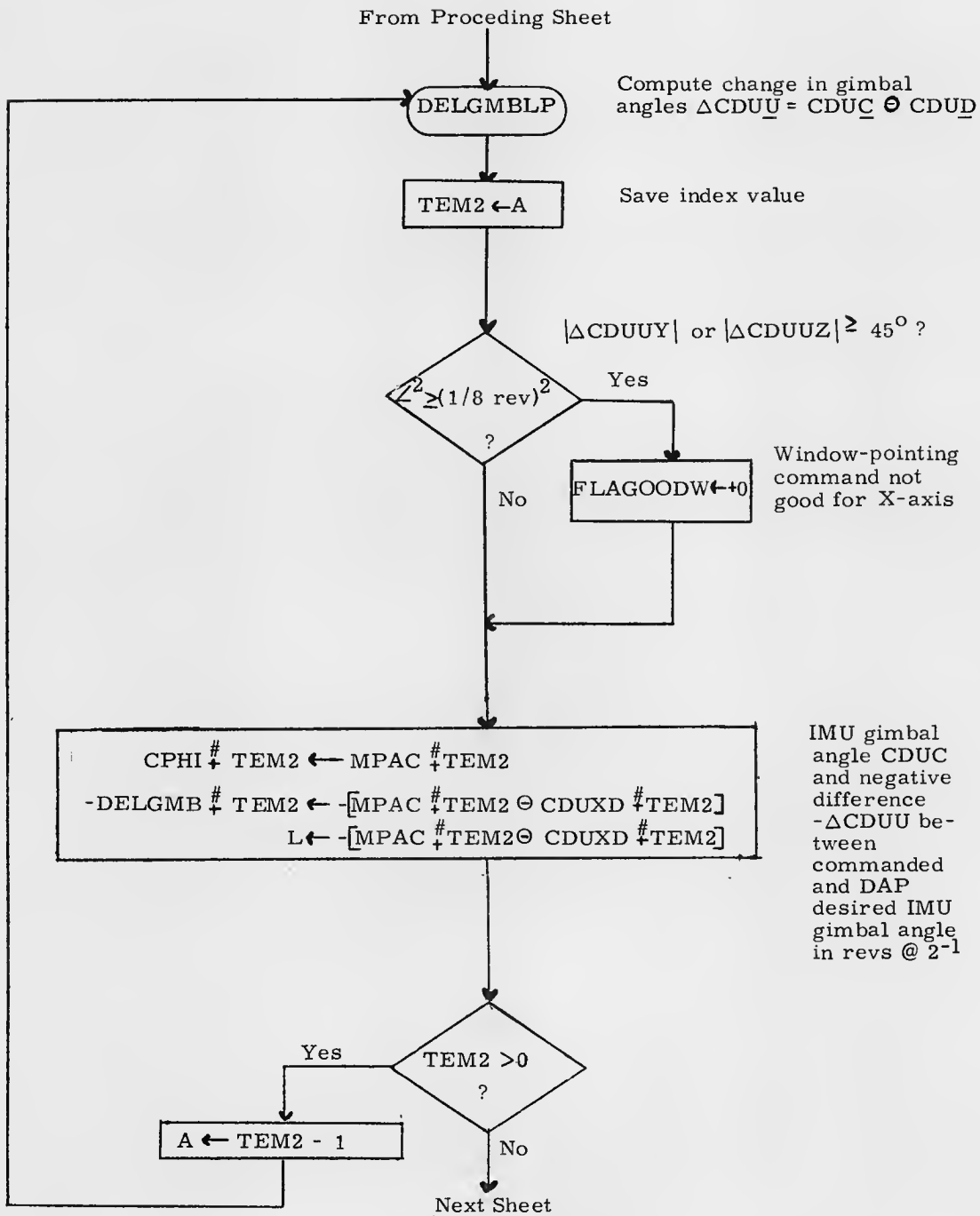
Next Sheet

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DRAWN: <i>Robert M. Carter</i>	<i>9/19/69</i>	FINDCDUW: Guidance - DAP Interface	
PRGMR		DOCUMENT NO.	
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DOCMR		REV	SHEET 12 OF 44
APPR'D: <i>Robert M. Carter</i>	<i>10/12/69</i>		

From Preceding Sheet

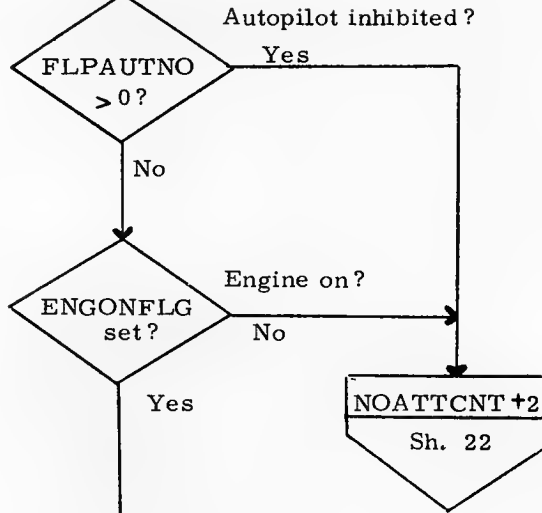


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DRAWN <i>Levinson</i>	9/19/69	FINDCDUW: Guidance - DAP Interface	
PRGMR		LUMINARY 1D	DOCUMENT NO. FC-3960
ANALST			
DOCMR			
APPR'D <i>Robert M. Evers</i>	12/24/69	REV	SHEET 13 OF 44



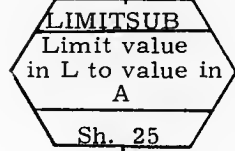
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i>	<i>10/30/67</i>	FINDCDUW: Guidance - DAP Interface	
PRGMR		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3960
DOCMR		REV	SHEET 14 OF 44
APPR'D <i>[Signature]</i>	<i>10/30/67</i>		

From Preceding Sheet



L ← -DELGMB +2
 A ← DAZMAX + NDXCDUW

-ΔCDUUZ in revs @ 2¹
 Appropriate limit value θ ZM (depending on whether docked to CSM) in revs @ 2⁻¹



Input: L = value to be limited
 A = limit value (with same scaling)
 Output: A = input value limited in magnitude to input limit

-DELGMB +2 ← A

Store - ΔCDUZ = limited value of - ΔCDUUZ in revs @ 2⁻¹

Next Sheet

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ANALST	DOCMR	LUMINARY 1D	DOCUMENT NO. FC-3960
APPR'D <i>[Signature]</i> 10/20/69	REV	SHEET 15 OF 44	

From Preceding Sheet

$L \leftarrow (-DELGMB + 1) \cdot COSCDUZ$ $A \leftarrow (DAY/2 \text{ MAX } \# \dagger NDXCDUW$	$-\Delta CDUUY \cdot \cos$ $(CDUDZ) \text{ in revs @ } 2^0$ 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

$A \leftarrow A \div COSCDUZ$	Obtain $-\Delta CDUY$ = limited value of $\frac{-\Delta CDUUY \cdot \cos(CDUDZ)}{\cos(CDUDZ)}$ in revs @ 2^{-1}
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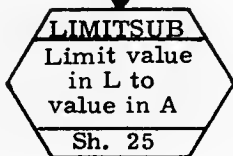
$A \leftrightarrow -DELGMB + 1$	Store $-\Delta CDUY$ and sim- ultaneously save original $-\Delta CDUUY$ in revs @ 2^{-1}
---------------------------------	---

$L \leftarrow -2^1 \cdot A \cdot SINCDUZ \ominus -DELGMB$ $A \leftarrow DAXMAX \# \dagger NDXCDUW$	$ACDUUX \ominus -\Delta CDUUY \cdot \sin$ $(CDUDZ) \text{ in revs @ } 2^{-1}$ $(2^1 \text{ factor is for scaling})$ Appropriate limit value θ_{XM} (depending on whether docked to CSM) in revs @ 2^{-1}
---	---

Next Sheet

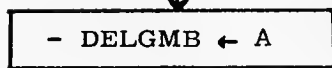
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>Robert M. Estes</i> 10/22/67	PRGMR	FINDCDUW: Guidance - DAP Interface	
ANALST	DOCMR	LUMINARY ID	DOCUMENT NO. FC-3960
APPR'D <i>Robert M. Estes</i> 10/22/67	REV		SHEET 16 OF 44

From Preceding Sheet

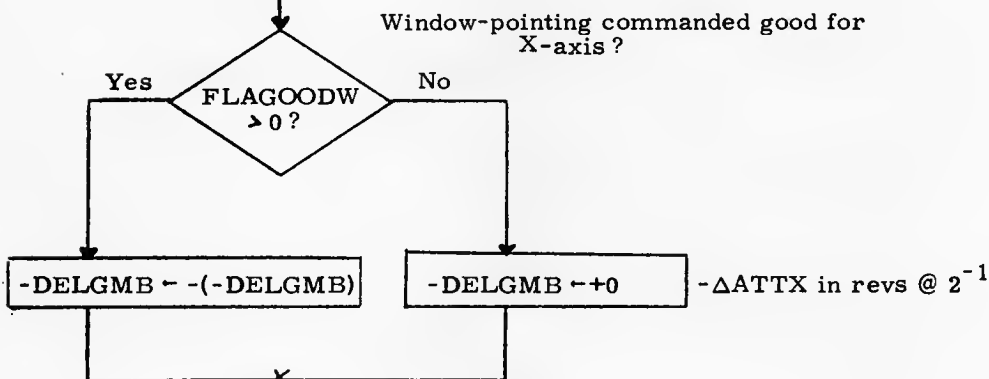


Input: L = value to be limited
A = limit value (same scaling)

Output: A = input value (limited in magnitude to input limit)

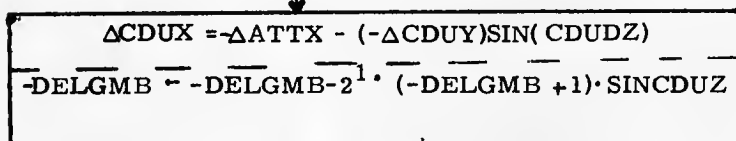


Store $\Delta ATTX$ = limited value of $\Delta CDUUX \ominus -\Delta CDUUY - \text{SIN}(CDUDZ)$ in revs @ 2^{-1}



Window-pointing commanded good for X-axis?

$-\Delta ATTX$ in revs @ 2^{-1}



$-\Delta CDUX$ in revs @ 2^{-1}
(2^1 factor is for scaling)

Next Sheet

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DRAWN <i>Luminaire</i>	<i>9/3/67</i>	FINDCDUW: Guidance - DAP Interface	
PRGMR		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3960
DOCMR		REV	SHEET 17 OF 44
APPR'D <i>Robert M. Egan</i>	<i>10/25/69</i>		

From Preceding Sheet

Compute commanded attitude rates in revs/sec @ 2^{-3}

$$\omega_{DXV} = [\Delta CDUX + \Delta CDUY \sin(CDUDZ)] \div 2 \text{ sec}$$

$$\text{OMEGAPD} = [-2^2(-\text{DELGMB}) - 2^3(-\text{DELGMB} + 1)\text{SINCDUZ}] \div 2 \text{ sec}$$

$2^2, 2^3$ factors are for scaling

$$\omega_{DYV} = [\Delta CDUY \cos(CDUDZ) \cos(CDUDX) + \Delta CDUZ \sin(CDUDX)] \div 2 \text{ sec}$$

$$\text{OMEGAQD} = [-2^4(-\text{DELGMB} + 1)\text{COSCDUZ} \text{COSCDUX} - 2^3(-\text{DELGMB} + 2)\text{SINCDUX}] \div 2 \text{ sec}$$

$2^3, 2^4$ factors are for scaling

$$\omega_{DZV} = [-\Delta CDUY \cos(CDUDZ) \sin(CDUDX) + \Delta CDUZ \cos(CDUDX)] \div 2 \text{ sec}$$

$$\text{OMEGARD} = [2^4(-\text{DELGMB} + 1)\text{COSCDUZ} \cdot \text{SINCDUX} - 2^3(-\text{DELGMB} + 2)\text{COSCDUX}] \div 2 \text{ sec}$$

$2^3, 2^4$ factors are for scaling

A ← +2

Initialize index value, loop counter

Next Sheet

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From Preceding Sheet

CDUWFXR

TEM2 ← A

Save index value

$$\delta \text{ CDU} = \frac{0.1 \text{ sec}}{2 \text{ sec}} \Delta \text{ CDU}$$

$$A \leftarrow \text{DT/DELT} (-\text{DELGMB} \# \text{ TEM2})$$

Obtain gimbal angle increment CDU from ΔCDU by multiplying by ratio of DAP control sample period to computation period

ONESTO2S
 Convert
 from 1's to
 2's complement
 Sh. 38

Input: A in 1's complement

Output: A in 2's complement (same scaling) here in revs @ 2^{-1}

DELCDUX # TEM2 ← A

Store $\delta \text{ CDU}$ in 2's complement in revs @ 2^{-1}

$$L \leftarrow 2^{-3} (\text{OMEGAPD} \# \text{ TEM2}) \cdot |\text{OMEGAPD} \# \text{ TEM2}|$$

$$2.1\text{JACC} \# \text{ TEM2}$$

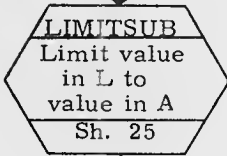
$$A \leftarrow .027777777775 \text{ rev}$$

$$\frac{\omega_{DV} |\omega_{DV}|}{2^{\alpha} X(Y, Z)}$$
 in revs @ 2^{-1}
 2^{-3} factor is for scaling
 10^0 limit value in revs @ 2^{-1}

Next Sheet

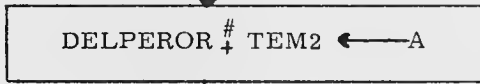
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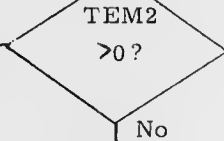


Input: L = value to be limited
A = limit value (same scaling)

Output: A = input value limited in magnitude
to input limit

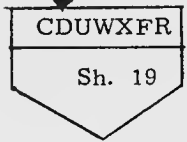


Store $\phi_{X(Y, Z)}$ = limited value
of $\frac{\omega_{DV} |\omega_{DV}|}{2\alpha_{X(Y, Z)}}$
in revs @ 2^{-1}



Yes

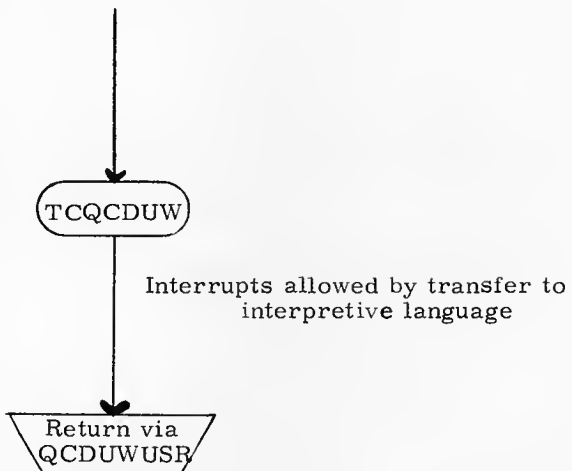
No



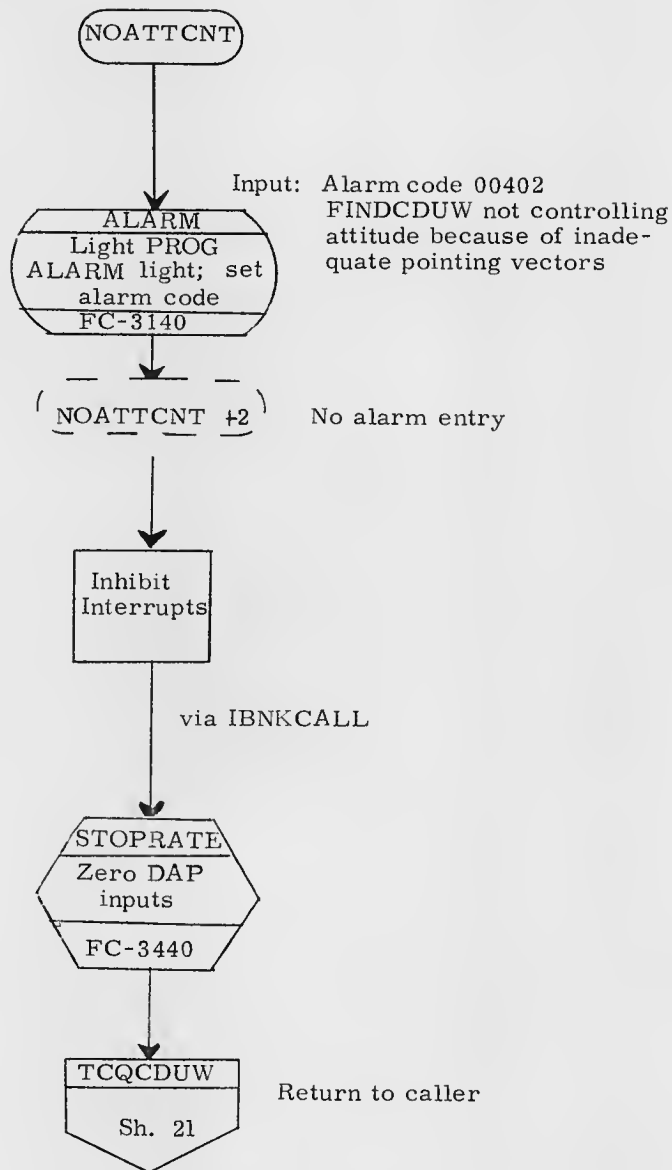
Next Sheet

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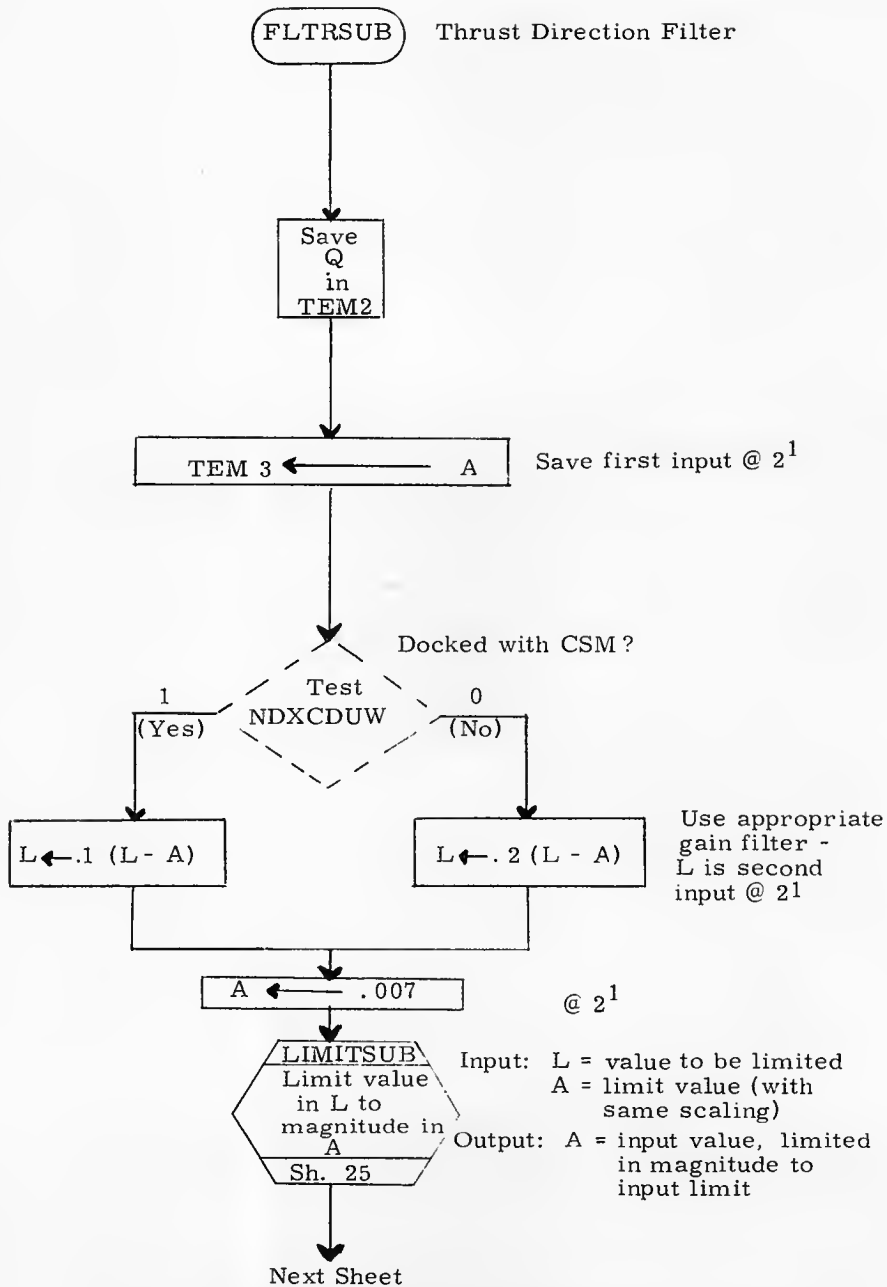
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DOCMR		REV	SHEET 2 OF 44
APPR'D	<i>Robert M. ... 10/20/69</i>		



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PRGMR		DOCUMENT NO.	
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From Preceding Sheet

$L \leftarrow A + TEM\ 3$

$A \leftarrow .129$

@ 2¹

LIMITSUB
Limit value
in L to magni-
tude in A
Sh. 25

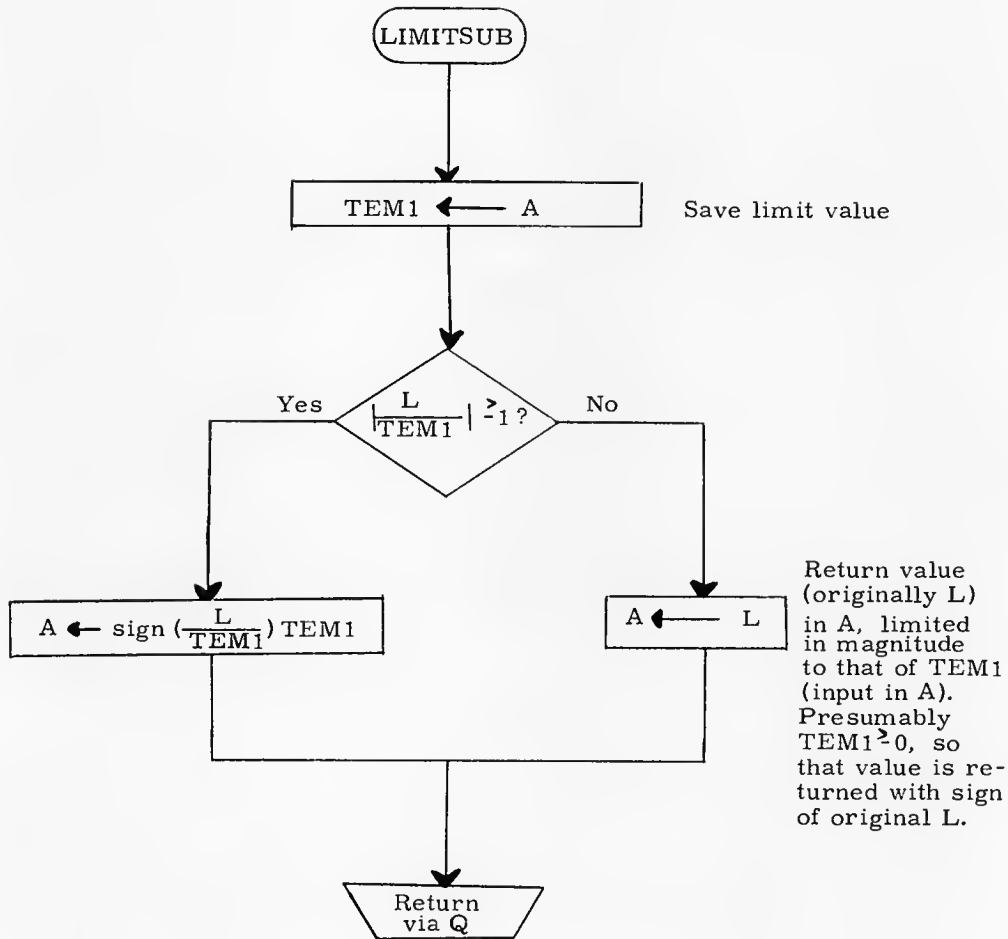
Input: L = value to be limited
A = limit value (with same
scaling)

Output: A = input value, limited
in magnitude to input
limit

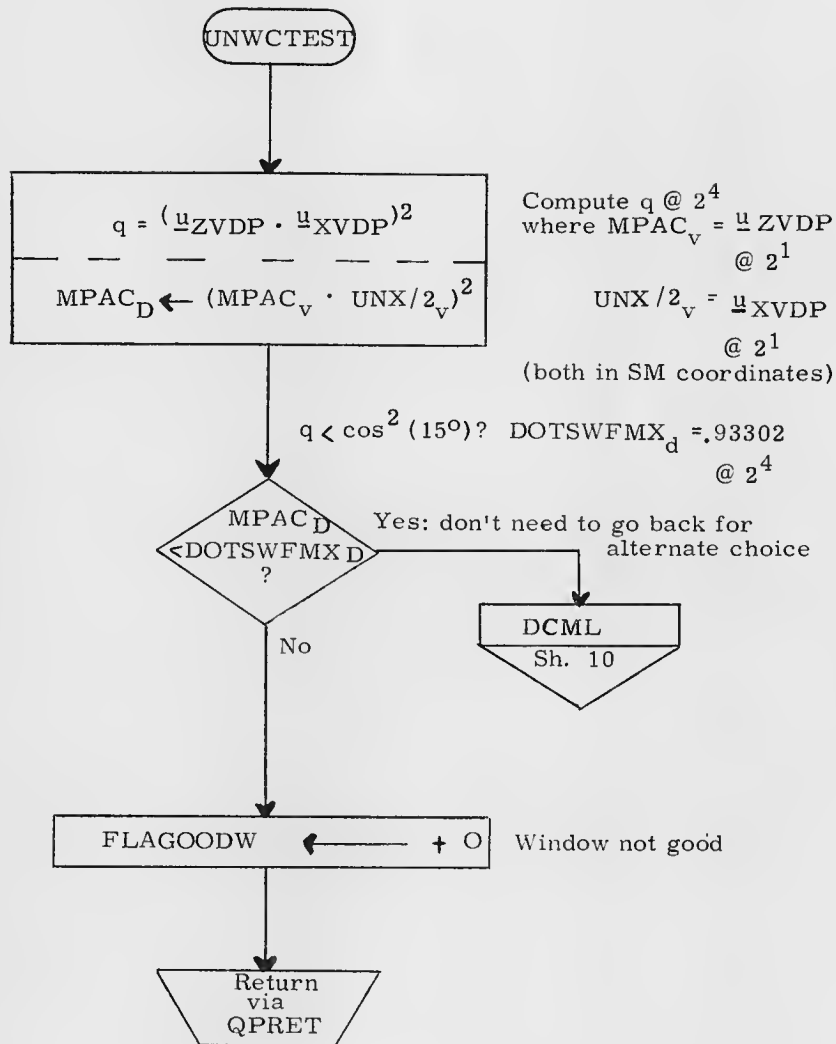
Result: $A \leftarrow \begin{cases} 1 \\ 2 \end{cases} (L-A) + A$
limited to
 $\pm .007$
limited to $\pm .129$

Return via
TEM2

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DRAWN <i>Robert M. East</i> 2/21/69		FINDCDUW: Guidance - DAP Interface	
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DOCMR			
APPR'D <i>Robert M. Enter</i>	<i>10/20/69</i>	REV	SHEET 26 OF 44

NB2CDUSP

Compute commanded IMU gimbal angles from desired NB axes (in SM coords)

Note: For additional information about NB2CDUSP, see Sh. 38, 39.

Input: $\begin{bmatrix} \text{UNX}/2 \\ \text{UNY}/2 \\ \text{UNZ}/2 \end{bmatrix}_V \begin{bmatrix} \text{XVDP} \\ \text{YVDP} \\ \text{ZVDP} \end{bmatrix}_U = \begin{matrix} \text{SM} \\ \text{coords} \\ @ 2^1 \end{matrix}$

$C_1^2 \leq 1?$

Yes $(\text{UNX}/2 + 2)^2 / D \leq 1?$

No = should be - assume $C_1^2 = 1$ to avoid imaginary roots

$\text{COS Z} = \sqrt{1 - C_1^2}$
 $\text{MPAC}_D \leftarrow \sqrt{1 - (\text{UNX}/2 + 2)^2 / D}$

$\text{MPAC}_D \leftarrow +0$ @ 2^1

$A, L \leftarrow 2^1 \cdot \text{MPAC}_D$ @ 2^0

$\text{Cos Z} = 1?$

Yes Overflow in A?

No

$\text{TEM5} \leftarrow \text{POSMAX}$

$\text{TEM5} \leftarrow A$

Store cos Z @ 2^0

$\text{POSMAX} = 1 - 2^{14}$ @ 2^0
 (closest allowable value to + 1)

Next Sheet

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ANALYST	DOCMR	LUMINARY 1D	DOCUMENT NO. FC-3960
APPR'D <i>Robert M. Estes</i> 10/20/69	REV	SHEET 27 OF 44	

From Preceding Sheet

A ← UNX/2 + 2
L ← MPAC

$$C_1 = \sin z @ 2^1$$

$$\cos z @ 2^1$$

ARCTRGSP
Perform arc-
trig function
Sh. 33

Input: A = sin (angle) @ 2¹
L = cos (angle) @ 2¹
Output: A = angle in revs @ 2⁻¹
(2's complement)

MPAC + 2 ← A

Save angle CDUCZ in revs
@ 2⁻¹

A ← + 0

Set up input to DVBYCOSM

DVBYCOSM
Divide
by
TEM5
Sh. 39

Input: A = X, where PLXD (in this case, PL_{0D} = UNX/2_D = C₀ @ 2¹) is to be divided
Output: L ← TEM1 = PLXD ÷ TEM5
(here, = $\frac{C_0}{\cos z} = \cos y @ 2^1$)

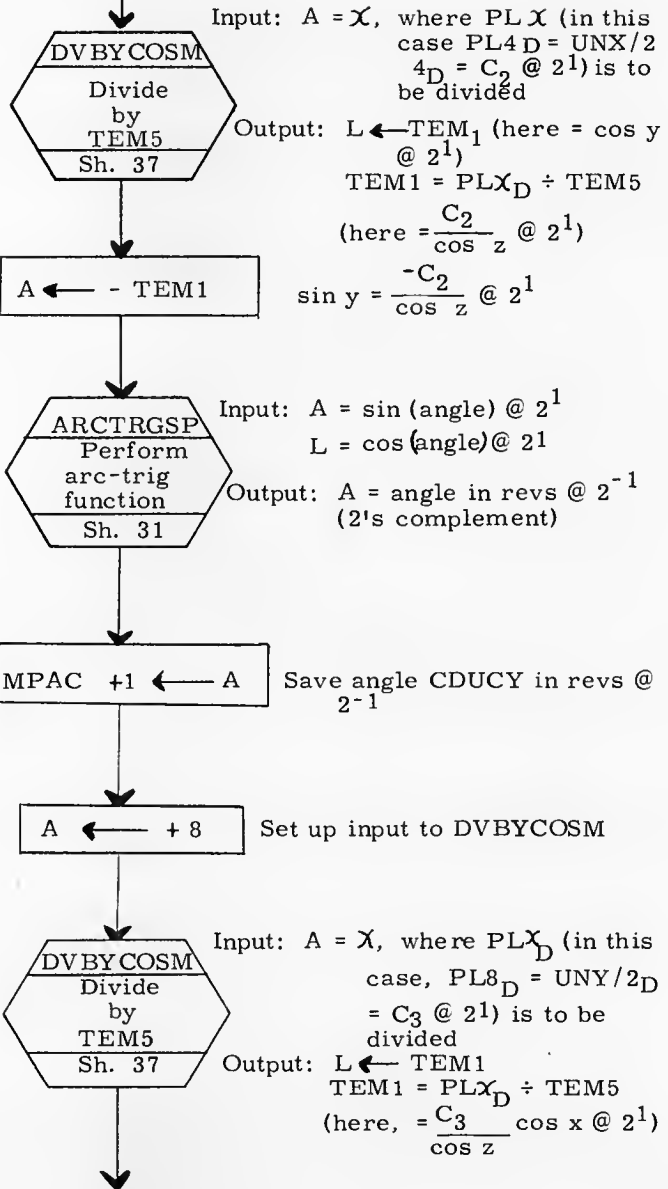
A ← + 4

Set up input to DVBYCOSM

Next Sheet

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DRAWN <i>Renaissance 2/24/69</i>		FINDCDUW: Guidance - DAP Interface	
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APPR'D <i>Roberta M. Ertel 10/20/69</i>			

From Preceding Sheet



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DRAWN <i>Robert M. Easton</i>	<i>9/30/69</i>	FINDCDUW: Guidance - DAP Interface	
PRGMR		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3960
DOCMR		REV	SHEET 29 OF 44
APPR'D <i>Robert M. Easton</i>	<i>10/29/69</i>		

From Preceding Sheet

A ← +14D

DVBYCOSM
Divide
by
TEM5
Sh. 37

Input: $A = X$, where PLx_D (in this case, $PL14D = UNZ/2 + 2D = C_7 @ 2^1$) is to be divided

Output: $L \leftarrow TEM1$ (here = $\cos x @ 2^1$)
 $TEM1 = PLx_D \div TEM5$
 (here = $\frac{C_7}{\cos z} @ 2^1$)

A ← - TEM1

$\sin x = \frac{C_7}{\cos z} @ 2^1$

ARCTRGSP
Perform
arc-trig
function
Sh. 31

Input: $A = \sin(\text{angle}) @ 2^1$
 $L = \cos(\text{angle}) @ 2^1$

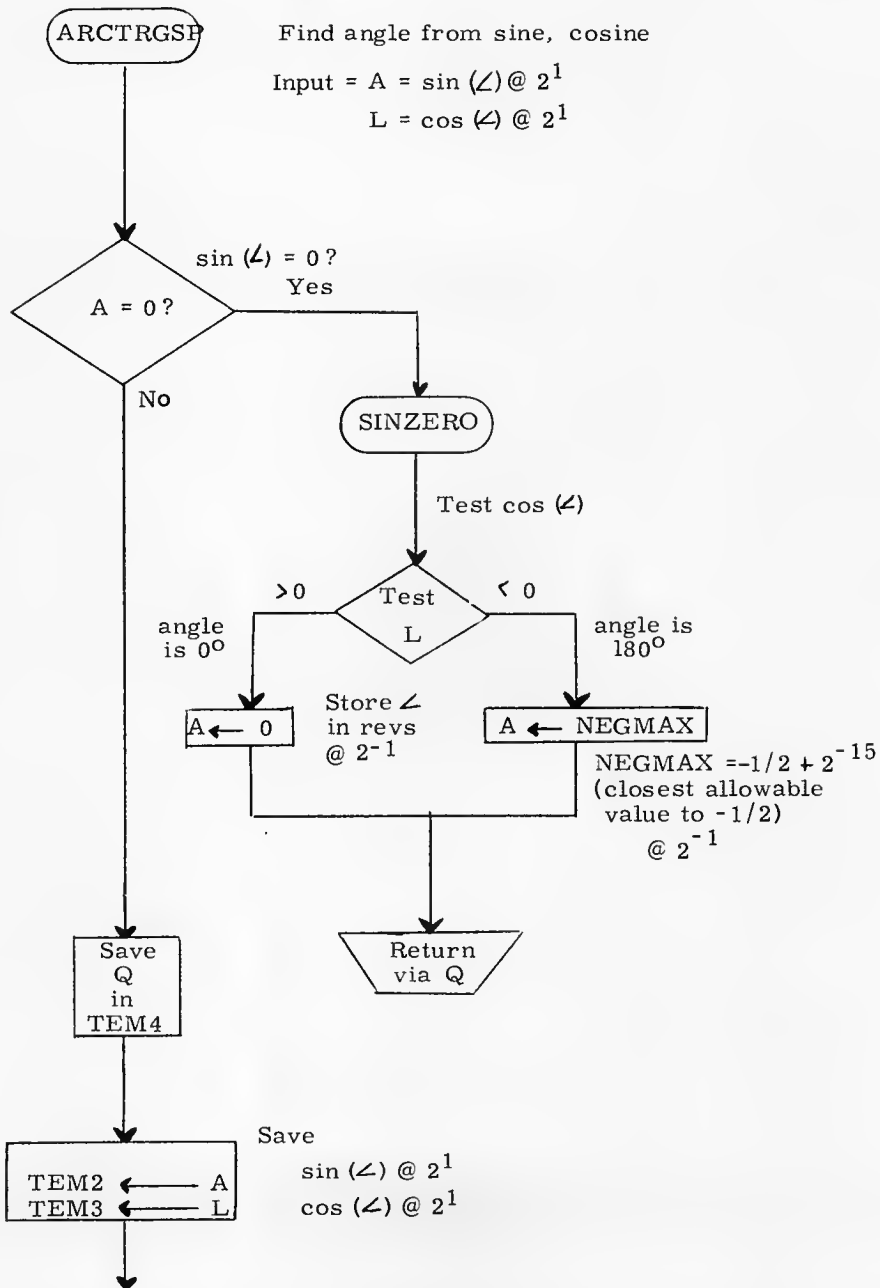
Output: $A = \text{angle in revs} @ 2^{-1}$
 (2's complement)

MPAC ← A

Save angle CDUCX in revs
 $A 2^{-1}$

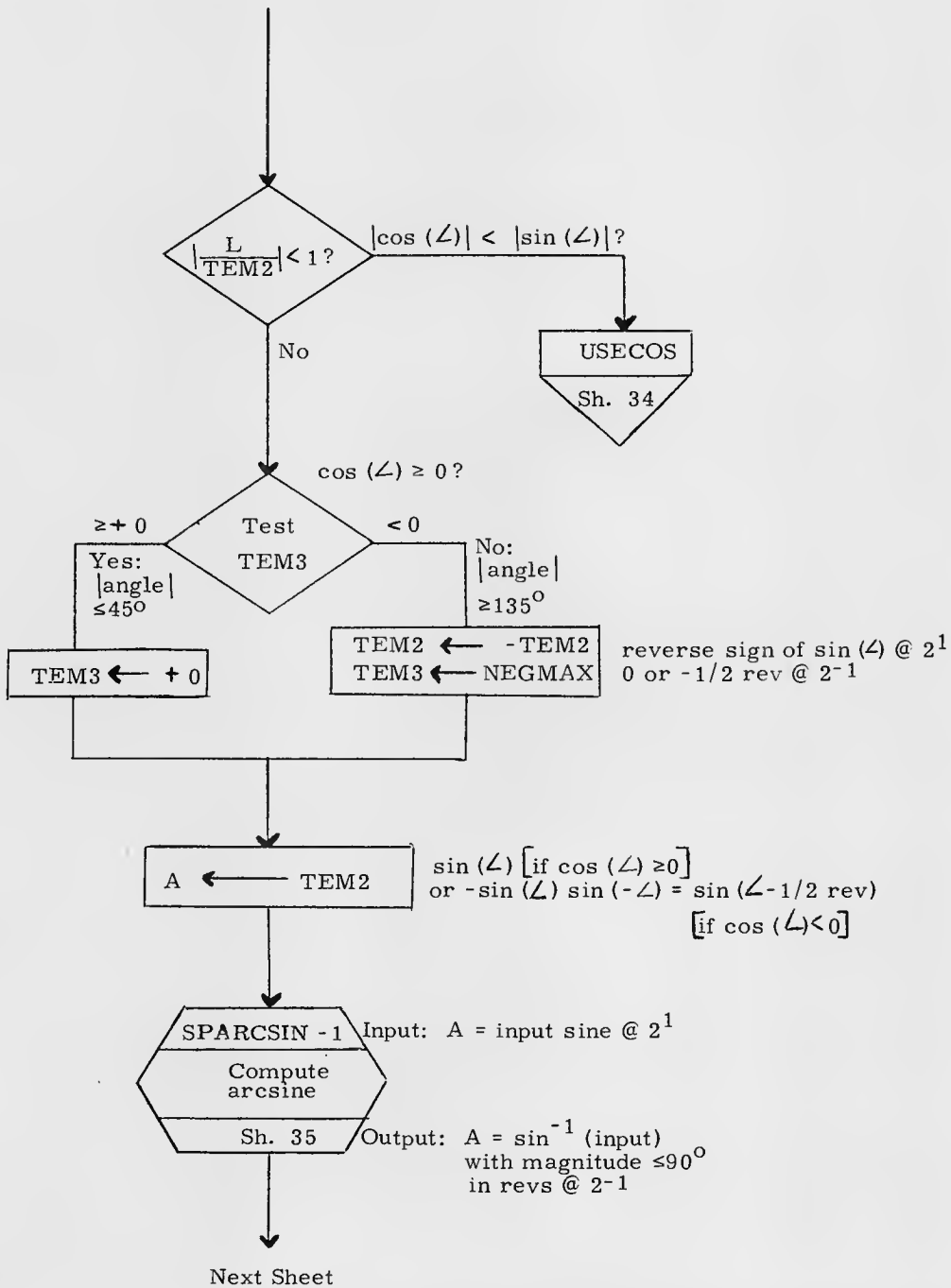
Return
via QPRET

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PRGMR		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3960
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APPR'D <i>Robert M. Euter</i>	<i>10/30/67</i>		



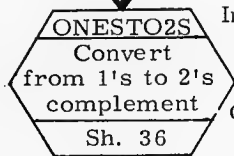
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DRAWN <i>Administrative</i> 1/30/67		FINDCDUW: Guidance - DAP Interface	
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DOCMR			
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From Preceding Sheet



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APPR'D <i>[Signature]</i>	<i>[Date]</i>		

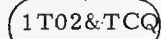
From Preceding Sheet



Input: A in 1's complement

Output: A in 2's complement (same scaling)

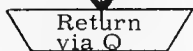
Get 1's complement difference of 2's complement values. If $\cos(\angle)$ input was $\geq +0$, $TEM3 = 0$; angle computed by SPARCSIN -1 needs no adjustment; but if $\cos(\angle)$ input was < 0 , $TEM3 = 1/2 \text{ rev} @ 2^{-1}$ and sine input to SPARCSIN -1 had sign reversed; angle computed above is $\sin^{-1}(\sin(\angle - 1/2 \text{ rev}) = \angle - 1/2 \text{ rev}$



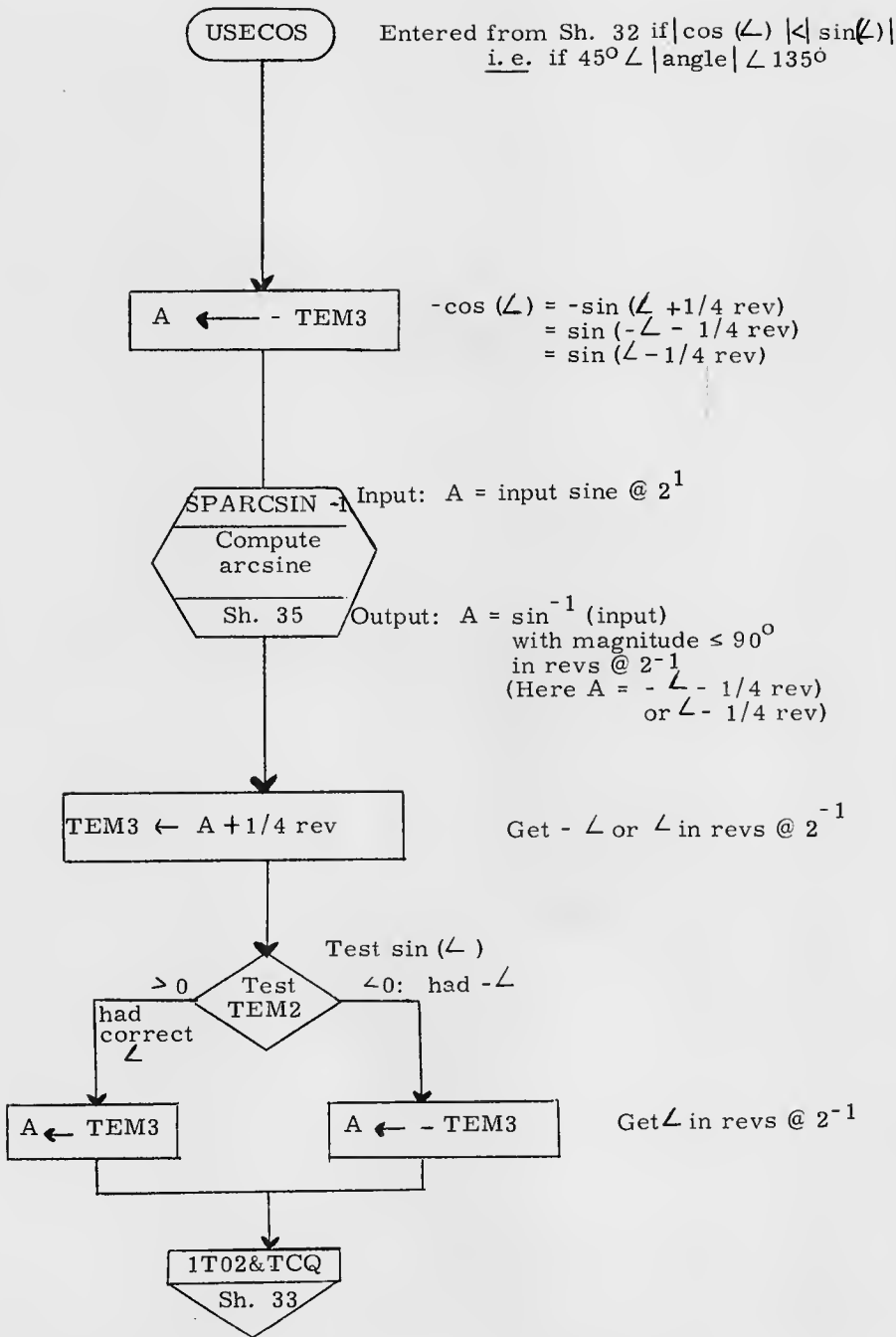
Input: A in 1's complement

Output: A in 2's complement with same scaling

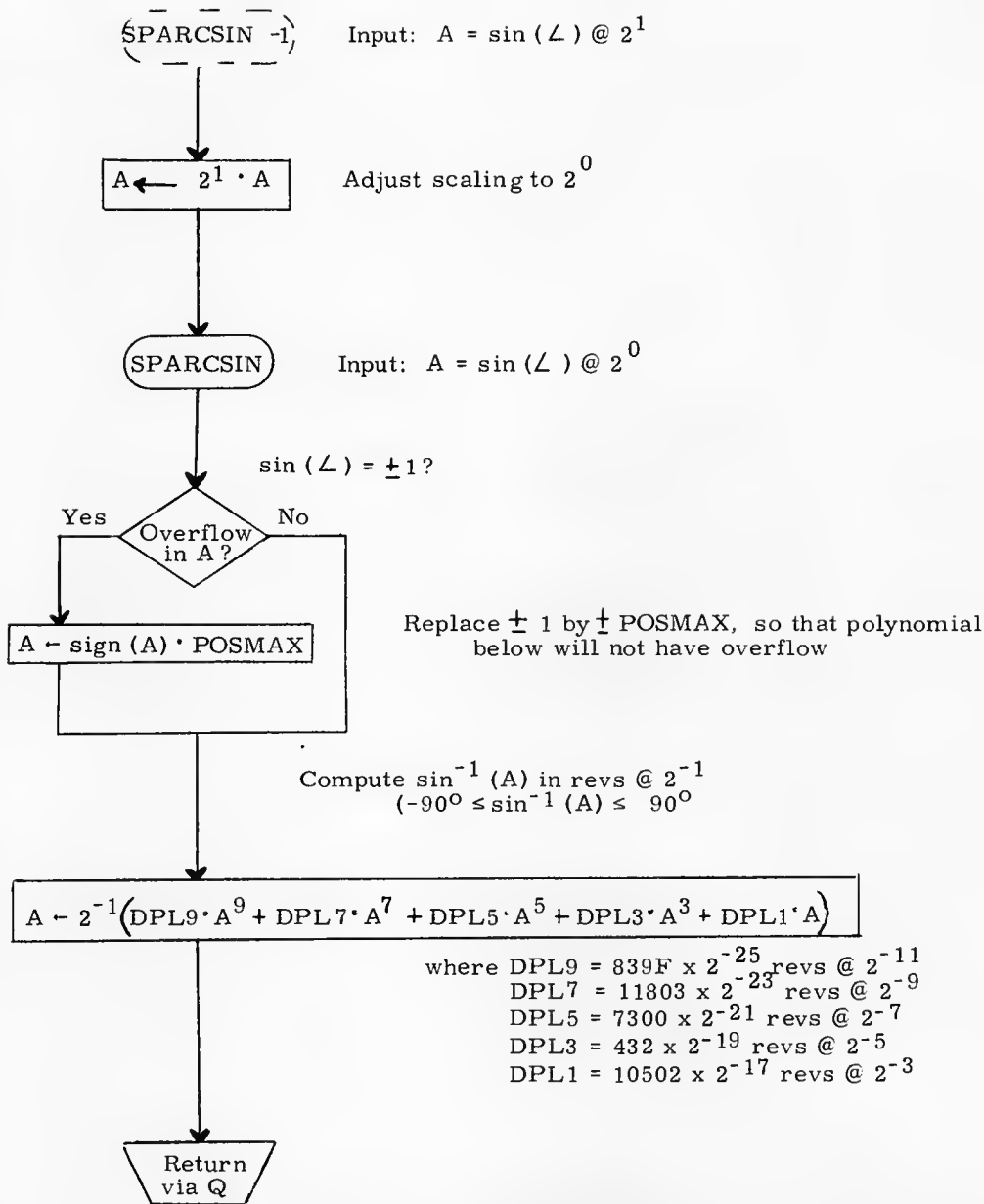
Here, $A = \angle$ in revs @ 2^{-1}



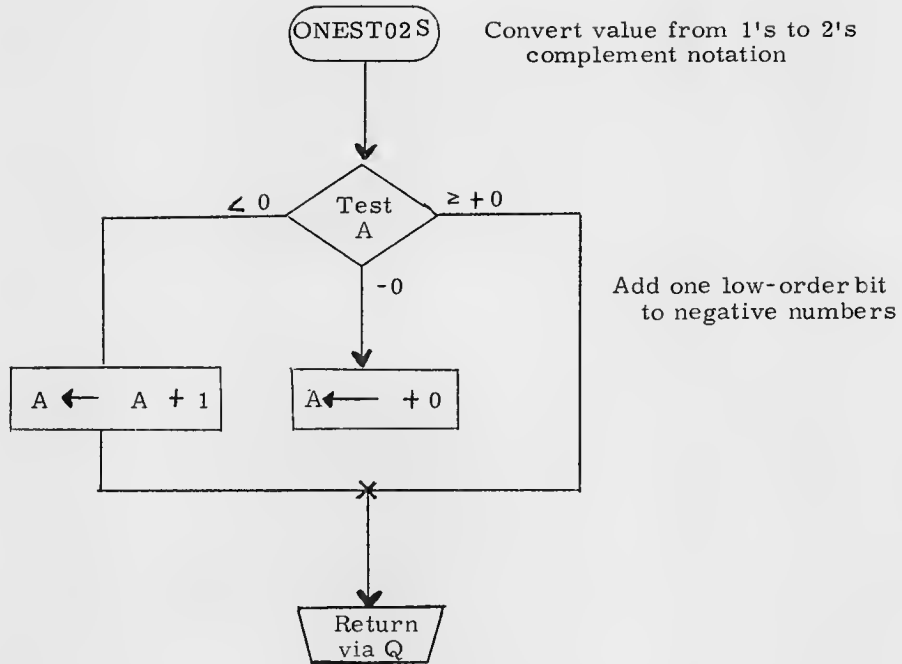
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
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DOCMR		REV	
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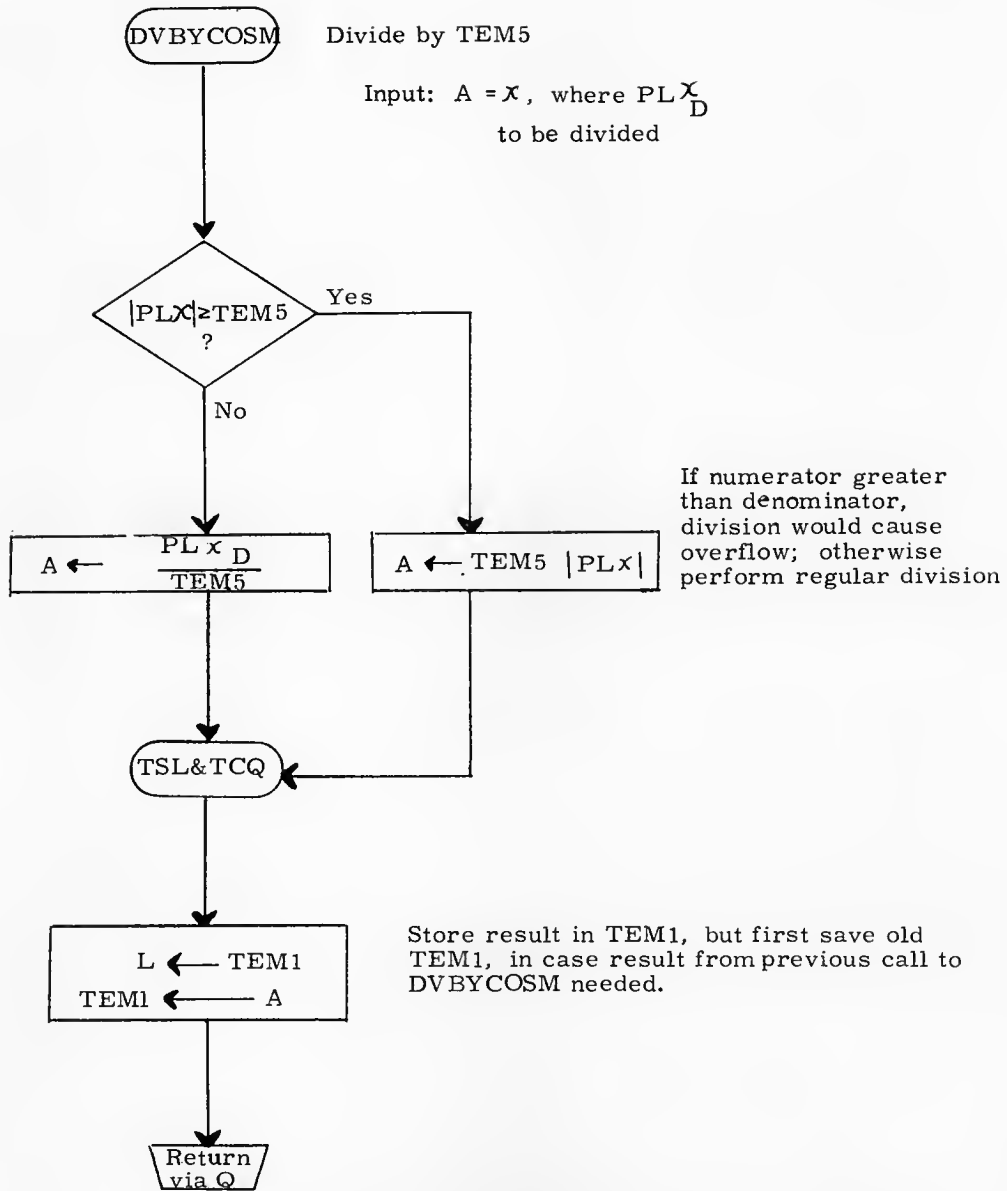
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>Robert M. Estes</i> 10/20/69		FINDCDUW: Guidance - DAP Interface	
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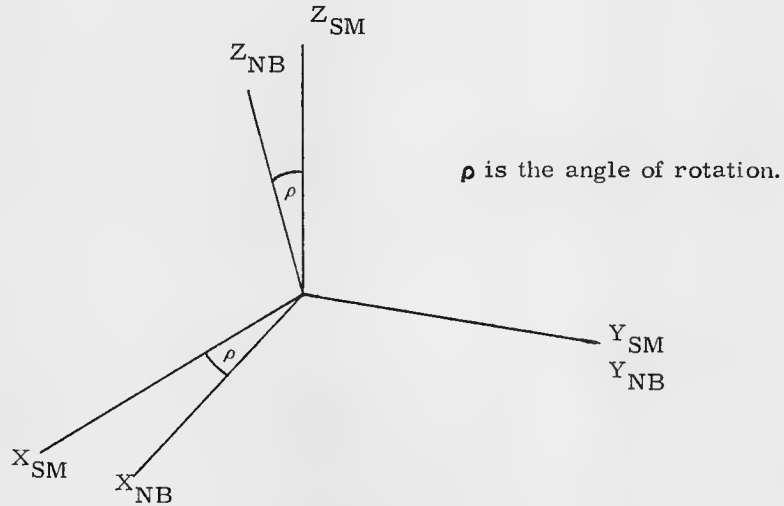


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ADDITIONAL INFORMATION ABOUT NB2CDUSP (Nav Base To CDU,
Single Precision)

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:



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,

$$\begin{bmatrix} D \end{bmatrix} = \begin{bmatrix} \cos \rho & 0 & -\sin \rho \\ 0 & 1 & 0 \\ \sin \rho & 0 & \cos \rho \end{bmatrix}, \text{ where the rows are unit vectors, parallel to the } X_{NB}, Y_{NB} \text{ and } Z_{NB} \text{ axes, expressed in stable member coordinates.}$$

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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] x [A] x [B] x [D], yields this matrix:

$$[C] = \begin{bmatrix} \cos \sigma \cos \rho & \sin \sigma & -\sin \rho \cos \tau \\ -\cos \tau \sin \sigma \cos \rho + \sin \tau \sin \rho & \cos \tau \cos \tau & \cos \rho \sin \tau + \sin \rho \cos \tau \sin \sigma \\ \cos \rho \sin \tau \sin \sigma + \cos \tau \sin \rho & -\sin \tau \cos \tau & \cos \tau \cos \rho - \sin \tau \sin \sigma \sin \rho \end{bmatrix} \quad \text{where } \tau, \rho, \text{ and } \sigma \text{ are the angles of rotation about the X, Y, and Z axes, respectively.}$$

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 $PL14_D$, one can easily compute the required angles.

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APPR'D <i>Roberta M. Estes</i> 10/20/69			

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		
<u>Flags</u>					
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
<u>Channel Bits</u>					
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

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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 angle (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}

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>Lewis</i>	<i>10/26/69</i>	FINDCDUW: Guidance - DAP Interface	
PROGR			DOCUMENT NO.
ANALST		LUMINARY 1D	FC-3960
DOCMR		REV	SHEET 41 OF 44
APPR'D <i>Robert M. Estes</i>	<i>10/20/69</i>		

Erasable Locations Used (Continued)

AGC Tag	GSOP Symbol	Meaning	Engineering Units	AGC Units	AGC Scaling
DELCDUX	δ CDUX	Commanded incremental change (for DAP) in outer IMU gimbal angle (2's complement)	degrees	revs	2^{-1}
DELCDUX 1	δ CDUY	Commanded incremental change (for DAP) in inner IMU gimbal angle (2's complement)	degrees	revs	2^{-1}
DELCDUX 2	δ 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	$\Delta \tilde{V}_P$	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 auto-pilot 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_{DYV}	Z-component of commanded attitude rate	deg/sec	revs/sec	2^{-3}

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>Remington</i>	<i>8/6/69</i>	FINDCDUW: Guidance - DAP Interface	
PRGMR		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3960
DOCMR		REV	SHEET 42 OF 44
APPR'D <i>Robert M. Estes</i>	<i>10/20/69</i>		

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	<u>FDP</u>	Commanded direction in SM coordinates			Variable
UNFV/2 _V (UNFV/2 _D) (UNFY/2 _D) (UNFZ/2 _D)	<u>FV</u>	Measured thrust direction in SM coordinates			2 ¹
UNWC/2 _V	<u>WDP</u>	Window-pointing direction command, in SM coordinates			2 ¹
UNX/2 _V = PL0 _V	<u>XVDP</u>	Commanded vehicle (NB) Y-axis, in SM coordinates			2 ¹
UNY/2 _V = PL6 _V	<u>YVDP</u>	Commanded vehicle (NB) Y-axis, in SM coordinates			2 ¹
UNZ/2 _V = PL12 _V	<u>ZVDP</u>	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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i> 10/6/67	PRGMR	FINDCDUW: Guidance - DAP Interface	
ANALST	DOCMR	DOCUMENT NO.	
APPR'D <i>[Signature]</i> 10/2/67		LUMINARY 1D	FC-3960
	REV	SHEET 43 OF 44	

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	.0555555555555555 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	.0055555555555555 rev	2^{-1}
DAY/2MAX	θ_{YM}	Maximum magnitude for command IMU inner gimbal angle change (for LM <u>not</u> docked with CSM)	20 degrees	.0555555555555555 rev	2^0
DAY/2MAX +1	θ_{YM}	Maximum magnitude for commanded IMU inner gimbal angle change (for LM docked with CSM)	2 degrees	.0055555555555555	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
<u>Pad-Loads</u>					
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}

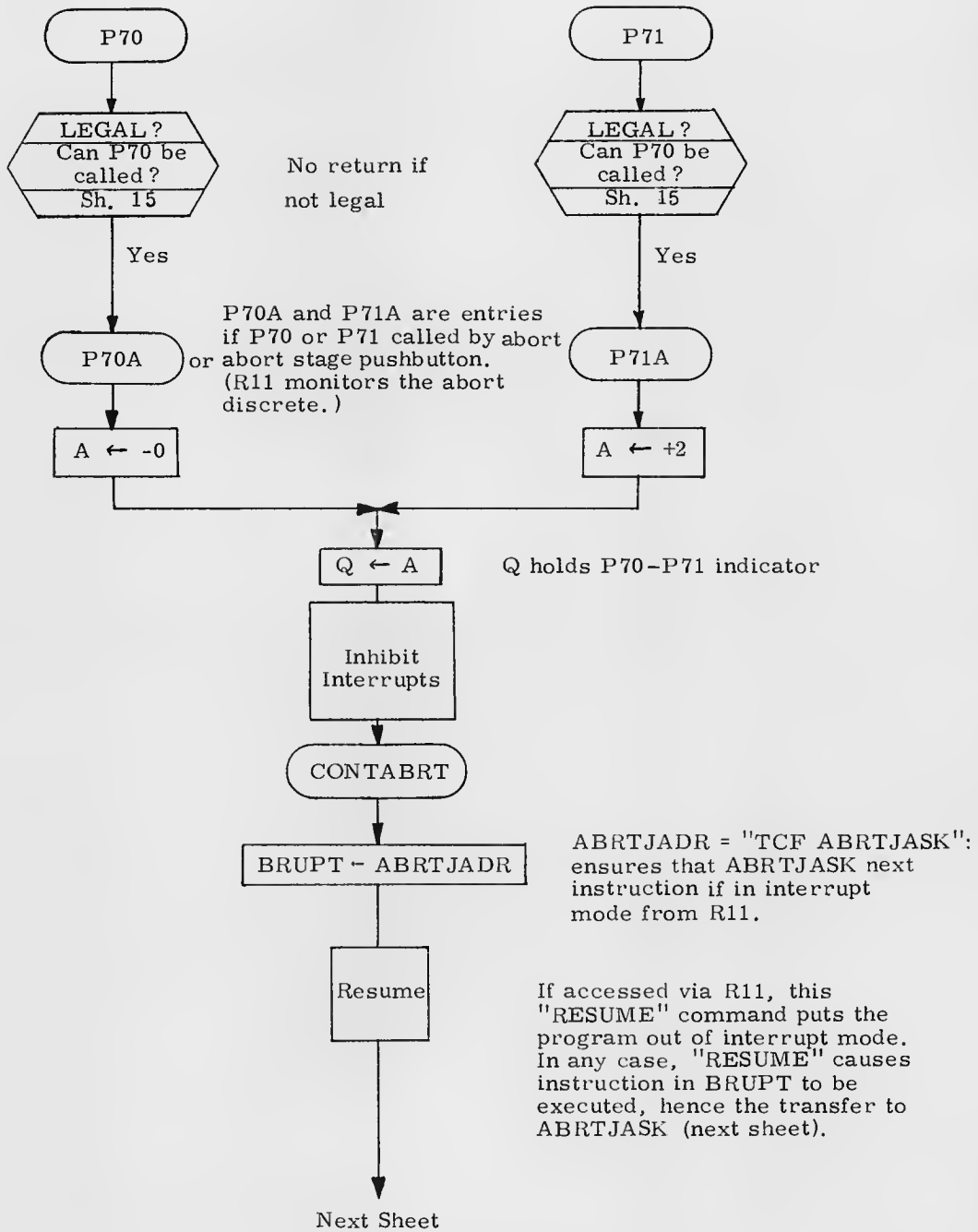
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>Robert M. Estes</i>	<i>10/22/69</i>	FINDCDUW: Guidance - DAP Interface	
PRGMR _____	_____	LUMINARY ID	DOCUMENT NO.
ANALST _____	_____		FC-3960
DOCMR _____	_____	REV	SHEET 44 OF 44
APPR'D <i>Robert M. Estes</i>	<i>10/22/69</i>		

P70 - P71 Abort Programs

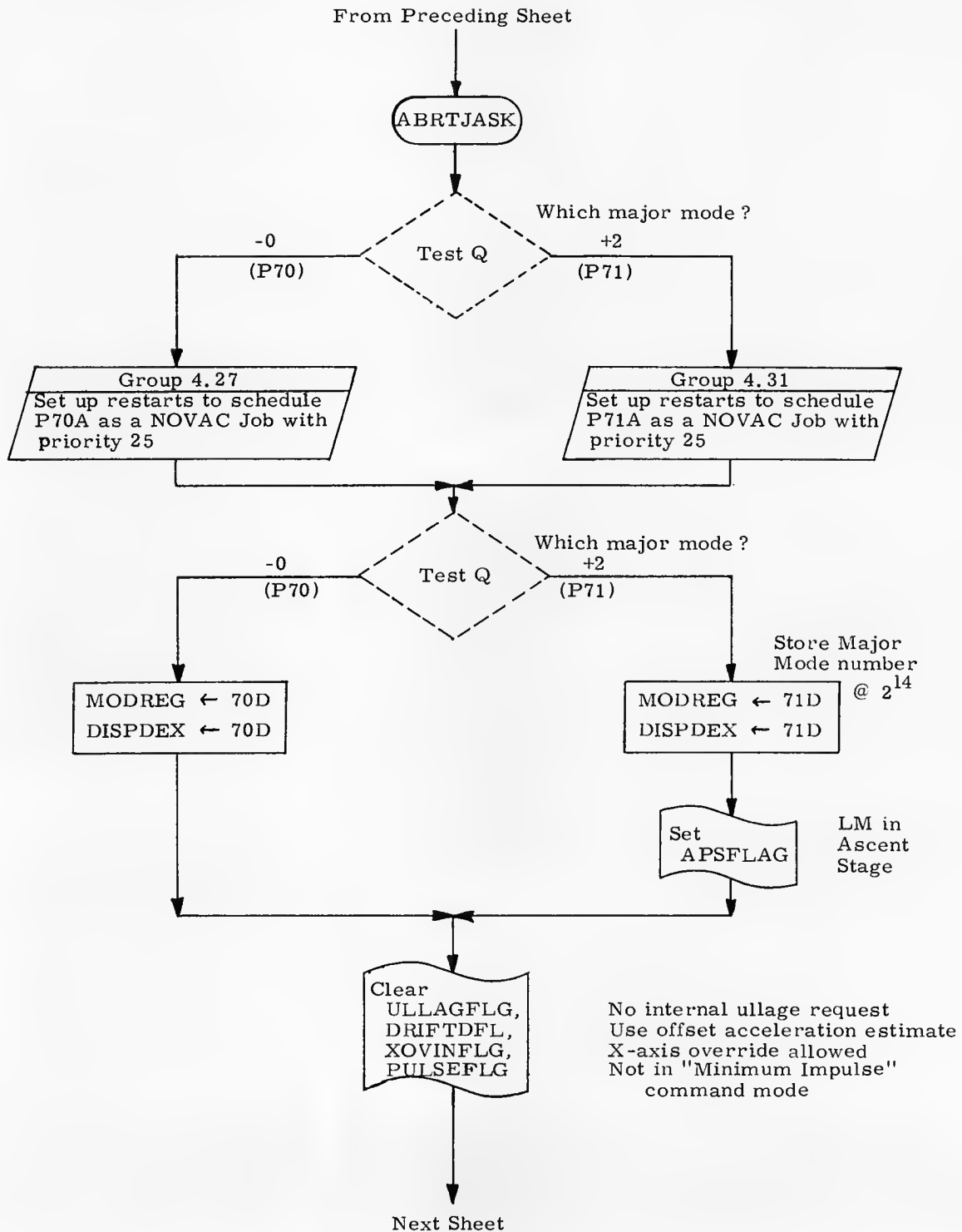
External Entry Points:

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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. Luchala</i> 11/25/69		Abort Programs	
PRGMR <i>J. Luchala</i> 11/26/69		LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3970
DOCMR <i>Robert M. Enter</i> 11/26/69		REV 3	SHEET 1 OF 25
APPR'D <i>Robert M. Enter</i> 11/26/69			



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		Abort Programs	
DRAWN	<i>A. D. Hart</i>	7-23-69	
PRGMR	<i>F. J. Gorman</i>	7/25/69	
ANALST	<i>F. J. Gorman</i>	7/25/69	LUMINARY 1D
DOCMR	<i>A. M. Servant</i>	7/23/69	DOCUMENT NO. FC-3970
APPR'D	<i>Alvin M. Servant</i>	7/25/69	REV 3
			SHEET 2 OF 25



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>F. J. Berman</i> 7/23/69		Abort Programs	
PRGMR <i>F. J. Berman</i> 7/23/69	ANALST <i>F. J. Berman</i> 7/23/69	LUMINARY 1D	DOCUMENT NO. FC-3970
DOCMR <i>A. M. Sorant</i> 7/23/69	APPR'D <i>Alex M. Sorant</i> 7/23/69	REV 3	SHEET 3 OF 25

From Preceding Sheet

DB ← 1DEGDB

Set DAP deadband to
1° @ 45

Set
ENGONFLG

Engine turned on

Clear bit 14,
set bit 13 of
Channel 11

Turn engine on

Set
LRBYPASS

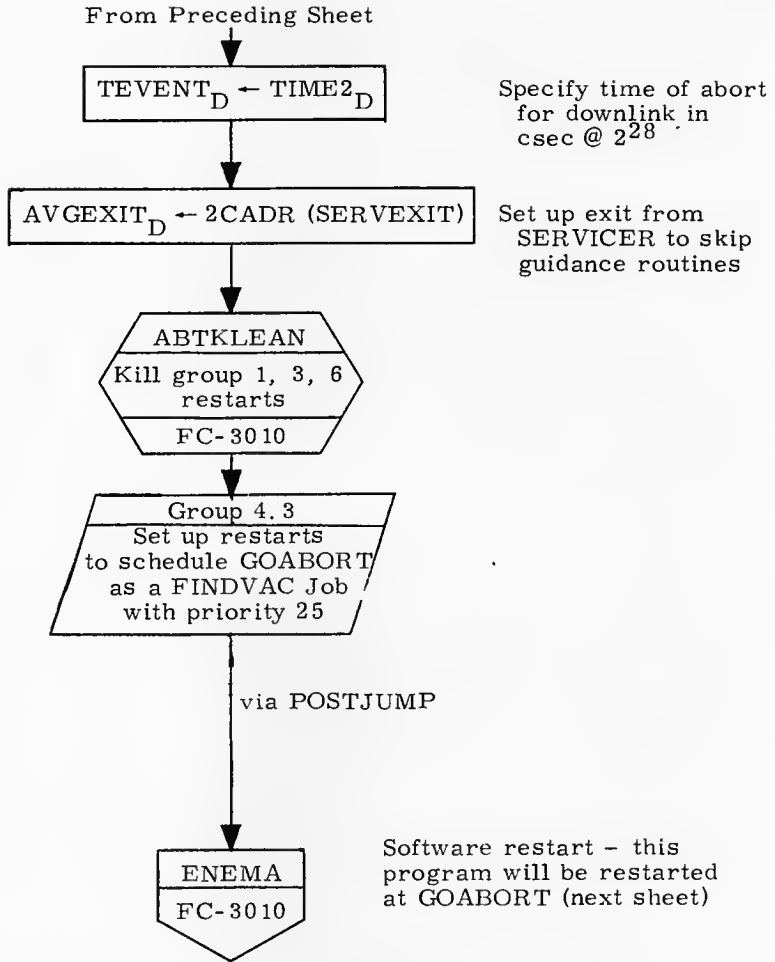
Bypass all landing radar
updates (R12)

Set
R10FLAG

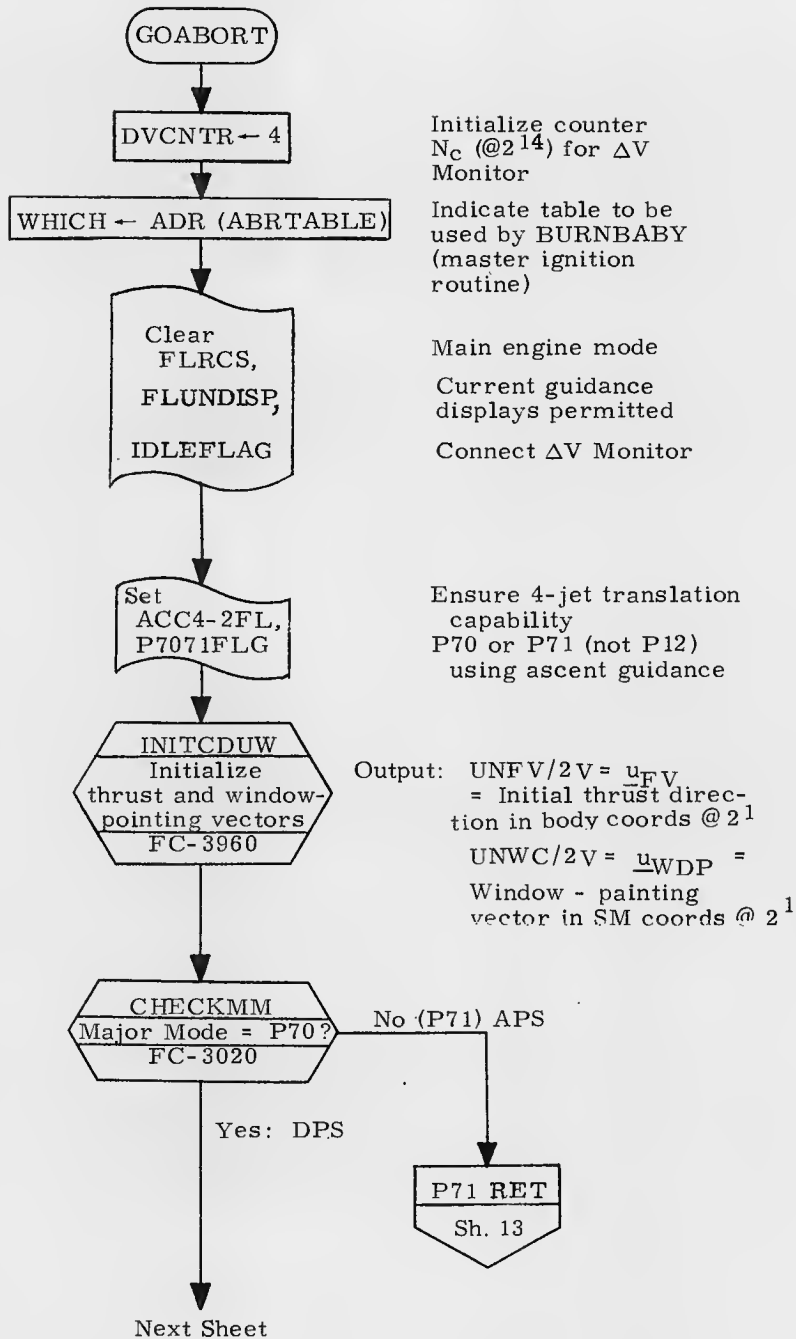
R10 will output
data to altitude,
altitude rate meters
only.

Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>R. Hart</i>	<i>7-23-69</i>	Abort Programs	
PRGMR	<i>L. J. Berman</i>	<i>10-16-69</i>	LUMINARY 1D	DOCUMENT NO. FC-3970
ANALST	<i>L. J. Berman</i>	<i>10-16-69</i>		
DOCMR				
APPR'D	<i>Robert M. Estes</i>	<i>10/14/69</i>	REV 3	SHEET 4 OF 25

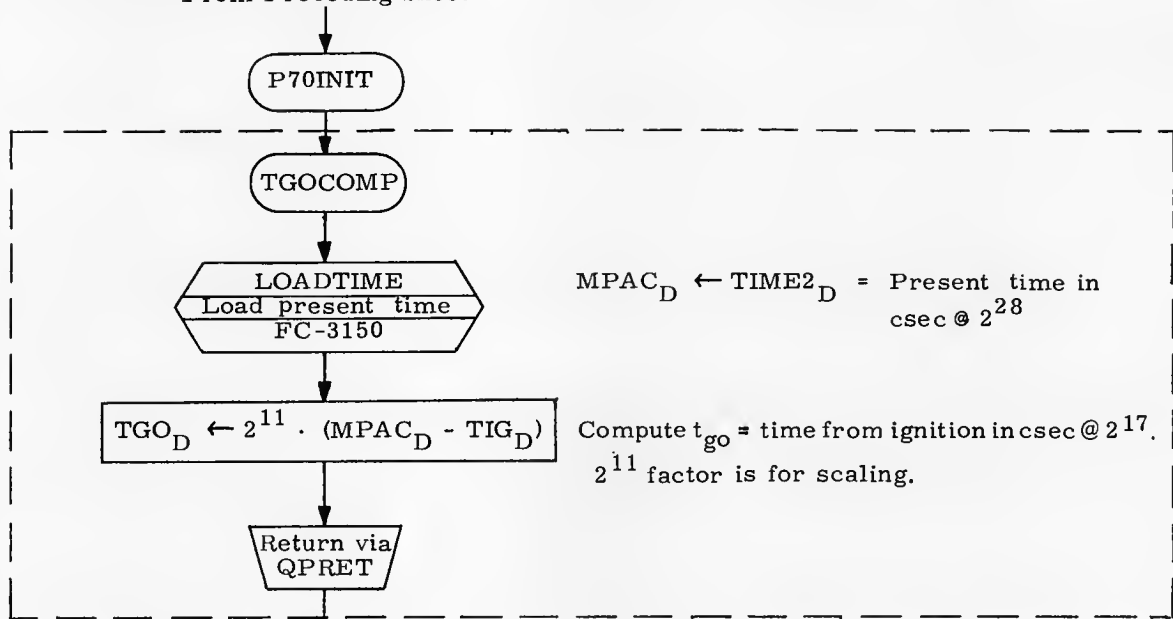


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>M. Putson</i>	7-23-69	Abort Programs	
PRGMR <i>R. J. Berman</i>	10-16-69	LUMINARY 1D	DOCUMENT NO. FC-3970
ANALST			
DOCMR			
APPR'D <i>Robert M. Estes</i>	10/14/69	REV 3	SHEET 5 OF 25



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		Abort Programs	
DRAWN	<i>F. West</i>	7-23-69	
PRGMR	<i>R. J. Berman</i>	10-16-69	
ANALST			
DOCMR			
APPR'D	<i>Robert M. Enter</i>	10/14/69	REV 3
		LUMINARY 1D	DOCUMENT NO. FC-3970
		SHEET 6 OF 25	

From Preceding Sheet



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

Compute t_{go} = time from ignition in csec @ 2^{17} . 2^{11} factor is for scaling.

$$\tau = \frac{m}{\dot{m}}$$

$$TBUP_D \leftarrow \frac{MASS_D}{2^4 \cdot MDOTDPS_D}$$

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.

$$\frac{1}{\Delta v_1} = \frac{1}{\Delta v_2} = \frac{1}{\Delta v_3} = \frac{1}{\Delta v_{IG}} = \frac{m}{\dot{m} V_e \Delta t}$$

$$MPAC_D \leftarrow \frac{MASS_D}{K(1/DV)_D \cdot 2}$$

$$1/DV1_D \leftarrow MPAC_D$$

$$1/DV2_D \leftarrow MPAC_D$$

$$1/DV3_D \leftarrow MPAC_D$$

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 $\frac{kg \cdot m}{csec} @ 2^9$

Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. M. Scaut</i> 7-23/69		Abort Programs	
PRGMR <i>J. J. Bernan</i> 7/25/69	ANALST <i>J. J. Bernan</i> 7/25/69	DOCUMENT NO.	FC-3970
DOCMR <i>A. M. Scaut</i> 7/23/69	APPR'D <i>A. M. Scaut</i> 7/25/69	LUMINARY 1D	REV 3
			SHEET 7 OF 25

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/csec² @ 2⁻⁹

where:

$$K(AT)_D = 1/\Delta t \text{ in csec}^{-1} @ 2^{-2}$$

$$TTO_D \leftarrow 100PCTTOD$$

Set $\Delta t_{\text{tail-off}}$ in csec @ 2¹⁷

where:

$$100PCTTOD = \Delta t_{\text{tail-off}} \text{ (DPS)}$$

in csec @ 2¹⁷

$$VE_D \leftarrow -2^{-2} \cdot \text{DPSVEX}$$

Set V_e = Exhaust velocity in m/csec @ 2⁷

where:

$$\text{DPSVEX} = -V_e \text{ (DPS)}$$

$$= \text{in m/csec} @ 2^5$$

2⁻² factor is for scaling.

COMMIT
Initialize
target parameters
 $R_D, Y_D, \dot{R}_D, \dot{Y}_D$
FC-3950

Input: $/LAND/_{D} = r_{LS}$ in m @ 2²⁴

$VRECTCSM_V = \underline{v}_c$ in reference coords

$RRECTCSM_V = \underline{r}_c$ in reference coords

Output: $RCO_D = R_D$ in m @ 2²⁴

$YCO_D = Y_D$ in m @ 2²⁴

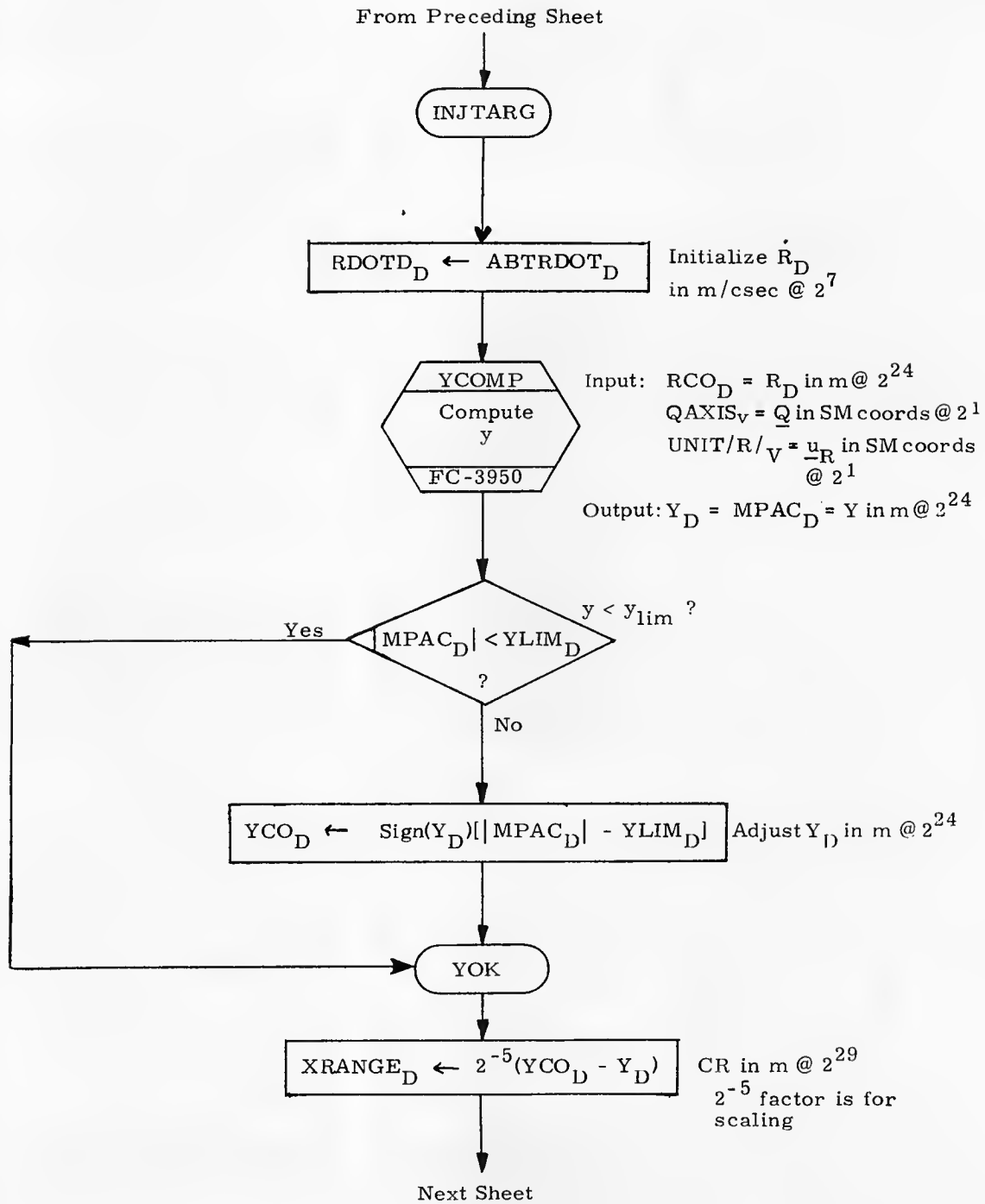
$YDOTD_D = \dot{Y}_D$ in m/csec @ 2⁷

$TXO_D = t_{x0}$ in csec @ 2²⁸

$QAXIS_V = \underline{Q}$ @ 2¹

Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>L. D. Hase</i> 7/23/69	Abort Programs	
PRGMR	<i>J. Bernan</i> 7/25/69	LUMINARY 1D	DOCUMENT NO.
ANALST	<i>J. Bernan</i> 7/25/69		FC-3970
DOCMR	<i>A. M. Grant</i> 7/23/69	REV 3	SHEET 8 OF 25
APPR'D	<i>Alfred M. Grant</i> 7/25/69		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		. APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. D. Kane</i> 7/23/69		Abort Programs	
PRGMR <i>J. Berman</i> 7/25/69		LUMINARY 1D	DOCUMENT NO.
ANALST <i>J. Berman</i> 7/25/69			FC-3970
DOCMR <i>R. M. Sorant</i> 7/23/69		REV 3	SHEET 9 OF 25
APPR'D <i>R. M. Sorant</i> 7/25/69			

From Preceding Sheet

Set
FLVR Vertical rise

THETCOMP
Compute
LM-CSM
phase
angle θ
FC-3950

Input: $R_V = R$ in m in SM coordinates
 $R(CSM)_V = R_c$ in m in SM coords
 $WM_V = \omega_\mu$ in rad/sec in SM coords

Output: $MPAC_D = \theta$ in revs @ 2°

$\theta \geq \theta_c ?$

No $MPAC_D \geq THETCRIT_D ?$ Yes

Set
ABTTGFLG J2, K2 parameters for abort targeting

STORPARM --- STORPARM

$JPARM_D \leftarrow J1PARM_D$ $JPARM_D \leftarrow J2PARM_D$
 $KPARM_D \leftarrow K1PARM_D$ $KPARM_D \leftarrow K2PARM_D$

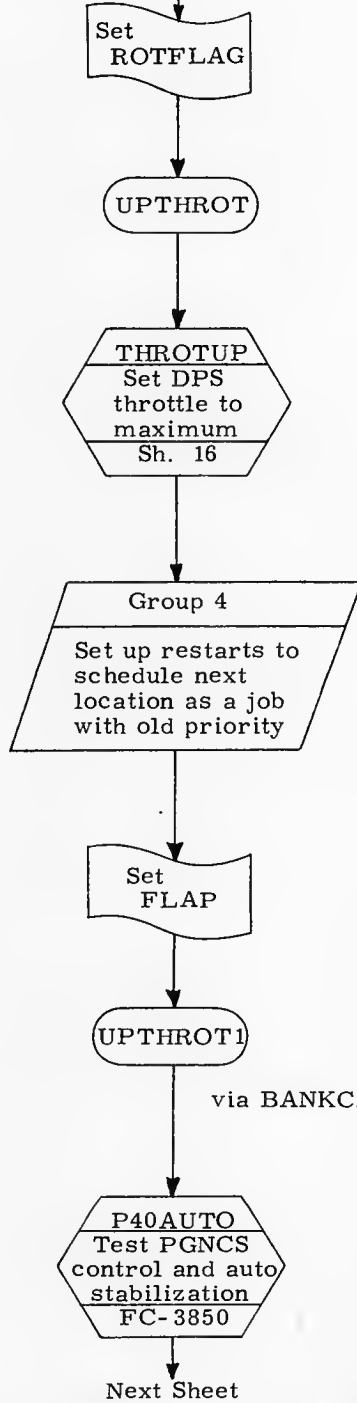
Set J in m @ 2^{23}
 K in m/rev @ 2^{23}

$R_P = R_D$ Initialize R_P in m @ 2^{24}
 $RP_D \leftarrow RCO_D$

Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R Hart</i>	<i>7/23/69</i>	Abort Programs	
PRGMR <i>P J Roman</i>	<i>10-16-69</i>	LUMINARY ID	DOCUMENT NO. FC-3970
ANALST		REV 3	SHEET 10 OF 25
DOCMR			

From Preceding Sheet



Force vehicle rotation in preferred direction

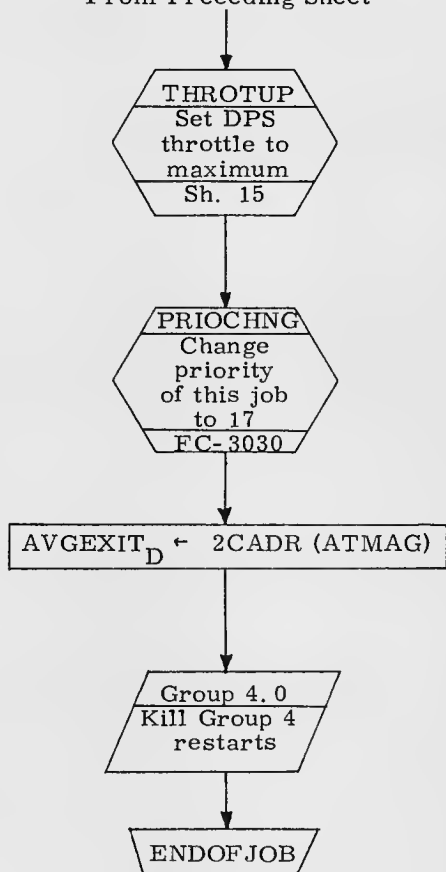
APS - continued abort

via BANKCALL

Astronaut should turn on auto stabilization and G&N switches if not on.

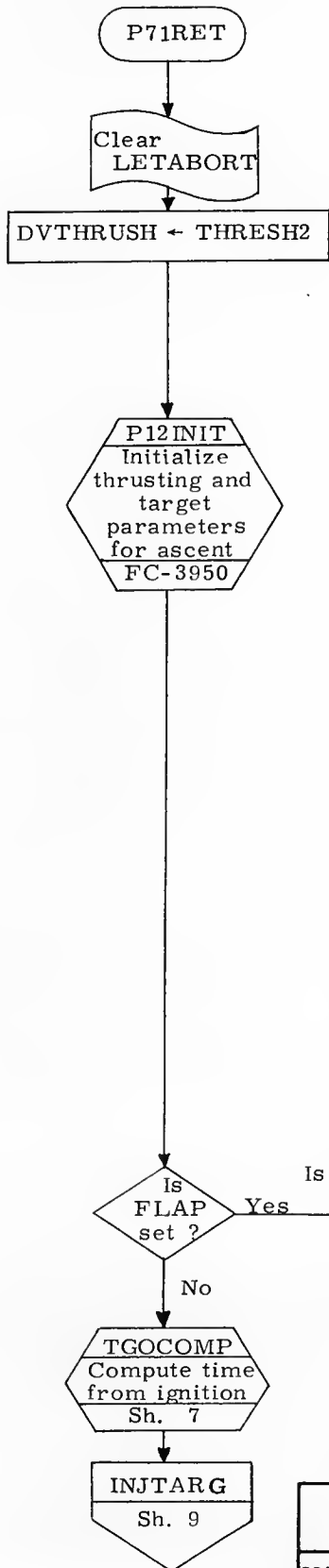
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>G. Welch</i> 10/16/69		Abort Programs	
PRGMR <i>F. J. Brennan</i> 10-16-69		LUMINARY 1D	DOCUMENT NO. FC-3970
ANALST			
DOCMR			
APPR'D <i>Robert M. Egan</i> 10/16/69		REV 3	SHEET 11 OF 25

From Preceding Sheet



Set up exit from SERVICER to ascent guidance computations at ATMAG (FC-3950)

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>R. J. Welch</i> 10/14/69		Abort Programs	
PRGMR <i>J. Bernan</i> 10-16-69		LUMINARY 1D	DOCUMENT NO. FC-3970
ANALST			
DOCMR			
APPR'D <i>Robert M. Euter</i> 10/14/69	REV 3	SHEET 12 OF 25	



Abort programs not allowed

Set Δv = minimum acceptable 2-second Δv to APS value
in m/csec @ $10^{-4} \times 2^{14}$

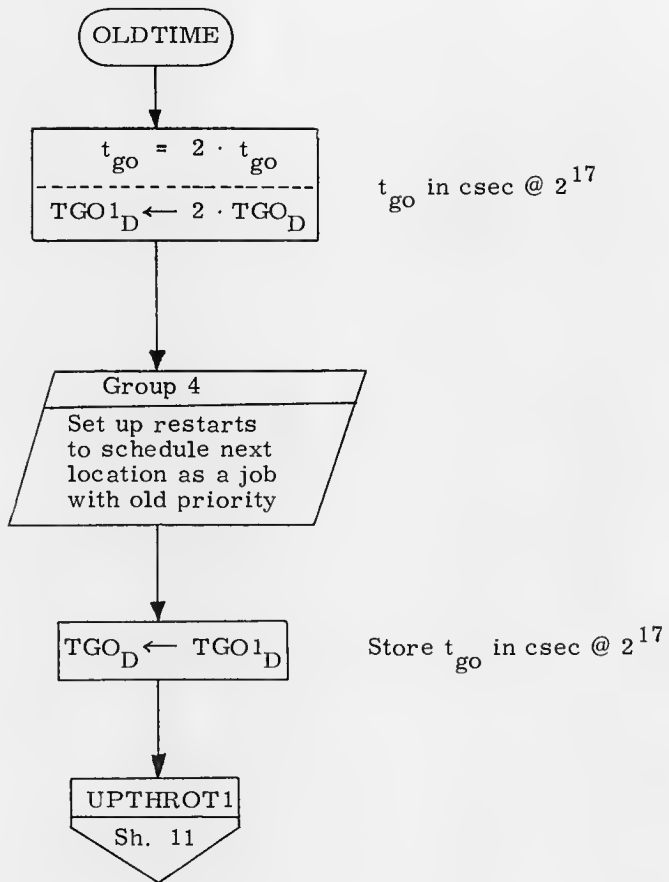
Input: $/LAND/D = r_{LS}$ in m @ 2^{24}
 $VRECTCSM_V = \underline{v}_c$ = CSM velocity in reference coords
 $RRECTCSM_V = \underline{r}_c$ = CSM position in reference coords

Output: $1/DV3_D, 1/DV2_D, 1/DV1_D$
 = thrust filter parameters in csec/m @ 2^7
 $AT_D = a_T$ in m/csec²₋₉ @ 2
 $TBUP_D = t$ in csec @ 2^{17}
 $TTO_D = \Delta t$ tail-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}
 $YDOTD_D = y_D$ in m/csec @ 2^7
 $QAXIS_V = \underline{Q}$ in SM coords @ 2^1

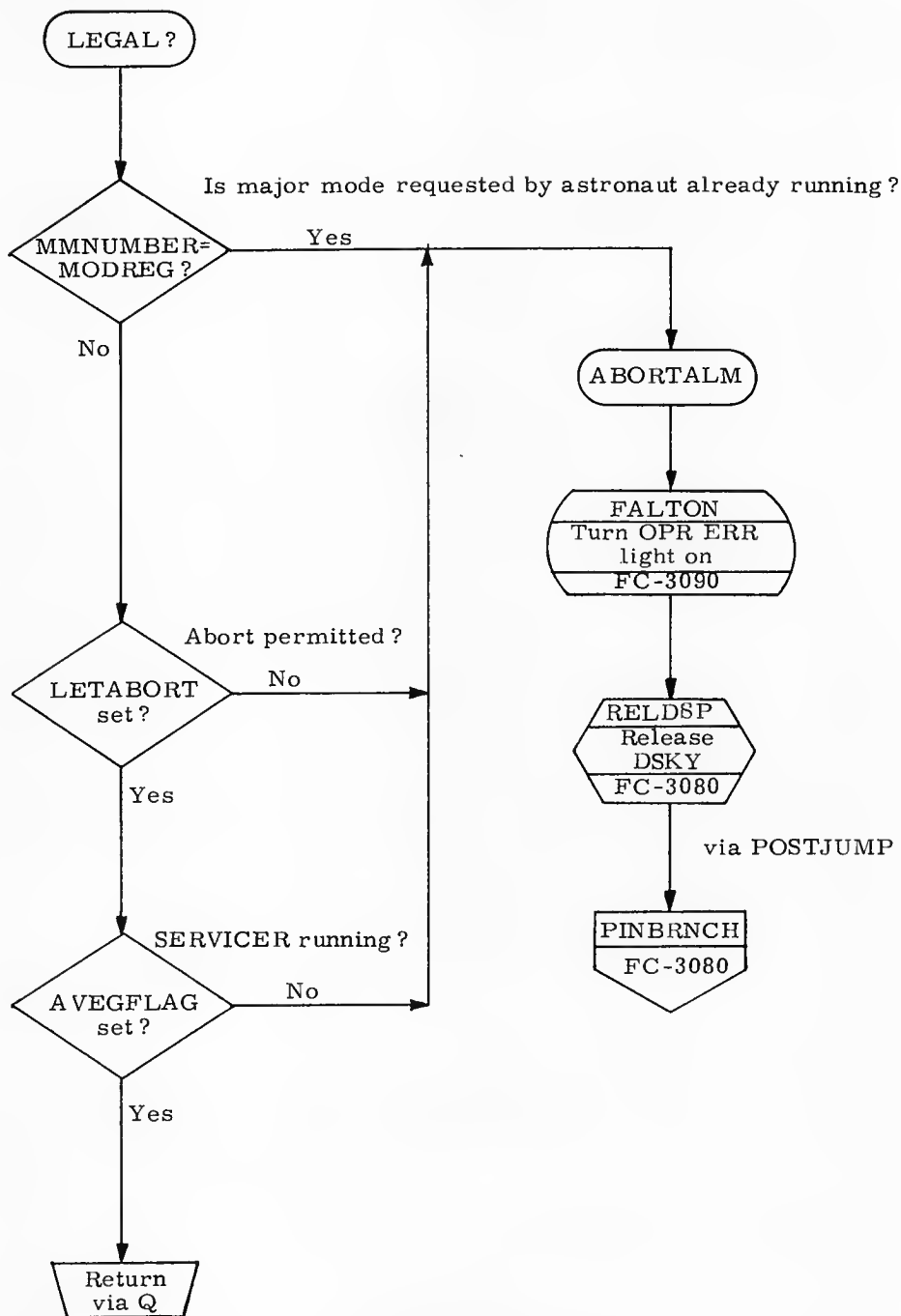
Is this APS continued abort after DPS staging?

Output: $TGO_D = t_{go}$ in csec @ 2^{17}

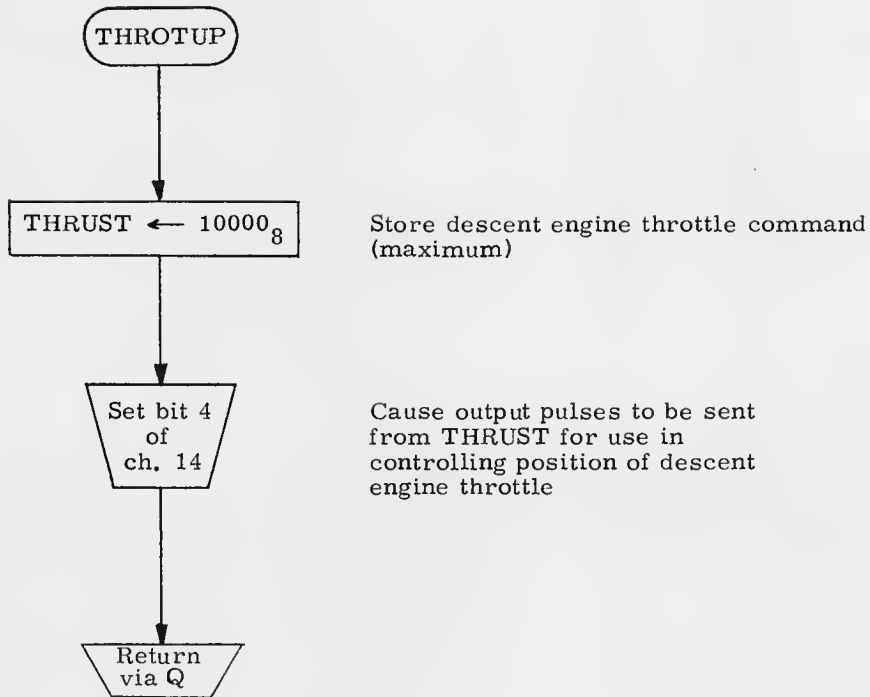
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>P. Welch</i>	<i>10/16/69</i>	Abort Programs	
PRGMR <i>J. Berman</i>	<i>10-16-69</i>	LUMINARY 1D	DOCUMENT NO. FC-3970
ANALST			
DOCMR			
APPR'D <i>Robert M. Estes</i>	<i>10/16/69</i>	REV 3	SHEET 13 OF 25



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>P. L. ...</i> 10/16/69		Abort Programs	
PRGMR <i>P. J. ...</i> 10-16-69		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3970
DOCMR		REV 3	SHEET 14 OF 25
APPR'D <i>Robert M. ...</i> 10/16/69			



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. J. Hart</i> 7/23/69		Abort Programs	
PRGMR <i>J. Berman</i> 7/23/69	LUMINARY ID	DOCUMENT NO.	
ANALST <i>J. Berman</i> 7/23/69		FC-3970	
DOCMR <i>A. M. Sarant</i> 7/23/69	REV 3	SHEET 15 OF 25	
APPR'D <i>L. M. Sarant</i> 7/23/69			



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>L. D. Hart</i> 7/25/68	Abort Programs	
PRGMR	<i>J. Berman</i> 7/25/68	LUMINARY 1D	DOCUMENT NO.
ANALST	<i>J. Berman</i> 7/25/68		FC-3970
DOCMR	<i>A. M. Sorant</i> 7/23/69	REV 3	SHEET 16 OF 25
APPR'D	<i>Alex M. Sorant</i> 7/25/69		

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 discretetes	Sh. 11
RELDSP	FC-3080	Release DSKY	Sh. 15
YCOMP	FC-3950	Compute cross-range distance Y	Sh. 9
Type		<u>DISPLAYS</u> Description of Registers	Where Called
Operator Error		OPR ERR light on; no effect on R1, R2, R3	Sh. 15

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>L. Goldstone</i>	Abort Programs	
PRGMR	<i>J. Brennan</i>		
ANALST		LUMINARY 1D	DOCUMENT NO. FC-3970
DOCMR			
APPR'D	<i>Robert M. Estes</i>	REV 3	SHEET 17 OF 25

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		
APSFFLAG (bit 13 of flagword 10)	LM in Ascent Stage	LM in Descent Stage	Sh. 3		
AVEGFLAG (bit 5 of flagword 7)	SERVICER is running	SERVICER is not running			Sh. 15
DRIFTDFL (bit 8 of flagword 13)	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	

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. Johnson</i>	<i>11/1/69</i>	Abort Programs	
PRGMR <i>P.J. Servino</i>	<i>10-26-69</i>	DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3970
DOCMR		REV 3	SHEET 18 OF 25
APPR'D <i>Robert M. Estes</i>	<i>10/16/69</i>		

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	
P7OP7IFLG (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	

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>L. Goldstein</i>	<i>11/1/68</i>	Abort Programs	
PRGMR <i>F. J. Berman</i>	<i>10-16-68</i>	DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3970
DOCMR		REV 3	SHEET 19 OF 25
APPR'D <i>Robert M. Enter</i>	<i>10/16/68</i>		

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		

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>L. Orlinone</i>	<i>10/1/69</i>	Abort Programs	
PRGMR <i>M. Berman</i>	<i>10-16-69</i>	DOCUMENT NO.	
ANALST		LUMINARY 1D FC-3970	
DOCMR		REV 3	
APPR'D <i>Robert M. Ewing</i>	<i>10/14/69</i>	SHEET 20 OF 25	

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	Q	Q - axis of target coordinate system, in SM coordinates			2 ¹

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>L. Johnston</i>	<i>10/2/69</i>	Abort Programs	
PRGMR <i>F. J. Berman</i>	<i>10-16-69</i>	LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3970
DOCMR		REV 3	SHEET 21 OF 25
APPR'D <i>Robert M. Ester</i>	<i>10/16/69</i>		

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	2 ²⁸
TEVENT _D	t _{EVENT}	Time of relevant event, for downlink	sec	csec	
THRUST		Commanded DPS engine throttle position			
TIG _D	t _{IG}	Time of ignition	sec	sec	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	ω_M	Moon rotational velocity in SM coordinates	rad/sec	rad/csec	2 ⁻¹⁷

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>L Goldstone</i>	10/2/69	Abort Programs	
PRGMR <i>J Bernan</i>	10-16-69	DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3970
DOCMR		REV 3	SHEET 22 OF 25
APPR'D <i>Robert M. Estes</i>	10/16/69		

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
YDOT _D	Y _D	Desired cross - range velocity	m/sec	m/csec	2 ⁷
/LAND/D	r _L S	Landing site radius	m	m	2 ²⁴
1/DV1 _D	$\frac{1}{\Delta v_1}$	Second 1/Δv thrust filter parameter	sec/m	csec/m	2 ⁷
1/DV2 _D	$\frac{1}{\Delta v_2}$	Third 1/Δv thrust filter parameter	sec/m	csec/m	2 ⁷
1/DV3 _D	$\frac{1}{\Delta v_3}$	Fourth 1/Δv thrust filter parameter	sec/m	csec/m	2 ⁷

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>J. Robinson</i> 10/16/69		Abort Programs	
PRGMR <i>J. Berman</i> 10-16-69		DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3970
DOCMR		REV 3	SHEET 23 OF 25
APPR'D <i>Robert M. Estlin</i> 10/16/69			

CONSTANTS

AGC Tag	GSP 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 $\Delta t = 2$ seconds	.5 sec ⁻¹	.005 csec ⁻¹	2^{-2}
K(1/DV) _D	$mV_e \left(\frac{\Delta t}{2}\right)$	Constant (mV . 1 sec) used in computation of initial $1/\Delta v$ parameters	43670 kg-m/sec	436.7 kg-m/csec	2^9 2^2
MDOTDPS _D	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	$10^{-4} \times 2$ $+14$
100PCTTOD	$\Delta t_{tail-off}$ (DPS)	DPS tail-off time (from 100 % thrust)	.38 sec	38 csec	2^{17}

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>L. Galatone</i>	<i>10/2/69</i>	Abort Programs	
PRGMR <i>F. J. Serman</i>	<i>10-16-69</i>	DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3970
DOCMR		REV 3	SHEET 24 OF 25
APPR'D <i>D. W. ...</i>	<i>10/16/69</i>		

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 (see above) when LM-CSM phase angle is less than 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}

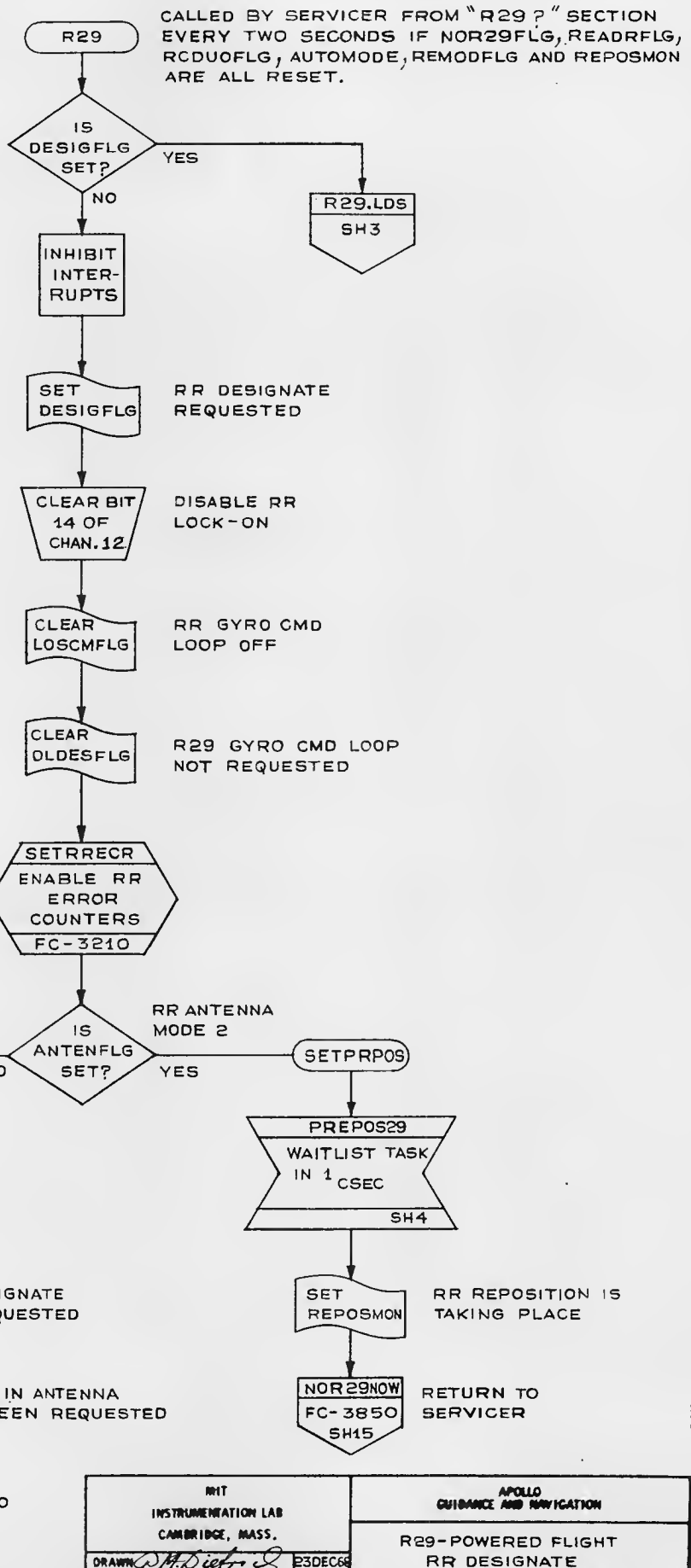
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	<i>L. Goldstone</i> 10/12/69	Abort Programs	
PRGMR	<i>P. Berman</i> 10-16-69	DOCUMENT NO.	
ANALST		LUMINARY 1D	FC-3970
DOCMR		REV 3	SHEET 25 OF 25
APPR'D	<i>Robert M. Entin</i> 10/14/69		

R29 - POWERED FLIGHT RR DESIGNATE
 MAJOR SUBROUTINES ON THIS CHART

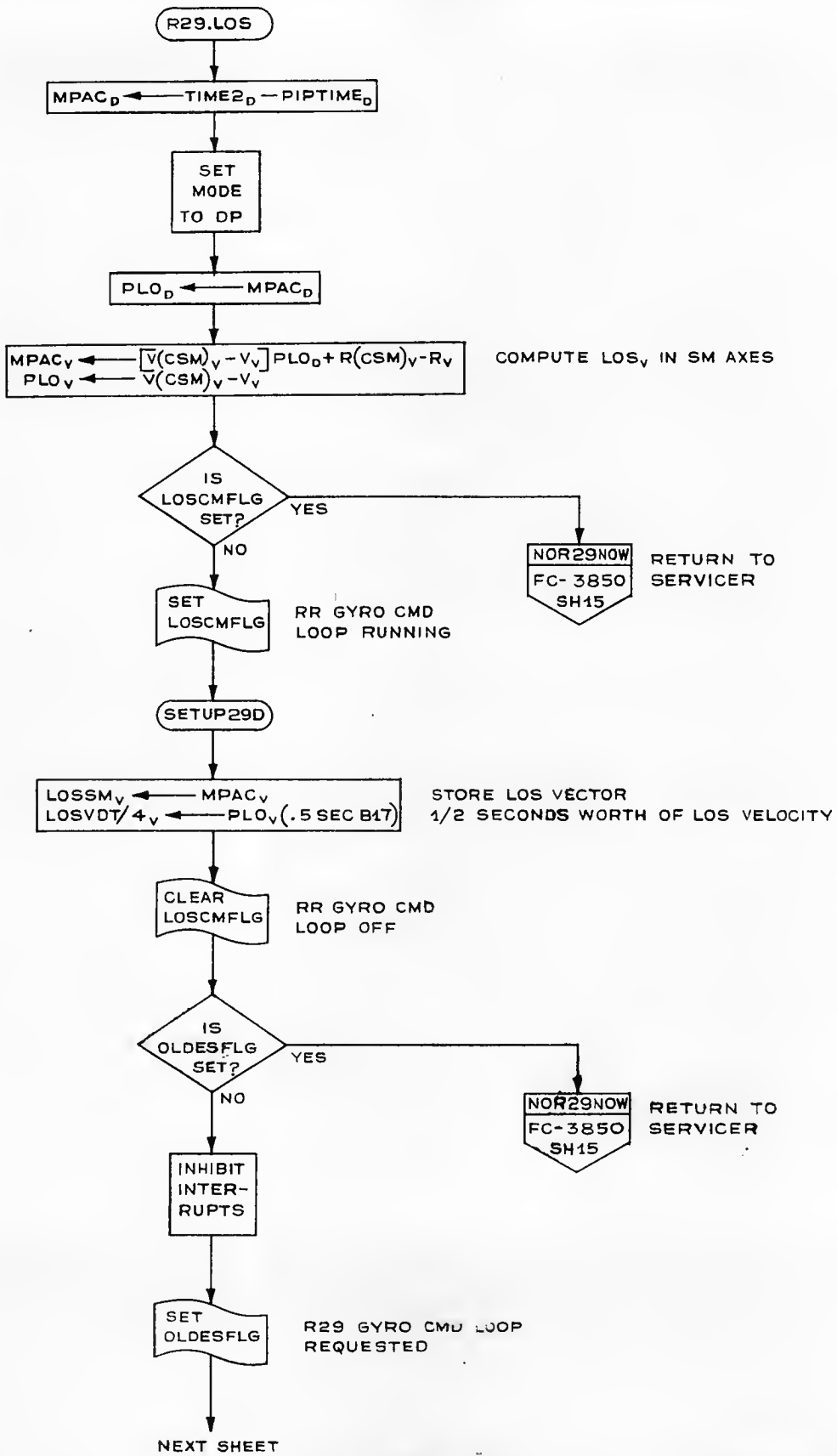
R29

Sh. 2

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>A. L. Wolfe</i>	<i>9/22/68</i>	R29-Powered Flight RR Designate	
PRGMR <i>Ray R. ...</i>	<i>10/9/69</i>	LUMINARY 1D	DOCUMENT NO.
ANALST			FC-3980
DOCMR <i>W. D. ...</i>	<i>10/1/69</i>	REV 3	SHEET 1 OF 14
APPR'D <i>R. ...</i>	<i>10/19/67</i>		

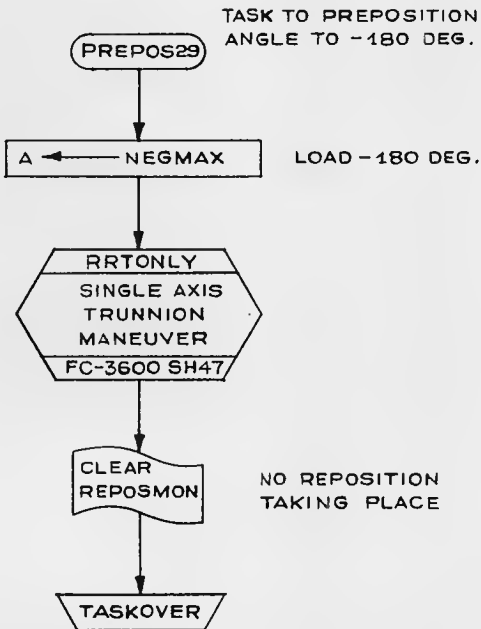
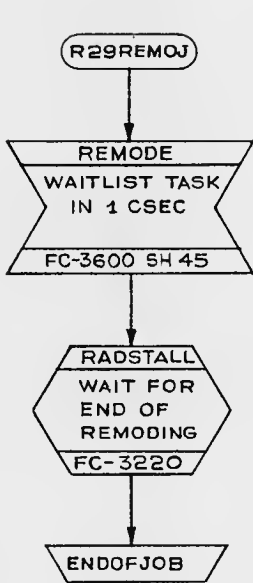
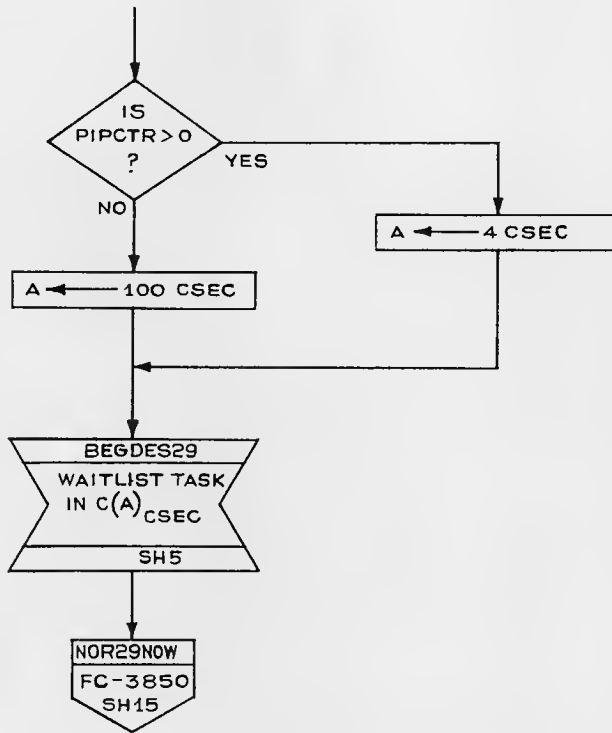


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		R29-POWERED FLIGHT RR DESIGNATE	
DRAWN <i>[Signature]</i>	23DEC68	LUMINARY 1D	DOCUMENT NO. FC-3980
PRGMR <i>[Signature]</i>	22MAY69		
ANALST			
DOCNR <i>[Signature]</i>	21MAY69		
APPR'D <i>[Signature]</i>	REV 3	SHEET 2 OF 14	



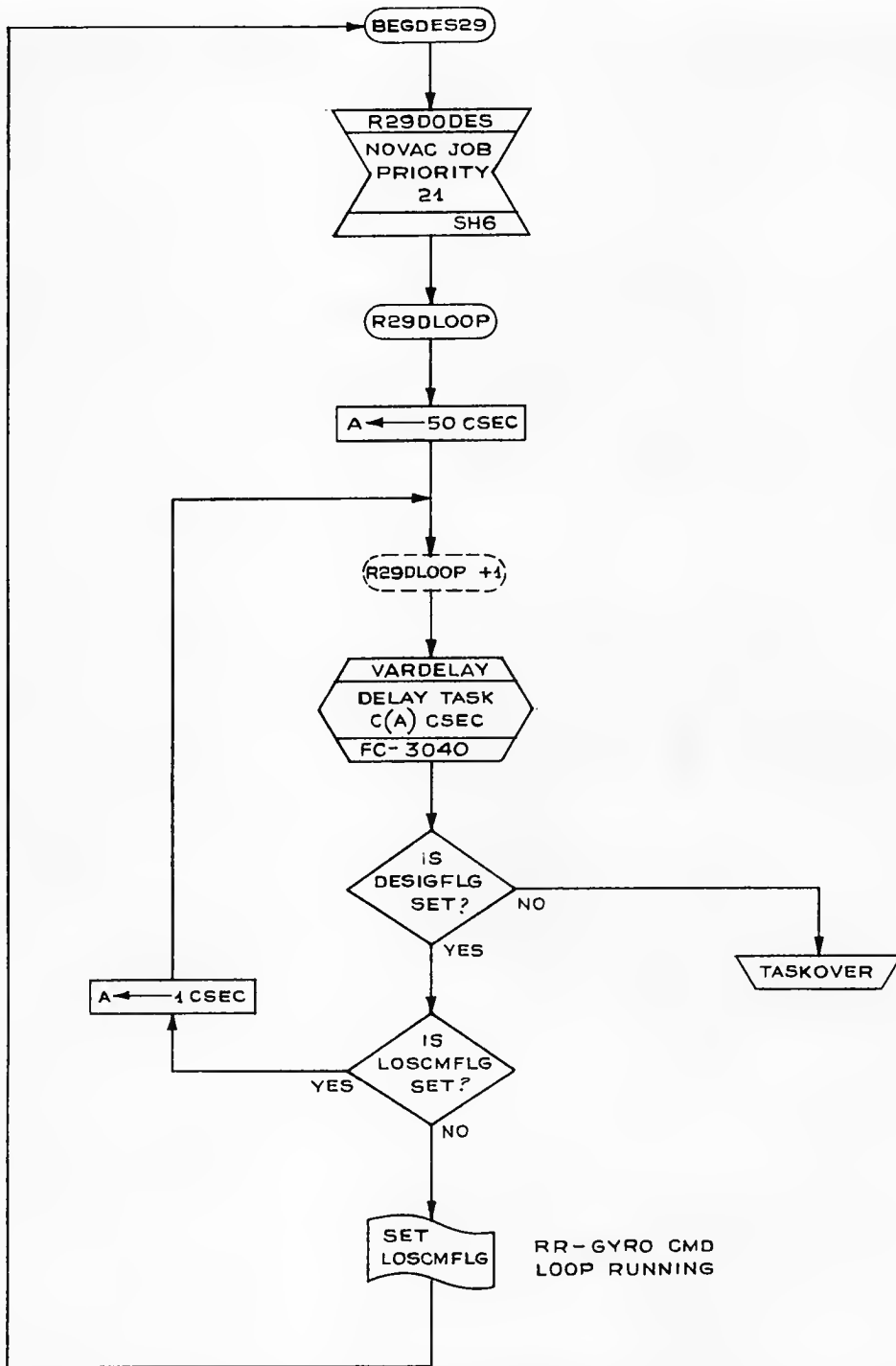
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		R29 - POWERED FLIGHT RR DESIGNATE	
DRAWN <i>DM Dickerson</i>	23DEC68	LUMINARY 1D	DOCUMENT NO.
PROGRM <i>High Rate Loop</i>	21MAY69		FC-3980
ANALST			
DOCNR <i>21MAY69</i>	21MAY69		
APPR'D <i>John W. Smith</i>	22MAY69	REV	SHEET 3 OF 14

FROM PRECEDING SHEET

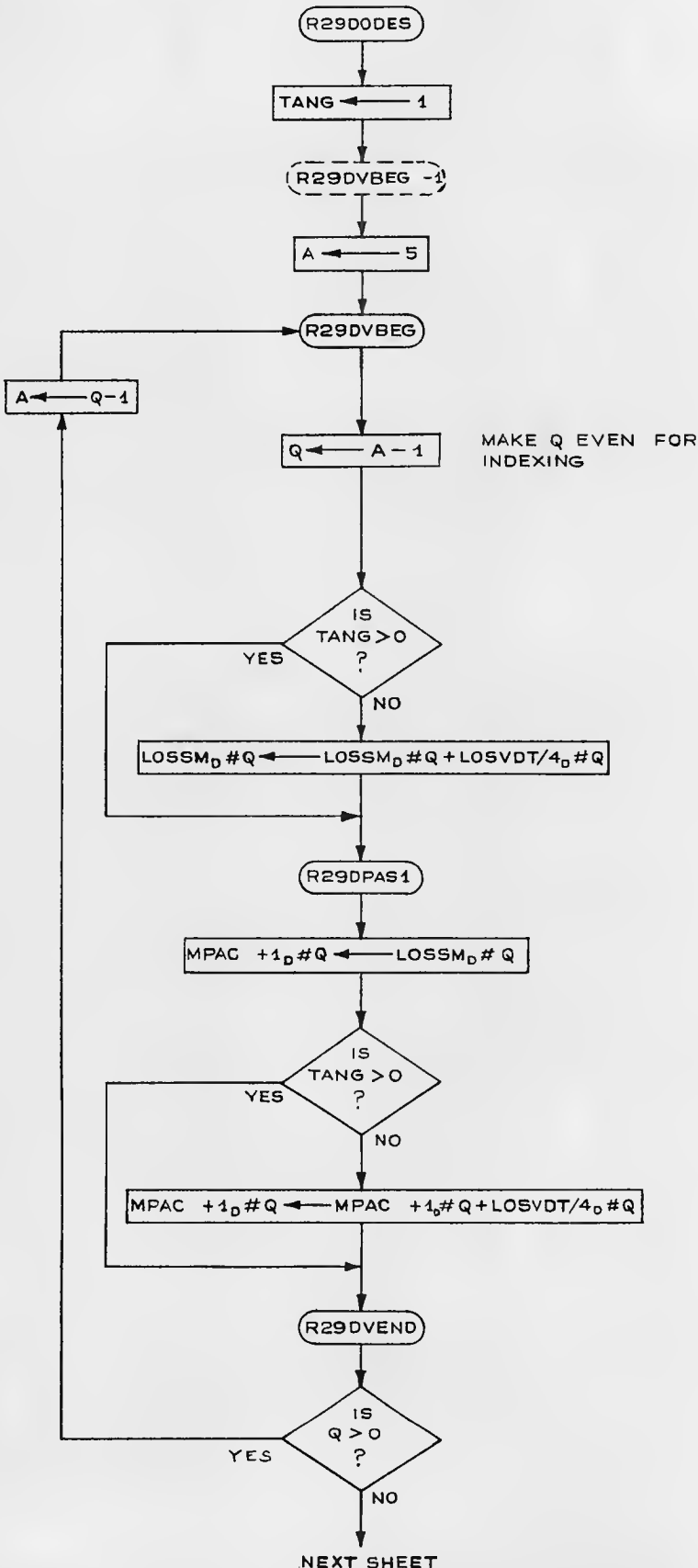


TASK TO PREPOSITION RR TRUNNION ANGLE TO -180 DEG.

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>M. DeJong</i> 26 DEC 68		R29 - POWERED FLIGHT RR DESIGNATE	
PROGRAM <i>High Rate Servo</i> 22 MAY 69	ANALYST	LUMINARY 1D	DOCUMENT NO.
DOCWR <i>M. DeJong</i> 21 MAY 69	APPR'D <i>David M. Stewart</i> 22 MAY 69	REV 3	FC-3980
			SHEET 4 OF 14



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i> 26 DEC 63		R29-POWERED FLIGHT RR DESIGNATE	
PROGRAM <i>[Signature]</i> 22 MAY 64	ANALYST	LUMINARY 1D	DOCUMENT NO. FC-3980
DOOR <i>[Signature]</i>	APPROV <i>[Signature]</i>	REV 3	SHEET 5 OF 14



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>P.M. Dickson</i>		R29-POWERED FLIGHT RR DESIGNATE	
PRGMR <i>Hugh H. ...</i>	27DEC68	LUMINARY ID	DOCUMENT NO.
ANALST	22 MAY 69		FC-3980
DOCMR <i>W.D. ...</i>	21 MAY 69		
APPR'D <i>...</i>	22 MAY 69	REV 3	SHEET 6 OF 14

FROM PRECEDING SHEET

MPAC_D ← MPAC + 1_D

FIXLOC ← R29FXLOC

MPAC_V ← UNIT (MPAC_V)

MPACVBUF
MOVE MPAC_V
INTO VBUF_V
FC-3070

INPUT : MPAC_V = INPUT VECTOR
OUTPUT : VBUF_V = OUTPUT VECTOR

IS
TANG > 0
?

NO

YES

INHIBIT
INTER-
RUPTS

SAVECDUT_D ← CDUT_D
CDUSPOT ← CDUY
CDUSPOT + 2 ← CDUZ
CDUSPOT + 4 ← CDUX

QUICTRIG
COMPUTE SINES
AND COSINES OF
INPUT ANGLES
FC-3320

INPUT : CDUSPOT, +2, +4 = INPUT ANGLES
OUTPUT : SINCDU, +2, +4 = SINE OF INPUT ANGLES
COSCDU, +2, +4 = COSINE OF INPUT ANGLES

GOTANGLS

A ← -3

AX*SR*
TRANSFORM
INPUT UNIT
LOS VECTOR
FC-3320

INPUT : A = -3
VBUF_V = INPUT UNIT LOS VECTOR IN SM
COORDINATES
OUTPUT : VBUF_V = UNIT LOS VECTOR IN NB COORDINATES

IS
TANG > 0
?

NO

YES

R29DPAS2
SH9

INHIBIT
INTER-
RUPTS

NEXT SHEET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>[Signature]</i> 7MAY 69		R29-POWERED FLIGHT RR DESIGNATE	
PROGRAM <i>[Signature]</i> 22 MAY 69	ANALYST	LUMINARY ID	DOCUMENT NO.
DOCNR <i>[Signature]</i> 21 MAY 69	APPR'D <i>[Signature]</i> 22 MAY 69	FC-3980	FC-3980
REV 3		SHEET 7 OF 14	

FROM PRECEDING SHEET

TANG ← TANG - 1 = 0

PUSHLOC ← COS(SAVECDUT) COS T
MODE ← SIN(-SAVECDUT) -SIN T

MPAC_D ← SIN(-SAVECDUT)(VBUF + 2) -SIN T (ULOSNB Y)

SAVECDUT ← SIN(SAVECDUT + 1) SIN S

MPAC_D ← MPAC_D + SAVECDUT (PUSHLOC) VBUF -SIN T (ULOSNB Y) + SIN S (COS T) ULOSNB X

SAVECDUT + 1 ← COS(SAVECDUT + 1) COS S

MPAC_D ← MPAC_D + (SAVECDUT + 1) PUSHLOC (VBUF + 4) -SIN T (ULOSNB Y) + SIN S (COS T) ULOSNB X + COS S (COS T) ULOSNB Z
= 1/2 COS (ERROR) BECAUSE ULOSNB IS A HALF-UNIT VECTOR.

TESTCOS

MPAC_D ← 2(MPAC_D)

DID MPAC_D OVERFLOW?
YES
NO

WRITE BIT 14 OF CHAN. 12

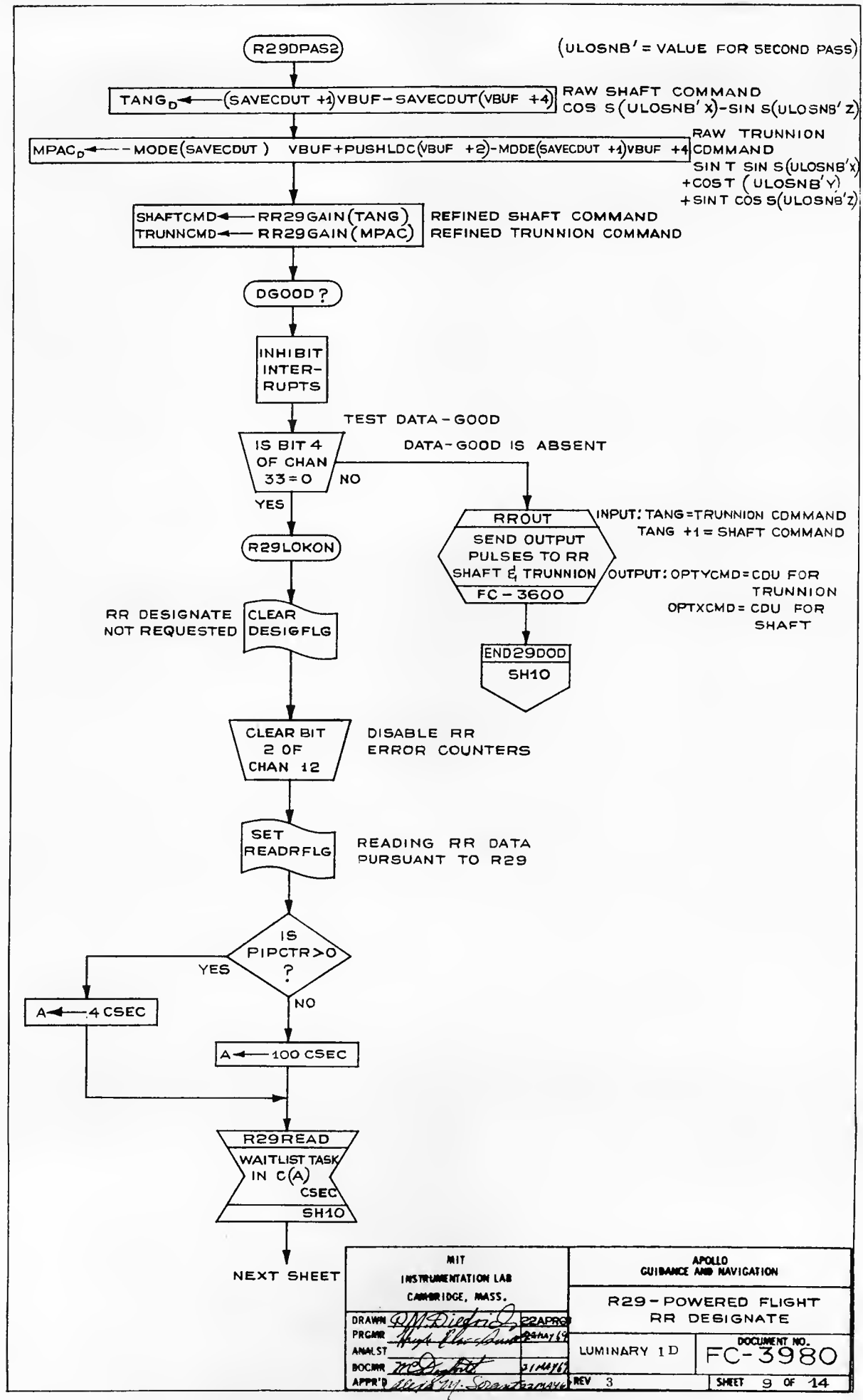
ENABLE RR LOCK-ON

ALLOW INTERRUPTS

R29DVBEG - 1

SH 6

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D.M. Dickson</i> 22 APR 69		R29 - POWERED FLIGHT RR DESIGNATE	
PRGMR <i>Hugh Blair</i> 22 MAY 69	ANALST	LUMINARY ID	DOCUMENT NO. FC-3980
DOCMR <i>M. DeFrost</i> 21 MAY 69	APPR'D <i>David W. Swann</i> 22 MAY 69	REV 3	SHEET 8 OF 14



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>DM Dietrich</i> 22APRO		R29 - POWERED FLIGHT RR DESIGNATE	
PRGRM <i>High Elec Serv</i> 22MAY 69		LUMINARY 1D	DOCUMENT NO.
ANALST <i>MC Dietrich</i> 21MAY 69			FC-3980
BOCMR <i>MC Dietrich</i> 21MAY 69		REV 3	SHEET 9 OF 14
APPR'D <i>W. J. S. O'Connell</i>			

FROM PRECEDING SHEET

END29DOD

CLEAR
LOSCMFLG

RR GYRO CMD
LOOP OFF

ENDOFJOB

R29READ

R29RDJOB
NOVAC JOB
PRIORITY
26
SH11

A ← 2 SECS

VARDELAY
DELAY TASK
2 SEC.
FC-3040

READING STILL
ALLOWED

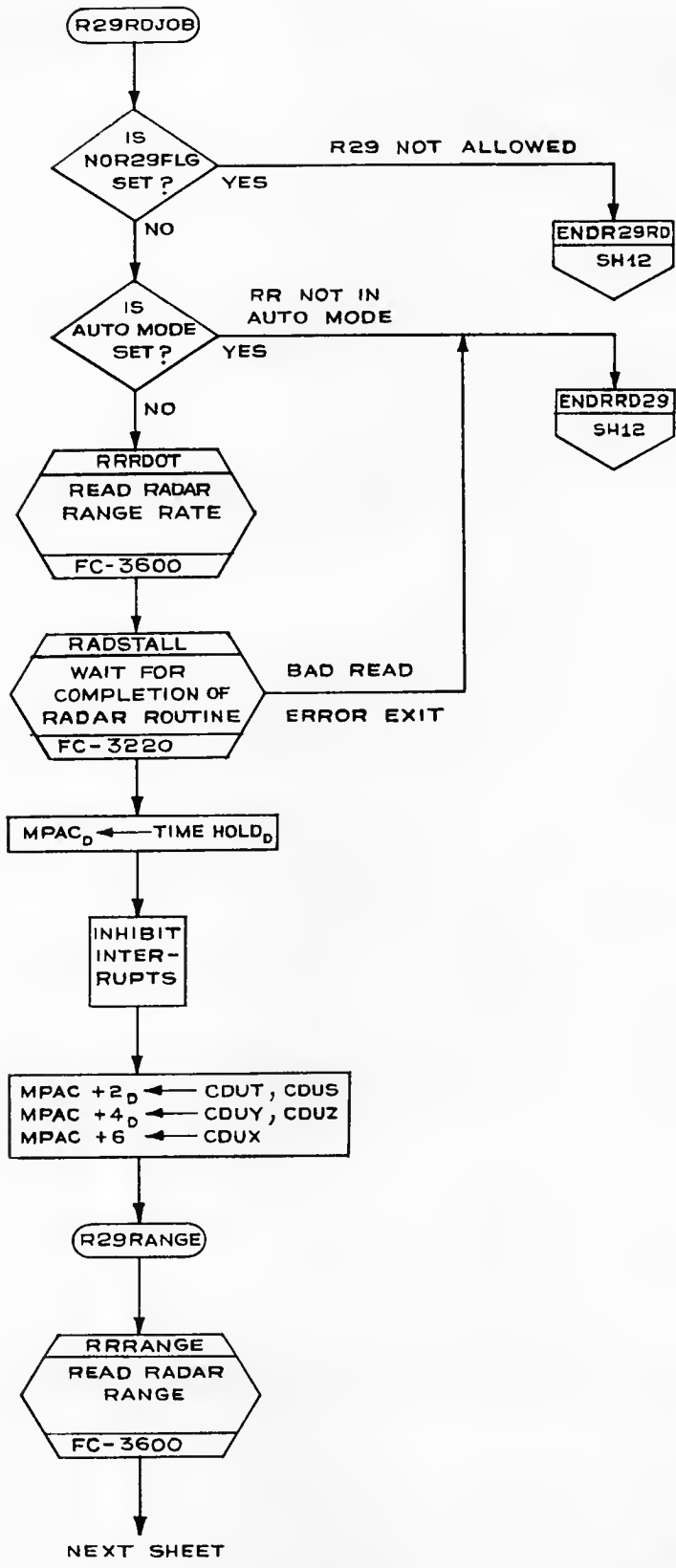
YES

IS
READRFLG
SET
?

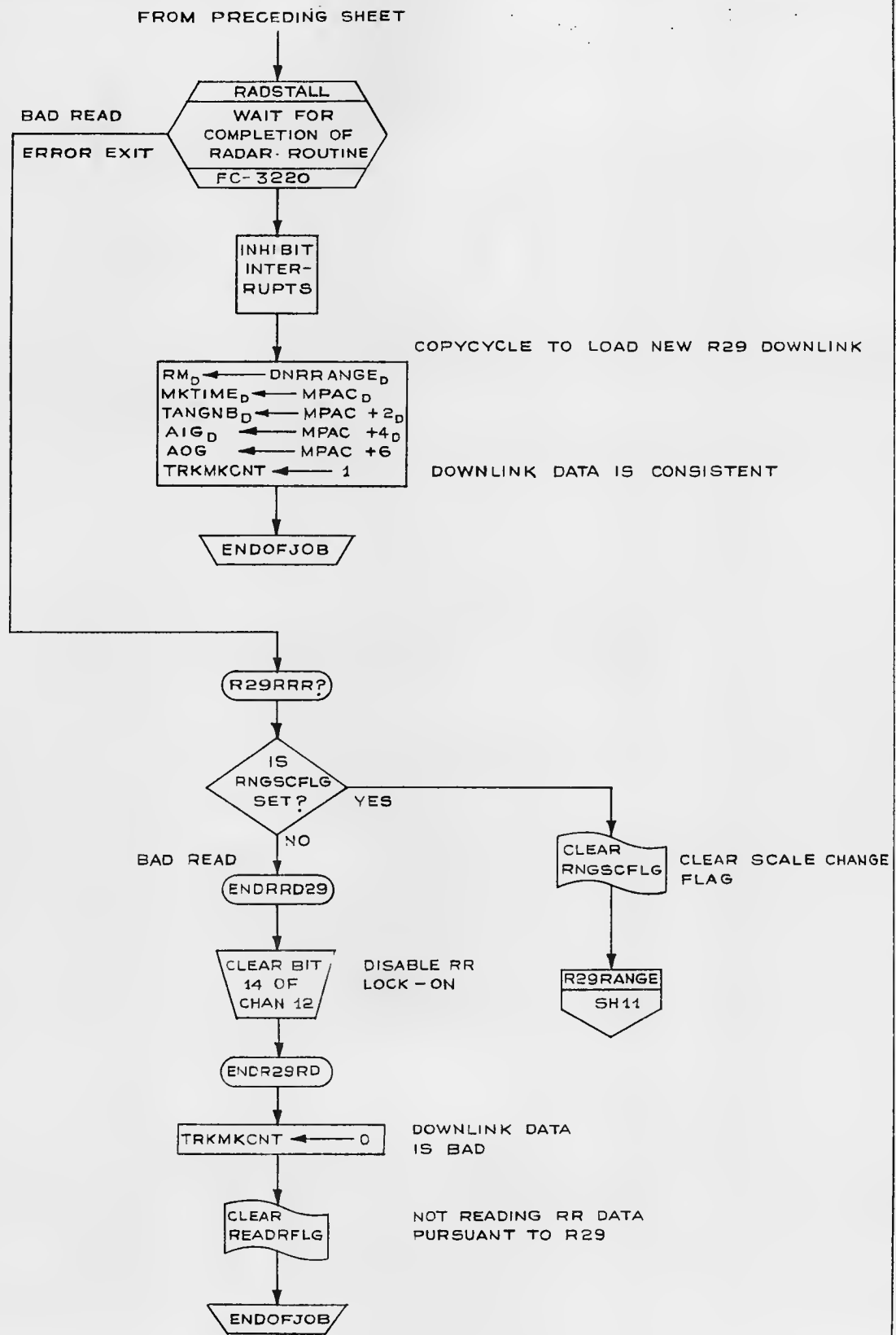
NO

TASKOVER

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>P.M. Dietrich</i>		R29-POWERED FLIGHT RR DESIGNATE	
PRGMR <i>Henry H. ...</i>	22 APR 68	LUMINARY 1D	DOCUMENT NO. FC-3980
ANALST	22 MAY 68	REV 3	SHEET 10 OF 14
DOCMR <i>W.D. ...</i>	21 MAY 68		
APPR'D <i>Henry H. ...</i>	22 MAY 68		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>P.M. Dyer</i>		R29-POWERED FLIGHT RR DESIGNATE	
PRGMR <i>Rich. W. Smith</i>	23 APR 65	LUMINARY 1D	DOCUMENT NO.
ANAL ST	22 MAY 67		FC-3980
DOCNR <i>77-01-01-01</i>	1 MAY 67		
APPR'D <i>Rich. W. Smith</i>	22 APR 67	REV 3	SHEET 11 OF 14



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>P.M.D. [Signature]</i>		R29-POWERED FLIGHT RR DESIGNATE	
PRGMR <i>High [Signature]</i>	23 APR 65	LUMINARY ID	DOCUMENT NO.
ANALST	22 MAY 65		FC-3980
DOCNR <i>W.D. [Signature]</i>	21 MAY 65	REV 3	SHEET 12 OF 14
APPR'D <i>[Signature]</i>	22 MAY 65		

ERASABLE LOCATIONS USED

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
LOSSM _V	\underline{L} LOS	LINE OF SIGHT VECTOR	METERS	METERS	2^{24}
LOSVIDT/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
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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

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN <i>D.M. Dugan</i>		R29 - POWERED FLIGHT RR DESIGNATE	
PROGR <i>Hubb Pm - 6-22-68</i>	EAAPRES	LUMINARY ID	DOCUMENT NO. FC-3980
ANALST			
DOCNR <i>112-1000</i>	21 MAY 68		
APPR'D <i>W. J. ...</i>	REV 3		SHEET 13 OF 14

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		
REPOSOMON 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 <i>[Signature]</i> 23 APR 69		R29-POWERED FLIGHT RR DESIGNATE	
PROGRAM <i>[Signature]</i> 22 MAY 69	ANALYST	LUMINARY 1D	DOCUMENT NO. FC-3980
BDCAM <i>[Signature]</i> 21 MAY 69	APPROV <i>[Signature]</i> 22 MAY 69	REV 3	SHEET 14 OF 14

13.0 INDEX

INDEX

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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NBSM	FC-3600	CALLED	42	
NBSM	FC-3900	CALLED	31	
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SMNB	FC-3520	CALLED	20	
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ABTKLEAN	FC-3970	CALLED	5	
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G&N,AUTO	FC-3840	CALLED	11		
GAMCOMP	FC-3355	ENTRY	24		
GCOMP SUB	FC-3230	ENTRY	10		
GCOMPZER	FC-3520	CALLED	17		
GENTRAN	FC-3050	ENTRY	9		
GENTRAN	FC-3605	CALLED	2		
GEOM	FC-3360	ENTRY	35		
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GETDT	FC-3820	ENTRY	3		
GET.LVC	FC-3710	CALLED	3		
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GOMARKF	FC-3120	CALLED	4,5,6		
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GOODEND	FC-3530	CALLED	14		
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GOPERF4R	FC-3510	CALLED	2		
GOPIN	FC-3440	ENTRY	37		
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GOPROG2	FC-3140	CALLED	13,18		
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GPMATRIX	FC-3210	ENTRY	57		
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GUIDINIT	FC-3900	CALLED	3		
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GUILDRET	FC-3940	CALLED	3		
GVDETER	FC-3520	ENTRY	11		
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IMUCOARS	FC-3500	CALLED	10		
IMUFAIL	FC-3210	ENTRY	31		
IMUFINE	FC-3220	ENTRY	15		
IMUFINE	FC-3500	CALLED	10		
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IMUSTALL	FC-3500	CALLED	10		
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IMUZERO2	FC-3220	ENTRY	4		
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INITVEL	FC-3760	ENTRY	4		
INITVEL	FC-3800	CALLED	6		
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INTEGRVS	FC-3740	CALLED	23		
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INTGRATE	FC-3355	ENTRY	9		
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INTINT	FC-3730	CALLED	2		
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INTSTALL	FC-3010	CALLED	26		
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INTSTALL	FC-3605	CALLED	2		
INTSTALL	FC-3610	CALLED	3		
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INTSTALL	FC-3900	CALLED	19		
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INTWAKE	FC-3605	CALLED	3		
INTWAKEU	FC-3120	CALLED	13		
INTWAKEU	FC-3350	ENTRY	20		
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INTWAKEO	FC-3600	CALLED	14		
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JOBWAKE	FC-3350	CALLED	19		
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KEPLERN	FC-3360	ENTRY	3		
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LALOTORV	FC-3510	CALLED	16		
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LAMBERT	FC-3760	CALLED	6		
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LAT-LONG	FC-3510	CALLED	14		
LAT-LONG	FC-3610	CALLED	5		
LAT-LONG	FC-3910	CALLED	2		
LEGAL?	FC-3970	ENTRY	15		
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LEMCONIC	FC-3400	CALLED	3		
LEMCONIC	FC-3435	CALLED	3		
LEMCONIC	FC-3510	CALLED	13		
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LEMPREC	FC-3760	CALLED	15		
LEMPREC	FC-3780	CALLED	3,4		
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LEMPREC	FC-3900	CALLED	3		
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MAKECADR	FC-3050	CALLED	8		
MAKECADR	FC-3060	ENTRY	4		
MAKECADR	FC-3220	CALLED	35		
MAKECADR	FC-3420	CALLED	2		
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MPACVBUF	FC-3320	CALLED	9,10		
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MUNFLAG	FC-3210				T-14
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MUNFLAG	FC-3950	S-3			
MUNGRAV	FC-3840	CALLED	3		

MUNGRAV	FC-3900	CALLED	4		
MUNGRAV	FC-3935	CALLED	16		
MUNGRAV	FC-3950	CALLED	6		
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PIPSRINE	FC-3520	CALLED	17,18	
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PRIOCHNG	FC-3900	CALLED	8	
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P12INIT	FC-3970	CALLED	13		
P12LM	FC-3950	ENTRY	2		
P12NIT	FC-3950	ENTRY	44		
P12RET	FC-3950	ENTRY	10		
P20FLGON	FC-3730	CALLED	1		
P20FLGON	FC-3750	CALLED	2		
P21FLAG	FC-3610	S-4			T-3
P25FLAG	FC-3600			C-2	T-2,24
P25FLAG	FC-3620	S-2			T-3
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P3XORP7X	FC-3720	ENTRY	24		
P30	FC-3700	ENTRY	2		
P31	FC-3710	ENTRY	2		
P32	FC-3720	ENTRY	2		
P33	FC-3730	ENTRY	1		
P34	FC-3740	ENTRY	2		
P35	FC-3750	ENTRY	2		
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P40LM	FC-3800	ENTRY	2		
P40SXT4	FC-3800	ENTRY	4		
P40SXT4	FC-3810	CALLED	4		
P41LM	FC-3810	ENTRY	2		
P42LM	FC-3820	ENTRY	2		
P47LM	FC-3830	ENTRY	1		
P51	FC-3500	ENTRY	2		
P57	FC-3520	ENTRY	2		
P57OPT0	FC-3520	ENTRY	21		
P57OPT1	FC-3520	ENTRY	23		
P57OPT2	FC-3520	ENTRY	25		
P57OPT3	FC-3520	ENTRY	24		
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P70	FC-3970	ENTRY	2		
P70A	FC-3930	CALLED	5		
P70A	FC-3970	ENTRY	2		
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P71	FC-3970	ENTRY	2		
P71A	FC-3930	CALLED	4		
P71A	FC-3970	ENTRY	2		
P72	FC-3720	ENTRY	2		
P73	FC-3730	ENTRY	1		
P74	FC-3740	ENTRY	2		
P75	FC-3750	ENTRY	2		
P76	FC-3640	ENTRY	2		
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R31CALL	FC-3780	ENTRY	2	
R33	FC-3240	ENTRY	2	
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R51	FC-3510	ENTRY	22	
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R52	FC-3510	ENTRY	42	
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R60LEM	FC-3400	CALLED	4	
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R65LEM	FC-3620	CALLED	3	
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R77END	FC-3280	ENTRY	5	
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SELECTMU	FC-3730	CALLED	1	
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