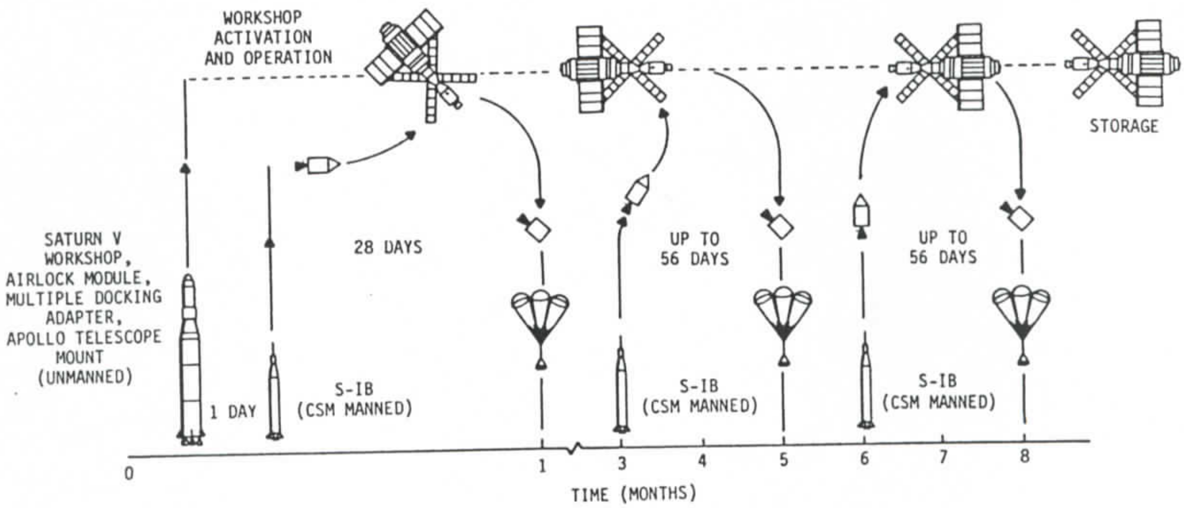
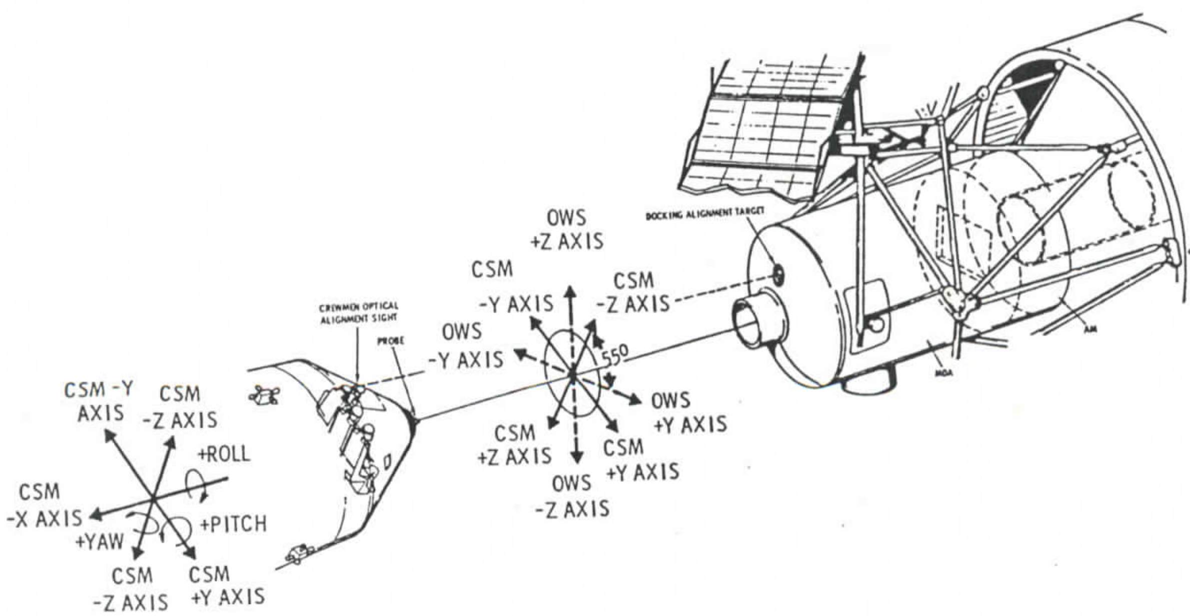
Skylab rendezvous profile

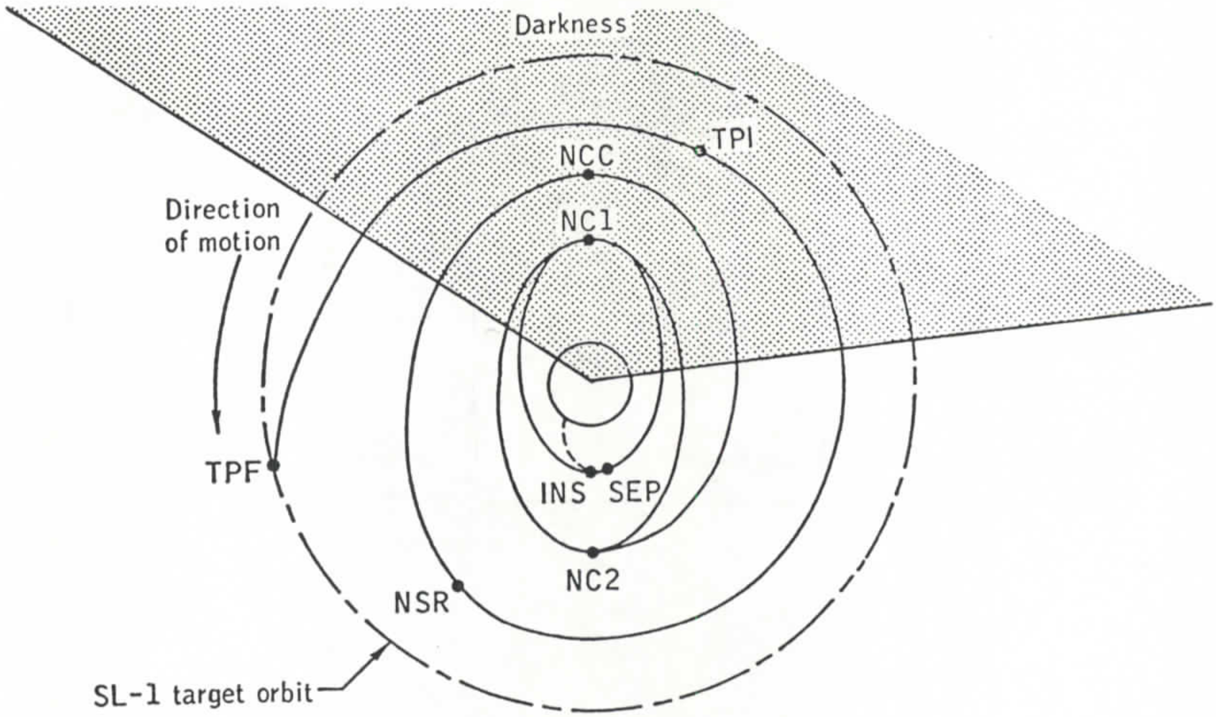
SKYLAB MISSION PROFILE



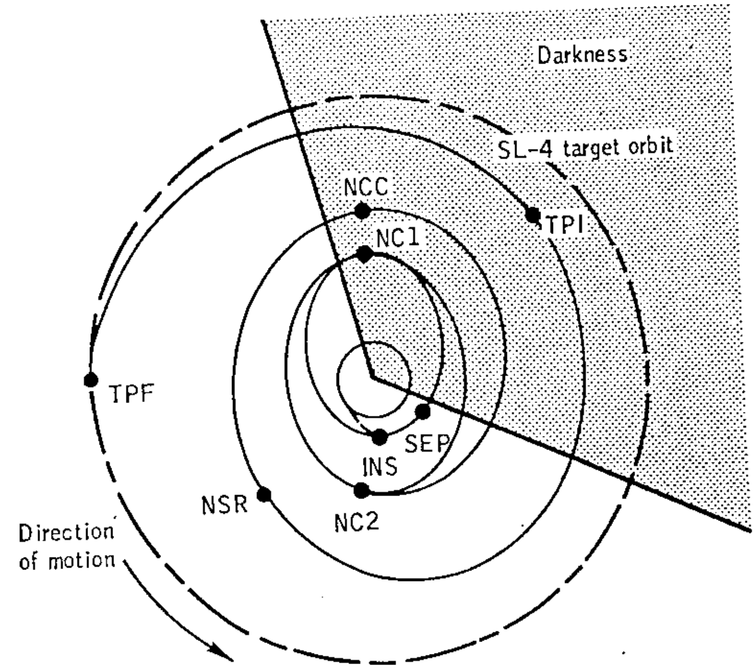
CSM/SWS DOCKING ALIGNMENT



RENDEZVOUS-PROFILE-EVENT SUMMARY (SL-2)



		Time, g.e.t., hr:min:sec	ΔV, fps	Resultant perigee/apogee, n. mi.
INS	Insertion	0:09:50		81.0/120.1
SEP	Separation	0:16:00	3.0	81.0/121.6
NC1	Phasing 1	2:20:12	218.8	121.4/204.7
NPC	Plane change	Plane change, if necessary, occurs at node between NC1 and NC2.		
NC2	Phasing 2	4:36:03	160.7	203.8/213.5
NCC	Corrective combination	5:22:12	30.6	213.2/223.1
NSR	Coelliptic	5:59:12	19.1	222.3/223.6
TPI	Terminal phase initiation	6:49:01	20.6	224.1/234.2
TPF	Terminal phase finalization	7:22:39	27.9	232.0/235.2



		Time, g.e.t., hr:min:sec	ΔV, fps	Resultant perigee/apogee, n. mi.
INS	Insertion	00:09:50.6		81/120
SEP	Separation	00:25:00.0	3.0	81/121
NC1	Phasing 1	02:20:53.6	216.1	121/203
NPC	Plane change	Plane change, if necessary, occurs at node between NC1 and NC2		
NC2	Phasing 2	04:36:42.0	160.4	203/213
NCC	Corrective combination	05:22:50.1	29.6	213/221
NSR	Coelliptic	05:56:50.1	18.9	221/224
TPI	Terminal phase initiation	06:44:00.7	20.6	224/232
TPF	Terminal phase finalization	07:17:37.8	28.0	231/234
	Docking	08:03:25	0.0	231/234

Figure 5-4.- SL-4 rendezvous orbital geometry.

SKYLAB 2 POWERED MANEUVER SUMMARY

Event	Date	Calendar day[a]	Time of burn initiation: G. m. t., hr:min:sec	Time of burn initiation: CSM g. e. t., d:hr:min:sec	Time of burn initiation: SWS g. e. t., d:hr:min:sec	SWS rev	ΔV, fps	Burn duration sec	Lighting	Altitude n. mi.[b]	Geocentric latitude, deg	Longitude, deg	Resultant perigee/apogee[b], n. mi.
Sl-1 lift-off	May 14	134	17:30:00. 0	-00:23:29:36. 0	00:00:00:00. 0	--	--	--	Day	--	28. 45	- 80. 60	--
Insertion	May 14	135	17:39:47. 8	-00:23:19:48. 2	00:00:09:47. 8	1	--	--	Day	233. 9	39. 47	- 66. 18	232. 0/ 234. 8
SL 2 lift-off	May 15	135	16:59:36. 0	00:00:00:00. 0	00:23:29:36. 0	15	--	--	Day	--	28. 47	- 80. 62	--
Insertion	May 15	135	17:09:25. 8	00:00:09:49. 8	00:23:39:25. 8	15	--	--	Day	81. 0	39. 01	- 65. 32	81. 0/ 120. 1
CSM/S-IVB separation[c]	May 15	135	17:15:36. 0	00:00:16:00. 0	00:23:45:36. 0	15	3. 0	7. 4	Day	83. 0	49. 10	- 33. 98	81. 0/121. 6
Phasing 1 (NC1)	May 15	135	19:19:47. 9	00:02:20:11. 9	01:01:49:47. 9	16	218. 9	9. 6	Night	121. 4	-34. 37	73. 68	121. 4/204. 7
Phasing 2 (NC2)	May 15	135	21:35:39. 3	00:04:36:03. 3	01:04:05:39. 3	17	160. 6	6. 9	Day	204. 6	34. 36	-140. 61	203. 8/213. 5
Corrective combination (NCC)	May 15	135	22:21:48. 5	00:05:22:12. 5	01:04:51:48. 5	18	30. 5	1. 2	Night	213. 3	-34. 73	27. 92	213. 2/223. 1
Coelliptic (NSR)	May 15	135	22:58:48. 5	00:05:59:12. 5	01:05:28:48. 5	18	19. 1	0. 7	Day	223. 4	9. 09	170. 64	222. 3/223. 6
Terminal phase initialization (TPI)	May 15	135	23:49:14. 7	00:06:49:38. 7	01:06:19:14. 7	19	20. 6	0. 7	Night	224. 2	-18. 98	- 12. 97	224. 1/234. 2
Terminal phase finalization (TPF)[c]	May 16	136	00:22:52. 1	00:07:23:16. 1	01:06:52:52. 1	19	[d]27. 9	65. 4	Day	232. 8	-18. 59	125. 31	232. 0/235. 2
Docking	May 16	136	00:39:36. 0	00:07:40:00. 0	01:07:09:36. 0	19	--	--	Day	233. 6	31. 16	167. 80	232. 0/235. 2
Orbit trim 1-PM[c]	May 16	136	15:22:59. 7	00:22:23:23. 7	01:21:52:59. 7	28	0	0	Night	234. 1	-26. 70	117. 69	232. 0/235. 2
Orbit trim 1-RN[c]	May 16	136	16:09:35. 7	00:23:09:59. 7	01:22:39:35. 7	29	0	0	Day	233. 4	26. 80	- 74. 03	232. 0/235. 2
Orbit trim 2-PM[c]	May 23	143	12:08:42. 4	07:19:09:06. 4	08:18:38:42. 4	127	0. 4	6. 4	Night	233. 8	-47. 92	167. 94	231. 2/237. 0
Orbit trim 2-RN[c]	May 23	143	12:55:20. 2	07:19:55:44. 2	08:19:25:20. 2	128	0	0	Day	232. 4	48. 01	- 23. 41	231. 2/237. 0
Orbit trim 3-PM[c]	June 8	159	12:02:00. 6	23:19:02:24. 6	24:18:32:00. 6	358	3. 1	49. 8	Night	231. 5	-14. 95	171. 08	227. 8/240. 6
Undocking	June 12	164	12:46:55. 0	27:19:47:19. 0	28:19:16:55. 0	416	--	--	Dawn	227. 0	42. 30	-160. 35	227. 0/241. 1
Separation	June 12	164	13:33:37. 0	27:20:34:01. 0	28:20:03:37. 0	417	5. 0	11. 5	Dusk	237. 6	-46. 06	74. 19	224. 5/240. 4
Shaping (SPS-1)	June 12	164	14:01:22. 4	27:21:01:46. 4	28:20:31:22. 4	417	264. 1	11. 0	Night	227. 9	9. 02	137. 05	90. 4/229. 6
Deorbit (SPS-2)	June 12	164	17:03:01. 0	28:00:03:25. 0	28:23:33:01. 0	419	193. 8	7. 8	Night	226. 8	11. 71	93. 19	-12. 7/229. 6
Landing	June 12	164	17:44:07. 0	28:00:44:31. 0	29:00:14:07. 0	419	--	--	Day	--	26. 78	-130. 09	--

PM = Posigrade Maneuver at Orbital Midnight

RN = Retrograde Maneuver at Orbital Noon

[a]Time base convention - G. m. t. with days beginning $0^h0^m0^s$ January 1 (day 120 is April 30)

[b]Above a spherical earth of radius 3443. 93-n. mi. radius.

[c]RCS.

[d]Theoretical cost, actual cost for line-of-sight control, stationkeeping, flyaround, and docking is an additional 26 fps.

TABLE 5-IV.- MAJOR MANEUVER AND TRAJECTORY EVENTS SUMMARY FOR SL-4

(NOVEMBER 11, 1973, LAUNCH)

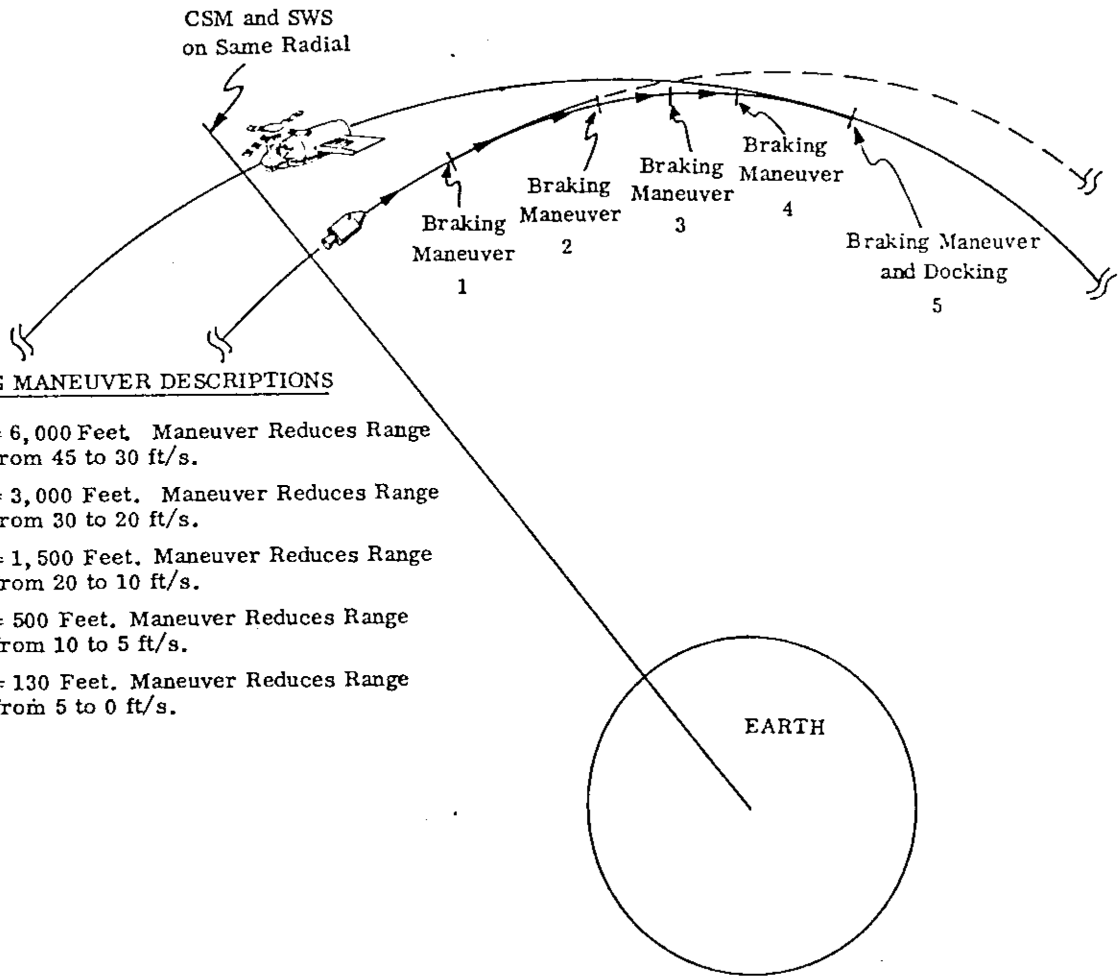
Event	Date	Calendar day[a]	Time of burn initiation			SWS rev	ΔV, fps	Burn duration, sec	Lighting	Altitude, n. mi.[b]	Geocentric latitude, deg	Longitude, deg	Resultant perigee/apogee,[b] n. mi.
			G.m.t., hr:min:sec	CSM g.e.t., d:hr:min:sec	SWS g.e.t., d:hr:min:sec								
SL-1 lift-off	May 14 (73)	134	17:30:00.6	--	00:00:00:00	--	--	--	Daylight	--	28.45	-80.60	--
Insertion	May 14 (73)	134	17:39:58.6	--	00:00:09:58	1	--	--	Daylight	234.0	39.5	-66.2	233/234
SL-4 lift-off	Nov. 11 (73)	315	16:03:59.0	00:00:00:00.0	180:22:33:58.4	2614	--	--	Daylight	--	28.45	-80.60	--
Insertion	Nov. 11 (73)	315	16:13:49.6	00:00:09:50.6	180:22:43:49.0	2614	--	--	Daylight	81.0	38.68	-64.94	81/120
CSM/S-IVB separation[c]	Nov. 11 (73)	315	16:28:59.0	00:00:25:00.0	180:22:58:58.4	2614	3.0	8.0	Dusk	92.1	43.00	17.50	81/121
Phasing 1 (NC1)	Nov. 11 (73)	315	18:24:52.6	00:02:20:53.6	181:00:54:52.0	2615	216.1	10.5	Darkness	120.9	-35.7	76.6	121/203
Phasing 2 (NC2)	Nov. 11 (73)	315	20:40:41.0	00:04:36:42.0	181:03:10:40.4	2616	160.4	7.6	Daylight	203.4	35.9	-137.6	203/213
Corrective combination (NCC)	Nov. 11 (73)	315	21:26:49.1	00:05:22:50.1	181:03:56:48.5	2617	29.6	1.3	Darkness	212.6	-36.1	30.9	213/221
Coelliptic (NSR)	Nov. 11 (73)	315	22:03:49.1	00:05:59:50.1	181:04:33:48.5	2617	18.9	0.8	Daylight	221.3	10.8	-173.0	221/224
Terminal phase initialization (TPI)	Nov. 11 (73)	315	22:47:59.7	00:06:44:00.7	181:05:17:59.1	2618	20.6	0.8	Darkness	224.2	-4.3	-23.8	224/232
Terminal phase finalization (TPF)[c]	Nov. 11 (73)	315	23:21:36.8	00:07:17:37.8	181:05:51:36.2	2618	28.0	71.5	Daylight	230.6	-32.2	112.1	231/234
Docking	Nov. 12 (73)	316	00:07:24.2	00:08:03:25.2	181:06:37:23.6	2618	--	--	Dusk	233.9	34.1	-82.2	231/234
Orbit trim 1-PM[c]	Nov. 15 (73)	319	13:49:34.6	03:21:45:35.6	184:20:19:34.0	2656	4.7	71.6	Darkness	234.4	-24.9	108.0	232/235
Undocking	Jan. 6 (74)	6	17:29:21.0	56:01:25:21.8	236:23:59:20.2	3423	--	--	Dawn	244.0	-49.5	160.0	227/239
Separation[c]	Jan. 6 (74)	6	18:16:00.0	56:02:12:00.8	237:00:45:59.2	3424	5.0	24.8	Dusk	228.0	49.9	-32.6	227/236
Shaping (SPS-1)	Jan. 6 (74)	6	18:57:14.1	56:02:53:14.9	237:01:27:13.3	3424	252.1	11.0	Dawn	233.0	-44.8	107.6	91/233
Deorbit (SPS-2)	Jan. 6 (74)	6	22:02:34.9	56:05:58:35.7	237:04:32:34.1	3426	176.4	7.6	Dawn	228.5	-49.7	84.7	-3/233
Landing	Jan. 6 (74)	6	22:44:11.0	56:06:40:11.8	237:05:14:10.2	3426	--	--	Daylight	--	25.75 (geodetic)	-159.25	--

[a]Time base convention - G.m.t. with days beginning $0^h0^m0^s$ January 1.

[b]Above a spherical earth of radius 3443.93-n. mi. radius.

[c]RCS.

CSM RENDEZVOUS FINAL PHASE



BRAKING MANEUVER DESCRIPTIONS

1. At R = 6,000 Feet. Maneuver Reduces Range Rate from 45 to 30 ft/s.
2. At R = 3,000 Feet. Maneuver Reduces Range Rate from 30 to 20 ft/s.
3. At R = 1,500 Feet. Maneuver Reduces Range Rate from 20 to 10 ft/s.
4. At R = 500 Feet. Maneuver Reduces Range Rate from 10 to 5 ft/s.
5. At R = 130 Feet. Maneuver Reduces Range Rate from 5 to 0 ft/s.

BRAKING GATES			
R(NM)	$\dot{R}$ (FPS)	SWS DIAMETER RETICLE ANG (DEG)	R (FT)
1.00	30	.2	6000
.50	20	.4	3000
.25	10	.8	1500
.08	5	2.5	500
.05		4.2	300
.03		6.3	200
.02		10.0	130

Operational Trajectory of SL-4, MPAD, Oct 16, 1973

5.4 Rendezvous Phase

The nominal rendezvous of SL-4 with the Saturn workshop occurs as follows:

The SL-4 orbital insertion occurs at $16^h13^m49.6^s$ G.m.t. on November 11, 1973. The opening of the M=5 phase pane requires an insertion phase angle of 47° with the CSM in an 81- by 120-n. mi. orbit.

The CSM separates from the S-IVB with a 3-fps posigrade separation maneuver using the SM-RCS thrusters (ref. 13) made at 25^m CSM g.e.t., and the CSM resultant orbit is 81.0 by 121.0 n. mi. Table 5-II gives the REFSMMAT, target load, and gimbal angles for this maneuver.

Approximately 1 hour 56 minutes after the separation maneuver, the first phasing (NC1) maneuver is performed near second apogee at $2^h20^m53.6^s$ CSM g.e.t. This SPS maneuver imparts a ΔV of 216.1 fps and results in a 121- by 203-n. mi. orbit. The NC1 and all other maneuvers through the coelliptic maneuver (NSR) are performed in the heads-down attitude. This is a technique needed to minimize the maneuver from onboard tracking attitude to burn attitude for NC2, NCC, and NSR. NC1 is performed in the heads-down attitude simply for consistency of crew procedures.

A plane change (NPC) maneuver nominally is not performed. However, the decision of whether the maneuver is to be performed depends on the size of the yaw gimbal angles at the times of the combination phase/height/out-of-plane (NCC) maneuver and the coelliptic (NSR) maneuver if the plane change maneuver is not performed. If the yaw gimbal angles for NCC and/or NSR are ≤60°, the maneuver is omitted and any out-of-plane error remaining is cancelled during the NCC and NSR maneuvers. If a plane change maneuver is required, it is performed between the first and second phasing maneuvers. The time of NPC is controlled by forcing a common node to occur 90° after NC1; that is, an anti-node is created at NC1. The NPC will then be executed at the second common node after NC1, or approximately 270° of orbital travel after NC1.

One and one-half revolutions after the first phasing maneuver, the second phasing (NC2) maneuver is performed at $4^h36^m42^s$ g.e.t. This SPS maneuver provides a ΔV of 160.4 fps and results in a 203- by 213-n. mi. orbit. At $5^h22^m50.1^s$ CSM g.e.t., the corrective combination (NCC) maneuver is performed one-half revolution after NC2. This SPS maneuver imparts a ΔV of 29.6 fps and results in a 213- by 221-n. mi. orbit. The range to the SWS 36 minutes prior to NCC is approximately 246 n. mi., and VHF ranging and optical tracking may be performed to permit computation of the NCC maneuver by the CSM using onboard navigation knowledge. However, to conserve TACS the SWS may not be maneuvered into a Z-LV attitude; thus, VHF tracking at long ranges may be intermittent. Onboard maneuver computation will continue through the terminal phase.

The NSR maneuver is performed 37 minutes after NCC at $5^h59^m50.1^s$ CSM g.e.t., creating a coelliptic orbit 10 n. mi. below that of the SWS. This SPS maneuver provides a ΔV of 29.6 fps. Because of the small ΔV requirements for NSR (and TPI), these burns are not long enough for the SPS to attain steady-state conditions. In simulating these burns, the short-burn thrust parameters as presented in table 3-I were used. These parameters were computed from a minimum impulse curve contained in reference 14.

Approximately 44 minutes after NSR, the terminal phase initiation (TPI) maneuver is performed at $6^h44^m00^s$ CSM g.e.t. This SPS maneuver, which imparts 20.6 fps, will be performed when the elevation angle to the SWS reaches 27.0°. The range at this time is approximately 22 n. mi., and the vehicles will be approximately 16 minutes into darkness.

At $7^h17^m38^s$ CSM g.e.t., when the CSM is approximately 1 n. mi. from the SWS, the braking approach will begin. The theoretical terminal phase finalization (TPF) maneuver requires 28 fps. However, the nominal operational cost for braking, stationkeeping, and docking will be approximately 55 fps. During stationkeeping, the SWS will be photographed and television coverage will be sent through the U.S. STDN sites. The acquisition of signal for the GDS STDN site occurs at $7^h53^m7.9^s$ g.e.t., which is followed by continuous STDN TV contact to the MLA STDN loss of signal at $8^h09^m56^s$ g.e.t. The CSM will dock axially with the SWS, at port 5 of the multiple docking adapter (MDA) at $8^h03^m25^s$ CSM g.e.t.

All SPS maneuvers except TPI and the deorbit burns are preceded by a 2-jet, 20-second ullage plus a 1-second overlap with the main engine burn. TPI and the deorbit burns are preceded by 4-jet, 14-second ullages with a 1-second overlap because the 4-jet ullage provides proper quad configurations for midcourse corrections and terminal phase braking. Table 5-III gives the REFSMMAT, target loads, and gimbal angles for the rendezvous maneuvers through the TPI. A detailed summary of major maneuver and trajectory events is presented in table 5-IV. The SPS propellant budget presented in table 5-V indicates that a propellant margin of 3183 pounds exists. This is equivalent to approximately 1038 fps at the start of mission and is available for variations in the mission plan and contingencies allowance.

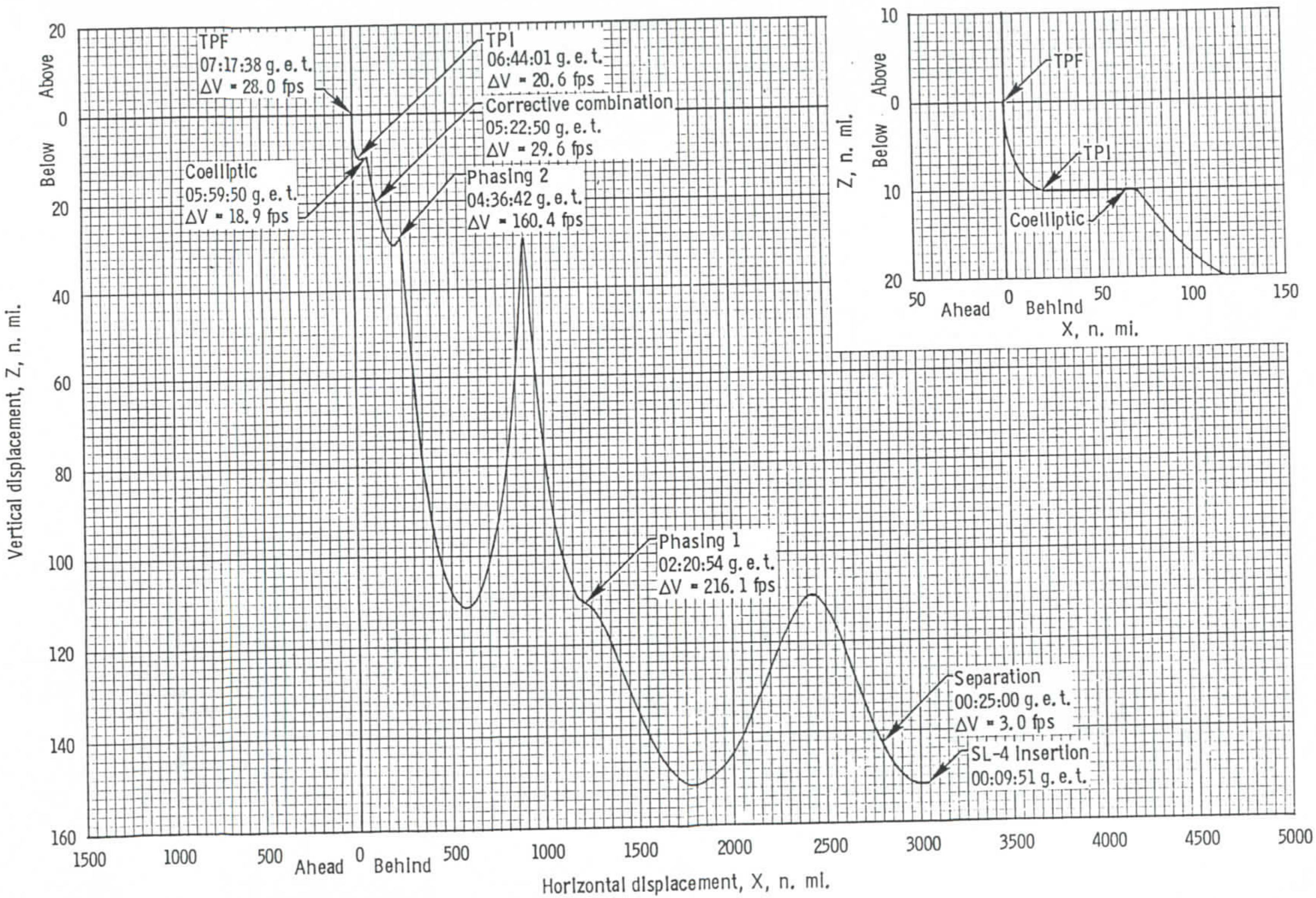


Figure 5-5. - Relative motion of CSM in SWS curvilinear coordinate system from insertion to rendezvous.

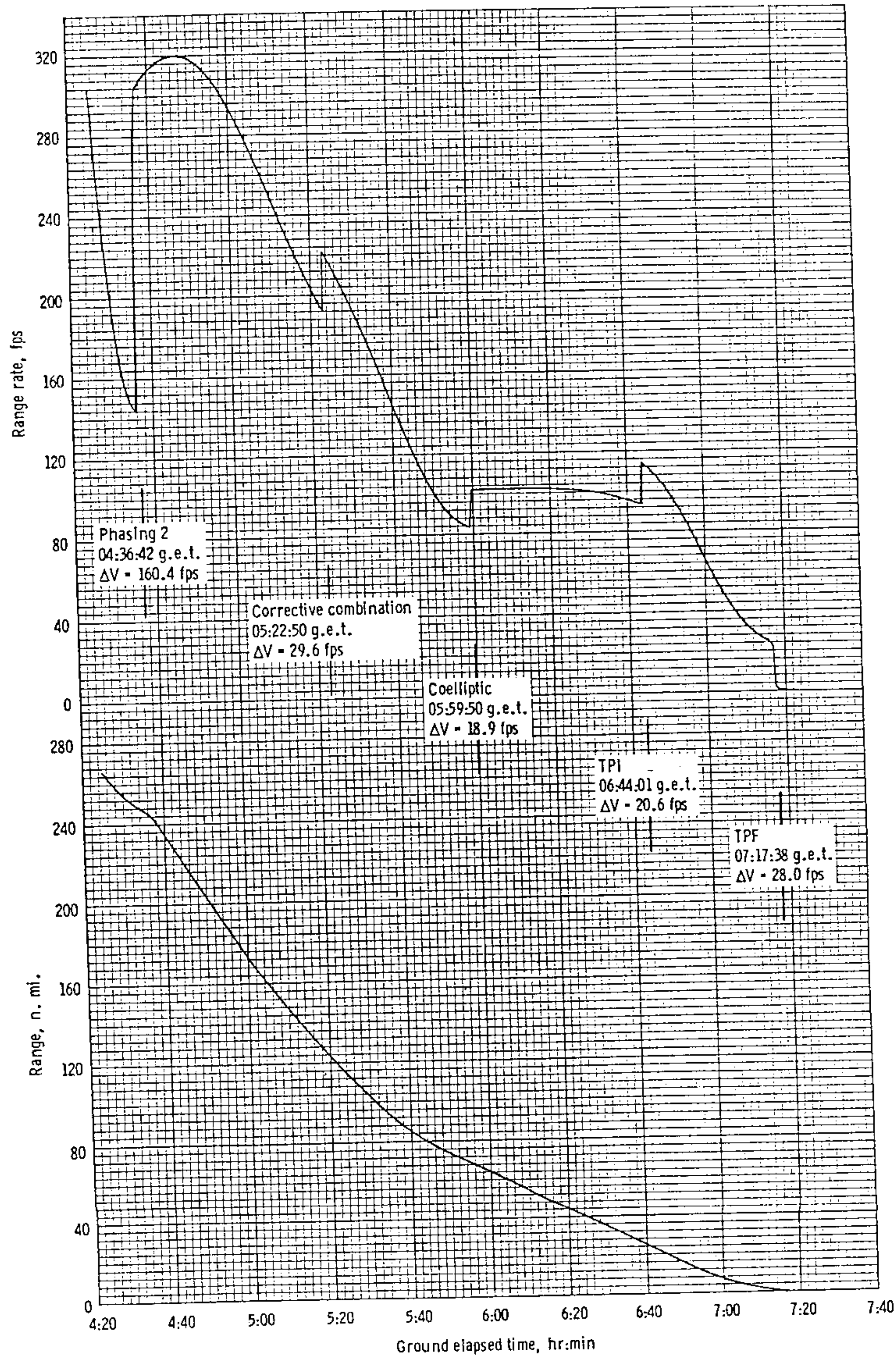


Figure 5-6.- CSM range and range rate to SWS from 320 n. mi. to rendezvous.

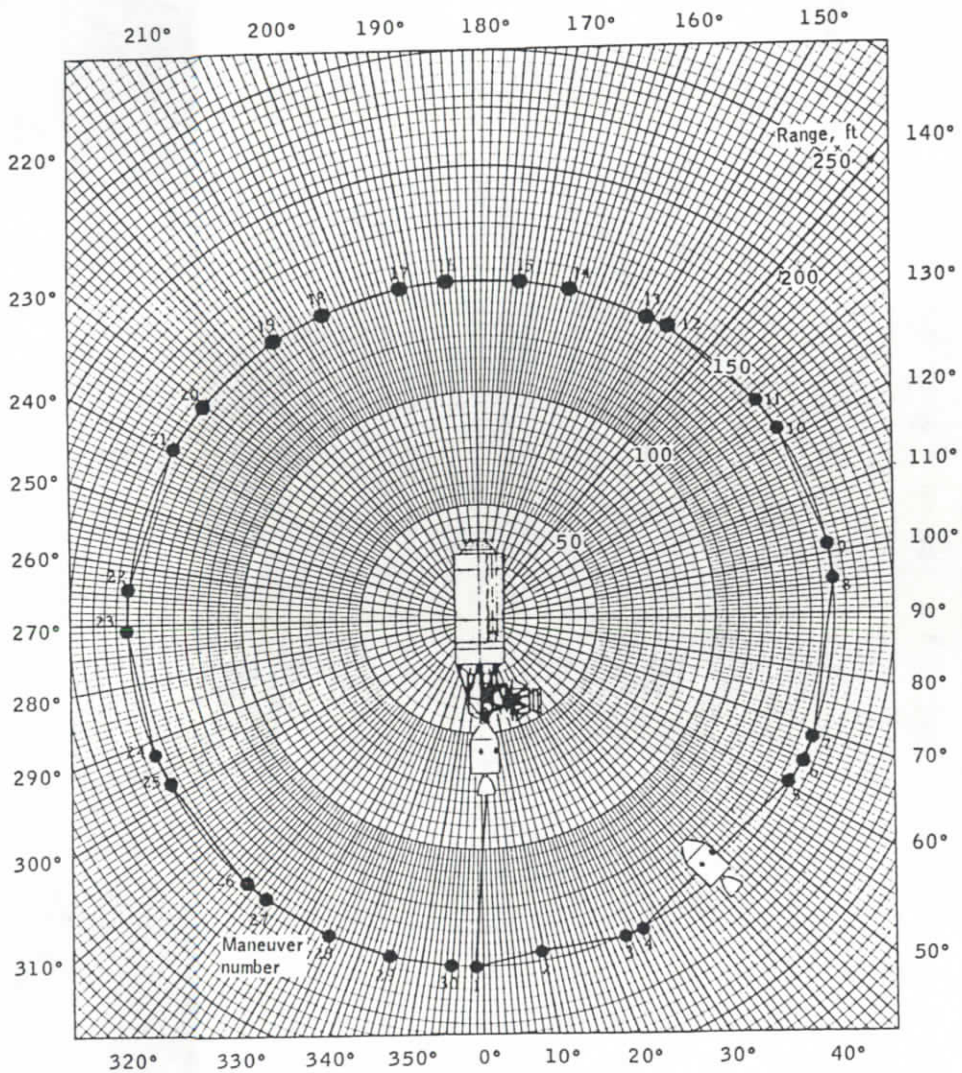
5.8 Separation and Deorbit

The deorbit sequence is initiated by IMU alinements, undocking, flyaround inspection, and then a separation maneuver. The IMU alinements occur in night passes prior to undocking and the remaining operations begin at daybreak and occupy one daylight pass. The first deorbit maneuver (SPS-1) occurs in daylight approximately 46.5 minutes after separation. The second deorbit maneuver (SPS-2) occurs two orbits later at the same orbital position and attitude as SPS-1. The deorbit sequence can be found in table 5-IV and figure 5-8.

The IMU alinements P51 and P52 will be performed during the two night passes preceding undocking. The SL-4 CSM will undock from the workshop January 6, 1974 at $17^h29^m21^s$ G.m.t. [$15^h26^m46^s$ deorbit phase elapsed time (p.e.t.) where SPS-2 ignition is defined as $20^h0^m0^s$ p.e.t.]. The undocking impulse will initiate a workshop circumnavigation sequence which will allow the crew to photograph and inspect the workshop. A typical CSM circumnavigation relative motion profile around the SWS is presented in figure 5-9. The relative motion is based on a computer simulation of the circumnavigation sequence described in the Skylab entry checklist (ref. 20). The sequence begins with undocking at the earth sunrise terminator and ends with a separation maneuver 47 minutes later at the earth sunset terminator, as shown in figure 5-10. After undocking, the crew begins a monitoring and flyaround procedure by which the CSM will circumnavigate the SWS in 35 to 45 minutes. The flyaround is executed primarily by continuously monitoring the SWS through the crew optical alinement sight (COAS) and performing small (0.5 sec) +X or +Z two-jet SM-RCS translation to maintain a range of approximately 150 feet and a relative radial angular rate around the SWS of 9° to 12° per minute. A diagram of the circumnavigation sequence is given in figure 5-10. The separation maneuver is used to evade the workshop and is performed at the earth sunset terminator at $18^h16^m00^s$ G.m.t. ($16^h13^m25^s$ p.e.t.).

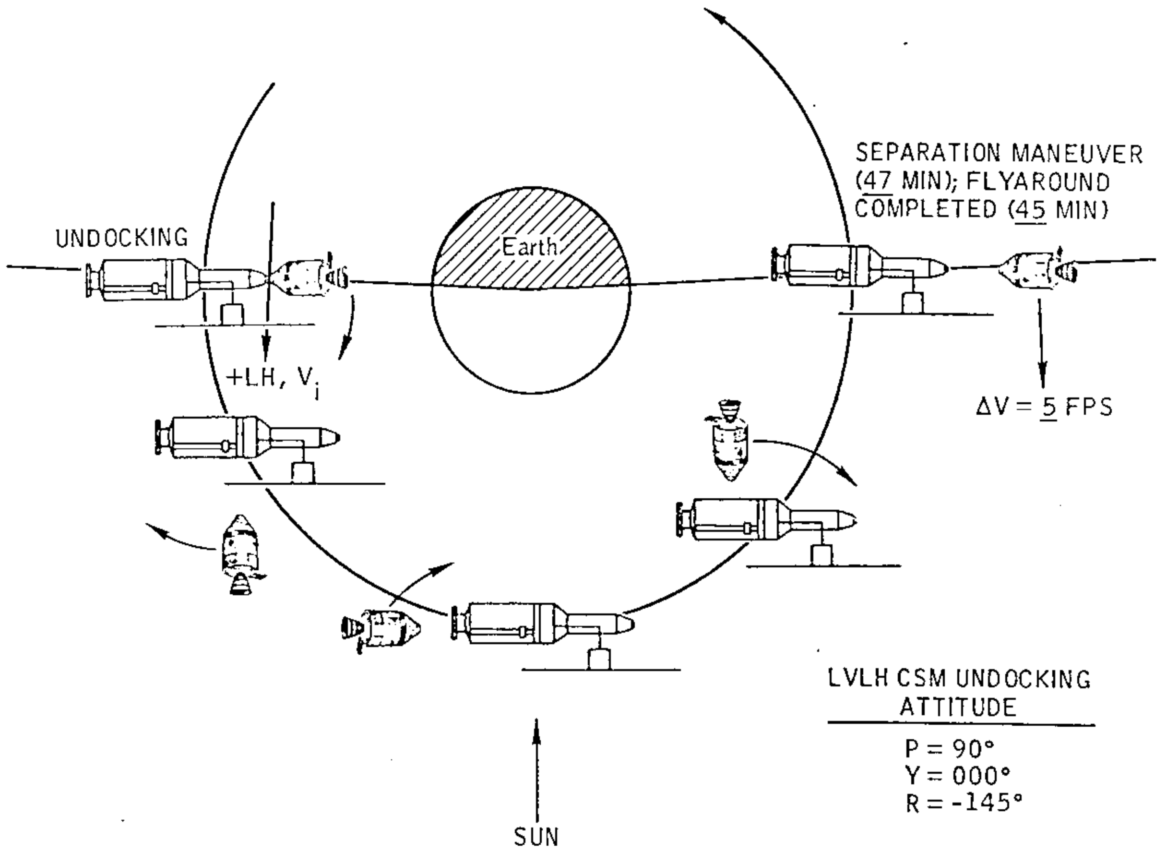
Figure 5-11 presents the evasive maneuver, which is a two-jet -Z SM RCS retrograde translation (along the retrograde local horizontal) of 5 fps. Burn time is 23.0 seconds. At ignition, the CSM should be located 150 feet or more above the SWS. After the evasive maneuver, the CSM translates behind and below the SWS, crossing below and behind the SWS at a range of approximately 800 feet in 2 minutes. The CSM continues below and moves ahead of the SWS just prior to shaping (SPS-1). Vertical clearance is 1.1 n. mi. at 19 minutes. This maneuver translates the CSM to the correct relative position with respect to the SWS for the shaping maneuver, which occurs approximately 41 minutes later. At shaping, the CSM is 5.6 n. mi. ahead of the SWS. A diagram of the separation burn attitude is given in figure 5-11.

The control mode for the SPS firings is primary guidance and navigation control system (PGNCS) in a horizon-monitor, heads-down attitude. Burn attitude is such that



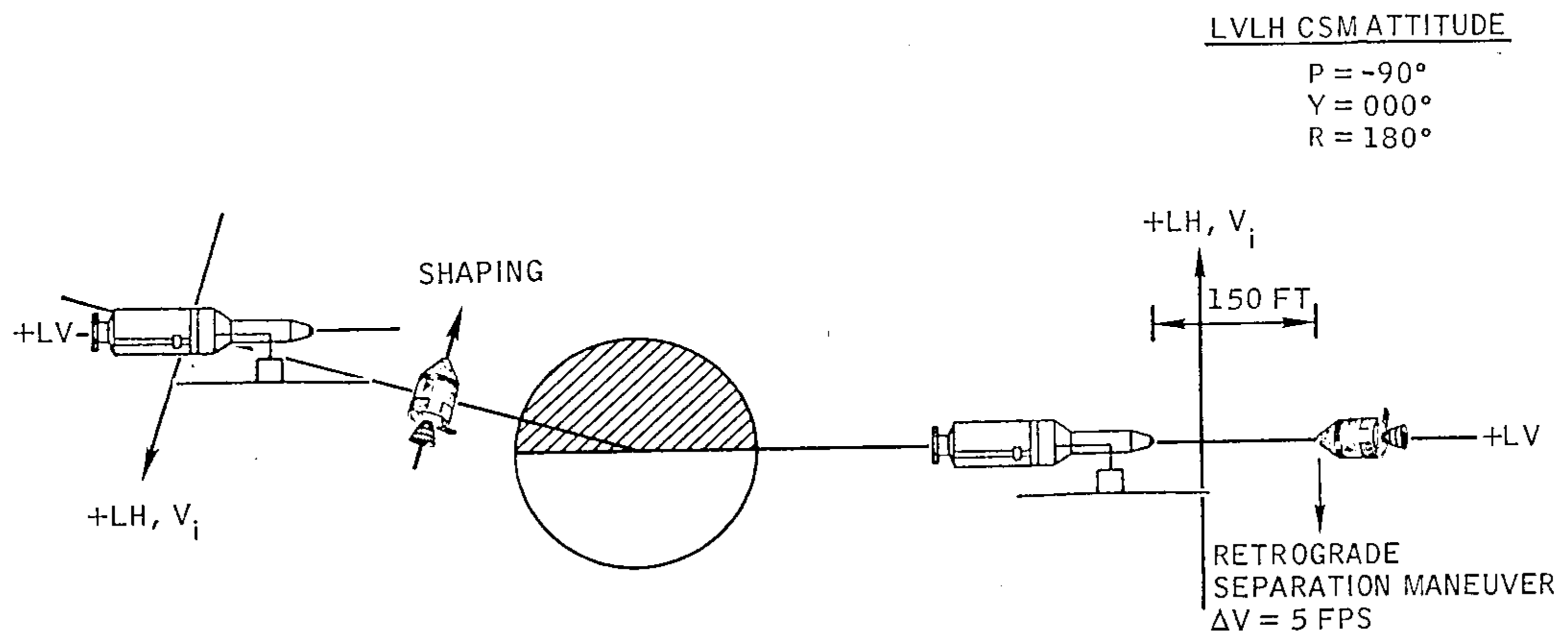
Maneuver number	Type of maneuver	Delta velocity (fps)	Time from undocking (min:sec)	Coast time to next maneuver (seconds)
	Undocking	.4	0:00	240
1 (Initiation)	2.5 sec +X, 1.5 sec -Z	.630	4:00	90
2	.5 sec -Z	.108	5:30	90
3	.5 sec +X	.108	7:00	20
4	.5 sec +X	.108	7:20	260
5	.5 sec -Z	.108	11:40	20
6	.5 sec +X	.108	12:00	30
7	.5 sec +X	.108	12:30	160
8	.5 sec +X	.108	15:10	40
9	.5 sec +X	.108	15:50	120
10	.5 sec +X	.108	17:50	30
11	.5 sec +X	.108	18:20	100
12	.5 sec +X	.108	20:00	20
13	.5 sec +X	.108	20:20	70
14	.5 sec +X	.108	21:30	40
15	.5 sec +X	.108	22:10	60
16	.5 sec +X	.108	23:10	40
17	.5 sec +X	.108	23:50	70
18	.5 sec +X	.108	25:00	50
19	.5 sec +X	.108	25:50	90
20	.5 sec +X	.108	27:20	50
21	.5 sec +X	.108	28:10	150
22	.5 sec +X	.108	30:40	40
23	.5 sec +X	.108	31:20	120
24	.5 sec +X	.108	33:20	30
25	.5 sec +X	.108	33:50	110
26	.5 sec +X	.108	35:40	20
27	.5 sec +X	.108	36:00	60
28	.5 sec +X	.108	37:00	50
29	.5 sec +X	.108	37:50	50
30	.5 sec +X	.108	38:40	30

Figure 5-9.- Relative motion of the CSM for a typical flyaround sequence.



- CSM UNDOCKING IS PERFORMED AT THE EARTH SUNRISE TERMINATOR. ΔV = 0.4 FPS (NOMINAL) CSM ROLLS TO 180° (LVLH)
- AT 150 FT RANGE, CSM NULLS RANGE RATE (2.5 SEC +X RCS, 2 JET, ΔV = 0.5 FPS) AND ESTABLISHES ANGULAR RATE AROUND SWS (1.5 SEC -Z RCS, 2 JET, ΔV = 0.3 FPS)
- CSM CONTINUOUSLY MONITORS AND MAINTAINS POINTING ATTITUDE AT SWS. A RANGE OF APPROXIMATELY 150 FT (C.G. TO C.G.) AND RADIAL ANGULAR RATE OF 9 TO 12 DEG PER MIN IS MAINTAINED BY USING SHORT (0.5 SEC) +X AND ±Z RCS, 2 JET PULSE DURATIONS
- CSM COMPLETES FLYAROUND IN 35 MIN TO 45 MIN

Figure 5-10.- CSM/SWS undocking and CSM circumnavigation of SWS.



- CSM EXECUTES RETROGRADE SEPARATION MANEUVER FROM THE SWS AT THE EARTH SUNSET TERMINATOR
- SEPARATION MANEUVER IS 2 JET -Z RCS TRANSLATION, ΔV = 5.0 FPS ALONG RETROGRADE LH, ΔT = 23.0 SEC
- AT IGNITION, THE CSM SHOULD BE LOCATED 150 FT OR MORE ABOVE THE SWS. AT 2 MIN AFTER IGNITION, THE CSM WILL PASS BELOW THE SWS AT AN UP-RANGE DISTANCE OF 800 FT
- AT SHAPING, THE CSM IS 3.0 N. MI. BELOW AND 5.6 N. MI. AHEAD OF THE SWS

Figure 5-11.- CSM evasive maneuver at the completion of the circumnavigation of the SWS.

SL-3 mission report, section 10 ("Rendezvous")

The rendezvous timeline was straightforward and easily followed. Coordination with ground control was smooth and all required data were transmitted from the ground on time.

Several events occurred during the rendezvous that prevented a completely normal sequence. Prior to the first phasing maneuver, the spacecraft was not aligned along the orbit track, but was yawed about 0.5 radian to the right. No apparent reason for this misalignment, other than a possible accidental striking of the hand controller, could be found. The spacecraft was returned to the zero-yaw position immediately. Shortly thereafter, fireflys coming from the vicinity of the service module were observed through the right-hand window. After discussions with the ground, the service module reaction control system quad B was deactivated. An abbreviated troubleshooting procedure was performed over the next few minutes and the forward-firing thruster on quad B was found to have an oxidizer valve stuck in the open position. This quad was isolated for the remainder of the visit.

Immediately prior to the first phasing maneuver, a horizon check was attempted through the forward window. The horizon was not within plus or minus 0.01 radian of the proper window mark, but closer to the 0.6 radian window mark. Discussions with the ground revealed that the light/dark demarcation line was not the horizon, but the terminator. Future crews should be made aware of this similarity, and also that the onboard data should reflect both the real horizon line and the terminator line.

Since the spacecraft apparently failed to pass the horizon check because of the confusion concerning the horizon, the Scientist Pilot attempted to perform an inertial measuring unit star check using the optics. However, the optics could not be driven manually. The phasing maneuver was made on time using the previous inertial measurement unit attitude, since the inertial measurement unit had been recently aligned and agreed closely with the gyro display coupler. After the maneuver, the optics performed normally. This discrepancy was reported to the ground, and the ground later indicated that the optics were working normally. Section 7.6 contains a discussion of this discrepancy.

All rendezvous maneuvers were executed on time. The service propulsion system had a solid initial start transient each time it was fired. However, the subjective feeling was that the engine started about 1 to 1 1/2 seconds later than the ignition time.

The rendezvous was completed following the nominal timeline. All alignments were satisfactory. VHF ranging lock-on was accomplished normally and the flashing light beacon became visible in the optics about 5 1/2 hours after lift-off. The ground-computed ranges for acquisition of both the VHF and the beacon were accurate.

As a result of the quad B propellant leak, the reaction control system auto switches were repositioned to provide up and down translation during braking. The terminal phase initiation maneuver was executed normally with very small residuals. Information on the magnitude of all engine firings and the resulting residuals are contained in section 7.6 of this document.

The command module computer and the backup charts were in close agreement for the first midcourse correction. However, for the second midcourse correction, the command module computer solutions indicated 2.44 meters per second forward, 0.18 meter per second right, and 0.91 meter per second up, whereas the backup charts indicated 1.0 meter per second forward and 0.76 meter per second up. The command module computer solution was selected as the best and the maneuver was executed. The computer solution values were larger than expected. Also unexpected was the fact that the command module computer and backup chart solutions differed so greatly. Postflight investigation has shown that these widely differing solutions were not the result of an inflight procedural error, but were inherent in the integration calculations of the command module computer.

The VHF range and range-rate information displayed on the command module computer showed that the spacecraft passed the 1.85 kilometer braking gate at a nominal 9.1 meters per second. From this point until stationkeeping with the Workshop, braking was almost continuous because only the two-quad minus-X-axis thrusting capability existed. The almost continuous thrusting precluded the VHF from presenting accurate range-rate information to aid in the braking maneuver.

10.1.3 Stationkeeping and Docking

The transition from braking to stationkeeping was not easy to define. It was obvious when the relative motion between the command and service module and the Saturn Workshop had decreased to zero; however, accurate distance determination still was not possible. The best estimate of the separation distance is about 60 meters on the minus Z side of the Workshop (fig. 10-2). Because of the difficulty in accurately determining ranges by eye, the range-rate must be reduced to near zero prior to the point where it is possible to visually estimate the closing rate. The separation distance had to be reduced to less than 30 meters before left/right or up/down velocities, as well as closing or opening velocities, could be easily determined. Starting from a position near the minus Z axis scientific airlock, a flyaround inspection of the Saturn Workshop was made ending at the front of the Multiple Docking Adapter about 1 radian above the plus X axis. The television transmission became partially obscured because of a stuck color wheel during the flyaround inspection. The spacecraft was flown too near the thermal parasol which was extending from the plus Z scientific airlock. Thruster gas striking the parasol caused movement that might have resulted in parasol damage. Consequently, the command and service module was immediately flown away from the area of the parasol even though additional thruster impingement occurred during this process.

Maneuvering to the pre-docking position in front of the Multiple Docking Adapter was easily accomplished. However, to get a good line-up with the docking target, the spacecraft was positioned a little further away than had been required in the simulator. The two forwardmost Apollo Telescope Mount solar panels appeared to extend beyond the Multiple Docking Adapter further than was simulated, and it would be easy for the spacecraft to encroach upon the envelope of the two panels.

Docking velocity was estimated to be less than 0.3 meter per second at probe contact. After probe contact, plus X thrusting was performed until the capture latches locked. The required reaction control system thrusters were disabled, the command and service module was more precisely aligned in the roll and yaw axes, and the hard dock was completed.

SL-4

THIRD SKYLAB MISSION

(NOVEMBER 15, 1973 LAUNCH)

FINAL

REVISION C

SKYLAB CSM RENDEZVOUS BOOK

PREPARED BY

FLIGHT PROCEDURES BRANCH

CREW PROCEDURES DIVISION

National Aeronautics and Space Administration

LYNDON B. JOHNSON SPACE CENTER

Houston, Texas

NOVEMBER 8, 1973

SKYLAB SL-4
(NOVEMBER 15, 1973 LAUNCH)
CSM RENDEZVOUS BOOK

NOVEMBER 8, 1973

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FLIGHT PROCEDURES BRANCH

APPROVED BY: Paul C Kramer
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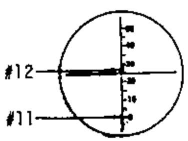
Distribution of this document is controlled by John O'Neill, Chief, Flight Planning Branch, Crew Procedures Division.

PSM ACTIVATION SWITCH LIST

SM RCS PSM 1 He-OPEN, tb-gray
SM RCS QUAD PRPLNT B-CLOSE, tb(2)-bp
SM RCS PSM PRPLNT B-OPEN , tb-gray
SM RCS QUAD PRPLNT C-CLOSE, tb(2)-bp
SM RCS PSM PRPLNT C-OPEN , tb-gray
SM RCS QUAD PRPLNT A-CLOSE, tb(2)-bp
SM RCS PSM PRPLNT A-OPEN , tb-gray
SM RCS QUAD PRPLNT D-CLOSE, tb(2)-bp
SM RCS PSM PRPLNT D-OPEN , tb-gray
SM RCS QUAD He(4)-CLOSE, tb(4)-bp

STAR AVAILABILITY

1.) BACKUP GDC ALIGN STARS ARE VISIBLE FROM SS TO SR



SHAFT = 0°
TRUN = 352.5°

2.) STAR ACQUISITION STARS ARE VISIBLE FROM SS+4 MIN TO SR+24 MIN

DEFINITIONS

H = AVERAGE ALTITUDE
θ_p = ORDEAL FDAI PITCH
TA = TRUNNION ANGLE

NC1 TARGETING PAD

		NOMINAL						NOMINAL UPDATE						PRELAUNCH UPDATE					
N95	HR	+	X	X	0	0	2	+	X	X				+	X	X			
TIG NC1	MIN	+	X	X	X	2	4	+	X	X	X			+	X	X	X		
	SEC	+	X	0	5	3	0	+	X					+	X				
N57 HALF REVS		X	X	X	X	0	3	X	X	X	X			X	X	X	X		
N37	HR	+	X	X	0	0	6	+	X	X				+	X	X			
TIG TPI	MIN	+	X	X	X	5	4	+	X	X	X			+	X	X	X		
	SEC	+	X	1	5	7	0	+	X					+	X				

TALIGN PAD

		NOMINAL						NOMINAL UPDATE						PRELAUNCH UPDATE					
N34	HR	+	X	X	0	0	6	+	X	X				+	X	X			
GET	MIN	+	X	X	X	4	7	+	X	X	X			+	X	X	X		
ALIGN	SEC	+	X	0	1	1	0	+	X					+	X				

BACKUP GDC ALIGN PAD

		NOMINAL						NOMINAL UPDATE						UPDATE					
0°/R STARS		1	1	/	1	2	X			/			X			/			X
ASCP tw	R	X	X	1	0	4	4	X	X					X	X				
	P	X	X	0	1	0	0	X	X					X	X				
(RNDZ REFSMMAT)	Y	X	X	0	1	9	7	X	X					X	X				

STAR ACQUISITION PAD

		NOMINAL						NOMINAL UPDATE						UPDATE					
N22 (NC1)	R	+	1	8	0	0	0	+				0	0	+				0	0
	P	+	3	3	5	0	0	+				0	0	+				0	0
(RNDZ REFSMMAT)	Y	+	0	0	2	0	0	+				0	0	+				0	0
N71 1ST STAR		X	X	X	X	0	4	X	X	X	X			X	X	X	X		
TPAC	SA	X	2	1	5	2	0	X					0	X					0
ANGLES	TA	X	0	2	8	8	0	X	0				0	X	0				0
N71 2ND STAR		X	X	X	X	1	4	X	X	X	X			X	X	X	X		
TPAC	SA	X	3	4	8	0	0	X					0	X					0
ANGLES	TA	X	0	1	3	9	0	X	0				0	X	0				0
N71 3RD STAR		X	X	X	X	1	7	X	X	X	X			X	X	X	X		

0+00 SL-4 LIFT-OFF

BDA

0+10 SL-4 INSERTION

ARIA

CSM/SIVB SEP (180,0/309,0)

0+20 MAD

BACKUP GDC ALIGN PAD (IF REQD, COPY Pg 1-a)
LAUNCH/RNDZ REALIGN PAD (IF REQD, COPY Pg 5-a)

COMPLETE LAUNCH C/L THRU STEP 4, Pg L/3-1

SEP
VERIFY FOLLOWING PADS (REF LAUNCH C/L Pgs L/1-16 & L/2-13) COPIED INTO RNDZ BOOK: NC1 TARGETING PAD, TALIGN PAD, & BACKUP GDC ALIGN PAD (Pg 1-a), AND LAUNCH/RNDZ REALIGN PAD (Pg 5-a)
(11002) (01111) V48E (LOAD 2 JET AND 0.5°/SEC RATE); V62E

P00
V49 (MNVR TO 179,163,358)(LAUNCH REFSMMAT)

DIM LIGHTS

0+30

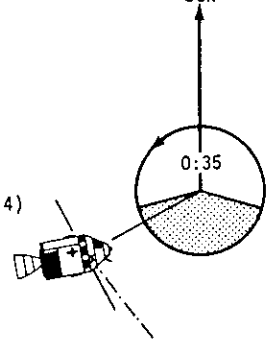
PLT SYSTEMS CHECKS

- MAIN REG CHECK
- SEC RAD LEAK CHECK
- ECS POST INSERTION CONFIG
- SM RCS MONITORING CHECK
- CM RCS MONITORING CHECK
- C/W OPERATIONAL CHECK
- EPS MONITORING CHECK
- ECS MONITORING CHECK
- SECONDARY GLYCOL LOOP CHECK
- SPS MONITORING CHECK
- EXTEND DOCKING PROBE

0+30

(11002)
(01111)

PERFORM EMS ΔV TEST & NULL BIAS CHECK CHECKLIST (Pg 1-2)



P52 (OPT 3) (RECORD)
REF STAR ACQ PAD STARS (Pg 1-a) (4,14)

0+40

P52 (OPT 2: COARSE ALIGN) (RECORD)
REF TALIGN PAD (Pg 1-a)
(NOMINAL N22=180,335,2) (4,14)

0:00

START SCS DRIFT CHECK (BMAG 2)
ALIGN GDC
RESET AND START DET COUNTING UP

0+50

PERFORM COAS LOS DETERMINATION CHECKLIST (Pg 1-2)

BORESIGHT STAR
14 - CANOPUS
(180,19,4)

ADVISE STDN ON SEPARATION EXECUTION

ARIA

P31; BYPASS MINKEY OPT & AUTO MNVR
LOAD NC1 TARGETING PAD (Pg 1-a)

CRO

P31 (FINAL COMP: RECORD)
V56E

1+00

EMS ΔV TEST & NULL BIAS CHECK CHECKLIST

EMS MODE-STBY
EMS FUNC-ΔV SET/VHF RNG
SET ΔV ind to 1586.8 fps
EMS MODE-NORMAL
EMS FUNC-ΔV TEST
SPS THRUST Lt-on/off (10 sec)
ΔV ind stops at -0.1 to -41.5

EMS MODE-STBY
EMS FUNC-ΔV SET/VHF RNG
SET ΔV ind to (-100.0) fps
CMC MODE-FREE
EMS FUNC-ΔV (wait 5 sec)
EMS MODE-NORMAL (for 1 min 40 sec)
EMS MODE-STBY
If ΔV≤1 fps, do not bias
If ΔV>1 fps but ≤10 fps, bias if desired
If ΔV>10 fps, EMS is NO-GO
CMC MODE-AUTO

P52 (OPTION 3)

N71 1ST STAR	X	0	0	0		
N71 2ND STAR	X	0	0	0		
N05(R1) ϑ ERR	X					
N93 GYRO TORQUING ANGLES X						
Y						
Z						
TIME OF GYRO TORQUE HR	+	0	0	0		
MIN	+	0	0	0		
SEC	+	0				

P52 (OPTION 2)

N71 1ST STAR	X	0	0	0		
N71 2ND STAR	X	0	0	0		
N05(R1) ϑ ERR	X					
N93 GYRO TORQUING ANGLES X						
Y						
Z						
TIME OF GYRO TORQUE HR	+	0	0	0		
MIN	+	0	0	0		
SEC	+	0				

COAS LOS DETERMINATION CHECKLIST

1. COAS PWR-ON(up)
MNVR TO BORESIGHT ATTITUDE
CMC MODE-FREE
V37E52E
F 04 06 R1 00001
R2 00003
PRO
F 50 25 00015
ENTER
F 01 70 000DE STAR CODE
LOAD BORESIGHT STAR CODE
OPT MODE-CMC(verify)
OPT ZERO-OFF
PRO
06 92 SHAFT,TRUN

2. BORESIGHT ON STAR AND MARK with VERB key
RECORD SHAFT,TRUN
(NOMINAL = 0°,+57.470°)
TO VERIFY: KEY RLSE AND REPEAT STEP 2

3. V37E00E
CMC MODE-AUTO
OPT MODE-MAN
OHC-Drive trun<10°
OPT ZERO-ZERO

COAS LOS DETERMINATION

N92	SA	+					
	TA	+					

P31 FINAL COMP

N84	ΔV_{NC2}	+	0				
	ΔH_{NC2}	+	0				
	ΔV_{NCC}	+	0				
N81 ΔV_{NC1}	ΔV_X	+	0				
	ΔV_Y	+	0	0	0	0	0
	ΔV_Z	+	0	0	0	0	0

1+00	P20 (OPT 5) (N78 = +0,+9000,+18000) (TRK EARTH N70 = 47)
(11002) (01111)	PERFORM PGA DOFFING & STOWAGE CHECKLIST (Pg 1-3)
	UNSTOW CUE CARDS (DATA CARD KIT-R3)
	UNSTOW AND MOUNT ORDEAL BOX (U3)
1+10	
+30:00	END SCS DRIFT CHECK (BMAG 2); PERFORM GDC/IMU COMPARISON CHECKLIST (Pg 1-3)
0:00 1+20	****IF BMAG 2>10°/HR/AXIS************ * START SCS DRIFT CHECK (BMAG 1) * * ALIGN GDC * * BMAG MODE(3)-RATE 1 * * RESET AND START DET COUNTING UP * ************************************
1+30	

PGA DOFFING AND STOWAGE CHECKLIST

STOW LIFE VESTS (Disp Bag A)
STOW WRIST DAMS & NECK DAMS (Disp Bag A)
STOW C/L POCKETS WITH SCISSORS (Disp Bag A)
(CDR SCISSORS IN Disp Bag B)
STOW IN Disp Bag B: SUNGLASSES, PEN, PENCIL, MARKER, WATCH W/BAND & PRD.
LEAVE PENLIGHT IN PGA
STOW OTHER CREW OPTIONAL EQPT AS REQD

AUDIO CONT(3)-NORM (verify) (PNLS 6,9,10)
PWR(3)-OFF (PNLS 6,9,10)
SUIT PWR(3)-OFF (PNLS 6,9,10)
DISCONN COMM CARRIER & STOW (Disp Bag B)
SUIT FLOW VLV-OFF
DISCONN O2 HOSES & ELECTRICAL, SNAP TO BKH
UNSTOW 3 O2 UMBILICAL SCREEN CAPS AND 3 PGA ELECT CONNECTOR COVERS (B2)
INSTALL PGA ELECT CONNECTOR COVERS ON PGAs
INSTALL HOSE SCREENS ON RETURN HOSES (RED)
SUIT FLOW VLV-FULL FLOW

DOFF PGAs

CAUTION
DO NOT PULL RED LANYARD

INSTALL HELMETS & IV GLOVES (ACCESSORY BAGS) ON PGAs
SECURE HELMET BAGS TO HELMETS
DOFF OBS/BIOBELTS
CLEAN ELECTRODES WITH TISSUES (ON A8)
STOW OBS/BIOBELTS (ACCESSORY BAGS)
SECURE ACCESSORY BAGS TO HELMET BAGS
STOW PGAs IN PGA BAGS (U2) (CREW OPTION)
STOW PGAs (UNDER COUCH)

DON TROUSERS, JACKETS & BOOTS (U2)
DON CWG HARNESSES (U2) & COMM CARRIERS (Disp Bag B)
CONN COMM CARRIER TO CWG HARNESS
PWR(3)-AUDIO/TONE (PNLS 6,9,10)
SUIT PWR(3)-ON(up) (PNLS 6,9,10)
DON PRD & WATCH (Disp Bag B) (SHORT WATCH BANDS AVAILABLE LATER E625)
PLACE LOOSE POCKET ITEMS (Disp Bag B) IN TROUSER PKTS
DOFF UCTAs (WHEN FULL)
PLACE UCTA CLAMPS (ON A9) ON UCTAs
STOW UCTAs AND CLAMPS IN PORTABLE WASTE STOWAGE CONTAINER (ON A9) & TEMP STOW
DON UCTAs (ON A9)

GDC/IMU COMPARISON CHECKLIST

V16N20E
FDAI SELECT-1
FDAI SOURCE-ATT SET
ATT SET-GDC
ZERO FDAI 1 err needles with ASCP tw
Key VERB when ZERO
RECORD N20 values
RECORD ASCP tw values
RECORD DET
FDAI SELECT-1/2

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
X TOTAL ATTITUDE DIFFERENCE GREATER X
X THAN 10 DEG/HR PER AXIS IS X
X UNACCEPTABLE. X
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

BMAG 2 GDC/IMU COMPARISON RESULTS

N20 IMU	R	+					
	P	+					
	Y	+					
ASCP tw GDC	R	X					X
	P	X					X
	Y	X					X
DET (30:00)	ΔT	X	X				

BMAG 1 GDC/IMU COMPARISON RESULTS

N20 IMU	R	+					
	P	+					
	Y	+					
ASCP tw GDC	R	X					X
	P	X					X
	Y	X					X
DET (30:00)	ΔT	X	X				

DATE 11/8/73

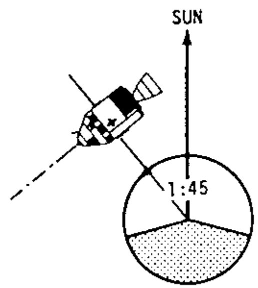
1+30

(11002)
(01111)

TO ENABLE REFSMMAT DOWNLINK
 CMC MODE-FREE
 V37E52E (HOLD FOR 30 SECONDS)
 V37E20E
 CMC MODE-AUTO
NC1 PRELIMINARY PAD (COPY Pg 1-5)
NPC ADVISORY
TRANSMIT GYRO TORQUE ANGLES AND TIME OF GYRO TORQUE
 (OPT 3 & OPT 2; Pg 1-2)
TRANSMIT EMS ΔV TEST RESULTS
TRANSMIT GDC/IMU COMPARISON RESULTS (Pg 1-3)

TEX

1+40



+30:00

1+50

*****IF BMAG 2>10°/HR/AXIS****************
* END SCS DRIFT CHECK (BMAG 1); PERFORM *
* GDC/IMU COMPARISON CHECKLIST (Pg 1-3) *
****

STDN UPLINK (P27) [CSM & SWS STATE VECTORS, PIPA BIAS UPDATE]

MAD

NC1 FINAL PAD (COPY Pg 1-5)
STAR ACQ PAD (COPY Pg 1-a)

V48E (LOAD WT, PT & YT IF REQD)

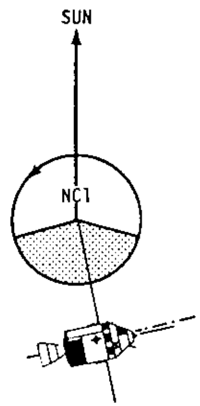
P31; BYPASS MINKEY OPT & AUTO MNVR
LOAD N95 NC1 TIG PAD VALUE (Pg 1-5)
SET DET

P31 (FINAL COMP: RECORD Pg 1-5)

2+00

2+00	
(11002) (01111)	P00 V49E (MNVR TO STAR ACQ PAD ATT (Pg 1-a)) (NOMINAL ATT=(180,335,2)
	P52 (OPT 3) (RECORD Pg 1-6) (4,14)
2+10	
-12:00	
	GO TO SPS BURN CUE CARD (BANK A & B)
	P40
2+20	
0:00	NC1 (180,359/335,2) (TRIM VGX +0.2) RECORD BURN STATUS
	P20 (OPT 5) (N78 = +0,+9000,+18000) (TRK EARTH N70 = 47)
2+30	ARIA

```
*****IF P52 N93 RSS>1°**************************************
* TIG > 15 MIN:  PERFORM BACKUP GDC ALIGN (G/3-18)         *
*                REF PAD (Pg 1-a)                          *
*                AND                                       *
* TIG < 15 MIN:  PERFORM GDC CHECK AT STAR ACQ PAD ATT     *
*                (OHC TO FIRST PAD STAR SA/TA)             *
*****IF STAR > 5° FROM CENTER OF SCT************************
* APPLY ΔVX USING 16° WINDOW MARK FOR BURN ATT             *
* IF DESIRED, PERFORM BURN ATT CHECK AT THE BURN ATT       *
************************************************************
```



NC1 PAD DATA

		NOMINAL	PRELIMINARY	FINAL
N95	HR	+XX002	+XX	+XX
TIG NC1	MIN	+XXX24	+XXX	+XXX
	SEC	+X05.30	+X .	+X .
N81	ΔV_X	+X213.3	X .	X .
ΔV_{NC1}	ΔV_Y	+X000.0	X .	X .
	ΔV_Z	+X000.0	X .	X .
N22	R	+180.00	+ .00	+ .00
NC1	P	+335.00	+ .00	+ .00
	Y	+002.00	+ .00	+ .00
	ΔV_C	XX200.7	XX .	XX .
	BT	XX00:10	XX :	XX :

WT	+	PT	.	YT	.

BURN ATT CHECK

STAR	XXXX
SA	+ . 0
TA	+ . 00

BURN ATT CHECK UPDATE

STAR	XXXX
SA	+ . 0
TA	+ . 00

NC1 ONBOARD DATA

SPS BURN STATUS

ΔTIG		XX :
AFTER TRIM		
ΔVC		X .
FDAI (IF ATTITUDE NOT NOMINAL)	R	+ . XX
	P	+ . XX
	Y	+ . XX
N85 (IF VG >.2)	VGX	00 .
	VGY	00 .
	VGZ	00 .
TRANSMIT N81 APPLIED		

P31 FINAL COMP

N84	ΔV_{NC2}	+0 .
	ΔH_{NC2}	+0 .
	ΔV_{NCC}	+0 .
N81	ΔV_X	+0 .
ΔV_{NC1}	ΔV_Y	+0000.0
	ΔV_Z	+0000.0

```
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
X N81 COMP LIMITS +0.5 FPS       X
X                                X
X CMC/STDN WITHIN LIMITS GO CMC  X
X NO AGREEMENT GO STDN           X
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
```

2+30 ARIA (11002) (01111)

H_2 PURGE LINE HTR-ON(up)

UNSTOW NK CAMERA (U1) AND PLACE IN TSB

HSK

2+40

2+50

FUEL CELL PURGE (S/1-3) (20 MIN AFTER LINE HTR-ON)

3+00

H_2 PURGE LINE HTR-OFF (10 MIN AFTER PURGE)

P52 (OPTION 3)

N71 1ST STAR	X	0	0	0		
N71 2ND STAR	X	0	0	0		
N05(R1) θ ERR	X					
N93 X						
GYRO TORQUING Y						
ANGLES Z						
HR	+	0	0	0		
TIME OF GYRO MIN	+	0	0	0		
TORQUE SEC	+	0				

3+00
(11002)
(01111)

GDS

TRANSMIT NC1 SPS BURN STATUS (Pg 1-5)
TRANSMIT GYRO TORQUE ANGLES AND TIME OF GYRO TORQUE (Pg 1-6)

*****IF NPC REQUIRED***************
* P00 *
* STDN UPLINK (P27) [CSM & SWS STATE VECTORS] *
* NPC PAD (COPY) *
* V48E (LOAD 2°/SEC) (11003) *
* (LOAD WT, PT & YT IF REQD) *
****

TEX

3+10

NC2 PRELIMINARY PAD (COPY Pg 1-10)

PLT PREPARE LUNCH

BDA

3+20

*****IF NPC REQUIRED***************
* IF NO COMM (NO NPC PAD)- DO NOT BURN NPC. *
* ENTER P38 (G/5-14) 14 MIN PRIOR TO TIG (STDN MAY ADVISE P30 INSTEAD OF P38) *
* BYPASS AUTO MNVR *
* LOAD PAD VALUES IN N33 & N81 *
* SET DET *
* GDC ALIGN BEFORE P38 IMU TORQUE *
* GO TO SPS BURN CUE CARD (BANK A) *
***

PNL 7 DIRECT O_2 VLV-CLOSE(cw)

STDN UPLINK (P27) [CSM & SWS STATE VECTORS]

****
* GYRO COMP UPDATE *
****

CYI
MAD

***
* P40 *

3+30

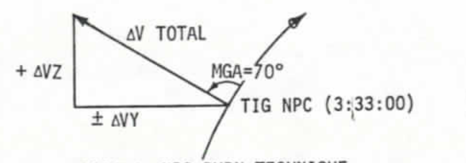
NPC PAD DATA

N33 TIG NPC	HR	+	X	X				
	MIN	+	X	X	X			
	SEC	+	X			.		
N81 ΔV_{NPC}	ΔV_X		X				.	
	ΔV_Y		X				.	
	ΔV_Z		X				.	
N22 NPC	R	+			.	0	0	
	P	+			.	0	0	
	Y	+			.	0	0	
	ΔV_C	X	X				.	
	BT	X	X			:		
	ΔVC AT IGN	+	X	X	X		.	
	ΔVC TAILOFF	-	X	X			.	

WT	+					

PT			.		

YT			.		



P30/P40 NPC BURN TECHNIQUE

3+30 — MAD CYI
(11002)
(01111)

* NPC (TRIM VGY & VGZ ± 0.2) *
* RECORD BURN STATUS *
* TRANSMIT NPC SPS BURN STATUS *

* GDC ALIGN AFTER P38 IMU TORQUE *
* V48E (LOAD 0.5°/SEC)(11002) *
****

P52 (OPT 3) (RECORD) (IF STARS NOT AVAILABLE
REF STAR ACQ PAD (Pg 1-a)) (4,14)

3+40

P32

PERFORM VHF RANGING SWITCH LIST (Pg 1-8)

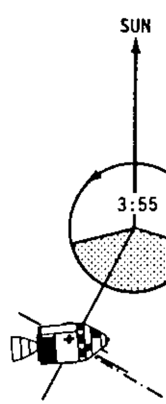
ATTEMPT VHF ACQUISITION (R=411 NM) TO CHECK OUT VHF RANGING SYSTEM
(OPTIMUM LOCK-ON PERIOD IS ~3+52 TO 4+05 FOR SWS IN SI ATTITUDE)

3+50

SET DET

-49:00 — SXT

AT 3+58
R=370 NM



XXXXXXXXXXXXXXXXXXXXXXX
X UNREASONABLE UPDATE X
X 1.00 NM, 6.0 FPS X
XXXXXXXXXXXXXXXXXXXXXXX

4+00

SPS BURN STATUS

ΔTIG	X	X				
AFTER TRIM						
ΔVC		X				
FDAI (IF ATTITUDE NOT NOMINAL) R	+				X	X
P	+				X	X
Y	+				X	X
N85 (IF VG >.2) VGX		0	0			
VGY		0	0			
VGZ		0	0			
TRANSMIT N81 APPLIED						

P52 (OPTION 3)

N71 1ST STAR	X	0	0	0		
N71 2ND STAR	X	0	0	0		
N05(R1) ϑ ERR	X					
N93 GYRO TORQUING ANGLES X						
Y						
Z						
TIME OF GYRO TORQUE HR	+	0	0	0		
MIN	+	0	0	0		
SEC	+	0				

P52 (OPTION 3)
(FOR M>5)

N71 1ST STAR	X	0	0	0		
N71 2ND STAR	X	0	0	0		
N05(R1) ϑ ERR	X					
N93 GYRO TORQUING ANGLES X						
Y						
Z						
TIME OF GYRO TORQUE HR	+	0	0	0		
MIN	+	0	0	0		
SEC	+	0				

VHF RANGING SWITCH LIST

VHF AM A-OFF(ctr)
VHF AM B-DUPLEX
VHF RANGING-ON(up)
VHF ANTENNA-RIGHT
EMS FUNC-ΔV SET/VHF RNG
EMS MODE-BACKUP/VHF RNG
PANEL 6,9,10:
VHF AM-RCV

4+00

(11002)
(01111)

S
X
T

XXXXXXXXXXXXXXXXXXXXXXX
X UNREASONABLE UPDATE X
X 1.00 NM, 6.0 FPS   X
XXXXXXXXXXXXXXXXXXXXXXX

****
* IF STDN CSM STATE VECTOR   *
* UPLINK REQUIRED-DELETE   *
* REMAINING PRE-NC2 SXT MARKS *
****

4+10

H
S
K

NC2 FINAL PAD (COPY Pg 1-10)
NCC PRELIMINARY PAD (COPY Pg 1-11)
NSR PRELIMINARY PAD (COPY Pg 1-12)
TRANSMIT GYRO TORQUE ANGLES AND
TIME OF GYRO TORQUE (Pg 1-8)

V48E (LOAD WT, PT & YT IF REQD)

S
X
T

RECALL P32 (LOAD N28 NC2 TIG PAD VALUE (Pg 1-10))

4+20

-12:00

38

P32 (FINAL COMP: RECORD Pg 1-10)

4+30

NOMINAL M-5

DATE 11/8/73

NOMINAL M-5

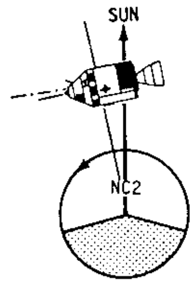
4+30

(11002)
(01111)

H A W

GO TO SPS BURN CUE CARD
(BANK A)

P40



4+40
0:00

NC2 (180,359/154,1) (TRIM VGX ± 0.2)
RECORD BURN STATUS
TRANSMIT NC2 SPS BURN STATUS

G D S

P33 (USE CMC TIG)
SET DET

-41:00

S X T

```
XXXXXXXXXXXXXXXXXXXXXXX
X UNREASONABLE UPDATE X
X 1.00 NM, 6.0 FPS    X
XXXXXXXXXXXXXXXXXXXXXXX
```

RANGE DATA FOR NCC
CHART SOLN NOT PROBABLE
WITH SWS IN SI ATT

```
*****IF SWS IN R-ZLV**********
* OBTAIN NCC/NSR CHART SOLNS *
******************************
```

4+50

B D A

5+00

NC2 PAD DATA

		NOMINAL	PRELIMINARY	FINAL
N28 TIG NC2	HR	+ 004	+	+
	MIN	+ 42	+	+
	SEC	+ 08.70	+ .	+ .
N81 ΔV_{NC2}	ΔV_X	+ 020.6	.	.
	ΔV_Y	+ 000.0	.	.
	ΔV_Z	+ 000.0	.	.
N22 NC2	R	+ 180.00	+ .00	+ .00
	P	+ 154.00	+ .00	+ .00
	Y	+ 001.00	+ .00	+ .00
	ΔV_C	008.0	.	.
	BT	00:01	:	:

WT	+
PT	.
YT	.

NC2 ONBOARD DATA

SPS BURN STATUS

ΔTIG			:
AFTER TRIM			
ΔVC			.
FDAI (IF ATTITUDE NOT NOMINAL)	R	+	.
	P	+	.
	Y	+	.
N85 (IF VG > .2)	VGX	00	.
	VGY	00	.
	VGZ	00	.
TRANSMIT N81 APPLIED			

P32 FINAL COMP

N84	ΔV_{NCC}	+	0 .
	ΔH_{NCC}	+	00 .
	ΔV_{NSR}	+	00 .
N81 ΔV_{NC2}	ΔV_X	+	0 .
	ΔV_Y	+	0000.0
	ΔV_Z	+	0000.0

```
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
X N81 COMP LIMITS ±0.5 FPS      X
X                               X
X CMC/STDN WITHIN LIMITS GO CMC X
X NO AGREEMENT GO STDN          X
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
```

5+00 (11002) (01111)	SXT
	CYI
5+10	
	ACN
-12:00	30
5+20	
0:00	
5+30	

NCC FINAL PAD (COPY)
NSR FINAL PAD (COPY Pg 1-12)

DO NOT OVERWRITE NCC TIG (N11) UNLESS ADVISED BY STDN - RECALL P33 TO OVERWRITE

V48E (LOAD WT, PT & YT IF REQD)

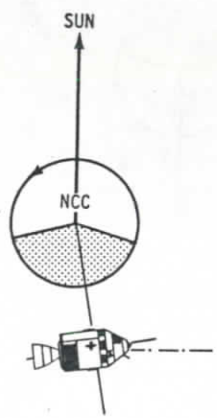
XXXXXXXXXXXXXXXXXXXXXXX
X UNREASONABLE UPDATE X
X 1.00 NM, 6.0 FPS X
XXXXXXXXXXXXXXXXXXXXXXX

ATTEMPT VHF ACQUISITION (R=170 NM) TO CHECK OUT VHF RANGING SYSTEM (OPTIMUM LOCK-ON PERIOD IS ~5+16 TO 5+52 FOR SWS IN SI ATTITUDE)

P33 (FINAL COMP: RECORD)

GO TO SPS BURN CUE CARD (BANK A)

P40



NCC (180,359/334,0) (TRIM VG'S ±0.2)
RECORD BURN STATUS

IF NCC EXECUTION IS QUESTIONABLE START RECORDING CHART DATA AT NSR-28

ATTEMPT VHF ACQUISITION (R=121NM) TO CHECK OUT VHF RANGING SYSTEM (OPTIMUM LOCK-ON PERIOD IS ~5+16 TO 5+52 FOR SWS IN SI ATTITUDE)

NCC PAD DATA

		NOMINAL	PRELIMINARY	FINAL
N11 TIG NCC	HR	+ 005	+	+
	MIN	+ 28	+	+
	SEC	+ 16.70	+ .	+ .
N81 ΔV_{NCC}	ΔV_X	+ 029.7	.	.
	ΔV_Y	+ 000.0	.	.
	ΔV_Z	+ 000.1	.	.
N22 NCC	R	+ 180.00	+ .00	+ .00
	P	+ 334.00	+ .00	+ .00
	Y	+ 000.00	+ .00	+ .00
	ΔV_C	017.1	.	.
	BT	00:01	:	:

WT	+	PT	.	YT	.

NCC ONBOARD DATA

P33 FINAL COMP

N82 ΔV_{NSR}	ΔV_X	0 .
	ΔV_Y	0 .
	ΔV_Z	0 .
N81 ΔV_{NCC}	ΔV_X	0 .
	ΔV_Y	0 .
	ΔV_Z	0 .

SPS BURN STATUS

ΔTIG		:
AFTER TRIM		
ΔVC		.
FDAI (IF ATTITUDE NOT NOMINAL)	R	+ .
	P	+ .
	Y	+ .
N85 (IF VG >.2)	VGX	00 .
	VGY	00 .
	VGZ	00 .
TRANSMIT N81 APPLIED		

NCC CHART SOLN

ΔV_X	.
ΔV_Y	
ΔV_Z	.

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
X N81 COMP LIMITS ±1.5,±5.0,±10.0 FPS X
X X
X CMC/CHART WITHIN LIMITS GO CMC X
X IF NOT CMC/STDN WITHIN LIMITS GO CMC X
X IF NOT CHART/STDN WITHIN LIMITS GO STDN X
X NO AGREEMENT-NORMALLY GO STDN X
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

5+30 (11002) (01111)	P34
	V32E (P34 RECYCLE: RECORD CMC MATCHED PAIR)
	SET DET
-30:00	SXT ⊗
	XXXXXXXXXXXXXXXXXXXXXX X UNREASONABLE UPDATE X X 1.00 NM, 6.0 FPS X XXXXXXXXXXXXXXXXXXXXXX
5+40	AT 5+40 R=100 NM
CRO	TRANSMIT NCC SPS BURN STATUS (Pg 1-11)
	V48E (LOAD WT, PT & YT IF REQD)
5+50 HSK	
-12:00 (19)	SET HDSUPFLG (V25N7E, 106E, 2000E, 1E)
	P34 (FINAL COMP: RECORD)
	IF NCC EXECUTION IS QUESTIONABLE THEN CMC FINAL COMP IS PRIME
	GO TO SPS BURN CUE CARD (BANK A)
	P40
6+00	

NSR PAD DATA

TIG NSR(N13)=TIG NCC(N11) + 00:37:00= ____:____:____.____

		NOMINAL	PRELIMINARY	FINAL
N81 ΔV_{NSR}	ΔV_X	+ X 018.7	X ___.__	X ___.__
	ΔV_Y	+ X 000.0	X ___.__	X ___.__
	ΔV_Z	+ X 000.5	X ___.__	X ___.__
N22 NSR	R	+ 180.00	+ ___.00	+ ___.00
	P	+ 189.00	+ ___.00	+ ___.00
	Y	+ 000.00	+ ___.00	+ ___.00
	ΔV_C	X X ___.__	X X ___.__	X X ___.__
	BT	X X 00:01	X X __:__	X X __:__
ΔVC AT IGN		+ X X X __.__	+ X X X __.__	+ X X X __.__
ΔVC TAILOFF		- X X __.__	- X X __.__	- X X __.__

WT	PT	YT
+ ____	___.__	___.__

NSR ONBOARD DATA

		P34 RECYCLE	P34 FINAL COMP
N75	ΔH_{NSR}	+ 00__.__	+ 00__.__
	ΔT(NSR/TPI)	+ __B__	+ __B__
	ΔT(TPI/TPI)	__B__	__B__
N81 ΔV_{NSR}	ΔV_X	0__.__	0__.__
	ΔV_Y	0__.__	0__.__
	ΔV_Z	0__.__	0__.__

SPS BURN STATUS

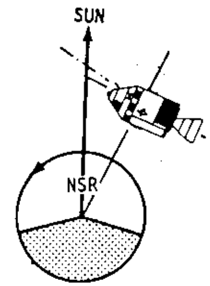
ΔTIG		X X __:__
AFTER TRIM		
ΔVC		X __.__
FDAI (IF ATTITUDE NOT NOMINAL)	R	+ ___ X X
	P	+ ___ X X
	Y	+ ___ X X
N85 (IF VG >.2)	VGX	00__.__
	VGY	00__.__
	VGZ	00__.__
TRANSMIT N81 APPLIED		

NSR CHART SOLN

ΔV_X	X ___.__
ΔV_Y	X X X X X X
ΔV_Z	X ___.__

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
X N81 COMP LIMITS NA,NA,NA FPS X
X X
X USE P34 FINAL COMP ΔVY FOR CMC SOLN X
X X
X BURN P34 RECYCLE, STDN OR CHART SOLN X
X IF NCC WAS BURNED CMC, STDN X
X OR CHART, RESPECTIVELY X
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

6+00	
(11002) (01111)	
0:00	NSR (180,357/189,0) (TRIM VG'S ± 0.2)
	RECORD BURN STATUS (Pg 1-12)
	P00
(11103)	V48E (LOAD 4 JET, 2°/SEC)
(01111)	RECALL P35 (ACCEPT AUTO MNVR TO HEADS UP TRACK ATT)
	TRANSMIT NSR SPS BURN STATUS (Pg 1-12)
HAW	V32E (1ST P35 RECYCLE: RECORD) (RECORD N37 (Pg 1-13))
	(REF TPI EARLY/LATE LOGIC (Pg 1-13))
	REACQUIRE VHF RANGING (R=67 NM) FOR CHART DATA
6+10	**MOMENTARY LOSS OF VHF LOCK-ON CAN BE EXPECTED WHILE TAKING TPI CHART DATA.
	IF VHF DATA NOT AVAILABLE FOR 1ST TPI CHART DATA POINT (TPI-32) DELAY ALL TPI CHART DATA POINTS 4 MINUTES AND ATTEMPT REACQUISITION PRIOR TO TPI-28.
	SET DET
	V76E (LOAD N72 WITH CHART TPI TIG 1-32)
-40:00	
SXT ⊗	
6+20	
GDS	TPI PRELIMINARY PAD (COPY Pg 1-14)
	DOCKING ATT PAD (COPY Pg 1-16)
	XXXXXXXXXXXXXXXXXXXXXXX X UNREASONABLE UPDATE X X 0.50 NM, 3.0 FPS X XXXXXXXXXXXXXXXXXXXXXXX
-32:00	R CHART DATA FOR TPI-32 (GET)
	SECS PYRO ARM(2)-SAFE(VERIFY)
	SECS LOGIC(2)-OFF(VERIFY)
	cb SECS ARM(2)-CLOSE
	cb SECS LOGIC(2)-CLOSE(VERIFY)
	**AFTER STDN GO-SECS LOGIC(2)-ON(up)
	RECEIVE STDN GO/NO GO FOR PYRO ARM
-28:00	R CHART DATA FOR TPI-28 (GET)
	V32E (2ND P35 RECYCLE: RECORD Pg 1-13)(RECORD N37 (Pg 1-13))
BDA	TPI FINAL PAD (COPY Pg 1-14)
6+30	V48E (LOAD WT, PT & YT IF REQD)



*******TPI EARLY/LATE LOGIC***

1ST RECYCLE
IF 2 SOLUTIONS INDICATE TIG SLIP > ±8 MIN FROM PRELAUNCH N37:
- ADJUST LOCATION OF 2ND RECYCLE ±8 MIN

2ND RECYCLE
IF CMC SOLUTION INDICATES TIG SLIP > ±10 MIN FROM PRELAUNCH N37:
- USE CMC TIG OPTION:
  - RECALL P35, PRO TO N37, LOAD PRELAUNCH N37±10 MIN
  - PRO TO N55, SPECIFY TIG OPTION (V22E,+E)
- CONTINUE CHART 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 CHART TPI TIG 2.

****

CHART TPI TIG 1							
-			3	2			
N72							

TPI TIG (N37)

PRELAUNCH (Pg 1-a)							
RECYCLES 1ST							
2ND							
STDN PREL							
CHART TPI TIG 2							

1ST P35 RECYCLE

N37 TIG TPI	HR	+	0	0	0		
	MIN	+	0	0	0		
	SEC	+	0				
N58	ΔV_{TPI}	+	0	0			
	ΔV_{TPF}	+	0	0			
	ΔT(TPI/TPI)				B		
N81 ΔV_{TPI}	ΔV_X		0	0			
	ΔV_Y		0	0			
	ΔV_Z		0	0			
N59 ΔV(LOS)	ΔV_F		0	0			
	ΔV_R		0	0			
	ΔV_D		0	0			

2ND P35 RECYCLE

+	0	0	0			
+	0	0	0			
+	0					
+	0	0				
+	0	0				
			B			
	0	0				
	0	0				
	0	0				
	0	0				
	0	0				
	0	0				

NOMINAL M=5

6+30 — BDA MIL — SXT

-24:00 R CHART DATA FOR TPI-24 (GET)

(11103)
(01111)

-16:00 R CHART DATA FOR TPI-16 (GET)

V77E
V83E; SET ORDEAL (FDAI 1)

H=229NM

6+40

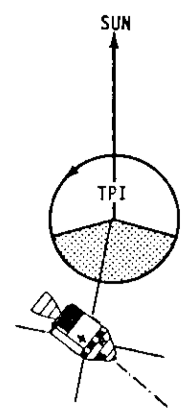
-12:00 (28) P35 (FINAL COMP: RECORD)
PNL 252 WASTE STOW VENT VLV-CLOSE(cw)

GO TO SPS BURN CUE CARD
ULLAGE AT -14 SEC
(BANK A)

ACN

P40

6+50



0:00 TPI (359,25/27,1) (TRIM VG'S ± 0.2)

P36

CENTER SWS IN SXT WHEN
READING CHART DATA Θp & TA

REACQUIRE VHF RANGING (R=20 NM)

+3:00 V87E; FDAI 1-ORB RATE

XXXXXXXXXXXXXXXXXXXXXX
X UNREASONABLE UPDATE X
X 0.50 NM, 3.0 FPS X
XXXXXXXXXXXXXXXXXXXXXX

+4:30 Θp & TA CHART DATA FOR TPI+4:30

7+00 — SXT/VHF

TPI PAD DATA

		NOMINAL	PRELIMINARY	FINAL
N37 TIG TPI	HR	+ X X 0 0 6	+ X X	+ X X
	MIN	+ X X X 5 4	+ X X X	+ X X X
	SEC	+ X 1 5.7 0	+ X	+ X
N81 ΔV_{TPI}	ΔV_X	+ X X 1 8.8	X X	X X
	ΔV_Y	+ X X 0 0.0	X X	X X
	ΔV_Z	- X X 0 8.5	X X	X X
N59 (RCS) ΔV (LOS)	ΔV_F/BT	+ 2 0.6/5 4	/	/
	ΔV_R/BT	+ 0 0.0/0 0	/	/
	ΔV_D/BT	+ 0 1.0/0 5	/	/
	ΔV_C	X X	X X	X X
	BT	X X 0 0:0 1	X X	X X
N22 (SPS USING N81)	R	+ 3 5 9.0 0	+ 0 0	+ 0 0
	P	+ 0 2 7.0 0	+ 0 0	+ 0 0
	Y	+ 0 0 1.0 0	+ 0 0	+ 0 0
ΔVC AT IGN		+ X X X	+ X X X	+ X X X
ΔVC TAILOFF		- X X	- X X	- X X

WT	PT	YT
+		

TPI ONBOARD DATA

TPI CHART SOLN

ΔV_X	X
ΔV_Y	X X X X X X
ΔV_Z	X

P35 FINAL COMP

N37 TIG TPI	HR	+ 0 0 0
	MIN	+ 0 0 0
	SEC	+ 0
N58	ΔV_{TPI}	+ 0 0
	ΔV_{TPF}	+ 0 0
	ΔT(TPI/TPI)	B
N81 ΔV_{TPI}	ΔV_X	0 0
	ΔV_Y	0 0
	ΔV_Z	0 0
N59 $\Delta V_{(LOS)}$	ΔV_F	0 0
	ΔV_R	0 0
	ΔV_D	0 0

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
X N81 COMP LIMITS ±1.0,±3.0,±3.0 FPS X
X X
X CMC/CHARTS WITHIN LIMITS GO CMC X
X IF NOT CMC/STDN WITHIN LIMITS GO CMC X
X IF NOT CHART/STDN WITHIN LIMITS GO CHART X
X NO AGREEMENT GO STDN X
X X
X FOR CHART/STDN-USE CMC TIG OPTION: X
X RECALL P35, PRO TO N37, LOAD CHART/STDN TIG; X
X PRO TO N55, SPECIFY TIG OPTION (V22E, +E). X
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

7+00	S/V	
(11103) (01111)		
+7:30		R CHART DATA FOR TPI+7:30
+8:30		R, θp & TA CHART DATA FOR TPI+8:30
+9:00	7	PRO (P36 FINAL COMP: RECORD)
		P41
+12:00		TPM1
		P36
		V25N33E (LOAD TPI TIG)
+15:00	SXT/VHF	⊗
7+10		CENTER SWS IN SXT WHEN READING CHART DATA θp & TA
+16:30		θp & TA CHART DATA FOR TPI+16:30
		XXXXXXXXXXXXXXXXXXXXXX X UNREASONABLE UPDATE X X 0.50 NM, 3.0 FPS X XXXXXXXXXXXXXXXXXXXXXX
+19:30		R CHART DATA FOR TPI+19:30
+20:30		R, θp & TA CHART DATA FOR TPI+20:30
+21:00	7	PRO (P36 FINAL COMP: RECORD)
		P41
+24:00	CRO	TPM2
7+20	VHF	⊗ P37 (N54-R, $\dot{R}$, θ FROM NAVIGATED STATE VECTORS) CMC MODE-HOLD (MONITOR LOS RATES & RANGE RATE) PERFORM PRE-BRAKING SWITCH LIST (Pg 1-15) PERFORM EVAP DEACT SWITCH LIST (Pg 1-15)
(11102) (01111)		PRO (P48)(N77=R, $\dot{R}$, θ)(R, $\dot{R}$ FROM VHF RANGING FILTER) V48E (LOAD 0.5°/SEC) NULL LOS RATES AND ADJUST RANGE RATE TO BRAKING GATES. N83(ΔVX, ΔVY, ΔVZ CONT)(OPTIONAL)
		NK-60 FRAMES (1000 FT) CM4/(f8, 1/250, ∞)
7+30		

TPM1 ONBOARD DATA

P36 FINAL COMP

N59	ΔV_F		0	0		
$\Delta V_{(LOS)}$	ΔV_R		0	0		
	ΔV_D		0	0		

TPM1 CHART SOLN

TPM2 ONBOARD DATA

P36 FINAL COMP

N59	ΔV_F		0	0		
$\Delta V_{(LOS)}$	ΔV_R		0	0		
	ΔV_D		0	0		

TPM2 CHART SOLN

PRE-BRAKING SWITCH LIST

- FDAI SCALE-5/1
- FDAI SELECT-1/2
- FDAI SOURCE-ATT SET
- ATT SET-GDC
- MAN ATT(3)-RATE CMD
- LIMIT CYCLE-OFF
- DBD/RATE-MIN/LOW
- THC PWR-ON(up)
- RHC PWR NORMAL(2)-AC/DC
- RHC PWR DIRECT(2)-MNA/MNB
- SC CONT/MODE-CMC/HOLD
- BMAG MODE(3)-ATT 1/RATE 2
- AUTO RCS SELECT(16)-MNA/MNB (FOR SINGLE QUAD FAILED CONFIGURATION-SEE Pg 7-2)
- THC-ARMED, RHC#2-ARMED

GLYCOL EVAPORATOR DEACTIVATION SWITCH LIST

- GLYCOL EVAP H2O FLOW-OFF
- GLYCOL EVAP STEAM PRESS-MAN
- GLYCOL EVAP STEAM PRESS-INCR (for 58 sec)

BRAKING GATES

R(NM)	$\dot{R}$(FPS)	RETICLE ANGLE(DEG) SWS DIA	SAS + DIA	ATM ARRAYS	R(FT)
1.00	30	.2	.5	.6	6000
.50	20	.4	1.1	1.2	3000
.25	10	.8	2.2	2.5	1500
.08	5	2.5	6.6	7.3	500
.05		4.2			300
.03		6.3			200
.02		10.0			130

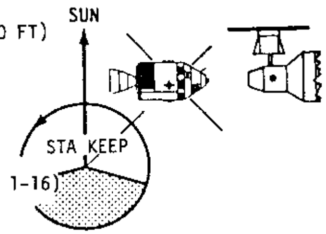
7+30
(11102)
(01111)

GWM

STATION KEEP ON SWS +X AXIS (R ~ 100 FT)
P00; V93E
CMC MODE-AUTO
BMAG MODE(3)-RATE 2
V49E (MNVR TO DOCKING ATT)(Pg 1-16)

STOW NK (U1)
PERFORM PRE-DOCKING SWITCH LIST (Pg 1-16)

PERFORM DOCKING CHECKLIST (Pg 1-16)



7+40

CSM/SWS DOCKING

GO TO SWS ACTIVATION C/L (R3)

7+50

GDS

8+00

SUNSET AT 8+18

DOCKING ATTITUDE

		NOMINAL	UPDATE
N22	R	+154.00	+ . 0 0
	P	+008.00	+ . 0 0
	Y	+008.00	+ . 0 0

PRE-DOCKING SWITCH LIST

BMAG MODE(3)-ATT 1/RATE 2
cb DOCK PROBE(2)-CLOSE
DOCKING PROBE RETRACT(2)-OFF(ctr)
DOCKING PROBE EXTD/REL-RETRACT
DOCKING PROBE EXTD/REL tb(2)-gray
SPOT LIGHT-ON(down)
SECS PYRO ARM(2)-ON(up)
FC REACS VALVES-LATCH

DOCKING CHECKLIST

TO INITIATE CAPTURE

VERIFY STATION KEEPING ON SWS +X AXIS
  (RANGE=40 TO 100 FT) (DOCK TGT=1.8 TO 0.8° IN COAS)
LOAD EMS WITH (-100.0) FPS
EMS FUNC/MODE-ΔV/NORMAL
THC-INITIATE 0.4 ±0.1 FPS CLOSING RATE
RHC-MAINTAIN MINIMUM RELATIVE ALIGNMENT ANGLES

AT CAPTURE (IF NO CAPTURE-SEE BACKUP DOCKING PROCEDURES (S/2-1))

DOCKING PROBE EXTD/REL tb(either)-bp (IF GRAY-SEE DOCKING MALFUNCTION
  PROCEDURES #2, Pg 15-3 IN CSM MALFUNCTION PROCEDURES BOOK)
CMC MODE-FREE
RHC PWR DIRECT(2)-OFF(ctr)
REPORT CAPTURE TO STDN
ALLOW PROBE TO DAMP SC MOTION (10 SEC)
THC-NULL PITCH AND YAW MISALIGNMENT<3°
RHC-NULL ROLL MISALIGNMENT<5°
DOCKING PROBE RETRACT PRIM-1 (SEC-1 IF REQD)

AT DOCK LATCH

DOCKING PROBE EXTD/REL tb(2)-gray

AFTER HARD DOCK

V45E
SECS PYRO ARM(2)-SAFE
SECS LOGIC(2)-OFF
cb SECS ARM(2)-OPEN
cb DOCK PROBE(2)-OPEN
DOCKING PROBE EXTD/REL-OFF
DOCKING PROBE RETRACT(2)-OFF(ctr)
SPOT LIGHT-OFF(up)
FC REACS VALVES-NORM
VHF AM B-OFF(ctr)
VHF RANGING-OFF
COAS PWR-OFF
EMS FUNC/MODE-OFF/STBY
DBD/RATE-MIN/LOW
THC PWR-OFF
RHC PWR NORMAL#1-OFF(ctr)
RHC PWR DIRECT(2)-OFF(ctr)
SC CONT/MODE-CMC/FREE
BMAG MODE(3)-RATE 2
AUTO RCS SELECT(A1,D2,A3,C4,B3,D4)-OFF
cb SCS A/C & B/D ROLL(4)-OPEN
cb SCS PITCH & YAW(4)-OPEN
THC-LOCKED
RHC(2)-LOCKED

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SL-3 Crew Debriefing,
section 4.0 ("Rendezvous & Docking")

BEAN Rendezvous and orientation: I thought that our rendezvous time line was easy to follow and pretty straightforward.

NC 1 burn: A comment about all the burns. The engine, when ignited, really kicked us in the pants. Perhaps it was because we weren't fully strapped in but it was a surprise to me, even for a short burn, to feel the hard bump when it lit. I guess that's par for the course. It always seemed to me like it fired up about a second after the time was zero. You'd reach time zero and nothing happened. Then about a second later it'd kick. You always had a feeling that it didn't start. Just about the time you'd think it didn't start, it started. It was just consistent.

VHF powerup: Didn't we power up the VHF out of range? They wanted us to do it earlier. I seem to remember they asked us to. We were in solar inertial. The vehicle was in solar inertial and they wanted us to check it.

LOUSMA When we did power it up and started using it for range, taking marks around it, it worked as advertised.

BEAN Sextant marks: We had some sextant problems. But I can't remember what they were. One time the sextant was drifting

BEAN (CONT'D) or something, or didn't go to the target, but I can't remember exactly what it was. The ground thought the reason was because we went to optics zero. It was some problem that we should have been aware of but we weren't. I can't remember what it was. We either went out of the problem or into the program and didn't zero it. We need to have somebody look up exactly what it was, because it should happen that way but it didn't do it that way in the simulator.

GARRIOTT Aside from that it didn't drive normally; it didn't jettison normally. It couldn't be steered manually. Part of the problem was, I remember now, that in manual, it didn't track at the right speed or something like that.

BEAN One other thing I thought about the optics. The optics drive about the same as they do in the simulator, medium and high. But in low, in the spacecraft, they drove about one-third of the low speed of the simulator. In low, I thought it was not even tracking. I looked down and said, "Yes, it is." Then I tried the other two and they seemed low also but the low seemed much slower than the low in the simulator.

BEAN One other thing about the NC 1 burn - We flunked the horizon check because, out in front of us, the thing that I took for the horizon was really the terminator. The terminator is not in our simulator. During the burn time, you're going to see

BEAN (CONT'D) the terminator and the horizon will be out ahead of it somewhere. You're going to have to get your cockpit lights down and look for a dark horizon. It's hard to tell from orbital altitude exactly whether or not you're looking at the horizon or a terminator as it moves across the Earth, unless of course it is right below you. Particularly if it's right in front of you, the difference between the horizon and terminator, 10 or 15 degrees is going to be tough to tell.

GARRIOTT I doubt you would have made that mistake at reentry. After a few days, you learn to work with it.

BEAN They called us up and told us not to make that mistake. I thought was smart. It ought to be pointed out on the onboard data.

GARRIOTT I thought the ground had made a mistake. They didn't intend to have a dark horizon. They really thought it was a light horizon and there was a slip up.

BEAN The onboard data should say, terminator here 15 degrees, horizon 10 degrees or whatever it is. Then you can do them both or either.

LOUSMA Backup charts: The backup charts worked just like in the simulator. Solutions were within the limits to the solution

LOUSMA (CONT'D) we actually burned. I don't know the numbers now, but we did record them. I recall, the errors were consistently similar to what we'd seen in simulations. We didn't burn them but they did verify the solution.

BEAN One thing that might be worth mentioning here is somewhere in this area, and I don't recall where, is when we had our quad B problem. This was the first note that we had a quad B problem, although I didn't psych it out at the time. I looked at the attitude and we're off about 25 degrees in yaw. I said, "Wonder what we're doing over here" and I flew it back to zero. I couldn't understand at the time why we were off in yaw because I didn't think we had done anything to maneuver it over there. I just wrote it up as maybe an accidental bump of the hand controller. I was looking out the window some time later and noticed some sparklers go by. I watched those for a while. Then Jack said "There is something going by the window." That's when we started to think about it. I can't remember whether we figured it out or the ground said we had a quad B problem and suggested that we turn it off. Do you remember, Jack?

LOUSMA I remember a lot of sparklies at sunrise or sunset going from -X to +X past my window and reported them. The ground told us to turn off the proper quad. I noticed the gradual

LOUSMA (CONT'D) diminishing of sparklies going by. Later on they had us turn it on again and there they went again. That confirmed the problem. I noticed one time during this period that a chunk of ice which had the same shape and marks on it as I remember the thruster having. Maybe that was the thruster. That piece of ice was shaped just like the thruster bell.

BEAN I remember Jack saying that. We went through the procedures and changed around our DAP. It was here the ground noted where we had our DAP and we talked about it and we followed the procedures. The one thing we didn't do, and we should look back to see if the procedure is correct or we didn't execute them right, when you follow the procedures as pointed out in mal procedures, you end up fixing the problem so that you can attitude maneuver real good, but then you can't translate. You can translate fore and aft but you disable the quad that allows you to translate up and down. And it seems to me that nobody on the ground ever told me to reactivate those two until prior to TPI when I started thinking about it myself. I decided we had better activate a couple of thrusters that were deactivated in order to get anything up and down. It appears to me that if we hadn't done that the rendezvous would have really been a mess. We should look back and see if we really are setting ourselves up in the malfunction procedure so we don't have up and down

BEAN (CONT'D) translation for a failure like that and look at the other failures also. In other words, do we not also fix the attitude problem and at the same time keep the maximum amount of translation capability? I called the ground and told them I did such and such, what'd you think? They said okay. We need to get our onboard charts so they put you in the right configuration.

LOUSMA I should correct something I said earlier about the backup charts. I think they confirmed the solution except when we got the midcourse solution. I had some fairly good size numbers - around 6 to 9 feet/second. Six to 9 feet a second for solution and it did confirm the solution in the CMC. I don't know which is right. We burned the CMC. We did not use the backup chart solution. The back up chart did not coincide with CMC. I think it was on one of the midcourse burners.

GARRIOTT The second one.

BEAN I agree with Jack. That's one of the biggest questions I have from this flight is why did we get an 8 foot/second midcourse correction on a second midcourse? I don't understand how we got that. It seems to me I put that in and then just a few seconds later, I took it out because we had to start braking. So I'm convinced that something happened in

BEAN (CONT'D) those midcourse maneuvers that made them not come out like the simulator. Like I say, I never say any midcourse corrections like that. We burned everything that came up. We had a good TPI. When that 8 foot/second midcourse came up, I could hardly believe it. I don't think I had much of a choice except to burn it.

LOUSMA I had a first midcourse of a zero X and a minus 9, which could have been up Z. The second midcourse was nominal around plus 3-1/2 and a minus 2-1/2. The first midcourse was the one we didn't believe.

BEAN The midcourses didn't work right and the TPI was good. I'm still puzzled over that.

BEAN Final phase and prebraking: I like everything about the flight except the braking. I wasn't happy with the braking. I felt it was a noncontrolled operation even though we had one quad out. There were no problems in other quads, but with one quad out you had problems with the other quads. If you made up and down corrections, which you had to do once in a while that resulted in some other inputs. I don't know what they were exactly. The whole point is I didn't fully appreciate the problem of having one quad out and the braking phase. I think we should rectify that so that Jerry fully understands it before he goes. His onboard data should say

BEAN (CONT'D) that if this quad is out, expect the following phenomena to occur. I knew what was going on but I felt that it was not a precise operation like the rest of the rendezvous had been. I personally wasn't particularly happy with the braking. If Owen hadn't been there and kept saying I had to brake some more, it really would have been difficult. I kept answering that I had already put in enough braking and he would say that I had not. I believe he was right. I want to read the data that showed what we did exactly and then try to understand it. I felt that it was a nonprecise operation and I didn't like it.

LOUSMA Let me say one more thing about the backup charts. We had enough VHF ranging to get an NSR solution, TPI, and both midcourse solutions and they're recorded in the book for those people that want to look at it.

BEAN Stationkeeping: I thought that stationkeeping was more different than I thought with one quad out. I think a lot of that was the fact that I didn't appreciate what effect the thrusters had on the vehicle itself, particularly around the parasol. You don't have to be too close to that vehicle before the thrusters start impinging and moving around the parasol. When they start doing that, your only recourse is to thrust away, which impinges it even more. You're caught in a situation where, when you know you are too close, the

BEAN maneuver that rectifies being too close gives you more problems. I would suggest that there be no flyaround on the SL-4 mission. I don't think there's a big advantage to doing it. All you do is spray the vehicle down and take a few pictures which is nice. The main thing is, you don't know you have a problem of being too close until you're too close and then you can't get out of it easily, because getting out of it gives you more of the same problems.

GARRIOTT That's even more true with the ATM doors open.

BEAN That's right. I don't think we should have done it. I didn't do it very well, either. Even when I was doing it well, I would get caught. You can't float anywhere. You can't float when you get away from it, but you're standing there close and you want to back out but you don't back out naturally.

LOUSMA The whole operation was for television. We had the right positions and the right attitudes to get good TV pictures except that the TV wasn't working right. We could only get half a picture out of it. We tried to keep the workshop in that half of the picture which was good. I thought Al put the workshop and the Earth in the right prespective to get the television as planned prior to the flight. The rest of the flyaround was compromised by the fact that the

LOUSMA (CONT'D) thrusters weren't all working. I think what you said about another flyaround for S1-4 is correct. I don't think you should do it because you are going to mess something up.

BEAN That's right. You're liable to break those twin-pole sunshades out there and then you have a huge problem. I looked down there and I was worried that we were going to break that parasol. It was whipping around and I kept saying I've got to back out of here. Every time I gave a little bit of a backout, it whipped more.

GARRIOTT Did you see the parasol flapping on TV? Do you know?

LOUSMA I think so.

BEAN Could you see it down here? Did you watch it?

SLAYTON No.

GARRIOTT I thought an accurate description is the way a big flag would look in about a 20-knot wind.

BEAN That's about right.

GARRIOTT It flopped about like that and you were probably out about 100 feet at that time.

BEAN I wanted to be a few hundred. I wanted to get back. I wouldn't do that any more. That's not a good thing.

LOUSMA OWS photos: We took them.

BEAN Docking: Docking I though was straightforward. It takes a little time to get into position. The docking angles were beautiful. Just slid right on in. You've got to get into position a little further out than on the simulator. You've got these ATM wings and things out pretty far, so you've got to get in a pretty good position and then slide on in. It was easv docking. After docking, I tried to get a good alignment before I went harddock by using the translator in the roll. It looked to me like I had gotten a pretty good one. Look to me like I got a pretty good alignment although, when we locked up, it moved us around a little bit. I didn't feel that was extensive and looked okay.

BEAN Docking latch verification: We had about two or three latches, I don't recall now, but it's all on the records, that were not made. Everything had fired but they were not touching. So when we went out there and checked them, they had gone down and I left them just like that for the whole flight. I did not want to get into any latch problem.

Hatch integrity check: Great. Everything worked fine for us.

SL-4 Crew Debriefing, section 4.0 ("Rendezvous & Docking")

POGUE Jer, you may want to comment on the flow of the checklist. That's mostly yours and Ed's work. It looked as if it went very good.

CARR The whole rendezvous sequence was just as smooth as glass. We had no big problems. The rendezvous went very good. I had very few comments in my checklist.

GIBSON That was one phase of flight for which we were well trained. We had few systems problems. We just knocked it off rather quickly and efficiently. We had no problems at all with the rendezvous.

POGUE We had a dramatic surprise at first SPS burn in the awareness of fluid noises.

CARR Battery A charge was nominal. Tunnel hatch removal, tunnel pressure integrity, et cetera was nominal.

CARR Command module RCS propellant reconfiguration, no problems. We did not turn up any RCS propellant configuration problems until later in the mission. It was right after the first trim burn. The ground decided we had leakage or a problem with the isolation valve. We closed PSM Bravo and opened primary propellant Bravo. The P52 was no problem. GDC alignment was completely uneventful and the P50 was strictly nominal.

CARR Rendezvous and orientation, no problems at all with the separation maneuver. After the separation maneuver, we reloaded the DAP to get two jets and half a degree per second rate. We then maneuvered to the launch REFSMMAT attitude in preparation for getting our P52's down at sunset. We encountered no problems there. We did the EMS delta-V test with null bias check and sent the data to the ground. The data indicated that we had some bias, but it wasn't too bad in the delta-V counter. It was something like 4 degrees per hour or 4.4 feet per second from ENTER. It was very small and was acceptable. We noted after 84 days up there, when I did some delta-V tests and null bias check, we got the same numbers. The P52's that were done at a ground-elapsed time of about 040 were quite nominal. We had no problems at all with them. We had a very good platform alignment. We did option 2 and aligned to the rendezvous REFSMMAT. There were no problems whatsoever with that. Everything worked very nicely. I noticed at ground-elapsed time of 1 plus 22, we had some puffs from the SIVB. That was probably venting when we made our separation from the SIVB. I reported that on the air to ground.

CARR NC 1 Burn: The final NC 1 pad had one change. That was a 1.2 pitch change; from 11 to 13 degrees. The NC 1 was nominal burn. The ignition, shutdown were good and the residuals were in good shape. We did little nulling. We were all surprised at the kick

CARR (CONT'D) in the pants that we got. We had been told by other crews that the SPS burn was a good solid kick in the pants, similar to the afterburn in an airplane. Once we had experienced the first burn, we were convinced that it was considerably more than a kick in the pants or the afterburn in an airplane. It really plasters you back into your seat. I was dubious as to whether or not I could have accomplished a good MANUAL takeover had the situation arisen.

POGUE I was aware that we would get approximately one-g acceleration and had braced my arms. It was still a surprise. I was able to time the burns properly, although cutoff was all over by the time I said anything. The ball valve was slow as reported by the other crew. It was a very slow delivery rather than a very sharp swing of the needle as in the simulator.

CARR This was the 2-second burn. I was impressed by the fact that it seemed to be a lot wilder than I had anticipated.

GIBSON It felt greater than one-g.

POGUE VHF powerup: Nothing really impressed me about that. We did it and it worked.

CARR VHF ranging: We picked that up about the nominal time that we needed it.

GIBSON Sextant marks: They were very easy to control and we had exceptionally good visibility. I had no problems seeing the stars. The Apollo telescope, sextant, and the sextant marks were more simple than the simulator.

POGUE Marking on the workshop was no problem either. As per Owen's briefing, we started seeing the shape and configuration of the workshop prior to the first Moon force. But I just wanted to center the vehicle in the mark.

CARR NC 2 burn: It was about a 7-second burn. The chamber pressure was about 93 percent. The NC 1 burn was so short we had just an impression of chamber pressure. It was above 90 percent. The NC 2 burn was long enough that to judge and we recorded 93 percent. It was a good burn with the exception of VG_Z which was minus 0.7 feet per second. The solution was very close to the ground's. The ground solution for Noun 81 was 153.2. We got a final computation of 153.1.

CARR NCC Burn: Noun 81 was less than a foot per second in X and less than 2 feet per second in Y and Z. We had good agreement. The NCC solution was a computer solution. We felt very comfortable about it. The NCC burn was 10 seconds long. We trimmed the residuals back to within 0.1.

CARR NSR Burn: NSR solutions were good. The X solution was identical to the pad. The solution for Y was 5.4 in the pad and 6.9 in the computer. The solution for Z was in the pad and 4.9 in the computer. So we had good agreement. However, we did burn the first recycle on NSR. After NSR, the checklist here said P00. We're not sure, but we think we got one mark in before we did the recycle. We were supposed to recycle before marking. We were going a little too fast and we marked before we did the recycle, right after NSR.

GIBSON I've recorded that you had 24.6 in X, the computer got 24.6, and the pad was 23.7. In Z, I got 2.5, the pad gave us 4.8, and the computer gave us 4.4.

CARR TPI Burn: The TPI was so stable the ground did not update the preliminary pad. The pad NOUN 81 in X was plus 19.0 and we got plus 19.1. In Y, the pad was plus 00.7 and the computer got 00.1. In Z, the pad was minus 08.6 and the computer was minus 09.0. We had a fantastic agreement on TPI. We had a little difference on TPI times. The the pad was 6460453, and the one we burned was 6473664.

GIBSON I got 648.

CARR The first recycle was 648.56. The second recycle was 648.26. The PI chart solution was X of plus 18.8, the computer had a

CARR (CONT'D) 19.2, and the pad was 19.8. The comparison was good. For Z, the pad gave us minus 8.6, the chart was minus 8.6, and the computer was minus 9.0. So we went with the computer solution. We had residuals nulled to 0.1 and the delta-VC we copied was minus 13.3 after TPI. We got into the midcourse gain. We had problems with theta. We don't think the theta mark at 04:30 was any good. So we didn't believe the chart solution; and because of that theta error, it caused the chart solution to be late.

GIBSON Our data solution was minus 2.76 in X and Z was minus 6.9.

CARR The computer solution was minus 2.0 and plus 0.6. There was a lot of discrepancy in up/down, but 4.5 was not too terribly bad.

GIBSON It's the up/down that depends on theta.

CARR In looking at the polar plot, the polar plot did agree with the CMC and with that, we just decided to go with the solution of the CMC and decided that the chart solution was bad because of theta.

POGUE The polar plot was following a nominal line of the family of curves and it was so good that I don't think I even said much. Finally I said, "From here on in, it's all by eyeball."

CARR Okay. Then we started on the markings for TPI_2, and I have no notes concerning TPI_2. The computer solution was forward 3.5 and up 1.4 and the chart solution in which we had confidence was forward 2.5 and zero up/down. The polar plot agreed with us. We went with the CMC solution and came out beautifully.

We have no notes that indicate we had any problem with the switch list, prebraking switch list, or the predocking switch list. Braking was no problem. We just followed our braking gates and never at any time felt there was any line-of-sight rates or any kind of rates that were out of control. I never felt a lack in depth perception on in the necessary visual cues I needed to get in. The workshop is large, with visual cues in different directions. It was much easier than the simulator.

Stationkeeping was very simple. It was very stable and no problem at all.

POGUE Workshop photos: I have not seen any of the photos. We used the narrow-angle lens on that and I did have a viewfinder. The photos were probably nominal. I took perhaps 30 to 50 photographs. I tried to frame the workshop in the camera against the darkness of space with the top of the workshop at the top of the frame so there would be no appearance of rolling as we came in. I took a few photographs of specific areas of the vehicle as we got in very close. I took some photographs of

POGUE (CONT'D) the underside of the ATM solar panels as we came in for the docking maneuver. Those can be compared with photographs taken on the EVAs if anyone is interested in progressive degradation.

CARR Docking: phase. We aligned with the workshop plus X axis. It was very solid. I initiated the maneuver to move toward the workshop. It was surprisingly easy. I made a few corrections coming in and had no problems at all. We had a nice slow rate of closure. We did our predocking switch list and were ready for capture. We went in very, very gently, made contact, and got a capture. We got a barber pole and thought everything was really copacetic. Then had the definite impression the workshop was backing away from us a little bit. We had apparently tripped the capture latches, but had not captured the drogue and were very very slowly drifting out. I threw in some plus X while we were reasonably well aligned and tried to jam us back into the drogue again. That was a mistake. We should have recocked our capture latches, but we didn't. Had we recocked our capture latches, capture might have been made the second time because we still had good alignment. We were approximately 8 inches to 1 foot away. I gave it a small plus X and went back into the drogue and we hit slightly off center. We got up into the center of it, but did not capture and bounced back

CARR (CONT'D) out again, picking up pitch down yaw right drift rate. I backed out and aligned for a new start. At that time, the ground came up and we discussed the problem. The ground reminded us to recock our capture latches, which we did. As we approached, we had approximately 0.2 or 0.3 feet per second closing rate. However, I increased the rate slightly as we were approached contact position. We hit the workshop approximately 0.8 to a foot per second. We hit it hard and rebounded. We got a barber pole. We felt the workshop hesitate momentarily and then snap back. Apparently we stroked the probe and then when it was fully extented, we were on the end of it and it snapped. We immediately did a retrack, pulled right in, and locked up.

Mission Timer Update: We had no problem syncing. Everything went nominal.

GIBSON Because we had so much training in that area, when there were no real systems problems, it was just piece of cake to pull it off.

CARR It was very smooth. We were concerned mostly with getting behind as we came up on burns. And we just didn't allow that to happen. We found ourselves Prior to every burn, just lying there waiting. However we were ahead all the way. The only time we were behind was at ignition. But with each successive burn, we were a little closer.

GIBSON Once we understood what was going to happen when the burn started, we braced ourselves for it. I pushed myself back into the couch before the burn started so there would be no sudden thrust back.

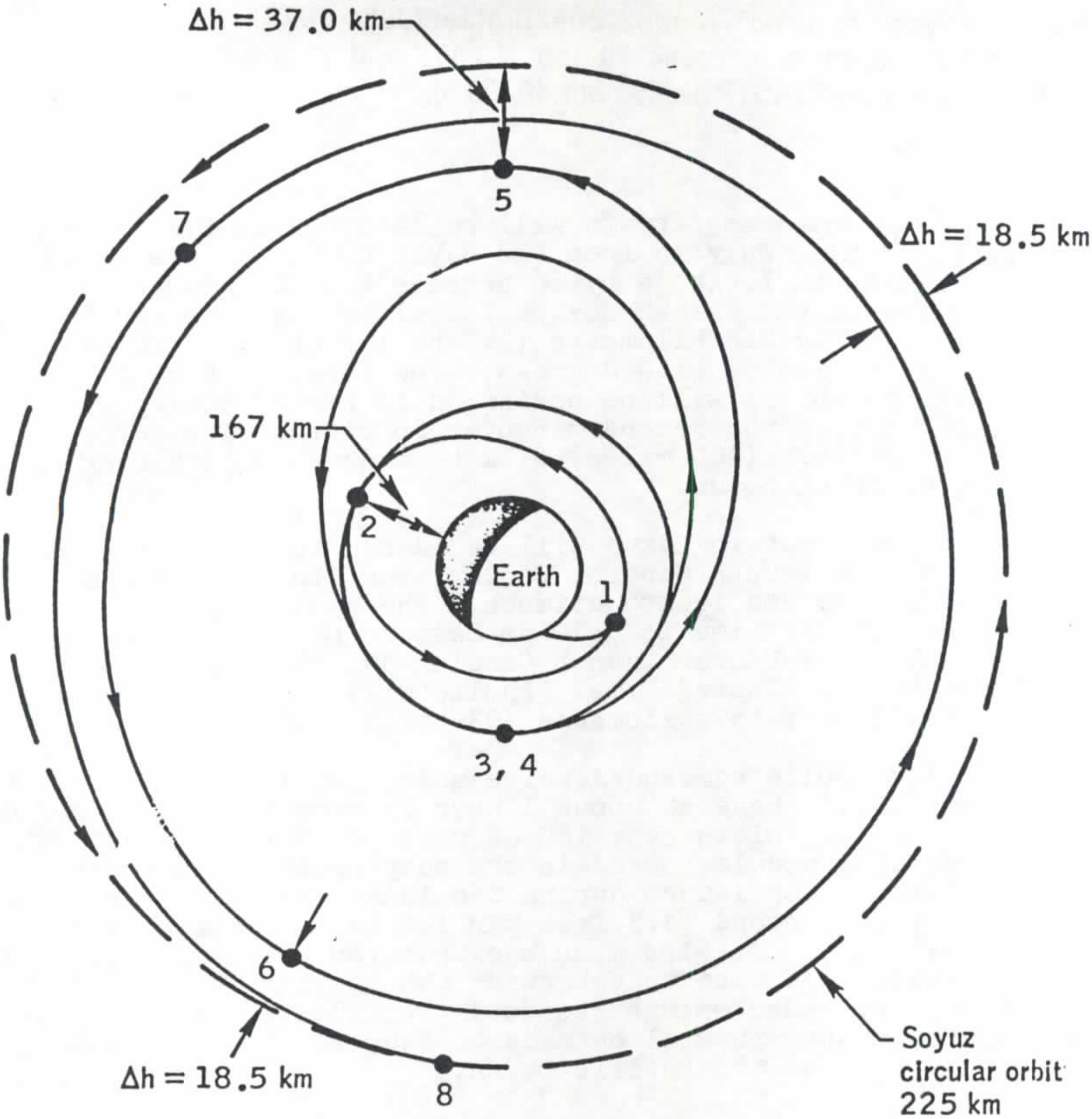
The **Apollo-Soyuz** "classic" rendezvous profile (July 1975) was briefly described in the pre-mission press kit (pp. 15-17) and in more detail in the TRAJECTORY PLAN (ASTP Document 40200.5).

The Soyuz spacecraft will be launched at 8:20 am Eastern Daylight Time July 15 from the Baykonur Cosmodrome (47.8 degrees North Latitude by 66 degrees East Longitude) near Tyuratam in the Kazakh Soviet Socialist Republic and inserted into a 188 by 228 kilometer (117 by 142 mile) Earth orbit at an inclination of 51.8 degrees. The first of two circularization maneuvers will be performed if needed during the fourth orbit; the second maneuver to circularize Soyuz at 225 kilometers (140 miles) will be made July 16 during the 17th orbit of Soyuz.

Soyuz tracking data will be passed to Apollo Mission Control and Launch Control Centers for fine-tuning the Apollo liftoff time and launch azimuth. The Apollo spacecraft predicted liftoff time is 3:50 pm Eastern Daylight Time from Kennedy Space Center Launch Complex 39B at 7 hours 30 minutes Soyuz Ground Elapsed Time. Apollo will be inserted into an initial 150 by 167 kilometer (93 by 104 mile) orbit.

The Apollo command/service module will separate from the Saturn S-IVB stage at about 1 hour 13 minutes Apollo Ground Elapsed Time, pitch over 180 degrees and dock with and extract the docking module housed in the adapter where lunar modules were stowed for launch during the lunar landing program. A 1 meter per second (3.3 feet per second) posigrade evasive maneuver after docking module extraction will eliminate any possibility of recontact between the spacecraft and rocket stage. Provided enough residual propellants are aboard the S-IVB, an attempt will be made to deorbit the stage into a remote area of the Pacific Ocean.

The classic rendezvous technique, similar to the sequence followed by the command/service module in reaching the Skylab space station, will begin after Apollo has circularized at 169 kilometers (105 miles) with a 6.3 meters per second (20.7 feet per second) service propulsion system posigrade burn at 7:35 pm Eastern Daylight Time. Rendezvous maneuvers will be Phasing 1 (NC1) at 9:30 pm Eastern Daylight Time (service propulsion system, 20.2 meters per second (66.3 feet per second) posigrade) followed at 10:35 pm Eastern Daylight Time with an opportunity for a plane-change maneuver, if needed, to correct for any out-of-plane angles in Apollo's orbit. Soyuz will circularize to 225 kilometers (140 miles) at 8:46 am Eastern Daylight Time July 16 with a 12.2 meters per second (40 feet per second) posigrade maneuver.



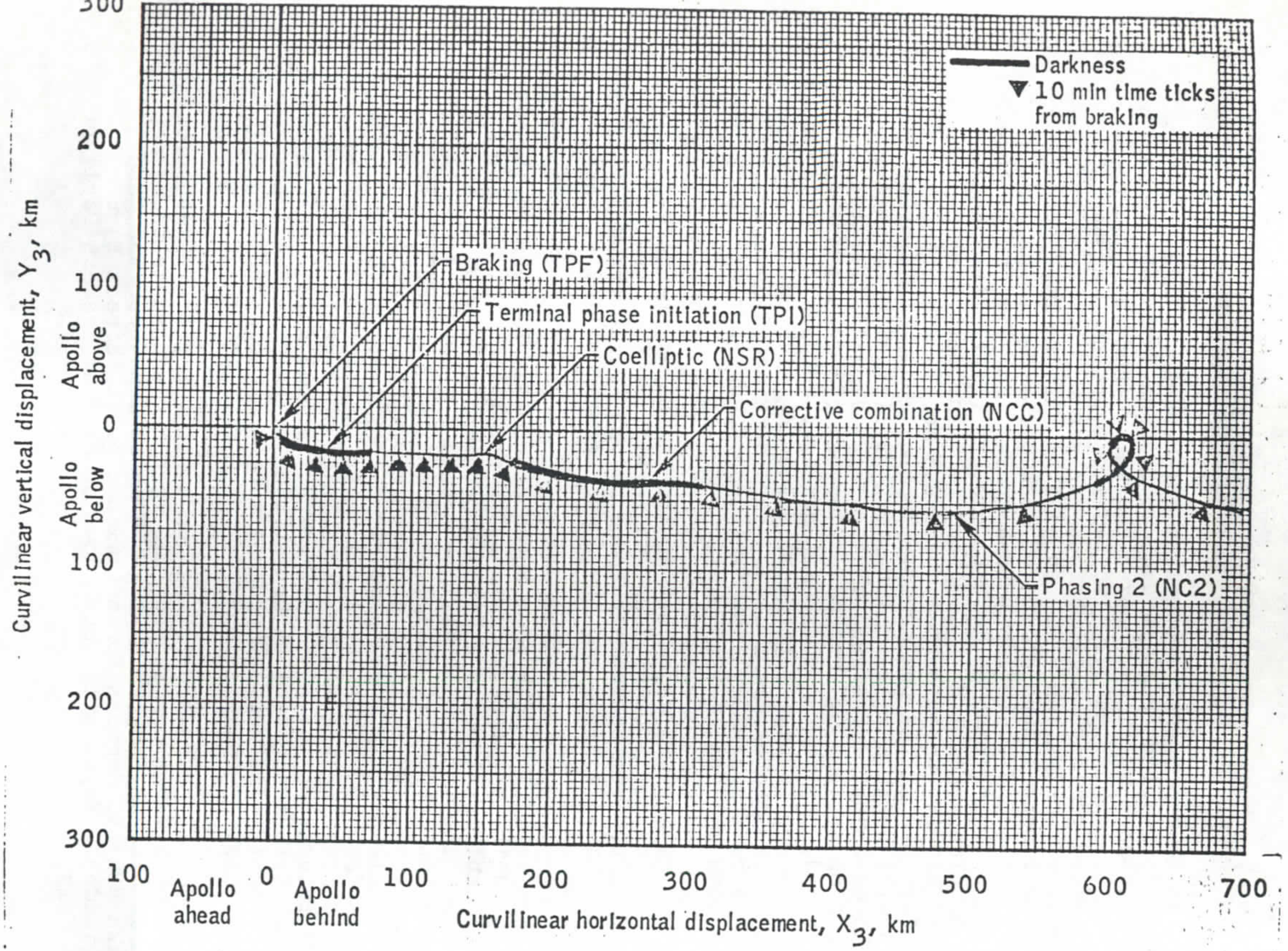
1 Insertion - 150 by 167 km
2 Circularization
3 Phasing 1 (NC1)
4 Phasing 2 (NC2)
5 Corrective combination (NCC)
6 Coelliptic (NSR)
7 TPI
8 Braking (TPF)

Apollo maneuvers to complete the rendezvous are: phasing correction (PCM) at 4:42 pm Eastern Daylight Time -- nominally zero velocity change; phasing 2 (NC2) at 8:54 am Eastern Daylight Time July 17, service propulsion system, 11.1 meters per second (36.4 feet per second) posigrade; corrective combination (NCC) at 9:38 am Eastern Daylight Time, 12.2 meters per second (40 feet per second) posigrade; coelliptic (NSR) at 10:15 am Eastern Daylight Time to produce a differential height of 18.5 kilometers (11.1 miles) and a rate of closure of 1.85 kilometers per minute (1.1 miles per minute) service propulsion system, 8.3 meters per second (27.2 feet per second posigrade. Terminal phase initiation (TPI) will begin at 11:14 am Eastern Daylight Time when the Apollo-to-Soyuz line of sight reaches 27 degrees (service propulsion system, 6.7 meters per second (22 feet per second) posigrade); braking should begin at 11:43 am Eastern Daylight time, and Apollo will begin stationkeeping with Soyuz at 11:52 am Eastern Daylight Time. Hard docking will take place at 12:15 pm Eastern Daylight Time over Europe during the Soyuz 36th and Apollo 29th orbit.

During the two days that Apollo and Soyuz are docked together for joint operations, there will be four crew transfers between spacecraft. One or two Apollo crewmen will visit Soyuz at a time, and one Soyuz crewman will visit Apollo at a time.

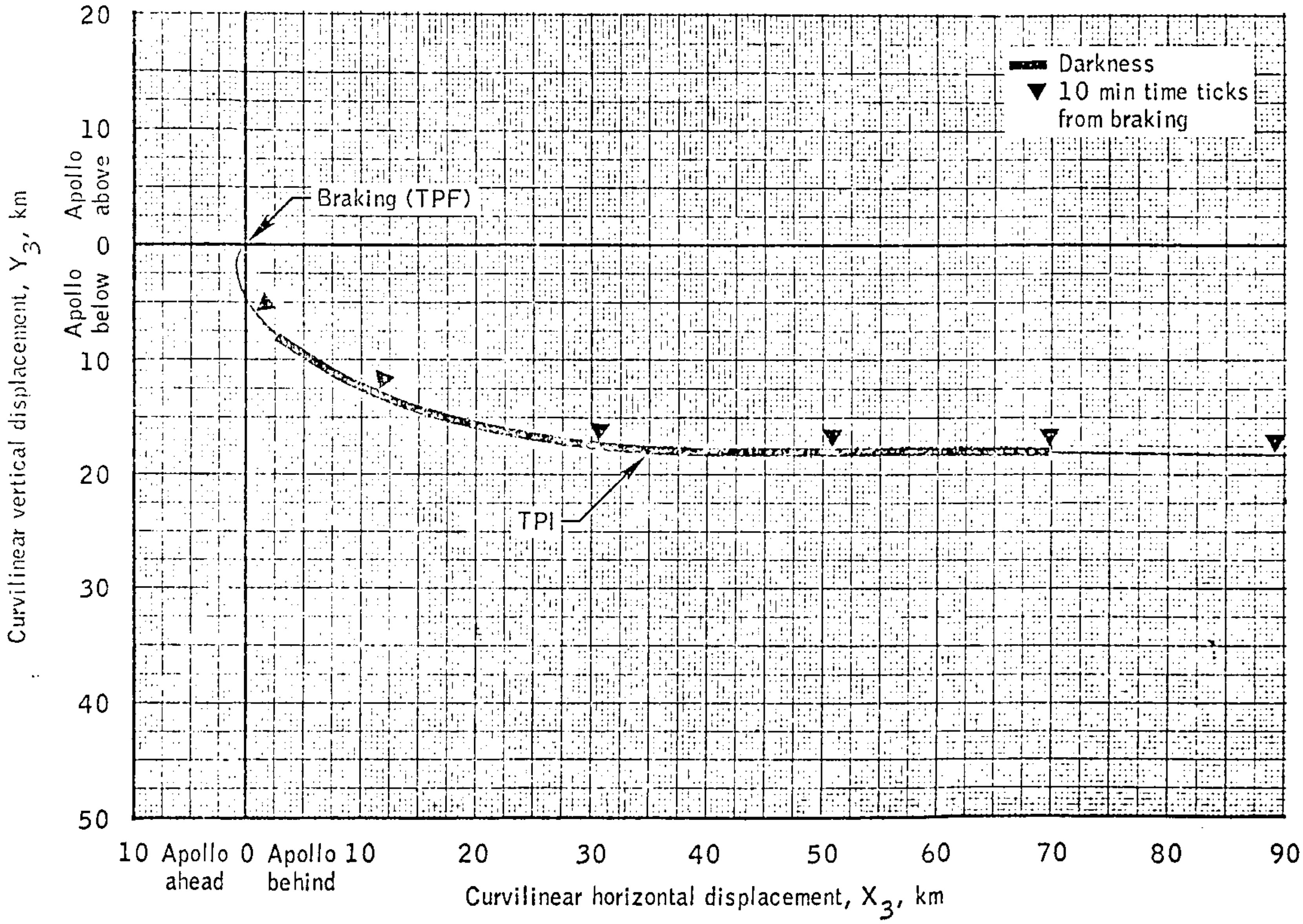
Apollo will undock from Soyuz at 8:02 am Eastern Daylight Time on July 19 and serve as a solar occulting disc for the MA-148 Artificial Solar Eclipse experiment conducted by Soyuz. The Soyuz docking system will be active for a second docking test following the artificial eclipse experiment and final undocking will be at 11:01 am Eastern Daylight Time July 19. Apollo will perform a "fly-around" of Soyuz at distances ranging from 150 meters to 1 kilometer (492 feet to .6 miles) while performing the MA-059 Ultraviolet Absorption experiment. A 0.7 meters per second (2.3 feet per second) Apollo reaction control system separation burn at 4:04 pm Eastern Daylight Time July 19 will prevent recontact by the two spacecraft for the rest of the mission.

About 43 hours after final undocking, Soyuz will deorbit with a 65.2 meter per second (214 feet per second) retrograde burn at 6:06 am Eastern Daylight Time to land near Karaganda, Kazakh SSR (50 degrees North Latitude by 71 degrees East Longitude). Soyuz will touch down at 6:51 am Eastern Daylight Time July 21.



(a) NC2 through braking.

Figure 1.- Relative motion of the Apollo with respect to the Soyuz for the first Apollo launch opportunity.



ASTP 40200.5

(b) TPI through braking.

Figure 1.- Concluded.

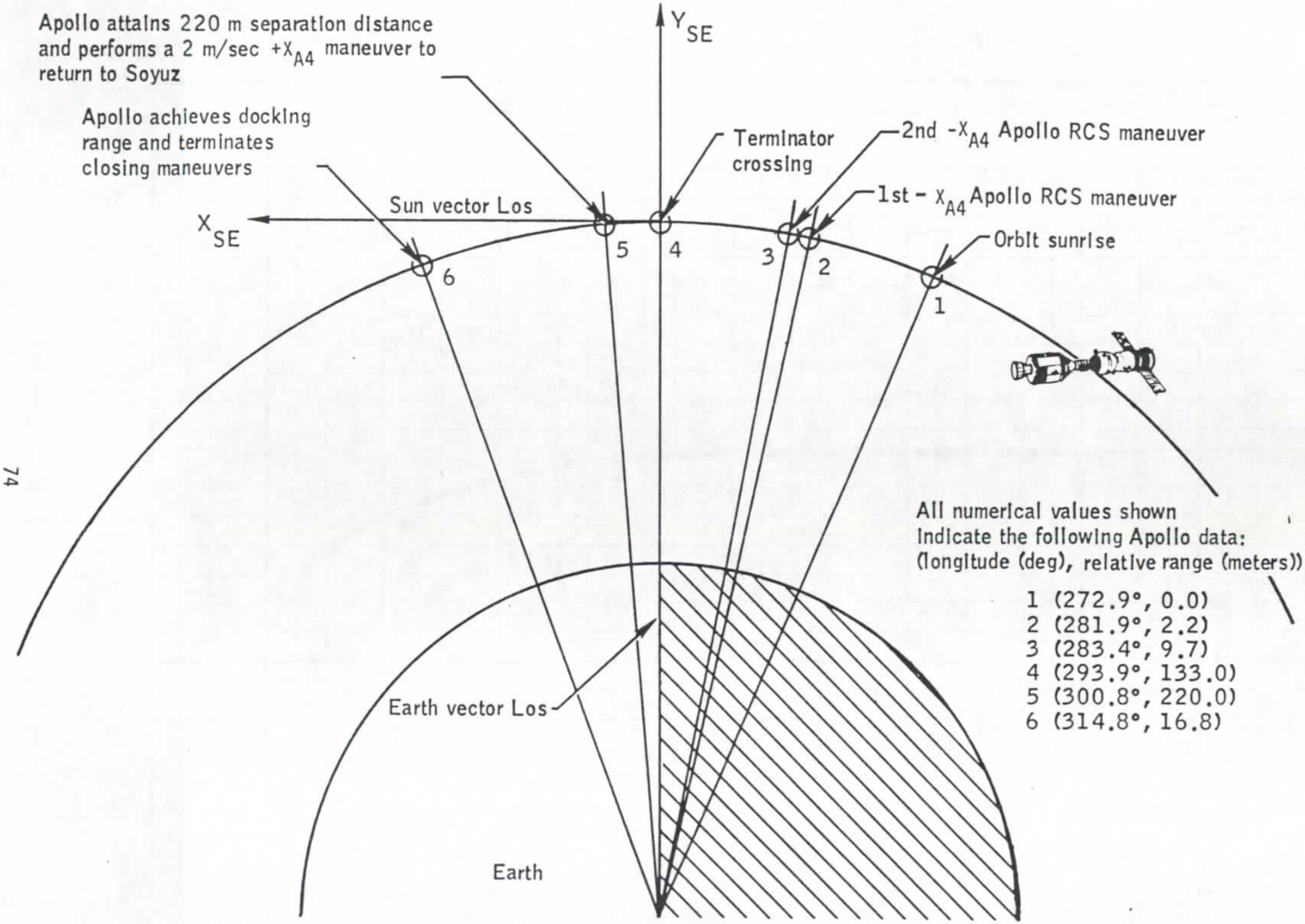


Figure 12.- Artificial solar eclipse orbit profile during the Apollo 57th revolution and Soyuz 65th orbit.

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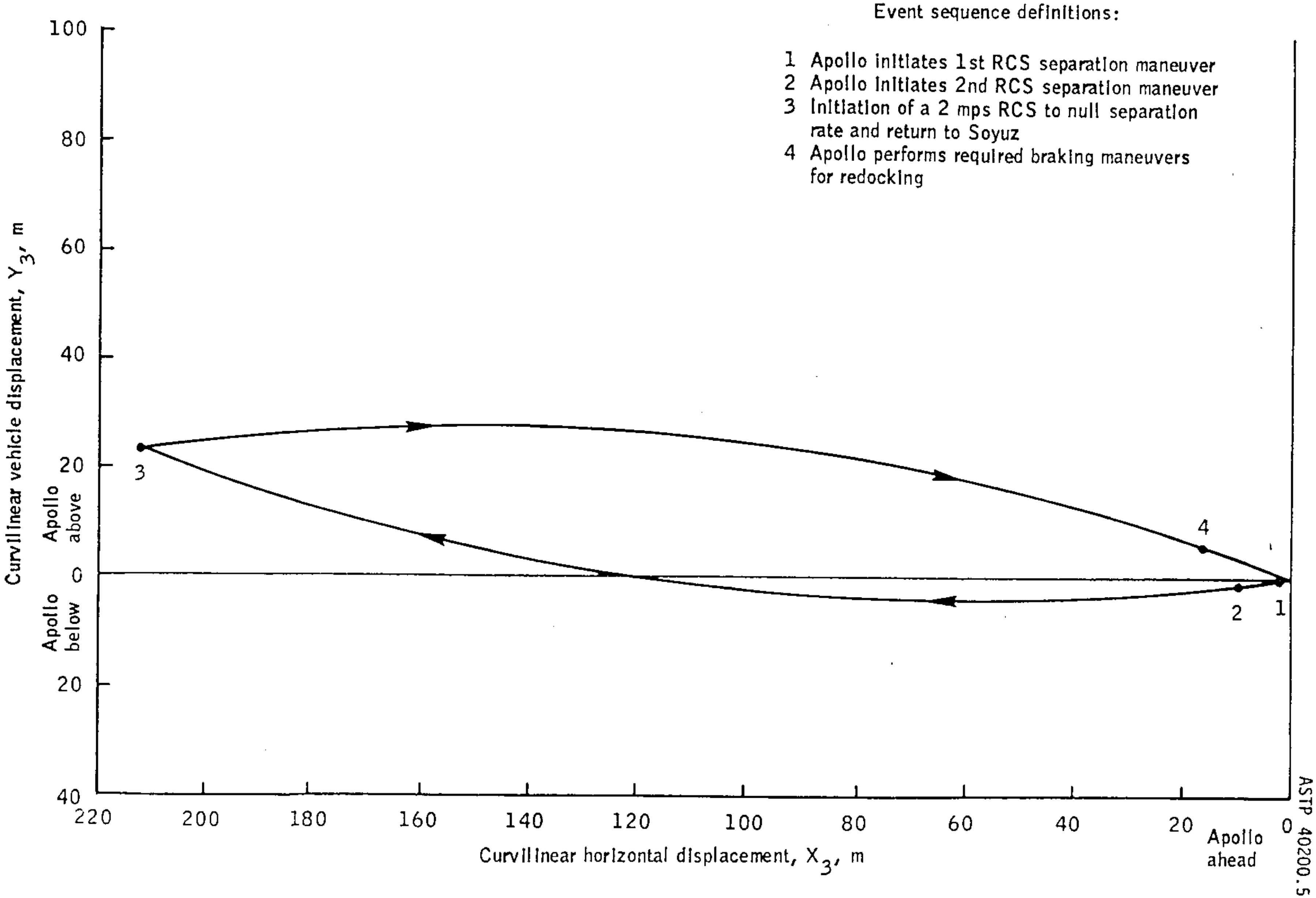

Figure 13.- Apollo and Soyuz relative motion profile during the artificial solar eclipse experiment.

TABLE II.- SEQUENCE OF EVENTS FOR FIRST APOLLO LAUNCH OPPORTUNITY

Event	Time of initiation from Soyuz launch, hr:min:sec g.e.t.	Time of initiation from Apollo launch, hr:min:sec g.e.t.	Burn duration, sec	Total ΔV, m/sec	Resultant apogee/perigee[a], km	Altitude[a], km	Phase angle, deg
Soyuz lift-off	00:00:00.0	-07:30:00.0	NA	NA	NA	NA	NA
Soyuz insertion	00:09:05.0	-07:20:55.0	NA	NA	228/188	188	NA
Soyuz first maneuver	05:19:00.0	-02:11:00.0	0.0	0.0	228/188	228	NA
Apollo lift-off	07:30:00.0	00:00:00.0	NA	NA	NA	NA	NA
Apollo insertion	07:39:52.1	00:09:52.1	NA	NA	167/150	150	59.6
Begin transposition, docking, and docking module extraction	08:44:00.0	01:14:00.0	NA	(b)	167/150	159	57.5
Apollo evasive maneuver from S-IVB	10:04:00.0	02:34:00.0	8.7	1.0	167/150	160	52.4
Apollo circularization maneuver	11:15:00.0	03:45:00.0	0.9	6.3	169/168	167	49.3
Phasing 1 (NC1)	13:11:28.1	05:41:28.1	3.1	20.2	233/169	169	44.6
Plane change (NPC)[c]	14:17:52.0	06:47:52.0	0.0	[c]0.0	227/169	227	44.1
Soyuz circularization maneuver	24:26:00.0	16:56:00.0	19.9	12.2	225/225	225	40.8
Phasing correction maneuver[d] (PCM)	32:21:36.5	24:51:36.5	0.0	[d]0.0	228/167	167	28.9
Phasing 2 (NC2)	48:34:04.1	41:04:04.1	1.6	11.1	186/165	165	4.3
Corrective combination (NCC)	49:18:03.4	41:48:03.4	1.8	12.3	206/186	186	2.3
Coelliptic (NSR)	49:55:03.7	42:25:03.7	1.2	8.3	205/204	204	1.3
Terminal phase initiation (TPI)	50:54:25.1	43:24:25.1	0.8	6.7	225/205	205	0.3
Begin braking	51:22:55.0	43:52:55.0	NA	[e]18.3	225/221	223	0.02
Begin stationkeeping	51:31:55.0	44:01:55.0	NA	(b)	222/221	222	0.0
Docking	51:55:00.0	44:25:00.0	NA	(b)	221/221	221	0.0
Apollo first undocking from Soyuz	95:42:05.0	88:12:05.0	NA	NA	218/218	217	0.0
Apollo final undocking from Soyuz	99:06:00	91:36:00	NA	NA	218/218	217	0.0
Apollo separation from Soyuz	102:08:00	94:38:00	5.8	0.7	219/217	217	0.0
Soyuz deorbit maneuver	141:46:00.0	134:16:00.0	105.6	65.2	218/0	214	2.8
Soyuz landing	142:31:00.0	135:01:00.0	NA	NA	NA	0	NA
Docking module jettison	199:21:00.0	191:51:00.0	NA	0.3	215/212	212	0
CSM separation maneuver from DM (DM1)	199:56:00.0	192:26:00.0	0.7	6.3	233/211	211	0.02
CSM stable orbit maneuver (DM2)	204:22:55.3	196:52:55.3	0.6	6.2	212/211	211	2.9
CSM deorbit maneuver (ADM)	224:17:33.1	216:47:33.1	6.7	58.4	212/16	212	NA
Entry interface	224:37:47.3	217:07:47.3	NA	NA	NA	122	NA
Main parachute deployment	224:53:10.3	217:23:10.3	NA	NA	NA	3	NA
CM landing	224:57:55.3	217:27:55.3	NA	NA	NA	0	NA

[a]Approximate predicted value above a spherical earth of 6378.16-km radius.

[b]Translation away and back during transposition and docking does not effectively change orbit.

[c]Nominally, NPC is not required. However, it may be used to correct any out-of-plane errors previously incurred.

[d]Nominally, the phasing correction maneuver is not required.

[e]Theoretical TPF ΔV is 8.7 m/sec. Additional costs include midcourse and line-of-sight corrections.

ASTP Mission Report, section 10.1.3 (Rendezvous/Docking)

10.0 PILOT'S REPORT

This section contains the crew's evaluation of the Apollo Soyuz mission and the preparations for the mission as related by Thomas P. Stafford, Commander; Vance D. Brand, Command Module Pilot; and Donald K. Slayton, Docking Module Pilot. A timeline of the mission as it was conducted is included in appendix B.

10.1 CREW OPERATIONS

10.1.1 Final Prelaunch Activities

The entire prelaunch phase, including suitup, transfer to the pad, ingress, and the final countdown were normal and no problems were encountered. The simulated lightning test that had been conducted (ref. 3) and the changes to the Launch Mission Rules pertaining to launching under adverse weather conditions (sec. 13.2) reassured the crew that the nominal launch window would be met.

10.1.2 Launch Through Docking Module Extraction

The lift-off was accompanied by a slight longitudinal vibration, but it had disappeared by the time the launch umbilical tower was cleared. The entire boost phase was normal.

The timeline requiring the crew to perform the transposition, docking and extraction maneuvers approximately 1 hour and 4 minutes after insertion was extremely crowded; however, practice in the simulator using realistic stowage enabled the crew to perform each step on time. The transposition maneuver was initiated exactly on time, the turnaround maneuver was performed, and then the first problem was encountered. The inertial attitude of the S-IVB/docking module required the Commander to look down at the earth, making the reticle pattern in the optical alignment sight impossible to see. The sight had been checked approximately 40 minutes after launch and was found to be satisfactory, but the reflected light from the earth was so intense that the crosshairs image was completely obscured. The Commander closed on the S-IVB/docking module to a distance of approximately 10 meters using the standoff cross on the docking module truss as a reference. Stationkeeping was accomplished by using the standoff cross as a reference for pitch and yaw, and by approximating roll. As the S-IVB/docking module appeared to move slowly toward the horizon, the Commander occasionally glimpsed a small portion of the reticle pattern. By squinting his eyes and moving his head slightly to one side, he could observe a faint vertical line for roll reference. Closure was made using this reference and a soft dock was obtained. The retraction sequence was then initiated and a hard dock was obtained. The entire timeline from then on, including the docking module extraction and the evasive maneuver, was normal.

10.1.3 Rendezvous and Docking

All rendezvous maneuvers were nominal and the crew was confident that things would go well because of the many simulations that had been conducted. The two midcourse maneuvers after transfer phase initiation were probably the smallest yet encountered. The first was 0.2 meter per second; the second was 0.4 meter per second. The line-of-sight rates were completely nulled, and the Commander used the control mode of autopilot on and the spacecraft under automatic control for the 1.85-kilometer and 0.93-kilometer braking gates to save fuel. Even at the 0.46-kilometer gate, there was no relative movement of the Soyuz. A slight relative movement was subsequently detected and was immediately corrected for.

After a period of stationkeeping, a flyaround over the top of the Soyuz was initiated. As the Apollo spacecraft flew above the Soyuz, the reticle pattern completely disappeared when looking down at the earth. As planned, stationkeeping was continued above the Soyuz and looking down, holding inertial attitude, with the Soyuz slowly moving up relative to the horizon. When the Soyuz approached the horizon, the reticle pattern reappeared and the Commander was able to hold a more precise position.

The Soyuz went to its programmed inertial attitude in pitch and then completed the roll maneuver. At that time, Apollo was ready to close for docking. The Commander initiated the final closing maneuver with very precise alignment. At the point of contact he estimated that he had a closing velocity somewhat in excess of 0.1 meter per second. The docking was very soft. Simultaneous indications were obtained of both contact and capture. The Commander went to the control mode of autopilot on and the spacecraft under manual control, and the reticle was aligned precisely with the Soyuz docking target standoff cross. After hard docking was completed, the Commander observed that the reticle pattern (the center of the crosshairs) was aligned with the center of the bolt that fastened the standoff cross; thus, the alignment was very good. The crew had earlier been concerned about the accuracy of the fixtures that had been used to align the docking targets between the two spacecraft.