MASSACHUSETTS INSTITUTE OF TECHNOLOGY

APOLLO

GUIDANCE, NAVIGATION AND CONTROL

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APOLLO GUIDANCE AND NAVIGATION PROGRAM

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INSTRUMENTATION LABORATORY

E-2456

APOLLO GUIDANCE AND NAVIGATION FLOW CHARTS

PROGRAM COLOSSUS 2C COMANCHE 67

NOVEMBER 1969

MIT INSTRUMENTATION LABORATORY
CAMBRIDGE 39, MASSACHUSETTS

ACKNOWLEDGEMENT

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FOREWORD

This document comprises all flowcharts completed by the date of publication for COLOSSUS 2C 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 completed and 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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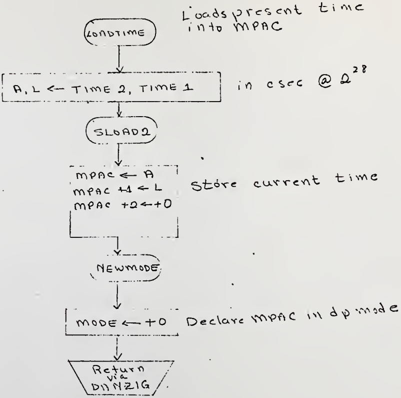
RTB Op Codes

PRELIMINARY

RTB Op Codes
COLOSSUS IIC FC-2100



PRELIMINARY

RTB Op Codes

COLOSSUS IIC   FC-2100

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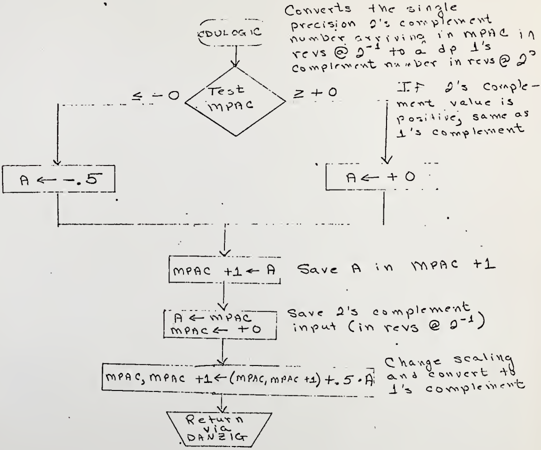
R. Enters

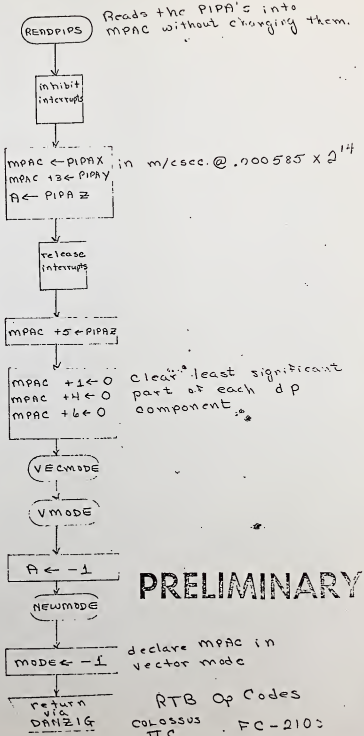


PRELIMINARY

RTB Op Codes

COLOSSUS IIC FC-2100

R Entrs



PRELIMINARY

RTB Op Codes

COLOSSUS IIC . FC-2103

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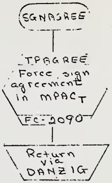
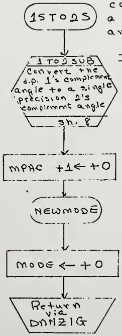
R. Entes



Forces sign agreement in $MPAC_T$



Converts the d.p. 1's complement angle in revs @ 2^0 to a single precision 2's complement angle in revs @ 2^{-1}

Input:
$MPAC_D$ = 1's complement angle in revs @ 2^0

Output:
A = MPAC = 2's complement angle in revs @ 2^{-1}

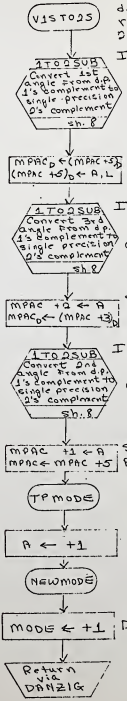
Declare MPAC in d.p. mode

PRELIMINARY

RTB Op Codes

COLOSSUS IIC FC-2100

R. Entes



Converts (on 3 angles) the d.p. 1's complement angles in revs @ 2^0 to single precision 2's complement angles in revs @ 2^{-1}

Input:
$MPAC_D$ = 1st 1's complement angle in revs @ 2^0
Output:
A = MPAC = 2's complement angle in revs @ 2^{-1}

Put 3rd angle into $MPAC_D$
Save 1st angle result in $(MPAC+5)_D$.

Input:
$MPAC_D$ = 3rd 1's complement angle in revs @ 2^0
Output:
A = MPAC = 2's complement angle in revs @ 2^{-1}

Save 3rd angle result in MPAC +2
Put 2nd angle into $MPAC_D$

Input:
$MPAC_D$ = 2nd 1's complement angle in revs @ 2^0
Output:
A = MPAC = 2's complement angle in revs @ 2^{-1}

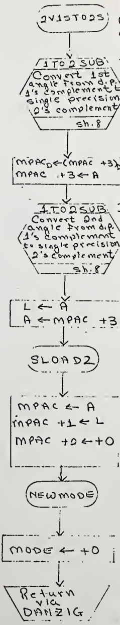
Save 2nd angle result in MPAC +1
Put 1st angle into MPAC

PRELIMINARY

Declare MPAC in t.p. mode

RTB Op Codes
COLOSSUS IIC FC-2100

R. Entes



Converts (on 2 angles) the d.p. 1's complement angles in revs @ 2^0 to single precision 2's complement angles in revs @ 2^{-1}

Input:
$MPAC_D$ = 1st 1's complement angle in revs @ 2^0
Output:
A = MPAC = 2's complement angle in revs @ 2^{-1}

Load 2nd angle for input.
Save 1st angle result in MPAC +3.

Input:
$MPAC_D$ = 2nd 1's complement angle in revs @ 2^0
Output:
A = MPAC = 2's complement angle in revs @ 2^{-1}

Save 2nd angle result in L
Put 1st angle result into A

Store 1st angle result in MPAC and store 2nd angle result in MPAC +1

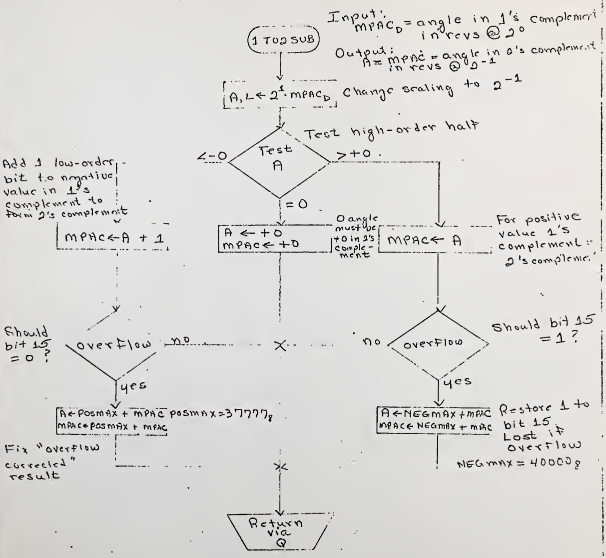
Declare MPAC in d.p. mode

PRELIMINARY

RTB Op Codes

COLOSSUS II C FC-2100

R. Entes



PRELIMINARY

RTB Op Codes

COLOSSUS IIC FC - 2100

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R. Enters

(INCRCDUS)

Increment CDU's
Input: angles in MPAC, +3, +5 in ... @ $2^{...}$ in 1's complement
THETAD, +1, +2 in 2's complem...

BUF ← ADR(THETAD)
A ← MPAC

CDUINC
Increment THETAD in 2's complement by 1's complement quantity in A
sh. 10

Input: A = MPAC
BUF = address of quantity to be incremented (here = address of THETAD)
Result: ADR^{-1} (BUF) = THETAD incremented in 2's complement by 1's complement quantity in MPAC

BUF ← ADR(THETAD +1)
A ← MPAC +3

CDUINC
Increment THETAD +1 in 2's complement by 1's complement quantity in A
sh. 10

Input: A = MPAC +3
BUF = address of quantity to be incremented (here = address of THETAD +1)
Result: ADR^{-1} (BUF) = THETAD +1 incremented in 2's complement by 1's complement quantity in MPAC +3

BUF ← ADR(THETAD +2)
A ← MPAC +5

CDUINC
Increment THETAD +2 in 2's complement by 1's complement quantity in A
sh. 10

Input: A = MPAC +5
BUF = address of quantity to be incremented (here = address of THETAD +2)
Result: ADR^{-1} (BUF) = THETAD +2 incremented in 2's complement by 1's complement quantity in MPAC +5

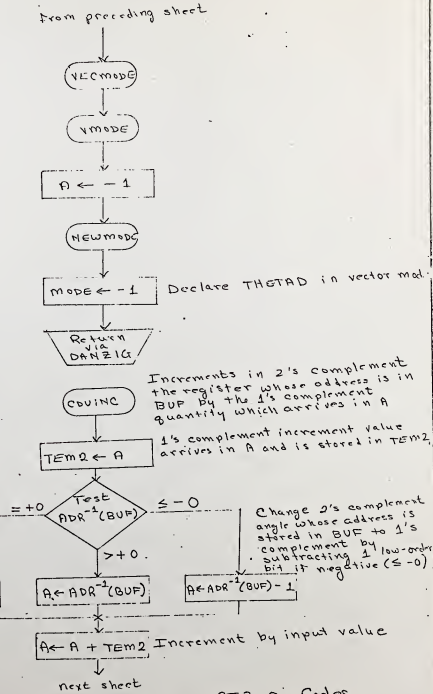
next sheet

PRELIMINARY

RTB Op Codes

COLOSSUS IIC FC-2100

R. Entes



RTB Op Codes

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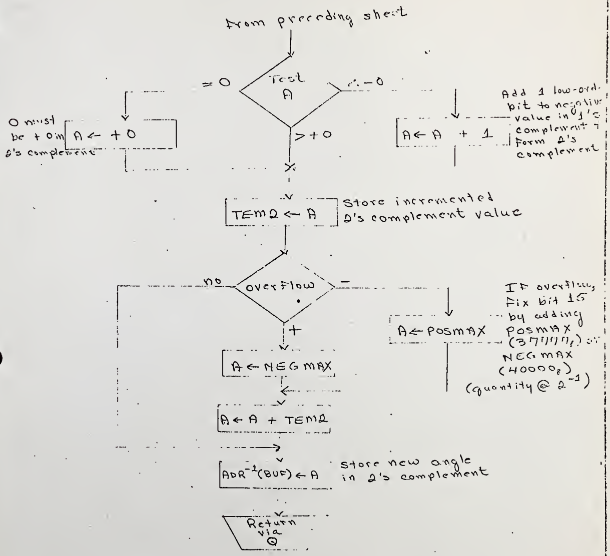
COLOSSUS IIC FC-2100

R. Entes



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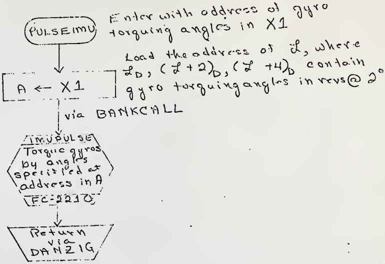
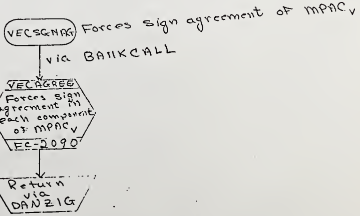




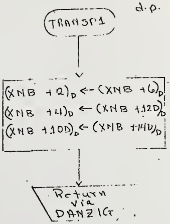
PRELIMINARY

RTB Op Codes

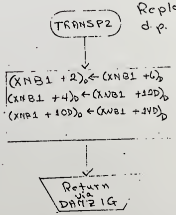
COLOSSUS IIC FC-2100

R. Entes

Replaces a 3X3 matrix in d.p. with the transpose matrix



Replaces a 3X3 matrix in d.p. with the transpose matrix

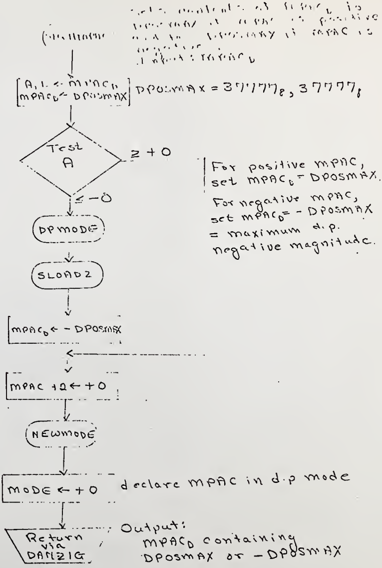


PRELIMINARY

RTB Op Codes

COLOSSUS II.C FC-2100

R. Entes



PRELIMINARY

RTB Op Codes

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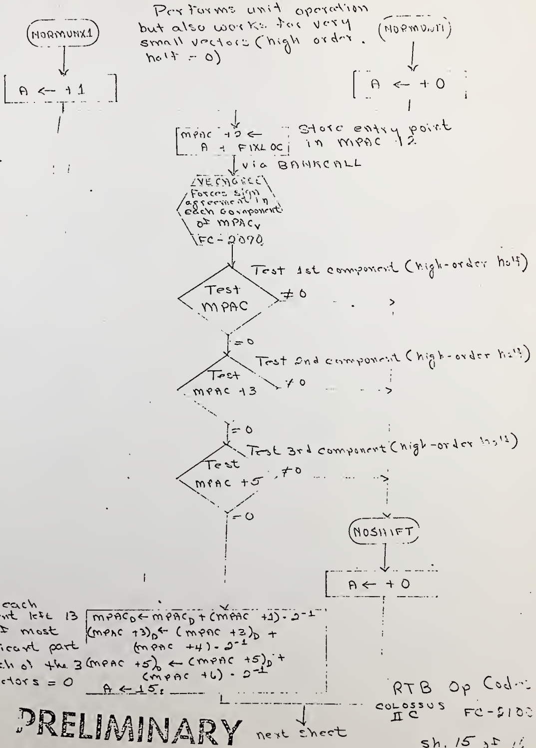
R. Enters



PRELIMINARY

R Enters

RTB Op Codes
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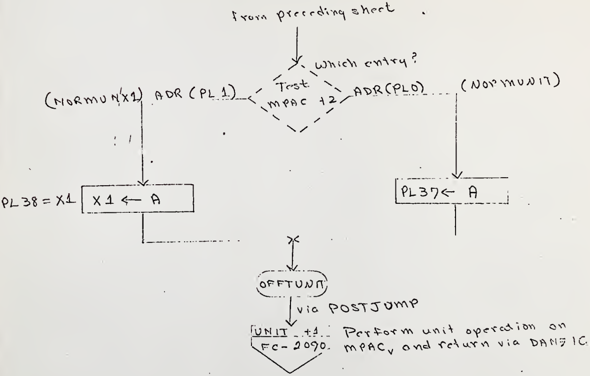

PRELIMINARY

RTB Op Codes
COLOSSUS IIC FC-2100

R. Entes

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ALARM AND ABORT

THE ALARM ROUTINE AND ITS ASSOCIATED ENTRIES ARE USED FOR SETTING THE ALARM CODE INTO ONE OF FAILREG REGISTERS. IT TURNS ON THE PROGRAM ALARM LIGHT (BY SETTING BIT-POSITION 9 OF REGISTER DSPTAB+11D TO ONE) IF THIS IS THE FIRST ALARM SINCE THE FAILREG REGISTERS WERE LAST CLEARED BY DEPRESSING THE ERROR LIGHT RESET KEY OR BY A FRESH START. THE ALARM CODE (OR CODES) IS THEN AVAILABLE FOR DISPLAY. ALSO, THE 2CADR OF THE LOCATION WHERE THE ALARM CONDITION OCCURRED IS SET INTO THE ALMCADR REGISTERS SO IT IS AVAILABLE FOR DISPLAY.

THERE ARE THREE FAILREG REGISTERS FOR STORING ALARM CODES. THE FIRST ALARM CODE IS SET INTO REGISTER FAILREG, THE SECOND ALARM CODE IS SET INTO REGISTER FAILREG+1 AND THE LAST (3RD OR MORE) IS SET INTO REGISTER FAILREG+2. SUBSEQUENT ALARM CODES (4TH OR MORE) WILL REPLACE THE EXISTING ALARM CODE IN REGISTER FAILREG+2 AND ALSO SET BIT-POSITION 15 OF REGISTER FAILREG+2. THIS WILL CONTINUE AS ADDITIONAL ALARM CONDITIONS ARE ENCOUNTERED UNTIL THE OPERATOR DEPRESSES THE ERROR LIGHT RESET KEY. BEFORE DEPRESSING THIS KEY, THE OPERATOR WILL NORMALLY KEY IN VERB 05 AND NOUN 09, WHICH WILL CAUSE THE CONTENTS OF ALL THREE OF THE FAILREG REGISTERS TO BE DISPLAYED SO THAT THE OPERATOR CAN DETERMINE THE TYPE OF ALARM CONDITION FROM THE ALARM CODE (SEE TABLE OF ALARM CODES VERSUS ALARM CONDITIONS, ETC. ON SHEET 6) AND CAN RESPOND WITH APPROPRIATE ACTION. IF FURTHER INFORMATION IS NECESSARY, THE OPERATOR WILL ALSO KEY IN VERB 05 AND NOUN 08, WHICH WILL CAUSE THE CONTENTS OF REGISTERS ALMCADR, ALMCADR+1 AND ERCOUNT TO BE DISPLAYED. THE OPERATOR CAN THEN DETERMINE THE LOCATION OF THE ALARM CONDITION FROM THE 2CADR IN REGISTERS ALMCADR AND ALMCADR+1 AND DETERMINE THE NUMBER OF ERRORS DETECTED IN THE SELF CHECK PROGRAM (SINCE FRESH START) FROM THE COUNT IN REGISTER ERCOUNT. THESE ERRORS ARE IDENTIFIED BY ALARM CODE OCT 1102. DEPRESSING THE ERROR LIGHT RESET KEY WILL CLEAR ALL THE FAILREG REGISTERS AND TURN OFF THE PROGRAM ALARM LIGHT. A FRESH START WILL ALSO DO THIS. REGISTERS ALMCADR AND ALMCADR+1 ARE NEVER CLEARED TO ZERO. THEIR CONTENTS ARE REPLACED EACH TIME AN ALARM CONDITION OCCURS. REGISTER ERCOUNT IS CLEARED TO ZERO ONLY DURING FRESH START. EACH TIME AN ERROR IS DETECTED BY SELF CHECK, REGISTER ERCOUNT IS INCREMENTED BY ONE.

ALARM CONDITIONS ARE DUE TO PROGRAM FAILURES (NOT HARDWARE FAILURES). IF THE FAILURE IS NOT SERIOUS, CONTROL RETURNS TO THE CALLING SEQUENCE. IF THE FAILURE IS SERIOUS, NO RETURN IS MADE, AND AN ABORT IS MADE RESULTING IN A SOFTWARE RESTART. FAILURES WHICH ARE NOT SERIOUS USE THE FOLLOWING ENTRIES: PRIOLARM, VARALARM, CURTAINS, AND ALARM. FAILURES WHICH ARE SERIOUS USE THE FOLLOWING ENTRIES: BAILOUT, POODOO, AND CCSHOLE.

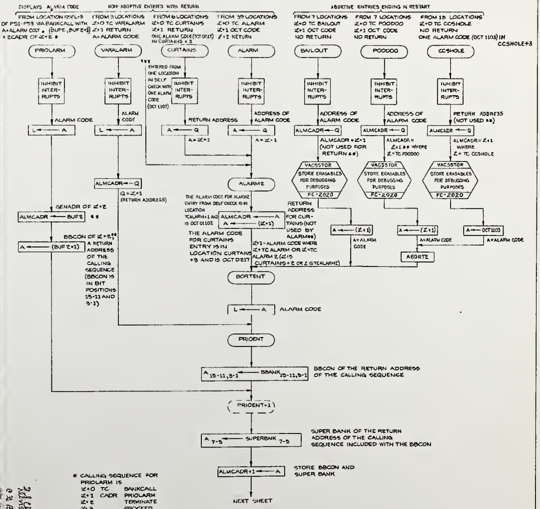
EACH ENTRY WILL MAKE THE ALARM CODE AVAILABLE FOR DISPLAY AND TURN ON THE PROGRAM ALARM LIGHT (IF OFF). ONLY ENTRY PRIOLARM WILL DISPLAY THE ALARM CODES IN THE THREE FAILREG REGISTERS. THE RETURN LOCATION AND THE LOCATION CONTAINING THE ALARM CODE IS GIVEN IN THE CALLING SEQUENCE FOR EACH ENTRY SHOWN AT THE TOP OF THE NEXT SHEET.

BESIDES TURNING ON THE PROGRAM ALARM LIGHT (IF OFF) AND MAKING THE ALARM CODE AVAILABLE FOR DISPLAY, OTHER FUNCTIONS OF EACH ENTRY ARE

PRIOLARM	DISPLAYS THE ALARM CODES VIA PRIODSPR (V05N09) AND RETURNS. USED BY THE "TARGET OUT OF VIEW" ALARM CONDITION.
VARALARM	CALLING SEQUENCE OBTAINS A VARIABLE ALARM CODE FROM AN APPLICABLE REGISTER. RETURNS TO CALLING SEQUENCE.
CURTAINS	ALARM CODE OCT 217 IS ONLY ONE USED. USED FOR BAD RETURNS FROM STALL ROUTINES. RETURNS TO CALLING SEQUENCE.
ALARM	USED FOR ALARM CONDITIONS SUCH AS IMPROPER INPUT DATA, ETC. RETURNS TO CALLING SEQUENCE.
BAILOUT	TERMINATES IN A SOFTWARE RESTART. USED BY ALARM CONDITIONS SUCH AS NO VAC AREAS AVAILABLE, TOO MANY TASKS, ETC.
POODOO	CLEARS AVEGFLAG AND V37FLAG. INACTIVATES ALL RESTART GROUPS AND TERMINATES IN A SOFTWARE RESTART, AND GOTOPOOH AND FLASH VERB 37 FOR OPERATOR TO SELECT NEW MAJOR MODE. USED BY ALARM CONDITIONS SUCH AS AN ATTEMPT TO TAKE THE SQUARE ROOT OF A NEGATIVE NUMBER, ILLEGAL FLASHING DISPLAY, ETC.
CCSHOLE	ALARM CODE OCT 1103 IS ONLY CODE USED. CLEARS AVEGFLAG AND V37FLAG, INACTIVATES ALL RESTART GROUPS AND TERMINATES IN A SOFTWARE RESTART, AND GOTOPOOH AND FLASH VERB 37 FOR OPERATOR TO SELECT NEW MAJOR MODE. USED WHEN UNUSED CCS BRANCH IS EXECUTED.
ALARM2	ALARM CODE OCT 1102 IS ONLY CODE USED. USED ONLY BY SELF CHECK PROGRAM WHEN AN ERROR IS DETECTED.

NOTE: SYMBOL "=" MEANS "CONTAINS" IN THIS FLOW CHART

ALARM AND ABORT ROUTINE



* CALLING SEQUENCE FOR PRIOLARM IS

ℒ+0	TC	BANKCALL
ℒ+1	CADR	PRIOLARM
ℒ+2		TERMINATE
ℒ+3		PROCEED
ℒ+4		ENTER
ℒ+5		IMMEDIATE RETURN

** THE ADDRESS STORED IN REGISTER ALMCADR IS NOT USED AS A RETURN ADDRESS FOR THESE ENTRIES (PRIOLARM, ALARM, ALARM2 VIA SELF CHECK, BAILOUT POODOO AND CCSHOLE) WHILE THE OTHER TWO ENTRIES (VARALARM AND CURTAINS) DO USE THE ADDRESS AS A RETURN ADDRESS. HOWEVER, THE ADDRESS ASSOCIATED WITH EACH ENTRY IN REGISTER ALMCADR AND ITS BBCON IN REGISTER ALMCADR+1 AND THE CONTENTS OF REGISTER ERCOUNT ARE AVAILABLE FOR DISPLAY BY VERB 05 AND NOUN 08

*** ENTERED FROM LOCATION TCALARM2 OF SELF CHECK PROGRAM. CALLING SEQUENCE IS:

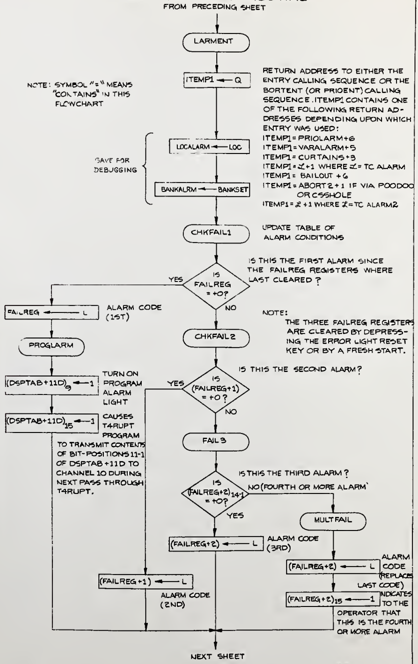
ℒ+0	TC	ALARM2
ℒ+1	OCT	01102
ℒ+2		RETURN

COLOSSUS II-A

ALARM AND ABORT

FC-2140

ALARM AND ABORT ROUTINE



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ALARM AND ABORT

COLOSSUS IIA FC-2140

REV 1

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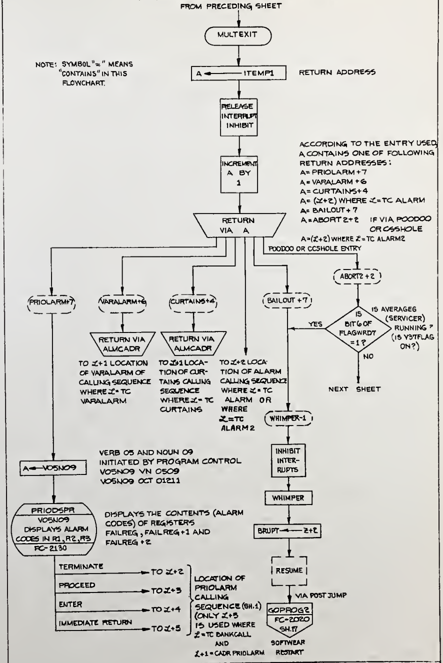
ALARM AND ABORT ROUTINES



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
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PRGMR Densmore 18APR69	
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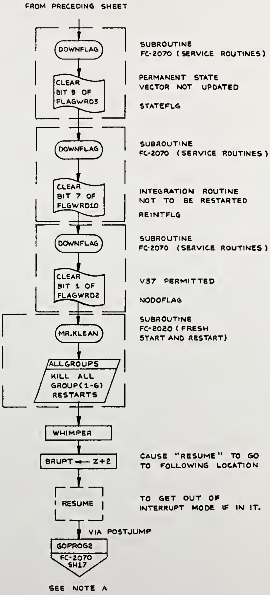
DOCMR [signature] 4-16-69	
APPR'D [signature] 22 Apr 69	REV 1 — SHEET 5 OF 9



NOTE A:
GO TO ROUTINE GOTOPOOH AND DISPLAY FLASHING VERB 37 UNLESS NO MAJOR MODE WAS ACTIVE IN WHICH CASE CONTROL GOES TO DUMMYJOB+2 (SEE RESTART, SHEET 20 OF FC-2020.)

ALARM AND ABORT

COLOSSUS II-A

FC-2140

ALARM AND ABORT

TABLE OF ALARM CODES

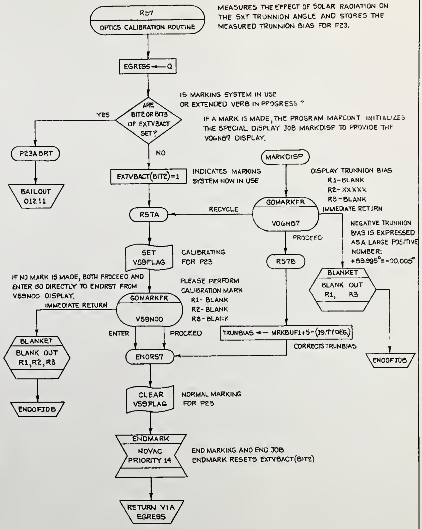
ALARM CODE	ALARM CONDITION	SET BY	ALARM ENTRY USED
00110	NO MARK SINCE LAST MARK REJECT	SXTMARK	ALARM
00112	MARK NOT BEING ACCEPTED	SXTMARK	ALARM
00113	NO INBITS	SXTMARK	ALARM
00114	MARK MADE, BUT NOT DESIRED	SXTMARK	ALARM
00115	OPTICS TORQUE REQUEST WITH SWITCH NOT AT CMC	EXT VERB OPTICS CDU	ALARM
00116	OPTICS SWITCH ALTERED BEFORE 15 SEC ZERO TIME ELAPSED	T4RUPT	ALARM
00117	OPTICS TORQUE REQUEST WITH OPTICS NOT AVAILABLE (OPTIND=-0)	EXT VERB OPTICS CDU	ALARM
00120	OPTICS TORQUE REQUEST WITH OPTICS NOT ZEROED	T4RUPT	ALARM
00121	CDUS NO GOOD AT TIME OF MARK	SXTMARK	ALARM
00122	MARKING NOT CALLED FOR	SXTMARK	ALARM
00124	TPI SEARCH – NO SAFE PERICTR HERE	P17, P77	ALARM
00205	BAD PIPA READING	SERVICER	ALARM
00206	ZERO ENCODE NOT ALLOWED WITH COARSE ALIGN + GIMBAL LOCK	IMU MODE SWITCH IMU-2	ALARM
00207	ISS TURNON REQUEST NOT PRESENT FOR 90 SEC	T4RUPT	ALARM
00210	IMU NOT OPERATING	IMU MODE SWITCH, IMU-2, R02, P51	ALARM VARALARM
00211	COARSE ALIGN ERROR – DRIVE >2 DEGREES	IMU MODE SWITCH	ALARM
00212	PIPA FAIL BUT PIPA IS NOT BEING USED	IMU MODE SWITCH, T4RUPT	ALARM
00213	IMU NOT OPERATING WITH TURN-ON REQUEST	T4RUPT	ALARM
00214	PROGRAM USING IMU WHEN TURNED OFF	T4RUPT	ALARM
00215	PREFERRED ORIENTATION SELECTED BUT NOT SPECIFIED	P52, P54	ALARM
00217	BAD RETURN FROM STALL ROUTINES	CURTAINS	ALARM2
00220	IMU NOT ALIGNED – NO REFSMMAT	R02	VARALARM
00401	DESIRED GIMBAL ANGLES YIELD GIMBAL LOCK	INF ALIGN, IMU-2	ALARM
00404	TARGET OUT OF VIEW – TRUN ANGLE >90 DEG	R52	PRIOLARM
00405	TWO STARS NOT AVAILABLE	P52, P54	ALARM
00406	REND NAVIGATION NOT OPERATING	R21, R23	ALARM

ALARM CODE	ALARM CONDITION	SET BY	ALARM ENTRY USED
00407	MT TO OPTICS REQUEST TRUN ANGLE > 50 DEG (TARGET OUT OF VIEW)	R52	ALARM
00421	W-MATRIX OVERFLOW	INTEGRV	ALARM
00430 *	INTEG. ABORT DUE TO SUBSURFACE S.V.	ALL CALLS TO INTEGRATION	POODOO
00600	IMAGINARY ROOTS ON FIRST ITERATION	P32, P72	VARALARM
00601	PERIGEE ALTITUDE LT PMIN1	P32, P72	VARALARM
00602	PERIGEE ALTITUDE LT PMIN2	P32, P72	VARALARM
00603	CSI TO CDH TIME LT PMIN22	P32, P33, P72, P73	VARALARM
00604	CDH TO TPI TIME LT PMIN23	P32, P72	VARALARM
00605	NUMBER OF ITERATIONS EXCEEDS LOOP MAXIMUM	P32, P37, P72	VARALARM
00606	DV EXCEEDS MAXIMUM	P32, P72	VARALARM
00607 *	NO SOLUTION FROM TIME THETA OR TIME RADIUS ROUTINE	TIMETHET, TIMERAD	POODOO
00610 *	LAMDA LESS THAN UNITY	P37	POODOO
00611	NO TIG FOR GIVEN ELEV. ANGLE	P34, P74	ALARM
00612	STATE VECTOR IN WRONG SPHERE OF INFLUENCE	P37	VARALARM
00613	REENTRY ANGLE OUT OF LIMITS	P37	VARALARM
00777	PIPA FAIL CAUSED THE ISS WARNING	T4RUPT	VARALARM
01102	CMC SELF TEST ERROR	SELF CHECK	ALARM2
01103 *	UNUSED CCS BRANCH EXECUTED	CCSHOLE	ABORT2
01104 *	DELAY ROUTINE BUSY	SERVICE ROUTINES	BAILOUT
01105	DOWNLINK TOO FAST	T4RUPT	ALARM
01106	UPLINK TOO FAST	T4RUPT	ALARM
01107	PHASE TABLE FAILURE. ASSUME ERASABLE MEMORY IS DESTROYED	RESTART	ALARM
01201 *	EXECUTIVE OVERFLOW - NO VAC AREAS	EXEC	BAILOUT
01202 *	EXECUTIVE OVERFLOW - NO CORE SETS	EXEC	BAILOUT
01203 *	WAITLIST OVERFLOW - TOO MANY TASKS	WAITLIST	BAILOUT
01204 *	NEGATIVE OR ZERO DELTA TIME - WAITLIST CALL	WAITLIST	POODOO
01206 *	SECOND JOB ATTEMPTS TO GO TO SLEEP VIA KEYBOARD AND DISPLAY PROGRAM	PINBALL	POODOO
01207 *	NO VAC AREA FOR MARKS	SXTMARK	BAILOUT
01210 *	TWO PROGRAMS USING DEVICE AT SAME TIME	IMU MODE SWITCH	POODOO
01211 *	ILLEGAL INTERRUPT OF EXTENDED VERB	SXTMARK	BAILOUT
01301	ARCSIN-ARCCOS INPUT ANGLE TOO LARGE	INTERPRETER	ALARM
01302 *	SQRT CALLED WITH NEGATIVE ARGUMENT. ABORT	INTERPRETER	POODOO
01407	VG INCREASING	S40.8	ALARM
01426	IMU UNSATISFACTORY	P61, P62	ALARM
01427	IMU REVERSED	P61, P62	ALARM

ALARM CODE		ALARM CONDITION	SET BY	ALARM ENTRY USED
01501	*	KEYBOARD AND DISPLAY ALARM DURING INTERNAL USE (NVSUB). ABORT	PINBALL	POODOO
01502	*	ILLEGAL FLASHING DISPLAY	GOPLAY	POODOO
01520		V37 REQUEST NOT PERMITTED AT THIS TIME	V37	ALARM
01521	*	P01 OR P07 ILLEGALLY SELECTED	P01, P07	POODOO
01600		OVERFLOW IN DRIFT TEST	OPT PRE ALIGN CALIB	ALARM
01601		BAD IMU TORQUE	OPT PRE ALIGN CALIB	ALARM
01602		BAD OPTICS DURING VERIFICATION	OPTALGN CALIB(CSM)	ALARM
01703		INSUF. TIME FOR INTEG., TIG HAS SLIPPED	R41	ALARM
03777		ICDU FAIL CAUSED THE ISS WARNING	T4RUPT	VARALARM
04777		ICDU, PIPA FAILS CAUSED THE ISS WARNING	T4RUPT	VARALARM
07777		IMU FAIL CAUSED THE ISS WARNING	T4RUPT	VARALARM
10777		IMU, PIPA FAILS CAUSED THE ISS WARNING	T4RUPT	VARALARM
13777		IMU, ICDU FAILS CAUSED THE ISS WARNING	T4RUPT	VARALARM
14777		IMU, ICDU, PIPA FAILS CAUSED THE ISS WARNING	T4RUPT	VARALARM

*INDICATES ABORT TYPE. ALL OTHERS ARE NON-ABORTIVE

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A. A. Laquelle 7APR69	ALARM AND ABORT
PROGMR N. Bernstein 18 APR 69	
ANALYST	COLOSSUS II-A — DOCUMENT NO. FC-2140
DOCMR C. H. Beck 4-16-69	
APPR'D John A. Moore 22 April 69	REV 1 — SHEET 9 OF 9

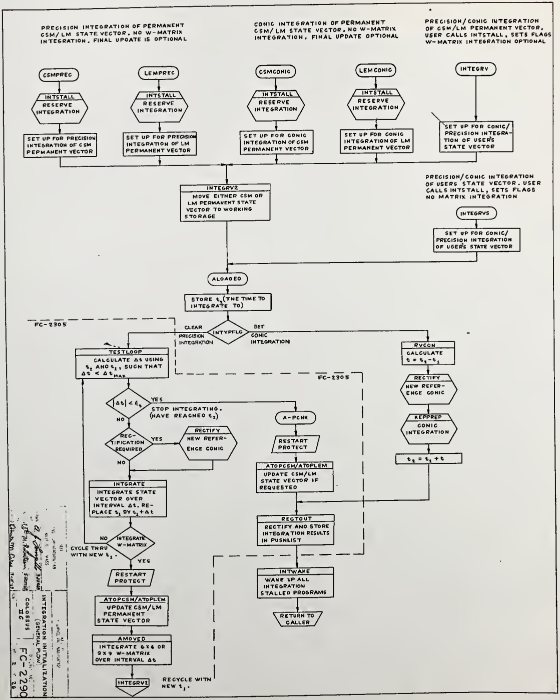


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 30CT68 PRGMR N. W. BRODEUR 6JAN69 ANALST DOCMR [signature] [illegible] APPR'D [signature] 7FEB69	R57 OPTICS CALIBRATION COLOSSUS II DOCUMENT NO FC-2242 REV SHEET 1 OF 1

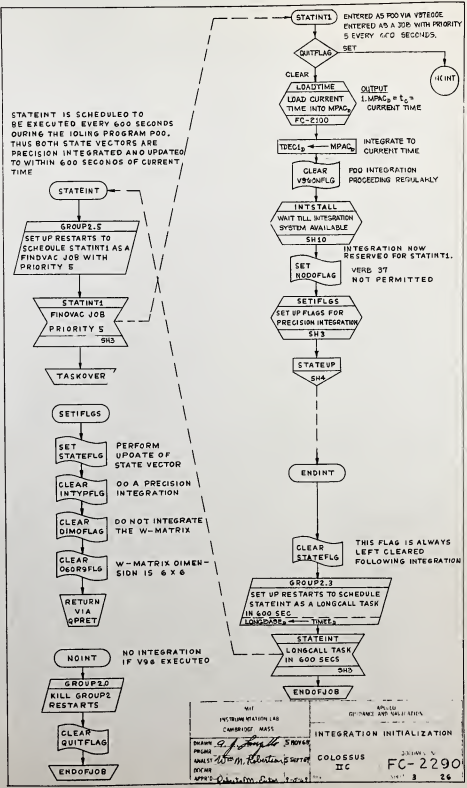
MAJOR SUBROUTINES AND EXTERNAL ENTRY POINTS		
STATINT1	POO: PRECISION INTEGRATES BOTH STATE VECTORS TO WITHIN 10 MINUTES OF CURRENT TIME	SH. 3
STATINT	SCHEDULES STATINT1	SH. 3
ATOPCSM	UPDATE PERMANENT CSM STATE VECTOR	SH. 5
ATOPLEM	UPDATE PERMANENT LM STATE VECTOR	SH. 5
PTOACSM	MOVE PERMANENT CSM STATE VECTOR TO WORKING STORAGE	SH. 5
PTOALEM	MOVE PERMANENT LM STATE VECTOR TO WORKING STORAGE	SH. 5
CSMPREC	ENTRY FOR CSM STATE VECTOR PRECISION INTEGRATION	SH. 6
LEMPREC	ENTRY FOR LM STATE VECTOR PRECISION INTEGRATION	SH. 6
CSMCONIC	ENTRY FOR CSM STATE VECTOR CONIC INTEGRATION	SH. 7
LEMCONIC	ENTRY FOR LM STATE VECTOR CONIC INTEGRATION	SH. 7
INTEGRVS	INTEGRATE STATE VECTOR PROVIDED BY CALLER	SH. 8
INTEGRV	INTEGRATE CSM/LM STATE VECTOR AND W-MATRIX	SH. 8
INTEGRV2	ENTRY POINT FROM ORBITAL INTEGRATION PACKAGE, FC#2305 FOR NEXT PASS THROUGH INTEGRATION LOOP	SH. 8
RVCON	ENTRY FOR PERFORMING A CONIC INTEGRATION	SH. 9
INTSTALL	INTEGRATION STALL ROUTINE THAT PREVENTS AN ACTIVE JOB FROM CALLING THE INTEGRATION ROUTINE IF IT IS BUSY	SH.10
INTWAKEO	INTERPRETIVE ENTRY TO INTEGRATION WAKE ROUTINE TO WAKE UP ALL JOBS PUT TO SLEEP BY INTSTALL	SH.12
INTWAKE	BASIC CODE ENTRY TO INTEGRATION WAKE ROUTINE	SH.12
INTWAKEU	CALLED BY THE UPDATE PROGRAM P27 TO RELEASE ITS GRAB OF THE INTEGRATION ROUTINE	SH.14
AVETOMID	TRANSITION ROUTINE FROM THRUSTING PHASE TO COASTING PHASE	SH.16
MIDTOAV1	PRECISION INTEGRATES CSM PERMANENT STATE VECTOR TO SPECIFIED TIME	SH.19
MIDTOAV2	PRECISION INTEGRATES CSM PERMANENT STATE VECTOR TO CURRENT TIME PLUS 10 SECONDS	SH.19
USEPIOS	CALCULATES THE LM STATE VECTOR USING THE PLANETARY INERTIAL ORIENTATION SUBROUTINE WHEN LM ON LUNAR SURFACE	SH.21

REFERENCES FOR INTEGRATION INITIALIZATION

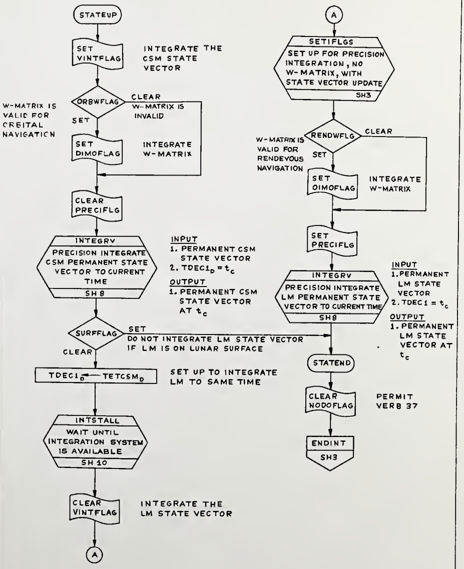
1. GUIDANCE SYSTEM OPERATIONS PLAN USING PROGRAM COLOSSUS (GSOP), R-577, SECTION 5, GUIDANCE EQUATIONS, MAY, 1968.
2. OSTANEK, W. F., USER'S GUIDE FOR ORBITAL INTEGRATION ROUTINE FOR FLIGHT 504, FLIGHT 504 MEMO 5, REV 1, JUNE, 1967.
3. OSTANEK AND KEFAUVER, LEVEL II TEST PACKAGE FOR COASTING INTEGRATION SUBROUTINE, MIT/IL, NOVEMBER, 1967.



PRECISION INTEGRATION OF PERMANENT CSM/LM STATE VECTOR. NO W-MATRIX INTEGRATION. FINAL UPDATE IS OPTIONAL
CONIC INTEGRATION OF PERMANENT CSM/LM STATE VECTOR. NO W-MATRIX INTEGRATION. FINAL UPDATE OPTIONAL
PRECISION/CONIC INTEGRATION OF CSM/LM PERMANENT VECTOR. USER CALLS INTSTALL, SETS FLAGS W-MATRIX INTEGRATION OPTIONAL
CSMPREC
LEMPREC
CSMCONIC
LEMCONIC
INTEGRV
INTSTALL
RESERVE INTEGRATION
SET UP FOR PRECISION INTEGRATION OF CSM PERMANENT VECTOR
SET UP FOR PRECISION INTEGRATION OF LM PERMANENT VECTOR
SET UP FOR CONIC INTEGRATION OF CSM PERMANENT VECTOR
SET UP FOR CONIC INTEGRATION OF LM PERMANENT VECTOR
SET UP FOR CONIC/PRECISION INTEGRATION OF USER'S STATE VECTOR
INTEGRV2
MOVE EITHER CSM OR LM PERMANENT STATE VECTOR TO WORKING STORAGE
PRECISION/CONIC INTEGRATION OF USERS STATE VECTOR. USER CALLS INTSTALL, SETS FLAGS NO MATRIX INTEGRATION
INTEGRVS
SET UP FOR CONIC/PRECISION INTEGRATION OF USER'S STATE VECTOR
ALOADED
STORE t_2 (THE TIME TO INTEGRATE TO)
FC-2305
CLEAR PRECISION INTEGRATION
INTYPFLG
SET CONIC INTEGRATION
TESTLOOP
CALCULATE Δt USING t_2 AND t_1, SUCH THAT $\Delta t < \Delta t_{MAX}$
$|\Delta t| < \epsilon_0$
YES
STOP INTEGRATING. (HAVE REACHED t_2)
NO
REC-TIFICATION REQUIRED
RECTIFY
NEW REFERENCE CONIC
INTGRATE
INTEGRATE STATE VECTOR OVER INTERVAL Δt. REPLACE t_1 BY $t_1 + \Delta t$
INTEGRATE W-MATRIX
CYCLE THRU WITH NEW t_1.
RESTART PROTECT
ATOPCSM/ATOPLEM
UPDATE CSM/LM PERMANENT STATE VECTOR
AMOVED
INTEGRATE 6X6 OR 9X9 W-MATRIX OVER INTERVAL Δt
INTEGRV2
RECYCLE WITH NEW t_1.
A-PCHK
RESTART PROTECT
ATOPCSM/ATOPLEM
UPDATE CSM/LM STATE VECTOR IF REQUESTED
RECTOUT
RECTIFY AND STORE INTEGRATION RESULTS IN PUSHLIST
INTWAKE
WAKE UP ALL INTEGRATION STALLED PROGRAMS
RETURN TO CALLER
RVCON
CALCULATE $t = t_2 - t_1$
RECTIFY
NEW REFERENCE CONIC
KEPPREP
CONIC INTEGRATION
$t_2 = t_1 + t$
INTEGRATION INITIALIZATION (GENERAL FLOW)
COLOSSUS IIC
FC-2290

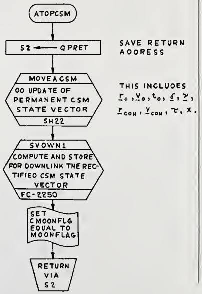

STATINT1
ENTERED AS P00 VIA V37E00E
ENTERED AS A JOB WITH PRIORITY 5 EVERY 600 SECONDS.
QUITFLAG
SET
NOINT
CLEAR
LOADTIME
LOAD CURRENT TIME INTO MPAC_D
FC-2100
OUTPUT
1. MPAC_D = t_c = CURRENT TIME
TDEC1_D ← MPAC_D
INTEGRATE TO CURRENT TIME
CLEAR V96ONFLG
P00 INTEGRATION PROCEEDING REGULARLY
INTSTALL
WAIT TILL INTEGRATION SYSTEM AVAILABLE
SH10
INTEGRATION NOW RESERVED FOR STATINT1.
SET NODOFLAG
VERB 37 NOT PERMITTED
SETIFLGS
SET UP FLAGS FOR PRECISION INTEGRATION
SH3
STATEUP
SH4
ENDINT
CLEAR STATEFLG
THIS FLAG IS ALWAYS LEFT CLEARED FOLLOWING INTEGRATION
GROUP2.3
SET UP RESTARTS TO SCHEDULE STATEINT AS A LONGCALL TASK IN 600 SEC
LONGBASE_D ← TIMEE_D
STATEINT
LONGCALL TASK IN 600 SECS
SH3
ENDOFJOB
STATEINT IS SCHEDULED TO BE EXECUTED EVERY 600 SECONDS DURING THE IDLING PROGRAM P00. THUS BOTH STATE VECTORS ARE PRECISION INTEGRATED AND UPDATED TO WITHIN 600 SECONDS OF CURRENT TIME
STATEINT
GROUP2.5
SET UP RESTARTS TO SCHEDULE STATINT1 AS A FINDVAC JOB WITH PRIORITY 5
STATINT1
FINDVAC JOB
PRIORITY 5
SH3
TASKOVER
SETIFLGS
SET STATEFLG
PERFORM UPDATE OF STATE VECTOR
CLEAR INTYPFLG
DO A PRECISION INTEGRATION
CLEAR DIMOFLAG
DO NOT INTEGRATE THE W-MATRIX
CLEAR D6OR9FLG
W-MATRIX DIMENSION IS 6 X 6
RETURN VIA QPRET
NOINT
NO INTEGRATION IF V96 EXECUTED
GROUP2.0
KILL GROUP2 RESTARTS
CLEAR QUITFLAG
ENDOFJOB
MIT
INSTRUMENTATION LAB
CAMBRIDGE, MASS
APOLLO
GUIDANCE AND NAVIGATION
INTEGRATION INITIALIZATION
DRAWN
PRGMR
ANALST
DOCMR
APPR'D
COLOSSUS
IIC
FC-2290
3
26

STATEUP DOES THE P00 INTEGRATION. IT PRECISION INTEGRATES BOTH CSM AND LM STATE VECTORS TO CURRENT TIME WITH A PERMANENT UPDATE OF BOTH VECTORS. IT INTEGRATES THE W-MATRIX IF IT IS VALID.

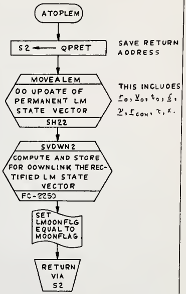


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A. J. Lanza 4 JUN 69	INTEGRATION INITIALIZATION
PRGMR	
ANALST Wm. M. Robertson 5 SEPT 69	COLOSSUS IIC — DOCUMENT NO. FC-2290
DOCMR	
APPR'D Robert M. Peters 9-5-69	REV — SHEET 4 OF 26

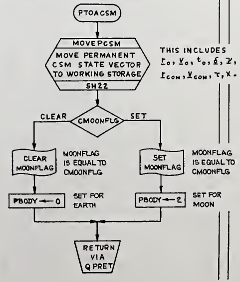
PERFORM AN UPDATE OF PERMANENT CSM STATE VECTOR AND FLAG CMOONFLG



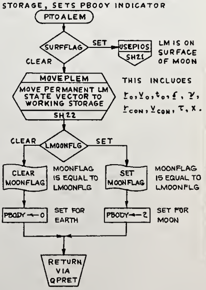
PERFORMS AN UPDATE OF PERMANENT LM STATE VECTOR AND FLAG LMOONFLG



MOVES PERMANENT CSM STATE VECTOR AND FLAG CMOONFLG TO WORKING STORAGE, SETS PBODY INDICATOR

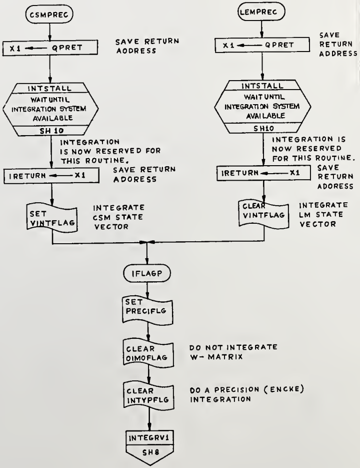


MOVES PERMANENT LM STATE VECTOR AND FLAG LMOONFLG TO WORKING STORAGE, SETS PBODY INDICATOR



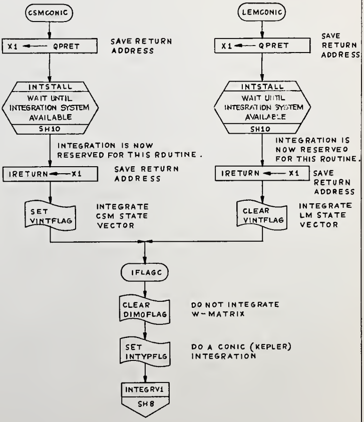
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS	APOLLO GUIDANCE AND NAVIGATION
DRAWN A. J. Longills 5 NOV 68	INTEGRATION INITIALIZATION
PRGMR	
ANALYST Wm. M. Robertson 5 SEPT 69	COLOSSUS IIC — DOCUMENT NO FC-2290
DOCMR	
APPR'D Robert M. Crabtree 9-5-69	REV — SHEET 5 OF 26

CSMPREC AND LEMPREC ARE ENTRIES TO THE INTEGRATION ROUTINE FOR PERFORMING ORBIT INTEGRATION BY THE PRECISION (ENCKE) METHOD OF THE PERMANENT STATE VECTOR OF THE CSM AND LM RESPECTIVELY. ACCELERATIONS DUE TO OBLATENESS ARE INCLUDED. NO W-MATRIX INTEGRATION IS PERFORMED. A FINAL STATE VECTOR UPDATE IS OPTIONAL. THE CALLER MUST STORE THE TIME TO INTEGRATE TO IN $TDEC1_D = t_2$. THE ENTRIES AUTOMATICALLY LOAD THE APPROPRIATE STATE VECTOR AND TIME OF VALIDITY FROM PERMANENT STORAGE INTO RCV_V, VCV_V AND TET_D. THESE ENTRIES SET UP ALL THE FLAGS REQUIRED BY THE INTEGRATION ROUTINE AND PERFORM THE CALL TO INTSTALL. OUTPUT INCLUDES THE INTEGRATED STATE VECTOR STORED IN THE PUSH LIST IN LOCATIONS $RATT_V$, $VATT_V$ AND THE TIME ACTUALLY INTEGRATED TO IN PUSH LIST LOCATION TAT_D.



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A. J. Longello 6NOV68	INTEGRATION INITIALIZATION
PRGMR	
ANALYST Wm. M. Robertson 5SEP69	COLOSSUS IIC — FC-2290
DOC MR	
APPR'D Robert M. Curtis 19-5-69	REV — SHEET 6 OF 26

CSMCONIC AND LEMCONIC ARE ENTRIES TO THE INTEGRATION ROUTION FOR PERFORMING ORBIT INTEGRATION BY THE CONIC (KEPLER) METHOD OF THE PERMANENT STATE VECTOR OF THE CSM AND LM RESPECTIVELY. NO DISTURBING ACCELERATIONS ARE INCLUDED. THE STATE VECTOR IS RECTIFIED IMMEDIATELY PRIOR TO THE KEPLER SOLUTION. THE CALLER MUST STORE THE TIME TO INTEGRATE TO IN TDEC1 = t_2. THE ENTRIES AUTOMATICALLY LOAD THE APPROPRIATE STATE VECTOR AND TIME OF VALIDITY FORM PERMANENT STORAGE INTO RCV_V, VCV_V AND TET_D. THESE ENTRIES SET UP ALL THE FLAGS REQUIRED BY THE INTEGRATION ROUTINE AND PERFORM THE CALL TO INTSTALL. OUTPUT INCLUDES THE INTEGRATED STATE VECTOR STORED IN THE PUSH LIST IN LOCATIONS $RATT_V$, $VATT_V$ AND THE TIME ACTUALLY INTEGRATED TO IN PUSH LIST LOCATION TAT_D.



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS

APOLLO GUIDANCE AND NAVIGATION

DRAWN A. J. [signature] 6NOV68
PRGMR
ANALST Wm. M. Robertson 5SEPT69
DOCMR
APPR'D [signature] 9-5-69

INTEGRATION INITIALIZATION

COLOSSUS IIC

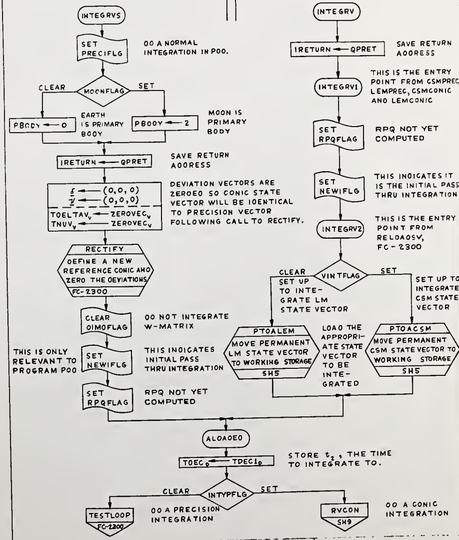
DOCUMENT NO FC-2290

REV

7 OF 26

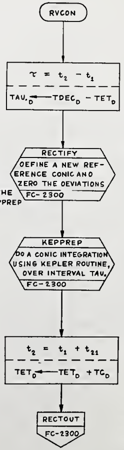
INTEGRVS IS AN ENTRY TO THE INTEGRATION ROUTINE FOR PERFORMING INTEGRATION (PRECISION OR CONIC) OF A STATE VECTOR PROVIDED BY THE CALLER. THE CALLER MUST CALL ROUTINE INTSTALL, SET UP THE FLAGS INTYPFLG, MOONFLAG AND LOAD THE STATE VECTOR TO BE INTEGRATED AND TIME INTO LOCATIONS RCV_v, VCV_v AND TET_D. THE TIME TO INTEGRATE TO MUST BE LOADED IN $TDEC1_D = t_2$.

INTEGRV IS AN ENTRY TO THE INTEGRATION ROUTINE FOR PERFORMING INTEGRATION (PRECISION OR CONIC) OF THE CSM OR LM PERMANENT STATE VECTOR. THE CALLER MUST CALL ROUTINE INTSTALL AND SET UP THE FLAGS INTYPFLG, VINTFLAG, DIMOFLAG, D6OR9FLG AND STATEFLG. THE TIME TO INTEGRATE TO MUST BE LOADED IN $TDEC1_D = t_2$. THIS ENTRY LOADS THE APPROPRIATE STATE VECTOR AND TIME FROM PERMANENT STORAGE INTO RCV_v, VCV_v AND TET_D. THIS IS THE ONLY ENTRY THAT PERMITS W-MATRIX INTEGRATION AS AN OPTION. THIS ENTRY IS USED GENERALLY BY THE NAVIGATION PROGRAMS.



MIT INSTRUMENTATION LAB CAMBRIDGE MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A. J. Lanzillo 7 NOV 68	INTEGRATION INITIALIZATION
PRGMR	
ANALYST M. Robertson 5 SEPT 69	COLOSSUS IIC
DCLMR	FC-2290
APPR'D Robert M. ... 9-5-69 REV	SHEET 8 26

RVCON SETS UP ORBIT INTEGRATION TO DO A CONIC SOLUTION FOR POSITION AND VELOCITY OVER THE TIME INTERVAL FROM TET TO TDEC. IT CALLS THE KEPPREP SUBROUTINE WHICH IN TURN CALLS THE KEPLER SUBROUTINE. RVCON IS ENTERED IF CSMCONIC OR LEMCONIC WAS CALLED OR IF INTEGRVS OR INTEGRV WAS CALLED WITH INTYPFLG SET.



$TAU._D$ IS INPUT TO KEPPREP
TET_D IS TIME OF VALIDITY OF PRESENT CONIC STATE VECTOR $\underline{r}_{CON}, \underline{v}_{CON}$
$TDEC_D$ IS TIME TO INTEGRATE TO

THE STATE VECTOR MUST BE RECTIFIED PRIOR TO THE CALL TO KEPPREP

INPUT

1. $RCV_V = \underline{r}_{CON}$
2. $VCV_V = \underline{v}_{CON}$
3. $TDELTAV_V = \underline{\delta}$
4. $TNUV_V = \underline{\nu}$
5. X2 = PBODY

OUTPUT

1. $RRECT_V = \underline{r}_0 = \underline{r}_{CON} + \underline{\delta}$
2. $VRECT_V = \underline{v}_0 = \underline{v}_{CON} + \underline{\nu}$
3. $RCV_V = \underline{r}_{CON} = NEW\ \underline{r}_0$
4. $VCV_V = \underline{v}_{CON} = NEW\ \underline{v}_0$
5. $TDELTAV_V = \underline{\delta} = (0,0,0)$
6. $TNUV_V = \underline{\nu} = (0,0,0)$
7. $TC_D = \tau = 0$
8. $XKEP_D = x = 0$

INPUT

1. $RCV_V = \underline{r}_{CON}$
2. $VCV_V = \underline{v}_{CON}$
3. $TAU._D = t_D\ (= t_{21})$
4. $XKEP_D = x'$
5. $TC_D = t'_{21}$
6. PBODY = 0 FOR EARTH, = 2 FOR MOON
7. MOONFLAG: CLEAR FOR EARTH, SET FOR MOON.

OUTPUT:

1. $RCV_V = \underline{r}(t_2)$
2. $VCV_V = \underline{v}(t_2)$
3. $TC_D = t_2$ = TIME TO WHICH ITERATION CONVERGED $\approx t_D$
4. $XPREV_D = x' = XKEP_D$

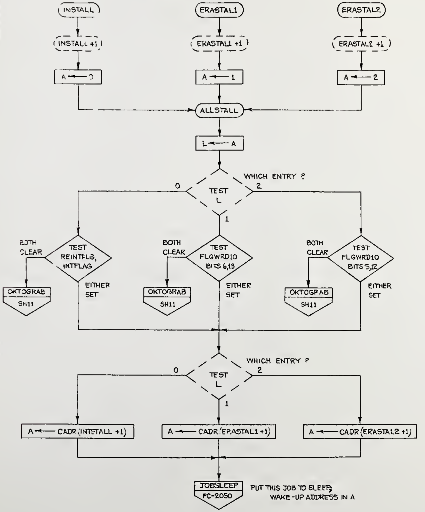
NOTE: OUTPUT IS FOR ENTIRE KEPPREP AND KEPLERN COMPUTATIONS (SEE FC-2310, CONIC SUBROUTINES).

COMPUTE THE TIME OF VALIDITY OF THE KEPLER OUTPUT $\underline{r}_{CON}, \underline{v}_{CON}$. $TC_D = t_{21}$ IS THE TIME INCREMENT THAT KEPLER ACTUALLY INTEGRATED OVER

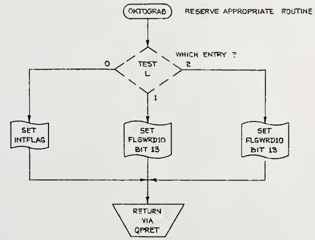
RECTOUT COMPLETES THE INTEGRATION PROCEDURE BY RECTIFYING, STORING THE STATE VECTOR INTO THE OUTPUT LOCATIONS, SETTING APPROPRIATE FLAGS, AND GOING TO INTWAKE

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A. J. Longelle 7NOV68 / PRGMR / ANALYST Wm. M. Robertson 5SEPT69 / DOCMR / APPR'D Robert M. Estes 12-5-69	INTEGRATION INITIALIZATION
REV	COLOSSUS IIC — DOCUMENT NO. FC-2290 — SHEET 9 OF 26

THE INTEGRATION STALL ROUTINE PREVENTS AN ACTIVE JOB FROM CALLING THE INTEGRATION SUBROUTINE IF (1) IT HAS BEEN CALLED BY ANOTHER PROGRAM (WHICH IS PRESENTLY INACTIVE) AND (2) IT HAS NOT COMPLETED ITS CALCULATIONS AND RETURNED CONTROL TO THE CALLING PROGRAM. IF THE INTEGRATION SUBROUTINE IS AVAILABLE, THEN IT IS RESERVED FOR THE CALLING PROGRAM. IF THE INTEGRATION SUBROUTINE IS IN USE OR ALREADY RESERVED, THE CALLING PROGRAM IS PUT TO SLEEP.

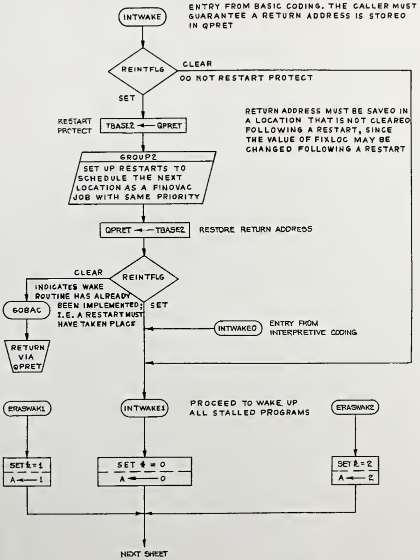


MIT INSTRUMENTATION LAB CAMBRIDGE MASS.	APOLLO GUIDANCE AND NAVIGATION
	INTEGRATION INITIALIZATION
DRAWN A.C. WILLIAMS 20JUN69	
PRGMR	
ANALYST Wm M. Robertson 5SEPT69	COLOSSUS IIC — DOCUMENT NO. FC-2290
DOCMR	
APP'D Robert M. Estes 9-?-69	REV — SHEET 10 OF 26

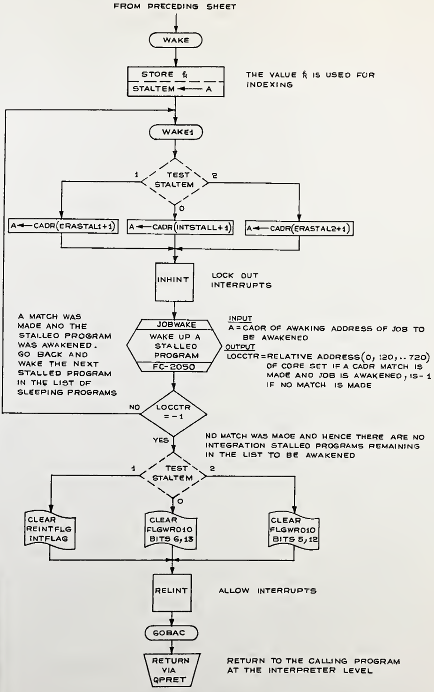


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 20JUN69	INTEGRATION INITIALIZATION
PRGMR	
ANALSY Wm M. Robertson 5SEPT69	COLOSSUS IIC — DOCUMENT NO FC-2290
DOCMR	
APPR'D Robert M. Estes 9-5-69	REV — SHEET 11 OF 26

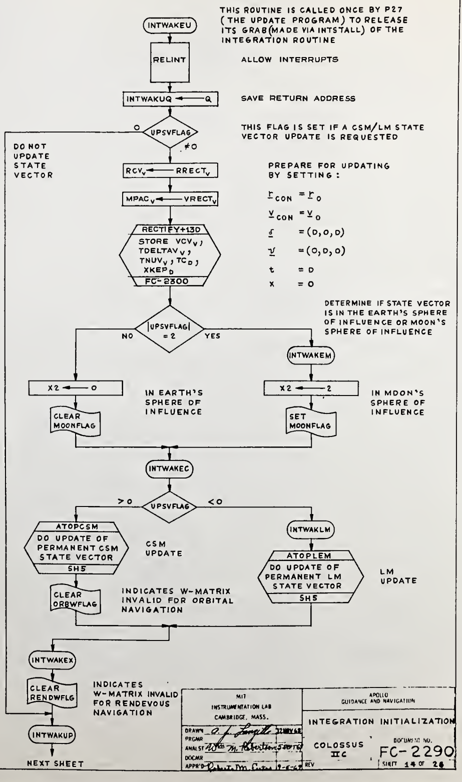
THE INTEGRATION WAKE ROUTINE WAKES UP ALL PROGRAMS THAT HAVE BEEN PUT TO SLEEP (I.E. STALLED) BY THE INTEGRATION STALL ROUTINE INTSTALL.



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN	INTEGRATION INITIALIZATION
PRGMR	
ANALST 5 SEPT 69	COLOSSUS IIC
DOCMR	DOCUMENT NO. FC-2290
APPR'D 9-5-69	REV
	SHEET 12 OF 26



MIT INSTRUMENTATION LAB
CAMBRIDGE MASS
25JUNE69
5SEPT69
APOLLO
INTEGRATION INITIALIZATION
COLOSSUS IIC
FC-2290
13 26


THIS ROUTINE IS CALLED ONCE BY P27 (THE UPDATE PROGRAM) TO RELEASE ITS GRAB (MADE VIA INTSTALL) OF THE INTEGRATION ROUTINE
INTWAKEU
RELINT
ALLOW INTERRUPTS
INTWAKUQ ← Q
SAVE RETURN ADDRESS
UPSVFLAG
0
≠0
THIS FLAG IS SET IF A CSM/LM STATE VECTOR UPDATE IS REQUESTED
DO NOT UPDATE STATE VECTOR
RCV_V ← RRECT_V
MPAC_V ← VRECT_V
PREPARE FOR UPDATING BY SETTING:
r_CON = r_0
v_CON = v_0
δ = (0,0,0)
ν = (0,0,0)
t = 0
x = 0
RECTIFY+13D
STORE VCV_V, TDELTAV_V, TNUV_V, TC_D, XKEP_D
FC-2300
DETERMINE IF STATE VECTOR IS IN THE EARTH'S SPHERE OF INFLUENCE OR MOON'S SPHERE OF INFLUENCE
|UPSVFLAG| = 2
NO
YES
INTWAKEM
X2 ← 0
IN EARTH'S SPHERE OF INFLUENCE
CLEAR MOONFLAG
X2 ← 2
IN MOON'S SPHERE OF INFLUENCE
SET MOONFLAG
INTWAKEC
UPSVFLAG
> 0
< 0
ATOPCSM
DO UPDATE OF PERMANENT CSM STATE VECTOR
SH5
CSM UPDATE
INTWAKLM
ATOPLEM
DO UPDATE OF PERMANENT LM STATE VECTOR
SH5
LM UPDATE
CLEAR ORBWFLAG
INDICATES W-MATRIX INVALID FOR ORBITAL NAVIGATION
INTWAKEX
CLEAR RENDWFLG
INDICATES W-MATRIX INVALID FOR RENDEVOUS NAVIGATION
INTWAKUP
NEXT SHEET
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.
APOLLO GUIDANCE AND NAVIGATION
INTEGRATION INITIALIZATION
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DOCUMENT NO.
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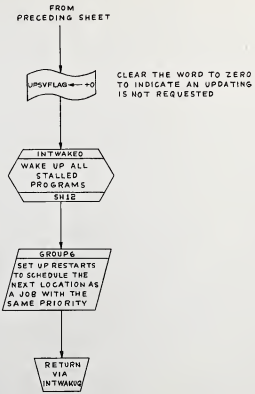
SHEET 14 OF 28



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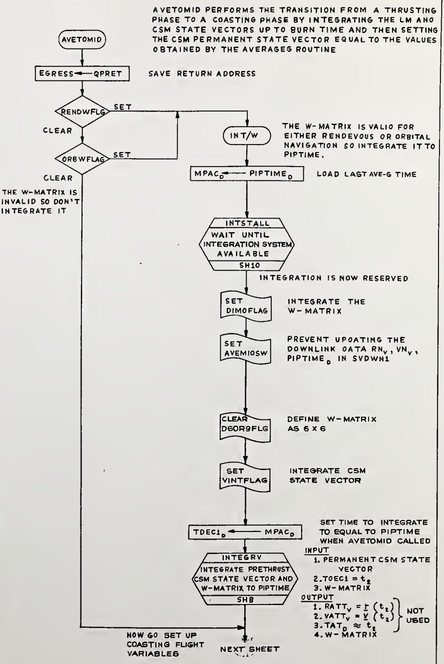
PROG MR	
ANALYST Wm. M. Robertson 5SEPT69	COLOSSUS IIC
DIV MR	FC-2290
APPR Robert M. Estes 9-5-69	15 26



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DRAWN G. J. Levesque 13NOV68	INTEGRATION INITIALIZATION
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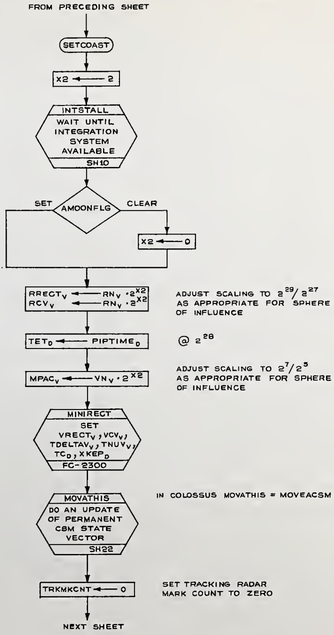

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DRAWN P.M. Dietrich 25 JUNE 68	INTEGRATION INITIALIZATION
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ANALYST Wm. M. Robertson 5 SEPT 68	COLOSSUS IIC — DOCUMENT NO. FC-2290
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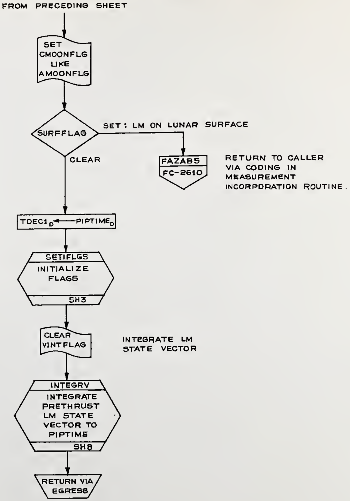
APPR'D Roberta M. Eaton 19-5-69	REV. — SHEET 17 OF 26



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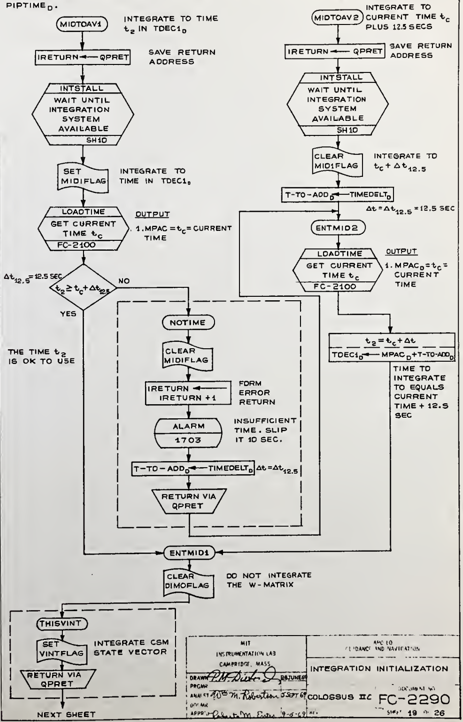
MIDTOAV1 DOES PRECISION INTEGRATION OF THE CSM PERMANENT STATE VECTOR TO THE TIME t_2 SPECIFIED IN $TDEC1_D$. IF THIS TIME IS LESS THAN CURRENT TIME PLUS 10 SECONDS IT IS AUTOMATICALLY SET TO THIS VALUE, ALARM 1703 IS SET AND FOLLOWING THE INTEGRATION RETURN IS TO THE RETURN ADDRESS PLUS ONE. MIDTOAV2 DOES A PRESISION INTEGRATION OF CSM PERMANENT STATE VECTOR TO CURRENT TIME PLUS 12.5 SECONDS. IN EITHER CASE THE INTEGRATED STATE VECTOR AND TIME ARE STORED IN RN_V, VN_V, $PIPTIME_D$.



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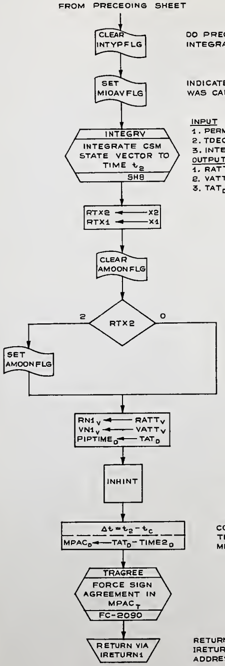


DO PRECISION INTEGRATION

INDICATE TO INTEGRATION THAT IT WAS CALLEO BY THE MIOTOAVE ROUTINE

INPUT
1. PERMANENT CSM STATE VECTOR
2. $TDEC1_D = t_2$
3. INTERPRETIVE FLAGS

OUTPUT
1. $RATT_V = \underline{r}(t_2)$
2. $VATT_V = \underline{V}(t_2)$
3. $TAT_D \approx t_2$

SET FLAG ACCORDING TO SPHERE OF INFLUENCE (FOR SCALING OF STATE VECTOR)

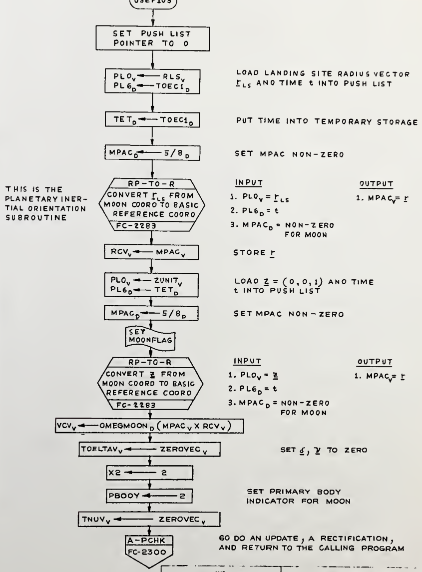
STORE THE OUTPUT OF INTEGRV

INHIBIT INTERRUPTS

COMPUTE A DELTA TIME EQUAL TO TIME ACTUALLY INTEGRATEO TO MINUS THE CURRENT TIME IN TIME2, TIME1

RETURN IS MADE VIA SUBROUTINE BANK JUMP. IRETURN1 CONTAINS EITHER NORMAL RETURN ADDRESS DR ERROR RETURN ADDRESS

USEPIOS IS EXECUTED INSTEAD OF THE NORMAL CODING IN PTOALEM IF THE LM IS ON THE SURFACE OF THE MOON. THE LM POSITION AND VELOCITY VECTORS ARE CALCULATED USING THE PLANETARY INERTIAL ORIENTATION SUBROUTINE INSTEAD OF USING THE NORMAL INTEGRATION ROUTINES. SINCE THE LANDING SITE MOVES RELATIVE TO THE BASIC REFERENCE SYSTEM BECAUSE OF LUNAR ROTATION IT IS MORE CONVENIENT TO STORE THE LM STATE VECTOR IN THE MOON FIXED COORDINATE SYSTEM WHERE IT DOES NOT CHANGE IN TIME. THIS ROUTINE CONVERTS THE RLS TO THE BASIC REFERENCE COORDINATE SYSTEM.



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DRAWN A. J. Longello 18NOV68; PRGMR; ANALST Wm. M. Robertson 5 Sept 69; DOC MR; APPR'D Robert M. Eaton 9-8-69	INTEGRATION INITIALIZATION
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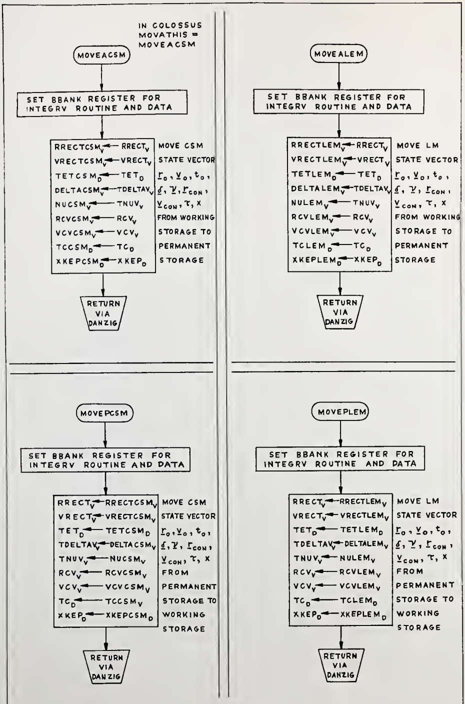

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APOLLO GUIDANCE AND NAVIGATION

INTEGRATION INITIALIZATION

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SUBROUTINES CALLED WHICH ARE
FLOWED ON OTHER FLOW CHARTS

SUBROUTINE NAME	FLOW CHART	DESCRIPTION	WHERE CALLED
LOADTIME	2100	LOAD TIME1 AND TIME2 (CURRENT TIME) INTO MPAC	SH. 3, 19
JOBSLEEP	2050	PUT CALLING PROGRAM TO SLEEP	SH. 10
SVDWN1	2250	GET RECTIFIED CSM STATE VECTOR FOR DOWNLINK	SH. 5
SVDWN2	2250	GET RECTIFIED LM STATE VECTOR FOR DOWNLINK	SH. 5
RECTIFY	2300	DEFINE A NEW REFERENCE CONIC AND ZERO THE DEVIATIONS	SH. 8, 9
RECTIFY +13D	2300	SPECIAL ENTRY TO RECTIFY (ABOVE)	SH. 14
TESTLOOP	2300	ENTRY POINT FOR PRECISION INTEGRATION	SH. 8
MINIRECT	2300	SPECIAL ENTRY TO RECTIFY (ABOVE)	SH. 17
KEPPREP	2300	ENTRY POINT FOR CONIC (KEPLER) INTEGRATION	SH. 9
RECTOUT	2300	ENTRY POINT FOR COMPLETING AN INTEGRATION	SH. 9
JOBWAKE	2050	WAKE UP A SLEEPING JOB	SH. 13
FAZAB5	2610	ENTRY POINT IN INCORP ROUTINE FOR ENDING AVETOMID ROUTINE	SH. 18
RP-TO-P	2283	CONVERT A VECTOR FROM MOON COORDINATES TO BASIC REFERENCE COORDINATES	SH. 21
A-PCHK	2300	ENTRY POINT FOR PERFORMING AN UPDATE AND RECTIFICATION	SH. 21

FLAGS

NAME (BIT, FLAGWRD)	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
INTYPFLG (4, 3)	DO CONIC (KEPLER) INTEGRATION	DO PRECISION (ENCKE) INTEGRATION	SH. 7	SH. 3, 6, 20	SH. 8
VINTFLAG (3, 3)	INTEGRATE THE CSM STATE VECTOR	INTEGRATE THE LM STATE VECTOR	SH. 4, 6, 7, 16, 19	SH. 4, 6, 7, 18	SH. 8
DIMOFLAG (1, 3)	INTEGRATE THE W-MATRIX	DO NOT INTEGRATE THE W-MATRIX	SH. 4, 16	SH. 3, 6, 7, 8, 19	
D6OR9FLG (2, 3)	W-MATRIX IS 9x9	W-MATRIX IS 6x6		SH. 3, 16	
STATEFLG (5, 3)	UPDATE PERMANENT CSM/LM STATE VECTOR	DO NOT UPDATE PERMANENT CSM/LM STATE VECTOR	SH. 3	SH. 3	
NODOFLAG (1, 2)	VERB 37 IS NOT PERMITTED	VERB 37 IS PERMITTED	SH. 3	SH. 4	
QUITFLAG (5, 9)	DISCONTINUE INTEGRATION AT START OF NEXT TIMESTEP	CONTINUE INTEGRATION		SH. 3	SH. 3
SURFFLAG (8, 8)	LM IS ON LUNAR SURFACE	LM IS NOT ON LUNAR SURFACE			SH. 4, 5, 18
RENDWFLG (1, 5)	W-MATRIX IS VALID FOR RENDEZVOUS NAVIGATION	W-MATRIX IS INVALID FOR RENDEZVOUS NAVIGATION		SH. 14	SH. 4, 16

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FLAGS (CONTINUED)

NAME (BIT, FLAGWRD)	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
PRECIFLG (8, 3)	CSMPREC OR LEMPREC WAS CALLED	INTEGRV OR INTEGRVS WAS CALLED	SH. 4, 6, 8	SH. 4	
MOONFLAG (12, 0)	INSIDE LUNAR SPHERE OF INFLUENCE	OUTSIDE LUNAR SPHERE OF INFLUENCE	SH. 5, 14, 21	SH. 5,14	SH. 5, 8
CMOONFLG (12, 8)	(PERMANENT CSM REPRESENTATION OF MOONFLAG)		SH. 5, 18	SH. 5, 18	SH. 5
LMOONFLG (11, 8)	(PERMANENT LM REPRESENTATION OF MOONFLAG)		SH. 5	SH. 5	SH. 5
NEWIFLG (13, 8)	INITIAL PASS THROUGH INTEGRATION LOOP	SUBSEQUENT PASS THROUGH INTEGRATION LOOP	SH. 8		
RPQFLAG (15, 8)	RPQ NOT COMPUTED	RPQ COMPUTED	SH. 8		
INTFLAG	INTEGRATION IS IN PROGRESS	INTEGRATION IS NOT IN PROGRESS	SH. 11	SH. 13	SH. 10
REINTFLG (7, 10)	RESTART THIS ROUTINE IF STALLED AND RESTART OCCURS	DO NOT RESTART THIS ROUTINE IF STALLED AND RESTART OCCURS		SH. 13	SH. 10, 12
MIDAVFLG (2, 9)	INTEGRATION WAS CALLED BY THE MIDTOAV ROUTINE	INTEGRATION WAS NOT CALLED BY THE MIDTOAV ROUTINE	SH. 20		
MID1FLAG (3, 9)	INTEGRATE TO TIME IN TDEC1	INTEGRATE TO CURRENT TIME PLUS 10 SECONDS	SH. 19	SH. 19	
V96ONFLG (3, 8)	POO INTEGRATION INHIBITED BY V96	POO INTEGRATION PROCEEDING REGULARLY		SH. 3	
AVEMIDSW (1, 9)	PREVENT UPDATING THE CSM DOWNLINK DATA RN, VN, PIPTIME	ALLOW UPDATING THE CSM DOWNLINK DATA RN, VN, PIPTIME	SH. 16		
UPSVFLAG	CSM/LM STATE VECTOR UPDATE IS REQUESTED	CSM/LM STATE VECTOR UPDATE NOT REQUESTED		SH. 15	SH. 14
ORBWFLAG (6, 3)	W-MATRIX IS VALID FOR ORBITAL NAVIGATION	W-MATRIX IS INVALID FOR ORBITAL NAVIGATION		SH. 14	SH. 4, 16
AMOONFLG (2, 0)	STATE VECTOR IN LUNAR SPHERE AT MIDTOAVE	STATE VECTOR IN EARTH SPHERE AT MIDTOAVE	SH. 20	SH. 20	SH. 17, 18

DISPLAYS

VERB-NOUN	TYPE OF DISPLAY	DESCRIPTION OF EACH REGISTER	WHERE EXECUTED
	ALARM	ALARM CODE = 1703 INSUFFICIENT TIME FOR INTEGRATION, TIG WAS SLIPPED	SH. 19

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INTEGRATION INITIALIZATION
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APPR'D Robert M. Estes 9-5-69
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ERASABLE LOCATIONS USED

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
$TDEC1_D$	t	TIME TO INTEGRATE TO	CSEC	CSEC	2^{28}
$TETCSM_D$	t	TIME TO INTEGRATE TO IN P00	CSEC	CSEC	2^{28}
RCV_V	$\underline{r}_{con}$	CONIC POSITION VECTOR	M	M	$2^{29}/2^{27}$
VCV_V	$\underline{v}_{con}$	CONIC VELOCITY VECTOR	M/CSEC	M/CSEC	2^{7} 2^{5}
TET_D	t	TIME OF VALIDITY OF STATE VECTOR	CSEC	CSEC	2^{28}
$RRECT_V$	$\underline{r}_{o}$	POSITION VECTOR AT RECTIFICATION	M	M	$2^{29}/2^{27}$
$VRECT_V$	$\underline{v}_{o}$	VELOCITY VECTOR AT RECTIFICATION	M/CSEC	M/CSEC	2^{7} 2^{5}
$TDELTAV_V$	$\underline{\delta}$	POSITION DEVIATION VECTOR	M	M	2^{22} 2^{18}
$TNUV_V$	$\underline{\nu}$	VELOCITY DEVIATION VECTOR	M/CSEC	M/CSEC	$2^{3}/2^{-1}$
TC_D	t_{2I}	TIME SINCE RECTIFICATION	CSEC	CSEC	2^{28}
$XKEP_D$	x	UNIVERSAL VARIABLE	$M^{1/2}$	$M^{1/2}$	$2^{17}/2^{16}$
$TDEC_D$	t	TIME TO INTEGRATE TO	CSEC	CSEC	2^{28}
PBODY	P	PRIMARY BODY INDICATOR	INTEGER	INTEGER	
IRETURN		LOCATION FOR STORING RETURN ADDRESS	INTEGER	INTEGER	
$TAU._D$	τ	TIME INTERVAL FOR CONIC INTEGRATION	CSEC	CSEC	2^{28}
TBASE2		TEMPORARY STORAGE FOR RETURN ADDRESS	INTEGER	INTEGER	
STALTEM		TEMPORARY STORAGE FOR SUBSCRIPT k	INTEGER	INTEGER	
EGRESS		LOCATION FOR STORING RETURN ADDRESS	INTEGER	INTEGER	
$PIPTIME_D$	t	BURN TIME	CSEC	CSEC	2^{28}
TAT_D	t	TIME ACTUALLY INTEGRATED TO	CSEC	CSEC	2^{28}
TRKMKCNT		TRACKING RADAR MARK COUNT	INTEGER	INTEGER	
RN_V	$\underline{r}_{con}$	POSITION VECTOR OF CSM FOR DOWNLINK	M	M	2^{29} 2^{27}
VN_V	$\underline{v}_{con}$	VELOCITY VECTOR OF CSM FOR DOWNLINK	M/CSEC	M/CSEC	2^{7} 2^{5}
$R\text{-}OTHER_V$	$\underline{r}_{con}$	POSITION VECTOR OF LM FOR DOWNLINK	M	M	$2^{29}/2^{27}$
$V\text{-}OTHER_V$	$\underline{v}_{con}$	VELOCITY VECTOR OF LM FOR DOWNLINK	M/CSEC	M/CSEC	2^{7} 2^{5}

PROGRAM CONSTANTS

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING VALUE AND UNITS	AGC VALUE AND UNITS	AGC SCALING
OMEGMOON$_D$			$2.66169947 \times 10^{-8}$	$2.66169947 \times 10^{-8}$	2^{-23}
ZEROVEC$_V$	(0, 0.0)	THE ZERO VECTOR	(0.0, 0.0, 0.0)	(0, 0, 0)	ANY
(PMNS\ CD$_D$		INTEGER 2	2	2	2^{14}
TIMEDELT$_D$	$\Delta t_{12.5}$	USED IN TEST TO DETERMINE IF TIME TO INTEGRATE TO MUST BE SLIPPED	12.5 SEC	1250 CSEC	2^{28}
5 8$_D$		A NON-ZERO CONSTANT	5/8	5/8	2^{3}

PAD LOADS

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING VALUE AND UNITS	AGC VALUE AND UNITS	AGC SCALING	OCTAL VALUE
RLS$_V$	$\underline{r}_{LS}$	LUNAR LANDING SIGHT VECTOR				

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APOLLO GUIDANCE AND NAVIGATION

INTEGRATION INITIALIZATION

COLOSSUS IIC

DOCUMENT NO FC-2290

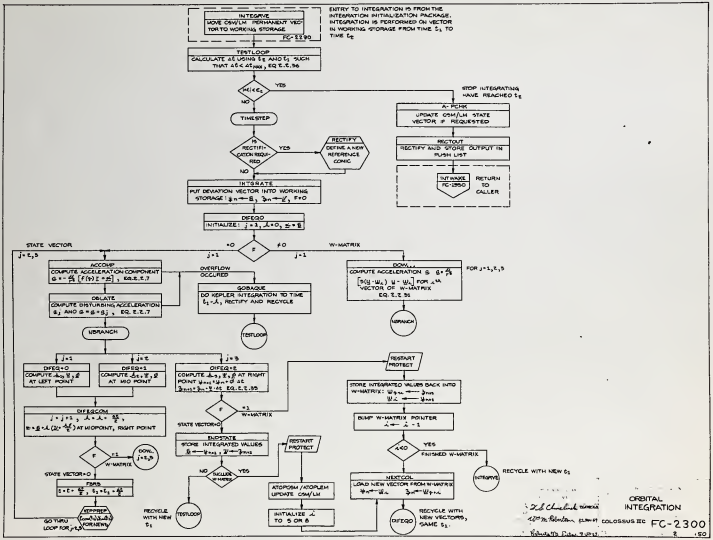
REV

MAJOR SUBROUTINES AND EXTERNAL ENTRY POINTS

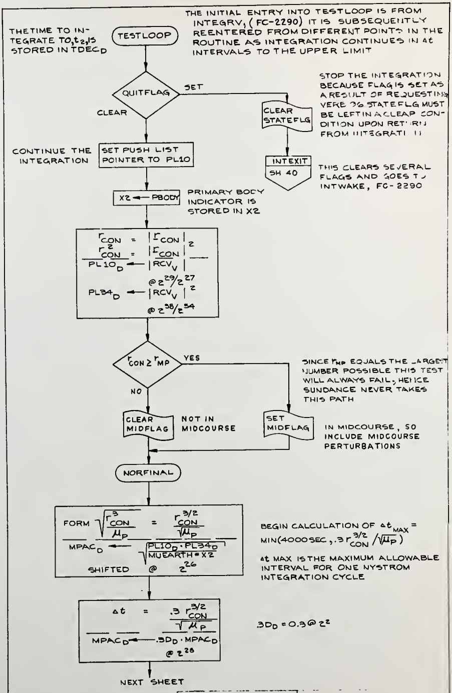
TESTLOOP	ENTRY TO ACTUAL INTEGRATION LOOP	SH. 4
TIMESTEP	INTERMEDIATE ENTRY POINT IN INTEGRATION LOOP	SH. 6
INTGRATE	INTERMEDIATE ENTRY POINT IN INTEGRATION LOOP THAT INITIALIZES LOCATIONS FOR FIRST PASS THROUGH LOOP	SH. 8
ACCOMP	COMPUTES THE ACCELERATION COMPONENTS FOR EARTH AND MOON	SH. 9
GAMCOMP	SUBROUTINE THAT COMPUTES ACCELERATION $\underline{a}_p$ DUE TO THE ATTRACTION OF THE PRIMARY BODY	SH. 23
DIFEQ+0	EVALUATE $\underline{\psi}$ AND $\underline{\phi}$ AT THE LEFT HAND POINT	SH. 27
DIFEQ+1	EVALUATE $\underline{\psi}$ AND $\underline{\phi}$ AT THE MID-POINT	SH. 27
FBR3	CALCULATE TIME AND CONIC STATE VECTOR AT MIDPOINT AND RIGHT HAND POINT	SH. 28
KEPPREP	SUBROUTINE COMPUTES ESTIMATE OF x AND THEN CALLS KEPLER SUBROUTINE TO CALCULATE CONIC STATE VECTOR	SH. 29
DIFEQ+2	EVALUATE $\underline{\psi}$ AND $\underline{\phi}$ AT THE RIGHT HAND POINT AND THEN CALCULATE THE FUNCTION $\underline{y}$ AND ITS DERIVATIVE $\underline{z}$ AT RIGHT HAND POINT	SH. 32
NEXTCOL	INTERMEDIATE ENTRY POINT FOR INTEGRATING A COLUMN OF THE W-MATRIX	SH. 35
CKMID2	ROUTINE ENTERED BY INTEGRATION IF CALLED BY MIDTOAV	SH. 36
A-PCHK	WRAPS UP THE INTEGRATION ROUTINE WITH A STATE VECTOR UPDATE IF REQUESTED AND A RECTIFICATION	SH. 38
RECTOUT	DOES RECTIFICATION AND STORES OUTPUT IN PUSHLIST	SH. 40
DOW..	ROUTINE THAT CONTROLS THE CALCULATION OF THE ACCELERATION TERMS USED FOR INTEGRATING THE W-MATRIX	SH. 41
DOW..1	SUBROUTINE THAT CALCULATES THE ACCELERATIONS $\underline{a}_p$ AND $\underline{a}_q$	SH. 42
RECTIFY	DEFINE A NEW REFERENCE CONIC AND ZERO THE DEVIATIONS	SH. 43
MINIRECT	ENTRY POINT IN RECTIFY IF $\underline{\delta}$, $\underline{\nu}$ MUST BE INITIALLY ZERO	SH. 43
RECTIFY +13D	ENTRY POINT IN MINIRECT IF $VRECT_V$ ALREADY STORED	SH. 43
ORIGCHNG	CHANGE ORIGIN OF COORDINATE SYSTEM	SH. 44

REFERENCES FOR ORBITAL INTEGRATION

1. GUIDANCE SYSTEM OPERATIONS PLAN USING PROGRAM COLOSSUS (GSOP), R-577. SECTION 5, GUIDANCE EQUATIONS, MAY, 1968.
2. OSTANEK, W. F., USER'S GUIDE FOR ORBITAL INTEGRATION ROUTINE FOR FLIGHT 504, FLIGHT 504 MEMO 5, REV I, JUNE, 1967.
3. OSTANEK AND KEFAUVER, LEVEL II TEST PACKAGE FOR COASTING INTEGRATION SUBROUTINE, MIT/IL, NOVEMBER, 1967.



INTEGRVE
MOVE CSM/LM PERMANENT VECTOR TO WORKING STORAGE
FC-2290
ENTRY TO INTEGRATION IS FROM THE INTEGRATION INITIALIZATION PACKAGE. INTEGRATION IS PERFORMED ON VECTOR IN WORKING STORAGE FROM TIME t_1 TO TIME t_2
TESTLOOP
CALCULATE Δt USING t_2 AND t_1 SUCH THAT $\Delta t < \Delta t_{MAX}$, EQ 2.2.36
$|\Delta t| < \epsilon_2$
YES
NO
STOP INTEGRATING HAVE REACHED t_2
A-PCHK
UPDATE CSM/LM STATE VECTOR IF REQUESTED
RECTOUT
RECTIFY AND STORE OUTPUT IN PUSH LIST
INTWAKE
FC-1950
RETURN TO CALLER
TIMESTEP
IS RECTIFICATION REQUIRED
RECTIFY
DEFINE A NEW REFERENCE CONIC
INTGRATE
PUT DEVIATION VECTOR INTO WORKING STORAGE: $\psi_n \leftarrow \delta$, $\zeta_n \leftarrow \nu$, F=0
DIFEQO
INITIALIZE: $j=1$, $\lambda=0$, $\alpha=\delta$
F
=0
≠0
STATE VECTOR
W-MATRIX
j=2,3
j=1
ACCOMP
COMPUTE ACCELERATION COMPONENT $a = -\frac{\mu}{r^3}[f(q)r + \alpha]$, EQ.2.2.7
OBLATE
COMPUTE DISTURBING ACCELERATION a_j AND $a = a + a_j$, EQ. 2.2.7
OVERFLOW OCCURED
GOBAQUE
DO KEPLER INTEGRATION TO TIME $t_1 - \lambda$, RECTIFY AND RECYCLE
TESTLOOP
DOW..
COMPUTE ACCELERATION a $a = \frac{\mu}{r^5}[3(\underline{u} \cdot \underline{w}_i)\underline{u} - \underline{w}_i]$ FOR i^{th} VECTOR OF W-MATRIX EQ. 2.2.31
FOR j=1,2,3
NBRANCH
j=1
j=2
j=3
DIFEQ+0
COMPUTE h_1, ψ, ϕ AT LEFT POINT
DIFEQ+1
COMPUTE h_2, ψ, ϕ AT MID POINT
DIFEQ+2
COMPUTE h_3, ψ, ϕ AT RIGHT POINT $\psi_{n+1} = \psi_n + \phi\Delta t$, $\zeta_{n+1} = \zeta_n + \psi\Delta t$ EQ.2.2.35
DIFEQCOM
$j = j+1$, $\lambda = \lambda + \frac{\Delta t}{2}$,
$\alpha = \delta + \lambda(\nu + \frac{\Delta t}{2})$ AT MIDPOINT, RIGHT POINT
F
=1
W-MATRIX
DOW.. j=2,3
STATE VECTOR=0
FBRB
$t = t - \frac{\Delta t}{2}$, $t_1 = t_1 + \frac{\Delta t}{2}$
KEPPREP
FOR NEW
GO THRU LOOP FOR j=2,3
STATE VECTOR=0
ENDSTATE
STORE INTEGRATED VALUES $\delta \leftarrow \psi_{n+1}$, $\nu \leftarrow \zeta_{n+1}$
INCLUDE W-MATRIX
NO
YES
TESTLOOP
RECYCLE WITH NEW t_1
RESTART PROTECT
ATOPCSM / ATOPLEM
UPDATE CSM/LM
INITIALIZE i TO 5 OR 8
RESTART PROTECT
STORE INTEGRATED VALUES BACK INTO W-MATRIX: $w_{i+1} \leftarrow \zeta_{n+1}$, $w_i \leftarrow \psi_{n+1}$
BUMP W-MATRIX POINTER $i \leftarrow i - 1$
$i<0$
YES
FINISHED W-MATRIX
INTEGRVE
RECYCLE WITH NEW t_1
NEXTCOL
LOAD NEW VECTOR FROM W-MATRIX $\psi_n \leftarrow w_i$, $\zeta_n \leftarrow w_{i+1}$
DIFEQO
RECYCLE WITH NEW VECTORS, SAME t_1.
ORBITAL INTEGRATION
COLOSSUS IIC
FC-2300
2
150



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DRAWN D. S. Chmielewski 17 OCT 68
PRGMR
ANALST Wm. M. Robertson 22 SEPT 69
DOCMR
APPR'D Roberta M. Sutis 9-23-69

APOLLO GUIDANCE AND NAVIGATION

ORBITAL INTEGRATION

COLOSSUS IIC

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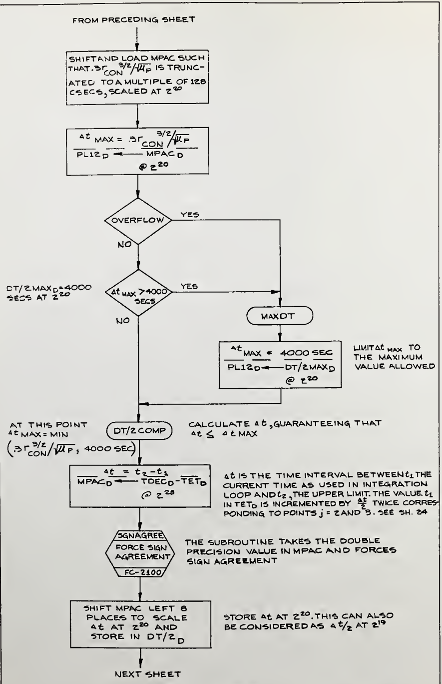

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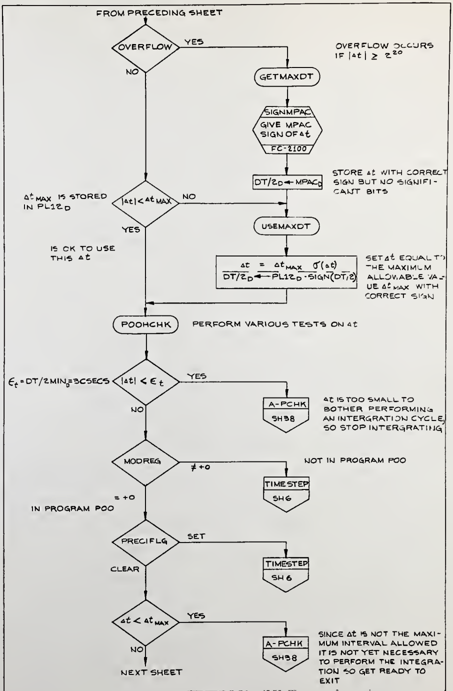

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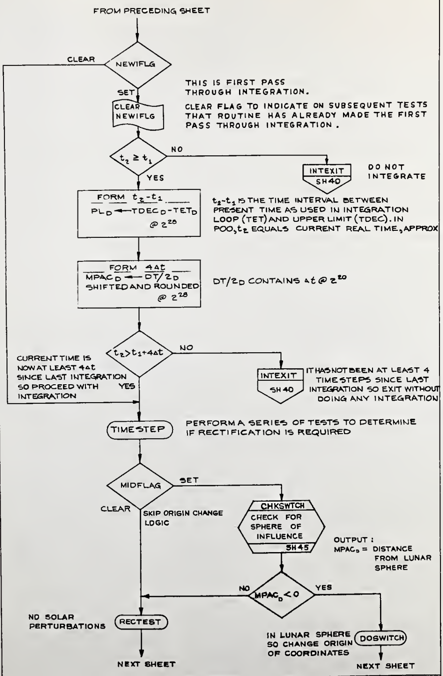

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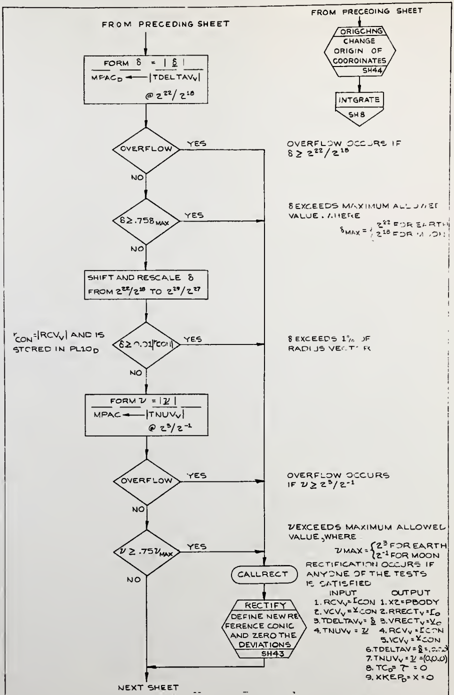

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CHECKED:
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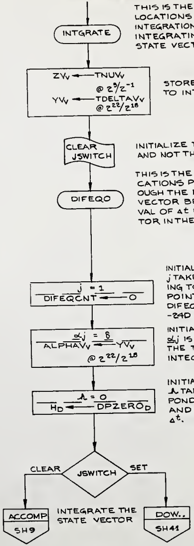

THIS IS THE ENTRY SEQUENCE FOR INITIALIZING LOCATIONS FOR THE FIRST PASS THROUGH THE INTEGRATION LOOP. LOCATIONS ARE SET UP FOR INTEGRATING THE STATE VECTOR SINCE THE STATE VECTOR IS ALWAYS INTEGRATED FIRST

STORE ν, δ IN WORKING STORAGE PRIOR TO INTEGRATING THE STATE VECTOR

INITIALIZE TO INDICATE THE STATE VECTOR AND NOT THE W-MATRIX IS BEING INTEGRATED

THIS IS THE ENTRY POINT FOR INITIALIZING LOCATIONS PRIOR TO MAKING THREE PASSES THROUGH THE INTEGRATION LOOP (FOR $j = 1, 2, 3$). THE VECTOR BEING INTEGRATED OVER A TIME INTERVAL OF Δt IS EITHER A STATE VECTOR OR A VECTOR IN THE W-MATRIX

INITIALIZE j

j TAKES ON THE VALUES 1, 2, 3 CORRESPONDING TO THE LEFT POINT, MIDPOINT, AND RIGHT POINT OF AN INTERVAL OF LENGTH Δt. DIFEQCNT TAKES ON THE VALUES 0, -12D, -24D

INITIALIZE α_j

α_j IS THE ESTIMATE OF δ USED ON EACH OF THE THREE PASSES THROUGH THE INTEGRATION LOOP

INITIALIZE h.

h TAKES ON THE VALUES 0, $\frac{\Delta t}{2}$, Δt CORRESPONDING TO THE LEFT POINT, MID POINT, AND RIGHT POINT VALUE OF THE INTERVAL Δt.

INTEGRATE THE STATE VECTOR

INTEGRATE A VECTOR FROM THE W-MATRIX

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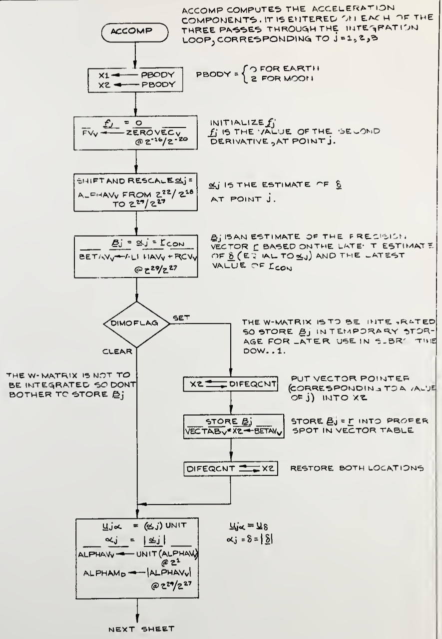

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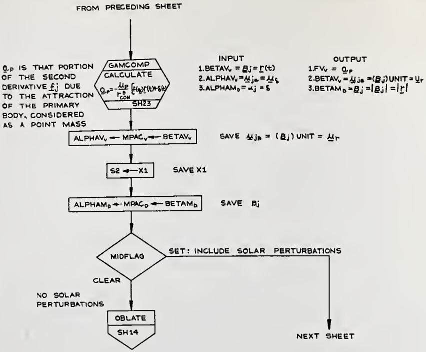

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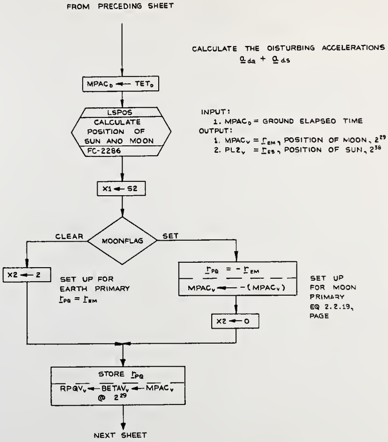

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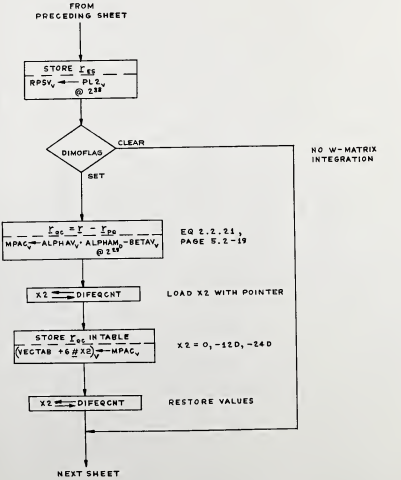

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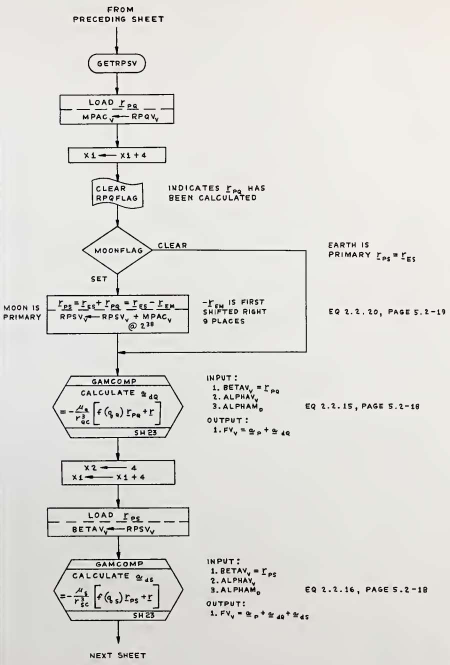

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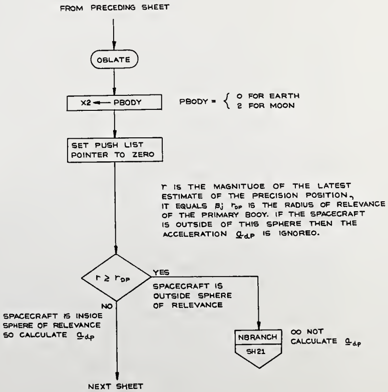

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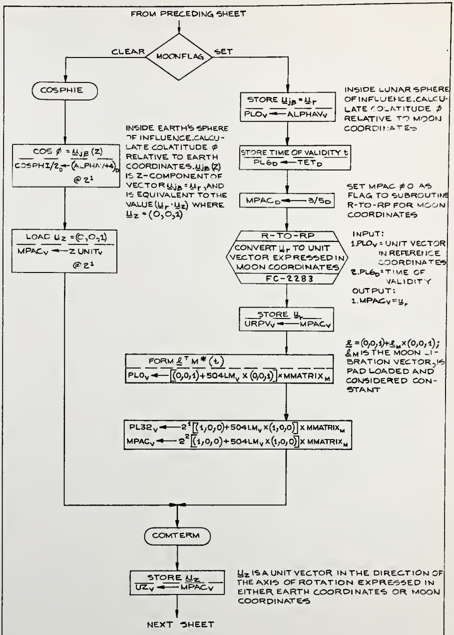

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$P_2' = 3\cos\phi$

PLO$_D$ ← COSPHI/2$_D$ · 3/32$_D$ @ 2^6

$3/32_D = 3.0 @ 2^5$

FORM $15\cos^2\phi$

MPAC$_D$ ← (COSPHI/2$_D$)^2 · 15/16$_D$ @ 2^6

$15/16_D = 15.0 @ 2^4$

$P_3' = \frac{1}{2}(15\cos^2\phi - 3)$

PL2$_D$ ← MPAC$_D$ ← (MPAC$_D$ − 3/64$_D$)/2 @ 2^3

$3/64_D = 3.0 @ 2^6$
DIVISION BY 2 IS ACCOMPLISHED BY A CHANGE IN THE SCALE FACTOR

FORM $\frac{7}{3}\cos\phi\, P_3'$

PL4$_D$ ← 7/12$_D$ · COSPHI/2$_D$ · MPAC$_D$ SHIFTED @ 2^7

$7/12_D = \frac{7}{3} @ 2^2$

FORM $\frac{4}{3} P_2'$

MPAC$_D$ ← 2/3$_D$ · PLO$_D$ @ 2^7

$2/3_D = \frac{4}{3} @ 2^1$

$P_4' = \frac{7}{3}\cos\phi\, P_3' - \frac{4}{3} P_2'$

PL4$_D$ ← MPAC$_D$ ← PL4$_D$ − MPAC$_D$ @ 2^7

FORM $\frac{9}{4}\cos\phi\, P_4'$

PL6$_D$ ← 9/16$_D$ · COSPHI/2$_D$ MPAC$_D$ @ 2^{10}

$9/16_D = \frac{9}{4} @ 2^2$

$P_5' = \frac{9}{4}\cos\phi\, P_4' - \frac{5}{4} P_3'$

MPAC$_D$ ← PL6$_D$ − 5/128$_D$ · PL2$_D$ @ 2^{10}

$5/128_D = \frac{5}{4} @ 2^5$

FORM $\frac{J_{4P}\, r_P}{J_{3P}} P_5'$

MPAC$_D$ ← (J4REQ/J3#X2)$_D$ · MPAC$_D$ @ 2^{36}

$$\frac{J_{4P} r_P}{J_{3P}} = \begin{cases} \frac{J_{4E} r_E}{J_{3E}} = 4991607.391 @ 2^{26} & \text{FOR EARTH} \\ \frac{J_{4M} r_M}{J_3} = -176236.02 @ 2^{28} & \text{FOR MOON} \end{cases}$$

NEXT SHEET

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FORM $\frac{J_{4P} r_P P_5'}{J_{3P}} / r + P_4' = \frac{J_{4P}}{J_{3P}} \left(\frac{r_P}{r}\right) P_5' + P_4'$

$MPAC_D \leftarrow MPAC_D / ALPHAM_D + PL4_D$ @ 2^7

FORM $\left[\frac{J_{4P}}{J_{3P}} \left(\frac{r_P}{r}\right) P_5' + P_4'\right] \frac{J_{3P} r_P}{J_{2P}} / r = \frac{J_{4P}}{J_{2P}} \left(\frac{r_P}{r}\right)^2 P_5' + \frac{J_{3P}}{J_{2P}} \left(\frac{r_P}{r}\right) P_4'$

$MPAC_D \leftarrow MPAC_D \cdot (2J3RE/J2*X2)_D / ALPHAM_D$ @ 2^5

$$\frac{J_{3P} r_P}{J_{2P}} = \begin{cases} \frac{J_{3E} r_E}{J_{2E}} = 13554.263 \text{ o3 @ } 2^{27} \text{ FOR EARTH} \\ \frac{J_{3M} r_M}{J_{2M}} = .3067493316 \times 10^{18} \text{ @ } 2^{+60} \text{ FOR MOON} \end{cases}$$

FORM $K_1 u_r = \left[\frac{J_{4P}}{J_{2P}} \left(\frac{r_P}{r}\right)^2 P_5' + \frac{J_{3P}}{J_{2P}} \left(\frac{r_P}{r}\right) P_4' + P_3'\right] \underline{u_r}$

$TVEC_V \leftarrow [MPAC_D + PL2_D] \, ALPHAV_V$ @ 2^6

FORM $\frac{J_{4P} r_P}{J_{3P}} P_4'$

$MPAC_D \leftarrow (J4REQ/J3*X2)_D \cdot PL4_D$ SHIFTED @ 2^{34}

FORM $\frac{J_{4P} r_P}{J_{3P}} P_4' / r + P_3' = \frac{J_{4P}}{J_{3P}} \left(\frac{r_P}{r}\right) P_4' + P_3'$

$MPAC_D \leftarrow MPAC_D / ALPHAM_D + PL2_D$ @ 2^3

FORM $\left[\frac{J_{4P}}{J_{3P}} \left(\frac{r_P}{r}\right) P_4' + P_3'\right] \frac{J_{3P} r_P}{J_{2P}} / r = \frac{J_{4P}}{J_{2P}} \left(\frac{r_P}{r}\right)^2 P_4' + \frac{J_{3P}}{J_{2P}} \left(\frac{r_P}{r}\right) P_3'$

$MPAC_D \leftarrow MPAC_D \cdot (2J3RE/J2*X2)_D / ALPHAM_D$ SHIFTED @ 2^6

FORM $K_2 u_z = \left[\frac{J_{4P}}{J_{2P}} \left(\frac{r_P}{r}\right)^2 P_4' + \frac{J_{3P}}{J_{2P}} \left(\frac{r_P}{r}\right) P_3' + P_2'\right] \underline{u_z}$

$MPAC_V \leftarrow [MPAC_D + PL0_D] \, UZ_V$ SHIFTED @ 2^6

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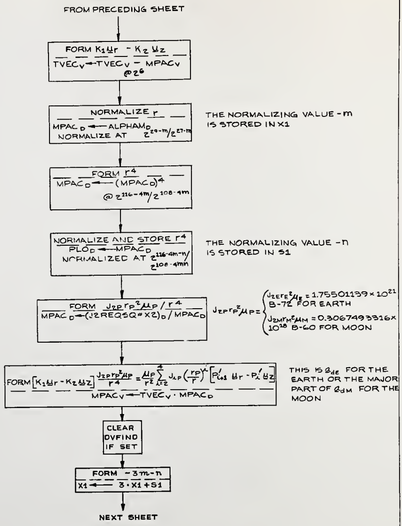

$$\left\{K_1\underline{u}_r - K_2\underline{u}_z\right\}\frac{J_{2P}r_P^2\mu_P}{r^4}$$

$$=\left\{\left[\frac{J_{4P}}{J_{2P}}\left(\frac{r_P}{r}\right)^2 P_5' + \frac{J_{3P}}{J_{2P}}\left(\frac{r_P}{r}\right)P_4' + P_3'\right]\underline{u}_r - \left[\frac{J_{4P}}{J_{2P}}\left(\frac{r_P}{r}\right)^2 P_4' + \frac{J_{3P}}{J_{2P}}\left(\frac{r_P}{r}\right)P_3' + P_2'\right]\underline{u}_z\right\}\frac{J_{2P}r_P^2\mu_P}{r^4}$$

$$=\frac{\mu_P}{r^2}\left\{\left[J_{4P}\left(\frac{r_P}{r}\right)^4 P_5' + J_{3P}\left(\frac{r_P}{r}\right)^3 P_4' + J_{2P}\left(\frac{r_P}{r}\right)^2 P_3'\right]\underline{u}_r - \left[J_{4P}\left(\frac{r_P}{r}\right)^4 P_4' + J_{3P}\left(\frac{r_P}{r}\right)^3 P_3' + J_{2P}\left(\frac{r_P}{r}\right)^2 P_2'\right]\underline{u}_z\right\}$$

$$=\frac{\mu_P}{r^2}\sum_{i=2}^{4} J_{iP}\left(\frac{r_P}{r}\right)^i\left[P_{i+1}'\,\underline{u}_r - P_i'\,\underline{u}_z\right]$$

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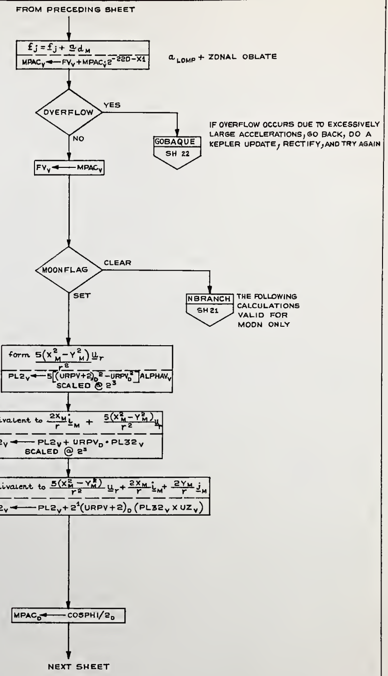

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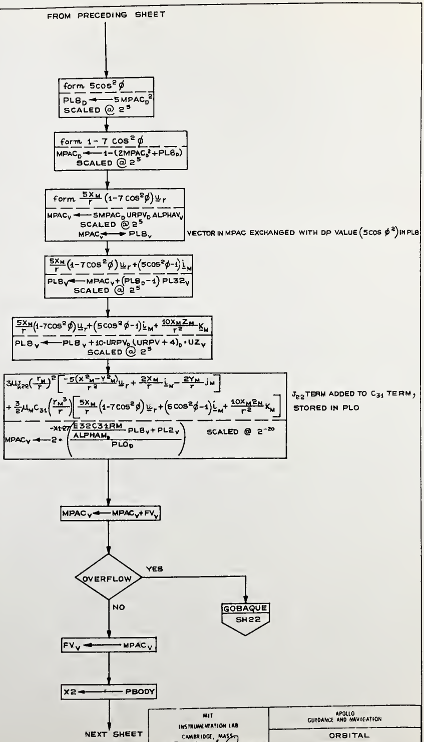

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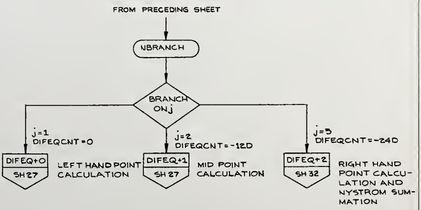

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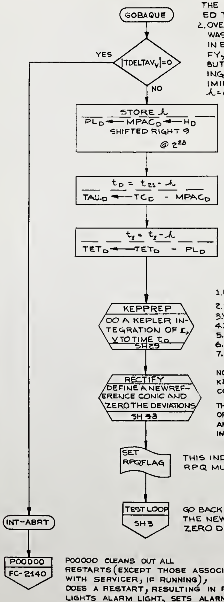

GOBAQUE IS ENTERED IF EITHER:

1. OVERFLOW OCCURED IN GAMCOMP WHEN THE SECOND DERIVATIVE INCREMENT WAS ADDED TO $\underline{f}j$, OR,
2. OVERFLOW OCCURED IN OBLATE WHEN g_{dp} WAS ADDED TO g_p.

IN EITHER CASE DO A KEPLER UPDATE, RECTIFY, AND GO BACK AND INTEGRATE AGAIN BUT NOW WITH A NEW REFERENCE CONIC. HAVING A NEW REFERENCE CONIC SHOULD ELIMINATE THE PROBLEM OF OVERFLOW.
$\lambda = 0, \frac{\Delta t}{2}, \Delta t$

$\lambda = 0, \frac{\Delta t}{2}, \Delta t$

t_D = DESIRED TRANSFER TIME. IT MUST BE REDUCED BY λ TO MAKE TIME CORRESPOND TO THE PREVIOUS VALUE OF j SINCE RESULTS WERE VALID FOR THAT VALUE OF j (I.E. THERE WAS NO OVERFLOW)

t_2 IS REDUCED BY λ TO MAKE IT AGREE WITH TIME OF VALIDITY OF RCV_V, VCV_V

INPUT

1. PBODY = {0 FOR EARTH; 2 FOR MOON}
2. $RCV_V = \underline{r}'(t'_{21})$
3. $VCV_V = \underline{v}'(t'_{21})$
4. $XKEP_D = X'$
5. $TAU_\cdot = t_D$, DESIRED TIME
6. $TC_D = t'_{21}$
7. MOONFLAG {CLEAR FOR EARTH; SET FOR MOON}

OUTPUT

1. $RCV_V = \underline{r}(t_2)$
2. $VCV_V = \underline{v}(t_2)$
3. $TC_D = t_2$, TIME CONVERGED TO $\approx t_D$
4. $XPREV_D = X' = XKEP_D$

NOTE: OUTPUT IS FOR ENTIRE KEPPREP AND KEPLERN COMPUTATIONS (SEE FC-2310: CONIC SUBROUTINES)

THE NEW REFERENCE CONIC IS BASED ON THE OUTPUT OF THE KEPLER UPDATE OF THE STATE VECTOR AND THE DEVIATIONS CALCULATED BY PRECISION INTEGRATION

THIS INDICATES THE VECTOR RPQ MUST BE CALCULATED

GO BACK AND INTEGRATE AGAIN USING THE NEW REFERENCE CONIC AND ZERO DEVIATIONS

P00000 CLEANS OUT ALL RESTARTS (EXCEPT THOSE ASSOCIATED WITH SERVICER, IF RUNNING), DOES A RESTART, RESULTING IN P00. LIGHTS ALARM LIGHT, SETS ALARM CODE (OCT 20430: POSITION DEVIATION VECTOR = 0)

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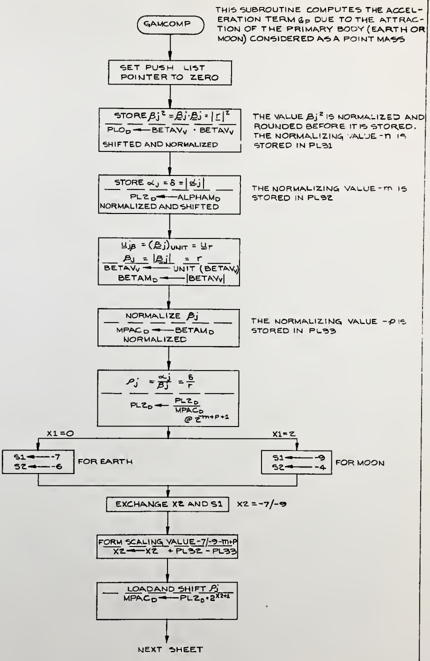

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EXCHANGE S1 AND X2

STORE ρ_j

$PL4_D \leftarrow MPAC_D$ @ 2^1

STORE ρ_j

$PL6_D \leftarrow MPAC_D$ SHIFTED @ 2^2

FORM $2\underline{u}_{j\alpha} \cdot \underline{u}_{j\beta}$

$MPAC_D \leftarrow 2ALPHAV_V \cdot BETAV_V$ @ 2^2

MULTIPLICATION BY 2 IS ACCOMPLISHED BY A LEFT SHIFT OF ONE PLACE

FORM $\rho_j - 2\underline{u}_{j\alpha} \cdot \underline{u}_{j\beta} = \frac{q_j}{\rho_j}$

$PL6_D \leftarrow MPAC_D \leftarrow PL6_D - MPAC_D$ @ 2^2

$q_j = (\rho_j - 2\underline{u}_{j\alpha} \cdot \underline{u}_{j\beta})\ \rho_j$

$PL8_D \leftarrow MPAC_D \leftarrow MPAC_D \cdot PL4_D$ SHIFTED @ 2^2

FORM $1 + q_j$

$PL10_D \leftarrow MPAC_D \leftarrow DQUARTER_D + MPAC_D$ @ 2^2

$DQUARTER_D = 1.0$ @ 2^2

FORM $(1 + q_j)^{3/2}$

$PL12_D \leftarrow MPAC_D \leftarrow PL10_D \cdot \sqrt{MPAC_D}$ @ 2^3

FORM $1 + (1 + q_j)^{3/2}$

$PL14_D \leftarrow DQUARTER_D + MPAC_D$ @ 2^2

MPAC IS FIRST SHIFTED LEFT 1 TO A SCALING OF 2^2

FORM $\frac{(1+q_j+2)q_j+3}{1+(1+q_j)} = \frac{3+3q_j+q_j^2}{1+(1+q_j)^{3/2}} = \frac{f(q_j)}{q_j}$

$MPAC_D \leftarrow \frac{(PL10_D + HALFDP_D) \cdot PL8_D + THREE/8_D}{PL14_D}$ @ 2^1

EQ 2.2.10, REF 1
$HALFDP_D = 2.0$ @ 2^2
$THREE/8_D = 3.0$ @ 2^3
THE NUMERATOR IS SHIFTED LEFT 1 PLACE PRIOR TO ADDING $THREE/8_D$

NEXT SHEET

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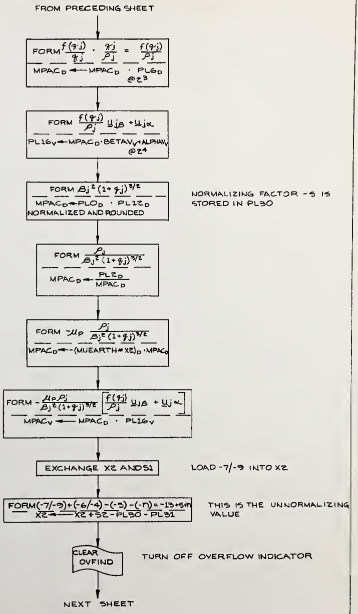

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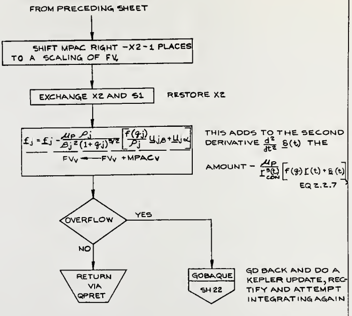
APPR'D Robert M. Estes 9-23-69	REV	SH 25 OF 50



THE DIFFERENTIAL EQUATION FOR THE ENCKE VARIABLE $\underline{\delta}(t)$ CAN BE WRITTEN AS:

$$\frac{d^2}{dt^2}\underline{\delta}(t) = -\frac{\mu_P}{r^3_{CON}(t)}\left[f(q)\underline{r}(t)+\underline{\delta}(t)\right] + \underline{a}_{dP}(t) \qquad (2.2.7)$$

THE FIRST TERM ON THE RIGHT, CALLED γ, IS EVALUATED IN GAMCOMP AS PART OF THE NYSTROM INTEGRATION SCHEME IN THE SUBSCRIPTED FORM:

$$\gamma_j = -\frac{\mu_P \rho_j}{\beta_j^2(1+q_j)^{3/2}}\left[\frac{f(q_j)}{\rho_j}\underline{u}_{j\beta} + \underline{u}_{j\alpha}\right], \text{ FOR A GIVEN } j.$$

THE FOLLOWING SHOWS THAT γ_j IS EQUIVALENT TO THE FIRST TERM IN 2.2.7. LET $\underline{\delta}(t) = \underline{\alpha}_j = \alpha_j \underline{u}_{j\alpha}$ AND $\underline{r}(t) = \underline{\beta}_j = \beta_j \underline{u}_{j\beta}$, WHERE α_j AND β_j ARE MAGNITUDES OF THE RESPECTIVE VECTORS. DEFINE $\rho_j = \alpha_j/\beta_j$. THEN γ CAN BE WRITTEN AS

$$\gamma_j = -\frac{\mu_P}{\beta_j^3(1+q_j)^{3/2}}\left[f(q_j)\underline{\beta}_j + \underline{\alpha}_j\right],$$ WHERE r^3_{CON} HAS BEEN REPLACED BY $\beta_j^3(1+q_j)^{3/2}$. CONTINUING,

$$\gamma_j = -\frac{\mu_P}{\beta_j^3(1+q_j)^{3/2}}\left[f(q_j)\beta_j\underline{u}_{j\beta} + \alpha_j\underline{u}_{j\alpha}\right]$$

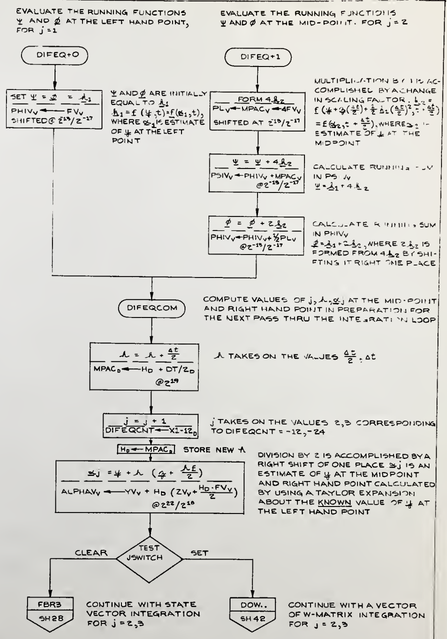
$$= -\frac{\mu_P}{\beta_j^2(1+q_j)^{3/2}}\left[f(q_j)\underline{u}_{j\beta} + \frac{\alpha_j}{\beta_j}\underline{u}_{j\alpha}\right]$$

$$= -\frac{\mu_P \rho_j}{\beta_j^2(1+q_j)^{3/2}}\left[\frac{f(q_j)}{\rho_j}\underline{u}_{j\beta} + \underline{u}_{j\alpha}\right]$$

THE VARIABLE q IS EVALUATED AS,

$$q_j = \frac{(\underline{\alpha}_j - 2\underline{\beta}_j)\cdot\underline{\alpha}_j}{\beta_j^2} = \frac{(\alpha_j\underline{u}_{j\alpha} - 2\beta_j\underline{u}_{j\beta})\cdot\alpha_j\underline{u}_{j\alpha}}{\beta_j^2}$$

$$= \left[\left(\frac{\alpha_j}{\beta_j}\right)\underline{u}_{j\alpha} - 2\underline{u}_{j\beta}\right]\left(\frac{\alpha_j}{\beta_j}\right)\underline{u}_{j\alpha} = \rho_j\left[\rho_j - 2\underline{u}_{j\alpha}\cdot\underline{u}_{j\beta}\right]$$



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DRAWN [signature] 31OCT68

ANALYST Wm. M. Robertson 22Oct69

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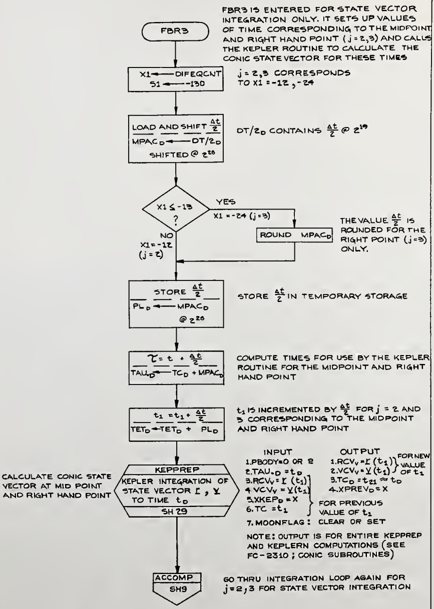
COLOSSUS IIC

ORBITAL INTEGRATION

FC-2300

27 50



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN 2. J. Chmielinski 3 NOV 68	ORBITAL INTEGRATION
PRGMR	
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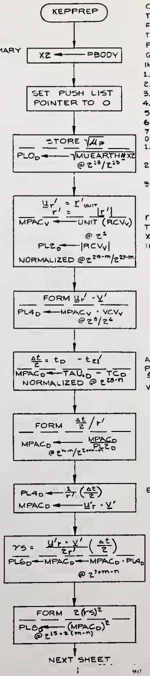
THIS SUBROUTINE COMPUTES AN ESTIMATE OF THE VARIABLE X AT TIME t_D BASED ON THE VALUES X', $\underline{r}'(t_{21}')$, $\underline{V}'(t_{21}')$ AT TIME t_{21}' FROM THE PREVIOUS COMPUTATION CYCLE. THIS INITIAL ESTIMATE OF X IS USED AS INPUT TO KEPLER TO SPEED UP CONVERGENCE.

INPUT:

1. PBODY = 0 FOR EARTH PRIMARY, 2 FOR MOON
2. $RCV_V = \underline{r}' = \underline{r}_{con}(\tau - \frac{\Delta t}{2})$ } THE STATE VECTOR CORRESPONDING TO PREVIOUS CYCLE
3. $VCV_V = \underline{V}' = \underline{V}_{con}(\tau - \frac{\Delta t}{2})$ }
4. $XKEP_D = X' = X(\tau - \frac{\Delta t}{2})$
5. $TAU._D = t_D$, DESIRED TRANSFER TIME
6. $TC_D = t_{21}' = \tau - \frac{\Delta t}{2}$, PREVIOUS TRANSFER TIME
7. MOONFLAG: CLEAR FOR EARTH, SET FOR MOON

OUTPUT: (OUTPUT FOR KEPPREP ONLY)

1. $XKEPNEW = X_t$, FIRST ESTIMATE OF X CORRESPONDING TO THE TRANSFER TIME t_D
2. $X1 = \mu$-TABLE POINTER, -2 FOR EARTH, -10 FOR MOON
3. PUSH LIST POINTER AT PL4



LOAD X2 WITH PRIMARY BODY INDICATOR

r' IS STORED IN NORMALIZED FORM THE VALUE -m IS STORED IN PL36

r' IS STORED IN NORMALIZED FORM AND THE NORMALIZING VALUE -m IS STORED IN X1. THE UNIT OPERATION ALSO STORES r' IN PL36 @ $2^{29}/2^{27}$

A COMPLETE INTEGRATION STEP CORRESPONDS TO TWO $\frac{\Delta t}{2}$ INCREMENTS. THE VALUE $\frac{\Delta t}{2}$ IS NORMALIZED AND THE NORMALIZING VALUE -n IS STORED IN S1

EXCHANGE MPAC AND PL4

DIVISION BY 2 IS ACCOMPLISHED BY A CHANGE IN THE SCALING FACTOR

MULTIPLICATION BY 2 IS ACCOMPLISHED BY A CHANGE IN THE SCALING FACTOR

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DRAWN K. S. Chmielinski 2 NOV 6_

ANALYST Wm. M. Robertson 22 SEPT 67

APPR'D Robert M. Ewing 8-23-6_

ORBITAL INTEGRATION

COLOSSUS IIC

FC-2300

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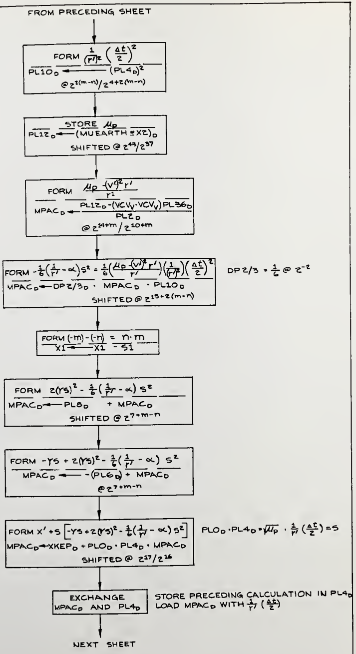

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DRAWN Y. S. Chinchuk 5NOV68
PRGMR
ANALST Wm. M. Robertson
DOCMR
APPR'D Robert M. Estes 7-23-69

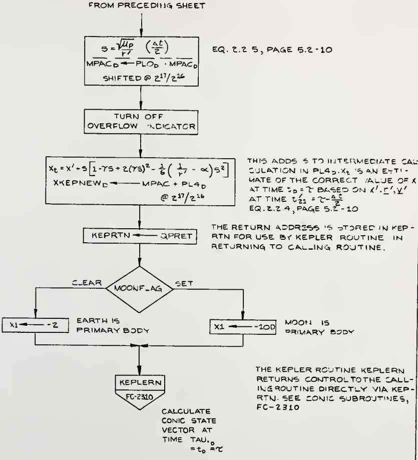
APOLLO
GUIDANCE AND NAVIGATION

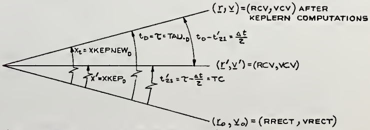
ORBITAL INTEGRATION

COLOSSUS IIC

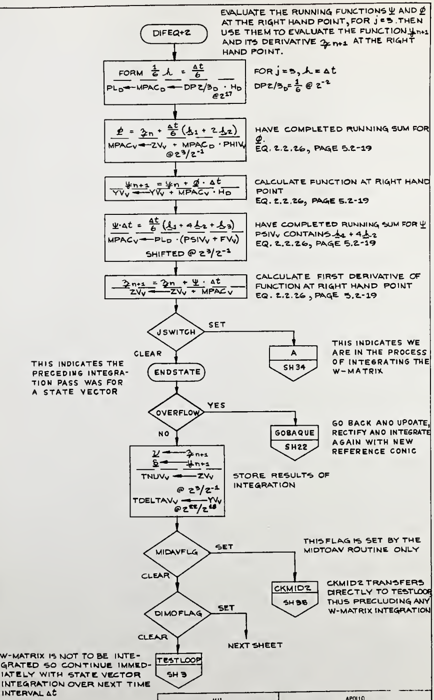
DOCUMENT NO FC-2300

REV

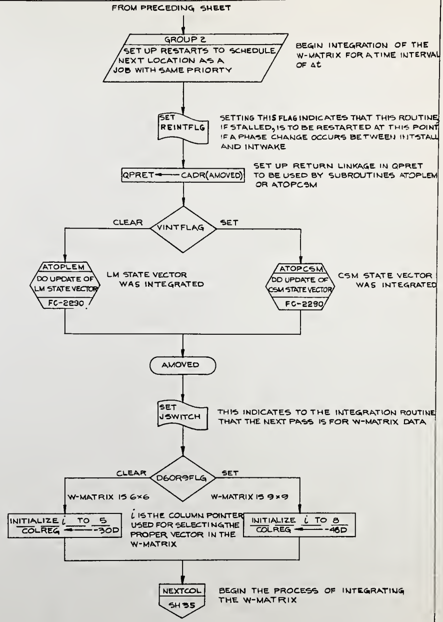




$X', \underline{r}', \underline{v}'$ CORRESPOND TO THE PREVIOUS TIME t'_{21}. A VALUE OF X FOR TIME t_D IS CALCULATED BY A TAYLOR EXPANSION TYPE METHOD FOR AN INTERVAL OF TIME $\frac{\Delta t}{2} = t_D - t'_{21}$ TO GET AN ESTIMATE X_t FOR TIME t_D.



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN Z. S. Chmielinski [date]	ORBITAL INTEGRATION
PRGMR	
ANALYST Wm. M. Robertson [date]	COLOSSUS IIC — DOCUMENT NO. FC-2300
DOCMR	
APPR'D Robert M. Estes 8-22-69	REV — SHEET 32 OF 50



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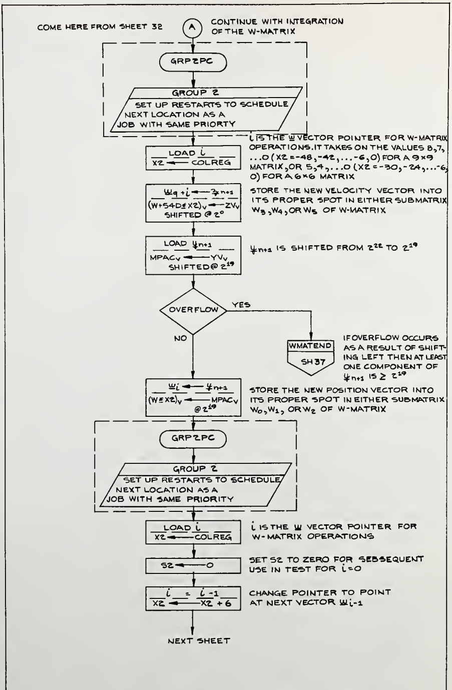
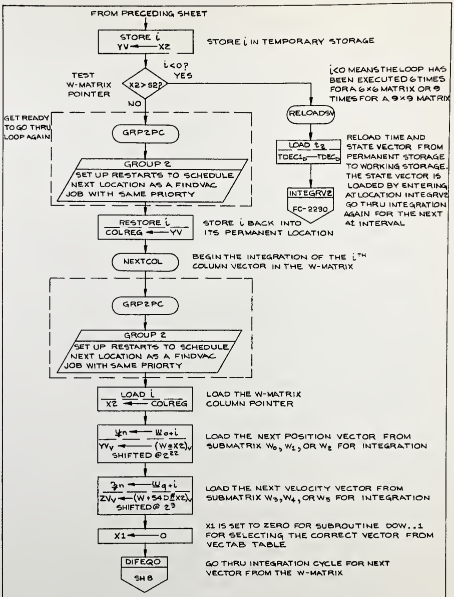
DRAWN J. L. Chmielinski 6 NOV 68	ORBITAL INTEGRATION
PRGMR	
ANALST Wm. M. Robertson 12 SEPT 69	COLOSSUS IIC — DOCUMENT NO. FC-2300
DOCMR	
APPR'D Robert M. Estes 9-23-69	REV — SHEET 33 OF 50



MIT INSTRUMENTATION LAB CAMBRIDGE MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN [signature] 3 NOV 69	ORBITAL INTEGRATION
PRGMR	
ANALYST Wm. M. Robertson [date]	COLOSSUS IIC — DOCUMENT NO. FC-2300
DOCMR	
APPR'D Robert M. Eaton [date]	REV — SHEET 34 OF 50



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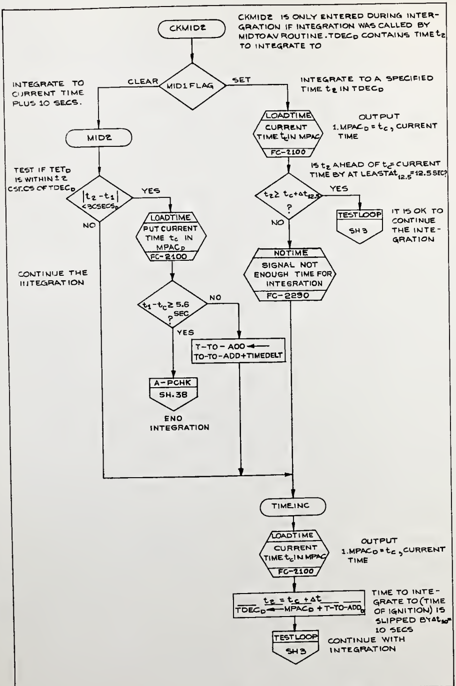
DRAWN Y.S. Chmiel 6NOV69	ORBITAL INTEGRATION
PRGMR	
ANALST Wm. M. Robertson 22SEPT69	COLOSSUS IIC — DOCUMENT NO. FC-2300
DOCMR	
APPR'D Robert M. Estes 12-23-69	REV — SHEET 35 OF 150



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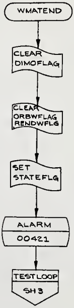
DRAWN Z. J. Chmielinski 2 NOV 68	ORBITAL INTEGRATION
PRGMR	
ANALST Wm. M. Robertson 22 SEPT 69	COLOSSUS II C — DOCUMENT NO. FC-2300
DOCMR	
APPR'D Robert M. Entin 9-23-69	REV — SHEET 36 OF 50



THIS ROUTINE IS ENTERED FROM DIFEQ+2 IF OVERFLOW OCCURRED DURING INTEGRATION OF THE W-MATRIX. THIS ROUTINE ENDS W-MATRIX INTEGRATION.

BECAUSE OVERFLOW OCCURRED THIS FLAG IS CLEARED SO THE INTEGRATION ROUTINE WILL NO LONGER INTEGRATE THE W-MATRIX AS IT CONTINUES INTEGRATING THE STATE VECTOR.

CLEAR BOTH FLAGS TO INDICATE TO BOTH ORBITAL NAVIGATION AND RENDEVOUS NAVIGATION THAT THE W-MATRIX IS INVALID

SET FLAG TO FORCE A STATE VECTOR UPDATE IN A-PCHK, SHEET 34

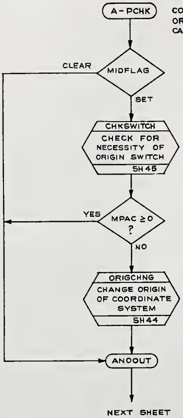
ALARM 00421 INDICATES A W-MATRIX OVERFLOW

CONTINUE INTEGRATING WITHOUT THE W-MATRIX

MIT INSTRUMENTATION LAB CAMBRIDGE MASS	APOLLO GUIDANCE AND NAVIGATION
DRAWN Z. L. Chmielinski 3NOV69	ORBITAL INTEGRATION
ANALST Wm M. Robertson 22SEPT69	COLOSSUS IIC — DOCUMENT NO. FC-2300
APPR'D Robert M. Estes 9-23-69	SHEET 37 OF 50

A-PCHK CHECKS TO SEE IF AN UPDATE IS DESIRED AND, IF SO, PERFORMS IT.

COME HERE FROM POOHCHK IF $|\Delta t| \leq 2$ CSEC OR IF $\Delta t < \Delta t_{MAX}$ AND INTEGRATION WAS CALLED BY P00



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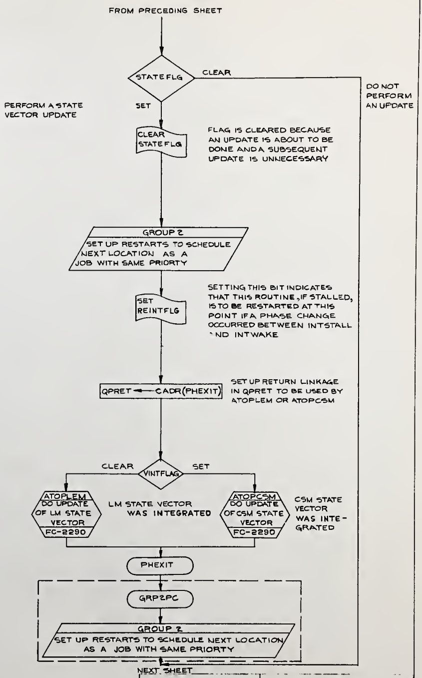
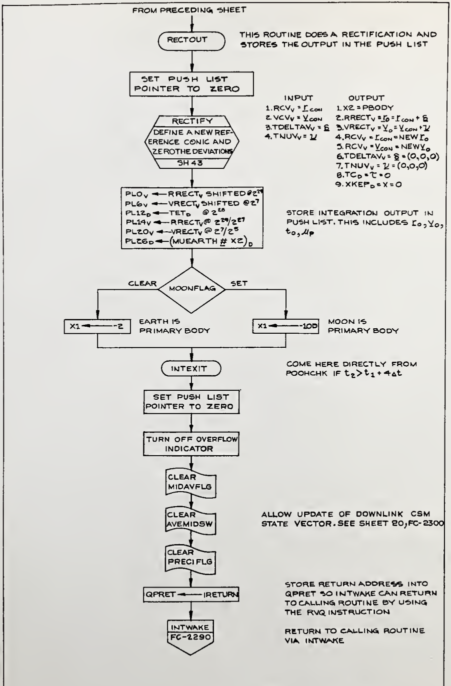
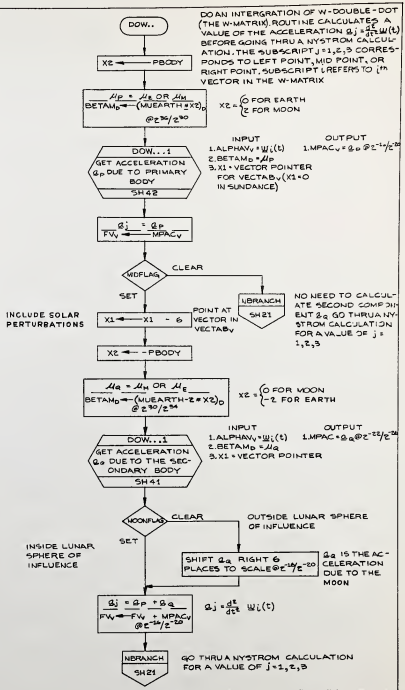
DRAWN 28 JULY 69	ORBITAL INTEGRATION
PRGMR	
ANALST Wm M. Robertson 22 SEPT 69	COLOSSUS IIC — DOCUMENT NO. FC-2300
DOCMR	
APPR'D Robert M. Estes 9-23-69	REV — SHEET 38 OF 50



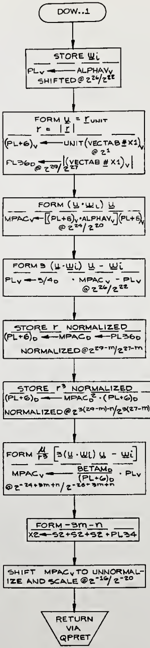
MIT INSTRUMENTATION LAB CAMBRIDGE MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN D. S. Chmielewski 7NOV69	ORBITAL INTEGRATION
PRGMR	
ANALST Wm M. Robertson 22SEPT69	COLOSSUS IIC — DOCUMENT NO. FC-2300
DOCMR	
APPR'D Robert M. Eates 8-23-69	REV — SHEET 39 OF 50



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN J. S. Chmielewski 7 NOV 68	ORBITAL INTEGRATION
PRGMR	
ANALYST Wm. M. Robertson 22 SEPT 69	COLOSSUS IIC — DOCUMENT NO. FC-2300
DOCMR	
APPR'D Robert M. Estes 9-23-69	REV — SHEET 40 OF 50



MIT INSTRUMENTATION LAB CAMBRIDGE MASS	APOLLO GUIDANCE AND NAVIGATION
DRAWN T. S. Chwilecki 8 NOV 68	ORBITAL INTEGRATION
PRGMR	
ANALST Wm. M. Robertson 22 SEPT 69	COLOSSUS II C — DOCUMENT NO. FC-2300
DOC MR	
APPR Robert M. Eaton 9-23-69	REV — SHEET 41 OF 50



CALCULATE THE ACCELERATION COMPONENT $\underline{a}_p$ OR $\underline{a}_q$ FOR A GIVEN $\underline{\omega}_i$

X1 IS A POINTER USED TO SELECT EITHER $\underline{r}(t)$ OR $\underline{r}_{qc}(t)$ FROM A TABLE. IN SUNDANCE X1=0.

PROJECT $\underline{\omega}_i$ ONTO $\underline{r}$ WHERE $\underline{u} \cdot \underline{\omega}_i$ IS THE MAGNITUDE OF $\underline{\omega}_i$ IN THE DIRECTION OF $\underline{r}$.

$3/4 = 3.0 @ 2^2$

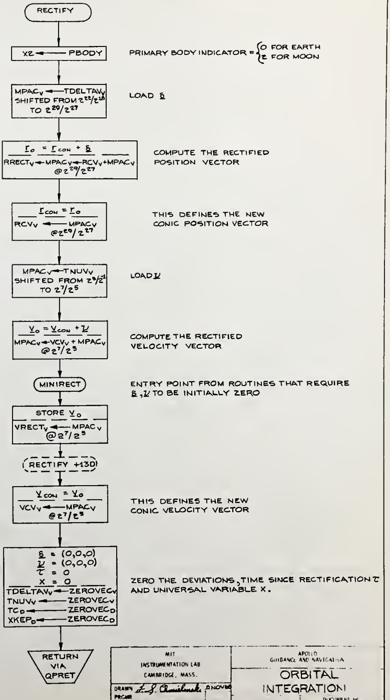
THE NORMALIZING COUNT $-m$ IS STORED IN S2

THE NORMALIZING COUNT $-n$ IS STORED IN PL34.

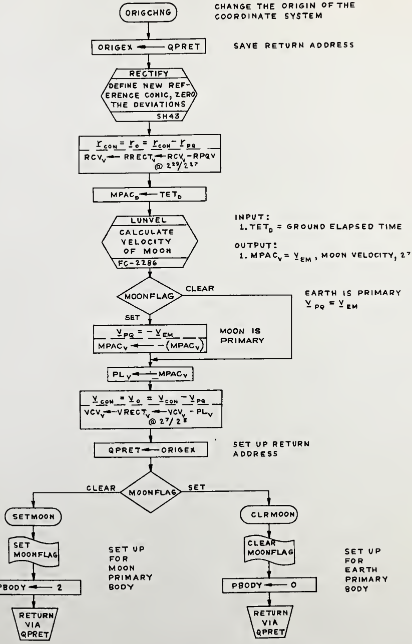
THIS IS THE ACCELERATION COMPONENT $\underline{a}_p$ OR $\underline{a}_q$.
EQ 2.2.31, PAGE 5.2-23

$-3m-n$ IS THE UNNORMALIZING COUNT

THE RECTIFY SUBROUTINE IS CALLED BY THE INTEGRATION ROUTINE AND OCCASIONALLY BY THE MEASUREMENT INCORPORATION ROUTINES TO DEFINE A NEW REFERENCE CONIC.



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
	ORBITAL INTEGRATION
DRAWN L. J. Chmielinski 6 NOV 68	
PRGMR	
ANALYST Wm. M. Robertson 22 SEPT 69	COLOSSUS IIC — DOCUMENT NO. FC-2300
DOCMR	
APPR'D Robert M. Sites 9-23-69	REV — SHEET 43 OF 5??



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

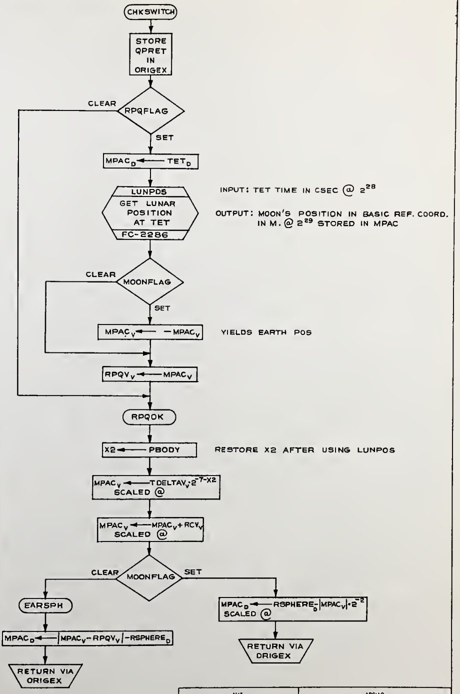
ORBITAL INTEGRATION

DRAWN A. J. Langille 4APR69
ANALYST Wm. M. Robertson 22SEPT69
APPR'D Roberta M. Cutts 9-23-69

COLOSSUS IIC

DOCUMENT FC-2300

SHT 44 OF 50



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DRAWN P.M. Dittmar 9 JUNE 69	ORBITAL INTEGRATION
PRGMR	
ANALYST Wm. M. Robertson 22 SEPT 69	COLOSSUS IIC DOCUMENT NO. FC-2300
DOCMR	
APPR'D Robert M. Estes 9-23-69	REV SHEET 45 OF 50

SUBROUTINES CALLED WHICH ARE
FLOWED ON OTHER FLOW CHARTS

SUBROUTINE NAME	FLOW CHART	DESCRIPTION	WHERE CALLED
SGNAGREE	FC2100	FORCE SIGN AGREEMENT OF NUMBER IN MPAC	SH. 4
SIGNMPAC	FC2100	LOAD MPAC WITH SIGNUM (MPAC)	SH. 5
R-TO-RP	FC2283	CONVERT A VECTOR FROM BASIC REFERENCE COORDINATES TO MOON COORDINATES	SH. 15
RP-TO-R	FC2283	CONVERT VECTOR FROM MOON TO REFERENCE COORDINATES	SH. 20
KEPLERN	FC2310	KEPLER ROUTINE COMPUTES THE NEW CONIC STATE VECTOR	SH. 31
ATOPLEM	FC2290	DO UPDATE OF PERMANENT LM STATE VECTOR	SH. 33, 38
ATOPCSM	FC2290	DO UPDATE OF PERMANENT CSM STATE VECTOR	SH. 33, 38
INTEGRV2	FC2290	ENTRY POINT IN INTEGRATION INITIALIZATION FOR NEXT PASS THROUGH INTEGRATION WITH NEXT t VALUE	SH. 35
LOADTIME	FC2100	LOAD TIME1 AND TIME2 (CURRENT TIME) INTO MPAC	SH. 36
INTWAKE	FC2290	ENTRY POINT FOR WAKING UP ALL INTEGRATION STALLED PROGRAMS, WHEN PRESENT INTEGRATION IS COMPLETED	SH. 40
LSPOS	FC2286	CALCULATE POSITION OF SUN, MOON	SH. 11
LUNPOS	FC2286	CALCULATE POSITION OF MOON	SH. 45
LUNVEL	FC2286	CALCULATE VELOCITY OF MOON	SH. 44
POODOO	FC2140	TERMINATE MAJOR MODE IN RESTART	SH. 22

FLAGS

NAME (BIT FLAGWORD)	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
VINTFLAG (3, 3)	INTEGRATE THE CSM STATE VECTOR	INTEGRATE THE LM STATE VECTOR			SH. 33 38
DIMOFLAG (1, 3)	INTEGRATE THE W-MATRIX	DO NOT INTEGRATE THE W-MATRIX		SH. 37	SH. 9, 12, 32
D6OR9FLG (2, 3)	W-MATRIX IS 9X9	W-MATRIX IS 6X6			SH. 33
STATEFLG (5, 3)	UPDATE PERMANENT CSM/LM STATE VECTOR	DO NOT UPDATE PERMANENT CSM/LM STATE VECTOR	SH. 37	SH. 3, 38	SH. 38
QUITFLAG (5, 9)	DISCONTINUE INTEGRATION AT START OF NEXT TIMESTEP	CONTINUE INTEGRATION			SH. 3
MIDFLAG (13, 0)	INTEGRATE WITH SOLAR PERTURBATIONS	INTEGRATE WITHOUT SOLAR PERTURBATIONS	SH. 3	SH. 3	SH. 6, 10 38, 41
PRECIFLG (8, 3)	CSMPREC OR LEMPREC CALLED	INTEGRV OR INTEGRVS CALLED		SH. 40	SH. 5
NEWIFLG (13, 8)	FIRST PASS THROUGH INTEGRATION LOOP	SUBSEQUENT PASS THROUGH INTEGRATION LOOP		SH. 6	SH. 6
JSWITCH (14, 0)	INTEGRATE A VECTOR FROM THE W-MATRIX	INTEGRATE THE STATE VECTOR	SH. 33	SH. 8	SH. 8, 27, 32

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lutkauck	ORBITAL INTEGRATION	
PRGMR		DOCUMENT NO.
ANALST Wm. M. Robertson	COLOSSUS IIC	FC-2300
DOCMR		
APPR'D Robert M. Eaton 12-23-67	REV	SHEET 46 OF 50

FLAGS (CONTINUED)

NAME (BIT, FLAGWORD)	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
MOONFLAG (12, 0)	INSIDE LUNAR SPHERE OF INFLUENCE	OUTSIDE LUNAR SPHERE OF INFLUENCE	SH.44	SH. 44	SH. 11, 13,15 ,19., 31,40, 41, 44,45
RPQFLAG (15, 8)	CALCULATE THE VECTOR RPQ	DO NOT CALCULATE THE VECTOR RPQ	SH. 22		SH, 44
MIDAVFLG (2, 9)	INTEGRATION CALLED BY THE MIDTOAV ROUTINE	INTEGRATION NOT CALLED BY THE MIDTOAV ROUTINE		SH. 40	SH. 32
REINTFLG (7, 10)	RESTART THIS ROUTINE IF STALLED AND RESTART OCCURS	DO NOT RESTART THIS ROUTINE IF STALLED AND RESTART OCCURS	SH. 33, 38		
MIDIFLAG (3, 9)	INTEGRATE TO A SPECIFIED TIME t_2 STORED IN TDEC	INTEGRATE TO CURRENT TIME PLUS 10 SECONDS			SH. 36
ORBWFLAG (6, 3)	W-MATRIX IS VALID FOR ORBITAL NAVIGATION	W-MATRIX IS INVALID FOR ORBITAL NAVIGATION		SH. 37	
RENDWFLG (1, 5)	W-MATRIX IS VALID FOR RENDEZVOUS NAVIGATION	W-MATRIX IS INVALID FOR RENDEZVOUS NAVIGATION		SH. 37	
AVEMIDSW (1, 9)	PREVENT UPDATING THE CSM DOWNLINK DATA RN, VN, PIPTIME	ALLOW UPDATING THE CSM DOWNLINK DATA RN, VN, PIPTIME		SH. 40	

DISPLAYS

VERB-NOUN	TYPE OF DISPLAY	DESCRIPTION OF EACH REGISTER	WHERE EXECUTED
	ALARM	PROG ALARM LIGHT ON; R1, R2, R3, NOT AFFECTED	SH. 37

ERASABLE LOCATIONS USED

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
$DT/2_D$	t	TIME INTERVAL FOR ONE INTEGRATION CYCLE	CSEC	CSEC	2^{20}
$TDECI_D$	t_2	TIME TO INTEGRATE TO	CSEC	CSEC	2^{28}
RCV_V	$\underline{r}_{con}$	CONIC POSITION VECTOR	M	M	$2^{29}/2^{27}$
VCV_V	$\underline{v}_{con}$	CONIC VELOCITY VECTOR	M/CSEC	M/CSEC	$2^7/2^5$
TET_D	t	TIME OF VALIDITY OF STATE VECTOR	CSEC	CSEC	2^{28}
$RRECT_V$	$\underline{r}_o$	POSITION VECTOR AT RECTIFICATION	M	M	$2^{29}/2^{27}$

ERASABLE LOCATIONS USED (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
$VRECT_V$	$\underline{v}_o$	VELOCITY VECTOR AT RECTIFICATION	M/CSEC	M/CSEC	$2^7/2^5$
$TDELTAV_V$	$\underline{\delta}$	POSITION DEVIATION VECTOR	M	M	$2^{22}/2^{18}$
$TNUV_V$	$\underline{\nu}$	VELOCITY DEVIATION VECTOR	M/CSEC	M/CSEC	$2^3/2^{-4}$
TC_D	t_{21}	TIME SINCE RECTIFICATION	CSEC	CSEC	2^{28}
$XKEP_D$	x	UNIVERSAL VARIABLE	$M^{1/2}$	$M^{1/2}$	$2^{17}/2^{16}$
YV_V	$\underline{\delta}$	INTERMEDIATE VALUE OF $\underline{\delta}$	M	M	$2^{22}/2^{18}$
ZV_V	$\underline{\nu}$	INTERMEDIATE VALUE OF $\underline{\nu}$	M/CSEC	M/CSEC	$2^3/2^{-4}$
DIFEQCNT	j	SUBSCRIPT FOR LEFT, MID, AND RIGHT POINTS	INTEGER	INTEGER	
$ALPHAV_V$	$\underline{\alpha}_j$	INTERMEDIATE VALUE OF $\underline{\delta}$	M	M	$2^{22}/2^{18}$
H_D	h	RUNNING TIME INCREMENT EQUALS 0, $\Delta 1/2$, Δt	CSEC	CSEC	2^{19}
FV_V	$\underline{f}_j$	VALUE OF SECOND DERIVATIVE AT POINT j	$M/(CSEC)^2$	$M/(CSEC)^2$	$2^{-16}/2^{-20}$
$BETAV_V$	$\underline{\beta}_j$	INTERMEDIATE VALUE OF r_o	M	M	$2^{29}/2^{27}$
$VECTAB_V$	$\underline{\beta}_j$	WORKING STORAGE FOR $\underline{\beta}_j$	M	M	$2^{29}/2^{27}$
$ALPHAM_D$	α_j	$\lvert\underline{\alpha}_j\rvert$, MAGNITUDE OF $\underline{\alpha}_j$	M	M	$2^{29}/2^{27}$
$BETAM_D$	β_j	$\lvert\underline{\beta}_j\rvert$, MAGNITUDE OF $\underline{\beta}_j$	M	M	$2^{29}/2^{27}$
UZ_V	$\underline{u}_z$	UNIT VECTOR IN DIRECTION OF ROTATION AXIS			2^1
$COSPHI/2_D$	COS φ	COSINE OF COALTITUDE φ			2^1
$URPV_V$	$\underline{u}_r$	UNIT VECTOR OF POSITION IN MOON COORDINATES			2^1
$TVEC_V$	$\underline{a}_v$	THE DISTURBING ACCELERATION	$M/(CSEC)^2$	$M/(CSEC)^2$	
$TAU._D$	t_D	DESIRED TRANSFER TIME	CSEC	CSEC	2^{28}
$PHIV_V$	$\underline{\varphi}$	RUNNING SUM OF $\underline{k}_1+2k_2$	$M/(CSEC)^2$	$M/(CSEC)^2$	$2^{-13}/2^{-17}$
$PSIV_V$	$\underline{\psi}$	RUNNING SUM OF $\underline{k}_1+\underline{k}_2+\underline{k}_3$	$M/(CSEC)^2$	$M/(CSEC)^2$	$2^{-13}/2^{-17}$
PBODY	P	PRIMARY BODY INDICATOR	INTEGER	INTEGER	
$XKEPNEW_D$	x	INITIAL ESTIMATE OF NEW VALUE OF x	$M^{1/2}$	$M^{1/2}$	$2^{17}/2^{16}$
W_M	W	W-MATRIX	M, M/CSEC	M, M/CSEC	2^{19}, 2^0

PROGRAM CONSTANTS

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING VALUE AND UNITS	AGC VALUE AND UNITS	AGC SCALING
$.3D_D$			.3	.3	2^2
DT 2MAX$_D$		LIMIT ON SIZE OF t	1000 SEC	100,000 CSEC	2^{20}
DT 2MIN$_D$	ϵ_t	MINIMUM VALUE OF t ALLOWED	3 CSEC	3 CSEC	2^{20}
3·4$_D$			0.75	3	2^2
RECRATIO$_D$			0.01	.01	2^0
ZEROVEC$_V$		(0, 0, 0)	(0.0, 0.0, 0.0)		
RDE$_D$	r_{DE}	RADIUS OF RELEVANCE OF EARTH	80467200 M	SAME	2^{29}
RDM$_D$	r_{DM}	RADIUS OF RELEVANCE OF MOON	16093440 M	SAME	2^{27}
3/5$_D$			3/5	.6	2^2
ZUNIT$_V$		(0, 0, 1)	(0.0, 0.0, 1.0)	(0.0, 0.0, 0.5)	2^1
3/32$_D$			3.0	3.0	2^5
15 16$_D$			15.0	15.0	2^4
7/12$_D$			7/3	.5833...33	2^0
2·3$_D$			4/3	.666...67	2^0
9·16$_D$			9/4	9.0	2^4
5/128$_D$			5/4	5.0	2^7
J4REZ/J3$_D$	$J_{4E}r_E$ / J_{3E}	RATIO OF COEFFICIENTS OF FOURTH AND THIRD HARMONICS OF EARTH'S POTENTIAL FUNCTION	4991607.391	SAME	2^{26}
2J3RE/J2$_D$	$J_{3E}r_E$ / J_{2E}	RATIO OF COEFFICIENTS OF THIRD AND SECOND HARMONICS OF EARTH'S POTENTIAL FUNCTION	13554.26363	SAME	2^{27}
J2REQSQ$_D$	$J_{2E}r_E^2\mu_E$	SECOND HARMONIC, RADIUS AND MU OF EARTH	$1.75501139 \times 10^{21}$	SAME	2^{72}
J2REQSQ$_D$ -2	$J_{2M}r_M^2\mu_M$	SECOND HARMONIC, RADIUS AND MU OF MOON	$.3067493316 \times 10^{18}$	SAME	2^{60}
5/8$_D$			5.0	5.0	2^3
3J22R2MU$_D$	$3.1_{22M}r_M^2\mu_M$		$9.20479048 \times 10^{-16}$	SAME	2^{58}
DQUARTER$_D$			1.0	0.25	2^0
HALFDP$_D$			2.0	0.5	2^0
THREE/8			3.0	0.375	2^0

PROGRAM CONSTANTS (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING VALUE AND UNITS	AGC VALUE AND UNITS	AGC SCALING
$MUEARTH_D$	μ_E	GRAVITATIONAL PARAMETER OF EARTH	3.986032×10^{10} $M^3/CSEC^2$	SAME	2^{36}
$MUEARTH_D$ -2	μ_M	GRAVITATIONAL PARAMETER OF MOON	4.902778×10^{8} $M^3/CSEC^2$	SAME	2^{30}
$MUEARTH_D$ -4	μ_S	GRAVITATIONAL PARAMETER OF SUN	$1.32715445 \times 10^{16}$ $M^3/CSEC^2$	SAME	2^{54}
DP2 3			1/6	.66...67	2^0
3CSECS			3 CSEC	3 CSEC	2^{28}
RME_D	r_{ME}	RADIUS OF INFLUENCE OF EARTH	7178165 M	SAME	2^{29}
RMM_D	r_{MN}	RADIUS OF INFLUENCE OF MOON	2538090 M	SAME	2^{27}

PAD LOADS

AGC TAG	GSOP TAG	MEANING	ENGINEERING VALUE AND UNITS	AGC VALUE AND UNITS	AGC SCALING	OCTAL VALUE
$504LM_V$	M	MOON LIBRATION VECTOR				

MIT
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CAMBRIDGE MASS.

DRAWN A. J. Lanzillo 26NOV68
PRGMR
ANALYST Wm M. Robertson [illegible]
DOC MR
APPR'D Roberto M. [illegible] 2-23-69

APOLLO GUIDANCE AND NAVIGATION

ORBITAL INTEGRATION

COLOSSUS IIC

FC-2300

REV

50 · 50

CONIC SUBROUTINES

ENCLOSED ARE REVISED SHEETS (SH. 12, [illegible]) TO UPDATE THE COLOSSUS IIA FLOWCHART FC-2310, REV. 1, TO THE COLOSSUS IIC FLOWCHART FC-2310, REV. 2.

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
	CONIC SUBROUTINES
COLOSSUS [illegible]	DOCUMENT NO. FC-2310
REV. [illegible]	SHEET OF

FLOW CHART CONVENTIONS FOR THE CONIC SUBROUTINES

1.

$c_1 = \sqrt{P_N}\, r_1(t) \cot\gamma$
KEPC1 ← $\sqrt{P \cdot R1}$ · COGA
SCALED AT $2^{17}/2^{16}$

PAGE 42, REF. 3

In boxes divided by a broken line, the upper half represents the mathematical formulation of the statement and the lower half represents how the statement was coded in the computer. The arrow implies that the quantity computed on the right side of the arrow was stored into the location specified on the left side, or mathematically the quantity on the left was set equal to the quantity on the right. Where possible, equations are referenced by equation, page and reference number.

2. All values are considered to be double-precision numbers (28 bits of precision plus sign) unless subscripted with an $_s$ for single-precision (14 bits plus sign) or subscripted with a $_v$ for a vector quantity (3 double-precision components). All flags are considered to be one-bit indicators unless shown otherwise.

3. Double-precision numbers are considered to be scaled fractions lying in the range between -1.0 and 1.0. The scaling factor included in the box is the value by which the number as stored internally must be multiplied to obtain its true value. It can also be interpreted as defining the binary point. Thus a scaling of 2^5 means that the binary point lies to the right of bit -5, where bit positions are labeled 0, -1, -2 ... going from left to right, starting with the sign bit. In cases where a pair of scaling factors are included, the first applies to the nominal situation and the second applies to the off-nominal situation. A scaling of 2^{28} indicates the double-precision number is an integer. Thus, all values of time are given as an integral number of centiseconds.

4. A push list is available for temporary storage of data and for storage of data common to several subroutines. Locations within the push list are referred to relative to its initial location and are given as decimal numbers. Thus 6D refers to location 6 in the push list, counting from zero. The values can range from 0D to 42D. For a general location within the push list the name PL is used.

5. MPAC The name MPAC refers to the multipurpose accumulator used by the interpreter routine. It consists of seven consecutive locations within erasable memory and holds the results of interpretive arithmetic operations. It is functionally equivalent to the actual accumulator register within the AGC.

6.

$\underline{r}(t_1)$ UNIT
UNIT (RIVEC$_v$)

The unit operation, corresponding to the subscript unit, computes a vector of unit length parallel to the specified vector, and leaves the result in MPAC with a scaling of 2^1. It also automatically stores the magnitude in double-precision in push list location 36D.

7.

$\lvert \underline{r}(t_1) \rvert$
$\lvert$ RIVEC$_v$ $\rvert$

Vertical bars enclosing a quantity imply forming the absolute value of the quantity, which may be either a scaler or a vector.

8. OVERFLOW — YES / NO

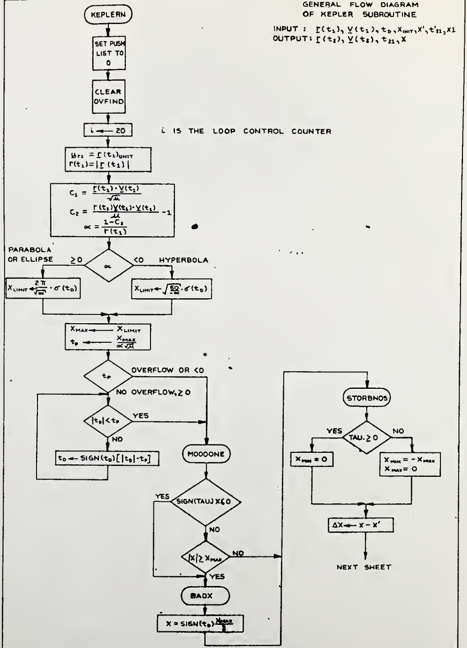
Testing the overflow indicator automatically turns it off.

REFERENCES FOR CONIC SUBROUTINES

1. Battin, R.H., Astronautical Guidance, McGraw-Hill,Inc., New York, 1964.
2. Hildebrand, F.B., Introduction to Numerical Analysis, McGraw-Hill Inc., New York, 1956.
3. Guidance System Operations Plan Using Program COLOSSUS II, (GSOP), R-577, Section 5, Guidance Equations, March 1969.
4. Marscher, W.F., A Unified Method of Generating Conic Sections, R-479, MIT/IL, February 1965.
5. Robertson, W.M., Explicit Universal Series Solutions for the Universal Variable X, MIT/IL, SGA Memo 6-67, May 1967.
6. Newman, C.M., Power Series Economization, MIT/IL, SGA Memo 11-67, August 1967.
7. Krause, K., Generalized Slope Iterator, MIT/IL, SGA Memo 4-67, February 1967.

GENERAL FLOW DIAGRAM
OF KEPLER SUBROUTINE

INPUT : $\underline{r}(t_1)$, $\underline{V}(t_1)$, t_D, X_{LIMIT}, X', t'_{21}, X1
OUTPUT: $\underline{r}(t_2)$, $\underline{V}(t_2)$, t_{21}, X



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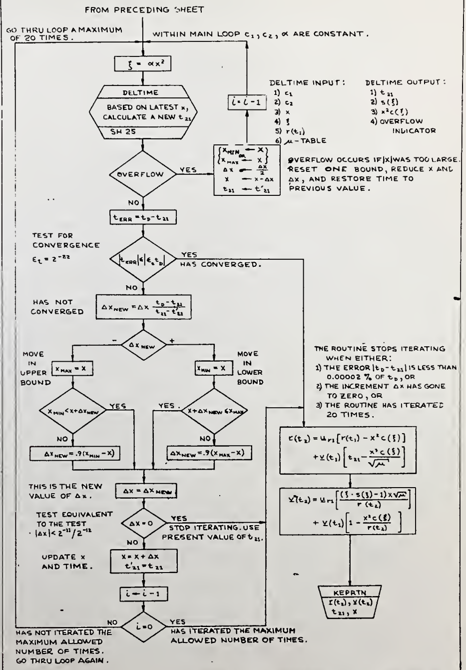
APOLLO GUIDANCE AND NAVIGATION

CONIC SUBROUTINES (KEPLERN)

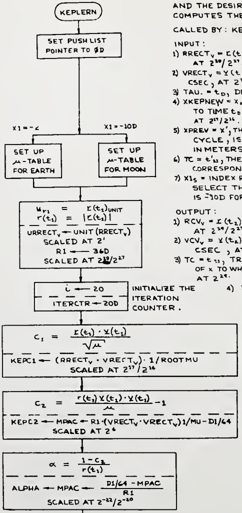
COLOSSUS IIA

DOCUMENT NO. FC-2310

SHEET 2 OF 4



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN 7 [illegible]	[illegible]	CONIC SUBROUTINES (KEPLERK)
PROGR		
ANALYST [illegible] M. [illegible]	3/31/66	DOCUMENT NO. FC-2310
DOCMR [illegible]	[illegible]	
APPR'D [illegible]	[illegible]	REV / SHEET 3 OF 48



TO NEXT SHEET

GIVEN THE INITIAL STATE VECTOR $r(t_1)$ AND $v(t_1)$, AND THE DESIRED TRANSFER TIME t_D, THIS ROUTINE COMPUTES THE NEW STATE VECTOR $r(t_2)$ AND $v(t_2)$.

CALLED BY: KEPPREP

INPUT:

1) $RRECT_v = r(t_1)$, INITIAL POSITION VECTOR, IN METERS, AT $2^{29}/2^{27}$.
2) $VRECT_v = v(t_1)$, INITIAL VELOCITY VECTOR, IN METERS/CSEC, AT $2^7/2^5$.
3) TAU. = t_D, DESIRED TRANSFER TIME, IN CSECS, AT 2^{28}
4) XKEPNEW = x_{INIT}, THE FIRST GUESS OF x CORRESPONDING TO TIME t_D, IS THE OUTPUT OF KEPPREP, IN METERS$^{1/2}$, AT $2^{17}/2^{16}$.
5) XPREV = x′, THE VALUE OF x FROM A PREVIOUS COMPUTATION CYCLE, IS USED ONLY TO CALCULATE AN INITIAL Δx, IN METERS$^{1/2}$, AT $2^{17}/2^{16}$.
6) TC = t'_{21}, THE PREVIOUS VALUE OF TRANSFER TIME CORRESPONDING TO x′, IN CSECS, AT 2^{28}.
7) $X1_S$ = INDEX REGISTER 1 CONTAINING A VALUE USED TO SELECT THE PROPER μ-TABLE, IS -2 FOR EARTH, IS -10D FOR MOON.

OUTPUT:

1) $RCV_v = r(t_2)$, TERMINAL POSITION VECTOR, IN METERS, AT $2^{29}/2^{27}$.
2) $VCV_v = v(t_2)$, TERMINAL VELOCITY VECTOR, IN METERS/CSEC, AT $2^7/2^5$.
3) TC = t_{21}, TRANSFER TIME CORRESPONDING TO THE VALUE OF x TO WHICH KEPLER ROUTINE CONVERGED, IN CSECS, AT 2^{28}.
4) XPREV = MPAC = x, THE VALUE OF x TO WHICH KEPLER CONVERGED, IN METERS$^{1/2}$, AT $2^{17}/2^{16}$.
5) PUSH LIST POINTER IS AT ØD.

NOTE: IF x_i IS CONSIDERED TO BE THE i^{th} ITERATE OF x, THEN x′ AND x_{INIT} CAN BE CONSIDERED TO BE x_{-1} AND x_0 RESPECTIVELY.

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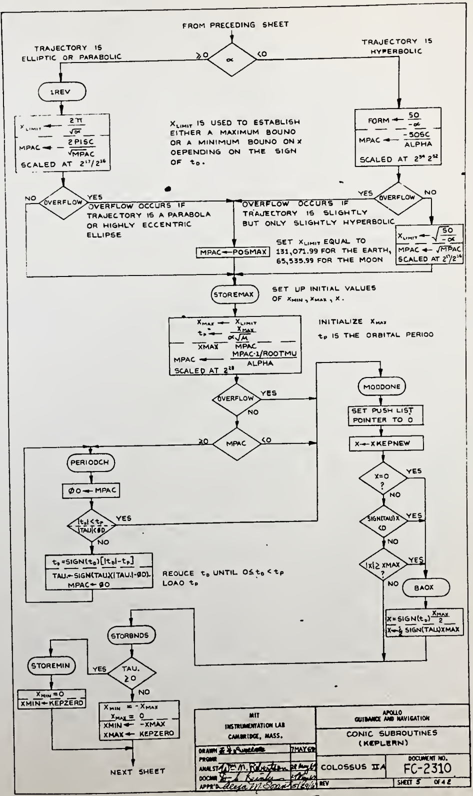
DRAWN *F. Ransom*	CONIC SUBROUTINES (KEPLERN)
CHECKED	DOCUMENT NO.
ANALYST *W. M. Robertson* 31 JUL 68	COLOSSUS	FC 2310
DOCMR *[illegible]* 11/06/68	
APPR'D *John A. Moore* 5 AUG 68	REV:	SHEET 4 OF 42



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APOLLO GUIDANCE AND NAVIGATION

CONIC SUBROUTINES (KEPLERN)

COLOSSUS IIA

DOCUMENT NO. FC-2310

SHEET 5 OF 42

FROM PRECEDING SHEET

DXCOMP

COMPUTE AN INITIAL VALUE OF Δx FOR USE IN FIRST PASS THROUGH MAIN LOOP.

$\epsilon = |\epsilon_t \cdot t_D|$

EPSILONT ← |BEE22 · TAU.|
SCALED AT 2^{28}

$\epsilon_t = 2^{-22}$

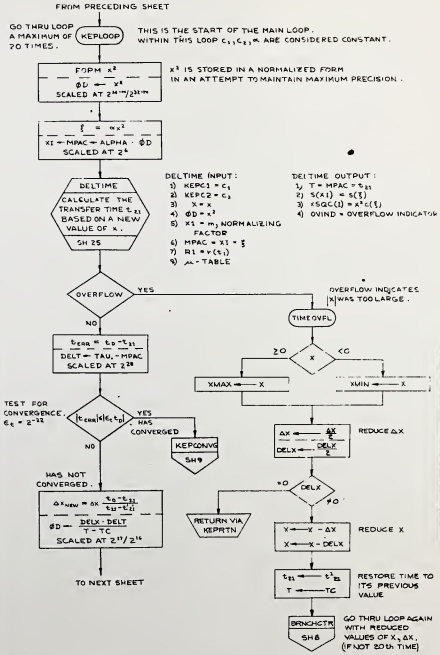
CALCULATE Δx

$\Delta x = x - x'$

DELX ← X - XPREV
SCALED AT $2^{17}/2^{16}$

TO NEXT SHEET

NOTE: x' AND t'_{21} ARE NON-ZERO ONLY IF THE SUBROUTINE IS BEING USED REPETITIVELY.



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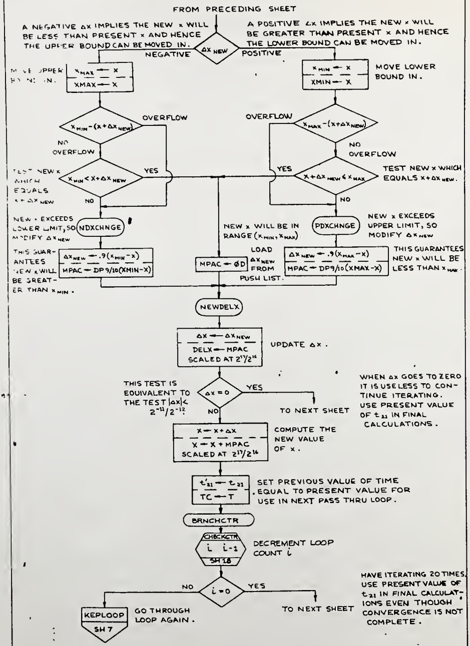
DRAWN F. Beamon	14JUN68	CONIC SUBROUTINES (KEPLERN)
PROGMR		
ANALST W. M. Robertson	31JUL68	COLOSSUS IIA — DOCUMENT NO. FC-2310
DOCMR L. A. Clark	11JUL68	
APPR'D John A. Moore	5AUG68	REV 1 — SHEET 7 OF 42



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DRAWN F. Raymond Jr. 19 JUN 68	CONIC SUBROUTINES (KEPLERN)
PRGMR	
ANALST Wm M. Robertson 31 JUL 68	COLOSSUS 2D4 DOCUMENT NO. FC 2310
DOCMR G. A. Black	
APPR'D John A. Moore 5 AUG 68	REV SHEET 8 OF 48

FROM PRECEDING SHEET

KEPCONVG

FORM $\underline{u}_{r1}[r(t_1) - x^2 c(\xi)]$

$\phi D_v \leftarrow$ URRECT$_v$[R1 - XSQC(XI)]

SCALED AT $2^{33}/2^{31}$

FORM $\underline{v}(t_1)\left[t_{21} - \frac{x^3 s(\xi)}{\sqrt{\mu}}\right]$

MPAC$_v \leftarrow$ VRECT$_v$[T - X^3 · 1/ROOTMU · S(XI)

SCALED AT $2^{33}/2^{31}$

$\underline{r}(t_2) = \underline{u}_{r1}[r(t_1) - x^2 c(\xi)] + \underline{v}(t_1)\left[t_{21} - \frac{x^3 s(\xi)}{\sqrt{\mu}}\right]$

RCV$_v \leftarrow$ MPAC$_v \leftarrow \phi D_v$ + MPAC$_v$

SCALED AT $2^{29}/2^{27}$

COMPUTE $\underline{r}(t_2)$

$r(t_2) = |\underline{r}(t_2)|$

RCNORM $\leftarrow$ |MPAC$_v$|

SCALED AT $2^{29-m}/2^{27-m}$

$r(t_2)$ IS STORED IN NORMALIZED FORM.

FORM $\underline{u}_{r1}\left[\frac{\{\xi\, s(\xi) - 1\} x \sqrt{\mu}}{r(t_2)}\right]$

$\dot{\phi} D_v \leftarrow$ URRECT$_v\left[\frac{(XI \cdot S(XI) - D1/128 \cdot X \cdot ROOTMU}{RCNORM}\right]$

SCALED AT $2^{15}/2^{13}$

FORM $\underline{v}(t_1)\left[1 - \frac{x^2 c(\xi)}{r(t_2)}\right]$

MPAC$_v \leftarrow$ VRECT$_v\left[D1/256 - \frac{XSQC(XI)}{RCNORM}\right]$

SCALED AT $2^{15}/2^{13}$

$\underline{v}(t_2) = \underline{u}_{r1}\left[\frac{\{\xi\, s(\xi) - 1\} x \sqrt{\mu}}{r(t_2)} + \underline{v}(t_1)\left[1 - \frac{x^2 c(\xi)}{r(t_2)}\right]\right]$

VCV$_v \leftarrow \phi D_v$ + MPAC$_v$

SCALED AT $2^7/2^5$

COMPUTE $\underline{v}(t_2)$.

TC $\leftarrow$ T

THE FINAL VALUES OF t_{21} AND x ARE STORED IN THEIR OUTPUT LOCATIONS

XPREV $\leftarrow$ MPAC $\leftarrow$ X

KEPRTN

$\underline{r}(t_2)$, $\underline{v}(t_2)$, t_{21}, x

THE RETURN ADDRESS IN KEPRTN IS SET UP BY THE PROGRAM CALLING KEPLER (I.E. KEPPREP) AND NOT BY KEPLER.

KEPLER TERMINATES THE ITERATION WHEN EITHER:

1) THE INDEPENDENT VARIABLE t_{21} HAS CONVERGED TO WITHIN 0.00002 % OF THE DESIRED TIME t_D, OR
2) THE CHANGE IN THE DEPENDENT VARIABLE x HAS GONE TO ZERO (I.E. LESS THAN $2^{-11}/2^{12}$), OR
3) IT HAS ITERATED THE MAXIMUM (20) NUMBER OF TIMES.

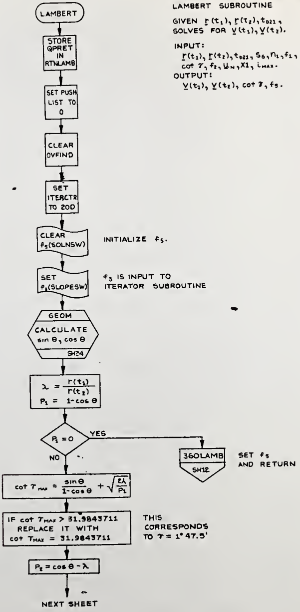
AT RETURN TIME THERE IS NO INDICATION OF WHICH CRITERION STOPPED THE ITERATION.

GENERAL FLOW DIAGRAM OF LAMBERT SUBROUTINE

GIVEN $\underline{r}(t_1)$, $\underline{r}(t_2)$, t_{D21}, SOLVES FOR $\underline{V}(t_1)$, $\underline{V}(t_2)$.

INPUT:
$\underline{r}(t_1)$, $\underline{r}(t_2)$, t_{D21}, S_6, n_1, f_1, cot γ, f_2, U_N, X1, i_{MAX}.

OUTPUT:
$\underline{V}(t_1)$, $\underline{V}(t_2)$, cot γ, f_5.



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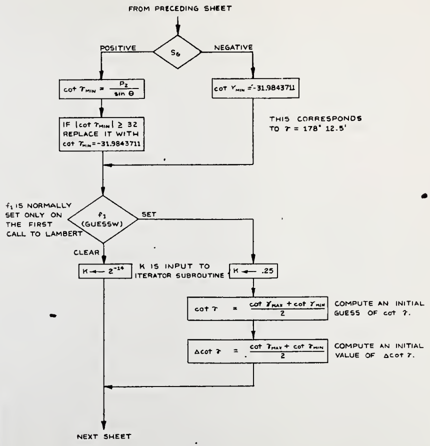
DRAWN	7 MAY 68	CONIC SUBROUTINES (LAMBERT)	
PRGMR			
ANALST	28 May 68	COLOSSUS IIA	DOCUMENT NO. FC-2310
DOCMR			
APPR'D		REV	SHEET 10 OF 48



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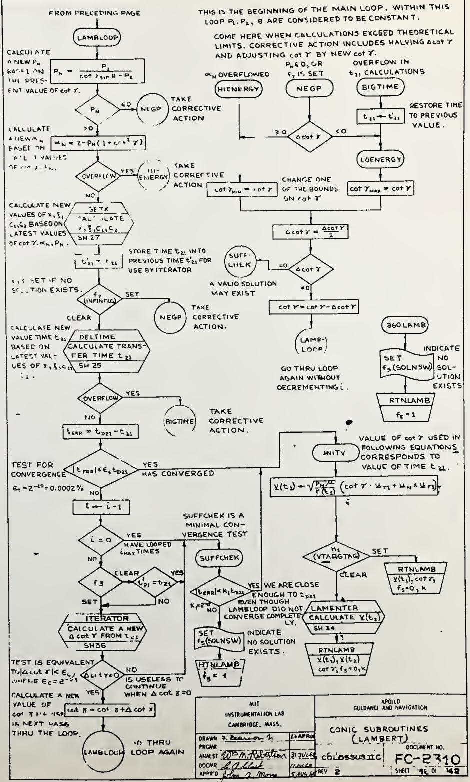
DRAWN / PROGR / ANALYST / DOCMR / APPR'D	CONIC SUBROUTINES (LAMBERT)
	COLOSSUS IIA — DOCUMENT NO. FC-2310
	REV — SHEET 11 OF 42



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DRAWN F. Pearson Jr. 23 APR 68	CONIC SUBROUTINES (LAMBERT)	
PRGMR		DOCUMENT NO.
ANALST Wm. M. Robertson 31 JUL 68	COLOSSUS IIC	FC-2310
DOCMR [illegible] 1 AUG 68		
APPR'D John A. Moss 5 AUG 68	REV 2	SHEET 95 OF 148

LAMBERT

THIS SUBROUTINE CALCULATES THE INITIAL VELOCITY REQUIRED TO TRANSFER A POINT-MASS ALONG A CONIC TRAJECTORY FROM AN INITIAL POSITION $\underline{r}(t_1)$ TO A TERMINAL POSITION $\underline{r}(t_2)$ IN A PRESCRIBED TIME INTERVAL t_{D21}. THE RESULTING TRAJECTORY MAY BE A SECTION OF A CIRCLE, ELLIPSE, PARABOLA OR HYBERBOLA WITH RESPECT TO EITHER THE EARTH OR THE MOON. THE RESTRICTIONS ARE:

1) RECTILINEAR TRAJECTORIES CAN NOT BE COMPUTED.
2) ACCURACY DEGRADATION OCCURS AS $\cos\theta$ APPROACHES 1.0.
3) THE ANGLE γ BETWEEN ANY POSITION VECTOR AND ITS VELOCITY VECTOR MUST BE IN THE RANGE $(1°47.5', 178°12.5')$.
4) A NEGATIVE TRANSFER TIME IS AMBIGUOUS AND WILL RESULT IN NO SOLUTION.

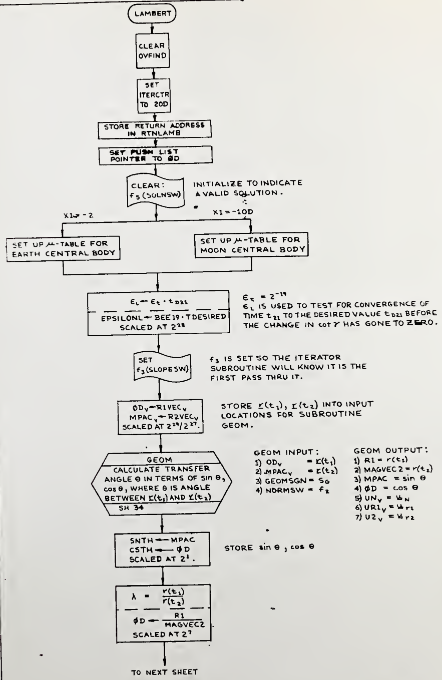
CALLED BY: INITVEL

INPUT:

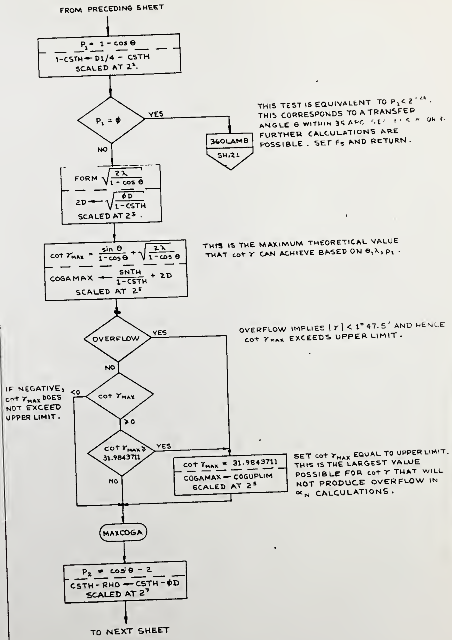
1) $RIVEC_v = \underline{r}(t_1)$, INITIAL POSITION VECTOR, IN METERS, AT $2^{29}/2^{27}$.
2) $R2VEC_v = \underline{r}(t_2)$, TERMINAL POSITION VECTOR, IN METERS, AT $2^{29}/2^{27}$.
3) TDESIRED = t_{D21}, DESIRED TRANSFER TIME, IN CSEC, AT 2^{28}.
4) GEOMSGN = S_G, A FLAG, IS POSITIVE IF THE DESIRED TRANSFER ANGLE θ IS $\leq 180°$, IS NEGATIVE IF $\theta > 180°$.
5) $VTARGTAG_s = n_1$, A FLAG, IS CLEAR IF THE TERMINAL VELOCITY VECTOR $\underline{v}(t_2)$ IS TO BE CALCULATED, IS SET IF $\underline{v}(t_2)$ IS NOT TO BE CALCULATED.
6) GUESSW = f_1, A FLAG, IS CLEAR IF AN INITIAL GUESS OF $\cot\gamma$ IS INCLUDED AS INPUT, IS SET IF AN INITIAL GUESS IS NOT INPUT BUT MUST BE CALCULATED BY THE LAMBERT ROUTINE.
7) COGA = $\cot\gamma$, AN INITIAL GUESS OF VALUE IF f_1 IS CLEAR, IS IGNORED IF f_1 IS SET, AT 2^5
8) NORMSW = f_2, A FLAG, IS CLEAR IF $\underline{u}_N$ IS TO BE COMPUTED BY THE GEOM SUBROUTINE CALLED BY LAMBERT, IS SET IF $\underline{u}_N$ IS INCLUDED AS INPUT TO LAMBERT.
9) $UN_v = \underline{u}_N$, A UNIT VECTOR NORMAL TO THE DESIRED ORBIT PLANE IN THE DIRECTION OF THE RESULTING ANGULAR MOMENTUM VECTOR, IS IGNORED IF f_2 IS CLEAR, AT $2'$.
10) X1 = INDEX REGISTER 1 CONTAINING VALUE USED TO SELECT PROPER μ-TABLE, IS -2 IF EARTH IS CENTRAL BODY, IS -10D IF MOON IS CENTRAL BODY.

OUTPUT:

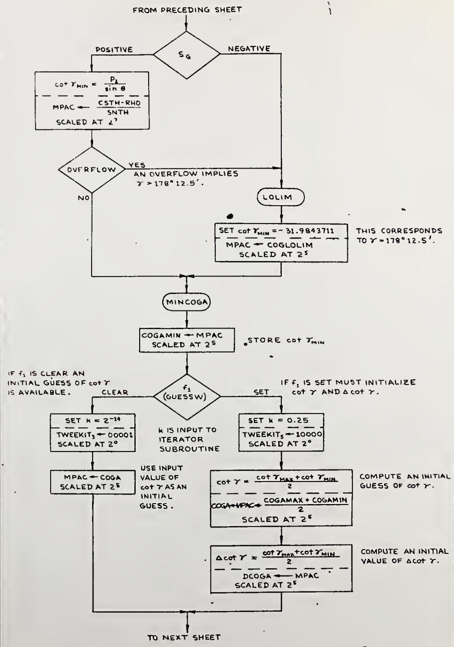
1) $VVEC_v = \underline{v}(t_1)$, INITIAL VELOCITY VECTOR, IN METERS/CSEC, AT $2^7/2^5$.
2) $VTARGET_v = \underline{v}(t_2)$, TERMINAL VELOCITY VECTOR, IS COMPUTED ONLY IF n_1 IS CLEAR, IN METERS/CSEC, AT $2^7/2^5$.
3) $MPAC_v$ = $VVEC_v$ IF n_1 IS SET, IS $VTARGET_v$ IF n_1 IS CLEAR.
4) COGA = $\cot\gamma$, COTANGENT OF FLIGHT PATH ANGLE MEASURED FROM THE VERTICAL, CORRESPONDS TO LAST CALCULATED VALUE OF TIME t_{21}, AT 2^5.
5) SOLNSW = f_5, A FLAG, IS CLEAR IF LAMBERT WAS ABLE TO CALCULATE A VALID SOLUTION, IS SET IF NO SOLUTION WAS POSSIBLE DUE TO A TRANSFER ANGLE TOO CLOSE TO 0° OR 360°, OR A TIME t_{21} TOO SMALL.
6) PUSH LIST POINTER IS LEFT AT ØD.



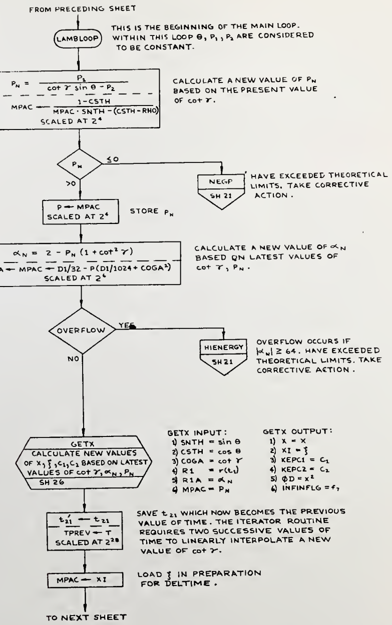
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN F. Reasoner Jr.	24APR6	CONIC SUBROUTINES (LAMBERT)	
PRGMR			DOCUMENT NO.
ANALST Wm M. Robertson	31 JUL 6	COLOSSUS IIIA	FC 2310
DOCMR C. A. Clark	11 AUG 68	REV	SHEET 14 OF 48
APPR'D John A. Moore	5 AUG 68		



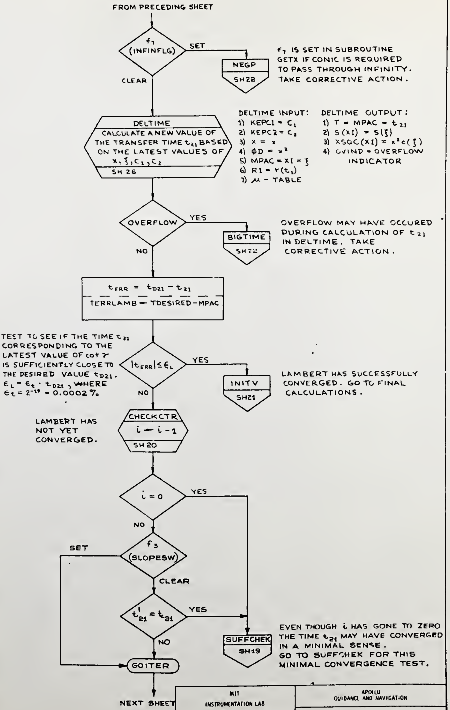
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN F. Reenan	24 APR 68	CONIC SUBROUTINES (LAMBERT)	
PROMR			
ANALST Wm M. Robertson	31 JUL 68	COLOSSUS IIA	DOCUMENT NO. FC 2310
DOCMR			
APPR'D John A. Moore		REV	SHEET 15 OF 42



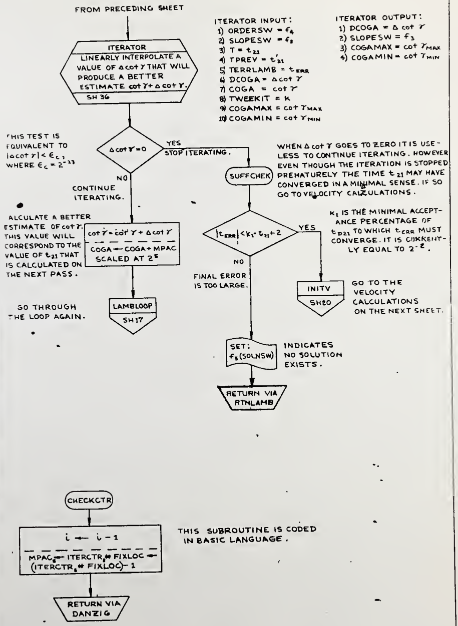
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	25 APR	CONIC SUBROUTINES (LAMBERT)	
PRGMR			
ANALST Wm M. Robertson	21 JUL	COLOSSUS	DOCUMENT NO. FC 2310
DOCMR			
APPR'D John A. Moore	AUG	REV	SHEET 18 OF 42



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN 7 Reasor A.	25 APRIL	CONIC SUBROUTINES (LAMBERT)
PRGMR		
ANALST W. M. Robertson	31 JUL	COLOSSUS IIA — DOCUMENT NO. FC-2310
DOCMR	11 JUL	
APPR'D John A. Moran	5 AUG	REV — SHEET 17 OF 42



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN J Reardon	25 APRIL	CONIC SUBROUTINES (LAMBERT)
PRGMR		
ANALST Wm M. Robertson	31 JUL 68	COLOSSUS IIC — DOCUMENT NO. FC-2310
DOCMR L. A. Clark		
APPR'D John A. Moran	5 AUG 68	REV 2 — SHEET 18 OF 42



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN [signature]	CONIC SUBROUTINES (LAMBERT)
CHECKED	DOCUMENT NO. FC2310
APPROVED [signature] 31 JUL 6?	
APPROVED [signature]	REV
APPROVED John A. [signature] 5 AUG 6?	SHEET 19 OF 48

LAMBERT TERMINATES ITERATING AND COMES HERE FOR THE FINAL CALCULATIONS IF EITHER:

1) THE ERROR $|t_{D21} - t_{21}|$ FOR INTERMEDIATE VALUES OF t_{21} AND cot γ IS LESS THAN 0.0002 % OF THE DESIRED TIME t_{D21}, OR
2) IT HAS GONE THROUGH THE LOOP $\mathcal{J}_{MAX}$ AND THE ERROR $|t_{D21} - t_{21}|$ IS LESS THAN 2^{-17} OF THE DESIRED TIME t_{D21}.

INITV

$$\underline{v}(t_1) = \sqrt{\frac{P_N \mu}{r(t_1)}} \left(\cot \gamma \cdot \underline{u}_{r1} + \underline{u}_N \times \underline{u}_{r1} \right)$$

$$VVEC_v \leftarrow MPAC_v \leftarrow \sqrt{\frac{P}{R1}} \cdot ROOTMU(COGA \cdot UR1_v) + \sqrt{\frac{P}{R1}} \cdot ROOTMU(UN_v \times UR1_v)$$

SCALED AT $2^7/2^5$

CALCULATE INITIAL VELOCITY VECTOR.

THE VALUE OF cot γ USED IN THE FOLLOWING CALCULATIONS CORRESPONDS TO THE LAST CALCULATED VALUE OF TIME t_{21}.

Decision: n_1 (VTARGTAG$_S$)

- SET → RTNLAMB: $\underline{v}(t_1)$, cot γ, $f_S = 0$, k

  IF n_1 IS SET DO NOT CALCULATE TERMINAL VELOCITY.

- CLEAR ↓

MPAC ← MAGVEC2 SCALED AT $2^{29}/2^{27}$

LOAD $r(t_2)$ FOR ENTRY INTO NEWSTATE AT LAMENTER.

LAMENTER: CALCULATE TERMINAL VELOCITY VIA ENTRY WITHIN NEWSTATE (SH 35)

LAMENTER IS ACTUALLY AN ENTRY POINT WITHIN SUBROUTINE NEWSTATE.

LAMENTER INPUT:

1) $VVEC_v = \underline{v}(t_1)$
2) $MPAC = r(t_1)$
3) $UR1_v = \underline{u}_{r1}$
4) $X = x$
5) $XI = \xi$
6) $S(XI) = s(\xi)$
7) $XSQC(XI) = x^2 c(\xi)$
8) μ - TABLE

LAMENTER OUTPUT:

1) $MPAC_v = \underline{v}(t_2)$

$VTARGET_v \leftarrow MPAC_v$ SCALED AT $2^7/2^5$

STORE TERMINAL VELOCITY VECTOR $\underline{v}(t_2)$.

RTNLAMB: $\underline{v}(t_1)$, $\underline{v}(t_2)$, cot γ, $f_S = 0$, k

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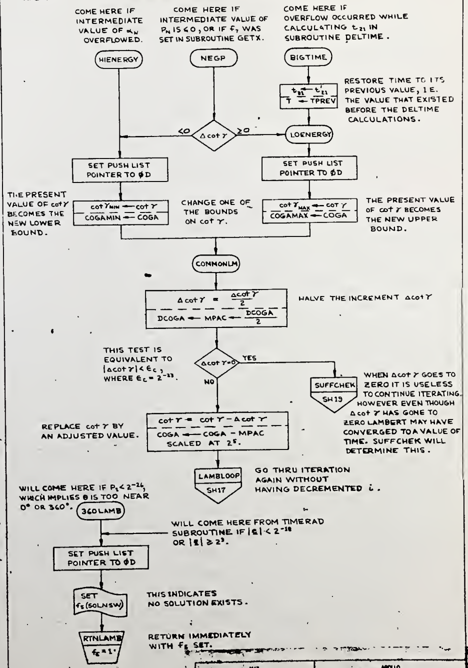
DRAWN [signature]	CONIC SUBROUTINES (LAMBERT)
ANALYST [signature] 21 JULY	COLOSSUS IIA — DOCUMENT NO. FC 4310
DOCMR [signature]	REV
APPR'D John A. [signature] 5 AUG 6?	SHEET 20 OF 43

PROGRAM COMES TO ONE OF THESE ENTRIES WHENEVER THE CALCULATIONS EXCEED THE THEORETICAL BOUNDS. CORRECTIVE ACTION IS TAKEN BY HALVING THE INCREMENT $\Delta \cot \gamma$ AND THEN ADJUSTING THE VALUE OF $\cot \gamma$ WITH THE NEW $\Delta \cot \gamma$.



MIT INSTRUMENTATION LAB
CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

CONIC SUBROUTINES (LAMBERT)

DOCUMENT NO. FC 2310

SHEET [illegible] OF [illegible]

GIVEN THE INITIAL STATE VECTOR $\underline{r}(t_1)$ AND $\underline{v}(t_1)$ AND THE DESIRED TRUE ANOMALY DIFFERENCE θ, THIS SUBROUTINE CALCULATES THE CORRESPONDING TIME OF FLIGHT t_{21} AND OPTIONALLY THE FINAL STATE VECTOR $\underline{r}(t_2)$ AND $\underline{v}(t_2)$.

CALLED BY:

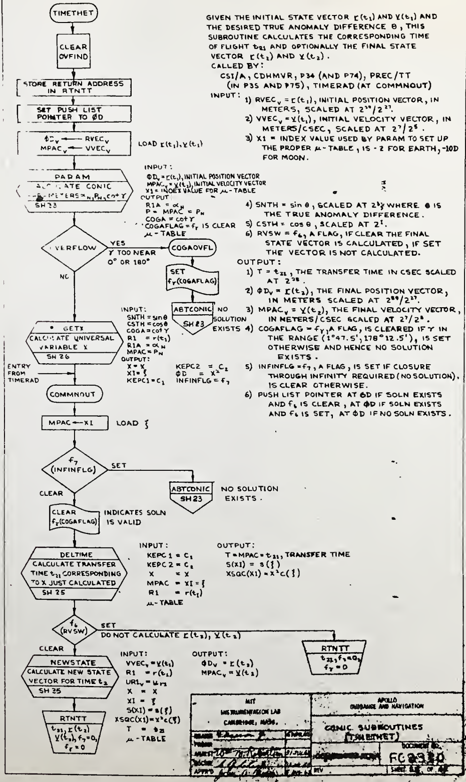
CSI/A, CDHMVR, P34 (AND P74), PREC/TT (IN P35 AND P75), TIMERAD (AT COMMNOUT)

INPUT:

1) $RVEC_v = \underline{r}(t_1)$, INITIAL POSITION VECTOR, IN METERS, SCALED AT $2^{29}/2^{27}$.
2) $VVEC_v = \underline{v}(t_1)$, INITIAL VELOCITY VECTOR, IN METERS/CSEC, SCALED AT $2^7/2^5$.
3) X1 = INDEX VALUE USED BY PARAM TO SET UP THE PROPER μ-TABLE, IS -2 FOR EARTH, -10D FOR MOON.
4) SNTH = sin θ, SCALED AT 2^1 WHERE θ IS THE TRUE ANOMALY DIFFERENCE.
5) CSTH = cos θ, SCALED AT 2^1.
6) RVSW = f_6, A FLAG, IF CLEAR THE FINAL STATE VECTOR IS CALCULATED, IF SET THE VECTOR IS NOT CALCULATED.

OUTPUT:

1) T = t_{21}, THE TRANSFER TIME IN CSEC SCALED AT 2^{28}.
2) $\Phi D_v = \underline{r}(t_2)$, THE FINAL POSITION VECTOR, IN METERS SCALED AT $2^{29}/2^{27}$.
3) $MPAC_v = \underline{v}(t_2)$, THE FINAL VELOCITY VECTOR, IN METERS/CSEC SCALED AT $2^7/2^5$.
4) COGAFLAG = f_γ, A FLAG, IS CLEARED IF γ IN THE RANGE (1°47.5', 178°12.5'), IS SET OTHERWISE AND HENCE NO SOLUTION EXISTS.
5) INFINFLG = f_7, A FLAG, IS SET IF CLOSURE THROUGH INFINITY REQUIRED (NO SOLUTION), IS CLEAR OTHERWISE.
6) PUSH LIST POINTER AT ΦD IF SOLN EXISTS AND f_6 IS CLEAR, AT ΦD IF SOLN EXISTS AND f_6 IS SET, AT ΦD IF NO SOLN EXISTS.



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APOLLO GUIDANCE AND NAVIGATION

CONIC SUBROUTINES (TIMETHET)

DOCUMENT NO. FC 9330

GIVEN THE INITIAL STATE VECTOR $\underline{r}(t_1)$ AND $\underline{v}(t_1)$ AND A DESIRED RADIUS $r(t_2)$ TO WHICH THE STATE VECTOR IS TO BE UPDATED, THIS SUBROUTINE CALCULATES THE TRANSFER TIME t_{21} AND OPTIONALLY THE NEW STATE VECTOR.

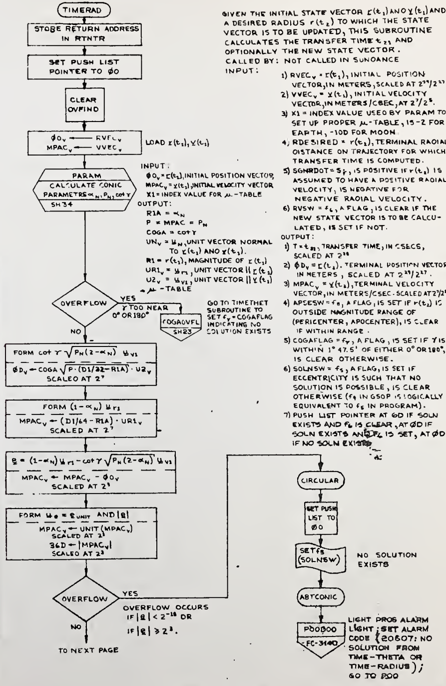
CALLED BY: NOT CALLED IN SUNDANCE

INPUT:

1) $RVEC_v = \underline{r}(t_1)$, INITIAL POSITION VECTOR, IN METERS, SCALED AT $2^{29}/2^{27}$
2) $VVEC_v = \underline{v}(t_1)$, INITIAL VELOCITY VECTOR, IN METERS/CSEC, AT $2^7/2^5$.
3) X1 = INDEX VALUE USED BY PARAM TO SET UP PROPER μ-TABLE, 15-2 FOR EARTH, -10D FOR MOON.
4) RDESIRED = $r(t_2)$, TERMINAL RADIAL DISTANCE ON TRAJECTORY FOR WHICH TRANSFER TIME IS COMPUTED.
5) SGNRDOT = $S_{\dot{r}}$, IS POSITIVE IF $r(t_2)$ IS ASSUMED TO HAVE A POSITIVE RADIAL VELOCITY, IS NEGATIVE FOR NEGATIVE RADIAL VELOCITY.
6) RVSW = f_6, A FLAG, IS CLEAR IF THE NEW STATE VECTOR IS TO BE CALCULATED, IS SET IF NOT.

OUTPUT:

1) $T = t_{21}$, TRANSFER TIME, IN CSECS, SCALED AT 2^{28}
2) $\phi D_v = \underline{r}(t_2)$. TERMINAL POSITION VECTOR IN METERS, SCALED AT $2^{29}/2^{27}$.
3) $MPAC_v = \underline{v}(t_2)$, TERMINAL VELOCITY VECTOR, IN METERS/CSEC. SCALED AT $2^7/2^5$.
4) APSESW = f_8, A FLAG, IS SET IF $r(t_2)$ IS OUTSIDE MAGNITUDE RANGE OF (PERICENTER, APOCENTER), IS CLEAR IF WITHIN RANGE.
5) COGAFLAG = f_7, A FLAG, IS SET IF γ IS WITHIN 1° 47.5' OF EITHER 0° OR 180°, IS CLEAR OTHERWISE.
6) SOLNSW = f_5, A FLAG, IS SET IF ECCENTRICITY IS SUCH THAT NO SOLUTION IS POSSIBLE, IS CLEAR OTHERWISE (f_9 IN GSOP IS LOGICALLY EQUIVALENT TO f_5 IN PROGRAM).
7) PUSH LIST POINTER AT 6D IF SOLN EXISTS AND f_6 IS CLEAR, AT ØD IF SOLN EXISTS AND f_6 IS SET, AT ØD IF NO SOLN EXISTS.

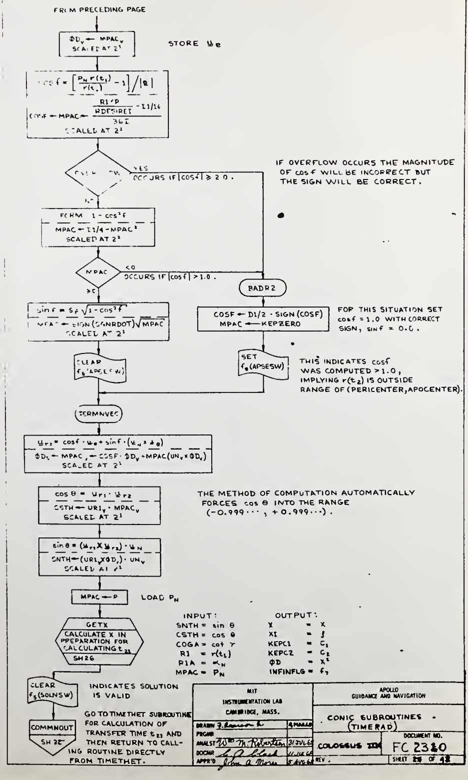


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

CONIC SUBROUTINES (TIMERAD)

FC-2310



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

DRAWN F. Lawson 4 MAR 66
PRGMR
ANALST Wm M. Robertson 31 JUL 65
DOCMR [signature] 11 JUL 66
APPR'D John A. Morse 5 AUG 66

APOLLO GUIDANCE AND NAVIGATION

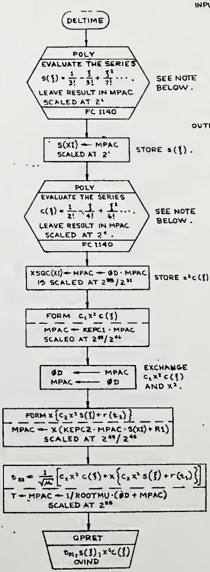
CONIC SUBROUTINES - (TIMERAD)

COLOSSUS IIIC

DOCUMENT NO. FC 2310

REV.

SHEET 26 OF 42



GIVEN A VALUE OF THE UNIVERSAL VARIABLE x, AND THE VALUES c_1, c_2, AND ξ, THIS SUBROUTINE CALCULATES THE CORRESPONDING TRANSFER TIME t_{21}.

CALLED BY:
KEPLERN, LAMBERT, TIMETHET.

INPUT:
1) KEPC1 = c_1 AT $2^{17}/2^{16}$.
2) KEPC2 = c_2 AT 2^6.
3) X = x, UNIVERSAL VARIABLE, AT $2^{17}/2^{16}$.
4) ØD = x^2, NORMALIZED AT $2^{34-n}/2^{32-n}$.
5) X1 = INDEX REGISTER CONTAINING THE NORMALIZING VALUE $-n$.
6) MPAC = ξ, AT 2^6.
7) R1 = $r(t_1)$, THE MAGNITUDE OF $\underline{r}(t_1)$, AT $2^{29}/2^{27}$.
8) μ-TABLE APPROPRIATE FOR EITHER EARTH OR MOON.
9) THE PUSH LIST POINTER IS AT 2D.

OUTPUT:
1) T = MPAC = t_{21}, TRANSFER TIME, IN CSECS, AT 2^{28}.
2) S(XI) = $s(\xi)$, AT 2^1.
3) XSQC(XI) = $x^2 c(\xi)$, AT $2^{33}/2^{31}$.
4) OVFIND = THE OVERFLOW INDICATOR, IT MAY BE TURNED ON AS A RESULT OF t_{21} CALCULATION, IMPLYING THE VALUE OF X AT INPUT WAS TOO LARGE.
5) PUSH LIST POINTER IS LEFT AT ØD.

NOTE:
THE INFINITE SERIES $s(\xi)$ AND $c(\xi)$ ARE APPROXIMATED BY POLYNOMIALS OF DEGREE 9. THE COEFFICIENTS USED ARE THE RESULT OF A CHEBYSHEV POLYNOMIAL APPROXIMATION TO EACH SERIES. SEE REF. 6 AND REF. 2, PAGES 391-5. THE COEFFICIENTS USED ARE AS FOLLOWS.

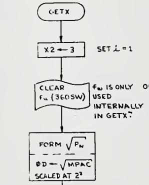
$s(\xi)$	$c(\xi)$
0.083333334×2^{1}	0.031250001×2^{4}
$-0.266666684 \times 2^{-5}$	$-0.166666719 \times 2^{-2}$
$0.406349155 \times 2^{-11}$	$0.355555413 \times 2^{-8}$
$-0.361198675 \times 2^{-17}$	$-0.406347410 \times 2^{-14}$
$0.210153242 \times 2^{-23}$	$0.288962094 \times 2^{-20}$
$-0.086221951 \times 2^{-29}$	$-0.140117894 \times 2^{-26}$
$0.026268812 \times 2^{-35}$	$0.049247387 \times 2^{-32}$
$-0.006163316 \times 2^{-41}$	$-0.013081923 \times 2^{-38}$
$0.001177342 \times 2^{-47}$	$0.002806389 \times 2^{-44}$
$-0.000199055 \times 2^{-53}$	$-0.000529414 \times 2^{-50}$

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN / FROM / ANALYST / DOCUMENT / APPROVED (signatures)	CONIC SUBROUTINES (DELTIME)
	DOCUMENT NO. FC 2310
REV	SHEET 25 OF 42

THIS SUBROUTINE COMPUTES THE UNIVERSAL VARIABLE X REQUIRED BY THE TIME EQUATION.
CALLED BY: LAMBERT, TIMERAD, TIMETHET

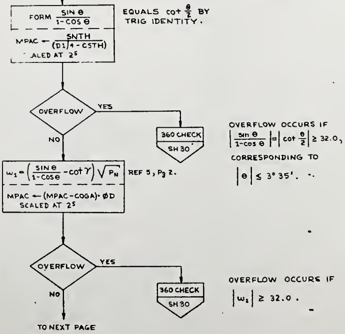
INPUT:

1 SNTH = $\sin\theta$ SCALED AT 2^1, WHERE θ IS THE TRANSFER ANGLE.
2 CSTH = $\cos\theta$ SCALED AT 2^1.
3 COGA = $\cot\gamma$, THE COTANGENT OF THE FLIGHT PATH ANGLE MEASURED FROM THE VERTICAL, SCALED AT 2^5
4 R1 = $r(t_1)$, THE MAGNITUDE OF $\underline{r}(t_1)$, SCALED AT $2^{29}/2^{27}$.
5 R1A = α_N, THE RATIO OF $r(t_1)$ TO THE SEMI-MAJOR AXIS a, SCALED AT 2^6.
6 MPAC = P_N, THE RATIO OF THE SEMI-LATUS RECTUM TO $r(t_1)$, SCALED AT 2^4.
7 THE PUSH LIST POINTER CAN BE AT ANY VALUE PL, WHERE $0 \le PL \le 27D$; IS NORMALLY AT ØD.

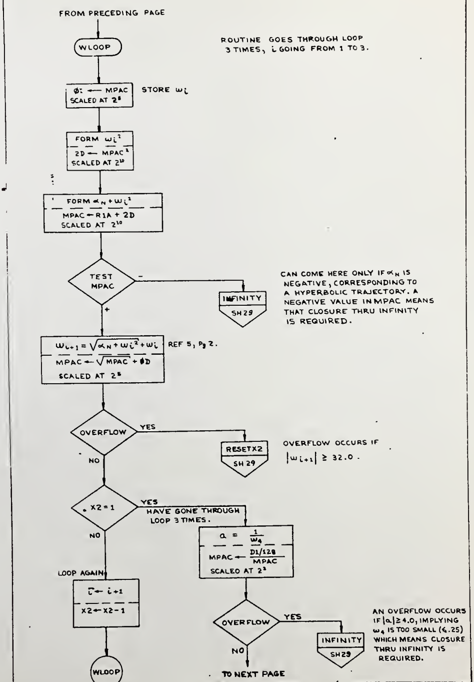


OUTPUT:

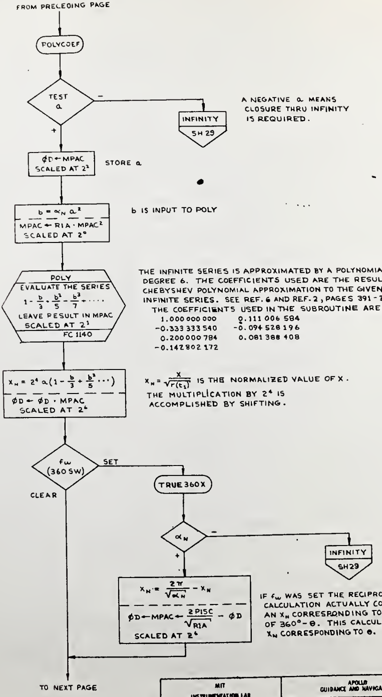
1 X = x, THE UNIVERSAL CONIC PARAMETER, SCALED AT $2^{17}/2^{16}$.
2 XI = ξ, WHERE $\xi = \alpha_N x_N^2$, SCALED AT 2^6.
3 KEPC1 = c_1, SCALED AT $2^{17}/2^{16}$
4 KEPC2 = c_2, SCALED AT 2^6.
5 ØD = x^3, NORMALIZED SCALED AT $2^{34-N1}/2^{32-N1}$, AND -N1 IS IN X1.
6 INFINFLG = f_7, A FLAG, IS SET IF TRAJECTORY IS REQUIRED TO CLOSE THROUGH INFINITY, IS CLEAR IF SOLUTION IS VALID.
7 PUSH LIST POINTER IS LEFT AT PL+2 IF SOLUTION VALID, IS LEFT AT ØD IF f_7 IS SET.



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN / PROGMR / ANALYST / DOCMR / APP'D	CONIC SUBROUTINES (GETX)
	DOCUMENT NO. FC2310
REV	SHEET 10 OF 48



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN F. Reason 1 APR 6	CONIC SUBROUTINES (SETX)
ANALYST W. M. Robertson 31 JUL 6	DOCUMENT NO. FC 2310
APPRVD John A. Moore 5 AUG 6	SHEET 29 OF 48



A NEGATIVE a MEANS CLOSURE THRU INFINITY IS REQUIRED.

STORE a

b IS INPUT TO POLY

THE INFINITE SERIES IS APPROXIMATED BY A POLYNOMIAL OF DEGREE 6. THE COEFFICIENTS USED ARE THE RESULT OF A CHEBYSHEV POLYNOMIAL APPROXIMATION TO THE GIVEN INFINITE SERIES. SEE REF. 6 AND REF. 2, PAGES 391 - 395.

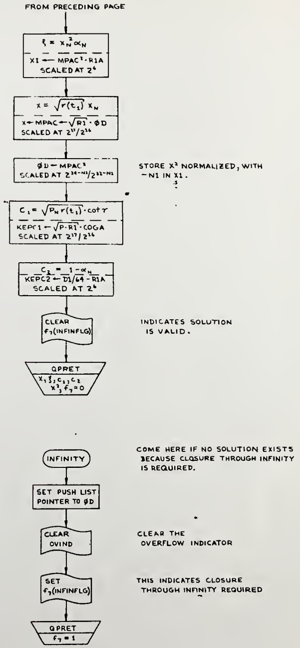
THE COEFFICIENTS USED IN THE SUBROUTINE ARE:

1.000 000 000	0.111 006 584
-0.333 333 540	-0.094 528 196
0.200 000 784	0.081 388 408
-0.142 802 172	

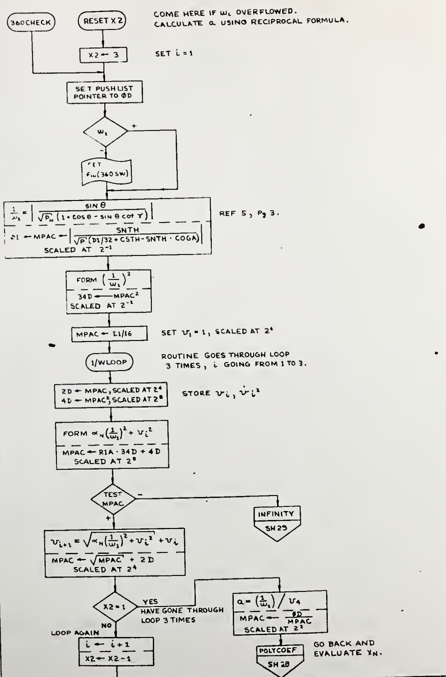
$x_N = \frac{x}{\sqrt{r(t_1)}}$ IS THE NORMALIZED VALUE OF X. THE MULTIPLICATION BY 2^4 IS ACCOMPLISHED BY SHIFTING.

IF f_w WAS SET THE RECIPROCAL CALCULATION ACTUALLY COMPUTED AN X_N CORRESPONDING TO AN ANGLE OF 360° − θ. THIS CALCULATES THE X_N CORRESPONDING TO θ.

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN 7. Pearson Jr.	[illegible]	CONIC SUBROUTINES (GETX)	
PRGMR			DOCUMENT NO. FC2310
ANALYST Wm. M. Robertson	21 JUL 6[illegible]	[illegible]	
DOCMR [illegible]	11 [illegible]	REV	SHEET 2[illegible] OF [illegible]
APPR'D John A. Moore	5 AUG [illegible]		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN F. Raamer Jr.	[illegible]	CONIC SUBROUTINES (GETX)	
PROGMR			DOCUMENT NO.
ANALST Wm. M. Robertson	31 JUL 6[illegible]	COLOSSUS [illegible]	FC 2310
DOCMR G. A. Black	[illegible]		
APPR'D John A. Moore	5 AUG 6[illegible]	REV.	SHEET [illegible] OF 42



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN F. Pearson Jr.	CONIC SUBROUTINES (GETX)
PRGMR	DOCUMENT NO. FC 2310
ANALST Wm. M. Robertson 31 JUL 6[illegible]	
DOCMR [illegible]	REV 1
APPR'D John A. Morse 5 AUG 6[illegible]	SHEET 30 OF 48

RELATING EQUATIONS IN SUBROUTINE TO EQUATIONS GIVEN IN REFRENCE 5

THE EQUATIONS USED IN SUBROUTINE GETX FOR CALCULATING THE VARIABLE X ARE NOT IDENTICAL TO THE EQUATIONS GIVEN IN REF. 5, PAGES 2 AND 3, BUT ARE AN EQUIVALENT SET OF NORMALIZED EQUATIONS. THE FOLLOWING DEMONSTRATES THEIR EQUIVALENCE.

NOTATION

- r = POSITION VECTOR MAGNITUDE
- γ = FLIGHT PATH ANGLE
- p = SEMI-LATUS RECTUM
- $p_N = p/r$
- α = RECIPROCAL OF SEMI-MAJOR AXIS
- $\alpha_N = r\alpha$
- θ = TRANSFER ANGLE
- x = UNIVERSAL VARIABLE
- $x_N = x/\sqrt{r}$

THE VARIABLE X CAN BE EXPRESSED EXPLICITLY AS:

$$x = \frac{2^i}{W_i}\left[1 - \frac{1}{3}\left(\frac{\alpha}{W_i^2}\right) + \frac{1}{5}\left(\frac{\alpha}{W_i^2}\right)^2 - \cdots\right],$$

WHERE THE VARIABLE W_i IS THE i^{TH} VALUE IN A SEQUENCE DEFINED RECURSIVELY AS:

$$W_1 = \left(\frac{\sin\theta}{1-\cos\theta} - \cot\gamma\right)\frac{\sqrt{p}}{r},$$

$$W_i = \sqrt{\alpha + W_{i-1}^2} + W_{i-1} \quad \text{FOR } i = 2, 3, \cdots$$

IT HAS BEEN ESTABLISHED THAT IT IS SUFFICIENT TO GO ONLY TO W_4 TO EVALUATE X WITH THE REQUIRED ACCURACY. THUS

$$W_4 = \sqrt{\alpha + W_3^2} + W_3 \quad \text{AND}$$

$$x = \frac{2^4}{W_4}\left[1 - \frac{1}{3}\left(\frac{\alpha}{W_4^2}\right) + \frac{1}{5}\left(\frac{\alpha}{W_4^2}\right)^2 - \cdots\right]$$

THE SUBROUTINE EVALUATES A VARIABLE w_i RECURSIVELY THROUGH w_4 AS:

$$w_1 = \left(\frac{\sin\theta}{1-\cos\theta} - \cot\gamma\right)\sqrt{\frac{p}{r}},$$

$$w_i = \sqrt{\alpha_N + w_{i-1}^2} + w_{i-1} \quad \text{FOR } i = 2, 3, 4 .$$

THE RELATION BETWEEN w_i AND W_i IS AS FOLLOWS:

$$w_1 = \sqrt{r}\, W_1$$

$$w_2 = \sqrt{\alpha_N + w_1^2} + w_1 = \sqrt{r\alpha + rW_1^2} + \sqrt{r}\,W_1 = \sqrt{r}\,W_2$$

$$w_3 = \sqrt{\alpha_N + w_2^2} + w_2 = \sqrt{r\alpha + rW_2^2} + \sqrt{r}\,W_2 = \sqrt{r}\,W_3$$

$$w_4 = \sqrt{\alpha_N + w_3^2} + w_3 = \sqrt{r\alpha + rW_3^2} + \sqrt{r}\,W_3 = \sqrt{r}\,W_4$$

SUBSTITUTING $\frac{\sqrt{r}}{w_4}$ FOR $\frac{1}{W_4}$ IN THE EQUATION FOR X GIVES:

$$x = \frac{2^4\sqrt{r}}{w_4}\left[1 - \frac{1}{3}\left(\frac{r\alpha}{w_4^2}\right) + \frac{1}{5}\left(\frac{r\alpha}{w_4^2}\right)^2 - \cdots\right]$$. REPLACING $r\alpha$ BY α_N

GIVES

$$x_N = \frac{x}{\sqrt{r}} = \frac{2^4}{w_4}\left[1 - \frac{1}{3}\left(\frac{\alpha_N}{w_4^2}\right) + \frac{1}{5}\left(\frac{\alpha_N}{w_4^2}\right)^2 - \cdots\right].$$

LET $a = \frac{1}{w_4}$ AND $b = \alpha_N a^2 = \frac{\alpha_N}{w_4^2}$ AND SUBSTITUTE IN EQUATION TO GET

$$x_N = 2^4 a\left[1 - \frac{1}{3}b + \frac{1}{5}b^2 - \frac{1}{7}b^3 + \cdots\right].$$

THIS IS THE FORM OF THE EQUATION AS IT IS CODED IN THE SUBROUTINE USING THE ABOVE VALUES OF a AND b.
FOR THE RECIPROCAL CASE, THE RECIPROCAL OF W_1 IS GIVEN BY

$$\frac{1}{W_1} = \frac{\sin\theta}{1+\cos\theta - \sin\theta\cot\gamma}\left(\frac{r}{\sqrt{p}}\right).$$

A VARIABLE V_i IS DEFINED RECURSIVELY IN REF. 5 AS

$$V_1 = 1$$

$$V_i = \sqrt{\frac{\alpha}{W_1^2} + V_{i-1}^2} + V_{i-1} \quad \text{FOR } i = 2, 3, \cdots .$$

THE RECIPROCAL $\frac{1}{W_4}$ IS DEFINED AS

$$\frac{1}{W_4} = \left(\frac{1}{W_1}\right) \Big/ V_4 \; .$$

THE SUBROUTINE EVALUATES INSTEAD THE VARIABLE $\frac{1}{\omega_1}$ AND VARIABLE v_i RECURSIVELY THROUGH v_4 AS:

$$\frac{1}{\omega_1} = \frac{\sin\theta}{1 + \cos\theta - \sin\theta\cot\gamma}\left(\frac{1}{\sqrt{P_N}}\right) , \quad \text{WHERE } \frac{1}{\sqrt{P_N}} = \sqrt{\frac{r}{P}} \; ,$$

$$v_1 = 1$$

$$v_i = \sqrt{\frac{\alpha_N}{\omega_1^2} + v_{i-1}^2} + v_{i-1} \qquad \text{FOR } i = 2, 3, 4 .$$

THE RELATIONS BETWEEN $\frac{1}{\omega_1}$ AND $\frac{1}{W_1}$, AND v_i AND V_i ARE AS FOLLOWS:

$$\frac{1}{\omega_1} = \frac{1}{\sqrt{r}}\frac{1}{W_1} \qquad \text{AND HENCE } \frac{\alpha_N}{\omega_1^2} = \frac{\alpha}{W_1^2} \; ,$$

$$v_1 = V_1$$

$$v_2 = \sqrt{\frac{\alpha_N}{\omega_1^2} + v_1^2} + v_1 = \sqrt{\frac{\alpha}{W_1^2} + V_1^2} + V_1 = V_2$$

$$v_3 = \sqrt{\frac{\alpha_N}{\omega_1^2} + v_2^2} + v_2 = \sqrt{\frac{\alpha}{W_1^2} + V_2^2} + V_2 = V_3$$

$$v_4 = \sqrt{\frac{\alpha_N}{\omega_1^2} + v_3^2} + v_3 = \sqrt{\frac{\alpha}{W_1^2} + V_3^2} + V_3 = V_4$$

SUBSTITUTING THESE VALUES OF $\frac{1}{W_1}$ AND V_4 BACK INTO THE EQUATION FOR $\frac{1}{W_4}$ GIVES

$$\frac{1}{W_4} = \left(\frac{1}{W_1}\right)\Big/ V_4 = \left(\frac{\sqrt{r}}{\omega_1}\right)\Big/ v_4 = \frac{\sqrt{r}}{\omega_1 v_4}$$

SUBSTITUTING THIS INTO THE EQUATION FOR X GIVES

$$X = \frac{2^4\sqrt{r}}{\omega_1 v_4}\left[1 - \frac{1}{3}\alpha\left(\frac{r}{\omega_1^2 v_4^2}\right) + \frac{1}{5}\alpha^2\left(\frac{r}{\omega_1^2 v_4^2}\right)^2 - \cdots\right] .$$

LETTING $a = \frac{1}{\omega_1 v_4}$ AND $b = \alpha_N a^2 = \frac{\alpha_N}{\omega_1^2 v_4^2}$; AND RECALLING THAT $\alpha_N = \alpha r$, GIVES

$$X_N = \frac{X}{\sqrt{r}} = 2^4 a\left[1 - \frac{1}{3}b + \frac{1}{5}b^2 - \frac{1}{7}b^3 + \cdots\right] ,$$

THIS IS EXACTLY THE SAME FORM FOR EVALUATING X_N AS IN THE PREVIOUS CASE, USING THE ABOVE VALUES OF a AND b.

THIS SUBROUTINE COMPUTES THE CONIC PARAMETERS α_N, p_N, $\cot\gamma$ FOR A GIVEN TIME t_1.

CALLED BY:

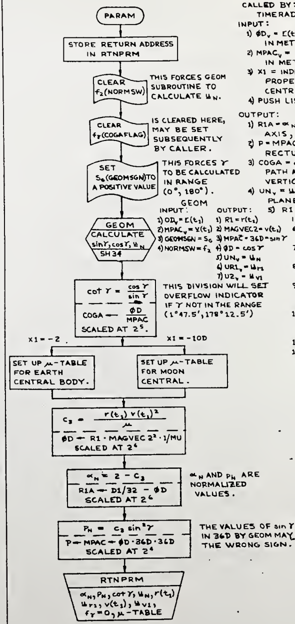
TIMERAD, TIMETHET

INPUT:

1) $\phi D_v = \underline{r}(t_1)$, THE INITIAL POSITION VECTOR, IN METERS AT $2^{29}/2^{27}$.
2) $MPAC_v = \underline{v}(t_1)$, THE INITIAL VELOCITY VECTOR, IN METERS/CSEC, AT $2^7/2^5$.
3) X1 = INDEX VALUE USED TO SET UP THE PROPER μ-TABLE, IS -2 IF EARTH IS CENTRAL BODY, IS -10D FOR THE MOON.
4) PUSH LIST POINTER IS AT 6D.

OUTPUT:

1) $R1A = \alpha_N$, THE RATIO OF $|\underline{r}(t_1)|$ TO SEMI-MAJOR AXIS, AT 2^6.
2) $P = MPAC = p_N$, THE RATIO OF THE SEMI-LATUS RECTUM TO $|\underline{r}(t_1)|$, AT 2^4.
3) $COGA = \cot\gamma$, THE COTAN OF THE FLIGHT PATH ANGLE, MEASURED FROM THE VERTICAL, AT 2^5.
4) $UN_v = \underline{u}_N$, A UNIT VECTOR NORMAL TO PLANE OF THE INPUT VECTORS, AT 2^1.
5) $R1 = r(t_1)$, THE MAGNITUDE OF $\underline{r}(t_1)$, IN METERS, AT $2^{29}/2^{27}$.
6) $UR1_v = \underline{u}_{r1}$, A UNIT VECTOR IN DIRECTION OF $\underline{r}(t_1)$, AT 2^1.
7) $MAGVEC2 = v(t_1)$, THE MAGNITUDE OF $\underline{v}(t_1)$, IN METERS/CSEC, AT $2^7/2^5$.
8) $U2_v = \underline{u}_{v1}$, UNIT VECTOR IN DIRECTION $\underline{v}(t_1)$, AT 2^1.
9) μ-TABLE APPROPRIATE TO EITHER EARTH CENTERED OR MOON CENTERED SYSTEM.
10) OVIND = THE OVERFLOW INDICATOR MAY BE SET IN CALCULATION OF $\cot\gamma$.
11) $COGAFLAG = f_\gamma$ IS CLEARED.
12) PUSH LIST POINTER AT ϕD.



MIT INSTRUMENTATION LAB, CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

CONIC SUBROUTINES (PARAM)

COLOSSUS

DOCUMENT NO. FC 2310

REV

SHEET 38 OF 48

GIVEN TWO VECTORS $\underline{r}_1$ AND $\underline{r}_2$, THIS SUBROUTINE COMPUTES THE SINE AND COSINE OF THE ANGLE ϕ BETWEEN THEM, AND OPTIONALLY A UNIT VECTOR $\underline{u}_N$ NORMAL TO THE PLANE DEFINED BY THE VECTORS.

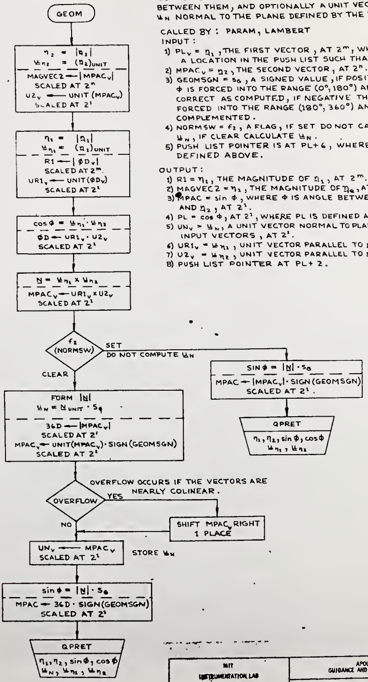
CALLED BY: PARAM, LAMBERT

INPUT:

1) $PL_v = \underline{r}_1$, THE FIRST VECTOR, AT 2^m, WHERE PL IS A LOCATION IN THE PUSH LIST SUCH THAT $0 \leq PL \leq 30D$.
2) $MPAC_v = \underline{r}_2$, THE SECOND VECTOR, AT 2^n.
3) GEOMSGN = s_G, A SIGNED VALUE, IF POSITIVE THEN ϕ IS FORCED INTO THE RANGE (0°, 180°) AND $\underline{u}_N$ IS CORRECT AS COMPUTED, IF NEGATIVE THEN ϕ IS FORCED INTO THE RANGE (180°, 360°) AND $\underline{u}_N$ IS COMPLEMENTED.
4) NORMSW = f_2, A FLAG, IF SET DO NOT CALCULATE $\underline{u}_N$, IF CLEAR CALCULATE $\underline{u}_N$.
5) PUSH LIST POINTER IS AT PL+6, WHERE PL IS DEFINED ABOVE.

OUTPUT:

1) R1 = r_1, THE MAGNITUDE OF $\underline{r}_1$, AT 2^m.
2) MAGVEC2 = r_2, THE MAGNITUDE OF $\underline{r}_2$, AT 2^n.
3) MPAC = $\sin\phi$, WHERE ϕ IS ANGLE BETWEEN $\underline{r}_1$ AND $\underline{r}_2$, AT 2^1.
4) PL = $\cos\phi$, AT 2^1, WHERE PL IS DEFINED ABOVE.
5) $UN_v = \underline{u}_N$, A UNIT VECTOR NORMAL TO PLANE OF INPUT VECTORS, AT 2^1.
6) $UR1_v = \underline{u}_{r1}$, UNIT VECTOR PARALLEL TO $\underline{r}_1$, AT 2^1.
7) $U2_v = \underline{u}_{r2}$, UNIT VECTOR PARALLEL TO $\underline{r}_2$, AT 2^1.
8) PUSH LIST POINTER AT PL+2.



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN	CONIC SUBROUTINES (GEOM)
PROGR	DOCUMENT NO.
ANALYST D. M. Robertson	COLOSSUS II-A · FC 2310
DOCUMT	
APPR'D	REV · SHEET 3 OF 4

THIS SUBROUTINE CALCULATES THE NEW STATE VECTORS $\underline{r}(t_2)$ AND $\underline{v}(t_2)$.
IT IS CALLED BY: TIMETHET
LAMBERT (AT LOCATION LAMENTER)

INPUT:

1) VVEC$_v$ = $\underline{v}(t_1)$, THE INITIAL VELOCITY VECTOR, IN METERS/CSEC, SCALED AT $2^7/2^5$.
2) R1 = $r(t_1)$, THE MAGNITUDE OF INITIAL POSITION VECTOR, IN METERS, SCALED AT $2^{29}/2^{27}$.
3) URI$_v$ = $\underline{u}_{r1}$, A UNIT VECTOR IN DIRECTION OF INITIAL POSITION VECTOR $\underline{r}(t_1)$, SCALED AT 2^1.
4) X = x, THE UNIVERSAL VARIABLE, SCALED AT $2^{17}/2^{16}$.
5) XI = $\xi = \alpha x^2$, SCALED AT 2^6.
6) S(XI) = $s(\xi)$, SCALED AT 2^1.
7) XSQC(XI) = $x^2 c(\xi)$, SCALED AT $2^{33}/2^{31}$.
8) T = t_{21}, THE TRANSFER TIME, SCALED AT 2^{28}.
9) THE μ-TABLE APPROPRIATE FOR EITHER THE EARTH OR MOON.
10) PUSH LIST POINTER IS AT THE GENERAL VALUE PL IF ENTRY AT NEWSTATE, AT PL+6 IF ENTRY AT LAMENTER, WHERE 0 ≤ PL ≤ 8D.

OUTPUT:

1) ϕD_v = $\underline{r}(t_2)$, THE TERMINAL POSITION VECTOR, IN METERS, SCALED AT $2^{29}/2^{27}$.
2) MPAC$_v$ = $\underline{v}(t_2)$, THE TERMINAL VELOCITY VECTOR, IN METERS/CSEC, SCALED AT $2^7/2^5$.
3) PUSH LIST POINTER AT PL+6 NORMALLY; AT PL IF ROUTINE WAS ENTERED BY LAMBERT AT LOCATION LAMENTER, WHERE PL IS THE ENTRY VALUE.

(NEWSTATE)

FORM $\underline{u}_{r1}\left[r(t_1) - x^2 c(\xi)\right]$
$\phi D_v \leftarrow$ URI$_v$[R1-XSQC(XI)]
SCALED AT $2^{33}/2^{31}$

FORM $\underline{v}(t_1)\left[t_{21} - \frac{x^3 s(\xi)}{\sqrt{\mu}}\right]$
MPAC$_v \leftarrow$ VVEC$_v$[T-X² X·1/ROOTMU·S(XI)]
SCALED AT $2^{33}/2^{31}$

$\underline{r}(t_2) = \underline{u}_{r1}\left[r(t_1) - x^2 c(\xi)\right] + \underline{v}(t_1)\left[t_{21} - \frac{x^3 s(\xi)}{\sqrt{\mu}}\right]$
$\phi D_v \leftarrow$ MPAC$_v \leftarrow \phi D_v$ + MPAC$_v$
SCALED AT $2^{29}/2^{27}$

$r(t_2) = |\underline{r}(t_2)|$
MPAC ← |MPAC$_v$|
SCALED AT $2^{29}/2^{27}$

(LAMENTER) THIS IS THE ENTRY POINT FROM THE LAMBERT ROUTINE, IN WHICH CASE $\underline{r}(t_2)$ IS NOT CALCULATED IN THIS ROUTINE.

NORMALIZE AND STORE $r(t_2)$
R2 ← MPAC
SCALED AT $2^{29-N1}/2^{27-N1}$

NORMALIZING VALUE IS −N1, STORED IN X1.

FORM $\underline{u}_{r1}\left[\frac{\sqrt{\mu}\, x}{r(t_2)}(\xi s(\xi) - 1)\right]$
6D$_v \leftarrow$ URI$_v\left[\frac{\text{ROOTMU} \cdot X}{\text{R2}}(\text{XI} \cdot \text{S(XI)} - \text{D1/128})\right]$
SCALED AT $2^{15}/2^{13}$

FORM $\underline{v}(t_1)\left[1 - \frac{x^2 c(\xi)}{r(t_2)}\right]$
MPAC$_v \leftarrow$ VVEC$_v\left[\text{D1/256} - \frac{\text{XSQC(XI)}}{\text{R2}}\right]$
SCALED AT $2^{15}/2^{13}$

$\underline{v}(t_2) = \underline{u}_{r1}\left[\frac{\sqrt{\mu}\, x}{r(t_2)}(\xi s(\xi) - 1)\right] + \underline{v}(t_1)\left[1 - \frac{x^2 c(\xi)}{r(t_2)}\right]$
MPAC$_v \leftarrow$ 6D$_v$ + MPAC$_v$
SCALED AT $2^7/2^5$

QPRET
$\underline{r}(t_2), \underline{v}(t_2)$

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN	3 APR 68	CONIC SUBROUTINES (NEWSTATE)
PROGMR		
ANALYST Wm. M. Robertson	31 JUL 68	COLOSSUS II A — DOCUMENT NO. FC2310
DOCMR		
APPR'D	5 AUG 68	REV — SHEET 35 OF 48

THE ITERATOR SUBROUTINE GENERATES BY LINEAR INTERPOLATION AN INCREMENT Δz IN THE INDEPENDENT VARIABLE z, THUS PROVIDING A NEW ESTIMATE OF z TO PRODUCE A VALUE OF THE DEPENDENT VALUE y CLOSER TO THE DESIRED VALUE y_{final}.

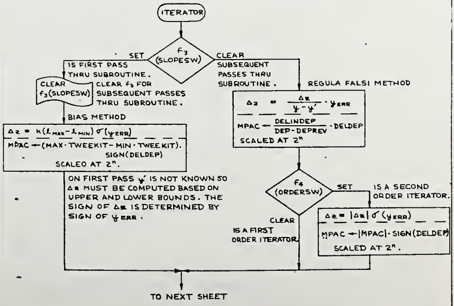
CALLED BY: LAMBERT, P1Ø AND P11.

INPUT:

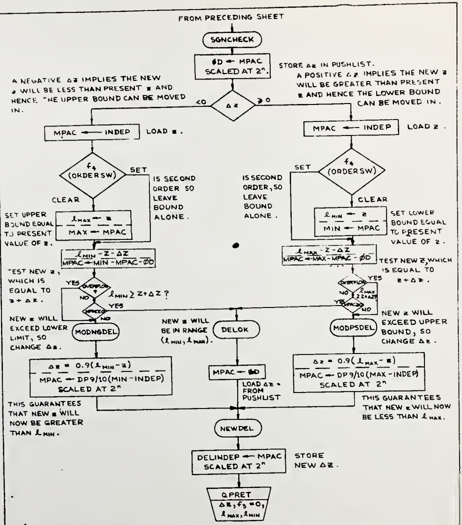
1) ORDERSW = f_4, A FLAG, IF CLEAR SUBROUTINE ACTS AS A FIRST ORDER ITERATOR, IF SET ACTS AS SECOND ORDER ITERATOR.
2) SLOPESW = f_3, A FLAG, IF SET IS FIRST PASS THRU AND MUST USE BIAS METHOD TO CALCULATE Δz, IF CLEAR IS SUBSEQUENT PASS AND CAN USE THE REGULA FALSI METHOD TO CALCULATE Δz.
3) DEP = y, PRESENT VALUE OF DEPENDENT VARIABLE, AT 2^m
4) DEPREV = y', PREVIOUS VALUE OF y, AT 2^m
5) DELDEP = y_{ERR}, ERROR IN y, EQUAL TO $y_{FINAL} - y$, AT 2^m.
6) DELINDEP = Δz, INCREMENT IN INDEPENDENT VARIABLE THAT PRODUCED THE PREVIOUS INCREMENT $y - y'$, AT 2^n.
7) INDEP = z, PRESENT VALUE OF INDEPENDENT VARIABLE, AT 2^n.
8) TWEEKIT = K, A FRACTION BETWEEN 0 AND 1, DETERMINES MAGNITUDE OF Δz ON FIRST PASS THROUGH SUBROUTINE, AT 2^0.
9) MAX = ℓ_{MAX}, PRESTABLISHED UPPER BOUND ON z, AT 2^7.
10) MIN = ℓ_{MIN}, PRESTABLISHED LOWER BOUND ON z, AT 2^7.
11) PUSH LIST POINTER MUST BE AT ØD.

OUTPUT:

1) DELINDEP = MPAC = Δz, A NEW INCREMENT IN z SUCH THAT THE NEW VALUE OF z, EQUAL TO $z + \Delta z$, WILL PRODUCE AN ERROR y_{ERR} OF SMALLER MAGNITUDE, AT 2^n.
2) SLOPESW = f_3, A FLAG, IS CLEARED BY SUBROUTINE ON THE FIRST PASS FOR SUBSEQUENT PASSES.
3) MAX = ℓ_{MAX}, IF f_4 IS CLEAR A NEW UPPER BOUND MAY BE ESTABLISHED BY THE SUBROUTINE, AT 2^n.
4) MIN = ℓ_{MIN}, IF f_4 IS CLEAR A NEW LOWER BOUND MAY BE ESTABLISHED BY THE SUBROUTINE, AT 2^n.
5) PUSH LIST POINTER IS AT ØD.



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN	F. Pepper	CONIC SUBROUTINES (ITERATOR)
PRGMR		
ANALST	Wm. M. Robertson	DOCUMENT NO. FC 2310
DOCMR	G. A. Cloud	COLOSSUS 2A
APPRO	John A. Moss, 5 AUG 68	REV — SHEET 38 OF 48



THE ITERATOR SUBROUTINE IS DESIGNED TO BE CALLED ONCE ON EACH PASS THROUGH A LOOP THAT IS ATTEMPTING TO CONVERGE ON A SOLUTION TO AN EQUATION OF THE FORM $y = y(z)$, WHERE A VALUE OF THE DEPENDENT VARIABLE y (CALLED y_{FINAL}) IS GIVEN AND THE PROGRAM IS SOLVING FOR THE CORRESPONDING VALUE OF THE INDEPENDENT VARIABLE z. EACH CALL TO THE ITERATOR GENERATES AN INCREMENT Δz WHICH IS A LINEAR APPROXIMATION ANSWER TO THE QUESTION: IF A CHANGE IN z EQUAL TO Δz_{i-1} PRODUCED A CHANGE IN y EQUAL TO $y_i - y_{i-1}$, THEN WHAT CHANGE IN z WILL NOW PRODUCE A CHANGE IN y EQUAL TO $y_{FINAL} - y_i$? THIS NEW CHANGE IN z IS CALLED Δz_i AND THE VALUES y_i, y_{i-1} ARE THE PRESENT AND PREVIOUS VALUES OF y, RESPECTIVELY. THE RELATIONSHIP CAN BE EXPRESSED AS:

$$\frac{\Delta z_{i-1}}{y_i - y_{i-1}} = \frac{\Delta z_i}{y_{FINAL} - y_i} \text{ , OR AS } \Delta z_i = \frac{\Delta z_{i-1}}{y_i - y_{i-1}} \cdot (y_{FINAL} - y_i) \text{ .}$$

HENCE ADDING Δz_i TO z_i SHOULD NULL OUT THE ERROR BETWEEN y_{FINAL} AND y_i, IMPLYING THAT $z_{i+1} = z_i + \Delta z_i$ IS THE SOLUTION TO THE EQUATION. A NECESSARY CONDITION FOR CONVERGENCE IS THAT y MUST BE MONOTONICALLY INCREASING (OR DECREASING) THROUGHOUT THE RANGE (ℓ_{MIN}, ℓ_{MAX}) OF THE INDEPENDENT VARIABLE. REFER TO REFERENCE 7.

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DRAWN [illegible]	CONIC SUBROUTINES (ITERATOR)
ANALYST [illegible] M. Robertson	DOCUMENT NO. FC 2310
CHECKED L. A. Clark	
APPROVED John A. Moore	SHEET 37 OF 42

THIS ROUTINE CALCULATES THE RADIUS OF PERICENTER, RADIUS OF APOCENTER AND ECCENTRICITY OF A GIVEN CONIC.

CALLED BY: PERIAPO

INPUT:

1) $RVEC_v = \underline{r}(t_1)$, THE INITIAL POSITION VECTOR, IN METERS, AT $2^{29}/2^{27}$.
2) $VVEC_v = \underline{v}(t_1)$, THE INITIAL VELOCITY VECTOR, IN METERS/CSEC, AT $2^7/2^5$.
3) X1 = INDEX VALUE USED TO SET UP THE PROPER μ - TABLE; IS -2 IF EARTH IS CENTRAL BODY; IS -10D IF MOON IS CENTRAL BODY.

OUTPUT:

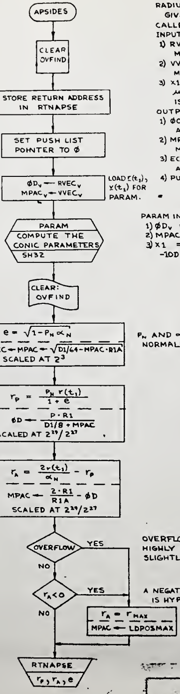
1) $\phi 0 = r_P$, THE RADIUS OF PERICENTER, IN METERS, AT $2^{29}/2^{27}$.
2) MPAC = r_A, THE RADIUS OF APOCENTER, IN METERS AT $2^{29}/2^{27}$.
3) ECC = e, THE ECCENTRICITY OF CONIC TRAJECTORY, AT 2^3.
4) PUSH LIST POINTER AT ϕD.

PARAM INPUT:

1) $\phi D_v = \underline{r}(t_1)$
2) $MPAC_v = \underline{v}(t_1)$
3) X1 = -2 FOR EARTH, -10D FOR MOON

PARAM OUTPUT:

1) R1A = α_N
2) P = MPAC = P_N
3) COGA = cot γ
4) R1 = $r(t_1)$
5) μ - TABLE



P_N AND α_N ARE NORMALIZED VALUES.

OVERFLOW OCCURS IF TRAJECTORY IS HIGHLY ELLIPTIC, PARABOLIC, OR SLIGHTLY HYPERBOLIC.

A NEGATIVE VALUE IMPLIES TRAJECTORY IS HYPERBOLIC.

SET RADIUS OF APOCENTER EQUAL TO r_{MAX}, THE LARGEST VALUE POSSIBLE,

WHERE $r_{MAX} = \begin{cases} 2^{29}-2 \text{ FOR THE EARTH.} \\ 2^{27}-.5 \text{ FOR THE MOON.} \end{cases}$

GENERAL INFORMATION FOR CONICS

SUBROUTINES CALLED ON OTHER CHARTS

NAME	DESCRIPTION	CALLED BY
POLY	EVALUATE A POLYNOMIAL OF SPECIFIED DEGREE	DELTIME, GETX
TPMODE	SET MODE TO TRIPLE PRECISION	DELTIME

FLAGS USED

NAME	MEANING		WHERE SET	WHERE CLEARED	WHERE TESTED
	SET	CLEAR			
GUESSW (f_1)	INITIAL GUESS OF cot γ NOT AVAILABLE	INITIAL GUESS OF cot γ IS AVAILABLE	INITVEL	INITVEL	LAMBERT
NORMSW (f_2)	μ_N IS INPUT TO LAMBERT	μ_N IS COMPUTED BY LAMBERT	INITVEL	PARAM, INITVEL	GEOM, S40.1 S40.9
SLOPESW (f_3)	INITIAL CALL TO ITERATOR	SUBSEQUENT CALL TO ITERATOR	LAMBERT, P10	ITERATOR	ITERATOR
ORDERSW (f_4)	SECOND ORDER ITERATION	FIRST ORDER ITERATION	(NO WHERE)	P10	ITERATOR (3)
SOLNSW (f_5)	NO SOLN POSSIBLE	SOLN VALID	LAMBERT (2)	LAMBERT, TIMERAD	(NO WHERE)
RVSW (f_6)	DO NOT COMPUTE NEW STATE VECTOR	COMPUTE NEW STATE VECTOR	P39, P34, CSI/A (2)	CDHMVR	TIMETHET
INFINFLG (f_7)	CONIC PASSES THRU INFINITY	CONIC SOLN EXISTS	GETX	GETX	LAMBERT, TIMETHET
APSESW (f_8)	POSITION VECTOR OUTSIDE RANGE (PERICENTER, APOCENTER)	POSITION VECTOR WITHIN RANGE (PERICENTER, APOCENTER)	TIMERAD	TIMERAD	(NO WHERE)
360SW (f_ω)	TRANSFER ANGLE NEAR 360°	TRANSFER ANGLE NOT NEAR 360°	GETX	GETX	GETX
COGAFLAG (f_γ)	NO SOLN EXISTS, TOO CLOSE TO RECTILINEAR	SOLN EXISTS	TIMETHET	TIMETHET, PARAM	(NO WHERE)
VTARGTAG$_s$	$\underline{v}(t_2)$ NOT CALCULATED	$\underline{v}(t_2)$ IS CALCULATED	INITVEL	INITVEL	LAMBERT, INITVEL (2)
GEOMSGN$_s$ (s_G)	IS MINUS IF TRANSFER ANGLE > 180°	IS PLUS IF TRANSFER ANGLE ≤ 180°	INITVEL	INITVEL, PARAM	LAMBERT, GEOM (3)
SGNRDOT$_s$ ($s_{\dot{r}}$)	IS MINUS IF RADIAL VELOCITY NEGATIVE	IS PLUS IF RADIAL VELOCITY POSITIVE	(NO WHERE)	(NO WHERE)	TIMERAD

VARIABLES USED (BOTH PUSH LIST AND ERASABLE)

NAME	MEANING	SCALING	LOCATION
ALPHA	RECIPROCAL OF SEMI-MAJOR AXIS	$2^{-22}/2^{-20}$	8D
MIN	LOWER BOUND ON z	2^n	8D
COGAMIN	LOWER BOUND ON cot γ	2^5	8D
XMAX	MAXIMUM VALUE OF x	$2^{17}/2^{16}$	10D
XMIN	MINIMUM VALUE OF x	$2^{17}/2^{16}$	12D
DELINDEP	Δz	2^n	12D
DCOGA	Δcot γ	2^5	12D
MAX	UPPER BOUND ON z	2^n	14D
COGAMAX	UPPER BOUND ON cot γ	2^5	14D
I/MU	$1/\mu$	$2^{-34}/2^{-28}$	14D
ROOTMU	$\sqrt{\mu}$	$2^{18}/2^{15}$	16D

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PRGMR
ANALST Wm. M. Robertson 31 JUL 68
DOCMR C. A. Black 11 JUL 68
APPR'D John A. Morse 5 AUG 68

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CONIC SUBROUTINES

COLOSSUS IIA

DOCUMENT NO. FC-2310

REV

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VARIABLES USED (BOTH PUSH LIST AND ERASABLE)(CONT.)

NAME	MEANING	SCALING	LOCATION
[illegible]	$1/\sqrt{\mu}$	$2^{-17}/2^{14}$	18D
X	UNIVERSAL VARIABLE x	$2^{17}/2^{16}$	20D
$ITERCTR_s$	ITERATION COUNTER	2^{14}	22D
COSF	cos (f)	2^1	24D
XI	αx^2	2^6	24D
S (XI)	s (ξ)	2^1	26D
XSQC (XI)	$x^2 c$ (ξ)	$2^{33}/2^{31}$	28D
[illegible]	PRESENT VALUE OF x	2^m	30D
[illegible]	TRANSFER TIME, CSEC	2^{28}	30D
[illegible]	MAGNITUDE OF POSITION VECTOR, METERS	$2^{29}/2^{27}$	32D
[illegible]NORM	NORMALIZED VECTOR MAGNITUDE, METERS	$2^{29-m}/2^{27-m}$	34D
KEPC1	c_1	$2^{17}/2^{16}$	34D
KEPC2	c_2	2^6	36D
TWEEKIT	k, FRACTION BETWEEN 0 AND 1	2^0	40D
$RRECT_v$	r (t), POSITION VECTOR, METERS	$2^{29}/2^{27}$	E3, 1502
$VRECT_v$	v (t), VELOCITY VECTOR, METERS/CSEC	$2^7/2^5$	E3, 1510
RCV_v	r (t), POSITION VECTOR, METERS	$2^{29}/2^{27}$	E3, 1534
VCV_v	v (t), VELOCITY VECTOR, METERS/CSEC	$2^7/2^5$	E3, 1542
TC	PREVIOUS VALUE OF TIME, CSEC	2^{28}	E3, 1550
XPREV	PREVIOUS VALUE OF x	$2^{17}/2^{16}$	E3, 1552
TAU.	DESIRED TRANSFER TIME, CSEC	2^{28}	E4, 1475
$KEPRTN_s$	RETURN ADDRESS FROM KEPLER		E4, 1514
XKEPNEW	GUESS OF VARIABLE x	$2^{17}/2^{16}$	E4, 1531
			.
			.
EPSILONT	CONVERGENCE CRITERION, CSEC	2^{28}	E4, 1604
DELX	Δx	$2^{17}/2^{16}$	E5, 1642
DELT	t_{ERR}, CSEC	2^{28}	E5, 1644
$URRECT_v$	UNIT VECTOR	2^1	E5, 1646
$R1VEC_v$	r (t), POSITION VECTOR, METERS	$2^{29}/2^{27}$	E5, 1654
$RVEC_v$	r (t), POSITION VECTOR, METERS	$2^{29}/2^{27}$	E5, 1654
$R2VEC_v$	r (t), POSITION VECTOR, METERS	$2^{29}/2^{27}$	E5, 1662
TDESIRED	DESIRED TRANSFER TIME, CSEC	2^{28}	E5, 1670
$GEOMSGN_s$	s_G, A FLAG	2^0	E5, 1672
UN_v	u_N, UNIT NORMAL VECTOR	2^1	E5, 1673
$VTARGTAG_s$	n_1, A FLAG	2^0	E5, 1701
$VTARGET_v$	TARGET VELOCITY VECTOR, METERS/CSEC	$2^7/2^5$	E5, 1702
$RTNLAMB_s$	RETURN ADDRESS FROM LAMBERT		E5, 1710
$RTNTT_s$	RETURN ADDRESS FROM TIMETHET		E5, 1710

VARIABLES USED (BOTH PUSH LIST AND ERASABLE) (CONT.)

NAME	MEANING	SCALING	LOCATION
$RTNTR_S$	RETURN ADDRESS FROM TIMERAD		E5, 1710
$RTNAPSE_S$	RETURN ADDRESS FROM APSIDES		E5, 1710
$U2_V$	UNIT VECTOR	2^1	E5, 1711
MAGVEC2	VECTOR MAGNITUDE, METERS/CSEC	$2^7/2^5$	E5, 1717
R2	NORMALIZED VECTOR MAGNITUDE, METERS/CSEC	$2^{29-m}/2^{27-m}$	E5, 1717
$UR1_V$	UNIT VECTOR	2^1	E5, 1721
SNTH	sin (φ)	2^1	E5, 1727
CSTH	cos (φ)	2^1	E5, 1731
1-CSTH	1 cos (φ)	2^2	E5, 1733
CSTH-RHO	cos (θ) - λ	2^7	E5, 1735
P	$p_N = p/r_1$	2^4	E5, 1737
R1A	$\rho_N = r_1/a$	2^6	E5, 1741
$VVEC_V$	VELOCITY VECTOR, METERS/CSEC	$2^7/2^5$	E5, 1743
ECC	ECCENTRICITY	2^3	E5, 1751
$RTNPRM_S$	RETURN ADDRESS FROM PARAM		E5, 1753
$SGNRDOT_S$	s_r, SIGN OF RADIAL VELOCITY	2^0	E5, 1754
RDESIRED	RADIAL DISTANCE, METERS	$2^{29}, 2^{27}$	E5, 1755
DELDEP	y_{ERR}	2^m	E5, 1757
TERRLAMB	CONVERGENCE CRITERION, CSEC	2^{28}	E5, 1757
DEPREV	PREVIOUS VALUE OF y	2^m	E5, 1761
TPREV	PREVIOUS TIME, CSEC	2^{28}	E5, 1761
EPSILONL	CONVERGENCE CRITERION, CSEC	2^{28}	E5, 1763
COGA	cot γ	2^5	E5, 1765
INDEP	z	2^n	E5, 1765

CONSTANTS USED

NAME	PHYSICAL MEANING	SCALING	COMPUTER VALUE
DP1/4	1.0	2^2	1.0 B-2
DP1/8	1.0	2^3	1.0 B-3
DP1/16	1.0	2^4	1.0 B-4
DP1/32	2.0	2^6	1.0 B-5
DP1/64	1.0	2^6	1.0 B-6
DP1/128	1.0	2^7	1.0 B-7
DP1/256	1.0	2^8	1.0 B-8
DP1/1024	1.0	2^{10}	1.0 B-10
DP1/4	1.0	2^2	1.0 B-2
BEE19	$\epsilon_t = 2^{-19}$	2^0	0000001000_8
BEE22	$\epsilon_t = 2^{-22}$	2^0	0000000100_8
ONEBIT	2^{-28}	2^0	1.0 B-28
2PISC	2π	2^6	6.28318530 B-6
-50SC	-50.0	2^{12}	-50.0 B-12
DP9/10	0.9	2^0	0.9 B0
COGUPLIM	$\cot \gamma_{max} = 31.9843711$	2^5	0.999511597 B0
COGLOLIM	$\cot \gamma_{min} = -31.9843711$	2^5	-0.999511597 B0
MUTABLE +2	$1/\mu$	2^{-34}	$0.25087606 \times 10^{-10}$ B34
MUTABLE +4	$\sqrt{\mu_E}$	2^{18}	[illegible]650495 $\times 10^5$ B-18
MUTABLE +6	$1/\sqrt{\mu_E}$	2^{-17}	$0.50087529 \times 10^{-5}$ B17
MUTABLE +10D	$1/\mu_M$	2^{-28}	0.203966×10^{-8} B28
MUTABLE +12D	$\sqrt{\mu_M}$	2^{15}	2.21422176×10^4 B-15
MUTABLE +14D	$1/\sqrt{\mu_M}$	2^{-14}	$0.45162595 \times 10^{-4}$ B14
BEE17	$k_1 = 2^{-17}$	2^0	0000004000_8

DAP INTERFACE AND SERVICE ROUTINES

THE ENCLOSED SHEETS UPDATE THE COLOSSUS II FLOWCHART FC-2370, REV. 0, TO THE COLOSSUS IIA FLOWCHART FC-2370, REV. 1.

IN ADDITION, THE SHEETS HAVE BEEN RENUMBERED TO INCLUDE A TITLE SHEET.

EFFECTIVE SHEETS FOR COLOSSUS IIA FC-2370, REV. 1 ARE:

SH. 1	REV. 1
SH. 2-4	REV. 0
SH. 5	REV. 1
SH. 6-7	REV. 0
SH. 8	REV. 1
SH. 9-20	REV. 0

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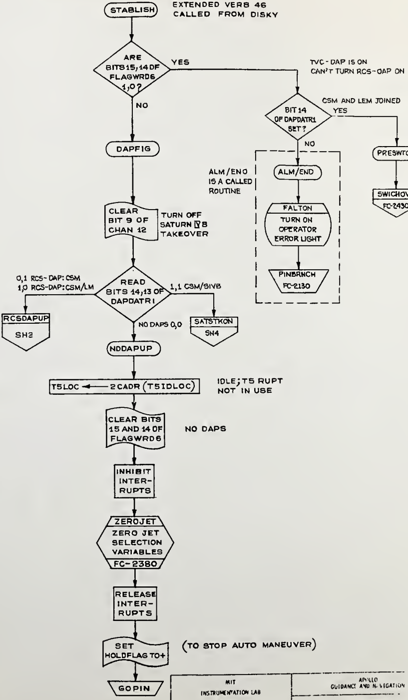
DRAWN [illegible]	[illegible]	DAP INTERFACE AND SERVICE ROUTINE	
PRGMR [illegible]	[illegible]	COLOSSUS II-A	DOCUMENT NO FC-2370
ANALST			
DOCMR [illegible]	[illegible]		
APPR'D [illegible]	[illegible]	REV 1	SHEET 1 OF 20

EXTENDED VERB 46: RCS DAP TURN-ON



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DRAWN [signature] 31DEC68
PRGMR [signature] 10APR69
ANALST
DOCMR [signature] 10APR69
APPR'D [signature] 10April69

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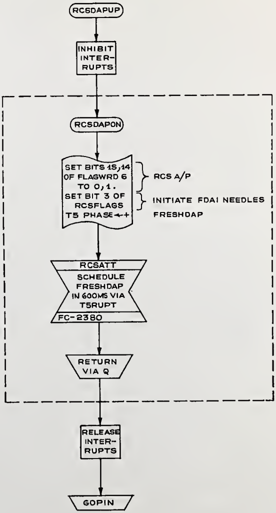
DAP INTERFACE AND SERVICE ROUTINES

COLOSSUS IIA

DOCUMENT NO. FC-2370

REV 1

SHEET 2 OF 20



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PRGMR	J.F. Turnbull	16 APR 69
ANALST		
DOCMR	W.A. Tomon	16 APR 69
APPR'D	John A. Moore	19 Apr 69

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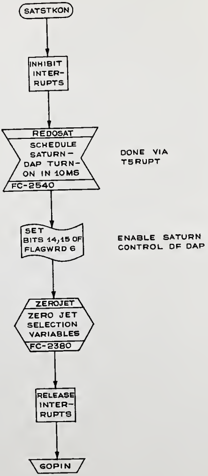
DAP INTERFACE AND SERVICE ROUTINES

COLOSSUS IIA — DOCUMENT NO. FC-2370

REV 1 — SHT 3 OF 20



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PRGMR J. F. Turnbull
ANALST
DOCMR
APPR'D John A. Moore

DAP INTERFACE AND SERVICE ROUTINES

COLOSSUS IIA

DOCUMENT NO. FC-2370

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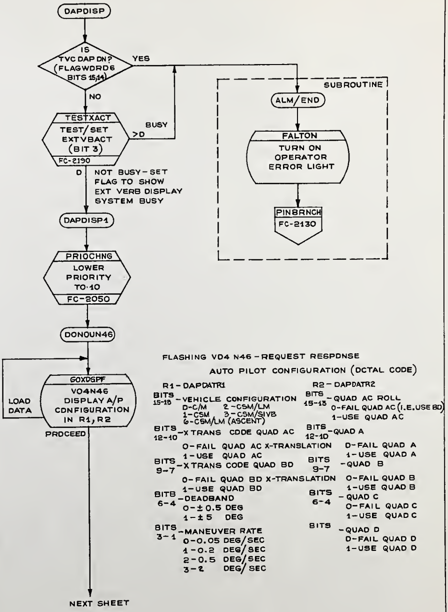
SHEET 4 OF 20

VERB 48 LOAD AUTO PILOT DATA



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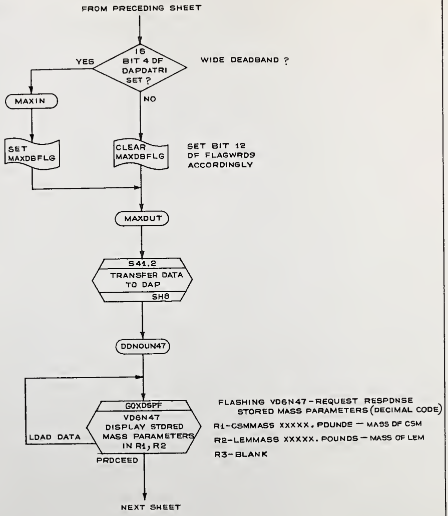
PRGMR J.F. Turnbull 10APR69	
ANALYST	
DOCMN M.A. Jonan 10APR69	COLOSSUS IIA FC-2370
APPR'D John A. Moore 10April 69	REV 1 SHEET 5 OF 20



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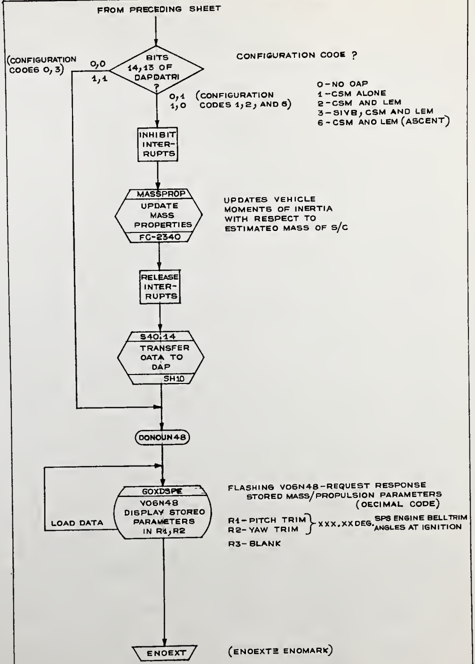
DRAWN 6JAN69 PRGMR ANALST DOCMR APPR'D	DAP INTERFACE AND SERVICE ROUTINES
	COLOSSUS IIA DOCUMENT NO. FC-2370
	REV 1 SHEET 6 OF 20



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DRAWN / PRGMR / ANALST / DOCAN / APPR'D (signatures) 6 JAN 69	OAP INTERFACE ANO SERVICE ROUTINES
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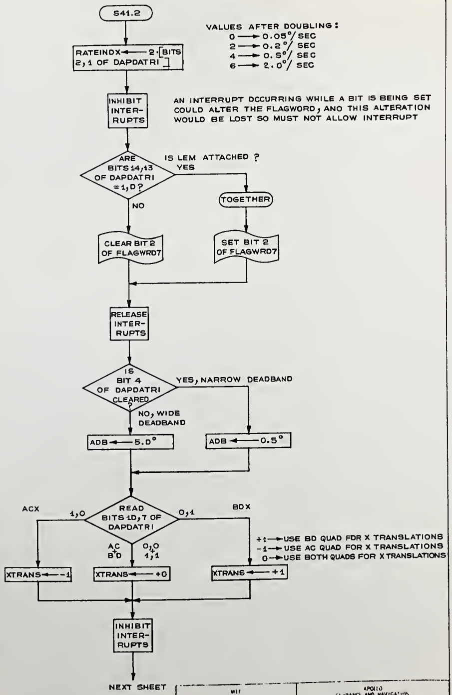
S41.2, S40.14 AND S40.15-DECODE DAP DATA NOUNS



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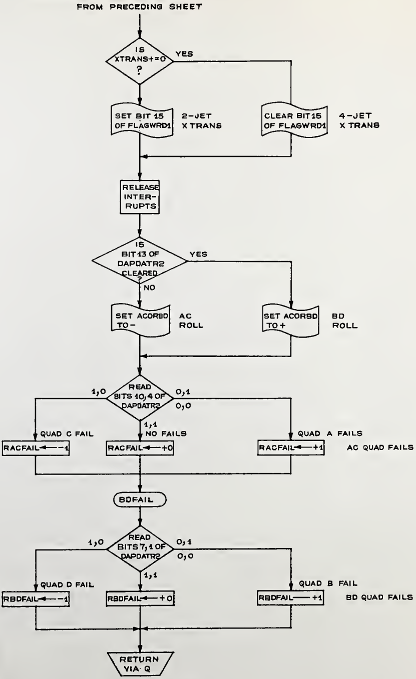
DRAWN 7 JAN 69	DAP INTERFACE AND SERVICE ROUTINES
PRGMR	
ANALYST	COLOSSUS IIA DOCUMENT NO. FC-2370
DOCMR	
APPR'D	R. 1 SHEET 8 OF 20



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DAP INTERFACE AND SERVICE ROUTINES

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ANALST		
DOCMR	G. Zimmon	10 APR 69
APPR'D	John A. Moore	10 Apr 69

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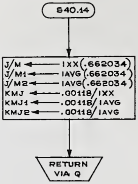
SHEET 9 OF 20



S/C INERTIA TO TORQUE RATIO-X AXIS
S/C INERTIA TO TORQUE RATIO-Y AXIS
S/C INERTIA TO TORQUE RATIO-Z AXIS
S/C TORQUE TO INERTIA RATIO-X AXIS
S/C TORQUE TO INERTIA RATIO-Y AXIS
S/C TORQUE TO INERTIA RATIO-Z AXIS

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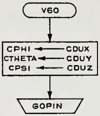
DOCMR	
APPR'D 10April69	REV 1 SHEET 10 OF 20

EXTENDED VERB 58 - ENABLE AUTOMATIC MANEUVERS

EXTENDED VERB 58 - RESET STIKFLAG
(ENABLE AUTOMATIC MANEUVERS)

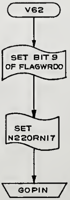
RESET FLAG SO THAT R61 MAY PERFORM AUTOMATIC TRACKING MANEUVERS AFTER INTERRUPT BY RHC ACTIVITY (STIKFLAG = FLAGWRD 1 BIT 14)

EXTENDED VERBS 60 - 63 DAP ERROR DISPLAY CONFIGURATION



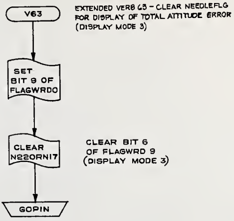
EXTENDED VERB 60 - SET ERROR NEEDLE REFERENCE ANGLES TO CURRENT CDU READINGS

EXTENDED VERB 61 - CLEAR NEEDLEFLG FOR DISPLAY OF A/P FOLLOWING ERROR (DISPLAY MODE 1)



EXTENDED VERB 62 - SET NEEDLEFLG FOR DISPLAY OF TOTAL ATTITUDE ERROR (DISPLAY MODE 2)

SET BIT 6 OF FLAGWRD9 (DISPLAY MODE 2)



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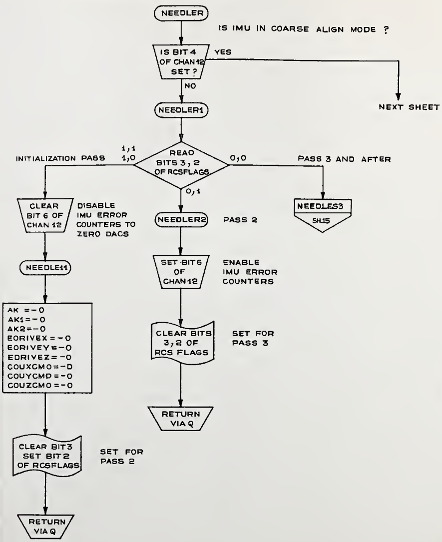
FDAI NEEDLE DRIVE ROUTINE



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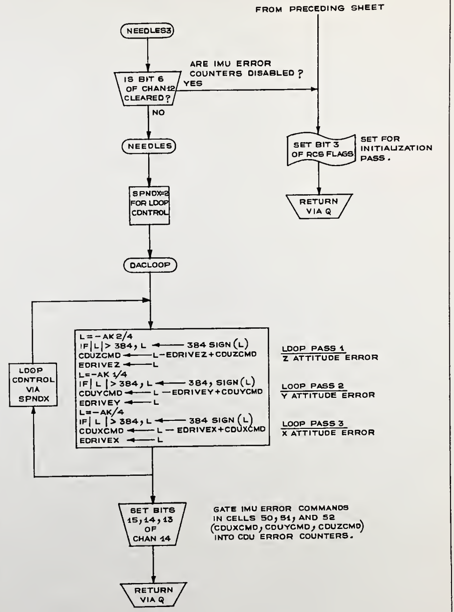
PRGMR 10APR69	DOC. NO.
ANAL	COLOSSUS IIA FC-2370
CHKD 10APR69	REV 1
APPROVED 10 April 69	SH 14 OF 20



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ANALYST
DOCMGR
APPR'D 16 April 69

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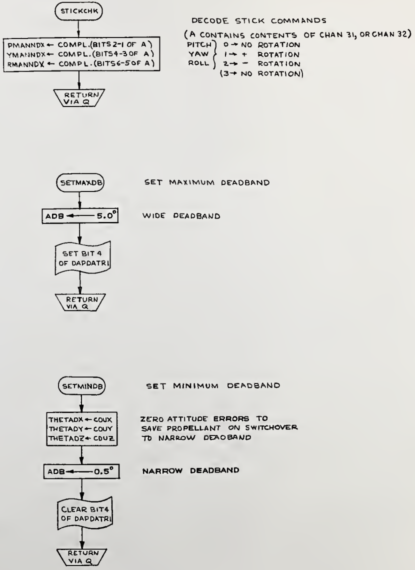
DAP INTERFACE AND SERVICE ROUTINES

COLOSSUS IIA FC-2370

REV 1

RCS - DAP SUBROUTINES



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DOCMR G. Tomon 10 APR 69
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DAP INTERFACE
AND SERVICE ROUTINES

COLOSSUS IIA
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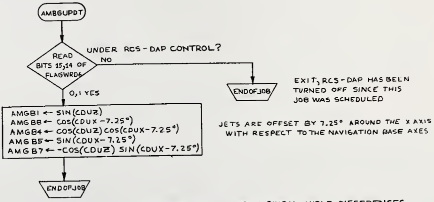
REV 1
SHEET 16 OF 20

MATRIX UPDATE SUBROUTINE

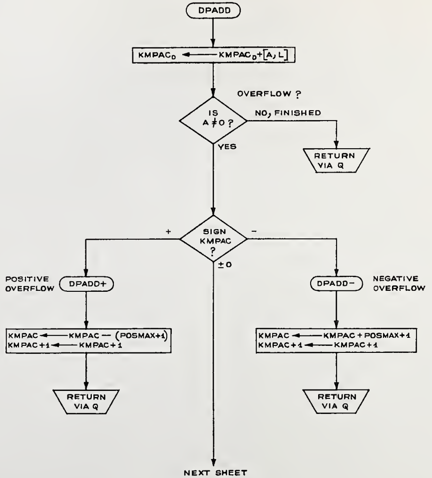


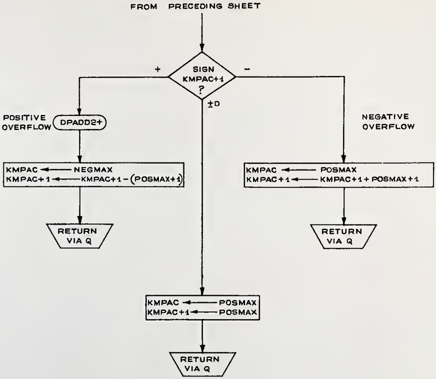
TRANSFORMATION MATRIX: GIMBAL ANGLE DIFFERENCES TO BODY ANGLE DIFFERENCES

$$\begin{pmatrix} 1 & \sin(CDUZ) & 0 \\ 0 & \cos(CDUZ)\cos(CDUX-7.25) & \sin(CDUX-7.25) \\ 0 & -\cos(CDUZ)\sin(CDUX-7.25) & \cos(CDUX-7.25) \end{pmatrix}$$

$$\overset{*}{MGB} = \begin{pmatrix} 1 & \sin\psi & 0 \\ 0 & \cos\psi\cos\phi & \sin\phi \\ 0 & -\cos\psi\sin\phi & \cos\phi \end{pmatrix}$$

MYSUBS ARITHMETIC SUBROUTINES





THE REAL VALUE OF THE ANGLE STORED IN KMPAC LIES ALWAYS BETWEEN ± 360°. THE STORAGE CAPACITY OF KMPAC, HOWEVER, IS BETWEEN ± 180°. IF POSITIVE OVERFLOW, THE REAL VALUE LIES BETWEEN + 180° AND +360°, WHILE THE STORED VALUE IS 180° SMALLER. HOWEVER, BY SUBTRACTING 180° (POSMAX + 1) FROM THIS STORED VALUE, IT BECOMES EQUIVALENT TO THE REAL VALUE (AS θ − 360° = θ) AND THIS DERIVED VALUE LIES BETWEEN 0° AND −180°, AND HENCE IS STORABLE. A SIMILAR LOGIC APPLIES TO NEGATIVE OVERFLOW. IN THE CASE WHERE BOTH KMPAC AND KMPAC+1 = ±0, THEN THE REAL ANGLE IS 180° (−= 180°) AND THE CLOSEST APROXIMATION IS DOUBLE PRECISION POSMAX.

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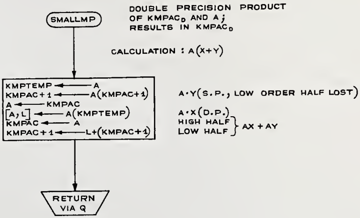
ANALYST	
DOCMR 10APR69	COLOSSUS IIA FC-2370
APPR'D John A. Miller 10Apr69	REV 1 SHEET 19 OF 20



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DOCMR 10APR69
APPR'D 10Apr69

APOLLO GUIDANCE AND NAVIGATION

DAP INTERFACE AND SERVICE ROUTINES

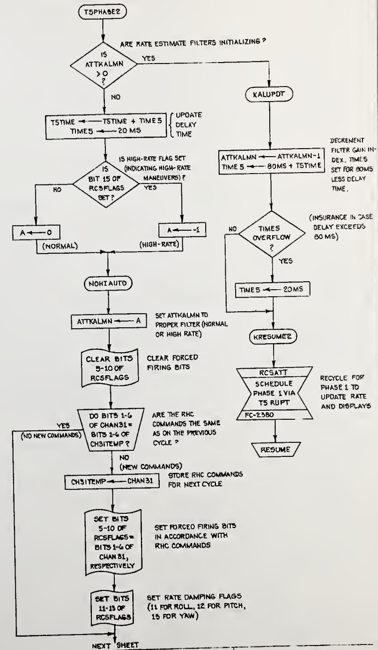
COLOSSUS IIA

DOCUMENT NO. FC-2370

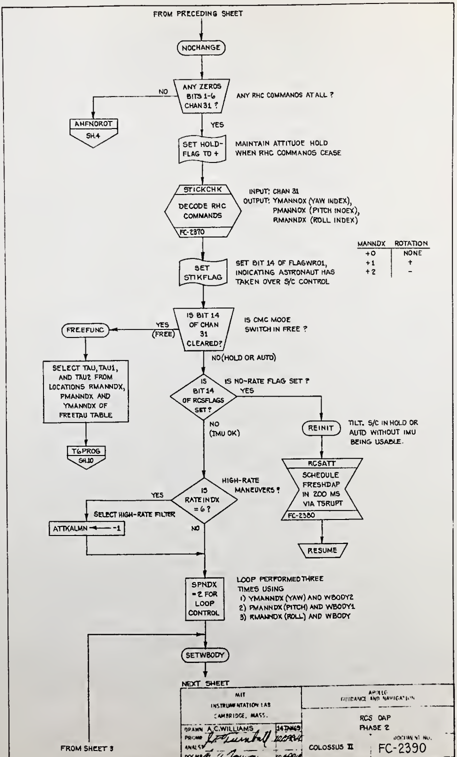
REV 1

SHEET 20 OF 20

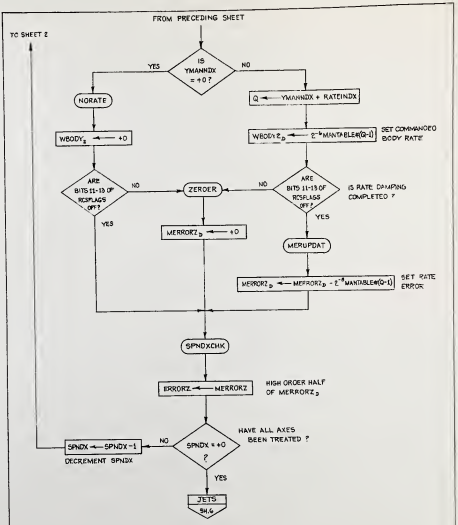
RCS-DAP PHASE 2



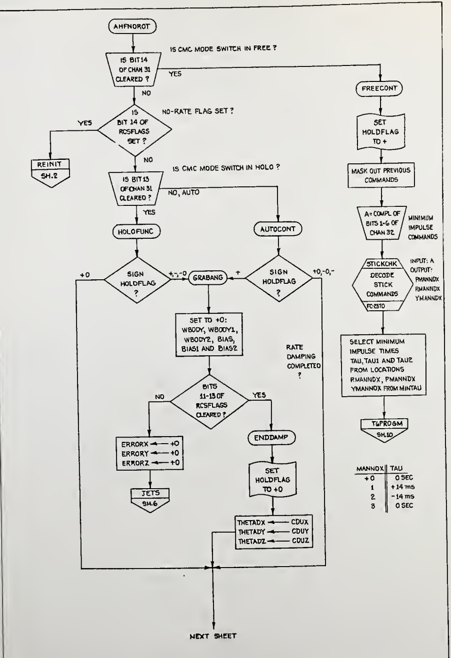
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 14 JAN 69	RCS DAP PHASE 2
PRGMR	COLOSSUS II
ANALST	DOCUMENT NO FC-2390
DOCMR	
APPR'D	REV SHT 1 OF 10



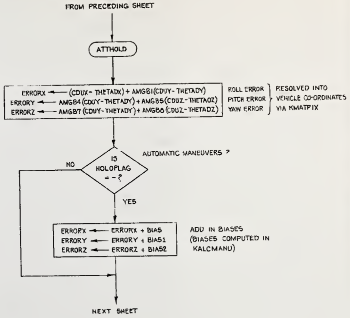
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 14 JAN 69	RCS DAP PHASE 2
PRGMR J. Turnbull	DOCUMENT NO.
ANALST	COLOSSUS II — FC-2390
DOC MGR	
APPR'D John A. Moore 10 April 69	REV — SHEET 2 OF 10



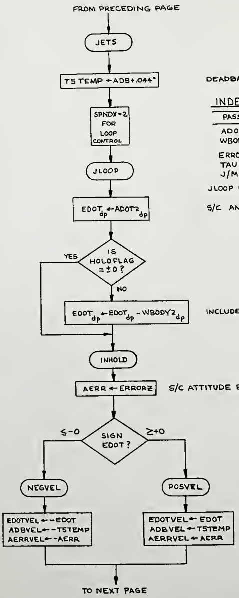
MIT INSTRUMENTATION LAB CAMBRIDGE MASS	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 15JAN65	RCS DAP PHASE 2
PRGMR J. Turnbull 10APR69	
ANA: ST	COLOSSUS II FC-2390
DOCMR M. G. Kanzer 10APR69	
APPR'D John A. Moore 10 April 69	REV 3 10



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 15JAN69	RCS DAP PHASE 2
PRGMR J. Turnbull	COLOSSUS II
ANALYST	DOCUMENT NO. FC-2390
DOCMR R. G. Zeman	SHEET 4 of 10
APPR'D John A. Moore 10Apr1969	



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C. WILLIAMS 15JAN69	RCS DAP PHASE 2
PROGMR J. F. Turnbull 10APR69	
ANALYST	COLOSSUS II
DESIGNER 10APR69	FC-2390
APPR'D John A. Morse 10 April 69	5 10



DEADBAND + FLAT REGION

INDEXED VARIABLES IN JLOOP

PASS 1	PASS 2	PASS 3
$ADOT2_{dp}$	$ADOT1_{dp}$	$ADOT_{dp}$
$WBODY2_{dp}$	$WBODY1_{dp}$	$WBODY_{dp}$
ERRORZ	ERRORY	ERRORX
TAU2	TAU1	TAU
J/M2	J/M1	J/M

JLOOP IS EXECUTED ONCE FOR EACH AXIS

S/C ANGULAR RATE (ESTIMATE)

INCLUDE AUTOMATIC MANEUVER RATES

S/C ATTITUDE ERROR

SINCE THE PHASE PLANE IS SYMMETRIC ABOUT THE ORIGIN, THE RATE IS TAKEN AS POSITIVE AND THE SIGNS OF EDOT, T5TEMP AND AERR ADJUSTED ACCORDINGLY. THE SUFFIX "VEL" IN THE MNEMONIC DESIGNATES THE ADJUSTED VALUES.

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

DRAWN [signature] 8-25-67
PROGRAMMER [signature] 10-16-67
DOCMN [signature] 10-16-67
APPR'D [signature] 10-18-67

APOLLO GUIDANCE AND NAVIGATION

RCS DAP PHASE 2

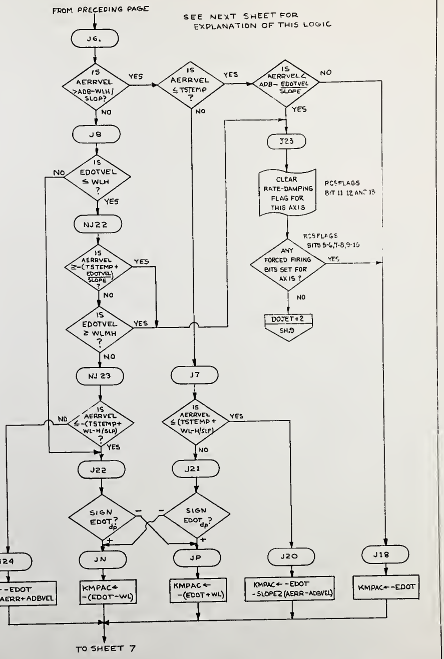
COLOSSUS II

DOCUMENT NO. FC2390

USED ON

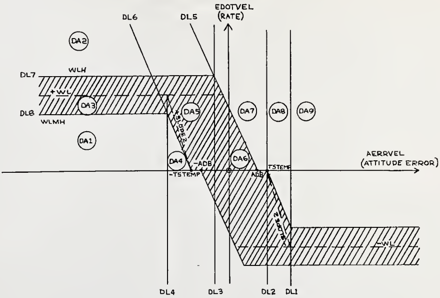
REV

SHEET 6 OF 10



	MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
			RCS DAP PHASE 2
	DRAWN F. Pearson J.	9-25-67	
	PROGR D. W. Keene	10-16-67	COLOSSUS II — DOCUMENT NO. FC 2390
	DOCMR J. A. Moore	10-16-67	
USED ON	APPR'D J. J. Heinz	10-18-67	REV — SHEET 7 OF 10

PHASE PLANE LOGIC



DECISION LOGIC

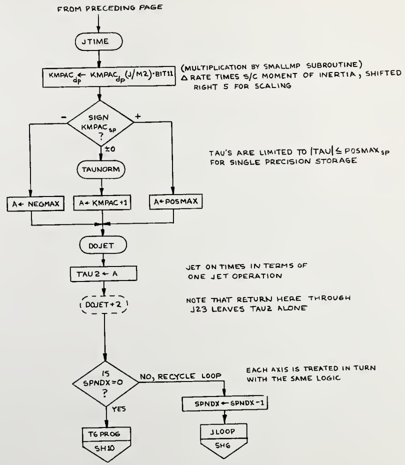
DECISION LINE (DL) ON GRAPH	1	2	3	4	5	6	7	8
DECISION POINT IN LOGIC	J7	J6+1	J6	NJ23	J6+2	NJ22	J8	NJ22+1
OUTCOME { LOGICAL "YES"	LEFT	LEFT	RIGHT	LEFT	LEFT	RIGHT	BELOW	ABOVE
OUTCOME { LOGICAL "NO"	RIGHT	RIGHT	LEFT	RIGHT	RIGHT	LEFT	ABOVE	BELOW

LOGICAL PATHS

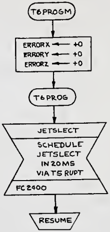
DECISION AREA (DA)	LOGICAL PATHS	RESPONSE
DA 1	J6. – J8 – NJ22 – NJ22 + 1 – NJ23 – J22 →	DRIVE RATE TO +WL
DA 2	J6. – J8 – J22 →	DRIVE RATE TO +WL
DA 3	J6. – J8 – NJ22 – NJ22 + 1 – J23 →	NO ACTION*
DA 4	J6. – J8 – NJ22 – NJ22 + 1 – NJ23 – J24 →	DRIVE RATE TO + SLOPE 2
DA 5	J6. – J8 – NJ22 – J23 →	NO ACTION*
DA 6	J6. – J6+1 – J6+2 – J23 →	NO ACTION*
DA 7	J6. – J6+1 – J6+2 – J18 →	DRIVE RATE TO ZERO
DA 8	J6. – J6+1 – J7 – J20 →	DRIVE RATE TO – SLOPE 2
DA 9	J6. – J6+1 – J7 – J21 →	DRIVE RATE TO – WL

* IF THERE ARE ANY RHC COMMANDS, THEN THE RATE IS DRIVEN TO ZERO BEFORE EXECUTION OF THE COMMANDS.

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN [signature]	8-29-67	RCS DAP PHASE 2
PROGR. D. W. Keene	10-16-67	
DOCMR J. A. Morse	10-16-67	COLOSSUS II — DOCUMENT NO. FC2390
USED ON — APP'D J. J. Hoag	10-18-67	REV — SHEET 8 OF 30

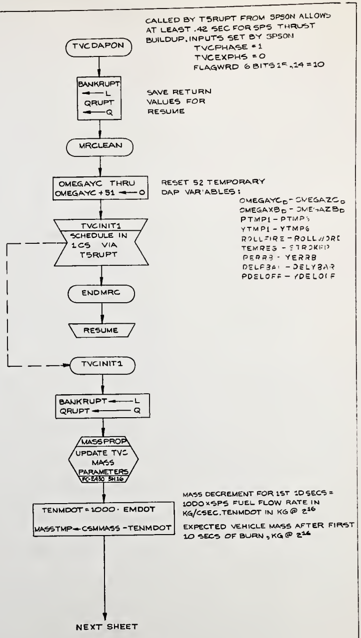


	MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
		RCS DAP PHASE 2
	DRAWN F. Peters 8-28-67	
	PROGR J. W. Kuhne 10-16-67	DOCUMENT NO.
	DOCMR J. A. Moore 10-16-67	COLOSSUS II FC2390
USED ON	APPR'D J. Henize 10-18-67	REV SHEET 9 OF 10



ZERO ATTITUDE ERROR IF IN FREE MODE, OR IF MANUAL COMMANDS ARE BEING RECOGNIZED

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN / PROGR / DOCMA / APPR	RCS DAP PHASE-2	
USED ON	COLOSSUS II	DOCUMENT NO. FC2390
	REV	SHEET 10 OF 10



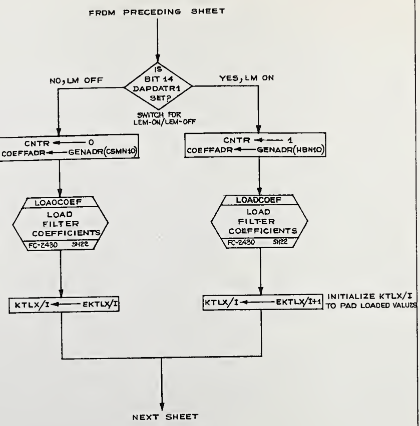
INSTRUMENTATION LAB
CAMBRIDGE, MA

TVC START-UP AND EXECUTIVE ROUTINES

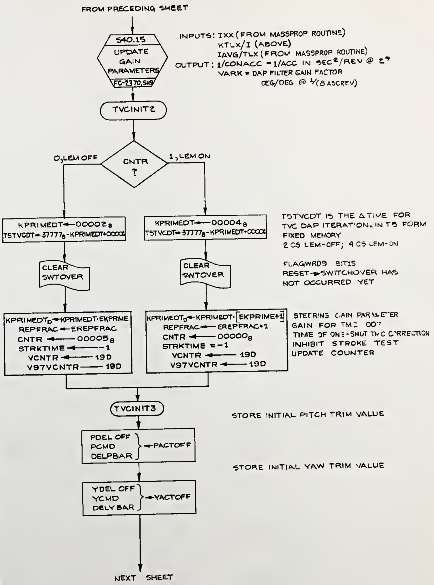
DRAWN Z. J. Chmielinski
PRGMR
ANALYST R. F. Sellundi 4/9/69
DOCMR
APPR'D John A. Miller 9 April 69

COLOSSUS IIA FC-2430

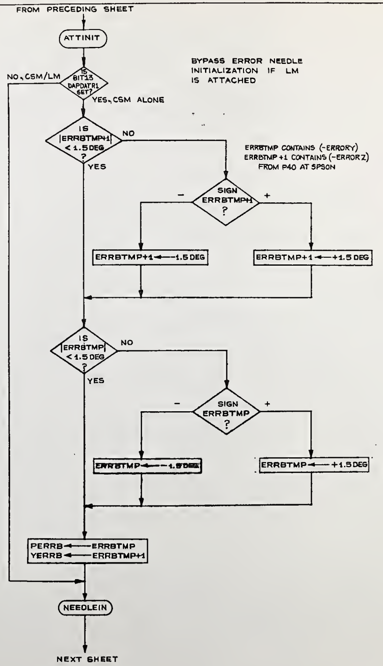
SHEET 1 22



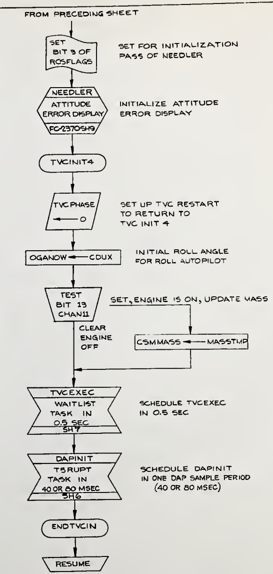
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN D.M. Dietrich 27 FEB69	TVC START-UP AND EXECUTIVE ROUTINES
PRGMR	
ANALYST R.A. Schlundt 4/4/69	COLOSSUS IIA DOCUMENT NO. FC-2430
DOCMR	
APPR'D John A. Moore 9 Apr 69	REV SHEET 2 OF 22



MIT INSTRUMENTATION LAB CAMBRIDGE MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN D.S. Chmielinski (signature)	TVC START-UP AND EXECUTIVE ROUTINES
PRGMR	
ANALYST R.A. Schlundt (signature) 4/4/69	COLOSSUS IIA FC-2430
DOCMR	
APPR'D John A. Mons (signature) 9 April 69	SH 3 OF 22



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN D.M. Dietz 28 FEB 69	TVC START-UP AND EXECUTIVE ROUTINES
PRGMR	
ANALST K. Goldblatt 4/9/69	COLOSSUS IIA — DOCUMENT NO. FC-2430
DOCMR	
APPR'D John A. Rowe 9 Apr 69	REV — SHEET 4 OF 22



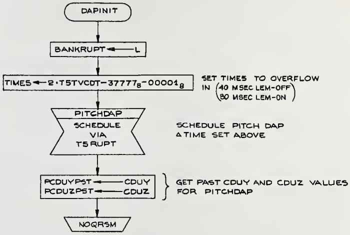
MIT INSTRUMENTATION LAB CAMBRIDGE MA

DRAWN Z. S. Chmielinski 20 NOV 68
PRGMR
ANALST R. F. Schlundt 4/4/69
DOCMR
APPR'D John A. Morse 9 April 69

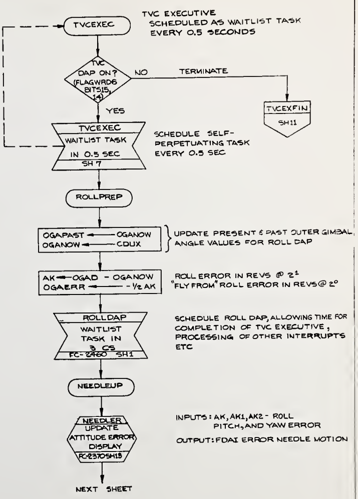
TVC START-UP AND EXECUTIVE ROUTINES

COLOSSUS IIA FC-2430

SHEET 5 22



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN [signature] 21NOV68	TVC START-UP AND EXECUTIVE ROUTINES
PRGMR	
ANALST [signature] 4/9/69	COLOSSUS IIA — DOCUMENT NO. FC-2430
DOCMR	
APPR'D John A. Morse 9 April 69	REV — SHEET 6 OF 22



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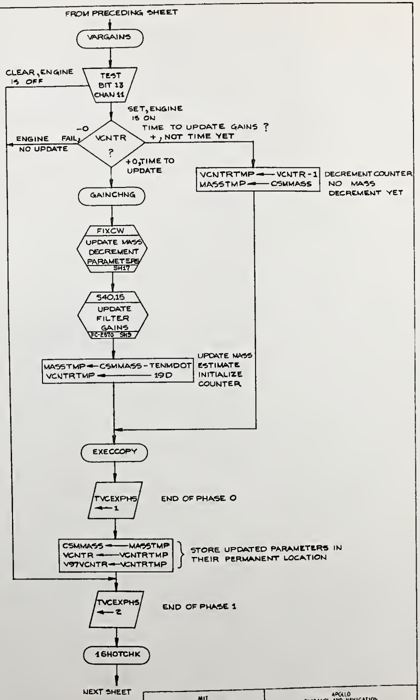
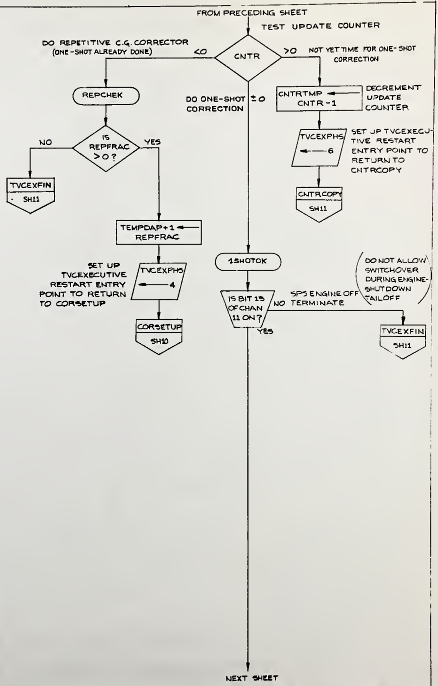
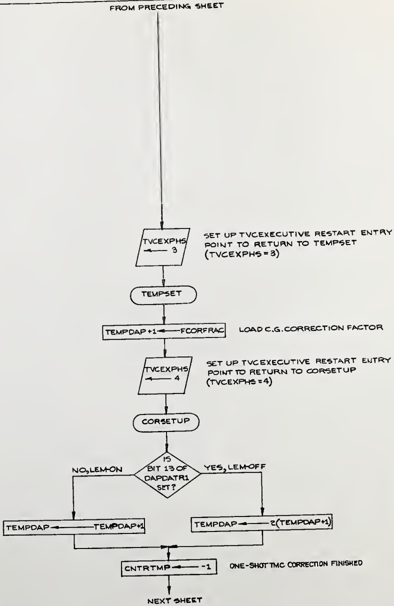
DRAWN / PRGMR / ANALST / DOCMR / APPR'D	TVC START-UP AND EXECUTIVE ROUTINES
	COLOSSUS IIA — DOCUMENT FC-2430
	REV — SHEET 7 OF 22



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN / PRGMR / ANALST 1/9/69 / DOCMR / APPR'D	TVC START-UP AND EXECUTIVE ROUTINES
COLOSSUS IIA	DOCUMENT NO. FC-2430
REV	SHEET 8 OF 22



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS	TVC START-UP AND EXECUTIVE ROUTINES
DRAWN / PRGMR / ANALST 4/4/69 / DOCMR / APPR'D 9 April 69	COLOSSUS IIA FC-2430
REV	9 of 22



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN	TVC START-UP AND EXECUTIVE ROUTINES
PRGMR	
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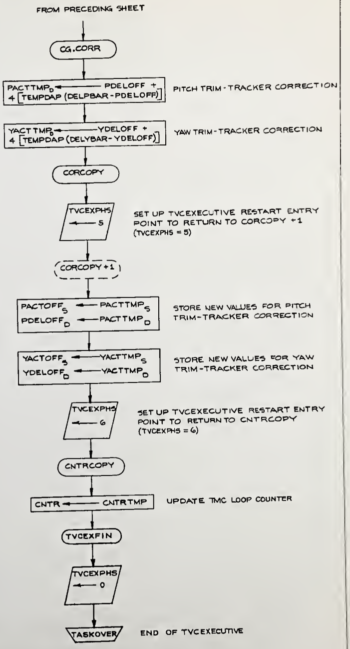
DOCMR	
APPR'D 9 April 69	REV — SHEET 10 OF 22



MIT INSTRUMENTATION LAB CAMBRIDGE MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN [signature] 25NOV68	TVC START-UP AND EXECUTIVE ROUTINES
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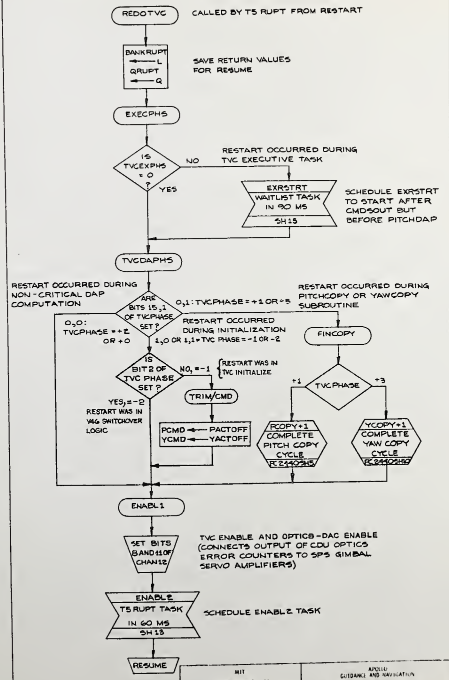
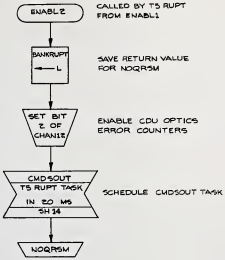
DOCMR	
APPR'D John A. Moore 9 April 69	REV 11 22

TVC RESTART PACKAGE



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN *J. S. Chudinski* [illegible]	TVC START-UP AND EXECUTIVE ROUTINES
PRGMR	
ANALST *[illegible]* 4/9/69	COLOSSUS IIA DOCUMENT NO. FC-2430
DOC MR	
APPR'D *John A. Moore* 9 April 69	REV SHEET 12 OF 22



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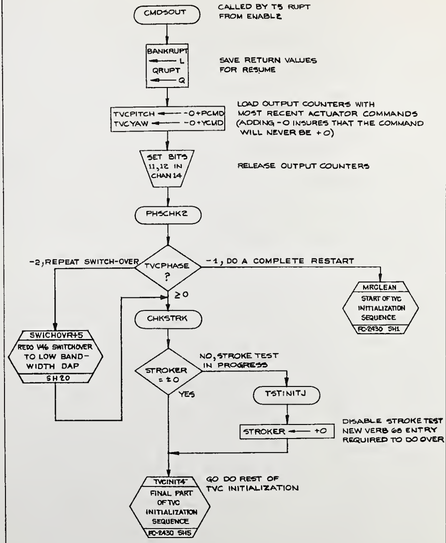
CAMBRIDGE MASS.

DRAWN
PRGMR
ANALST
DOCMR
APPR'D

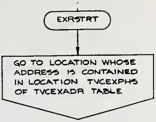
TVC START-UP AND
EXECUTIVE ROUTINES

COLOSSUS IIA FC-2430

13 22



MIT INSTRUMENTATION LAB CAMBRIDGE MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN	TVC START-UP AND EXECUTIVE ROUTINES
PRGMR	
ANALST 9/4/69	COLOSSUS IIA — DOCUMENT NO FC-2430
DOCMR	
APPR'D 9 April 69	REV — SHEET 14 OF 22



TVCEXPHS VALUE	ENTRY POINT	FC2430 SHEET NO.
1	EXECCOPY+1	8
2	1SHOTCHK	8
3	TEMPSET	10
4	CORSETUP	10
5	CORCOPY+1	11
6	CNTRCOPY	11

MIT
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CAMBRIDGE, MASS.

APOLLO
GUIDANCE AND NAVIGATION

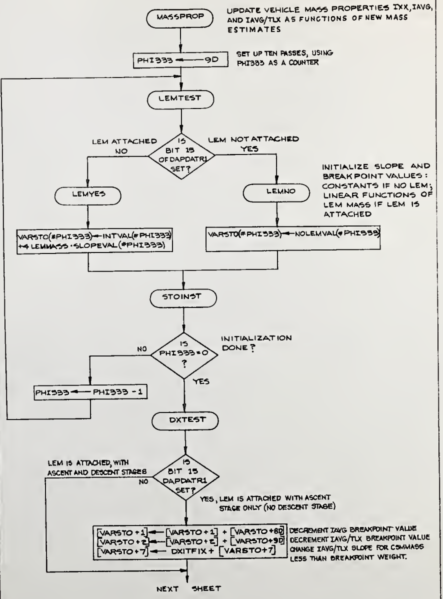
TVC START-UP AND EXECUTIVE ROUTINES

DRAWN [signature] 26NOV68
PRGMR
ANALST [signature] 4/9/69
DOCMR
APPR'D John A. Moore 9 April 69

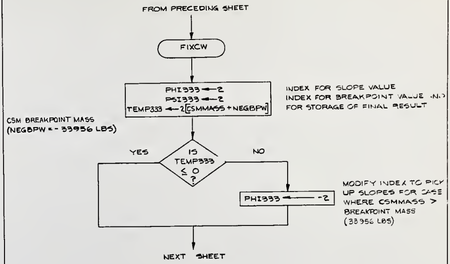
COLOSSUS IIA

DOCUMENT NO. FC-2430

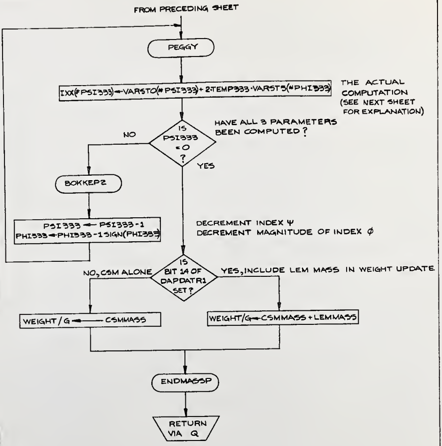
REV



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN [signature]	TVC START-UP AND EXECUTIVE ROUTINES
PRGMR	
ANALST [signature] 4/9/69	COLOSSUS IIA — DOCUMENT NO. FC-2430
DOCMR	
APPR'D John A. [signature] 9 April 69	REV — SHEET 16 OF 22



MIT INSTRUMENTATION LAB CAMBRIDGE MASS	TVC START-UP AND EXECUTIVE ROUTINES
DRAWN J.S. Chmielecki 27NOV68 PRGMR ANALST R.L. Schlundt 4/4/69 DOCMR APPR'D John A. Moore 4 April 69	COLOSSUS IIA FC-2430 17 22



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN [signature]	TVC START-UP AND EXECUTIVE ROUTINES
PRGMR	
ANALYST [signature] 4/9/69	COLOSSUS IIA — DOCUMENT NO. FC-2430
DOCMR	
APPR'D [signature] 9 April 69	REV — SHEET 18 OF 22

MASSPROP COMPUTATION:

STEP 1: COMPUTE COEFFICIENTS ON BASIS OF LEM MASS (M_{LEM}) (LEMTEST)

NO LEM	LEM ON
$V_0 = 25445$ (KGM^2)	$V_0 = 26850$ (KGM^2) $+ 1.96307$ (M^2) $\cdot M_{LEM}$ (KG)
$V_1 = 87450$ (KGM^2)	$V_1 = 127518$ (KGM^2) $+ 27\,5774$ (M^2) $\cdot M_{LEM}$ (KG)
$V_2 = .50715$ (SEC^2)	$V_2 = .54059$ (SEC^2) $+ 2.3548 \cdot 10^{-5}$ (SEC^2/KG) $\cdot M_{LEM}$ (KG)
$V_3 = 1.22877\ 10^{-5}$ (SEC^2/KG)	$V_3 = .153964 \cdot 10^{-4}$ (SEC^2/KG) $+ 2.1777 \cdot 10^{-9}$ (SEC^2/KG^2) $\cdot M_{LEM}$ (KG)
$V_4 = 1.6096$ (M^2)	$V_4 = -.742923$ (M^2) $+ 1.044 \cdot 10^{-3}$ (M^2/KG) $\cdot M_{LEM}$ (KG)
$V_5 = 1.54$ (M^2)	$V_5 = 1.5598$ (M^2) $+ 0$
$V_6 = 7.77177$ (M^2)	$V_6 = 9.68$ (M^2) $+ 2.21068 \cdot 10^{-3}$ (M^2/KG) $\cdot M_{LEM}$ (KG)
$V_7 = 3.46458\ 10^{-5}$ (SEC^2/KG)	$V_7 = .647625 \cdot 10^{-4}$ (SEC^2/KG) $+ 1.5166\ 10^{-9}$ (SEC^2/KG^2) $\cdot V_{LEM}$ (KG)
V_8 } COMPUTED, BUT NOT	$V_8 = -27228$ (KGM^2) $- 1.284$ (M^2) $\cdot M_{LEM}$ (KG)
V_9 } MEANINGFUL AND NOT USED	$V_9 = -.206476$ (SEC^2) $+ 2 \cdot 10^{-5}$ (SEC^2/KG) $\cdot M_{LEM}$ (KG)

STEP 2: IF LEM ASCENT STAGE ONLY ATTACHED, MODIFY V_1, V_2 AND V_7: (DXTEST)

$V_1 = V_1$ (KGM^2) $+ V_8$ (KGM^2)
$V_2 = V_2$ (SEC^2) $+ V_9$ (SEC^2)
$V_7 = V_7$ (SEC^2/KG) $- 1.88275 \cdot 10^{-5}$ (SEC^2/KG)

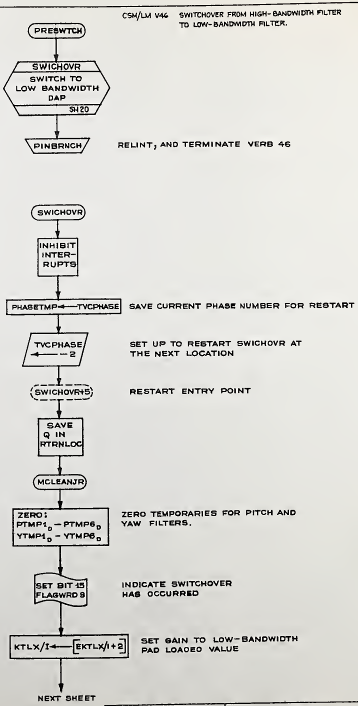
STEP 3: COMPUTE IXX(KGM^2), IAVG (KGM^2), AND IAVG/TLX (SEC^2): (PEGGY)

CSM WEIGHT $\leq$ 33956 LBS (15402.17 KG)	CSM WEIGHT > 33956 LBS (15402.17 KG)
IXX $= V_0$(KGM^2) $+ V_5$ (M^2)($M_{CSM} - 15402.17$) (KG)	IXX $= V_0$(KGM^2) $+ V_5$ (M^2)($M_{CSM} - 15402.17$)(KG)
IAVG $= V_1$(KGM^2) $+ V_6$ (M^2) ($M_{CSM} - 15402.17$) (KG)	IAVG $= V_1$ (KGM^2) $+ V_4$(M^2)($M_{CSM} - 15402.17$)(KG)
IAVG/TLX $= V_2$(SEC^2) $+ V_7$ (SEC^2/KG)($M_{CSM} - 15402.17$)(KG)	IAVG/TLX $= V_2$ (SEC^2) $+ V_3$ (SEC^2/KG)($M_{CSM} - 15402.17$)(KG)

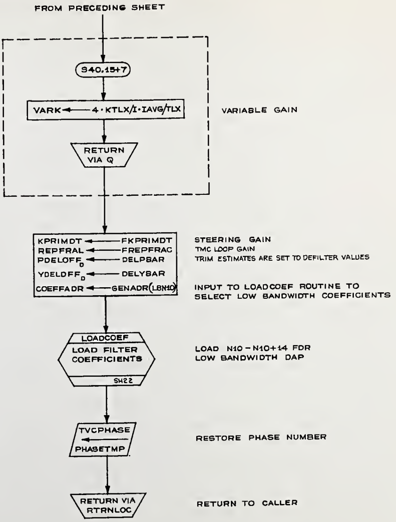
IN THE ABOVE EQUATIONS

IXX = MOMENT OF INERTIA ABOUT VEHICLE X AXIS	IN KG M^2 @ 2^{20}
IAVG = AVERAGE MOMENT OF INERTIA ABOUT Y AND Z AXIS	IN KG M^2 @ 2^{20}
IAVG/TLX = IAVG/(VEHICLE GAIN)	IN SEC^2 @ 2^2
M_{CSM} = CSM MASS	IN KG @ 2^{16}
M_{LEM} = LEM MASS	IN KG @ 2^{16}

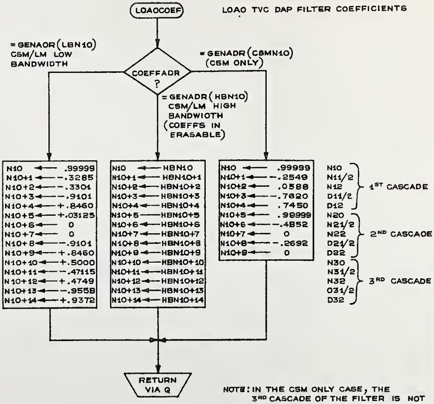
NOTE: VEHICLE MASS IS KEYED IN IN POUNDS, BUT INTERNALLY, MASS IS STORED IN KG.



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS	APOLLO GUIDANCE AND NAVIGATION
DRAWN P.M. Dietrich 4 MAR 69	TVC START-UP AND EXECUTIVE ROUTINES
PRGMR	
ANALST R.A. Gilbert 4/9/69	COLOSSUS IIA DOCUMENT NO. FC-2430
DOCMR	
APPR'D John A. Moore 9 Apr 69	REV SHEET 20 OF 22

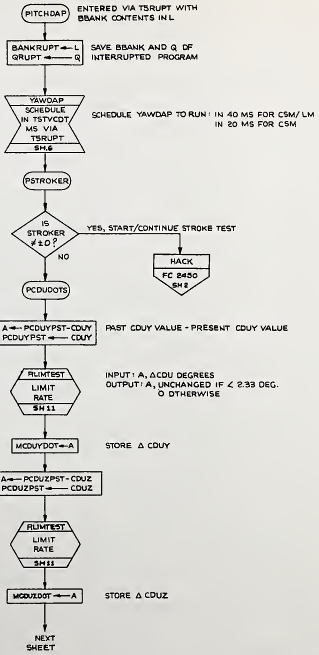


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN P.M. Didonato 5MAR69	TVC START-UP AND EXECUTIVE ROUTINES
PROGMR	DOCUMENT NO.
ANALYST R. L. Schlundt 4/9/69	COLOSSUS IIA FC-2430
DOCMR	
APPR'D John A. Moore 9 April 69	REV — SHEET 21 OF 22

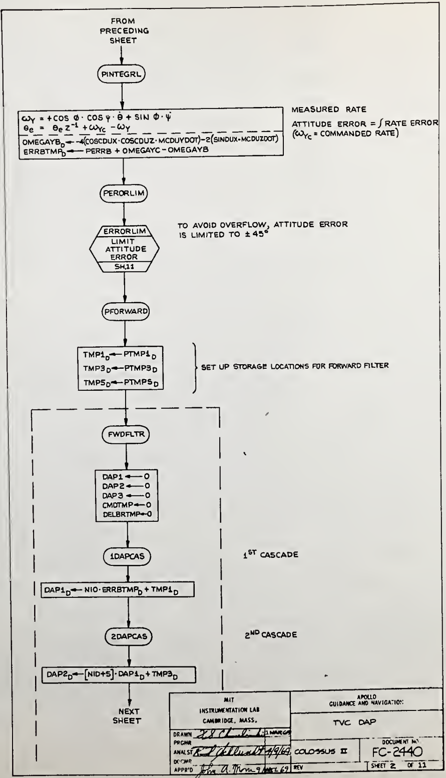


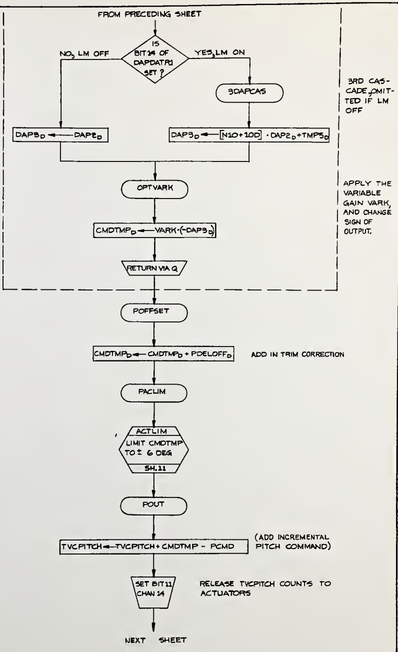
NOTE: IN THE CSM ONLY CASE, THE 3RD CASCADE OF THE FILTER IS NOT USED. THE COEFFICIENTS ARE IN FACT INITIALIZED BUT TO MEANINGLESS VALUES WHICH ARE NOT USED. AS OF THE RELEASED VERSION OF COLOSSUS II, THESE VALUES ARE AS FOLLOWS:

N10+10 ← .99999
N10+11 ← -.3285
N10+12 ← -.3301
N10+13 ← -.9101
N10+14 ← +.8460

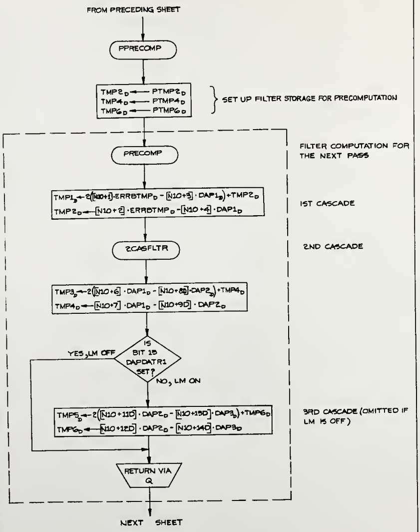


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN 1 MAR 69	TVC DAP
PRGMR	
ANALST 4/9/69	COLOSSUS II — DOCUMENT NO. FC-2440
DOCMR	
APPR'D John A. Moore 9 APRIL 69	REV — SHEET 1 OF 11


FROM PRECEDING SHEET
PINTEGRL
ωY = +COS Φ · COS ψ · θ̇ + SIN Φ · ψ̇
θe = θe Z^-1 + ωYc − ωY
OMEGAYB_D ← -4(COSCDUX · COSCDUZ · MCDUYDOT) - 2(SINDUX · MCDUZDOT)
ERRBTMP_D ← PERRB + OMEGAYC − OMEGAYB
MEASURED RATE
ATTITUDE ERROR = ∫ RATE ERROR
(ωYc = COMMANDED RATE)
PERORLIM
ERRORLIM
LIMIT ATTITUDE ERROR
SH.11
TO AVOID OVERFLOW, ATTITUDE ERROR IS LIMITED TO ±45°
PFORWARD
TMP1_D ← PTMP1_D
TMP3_D ← PTMP3_D
TMP5_D ← PTMP5_D
SET UP STORAGE LOCATIONS FOR FORWARD FILTER
FWDFLTR
DAP1 ← 0
DAP2 ← 0
DAP3 ← 0
CMDTMP ← 0
DELBRTMP ← 0
1DAPCAS
1ST CASCADE
DAP1_D ← N10 · ERRBTMP_D + TMP1_D
2DAPCAS
2ND CASCADE
DAP2_D ← [N10+5] · DAP1_D + TMP3_D
NEXT SHEET
MIT
INSTRUMENTATION LAB
CAMBRIDGE, MASS.
APOLLO
GUIDANCE AND NAVIGATION
TVC DAP
DRAWN
PRGMR
ANALST
DOCMR
APPR'D
COLOSSUS II
DOCUMENT NO
FC-2440
REV
SHEET 2 OF 11



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
	TVC DAP
DRAWN [signature] 11 MAR 69	
PRGMR	
ANALST [signature] 4/9/69	COLOSSUS II — DOCUMENT NO. FC-2440
DOCMR	
APPR'D John A. Miller 9 Apr 69	REV — SHEET 3 OF 11



MIT
INSTRUMENTATION LAB
CAMBRIDGE, MASS.

APOLLO
GUIDANCE AND NAVIGATION

TVC DAP

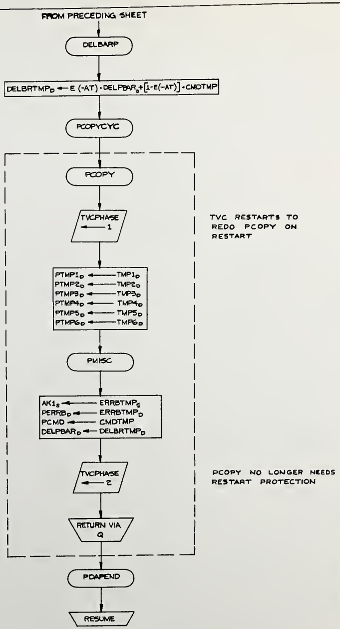
DRAWN 7 L Chislink 4 MAR 69
PRGMR
ANALST R L Schlundt 4/9/69
DOCMR
APPR'D John A. Miller 9 Apr 69

COLOSSUS II

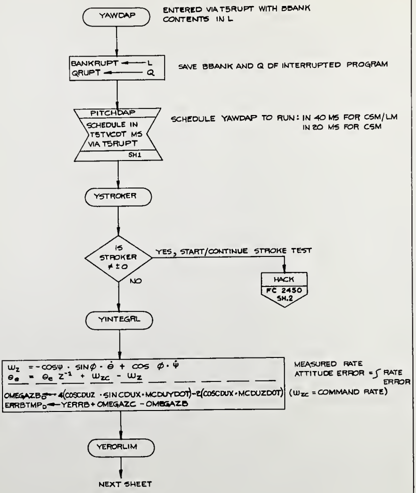
REV

DOCUMENT NO. FC-2440

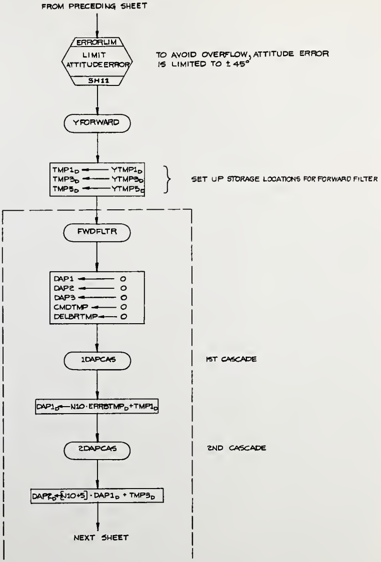
SHEET 4 OF 11



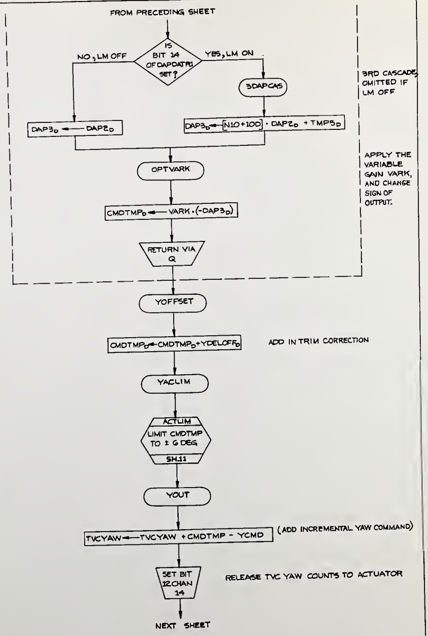
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN [signature] 8 MAR 69	TVC DAP
PRGMR	
ANALST [signature] 4/9/69	COLOSSUS II — DOCUMENT NO. FC-2440
DOCMR	
APPR'D John A. Miller 9 April 69	REV — SHEET 5 OF 11



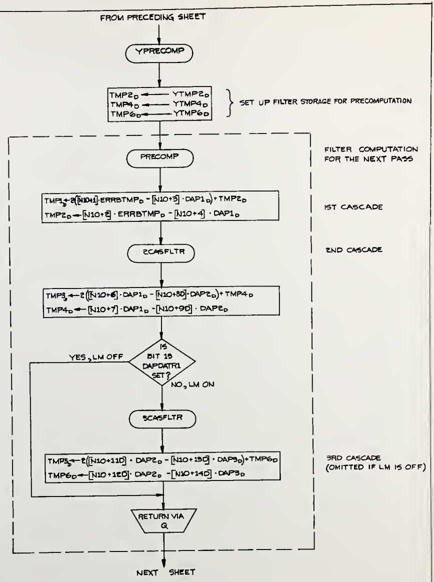
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN	TVC DAP	
PRGMR		DOCUMENT NO.
ANALST 4/9/69	COLOSSUS II	FC-2440
DOCMR		
APPR'D 9 April 69	REV	SHEET 6 OF 11



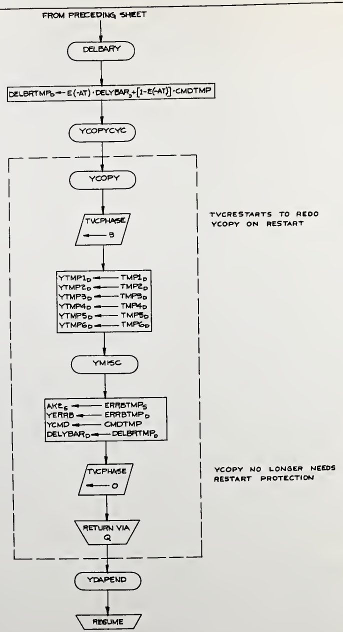
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN Z.S. Chmielinski SMRG	TVC DAP
PRGMR	
ANALST K.H. Kallundt 4/2/69	COLOSSUS II — DOCUMENT NO. FC-2440
DOCMR	
APPR'D John A. Miller 9 April 69	REV — SHEET 7 OF 11



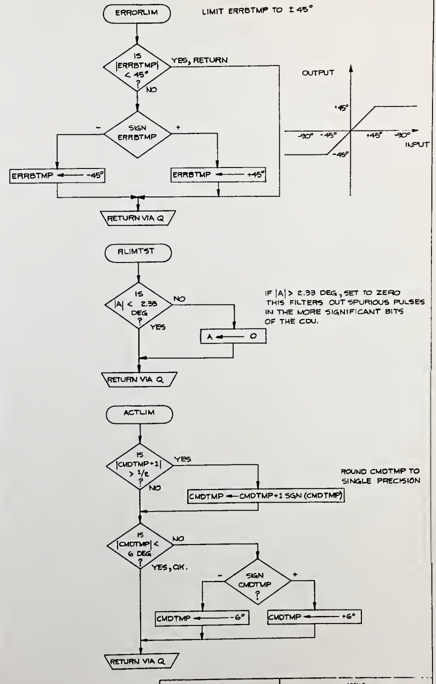
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
	TVC DAP	
DRAWN / PRGMR / ANALST / DOCMR / APPR'D	COLOSSUS II	DOCUMENT NO. FC-2440
	REV	SHEET 8 OF 11



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		TVC DAP	
DRAWN	Z. L. Chamberlain	CHARGE	
PRGMR			DOCUMENT NO.
ANALST	B. Kahlmeier 4/9/68	COLOSSUS II	FC-2440
DOCMR			
APPR'D	John A. Moro 9 April 68	REV	SHEET 9 OF 11



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
	TVC DAP	
DRAWN / PRGMR / ANALST 4/9/69 / DOCMR / APPR'D 9 April 69	COLOSSUS II	DOCUMENT NO. FC-2440
	REV	SHEET 10 OF 11



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN [signature] 7 MAR 69	TVC DAP
PRGMR	
ANALST [signature] 4/9/69	COLOSSUS II — DOCUMENT NO FC-2440
DOCMR	
APPR'D John A. Moore 9 April 69	REV — SHEET 11 OF 11

R35 – LUNAR LANDMARK SELECTION
ENTERED VIA A V79E CALL BY ASTRONAUT

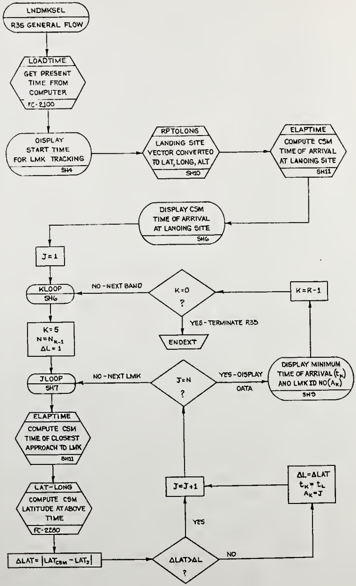
MAJOR SUBROUTINES

- RPTOLONG – CONVERTS RADIUS VECTOR IN PLANETARY COORDINATES TO LAT, LONG AND ALT.
- ELAPTIME – COMPUTES TIME TO POINT OF CLOSEST ARRIVAL OF LANDING SITE OR LANDMARK.

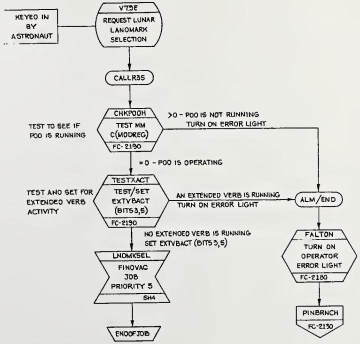
SPECIAL CONVENTIONS

1) SCALING INDICATED AS $2^X/2^Y$ MEANS 2^X IS THE SCALING WHEN IN EARTH SPHERE OF INFLUENCE AND 2^Y IS FOR MOON SPHERE OF INFLUENCE.
2) "VARIABLE" IN THE SCALING FIELD OF THE SUMMARY SHEETS INDICATES THAT THE ERASABLE LOCATION IS USED AS A TEMPORARY REGISTER HAVING MANY SCALINGS.
3) THE SYMBOL # INDICATES INDIRECT ADDRESSING, i.e. ABLE #X1 MEANS ABLE IS INDIRECTLY ADDRESSED BY X1.

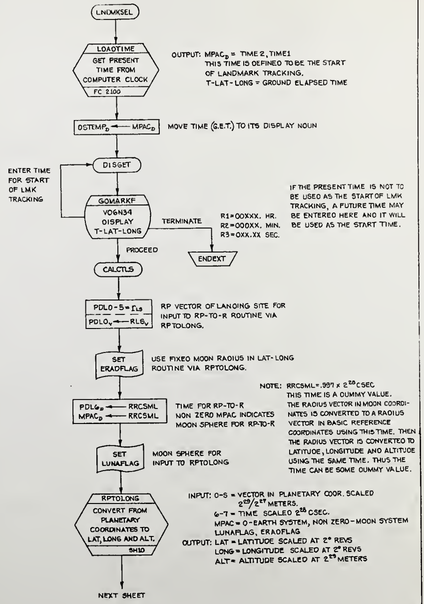
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	10OCT68	R35 – LUNAR LANDMARK SELECTION
PRGMR T. E. Crocker	23OCT68	COLOSSUS 237
ANALST		DOCUMENT NO. FC-2595
DOCMR R. Piscatelli	23OCT68	REV
APPR'D [illegible]	[illegible]	SHEET 1 OF 18



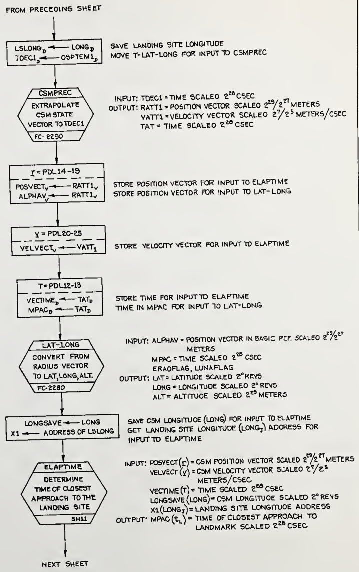
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
	R35-LUNAR LANDMARK SELECTION
DRAWN A.C WILLIAMS 10OCT68	
PRGMR F.E Crocker 23OCT68	COLOSSUS 237
ANALYST	DOCUMENT NO. FC-2595
DOCMR [signature] 23OCT68	
APPR'D John A. Moore 24OCT68	REV SHEET 2 OF 18



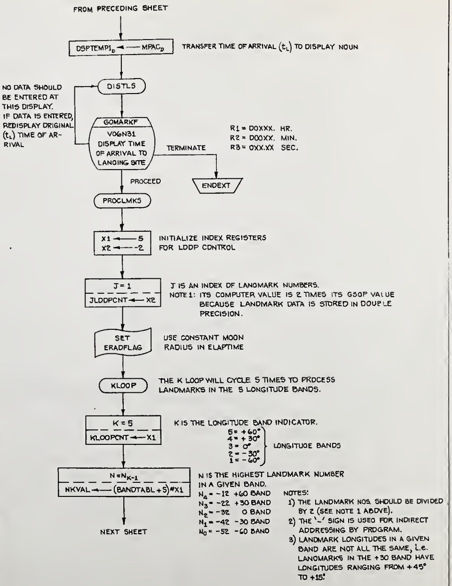
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	10OCT68	R35-LUNAR LANDMARK SELECTION
PRGMR T.E. Crocker	23OCT68	COLOSSUS 237
ANALST		DOCUMENT NO. FC-2595
DOCMR R. Pysetill	23OCT68	REV
APPR'D John A. Moore	24OCT68	SHEET 3 OF 18



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
	R35- LUNAR LANDMARK SELECTION
DRAWN A.C.WILLIAMS 11OCT68	
PRGMR T E Crocker 23OCT68	COLOSSUS 237
ANALST	DOCUMENT NO. FC-2595
DOCMR R. Ricciatti 23OCT68	
APPR'D John A. Moore Nov 68	REV / SHEET 4 OF 18



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
		R35 - LUNAR LANDMARK SELECTION
DRAWN A.C. WILLIAMS	14OCT68	
PRGMR T.E. Crocker	23OCT68	COLOSSUS 237 — DOCUMENT NO. FC-2595
ANALST		
DOCMR R.P. [illegible]	23Oct68	
APPR'D John A. Nom	21Oct68	REV — SHEET 5 OF 18



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P35-LUNAR LANDMARK SELECTION	
DRAWN A C WILLIAMS	14OCT68	COLOSSUS 237	DOCUMENT NO. FC-2595
PRGMR T E Crocker	23OCT68		
ANALST			
DOCMR R. Pescatello	23OCT68		
APPR'D John A. Miller	24OCT68	REV	SHEET 6 OF 18

FROM PRECEDING SHEET

$\Delta_L = 1$ / $DELTAL_D \leftarrow DPPOSMAX_D$ — INITIALIZE LATITUDE TEST VALUE. DPPOSMAX = DEC .999999996

JLOOPP — THIS LOOP CYCLED 5 TIMES TO DETERMINE WHICH LANDMARK IN THE N_{K-1} BAND IS CLOSEST TO THE CSM GROUND TRACK.

X1 ← ADDRESS OF (LONGTAB-2) — LONGTAB IS THE BEGINNING ADDRESS OF THE LONGITUDE TABLE

X1 ← X1 - JLOOPCNT — DETERMINE THE ADDRESS OF $LONG_J$ - THE LONGITUDE OF THE J^{TH} LANDMARK.

ELAPTIME — DETERMINE TIME OF CLOSEST APPROACH TO THIS LANDMARK (SH11)

INPUT: POSVECT(r) = CSM POSITION VECTOR SCALED $2^{29}/2^{27}$ METERS
VELVECT(v) = CSM POSITION VECTOR SCALED $2^7/2^5$ METERS/CSEC
VECTIME(T) = TIME SCALED 2^{28} CSEC
LONGSAVE(LONG) = CSM LONGITUDE SCALED 2^0 REVS
X1($LONG_J$) = LANDMARK LONGITUDE ADDRESS
OUTPUT: MPAC(t_L) = TIME OF CLOSEST APPROACH TO LANDMARK SCALED 2^{28} CSEC

$XR1HOLD_D \leftarrow MPAC_D$ — SAVE TIME FOR POSSIBLE USE IF THIS LANDMARK IS CLOSEST TO THE CSM GROUND TRACK FOR THIS BAND.

SET LUNAFLAG — USE MOON SPHERE IN LAT-LONG

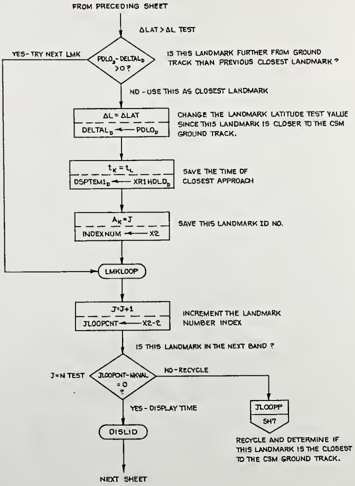
LAT-LONG — CONVERT RADIUS VECTOR TO LAT, LONG, ALT. (FC-2280)

INPUT: ALPHAV = CSM POSITION VECTOR SCALED 2^{29} METERS
MPAC = TIME SCALED 2^{28} CSEC
ERADFLAG, LUNAFLAG
OUTPUT: LAT = LATITUDE SCALED 2^0 REVS
LONG = LONGITUDE SCALED 2^0 REVS
ALT = ALTITUDE SCALED 2^{29} METERS

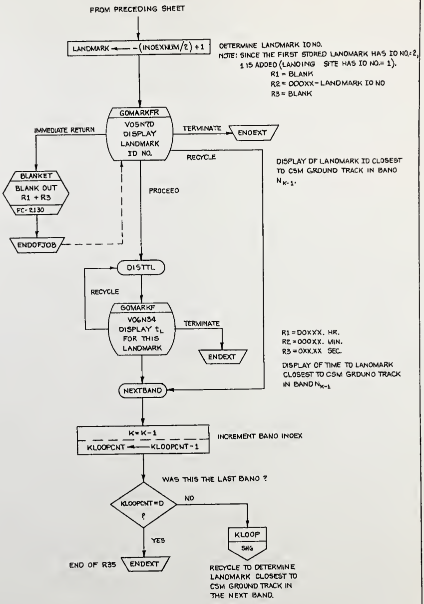
$\Delta LAT = |LAT - LAT_J|$ / $POLO_D \leftarrow$ ABS [LAT-(LATTAB-2)#JLOOPCNT] — COMPUTE THE DIFFERENCE BETWEEN THE CSM AND LANDMARK LATITUDES AT THE TIME OF CLOSEST APPROACH.

NEXT SHEET

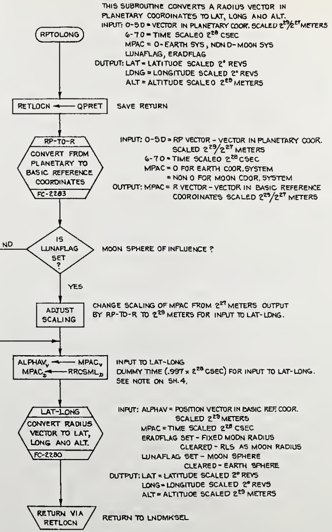
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	15OCT68	R35-LUNAR LANDMARK SELECTION
PRGMR T. E. Crocker	13Oct68	
ANALST		COLOSSUS 237 — DOCUMENT NO. FC-2595
DOCMR P. Puccatelli	13Oct68	
APPR'D John A. Miller	14Oct68	REV — SHEET 7 OF 18



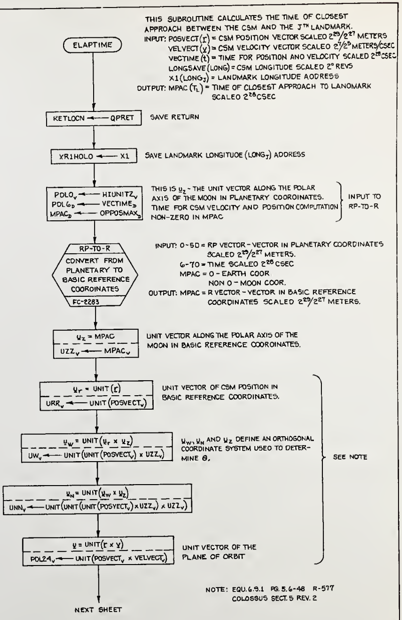
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS	15OCT68	R35-LUNAR LANDMARK SELECTION	
PRGMR T.E. Crocker	23OCT68	COLOSSUS 237	DOCUMENT NO. FC-2595
ANALST			
DOCMR R. Pizzitelli	23OCT68		
APPR'D John A. Moore	23OCT68	REV	SHEET 8 OF 18



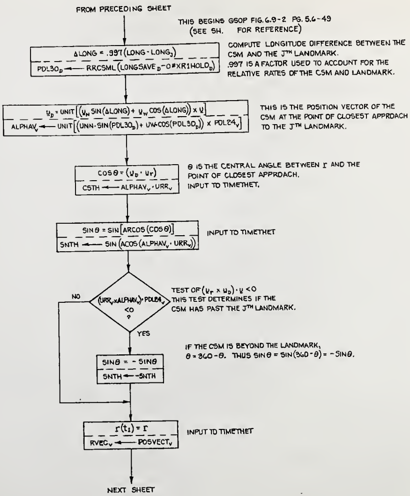
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS	15OCT68	P35 - LUNAR LANDMARK SELECTION	
PRGMR T. E. Crocker	23OCT68		DOCUMENT NO.
ANALST		COLDSSUS 237	FC-2595
DOCMR R. Pescatill	23OCT68		
APPR'D John A. More	24OCT68	REV	SHEET 9 OF 18



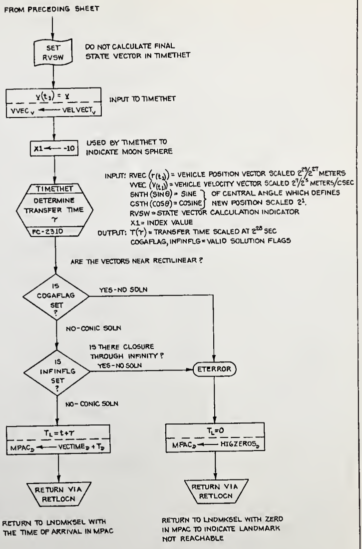
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		R35 - LUNAR LANDMARK SELECTION	
DRAWN A.C.WILLIAMS	15OCT68		DOCUMENT NO.
PROGMR T.E. Crocker	23OCT68	COLOSSUS 237	FC-2595
ANALYST			
DOCMN [illegible signature]	30OCT68		
APPR'D John A. [illegible]	24Oct68	REV	SHEET 10 OF 18



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C. WILLIAMS 16OCT68	R35-LUNAR LANDMARK SELECTION
PRGMR T.F. Crocker 23OCT68	
ANALST	COLOSSUS 237 — DOCUMENT NO. FC-2595
DOCMR R. Ruscetti 23OCT68	
APPR'D John A. Mora	REV — SHEET 11 OF 18



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS	16OCT68	R35-LUNAR LANDMARK SELECTION	
PRGMR T.E. Crocker	23OCT68	COLOSSUS 237	DOCUMENT NO. FC-2595
ANALST			
DOCMR R. Pucstelli	23OCT68	REV	SHEET 12 OF 18
APPR'D John A. Moss	24 OCT 68		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 17OCT68	R35-LUNAR LANDMARK SELECTION
PRGMR T.E. Crocker 25OCT68	
ANALST	COLOSSUS 237 — DOCUMENT NO. FC-2595
DOCMR T. Pristell 23OCT68	
APPR'D John A. Moo...	REV — SHEET 15 OF 18

SUBROUTINES CALLED WHICH ARE
FLOWED ON OTHER FLOW CHARTS

SUBROUTINE NAME	FLOW CHART	DESCRIPTION	WHERE CALLED
CHKPOOH	2190	TESTS TO SEE IF POO IS RUNNING	SH3
TESTXACT	2190	TESTS FOR EXTENDED VERB ACTIVITY	SH3
FALTON	2180	TURN ON OPERATOR ERROR LIGHT	SH3
LOADTIME	2100	GET PRESENT TIME FROM COMPUTER CLOCK	SH4
CSMPREC	2290	EXTRAPOLATE CSM STATE VECTOR TO TDEC1	SH5
LAT-LONG	2280	CONVERT FROM RADIUS VECTOR TO LAT, LONG, ALT	SH5,7,10
RP-TO-R	2283	CONVERT FROM PLANETARY TO BASIC REFERENCE COORDINATES	SH10,11
TIMETHET	2310	DETERMINE TRANSFER TIME	SH13
BLANKET	2130	BLANK OUT R1 AND R3	SH9

FLAGS

NAME	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
ERADFLAG FLAGWORD1 BIT13	EARTH: COMPUTE FISHER ELLIPSOID RADIUS MOON: USE FIXED RADIUS	EARTH: USE FIXED RADIUS MOON: USE RLS FOR LUNAR RADIUS	SH4, 6		
LUNAFLAG FLAGWORD3 BIT12	LAT-LONG IS FOR MOON	LAT-LONG IS FOR EARTH	SH4, 7		SH10
RVSW FLAGWORD7 BIT9	DO NOT COMPUTE FINAL STATE VECTOR IN TIMETHET	COMPUTE FINAL STATE VECTOR IN TIMETHET	SH13		
COGAFLAG FLAGWORD8 BIT4	NO CONIC SOLUTION, TOO CLOSE TO RECTILINEAR	CONIC SOLUTION EXISTS			SH13
INFINFLG FLAGWORD8 BIT7	NO CONIC SOLUTION, CLOSURE THROUGH INFINITY REQUIRED	CONIC SOLUTION EXISTS			SH13

DISPLAYS

VERB-NOUN	TYPE OF DISPLAY	DESCRIPTION OF EACH REGISTER	WHERE EXECUTED
V06N34	FLASHING	R1 = 00XXX. HR. R2 = 000XX. MIN. TIME OF EVENT R3 = 0XX.XX SEC.	SH4, 9
V06N31	FLASHING	R1 = 00XXX. HR. R2 = 000XX. MIN. TIME OF ARRIVAL TO LANDING SITE R3 = 0XX.XX SEC.	SH6
V05N70	FLASHING	R1 = BLANK R2 = 000XX - LANDMARK ID NUMBER R3 = BLANK	SH9

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN G. L. Fongille 40CT68	R35 LUNAR LANDMARK SELECTION
PRGMR T. F. Coultier 7OCT68	
ANALST	COLOSSUS 237 — DOCUMENT NO. FC-2595
DOCMR P. Pucatelli 8OCT68	
APPR'D John A. Moore 24OCT68	REV — SHEET 14 OF 18

ERASABLE LOCATIONS USED

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
DSPTEMP		REGISTER USED TO DISPLAY TIME	HR.,MIN.,SEC.	CSEC	2^{28}
RLS	$\underline{r}_{LS}$	LANDING SITE RADIUS VECTOR	NAUT.MI.	METERS	$2^{29}/2^{27}$
LDNG		LONGITUDE OUTPUT OF LAT-LONG SUBROUTINE	DEGS.	REVS	2^0
LSLONG		LANDING SITE LONGITUDE	DEGS.	REVS	2^0
RATT1		STATE VECTOR POSITION COMPONENT		METERS	$2^{29}/2^{27}$
VATT1		STATE VECTDR VELOCITY CDMPDNENT		METERS/ CSEC	$2^7/2^5$
TAT		TIME FOR ABDVE STATE VECTDR		CSEC	2^{28}
PDSVECT	$\underline{r}$	CSM POSITION AT TIME T		METERS	$2^{29}/2^{27}$
VELVECT	$\underline{v}$	CSM VELOCITY AT TIME T		METERS/ CSEC	$2^7/2^5$
VECTIME	T	TIME FDR ABOVE POSITION AND VELOCITY		CSEC	2^{28}
LONGSAVE	LDNG	CSM LONGITUDE	DEGS.	REVS	2^0
JLOOPCNT	J	INDEX FDR LANDMARK ID NOS.		(INTEGER)	2^{14}
KLOOPCNT	K	INDEX FDR BAND NOS.		(INTEGER)	2^{14}
NKVAL	N	HIGHEST LANDMARK ID NO. IN A GIVEN BAND		(INTEGER)	2^{14}
DELTAL	ΔL	MINIMUM LATITUDE DEVIATION TEST VALUE	DEGS.	REVS	2^0
LAT		LATITUDE OUTPUT OF LAT-LONG SOBRDUTINE	DEGS.	REVS	2^0
XR1HOLD		TEMPORARY STORAGE REGISTER			VARIABLE
INDEXNUM	A_K	TEMPORARY STORAGE OF LANDMARK ID NO.		(INTEGER)	2^{14}
LANDMARK		DISPLAY NOUN FOR LANDMARK ID NO.		(INTEGER)	2^{14}
RETLOCN		RETURN ADDRESS REGISTER		(INTEGER)	2^{14}
ALPHAV		POSITION VECTOR INPUT TO LAT-LONG		METERS	2^{29}
UZZ	$\underline{u}_Z$	UNIT VECTOR OF MOON POLAR COORDINATE			2^1
URR	$\underline{u}_r$	UNIT VECTDR OF CSM POSITION			2^1
UW	$\underline{u}_W$	USED WITH $\underline{u}_Z$ TO DEFINE			2^1
UNN	$\underline{u}_N$	AN ORTHOGONAL COORDINATE SYSTEM			2^1
CSTH		COS θ } θ IS THE CENTRAL ANGLE BETWEEN			2
SNTH		SIN θ } $\underline{r}$ AND POINT OF CLOSEST APPROACH			2
RVEC	$\underline{r}_{(t_1)}$	CSM POSITION VECTOR } INPUT TO		METERS	$2^{29}/2^{27}$
VVEC	$\underline{v}_{(t_1)}$	CSM VELOCITY VECTOR } TIMETHET		METERS/ CSEC	$2^7/2^5$
T	τ	TRANSFER TIME FROM TIMETHET	SEC	CSEC	2^{28}

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

DRAWN A. A. Smith 4 OCT 68
PROGMR T/E Conklin 4 OCT 68
ANALST
DOCMR R. Pisciotta 30 OCT 68
APPR'D John A. Moore 24 OCT 68

APOLLO GUIDANCE AND NAVIGATION

R35 LUNAR LANDMARK SELECTION

COLOSSUS 237

DOCUMENT NO. FC-2595

REV

PROGRAM CONSTANTS

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING VALUE AND UNITS	AGC VALUE AND UNITS	AGC SCALING
RRCSML		FACTOR USED TD ACCOUNT FDR RDTATION OF MOON	.997	37716 33106	2^0
BANDTABL		BEGINNING DF TABLE CDNTAINING BAND LIMITS		(INTEGER)	2^{14}
DPPDSMAX		DOUBLE PRECISIDN REGISTER CONTAINING MAXIMUM VALUE	.999999996	37777 37777	2^0
LONGTAB		BEGINNING ADDRESS FOR LDNGITUDES OF STORED LANDMARKS	SEE BELOW	(INTEGER)	2^{14}
LATTAB		BEGINNING ADDRESS FOR LATITUDES OF STORED LANDMARKS	SEE BELOW	(INTEGER)	2^{14}
HIUNITZ		UNIT VECTOR IN Z DIRECTION	(0,0,1)	(00000 00000, 00000 00000, 20000 00000)	$(2^1, 2^1, 2^1)$
HI6ZEROS		BEGINNING ADDRESS FOR 6 REGISTERS IN HIGH CORE CONTAINING ZERO		(INTEGER)	2^{14}

LUNAR LANDMARK TABLE

AGC TAG	LANDMARK NUMBER (OCTAL) AND COORDINATE TYPE		ENGINEERING VALUE AND UNITS		AGC VALUE AND UNITS	AGC SCALING
LATTAB	LATITUDE	LMK ID NO 2	$5^{\circ}29'$	SOUTH	-.015231461 REVS	2^0
LATTAB+2	LATITUDE	LMK ID NO 3	$0^{\circ}47'$	NORTH	.002175926 REVS	2^0
+4	↓	↓ 4	$0^{\circ}51'$	N	.002361111 ↓	↓
+6		5	$0^{\circ}40'$	S	-.001851652	
+8		6	$1^{\circ}00'$	N	.002777776	
+10		7	$1^{\circ}03'$	S	-.002916667	
+12		10	$1^{\circ}56'$	S	-.005462963	
+14		11	$2^{\circ}24'$	N	.006666667	
+16		12	$6^{\circ}49'$	N	.016935185	
+16		13	$0^{\circ}54'$	N	.002500000	
+20		14	$1^{\circ}14'$	N	.003425926	
+22		15	$1^{\circ}42'$	S	-.004722222	
+24		16	$0^{\circ}32'$	S	-.001461461	
+26		17	$1^{\circ}07'$	N	.003101852	
+26		20	$1^{\circ}15'$	N	.003472222	
+30		21	$4^{\circ}30'$	S	-.012500000	

LUNAR LANDMARK TABLE (CONTINUED)

AGC TAG	LANDMARK NUMBER (OCTAL) AND COORDINATE TYPE		ENGINEERING VALUE AND UNITS		AGC VALUE AND UNITS	AGC SCALING
LATTAB+32	LATITUDE	LMK ID NO 22	0°08'	NORTH	000277777 REVS	2^0
↓ +34	↓	↓ 23	4°05'	N	.011342592 ↓	↓
+36		24	1°26'	N	.003981481	
+38		25	2°53'	S	-.008009259	
+40		28	1°10'	N	.003240741	
+42		27	2°03'	S	-.005694444	
+44		30	0°49'	N	.002268518	
+46		31	2°49'	S	-.007824074	
+48		32	1°57'	N	.005416667	
LONGTAB	LONGITUDE	2	58°01'	EAST	.161157407	
↓ +2	↓	↓ 3	57°37'	↓	.160046296	
+4		4	51°35'		.143287037	
+6		5	41°46'		.116018518	
+8		6	38°28'		.106851852	
+10		7	37°41'		.104675928	
+12		10	34°02'		.094537037	
+14		11	33°55'		.094212963	
+16		12	33°03'		.091805555	
+18		13	30°05'		.083564815	
+20		14	23°42'		.065833333	
+22		15	18°20'		.050925926	
+24		18	15°21'		.042638889	
+26		17	18°17'		.023009259	
+28		20	3°45'		.010416667	
+30		21	0°01'		.000046296	
+32		22	1°20'	WEST	-.003703704	
+34		23	7°27'	↓	-.020694444	
+36		24	8°32'		-.023703704	
+38		25	18°31'		-.051435185	
+40		26	24°30'		-.068055556	
+42		27	30°38'		-.085092593	
+44		30	37°18'		-.100833333	
+48		31	36°42'		-.101944444	
+48		32	42°16'		-.117407407	
ALTTAB	ALTITUDE	2	-6857	FEET*	-2029 METERS*	2^{29}
↓ +2	↓	3	-6857	↓	-2029 ↓	↓
+4		4	-6673		-1790	

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DRAWN / FROM / ANALYST / DOCMR / APPR'D

APOLLO GUIDANCE AND NAVIGATION

R35 LUNAR LANDMARK SELECTION

COLOSSUS 237

DOCUMENT NO. FC-2595

REV

LUNAR LANDMARK TABLE (CONTINUED)

AGC TAG	LANDMARK NUMBER (OCTAL) AND COORDINATE TYPE		ENGINEERING VALUE AND UNITS	AGC VALUE AND UNITS	AGC SCALING
ALTTAB+6	ALTITUDE	LMK ID NO 5	-3576 FEET*	-1090 METERS*	2^{29}
↓ +8	↓	↓ 6	-3084 ↓	-940 ↓	↓
+10		7	-952	-290	
+12		10	-951	-290	
+14		11	-5082	-1549	
+16		12	-2920	-890	
+18		13	-4889	-1490	
+20		14	-10600	-3230	
+22		15	16770	5110	
+24		16	22670	6910	
+26		17	16760	5110	
+28		20	9876	3010	
+30		21	12830	3910	
+32		22	-3070	-935	
+34		23	7743	2360	
+36		24	8235	2510	
+38		25	689	210	
+40		28	3150	960	
+42		27	4298	1310	
+44		30	4626	1410	
+46		31	-8609	-2624	
+48		32	8022	-2445	
				*MEASURED ABOVE MEAN LUNAR RADIUS	

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A. J. Tonzile	30 OCT 68	R35 LUNAR LANDMARK SELECTION
PRGMR T. E. Crocker	7 Nov 68	
ANALST		COLOSSUS 237 — DOCUMENT NO. FC-2595
DOCMR R. Fricatilli	7 Nov 68	
APPR'D John A. Moore	7 Nov 68	REV — SHEET 18 OF 18

P23 - CISLUNAR MIDCOURSE NAVIGATION
CALLED FROM DSKY

MAJOR SUBROUTINES

POINTAXS - COMPUTES THE CSM TO LANDMARK/HORIZON POINTING VECTOR
HORIZ - COMPUTES HORIZON LOCATION VECTOR

SPECIAL CONVENTIONS

1) SCALING INDICATED AS $2^X/2^Y$ MEANS 2^X IS THE SCALING IN EARTH SPHERE OF INFLUENCE AND 2^Y IS THE SCALING IN MOON SPHERE OF INFLUENCE

2) "VARIABLE" IN THE SCALING FIELD OF THE SUMMARY SHEETS INDICATES THAT THE ERASABLE LOCATION IS EITHER A MATRIX WHOSE COMPONENTS HAVE DIFFERENT SCALING OR A TEMPORARY REGISTER WITH MANY DIFFERENT SCALINGS.

3) THE SYMBOL "#" INDICATES INDIRECT ADDRESSING,
i.e. ABLE # X1 MEANS ABLE IS INDIRECTLY ADDRESSED BY X1. (SEE NOTE)

4) THE NOTATION "LANDMARK/HORIZON" IS USED WHEN THE TARGET COULD BE EITHER A LANDMARK OR A HORIZON.

NOTE: IF THE QUANTITY TO THE RIGHT OF "#" SIGN IS X1 (OR X2), THEN THE ADDRESS IS FORMED BY SUBTRACTING X1 (OR X2) FROM THE QUANTITY ON THE LEFT OF THE "#".
IF THE QUANTITY ON THE RIGHT OF THE "#" SIGN IS NOT X1 (OR X2), THE READER SHOULD REFER TO THE CODING TO DETERMINE IF IT MUST BE ADDED TO OR SUBTRACTED FROM THE QUANTITY ON THE LEFT OF THE "#" TO FORM THE ADDRESS.

5) WHILE THE GENERAL MEANING OF A DISPLAY NOUN IS A 2 DIGIT NUMBER, i.e. N70, IN THIS CHART THE CELL CONTAINING THE DATA USED BY THE NOUN (VIA PINBALL) WILL BE CALLED THE DISPLAY NOUN; i.e. "LANDMARK" WILL BE CALLED A DISPLAY NOUN ALTHOUGH IT IS REALLY THE CELL CONTAINING INFORMATION USED BY "N70".

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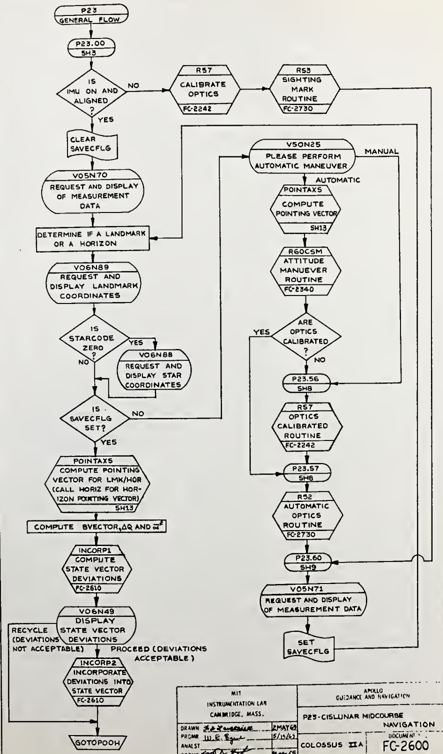
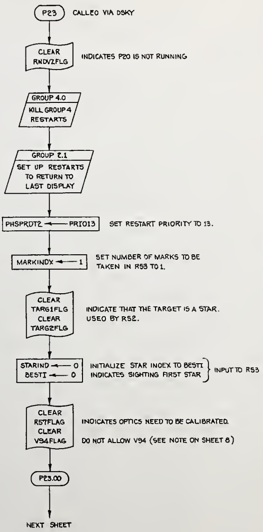
DRAWN A.C. WILLIAMS	7NOV68	P23 - CISLUNAR MIDCOURSE NAVIGATION
PROGMR W. E. Byrne	5/19/69	
ANALST		COLOSSUS II A — DOCUMENT NO. FC-2600
DOCMR [signature]	4/29/69	
APPR'D John A. Moses	14 May 69	REV 0 — SHEET 1 OF 27



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN [signature]	2MAY69	P23-CISLUNAR MIDCOURSE NAVIGATION
PRGMR W. E. Byrd	5/19/69	
ANALST		COLOSSUS IIA — DOCUMENT FC-2600
DOCMR [signature]	9 May 69	
APPR'D John A. Morse	21 May 69	REV O — SHEET 2 OF 27



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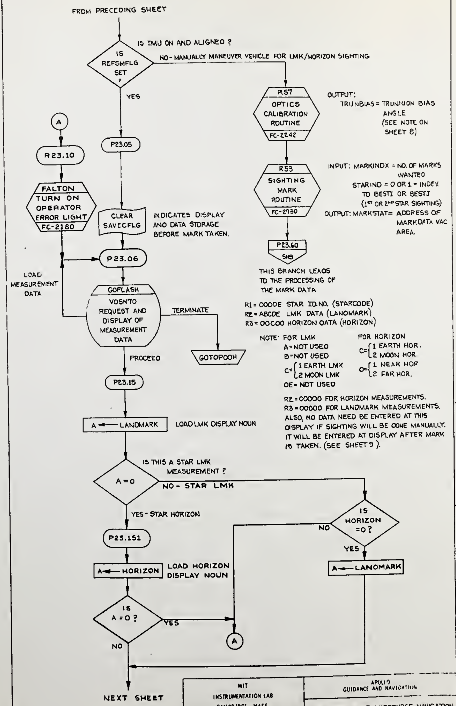
INSTRUMENTATION LAB
CAMBRIDGE, MASS.

DRAWN A.C.WILLIAMS 8NOV68
PRGMR W.E. Byrne 5/13/69
ANALST
DOCMR W.C. Deprett 4/23/69
APPR'D John A. Mouse 21May69

APOLLO
GUIDANCE AND NAVIGATION

P23 - CISLUNAR MIDCOURSE NAVIGATION

COLOSSUS IIA
REV 0
DOCUMENT NO. FC-2600
SHEET 3 OF 27



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APOLLO GUIDANCE AND NAVIGATION

P23 - CISLUNAR MIDCOURSE NAVIGATION

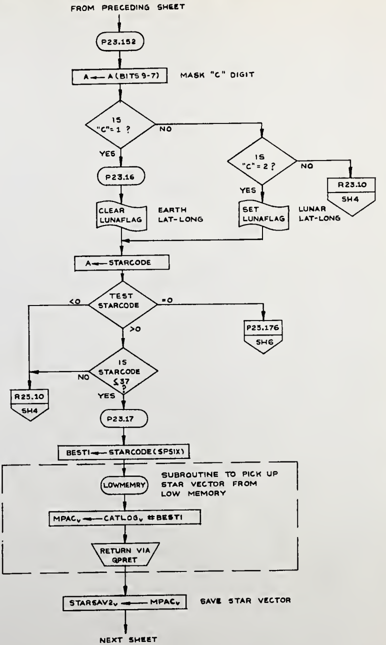
DRAWN	A.C.WILLIAMS	18NOV68
PRGMR	W. E. Byrne	5/16/69
ANALST		
DOCMR	W. C. Dugdale	4/23/69
APPR'D	John A. Moore	26 May 69

REV O

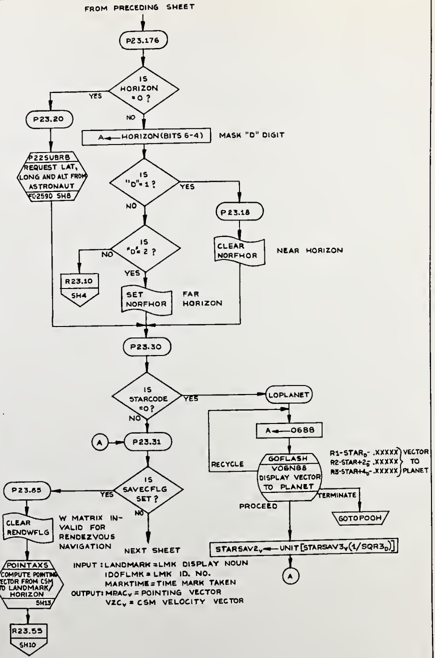
COLOSSUS IIA

DOCUMENT NO. FC-2600

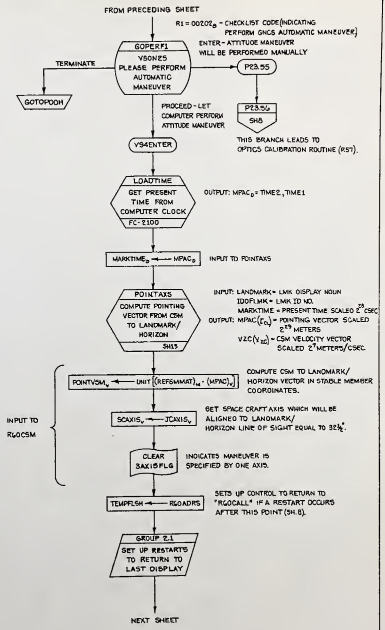
SHEET 4 OF 27



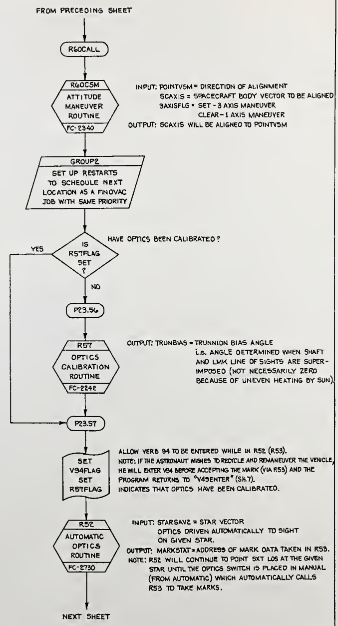
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		P23-CISLUNAR MIDCOURSE NAVIGATION	
DRAWN	16APR69		
PRGMR W. E. Byrne	5/16/69		DOCUMENT NO.
ANALST		COLOSSUS IIA	FC-2600
DOCMR	4/23/69		
APPR'D		REV 0	SHEET 5 OF 27



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN [signature] 17APR69	P23 - CISLUNAR MIDCOURSE NAVIGATION
PROMR W.E. Byrd 5/19/69	
ANALST	COLOSSUS IIA — DOCUMENT # FC-2600
DOCMR [signature] 4/29/69	REV 0 — SHEET 6 OF 27
APPR'D John A. Moore 21 May 69	



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS	15NOV68	P23-CISLUNAR MIDCOURSE NAVIGATION	
PREPAR [signature]	5/13/69	COLOSSUS IIA	DOCUMENT NO. FC-2600
ANALST			
DOCMR [signature]	4/25/69		
APPR'D [signature]	[date]	REV 0	SHEET 7 OF 27



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

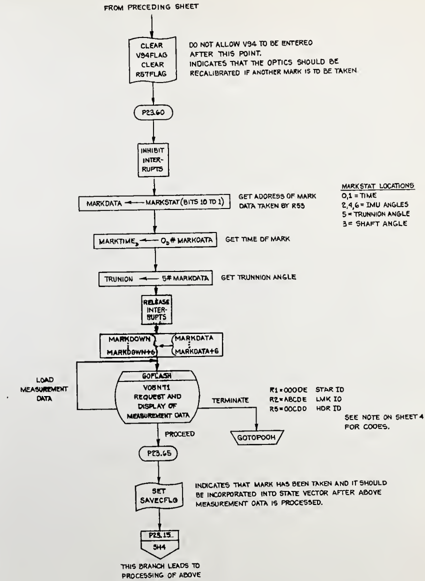
P23-CISLUNAR MIDCOURSE NAVIGATION

DRAWN	A.C.WILLIAMS	15NOV68
PRGMR	W.E. Byrne	5/15/69
ANALST		
DOCMR	W.C. Dughut	4/23/69
APPR'D	John A. Moore	23 May 69

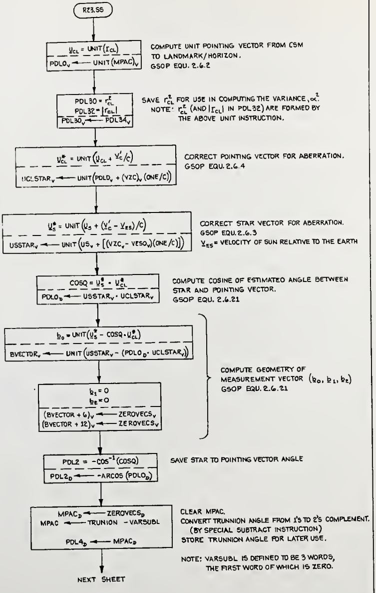
COLOSSUS IIA

DOCUMENT NO. FC-2600

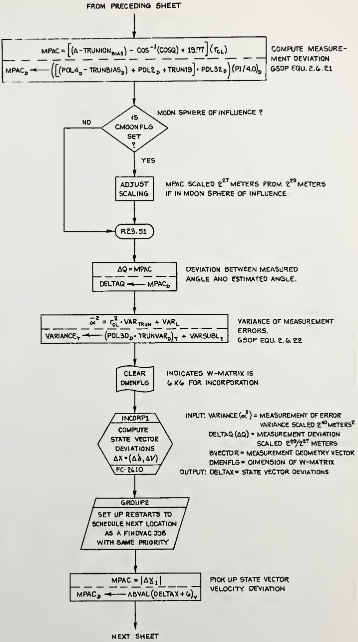
REV O



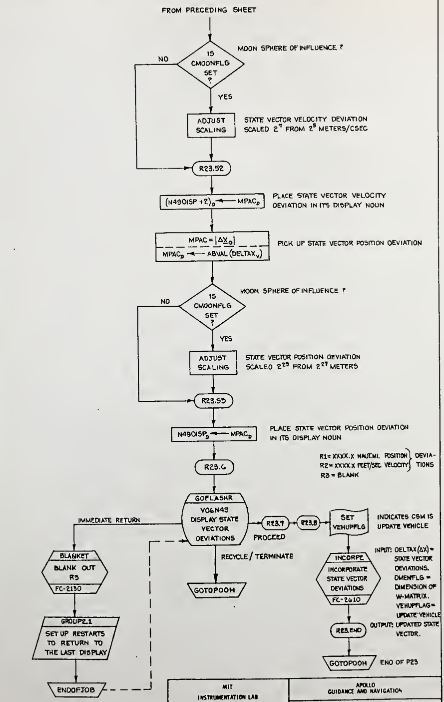
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS	15NOV68	P23 - CISLUNAR MIDCOURSE NAVIGATION	
PRGMR W. E. Byrne	5/1/69	COLOSSUS IIA	DOCUMENT NO. FC-2600
ANALYST			
DOCMR McDonald	6/23/69		
APPR'D John A. Miller	21 May 69	REV O	SHEET 5 OF 27



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C. WILLIAMS 14NOV68	P23-CISLUNAR MIDCOURSE NAVIGATION
PRGMR W. F. [illegible] 5/15/69	
ANALYST	COLOSSUS IIA — DOCUMENT NO. FC-2600
DOCMR W.C. [illegible] 4/23/69	
APPR'D John A. [illegible] 2 May 69	REV 0 — SHEET 10 OF 27



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	14NOV68	P23 - CISLUNAR MIDCOURSE NAVIGATION
PRGMR W. F. Bryne	5/19/69	COLOSSUS IIA — DOCUMENT NO. FC-2600
ANALST		
DOCMR M.C.Dugdale	4/29/69	
APPR'D John W. Moore	21 May 69	REV O — SHEET 11 OF 27



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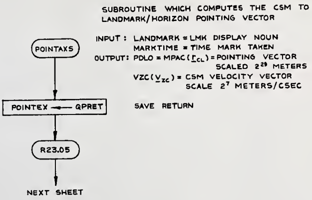
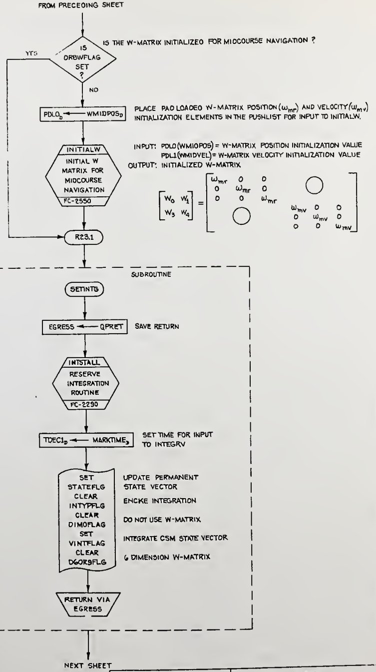
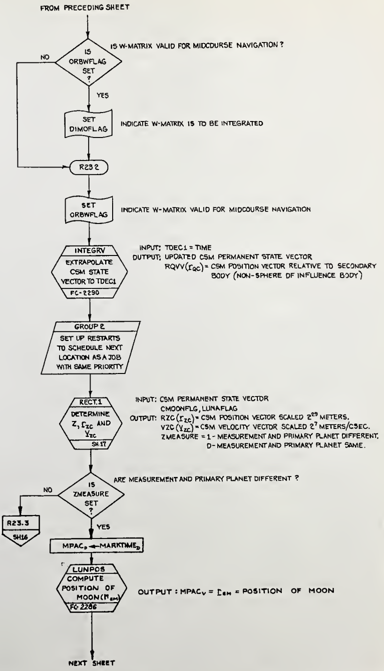
DRAWN A.C.WILLIAMS 15NOV68	P23-CISLUNAR MIDCOURSE NAVIGATION	
PRGMR W. E. Byrne 5/19/69	COLOSSUS IIA	DOCUMENT NO. FC-2600
ANALST		
DOCMR [signature] 5/21/69		
APPR'D [signature] 21 May 69	REV O	SHEET 12 OF 27



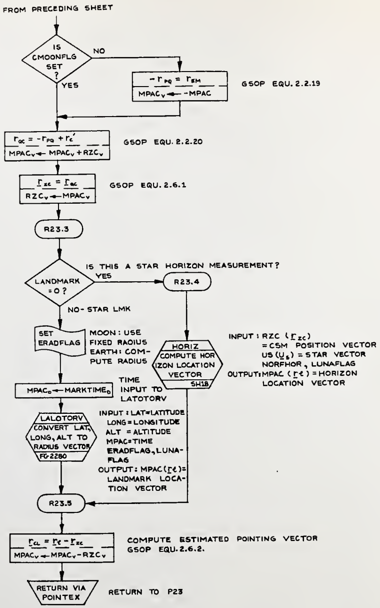
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN 2MAY69	P23 CISLUNAR MIDCOURSE NAVIGATION
PRGMR 5/13/69	
ANALST	COLOSSUS IIA — DOCUMENT NO. FC-2600
DOCMR May 69	
APPR'D 21 May 69	REV 0 — SHEET 13 OF 27



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C. WILLIAMS	25NOV68	P23 - CISLUNAR MIDCOURSE NAVIGATION
PRGMR W.E. Byrne	5/20/69	
ANALST		COLOSSUS IIA — DOCUMENT NO. FC-2600
DOCMR [signature]	4/23/69	
APPR'D John D. Moore	21 May 69	REV O — SHEET 14 OF 27

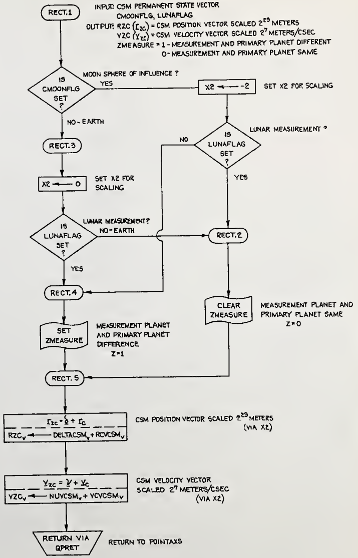


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	25NOV68	P23-CISLUNAR MIDCOURSE NAVIGATION
PRGMR W. E. Byrne	5/1969	
ANALST		COLOSSUS IIA — DOCUMENT NO. FC-2600
DOCMR McDonald	4/23/69	
APPR'D John H. Moore	21 May 69	REV 0 — SHEET 15 OF 27



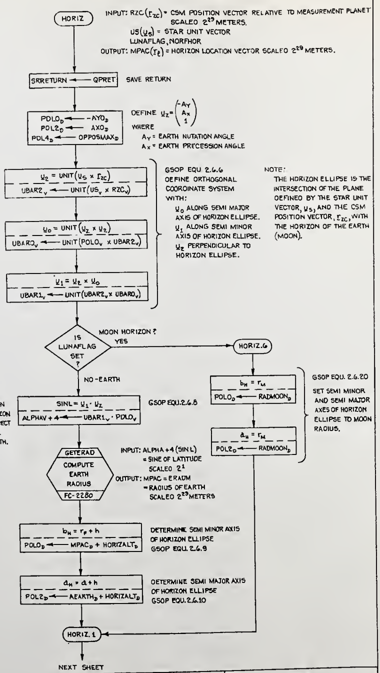
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN [signature]	5 MAY 69	P23 CISLUNAR MIDCOURSE NAVIGATION	
PRGMR [signature]	5/15/69		
ANALST		COLOSSUS IIA	DOCUMENT NO. FC-2600
DOCMR [signature]	[illegible]		
APPR'D [signature]	2 May 69	REV 0	SHEET 16 OF 27

SUBROUTINE TO COMPUTE Z, $\underline{r}_{zc}$ AND $\underline{v}_{zc}$

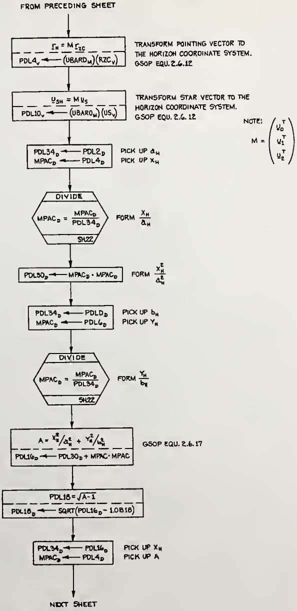


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS 25NOV68	P23-CISLUNAR MIDCOURSE NAVIGATION	
PRGMR W.E. [signature] 5/10/69	COLOSSUS IIA	DOCUMENT NO. FC-2600
ANALST		
DOCMR [signature] 4/29/69		
APPR'D [signature] 21 May 69	REV O	SHEET 17 OF 27

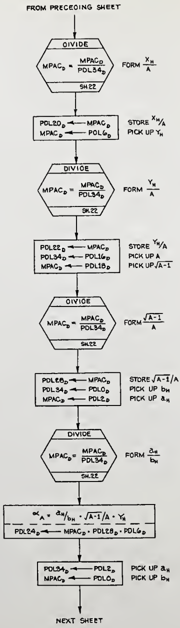
SUBROUTINE WHICH COMPUTES HORIZON LOCATION VECTOR



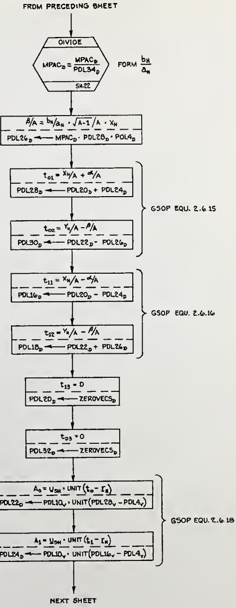
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 26NOV66	P23-CISLUNAR MIDCOURSE NAVIGATION
PRGMR W. E. Byrne 5/12/67	COLOSSUS IIA — DOCUMENT NO. FC-2600
ANALST	
DOCMR [signature] 9/13/67	
APPR'D [signature] 21 May 67	REV 0 — SHEET 18 OF 27



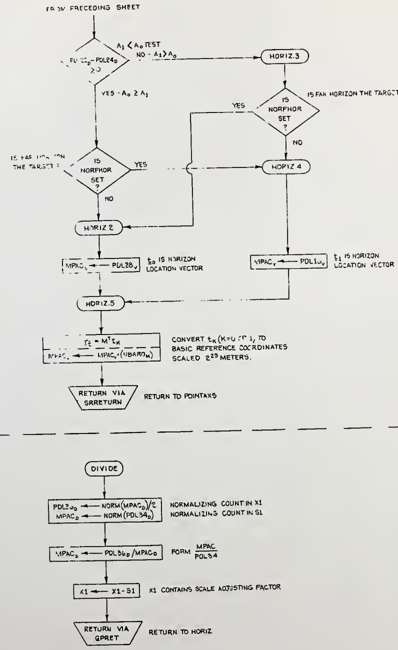
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS 26 NOV 68	P23 - CISLUNAR MIDCOURSE NAVIGATION	
PROGR W.F. Byrd 5/19/69	COLOSSUS IIA	DOCUMENT NO. FC-2600
ANALYST		
SUPVR [signature] 4/23/69		
APPR'D John A. Moran 21 May 69	REV O	SHEET 15 OF 27



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 26NOV68	P23 - CISLUNAR MIDCOURSE NAVIGATION
PRGMR W.E. Byrne 5/10/69	COLOSSUS IIA — DOCUMENT NO. FC-2600
ANALST	
DOCMR McDaghit 4/23/69	
APPR'D John A. Mason 2 May 69	REV O — SHEET 20 of 27



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS	27NOV68	R23-CISLUNAR MIDCOURSE NAVIGATION	
PRGMR W.E. Byrne	5/19/69	COLOSSUS IIA	DOCUMENT NO. FC-2600
ANALST			
DOCMR [signature]	4/23/69		
APPR'D [signature]	21 May 69	REV 0	SHEET 21 OF 27



MIT
INSTRUMENTATION LAB
CAMBRIDGE MASS

DRAWN A.C. WILLIAMS 27NOV68
W.E. Byrne 5/11/69
ANALYST
McDysart 4/29/69
APPR'T John A. Norse 21May69

APOLLO GUIDANCE AND NAVIGATION

R23-CISLUNAR MIDCOURSE NAVIGATION

COLOSSUS IIA FC-2600

REV 0 22 27

SUBROUTINES CALLED WHICH ARE
FLOWED ON OTHER FLOW CHARTS

SUBROUTINE NAME	FLOW CHART	DESCRIPTION	WHERE CALLED
R57	2242	OPTICS CALIBRATION ROUTINE	SH 4, 8
FALTON	2180	TURN ON OPERATOR ERROR LIGHT	SH 4
R53	2730	SIGHTING MARK ROUTINE	SH 4
P22SUBRB	2590	REQUEST LAT, LONG AND ALT FROM ASTRONAUT	SH 6
LOADTIME	2100	GET PRESENT TIME FROM COMPUTER CLOCK	SH 7
R60CSM	2340	ATTITUDE MANEUVER ROUTINE	SH 8
R52	2730	AUTOMATIC OPTICS ROUTINE	SH 8
INCORP1	2610	COMPUTE STATE VECTOR DEVIATIONS	SH 11
INCORP2	2610	INCORPORATE STATE VECTOR DEVIATIONS	SH 12
BLANKET	2130	BLANK OUT CERTAIN DISPLAY REGISTERS	SH 12
INTSTALL	2290	RESERVE INTEGRATION ROUTINE	SH 14
INTEGRV	2290	EXTRAPOLATE CSM STATE VECTOR TO TDEC1	SH 15
LUNPOS	2286	COMPUTE POSITION OF MOON	SH 15
LALOTORV	2280	CONVERT LAT, LONG, ALT TO RADIUS VECTOR	SH 16
GETERAD	2280	COMPUTE EARTH RADIUS	SH 18

FLAGS

NAME	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
RNDVZFLG FLAGWORD 0 BIT 7	P20 IS RUNNING	P20 IS NOT RUNNING		SH 3	
TARG1FLG FLAGWORD 1 BIT 10	SIGHTING ON LEM	NOT SIGHTING ON LEM		SH 3	
TARG2FLG FLAGWORD 1 BIT 9	SIGHTING LANDMARK	SIGHTING STAR		SH 3	
R57FLAG FLAGWORD 8 BIT 8	DO NOT DO R57, TRUNNION BIAS HAS BEEN OBTAINED	DO R57, TRUNNION BIAS NEEDED	SH 8	SH 3, 9	SH 8
V94FLAG FLAGWORD 9 BIT 11	V94 ALLOWED DURING P23	V94 NOT ALLOWED DURING P23	SH 8	SH 3, 9	
REFSMFLG FLAGWORD 3 BIT 13	IMU ON AND ALIGNED	IMU NOT ALIGNED			SH 4
SAVECFLG FLAGWORD 9 BIT 10	P23 DISPLAY AND DATA STORAGE AFTER MARK IS TAKEN	P23 DISPLAY AND DATA STORAGE BEFORE MARK IS TAKEN	SH 9	SH 4	SH 6
LUNAFLAG FLAGWORD 3 BIT 12	LUNAR LAT-LONG	EARTH LAT-LONG	SH 5	SH 5	SH 17, 18
NORFHOR FLAGWORD 0 BIT 11	SIGHTING ON FAR HORIZON	SIGHTING ON NEAR NORIZON	SH 8	SH 6	SH 22
RENDWFLG FLAGWORD 5 BIT 1	W- MATRIX VALID FOR RENDEZVOUS NAVIGA-TION	W- MATRIX INVALID FOR RENDEZVOUS NAVIGATION		SH 6	
3AXISFLG FLAGWORD 5 BIT 6	MANEUVER SPECIFIED BY 3 AXES	MANEUVER SPECIFIED BY 1 AXIS		SH 7	

FLAGS (CONTINUED)

NAME	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
CMOONFLG FLAGWORD 8 BIT 12	PERMANENT CSM STATE VECTOR IN LUNAR SPHERE	PERMANENT CSM STATE VECTOR IN EARTH SPHERE			SH 11, 12, 17
DMENFLG FLAGWORD 5 BIT 9	DIMENSION OF W-MATRIX IS 9 FOR INCORPORATION	DIMENSION OF W- MATRIX IS 6 FOR INCORPORATION		SH 11	
VEHUPFLG FLAGWORD 1 BIT 8	CSM STATE VECTOR IS BEING UPDATED	LEM STATE VECTOR IS BEING UPDATED	SH 12		
ORBWFLAG FLAGWORD 3 BIT 6	W- MATRIX VALID FOR MIDCOURSE NAVIGATION	W- MATRIX INVALID FOR MIDCOURSE NAVIGATION	SH 15		SH 14, 15
STATEFLG FLAGWORD 3 BIT 5	PERMANENT STATE VECTOR TO BE UPDATED	PERMANENT STATE VECTOR NOT TO BE UPDATED	SH 14		
INTYPFLG FLAGWORD 3 BIT 4	CONIC INTEGRATION	ENCKE INTEGRATION		SH 14	
DIMOFLAG FLAGWORD 3 BIT 1	W - MATRIX IS TO BE USED	W- MATRIX NOT TO BE USED	SH 15	SH 14	
VINTFLAG FLAGWORD 3 BIT 3	CSM STATE VECTOR TO BE INTEGRATED	LEM STATE VECTOR TO BE INTEGRATED	SH 14		
D6OR9FLG FLAGWORD 3 BIT 2	DIMENSION OF W-MATRIX IS 9 FOR INTEGRATION	DIMENSION OF W- MATRIX IS 6 FOR INTEGRATION		SH 14	
ZMEASURE FLAGWORD 0 BIT 10	MEASUREMENT PLANET AND PRIMARY PLANET DIFFERENT	MEASUREMENT PLANET AND PRIMARY PLANET SAME	SH 17	SH 17	SH 15
ERADFLAG FLAGWORD I BIT 13	EARTH: COMPUTE FISCHER ELLIPSOID RADIUS	EARTH: USE FIXED RADIUS	SH 16		
	MOON: USE FIXED RADIUS	MOON: USE RLS FOR RADIUS			

DISPLAYS

VERB-NOUN	TYPE OF DISPLAY	DESCRIPTION OF EACH REGISTER		WHERE EXECUTED
V05N70	FLASHING	R1 = 000DE = STAR ID NO R2 = ABCDE = LMK DATA R3 = 00CD0 = HORIZON DATA	REQUEST MEASUREMENT DATA BEFORE MARK IS TAKEN	SH 4
V06N88	FLASHING	R1 = $STAR_D$ − .XXXXX R2 = $STAR+2_D$ − .XXXXX R3 = $STAR+4_D$ − .XXXXX	VECTOR TO PLANET	SH 6
V50N25	FLASHING	R1 = 00202 PLEASE PERFORM AUTOMATIC MANEUVER		SH 7
V05N71	FLASHING	R1 = 000DE = STAR ID NO R2 = ABCDE = LMK DATA R3 = 000CD0 = HORIZON DATA	REQUEST MEASUREMENT DATA AFTER MARK IS TAKEN	SH 9
V06N49	FLASHING	R1 = XXXX.X NAUT. MI. POSITION DEVIATION R2 = XXXX.X FEET/SEC VELOCITY DEVIATION R3 = BLANK		SH 12

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION P23-CISLUNAR MIDCOURSE NAVIGATION
DRAWN / PRGMR / ANALST / DOCMR / APPR'D	COLOSSUS IIA — DOCUMENT NO. FC-2600
	REV 0 — SHEET 24 OF 27

ERASABLE LOCATIONS USED

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNIT	AGC UNIT	AGC SCALING
PHSPRDT2		RESTART PRIORITY REGISTER		(INTEGER)	2^{14}
MARKINDX		NUMBER OF MARKS WANTED REGISTER		(INTEGER)	2^{14}
STARIND		STAR INDEX TO BESTI OR BESTJ		(INTEGER)	2^{14}
BESTI		RELATIVE ADDRESS OF DESIRED IN STAR TABLES		(INTEGER)	2^{14}
LANDMARK		LANDMARK DATA DISPLAY NOUN		(INTEGER)	2^{14}
HORIZON		HORIZON DATA DISPLAY NOUN		(INTEGER)	2^{14}
STARCODE		STAR ID NO DISPLAY NOUN		(INTEGER)	2^{14}
STARSAV2 (ALSO TAGGED US)		TEMPORARY STORAGE OF STAR 1 UNIT VECTOR			$(2^1, 2^1, 2^1)$
IDOFLMK		LANDMARK ID NUMBER		(INTEGER)	2^{14}
MARKTIME		TIME OF MARK	SEC	CSEC	2^{28}
REFSMMAT		TRANSFORMATION MATRIX BASIC REFERENCE TO STABLE MEMBER COORDINATES			2^1
POINTVSM		DESIRED TRACK AXIS			$(2^1, 2^1, 2^1)$
SCAXIS		SPACE CRAFT AXIS TO BE ALIGNED WITH POINTVSM			$(2^1, 2^1, 2^1)$
R60ADRS		DESIRED ADDRESS OF 'R60 CALL'		(INTEGER)	2^{14}
TEMPFLSH		RESTART RETURN ADDRESS		(INTEGER)	2^{14}
MARKDATA		ADDRESS OF MARK DATA STORAGE LOCATIONS		(INTEGER)	2^{14}
MARKSTAT		MARK DATA INFORMATION REGISTER FROM R53		(INTEGER)	2^{14}
TRUNNION		MEASURED TRUNNION ANGLE	DEG	REV	2^3
UCLSTAR	$\underline{u}^*_{CL}$	CSM TO LANDMARK/HORIZON UNIT VECTOR CORRECTED FOR ABERRATION			$(2^1, 2^1, 2^1)$
VZC	$\underline{v}'_C$	CSM VELOCITY VECTOR	FEET/SEC	METERS/ CSEC	$(2^7, 2^7, 2^7)$
USSTAR	$\underline{u}^*_S$	STAR UNIT VECTOR CORRECTED FOR ABERRATION			$(2^1, 2^1, 2^1)$
US	$\underline{u}_S$	STAR UNIT VECTOR			$(2^1, 2^1, 2^1)$
BVECTOR	$(\underline{b}_0, \underline{b}_1, \underline{b}_2)$	GEOMETRY OF MEASUREMENT MATRIX			VARIABLE
TRUNBIAS		CALIBRATION ANGLE FOR SEXTANT	DEG	REV	2^3
DELTAQ	δQ	MEASURED AND ESTIMATED DEVIATION	NAUT. MI.	METERS	$2^{29}/2^{27}$
VARIANCE	$-\alpha^2$	VARIANCE OF MEASUREMENT ERRORS		$METERS^2$	2^{40}
DELTAX	$\delta\underline{x}_0$	STATE VECTOR POSITION DEVIATIONS	NAUT. MI.	METERS	$2^{29}/2^{27}$
DELTAX+6	$\delta\underline{x}_1$	STATE VECTOR VELOCITY DEVIATIONS	FEET/SEC	METERS/ CSEC	$2^7/2^5$
N49DISP		DISPLAY NOUN FOR DELTAX	NAUT. MI.	METERS	2^{29}
N49DISP+6		DISPLAY NOUN FOR DELTAX+6	FEET/SEC	METERS/ CSEC	2^7
POINTEX		RETURN ADDRESS FROM POINTAXS		(INTEGER)	2^{14}

ERASABLE LOCATIONS USED (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNIT	AGC UNIT	AGC SCALING
ALT		ALTITUDE	NAUT. MI	METERS	2^{29}
LAT		LATITUDE	DEG	REV	2^{0}
LONG		LONGITUDE	DEG	REV	2^{0}
LANDALT		ALTITUDE DISPLAY NOUN	NAUT. MI.	METERS	2^{29}
LANDLONG		LONGITUDE DISPLAY NOUN	DEG	REV	2^{0}
EGRESS		SUBROUTINE RETURN ADDRESS		(INTEGER)	2^{14}
TDEC1		TIME FOR INTEGRATION	SEC	CSEC	2^{28}
RZC	$\underline{r}_{ZC}$	CSM POSITION VECTOR RELATIVE TO MEASUREMENT PLANET		METERS	2^{29}
RQVV	$\underline{r}_{QC}$	CSM POSITION VECTOR RELATIVE TO SECONDARY PLANET		METERS	2^{29}
RL	$\underline{r}_{\ell}$	LANDMARK/HORIZON LOCATION VECTOR		METERS	2^{29}
RCLL	$\underline{r}_{CL}$	CSM TO LANDMARK/HORIZON VECTOR		METERS	2^{29}
DELTACSM	$\underline{\delta}$	CSM CONIC POSITION DEVIATION		METERS	$2^{22}/2^{18}$
RCVCSM	$\underline{r}_{C}$	CSM REFERENCE CONIC POSITION		METERS/ CSEC	$2^{29}/2^{27}$
NUVCSM	$\underline{\nu}$	CSM CONIC VELOCITY DEVIATION		METERS/ CSEC	$2^{'}/2^{5}$
VCVCSM	$\underline{v}_{C}$	CSM REFERENCE CONIC VELOCITY		METERS/ CSEC	$2^{3}/2^{-1}$
SRRETURN		RETURN ADDRESS FROM HORIZ			
UBAR0	$\underline{U}_0$	DEFINE HORIZON COORDINATE SYSTEM			$(2^1, 2^1, 2^1)$
UBAR1	$\underline{U}_1$				$(2^1, 2^1, 2^1)$
UBAR2	$\underline{U}_2$				$(2^1, 2^1, 2^1)$
ALPHAV+4		SINE OF LATITUDE (FOR GETERAD)			2^{1}

PROGRAM CONSTANTS

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING VALUE AND UNITS	AGC VALUE AND UNITS	AGC SCALING
PRI013		PRIORITY 13 REGISTER	13	13000	2^{14}
SPSIX		SINGLE PRECISION 6	9	00006	2^{14}
CATLOG		BEGINNING ADDRESS OF STORED STAR VECTORS		(INTEGER)	2^{14}
JCAXIS		TRACK AXIS VECTOR	$57^{1/2°}$ $90°$ $32^{1/2°}$	.269649905 0 .421695725	2^1 2^1 2^1
ONE/C		RECIPROCAL OF SPEED OF LIGHT	$1/9.935712 \times 10^{-9}$ FT/SEC	$.333564049 \times 10^{-6}$ CSEC/METERS	2^{-21}
ZEROVECS		BEGINNING ADDRESS OF 6 REGISTERS OF 0	0	0	2^{14}
VARSUBL		LANDMARK/HORIZON ERROR VARIANCE		3.4299040×10^6	2^{40}
TRUN19		TRUNNION BIAS ANGLE	19.77 DEG	.055 REVS	2^0
PI/4.0		CONVERSION FACTOR REVS TO RADIANS	$2\pi \frac{RAD}{REV}$	$.1592 \frac{RAD}{REV}$	2^3
TRUNVAR		TRUNNION ERROR VARIANCE		2.5×10^{-9}	2^{-19}
9DWID		DECIMAL 2		(INTEGER)	2^{14}
LATTAB		BEGINNING ADDRESSES OF STORED LANDMARK LATITUDE, LONGITUDE, AND ALTITUDE TABLES		(INTEGER)	2^{14}
LONGTAB					
ALTTAB					
DPPOSMAX		DOUBLE PRECISION REGISTER CONTAINING MAXIMUM VALUE	.999999996	37777 37777	2^0
PADMOON	r_m	RADIUS OF MOON		1739090 METERS	2^{29}
AEARTH	a	A - AXIS OF EARTH		6379169 METERS	2^{29}

PAD LOADS

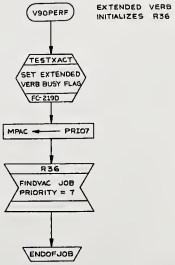
AGC TAG	GSOP TAG	MEANING
WMIDPOS	w_{mr}	W - MATRIX POSITION INITIALIZATION VALUE
WMIDVEL	w_{vr}	W - MATRIX VELOCITY INITIALIZATION VALUE
VESO	$\underline{V}_{ES}$	VELOCITY OF SUN RELATIVE TO EARTH
AYO	A_Y	EARTH NUTATION ANGLE
AXO	A_X	EARTH PRECESSION ANGLE
HORIZALT	h	EARTH HORIZON ALTITUDE

R36: OUT-OF-PLANE RENDEZVOUS ROUTINE

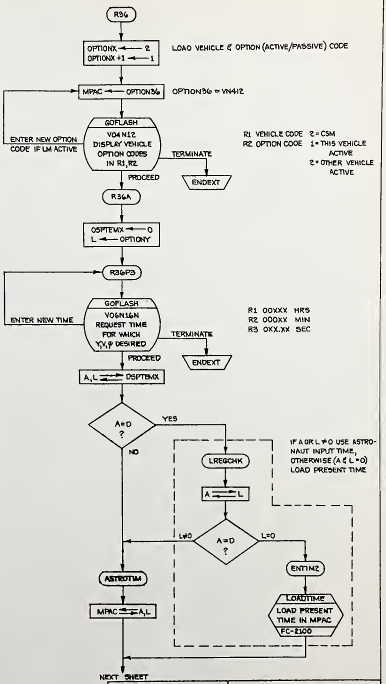
FC-2631

V90PERF, R36

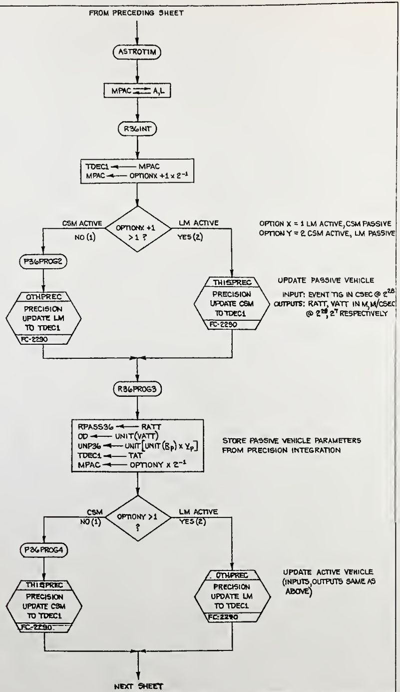
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS	10APR69	R36 RENDEZVOUS OUT-OF-PLANE DISPLAY	
PRGMR J.E. Cocken	25APR69		DOCUMENT NO.
ANALST		COLOSSUS II-A	FC-2631
DOCMR [signature]	15 April 69		
APPR'D John A. Moss	1 May 69	REV 1	SHEET 1 OF 7



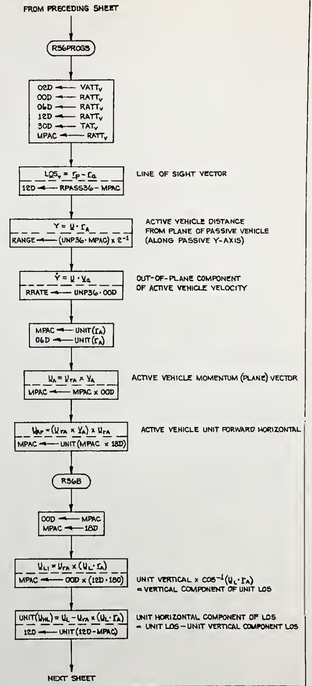
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
	R36 RENDEZVOUS OUT-OF-PLANE DISPLAY
DRAWN [illegible] 27 May 69 PRGMR J. E. [illegible] [illegible] ANALST DOCMR [illegible] [illegible] APPR'D [illegible]	COLOSSUS II-A — DOCUMENT NO. FC-2631
	REV 1 — SHEET 2 OF 7



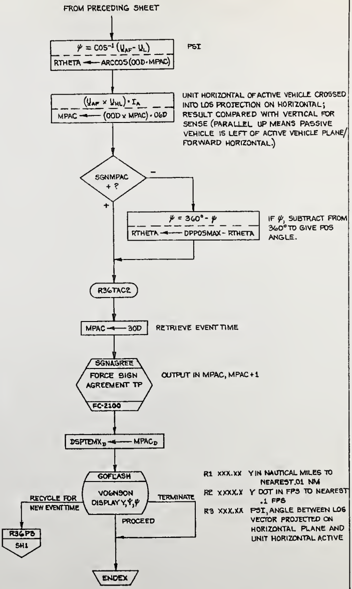
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C. WILLIAMS 30APR69	R36 RENDEZVOUS OUT-OF-PLANE DISPLAY
PRGMR 22APR69	COLOSSUS II-A
ANALYST	DOCUMENT NO. FC-2631
DOCMR 23 April 69	
APPR'D 1 May 69	REV 1 — SHEET 3 OF 7



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	11APR69	R36 RENDEZVOUS OUT-OF-PLANE DISPLAY
PRGMR [signature]	23APR69	
ANALST		COLOSSUS II-A — DOCUMENT NO. FC-2631
DOCMR [signature]	23 April 69	
APPR'D [signature]	1 May 69	REV — SHEET 4 OF 7



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C. WILLIAMS 11APR69	R36 RENDEZVOUS OUT-OF-PLANE DISPLAY
PRGMR 23APR69	
ANALST	COLOSSUS II-A — DOCUMENT NO. FC-2631
DOCMR	
APPR'D	REV 1 — SHEET 5 OF 7



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C. WILLIAMS 11APR69	R36 RENDEZVOUS OUT-OF-PLANE DISPLAY
PRGMR [signature]	COLOSSUS II-A
ANALST	DOCUMENT NO. FC-2631
DOCMR [signature]	REV 1
APPR'D [signature]	SHEET 6 OF 7

SUBROUTINES

LOADTIME	LOADS PRESENT TIME INTO MPAC	SH 3
THISPREC	ENKE UPDATE OF CSM	SH 4
OTHPREC	ENKE UPDATE OF LM	SH 4
SGNAGREE	FORCE SIGN AGREEMENT (TRIPLE PRECISION)	SH 6
TESTXACT	SETS EXTENDED VERB BUSY FLAG	SH 2

DISPLAYS

		WHERE
V04N12	DISPLAY VEHICLE CODE (1=LM, 2=CSM) IN R1 AND OPTION CODE (1= THIS VEHICLE ACTIVE, 2 = PASSIVE) IN R2	SH1
V06N16N	REQUEST TIME FOR WHICH Y, Ẏ, ψ DESIRED	SH1
V06N90N	DISPLAY Y, Ẏ, ψ	SH4

ERASABLES

		UNITS	SCALING
OPTIONX	VEHICLE OPTION CODE (LM=1, CSM=2)		2^1
OPTIONX +1	(EQUALS OPTIONY) VEHICLE CODE (1=CSM ACTIVE, 2= LM ACTIVE)		2^1
DSPTEMX	DISPLAY BUFFER AREA (SAME AS OPTIONX)		
TDEC1	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	Ẏ, ACTIVE VEHICLE VELOCITY COMPONENT NORMAL TO PASSIVE PLANE	M/CSEC	
RTHETA	ψ, ANGLE BETWEEN ACTIVE VEHICLE UNIT FORWARD HORIZONTAL & LOS PROJECTED INTO HORIZONTAL PLANE		

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C. WILLIAMS 24APR69	R36 RENDEZVOUS OUT-OF-PLANE DISPLAY
PRGMR J E Cooke 23 MAY	
ANALST	COLOSSUS II -A — DOCUMENT NO. FC-2631
DOCMR [signature] 29 Apr 69	
APPR'D John A. Moore 1 May 69	REV 1 — SHEET 7 OF 7

MAJOR SUBROUTINES

V2T100 SETS UP INTERMEDIATE VARIABLES FOR GAMDV10 ITERATOR, LIMITS X(T1) CHANGE, TESTS RESULTS

GAMDV10 SUBROUTINE WHICH PRODUCES MINIMUM SOLUTIONS FROM ITERATION ON X(T1)

PREC100 PRODUCES PRECISION TRAJECTORY CLOSE TO FINAL RADIUS AND FLIGHT PATH ANGLE PRODUCED BY CONIC SECTION

RTEVN COMPUTES AND DISPLAYS LANDING SITE

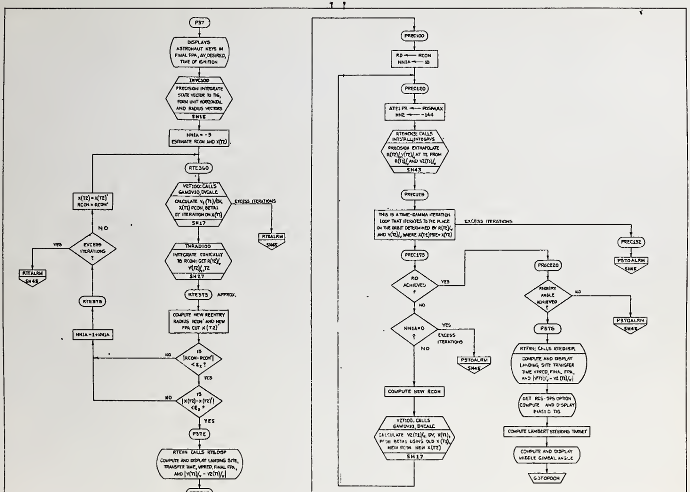
SPECIAL CONVENTIONS

BECAUSE OF THE WIDE VARIETY OF SITUATIONS WHICH THIS PROGRAM MUST HANDLE, EXTENSIVE USE IS MADE OF FLOATING POINT ARITHMETIC. THIS INVOLVES NORMALIZATION, WITH THE SHIFT COUNT PUT INTO X1, X2, S1 OR S2. AN OPERATION WHICH NORMALIZES A QUANTITY Z, AND PUTS SHIFT COUNT INTO X1 IS SHOWN BY $NORM_{X1}(Z)$.

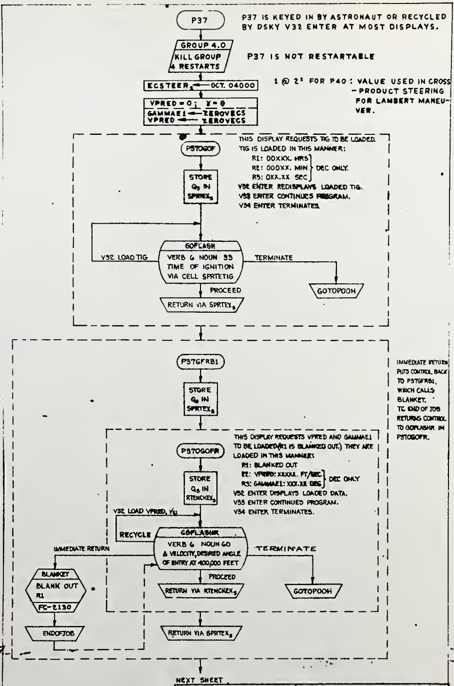
ALL QUANTITIES ARE DOUBLE PRECISION UNLESS INDICATED IN THIS MANNER SUBSCRIPT S FOR SINGLE PRECISION, SUBSCRIPT T FOR TRIPLE, SUBSCRIPT V FOR VECTOR.

ENCLOSED IS A REPLACEMENT SHEET (SH. 17) TO UPDATE THE COLOSSUS II FLOW CHART FC-2642, REV. 0, TO THE COLOSSUS IIC FLOW CHART FC-2642, REV. 1

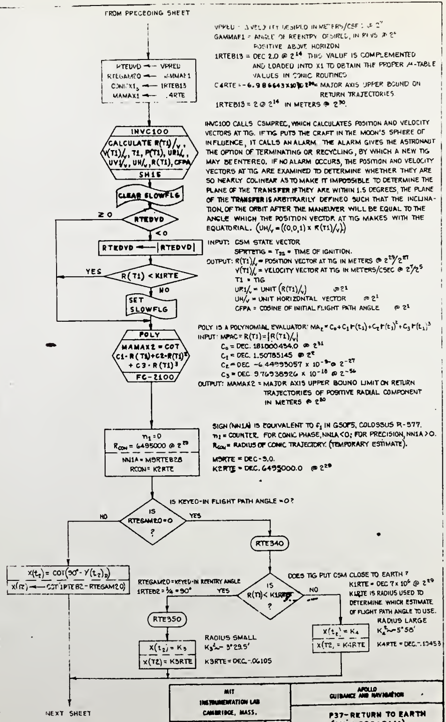
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN / PROGMR / ANALST / SUBMIT / APPVD (signatures)	F P37 RETURN TO EARTH
	COLOSSUS IIC — DOCUMENT NO. FC-2642
	REV. 1 — SHEET 1 OF 53



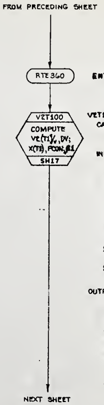
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A. C. WILLIAMS	19DEC68	P37 - RETURN TO EARTH (GENERAL FLOW)	
PRGMR			
ANALST		COLOSSUS II	DOCUMENT NO. FC-2642
DOCMR			
APPR'D		REV	SHEET 2 OF 53



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS		P37 - RETURN TO EARTH (MAIN PROGRAM)	
PRGMR			
ANALST		COLOSSUS II	DOCUMENT NO. FC-2642
DOCMR			
APPR'D		REV	SHEET 5 OF 63



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 28DEC68	P37-RETURN TO EARTH (MAIN PROGRAM)
PROGR [signature] 9APR69	COLOSSUS II
ANALYST [signature]	DOCUMENT NO. FC-2642
DOCMR [signature] 7Apr69	
APPR'D John A. Morse 9 April 69	REV — SHEET 4 OF 53



ENTRANCE FROM RTE390

V2T100

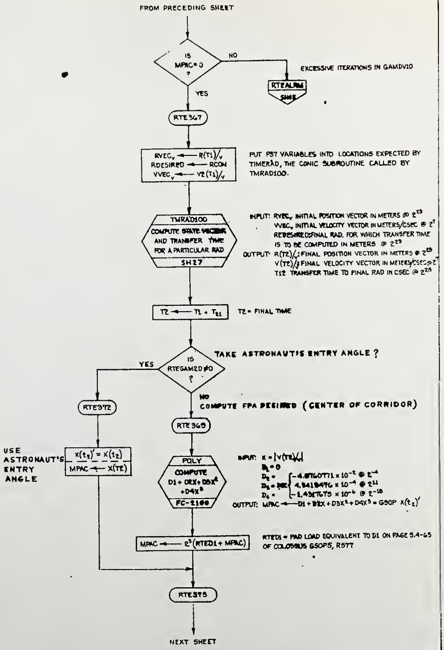
CALLS: GAMDV10
XT1LIM
DVCALC

INPUT:

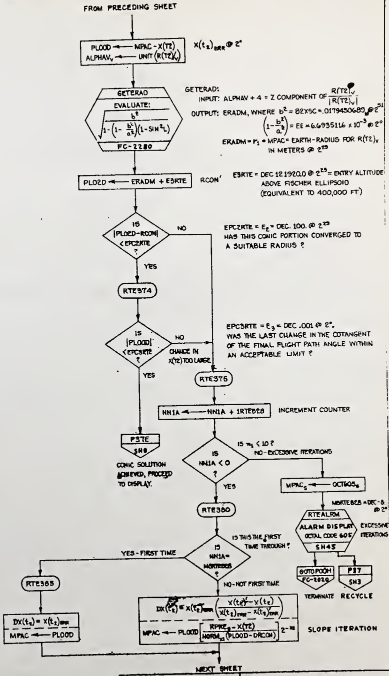
1) R(T1) = MAGNITUDE OF INITIAL POSITION VECTOR IN METERS @ 2^{29}
2) RCON = MAGNITUDE OF FINAL POSITION VECTOR IN METERS @ 2^{29}
3) V(T1)/V = INITIAL VELOCITY VECTOR IN METERS/CSEC @ 2^7
4) RTEDVD = Δ VELOCITY DESIRED IN METERS/CSEC @ 2^7
5) UR1/V = UNIT INITIAL POSITION VECTOR @ 2^1
6) UH/V = UNIT HORIZONTAL VECTOR @ 2^1
7) X(T2) = COT OF FINAL FLIGHT PATH ANGLE @ 2^0
8) CFPA = COS OF INITIAL FLIGHT PATH ANGLE @ 2^1
9) MAMAX1 } TEMPORARY { LOWER } BOUND ON GAMDV INTERATOR
10) MAMAX2 } TEMPORARY { UPPER } BOUND ON GAMDV INTERATOR
IN METERS @ 2^{30}
11) NN1A = CONIC ITERATION COUNTER. (NN1A < 0 IMPLIES THIS IS CONIC PHASE.)

OUTPUT:

1) V2(T1)/V = POST-IMPULSE INITIAL VELOCITY VECTOR IN METERS/CSEC @ 2^7
2) DV = INITIAL DELTA V IN METERS/CSEC @ 2^7
3) X(T1) = COTAN OF INITIAL FPA (POST-IMPULSE) @ 2^5
4) PCON = SEMI-LATUS RECTUM IN METERS @ 2^{28}
5) BETA1 = 1 + X(T2)^2
6) MPAC = 0, NORMAL EXIT
MPAC ≠ 0, ALARM CODE OCT 605 - EXCESSIVE ITERATIONS IN GAMDV10.
7) ABORT EXIT TO POODOO : OCT 610



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A. C. WILLIAMS	P37 - RETURN TO EARTH (MAIN PROGRAM)
PROGR.	COLOSSUS	DOCUMENT NO. FC-2642
ANALYST	
SUPVR	
APP'D	SHEET 6 OF 13



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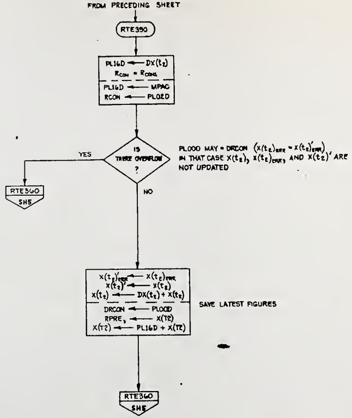
DRAWN A.C. WILLIAMS	P37 - RETURN TO EARTH (MAIN PROGRAM)	
PROGR		
ANALST	COLOSSUS II	DOCUMENT NO. FC-2642
DOCMR		
APPR'D	REV	SHEET 7 OF 53



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DRAWN A.C. WILLIAMS	P37 – RETURN TO EARTH (MAIN PROGRAM)
PROGR / ANALYST / DOCMR / APPR'D	COLOSSUS II — DOCUMENT NO. FC-2642
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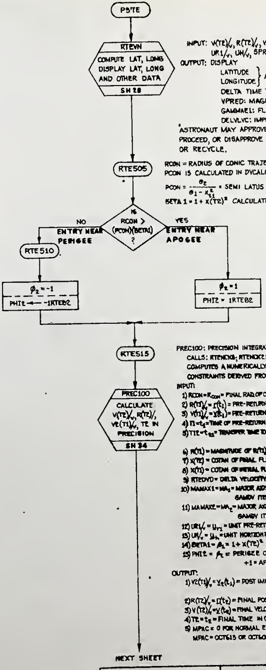

INPUT: V(T2)/v, R(T2)/v, V2(T1)/v, V(T1)/v,
UR1/v, UH/v, 5PRETIG, T2.

OUTPUT: DISPLAY
LATITUDE } AT 400,000 FT.
LONGITUDE }
DELTA TIME TO 400,000 FT
VPRED: MAGNITUDE OF VELOCITY AT 400,000 FT.
GAMMAE1: FLIGHT PATH ANGLE AT 400,000 FT.
DELVLVC: IMPULSIVE DELTA V

*ASTRONAUT MAY APPROVE OF THESE CALCULATIONS AND PROCEED, OR DISAPPROVE AND EITHER TERMINATE OR RECYCLE.

RCON = RADIUS OF CONIC TRAJECTORY.
PCON IS CALCULATED IN DVCALC.

PCON = $\frac{\theta_2}{\theta_1 - x_{t1}^2}$ = SEMI LATUS RECTUM

BETA 1 = 1 + X(T2)^2 CALCULATED IN V2T100

(THIS OCCURS ONLY FOR NEARLY CIRCULAR ORBITS.)

PREC100: PRECISION INTEGRATION SUBROUTINE
CALLS: RTENCK3; RTENCK2; PARAM; TIMERAD; V2T100, INTSTALL
COMPUTES A NUMERICALLY INTEGRATES A TRAJECTORY, USING CONSTRAINTS DERIVED FROM THE CONIC INTEGRATION.

INPUT:
1) RCON = R_{CON} = FINAL RAD. OF CONIC TRAJECTORY IN METERS @ 2^{29}
2) R(T1)/v = $\underline{r}(t_1)$ = PRE-RETURN POS. VECTOR IN METERS @ 2^{29}
3) V(T1)/v = $\underline{v}(t_1)$ = PRE-RETURN VELOCITY VECTOR IN M/CSEC @ 2^7
4) T1 = t_1 = TIME OF PRE-RETURN STATE VECTOR IN CSEC @ 2^{28}
5) T12 = t_{12} = TRANSFER TIME TO T2, THE FINAL POSITION TIME, IN CSEC @ 2^{28}
6) R(T1) = MAGNITUDE OF R(T1)/v, IN METERS @ 2^{29}
7) X(T2) = COTAN OF FINAL FLIGHT PATH ANGLE @ 2^0
8) X(T1) = COTAN OF INITIAL FLIGHT PATH ANGLE @ 2^5
9) RTEDVD = DELTA VELOCITY DESIRED IN METERS/CSEC @ 2^7
10) MAMAX1 = MA_1 = MAJOR AXIS LIMIT ON LOWER BOUND OF GAMDV ITERATOR IN METERS @ 2^{30}
11) MAMAX2 = MA_2 = MAJOR AXIS LIMIT ON UPPER BOUND OF GAMDV ITERATOR IN METERS @ 2^{30}
12) UR1/v = $\underline{u}_{r1}$ = UNIT PRE-RETURN POSITION VECTOR @ 2^1
13) UH/v = $\underline{u}_h$ = UNIT HORIZONTAL VECTOR @ 2^1
14) BETA1 = β_1 = 1 + X(T2)^2 @ 2^1
15) PHI2 = ϕ_2 = PERIGEE OR APOGEE @ 2^2
+1 = APOGEE -1 = PERIGEE

OUTPUT:
1) V2(T1)/v = $\underline{v}_2(t_1)$ = POST IMPULSE INITIAL VELOCITY VECTOR IN METERS/CSEC @ 2^7
2) R(T2)/v = $\underline{r}(t_2)$ = FINAL POSITION VECTOR IN METERS @ 2^{29}
3) V(T2)/v = $\underline{v}(t_2)$ = FINAL VELOCITY VECTOR IN METERS/CSEC @ 2^7
4) T2 = t_2 = FINAL TIME IN CSEC @ 2^{28}
5) MPAC = 0 FOR NORMAL EXIT
MPAC = OCT615 OR OCT605 FOR ALARM EXIT.

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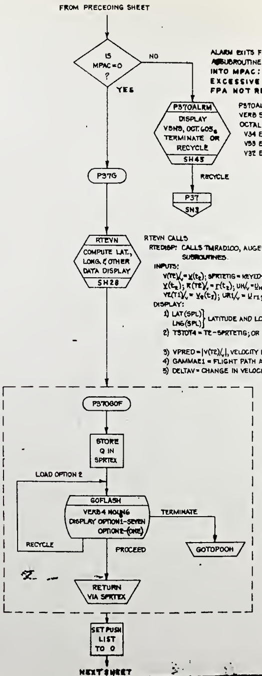
DRAWN A. C. WILLIAMS	[illegible]	P37- RETURN TO EARTH (MAIN PROGRAM)
CHECKED [illegible]	[illegible]	COLOSSUS II / DOCUMENT NO. FC-2642
ANALYST [illegible]	[illegible]	
DOCMN [illegible]	[illegible]	
APPR'D [illegible]	[illegible]	REV / SHEET 9 OF 53



ALARM EXITS FROM PREC100, AND GAMDV10, SUBROUTINE, LOAD 605 OR 613 OCT INTO MPAC:
EXCESSIVE ITERATIONS OR FINAL FPA NOT REACHED.

P37OALRM CALLS GOFLASH, WITH A VERB 5 NOUN 9, AND DISPLAYS OCTAL 605 OR 613 ALARM CODE.
V34 ENTER TERMINATES PROGRAM
V33 ENTER CONTINUES THE FLASH
V32 ENTER RECYCLES P37.

RTEVN CALLS
RTEDISP: CALLS TMRAD100, AUGEKUGL AND LAT-LONG SUBROUTINES.

INPUTS:
V(T2)/$_v$ = $\underline{v}(t_2)$; SPRTETIG = KEYED-IN TIG; T2 = TEMPORARY TIME OF $\underline{v}(t_2)$; R(T2)/$_v$ = $\underline{r}(t_2)$; UH/$_v$ = $\underline{u}_H$; V(T1)/ = $\underline{v}_1(t_1)$.
VE(T1)/$_v$ = $\underline{v}_e(t_2)$; UR1/$_v$ = $\underline{u}_{r1}$;

DISPLAY:
1) LAT(SPL), LNG(SPL) — LATITUDE AND LONGITUDE OF SPLASHDOWN.
2) TSTOT4 = T2 − SPRTETIG; OR $t_2 - T_{IG}$ = TRANSFER TIME TO 400,000 FT.
3) VPRED = |V(T2)/$_v$|, VELOCITY MAGNITUDE AT 400,000 FT.
4) GAMMAE1 = FLIGHT PATH ANGLE.
5) DELTAV = CHANGE IN VELOCITY MAGNITUDE.

DISPLAY OPTION CODE, AND SPS OPTION
OPTION1 = SEVEN = RCS-SPS OPTION
OPTION2 = ONE = SPS OPTION (ASSUMED)

FOR SPS – PROCEED (OR LOAD R2 WITH OCT 1)
FOR RCS – LOAD OPTION2 WITH OCT. 0002.

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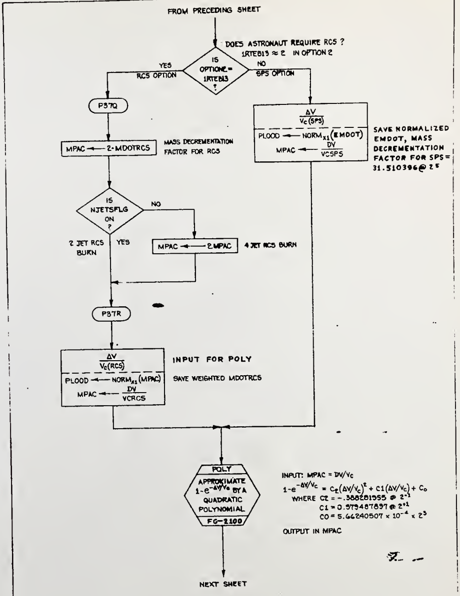
DOCMN		
APPR'D	REV	SHEET 10 OF 53



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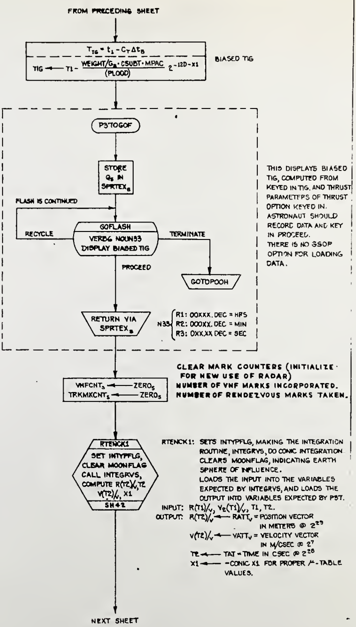
DRAWN A.C.WILLIAMS	6 JAN 69	P37– RETURN TO EARTH (MAIN PROGRAM)	
PROGR [signature]	[date]		
ANALST [signature]	[date]	COLOSSUS II	DOCUMENT NO. FC-2642
DOCMR [signature]	[date]		
APPR'D [signature]	[date]	REV	SHEET 11 OF 53



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DRAWN A.C.WILLIAMS 6 JAN 69	P37- RETURN TO EARTH (MAIN PROGRAM)
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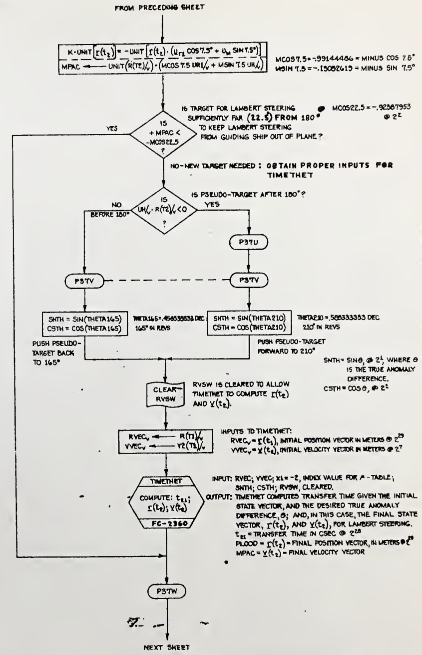
DOCMR [signature] 7 Apr 69	
APPR'D John A. Moran April 69	REV / SHEET 12 OF 53



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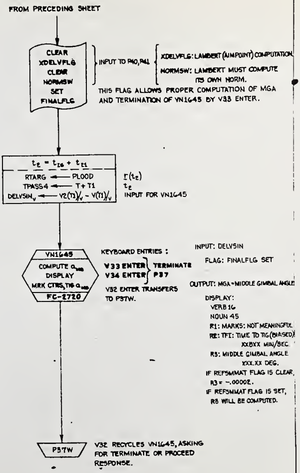
DRAWN A.C. WILLIAMS	P37- RETURN TO EARTH (MAIN PROGRAM)
PRGMR	COLOSSUS II — DOCUMENT NO. FC-2642
ANALST	
DOCMR	
APPR'D	REV — SHEET 15 OF 53



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DRAWN A.C. WILLIAMS	7JAN68	P37– RETURN TO EARTH (MAIN PROGRAM)	
PROGMR [signature]	9/1/68	COLOSSUS II	DOCUMENT NO. FC-2642
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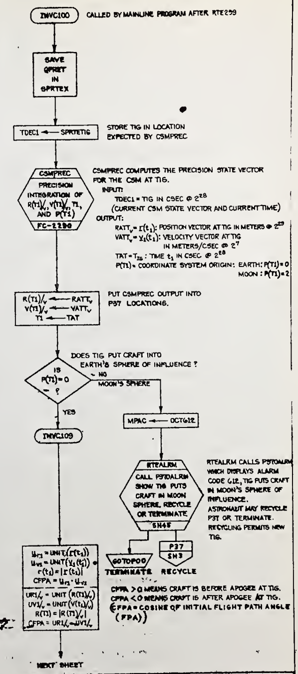
DOCMR [signature]	7 Apr 69		
APPR'D [signature]	[illegible]	REV	SHEET 14 OF 53



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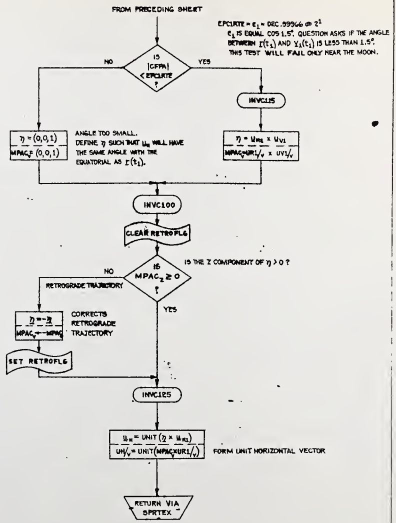
DESIGN A.C. WILLIAMS		P37—RETURN TO EARTH (INVC100)	
PROGR			
ANALYST		COLOSSUS 2E	DOCUMENT NO. FC-2642
DESIGN			
APPR John A. Mann		REV	SHEET 15 OF 35



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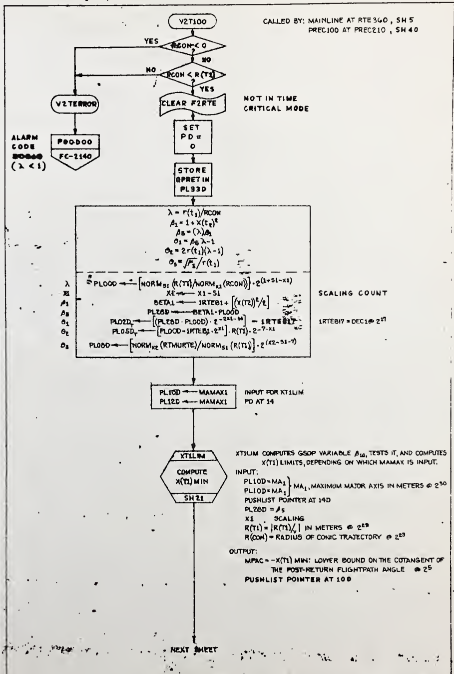
DRAWN A.C.WILLIAMS	P37- RETURN TO EARTH (INVC100)
CHECKED	COLOSSUS II — DOCUMENT NO. FC-2642
ANALYST	
SOCIAL	
APPR'D	REV — SHEET 16 OF 53



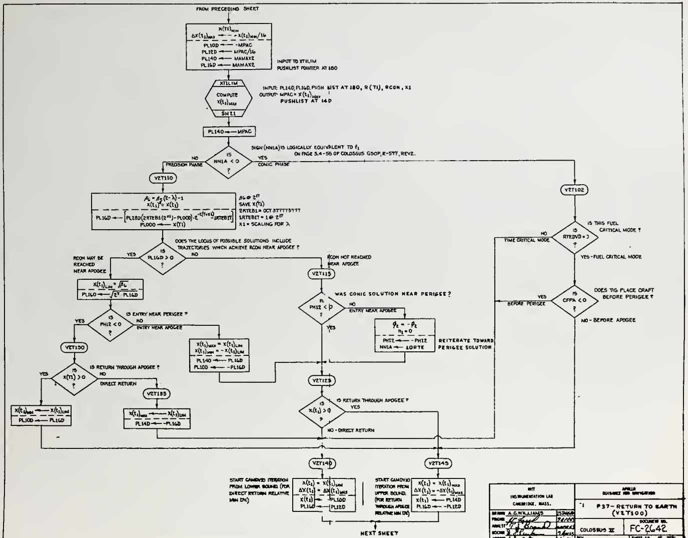
MIT INSTRUMENTATION LAB. CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

P37 - RETURN TO EARTH (V2T100)

COLOSSUS 3 [illegible]

FC-2642



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APOLLO GUIDANCE AND NAVIGATION

P37 - RETURN TO EARTH (V2T100)

DRAWN A.C.WILLIAMS

COLOSSUS II

DOCUMENT NO. FC-2642

SHEET 18 OF 33

FROM PRECEDING SHEET

V2T150

GAMDV10

COMPUTE $V2(T1)/_v$, DV, X(T1), PCON

SH23

GAMDV10 CALLS DVCALC BY ITERATION, IT CALCULATES $V2(T1)/_v = \underline{V}_2(t_1)$, $DV = \Delta V$, $X(T1) = x(t_1)$ AND $PCON = P_{CON}$.

INPUT:

PUSHLIST:

02D $\theta_1 = \beta_5 \lambda - 1$

05D $\theta_2 = 2r(t_1)(\lambda - 1)$

08D $\theta_3 = \sqrt{\mu_E} / r(t_1)$

10D $x(t_1)_{MIN}$ = LOWER BOUND ON INDEPENDENT VAR $x(t_1)$

12D $\Delta x(t_1)_{MAX}$ = MAXIMUM $\Delta X(T1)$

14D $X(T1)_{MAX}$ = UPPER BOUND ON IND. VAR $x(t_1)$.

16D $\Delta x(t_1)$ = CHANGE IN $x(t_1)$

OTHER:

$V(T1)/_v = \underline{V}(t_1)$ = INITIAL, PRE-IGNITION VELOCITY VECTOR IN METERS/CSEC @ 2^7

$RTEDVD = \Delta V_D$ = KEYED-IN Δ VELOCITY DESIRED IN METERS/CSEC @ 2^7

$U(R1)/_v = \underline{U}_{R1}$ = UNIT POSITION VECTOR AT T_{16}.

$UH/_v = \underline{U}_H$ = UNIT HORIZONTAL VECTOR: UNIT($\eta \times R(T1)/_v$)

X(T1) = COTANGENT OF INITIAL FLIGHT PATH ANGLE FROM THE VERTICAL.

F2RTE = FLAG ON MEANS TIME CRITICAL MODE. FLAG OFF MEANS NOT IN TIME CRITICAL MODE.

OUTPUT:

$V2(T1)/_v = \underline{V}_2(t_1)$ = POST-IMPULSE VELOCITY VECTOR IN METERS/CSEC @ 2^7

$DV = \Delta V$ = CHANGE IN VELOCITY

X(T1) = COT. OF INITIAL POST-RETURN FLIGHT PATH ANGLE FROM VERTICAL.

$PCON = P_{CON}$ = SEMI-LATUS RECTUM IN METERS @ $2^{28}/2^{26}$

MPAC ← RTEDVD

IS RTEDVD = 0 ?

IS THIS FUEL CRITICAL MODE ?

YES

V2TIX

RETURN VIA $33D_B$

NO

NEXT SHEET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS	13JAN69	P37 – RETURN TO EARTH (V2T100)	
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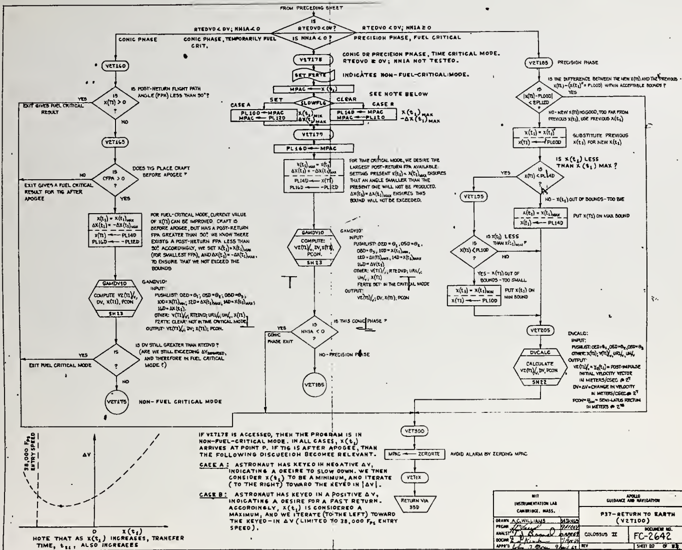
DOCMR [signature]	9Apr69		
APPR'D [signature]	9Apr69	REV	SHEET 19 OF 53


FROM PRECEDING SHEET
IS RTEDVD < DV? IS NNIA < 0?
RTEDVD < DV; NNIA < 0
RTEDVO < DV; NNIA ≥ 0
CONIC PHASE
CONIC PHASE, TEMPORARILY FUEL CRIT.
PRECISION PHASE, FUEL CRITICAL
CONIC OR PRECISION PHASE, TIME CRITICAL MODE. RTEDVD ≥ DV; NNIA NOT TESTED.
V2T17E
SET F2RTE
INDICATES NON-FUEL-CRITICAL MODE.
MPAC ← X(t₁)
SLOWFLG
SET
CLEAR
SEE NOTE BELOW
CASE A
CASE B
PL10D ← MPAC
MPAC ← PL12D
X(t₁) MIN
ΔX(t₁) MAX
PL14D ← MPAC
MPAC ← PL12D
X(t₁) MAX
-ΔX(t₁) MAX
V2T177
PL16D ← MPAC
X(t₁)MAX = X(t₁)
ΔX(t₁) = -ΔX(t₁)MAX
PL14D ← X(T1)
PL16D ← -PL12D
FOR TIME CRITICAL MODE, WE DESIRE THE LARGEST POST-RETURN FPA AVAILABLE. SETTING PRESENT X(t₁) = X(t₁)MAX ENSURES THAT AN ANGLE SMALLER THAN THE PRESENT ONE WILL NOT BE PRODUCED. ΔX(t₁) = ΔX(t₁)MAX ENSURES THIS BOUND WILL NOT BE EXCEEDED.
V2T160
IS X(T1) > 0 ?
IS POST-RETURN FLIGHT PATH ANGLE (FPA) LESS THAN 90°?
YES
EXIT GIVES FUEL CRITICAL RESULT
NO
V2T165
IS CFPA > 0 ?
DOES TIG PLACE CRAFT BEFORE APOGEE ?
NO
EXIT GIVES A FUEL CRITICAL RESULT FOR TIG AFTER APOGEE
YES
X(t₁) = X(t₁)MAX
ΔX(t₁) = -ΔX(t₁)MAX
X(T1) ← PL14D
PL16D ← -PL12D
FOR FUEL-CRITICAL MODE, CURRENT VALUE OF X(T1) CAN BE IMPROVED. CRAFT IS BEFORE APOGEE, BUT HAS A POST-RETURN FPA GREATER THAN 90°. WE KNOW THERE EXISTS A POST-RETURN FPA LESS THAN 90°. ACCORDINGLY, WE SET X(t₁) = X(t₁)MAX (FOR SMALLEST FPA), AND ΔX(t₁) = -ΔX(t₁)MAX, TO ENSURE THAT WE NOT EXCEED THE BOUNDS
GAMDV10
COMPUTE V2(T1)/V, DV, X(T1), PCON
SH23
GAMDV10:
INPUT:
PUSHLIST: 02D = θ₁; 05D = θ₂; 08D = θ₃; 10D = X(T1)MIN; 12D = ΔX(t₁)MAX; 14D = X(t₁)MAX; 16D = ΔX(t₁).
OTHER: V(T1)/V, RTEDVD; UR1/V, UH/V, X(T1).
F2RTE: CLEAR: NOT IN TIME CRITICAL MODE.
OUTPUT: V2(T1)/V, DV; X(T1); PCON.
IS DV STILL GREATER THAN RTEDVD ? (ARE WE STILL EXCEEDING ΔV, AND THEREFORE IN FUEL CRITICAL MODE ?)
YES
EXIT FUEL CRITICAL MODE
NO
V2T175
NON-FUEL CRITICAL MODE
GAMDV10
COMPUTE: V2(T1)/V, DV, X(T1), PCON.
SH23
GAMDV10:
INPUT:
PUSHLIST: 02D = θ₁, 05D = θ₂, 08D = θ₃, 10D = X(t₁)MIN, 12D = ΔV(T1)MAX, 14D = X(t₁)MAX, 16D = ΔV(t₁)
OTHER: V(T1)/V, RTEDVD; UR1/V, UH/V, X(T1)
F2RTE SET IN THE CRITICAL MODE
OUTPUT: V2(T1)/V; DV, X(T1), PCON
IS NNIA < 0 ?
IS THIS CONIC PHASE ?
YES
CONIC PHASE EXIT
NO - PRECISION PHASE
V2T185
V2T185
PRECISION PHASE
IS THE DIFFERENCE BETWEEN THE NEW X(T1) AND THE PREVIOUS X(T1) - (X(t₁)* = PLOOD) WITHIN ACCEPTABLE BOUNDS ?
IS |X(T1) - PLOOD| < 2PL12D ?
YES
NO - NEW X(T1) NO GOOD, TOO FAR FROM PREVIOUS X(t₁). USE PREVIOUS X(t₁)
X(t₁) = X(t₁)*
X(T1) ← PLOOD
SUBSTITUTE PREVIOUS X(t₁) FOR NEW X(t₁)
IS X(t₁) LESS THAN X(t₁) MAX ?
IS X(T1) < PL14D ?
YES
NO - X(t₁) OUT OF BOUNDS - TOO BIG
X(t₁) = X(t₁)MAX
X(t₁) ← PL14D
PUT X(T1) ON MAX BOUND
V2T195
IS X(T1) < PL10D ?
IS X(t₁) LESS THAN X(t₁)MIN ?
NO
YES - X(T1) OUT OF BOUNDS - TOO SMALL
X(t₁) = X(t₁)MIN
X(T1) ← PL10D
PUT X(t₁) ON MIN BOUND
V2T205
DVCALC
CALCULATE V2(T1)/V, DV, PCON
SN22
DVCALC:
INPUT:
PUSHLIST: 02D = θ₁, 05D = θ₂, 08D = θ₃
OTHER: X(T1); V(T1)/V, UR1/V, UH/V
OUTPUT:
V2(T1)/V = V2(t₁) = POST-IMPULSE INITIAL VELOCITY VECTOR IN METERS/CSEC @ 2⁷
DV = ΔV = CHANGE IN VELOCITY IN METERS/CSEC @ 2⁷
PCON = P₂ = SEMI-LATUS RECTUM IN METERS @ 2²⁹
V2T300
MPAC ← ZERORTE
AVOID ALARM BY ZEROING MPAC
V2TIX
RETURN VIA 33D
38,000 Fps ENTRY SPEED
ΔV
0
X(t₁)
NOTE THAT AS X(t₁) INCREASES, TRANSFER TIME, t₁₂, ALSO INCREASES
IF V2T17E IS ACCESSED, THEN THE PROGRAM IS IN NON-FUEL-CRITICAL MODE. IN ALL CASES, X(t₁) ARRIVES AT POINT P. IF TIG IS AFTER APOGEE, THAN THE FOLLOWING DISCUSSION BECOMES RELEVANT.
CASE A: ASTRONAUT HAS KEYED IN NEGATIVE ΔV, INDICATING A DESIRE TO SLOW DOWN. WE THEN CONSIDER X(t₁) TO BE A MINIMUM, AND ITERATE (TO THE RIGHT) TOWARD THE KEYED IN |ΔV|.
CASE B: ASTRONAUT HAS KEYED IN A POSITIVE ΔV, INDICATING A DESIRE FOR A FAST RETURN. ACCORDINGLY, X(t₁) IS CONSIDERED A MAXIMUM, AND WE ITERATE (TO THE LEFT) TOWARD THE KEYED-IN ΔV (LIMITED TO 38,000 Fps ENTRY SPEED).
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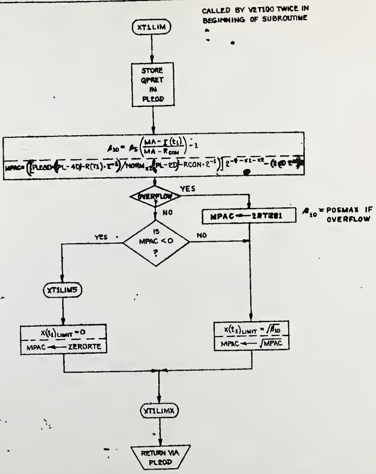
APOLLO GUIDANCE AND NAVIGATION
P37-RETURN TO EARTH (V2T100)
DRAWN A.C. WILLIAMS
PRGMR
ANALST
DOCMR
APP'D
COLOSSUS II
DOCUMENT NO. FC-2642
REV
SHEET 20 OF



XT1LIM IS USED TWICE: ONCE USING MAMAX1 AND ONCE USING MAMAX2.

WHEN MAMAX1 IS USED, XT1LIM DETERMINES WHETHER THE PRESENT TRAJECTORY IS CLOSE TO PARABOLIC. IF IT IS, THE POST-IMPULSE FLIGHT PATH ANGLE IS NOT PERMITTED TO HAVE A NEGATIVE RADIAL COMPONENT.

WHEN MAMAX2 IS USED, XT1LIM DETERMINES WHETHER R(T1), THE ABSOLUTE VALUE OF THE POSITION VECTOR, IS GREATER THAN MAMAX2. IN THAT CASE, THE MAXIMUM RADIUS IS TAKEN TO BE R(T1) ITSELF. THE POST-IMPULSE FPA IS THEREFORE NOT PERMITTED TO HAVE A POSITIVE RADIAL COMPONENT.

M.I.T. INSTRUMENTATION LAB CAMBRIDGE, MASS.

DRAWN A.C. WILLIAMS

PROGR

ANALST

DOCMN

APPR'D

APOLLO GUIDANCE AND NAVIGATION

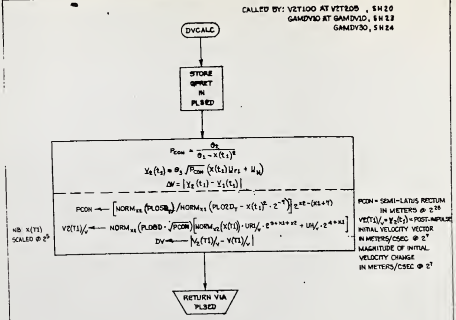
P37 - RETURN TO EARTH (XT1LIM)

COLOSSUS II

DOCUMENT NO. FC-2642

REV

SHEET 21 OF [illegible]



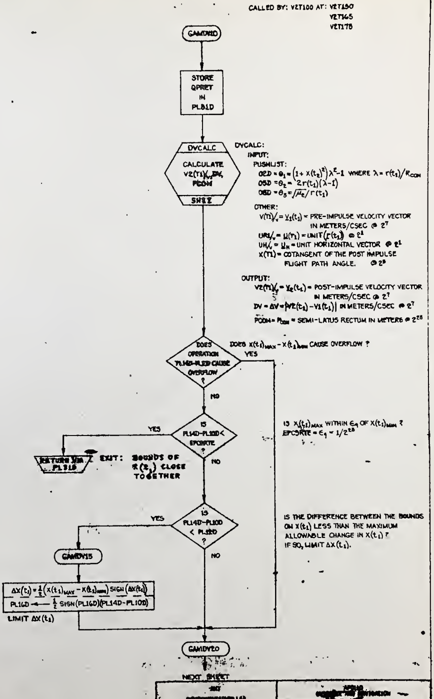
PCON

PCON SATISFIES THE EQUATION: $P_{CON} = \dfrac{2r(t_1)\left(\frac{r(t_1)}{R_{CON}} - 1\right)}{\frac{(r(t_1))^2}{R_{CON}^2}\left(1 + (X(t_1))^2\right) - \left(1 + (X(t_1))^2\right)}$ WHERE

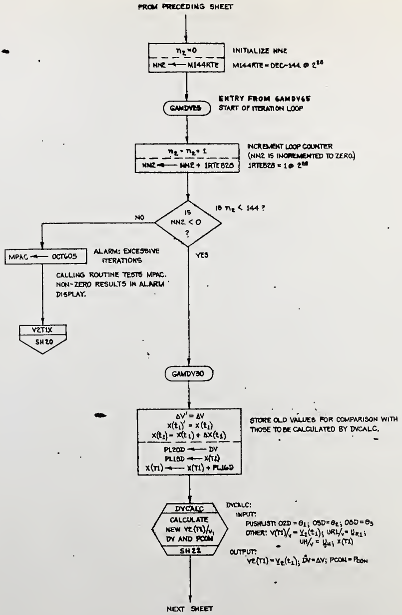
$\theta_2 = 2r(t_1)\left(\frac{r(t_1)}{R_{CON}} - 1\right)$ AND $\theta_1 = \frac{(r(t_1))^2}{R_{CON}^2}\left(1 + (X(t_1))^2\right) - 1$, WHERE $r(t_1)$ = RADIUS.

AT T_{16}; R_{CON} = FINAL RADIUS AND $X(t_2)$ = COTANGENT OF THE FINAL FLIGHT PATH ANGLE.
X(T1) IS THE INDEPENDENT VARIABLE, EQUALING COTANGENT OF THE INITIAL FLIGHT PATH ANGLE.

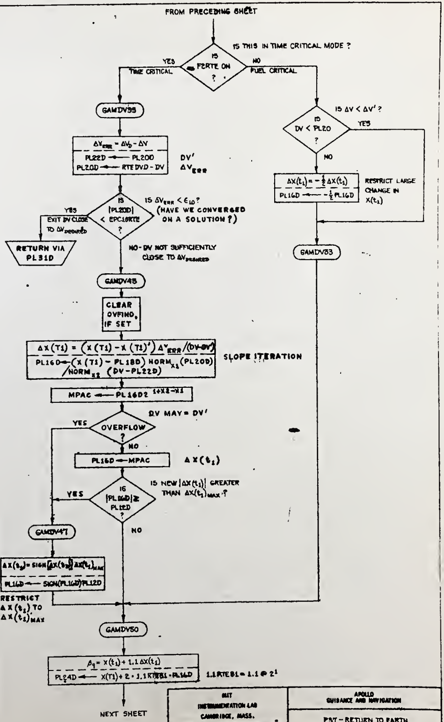
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS	P37 - RETURN TO EARTH (DVCALC)	
PRGMR	COLOSSUS II	DOCUMENT NO. FC-2642
ANALYST		
DOCMR	REV	SHEET 2[illegible] OF 5[illegible]
APPR'D		



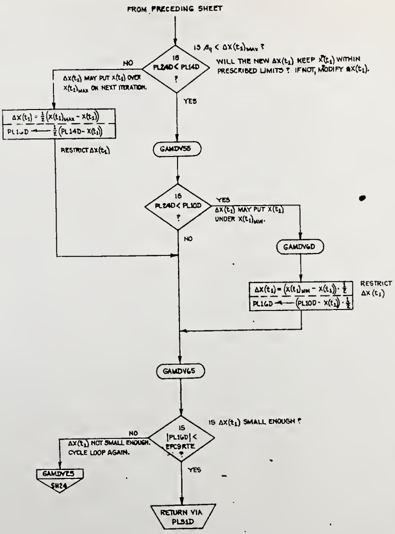
MIT INSTRUMENTATION LAB, CAMBRIDGE, MASS.	APOLLO [illegible]	
DRAWN A.C. [illegible]	P37- RETURN TO EARTH (GAMDV10)	
PRGMR	COLOSSUS II	DOCUMENT NO. FC-2642
ANALST		
DOCMR		
APPR'D	REV	SHEET 23 OF 53



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.HALLSTROM	P37 - RETURN TO EARTH (GAMDV10)
PROGMR	COLOSSUS II
ANALST	DOCUMENT NO. FC-2642
DOCMR	
APPR'D	REV
	SHEET 24 OF 53



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	P37 - RETURN TO EARTH (GAMDV10)
CHKR / ANALST / DOCMR / APPR'D (signatures, dated)	COLOSSUS II — DOCUMENT NO. FC-2642
REV	SHEET 25 OF 53



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.	P37 - RETURN TO EARTH (GAMDV10)	
CHECKED		
ANALYST	COLOSSUS II	DOCUMENT NO. FC-2642
DOCMR		
APPR'D	REV	SHEET 26 OF 53

TIME RADIUS CALLING SUBROUTINE

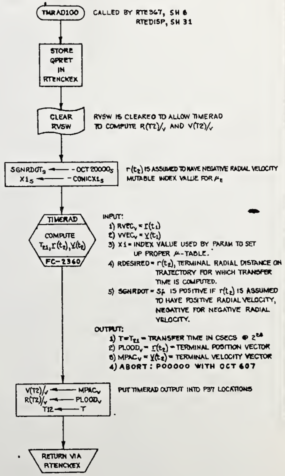
INPUT:

RVEC	INITIAL POSITION VECTOR	VECT. @ 2^{29} MTRS
VVEC	INITIAL VELOCITY VECTOR	VECT. @ 2^{7} MTRS/CSEC
RDESIRED	FINAL RADIUS FOR WHICH TRANSFER TIME IS TO BE COMPUTED	DP. @ 2^{29} METERS

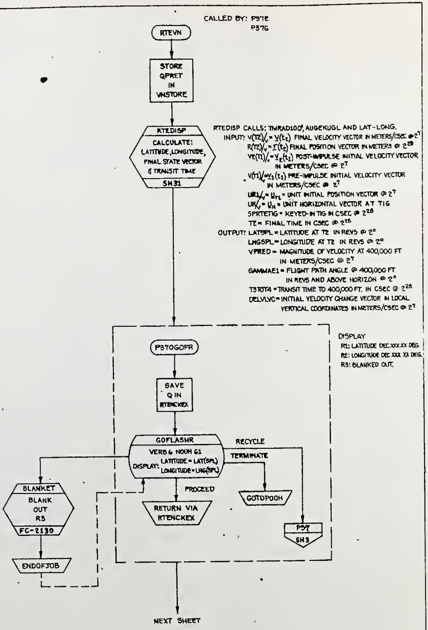
OUTPUT:

R(T2)/v	FINAL POSITION VECTOR	VECT. @ 2^{29} METERS
V(T2)/v	FINAL VELOCITY VECTOR	VECT. @ 2^{7} MTRS/CSEC
T12	TRANSFER TIME TO FINAL RADIUS	DP. @ 2^{28} CSEC

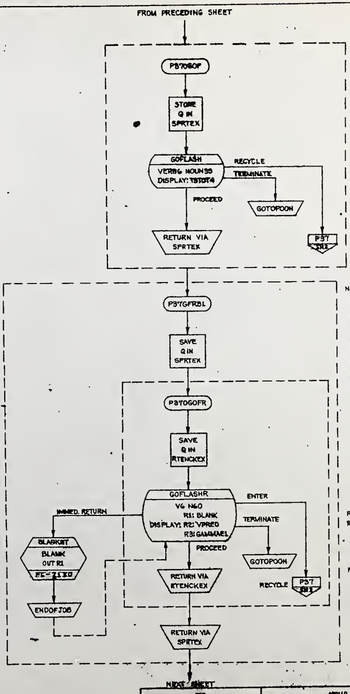
ABORT EXIT FOR NO SOLUTION:
POODOO, WITH OCT 607



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS	5 DEC 68	P37 - RETURN TO EARTH (TMRAD100)	
PRGMR	8 APR 69		DOCUMENT NO.
ANALST	8 APR 69	COLOSSUS II	FC-2642
DOCMR	24 Apr 69		
APPR'D	24 Apr 69	REV	SHEET 27 OF 83



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS	P37-RETURN TO EARTH	
PROGMR / ANALST / DOCMR / APPR'D	COLOSSUS II	DOCUMENT NO. FC-2642
	REV	SHEET 20 OF 53

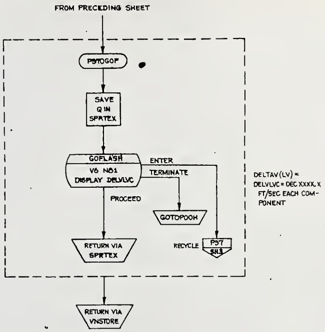


DISPLAY: T3TOT4
TRANSFER TIME
TO 400,000 FT.
R1: HRS: 00XXX.
R2: MIN: 000XX.
R3: SEC: 0XX.XX
} DECIMAL

NOTE: P37GFRB1 INTERLOCKS WITH P37OGOFR IN THIS MANNER:
IMMEDIATE RETURN FROM GOFLASHR IN P37OGOFR TO BLANKET, WHICH IS CONTAINED IN P37GFRB1. ENDOFJOB RETURNS DISPLAY FOR ASTRONAUT RESPONSE.

R1: BLANK
R2: VPRED DEC XXXXX. IN FT/SEC = VELOCITY MAGNITUDE AT 400,000 FT.
R3: GAMMAE1 DEC XXX.XX IN DEGREES = FLIGHT PATH ANGLE AT 400,000 FT.

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.G. WILLIAMS	P37 - RETURN TO EARTH (RTE)
PROGR	COLOSSUS II
ANALST	DOCUMENT NO. FC-2642
DOCMR	
APPR'D	REV / SHEET 29 OF 53



MIT
INSTRUMENTATION LAB
CAMBRIDGE, MASS.

APOLLO
GUIDANCE AND NAVIGATION

P37- RETURN TO EARTH
(RTEVN)

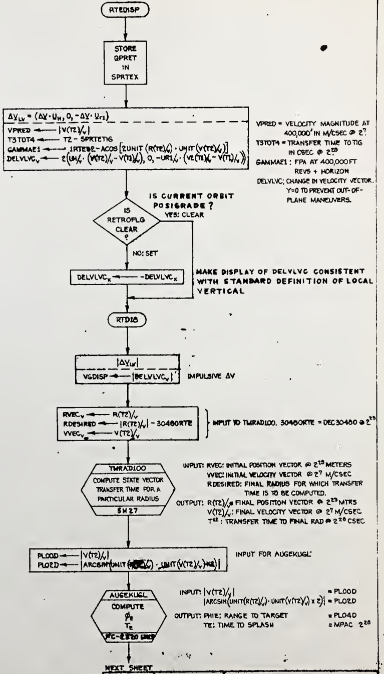
DRAWN A.C. WILLIAMS
PROGMR
ANALST
DOCMR
APPR'D

COLOSSUS II

DOCUMENT NO.
FC-2642

REV

SHEET 30 OF 53



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

DRAWN A.C.WILLIAMS	24JAN69
PRGMR [signature]	
ANALST [signature]	
DOCMR [signature]	
APPR'D [signature]	

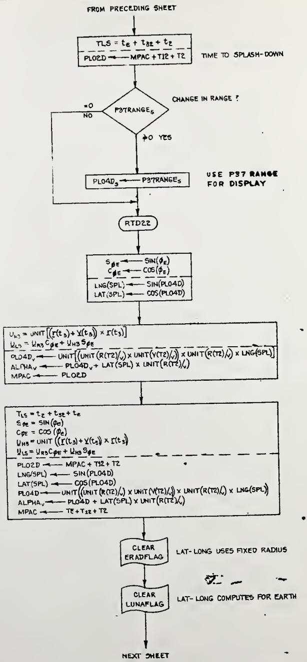
APOLLO GUIDANCE AND NAVIGATION

P37 – RETURN TO EARTH (RTEDISP)

COLOSSUS II — DOCUMENT NO. FC-2642

REV

SHEET 51 OF 53



MIT INSTRUMENTATION LAB
CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

P37 - RETURN TO EARTH (RTEDISP)

DRAWN A.C.WILLIAMS

PRGMR

ANALST

DOCMR

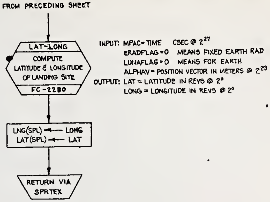
APPR'D

COLOSSUS II

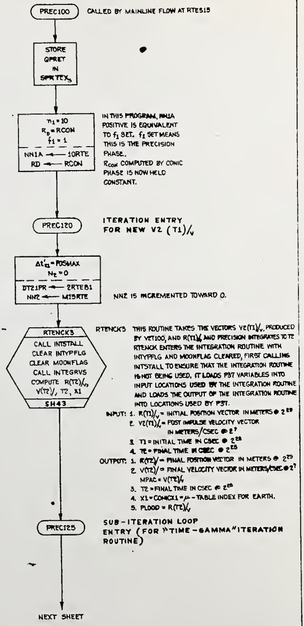
DOCUMENT NO. FC-2642

REV

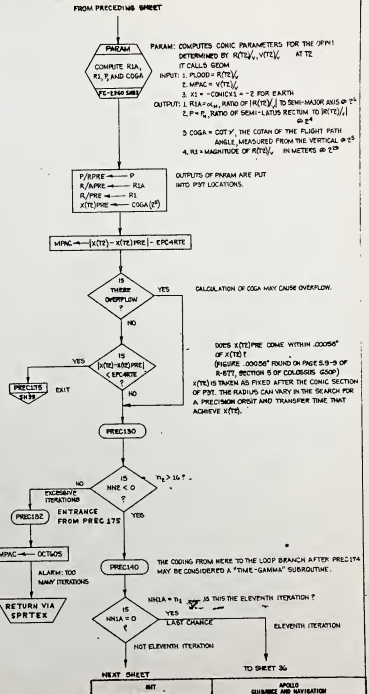
SHEET 02 OF 03



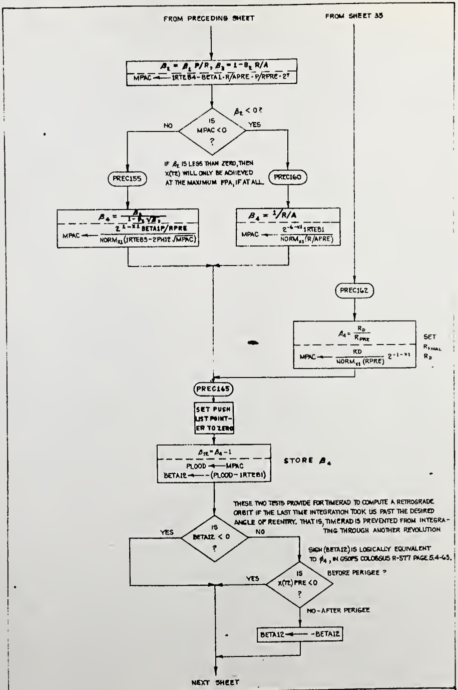
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS		P37—RETURN TO EARTH (RTEDISP)	
PRGMR		COLOSSUS II	DOCUMENT NO. FC-2642
ANALST			
DOCMR			
APPR'D		REV	SHEET 53 OF 53



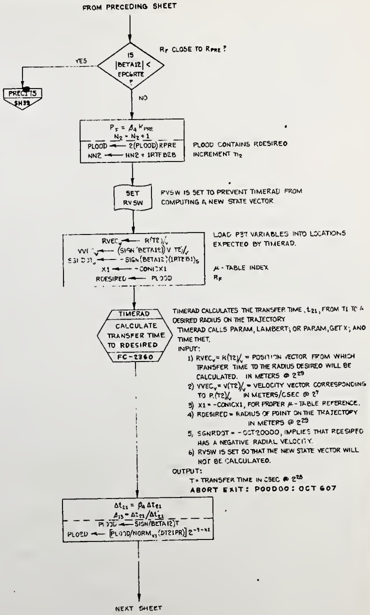
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C. WILLIAMS	P37 - RETURN TO EARTH (PREC100)
PRGMR	COLOSSUS II — DOCUMENT NO. FC-2642
ANALST	
DOCMR	
APPR'D	REV — SHEET 34 OF [illegible]



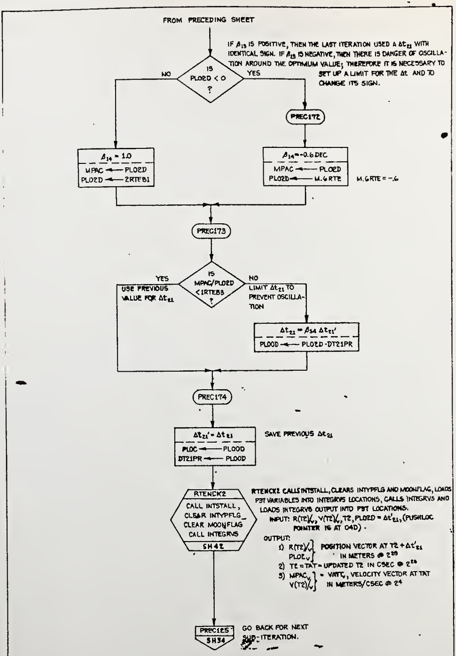
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	P37- RETURN TO EARTH (PREC100)
PRGMR	
ANALST	COLOSSUS II — DOCUMENT NO. FC-2642
DOCMR	
APPR'D	REV — SHEET 35 OF 53



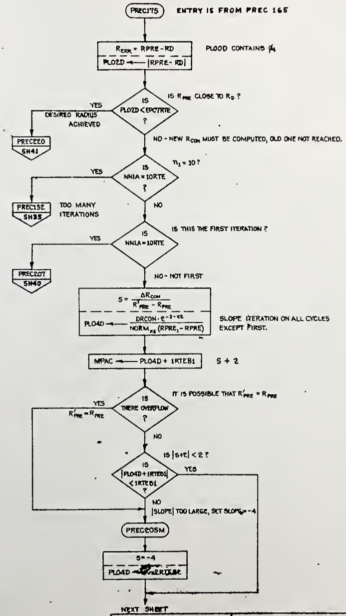
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	P37- RETURN TO EARTH (PREC100)
PROGMR	
ANALYST	COLOSSUS II — DOCUMENT NO. FC-2642
DOCMR	
APPR'D	REV — SHEET 36 OF 53



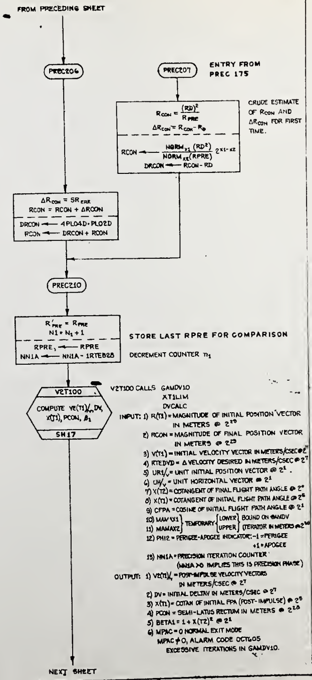
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS	29 JAN 69	P37- RETURN TO EARTH (PREC100)	
PRGMR [signature]	4/APR/69		
ANALST [signature]	4 APR 69	COLOSSUS II	DOCUMENT NO. FC-2642
DOCMR [signature]	4/1/69		
APPR'D [signature]	4 April 69	REV	SHEET 37 OF 53



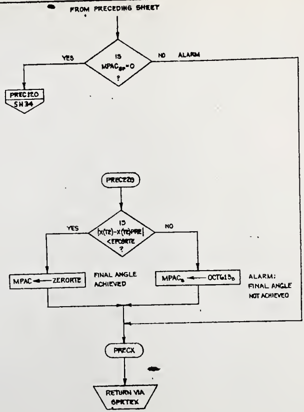
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C. WILLIAMS	P37-RETURN TO EARTH (PREC100)
PROGR	COLOSSUS II — DOCUMENT NO. FC-2642
ANALST	REV — SHEET 36 OF [illegible]
DOCMR	
APPR'D	



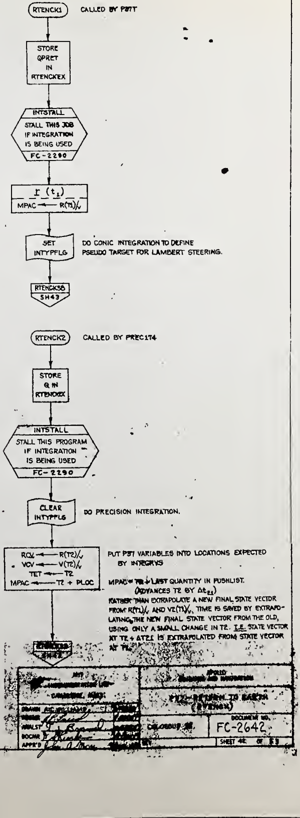
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C. WILLIAMS	P67 - RETURN TO EARTH (PREC100)
COLOSSUS II	DOCUMENT NO. FC-2642
REV	SHEET 39 OF 53



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C. WILLIAMS	P37- RETURN TO EARTH (PREC100)
PROGMR	
ANALST	COLOSSUS II / DOCUMENT NO. FC-2642
DOCMR	
APPR'D	REV / SHEET 40 OF [illegible]



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C. WILLIAMS	P37 - RETURN TO EARTH (PREC100)
PROGR	COLOSSUS II — DOCUMENT NO. FC-2642
ANALST	
SOCMR	
APPR'D	REV — SHEET 41 OF 53



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

P37—RETURN TO EARTH (RTENCK)

DRAWN [illegible]

CHECKED [illegible]

ANALYST [illegible]

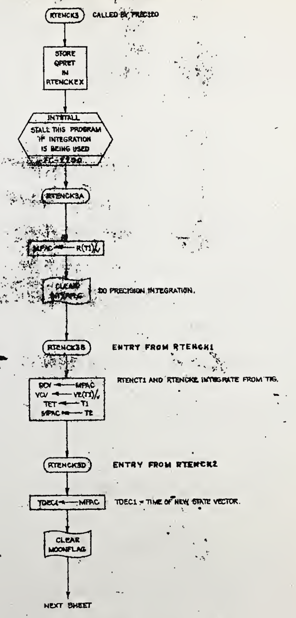
DOCMR [illegible]

APPR'D [illegible]

COLOSSUS 2E

DOCUMENT NO. FC-2642

SHEET 42 OF 53



MIT INSTRUMENTATION LAB
CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

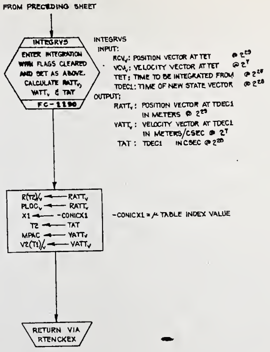
P37- RETURN TO EARTH (RTENCK)

COLOSSUS 2E

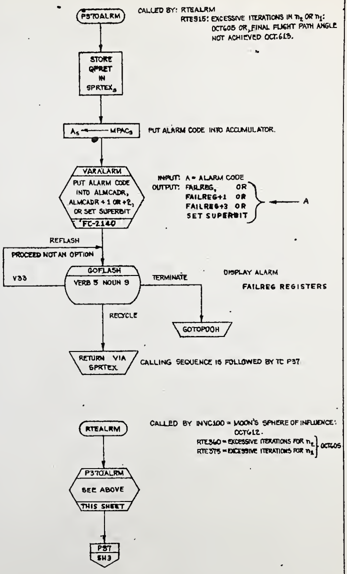
DOCUMENT NO. FC-2642

REV

SHEET [illegible] OF 53



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C. WILLIAMS	P37—RETURN TO EARTH (RTENCK)
PROGR	COLOSSUS 2E — DOCUMENT NO. FC-2642
ANALST	REV — SHEET 44 OF 52
DOCMN	
APPR'D	



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C. WILLIAMS	P37 – RETURN TO EARTH (P370ALARM)
PROGR	
ANALYST	COLOSSUS II — DOCUMENT NO. FC-2642
DOCUMENT	
APPR'D	REV — SHEET 45 OF 53

ERASABLE LOCATIONS USED

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
$ALPHAV_V$	$\underline{r}(t_2)$	INPUT TO GETERAD (UNIT $(R(T2)_V)$			
$BETA1_D$	β_1	$1 + x(t_2)^2$			2^1
$BETA2_D$	φ_4	SIGN INDICATOR FOR TIMERAD			
$CFPA_D$	C_{FPA}	COSINE OF PRE-RETURN FPA			2^1
$COGA_D$	$x(t_2)_{PRE}$	OUTPUT OF PARAM COT OF PRECISION ORBIT AT T2			2^5
$CSTH_D$		INPUT TO TIMETHET- COS OF 165^0 OR 210^0			2^2
$CONICX1_S$		CONIC μ -TABLE INDEX			
$DELVSIN_D$	$\underline{V}_2(t_1)$	$\underline{V}_2(t_1) - \underline{V}_1(t_1)$ INPUT TO VN2645	FT/SEC	M/CSEC	2^7
$DRCON_D$	ΔR_{CON}	RCON SLOPE ITERATOR	METERS	METERS	2^{29}
$DT21PR_D$	$\Delta t'_{21}$	PREVIOUS $\Delta t21$	SECONDS	CSEC	2^{28}
DV_D	ΔV	TEMP ABSOLUTE VALUE OF ΔVELOCITY AT TIG	FT/SECOND	M/CSEC	2^7
$ECSTEER_S$ *		STEERING CONSTANT FOR LAMBERT STEERING	EQUALS 1 @ 2^1		.5@ 2^2
$ERADM_D$		RADIUS OF FISCHER ELLIPSOID FOR T2	METERS	METERS	2^{29}
$GAMMAE1_D$		DISPLAY LOCATION FOR NOUN 60-FINAL FPA	DEGREES	REVS	2^0
$MAMAX1_D$	MA_1	MAJOR AXIS CLOSE TO PARABOLIC TRAJECTORY USED TO COMPUTE LOWER BOUND ON x(T1), COT OF POST IMPULSE FPA	METERS	METERS	2^{30}
$MAMAX2_D$	MA_2	MAXIMUM MAJOR AXIS USED FOR COMPUTING UPPER BOUND ON x(T1)	METERS	METERS	2^{30}
$NN1A_D$	n_1	COUNTER #1 FOR ITERATION			
SIGN(NN1A)	f_1	POSITIVE = PRECISION PHASE NEGATIVE = CONIC PHASE			
$NN2_D$	n_2	COUNTER #2 FOR ITERATION			
$P/RPRE_D$	P/R_{PRE}	RATIO OF SEMI-LATUS RECTUM TO $\lvert R(T2)/_V \rvert$			2^4
$PCON_D$	P_{CON}	TEMPORARY SEMI-LATUS RECTUM	METERS	METERS	2^{29}
$PHIE_D$	φ_E	RANGE FROM 400,000 FT ENTRY ALTITUDE TO SPLASHDOWN	NAUTICAL MILES	METERS	2^{29}
$PHI2_D$	φ_2	PERIGEE-APOGEE INDICATOR: +1=APOGEE -1=PERIGEE			
*EMDOT	$\dot{M}$	MASS DECREMENTATION FACTOR FOR CSM	LB/SEC	KG/CSEC	2^3

P37RANGE		RANGE FROM 300 K FT TO SPLASH IF ≠ 0. IF = 0, USE AUGEKUGL COMPUTATION.	NAUTICAL MILES	REVS	2^0
$P(T1)_D$	$P(t_I)$	PRIMARY BODY AT TIG 1 = MOON 0 = EARTH			
$R'APRE_D$	ρR_{PRE}	RATIO OF |R(T2)/V| TO SEMI-MAJOR AXIS			2^6
$RATT_V$		RADIUS VECTOR OUTPUT OF INTEGRATION ROUTINES	METERS	METERS	2^{29}
$RCON_D$	R_{CON}	TEMP FINAL RADIUS OF CONIC TRAJECTORY	METERS	METERS	2^{29}
RCV_V		RADIUS VECTOR INPUT TO INTEGRVS	METERS	METERS	2^{29}
RD_D	R_D	FINAL RADIUS DESIRED	METERS	METERS	2^{29}
$RDESIRED_D$	R_F	TEMPORARY FINAL RADIUS	METERS	METERS	2^{29}
$RPRE_D$	R_{PRE}	TEMP FINAL RADIUS OF A PRECISION TRAJECTORY	METERS	METERS	2^{29}
$RPRE'_D$	$x(t_2)$ R'_{PRE}	LAST $x(t_2)$ COT (FINAL FPA) (FOR CONIC) LAST R_{PRE} (FOR PRECISION)			2^0
$RTARG_D$	$r(t_2)_D$	INPUT TO VN1645 RADIUS VECTOR AT FINAL TIME	METERS	METERS	2^{29}
$RTEDVD_D$	ΔV_D	Δ VELOCITY DESIRED	METERS/ SEC	M/CSEC	2^7
$RTEGAM2D_D$	$\tau(t_2)_D$	FINAL FPA DESIRED	DEGREES	REVS	2^0
$RTENCKEX_S$		RETURN ADDRESS STORAGE			
$RVEC_V$		INPUT TO CONIC SUBROUTINES (RADIUS VECTOR)	METERS	METERS	2^{29}
$R(T1)_D$	$r(t_1)$	RADIUS MAGNITUDE AT TIG	METERS	METERS	2^{29}
$R(T1)/_V$	$\underline{r}(t_1)$	RADIUS VECTOR AT TIG	METERS	METERS	2^{29}
$R(T2)/_V$	$\underline{r}(t_2)$	RADIUS VECTOR AT T_2	METERS	METERS	2^{29}
$SGNRDOT_S$		INPUT TO TIMERAD POSITIVE FOR POSITIVE RADICAL VELOCITY NEGATIVE FOR NEGATIVE RADICAL VELOCITY			
$SNTH_D$		INPUT TO TIMETHET SINE OF 165° OT 210°			2^1
$SPRTETIG_D$	T_{IG}	TIME OF IGNITION	SECONDS	CSEC	2^{28}
$SPRTEX_S$		RETURN ADDRESS STORAGE			
TAT_D		TIME OF OUTPUT VECTORS OF CONIC SUBROUTINES	SECONDS	CSEC	2^{28}

SUBROUTINES CALLED WHICH ARE
FLOWED ON OTHER FLOW CHARTS

SUBROUTINE NAME	FLOW CHART	DESCRIPTION	WHERE CALLED
POLY	2100	DOUBLE PRECISION POLYNOMIAL EVALUATOR	SH. 4, 6, 11
GETERAD	2280	COMPUTE EARTH RADIUS	SH. 7
TIMETHET	2360	COMPUTE TIME AND, IF RVSW IS CLEAR, STATE VECTOR TO A PARTICULAR ANGLE, THETA.	SH. 13
VN1645	2720	COMPUTE AND DISPLAY MIDDLE GIMBAL ANGLE	SH. 14
CSMPREC	2290	EXTRAPOLATE PRECISION STATE VECTOR TO TIME (IN THIS CASE, TIG)	SH. 15
TIMERAD	2360	COMPUTE TIME TO A PARTICULAR RADIUS	SH. 27, 37
AUGEKUGI	2650	COMPUTE RANGE FROM 400,000 FT ENTRY TO SPLASHDOWN	SH. 31
LAT-LONG	2280	GIVEN TIME AND STATE VECTOR AT THAT TIME COMPUTE LATITUDE AT THAT TIME	SH. 33
PARAM	2360	COMPUTE ORBITAL PARAMETERS FOR A GIVEN STATE VECTOR	SH. 35
INTSTALL	2290	STALL P37 IF INTEGRVS IS BEING USED	SH. 42, 43
INTEGRVS	2290	EXTRAPOLATE BY CONIC OR ENCKE METHOD FROM A STATE VECTOR TO A GIVEN TIME	SH. 44
VARALARM	2140	PUT ALARM CODE INTO A FAILREG REGISTER, OR SET SUPERBIT	SH. 45

FLAGS

NAME	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
RVSW	DO NOT COMPUTE FINAL STATE VECTOR IN TIME-THETA, TIMERAD	COMPUTE FINAL STATE VECTOR IN TIME-THETA, TIMERAD	SH. 37	SH. 13, 27	
XDELVFLG	EXTERNAL DELTA VG COMPUTATION	LAMBERT (AIM POINT) VG COMPUTATIONS		SH. 14	
NORMSW	UNIT NORMAL INPUT TO LAMBERT	LAMBERT COMPUTES ITS OWN UNIT NORMAL		SH. 14	
FINALFLG	LAST PASS THROUGH RENDEZVOUS PROGRAM COMPUTATIONS	INTERIM PASS THROUGH RENDEZVOUS PROGRAM COMPUTATIONS	SH. 14		
F2RTE	IN TIME CRITICAL MODE	IN FUEL CRITICAL MODE	SH. 20	SH. 17	SH. 25
ERADFLAG	COMPUTE USING FISCHER ELLIPSOID	COMPUTE USING FIXED RADIUS		SH. 32	
LUNAFLAG	LUNAR LAT-LONG	EARTH LAT-LONG		SH. 32	
INTYPFLG	CONIC INTEGRATION	ENCKE INTEGRATION	SH. 42	SH. 42, 43	
MOONFLAG	MOON IS SPHERE OF INFLUENCE	EARTH IS SPHERE OF INFLUENCE		SH. 43	
NJETSFLG	2 JET RCS BURN	4 JET RCS BURN			SH. 11
RETROFLG	ORBIT RETROGRADE	ORBIT NOT RETROGRADE	SH. 16	SH. 16	SH. 31
SLOWFLG	COAST SLOWDOWN IS DESIRED	COAST SLOWDOWN IS NOT DESIRED	SH. 4	SH. 4	SH. 20

ERASABLE LOCATIONS USED (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
$TDEC1_D$		INPUT TO INTEGRVS: TIME TO BE INTEGRATED TO	SECONDS	CSEC	2^{28}
TE_D	t_e	TIME FROM ENTRY TO SPLASHDOWN	SECONDS	CSEC	2^{28}
TET_D		TIME INPUT TO INTEGRVS	SECONDS	CSEC	2^{28}
$TPASS4_D$		TIME INPUT TO S40.9	SECONDS	CSEC	2^{28}
$TRKMKCNT_S$		TRACKING MARK COUNTER			
$T1_D$	t_1	INITIAL VECTOR TIME (TIG)	SECONDS	CSEC	2^{28}
$T12_D$	t_{12}	TRANSFER TIME TO FINAL RADIUS	SECONDS	CSEC	2^{28}
$T2_D$	t_2	TIME OF RE-ENTRY	SECONDS	CSEC	2^{28}
UH'_V	$\underline{u}_H$	UNIT HORIZONTAL VECTOR			
$UR1/_V$	$\underline{u}_{R1}$	UNIT RADIUS VECTOR AT t_1			
$UV1/_V$	$\underline{u}_{V1}$	UNIT VELOCITY VECTOR AT t_I			
$V(T1)/_V$	$\underline{v}_1(t_1)$	VELOCITY VECTOR AT t_1 (PRE-IMPULSE)	FT/SEC	M/CSEC	2^7
$V2(T1)/_V$	$\underline{v}_2(t_1)$	VELOCITY VECTOR AT t_1 (POST-IMPULSE)	FT/SEC	M/CSEC	2^7
$V(T2)_V$	$\underline{v}(t_2)$	VELOCITY VECTOR AT t_2	FT/SEC	M/CSEC	2^7
$VHFCNT_S$		VHFMARK COUNTER			
$VNSTORE_S$		RETURN ADDRESS STORAGE			
$VPRED_D$		KEYED IN ΔV DESIRED, OR FINAL VELOCITY	FT/SEC	M/CSEC	2^7
$VVEC_V$		INPUT TO CONIC ROUTINES $(V(T1)/_V)$	FT/SEC	M/CSEC	2^7
$WEIGHT/G_D$		MASS OF VEHICLE	POUNDS	KG	2^{16}
$X(T1)_D$	$x(t_1)$	COTAN (INITIAL POST-IMPULSE FPA)			2^5
$X(T2)_D$	$x(t_2)$	COTAN (FINAL FPA)			2^0
$X(T2)PRE_D$	$x(t_2)_{PRE}$	COTAN OF FINAL FPA OF PRECISION TRAJECTORY			2^0

DISPLAYS

VERB-NOUN	TYPE OF DISPLAY	DESCRIPTION OF EACH REGISTER	WHERE EXECUTED
V06N33	GOFLASH	R1 00XXX. HRS R2 000XX. MIN — DEC ONLY TIG R3 0XX.XX SEC	SH. 3
V06N60	GOFLASHR	R1 BLANKED OUT — DEC ONLY R2 VPRED XXXXX. FT/SEC — Δ V DESIRED R3 GAMMAE1 (FLIGHT PATH ANGLE) — FINAL FPA DESIRED	SH. 3
V04N06	GOFLASH	R1 OPTION CODE R2 ASSUMED OPTION — OCTAL RCS-SPS OPTION R3 NOT USED	SH. 10
V06N33	GOFLASH	R1 00XXX. HRS R2 000XX. MIN — DEC ONLY: BIASED TIG R3 0XX.XX SEC	SH. 12
V06N61	GOFLASHR	R1 XXX.XX — LATITUDE R2. XXX.XX — LONGITUDE } DEGREES R3 BLANKED OUT	SH. 28
V06N39	GOFLASH	R1 00XXX. HRS R2 000XX. MIN — DECIMAL TRANSFER TIME R3 0XX.XX SEC	SH. 29
V06N60	GOFLASHR	R1: BLANKED OUT — PREDICTED V R2 VPRED XXXXX. FT/SEC — DEC ONLY R3 GAMMAE1 XXX.XX DEGREES — PREDICTED FINAL FPA	SH. 29
V06N81	GOFLASH	R1 XXXX.X FT/SEC R2 XXXX.X FT/SEC — Δ V VECTOR R3 XXXX.X FT/SEC	SH. 30
V05N09	GOFLASH	R1 OCTAL ALARM CODE FROM MPAC, 00XXX, IN ONE R2 REGISTER. [illegible] R3 [illegible]	SH. 45

PAD LOADS

AGC TAG	GSOP TAG	MEANING	ENGINEERING VALUE AND UNITS	AGC VALUE AND UNITS	AGC SCALING	OCTAL VALUE
$RTED1_D$	D_1	X^o COEFFICIENT IN COMPUTATION OF $x(t_2)$	.2075330	1.6602637	2^3	

PROGRAM CONSTANTS

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING VALUE AND UNITS	AGC VALUE AND UNITS	AGC SCALING
$CSUBT_P$	C_T	VALUE USED IN CALCULATING BIASED TIG	1/2	.5	2^0
$C4RTE_D$	MA1	MAXIMUM MAJOR AXIS FOR R(T1)/V WITH NEGATIVE RADIAL COMPONENT	8. x 10^8 METERS	8 x 10^8 METERS	2^{30}
$EPC1RTE_D$	ε_1	VALUE USED TO TEST WHETHER RADIUS AND VELOCITY VECTORS ARE NEARLY COLINEAR	COS(1.5°)	.99966	2^1

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING VALUE AND UNITS	AGC VALUE AND UNITS	AGC SCALING
$EPC2RTE_D$	ε_2	CRITERION USED TO DETERMINE WHETHER CONIC PORTION HAS CONVERGED TO A SUITABLE REENTRY RADIUS	100 METERS	100 METERS	2^{29}
$EPC3RTE_D$	ε_2	CRITERION USED TO DETERMINE WHETHER CONIC PORTION HAS CONVERGED TO A SUITABLE REENTRY ANGLE (ALTHOUGH THE TEST IS MADE ON THE COTANGENT OF THE ANGLE, IT IS EQUIVALENT TO $.058^o$)	.001	.001	2^0
$EPC4RTE_D$	ε_4	CRITERION USED TO DETERMINE WHETHER PRECISION PORTION OF FINAL STATE VECTOR COMPUTATION HAS REACHED THE DESIRED REENTRY ANGLE (TEST MADE ON COTANGENT EQUIVALENT TO $.00058^o$)	.00001	.00001	2^0
$EPC6RTE_D$	ε_6	CRITERION USED TO DETERMINE WHETHER FINAL STATE VECTOR COMPUTATION HAS ALREADY REACHED THE DESIRED REENTRY ANGLE	.000007	.000007	2^1
$EPC7RTE_D$	ε_7	CRITERION USED TO DETERMINE WHETHER PRECISION SECTION HAS CONVERGED UPON THE REENTRY RADIUS SELECTED IN CONIC PORTION	1000 METERS	1000 METERS	2^{29}
$EPC8RTE_D$	ε_8	CRITERION USED TO MAKE FINAL CHECK ON REENTRY ANGLE REACHED IN PRECISION PORTION (TEST ON COTANGENT, EQUIVALENT TO $.116^o$)	.002	.002	2^0
$EPC9RTE_D$	ε_9	CRITERION USED TO DETERMINE IF GAMDV10 ITERATOR HAS REACHED A MINIMUM	2^{-20}	2^{-20}	2^5
$EPC10RTE_D$	ε_{10}	CRITERION USED TO DETERMINE WHETHER GAMDV10 ITERATOR HAS REACHED DESIRED ΔV	0.01 M/SEC	0.0001 M/CSEC	2^7
$E3RTE_D$	E_3	REENTRY ALTITUDE ABOVE FISCHER ELLIPSOID	121920 M	121420 M	2^{29}
$K1RTE_D$	K_1	RADIUS USED TO DETERMINE WHICH ESTIMATE OF REENTRY ANGLE TO BE USED	7.0×10^6 M	7.0×10^6 M	2^{29}
$K2RTE_D$	K_2	INITIAL ESTIMATE OF REENTRY RADIUS	6.495×10^6 M	6495000 M	2^{29}
$K3RTE_D$	K_3	INITIAL ESTIMATE OF COTANGENT OF REENTRY ANGLE USED WHEN $\lvert R(T1)/V \rvert < K1$ (EQUIVALENT TO $-3^o 29.5'$)	-.06105	-.06105	2^0

PROGRAM CONSTANTS (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING VALUE AND UNITS	AGC VALUE AND UNITS	AGC SCALING
$K4RTE_D$	K_4	INITIAL ESTIMATE OF COTANGENT OF REENTRY ANGLE USED WHEN $\lvert R(T1)/V \rvert > K1$ (EQUIVALENT TO $-5^{\circ}58'$	-.10453	-.10453	2^0
$MCOS7.5_D$	$-COS\ 7.5^{\circ}$	USED IN DETERMINING GSOP QUANTITY K	-.99144486	-.99144488	2^0
$MCOS22.5_D$	$-COS\ 22.5^{\circ}$	CRITERION USED TO DETERMINE WHETHER TARGET FOR LAMBERT STEERING IS TOO CLOSE TO 180°	-.82387853 -.	-.82387953	2^2
$MDOTHI_D$	$\dot{m}(SPS)$	MASS DECREMENTATION FACTOR FOR SPS BURN	63.8 LB/SEC	.289391932 KG/CSEC	2^3
$MDOTRCS_D$	$\dot{m}(RCS)$	MASS DECREMENTATION FACTOR FOR RCS BURN	.16375 KG/SEC	.0016375 KG/CSEC	2^3
$MSIN7.5_D$	$-SIN\ 7.5^{\circ}$	USED IN DETERMINING GSOP QUANTITY K	-.13052619	-.13052619	2^0
$RTMURTE_D$	$\sqrt{\mu_E}$	SQUARE ROOT OF EARTH GRAVITATIONAL CONSTANT	19965050.1 $M^{3/2}$/SEC	199650.501 $M^{3/2}$/CSEC	2^{18}
$THETA165_D$	165°	165° = POSITION OF NEW TARGET FOR LAMBERT STEERING	165°	.458333333 REVS	2^0
$THETA210_D$	210°	210° = POSITION OF ALTERNATE NEW TARGET FOR LAMBERT STEERING	210°	.58333333 REVS	2^0
$VCRCS_D$	$V_C(RCS)$	THRUST VELOCITY OF RCS JETS	2706.64 METERS/SEC	27.0664 METERS/CSEC	2^5
$VCSPS_D$	$V_C(SPS)$	THRUST VELOCITY OF SPS ENGINE	3088.11 METERS/SEC	30.8811 METERS/CSEC	2^5
$2RTEB1_D$	POSMAX	INITIAL SETTING OF Δt_{21}	3777737777 OCT	3777737777 OCT	2^0
$30480RTE_D$	30480	INPUT TO TIMERAD = R(T2)/V - 30480	30480 METERS	30480 METERS	2^{29}

THE FOLLOWING ARE INPUTS TO THE POLY SUBROUTINE. CALLED TO COMPUTE MAMAX2, X(t2)', AND $\frac{-\Delta v/v_e}{(1-e)}$, IN THE ORDER THEY APPEAR. (ALL VALUES DP; NO AGC TAGS - POLY USES INDEXED ADDRESSING.)

		ENGINEERING VALUE AND UNITS	AGC VALUE AND UNITS	AGC SCALING
C_0	COEFFICIENTS USED TO COMPUTE MA_2	1.81000434×10^8 M	181000434 M	2^{31}
C_1		1.50785145	1.50785145	2^2
C_2		$-6.49983057 \times 10^{-9}$ M^{-1}	-6.49993057 $\times 10^{-9}$ M^{-1}	2^{-27}
C_3		$8.76938926 \times 10^{-18}$ M^{-2}	9.76938926 $\times 10^{-18}$ M^{-2}	2^{-56}

PROGRAM CONSTANTS (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING VALUE AND UNITS	AGC VALUE AND UNITS	AGC SCALING
	D_1	COEFFICIENTS USED TO COMPUTE x(T2)'		0	
	D_2		$-4.8760771 \times 10^{-4}$ S/M	$-4.8760771 \times 10^{-2}$ CSEC/M	2^{-4}
	D_3		4.5419478×10^{-8} S^2/M^2	4.5419476×10^{-4} $CSEC^2/M^2$	2^{11}
	D_4		$-1.4317675 \times 10^{-12}$ S^3/M^3	$-1.4317675 \times 10^{-6}$ $CSEC^3/M^3$	2^{-18}
–		C_0 COEFFICIENTS USED TO COMPUTE $(1-e^{-\Delta v/vc})$		$5.66240507 \times 10^{-4}$	2^3
–		C_1		0.979487897	2^1
–		C_2		-.388281955	2^{-1}

ORBITAL PARAMETERS DISPLAY

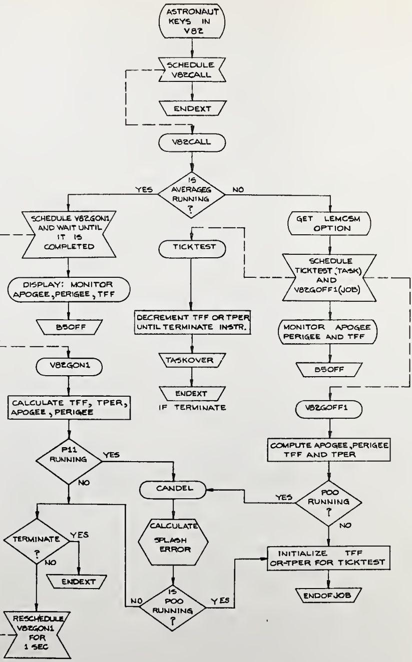
MAJOR SUBROUTINES AND EXTERNAL ENTRY POINTS

DRAWN 4 FEB 69
PROGMR
ANALYST
DOCMR 28 Feb 69
APPR'D 6 MAR 69

ORBITAL PARAMETERS DISPLAY

COLOSSUS II FC-2650

REV 1 17



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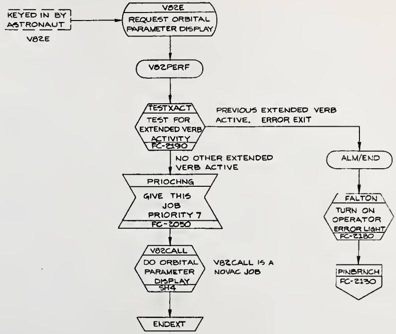
ORBITAL PARAMETERS DISPLAY

COLOSSUS II

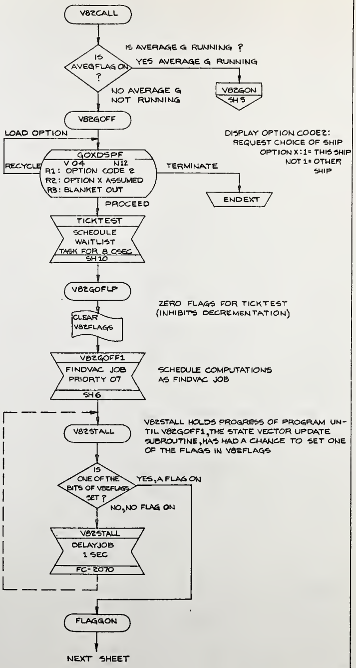
DOCUMENT NO. FC-2650

REV

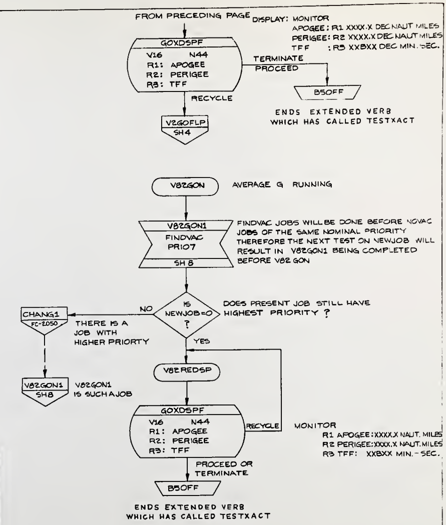
SHEET 2 OF 17



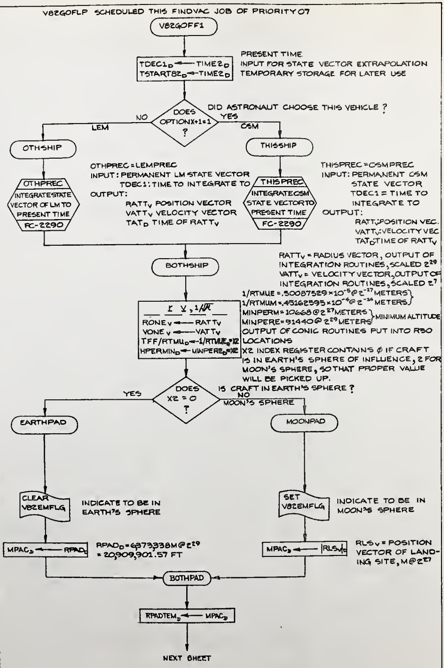
MIT INSTRUMENTATION LAB CAMBRIDGE MASS		ORBITAL PARAMETERS DISPLAY
DRAWN [illegible]	2DEC68	
PRGMR [illegible]	28Feb69	
ANALST		COLOSSUS II FC-2650
DOCMR [illegible]		
APPR'D [illegible]		REV 3 17



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN D. S. Chmelewski 20DEC68	ORBITAL PARAMETERS DISPLAY
PRGMR C. M. Brock 28JAN69	
ANALST	COLOSSUS II — DOCUMENT NO. FC-2650
DOCMR D. Brink 23FEB69	
APPR'D John A. Moore 6 MAR 69	REV — SHEET 4 OF 17



MIT INSTRUMENTATION LAB CAMBRIDGE MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN Z.S. Chmielinski 20DEC65	ORBITAL PARAMETERS DISPLAY
PRGMR C. M. Beals 28FEB69	
ANALYST	COLOSSUS II FC-2650
DOCMR D. Rueben 27FEB69	
APPR'D John A. Miller 6 MAR 69	REV 5 17



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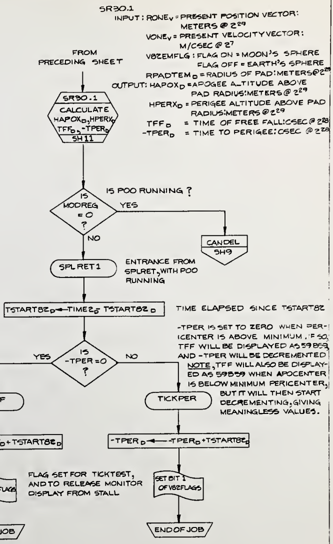
DRAWN 2.S. Chmelnicki	ORBITAL PARAMETERS DISPLAY
PRGMR e. m. Grace	COLOSSUS II
ANALST	DOCUMENT NO FC-2650
DOCMR R. Rinker	
APPR'D John A. Moore	REV — SHEET 6 OF 17



DRAWN Z.S. Chmielewski 13DEC68
PROG MR C. M. Beals 28Feb69
PROG MR D. Rinker 28Feb.69
APPD John A. Moore 6MAR69

ORBITAL PARAMETERS DISPLAY

COLOSSUS II FC-2650

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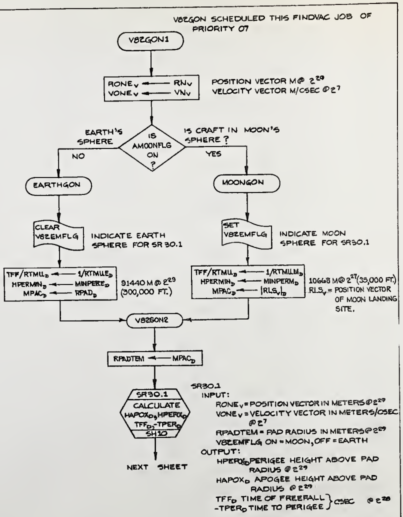

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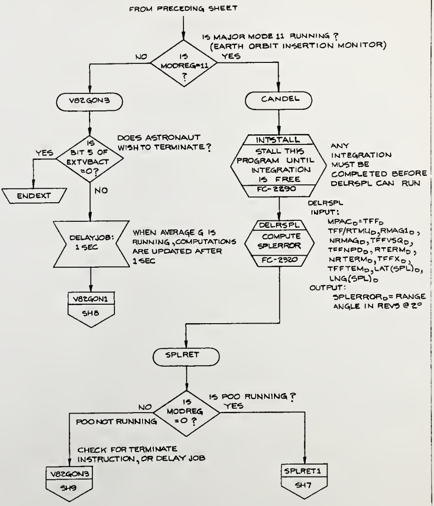
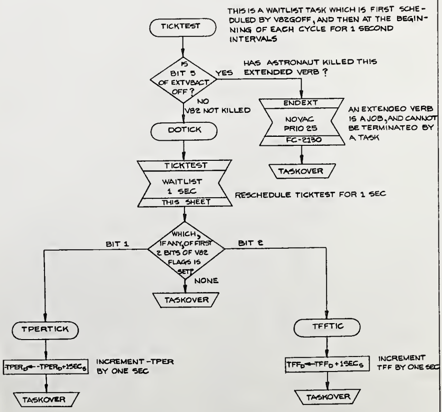
DRAWN	ORBITAL PARAMETERS DISPLAY
PRGMR	
ANALST	COLOSSUS II — DOCUMENT NO. FC-2650
DOCMR	
APPR'D	REV — SHEET 8 OF 17



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS	ORBITAL PARAMETERS DISPLAY
DRAWN D.J. Chmielinski 26DEC68	
PROGRAM C. M. Beals 28JUL69	
ANALYST	COLOSSUS II FC-2650
DOCMR D. Rumble 4Feb69	
APPR'D John A. Moore 14MAR69	9 17



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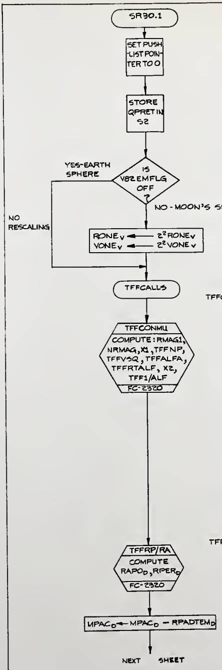
SHEET 10 OF 17



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}

$TFFVSQ_D$: $\underline{V}/\sqrt{\mu} \cdot \underline{V}/\sqrt{\mu}$ 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 @ 2^{22+2NA} E @ 2^{20+2NA} M

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

TFFRP/RA:

INPUT:

$TFFALFA_D$ = α = $(\text{SEMI-MAJOR AXIS})^{-1}$ 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 @ $2^{29}/2^{2}$

$RAPO_D$ = APOGEE RADIUS IN METERS @ $2^{29}/2^{2}$

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DRAWN J. J. Chmylenski
PRGMR C. M. Braks 25Feb69
ANALYST
DOCMR D. Fein... 21Feb69
APPR'D John A. Miller 6MAR69

ORBITAL PARAMETERS DISPLAY

COLOSSUS II

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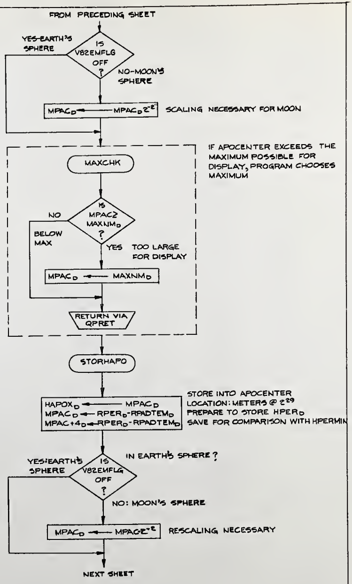
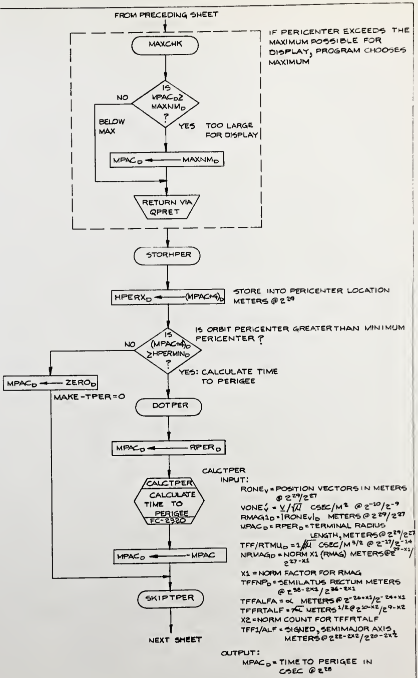


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
	ORBITAL PARAMETERS DISPLAY
DRAWN Z.J. Chmielinski 17 Dec 68	COLOSSUS II
PRGMR C. M. Boal 28 Feb 69	DOCUMENT NO. FC-2650
ANALYST	
DOCMR D. Reinke 27 Feb 69	
APPR'D John A. Moon 6 Mar 69	REV / SHEET 12 OF 17



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DRAWN Z.S. Chmielinski 27DEC68
CHECKED M. Beals 28FEB69
ANALYST
DECMR J. Rinker 28 Feb 69
APPROVED John A. Moore 6 MAR 69
REV

ORBITAL PARAMETERS DISPLAY

COLOSSUS II FC-2650

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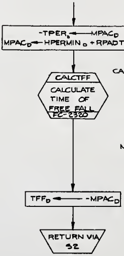

CALCTFF

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 = TIME OF FREE-FALL, IN CSEC @ 2^{28}

NOTE:

IF THE TRAJECTORY FAILS TO REACH HPERMIN + RPADTEM (300,000′ OR 35,000′) THEN TFF WILL BE DISPLAYED AS 59B59

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
	ORBITAL PARAMETERS DISPLAY
DRAWN	
PRGMR C. M. Beals	
ANALST	COLOSSUS II — DOCUMENT NO. FC-2650
DOCMR J. Reinke	
APPR'D John A. Moore	REV — SHEET 14 OF 17

DISPLAYS

VERB NOUN	TYPE OF DISPLAY	DESCRIPTION OF EACH REGISTER	WHERE EXECUTED
	FALTON	TURN ON OPERATOR ERROR LIGHT: PREVIOUS EXTENDED VERB ACTIVE.	SH. 3
04-12	GOXDSPF	R1 OPTION CODE 2 R2 OPTION I ASSUMED R3 BLANKED OUT	SH. 4
16-44	GOXDSPF	R1 APOGEE: XXXX.X D NAUT MILES R2 PERIGEE XXXX.X D NAUT MILES R3 TFF. XXBXX D MIN, SEC	SH. 5

FLAGS

NAME	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
AVEGFLAG	AVERAGEG RUNNING	AVERAGEG NOT RUNNING			SH. 4
BIT 5 OF EXTVBACT	DO NOT TERMINATE EXTENDED VERB	TERMINATE EXTENDED VERB			SH.
AMOONFLG	IN MOON'S SPHERE	IN EARTH'S SPHERE			SH. 8
V82EMFLG	IN MOON'S SPHERE	IN EARTH'S SPHERE	SH. 6,8	SH. 6,8	SH. 11, 12, 12
V82FLAGS	EITHER SET: START DISPLAY	NEITHER SET: HOLD DISPLAY	SH.	SH. 4	SH. 4
BIT 1 OF V82FLAGS	TICKPER OPERATING	TICKPER NOT OPERATING	SH.7		
BIT 2 OF V82FLAG	TICKTFF OPERATING	TICKTFF NOT OPERATING	SH.7		

SUBROUTINES CALLED WHICH ARE FLOWED ON OTHER FLOW CHARTS

SUBROUTINE NAME	FLOW CHART	DESCRIPTION	WHERE CALLED
CALCTFF	2370	CALCULATES TIME OF FREE FALL TO A PARTICULAR RADIUS	SH.14
CALCTPER	2320	CALCULATES TIME OF FREE FALL TO PERICENTER	SH.13
DELAYJOB	2070	DELAYS A JOB FOR A PARTICULAR TIME PERIOD	SH.
DELRSPL	2320	CALCULATES ERROR IN SPLASHDOWN BETWEEN CALCULATED AND PREDICTED	SH.9
ENDEXT	2130	ENDS AN EXTENDED VERB	SH.10
FALTON	2130	TURNS ON OPERATOR ERROR LIGHT	SH.3
OTHPREC	2300	UPDATE LEM VECTOR TO A PARTICULAR TIME	SH.6
PRIOCHNG	2050	CHANGE CALLING JOB'S PRIORITY	SH.3
TESTXACT	2190	TEST FOR EXTENDED VERB ACTIVITY	SH.3
TFFCONMU	2320	COMPUTES VARIOUS PARAMETERS USED IN THE TFF ROUTINES, AND ESTABLISHES THEM IN THE PUSH LIST AREA	SH.11
TFFRP/RA	2320	CALCULATES PERIGEE AND APOGEE RADIUS FOR A GIVEN CONIC	SH.11
THISPREC	2300	UPDATE CSM STATE VECTOR TO A PARTICULAR TIME	SH.6
INTSTALL	2300	STALL CALLING PROGRAM UNTIL INTEGRATION IS NOT IN USE. THEN INHIBIT ANY OTHER PROGRAM FROM USING INTEGRATION UNTIL INTWAKE IS CALLED.	SH.9

MIT INSTRUMENTATION LAB. MASS.

DRAWN 22 JAN 69 · CHECKED 28 FEB 69 · APPROVED John A. Moore 6 MAR 69

ORBITAL PARAMETERS DISPLAY

COLOSSUS II FC-2650

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	$2^{29}/2^{27}$
MODREG		MAJOR MODE INDICATION			
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}
$\lvert RLS_V\rvert_D$	r_{LS}	LUNAR LANDING SITE RADIUS	FEET	METERS	2^{27}
$RMAG1_D$	r	MAGNITUDE OF RADIUS VECTOR	FEET	METERS	$2^{27}/2^{29}$
RN_V	$\underline{r}$	RADIUS VECTOR AS GIVEN BY AVERAGEG	FEET	METERS	2^{29}
$RONE_V$	$\underline{r}$	RADIUS VECTOR INPUT TO INTEGRATION	FEET	METERS	$2^{29}/2^{27}$
$RPADTEM_D$		LOCATION FOR STORING PAD RADIUS	FEET	METERS	$2^{29}/2^{27}$
$RPER_D$	r_p	MAGNITUDE OF PERICENTER	FEET	METERS	$2^{27}/2^{29}$
TFF_D	t_{ff}	TIME OF FREE FALL TO A CERTAIN ALTITUDE	SECONDS	CSEC	2^{28}
$TFF/RTMU_D$	$1/\sqrt{\mu}$	INVERSE OF SQUARE ROOT OF MU	$SEC/FEET^{3/2}$	$CSEC/M^{3/2}$	$2^{14}/2^{17}$
$TFFALFA_D$	α	INVERSE OF THE SEMIMAJOR AXIS OF A CONIC	1/FEET	1/METERS	$2^{-26-x1}/2^{-24-x1}$
$TFFNP_D$	p	SEMILATUS RECTUM, NORMALIZED	FEET	METERS	$2^{28+x1}/2^{36+x1}$
$TFFRTALF_D$	$\sqrt{\alpha}$	SQUARE ROOT OF ALPHA	$1/FEET^{1/2}$	$1/M^{1/2}$	$2^{-10-x1}/2^{-9-x1}$
$TFFVSQ_D$	$(v')^2$	VELOCITY/$\sqrt{u}$	$1/FEET^{1/2}$	$1/M^{1/2}$	$2^{-20}/2^{-18}$
$TFF1/ALF_D$		SIGNED, SEMI-MAJOR AXIS, WEIGHTED BY X2	FEET	METERS	$2^{22-2x2}/2^{20-2x2}$
$TIME2_D$		TIMING REGISTERS	SECONDS	CSEC	2^{28}
$TSTART82_D$		STORAGE FOR TIME2 INPUT	SECONDS	CSEC	2^{28}
$TDEC1_D$		TIME TO BE INTEGRATED TO	SECONDS	CSEC	2^{28}

ERASABLE LOCATIONS USED (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
$VATT_V$		VELOCITY OUTPUT OF INTEGRATION ROUTINES	FEET/SEC	METERS/CSEC	2^7
VN_V		VELOCITY VECTOR, OUTPUT OF AVERAGEG	FEET/SEC	M/CSEC	2^7
$VONE_V$		VELOCITY VECTOR	FEET/SEC	M/CSEC	2^7
$VONE'_V$		$VONE/\sqrt{\mu}$	$FEET^{-1/2}$	$M^{-1/2}$	$2^{-10}/2^{-9}$

PROGRAM CONSTANTS

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING VALUE AND UNITS	AGC VALUE AND UNITS	AGC SCALING
MAXNM		MAXIMUM DISPLAY VALUE POSSIBLE	9999.9 NM	$01065\ 05603_8$	2^0
MINPERE	r_{pMIN}	300,000 FT REFERENCE ALT FOR EARTH	300,000 FT	91440 METERS	2^{29}
MINPERM	r_pMIN	35,000 FT REFERENCE ALT FOR MOON	35,000 FT	1068 METERS	2^{27}
RPAD		STANDARD PAD RADIUS	20910922 FT	6373338 M	2^{29}
1/RTMUE	$1/\sqrt{u_e}$	INVERSE OF THE SQUARE ROOT OF MU FOR EARTH	$.0008427916 \times 10^{-5}$	50087529×10^{-5}	2^{-17}
1/RTMU	$1/\sqrt{u_M}$	INVERSE OF THE SQUARE ROOT OF MU FOR MOON	$.007599228 \times 10^{-4}\ SEC/FT^{3/2}$	$.45162595 \times 10^{-4}\ CSEC/M^{3/2}$	2^{-14}

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CAMBRIDGE, MASS.

DRAWN 22JAN69
PRGMR 25Feb69
ANALST
DOCMR 28Feb69
APPR'D 6MAR69

ORBITAL PARAMETERS DISPLAY

COLOSSUS II

DOCUMENT NO. FC-2650

REV

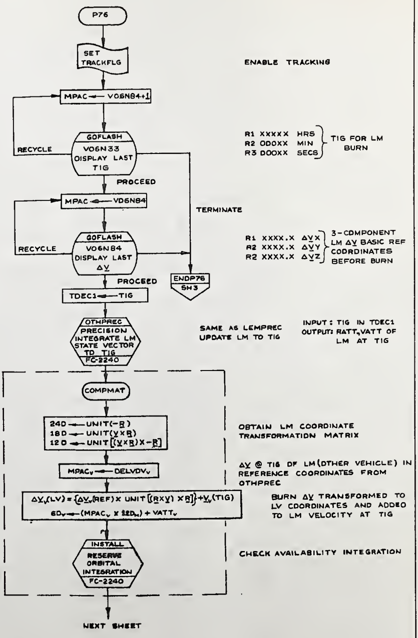
P-76 TARGET DELTA VELOCITY

MAJOR SUBROUTINES & EXTERNAL ENTRY POINTS:

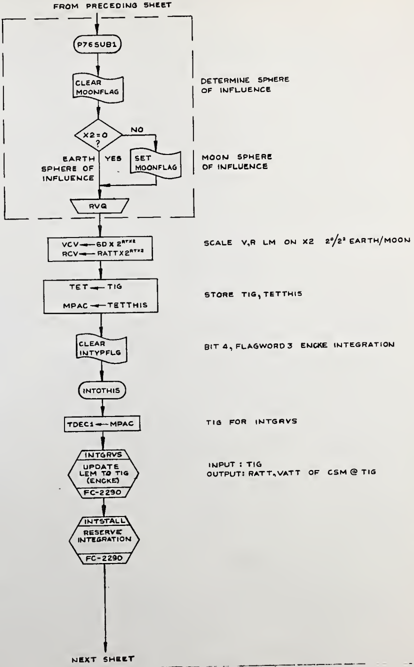
COMPMAT(SH2), P76SUB1(SH3)

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS		P-76 TARGET DELTA V
F.B. Lawrence	27 MAR 69	
T.E. Lecher	15 APR 69	
Dan Millard	15 APR 69	COLOSSUS IIC FC-2670
John A. Moore	2 May 69	REV 1 SH 1 OF 6

14



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN [signature]	P-76 TARGET DELTA V
PRGMR [signature]	
ANALST	COLOSSUS IIC — DOCUMENT NO. FC-2670
DOCMR [signature]	
APPR'D [signature]	REV 1 — SHEET 2 OF 6



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

DRAWN	F. D. Laverriere	31MAR69
PRGMR	J.E. ...	15APR69
ANALYST		
DOCMD	...	2 May 69
APPR'D	John A. ...	2 May 69

APOLLO GUIDANCE AND NAVIG.

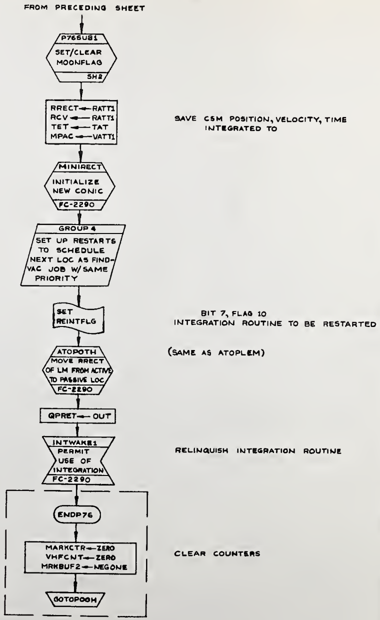
P76

TARGET DELTA V

COLOSSUS IIC

FC-2670

REV 1 SHEET 3 OF 6



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	31MAR69	P76 TARGET DELTA V	
PRGMR	15APR69	COLOSSUS IIC	DOCUMENT NO. FC-2670
ANALST			
DOCMR	2 May 69		
APPR'D	2 May 69	REV 1	SHEET 4 OF 6

SUBROUTINES CALLED

SUBROUTINE NAME	DESCRIPTION
OTHPREC	(SAME AS LEMPREC) PRECISION INTEGRATION OF LM
INTSTALL	RESERVES ORBITAL INTEGRATION
INTGRVS	ENKE UPDATE OF LEM TO TIG
MINIRECT	INITIALIZE NEW CONIC
ATOPOTH	MOVES LM STATE VECTOR TO PASSIVE STORAGE LOC
INTWAKE1	RELEASES INTEGRATION ROUTINES

FLAGS

NAME	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
TRACKFLG	ENABLE MARKTAKING	INHIBIT MARKTAKING	SH. 1		
MOONFLAG	MOON SPHERE OF INFLUENCE	EARTH SPHERE OF INFLUENCE	SH. 2	SH. 2	
INTYPFLAG	ENKE INTEGRATION	CONIC INTEGRATION		SH. 2	
REINTFLAG	RESTART INTEGRATION	DO NOT RESTART INTEGRATION	SH. 3		

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 (LM)		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 CSM STATE VECTOR		CSEC	2^{28}
RRECT		TEMPORARY POSITION AT RECT TIME		M	2^{29}
MARKCTR		MARK COUNTER (USED BY R32)			2^{0}
VHFCNT		VHF MARK COUNTER			2^{0}
MRKBUF2		TEMP MARK COUNTER FOR R21			2^{0}
NEGONE		NEGATIVE 1			2^{14}

DISPLAYS

VERB-NOUN	TYPE OF DISPLAY	DESCRIPTION OF EACH REGISTER	WHERE EXECUTED
V06N84		DISPLAY LAST $\Delta \underline{V}$	SH. 1
V06N83		DISPLAY LAST TIG	SH. 1

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN [signature] 1APR69	P76 TARGET DELTA V	
PRGMR J.E. [signature] [date]		
ANALST	COLOSSUS IIC	DOCUMENT NO. FC-2670
DOCMR [signature] 2 May 69		
APPR'D [signature] 2 May 69	REV 1	SHEET 6 OF 6

STEERING

MAJOR SUBROUTINES AND EXTERNAL ENTRY POINTS		
STEERING:	CAUSES VELOCITY-TO-BE-GAINED UPDATE AND STEERING COMPUTATIONS	SH 3
CALCN85	PREPARES NOUN 85 (VELOCITY-TO-BE-GAINED) FOR DISPLAY	SH 5
P40CNV85	CONVERTS VELOCITY-TO-BE-GAINED TO CONTROL COORDINATES	SH 5
UPDATEVG:	SETS UP VELOCITY-TO-BE-GAINED AND CROSS-PRODUCT STEERING COMPUTATIONS	SH 6
S40.8:	COMPUTES REMAINING BURN TIME AND, IF NECESSARY, STEERING COMMANDS	SH 9
S40.9:	UPDATES VELOCITY-TO-BE-GAINED, USING LAMBERT ROUTINE	SH 14
REDO40.9:	POSSIBLE RESTART ENTRY TO S40.9	SH 17

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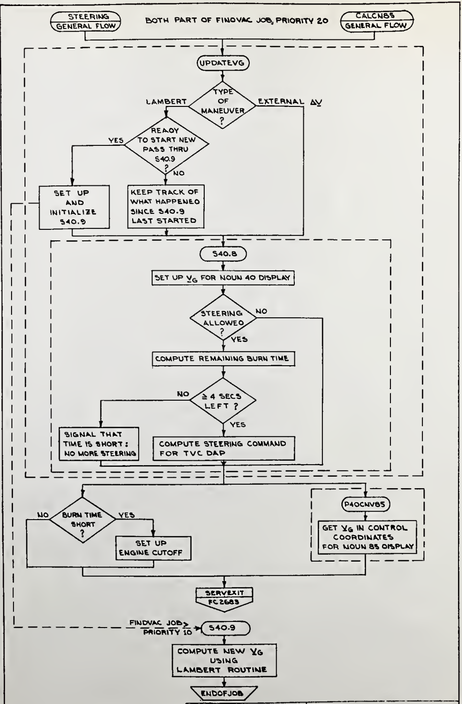
DRAWN G. A. Langille 25OCT68
PRGMR A. J. Engel Jr. 3/31/69
ANALST Peter J. Philliou 28 March 69
DOC.MR Joseph M. Lorant 28MAR69
APPR'D John A. Moore 31 MAR 69

STEERING

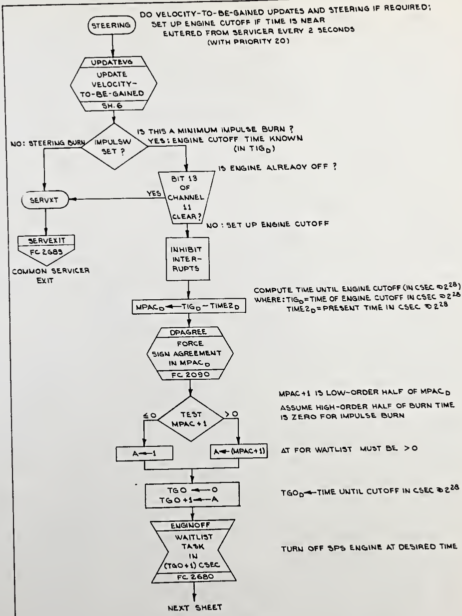
COLOSSUS II

FC-2682

SHEET 1 OF 21



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN T.B. 27 NOV 68	STEERING
PRGMR 1/31/69	
ANALST 24 Mar 69	COLOSSUS II — DOCUMENT NO. FC-2682
DOCMR 28 Mar 69	
APPR'D 31 Mar 69	REV — SHEET 2 OF 21



MIT INSTRUMENTATION LAB
CAMBRIDGE MASS

DRAWN TJB 10DEC68
PROGRAMMED 3/21/69
ANALYST
DOCUMENTED 28MAR69
APPROVED 31MAR69

STEERING

COLOSSUS II

FC-2682

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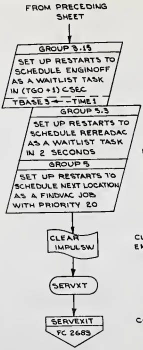

NOTE: Δ TIMES FOR THIS AND OTHER GROUP 5 WAITLIST TASK RESTARTS ARE MEASURED FROM THE LAST TIME READACCS WAS SCHEDULED

CUTOFF-TIME NO LONGER NEEDED—ENGINOFF ALREADY SET UP

COMMON SERVICER EXIT

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APOLLO GUIDANCE AND NAVIGATION

STEERING

DRAWN T.B.
PRGMR
ANALST
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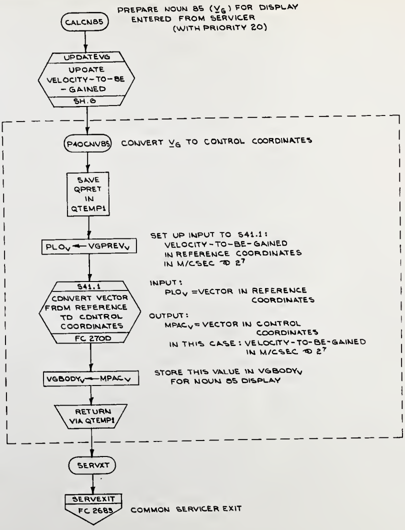
COLOSSUS II

REV

DOCUMENT NO. FC-2682

SHEET 4 OF 21



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DRAWN TB 26 NOV 68
PRGMR 3/21/69
ANALST
DOC MB 28 MAR 69
APPR'D 31 MAR 69

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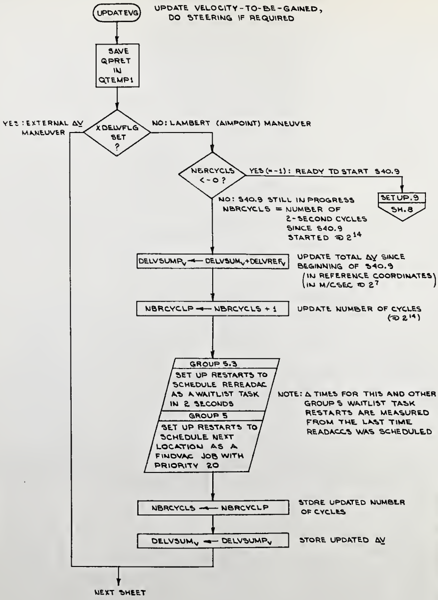
COLOSSUS II

FC-2682

REV 5 21



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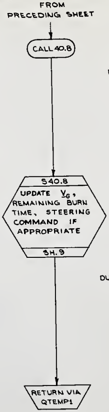
DRAWN T.B. 2DEC68	STEERING
PRGMR 3/11/69	
ANALST	COLOSSUS II — DOCUMENT NO. FC-2682
DOCMR	
APP'D	REV — SHEET 6 OF 21



INPUTS: $VGPREV_V$ = LAST VALUE OF VELOCITY-TO-BE-GAINED IN REFERENCE COORDINATES, IN M/CSEC $\text{⊕} 2^7$

BDT_V = CHANGE IN REQUIRED VELOCITY, CORRECTED FOR GRAVITATIONAL EFFECTS, OVER 2 SECONDS IN REFERENCE COORDINATES, IN M/CSEC $\text{⊕} 2^7$

$DELVREF_V$ = SENSED VELOCITY CHANGE IN REFERENCE COORDINATES, IN M/CSEC $\text{⊕} 2^7$

IDLEFAIL – INDICATES WHETHER ENGINE FAIL INHIBITED

STEERSW – INDICATES WHETHER STEERING IS TO BE DONE

$PIPTIME_D$ = TIME OF LAST ΔV MEASUREMENT, IN CSEC $\text{⊕} 2^{28}$

CSTEER = CROSS PRODUCT STEERING CONSTANT $\text{⊕} 2^2$

$KPRIMEDT_D$ = STEER LAW GAIN × TVC DAP CYCLE TIME (FROM TVC DAP) IN REVS $\text{⊕} 2^{-4}$

OUTPUTS: $VGPREV_V = VG_V$ = NEW VELOCITY-TO-BE-GAINED IN REFERENCE COORDINATES, IN M/CSEC $\text{⊕} 2^7$

$VGDISP_D$ = MAGNITUDE OF V_G FOR DISPLAY IN M/CSEC $\text{⊕} 2^7$

TGO_D = BURN TIME REMAINING IN CSEC $\text{⊕} 2^{28}$

$OMEGAC_V$ = ROTATIONAL STEERING COMMAND (FOR TVC DAP) IN NAV. BASE COORDINATES IN REVS $\text{⊕} 2^{-1}$

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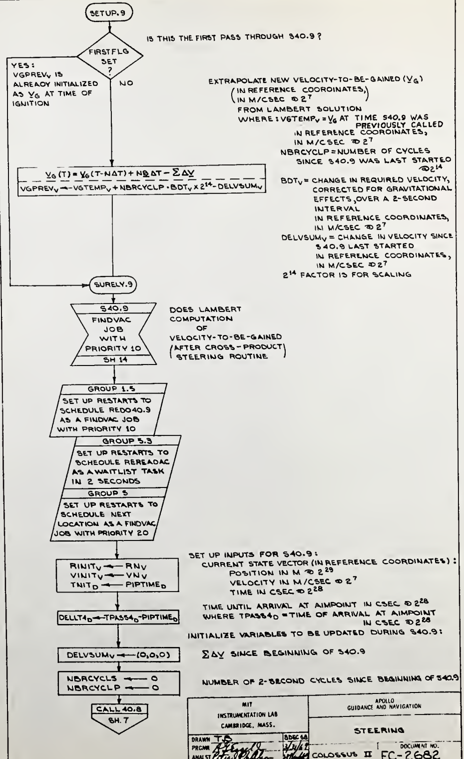
DRAWN T.B.	2 DEC 68	STEERING
PRGMR	3/31/69	
ANALST		COLOSSUS II FC-2682
DOCMR	28 MAR 69	
APPR'D	31 MAR 69	SHEET 7 21



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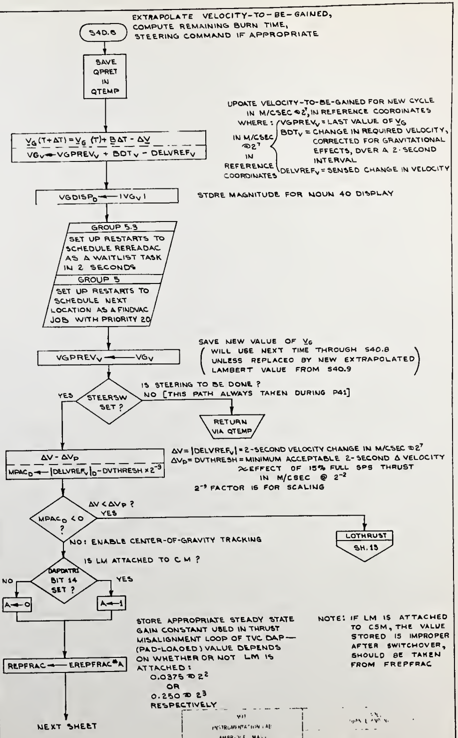
		STEERING
DRAWN T.S.	8DEC68	
PRGMR		
ANALST		COLOSSUS II — DOCUMENT NO. FC-2682
DOCMR		
APPR'D		REV — SHEET 8 OF 21



MIT INSTRUMENTATION LAB CAMBRIDGE MASS.

DRAWN T.B. 4DEC68
PRGMR A. Engel Jr. 3/31/69
ANALYST Peter P. Weller
DOCMR Alex M. Grant 28MAR69
APPR'D John A. Morse 31MAR69

STEERING

COLOSSUS II FC-2682

9 21

FROM PRECEDING SHEET

TGOCALC

UNIT$(\Delta \underline{V}_G) \cdot \underline{V}_G$

$PLO_D \leftarrow UNIT(BDT_V - DELVREF_V) \cdot VG_V$

DETERMINE COMPONENT OF V_G IN THE DIRECTION OF ΔV_G IN M/CSEC ⊕ 2^8
WHERE: $VG_V = \underline{V}_G$ IN REFERENCE COORDINATES IN M/CSEC ⊕ 2^7
$DELVREF_V$ = SENSED ΔV OVER 2 SECONDS IN REFERENCE COORDINATES IN M/CSEC ⊕ 2^7
BDT_V = CHANGE IN REQUIRED VELOCITY, CORRECTED FOR GRAVITATIONAL EFFECTS, OVER 2 SECONDS IN REFERENCE COORDINATES IN M/CSEC ⊕ 2^7
UNIT OPERATION CREATES UNIT VECTOR ⊕ 2^1

$|\Delta \underline{V}_G| = |\underline{B}\Delta T - \Delta \underline{V}|$

$PL36_D \leftarrow |BDT_V - DELVREF_V|$

MAGNITUDE OF ΔV_G (IN M/CSEC ⊕ 2^7) SAVED (BY UNIT OPERATION)

IS $\Delta \underline{V}_G$ IN SAME DIRECTION AS $\underline{V}_G$?

$PLO_D \geq 0$?

YES → **INCRSVG**

ALARM: TURN ON ALARM LIGHT, SET ALARM CODE (FC 2140)

INPUT: ALARM CODE 1407 (INCREASING $\underline{V}_G$)

RETURN VIA QTEMP

NO ↓

$$T_{GO} = \left(1 - 1/2 \frac{|UNIT(\Delta \underline{V}_G) \cdot \underline{V}_G|}{V_E}\right)\left(\frac{|UNIT(\Delta \underline{V}_G) \cdot \underline{V}_G|}{|\Delta \underline{V}_G|}\right) \Delta T - \Delta T_{TAIL-OFF}$$

$$TGO_D \leftarrow \left[\left(2^{-1} + \frac{PLO_D}{2VEXHUST_D}\right)\left(\frac{PLO_D}{PL36_D}\right)(-FOURDT_D) \times 2^{-10}\right] - \left[ETDECAY \times 2^{-14}\right]$$

COMPUTE TIME TO GO UNTIL ENGINE CUTOFF, IN CSEC ⊕ 2^{28}
WHERE:
2VEXHUST = $2V_E$, WHERE
V_E = ENGINE EXHAUST VELOCITY = 31.510396 M/CSEC ⊕ 2^7
$-FOURDT_D$ = -200 CSEC ⊕ 2^{16}
ETDECAY = ENGINE TAIL-OFF TIME IN CSEC ⊕ 2^{14} (PAD LOADED)
$2^{-1} = 1$ ⊕ 2^1
2^{-10} AND 2^{14} FACTORS ARE FOR SCALING

$TIG_D \leftarrow PIPTIME_D + TGO_D$

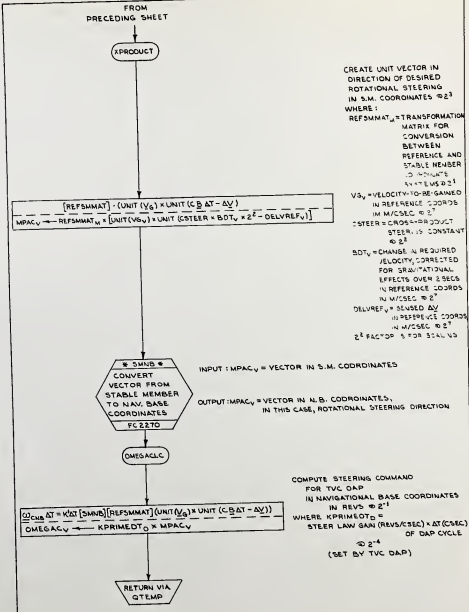
STORE ENGINE CUTOFF TIME (IN CSEC ⊕ 2^{28}) = TIME-TO-GO FROM LAST MEASUREMENT TIME

$TGO_D < 4$ SEC?

YES → S40.81 SH. 12

NO: STILL TIME FOR STEERING

NEXT SHEET



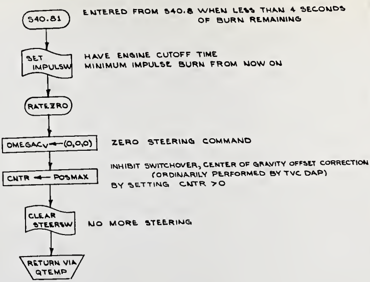
MIT INSTRUMENTATION LAB CAMBRIDGE MASS.

DRAWN TJB 5DEC68
PRGMR A.Engel Jr. 3/31/69
ANAL Peter Kachmar(?) [illegible]
DOCMR Alexa M. Szwant 28MAR69
APPR'D John A. Morse 31 MAR 69

STEERING

COLOSSUS II FC-2682

11 21



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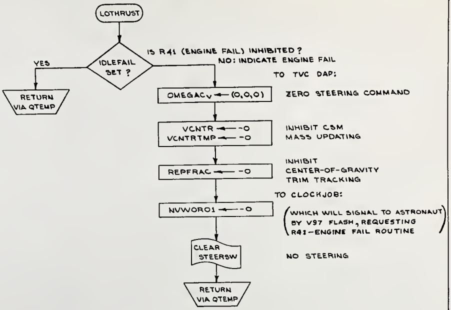
DRAWN / PRGMR / ANALST / DOCMR / APPR'D	STEERING
	COLOSSUS II — DOCUMENT NO. FC-2682
	REV — SHEET 12 OF 21



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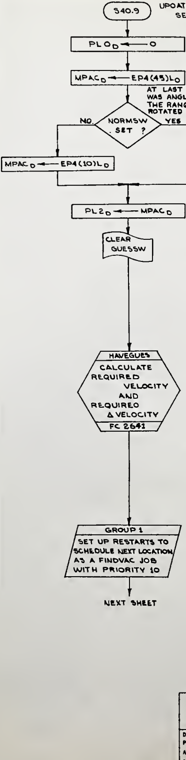
STEERING

DRAWN T.B 4DEC68
PRGMR A. H. Engel Jr. 3/3/69
ANALYST Peter J. Philliou
DOCMR Alexis M. Savant 28MAR69
APPR'D John A. Moore 31MAR69

COLOSSUS II FC-2682

SHEET 13 21



UPDATE VELOCITY-TO-BE-GAINED, B ΔT, USING LAMBERT METHODS SET UP BY UPDATEVG WITH PRIORITY 10

SET PARAMETER FOR HAVEGUES:
= NUMBER OF ITERATIONS-1
(0 INDICATES LAMBERT)

INITIALIZE $MPAC_D$ TO 45°

AT LAST PASS, WAS ANGLE BETWEEN INITIAL AND TARGET POSITION VECTORS IN THE RANGE SUCH THAT THE TARGET VECTOR SHOULD BE ROTATED INTO THE POSITION-VELOCITY PLANE?

IF SO, WANT THIS RANGE TO BE LARGE SO THAT ANGLE BETWEEN INITIAL AND TARGET VECTORS WILL REMAIN IN THE RANGE.

IF NOT, WANT THIS RANGE TO BE SMALL SO THAT ANGLE BETWEEN INITIAL AND TARGET VECTORS WILL REMAIN OUT OF THE RANGE.

SET ε (IN REVS @ 2°) SUCH THAT:
IF ANGLE BETWEEN INITIAL AND TARGET VECTORS IS WITHIN ε OF 1/2 REV (180°), HAVEGUES WILL ROTATE THE TARGET VECTOR INTO THE POSITION-VELOCITY PLANE

HAVE INITIAL VALUE FOR ITERATION

INPUTS: $RINIT_V$ = INITIAL POSITION VECTOR IN REFERENCE COORD'S, IN M @ 2^{29}
$VINIT_V$ = INITIAL VELOCITY VECTOR IN REFERENCE COORD'S, IN M/CSEC @ 2^7
$RTARG_V$ = OFFSET TARGET VECTOR IN REFERENCE COORD'S, IN M @ 2^{29}
$DELLT4_D$ = TIME OF FLIGHT FROM $RINIT_V$ TO $RTARG_V$ IN CSEC @ 2^{28}
PLO_D = NUMBER OF ITERATIONS-1 (0 INDICATES LAMBERT)
$PL2_D$ = ANGLE ε (IN REVS @ 2°) WHICH DETERMINES SITUATION IN WHICH TARGET VECTOR MUST BE ROTATED.
RTX1 - INDICATES WHETHER REFERENCE COORDINATE SYSTEM IS EARTH-OR-MOON-CENTERED, BY VALUE OF -2 OR -10, RESPECTIVELY
RTX2 - SAME AS RTX1, EXCEPT VALUE IS 0 OR 2, RESPECTIVELY

OUTPUTS: $VIPRIME_V$ = INITIAL (ΔT $RINIT_V$) VELOCITY REQUIRED FOR MANEUVER IN REFERENCE COORD'S, IN M/CSEC @ 2^7
$VGTEMP_V$ (= $DELVEET3_V$) = INITIAL CHANGE IN VELOCITY REQUIRED FOR MANEUVER, IN REFERENCE COORD'S, IN M/CSEC @ 2^7
NORMSW - INDICATES WHETHER ANGLE BETWEEN INITIAL AND TARGET POSITION VECTORS IN WITHIN ε OF 180°

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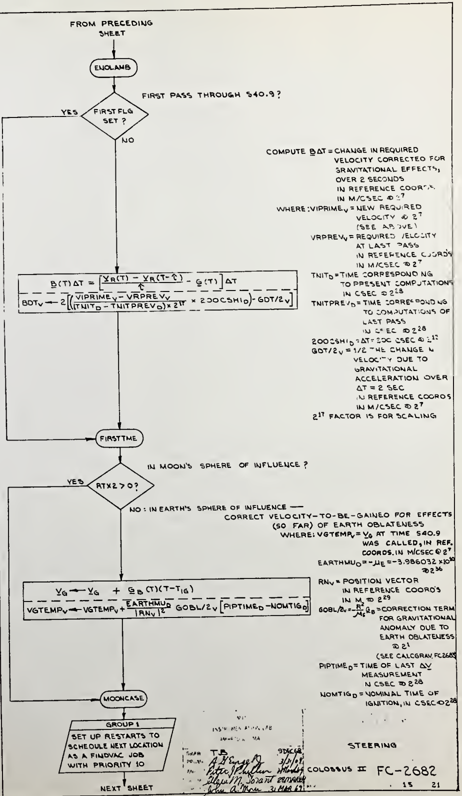
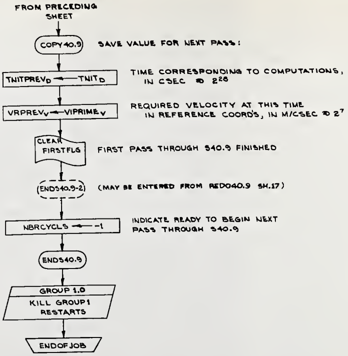
ANALST Peter Phillips	3/17/69	
DOCMR Alex M. Durant	3/27/69	
APP'D John A. Moor	31MAR69	REV — SHEET 14 OF 21


FROM PRECEDING SHEET
ENOLAMB
FIRST PASS THROUGH S40.9?
FIRSTFLG SET ?
YES
NO
COMPUTE BΔT = CHANGE IN REQUIRED VELOCITY CORRECTED FOR GRAVITATIONAL EFFECTS, OVER 2 SECONDS IN REFERENCE COORDS. IN M/CSEC ⊗ 2^7
WHERE: VIPRIME_V = NEW REQUIRED VELOCITY ⊗ 2^7 (SEE ABOVE)
VRPREV_V = REQUIRED VELOCITY AT LAST PASS IN REFERENCE COORDS IN M/CSEC ⊗ 2^7
TNIT_D = TIME CORRESPONDING TO PRESENT COMPUTATIONS IN CSEC ⊗ 2^28
TNITPREV_D = TIME CORRESPONDING TO COMPUTATIONS OF LAST PASS IN CSEC ⊗ 2^28
200CSHI_D = ΔT = 200 CSEC ⊗ 2^17
GDT/2_V = 1/2 THE CHANGE IN VELOCITY DUE TO GRAVITATIONAL ACCELERATION OVER ΔT = 2 SEC IN REFERENCE COORDS IN M/CSEC ⊗ 2^7
2^17 FACTOR IS FOR SCALING
B(T)ΔT = [(V_R(T) − V_R(T−τ))/τ − G(T)] ΔT
BDT_V ← 2[((VIPRIME_V − VRPREV_V)/((TNIT_D − TNITPREV_D) × 2^17) × 200CSHI_D) − GDT/2_V]
FIRSTTME
IN MOON'S SPHERE OF INFLUENCE ?
RTX2 > 0?
YES
NO : IN EARTH'S SPHERE OF INFLUENCE — CORRECT VELOCITY-TO-BE-GAINED FOR EFFECTS (SO FAR) OF EARTH OBLATENESS
WHERE: VGTEMP_V = V_G AT TIME S40.9 WAS CALLED, IN REF. COORDS. IN M/CSEC ⊗ 2^7
EARTHMU_D = −μ_E = −3.986032 x10^14 ⊗ 2^36
RN_V = POSITION VECTOR IN REFERENCE COORDS IN M, ⊗ 2^29
GOBL/2_V = −(R^2/μ_E) G_B = CORRECTION TERM FOR GRAVITATIONAL ANOMALY DUE TO EARTH OBLATENESS ⊗ 2^1 (SEE CALCGRAV, FC2685)
PIPTIME_D = TIME OF LAST ΔV MEASUREMENT IN CSEC ⊗ 2^28
NOMTIG_D = NOMINAL TIME OF IGNITION, IN CSEC ⊗ 2^28
V_G ← V_G + G_B(T)(T−T_IG)
VGTEMP_V ← VGTEMP_V + (EARTHMU_D/|RN_V|^2) GOBL/2_V [PIPTIME_D − NOMTIG_D]
MOONCASE
GROUP 1
SET UP RESTARTS TO SCHEDULE NEXT LOCATION AS A FINDVAC JOB WITH PRIORITY 10
NEXT SHEET
DRAW TB 9DEC68
STEERING
COLOSSUS II FC-2682
15 21



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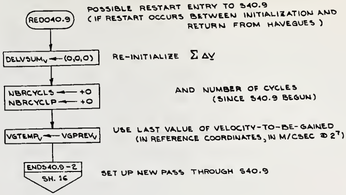
APPR'D	SHEET 16 OF 21



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DOCMR 28MAR69
APPR'D 31 MAR 69

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SHEET 17 OF 21

SUBROUTINES CALLED WHICH ARE
FLOWED ON OTHER FLOW CHARTS

SUBROUTINE NAME	FLOW CHART	DESCRIPTION	WHERE CALLED
ALARM	2140	TURNS ON ALARM LIGHT; SETS ALARM CODE	SH. 10
DPAGREE	2090	FORCES SIGN AGREEMENT IN DOUBLE PRECISION MPAC	SH. 3
ENGINOFF	2680	TURNS OFF SPS ENGINE	SH. 3
HAVEGUES	2641	CALCULATES VELOCITY AND Δ VELOCITY REQUIRED FOR A MANEUVER	SH. 14
SERVEXIT	2683	COMMON EXIT FROM SERVICER ROUTINES	SH. 4, 5
S41.1	2700	CONVERTS VECTOR FROM REFERENCE TO CONTROL COORDINATE SYSTEM	SH. 5
SMNB	2270	CONVERTS VECTOR FROM STABLE MEMBER TO NAVIGATION BASE COORDINATE SYSTEM	SH. 11

FLAGS

NAME	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
DAPDATR1 BIT 14	LM ATTACHED TO CM	LM NOT ATTACHED TO CM			SH. 9
FIRSTFLG FLAGWRD2 BIT 7	FIRST PASS THROUGH S40.9	LATER THAN FIRST PASS THROUGH S40.9		SH. 16	SH. 8 SH. 15
GUESSW FLAGWRD1 BIT 2	NO STARTING VALUE FOR ITERATION	HAVE STARTING VALUE FOR ITERATION		SH. 14	
IDLEFAIL FLAGWRD1 BIT 6	R41 (ENGINE FAIL) INHIBITED	R41 (ENGINE FAIL) ENABLED			SH. 13
IMPULSW FLAGWRD2 BIT 9	MINIMUM IMPULSE BURN - CUTOFF TIME KNOWN	CUTOFF TIME NOT DETERMINED	SH. 13	SH. 4	SH. 4
NORMSW FLAGWRD7 BIT 10	ANGLE BETWEEN INITIAL AND TARGET POSITION VECTORS IS SUCH THAT TARGET VECTOR NEED NOT BE ROTATED INTO POSITION VELOCITY PLANE	ANGLE BETWEEN INITIAL AND TARGET POSITION VECTORS IS SUCH THAT TARGET VECTOR MUST BE ROTATED INTO POSITION VELOCITY PLANE			SH. 14
STEERSW FLAGWRD2 BIT 11	STEERING TO BE DONE	STEERING OMITTED		SH. 12, 13	SH. 9
XDELVFLG FLAGWRD2 BIT 8	EXTERNAL $\Delta \underline{V}$ MANEUVER	LAMBERT (AIMPOINT) MANEUVER			SH. 6

DISPLAYS

VERB-NOUN	TYPE OF DISPLAY	DESCRIPTION OF EACH REGISTER	WHERE EXECUTED
	ALARM	ALARM LIGHT ON; R1, R2, R3 NOT AFFECTED	SH. 10

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ERASABLE LOCATIONS USED

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
BDT_V	$\underline{B}\Delta T$	CHANGE IN REQUIRED VELOCITY, CORRECTED FOR GRAVITATIONAL EFFECTS, OVER ΔT = 2 SECONDS	M/SEC	M/CSEC	2^7
CNTR		USED HERE AS INDICATOR TO TVC DAP OF WHETHER SWITCHOVER, CENTER OF GRAVITY OFFSET CORRECTION SHOULD BE DONE			
CSTEER	C	CROSS - PRODUCT STEERING CONSTANT			2^2
$DELLT4_D$		TIME OF FLIGHT TO AIMPOINT	SEC	CSEC	2^{28}
$DELVREF_V$	$\Delta\underline{V}$	SENSED VELOCITY CHANGE IN REFERENCE COORDINATES	M/SEC	M/CSEC	2^7
$DELVSUM_V$	$\sum\Delta\underline{V}$	TOTAL SENSED VELOCITY CHANGE SINCE LAST TIME S40.9 STARTED, IN REFERENCE COORDINATES	M/SEC	M/CSEC	2^7
$DELVSUMP_V$		TEMPORARY UPDATED VERSION OF $DELVSUM_V$ (ABOVE)	M/SEC	M/CSEC	2^7
$KPRIMEDT_D$	$K'\Delta T$	STEER LAW GAIN x TVC DAP CYCLE TIME	DEGREES	REVS	2^{-4}
NBRCYCLP		TEMPORARY UPDATED VERSION OF NBRCYCLS (BELOW)			2^{14}
NBRCYCLS	N	NUMBER OF 2-SECOND CYCLES SINCE S40.9 LAST STARTED			2^{14}
NVWORD1		INDICATES WHETHER ANY DISPLAY IS TO BE DONE BY CLOCKJOB AND, IF SO, WHICH ONE.			
$OMEGAC_V$	$\underline{\omega}_{CNB}\Delta T$	ROTATIONAL STEERING COMMAND (TO TVC DAP) IN NAVIGATION BASE COORDINATES	DEGREES	REVS	2^{-1}
$PIPTIME_D$	T	TIME OF LATEST ACCELEROMETER READING	SEC	CSEC	2^{28}
$REFSMMAT_M$	[REFSMMAT]	TRANSFORMATION MATRIX FOR CONVERSION BETWEEN STABLE MEMBER AND REFERENCE COORDINATE SYSTEM			2^1
REPFRAC		STEADY STATE GAIN CONSTANT USED IN THRUST MISALIGNMENT LOOP OF TVC DAP - VALUE AND SCALING DEPENDS ON WHETHER LM IS ATTACHED TO CM (SEE SH. 9)			2^2 OR 2^3
$RINIT_V$	$\underline{R}$	INITIAL POSITION VECTOR IN REFERENCE COORDINATES	M	M	2^{29}
RN_V	$\underline{R}$	POSITION VECTOR IN REFERENCE COORDINATES	M	M	2^{29}
TGO_D	T_{GO}	TIME UNTIL ENGINE CUTOFF	SEC	CSEC	2^{28}
TIG_D	T_{IG}	TIME OF ENGINE IGNITION OR CUTOFF, WHICHEVER IS CURRENTLY RELEVANT	SEC	CSEC	2^{28}
$TIME2_D$		PRESENT TIME	SEC	CSEC	2^{28}

ERASABLE LOCATIONS USED (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
$GDT/2_V$	$1/2(\underline{G}\Delta T)$	1/2 THE CHANGE IN VELOCITY DUE TO GRAVITATIONAL ACCELERATION OVER ΔT (2 SECONDS), IN REFERENCE COORDINATES	M/SEC	M/CSEC	2^7
$GOBL/2_V$	$\frac{-R^2}{\mu_E}\,\underline{G}_B(T)$	CORRECTION TERM FOR GRAVITATIONAL ANOMALY DUE TO EARTH OBLATENESS - SATISFIES THE EQUATION: $\underline{G}_{(AT\ \underline{R})} = \frac{-\mu_E}{R^2}\ \mathrm{UNIT}(\underline{R}) + \underline{G}_B$			2^1
$TNIT_D$	T	INITIAL TIME - CORRESPONDING TO $RINIT_V$, $VINIT_V$	SEC	CSEC	2^{28}
$TPASS4_D$		TIME OF ARRIVAL AT AIMPOINT	SEC	CSEC	2^{28}
VCNTR		VARIABLE - GAIN UPDATE COUNTER USED BY TVC DAP			
VCNTRTMP		TEMPORARY STORAGE FOR VCNTR(ABOVE)			
VG_V	$\underline{V}_G(T+\Delta T)$	VELOCITY-TO-BE-GAINED, IN REFERENCE COORDINATES	M/SEC	M/CSEC	2^7
$VGBODY_V$	$\underline{V}_G$	VELOCITY-TO-BE-GAINED, IN CONTROL COORDINATES (FOR NOUN 85 DISPLAY)	M/SEC	M/CSEC	2^7
$VGDISP_D$	$\lvert\underline{V}_G\rvert$	MAGNITUDE OF VELOCITY-TO-BE-GAINED, FOR NOUN 40 DISPLAY	M/SEC	M/CSEC	2^7
$VGTEMP_V$ =$DELVEET3_V$	$\underline{V}_G$	UPDATED VELOCITY-TO-BE-GAINED, IN REFERENCE COORDINATES	M/SEC	M/CSEC	2^7
$VGPREV_V$	$\underline{V}_G(T)$	VELOCITY-TO-BE-GAINED AT PREVIOUS PASS THROUGH S40.8, IN REFERENCE COORDINATES	M/SEC	M/CSEC	2^7
$VINIT_V$	$\underline{V}$	INITIAL VELOCITY VECTOR IN REFERENCE COORDINATES	M/SEC	M/CSEC	2^7
VN_V	$\underline{V}(T)$	VELOCITY VECTOR IN REFERENCE COORDINATES	M/SEC	M/CSEC	2^7

PROGRAM CONSTANTS

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING VALUE AND UNITS	AGC VALUE AND UNITS	AGC SCALING
$EP4(10)L_D$	10°	POSSIBLE VALUE FOR MINIMUM ANGLE BETWEEN INITIAL AND FINAL POSITION VECTORS SUFFICIENT TO DEFINE PLANE OF FLIGHT	10 DEGREES	.027777777 REV	2^0
$EP4(45)L_D$	45°	POSSIBLE VALUE FOR MINIMUM ANGLE BETWEEN INITIAL AND FINAL POSITION VECTORS SUFFICIENT TO DEFINE PLANE OF FLIGHT	45 DEGREES	.125 REV	2^0
$2VEXHUST_D$	$2 \times V_E$	2 x ENGINE EXHAUST VELOCITY	8302.0792 M/SEC	63.020792 M/CSEC	2^7

PAD LOADS

AGC TAG	GSOP TAG	MEANING	ENGINEERING VALUE AND UNITS	AGC VALUE AND UNITS	AGC SCALING	OCTAL VALUE
DVTHRESH	ΔV_P	MINIMUM ACCEPTABLE 2-SECOND VELOCITY CHANGE ≈ 15% OF FULL SPS THRUST FOR 2 SECONDS	.65654715 M/SEC	.0065654715 M/CSEC	2^{-2}	00656
EREPFRAC		STEADY STATE GAIN CONSTANT USED IN THRUST MISALIGNMENT LOOP OF TVC DAP - FOR LM NOT ATTACHED TO CM	0.25	0.25	2^{3}	01000
EREPFRAC+1		STEADY STATE GAIN CONSTANT USED IN THRUST MISALIGNMENT LOOP OF TVC DAP - FOR LM ATTACHED TO CM (BEFORE SWITCH-OVER - SEE SH. 9)	0.0375	0.0375	2^{2}	00232
ETDECAY	$\Delta T_{tail\text{-}off}$	ENGINE TAIL-OFF TIME	.59 SEC	59 CSEC	2^{14}	00073

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ANALST Peter J. Phillips		COLOSSUS II — FC-2682
DOCMR		
APPR John A. Moore	31MAR69	REV — 21 OF 21

SERVICER

MAJOR SUBROUTINES AND EXTERNAL ENTRY POINTS		
PREREAD.	INITIALIZES SERVICER	SH. 3
PREREAD1	ZERO PIPAS	SH. 3
NORMLIZE:	DOES INITIAL STATE VECTOR UPDATE	SH. 5
READACCS:	READS ACCELEROMETERS, SETS UP SERVICER, RESCHEDULES ITSELF EVERY 2 SECONDS UNTIL STOPPED	SH. 6
PIPASR:	READS PIPA COUNTERS	SH. 9
REREADAC:	POSSIBLE RESTART ENTRY TO READACCS - IN CASE ACCELEROMETERS MUST BE REREAD	SH. 10
QUIKREAD:	TAKES QUICK ACCELEROMETER READINGS FOR DOWNLINK TELEMETRY	SH. 12
SERVICER:	CHECKS Δ VELOCITY VALUES READ IN, DOES PERMANENT STATE VECTOR UPDATE USING SENSED Δ VELOCITY	SH. 13
CALCRVG:	COMPUTES NEW STATE VECTOR	SH. 16
CALCGRAV:	CALCULATES GRAVITATIONAL ACCELERATION AT SPECIFIED POSITION	SH. 17
AVGEND:	FINAL EXIT FROM SERVICER: PERFORMS TRANSITION TO COASTING FLIGHT ROUTINES	SH. 19
SERVEXIT:	COMMON END OF SERVICER ROUTINES	SH. 21

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SERVICER

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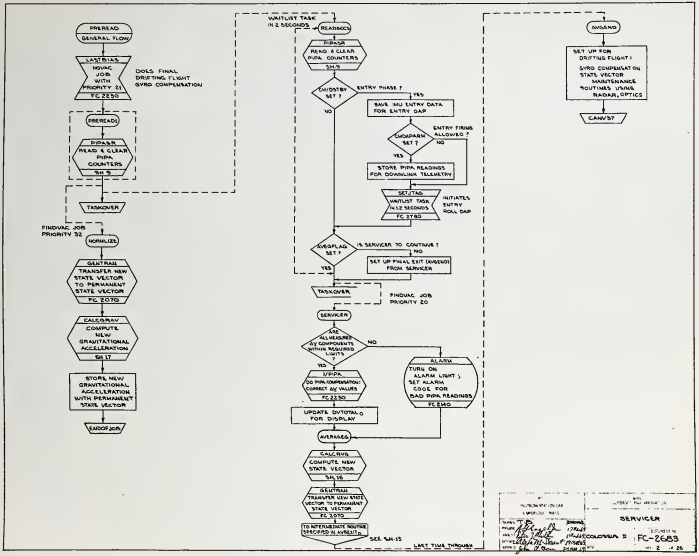
PREREAD
GENERAL FLOW
LASTBIAS
NOVAC JOB WITH PRIORITY 21
FC 2230
DOES FINAL DRIFTING FLIGHT GYRO COMPENSATION
PREREAD1
PIPASR
READ & CLEAR PIPA COUNTERS
SH 9
TASKOVER
FINDVAC JOB PRIORITY 32
NORMLIZE
GENTRAN
TRANSFER NEW STATE VECTOR TO PERMANENT STATE VECTOR
FC 2070
CALCGRAV
COMPUTE NEW GRAVITATIONAL ACCELERATION
SH 17
STORE NEW GRAVITATIONAL ACCELERATION WITH PERMANENT STATE VECTOR
ENDOFJOB
WAITLIST TASK IN 2 SECONDS
READACCS
PIPASR
READ & CLEAR PIPA COUNTERS
SH.9
CM/DSTBY SET ?
ENTRY PHASE ?
YES
NO
SAVE IMU ENTRY DATA FOR ENTRY DAP
CMDAPARM SET ?
ENTRY FIRING ALLOWED ?
NO
YES
STORE PIPA READINGS FOR DOWNLINK TELEMETRY
SETJTAG
WAITLIST TASK IN 1.2 SECONDS
FC 2780
INITIATES ENTRY ROLL DAP
AVEGFLAG SET ?
IS SERVICER TO CONTINUE ?
NO
YES
SET UP FINAL EXIT (AVGEND) FROM SERVICER
TASKOVER
FINDVAC JOB PRIORITY 20
SERVICER
ARE ALL MEASURED ΔV COMPONENTS WITHIN REQUIRED LIMITS ?
NO
YES
1/PIPA
DO PIPA COMPENSATION: CORRECT ΔV VALUES
FC 2230
ALARM
TURN ON ALARM LIGHT ; SET ALARM CODE FOR BAD PIPA READINGS
FC 2140
UPDATE DVTOTAL FOR DISPLAY
AVERAGEG
CALCRVG
COMPUTE NEW STATE VECTOR
SH.16
GENTRAN
TRANSFER NEW STATE VECTOR TO PERMANENT STATE VECTOR
FC 2070
TO INTERMEDIATE ROUTINE SPECIFIED IN AVGEXIT
SEE SH-15
LAST TIME THROUGH
AVGEND
SET UP FOR DRIFTING FLIGHT: GYRO COMPENSATION STATE VECTOR MAINTENANCE ROUTINES USING RADAR, OPTICS
CANV37
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SERVICER
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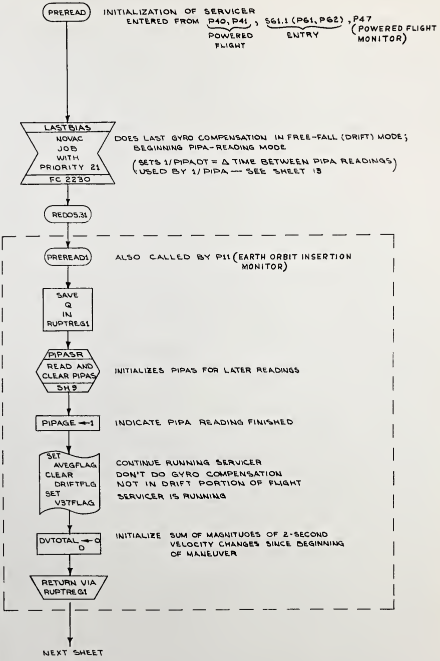

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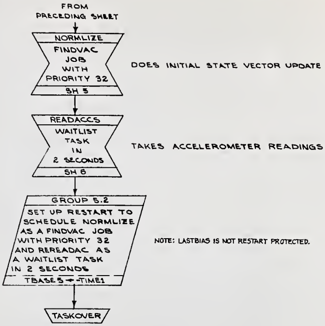
APPR'D 24MAR69	REV — SHEET 3 OF 26



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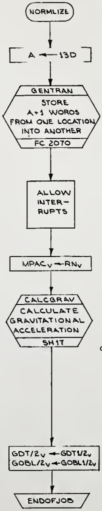

DO INITIAL STATE-VECTOR UPDATE
SET UP BY PREREAD WITH PRIORITY 32
ALSO CALLED BY P11

SET PARAMETER FOR GENTRAN
A+1 = NUMBER OF WORDS TO BE MOVED

INPUT: RN1 = FIRST WORD TO BE STORED
RN = FIRST WORD TO BE STORED INTO

RESULT: $RN_V \leftarrow RN1_V$
$VN_V \leftarrow VN1_V$
$PIPTIME_C \leftarrow PIPTIME1_D$
(UPDATE POWERED FLIGHT PERMANENT STATE VECTOR)

GENTRAN INHIBITS INTERRUPTS

SET UP INPUT TO CALCGRAV

INPUT: $MPAC_V$ = POSITION VECTOR IN REFERENCE COORDINATES IN M @ 2^{29}
RTX2 — INDICATES WHETHER IN EARTH OR MOON SPHERE OF INFLUENCE, BY VALUE OF 0 OR 2 RESPECTIVELY

OUTPUT: $MPAC_V = GDT1/2_V$ = ONE-HALF THE VELOCITY CHANGE DUE TO GRAVITATIONAL ACCELERATION AT THE SPECIFIED POSITION OVER A TWO-SECOND INTERVAL, IN REFERENCE COORDINATES IN M/CSEC @ 2^7

AND IF IN EARTH'S SPHERE OF INFLUENCE:
$GOBL1/2_V$ = CORRECTION TERM FOR GRAVITATIONAL ANOMALY DUE TO EARTH OBLATENESS @ 2^1

STORE NEW VALUES FROM CALCGRAV

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SERVICER

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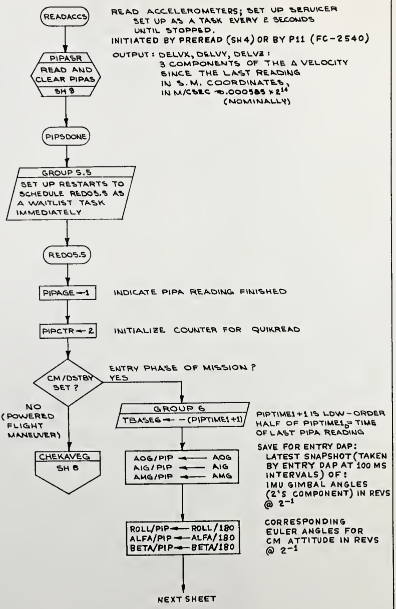

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DOCMR		
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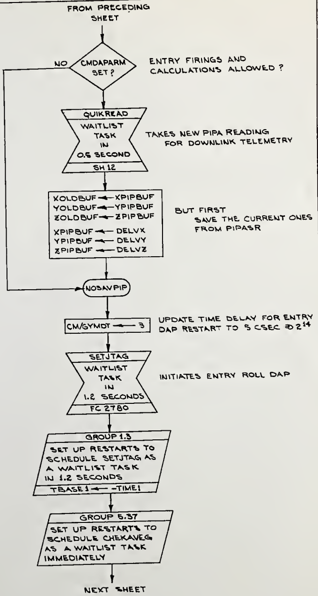

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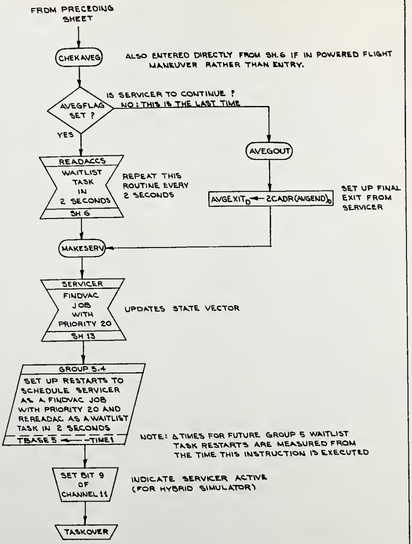
SHEET 7 OF 26



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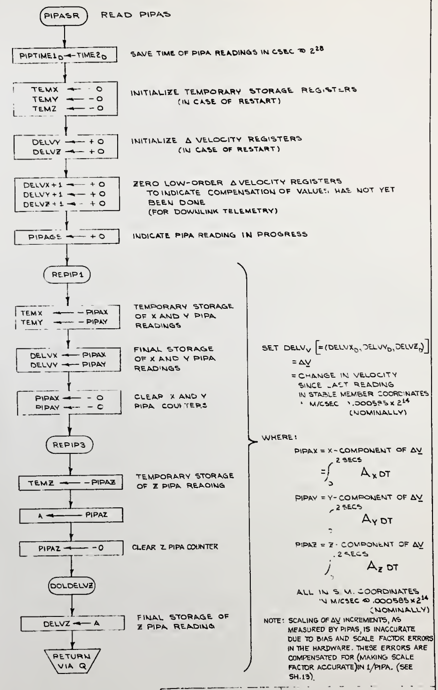
DRAWN TB 14DEC68	SERVICER
PRGMR [signature] 17Jan69	
ANALST [signature] 11Mar69	COLOSSUS II — DOCUMENT NO FC-2683
DOCMR [signature]	
APPR'D [signature] 24 MAR 69 REV	SHEET 8 OF 26



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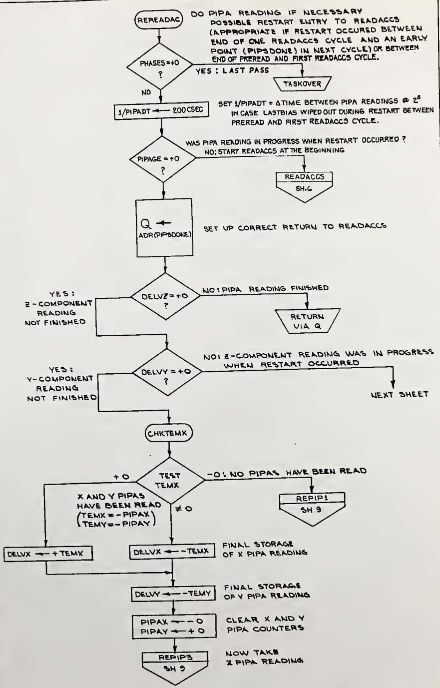
SERVICER

DRAWN T.B.	12NOV68	
PRGMR	17Mar69	
ANALST	17Mar69	COLOSSUS II
DOCMT	19Mar69	
APPR'D	24 MAR 69	REV

DOCUMENT NO. FC-2683

SH 9 OF 26



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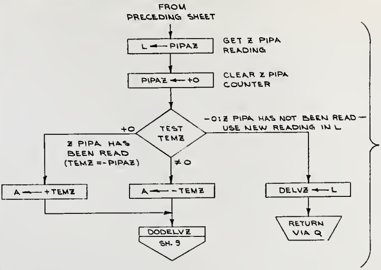
DRAWN TJB 13NOV68 PRGMR [signature] ANALST [signature] DOCMR Alex M. Sloan [date] APPR'D John A. Moro 24MAR 69	SERVICER COLOSSUS II DOCUMENT NO. FC-2683 REV SHEET 10 OF 26



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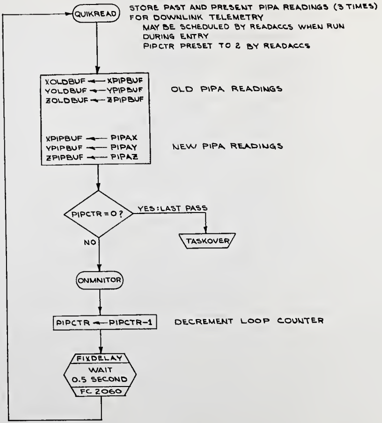
DRAWN TB 13NOV68	SERVICER
PROGMR	
ANALST	COLOSSUS II — FC-2683
DOC	
APPR'D 24MAR 69	REV — SHEET 11 OF 26



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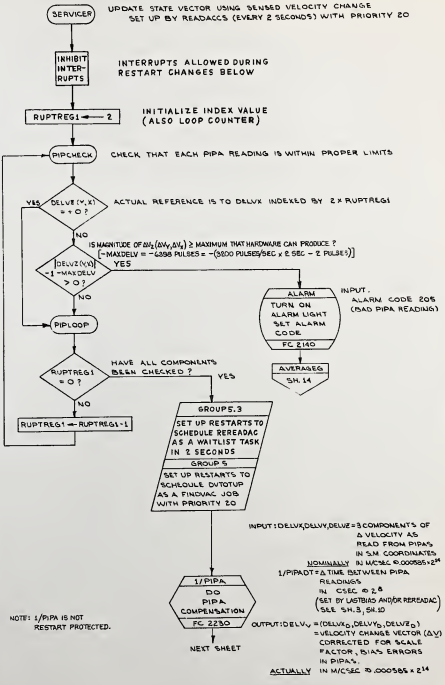

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DRAWN T.B. 14NOV68	SERVICER
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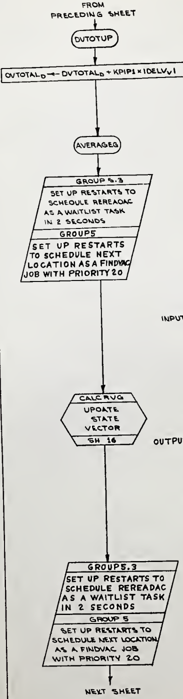
ANALYST [signature] 17Mar69	COLOSSUS II — DOCUMENT NO. FC-2683
[signature] 19MAR69	
APPR'D [signature] 24 MAR 69	SH 13 OF 26



UPDATE DVTOTAL$_D$ = SUM OF THE MAGNITUDES OF 2-SECOND VELOCITY CHANGES SINCE BEGINNING OF THE MANEUVER IN M/CSEC @ 2^7

WHERE KPIP1 = .000585 × 2^7 SCALING FACTOR FOR DELV$_V$

INPUT: DELV$_V$ = 2-SECOND VELOCITY CHANGE IN S.M. COORDINATES IN M/CSEC @ .000585 × 2^{14}

RN$_V$ = OLD POSITION VECTOR IN REFERENCE COORDINATES IN M @ 2^{29}

VN$_V$ = OLD VELOCITY VECTOR IN REFERENCE COORDINATES IN M/CSEC @ 2^7

GDT/2$_V$ = 1/2 THE CHANGE IN VELOCITY DUE TO GRAVITATIONAL ACCELERATION AT RN$_V$ OVER AN INTERVAL OF 2-SECS, IN REFERENCE COORDINATES, IN M/CSEC @ 2^7

RTX2 — INDICATES WHETHER IN EARTH OR MOON SPHERE OF INFLUENCE, BY VALUE OF 0 OR 2, RESPECTIVELY

OUTPUT: DELVREF$_V$ = SENSED VELOCITY CHANGE IN REFERENCE COORDINATES IN M/CSEC @ 2^7

RN1$_V$ = UPDATED POSITION VECTOR IN REFERENCE COORDINATES IN M @ 2^{29}

VN1$_V$ = UPDATED VELOCITY VECTOR IN REFERENCE COORDINATES IN M/CSEC @ 2^7

GDT1/2$_V$ = 1/2 THE CHANGE IN VELOCITY DUE TO GRAVITATIONAL ACCELERATION AT RN1$_V$ OVER AN INTERVAL OF 2 SECS IN REFERENCE COORDINATES, IN M/CSEC @ 2^7

AND IF IN EARTH'S SPHERE OF INFLUENCE:

GOBL1/2$_V$ = GRAVITATIONAL ANOMALY DUE TO EARTH OBLATENESS @ 2^1

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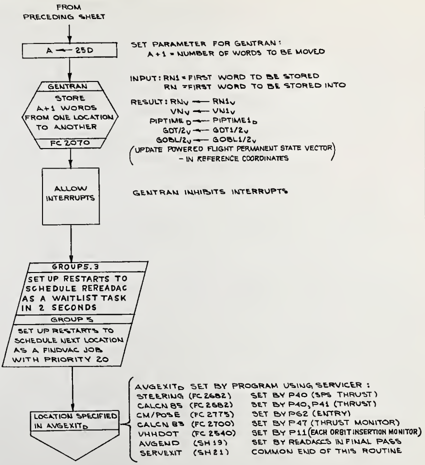
DOCMR [signature] 19 Mar 69		
APPR'D [signature] 24 MAR 69	REV	SHEET 14 OF 26



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CALCRVG — UPDATE STATE VECTOR

$\Delta\underline{V}_{REF} = \Delta\underline{V}_{SM}$ [REFSMMAT]

$DELVREF_V \leftarrow KPIP1 \times DELV_V \times REFSMMAT_M \times 2^1$

CONVERT $\Delta\underline{V}$ SENSED INTO REFERENCE COORDINATES IN M/CSEC @ 2^7

WHERE: $DELV_V = \Delta\underline{V}$ IN S.M. COORDINATES IN M/CSEC @ $.000585 \times 2^{14}$

KPIP1 = $.000585 \times 2^7$ (FOR SCALING $DELV_V$)

$REFSMMAT_M$ = TRANSFORMATION MATRIX FOR CONVERSION BETWEEN S.M. AND REFERENCE COORDS @ 2^1

2^1 FACTOR IS FOR SCALING

$PLO_V \leftarrow 1/2\ DELVREF_V$

SAVE INTERMEDIATE RESULTS:

1/2 $\Delta\underline{V}$ (IN REFERENCE COORDS, IN M/CSEC @ 2^7)

$PL6_V \leftarrow GDT/2_V + 1/2\ DELVREF_V$

1/2 $\underline{G}$(T)ΔT + 1/2 $\Delta\underline{V}$ (IN REFERENCE COORDS IN M/CSEC @ 2^7)

$\underline{R}(T+\Delta T) = \underline{R}(T) + \Delta T\ [\underline{V}(T) + \underline{G}(T)\Delta T/2 + \Delta\underline{V}/2]$

$MPAC_V \leftarrow RN_V + 2SEC(22)_D [VN_V + GDT/2_V + \frac{1}{2}\ DELVREF_V]$

COMPUTE NEW POSITION VECTOR IN REFERENCE COORD'S, IN M @ 2^{29}

WHERE: RN_V = OLD POSITION VECTOR IN REFERENCE COORDINATES IN M @ 2^{29}

VN_V = OLD VELOCITY VECTOR IN REFERENCE COORDINATES IN M/CSEC @ 2^7

$GDT/2_V$ = 1/2 THE VELOCITY CHANGE DUE TO GRAVITATIONAL ACCELERATION AT RN_V OVER A 2-SECOND INTERVAL IN REFERENCE COORDINATES IN M/CSEC @ 2^7

$2SEC(22)_D$ = 200 CSEC @ 2^{22}

SAVE QPRET IN PL31

$RN1_V \leftarrow MPAC_V$

SAVE NEW POSITION VECTOR

CALCGRAV — CALCULATE GRAVITATIONAL ACCELERATION — SH 17

INPUT: $MPAC_V$ = POSITION VECTOR IN REFERENCE COORDINATES IN M @ 2^{29}

RTX2 – INDICATES WHETHER IN EARTH OR MOON SPHERE OF INFLUENCE, BY VALUE OF 0 OR 2, RESPECTIVELY

OUTPUT: $MPAC_V = GDT1/2_V$ = 1/2 THE CHANGE IN VELOCITY DUE TO GRAVITATIONAL ACCELERATION AT THE SPECIFIED POSITION OVER A 2-SECOND INTERVAL IN REFERENCE COORDINATES IN M/CSEC @ 2^7

AND IF IN EARTH'S SPHERE OF INFLUENCE:

$GOBL1/2_V$ = GRAVITATIONAL ANOMALY DUE TO EARTH OBLATENESS @ 2^1

$\underline{V}(T+\Delta T) = \underline{V}(T) + \left(\frac{\underline{G}(T+\Delta T)+\underline{G}(T)}{2}\right)\Delta T + \Delta\underline{V}$

$VN1_V \leftarrow VN_V + MPAC_V + PL6_V + PLO_V$

COMPUTE NEW VELOCITY VECTOR IN REFERENCE COORDS, IN M/CSEC @ 2^1

WHERE: VN_V = OLD VELOCITY VECTOR IN REFERENCE COORDINATES IN M/CSEC @ 2^7

$PL6_V$, PLO_V } INTERMEDIATE RESULTS SAVED ABOVE

RETURN VIA PL31

CALCGRAV

CALCULATE GRAVITATIONAL ACCELERATION AT POSITION GIVEN IN $MPAC_V$ (IN REFERENCE COORDINATES) (IN M @ 2^{29})

$\underline{U}_R$ = UNIT ($\underline{R}$)
$UNITR_V$ ← UNIT($MPAC_V$)
PLX_V ← UNIT($MPAC_V$)

GET UNIT VECTOR IN DIRECTION OF POSITION VECTOR IN REFERENCE COORDINATES @ 2^1

NOTE: PLX REFERS TO LOCATION IN PUSHLIST TO WHICH POINTER (PUSHLOC) REFERS WHEN THIS ROUTINE IS CALLED

$R^2 = \underline{R} \cdot \underline{R}$
$PL34_D$ ← $MPAC_V \cdot MPAC_V$

R^2 IS SAVED (IN M^2 @ 2^{58})

X1 ← − RTX2

SAVE RTX2 = INDICATOR OF EARTH OR MOON SPHERE OF INFLUENCE BY VALUE OF 0 OR 2 RESPECTIVELY

X1 = 0 ?

IN EARTH'S SPHERE OF INFLUENCE ?

NO: MOON → NEXT SHEET

YES: MUST MAKE CORRECTION FOR EARTH OBLATENESS

$\cos \phi = \underline{U}_R \cdot \underline{U}_Z$
PLX_D ← $PLX_V \cdot UNITW_V$

COMPUTE $\cos \phi$ AT 2^1

WHERE: ϕ = ANGLE BETWEEN POSITION VECTOR AND EARTH POLAR AXIS

$UNITW_V = \underline{U}_Z$ = UNIT VECTOR IN DIRECTION OF $\underline{Z}$ = EARTH ROTATION VECTOR (POLAR AXIS) IN REFERENCE COORDINATES @ 2^0

$-\frac{R^2}{\mu_E}\underline{G}_B = 3/2\, J_{2E} (R_E/R)^2 \left[(1-5\cos^2\phi)\underline{U}_R + 2\cos\phi\, \underline{U}_Z\right]$
$GOBL1/2_V$ ← $20J_D \frac{RESQ_D}{PL34_D} (DP1/20_D - PLX_D^2)\, UNITR_V + 2J_D \frac{RESQ_D}{PL34_D} PLX_D\, UNITW_V$

COMPUTE GRAVITATIONAL ANOMALY DUE TO EARTH OBLATENESS @ 2^1 (REFERENCE COORDS)

WHERE:

$20J_D = 20 \times 3/2\, J_{2E}$ @ 2^{-1}

WHERE $J_{2E} = .10823067 \times 10^{-2}$ = 2ND HARMONIC OF EARTH'S POTENTIAL FUNCTION

$2J_D = 2 \times 3/2\, J_{2E}$ @ 2^{-1}

$RESQ_D = R_E^2$ = SQUARE OF EQUATORIAL RADIUS OF THE EARTH $= 40.6809913 \times 10^{12}\ M^2$ @ 2^{55}

$DP1/20_D = .05 = 1/20$

PLX_V ← $UNITR_V + GOBL1/2_V$

WHEN IN EARTH SPHERE OF INFLUENCE, MUST CORRECT FOR EARTH OBLATENESS BY ADDING IN $\underline{G}_B$ (@ 2^1)

NEXT SHEET

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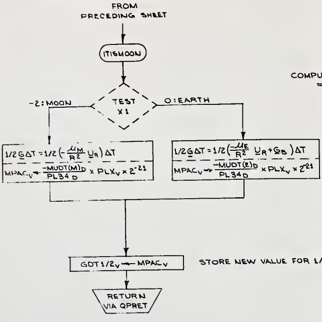
DRAWN TJB 21 NOV 68	SERVICER
PROGMR [signature] [date]	
ANALYST [signature] 17 Mar 69	COLOSSUS II FC-2683
DOCMR [signature] 19 MAR 69	
APP'D John A. Moore 24 MAR 69	REV. 17 26



COMPUTE 1/2 $\underline{G}\,\Delta T$
= 1/2 THE ΔVELOCITY DUE TO GRAVITATIONAL ACCELERATION (AT SPECIFIED POSITION) OVER 2 SECONDS IN REFERENCE COORDINATES IN M/CSEC @ 2^7

WHERE:

$-MUDT(M)_D = -\mu_M \Delta T$

$= -(.4902778 \times 10^9 \frac{M^3}{CSEC^2}) \times (200 CSEC)$ @ 2^{44}

$-MUDT(E)_D = -\mu_E \Delta T$

$= -(.398603225 \times 10^{11} \frac{M^3}{CSEC^2}) \times (200 CSEC)$ @ 2^{44}

2^{-21} FACTOR IS FOR SCALING

STORE NEW VALUE FOR 1/2 $\underline{G}\,\Delta T$

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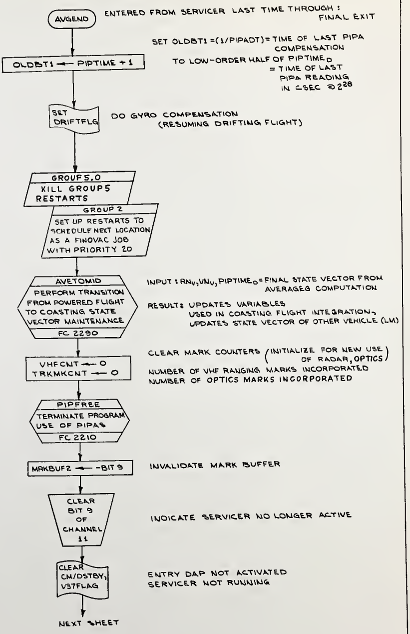
APOLLO
GUIDANCE AND NAVIGATION
SERVICER
DRAWN T.B. 21AUG68
PROGRAMMER A. Klugell
ANALYST Peter J. Volante
DOC MGR Alexa M. Sorant 19MAR69
APPROVED John A. Moore 24 MAR 69
COLOSSUS II
DOCUMENT NO. FC-2683
REV
SH 18 OF 26



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DRAWN TJB 25 NOV 68
PRGMR 17 Mar 69
ANALST 17 Mar 69
DOCMR 19 MAR 69
APPR'D 24 MAR 69

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COLOSSUS II

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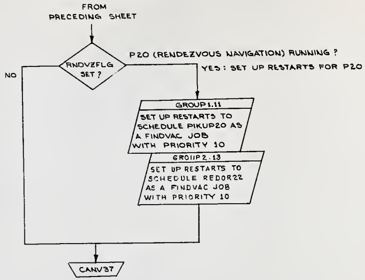
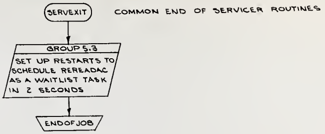


MIT INSTRUMENTATION LAB CAMBRIDGE MASS	APOLLO GUIDANCE AND NAVIGATION
DRAWN TB PRGMR ANALST DOCMB APPR'D 24 MAR 69	SERVICER
COLOSSUS II	DOCUMENT NO. FC-2683
REV	SHEET 20 OF 26



MIT INSTRUMENTATION LAB CAMBRIDGE MASS.		SERVICER
DRAWN TB	20MAR69	
PRGMR	17MAR69	
ANAL	17MAR69	COLOSSUS II FC-2683
DOCMR	19MAR69	
APPD John A. Moss	24 MAR 69	21 OF 26

SUBROUTINES CALLED WHICH ARE
FLOWED ON OTHER FLOW CHARTS

SUBROUTINE NAME	FLOW CHART	DESCRIPTION	WHERE CALLED
ALARM	2140	TURNS ON ALARM LIGHT; SETS ALARM CODE	SH.13
AVETOMID	2290	PERFORMS TRANSITION FROM POWERED FLIGHT TO COASTING FLIGHT MAINTENANCE OF STATE VECTOR. UPDATES STATE VECTOR OF OTHER VEHICLE (LM)	SH 19
CALCN83	2700	UPDATES TOTAL ΔV FOR NOUN 83 DISPLAY AND INERTIAL V, RATE OF CHANGE OF V, ALTITUDE ABOVE PAD FOR NOUN 62 DISPLAY	SH. 15
CALCN85	2682	UPDATES VELOCITY-TO-BE-GAINED FOR NOUN 85 DISPLAY	SH. 15
CM POSE	2775	RETURN POINT TO RE-ENTRY CONTROL	SH. 15
GENTRAN	2070	TRANSFERS A STRING OF DATA WORDS FROM ONE LOCATION TO ANOTHER	SH. 5 SH 15
LASTBIAS	2230	DOES LAST GYRO COMPENSATION IN FREE FALL (DRIFTING) MODE	SH.3
PIPFREE	2210	TERMINATES PROGRAM USE OF PIPAS	SH.19
SETJTAG	2780	INITIATES ENTRY ROLL DAP	SH. 7
STEERING	2682	UPDATES VELOCITY-TO-BE-GAINED, COMPUTES STEERING RATE COMMANDS FOR TVC DAP	SH.15
VHHDOT	2540	UPDATES AND DISPLAYS INERTIAL V, RATE OF CHANGE OF V, ALTITUDE ABOVE PAD (NOUN 62)	SH.15
1 PIPA	2230	DOES PIPA COMPENSATION CORRECTS SENSED ΔV VALUES FOR SCALE-FACTOR, BIAS ERRORS	SH.13

FLAGS

NAME	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
AVEGFLAG FLAGWRD1 BIT1	SERVICER TO CONTINUE RUNNING	SERVICER TO STOP RUNNING	SH. 3		SH 8
CMDAPARM FLAGWRD6 BIT12	ENTRY FIRINGS AND CALCULATIONS ALLOWED	ENTRY FIRINGS AND CALCULATIONS INHIBITED			SH.7
CM DSTBY FLAGWRD6 BIT2	ENTRY DAP ACTIVATED	ENTRY DAP NOT ACTIVATED		SH.19	SH.6
DRIFTFLG FLAGWRD2 BIT15	DRIFTING FLIGHT GYRO COMPENSATION DONE	NOT DRIFTING NO GYRO COMPENSATION DONE	SH.19	SH. 3	
RNDVZFLG FLAGWRD0 BIT7	P20 RUNNING	P20 NOT RUNNING			SH.20
V37FLAG FLAGWRD7 BIT6	SERVICER RUNNING	SERVICER NOT RUNNING	SH.3	SH.19	

CHANNEL BITS

CHANNEL BIT	EFFECT WHEN SET	EFFECT WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
CHANNEL 11 BIT 9	SERVICER ACTIVE (FOR HYBRID SIMULATOR)	SERVICER NOT ACTIVE (FOR HYBRID SIMULATOR)	SH. 8	SH. 19	

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DRAWN G. A. Langillo 25OCT68	SERVICER
PRGMR 17Mar69	
ANALST Peter E. Philliou	COLOSSUS II — DOCUMENT NO. FC-2683
DOCMR 19MAR69	
APPR'D John A. Moore 24 MAR 69	REV — SHEET 22 OF 26

VERB — NOUN	TYPE OF DISPLAY	DESCRIPTION OF EACH REGISTER	WHERE EXECUTED
	ALARM	ALARM LIGHT ON, R1, R2, R3 NOT AFFECTED	SH 13

ERASABLE LOCATIONS USED

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
AIG		SNAPSHOT OF INNER IMU GIMBAL ANGLE (2'S COMPLEMENT)	DEGREES	REVS	2^{-1}
AIG/PIP		VALUE OF AIG (ABOVE) AT TIME OF LAST PIPA READING (USED BY ENTRY DAP)	DEGREES	REVS	2^{-1}
ALFA/PIP		VALUE OF ALFA/180 (BELOW) AT TIME OF LAST PIPA READING (USED BY ENTRY DAP)	DEGREES	REVS	2^{-1}
ALFA/180		THIRD EULER ANGLE FOR CM ATTITUDE	DEGREES	REVS	2^{-1}
AMG		SNAPSHOT OF MIDDLE IMU GIMBAL ANGLE (2'S COMPLEMENT)	DEGREES	REVS	2^{-1}
AMG/PIP		VALUE OF AMG (ABOVE) AT TIME OF LAST PIPA READING (USED BY ENTRY DAP)	DEGREES	REVS	2^{-1}
AOG		SNAPSHOT OF OUTER IMU GIMBAL ANGLE (2'S COMPLEMENT)	DEGREES	REVS	2^{-1}
AOG/PIP		VALUE OF AOG (ABOVE) AT TIME OF LAST PIPA READING (USED BY ENTRY DAP)	DEGREES	REVS	2^{-1}
$AVGEXIT_D$		2CADR OF LOCATION WHICH BEGINS ROUTINE TO RUN AFTER SERVICER			
BETA/PIP		VALUE OF BETA/180 (BELOW) AT TIME OF LAST PIPA READING (USED BY ENTRY DAP)	DEGREES	REVS	2^{-1}
BETA/180		SECOND EULER ANGLE FOR CM ATTITUDE	DEGREES	REVS	2^{-1}
$DELVREF_V$	$\underline{\Delta V}_{REF}$	SENSED VELOCITY CHANGE IN REFERENCE COORDINATES	M/SEC	M/CSEC	2^7
$DELV_V = \begin{pmatrix} DELVX_D \\ DELVY_D \\ DELVZ_D \end{pmatrix}$	$\underline{\Delta V}$	SENSED VELOCITY CHANGE IN STABLE MEMBER COORDINATES	M/SEC	M/CSEC	$.000585 \times 2^{14}$
$DELVX_D$	ΔV_X	X- COMPONENT OF SENSED VELOCITY CHANGE IN S.M. COORDINATES	M/SEC	M/CSEC	$.000585 \times 2^{14}$
$DELVY_D$	ΔV_Y	Y- COMPONENT OF SENSED VELOCITY CHANGE IN S.M. COORDINATES	M/SEC	M/CSEC	$.000585 \times 2^{14}$
$DELVZ_D$	ΔV_Z	Z- COMPONENT OF SENSED VELOCITY CHANGE IN S.M. COORDINATES	M/SEC	M/CSEC	$.000585 \times 2^{14}$
$DVTOTAL_D$		SUM OF THE MAGNITUDES OF 2-SECOND VELOCITY CHANGES SINCE BEGINNING OF THE MANEUVER	M/SEC	M/CSEC	2^7
$GDT/2_V$	$1/2\ \underline{G}(T)\Delta T$	1/2 THE CHANGE IN VELOCITY DUE TO GRAVITATIONAL ACCELERATION OVER A 2-SECOND INTERVAL, IN REFERENCE COORDINATES	M/SEC	M/CSEC	2^7

ERASABLE LOCATIONS USED (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
GDT1/2$_V$	$1/2\ \underline{G}(T+\Delta T)\Delta T$	TEMPORARY STORAGE FOR UPDATED VERSION OF GDT/2$_V$ (ABOVE)	M/SEC	M/CSEC	2^7
GOBL/2$_V$	$\frac{-R^2}{\mu_E}\underline{G}_B(T)$	CORRECTION TERM (IN REFERENCE COORDINATES) FOR GRAVITATIONAL ANOMALY DUE TO EARTH OBLATENESS - SATISFIES THE EQUATION. $\underline{G}(\text{AT } \underline{R}) = \frac{-\mu_E}{R^2}\ \text{UNIT}\ (\underline{R}) + \underline{G}_B$			2^1
GOBL1/2$_V$	$\frac{-R^2}{\mu_E}\underline{G}_B(T+\Delta T)$	TEMPORARY STORAGE FOR UPDATED VERSION OF GOBL/2$_V$ (ABOVE)			2^1
MRKBUF2		TEMPORARY STORAGE FOR MARKS—USED IN RENDEZVOUS TRACKING. INVALID IF NEGATIVE			
OLDBT1 =1/PIPADT		Δ TIME BETWEEN PIPA READINGS OR TIME OF LAST PIPA COMPENSATION	SEC	CSEC	2^8 OR 2^{14}
PHASE 5		INDICATES WHETHER CERTAIN ROUTINES ARE TO BE RESTARTED AND, IF SO, AT WHAT POINT			
PIPAGE		INDICATES WHETHER OR NOT PIPA READING IS IN PROGRESS, BY VALUE OF 0 OR 1, RESPECTIVELY			
PIPAX		COUNTER ACCUMULATING X-COMPONENT VELOCITY CHANGE (IN S.M. COORDINATES) SINCE LAST READING	M/SEC	M/CSEC	$.000585 \times 2^{14}$ (NOMINALLY)
PIPAY		COUNTER ACCUMULATING Y-COMPONENT VELOCITY CHANGE (IN S.M. COORDINATES) SINCE LAST READING	M/SEC	M/CSEC	$.000585 \times 2^{14}$ (NOMINALLY)
PIPAZ		COUNTER ACCUMULATING Z-COMPONENT VELOCITY CHANGE (IN S.M. COORDINATES) SINCE LAST READING	M/SEC	M/CSEC	$.000585 \times 2^{14}$ (NOMINALLY)
PIPTIME$_D$		TIME OF LAST PIPA READING	SEC	CSEC	2^{28}
PIPTIME1$_D$		TEMPORARY UPDATED VERSION OF PIPTIME$_D$ (ABOVE)	SEC	CSEC	2^{28}
REFSMMAT$_M$	[REFSMMAT]	TRANSFORMATION MATRIX FOR CONVERSION BETWEEN S.M. AND REFERENCE COORDINATE SYSTEMS			2^1
RN$_V$	$\underline{R}(T)$	POSITION VECTOR IN REFERENCE COORDINATES	M	M	2^{29}
RN1$_V$	$\underline{R}(T+\Delta T)$	TEMPORARY UPDATED VERSION OF RN$_V$ (ABOVE)	M	M	2^{29}
ROLL/PIP		VALUE OF ROLL/180 (BELOW) AT TIME OF LAST PIPA READING (USED BY ENTRY DAP)	DEGREES	REVS	2^{-1}
ROLL/180		FIRST EULER ANGLE FOR CM ATTITUDE	DEGREES	REVS	2^{-1}
RTX2		INDICATOR OF WHETHER VEHICLE IS IN EARTH OR MOON SPHERE OF INFLUENCE, BY VALUE OF 0 OR 2, RESPECTIVELY			
TEMX		TEMPORARY STORAGE FOR PIPA READING (PIPAX ABOVE)	M/SEC	M/CSEC	$-.000585 \times 2^{14}$

ERASABLE LOCATIONS USED (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
TEMY		TEMPORARY STORAGE FOR PIPA READING (PIPAY ABOVE)	M/SEC	M/CSEC	$-.000585 \times 2^{14}$
TEMZ		TEMPORARY STORAGE FOR PIPA READING (PIPAZ ABOVE)	M/SEC	M/CSEC	$-.000585 \times 2^{14}$
$TIME2_D = \begin{pmatrix}TIME2\\TIME1\end{pmatrix}$		PRESENT TIME	SEC	CSEC	2^{28}
TRKMKCNT		NUMBER OF OPTICS MARKS INCORPORATED			
$UNITR_V$	$\underline{U}_R$	UNIT VECTOR IN DIRECTION OF POSITION VECTOR (IN REFERENCE COORDINATES)			2^1
VHFCNT		NUMBER OF VHF RANGING MARKS INCORPORATED			
VN_V	$\underline{V}(T)$	VELOCITY VECTOR IN REFERENCE COORDINATES	M/SEC	M/CSEC	2^7
$VN1_V$	$\underline{V}(T+\Delta T)$	TEMPORARY UPDATED VERSION OF VN_V (ABOVE)	M/SEC	M/CSEC	2^7
XOLDBUF		OLD PIPAX (SEE ABOVE) READING FOR DOWNLINK TELEMETRY	M/SEC	M/CSEC	$.000585 \times 2^{14}$
XPIPBUF		NEW PIPAX (SEE ABOVE) READING FOR DOWNLINK TELEMETRY	M/SEC	M/CSEC	$.000585 \times 2^{14}$
YOLDBUF		OLD PIPAY (SEE ABOVE) READING FOR DOWNLINK TELEMETRY	M/SEC	M/CSEC	$.000585 \times 2^{14}$
YPIPBUF		NEW PIPAY (SEE ABOVE) READING FOR DOWNLINK TELEMETRY	M/SEC	M/CSEC	$.000585 \times 2^{14}$
ZOLDBUF		OLD PIPAZ (SEE ABOVE) READING FOR DOWNLINK TELEMETRY	M/SEC	M/CSEC	$.000585 \times 2^{14}$
ZPIPBUF		NEW PIPAZ (SEE ABOVE) READING FOR DOWNLINK TELEMETRY	M/SEC	M/CSEC	$.000585 \times 2^{14}$

PROGRAM CONSTANTS

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING VALUE AND UNITS	AGC VALUE AND UNITS	AGC SCALING
KPIP1		SCALING FACTOR FOR CONVERTING $\underline{\Delta V}$ SENSED TO USUAL SCALING	$.000585 \times 2^7$	$.000585 \times 2^7$	2^0
-MAXDELV		$-\begin{pmatrix}\text{MAXIMUM } \Delta V \text{ COMPONENT}\\ \text{HARDWARE CAN SENSE} - 2\end{pmatrix}$	-6398 PULSES	-6398 PULSES	2^{14}
$-MUDT(E)_D$	$-\mu_E \Delta T$	-(EARTH GRAVITATIONAL CONSTANT) x (2 SECONDS)	$-.79720645 \times 10^{15}$ M^3/SEC	$-.79720645 \times 10^{13}$ $M^3/CSEC$	2^{44}

PROGRAM CONSTANTS (CONTINUED)

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING VALUE AND UNITS	AGC VALUE AND UNITS	AGC SCALING
$-MUDT(M)_D$	$-\mu_M \Delta T$	-(MOON GRAVITATIONAL CONSTANT) x (2 SECONDS)	$-.9805556 \times 10^{13}$ M^3/SEC	$-.9805556 \times 10^{11}$ $M^3/CSEC$	2^{44}
$RESQ_D$	R_E^2	SQUARE OF EQUATORIAL RADIUS OF THE EARTH	$40.6809913 \times 10^{12}$ M^2	$40.6809913 \times 10^{12}$ M^2	2^{59}
$2J_D$	$2 \times (3/2\ J_{2E})$	2 x 3/2 x THE 2ND HARMONIC OF EARTH'S POTENTIAL FUNCTION	3.2469201×10^{-3}	3.2469201×10^{-3}	2^{-1}
$20J_D$	$20 \times (3/2\ J_{2E})$	20 x 3/2 x THE 2ND HARMONIC OF EARTH'S POTENTIAL FUNCTION	3.2469201×10^{-2}	3.2469201×10^{-2}	2^{-1}

AGC TAG	GSOP TAG	MEANING	ENGINEERING VALUE AND UNITS	AGC VALUE AND UNITS	AGC SCALING	OCTAL VALUE
$UNITW_V$	$\underline{U}_Z$	UNIT VECTOR IN THE DIRECTION OF EARTH ROTATION VECTOR (Z) IN REFERENCE COORDINATES	$(-3.32402568949 \times 10^{-6},\ 4.18407084553 \times 10^{-5},\ 9.99999998 \times 10^{-1})$	SAME	2^0	(77777 76203, 00000 25740, 37777 37777)

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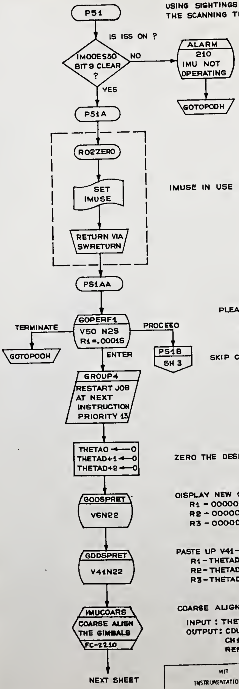
DRAWN / PRGMR / ANALST / DOCMR / APP'D	SERVICER
COLOSSUS II	DOCUMENT NO. FC-2683
REV	SHEET 26 OF 26

P51, P53

DETERMINE THE INERTIAL ORIENTATION OF THE IMU USING SIGHTINGS ON TWD CELESTIAL BDOIES USING THE SCANNING TELEBCOPE OR THE SEXTANT.



IMU MUST BE TURNEO ON BEFORE THIS PROGRAM CAN OPERATE .

IMUSE IN USE

PLEASE PERFORM CELESTIAL BDDY AQUISITION
R1 - 00015
R2 - BLANK
R3 - BLANK

SKIP COARSE ALIGN

ZERO THE DESIRED GIMBAL ANGLES

OISPLAY NEW CDU ANGLES
R1 - 00000
R2 - 00000
R3 - 00000

PASTE UP V41 - LEAVE REMAINDER OF DISPLAY V41N22
R1 - THETAD = OG YAW
R2 - THETAD+1 = IG PITCH
R3 - THETAD+2 = MG ROLL

COARSE ALIGN ISS

INPUT : THETAD, +1, +2
OUTPUT: CDUXCMD, CDUYCMD, CDUZCMD, (COMMAND REGISTERS) CH14(15,14,13) TURN ON NO ATT LIGHT, CLEAR REFSMFLG

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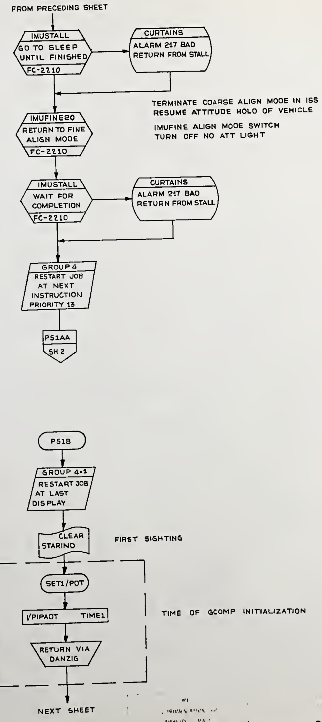
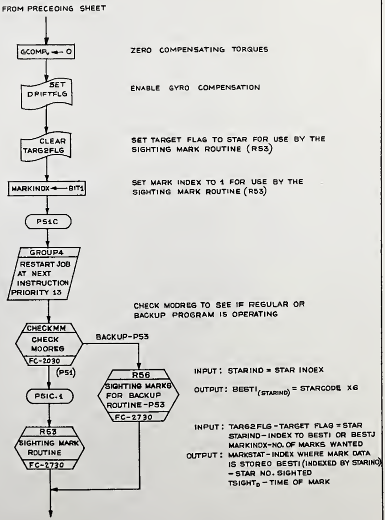
DRAWN / PRGMR / ANALST / DOCMR / APPR'D	P51, P53 IMU ORIENTATION DETERMINATION
	COLOSSUS II-A FC-2710
	REV 1 SHEET 2 11



DRAWN D. M. Dietz 20AUG68
CHECKED K. [illegible] 7NOV
APPROVED E. S. Nall 7Nov68
APPROVED John A. Morse 11FEB69

P51, P53
IMU ORIENTATION DETERMINATION
COLOSSUS II-A FC-2710
1 3 11



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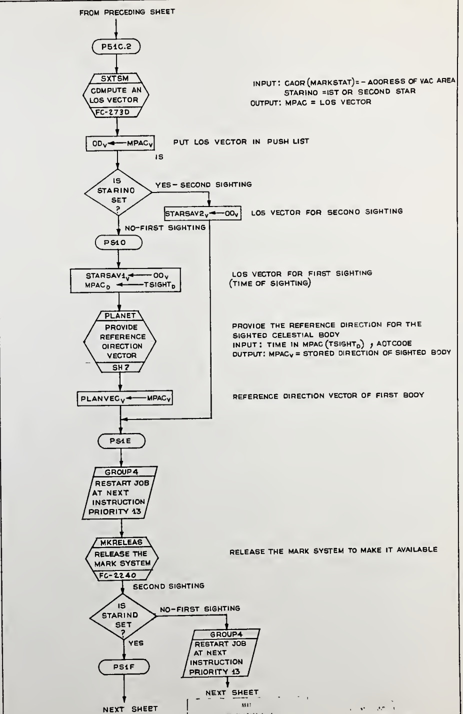
DRAWN P.N. Dietz 20AUG68	P51, P53 IMU ORIENTATION DETERMINATION
PRGMR K. Vincent 7Nov	
ANALST	DOCUMENT NO
DOCMR E. S. Nelly 7Nov68	COLOSSUS II-A FC-2710
APPR'D John A. Miller 11FEB69	REV 1 SHEET 4 OF 11



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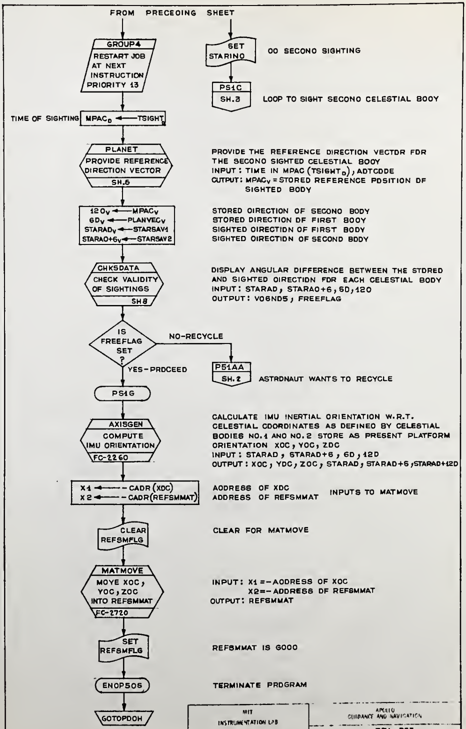
DRAWN P.M. Zielinski 21 AUG 68
CHECKED K. Jucoski 7 Nov
ANALYST
DOCMR 7 Jan 69
APPR John A. Miller 11 FEB 69

P51, P53 IMU ORIENTATION DETERMINATION

COLOSSUS II-A FC-2710

1 5 11



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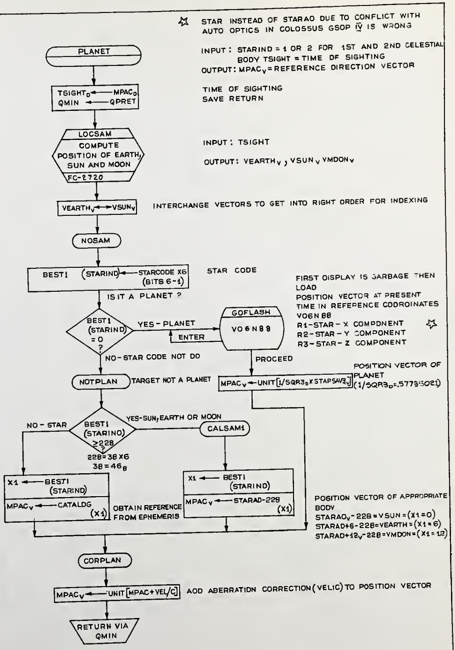
DRAWN P. M. Dietrich 21AUG68	P51, P53 IMU ORIENTATION DETERMINATION
PRGMR K. Vincent 7Nov	
ANALST	COLOSSUS II-A DOCUMENT NO. FC-2710
DOCMR 7Feb	
APPR'D 11FEB 69	REV 1 SHT 6 OF 11

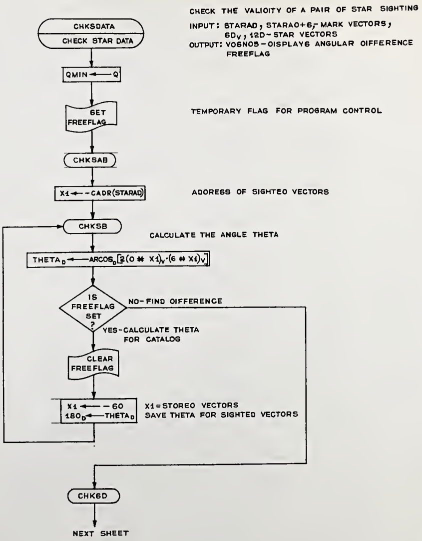


DRAWN P. M. Dietrich 8SEP68
7NOV
E. S. Hall 7NOV68
John A. Moke 11FEB69

PS1, P53
IMU ORIENTATION DETERMINATION

COLOSSUS II FC-2710

1 7 11



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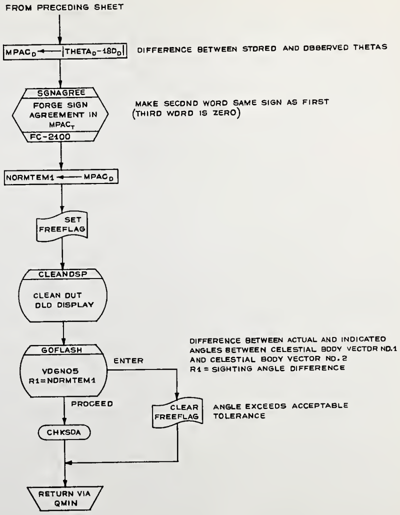
P51, P53
IMU ORIENTATION OETERMINATION

DOCUMENT NO
COLOSSUS II-A FC-2710

SHEET 8 OF 11



MIT INSTRUMENTATION LAB CAMBRIDGE MASS

DRAWN P. M. Dietz Jr 10 SEP 68
PRGMR G. Vincent Jr 3 FEB 69
ANALYST
DOCMR 10 Jan 69
APPR'D John A. Moore 11 FEB 69

P51, P53
IMU ORIENTATION DETERMINATION

COLOSSUS II-A FC-2710

OF 1 9 11

SUBROUTINES CALLED WHICH ARE FLOWED ON OTHER FLOW CHARTS

SUBROUTINE NAME	FLOW CHART	DESCRIPTION	WHERE CALLED
IMUCOARS	FC-2210	COARSE ALIGN THE GIMBALS	SH. 2
IMUSTALL	FC-2210	WAIT FOR COMPLETION	SH. 3
IMUFINE20	FC-2210	RETURN TO FINE ALIGN MODE	SH. 3
R53	FC-2730	SIGHTING MARK ROUTINE	SH. 4
R56	FC-2730	SIGHTING MARKS FOR BACKUP ROUTINE	SH. 4
SXTSM	FC-2730	COMPUTE AN LOS VECTOR	SH. 5
MKRELEAS	FC-2240	RELEASE THE MARK SYSTEM	SH. 5
AXISGEN	FC-2260	COMPUTE IMU ORIENTATION	SH. 6
MATMOVE	FC-2720	MOVE XDC, YDC INTO REFSMMAT	SH. 6
LOCSAM	FC-2720	COMPUTE POSITION OF EARTH, SUN AND MOON	SH. 7
SGNAGREE	FC-2100		

FLAGS

NAME	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
DRIFTFLG	ENABLE GYRO COMPENSATION	T3RUPT DOES NO GYRO COMPENSATION	SH. 3		
IMUSE	IMU IN USE	IMU NOT IN USE	SH. 2		
STARIND	2ND SIGHTING	FIRST SIGHTING	SH. 6	SH. 4	SH. 5
TARG2FLG	SIGHTING LANDMARK	SIGHTING STAR		SH. 4	
REFSMFLG	REFSMMAT GOOD	REFSMMAT NO GOOD	SH. 6	SH. 6	
FREEFLAG	TEMP FLAG	TEMP FLAG	SH. 8, 9	SH. 8, 9	SH. 6, 8

DISPLAYS

VERB-NOUN	TYPE OF DISPLAYS	DESCRIPTION OF EACH REGISTER	WHERE CALLED
		ALARM - 210 - IMU NOT OPERATING	SH. 2
V06N22	OBSERVE	DISPLAY NEW CDU ANGLES R1 - 00000 R2 - 00000 R3 - 00000	SH. 2
V41N22	OBSERVE	PASTE UP V41 R1 - THETAD R2 - THETAD+1 R3 - THETAD+2	SH. 2
		CURTAINS - 217 - BAD RETURN FROM STALL	SH. 3
V06N88	FLASHING	LOAD POSITION VECTOR R1 - STAR X COMPONENT R2 - STAR Y COMPONENT R3 - STAR Z COMPONENT	SH. 7
V06N05	FLASHING	R1 - SIGHTING ANGLE DIFFERENCE R2 - BLANK R3 - BLANK	SH. 9

MIT INSTRUMENTATION LAB CAMBRIDGE MASS.

DRAWN R. D. Hart 3 Feb 69
PRGMR R. Vincent Jr. 3 Feb 69
ANALST __
DOCMR G S NALLY 3FEB69
APPR'D John A. Miller 11FEB 69

GUIDANCE AND NAVIGATION

P51, P53 IMU ORIENTATION DETERMINATION

COLOSSUS II-A FC-2710

REV 1 SHT 10 11

ERASABLE LOCATIONS USED

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
THETAD		GIMBAL ANGLES			
PLANVEC		REFERENCE VECTOR			
STARAD		SIGHTED DIRECTION OF FIRST BODY			
STARAD+6		SIGHTED DIRECTION OF SECOND BODY			
1 PIPADT		TIME OF GCOMP INITIALIZATION			
STARSAV1		MARK VECTOR NO 1			
STARSAV2		MARK VECTOR NO 2			
GCOMP		COMPENSATION PULSES FOR FREEFAL DRIFT			
TSIGHT		TIME OF SIGHTING			
VEARTH		UNIT POSITIONAL VECTOR OF EARTH			
VSUN		UNIT POSITIONAL VECTOR OF SUN			
BESTI					
BESTJ					
VEL/C		ABERRATION CORRECTION			
STAR		SAME AS STARAD			
NORMTEM1		SIGHTED ANGLE DIFFERENCE			

A.C. WILLIAMS 9JAN69
3Feb69
G S NALLY 3FEB69
11FEB 69

P51, P53
IMU ORIENTATION DETERMINATION

COLOSSUS II-A FC-2710

1

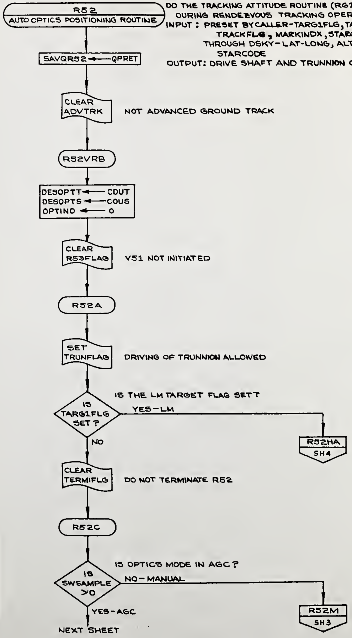
R52, R53, R56

R52	AUTO OPTICS POSITIONING ROUTINE	SH. 2
ADVORB	SET UP ADVANCED ORBIT TRACKING	SH. 5
SR52.1	TARGET DETERMINATION	SH. 6
ROTA	ROTATE VECTOR	SH. 10
R53	SIGHTING MARK ROUTINE	SH. 11
CHKSCODE	CHECK STARCODE	SH. 12
SXTSM	COMPUTE LOS VECTOR IN SM COORDINATES	SH. 13
R56	ALTERNATE SIGHTING MARK ROUTINE	SH. 14

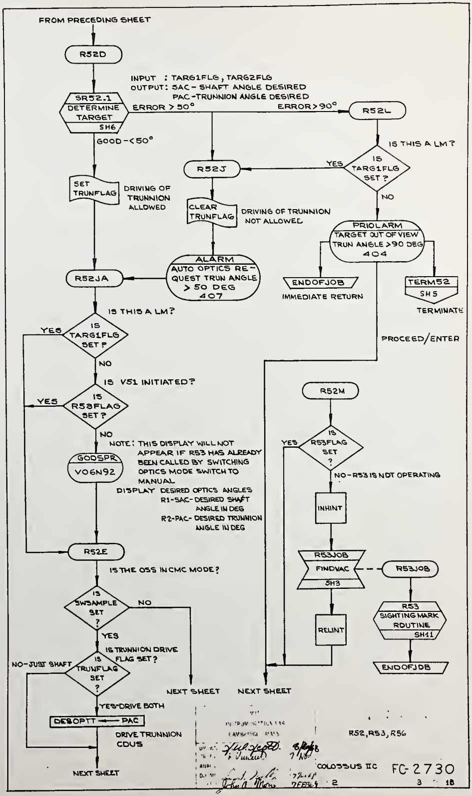
ENCLOSED IS A REPLACEMENT SHEET (SH. 6) TO UPDATE THE COLOSSUS IIA FLOWCHART FC-2730, REV. 1, TO THE COLOSSUS IIC FLOWCHART FC-2730, REV. 2.

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN 28MAY69 PRGMR Sharon Albert 6/4/69 ANALST DOCMP G.S. NALLY APPR'D Aleta McDonald 6/4/69	R52, R53 R56 COLOSSUS II C — DOCUMENT NO FC-2730 REV 2 — SHEET 1 OF 18

POINT THE STAR LOS OF THE OPTICS AT A STAR OR LANDMARK DEFINED BY THE PROGRAM OR BY DSKY INPUT
POINT THE STAR LOS OF THE OPTICS AT THE LM DURING RENDEZVOUS TRACKING OPERATION
DO THE TRACKING ATTITUDE ROUTINE (R61) EVERY 16 SEC. DURING RENDEZVOUS TRACKING OPERATIONS
INPUT : PRESET BY CALLER-TARG1FLG, TARG2FLG, RNDVZFLG, TRACKFLG, MARKINDX, STARCODE
THROUGH DSKY-LAT-LONG, ALT OF LANDMARK, STARCODE
OUTPUT: DRIVE SHAFT AND TRUNNION CDUS



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN / PRGMR / ANALST / DOCMR / APPR'D	R52, R53, R56
COLOSSUS IIC	DOCUMENT NO. FC-2730
REV 2	SH 2 OF 18



FROM PRECEDING SHEET
R52D
INPUT : TARG1FLG, TARG2FLG
OUTPUT: SAC - SHAFT ANGLE DESIRED
PAC - TRUNNION ANGLE DESIRED
SR52.1
DETERMINE TARGET
SH6
ERROR > 50°
ERROR > 90°
R52L
GOOD - < 50°
IS THIS A LM?
YES
IS TARG1FLG SET ?
R52J
SET TRUNFLAG
DRIVING OF TRUNNION ALLOWED
CLEAR TRUNFLAG
DRIVING OF TRUNNION NOT ALLOWED
NO
PRIOLARM
TARGET OUT OF VIEW
TRUN ANGLE > 90 DEG
404
ENDOFJOB
IMMEDIATE RETURN
TERM52
SH5
TERMINATE
ALARM
AUTO OPTICS REQUEST TRUN ANGLE > 50 DEG
407
R52JA
IS THIS A LM?
YES
IS TARG1FLG SET ?
NO
PROCEED/ENTER
IS V51 INITIATED?
YES
IS R53FLAG SET ?
NO
R52M
NOTE: THIS DISPLAY WILL NOT APPEAR IF R53 HAS ALREADY BEEN CALLED BY SWITCHING OPTICS MODE SWITCH TO MANUAL
GOODSPR
V06N92
DISPLAY DESIRED OPTICS ANGLES
R1-SAC- DESIRED SHAFT ANGLE IN DEG
R2-PAC- DESIRED TRUNNION ANGLE IN DEG
YES
IS R53FLAG SET ?
NO - R53 IS NOT OPERATING
INHINT
R52E
IS THE OSS IN CMC MODE?
R53JOB
FINDVAC
SH3
R53JOB
IS SWSAMPLE SET ?
NO
R53
SIGHTING MARK ROUTINE
SH11
YES
RELINT
IS TRUNNION DRIVE FLAG SET ?
NO - JUST SHAFT
IS TRUNFLAG SET ?
ENDOFJOB
NEXT SHEET
NEXT SHEET
YES - DRIVE BOTH
DESOPTT ← PAC
DRIVE TRUNNION CDUS
NEXT SHEET
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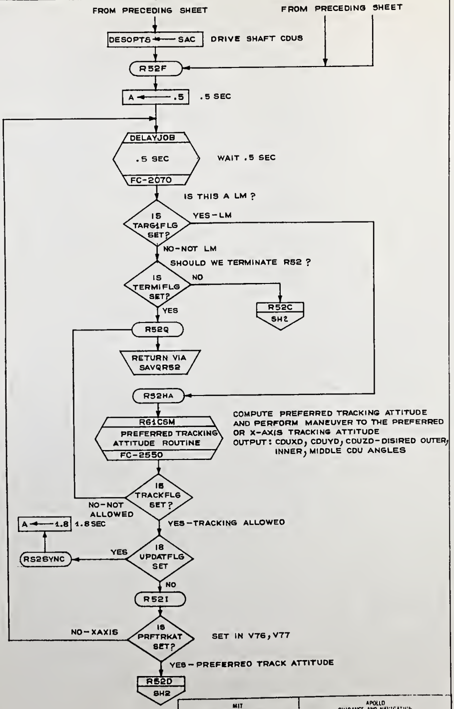
CAMBRIDGE, MASS
R52, R53, R56
COLOSSUS IIC
FC-2730
2
3
18



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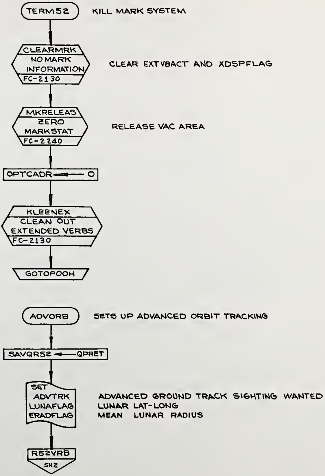
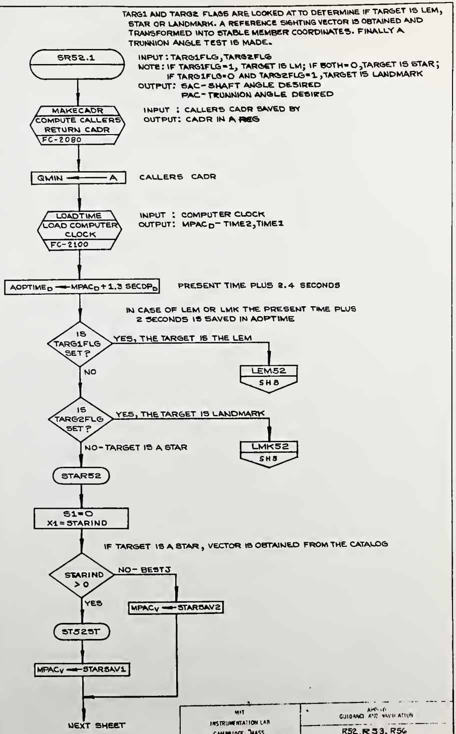
DRAWN — 16 AUG 68	R52, R53, R56
PRGMR — 7 FEB 69	
ANALST	COLOSSUS IIC — DOCUMENT NO FC-2730
DOCMR	REV 2 — SHEET 4 OF 16
APPR'D	



MIT INSTRUMENTATION LAB CAMBRIDGE MASS.	R52, R53, R56
DRAWN / PRGMR / ANALST / DOCMR / APPR'D	COLOSSUS IIC FC-2730
	REV 2 SHEET 5 OF 18



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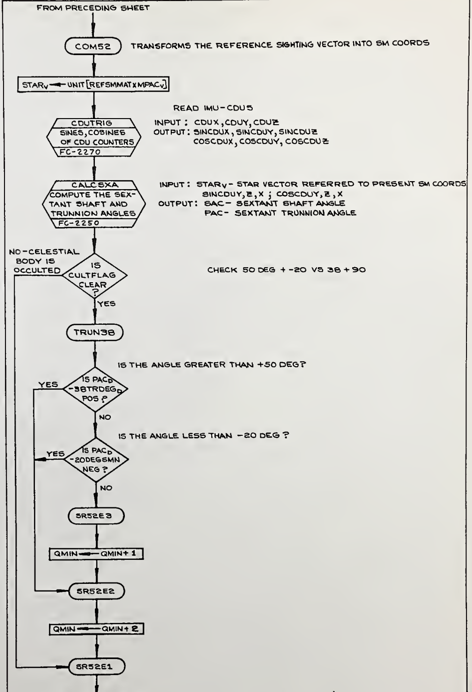
DRAWN / PRGMR / ANALST / DOCMR / APPR'D

APOLLO GUIDANCE AND NAVIGATION

R52, R53, R56

COLOSSUS IIC — FC-2730

REV 2 — SHEET 6 OF 18



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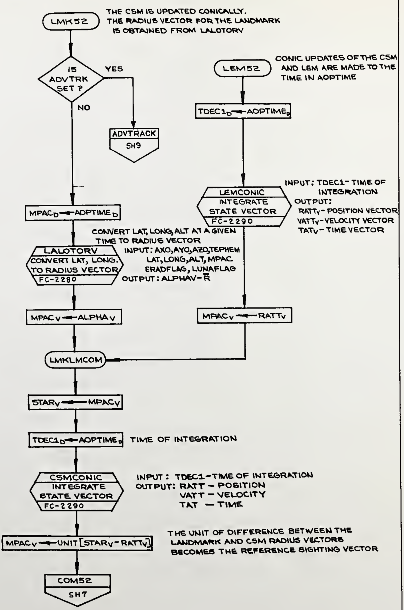
DRAWN
PRGMR
ANALST
DOCMR
APPR'D

R52, R53, R56

COLOSSUS IIC FC-2730

2 7 18



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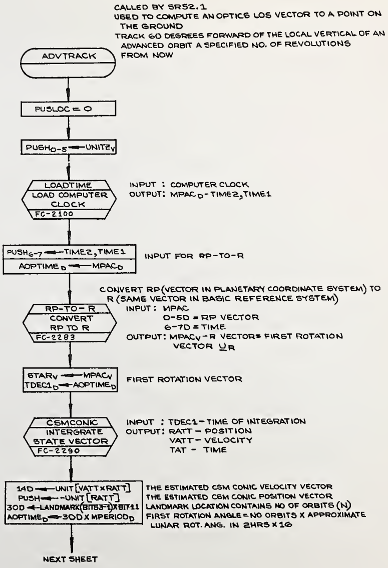
DRAWN [signature] 27 Jul 68	R52, R53, R56
PRGMR [signature] 7 Nov	DOCUMENT NO.
ANALST	COLOSSUS IIC FC-2730
DOCMR [signature] 7 Mar 69	REV 2 SHEET 8 OF 18
APPR'D [signature]	



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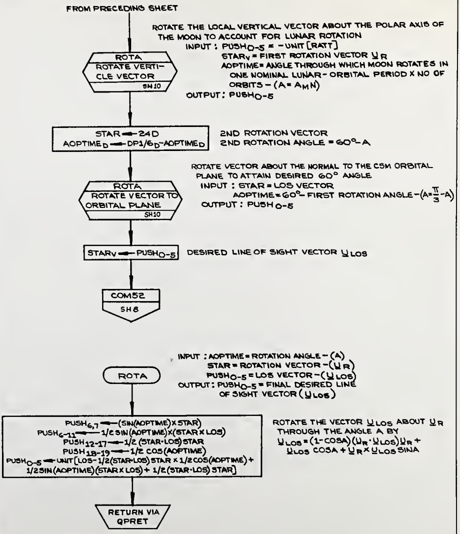
R52, R53, R56

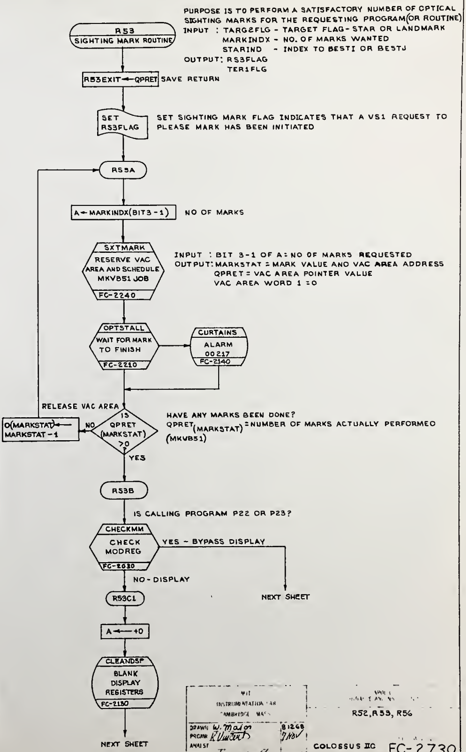
DRAWN
PRGMR
ANALST
DOCMR
APPR'D 7FEB69

COLOSSUS IIC FC-2730

REV 2 SHEET 9 18



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN	R52, R53, R56
PRGMR	
ANALST	COLOSSUS IIC — DOCUMENT NO. FC-2730
DOCMP	
APPR'D	REV 2 — SHEET 10 OF 18



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DRAWN W. Mason 8 12 68
PROGRM R Vincent 7 Nov
ANALST
DOC MP
APPR'D

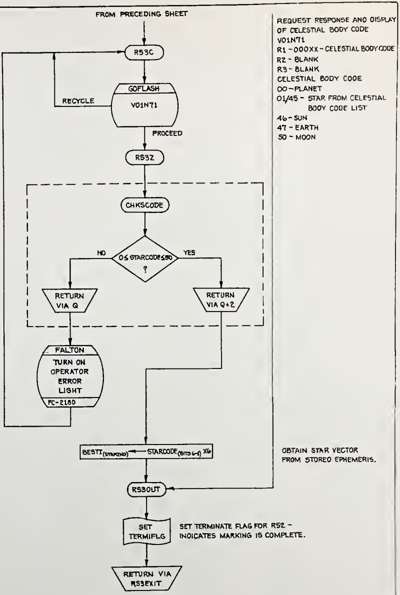
R52, R53, R56

COLOSSUS IIC

FC-2730

2

11 of 18



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DRAWN	A.C.WILLIAMS	5FEB69
PRGMR	K. Vincent	7FEB69
ANALST		
DOCMR	G.S. NALLY	2-7-69
APPR'D	John A. Mora	7FEB69

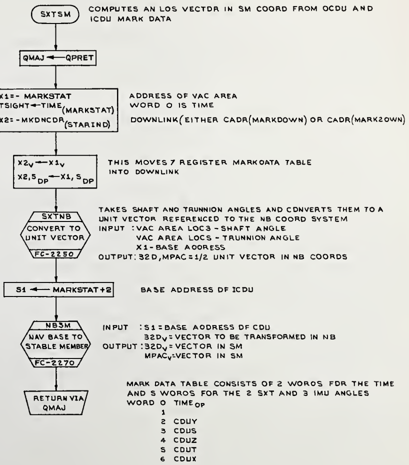
APOLLO GUIDANCE AND NAVIGATION

R52, R53, R56

COLOSSUS IIC

FC-2730

REV 2 SHEET 12 OF 18



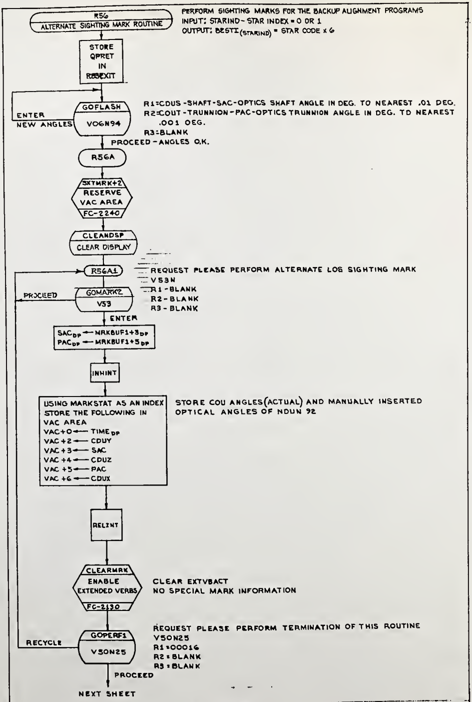
CAMBRIDGE, MASS.

R52, R53, R56

COLOSSUS IIC

FC-2730

13 13



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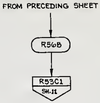
DRAWN W. Mason 8 14 68	R52, R53, R56
PRGMR K. Womack 1 NOV	
ANALYST	COLOSSUS IIC — DOCUMENT NO FC-2730
DOCMR 2 Dec 68	
APPR'D 17 Dec 68	REV B — SHEET 14 OF 18



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS	GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 5FEB69	R52, R53, R56
PRGMR K. Vincent 7Feb69	
ANALYST	COLOSSUS II C FC-2730
DOCMR G. S. NALLY 2 7-69	
APPR'D John A. Moss 7FEB69	REV 2 SH 15 OF 18

SUBROUTINES CALLED WHICH ARE FLOWED ON OTHER FLOW CHARTS

SUBROUTINE NAME	FLOW CHART	DESCRIPTION	WHERE CALLED
R61CSM	FC-2550	PREFERRED TRACKING ATTITUDE	SH. 4
CLEARMRK	FC-2130	NO MARK INFORMATION	SH. 5, 14
MKRELEAS	FC-2240	ZERO MARKSTAT	SH. 5
KLEENEX	FC-2130	CLEAN OUT EXTENDED VERBS	SH. 5
MAKECADR	FC-2080	COMPUTE CALLERS RETURN CADR	SH. 6
LOADTIME	FC-2100	LOAD COMPUTER CLOCK	SH. 6
CDUTRIG	FC-2270	SINES, COSINES OF CDU COUNTERS	SH. 7
CALCSCA	FC-2250	COMPUTE THE SEXTANT SHAFT AND TRUNNION ANGLES	SH. 7
LALOTORV	FC-2280	CONVERT LAT, LONG TO RADIUS VECTOR	SH. 8
LEMCONIC	FC-2290	INTEGRATE STATE VECTOR	SH. 8
CSMCONIC	FC-2290	INTEGRATE STATE VECTOR	SH. 8, 9
LOADTIME	FC-2100	LOAD COMPUTER CLOCK	SH. 9
RP-TO-R	FC-2283	CONVERT RP TO R	SH. 9
SXTMARK	FC-2240	RESERVE VAC AREA AND SCHEDULE MKVB51 JOB	SH. 11, 14
OPTSTALL	FC-2210	WAIT FOR MARK TO FINISH	SH. 11
CHECKMM	FC-2030	CHECK MODREG	SH. 11
SXTNB	FC-2250	CONVERT TO UNIT VECTOR	SH. 13
NBSM	FC-2270	NAV BASE TO STABLE MEMBER	SH. 13

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.
APOLLO GUIDANCE AND NAVIGATION
R52, R53, R56

DRAWN [signature] 17JAN69
PRGMR K. Duncan 7FEB69
ANALST
DOCMR G. S. NALLY 2-7-69
APPR'D John A. Moss 7FEB69

COLOSSUS IIA
DOCUMENT NO. FC-2730
REV 2
SHEET 16 OF 18

FLAGS					
NAME	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
ADVTRK	ADVANCE GROUND TRACK WANTED	NOT ADVANCED GROUND TRACK	SH. 5	SH. 2	SH. 8
TRUNFLAG	DRIVING OF TRUNNION ALLOWED	DRIVING OF TRUNNION NOT ALLOWED	SH. 2, 3	SH. 3	SH. 3
TERMIMFLG	TERMINATE R52	DO NOT TERMINATE R52		SH. 2, 12	SH. 4
R53FLAG	V51 INITIATED	V51 NOT INITIATED	SH. 11		SH. 3
TARG1FLG	SIGHTING LEM	NOT SIGHTING LEM			SH. 3 4 6
TRACKFLG	TRACKING ALLOWED	TRACKING NOT ALLOWED			SH. 4
UPDATFLG	UPDATING BY MARKS ALLOWED	UPDATING BY MARKS NOT ALLOWED			SH. 4
LUNAFLAG	LUNAR LAT-LONG	EARTH LAT-LONG	SH. 5		
ERADFLAG	USE FIXED RADIUS	USE RLS FOR LUNAR RADIUS	SH. 5		
TARG2FLG	SIGHTING LANDMARK	SIGHTING STAR			SH. 6
CULTFLAG	STAR OCCULTED	STAR NOT OCCULTED			SH. 7

DISPLAYS			
VERB-NOUN	TYPE OF DISPLAYS	DESCRIPTION OF EACH REGISTER	WHERE EXECUTED
		PRIOLARM – TARGET OUT OF VIEW – 404	SH. 3
		ALARM – AUTO OPTICS REQUEST TRUN ANGLE – 407	SH. 3
		CURTAINS – ALARM 217	SH. 11
V01N71	FLASHING	RESPONSE AND DISPLAY OF CELESTIAL BODY CODE R1 – CELESTIAL BODY CODE R2 – BLANK R3 – BLANK	SH. 12
V53	PLEASE PERFORM	PLEASE PERFORM ALTERNATE LOS SIGHTING MARK R1 – BLANK R2 – BLANK R3 – BLANK	SH. 14
V06N94	FLASHING	R1 – CDUS - SHAFT R2 – CDUT - TRUNNION R3 – BLANK	SH. 14
V50N25	PLEASE PERFORM	PLEASE PERFORM TERMINATION OF THIS ROUTINE R1 – 00016 R2 – BLANK R3 – BLANK	SH. 14

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

R52, R53, R56

DRAWN J. S. Chmelnik 17JAN69
PRGMR K. Dwcent 7FEB69
ANALST
DOCMR G. S. NALLY 2-7-69
APPR'D John A. Moore 3FEB69

COLOSSUS IIC

FC-2730

REV 2

17 18

ERASABLE LOCATIONS USED					
AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
CDUT		OPTICS TRUNNION ANGLE	DEGREES	REVS	2^{-3}
CDUS		OPTICS SHAFT ANGLE	DEGREES	REVS	2^{-1}
DESOPTT		DISPLAY NOUN FOR TRUNNION ANGLE	DEGREES	REVS	2^{-1}
DESOPTS		DISPLAY NOUN FOR SHAFT ANGLE	DEGREES	REVS	2^{+1}
STARSAV2		STAR2 UNIT VECTOR			2^{1}
STARSAV1		STAR1 UNIT VECTOR			2^{1}
$RATT_V$		CONIC POSITION VECTOR	M	M	2^{29}
$VATT_V$		CONIC VELOCITY VECTOR	M/SEC	M/CSEC	2^{7}
TAT_D		TIME OF $RATT_V$, $VATT_V$	SEC	CSEC	2^{28}
$ALPHAV_V$		RADIUS VECTOR	M	M	2^{29}
LANDMARK		NO OF REVOLUTIONS			
AOPTIME		TEMPORARY			
$STAR_V$		TEMPORARY			
STARIND		STAR INDICATOR			
$TDEC1_D$		TIME VARIABLE	SEC	CSEC	2^{28}
$TSIGHT_D$		TIME OF SIGHTING	SEC	CSEC	2^{28}
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}

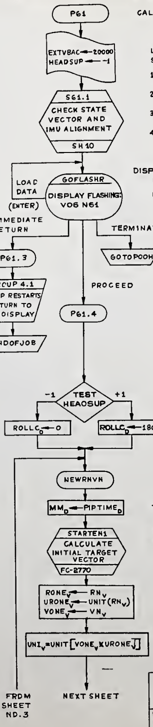
PROGRAM CONSTANTS					
AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING VALUE AND UNITS	AGC VALUE AND UNITS	AGC SCALING
36TRDEG		50° TO 65° ANGLE CHECK	60 DEGS	.16666667 REV	2^{-2}
20DEGSMN		85° TO 90° ANGLE CHECK	-36 DEGS	-.1098 REV	2^{-2}
MPERIOD		LUNAR ANGULAR .. ROTATION IN 2 HOURS	1.071432 DEGS	.0029762 REV	2^{-4}
DP1/6		1/8 REVOLUTION = 80°	60 DEGS	.16666666 REV	2^{0}

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN [signature] 27JAN69	R52, R53, R56
PRGMR Ken Vincent 7Feb69	
ANALST	COLOSSUS IIC — DOCUMENT NO FC-2730
DOCMR G. S. NALLY 2-7-69	
APPR'D [signature] 3FEB69	REV 8 — SHEET 18 OF 18

P60'S - ENTRY PROGRAMS		
P61	MANEUVER TO CM SM SEPARATION ATTITUDE	SH. 2
P62	CM SM SEPARATION AND PRE-ENTRY MANEUVER	SH. 4
WAKEP62	SCHEDULE P63	SH. 5
63	ENTRY INITIALIZATION	SH. 6
P64	POST .05G ENTRY MODE	SH. 6
P65	UP CONTROL ENTRY MODE	SH. 7
P66	BALLISTIC ENTRY MODE	SH. 8
P67	FINAL ENTRY MODE	SH. 8
P67.1	FINAL ENTRY DISPLAY (N67)	SH. 9
P67.2	CALCULATION FOR N67 DISPLAY	SH. 9
S61.1	CHECK FOR PROPER IMU ALIGNMENT AND ENSURE THAT AVERAGEG IS STARTED	SH. 10
S61.1C	START AVERAGEG	SH. 11
S61.1A	CHECK ENTRY IMU ALIGNMENT	SH. 11
S61.2	CALCULATION FOR N60, N63 DISPLAYS	SH. 12
DISPTARG	RANGE ESTIMATOR	SH. 16
P62.3	COMPUTE DESIRED ENTRY ATTITUDE	SH. 17

P.M. Didrik 30APR69
Bairnsfather 11JUL69
M LEMAN
Alida M. Grant 11JULY69

P61: MANEUVER TO CM/SM SEPARATION ATTITUDE



CALLED FROM OSKY VIA V37E61E

LOCK OUT EXTENDED VERBS (PROTECT TFF ROUTINES FROM V82)
SET HEADSUP FLAG TO HEAD DOWN (LIFT UP)

1. CALL RD2 CHECK REFSMMAT & IMU STATUS. SET IMUSE FLAG
2. UPDATE STATE VECTORS VN_V, RN_V TO PRESENT TIME + A SMALL TOLERANCE
3. START AVERAGEG AS PART OF SERVICER 2 SEC. UPDATE SEQUENCE
4. CHECK IMU ALIGNMENT AND DO ALARM IF NOT SATISFACTORY (10 SEC DISPLAY)

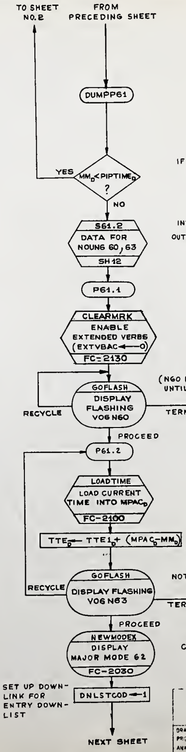
DISPLAY NOUN 61:
R1 – LATITUDE (SPLASH) XXX.XX DEG
R2 – LONGITUDE (SPLASH) XXX.XX DEG
R3 – HEADSUP: +1 = HEADS UP (LIFT DOWN)
−1 = HEADS DOWN (LIFT UP)

IF HEADSUP = +1,
COMMAND 180° ROLL (LIFT DOWN)
IF HEADSUP = −1,
COMMAND 0° ROLL (LIFT UP)

TEMPORARY STORAGE FOR TEST BELOW

INPUT: $PIPTIME_D$ FROM AVERAGEG, $LAT(SPL)_D$, $LNG(SPL)_D$
OUTPUT: $RTINIT_V$ – INITIAL TARGET VECTOR (AT PIPTIME)
$RTEAST_V$ – EASTWARD COMPONENT OF $RTINIT_V$
$RTNORM_V$ – NORMAL COMPONENT OF $RTINIT_V$
RT_V – TARGET VECTOR AT ESTIMATED IMPACT TIME
DTEAROT – ESTIMATED TIME TO IMPACT
TIME/RTO_D – TIME OF INITIAL TARGET VECTOR

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A. J. Smith 11 JUL 68	P60's
PRGMR [illegible]	
ANALST	COLOSSUS II-A — DOCUMENT NO FC-2760
DOCMR M. LEMAN	
APPR'D [illegible]	REV — SHEET 2 OF 17



IF PIPTIME HAS BEEN UPDATED, IT MEANS THAT AVERAGEG HAS RUN, SO ABOVE CALCULATIONS ARE INVALID AND MUST BE REDONE USING NEW STATE VECTOR

INPUT: $RONE_V$, $VONE_V$, $URONE_V$, UNI_V, $UNITW_V$, EMSALT

OUTPUT:
- GMAX = MAXIMUM PREDICTED DECELERATION DURING ENTRY (IN g'S)
- VPRED = PREDICTED INERTIAL VELOCITY AT 400,000 FT
- GAMMAEI = PREDICTED FLIGHT PATH ANGLE (γ) AT 400,000 FT

} NOUN 60

- RTOGO = RANGE FROM EMS ALTITUDE TO SPLASH
- VIO = PREDICTED INERTIAL VELOCITY AT EMS ALTITUDE
- TTE = TIME TO GO FROM PRESENT POSITION TO EMS ALTITUDE
  (EMS ALTITUDE = ALTITUDE AT .05g G. VALUE = 284,643 FT ORBITAL ENTRY
  = 297,431 FT LUNAR ENTRY)

} NOUN 63

(N60 & N63 ARE UNMOLESTED UNTIL P64)

R1: XXX.XXG (GMAX)
R2: XXXXX. FT/SEC (VPRED)
R3: XXX.XX DEG (GAMMAEI)

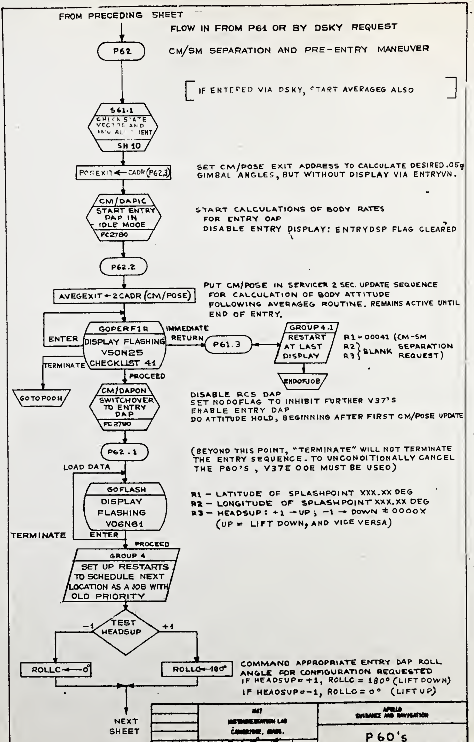
CORRECT TTE_D FOR TIME USED SINCE CALCULATION. (MM_D = TIME OF AVERAGEG WHEN $RONE_V$ AND $VONE_V$ WERE SAVED. BOTH TTE & TTE1 ARE NEGATIVE)

NOTE: "V32E" MAY BE USED TO UPDATE TTE ON DEMAND.

R1: XXXX.X NM (RTGO)
R2: XXXXX. FT/SEC (VIO)
R3: XX-XX MIN, SEC (TTE)

CHANGE MAJOR MODE TO P62, AND FALL INTO P62

MIT INSTRUMENTATION LAB CAMBRIDGE MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN 11JUL68	P60's
PRGMR	
ANALST	
DOCMR M. LEMAN	COLOSSUS IIA FC-2760
APVD	3 17



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

P 60's

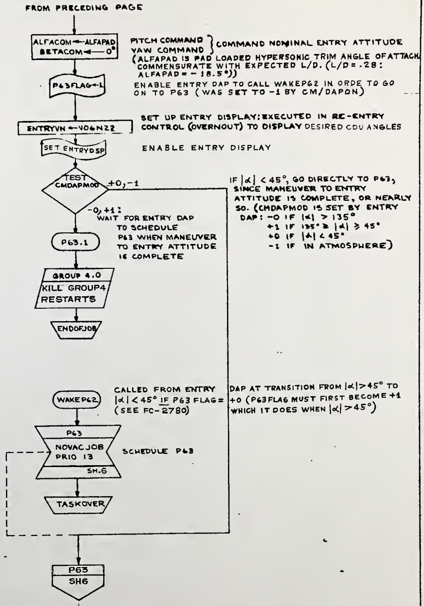
12 JUL

M. LEMAN

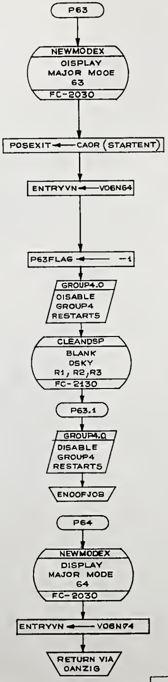
COLOSSUS IIA

DOCUMENT NO. FC-2760

SHEET 4 OF 17



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN O. L. Linville	12 JUL 68	P60's
PROJ. ENGR.		
ANALYST		COLOSSUS II-A / DOCUMENT NO. FC-2760
DESIGNER M. LEMAN		
APPROVED		SHEET 5 OF 7



CALLED FROM WAKEP62, OR FLOW IN FROM P62, WHEN ENTRY ATTITUDE HAS BEEN ACHIEVED. ACTIVATE ENTRY GUIDANCE

MAJOR MODE DISPLAY : P63

PUT STARTENT INTO 2 SEC UPDATE SEQUENCE FOLLOWING CM/POSE TO INITIALIZE ENTRY STEERING. (STARTENT WILL SET POSEXIT TO CADR (SCALEPOP) FOR SUBSEQUENT PASSES) (STARTENT OMITS DISPLAY)

SET UP ENTRY DISPLAY EXECUTED IN RE-ENTRY CONTROL (OVERNOUT) TO DISPLAY NOUN 64 EACH 2 SEC :

R1 – XXX.XX G DRAG ACCELERATION
R2 – XXXXX FPS VELOCITY
R3 – XXXX.X NM DISTANCE TO SPLASH POINT (NEGATIVE IF WILL FALL SHORT)

ASSURE THAT P63 WILL NOT BE CALLED OUT OF SEQUENCE BY SKIP PHASE IS P66 OR P67

DISABLE GROUP4 - DISPLAY IS RESTARTED IN RE-ENTRY CONTROL (GROUP5)

REMOVE V06N22, IF PRESENT. P63 DISPLAY BEGINS ON SECOND PASS THRU ENTRY STEERING

DISABLE GROUP4 - DISPLAY IS RESTARTED IN RE-ENTRY CONTROL (GROUP 5)

CALLED FROM RE-ENTRY CONTROL WHEN .05 G IS INITIALLY EXCEEDED

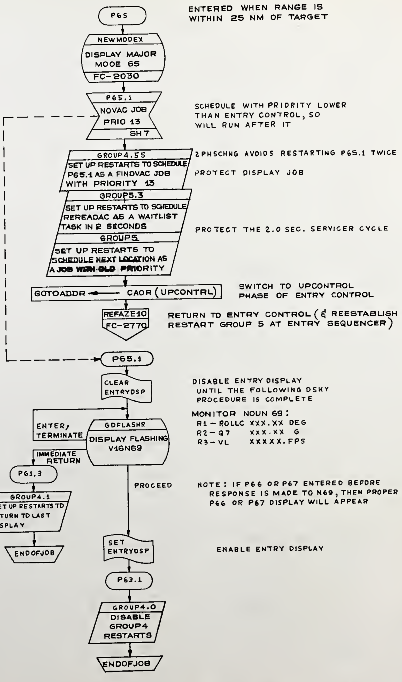
MAJOR MODE DISPLAY P64

SET UP ENTRY DISPLAY EXECUTED IN RE-ENTRY CONTROL (OVERNOUT) TO DISPLAY NOUN 74 EACH 2 SEC :

R1 –	XXX.XX DEG	ROLL COMMAND	(ROLLC)
R2 –	XXXXX. FPS	VELOCITY	(VMAGI)
R3 –	XXX.XX G	DRAG	(D)

(NOUN 68 DISPLAY MAY STILL BE CALLED UP)

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN R.M. Dietrich 2 MAY 69	P60'S
PRGMR R. Bairnsfather 11 Ju 69	DOCUMENT NO.
ANALST	COLOSSUS II-A FC-2760
DOCMR M. LEMAN	
APPR'D	REV SHEET 6 OF 17



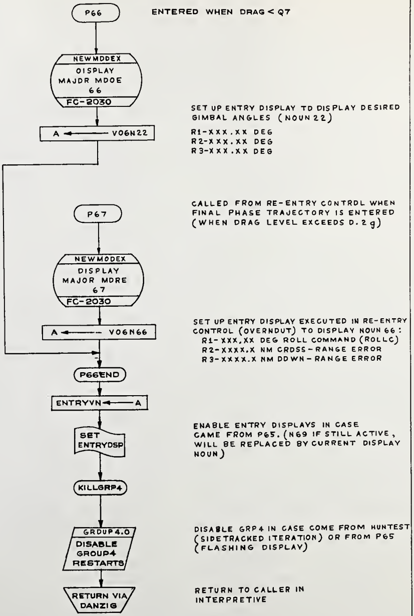
2AUG68

M. LEMAN

P60's

COLOSSUS II-A FC-2760

7 17



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS

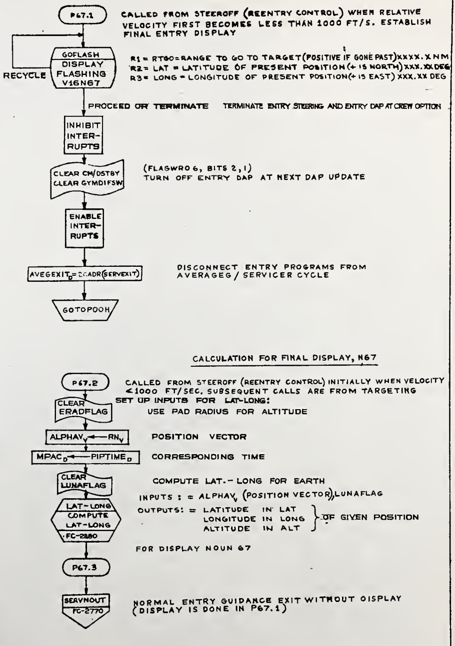
DRAWN [signature] 18SEP68
PRGMR [signature]
ANALYST
DOCMR M. LEMAN
APPR'D [signature]

APOLLO GUIDANCE AND NAVIGATION

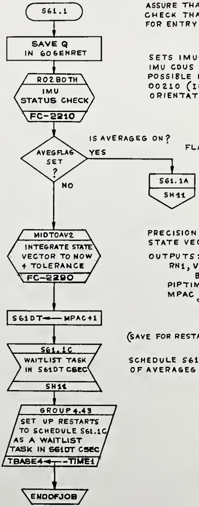
P60's

COLOSSUS IIA FC-2760

8 of 17



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION	
DRAWN A. G. Laquille 17JUL68	P 60'S	
CHECKED [signature]		
APPROVED M. LEMAN	COLOSSUS II-A	DOCUMENT NO. FC-3760
		SHEET 9 OF 17



ASSURE THAT AVERAGEG IS OPERATING AND CHECK THAT IMU IS ALIGNED PROPERLY FOR ENTRY

SETS IMUSE FLAG TO PREVENT ZEROING IMU CDUS BY A RESTART
POSSIBLE PROG ALARM, WITH ALARM CODE 00210 (IMU NOT ON) OR 00220 (IMU NOT ORIENTATION NOT KNOWN IE, NO REFSMMAT)

IS AVERAGEG ON?

FLAG SET OR RESET IN SERVICER

IF AVERAGEG ON, SKIP START-UP SEQUENCE

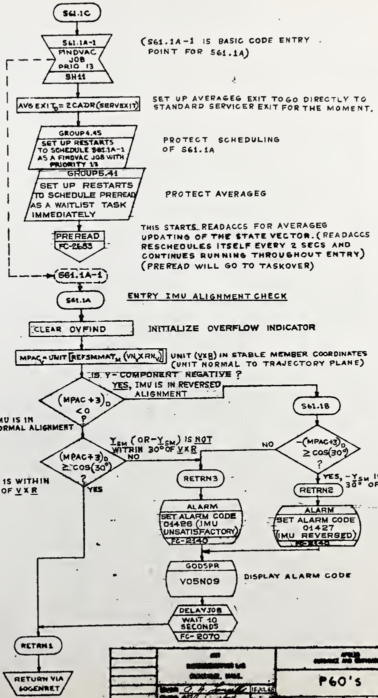
PRECISION INTEGRATION OF STATE VECTOR

OUTPUTS:

RN1, VN1 : STATE VECTOR IN FUTURE BY AMOUNT OF TOLERANCE
PIPTIME1 : TIME OF RN1, VN1
$MPAC_{dp}$: Δ TIME, CURRENT TIME TO PIPTIME1

(SAVE FOR RESTART PROTECTION RELATIVE TO TBASE4)

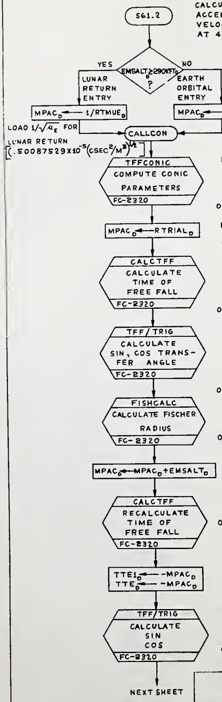
SCHEDULE S61.1C TO BEGIN AT THE START OF AVERAGEG TO ESTABLISH PREREAD



	15 JUL 68	P60's
	M. LEMAN	COLOSSUS II-A
		FC-2760
		16 of 17

NOUN 60 AND NOUN 63 CALCULATION SUBROUTINE

CALCULATE ENTRY DISPLAY (NOUN 60) OF MAXIMUM ACCELERATION EXPECTED, ALSO EXPECTED INERTIAL VELOCITY AND ENTRY ANGLE, THAT WILL OBTAIN AT 400K FT ABOVE FISCHER ELLIPSOID



$\mu = 1.0012\ \mu_E$

LOAD $1/\sqrt{\mu}$ FOR EARTH ORBIT

$[.5005750271 \times 10^{-5}\ (CSEC^2/M^3)^{1/2}]$

INPUT: $MPAC_D$: $1/\sqrt{\mu}$ FOR EARTH
$RONE_V$, $URONE_V$, $VONE_V$, UNI_V — SAVED FROM SERVICER BY NEWRNVN (P61)

OUTPUT: CONIC PARAMETERS IN PUSHLIST (FOR USE BY TFF SUBROUTINES)

FIRST GUESS AT TERMINAL RADIUS (R_h) AT NOMINAL EMS ALTITUDE

$RTRIAL_D$ = RPAD + NOMINAL 0.05G ALTITUDE
= 20,909,901.57 FT + 284,643 FT
= 21,194,545 FT

INPUT: TERMINAL RADIUS ($MPAC_D$)(R_h)
CONIC PARAMETERS IN PUSHLIST (FROM TFFCONIC)

OUTPUT: NRTERM = NORMALIZED R_h
TFFX $= \alpha z^2$ OR $\frac{1}{\alpha z^2}$
TFFTEM $= P z |z|$ OR $\frac{P}{\alpha}$ SGN$(Q_0 + \frac{R_0}{z})$

INPUT: NRTERM, TFFX, TFFTEM — FROM CALCTFF
NRMAG — FROM TFFCONIC

OUTPUT: MPAC = SIN (δf), WHERE (δf) IS TRANSFER ANGLE FROM PRESENT TO EMS ALTITUDE.
CDELF/2 = COS (δf)

INPUT: $MPAC_D$ = SIN (δf), UNI_V = UNIT ($V_0 \times R_0$)
CDELF/2 = COS (δf)

OUTPUT: $MPAC_D$ = ERADM = RADIUS OF EARTH (R_e) AT LATITUDE OF ESTIMATED TERMINAL RADIUS (R_h)

CORRECTED ESTIMATE OF TERMINAL RADIUS (R_h).
$EMSALT_D$ = 284,643 FT (PAD LOADED, EARTH ORBITAL)
$EMSALT_D$ = 297,431 FT (PAD LOADED, LUNAR RETURN)

INPUT: $MPAC_D$ = TERMINAL RADIUS (R_h)

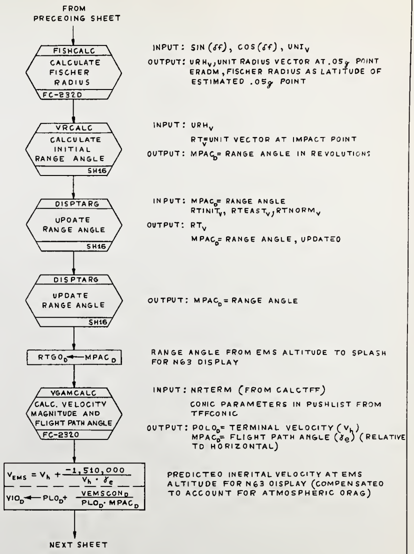
OUTPUT: $MPAC_D$ = TIME OF FLIGHT TO EMS ALTITUDE FROM PRESENT POSITION.
NRTERM = NORMALIZED R_h
TFFX $= \alpha z^2$ OR $\frac{1}{\alpha z^2}$
TFFTEM $= P z |z|$ OR $\frac{P}{\alpha}$ SGN$(Q_0 + \frac{R_0}{z})$

TIME TILL ENTRY (.05G) (NEGATIVE AS IN COUNTDOWN) FOR N63 DISPLAY

INPUT: NRTERM, TFFX, TFFTEM — FROM CALCTFF
NRMAG — FROM TFFCONIC

OUTPUT: $MPAC_D$ = SIN (δf)
CDELF/2 = COS (δf)

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN Q. G. Longill 23SEP68	P60's
PRGMR [signature] 11 Jul 68	DOCUMENT NO.
ANALST	COLOSSUS II-A FC-2760
DOCMR M. LEMAN	
APPR'D [signature] 11 Jul 68	SHEET 12 OF 17



DRAWN Q. J. Longillo 23SEP68
M. LEMAN

P60's

COLOSSUS II-A FC-2760

FROM PRECEDING PAGE

OBTAIN V_h AND γ_e AT 300 K FEET ALTITUDE FOR USE IN GMAX ALGORITHM

$MPAC_D \leftarrow ERADM_D + 300KFT_D$

ERADM = EARTH RADIUS AT EMS LATITUDE (FROM FISHCALC)

$RTERM_D \leftarrow MPAC_D$

PREVGAM — CALC. VELOCITY MAGNITUDE AND FLIGHT PATH ANGLE — FC-2320

INPUT: $MPAC_D = R_h$
CONIC PARAMETERS IN PUSHLIST FROM TFFCONIC

OUTPUT: PLO_D = TERMINAL VELOCITY (V_h)
$MPAC_D$ = FLIGHT PATH ANGLE (γ_e)

CALCULATION OF MAXIMUM G FOR DISPLAY (NOUN 60)

$PL2_D \leftarrow MPAC_D$

PREDICTED FLIGHT PATH ANGLE AT 300,000 FEET (γ_e)

$$V^2 = \left(\frac{V_h - 36{,}000}{20{,}000}\right)^2$$

$$PLO_D \leftarrow \left(\frac{PLO_D - 36KFT/S_D}{20KFT/S_D}\right)^2 \qquad \overline{V}^2$$

$$G_{MAX} = \frac{4(\gamma_e - 6.05 - 2.4\,V^2)}{1 + 4.8\,V^2} + 10$$

$$MPAC_D \leftarrow \frac{KR2_D\left[PL2_D + (-6.05DEG)_D + (KR1_D \cdot PLO_D)\right]}{DP2(-4)_D + (PLO_D/KR4_D)} + KR3_D$$

IS MPAC ≥ 0 ?

NO: $MPAC_D \leftarrow +0$

YES

PREVENT NEGATIVE VALUE

$GMAX_D \leftarrow MPAC_D$

MAXIMUM G'S FOR N60 DISPLAY

$MPAC_D \leftarrow ERADM_D + 400KFT_D$

FIRST GUESS OF TERMINAL RADIUS AT 400K FT
$ERADM_D$ = EARTH RADIUS AT EMS LATITUDE (FROM FISHCALC)

CALCTFF — CALCULATE TIME OF FREE FALL TO 400K FT — FC-2320

INPUT: $MPAC_D$ = TERMINAL RADIUS
CONIC PARAMETERS IN PUSHLIST FROM TFFCONIC

OUTPUT: NRTERM, TFFX, TFFTEM

TFF/TRIG — CALCULATE SIN, COS TRANSFER ANGLE — FC-2320

INPUT: NRTERM, TFFX, TFFTEM FROM CALCTFF
NRMAG FROM TFFCONIC

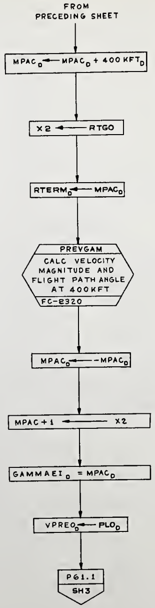
OUTPUT: $MPAC_D$ = SIN (δf) WHERE (δf) IS THE TRANSFER ANGLE
CDELF/2 = COS (δf) FROM PRESENT POSITION TO 400K FT

FISHCALC — CALCULATE FISCHER RADIUS — FC-2320

INPUT: $MPAC_D$ = SIN (δf)
CDELF/2 = COS (δf)
UNI_V = UNIT($V_o \times R_o$)

OUTPUT: $MPAC_D$ = RADIUS OF EARTH AT LATITUDE OF 400K FT TERMINAL RADIUS = ERADM

TO NEXT PAGE



CORRECTED ESTIMATE OF RADIUS AT 400KFT

SAVE RANGE ANGLE FROM EMS ATTITUDE (HIGH ORDER HALF) FOR DOWNLINK

INPUT: $MPAC_D$ = TERMINAL RADIUS CONIC PARAMETERS IN PUSHLIST FROM TFFCONIC

OUTPUT: $MPAC_D$ = FLIGHT PATH ANGLE AT 400KFT (γ_e)

$POLO_D$ = VELOCITY 400KFT (V_h)

GAMMAEI IS NEGATIVE FOR ENTRY

FROM PACKED WORD FOR DOWNLINK: PUT RTGO (HI-WD) INTO LO-WD OF GAMMAEI

FLIGHT PATH ANGLE AT 400KFT FOR N60.
DOWN-LINK QUANTITY:
HIGH-WORD = γ_e
LOW-WORD = RANGE TO GO

CONIC VELOCITY AT 400KFT FOR NOUN 60 DISPLAY

NOTE: EFFECT OF RTGO IN LO-WD OF GAMMAEI ON DSKY IS NEGLIGIBLE ($\approx$ .005° DEG)

MIT INSTRUMENTATION LAB CAMBRIDGE MA

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PRGMR [illegible] 11 Jun 69
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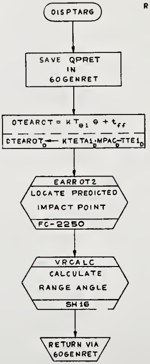
APPR'D [illegible] 11 JUL 69

P60's

COLOSSUS II-A FC-2760

15 17

RANGE ESTIMATOR



C ($MPAC_D$) = RANGE ANGLE ESTIMATE

$KT_{\theta 1} = 1100$

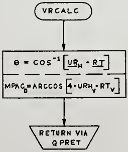
$TTE = -t_{ff} = -$(TIME OF FREE FALL)

INPUT: $DTEAROT_D$ (ESTIMATED FLIGHT TIME) $RTINIT_V$, $RTEAST_V$, $RTNORM_V$, $TIME/RTO_D$

OUTPUT: RT_V, PREDICTED TARGET VECTOR

INPUT: URH_V, RT_V

OUTPUT: $MPAC_D$, RANGE ANGLE IN REVOLUTIONS



INPUT: URH_V (UNIT RADIUS AT .05g POINT)

RT_V (UNIT TARGET VECTOR)

OUTPUT: $MPAC_D$, RANGE ANGLE IN REVOLUTIONS

P62.3

IF ENTRYDSP = 0, OMIT ENTRY DISPLAY (ENTRYVN)
IF ENTRYDSP = 1, DO ENTRY DISPLAY (ENTRYVN)

QPRET ← CADR [ENDEXIT]

S62.3

1. COMPUTE DESIRED GIMBAL ANGLES FOR ENTRY ATTITUDE
2. GENERATE DESIRED BODY TRIAD FOR TRIMMED FLIGHT WITH RESPECT TO RELATIVE VELOCITY

$YNB_V \leftarrow UYA/2_V \cdot COS(ROLLC_D) + UZA/2_V \cdot SIN(ROLLC_D)$

YNB_V = DESIRED BODY Y AXIS IN REFERENCE COORDINATES
$UYA/2_V$ = NORMAL TO TRAJECTORY PLANE IN REFERENCE COORDINATES (FROM CM/POSE)
$ROLLC_D$ = ROLL COMMAND
$UZA/2_V$ = TRAJECTORY TRIAD Z AXIS IN REFERENCE COORDINATES (FROM CM/POSE)

$XNB_V \leftarrow UXA/2_V \cdot COS(ALFAPAD) + (YNB_V \times UXA/2_V) \cdot SIN(ALFAPAD)$

$UXA/2_V$ = TRAJECTORY TRIAD X AXIS IN REFERENCE COORDINATES (FROM CM/POSE)
ALFAPAD = PAD LOADED PITCH TRIM ANGLE

$ZNB_V \leftarrow XNB_V \times YNB_V$

Z AXIS TO COMPLETE THE TRIAD

$XSM_V \leftarrow REFSMMAT_V$
$YSM_V \leftarrow REFSMMAT+6D_V$
$ZSM_V \leftarrow REFSMMAT+12D_V$

REFERENCE COORDINATE SYSTEM TO STABLE MEMBER TRANSFORMATION MATRIX, FOR USE BY CALCGA

CLEAR CPHIFLAG

CPHIFLAG CAUSES CALCGA TO STORE RESULTING ANGLES IN TP IN CPHI

CALCGA
CALCULATE DESIRED GIMBAL ANGLE
FC-226D

INPUTS: XNB_V, YNB_V, ZNB_V, XSM_V, YSM_V, ZSM_V
OUTPUTS: 3 GIMBAL ANGLES IN MPAC, MPAC+1 AND MPAC+2
ALSO IN CPHI, +2

FROM CALCGA

RETURN VIA QPRET

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A. J. Lorzillo 25 SEP 68	P60's
PROGR [signature] 11 Jul 69	
ANALYST	COLOSSUS II-A DOCUMENT FC-2760
DOC MGR M. LEMAN	
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AMBGUPDT	FC-2460	ROLL AUTOPILOT	CALLED 8		
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AVFLAGA	FC-2627	P33, P73 - CDH	CALLED 1		
AVFLAGA	FC-2630	TPI TARGETTING	CALLED 2		
AVFLAGA	FC-2640	TPM TARGETTING	CALLED 1		
AVFLAGP	FC-2545	TPI SEARCH PROG	CALLED 3		
AVFLAGP	FC-2626	P32, P72 - CSI	ENTRY 2		
AVFLAGP	FC-2627	P33, P73 - CDH	CALLED 1		
AVFLAGP	FC-2630	TPI TARGETTING	CALLED 2		
AVFLAGP	FC-2640	TPM TARGETTING	CALLED 1		
AVFLAGP	FC-2644	P38-P78; P39-P79	CALLED 3,9		
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BLANKET	FC-2590 P22 ORBITAL NAV	CALLED 3,6,16			
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CHKPOOH	FC-2595	LUNAR LAND SELECT	CALLED 3		
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CSMCONIC	FC-2360	-S-BAND ANTENNA	CALLED 3		
CSMCONIC	FC-2361	V89 (R63)	CALLED 4		
CSMCONIC	FC-2545	TPI SEARCH PROG	CALLED 4,5		
CSMCONIC	FC-2590	P22 ORBITAL NAV	CALLED 3		
CSMCONIC	FC-2720	IMU REALIGN PROG	CALLED 11		
CSMCONIC	FC-2730	R52, R53, R53	CALLED 8,9		
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CSMPREC	FC-2325	RENDEZ PAR DISPLAY	CALLED 7		
CSMPREC	FC-2590	P22 ORBITAL NAV	CALLED 19		
CSMPREC	FC-2595	LUNAR LAND SELECT	CALLED 5		
CSMPREC	FC-2642	RETURN TO EARTH	CALLED 15		
CSMPREC	FC-2644	P38-P78; P39-P79	CALLED 12		

CSMPREC	FC-2720	IMU REALIGN PROG	CALLED 8,10		
CSMSTORE	FC-2545	TPI SEARCH PROG	CALLED 4		
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DELAYJOB	FC-2550	P20 RENDEZVOUS NAV	CALLED 31		
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ERADFLAG	FC-2590	P22 ORBITAL NAV	S-4		
ERADFLAG	FC-2595	LUNAR LAND SELECT	S-4,6		
ERADFLAG	FC-2600	CISLUNAR MID NAV	S-16		
ERADFLAG	FC-2642	RETURN TO EARTH		C-32	
ERADFLAG	FC-2720	IMU REALIGN PROG	S-7		
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FALTON	FC-2190	PINBALL	CALLED 2		
FALTON	FC-2325	RENDEZ PAR DISPLAY	CALLED 2		
FALTON	FC-2330	CREW DEF MANEUVER	CALLED 2		

FALTON	FC-2360	-S-BAND ANTENNA	CALLED 2		
FALTON	FC-2361	V89 (R63)	CALLED 2		
FALTON	FC-2550	P20 RENDEZVOUS NAV	CALLED 17		
FALTON	FC-2595	LUNAR LAND SELECT	CALLED 3		
FALTON	FC-2600	CISLUNAR MID NAV	CALLED 4		
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FALTON	FC-2650	ORB PARAM DISPLAY	CALLED 2		
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GETERAD	FC-2642	RETURN TO EARTH	CALLED 7	
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GET+MGA	FC-2626	P32, P72 - CSI	CALLED 6	
GETUM	FC-2550	P20 RENDEZVOUS NAV	ENTRY 38	
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GOINT	FC-2630	TPI TARGETTING	ENTRY 14	
GOODEND	FC-2550	P20 RENDEZVOUS NAV	CALLED 34	
GOPROG	FC-2020	FRESH START	ENTRY 13	
GOPROG2	FC-2020	FRESH START	ENTRY 20	
GOTOPOOH	FC-2020	FRESH START	ENTRY 24	
GTSCPSS1	FC-2530	PRELAUNCH INIT	ENTRY 2	
GUESSW	FC-2310	CONIC SUBROUTINES		T-11,16
GUESSW	FC-2682	STEERING		C-14
GYMDIFSW	FC-2760	ENTRY PROGRAMS		C-9
HACK	FC-2440	TVC DAP	CALLED 1,6	
HACK	FC-2450	STROKE TEST PKG	ENTRY 2	
HACKWLST	FC-2450	STROKE TEST PKG	ENTRY 2	
HAVEGUES	FC-2682	STEERING	CALLED 14	

HIENERGY	FC-2310	CONIC SUBROUTINES	ENTRY 21		
HORIZ	FC-2600	CISLUNAR MID NAV	ENTRY 18		
IBNKCALL	FC-2080	INT BNK COMMUN	ENTRY 4		
IDLEFAIL	FC-2681	CLOKTASK- CLOCKJOB	S-10	C-10	
IDLEFAIL	FC-2682	STEERING			T-13
IGNFLAG	FC-2680	THRUST PROGRAMS	S-20		
IGNFLAG	FC-2681	CLOKTASK- CLOCKJOB	S-13		T-6
IGNITION	FC-2630	TPI TARGETTING	ENTRY 20		
IGNITION	FC-2681	CLOKTASK-CLOCKJOB	CALLED 6		
IMPULSW	FC-2680	THRUST PROGRAMS	S-17	C-19,21	T-21
IMPULSW	FC-2682	STEERING	S-13	C-4	T-4
IMUBAD	FC-2200	T4RUPT	CALLED 35		
IMUCAGE	FC-2200	T4RUPT	ENTRY 31		
IMUCOARS	FC-2710	P51, P53 IMU ORIENT	CALLED 2		
IMUCOARS	FC-2720	IMU REALIGN PROG	CALLED 23		
IMUFINE2	FC-2710	P51, P53 IMU ORIENT	CALLED 3		
IMUFIN20	FC-2720	IMU REALIGN PROG	CALLED 23		
IMUMON	FC-2200	T4RUPT	ENTRY 25		
IMUOP	FC-2200	T4RUPT	ENTRY 32		
IMUPULSE	FC-2720	IMU REALIGN PROG	CALLED 26		
IMUSE	FC-2550	P20 RENDEZVOUS NAV		C-8	
IMUSE	FC-2710	P51, P53 IMU ORIENT	S-2		
IMUSEFLA	FC-2200	T4RUPT		C-32	T-34,35
IMUSTALL	FC-2710	P51, P53 IMU ORIENT	CALLED 3		
IMUSTALL	FC-2720	IMU REALIGN PROG	CALLED 23,26		
IMUSTLLG	FC-2530	PRELAUNCH INIT	ENTRY 36		
INCORFLG	FC-2550	P20 RENDEZVOUS NAV	S-22,24	C-28	T-24,27,28
INCORFLG	FC-2590	P22 ORBITAL NAV	S-14	C-17	T-17
INCORP1	FC-2550	P20 RENDEZVOUS NAV	CALLED 26		

INCORP1	FC-2590	P22 ORBITAL NAV	CALLED 15		
INCORP1	FC-2600	CISLUNAR MID NAV	CALLED 11		
INCORP1	FC-2610	MEASUREMENT INCOR	ENTRY 3		
INCORP2	FC-2550	P20 RENDEZVOUS NAV	CALLED 27		
INCORP2	FC-2590	P22 ORBITAL NAV	CALLED 16		
INCORP2	FC-2600	CISLUNAR MID NAV	CALLED 12		
INCORP2	FC-2610	MEASUREMENT INCOR	ENTRY 9		
INCRCDUS	FC-2100	SINGLE PREC SUBROUTS	ENTRY 9		
INFINFLG	FC-2310	CONIC SUBROUTINES	S-29	C-29	T-12,18,22
INFINFLG	FC-2595	LUNAR LAND SELECT			T-13
INFINITY	FC-2310	CONIC SUBROUTINES	ENTRY 29		
INITIALW	FC-2550	P20 RENDEZVOUS NAV	ENTRY 36		
INITSUR	FC-2020	FRESH START	ENTRY 25		
INITV	FC-2310	CONIC SUBROUTINES	ENTRY 20		
INITVEL	FC-2545	TPI SEARCH PROG	CALLED 8		
INITVEL	FC-2630	TPI TARGETTING	CALLED 12		
INITVEL	FC-2680	THRUST PROGRAMS	CALLED 39		
INSTALL	FC-2580	P21 GRD TRACK DET	CALLED 3		
INSTALL	FC-2610	MEASUREMENT INCORP	CALLED 7		
INTEGREV	FC-2580	P21 GRD TRACK DET	CALLED 4		
INTEGRV	FC-2290	INTEG INITIAL	ENTRY 8		
INTEGRV	FC-2550	P20 RENDEZVOUS NAV	CALLED 4,5,21,22		
INTEGRV	FC-2580	P21 GRD TRACK DET	CALLED 4		
INTEGRV	FC-2590	P22 ORBITAL NAV	CALLED 12		
INTEGRV	FC-2600	CISLUNAR MID NAV	CALLED 15		
INTEGRVS	FC-2290	INTEG INITIAL	ENTRY 8		
INTEGRVS	FC-2325	RENDEZ PAR DISPLAY	CALLED 9		
INTEGRVS	FC-2630	TPI TARGETTING	CALLED 15		
INTEGRVS	FC-2642	RETURN TO EARTH	CALLED 44		

INTEGRV2	FC-2290	INTEG INITIAL	ENTRY 8		
INTEGRV2	FC-2300	ORB INTEGRATION	CALLED 35		
INTFLAG	FC-2290	INTEG INITIAL	S-11	C-13	T-10
INTGRATE	FC-2300	ORB INTEGRATION	ENTRY 8		
INTGRVS	FC-2670	TARGET DELTA V PROG	CALLED 3		
INTINT	FC-2626	P32, P72 - CSI	CALLED 3,15,16		
INTINT	FC-2627	P33, P73 - CDH	CALLED 2		
INTINT	FC-2630	TPI TARGETTING	ENTRY 14		
INTINT2C	FC-2626	P32, P72 - CSI	ENTRY 15		
INTINT3P	FC-2627	P33, P73 - CDH	ENTRY 2		
INTRPVP	FC-2644	P38-P78; P39-P79	ENTRY 12		
INTSTALL	FC-2020	FRESH START	CALLED 35		
INTSTALL	FC-2290	INTEG INITIAL	ENTRY 10		
INTSTALL	FC-2325	RENDEZ PAR DISPLAY	CALLED 8,9,10		
INTSTALL	FC-2550	P20 RENDEZVOUS NAV	CALLED 7,9		
INTSTALL	FC-2590	P22 ORBITAL NAV	CALLED 10,18		
INTSTALL	FC-2600	CISLUNAR MID NAV	CALLED 14		
INTSTALL	FC-2605	NAV EXTENDED VERBS	CALLED 3		
INTSTALL	FC-2642	RETURN TO EARTH	CALLED 42,43		
INTSTALL	FC-2650	ORB PARAM DISPLAY	CALLED 13		
INTSTALL	FC-2670	TARGET DELTA V PROG	CALLED 2,3		
INTWAKE	FC-2290	INTEG INITIAL	ENTRY 12		
INTWAKE	FC-2300	ORB INTEGRATION	CALLED 40		
INTWAKE	FC-2320	TFFCONICS	CALLED 14		
INTWAKE	FC-2605	NAV EXTENDED VERBS	CALLED 4		
INTWAKE	FC-2610	MEASUREMENT INCORP	CALLED 12		
INTWAKE0	FC-2290	INTEG INITIAL	ENTRY 12		
INTWAKE0	FC-2320	TFFCONICS	CALLED 14		
INTWAKEU	FC-2290	INTEG INITIAL	ENTRY 14		

INTWAKE1	FC-2670	TARGET DELTA V PROG	CALLED 4		
INTYPFLA	FC-2670	TARGET DELTA V PROG		C-2	
INTYPFLG	FC-2290	INTEG INITIAL	S-7	C-3,6,20	T-8
INTYPFLG	FC-2325	RENDEZ PAR DISPLAY	S-8,9	C-8,9	
INTYPFLG	FC-2550	P20 RENDEZVOUS NAV		C-7	
INTYPFLG	FC-2580	P21 GRD TRACK DET		C-4	
INTYPFLG	FC-2590	P22 ORBITAL NAV		C-10,18	
INTYPFLG	FC-2600	CISLUNAR MID NAV		C-14	
INTYPFLG	FC-2630	TPI TARGETTING	S-14	C-14	
INTYPFLG	FC-2642	RETURN TO EARTH	S-42	C-42,43	
ISWCALL	FC-2080	INT BNK COMMUN	ENTRY 4		
ISWRETRN	FC-2080	INT BNK COMMUN	ENTRY 4		
ITERATOR	FC-2310	CONIC SUBROUTINES	ENTRY 36		
ITSWICH	FC-2545	TPI SEARCH PROG	S-10	C-7	T-10
ITSWICH	FC-2627	P33, P73 - CDH	S-4		
ITSWICH	FC-2630	TPI TARGETTING	S-3	C-3,4	T-4,7
ITURNOM	FC-2200	T4RUPT	ENTRY 29		
JETSLECT	FC-2380	RCS DAP INIT	CALLED 2		
JETSLECT	FC-2390	RCS DAP PHASE 2	CALLED 10		
JETSLECT	FC-2400	RCS DAP JET SELECT	ENTRY 1		
JETSLECT	FC-2460	ROLL AUTOPILOT	CALLED 2		
JOBSLEEP	FC-2290	INTEG INITIAL	CALLED 10		
JOBWAKE	FC-2290	INTEG INITIAL	CALLED 13		
JOBWAKE	FC-2670	TARGET DELTA V PROG	CALLED 10		
JSWITCH	FC-2300	ORB INTEGRATION	S-33	C-8	T-8,27
KALCMAN3	FC-2340	ATTITUDE MANEUVER	CALLED 4		
KEPLERN	FC-2310	CONIC SUBROUTINES	ENTRY 4		
KEPLERN	FC-2300	ORB INTEGRATION	CALLED 31		
KEPPREP	FC-2300	ORB INTEGRATION	ENTRY 29		

KEPPREP	FC-2290	INTEG INITIAL	CALLED 9		
KEYCOM	FC-2150	KEYRUPT AND UPRUPT	ENTRY 4		
KEYCOM	FC-2240	SXTMARK	CALLED 4		
KEYRUPT1	FC-2150	KEYRUPT AND UPRUPT	ENTRY 3		
KFLAG	FC-2545	TPI SEARCH PROG	S-4,5	C-4,5	T-5,6,7,10,11
KLEENEX	FC-2240	SXTMARK	CALLED 8		
KLEENEX	FC-2550	P20 RENDEZVOUS NAV	CALLED 18		
KLEENEX	FC-2730	R52, R53, R53	CALLED 5		
KNOWNFLG	FC-2590	P22 ORBITAL NAV	S-6	C-6	T-7,13
LALOTORV	FC-2320	TFFCONICS	CALLED 14		
LALOTORV	FC-2540	EARTH ORBIT INSERT	CALLED		
LALOTORV	FC-2590	P22 ORBITAL NAV	CALLED 23		
LALOTORV	FC-2600	CISLUNAR MID NAV	CALLED 16		
LALOTORV	FC-2720	IMU REALIGN PROG	CALLED 8		
LALOTORV	FC-2730	R52, R53, R53	CALLED 8		
LAMBERT	FC-2310	CONIC SUBROUTINES	ENTRY 14		
LAMENTER	FC-2310	CONIC SUBROUTINES	ENTRY 35		
LASTBIAS	FC-2683	SERVICER	CALLED 3		
LATAZCHK	FC-2530	PRELAUNCH INIT	ENTRY 47		
LAT-LONG	FC-2580	P21 GRD TRACK DET	CALLED 5		
LAT-LONG	FC-2590	P22 ORBITAL NAV	CALLED 7,20		
LAT-LONG	FC-2595	LUNAR LAND SELECT	CALLED 5,7,10		
LAT-LONG	FC-2642	RETURN TO EARTH	CALLED 33		
LAT-LONG	FC-2720	IMU REALIGN PROG	CALLED 7		
LAT-LONG	FC-2760	ENTRY PROGRAMS	CALLED 9		
LEMCONIC	FC-2190	PINBALL	CALLED 4		
LEMCONIC	FC-2361	V89 (R63)	CALLED 4		
LEMCONIC	FC-2545	TPI SEARCH PROG	CALLED 3,8		
LEMCONIC	FC-2730	R52, R53, R53	CALLED 8		

LEMPREC	FC-2290	INTEG INITIAL	ENTRY 6		
LEMPREC	FC-2325	RENDEZ PAR DISPLAY	CALLED 7,10		
LEMSTORE	FC-2545	TPI SEARCH PROG	CALLED 3		
LETFLGON	FC-2530	PRELAUNCH INIT	ENTRY 33		
LINUS	FC-2340	ATTITUDE MANEUVER	CALLED 8		
LINVEL	FC-2300	ORB INTEGRATION	CALLED 44		
LISTINGO	FC-2550	P20 RENDEZVOUS NAV	ENTRY 1		
LISTINGO	FC-2580	P21 GRD TRACK DET	ENTRY 1		
LISTINGO	FC-2605	NAV EXTENDED VERBS	ENTRY 1		
LISTINGO	FC-2760	ENTRY PROGRAMS	ENTRY 1		
LITTLSUB	FC-2530	PRELAUNCH INIT	ENTRY 46		
LLASRD	FC-2720	IMU REALIGN PROG	CALLED 7		
LLASRDA	FC-2720	IMU REALIGN PROG	CALLED 8		
LMOONFLG	FC-2290	INTEG INITIAL	S-5	C-5	T-5
LMOONFLG	FC-2550	P20 RENDEZVOUS NAV			T-35
LMPREC	FC-2644	P38-P78; P39-P79	CALLED 12		
LOADCOEF	FC-2430	TVC ROUTINES	ENTRY 22		
LOADTIME	FC-2100	SINGLE PREC SUBROUTS	ENTRY 2		
LOADTIME	FC-2190	PINBALL	CALLED 3		
LOADTIME	FC-2290	INTEG INITIAL	CALLED 3,19		
LOADTIME	FC-2300	ORB INTEGRATION	CALLED 36		
LOADTIME	FC-2360	-S-BAND ANTENNA	CALLED 3		
LOADTIME	FC-2361	V89 (R63)	CALLED 3		
LOADTIME	FC-2550	P20 RENDEZVOUS NAV	CALLED 3,11,19,20		
LOADTIME	FC-2580	P21 GRD TRACK DET	CALLED 5		
LOADTIME	FC-2590	P22 ORBITAL NAV	CALLED 3,7		
LOADTIME	FC-2595	LUNAR LAND SELECT	CALLED 4		
LOADTIME	FC-2600	CISLUNAR MID NAV	CALLED 7		
LOADTIME	FC-2631	R36 (V90)	CALLED 3		

LOADTIME	FC-2640	TPM TARGETTING	CALLED 1		
LOADTIME	FC-2650	ORB PARAM DISPLAY	CALLED 6		
LOADTIME	FC-2720	IMU REALIGN PROG	CALLED 5,18		
LOADTIME	FC-2730	R52, R53, R53	CALLED 6,9		
LOADTIME	FC-2760	ENTRY PROGRAMS	CALLED 3		
LOCSAM	FC-2710	P51, P53 IMU ORIENT	CALLED 7		
LOCSAM	FC-2720	IMU REALIGN PROG	ENTRY 11		
LODSAMPT	FC-2150	KEYRUPT AND UPRUPT	CALLED 3,5		
LOMAT	FC-2630	TPI TARGETTING	ENTRY 14,15		
LOMAT	FC-2620	P30, P31	CALLED 3		
LONGCALL	FC-2060	WAITLIST	ENTRY 21		
LOWMEMRY	FC-2600	CISLUNAR MID NAV	ENTRY 5		
LSPOS	FC-2300	ORB INTEGRATION	CALLED 11		
LSPOS	FC-2720	IMU REALIGN PROG	CALLED 11		
LUMPOS	FC-2300	ORB INTEGRATION	CALLED 45		
LUNAFLAG	FC-2580	P21 GRD TRACK DET	S-4	C-4	
LUNAFLAG	FC-2590	P22 ORBITAL NAV	S-4,20,22,24	C-4,20,22,24	
LUNAFLAG	FC-2595	LUNAR LAND SELECT	S-4,7		T-10
LUNAFLAG	FC-2600	CISLUNAR MID NAV	S-5	C-5	T-17,18
LUNAFLAG	FC-2642	RETURN TO EARTH		C-32	
LUNAFLAG	FC-2730	R52, R53, R56	S-5		
LUNAFLAG	FC-2760	ENTRY PROGRAMS		C-9	
LUNAFLG	FC-2720	IMU REALIGN PROG	S-7		
LUNPOS	FC-2190	PINBALL	CALLED 3		
LUNPOS	FC-2360	-S-BAND ANTENNA	CALLED 3		
LUNPOS	FC-2600	CISLUNAR MID NAV	CALLED 15		
MAINRTNE	FC-2644	P38-P78; P39-P79	ENTRY 6		
MAKECADR	FC-2080	INT BNK COMMUN	ENTRY 2		
MAKECADR	FC-2340	ATTITUDE MANEUVER	CALLED 2		

MAKECADR	FC-2550	P20 RENDEZVOUS NAV	CALLED 10		
MAKECADR	FC-2670	TARGET DELTA V PROG	CALLED 10		
MAKECADR	FC-2720	IMU REALIGN PROG	CALLED 13		
MAKECADR	FC-2730	R52, R53, R53	CALLED 6		
MARKCONT	FC-2240	SXTMARK	ENTRY 5		
MARKDIF	FC-2240	SXTMARK	ENTRY 9		
MARKDISP	FC-2240	SXTMARK	CALLED 5		
MARKDISP	FC-2242	OPTICS CAL ROUTINE	ENTRY 4		
MARKINDX	FC-2720	IMU REALIGN PROG	S-18		
MARKIT	FC-2240	SXTMARK	ENTRY 9		
MARKRUPT	FC-2240	SXTMARK	ENTRY 4		
MARK2	FC-2240	SXTMARK	ENTRY 6		
MASSPROP	FC-2430	TVC ROUTINES	ENTRY 16		
MASSPROP	FC-2020	FRESH START	CALLED 31		
MASSPROP	FC-2370	DAP INTER-SERV ROUT	CALLED 7		
MASSPROP	FC-2680	THRUST PROGRAMS	CALLED 25		
MATMOVE	FC-2720	IMU REALIGN PROG	ENTRY 27		
MATMOVE	FC-2710	P51, P53 IMU ORIENT	CALLED 6		
MATRXJOB	FC-2540	EARTH ORBIT INSERT	ENTRY 7		
MAXCHK	FC-2620	P30, P31	CALLED 4,8		
MAXDBFLG	FC-2370	DAP INTER-SERV ROUT	S-6	C-6	
MIDAVFLG	FC-2290	INTEG INITIAL	S-20		
MIDAVFLG	FC-2300	ORB INTEGRATION		C-40	T-32
MIDFLAG	FC-2300	ORB INTEGRATION	S-3	C-3	T-6,10,38,41
MIDGIM	FC-2620	P30, P31	CALLED 8		
MIDGIM	FC-2680	THRUST PROGRAMS	CALLED 34,36		
MIDTOAV1	FC-2290	INTEG INITIAL	ENTRY 19		
MIDTOAV1	FC-2680	THRUST PROGRAMS	CALLED 12		
MIDTOAV2	FC-2290	INTEG INITIAL	ENTRY 19		

MIDTOAV2	FC-2700	P47 THRUST MONITOR	CALLED 3		
MIDTOAV2	FC-2760	ENTRY PROGRAMS	CALLED 10		
MID1FLAG	FC-2290	INTEG INITIAL	S-19	C-19	
MID1FLAG	FC-2300	ORB INTEGRATION			T-36
MINIRECT	FC-2300	ORB INTEGRATION	ENTRY 43		
MINIRECT	FC-2290	INTEG INITIAL	CALLED 17		
MINIRECT	FC-2670	TARGET DELTA V PROG	CALLED 4		
MKREJECT	FC-2240	SXTMARK	ENTRY 7		
MKRELEAS	FC-2240	SXTMARK	ENTRY 3		
MKRELEAS	FC-2590	P22 ORBITAL NAV	CALLED 9		
MKRELEAS	FC-2710	P51, P53 IMU ORIENT	CALLED 5		
MKRELEAS	FC-2720	IMU REALIGN PROG	CALLED 19		
MKRELEAS	FC-2730	R52, R53, R53	CALLED 5		
MKRLEES	FC-2550	P20 RENDEZVOUS NAV	CALLED 7		
MKVB51	FC-2240	SXTMARK	ENTRY 8		
MMDSPLAY	FC-2020	FRESH START	CALLED 21		
MOONTHIS	FC-2325	RENDEZ PAR DISPLAY			T-8,9
MOONTHIS	FC-2610	MEASUREMENT INCOR			T-10
MOVEACSM	FC-2610	MEASUREMENT INCORP	CALLED 11		
MOVEALEM	FC-2610	MEASUREMENT INCORP	CALLED 11		
MOVEPCSM	FC-2610	MEASUREMENT INCORP	CALLED 10		
MOVEPLEM	FC-2610	MEASUREMENT INCORP	CALLED 10		
MOONFLAG	FC-2290	INTEG INITIAL	S-5,14,21	C-5,14	T-5,8
MOONFLAG	FC-2300	ORB INTEGRATION	S-44	C-44	T-11,13,15,19 31,40,41,44 45
MOONFLAG	FC-2325	RENDEZ PAR DISPLAY	S-8,9	C-8,9	
MOONFLAG	FC-2580	P21 GRD TRACK DET	S-4	C-3	
MOONFLAG	FC-2630	TPI TARGETTING	S-14	C-14	

MOONFLAG	FC-2642	RETURN TO EARTH		C-43	
MOONFLAG	FC-2670	TARGET DELTA V PROG	S-2	C-2	
MR KLEAN	FC-2020	FRESH START	ENTRY 7		
MR.KLEAN	FC-2140	ALARM AND ABORT	CALLED 6,13		
MXM3	FC-2350	MANEUV CALC & STEER	ENTRY 25		
MXM3	FC-2340	ATTITUDE MANEUVER	CALLED 6,7		
NBDONLY	FC-2060	WAITLIST	CALLED 20		
NBSM	FC-2550	P20 RENDEZVOUS NAV	CALLED 38		
NBSM	FC-2730	R52, R53, R53	CALLED 13		
*NBSM	FC-2325	RENDEZ PAR DISPLAY	CALLED 5		
NEEDFLG	FC-2380	RCS DAP INIT			T-5
NEEDLER	FC-2380	RCS DAP INIT	CALLED 5		
NEEDLER	FC-2430	TVC ROUTINES	CALLED 5,7		
NEEDLER	FC-2460	ROLL AUTOPILOT	CALLED 5		
NEEDLER	FC-2540	EARTH ORBIT INSERT	CALLED 4,16,17,20,21		
NEEDLES3	FC-2370	DAP INTER-SERV ROUT	ENTRY 15		
NEEDLFLG	FC-2680	DAP INTER SERV ROUT	S-12,13	C-12	
NEGP	FC-2310	CONIC SUBROUTINES	ENTRY 21		
NEWIFLG	FC-2290	INTFG INITIAL	S-8		
NEWIFLG	FC-2300	ORB INTEGRATION		C-6	T-6
NEWMODEA	FC-2030	PHASE TABLE MAINT	ENTRY 2		
NEWMODEA	FC-2020	FRESH START	CALLED 42		
NEWMODEX	FC-2030	PHASE TABLE MAINT	ENTRY 2		
NEWMODEX	FC-2540	EARTH ORBIT INSERT	CALLED 4		
NEWMODEX	FC-2760	ENTRY PROGRAMS	CALLED 3,6,7,8		
NEWPHASE	FC-2030	PHASE TABLE MAINT	ENTRY 4		
NEWSTATE	FC-2310	CONIC SUBROUTINES	ENTRY 35		
NEXTCOL	FC-2300	ORB INTEGRATION	ENTRY 35		
NJETSFLG	FC-2680	THRUST PROGRAMS			T-5,17

NJETSFLG	FC-2642	RETURN TO EARTH			T-11
NOACY	FC-2400	RCS DAP JET SELECT	ENTRY 8		
NOATTOFF	FC-2200	T4RUPT	CALLED 34,35		
NOBDZ	FC-2400	RCS DAP JET SELECT	ENTRY 6		
NODDFLAG	FC-2290	INTEG INITIAL	S-3	C-4	
NODDFLAG	FC-2140	ALARM AND ABORT		C-6	
NODOP01	FC-2540	EARTH ORBIT INSERT	S-4		
NOEBANK	FC-2120	AGC SELFCHECK	ENTRY 6		
NORFHOR	FC-2600	CISLUNAR MID NAV	S-6	C-6	T-22
NORMLIZE	FC-2683	SERVICER	ENTRY 5		
NORMLIZE	FC-2540	EARTH ORBIT INSERT	CALLED 9		
NORMSW	FC-2310	CONIC SUBROUTINES		C-33	T-34
NORMSW	FC-2620	P30, P31		C-7	
NORMSW	FC-2642	RETURN TO EARTH		C-14	
NORMSW	FC-2680	THRUST PROGRAMS			T-38
NORMSW	FC-2682	STEERING			T-14
NORMUNIT	FC-2100	SINGLE PREC SUBROUTS	ENTRY 15		
NORMUNX1	FC-2100	SINGLE PREC SUBROUTS	ENTRY 15		
NO2Y	FC-2400	RCS DAP JET SELECT	ENTRY 10		
N22ORN17	FC-2370	DAP INTER-SERV ROUT	S-12	C-13	
N22ORN17	FC-2380	RCS DAP INIT			T-5
OPTMODES	FC-2070	SERVICE ROUTINES	S-13		
OPTMON	FC-2200	T4RUPT	ENTRY 11		
OPTNSW	FC-2644	P38-P78; P39-P79	S-4	C-4	T-5
OPTSTALL	FC-2730	R52, R53, R53	CALLED 11		
OPTTEST	FC-2200	T4RUPT	ENTRY 6		
ORBWFLAG	FC-2290	INTEG INITIAL		C-14	T-4,16
ORBWFLAG	FC-2300	ORB INTEGRATION		C-37	
ORBWFLAG	FC-2550	P20 RENDEZVOUS NAV		C-22	

ORBWFLAG	FC-2590	P22 ORBITAL NAV		C-39	T-11,18
ORBWFLAG	FC-2600	CISLUNAR MID NAV	S-15		T-14,15
ORBWFLAG	FC-2605	NAV EXTENDED VERBS		C-5,7	
ORDERSW	FC-2310	CONIC SUBROUTINES			T-36,37
ORIGCHNG	FC-2300	ORB INTEGRATION	ENTRY 44		
OTHPREC	FC-2631	R36 (V90)	CALLED 4		
OTHPREC	FC-2650	ORB PARAM DISPLAY	CALLED 7		
OVERFFIX	FC-2530	PRELAUNCH INIT	ENTRY 36		
PARAM	FC-2310	CONIC SUBROUTINES	ENTRY 33		
PARAM	FC-2642	RETURN TO EARTH	CALLED 35		
PASSIVF	FC-2626	P32, P72 - CSI	CALLED 3		
PASSIVE	FC-2627	P33, P73 - CDH	CALLED 2		
PCOPY	FC-2430	TVC ROUTINES	CALLED 12		
PCOPY	FC-2440	TVC DAP	ENTRY 8		
PDSPFLAG	FC-2340	ATTITUDE MANEUVER	S-8		T-4,8
PDSPFLAG	FC-2550	P20 RENDEZVOUS NAV	S-10	C-10	T-34
PERIAPO	FC-2545	TPI SEARCH PROG	CALLED 9		
PERIAPO	FC-2626	P32, P72 - CSI	CALLED 13		
PERIAPOI	FC-2620	P30, P31	CALLED 4,8		
PERIAPO1	FC-2626	P32, P72 - CSI	CALLED 16		
PERIAPO1	FC-2630	TPI TARGETTING	CALLED 5		
PERIAPO1	FC-2644	P38-P78; P39-P79	CALLED 7		
PFAILOK	FC-2200	T4RUPT	CALLED 37		
PFRATFLG	FC-2680	THRUST PROGRAMS	S-6		
PFRATFLG	FC-2720	IMU REALIGN PROG		C-4,20	
PHASCHNG	FC-2030	PHASE TABLE MAINT	ENTRY 5		
PICAPAR	FC-2720	IMU REALIGN PROG	ENTRY 13		
PINBRNCH	FC-2370	DAP INTER-SERV ROUT	CALLED 2.5		
PINBRNCH	FC-2605	NAV EXTENDED VERBS	CALLED 2,6,7		

PIPACHK	FC-2530	PRELAUNCH INIT	ENTRY 6		
PIPASR	FC-2683	SERVICER	ENTRY 9		
PIPATASK	FC-2530	PRELAUNCH INIT	ENTRY 7		
PIPFAIL	FC-2200	T4RUPT	ENTRY 41		
PIPFREE	FC-2683	SERVICER	CALLED 19		
PIPJOBB	FC-2530	PRELAUNCH INIT	ENTRY 8		
PITCHDAP	FC-2440	TVC DAP	ENTRY 2		
PITCHDAP	FC-2430	TVC ROUTINES	CALLED 6		
PITCHTIM	FC-2400	RCS DAP JET SELECT	ENTRY 11		
PLANET	FC-2710	P51, P53 IMU ORIENT	ENTRY 7		
PLANET	FC-2720	IMU REALIGN PROG	CALLED 18,19		
POINTAXS	FC-2600	CISLUNAR MID NAV	ENTRY 13		
POLY	FC-2310	CONIC SUBROUTINES	CALLED 25,28		
POLY	FC-2642	RETURN TO EARTH	CALLED 4,6,11		
POODOO	FC-2140	ALARM AND ABORT	ENTRY 3		
POODOO	FC-2060	WAITLIST	CALLED 9		
POODOO	FC-2300	ORB INTEGRATION	CALLED 22		
POOKLEAN	FC-2020	FRESH START	ENTRY 7		
POSN17C	FC-2530	PRELAUNCH INIT	ENTRY 36		
POSTBURN	FC-2630	TPI TARGETTING	ENTRY 29		
POSTJUMP	FC-2080	INT BNK COMMUN	ENTRY 2		
POST41	FC-2630	TPI TARGETTING	ENTRY 30		
POST41	FC-2681	CLOKTASK-CLOCKJOB	CALLED 5		
POWRSERS	FC-2540	EARTH ORBIT INSERT	CALLED 11		
PRECIFLG	FC-2290	INTEG INITIAL	S-4,6,8	C-4	
PRECIFLG	FC-2300	ORB INTEGRATION		C-40	T-5
PRECOMP	FC-2440	TVC DAP	ENTRY 7		
PREC/TT	FC-2644	P38-P78; P39-P79	ENTRY 11		
PRECSET	FC-2626	P32, P72 - CSI	CALLED 9		

PRECSET	FC-2630	TPI TARGETTING	CALLED	4		
PRECSET	FC-2640	TPM TARGETTING	CALLED	1		
PRECSET	FC-2644	P38-P78: P39-P79	CALLED	10,11		
PREC100	FC-2642	RETURN TO EARTH	ENTRY	34		
PREREAD	FC-2680	THRUST PROGRAMS	CALLED	15		
PREREAD	FC-2683	SERVICER	ENTRY	3,4,11,15		
PREREAD	FC-2700	P47 THRUST MONITOR	CALLED	4		
PREREAD	FC-2760	ENTRY PROGRAMS	CALLED	11		
PREREAD1	FC-2683	SERVICER	ENTRY	3		
PREREAD1	FC-2540	EARTH ORBIT INSERT	CALLED	4		
PRESWTCH	FC-2430	TVC ROUTINES	ENTRY	20		
PREVGAM	FC-2320	TFFCONICS	ENTRY	11		
PREVGAM	FC-2760	ENTRY PROGRAMS	CALLED	14,15		
PRE40.6	FC-2680	THRUST PROGRAMS	ENTRY	44		
PRE40.6	FC-2681	CLOKTASK-CLOCKJOB	CALLED	13		
PRETRKAT	FC-2190	EXTENDED VERBS	S-3		C-3	T-5
PRETRKAT	FC-2361	V89 (R63)	S-3		C-3	T-5
PRETRKAT	FC-2550	P20 RENDEZVOUS NAV	S-3			
PRIOCHNG	FC-2340	ATTITUDE MANEUVER	CALLED	8		
PRIOCHNG	FC-2370	DAP INTER-SERV ROUT	CALLED	5		
PRIOCHNG	FC-2550	P20 RENDEZVOUS NAV	CALLED	6,19,31		
PRIOCHNG	FC-2650	ORB PARAM DISPLAY	CALLED	2		
PRIOCHNG	FC-2700	P47 THRUST MONITOR	CALLED	5		
PRIOLARM	FC-2140	ALARM AND ABORT	ENTRY	3		
PROCKEY	FC-2200	T4RUPT	CALLED	5		
PROG 21	FC-2580	P21 GRD TRACK DET	ENTRY	2		
PROG20	FC-2550	P20 RENDEZVOUS NAV	ENTRY	3		
PROG22	FC-2590	P22 ORBITAL NAV	ENTRY	2		
PROG52	FC-2720	IMU REALIGN PROG	ENTRY	1		

PROUT	FC-2530	PRELAUNCH INIT	ENTRY 37		
PROUT	FC-2540	EARTH ORBIT INSERT	CALLED 5		
PTHPREC	FC-2670	TARGET DELTA V PROG	CALLED 2		
PTOACSM	FC-2290	INTEG INITIAL	ENTRY 5		
PTOALEM	FC-2290	INTEG INITIAL	ENTRY 5		
PULSEIMU	FC-2100	SINGLE PREC SUBROUTS	ENTRY 12		
P11	FC-2540	EARTH ORBIT INSERT	ENTRY 3		
P17	FC-2545	TPI SEARCH PROG	ENTRY 3		
P17.1	FC-2545	TPI SEARCH PROG	ENTRY 3		
P17.2	FC-2545	TPI SEARCH PROG	ENTRY 5		
P17.3	FC-2545	TPI SEARCH PROG	ENTRY 12		
P20FLGON	FC-2545	TPI SEARCH PROG	CALLED 3		
P20FLGON	FC-2627	P33, P73 - CDH	CALLED 1		
P20FLGON	FC-2630	TPI TARGETTING	CALLED 2		
P20FLGON	FC-2640	TPM TARGETTING	CALLED 6		
P20FLGON	FC-2644	P38-P78; P39-P79	CALLED 3,9		
P21FLAG	FC-2580	P21 GRD TRACK DET	S-4		T-3
P22MKFLG	FC-2590	P22 ORBITAL NAV	S-9	C-4	
P22SUBRB	FC-2600	CISLUNAR MID NAV	CALLED 6		
P23	FC-2600	CISLUNAR MID NAV	ENTRY 3		
P3XORP7X	FC-2626	P32, P72 - CSI	ENTRY 23		
P30	FC-2620	P30, P31	ENTRY 2		
P30/P31	FC-2620	P30, P31	ENTRY 2		
P31	FC-2620	P30, P31	ENTRY 7		
P32	FC-2626	P32, P72 - CSI	ENTRY 2		
P33	FC-2627	P33, P73 - CDH	ENTRY 1		
P34	FC-2630	TPI TARGETTING	ENTRY 2		
P35	FC-2640	TPM TARGETTING	ENTRY 1		
P37	FC-2642	RETURN TO EARTH	ENTRY 3		

P38	FC-2644	P38-P78; P39-P79	ENTRY	3		
P39	FC-2644	P38-P78; P39-P79	ENTRY	9		
P39/79SW	FC-2644	P38-P78; P39-P79	S-9			T-6,8
P40CNV85	FC-2680	THRUST PROGRAMS	CALLED	11		
P40CNV85	FC-2681	CLOKTASK-CLOCKJOB	CALLED	4		
P40CSM	FC-2630	TPI TARGETTING	ENTRY	4		
P40RCS	FC-2630	TPI TARGETTING	ENTRY	29		
P40RCS	FC-2681	CLOKTASK-CLOCKJOB	CALLED	7		
P41CSM	FC-2630	TPI TARGETTING	ENTRY	5		
P47BODY	FC-2700	P47 THRUST MONITOR	ENTRY	5		
P47CSM	FC-2700	P47 THRUST MONITOR	ENTRY	3		
P51	FC-2710	P51, P53 IMU ORIENT	ENTRY	2		
P52LS	FC-2720	IMU REALIGN PROG	ENTRY	7		
P72	FC-2626	P32, P72 - CSI	ENTRY	2		
P73	FC-2627	P33, P73 - CDH	ENTRY	1		
P74	FC-2630	TPI TARGETTING	ENTRY	2		
P75	FC-2640	TPM TARGETTING	ENTRY	1		
P76SUB1	FC-2670	TARGET DELTA V PROG	ENTRY	3		
P77	FC-2545	TPI SEARCH PROG	ENTRY	3		
P78	FC-2644	P38-P78; P39-P79	ENTRY	3		
P79	FC-2644	P38-P78; P39-P79	ENTRY	9		
QUICTRIG	FC-2681	CLOKTASK-CLOCKJOB	CALLED	4		
QUIKDSP	FC-2200	T4RUPT	ENTRY	46		
QUIKREAD	FC-2683	SERVICER	ENTRY	12		
QUITFLAG	FC-2290	INTEG INITIAL			C-3	T-3
QUITFLAG	FC-2300	ORB INTEGRATION				T-3
RADSTALL	FC-2550	P20 RENDEZVOUS NAV	CALLED	32		
RANGERD	FC-2550	P20 RENDEZVOUS NAV	ENTRY	32		
RATELIM	FC-2460	ROLL AUTOPILOT	ENTRY	4		

RCSATT	FC-2370 DAP INTER-SERV ROUT	CALLED 3		
RCSATT	FC-2380 RCS DAP INIT	ENTRY 2		
RCSATT	FC-2390 RCS DAP PHASE 2	CALLED 1,2		
RCSATT	FC-2400 RCS DAP JET SHEET	CALLED 16		
RCSDAPON	FC-2370 DAP INTER-SERV ROUT	ENTRY 3		
RCSDAPON	FC-2020 FRESH START	CALLED 31		
RCSDAPON	FC-2380 RCS DAP INIT	CALLED 2		
RCSDAPON	FC-2460 ROLL AUTDPILOT	CALLED 2		
RCSDAPON	FC-2680 THRUST PRDGRAMS	CALLED 25		
RCSDAPON	FC-2681 CLDKTASK-CLOCKJOB	CALLED 9,13		
RCSDAPUP	FC-2370 DAP INTER-SERV ROUT	ENTRY 3		
RCSFLAGS	FC-2350 MANEUV CALC & STEER	S-10	C-26	
RCSFLAGS	FC-2370 DAP INTER-SERV ROUT	S-3,15,14	C-14	T-14
RCSFLAGS	FC-2380 RCS DAP INIT	S-2,3,8,5	C-8,5	T-3,5
RCSFLAGS	FC-2390 RCS DAP PHASE 2	S-1	C-1,7	T-1,2,3,4,7
RCSFLAGS	FC-2400 RCS DAP JET SELECT	S-17	C-16	T-17
RCSFLAGS	FC-2430 TVC ROUTINES	S-5		
RCSFLAGS	FC-2540 EARTH ORBIT INSERT	S-4,17,20		
RCSUP	FC-2380 RCS DAP INIT	ENTRY 2		
RDCDUS	FC-2720 IMU REALIGN PROG	ENTRY 27		
READACCS	FC-2683 SERVICER	ENTRY 6		
READCDUK	FC-2350 MANEUV CALC & STEER	ENTRY 24		
READCDUK	FC-2340 ATTITUDE MANEUVER	CALLED 5		
READPIPS	FC-2100 SINGLE PREC SUBRDUTS	ENTRY 4		
RECT.1	FC-2600 CISLUNAR MID NAV	ENTRY 17		
RECTIFY	FC-2300 ORB INTEGRATION	ENTRY 43		
RECTIFY	FC-2290 INTEG INITIAL	CALLED 8,9		
RECTIFY	FC-2610 MEASUREMENT INCORP	CALLED 11		
RECTIFY+	FC-2290 INTEG INITIAL	CALLED 14		

RECTOUT	FC-2300	ORB INTEGRATION	ENTRY 40		
RECTOUT	FC-2290	INTEG INITIAL	CALLED 9		
REDO	FC-2530	PRELAUNCH INIT	ENTRY 31		
REDORCS	FC-2380	RCS DAP INIT	ENTRY 2		
REDOSAT	FC-2540	EARTH ORBIT INSERT	ENTRY 20		
REDOSAT	FC-2370	DAP INTER-SERV ROUT	CALLED 4		
REDOTVC	FC-2430	TVC ROUTINES	ENTRY 12		
REEFLG	FC-2720	IMU REALIGN PROG			T-20
REFAZE10	FC-2760	ENTRY PROGRAMS	CALLED 7		
REFSMFLG	FC-2200	T4RUPT		C-32,33	
REFSMFLG	FC-2540	EARTH ORBIT INSERT	S-8		
REFSMFLG	FC-2550	P20 RENDEZVOUS NAV			T-6,31
REFSMFLG	FC-2600	CISLUNAR MID NAV			T-4
REFSMFLG	FC-2620	P30, P31			T-5,9
REFSMFLG	FC-2626	P32, P72 - CSI			T-6
REFSMFLG	FC-2710	P51, P53 IMU ORIENT	S-6	C-6	
REFSMFLG	FC-2720	IMU REALIGN PROG	S-4,5	C-3	
REINTFLA	FC-2670	TARGET DELTA V PROG	S-3		
REINTFLG	FC-2140	ALARM AND ABORT		C-6	
REINTFLG	FC-2290	INTEG INITIAL		C-13	T-10,12
REINTFLG	FC-2300	ORB INTEGRATION	S-33,38		
REINTFLG	FC-2610	MEASUREMENT INCOR	S-7		
RELDSP	FC-2020	FRESH START	CALLED 32,37,42		
RENDWFLG	FC-2290	INTEG INITIAL		C-14	T-4,16
RENDWFLG	FC-2300	ORB INTEGRATION		C-37	
RENDWFLG	FC-2550	P20 RENDEZVOUS NAV	S-23		T-4,21,23
RENDWFLG	FC-2590	P22 ORBITAL NAV		C-3,11	
RENDWFLG	FC-2600	CISLUNAR MID NAV		C-6	
RENDWFLG	FC-2605	NAV EXTENDED VERBS		C-5,7	

REPLACER	FC-2400 RCS DAP JET SELECT	ENTRY 19			
REPLACEY	FC-2400 RCS DAP JET SELECT	ENTRY 19			
REP11	FC-2540 EARTH ORBIT INSERT	ENTRY 6			
REREADAC	FC-2683 SERVICER	ENTRY 10			
RESETX2	FC-2310 CONIC SUBROUTINES	ENTRY 30			
RESTARTS	FC-2020 FRESH START	ENTRY 43			
RETROFLG	FC-2642 RETURN TO EARTH	S-16	C-16	T-31	
RLIMTEST	FC-2440 TVC DAP	ENTRY 15			
RNDREFDR	FC-2200 T4RUPT	CALLED 31,32			
RNDVZFLG	FC-2200 T4RUPT		C-33		
RNDVZFLG	FC-2550 P20 RENDEZVOUS NAV	S-3	C-8	T-8,17	
RNDVZFLG	FC-2590 P22 ORBITAL NAV		C-3		
RNDVZFLG	FC-2600 CISLUNAR MID NAV		C-3		
RNDVZFLG	FC-2683 SERVICER			T-20	
ROLLDAP	FC-2460 ROLL AUTOPILOT	ENTRY 1			
ROLLTIME	FC-2400 RCS DAP JET SELECT	ENTRY 9			
RODDAP	FC-2430 TVC ROUTINES	CALLED 7			
ROTA	FC-2730 R52, R53, R56	ENTRY 10			
ROTATE	FC-2626 P32, P72 - CSI	ENTRY 9			
ROUTINER	FC-2070 SERVICE ROUTINES	ENTRY 12			
RPQFLAG	FC-2290 INTEG INITIAL	S-8			
RPQFLAG	FC-2300 ORB INTEGRATION	S-22		T-44	
RP-TO-R	FC-2290 INTEG INITIAL	CALLED 21			
RP-TO-R	FC-2300 ORB INTEGRATION	CALLED 20			
RP-TO-R	FC-2590 P22 ORBITAL NAV	CALLED 7,14			
RP-TO-R	FC-2595 LUNAR LAND SELECT	CALLED 10,11			
RP-TO-R	FC-2720 IMU REALIGN PROG	CALLED 7			
RP-TO-R	FC-2730 R52, R53, R53	CALLED 9			
RTEVN	FC-2642 RETURN TO EARTH	ENTRY 28			

RVCON	FC-2290 INTEG INITIAL	ENTRY 9		
RVSW	FC-2310 CONIC SUBROUTINES			T-22
RVSW	FC-2545 TPI SEARCH PROG	S-6		
RVSW	FC-2595 LUNAR LAND SELECT	S-13		
RVSW	FC-2626 P32, P72 - CSI	S-13,14		
RVSW	FC-2627 P33, P73 - CDH		C-8	
RVSW	FC-2630 TPI TARGETTING	S-4		
RVSW	FC-2642 RETURN TO EARTH	S-37	C-13,27	
R-TO-RP	FC-2300 ORB INTEGRATION	CALLED 15		
R-TO-RP	FC-2590 P22 ORBITAL NAV	CALLED 13,21		
R02BOTH	FC-2190 PINBALL	CALLED 2,3		
R02BOTH	FC-2360 -S-BAND ANTENNA	CALLED 3		
R02BOTH	FC-2361 V89 (R63)	CALLED 2		
R02BOTH	FC-2550 P20 RENDEZVOUS NAV	CALLED 3		
R02BOTH	FC-2590 P22 ORBITAL NAV	CALLED 3		
R02BOTH	FC-2680 THRUST PROGRAMS	CALLED 6		
R02BOTH	FC-2700 P47 THRUST MONITOR	CALLED 3		
R02BOTH	FC-2720 IMU REALIGN PROG	CALLED 1		
R02BOTH	FC-2760 ENTRY PROGRAMS	CALLED 10		
R21MARK	FC-2550 P20 RENDEZVOUS NAV	S-18	C-18	
R21MARK	FC-2780 ENT DIG AUTOPILOT			T-7
R22	FC-2550 P20 RENDEZVOUS NAV	ENTRY 19		
R23CSM	FC-2550 P20 RENDEZVOUS NAV	ENTRY 18		
R23FLG	FC-2550 P20 RENDEZVOUS NAV	S-17	C-17	T-17,18,25
R23.55	FC-2600 CISLUNAR MID NAV	ENTRY 10		
R31FLAG	FC-2325 RENDEZ PAR DISPLAY	S-2	C-2	T-3,4
R36	FC-2631 R36 (V90)	ENTRY 3		
R51	FC-2720 IMU REALIGN PROG	ENTRY 18		
R52	FC-2730 R52, R53, R56	ENTRY 2		

R52	FC-2550	P20 RENDEZVOUS NAV	CALLED 7		
R52	FC-2590	P22 ORBITAL NAV	CALLED 4		
R52	FC-2600	CISLUNAR MID NAV	CALLED 8		
R52	FC-2720	IMU REALIGN PROG	CALLED 19		
R53	FC-2730	R52, R53, R56	ENTRY 11		
R53	FC-2600	CISLUNAR MID NAV	CALLED 4		
R53	FC-2710	P51, P53 IMU ORIENT	CALLED 4		
R53FLAG	FC-2730	R52, R53, R56	S-11		T-3
R55	FC-2720	IMU REALIGN PROG	ENTRY 26		
R56	FC-2730	R52, R53, R56	ENTRY 14		
R56	FC-2710	P51, P53 IMU ORIENT	CALLED 4		
R56	FC-2720	IMU REALIGN PROG	CALLED 19		
R57	FC-2242	OPTICS CAL ROUTINE	ENTRY 1		
R57	FC-2600	CISLUNAR MID NAV	CALLED 4,8		
R57FLAG	FC-2600	CISLUNAR MID NAV	S-8	C-3,9	T-8
R60CSM	FC-2340	ATTITUDE MANEUVER	ENTRY 2		
R60CSM	FC-2190	PINBALL	CALLED 3		
R60CSM	FC-2330	CREW DEF MANEUVER	CALLED 3		
R60CSM	FC-2361	V89 (R63)	CALLED 3		
R60CSM	FC-2550	P20 RENDEZVOUS NAV	CALLED 10		
R60CSM	FC-2600	CISLUNAR MID NAV	CALLED 8		
R60CSM	FC-2680	THRUST PROGRAMS	CALLED 8		
R61CSM	FC-2550	P20 RENDEZVOUS NAV	ENTRY 10		
R61CSM	FC-2730	R52, R53, R53	CALLED 4		
R62DISP	FC-2330	CREW DEF MANEUVER	ENTRY 3		
R63	FC-2190	EXTENDED VERBS	ENTRY 4		
R63	FC-2361	V89 (R63)	ENTRY 4		
R63	FC-2550	P20 RENDEZVOUS NAV	CALLED 11		
SATSTICK	FC-2540	EARTH ORBIT INSERT	ENTRY 21		

SATSTKON	FC-2370	DAP INTER-SERV ROUT	ENTRY 4		
SATSTKON	FC-2540	EARTH ORBIT INSERT	ENTRY 19		
SAVECFLG	FC-2600	CISLUNAR MID NAV	S-9	C-4	T-6
SBANDANT	FC-2360	-S-BAND ANTENNA	ENTRY 3		
SCNDSOL	FC-2626	P32, P72 - CSI	ENTRY 21		
SELECTMU	FC-2630	TPI TARGETTING	ENTRY 17		
SELECTMU	FC-2626	P32, P72 - CSI	CALLED 2		
SELECTMU	FC-2627	P33, P73 - CDH	CALLED 1		
SELECTMU	FC-2640	TPM TARGETTING	CALLED 1		
SELECTMU	FC-2644	P38-P78; P39-P79	CALLED 4,9		
SELFCHK	FC-2080	INT BNK COMMUN	ENTRY 3		
SELFCHK	FC-2120	AGC SELFCHECK	ENTRY 2		
SERVEXIT	FC-2683	SERVICER	ENTRY 21		
SERVEXIT	FC-2682	STEERING	CALLED 4,5		
SERVEXIT	FC-2700	P47 THRUST MONITOR	CALLED 7		
SERVICER	FC-2683	SERVICER	ENTRY 13		
SERVNOUT	FC-2760	ENTRY PROGRAMS	CALLED 7		
SETCOARS	FC-2200	T4RUPT	CALLED 43		
SETGWLST	FC-2530	PRELAUNCH INIT	ENTRY 14		
SETINTG	FC-2600	CISLUNAR MID NAV	ENTRY 14		
SETISSW	FC-2200	T4RUPT	ENTRY 30		
SETJTAG	FC-2683	SERVICER	CALLED 7		
SETMAXDB	FC-2370	DAP INTER-SERV ROUT	ENTRY 16		
SETMAXDB	FC-2630	TPI TARGETTING	ENTRY 25		
SETMAXDB	FC-2020	FRESH START	CALLED 25		
SETMINDB	FC-2370	DAP INTER-SERV ROUT	ENTRY 16		
SETMINDB	FC-2630	TPI TARGETTING	ENTRY 7		
SETMINDB	FC-2020	FRESH START	CALLED 25		
SETRE	FC-2590	P22 ORBITAL NAV	CALLED 24		

SETT5	FC-2380	RCS DAP INIT	ENTRY 2		
SETVOARS	FC-2020	FRESH START	CALLED 19		
SET1/PDT	FC-2720	IMU REALIGN PROG	CALLED 23		
SGNAGREE	FC-2100	SINGLE PREC SUBROUTS	ENTRY 5		
SGNAGREE	FC-2300	ORB INTEGRATION	CALLED 4		
SGNAGREE	FC-2631	R36 (V90)	CALLED 6		
SGNAGREE	FC-2710	P51, P53 IMU ORIENT	CALLED 9		
SHOW	FC-2530	PRELAUNCH INIT	ENTRY 25		
SIGNMPAC	FC-2100	SINGLE PREC SUBROUTS	ENTRY 14		
SIGNMPAC	FC-2300	ORB INTEGRATION	CALLED 5		
SIGNMPAC	FC-2320	TFFCONICS	CALLED 9		
SIGNMPAC	FC-2350	MANEUV CALC & STEER	CALLED 7,16,17,18,19,20		
SKIPVHF	FC-2550	P20 RENDEZVOUS NAV		C-32	T-34
SLAPI	FC-2020	FRESH START	ENTRY 2		
SLOPES W	FC-2310	CONIC SUBROUTINES	S-10,14	C-36	T-12,18,36
SLOWFLG	FC-2642	RETURN TO EARTH	S-4	C-4	T-20
SMALLMP	FC-2370	DAP INTER-SERV ROUT	ENTRY 20		
SMCDURES	FC-2550	P20 RENDEZVOUS NAV	CALLED 13		
SMNB	FC-2190	PINBALL	CALLED 4		
SMNB	FC-2360	-S-BAND ANTENNA	CALLED 4		
SMNB	FC-2550	P20 RENDEZVOUS NAV	CALLED 14		
SMNB	FC-2682	STEERING	CALLED 11		
SMNB	FC-2700	P47 THRUST MONITOR	CALLED 8		
SOLNSW	FC-2310	CONIC SUBROUTINES	S-12,19,21,23	C-10,14,24	
SOMEERRR	FC-2530	PRELAUNCH INIT	ENTRY 37		
SOMERR2	FC-2530	PRELAUNCH INIT	ENTRY 37		
SOPTION	FC-2120	AGC SELFCHECK	ENTRY 13		
SPCOS	FC-2110	SINGLE PREC SUBROUTS	ENTRY 2		
SPSIN	FC-2110	SINGLE PREC SUBROUTS	ENTRY 2		

SPSOFF	FC-2630	TPI TARGETTING	ENTRY 27		
SPSOFF	FC-2020	FRESH START	CALLED 30		
SPSOFF	FC-2681	CLOKTASK-CLOCKJOB	CALLED 9,12		
SR30.1	FC-2650	ORB PARAM DISPLAY	ENTRY 15		
SR52.1	FC-2730	R52, R53, R56	ENTRY 6		
STABLISH	FC-2370	DAP INTER-SERV ROUT	ENTRY 2		
STARIND	FC-2710	P51, P53 IMU ORIENT	S-6	C-4	T-5
STARIND	FC-2720	IMU REALIGN PROG	S-18		T-19,20
SOURCFLG	FC-2550	P20 RENDEZVOUS NAV	S-33	C-20	T-24,26,27 29,30
STARTEN1	FC-2760	ENTRY PROGRAMS	CALLED 2		
STARTSB2	FC-2020	FRESH START	ENTRY 8		
STARTSUB	FC-2020	FRESH START	ENTRY 8		
STARTSW	FC-2020	FRESH START	ENTRY 2		
STATEFLG	FC-2140	ALARM AND ABORT		C-6	
STATEFLG	FC-2290	INTEG INITIAL	S-3	C-3	
STATEFLG	FC-2300	ORB INTEGRATION	S-37	C-3,38	T-38
STATEFLG	FC-2550	P20 RENDEZVOUS NAV	S-7		
STATEFLG	FC-2590	P22 ORBITAL NAV	S-10,18		
STATEFLG	FC-2600	CISLUNAR MID NAV	S-14		
STATINT	FC-2290	INTEG INITIAL	ENTRY 3		
STATINT1	FC-2290	INTEG INITIAL	ENTRY 3		
STEERING	FC-2683	SERVICER	CALLED 15		
STEERSW	FC-2680	THRUST PROGRAMS	S-23		
STEERSW	FC-2681	CLOKTASK- CLOCKJOB	S-10		
STEERSW	FC-2682	STEERING		C-12,13	T-9
STICKCHK	FC-2370	DAP INTER-SERV ROUT	ENTRY 16		
STICKCHK	FC-2540	EARTH ORBIT INSERT	CALLED 21		
STIKFLAG	FC-2370	DAP INTER-SERV ROUT		C-11	

STIKFLAG	FC-2390	RCS DAP PHASE 2	S-2		
STOPRATE	FC-2350	MANEUV CALC & STEER	ENTRY 26		
STOPRATE	FC-2020	FRESH START	CALLED 21,25		
STOPRATE	FC-2550	P20 RENDEZVOUS NAV	CALLED 9		
STRKTST1	FC-2450	STROKE TEST PKG	ENTRY 1		
STROKON	FC-2450	STROKE TEST PKG	ENTRY 1		
STRULLSW	FC-2680	THRUST PROGRAMS	S-21	C-21	T-23
STSHOSUM	FC-2120	AGC SELFCHECK	ENTRY 7		
SUPDACAL	FC-2080	INT BNK COMMUN	ENTRY 3		
SUPDACAL	FC-2120	AGC SELFCHECK	CALLED 9		
SUPERSW	FC-2080	INT BNK COMMUN	ENTRY 2		
SURFFLAG	FC-2290	INTEG INITIAL			T-4,5,18
SURFFLAG	FC-2325	RENDEZ PAR DISPLAY			T-8,9,10
SVDWN1	FC-2290	INTEG INITIAL	CALLED 5		
SVDWN1	FC-2610	MEASUREMENT INCORP	CALLED 11		
SVDWN2	FC-2290	INTEG INITIAL	CALLED 5		
SVDWN2	FC-2610	MEASUREMENT INCORP	CALLED 11		
SWCALL	FC-2080	INT BNK COMMUN	ENTRY 1		
SWICHOVR	FC-2430	TVC ROUTINES	ENTRY 20		
SWICHOVR	FC-2370	DAP INTER-SERV ROUT	CALLED 2		
SWRETURN	FC-2080	INT BNK COMMUN	ENTRY 1		
SWTOVER	FC-2430	TVC ROUTINES	S-20	C-3	
SXTMARK	FC-2730	R52, R53, R53	CALLED 11,14		
SXTNB	FC-2325	RENDEZ PAR DISPLAY	CALLED 6		
SXTNB	FC-2550	P20 RENDEZVOUS NAV	CALLED 38		
SXTNB	FC-2730	R52, R53, R53	CALLED 13		
SXTSM	FC-2730	R52, R53, R56	ENTRY 13		
SXTSM	FC-2710	P51, P53 IMU ORIENT	CALLED 5		
SXTSM	FC-2720	IMU REALIGN PROG	CALLED 19		

SYSTEST	FC-2530	PRELAUNCH INIT	ENTRY 31		
S11.1	FC-2540	EARTH ORBIT INSERT	ENTRY 18		
S11.1	FC-2700	P47 THRUST MONITOR	CALLED 6		
S17.1	FC-2545	TPI SEARCH PROG	ENTRY 3		
S17.2	FC-2545	TPI SEARCH PROG	ENTRY 6		
S22.1	FC-2590	P22 ORBITAL NAV	ENTRY 9		
S30.1	FC-2620	P30, P31	ENTRY 2		
S31.1	FC-2620	P30, P31	ENTRY 7		
S32.1F1	FC-2626	P32, P72 - CSI		C-11,21	T-12
S32.1F2	FC-2626	P32, P72 - CSI	S-11,21	C-18	T-18
S32.1F3A	FC-2626	P32, P72 - CSI	S-18,19	C-11,21	T-12,18,21
S32/33.X	FC-2626	P32, P72 - CSI	ENTRY 8		
S32/33.1	FC-2626	P32, P72 - CSI	ENTRY 5		
S32/33.1	FC-2627	P33, P73 - CDH	CALLED 4		
S32,1F3B	FC-2626	P32, P72 - CSI	S-11,19	C-18,21	T-12,18,21
S33/34.1	FC-2630	TPI TARGETTING	ENTRY 6		
S33/34.1	FC-2627	P33, P73 - CDH	CALLED 3		
S33-34.1	FC-2630	TPI TARGETTING	ENTRY 6		
S34/35.1	FC-2630	TPI TARGETTING	ENTRY 6		
S34/35.1	FC-2640	TPM TARGETTING	CALLED 1		
S34/35.1	FC-2644	P38-P78; P39-P79	CALLED 11		
S34/35.2	FC-2630	TPI TARGETTING	ENTRY 11		
S34/35.2	FC-2640	TPM TARGETTING	CALLED 2		
S34/35.3	FC-2630	TPI TARGETTING	ENTRY 13		
S34/35.4	FC-2630	TPI TARGETTING	ENTRY 16		
S34/35.5	FC-2630	TPI TARGETTING	ENTRY 16		
S34/35.5	FC-2640	TPM TARGETTING	CALLED 2		
S3435.25	FC-2630	TPI TARGETTING	ENTRY 11		
S3435.25	FC-2644	P38-P78; P39-P79	CALLED 6,10		

S40.1	FC-2680	THRUST PROGRAMS	ENTRY 32		
S40.13	FC-2630	TPI TARGETTING	ENTRY 17		
S40.13	FC-2681	CLOKTASK-CLOCKJOB	CALLED 14		
S40.14	FC-2370	DAP INTER-SERV ROUT	ENTRY 10		
S40.14	FC-2380	RCS DAP INIT	CALLED 6		
S40.14	FC-2460	ROLL AUTOPILOT	CALLED 6		
S40.15	FC-2430	TVC ROUTINES	CALLED 3,8		
S40.2,3	FC-2680	THRUST PROGRAMS	ENTRY 40		
S40.6	FC-2680	THRUST PROGRAMS	ENTRY 44		
S41.1	FC-2700	P47 THRUST MONITOR	ENTRY 8		
S41.1	FC-2682	STEERING	CALLED 5		
S41.2	FC-2370	DAP INTER-SERV ROUT	ENTRY 8		
S41.2	FC-2380	RCS DAP INIT	CALLED 6		
S41.2	FC-2460	ROLL AUTOPILOT	CALLED 6		
S50	FC-2720	IMU REALIGN PROG	ENTRY 11		
S52.2	FC-2720	IMU REALIGN PROG	ENTRY 9		
S52.3	FC-2720	IMU REALIGN PROG	ENTRY 10		
TAR EREF	FC-2530	PRELAUNCH INIT	ENTRY 45		
TARGDRVE	FC-2530	PRELAUNCH INIT	ENTRY 43		
TARG1FLG	FC-2340	ATTITUDE MANEUVER			T-8
TARG1FLG	FC-2550	P20 RENDEZVOUS NAV	S-6		
TARG1FLG	FC-2590	P22 ORBITAL NAV		C-7	
TARG1FLG	FC-2600	CISLUNAR MID NAV		C-3	
TARG1FLG	FC-2720	IMU REALIGN PROG	S-18		
TARG1FLG	FC-2730	R52, R53, R56			T-3,4,6
TARG2FLG	FC-2590	P22 ORBITAL NAV	S-7		
TARG2FLG	FC-2600	CISLUNAR MID NAV		C-3	
TARG2FLG	FC-2710	P51, P53 IMU ORIENT		C-4	
TARG2FLG	FC-2720	IMU REALIGN PROG	S-18		

TARG2FLG	FC-2730	R52, R53, R56			T-6
TASKOVER	FC-2060	WAITLIST	ENTRY 18		
TERMINFL	FC-2730	R52, R53, R56		C-2,12	T-4
TESTLOOP	FC-2300	ORB INTEGRATION	ENTRY 3		
TESTLOOP	FC-2290	INTEG INITIAL	CALLED 8		
TESTXACT	FC-2190	PINBALL	CALLED 2		
TESTXACT	FC-2325	RENDEZ PAR DISPLAY	CALLED 2		
TESTXACT	FC-2330	CREW DEF MANEUVER	CALLED 2		
TESTXACT	FC-2360	-S-BAND ANTENNA	CALLED 2		
TESTXACT	FC-2361	V89 (R63)	CALLED 2		
TESTXACT	FC-2370	DAP INTER-SERV ROUT	CALLED 5		
TESTXACT	FC-2595	LUNAR LAND SELECT	CALLED 3		
TESTXACT	FC-2605	NAV EXTENDED VERBS	CALLED 2		
TESTXACT	FC-2631	R36 (V90)	CALLED 2		
TESTXACT	FC-2650	ORB PARAM DISPLAY	CALLED 2		
TFFCONIC	FC-2320	TFFCONICS	ENTRY 3		
TFFCONIC	FC-2760	ENTRY PROGRAMS	CALLED 12		
TFFCONMU	FC-2320	TFFCONICS	ENTRY 3		
TFFCONMU	FC-2650	ORB PARAM DISPLAY	CALLED 16		
TFFRP/RA	FC-2320	TFFCONICS	ENTRY 4		
TFFRP/RA	FC-2650	ORB PARAM DISPLAY	CALLED 16		
TFF/TRIG	FC-2320	TFFCONICS	ENTRY 11		
TFF/TRIG	FC-2760	ENTRY PROGRAMS	CALLED 12,14		
TFFSW	FC-2320	TFFCONICS	S-5	C-5	T-5
THISPREC	FC-2620	P30, P31	CALLED 3		
THISPREC	FC-2631	R36 (V90)	CALLED 4		
THISPREC	FC-2650	ORB PARAM DISPLAY	CALLED 7		
THISPREC	FC-2680	THRUST PROGRAMS	CALLED 38		
TICKTEST	FC-2650	ORB PARAM DISPLAY	ENTRY 14		

TIGAVEG	FC-2630	TPI TARGETTING	ENTRY 15		
TIGBLNK	FC-2630	TPI TARGETTING	ENTRY 14		
TIGNOW	FC-2630	TPI TARGETTING	ENTRY 30		
TIGON	FC-2700	P47 THRUST MONITOR	ENTRY 4		
TIG-0	FC-2630	TPI TARGETTING	ENTRY 20		
TIG-5	FC-2630	TPI TARGETTING	ENTRY 16		
TIMERAD	FC-2310	CONIC SUBROUTINES	ENTRY 23		
TIMERAD	FC-2642	RETURN TO EARTH	CALLED 27,37		
TIMERFLG	FC-2620	P30, P31	S-6,10	C-6,10	
TIMESTEP	FC-2300	ORB INTEGRATION	ENTRY 6		
TIMETHET	FC-2310	CONIC SUBROUTINES	ENTRY 22		
TIMETHET	FC-2545	TPI SEARCH PROG	CALLED 7		
TIMETHET	FC-2595	LUNAR LAND SELECT	CALLED 13		
TIMETHET	FC-2626	P32, P72 - CSI	CALLED 13,14		
TIMETHET	FC-2627	P33, P73 - CDH	CALLED 5		
TIMETHET	FC-2630	TPI TARGETTING	CALLED 5		
TIMETHET	FC-2642	RETURN TO EARTH	CALLED 13		
TIMETHET	FC-2644	P38-P78; P39-P79	CALLED 11		
TIMFLAG	FC-2681	CLOKTASK- CLOCKJOB			T-3
TIMRFLAG	FC-2680	THRUST PROGRAMS	S-8	C-28,31	
TLIM	FC-2200	T4RUPT	ENTRY 28		
TNONTEST	FC-2200	T4RUPT	ENTRY 33		
TORQUE	FC-2530	PRELAUNCH INIT	ENTRY 25		
TPAGREE	FC-2680	THRUST PROGRAMS	CALLED 19		
TRACKFLG	FC-2200	T4RUPT		C-32,33	
TRACKFLG	FC-2340	ATTITUDE MANEUVER			T-8
TRACKFLG	FC-2545	TPI SEARCH PROG	S-3		
TRACKFLG	FC-2550	P20 RENDEZVOUS NAV	S-3	C-8	T-6,8,17,31
TRACKFLG	FC-2620	P30, P31	S-2,7		

TRACKFLG	FC-2626	P32, P72 - CSI	S-2			
TRACKFLG	FC-2627	P33, P73 - CDH	S-1			
TRACKFLG	FC-2630	TPI TARGETTING			S-2	
TRACKFLG	FC-2640	TPM TARGETTING	S-1			
TRACKFLG	FC-2644	P38-P78; P39-P79	S-3			
TRACKFLG	FC-2670	TARGET DELTA V PROG	S-1			
TRACKFLG	FC-2720	IMU REALIGN PROG			C-1	
TRACKFLG	FC-2730	R52, R53, R56				T-4
TRANSANG	FC-2545	TPI SEARCH PROG	ENTRY	14		
TRANSP1	FC-2100	SINGLE PREC SUBROUTS	ENTRY	13		
TRANSP2	FC-2100	SINGLE PREC SUBROUTS	ENTRY	13		
TRFAILOF	FC-2070	SERVICE ROUTINES	ENTRY	13		
TRFAILOF	FC-2550	P20 RENDEZVOUS NAV	CALLED	33		
TRFAILOF	FC-2605	NAV EXTENDED VERBS	CALLED	7		
TRFAILON	FC-2070	SERVICE ROUTINES	ENTRY	13		
TRFAILON	FC-2550	P20 RENDEZVOUS NAV	CALLED	32		
TRUNFLAG	FC-2730	R52, R53, R56	S-2,3		C-3	T-3
TTG/0	FC-2630	TPI TARGETTING	ENTRY	31		
TVCDAPON	FC-2430	TVC ROUTINES	ENTRY	1		
TVCDAPON	FC-2680	THRUST PROGRAMS	CALLED	22		
TVCEXEC	FC-2430	TVC ROUTINES	ENTRY	7		
TVCINIT	FC-2430	TVC ROUTINES	ENTRY	1		
TVCZAP	FC-2630	TPI TARGETTING	ENTRY	28		
TVCZAP	FC-2020	FRESH START	CALLED	31		
TVCZAP-1	FC-2681	CLOKTASK-CLOCKJOB	CALLED	5,7		
TWIDDLE	FC-2060	WAITLIST	ENTRY	9		
T3RUPT	FC-2060	WAITLIST	ENTRY	16		
T4RUPT	FC-2200	T4RUPT	ENTRY	3		
T5IDLOC	FC-2020	FRESH START	ENTRY	17		

T5IDLOC	FC-2380	RCS DAP INIT	ENTRY 2		
T5PHASE	FC-2460	ROLL AUTOPILOT	CALLED 2		
T5PHASE2	FC-2390	RCS DAP PHASE 2	ENTRY 1		
T5PHASE2	FC-2380	RCS DAP INIT	CALLED 2		
T6PROGM	FC-2390		ENTRY 10		
T6SETUP	FC-2400	RCS DAP JET SELECT	ENTRY 15		
T6START	FC-2400	RCS DAP JET SELECT	ENTRY 17		
T6START	FC-2380	RCS DAP INIT	CALLED 7		
T6START	FC-2460	ROLL AUTOPILOT	CALLED 7		
UPACTOFF	FC-2020	FRESH START	CALLED 36		
UPACTOFF	FC-2550	P20 RENDEZVOUS NAV	CALLED 12		
UPDATFLG	FC-2545	TPI SEARCH PROG	S-3,4,12,13	C-3,5	
UPDATFLG	FC-2550	P20 RENDEZVOUS NAV	S-3	C-8	T-31,34
UPDATFLG	FC-2620	P30, P31	S-2,7	C-2,7	
UPDATFLG	FC-2626	P32, P72 - CSI	S-2,3	C-7	
UPDATFLG	FC-2627	P33, P73 - CDH	S-4		
UPDATFLG	FC-2630	TPI TARGETTING	S-2,16		
UPDATFLG	FC-2640	TPM TARGETTING	S-1		
UPDATFLG	FC-2644	P38-P78; P39-P79	S-3,6,7	C-7,9	
UPDATFLG	FC-2720	IMU REALIGN PROG		C-1	
UPDATFLG	FC-2730	R52, R53, R56			T-4
UPENT2	FC-2070	SERVICE ROUTINES	ENTRY 2		
UPFLAG	FC-2070	SERVICE ROUTINES	ENTRY 4		
UPLOCKFL	FC-2150	KEYRUPT AND UPRUPT	S-7	C-8	T-8
UPRUPT	FC-2150	KEYRUPT AND UPRUPT	ENTRY 5		
UPSVFLAG	FC-2290	INTEG INITIAL		C-15	T-14
UPTMFAST	FC-2200	T4RUPT	ENTRY 42		
USEPIOS	FC-2290	INTEG INITIAL	ENTRY 21		
USPRCADR	FC-2080	INT BNK COMMUN	ENTRY 5		

V1S TO 2	FC-2100	SINGLE PREC SUBROUTS	ENTRY 6		
VAC5STOR	FC-2020	FRESH START	ENTRY 27		
VAC5STOR	FC-2140	ALARM AND ABORT	CALLED 3,5		
VALMIS	FC-2530	PRELAUNCH INIT	ENTRY 24		
VARALARM	FC-2140	ALARM AND ABORT	ENTRY 3		
VARALARM	FC-2200	T4RUPT	CALLED 30		
VARALARM	FC-2626	P32, P72 - CSI	CALLED 22		
VARALARM	FC-2642	RETURN TO EARTH	CALLED 45		
VARDELAY	FC-2060	WAITLIST	ENTRY 10		
VECPOINT	FC-2340	ATTITUDE MANEUVER	ENTRY 5		
VECPOINT	FC-2190	PINBALL	CALLED 5		
VECPOINT	FC-2361	V89 (R63)	CALLED 5		
VECSGNAG	FC-2100	SINGLE PREC SUBROUTS	ENTRY 12		
VEHUPFLG	FC-2550	P20 RENDEZVOUS NAV		C-3	T-4,5,21,24, 25,28,35
VEHUPFLG	FC-2590	P22 ORBITAL NAV	S-15		
VEHUPFLG	FC-2600	CISLUNAR MID NAV	S-12		
VEHUPFLG	FC-2610	MEASUREMENT INCOR			T-10,11
VERB65	FC-2360	-S-BAND ANTENNA	ENTRY 2		
VFLAG	FC-2720	IMU REALIGN PROG	S-13,16	C-16	T-14,16
VGAMCALC	FC-2320	TFFCONICS	ENTRY 11		
VGAMCALC	FC-2760	ENTRY PROGRAMS	CALLED 13		
VHFRFLAG	FC-2550	P20 RENDEZVOUS NAV			T-20
VHFRFLG	FC-2605	NAV EXTENDED VERBS	S-7	C-7	
VHHDOT	FC-2540	EARTH ORBIT INSERT	ENTRY 18		
VHHDOT	FC-2683	SERVICER	CALLED 15		
VINTFLAG	FC-2290	INTEG INITIAL	S-4,6,7,16,19	C-4,6,7,18	T-8
VINTFLAG	FC-2300	ORB INTEGRATION			T-33,38
VINTFLAG	FC-2550	P20 RENDEZVOUS NAV	S-7	C-4,5,21	

VINTFLAG	FC-2580	P21 GRD TRACK DET	S-3	C-3	
VINTFLAG	FC-2590	P22 ORBITAL NAV	S-10,18		
VINTFLAG	FC-2600	CISLUNAR MID NAV	S-14		
VNDSPLY	FC-2644	P38-P78; P39-P79	ENTRY 12		
VNPOOH	FC-2626	P32, P72 - CSI	CALLED 2,4		
VNPOOH	FC-2627	P33, P73 - CDH	CALLED 1		
VN1645	FC-2626	P32, P72 - CSI	ENTRY 6		
VN1645	FC-2627	P33, P73 - CDH	CALLED 1,4		
VN1645	FC-2630	TPI TARGETTING	CALLED 3		
VN1645	FC-2640	TPM TARGETTING	CALLED 1,2		
VN1645	FC-2642	RETURN TO EARTH	CALLED 14		
V1STO2S	FC-2340	ATTITUDE MANEUVER	CALLED 7		
V1STO2S	FC-2350	MANEUV CALC & STEER	CALLED 10		
V1STO2S	FC-2540	EARTH ORBIT INSERT	CALLED 14		
V1STO25	FC-2340	ATTITUDE MANEUVER	CALLED 7		
V2T100	FC-2642	RETURN TO EARTH	ENTRY 17		
V37	FC-2020	FRESH START	ENTRY 30		
V37FLAG	FC-2140	ALARM AND ABORT			T-5,11
V37FLAG	FC-2320	TFFCONICS			T-14
V37FLAG	FC-2325	RENDEZ PAR DISPLAY			T-8
V37FLAG	FC-2683	SERVICER	S-3	C-19	
V37KLEAN	FC-2020	FRESH START	ENTRY 7		
V37XEQ	FC-2020	FRESH START	ENTRY 40		
V50N18FL	FC-2550	P20 RENDEZVOUS NAV	S-3	C-10	T-16
V54E	FC-2550	P20 RENDEZVOUS NAV	ENTRY 17		
V56E	FC-2550	P20 RENDEZVOUS NAV	ENTRY 8		
V57E	FC-2550	P20 RENDEZVOUS NAV	ENTRY 17		
V59FLAG	FC-2242	OPTICS CAL ROUTINE	S-1,3	C-1,3	
V60	FC-2370	DAP INTER-SERV ROUT	ENTRY 12		

V61	FC-2370	DAP INTER-SERV ROUT	ENTRY 12		
V62	FC-2370	DAP INTER-SERV ROUT	ENTRY 12		
V63	FC-2370	DAP INTER-SERV ROUT	ENTRY 13		
V82CALL	FC-2650	ORB PARAM DISPLAY	ENTRY 4		
V82EMFLG	FC-2650	ORB PARAM DISPLAY	S-6,8,11	C-6,8,11	T-11,12,18
V82FLAGS	FC-2650	ORB PARAM DISPLAY	S-10	C-4	T-4,14
V82PERF	FC-2650	ORB PARAM DISPLAY	ENTRY 2		
V89CALL	FC-2190	EXTENDED VERBS	ENTRY 2		
V89CALL	FC-2361	V89 (R63)	ENTRY 2		
V89PERF	FC-2190	EXTENDED VERBS	ENTRY 2		
V89PERF	FC-2361	V89 (R63)	ENTRY 2		
V90PERF	FC-2631	R36 (V90)	ENTRY 2		
V94FLAG	FC-2600	CISLUNAR MID MAV	S-8	C-3,9	
V960NFLG	FC-2290	INTEG INITIAL		C-3	
V97E	FC-2681	CLOKTASK- CLOCKJOB	ENTRY 11		
V97P	FC-2681	CLOKTASK- CLOCKJOB	ENTRY 10		
V97T	FC-2681	CLOKTASK- CLOCKJOB	ENTRY 8		
V99E	FC-2681	CLOKTASK- CLOCKJOB	ENTRY 7		
V99P	FC-2681	CLOKTASK- CLOCKJOB	ENTRY 6		
V99T	FC-2681	CLOKTASK- CLOCKJOB	ENTRY 5		
WAITLIST	FC-2060	WAITLIST	ENTRY 9		
XDELVFLG	FC-2620	P30, P31	S-1,6	C-10	
XDELVFLG	FC-2626	P32, P72 - CSI	S-9		
XDELVFLG	FC-2627	P33, P73 - CDH	S-6		
XDELVFLG	FC-2630	TPI TARGETTING		C-16	
XDELVFLG	FC-2642	RETURN TO EARTH		C-14	
XDELVFLG	FC-2644	P38-P78; P39-P79		C-7	
XDELVFLG	FC-2680	THRUST PROGRAMS			T-4,32
XDELVFLG	FC-2682	STEERING			T-6

YAWDAP	FC-2440	TVC DAP	ENTRY 6,9		
YAWTIM	FC-2400	RCS DAP JET SELECT	ENTRY 13		
YCOPY	FC-2430	TVC ROUTINES	CALLED 12		
YCOPY	FC-2440	TVC DAP	ENTRY 13		
ZEROICDU	FC-2200	T4RUPT	CALLED 34,36		
ZEROING	FC-2530	PRELAUNCH INIT	ENTRY 35		
ZEROJET	FC-2370	DAP INTER-SERV ROUT	CALLED 2,4		
ZEROJET	FC-2540	EARTH ORBIT INSERT	CALLED 19		
ZMEASURE	FC-2600	CISLUNAR MID NAV	S-17	C-17	T-15
(JETSFLG	FC-2370	DAP INTER SERV ROUT	S-9	C-9	
-1CHK	FC-2120	AGC SELFCHECK	ENTRY 16		
1/PIPA	FC-2683	SERVICER	CALLED 13		
1S TO 2S	FC-2100	SINGLE PREC SUBROUTS	ENTRY 5		
1 TO SUB	FC-2100	SINGLE PREC SUBROUTS	ENTRY 8		
2EBANK	FC-2120	AGC SELFCHECK	ENTRY 6		
2PHSCHNG	FC-2030	PHASE TABLE MAINT	ENTRY 11		
22DSPFLG	FC-2590	P22 ORBITAL NAV		C-16	T-16
2V1S TO	FC-2100	SINGLE PREC SUBROUTS	ENTRY 7		
3AXISFLG	FC-2190	EXTENDED VERBS		C-3	
3AXISFLG	FC-2330	CREW DEF MANEUVER	S-3		
3AXISFLG	FC-2340	ATTITUDE MANEUVER		C-4	T-2,3
3AXISFLG	FC-2361	VB9 (R63)		C-3	
3AXISFLG	FC-2550	P20 RENDEZVOUS NAV		C-10	
3AXISFLG	FC-2600	CISLUNAR MID NAV		C-7	
3AXISFLG	FC-2680	THRUST PROGRAMS		C-8	
360CHECK	FC-2310	CONIC SUBROUTINES	ENTRY 30		
:ELAYJOB	FC-2650	ORB PARAM DISPLAY	CALLED 12		
9DWTO6DW	FC-2590	P22 ORBITAL NAV	ENTRY 33		

%%ENDJOB

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EXDAPOFF	FC-2530 PRELAUNCH INIT	ENTRY 31		
EXRSTRT	FC-2430 TVC ROUTINES	ENTRY 15		
EXTVBACT	FC-2070 SERVICE ROUTINES		C-12	
EXTVBACT	FC-2242 OPTICS CAL ROUTINE	S-2		T-2
EXTVBACT	FC-2325 RENDEZ PAR DISPLAY	S-5		T-3,5
EXTVBACT	FC-2650 ORB PARAM DISPLAY			T-12,14
FALTON	FC-2020 FRESH START	CALLED 33		
FALTON	FC-2190 PINBALL	CALLED 2		

FALTON	FC-2325	RENDEZ PAR DISPLAY	CALLED 2		
FALTON	FC-2330	CREW DEF MANEUVER	CALLED 2		
FALTON	FC-2360	-S-BAND ANTENNA	CALLED 2		
FALTON	FC-2361	V89 (R63)	CALLED 2		
FALTON	FC-2550	P20 RENDEZVOUS NAV	CALLED 17		
FALTON	FC-2595	LUNAR LAND SELECT	CALLED 3		
FALTON	FC-2600	CISLUNAR MID NAV	CALLED 4		
FALTON	FC-2605	NAV EXTENDED VERBS	CALLED 2,6		
FALTON	FC-2650	ORB PARAM DISPLAY	CALLED 2		
FAZAB5	FC-2290	INTEG INITIAL	CALLED 18		
FBR3	FC-2300	ORB INTEGRATION	ENTRY 28		
FINALFLG	FC-2626	P32, P72 - CSI	S-7		T-3,6
FINALFLG	FC-2627	P33, P73 - CDH			T-4
FINALFLG	FC-2630	TPI TARGETTING			T-16
FINALFLG	FC-2642	RETURN TO EARTH	S-14		
FINALFLG	FC-2644	P38-P78: P39-P79	S-7,9		T-5,6,7,9
FINETIME	FC-2530	PRELAUNCH INIT	ENTRY 40		
FIRSTFLG	FC-2680	THRUST PROGRAMS	S-32		
FIRSTFLG	FC-2682	STEERING		C-16	T-8,15
FISHCALC	FC-2320	TFFCONICS	ENTRY 12		
FISHCALC	FC-2760	ENTRY PROGRAMS	CALLED 12,13, 14		
FIXDELAY	FC-2060	WAITLIST	ENTRY 10		
FREEFLAG	FC-2710	P51, P53 IMU ORIENT	S-8,9	C-8,9	T-6,8
FRESHDAP	FC-2380	RCS DAP INIT	ENTRY 6		
FXFX	FC-2120	AGC SELFCHECK	ENTRY 10		
FWDFLTR	FC-2440	TVC DAP	ENTRY 4		
F2RTE	FC-2642	RETURN TO EARTH	S-20	C-17	
GAMCOMP	FC-2300	ORB INTEGRATION	ENTRY 23		
GAMDV10	FC-2642	RETURN TO EARTH	ENTRY 23		

GENTRAN	FC-2020	FRESH START	CALLED 28		
GENTRAN	FC-2070	SERVICE ROUTINES	ENTRY 11		
GENTRAN	FC-2240	SXTMARK	CALLED 5		
GENTRAN	FC-2550	P20 RENDEZVOUS NAV	CALLED 18,20		
GENTRAN	FC-2683	SERVICER	CALLED 5,15		
GENTRAN	FC-2700	P47 THRUST MONITOR	CALLED 7		
GEOM	FC-2310	CONIC SUBROUTINES	ENTRY 34		
GETERAD	FC-2320	TFFCONICS	CALLED 12		
GETERAD	FC-2600	CISLUNAR MID NAV	CALLED 18		
GETERAD	FC-2642	RETURN TO EARTH	CALLED 7		
GET+MGA	FC-2620	P30, P31	CALLED 5,9		
GET+MGA	FC-2626	P32, P72 - CSI	CALLED 6		
GETUM	FC-2550	P20 RENDEZVOUS NAV	ENTRY 38		
GETUM	FC-2590	P22 ORBITAL NAV	CALLED 12		
GETX	FC-2310	CONIC SUBROUTINES	ENTRY 26		
GLOCKMON	FC-2200	T4RUPT	ENTRY 43		
GOESTIMS	FC-2530	PRELAUNCH INIT	ENTRY 5		
GOINT	FC-2630	TPI TARGETTING	ENTRY 14		
GOODEND	FC-2550	P20 RENDEZVOUS NAV	CALLED 34		
GOPROG	FC-2020	FRESH START	ENTRY 13		
GOPROG2	FC-2020	FRESH START	ENTRY 20		
GOTOPOOH	FC-2020	FRESH START	ENTRY 24		
GTSCPSS1	FC-2530	PRELAUNCH INIT	ENTRY 2		
GUESSW	FC-2310	CONIC SUBROUTINES			T-11,16
GUESSW	FC-2682	STEERING		C-14	
GYMDIFSW	FC-2760	ENTRY PROGRAMS		C-9	
HACK	FC-2440	TVC DAP	CALLED 1,6		
HACK	FC-2450	STROKE TEST PKG	ENTRY 2		
HACKWLST	FC-2450	STROKE TEST PKG	ENTRY 2		

HAVEGUES	FC-2682	STEERING	CALLED 14		
HIENERGY	FC-2310	CONIC SUBROUTINES	ENTRY 21		
HORIZ	FC-2600	CISLUNAR MID NAV	ENTRY 18		
IBNKCALL	FC-2080	INT BNK COMMUN	ENTRY 4		
IDLEFAIL	FC-2681	CLOKTASK- CLOCKJOB	S-10	C-10	
IDLEFAIL	FC-2682	STEERING			T-13
IGNFLAG	FC-2680	THRUST PROGRAMS	S-20		
IGNFLAG	FC-2681	CLOKTASK- CLOCKJOB	S-13		T-6
IGNITION	FC-2630	TPI TARGETTING	ENTRY 20		
IGNITION	FC-2681	CLOKTASK-CLOCKJOB	CALLED 6		
IMPULSW	FC-2680	THRUST PROGRAMS	S-17	C-19,21	T-21
IMPULSW	FC-2682	STEERING	S-13	C-4	T-4
IMUBAD	FC-2200	T4RUPT	CALLED 35		
IMUCAGE	FC-2200	T4RUPT	ENTRY 31		
IMUCOARS	FC-2710	P51, P53 IMU ORIENT	CALLED 2		
IMUCOARS	FC-2720	IMU REALIGN PROG	CALLED 23		
IMUFINE2	FC-2710	P51, P53 IMU ORIENT	CALLED 3		
IMUFIN20	FC-2720	IMU REALIGN PROG	CALLED 23		
IMUMON	FC-2200	T4RUPT	ENTRY 25		
IMUOP	FC-2200	T4RUPT	ENTRY 32		
IMUPULSE	FC-2720	IMU REALIGN PROG	CALLED 26		
IMUSE	FC-2550	P20 RENDEZVOUS NAV		C-8	
IMUSE	FC-2710	P51, P53 IMU ORIENT	S-2		
IMUSEFLA	FC-2200	T4RUPT		C-32	T-34,35
IMUSTALL	FC-2710	P51, P53 IMU ORIENT	CALLED 3		
IMUSTALL	FC-2720	IMU REALIGN PROG	CALLED 23,26		
IMUSTLLG	FC-2530	PRELAUNCH INIT	ENTRY 36		
INCORFLG	FC-2550	P20 RENDEZVOUS NAV	S-22,24	C-28	T-24,27,28
INCORFLG	FC-2590	P22 ORBITAL NAV	S-14	C-17	T-17

INCORP1	FC-2550	P20 RENDEZVOUS NAV	CALLED 26		
INCORP1	FC-2590	P22 ORBITAL NAV	CALLED 15		
INCORP1	FC-2600	CISLUNAR MID NAV	CALLED 11		
INCORP1	FC-2610	MEASUREMENT INCOR	ENTRY 3		
INCORP2	FC-2550	P20 RENDEZVOUS NAV	CALLED 27		
INCORP2	FC-2590	P22 ORBITAL NAV	CALLED 16		
INCORP2	FC-2600	CISLUNAR MID NAV	CALLED 12		
INCORP2	FC-2610	MEASUREMENT INCOR	ENTRY 9		
INCRCDUS	FC-2100	SINGLE PREC SUBROUTS	ENTRY 9		
INFINFLG	FC-2310	CONIC SUBROUTINES	S-29	C-29	T-12,18,22
INFINFLG	FC-2595	LUNAR LAND SELECT			T-13
INFINITY	FC-2310	CONIC SUBROUTINES	ENTRY 29		
INITIALW	FC-2550	P20 RENDEZVOUS NAV	ENTRY 36		
INITSUR	FC-2020	FRESH START	ENTRY 25		
INITV	FC-2310	CONIC SUBROUTINES	ENTRY 20		
INITVEL	FC-2545	TPI SEARCH PROG	CALLED 8		
INITVEL	FC-2630	TPI TARGETTING	CALLED 12		
INITVEL	FC-2680	THRUST PROGRAMS	CALLED 39		
INSTALL	FC-2580	P21 GRD TRACK DET	CALLED 3		
INSTALL	FC-2610	MEASUREMENT INCORP	CALLED 7		
INTEGREV	FC-2580	P21 GRD TRACK DET	CALLED 4		
INTEGRV	FC-2290	INTEG INITIAL	ENTRY 8		
INTEGRV	FC-2550	P20 RENDEZVOUS NAV	CALLED 4,5,21,22		
INTEGRV	FC-2580	P21 GRD TRACK DET	CALLED 4		
INTEGRV	FC-2590	P22 ORBITAL NAV	CALLED 12		
INTEGRV	FC-2600	CISLUNAR MID NAV	CALLED 15		
INTEGRVS	FC-2290	INTEG INITIAL	ENTRY 8		
INTEGRVS	FC-2325	RENDEZ PAR DISPLAY	CALLED 9		
INTEGRVS	FC-2630	TPI TARGETTING	CALLED 15		

INTEGRVS	FC-2642	RETURN TO EARTH	CALLED 44		
INTEGRV2	FC-2290	INTEG INITIAL	ENTRY 8		
INTEGRV2	FC-2300	ORB INTEGRATION	CALLED 35		
INTFLAG	FC-2290	INTEG INITIAL	S-11	C-13	T-10
INTGRATE	FC-2300	ORB INTEGRATION	ENTRY 8		
INTGRVS	FC-2670	TARGET DELTA V PROG	CALLED 3		
INTINT	FC-2626	P32, P72 - CSI	CALLED 3,15,16		
INTINT	FC-2627	P33, P73 - CDH	CALLED 2		
INTINT	FC-2630	TPI TARGETTING	ENTRY 14		
INTINT2C	FC-2626	P32, P72 - CSI	ENTRY 15		
INTINT3P	FC-2627	P33, P73 - CDH	ENTRY 2		
INTRPVP	FC-2644	P38-P78; P39-P79	ENTRY 12		
INTSTALL	FC-2020	FRESH START	CALLED 35		
INTSTALL	FC-2290	INTEG INITIAL	ENTRY 10		
INTSTALL	FC-2325	RENDEZ PAR DISPLAY	CALLED 8,9,10		
INTSTALL	FC-2550	P20 RENDEZVOUS NAV	CALLED 7,9		
INTSTALL	FC-2590	P22 ORBITAL NAV	CALLED 10,18		
INTSTALL	FC-2600	CISLUNAR MID NAV	CALLED 14		
INTSTALL	FC-2605	NAV EXTENDED VERBS	CALLED 3		
INTSTALL	FC-2642	RETURN TO EARTH	CALLED 42,43		
INTSTALL	FC-2650	ORB PARAM DISPLAY	CALLED 13		
INTSTALL	FC-2670	TARGET DELTA V PROG	CALLED 2,3		
INTWAKE	FC-2290	INTEG INITIAL	ENTRY 12		
INTWAKE	FC-2300	ORB INTEGRATION	CALLED 40		
INTWAKE	FC-2320	TFFCONICS	CALLED 14		
INTWAKE	FC-2605	NAV EXTENDED VERBS	CALLED 4		
INTWAKE	FC-2610	MEASUREMENT INCORP	CALLED 12		
INTWAKE0	FC-2290	INTEG INITIAL	ENTRY 12		
INTWAKE0	FC-2320	TFFCONICS	CALLED 14		

INTWAKEU	FC-2290	INTEG INITIAL	ENTRY 14		
INTWAKE1	FC-2670	TARGET DELTA V PROG	CALLED 4		
INTYPFLA	FC-2670	TARGET DELTA V PROG		C-2	
INTYPFLG	FC-2290	INTEG INITIAL	S-7	C-3,6,20	T-8
INTYPFLG	FC-2325	RENDEZ PAR DISPLAY	S-8,9	C-8,9	
INTYPFLG	FC-2550	P20 RENDEZVOUS NAV		C-7	
INTYPFLG	FC-2580	P21 GRD TRACK DET		C-4	
INTYPFLG	FC-2590	P22 ORBITAL NAV		C-10,18	
INTYPFLG	FC-2600	CISLUNAR MID NAV		C-14	
INTYPFLG	FC-2630	TPI TARGETTING	S-14	C-14	
INTYPFLG	FC-2642	RETURN TO EARTH	S-42	C-42,43	
ISWCALL	FC-2080	INT BNK COMMUN	ENTRY 4		
ISWRETRN	FC-2080	INT BNK COMMUN	ENTRY 4		
ITERATOR	FC-2310	CONIC SUBROUTINES	ENTRY 36		
ITSWICH	FC-2545	TPI SEARCH PROG	S-10	C-7	T-10
ITSWICH	FC-2627	P33, P73 - CDH	S-4		
ITSWICH	FC-2630	TPI TARGETTING	S-3	C-3,4	T-4,7
ITURNOM	FC-2200	T4RUPT	ENTRY 29		
JETSLECT	FC-2380	RCS DAP INIT	CALLED 2		
JETSLECT	FC-2390	RCS DAP PHASE 2	CALLED 10		
JETSLECT	FC-2400	RCS DAP JET SELECT	ENTRY 1		
JETSLECT	FC-2460	ROLL AUTOPILOT	CALLED 2		
JOBSLEEP	FC-2290	INTEG INITIAL	CALLED 10		
JOBWAKE	FC-2290	INTEG INITIAL	CALLED 13		
JOBWAKE	FC-2670	TARGET DELTA V PROG	CALLED 10		
JSWITCH	FC-2300	ORB INTEGRATION	S-33	C-8	T-8,27
KALCMAN3	FC-2340	ATTITUDE MANEUVER	CALLED 4		
KEPLERN	FC-2310	CONIC SUBROUTINES	ENTRY 4		
KEPLERN	FC-2300	ORB INTEGRATION	CALLED 31		

KEPPREP	FC-2300	ORB INTEGRATION	ENTRY 29		
KEPPREP	FC-2290	INTEG INITIAL	CALLED 9		
KEYCOM	FC-2150	KEYRUPT AND UPRUPT	ENTRY 4		
KEYCOM	FC-2240	SXTMARK	CALLED 4		
KEYRUPT1	FC-2150	KEYRUPT AND UPRUPT	ENTRY 3		
KFLAG	FC-2545	TPI SEARCH PROG	S-4,5	C-4,5	T-5,6,7,10,11
KLEENEX	FC-2240	SXTMARK	CALLED 8		
KLEENEX	FC-2550	P20 RENDEZVOUS NAV	CALLED 18		
KLEENEX	FC-2730	R52, R53, R53	CALLED 5		
KNOWNFLG	FC-2590	P22 ORBITAL NAV	S-6	C-6	T-7,13
LALOTORV	FC-2320	TFFCONICS	CALLED 14		
LALOTORV	FC-2540	EARTH ORBIT INSERT	CALLED		
LALOTORV	FC-2590	P22 ORBITAL NAV	CALLED 23		
LALOTORV	FC-2600	CISLUNAR MID NAV	CALLED 16		
LALOTORV	FC-2720	IMU REALIGN PROG	CALLED 8		
LALOTORV	FC-2730	R52, R53, R53	CALLED 8		
LAMBERT	FC-2310	CONIC SUBROUTINES	ENTRY 14		
LAMENTER	FC-2310	CONIC SUBROUTINES	ENTRY 35		
LASTBIAS	FC-2683	SERVICER	CALLED 3		
LATAZCHK	FC-2530	PRELAUNCH INIT	ENTRY 47		
LAT-LONG	FC-2580	P21 GRD TRACK DET	CALLED 5		
LAT-LONG	FC-2590	P22 ORBITAL NAV	CALLED 7,20		
LAT-LONG	FC-2595	LUNAR LAND SELECT	CALLED 5,7,10		
LAT-LONG	FC-2642	RETURN TO EARTH	CALLED 33		
LAT-LONG	FC-2720	IMU REALIGN PROG	CALLED 7		
LAT-LONG	FC-2760	ENTRY PROGRAMS	CALLED 9		
LEMCONIC	FC-2190	PINBALL	CALLED 4		
LEMCONIC	FC-2361	V89 (R63)	CALLED 4		
LEMCONIC	FC-2545	TPI SEARCH PROG	CALLED 3,8		

LEMCONIC	FC-2730	R52, R53, R53	CALLED 8		
LEMPREC	FC-2290	INTEG INITIAL	ENTRY 6		
LEMPREC	FC-2325	RENDEZ PAR DISPLAY	CALLED 7,10		
LEMSTORE	FC-2545	TPI SEARCH PROG	CALLED 3		
LETFLGON	FC-2530	PRELAUNCH INIT	ENTRY 33		
LINUS	FC-2340	ATTITUDE MANEUVER	CALLED 8		
LINVEL	FC-2300	ORB INTEGRATION	CALLED 44		
LISTINGO	FC-2550	P20 RENDEZVOUS NAV	ENTRY 1		
LISTINGO	FC-2580	P21 GRD TRACK DET	ENTRY 1		
LISTINGO	FC-2605	NAV EXTENDED VERBS	ENTRY 1		
LISTINGO	FC-2760	ENTRY PROGRAMS	ENTRY 1		
LITTLSUB	FC-2530	PRELAUNCH INIT	ENTRY 46		
LLASRD	FC-2720	IMU REALIGN PROG	CALLED 7		
LLASRDA	FC-2720	IMU REALIGN PROG	CALLED 8		
LMOONFLG	FC-2290	INTEG INITIAL	S-5	C-5	T-5
LMOONFLG	FC-2550	P20 RENDEZVOUS NAV			T-35
LMPREC	FC-2644	P38-P78: P39-P79	CALLED 12		
LOADCOEF	FC-2430	TVC ROUTINES	ENTRY 22		
LOADTIME	FC-2100	SINGLE PREC SUBROUTS	ENTRY 2		
LOADTIME	FC-2190	PINBALL	CALLED 3		
LOADTIME	FC-2290	INTEG INITIAL	CALLED 3,19		
LOADTIME	FC-2300	ORB INTEGRATION	CALLED 36		
LOADTIME	FC-2360	-S-BAND ANTENNA	CALLED 3		
LOADTIME	FC-2361	V89 (R63)	CALLED 3		
LOADTIME	FC-2550	P20 RENDEZVOUS NAV	CALLED 3,11,19,20		
LOADTIME	FC-2580	P21 GRD TRACK DET	CALLED 5		
LOADTIME	FC-2590	P22 ORBITAL NAV	CALLED 3,7		
LOADTIME	FC-2595	LUNAR LAND SELECT	CALLED 4		
LOADTIME	FC-2600	CISLUNAR MID NAV	CALLED 7		

LOADTIME	FC-2631	R36 (V90)	CALLED 3		
LOADTIME	FC-2640	TPM TARGETTING	CALLED 1		
LOADTIME	FC-2650	ORB PARAM DISPLAY	CALLED 6		
LOADTIME	FC-2720	IMU REALIGN PROG	CALLED 5,18		
LOADTIME	FC-2730	R52, R53, R53	CALLED 6,9		
LOADTIME	FC-2760	ENTRY PROGRAMS	CALLED 3		
LOCSAM	FC-2710	P51, P53 IMU ORIENT	CALLED 7		
LOCSAM	FC-2720	IMU REALIGN PROG	ENTRY 11		
LODSAMPT	FC-2150	KEYRUPT AND UPRUPT	CALLED 3,5		
LOMAT	FC-2630	TPI TARGETTING	ENTRY 14,15		
LOMAT	FC-2620	P30, P31	CALLED 3		
LONGCALL	FC-2060	WAITLIST	ENTRY 21		
LOWMEMRY	FC-2600	CISLUNAR MID NAV	ENTRY 5		
LSPOS	FC-2300	ORB INTEGRATION	CALLED 11		
LSPOS	FC-2720	IMU REALIGN PROG	CALLED 11		
LUMPOS	FC-2300	ORB INTEGRATION	CALLED 45		
LUNAFLAG	FC-2580	P21 GRD TRACK DET	S-4	C-4	
LUNAFLAG	FC-2590	P22 ORBITAL NAV	S-4,20,22,24	C-4,20,22,24	
LUNAFLAG	FC-2595	LUNAR LAND SELECT	S-4,7		T-10
LUNAFLAG	FC-2600	CISLUNAR MID NAV	S-5	C-5	T-17,18
LUNAFLAG	FC-2642	RETURN TO EARTH		C-32	
LUNAFLAG	FC-2730	R52, R53, R56	S-5		
LUNAFLAG	FC-2760	ENTRY PROGRAMS		C-9	
LUNAFLG	FC-2720	IMU REALIGN PROG	S-7		
LUNPOS	FC-2190	PINBALL	CALLED 3		
LUNPOS	FC-2360	-S-BAND ANTENNA	CALLED 3		
LUNPOS	FC-2600	CISLUNAR MID NAV	CALLED 15		
MAINRTNE	FC-2644	P38-P78; P39-P79	ENTRY 6		
MAKECADR	FC-2080	INT BNK COMMUN	ENTRY 2		

MIDTOAV2	FC-2290	INTEG INITIAL	ENTRY 19		
MIDTOAV2	FC-2700	P47 THRUST MONITOR	CALLED 3		
MIDTOAV2	FC-2760	ENTRY PROGRAMS	CALLED 10		
MID1FLAG	FC-2290	INTEG INITIAL	S-19	C-19	
MID1FLAG	FC-2300	ORB INTEGRATION			T-36
MINIRECT	FC-2300	ORB INTEGRATION	ENTRY 43		
MINIRECT	FC-2290	INTEG INITIAL	CALLED 17		
MINIRECT	FC-2670	TARGET DELTA V PROG	CALLED 4		
MKREJECT	FC-2240	SXTMARK	ENTRY 7		
MKRELEAS	FC-2240	SXTMARK	ENTRY 3		
MKRELEAS	FC-2590	P22 ORBITAL NAV	CALLED 9		
MKRELEAS	FC-2710	P51, P53 IMU ORIENT	CALLED 5		
MKRELEAS	FC-2720	IMU REALIGN PROG	CALLED 19		
MKRELEAS	FC-2730	R52, R53, R53	CALLED 5		
MKRLEES	FC-2550	P20 RENDEZVOUS NAV	CALLED 7		
MKVB51	FC-2240	SXTMARK	ENTRY 8		
MMDSPLAY	FC-2020	FRESH START	CALLED 21		
MOONTHIS	FC-2325	RENDEZ PAR DISPLAY			T-8,9
MOONTHIS	FC-2610	MEASUREMENT INCOR			T-10
MOVEACSM	FC-2610	MEASUREMENT INCORP	CALLED 11		
MOVEALEM	FC-2610	MEASUREMENT INCORP	CALLED 11		
MOVEPCSM	FC-2610	MEASUREMENT INCORP	CALLED 10		
MOVEPLEM	FC-2610	MEASUREMENT INCORP	CALLED 10		
MOONFLAG	FC-2290	INTEG INITIAL	S-5,14,21	C-5,14	T-5,8
MOONFLAG	FC-2300	ORB INTEGRATION	S-44	C-44	T-11,13,15,19 31,40,41,44 45
MOONFLAG	FC-2325	RENDEZ PAR DISPLAY	S-8,9	C-8,9	
MOONFLAG	FC-2580	P21 GRD TRACK DET	S-4	C-3	

MOONFLAG	FC-2630	TPI TARGETTING	S-14	C-14	
MOONFLAG	FC-2642	RETURN TO EARTH		C-43	
MOONFLAG	FC-2670	TARGET DELTA V PROG	S-2	C-2	
MR.KLEAN	FC-2020	FRESH START	ENTRY 7		
MR.KLEAN	FC-2140	ALARM AND ABORT	CALLED 6,13		
MXM3	FC-2350	MANEUV CALC & STEER	ENTRY 25		
MXM3	FC-2340	ATTITUDE MANEUVER	CALLED 6,7		
NBDONLY	FC-2060	WAITLIST	CALLED 20		
NBSM	FC-2550	P20 RENDEZVOUS NAV	CALLED 38		
NBSM	FC-2730	R52, R53, R53	CALLED 13		
*NBSM	FC-2325	RENDEZ PAR DISPLAY	CALLED 5		
NEEDFLG	FC-2380	RCS DAP INIT			T-5
NEEDLER	FC-2380	RCS DAP INIT	CALLED 5		
NEEDLER	FC-2430	TVC ROUTINES	CALLED 5,7		
NEEDLER	FC-2460	ROLL AUTOPILOT	CALLED 5		
NEEDLER	FC-2540	EARTH ORBIT INSERT	CALLED 4,16,17,20,21		
NEEDLES3	FC-2370	DAP INTER-SERV ROUT	ENTRY 15		
NEEDLFLG	FC-2680	DAP INTER SERV ROUT	S-12,13	C-12	
NEGP	FC-2310	CONIC SUBROUTINES	ENTRY 21		
NEWIFLG	FC-2290	INTEG INITIAL	S-8		
NEWIFLG	FC-2300	ORB INTEGRATION		C-6	T-6
NEWMODEA	FC-2030	PHASE TABLE MAINT	ENTRY 2		
NEWMODEA	FC-2020	FRESH START	CALLED 42		
NEWMODEX	FC-2030	PHASE TABLE MAINT	ENTRY 2		
NEWMODEX	FC-2540	EARTH ORBIT INSERT	CALLED 4		
NEWMODEX	FC-2760	ENTRY PROGRAMS	CALLED 3,6,7,8		
NEWPHASE	FC-2030	PHASE TABLE MAINT	ENTRY 4		
NEWSTATE	FC-2310	CONIC SUBROUTINES	ENTRY 35		
NEXTCOL	FC-2300	ORB INTEGRATION	ENTRY 35		

NJETSFLG	FC-2370	DAP INTER SERV ROUT	S-9	C-9	
NJETSFLG	FC-2680	THRUST PROGRAMS			T-5,17
NJETSFLG	FC-2642	RETURN TO EARTH			T-11
NOACY	FC-2400	RCS DAP JET SELECT	ENTRY 8		
NOATTOFF	FC-2200	T4RUPT	CALLED 34,35		
NOBDZ	FC-2400	RCS DAP JET SELECT	ENTRY 6		
NODOFLAG	FC-2290	INTEG INITIAL	S-3	C-4	
NODOFLAG	FC-2140	ALARM AND ABORT		C-6	
NODOP01	FC-2540	EARTH ORBIT INSERT	S-4		
NOEBANK	FC-2120	AGC SELFCHECK	ENTRY 6		
NORFHOR	FC-2600	CISLUNAR MID NAV	S-6	C-6	T-22
NORMLIZE	FC-2683	SERVICER	ENTRY 5		
NORMLIZE	FC-2540	EARTH ORBIT INSERT	CALLED 9		
NORMSW	FC-2310	CONIC SUBROUTINES		C-33	T-34
NORMSW	FC-2620	P30, P31		C-7	
NORMSW	FC-2642	RETURN TO EARTH		C-14	
NORMSW	FC-2680	THRUST PROGRAMS			T-38
NORMSW	FC-2682	STEERING			T-14
NORMUNIT	FC-2100	SINGLE PREC SUBROUTS	ENTRY 15		
NORMUNX1	FC-2100	SINGLE PREC SUBROUTS	ENTRY 15		
NO2Y	FC-2400	RCS DAP JET SELECT	ENTRY 10		
N22ORN17	FC-2370	DAP INTER-SERV ROUT	S-12	C-13	
N22ORN17	FC-2380	RCS DAP INIT			T-5
OPTMODES	FC-2070	SERVICE ROUTINES	S-13		
OPTMON	FC-2200	T4RUPT	ENTRY 11		
OPTNSW	FC-2644	P38-P78; P39-P79	S-4	C-4	T-5
OPTSTALL	FC-2730	R52, R53, R53	CALLED 11		
OPTTEST	FC-2200	T4RUPT	ENTRY 6		
ORBWFLAG	FC-2290	INTEG INITIAL		C-14	T-4,16

ORBWFLAG	FC-2300	ORB INTEGRATION		C-37	
ORBWFLAG	FC-2550	P20 RENDEZVOUS NAV		C-22	
ORBWFLAG	FC-2590	P22 ORBITAL NAV		C-39	T-11,18
ORBWFLAG	FC-2600	CISLUNAR MID NAV	S-15		T-14,15
ORBWFLAG	FC-2605	NAV EXTENDED VERBS		C-5,7	
ORDERSW	FC-2310	CONIC SUBROUTINES			T-36,37
ORIGCHNG	FC-2300	ORB INTEGRATION	ENTRY 44		
OTHPREC	FC-2631	R36 (V90)	CALLED 4		
OTHPREC	FC-2650	ORB PARAM DISPLAY	CALLED 7		
OVERFFIX	FC-2530	PRELAUNCH INIT	ENTRY 36		
PARAM	FC-2310	CONIC SUBROUTINES	ENTRY 33		
PARAM	FC-2642	RETURN TO EARTH	CALLED 35		
PASSIVE	FC-2626	P32, P72 - CSI	CALLED 3		
PASSIVE	FC-2627	P33, P73 - CDH	CALLED 2		
PCOPY	FC-2430	TVC ROUTINES	CALLED 12		
PCOPY	FC-2440	TVC DAP	ENTRY 8		
PDSPFLAG	FC-2340	ATTITUDE MANEUVER	S-8		T-4,8
PDSPFLAG	FC-2550	P20 RENDEZVOUS NAV	S-10	C-10	T-34
PERIAPO	FC-2545	TPI SEARCH PROG	CALLED 9		
PERIAPO	FC-2626	P32, P72 - CSI	CALLED 13		
PERIAPOI	FC-2620	P30, P31	CALLED 4,8		
PERIAPO1	FC-2626	P32, P72 - CSI	CALLED 16		
PERIAPO1	FC-2630	TPI TARGETTING	CALLED 5		
PERIAPO1	FC-2644	P38-P78; P39-P79	CALLED 7		
PFAILOK	FC-2200	T4RUPT	CALLED 37		
PFRATFLG	FC-2680	THRUST PROGRAMS	S-6		
PFRATFLG	FC-2720	IMU REALIGN PROG		C-4,20	
PHASCHNG	FC-2030	PHASE TABLE MAINT	ENTRY 5		
PICAPAR	FC-2720	IMU REALIGN PROG	ENTRY 13		

PINBRNCH	FC-2370	DAP INTER-SERV ROUT	CALLED 2,5		
PINBRNCH	FC-2605	NAV EXTENDED VERBS	CALLED 2,6,7		
PIPACHK	FC-2530	PRELAUNCH INIT	ENTRY 6		
PIPASR	FC-2683	SERVICER	ENTRY 9		
PIPATASK	FC-2530	PRELAUNCH INIT	ENTRY 7		
PIPFAIL	FC-2200	T4RUPT	ENTRY 41		
PIPFREE	FC-2683	SERVICER	CALLED 19		
PIPJOBB	FC-2530	PRELAUNCH INIT	ENTRY 8		
PITCHDAP	FC-2440	TVC DAP	ENTRY 2		
PITCHDAP	FC-2430	TVC ROUTINES	CALLED 6		
PITCHTIM	FC-2400	RCS DAP JET SELECT	ENTRY 11		
PLANET	FC-2710	P51, P53 IMU ORIENT	ENTRY 7		
PLANET	FC-2720	IMU REALIGN PROG	CALLED 18,19		
POINTAXS	FC-2600	CISLUNAR MID NAV	ENTRY 13		
POLY	FC-2310	CONIC SUBROUTINES	CALLED 25,28		
POLY	FC-2642	RETURN TO EARTH	CALLED 4,6,11		
POODOO	FC-2140	ALARM AND ABORT	ENTRY 3		
POODOO	FC-2060	WAITLIST	CALLED 9		
POODOO	FC-2300	ORB INTEGRATION	CALLED 22		
POOKLEAN	FC-2020	FRESH START	ENTRY 7		
POSN17C	FC-2530	PRELAUNCH INIT	ENTRY 36		
POSTBURN	FC-2630	TPI TARGETTING	ENTRY 29		
POSTJUMP	FC-2080	INT BNK COMMUN	ENTRY 2		
POST41	FC-2630	TPI TARGETTING	ENTRY 30		
POST41	FC-2681	CLOKTASK-CLOCKJOB	CALLED 5		
POWRSERS	FC-2540	EARTH ORBIT INSERT	CALLED 11		
PRECIFLG	FC-2290	INTEG INITIAL	S-4,6,8	C-4	
PRECIFLG	FC-2300	ORB INTEGRATION		C-40	T-5
PRECOMP	FC-2440	TVC DAP	ENTRY 7		

PREC/TT	FC-2644 P38-P78; P39-P79	ENTRY 11			
PRECSET	FC-2626 P32, P72 - CSI	CALLED 9			
PRECSET	FC-2630 TPI TARGETTING	CALLED 4			
PRECSET	FC-2640 TPM TARGETTING	CALLED 1			
PRECSET	FC-2644 P38-P78; P39-P79	CALLED 10,11			
PREC100	FC-2642 RETURN TO EARTH	ENTRY 34			
PREREAD	FC-2680 THRUST PROGRAMS	CALLED 15			
PREREAD	FC-2683 SERVICER	ENTRY 3,4,11,15			
PREREAD	FC-2700 P47 THRUST MONITOR	CALLED 4			
PREREAD	FC-2760 ENTRY PROGRAMS	CALLED 11			
PREREAD1	FC-2683 SERVICER	ENTRY 3			
PREREAD1	FC-2540 EARTH ORBIT INSERT	CALLED 4			
PRESWTCH	FC-2430 TVC ROUTINES	ENTRY 20			
PREVGAM	FC-2320 TEECONICS	ENTRY 11			
PREVGAM	FC-2760 ENTRY PROGRAMS	CALLED 14,15			
PRE40.6	FC-2680 THRUST PROGRAMS	ENTRY 44			
PRE40.6	FC-2681 CLOKTASK-CLOCKJOB	CALLED 13			
PRETRKAT	FC-2190 EXTENDED VERBS	S-3	C-3	T-5	
PRETRKAT	FC-2361 V89 (R63)	S-3	C-3	T-5	
PRETRKAT	FC-2550 P20 RENDEZVOUS NAV	S-3			
PRIOCHNG	FC-2340 ATTITUDE MANEUVER	CALLED 8			
PRIOCHNG	FC-2370 DAP INTER-SERV ROUT	CALLED 5			
PRIOCHNG	FC-2550 P20 RENDEZVOUS NAV	CALLED 6,19,31			
PRIOCHNG	FC-2650 ORB PARAM DISPLAY	CALLED 2			
PRIOCHNG	FC-2700 P47 THRUST MONITOR	CALLED 5			
PRIOLARM	FC-2140 ALARM AND ABORT	ENTRY 3			
PROCKEY	FC-2200 T4RUPT	CALLED 5			
PROG21	FC-2580 P21 GRD TRACK DET	ENTRY 2			
PROG20	FC-2550 P20 RENDEZVOUS NAV	ENTRY 3			

PROG22	FC-2590	P22 ORBITAL NAV	ENTRY 2		
PROG52	FC-2720	IMU REALIGN PROG	ENTRY 1		
PROUT	FC-2530	PRELAUNCH INIT	ENTRY 37		
PROUT	FC-2540	EARTH ORBIT INSERT	CALLED 5		
PTHPREC	FC-2670	TARGET DELTA V PROG	CALLED 2		
PTOACSM	FC-2290	INTEG INITIAL	ENTRY 5		
PTOALEM	FC-2290	INTEG INITIAL	ENTRY 5		
PULSEIMU	FC-2100	SINGLE PREC SUBROUTS	ENTRY 12		
P11	FC-2540	EARTH ORBIT INSERT	ENTRY 3		
P17	FC-2545	TPI SEARCH PROG	ENTRY 3		
P17.1	FC-2545	TPI SEARCH PROG	ENTRY 3		
P17.2	FC-2545	TPI SEARCH PROG	ENTRY 5		
P17.3	FC-2545	TPI SEARCH PROG	ENTRY 12		
P20FLGON	FC-2545	TPI SEARCH PROG	CALLED 3		
P20FLGON	FC-2627	P33, P73 - CDH	CALLED 1		
P20FLGON	FC-2630	TPI TARGETTING	CALLED 2		
P20FLGON	FC-2640	TPM TARGETTING	CALLED 6		
P20FLGON	FC-2644	P38-P78; P39-P79	CALLED 3,9		
P21FLAG	FC-2580	P21 GRD TRACK DET	S-4		T-3
P22MKFLG	FC-2590	P22 ORBITAL NAV	S-9	C-4	
P22SUBRB	FC-2600	CISLUNAR MID NAV	CALLED 6		
P23	FC-2600	CISLUNAR MID NAV	ENTRY 3		
P3XORP7X	FC-2626	P32, P72 - CSI	ENTRY 23		
P30	FC-2620	P30, P31	ENTRY 2		
P30/P31	FC-2620	P30, P31	ENTRY 2		
P31	FC-2620	P30, P31	ENTRY 7		
P32	FC-2626	P32, P72 - CSI	ENTRY 2		
P33	FC-2627	P33, P73 - CDH	ENTRY 1		
P34	FC-2630	TPI TARGETTING	ENTRY 2		

P35	EC-2640	TPM TARGETTING	ENTRY 1		
P37	FC-2642	RETURN TO EARTH	ENTRY 3		
P38	EC-2644	P38-P78; P39-P79	ENTRY 3		
P39	FC-2644	P38-P78; P39-P79	ENTRY 9		
P39/79SW	FC-2644	P38-P78; P39-P79	S-9		T-6,8
P40CNV85	FC-2680	THRUST PROGRAMS	CALLED 11		
P40CNV85	FC-2681	CLOKTASK-CLOCKJOB	CALLED 4		
P40CSM	FC-2630	TPI TARGETTING	ENTRY 4		
P40RCS	FC-2630	TPI TARGETTING	ENTRY 29		
P40RCS	FC-2681	CLOKTASK-CLOCKJOB	CALLED 7		
P41CSM	FC-2630	TPI TARGETTING	ENTRY 5		
P47BODY	FC-2700	P47 THRUST MONITOR	ENTRY 5		
P47CSM	FC-2700	P47 THRUST MONITOR	ENTRY 3		
P51	FC-2710	P51, P53 IMU ORIENT	ENTRY 2		
P52LS	FC-2720	IMU REALIGN PROG	ENTRY 7		
P72	FC-2626	P32, P72 - CSI	ENTRY 2		
P73	FC-2627	P33, P73 - CDH	ENTRY 1		
P74	FC-2630	TPI TARGETTING	ENTRY 2		
P75	FC-2640	TPM TARGETTING	ENTRY 1		
P76SUB1	FC-2670	TARGET DELTA V PROG	ENTRY 3		
P77	FC-2545	TPI SEARCH PROG	ENTRY 3		
P78	FC-2644	P38-P78; P39-P79	ENTRY 3		
P79	FC-2644	P38-P78; P39-P79	ENTRY 9		
QUICTRIG	FC-2681	CLOKTASK-CLOCKJOB	CALLED 4		
QUIKDSP	FC-2200	T4RUPT	ENTRY 46		
QUIKREAD	FC-2683	SERVICER	ENTRY 12		
QUITFLAG	FC-2290	INTEG INITIAL		C-3	T-3
QUITFLAG	FC-2300	ORB INTEGRATION			T-3
RADSTALL	FC-2550	P20 RENDEZVOUS NAV	CALLED 32		

RANGERD	FC-2550	P20 RENDEZVOUS NAV	ENTRY 32		
RATELIM	FC-2460	ROLL AUTOPILOT	ENTRY 4		
RCSATT	FC-2370	DAP INTER-SERV ROUT	CALLED 3		
RCSATT	FC-2380	RCS DAP INIT	ENTRY 2		
RCSATT	FC-2390	RCS DAP PHASE 2	CALLED 1,2		
RCSATT	FC-2400	RCS DAP JET SHEFT	CALLED I6		
RCSDAPON	FC-2370	DAP INTER-SERV ROUT	ENTRY 3		
RCSDAPON	FC-2020	FRESH START	CALLED 31		
RCSDAPON	FC-2380	RCS DAP INIT	CALLED 2		
RCSDAPON	FC-2460	ROLL AUTOPILOT	CALLED 2		
RCSDAPON	FC-2680	THRUST PROGRAMS	CALLED 25		
RCSDAPON	FC-2681	CLOKTASK-CLOCKJOB	CALLED 9,13		
RCSDAPUP	FC-2370	DAP INTER-SERV ROUT	ENTRY 3		
RCSFLAGS	FC-2350	MANEUV CALC & STEER	S-10	C-26	
RCSFLAGS	FC-2370	DAP INTER-SERV ROUT	S-3,15,14	C-14	T-14
RCSFLAGS	FC-2380	RCS DAP INIT	S-2,3,8,5	C-8,5	T-3,5
RCSFLAGS	FC-2390	RCS DAP PHASE 2	S-1	C-1,7	T-1,2,3,4,7
RCSFLAGS	FC-2400	RCS DAP JET SELECT	S-17	C-16	T-17
RCSFLAGS	FC-2430	TVC ROUTINES	S-5		
RCSFLAGS	FC-2540	EARTH ORBIT INSERT	S-4,17,20		
RCSUP	FC-2380	RCS DAP INIT	ENTRY 2		
RDCDUS	FC-2720	IMU REALIGN PROG	ENTRY 27		
READACCS	FC-2683	SERVICER	ENTRY 6		
READCDUK	FC-2350	MANEUV CALC & STEER	ENTRY 24		
READCDUK	FC-2340	ATTITUDE MANEUVER	CALLED 5		
READPIPS	FC-2100	SINGLE PREC SUBROUTS	ENTRY 4		
RECT.1	FC-2600	CISLUNAR MID NAV	ENTRY 17		
RECTIFY	FC-2300	ORB INTEGRATION	ENTRY 43		
RECTIFY	FC-2290	INTEG INITIAL	CALLED 8,9		

RECTIFY	FC-2610	MEASUREMENT INCORP	CALLED 11		
RECTIFY+	FC-2290	INTEG INITIAL	CALLED 14		
RECTOUT	FC-2300	ORB INTEGRATION	ENTRY 40		
RECTOUT	FC-2290	INTEG INITIAL	CALLED 9		
REDO	FC-2530	PRELAUNCH INIT	ENTRY 31		
REDORCS	FC-2380	RCS DAP INIT	ENTRY 2		
REDOSAT	FC-2540	EARTH ORBIT INSERT	ENTRY 20		
REDOSAT	FC-2370	DAP INTER-SERV ROUT	CALLED 4		
REDOTVC	FC-2430	TVC ROUTINES	ENTRY 12		
REFFLG	FC-2720	IMU REALIGN PROG			T-20
REFA7E10	FC-2760	ENTRY PROGRAMS	CALLED 7		
REFSMFLG	FC-2200	T4RUPT		C-32,33	
REFSMFLG	FC-2540	EARTH ORBIT INSERT	S-8		
REFSMFLG	FC-2550	P20 RENDEZVOUS NAV			T-6,31
REFSMFLG	FC-2600	CISLUNAR MID NAV			T-4
REFSMFLG	FC-2620	P30, P31			T-5,9
REFSMFLG	FC-2626	P32, P72 - CSI			T-6
REFSMFLG	FC-2710	P51, P53 IMU ORIENT	S-6	C-6	
REFSMFLG	FC-2720	IMU REALIGN PROG	S-4,5	C-3	
REINTFLA	FC-2670	TARGET DELTA V PROG	S-3		
REINTFLG	FC-2140	ALARM AND ABORT		C-6	
REINTFLG	FC-2290	INTEG INITIAL		C-13	T-10,12
REINTFLG	EC-2300	ORB INTEGRATION	S-33,38		
REINTFLG	FC-2610	MEASUREMENT INCOR	S-7		
RELDSP	FC-2020	FRESH START	CALLED 32,37,42		
RENDWFLG	FC-2290	INTEG INITIAL		C-14	T-4,16
RENDWFLG	FC-2300	ORB INTEGRATION		C-37	
RENDWFLG	FC-2550	P20 RENDEZVOUS NAV	S-23		T-4,21,23
RENDWFLG	FC-2590	P22 ORBITAL NAV		C-3,11	

RENDWFLG	FC-2600	CISLUNAR MID NAV		C-6	
RENDWFLG	FC-2605	NAV EXTENDED VERBS		C-5,7	
REPLACER	FC-2400	RCS DAP JET SELECT	ENTRY 19		
REPLACEY	FC-2400	RCS DAP JET SELECT	ENTRY 19		
REP11	FC-2540	EARTH ORBIT INSERT	ENTRY 6		
REREADAC	FC-2683	SERVICER	ENTRY 10		
RESETX2	FC-2310	CONIC SUBROUTINES	ENTRY 30		
RESTARTS	FC-2020	FRESH START	ENTRY 43		
RETROFLG	FC-2642	RETURN TO EARTH	S-16	C-16	T-31
RLIMTEST	FC-2440	TVC DAP	ENTRY 15		
RNDREFDR	FC-2200	T4RUPT	CALLED 31,32		
RNDVZFLG	FC-2200	T4RUPT		C-33	
RNDVZFLG	FC-2550	P20 RENDEZVOUS NAV	S-3	C-8	T-8,17
RNDVZFLG	FC-2590	P22 ORBITAL NAV		C-3	
RNDVZFLG	FC-2600	CISLUNAR MID NAV		C-3	
RNDVZFLG	FC-2683	SERVICER			T-20
ROLLDAP	FC-2460	ROLL AUTOPILOT	ENTRY 1		
ROLLTIME	FC-2400	RCS DAP JET SELECT	ENTRY 9		
ROLLDAP	FC-2430	TVC ROUTINES	CALLED 7		
ROTA	FC-2730	R52, R53, R56	ENTRY 10		
ROTATE	FC-2626	P32, P72 - CSI	ENTRY 9		
ROUTINER	FC-2070	SERVICE ROUTINES	ENTRY 12		
RPOFLAG	FC-2290	INTEG INITIAL	S-8		
RPOFLAG	FC-2300	ORB INTEGRATION	S-22		T-44
RP-TO-R	FC-2290	INTEG INITIAL	CALLED 21		
RP-TO-R	FC-2300	ORB INTEGRATION	CALLED 20		
RP-TO-R	FC-2590	P22 ORBITAL NAV	CALLED 7,14		
RP-TO-R	FC-2595	LUNAR LAND SELECT	CALLED 10,11		
RP-TO-R	FC-2720	IMU REALIGN PROG	CALLED 7		

RP-TO-R	FC-2730	R52, R53, R53	CALLED 9		
RTEVN	FC-2642	RETURN TO EARTH	ENTRY 28		
RVCON	FC-2290	INTEG INITIAL	ENTRY 9		
RVSW	FC-2310	CONIC SUBROUTINES			T-22
RVSW	FC-2545	TPI SEARCH PROG	S-6		
RVSW	FC-2595	LUNAR LAND SELECT	S-13		
RVSW	FC-2626	P32, P72 - CSI	S-13,14		
RVSW	FC-2627	P33, P73 - CDH		C-8	
RVSW	FC-2630	TPI TARGETTING	S-4		
RVSW	FC-2642	RETURN TO EARTH	S-37	C-13,27	
R-TO-RP	FC-2300	ORB INTEGRATION	CALLED 15		
R-TO-RP	FC-2590	P22 ORBITAL NAV	CALLED 13,21		
R02BOTH	FC-2190	PINBALL	CALLED 2,3		
R02BOTH	FC-2360	-S-BAND ANTENNA	CALLED 3		
R02BOTH	FC-2361	V89 (R63)	CALLED 2		
R02BOTH	FC-2550	P20 RENDEZVOUS NAV	CALLED 3		
R02BOTH	FC-2590	P22 ORBITAL NAV	CALLED 3		
R02BOTH	FC-2680	THRUST PROGRAMS	CALLED 6		
R02BOTH	FC-2700	P47 THRUST MONITOR	CALLED 3		
R02BOTH	FC-2720	IMU REALIGN PROG	CALLED 1		
R02BOTH	FC-2760	ENTRY PROGRAMS	CALLED 10		
R21MARK	FC-2550	P20 RENDEZVOUS NAV	S-18	C-18	
R21MARK	FC-2780	ENT DIG AUTOPILOT			T-7
R22	FC-2550	P20 RENDEZVOUS NAV	ENTRY 19		
R23CSM	FC-2550	P20 RENDEZVOUS NAV	ENTRY 18		
R23FLG	FC-2550	P20 RENDEZVOUS NAV	S-17	C-17	T-17,18,25
R23.55	FC-2600	CISLUNAR MID NAV	ENTRY 10		
R31FLAG	FC-2325	RENDEZ PAR DISPLAY	S-2	C-2	T-3,4
R36	FC-2631	R36 (V90)	ENTRY 3		

R51	FC-2720 IMU REALIGN PROG	ENTRY 18		
R52	FC-2730 R52, R53, R56	ENTRY 2		
R52	FC-2550 P20 RENDEZVOUS NAV	CALLED 7		
R52	FC-2590 P22 ORBITAL NAV	CALLED 4		
R52	FC-2600 CISLUNAR MID NAV	CALLED 8		
R52	FC-2720 IMU REALIGN PROG	CALLED 19		
R53	FC-2730 R52, R53, R56	ENTRY 11		
R53	FC-2600 CISLUNAR MID NAV	CALLED 4		
R53	FC-2710 P51, P53 IMU ORIENT	CALLED 4		
R53FLAG	FC-2730 R52, R53, R56	S-11		T-3
R55	FC-2720 IMU REALIGN PROG	ENTRY 26		
R56	FC-2730 R52, R53, R56	ENTRY 14		
R56	FC-2710 P51, P53 IMU ORIENT	CALLED 4		
R56	FC-2720 IMU REALIGN PROG	CALLED 19		
R57	FC-2242 OPTICS CAL ROUTINE	ENTRY 1		
R57	FC-2600 CISLUNAR MID NAV	CALLED 4,8		
R57FLAG	FC-2600 CISLUNAR MID NAV	S-8	C-3,9	T-8
R60CSM	FC-2340 ATTITUDE MANEUVER	ENTRY 2		
R60CSM	FC-2190 PINBALL	CALLED 3		
R60CSM	FC-2330 CREW DEF MANEUVER	CALLED 3		
R60CSM	FC-2361 V89 (R63)	CALLED 3		
R60CSM	FC-2550 P20 RENDEZVOUS NAV	CALLED 10		
R60CSM	FC-2600 CISLUNAR MID NAV	CALLED 8		
R60CSM	FC-2680 THRUST PROGRAMS	CALLED 8		
R61CSM	FC-2550 P20 RENDEZVOUS NAV	ENTRY 10		
R61CSM	FC-2730 R52, R53, R53	CALLED 4		
R62DISP	FC-2330 CREW DEF MANEUVER	ENTRY 3		
R63	FC-2190 EXTENDED VERBS	ENTRY 4		
R63	FC-2361 V89 (R63)	ENTRY 4		

R63	FC-2550	P20 RENDEZVOUS NAV	CALLED 11		
SATSTICK	FC-2540	EARTH ORBIT INSERT	ENTRY 21		
SATSTKON	FC-2370	DAP INTER-SERV ROUT	ENTRY 4		
SATSTKON	FC-2540	EARTH ORBIT INSERT	ENTRY 19		
SAVECFLG	FC-2600	CISLUNAR MID NAV	S-9	C-4	T-6
SBANDANT	FC-2360	-S-BAND ANTENNA	ENTRY 3		
SCNDSOL	FC-2626	P32, P72 - CSI	ENTRY 21		
SELECTMU	FC-2630	TPI TARGETTING	ENTRY 17		
SELECTMU	FC-2626	P32, P72 - CSI	CALLED 2		
SELECTMU	FC-2627	P33, P73 - CDH	CALLED 1		
SELECTMU	FC-2640	TPM TARGETTING	CALLED 1		
SELECTMU	FC-2644	P38-P78; P39-P79	CALLED 4,9		
SELFCHK	FC-2080	INT BNK COMMUN	ENTRY 3		
SELFCHK	FC-2120	AGC SELFCHECK	ENTRY 2		
SERVEXIT	FC-2683	SERVICER	ENTRY 21		
SERVEXIT	FC-2682	STEERING	CALLED 4,5		
SERVEXIT	FC-2700	P47 THRUST MONITOR	CALLED 7		
SERVICER	FC-2683	SERVICER	ENTRY 13		
SERVNOUT	FC-2760	ENTRY PROGRAMS	CALLED 7		
SETCOARS	FC-2200	T4RUPT	CALLED 43		
SETGWLST	FC-2530	PRELAUNCH INIT	ENTRY 14		
SETINTG	FC-2600	CISLUNAR MID NAV	ENTRY 14		
SETISSW	FC-2200	T4RUPT	ENTRY 30		
SETJTAG	FC-2683	SERVICER	CALLED 7		
SETMAXDB	FC-2370	DAP INTER-SERV ROUT	ENTRY 16		
SETMAXDB	FC-2630	TPI TARGETTING	ENTRY 25		
SETMAXDB	FC-2020	FRESH START	CALLED 25		
SETMINDB	FC-2370	DAP INTER-SERV ROUT	ENTRY 16		
SETMINDB	FC-2630	TPI TARGETTING	ENTRY 7		

SETMINDB	FC-2020	FRESH START	CALLED 25		
SETRF	FC-2590	P22 ORBITAL NAV	CALLED 24		
SETT5	FC-2380	RCS DAP INIT	ENTRY 2		
SETVOARS	FC-2020	FRESH START	CALLED 19		
SET1/PDT	FC-2720	IMU REALIGN PROG	CALLED 23		
SGNAGREE	FC-2100	SINGLE PREC SUBROUTS	ENTRY 5		
SGNAGREE	FC-2300	ORB INTEGRATION	CALLED 4		
SGNAGREE	FC-2631	R36 (V90)	CALLED 6		
SGNAGREE	FC-2710	P51, P53 IMU ORIENT	CALLED 9		
SHOW	FC-2530	PRELAUNCH INIT	ENTRY 25		
SIGNMPAC	FC-2100	SINGLE PREC SUBROUTS	ENTRY 14		
SIGNMPAC	FC-2300	ORB INTEGRATION	CALLED 5		
SIGNMPAC	FC-2320	TFFCONICS	CALLED 9		
SIGNMPAC	FC-2350	MANEUV CALC & STEER	CALLED 7,16,17,18,19,20		
SKIPVHF	FC-2550	P20 RENDEZVOUS NAV		C-32	T-34
SLAPI	FC-2020	FRESH START	ENTRY 2		
SLOPESW	FC-2310	CONIC SUBROUTINES	S-10,14	C-36	T-12,18,36
SLOWFLG	FC-2642	RETURN TO EARTH	S-4	C-4	T-20
SMALLMP	FC-2370	DAP INTER-SERV ROUT	ENTRY 20		
SMCDURES	FC-2550	P20 RENDEZVOUS NAV	CALLED 13		
SMNB	FC-2190	PINBALL	CALLED 4		
SMNB	FC-2360	-S-BAND ANTENNA	CALLED 4		
SMNB	FC-2550	P20 RENDEZVOUS NAV	CALLED 14		
SMNB	FC-2682	STEERING	CALLED 11		
SMNB	FC-2700	P47 THRUST MONITOR	CALLED 8		
SOLNSW	FC-2310	CONIC SUBROUTINES	S-12,19,21,23	C-10,14,24	
SOMEERRR	FC-2530	PRELAUNCH INIT	ENTRY 37		
SOMERR2	FC-2530	PRELAUNCH INIT	ENTRY 37		
SOPTION	FC-2120	AGC SELFCHECK	ENTRY 13		

SPCOS	FC-2110	SINGLE PREC SUBROUTS	ENTRY 2		
SPSIN	FC-2110	SINGLE PREC SUBROUTS	ENTRY 2		
SPSOFF	FC-2630	TPI TARGETTING	ENTRY 27		
SPSOFF	FC-2020	FRESH START	CALLED 30		
SPSOFF	FC-2681	CLOKTASK-CLOCKJOB	CALLED 9,12		
SR30.1	FC-2650	ORB PARAM DISPLAY	ENTRY 15		
SR52.1	FC-2730	R52, R53, R56	ENTRY 6		
STABLISH	FC-2370	DAP INTER-SERV ROUT	ENTRY 2		
STARIND	FC-2710	P51, P53 IMU ORIENT	S-6	C-4	T-5
STARIND	FC-2720	IMU REALIGN PROG	S-18		T-19,20
SOURCFLG	FC-2550	P20 RENDEZVOUS NAV	S-33	C-20	T-24,26,27, 29,30
STARTEN1	FC-2760	ENTRY PROGRAMS	CALLED 2		
STARTSB2	FC-2020	FRESH START	ENTRY 8		
STARTSUB	FC-2020	FRESH START	ENTRY 8		
STARTSW	FC-2020	FRESH START	ENTRY 2		
STATEFLG	FC-2140	ALARM AND ABORT		C-6	
STATEFLG	FC-2290	INTEG INITIAL	S-3	C-3	
STATEFLG	FC-2300	ORB INTEGRATION	S-37	C-3,38	T-38
STATEFLG	FC-2550	P20 RENDEZVOUS NAV	S-7		
STATEFLG	FC-2590	P22 ORBITAL NAV	S-10,18		
STATEFLG	FC-2600	CISLUNAR MID NAV	S-14		
STATINT	FC-2290	INTEG INITIAL	ENTRY 3		
STATINT1	FC-2290	INTEG INITIAL	ENTRY 3		
STEERING	FC-2683	SERVICER	CALLED 15		
STEERSW	FC-2680	THRUST PROGRAMS	S-23		
STEERSW	FC-2681	CLOKTASK- CLOCKJOB	S-10		
STEERSW	FC-2682	STEERING		C-12,13	T-9
STICKCHK	FC-2370	DAP INTER-SERV ROUT	ENTRY 16		

STICKCHK	FC-2540	EARTH ORBIT INSERT	CALLED 21		
STIKFLAG	FC-2370	DAP INTER-SERV ROUT		C-11	
STIKFLAG	FC-2390	RCS DAP PHASE 2	S-2		
STOPRATE	FC-2350	MANEUV CALC & STEER	ENTRY 26		
STOPRATE	FC-2020	FRESH START	CALLED 21,25		
STOPRATE	FC-2550	P20 RENDEZVOUS NAV	CALLED 9		
STRKTST1	FC-2450	STROKE TEST PKG	ENTRY 1		
STROKON	FC-2450	STROKE TEST PKG	ENTRY 1		
STRULLSW	FC-2680	THRUST PROGRAMS	S-21	C-21	T-23
STSHOSUM	FC-2120	AGC SELFCHECK	ENTRY 7		
SUPDACAL	FC-2080	INT BNK COMMUN	ENTRY 3		
SUPDACAL	FC-2120	AGC SELFCHECK	CALLED 9		
SUPERSW	FC-2080	INT BNK COMMUN	ENTRY 2		
SURFFLAG	FC-2290	INTEG INITIAL			T-4,5,18
SURFFLAG	FC-2325	RENDEZ PAR DISPLAY			T-8,9,10
SVDWN1	FC-2290	INTEG INITIAL	CALLED 5		
SVDWN1	FC-2610	MEASUREMENT INCORP	CALLED 11		
SVDWN2	FC-2290	INTEG INITIAL	CALLED 5		
SVDWN2	FC-2610	MEASUREMENT INCORP	CALLED 11		
SWCALL	FC-2080	INT BNK COMMUN	ENTRY 1		
SWICHOVR	FC-2430	TVC ROUTINES	ENTRY 20		
SWICHOVR	FC-2370	DAP INTER-SERV ROUT	CALLED 2		
SWRETURN	FC-2080	INT BNK COMMUN	ENTRY 1		
SWTOVER	FC-2430	TVC ROUTINES	S-20	C-3	
SXTMARK	FC-2730	R52, R53, R53	CALLED 11,14		
SXTNB	FC-2325	RENDEZ PAR DISPLAY	CALLED 6		
SXTNB	FC-2550	P20 RENDEZVOUS NAV	CALLED 38		
SXTNB	FC-2730	R52, R53, R53	CALLED 13		
SXTSM	FC-2730	R52, R53, R56	ENTRY 13		

SXTSM	FC-2710	P5I, P53 IMU ORIENT	CALLED 5		
SXTSM	FC-2720	IMU REALIGN PROG	CALLED 19		
SYSTEST	FC-2530	PRELAUNCH INIT	ENTRY 31		
S11.1	FC-2540	EARTH ORBIT INSERT	ENTRY 18		
S11.1	FC-2700	P47 THRUST MONITOR	CALLED 6		
S17.1	FC-2545	TPI SEARCH PROG	ENTRY 3		
S17.2	FC-2545	TPI SEARCH PROG	ENTRY 6		
S22.1	FC-2590	P22 ORBITAL NAV	ENTRY 9		
S30.1	FC-2620	P30, P31	ENTRY 2		
S31.I	FC-2620	P30, P31	ENTRY 7		
S32.IF1	FC-2626	P32, P72 - CSI		C-11,21	T-12
S32.1F2	FC-2626	P32, P72 - CSI	S-11,21	C-18	T-18
S32.1F3A	FC-2626	P32, P72 - CSI	S-18,19	C-11,21	T-12,18,21
S32/33.X	FC-2626	P32, P72 - CSI	ENTRY 8		
S32/33.1	FC-2626	P32, P72 - CSI	ENTRY 5		
S32/33.1	FC-2627	P33, P73 - CDH	CALLED 4		
S32,1F3B	FC-2626	P32, P72 - CSI	S-11,19	C-18,21	T-12,18,21
S33/34.1	FC-2630	TPI TARGETTING	ENTRY 6		
S33/34.1	FC-2627	P33, P73 - CDH	CALLED 3		
S33-34.1	FC-2630	TPI TARGETTING	ENTRY 6		
S34/35.1	FC-2630	TPI TARGETTING	ENTRY 6		
S34/35.1	FC-2640	TPM TARGETTING	CALLED 1		
S34/35.1	FC-2644	P38-P78; P39-P79	CALLED 11		
S34/35.2	FC-2630	TPI TARGETTING	ENTRY 11		
S34/35.2	FC-2640	TPM TARGETTING	CALLED 2		
S34/35.3	FC-2630	TPI TARGETTING	ENTRY 13		
S34/35.4	FC-2630	TPI TARGETTING	ENTRY 16		
S34/35.5	FC-2630	TPI TARGETTING	ENTRY 16		
S34/35.5	FC-2640	TPM TARGETTING	CALLED 2		

S3435.25	FC-2630	TPI TARGETTING	ENTRY 11		
S3435.25	FC-2644	P38-P78; P39-P79	CALLED 6,10		
S40.1	FC-2680	THRUST PROGRAMS	ENTRY 32		
S40.13	FC-2630	TPI TARGETTING	ENTRY 17		
S40.13	FC-2681	CLOKTASK-CLOCKJOB	CALLED 14		
S40.14	FC-2370	DAP INTER-SERV ROUT	ENTRY 10		
S40.14	FC-2380	RCS DAP INIT	CALLED 6		
S40.14	FC-2460	ROLL AUTOPILOT	CALLED 6		
S40.15	FC-2430	TVC ROUTINES	CALLED 3,8		
S40.2,3	FC-2680	THRUST PROGRAMS	ENTRY 40		
S40.6	FC-2680	THRUST PROGRAMS	ENTRY 44		
S41.1	FC-2700	P47 THRUST MONITOR	ENTRY 8		
S41.1	FC-2682	STEERING	CALLED 5		
S41.2	FC-2370	DAP INTER-SERV ROUT	ENTRY 8		
S41.2	FC-2380	RCS DAP INIT	CALLED 6		
S41.2	FC-2460	ROLL AUTOPILOT	CALLED 6		
S50	FC-2720	IMU REALIGN PROG	ENTRY 11		
S52.2	FC-2720	IMU REALIGN PROG	ENTRY 9		
S52.3	FC-2720	IMU REALIGN PROG	ENTRY 10		
TAR/EREF	FC-2530	PRELAUNCH INIT	ENTRY 45		
TARGDRVE	FC-2530	PRELAUNCH INIT	ENTRY 43		
TARG1FLG	FC-2340	ATTITUDE MANEUVER			T-8
TARG1FLG	FC-2550	P20 RENDEZVOUS NAV	S-6		
TARG1FLG	FC-2590	P22 ORBITAL NAV		C-7	
TARG1FLG	FC-2600	CISLUNAR MID NAV		C-3	
TARG1FLG	FC-2720	IMU REALIGN PROG	S-18		
TARG1FLG	FC-2730	R52, R53, R56			T-3,4,6
TARG2FLG	FC-2590	P22 ORBITAL NAV	S-7		
TARG2FLG	FC-2600	CISLUNAR MID NAV		C-3	

TARG2FLG	FC-2710	P51, P53 IMU ORIENT		C-4	
TARG2FLG	FC-2720	IMU REALIGN PROG	S-18		
TARG2FLG	FC-2730	R52, R53, R56			T-6
TASKOVER	FC-2060	WAITLIST	ENTRY 18		
TERMIMFL	FC-2730	R52, R53, R56		C-2,12	T-4
TESTLOOP	FC-2300	ORB INTEGRATION	ENTRY 3		
TESTLOOP	FC-2290	INTEG INITIAL	CALLED 8		
TESTXACT	FC-2190	PINBALL	CALLED 2		
TESTXACT	FC-2325	RENDEZ PAR DISPLAY	CALLED 2		
TESTXACT	FC-2330	CREW DEF MANEUVER	CALLED 2		
TESTXACT	FC-2360	-S-BAND ANTENNA	CALLED 2		
TESTXACT	FC-2361	V89 (R63)	CALLED 2		
TESTXACT	FC-2370	DAP INTER-SERV ROUT	CALLED 5		
TESTXACT	FC-2595	LUNAR LAND SELECT	CALLED 3		
TESTXACT	FC-2605	NAV EXTENDED VERBS	CALLED 2		
TESTXACT	FC-2631	R36 (V90)	CALLED 2		
TESTXACT	FC-2650	ORB PARAM DISPLAY	CALLED 2		
TFFCONIC	FC-2320	TFFCONICS	ENTRY 3		
TFFCONIC	FC-2760	ENTRY PROGRAMS	CALLED 12		
TFFCONMU	FC-2320	TFFCONICS	ENTRY 3		
TFFCONMU	FC-2650	ORB PARAM DISPLAY	CALLED 16		
TFFRP/RA	FC-2320	TFFCONICS	ENTRY 4		
TFFRP/RA	FC-2650	ORB PARAM DISPLAY	CALLED 16		
TFF/TRIG	FC-2320	TFFCONICS	ENTRY 11		
TFF/TRIG	FC-2760	ENTRY PROGRAMS	CALLED 12,14		
TFFSW	FC-2320	TFFCONICS	S-5	C-5	T-5
THISPREC	FC-2620	P30, P31	CALLED 3		
THISPREC	FC-2631	R36 (V90)	CALLED 4		
THISPREC	FC-2650	ORB PARAM DISPLAY	CALLED 7		

THISPREC	FC-2680	THRUST PROGRAMS	CALLED 38		
TICKTEST	FC-2650	ORB PARAM DISPLAY	ENTRY 14		
TIGAVEG	FC-2630	TPI TARGETTING	ENTRY 15		
TIGBLNK	FC-2630	TPI TARGETTING	ENTRY 14		
TIGNOW	FC-2630	TPI TARGETTING	ENTRY 30		
TIGON	FC-2700	P47 THRUST MONITOR	ENTRY 4		
TIG-0	FC-2630	TPI TARGETTING	ENTRY 20		
TIG-5	FC-2630	TPI TARGETTING	ENTRY 16		
TIMERAD	FC-2310	CONIC SUBROUTINES	ENTRY 23		
TIMERAD	FC-2642	RETURN TO EARTH	CALLED 27,37		
TIMERFLG	FC-2620	P30, P31	S-6,10	C-6,10	
TIMESTEP	FC-2300	ORB INTEGRATION	ENTRY 6		
TIMETHET	FC-2310	CONIC SUBROUTINES	ENTRY 22		
TIMETHET	FC-2545	TPI SEARCH PROG	CALLED 7		
TIMETHET	FC-2595	LUNAR LAND SELECT	CALLED 13		
TIMETHET	FC-2626	P32, P72 - CSI	CALLED 13,14		
TIMETHET	FC-2627	P33, P73 - CDH	CALLED 5		
TIMETHET	FC-2630	TPI TARGETTING	CALLED 5		
TIMETHET	FC-2642	RETURN TO EARTH	CALLED 13		
TIMETHET	FC-2644	P38-P78; P39-P79	CALLED 11		
TIMFLAG	FC-2681	CLOKTASK- CLOCKJOB			T-3
TIMRFLAG	FC-2680	THRUST PROGRAMS	S-8	C-28,31	
TLIM	FC-2200	T4RUPT	ENTRY 28		
TNONTEST	FC-2200	T4RUPT	ENTRY 33		
TORQUE	FC-2530	PRELAUNCH INIT	ENTRY 25		
TPAGREE	FC-2680	THRUST PROGRAMS	CALLED 19		
TRACKFLG	FC-2200	T4RUPT		C-32,33	
TRACKFLG	FC-2340	ATTITUDE MANEUVER			T-8
TRACKFLG	FC-2545	TPI SEARCH PROG	S-3		

TRACKFLG	FC-2550	P20 RENDEZVOUS NAV	S-3	C-8	T-6,8,17,31
TRACKFLG	FC-2620	P30, P31	S-2,7		
TRACKFLG	FC-2626	P32, P72 - CSI	S-2		
TRACKFLG	FC-2627	P33, P73 - CDH	S-1		
TRACKFLG	FC-2630	TPI TARGETTING		S-2	
TRACKFLG	FC-2640	TPM TARGETTING	S-1		
TRACKFLG	FC-2644	P38-P78; P39-P79	S-3		
TRACKFLG	FC-2670	TARGET DELTA V PROG	S-1		
TRACKFLG	FC-2720	IMU REALIGN PROG		C-1	
TRACKFLG	FC-2730	R52, R53, R56			T-4
TRANSANG	FC-2545	TPI SEARCH PROG	ENTRY 14		
TRANSP1	FC-2100	SINGLE PREC SUBROUTS	ENTRY 13		
TRANSP2	FC-2100	SINGLE PREC SUBROUTS	ENTRY 13		
TREAILOF	FC-2070	SERVICE ROUTINES	ENTRY 13		
TREAILOF	FC-2550	P20 RENDEZVOUS NAV	CALLED 33		
TREAILOF	FC-2605	NAV EXTENDED VERBS	CALLED 7		
TREAILON	FC-2070	SERVICE ROUTINES	ENTRY 13		
TREAILON	FC-2550	P20 RENDEZVOUS NAV	CALLED 32		
TRUNFLAG	FC-2730	R52, R53, R56	S-2,3	C-3	T-3
TTG/0	FC-2630	TPI TARGETTING	ENTRY 31		
TVCDAPON	FC-2430	TVC ROUTINES	ENTRY 1		
TVCDAPON	FC-2680	THRUST PROGRAMS	CALLED 22		
TVCEXEC	FC-2430	TVC ROUTINES	ENTRY 7		
TVCINIT	FC-2430	TVC ROUTINES	ENTRY 1		
TVCZAP	FC-2630	TPI TARGETTING	ENTRY 28		
TVCZAP	FC-2020	FRESH START	CALLED 31		
TVCZAP-1	FC-2681	CLOKTASK-CLOCKJOB	CALLED 5,7		
TWIDDLE	FC-2060	WAITLIST	ENTRY 9		
T3RUPT	FC-2060	WAITLIST	ENTRY 16		

T4RUPT	FC-2200 T4RUPT	ENTRY 3		
T5IDLOC	FC-2020 FRESH START	ENTRY 17		
T5IDLOC	FC-2380 RCS DAP INIT	ENTRY 2		
T5PHASE	FC-2460 ROLL AUTOPILOT	CALLED 2		
T5PHASE2	FC-2390 RCS DAP PHASE 2	ENTRY 1		
T5PHASE2	FC-2380 RCS DAP INIT	CALLED 2		
T6PROGM	FC-2390	ENTRY 10		
T6SETUP	FC-2400 RCS DAP JET SELECT	ENTRY 15		
T6START	FC-2400 RCS DAP JET SELECT	ENTRY 17		
T6START	FC-2380 RCS DAP INIT	CALLED 7		
T6START	FC-2460 ROLL AUTOPILOT	CALLED 7		
UPACTOFF	FC-2020 FRESH START	CALLED 36		
UPACTOFF	FC-2550 P20 RENDEZVOUS NAV	CALLED 12		
UPDATFLG	FC-2545 TPI SEARCH PROG	S-3,4,12,13	C-3,5	
UPDATFLG	FC-2550 P20 RENDEZVOUS NAV	S-3	C-8	T-31,34
UPDATFLG	FC-2620 P30, P31	S-2,7	C-2,7	
UPDATFLG	FC-2626 P32, P72 - CSI	S-2,3	C-7	
UPDATFLG	FC-2627 P33, P73 - CDH	S-4		
UPDATFLG	FC-2630 TPI TARGETTING	S-2,16		
UPDATFLG	FC-2640 TPM TARGETTING	S-1		
UPDATFLG	FC-2644 P38-P78; P39-P79	S-3,6,7	C-7,9	
UPDATFLG	FC-2720 IMU REALIGN PROG		C-1	
UPDATFLG	FC-2730 R52, R53, R56			T-4
UPENT2	FC-2070 SERVICE ROUTINES	ENTRY 2		
UPFLAG	FC-2070 SERVICE ROUTINES	ENTRY 4		
UPLOCKFL	FC-2150 KEYRUPT AND UPRUPT	S-7	C-8	T-8
UPRUPT	FC-2150 KEYRUPT AND UPRUPT	ENTRY 5		
UPSVFLAG	FC-2290 INTEG INITIAL		C-15	T-14
UPTMEAST	FC-2200 T4RUPT	ENTRY 42		

USEPIOS	FC-2290	INTEG INITIAL	ENTRY 21		
USPRCADR	FC-2080	INT BNK COMMUN	ENTRY 5		
VAC5STOR	FC-2020	FRESH START	ENTRY 27		
VAC5STOR	FC-2140	ALARM AND ABORT	CALLED 3,5		
VALMIS	FC-2530	PRELAUNCH INIT	ENTRY 24		
VARALARM	FC-2140	ALARM AND ABORT	ENTRY 3		
VARALARM	FC-2200	T4RUPT	CALLED 30		
VARALARM	FC-2626	P32, P72 - CSI	CALLED 22		
VARALARM	FC-2642	RETURN TO EARTH	CALLED 45		
VARDELAY	FC-2060	WAITLIST	ENTRY 10		
VECPOINT	FC-2340	ATTITUDE MANEUVER	ENTRY 5		
VECPOINT	FC-2190	PINBALL	CALLED 5		
VECPOINT	FC-2361	V89 (R63)	CALLED 5		
VECSGNAG	FC-2100	SINGLE PREC SUBROUTS	ENTRY 12		
VEHUPFLG	FC-2550	P20 RENDEZVOUS NAV		C-3	T-4,5,21,24, 25,28,35
VEHUPFLG	FC-2590	P22 ORBITAL NAV	S-15		
VEHUPFLG	FC-2600	CISLUNAR MID NAV	S-12		
VEHUPFLG	FC-2610	MEASUREMENT INCOR			T-10,11
VERB65	FC-2360	-S-BAND ANTENNA	ENTRY 2		
VFLAG	FC-2720	IMU REALIGN PROG	S-13,16	C-16	T-14,16
VGAMCALC	FC-2320	TFFCONICS	ENTRY 11		
VGAMCALC	FC-2760	ENTRY PROGRAMS	CALLED 13		
VHFRFLAG	FC-2550	P20 RENDEZVOUS NAV			T-20
VHFRFLG	FC-2605	NAV EXTENDED VERBS	S-7	C-7	
VHHDOT	FC-2540	EARTH ORBIT INSERT	ENTRY 18		
VHHDOT	FC-2683	SERVICER	CALLED 15		
VINTFLAG	FC-2290	INTEG INITIAL	S-4,6,7,16,19	C-4,6,7,18	T-8
VINTFLAG	FC-2300	ORB INTEGRATION			T-33,38

VINTFLAG	FC-2550	P20 RENDEZVOUS NAV	S-7		C-4,5,21	
VINTFLAG	FC-2580	P21 GRD TRACK DET	S-3		C-3	
VINTFLAG	FC-2590	P22 ORBITAL NAV	S-10,18			
VINTFLAG	FC-2600	CISLUNAR MID NAV	S-14			
VNDSPLY	FC-2644	P38-P78; P39-P79	ENTRY	12		
VNPOOH	FC-2626	P32, P72 - CSI	CALLED	2,4		
VNPOOH	FC-2627	P33, P73 - CDH	CALLED	1		
VN1645	FC-2626	P32, P72 - CSI	ENTRY	6		
VN1645	FC-2627	P33, P73 - CDH	CALLED	1,4		
VN1645	FC-2630	TPI TARGETTING	CALLED	3		
VN1645	FC-2640	TPM TARGETTING	CALLED	1,2		
VN1645	FC-2642	RETURN TO EARTH	CALLED	14		
V1ST02	FC-2100	SINGLE PREC SUBROUTS	ENTRY	6		
V1ST02S	FC-2340	ATTITUDE MANEUVER	CALLED	7		
V1ST02S	FC-2350	MANEUV CALC & STEER	CALLED	10		
V1ST02S	FC-2540	EARTH ORBIT INSERT	CALLED	14		
V2T100	FC-2642	RETURN TO EARTH	ENTRY	17		
V37	FC-2020	FRESH START	ENTRY	30		
V37FLAG	FC-2140	ALARM AND ABORT				T-5,11
V37FLAG	FC-2320	TFFCONICS				T-14
V37FLAG	FC-2325	RENDEZ PAR DISPLAY				T-8
V37FLAG	FC-2683	SERVICER	S-3		C-19	
V37KLEAN	FC-2020	FRESH START	ENTRY	7		
V37XEQ	FC-2020	FRESH START	ENTRY	40		
V50N18FL	FC-2550	P20 RENDEZVOUS NAV	S-3		C-10	T-16
V54E	FC-2550	P20 RENDEZVOUS NAV	ENTRY	17		
V56E	FC-2550	P20 RENDEZVOUS NAV	ENTRY	8		
V57E	FC-2550	P20 RENDEZVOUS NAV	ENTRY	17		
V59FLAG	FC-2242	OPTICS CAL ROUTINE	S-1,3		C-1,3	

V60	FC-2370	DAP INTER-SERV ROUT	ENTRY 12		
V61	FC-2370	DAP INTER-SERV ROUT	ENTRY 12		
V62	FC-2370	DAP INTER-SERV ROUT	ENTRY 12		
V63	FC-2370	DAP INTER-SERV ROUT	ENTRY 13		
V82CALL	FC-2650	ORB PARAM DISPLAY	ENTRY 4		
V82EMFLG	FC-2650	ORB PARAM DISPLAY	S-6,8,11	C-6,8,11	T-11,12,18
V82FLAGS	FC-2650	ORB PARAM DISPLAY	S-10	C-4	T-4,14
V82PERF	FC-2650	ORB PARAM DISPLAY	ENTRY 2		
V89CALL	FC-2190	EXTENDED VERBS	ENTRY 2		
V89CALL	FC-2361	V89 (R63)	ENTRY 2		
V89PERF	FC-2190	EXTENDED VERBS	ENTRY 2		
V89PERF	FC-2361	V89 (R63)	ENTRY 2		
V90PERF	FC-2631	R36 (V90)	ENTRY 2		
V94FLAG	FC-2600	CISLUNAR MID MAV	S-8	C-3,9	
V96ONFLG	FC-2290	INTEG INITIAL		C-3	
V97E	FC-2681	CLOKTASK- CLOCKJOB	ENTRY 11		
V97P	FC-2681	CLOKTASK- CLOCKJOB	ENTRY 10		
V97T	FC-2681	CLOKTASK- CLOCKJOB	ENTRY 8		
V99E	FC-2681	CLOKTASK- CLOCKJOB	ENTRY 7		
V99P	FC-2681	CLOKTASK- CLOCKJOB	ENTRY 6		
V99T	FC-2681	CLOKTASK- CLOCKJOB	ENTRY 5		
WAITLIST	FC-2060	WAITLIST	ENTRY 9		
XDELVFLG	FC-2620	P30, P31	S-1,6	C-10	
XDELVFLG	FC-2626	P32, P72 - CSI	S-9		
XDELVFLG	FC-2627	P33, P73 - CDH	S-6		
XDELVFLG	FC-2630	TPI TARGETTING		C-16	
XDELVFLG	FC-2642	RETURN TO EARTH		C-14	
XDELVFLG	FC-2644	P38-P78; P39-P79		C-7	
XDELVFLG	FC-2680	THRUST PROGRAMS			T-4,32

XDELVFLG	FC-2682	STEERING				T-6
YAWDAP	FC-2440	TVC DAP	ENTRY	6,9		
YAWTIM	FC-2400	RCS DAP JET SELECT	ENTRY	13		
YCOPY	FC-2430	TVC ROUTINES	CALLED	12		
YCOPY	FC-2440	TVC DAP	ENTRY	13		
ZEROICDU	FC-2200	T4RUPT	CALLED	34,36		
ZEROING	FC-2530	PRELAUNCH INIT	ENTRY	35		
ZEROJET	FC-2370	DAP INTER-SERV ROUT	CALLED	2,4		
ZEROJET	FC-2540	EARTH ORBIT INSERT	CALLED	19		
ZMEASURE	FC-2600	CISLUNAR MID NAV	S-17		C-17	T-15
-1CHK	FC-2120	AGC SELFCHECK	ENTRY	16		
1/PIPA	FC-2683	SERVICER	CALLED	13		
1STO2S	FC-2100	SINGLE PREC SUBROUTS	ENTRY	5		
1TOSUB	FC-2100	SINGLE PREC SUBROUTS	ENTRY	8		
2EBANK	FC-2120	AGC SELFCHECK	ENTRY	6		
2PHSCHNG	FC-2030	PHASE TABLE MAINT	ENTRY	11		
22DSPFLG	FC-2590	P22 ORBITAL NAV			C-16	T-16
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