BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B68 11084

SUBJECT: Colossus on C-Prime - Case 310

DATE: November 26, 1968

FROM: W. G. Heffron

MEMORANDUM FOR FILE

The attached viewgraphs were used in a presentation to Dr. G. E. Mueller and Lt. Gen. S. C. Phillips on October 23 at MSFC-10B. The purpose was to review how the capabilities of the CM computer program Colossus might affect the Lunar Orbital alternative of the C-Prime mission.

Also attached are responses generated by Department 2014 and 2013 to questions asked at the presentation.

2014-WGH-bjh

W. G. Heffron

Attachments

[redacted]

BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B68 11084

SUBJECT: Computer Problems on Mission C - Case 310

DATE: October 24, 1968

FROM: W. G. Heffron

Lt. Gen. S. C. Phillips - NASA/M:
Dr. G. E. Mueller - NASA/M:

This note concerns problems with the use of the guidance computer on Mission C, as requested on October 23, 1968 in a meeting at FOB-10B. The information is preliminary and was furnished by Mr. Jack Garman, the prime shift computer expert for the Mission.

1. Star code 00 was used with auto optics while in platform alignment determination. It is not valid for Sundisk and a restart occurred with no mission impact in any way. It had occurred in training. It occurred in flight three times. Code 00 is valid for Colossus.

2. Use of P-30 (external ΔV pre-thrust) with $\Delta V = 0$ to obtain an accurate display of apogee and perigee is an AOH (workaround) procedure. The computer coding in P-30 is such that for the pathological case of the vector $\Delta V = 0$, it gives unit $(\Delta V) = (2, 0, 0)$. If REFSMMAT (IMU attitude matrix) has element (1,2) greater than 0.5 then unit $(\Delta V) \cdot$ REFSMMAT row 2 is greater than 1. The arc-cosine programming causes a restart for arc-cosine (1+). This occurred twice (first use and retry) in flight. Note, if the REFSMMAT value is less than 0.5 there is no problem, which apparently was the case in training, where the procedure was used. There was no mission effect. The arc-cosine error in Colossus causes a "go to P-00" abort.

3. The crew operated V37 within 20 seconds after a restart in violation of a Sundisk program note. This would cause PIPA fail to go undetected. It was noticed by the ground but the crew was not informed because the computer was going to standby. The flag was reset properly automatically when the computer came up later. No mission effect. Same note exists for Colossus.

4. Calculations for platform alignment for a burn were made more than one orbit before it. The position calculation routine gives a wrong answer in such a case (program note exists) and alignment was about 30° - 40° off in yaw. It was noticed, in good time, by the crew during P-30 pre-thrust (less than one orbit before the burn) and corrected. The burn could have been conducted with the FDAI 30° - 40° off 000, but probably would have been skipped if noticed too late.

5. The crew thought P-21 (ground track determination) was hung up one time. This was over a station with no computer downlink. Over the next station, with downlink, by the time the ground diagnosed the problem it had gone away -- the time inserted into P-21 was considerably later than "now" and P-21 simply took a long time to finish. No mission problem. Colossus has V96E to stop P-21 in such a case, but the same problem would exist otherwise.

6. The DTO inserted late in the mission called for the optics line of sight to be aimed above the horizon. The computer tried to solve the problem of distance to the earth's surface, for which there is no solution in this case, and gave a restart on "square root of a negative number." The procedure was wrong and must not have been tested prior to transmittal to the crew.

The restart was "perpetual," once every 0.5 seconds. A fresh start was required but V36E cannot be keyed in within 0.5 seconds. The crew was forced to simultaneous depression of Error Reset and Mark Reject to cause the fresh start. In Colossus this error causes a "go to P-00" abort, not a restart.

7. When flashing verb 51 requests an optics mark, the correct response is ENTER if no more marks will be taken, followed by V37E00E to go to P-00. The crew skipped the E -- this left a flag in the wrong state and the mark button did not work the next time it was used. A workaround procedure was devised by Steve Copps, MIT, sent to the crew and they used it successfully. When the problem was diagnosed by the ground, a procedure was devised to reset the flag and all became normal. The crew could also have reset the flags directly if they had known which ones. Mission effect was to delay optics use for some time.

This is a general problem in responding to flashing verbs and exists in Colossus also. Crew must observe correct procedures, with no short cuts. It would have occurred in training.

8. If the optics trunnion angle desired exceeds 38°, the trunnion drive simply stops where it is, without driving over to the maximum value possible. Optics shaft drive has no limits. This caused two problems.

A. In post-rendezvous tracking of the SIVB, it suddenly went out of view and tracking was abandoned. The SCS was being used for attitude control and 38° was exceeded. The computer showed an alarm (over 38° commanded), but the crew had given up. If attitude had been under computer control, the CSM would have been rotated to reduce the command to less than 38° and track would have been maintained (except for a transient). But such sudden attitude changes had been experienced earlier by the crew and objected to by the crew, so they selected SCS.

With the eyes at the optics and the optics shaft drive running, it is difficult to notice either the DSKY alarm or the cessation of trunnion motor operation. Best procedure is to use the computer autopilot and endure the transient.

B. Before landmark tracking, the optics are zeroed. If the landmark requires over 38° trunnion, the optics stay at zero trunnion. This persists until the landmark trunnion is less than 38, but then the landmark is moving one way (decreasing trunnion) and the optics the other way (from 0 up towards the command) and lock on the landmark gets difficult.

After this happened in flight, the ground suggested a manual motion to 35° after optics zero. It worked very well.

I couldn't find a program note on this. The crew can readout the desired and actual angles and see if the optics are pointed properly. The error probably exists in Colossus also, and should have been observed in training.

9. Pre-retrofire the correct procedure involves V48E (DAP data load) followed by V46E (turn DAP on). Apparently the crew did V46E, V48E and the DAP was not on. The ground caught it from the flag words, requested V46E, the crew did it and the DAP went on.

If not observed by the ground, the crew would have observed lack of attitude control and switched to SCS. It applies for any burn and would have shown up in training. Will occur in Colossus, also.

10. The crew keyed in + xxx.xx for latitude of a landmark instead of - xxx.xx. Not seeing the landmark in the optics, they could have switched to "unknown landmark tracking."

Additionally, for your information, V36E (Fresh Start) does not zero the state vector.

W. G. Heffron

2014-WGH-ek

Copy to
Messrs. G. H. Hage - NASA/MA
C. M. Lee - NASA/MA

A. P. Boysen, Jr.
D. A. Chisholm
D. A. Corey
B. G. Niedfelt
I. M. Ross
R. V. Sperry
R. L. Wagner
Central Files

BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

SUBJECT: Colossus Program Notes - Case 310

DATE: October 25, 1968

FROM: W. G. Heffron

Dr. G. E. Mueller - NASA/M:
Lt. General S. C. Phillips - NASA/MA:

I believe the attached letter to Mr. C. C. Kraft, which has been sent, is the best way to settle the questions you asked on October 23, 1968 regarding possible problems with the computer during pre-thrust and thrusting operations on Mission C-Prime.

2014-WGH-sep

W. G. Heffron

Attachment

Copy to
Messrs. G. H. Hage - NASA/MA
C. M. Lee - NASA/MA

A. P. Boysen, Jr.
D. A. Chisholm
D. A. Corey
B. G. Niedfeldt
I. M. Ross
R. V. Sperry
R. L. Wagner
Central Files

SUBJECT: Review of Colossus Program Notes - Case 310

October 25, 1968

Mr. C. C. Kraft
Director of Flight Operations
Manned Spacecraft Center
National Aeronautics and Space Administration
Houston, Texas 77058

Code: FA

Dear Chris:

Review of the Colossus Program Notes, particularly numbers 1.2.8, 1.79, 3.7.2, 3.7.4, 3.7.5 (see attachment), causes me some concern about the susceptibility of the pre-thrust and thrusting programs to restarts and aborts.

I would appreciate it if these problems receive special attention at the Colossus FSRR on November 8, 1968, addressing the following aspects:

1. Should crew procedures in P30, P40 and P41 be written to minimize computer activity (avoidance of special displays, for example)?

2. Should special crew training and procedures for overcoming possible problems be required?

3. A report at the FSRR regarding how often problems of this type have occurred during Colossus testing and use is also requested.

Best regards,

ORIGINAL SIGNED BY

2014-WGH-bjh

W. G. Heffron
Department Head
Guidance and Navigation

Attachment

ATTACHMENT

1.2.8 Since some extended verbs (notably V82, V83, and V85) use several JOB areas, a software restart may be generated if these verbs are selected in periods of high activity due to VAC or Core Set overflow. In this case the Program Alarm light will be lit and alarm code 1201 or 1202 will be stored. Extended verb activity will be lost and the verb must be reselected. Typical periods of high activity when this might occur are (1) V83 in P3X or P7X with P20 in the background, and (2) V82 in P4X with Lambert.

1.7.9 An interpreter abort (codes 1301 and 1302) during average G will request a new program (flashing V37) and leave the permanent state vector at its value before average G was intitiated. The result is that all subsequent onboard computations will not account for the ΔV added during average G. However, until the next permanent integration, the quantities on the downlist will have accounted for the ΔV. After the integration, this information is lost. This type of abort will most probably require a new uplink.

3.7.4 If a restart occurs between TIG + 0 and TIG + 0.4 seconds, the TVC gimbal actuator interface will not be re-established. Avoidance procedure: none. Recovery procedure: After a restart select P00 and then retarget via P3X. An alternative would be to exercise V69E immediately. This will force a hardware restart and re-establish proper TVC control.

3.7.5 If a P00D00 type of ABORT (aborts 1206, 1210, 1301, 1302, 1501, 1502) occurs during SERVICER, SERVICER is never finished. This means that the state vector is lost if a burn has occurred. Also, this means PIPA compensation information is left in an incorrect state with the results PIPA compensation will not take place after this type of abort. Avoidance procedure: none. Recovery procedure: Uplink new state vector. Select P47 in order to establish proper PIPA compensation. Select new desired program after the first display in P47.

BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

SUBJECT: Use of NR Simulator for C-Prime Case 310

DATE: October 24, 1968

FROM: W. G. Heffron

Dr. G. E. Mueller - NASA/M:
Lt. Gen. S. C. Phillips - NASA/MA:

This note concerns use of the NR Mission Evaluator for C-Prime mission validation, as requested on October 23, 1968 in a meeting at FOB-10B.

The NR simulations will be used for two weeks on C-Prime high speed entries with prime crew participation. Otherwise it will be used for the D mission (using Colossus I until IA becomes available).

The reason is that the facility does not have cislunar or lunar capability at present. It is under development and will be ready in early 1969 for the mission after D. Mr. Low decided it was too expensive to advance the date for this capability.

The CMS is therefore the only facility available for lunar operations training, and is being so used.

This information was furnished by Mr. D. Cheatham,GCD, MSC.

2014-WGH-bjh

W. G. Heffron

Copy to
Messrs. G. H. Hage - NASA/MA
C. M. Lee - NASA/MA

A. P. Boysen, Jr.
D. A. Chisholm
D. A. Corey
B. G. Niedfeldt
I. M. Ross
R. V. Sperry
R. L. Wagner

BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

SUBJECT: Computer Voltage Limits
Case 310

DATE: October 25, 1968

FROM: W. G. Heffron

Dr. G. E. Mueller - NASA/M:
Lt. Gen. S. C. Phillips - NASA/MA:

The spacecraft computer include circuits which warn of under--and over--voltage in the power supplies.

Although there have been demonstrations that the computer will work properly outside the assigned ranges, the present tolerances are considered by GCD as proper and judicious, and have been the subject of several reviews. GCD does not consider that there is sufficient evidence at the present to warrant broadening the range of acceptability voltages.

Changing the limit values would involve redesign of the modules involved, as well as the effort to determine the new values to be used.

This information was furnished by Mr. Holley, GCD, MSC.

W. G. Heffron

2014-WGH-bjh

Copy to
Messrs. G. H. Hage - NASA/MA
C. M. Lee - NASA/MA

A. P. Boysen, Jr.
D. A. Chisholm
D. A. Corey
B. G. Niedfeldt
I. M. Ross
R. V. Sperry
R. L. Wagner
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BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

SUBJECT: Validation of RTCC ODP - Case 310

DATE: October 25, 1968

FROM: B. G. Niedfeldt

Mr. W. G. Heffron:

The validation of the RTCC Orbit Determination Program (ODP) is being based upon reprocessing of tracking data collected during the Lunar Orbiter Missions. Tracking data arcs are selected so that they are identical to those previously processed at JPL. The resulting converged ODP solution and the residuals of the fit are then compared to those obtained by JPL. Discrepancies in the results are then checked out. RTCC ODP runs are being made using translunar and lunar parking orbit tracking data.

The Doppler tracking data, which is available for this validation effort, is from the DSN and MSFN. Only three-way Doppler tracking data from the MSFN is available during translunar coast. Range and two and three-way Doppler tracking data is available from the MSFN during lunar orbiting phases. Range and Doppler tracking data is available from the DSN during both phases.

During an Apollo lunar mission, three independent data types will be available for ODP processing; range, Doppler, and on-board sextant sightings. An RTCC ODP solution will be based only on Doppler data. This converged solution will then be passed through the other two data types and the quality of the fit will be determined in real time. This procedure will be carried out through the entire mission.

2014-BGN-bjh

B. G. Niedfeldt

BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

SUBJECT: Some Trajectory and Abort Options for the C-Prime Mission - Case 310

DATE: October 30, 1968

FROM: R. A. Bass
T. B. Hoekstra

MEMORANDUM FOR FILE

The attached charts were prepared for use by Mr. A. P. Boysen, Jr. at the C-Prime Mission Planning Meeting, October 28, 1968 at MSC.

R. A. Bass

T. B. Hoekstra

2013-RAB/TBH-srb

Attachments

Copy to
Messrs. D. R. Anselmo
A. P. Boysen, Jr.
J. O. Cappellari, Jr.
D. A. Chisholm
D. R. Hagner
W. G. Heffron
B. T. Howard
D. B. James
J. L. Marshall, Jr.
J. Z. Menard
V. S. Mummert
P. E. Reynolds
I. M. Ross
R. V. Sperry
J. W. Timko
R. L. Wagner
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SOME TRAJECTORY AND ABORT OPTIONS FOR C-PRIME

ALL DATA PRESENTED IS BASED ON PATCHED CONIC TRAJECTORIES DEVELOPED FOR A C-PRIME MISSION LAUNCHED ON DECEMBER 21, 1968 WITH PACIFIC INJECTION AND AT A LAUNCH AZIMUTH OF 72 DEGREES.

FIGURE 1

- RCS CIRCUMLUNAR ABORTS

  THIS FIGURE SHOWS THE RCS ΔV COSTS FOR CIRCUMLUNAR ABORTS AT 6 1/2 HOURS AFTER TLI. BOTH UNDERBURN AND OVERBURN AT TLI ARE CONSIDERED. A 50 FPS ERROR IN TLI VELOCITY CORRESPONDS TO APPROXIMATELY A ONE SECOND ERROR IN BURN TIME. THE THREE SIGMA VARIATION IN TLI VELOCITY IS EXPECTED TO BE FIFTEEN FPS.

  THE RCS ΔV COSTS WERE DETERMINED ALLOWING FULL OPTIMIZATION OF BOTH POST ABORT PERILUNE DISTANCE AND RETURN INCLINATION.

FIGURE 2

- THE ΔV COST FOR TARGETING TO INCREASED PERILUNE ALTITUDE

  THIS CURVE PRESENTS THE ΔV PENALTY RESULTING FROM TARGETING THE C-PRIME TRAJECTORY TO HIGHER PERILUNE ALTITUDES FOLLOWED BY A LATER TRANSFER TO THE NOMINAL 60 N.M. CIRCULAR ORBIT. THE ΔV PENALTY INCLUDES THE TRANSFER COSTS. THIS OPTION WOULD REQUIRE AN ADDITIONAL SPS BURN PLUS A RETARGETED TLI.

FIGURE 3

- CURVE #1 SHOWS ΔV REQUIRED TO ABORT FROM HIGH APOGEE ELLIPSES RESULTING FROM TLI UNDERBURNS (ABORT CARRIED OUT AT APOGEE).

- CURVE #2 SHOWS TLI ΔV DEFICIENCY VS BURN TIME (AT END OF BURN, 1 SECOND IS EQUIVALENT TO ABOUT 50 FPS IN TLI ΔV).

- CURVE #3 SHOWS APPROXIMATE TIME FROM TLI TO REENTRY FOR HIGH ELLIPSE ABORTS.

NOTE: 3 BODY EFFECTS MAKE IT INVALID TO EXTRAPOLATE THE ABORT ΔV CURVE BEYOND ABOUT 305 SECONDS.

FIGURE 4

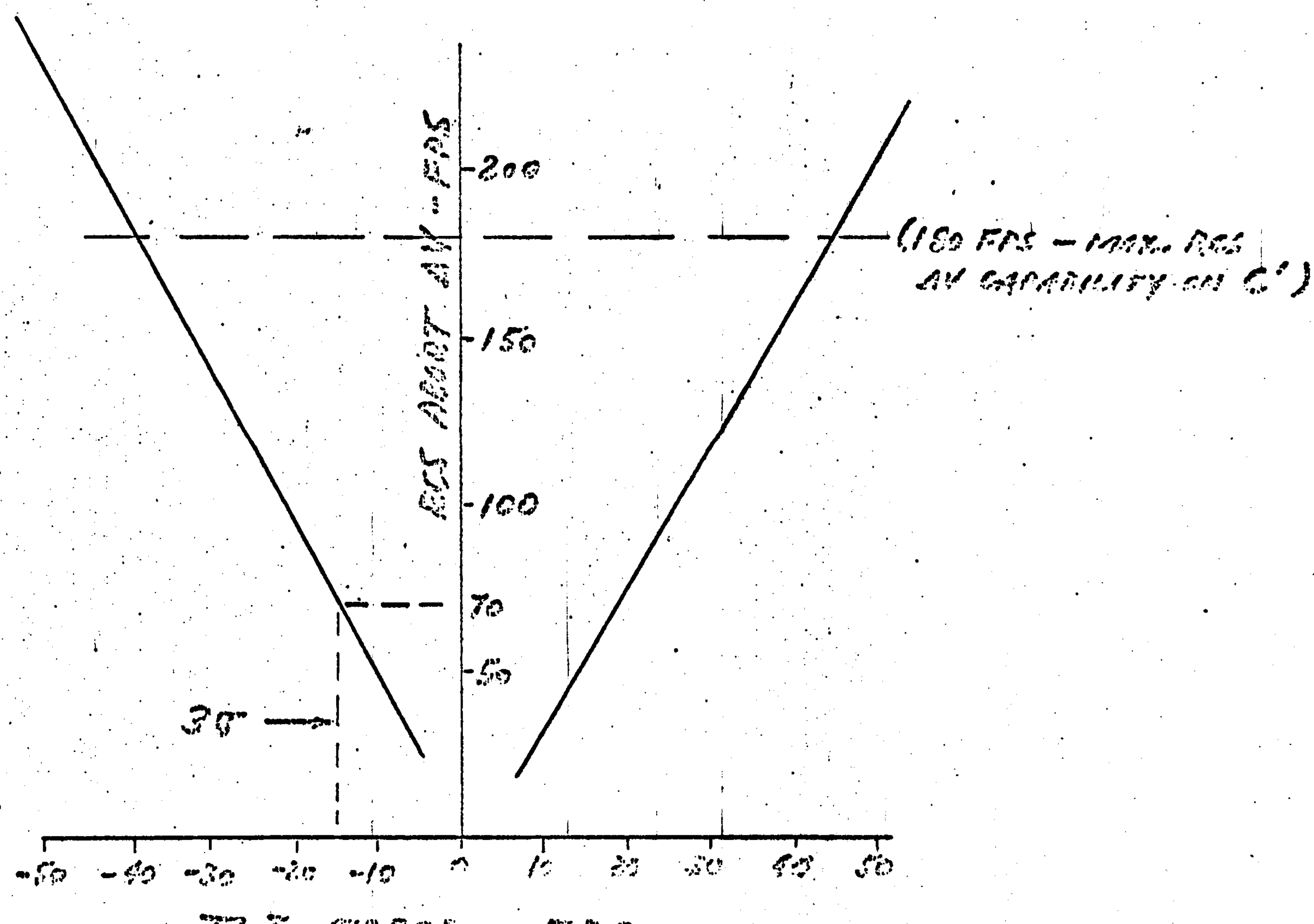
- SHOWS ΔV REQUIRED TO CORRECT TEI ΔV ERRORS FOR VARIOUS COAST TIMES FROM TEI TO CORRECTION.
- ASSUMES TEI VELOCITY ERROR IS COLLINEAR WITH TEI ΔV.
- CONCLUSIONS
  - ABOUT 3 FPS OF CORRECTION IS NEEDED FOR EVERY 1 FPS OF TEI ERROR IF THE CORRECTION OCCURS BETWEEN 3 AND 12 HOURS AFTER TEI (THE MSI IS PASSED ABOUT 12 HOURS AFTER TEI).
  - CORRECTIONS OCCURRING LESS THAN 3 HOURS AFTER TEI HAVE A LOWER $\Delta V_{CORRECTION} / \Delta V_{ERROR}$ - SEE FIGURE 5.
  - THE RCS ΔV CAPABILITY WILL PROBABLY BE NEAR 100 FPS AT TEI WHICH PERMITS ABOUT A 35 FPS TEI ΔV ERROR (THIS WOULD BE ABOUT A 1 1/2 SECOND MAXIMUM OVERBURN OR UNDERBURN).

FIGURE 5

- SHOWS $\Delta V_{CORRECTION} / \Delta V_{ERROR}$ FOR VARIOUS COAST TIMES FROM TEI TO CORRECTION.
- ASSUMPTIONS SAME AS FIGURE 4.
- CONCLUSIONS
  - DO CORRECTION AS SOON AS POSSIBLE.
  - IF DELAY IS OVER 3 HOURS, IT DOES NOT HURT TO WAIT A FEW HOURS LONGER.

FIGURE 1

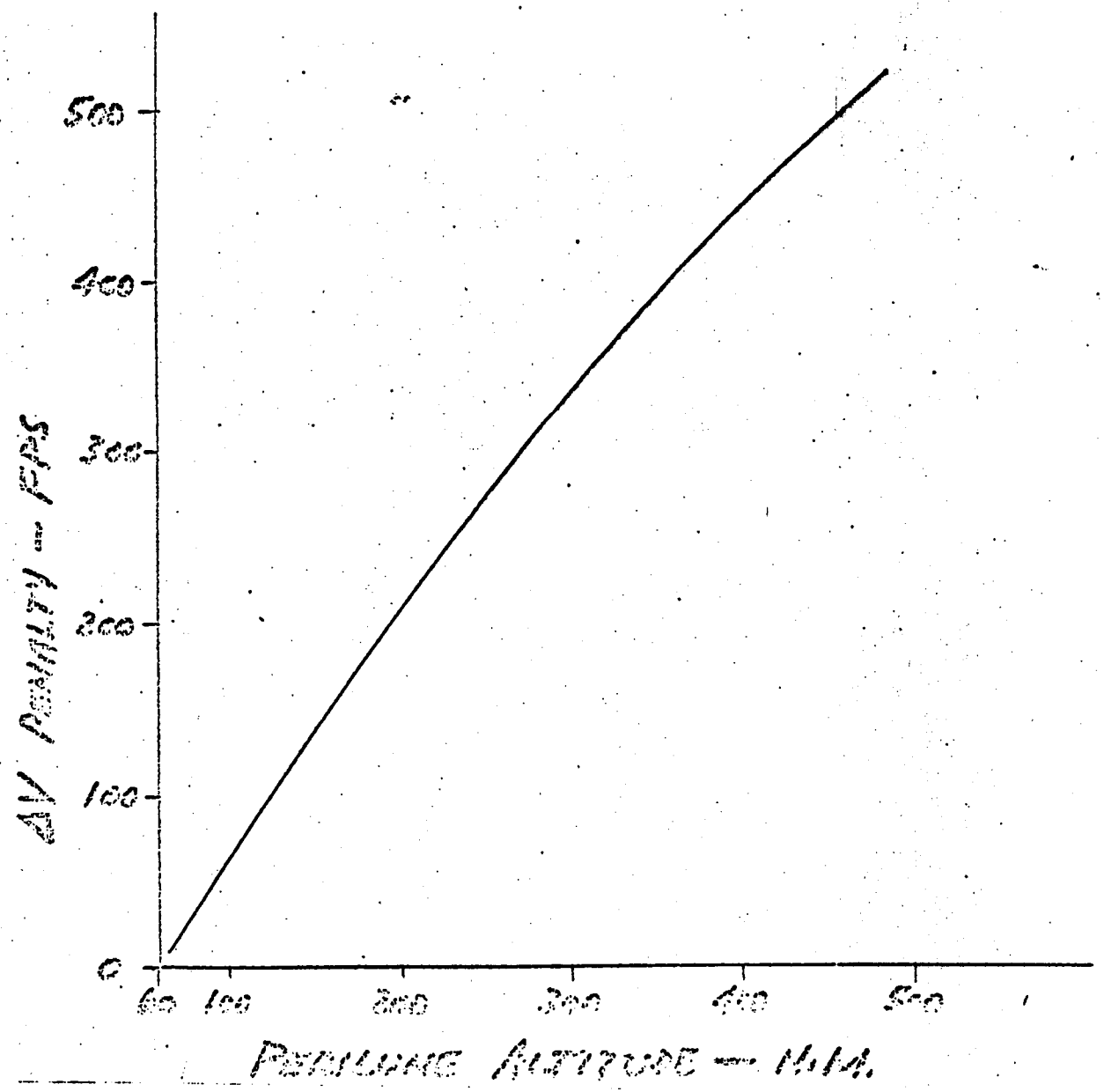
RCS CIRCUMLUNAR ABORT FROM TLI OVERBURN
WITH SPS ENGINE FAILURE



① 50 FPS IS APPROXIMATELY ONE SECOND TLI OVERBURN
② ABORT TIME IS 6½ HOURS PAST TLI

Figure 2

Cost of Targeting to Increased Terminal Altitude Followed by Transfer to 60 n.m. Circular Orbit



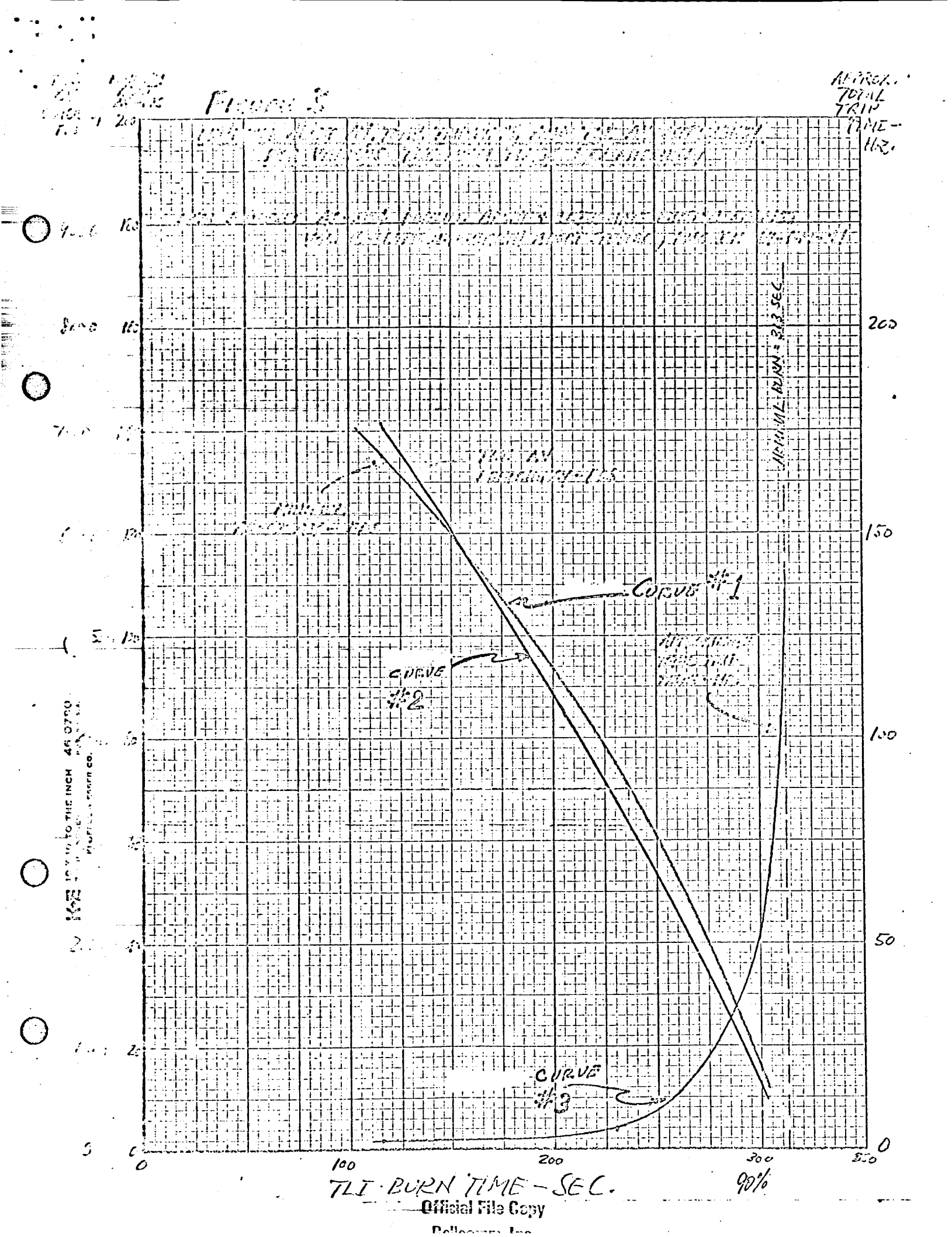


FIGURE 4
ΔV REQUIRED TO CORRECT TEI ΔV ERRORS

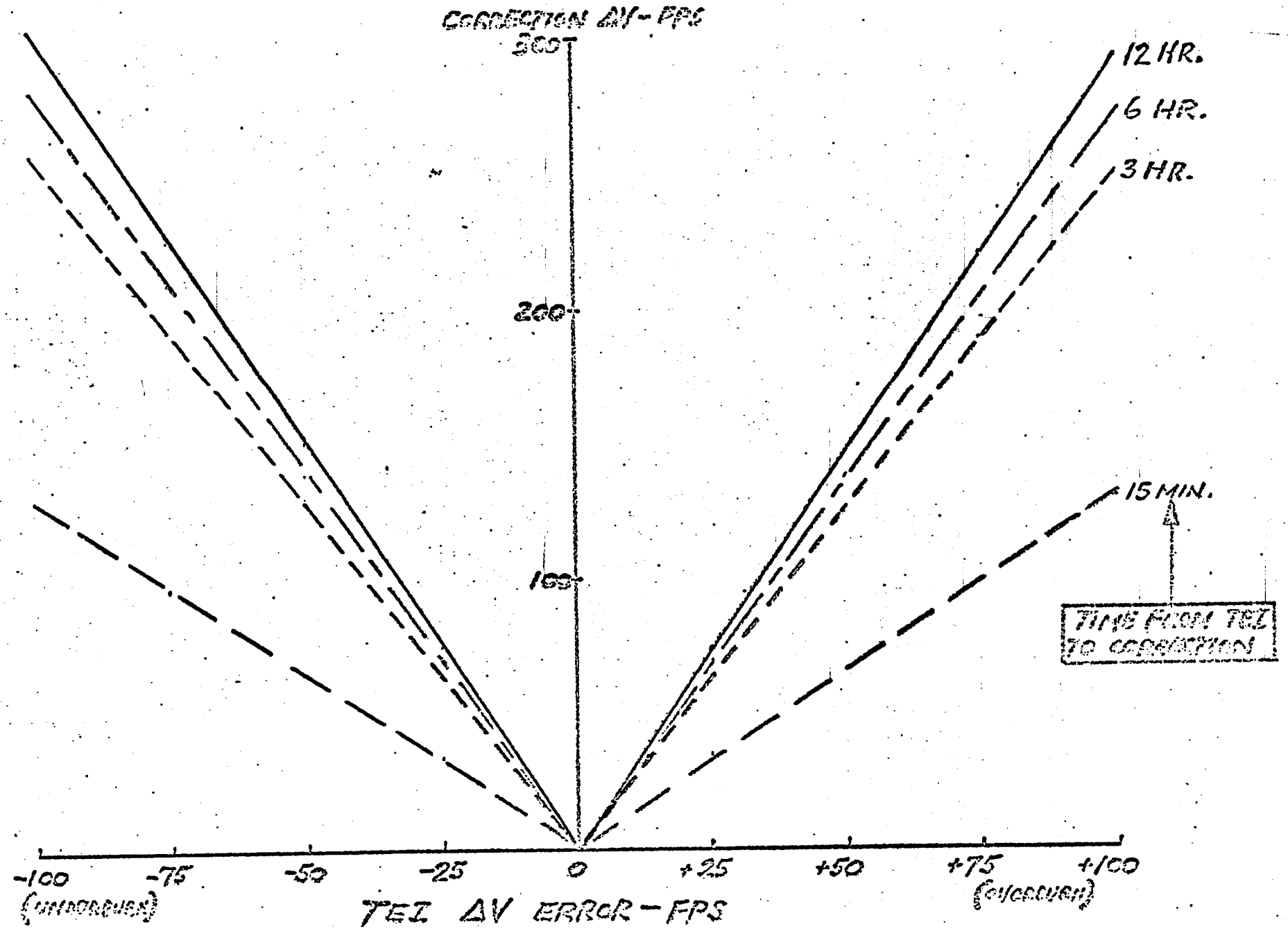
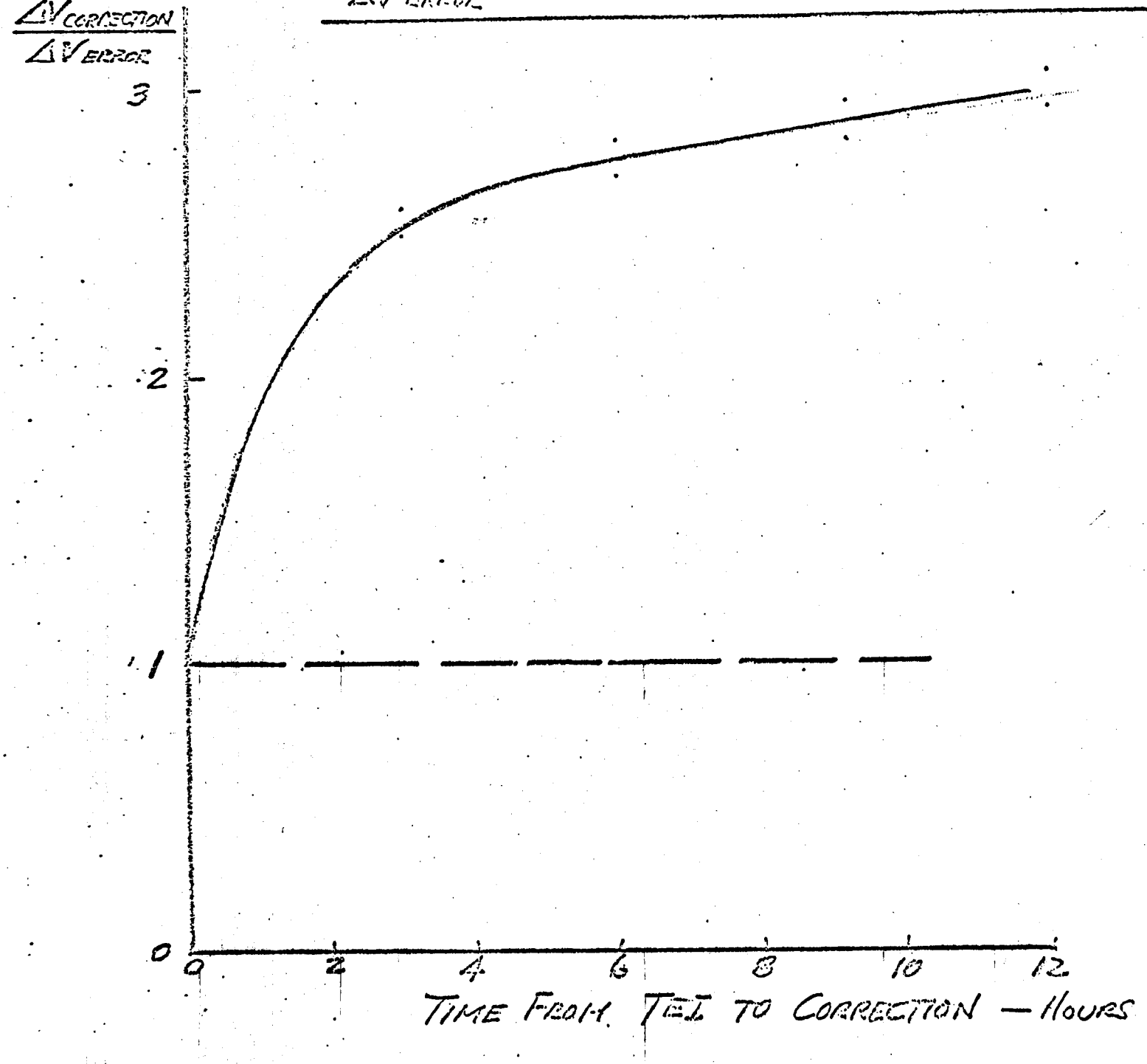


FIGURE 5 — $\frac{\Delta V_{CORRECTION}}{\Delta V_{ERROR}}$ FOR VARIOUS TEI TO CORRECTION TIMES



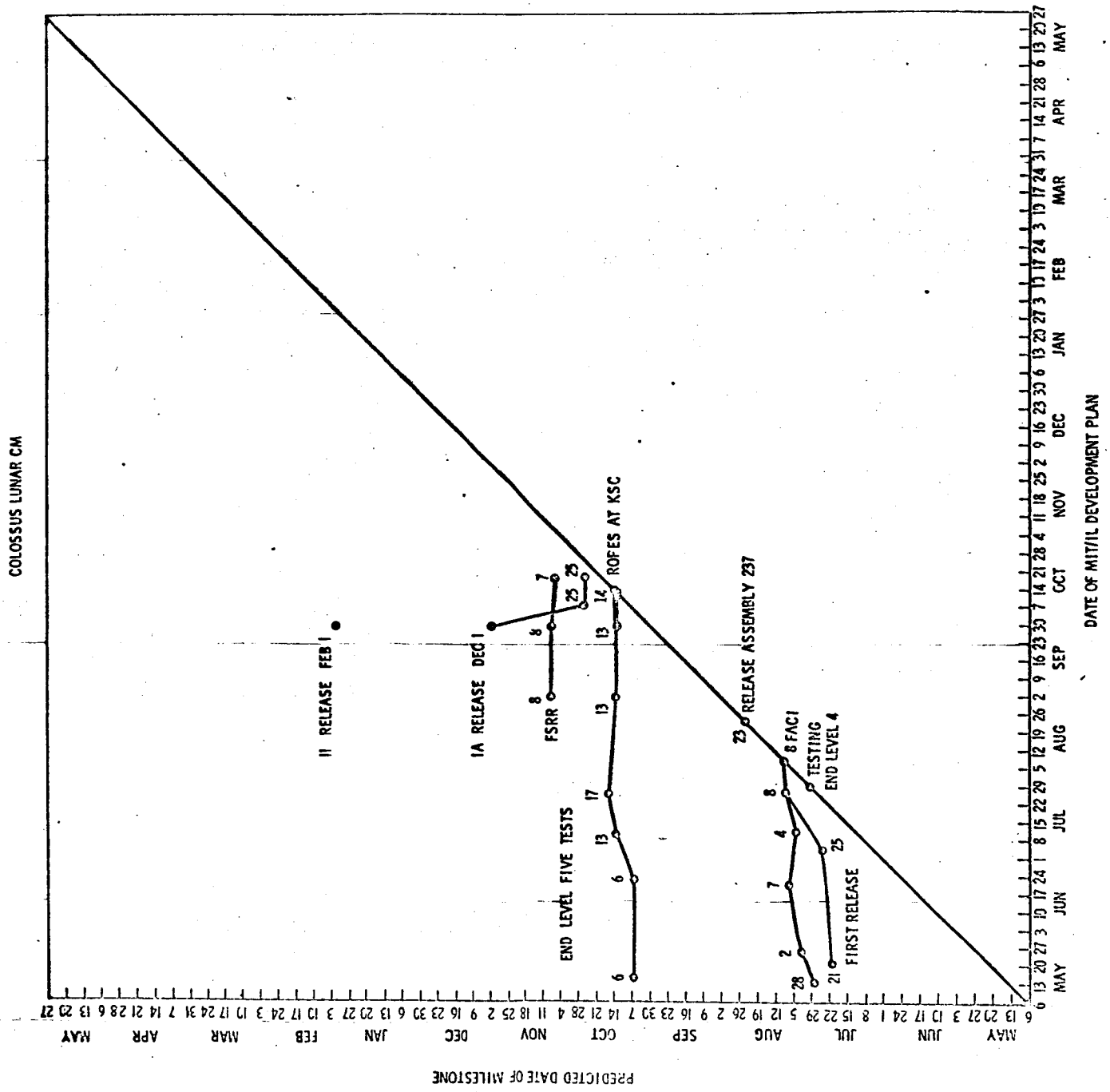
COLOSSUS

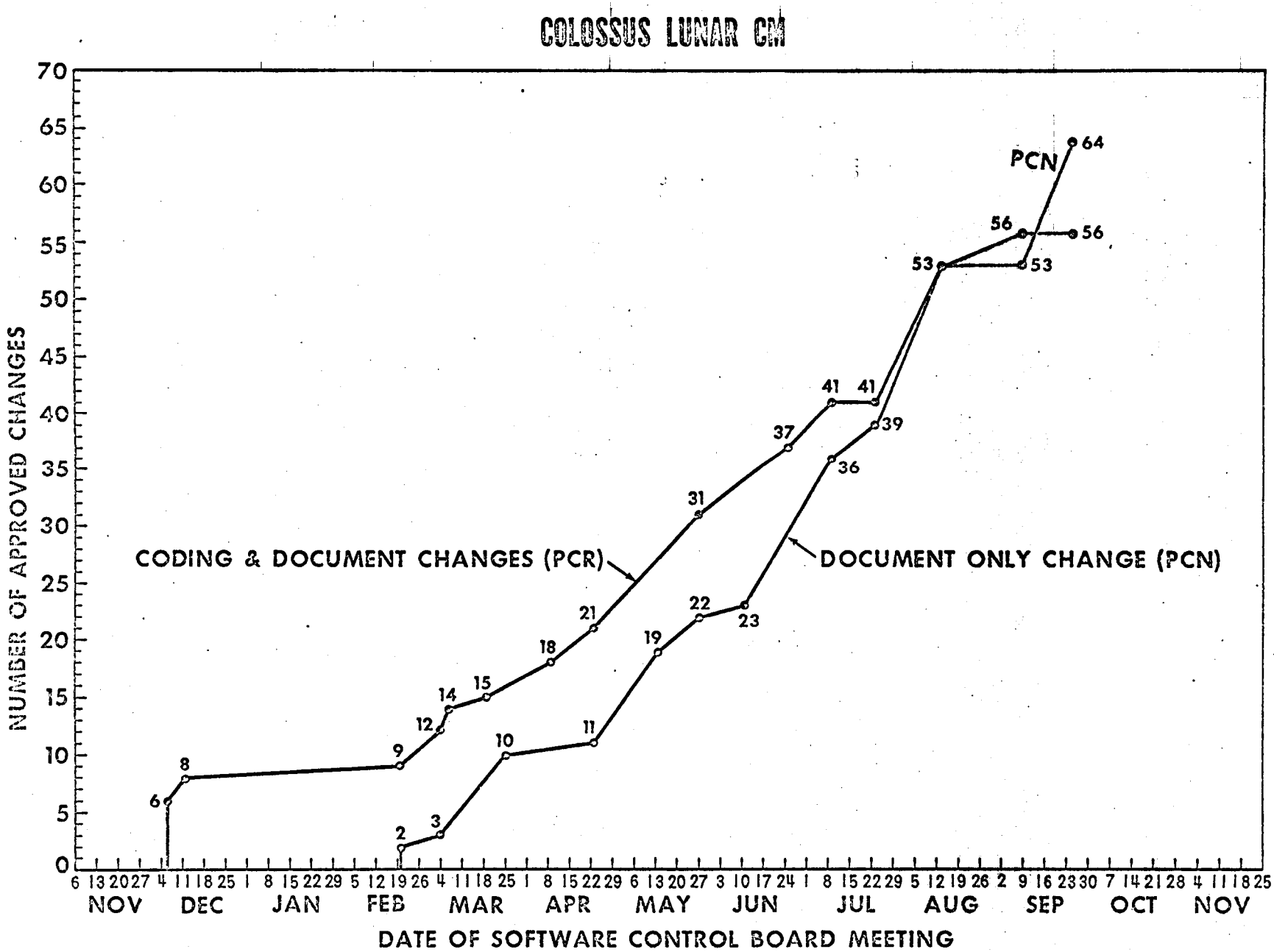
ON

C-PRIME

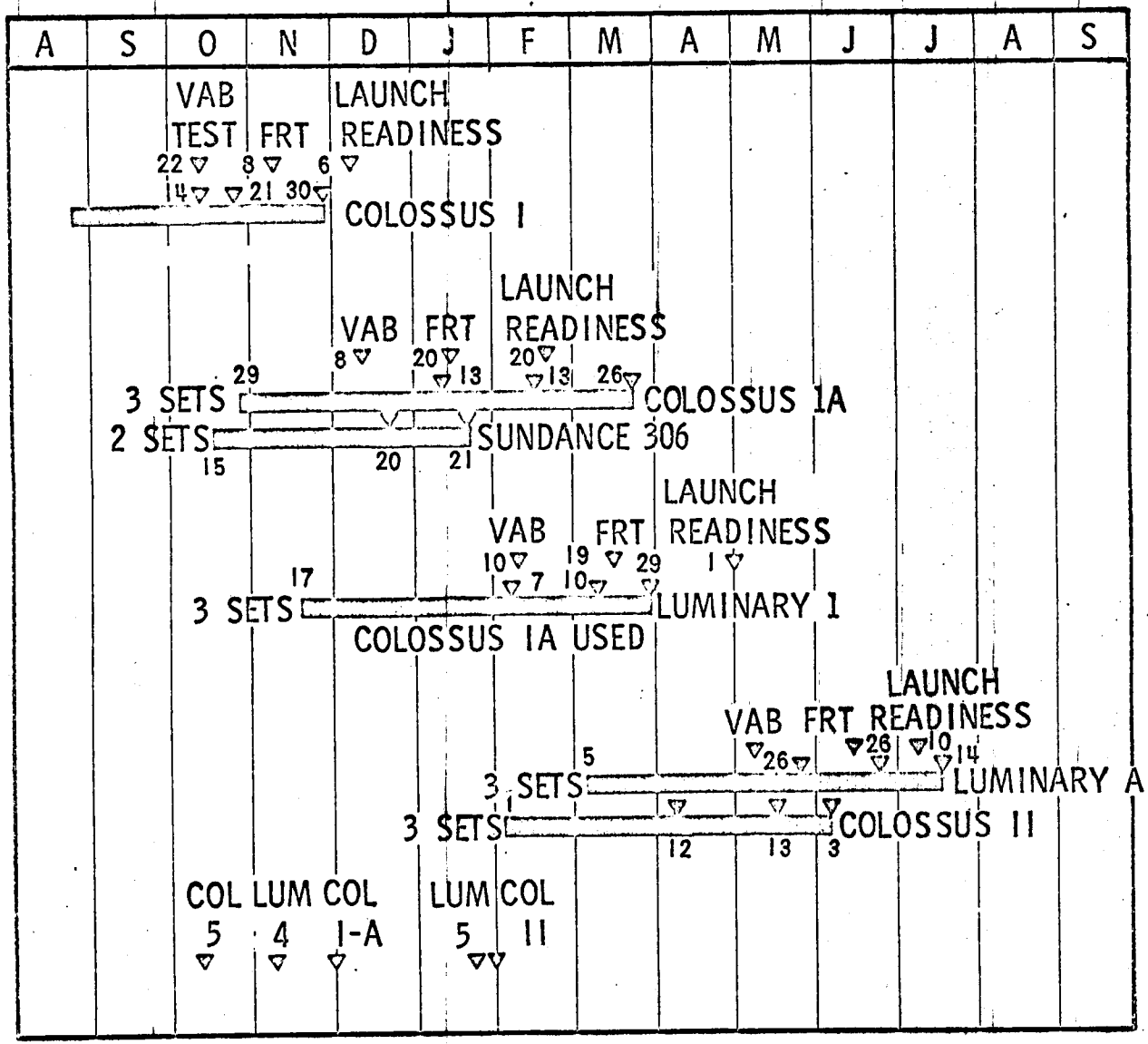
REVIEW

- COLOSSUS DEVELOPMENT AND VERIFICATION HISTORY
- C-PRIME USE OF COLOSSUS
- PROGRAM NOTES AND ANOMALIES
- RESTARTS, FRESH STARTS, OPERATOR ERRORS

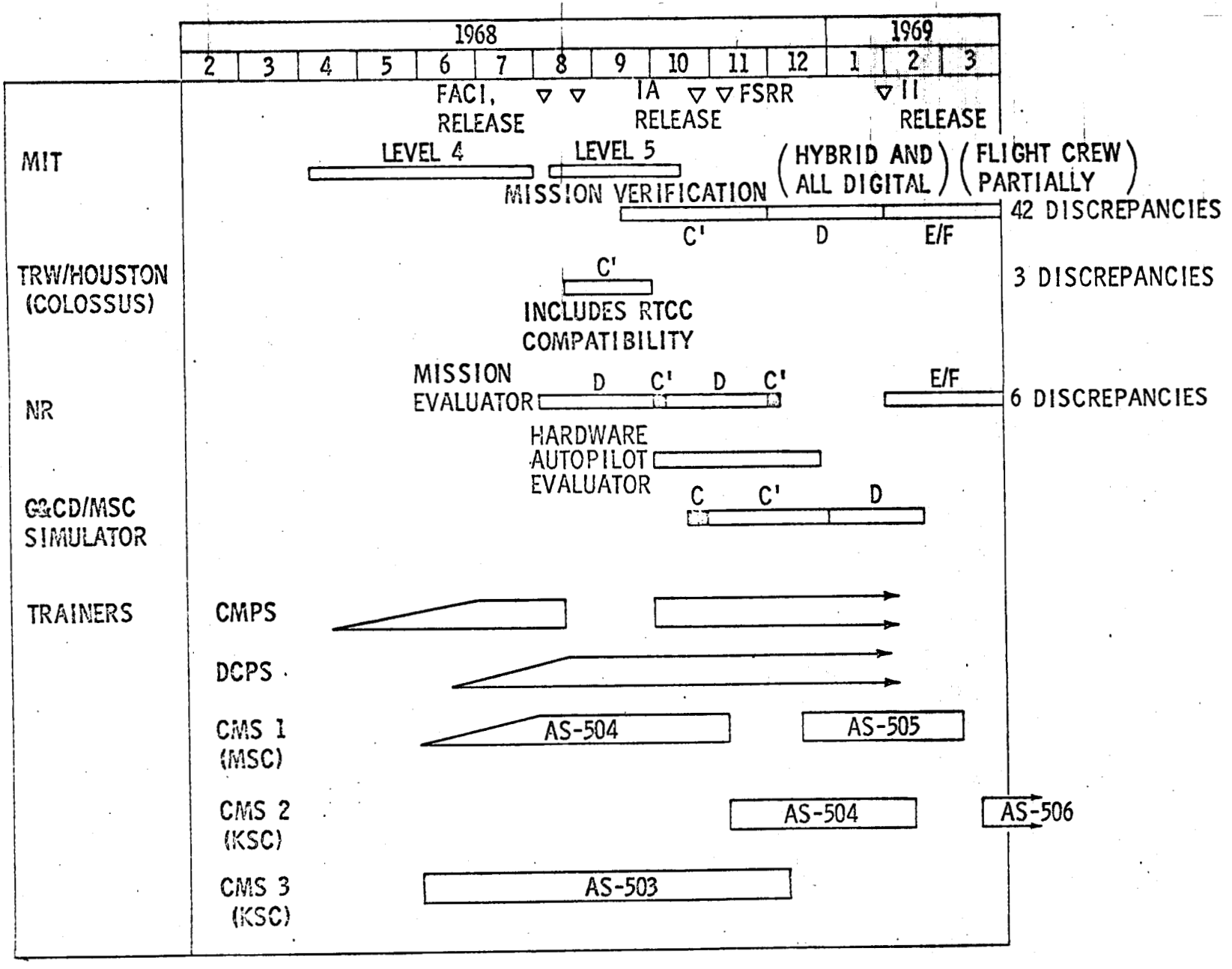

COLOSSUS LUNAR CM
PREDICTED DATE OF MILESTONE
DATE OF MIT/IL DEVELOPMENT PLAN
MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY
II RELEASE FEB I
IA RELEASE DEC I
FSRR
ROFES AT KSC
END LEVEL FIVE TESTS
RELEASE ASSEMBLY 237
8 FACI
TESTING
END LEVEL 4
FIRST RELEASE



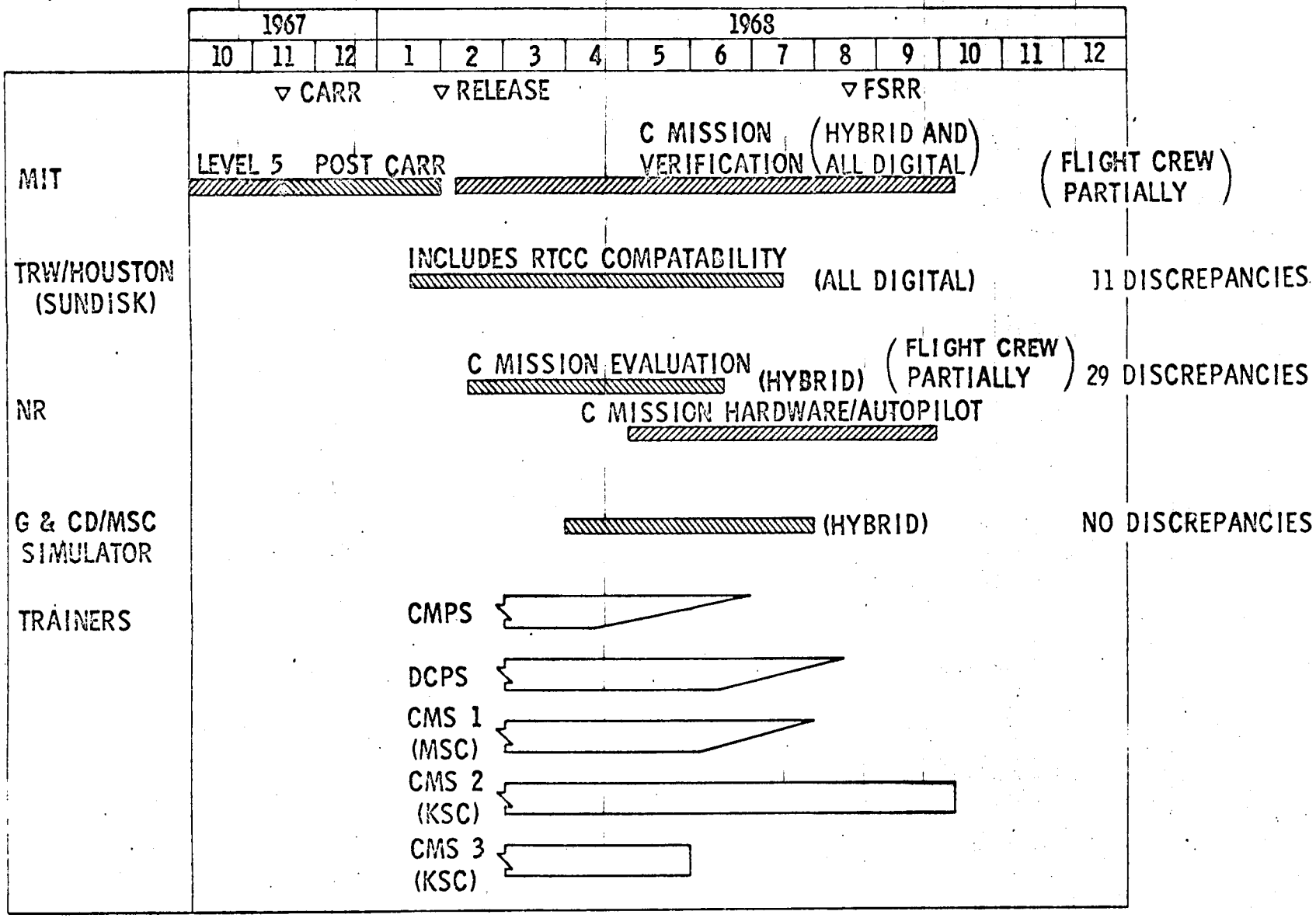
POSSIBLE SCHEDULES FOR S/C ROPE MANUFACTURE



SOFTWARE TESTING - COLOSSUS - CM - AS-503 AND UP



SOFTWARE TESTING - SUNDISK AS-205



TRW TASK E-47 FOR GCD/MSC

C-PRIME MISSION PHASES / G&C FUNCTIONS	PRELAUNCH	LAUNCH	EARTH PARKING ORBIT	TRANSLUNAR INJECTION	SEPARATION, TRANSPOSITION & SIMULATED DOCKING	1st MCC	2nd MCC	3rd MCC	LUNAR ORBIT INSERTION	CIRCULARIZATION BURN	LUNAR ORBIT PERIOD	TRANSEARTH INJECTION	1st MCC	2nd MCC	3rd MCC	PREENTRY	ENTRY
PRELAUNCH	YES																
LAUNCH& ABORT		YES															
S-IVB MONITOR				YES													
CMC UPDATE			YES		YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES		
IMU ALIGN			YES			YES	YES	YES	YES	YES	YES	YES	YES	YES	YES		
LANMARK TRK			YES							?	YES						
STAR NAVIGATION						YES	YES	YES					YES	YES	YES		
ATTITUDE HOLD,					YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES		
ATTITUDE MAN.					YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES		
FREE DRIFT						YES	YES	YES		YES	YES		YES	YES	YES		
PTC						YES	YES	YES		YES	YES		YES	YES	YES		
PRETHRUST						YES	YES	YES	YES	YES		YES	YES	YES	YES		
RCS ΔV					YES	?	?	?	YES	YES		YES	YES	YES	YES		
SPS ΔV						YES	YES	YES	YES	YES		YES	?	?	?		
PREENTRY																YES	
ENTRY																	YES

COLOSSUS

C-PRIME PROGRAMS

00	IDLING
01	PRE-LAUNCH INITIALIZE
02	PRE-LAUNCH GYROCOMPASS
03	PRE-LAUNCH AZ VERIFY
06	POWER DOWN
07	SYSTEM TEST (GROUND)
11	EOI MONITOR
21	GROUND TRACK COMPUTE
22	ORBITAL NAVIGATION
23	CISLUNAR NAVIGATION
27	UPDATE
30	EXTERNAL ΔV PRE-THRUST
37	RETURN TO EARTH TARGET
40	SPS BURN
41	RCS BURN
47	THRUST MONITOR
51	IMU DETERMINATION
52	IMU REALIGN
53	51-BACKUP LOS
54	52-BACKUP LOS
61	CM/SM SEP. ATTITUDE
62	SEP., PRE-ENTRY
63	ENTRY-INITIALIZE
64	ENTRY-POST .05 G
65	ENTRY-UPCONTROL
66	ENTRY-BALLISTIC
67	ENTRY-FINAL PHASE

RESTARTS

CAUSED BY:

1. 28 v SUPPLY BELOW 22.6 v, OR/4 v BELOW 12.5 v OR ABOVE 16 v, OR 4 v BELOW 3.65v OR ABOVE 4.4 v
2. COMPUTER OSCILLATOR FAILURE
3. "NIGHT WATCHMAN" - FAILURE TO ADDRESS CELL 0067 WITHIN 0.64 TO 1.92 SECONDS. (PROGRAM HANGUP)
4. 'TC" (TRANSFER CONTROL TO ---) OR 'TCF" (= "TC" BUT ONLY TO FIXED MEMORY) ORDER IN EFFECT FOR 5 TO 15 ms, OR NO "TC" OR "TCF" DONE IN THIS INTERVAL OR AFTER A COUNTER INTERRUPT. SOFTWARE USES 'TC-SELF'TO CAUSE A RESTART
5. PARITY FAIL ON A WORD READ IN EITHER ERASABLE OR FIXED MEMORY
6. PROGRAM INTERRUPT FAILURE ("RUPT" LOCK) - PROGRAM INTERRUPT CONTINUOUS FOR 140 TO 300 ms, OR IF NO PROGRAM INTERRUPT IN THIS INTERVAL
7. RECOVERY FROM STANDBY OPERATION
8. V69E BY CREW ON DSKY

WHEN A RESTART OCCURS, COMPUTER

1. TESTS "TRUE" AND "COMPLEMENT" DATA IN RESTART PHASE TABLES TO SEE IF THEY ARE GOOD

2. IF NOT OK, CALLS FOR FRESH START

3. IF OK, RESTARTS JOBS AND TASKS WHICH APPEAR IN THE TABLES

SOFTWARE HAS SIX RESTART GROUPS

1. POWERED FLIGHT NAVIGATION
2. ORBITAL INTEGRATION
3. PRE-IGNITION, GENERAL
4. TIME DISPLAY ON DSKY
5. VELOCITY REQUIRED, LAMBERT
6. BURN TIME, PRE-IGNITION

MANY DISPLAYS ARE NOT RESTART PROTECTED

SOFTWARE ALARMS CAUSING RESTARTS (R), BAILOUTS (B), GO TO POO (P)

401	DESIRED GIMBAL ANGLES YIELD GIMBAL LOCK	
1103	UNPLANNED LOGIC BRANCH USED	
(B) 1104	DELAY ROUTINE BUSY	
(B) 1201	NO VAC. AREAS AVAILABLE	
(B) 1202	TOO MANY JOBS	
(B) 1203	TOO MANY TASKS	
(P) 1206	>1 PROGRAM USING DSKY	
(B) 1207	NO VAC AREA FOR MARKS	
(P) 1210	TWO PROGRAMS USING IMU OR OPTICS	
(B) 1211	ILLEGAL INTERRUPT OF EXTENDED VERB	
(P) 1301	ARCSIN-ARCCOS INPUT TOO LARGE	
(P) 1302	$\sqrt{\ }$ OF NEGATIVE NUMBER	
(P) 1501	INVALID DISPLAY DATA FROM INTERNAL PROGRAM	
(P) 1502	ILLEGAL FLASHING DISPLAY	
1601	BAD IMU TORQUE	

APOLLO 7 HAS HAD RESTARTS
(SEE MEMO ATTACHED FOR DETAILS AND ADDITIONS)

- WITH EVERY POWER UP/STANDBY (NORMAL)

3 INCORRECT USE OF STAR "PICK-A-PAIR" IN PLATFORM ALIGNMENT (2 ON 10/11/68, 1 ON 10/17/68) (WON'T HAPPEN IN COLOSSUS)

2 INCORRECT USE OF P-30 (EXTERNAL ΔV PRE-THRUST). TRYING TO GET H_A, H_P DISPLAYED, USED $\Delta V = 0$ WHICH CAUSED ARCSIN ARGUMENT RESTART. CAUSED BY WRONG EARTH RADIUS IN NOUN 44 WHICH IS PROPER DISPLAY. (FIXED IN COLOSSUS)

V09E	SPARE
V19E	SPARE
V29E	SPARE
V39E	SPARE
V49E	START CREW DEFINED MANEUVER
V59E	PLEASE MARK
V79E	START LUNAR LANDMARK SELECTION
V89E	RESET VHF RANGE FLAG
V99E	ENABLE ENGINE IGNTION
V60E	SET ATT. REF. TO NOW ATT.
V61E	MODE I ATT. ERROR
V62E	MODE II ATT. ERROR
V63E	MODE III ATT. ERROR
V64E	S-BAND ANT. CALCS.
V65E	START OPTICAL VERIFY OF PRELAUNCH
V66E	CSM STATE TO LM CELLS
V67E	W-MATRIX RMS DISPLAY
V68E	CSM STROKE TEST ON
V96E	STOP INTEGRATION, GO TO P00
N96E	X-AXIS ATTITUDE FDAI ANGLES

FRESH STARTS

- CAUSED BY:
  1. V36E
  2. RESTART DATA DESTROYED
  3. MARK REJECT AND ERROR RESET BUTTONS PUSHED SIMULTANEOUSLY. MARK REJECT REQUIRES OPTICS POWER ON
- ESSENTIALLY PUTS THE COMPUTER INTO "IDLING" (P00)
- RESETS EARTH/MOON TO EARTH
- SETS REFERENCE ATTITUDE FLAG TO NOT GOOD
- MAY DESTROY STATE VECTOR IF INTEGRATION WAS IN PROCESS

V36E

V06E	DISPLAY DECIMAL ON DSKY
V16E	MONITOR DECIMAL ON DSKY
V26E	SPARE
V46E	ACTIVATE DAP
V56E	TERMINATE TRACKING
V66E	CSM STATE INTO LM CELLS
V76E	SET PREFERRED ATT FLAG
V86E	REJECT REND BACKUP MARK
V96E	STOP INTEGRATION, GO TO P00
V30E	REQUEST EXECUTIVE
V31E	REQUEST WAITLIST
V32E	RECYCLE
V33E	PROCEED (ALSO A KEY)
V34E	TERMINATE
V35E	TEST LIGHTS
V37E	CHANGE PROGRAM TO XX
V38E	SPARE
V39E	SPARE
V63E	MODE 3 ATT ERROR DISPLAY
N36E	CMC CLOCK TIME

COLOSSUS NOTES AND ANOMALIES

GENERAL

1.2.1 DON'T CALL V37 FOR 20 SEC AFTER "NO ATT" GOES OFF, OR PIPA FAIL WILL GO UNDETECTED

1.2.8, 9 HIGH COMPUTER ACTIVITY OCCURS, WITH RESTART LIKELY, IN P3X (PRE-THRUSTING) OR P7X (PRE-THRUSTING FOR LM) WITH P20 (RENDEZVOUS NAVIGATION) RUNNING, PLUS EXTENDED VERB 83 (REND. PARAM. DISPLAY) - OR IN P4X (THRUSTING) WITH LAMBERT PLUS EXTENDED VERB 82 (ORB. PARAM. DISPLAY). RESTARTS WILL DUMP ALL EXTENDED VERBS.

COLOSSUS NOTES AND ANOMALIES

PRE-LAUNCH, LAUNCH, TLI MONITOR

NONE OF IMPORTANCE

COLOSSUS NOTES AND ANOMALIES

- AS OF OCT. 10, 1968, THERE ARE 73 NOTES, 59 OF WHICH APPLY FOR C-PRIME USES.

- AS OF OCT. 18, 1968, THERE HAVE BEEN 51 ANOMALIES DISCOVERED. 7 ARE TRIVIAL OR FALSE, 34 ARE ALREADY IN NOTES, 10 ARE OPEN.

PRE-LAUNCH

P07	SYSTEM TEST, IMU PARAMETERS
P01	INITIALIZE AZIMUTH, PAD AND VEHICLE DATA, OPTICAL TARGET DATE, IMU DATA. COARSE ALIGN PLATFORM
P02	FINE ALIGN
P03	CREW COMMANDS OPTICAL VERIFICATION
P02	CREW COMMANDS NEW AZIMUTH. 320 SEC FOR TORQUING AND RE-LEVELING PLATFORM
	LIFTOFF SIGNAN FROM S-IVB, BACKUP V75 E (KEY V75 AT T-2 MIN.). GO TO P11

LAUNCH, TLI MONITOR

LAUNCH

P11 DISPLAY ATTITUDE ERRORS ON FDAI FOR 163.8 SEC.
MONITOR VI, H DOT, H UNTIL SHUTDOWN

ABORTS ALL SCS AUTO MODE

TLI MONITOR

MONITOR VI, H DOT, H UNTIL SHUTDOWN, WHICH IS BACKED UP BY CREW USING TIME AFTER PREDICTED SHUTDOWN

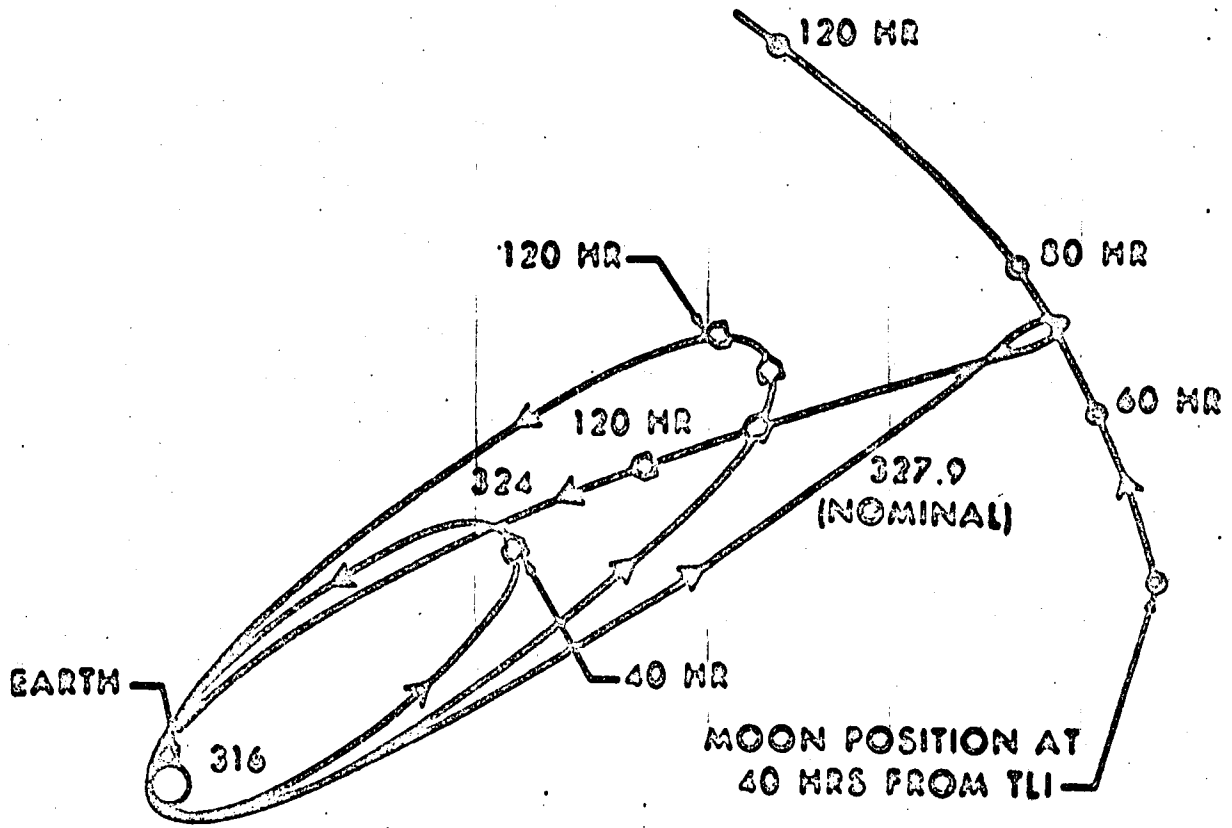
COLOSSUS NOTES AND ANOMALIES

PRE-LAUNCH, LAUNCH, TLI MONITOR

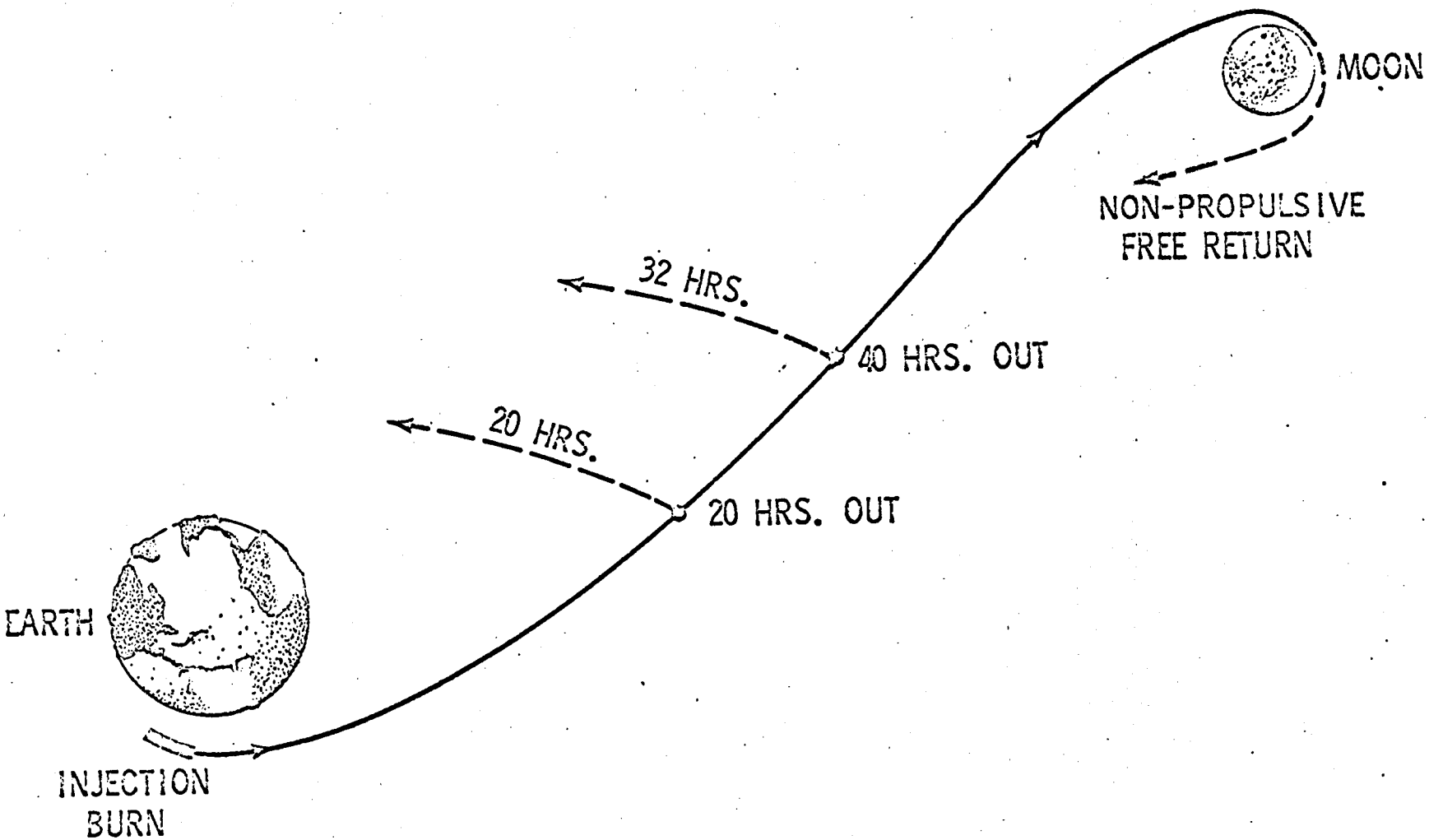
NONE OF IMPORTANCE

NASA-S-67 3054

TRANSLUNAR INJECTION PREMATURE SHUTDOWN TRAJECTORIES



CONTINGENCY RETURNS FROM TRANSLUNAR COAST USING SM PROPULSION



RTE ABORT FROM TRANSLUNAR LEG

P27 CMC UPDATE AND TARGETING FOR EXTERNAL ΔV BURN

P30 PRE-THRUST, EXTERNAL ΔV

P40 SPS THRUSTING

P23 CISLUNAR NAVIGATION

BACKUP

P37 RETURN TO EARTH TARGETING FOR EXTERNAL ΔV BURN. GIVEN TIME, ΔV BURN MAGNITUDE, LANDING SITE, ENTRY FLIGHT PATH ANGLE, P37 FIND BURN ATTITUDE FIRST BY PATCHED CONICS, THEN BY PRECISION INTEGRATION.

UP DATA CAPABILITY AT LUNAR RANGE

- WITH FULL CSM COMMUNICATIONS CAPABILITY (HIGH GAIN ANTENNA AVAILABLE)
  (CSM IN HIGH BIT RATE TELEMETRY MODE)

  UP DATA STATE VECTOR IN APPROXIMATELY 60 SECONDS
  VERIFICATION BY REMOTE SITE COMMAND COMPUTER AUTOMATICALLY

- WITH REDUCED CSM COMMUNICATIONS CAPABILITY (NO HIGH GAIN ANTENNA)
  (CSM IN LOW BIT RATE TELEMETRY MODE)

  UP DATE CAN BE TRANSMITTED TO CSM AT NORMAL RATE
  VERIFICATION WILL HAVE TO BE ACCOMPLISHED MANUALLY

  - ASTRONAUT READ OUT VIA VOICE LINK
  - FLIGHT CONTROLLER VERIFICATION POSSIBLE BY MANUAL COMPARISON OF TELEMETRY DATA AND LOAD

  UPDATE CAN ALSO BE VOICED UP

IMU AND OPTICS

IMU ON CONTINUALLY, PERIODICALLY REALIGNED

TELESCOPE - 4TH MAGNITUDE STARS REQUIRED FOR CONSTELLATION RECOGNITION

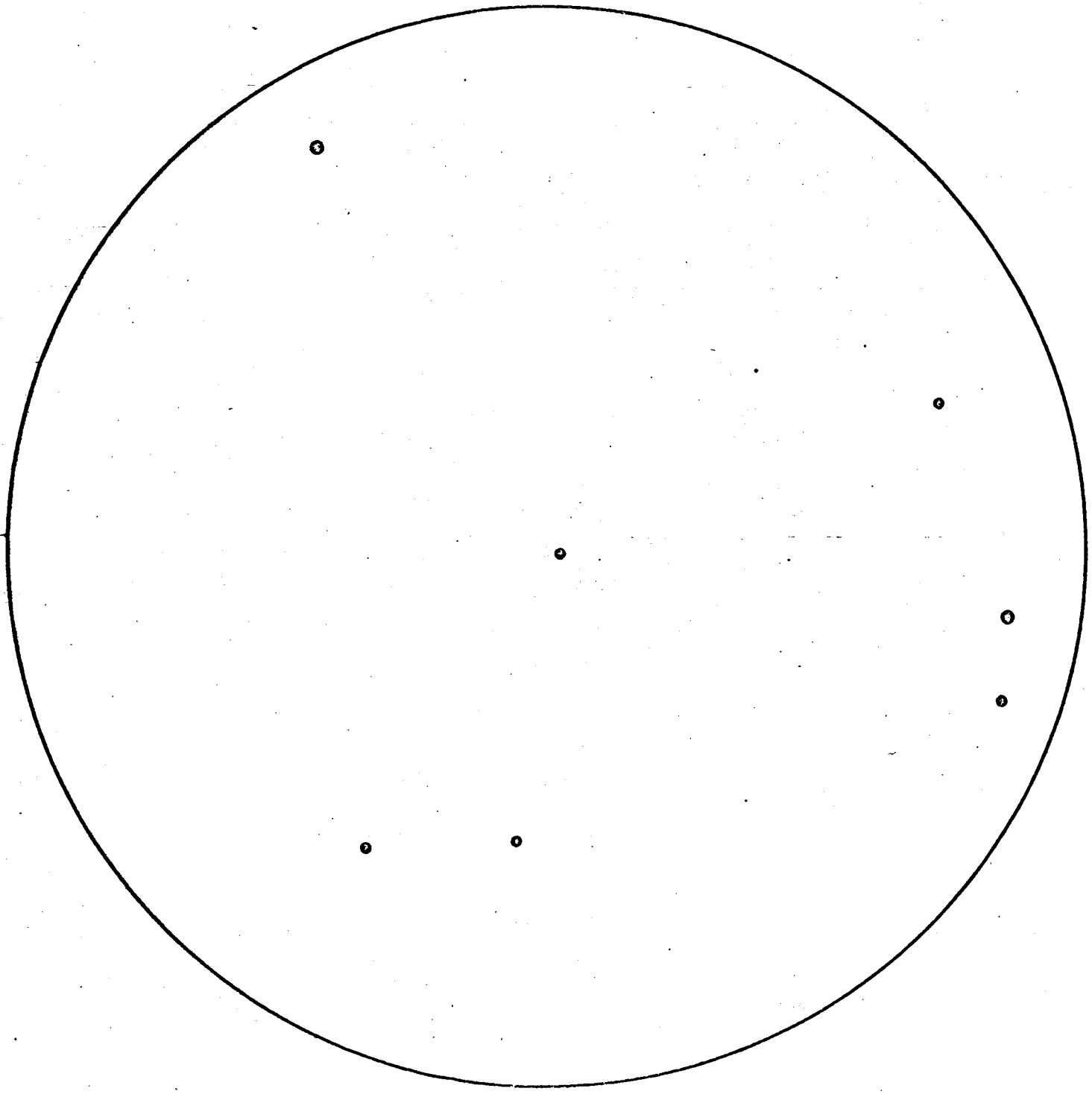
SEXTANT - 8TH MAGNITUDE STARS MAY BE VISIBLE AND FORM A PATTERN USABLE FOR STAR IDENTIFICATION IF TELESCOPE UNUSABLE. MAPS MAY BE CARRIED

SOFTWARE OPTIONS PERMIT USE OF SUN, EARTH, MOON, PLANETS (GROUND LOCATED) FOR ALIGNMENT. SUN FILTER FOR SXT AVAILABLE AND UP FOR CCB APPROVAL. $1/4^{0}$ ACCURACY SATISFACTORY FOR RTE.

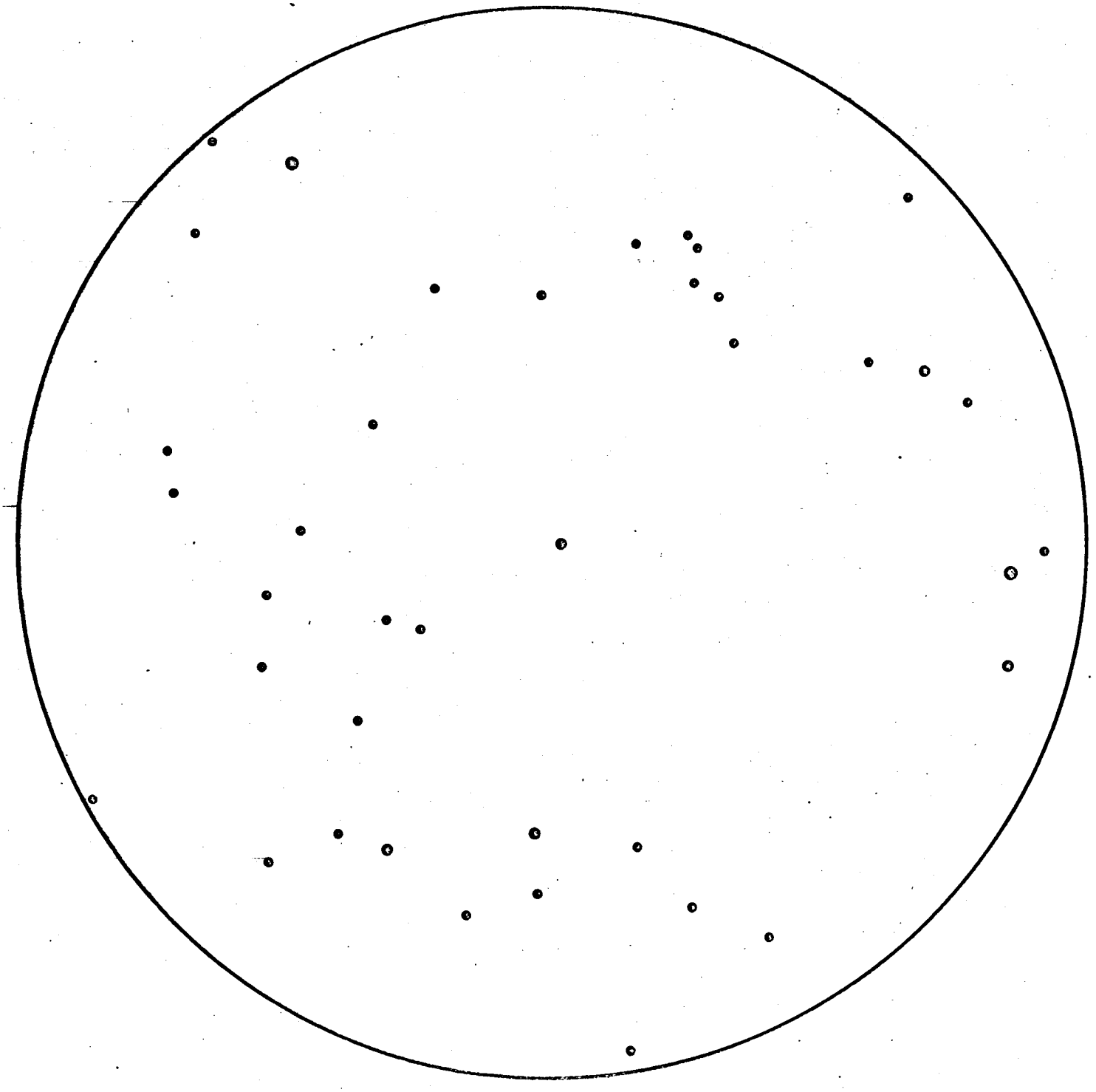
COAS AS BACKUP TO SCT AND SXT FOR ALIGNMENT

BMAGS, FDAI AS BACKUP TO IMU (6^{0}/HR, 3σ DRIFT)

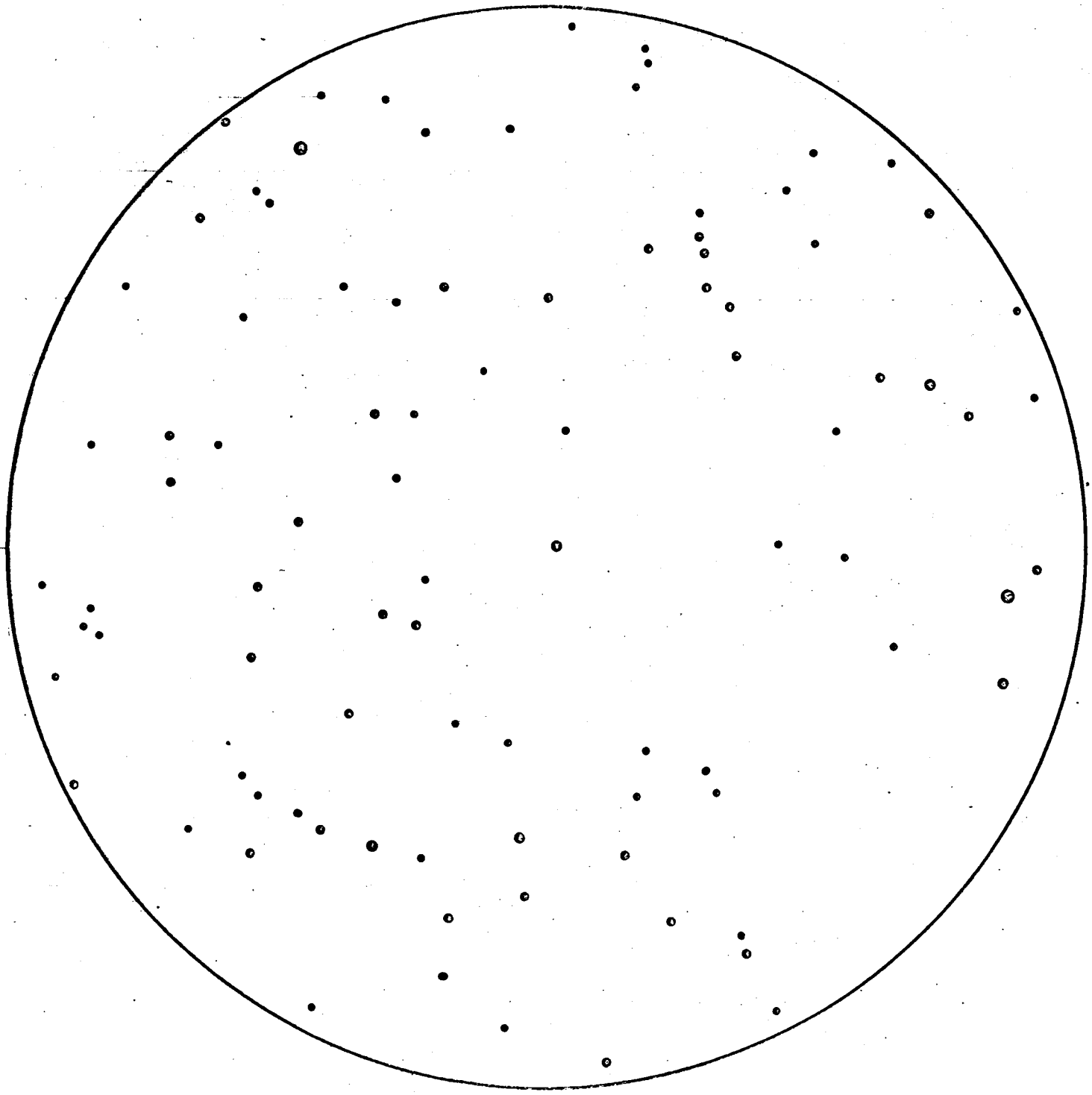
FIRST AND SECOND MAGNITUDE STARS



1 - 3 MAGNITUDE STARS



1 - 4 MAGNITUDE STARS



APOLLO 7
PRELIMINARY RESULTS

- TESTS ON NUMBER OF STARS SEEN IN TELESCOPE (SCT) ARE IN GOOD AGREEMENT WITH PROJECT MOSES DATA, LEND VALIDITY TO LM-DOCKED RESULTS FROM MOSES.

- NEED 4th MAGNITUDE STAR VISIBILITY IN SCT FOR CONSTELLATION/STAR VERIFICATION. SEEMS ACHIEVEABLE EXCEPT FOR A FEW MINUTES AFTER URINE DUMP (CAN BE SCHEDULED OR WATER DUMP (MAYBE NOT SCHEDULEABLE)

- REINFORCES TREND TOWARD STAR-EARTH HORIZON SIGHTINGS REPLACING STAR-EARTH LANDMARK SIGHTINGS

COLOSSUS NOTES AND ANOMALIES

NAVIGATION

1.4.5 MOON ROTATION IN 2 HOURS IS STORED AS 6.7^{0}, NOT 1.07^{0}. GROUND TRACK PREDICTIONS 2 HOURS OR MORE AHEAD WILL HAVE OUT-OF-PLANE ERROR. LESS TIME AHEAD - NO ERROR.

1.6.9 SXT AND CDU ANGLES ARE NOT DOWNLINKED FOR STAR MARKS WHILE DOING ALIGNMENT DETERMINATION OR FINE ALIGN (P50, 51, 52, 53). ALIGNMENT MATRIX IS ON DOWNLINK. SLOW WORKAROUNDS EXIST.

3.6.2 A RESTART IN ONE PART OF R51 (FINE ALIGN) REQUIRES A RECYCLE, KEY STROKES, NEW STAR SIGHTINGS

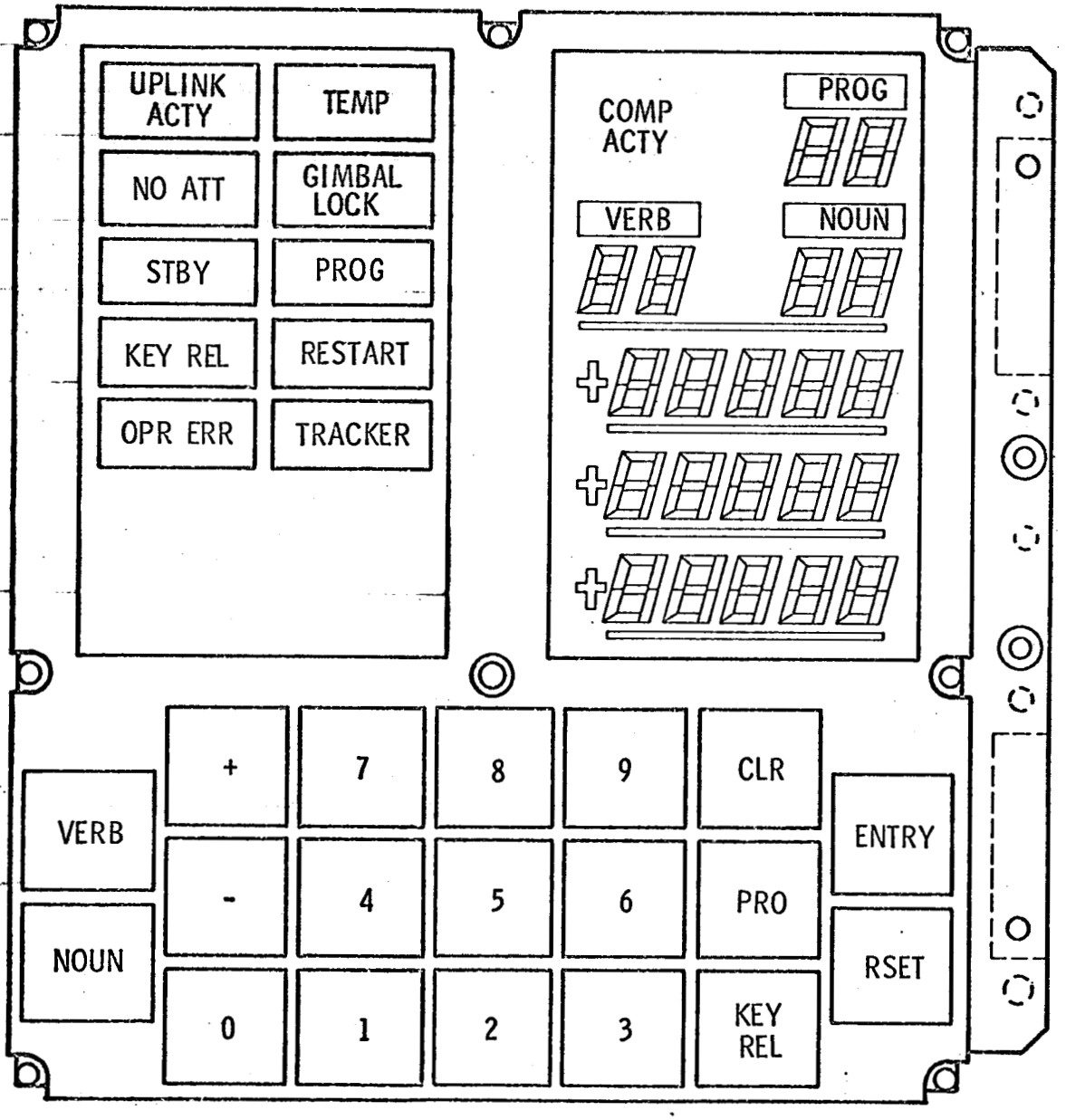
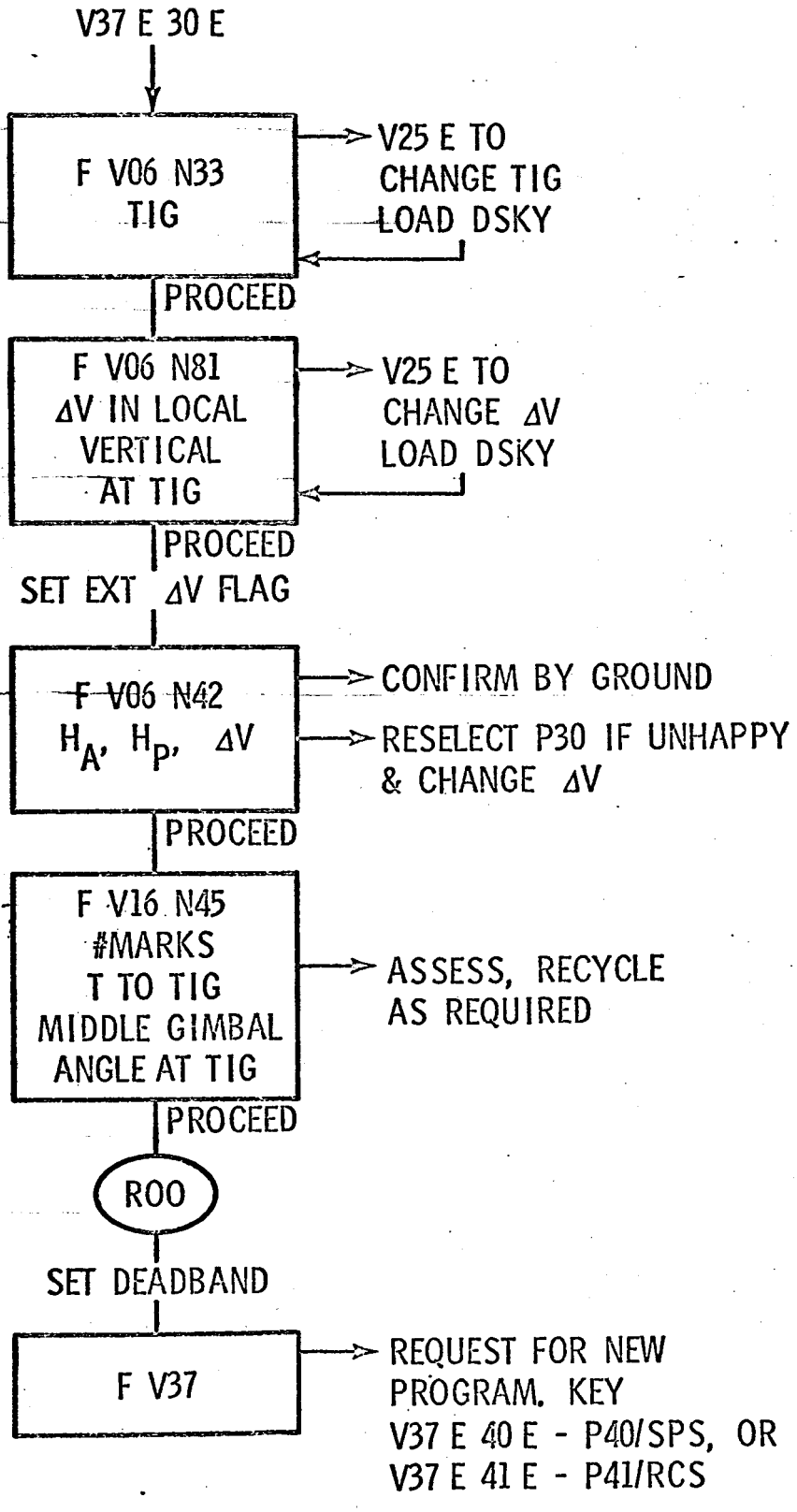
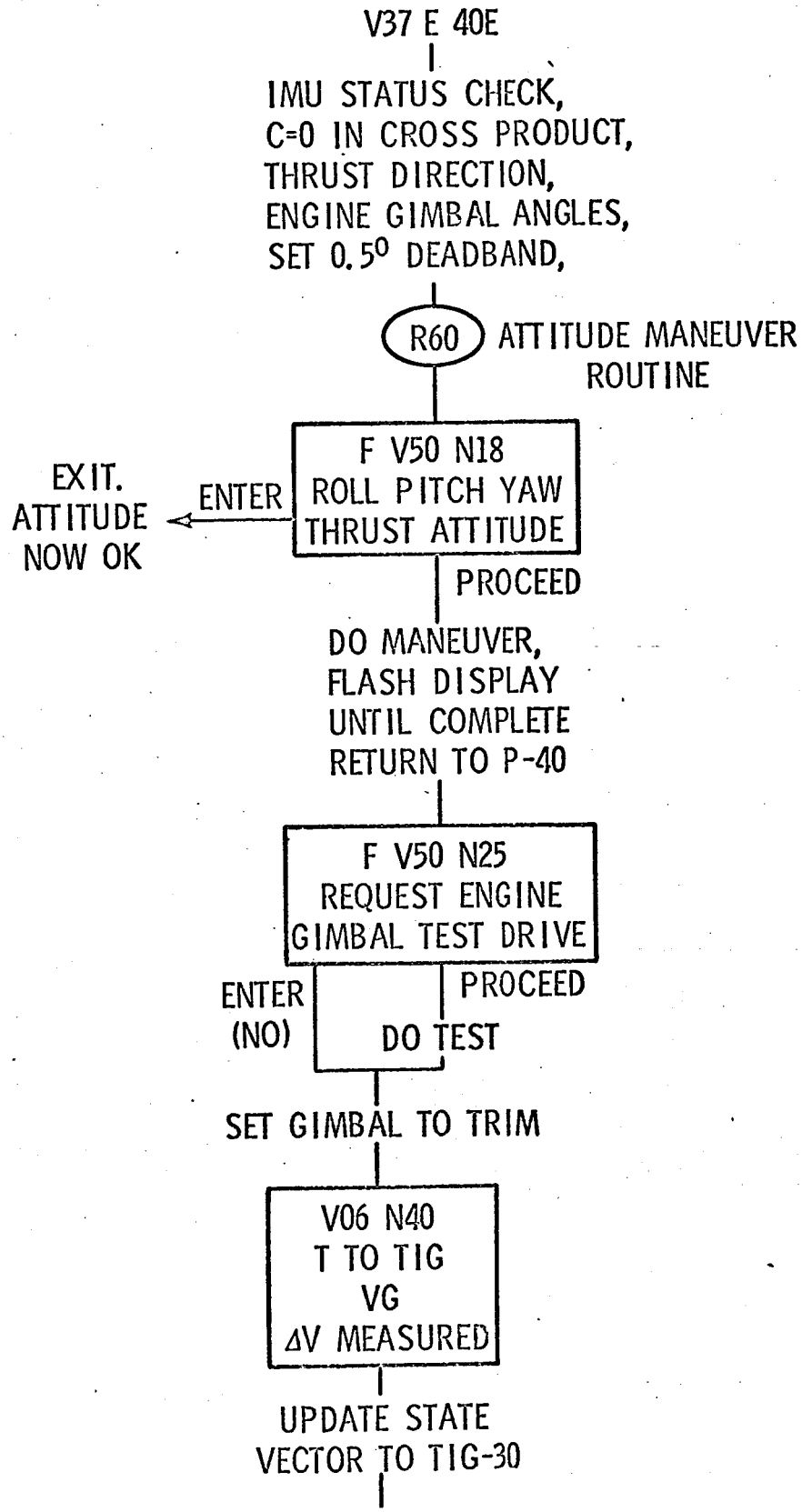


FIGURE 4-1 - DISPLAY AND KEYBOARD ASSEMBLY

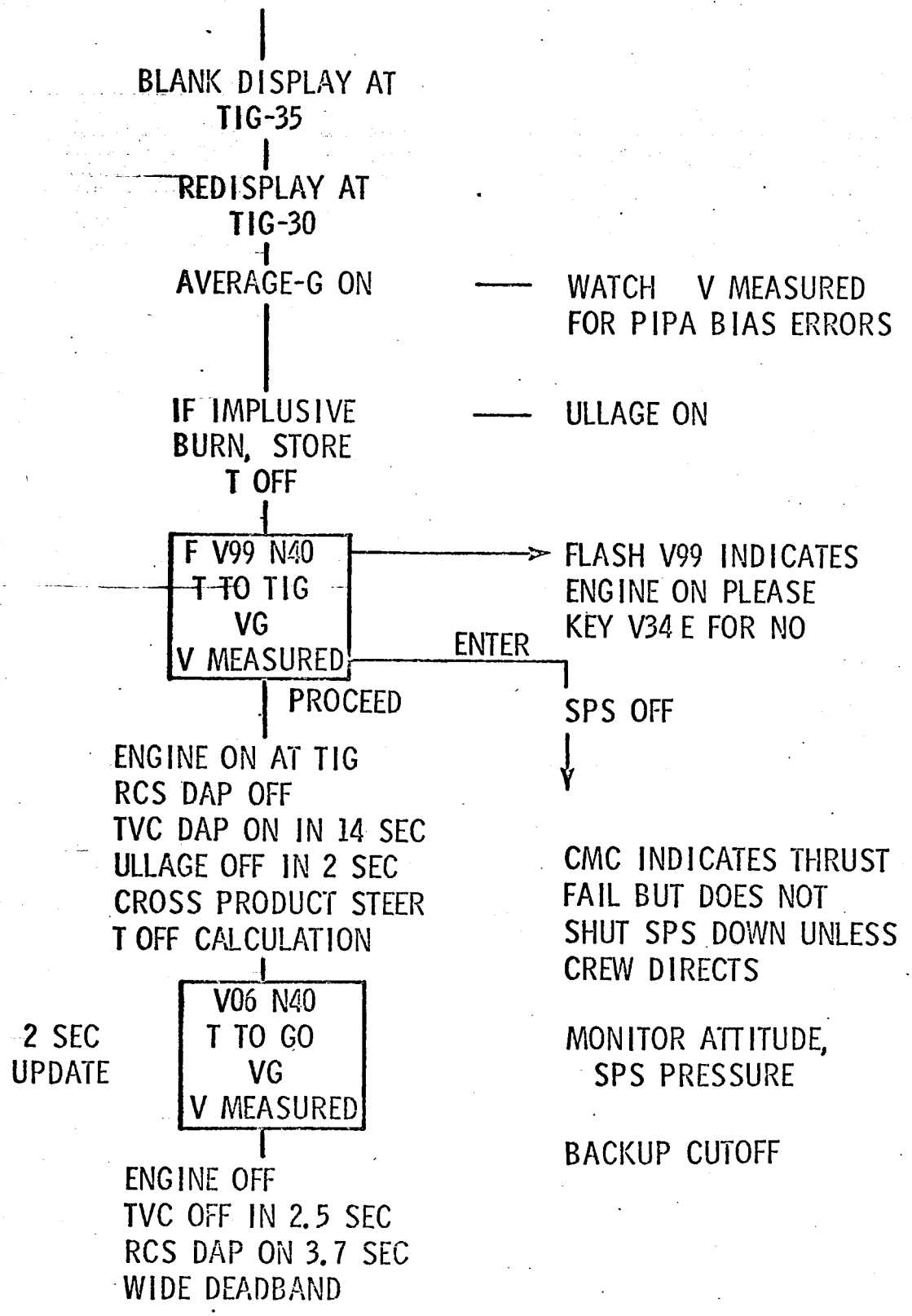
P-30 - EXTERNAL ΔV, PRE-THRUST



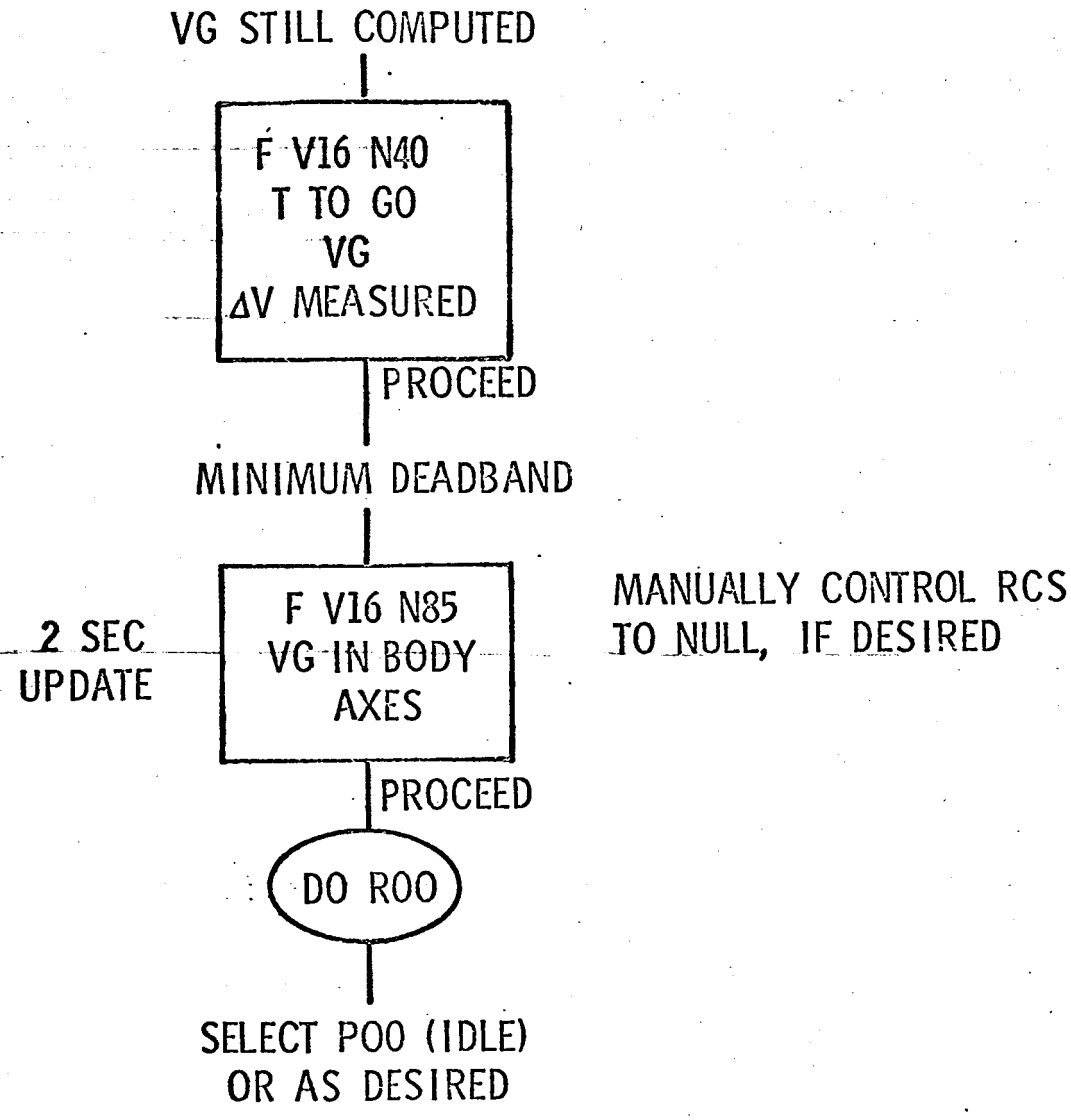
P-40 (SPS THRUST)



P-40 (CONTINUED)



P-40 (CONTINUED)



COLOSSUS NOTES AND ANOMALIES

PRE-THRUST & THRUSTING

1.5.7 V_G OR ΔV DISPLAYS IN BODY AXES HAVE TIME DELAYS OF 0.5 - 1.5 SEC.

3.7.2 RESTART IN ONE PART OF AVERAGE-G NAVIGATION CAUSES PARTIAL OR COMPLETE LOSS OF PIPA COMPENSATION. RESELECT PROGRAM

3.7.4 RESTART BETWEEN TIG AND TIG + 0.4 SECONDS STALLS TVC. DO V69E, OR GO TO POO, THEN RETARGET BURN.

3.7.5 A 1206, 1210, 1301, 1302, 1501, 1502 ALARM ABORT DURING AVERAGE-G NAVIGATION CAUSES THE THRUST OR DRAG EFFECT ON THE STATE VECTOR TO BE LOST, PLUS PIPA COMPENSATION STOPS. RESELECT P47 TO RENEW PIPA COMPENSATION, UPLINK NEW STATE VECTOR

COL 45 ALARMS 1104, 1201, 1203, 1206, 1207, 1210, 1211, 1301, 1302, 1501, 1502 MAY CAUSE ENGINE SHUTDOWN.

TRANSLUNAR LEG

P23 CISLUNAR NAVIGATION. ONBOARD AND MSFN STATE VECTORS ARE BOTH CARRIED, WITH MSFN USED IF AVAILABLE

P27 CMC UPDATE, MCC EXTERNAL ΔV TARGETING

P30 PRE-THRUST, EXTERNAL ΔV

P40/41 SPS/RCS BURNS

LACKING THE DPS AS BACKUP, MCC BURNS KEEP TRAJECTORY WITHIN RCS REACH OF FREE RETURN. MCC'S AT TLI + 6 HOURS AND AT TLI + 25 HOURS USE FREE RETURN BEST ADAPTIVE PATH FOR MISSION SUCCESS WITH A MINIMUM FUEL FREE RETURN BACKUP. CHANGE TIME, IF REQUIRED TO KEEP BACKUP WITHIN RCS CAPABILITY MCC'S AT LOI -22 HOURS AND LOI -8 HOURS WILL TARGET XYZT BUT IF 10 FPS, CHANGE MCC TIME UNTIL >10 FPS. IF THIS FAILS, THEN TARGET MINIMUM ΔV FREE RETURN (WITH WATER LANDING).

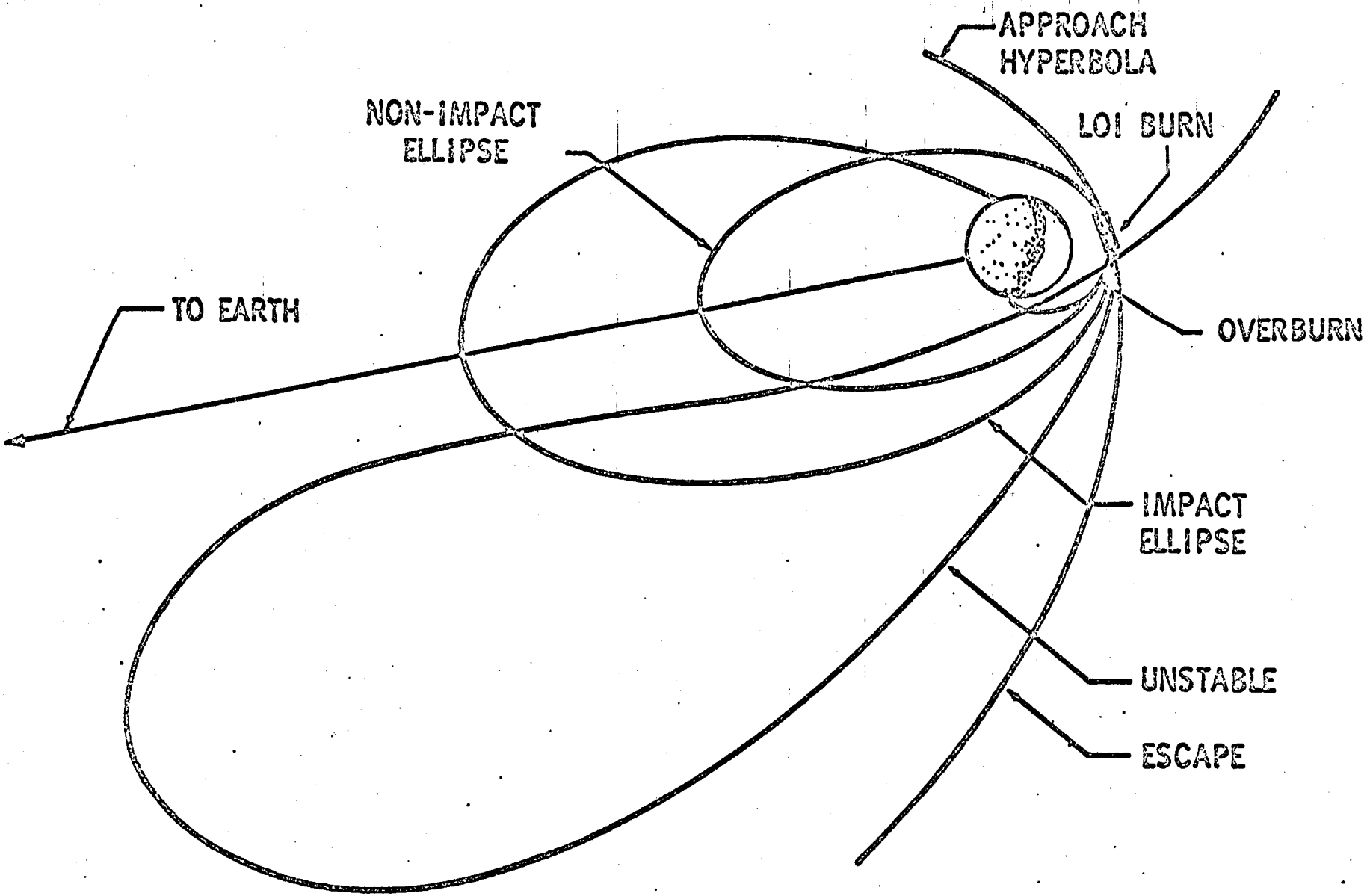
LUNAR ORBIT INSERTION

LOI-1 & 2	(60 x 170, 60 x 60 ORBITS)
P27	CMC UPDATE, TARGETING DATA FOR EXTERNAL ΔV
P30	PRE-THRUST, EXTERNAL ΔV (3000 FPS (1), 138 FPS (2))
P40	SCS THRUSTING
P30	ORBIT PARAMETER DISPLAY (H_A, H_P, TFF TO 300,000 FT (EARTH) OR 35,000 FT (MOON))
BACKUP	SCS

60 x 170 LOI-1 PERMITS CREW SHUTDOWN USING EMS ΔV COUNTER SAFELY, OVERBURN DUE TO ΔV COUNTER ERRORS (0.15 FT/SEC^2, 1.5%) STILL GIVES SAFE PERILUNE

LOI PREMATURE SHUTDOWN TRAJECTORIES

PRE-ABORT



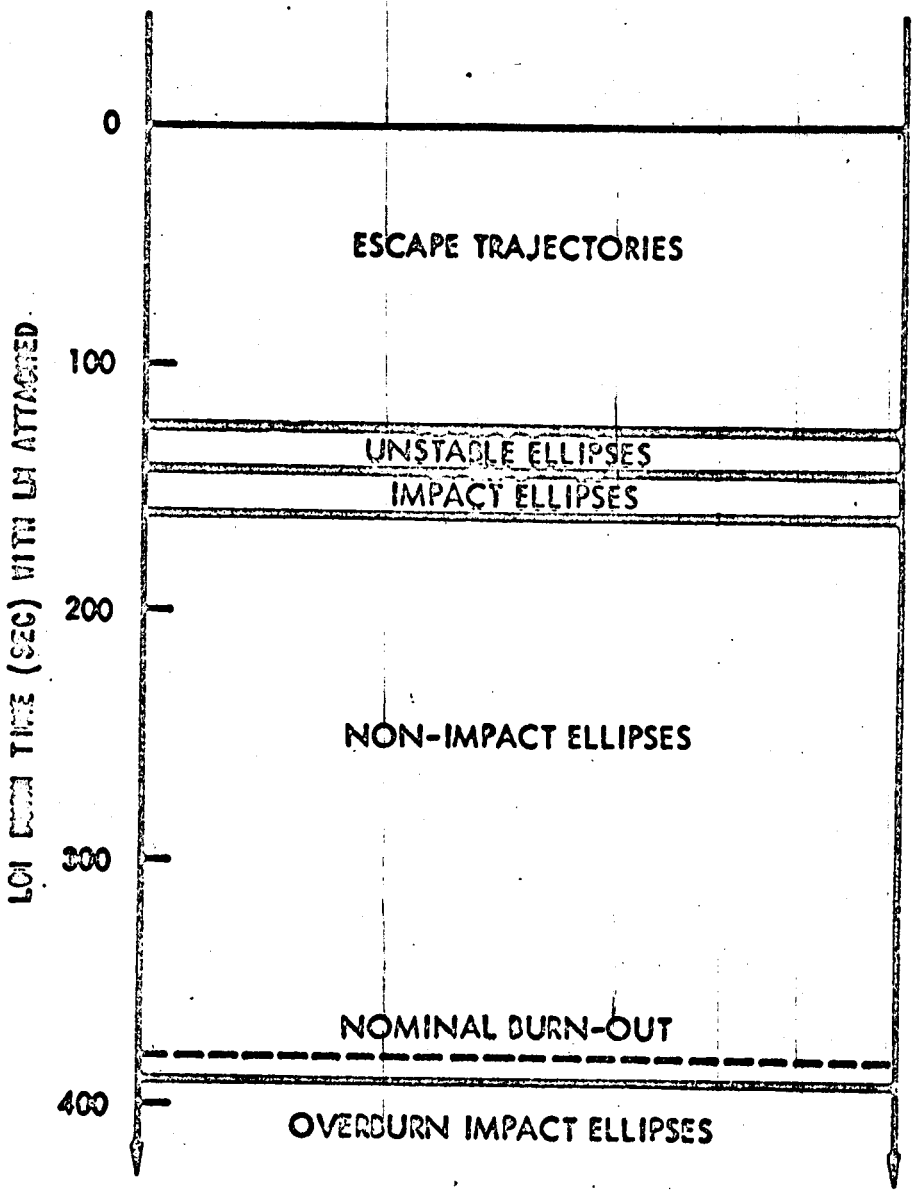


Figure 1. LOI Premature Shutdown Trajectory Families

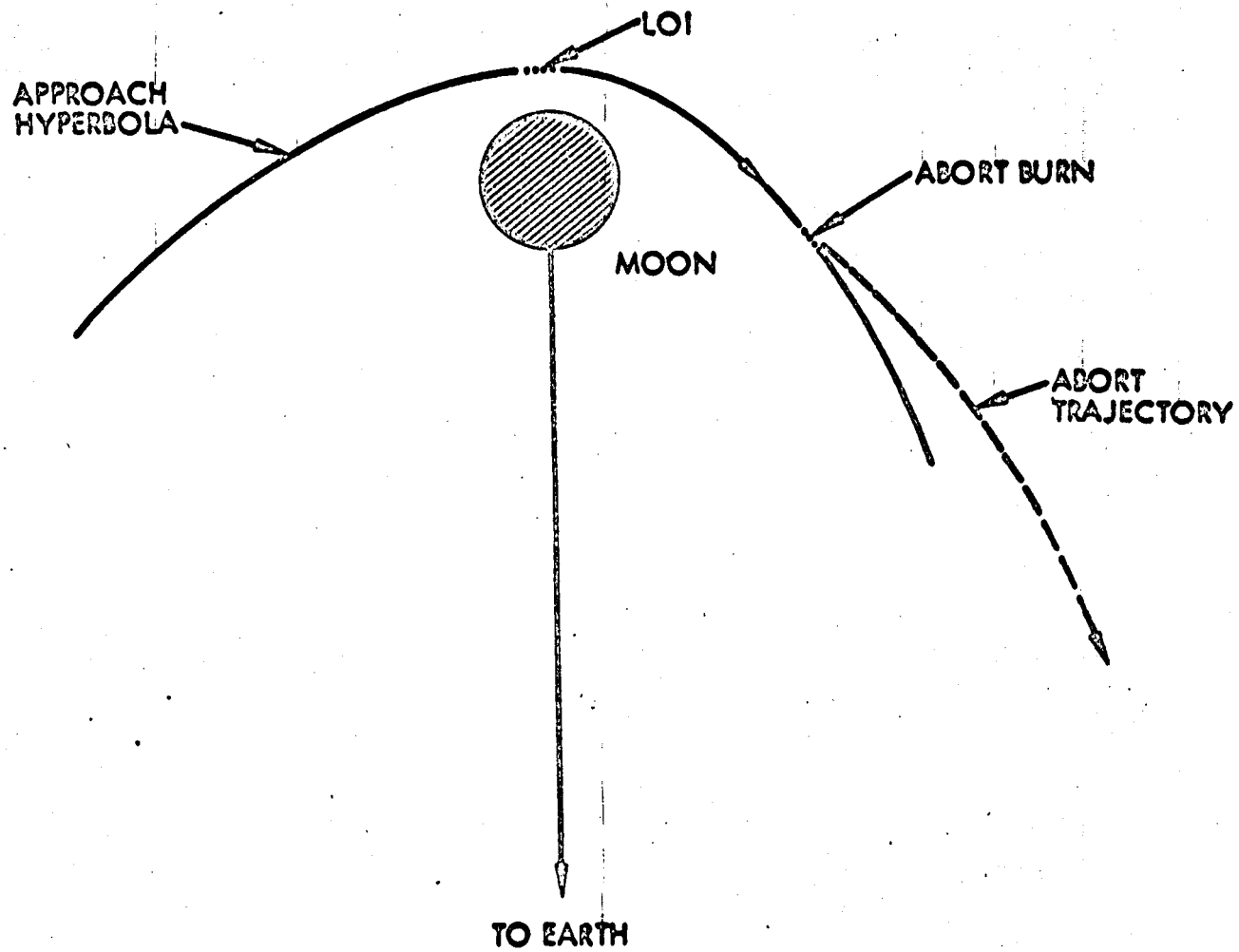


Figure 2. LOI Mode I Abort Geometry

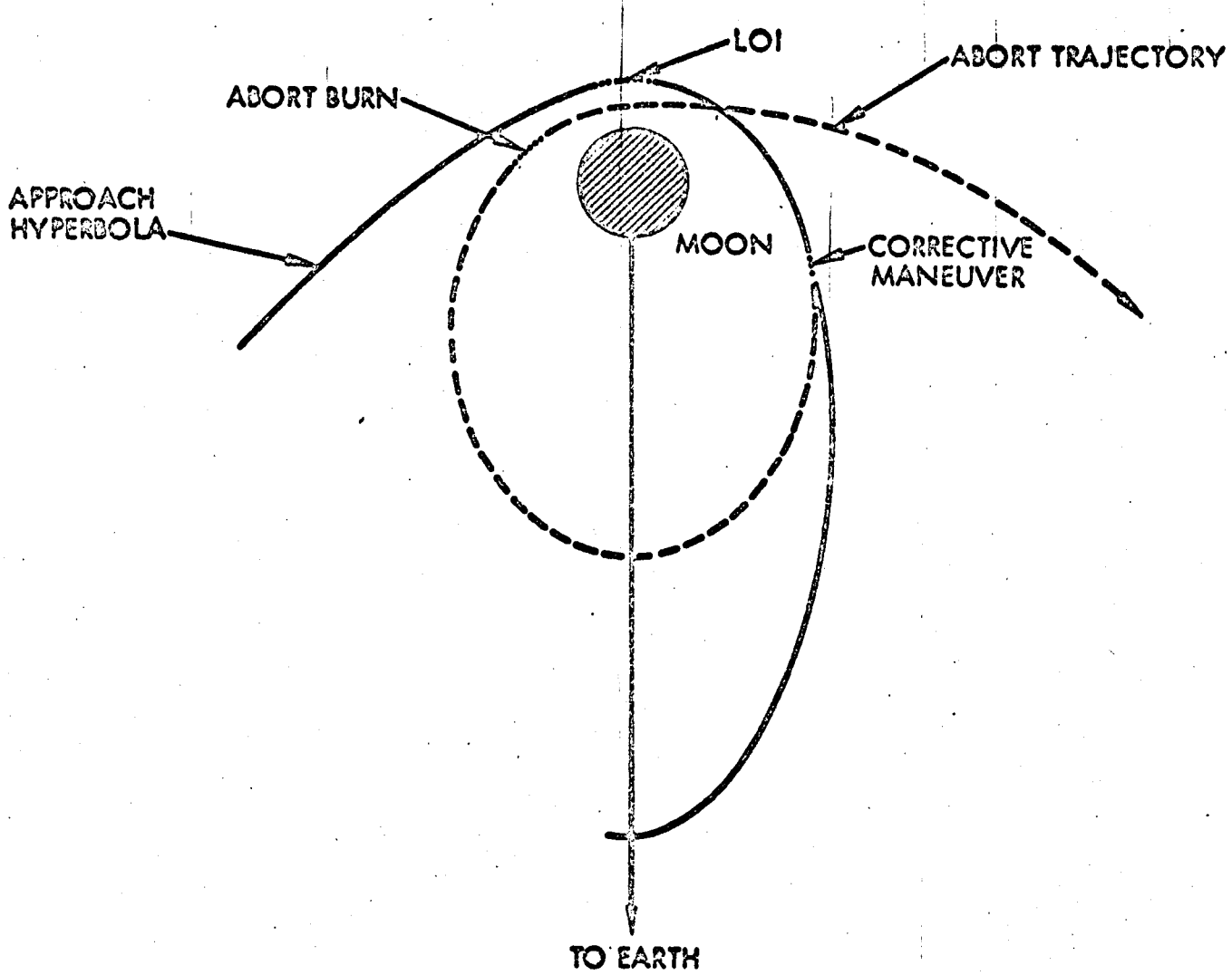


Figure 3. LOI Mode II Abort Geometry

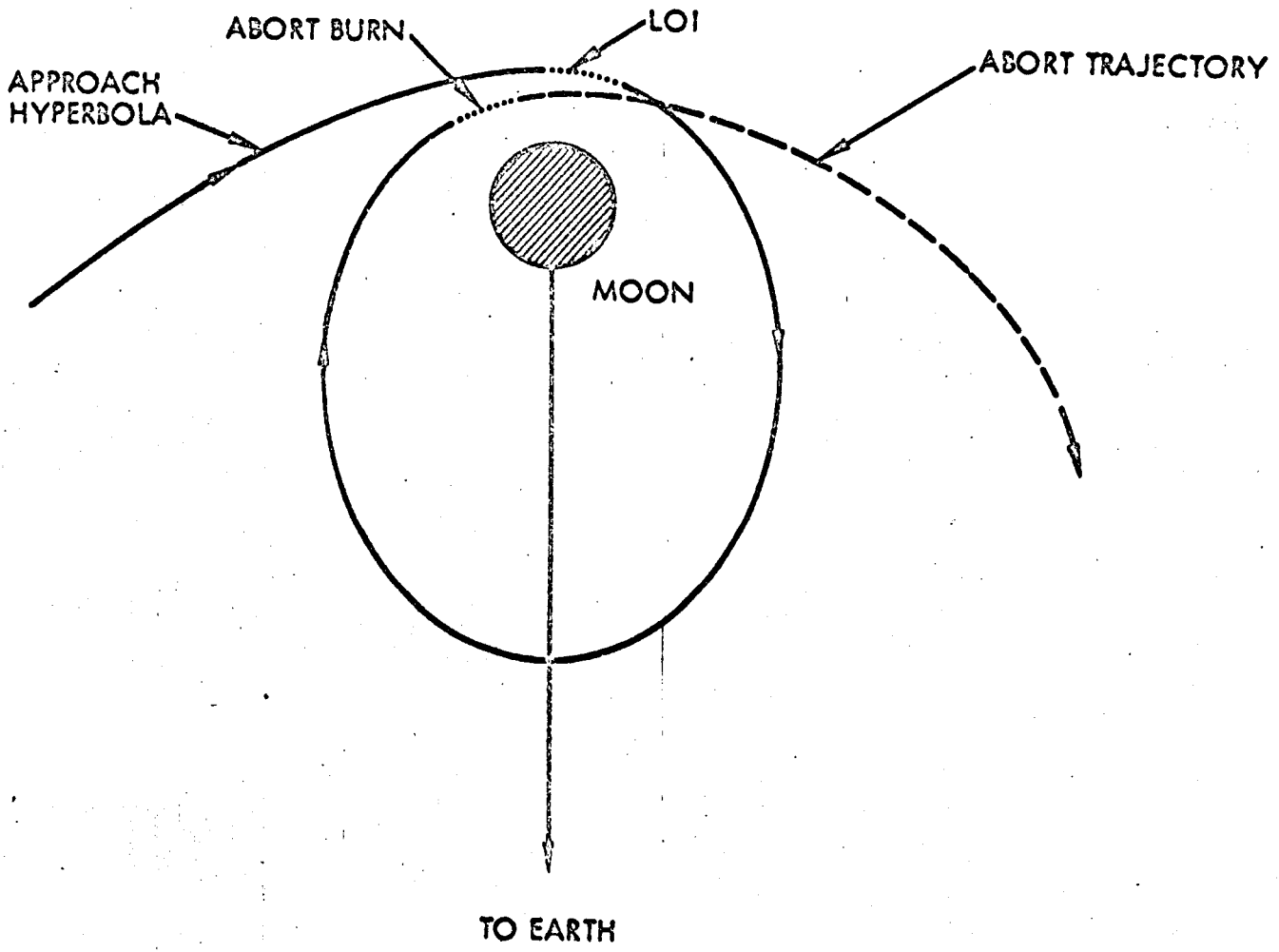


Figure 4. LOI Mode III Abort Geometry

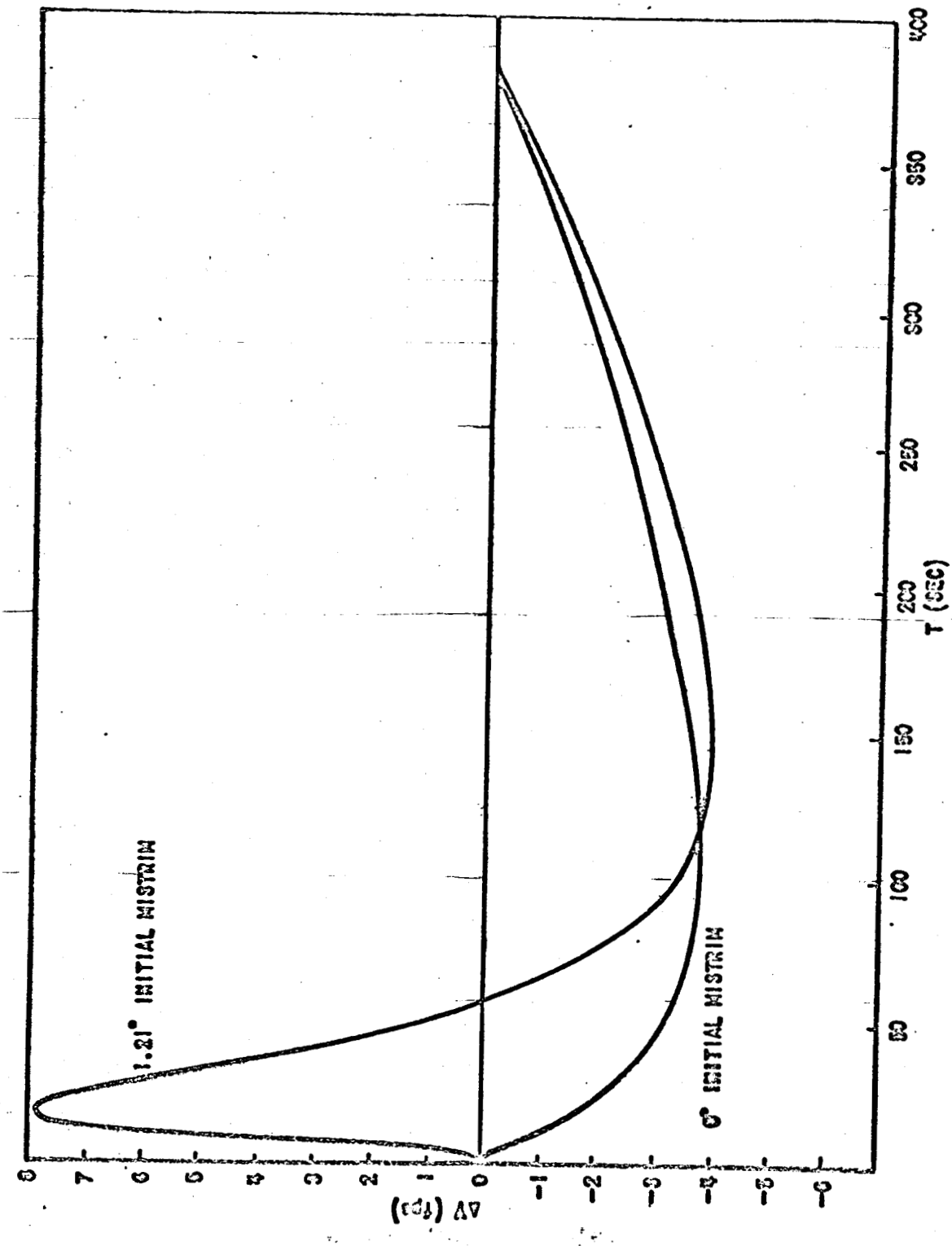


FIGURE 1. LOI MANEUVER-PITCH PLANE

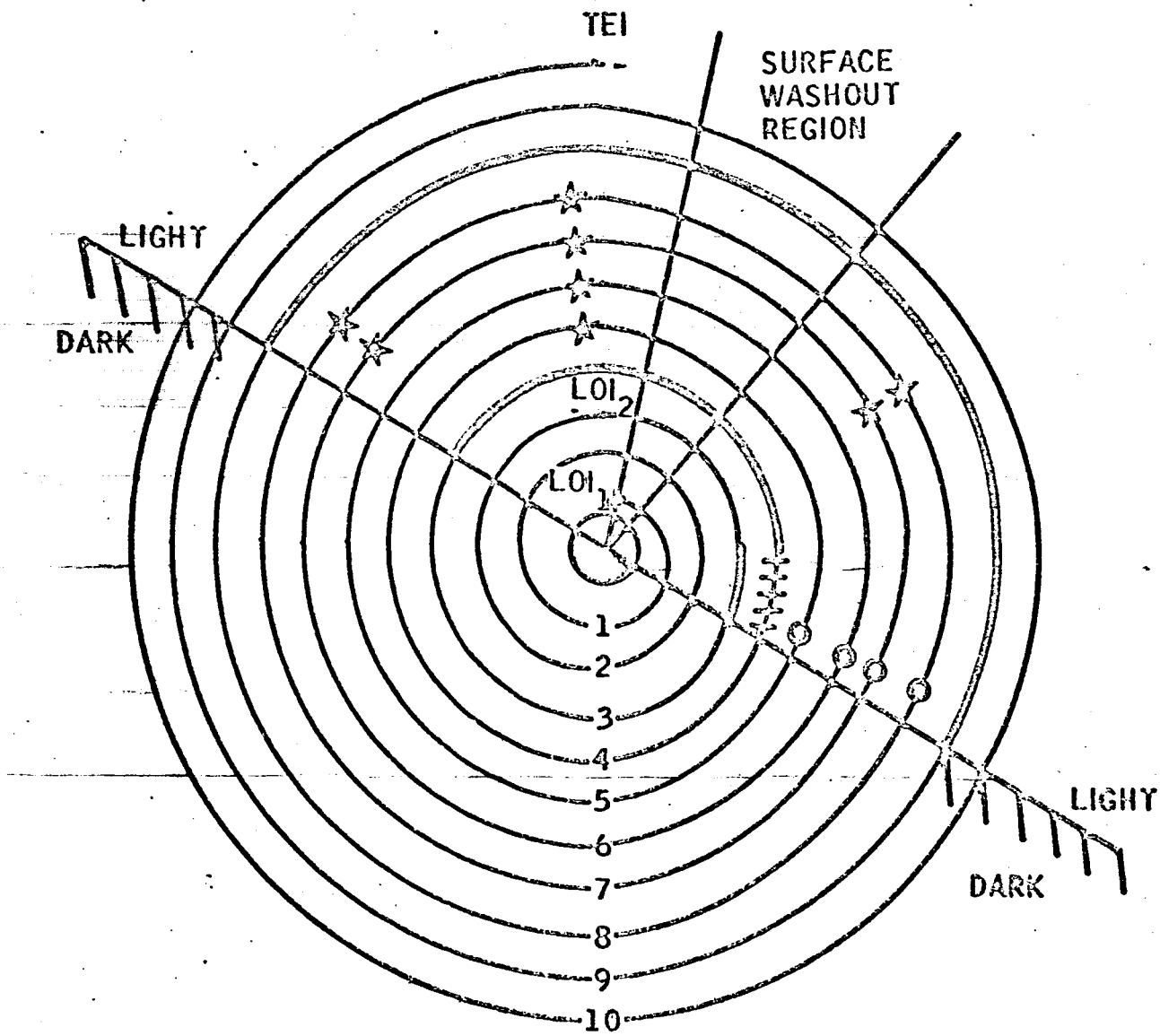


Figure .- Lunar orbit SC navigation for C' alternate 1.

TRANS-EARTH LEG

PROGRAMS AS IN TRANSLUNAR LEG WITH EMPHASIS ON BACKUP ON-BOARD NAVIGATION. (TEI + 1/2 HOUR ON). TWENTY EIGHT STAR/LUNAR HORIZON SETS OF MARKS, 23 STAR/EARTH HORIZON SETS, AND 3 STAR/EARTH LANDMARK SETS.

BASIC MCC PHILOSOPHY IS ACCEPT SPLASH POINT AND USE MCC'S TO CONTROL ENTRY FLIGHT PATH ANGLE.

BURNS ARE MADE IF OVER 1 FPS IS REQUIRED, AND THEY WILL BE MADE AS OFTEN AS REQUIRED. LAST BURN IS AT ENTRY-2 HOURS. SENSITIVITY IS 0.09^{0}/FPS AT THIS LAST BURN.

COLOSSUS NOTES AND ANOMALIES

RETURN TO EARTH

1.2.10 TFF - TIME TO ENTRY - MAY BE INACCURATE IN HYPERBOLIC ORBITS FOR CERTAIN RANGES OF TRUE ANOMALY

1.5.5 FOR PRE-APOGEE, LONG TIME ABORTS CONIC SOLUTIONS MAY YIELD BAD LANDING POINTS. PRECISION TRAJECTORIES MAY TAKE 10-30 MINUTES, WILL SHOW LANDING POINTS ACCURATELY. (PRECISION TRAJECTORIES ARE DONE AFTER CREW APPROVES CONIC SOLUTIONS)

3.5.1 P37 (RTE TARGETING) IS NOT RESTART PROTECTED. IF A RESTART OCCURS, RESELECT P37.

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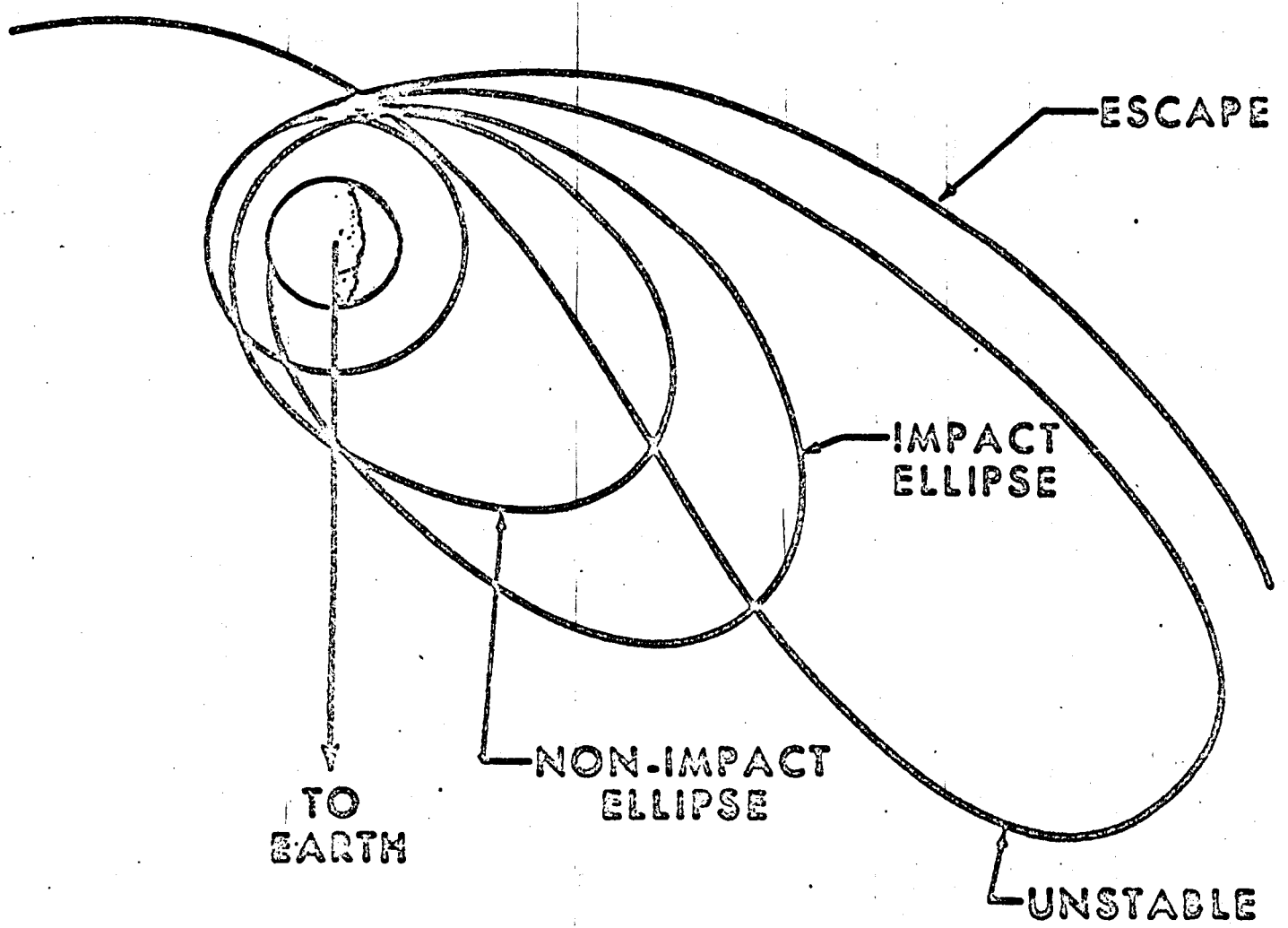
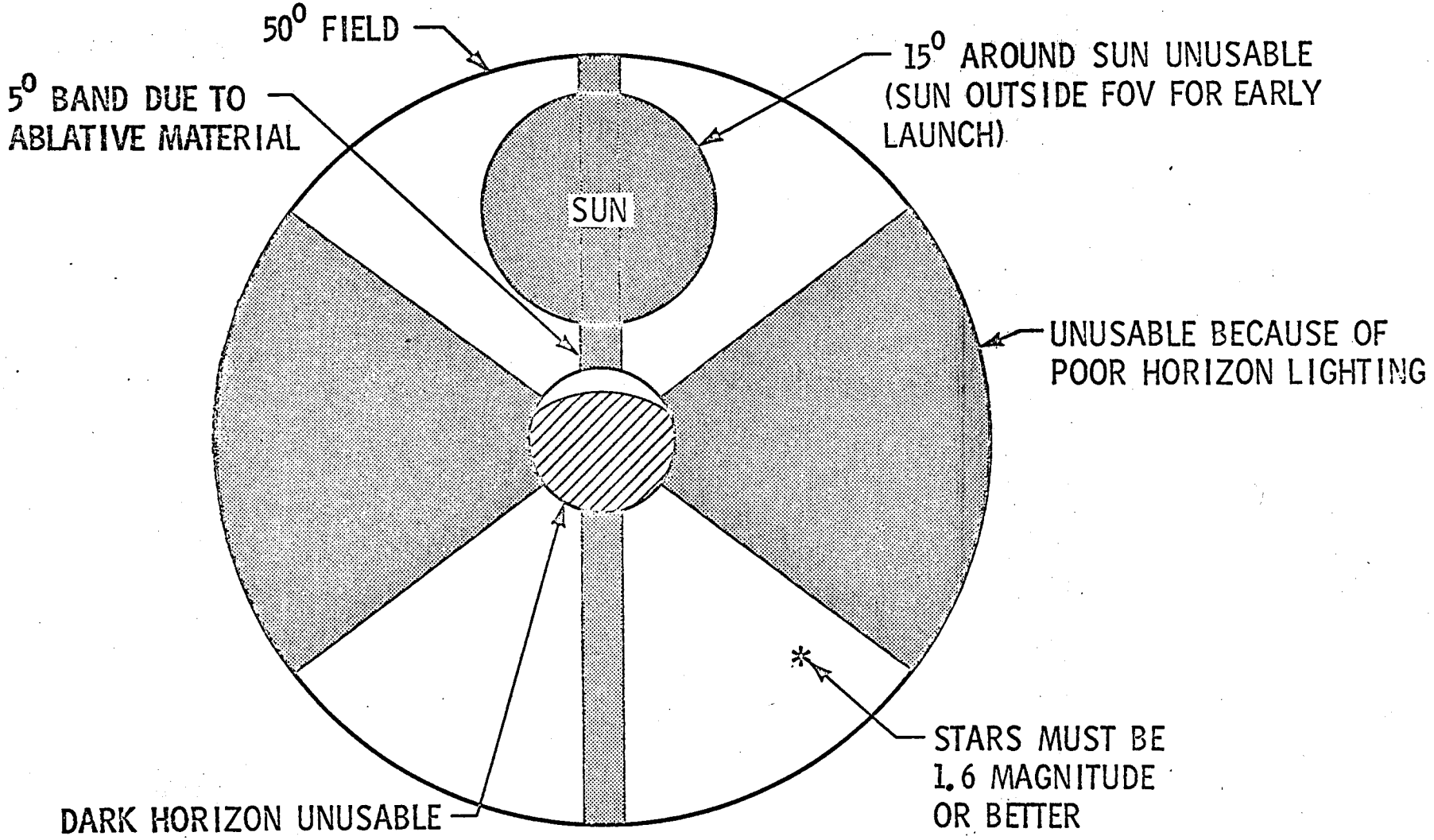
TEI PREMATURE SHUTDOWN TRAJECTORIES



STAR-EARTH HORIZON FIELD OF VIEW
RETURN TO EARTH - LATE DECEMBER LAUNCH



RESULT: FOR 8 HOURS DURING RTE FROM LAST PART OF WINDOW, ONLY 1 STAR IS AVAILABLE. BUT NAV ACCURACY IS STILL $\pm 1/4^0$ IN ENTRY FLIGHT PATH ANGLE, AND CORRIDOR IS $\pm 1^0$ WIDE.

ENTRY

- NOMINAL RANGE 1200 NM, FLIGHT PATH ANGLE -6.48°. BACKUP RANGE 1800 NM. CORRIDOR $\pm 1^{\circ}$ AT 36500 FPS.
- 10% LAND AREA AT 165°W, SOUTH OF EQUATOR, BUT GUIDANCE ACCURACY GOOD AT 1200 NM RANGE
- ENTRY SPLASH POINT RESULTING FROM TEI BURN WILL BE ACCEPTED IF FLEET CAN REACH IT. MCC'S THEN FOR FLIGHT PATH ANGLE CONTROL. OTHERWISE MCC AT MSI CORRECTS SPLASH POINT.
- 1200 NM RANGE HAS 6.1 G MAX AND NO SKIP (0.8 G MIN)

ALTERNATIVE MODES FOR ENTRY

- COMPLETELY AUTOMATIC
- CMC GUIDANCE + MANUAL ATTITUDE CONTROL
- ENTRY MONITOR SYSTEM - RANGE CONTROL
- G-METER-CONSTANT G-BANK REVERSAL TIMED
- SEAT OF PANTS

COLOSSUS NOTES AND ANOMALIES

ENTRY

1.2.2 IN ENTRY PROGRAM SEQUENCE (P 62 - SEP, TO P 67 - FINAL), V37 CAUSES A 1520 ALARM AND ENTRY KEEPS RUNNING, EXCEPT FOR V37N00-GO TO P00.

1.7.17 TRIM ATTITUDE YAW AND ROLL GIMBAL ANGLES DISPLAYED TO CREW WHEN EXOATMOSPHERIC MAY BE WRONG.

BELLCOMM, INC.

SUBJECT: Colossus on C-Prime
Case 310

FROM: W. G. Heffron

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