MSC Internal Note No. 69-FM-64

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSC INTERNAL NOTE NO. 69-FM-64

March 13, 1969

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BRIEFING CHARTS FOR LUNAR ORBIT NAVIGATION PROBLEM, FOR LM DESCENT, AND FOR HYBRID MISSION

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MISSION PLANNING AND ANALYSIS DIVISION

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

(NASA-TM-X-69710) BRIEFING CHARTS FOR LUNAR ORBIT NAVIGATION PROBLEM, FOR LM DESCENT, AND FOR HYBRID MISSION (NASA) 90 p

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BRIEFING CHARTS FOR LUNAR ORBIT NAVIGATION PROBLEM, FOR LM DESCENT, AND FOR HYBRID MISSION

By Mission Planning and Analysis Division

March 13, 1969

MISSION PLANNING AND ANALYSIS DIVISION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

Approved: _____
John P. Mayer, Chief
Mission Planning and Analysis Division

FOREWORD

The enclosed briefing charts were presented on March 9, 1969, at MSC for the benefit of Dr. George E. Mueller and Lt. Gen. Sam C. Phillips from the Office of Manned Space Flight. Three topics were included: the lunar orbit navigation problem, the LM descent, and a hybrid mission.

The briefing on the lunar orbit navigation problem summarized what was learned from the Apollo 8 flight and how this information applies to a lunar landing. This presentation was made by Jim McPherson, Chief of the Mathematical Physics Branch.

The charts on the LM descent presented the mission profile as it reflects recent software and targeting changes designed to improve the consistency between the automatic systems and manual control. The effects of the lunar orbital navigation uncertainties on descent and landing were shown. This presentation was made by Floyd Bennett, Chief of the Landing Analysis Branch.

The hybrid mission briefing provided the rationale to support the recommended use of a hybrid mission for specified launch dates. This presentation was made by Ron Berry, Chief of the Lunar Mission Analysis Branch. The effect on the DPS back-up during LOI was presented by Charles Foggatt from the Flight Analysis Branch.

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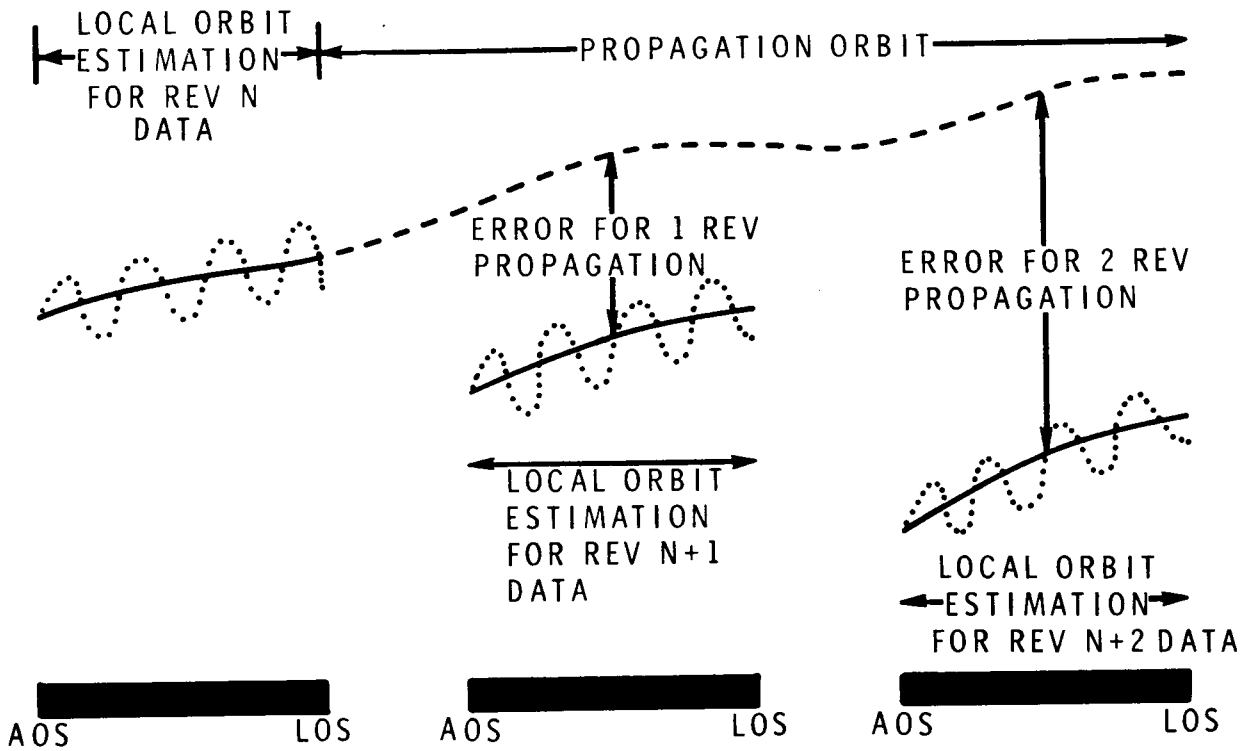
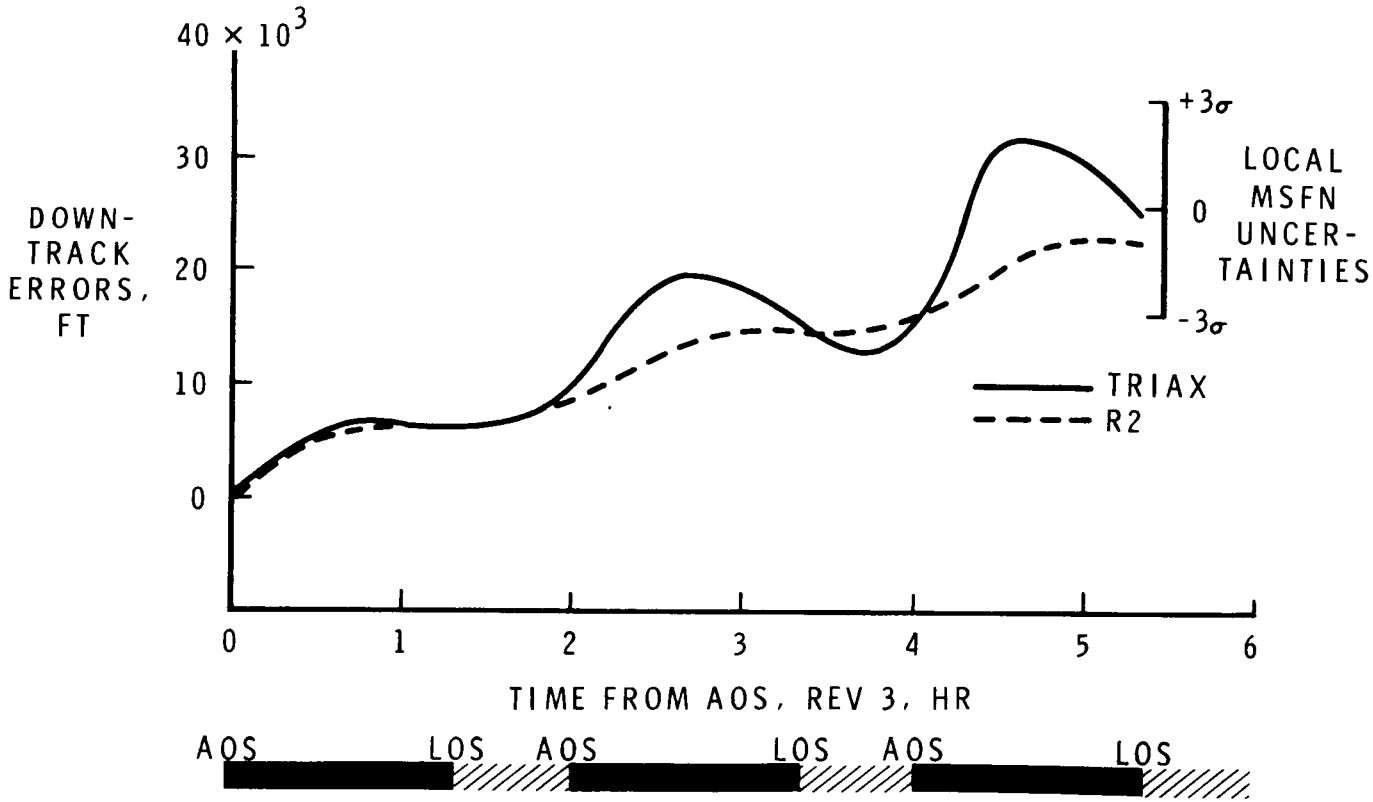
SUMMARY APOLLO 8 NAVIGATION PROBLEMS

- MSFN CALIBRATION
  - STATION LOCATIONS
  - FREQUENCY SYNCHRONIZATION
  - TIME SYNCHRONIZATION
- ORBIT PERTURBATIONS
  - WATER BOILER VENTING
  - WASTE WATER DUMPS
- SPACECRAFT NAVIGATION PROCEDURES
- LUNAR GRAVITY MODELING

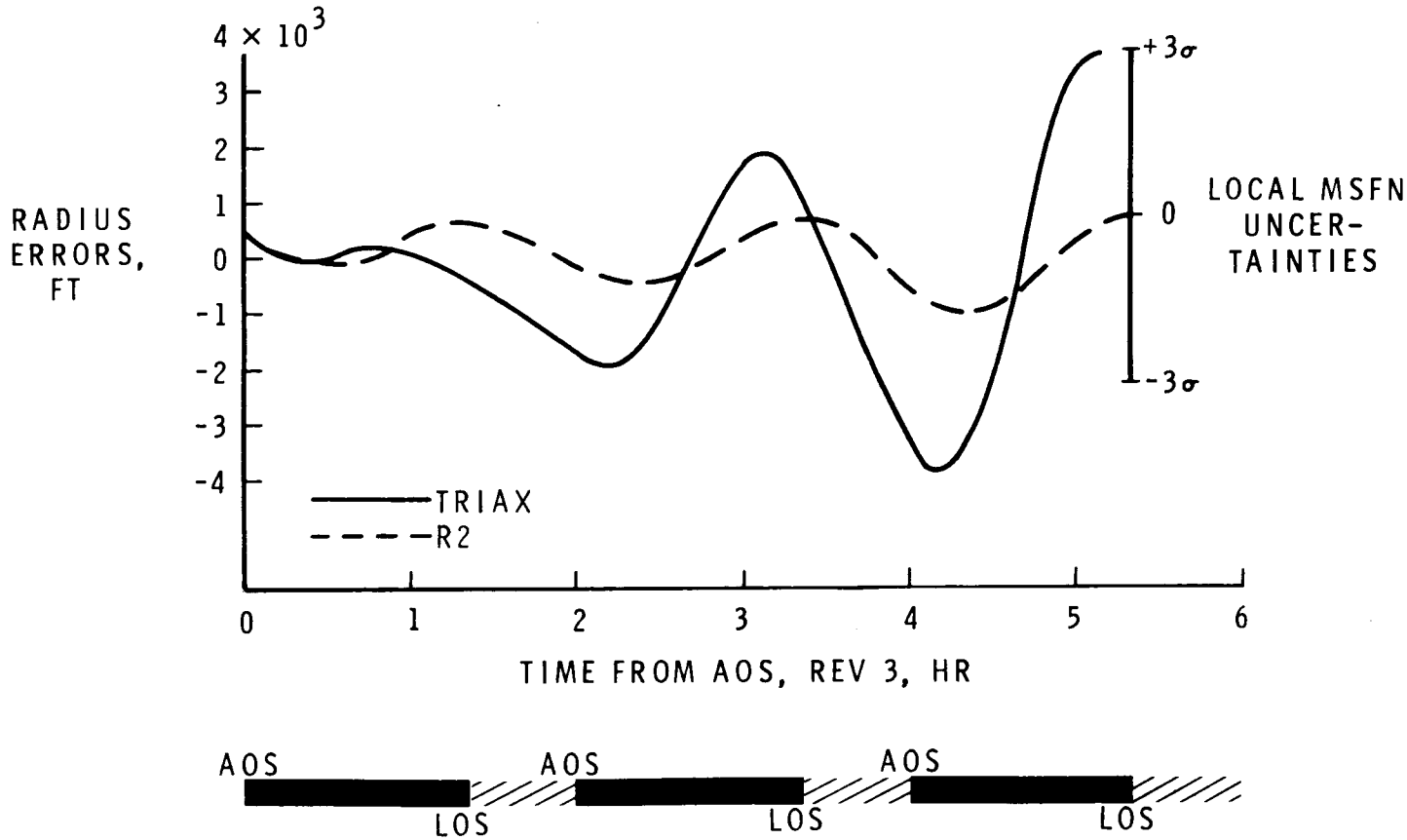
MSFN CONSISTENCY PROCEDURES



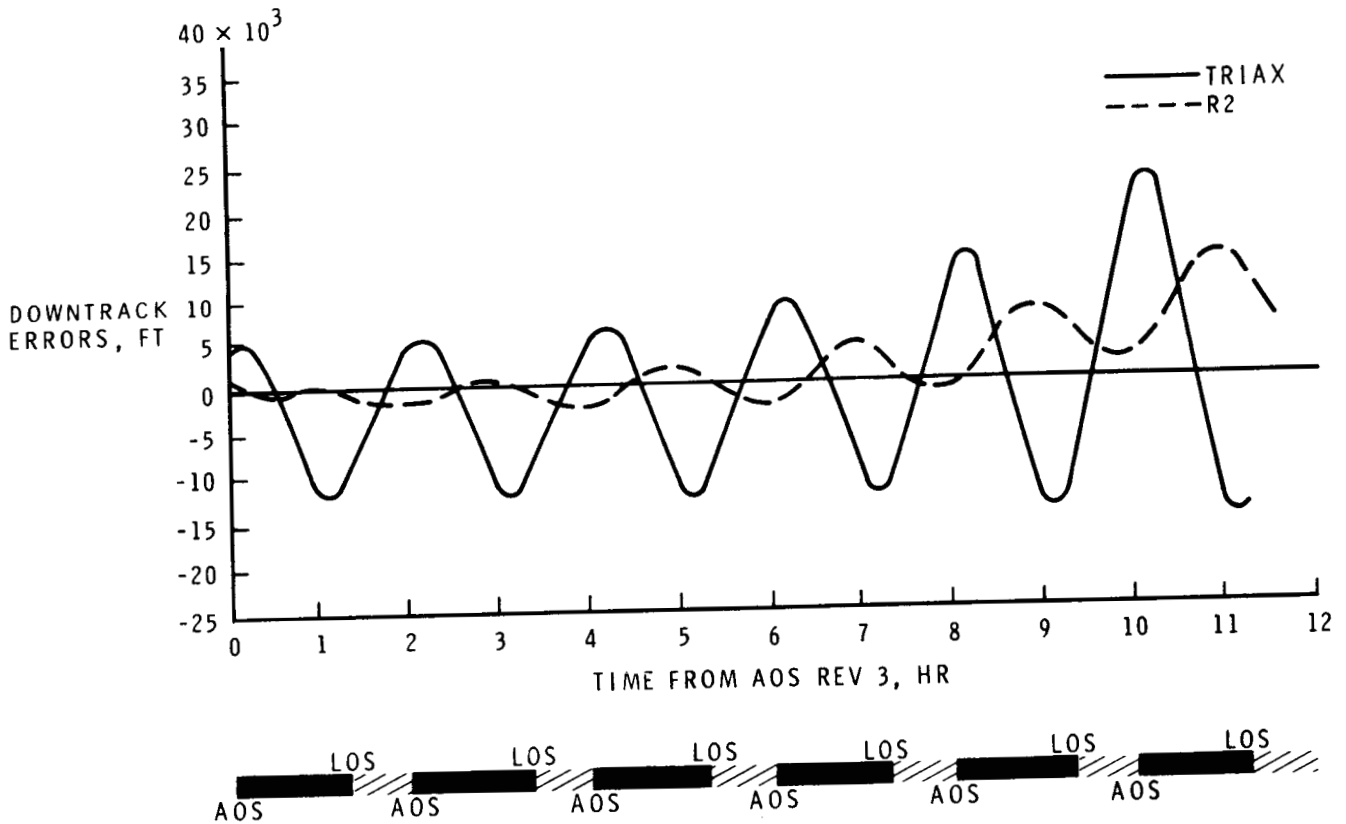
APOLLO 8 MSFN DOWNTRACK PREDICTION ERRORS BASED ON 1 PASS SOLUTIONS



APOLLO 8 MSFN RADIUS PREDICTION ERRORS BASED ON 1 PASS SOLUTIONS



APOLLO 8 MSFN DOWNTRACK PREDICTION ERRORS BASED ON 2 PASS SOLUTIONS



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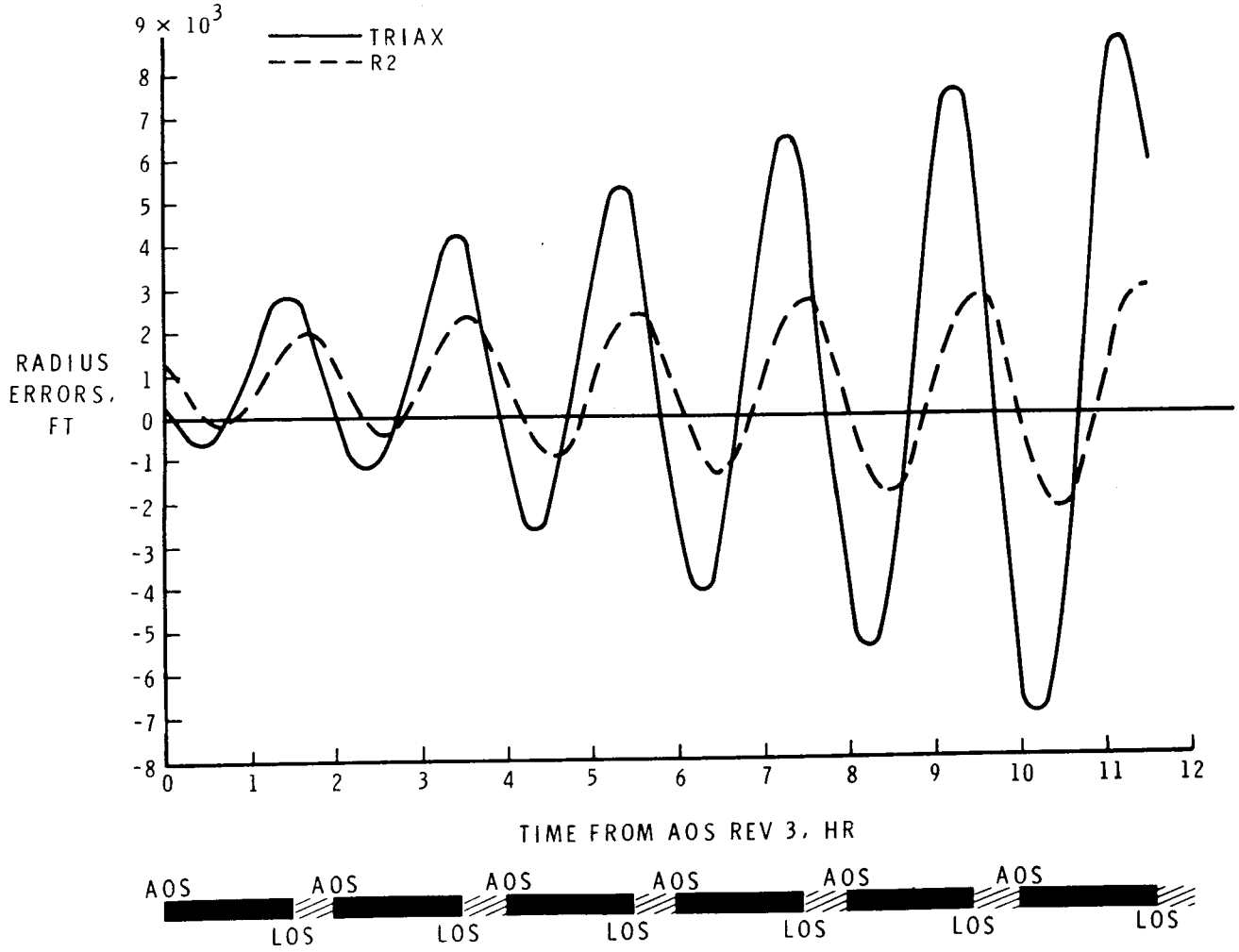
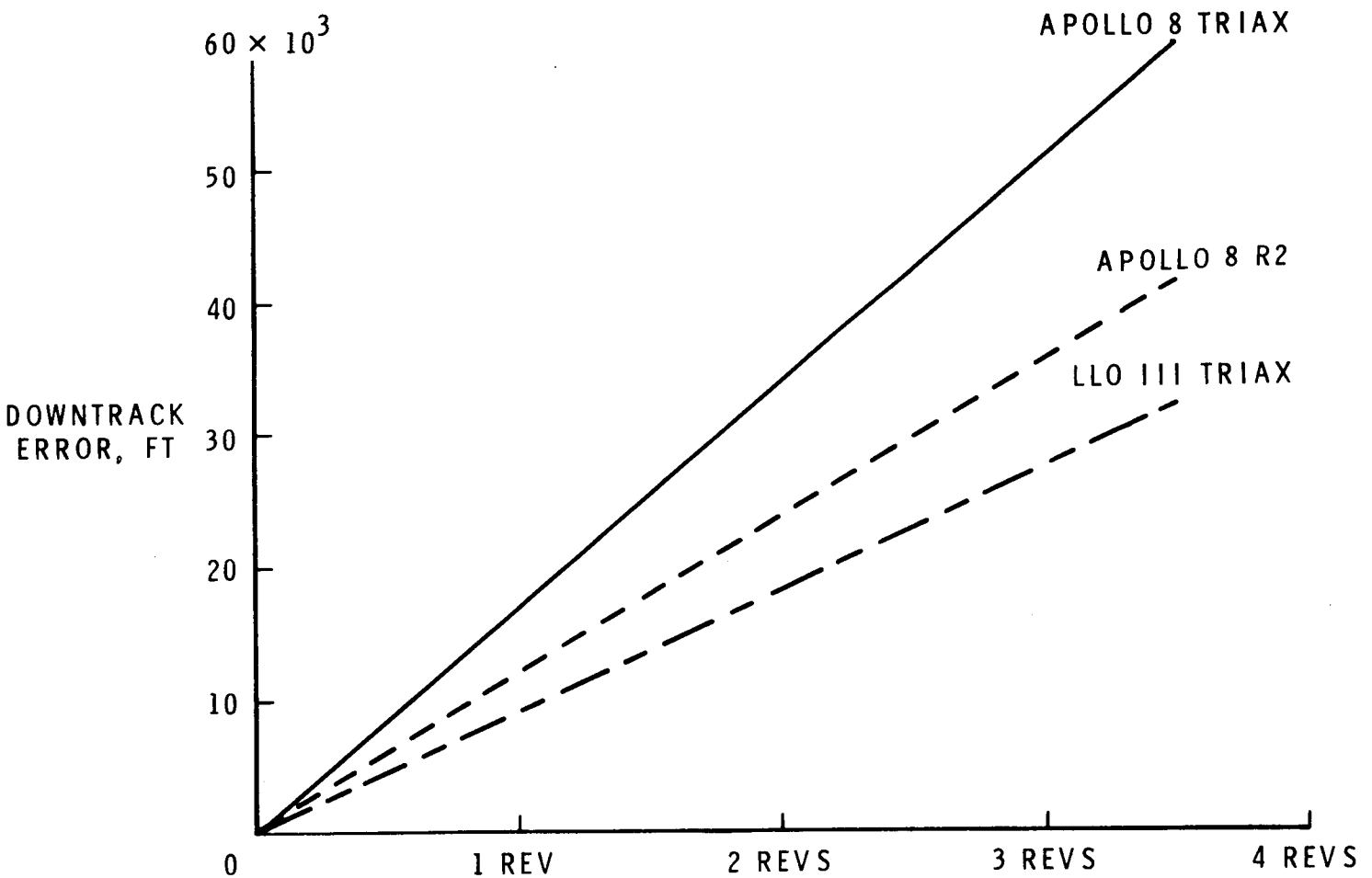
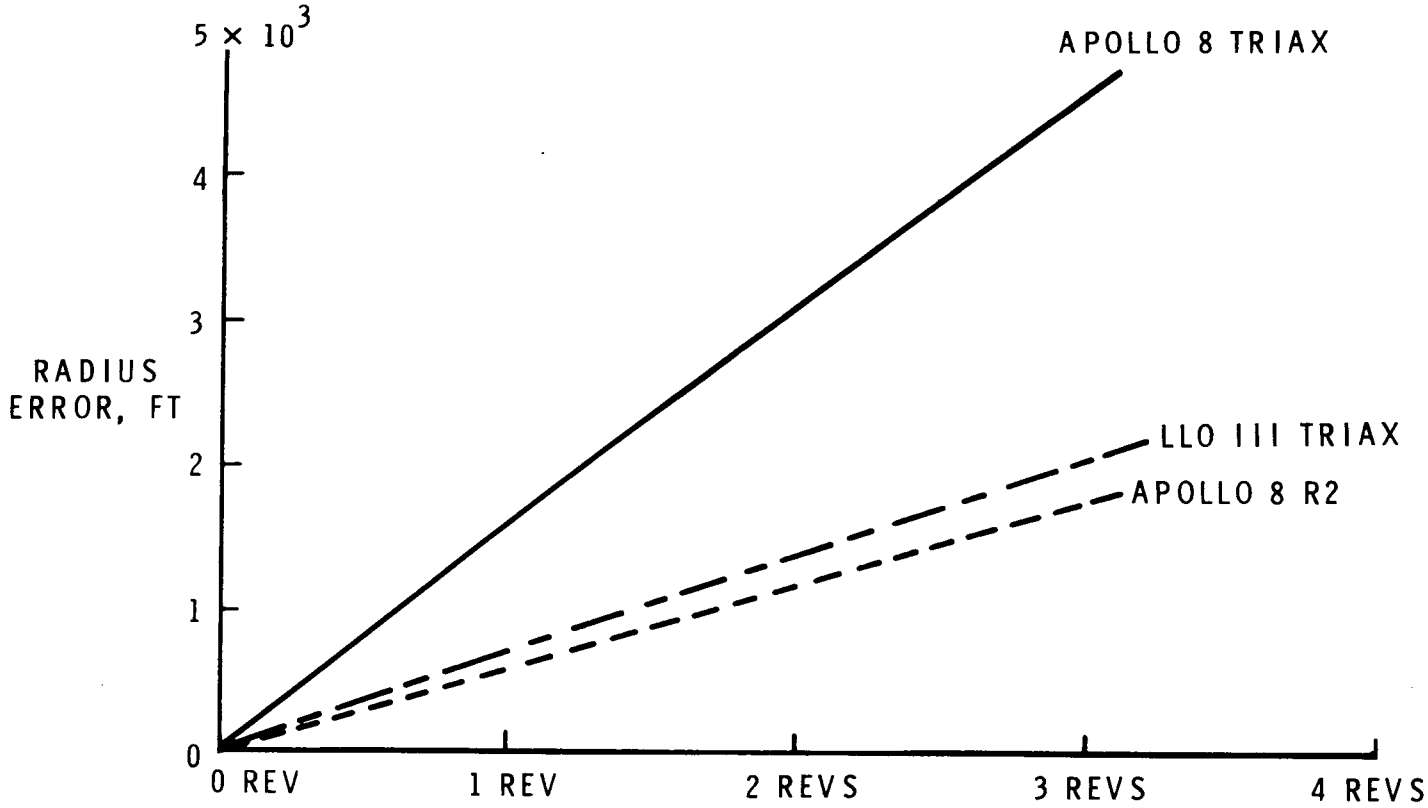


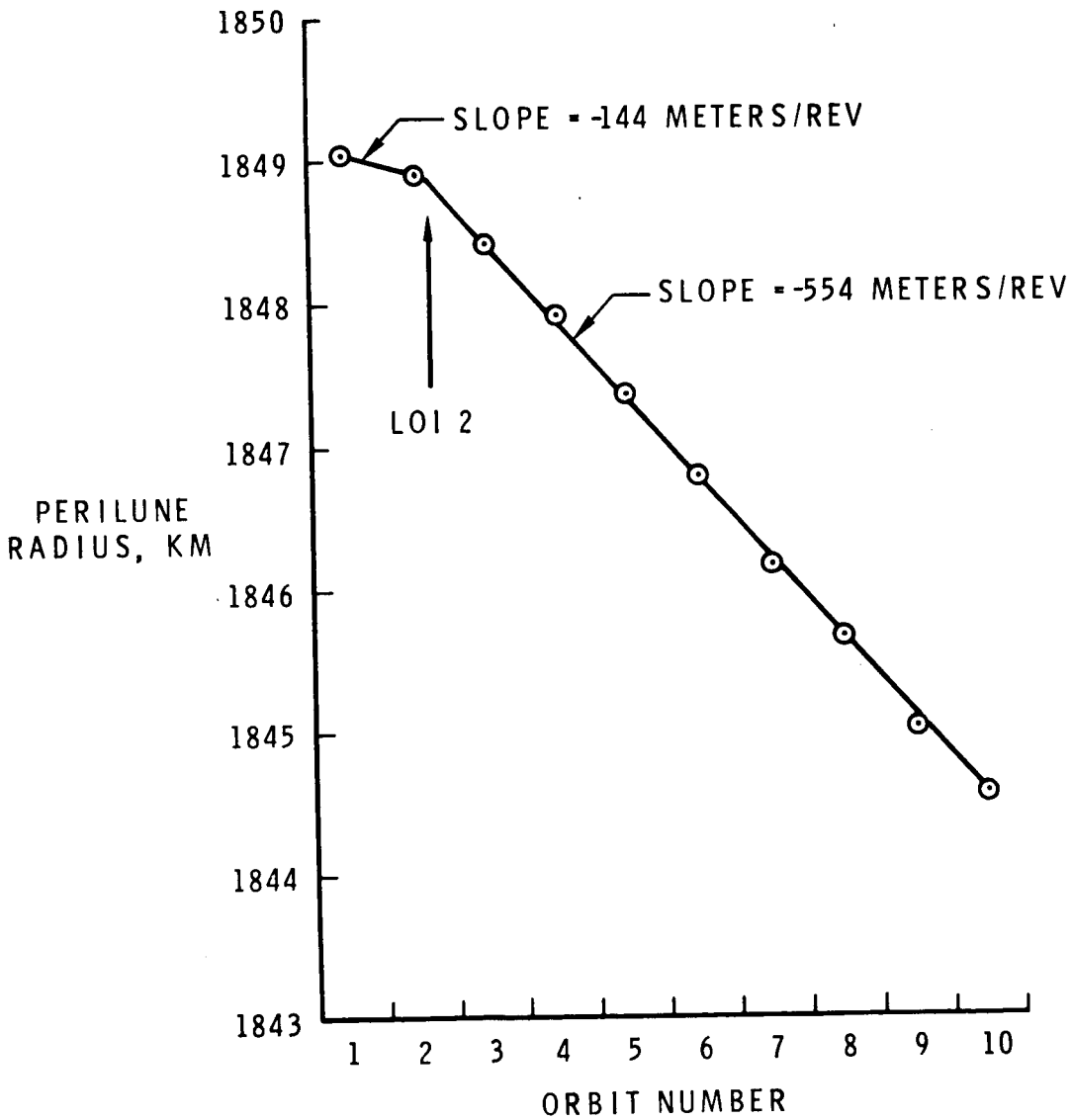
APOLLO 8 DOWNTRACK PROPAGATION ERRORS



APOLLO 8 RADIAL PROPAGATION ERRORS



APOLLO 8 LUNAR ORBIT PERILUNE RADIUS HISTORY



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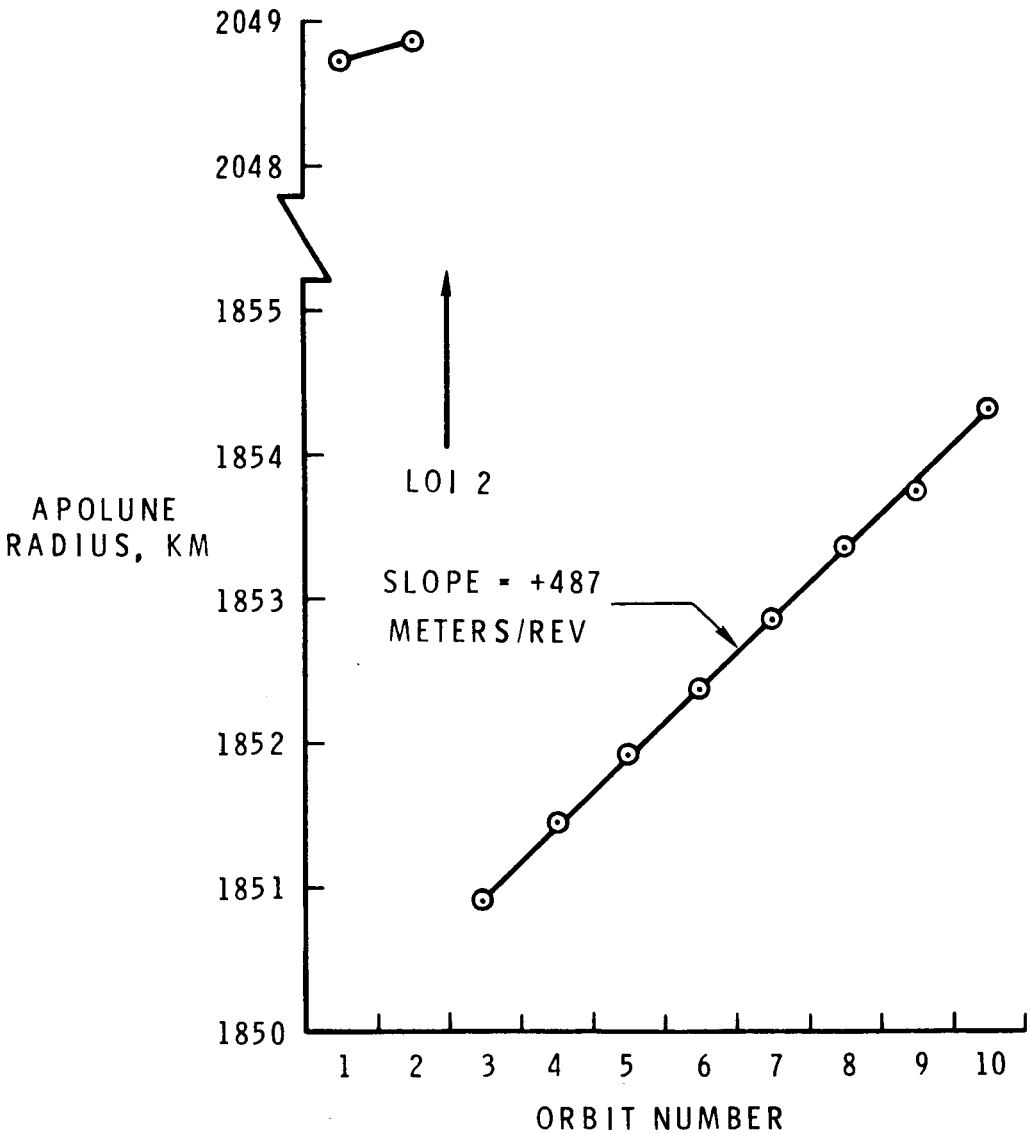
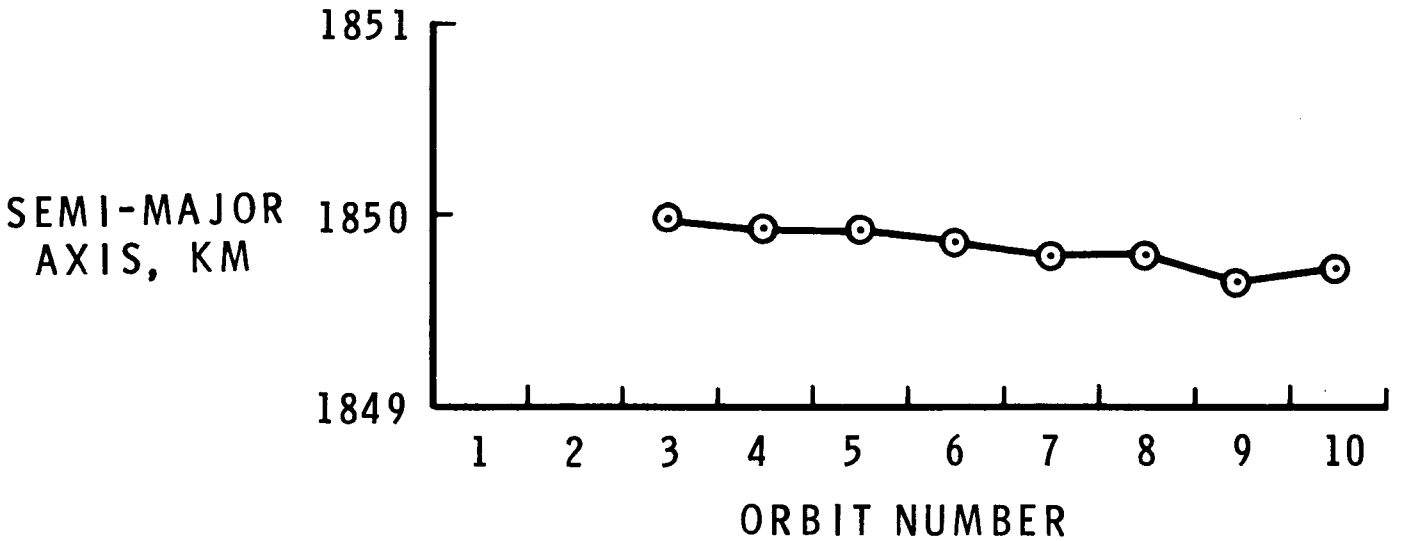
APOLLO 8 LUNAR ORBIT APOLUNE RADIUS



APOLLO 8 LUNAR ORBIT SEMI-MAJOR AXIS HISTORY



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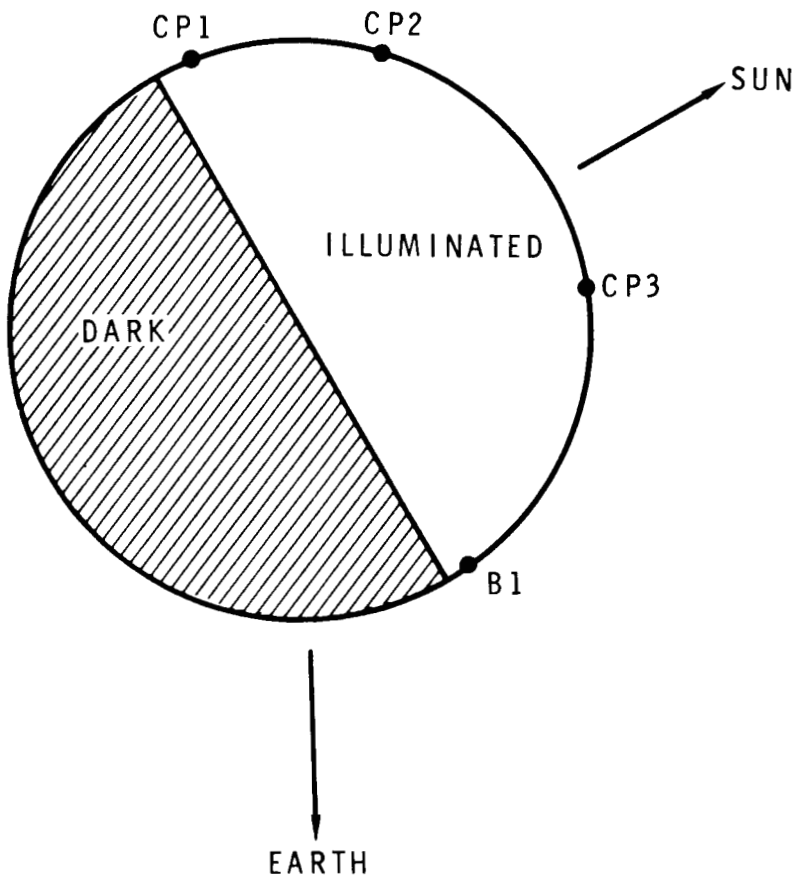
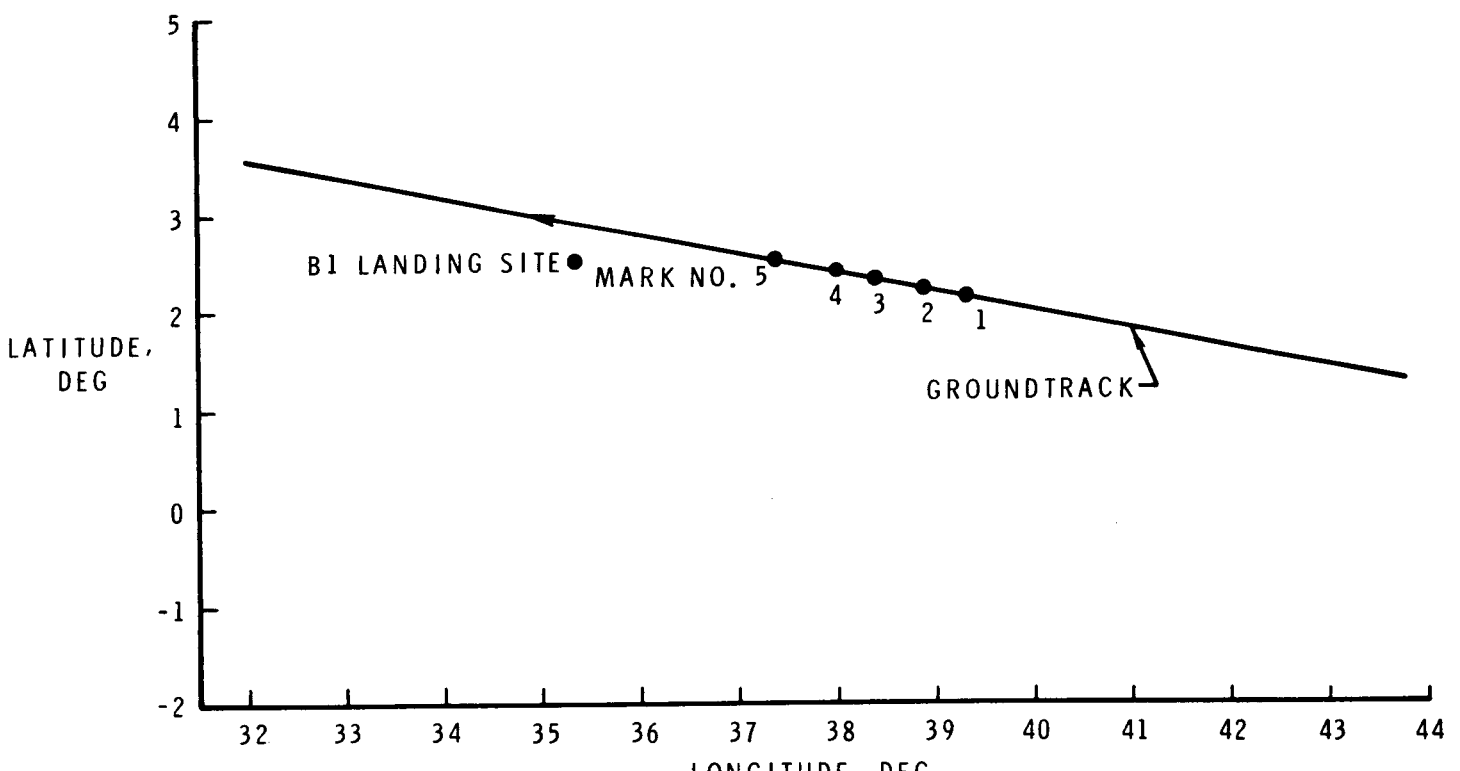
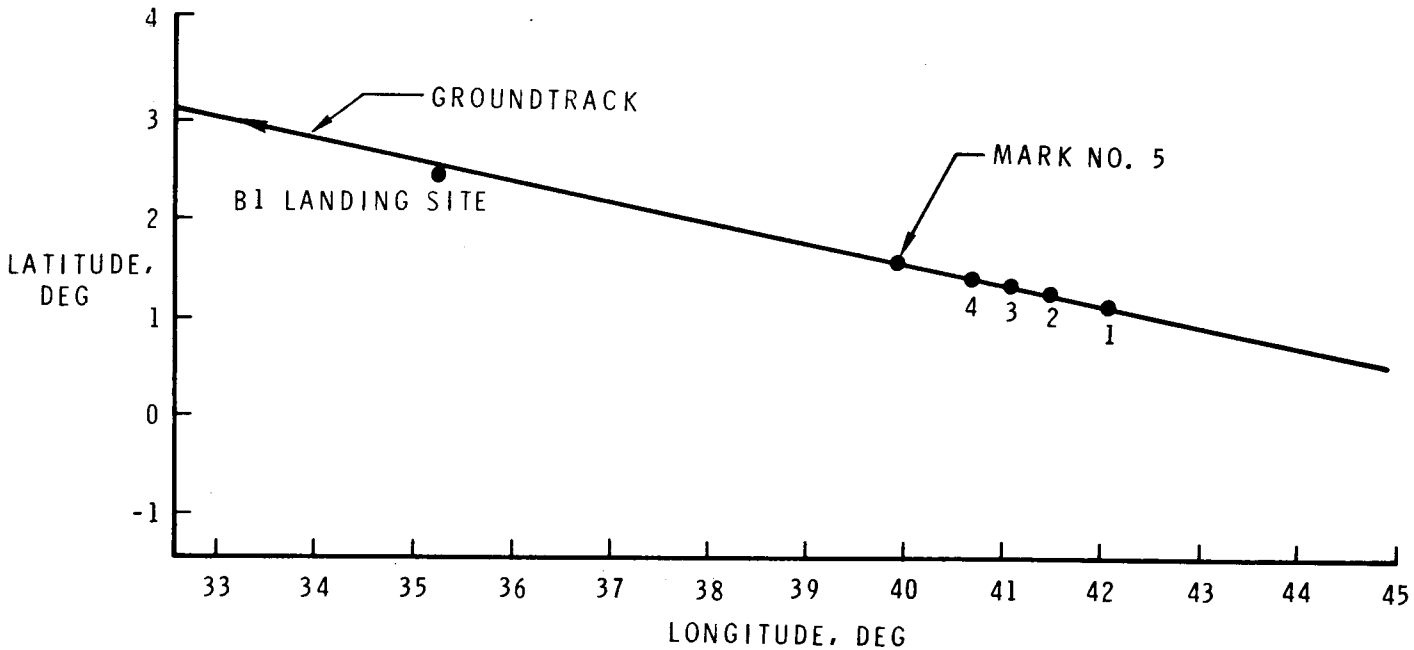
APOLLO 8 LANDMARK SIGHTING GEOMETRY



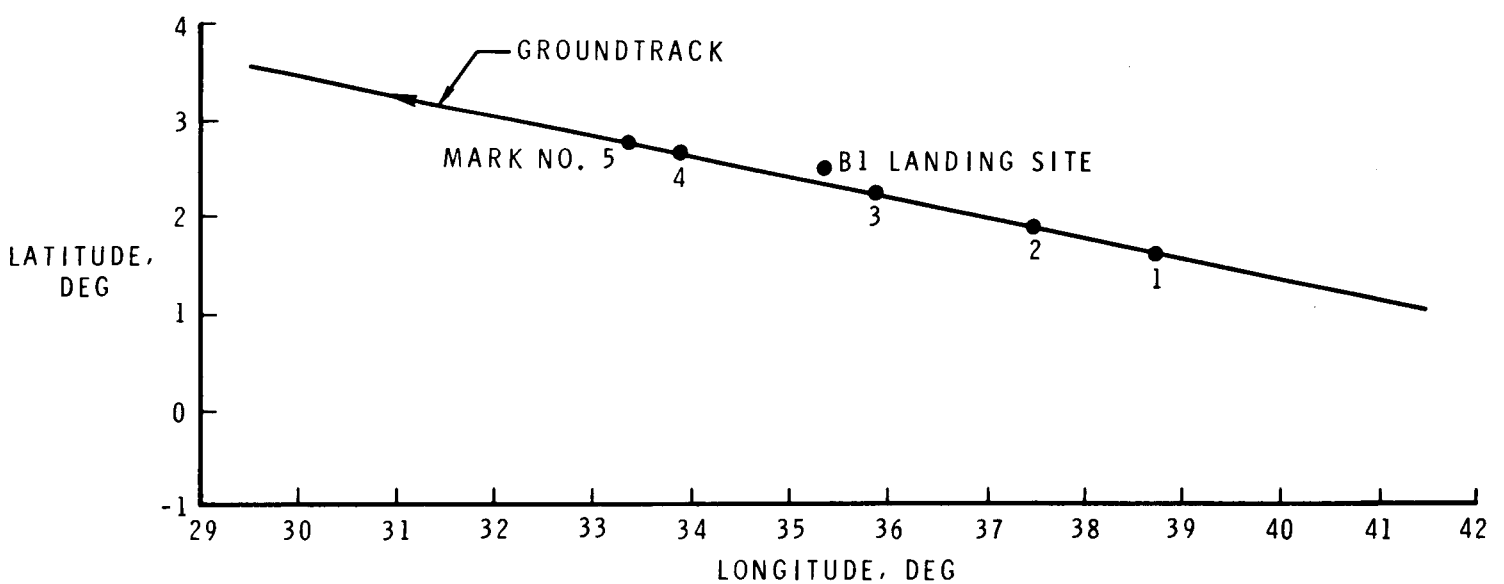
SUBSATELLITE POINTS AT MARK TIMES FOR APOLLO 8 (REV 5, B1)



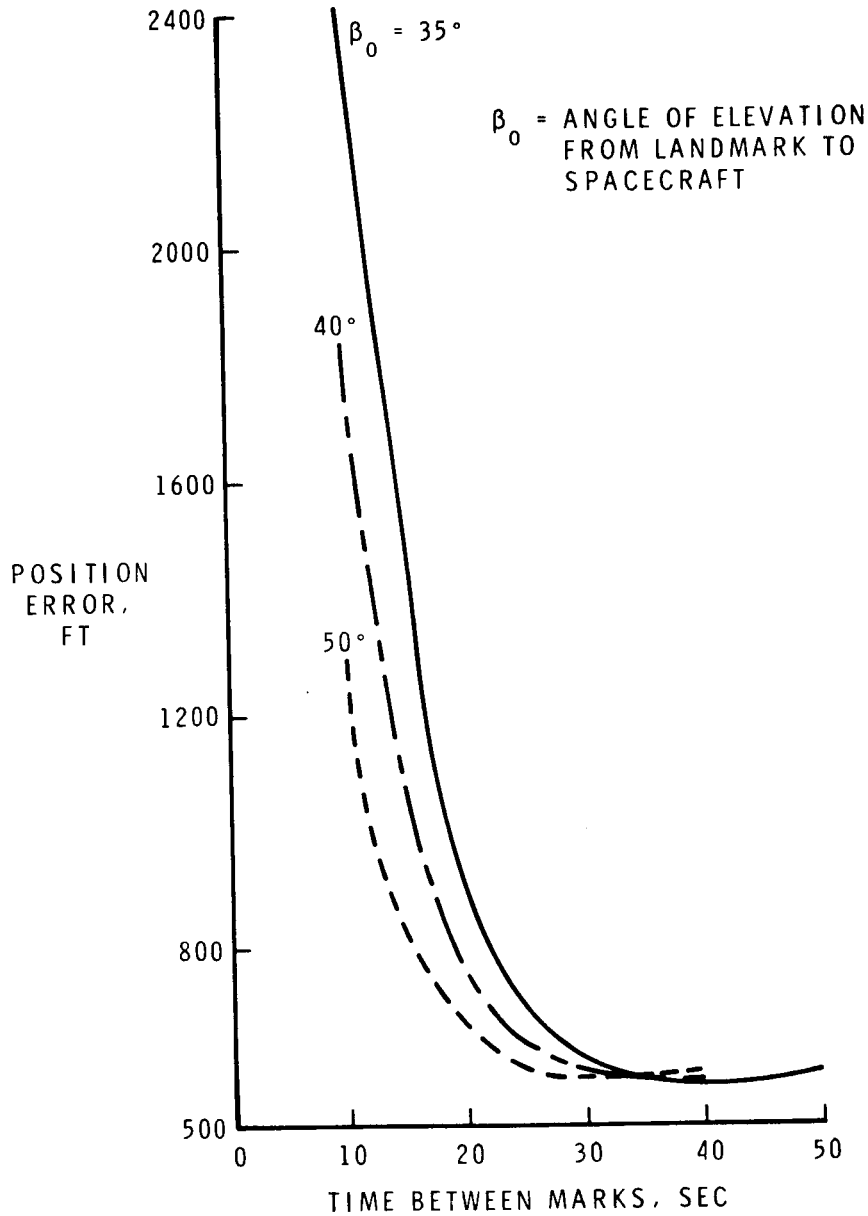
SUBSATELLITE POINTS AT MARK TIMES FOR APOLLO 8 (REV 6, B1)



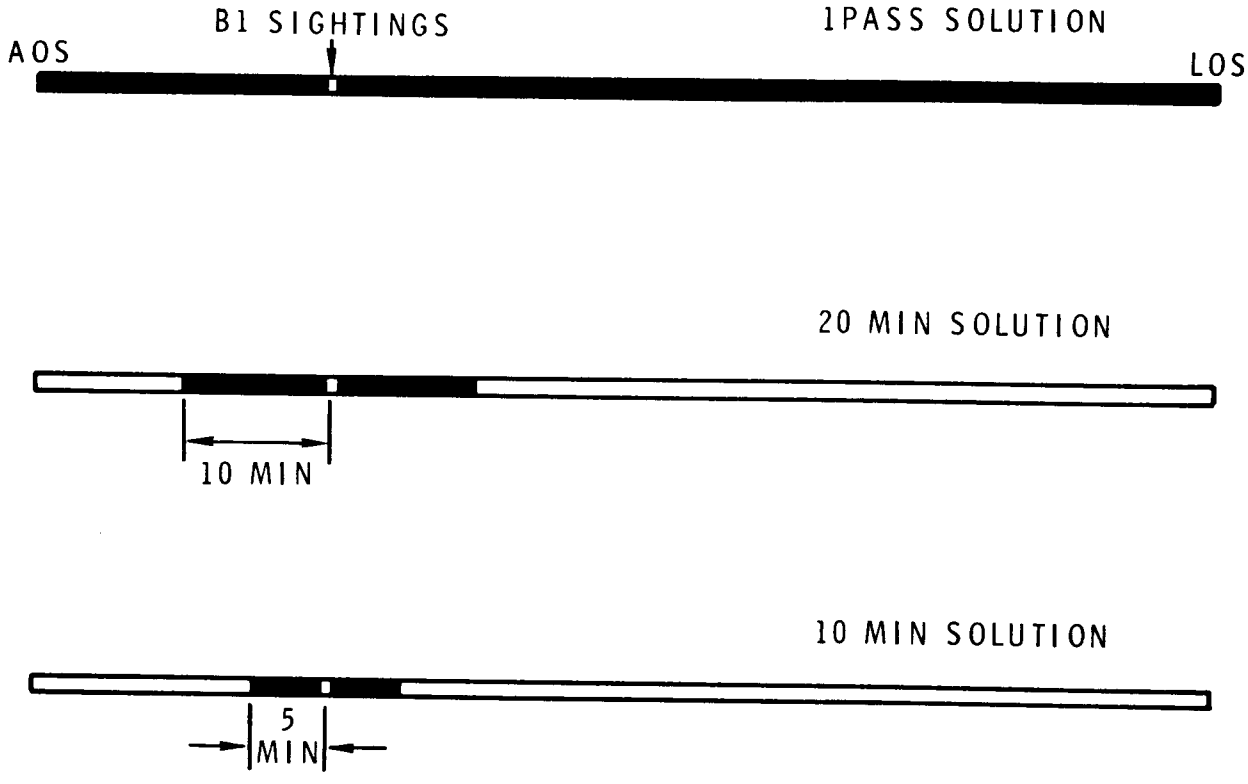
SUBSATELLITE POINTS AT MARK TIMES FOR APOLLO 8 (REV 7, B1)



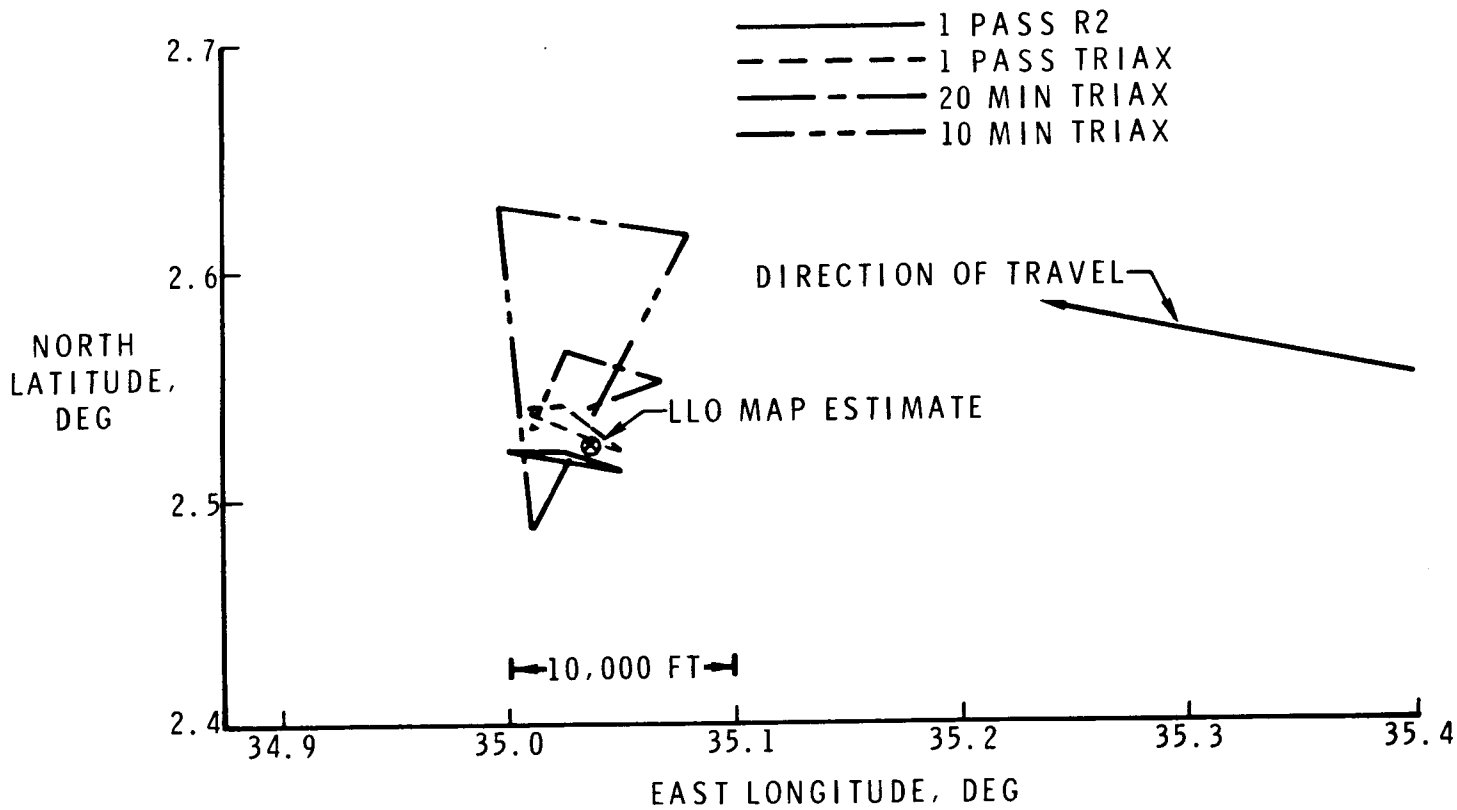
LUNAR LANDMARK POSITION DETERMINATION ERROR VERSES TIME BETWEEN OPTICAL MARKS



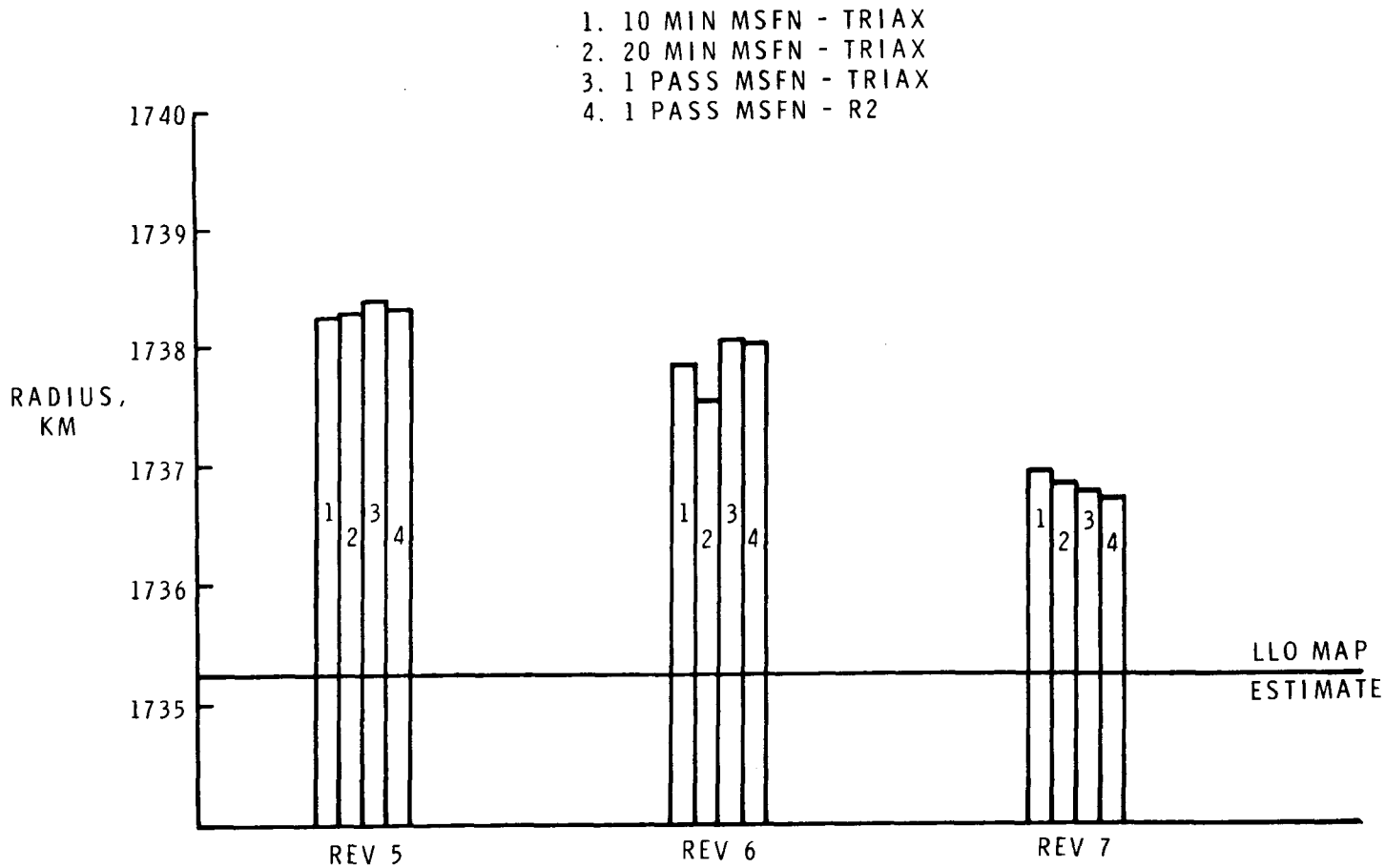
LANDMARK LOCATION PROCEDURES



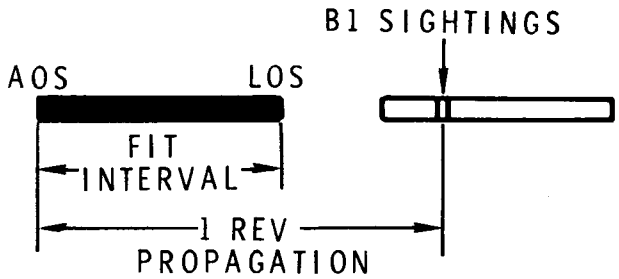
B1 LOCATION ESTIMATES BASED ON LOCAL MSFN SOLUTIONS

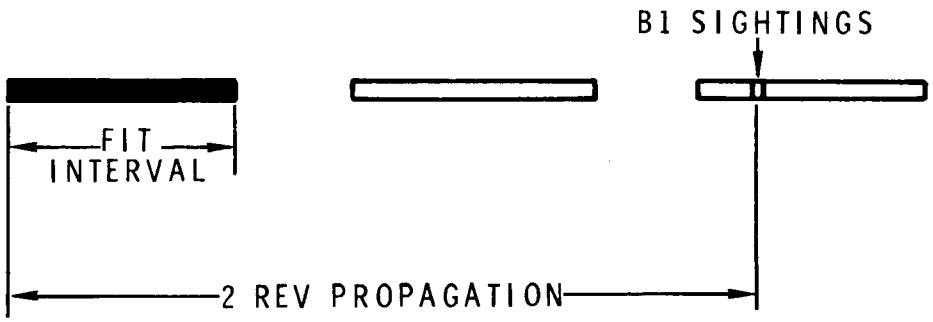


B1 RADIUS ESTIMATES



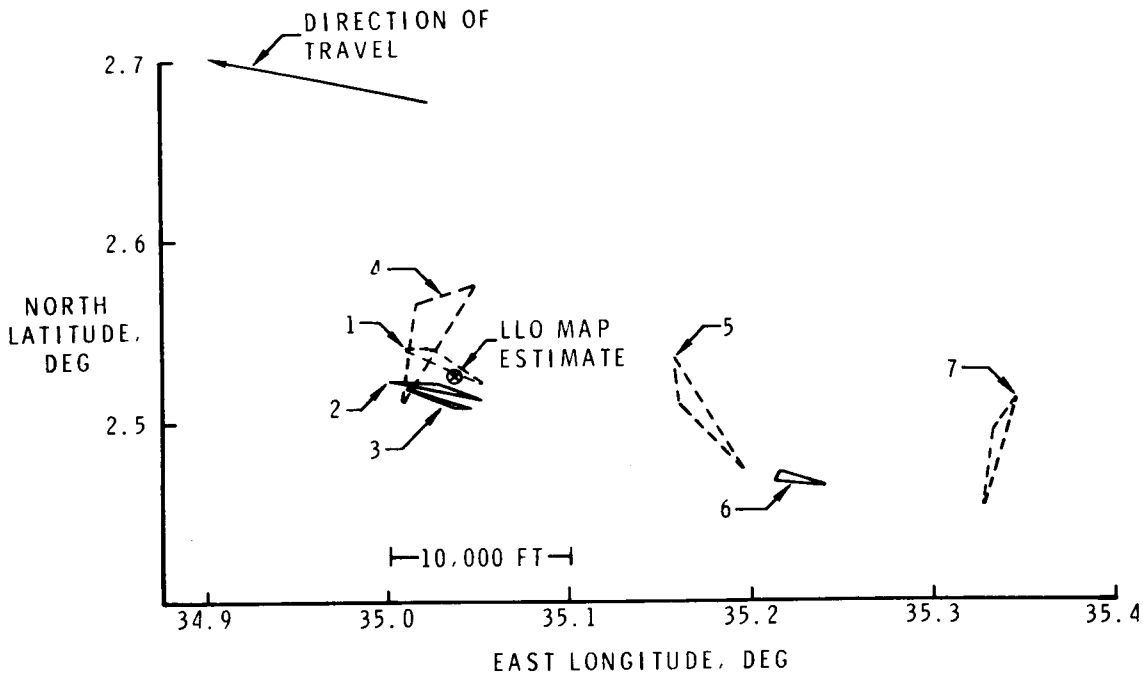
PROCEDURES FOR EVALUATING DESCENT TARGETING NAVIGATION





EVALUATION OF DESCENT TARGETING NAVIGATION

1. 1 PASS MSFN TRIAX LOCAL SOLUTION
2. 1 PASS MSFN R2 LOCAL SOLUTION
3. 1 PASS MSFN R2 SOLUTION PROPAGATED 2 REVS WITH $\Delta T = -3.9$ SEC
4. 1 PASS MSFN TRIAX SOLUTION PROPAGATED 2 REVS WITH $\Delta T = -6$ SEC
5. 1 PASS MSFN TRIAX SOLUTION PROPAGATED 1 REV
6. 1 PASS MSFN R2 SOLUTION PROPAGATED 2 REVS
7. 1 PASS MSFN TRIAX SOLUTION PROPAGATED 2 REVS



SUMMARY OF LANDMARK LOCATION RESULTS

- LLO MAP VALUE FOR B1 GOOD TO
  - $\Delta\phi \approx 1,500$ FT
  - $\Delta\lambda \approx 1,500$ FT
  - $\Delta r \approx 4,500$ FT
- LANDMARK DATA VERIFIES ESTIMATED MSFN PROPAGATION ERRORS
  - TRIAX { DOWNTRACK $\approx 15,000$ FT/REV; RADIAL $\approx 1,500$ FT/REV }
  - R2 { DOWNTRACK $\approx 11,000$ FT/REV; RADIAL ≈ 500 FT/REV }
- PROPAGATION ERRORS CAN BE REDUCED BY:
  - APPLYING IN-FLIGHT EMPIRICAL CORRECTIONS
  - IMPLEMENTING R2 GRAVITY FIELD IN REALTIME SOFTWARE

PLANNED NAVIGATION ACTIVITIES

- CONTINUE TO STUDY EMPIRICAL TECHNIQUES FOR REDUCING PROPAGATION ERRORS
  - EMPIRICALLY ADJUST LANDING SITE RADIUS (MAY)
  - CHANGE TIME TAG OF UPLINK SC POSITION AND VELOCITY VECTOR FOR LANDING (MAY)
- INVESTIGATE DATA PROCESSING TECHNIQUES FOR REDUCING LOCAL AND PROPAGATION ERRORS
  - ADD R2 MODEL IN RTCC (JUNE)
  - DETERMINE OPTIMUM DATA ARC LENGTH FOR MISSION SUPPORT (MAY)

NAVIGATION ACCURACY FOR LUNAR LANDING

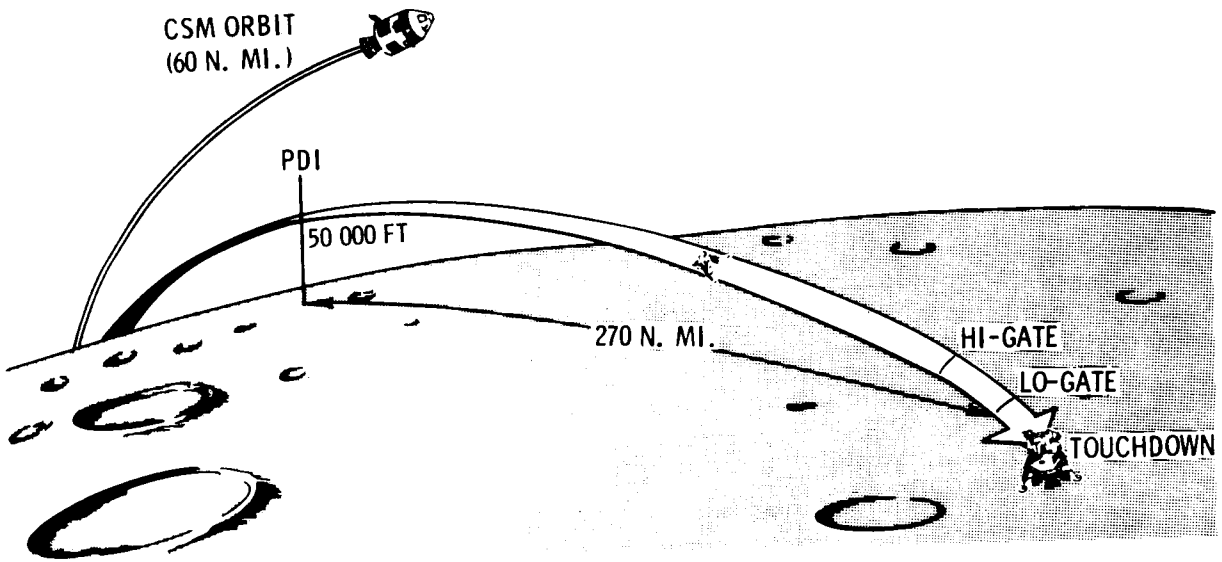
CASE 1 (R2 MODEL + APOLLO 8 OPTICS PERFORMANCE)

	LOCAL ERROR (3σ)	ERROR GROWTH (3σ)
DOWNTRACK	9,000 FT	33,000 FT/REV
RADIAL	13,500 FT	1,500 FT/REV

CASE 2 (R2 MODEL + EMPIRICAL TECHNIQUES + EXPECTED OPTICS CAPABILITY)

	LOCAL ERROR (3σ)	ERROR GROWTH (3σ)
DOWNTRACK	9,000 FT	9,000 FT/REV
RADIAL	1,800 FT	1,500 FT/REV

OPERATIONAL PHASES OF POWERED DESCENT



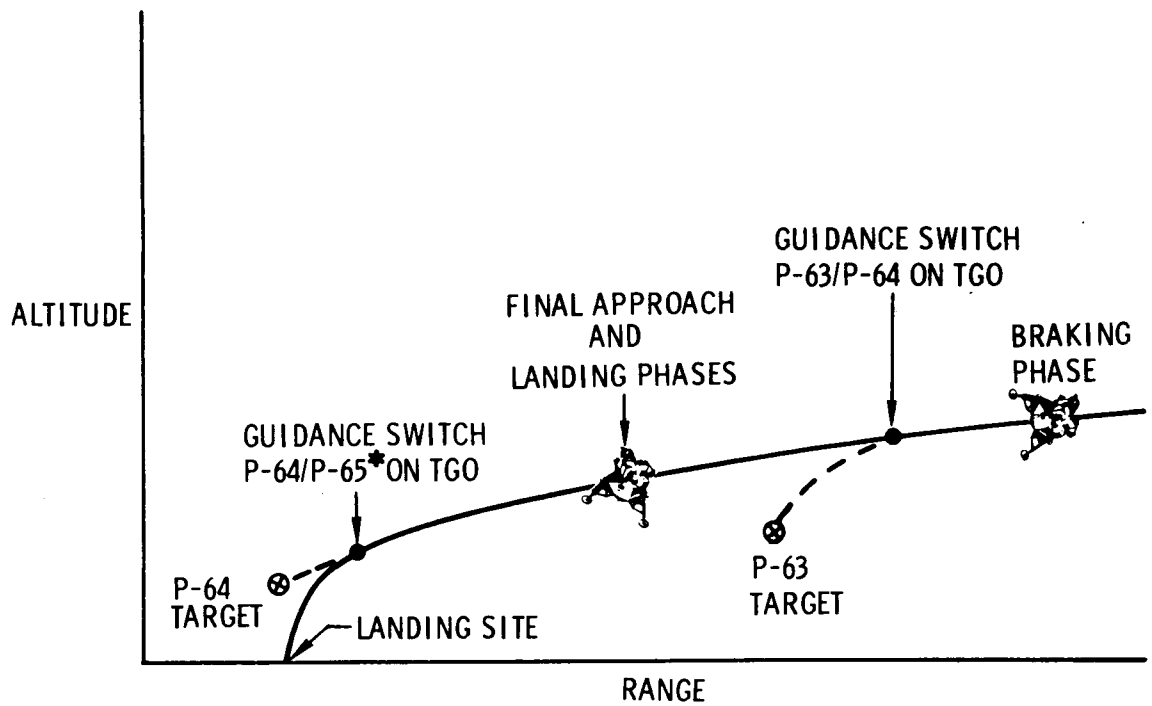
DESIGN CRITERIA

- BRAKING PHASE (PDI TO HI-GATE) - EFFICIENT REDUCTION OF ORBITAL VELOCITY
- FINAL APPROACH PHASE (HI-GATE TO LO-GATE) - CREW VISIBILITY (SAFETY OF FLIGHT AND SITE ASSESSMENT)
- LANDING PHASE (LO-GATE TO TOUCHDOWN) - MANUAL CONTROL TAKEOVER

CONSTRAINTS

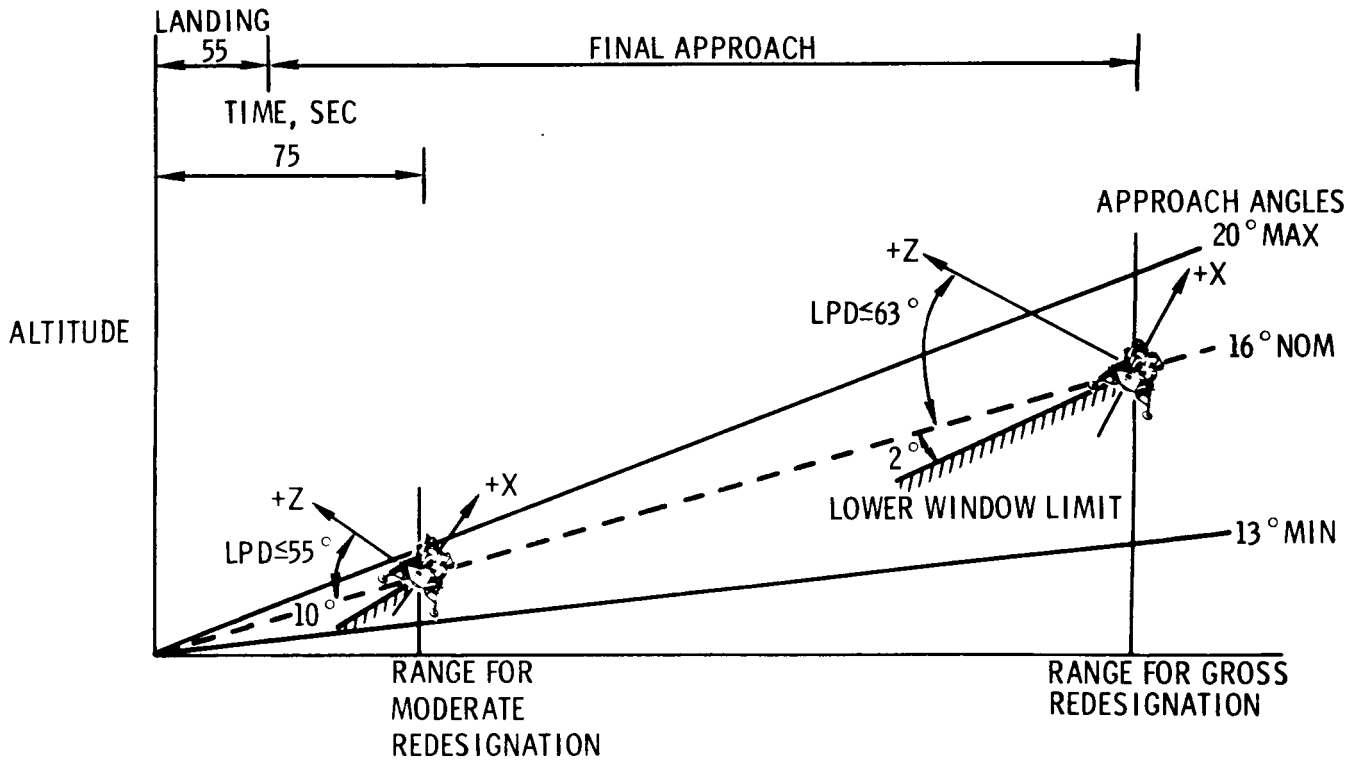
- APPROACH PHASE
  - VISIBILITY OF LANDING SITE
    - LIMITED AMOUNT FOR GROSS REDESIGNATION
    - INCREASED AMOUNT FOR MODERATE REDESIGNATION
    - ADEQUATE TIME FOR ASSESSMENT
  - SPECIFIED APPROACH CORRIDOR
    - MAXIMUM LIMIT FOR CREW
    - MINIMUM LIMIT FOR SUN LINE
- LANDING PHASE
  - MAINTAIN VISIBILITY
  - SLOW VELOCITIES
  - ADEQUATE TIME FOR ASSESSMENT
  - ATTITUDE NEAR VERTICAL
- OVERRIDING CONSTRAINTS
  - CREW SAFETY
  - PROPELLANT BUDGET

TARGET SEQUENCE FOR AUTOMATIC GUIDANCE



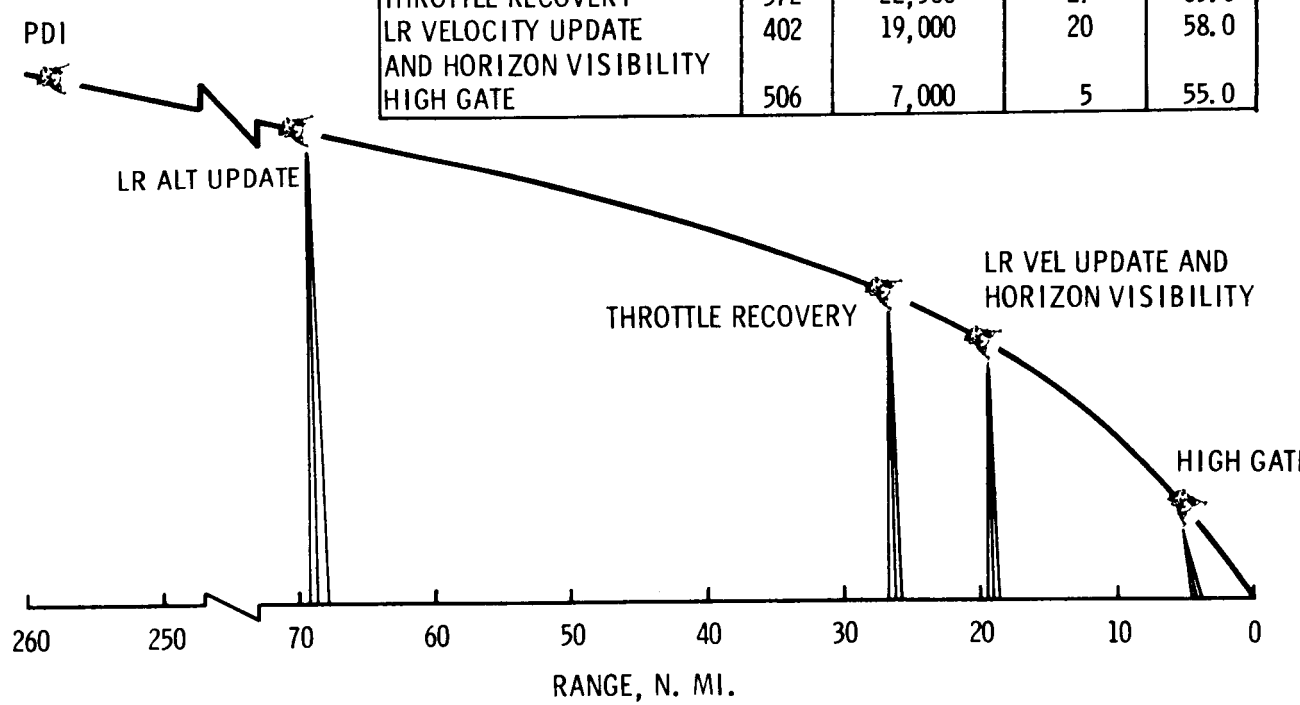
*GUIDANCE P-65 IS VELOCITY NULLING ONLY
(i.e. NO POSITION TARGET)

CONSTRAINTS ILLUSTRATED



NOMINAL TRAJECTORY BRAKING PHASE

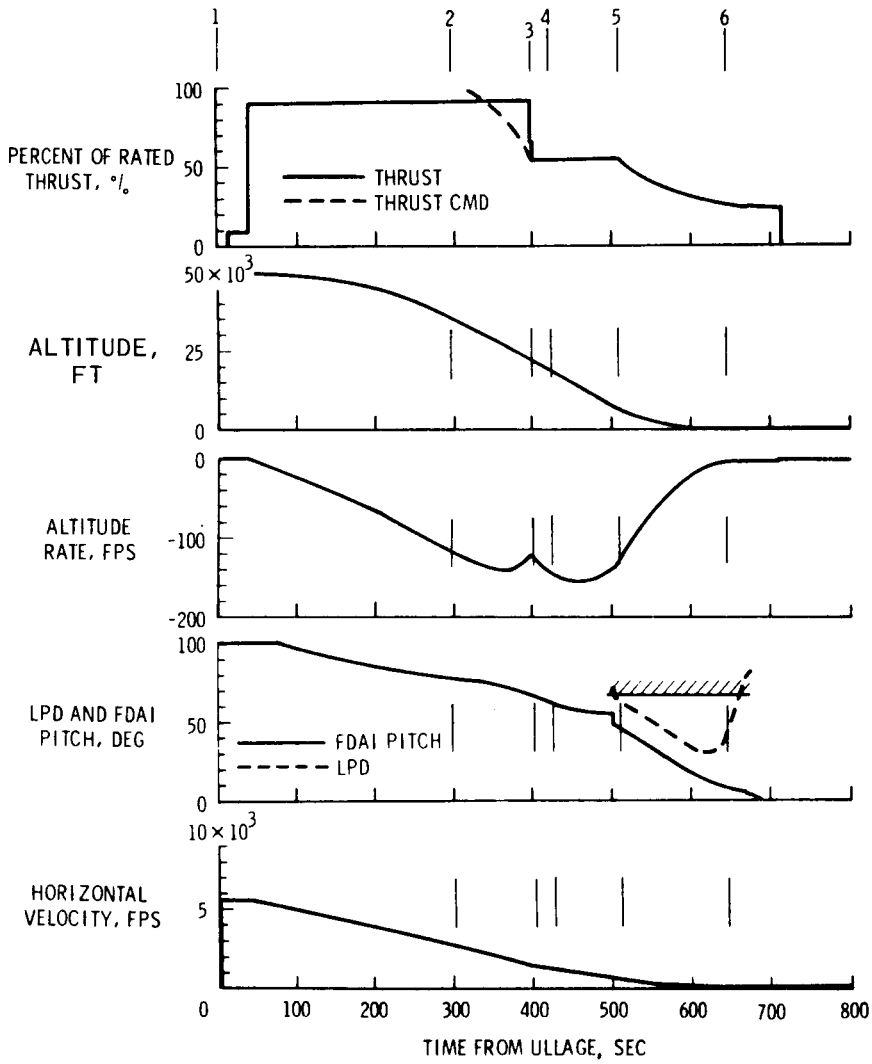
EVENT	TFIG, SEC	ALTITUDE, FT	RANGE, N. MI.	PITCH, DEG
PDI	0	50,000	258	92.5
LR ALTITUDE UPDATE	258	35,000	70	74.0
THROTTLE RECOVERY	372	22,500	27	65.0
LR VELOCITY UPDATE AND HORIZON VISIBILITY	402	19,000	20	58.0
HIGH GATE	506	7,000	5	55.0



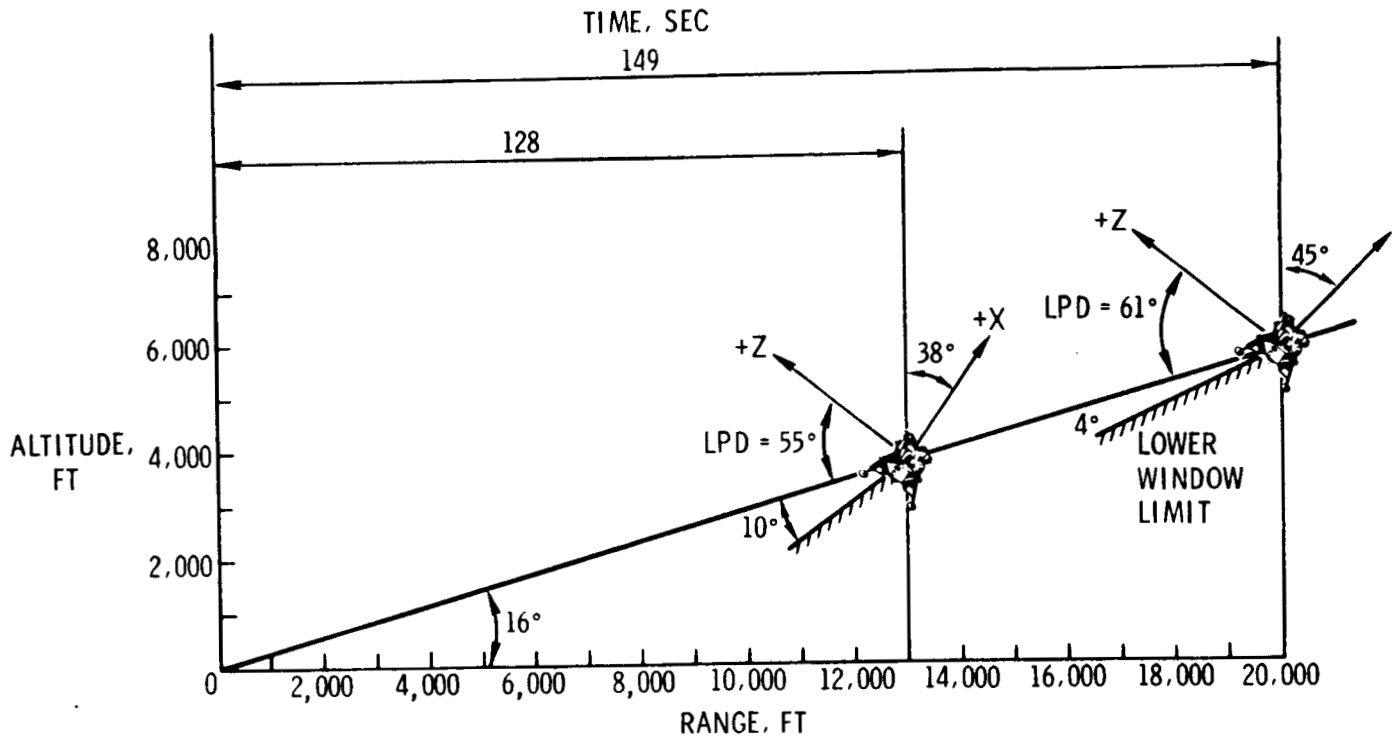
TIME HISTORIES OF DESCENT TRAJECTORY AND GUIDANCE PARAMETERS

SEQUENCE OF EVENTS

1 PDI
2 LR ALT UPDATE
3 THROTTLE RECOVERY
4 LR VEL UPDATE AND HORIZ VISIBILITY
5 HIGH GATE
6 INITIATE VERTICAL DESCENT

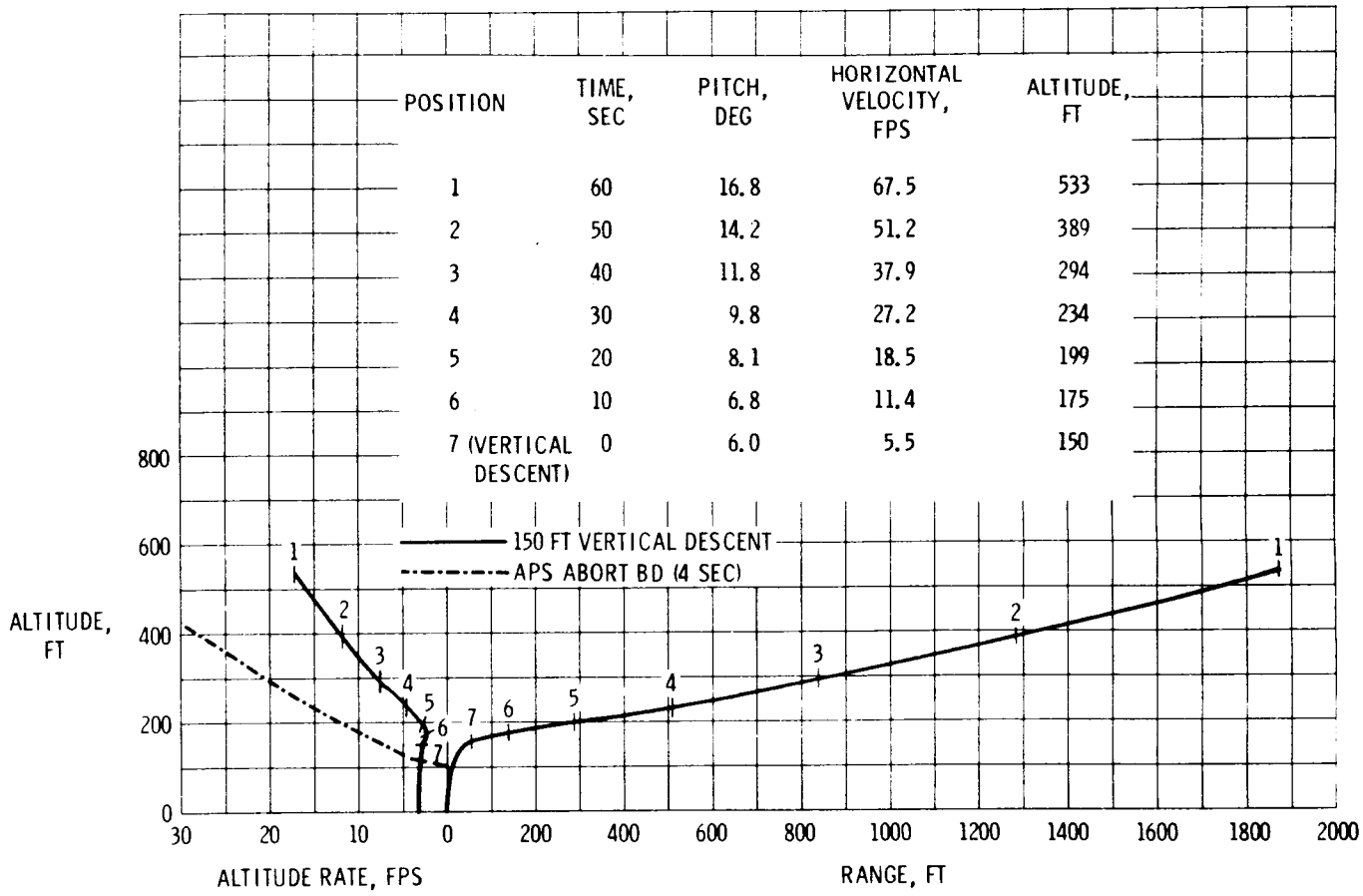


NOMINAL TRAJECTORY FINAL APPROACH

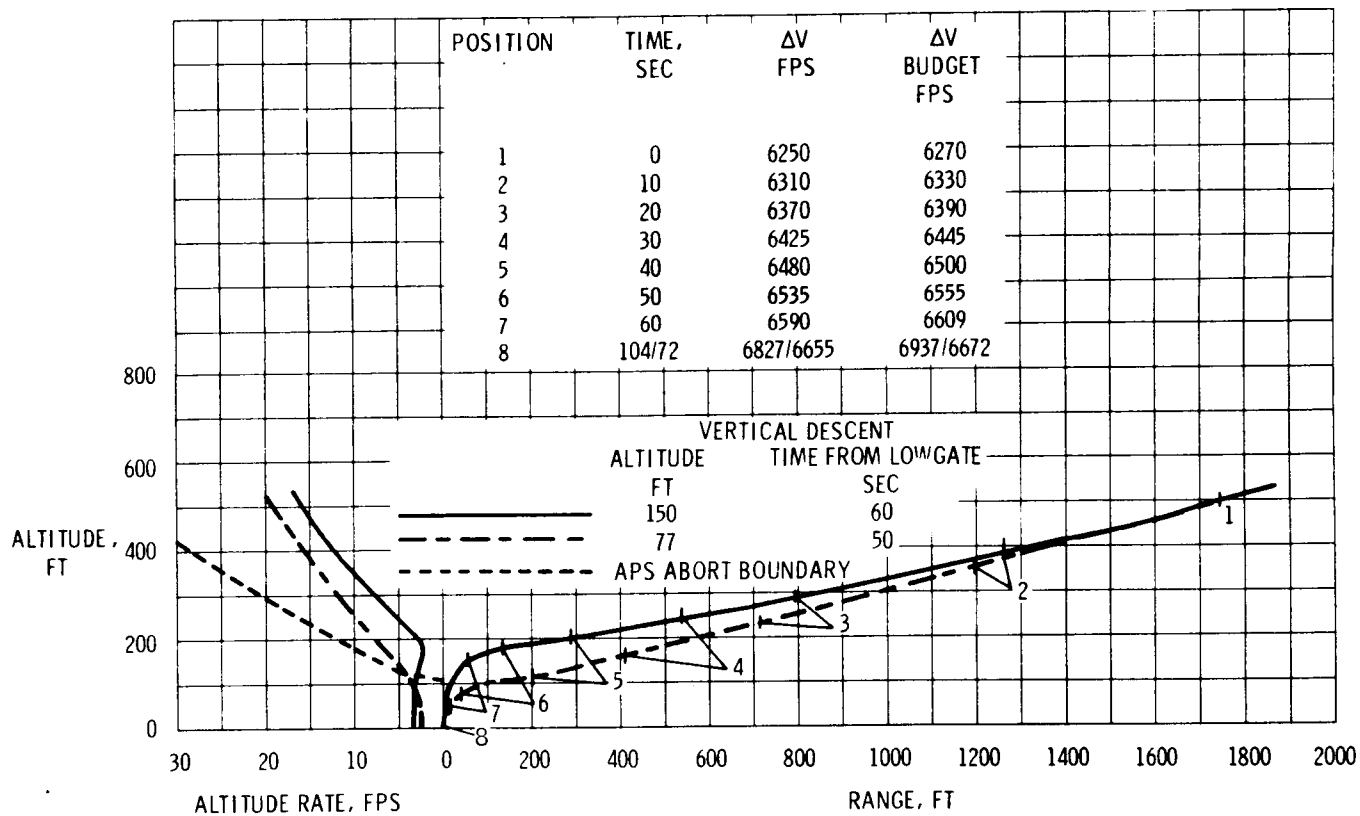


NOMINAL TRAJECTORY LANDING PHASE
(150 FOOT VERTICAL DESCENT)

POSITION	TIME, SEC	PITCH, DEG	HORIZONTAL VELOCITY, FPS	ALTITUDE, FT
1	60	16.8	67.5	533
2	50	14.2	51.2	389
3	40	11.8	37.9	294
4	30	9.8	27.2	234
5	20	8.1	18.5	199
6	10	6.8	11.4	175
7 (VERTICAL DESCENT)	0	6.0	5.5	150



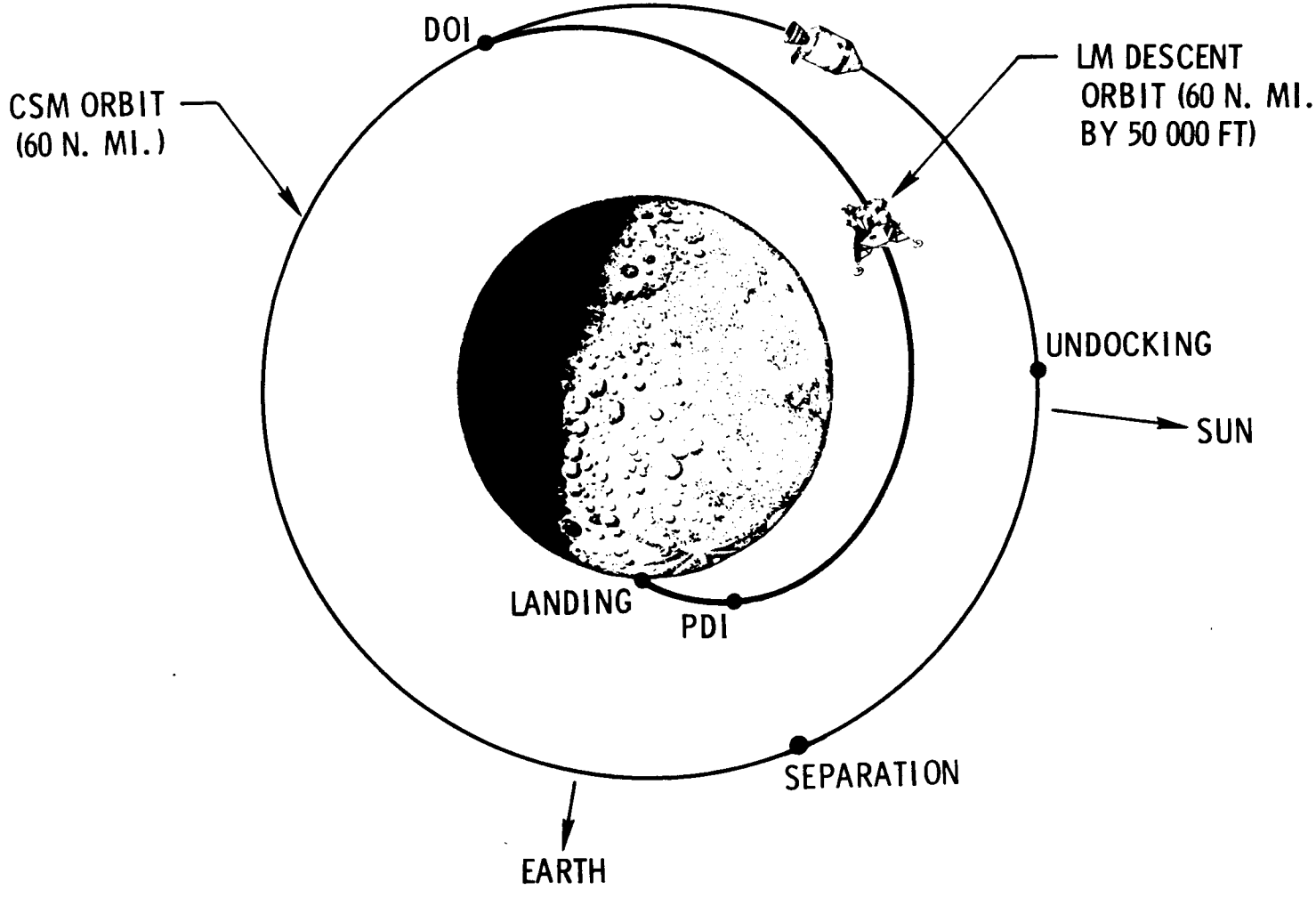
LANDING PHASE TRAJECTORY COMPARISON



DESCRIPTION OF DISPERSION ANALYSIS

- MONTE CARLO TECHINQUE
- INITIATE AT SEPARATION
- ORBIT NAVIGATION UNCENTAINTIES
- LUMINARY IA GUIDANCE LOGIC
- INCLUDES ALL SYSTEMS MODELS (IMU, DPS, LR)
- LUNAR ENVIRONMENT (TRIAXIAL, TERRAINS, SLOPES)
- TERMINATES AT TOUCHDOWN OR VIOLATION OF ABORT CRITERIA

LM DESCENT


DOI
CSM ORBIT
(60 N. MI.)
LM DESCENT
ORBIT (60 N. MI.
BY 50 000 FT)
UNDOCKING
SUN
LANDING
PDI
SEPARATION
EARTH

CRITERIA FOR DETERMINING UNSUCCESSFUL APPROACHES

- VIOLATION OF APS ABORT BOUNDARY PRIOR TO 600 FEET ALTITUDE
- PROPELLANT DEPLETION PRIOR TO TOUCHDOWN
- NO LANDING RADAR UPDATING PRIOR TO END OF BRAKING PHASE
- SURFACE IMPACT PRIOR TO VERTICAL DESCENT

NAVIGATION ACCURACY FOR LUNAR LANDING

CASE 1 (R2 MODEL + APOLLO 8 OPTICS PERFORMANCE)

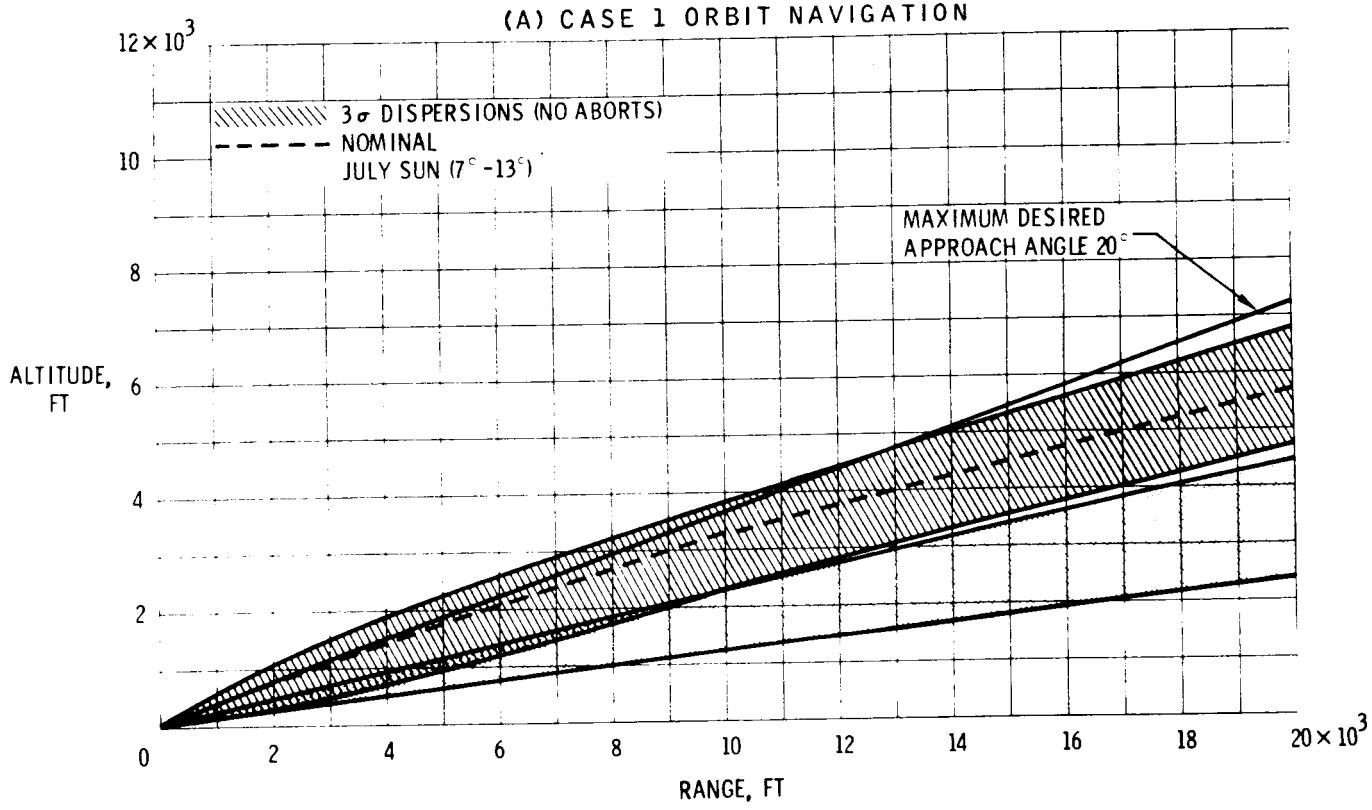
	LOCAL ERROR (3σ)	ERROR GROWTH (3σ)
DOWNTRACK	9,000 FT	33,000 FT/REV
RADIAL	13,500 FT	1,500 FT/REV

CASE 2 (R2 MODEL + EMPIRICAL TECHNIQUES + EXPECTED OPTICS CAPABILITY)

	LOCAL ERROR (3σ)	ERROR GROWTH (3σ)
DOWNTRACK	9,000 FT	9,000 FT/REV
RADIAL	1,800 FT	1,500 FT/REV

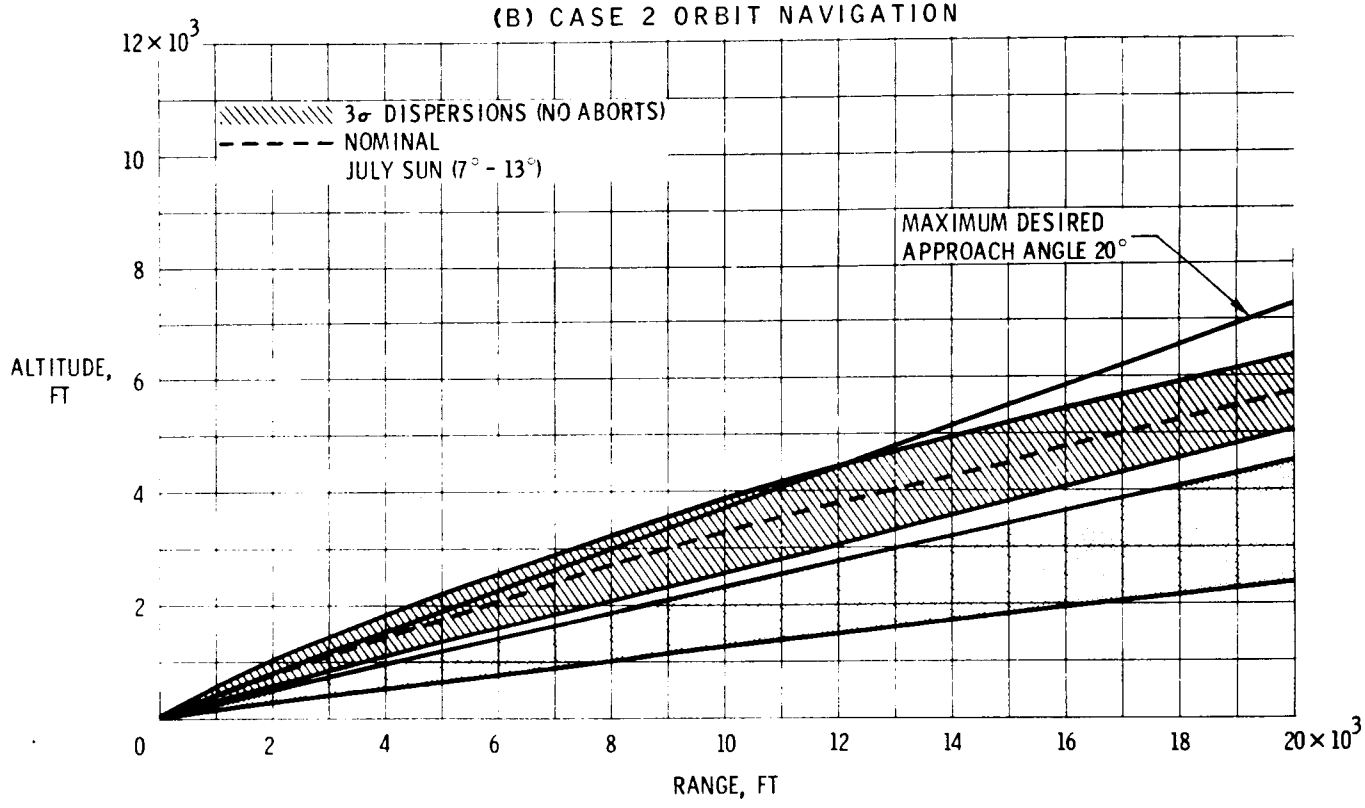
ALTITUDE DISPERSION CORRIDOR

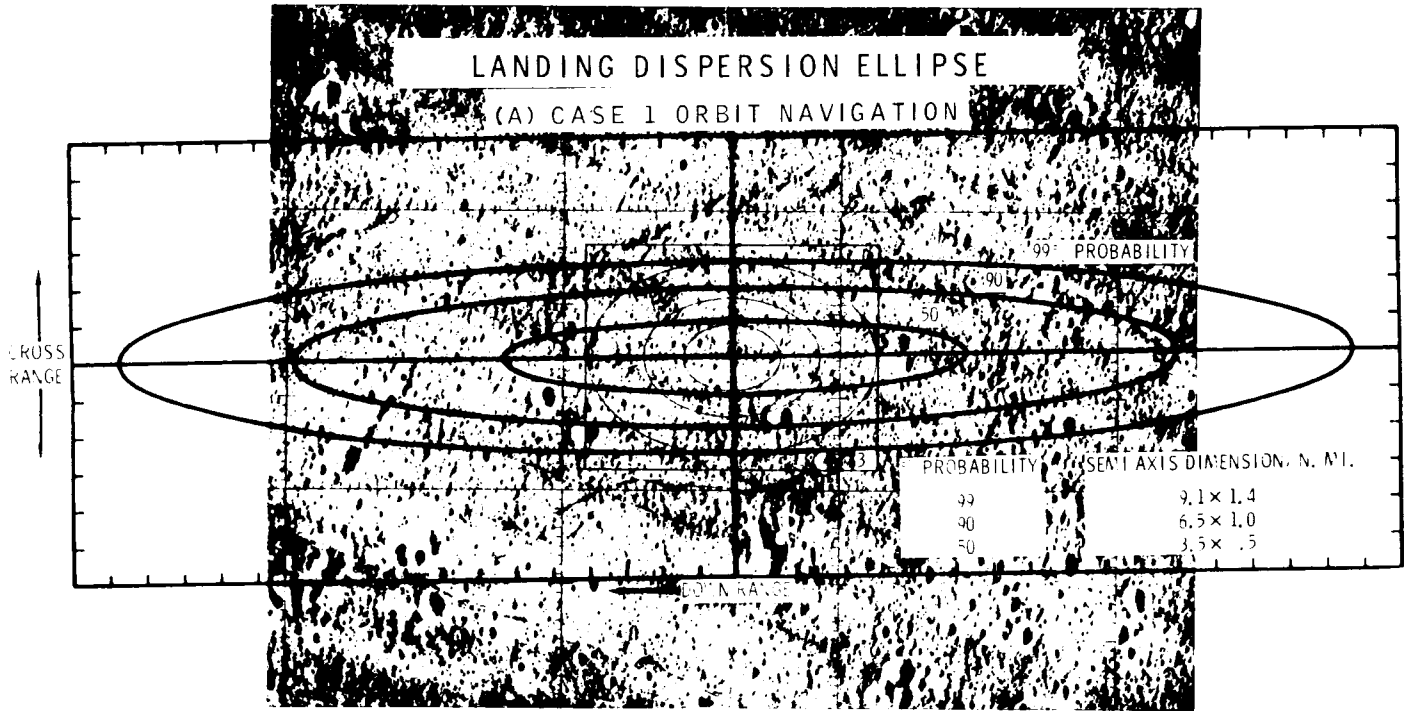
(A) CASE 1 ORBIT NAVIGATION



ALTITUDE DISPERSION CORRIDOR (CONCLUDED)

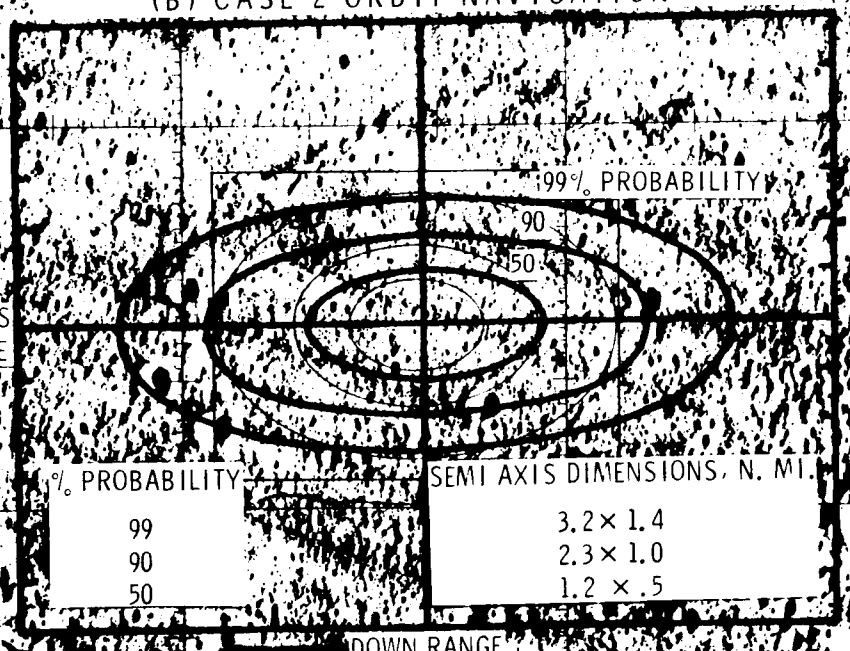
(B) CASE 2 ORBIT NAVIGATION




LANDING DISPERSION ELLIPSE
(A) CASE 1 ORBIT NAVIGATION
99% PROBABILITY
90
50
CROSS RANGE
DOWN RANGE
PROBABILITY
SEMI AXIS DIMENSION, N. MI.
99
9.1 × 1.4
90
6.5 × 1.0
50
3.5 × .5

LANDING DISPERSION ELLIPSE (CONCLUDED)

(B) CASE 2 ORBIT NAVIGATION



% PROBABILITY	SEMI AXIS DIMENSIONS, N. MI.
99	3.2 × 1.4
90	2.3 × 1.0
50	1.2 × .5

PERFORMANCE DISPERSIONS

CASE 1 ORBIT NAVIGATION

PARAMETER	NOMINAL	MEAN	1σ
LR ALTITUDE UPDATE, FT	34,092	36,189	± 2,766
LR VELOCITY UPDATE, FT	19,075	18,702	± 1,437
BURN TIME AT FTP, SEC	350	352	± 18.6
TGO AT THROTTLE RECOVERY, SEC	178	175	± 26
HORIZON VISIBILITY, h, FT	20,178	20,005	± 3,411
TOTAL TIME OF VISIBILITY, SEC	130	136	± 5.7
TOTAL BURN TIME, SEC	704	704	±8.7

TRAJECTORY DISPERSIONS

CASE 1 ORBIT NAVIGATION

20,000 FT RANGE

PARAMETER	NOMINAL	MEAN	1σ
HORIZONTAL VELOCITY, FPS	417	413	±4.9
VERTICAL VELOCITY, FPS	-108	-113	±13.3
PITCH FROM VERTICAL, DEG	45.7	44.9	±1.8
ALTITUDE, FT	5,707	5,777	±337
FLIGHT-PATH ANGLE, DEG	-14.5	-15.3	±1.7

10,000 FT RANGE

PARAMETER	NOMINAL	MEAN	1σ
HORIZONTAL VELOCITY, FPS	238	239.7	±3.2
VERTICAL VELOCITY, FPS	-70.6	-71.3	±4.8
PITCH FROM VERTICAL, DEG	36	35.3	±1.14
ALTITUDE, FT	3,281	3,065	±255
FLIGHT-PATH ANGLE, DEG	-16.5	-16.6	±1.1

TRAJECTORY DISPERSIONS (CONCLUDED)

CASE 1 ORBIT NAVIGATION (CONCLUDED)

2,000 FT RANGE

PARAMETER	NOMINAL	MEAN	1σ
HORIZONTAL VELOCITY, FPS	69.1	69.5	±1.2
VERTICAL VELOCITY, FPS	-24.1	-21.4	±3.4
PITCH FROM VERTICAL, DEG	16	17	±.36
ALTITUDE, FT	760	697	±128
FLIGHT-PATH ANGLE, DEG	-19.2	-17.1	±2.6

COMPARISON OF THE MONTE CARLO ΔV AND THE BUDGET ΔV

PARAMETER	MONTE CARLO ΔV, FPS	BUDGET ΔV, FPS
DOI		
MEAN	71.6	71
NOMINAL	71.5	71
DISPERSION (3σ)	±1.5	±0
HIGH GATE (7,000 FT)		
MEAN	5,436	5,462
NOMINAL	5,440	5,462
DISPERSION	±72	±59
LOW GATE (500 FT)		
MEAN	6,250	6,270
NOMINAL	6,250	6,270
DISPERSION	±72	±59
TOUCHDOWN		
MEAN	6,834	*6,937
NOMINAL	6,827	*6,937
DISPERSION	±150	±83

*INCLUDES 265 FEET PER SECOND FOR MANUAL CONTROL

TABLE 4-3

Assumptions for the Mission G DPS Propellant Budget

1.	Integrated average I_{SP} of 300.5 sec.
2.	Non ΔV consumables of 33.7 lb prior to LOI and 178.9 lbs. from LOI to lunar landing (linear function)
3.	LM separation weight of 33,033 lbs.

TABLE 4-4

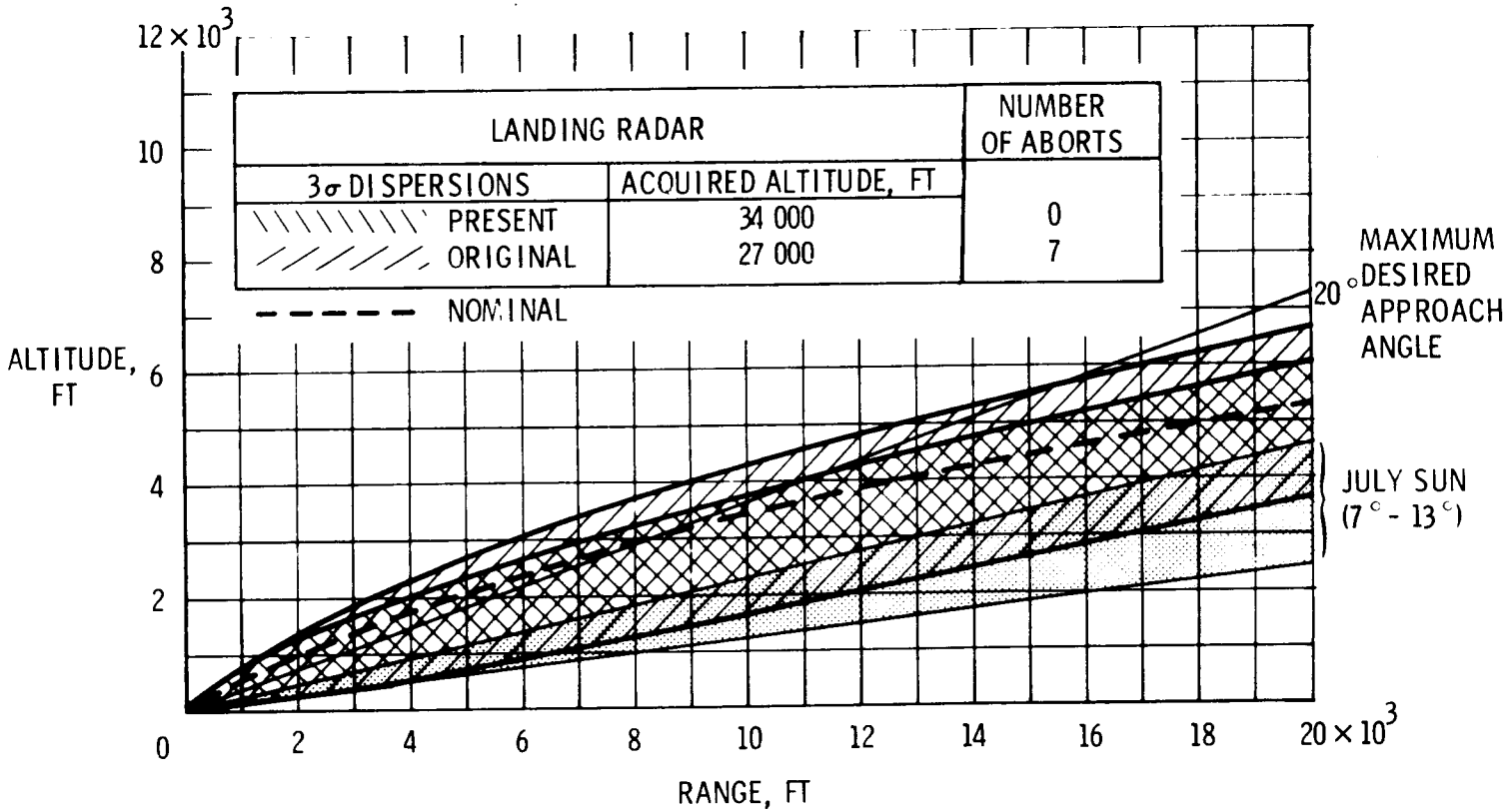
Mission G DPS Propellant Budget

Item	Propellant Required, lb.	Propellant Remaining, lb.
Loaded		17968.9
Trapped and unavailable[a]	222.5	17746.4
Outage[a]	47.9	17698.5
Contingencies[a]		
Engine value malfunction	41.8	17656.7
Redline low lever sensor	68.7	17588.0
Usable for ΔV		17588.0
Required for ΔV of 6267 fps	16975.1	612.9
-3 sigma dispersions[b]	262.9	350.0
Propellant margin above 3 sigma		350.0

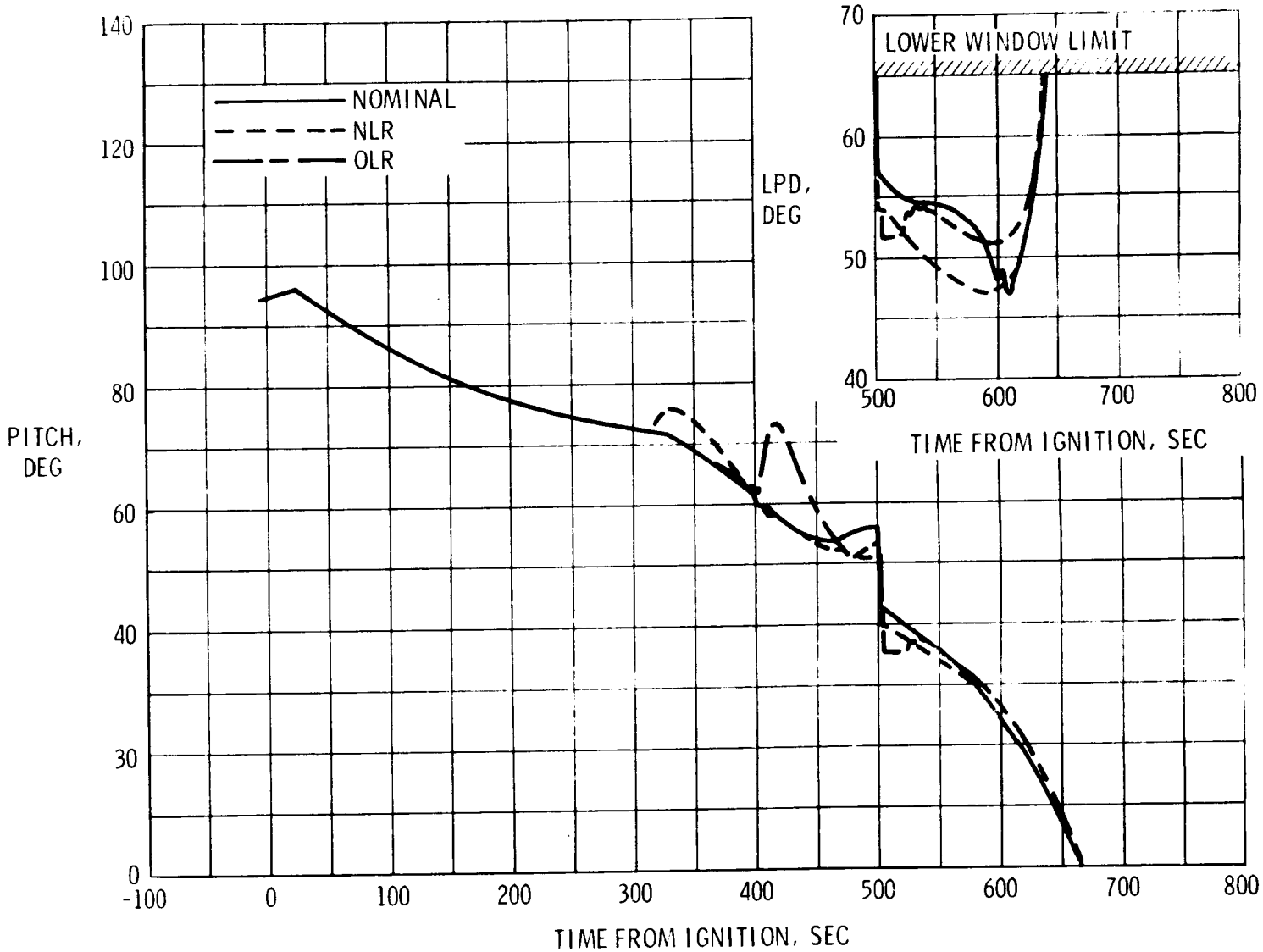
[a]Reference 2

[b]Dispersions due to 3 sigma uncertainties in propellant loading, mixture ratio, specific impulse, ΔV, vehicle weight, and consumables losses.

EFFECTS OF LANDING RADAR PERFORMANCE ON ALTITUDE DISPERSIONS



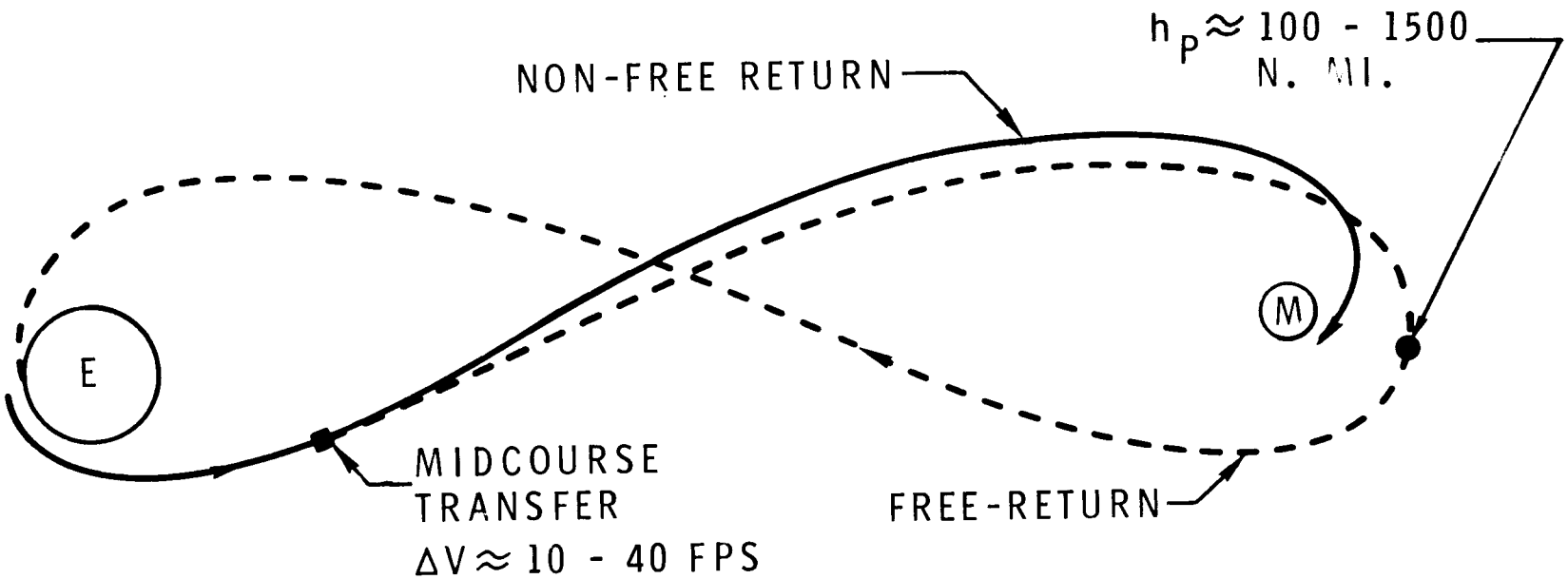
PITCH AND LPD TIME HISTORY - RUN 38



USE OF HYBRID PROFILE IN G MISSION LAUNCH WINDOW

- BACKGROUND:
  - DESCRIPTION OF HYBRID PROFILE
  - ADVANTAGES OF HYBRID PROFILE
- SPECIFIC LAUNCH WINDOW RECOMMENDATIONS
- EXPERIENCE, SAFETY, TRAINING, SOFTWARE, SH_e, DOCUMENTATION IMPLICATIONS

HYBRID LUNAR PROFILE

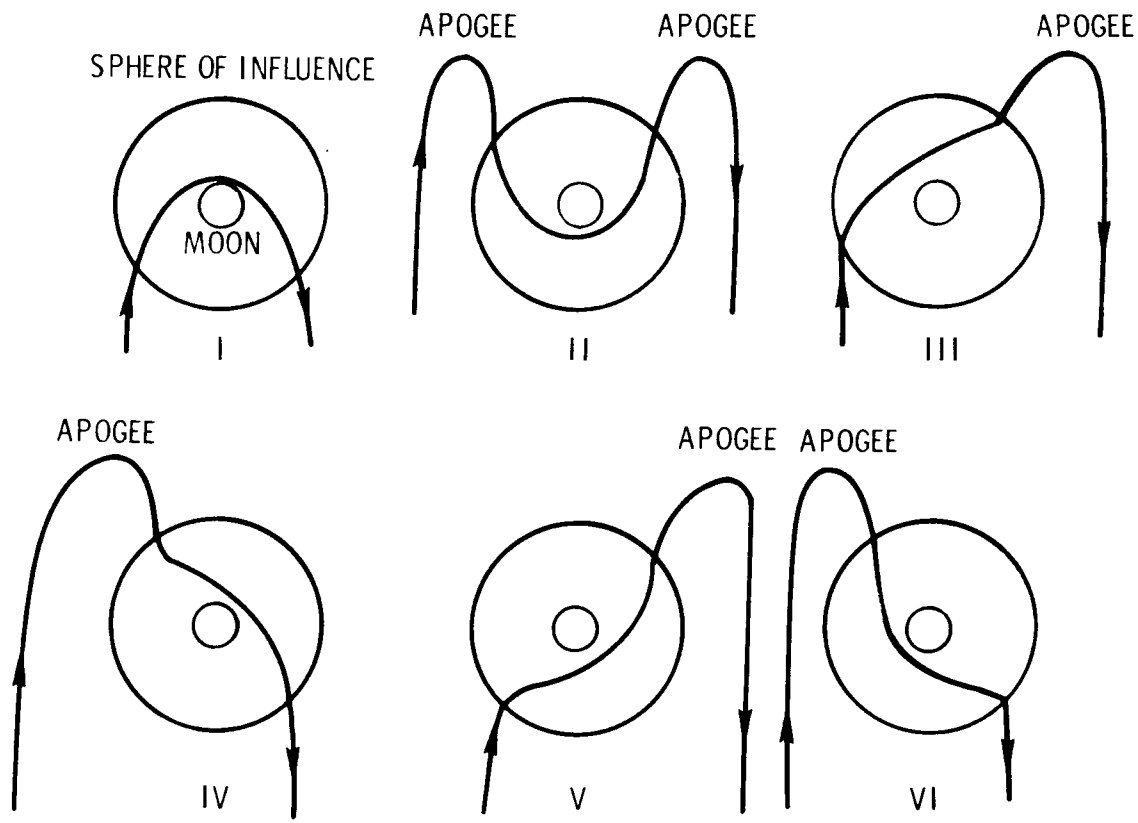


JENNESS/LMAB 2/17/69
G+P SUB PANEL/MARSHALL

HYBRID PROFILE DESCRIPTION

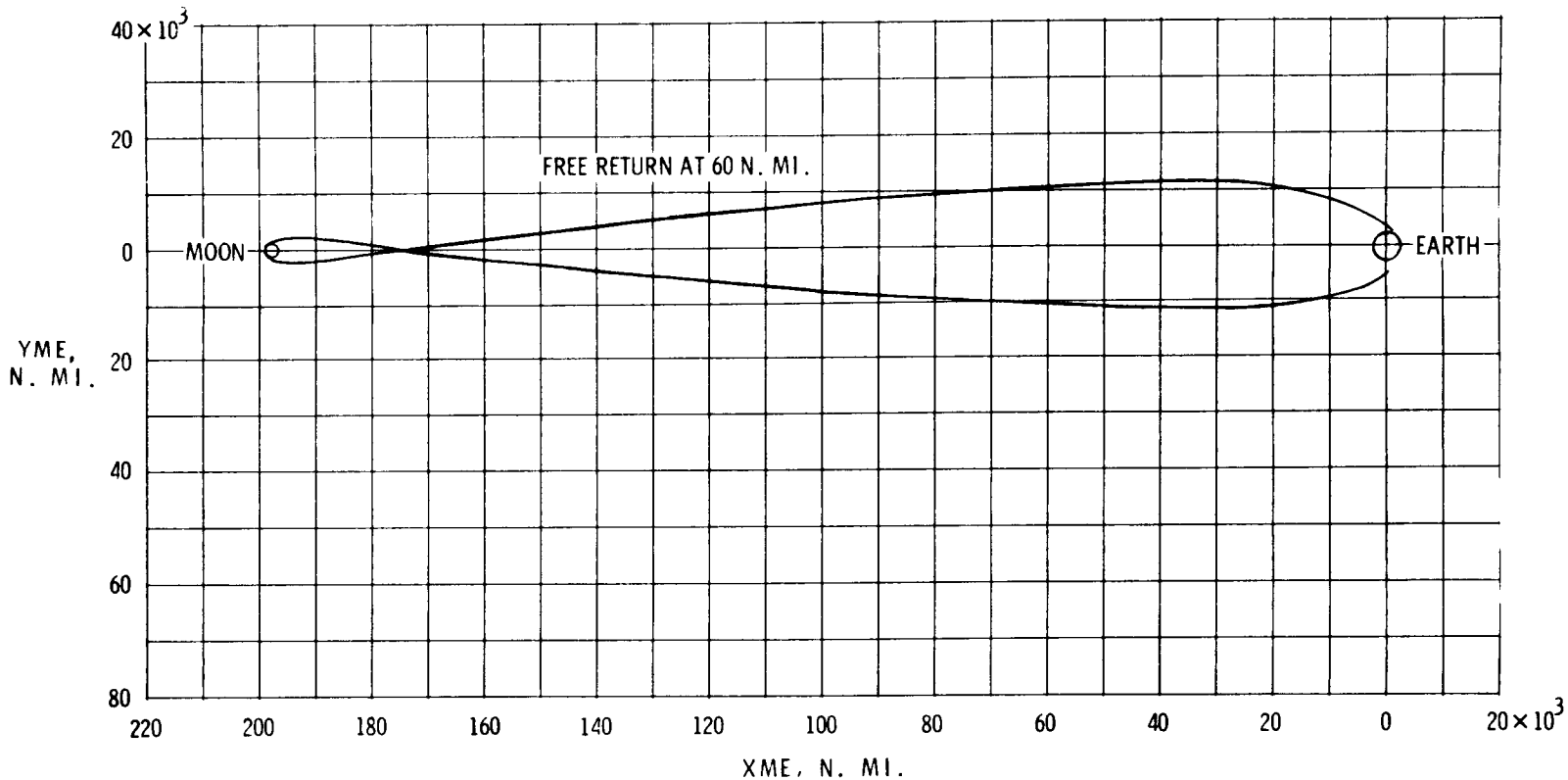
- TLI TARGETED FOR A FREE-RETURN CIRCUMLUNAR TRAJECTORY WITH $h_{PERILUNE} \approx 100$ TO 1,500 N. MI.
- AT TLI + 7 HRS SPS TRANSFER (10 - 40 FPS) TO A LOWER ENERGY TRANSLUNAR TRAJECTORY WITH $h_{PERILUNE} \approx 60$ N. MI.
- TRANSLUNAR FLIGHT TIME ≈ INITIAL FREE-RETURN TRANSLUNAR FLIGHT TIME (70 - 80 HRS)
- LOI $\Delta V \approx 100 - 300$ FPS LESS THAN FREE RETURN
- WITHIN SM/RCS RETURN CAPABILITY AT LEAST HALF WAY TO MOON
- WITHIN LM/DPS RETURN CAPABILITY AT LEAST 10 HOURS PAST PERILUNE
- SAME BASIC CLASS OF TRAJECTORIES AS FREE-RETURN

CLASSES OF CIRCUMLUNAR TRAJECTORIES



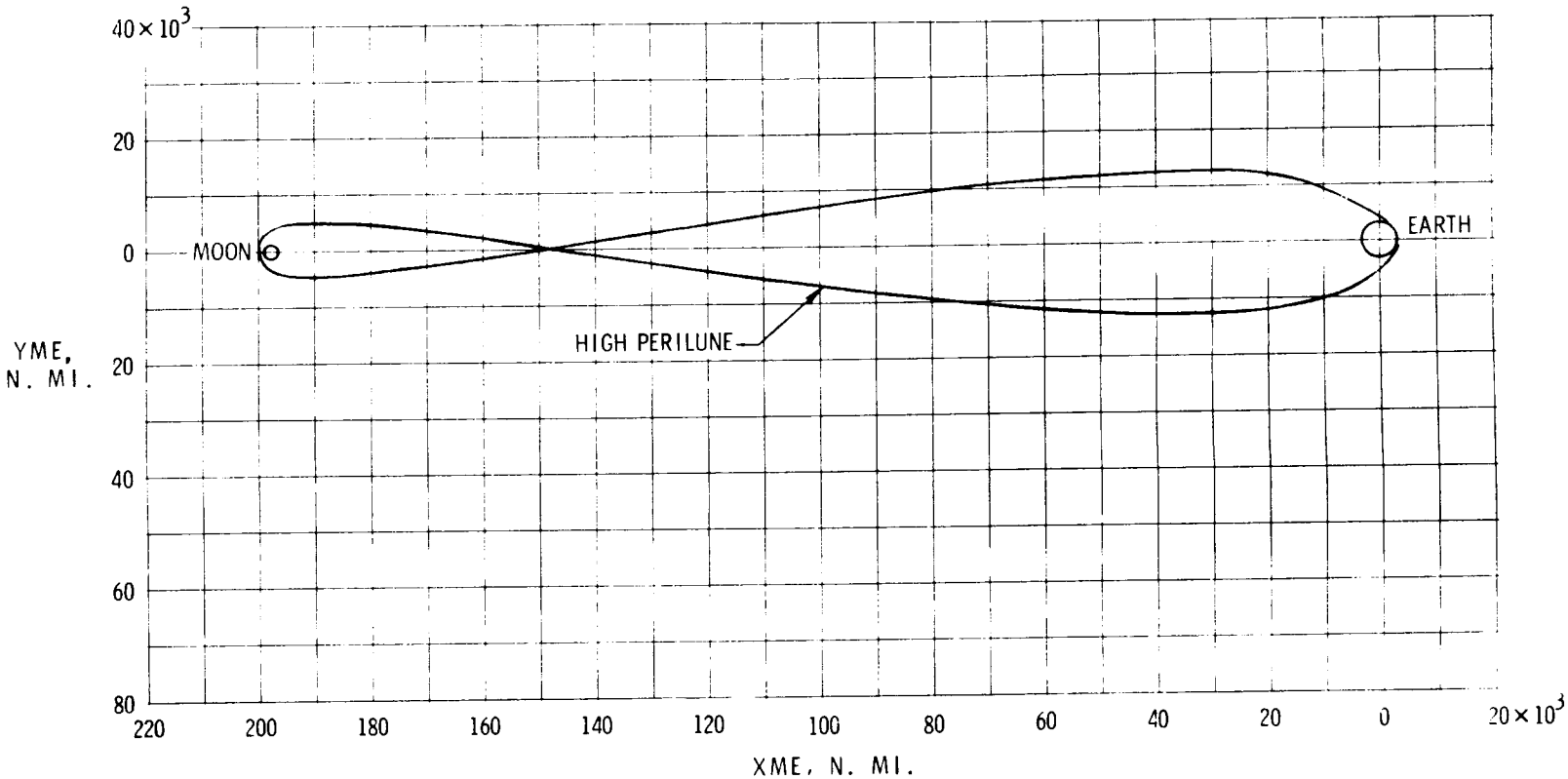
STANDARD FREE-RETURN PROFILE

MPAD 4853 S V(IU)



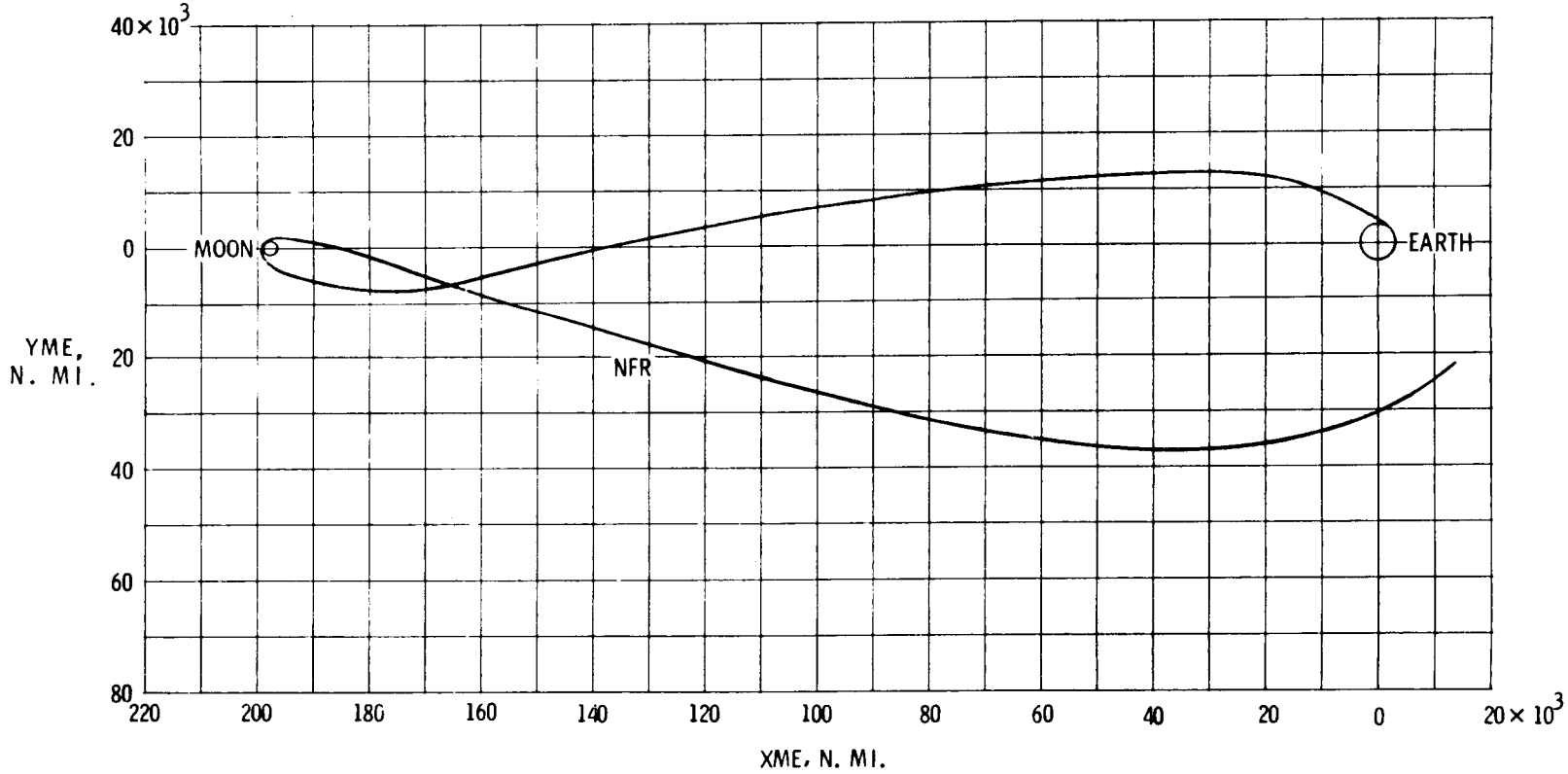
HIGH ALTITUDE PERILUNE FREE-RETURN PROFILE OF HYBRID

MPAD 4854 S V (IU)



MPAD 4855 S V (IU)

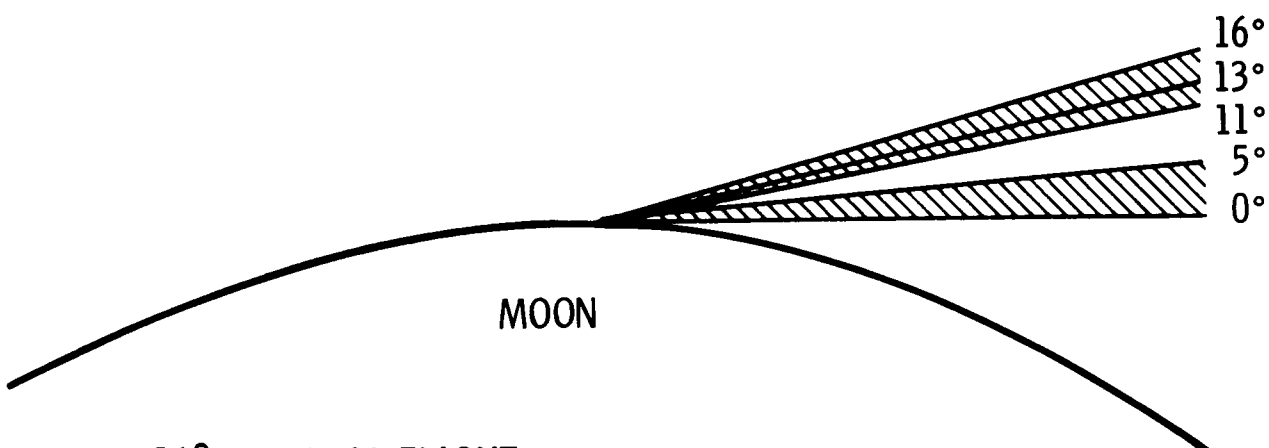
NONFREE-RETURN PROFILE OF HYBRID



OPERATIONAL ADVANTAGES OF HYBRID

- ALLOWS LUNAR LIGHTING ADJUSTMENT WITHOUT PERTURBING LUNAR ORBIT TIMELINE
- ALLOWS STANDARDIZATION OF LUNAR LANDING SITE APPROACH AZIMUTH
- ALLOWS PACIFIC INJECTION
  - DAYLIGHT LAUNCH
  - BETTER MSFN COVERAGE OF TLI AND ENTRY
  - BETTER/STANDARD EPO TIMELINE
- INCREASES SPS PERFORMANCE RESERVES

LUNAR LIGHTING GUIDELINES



16° NOMINAL FLIGHT-PATH ANGLE
13° 3σ LOW FLIGHT-PATH ANGLE
11° MAX PREFERABLE
5° MINIMUM

FREE RETURN LUNAR LIGHTING COMPARISON

RELATIVE LAUNCH DAY

		1	2	3	4	5	6	7	8
JULY	FR(P)	8-11°	10-13°		9-12°				13-16°
	FR(A)	14-17°	16-19°		16-19°				11-14°
AUG	FR(P)	13-16°	14-17°		12-15°			5-8°	
	FR(A)	8-11°	11-14°		10-13°				
SEPT	FR(P)	5-8°	6-9°						
	FR(A)	14-17°	16-19°		15-18°			10-13°	

BASIC TECHNIQUES FOR OPTIMIZING LUNAR LIGHTING

- LAUNCH DAY EARLIER WITH HYBRID AND ADJUST TRANSLUNAR FLIGHT TIME
  - ACCEPTABLE CREW WORK/REST CYCLE CAN EASILY BE WORKED OUT
- LAUNCH DAY EARLIER WITH FREE RETURN AND ADD LPO REVS
  - SIGNIFICANT DISRUPTION OF CREW WORK/REST CYCLE

LAUNCH WINDOW LUNAR LIGHTING COMPARISON

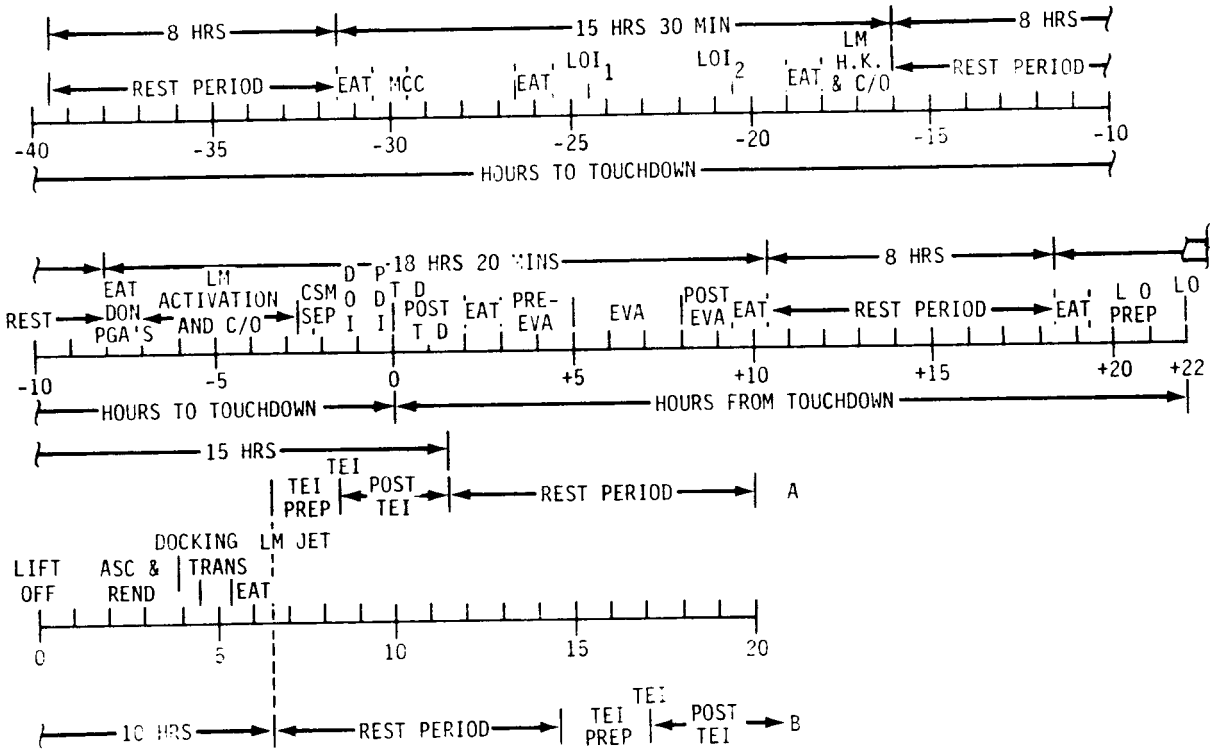
RELATIVE LAUNCH DAY		1	2	3	4	5	6	7	8
JULY	FR (P) FR (A) HYB (P)	8-11° 14-17°	10-13° 16-19°		9-12° 16-19°			6-9°	13-16° 11-14°
AUG	FR (P) FR (A) HYB (P)	13-16° 8-11° 6-9°	14-17° 11-14° 6-9°		12-15° 10-13° 6-9°			5-8°	9-12°
SEPT	FR (P) FR (A) HYB (P)	5-8° 14-17° 7-10°	6-9° 16-19° 7-10°		15-18° 7-10°			10-13° 7-10°	

ADDITIONAL LPO REVS REQ'D FOR LIGHTING

RELATIVE LAUNCH DAY

		1	2	3	4	5	6	7	8
JULY	FR(P)	0	0		0			4	
	FR(A)	3	1		1				6
AUG	FR(P)	4	3		5				
	FR(A)	9	0/6			0			0
SEPT	FR(P)	0	0						
	FR(A)	3	2		3				0

LUNAR ORBIT TIMELINE



LAUNCH WINDOW LUNAR SITE APPROACH AZIMUTH

RELATIVE LAUNCH DAY		1	2	3	4	5	6	7	8
JULY	FR (P)	-92°	-91°		-89°				-95°
	FR (A)	-101°	-101°		-99°				-92°
	HYB (P)							-86°	
AUG	FR (P)	-92°	-91°		-89°				
	FR (A)	-97°	-95°		-90.5°			-90°	
	HYB (P)	-92°	-91°		-89°				-86°
SEPT	FR (P)	-92°	-91°						
	FR (A)	-97°	-95°		-90.5			-90°	
	HYB (P)	-92°	-91°		-89			-78°	

ADVANTAGES OF DAYLIGHT LAUNCH

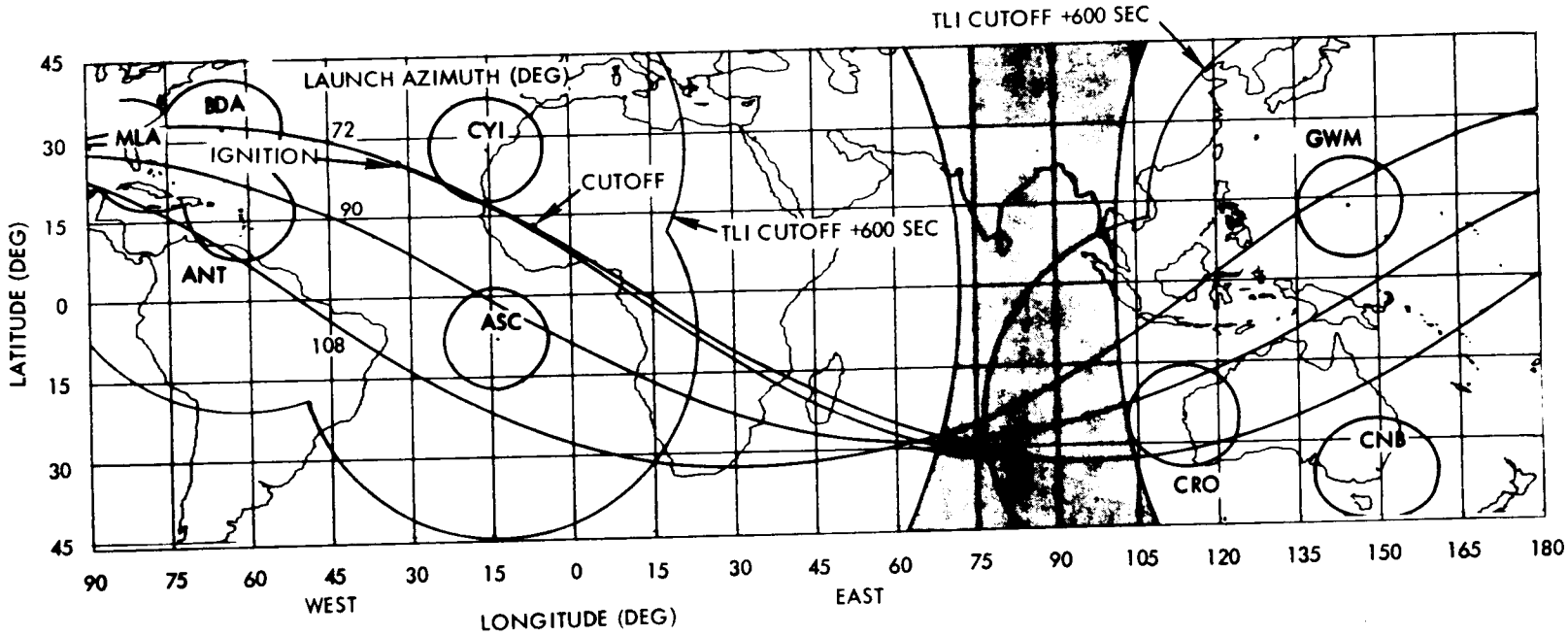
- PROVIDES MORE EASILY FOUND HORIZON ATTITUDE REFERENCE FOR HIGH ALTITUDE LAUNCH ABORTS
- RECOVERY OF LAUNCH ABORT EASIER
- PHOTOGRAPHIC COVERAGE

TLI AND ENTRY MSFN COVERAGE GUIDELINES

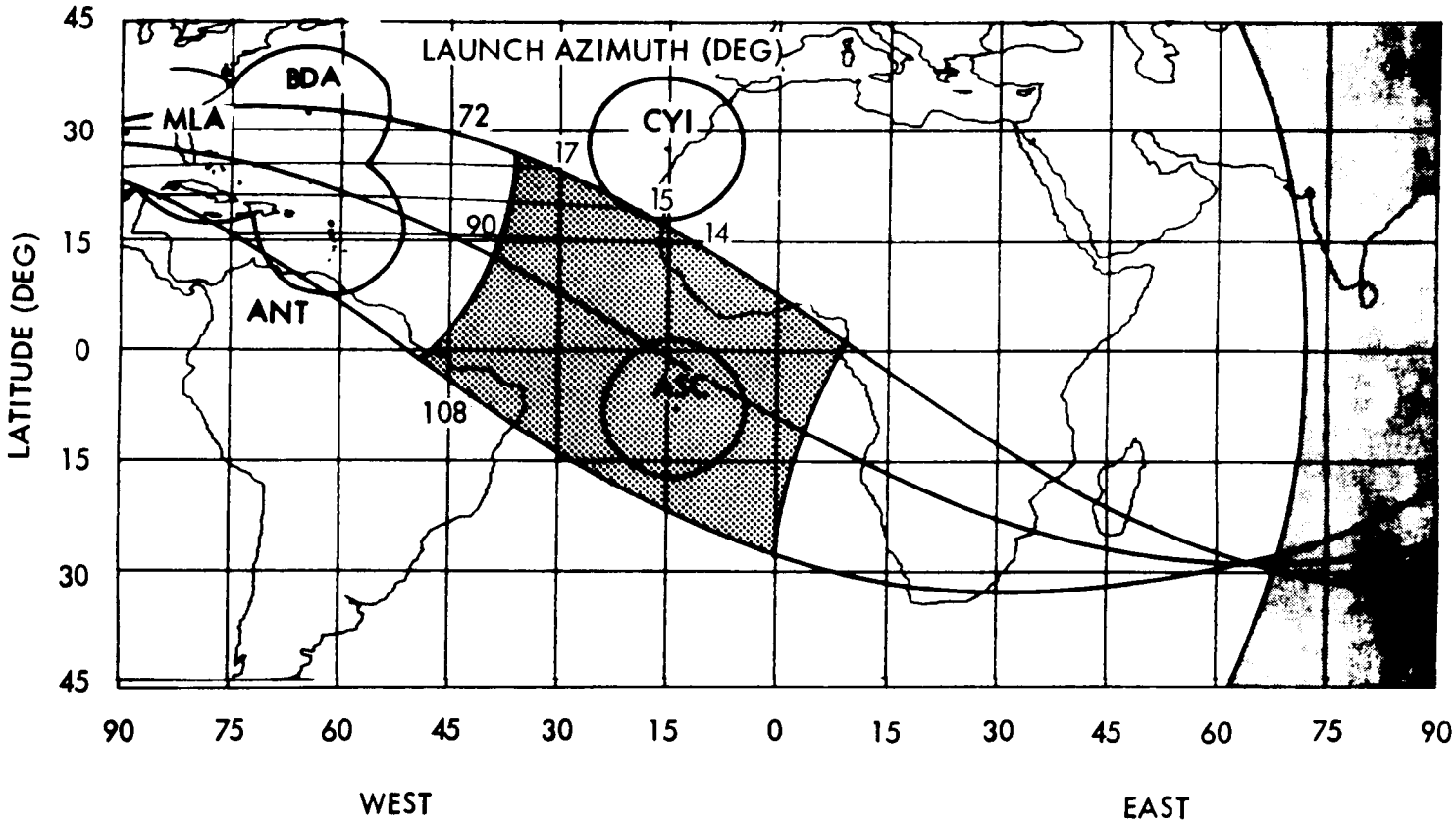
- MANDATORY: 10 OUT OF FIRST 20 MINUTES FOLLOWING TLI
- HIGHLY DESIRABLE: TLI PRE-IGNITION SEQUENCE (TLI - 9 MINUTES TO TLI IGN)
- DESIRABLE: TLI BURN
- DESIRABLE: PRE-BLACKOUT ENTRY PHASE

PACIFIC VERSUS ATLANTIC INJECTION FOR MSFN COVERAGE

- 10 OUT OF 20 MINUTES POST TLI REQUIREMENT ALWAYS SATISFIED WITH PERMANENT STATIONS FOR PACIFIC INJECTION BUT NOT ATLANTIC
- USE OF PACIFIC FREES SHIPS FOR PRE-IGNITION COVERAGE AND TLI BURN
- PACIFIC INJECTION ALLOWS USE OF INJECTION SHIPS TO ASSIST COVERAGE OF ENTRY
- LOGISTICS PROBLEMS IF OCEANS SWITCHED

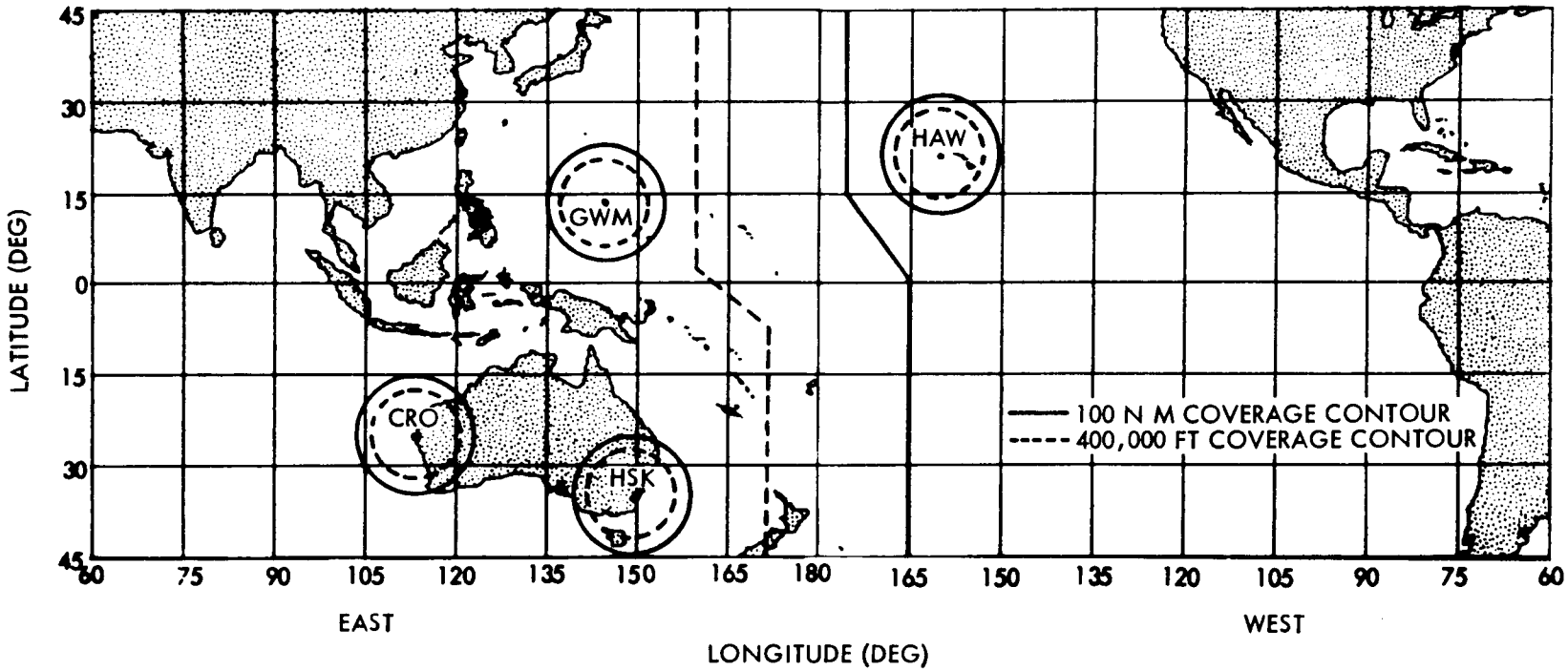


FOOTPRINT OF THE TRAJECTORY FROM TLI TO TLI CUTOFF PLUS 4 HOURS:
17 AUGUST 1969, 72 DEG LAUNCH AZIMUTH - FIRST OPPORTUNITY



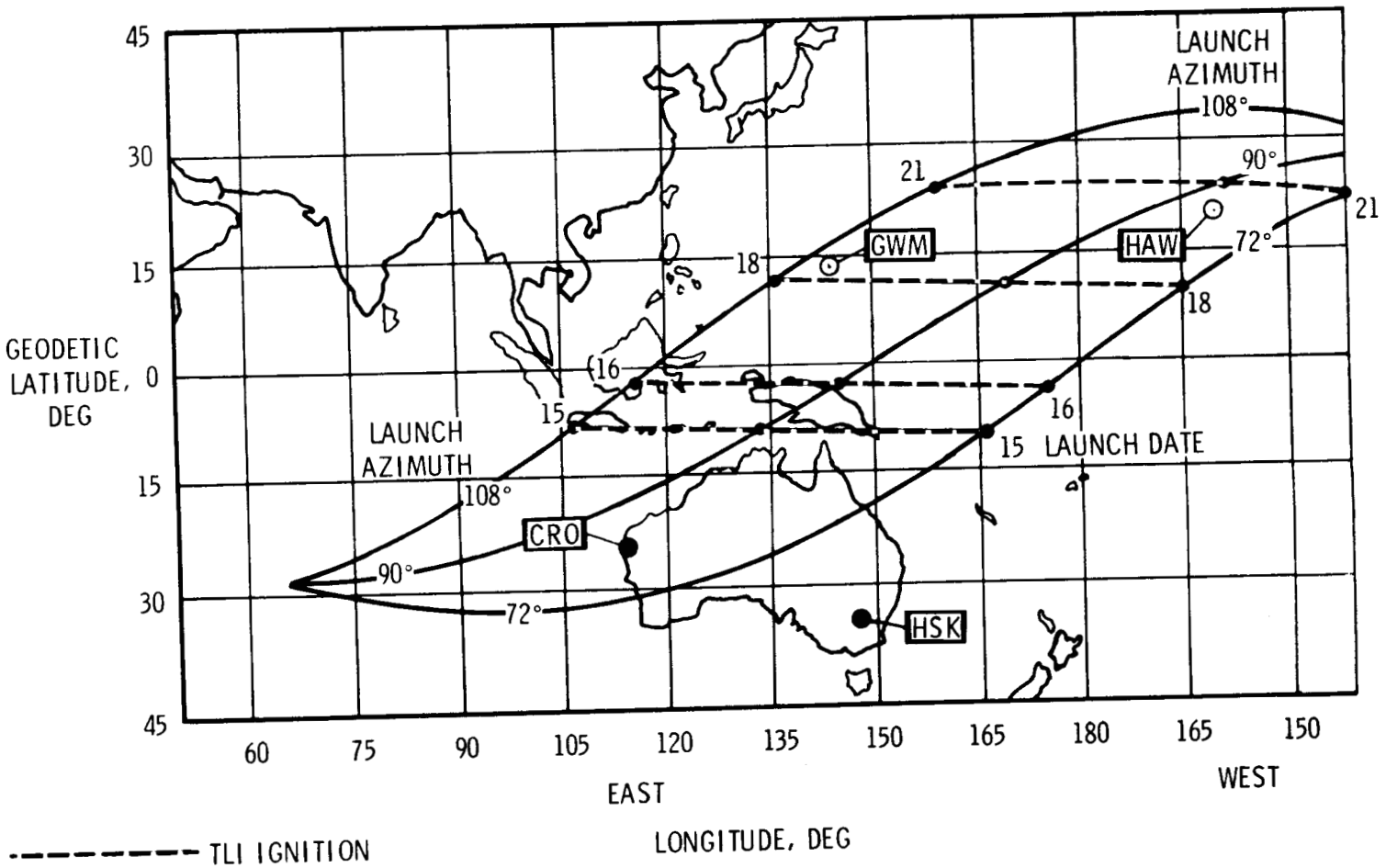
REGION OF TLI IGNITION POINTS IN WHICH THE MSFN STATIONS DO NOT SATISFY THE MINIMUM COVERAGE REQUIREMENTS: SECOND REVOLUTION

MPAD 4916 S (IU)

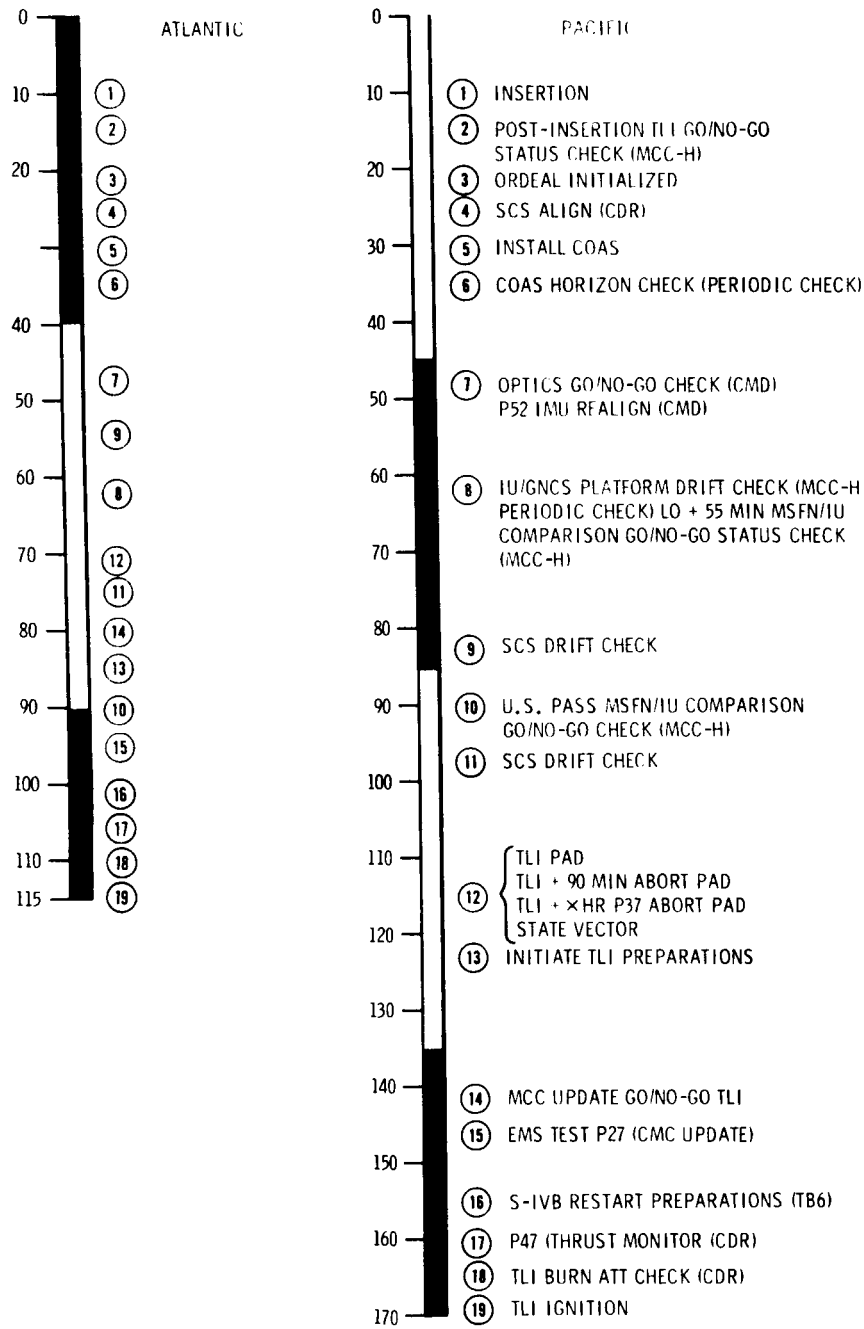


LOCI OF SPLASHDOWN POSITIONS AND OF ENTRY INTERFACE POSITIONS WITH MSFN COVERAGE CONTOURS IN ENTRY AREA

TRANSLUNAR INJECTION POSITIONS



EPO TIMELINE COMPARISON FOR AUGUST 14 LAUNCH



LAUNCH WINDOW OPERATIONAL GUIDELINES

- PACIFIC INJECTION
- LUNAR LIGHTING AT LANDING
  - 5 - 11° PREFERRED
- 4 LAUNCH DAYS PER MONTH
- FIXED LPO TIMELINE
- FREE-RETURN PROFILE PREFERRED BUT HYBRID ACCEPTABLE IF NECESSARY

PACIFIC INJECTION LAUNCH WINDOW ASSUMING FREE RETURN ONLY

RELATIVE LAUNCH DAY

		1	2	3	4	5	6	7	8
JULY 15 - 22	SITE:	1	2		3				5
	SEA:	8 - 11°	10 - 13°		9 - 12°				13 - 16°
	TLFT:	73.7	73.0		70.5				64.5
	RES:	2300	2300		2200				1600
AUG 14 -20	SITE:	1	2		3				
	SEA:	13 - 16°	14 - 17°		12 - 15°				
	TLFT:	72.5	70.7		67.0				
	RES:	2100	2000		1500				
SEPT 12 - 16	SITE:	1	2						
	SEA:	5 - 8°	6 - 9°						
	TLFT:	70.0	68.4						
	RES:	2200	2000						

LAUNCH WINDOW WITH HYBRID USED AS NECESSARY

RELATIVE LAUNCH DAY

		1	2	3	4	5	6	7	8
JULY 15 - 21	SITE:	1	2		3			5	
	SEA:	8 - 11°	10 - 13°		9 - 12°			6 - 9	
	TLFT:	73.7	73.0		70.5			74	
	RES:	2300	2300		2200			1900	
	PROFILE:	FR	FR		FR			HYB	
AUG 13 - 20	SITE:	1	2		3				5
	SEA:	6 - 9	6 - 9		6 - 9				9 - 12°
	TLFT:	81	78		79				70.0
	RES:	2800	2800		2800				800
	PROFILE:	HYB	HYB		HYB				HYB
SEPT 12 - 18	SITE:	1	2		3			5	
	SEA:	5 - 8°	6 - 9°		7 - 10°			7 - 10	
	TLFT:	70.0	70.3		78.8			76.0	
	RES:	2200	1700		1500			900	
	PROFILE:	FR	FR		HYB			HYB	

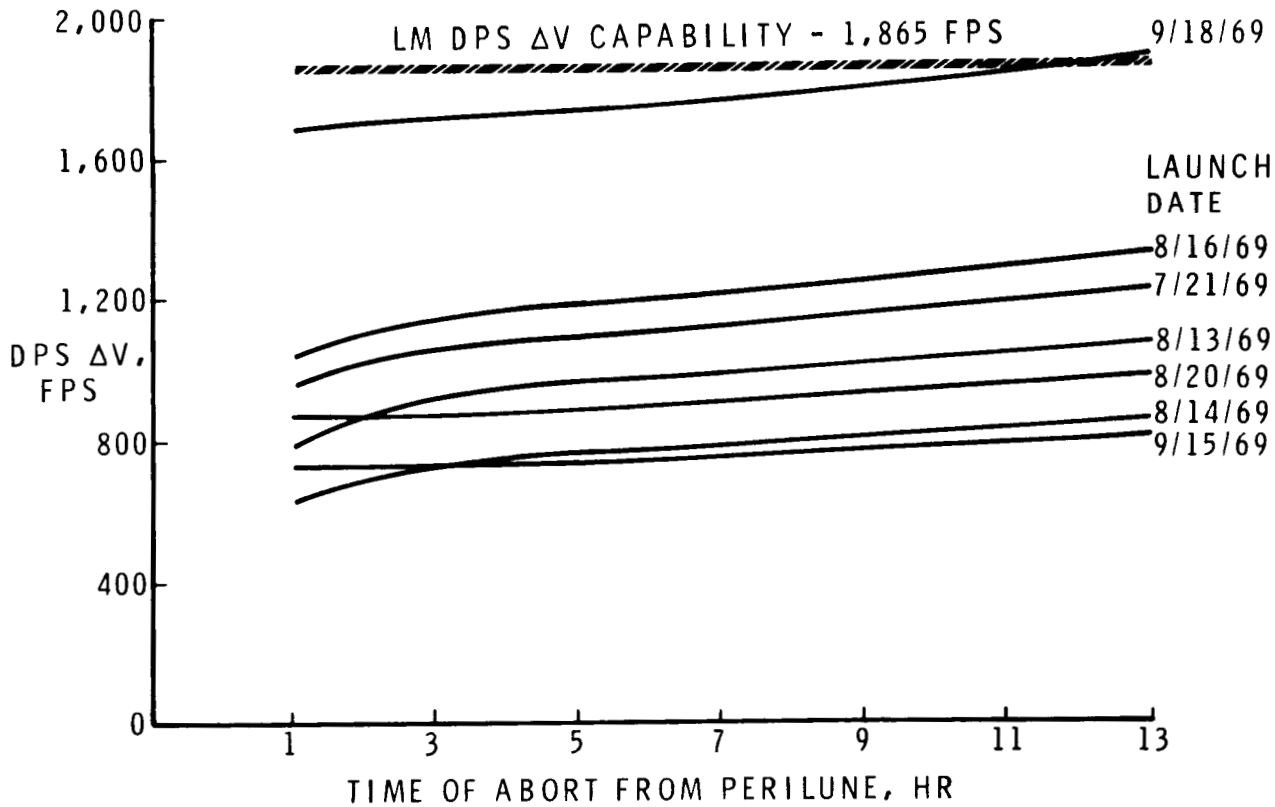
TRAJECTORY EXPERIENCE IMPLICATIONS

- HYBRID TRAJECTORIES ARE OF SAME BASIC CLASS AS FREE-RETURN
- TRAJECTORY PARAMETERS DISPLAY SAME CHARACTERISTICS AND TRENDS - ONLY OVER LARGER RANGES
- ALL FREE RETURN EXPERIENCE IS DIRECTLY APPLICABLE
- ABLE TO USE FREE-RETURN TRAJECTORY COMPUTER PROGRAMS WITH MINOR MODIFICATIONS

CREW SAFETY IMPLICATIONS

- WITHIN SM/RCS RETURN CAPABILITY UNTIL ≈ HALF WAY TO MOON
  - WILL HAVE PICKED UP LM/DPS FOR SPS BACKUP
  - WILL HAVE FIRED SPS
- WITHIN LM/DPS RETURN CAPABILITY UNTIL AT LEAST 10 HOURS AFTER PERILUNE
- LOI ABORTS
  - ABORT MODES IDENTICAL
  - WITHIN SPS CAPABILITY THROUGHOUT BURN
  - WITHIN LM/DPS CAPABILITY THROUGHOUT BURN EXCEPT FOR A 30 TO 60 SECOND PERIOD
- LOI MONITORING
  - NO ANTICIPATED IMPACT

LM DPS ABORT ΔV, NON-FREE RETURN TRAJECTORIES



CREW TRAINING IMPLICATIONS

- NO ADDITIONAL TRAINING ANTICIPATED
- SIMPLIFIES TRAINING DUE TO STANDARDIZATION OF EPO AND LPO TIMELINES AND APPROACH AZIMUTHS TO LUNAR LANDING SITE

SOFTWARE IMPLICATIONS

- LV TARGETING INTERFACE
  - SAME TARGETING PARAMETERS USED - JUST DIFFERENT NUMERICAL VALUES
  - SEVERAL SAMPLE TARGETING CASES ALREADY PERFORMED WITH NO PROBLEMS
  - SLINGSHOT ANALYSIS REQUIRED
- RTCC
  - CURRENT LOI AND RETURN-TO-EARTH TARGETING DIRECTLY APPLICABLE
  - TRANSLUNAR MIDCOURSE TARGETING
    - PLANNED ANYWAY FOR FREE-RETURN CONTINGENCIES
    - LOGIC COMPLETELY DEFINED AND CODED IN RTCC DEVELOPMENT PROGRAM
    - VERIFICATION IN PROGRESS
    - INDEPENDENT FORMULATION BACKUP IN RTACF

LM SUPER-CRITICAL H_e IMPLICATIONS

- ALL MISSIONS KEPT WITHIN 138 HOUR LIMIT (ASSUMES 10 PSIA/HR)
- WORST CASE LAUNCH/TLI SITUATION ALLOWS MAX TL FLIGHT TIME OF 82 HOURS

DOCUMENTATION IMPLICATIONS

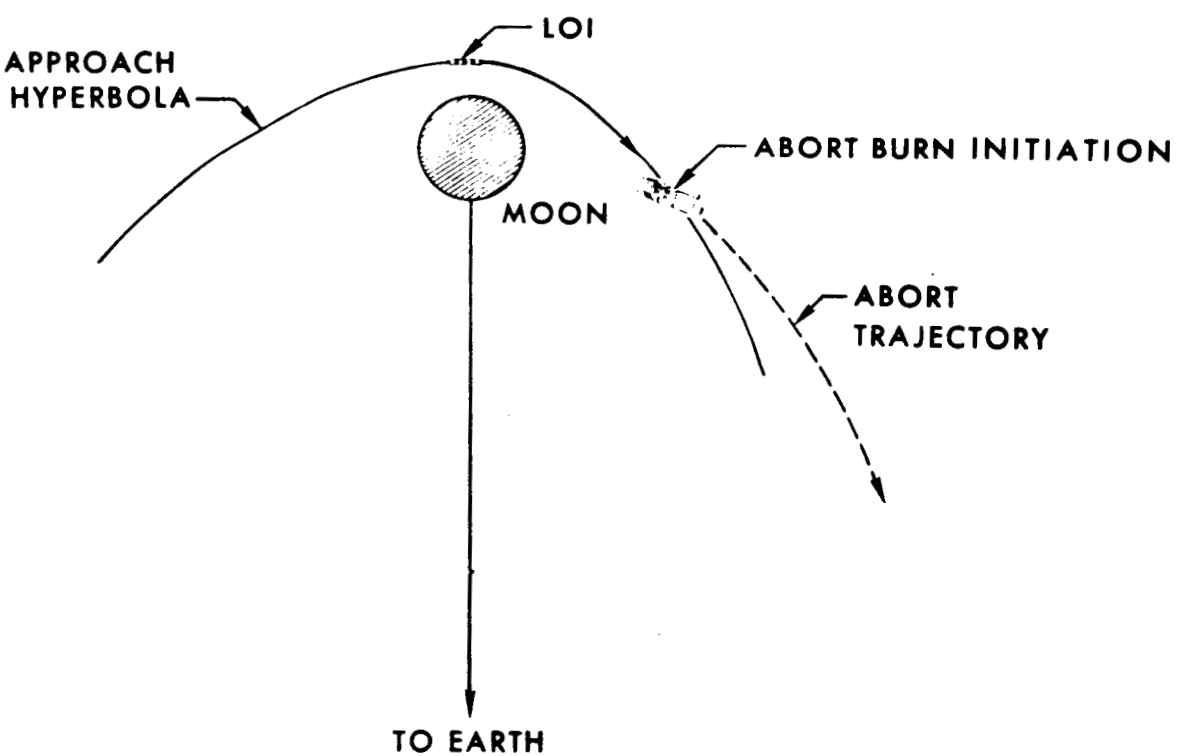
- SUPPLEMENT TO OPERATIONAL TRAJECTORY SHOWING DETAILED TRANSLUNAR PHASE FOR AUGUST 13
- ALL HYBRID WINDOWS SHOWN IN SUMMARY DOCUMENTS
- ADDITIONAL TRANSLUNAR MCC AND LOI DISPERSION ANALYSIS FOR AUGUST 13
- SUPPLEMENT TO ABORT DOCUMENT SHOWING LOI ABORTS
- SUPPLEMENT TO LUNAR ALTERNATE MISSION DOCUMENT SHOWING HYBRID EFFECTS

LV TARGETING STATUS FOR G MISSION

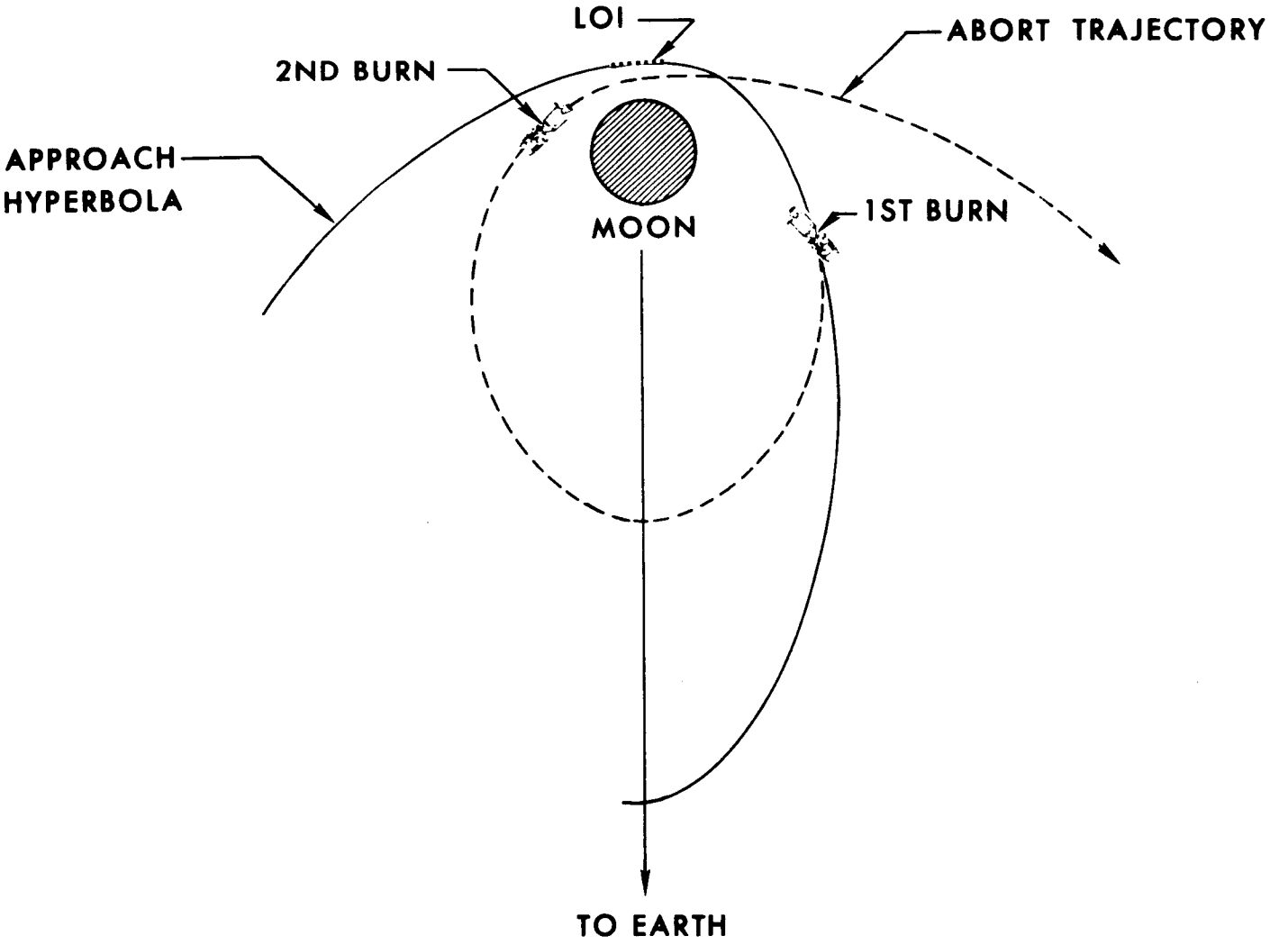
- JULY/1969 OBJECTIVES TRANSMITTED 2/17/69
  - FIRST THREE DAYS - FREE RETURN
  - LAST DAY - HYBRID
- AUGUST/1969 OBJECTIVES DUE 3/15/69
  - ALL FOUR DAYS - HYBRID
- SEPTEMBER/1969 OBJECTIVES DUE 4/15/69
  - FIRST TWO DAYS - FREE RETURN
  - LAST TWO DAYS - HYBRID

MPAD 3859 S

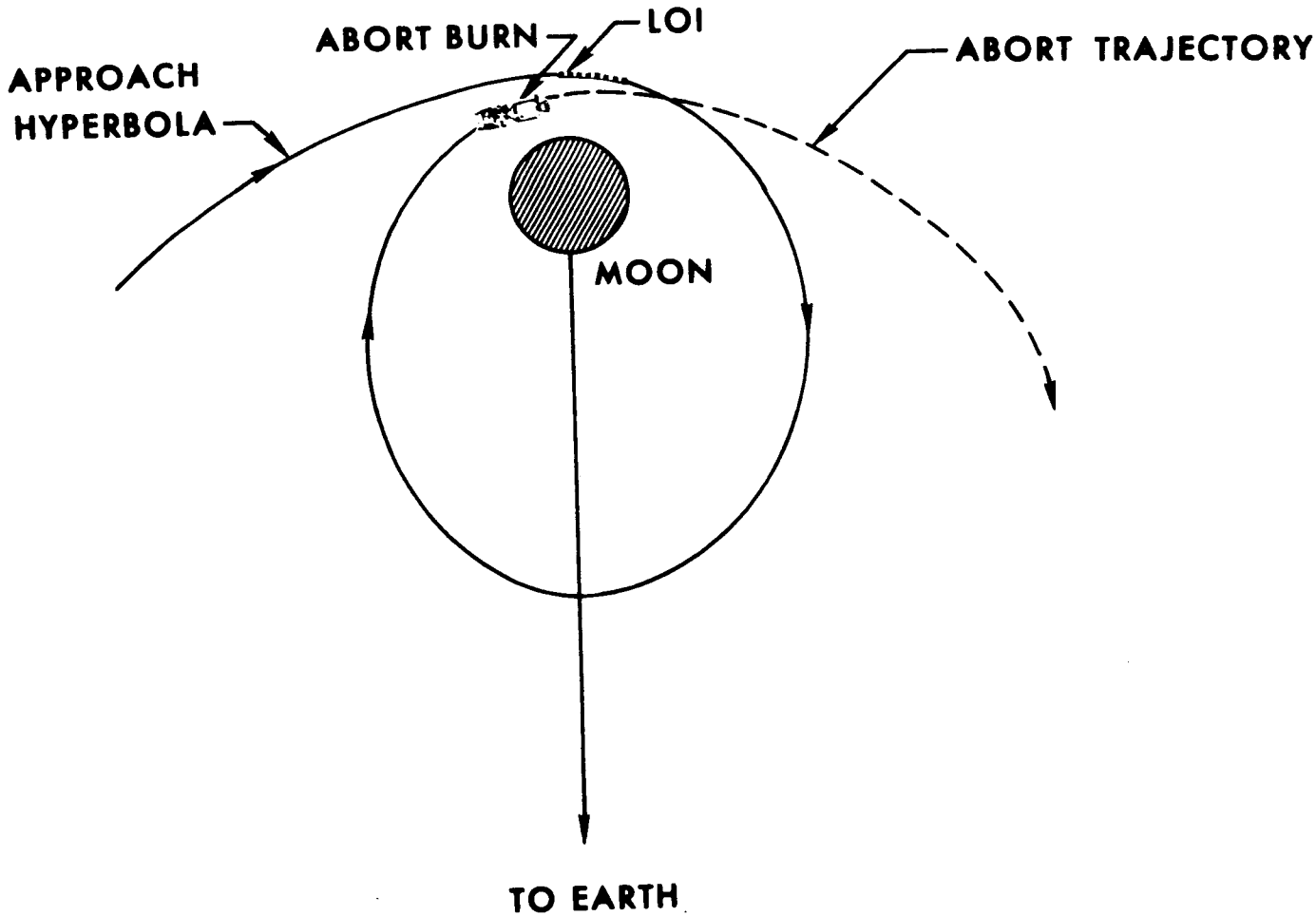
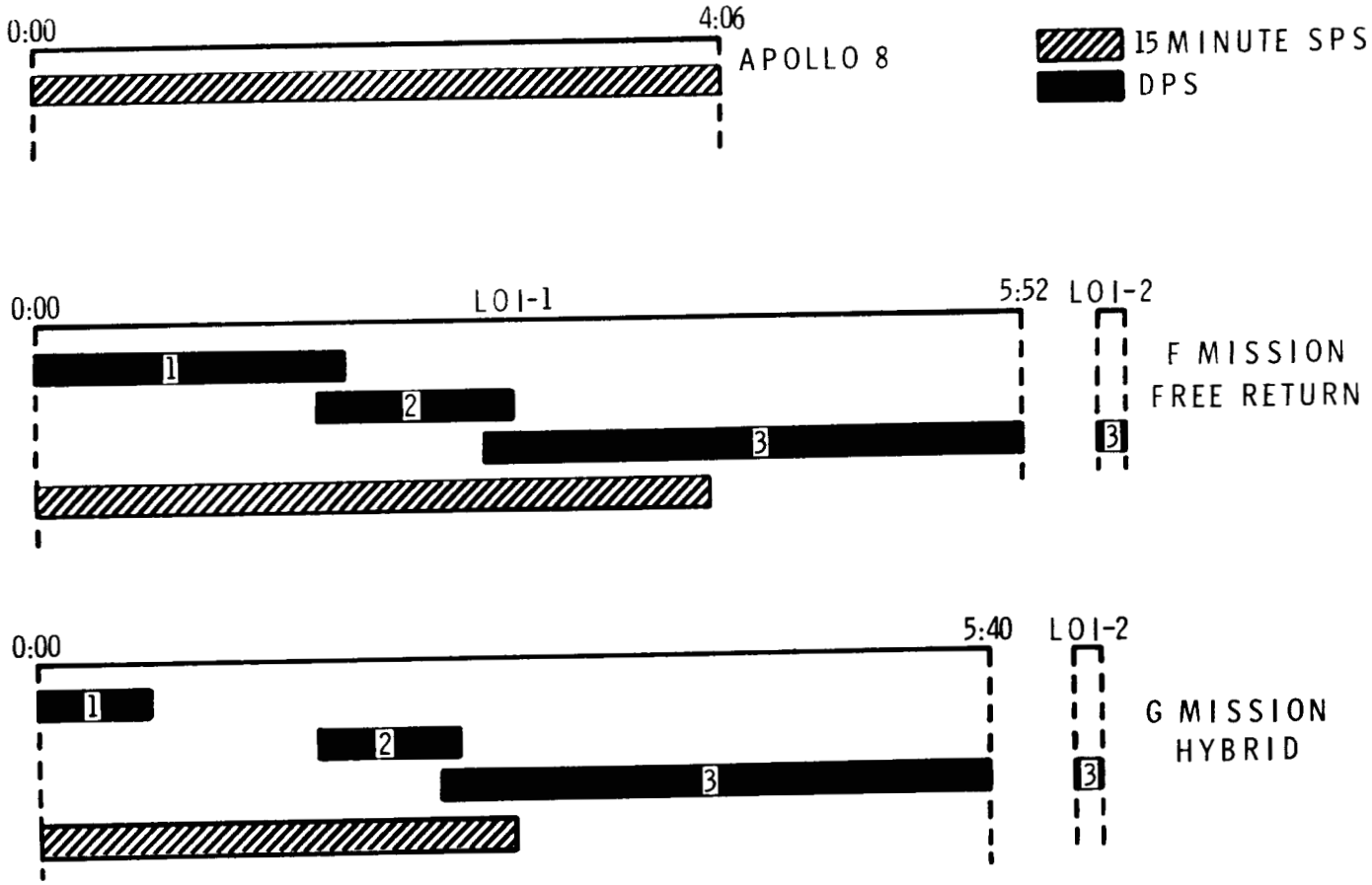
LOI MODE 1 ABORT



LOI MODE II ABORT



LOI MODE III ABORT



BACKUP ABORT CAPABILITY DURING LUNAR ORBIT INSERTION