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MSC-01855
Supplement 1

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 12 MISSION REPORT

TRAJECTORY RECONSTRUCTION AND POSTFLIGHT ANALYSIS

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MANNED SPACECRAFT CENTER
HOUSTON, TEXAS
August 1970

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APOLLO 12 MISSION REPORT

SUPPLEMENT 1

TRAJECTORY RECONSTRUCTION AND POSTFLIGHT ANALYSIS

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PROJECT APOLLO

TASK MSC/TRW A-50

APOLLO MISSION 12, TRAJECTORY RECONSTRUCTION AND POSTFLIGHT ANALYSIS VOLUME 1

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Prepared for
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NAS 9-8166

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FOREWORD

This report is submitted to the NASA Manned Spacecraft Center in accordance with MSC/TRW Task A-50 Contract NAS 9-8166. This report contains the postflight analysis performed in conjunction with the Apollo 12 mission and is issued as Supplement 1 to the Apollo 12 Mission Report.

The report is issued in two volumes. Volume I contains details of the analysis and results obtained, including appendices; Volume II contains a listing of the 45-Day Best Estimated Trajectory (BET) for the Apollo 12 mission in the NASA Apollo Trajectory (NAT) format. The listing is not generally distributed but is available from NASA/MSC upon request. Requests should be made to:

NASA/MSC Computations and Analysis Division
Central Metric Data File
Code ED-5, Building 12, Room 133
Houston, Texas 77058

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SYMBOLS AND NOMENCLATURE

AOS	acquisition of signal
APS	ascent propulsion system
BET	best estimated trajectory
CDH	constant delta height
CM	command module
CSI	coelliptic sequence initiation
CSM	command and service module
DOI	descent orbit insertion
DPS	descent propulsion system
ECI	earth centered inertial
GET	ground elapsed time
GMT	Greenwich mean time
IMU	inertial measurement unit
LGC	LM guidance computer
LLS	lunar landing site
LM	lunar module
LR	landing radar
LOI	lunar orbit insertion
LOPC	lunar orbit plane change
LOS	loss of signal
MCC	midcourse correction
MCI	moon centered inertial
MLR	mean lunar radius
MNBY	mean of nearest Besselian year
MSFN	Manned Space Flight Network
NAT	NASA Apollo Trajectories
PDI	powered descent initiation
PGNCS	primary guidance and navigation control subsystem
RCS	reaction control system
RR	rendezvous radar

Symbols and Nomenclature (Continued)

RTCC	Real-Time Computer Complex
SOI	sphere of influence
SXT	sextant
T&D	transposition and docking
TEI	transearth injection
TLI	translunar injection
TPI	terminal phase initiation
VHF	very high frequency
wrt	with respect to
ΔV	change in velocity caused by thrusting
ΔT	change in time
δR, δV	square root of the sum of the squares of the differences between position or velocity components

5.0 APOLLO 12 MISSION TRAJECTORY RECONSTRUCTION AND POSTFLIGHT REPORT

5.1 INTRODUCTION AND SUMMARY

Apollo 12 was the sixth manned flight of the Apollo series and the second manned lunar landing. The 10-day Apollo 12 mission has contributed and will continue to contribute to a greater scientific understanding of the lunar environment. The crew were Charles Conrad, Jr., Commander; Richard F. Gordon, Command Module Pilot; and Alan L. Bean, Lunar Module Pilot.

The space vehicle was launched from Kennedy Space Center, Florida, with range zero (the integral second before lift-off) occurring at 16:22:00 Greenwich Mean Time (GMT), November 14, 1969. A sequence of events list for the Apollo 12 mission is presented in Table 5.1.

The descent phase of the Apollo 12 mission was initiated on the thirteenth revolution of the moon at approximately 107 hours 54 minutes Ground Elapsed Time (GET). The Lunar Module (LM) successfully landed on the lunar surface at approximately 110 hours 32 minutes GET.

The rendezvous phase began with ascent ignition during Command and Service Modules (CSM) revolution 30 and ended with docking at 145 hours 36 minutes GET. A summary of the CSM and LM maneuvers performed during descent and rendezvous is presented in Table 5.2. Figure 5-1 shows the CSM and LM ground based and onboard tracking data that were available during the descent and rendezvous phases of the Apollo 12 mission.

The objective of the postflight analysis task is, in general, to generate trajectory parameters and data for the CSM and LM vehicles from S-IVB/CSM separation to the end of the mission. During the early Apollo missions this was accomplished by developing a best estimate of trajectory (BET) from available tracking and telemetry data. Comparisons of the BET and the Real-Time Computer Complex (RTCC) state vectors after the early Apollo missions indicated that the RTCC state vectors were of good quality and that, in general, only small differences existed between the two trajectory sources. Consequently, RTCC state vectors were used to generate the preliminary NAT's for Apollo's 9, 10 and 11. It was decided

TABLE 5.1. APOLLO MISSION 12 SEQUENCE OF EVENTS

	GET(h:m:s)	GMT(d:h:m:s)
Range Zero		14:16:22:00.0
Translunar Injection	2:47:22.7	14:19:09:22.7
ΔT = 341.3 ΔV = 10,515	2:53:14.0	14:19:15:14.0
S-IVB/Command Module Separation	3:18:04.9	14:19:40.04.9
First Docking	3:26:53.3	14:19:48:53.3
Spacecraft Ejection	4:13:00.9	14:20:35:00.9
Evasive Manuever (S-IVB APS)	4:28:01.4	14:20:50:01.4
ΔT = 80	4:28:01.4	14:20:50:01.4
Midcourse Correction #1	30:52:44.4	15:23:14:44.4
ΔT = 9.2 ΔV = 61.8	30:52:53.6	15:23:14:53.6
Enter Moon's Sphere of Influence	68:30:00.	17:12:50:00.
Lunar Orbit Insertion #1	83:25:23.4	18:03:47:23.4
ΔT = 352.3 ΔV = 2889.5	83:31:15.7	18:03:53:15.7
Lunar Orbit Insertion #2	87:48:48.1	18:08:10:48.1
ΔT = 16.9 ΔV = 165.2	87:49:05.0	18:08:11:05.0
Undocking	107:54:02.3	19:04:16:02.3
CSM Active Separation	108:24:36.8	19:04:46:36.8
ΔT = 14.4 ΔV = 2.4	108:24:51.2	19:04:46:51.2
Descent Orbit Insertion	109:23:39.9	19:05:45:39.9
ΔT = 29 ΔV = 72.4	109:24:08.9	19:05:46:08.9
Powered Descent Initiation	110:20:38.1	19:06:42:38.1
ΔT = 717		
Touchdown	110:32:36.2	19:06:54:36.2
CSM Plane Change #1	119:47:13.2	19:16:09:13.2
ΔT = 18.2 ΔV = 350	119:47:31.4	19:16:09:31.4
Ascent	142:03:47.7	20:14:25:47.7
ΔT = 423.2 ΔV = 6057		
Insertion	142:10:50.9	20:14:32:50.9
Coelliptic Sequence Initiation	143:01:51.0	20:15:23:51.0
ΔT = 41.1 ΔV = 45	143:02:32.1	20:15:24:32.1
Constant Differential Height	144:00:02.6	20:16:22:02.6
ΔT = 13 ΔV = 13.8	144:00:15.6	20:16:22:15.6
Terminal Phase Initiation	144:36:26.	20:16:58:26.
ΔT = 26 ΔV = 29	144:36:52.	20:16:58:52.
Lunar Docking	145:36:20.2	20:17:58:20.2
Lunar Module Jettison	147:59:31.6	20:20:21:31.6

TABLE 5.1. APOLLO MISSION 12 SEQUENCE OF EVENTS (Con't)

	GET (h:m:s)	GMT(d:h:m:s)
CSM Separation	148:04:30.9	20:20:26:30.9
ΔT = 5.4 ΔV = 1.0	148:04:36.3	20:20:26:36.3
Lunar Module Deorbit	149:28:14.8	20:21:50:14.8
ΔT = 82.1 ΔV = 196.2	149:29:36.9	20:21:51:36.9
Lunar Module Impact	149:55:16.4	20:22:17:16.4
CSM Plane Change #2	159:04:45.5	21:07:26:45.5
ΔT = 19.3 ΔV = 382	159:05:04.8	21:07:27:04.8
Transearth Injection	172:27:16.8	21:20:49:15.8
ΔT = 130.3 ΔV = 3042	172:29:27.1	21:20:51:27.1
Midcourse Correction #2	188:27:15.8	22:12:49:15.8
ΔT = 4.4 ΔV = 2.0	188:27:20.2	22:12:49:20.2
Midcourse Correction #3	241:21:59.7	24:17:43:59.7
ΔT = 5.7 ΔV = 2.4	241:22:05.4	24:17:44:05.4
CM/SM Separation	244:07:20.1	24:20:29:20.1
Entry Interface	244:22:19.1	24:20:44:19.1

ΔT burn duration in seconds
ΔV velocity change in feet per second

Table 5.2 DESCENT AND RENDEZVOUS MANEUVER SUMMARY FOR APOLLO 12

Maneuver	Type of Maneuver	Ignition Time (h:M:S) GET	Cutoff Time (h:M:S) GET	T/M Coverage
Separation	CSM/RCS	108:24:36.8	108:24:51.2	Yes
DOI	LM/DPS	109:23:39.9	109:24:08.9	No
PDI	LM/DPS	110:20:38.1	110:32:35.1	Yes
Ascent	LM/APS	142:03:47.7	142:10:50.9	Yes
CSI	LM/RCS	143:01:51	143:02:32.1	No
CDH	LM/RCS	144:00:02.6	144:00:15.6	Yes
TPI	LM/RCS	144:36:26	144:36:52	No

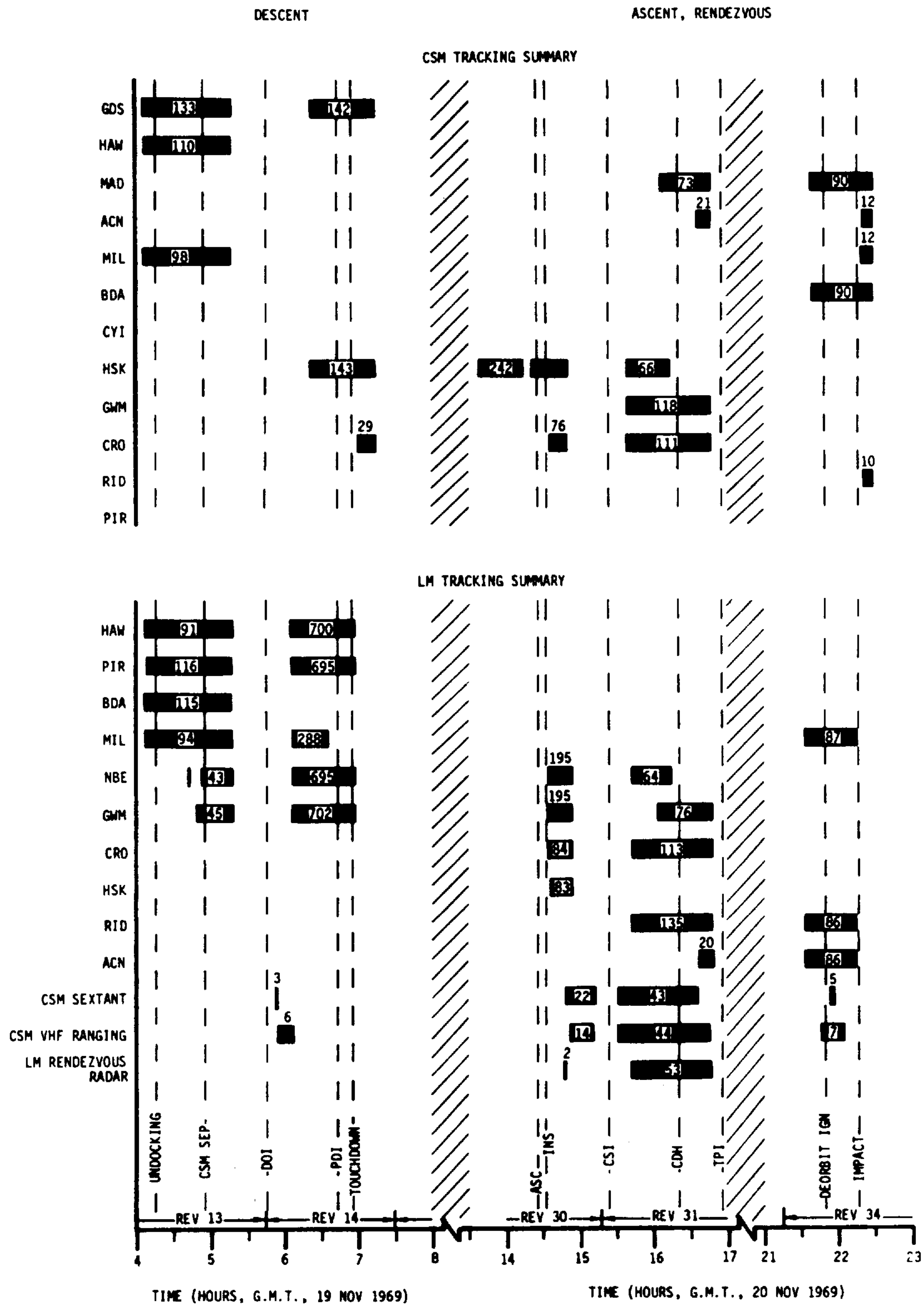

Figure 5-1. Tracking Summary for Descent and Rendezvous

to utilize the RTCC state vectors again for generation of the Apollo 12 preliminary NAT (NASA Apollo Trajectory) and to limit Apollo 12 postflight trajectory reconstruction to the descent and rendezvous phases of the lunar mission. The bulk of the postflight analysis effort was then concentrated on reconstruction of the two periods of flight from LM/CSM undocking to LM touchdown (descent phase) and from LM ascent to LM/CSM docking (rendezvous phase), along with the LM trajectory from deorbit to lunar impact.

The final NAT was produced by updating the preliminary NAT to include reconstructions of critical maneuvers for which telemetered acceleration data was available and to reflect the results of the trajectory reconstruction efforts performed on the descent and rendezvous periods of the mission. These reconstructions will be discussed in detail in Section 5.3.

The mission was essentially nominal and the analysis was carried out in accordance with the postflight analysis plan. Data quality was satisfactory, and no special difficulties were encountered in the trajectory reconstruction.

Table 5.3 PRELIMINARY NAT CSM SEGMENT 1 - POST TLI TO LUNAR SOI

RTCC Vector ID	Propagation Interval Hr:Min:Sec (GET) Start	Stop	δR (ft)	δV (ft/sec)	Comments
HSRC 001	02:53:00	04:03:00	57,275.*	7.3*	Post TLI to Ejection
BDAX 074	04:13:00	11:31:00	16,056.	0.5**	Ejection to Water Dump
MILX 163	11:38:00	30:48:00	19,928.	0.4	Water Dump to MCC2
HSKX 236	30:52:52.5	42:18:00	20.419	0.3	MCC2 to 42:18
BDAX 326	42:20:00	68:28:00	21,766	0.2***	42:20 to Lunar SOI

*The HSRC 001 segment is of low quality because HSRC 001 was a TLI cutoff vector which preceeded approximately 10 minutes of unmodeled S-IVB venting. Unmodeled T&D and Ejection maneuvers added to the ΔV also.

**ΔV due to the water dump is not modeled.

***Comparison is made with the first propagation interval of the 'CSM Segment 2' BET.

5.2 PRELIMINARY NAT

The CSM preliminary NAT was generated in four segments; the Command Module (CM) preliminary entry NAT in one segment; and the LM preliminary NAT in three BET segments. Each individual segment will be discussed in later sections.

Best Estimated Trajectory (BET) ephemerides for the CSM and LM vehicles were generated from the best RTCC trajectories determined during the mission (RTCC anchor vectors). A preliminary NAT for each vehicle was then formed by propagating and transforming these BET's into several standard Apollo coordinate systems. The LM preliminary NAT was augmented by the inclusion of the lunar powered descent and ascent trajectories which were reconstructed in near real time, and also by the deorbit to lunar impact trajectory.

The various preliminary NAT BET deliverables were generated in the form of magnetic tapes and listings (hard copy and 16 mm film) according to prescribed delivery schedules.

5.2.1 CSM Segment 1 - TLI Burn Cutoff to Lunar SOI

The "CSM Segment 1" free flight BET for the period from TLI burn cutoff to lunar SOI (sphere of influence) was generated from five selected RTCC state vectors which were propagated at 10-minute intervals. A summary of the five trajectory intervals is given in Table 5.3. As a check on the consistency of the segments, the RSS position and velocity differences (δR, δV) were computed at a common epoch for successive trajectory segments. Unless otherwise noted, δV has been corrected for known thrust velocity increments.

5.2.2 CSM Segment 2 - Lunar SOI to LOPC-1

The "CSM Segment 2" free flight BET for the period from lunar SOI to lunar orbit plane change-1 (LOPC-1) was generated from 19 selected RTCC state vectors. The state vectors were propagated at 1-minute intervals in lunar orbit and at 10-minute intervals during the translunar coast prior to LOI-1. As an indicator of the consistency of the 19 trajectory segments, the RSS position and velocity differences (δR and δV (corrected for thrust velocity across burns)) are computed at a common epoch for successive segments. The 19 free flight intervals are defined in Table 5.4.

NOTE: The selenographic orbit inclination in this segment (data word No. 56) was improperly coded in the NAT program and should be ignored.

Table 5.4 PRELIMINARY NAT CSM SEGMENT 2 - LUNAR SOI TO LOPC-1

RTCC Vector ID	Propagation Interval Hr:Min:Sec (GET) Start	Stop	δR (ft)	δV (ft/sec)	Comments
MILX 473	68:51:00	83:25:22.7*	----	----	Lunar SOI to LOI-1
HSKX 497	83:31:14.7	85:34:00	892	1.6	Rev 1
GWMX 504	85:35:00	87:48:47.4**	3017	1.0	Rev 2
HAWX 519	87:49:04.4	89:39:00	1773	1.8	Rev 3
HSKX 524	89:40:00	91:39:00	2146	1.7	Rev 4
HSKX 530	91:40:00	93:39:00	4906	9.1	Rev 5
NBEX 541	93:40:00	95:34:00	3366	5.0	Rev 6
ACNX 550	95:35:00	97:34:00	3701	2.9	Rev 7
BDAX 556	97:35:00	99:34:00	4087	3.3	Rev 8
CYIX 564	99:35:00	101:29:00	4198	3.8	Rev 9
GDSX 575	101:30:00	103:29:00	2763	6.9	Rev 10
GDSX 586	103:30:00	105:24:00	8494	3.0	Rev 11
HAWX 595	105:25:00	107:24:00	4750	4.4	Rev 12
NBEX 128	107:25:00	108:23:00	2326	2.3	Rev 13 to Sep.
CROX 609	108:24:00	111:19:00			Sep. Rev 13 through Rev 14
CROX 614	111:20:00	113:19:00	2886	4.3	Rev 15
CROX 618	113:20:00	115:19:00	3269	4.0	Rev 16
CROX 621	115:20:00	116:45:00	5534	6.0	Rev 17 (short)
HSKX 624	116:46:00	119:47:12.5	7086	3.3	Rev 18 to LOPC-1
			6617	1.1	

*LOI-1 ignition (ignore BET time points between ignition and cutoff)

**LOI-2 ignition (ignore BET time points between ignition and cutoff)

5.2.3 CSM Segment 3 - LOPC-1 to Lunar SOI

The "CSM Segment 3" free flight BET for the period from LOPC-1 to lunar SOI was generated from 27 selected RTCC state vectors which were propagated at 1-minute intervals in lunar orbit and at 10-minute intervals during the transearth coast. As a check on the consistency of these vectors, the RSS position and velocity differences (δR, δV) were computed at a common epoch for successive trajectory segments.

The 27 propagation intervals are summarized in Table 5.5.

5.2.4 CSM Segment 4 - Lunar SOI to Entry Interface

The "CSM Segment 4" free flight BET for the period from lunar SOI to entry interface was generated from seven selected RTCC state vectors which were propagated at 10-minute intervals. A summary of the seven trajectory propagation intervals is given in Table 5.6. As a consistency check, the RSS position and velocity differences (δR, δV) are computed at a common epoch for successive segments. Only the ΔV for MCC 2 and MCC 3 are accounted for. The segments do not match as well as in the translunar phase because of unmodeled thrust incurred during numerous attitude maneuvers, water dump, fuel cell purge, and CM/SM separation.

The GWMS 147 vector yields an entry interface (Geodetic Altitude = 400,000 ft) time of 244:22:19.09 GET. Selected trajectory parameters at entry interface are as follows:

Inertial velocity	36116.618	ft/sec
Inertial flight path angle	-6.4834	deg
Inertial heading	98.1699	deg
Geodetic latitude	-13.7947	deg
Geodetic longitude	173.5279	deg

5.2.5 CM Segment 1 - Preliminary Entry

The "CM Segment 1" preliminary entry BET was reconstructed at 2-second intervals from PIPA acceleration data, using the GWMX 164 state vector (determined by RTCC) for initial conditions. The GWMX 164 vector was propagated to 244:22:25.59 GET to initialize the BET. The initial state in ECI (mean of NBY) coordinates at this time is:

$X = 20,431,408.8$ ft　　$\dot{X} = 10,403.059$ ft/sec

$Y = -3,193,006.5$　　$\dot{Y} = -34,386.006$

$Z = -5,077,174.6$　　$\dot{Z} = -3,937.787$

Geodetic Altitude = 371,820.4 ft

Table 5.5 PRELIMINARY NAT CSM SEGMENT 3 - LOPC-1 TO LUNAR SOI

RTCC Vector ID	Propagation Interval Hr:Min:Sec (GET) Start	Stop	δR (ft)	δV (ft/sec)	Comments
ACNX 634	119:47:30.7	121:14:00	3571	3.4	LOPC-1 through Rev 19
ACNX 637	121:15:00	123:14:00	1949	4.2	Rev 20
MILX 641	123:15:00	125:09:00	2612	1.8	Rev 21
MILX 644	125:10:00	127:09:00	3399	2.5	Rev 22
GDSX 650	127:10:00	129:09:00	3590	5.3	Rev 23
HAWX 654	129:10:00	131:04:00	2816	2.0	Rev 24
HAWX 659	131:05:00	133:04:00	2838	2.4	Rev 25
HSKX 663	133:05:00	134:59:00	2982	2.6	Rev 26
CROX 668	135:00:00	136:59:00	2593	4.2	Rev 27
HAWX 672	137:00:00	138:59:00	3579	3.8	Rev 28
HSKX 678	139:00:00	140:54:00	1731	1.4	Rev 29
CROX 680	140:55:00	142:54:00	1765	2.4	Rev 30
ACNX 687	142:55:00	145:36:00	----	3.8	Rev 31 to Dock
MADX 700	145:37:00	148:49:00	6015	5.7	Dock through Rev 33
MADX 702	148:50:00	150:49:00	2365	6.9	Rev 34
GDSX 712	150:50:00	152:44:00	2967	2.1	Rev 35
HAWX 719	152:45:00	154:44:00	3813	3.4	Rev 36
ACNX 725	154:45:00	156:39:00	3451	3.4	Rev 37
GWMX 731	156:40:00	159:04:44.8	----	4.4	Rev 38 to LOPC-2
GWMX 747	159:05:04.0	160:39:00	5686	6.3	LOPC-2 through Rev 39
GDSX 764	160:40:00	162:34:00	6173	2.4	Rev 40
HAWX 771	162:35:00	164:34:00	1573	2.2	Rev 41
CROX 776	164:35:00	166:34:00	1333	1.2	Rev 42
RIDX 783	166:35:00	168:29:00	1834	1.6	Rev 43
ACNX 794	168:30:00	170:29:00	4538	5.4	Rev 44
BDAX 800	170:30:00	172:27:16.1	----	----	Rev 45 to TEI
HSKX 866	172:29:26.1	186:28:00			TEI to Lunar SOI

Table 5.6 PRELIMINARY NAT CSM SEGMENT 4 - LUNAR SOI TO ENTRY INTERFACE

RTCC Vector ID	Propagation Interval Hr:Min:Sec (GET) Start	Stop	δR (ft)	δV (ft/sec)	Comments
HSKX 855	186:38:00	188:18:00			Lunar SOI to MCC 5
			4832	0.4	
HAWX 881	188:27:18.23	193:48:00			P23 attitude maneuvers
			62999	1.2	
MADX 909	193:58:00	200:58:00			Urine dump @ ≈ 195:45
			40980	1.1	
HSKX 960	201:08:00	217:18:00			P23 @ ≈213:00
			22023	1.6	
MADX 012	217:28:00	223:28:00			Water dump & fuel cell purge @ ≈ 217:30
			39939	1.3	
NBEX 127	223:38:00	241:21:47.5			Nominal MCC 7 time
			16838	1.4	
GWMS 147	241:30:00	244:22:19.09			Post MCC 7 to Entry Interface

The IMU acceleration data has been corrected for a platform misalignment of 167.7 sec about the Y-axis. This is a "single error fit" which causes the altitudes at drogue deploy, main deploy, and splashdown to be near the nominally expected values and does not necessarily represent the accuracy of the pre-entry P52 alignment.

The coordinates of the spacecraft at drogue deployment are compared with the targeted values and the onboard navigated values, and they are as follows:

Drogue Deploy, 244:30:39.7 GET

	Latitude (deg)	Longitude (deg)
BET	-15.831	-165.168
Target	-15.8125	-165.1740
Onboard Nav.	-15.836	-165.171

Altitudes at drogue deploy, main deploy, and splashdown, and mean descent rate on the main chute are compared with the pre-mission nominal values in Table 5.7.

5.2.6 LM Segment I - Undock to PDI and Insertion to Impact

The "LM Segment 1" preliminary free flight BET, covering undock to PDI and insertion to lunar impact, was generated from seven selected RTCC state vectors which were propagated at one-minute intervals. As a check on the consistency of these vectors, the RSS velocity difference, δV, is computed at a common epoch for successive trajectory segments. The seven trajectory segments are summarized in Table 5.8.

The early (real-time) estimate of the Ascent stage impact time was 149:55:15.76 GET. The selenographic coordinates of the MILX 279 vector at this time are:

LAT = -3.9549 deg LONG = -21.1609 deg R = 937.7784 nm

Table 5.7 COMPARISON OF DROGUE DEPLOY, MAIN DEPLOY, AND SPLASHDOWN ALTITUDES AND THE MAIN CHUTE MEAN DESCENT RATE WITH PRE-MISSION NOMINAL VALUES

	BET	Pre-Mission Nominal
Drogue Deploy Altitude 244:30:39.7	23,735 ft	23,300 {+1600 ft / -1600 ft}
Main Deploy Altitude 244:31:30.2	10,892 ft	10,500 {+1000 ft / -1050 ft}
Splashdown - 27.4 sec, Altitude 244:35:57.59*	805 ft	770 ft
Mean Descent Rate of Main Chute	31.2 ft/sec	28 ft/sec

*The DSE ran out at this time - nominal altitude is based on nominal descent rate.

Table 5.8 PRELIMINARY NAT LM SEGMENT 1 - FREE FLIGHT BET

RTCC Vector ID	Propagation Interval Hr:Min:Sec (GET) Start	Stop	δV (ft/sec)	Comments
NBEX 128	107:45:00	109:23:39.4	4.6	Undock to DOI
PIRX 159	109:24:08.4	110:20:37		DOI to PDI
GWMX 234	142:11:48	142:01:40.6	6.8	Insertion to CSI
RIDX 245	143:02:31.7	144:00:01.5	0.4	CSI to CDH
ACNX 256	144:00:14.0	144:36:29.4		CDH to TPI
RIDX 273	147:29:00	149:24:00	6.0	Jettison to Deorbit
MILX 279	149:26:02.4	149:55:15.76		Deorbit to Impact

5.2.7 LM Segment 2 - Real Time Powered Descent

The "LM Segment 2" Real Time LM Powered Descent BET was reconstructed at two-second intervals from LM IMU acceleration measurements transmitted through the MSFN communication network. Initial conditions prior to ullage were obtained from the best rev 14 trajectory determined by the RTCC.

The quality of the LGC downlink data was generally very good, in that only a few isolated dropouts occurred.

Altitudes above the lunar surface are computed with respect to the pre-flight estimate of the radius to Surveyor III. BET altitudes may be adjusted to the current best estimate of the LLS radius by subtracting 924 feet.

Indicated velocities relative to the lunar surface after landing are:

V_x (vertical) = -0.321 ft/sec

V_y (north) = -3.070 ft/sec

V_z (west) = 1.500 ft/sec

The most probable causes of the -3.070 feet per second error in North direction are platform X-axis misalignment and out-of-plane errors in the rev 14 orbit. Correction for these types of errors will move the landing point approximately 2000 - 3000 feet to the North. Correction of the small westward velocity error will move the landing point approximately 1000 feet to the East. The net result of these corrections is to move the BET close to the real-time best estimate of the landing site.

Estimates of LLS coordinates from several sources are shown in Table 5.9.

5.2.8 LM Segment 3 - Real Time Ascent

The "LM Segment 3" Real Time LM Ascent BET, at two-second intervals, was initialized at 142:03:23.78 GET (23.22 sec before ignition) using the current best estimate of LLS coordinates.

Table 5.9 PRELIMINARY ESTIMATES OF LLS COORDINATES

Source of Estimate	Latitude (deg)	Longitude (deg)	Radius (n mi)
BET	-3.0442	-23.4286	937.31188 (-7179.8 ft wrt* MLR*)
Best Estimate (real time-Combination of LM P22 tracking and CSM P22 sightings)	-3.036	-23.418	937.3643 (-6861.3 ft wrt MLR)
P57A/T 2 (Least square fit of two alignments)	-3.069	-23.414	

*wrt - with respect to
MLR - mean lunar radius

LAT = -3.036 deg LONG = -23.418 deg R = 937.3643 nm

The trajectory was terminated at 142:12:15.78 GET (approximately 26 seconds after conclusion of the trim maneuver). The total thrust velocity accumulated by the PGNCS (uncorrected) between 142:03:45.78 and 142:11:49.78 is given below in platform coordinates:

ΔV_x = 1326.776 ft/sec ΔV_y = -1.064 ft/sec ΔV_z = -5590.449 ft/sec

Selected orbit insertion parameters are listed below:

Perilune Altitude wrt LLS = 8.867 nm

Apolune Altitude wrt LLS = 47.52 nm

Selenographic Orbit Inclination = -14.568 deg

5.3 FINAL NAT

The final NAT was produced by updating the preliminary NAT to include reconstructions of critical maneuvers for which telemetered acceleration data was available and to reflect the results of the trajectory reconstruction efforts performed on the descent and rendezvous periods of the mission. These reconstructions will be discussed in detail later. Note that the preliminary NAT serves as the final NAT for those periods where no update was made.

5.3.1 CSM LOI-1 and TEI Burn Trajectory Reconstructions

Postflight trajectory reconstruction of the LOI-1 and TEI burns were delivered to MSC on 13 December 1969. These trajectories were generated to satisfy the special request from North American Rockwell to the MPSO Postflight Trajectory Office, and were not generally distributed.

5.3.1.1 LOI-1 Burn

For the pre-burn comparison, the RTCC vector (MILX 473) was propagated in the HOPE Program using the L1 potential model. The RTCC propagated vector, time tagged 18 November 1969, 03:47:23.40 GMT (83:25:23.40 GET), was compared to the BET vector which was reconstructed, using the HOPE Program, from MSFN data covering a time interval of 870 minutes starting at 17 November 1969, 13:00:00 GMT.

For the post-burn comparisons, the RTCC vector (HSKX 497) was propagated in the HOPE Program using the L1 potential model. The RTCC propagated vector, time tagged 18 November 1969, 03:53:19.40 GMT (83:31:19.40 GET), was compared to the BET vector which was reconstructed from PIPA acceleration data using the pre-burn BET vector for initial conditions.

Likewise, a rev 1 trajectory was reconstructed with the HOPE Program using MSFN data covering a time interval of 85 minutes starting at 18 November 1969, 04:06:00 GMT. This was compared to the BET vector shortly after burn cutoff.

The results of these comparisons are tabulated in Table 5.10.

5.3.1.2 TEI-Burn

No pre-burn comparison was made.

For the post-burn comparison, the RTCC vector (HSKX 866) was propagated in the HOPE Program using the L1 potential model. The RTCC propa-

Table 5.10. LOI-1 AND TEI POWERED FLIGHT TRAJECTORIES

	Selenographic			Moon Inertial						Radius	
	Latitude	Longitude	Altitude	Path Angle	Heading	Velocity	Inclination	Right Ascension Node	Argument Perigee	Apolune	Perilune
	Deg	Deg	Ft	Deg	Deg	fps	Deg	Deg	Deg	N. Mi.	N. Mi.
PRE-LOI-1											
BET MSFN FIT	5.7566	175.6237	502963.1	-8.4476	229.3447	8173.587	---------	---------	---------	----------	1002.2976
RTCC	5.7438	175.6053	501438.0	-8.4365	229.3475	8174.511	---------	---------	---------	----------	1002.1005
Δ	+ .0128	+ .0184	+ 1525.1	- .0111	- .0028	- .924	---------	---------	---------	----------	+ .1971
POST LOI-1											
BET PIPA	-1.6900	153.8481	374824.8	- .5918	239.3104	5469.997	145.1314	163.6389	223.8094	1107.0664	999.0792
RTCC	-1.6702	153.8502	375030.6	- .6203	239.3549	5470.321	145.1770	163.6594	224.3505	1107.5601	999.0073
Δ	- .0198	- .0021	- 205.8	+ .0285	- .0445	- .324	- .0456	- .0205	- .5411	- .4937	+ .0719
BET PIPA	-1.6900	153.8481	374824.8	- .5918	239.3104	5469.997	145.1314	163.6389	223.8094	1107.0664	999.0792
MSFN	-1.6803	153.8493	375122.2	- .6205	239.3416	5470.263	145.1612	163.6620	224.3606	1107.5635	999.0217
Δ	- .0097	- .0012	- 297.4	+ .0287	- .0312	- .266	- .0298	- .0231	- .5512	- .4971	+ .0575
POST TEI											
BET PIPA	7.1977	176.4330	441203.7	5.6417	242.3095	8327.470	---------	---------	---------	----------	1001.7405
RTCC	7.1780	176.4092	439891.5	5.6630	242.2076	8328.854	---------	---------	---------	----------	1001.4603
Δ	+ .0197	+ .0238	+ 1312.2	- .0213	+ .1019	- 1.384	---------	---------	---------	----------	.2802

NOTE: All RTCC vectors referred to here are those used in generation of the Preliminary Free Flight BET.

Landing Site Radius is 937.3643 n.mi.

gated vector, time tagged 21 November 1969, 20:52:30.86 GMT (172:52:30.86 GET) was compared to the BET vector which was reconstructed from PIPA acceleration data using the propagated RTCC vector (BDAX 800) for initial conditions. The results are tabulated in Table 5.10.

5.3.2 LM Powered Descent

The "Final LM Powered Descent BET" update was delivered earlier than planned in response to requests for an improved surface relative trajectory during the visibility phase. The descent trajectory was initialized from the PIRX 159 vector determined by the RTCC and downrange/crossrange position errors are evident. Rev 14 trajectory determination subsequent to delivery of the BET improved the accuracy of the local solutions near PDI, causing the position errors at landing to decrease significantly. The relative trajectory, however, changed only slightly, and no further update to the BET was made.

The final version of the LM Powered Descent BET was initialized at 110:20:10.19 GET (2 seconds after Average G On). Initial conditions were taken from the PIRX 159 trajectory determined by the RTCC. The trajectory was reconstructed by integrating two-second IMU acceleration measurements with alignment corrections needed to satisfy the landing constraints.

5.3.2.1 IMU Corrections and Trajectory Constraints

In order to satisfy the velocity constraint at landing, the following set of alignment errors were used:

Error	Magnitude
PHIX (platform misalignment about X)	157.2 $\widehat{\text{sec}}$
PHIY (platform misalignment about Y)	-110.0 $\widehat{\text{sec}}$
XZMSL (X PIPA misalignment toward Z)	-53.8 $\widehat{\text{sec}}$
ZXMSL (Z PIPA misalignment toward X)	-59.5 $\widehat{\text{sec}}$

The "Best Estimate" of the coordinates of the Lunar Landing Site is derived from rev 15 rendezvous radar tracking of the CSM and rev 16 SXT sightings on the LM. The LM Ascent BET and the postflight processing of lunar surface alignment (P57) data are in close agreement with the "Best Estimate".

The coordinates of the Lunar Landing Site indicated by the BET are compared to the "Best Estimate" as follows:

LLS COORDINATES

Source	Latitude	Longitude	Altitude (With respect to MLR)
Powered Descent BET	-3.027 deg	-23.426 deg	-6354. ft
Best Estimate	-3.043 deg	-23.416 deg	-6861. ft

The unit error sensitivities of the state vector (in platform coordinates) at landing with respect to PHIX and PHIY (in sec) are as follows: Units are feet and feet per second.

	ΔX_{LLS}	ΔY_{LLS}	ΔZ_{LLS}	$\Delta \dot{X}_{LLS}$	$\Delta \dot{Y}_{LLS}$	$\Delta \dot{Z}_{LLS}$
PHIX	0	-11.4	0	0	-0.025	0
PHIY	12.8	0	2.1	0.033	0	0.011

The unit error sensitivities of the state vector (platform coordinates) at landing with respect to the initial state (near PDI) are as follows: Units are feet and feet per second.

	ΔX_{LLS}	ΔY_{LLS}	ΔZ_{LLS}	$\Delta \dot{X}_{LLS}$	$\Delta \dot{Y}_{LLS}$	$\Delta \dot{Z}_{LLS}$
ΔX_{PDI}	1.54	0	-0.09	1.60 E-3	0	0
ΔY_{PDI}	0	0.75	0	0	-0.63 E-3	0
ΔZ_{PDI}	-0.11	0	0.77	0	0	-0.61 E-3
$\Delta \dot{X}_{PDI}$	885.1	0	-11.5	1.57	0	-0.02
$\Delta \dot{Y}_{PDI}$	0	686.7	0	0	0.75	0
$\Delta \dot{Z}_{PDI}$	-12.9	0	688.3	-0.03	0	0.75

The position error in the LLS indicated by the BET is thus seen to be within reasonably expected error bounds for the PIRX 159 trajectory at PDI.

Two-second PIPA counts in the vicinity of landing are shown in Figure 5-2. The impulse caused by impact is evident in the interval 110:32:36.19 - 110:32:38.19 GET, indicating that the vehicle became stationary within this period. Altitude and descent rate from low gate to landing are shown in Figure 5-3, and the groundtrack is shown in Figure 5-4.

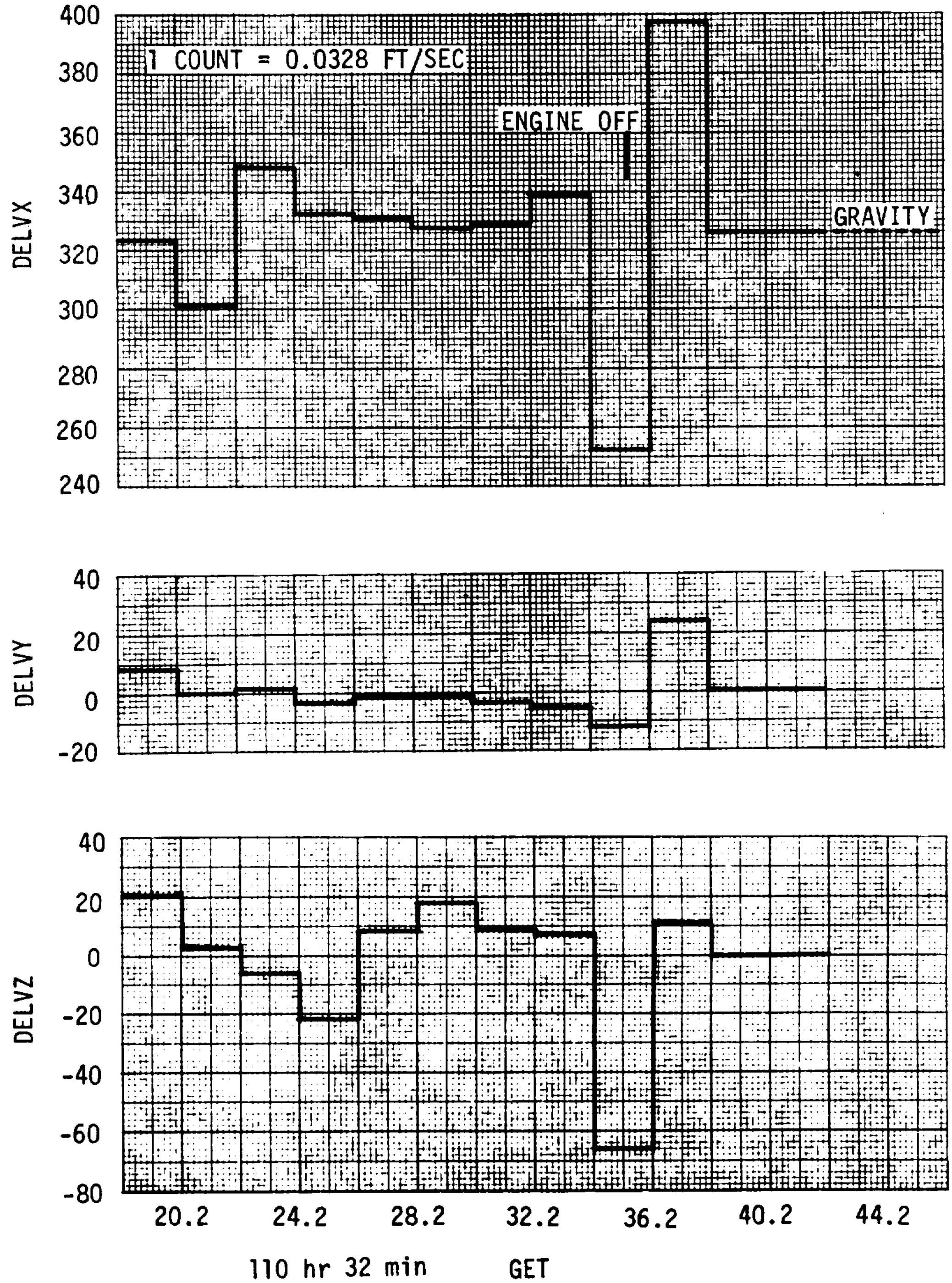

Figure 5-2. Two-Second PIPA Counts Near Landing Time

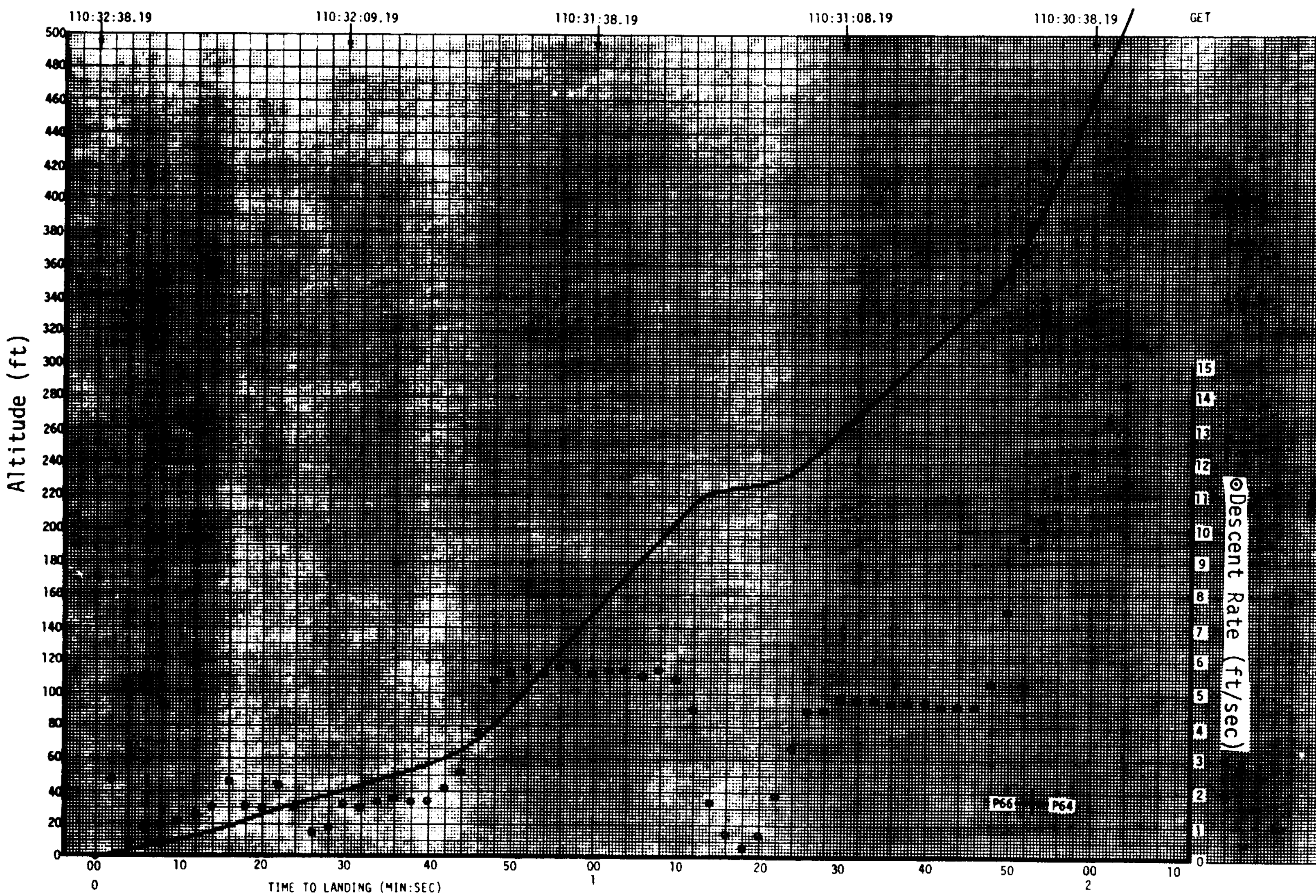

Figure 5-3. Altitude and Descent Rate: Low Gate to Landing

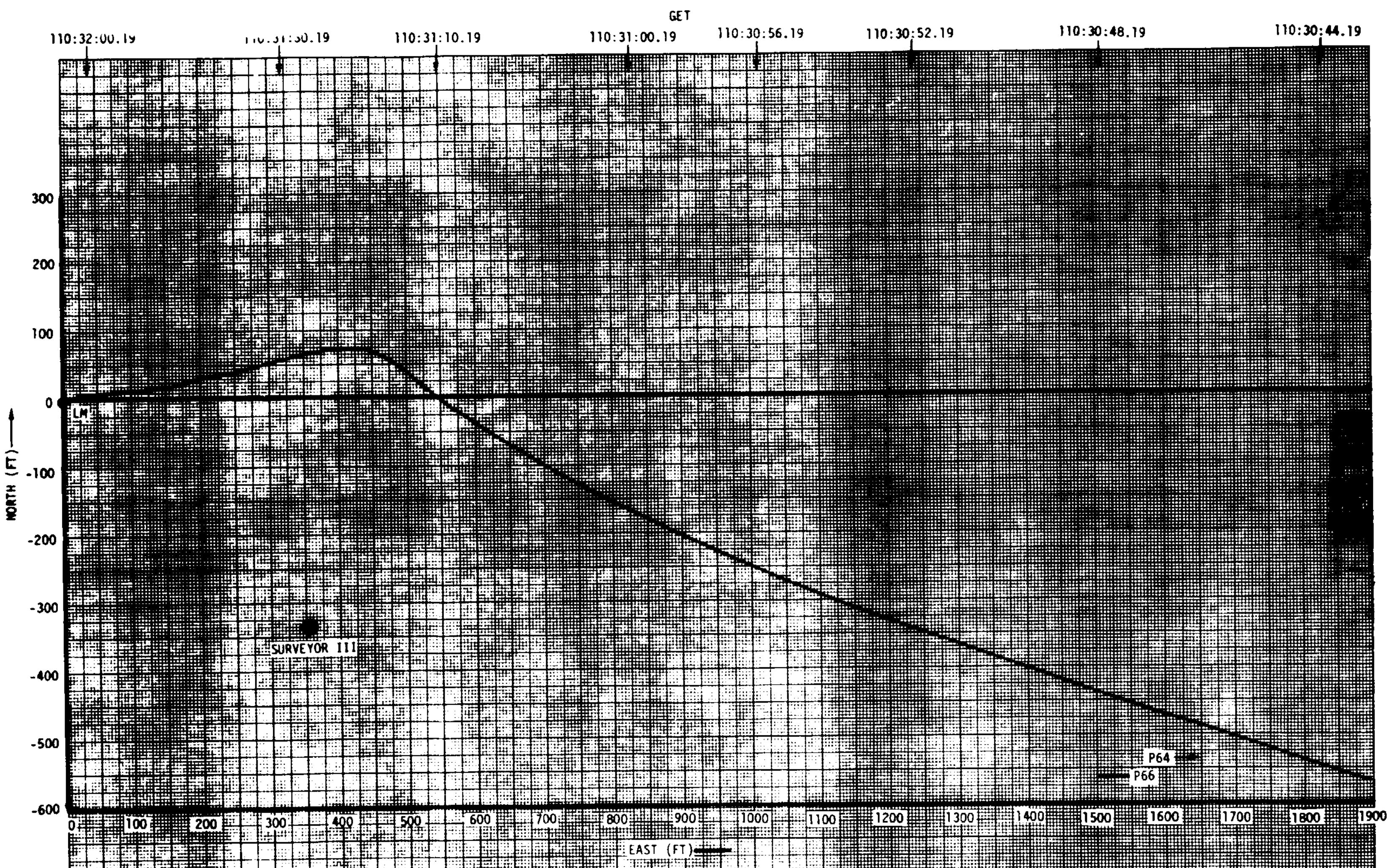

Figure 5-4. LM Groundtrack from Low Gate to Landing

5.3.2.2 Rev 14 Orbit Determination

Subsequent to the delivery of the BET, landing radar and high speed doppler data have been included in the HOPE Program orbit determination. The results are believed to indicate an improved local solution near PDI for the following reasons: 1) lower high speed doppler residuals; 2) LLS coordinates are closer to the "Best Estimate". The results of this further analysis of the LM powered descent trajectory is presented in Section 5.4.

5.3.3 LM Ascent and Insertion to CSI Trajectories

The postflight reconstruction of the LM trajectory from liftoff to CSI was delivered to MSC on 13 January 1969. This iteration superceeds the earlier (real time) version described in Section 5.2.8.

5.3.3.1 Ascent Trajectory

The powered flight trajectory (liftoff to orbit insertion) was reconstructed by integrating IMU acceleration data with corrections for known errors. The initial conditions were taken from the best available estimate of the LLS coordinates.*

LAT = -3.036 deg LONG = -23.418 deg R = 937.3643 nm

The powered flight reconstruction begins at 142:03:23.78 GET (APS ignition is 142:03:47.68) and ends at 142:11:51.78 (about 6 seconds after completion of RCS trim). Accumulated thrust velocities in platform coordinates (obtained from corrected IMU data) are as follows:

GET	ΔV_X ft/sec	ΔV_Y ft/sec	ΔV_Z ft/sec
142:03:47.78 (APS Ignition)	0	0	0
142:11:01.78 (APS Off)	1306.53	-5.66	5625.49
142:11:51.78 (End RCS Trim)	1313.12	-4.48	5595.18

*At the time of writing, the coordinates of the LLS were revised to LAT = -3.043 deg, LONG = -23.416 deg, R = 937.365 nm (Reference 1).

IMU Errors: The following corrections were made to the telemetered IMU acceleration data:

Accelerometer Bias	BX	= 0.15 cm/sec^2 (153 μg)
	BY	= 0.20 cm/sec^2 (204 μg)
	BZ	= -0.29 cm/sec^2 (-296 μg)
Platform Misalignment	PHIY	= -21.6 $\widehat{sec}$
	PHIZ	= -43.2 $\widehat{sec}$

The PIPA bias changes are computed from free orbit data on rev 14 (prior to PDI) and rev 30 (after insertion). The bias change is believed to be a result of removing power to the IMU.

Platform misalignments prior to liftoff have been estimated from lunar surface alignment (P57) data (Reference 14). The values obtained are as follows:

Misalignment Angle	Mean	RMS Uncertainty
ϕ_X	-0.013 deg	0.025 deg
ϕ_Y	-0.010 deg	0.025 deg
ϕ_Z	-0.007 deg	0.025 deg

The misalignments used in the BET were chosen so as to produce best agreement of insertion conditions with the free flight trajectory. They are well within the 1σ uncertainties of the P57 estimates.

5.3.3.2 Comparison of Insertion Conditions

Comparison of the powered flight trajectory reconstruction and the free flight trajectory near orbit insertion is given in Table 5.11. The time of the comparison is 142:11:51.77 GET.

The inertial platform is aligned such that X ≈ vertical, Y ≈ crossrange, Z ≈ downrange at liftoff. The sensitivities of the state vector at orbit insertion to the coordinates of the LLS are given in Table 5.12. All quantities are in feet and feet per second in platform coordinates.

It can be seen that the crossrange position difference will become insignificant if the LLS is moved approximately 1000 feet (.01 deg) to the South. This is consistent with the revised estimates of the LLS coordinates.

Table 5.11 COMPARISON OF POWERED FLIGHT AND FREE FLIGHT TRAJECTORY CONDITIONS NEAR INSERTION (142:11:51.77 GET)

Trajectory Parameter		Powered Flight Trajectory	Free Flight Trajectory	Delta (Powered Flight-F.F.)
Platform Coordinates	X	5604697.1 ft	5604377.1 ft	320 ft
	Y	736.1 ft	-293.3 ft	1029 ft
	Z	1317309.3 ft	1316757.5 ft	552 ft
	V_X	-1227.864 ft/sec	-1227.995 ft/sec	0.13 ft/sec
	V_Y	-1.051 ft/sec	-0.878 ft/sec	-0.17 ft/sec
	V_Z	5401.836 ft/sec	5403.272 ft/sec	-1.44 ft/sec
Perilune Altitude (above LLS)		8.9513 nm	8.9183 nm	199 ft
Apolune Altitude (above LLS)		50.9877 nm	51.7589 nm	-4696 ft
Selenographic Orbit Inclination		165.4679 deg	165.4698 deg	-.0019 deg
Inertial Flight Path		0.4205 deg	0.4179 deg	.0026 deg
Inertial Heading		-55.3418 deg	-55.3403 deg	-.0015 deg

Table 5.12 SENSITIVITIES OF THE STATE VECTOR AT ORBIT INSERTION TO THE COORDINATES OF THE LLS

	ΔX_{INS}	ΔY_{INS}	ΔZ_{INS}	$\Delta \dot{X}_{INS}$	$\Delta \dot{Y}_{INS}$	$\Delta \dot{Z}_{INS}$
ΔX_{LLS}	1.250	0	0.012	0.0010	0	0.0001
ΔY_{LLS}	0	0.882	0	0	-0.0005	0
ΔZ_{LLS}	0.010	0	0.883	0	0	-0.0004

Units are in ft and ft/sec

5.3.3.3 Free Flight Trajectory Insertion to CSI

The free flight LM trajectory from insertion to CSI was determined from 557 MSFN doppler observations, 22 SXT sightings, 14 VHF ranging observations, and 2 rendezvous radar marks. The converged residual statistics are summarized as follows:

Station	Type	No. Obs.	Mean	Sigma
HSK	MSFN	83	.070 cps	.477 cps
GWM	MSFN	195	-.027 cps	.558 cps
NBE	MSFN	195	-.018 cps	.555 cps
CRO	MSFN	84	.044 cps	.540 cps
CSM	SXT Shaft	22	-.002 deg	.022 deg
CSM	SXT Trunnion	22	-.006 deg	.007 deg
CSM	VHF Ranging	14	-232. ft	200. ft
LM	RR Range	2	323. ft	13. ft
LM	RR Range Rate	2	-.380 ft/sec	.157 ft/sec
LM	RR Shaft	2	.015 deg	.020 deg
LM	RR Trunnion	2	-.043 deg	.020 deg

Plots of the SXT and VHF ranging residuals are shown in Figures 5-5, 5-6, and 5-7.

The purpose of reconstructing the free flight trajectory is to obtain insertion conditions as accurately as possible. Since the bulk of the relative observations occur after rev 30 LOS, the MSFN data dominates the fit. This is reflected in the VHF range residuals which show a clearly defined trend. As a check on the quality of the onboard data, a fit was made without the MSFN. The residual statistics show substantial improvement:

Data Type	Mean	Sigma
SXT Shaft	-.002 deg	.022 deg
SXT Trunnion	.0003 deg	.004 deg
VHF Range	-37.8 ft	58.3 ft

The two trajectories agree very well just before LOS, since this region is included in both the MSFN and onboard data spans. Comparison of MCI state vectors (Relative - BET) at 142:25:00 GET yields:

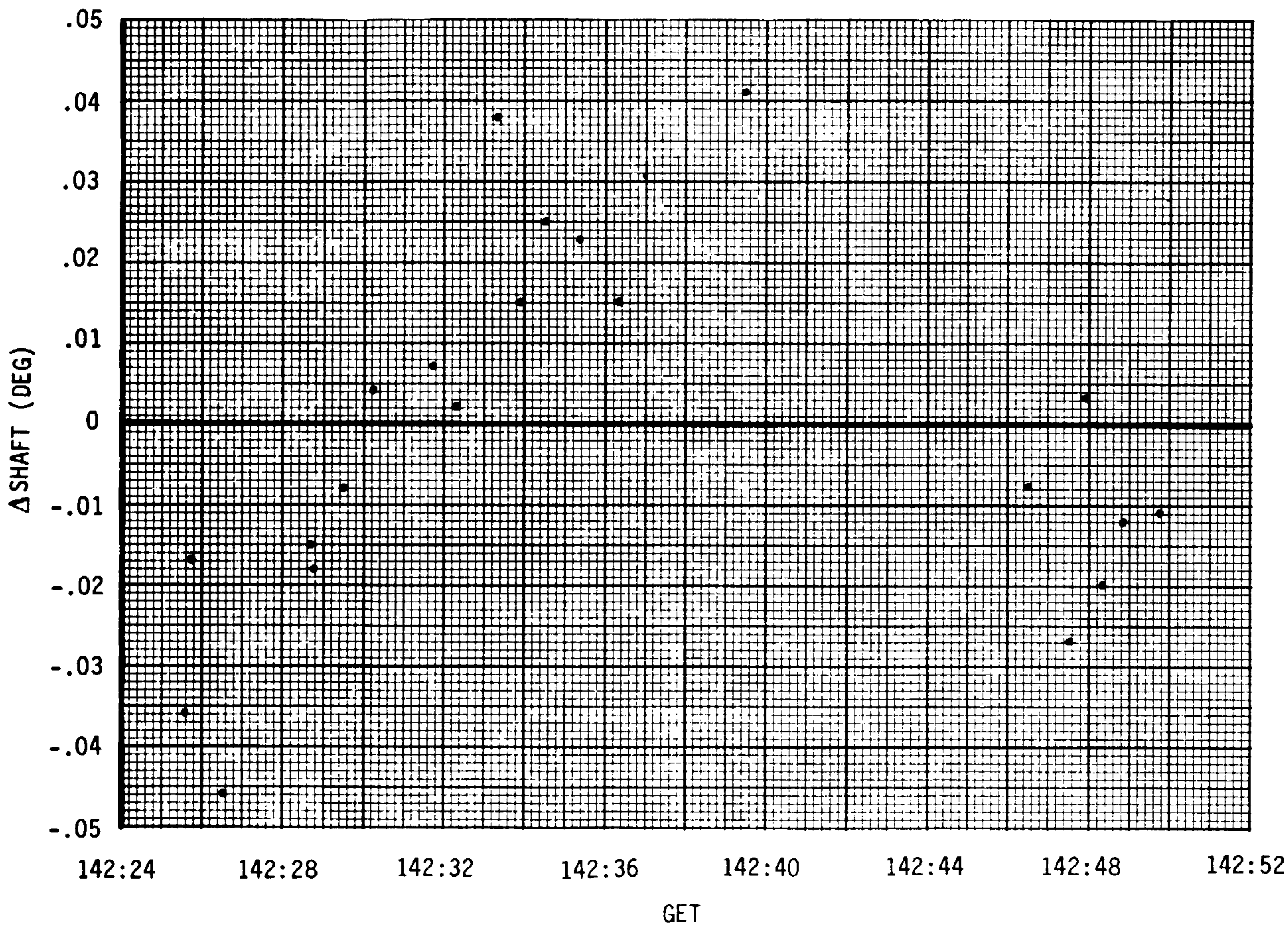

Figure 5-5. Converged SXT Shaft Residuals - Insertion to CSI

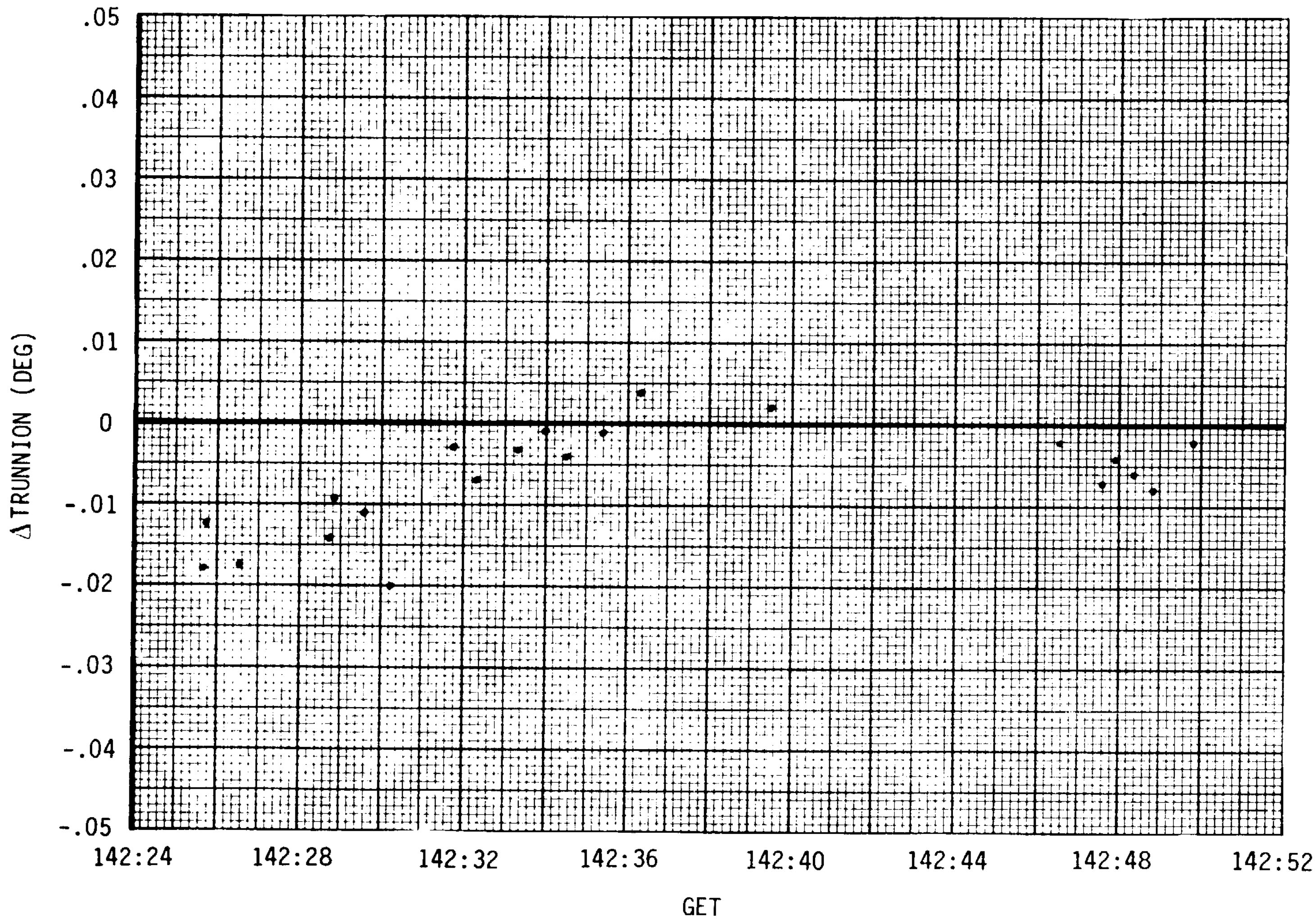

Figure 5-6. Converged SXT Trunnion Residuals - Insertion to CSI

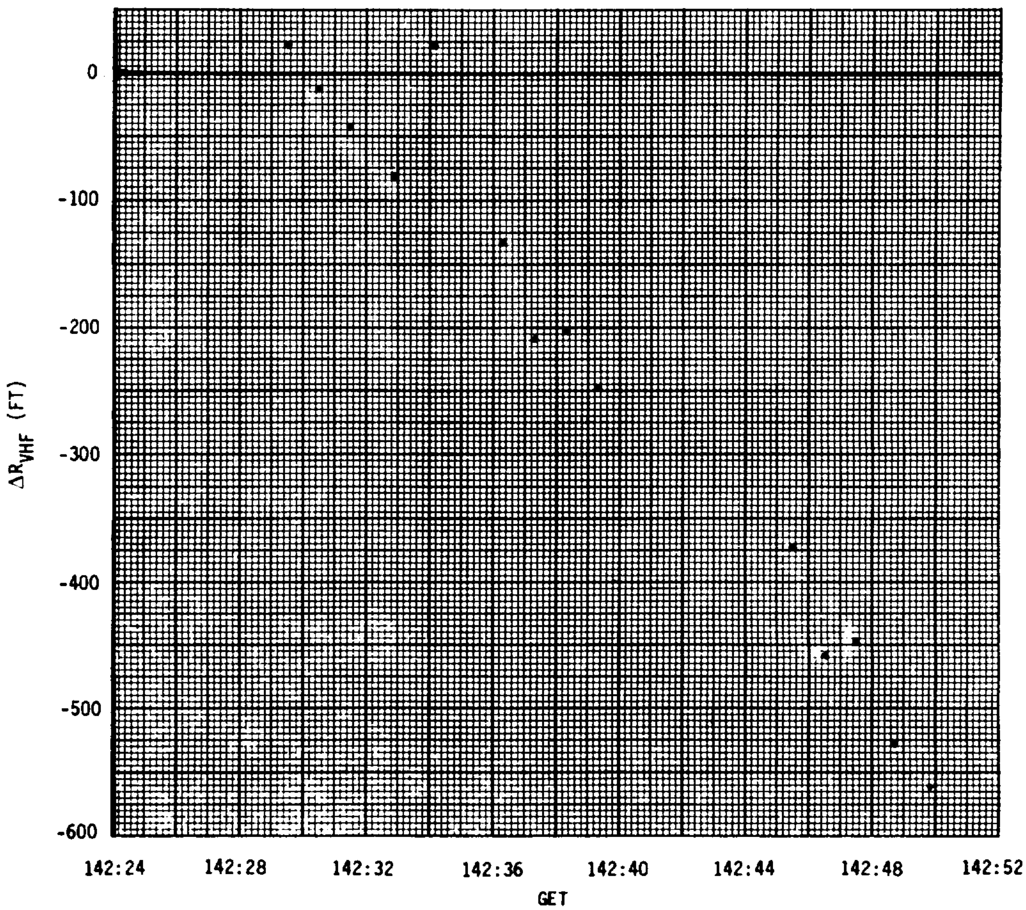

Figure 5-7. Converged VHF Ranging Residuals - Insertion to CSI

ΔX	ΔY	ΔZ	$\Delta \dot{X}$	$\Delta \dot{Y}$	$\Delta \dot{Z}$
-255 ft	334	202	0.50 $\frac{ft}{sec}$	-0.62	-0.39

5.3.4 LM Ascent Stage Impact Trajectory

The postflight trajectory for the LM on rev 34 (including the impact burn) is the final version of the rev 34 LM trajectory and superceeds the preliminary version of 25 November 1969.

The rev 34 (deorbit) trajectory for the LM was reconstructed from MSFN doppler data from RID (Madrid, 2-way), MIL, ACN (100 observations pre-burn and 159 observations post-burn), 5 SXT shaft angles, 2 SXT trunnion angles, 7 VHF ranging points, and the thrust profile of the deorbit burn obtained from IMU accelerometer data.

The converged residual statistics for all of the observations used in the fit are as follows:

No. OBS.	Station	Type	Mean	Sigma
86	RID	MSFN	.348 cps	1.404 cps
87	MIL	MSFN	.235 cps	1.416 cps
86	ACN	MSFN	.342 cps	1.356 cps
5	CSM	SXT Shaft	.001 deg	.019 deg
2	CSM	SXT Trunnion	.033 deg	.128 deg
7	CSM	VHF Range	-470 ft	506 ft

The accumulated thrust velocities in IMU platform coordinates due to the deorbit burn are:

$$\Delta V_X = -188.57 \text{ ft/sec}$$

$$\Delta V_Y = 54.15 \text{ ft/sec}$$

$$\Delta V_Z = -6.21 \text{ ft/sec}$$

The time of impact is estimated to be 149:55:16.46 GET. The selenographic coordinates of the impact point are:

LATITUDE = -3.944 deg
LONGITUDE = -21.196 deg
RADIUS = 5697847 ft

Selenographic Orbit Inclination = -14.531 deg
Relative Velocity Magnitude = 5517.2 ft/sec
Relative Flight Path Angle = 3.717 deg

5.4 POWERED DESCENT TRAJECTORY ANALYSIS

5.4.1 Rev. 14 Orbit Determination

Attempts to reconstruct the Rev. 14 trajectory from lo-speed doppler data yielded results not significantly different from PIRX-159 which was used to generate the Final BET (Section 5.3.2). The option for including Landing Radar velocity data in the HOPE orbit determination became available during the Apollo XII postflight period. All available trajectory data sources have now been used to determine the LM trajectory from AOS to Landing. These data include:

MSFN Lo-Speed (6 sec): AOS to PDI
MSFN Hi-Speed (compacted to 2 sec): PDI to Landing
Landing Radar Velocity
Thrust Acceleration Profile from LGC Telemetry.

The principal discrepancy in the Final BET is the large downrange position error at time of landing. ("Error" is defined as difference from the Best Estimate of the LLS.) As illustrated in Figure 5-8, the trajectory determination employing hi-speed doppler and landing radar reduces both the downrange and crossrange errors by about half. No further attempts were made to refine the crossrange error. Examination of the doppler residuals (2-way and 3-way) revealed a pattern similar to that of Figure 5-9. The time interval 110:04 - 110:13, containing the large "wiggle," is just the period in which the LM is passing over the Mare Nectaris. (The relative position of the LM during this period is listed in Appendix F.)

The nominal coordinates of the Mascon in the Mare Nectaris are: 15 deg S, 34 deg E, 100 km below MLR. The Mascon term with these coordinates was added to the L1 potential model. The size of the Mascon was varied in several trajectory fits in order to find the effects on: (a) the doppler residual pattern; and, (b) the state vector at PDI. These results are summarized in Figure 5-11.

(a) The peak-to-peak "wiggle" amplitude (i.e., the difference in the residuals at 110:10:09 and 110:06:57) was chosen as an indicator of the effectiveness of this fit technique.

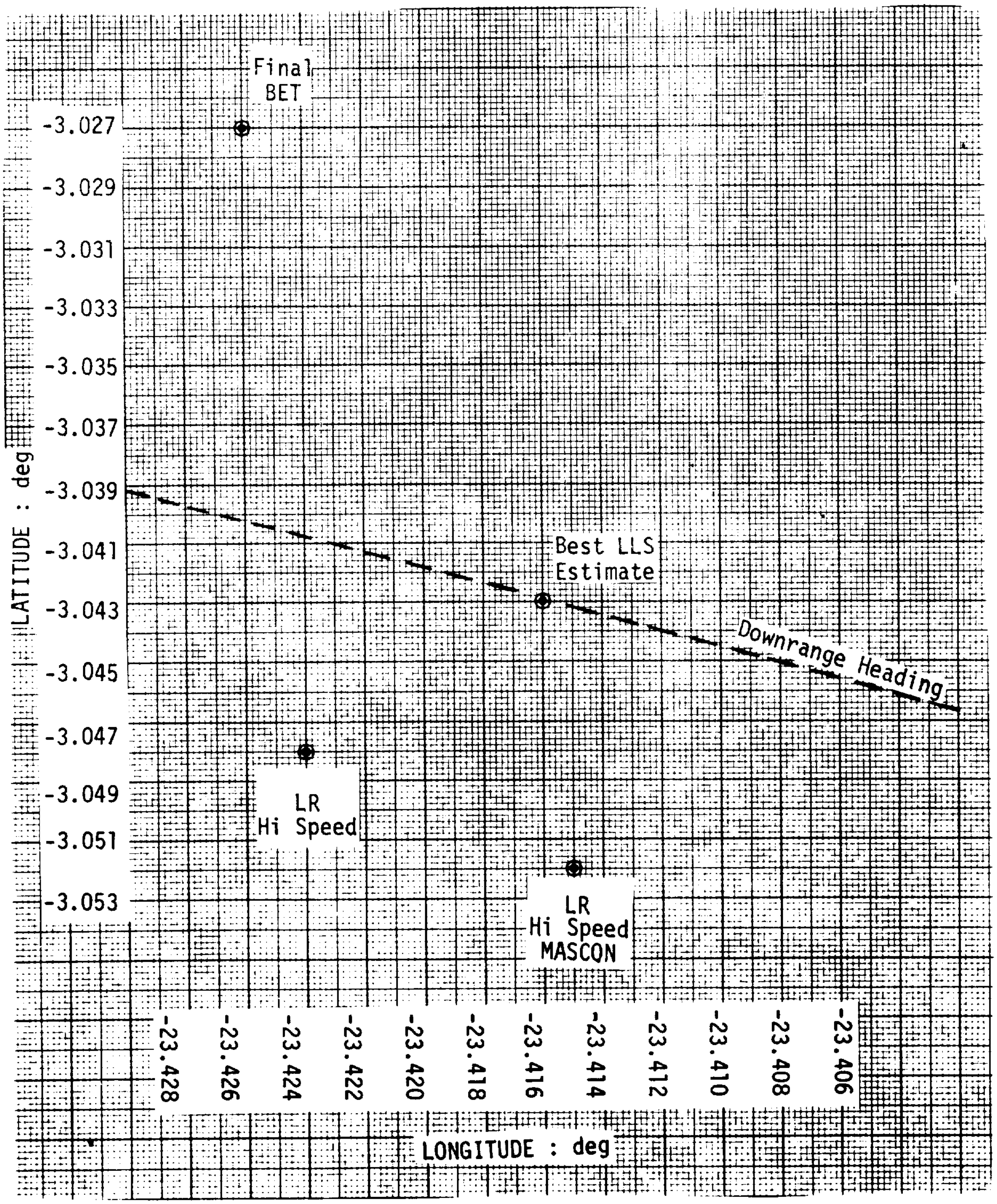

Figure 5-8 LLS COORDINATES

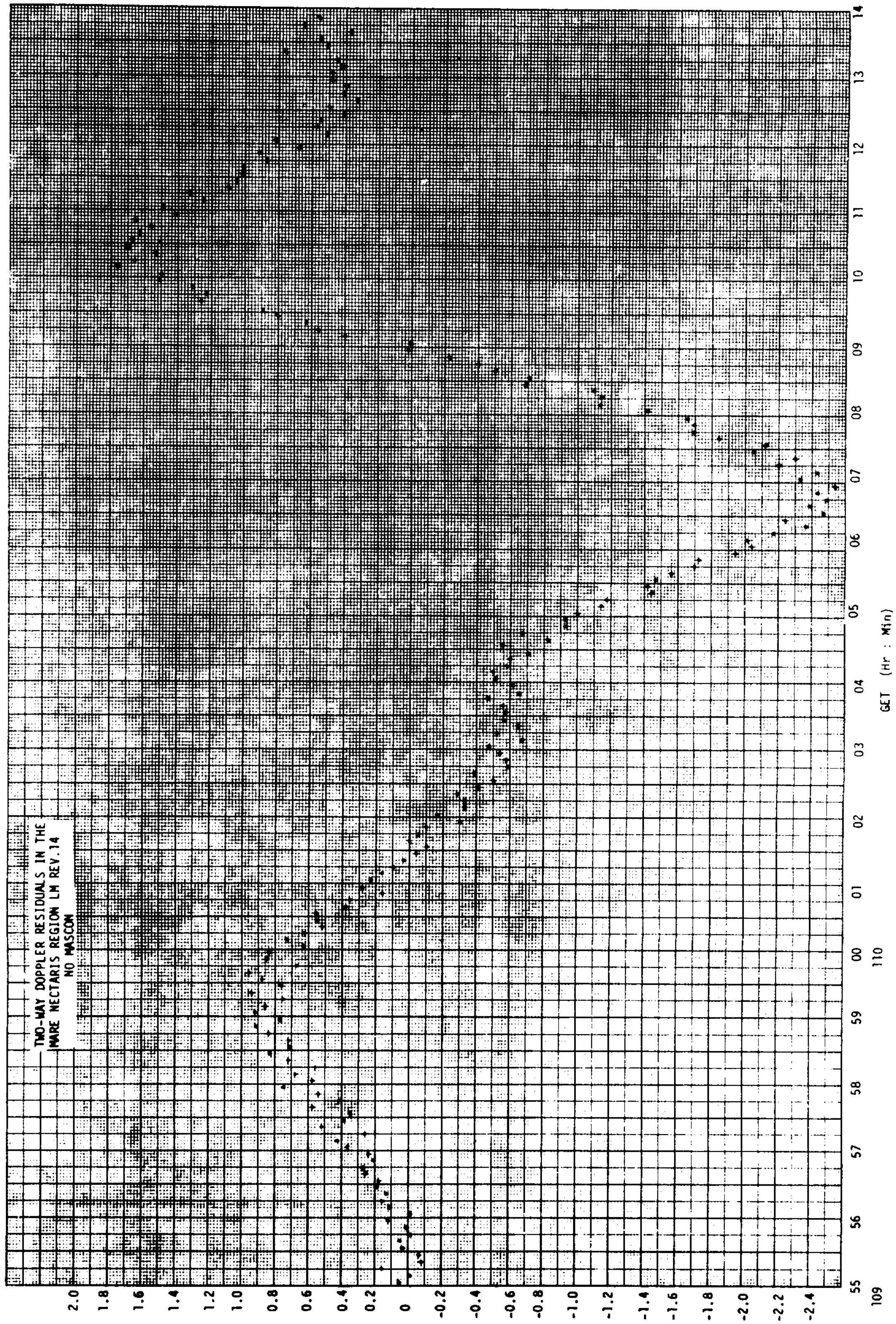

Figure 5-9 TWO-WAY DOPPLER RESIDUALS IN THE MARE NECTARIS REGION LM REV. 14 NO MASCON

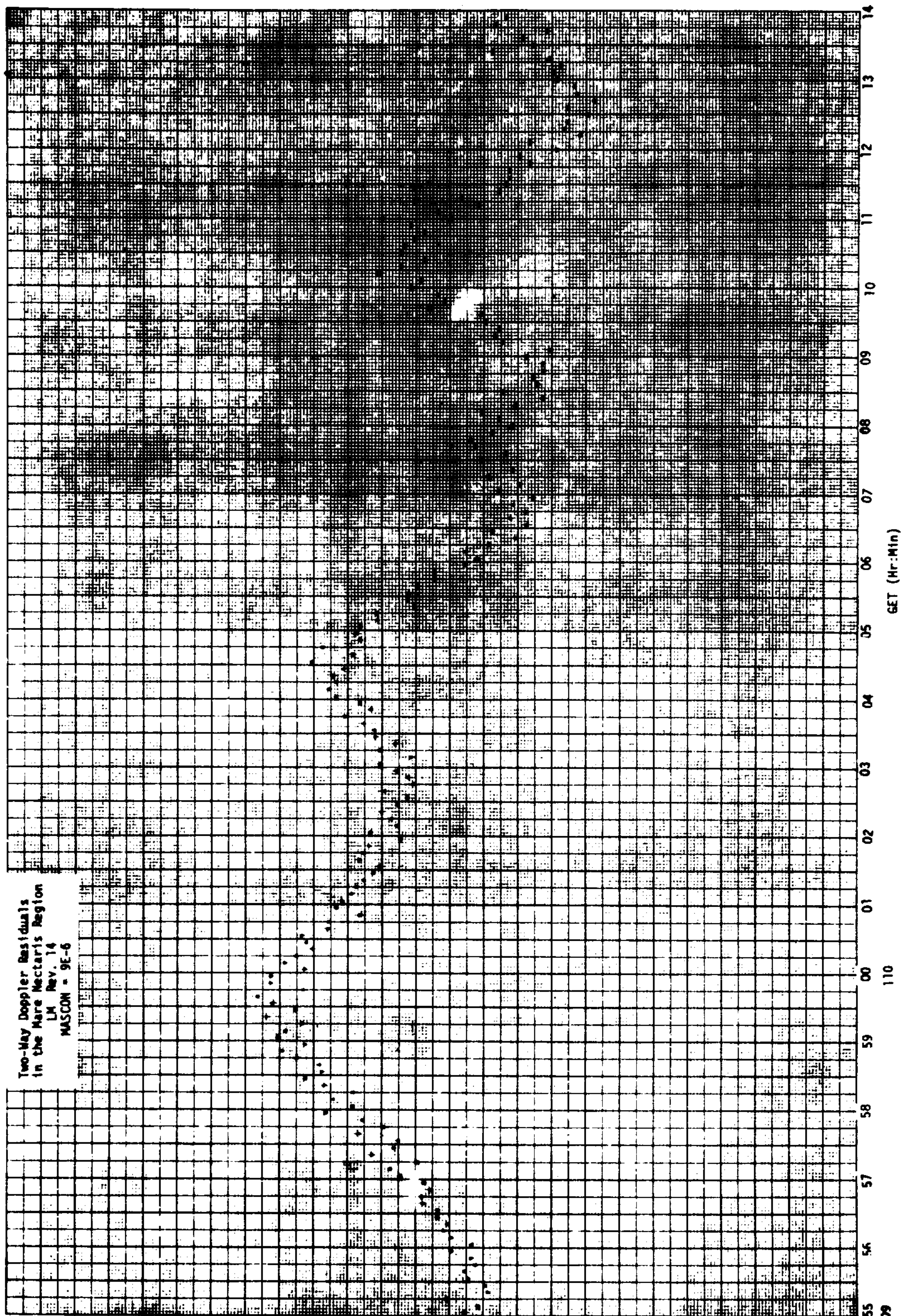

Figure 5-10 TWO-WAY DOPPLER RESIDUALS IN THE MARE NECTARIS REGION LM REV.14 MASCON = 9E-6

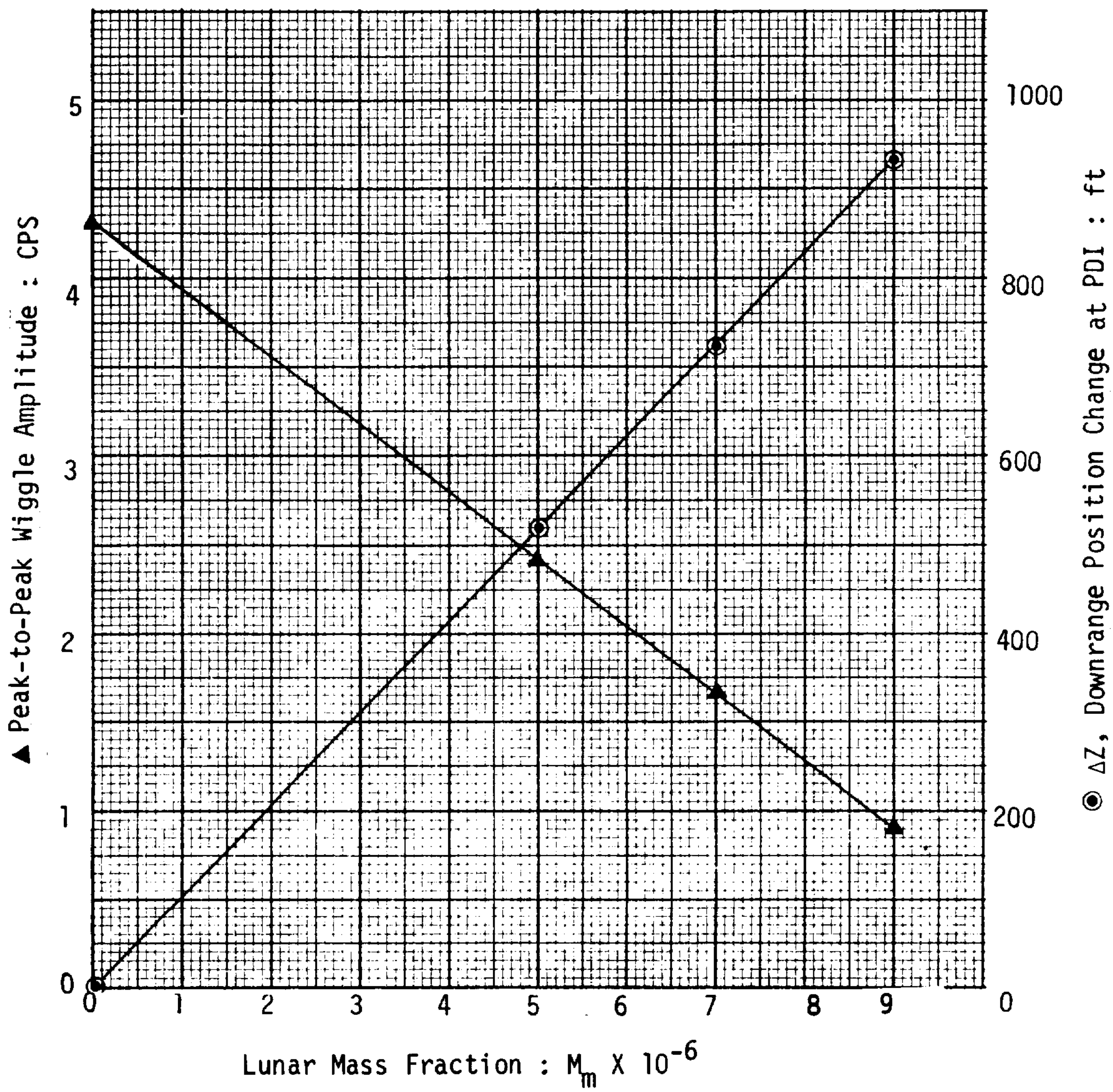

Figure 5-11 EFFECT OF MASCON MAGNITUDE ON TRAJECTORY DETERMINATION

Figure 5-11

The amplitude is seen to decrease linearly with Mascon size over the range of values used. The best fit was achieved with a value of 9E-6 lunar mass units. The 2-way doppler residuals from this fit are plotted in Figure 5-10.

(b) The only significant effect on the state vector at PDI is in the downrange position component. This quantity is seen to decrease linearly with Mascon size (Figure 5-11). The landing site resulting from the trajectory fit using a Mascon size of 9E-6 is shown in Figure 5-8. The downrange position component is in very close agreement with the Best LLS Estimate. The IMU errors required to null the relative velocity at landing are:

PHIX	=	85.9 sec
PHIY	=	-98.4 sec
ZXMSL	=	-40.7 sec
XZMSL	=	-30.0 sec

5.4.2 Analysis of Landing Radar Velocity Data

The analysis of the landing radar velocity data consisted of inspection of residuals (difference between observed measurement and computed measurement) obtained from selected LM trajectories.

The landing radar data were obtained by processing the downlink telemetry data with a special purpose computer program which outputs onboard observations on punched cards in a HOPE-compatible format.

The HOPE Program was used to compute simulated landing radar observables from the LM trajectories and from auxiliary information such as REFSMAT, gimbal angles, and radar operating mode. The LM trajectories were generated by the HOPE Program utilizing telemetered acceleration data in the IGS burn option to model the descent burn. Residuals were then formed by subtracting the computed from the actual observable value.

The trajectory used as an independent reference to evaluate these data was obtained from the PIRX159 state vector and associated platform misalignment corrections published as the final A-50 NAT (Section 5.3). This state vector was obtained in the RTCC from lo-speed MSFN doppler data obtained from AOS (acquisition of signal) to PDI on rev. 14. The

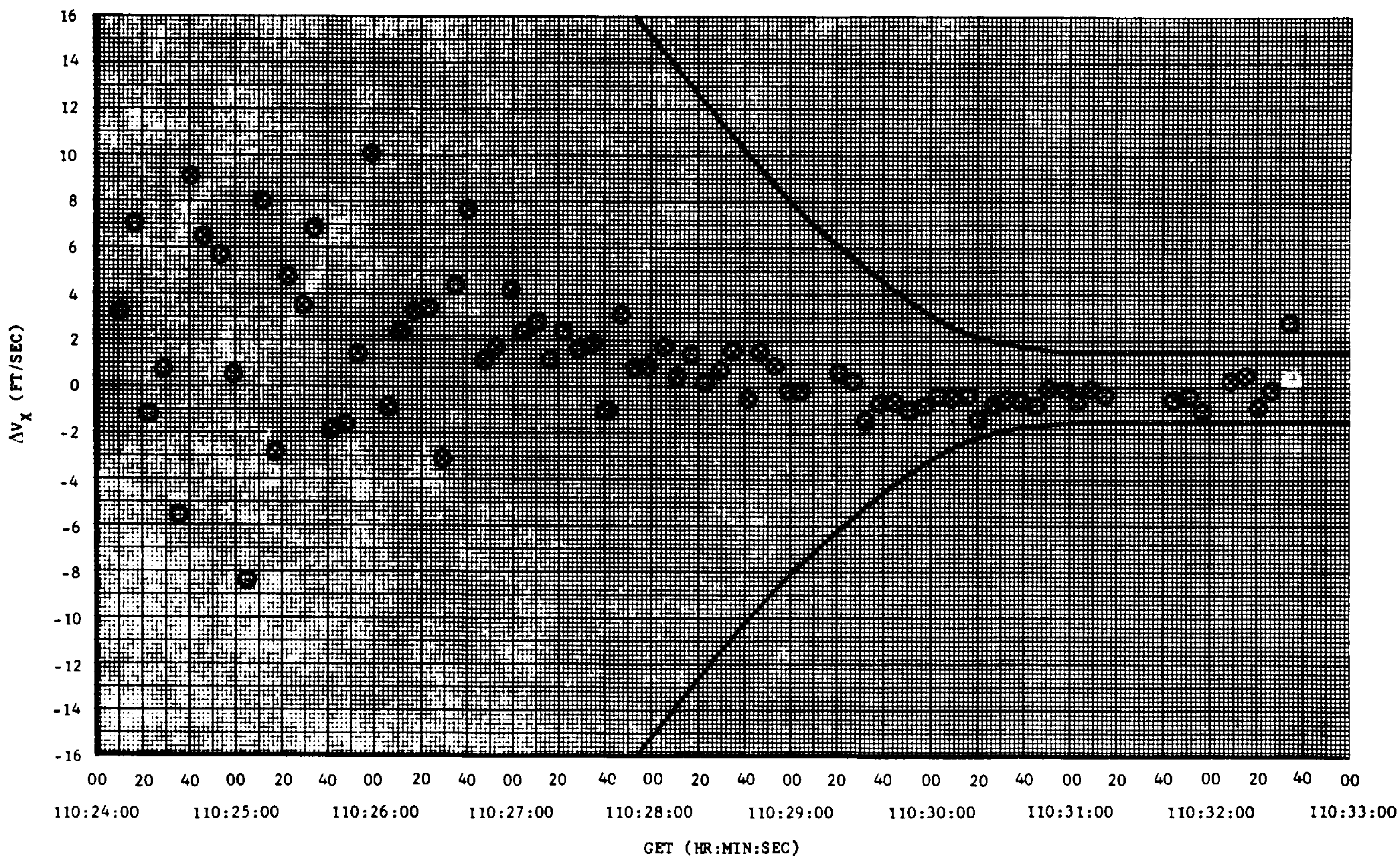

Figure 5-12 LANDING RADAR X-ANTENNA VELOCITY RESIDUALS (NOMINAL ANTENNA ORIENTATION)

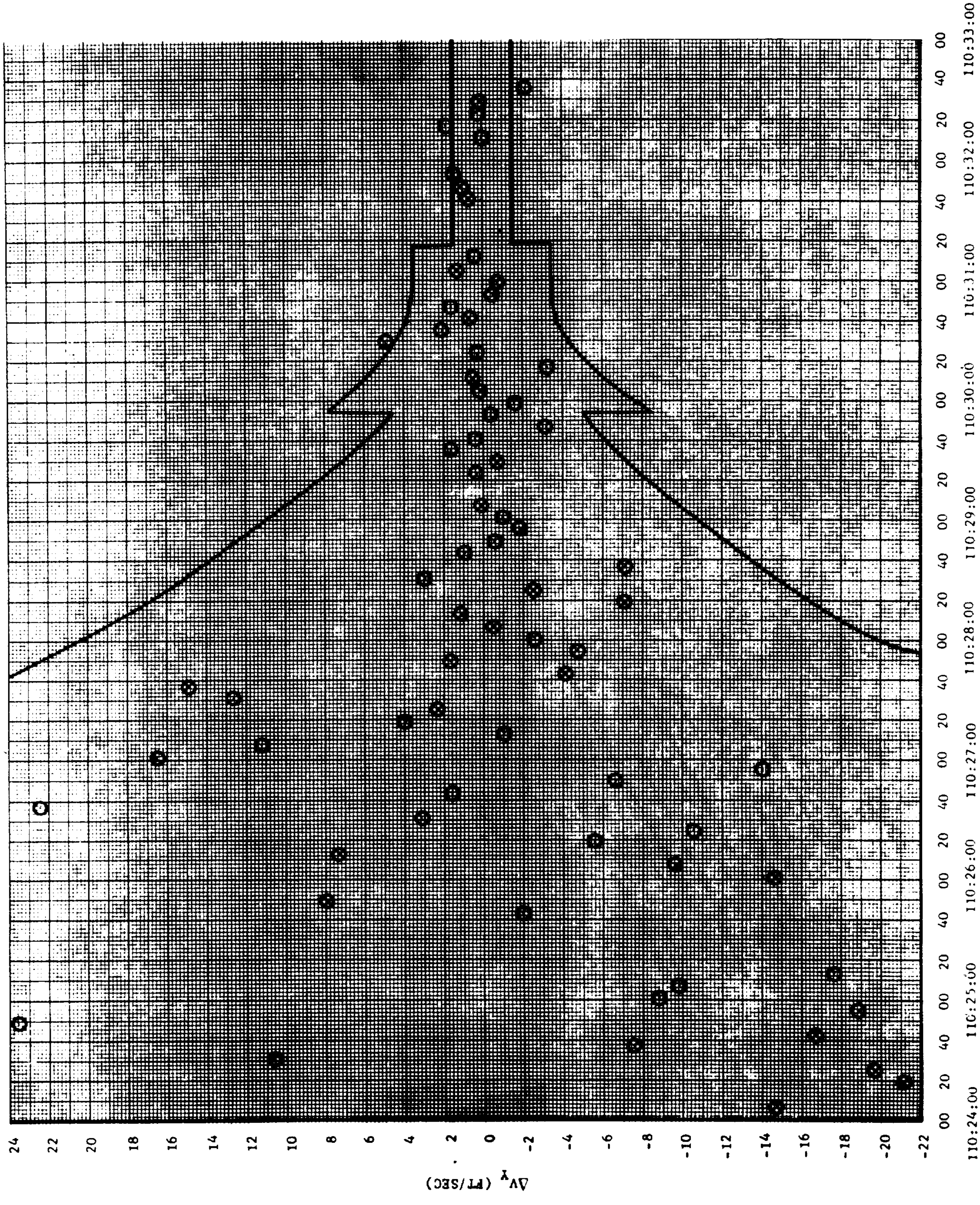

Figure 5-13 LANDING RADAR Y-ANTENNA VELOCITY RESIDUALS

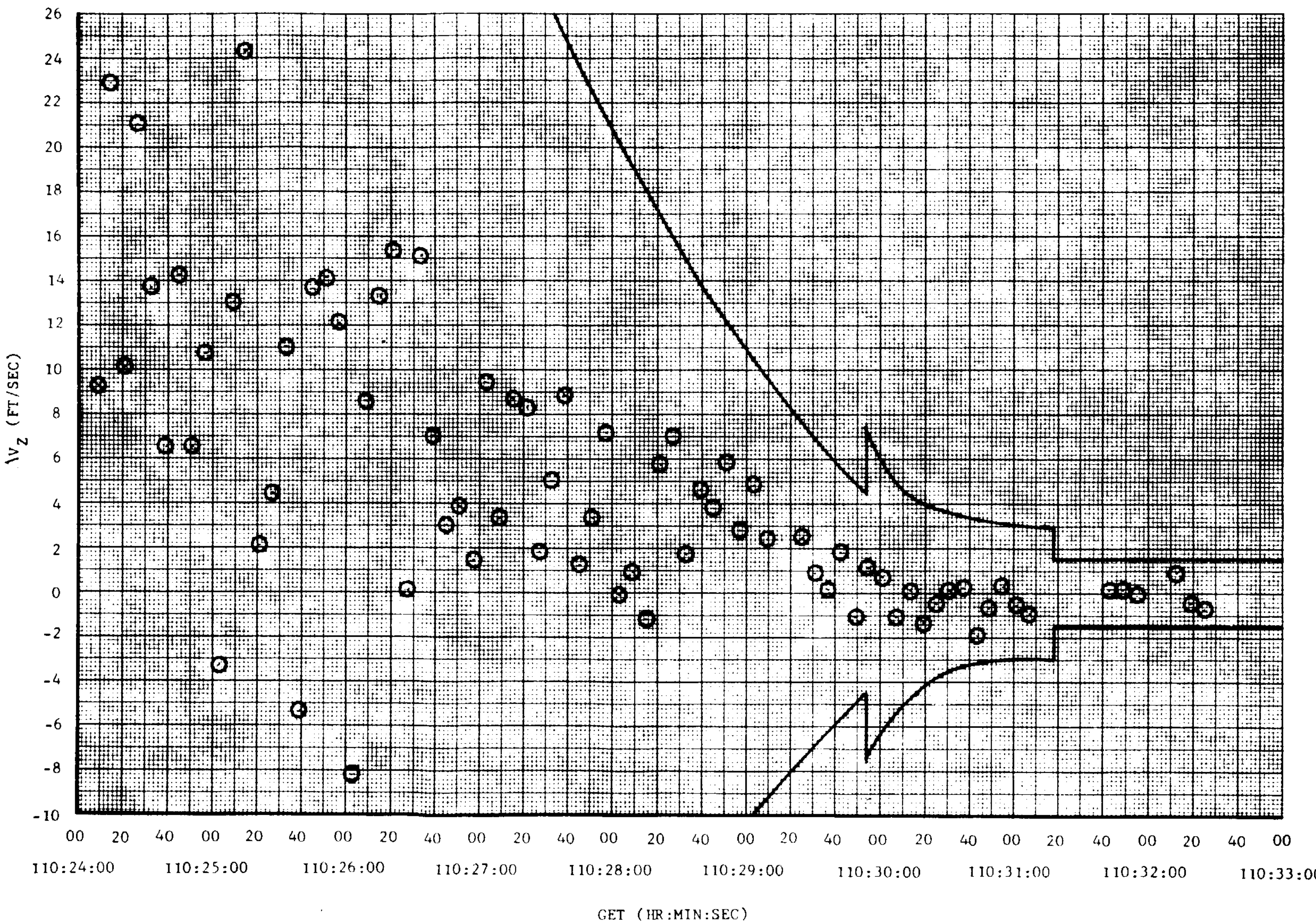

Figure 5-14 LANDING RADAR Z-ANTENNA VELOCITY RESIDUALS (NOMINAL ANTENNA ORIENTATION)

TABLE 5.13 LANDING RADAR VELOCITY RESIDUAL STATISTICS

	V_{XA}(fps)	V_{YA}(fps)	V_{ZA}(fps)	
Mean	1.09	-1.81	4.77	Nominal Antenna Orientation
St. Dev.	3.04	11.52	6.36	
Noise	3.13	11.32	5.22	
Mean	-1.74	-1.81	1.11	Y-Antenna Axis Misalignment Corrected
St. Dev.	3.11	11.52	4.91	
Noise	3.11	11.32	5.20	

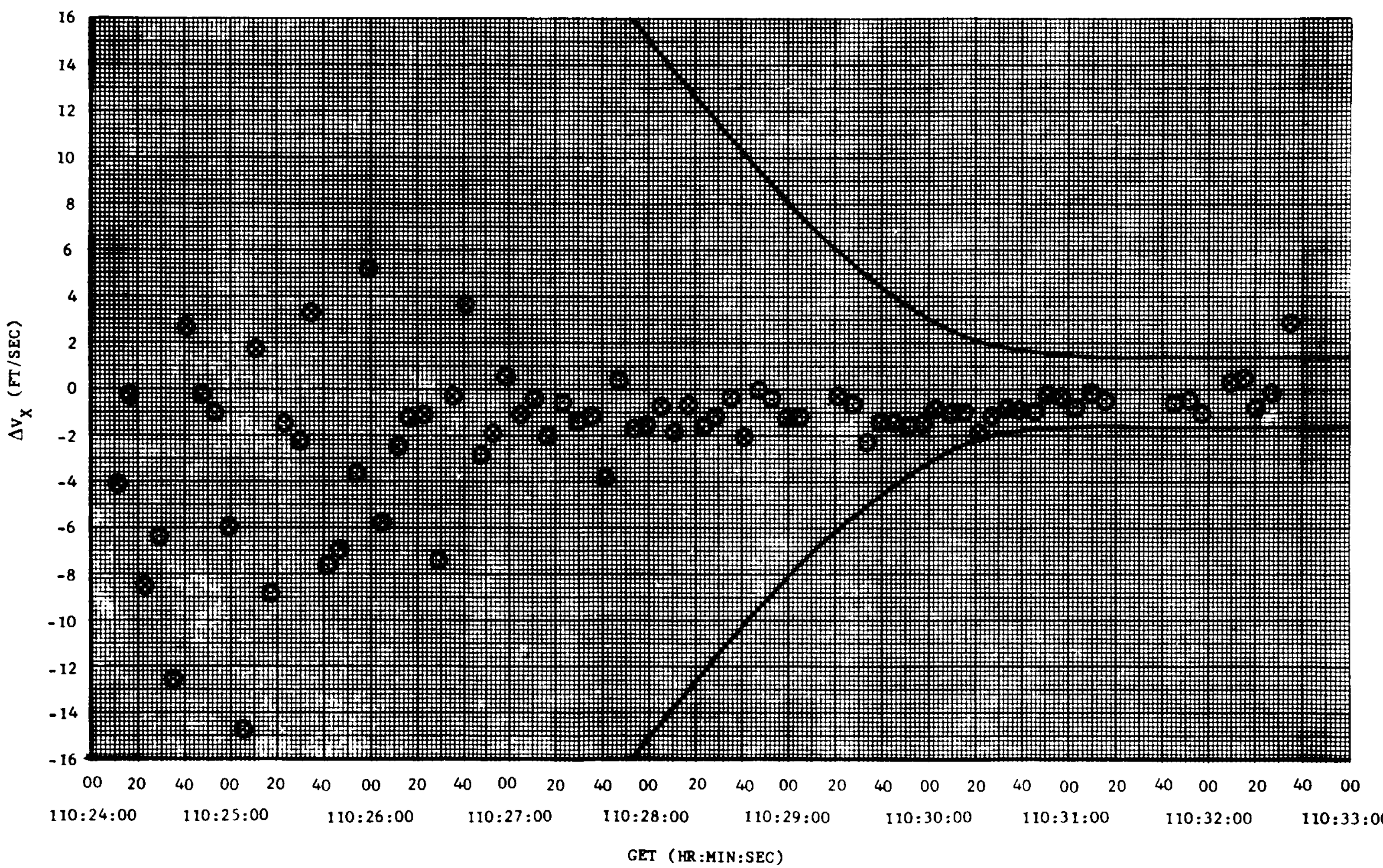

Figure 5-15 X ANTENNA VELOCITY RESIDUALS (CORRECTED ANTENNA ORIENTATION)

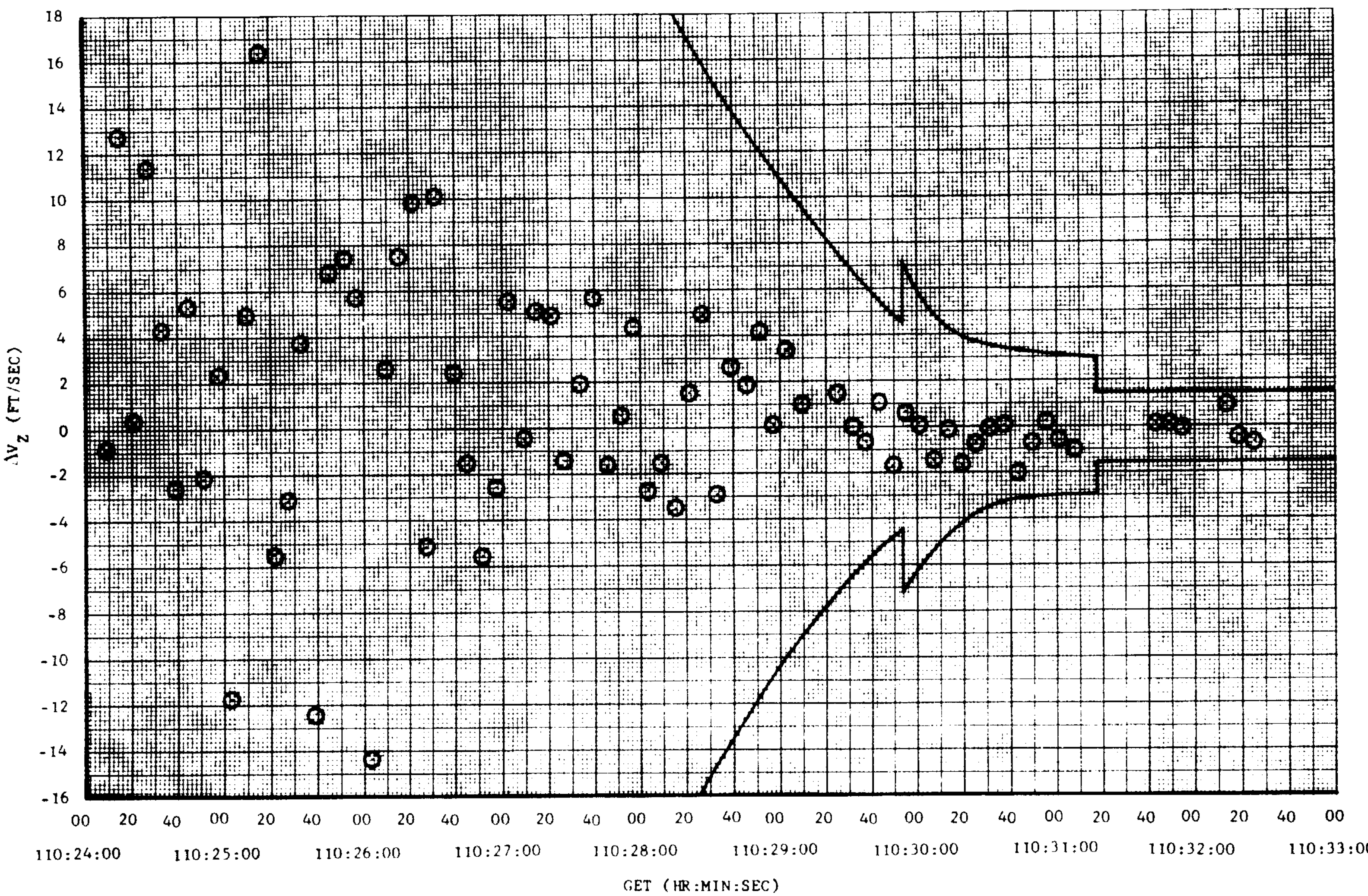

Figure 5-16 Z-ANTENNA VELOCITY RESIDUALS (CORRECTED ANTENNA ORIENTATION)

postflight reconstructions discussed in paragraph 5.4.3 were obtained using hi-speed MSFN doppler and mode 2 landing radar observations.

Figures 5-12, 5-13 and 5-14 show the velocity residuals computed from the PIRX159 trajectory. Note that a few values fell outside the specification limits plotted. The V_{YA} residuals are considerably more erratic than V_{XA} or V_{ZA}. This can be seen in the residual plot as well as in the high standard deviation listed in Table 5.13. The noise estimates listed in Table 5.13 indicate that this erratic residual pattern in V_{YA} (and to a lesser extent in V_{ZA}) is caused more probably by random noise than by a systematic measurement error.

Postflight analysis performed by other TRW tasks posed the possibility that the landing radar may have been misaligned by .2 degrees about the Y-antenna axis. When the nominal orientation figures are changed to reflect this misalignment, the residuals plotted in Figures 5-15 and 5-16 are produced. Notice that the V_{XA} and V_{ZA} mean values are significantly altered (Table 5.13). The resulting statistics are more desirable than those obtained with the nominal orientation values.

In conclusion, the landing radar velocity observation obtained from the Apollo 12 mission do not appear to be as good qualitatively as the Apollo 11 data (Reference 15). The residual statistics are significantly higher than corresponding Apollo 11 statistics, even when the apparent antenna misalignment is corrected.

5.4.3 Lunar Surface Altitude from LR Range

Landing Radar range residuals were used to compute surface altitude along the ground-track of the pierce point. The results are plotted in Figure 5-12. The time tags on the data points are in the LGC clock time (TLGC = GET - 0.68 sec).

The ground-track of the range beam pierce point is plotted on Lunar Map ORB-I-7 in Figure 5-18. The time ticks correspond to the 2-sec range measurement times indicated in Figure 5-17 and the time tags are in min:sec after 110 hours LGC time. The small ellipses show the approximate size of the range beam. The endpoint of the ground-track is located relative to the "Snowman" formation as shown in Reference 1, and the ground-track is plotted relative to this point. A full listing of surface altitude relative to LLS, latitude and longitude of range beam pierce point, central angle from LLS, and time may be obtained from the Task A-50 Monitor. These data are based on the MASCON = 9E-6 trajectory fit which yields the best absolute estimates of latitude and longitude. Note that these coordinates do not correspond to the grid markings on the ORB-I-7 map.

A very flat terrain over the final 2 deg. of the approach to the LLS is indicated by the contour map and verified by the Landing Radar data. The downhill slope between the final 2-3 deg. of the approach is also indicated by the radar, but it is difficult to make any quantitative comparisons. A very rough terrain is indicated over the first 3 deg. after range beam lock-on. Unfortunately, no suitable contour maps of this region are currently available.

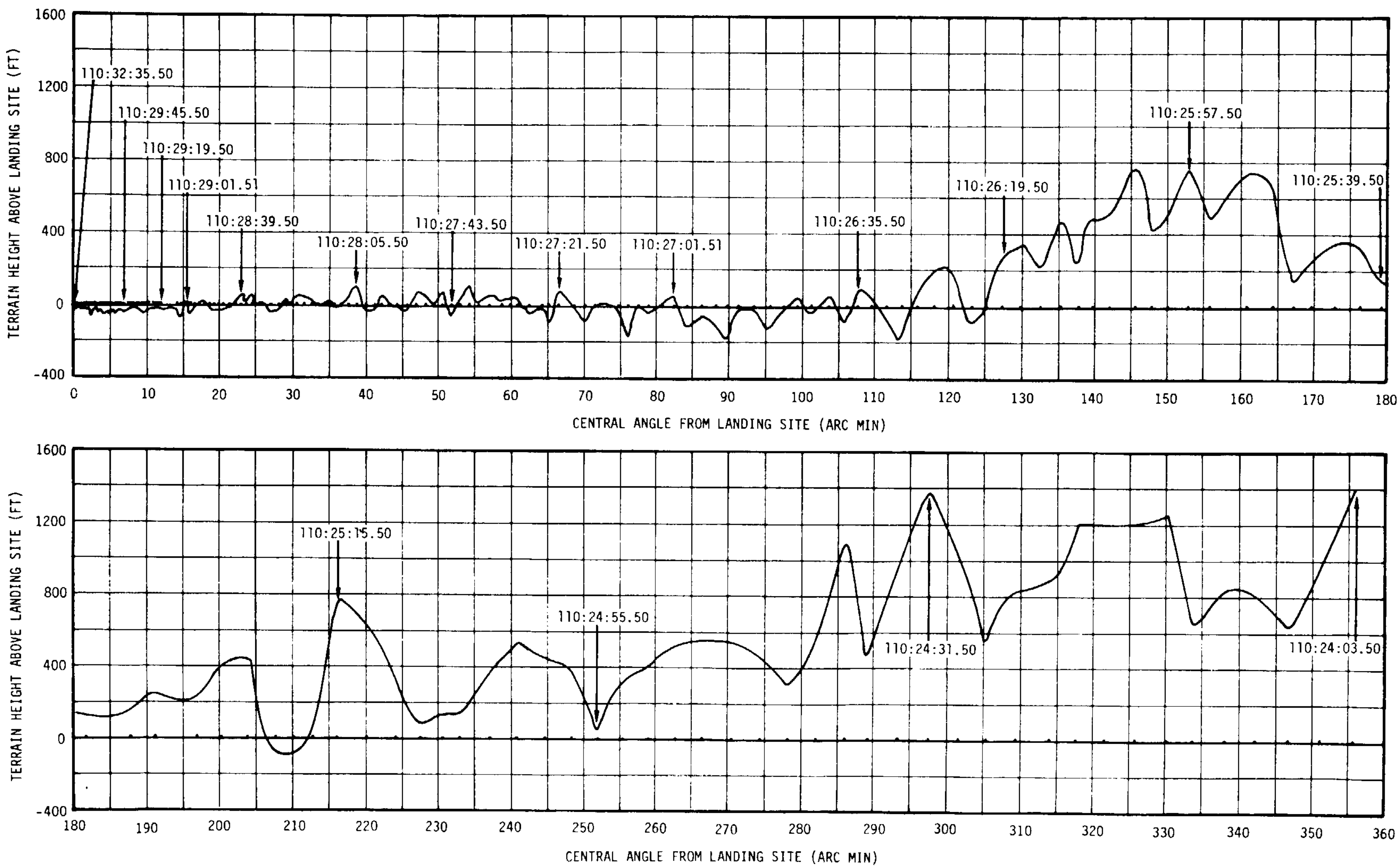

Figure 5-17 LUNAR SURFACE ALTITUDE

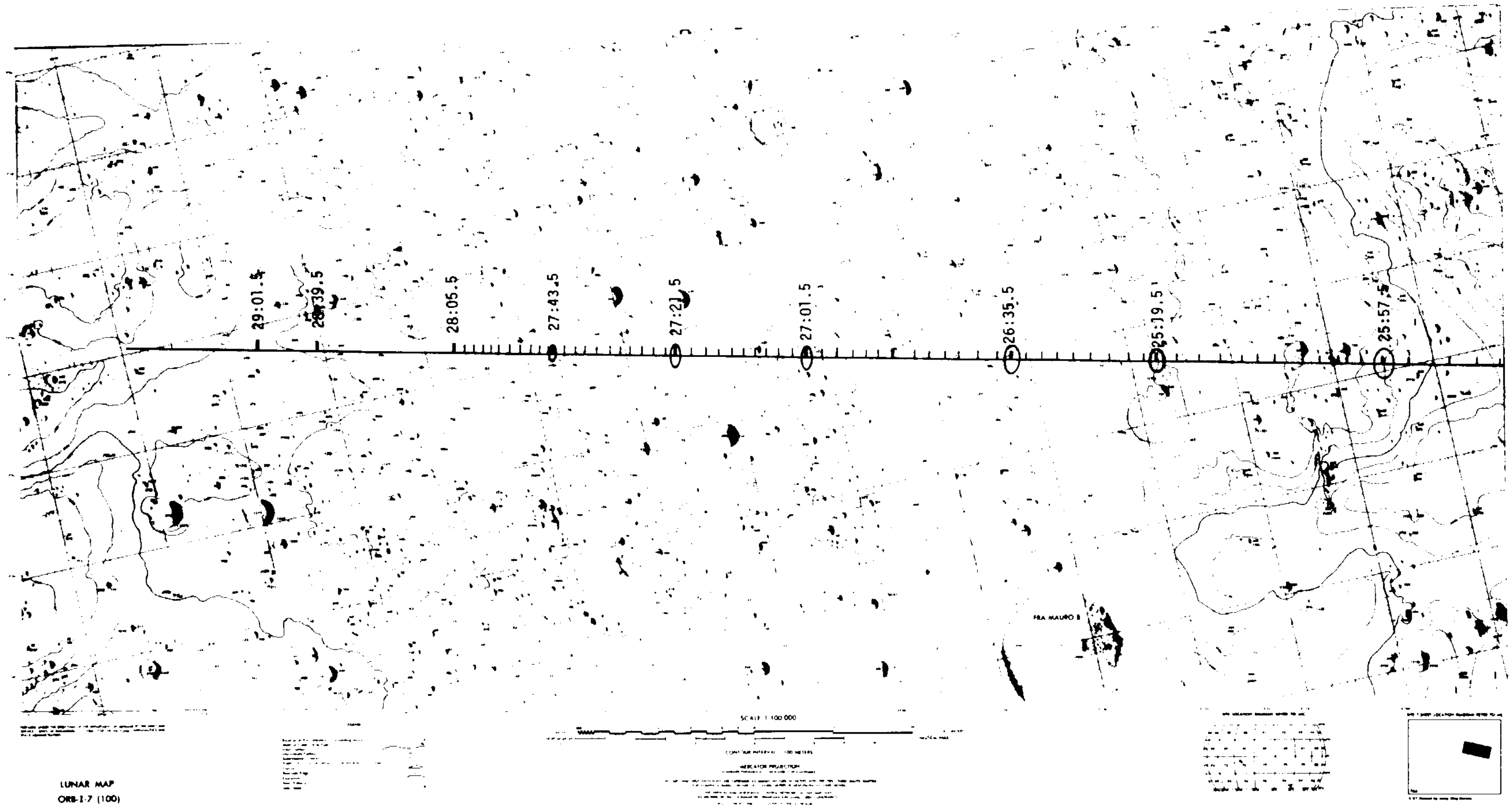

Figure 5-18 GROUNDTRACK OF LR RANGE BEAM

APPENDIX A

SUPPLEMENTARY DATA

Appendix A contains supplementary information which did not appear in the main body of the report. This information includes a summary of ground based and onboard data weights used in the HOPE Program, a summary of the components used in the L1 lunar potential model, and a summary of the USBS station locations.

Table A.1 lists the data weights used in the HOPE Program for ground based radar data and Table A.2 lists the data weights used in the HOPE Program for onboard data by type and observable.

Table A.3 lists the terms of the L1 potential model.

Table A.4 lists the S-band tracking stations and their locations as used in the Apollo 12 postflight analysis. All locations are referenced to the Fischer Ellipsoid of 1960. The surface refractivity for the month of November is also listed.

Table A.1 GROUND BASED RADAR DATA WEIGHTING

DATA TYPE	RADAR	WEIGHTING
Range	USB: 30-ft antenna 85-ft antenna	600 ft.
Doppler (2-way)	USB: 30-ft antenna 85-ft antenna	0.1 cycle/sec.
Doppler (3-way)	USB: 30-ft antenna 85-ft antenna	0.1 cycle/sec.

Table A.2 NOMINAL ONBOARD RADAR DATA WEIGHTING

DATA TYPE	SHAFT	TRUNNION	RANGE	RANGE RATE	V_X	V_Y	V_Z
Rendezvous Radar	.01	.01	30.	1.			
Sextant	.001	.001					
VHF Ranging			30.				
Landing Radar			50.		.1	.1	.1

Table A.3 L1 LUNAR POTENTIAL MODEL

TERM	VALUE
J2	2.07108×10^{-4}
J3	-2.1×10^{-5}
C22	2.0716×10^{-5}
C31	3.4×10^{-5}
C33	2.583×10^{-6}
	All other harmonics are zero

Table A.4 USBS Station Locations

Station	Antenna	Identification	Latitude* (deg)	Longitude* (deg)	Altitude* (ft)	Surface Refractivity
Antigua	30 ft	ANG	17.01692	298.24715	141.08	372
Ascension	30 ft	ACN	-7.95479	345.67287	1784.78	355
Bermuda	30 ft	BDA	32.35129	295.34182	68.90	345
Canary Island	30 ft	CYI	27.76454	344.36519	567.59	343
Honeysuckle Creek	85 ft	HSK	-35.58349	148.97829	3755.25	300
Carnarvon	30 ft	CRO	-24.90658	113.72546	65.62	329
Goldstone	85 ft	GDS	35.34159	243.12680	2976.05	276
Grand Bahama	30 ft	GBM	26.63286	281.76234	16.40	364
Guam	30 ft	GWM	13.31058	144.73692	301.84	375
Guaymas	30 ft	GYM	27.96321	249.27915	62.34	328
Hawaii	30 ft	HAW	22.12631	200.33433	3776.25	304
Madrid	85 ft	MAD	40.45499	355.83201	2553.81	299
Merritt Island	30 ft	MIL	28.50827	279.30658	32.81	349
Texas	30 ft	TEX	27.65375	262.62153	32.81	336
Honeysuckle Creek Wing	85 ft	NBE	-35.40099	148.98176	2196.85	300
Goldstone Wing	85 ft	PIR	35.38957	243.15103	3186.02	276
Madrid Wing	85 ft	RID	40.42829	355.75147	2527.56	299

*All quantities are referenced to the Fischer Ellipsoid of 1960.

APPENDIX B

ORBITAL PARAMETERS AT CERTAIN EVENT TIMES

Appendix B contains selected orbital parameters which were obtained by propagating RTCC state vector solutions or Task A-50 BET solutions to desired event times.

Table B.1 contains conditions for the desired events which were within the earth's SOI (sphere of influence). Table B.1 contains the following information: vector source, event, event time (GET), latitude, longitude, altitude, apogee, perigee, velocity, flight path angle, and heading angle. Apogee and perigee distances are referenced to the center of the earth.

Table B.2 contains the same information as Table B.1 with the exception that the desired events were within the lunar SOI. Altitude, apolune, and perilune distances are referenced to the Apollo 12 landing site radius (937.3643 N. Mi.).

The conditions at T_{CA} (time of closest approach to the moon) for a free-return circumlunar mission were obtained from an RTCC vector at 4 hours 13 minutes 09.96 seconds GET (TLI cutoff vector HSRC001 propagated through approximately 10 minutes of venting) and are given below:

TIME	83 hours 42 minutes 05.51 seconds GET
LATITUDE	25.33 S
LONGITUDE	172.51 E
ALTITUDE	470.7 N. Mi.
APOLUNE	N/A
PERILUNE	470.7 N. Mi.
VELOCITY	7172.3 FPS
FLIGHT PATH	0.000 DEG
HEADING	-112.10 DEG

In Table B.1 the listed values are referenced to an earth centered inertial (ECI), mean of nearest Besselian year coordinate system and in Table B.2 the values are referenced to a selenocentric, mean of nearest Besselian year coordinate system.

Table B.1 APOLLO 12 EARTH SOI ORBITAL PARAMETERS

SOURCE	EVENT	TIME GET	LATITUDE DEG N,S	LONGITUDE DEG E,W	ALTITUDE N.M.	APO* N.M.	PER* N.M.	VELOCITY FPS	FLIGHT PATH ANGLE DEG	HEADING ANGLE DEG
HSRC001	TLI C/O	02:53:14	16.19N	154.28W	199.5	233313.5	3559.8	35390.1	8.603	63.90
HSRC001	S-IVB/CM SEP	03:18:04.9	28.91N	79.76W	3820.1	228963.2	3559.9	24862.9	45.096	100.13
HSRC001	First Docking	03:26:53.3	26.70N	71.01W	5337.7	228894.9	3560.0	22535.1	49.896	105.29
BDAX074	S/C Ejection	04:13:00.9	18.59N	58.77W	12506.3	229584.5	3559.5	16451.1	60.941	114.52
MILX163	MCC1 IGN	30:52:44.4	1.11S	63.05W	116929.1	229852.2	3545.9	4317.4	75.833	120.80
HSKX236	MCC1 C/O	30:52:53.6	1.11S	63.09W	116935.4	228278.0	3146.6	4297.5	76.597	120.05
HSKX866	MCC2 IGN	188:27:15.8	15.97N	137.71E	180031.2	286180.0	2712.3	3035.6	-78.444	91.35
HAWX881	MCC2 C/O	188:27:20.2	15.97N	137.70E	180029.0	286198.5	2731.8	3036.0	-78.404	91.36
NBEX127	MCC3 IGN	241:21:59.7	14.86N	92.17E	25059.0	276203.7	3469.1	12082.9	-68.540	96.00
GWMS147	MCC3 C/O	241:22:05.4	14.87N	92.15E	25048.3	275925.5	3465.5	12084.7	-68.547	96.01
GWMS147	CM/SM SEP	244:07:20.1	0.32N	117.25E	1949.5	279020.0	3465.1	29029.1	-36.454	105.92
GWMS147	Entry Interface	244:22:19.1	13.80S	173.52E	65.8	285902.1	3463.8	36116.2	- 6.483	98.17

*Referenced to earth center

Table B.2 APOLLO 12 LUNAR SOI ORBITAL PARAMETERS

SOURCE	EVENT		LATITUDE DEG N,S	LONGITUDE DEG E,W	ALTITUDE* N.M.	APO* N.M.	PER* N.M.	VELOCITY FPS	FLIGHT PATH ANGLE DEG	HEADING ANGLE DEG
BET	LOI-1 IGN	83:25:23.4	5.76N	175.62E	83.91	NA	64.94	8173.6	-8.447	-130.66
BET	LOI-1 C/O	83:31:15.7	1.62S	154.03E	62.91	170.20	61.66	5470.1	-0.630	-120.70
GWMX504	LOI-2 IGN	87:48:48.1	1.67S	151.67E	62.79	170.37	61.42	5470.6	-0.662	-120.72
HAWX519	LOI-2 C/O	87:49:05	1.88S	150.85E	62.74	66.10	54.59	5331.4	0.301	-120.50
NBEX128	Undocking	107:54:02.3	13.52S	86.96E	63.02	63.08	56.91	5329.0	-0.034	- 92.75
NBEX128	CSM SEP IGN	108:24:36.8	6.61S	7.44W	59.22	63.91	56.99	5350.0	-0.177	- 54.83
CROX609	CSM SEP C/O	108:24:51.2	6.45S	8.14W	59.15	64.06	56.58	5350.5	-0.204	- 54.85
BET	DOI IGN	109:23:39.9	6.64N	172.21E	60.52	63.27	57.25	5343.0	0.172	-125.19
PIRX159	DOI C/O	109:24:08.9	6.29N	170.76E	61.52	61.53	8.70	5268.0	-0.024	-125.15
PIRX159	PDI IGN	110:20:38.1	6.76S	7.82W	7.96	62.30	7.96	5566.4	-0.025	- 54.86
HSKX624	CSM LOPC-1	119:47:13.2	14.01S	77.68E	62.20	62.50	57.61	5333.5	-0.068	- 90.73
BET	Insertion	142:10:50.9	0.59S	33.05W	9.97	51.93	9.21	5542.5	0.336	- 54.94
BET	CSI IGN	143:01:51	5.16N	164.68E	51.46	52.51	9.94	5310.3	0.055	-125.57
BET	CSI C/O	143:02:32.1	4.65N	162.64E	51.48	51.49	41.76	5354.9	0.015	-125.71
BET	TPI IGN	144:36:26	14.57N	128.99W	44.50	44.73	40.91	5382.5	0.052	-102.07
MADX700	Lunar Docking	145:36:20.2	14.53S	46.98E	58.14	63.43	58.04	5357.1	-0.040	- 75.71
BET	CSM SEP	148:04:30.9	1.40N	43.34W	59.94	64.66	59.08	5347.4	0.153	- 55.81
BET	LM Deorbit IGN	149:28:14.8	14.32S	62.86E	57.62	63.52	57.94	5361.8	-0.116	- 87.63
BET	LM Deorbit C/O	149:29:36.9	14.47S	58.62E	57.42	57.59	-63.15	5176.8	-0.274	- 84.10
BET	LM Lunar Impact	149:53:16.4	3.95S	21.20W	0.38	57.89	-63.79	5502.6	-3.728	- 54.14
GWMX731	CSM LOPC-2 IGN	159:04:45.5	6.65S	110.34E	58.70	64.23	56.58	5353.2	-0.196	-118.68
GWMX747	CSM LOPC-2 C/O	159:05:04.8	6.82S	109.40E	58.90	64.66	56.81	5353.0	-0.199	-114.18
BDAX800	TEI IGN	172:27:16.[illegible]	8.73N	170.26W	64.60	66.00	55.68	5322.9	-0.202	-115.73
HSKX866	TEI C/O	172:29:27.1	7.77N	178.60W	66.00	NA	64.10	8350.4	2.718	-116.45

* Referenced to landing site radius (937.3643 N.M.)

APPENDIX C

APOLLO 12 RELATIVE TRAJECTORY LISTING

A HOPE listing of the trajectories for both the LM and the CSM during periods of separated free flight was delivered to the Task Monitor on 5 February 1970. The trajectories used in generating this print were obtained from the best available fits using all available data types.

Table C.1 lists the trajectories by segment, the propagation interval, vector source, and RSS total position and velocity comparisons. The position and velocity deltas listed are comparisons between adjacent segments. Where a maneuver was performed between the segments, the ΔV produced by that maneuver has been removed from the RSS velocity differences (DOI = 72.4 ft/sec, CSI = 45 ft/sec). Note that all the comparisons are reasonable with the largest difference being between the CSM fits made on revs 13 and 14. This difference is partially attributable to the limited tracking coverage on rev 14 (see Figure 5-1, page 5-5). The residual statistics obtained from the CSM and LM trajectories are summarized in Tables C.2 and C.3.

CSM Trajectories

Note that the rev 13 CSM trajectory was obtained from a fit using low speed MSFN data and using the IGS burn option in HOPE to model the separation burn. No explanation was readily apparent for the high MSFN residual statistics. Since the requirement for a NAT update did not exist and task requirements were more immediate, an in-depth analysis was not performed. It was felt, however, that the trajectory obtained still represented the best overall fit of the data. The rev 14 CSM trajectory was obtained from a free flight fit using low speed MSFN data.

The trajectories used for the CSM on revs 30 and 31 were those obtained in real time by the RTCC. The rev 30 trajectory was from as SS2 type fit (solution constrained to the input inclination). It was necessary to use this fit technique because of the extremely poor tracking coverage (see Figure 5-1, page 5-5). The RTCC trajectories were used because no significant improvements were made in postflight fits (note the residual statistics in Table C.2).

LM Trajectories

The LM trajectory for the undock to DOI period was of good quality due to the good MSFN tracking. Table C.3 lists residual statistics obtained with the trajectory.

The trajectory from DOI to PDI was obtained from a fit which used CSM sextant, VHF ranging, high speed MSFN, and landing radar data. The fit also used telemetered accelerometer data to model the powered descent. The trajectory generated by this fit in the free flight segment (DOI to PDI) was considered the best available and, therefore, was chosen for the relative trajectory print. Although the relative trajectory extended only through free flight periods, the residual statistics listed in Table C.3 were taken from the entire data arc and do include observations taken during powered descent. (This trajectory was not published as a BET.)

The trajectories used for the insertion to CSI and CSI to TPI segments used both onboard relative (CSM sextant, VHF ranging, LM rendezvous radar) and ground based MSFN tracking data. As was stated in Reference 2, the presence of MSFN data caused the relatively large residual statistics for the onboard data types (especially in the CSI to TPI period where the onboard and ground based data arcs are coincident). Statistics obtained from free flight fits using only onboard data are listed in Table C.4 as a gross indication of data quality.

The insertion to CSI trajectory was obtained from a free flight fit and the CSI to TPI trajectory was obtained from a fit which modeled the

CDH maneuver with the HOPE IGS burn option. Since no tracking data were available after TPI, no trajectories after that point were included in the deliverable.

Note that the above-mentioned trajectories were not necessarily published as a BET. However, they represent the best trajectories obtained before Task A-50 was directed by MSC to de-emphasize rendezvous analysis.

TABLE C.1 RELATIVE TRAJECTORY SEGMENT SUMMARY

Segment	Propagation Interval		Vector Source	RSS Comparisons	
	Start (d:h:m:s GMT)	Stop (d:h:m:s GMT)		ΔR (feet)	ΔV (fps)
Pre Sep to DOI	19:04:45:00	19:05:45:39.9	CSM - Rev 13 IGS fit LM - Rev 13 Free Flight Fit	8524	2.3
DOI to PDI	19:05:46:08.9	19:06:42:38.1	CSM - Rev 14 Free Flight Fit LM - Rev 14 IGS Fit	3812	1.4
Insertion to CSI	20:14:32:50.9	20:15:23:51.0	CSM - RTCC Rev 30 (CROX 680) LM - Rev 30 Free Flight Fit	1765	2.4
CSI to TPI	20:15:24:32.1	20:16:58:26.0	CSM - RTCC Rev 31 (ACNX 687) LM - Rev 31 IGS Fit	2287	.04

TABLE C.2 CSM FIT RESIDUAL STATISTICS

CSM Rev 13 Fit

Data Type (station)	Number of Obs.	Mean	Std. Dev.
2 way doppler (GDS)	133	-.0233 cps	1.09 cps
Range (GDS)	17	-345. feet	8.26 feet
3 way doppler (HAW)	110	-.0074 cps	1.08 cps
3 way doppler (MIL)	98	-.0387	1.04

CSM Rev 14 Fit

Data Type (station)	Number of Obs.	Mean	Std. Dev.
2 way doppler (HSK)	143	.0251 cps	.560 cps
3 way doppler (GDS)	142	.0056	.564
3 way doppler (CRO)	29	.1051	.259

CSM Rev 30 (RTCC CROX 680)

Data Type (station)	Number of Obs.	Mean	Std. Dev.
2 way doppler (HSK)	242	.134 cps	.415 cps
3 way doppler (CRO)	76	.065	.186

CSM Rev 31 (RTCC ACNX 687)

Data Type (station)	Number of Obs.	Mean	Std. Dev.
2 and 3 way doppler (HSK)	66	.088 cps	.582 cps
2 way doppler (MAD)	73	.015	.545
3 way doppler (GWM)	118	-.033	.505
3 way doppler (CRO)	111	.035	.536
3 way doppler (ACN)	21	-.003	.188

TABLE C.3 LM FIT RESIDUAL STATISTICS

LM Undock to DOI (Rev 13)

Data Type (station)	Number of Obs.	Mean	Std. Dev.
2 way doppler (PIR)	116	.001 cps	.616 cps
3 way doppler (BDA)	115	-.015	.617
3 way doppler (HAW)	91	.071	.629
3 way doppler (MIL)	94	-.005	.622
3 way doppler (NBE)	43	.088	.376
3 way doppler (GWM)	45	-.118	.502

LM DOI to PDI (Rev 14 - DOI to Landing Fit)

Data Type (station)	Number of Obs.	Mean	Std. Dev.
2 way doppler (PIR)	695	.004 cps	.889 cps
3 way doppler (GWM)	702	-.047	.862
3 way doppler (NBE)	695	.043	.854
3 way doppler (MIL)	288	-.004	.852
3 way doppler (HAW)	700	-.014	.855
CSM sextant shaft	3	-.002 deg.	.062 deg.
CSM sextant trunnion	3	.443	.035
CSM VHF Ranging	6	687. feet	248. feet

LM Insertion to CSI (Rev 30)

Data Type (station)	Number of Obs.	Mean	Std. Dev.
2 way doppler (HSK)	83	.070 cps	.477 cps
3 way doppler (GWM)	195	-.027	.558
3 way doppler (NBE)	195	-.018	.555
3 way doppler (CRO)	84	.044	.540
CSM sextant shaft	22	-.002 deg.	.022 deg.
CSM sextant trunnion	22	-.006	.007
CSM VHF Ranging	14	-232. feet	200. feet
LM RR shaft	2	.015 deg.	.020 deg.
LM RR trunnion	2	-.043	.020
LM RR range	2	323. feet	13. feet
LM RR range rate	2	-.380 fps.	.157 fps.

LM CSI to TPI (Rev 31)

Data Type (station)	Number of Obs.	Mean	Std. Dev.
2 way doppler (RID)	134	-.061 cps	.950 cps
3 way doppler (NBE)	64	-.641	.788
3 way doppler (CRO)	112	-.034	.914
3 way doppler (GWM)	76	.309	.845
3 way doppler (ACN)	20	.699	.377
CSM sextant shaft	31	-.078 deg	.095 deg
CSM sextant trunnion	31	-.040	.028
CSM VHF ranging	32	-277. feet	63.2 feet
LM RR shaft	53	.011 deg	.026 deg
LM RR trunnion	53	-.120	.072
LM RR range	53	-122. feet	97.6 feet
LM RR range rate	53	-.331 fps	.285 fps

TABLE C.4 ONBOARD DATA FREE FLIGHT FIT RESIDUAL STATISTICS

Insertion to CSI

Data Type (station)	Number of Obs.	Mean	Std. Dev.
CSM sextant shaft	22	-.002 deg	.022 deg
CSM sextant trunnion	22	.0003	.004
CSM VHF ranging	14	-37.8 feet	53.3 feet
LM RR shaft	2	.030 deg	.019 deg
LM RR trunnion	2	-.041	.017
LM RR range	2	251.7 feet	8.81 feet
LM RR range rate	2	-.476 fps	.227 fps

CSI to CDH

Data Type (station)	Number of Obs.	Mean	Std. Dev.
CSM sextant shaft	35	-.007 deg	.034 deg
CSM sextant trunnion	35	-.007	.010
CSM VHF ranging	34	-25.2 feet	177. feet
LM RR shaft	30	.050 deg	.017 deg
LM RR trunnion	30	-.075	.051
LL RR range	30	10.8 feet	251. feet
LM RR range rate	30	-.672 fps	.390 fps

CDH to TPI

Data Type (station)	Number of Obs.	Mean	Std. Dev.
CSM sextant shaft	8	.001 deg	.007 deg
CSM sextant trunnion	8	-.003	.006
CSM VHF ranging	10	-85.5 feet	30.2 feet
LM RR shaft	23	.083 deg	.016 deg
LM RR trunnion	23	-.082	.028
LM RR range	23	29.9 feet	53.5 feet
LM RR range rate	23	-.434 fps	.292 fps

APPENDIX D

LM RENDEZVOUS RADAR DATA, CSM VHF RANGING DATA AND CSM SEXTANT (APOLLO 12)

The LM rendezvous radar data that was used in the analysis are listed in the two card format of the HOPE orbit determination program. The first card specifies the vehicle taking the observation, the vehicle that is being observed, the time of the observation (year (mod 1900), month, day, hour, minute, and second (GMT)), three code numbers, shaft observable, trunnion observable, range observable, and range rate observable. The second card specifies the inner, middle, and outer gimbal angles. The units are feet, degrees, and seconds.

The CSM VHF ranging data are also listed in the same format. The card format differences are the following: 1) vehicle ID's are reversed, 2) code numbers are different, 3) range is the only observable, and 4) gimbal angles are not needed to process the ranging data.

The CSM sextant data are also listed. The card format is also similar to the rendezvous radar cards.

DOI TO PDI

VEH1	VEH2	YYMMDDHHMMSS.SSS	XF	SHAFT(DEG) INNER(DEG)	TRUN(DEG) MIDDLE(DEG)	RANGE(FT) OUTER(DEG)	RRATE(FPS)	
CSM	LEM	691119 55424.539	62	.977783	20.376901			1
				328.3703613	3.6584473	4.8889160		2
CSM	LEM	691119 55427.398	62	.780029	20.511484			1
				328.2714844	3.6694336	4.8120117		2
CSM	LEM	691119 55513.129	62	.252686	22.648325			1
				326.7114258	3.9111328	5.2514648		2
CSM	LEM	691119 55543.867114				50978.608		1
								2
CSM	LEM	691119 55646.348114				55049.606		1
								2
CSM	LEM	691119 55752.566114				59485.170		1
								2
CSM	LEM	691119 55853.609114				63616.929		1
								2
CSM	LEM	691119 6 5 6.078114				95091.206055		1
								2
CSM	LEM	691119 6 7 3.359114				108701.7		1
								2

INS TO CSI

VEH1	VEH2	YYMMDDHHMMSS.SSS	XF	SHAFT(DEG) INNER(DEG)	TRUN(DEG) MIDDLE(DEG)	RANGE(FT) OUTER(DEG)	RRATE(FPS)	
LEM	CSM	691120144847.130	11	358.7036	359.4177	1205892.8	-347.8011	
				304.9036	16.7322	.0330		2
LEM	CSM	691120145013.727	11	359.0881	359.7363	1176552.2	-331.4781	
				299.8169	2.8784	.0989		2
CSM	LEM	691120145040.914	62	359.066162	22.044077			1
				62.8198242	.0983770	359.8242187		2
CSM	LEM	691120145128.984	114			1151849.203		1
								2
CSM	LEM	691120145042.953	62	359.011230	22.016611			1
				62.7429199	.0988770	359.7912598		2
CSM	LEM	691120145127.680	62	359.978027	21.934213			1
				60.3918457	.2307129	.5822754		2
CSM	LEM	691120145229.437	114			1133013.250		1
								2
CSM	LEM	691120145212.633	62	359.670410	22.631845			1
				57.2387695	.3955078	.6042480		2
CSM	LEM	691120145330.516	114			1114724.141		1
								2
CSM	LEM	691120145345.875	62	.087891	22.645578			1
				52.1411133	.7470703	1.3623047		2
CSM	LEM	691120145458.312	114			1089751.297		1
								2
CSM	LEM	691120145413.984	62	359.615479	22.447824			1
				50.7897949	.9008789	1.2524414		2
CSM	LEM	691120145515.219	62	.461426	19.918222			1
				49.9658203	.5822754	1.1865234		2
CSM	LEM	691120145610.414	114			1070550.781		1
								2
CSM	LEM	691120145553.977	62	1.153564	21.950693			1
				45.5273437	.5822754	1.7358398		2
CSM	LEM	691120145625.648	62	.780029	22.033090			1
				43.9672852	.4943848	1.3623047		2
CSM	LEM	691120145816.805	114			1039137.266		1
								2
CSM	LEM	691120145721.773	62	.296631	23.005380			1

			39.8913574	.4064941	.9448242	2
CSM	LEM	691120145918.023114			1025101.437	1
						2
CSM	LEM	69112015 019.258114			1011916.266	1
						2
CSM	LEM	69112015 120.703114			999399.469	1
						2
CSM	LEM	691120145815.906 62	.285645	23.063059		1
			36.8371582	.3295898	.8129883	2
CSM	LEM	69112015 124.430 62	359.439697	22.590647		1
			26.8066406	.5932617	.5163574	2
CSM	LEM	69112015 726.234114			940339.625	1
						2
CSM	LEM	69112015 828.758114			932622.961	1
						2
CSM	LEM	69112015 831.000 62	359.549561	23.499765		1
			2.0654297	1.5820313	1.9226074	2
CSM	LEM	69112015 930.328114			925756.945	1
						2
CSM	LEM	69112015 832.273 62	359.527588	23.508005		1
			1.9885254	1.5820313	1.9006348	2
CSM	LEM	69112015 933.789 62	.878906	22.730722		1
			359.3627930	1.6259766	2.8234863	2
CSM	LEM	69112015 953.695 62	.714111	22.406626		1
			358.5717773	1.6259766	2.6477051	2
CSM	LEM	691120151045.430114			918101.039	1
						2
CSM	LEM	691120151023.086 62	.109863	22.173166		1
			357.1765137	1.6259766	2.2302246	2
CSM	LEM	691120151146.125114			912389.492	1
						2
CSM	LEM	691120151048.984 62	359.494629	22.442331		1
			355.4736328	1.6918945	1.9226074	2
CSM	LEM	691120151148.656 62	359.143066	22.901010		1
			351.7272949	1.9226074	2.0214844	2
CSM	LEM	691120144736.453 62	.043945	22.005625		1
			72.7734375	359.2419434	359.3078613	2
CSM	LEM	691120144744.875 62	359.835205	21.967172		1
			72.3669434	359.2529297	359.1760254	2
CSM	LEM	691120144830.258 62	358.593750	22.222605		1
			69.6862793	359.4396973	358.6267090	2

CSI TO CDH

VEH1	VEH2	YYMMDDHHMMSS.SSS	XF	SHAFT(DEG) INNER(DEG)	TRUN(DEG) MIDDLE(DEG)	RANGE(FT) OUTER(DEG)	RRATE(FPS)
LEM	CSM	691120154257.062	11	.1648	.7910	797900.3	-75.3361
				130.8801	357.1545	359.1650	2
LEM	CSM	691120154449.758	11	359.0332	359.4727	789270.7	-77.8471
				126.4197	358.4399	.5164	2
LEM	CSM	691120154558.156	11	.2087	.5713	784017.9	-80.3581
				121.8823	357.2754	359.3738	2
LEM	CSM	6911201547 6.156	11	.2856	.8020	778465.0	-81.6141
				118.4436	358.0884	359.1211	2
LEM	CSM	691120154813.977	11	359.8352	.0549	772837.0	-83.4971
				115.5542	358.1433	359.8792	2
LEM	CSM	691120154921.914	11	359.8572	359.3079	767133.9	-86.0091
				112.2144	359.5386	.6152	2
LEM	CSM	691120155139.508	11	359.1541	359.0112	754977.4	-90.4031
				106.1829	359.8242	.9009	2
LEM	CSM	691120155243.75	11	.8789	359.2090	749124.3	-92.9141
				101.3049	.8130	.7031	2
LEM	CSM	691120155350.523	11	.1208	.3516	742821.0	-95.4261
				98.8220	1.5820	359.5386	2
LEM	CSM	691120155459.148	11	.0769	359.3188	736292.5	-97.3091
				95.5042	.8130	.5603	2
LEM	CSM	6911201556 7.109	11	.0220	.1208	729463.8	-100.4481
				92.2742	3.2410	359.7363	2
LEM	CSM	691120155715.109	11	359.3958	359.4946	722710.2	-102.9591
				89.6045	4.4934	.3186	2
LEM	CSM	691120155826.539	11	359.8572	.3296	715281.3	-106.0981
				85.6934	359.6265	359.5166	2
LEM	CSM	691120155934.453	11	359.6375	359.4617	708002.4	-108.6091
				82.6172	1.3403	.3625	2
LEM	CSM	69112016 042.453	11	359.7253	.7581	700498.4	-111.1211
				79.2773	359.4177	359.0771	2
CSM	LEM	691120152938.195114				853268.891	1
							2
CSM	LEM	6911201530 2.727	62	.560303	22.368173		1
				294.9060059	359.4177246	359.2309570	2

CSM	LEM	691120153038.289114			849197.891	1
						2
CSM	LEM	6911201530 6.680 62	.538330	22.403879		1
			294.6752930	359.4177246	359.2089844	2
CSM	LEM	691120153039.117 62	.351563	22.640085		1
			292.7966309	359.3957520	359.0551758	2
CSM	LEM	691120153139.508114			845066.133	1
						2
CSM	LEM	691120153111.516 62	.626221	21.439829		1
			292.3461914	359.1979980	358.9782715	2
CSM	LEM	691120153136.094 62	.417480	22.758188		1
			289.7973633	359.4067383	359.1320801	2
CSM	LEM	691120153239.687114			841055.898	1
						2
CSM	LEM	6911201532 5.750 62	359.912109	22.749948		1
			288.3032227	359.4506836	358.8464355	2
CSM	LEM	691120153244.727 62	.582275	22.500009		1
			286.5893555	359.5385742	359.4396973	2
CSM	LEM	691120153341.703114			836863.383	1
						2
CSM	LEM	691120153441.906114			832792.383	1
						2
CSM	LEM	691120153542.250114			828660.625	1
						2
CSM	LEM	691120153611.453 62	.549316	22.392893		1
			276.3061523	.1867676	.3735352	2
CSM	LEM	691120153643.727114			824468.102	1
						2
CSM	LEM	691120153613.406 62	.494385	22.368173		1
			276.2292480	.1867676	.3295898	2
CSM	LEM	691120153745.219114			820154.062	1
						2
CSM	LEM	6911201537 8.953 62	358.901367	21.920480		1
			273.9001465	.1538086	359.2639160	2
CSM	LEM	691120153751.758 62	359.692383	22.071543		1
			271.6040039	.1977539	359.8352051	2
CSM	LEM	691120153821.656 62	359.187012	22.129221		1
			270.0549316	.2087402	359.5275879	2
CSM	LEM	691120154226.484 62	.032959	21.854563		1
			258.1237793	359.1979980	358.7475586	2
CSM	LEM	691120154228.906 62	359.978027	21.857309		1

				258.0029297	359.2089844	358.7255859	2
CSM	LEM	691120154311.773	62	358.945312	22.208872		1
				255.5200195	359.4067383	358.3193918	2
CSM	LEM	691120154342.375	62	358.846436	22.068796		1
				254.1577148	359.4946289	358.4069824	2
CSM	LEM	6911201545 6.594	62	359.439697	22.140207		1
				249.8950195	358.8244629	357.8576660	2
CSM	LEM	691120155311.883	62	359.725342	22.206125		1
				226.0327148	359.0991211	358.6047363	2
CSM	LEM	691120155314.523	62	359.736328	22.200632		1
				225.9008789	359.0991211	358.6157227	2
CSM	LEM	691120155339.063	62	359.802246	22.153940		1
				224.7583008	359.1210937	358.7036133	2
CSM	LEM	6911201554 .805	62	359.802246	22.090769		1
				223.7695312	359.1430664	358.7585449	2
CSM	LEM	691120155444.312	62	359.725342	22.678537		1
				221.0668945	359.3298340	358.9562988	2
CSM	LEM	6911201555 9.789	62	359.934082	22.785654		1
				219.7265625	359.4506836	359.2749023	2
CSM	LEM	691120155622.258	62	.560303	22.464304		1
				216.5295410	359.7473145	.1647949	2
CSM	LEM	6911201557 7.297	62	1.186523	22.129221		1
				214.6838379	359.8901367	.7800293	2
CSM	LEM	691120155845.258	62	359.494629	22.491770		1
				209.5751953	.2416992	.2087402	2
CSM	LEM	691120155916.258	62	359.725342	22.763681		1
				207.8063965	.3735352	.5603027	2
CSM	LEM	691120155943.305	62	359.714355	22.634592		1
				206.6308594	.4614258	.6811523	2
CSM	LEM	69112016 020.562	62	359.626465	22.398386		1
				205.0598145	.6042480	.8569336	2
CSM	LEM	69112016 513.633	62	.834961	21.914987		1
				191.4367676	1.2304688	2.5927734	2
CSM	LEM	69112016 545.680	62	359.670410	21.923227		1
				189.8376953	1.5051270	2.2302246	2
CSM	LEM	69112016 618.477	62	359.923096	21.846323		1
				188.3715820	1.7797852	2.8015137	2
CSM	LEM	69112016 7 7.328	62	358.923340	22.178659		1
				185.6909180	2.0764160	2.5927734	2
CSM	LEM	69112016 756.773	62	.900879	22.637338		1
				182.8894043	1.8237305	3.6145020	2

CSM	LEM	69112016 850.344 62	.670166	22.217111			1
			180.7580566	1.6259766	3.1420898		2
LEM	CSM	69112016 228.648 11	358.989258	359.285889	688567.039	-114.8871	
			74.8828125	1.7907715	.4943848		2
LEM	CSM	69112016 312.633 11	359.044189	359.670410	683389.273	-116.7711	
			72.7294922	1.1206055	.0988770		2
LEM	CSM	69112016 417.750 11	359.230957	.263672	675735.195	-119.2821	
			69.4006348	1.4721680	359.5056152		2
LEM	CSM	69112016 543.266 11	.120850	359.956055	665379.672	-123.0491	
			64.4238281	1.4392090	359.8242187		2
LEM	CSM	69112016 651.234 11	358.494873	359.351807	657125.273	-125.5601	
			62.7758789	1.9445801	.3735352		2
LEM	CSM	69112016 759.062 11	359.978027	359.197998	648420.633	-127.4431	
			58.0737305	2.1093750	.5603027		2
LEM	CSM	69112016 9 5.844 11	.516357	359.373779	639791.039	-129.9551	
			54.3383789	2.5817871	.4064941		2
LEM	CSM	691120161012.656 11	359.868164	359.571533	631011.359	-133.0941	
			51.8225098	359.6484375	.1757813		2
LEM	CSM	691120161120.453 11	359.033203	359.307861	621931.516	-134.9771	
			49.4165039	359.8901367	.4504395		2
LEM	CSM	691120161253.234 11	359.747314	.395508	609324.797	-138.1161	
			44.3078613	.4394531	359.3408203		2
LEM	CSM	691120161337.016 11	358.692627	359.417725	603171.516	-139.9991	
			43.2641602	.5603027	.2966309		2
LEM	CSM	691120161356.430 11	359.351807	.878906	600470.078	-139.9991	
			41.6931152	358.7255859	358.8684082		2
LEM	CSM	691120161415.773 11	359.758301	359.505615	597768.633	-140.6271	
			40.3967285	2.5378418	.1977539		2
LEM	CSM	691120161435.133 11	358.374023	.725098	595142.234	-141.2551	
			40.8361816	2.8015137	358.9233398		2
LEM	CSM	691120161455.016 11	359.351807	359.121094	592290.719	-141.8831	
			38.9355469	1.9226074	.5712891		2
CSM	LEM	69112016 255.398114			685203.539		1
							2
CSM	LEM	69112016 6 3.828114			662721.906		1
							2
CSM	LEM	69112016 7 6.258114			654944.484		1
							2
CSM	LEM	69112016 818.625114			645708.789		1
							2
CSM	LEM	69112016 920.953114			637749.078		1

				2
CSM	LEM	691120161023.766114	629364.039	1
				2
CSM	LEM	691120161124.219114	621282.805	1
				2
CSM	LEM	691120153848.539114	815657.734	1
				2
CSM	LEM	691120153952.227114	811161.414	1
				2
CSM	LEM	691120154055.703114	806604.320	1
				2
CSM	LEM	691120154159.312114	801925.719	1
				2
CSM	LEM	6911201543 2.594114	797247.109	1
				2
CSM	LEM	6911201544 5.766114	792386.211	1
				2
CSM	LEM	6911201545 5.953114	787768.367	1
				2
CSM	LEM	6911201546 8.094114	782907.477	1
				2
CSM	LEM	691120155149.227114	753863.641	1
				2
CSM	LEM	691120155250.023114	748273.617	1
				2
CSM	LEM	691120155358.336114	741893.695	1
				2
CSM	LEM	6911201555 2.383114	735696.055	1
				2
CSM	LEM	6911201556 4.484114	729559.180	1
				2
CSM	LEM	6911201557 7.406114	723240.023	1
				2
CSM	LEM	6911201558 9.836114	716738.578	1
				2
CSM	LEM	691120155912.156114	709994.086	1
				2
CSM	LEM	69112016 016.039114	703188.836	1
				2
CSM	LEM	69112016 119.930114	696140.547	1
				2

CDH TO TPI

VEH1	VEH2	YYMMDDHHMMSS.SSS	XF	SHAFT(DEG) INNER(DEG)	TRUN(DEG) MIDDLE(DEG)	RANGE(FT) OUTER(DEG)	RRATE(FPS)
CSM	LEM	691120162813.687	62	359.637451	22.642832		1
				125.0244141	3.1091309	4.9218750	2
CSM	LEM	691120162816.266	62	359.626465	22.653818		1
				124.8815918	3.1420898	4.9658203	2
CSM	LEM	691120162839.289	62	359.461670	22.741709		1
				123.6730957	3.4497070	5.3063965	2
CSM	LEM	691120162920.258	62	359.846191	22.467050		1
				121.9921875	3.7133789	5.8996582	2
CSM	LEM	691120163453.703	62	.834961	22.236337		1
				106.7321777	2.5488281	4.8339844	2
CSM	LEM	691120163454.688	62	.845947	22.247324		1
				106.6662598	2.5378418	4.8339844	2
CSM	LEM	691120163658.812	62	.340576	22.291269		1
				100.9094238	2.4719238	4.4055176	2
CSM	LEM	691120163720.227	62	.131836	22.093515		1
				100.1293945	2.4938965	4.2626953	2
LEM	CSM	691120162423.500	11	357.890625	359.055176	509371.520	-143.1381
				13.4912109	1.4062500	.5493164	2
LEM	CSM	691120162525.055	11	359.439697	.527344	500591.836	-142.5111
				9.0087891	1.6040039	359.1210937	2
LEM	CSM	691120162633.000	11	359.549561	359.780273	490911.680	-142.5111
				5.6689453	3.3618164	359.8571777	2
LEM	CSM	691120162746.703	11	359.417725	.186768	480481.117	-141.8831
				2.2851563	2.6806641	359.4506836	2
LEM	CSM	691120162852.859	11	.307617	359.593506	471026.078	-142.5111
				358.2531738	1.1645508	.0659180	2
LEM	CSM	6911201630 .758	11	359.143066	359.318848	461495.996	-141.8831
				356.2426758	2.7795410	.2966309	2
LEM	CSM	6911201631 8.758	11	359.846191	.164795	451815.836	-141.2551
				352.3205566	2.8015137	359.4836426	2
LEM	CSM	691120163251.203	11	.274658	359.703369	437408.156	-141.2551
				347.0800781	358.6267090	359.9340820	2
LEM	CSM	691120163326.563	11	358.363037	359.516602	432380.477	-140.6271
				347.3327637	358.3300781	.1867676	2

LEM	CSM	691120163345.945 11	.527344	359.263916	429679.039	-141.2551
			344.2675781	356.7810059	.3625488	2
LEM	CSM	6911201634 5.250 11	359.890137	.131836	426977.598	-140.6271
			344.0258789	358.0224609	359.5385742	2
LEM	CSM	691120163510.656 11	.120850	.285645	417747.680	-140.6271
			340.7519531	357.8466797	359.3847656	2
LEM	CSM	691120163618.516 11	358.714600		408367.680	-140.6271
			339.0380859	357.3962402	359.7253418	2
LEM	CSM	691120163725.406 11	358.945312	359.033203	398987.680	-139.9991
			335.7531738	2.0983887	.5932617	2
LEM	CSM	691120163833.680 11	359.219971		389382.559	-139.3721
			332.3693848	1.9116211	359.6374512	2
LEM	CSM	691120163941.680 11	.197754	359.450684	380002.559	-138.7441
			328.2934570	1.1096191	.2197266	2
LEM	CSM	691120164049.594 11	359.022217	.384521	370547.520	-138.1161
			326.4257812	2.1643066	359.2639160	2
LEM	CSM	691120164157.578 11	.714111	359.714355	361242.559	-138.1161
			321.6796875	3.5156250	.0109863	2
LEM	CSM	6911201643 5.547 11	359.472656	.351563	351862.559	-137.4881
			319.9108887	2.2302246	359.3298340	2
LEM	CSM	691120164413.797 11	359.132080	359.252930	342482.559	-136.8601
			317.2521973	2.4279785	.4174805	2
LEM	CSM	691120164521.367 11	.164795	.483398	333252.637	-136.2331
			313.2641602	1.6259766	359.2309570	2
LEM	CSM	691120164629.688 11	359.956055	359.417725	324022.719	-136.2331
			310.5065918	3.0541992	.3076172	2
LEM	CSM	691120164737.750 11	359.318848	359.000244	314792.797	-135.6051
			308.2543945	1.9445801	.7031250	2
CSM	LEM	691120162621.656114			492408.395	1
						2
CSM	LEM	691120162940.383114			464215.219	1
						2
CSM	LEM	691120163318.148114			433470.074	1
						2
CSM	LEM	691120163421.930114			424538.187	1
						2
CSM	LEM	691120163740.617114			396648.816	1
						2
CSM	LEM	691120163841.805114			388203.016	1
						2
CSM	LEM	691120164246.789114			354359.051	1

				2
CSM	LEM	691120164348.023114	345913.250	1
				2
CSM	LEM	691120164449.297114	337588.973	1
				2
CSM	LEM	691120164550.555114	329264.695	1
				2

LM DEORBIT

VEH1	VEH2	YYMMDDHHMMSS.SSS XF	SHAFT(DEG) INNER(DEG)	TRUN(DEG) MIDDLE(DEG)	RANGE(FT) OUTER(DEG)	RRATE(FPS)	
CSM	LEM	691120215126.867114			25094.357		1
							2
CSM	LEM	691120215356.12 114			53287.532227		1
							2
CSM	LEM	691120215441.26 62	356.132812	22.192392			1
			211.9812012	14.3481445	357.4401855		2
CSM	LEM	6911202155 .016114			65318.241		1
							2
CSM	LEM	6911202156 3.83 114			77105.904297		1
							2
CSM	LEM	691120215610.12 62	357.604980	21.541452			1
			212.2668457	14.8974609	357.4182129		2
CSM	LEM	691120215615.48 62	357.868652	21.519480			1
			212.2778320	14.8974609	357.4951172		2
CSM	LEM	691120215636.40 62	357.121582	21.464548			1
			212.3657227	15.1831055	357.1325684		2
CSM	LEM	691120215714.91 114			89987.269531		1
							2
CSM	LEM	691120215830.547 62	356.528320	22.428598			1
			211.6735840	16.3146973	357.2204590		2
CSM	LEM	69112022 018.797114			122129.920		1
							2
CSM	LEM	69112022 420.445114			162839.893		1
							2

APPENDIX E

APOLLO 12 LANDING RADAR DATA

The LM landing radar data that was used in the analysis is listed in the two card format of the HOPE orbit determination program. The first card specifies the vehicle, the time of the observation (year (mod 1900), month, day, hour, minute, and second), three code numbers, V_{XA} measurement, V_{YA} measurement, V_{ZA} measurement, and the slant range measurement (ρ). The second card specifies the inner, middle, and the outer gimbal angles. The units are feet and feet per second.

LANDING RADAR OBSERVATIONS

VEH1	YYMMDDHHMMSS.SSS XF	VX(FPS) INNER(DEG)	VY(FPS) MIDDLE(DEG)	VZ(FPS) OUTER(DEG)	RANGE(FT)
LEM	691119 646 4.187125				47438.2341
		83.3422852	359.0222168	358.1433105	2
LEM	691119 646 6.687125		-244.823999		1
		83.1335449	359.0881348	358.0554199	2
LEM	691119 646 6.187125				47718.7741
		83.1555176	359.0441895	358.0773926	2
LEM	691119 646 8.797125			2126.260376	1
		83.1005859	359.2309570	358.0334473	2
LEM	691119 646 8.187125				47956.1551
		83.0017090	359.1760254	358.0334473	2
LEM	691119 64610.797125	-2947.201569			1
		83.1005859	359.1430664	357.9895020	2
LEM	691119 64610.187125				47643.2451
		83.0017090	359.1320801	357.9785156	2
LEM	691119 64612.797125		-284.819996		1
		82.9467773	359.0661621	357.9895020	2
LEM	691119 64612.187125				47432.8391
		82.9138184	359.0332031	357.9895020	2
LEM	691119 64614.797125			2104.937103	1
		82.7160645	359.0991211	357.9455566	2
LEM	691119 64614.187125				47476.0001
		82.8149414	359.0551758	357.9565430	2
LEM	691119 64616.797125	-2865.928772			1
		82.2326660	359.3737793	357.9125977	2
LEM	691119 64616.187125				46445.5551
		82.4414062	359.3737793	357.9345703	2
LEM	691119 64618.797125		-257.913597		1
		82.0349121	359.0222168	357.8906250	2
LEM	691119 64618.187125				46256.7291
		82.2106934	359.2199707	357.9016113	2
LEM	691119 64620.867125			2080.319977	1
		81.8151855	358.7805176	357.9125977	2
LEM	691119 64620.187125				46024.7451
		82.0129395	358.8684082	357.9235840	2
LEM	691119 64622.797125	-2805.779144			1

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                                     81.5844727 358.8574219 357.9125977           2
LEM          691119 64622.187125                                         45754.9951
                                     81.7163086 358.8134766 357.9125977           2
LEM          691119 64624.887125                -251.126400                       1
                                     81.5625000 359.1101074 357.8906250           2
LEM          691119 64624.187125                                         45868.2901
                                     81.4855957 358.9782715 357.9016113           2
LEM          691119 64626.859125                            2062.637268           1
                                     81.3977051 359.3078613 357.8027344           2
LEM          691119 64626.187125                                         45781.9701
                                     81.3757324 359.1870117 357.8137207           2
LEM          691119 64628.879125-2735.067963                                      1
                                     80.9912109 359.4726562 357.7697754           2
LEM          691119 64628.187125                                         45760.3901
                                     80.9582520 359.3627930 357.7587891           2
LEM          691119 64630.887125                -203.373598                       1
                                     80.9582520 359.4287109 357.8686523           2
LEM          691119 64630.187125                                         45037.4591
                                     80.8374023 359.4396973 357.8247070           2
LEM          691119 64632.879125                            2012.536209           1
                                     81.1560059 359.0441895 358.0554199           2
LEM          691119 64632.187125                                         44584.2801
                                     81.1120605 359.2529297 358.0114746           2
LEM          691119 64634.906125-2694.882355                                      1
                                     80.9912109 358.9782715 358.2092285           2
LEM          691119 64634.187125                                         44951.1401
                                     81.2658691 359.0222168 358.1982422           2
LEM          691119 64636.879125                -225.674400                       1
                                     80.5187988 359.2749023 358.3410645           2
LEM          691119 64636.187125                                         45226.2851
                                     80.8703613 359.2199707 358.3190918           2
LEM          691119 64638.879125                            2010.802612           1
                                     80.0573730 359.9450684 358.4399414           2
LEM          691119 64638.187125                                         44109.5201
                                     80.3100586 359.6923828 358.4179687           2
LEM          691119 64640.879125-2587.591949                                      1
                                     79.7607422    .2636719 358.4948730           2
LEM          691119 64640.187125                                         44406.2451
                                     79.8266602    .1977539 358.4729004           2
LEM          691119 64642.887125                -199.495199                       1
                                     79.7058105 359.8681641 358.4948730           2
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LEM         691119 64642.188125                                              44368.4791
                                79.5080566 359.9780273 358.4729004                    2
LEM         691119 64644.879125                        1975.957260                    1
                                79.7607422 359.5605469 358.4619141                    2
LEM         691119 64644.187125                                              44023.2001
                                79.5520020 359.5495605 358.4399414                    2
LEM         691119 64646.879125-2546.891174                                           1
                                79.8156738 359.5385742 358.4179687                    2
LEM         691119 64646.187125                                              43920.6951
                                79.7277832 359.5275879 358.3959961                    2
LEM         691119 64648.879125            -179.860798                                1
                                79.7058105 359.4506836 358.3410645                    2
LEM         691119 64648.187125                                              43785.8201
                                79.8046875 359.5715332 358.3630371                    2
LEM         691119 64650.906125                        1916.668152                    1
                                79.6289062 359.1430664 358.2861328                    2
LEM         691119 64650.187125                                              43699.5001
                                79.8486328 359.3518066 358.3081055                    2
LEM         691119 64652.887125-2476.952759                                           1
                                79.0905762 358.6596680 358.2421875                    2
LEM         691119 64652.187125                                              43505.2801
                                79.4750977 358.8024902 358.2861328                    2
LEM         691119 64654.887125            -249.429600                                1
                                79.1235352 358.9453125 358.3410645                    2
LEM         691119 64654.187125                                              43327.2451
                                79.1894531 358.8354492 358.3190918                    2
LEM         691119 64656.879125                        1900.545670                    1
                                78.8928223 359.3078613 358.3850098                    2
LEM         691119 64656.187125                                              43267.8991
                                78.6840820 358.9892578 358.3740234                    2
LEM         691119 64658.879125-2428.523956                                           1
                                78.9587402 359.5935059 358.3959961                    2
LEM         691119 64658.187125                                              42744.5841
                                78.7170410 359.5275879 358.3850098                    2
LEM         691119 647  .879125            -195.131998                                1
                                79.1015625 359.7143555 358.3850098                    2
LEM         691119 647  .188125                                              42620.5001
                                78.9038086 359.6923828 358.3959961                    2
LEM         691119 647 2.879125                        1818.719727                    1
                                79.2993164 359.7583008 358.2861328                    2
LEM         691119 647 2.188125                                              42571.9451
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LEM        691119 647 4.906125-2390.656769                                             1
                                         79.0136719 359.7143555 358.2092285            2
LEM        691119 647 4.187125                                                42625.8951
                                         79.4311523 359.7692871 358.2312012            2
LEM        691119 647 6.887125                  -196.343998                            1
                                         78.3764648 359.7912598 358.1323242            2
LEM        691119 647 6.187125                                                42496.4151
                                         78.8269043 359.7473145 358.1652832            2
LEM        691119 647 8.879125                              1844.897095                1
                                         77.7502441 359.9890137 358.0773926            2
LEM        691119 647 8.187125                                                41967.7051
                                         77.9370117 359.8132324 358.0773926            2
LEM        691119 64710.879125-2275.251953                                             1
                                         77.4536133    .1538086 358.0114746            2
LEM        691119 64710.187125                                                41595.4501
                                         77.2558594    .0329590 358.0114746            2
LEM        691119 64712.879125                  -193.192799                            1
                                         77.9589844    .0329590 357.9455566            2
LEM        691119 64712.187125                                                41212.4051
                                         77.4206543    .0988770 357.9345703            2
LEM        691119 64714.879125                              1747.815506                1
                                         79.1015625 359.8901367 357.8576660            2
LEM        691119 64714.187125                                                41401.2291
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LEM        691119 64716.879125-2304.489563                                             1
                                         79.6398926 359.8571777 357.8137207            2
LEM        691119 64716.187125                                                41536.1041
                                         80.0683594 359.9560547 357.8576660            2
LEM        691119 64718.937125                  -209.191198                            1
                                         78.5192871 359.8681641 357.7697754            2
LEM        691119 64718.187125                                                41854.4101
                                         79.3981934 359.6594238 357.8027344            2
LEM        691119 64720.879125                              1754.229828                1
                                         77.0361328    .5053711 357.7697754            2
LEM        691119 64720.187125                                                41136.8751
                                         77.5964355    .1977539 357.7917480            2
LEM        691119 64722.879125-2160.362366                                             1
                                         76.7944336    .4064941 357.8906250            2
LEM        691119 64722.187125                                                40424.7341
                                         76.1452402    .4504395 357.7478027            2
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                                 77.9479980 359.7143555 358.1982422                         2
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                                 77.2998047    .0549316 358.0773926                         2
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                                 78.3654785 359.5495605 358.4509277                         2
LEM         691119 64726.187125                                               40322.2291
                                 78.3544922 359.6154785 358.3740234                         2
LEM         691119 64728.879125-2131.897552                                                 1
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LEM         691119 64728.187125                                               40246.7001
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                                 77.2448730    .0659180 358.9672852                         2
LEM         691119 64732.187125                                               39361.9191
                                 76.9152832 359.9011230 358.9013672                         2
LEM         691119 64734.879125-2086.044769                                                 1
                                 77.8161621    .0219727 359.0332031                         2
LEM         691119 64734.187125                                               39475.2151
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                                 77.0141602    .4724121 359.0222168                         2
LEM         691119 64740.887125-1969.351974                                                 1
                                 75.1794434    .1428223 358.8134766                         2
LEM         691119 64740.187125                                               38363.8451
                                 75.8386230    .1208496 358.8793945                         2
LEM         691119 64742.887125                 -155.620798                                 1
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LEM         691119 64742.188125                                               37975.4051
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LEM         691119 64744.187125                                               38142.6491
                                 76.8164062 359.6813965 358.5278320                         2
LEM         691119 64746.906125-1963.040787                                                 1
                                 76.8164062    .0659180 358.4289551                         2
LEM         691119 64746.187125                                               38148.0441
                                 77.0141602    .0439453 358.4399414                         2
LEM         691119 64748.887125                 -144.470398                                 1
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                                             75.3332520    .2526855 358.3520508                  2
LEM          691119 64748.187125                                                        37678.6801
                                             75.9045410    .5163574 358.4179687                  2
LEM          691119 64750.887125                                     1502.164383                  1
                                             76.7175293    .3076172 358.2202148                  2
LEM          691119 64750.187125                                                        37058.2541
                                             76.3879395    .4064941 358.2751465                  2
LEM          691119 64752.879125-1909.975159                                                      1
                                             76.9372559    .4943848 358.1762695                  2
LEM          691119 64752.187125                                                        37149.9701
                                             77.3547363 359.8791504 358.1542969                  2
LEM          691119 64756.887125                                     1460.904709                  1
                                             75.9704590 359.0332031 358.0114746                  2
LEM          691119 64756.187125                                                        36448.6201
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LEM          691119 64758.887125-1841.968781                                                      1
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LEM          691119 64758.187125                                                        36324.5351
                                             76.7724609 359.1760254 357.9895020                  2
LEM          691119 648  .949125                        -110.776799                               1
                                             76.2780762   1.4611816 357.9235840                  2
LEM          691119 648  .188125                                                        36346.1151
                                             76.7504883    .7910156 357.9565430                  2
LEM          691119 648 2.887125                                     1428.833115                  1
                                             74.9047852   1.1425781 357.8466797                  2
LEM          691119 648 2.188125                                                        35801.2201
                                             75.2893066   1.2634277 357.8686523                  2
LEM          691119 648 4.879125-1768.295166                                                      1
                                             75.4321289    .0109863 357.8247070                  2
LEM          691119 648 4.187125                                                        34981.1801
                                             74.5971680    .0439453 357.7478027                  2
LEM          691119 648 6.887125                        -154.166399                               1
                                             76.5527344    .0439453 357.9455566                  2
LEM          691119 648 6.187125                                                        35612.3951
                                             76.2121582    .0988770 357.9125977                  2
LEM          691119 648 8.879125                                     1382.199265                  1
                                             75.0915527    .8239746 357.9785156                  2
LEM          691119 648 8.187125                                                        35412.7801
                                             76.1352539   1.0107422 358.0114746                  2
LEM          691119 64810.879125-1668.475174                                                      1
                                             73.6962891    .4943848 357.9345703                  2
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LEM	691119	64810.187125				34786.9591
			74.1137695	.4284668	357.9785156	2
LEM	691119	64812.887125		-96.232799		1
			75.0476074	1.2634277	357.9455566	2
LEM	691119	64812.187125				34436.2851
			74.4104004	.7910156	357.9345703	2
LEM	691119	64814.918125			1348.567429	1
			74.2565918	359.6704102	357.8576660	2
LEM	691119	64814.187125				34468.6551
			74.3334961	.3295898	357.8356934	2
LEM	691119	64816.898125	-1637.176788			1
			74.6740723	359.5825195	357.7697754	2
LEM	691119	64816.187125				34166.5351
			74.5092773	359.6484375	357.8137207	2
LEM	691119	64818.887125		-123.866399		1
			74.2016602	.9228516	357.7807617	2
LEM	691119	64818.187125				34123.3751
			74.7399902	.6921387	357.8027344	2
LEM	691119	64820.687125			1318.749496	1
			73.6413574	1.1096191	357.7697754	2
LEM	691119	64820.187125				33972.3141
			73.8830566	.9667969	357.7587891	2
LEM	691119	64822.879125	-1550.365570			1
			73.3117676	.1977539	357.8686523	2
LEM	691119	64822.187125				33524.5301
			72.8283691	.1428223	357.7917480	2
LEM	691119	64824.879125		-162.407999		1
			73.7402344	359.8352051	357.9016113	2
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1.757				28.4106445	.7360840	2.8894043		2
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4.240				28.6633301	.9887695	3.0212402		2
	LEM	691119	65134.187125				3555.305	1
3.427				28.5205078	.4943848	3.0102539		2
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3.581				28.7841797	1.2524414	2.9882813		2
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3.933				28.7841797	.9118652	3.0212402		2
	LEM	691119	65138.867125	-225.915195				1
3.175				28.6523437	.5163574	2.8125000		2
	LEM	691119	65138.187125				3134.495	1
3.240				28.7841797	.7690430	2.8784180		2
-18.66	LEM	691119	65140.879125		-25.936800			1
3.625				28.7841797	.2087402	2.5598145		2
	LEM	691119	65140.187125				2929.485	1
3.383				28.9599609	.3076172	2.6477051		2
	LEM	691119	65142.867125			206.991838		1
3.394				28.6853027	.8020020	2.4389648		2
	LEM	691119	65144.758125	-202.602396				1
3.515				28.8061523	.8679199	2.4609375		2
	LEM	691119	65142.188125				2773.030	1
2.680				28.7292480	1.2524414	2.4279785		2
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                                    248.1701
56.5612793 345.6518555                     2
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                                    134.8751
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              28.2348633   4.1857910 357.8027344                     2
5148.187125                                                  2310.1391
              28.3117676   3.2629395 358.0444336                     2
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5156.187125                                                  1800.8511
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52   .188125                                                 1578.5771
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52 4.187125                                                  1383.2781
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52 6.137125                                                  1296.9581
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LEM	691119	653 4.187125				289.1721	
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LEM	691119	653 7.297125			21.670000		1
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LEM	691119	653 6.187125				279.4611	
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LEM	691119	65315.297125		11.635200			1
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LEM	691119	65315.297125			8.321280		1
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LEM	691119	65340.719125		-7.514400			1
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LEM	691119	65342.188125				144.5861	
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LEM	691119	65344.187125				134.8751	
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LEM	691119	65347.199125		-1.939200			1
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LEM	691119	65349.289125			7.801200		1
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LEM	691119	65354.187125				77.6881
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LEM	691119	654 8.187125				56.1081
			2.2961426	.7580566	351.7932129	2
LEM	691119	65410.957125		-.969600		1
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LEM	691119	65410.187125				55.0291
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LEM	691119	65412.187125				45.3181
			2.1643066	.5822754	351.6284180	2
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			2.5488281	.6701660	351.7932129	2
LEM	691119	65414.187125				43.1601
			2.4279785	.7360840	351.3867187	2
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LEM	691119	65416.187125				43.1601
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LEM      691119 65420.187125                                               38.8441
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LEM      691119 65423.367125               .000000                               1
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LEM      691119 65425.297125                           -.173360                  1
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LEM      691119 65424.187125                                               18.3431
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LEM      691119 65427.289125   -1.288000                                         1
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LEM      691119 65426.187125                                               15.1061
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LEM      691119 65429.297125               -.242400                              1
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LEM      691119 65428.187125                                               25.8961
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LEM      691119 65431.289125                          14.215520                  1
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LEM      691119 65433.277125    7.341600                                         1
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LEM      691119 65432.187125                                               56.1081
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LEM      691119 65434.187125                                      38.844         1
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LEM      691119 65435.297125                         -2.080320                   1
                              357.4841309 358.5498047 351.2219238                2
LEM      691119 65435.297125    1.545600                                         1
                              357.4841309 358.5498047 351.2219238                2
LEM      691119 65435.297125              -2.908800                              1
                              357.4841309 358.5498047 351.2219238                2
LEM      691119 65436.187125                                                6.4741
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LEM      691119 65435.297125                         -2.080320                   1
                              357.4841309 358.5498047 351.2219238                2
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APPENDIX F

LM FREE FLIGHT TRAJECTORY, REV. 14

REGION OF MARE NECTARIS

ALTITUDE ABOVE MLR (FEET)	SELENOGRAPHIC LATITUDE (DEGREES)	SELENOGRAPHIC LONGITUDE (DEGREES)	GET (HR-MN- SEC)
158129.0	-15.1012	67.9194	109 58 .008
153844.2	-15.1773	66.2583	109 58 30.008
149594.1	-15.2414	64.5937	109 59 .008
145382.2	-15.2934	62.9257	109 59 30.008
141211.8	-15.3331	61.2546	110 0 .008
137086.3	-15.3604	59.5807	110 0 30.008
133009.0	-15.3754	57.9040	110 1 .008
128983.2	-15.3779	56.2249	110 1 30.008
125012.1	-15.3678	54.5435	110 2 .008
121099.0	-15.3452	52.8601	110 2 30.008
117247.1	-15.3099	51.1749	110 3 .008
113459.5	-15.2621	49.4882	110 3 30.008
109739.3	-15.2016	47.8002	110 4 .008
106089.5	-15.1285	46.1111	110 4 30.008
102513.3	-15.0428	44.4212	110 5 .008
99013.5	-14.9446	42.7306	110 5 30.008
95593.0	-14.8339	41.0397	110 6 .008
92254.7	-14.7107	39.3486	110 6 30.008
89001.4	-14.5752	37.6576	110 7 .008
85835.8	-14.4275	35.9669	110 7 30.008
82760.5	-14.2677	34.2767	110 8 .008
79778.2	-14.0958	32.5871	110 8 30.008
76891.3	-13.9120	30.8985	110 9 .008
74102.2	-13.7166	29.2110	110 9 30.008
71413.4	-13.5095	27.5248	110 10 .008
68827.1	-13.2911	25.8400	110 10 30.008
66345.6	-13.0614	24.1569	110 11 .008
63970.8	-12.8207	22.4755	110 11 30.008
61705.0	-12.5693	20.7960	110 12 .008
59549.9	-12.3072	19.1186	110 12 30.008
57507.5	-12.0348	17.4434	110 13 .008
55579.4	-11.7522	15.7704	110 13 30.008
53767.5	-11.4599	14.0999	110 14 .008
52073.2	-11.1579	12.4318	110 14 30.008
50497.9	-10.8465	10.7663	110 15 .008
49043.2	-10.5262	9.1034	110 15 30.008
47710.2	-10.1970	7.4432	110 16 .008
46500.0	-9.8594	5.7857	110 16 30.008
45413.9	-9.5136	4.1310	110 17 .008
44452.6	-9.1600	2.4791	110 17 30.008
43617.1	-8.7988	.8299	110 18 .008
42908.1	-8.4304	-.8164	110 18 30.008
42326.2	-8.0551	-2.4600	110 19 .008
41872.0	-7.6733	-4.1008	110 19 30.008
41464.3	-7.1521	-6.2940	110 20 9.500

REFERENCES

1. "Apollo 12 Descent Postflight Analysis," MSC Memo 69-FM22-324, to D. J. Incerto from Landing Analysis Branch, dated 19 December, 1969.

2. Girod, W. P., "Task A-50 BET Delivery - LM Ascent and Insertion to CSI Trajectory," TRW IOC 70:7254.3-6, dated 16 January 1969.

3. Girod, W. P., "Task A-50 BET Delivery CSM Segment 1 (Post TLI to Lunar SOI)," TRW IOC 69:7254.3-106, dated 20 November 1969.

4. Girod, W. P., "Task A-50 BET Delivery Real Time LM Powered Descent," TRW IOC 69:7254.3-108, dated 21 November 1969.

5. Girod, W. P., "Task A-50 BET Delivery Real Time LM Ascent," TRW IOC 69:7254.3-109, dated 21 November 1969.

6. Girod, W. P., "Task A-50 BET Delivery CSM Segment 2 (Lunar SOI to LOPC-1)," TRW IOC 69:7254.3-111, dated 25 November 1969.

7. Girod, W. P., "Task A-50 BET Delivery CSM Segment 3 (LOPC-1 to Lunar SOI)," TRW IOC 69:7254.3-113, dated 26 November 1969.

8. Girod, W. P., "Task A-50 BET Delivery Preliminary LM Free Flight BET," TRW IOC 69:7254.3-115, dated 26 November 1969.

9. Girod, W. P., "Task A-50 BET Delivery CSM Segment 4 (Lunar SOI to Entry Interface)," TRW IOC 69:7254.3-117, dated 2 December 1969.

10. Girod, W. P., "Task A-50 BET Delivery: Preliminary Entry," TRW IOC 69:7254.3-126, dated 22 December 1969.

11. Girod, W. P., "Task A-50 BET Delivery - LM Ascent Stage Impact Trajectory," TRW IOC 70:7254.3-4, dated 9 January 1970.

12. Girod, W. P., "Task A-50 BET Delivery Final LM Powered Descent," TRW IOC, dated 6 February 1970.

13. Moore, J. B., "Task A-50 BET Delivery - LOI-1 and TEI Powered Flight Trajectories, TRW IOC 70:7254.3-6, dated 19 January 1970.

14. "Support to the Postflight Analysis of the GN&C Systems on Apollo 12," TRW Letter 69:7254.3-124, to J. F. Hanaway (EG7) from D. L. Rue, dated 18 December 1969.

15. TRW Document 11176-H508-R0-00, "Apollo Mission 11, Trajectory Reconstruction and Postflight Analysis, Volume I," dated 16 March 1970

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