BELLCOMM, INC.

SUBJECT: System Hold and Recycle Capability for the First Lunar Landing Mission. Case 310

DATE: December 14, 1966

FROM: R. L. Wagner

MEMORANDUM FOR FILE

I. Introduction

At the MSF Program Review of September 20, 1966, an Apollo action item was assigned to, "... conduct a comprehensive study of launch recycle capability..." A task force was formed with the following individuals acting as central point of contact for their respective organizations:

Organization	Principal	Alternate
KSC	R. E. Moser	R. Harrington
MSC	C. Perrine	
MSF	R. L. Wagner	R. V. Sperry
MSFC	L. Bell	R. Beaman

The first presentation of results occurred at the MSF Program Review of November 22, 1966. This memorandum is a record of the principal findings, conclusions, and action items.

Prints of the viewgraphs used are attached.

II. Scope of the Task Force Effort

The Apollo system will have to function with launch opportunities and launch windows that are rigidly governed by laws of physics and will have to accommodate changes in the details of the mission plan for each successive launch attempt. It is thus important to identify the response characteristics of the Apollo lunar landing system as a whole and to bring the response time of the system and the planned pattern of mission opportunities into balance.

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This effort is concerned with:

1. Identifying the "recycle" functions and requirements of the Apollo system in the perspective of the total program and emphasizing the critical items.

2. Encouraging maximum specific definition of the "family" of lunar landing missions.

3. Propagating the results of 1 and 2 above so that the various elements of the Apollo program, including supporting activities, have adequately defined requirements and can appreciate their requirements in the context of the functions of the entire system.

III. Presentation Material

The presentation outline is shown on Viewgraph 1. The four sections are described below and the viewgraphs associated with each section are identified.

1. Pattern of Apollo Mission Opportunities.

   This section included a review of the constraining elements that determine the pattern of launch opportunities for the lunar landing mission (Viewgraph 2) and the rationale behind the selection of lunar landing sites for that mission (Viewgraphs 3 through 7). As an illustrative example, the gross characteristics of the sequence of missions during 1968 were identified (Viewgraphs 8 - 17) for a typical set of five lunar landing sites selected from the areas photographed by Orbiters I and II.

2. Mission Preparations Prior to Initial Launch Opportunity.

   This section included a description of the major activities leading to the first of a series of launch opportunities such as that indicated schematically in Viewgraph 18. These activities were divided into areas of, (1) Space Vehicle Hardware, (2) Space Vehicle Software, (3) Crew and Onboard Data, and (4) Ground Systems

[redacted]

(Viewgraph 19). Of particular importance in the description of the mission preparations (Viewgraphs 20 - 23) was the identification of when mission sensitive data are required in each of the four areas.

3. Apollo Systems Capability to:

   (a) Hold

   (b) Recycle

   (c) Reschedule

This section included a description of the capability to accommodate various kinds of launch delays. These are defined in the schematic diagram of Viewgraph 18. The capability to; a) hold for a launch occurring within four hours of the beginning of the launch window; b) recycle for a launch occurring a few days later; or c) reschedule for a launch one or more months later was reviewed (Viewgraphs 24 through 29). Viewgraph 30 contains a summary of system requirements and capabilities and shows the current understanding of the need for mission data and the ability to hold, recycle, or reschedule.

4. Summary

The presentation summary identified Program Requirements for the First Lunar Landing Mission (Viewgraph 31) and Continuing Program Effort to Meet the Needs of the First Lunar Landing Mission (Viewgraph 32). These are discussed in Sections IV and V respectively.

IV. Program Requirements

To give additional definition to the plans for the first lunar landing mission and to act as a unifying focus for related program activities the following four items have been identified. These are taken directly from Viewgraph 31 with brief explanations added.

Plan for Launch Opportunities on Only Three Days Per Month

Much of the mission sensitive data such as guidance constants and certain flight control data are to be pre-computed and stored. Each additional launch opportunity

thus represents an added workload in terms of mission preparations. Restricting the planning to launch opportunities on three days per month represents current judgment of a reasonable balance between convenience and cost.

The three launch opportunities lie within an eight-day period which is determined by the lighting constraint at LM landing and lunar landing site longitudes constrained to lie between ±45°. Assuming difficulties which elimiated the first planned day, two specific opportunities would remain. If additional opportunities were provided within the eight-day period, there would be a more finely graduated set from which to choose the next planned launch day. However, the space vehicle currently requires at least two days for a full recycle. It thus might be expected that three or at most four launch attempts could actually occur regardless of how many opportunities were available.

Plan for a Minimum of 44 Hours Between Launch Opportunities.

With the 7° to 20° LM lighting constraint and the ±45° bounds on lunar landing site longitude, the maximum spacings between three successive launch opportunities are limited to about three days. This assumes a favorable lunar surface and no other constraining conditions. It is thus marginally possible that three launch opportunities per month could be supported with a 68-hour recycle capability (The time between the end of one launch window and the beginning of the launch window on the third following day is 68 hours at a minimum). However, a 44-hour recycle capability provides margin to allow for some series repair time and imposes a more reasonable requirement on the pattern of lunar landing sites, i.e., there are larger regions within which to look for acceptable landing sites.

It is not yet certain that a 44-hour recycle can be a practical reality, however, preliminary work indicates it is possible.

Plan for Only Pacific Injections.

Using free return trajectories and a single, equatorial lunar landing site, the choice of Atlantic vs. Pacific launch window has historically been reserved to favor service module fuel requirements. With current lighting constraints on the LM landing, the Pacific launch window has a much higher

incidence of daylight earth launches than does the Atlantic window. By having a selection between landing sites near the lunar equator but slightly dispersed in latitude, the Pacific window can be used while maintaining acceptable service module fuel costs. Assuming a favorable moon such that the necessary landing sites can be found, there is no known disadvantage associated with the Pacific window.

The use of a single type of window for the first mission may have additional fringe advantages such as reducing the required mobility of ground support forces.

Plan for Two-Month Lead Time for Lunch Date and Lunar Landing Site Identification.

The need to precompute a separate package of data for each potential launch opportunity bears with it an implied cost for long lead times in the data preparation cycle. This stems from the fact that the launch date is difficult to predict far in advance and data packages need to be prepared for all possible opportunities. If the lead time exceeds the spacing between successive missions (e.g., AS-503, AS-504, AS-505), there may be additional parallel planning required to cover various contingency situations.

Other implications of long lead times are, (1) long delays if the lunar landing site(s) must be changed because of late information, and (2) possible problems in managing and maintaining the quality of the masses of precomputed data.

The two-month lead time has not yet been demonstrated. To be sure of achieving it, the mission constraints and the general region from which lunar landing sites are chosen should be identified early and remain fixed for all of the possible opportunities for the first lunar mission.

V. Action Items

Viewgraph 32 shows continuing program efforts prior to the MSF Program Review on November 22, 1966. The items below include these together with several additional actions identified during the review. The action items have been arranged in categories.

Mission Definiton:

(a) Review the earth launch window constraints with emphasis on determining the limits on the length of the window.

(b) Review the LM lighting constraint including the completeness and adequacy for safe landing and the impact on the pattern of launch opportunities of potential changes.

(c) Determine which earth parking orbit should be used for the initial translunar injection opportunity.

(d) Estimate the impact on the mission of a 68-hour minimum recycle time (measured from the end of a 4-hour launch window to the beginning of the launch window on the third following day).

Hardware Recyle and Reschedule

(a) Identify hardware constraints related to achieving a 44-hour recycle time (without series repair) for scrubs just prior to ignition and determine steps necessary to assure a 44-hour recycle capability.

(b) Determine feasibility and cost of requalifying S/C fuel cells and hypergolic components to achieve third month capability.

(c) Identify the capabilities and problems associated with checkout and testing after the systems have been wetted.

(d) Determine capability and/or desirability of extending the hold time of the vehicle to embrace two successive launch windows.

Software Preparations and Recycle

(a) Determine the schedule of events for a two-month response capability measured from the time the lunar landing sites are identified to the day of launch.

(b) Provide a "typical" mission data package for use prior to T-one month.

(c) Determine the computer work load associated with mission preparation work.

(d) Define on-board data that are mission sensitive or related to the particular lunar landing site used.

(e) Refine the requirements and sequence of events for map preparation and landmark identification.

R. L. Wagner

201-RLW-rms R. L. Wagner

Attached
Viewgraphs 1 - 32

Copy to
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E. E. Christensen - NASA/MO
L. E. Day - NASA/MAT
J. K. Holcomb - NASA/MAO
R. O. Middleton - NASA/MO-3
S. C. Phillips - NASA/MA
L. Reiffel - NASA/MA
M. L. Seccomb - NASA/MAP
J. H. Turnock - NASA/MA
G. C. White - NASA/MAR

A. G. Griffin - KSC/HC
R. D. Harrington - KSC/HC
R. E. Moser - KSC/HC (10)
J. G. Shinkle - KSC/DA

(Continued on next page)

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H. E. Clements - MSC/FS
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J. B. Hammack - MSC/FL
J. D. Hodge - MSC/FC
M. V. Jenkins - MSC/FM
C. C. Kraft - MSC/FA
R. W. Lanzkron - MSC/PF
J. P. Loftus - MSC/PM5
J. P. Mayer - MSC/FM
O. E. Maynard - MSC/PM
W. J. North - MSC/CF
C. H. Perrine - MSC/PM2 (10)
R. G. Rose - MSC/FA3
J. F. Shea - MSC/PA
D. K. Slayton - MSC/CA
R. W. Williams - MSC/PD
C. H. Woodling - MSC/CF3

R. E. Beaman - MSFC/I-V-E
L. B. Bell - MSFC/I-V-E (10)
C. T. Boone, Jr. - MSFC/R-P&VE-XK
J. W. Cremin - MSFC/R-AERO-DAP
E. T. Deaton, Jr. - MSFC/R-AERO-DAP
E. D. Geissler - MSFC/R-AERO-DIR
W. Haeussermann - MSFC/R-ASTR
W. R. Lucas - MSFC/R-P&VE-DIR
J. L. Mack - MSFC/R-ASTR-S
L. L. McNair - MSFC/R-AERO-P
R. V. Richards - MSFC/R-ASTR-NDF
A. L. Rudolph - MSFC/I-V-MGR
L. Sinko - MSFC/R-P&VE-VOR
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OUTLINE

I PATTERN OF APOLLO MISSION OPPORTUNITIES

II MISSION PREPARATIONS PRIOR TO INITIAL LAUNCH OPPORTUNITY

III APOLLO SYSTEMS CAPABILITY TO:

1. HOLD
2. RECYCLE
3. RESCHEDULE

IV SUMMARY

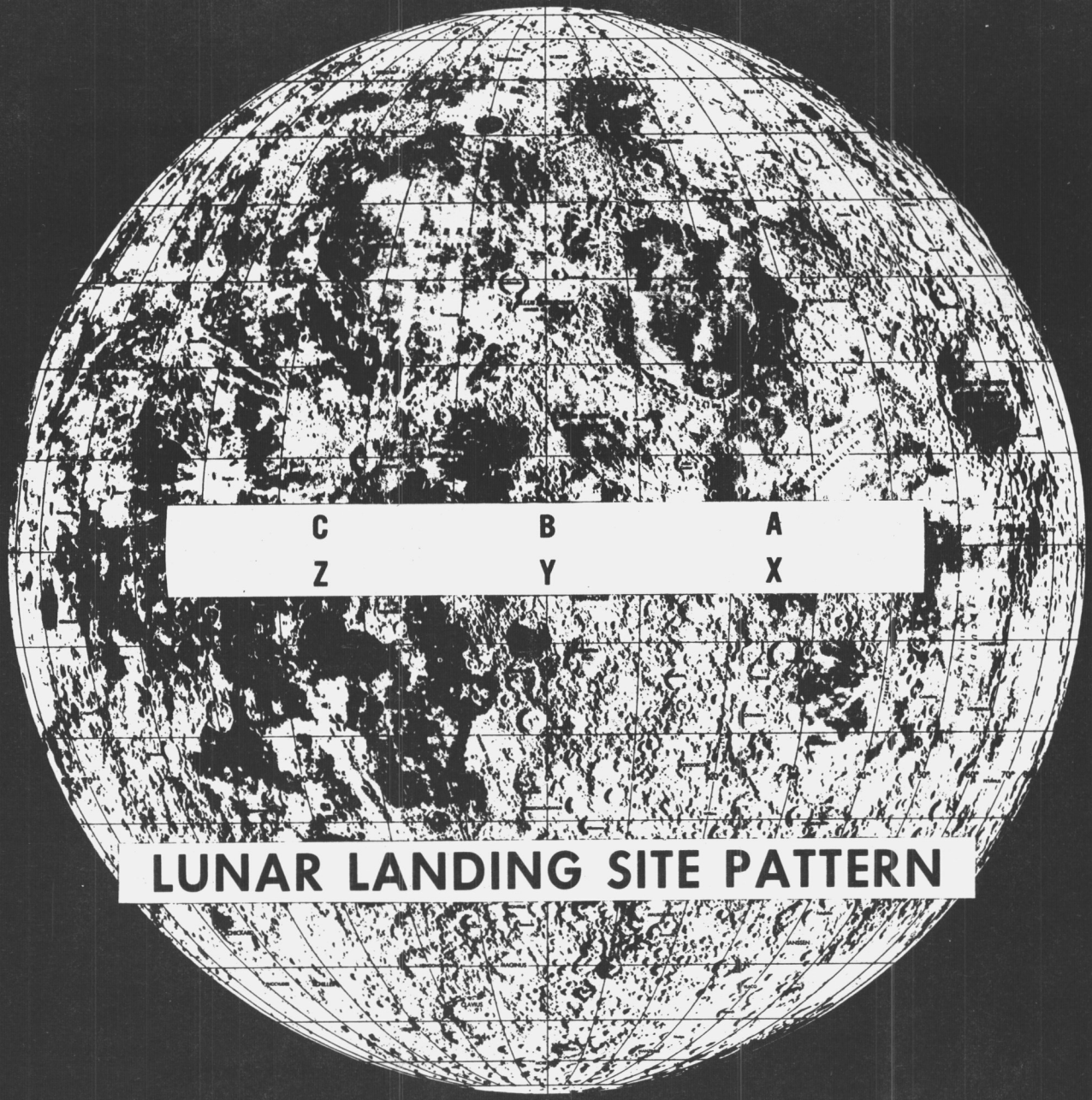
PLANNING OF THE FIRST LUNAR LANDING MISSION

CONSTRAINTS:

- HARDWARE AVAILABILITY (SYSTEM READINESS)
- PERFORMANCE LIMITS (FUEL)
- LIGHTING AT LM LANDING
- SET OF CERTIFIED LUNAR LANDING SITES

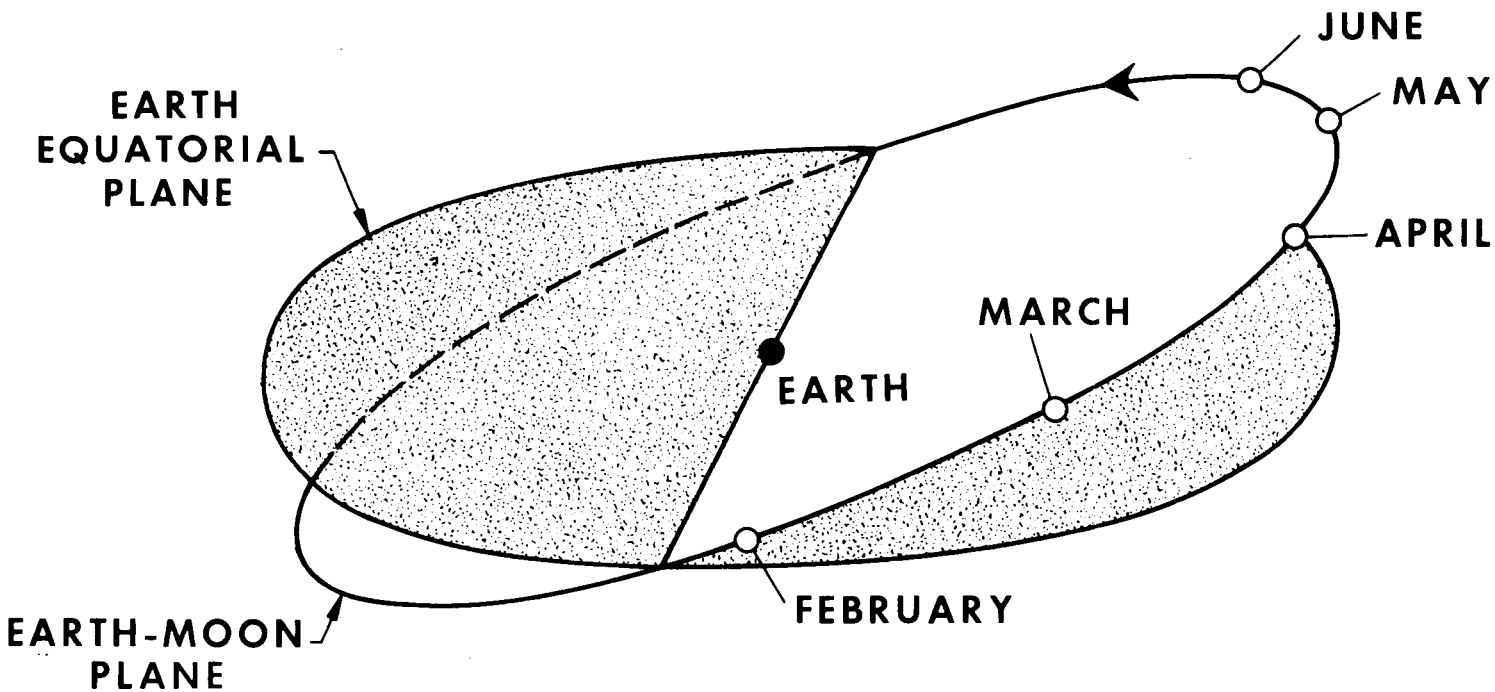
PREFERENCES:

- FREQUENCY OF LAUNCH OPPORTUNITIES
- PERFORMANCE MARGINS
- LIGHTING AT EARTH LAUNCH

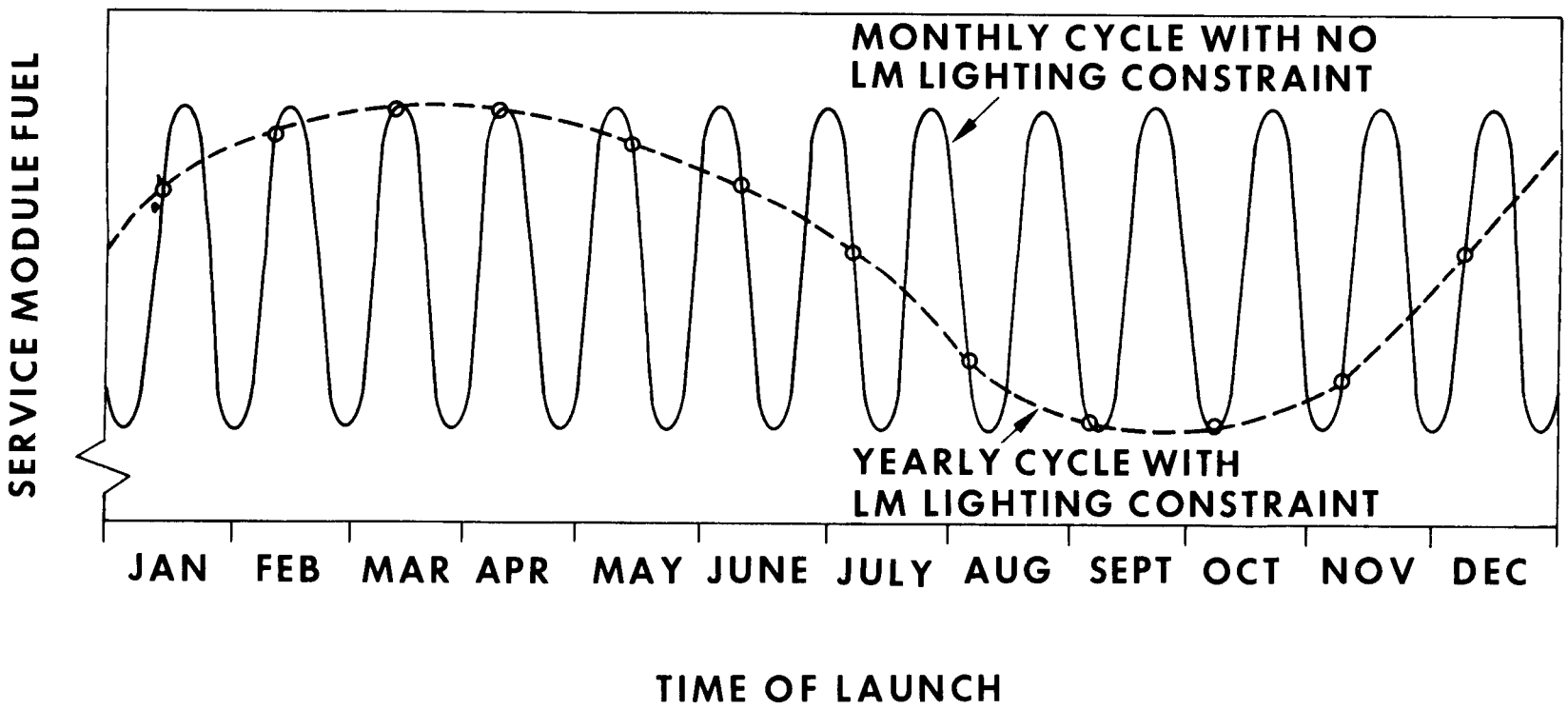


LUNAR LANDING SITE PATTERN

SAMPLING EFFECT OF LUNAR LIGHTING CONSTRAINT (7-20°) DURING 1968

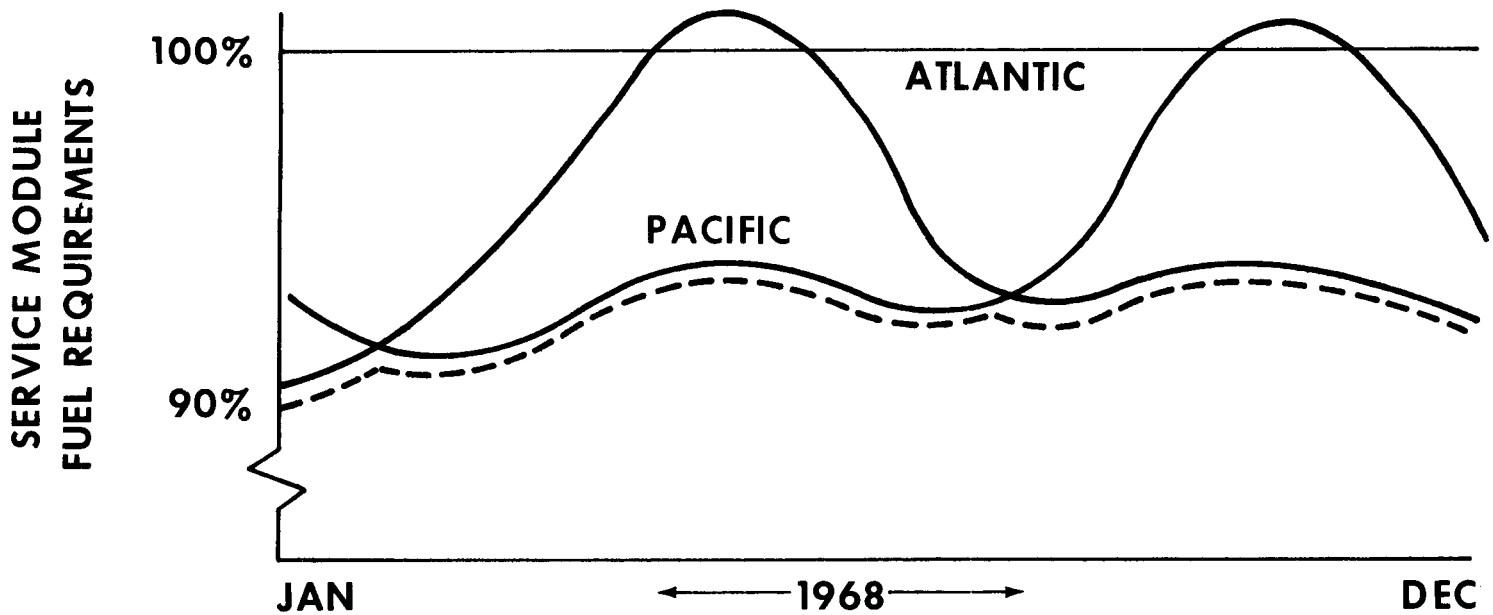


MONTHLY AND YEARLY SERVICE MODULE FUEL CYCLES

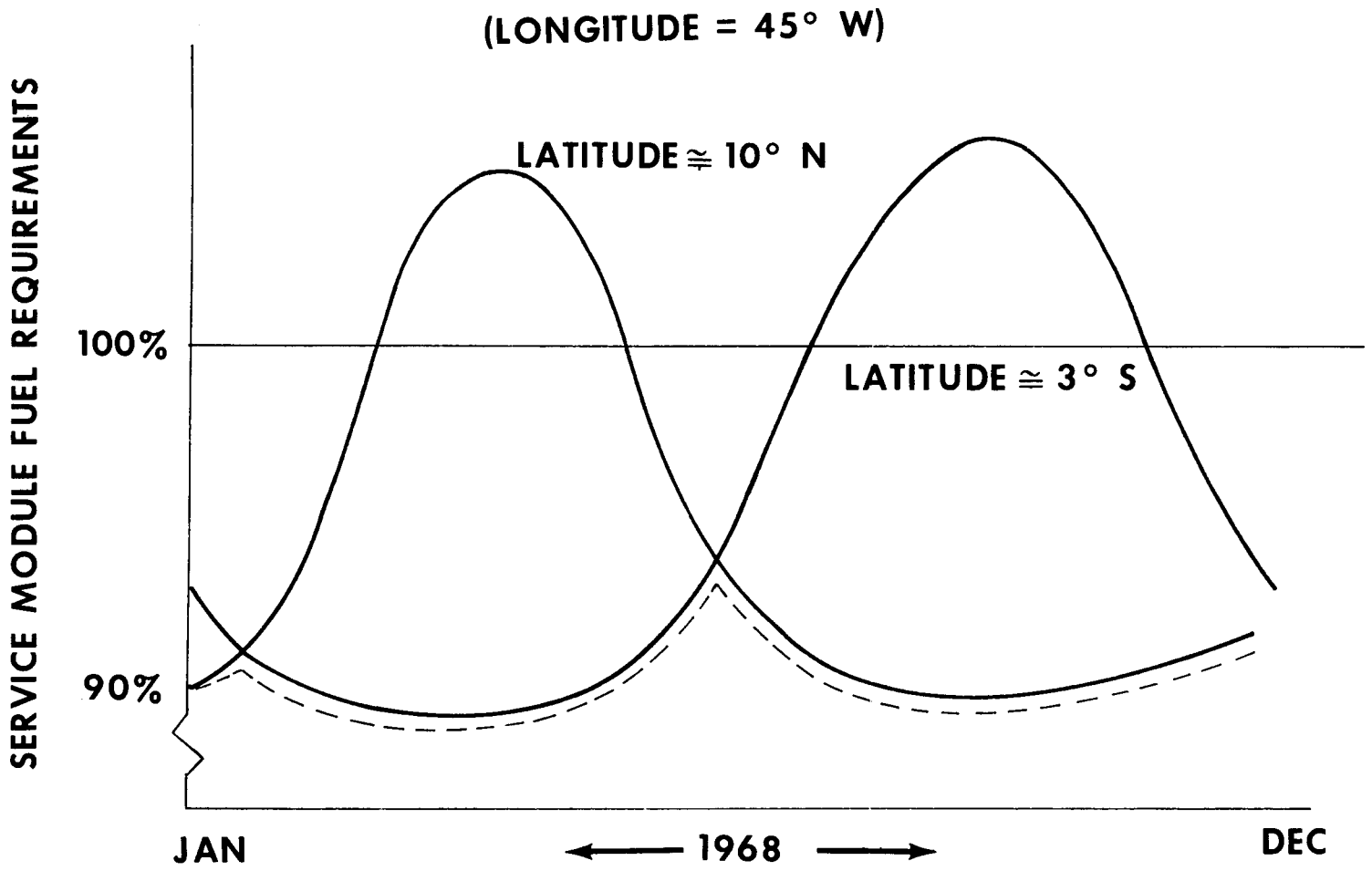


TYPICAL FUEL/TIME CURVES FOR LUNAR EQUATORIAL SITE

LOWEST AVERAGE FUEL REQUIREMENTS IF BOTH
ATLANTIC AND PACIFIC WINDOWS ARE UTILIZED
(LONGITUDE = 45° W)



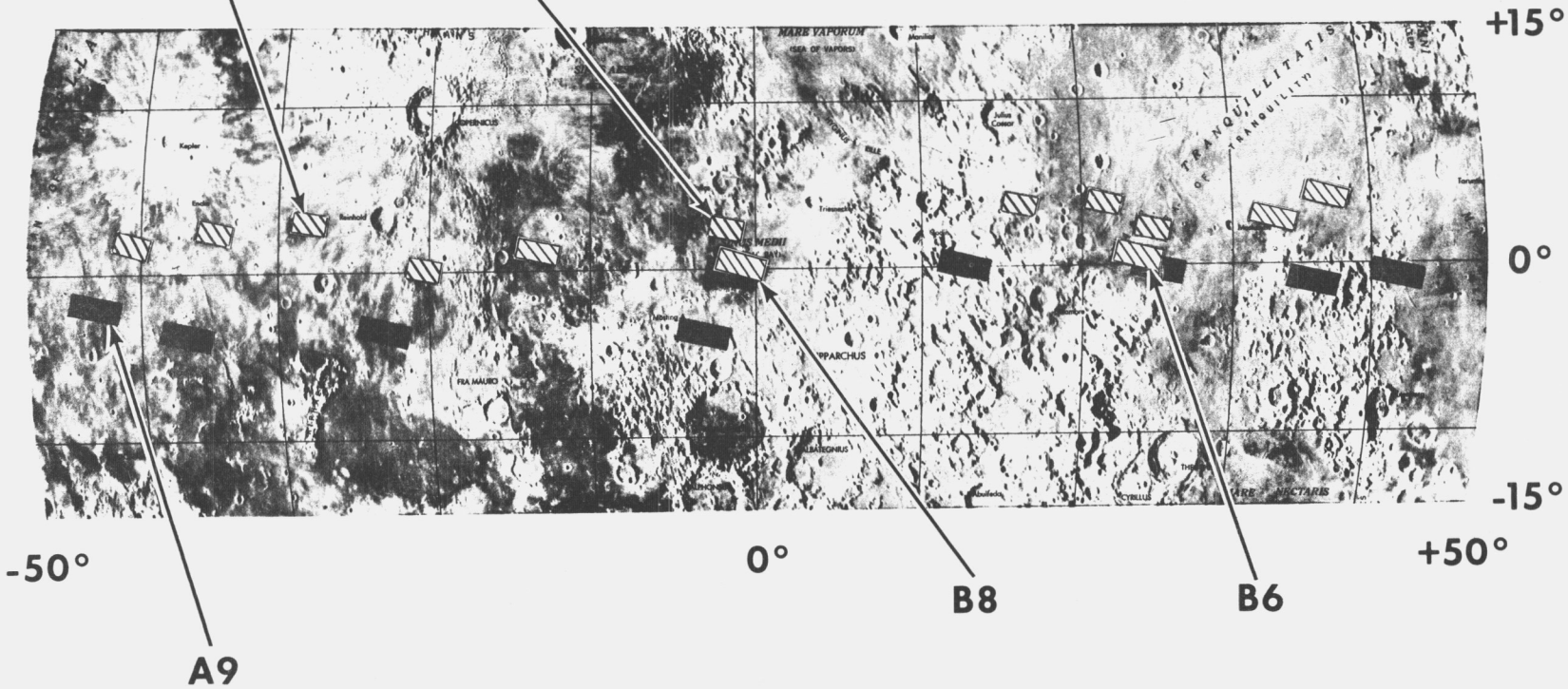
TYPICAL FUEL/TIME CURVES FOR PACIFIC WINDOW WHEN LANDING SITE CAN BE MOVED LATITUDINALLY TO MINIMIZE FUEL



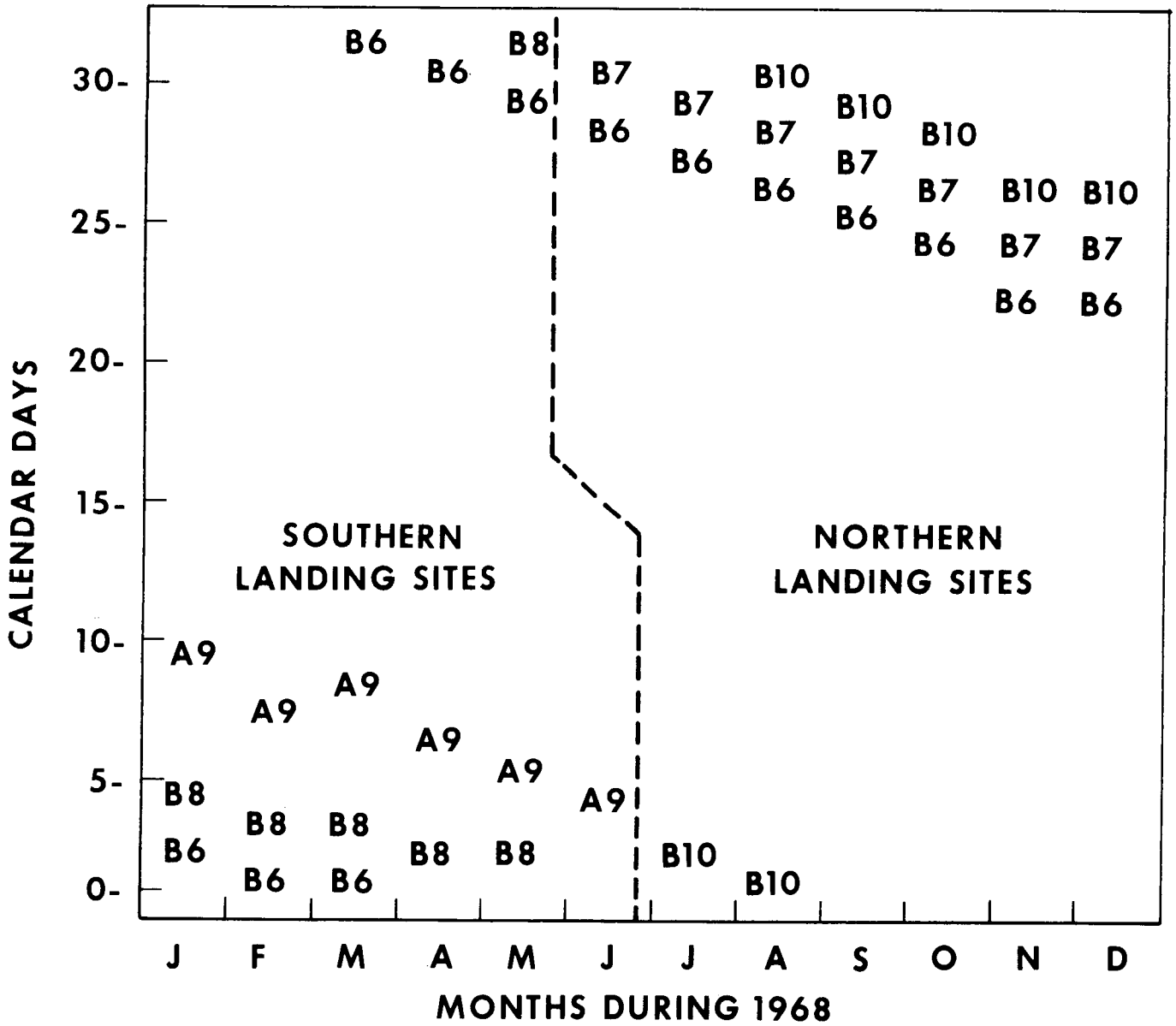
ORBITER SITES

'I' SITES

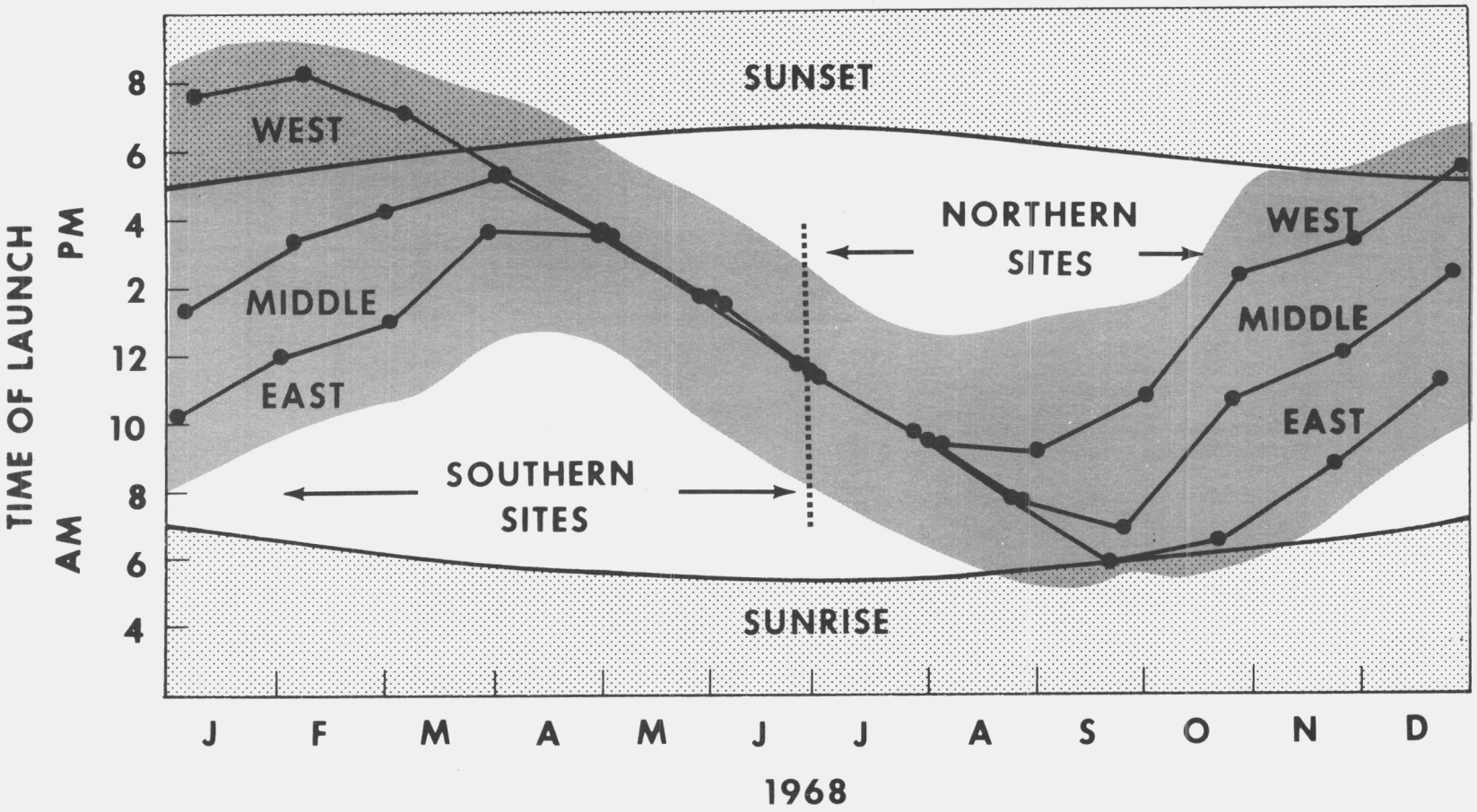
'B' SITES (PROPOSED AND APPROVED 9/29/66)



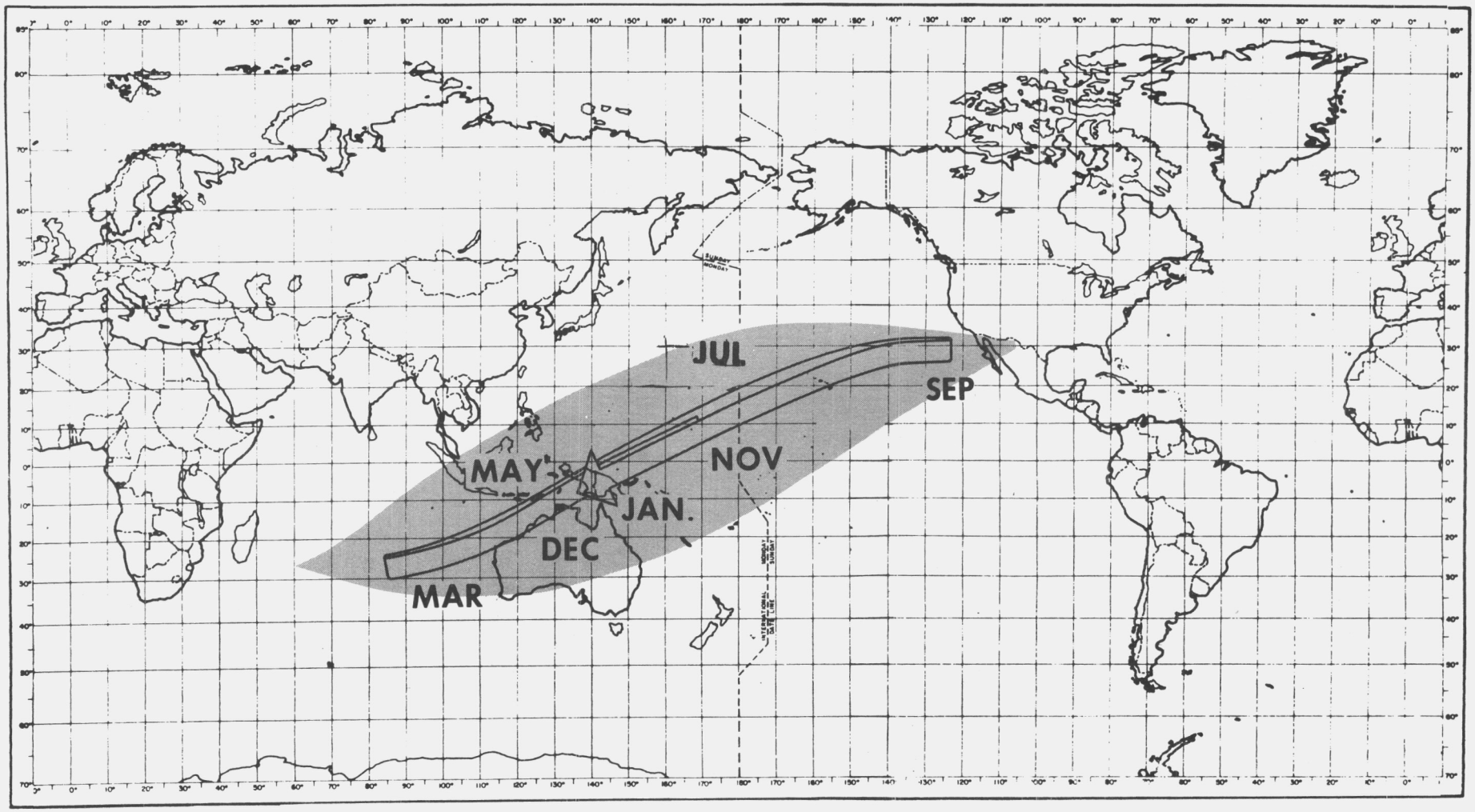
LUNAR LANDING MISSION LAUNCH OPPORTUNITIES



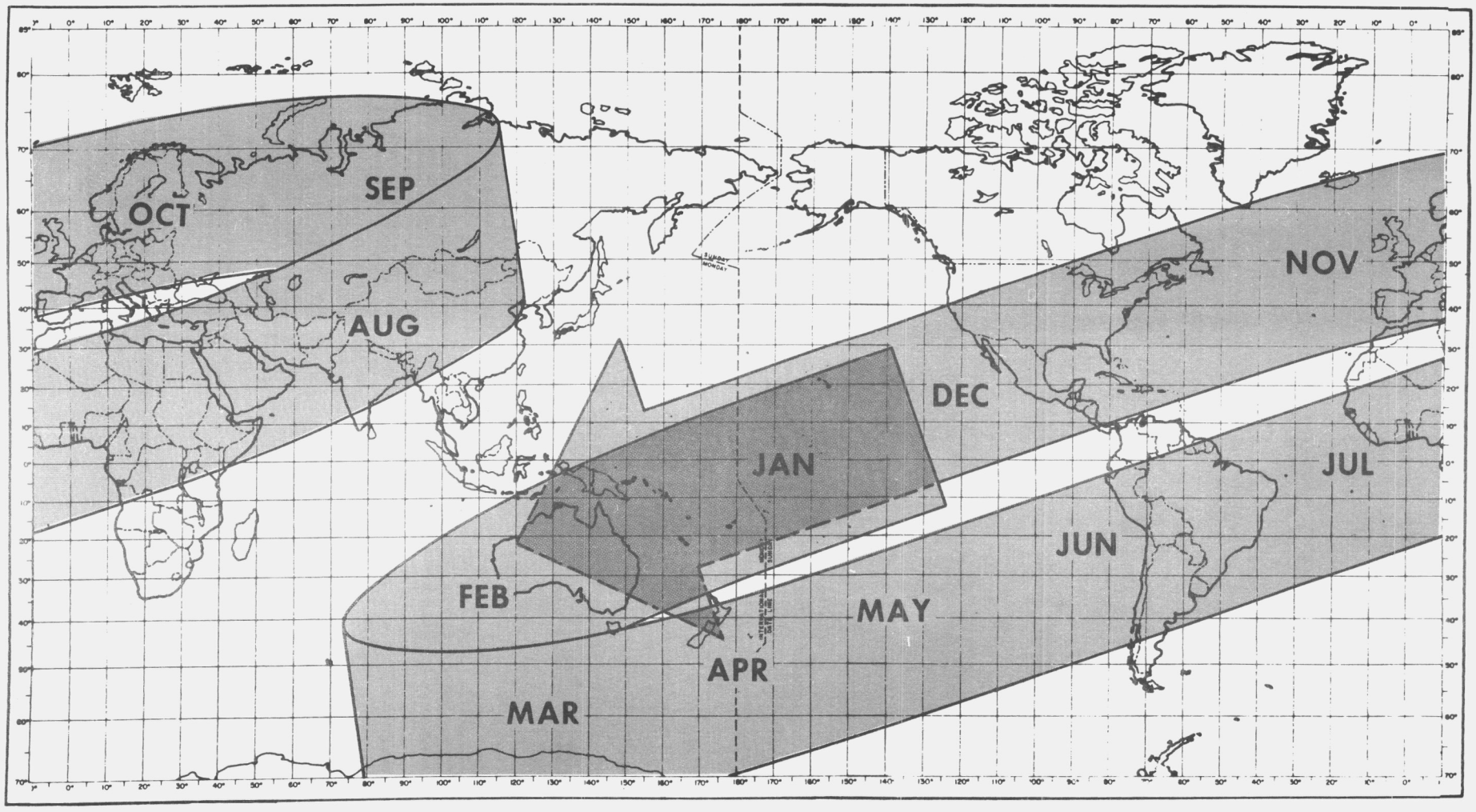
LIGHTING AT EARTH LAUNCH



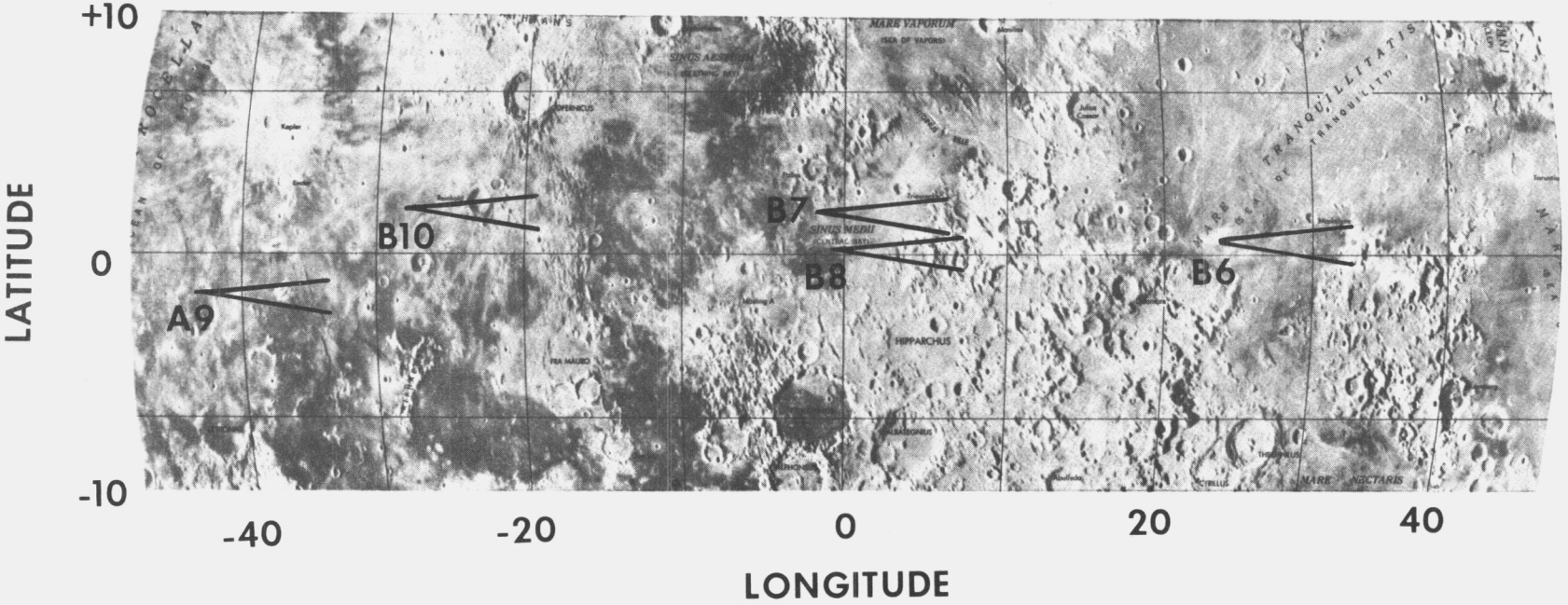
TRANSLUNAR INJECTION



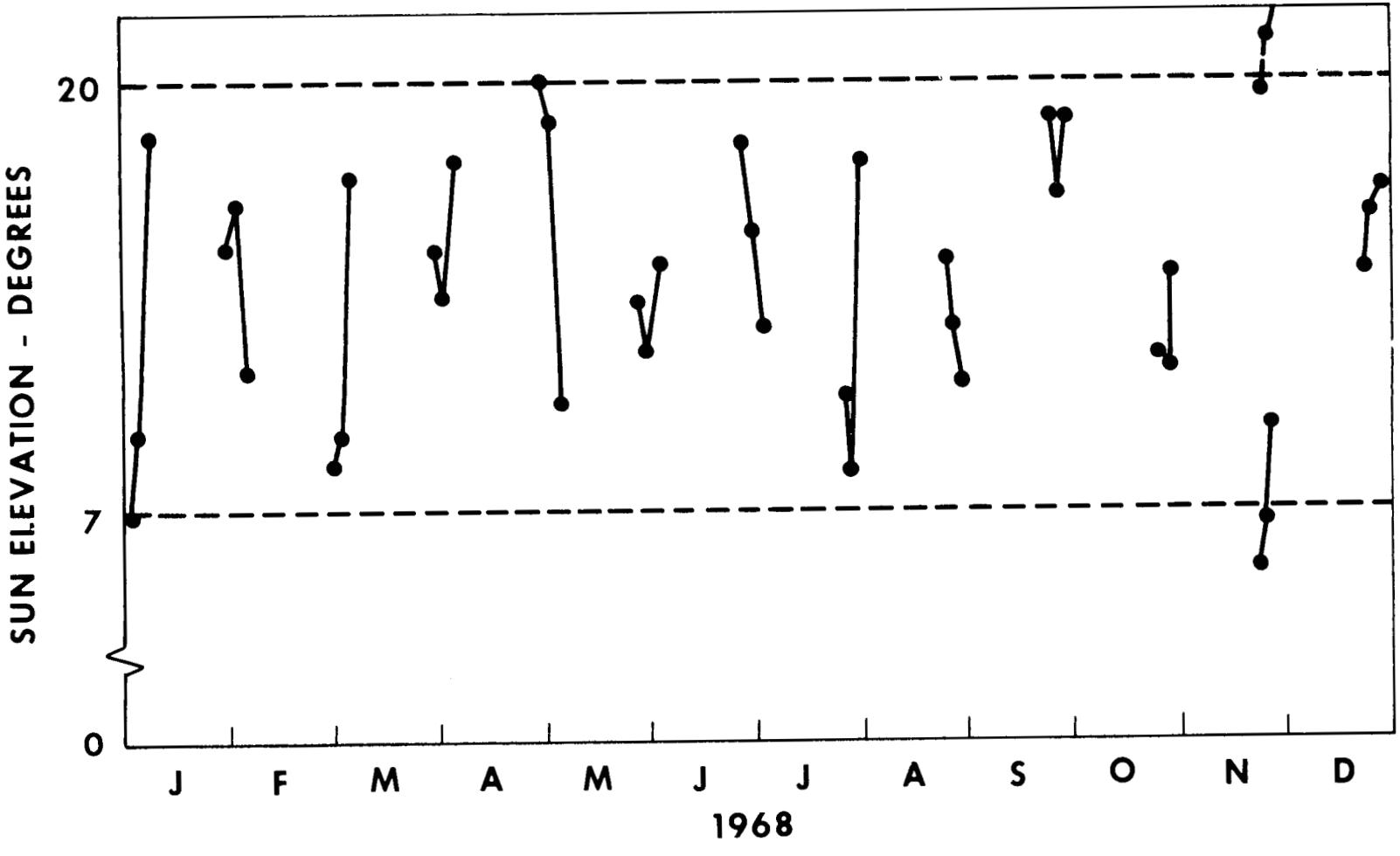
UNCORRECTED FREE RETURN LANDING



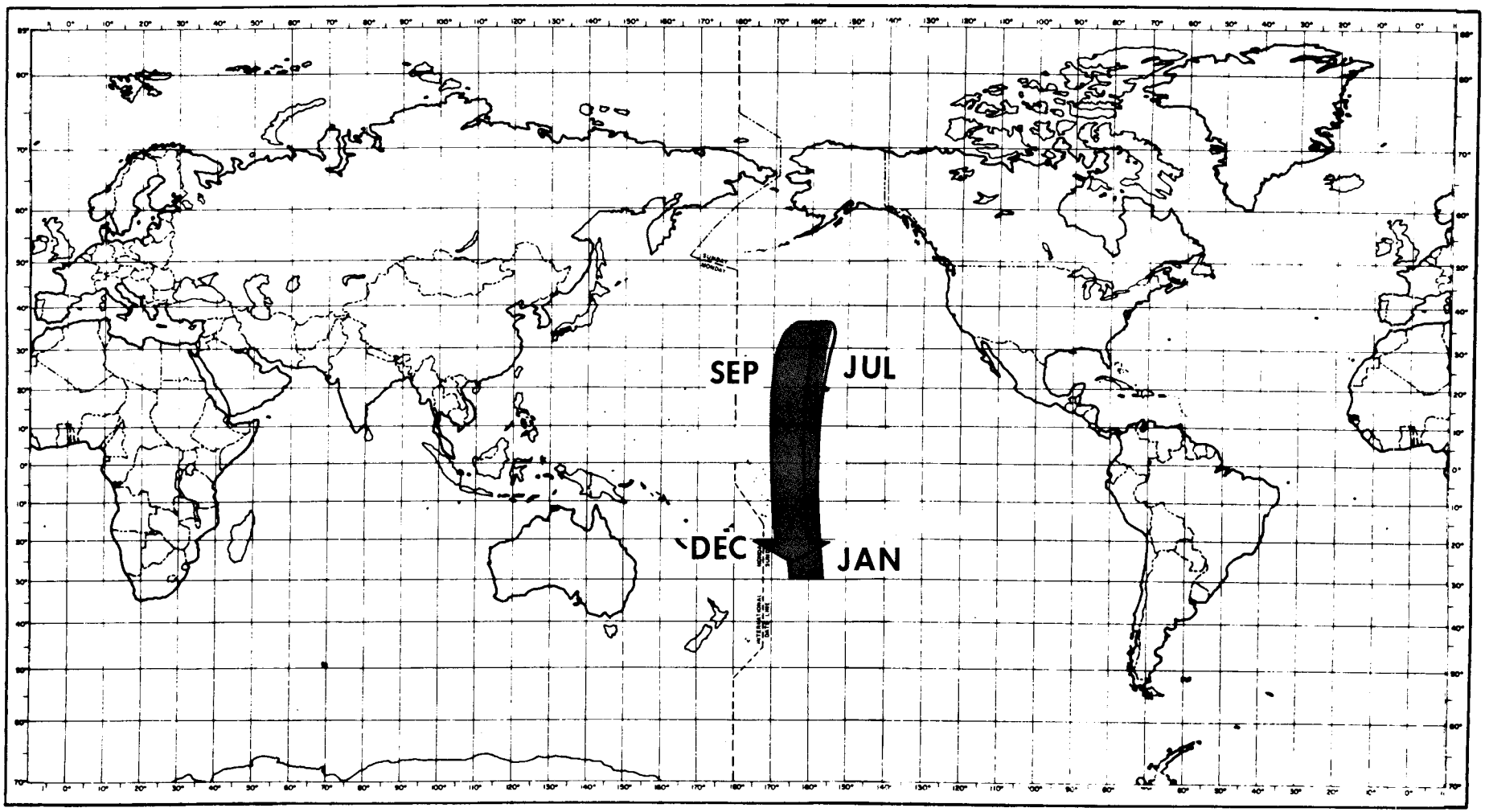
LUNAR APPROACH PATH VARIATION



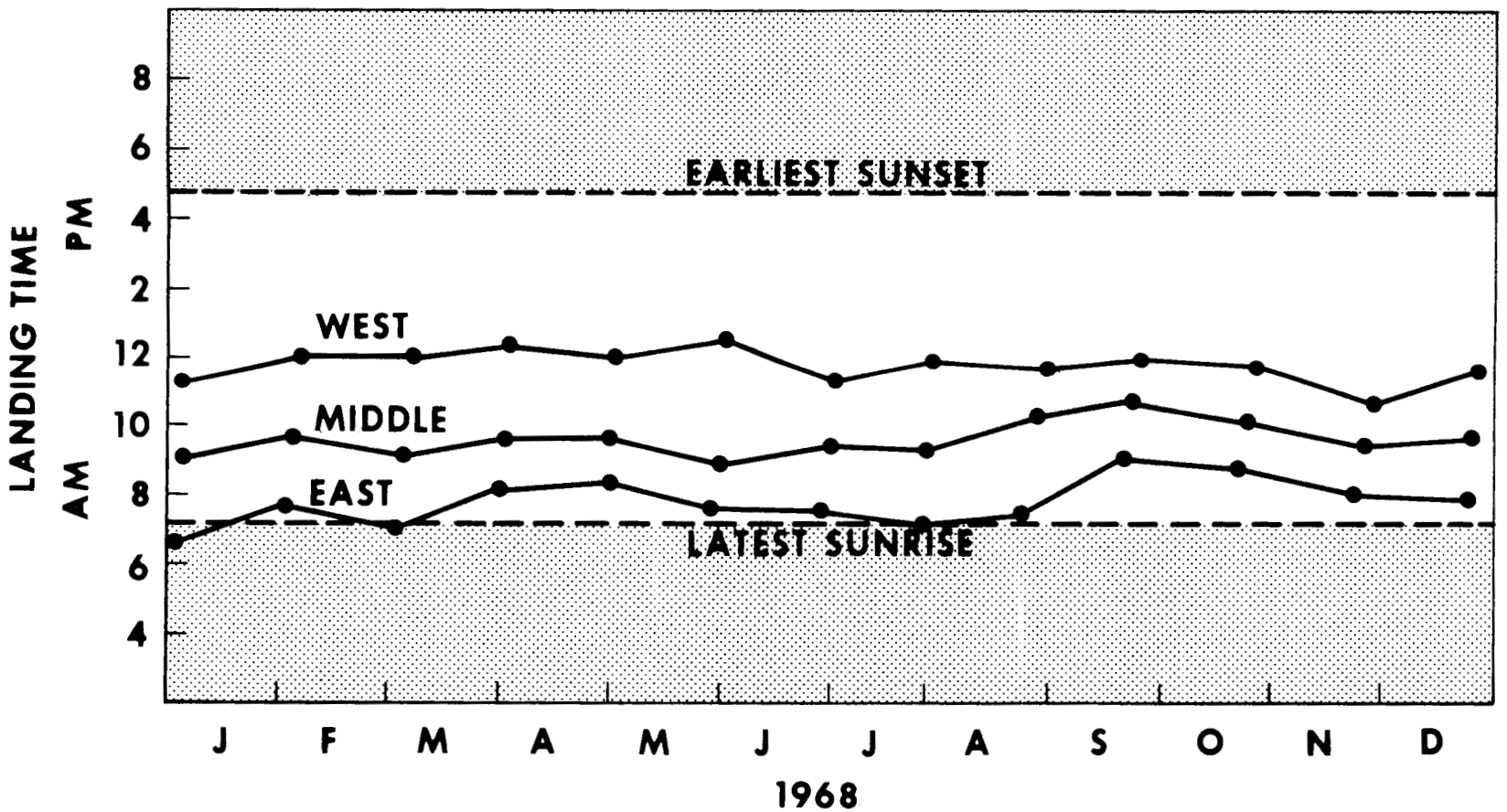
LIGHTING AT LM LANDING



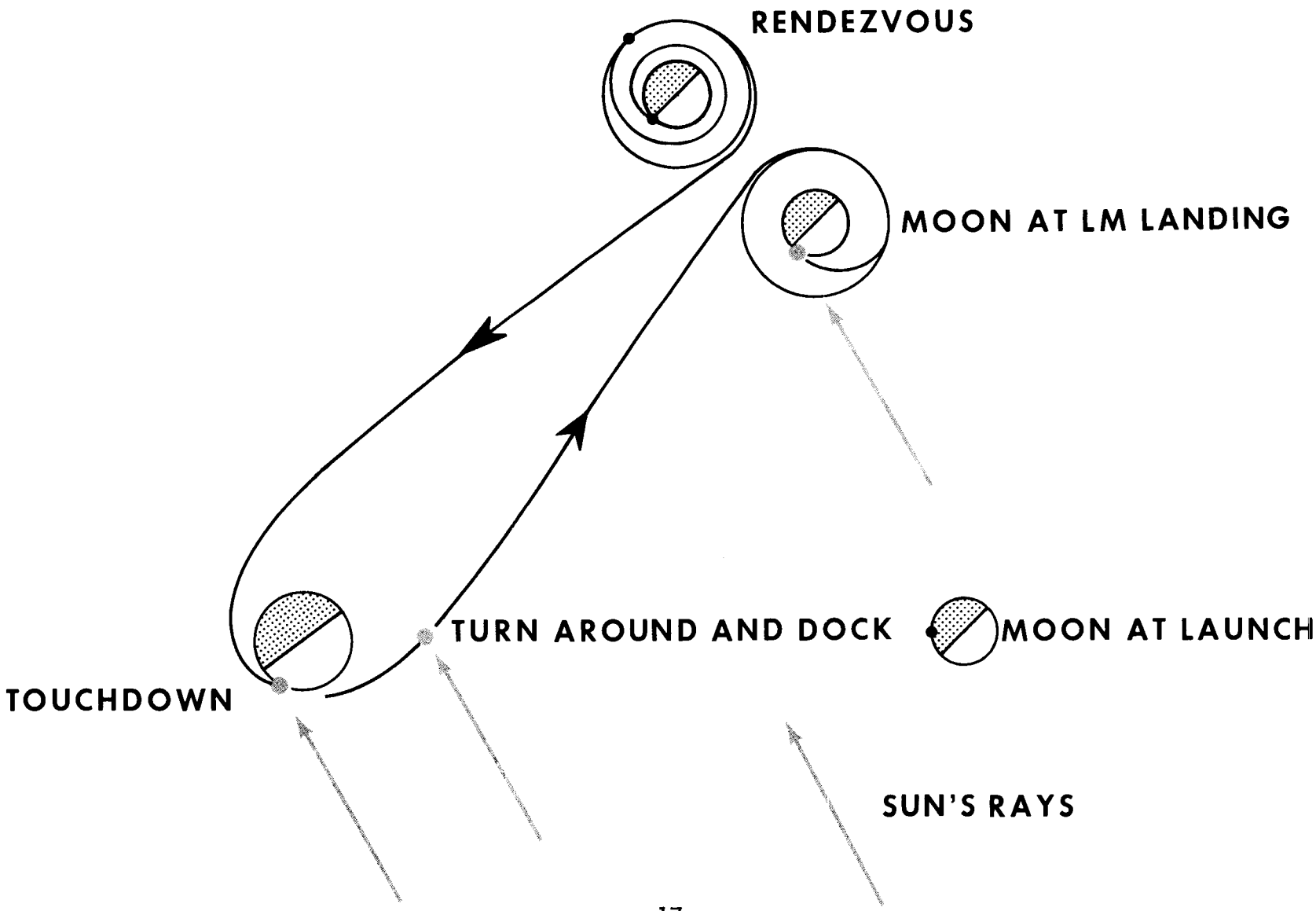
EARTH LANDING



LIGHTING AT EARTH LANDING



TYPICAL LIGHTING FOR THE LUNAR MISSION



NASA-S-66-11136 NOV 18

OUTLINE

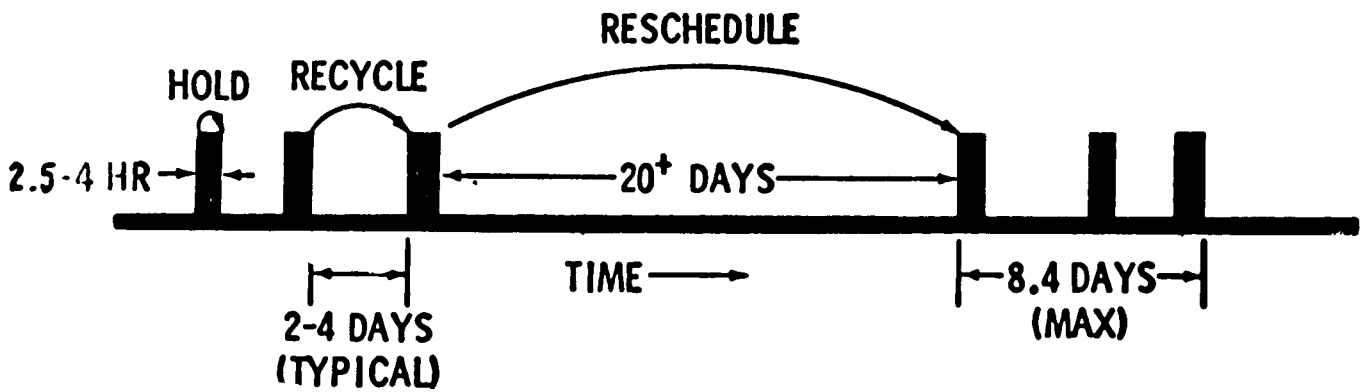
I PATTERN OF APOLLO MISSION OPPORTUNITIES

II MISSION PREPARATIONS PRIOR TO INITIAL LAUNCH OPPORTUNITY

1. SPACE VEHICLE HARDWARE
2. SPACE VEHICLE SOFTWARE
3. CREW AND ONBOARD DATA
4. GROUND SYSTEMS

III APOLLO SYSTEM'S CAPABILITY TO:

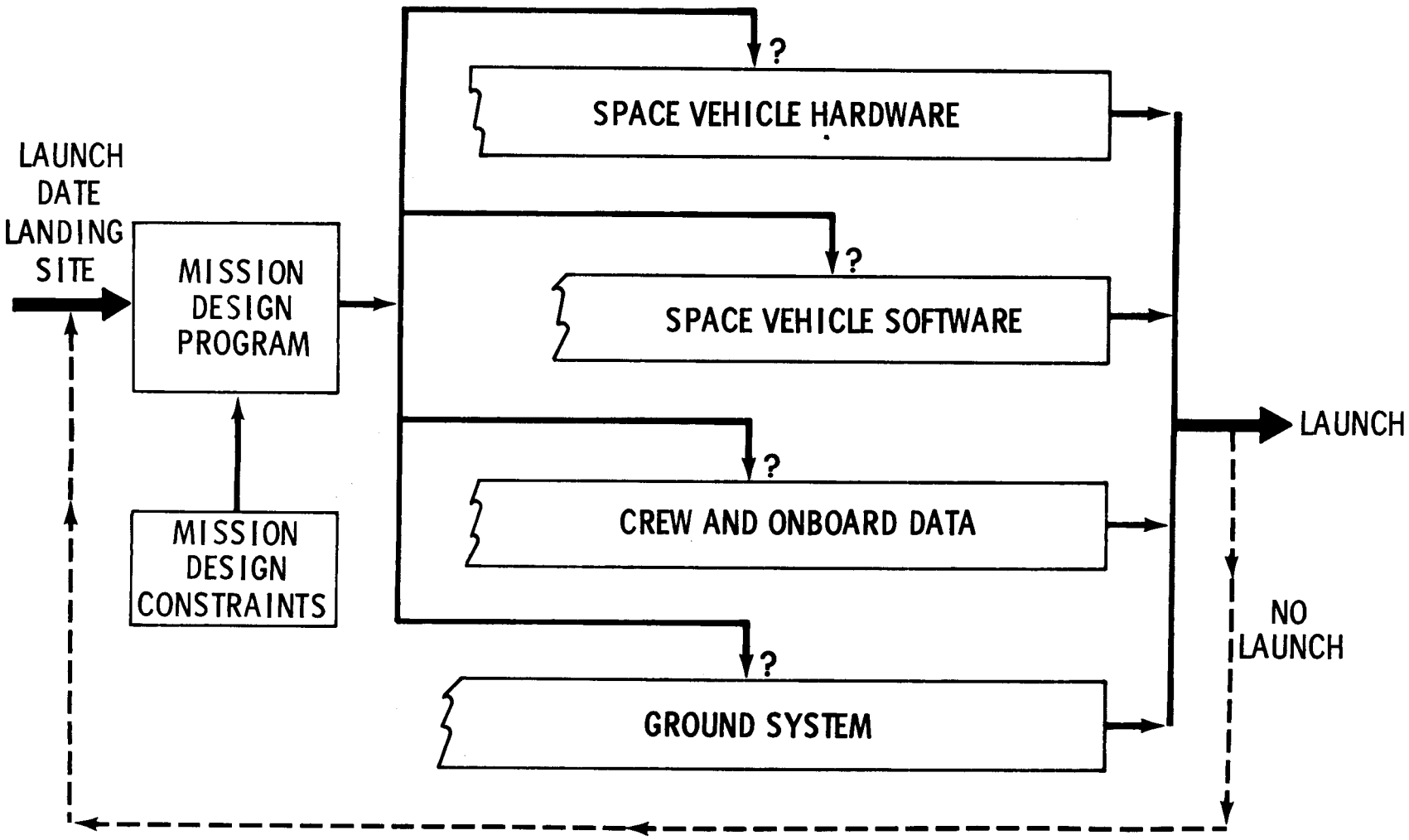
1. HOLD
2. RECYCLE
3. RESCHEDULE



IV SUMMARY

NASA-S-66-11140 NOV 18

LUNAR MISSION PREPARATION PROCESS



- WHAT ARE THE MAJOR STEPS IN THE PROCESS ?
- AT WHAT POINT IN EACH PROCESS IS MISSION DATA REQUIRED ?
- HOW FAST CAN THE PROCESS BE REPEATED ?

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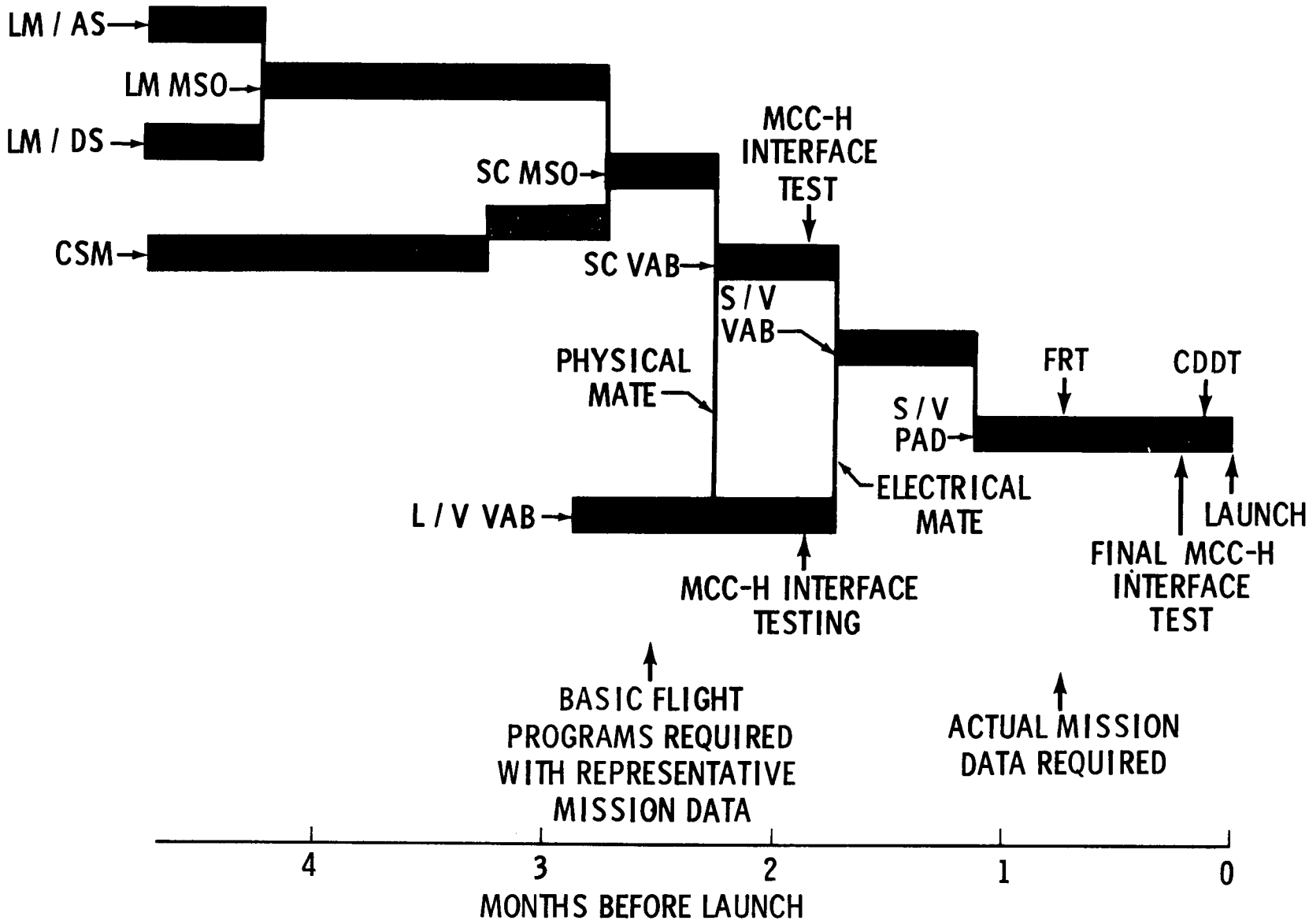
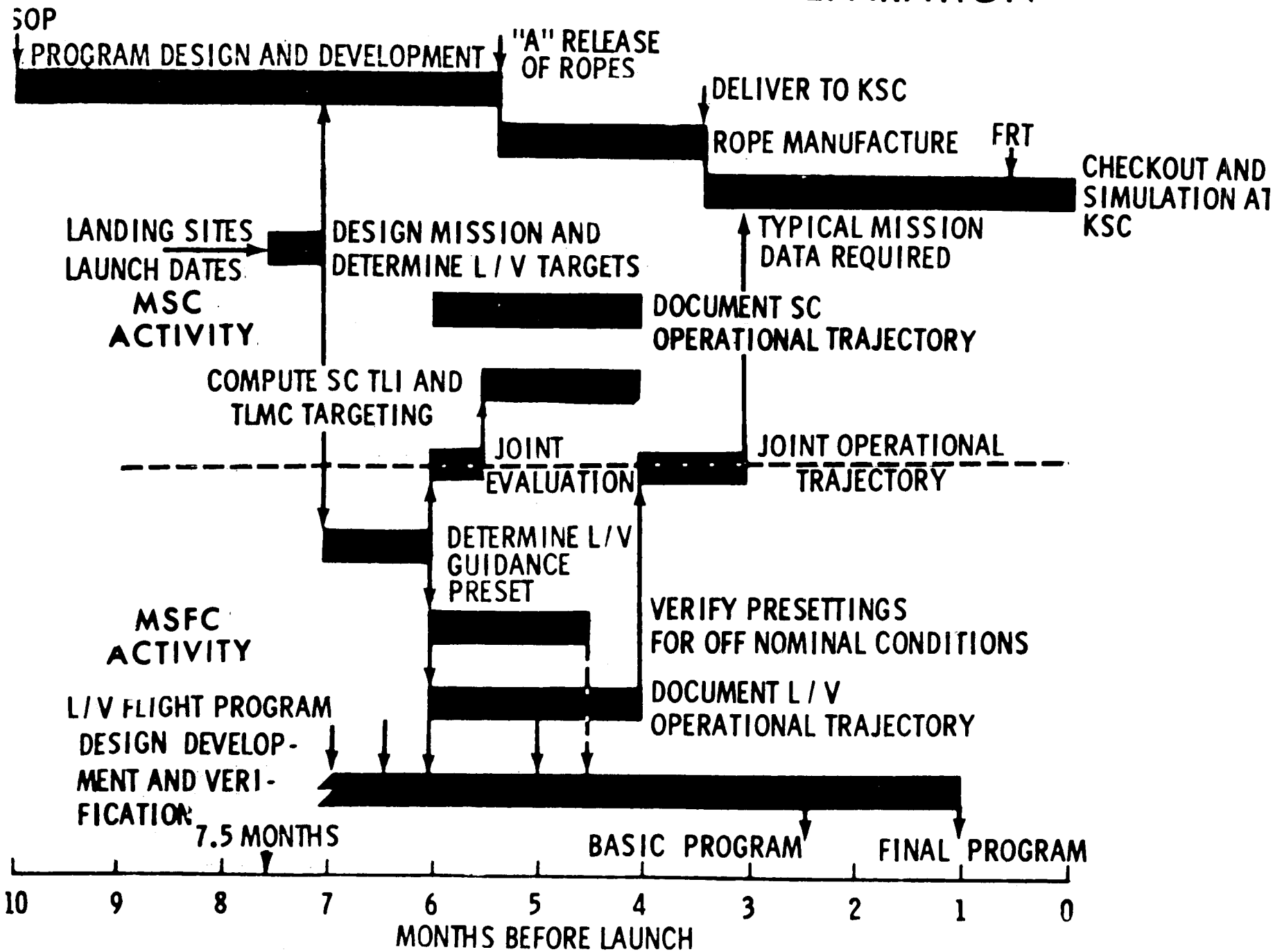
SPACE VEHICLE HARDWARE PREPARATION



SPACE VEHICLE SOFTWARE PREPARATION



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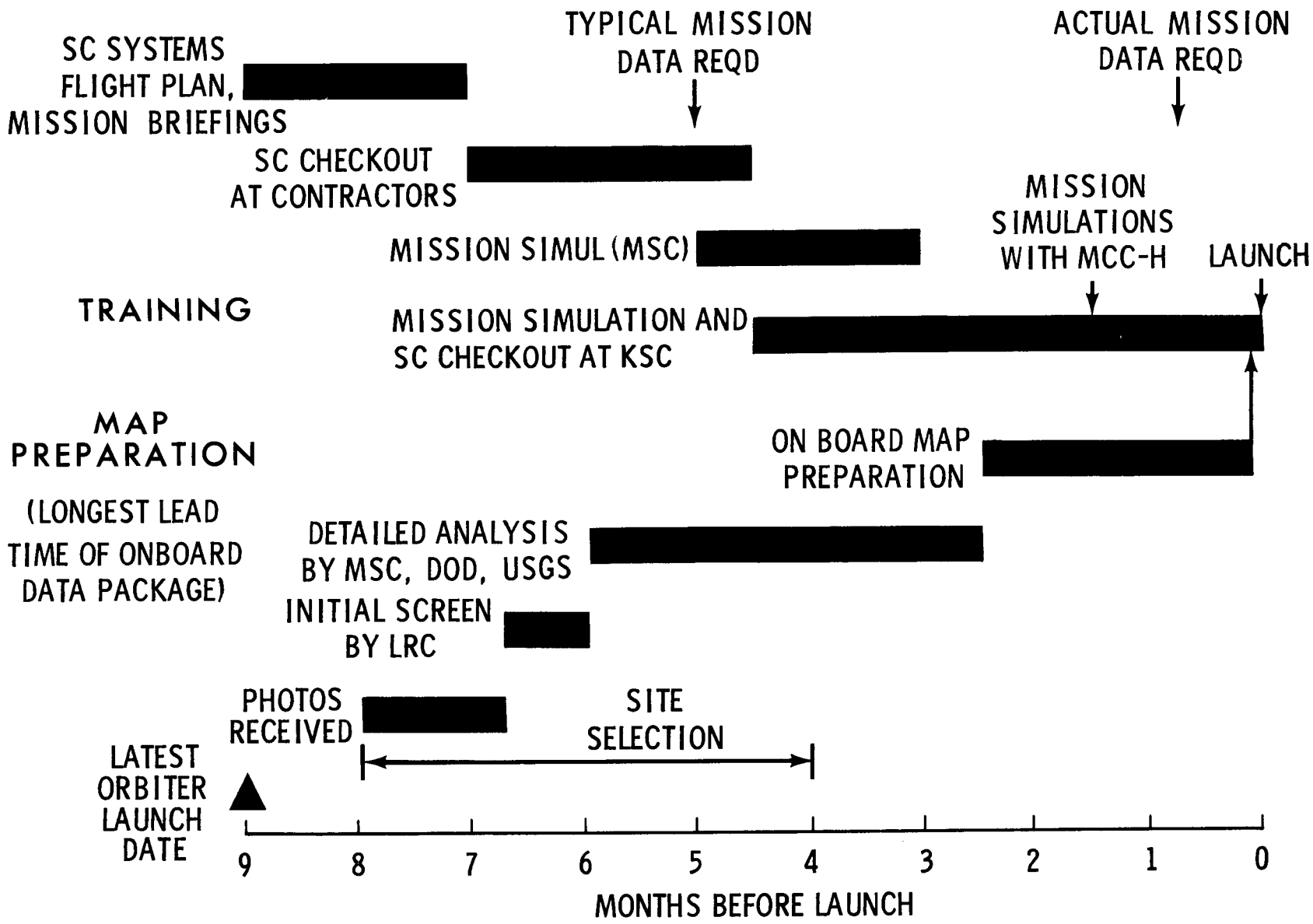
FLIGHT CREW TRAINING AND ONBOARD DATA PREPARATION



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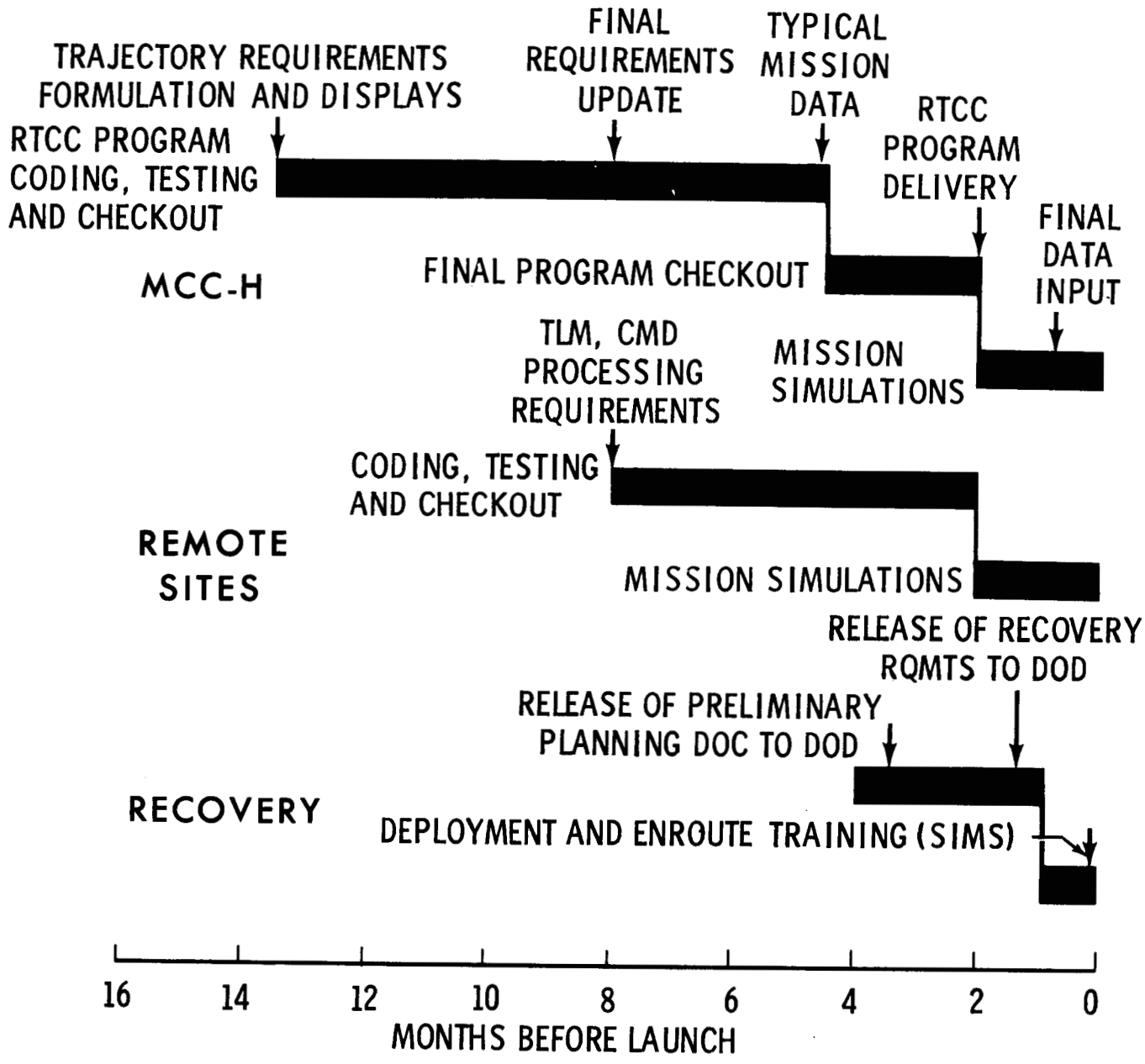
GROUND SYSTEM PREPARATION



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CAPABILITY TO HOLD

(HOLD IS DEFINED AS LAUNCH WITHIN WINDOW)

- SPACE VEHICLE HARDWARE
  - CAN HOLD THROUGH 4 HOUR WINDOW
  - HOLD AFTER T-5 MIN WILL REQUIRE RECYCLING TO APPROX T-15 MIN
- SPACE VEHICLE SOFTWARE
  - AZIMUTH UPDATE CAPABILITY THRU T-5 MIN
- CREW AND ONBOARD DATA
  - CAN HOLD THROUGH 4 HOUR WINDOW
- GROUND SYSTEM
  - REAL TIME COMPUTATIONS PROVIDE NECESSARY DATA TO GROUND SYSTEM TO HOLD THROUGH 4 HOUR WINDOW
  - RECOVERY SHIPS AND PLANES CAN RELOCATE AS REQUIRED

CAPABILITY TO RECYCLE

- SPACE VEHICLE HARDWARE
  - CRITICAL PATH REQUIRES 53 HOURS BETWEEN SCRUB AND NEXT LAUNCH WITHOUT TIME ALLOCATED FOR REPAIRS
  - ABILITY TO ACHIEVE 44 HOURS UNCERTAIN AT PRESENT
- SPACE VEHICLE SOFTWARE
  - NEW MISSION DESIGN AND S / V TARGETING WILL BE AVAILABLE AT TIME OF RECYCLE
  - RELOADING OF TARGETING CAN BE DONE WITHIN 44 HOURS OF LAUNCH
- CREW AND ONBOARD DATA
  - NO ADDITIONAL TRAINING REQUIRED
  - NEW ONBOARD DATA PACKAGE WILL BE AVAILABLE AT TIME OF RECYCLE
- GROUND SYSTEMS
  - NEW INPUT DATA FOR RTCC WILL BE PART OF EACH MONTHLY DATA INPUT
  - RELOCATION OF SHIPS AND PLANES CAN BE ACCOMPLISHED WITHIN 44 HOURS

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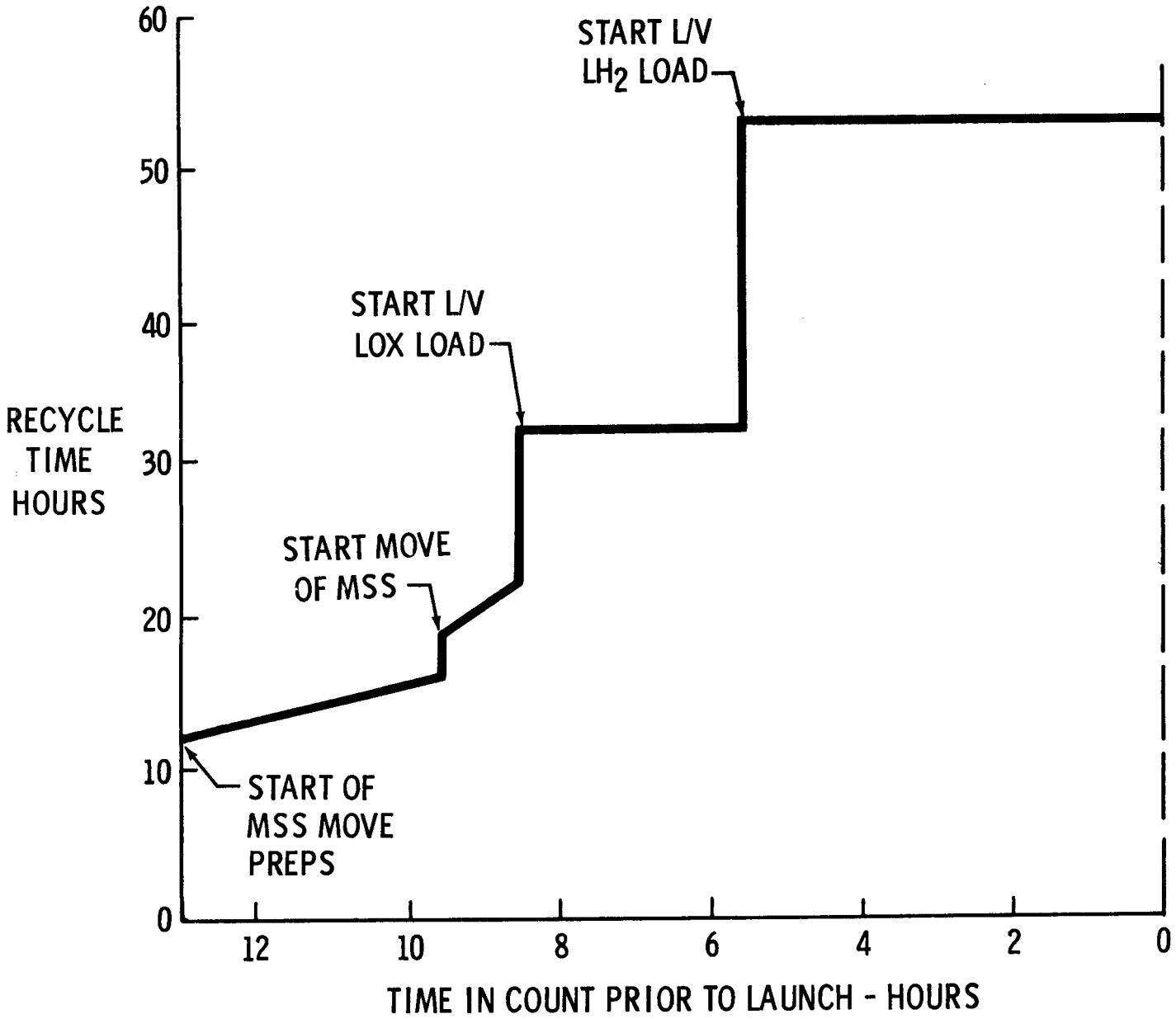
SATURN V RECYCLE TIME FROM SCRUB TO NEXT T-0



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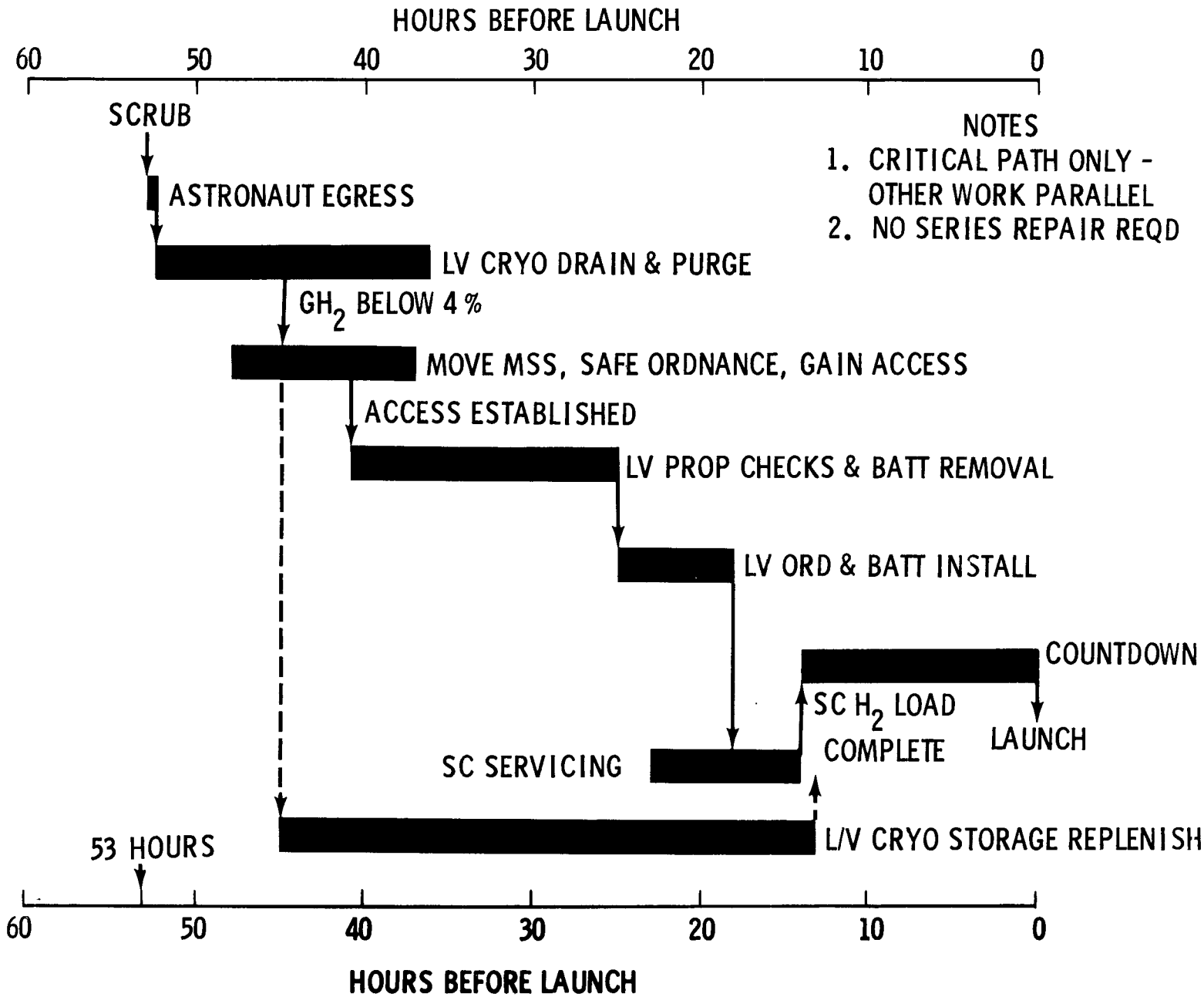
SPACE VEHICLE HARDWARE RECYCLE



NOTES
1. CRITICAL PATH ONLY - OTHER WORK PARALLEL
2. NO SERIES REPAIR REQD

NASA-S-66-11143 NOV 18

CAPABILITY TO RESCHEDULE

- SPACE VEHICLE HARDWARE
  - REPLACEMENT OF FUEL CELLS AND SOME HYPERGOLIC SUBSYSTEM COMPONENTS ON SPACECRAFT REQUIRED AFTER SECOND MONTH'S LAUNCH OPPORTUNITIES
  - THE REPLACEMENT OF THESE ITEMS CANNOT BE DONE IN TIME TO MEET THIRD MONTH'S WINDOW
  - REPLACEMENT OF SELECTED L / V AND OTHER SC COMPONENTS REQUIRED AFTER EACH MONTHLY WINDOW. THIS REPLACEMENT CAN BE DONE IN 18 DAYS
- SPACE VEHICLE SOFTWARE
  - MISSION DESIGN AND SPACE VEHICLE TARGETING WILL BE AVAILABLE AT TIME OF RESCHEDULE
  - RELOADING OF SPACE VEHICLE TARGETS CAN BE ACCOMPLISHED WITHIN 44 HOURS OF LAUNCH
- CREW AND ONBOARD DATA
  - CREW TRAINING WILL CONTINUE THROUGH RESCHEDULE BUT WILL NOT CONSTRAIN TIME REQUIRED TO RESCHEDULE
  - NEW ONBOARD DATA PACKAGE WILL BE ABAILABLE AT TIME OF RESCHEDULE
- GROUND SYSTEM
  - NO PROBLEM

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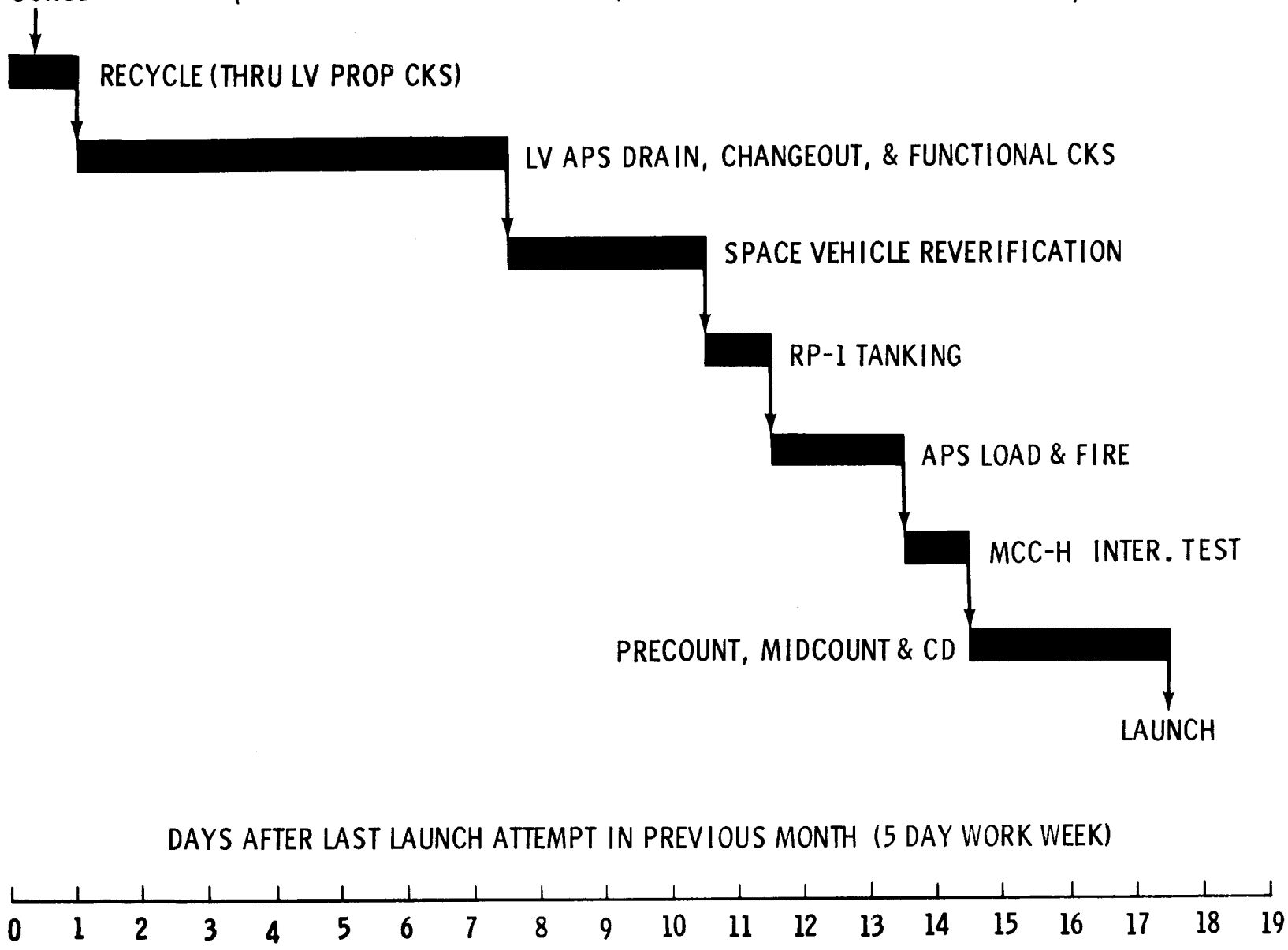
SPACE VEHICLE RESCHEDULE

(CRITICAL PATH ONLY, OTHER WORK PARALLEL)



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SUMMARY OF SYSTEM REQUIREMENTS AND CAPABILITIES

	NEED MISSION DATA		HOLD	RECYCLE	RESCHEDULE
	TYPICAL	ACTUAL			
SPACE VEHICLE HARDWARE	T-2 1/2 MOS	T-1 MO	NO PROBLEM	44 HOUR RECYCLE UNCERTAIN	SC WILL NOT BE READY FOR THIRD MONTHLY WINDOW
SPACE VEHICLE SOFTWARE	T-5 MOS	T-3 WKS	NO PROBLEM	NO PROBLEM	NO PROBLEM
CREW AND ON BOARD DATA	T-5 MOS	T-3 WKS	NO PROBLEM	NO PROBLEM	NO PROBLEM
GROUND SYSTEMS	T-4 MOS	T-3 WKS	NO PROBLEM	NO PROBLEM	NO PROBLEM

PROGRAM REQUIREMENTS FOR THE FIRST LUNAR LANDING MISSION

- PLAN FOR LAUNCH OPPORTUNITIES ON ONLY THREE DAYS PER MONTH
- PLAN FOR MINIMUM OF 44 HOURS BETWEEN LAUNCH OPPORTUNITIES
- PLAN FOR ONLY PACIFIC INJECTIONS
- PLAN FOR TWO MONTH LEAD TIME FOR LAUNCH DATE AND LUNAR LANDING SITE IDENTIFICATION

CONTINUING PROGRAM EFFORT TO MEET THE NEEDS OF THE FIRST LUNAR LANDING MISSION

- ASSURANCE OF 44 HOUR HARDWARE RECYCLE
- REDUCTION OF LEAD TIME FOR MISSION PLANNING AND TARGETING
- "TYPICAL" MISSION DATA PACKAGE FOR USE PRIOR TO T-ONE MONTH
- FEASIBILITY AND COST OF REQUALIFYING S/C FUEL CELLS AND HYPERGOLIC COMPONENTS TO ACHIEVE THIRD MONTH CAPABILITY
- DEFINITION OF ONBOARD DATA AND RELATED LEAD TIME
- INITIAL SELECTION OF LUNAR LANDING SITES FOR CERTIFICATION ANALYSIS
- ADEQUACY OF 2½ HOUR (MINIMUM) LAUNCH WINDOW