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FINAL

ASTP MISSION TECHNIQUES RENDEZVOUS BOOK

PREPARED BY

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ASTP MISSION TECHNIQUES
RENDEZVOUS BOOK

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NOTE: Charts and graphs contained herein are for illustrative purposes only and are not to be used for flight.

CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Continued)

APPENDICES

ILLUSTRATIONS

NOMENCLATURE

AC	Apollo Commander
AGET	Apollo ground elapsed time from lift-off
ASAP	as soon as practicable
ASTP	Apollo Soyuz Test Project
ATS-6	Application Technology Satellite - 6
BMAG	body mounted attitude gyros
BT	burn time
CCW	counterclockwise
CM	command module
CMC	command module computer
C/O	cutoff
CSM	command service module
DAP	digital autopilot
DET	digital event timer (spacecraft)
DM	docking module
DRPA	docking ring and probe assembly
DSKY	CMC display and keyboard
EMS	entry monitoring system
FD	Flight Director
FDAI	flight director attitude indicator
FDO	Flight Dynamics Officer
fps	feet per second
GET	ground elapsed time from lift-off
GETI	ground elapsed time of SPS ignition (measured from lift-off)
G&N	guidance and navigation system (spacecraft)
GMT	Greenwich Mean time
GN&C	guidance, navigation, and control system
GNCS	CSM's primary guidance and navigation system
GRD	ground
HAW	Hawaii (STDN)
IGN	ignition
IMU	inertial measurement unit
km	kilometer
LO	lift-off
LV	launch vehicle
M	number of maneuver line crossings in the rendezvous sequence prior to docking
MCC-H	Mission Control Center - Houston (also referred to in text as the ground)
mps	meters per second
NC1	first phasing maneuver
n mi	nautical miles
PAD	voice update
RCS	reaction control system

NOMENCLATURE (Continued)

RHC	rotational hand controller
RTCC	Real-Time Computer Complex (MCC-H)
SC	spacecraft
SCS	stabilization and control system
SEP	separation
SGET	Soyuz ground elapsed time from lift-off
SM	service module
SPS	service module propulsion system
STDN	Space Tracking Data Network
S-IVB	Saturn IVB second stage booster
T	lift-off time
T&D	transposition and docking
TD&E	transposition and docking and DM ejection
TGT	target
THC	translational hand controller (spacecraft)
TIG	time of ignition
TVC	thrust vector control
USSR	Union of Soviet Socialist Republics

SYMBOLS

h	vehicle altitude (measured in nautical miles above a spherical earth of launch-site radius)
h_a	apogee altitude (measured in nautical miles above a spherical earth of launch-site radius)
h_p	perigee altitude (measured in nautical miles above a spherical earth of launch-site radius)
P00	CMC idling mode program
P30	CMC External ΔV prethrust targeting program
P32	CMC NC2 prethrust targeting program
P33	CMC NCC prethrust targeting program
P34	CMC NSR prethrust targeting program
P35	CMC TPI prethrust targeting program
P36	CMC TPM prethrust targeting program
P38	CMC NPC prethrust targeting program
P40	CMC SPS thrusting program
P41	CMC RCS thrusting program
P52	CMC IMU realign program
ΔV	velocity increment (in feet/second)

1. INTRODUCTION

The purpose of this report is to document the various rendezvous profiles, crew procedures, ground procedures, and system verification processes that may be utilized during the ASTP mission.

The Mission Techniques document describing prelaunch targeting, launch aborts, and postinsertion timelines discusses the basic CSM timeline through the Apollo Evasive Maneuver (AEM) which serves as the final separation maneuver for the CSM/DM away from the S-IVB. This document will address the timeline from the AEM through the initial CSM/Soyuz docking sequence.

Section 2 of this document describes the nominal (M = 30) rendezvous sequence in detail. Sections 3 and 4 address the M = 14 and M = 13 profiles which are the nominals for the alternate launch days. Section 5 provides a brief description of the Soyuz rescue plan as it affects rendezvous techniques. Section 6 presents a brief description of the S-IVB rendezvous profile.

The format of each section is essentially constant. A general description of each rendezvous maneuver will be given, followed by a detailed timeline including crew and ground procedures, techniques, and system verification processes. Flow charts will accompany these detailed descriptions to put the entire sequence into perspective from a data flow standpoint.

Figure 1-1 presents a description of the Apollo launch windows for all five launch opportunities. It includes the nominal phase angles (at insertion) and the rendezvous profiles to be flown each day.

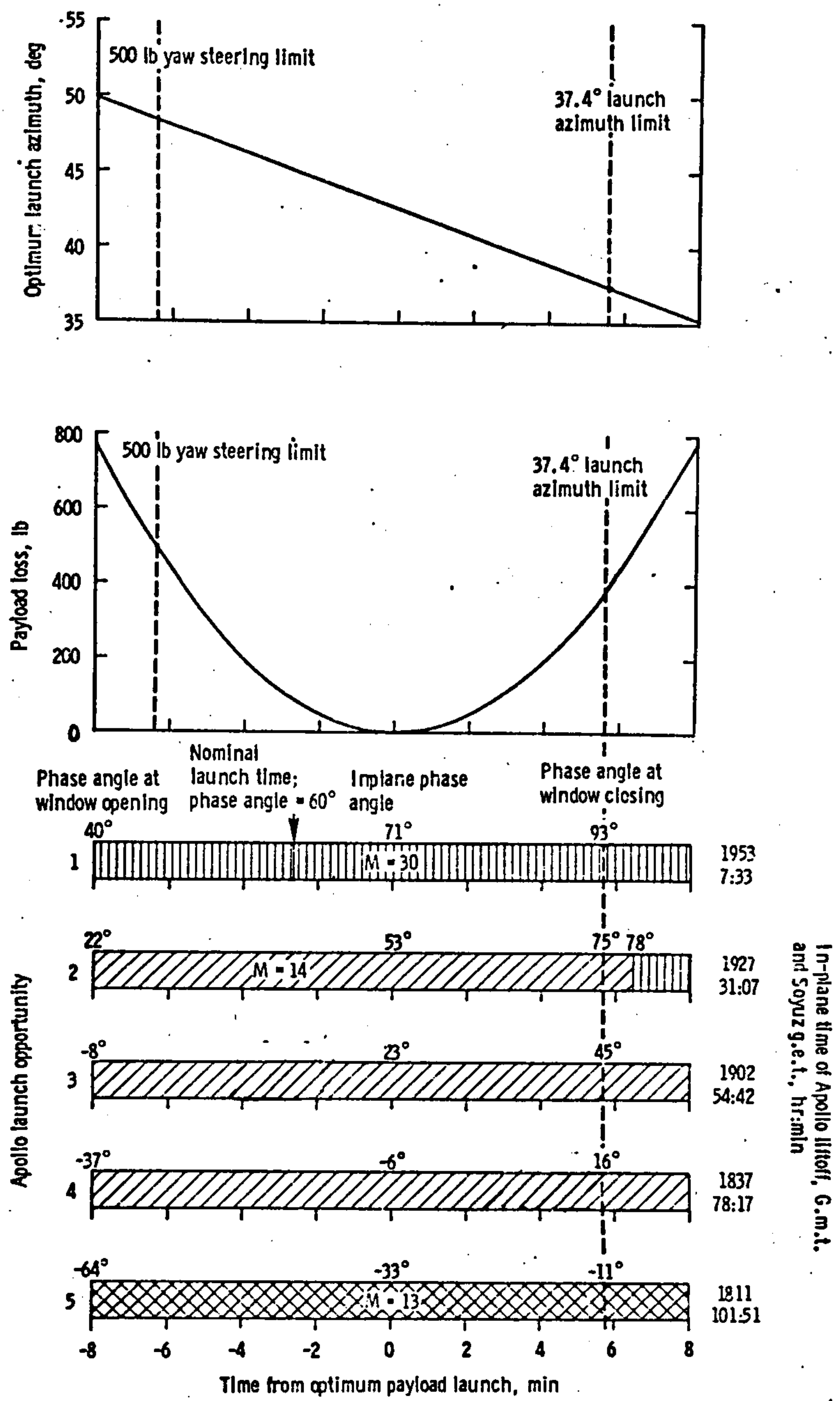


Figure 1-1. Launch Window (Apollo Launch Windows for the Soyuz in an Initial 225 km Circular Orbit)

2. NOMINAL PROFILE - M = 30

This section presents a general discussion of the rendezvous profile, a brief description of the sequence of events, and a detailed discussion of the rendezvous flow charts for the nominal rendezvous sequence.

2.1 MANEUVER SEQUENCE

A representative picture of the rendezvous orbital geometry is presented in Figure 2-1. The relative motion of the CSM with respect to the Soyuz is presented in Figure 2-2.

The rendezvous profile was designed to:

a) Provide acceptable Space Tracking Data Network (STDN) coverage

b) Provide acceptable onboard navigation opportunities for both the sextant and the VHF ranging system (See Figure 2-4 - nominal O/B navigation schedule)

c) Provide a standard sequence from NC2 on for the various launch opportunities

d) Conserve RCS fuel by using the SPS for all burns prior to the TPM maneuvers.

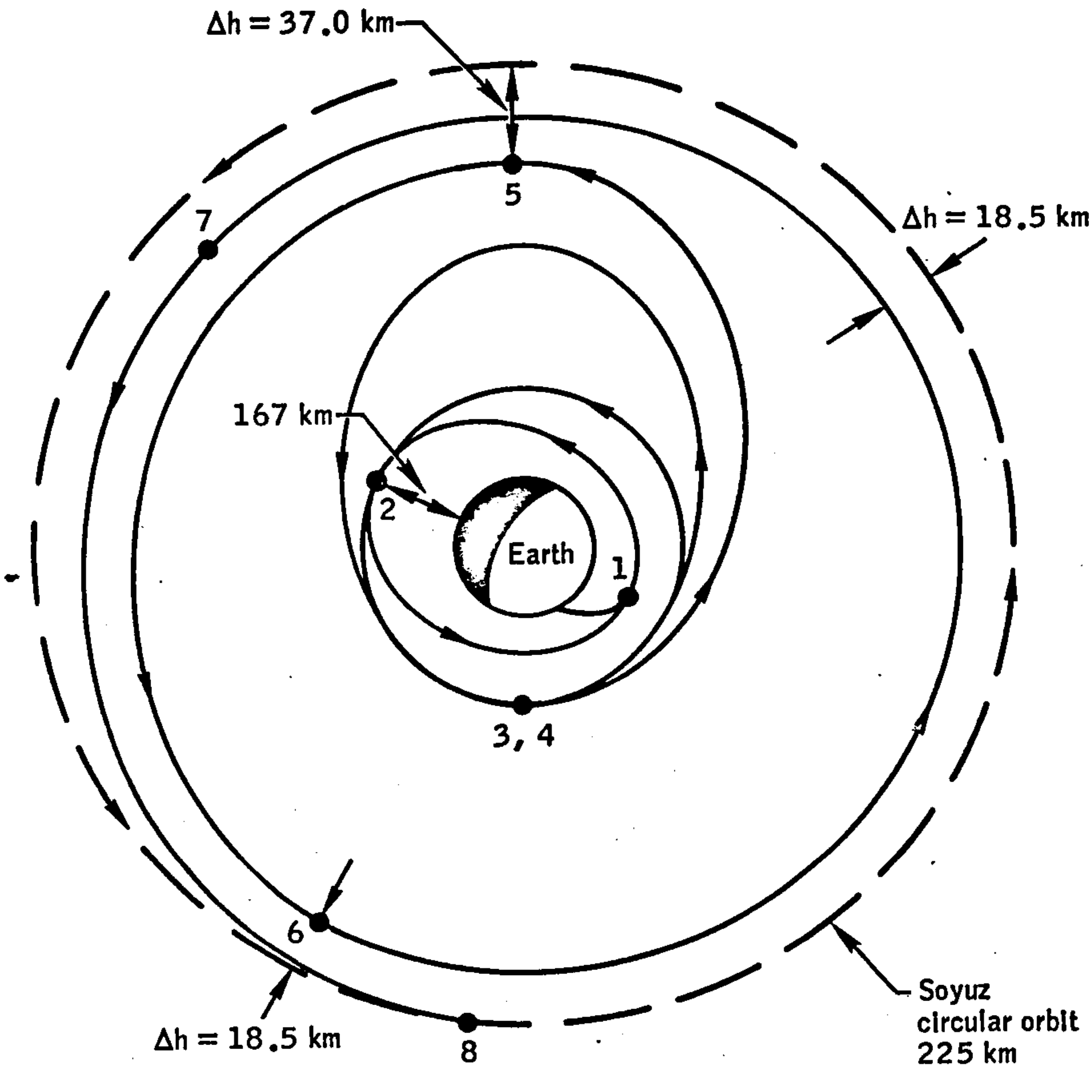
The maneuver times indicated in this text correspond to the time bases in which the actual mission will be flown. Specifically, all maneuvers performed on the first day are listed in AGET as this is the time-base for that day. At the end of the first day, a GET update will be performed and the remainder of the mission (until deorbit preparations begin) will be flown in SGET. Figure 2-3 lists the various maneuvers for all of the launch opportunities and the range of values that each maneuver may cover. Discussions of these maneuvers follow in the next section.

2.1.1 Apollo Circularization Maneuver (ACM)

The ACM will circularize the CSM orbit about the time of the third apogee, nominally at 3 hrs 45 min AGET. This 21-fps maneuver will be performed with the SPS and results in approximately a 91 n mi circular orbit (168 km).

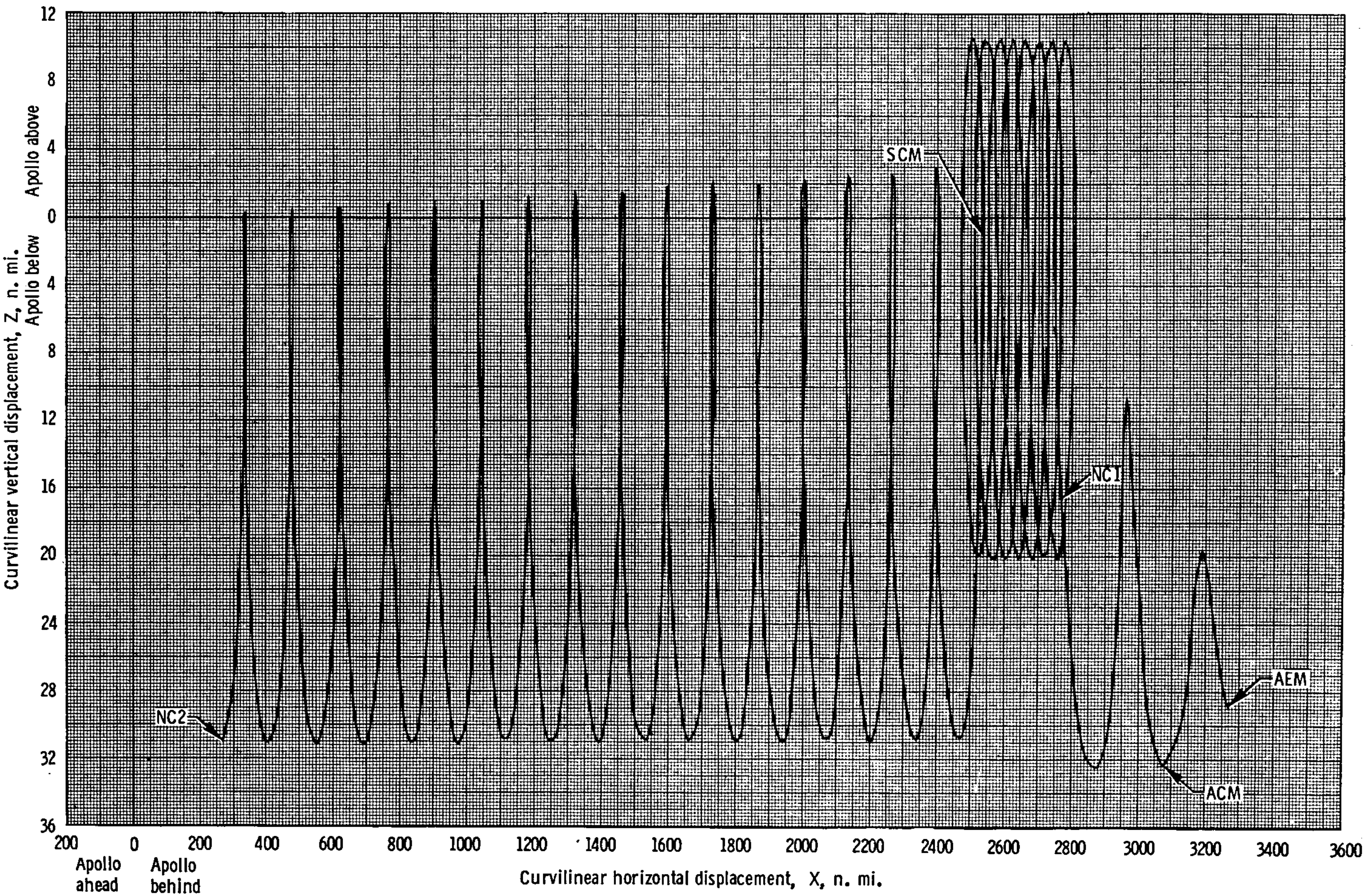
2.1.2 First Phasing Maneuver (NC1)

The NC1 maneuver is nominally an in-plane horizontal posigrade maneuver performed about two hours after the ACM (at approximately 5 hrs 45 min AGET). The magnitude of NC1 is a function of the insertion phase angle and the M-number of the rendezvous sequence. Figure 2-5 presents the relationship of the NC1 ΔV and insertion phase angle for the M = 30 profile. The nominal NC1 is a 66-fps SPS maneuver resulting in a 126 x 91 n mi CSM orbit. NC1 TIG is selected to provide optimum lighting conditions



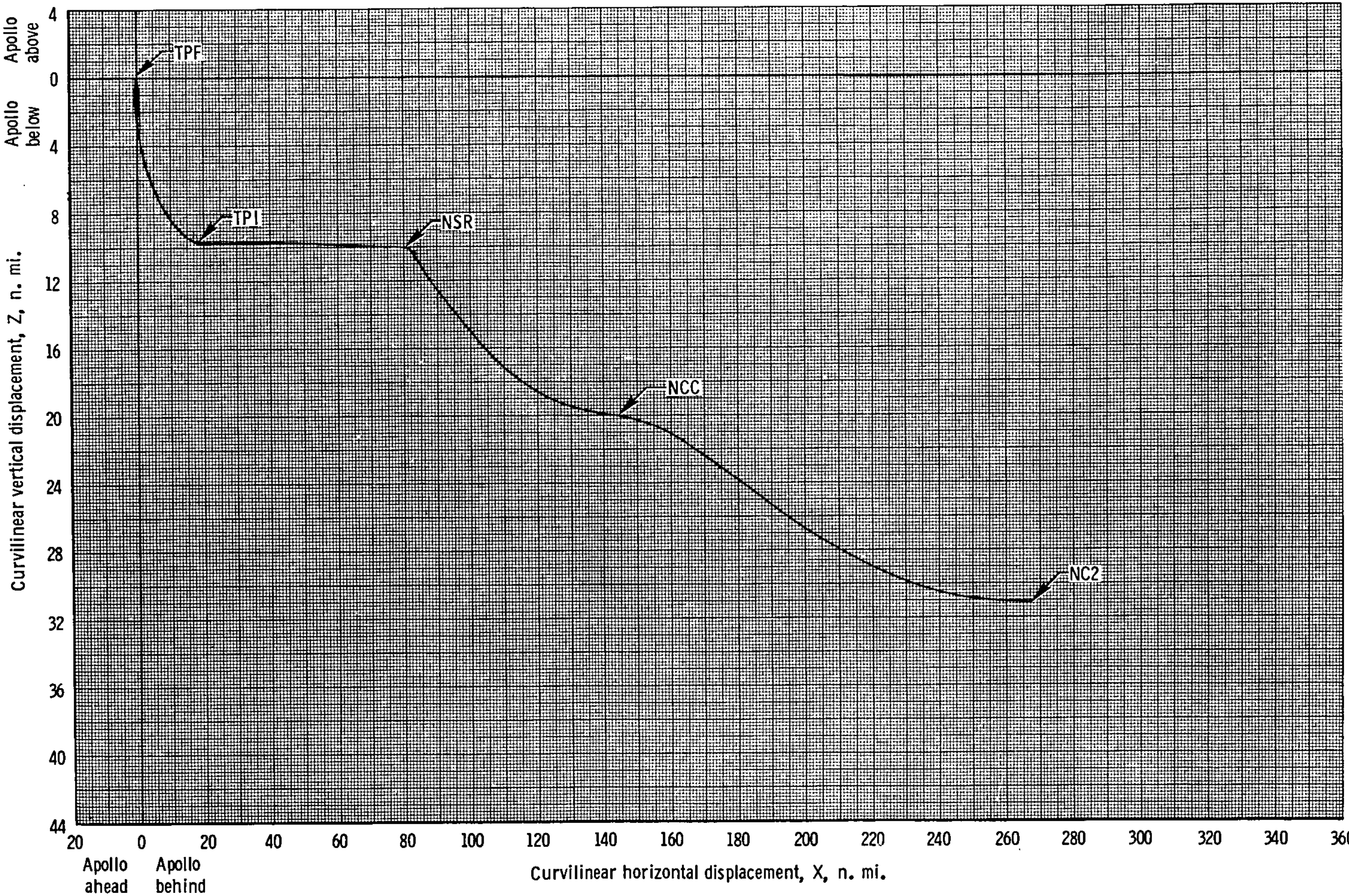
1 Insertion - 150 by 167 km
2 Circularization
3 Phasing 1 (NC1)
4 Phasing 2 (NC2)
5 Corrective combination (NCC)
6 Coelliptic (NSR)
7 TPI
8 Braking (TPF)

Figure 2-1. Orbital Geometry - M = 30 Profile



(a) AEM to NC2.

Figure 2-2. Relative Motion - M=30 Profile



(b) NC2 to TPF.

Figure 2-2. Relative Motion - M=30 Profile (Continued)

LAUNCH OPP	1	2	3	4	5
RNDZ PROFILE	M = 30	M = 14	M = 14	M = 14	M = 13
OHA ΔV	N/A	N/A	N/A	61	73
ACM ΔV	21	21	21	76	N/A
NC1 ΔV	66 → 140	52 → -35*	133 → 48	59 → -30	209 → 120
PCM ΔV	"0"	N/A	N/A	N/A	N/A
NC2 ΔV	-36 → -7	-28 → 59	-111 → -25	-104 → -15	-193 → -104
NCC ΔV	40	37	34	-26	-29
NSR ΔV	23	24	23	26	20
TPI ΔV	22	22	22	22	22

*This theoretical value of NC1 ΔV would produce an unacceptable orbit. The ACM maneuver will be retargeted to reduce the required NC1 ΔV and consequently produce a higher orbit.

Figure 2-3. Summary Maneuver Table

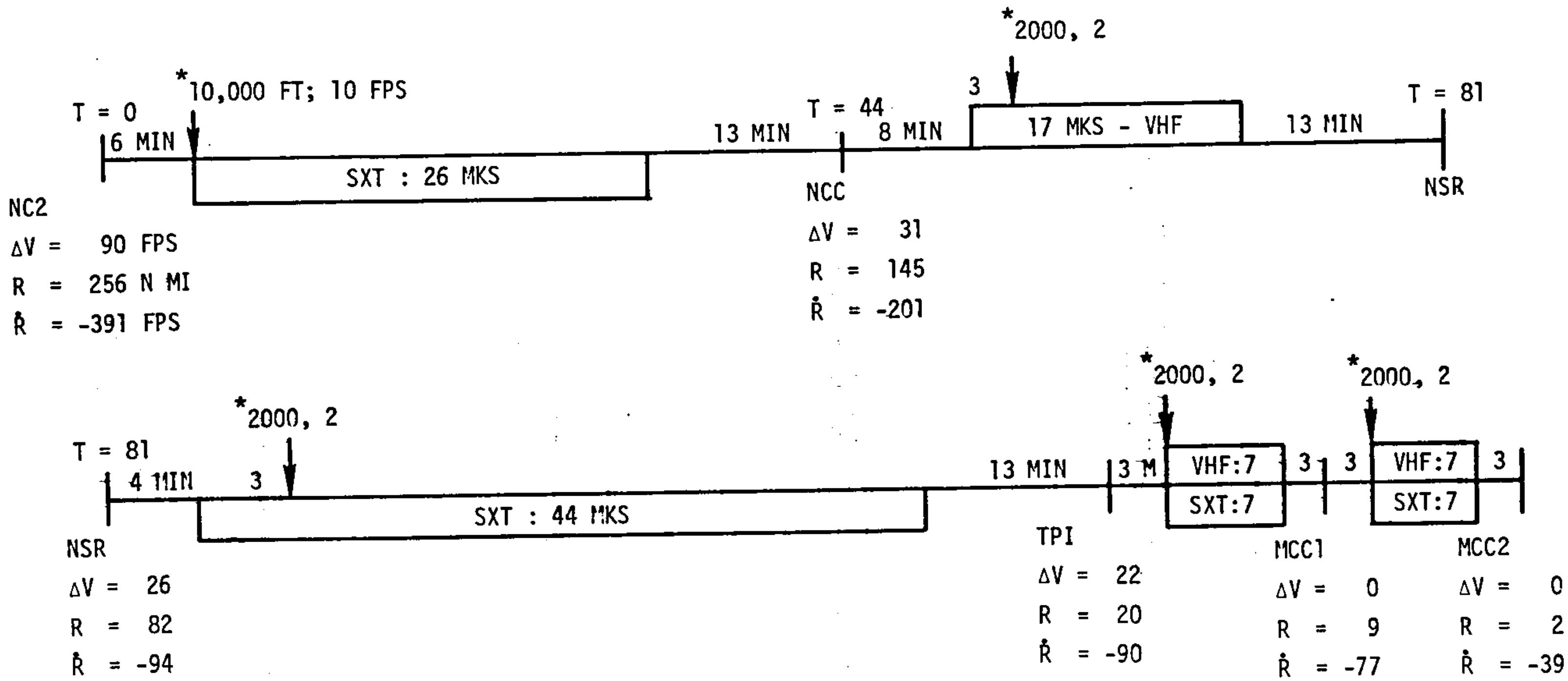


Figure 2-4. Onboard Navigation Schedule (Nominal)

for the navigation period preceding NCC (see Figure 2-4 for onboard navigation schedule). This is accomplished by targeting NCC to occur 10 minutes into darkness which forces the sextant navigation period preceding NCC to occur in daylight. Since the pre-NC1 orbit is circular, TIG can be chosen without concern over current line of apsides orientation. NC1 will be computed by the ground (MCC-H) and executed onboard via P30/P40 since the onboard rendezvous program (P31) would result in extremely long (and inaccurate) CMC integration. Although the Soyuz will not have performed its circularization maneuver at that time, the maneuver is computed using the predicted Soyuz orbit after its circularization. In the event that a plane change maneuver is required, NC1 will be targeted to locate the node between 180° and 270° after NC1. The desirability of accomplishing this planar correction is a function of the magnitude of the planar error involved.

2.1.3 Plane Change Maneuver (NPC)

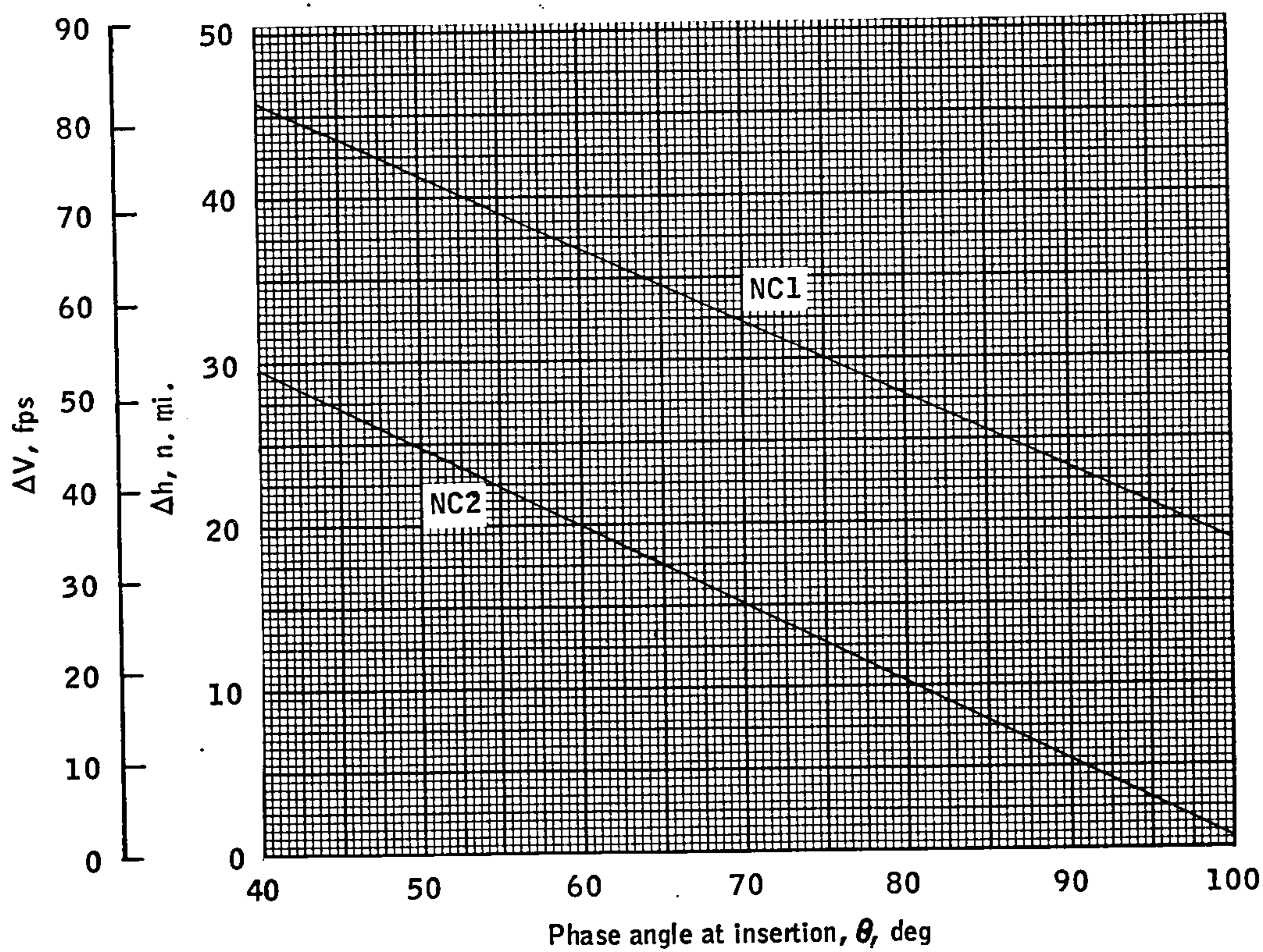
NPC is scheduled at the second nodal crossing after NC1, if required. This maneuver will not nominally be required since the launch vehicle (LV) will be targeted to achieve the proper insertion plane. For large planar errors (caused by LV insertion errors), NPC will be required and is executed via P38/P40, so that the CMC can pulse torque the platform 45 degrees out of the orbit plane to allow SPS execution of the maneuver without gimbal lock problems. The ground will provide the TIG time and ΔV components for loading into P38. For small planar errors, any or all of the rendezvous maneuvers could be utilized to reduce the plane change requirements, thus avoiding this additional maneuver. This is accomplished by executing a ΔV_Y component along with the required in-plane corrections. The ground will provide recommendations relative to this type of planar correction technique. The limiting factor here is allowable middle gimbal angle (MGA). Sixty degrees is considered the maximum desirable MGA for any burn.

2.1.4 Phasing Correction Maneuver (PCM)

PCM is a small correction maneuver designed to re-establish the desired phasing conditions at NC2. The need for PCM will be a function of the NC1 maneuver execution, the accuracy of the vectors used to compute NC1, the execution of the Soyuz circularization maneuver (SCM) (performed about 8 hours prior to the PCM), and our ability to predict drag, etc., in the relatively low orbits involved in the rendezvous sequence. The nominal time for PCM is about 32 hrs 21 min SGET (20 hrs 42 min AGET), and any required maneuver should be an RCS burn, barring serious problems with NC1 or the SCM. Although it is not designated as a nominal maneuver, it is very likely that a small, in-plane, horizontal PCM will be required, although its direction is not predictable.

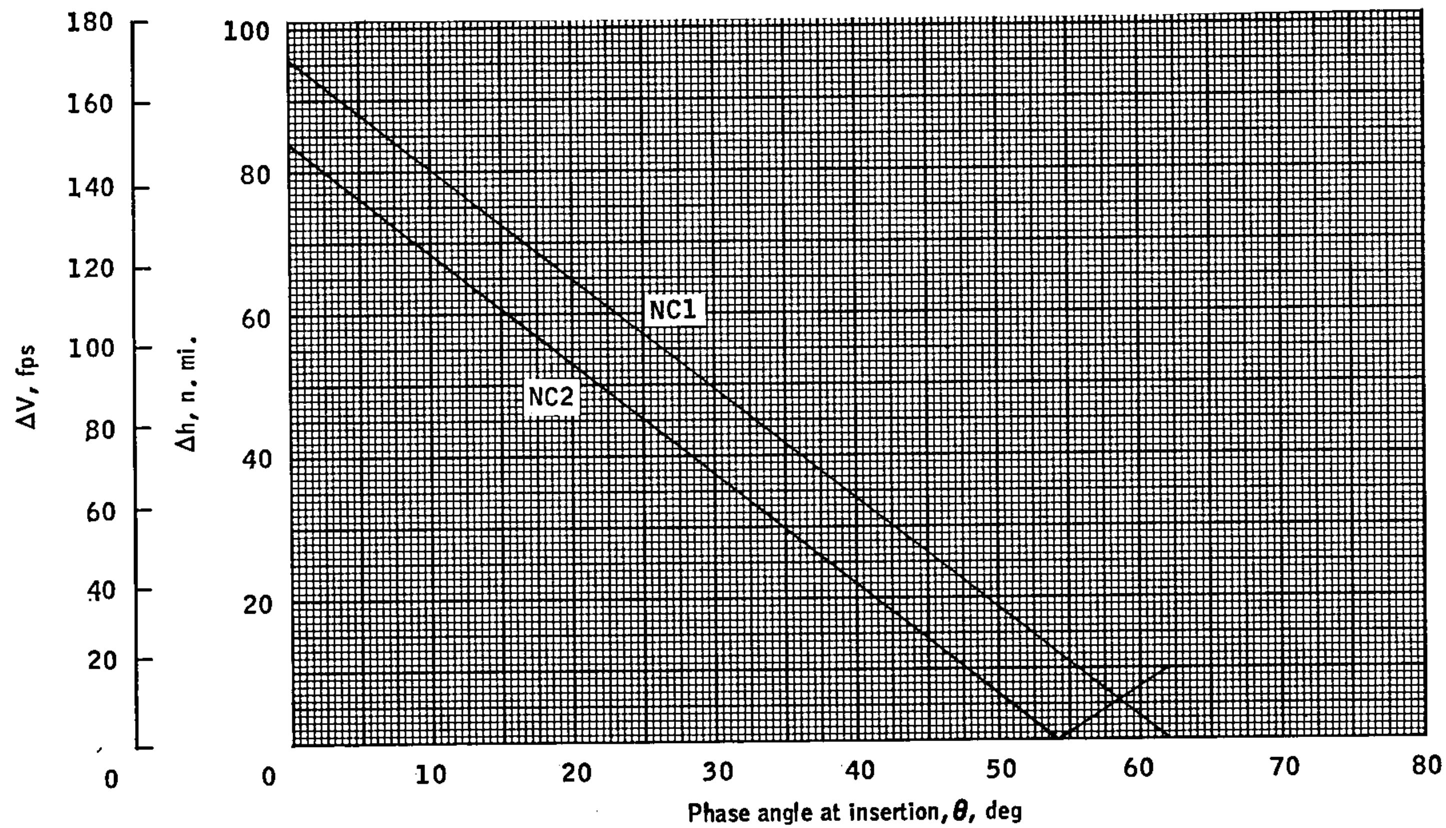
2.1.5 Second Phasing Maneuver (NC2)

NC2 is performed after crew wake-up on the third day of the flight, nominally about 48 hrs 34 min SGET. Although designated as a phasing maneuver, it is nominally only a height adjustment as the previous phasing burns should



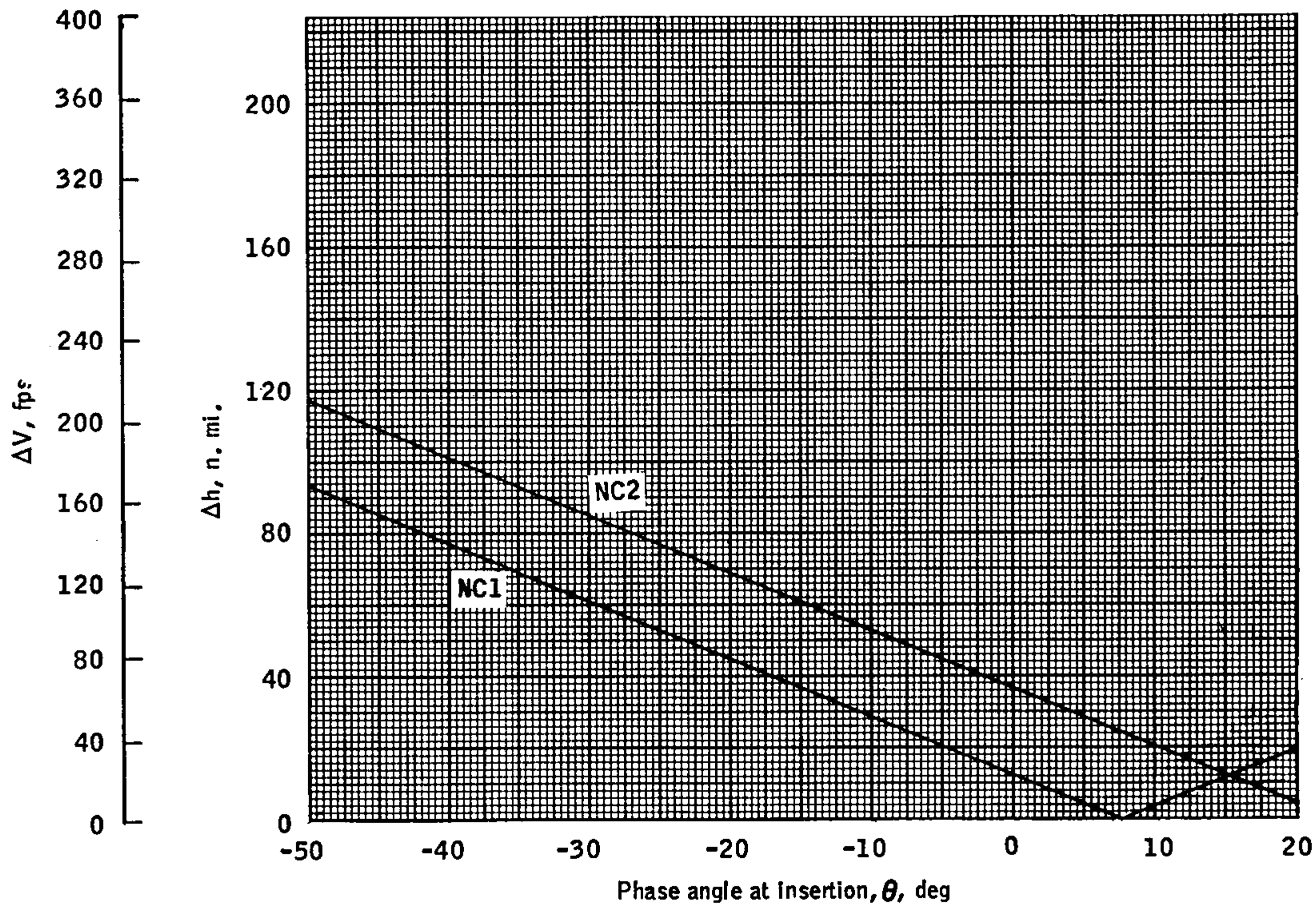
First Launch Opportunity

Figure 2-5. NC1 and NC2 ΔV Histories



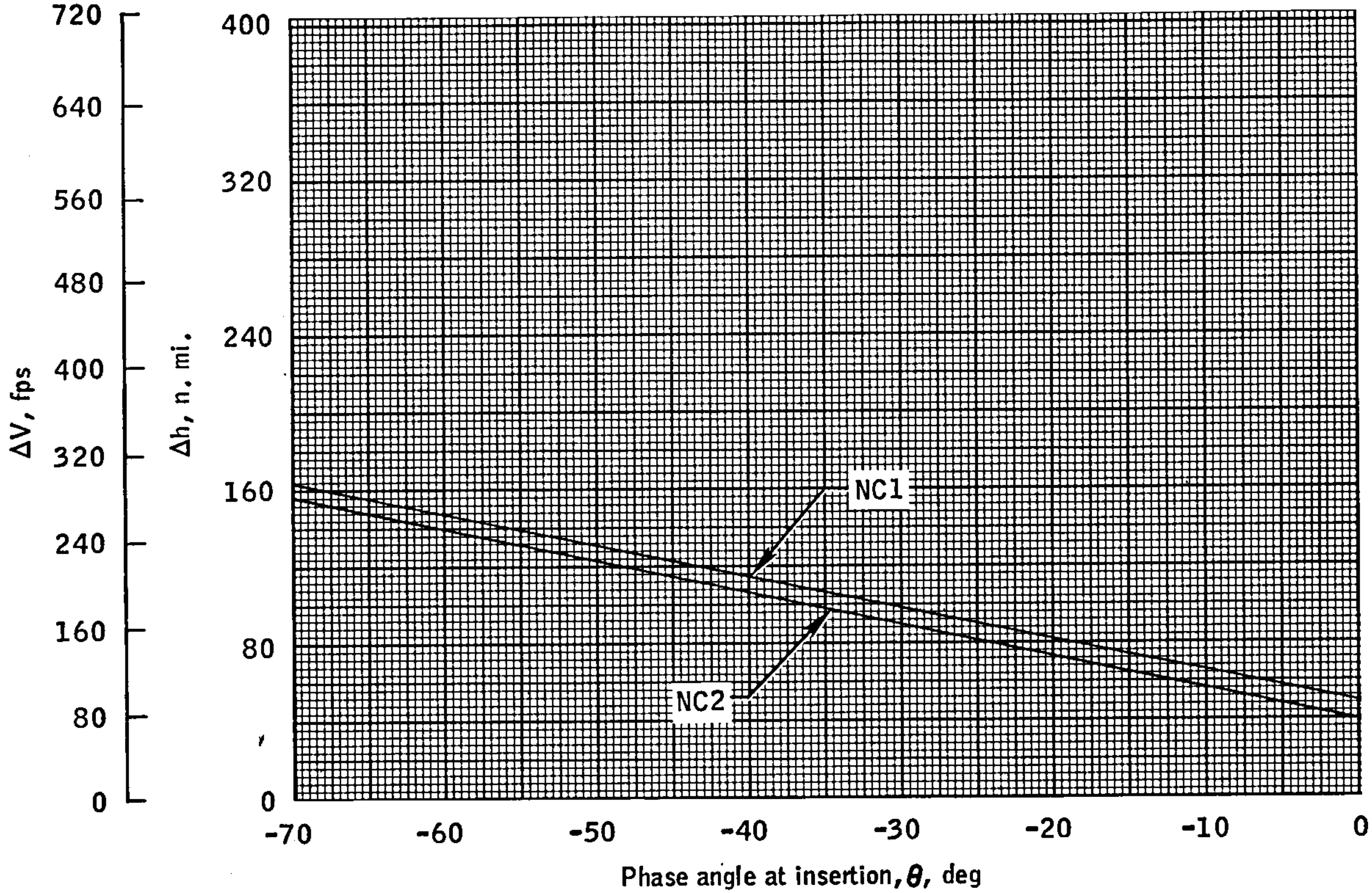
Second and Third Launch Opportunities

Figure 2-5. NC1 and NC2 ΔV Histories (Continued)



Fourth Launch Opportunity

Figure 2-5. NC1 and NC2 ΔV Histories (Continued)



Fifth Launch Opportunity

Figure 2-5. NC1 and NC2 ΔV Histories (Continued)

have established the proper phasing conditions. The ground is prime for computation of this maneuver and will provide the targeting parameters for the crew to execute the maneuver via P32/P40, which also initializes the other CMC rendezvous programs. NC2 is an in-plane, horizontal retrograde maneuver and should establish a relative (CSM/Soyuz) ΔH of 20 n mi at the NCC maneuver point, unless some additional phasing is required due to trajectory errors that developed after the PCM. The burn will utilize the SPS and should be about 36 fps. The magnitude of NC2 changes directly with the magnitude of NC1 for lift-off delays through the launch window, as depicted in Figure 2-5.

2.1.6 Corrective Combination Maneuver (NCC)

This maneuver is performed one-half revolution after NC2. It is essentially constant for all the rendezvous profiles (with one exception - see Section 3.1.6), being an SPS maneuver of about 40 fps. NCC and NSR are always computed as a "matched pair" which results in minimum TPI slips (due to compensating errors). Onboard navigation with the sextant is performed during the pre-NCC time interval, so the CMC is prime for this computation sequence. The voting logic between the CMC and ground solutions is presented in Section 2.5. NCC will generally be a three component burn, although the ΔV_Y component should be small. It provides the final phasing and planar adjustments and establishes the proper ΔH (10 n mi) at the NSR maneuver point.

2.1.7 Coelliptic Maneuver (NSR)

NSR is performed 37 minutes after NCC. This maneuver establishes a coelliptic orbit with the CSM below the Soyuz, nominally with a 10 n mi ΔH. NSR will generally consist of three components, but the majority of the required ΔV should be horizontal posigrade, nominally about 27 fps. The size of the maneuver, however, does vary with the size of NCC. Onboard navigation utilizing VHF ranging is nominally performed between NCC and NSR to maintain state vector accuracy, but these data do not affect the NSR maneuver since it was computed back at NCC ("matched pair").

2.1.8 Terminal Phase Initiation (TPI)

TPI nominally occurs 2 minutes prior to orbital midnight with a line-of-sight (LOS) elevation angle to the Soyuz of 27 degrees. TPI will not be allowed to slip more than ± 10 minutes from this time, due to lighting and potential VHF constraints during braking. TPI establishes an intercept trajectory for the CSM with a third quadrant approach. The nominal maneuver is 22 fps, utilizes the SPS, and occurs at 50 hrs 54 min 25 sec SGET. The CMC is prime for maneuver computation since ample time exists prior to TPI for sextant navigation. An HP65 solution will also be computed using VHF ranging information and a ground solution should be available. The voting logic for these solutions is described in Section 2.5.

2.1.9 Terminal Phase Midcourses (TPM1, TPM2)/Braking

Two midcourse correction maneuvers are performed in the timeframe from TPI to start of braking. These maneuvers are generally small and should re-establish the intercept trajectory. The CMC computes both maneuvers, using sextant plus VHF navigation to update the relative state, while the HP65 will provide backup solutions using VHF data. The crew will also maintain a polar plot to aid them in determining the relative merit of the two available solutions. The approach geometry is also maintained by these corrections, and should provide a comfortable braking schedule for the CSM. The crew manually controls LOS rates and observes a closing velocity vs range schedule, generally referred to as braking gates. This begins at about 1 n mi range and continues to station keeping, where range is about 50 feet and relative velocity is zero.

2.1.10 Docking

Docking nominally occurs at 51 hrs 55 min SGET, during the 36th Soyuz orbit. It must be accomplished prior to darkness on the daylight pass following TPI. Immediately prior to docking, both vehicles roll approximately 60 degrees so that ATS-6 coverage is provided for docking.

2.2 SPS AND RCS USAGE IN SPS FUEL-CRITICAL SITUATIONS

The SPS loading for ASTP was determined using the fourth launch opportunity as the driver and about 830 fps* of SPS will be loaded. The nominal mission has sufficient SPS margins that it is highly improbable that the SPS redline could come into play during the rendezvous. This same situation exists for day 2 launches (M = 14). For day 3 and day 4 launches, SPS fuel could become critical without major dispersions. Day 5 launches nominally require some RCS usage during the rendezvous to protect the SPS deorbit redline.

Mission rules have been developed defining the priority of maneuvers which should be executed with RCS in order to preserve SPS. The two primary factors considered in developing these rules were sensitivity of the maneuver to execution errors, since long RCS burns are statistically less accurate than short SPS burns, and the difficulty in performing the maneuver, which is influenced by the CMC steering mode. The factors which influence this schedule are RCS continuous-burn constraints and accumulated thruster-on times. These constraints are:

a) +X Jets - 150 sec max continous burn - also max accumulated in 45 min period

b) -X Jets - 150 sec max continuous burn - also max accumulated in 45 min period.

*Number is weight dependent.

The various execution techniques that will be considered, in order of priority are:

a) Execute entire maneuver using +X or -X jets

b) Execute maneuver with SPS after 100 sec +X ullage (4 jets)

c) Execute part of the maneuver using +X jets, pitch 180 degrees, and execute the remainder of the maneuver with -X jets

d) Same techniques as in b) but follow SPS burn with 180-degree pitch and finish maneuver with -X jets.

Whenever any of these techniques are required, the ground will compute the required maneuvers, and provide the crew with the necessary information. The priority for executing rendezvous maneuvers with any or all of these special techniques is:

a) OHA
b) ACM
c) NC1

These maneuvers (a–c) are all performed early in the rendezvous, where the sensitivity to maneuver execution errors is minimal.

d) NC2 - The least sensitive of all the maneuvers in the final phase of the rendezvous.

e) NSR - Another fairly insensitive burn which should always be executable with one continuous burn (+X or -X).

f) NCC and TPI will always be executed with the SPS since these are very critical maneuvers and utilize Lambert steering, which makes the ΔT of the execution more critical. There are no identifiable conditions which should ever require executing either of these maneuvers with the RCS, except SPS failures/leaks that occur immediately prior to the maneuvers.

2.3 INSERTION OVERSPEED/UNDERSPEED STRATEGY

The M = 30 rendezvous profile allows a relatively simple strategy concerning insertion velocity errors. Underspeeds are limited to about 40 fps, beyond which orbital insertion has not yet been achieved. If h_p is less than <u>70</u> n mi, a Mode IV maneuver must be performed (assuming the underspeed is not greater than about 120 fps). Mode IV maneuvers will generally result in perigees of approximately 82 n mi. Thus, the minimum underspeed orbit ends up around 80 x 70 n mi. In this orbit, as well as any up to the nominal 80 x 90 n mi, nominal procedures would be maintained through TD&E. Since circularization would result in the post-NC1 perigee being lower than nominal, the ACM maneuver will be scrubbed and replaced with an altitude adjust (NH) maneuver. NH would be performed either 1 1/2 or 1/2 rev prior to NC1 and would force the altitude at the NC1 maneuver point to be nominal (91.6 n mi). The phasing correction required by being in the low orbit for the first few revolutions (i.e., faster catch-up rate) will be made by the NC1 maneuver. NC1 must increase in size to slow down the catch-up rate and compensate for this initial problem, as well as compensate for the reduced post-NC1 perigee, which is a function of the size of the circularization orbit. Consequently, NC2 will be a larger maneuver, since it must lower the apogee NC1 creates. NCC would be nominal since the altitude at NC1 was nominal. In all of these cases, however, the deltas are small (10-12 n mi, 20-25 fps) and present no major problems for the M = 30 sequence.

Overspeeds present essentially the reverse situation. Crew back-up cutoff procedures should preclude overspeeds greater than approximately 150 fps. Again, the timeline is nominal through TD&E and the ACM can always be performed at the nominal 91 n mi point, although there could be a rather expensive radial ΔV penalty involved. NC1 is reduced in magnitude in order to compensate for the reduced catch-up rate of the initial revolutions. The post-NC1 orbit might be a 90 x 118 instead of the nominal 90 x 126, but the correction is relatively minor. NC2 is also reduced by about 15 fps. (This reduction becomes more significant for the M = 14/13 profiles where the NC1 maneuver would approach zero, and is discussed in detail in Section 3.2)

Since all corrections for overspeeds and underspeeds are made early in the rendezvous, the ground is prime for the computations and will provide the crew with the necessary targeting information on the maneuver pads. The precise target orbits are achieved via a simple iterative process and the crew should realize little inconvenience from this type anomoly. The only timeline perturbation of any consequence is the potential one-half revolution delay in the ACM for certain underspeed cases.

2.4 RENDEZVOUS TIMELINE

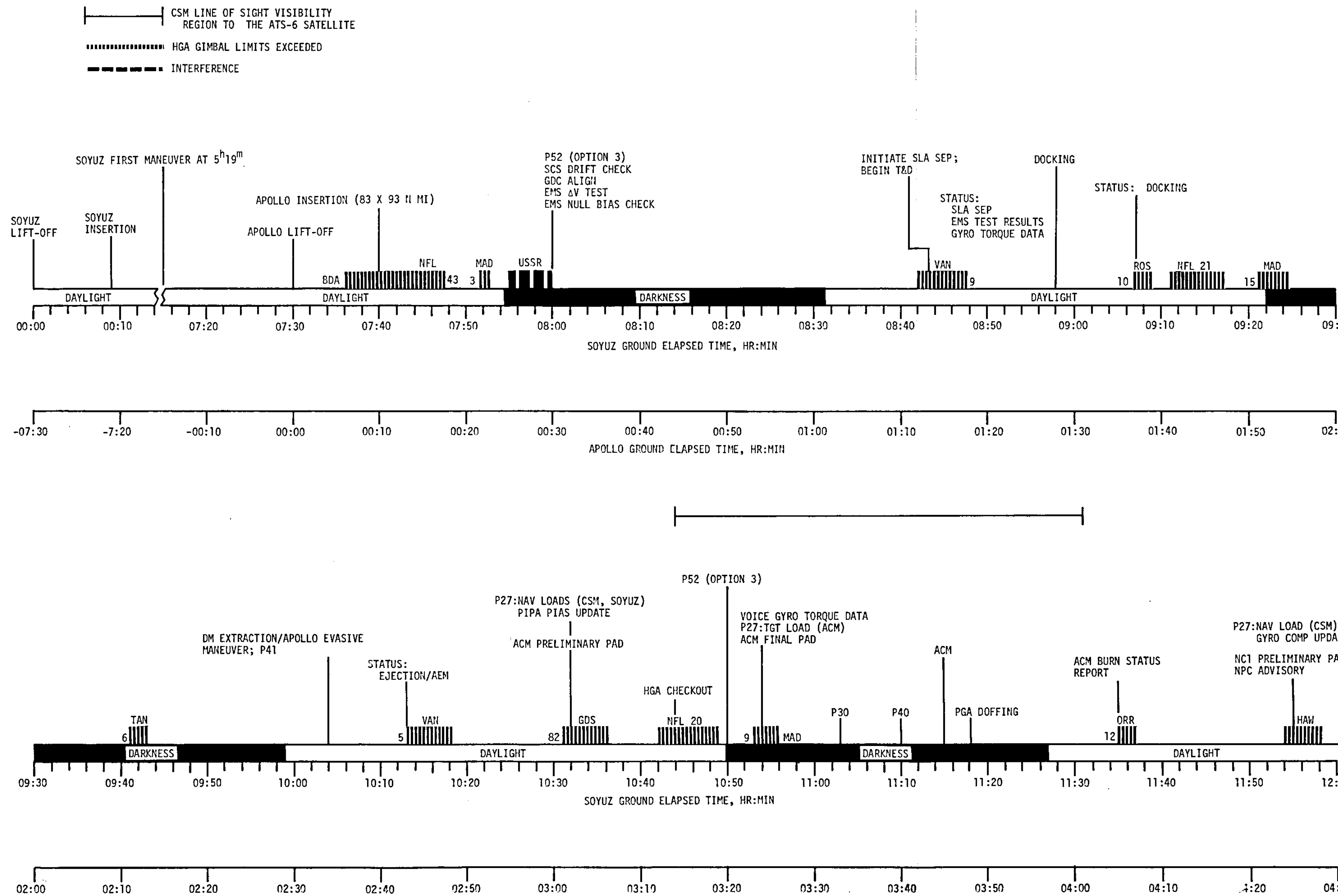
A summary timeline of major activities for the M = 30 profile is shown in Figure 2-6. A detailed discussion of these activities, as well as other rendezvous related procedures, follows in Section 2.5.

2.5 RENDEZVOUS FLOW CHARTS

This section will present the rationale for the significant events of the rendezvous timeline, as depicted in the flow charts (see Figure 2-7).

Some basic groundrules for the rendezvous sequence are:

a) Rendezvous burn computations are generally terminated at TIG-12 minutes to allow ample time for the crew to prepare for the maneuver. In the case of NPC, an additional 8 minutes is allowed for pulse-torquing the IMU.



(a) 0 HOURS THROUGH 12 HOURS, SOYUZ GROUND ELAPSED TIME.

Figure 2-6. Rendezvous Timeline - M = 30 Profile

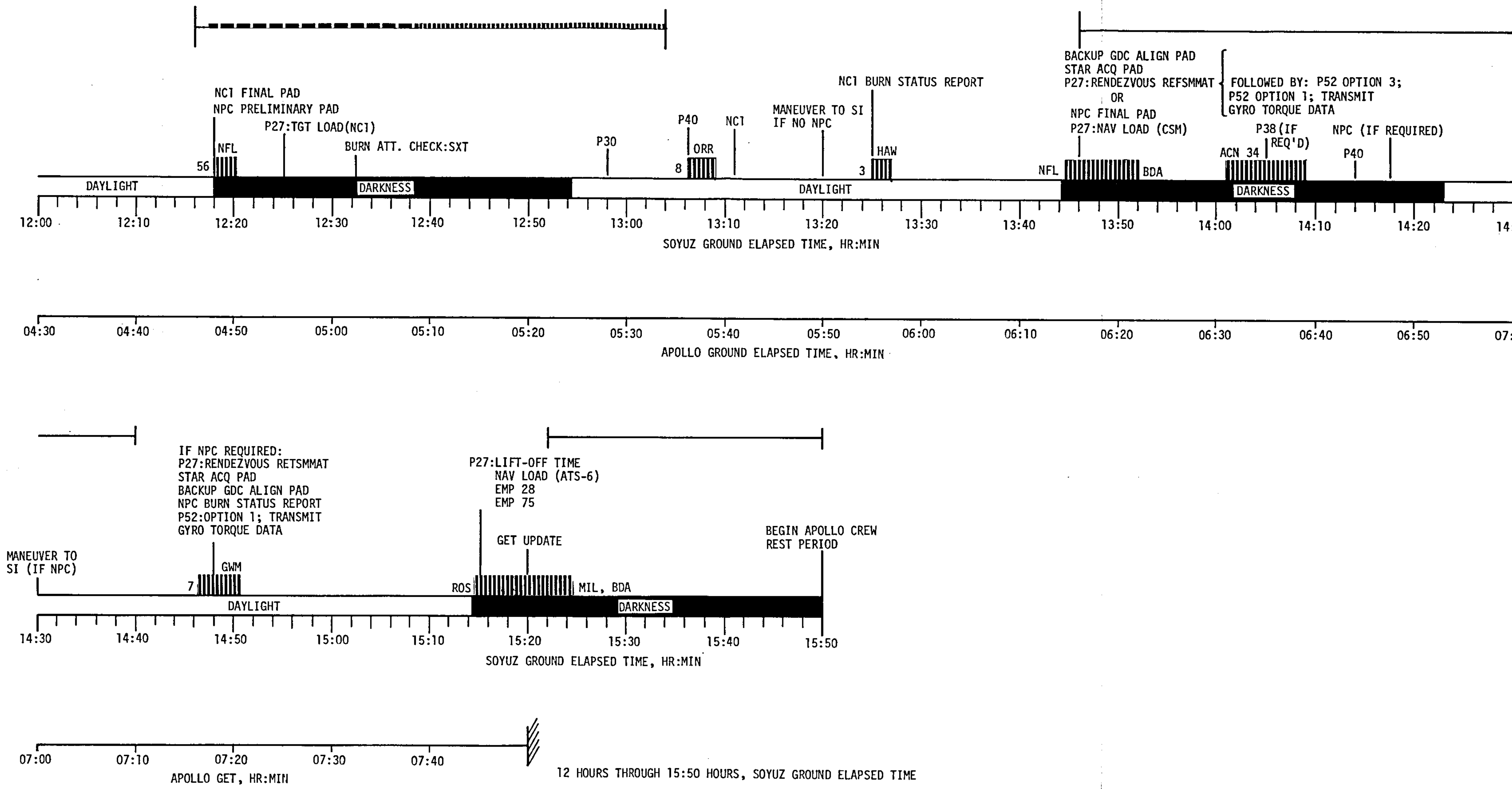


Figure 2-6. Rendezvous Timeline -
M = 30 Profile (Continued)

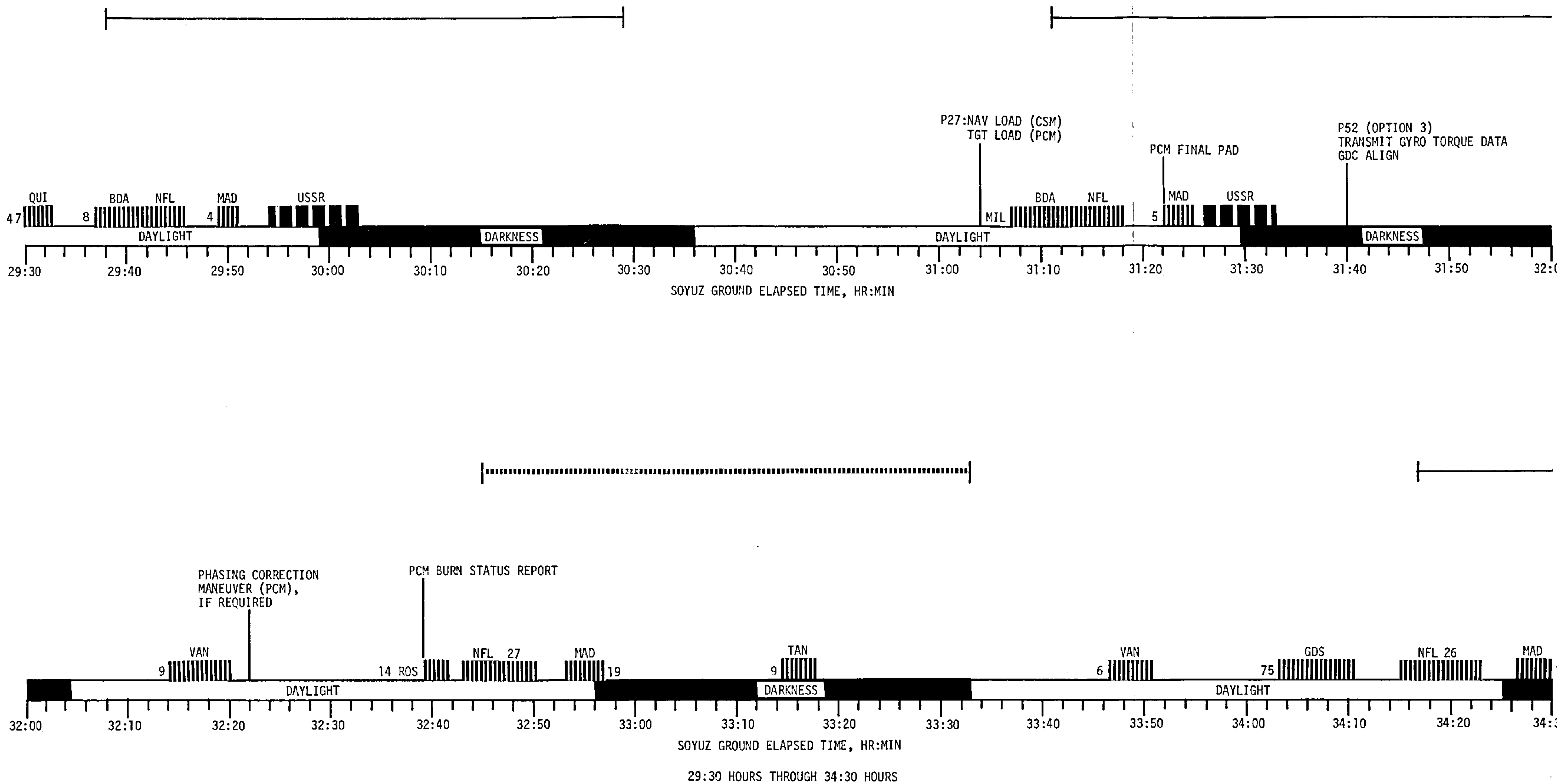


Figure 2-6. Rendezvous Timeline - M = 30 Profile (Continued)

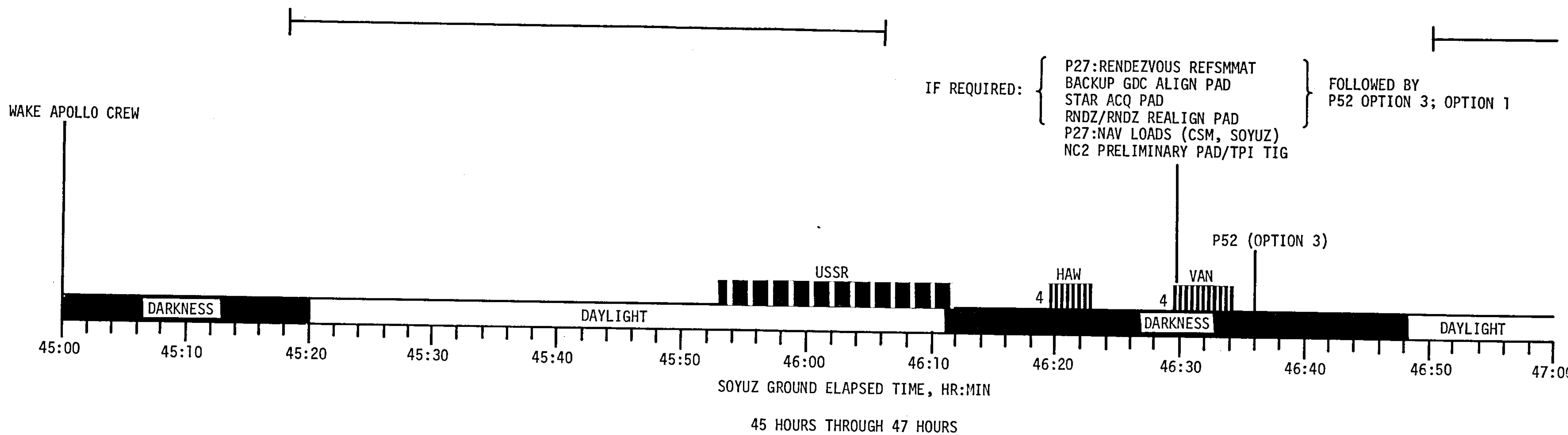


Figure 2-6. Rendezvous Timeline - M = 30 Profile (Continued)

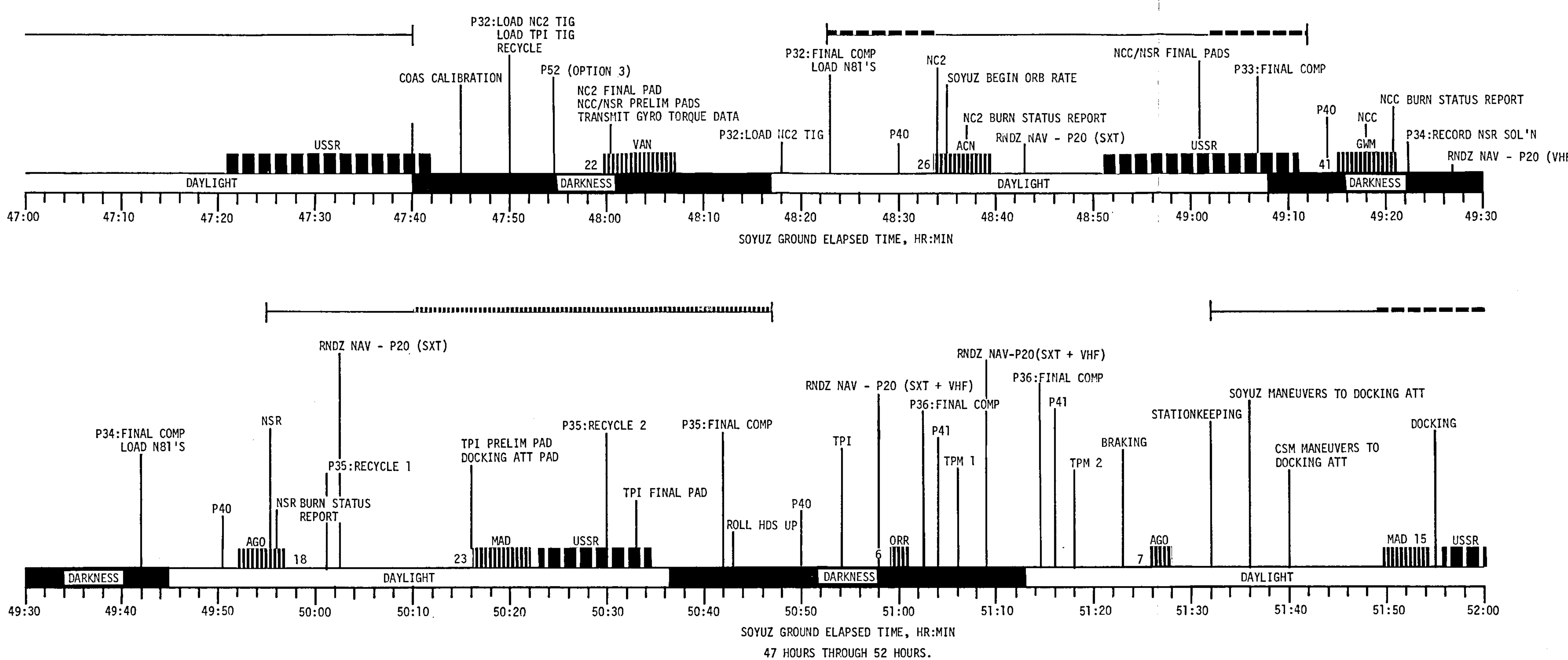


Figure 2-6. Rendezvous Timeline - M = 30 Profile (Concluded)

b) All SPS maneuvers (except TPI) are preceded by a 20-second, two-jet RCS ullage burn. TPI will utilize a 14 second, 4-jet burn so that the RCS is configured for the remainder of terminal phase, especially braking, where all quads and jets are active.

c) All rendezvous maneuvers except TPI and midcourse corrections are performed heads down. The rationale for a normal heads down attitude is:

1. Minimize attitude maneuver requirements from navigation attitude to burn attitude (NCC, NSR)

2. Provides good optics FOV for burn attitude checks when desired pre-ignition

3. Standardizes crew procedures

4. Provides the option of using the horizon for burn attitude check for local horizontal burns

5. Provides good hi-gain to ATS-6 visibility for communciations

<u>Note</u>: The terminal phase maneuvers are performed heads up to provide most desirable out-the-window monitoring of the Soyuz by the crew.

d) The MINKEY rendezvous sequence in the CMC will be utilized from NC2 through docking. This mode provides an automatic means of sequencing the various navigation, alignments, targeting, and thrusting tasks required to achieve rendezvous.

e) The standard checks and monitoring procedures the crew and/or ground perform repeatedly throughout the mission are:

1. Pulse integrating pendulous accelerometer (PIPA) bias check

2. Thrust vector control check

3. IMU drift check

4. Ignition attitude check (sextant star check)

5. Stabilization and control system (SCS) drift check

6. Gyro display coupler (GDC) align

7. Entry monitoring system (EMS) ΔV and null bias checks

8. SPS/RCS burn monitoring.

To minimize repetition in these flow charts, standard checks and monitoring procedures are simply inserted by title, while the detailed procedures for each of these checks appears in Appendix A. Rendezvous maneuver PAD formats are presented in Appendix C.

Finally, the following discussions have been formatted to provide a straightforward presentation of the major timeline activities that must be conducted. In some instances, they are not presented in the exact order they occur, especially in the case of ground uplinks.

2.5.1 AEM to ACM

After the evasive maneuver has been performed, the CSM will drift above and behind the S-IVB, and it is from this point that the rendezvous phase of the mission begins. The decision to initiate the rendezvous has essentially already been made since TD&E and the AEM were performed; however, this commitment is certainly minimal. The decision to execute the ACM will necessitate satisfactory operation of the ECS, the EPS, and either the GNCS or the SCS for maneuver execution and attitude control. Satisfactory operation of these systems, along with sufficient consumables to allow docking, some minimum docked time, and a retrofire sequence, are always prerequisites to continuing the rendezvous. Satisfactory systems operations and sufficient consumables will be assumed in this discussion from this point on.

2.5.1.1 ORDEAL Mounting

Shortly after the AEM, the crew will unstow and mount the ORDEAL box in the CSM. The ORDEAL is used throughout the rendezvous as a convenience for the crew and is not considered mandatory. However, in the event of CMC or IMU failures, it is required in order to compute HP65 solutions.

2.5.1.2 Burn Status Report (AEM)

About 10 minutes after the AEM, the CSM will be acquired over the VAN. At that time, the crew will provide a status report on the AEM. The major items of interest are any delays incurred or any ΔV residuals that were left untrimmed.

2.5.1.3 P52 Alignment

A P52 (Option 3) IMU realignment is performed about 25 minutes prior to the ACM. The gyro torque angles and the GET at which torquing was performed are passed to the ground shortly thereafter. This provides the ground with the platform drift information over the last three hours.

2.5.1.4 Ground Uplinks

Ground uplinks prior to ACM will consist of:

a) CSM and Soyuz state vectors

b) A PIPA bias update (if required)

c) The final ACM target load (P30).

2.5.1.5 Ground Updates

The following voice updates are made from the MCC-H to the CSM prior to the ACM:

a) ACM preliminary PAD

b) ACM final PAD.

2.5.1.6 Burn Preparation

Prior to beginning active burn preparations, the crew will update the DAP load by calling V48, and loading the CSM weight and the desired SPS pitch and yaw gimbal trim angles, all per the preliminary ACM PAD message. They will also load the DAP for 2-jet ullage. The CSM weight loaded will be the sum of the CSM and DM weights in order to provide accurate mass information for the TVC DAP.

About 15 minutes prior to the burn the crew will call P30 and verify that the ground uplinked values for N33 (TIG) and N81 (External ΔV components) match those on the final maneuver PAD. They will prepare the SPS for the maneuver per the SPS Burn Cue Card (Appendix B). P40 will be called about 4 minutes prior to the maneuver, and the crew can monitor time-to-go to ignition via N40.

2.5.1.7 ACM Burn

Following the standard 20-second, 2-jet RCS ullage burn, the SPS will ignite and a short maneuver will be performed (single bank) using the CMC short burn logic (i.e., no steering commands). Ignition slips are of little consequence for this burn, as they are for all of the early rendezvous maneuvers. In the event of serious timeline or system problem, the burn could be slipped an entire revolution with very little impact on the overall rendezvous profile. This maneuver and all ensuing rendezvous maneuvers, regardless of profile M-number, have two standard execution rules:

a) Maneuvers are terminated using the "tight" SPS limits:

FU/OX $\Delta P > 20$ and low P_c

FU/OX TK Press < 160 PSI and low P_c

$P_c < 80$ or drops 10 PSI

b) For G&N malfunctions (usually rates or attitude errors), take over and complete using SCS.

Most of the rendezvous maneuvers are so short, however, that these rules have limited application.

2.5.1.8 ACM Trim Rules

Following SPS shutdown, the X-axis residual is trimmed to within 0.2 fps. The other residuals are not trimmed, as that would waste RCS fuel for essentially no gain. The rendezvous is completely insensitive to the Y and Z residuals of this maneuver.

2.5.2 ACM to NC1

2.5.2.1 PGA Doffing

Immediately following the ACM, the crew will doff their PGA's which they have worn since prelaunch. PGA doffing and stowage are conducted utilizing checklist procedures.

2.5.2.2 Burn Status Report (ACM)

About 19 minutes after the ACM, the CSM will be acquired over ORR. At that time the crew will provide the ACM Burn Status Report if they have not previously done so via ATS-6. The standard Burn Status Report consists of the following information:

a) ΔTIG - ΔT that TIG was slipped (if TIG slip occurred)

b) ΔVC - The value of the EMS ΔV counter after trimming was concluded

c) FDAI Angles - The R, P, Y ball angles at which the untrimmed VG residuals were read, if this attitude is different from the ignition attitude

d) N85 - Any untrimmed VG residuals over 0.2 fps.

Since this report is standard, only changes from this report will be noted for all remaining discussions in this document.

2.5.2.3 Ground Uplinks

The ground will uplink the following data over HAW at 4 hr 22 min:

a) CSM State Vector

b) Gyro compensation update (if required).

The NC1 P30 target load will be uplinked via ATS-6 after the final maneuver has been computed.

2.5.2.4 Ground Updates

The ground will provide the following data via upvoice in this timeframe:

a) NC1 Preliminary PAD

b) NPC Advisory - Provides the crew with ground intentions concerning the execution of NPC

c) NC1 Final PAD

d) NPC Preliminary PAD (if required).

2.5.2.5 Burn Preparations

Eighteen minutes prior to the maneuver TIG on the final PAD, the crew will call P30 and verify N33 (TIG) and N81 (External ΔV components) per the final PAD. Additional time has been allocated in this timeframe to allow about 5 minutes for the maneuver to the NC1 attitude. (The CSM weight (V48) will have been loaded about a half-hour prior to this time, if required. The ground will pass a new CSM weight up with each preliminary maneuver PAD but the CMC WT estimate should differ from this by only a few pounds. These differences occur due to RCS and consumables usage. The crew will usually load the ground values, but crew discretion is the basic groundrule.) Prior to entering P40, the crew will call P00 and perform a V49 maneuver to the Final PAD burn attitude. They will then perform a sextant star check to verify the platform alignment. This procedure is as follows: (1) Drive sextant to indicated shaft and trunnion angles via V41N91, and (2) If star not in FOV, perform P52 Option 3. The SPS Burn Cue Card is followed and P40 is entered about TIG-4 min.

2.5.2.6 NC1 Burn

The NC1 burn should be a local horizontal posigrade maneuver. If NPC is required, a ΔV_Y component may be executed at NC1 to establish a node at an acceptable position relative to the maneuver line. As with ACM, TIG slips or even a one-revolution delay produces no significant penalty for any of the rendezvous profiles. A radial (ΔV_Z) component could be included in the maneuver for maneuver line location reasons, but this is improbable.

2.5.2.7 NC1 Trim Rules

Following SPS shutdown, the VGX residual is trimmed to within 0.2 fps. If a large out-of-plane or radial component were included in the maneuver, the crew will be advised not to trim the VGX residual, since it no longer represents the in-plane horizontal component which is the only component of interest.

2.5.3 NC1 to NPC

It is improbable that NPC will be required since small planar errors can be corrected in combination with the normal rendezvous, while large planar errors result from low probability LV failures. If NPC is not required, the crew will proceed immediately with the normal NPC to sleep period activities described in Section 2.5.4.

2.5.3.1 Burn Status Report (NC1)

The crew will provide the standard Burn Status Report over HAW about 14 minutes after NC1.

2.5.3.2 NPC Decision

The decision to execute the NPC was actually made prior to NC1. Depending on the location of the node, a ΔV_Y component might have been added to the NC1 maneuver to relocate the node. Per agreements with the crew, the nodal location will be established such that NPC will always occur between 45 and 68 minutes after NC1. This will always provide adequate time for all ground and onboard NPC preparations.

2.5.3.3 Ground Uplinks

The only uplink required in support of the NPC maneuver will be a CSM state vector which is uplinked about 30 minutes prior to the burn. Because of the use of P38 as the prethrust program, the crew must manually load the TIG and External ΔV targets as P38 would overwrite any uplinked values with its own computed values.

2.5.3.4 Ground Updates

The only ground update will be the final NPC maneuver PAD. The N22 information on the PAD (R, P, Y angles for the maneuver) will not be passed since the ground can only approximate the REFSMMAT the CMC will generate via P38 sequencing. The CSM-alone weight is included on this PAD message for loading into the DAP during presleep activity.

2.5.3.5 Burn Preparation

The crew will call V48, update the CSM weight, and specify 2°/sec attitude maneuver rates prior to entering P38. P38 is called about 20 minutes prior to TIG and the crew will manually load N33 and N81 using the final ground PAD. They will cycle into P40 and subsequently into P52, which is the MINKEY sequencing that provides for the pulse torquing of the platform to prevent gimbal lock problems during NPC. P52 will pulse torque the CSM platform 45 degrees in the same direction as the ΔV_Y component of the burn. This provides a 45-degree MGA for the burn, and a 315-degree MGA for an in-plane CSM orientation (or vice-versa). This alignment provides all necessary CSM maneuverability with no concern about gimbal lock. After the platform is aligned, the crew recycles into P40 and awaits the burn. The GDC is aligned (per Burn Cue Card procedures) identically with the IMU to provide maneuver takeover and completion capability.

2.5.3.6 NPC Burn

The NPC burn would probably be a pure out-of-plane maneuver, although some small ΔV_X component could be included to correct known phasing errors (e.g., resulting from an untrimmed NC1 residual). A large NPC, resulting from a significant LV navigation error, may provide the only opportunity to execute a dual bank SPS burn for the entire rendezvous sequence. After the burn, the CMC cycles back into P52 and the CSM platform is pulse-torqued back to its original alignment. Subsequently the GDC is realigned to the IMU. NPC is insensitive to TIG slips and can be scrubbed and rescheduled with no impact on ΔV requirements.

2.5.3.7 NPC Trim Rules

Small out-of-plane errors (due to vector uncertainty) will exist regardless of NPC execution, and result in some ΔV_Y components for NCC/NSR. Consequently, trimming the VGX residual merely wastes RCS fuel, and will not be done. However, the VGY residual is an in-plane ΔV_X component and will be trimmed to ± 0.2 fps to minimize phasing errors. It is unlikely that this residual will be large however, so very little trimming is anticipated.

2.5.4 NPC (or NC1) to Sleep Period

If NPC is executed, it is the last maneuver performed on day 1. Otherwise, NC1 is the final maneuver of the day. The presleep activity that follows the final maneuver is part of the rendezvous timeline and is included in this document for completeness.

2.5.4.1 Maneuver to Solar Inertial (SI)

Following the final maneuver, the crew will orient the CSM into the sleep attitude, SI + X-axis forward, per the checklist attitudes.

2.5.4.2 Burn Status Report

The crew will provide the ground with a Burn Status Report for the last maneuver (NC1 or NPC) over the first postburn STDN site.

2.5.4.3 Ground Uplinks

Prior to the crew rest period, the following uplinks are performed:

a) A CMC lift-off time update which will synchronize the CMC to Soyuz GET (see Section 2.5.4.7 for more details).

b) EMP 23 - This EMP is standard for sleep periods. By monitoring for jet-on failures, it provides protection against a stuck-on thruster, which could result in serious RCS losses if it occurred during an LOS period.

c) EMP 75 - This EMP will provide Hi-Gain antenna pointing angles for the crew to utilize in the event that they desire to manually acquire the ATS-6.

d) ATS-6 State Vector - The ATS-6 state vector will be uplinked into the OWS (Soyuz) slot in the CMC in support of EMP 75.

e) Rendezvous REFSMMAT - The nominal (OT) Rendezvous REFSMMAT is uplinked for use until immediately prior to NC2. This should minimize the number of flight plan attitude updates required to support activities in that time period.

2.5.4.4 Ground Updates

The only voice update nominally planned is the CSM-alone weight (over HAW at 5:56:00) which is loaded into the DAP during the presleep activity period.

2.5.4.5 P52

Following the REFSMMAT uplink, the crew will perform a P52 alignment sequence. If NPC was not performed, they first perform an Option 3, record the gyro torque information, and follow that with an Option 1 which coarse aligns the platform to the new orientation. The Option 3 information provides the ground with another drift check. If NPC was performed, the Option 3 data would be useless because of the pulse-torquing that went on in support of the burn, so only the Option 1 is performed. In both cases, the Option 1 gyro torque data is recorded and passed to the ground later.

2.5.4.6 GDC Align

Immediately after the P52, the GDC will be aligned to the IMU per standard procedures.

2.5.4.7 DAP Load

Prior to the sleep period, the CSM-alone DAP will be replaced by the CSM/LM-Ascent DAP since it provides for more efficient usage of RCS for attitude control in the CSM/DM configuration. This DAP is standard for the CSM/DM configuration where no SPS thrusting is planned. The DM weight (≈4500 lbs) is loaded into the LM slot and the CSM weight (see Section 2.5.4.4) is loaded into the CSM slot. Additionally, a 5° DB and 0.2°/sec maneuver rate are also specified.

2.5.4.8 GET Update

A GET update (lift-off time update) is performed prior to the sleep period. This update will place the CMC and the MCC-H on Soyuz GET, the designated timebase for the remainder of the mission. This entails stepping all GET clocks forward by about 7.5 hours. The exact value of this update is the precise delta between the Soyuz lift-off time and the Apollo lift-off time. The lift-off time uplink mentioned in Section 2.5.4.3 will effect the CMC update, while the update for the ground system is coordinated by the Flight Dynamics Officer, after the CMC is updated.

2.5.5 PCM (Day 2)

Although the PCM is nominally not executed, it will probably be required in real time as a small RCS maneuver. It will correct for any dispersions in the Soyuz circularization maneuver as well as those resulting from unpredicatable drag variations.

2.5.5.1 Ground Uplinks

The ground will uplink the following loads in support of the PCM:

a) CSM State Vector

b) PCM Target Load.

2.5.5.2 Ground Updates

The ground will provide a PCM maneuver PAD prior to the start of burn preparations.

2.5.5.3 P52/GDC Align

The crew will perform an Option 3 to remove any accumulated drift and pass the gyro torque data to the MCC-H. The GDC will be aligned to the IMU prior to the maneuver.

2.5.5.4 Burn Preparation

Since any required PCM will almost certainly be an RCS maneuver, the required burn preparations are relatively simple. The crew must perform the P30/P41 computer cycling and insure the RCS is configured for the desired translation (2 or 4 jet). The DAP maneuver rate and DB will also be updated to .5°/sec and .5 deg, respectively.

2.5.5.5 PCM Burn

The PCM burn is insensitive to TIG slips, and since it would be an RCS maneuver, takeover and completion criteria do not really apply. The burn should be a local horizontal maneuver; however, the direction (posigrade or retrograde) is unpredictable.

2.5.5.6 PCM Trim Rules

The VGX component will be executed to within ± 0.2 fps, or, in the remote event that an SPS maneuver was required, the VGX residual will be trimmed to within ± 0.2 fps.

2.5.6 Wake-Up to NC2

The crew will awake approximately 3-1/2 hours prior to NC2. After the standard postsleep operations, the following items are performed in support of the NC2 maneuver.

2.5.6.1 Ground Uplinks

The following uplinks will be performed pre-NC2:

a) CSM State Vector

b) Soyuz State Vector

c) Rendezvous REFSMMAT Update (if required).

> NOTE: REFSMMAT update is required if OT REFSMMAT differs from real time computed REFSMMAT by:
>
> PITCH $> \pm 5°$
>
> YAW $> \pm 2°$.

Nominally, these will be the last uplinks during the rendezvous sequence.

2.5.6.2 Ground Updates

The following up-voice data is supplied pre-NC2:

a) NC2 Preliminary PAD

b) TPI TIG

c) Backup GDC Align PAD (if required)

d) Star Acquisition PAD (if required)

e) IMU Realign PAD (for CMC-failure checklist) (if required)

f) NC2 Final PAD

g) NCC Preliminary PAD

h) NSR Preliminary PAD

Items c, d, e are supplied only in the event that the nominal (OT) rendezvous REFSMMAT is not acceptable for the remainder of the profile.

2.5.6.3 P52

About 46 hrs 30 min SGET, the crew will perform a standard P52 Option 3. They will follow this with an Option 1 to the new REFSMMAT if required. Another Option 3 is performed about an hour later. This is the final P52 during the rendezvous sequence. The gyro torque data for all options are passed to the ground at the first opportunity after they are recorded.

2.5.6.4 GDC Align

The GDC is realigned to the IMU after each P52.

2.5.6.5 COAS Calibration

About 47 hrs 45 min SGET (immediately after the 2nd P52 Option 3), the crew performs a COAS calibration which is designed to determine the actual COAS LOS in its mounted position. This procedure reduces the COAS pointing error to about 0.5 degree, which is as accurate as this instrument can be calibrated. This makes the COAS an adequate replacement for the sextant during terminal phase should the sextant fail.

2.5.6.6 CMC Loading/Preparation

About 56 minutes prior to NC2, the crew will call P32 and initialize the CMC for active rendezvous maneuver computations. They will load NC2 TIG (N28) and TPI TIG (N37) from the preliminary PAD and compute an NC2 maneuver. This is done simply to verify that the CMC is loaded and performing properly; the solution itself has no significance other than it would be reasonably close to the ground's preliminary solution. The maneuver is recomputed using the NC2 TIG on the final PAD at TIG - 12 minutes. After the CMC solution is computed (and recorded), they will overwrite the N81 values (ΔV components) with those on the final PAD.

2.5.6.7 Burn Preparation

In addition to the CMC-related procedures mentioned above, there are several premaneuver functions that must be performed. The DAP is reconfigured to a CSM-alone configuration where the CSM weight is the total CSM + DM weight (available on the preliminary PAD). The DAP DB and maneuver rate are also updated to .5° and .5°/sec. Both EMP's (Jet-On Monitor and Hi-Gain Antenna Pointing) are terminated early in the timeline. Several ECS purges/dumps are accomplished and the S/C is generally configured for the upcoming rendezvous activity. The SPS Cue Card contains the final burn preparations, initiated about TIG - 10 minutes.

2.5.6.8 NC2 Burn

The NC2 maneuver is nominally a retrograde burn performed in a heads-down attitude. This maneuver, although not sensitive to small TIG slips, must be performed or docking is delayed at least one revolution.

2.5.6.9 NC2 Trim Rules

The VGX residual is trimmed to written ± 0.2 fps.

2.5.7 NC2 to NCC

2.5.7.1 Burn Status Report (NC2)

NC2 may well occur over ACN, in which case the ground will monitor the burn and require only limited burn status data (i.e., ΔV_c). If the maneuver occurs prior to ACN, however, a regular burn status report should be transmitted over ACN.

2.5.7.2 Soyuz Attitude Maneuver

Just prior to NC2, the Soyuz will begin an orbit rate attitude profile, abandoning the Solar Inertial mode it had been in prior to that time. This mode will provide optimum navigation opportunities considering the Soyuz beacon (sextant tracking) and the location of the VHF antenna (VHF ranging).

2.5.7.3 Ground Updates

The only ground updates passed in this period are the NCC and NSR final PADS. These PADS will be voiced up via the ATS-6, or, in the event that communications link is unavailable, through the USSR communication network.

2.5.7.4 Sextant Tracking

Prior to initiating rendezvous navigation, the crew initializes the W-matrix update limits to 10,000 ft and 10 fps. The crew will then perform sextant navigation on the Soyuz from TIG - 36 minutes until TIG - 12 minutes. This navigation period is totally in daylight (i.e., reflected sunlight) and does not utilize the Soyuz beacon.

2.5.7.5 Burn Preparations

Prior to final computation, the crew will perform a weight update in the CMC, if required. The remainder of the burn preparations are essentially confined to selecting the NCC solution to execute and the standard SPS Cue Card configuration procedures. There are two NCC/NSR matched pair solutions available - the CMC and the ground. The CMC solution will be executed as long as it agrees with the final ground solution within the following tolerances:

$\Delta VX = \pm\ 1.5$ fps

$\Delta VY = \pm\ 7.0$ fps

$\Delta VZ = \pm\ 10.0$ fps.

If the ground solution is selected for execution, the crew must manually overwrite the P33 final computation N81's with the PAD values. The ground will procedurally insure that the TIG on the final PAD is precisely the same as the CMC TIG, therefore, that value need not be loaded with the N81's. (This TIG control is required to insure that the voting logic is valid.) Following these operations, the SPS Burn Cue Card becomes the preburn checklist.

2.5.7.6 NCC Burn

The NCC maneuver is a Lambert burn (CMC steering) and is the most sensitive maneuver in the entire profile. Small TIG slips are allowable but do cause TPI slips and off-nominal approaches. If the maneuver cannot be executed, TPI will slip at least two revolutions. The magnitude of the slip depends upon the SPS fuel available to re-establish the proper phasing conditions. The maneuver will generally have three components, but should be primarily a local horizontal posigrade burn.

2.5.7.7 NCC Trim Rules

Due to the extreme sensitivity of TPI to the NCC maneuver execution, the NCC residuals are trimmed to ± 0.2 fps in all axes.

2.5.8 NCC to NSR

2.5.8.1 NSR Computation

Immediately after the NCC residuals are trimmed, the crew cycles the CMC into P34, which recomputes the NSR solution. This solution (assuming the original CMC solution was executed) should be the same as the preburn NSR solution with the exception of those minor changes caused by the untrimmed VG-residuals (± 0.2 fps). This solution is considered the "matched pair" solution to the original CMC solution. If the ground NCC was executed, the final PAD NSR solution is considered the "matched pair" solution even though it does not consider the effects of the untrimmed residuals. The error in this solution is negligible however, as long as the residuals are trimmed to their specified level.

2.5.8.2 Burn Status Report (NCC)

NCC should occur immediately prior to, or over, the GWM site. If so, the ground will monitor the burn and require only an abbreviated burn report. An additional information requirement will now exist for this, and the remaining, rendezvous maneuvers. The crew is to transmit the N81's that were loaded via P33. This is required when the ground does not have coverage for the final computation/voting logic timeframe. This information is required for the ground to model the executed maneuver correctly.

2.5.8.3 VHF Tracking

After NCC, the CSM/Soyuz relative range is within the capability of the VHF ranging system to measure (≈ 146 n mi). Accordingly, VHF ranging is initiated shortly after acquisition. After lock-on, the crew will initiate R27 and enable VHF updates to the CMC. These ranging marks are incorporated between NCC and NSR merely to maintain a more accurate relative state, which in turn, results in a slight statistical improvement in TPI slips. Sextant navigation is not available in this period since it occurs in darkness and the Soyuz tracker light is not visible at these ranges.

2.5.8.4 HP65 Solution

The onboard charts, which have been carried in chart form since Gemini, will be programmed in an HP65 "pocket" computer for ASTP. The first available HP65 solution is an NSR solution which nominally has no purpose other than insuring proper procedural usage. In the event of questionable NCC execution however, this solution becomes the prime solution for execution as an "unmatched" NSR. The rationale for this decision was:

a) Although an "unmatched" CMC solution using VHF ranging would be available, the kinds of problems that cause questionable maneuver execution also result in questionable CMC solutions.

b) The ability of the ground to provide an "unmatched" NSR is marginal because of limited coverage and the short duration between NCC and NSR.

The NSR HP65 solution is computed using 5 range marks (taken at 4-minute intervals) off the EMS range display. Although the EMS range readout guarantees HP65 data in the event of a failed CMC, the crew may opt to use the CMC R27 range readout for the HP65 data in the normal operation. This is crew option and applies to all other HP65 solutions as well.

The HP65 solution for NSR consists of a ΔV_X and a ΔV_Z component. TIG is forced to be NCC TIG + 37 minutes. The HP65 does not compute a ΔV_Y component because VHF ranging data is insufficient to compute that parameter.

2.5.8.5 Burn Preparation

A CSM weight update is performed prior to final computations, if required. Final computation is initiated at TIG - 12 minutes, and this solution is nominally written over with "matched pair" solution discussed in 2.5.8.1. The SPS Cue Card is again used for final burn preparations.

2.5.8.6 NSR Burn

NSR will generally be a three component maneuver but the primary component should be local horizontal posigrade. The maneuver directly affects TPI time as it essentially forces the ΔH. Accordingly, TIG slips are undesirable and if the maneuver is not performed, TPI slips at least two revolutions.

2.5.8.7 NSR Trim Rules

NSR is trimmed to within ± 0.2 fps in all axes due to its significance in controlling TPI time and the planar conditions.

2.5.9 NSR to TPI

2.5.9.1 Burn Status Report (NSR)

Since AGO coverage of NSR is probable, an abbreviated burn report will be given. In the event that this coverage is not provided, a standard report plus the applied ΔV components is required.

2.5.9.2 Ground Updates

The following data is up-voiced prior to TPI:

a) TPI Preliminary PAD

b) TPI Final PAD

c) Docking Attitude PAD.

The final TPI PAD will be transmitted via ATS-6 with the USSR network as a backup due to STDN coverage limitations.

2.5.9.3 Sextant Tracking

Sextant navigation on the Soyuz will be conducted for about 40 minutes between NSR and TPI. All but the last seven marks occur in daylight, which reduces the impact of a failed Soyuz beacon to a minimal level. The marks may be taken in the standard one-per-minute format or may be "batched" in two groups of 12 marks, taken at the beginning and the end of the tracking interval. This is a crew preference item. VHF ranging data, though available in this timeframe, will not be included in the CMC navigation process. The primary reason for this is to preserve the independence of the CMC and chart solutions, as well as a slight statistical degradation in the CMC TPI solution resulting from dual sensor operation.

2.5.9.4 HP65 Solution

The HP65 solution for TPI will be computed based on 5 VHF range marks. These marks are taken at TPI-32, 28, 24, 23, and 16 minutes. The HP65 solution for TPI consists of a TIG, and the ΔV_X and ΔV_Z maneuver components. In the event that this solution is to be executed, the ground ΔV_Y is performed along with the HP65 in-plane solution.

2.5.9.5 TPI Slip Logic

In general, the most dramatic effect of maneuver execution errors, navigation uncertainties, and other such dispersions, is that TPI TIG moves. TPI TIG is computed based on the occurrence of the nominal 27-degree elevation angle of the LOS between the CSM and the Soyuz. This angle, in conjunction with the 130 degrees transfer between TPI and TPF, provides the desired approach geometry and relative vehicle rates. However, these desirable approach conditions must be foregone in the event TPI slips greater than ± 10 minutes due to more significant lighting and communication constraints. While late TPI slips present no particular pre-TPI timeline problems, early slips would force the TPI final computation and the 2nd recycle to be almost concurrent, which is undesirable. In order to prevent this situation, and provide a reasonably nominal timeline for TPI slip situations, a special logic box was inserted in the checklist.

```
*****TPI EARLY/LATE LOGIC*********************************************
* 1ST RECYCLE                                                        *
*  IF 2 SOLUTIONS INDICATE TIG SLIP>+8 MIN FROM PRE-NC2 N37(Pg 1-12) *
*  • ADJUST LOCATION OF 2ND RECYCLE ±8 MIN                           *
*                                                                    *
* 2ND RECYCLE                                                        *
*  IF CMC SOLUTION INDICATES TIG SLIP>±10 MIN FROM PRE-NC2 N37:      *
*  • USE CMC TIG OPTION:                                             *
*      RECALL P35, PRO TO N37, LOAD PRE-NC2 N37+10 MIN               *
*      PRO TO N55, SPECIFY TIG OPTION (V22E, +E)                     *
*  • CONTINUE HP-65 SOLUTION FOR FINAL ΔV COMPARISON                 *
*  • AT FINAL COMP-USE NOMINAL COMPARISON LOGIC                      *
*      IF ALL COMPARISONS DISAGREE-BURN THE SOLUTION                 *
*      WHOSE TIG (CMC 2ND RECYCLE, STDN PREL PAD)                    *
*      COMPARES CLOSEST WITH HP-65 TPI TIG 2.                        *
**********************************************************************
```

The first part of this logic ensures a reasonable timeline by rescheduling the 2nd recycle if indications are that TPI will slip more than 8 minutes early. (These early indicators should be accurate to within 3-4 minutes.) The second part of the logic is designed to do two things:

a) Force the CMC to compute a TIG option solution with TIG at ± 10 minutes for those cases when the CMC elevation angle solution slips greater than 10 minutes (from the nominal).

b) Establish a new voting procedure for the final solutions in the event that no agreement between solutions is reached. This new logic is necessitated by the fact that both the ground and the CMC final solutions may very well be a TIG-option solution, while the HP65 is incapable of computing this type solution. (It is constrained to compute an elevation angle solution.) This new logic simply compares the TIG times of the three solutions (CMC recycle, ground Preliminary PAD, HP-65) that will always be computed on elevation angle and assumes that if the TIG time between solution A and the HP65 agreed at that preliminary stage, then that same solution would agree with the HP65 at final computation had it been run using the elevation angle option.

2.5.9.6 Burn Preparation

Prior to TPI, several changes are made to the basic vehicle control configuration, primarily to establish the desired RCS configuration for terminal phase LOS control and braking. Four-jet translation for ullage maneuvers is enabled along with a higher vehicle maneuver rate (2 deg/sec). The HDS UP flag is set in MINKEY, and after final comp the crew will roll 180° so that TPI is performed in a heads-up attitude (local roll = 0 degree). Additionally, the crew will set R_3 in N78 to zero. This is the register which defines the roll attitude for the preferred tracking orientation. (The HDS UP flag would cause this register to be zeroed only if MINKEY were exited.) This mode is established at this time primarily to minimize the post-TPI attitude maneuver required to orient the vehicle for the TPM1/TPM2 tracking attitude which must be heads up. A final CSM WT update (V48) is also performed (if required). ORDEAL is also realigned prior to TPI for post-TPI usage.

There will be three solutions available for the TPI maneuver. These are, in order of priority:

a) CMC

b) HP65

c) Ground.

Generally, the highest priority solution of the agreeing solutions will be executed. Agreement is defined as:

$\Delta V_X \pm 1.5$ fps

$\Delta V_Y \pm 3.0$ fps

$\Delta V_Z \pm 3.0$ fps.

TPI ignition will be the TIG time of the solution chosen after applying the voting logic. If the ground or the HP65 solution is selected, it will be loaded into the CMC (overwrite N37 and N81 after recalling P35) for execution. Additionally, the crew must select the TIG option of P35 by entering V22E, + E on the N55 display.

2.5.9.7 TPI Burn

TPI will be a short SPS maneuver in the heads-up attitude. Lambert steering is utilized, so small TIG slips can be tolerated. Failure to perform TPI will slip docking by at least three revolutions. Although the nominal TPI produces burn components such that the + X-axis of the spacecraft is essentially pointed at the Soyuz, dispersions will undoubtedly alter this convenient pointing reference. TPI should however, be a pitch-up, posigrade type burn.

2.5.9.8 TPI Trim Rules

The TPI burn residuals are trimmed to within 0.2 fps in all axes.

2.5.10 TPI to Docking

This phase of the rendezvous is the most difficult and the most critical. The ground can provide essentially no trajectory assistance due to limitations of time and coverage. Accordingly, little air-to-ground interface is required for this phase. There are no uplinks or updates and even the TPI Burn Report has been omitted to ease the timeline. It is anticipated however, that the crew will nominally advise the ground on the execution of TPI, and would certainly report any maneuver anomalies.

2.5.10.1 Sextant/VHF Tracking

The crew will perform both sextant and VHF navigation in the tracking intervals prior to both midcourses. Each midcourse is preceded by a seven-minute tracking interval during which 7 marks with each sensor are taken. The tracking intervals end about three minutes prior to each burn. The primary purpose for using both sensors in this timeframe is to obtain accurate solutions in a short time, utilizing the significant geometry changes that occur between TPI and braking. The COAS is utilized in the event sextant tracking is not available. There is no backup for the VHF system, but sextant only solutions, though less accurate than dual sensor solutions, are acceptable.

2.5.10.2 HP65 Solutions

The HP65 will be utilized to provide backup solutions for both maneuvers. Each midcourse is calculated using two range marks and two angle readings (elevation). These solutions require VHF ranging, the sextant or the COAS, and the ORDEAL (which can be backed up by the CMC).

2.5.10.3 Maneuver Selection Logic

No formal voting logic between the CMC and HP65 solutions is documented in the checklist. There are too many variables involved in this process to set down a straightforward procedure. The basic groundrules are:

a) The CMC and the HP65 solutions are considered essentially equivalent, although the CMC is given priority.

b) The crew will maintain a polar plot which will indicate the direction and, to a lesser degree, the magnitude, of the required correction. This plot is utilized to break ties between the two available solutions in the event of significant disagreement.

The groundrules are always modified by the circumstances leading up to terminal phase, especially the performance of the individual systems involved.

2.5.10.4 TPM1/TPM2 Execution

After selecting the maneuver to be executed, the crew will immediately prepare for the maneuver. (If the HP65 solution is chosen, the P36 N59 ΔV_X and ΔV_Z LOS components must be overwritten after final computation.) P41 is then automatically called via MINKEY as midcourses are always performed with the RCS. The maneuvers are executed to within ± 0.2 fps in all axes as displayed on N85.

2.5.10.5 Braking

Terminal phase braking begins immediately prior to the point where the relative vehicle range equals 1 n mi. The crew will observe the Soyuz in the COAS and null the LOS rates continuously. At the same time, they will observe the following braking gate schedule:

Range (n mi)	Range Rate (fps)
1.00	30
.50	20
.25	10
.08	5

Braking is performed such that range rate never exceeds the appropriate "gate" value. From .08 n mi (500 feet) to station keeping, the crew will maintain a small closing rate (< 5 fps) per their discretion. All relative rates are nulled to zero at station keeping (50-foot range), with the CSM directly in back of the Soyuz, pointing CSM + X-axis at Soyuz + X-axis.

2.5.10.6 Maneuvers to Docking Attitude

In order to provide ATS-6 coverage for the initial docking, the CSM must roll approximately 60 degrees (CCW). Consequently, the Soyuz must also roll 60 degrees to maintain the proper relative orientation with the CSM. Procedurally, the Soyuz will perform its maneuver first, followed by the CSM. The docking attitude update, voiced up prior to TPI, is used to perform an automatic CMC maneuver (V49) to obtain the initial docking attitude. Final attitude for docking is controlled manually by the commander as he sights on the docking target during the final closing period. Docking will nominally occur shortly after LOS of MAD at 51 hrs 55 min SGET.

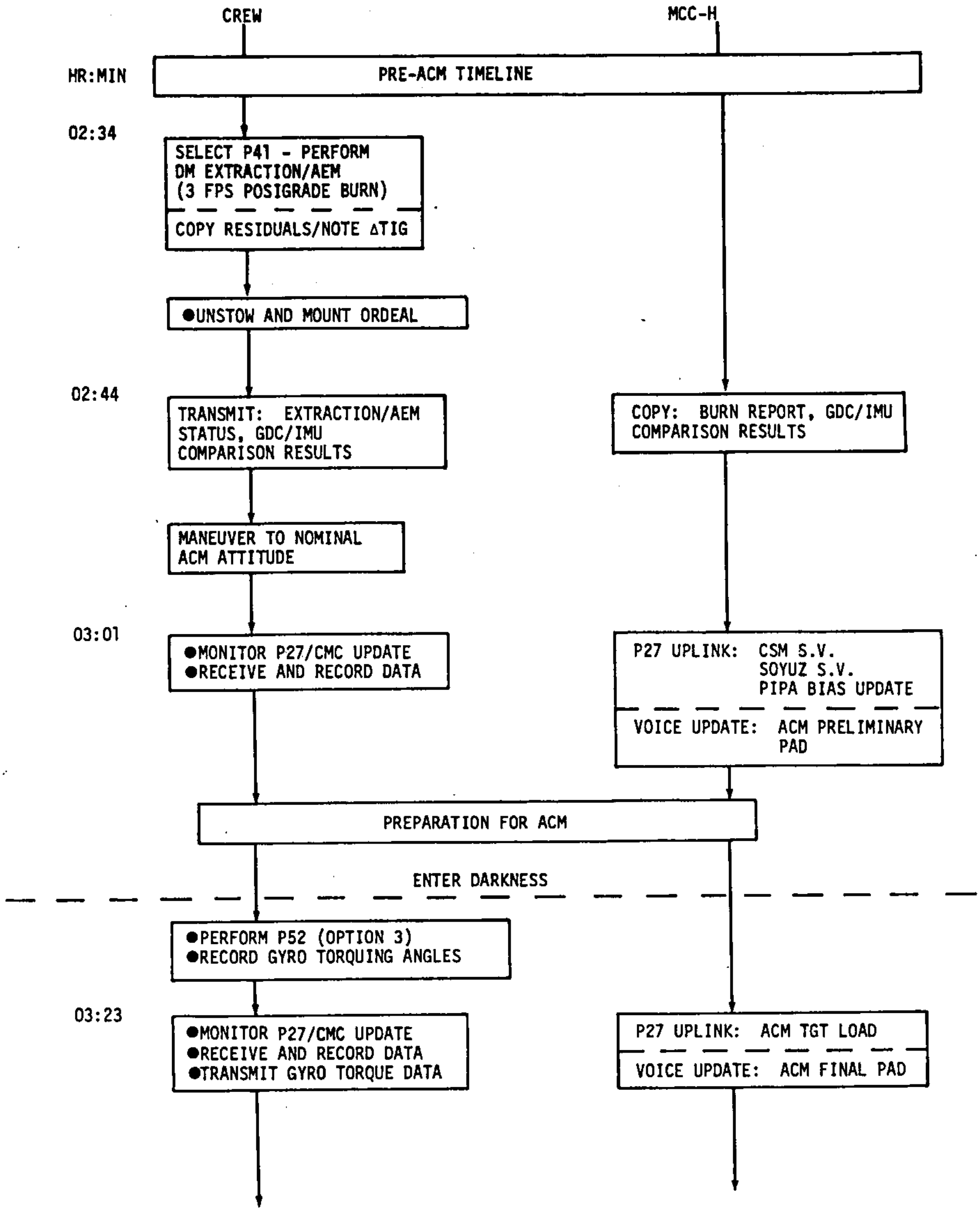


Figure 2-7. M = 30 Flow Chart

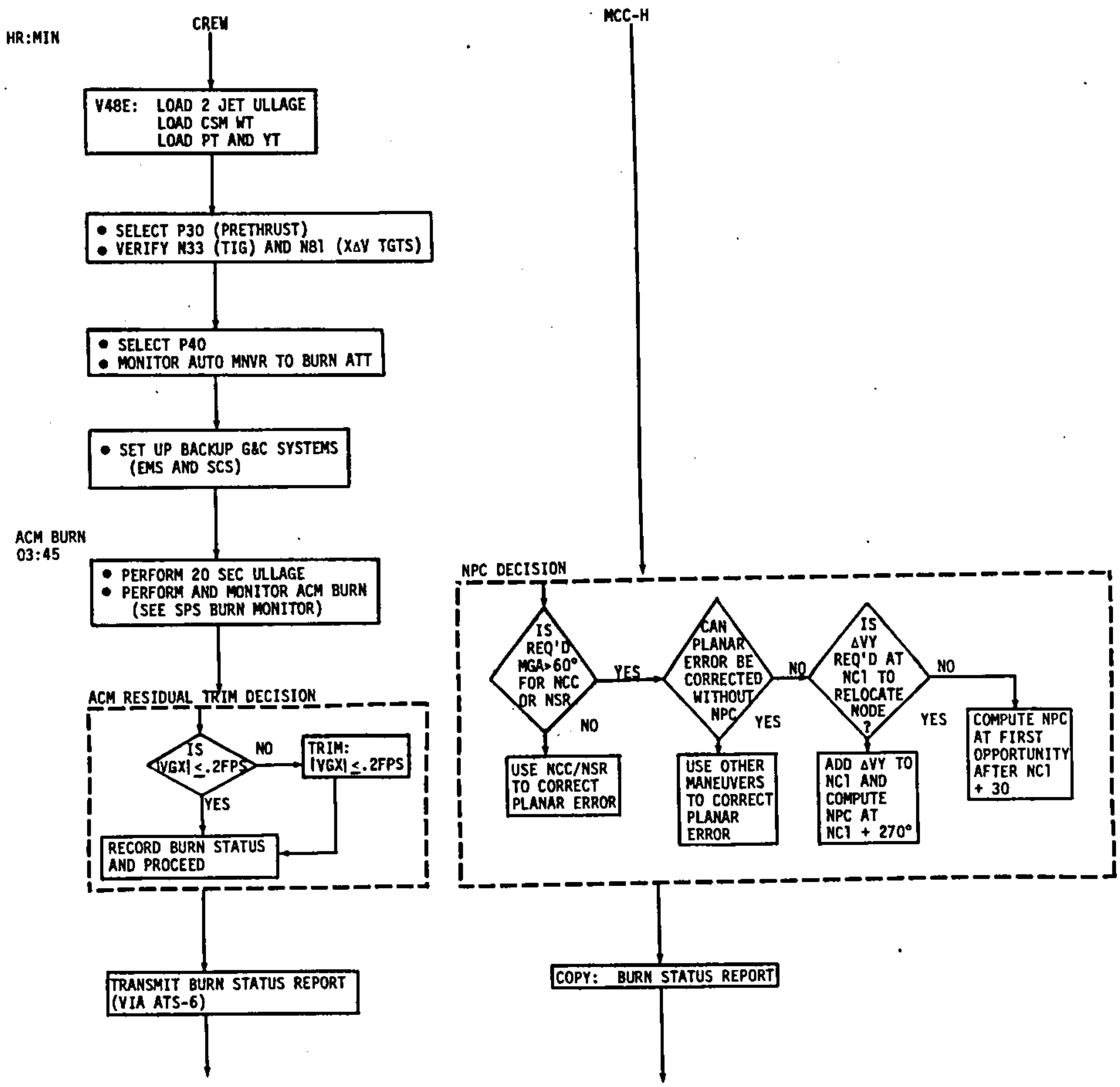


Figure 2-7. M = 30 Flow Chart (Continued)

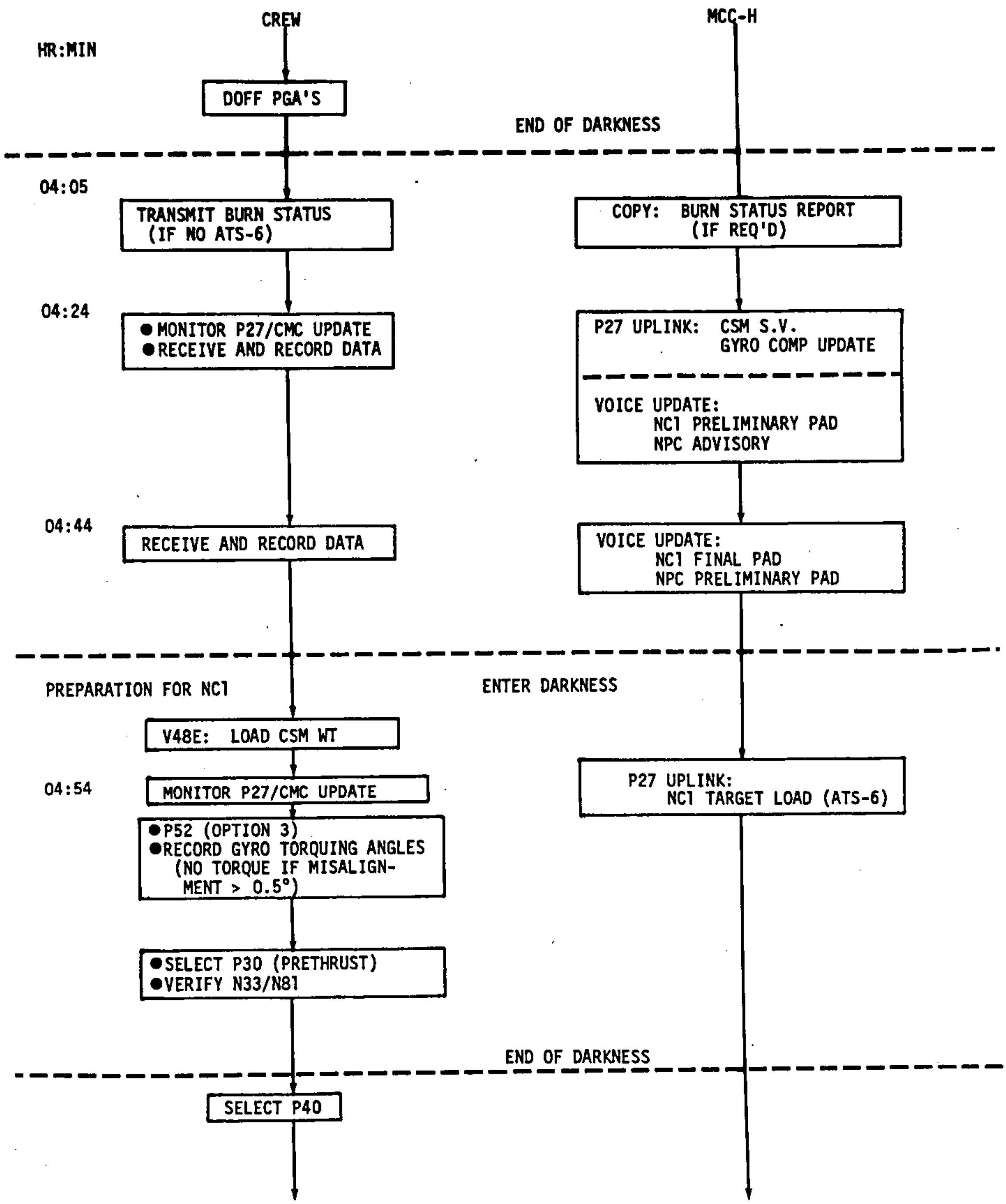


Figure 2-7. M = 30 Flow Chart (Continued)

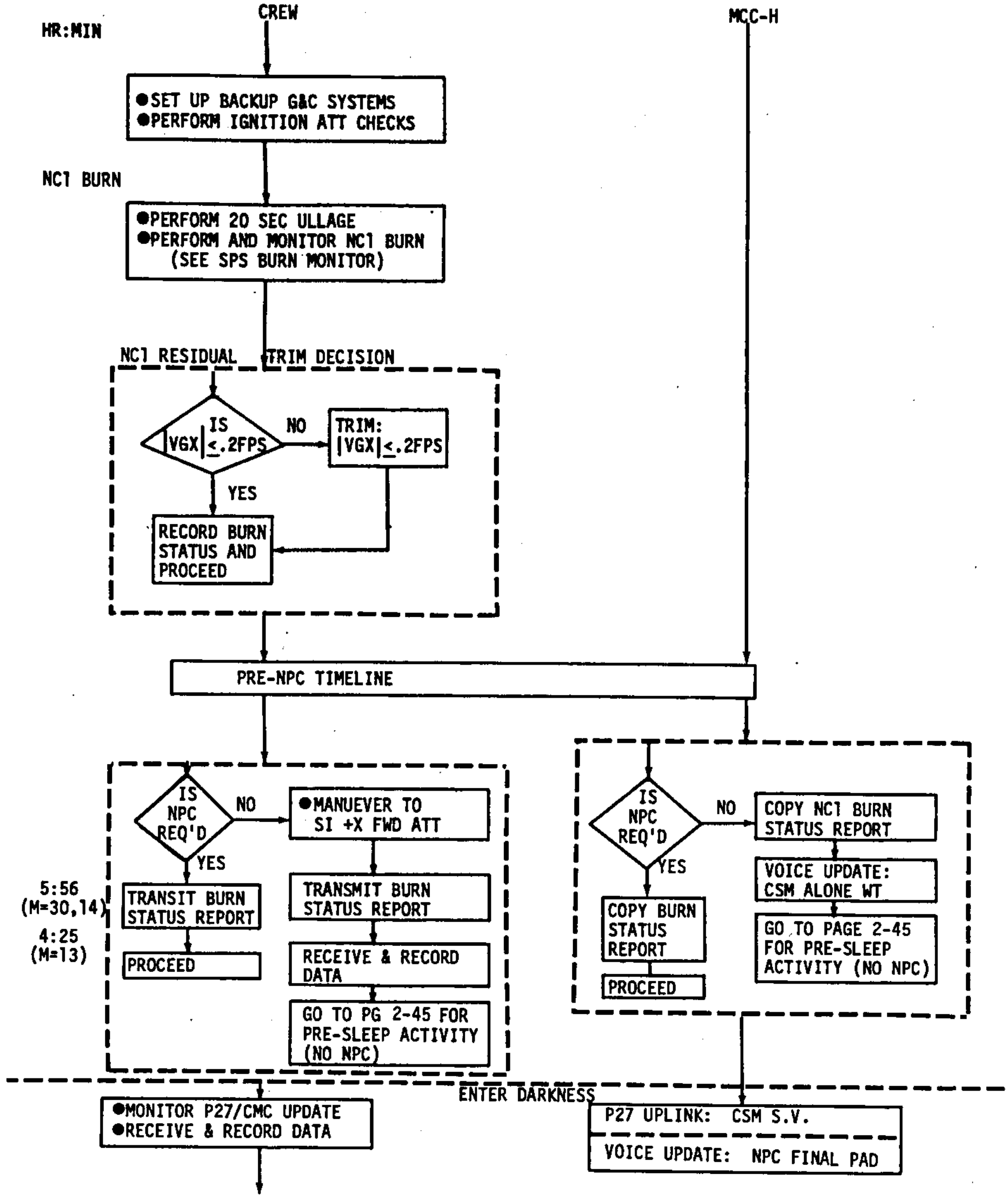
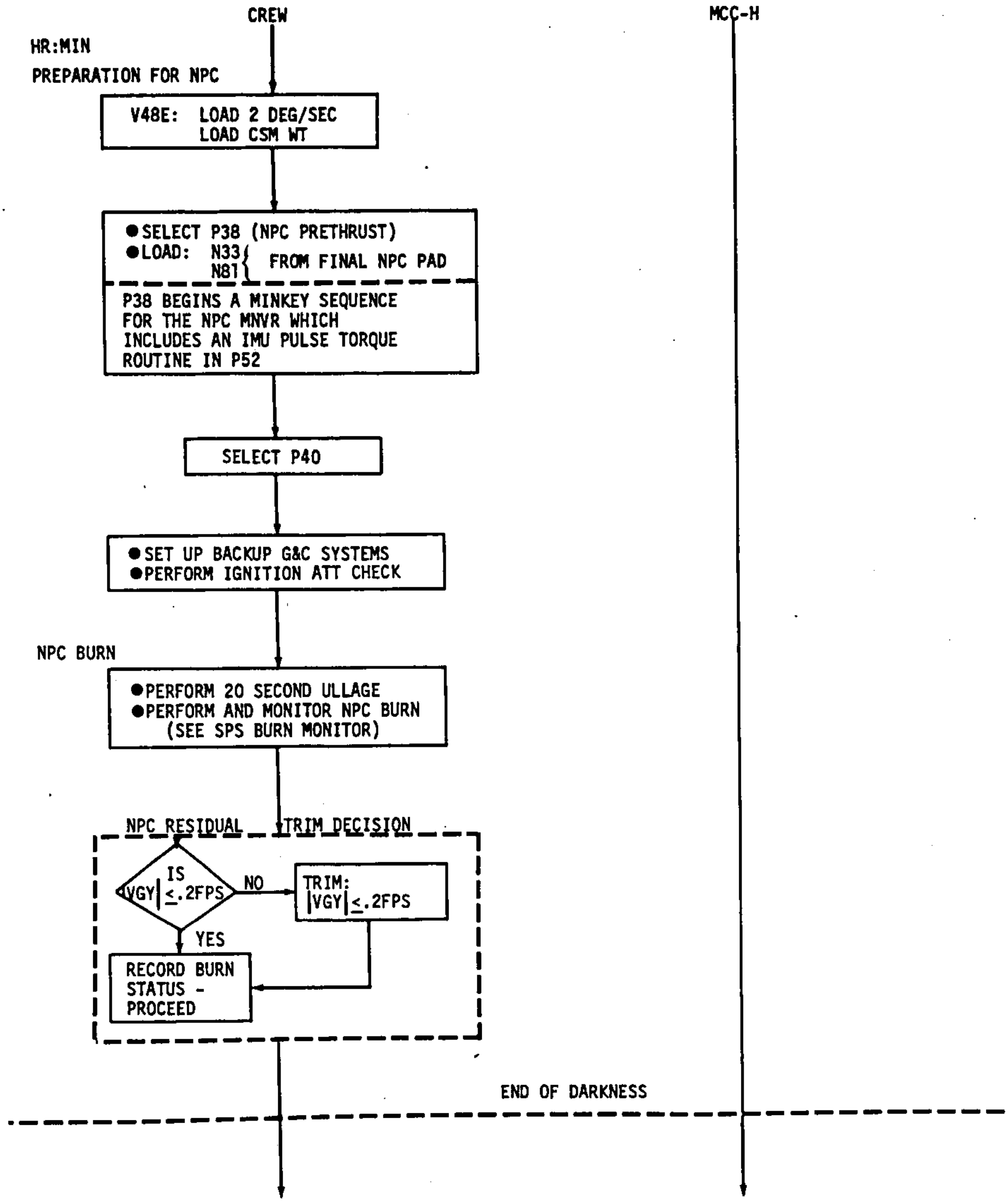


Figure 2-7. M = 30 Flow Chart (Continued)



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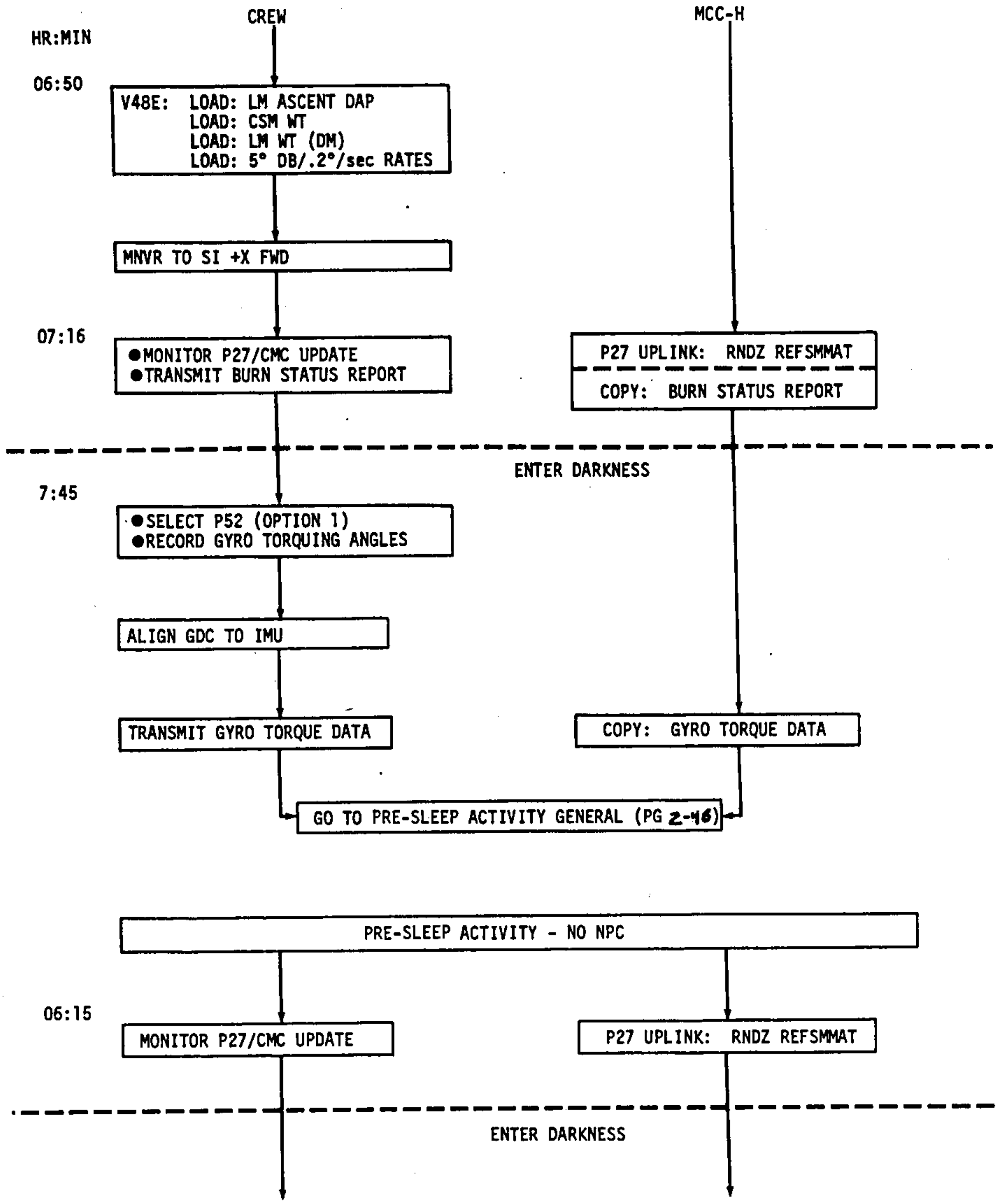


Figure 2-7. M = 30 Flow Chart (Continued)

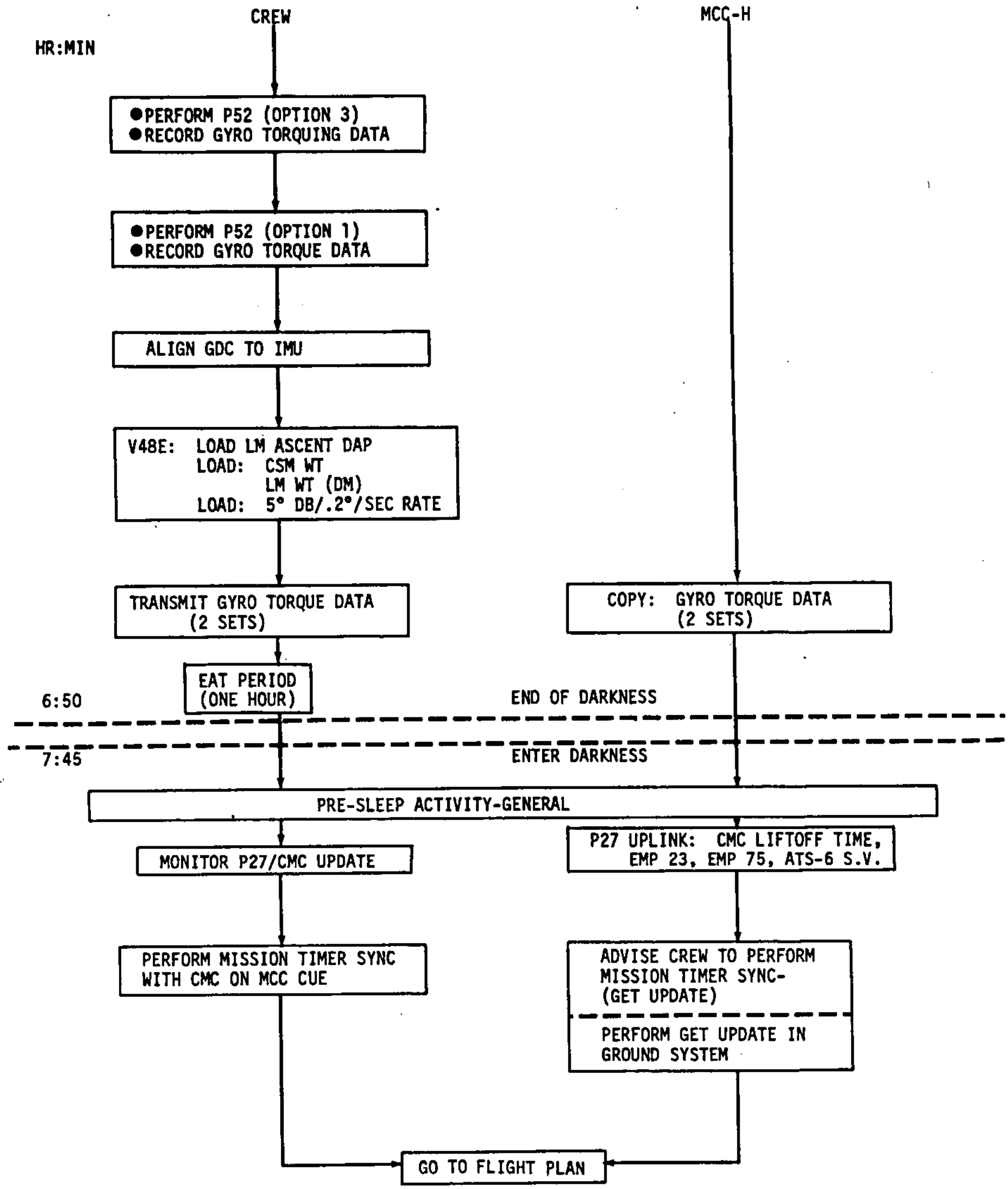


Figure 2-7. M = 30 Flow Chart (Continued)

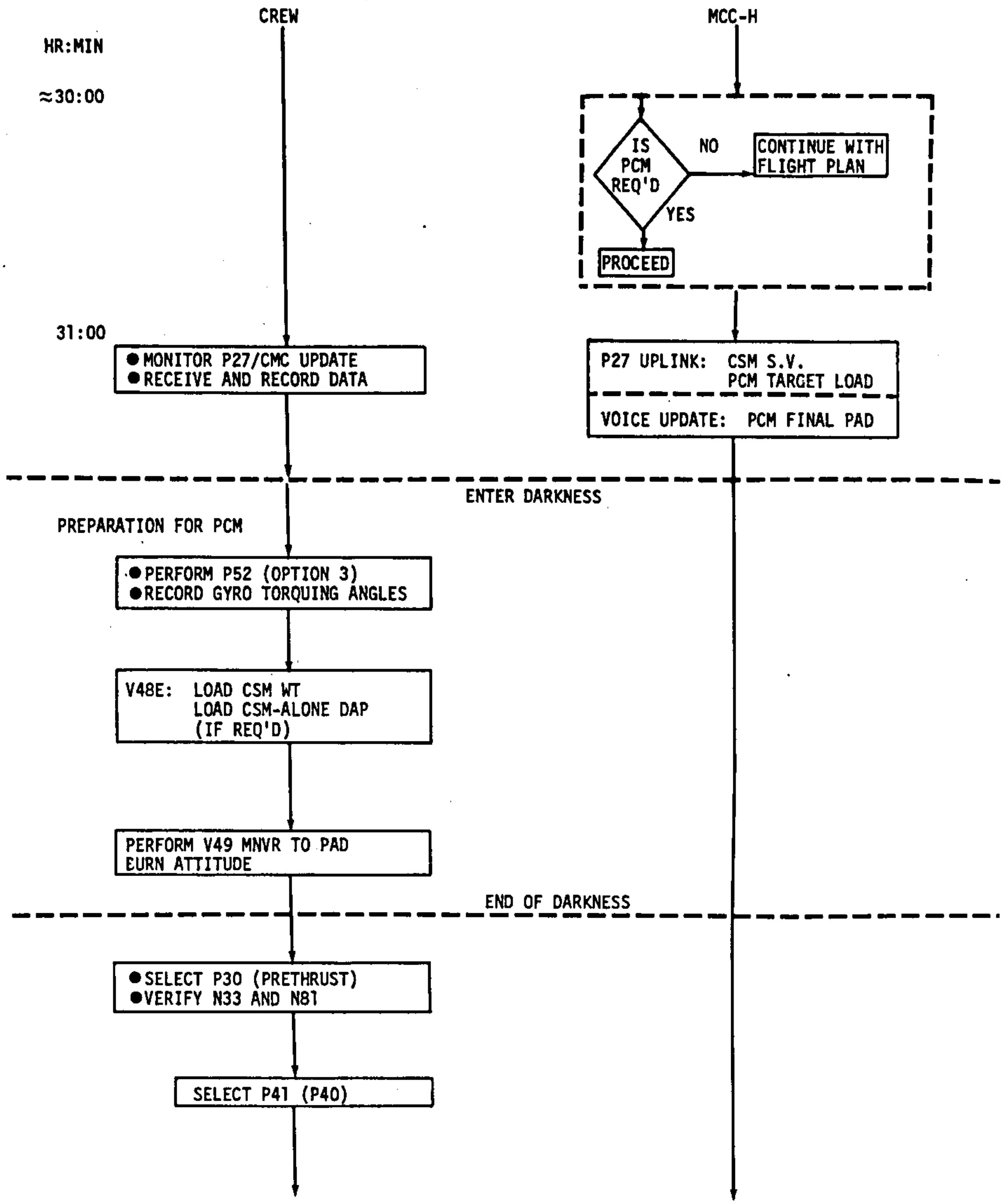
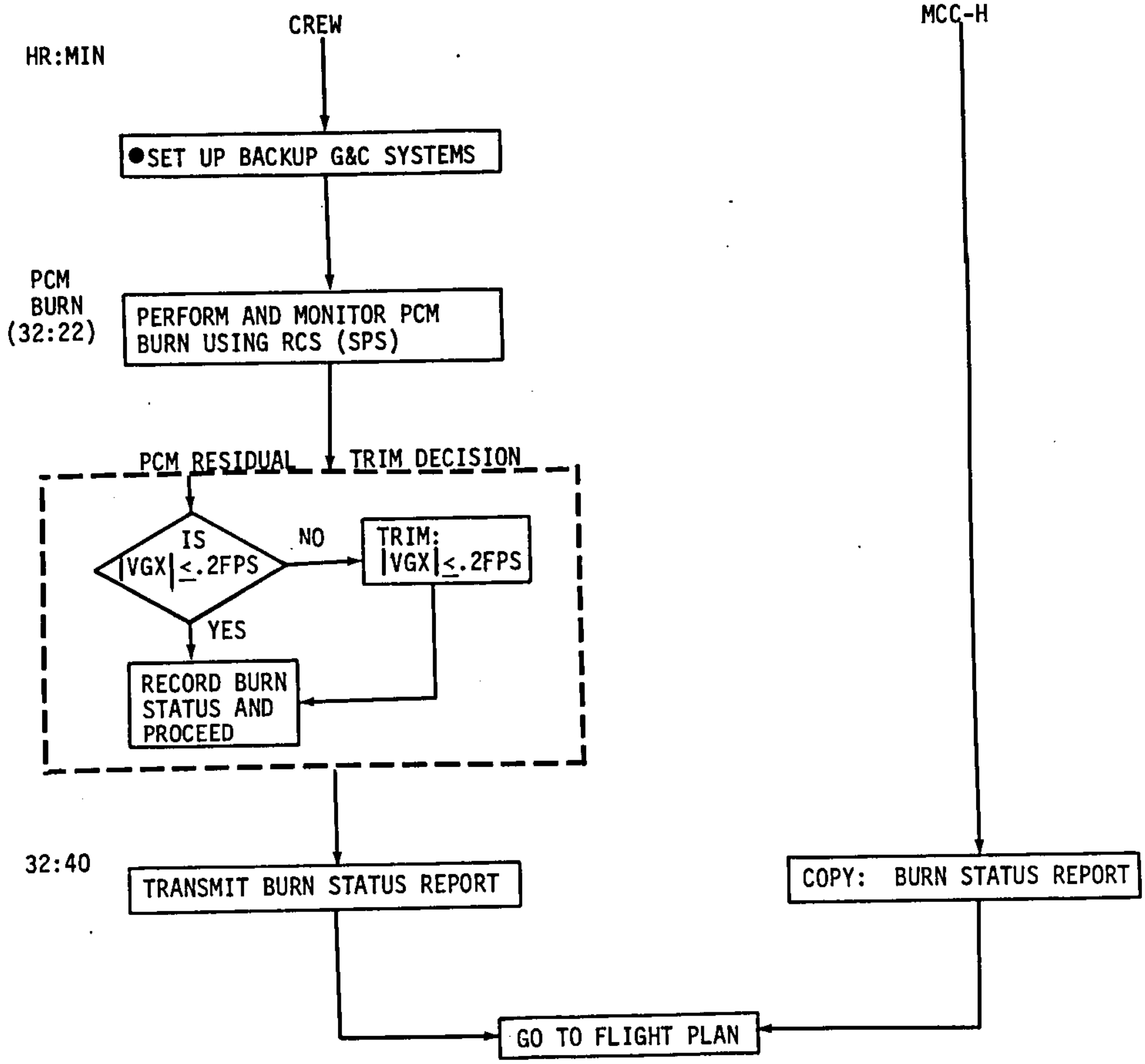


Figure 2-7. M = 30 Flow Chart (Continued)



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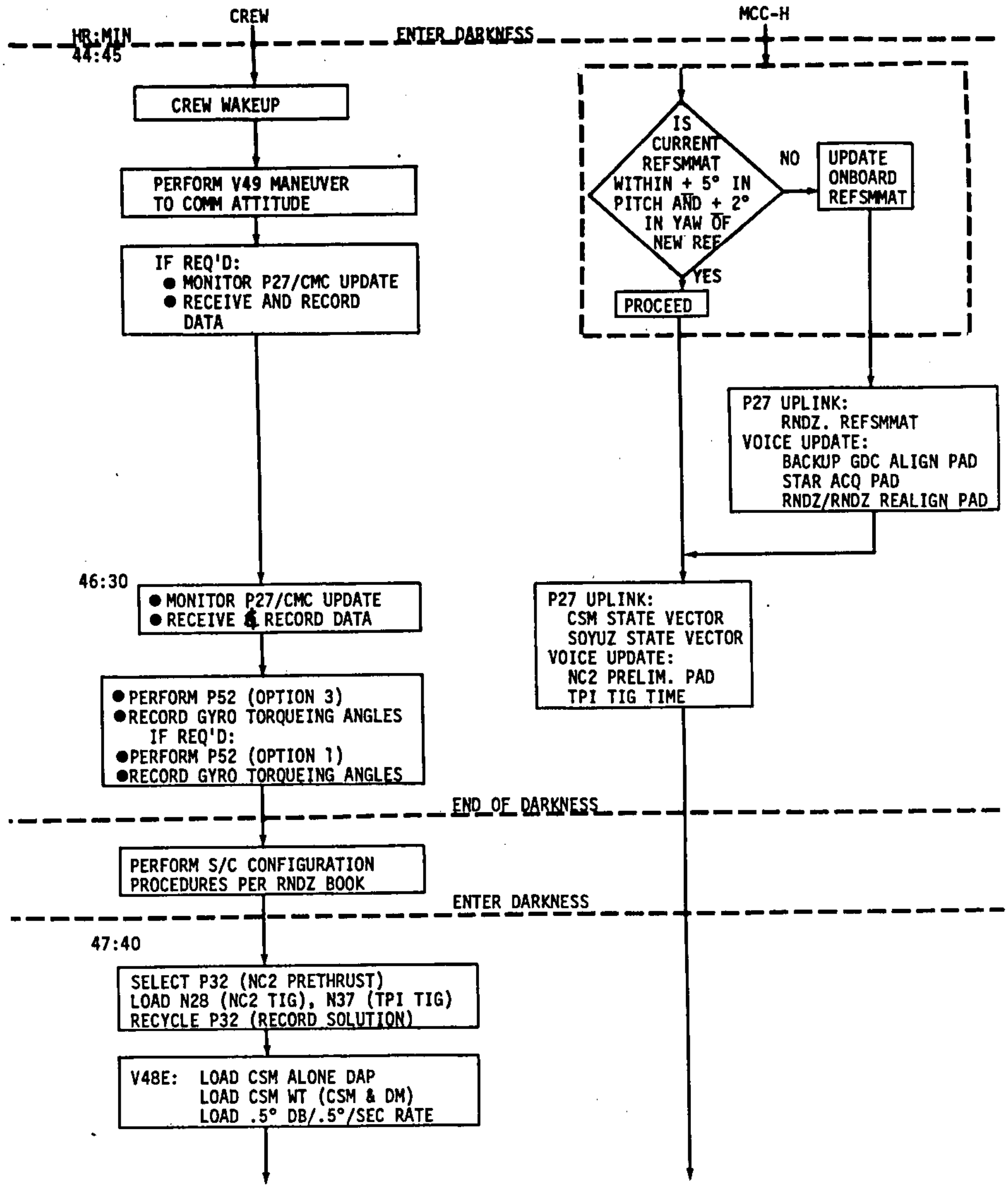
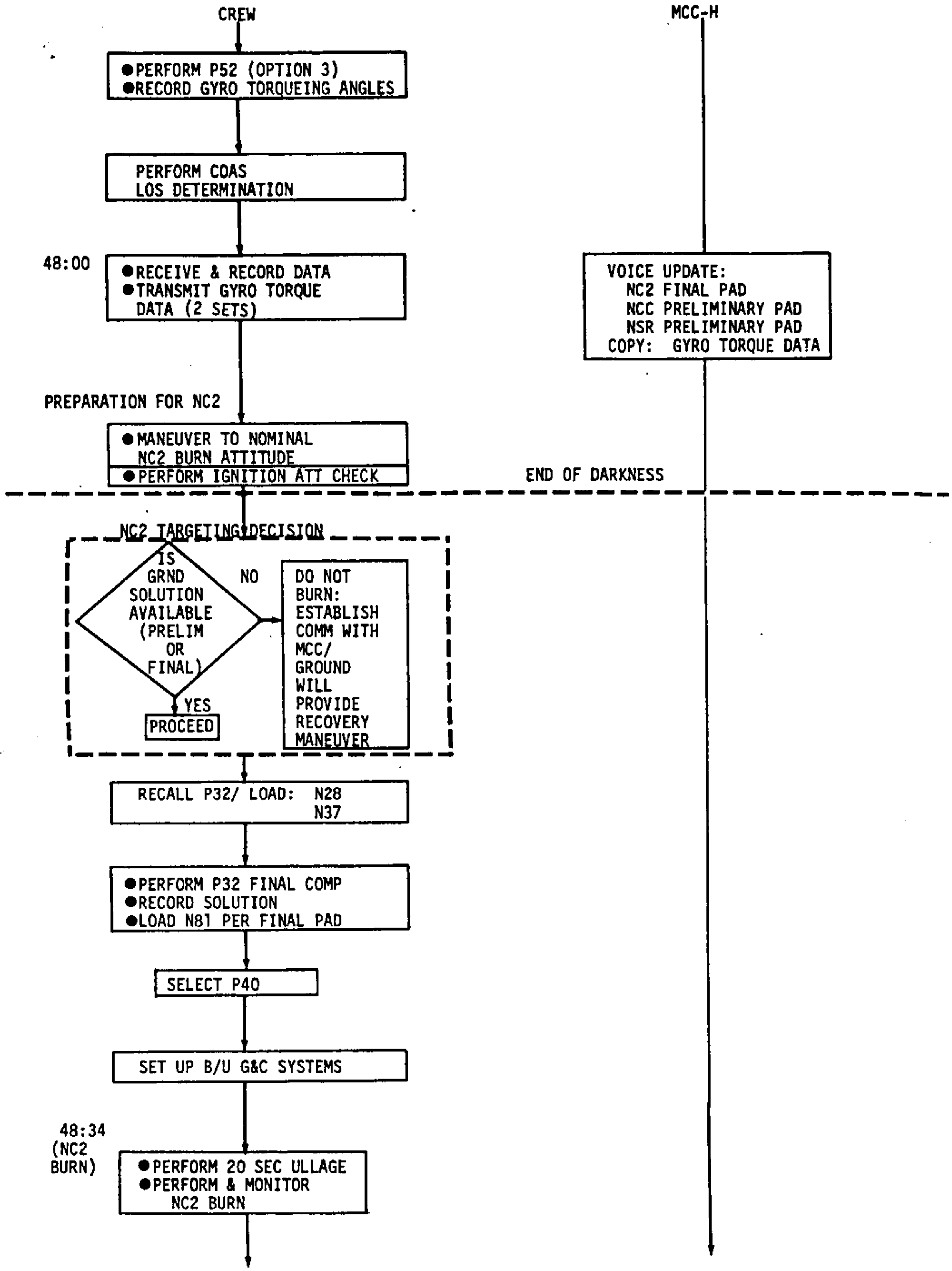


Figure 2-7. M = 30 Flow Chart (Continued)



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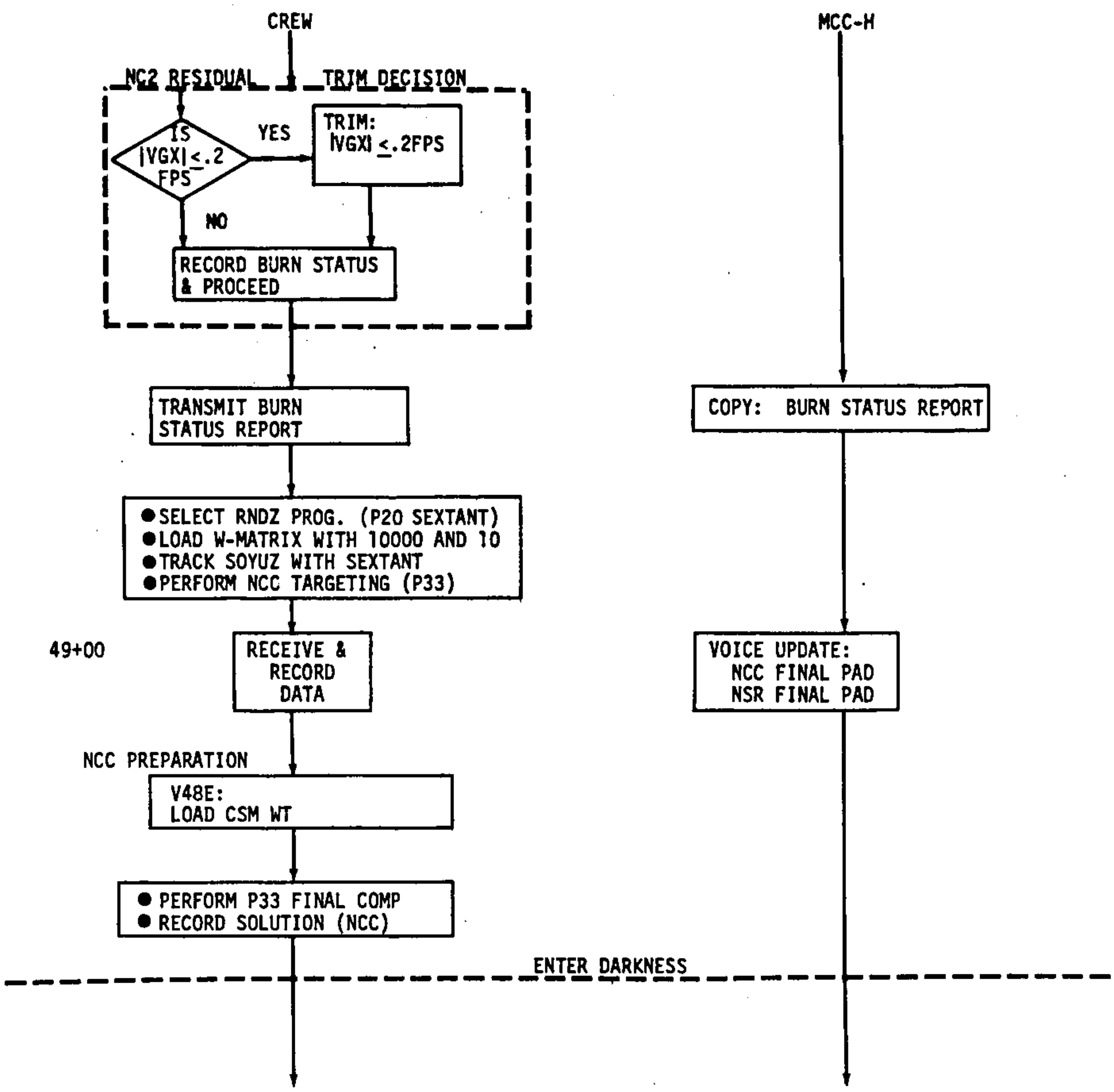


Figure 2-7. M = 30 Flow Chart (Continued)

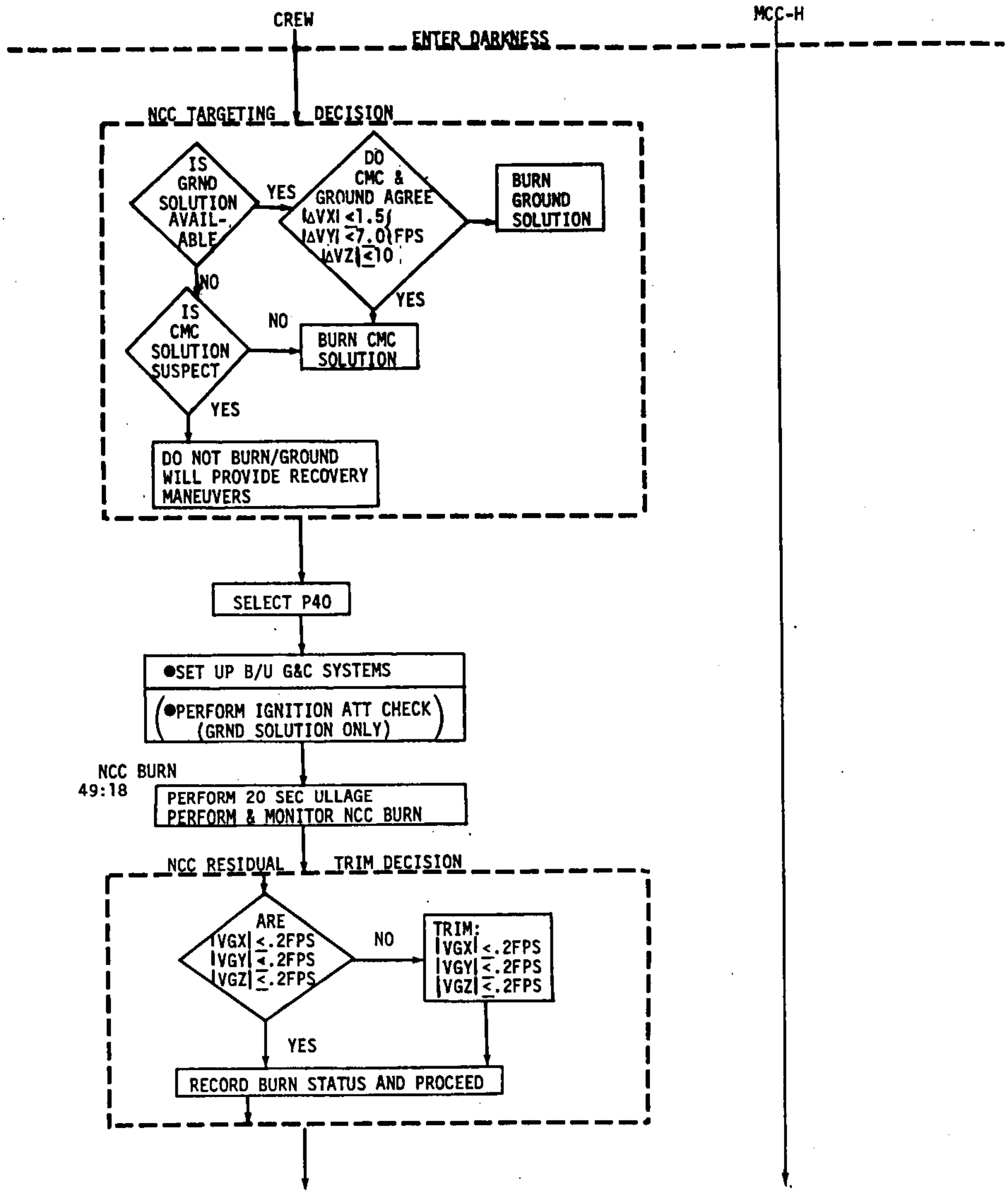


Figure 2-7. M = 30 Flow Chart (Continued)

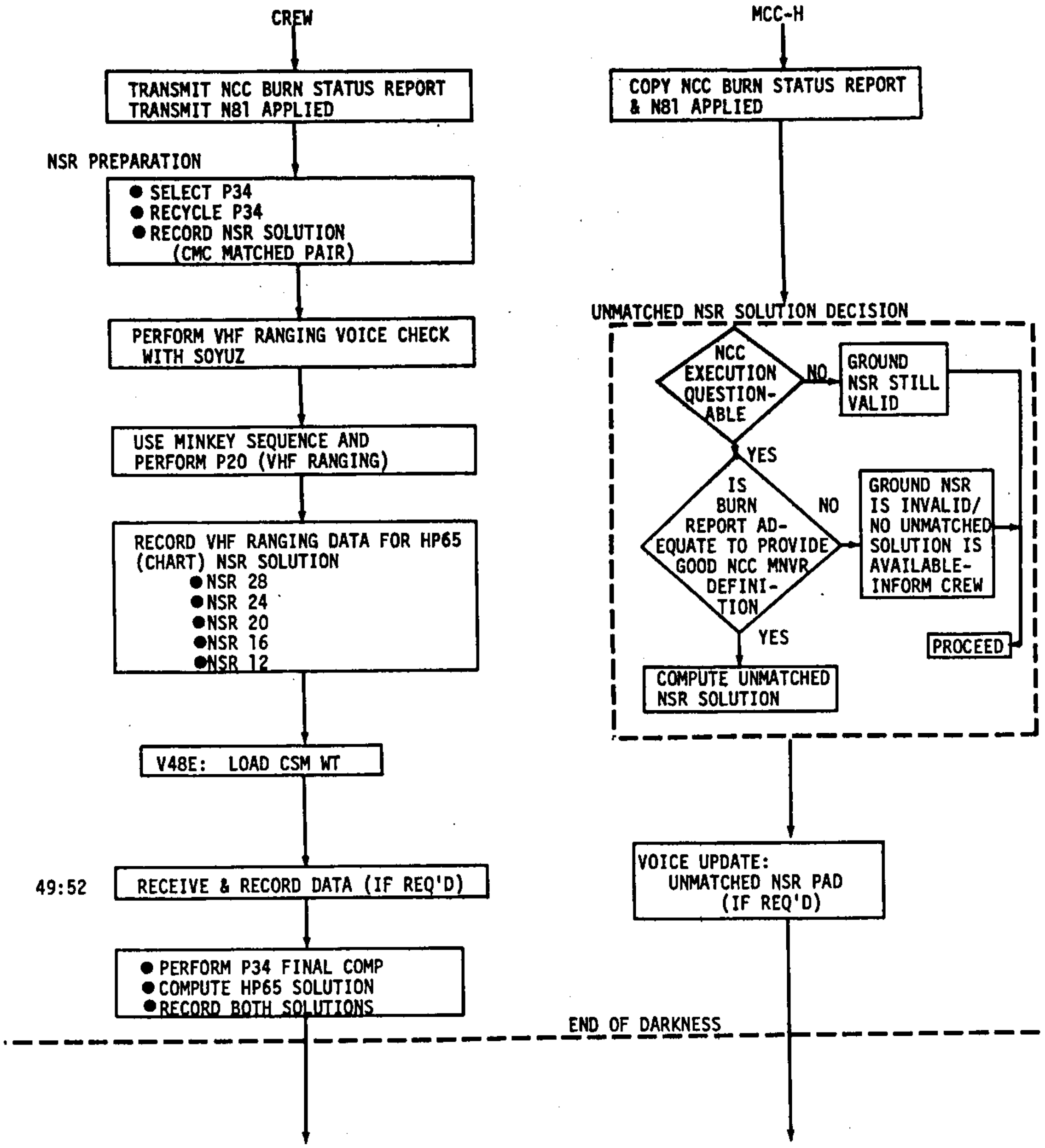


Figure 2-7. M = 30 Flow Chart (Continued)

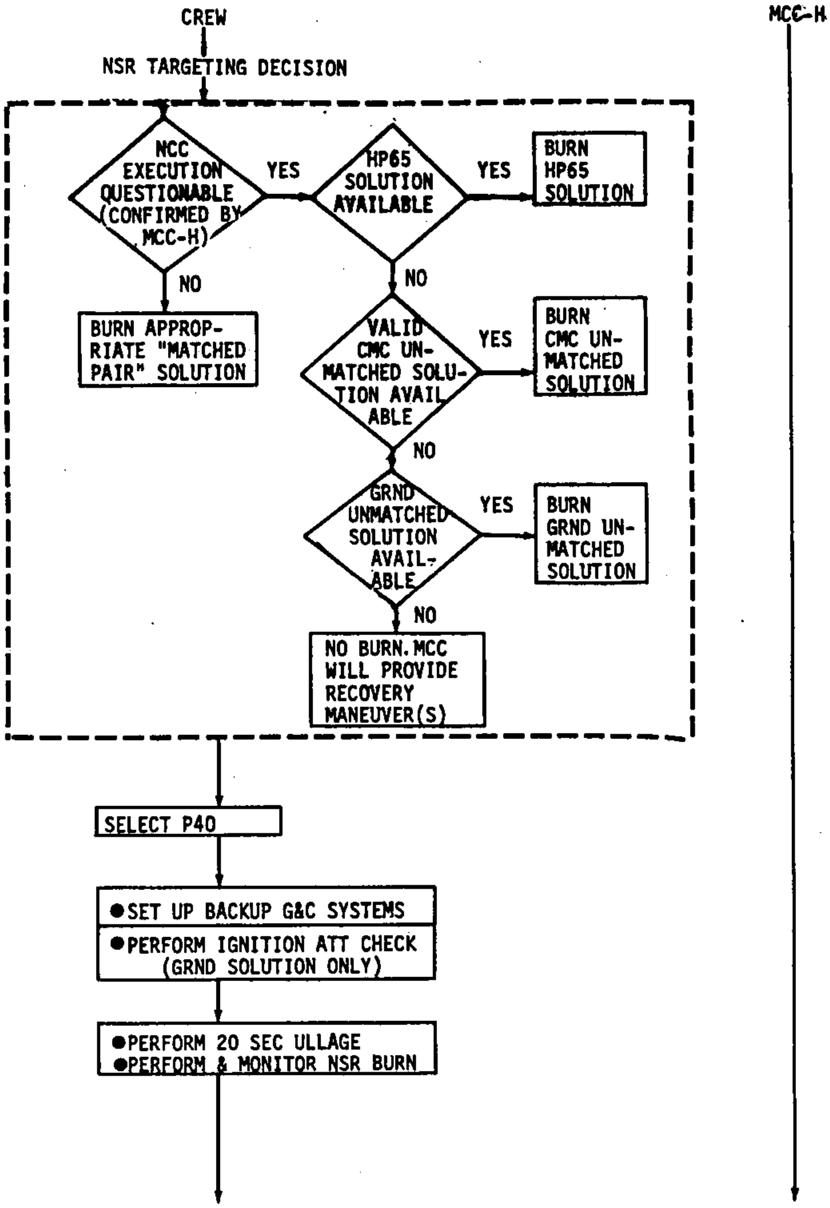


Figure 2-7. M = 30 Flow Chart (Continued)

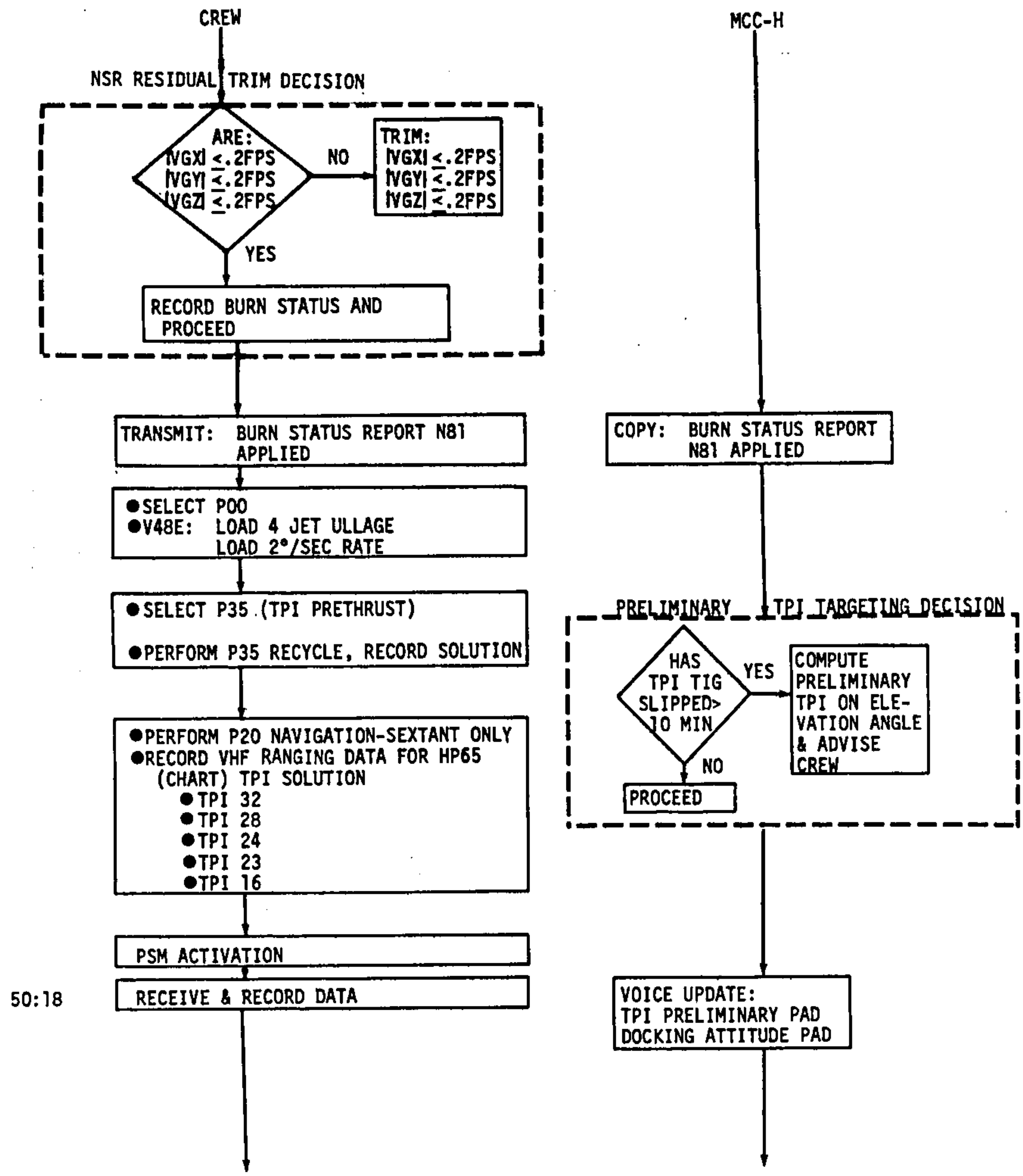


Figure 2-7. M = 30 Flow Chart (Continued)

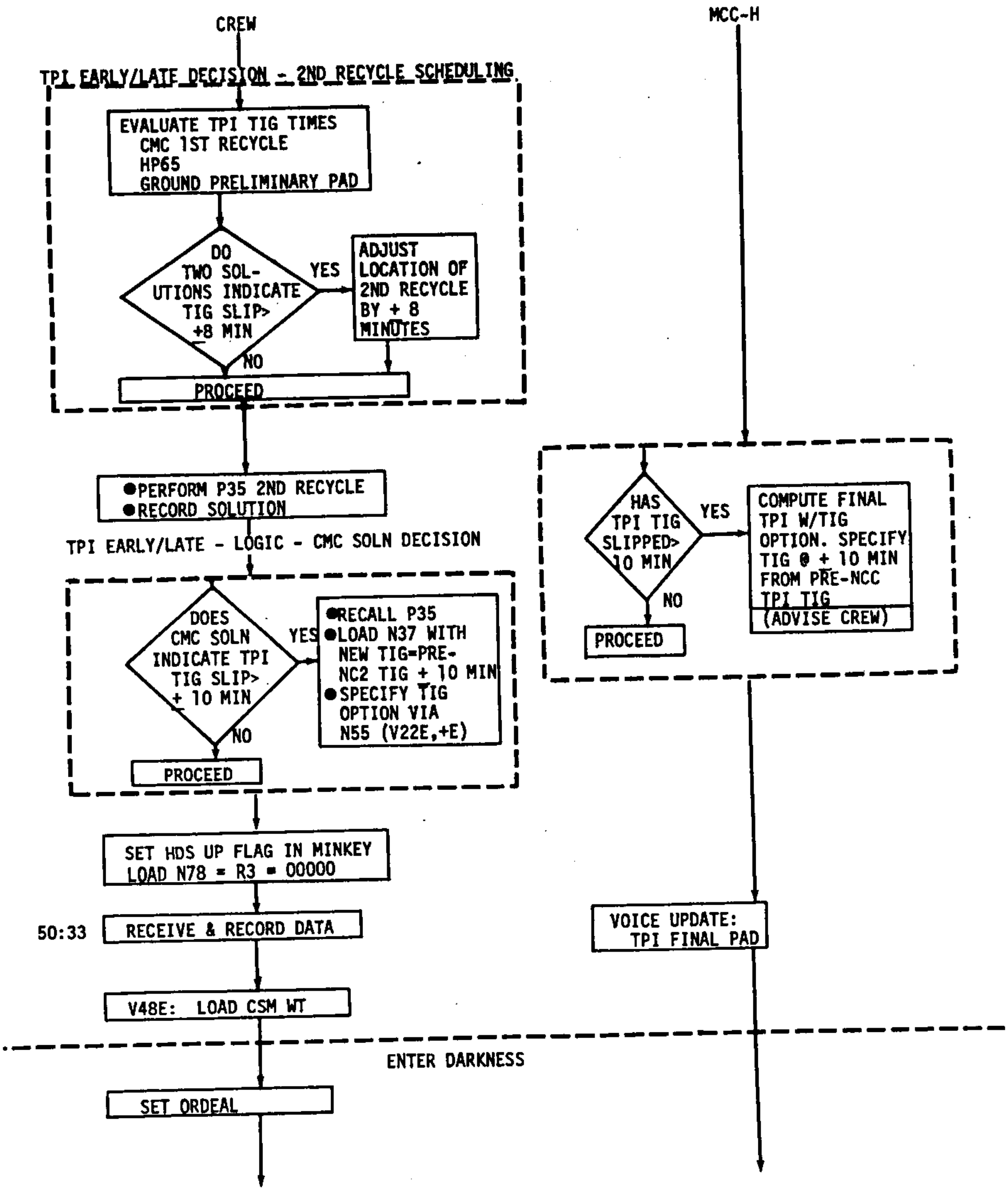


Figure 2-7. M = 30 Flow Chart (Continued)

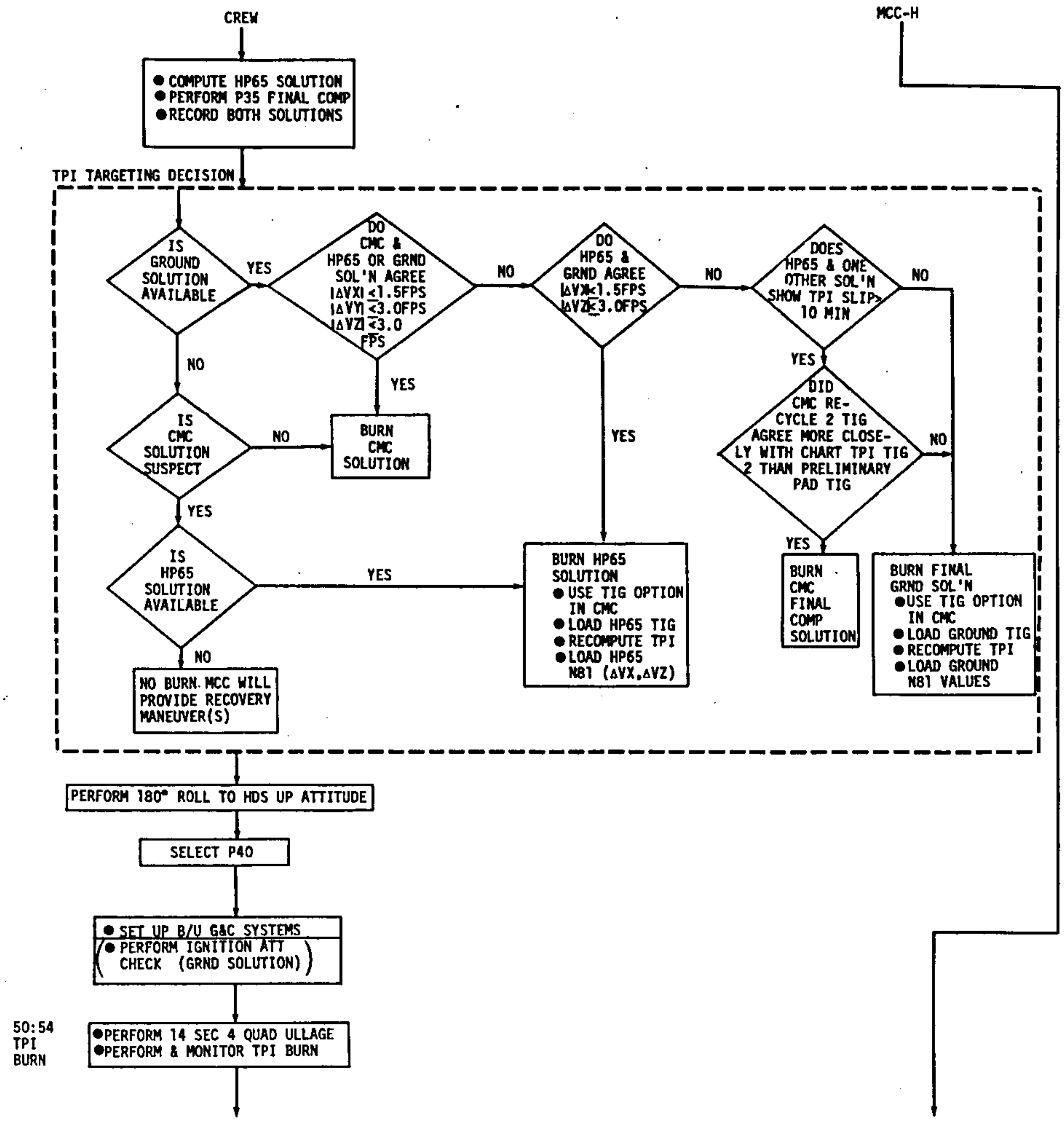


Figure 2-7. M = 30 Flow Chart (Continued)

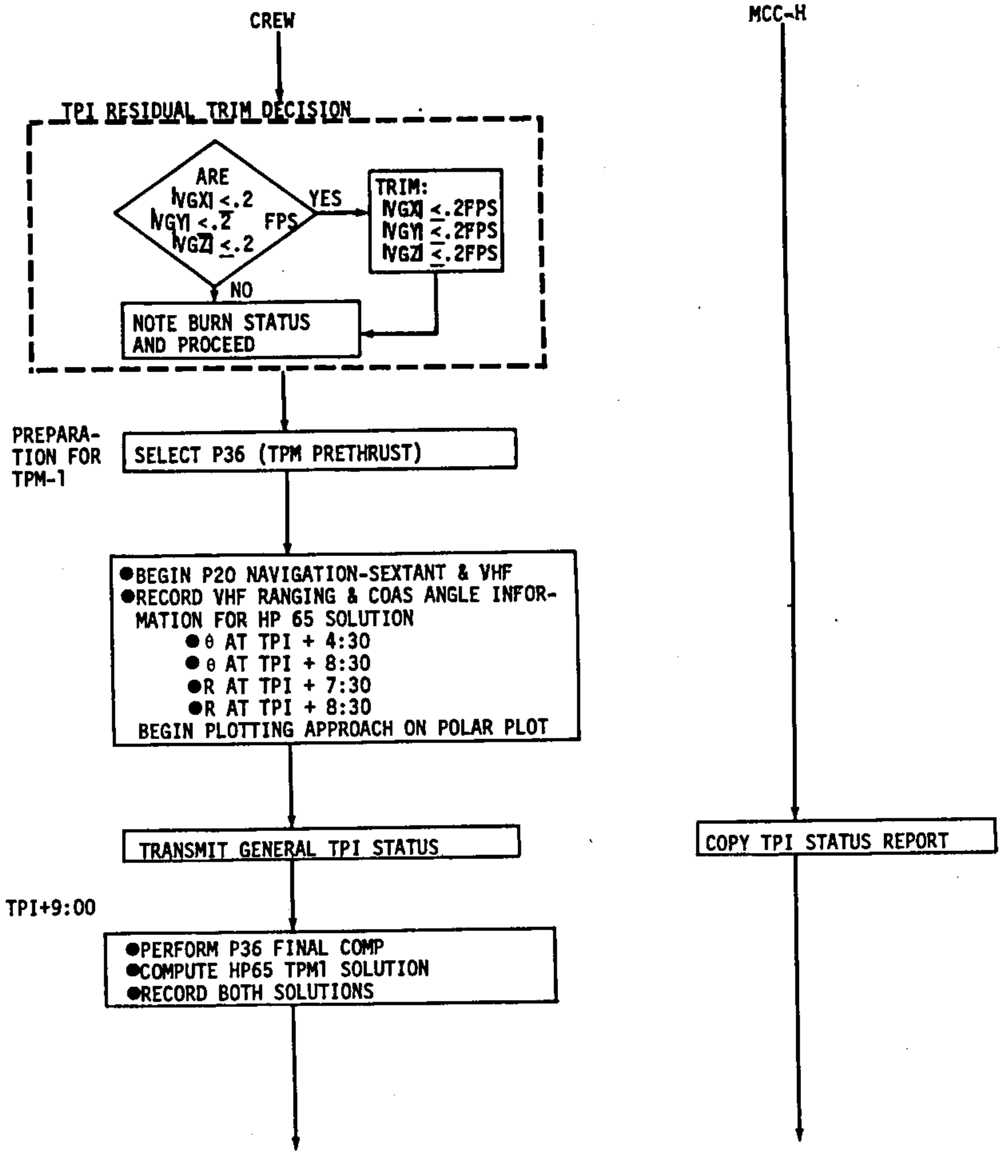


Figure 2-7. M = 30 Flow Chart (Continued)

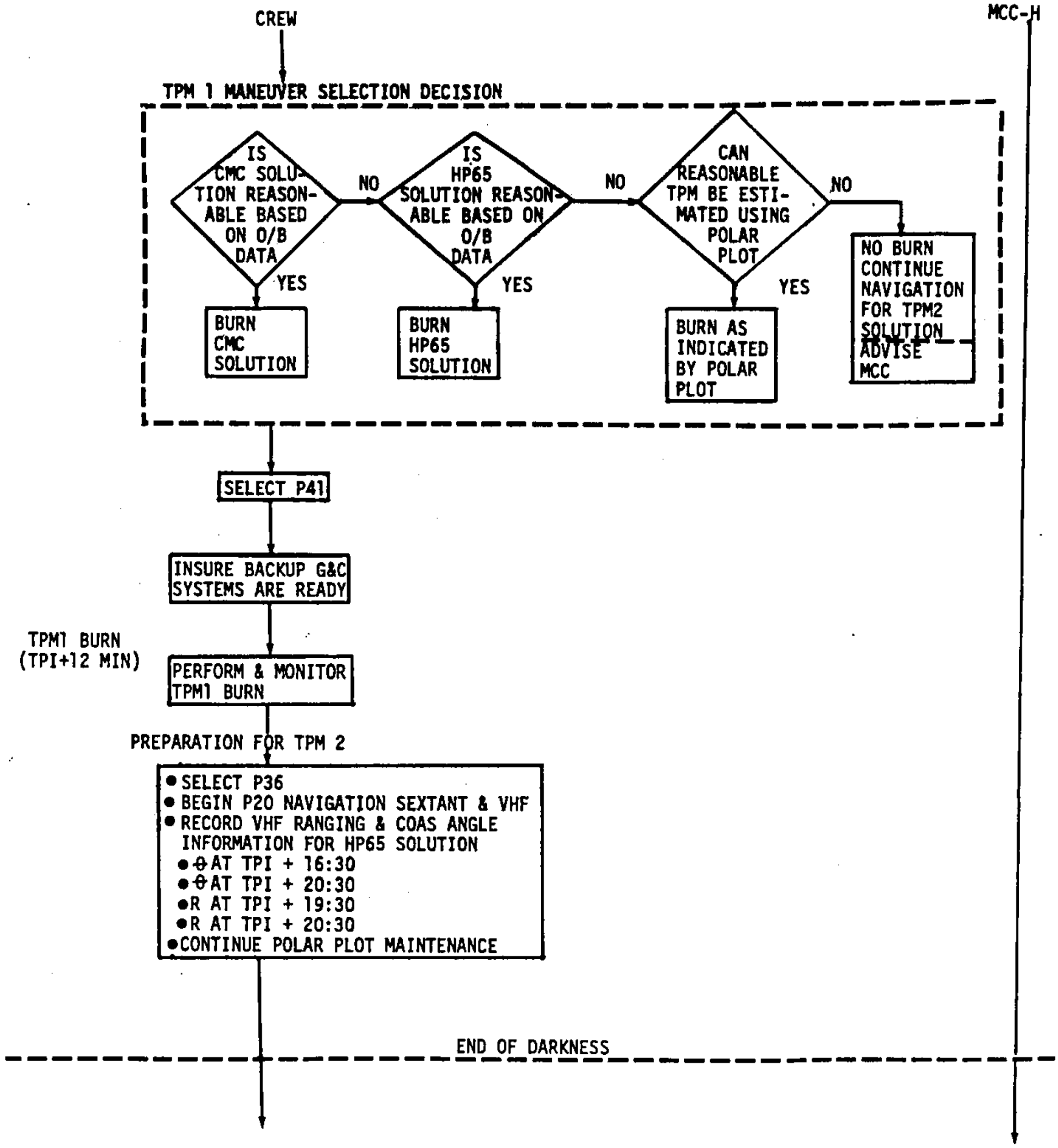


Figure 2-7. M = 30 Flow Chart (Continued)

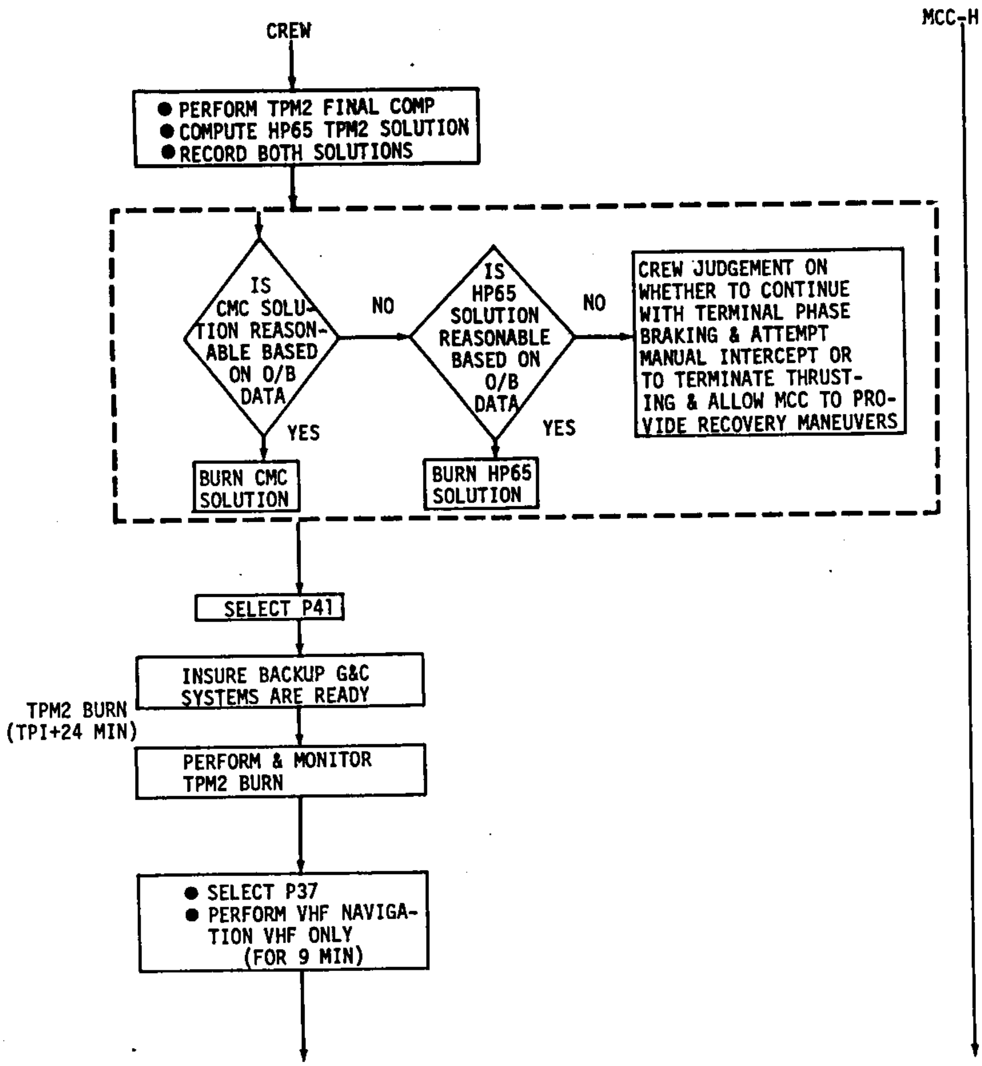


Figure 2-7. M = 30 Flow Chart (Continued)

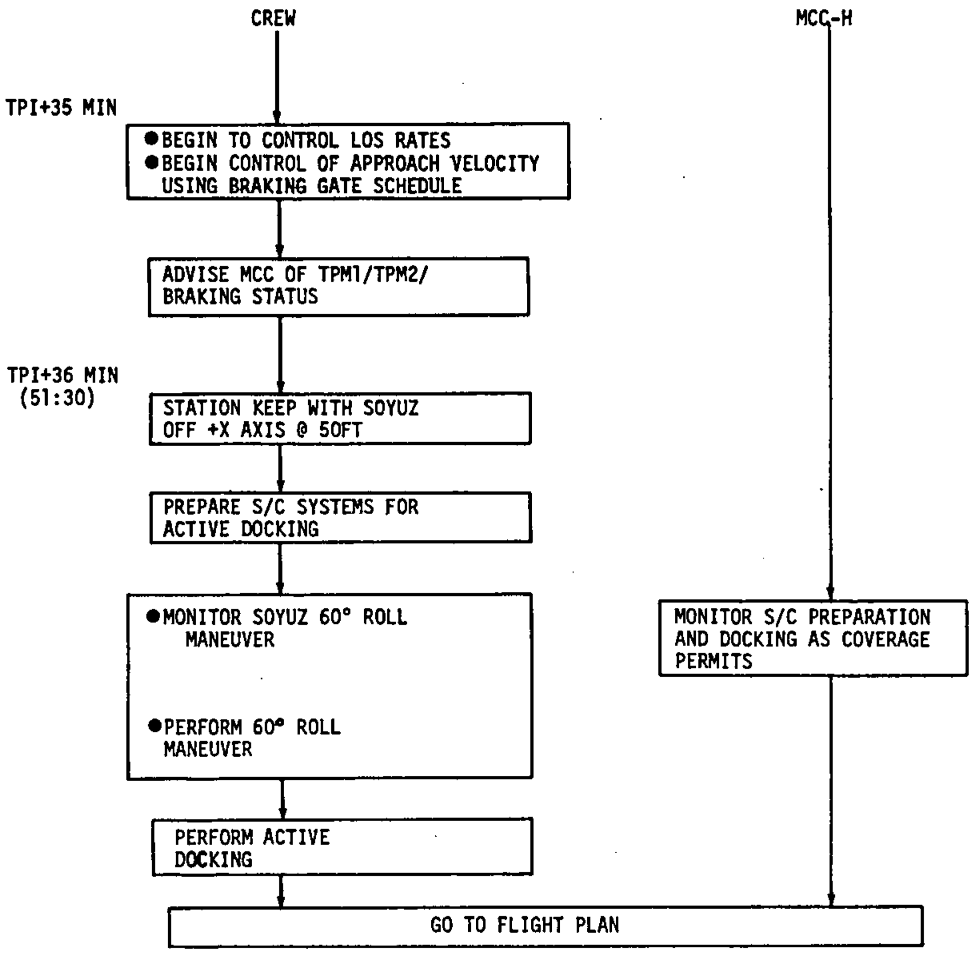


Figure 2-7. M = 30 Flow Chart (Concluded)

3. M = 14 PROFILE

This section presents a general discussion of the M = 14 rendezvous profile, a description of the sequence of events, and a detailed explanation of the rendezvous flow charts. The basic format of this section will be to describe those procedures and timelines which are unique to the M = 14 sequence. Those that are identical to the M = 30 sequence will be so noted. The M = 14 profile is flown for launches on days 2, 3, and 4. For day 2 launches, the SGET time of docking is the same as for the nominal mission, while the remaining launches slip docking one and two days, respectively.

3.1 MANEUVER SEQUENCE

The M = 14 sequence is essentially the M = 30 profile with day 2 completely removed. This means that there is no opportunity to perform PCM. However the need for this type of additional phasing maneuver is remote, since the Soyuz orbit is well established before the CSM is launched, which simplifies rendezvous targeting. The other major difference between the profiles is that for insertion phase angles of less than 18°, it is necessary to circularize the orbit approximately 5 n.mi. above the Soyuz orbit, rather than below (see Figure 3-1). This necessitates an additional maneuver, executed prior to the circularization burn, to create an apogee altitude of at least 126 n.mi. This profile is nominally required only for day 4 launches, but could also apply for some day 3 launches if the Soyuz orbit was slightly dispersed.

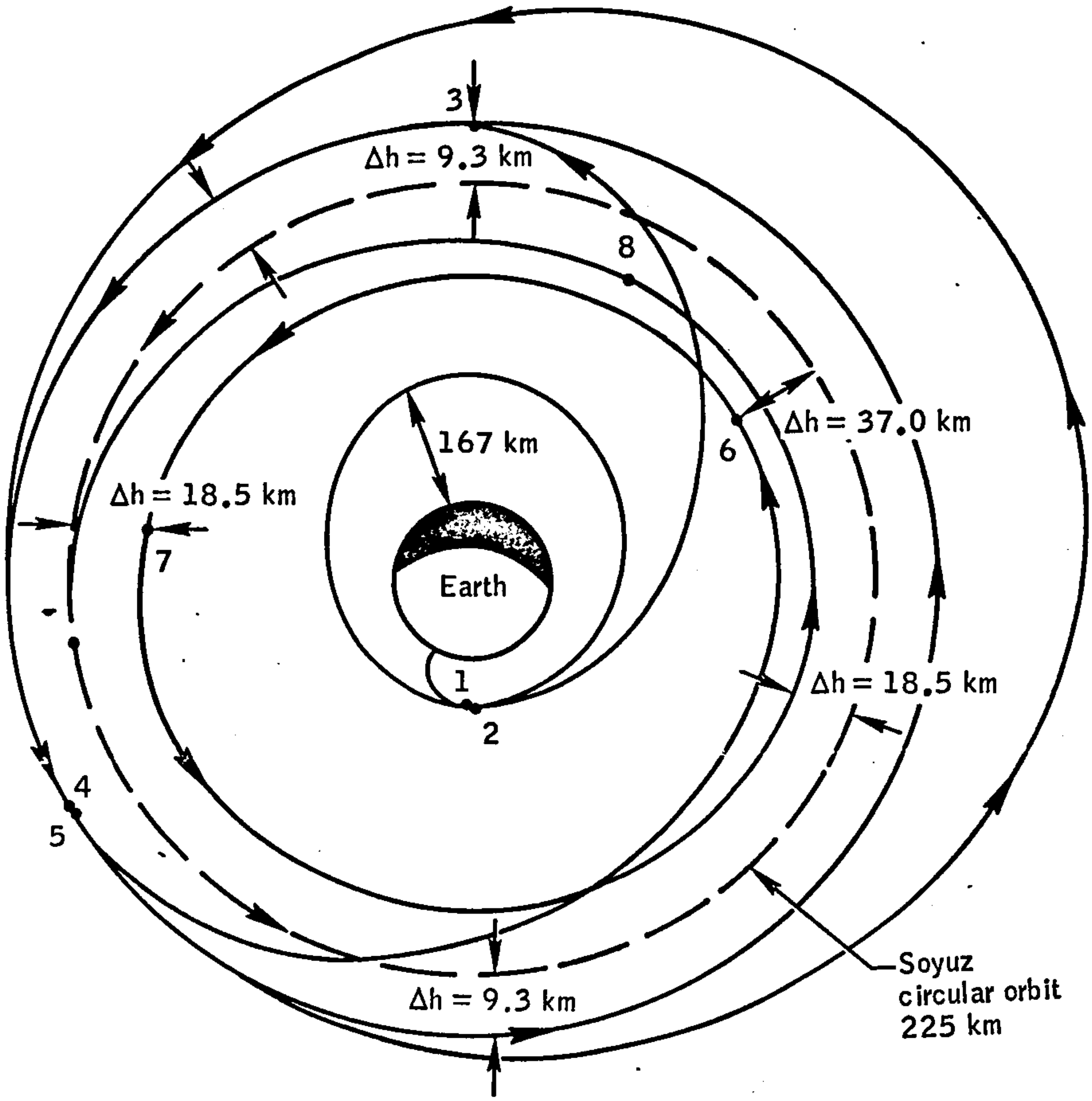
As in section 2, maneuver times are listed in the actual GET time-base in which they occur. The relative motion between the CSM and Soyuz for a typical M = 14 profile is shown in Figure 3-2. Figure 2-3 lists the various M = 14 maneuvers and their magnitudes for all launch opportunities.

3.1.1 Orbital Height Adjust Maneuver (OHA)

The OHA is the maneuver which creates an apogee about 5 n.mi. above the Soyuz circular orbit. It is nominally a local horizontal posigrade maneuver of about 60 fps, and is executed about 3 hr. 03 min. AGET, or about 1/2 hour after the AEM. As previously mentioned, it is required only when the insertion phase angle is less than 18° (day 4). The post-burn orbit is 126 x 91 n.mi.

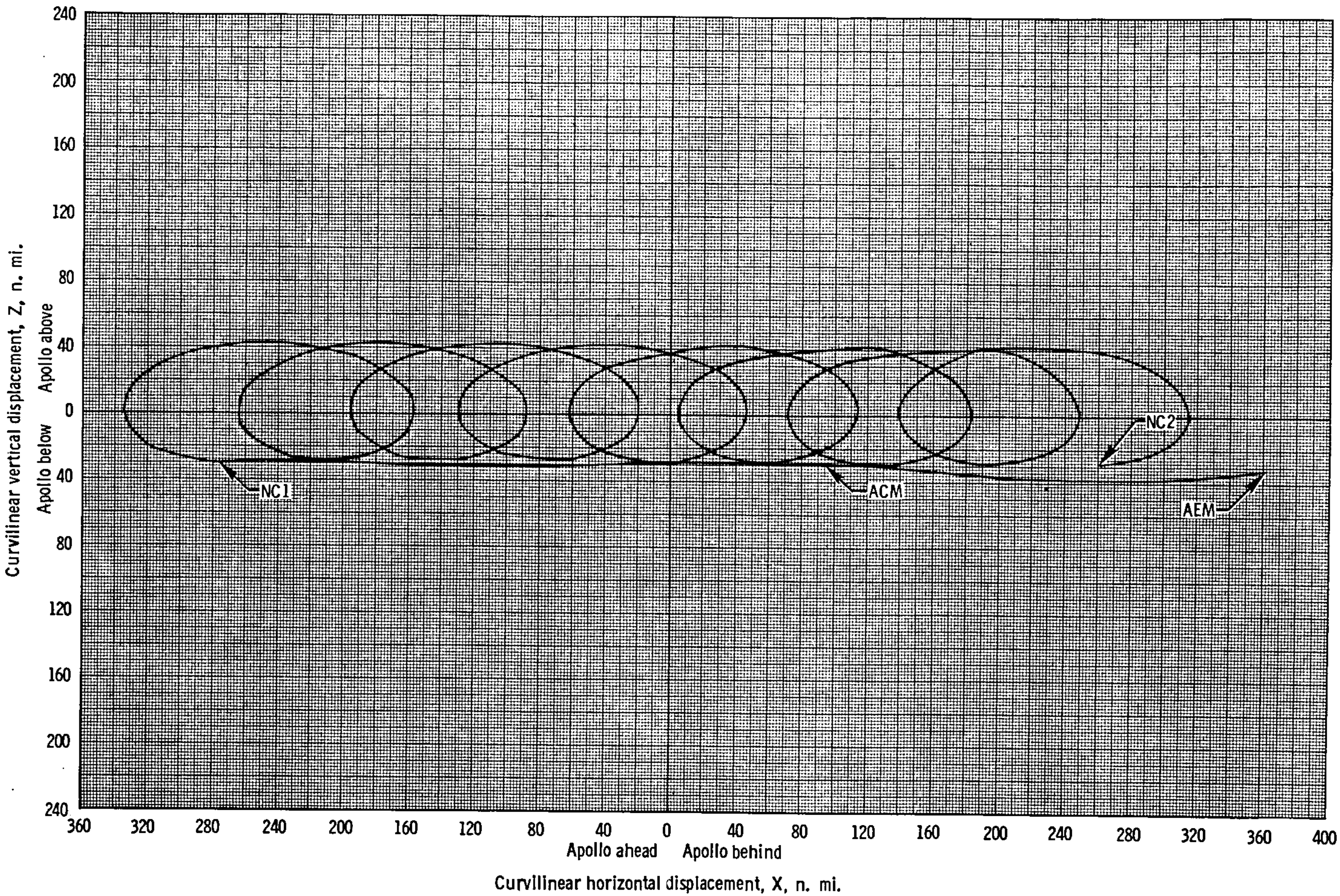
3.1.2 ACM

The ACM for the M = 14 is a variable burn depending upon the status of the OHA burn. When the OHA is not required, the ACM is identical to the M = 30 profile. When the OHA is executed however, the required ACM is



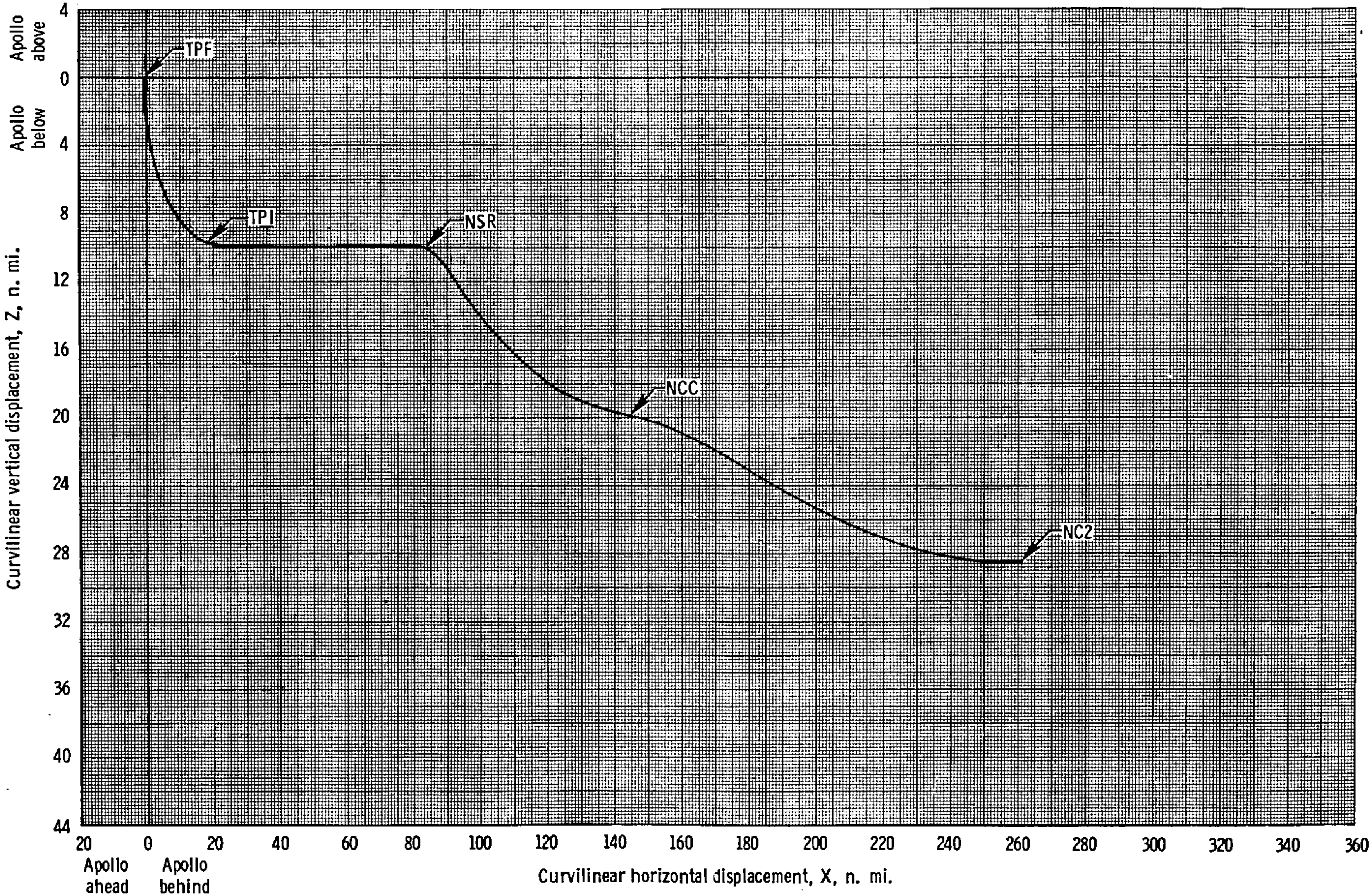
1 Insertion - 150 by 167 km
2 Orbit adjustment
3 Circularization
4 Phasing 1 (NC1)
5 Phasing 2 (NC2)
6 Corrective combination (NCC)
7 Coelliptic (NSR)
8 TPI

Figure 3-1. Orbital Geometry - M = 14 Profile (Day 4 Launch)



(a) AEM to NC2.

Figure 3-2. Relative Motion - M=14 Profile (Day 3)



(b) NC2 to TPF.

Figure 3-2. Relative Motion - M=14 Profile (Day 3) (Continued) approximately 73 fps and is executed one-half rev later (about 3 hr. 47 min. AGET). In this case, the post-burn orbit is approximately 126 n.mi. circular (229 km).

3.1.3 NC1

The NC1 maneuver for all M = 14 profiles is a local horizontal posigrade maneuver and the time of execution always occurs around 5 hr. 43 min. AGET. The ΔV of the burn does change significantly however, varying from 0 fps to 115 fps considering launches across the window on the three different launch days. Consequently the post-burn orbits are also different, varying from 91 x 91 n.mi. (day 2 launch at window close) to 156 x 124 n.mi. (day 4 launch at window opening). The computation technique utilized for this maneuver is identical to that for the nominal NC1 except that the ground will use the actual Soyuz orbit since the SCM will have already been performed.

3.1.4 NPC

The NPC computations, etc., described in Section 2.1.4 apply to this profile as long as NC1 is sufficiently large to accommodate this technique without gimbal lock problems. When this becomes a problem, NPC is handled as described in Section 3.4.3.1.

3.1.5 NC2

The NC2 maneuver for the three different launch opportunities always occurs about 17-1/2 hours after Apollo launch, but the actual TIG time in SGET increases by about 23 hr. 40 min. from day to day. The NC2 magnitude and direction will vary with the size of the NC1 maneuver. Although NC2 is generally a retrograde maneuver with the required ΔV extending up to 100 fps, it can also be a posigrade maneuver with ΔV requirements up to 20 fps (for launch near close of window on day 2). Targeting considerations for this maneuver are described in Section 2.1.5.

3.1.6 NCC

The NCC maneuver varies in direction, depending on whether the OHA was performed. If there was no OHA, the NCC for M = 14 is the same as that for M = 30. If OHA is performed, NCC becomes a retrograde burn of about 26 fps. It is always performed one half rev after NC2, but the SGET of the burn changes according to launch day. O/B targeting and navigation procedures are essentially the same for all launch opportunities.

3.1.7 NSR

NSR is always performed 37 minutes after NCC. All related targeting and navigation considerations are identical to the nominal (Section 2.1.7).

3.1.8 TPI through Docking

The entire terminal phase portion of the M = 14 profile is the same as that for an M = 30. The SGET of docking occurs at the nominal time (51:55) for day 2 launches, at 75 hr. 35 min. SGET for day 3 launches, and at 99 hr. 20 min. SGET for day 4 launches.

3.2 INSERTION OVERSPEED/UNDERSPEED STRATEGY

In order to simplify this discussion, the M = 14 profile is broken in two cases. The first strategy applies to situations where the OHA maneuver is not required (i.e., circular below the Soyuz). The second strategy applies when the OHA is to be executed.

3.2.1 M = 14 Profile/No OHA Maneuver Required

As discussed in Section 2.3, the minimum acceptable perigee for any underspeed case is 70 n.mi. In the general case, perigees above 75 n.mi. are anticipated when crew action is required to produce a cutoff. The major impact of underspeed orbits is that the ACM maneuver cannot attain the nominal orbit. In this case, ACM will be replaced by a NH maneuver which is performed either 1-1/2 or 1/2 rev prior to NC1. This maneuver will force the nominal (91.6 n.mi.) attitude at the NC1 maneuver point. After NH, the NC1 maneuver must increase in size to slow down the catch-up rate to compensate for the increased catch-up realized in the insertion orbit. For the worst case orbit, NC1 must increase about 35 fps (increase apogee by about 18 n.mi.) to produce this reduced catch-up. This also raises NC2 ΔV since that maneuver must lower the increased apogee down to 100 n.mi. NCC will be nominal as long as the NC1 maneuver altitude is nominal.

Overspeeds can present more complicated problems however. The problem with overspeeds is that NC1 must be reduced to compensate for the loss of catch-up in the initial 3 revs.

Considering worst case overspeeds of about 150 fps, this means that as long as the nominal NC1 was about 35 fps, no particular problems should be realized. If NC1 was smaller than this, as it is on some day 2 launches, then this maneuver must become retrograde. The worst case situation would take a nominally 0 ΔV NC1 maneuver and force it to be 35 fps retrograde which creates an orbit of 91 x 73 n.mi. However, this action is precluded by the Mission Rule concerning real time perigee maintenance (75 n.mi. minimum) since drag in that low an orbit could reduce perigee to lower than 70 prior to execution of NC2. Obviously these worst case situations must be procedurally avoided. The technique that will be implemented here is to lower the circularization orbit to preclude targeting for perigees below 80 n.mi. This technique will be utilized as required to preserve the nominal profile, but it must be recognized that for some phasing conditions even this cannot preserve the M = 14 sequence.

The previous paragraph assumes that the ACM burn is targeted to circularize the orbit at a near-nominal altitude, independent of the ΔV cost. This technique has two principal advantages:

a) It returns the orbit to near-nominal so that NC1 alone can correct the phasing errors, minimizing the impact of the overspeed on crew procedures.

b) It provides complete freedom in selecting the NC1 maneuver point which establishes the maneuver line.

Unfortunately, circularizing at the nominal altitude can be prohibitive in terms of ΔV cost since the burn must both remove most of the overspeed ΔV and include a large radial component since the maneuver point will not occur at an apsis. This ΔV expense may not be bearable for launches on days 3, 4, and 5, depending on where in the window launch occurs. When considering ΔV cost, impact on crew timeline, and maneuver point locations, many mission-dependent variables must be considered, consequently a fixed plan of attack is not feasible. Accordingly, there are three techniques that may be utilized to compensate for overspeeds. These are, in order of preference:

1. Perform ACM at near-nominal altitude and use NC1 to correct phasing. This is the most expensive technique but presents minimum impact to day 1 crew activities.

2. Optimize the post-ACM orbit to minimize the remaining ΔV cost of the rendezvous. This involves a lengthy iteration process to arrive at desired solution but may be the best compromise between ΔV and crew timeline considerations.

3. Obtain the desired circular orbit using an optimum two-maneuver sequence. While this is generally the cheapest solution, it also represents the most significant perturbation to the day 1 timeline.

The major factors that will influence the decision on which of these plans to adopt will be the magnitude of the overspeed and the ΔV penalties involved. In general, it will be considered undesirable to significantly alter the day 1 timeline and available fuel reserves will be utilized as required to preserve it.

In generalized terms, overspeeds cause ACM to go up, NC1 goes down, NC2 goes down until it changes direction and then goes back up, and NCC ΔV varies inversely with the altitude of the ACM orbit.

3.2.2 M = 14 Profile/OHA Required

The OHA maneuver and the accompanying circularization above the Soyuz orbit reduce the impact of both overspeeds and underspeeds considerably.

For underspeeds, since the circularization process is already a flexible two-maneuver sequence, the nominal circularization can be achieved by simply adjusting the magnitude of one or both maneuvers. The timeline can remain constant and the worst case increase in the OHA maneuver is essentially the magnitude of the maximum underspeed, i.e., about 40 fps. The ACM would be nearly nominal, and NC1 must be increased by less than 10 fps to compensate for the initial catch-up error. NC2 would increase by about the same amount with the remainder of the profile remaining unchanged. For overspeeds, the normally posigrade OHA will decrease in size until it reaches zero ΔV, change direction to become a retrograde burn, and begin to grow. Large retrograde OHA maneuvers should be about 1/2 the amount of the overspeed to reduce apogee to its desired value (126 n.mi.). ACM is performed nominally and NC1 must be reduced to compensate for the slower catch-up rate in the first two revs. Again, the worst case magnitude of the reduction is about 30 fps. In some cases, this could result in a retrograde NC1; however, the increased altitude of the circularization orbit eliminates low perigee problems. For all cases, NC2 ΔV should be reduced and the remainder of the profile should remain nominal.

It should be pointed out however, that while these cases can all be handled without significant procedural problems, the ΔV requirements are at times severe when considered relative to the ΔV available. Day 3 and day 4 launches are nominally marginal on SPS ΔV and insertion dispersions may require considerable RCS usage. When one realizes that overspeed/underspeed problems are often accompanied by planar errors (resulting from IU guidance or navigation problems), it is quite possible that these situations will necessitate either violation of certain deorbit redlines or in scrubbing the M = 14 profile and extending the rendezvous. Combinations of worst case conditions could significantly reduce or even eliminate the docked activity phase of the mission. Final procedures relative to these situations will be evaluated and prepared for by Flight Controllers and their support personnel. This level of strategy is not discussed further in this document due to the remoteness of the situation (multiple failures required to get there) and the number of variables that must be considered in real time before these decisions can be reached.

3.3 RENDEZVOUS TIMELINE

A summary of the major activities for the M = 14 profile is shown in Figure 3-3. A detailed discussion of these activities, as well as other related procedures, follows in Section 3.4.

3.4 RENDEZVOUS FLOW CHARTS

This section will present the rationale for the significant events that occur during the rendezvous, as depicted in the flow charts (see Figure 3-4). As in previous sections however, only the changes from the nominal sequence are discussed.

3.4.1 AEM to OHA

Since the M = 14 sequence is exactly like the M = 30 sequence (if there is no OHA maneuver), a new procedural timeline becomes required only when OHA is performed. Consequently, only this timeline is included.

3.4.1.1 Ordeal Set Up

Shortly after AEM, the ORDEAL is unstowed and mounted as in the nominal profile.

3.4.1.2 Burn Status Report (AEM)

About 10 minutes after the AEM, the CSM will be acquired over the VAN. At that time the crew will provide an AEM status report. As before, TIG slips and ΔV residuals are the primary items of interest.

3.4.1.3 Ground Uplinks

The ground will transmit two uplinks in support of OHA. These are:

a) CSM state vector

b) OHA target load

Both of these loads will go up over the VAN about 2 hr. 45 min. AGET.

3.4.1.4 Ground Updates

The ground will supply the following update messages in the pre-OHA timeframe.

a) OHA Preliminary PAD
b) ACM Preliminary PAD
} Voiced up prior to AEM

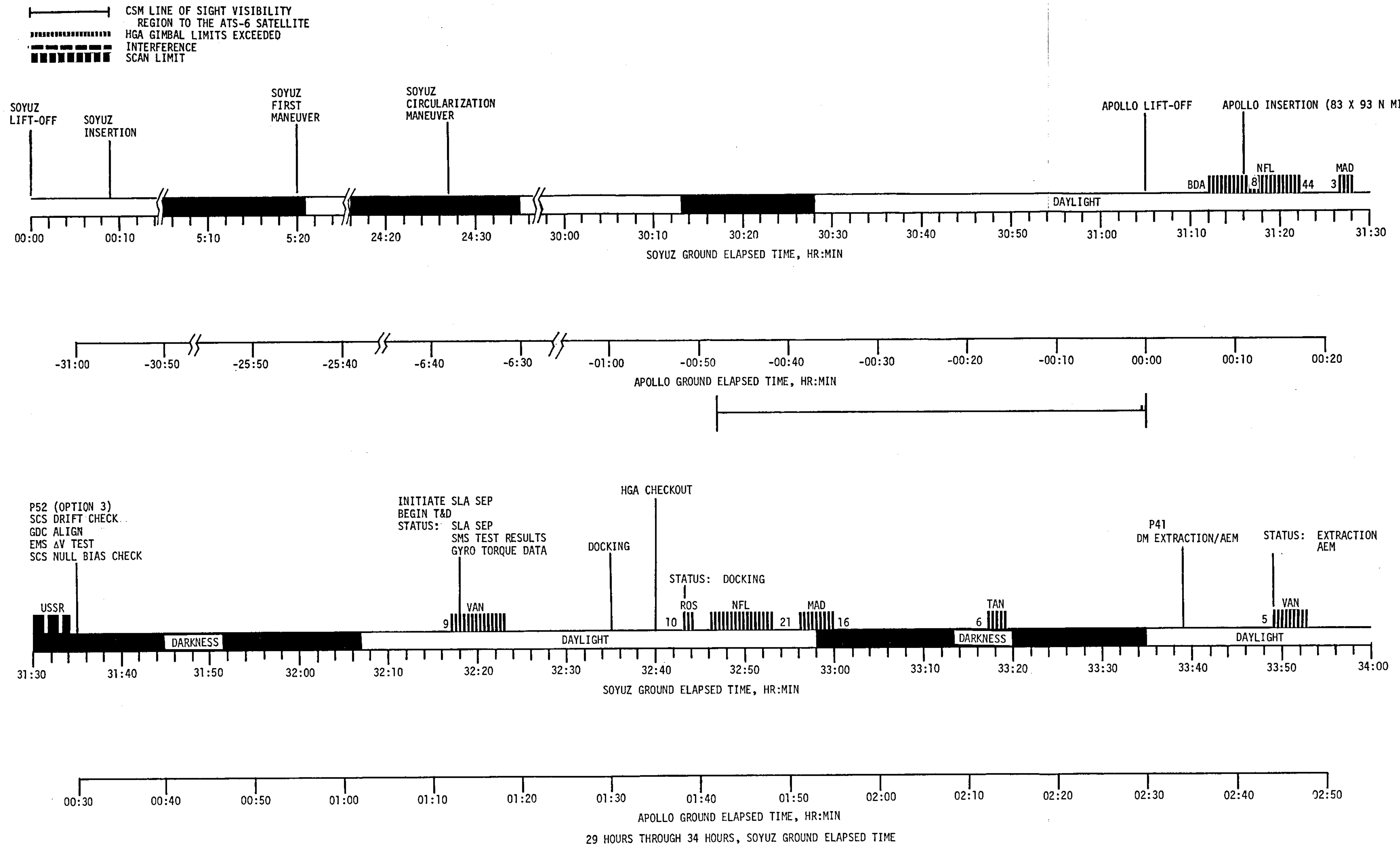


Figure 3-3. Rendezvous Timeline - 2nd Launch Opportunity

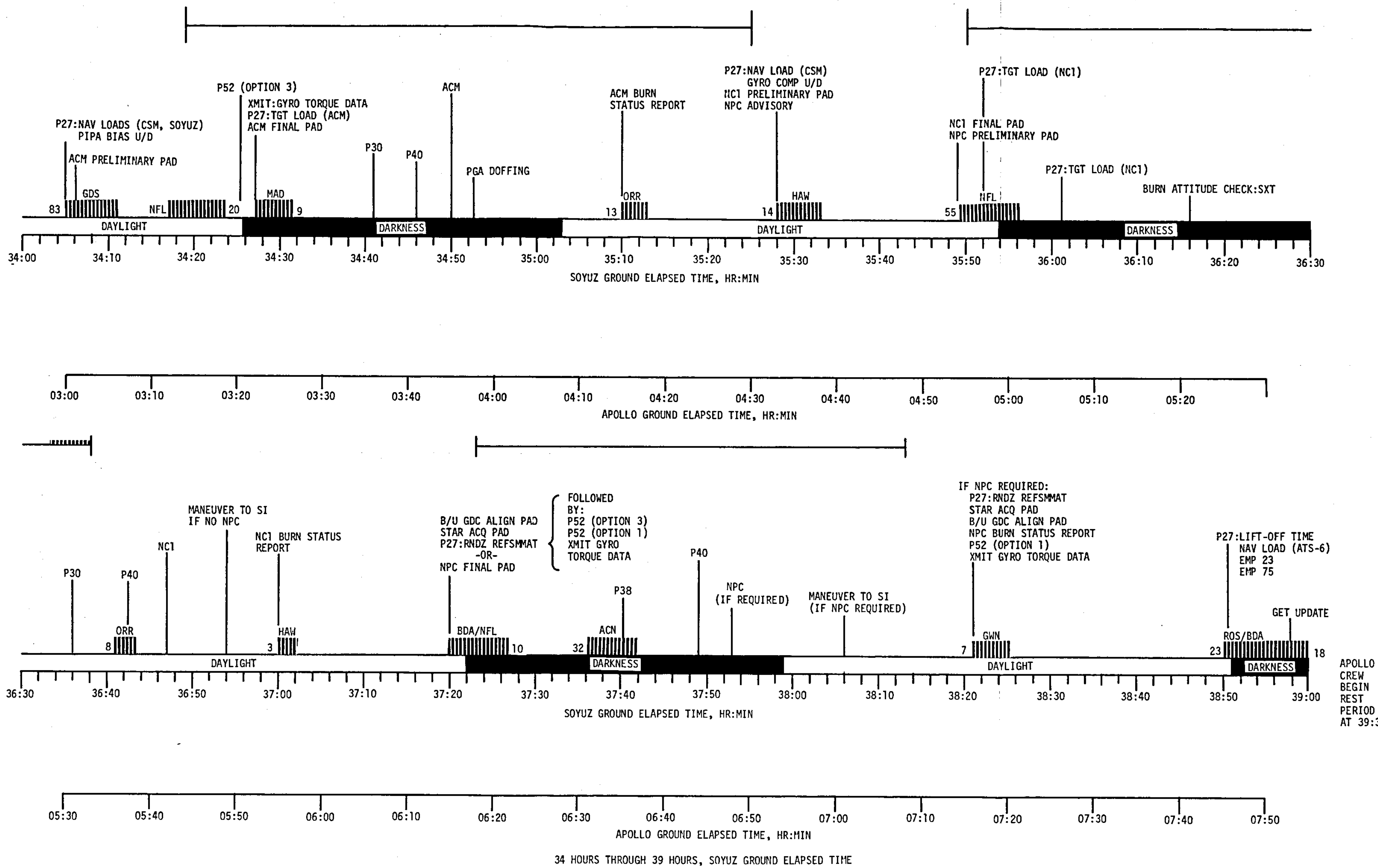


Figure 3-3. Rendezvous Timeline - 2nd Launch Opportunity (Continued)

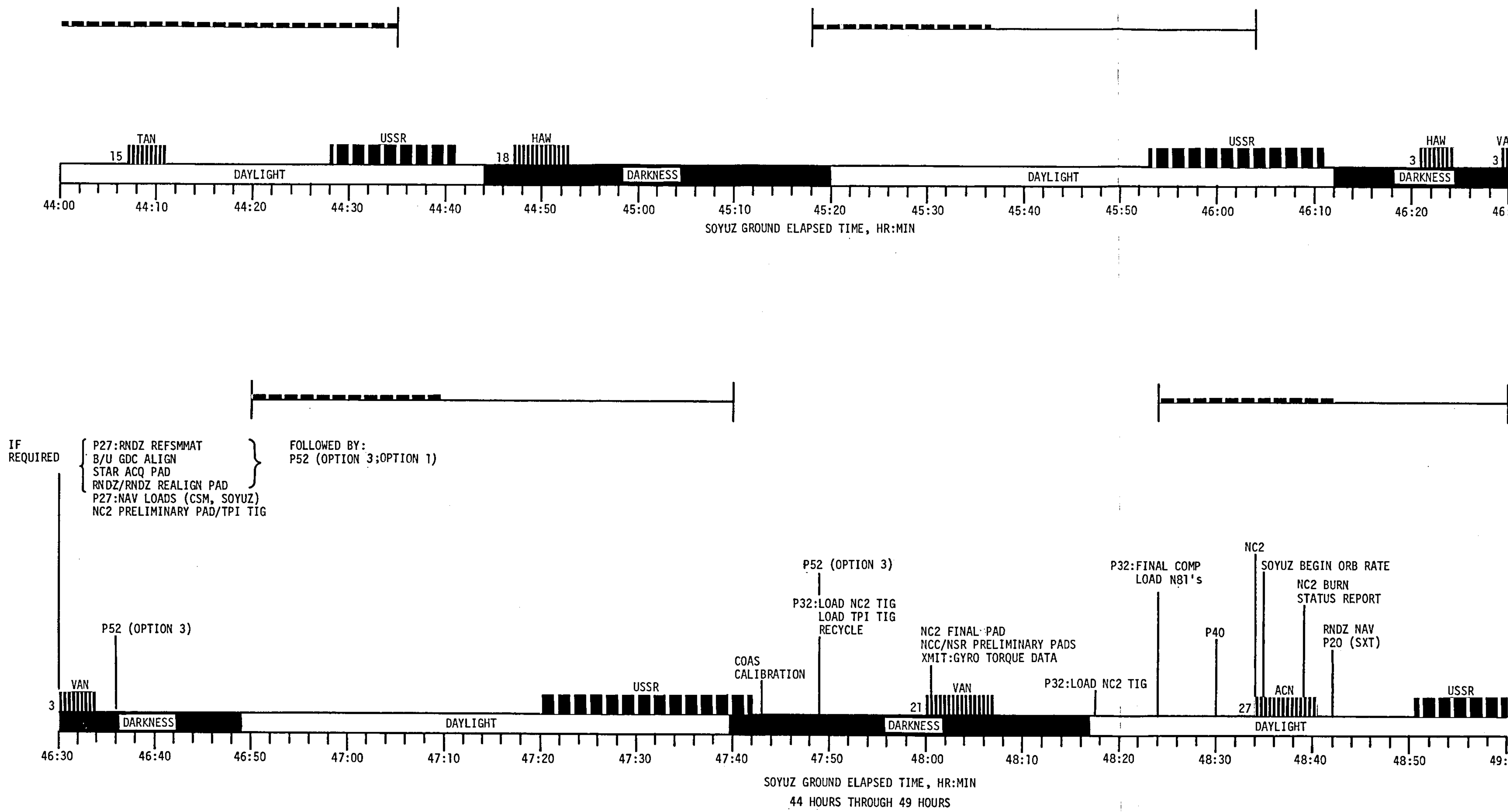
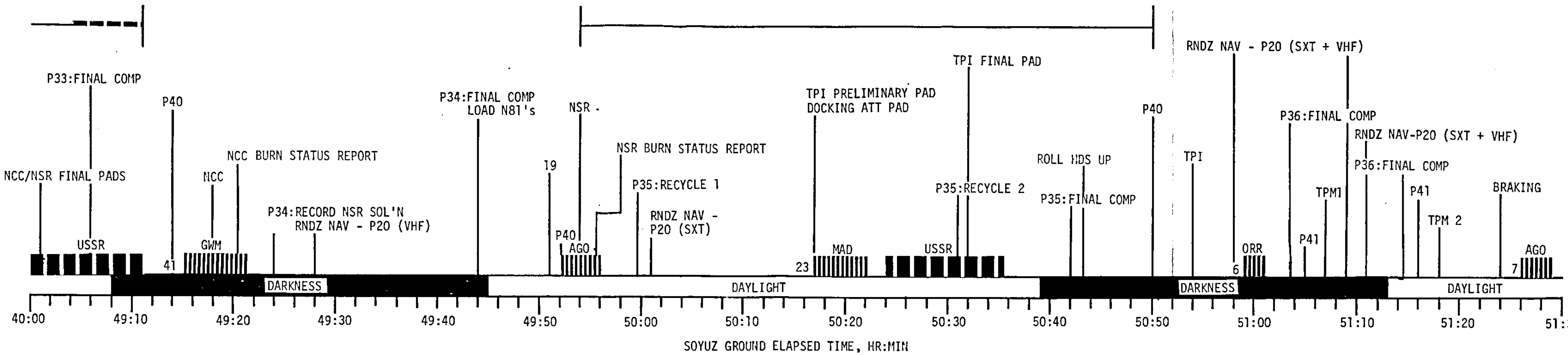


Figure 3-3. Rendezvous Timeline - 2nd Launch Opportunity (Continued)



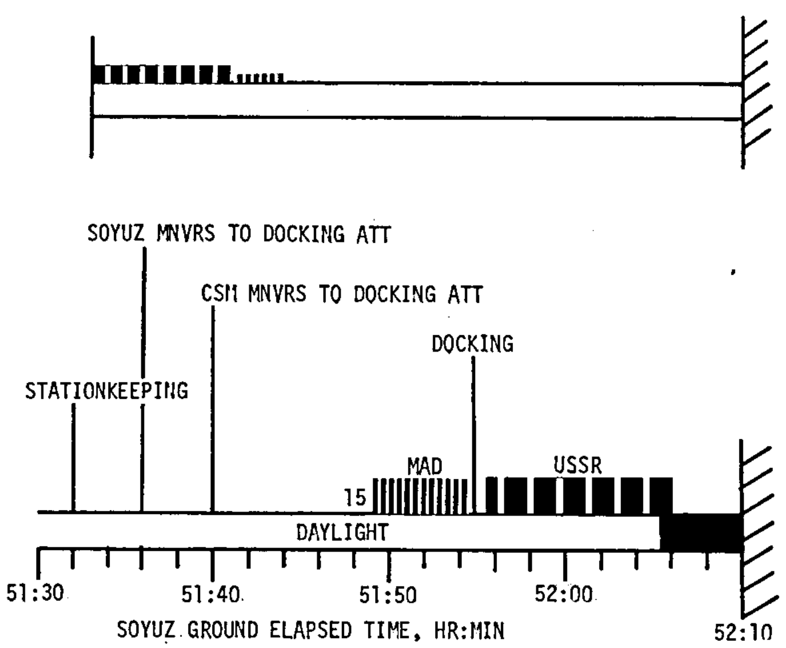


Figure 3-3. Rendezvous Timeline - 2nd Launch Opportunity (Concluded)

SOYUZ GROUND ELAPSED TIME, HR:MIN
49 HOURS THROUGH 52:10 HOURS

c) OHA Final PAD

d) PIPA Bias Update (if required)

The PIPA Bias Update must be voiced up due to lack of adequate command coverage to load the update prior to OHA.

3.4.1.5 Burn Preparation

The preparation time for OHA is limited due to the short ΔT between AEM and OHA (about 30 minutes). Consequently, certain preparations must be performed prior to AEM. These are mentioned here for completeness although they do not occur in the timeline covered in this section. The crew will perform a P52 alignment (Option 3) about 1 hr. 50 min. AGET. This alignment should remove the accumulated drift since launch. They will also perform an SCS Drift Check on BMAG set #1.

After AEM, burn preparation begins immediately. The crew will call V48E, load 2 jet ullage into the DAP, load a CSM weight (which equals the combined CSM and DM weights), and load the SPS pitch and yaw gimbal trim angles as indicated on the Preliminary PAD. They will then call P30 and verify that the N33 and N81 values agree precisely with those on the Final PAD. They will then proceed with the standard system checks per the SPS Burn Cue Card and call P40 at TIG-4 minutes.

3.4.1.6 OHA Burn

The OHA maneuver will be a horizontal posigrade SPS burn preceeded by the standard 2 jet, 20 sec ullage. TIG slips are not significant here and the maneuver could be slipped one rev if required with little penalty other than extending the first crew day by a rev.

3.4.1.7 OHA Trim Rules

The VGX residual is trimmed to within ±.2 fps. The other residuals have no significance to the rendezvous problem and are not trimmed.

3.4.2 OHA to ACM

After OHA is performed, the crew now must begin preparation for the ACM which will occur in one half revolution, about 45 minutes.

3.4.2.1 Burn Status Report (OHA)

The OHA burn status report is transmitted immediately after the burn via GDS. Nominally, GDS will be in acquisition for the burn so only an abbreviated report is required, primarily dealing with the EMS ΔV counter and any attitude excursions.

3.4.2.2 P52 Alignment

Another P52 (Option 3) alignment is performed about 25 minutes prior to the ACM maneuver. This alignment will measure the drift over the last 1.5 hours.

3.4.2.3 Ground Uplinks

The only uplink nominally scheduled in this timeframe is the ACM Target Load.

3.4.2.4 Ground Updates

The ACM Final PAD is the only voice update between OHA and ACM.

3.4.2.5 Burn Preparation

Since OHA precedes ACM by just one half rev, most of the required system and computer operations have already been performed. Computer operations are limited to calling P30 and verifying the N33 and N81 values agree with those on the Final Pad. After the crew verifies the GN&C systems with the SPS Burn Cue Card, they will cycle into P40.

3.4.2.6 ACM Burn

The ACM burn is usually an SPS posigrade maneuver of less than 3 seconds (i.e., short burn logic). It is preceded by a 20 sec, 2 jet ullage maneuver. The maneuver is insensitive to TIG slips and could be slipped an entire rev without significant impact to the rendezvous.

3.4.2.7 ACM Trim Rules

The VGX residual is trimmed to within ± 0.2 fps.

3.4.3 ACM to Docking

After ACM, most of the maneuver, burn preparation, navigation, and other rendezvous-related procedures are the same as for the M = 30 profile; consequently, they will not be repeated in this portion of the text. This section will deal with variations in procedures, targeting constraints, and other activities related to the rendezvous execution.

3.4.3.1 NC1/NPC

As previously mentioned, the NC1 maneuver varies considerably over the full range of launch windows and launch opportunities. These variations produce two principal effects on crew procedures. The first is that the maneuver may be too small to execute with the SPS, and become an RCS maneuver. Secondly, the maneuver could become retrograde considering the possible dispersions that must be dealt with. Neither of these changes cause any real problems however. As mentioned earlier (2.2), there are certain launch opportunities which require nominal usage of RCS to meet SPS redline constraints. Launches on days 3 and 4 could very easily fall into this category. If so, NC1 is one of the first maneuvers which would be considered for RCS execution or the 100-sec. ullage technique. This is considered a relatively minor crew impact item.

One significant problem that the reduced NC1 ΔV's could present is involved with NPC targeting. For the M = 30 profile, NC1 is large enough (66 fps) to provide considerable flexibility in dealing with planar problems (up to 115 fps of ΔV_Y could be combined with the NC1 ΔV_X to produce the desired nodal location and still not violate MGA constraints. This capability greatly reduces the probability of having to execute the NPC burn. However, as NC1 becomes smaller, the ability to combine ΔV_Y with the NC1 ΔV_X goes down proportionately. The worst case is that the ability to relocate the node goes away, and NPC must be executed wherever the node happens to lie. This could possibly present a less desirable timeline for maneuver execution but should not seriously impact the first day's activities.

3.4.3.2 GET Updates

GET Updates will be performed at the end of the first day for all launch opportunities. These updates are nominally:

Day 2 - 31 hrs. 5 min.

Day 3 - 54 hrs. 41 min.

Day 4 - 78 hrs. 15 min.

In all cases the CMC/RTCC clocks are stepped ahead by the indicated amount.

3.4.3.3 Rendezvous REFSMMATS

At the end of the first day's activities, a P52 (Option 1) is always performed to align the CSM platform to the "Rendezvous REFSMMAT." For each of the M = 14 launch opportunities a different REFSMMAT will be uplinked. These matrices are the "OT" REFSMMATS to which all Flight Plan attitudes, etc., are referenced. If required, the rendezvous REFSMMAT is updated prior to NC2 to provide the crew with as nominal as possible ball angles during the rendezvous. The criterion for updating the Rendezvous REFSMMAT is discussed in Section 2.5.6.1. The day 2 Rendezvous REFSMMAT is the same as the nominal (M = 30) REFSMMAT.

3.4.3.4 NC2

The M = 30 flow charts from crew wake-up through docking are essentially the same as the M = 14 and are not repeated. It should be noted however that the GET listed in the flow charts are wrong by:

Day 2 = no change

Day 3 = 23 hrs. 44 min.

Day 4 = 47 hrs. 24 min.

The variations that occur in NC2 are similar to those for NC1. It may become too small for SPS execution and can change direction from retrograde (normal) to posigrade. As previously mentioned, although NC2 is technically a phasing maneuver, its function nominally is to locate the NCC maneuver point 20 n.mi. below the Soyuz orbit. However, since the M = 14 profile does not provide an opportunity for the PCM, NC2 must be utilized to provide phasing corrections due to NC1 execution errors, state vector inaccuracies, drag uncertainties, etc.

If NC2 is required to adjust the phasing, the ΔV requirements for NCC/NSR will generally increase but the overall ΔV costs should not be significant, since only minor phasing corrections can be made with NC2.

3.4.3.5 NCC

The direction of NCC is directly tied to the OHA maneuver while the magnitude is nearly constant (about 30 fps). If OHA is performed, NCC is retrograde; if not, it is posigrade. NCC may peform a limited amount of phasing, and it also forces a planar position node at NSR. Consequently it will usually have three components, although ΔV_X should be the principal component.

3.4.3.6 NSR

NSR is computed to create a coelliptic and coplanar orbit with the Soyuz. Consequently, its ΔV_X component is almost totally dependent upon the altitude of the NCC maneuver point. The ΔV_Y and ΔV_Z components generally vary directly with those of NCC. It should usually be large enough to be an SPS maneuver although it may be performed with RCS on certain launch days to preserve SPS fuel.

3.4.3.7 TPI

TPI is essentially invariant for all rendezvous profiles. Nominally, it is performed at a 27° elevation angle (LOS) point from an orbit 10 n.mi. below the Soyuz at approximately 2 minutes prior to midnight. Accordingly, crew procedures leading up to TPI are constant for all rendezvous profiles.

3.4.3.8 Docking

The only unique procedure for the midcourse/braking/docking portion of the timeline is the manitude of the roll maneuver that each vehicle performs prior to docking. The following roll maneuvers are required:

Day 2 - 60° CCW

Day 3 - 55° CCW

Day 4 - 50° CCW

*Day 5 - 0° CCW

*ATS-6 coverage is not available for this launch opportunity.

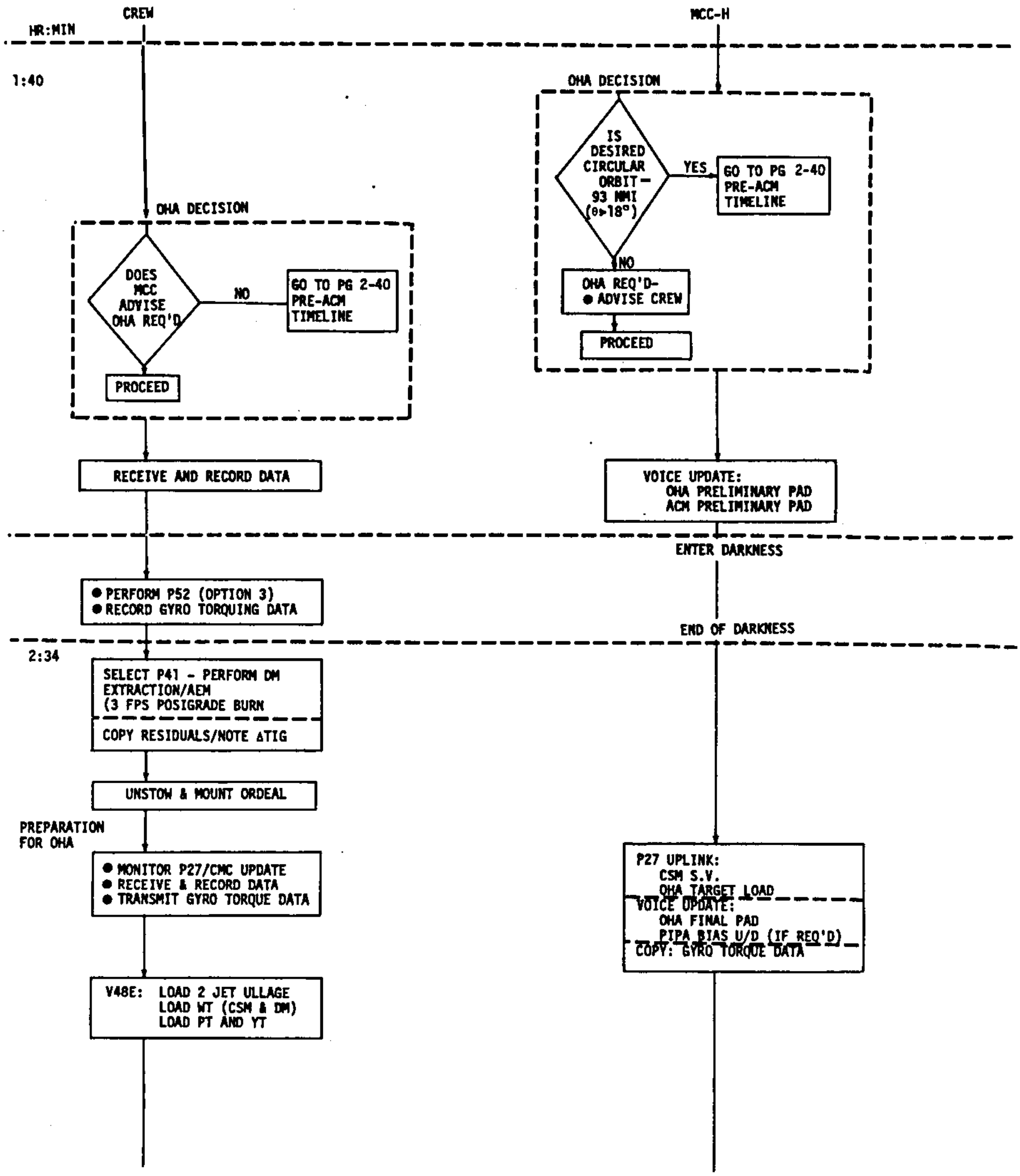


Figure 3-4. M = 14 Flow Chart

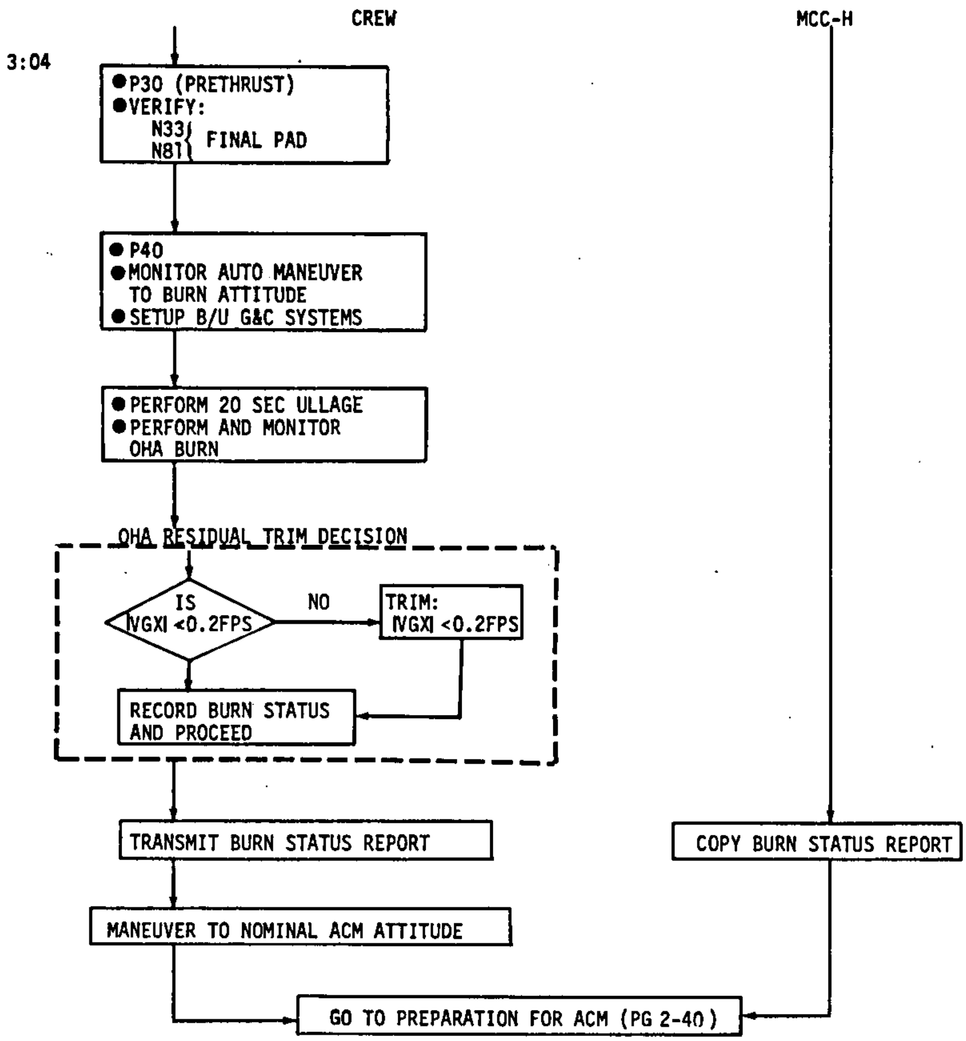


Figure 3-4. M = 14 Flow Chart (Concluded)

4. M = 13 PROFILE

This section presents a general discussion of the M = 13 rendezvous profile. Included in this section are descriptions of each maneuver, the sequence of events, and a detailed explanation of the rendezvous flow charts. As in Section 3, the format will be to explain those items that are different from the nominal (M = 30) sequence.

The M = 13 profile is flown only for launches on day 5. It was selected in lieu of the M = 14 to provide one additional rev of docked activity prior to undocking from the Soyuz. Day 5 launches, with this additional rev of docked time, result in only about 7.5 hrs of docked activity due to USSR constraints on total Soyuz mission duration (144 hrs).

All times are listed in the appropriate mission GET. The SGET of docking for this profile is three days later than nominal, about 121 hrs 33 min. Figure 4-1 depicts the nominal relative motion for this profile.

4.1 MANEUVER SEQUENCE

The M = 13 maneuver sequence is similar to the M = 14 profile that includes an OHA, except that ACM is not performed. The deletion of this burn causes considerable shifting of the timeline which is discussed in detail. Figure 4-2 illustrates the orbital geometry of this sequence.

4.1.1 OHA

The OHA maneuver is performed one hour after the AEM at 3 hrs 34 min. It is targeted to create an apogee 5 n.mi. above the Soyuz orbit. However, in order to orient the maneuver line such that the NCC lighting is proper (see Section 2.1.2), the maneuver is not performed at an apsis. It is performed approximately half-way between perigee and apogee (η = 100°) which may necessitate adding a radial component to the burn.

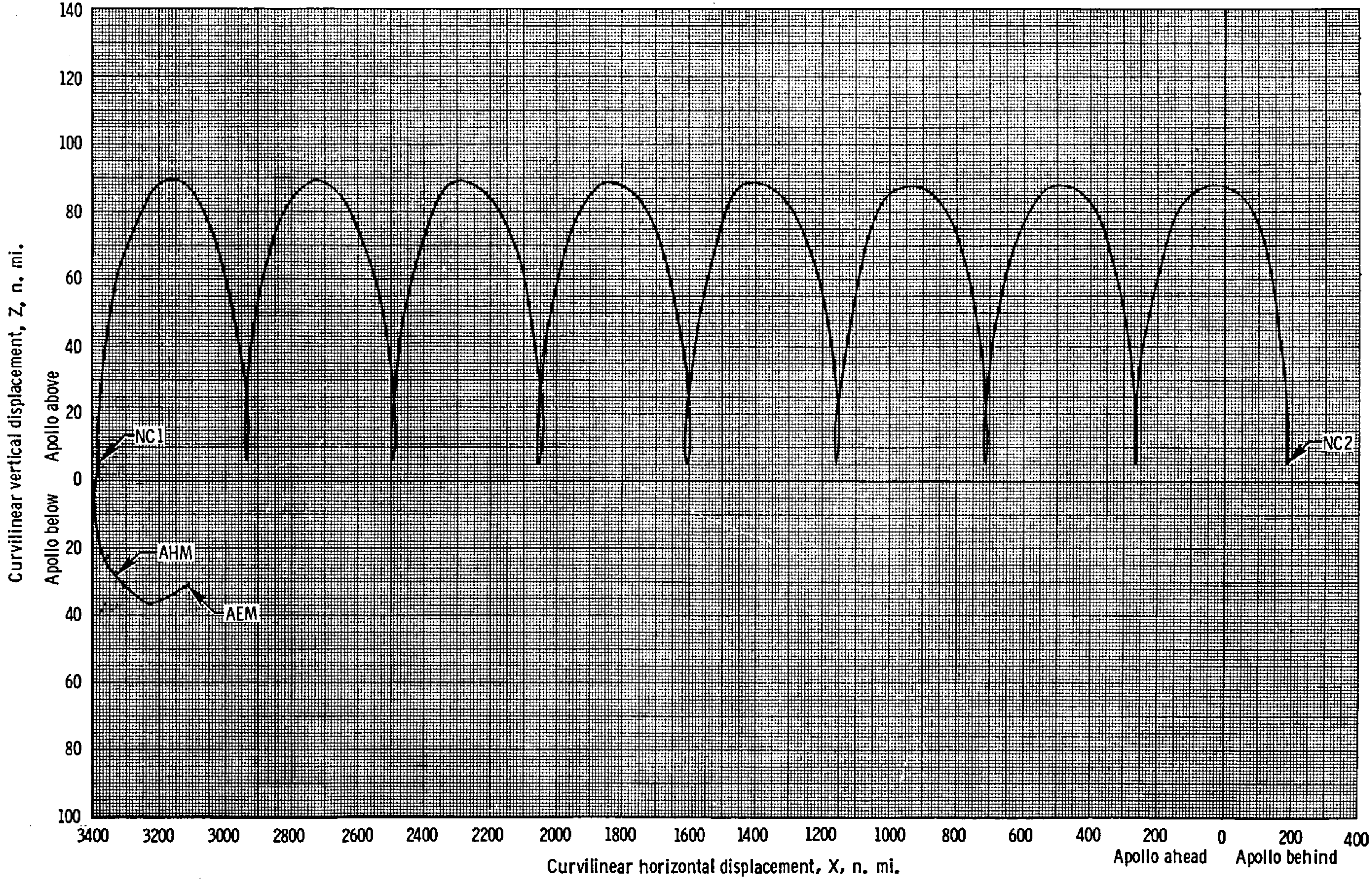
4.1.2 NC1/NPC

NC1 maneuver targeting considerations have already been discussed. The magnitude of the maneuver is dependent upon where in the window launch occurs. Nominally, it is about 200 fps and decreases to about 115 fps at the close of window. Since no ACM is required, NC1 is performed approximately one-half rev after OHA, which is about one rev earlier than in the M = 30 and M = 14 profiles. By making up this revolution pre-NC1, the crew timeline/maneuver sequence from NC1 through docking then becomes identical to that for the M = 14 profile. NC1 ignition, chosen based on lighting for the other profiles, is now forced by OHA since that maneuver will orient the line of apsides properly for lighting.

Since NC1 is always fairly large, planar errors can be handled as described in Section 2.1.3.

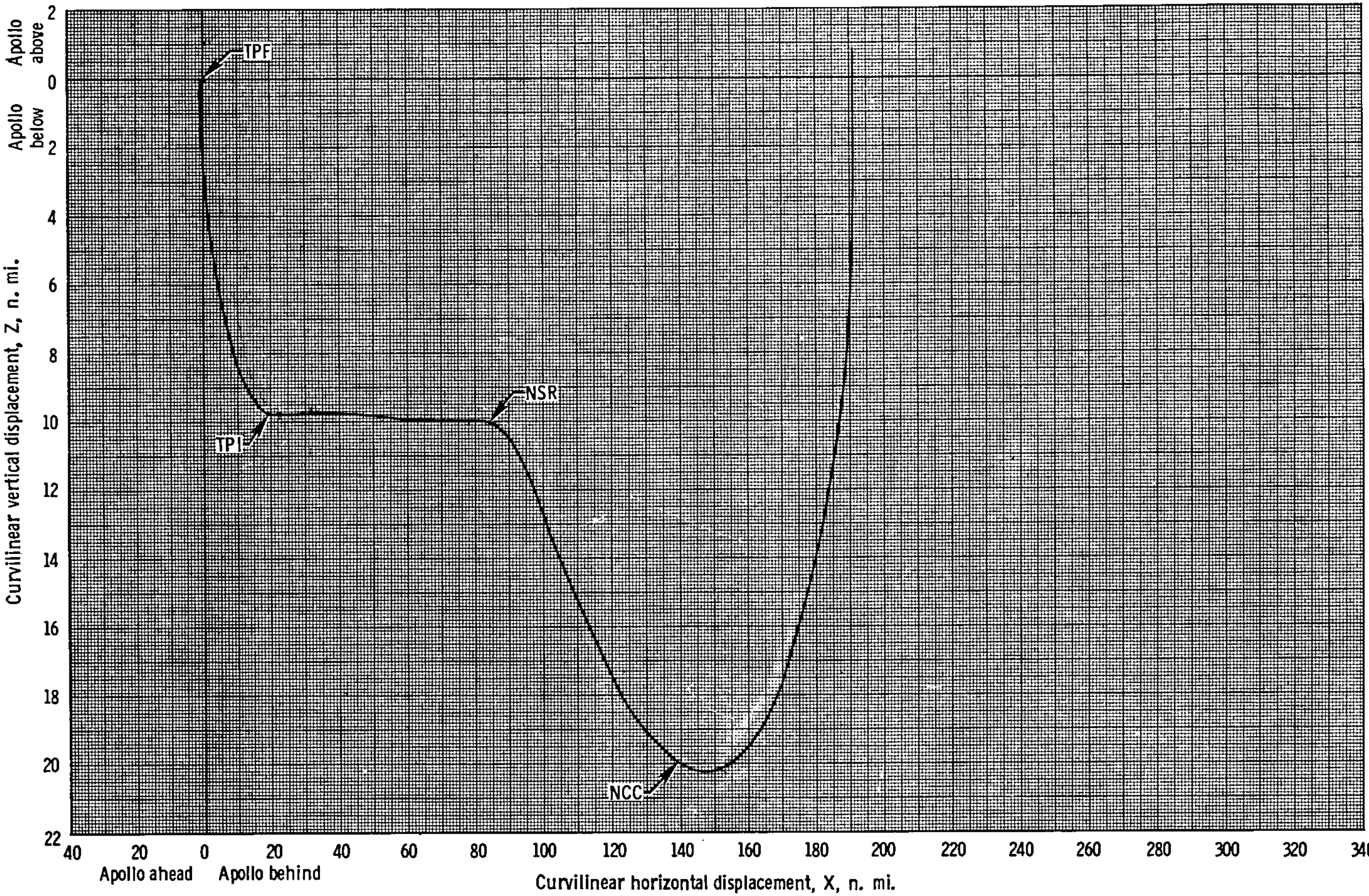
4.1.3 NC2

NC2 targeting is accomplished as in the other profiles. The magnitude



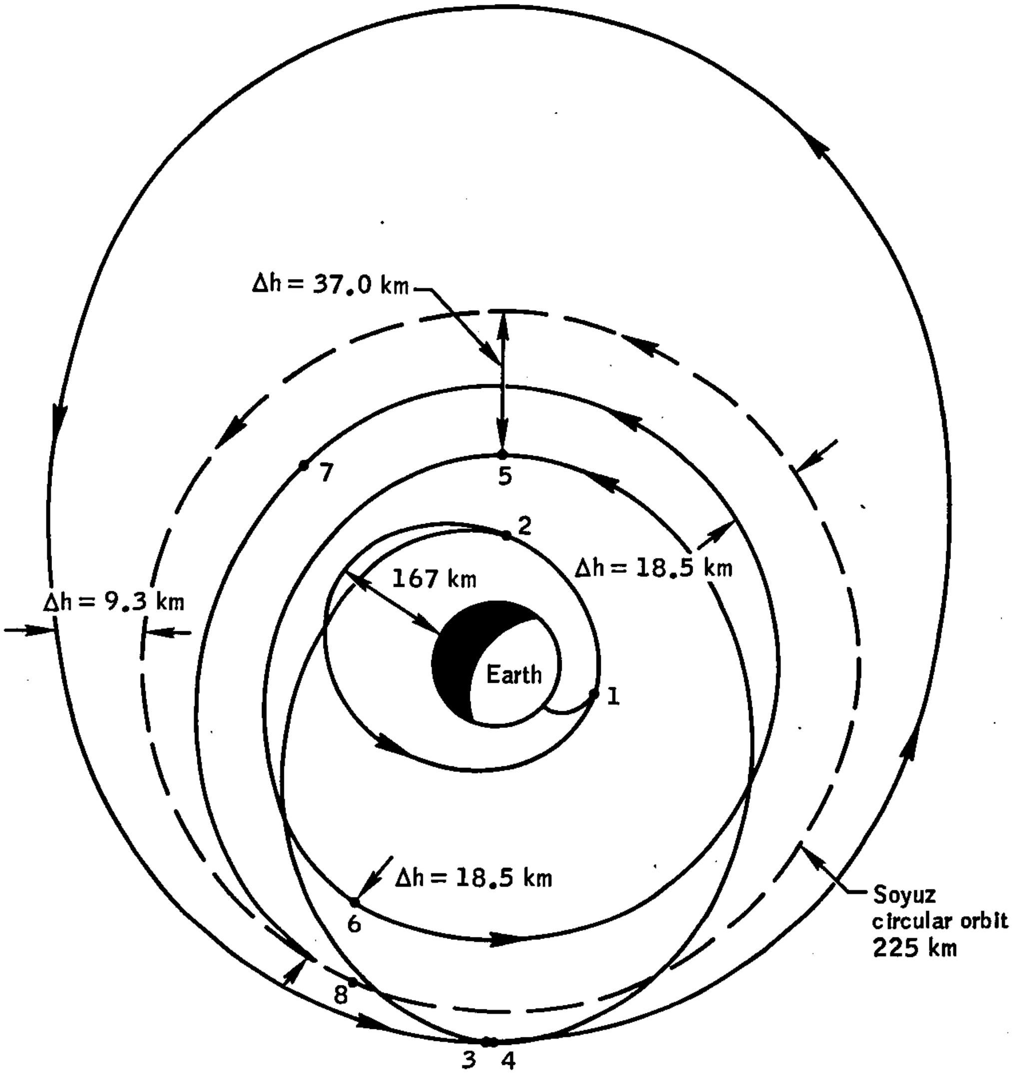
(a) AEM to NC2.

Figure 4-1. Relative Motion - M=13 Profile



(b) NC2 to TPF.

Figure 4-1. Relative Motion - M=13 Profile (Continued)



1 Insertion -150 by 167 km
2 Orbit adjustment
3 Phasing 1 (NC1)
4 Phasing 2 (NC2)
5 Corrective combination (NCC)
6 Coelliptic (NSR)
7 TPI
8 Braking (TPF)

Figure 4-2. Orbital Geometry - M = 13 Profile of NC2 varies directly with that of NC1. NC2 is nominally about 190 fps retrograde and drops to about 100 fps by the close of the window.

4.1.4 NCC

The ΔV of NCC is a function of the OHA target condition. That is, NCC will lower the apogee created by OHA to 112 n.mi. (10 n.mi. below the Soyuz orbit). As long as OHA creates an apogee 5 n.mi. above the Soyuz orbit, NCC will be a 30 fps retrograde burn. There will also be the usual small ΔV_Z and ΔV_Y components for NCC to provide small phasing and planar corrections.

4.1.5 NSR

The NSR targeting consideration for this profile is the same as for both the M = 30 and the M = 14 profiles.

4.1.6 TPI through Docking

Terminal phase of the M = 13 sequence is identical to that for the other two profiles. Docking occurs at 121 hrs. 33 min. SGET.

4.2 INSERTION OVERSPEED/UNDERSPEED STRATEGY

The M = 13 profile presents some unique problems when dealing with insertion velocity dispersions, primarily due to the absence of the ACM burn. In the other profiles the ACM was the primary source of the flexibility that the profile presented for contingencies like overspeeds. Without ACM much of the flexibility is gone, and the ΔV constraints on the M = 13 profile further complicate the situation.

In terms of phasing only, overspeeds are almost "desirable" as they achieve a high apogee early. The problem comes in that the line of apsides orientation is not correct for lighting (pre-NCC). The ΔV cost to simply rotate the orbit such that the line of apsides falls where it belongs is usually prohibitive so alternate techniques must be considered. Depending on the magnitude of the overspeed and the fuel availability, the following options will exist:

1. Perform OHA to orient the line of apsides and establish the proper ΔH above the Soyuz orbit. Perform a smaller than normal NC1 to compensate for decreased catch-up rate in initial orbit. This represents both the most expensive technique and the minimum impact on the crew timeline.

2. Perform a single maneuver to circularize the orbit at an altitude such that NC1 becomes a 0 ΔV maneuver. Although this does change the timeline somewhat, it probably is the best compromise between ΔV cost and procedural changes. This maneuver can be scheduled between the nominal OHA and NC1 maneuver points or one-half rev later depending on timeline considerations.

3. Perform an optimum two-maneuver circularization sequence to obtain a circular orbit. The size of the orbit can be selected to force any NC1 ΔV desired, with a 0 ΔV NC1 being the cheapest solution possible. This sequence does not significantly impact day 1 activities if NC1 is forced to be 0 ΔV. If not, the timeline impact grows but is still not considered prohibitive. In all cases, the NC2 ΔV would decrease proportionately to the post-NC1 apogee. The remaining maneuvers would not appreciably change.

The ability to recover from overspeeds is essentially independent from where launch occurs in the window. As the insertion phase angle becomes less negative, the optimum circularization orbit altitude would decrease, but the overall ΔV costs from a given overspeed would not vary appreciably.

Underspeeds present a less serious problem from both a timeline and a ΔV standpoint. The OHA maneuver will increase slightly since the change in altitude it is producing has increased. The NC1 maneuver would grow to compensate from both the increased catch-up rate during the first two revs and the decreased OHA maneuver point altitude. Neither of these ΔV increases are of significant magnitude to be of major concern. NC2 would increase since it must reduce the higher apogee created by NC1.

4.3 RENDEZVOUS TIMELINE

A summary of the major activities for the M = 13 profile is shown in Figure 4-3. Section 4.4 will present a detailed discussion of these and other related activities.

4.4 RENDEZVOUS FLOW CHARTS

This section discusses the various timeline activities depicted in the flow charts (see Figure 4-4), as well as the procedures involved in performing these tasks. Only the changes from the nominal (M = 30) timeline are presented in this section, with one exception. The maneuvers requiring either long RCS ullages or RCS execution are noted in this section but not in the flow charts since the changes they present to the overall data flow and crew procedures are minimal.

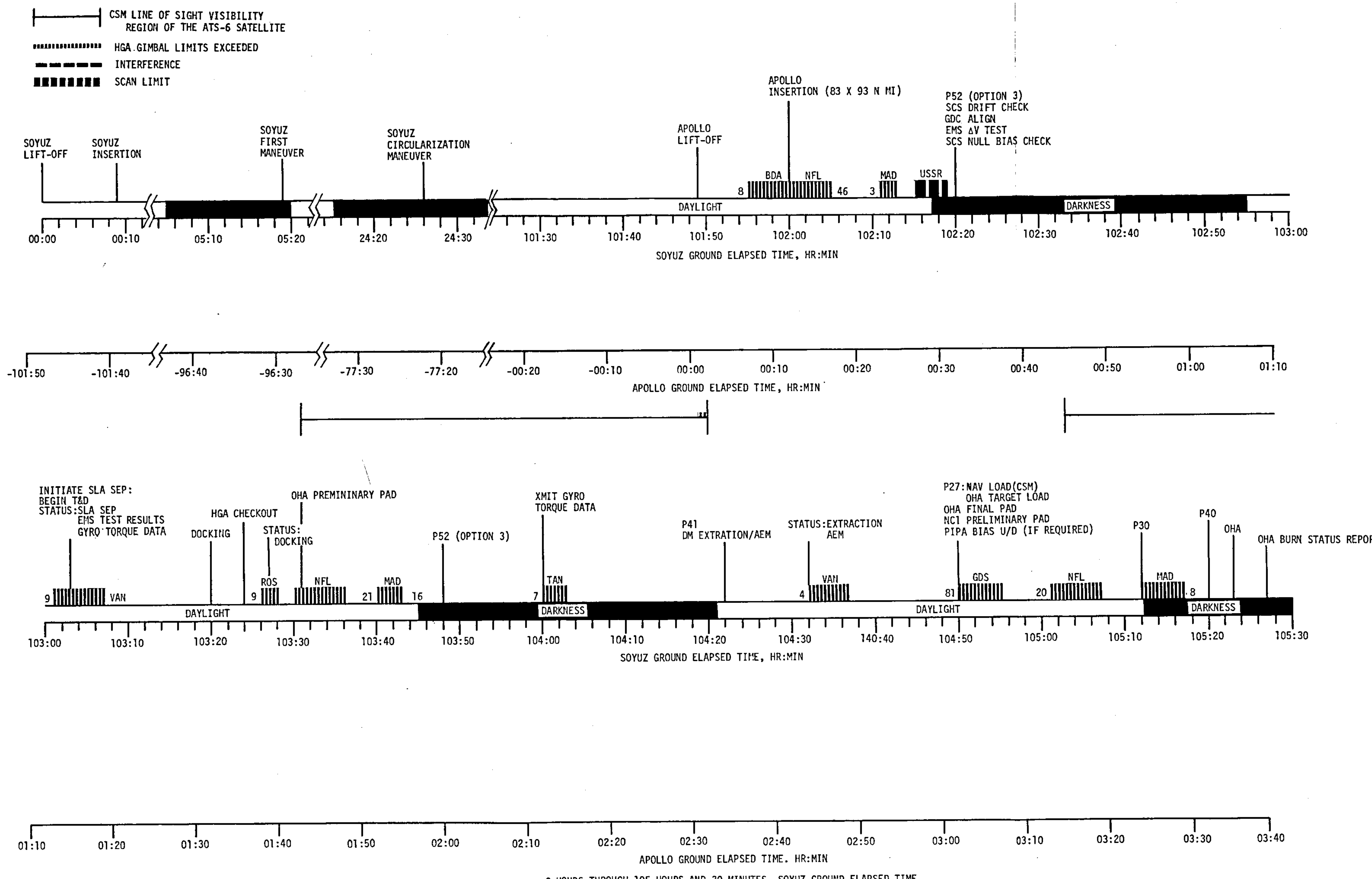


Figure 4-3. Rendezvous Timeline - 5th Launch Opportunity

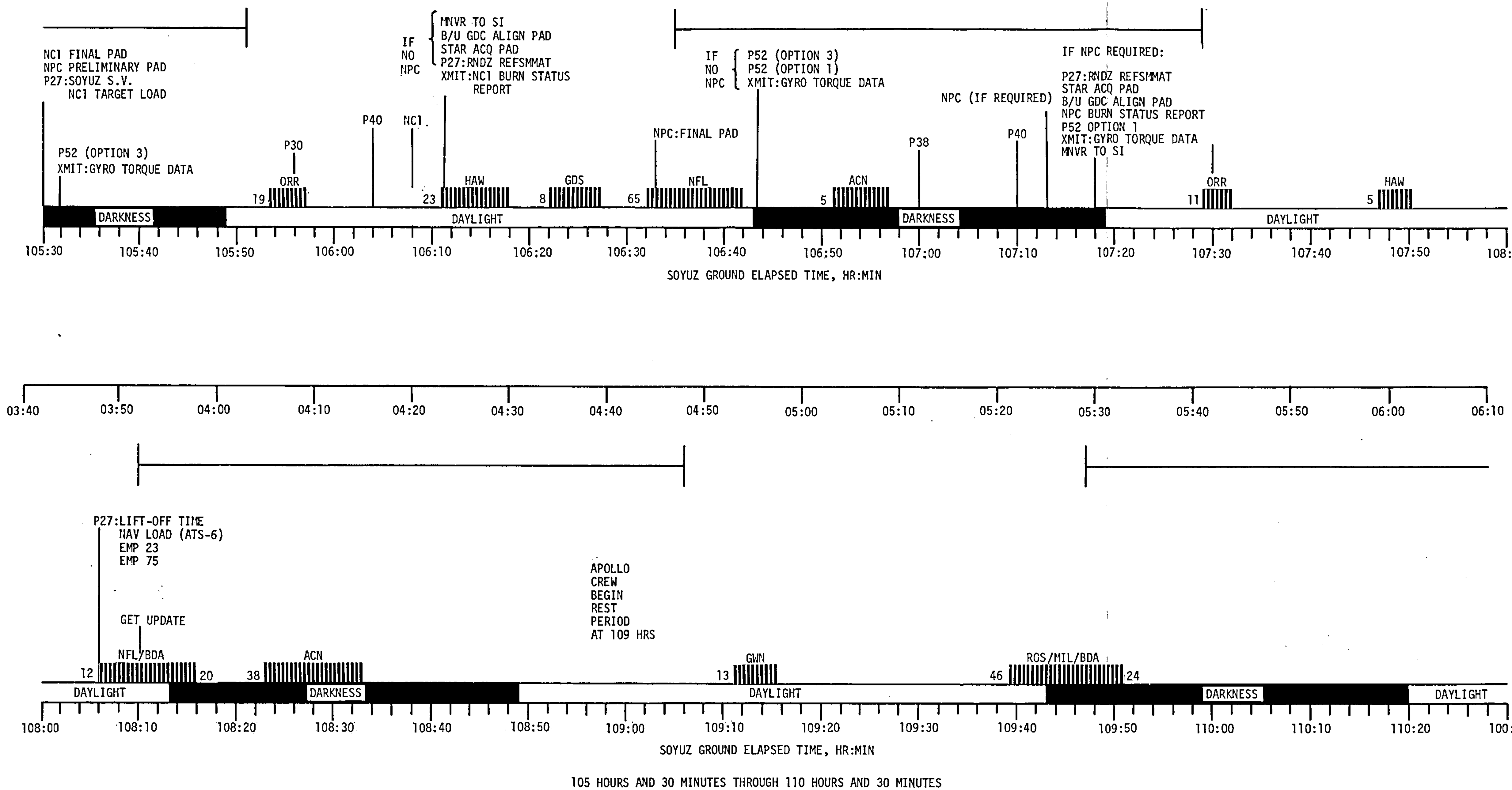
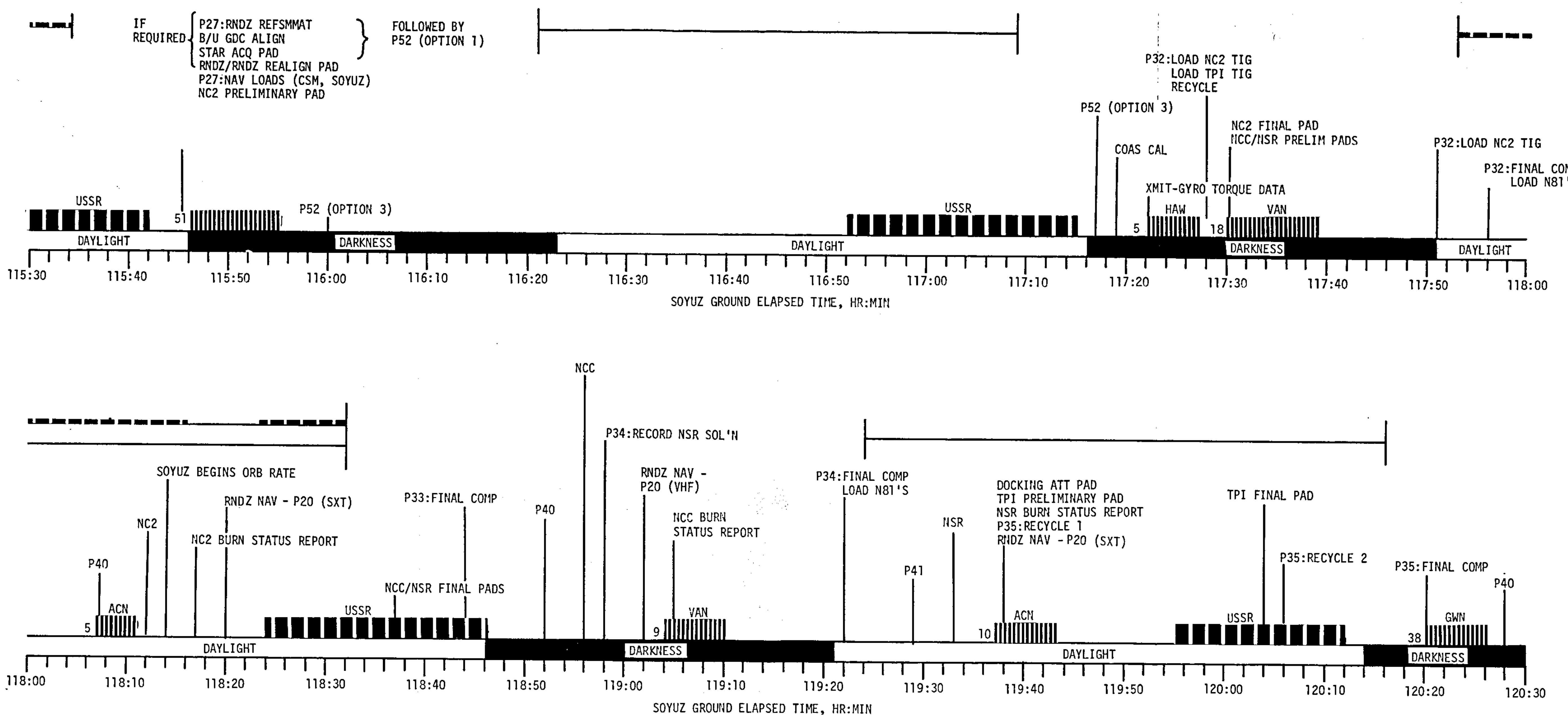
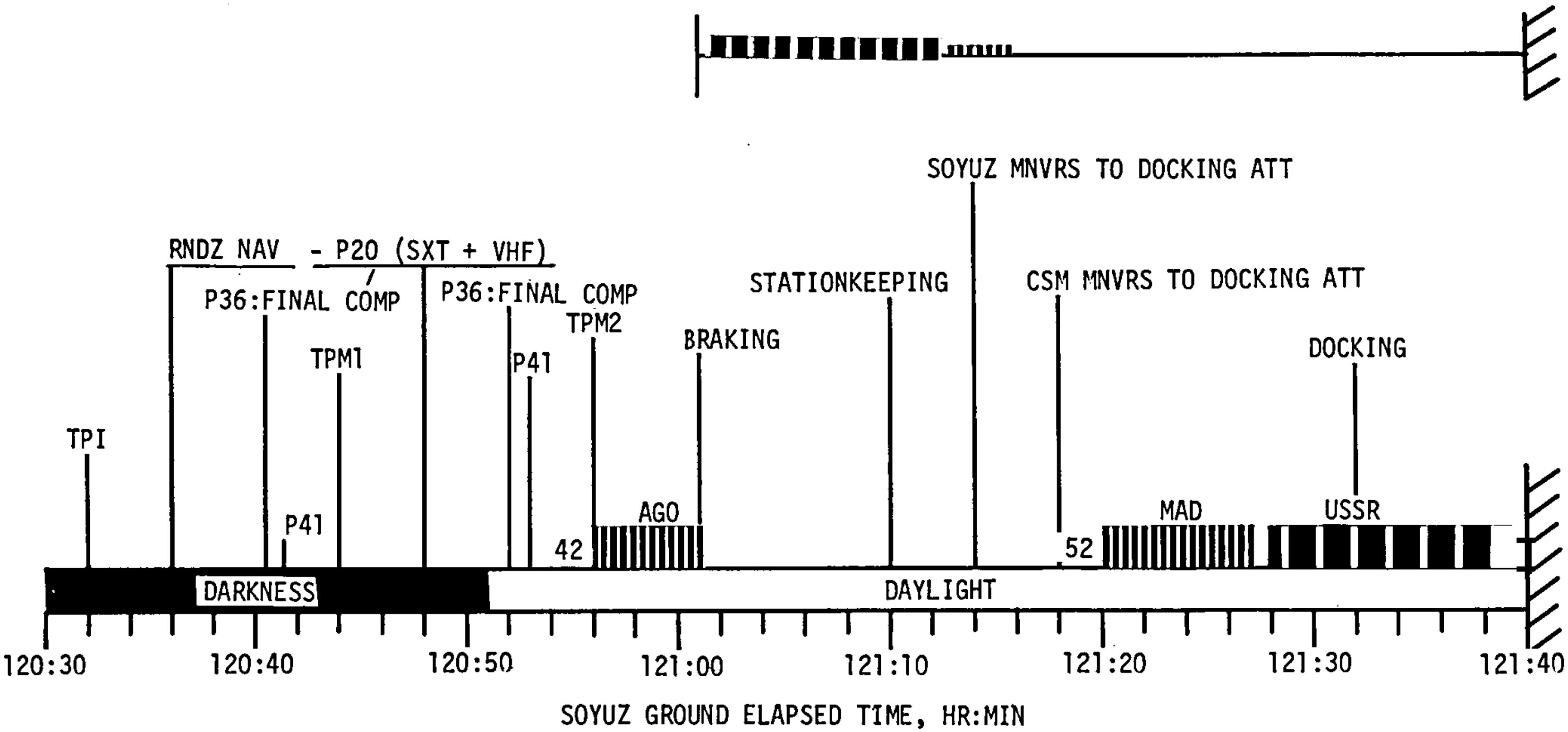


Figure 4-3. Rendezvous Timeline - 5th Launch Opportunity (Continued)



115 HOURS AND 30 MINUTES THROUGH 120 HOURS AND 30 MINUTES

Figure 4-3. Rendezvous Timeline - 5th Launch Opportunity (Continued)



(E) 120 HOURS AND 30 MINUTES THROUGH 121:40 HOURS

Figure 4-3. Rendezvous Timeline - 5th Launch Opportunity (Concluded)

4.4.1 AEM to OHA

This section will briefly discuss the timeline prior to OHA. It is almost exactly like that required for the M = 14 sequence when OHA is performed (Section 3.4.1).

4.4.1.1 Ordeal Set Up

The Ordeal is unstowed and mounted shortly after the AEM.

4.4.1.2 Burn Status Report (AEM)

The standard AEM burn report will be passed down by the crew about 10 minutes after the maneuver.

4.4.1.3 Ground Uplinks

The ground will uplink a CSM state vector and the OHA target load over the VAN shortly after the AEM.

4.4.1.4 Ground Updates

The following messages are upvoiced prior to OHA:

a) OHA Preliminary PAD } Passed up prior to AEM

b) OHA Final PAD

c) NC1 Preliminary PAD

d) PIPA Bias Update (if required)

4.4.1.5 Burn Preparation

The ΔT between AEM and OHA is about one hour, which provides a more leisurely timeline than the M = 14 sequence. The amount of crew preparation procedures is essentially unchanged, and is covered in Section 3.4.1.5. This extra time does provide an option of performing an additional P52 if desired, but it would have to be performed in daylight. An ignition attitude check could be performed in lieu of a P52, and only in the event of the star check failing would a P52 then be required.

4.4.1.6 OHA Burn

The OHA burn is executed as described in Section 3.4.1.6 with one exception. Due to the criticality of SPS fuel, the burn is preceded by a 100 second, 4 jet ullage burn. The rationale for this procedure is presented in Section 2.2.

4.4.1.7 OHA Trim Rules

Only the V_{GX} residual of the OHA burn is trimmed (±0.2 fps).

4.4.2 OHA to NC1

The deletion of ACM from the timeline causes procedural changes in the pre-NC1 timeline. In essence, the pre-NC1 timeline is shifted to replace the pre-ACM timeline, which is dropped out completely.

4.4.2.1 Burn Status Report (OHA)

The crew will provide the OHA burn status report as soon as possible after the burn. This will either be immediately after the burn via ATS-6 or over ORR about 20 minutes prior to NC1. If the STDN site is used, the NC1 maneuver must be computed assuming a nominal OHA. Any significant problems realized during OHA execution (TIG slips, large untrimmed residual, etc.) may require slipping NC1 by one rev in order to recompute a new maneuver.

4.4.2.2 P52 Alignment

A P52 (Option 3) will be performed during the same night pass in which OHA occurs.

4.4.2.3 Ground Uplinks

The following uplinks will be transmitted by the ground prior to NC1:

a) NC1 Target Load

b) Soyuz State Vector

c) Gyro Comp Update (if required)

4.4.2.4 Ground Updates

The only message nominally passed up in this time period is the NC1 final PAD.

4.4.2.5 Burn Preparation

The burn preparations required before NC1 are generally the same as for the other profiles. The crew must call P30 and verify N33 and N81. They will insure that the SPS Burn Cue Card procedures are performed and then call P40.

4.4.2.6 NC1 Burn

NC1 will be a large posigrade maneuver, preceded by the same 100 sec. 4 jet ullage burn as was OHA. A ΔV_Y component could be included if planar errors were incurred during launch. Similarly, a ΔV_Z component could be included to help reorient the maneuver line or compensate for dispersions. It is insensitive to TIG slips and could be slipped a rev without significant ΔV penalty.

4.4.2.7 NC1 Trim Rules

The VG_X residual is trimmed to within ± 0.2 fps.

4.4.3 NC1 to Docking

Since the M = 13 sequence is nearly identical to the M = 14 sequence from NC1 on, no further detailed flow chart discussions are required. This section will present some M = 13 unique items that occur between NC1 and docking.

4.4.3.1 NPC

While the same targeting criteria that apply to the other sequences would ideally apply to this profile, the criticality of SPS fuel for fifth opportunity launches may force a different approach. Since the OHA, NC1 and NC2 burns are always large maneuvers, a ΔV_Y component could be added to these maneuvers at almost no increase in total ΔV requirements. However, in order to effectively eliminate planar errors, these maneuvers cannot remain 180° apart. What this means is that a manual iteration process involving OHA, NC1, and NC2 geometry may have to be utilized to solve large planar errors. All of the maneuvers may end up with 3 large components although the total ΔV would not increase appreciably. While this technique would also apply to the M = 14 profile where ΔV is equally critical, the possibility of having very small NC1 and NC2 burns reduces the effectiveness of this kind of targeting.

4.4.3.2 GET Update

A GET update is performed at the end of the first day's activity to sync Apollo GET to Soyuz GET. The magnitude of the update is nominally 101 hours and 49 minutes.

4.4.3.3 Rendezvous REFSMMAT

At the end of the day 1 timeline, the crew will perform a P52 (Option 1) and realign the CSM platform to the nominal ("OT") rendezvous REFSMMAT for the fifth launch opportunity. If required, that REFSMMAT will be updated with another Rendezvous REFSMMAT, generated in real time, prior to NC2. The update criteria are listed in Section 2.5.6.1.

4.4.3.4 NC2

It should again be noted that while the M = 30 flow charts from pre-NC2 through docking are valid for the M = 13 profile, the times listed in the charts are in error by approximately 69 hrs. 38 min.

NC2 will always be a fairly large posigrade maneuver and should usually be executed with the SPS. Nominally, however, it will be preceded by a 100 sec., 4 jet ullage burn. As the launch slips through the launch window, the length of this ullage burn may decrease depending upon other dispersions. NC2 may well become a three component burn, but the retrograde ΔV_X component will always be the largest. As in the M = 14 sequence, the lack of a PCM burn may require that a small amount of phasing be performed with NC2, which presents no particular problems.

4.4.3.5 NCC

NCC should always be a retrograde SPS maneuver of around 35 fps. As in the other profiles, it will generally be a three component burn with the magnitudes of ΔV_Z and ΔV_Y directly correlated to the magnitude of dispersions realized during the rendezvous.

4.4.3.6 NSR

NSR for this profile will be executed with the RCS as a 4 quad maneuver. With this exception, all other details in Section 3.4.3.6 apply to this NSR.

4.4.3.7 TPI

TPI is performed identically to that of the M = 30 and M = 14 profiles (see Section 3.4.3.7).

4.4.3.8 Docking

The M = 13 profile will not include roll maneuvers prior to docking as no ATS-6 coverage is available for docking, independent of S/C roll, due to structural blockage incurred when observing the other docking attitude constraints.

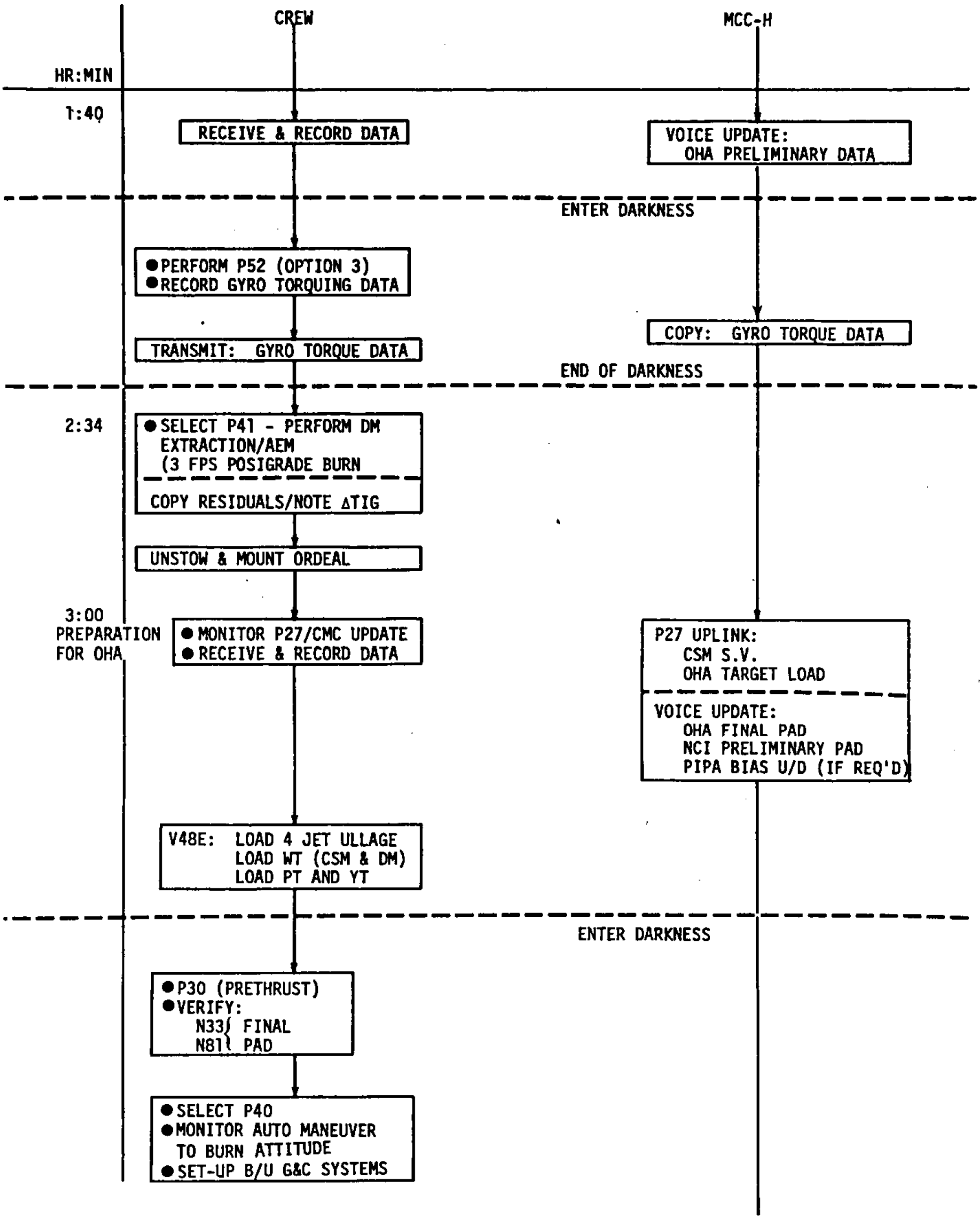


Figure 4-4. M = 13 Flow Chart

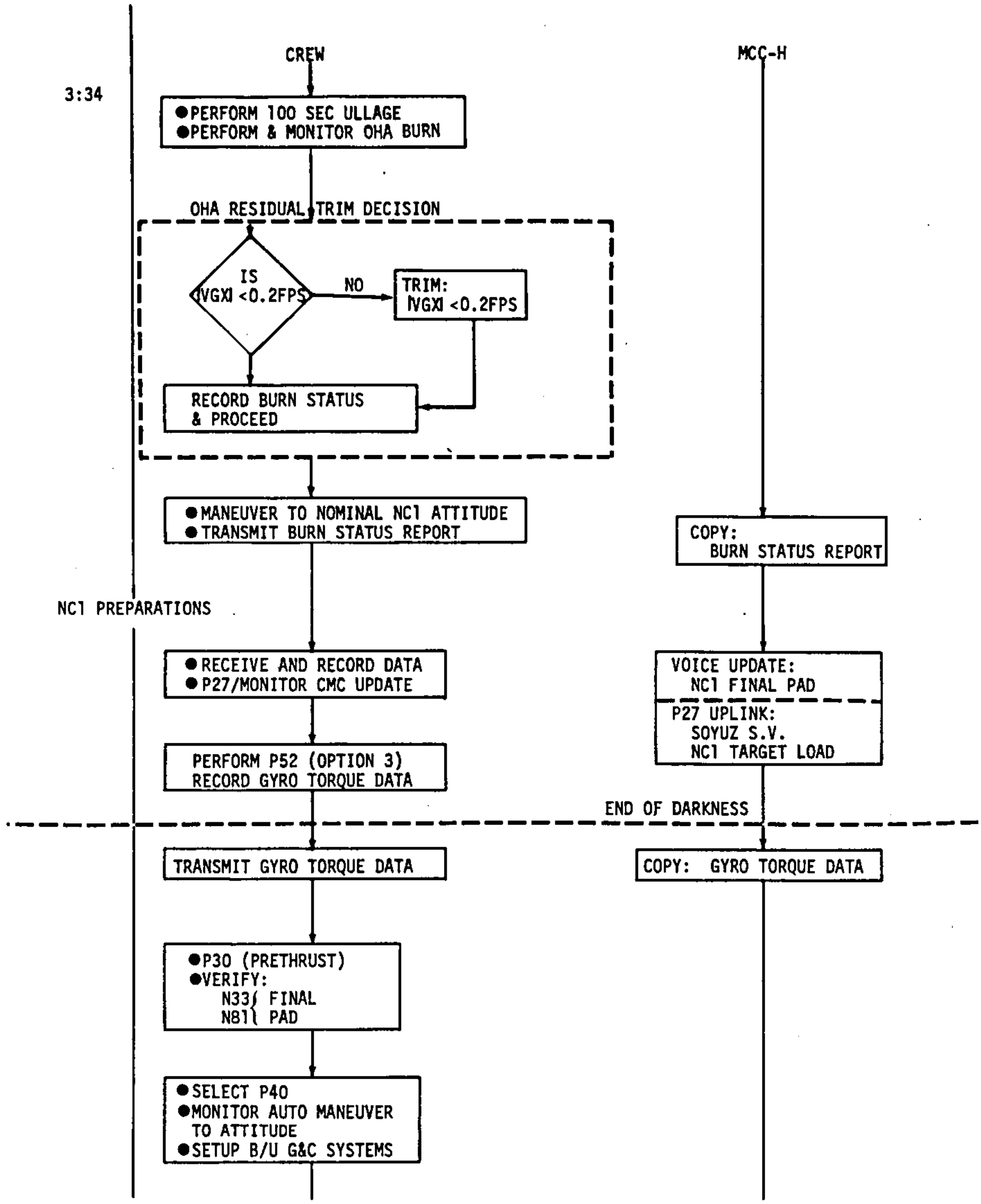


Figure 4-4. M = 13 Flow Chart (Continued)

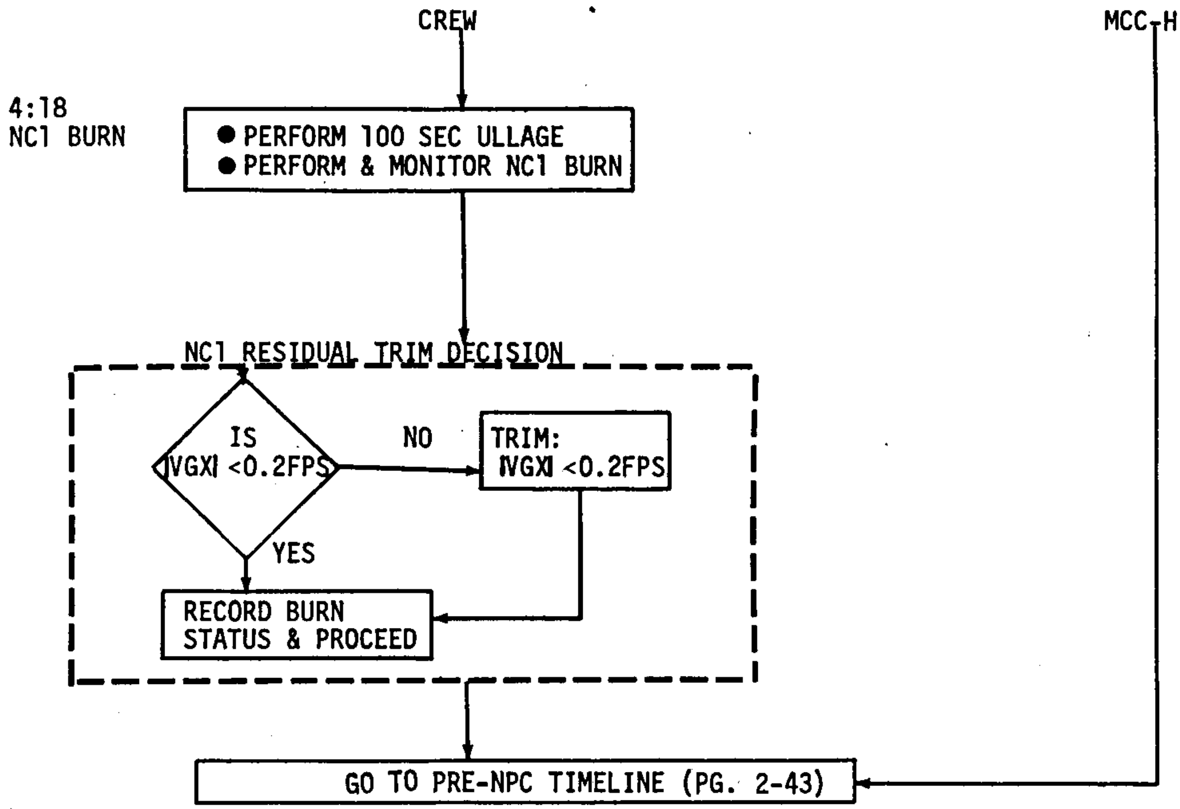


Figure 4-4. M = 13 Flow Chart (Concluded)

5. SOYUZ RESCUE

In the remote event that the Soyuz becomes disabled such that it can no longer provide a safe re-entry for the Russian crew, a CSM rescue capability is being developed. Rescue will involve a rendezvous (or re-rendezvous) with the Soyuz, transfer of the Russian crew into the CSM, and a reentry sequence with all five crewmen in the Command Module. This section will present a general discussion of the various situations from which rescue might have to be undertaken.

5.1 SOYUZ DISABLED PRIOR TO CSM LAUNCH

If the Soyuz is disabled before the CSM launches, certain actions will be taken to optimize the rescue. A "Rescue Kit" will be added to the CSM, consisting of some mattress-like devices on which the Soyuz crewmen will rest during reentry, and possibly other items to make the situation more comfortable. It is conceivable that certain stowage configurations will also be revised, but these items will not be discussed in this document. This discussion will present pertinent trajectory and procedural concerns.

One major philosophy must be explained prior to discussing rescue further. That is, it has been decided that if the need for a rescue is known prior to CSM launch, an M = 14 profile will be flown, and launch window computations will be conducted accordingly. The only exceptions to this groundrule are situations where the Soyuz anomaly is time-critical and rescue must be speeded up in order to prevent crew loss. In these instances, rendezvous profiles down to an M = 6 will be performed as required to effect the rescue.

5.1.1 Soyuz Does Not Perform Circ

If the Soyuz is disabled before it can perform the Circ burn, the CSM launch window will be computed based upon the Soyuz insertion orbit. This orbit characteristically provides excellent M = 14 rendezvous opportunities. Although it is unlikely that this type of failure could occur and be resolved quickly enough to allow a day 1 CSM launch, an M = 14 opportunity does exist. Figure 5-1 shows a typical day 1 launch window computed for the Soyuz insertion orbit. Although the data is not shown on the graph, the M = 6 phase pane occurs about 10 minutes prior to the inplane launch opportunity.

Figure 5-2 presents typical rendezvous phase panes for CSM launches for the remaining 4 launch days, all assuming the Soyuz remains in the nominal insertion orbit.

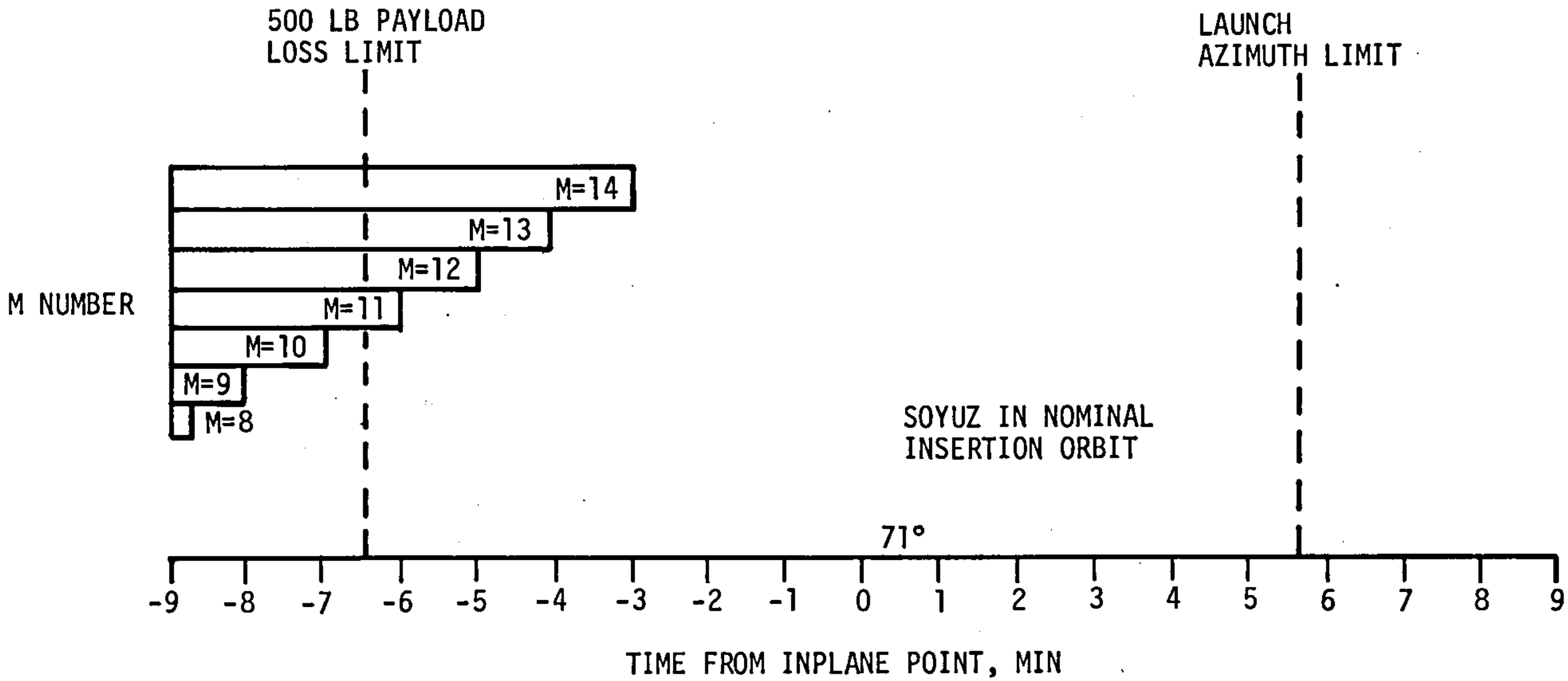
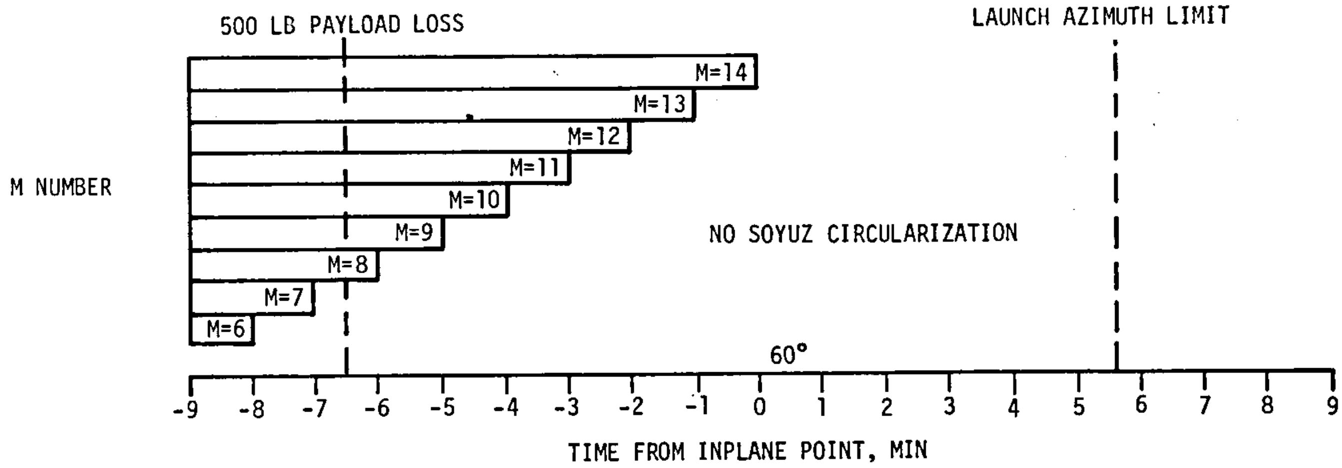
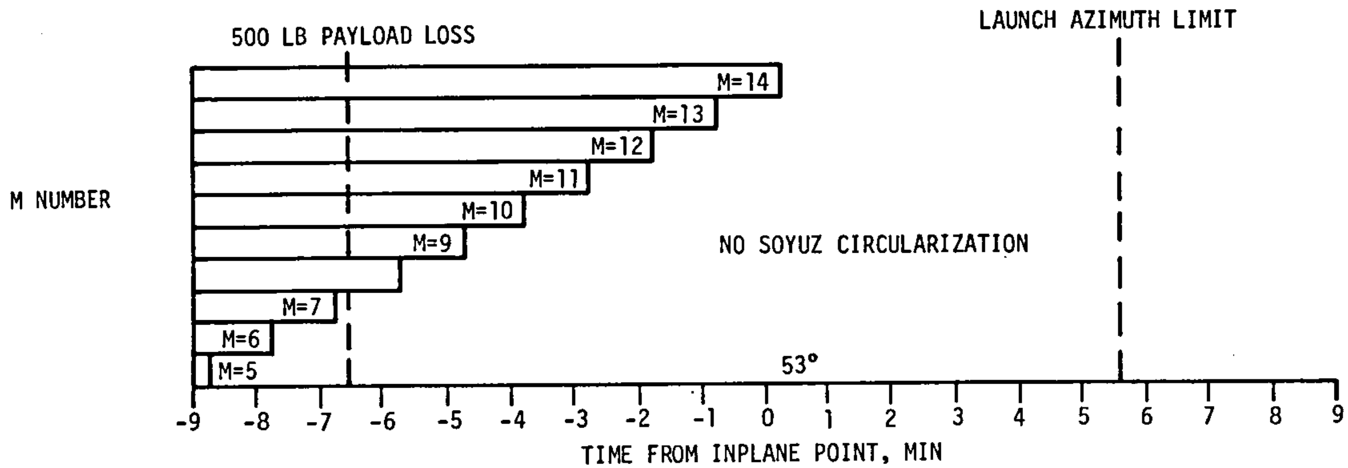


Figure 5-1. Day 1 Early Rendezvous Opportunities

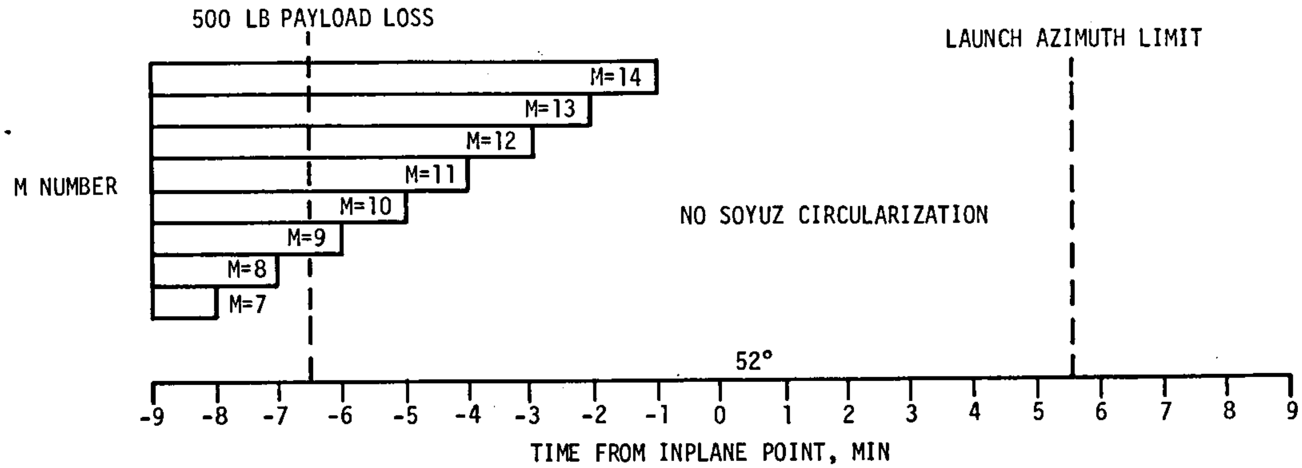


(a) DAY 2 EARLY RENDEZVOUS OPPORTUNITIES

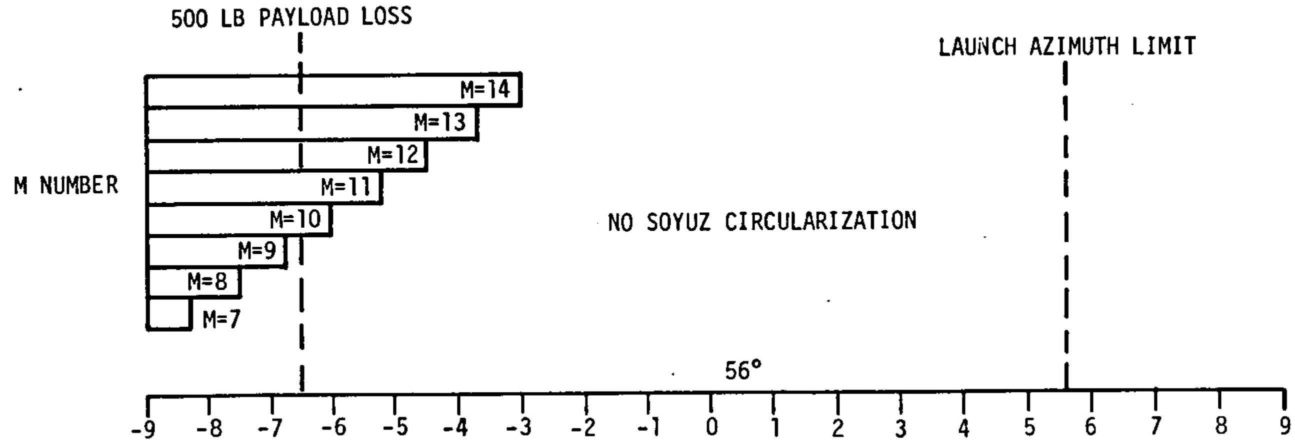


(b) DAY 3 EARLY RENDEZVOUS OPPORTUNITIES

Figure 5-2. Day 2 Through Day 5 Early Rendezvous Opportunities/Soyuz in Insertion Orbit



(c) DAY 4 EARLY RENDEZVOUS OPPORTUNITIES



(d) DAY 5 EARLY RENDEZVOUS OPPORTUNITIES

Figure 5-2. Day 2 Through Day 5 Early Rendezvous Opportunities/Soyuz in Insertion Orbit (Concluded)

5.1.2 Soyuz Performs Circ

If the nominal CSM launch is scrubbed, the Soyuz will perform the Circ maneuver prior to the second CSM launch opportunity. If the Soyuz is then disabled (prior to CSM launch), the rescue mission launch window (M = 14) will look exactly like the nominal launch window for day 2 through 5. Only in the event of the need for a faster rendezvous would any unique launch situations be presented. Figure 5-3 presents the various phase panes for days 2, 3, 4 and 5. If the M = 6 profile were desired, it can be achieved on all launch days although day 5 may require raising the insertion orbit apogee to place the phase pane within the launch window.

5.2 SOYUZ DISABLED AFTER CSM LAUNCH, PRIOR TO RENDEZVOUS

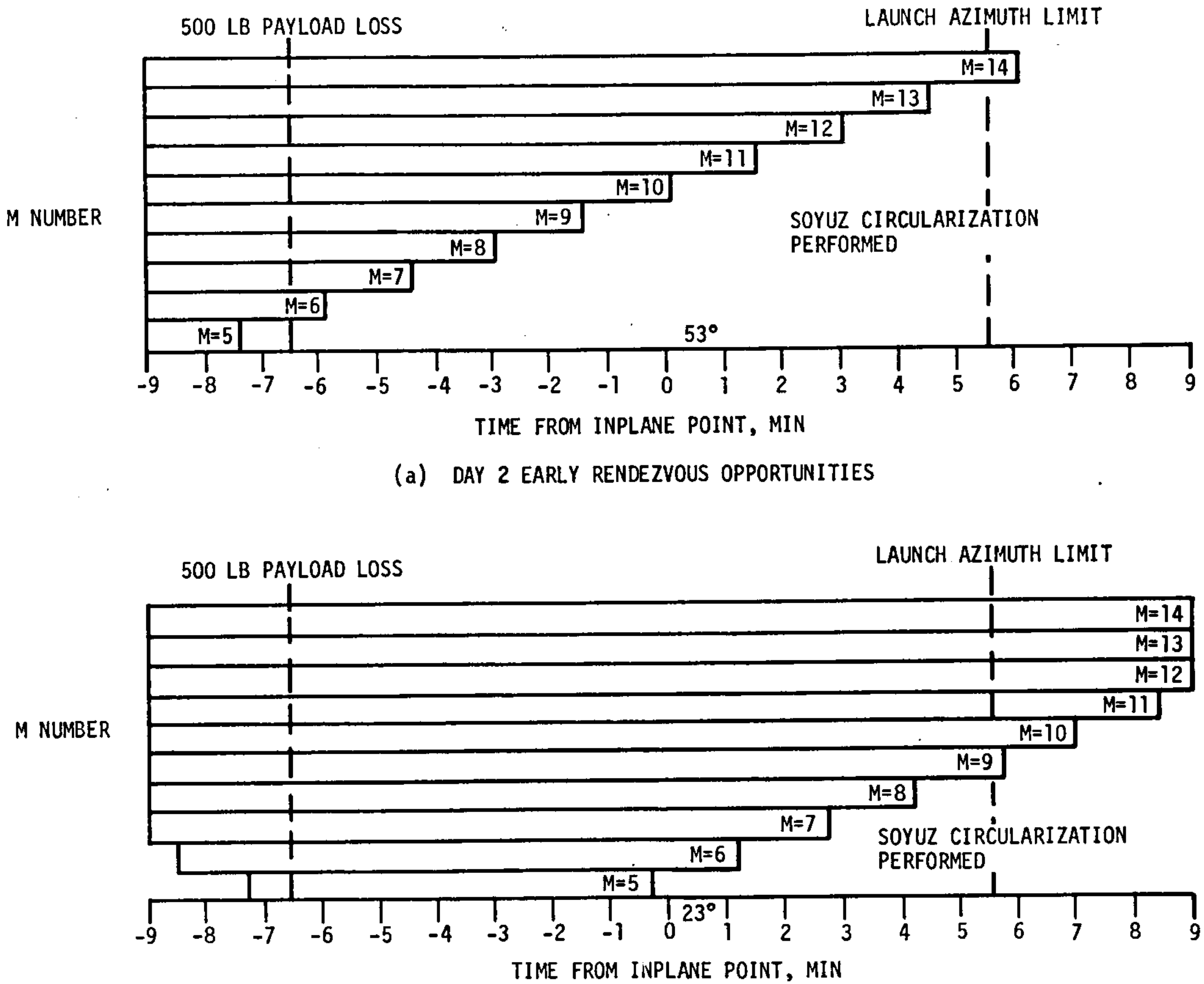
If the Soyuz is disabled after the rendezvous is in progress, the profile is continued nominally until docking. Although it may be possible to speed up the profile by a rev or two, this type of thing is considered undesirable and is ofter prohibitive from a ΔV standpoint. Accordingly, only in the most time-critical situations would the nominal profile be altered to effect rescue.

5.3 SOYUZ DISABLED AFTER FINAL UNDOCKING

After the final undocking, the CSM performs the UVA experiment. As the final part of that experiment, the CSM executes a small posigrade separation maneuver and begins drifting behind the Soyuz. In the event that the Soyuz is subsequently disabled, the CSM must re-rendezvous with the Soyuz to perform a rescue. Due to the many timeline, trajectory, and other related considerations, a stable orbit rendezvous has been selected as the nominal profile for re-rendezvous.

The stable orbit setup would be constant, although there would be a significant number of different trajectories that would be flown in order to arrive at the desired offset. These various profiles would include phasing, height and a stable orbit maneuver and would all end up with the CSM trailing the Soyuz by about 47 n.mi., but in the same same orbit. It would remain in this position until it was determined that a rescue was positively required.

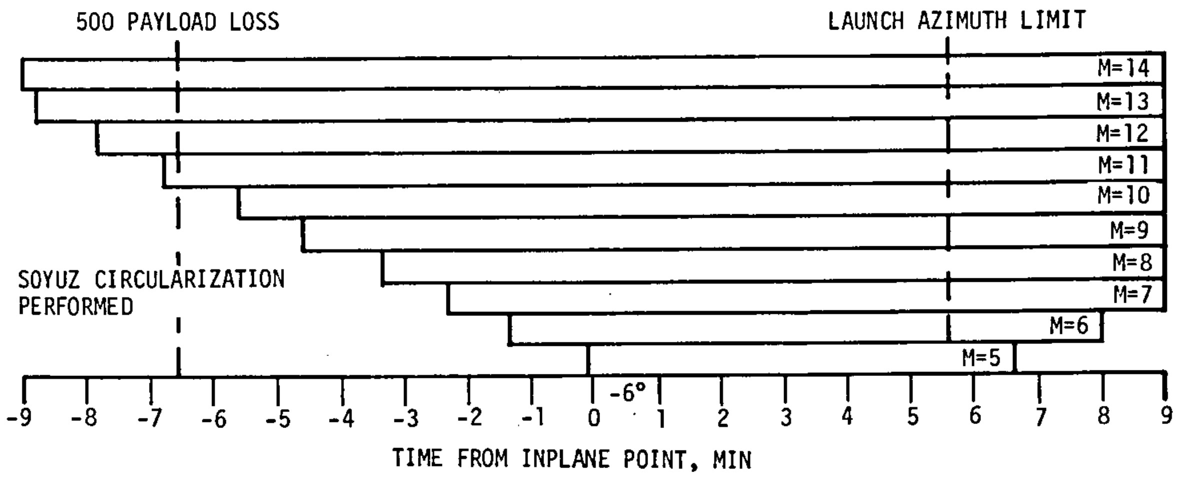
The maneuver required to intercept the Soyuz from the stable orbit offset is called TPI1. The 47 n.mi. offset, coupled with a transfer angle of 290° from TPI1 to docking produce not only the nominal 10 n.mi. ΔH point (at 130° prior to intercept) but also a nominal intercept trajectory from that point on. Although the approach velocity is slightly less than nominal, this trajectory will look (to the crew) identical to the nominal profile; maximizing the applicability of nominal terminal phase procedures. A second maneuver, nominally 0 ΔV, called TPI2 is scheduled at the 130° point.



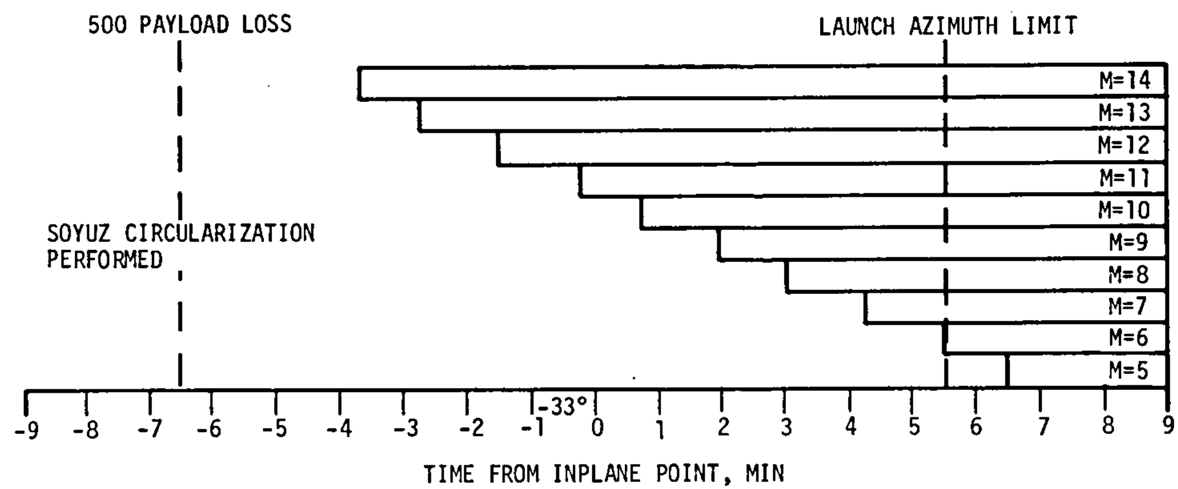
(a) DAY 2 EARLY RENDEZVOUS OPPORTUNITIES

(b) DAY 3 EARLY RENDEZVOUS OPPORTUNITIES

Figure 5-3. Day 2 Through Day 5 Early Rendezvous Opportunities/Soyuz in Nominal Orbit



(c) DAY 4 EARLY RENDEZVOUS OPPORTUNITIES



(d) DAY 5 EARLY RENDEZVOUS OPPORTUNITIES

Figure 5-3. Day 2 Through Day 5 Early Rendezvous Opportunities/Soyuz in Nominal Orbit (Concluded)

It will be computed in the CMC with the TIG option and should be a small RCS correction. It is preceded by a rendezvous navigation period which should provide good relative states in the CMC. From TPI2 on, all tracking, TPM, and braking procedures are per the nominal checklist.

This same profile will also apply to other Soyuz re-rendezvous cases not related to rescue (e.g., the initial docking cannot be accomplished on day 3 and it is desired to separate the two vehicles during the crew sleep period).

6. RENDEZVOUS WITH SIVB

There are certain types of malfunctions in various SIVB systems which, if they occur prior to the CSM docking with the DM, will force an "Emergency Sep" condition (where the CSM separates immediately and performs a 20 fps RCS maneuver). In some of these instances, ground commands could be utilized to reconfigure the SIVB such that the unsafe condition is corrected. Once the SIVB is "safed", a rendezvous can then be performed to retrieve the DM. Unfortunately, the SIVB is passive in terms of rendezvous navigation aids, reducing tracking options to only Sextant-in-daylight. This limitation severely restricts the rendezvous options that can be considered. Ground tracking has been determined to be inadequate to solve the re-rendezvous problem due to drag uncertainty and lack of adequate site coverage. This makes the CMC/SXT combination mandatory for committing to a re-rendezvous attempt

6.1 RENDEZVOUS PROFILE

The selected profile is similar to the stable orbit rendezvous profile discussed in Section 5.3; however, major modifications were necessitated to overcome the navigation problem. The stable orbit offset has been selected at 6 n.mi.

From the 6 n. mi. offset, a TPI maneuver (primarily radially down) will be performed to produce an intercept trajectory with a transfer angle of 200°. This transfer creates an approach which is considerably different from the nominal. Two CMC computed midcourse corrections will be executed to maintain an intercept trajectory. Braking is performed using the CMC range rate readout as well as visually.

6.2 STABLE ORBIT SETUP

The size, direction, and number of maneuvers required to establish the stable orbit offset depends on the direction in which the Emergency SEP burn is performed. (This maneuver can be in almost any direction depending upon when it is performed due to the S-IVB attitude profile.) Generally, three maneuvers will be required to obtain the 6 n.mi. offset. The nominal profile is a basic NH/NCC/NSR sequence. These maneuvers are targeted by the ground, but NCC/NSR computations will be done using O/B state vectors following periods of SXT navigation.

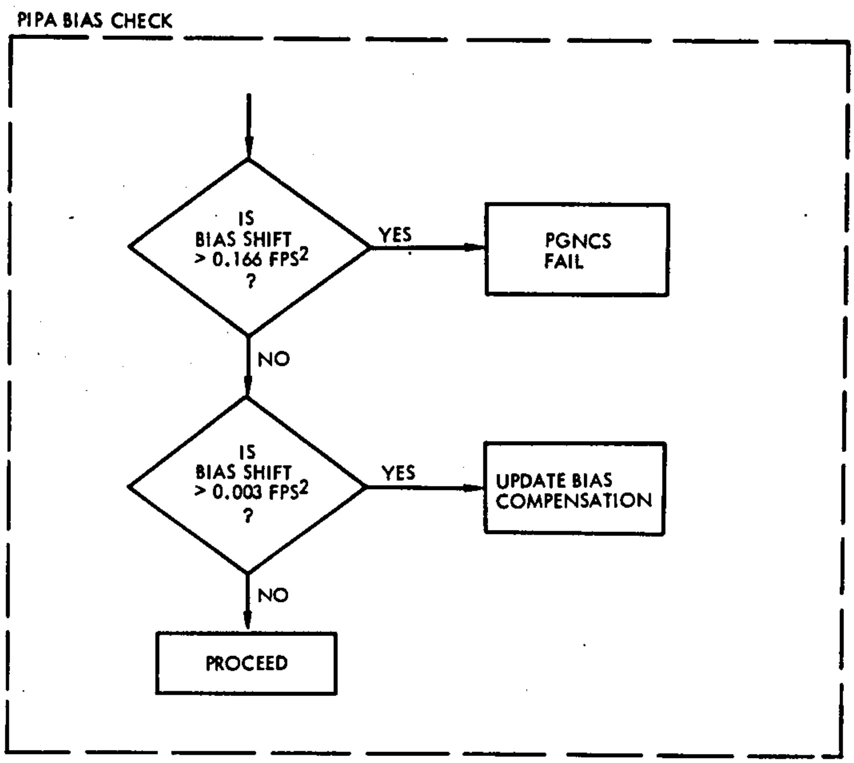
APPENDIX A

CREW AND GROUND STANDARD CHECKS AND MONITORING FUNCTIONS

The following checks and monitoring functions are performed by the ground or crew as required throughout the rendezvous. Flow charts are included for all functions except the GDC align.

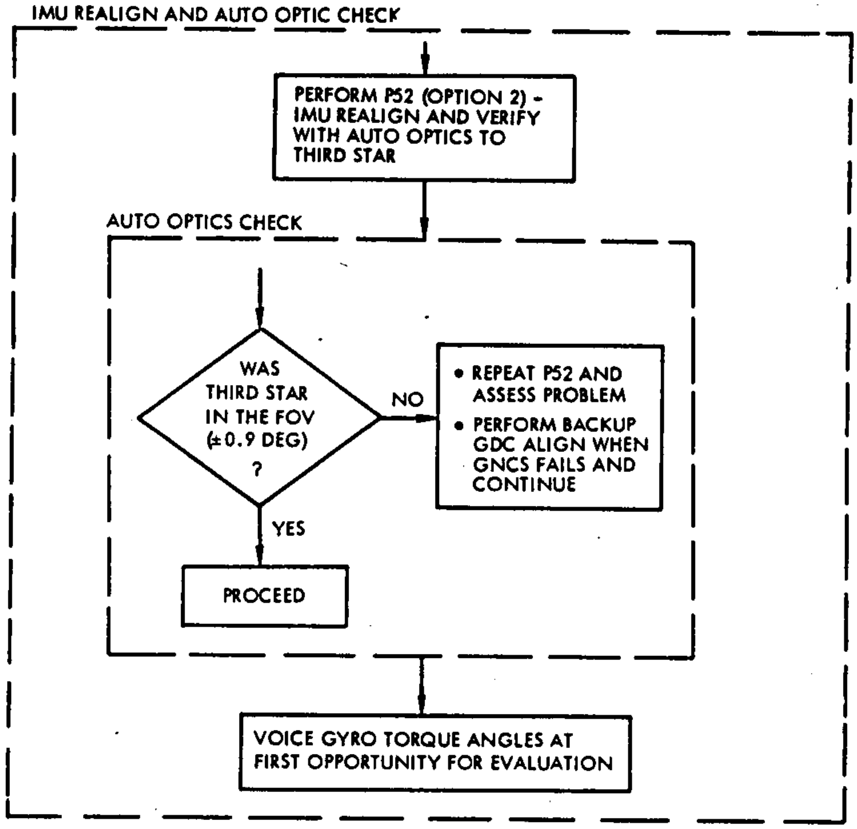
Pulse Integrating Pendulous Accelerometer (PIPA) Bias Check

Periodically during the mission, MCC-H will monitor PIPA bias with the CSM in free drift. If the accelerometer bias has shifted more than 0.166 foot per second per second, the GNCS has failed. The ground updates the bias compensation values when the bias shift is greater than 0.003 foot per second per second.



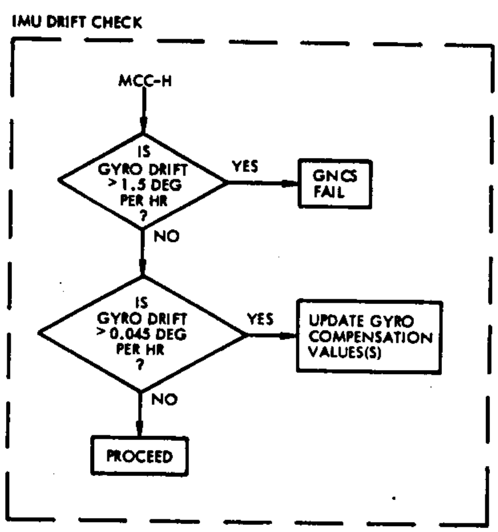
IMU Realign and Auto Optic Check

The IMU is realigned (as required) to minimize the effects of alignment errors on rendezvous navigation. The alignment is verified with auto optics pointing to a third star. If the third star is in the SXT field of view (FOV) ($\pm$0.9 degree), the alignment is verified.



IMU Drift Check

The ground processes the gyro torquing angles obtained from the P52 alignment to estimate gyro drift. If any of the torquing angles indicate a gyro failure (1.5 degrees/hour) the SCS is used to continue the mission. The gyro drift compensation value is updated by the ground when the indicated gyro drift exceeds 0.045 degree per hour.



Ignition Attitude Check

The purpose of this check is to insure that the proper attitude for maneuver execution has been attained. It is performed by maneuvering the S/C to the PAD attitude, positioning the SXT at the proper position, and observing to see if the selected star is within the SXT FOV. If not, the IMU has drifted enough to fail the test, and should be realigned. Unfortunately, in this instance, the alignment must be performed in darkness and requires a certain amount of time to perform. Consequently, if the check is made in daylight, the G&N is temporarily NO GO if the star check fails.

For rendezvous, acceptable maneuvers would generally be realized if the S/C is within 5° of the proper attitude. Accordingly, if the SXT star check fails, but enough time does not exist to realign the IMU, another option still exists if the S/C is in darkness. That is, the crew can maneuver to the PAD attitude on the GDC ball and verify that the selected star is within 5° of the SCT center. If this test passes, the crew can perform the maneuver using the SCS. This check also requires darkness (stars cannot be identified in SCT in daylight) and is therefore limited.

One final option exists for certain burns. That is, if the S/C is oriented such that the horizon is visible in the window, the same 5° reasonableness test can be applied to this check. Consequently, if the SXT star check fails and the S/C is in daylight (eliminating <u>all</u> realignment options), the horizon check can be made. If this passes, the crew can perform the burn in SCS.

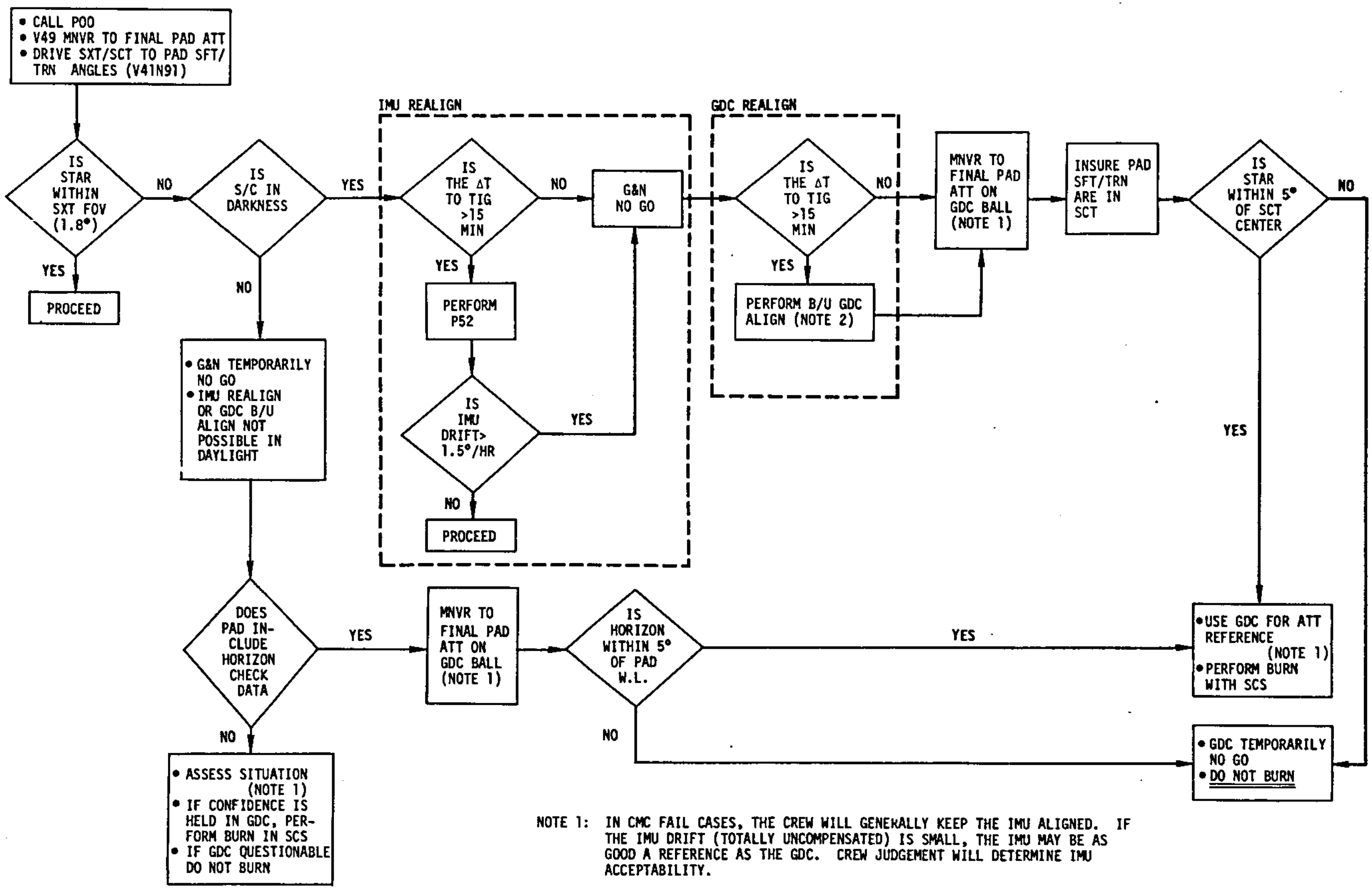
The flow diagram that follows details these various options. The end item of these various tests is that if the attitude cannot be verified, the maneuver is not performed.

GDC Align

The SCS source of inertial attitude is generated by the GDC. The GDC provides accurate information for relatively short periods. Therefore, it must be aligned periodically to the desired reference. The nominal alignment technique is to align the GDC to the GNCS IMU shortly before thrusting maneuvers. The GDC is used primarily to monitor the burn.

SCS Drift Check

Periodic SCS drift checks are made to assure that the GDC can be used for attitude monitoring during a burn. If there is no indication of IMU failure, the gimbal angles of a good GDC must indicate the IMU gimbal angles within the allowable drift rate of 10 degrees per hour for all axes. This limit is based on the three sigma drift rate of the SCS. If the GDC fails to indicate the IMU attitude within these limits, the SCS is switched

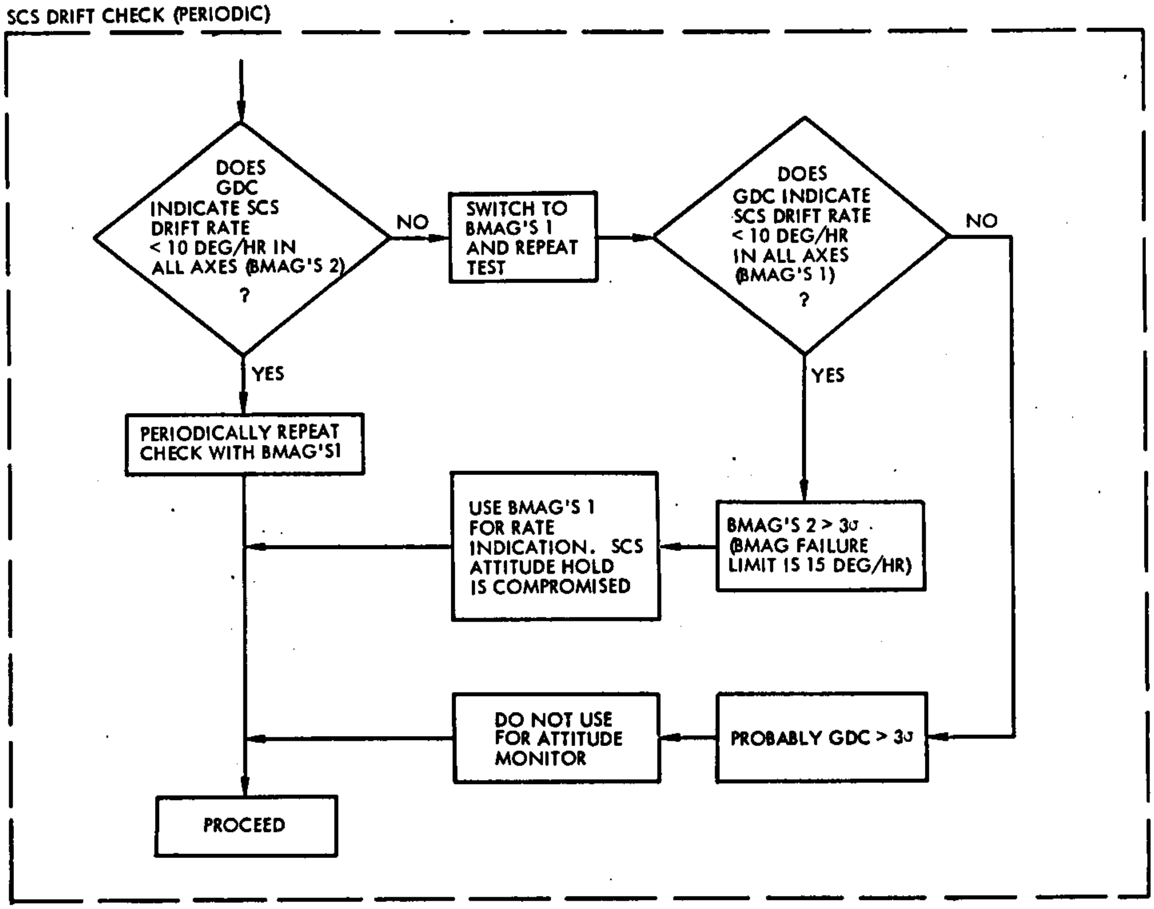


NOTE 1: IN CMC FAIL CASES, THE CREW WILL GENERALLY KEEP THE IMU ALIGNED. IF THE IMU DRIFT (TOTALLY UNCOMPENSATED) IS SMALL, THE IMU MAY BE AS GOOD A REFERENCE AS THE GDC. CREW JUDGEMENT WILL DETERMINE IMU ACCEPTABILITY.

NOTE 2: IN IMU FAIL CASES, THE PREFERRED TECHNIQUE FOR ALIGNING THE GDC IS TO USE P52 (EMP SL 50) RATHER THAN THE B/U GDC ALIGN TECHNIQUE.

to the backup BMAG's, and the GDC is realigned to the IMU. The SCS drift is checked again approximately one-half hour later against the allowable drift rate. Failure of the drift test again indicates SCS operation outside of the 3σ range. The failure limit for the SCS is 15 degrees per hour.

After the SCS drift test, the GDC is periodically aligned to the IMU.



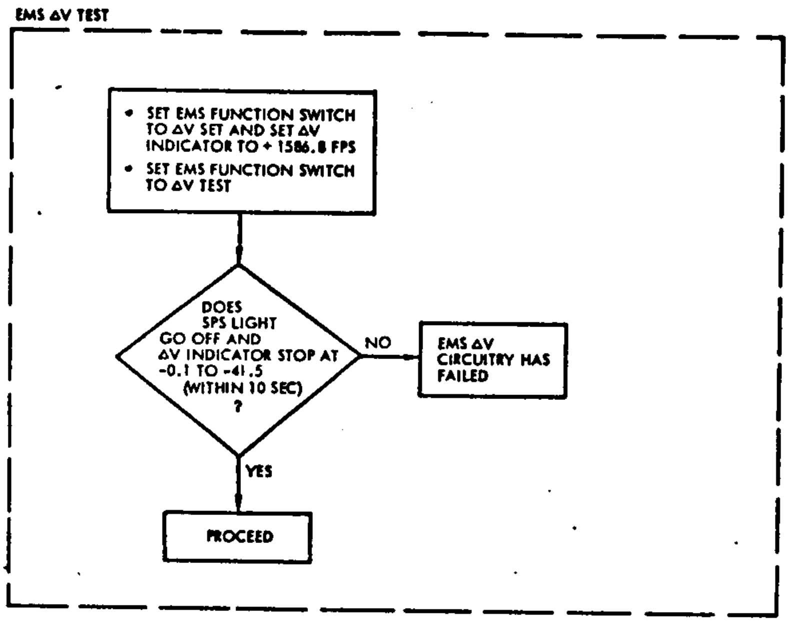
Entry Monitor System Checks

The EMS provides a visual monitor of automatic GNCS maneuvers. The EMS also provides a maneuver execution capability in event the primary guidance system fails. The EMS is capable of sending commands to the SCS for SPS engine cutoff. During rendezvous tracking, the EMS provides a display of VHF ranging information.

Tests are performed on the EMS to provide maximum system confidence prior to actual use.

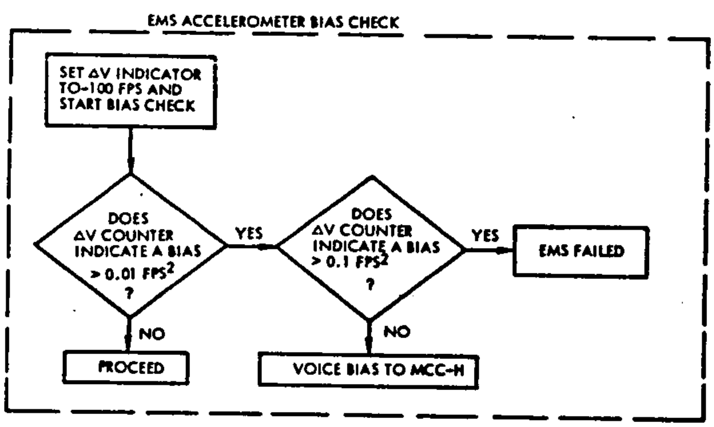
EMS Delta Velocity (ΔV) Test

To test the EMS ΔV circuitry, the EMS ΔV test is performed. The ΔV indicator is set to +1586.8 feet per second, and the EMS function switch is set to ΔV test. The SPS light goes off within 10 seconds, and the ΔV indicator stops between -0.1 and -41.5, when the EMS circuitry is operating properly.



EMS Accelerometer Bias Check

During an SCS-controlled SPS thrusting, a thrust-off command is supplied by the EMS. The thrust-off logic signal is supplied to the SPS engine ON-OFF circuit when the ΔV display reads zero or negative values of ΔV. It is very important, therefore, to determine the accelerometer bias and adjust the ΔV counter as required. Bias values greater than 0.01 foot per second per second but less than 0.1 foot per second per second are compensated. When the ΔV counter indicates a bias value greater than 0.1 foot per second per second, the EMS has failed.



SPS Burn Monitor Function

The program sequence prior to each GNCS-controlled SPS burn is a pre-thrust program and P40 (SPS Thrust Program). An automatic maneuver to the ignition attitude is then enabled. With the SC at the ignition attitude, the GDC will be aligned to the IMU and the BMAG 1 will be uncaged. The EMS ΔV counter will se set at the PAD value of velocity to allow auto cutoff if an SCS takeover is required.

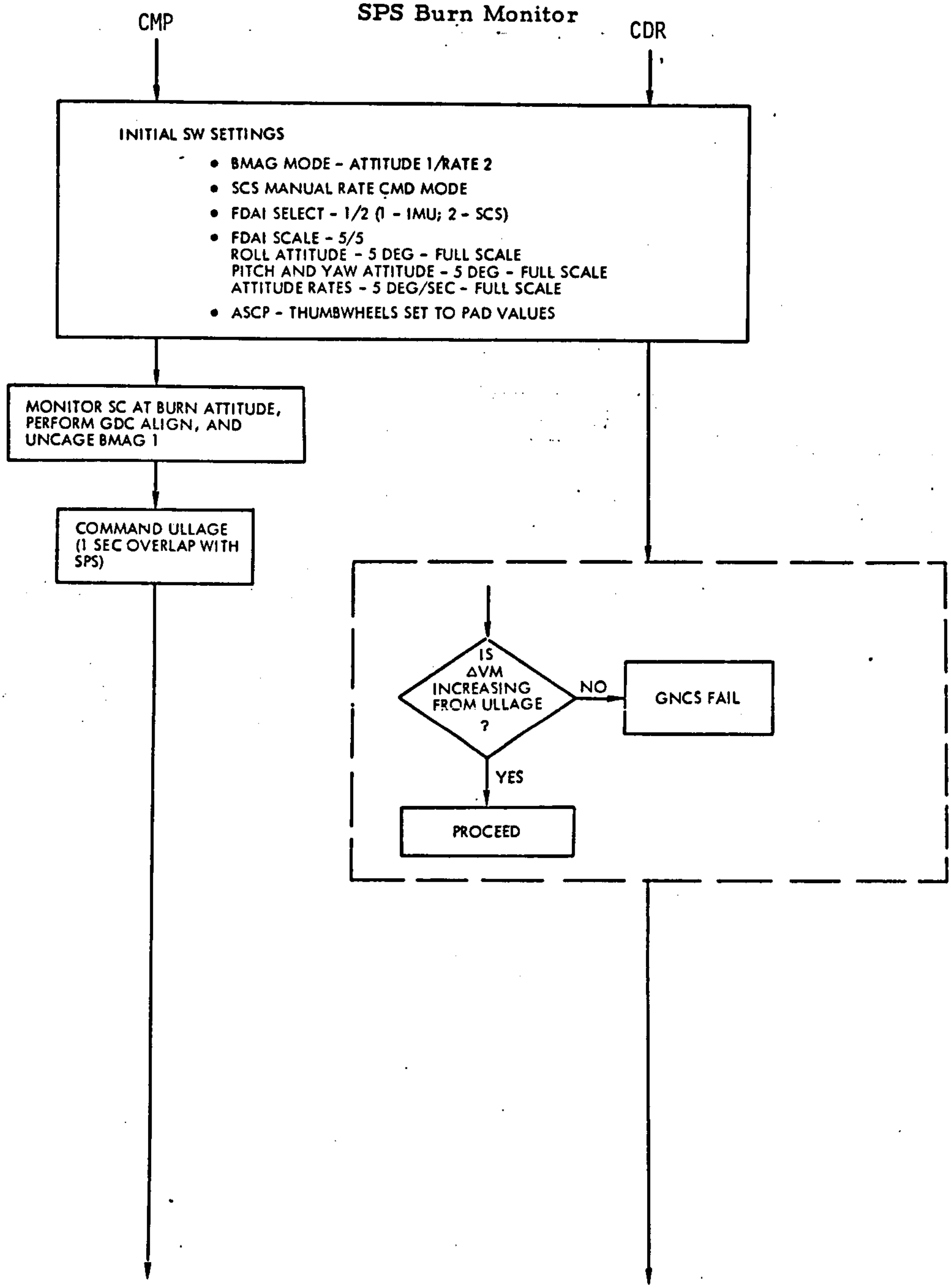
It is assumed that certain undetected double failures (both sets of BMAG's or one of the BMAG sets and the primary control system) will not occur during a single SPS burn. This means that if the BMAG's displays disagree, the one that is not nominal is assumed to have failed.

For confirmed rates greater than 5 degrees/second, (excluding start transient) the crew commander (CDR) will turn the translation hand controller clockwise. This places the backup attitude control system (SCS rate command mode) in command. It also places the secondary SPS actuator system in the thrust vector control (TVC) loop and activates the automatic EMS ΔV cutoff. The ΔV counter must be initialized with VC from PAD data which are compatible with an EMS automatic cutoff. The PAD VC value has been corrected for EMS biases.

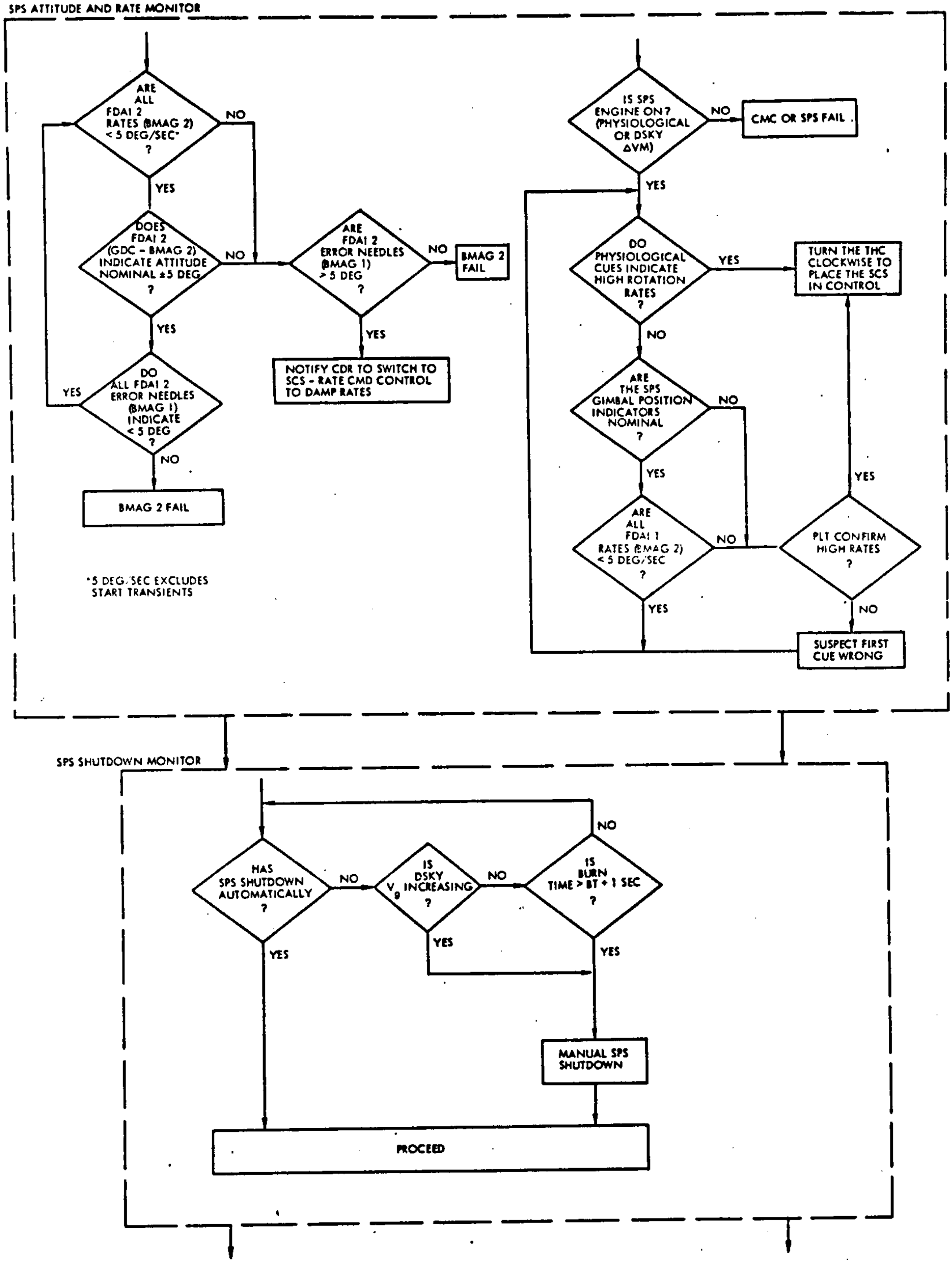
The vehicle attitudes are also monitored. If any attitude excursion exceeds 5 degrees and is confirmed, the backup mode is selected.

If the attitude and attitude rate are satisfactory and the SPS is still on, the magnitude of $\underline{VG}$ is monitored on the DSKY. If the magnitude is increasing, the SPS is shut down manually. The SPS burn will also be terminated manually if the engine has not shut down when the PAD burn time (BT) is exceeded by one second.

SPS Burn Monitor



SPS Burn Monitor (Continued)



RENDEZVOUS CUE CARDS

SPS BURN-RNDZ

3/10/75

G&N

AUTO RCS (12) - on
EMS ΔV CK (1586.8)
FDAI SCALE - 5/1
MAN ATT (3) - RATE CMD
ATT DB/RATE - MIN/LOW
*BMAG (3) - RATE 2
*SC CONT - CMC/AUTO
*FDAI (2) - INRTL
Set GDC tw

GMBL TRIM

P +0.70

Y -0.60

TAILOFF
13.0 1 BK
14.0 2 BK

HOOK VELCRO

CUT OUT THIS PART

cb SPS (8) & SCS (24) - close
SCS TVC (2) - RATE CMD
TVC GMBL DR P&Y - AUTO, ATVC - HI
RHC 2 - ARMED
Set EMS ΔV (Min 7)
Set DET (V16 N45)
*P40 to F50 18, PRO (MNVR)
GDC ALIGN

54:00 MN BUS TIE (2) - on
TAPE RCDR - HBR/RCD/FWD/CMD RESET
TVC SERVO PWR 1 - 1/A, 2 - 2/B
RHC PWR NORM (2) - AC, DIR (2) - OFF
BMAG (3) - 1/2

SC CONT - SCS
GMBL MOT P1 & Y1 - START, Set trim
✓ MTVC
*
THC - CW, ✓ NO MTVC
GMBL MOT P2 & Y2 - START, Set trim
*SC CONT - CMC
✓ MTVC
THC neutral, ✓ NO MTVC
*✓ GPI returns to 0,0
RHC PWR NORM (2) - AC/DC
RHC PWR DIR (2) - MNA/MNB
*BMAG (3) - RATE 2, PRO
*BMAG (3) - 1/2, ENTR
F 50 25 *GMBL TEST OPTION, PRO

HOOK VELCRO

HOOK VELCRO

SCS DELTA

BMAG (3) - 1/2
SC CONT - SCS
NO CMC CHART BURN:
FDAI 1 - ORB RT

4 PLY SHIM VELCRO

RHC to Burn ATT

SCS TVC (2) - AUTO

✓ SC CONT - SCS

GPI to trim

Ck Burn ATT
Omit this step
Omit this step

SPS BURN-RNDZ CONTD

3/10/75

06 40	*RATE HIGH	✓ RATE - LOW	06 40 BYP V21NOTE 3451E 37777E
	RHC 2 & THC - ARMED		
	✓ EMS, DET, SPS N2 & He		
59:00	EMS - NORM		
	THC PWR - ON		
59:30	ΔV THRUST A (B) - NORM		
	Ck PIPAS <2 fps 5 sec		
59:40	*ULLAGE	59:46 ULLAGE	

HOOK VELCRO

F 99 40	ENG ON ENABLE REQ		
	PRO		
00:00	*IGN	THRUST PB	
00:03	ΔV THRUST (2) - NORMAL	RATE - HIGH	
	*		
XX:XX	ECO		
F 16 40	ΔV THRUST (2) - OFF		
	PRO		
	AUTO RCS (all) - on		
F 16 85	Null residuals & log		
	PRO		
	AUTO RCS A/C ROLL - OFF		
	GMBL MOT (4) - OFF		
	TVC SERVO PWR 1 & 2 - OFF		
	*BMAG (3) - RATE 2	✓ 1/2	
	MN BUS TIE (2) - OFF		
	EMS FUNC - ΔV SET/VHF RNG		
	EMS MODE - BU/VHF RNG		
	VHF RNG - RESET		
	THC & RHC - LOCKED		
	RHC PWR DIR (2) - OFF		
	THC PWR - OFF		
	PCM BIT RATE - LOW		

4 PLY SHIM VELCRO

G&N Reignition
F97 40 ENTR
06 40
F99 40 ΔV THRUST
GMBL TRIM
ULLAGE
PRO: IGN

SCS Reignition
SC CONT - SCS
Ck ATT
BMAGS - 1/2
TVC (2) - AUTO
EMS - ΔV/NORM
ΔV THRUST ON
ULLAGE
THRUST PB

RCS Completion
F 97 40 ENTR
06 40
F 99 40 ENTR
F 16 85
Burn RCS/THC

HOOK VELCRO

HOOK VELCRO

SPS BURN RULES

1/20/75

NOMINAL LIMITS (FAIL CRITERIA)

FU/OX FEEDLINE 45-75°F (<40, >110)
FU/OX ΔT (>60)
He TEMP 35-150°F
FU/OX PRESS 170-195 psi (<115*, >200)
FU/OX ΔP <20 psi
Pc 95-105 (<70*)
GN2 2900 psi max (<400)

K4

*TIGHT LIMITS: FU/OX PRESS <160
Pc <80

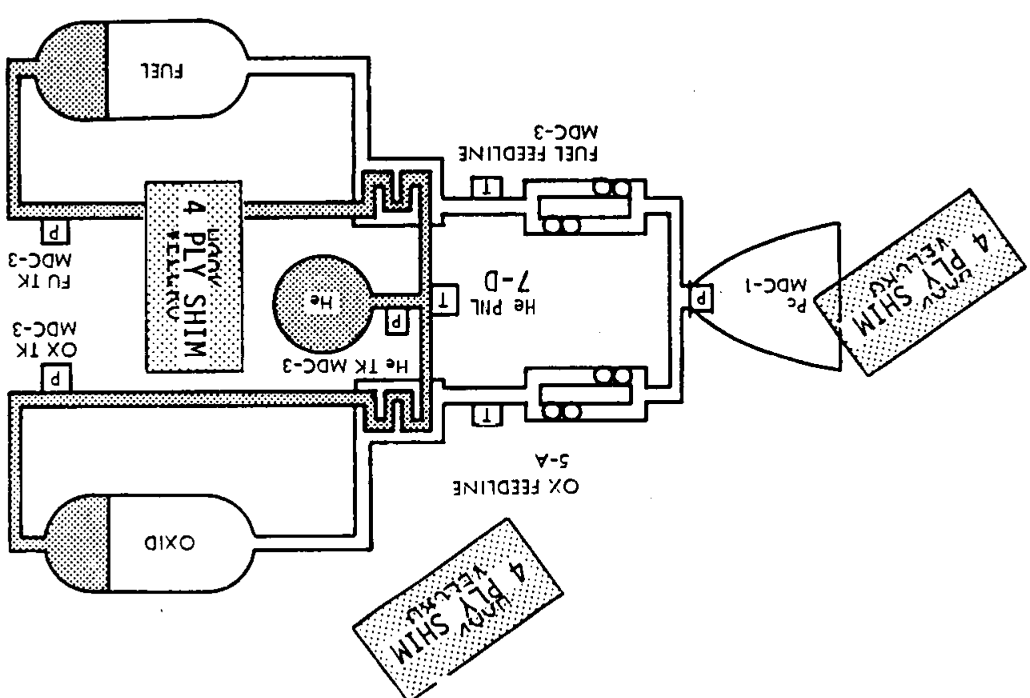
BURN: Start watch, INJ VLV(4) - OPEN, He VLV tb(2) - gray

SPS PRESS LT
Continue CRIT BURN
FU/OX LO (HI):
He VLV(2) - ON(OFF)
HI ΔP: He VLV (2) - ON
If condition persists,
OFF till Pc <70

EARLY SHUTDOWN
He VLV (2) - ON
✓ cb's closed:
PILOT VLV (2)
He VLV (2)
EPS GP 3 & 5
ΔV THRUST (2) - NORM

NO SHUTDOWN
ΔV THRUST (2) - OFF
THC - CW
THRUST DIR ON - OFF
cb PILOT VLV
(2) - open
cb EPS GP 5 - open

K4



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APPENDIX C

RENDEZVOUS MANEUVER PADS

MANEUVER UPDATE (P30)													
	PURPOSE												
N33-P30, 38	HRS	+	X	X				+	X	X			
N95-P31;N28-P32	MIN	+	X	X	X			+	X	X	X		
N11-P33;N13-P34	SEC	+	X					+	X				
N81 LOCAL VERT	ΔVX		X						X				
	ΔVY		X						X				
	ΔVZ		X						X				
N22	R	+				0	0	+				0	0
	P	+				0	0	+				0	0
	Y	+				0	0	+				0	0
	ΔVC	X	X					X	X				
	BT	X	X					X	X				

ULLAGE: ________ SECS ________ QUADS

N47 WT

+					

STAR

X	X	X	X		

GDC R

N48

PT		X	X			
YT		X	X			

SFT

+					0

GDC P

TRN

+				0	0

GDC Y

REMARKS:

ΔV_C AT IGNITION:

ΔV_C TAILOFF:

P34 TPI PAD

N37 TIG TPI	HRS	+	X	X			
	MIN	+	X	X	X		
	SEC	+	X				
N81 ΔV_{TPI}	ΔVX		X	.X			
	ΔVY		X	X			
	ΔVZ		X	X			
N59 ΔV (LOS)	ΔV_F/BT					/	
	ΔV_R/BT					/	
	ΔV_D/BT					/	
ΔVC		X	X				
BT		X	X				
N22	R	+				0	0
	P	+				0	0
	Y	+				0	0
ΔVC AT IGN		+	X	X	X		
ΔVC TAILOFF		-	X	X			

WT	+					

PT					YT				

DOCKING ATTITUDE

N22	R	+				0	0
	P	+				0	0
	Y	+				0	0

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