# TRAJECTORY DOCUMENTATION CHANGE NOTIFICATION
# MISSION PLANNING AND ANALYSIS DIVISION

INDEXING DATA

| DATE | OPR | # | T | PGM | SUBJECT | SIGNATOR | LOC |
|---|---|---|---|---|---|---|---|
| 10-30-72 | MSC | 72-FM-187 | R | APO | * | Bennett | 080-44D |

DATE 10/30/72

MISSION: Apollo 17

DOCUMENT: MSC IN 72-FM-187, Volume I

TITLE:* Spacecraft Operational Trajectory Apollo 17 Launch December 6, 1972, C.s.t. (December 7, 1972, G.m.t.), Volume I - Mission Profile

AMENDMENT 1

SHORT TITLE OF CHANGE: Amendment 1 to Spacecraft Operational Trajectory, Volume I

CHANGE DESCRIPTION: Upadted due to changes to trajectory. Replace the following pages: pp. 1-7 through 1-14; 4-23 through 4-27; 4-73 and 4-74; 4-119 through 4-122; 5-5 and 5-6; 5-17 through 5-20; 5-25 and 5-26.

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MSC FORM 295 (JULY 1969) OT

# RECORD OF AMENDMENTS

| AMENDMENT NO. | DESCRIPTION | DATE |
|---|---|---|
| 1 | 1-7 (table I-1): TD&E time line slipped 20 minutes to allow TV coverage of docking.<br><br>1-10: Time update: New DPS ignition time caused by DPS model update<br><br>1-12: Time change to accommodate change in LM ascent stage deorbit maneuver.<br><br>1-13: Changed to provide as large an RCS margin as possible.<br><br>4-24: Same plus yaw angle. Sign change from minus to plus in TD&E attitude.<br><br>4-26: Relative motion updated because of sign change in TD&E attitude yaw angle.<br><br>4-73: Fifth slope of a priori changed.<br><br>4-119: Line 8: "The major causes..." should read "The major effects...".<br>Line 13: "...reduced 9 to 6" changed to read "...reduced from 9 to 6".<br><br>4-120: Line 10: 67.3 changed to 66.4<br>Line 11: -89.4 changed to -90.4<br>Line 12: 4.8 changed to -4.8<br><br>4-121 (table 4.14-I):<br>Jettison latitude changed to 18.55<br>Jettison longitude changed to 35.26<br>Jett inertial velocity changed to 5341.7<br>Jett pitch changed to -90.2<br>Jett yaw changed to 11.5<br><br>5-6: DPS model updated.<br><br>5-18: Per crew request.<br><br>5-19: DPS ignition time and ignition targets changed because of DPS model update.<br><br>5-25 and 5-26: Changed to accommodate change in LM ascent stage deorbit maneuver. | 10/30/72 |

TABLE 1-I.- SEQUENCE OF MAJOR EVENTS

| Event | Time, hr:min:sec, g.e.t. | Time, hr:min:sec, c.s.t. | Data summary | |
|---|---|---|---|---|
| Launch | 00:00:00 | December 6, 1972 20:53:00.0 | Flight azimuth, deg<br>Launch complex | 72.1<br>39A |
| EPO insertion | 00:11:57.2 | 21:04:57.2 | Geodetic altitude, n. mi.<br>Geodetic latitude, deg<br>Longitude, deg<br>Velocity, fps | 93.3<br>32.7<br>-52.1<br>25 603.7 |
| Translunar injection[a]<br>Burn initiation | 03:20:57.6 | December 7, 1972 00:13:57.6 | Geodetic altitude, n. mi.<br>Geodetic latitude, deg<br>Longitude, deg<br>Velocity, fps<br>Apogee altitude, n. mi. | 90.7<br>18.0<br>-39.4<br>25 614.2<br>94.7 |
| Burn termination (guidance cutoff signal) | 03:26:31.3 | 00:19:31.3 | Geodetic altitude, n. mi.<br>Geodetic latitude, deg<br>Longitude, deg<br>Burn duration, sec<br>Plane change, deg<br>Apogee altitude, n. mi. | 156.2<br>4.1<br>-16.9<br>333.7<br>0.0<br>242 517.0 |
| Post-TLI events[a]<br>CSM/S-IVB separation | 04:12:04.7 | 01:05:04.7 | | |
| Docking | 04:22:04.7 | 01:15:04.7 | | |
| CSM/LM ejection | 05:07:04.7 | 02:00:04.7 | | |
| Evasive maneuver[a] (performed by S-IVB) | 05:30:04.7 | 02:23:04.7 | ΔV, fps | 9.8 |
| Translunar coast, midcourse correction maneuvers<br>MCC-1 | As required up to TLI + 9 hr | As required up to 09:20:00.0 hr December 8, 1972 | | |
| MCC-2 | TLI + ≈32 hr | 08:23:00.0 | Geodetic altitude, n. mi. | ≈ 127 500 |
| MCC-3 | LOI - ≈22 hr | December 9, 1972 15:48:00.0 | Geodetic altitude, n. mi. | ≈ 183 000 |

[a]This information is approximate. The official source is the MSFC LV operational trajectory.

TABLE 1-I.- SEQUENCE OF MAJOR EVENTS - Continued

| Event | Time, hr:min:sec, g.e.t. | Time, hr:min:sec, c.s.t. | Data summary | |
|---|---|---|---|---|
| Translunar coast, MCC maneuvers | | December 10, 1972 | | |
| MCC-4 | LOI - ≈5 hr | 08:48:00.0 | Altitude above mean lunar radius, n. mi. | ≈ 12 000 |
| SIM door jettison | LOI - 4.5 hr | 09:18:37.5 | Average ΔV imparted to door, fps | 13.7 |
| Lunar orbit insertion (LOI) | | | | |
| Burn initiation | 88:55:37.5 | 13:48:37.5 | Mass, lb | 102 766.2 |
| | | | Altitude above LLS radius, n. mi. | 77.5 |
| | | | Selenographic latitude, deg | -10.4 |
| | | | Selenographic longitude, deg | 174.1 |
| | | | Selenographic inclination, deg | 11.2 |
| | | | Velocity, fps | 8085.1 |
| | | | Perilune altitude above LLS radius, n. mi. | 51.3 |
| Burn termination | 89:02:12.9 | 13:55:12.9 | Altitude above LLS radius, n. mi. | 51.8 |
| | | | Selenographic latitude, deg | -5.7 |
| | | | Selenographic longitude, deg | 148.5 |
| | | | Selenographic inclination, deg | 20.1 |
| | | | Burn duration, sec | 395.4 |
| | | | Inertial burn arc, deg | 25.7 |
| | | | Plane change, deg | 11.3 |
| | | | ΔV, fps | 2979.9 |
| | | | SPS propellant used, lb | 26 185.5 |
| | | | Velocity, fps | 5519.1 |
| | | | Orbital period, hr:min:sec | 02:07:49.0 |
| | | | Perilune altitude above LLS radius, n. mi. | 51.4 |
| | | | Apolune altitude above LLS radius, n. mi. | 170.8 |
| S-IVB predicted lunar impact | 89:21:25.8 | 14:14:25.8 | Selenographic latitude, deg | -7.0 |
| | | | Selenographic longitude, deg | -8.0 |
| Descent orbit insertion (DOI-1) | | | | |
| Burn initiation | 93:13:08.5 | 18:06:08.5 | Mass, lb | 76 546.4 |
| | | | Altitude above LLS radius, n. mi. | 51.8 |
| | | | Selenographic latitude, deg | -10.2 |
| | | | Selenographic longitude, deg | 160.0 |
| | | | Velocity, fps | 5519.5 |
| | | | Perilune altitude above LLS radius, n. mi. | 51.3 |
| | | | Apolune altitude above LLS radius, n. mi. | 170.9 |

TABLE 1-I.- SEQUENCE OF MAJOR EVENTS - Continued

| Event | Time, hr:min:sec, g.e.t. | Time, hr:min:sec, c.s.t. | Data summary | |
|---|---|---|---|---|
| DOI-1 | | | | |
| Burn termination | 93:13:31.3 | December 10, 1972 18:06:31.3 | Altitude above LLS radius, n. mi. | 51.5 |
| | | | Selenographic latitude, deg | -9.8 |
| | | | Selenographic longitude, deg | 158.8 |
| | | | Selenographic inclination, deg | 20.1 |
| | | | Burn duration, sec | 22.9 |
| | | | Inertial burn arc, deg | 1.2 |
| | | | Plane change, deg | 0.0 |
| | | | ΔV, fps | 198.7 |
| | | | SPS propellant used, lb | 1487.2 |
| | | | Velocity, fps | 5329.9 |
| | | | Orbital period, hr:min:sec | 01:54:29.6 |
| | | | Perilune altitude above LLS radius, n. mi. | 15.0 |
| | | | Apolune altitude above LLS radius, n. mi. | 59.0 |
| | | | Revolution number | 3 |
| CSM/LM undock and SEP | 110:27:55.2 | December 11, 1972 11:20:55.2 | Selenographic latitude, deg | -5.1 |
| | | | Selenographic longitude, deg | 136.0 |
| | | | Revolution number | 12 |
| Circularization (CSM) | | | | |
| Burn initiation | 111:55:22.7 | 12:48:22.7 | Mass, lb | 38 130.6 |
| | | | Altitude above LLS, n. mi. | 59.2 |
| | | | Selenographic latitude, deg | -20.0 |
| | | | Selenographic longitude, deg | -142.0 |
| | | | Selenographic inclination, deg | 20.2 |
| | | | Velocity, fps | 5288.0 |
| | | | Perilune altitude above LLS, n. mi. | 13.6 |
| | | | Revolution number | 12 |
| Burn termination | 111:55:26.7 | 12:48:26.7 | Altitude above LLS, n. mi. | 59.2 |
| | | | Burn duration, sec | 4.0 |
| | | | Burn arc, deg | 0.2 |
| | | | ΔV, fps | 70.1 |
| | | | SPS propellant consumed, lb | 263.1 |
| | | | Velocity, fps | 5358.0 |
| | | | Orbital period, hr:min:sec | 01:59:00.0 |
| | | | Perilune altitude above LLS, n. mi. | 54.4 |
| | | | Apolune altitude above LLS, n. mi. | 70.3 |
| | | | Revolution number | 12 |

TABLE 1-I.- SEQUENCE OF MAJOR EVENTS - Continued

| Event | Time hr:min:sec, g.e.t. | Time, hr:min:sec, c.s.t. | Data summary | |
|---|---|---|---|---|
| Second descent orbit insertion (DOI-2) | | December 11, 1972 | | |
| Burn initiation | 112:00:33.7 | 12:53:33.7 | Altitude above LLS radius, n. mi. | 60.0 |
| | | | Selenographic latitude, deg | -19.9 |
| | | | Selenographic longitude, deg | -158.6 |
| | | | Velocity, fps | 5283.5 |
| | | | Perilune altitude above LLS radius, n. mi. | 13.8 |
| | | | Apolune altitude above LLS radius, n. mi. | 60.0 |
| | | | Revolution number | 12 |
| Burn termination | 112:01:00.6 | 12:54:00.6 | Altitude above LLS radius, n. mi. | 60.0 |
| | | | Selenographic latitude, deg | -19.8 |
| | | | Selenographic longitude, deg | -160.0 |
| | | | Burn duration, sec | 26.9 |
| | | | ΔV, fps | 9.4 |
| | | | Velocity, fps | 5274.1 |
| | | | Perilune altitude above LLS radius, n. mi. | 7.2 |
| | | | Apolune altitude above LLS radius, n. mi. | 60.0 |
| | | | Revolution number | 12 |
| PDI (DPS ignition time) | 112:49:38.5 | 13:42:38.5 | Altitude above LLS, ft | 56 543.4 |
| | | | Velocity, fps | 5568.8 |
| | | | Revolution number | 13 |
| High gate (P63 to P64) | 112:58:58.5 | 13:51:58.5 | Altitude above LLS, ft | 8181.2 |
| | | | Velocity, fps | 357.7 |
| Low gate | 113:00:18.5 | 13:53:18.5 | Altitude above LLS, ft | 710.5 |
| | | | Velocity, fps | 85.3 |
| Vertical descent (P64 to P66) | 113:01:00.5 | 13:54:00.5 | Altitude above LLS, ft | 208.5 |
| | | | Velocity, fps | 10.2 |
| LM landing | 113:01:38.4 | 13:54:38.4 | Selenographic latitude, deg | 20.2 |
| | | | Selenographic longitude, deg | 30.7 |
| | | | Burn duration, sec | 720.4 |
| | | | DPS propellant consumed, lb | 18 093.3 |
| | | | ΔV, fps | 6701.8 |
| | | | Revolution number | 13 |
| CSM first pass over LLS | 112:57:28.9 | 13:50:28.9 | Revolution number | 13 |

TABLE 1-I.- SEQUENCE OF MAJOR EVENTS - Continued

| Event | Time, hr:min:sec, g.e.t. | Time, hr:min:sec c.s.t. | Data summary | |
|---|---|---|---|---|
| CSM plane change | | December 14, 1972 | | |
| Burn initiation | 182:35:45.3 | 11:28:45.3 | Mass, lb | 37 686.1 |
| | | | Altitude above LLS, n. mi. | 61.6 |
| | | | Selenographic latitude, deg | 12.6 |
| | | | Selenographic longitude, deg | -56.5 |
| | | | Velocity, fps | 5344.4 |
| | | | Perilune altitude above LLS, n. mi. | 61.3 |
| | | | Apolune altitude above LLS, n. mi. | 63.0 |
| | | | Revolution number | 48 |
| Burn termination | 182:36:03.9 | 11:29:03.9 | Altitude above LLS, n. mi. | 61.6 |
| | | | Selenographic latitude, deg | 12.3 |
| | | | Selenographic longitude, deg | -57.4 |
| | | | Selenographic inclination, deg | 23.2 |
| | | | Burn duration, sec | 18.7 |
| | | | Plane change, deg | 3.6 |
| | | | ΔV, fps | 336.7 |
| | | | SPS propellant consumed, lb | 1232.5 |
| | | | Velocity, fps | 5344.4 |
| | | | Perilune altitude above LLS, n. mi. | 61.3 |
| | | | Apolune altitude above LLS, n. mi. | 63.0 |
| | | | Revolution number | 48 |
| CSM second pass over LLS | 188:04:10.1 | 16:57:10.1 | Revolution number | 51 |
| Ascent | | | | |
| LM lift-off | 188:03:14.6 | 16:56:14.6 | Mass, lb | 10 917.1 |
| | | | Selenographic latitude, deg | 20.2 |
| | | | Selenographic longitude, deg | 30.8 |
| | | | Revolution number | 51 |
| LM insertion | 188:10:32.3 | 17:03:32.3 | Mass, lb | 5933.4 |
| | | | Altitude above LLS, ft | 59 997.3 |
| | | | Selenographic latitude, deg | 21.9 |
| | | | Selenographic longitude, deg | 19.9 |
| | | | Burn duration, sec | 437.7 |
| | | | ΔV, fps | 6062.2 |
| | | | Perilune altitude above LLS, ft | 55 065.3 |
| | | | Apolune altitude above LLS, ft | 290 745.8 |

TABLE 1-I.- SEQUENCE OF MAJOR EVENTS - Continued

| Event | Time, hr:min:sec, g.e.t. | Time, hr:min:sec, c.s.t. | Data summary | |
|---|---|---|---|---|
| Rendezvous | | December 14, 1972 | | |
| TPI (APS ignition) | 188:57:32.3 | 17:50:32.3 | Burn duration, sec | 2.7 |
| Preceded by a 10-sec RCS ullage | | | $\Delta V$, fps | 54.8 |
| $\Delta V$ = 21.8 fps | | | Propellant used, lb | 32.7 |
| | | | Resultant $h_a/h_p$, n. mi. | 64.4/46.7 |
| | | | Range at cutoff, n. mi. | 32.5 |
| | | | Range rate at cutoff, fps | -131.7 |
| | | | Propulsion system | APS |
| | | | Revolution number | 51 |
| Braking | 189:38:59.3 | 18:31:59.3 | Burn duration, sec | 28.4 |
| | | | $\Delta V$, fps | 31.2 |
| | | | Propellant used, lb | 20.3 |
| | | | Range at final braking, n. mi. | 0.01 |
| | | | Range rate at final braking, fps | -0.22 |
| | | | $h_a/h_p$ at final braking, n. mi. | 62.4/61.8 |
| | | | Propulsion system | LM RCS |
| | | | Revolution number | 52 |
| Docking | 190:00:00.0 | 18:53:00.0 | | |
| LM jettison | 193:58:30.0 | 22:51:30.0 | Selenographic latitude, deg | 18.5 |
| | | | Selenographic longitude, deg | 35.3 |
| | | | Revolution number | 54 |
| CSM/LM separation | | | | |
| Burn initiation | 194:03:30.0 | 22:56:30.0 | Revolution number | 54 |
| Burn termination | 194:03:42.6 | 22:56:42.6 | Mass, lb | 36 833.5 |
| | | | Altitude above LLS radius, n. mi. | 62.3 |
| | | | Selenographic latitude, deg | 21.7 |
| | | | Selenographic longitude, deg | 18.8 |
| | | | Selenographic inclination, deg | 23.2 |
| | | | Burn duration, sec | 12.6 |
| | | | Plane change, deg | 0.0 |
| | | | $\Delta V$, fps | 2.0 |
| | | | Velocity, fps | 5343.3 |
| | | | Perilune altitude above LLS radius, n. mi. | 62.2 |
| | | | Apolune altitude above LLS radius, n. mi. | 64.0 |
| | | | Revolution number | 54 |

TABLE 1-I.- SEQUENCE OF MAJOR EVENTS - Continued

| Event | Time, hr:min:sec, g.e.t. | Time, hr:min:sec, c.s.t. | Data summary | |
|---|---|---|---|---|
| | | December 15, 1972 | | |
| LM deorbit | 195:39:12.5 | 00:32:12.5 | Mass, lb | 5230.4 |
| | | | Selenographic latitude, deg | -0.6 |
| | | | Selenographic longitude, deg | 87.1 |
| | | | Burn duration, sec | 116.4 |
| | | | ΔV, fps | 281.8 |
| LM impact | 195:58:25.1 | 00:51:25.1 | Mass, lb | 5069.9 |
| | | | Selenographic latitude, deg | 19.9 |
| | | | Selenographic longitude, deg | 30.5 |
| | | | Velocity, fps | 5478.0 |
| | | | Revolution number | 55 |
| Transearth injection | | December 16, 1972 | | |
| Burn initiation | 236:39:51.2 | 17:32:51.2 | Mass, lb | 36 616.9 |
| | | | Altitude above LLS radius, n. mi. | 64.1 |
| | | | Selenographic latitude, deg | -19.8 |
| | | | Selenographic longitude, deg | -171.5 |
| | | | Selenographic inclination, deg | 23.2 |
| | | | Velocity, fps | 5333.8 |
| | | | Perilune altitude above LLS, n. mi. | 59.2 |
| | | | Revolution number | 75 |
| Burn termination | 236:42:13.4 | 17:35:13.4 | Altitude above LLS radius, n. mi. | 66.5 |
| | | | Selenographic latitude, deg | -21.5 |
| | | | Selenographic longitude, deg | 179.0 |
| | | | Selenographic inclination, deg | 23.6 |
| | | | Burn duration, sec | 142.2 |
| | | | Inertial burn arc, deg | 9.1 |
| | | | Plane change, deg | 0.9 |
| | | | ΔV, fps | 3045.7 |
| | | | SPS propellant used, lb | 9506.0 |
| | | | Velocity, fps | 8368.0 |
| | | | Perilune altitude above LLS, n. mi. | 63.8 |
| Transearth coast midcourse correction maneuvers | | December 17, 1972 | | |
| MCC-5 | TEI + 17 hr | 10:35:13.4 | Geodetic altitude, n. mi. | ≈ 166 000 |
| | | December 18, 1972 | | |
| MCC-6 | EI - 22 hr | 15:11:01.5 | Geodetic altitude, n. mi. | ≈ 102 500 |

TABLE 1-I.- SEQUENCE OF MAJOR EVENTS - Concluded

| Event | Time, hr:min:sec, g.e.t. | Time, hr:min:sec, c.s.t. | Data summary | |
|---|---|---|---|---|
| Transearth coast MCC maneuvers | | December 19, 1972 | | |
| MCC-7 | EI - 3 hr | 10:11:01.5 | Geodetic altitude, n. mi. | 25 500 |
| CM/SM separation | EI - 15 min | 12:56:01.5 | Geodetic altitude, n. mi. | 1957.0 |
| Entry interface | 304:18:01.5 | 13:11:01.5 | Transearth coast time, hr | 68 |
| | | | Inertial velocity, fps | 36 090.3 |
| | | | Geodetic altitude, n. mi. (ft) | 65.8 (399 849.0) |
| | | | Inertial flight-path angle, deg | -6.5 |
| | | | Geodetic latitude, deg | 0.7 |
| | | | Longitude, deg | -173.2 |
| | | | Equatorial inclination (descending), deg | 66.5 |
| CM landing | 304:31:11 | 13:24:11 | Geodetic latitude, deg | -17.9 |
| | | | Longitude, deg | -166.0 |

## 4.5 Posttranslunar Injection

The summary of the major events from TLI cutoff through S-IVB LOX blowdown is given in table 4.5-I. To determine the separation attitude maneuver (TB7 plus 900 sec), the sun was constrained to between 32° and 90° of the LV +X-axis. This constraint provides over-the-shoulder lighting and avoids any CSM shadow on the S-IVB for the docking phase.

Upon ground command, the S-IVB performs an APS evasive maneuver approximately 23 minutes after CSM/LM separation. The S-IVB attitude for this maneuver will be the same as the separation attitude except that the sign of the middle gimbal angle (yaw gimbal) will be reversed. The APS burn will be 9.8 fps.

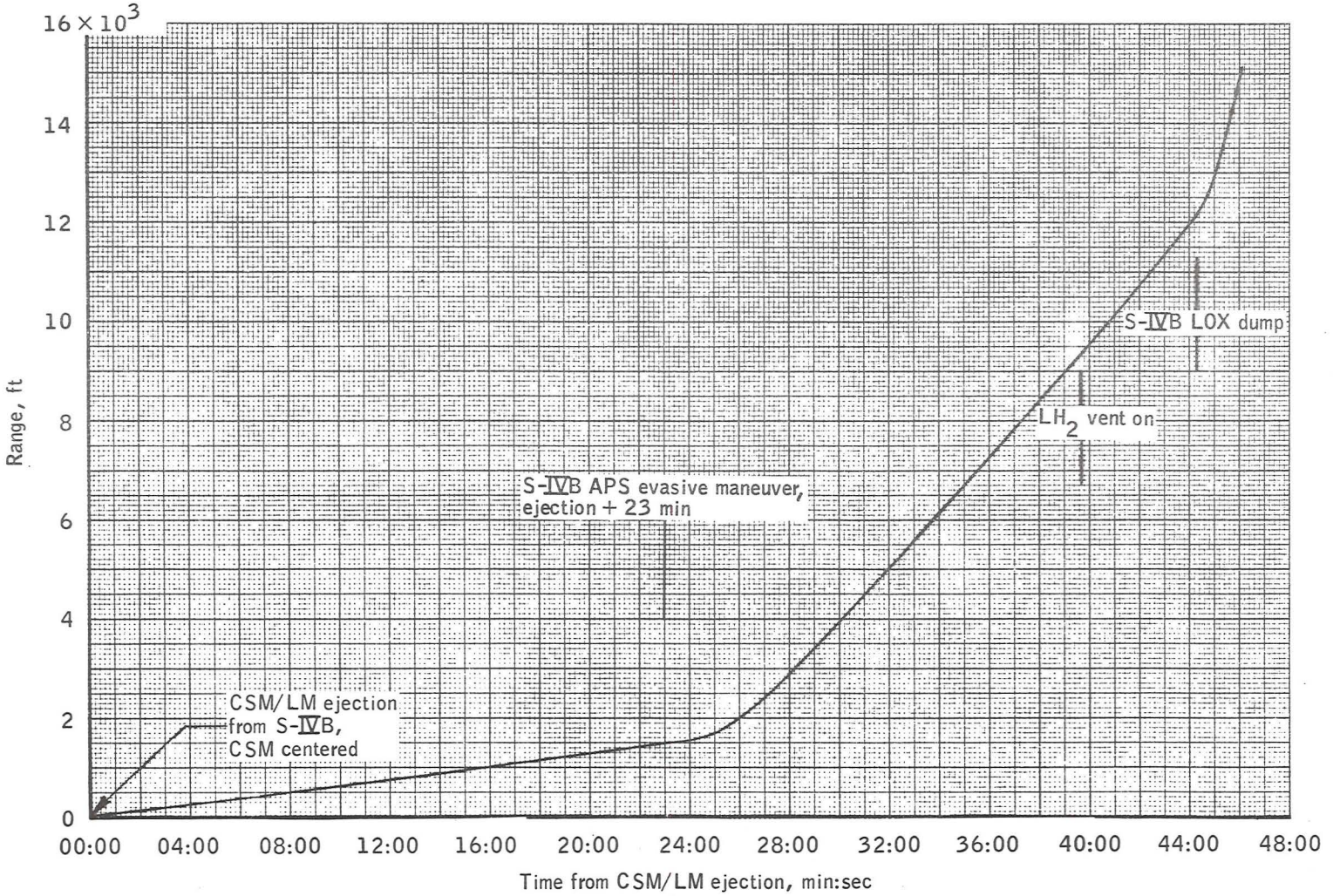
The S-IVB performs a LOX dump 21 minutes 20 seconds after the APS evasive maneuver. The local horizontal attitude for this dump is pitch 190°, yaw -19°, roll 180°.

The LOX dump maneuver is designed to reduce the probability of spacecraft recontact with the S-IVB and also to achieve an S-IVB impact on the moon. Nominally, an S-IVB APS lunar impact burn will be executed after the APS evasive and LOX dump maneuvers (g.e.t. is approximately $6^h30^m$) to target the S-IVB for a lunar impact 7.0° south and 8.0° west.

TABLE 4.5-I.- SUMMARY OF EVENTS FROM TLI CUTOFF THROUGH LOX DUMP

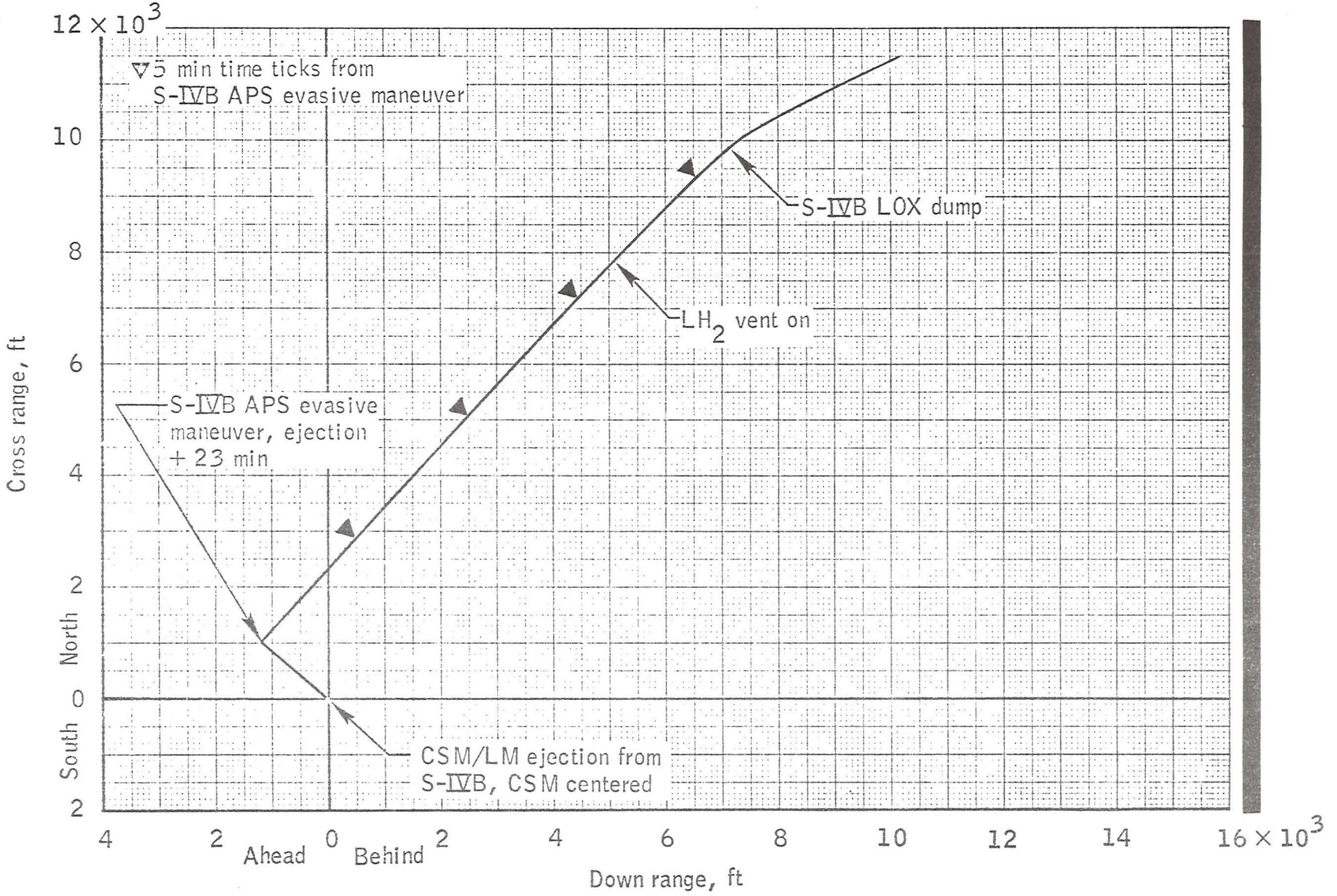
| Time from TB7, hr:min:sec | Event | ΔV, fps | Comments |
|---|---|---|---|
| 00:00:00 | Hold cutoff attitude | | |
| 00:00:20 | Command and hold local horizontal | | |
| 00:15:00 | Initiate maneuver to separation attitude | | Local horizontal attitude<br>Pitch = 120°<br>Yaw = 40°<br>Roll = 180°<br>0.8 deg/sec |
| 00:20:00 | Freeze separation attitude inertially | | Latest time for maneuver to be completed |
| 00:45:00 | Begin SC separation/SLA jettison | 0.5 | |
| 00:45:15 | AUTO maneuver to docking attitude | | 2.0 deg/sec |
| | Null rates and translation | | |
| | Initiate 0.7-fps closing rate | | 4-sec RCS +X |
| | Null 0.7-fps closing rate | 0.7 | -X RCS |
| 00:55:00 | Begin dock | | |
| 01:40:00 | LM/CSM ejection from S-IVB | 1.1 | Spring ejection and 3-sec -X RCS |
| 02:03:00 | S-IVB APS evasive maneuver | 9.8 | Start TB8 |
| 02:24:20 | S-IVB LOX dump | | Local horizontal attitude<br>Pitch = 190°<br>Yaw = -19°<br>Roll = 180° |

Amendment 1, October 30, 1972



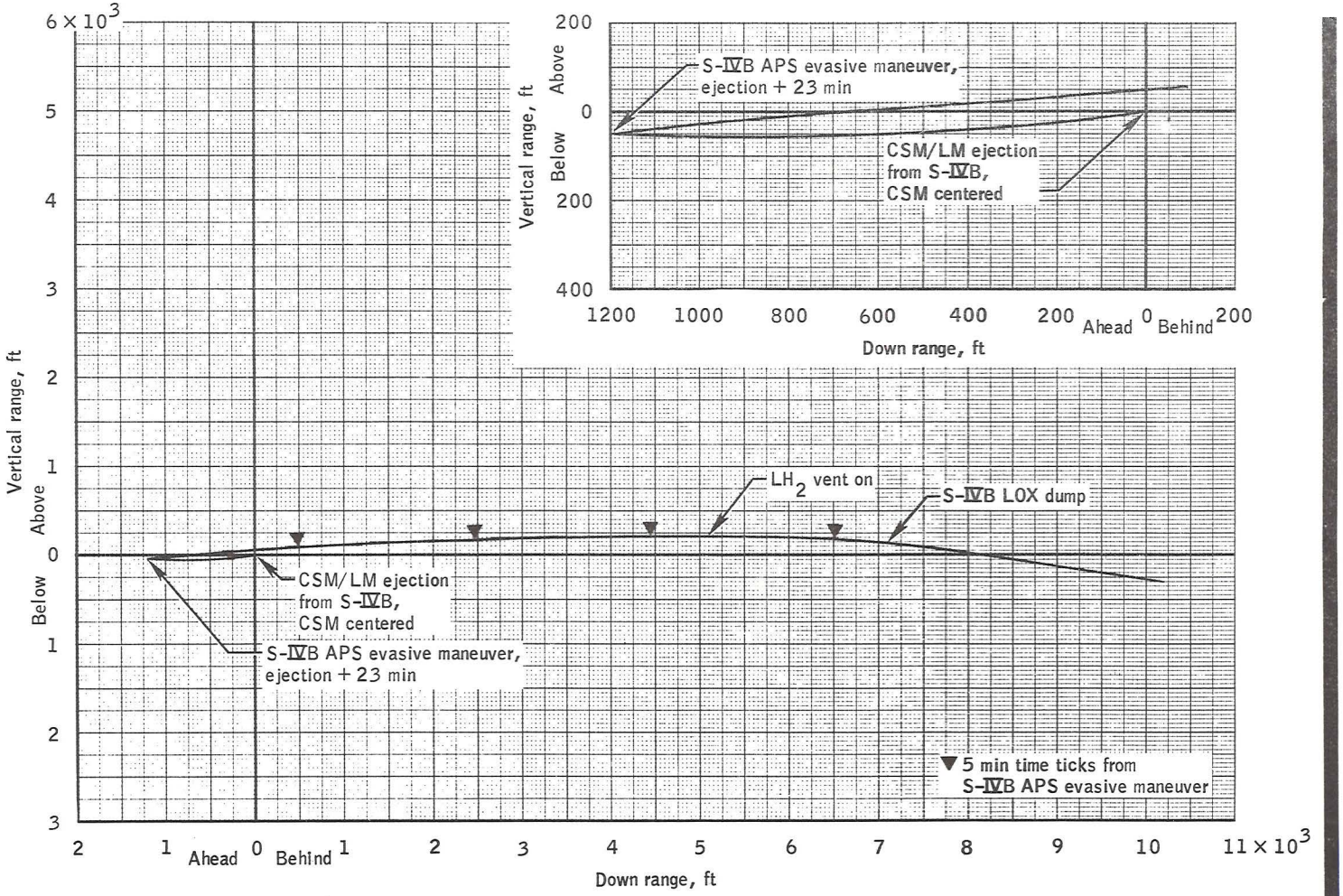

(a) Range versus time.

Figure 4.5-1.- Motion of the S-IVB relative to the spacecraft for the S-IVB evasive maneuver of Apollo 17.




(b) Cross range versus down range.

Figure 4.5-1.- Continued




(c) Vertical range versus down range.

Figure 4.5-1.- Concluded.

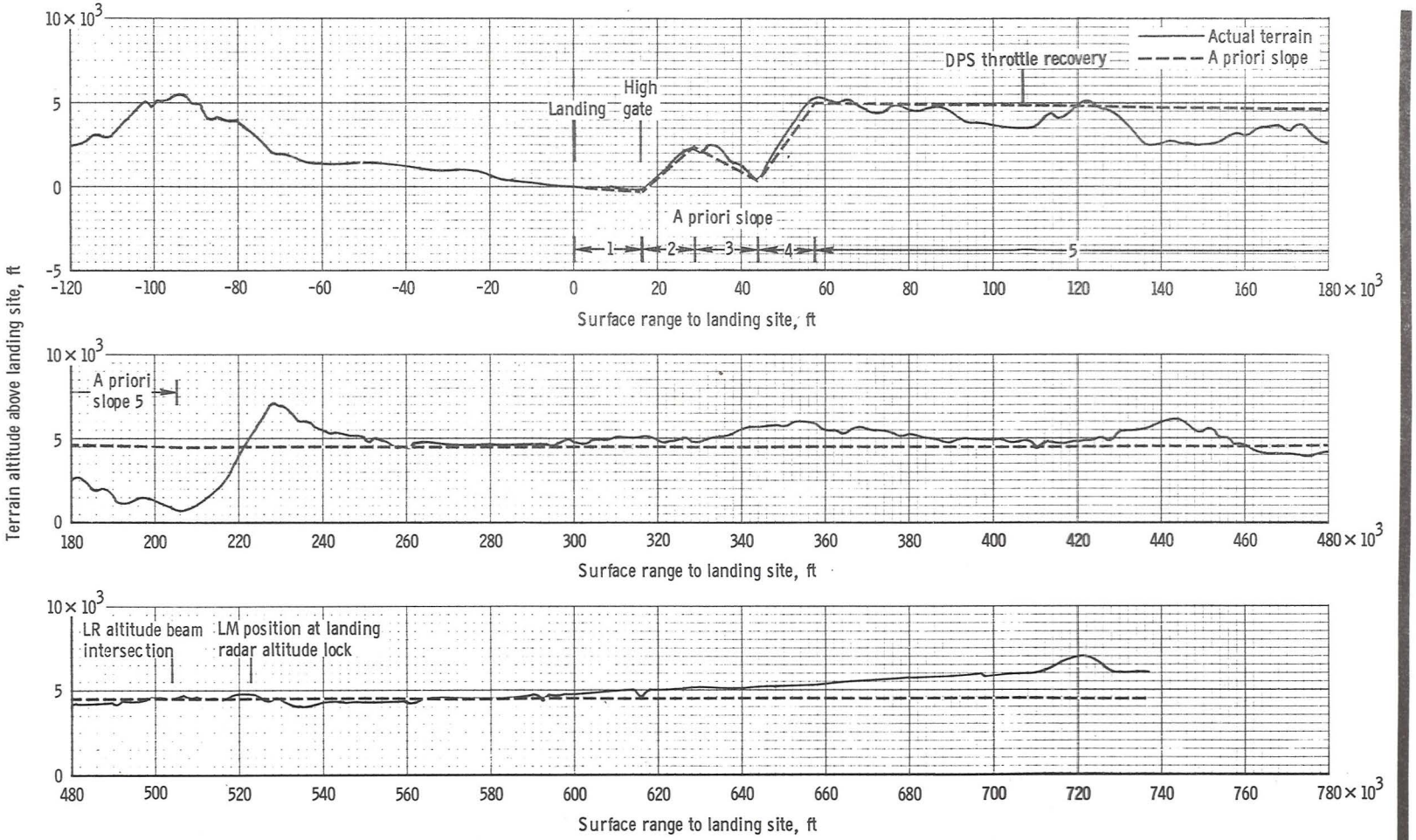
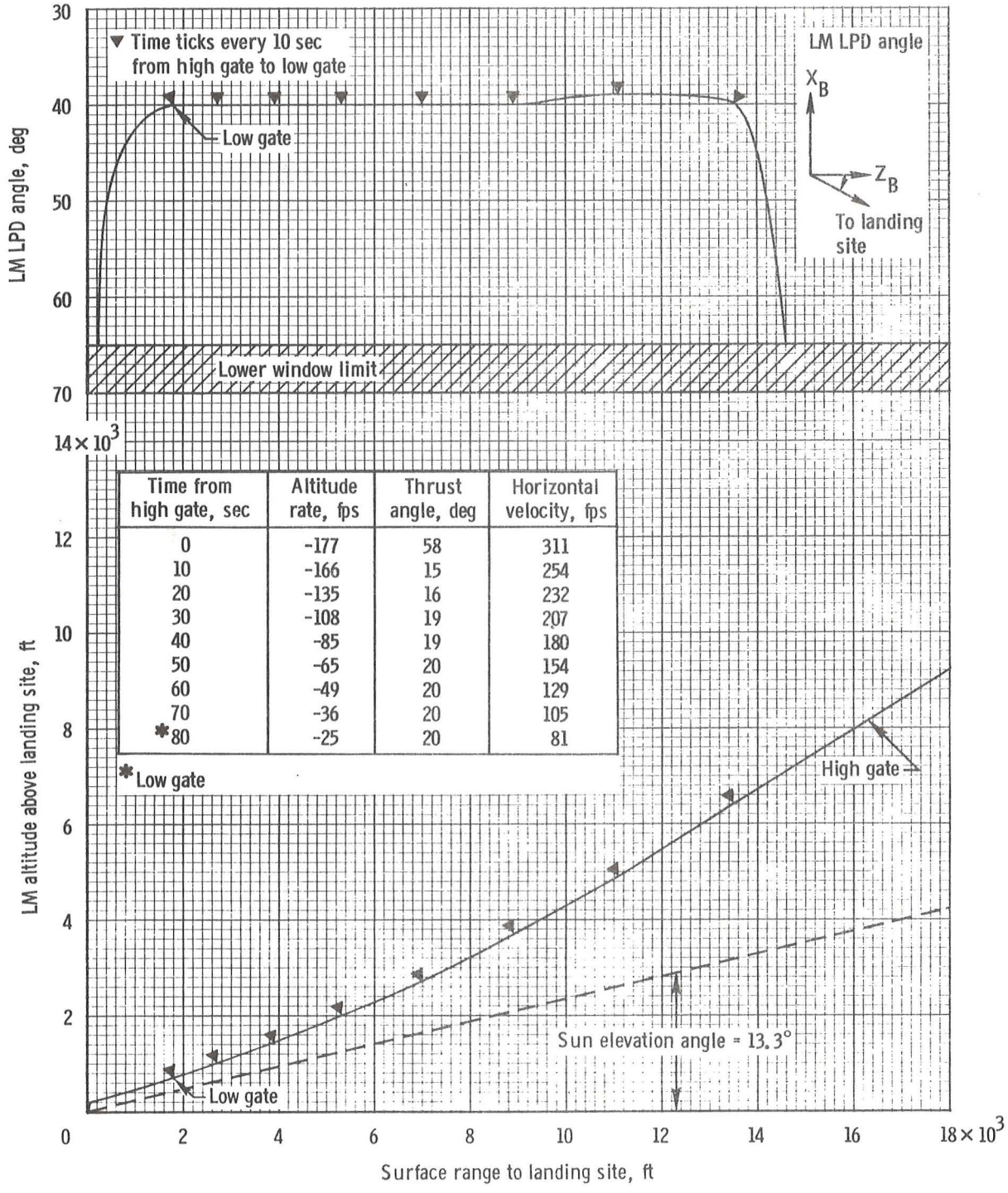



Figure 4. 10-5. - Taurus-Littrow terrain profile.




| Time from high gate, sec | Altitude rate, fps | Thrust angle, deg | Horizontal velocity, fps |
|---|---|---|---|
| 0 | -177 | 58 | 311 |
| 10 | -166 | 15 | 254 |
| 20 | -135 | 16 | 232 |
| 30 | -108 | 19 | 207 |
| 40 | -85 | 19 | 180 |
| 50 | -65 | 20 | 154 |
| 60 | -49 | 20 | 129 |
| 70 | -36 | 20 | 105 |
| *80 | -25 | 20 | 81 |

*Low gate

Figure 4. 10-6. - Approach phase summary.

## 4.14 LM Ascent Stage Jettison and Separation to CSM Transearth Injection

Since the publication of the operational trajectory, the time of LM deorbit has been moved approximately 2.5 minutes earlier to increase the travel arc from deorbit to LM impact from about 48° to 56°. This reduces the ΔV required for deorbit from 357.1 fps to 281.8 fps and increases the RCS propellant margin from 24 fps to 99 fps. The major effects of this LM deorbit time change are:

a. RCS propellant margin increased from 24 to 99 fps

b. Δt from AOS to deorbit reduced from 9 to 6 minutes

c. Deorbit ΔV reduced from 357 to 282 fps

d. Deorbit burn time reduced from 147 to 116 seconds

e. Flight-path angle at impact reduced from -6.1° to -4.8°

f. Impact velocity increased from 5394 fps to 5478 fps

Also, since the operational trajectory publication a detailed dispersion analysis has been done and the 3σ impact ellipse has been determined to be ±6.0 n. mi. down range and ±0.33 n. mi. cross range on a flat surface. Because of the terrain around the impact point, the actual dispersion ellipse is 0.87 n. mi. up range (to the east), 1.18 n. mi. down range (to the west), and ±0.33 n. mi. cross range.

The LM ascent stage is jettisoned from the CSM about two revolutions after docking at $193^{h}58^{m}30^{s}$ g.e.t. The LM is jettisoned radially up in the inertial attitude required for the LM deorbit maneuver which occurs about 101 minutes later. A 2.5-fps velocity is imparted to the LM at jettison due to a 1.5-psi tunnel pressure between the CSM and LM. Jettison occurs on the front side of the moon at a longitude of 35.3°E and a latitude of 18.5°N.

The CSM performs a 2-fps posigrade maneuver 5 minutes after jettison to avoid any recontact with the LM. The CSM target load for this separation maneuver is shown in table 5-XII.

The LM deorbit burn occurs at $195^{h}39^{m}12.5^{s}$ g.e.t. on the front side of the moon at a longitude of 87.1°E and a latitude of 0.6°S. There are about 6 minutes of STDN coverage prior to the derobit maneuver in which to command the LM for deorbit. The deorbit is targeted to impact the LM on the lunar surface at a longitude of 30.53°E and a latitude of 19.93°N. Because of the far easterly longitude of deorbit, the LM must be oriented

to a pitched-down attitude of about 35° from the pure retrograde attitude at the deorbit initiation in order that the LM steerable antenna be acquired by STDN stations. The local horizontal pitch and yaw angles are presented in table 4.14-I. The roll has been optimized for STDN communication. This RCS burn (+X, 4-jet) will be about 116 seconds long. The total ΔV required for deorbit is 281.8 fps. This ΔV leaves a 99-fps margin for excessive RCS use during the nominal mission. The target load for deorbit is shown in table 5-XIII.

After deorbit the LM coasts for about 17 minutes in a 66.4- by -90.4-n. mi. orbit prior to impacting the lunar surface. The velocity of impact is 5478.0 fps with a flight-path angle of -4.8°. The LM deorbit groundtrack prior to impact is shown in figure 4.14-1.

TABLE 4.14-I.- LM DEORBIT SUMMARY

| Event | Time, hr:min:sec g.e.t. | Latitude, deg | Longitude, deg | Burn duration, sec | ΔV, fps | Inertial velocity, fps | Mass, lb | Local horizontal attitudes, deg | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Pitch | Yaw |
| Jettison | 193:58:30.0 | 18.55 | 35.26 | -- | 2.5 | 5341.7 | 5230.4 | -90.2 | 11.5 |
| Deorbit | 195:39:12.5 | -0.55 | 87.11 | 116.4 | 281.8 | 5346.5 | 5230.4 | -145.5 | 11.5 |
| Impact | 195:58:25.1 | 19.93 | 30.54 | -- | -- | 5478.0 | 5069.9 | -86.5 | 12.0 |

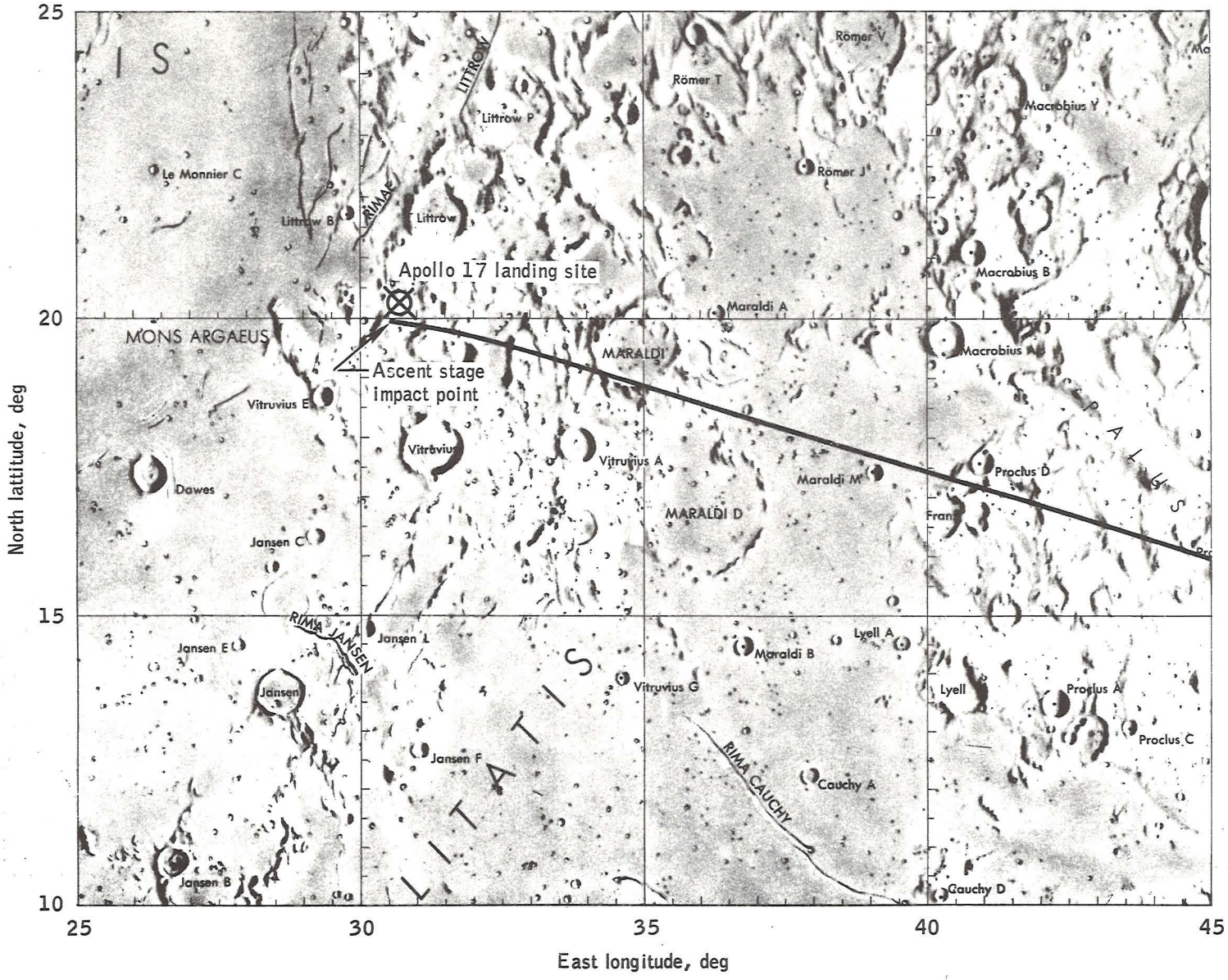



Figure 4.14-1.- Apollo 17 LM ascent stage impact groundtrack.

TABLE 5-III.- ENGINE PERFORMANCE SUMMARY

(a) Service module propulsion performance summary

| Burn | Propulsion system | $I_{sp}$, sec | Thrust, lb | Flow rate, lb/sec |
|---|---|---|---|---|
| LOI | SPS[a] | 314.89 | 20 779 | 66.0 |
| | SPS[b] | 314.95 | 21 007 | 66.7 |
| DOI | SPS[c] | 314.79 | 20 476 | 65.05 |
| Initial sep | RCS[d] | 269.13 | 355.25 | 1.32 |
| CIRC | SPS[c] | 314.81 | 20 572 | 65.35 |
| LOPC | SPS | 314.71 | 20 472 | 65.05 |
| Final sep | RCS[e] | 263.58 | 181.87 | 0.69 |
| TEI | SPS | 314.94 | 21 050 | 66.84 |

[a]Before crossover (260-sec burn time).

[b]After crossover (260-sec burn time).

[c]Single bore.

[d]Four-quad.

[e]Two-quad.

TABLE 5-III.- ENGINE PERFORMANCE SUMMARY - Concluded

(b) Lunar module performance tabular inputs

| Descent | | | | Ascent | | |
|---|---|---|---|---|---|---|
| DPS | | RCS | | APS + RCS | | |
| Thrust, lb | $I_{sp}$, sec | Thrust per engine, lb | $I_{sp}$, sec | Burn time, sec | Effective thrust, lb | Effective $I_{sp}$, sec |
| 1 379 | 298.8 | 79.5 | 281.0 | 0 | 3577.6 | 309.3 |
| 3 063 | 300.4 | | | 40 | 3562.3 | 309.6 |
| 3 989 | 301.2 | | | 80 | 3548.4 | 309.8 |
| 4 906 | 303.1 | | | 120 | 3535.4 | 309.9 |
| 5 878 | 306.6 | | | 160 | 3522.9 | 309.9 |
| 9 976 | 306.5 | | | 200 | 3510.6 | 309.9 |
| 10 005 | 305.3 | | | 240 | 3498.3 | 309.9 |
| | | | | 280 | 3485.8 | 309.8 |
| | | | | 320 | 3485.3 | 309.7 |
| | | | | 360 | 3498.2 | 309.5 |
| | | | | 400 | 3513.8 | 309.2 |
| | | | | 437.7 | 3531.5 | 309.1 |

TABLE 5-X.- LANDING SITE REFSMMAT, TARGET LOAD,

AND GIMBAL ANGLES - Continued

(f) Desired ΔV's for manual CSM separation maneuver

[Propulsion system: SM RCS]

| | |
|---|---|
| $t_{IG}$, hr:min:sec, g.e.t. | 110:27:55.2 |
| $\Delta V_X$, fps | 0.0 |
| $\Delta V_Y$, fps | 0.0 |
| $\Delta V_Z$, fps | 1.0 |
| CSM weight, lb | 38 150.0 |

(g) CSM gimbal angles at $t_{IG}$

| | |
|---|---|
| IGA, deg | 104.7 |
| MGA, deg | 0.0 |
| OGA, deg | 0.0 |

(h) Target load for CSM circularization maneuver

[Propulsion system: SM SPS; guidance: external ΔV]

| | |
|---|---|
| $t_{IG}$, hr:min:sec, g.e.t. | 111:55:22.7 |
| $\Delta V_X$, fps | 70.1 |
| $\Delta V_Y$, fps | 0.0 |
| $\Delta V_Z$, fps | -2.4 |
| CSM weight at $t_{IG}$, lb | 38 130.6 |

TABLE 5-X.- LANDING SITE REFSMMAT, TARGET LOAD,

AND GIMBAL ANGLES - Continued

(i) Gimbal angles at $t_{IG}$

| | |
|---|---|
| IGA, deg | 99.8 |
| MGA, deg | 358.0 |
| OGA, deg | 0.1 |

(j) Target load for DOI-2 maneuver

[Propulsion system: LM RCS]

| | |
|---|---|
| $t_{IG}$, hr:min:sec, g.e.t. | 112:00:33.7 |
| $\Delta V_X$, fps | -9.4 |
| $\Delta V_Y$, fps | 0.0 |
| $\Delta V_Z$, fps | 0.8 |
| Mass, lb | 36 709.2 |

(k) Gimbal angles at $t_{IG}$

| | |
|---|---|
| IGA, deg | 85.1 |
| MGA, deg | 0.0 |
| OGA, deg | 0.0 |

TABLE 5-X.- LANDING SITE REFSMMAT, TARGET LOAD,

AND GIMBAL ANGLES - Continued

(l) Target load for LM powered descent maneuver (P63)

[Propulsion system: LM DPS; guidance programs: P63, P64, P66]

| | |
|---|---|
| $t_{IG}$, hr:min:sec, g.e.t. . . . . | 112:49:38.5 |
| Ignition algorithm targets | |
| RIGXG, ft . . . . . | -156 145.03 |
| RIGZG, ft . . . . . | -1 541 941.8 |
| VIGG, fps . . . . . | 5542.8976 |
| Ignition algorithm correction factors | |
| $k_X$ . . . . . | 0.334 |
| $k_Y$, $ft^{-1}$ . . . . . | $2.207^{-7}$ |
| $k_V$, ft/fps . . . . . | 498.0 |

(m) Gimbal angles at $t_{IG}$

| | |
|---|---|
| IGA, deg . . . . . | 107.5 |
| MGA, deg . . . . . | 0.0 |
| OGA, deg . . . . . | 70.0 |

(n) Target load for braking phase (P63)[a]

[Propulsion system: LM DPS; guidance program P63]

| | |
|---|---|
| Position, ft | |
| $R_X$ . . . . . | -3118.3588 |
| $R_Y$ . . . . . | 0.0 |
| $R_Z$ . . . . . | -11 741.441 |

[a]TENDBRAK = 62 sec (time-to-go at program switch).

TABLE 5-X.- LANDING SITE REFSMMAT, TARGET LOAD, AND GIMBAL ANGLES - Continued

(n) Target load for braking phase (P63)[a] - Concluded

| | |
|---|---|
| Velocity, fps | |
| $V_X$ | -196.46916 |
| $V_Y$ | 0.0 |
| $V_Z$ | -166.75997 |
| Acceleration, ft/sec$^2$ | |
| $A_X$ | -0.71824813 |
| $A_Y$ | 0.0 |
| $A_Z$ | -8.3024504 |
| Jerk, ft/sec$^3$ | |
| $J_Z$ | -0.01512365 |

(o) Target load for approach phase (P64)[b]

[Propulsion system: LM DPS; guidance program P64]

| | |
|---|---|
| Position, ft | |
| $R_X$ | 158.500 |
| $R_Y$ | 0.0 |
| $R_Z$ | -27.3554 |
| Velocity, fps | |
| $V_X$ | -3.53476 |
| $V_Y$ | 0.0 |
| $V_Z$ | 0.0249505 |

[a] TENDBRAK = 62 sec (time-to-go at program switch).

[b] TENDAPP = 12 sec (time-to-go at program switch).

TABLE 5-XII.- LM ASCENT REFSMMAT, TARGET LOAD, AND GIMBAL ANGLES - Continued

(f) Target loads for TPI maneuver[a]

[Propulsion system: APS; guidance: external ΔV]

| | |
|---|---|
| $t_{IG}$,[b] hr:min:sec, g.e.t. | 188:57:22.3 |
| $\Delta V_X$, fps | 75.1 |
| $\Delta V_Y$, fps | -0.3 |
| $\Delta V_Z$, fps | 14.7 |
| Weight at $t_{IG}$, lb | 5933.4 |

(g) Gimbal angles at $t_{IG}$[b]

| | |
|---|---|
| IGA, deg | 99.1 |
| MGA, deg | -0.2 |
| OGA, deg | 0.0 |

(h) Target load for CSM separation maneuver following LM jettison

[Propulsion system: CSM RCS]

| | |
|---|---|
| $t_{IG}$, hr:min:sec, g.e.t. | 194:03:30.0 |
| $\Delta V_X$, fps | 2.0 |
| $\Delta V_Y$, fps | 0.0 |
| $\Delta V_Z$, fps | 0.0 |
| Weight, lb | 36 842.2 |

[a] All targets include ΔV's from ullage.

[b] $t_{IG}$ is ullage on time.

TABLE 5-XII.- LM ASCENT REFSMMAT, TARGET LOAD,

AND GIMBAL ANGLES - Concluded

(i) Gimbal angles at $t_{IG}$

| | |
|---|---|
| IGA, deg | 7.2 |
| MGA, deg | 348.6 |
| OGA, deg | 20.0 |

(j) Target load for LM deorbit

[Propulsion system: LM RCS]

| | |
|---|---|
| $t_{IG}$, hr:min:sec, g.e.t. | 195:39:12.5 |
| $\Delta V_X$, fps | -219.2 |
| $\Delta V_Y$, fps | 56.0 |
| $\Delta V_Z$, fps | 168.0 |
| Weight, lb | 5230.4 |

(k) Gimbal angles at $t_{IG}$

| | |
|---|---|
| IGA, deg | 187.2 |
| MGA, deg | 11.4 |
| OGA, deg | 280.0 |