MSC-PA-R-68-7
Supplement 2

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 5 MISSION REPORT

APOLLO MISSION 5/AS-204/LM-1 TRAJECTORY RECONSTRUCTION AND POSTFLIGHT ANALYSIS

VOLUME I

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MANNED SPACECRAFT CENTER
HOUSTON, TEXAS
May 1968

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VOLUME I

May 13, 1968

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

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PROJECT APOLLO

TASK MSC/TRW A-50

APOLLO MISSION 5/AS-204/LM-1 TRAJECTORY RECONSTRUCTION AND POSTFLIGHT ANALYSIS - APPENDIXES

VOLUME I

22 APRIL 1968

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FOREWORD

This report is submitted to the NASA Manned Spacecraft Center in accordance with Task MSC/TRW A-50.3 Contract NAS 9-4810. This report contains the postflight analysis performed in conjunction with the flight of Apollo Mission 5/AS-204/LM-1, and is issued as a supplement to Section 3, Trajectory Section, of the Apollo Program 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 LM-1 mission from S-IVB separation to the occurrence of the gimbal lock condition in the PRA-V burn sequence. This listing is in the NASA Apollo Trajectory (NAT) format which is shown below. The listing is not generally distributed, but is available from NASA/MSC upon request. Requests should be made to:

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

The listing is in three parts which are identified by time span covered and the corresponding accession number.

	Time Span (GET)	Accession No.
Part I	00:53:54 - 04:06:21	05 - 07334
Part II	04:06:00 - 06:17:56	05 - 07335
Part III	06:13:40 - 07:47:32	05 - 07336

NASA APOLLO TRAJECTORY INDEX

1	GMTR SECONDS	GMTC SECONDS	GMTC HOURS	GETS SECONDS		GRR SECONDS	GMTC HR MIN SEC
8	GEOCENTRIC LATITUDE DEGREES	GEODETIC LATITUDE DEGREES	GEODETIC LONGITUDE DEGREES	GEODETIC ALTITUDE FEET	INERTIAL VELOCITY FEET/SEC	INERTIAL PATH ANGLE DEGREES	INERTIAL HEADING DEGREES
15	DECLINATION DEGREES	ORBIT RADIUS FEET	RADIUS DERIVATIVE FEET/SEC	GEOCENTRIC ALTITUDE FEET	RELATIVE VELOCITY FEET/SEC	RELATIVE PATH ANGLE DEGREES	RELATIVE HEADING DEGREES
22	(BLANK)	CENTRAL ANGLE DEGREES	HORIZON ANGLE DEGREES	SUN THETA DEGREES	SUN PHI DEGREES	GROUND RANGE NMI	DISTANCE TRAVELED NMI
29	X ECI FEET	Y ECI FEET	Z ECI FEET	XDOT ECI FEET/SEC	YDOT ECI FEET/SEC	ZDOT ECI FEET/SEC	G SUB X FEET/SEC**2
36	X ECIG FEET	Y ECIG FEET	Z ECIG FEET	XDOT ECIG FEET/SEC	YDOT ECIG FEET/SEC	ZDOT ECIG FEET/SEC	G SUB Y FEET/SEC**2
43	X AGC FEET	Y AGC FEET	Z AGC FEET	XDOT AGC FEET/SEC	YDOT AGC FEET/SEC	ZDOT AGC FEET/SEC	G SUB Z FEET/SEC**2
50	P ESF FEET	Q ESF FEET	R ESF FEET	PDOT ESF FEET/SEC	QDOT ESF FEET/SEC	RDOT ESF FEET/SEC	G TOTAL FEET/SEC**2
57	U ECF FEET	V ECF FEET	W ECF FEET	UDDOT ECF FEET/SEC**2	VDDOT ECF FEET/SEC**2	WDDOT ECF FEET/SEC**2	ORBIT
64	XDDOT ECI FEET/SEC**2	YDDOT ECI FEET/SEC**2	ZDDOT ECI FEET/SEC**2	XDDOT ECIG FEET/SEC**2	YDDOT ECIG FEET/SEC**2	ZDDOT ECIG FEET/SEC**2	REVOLUTION
71	XDDOT AGC FEET/SEC**2	YDDOT AGC FEET/SEC**2	ZDDOT AGC FEET/SEC**2	APOGEE RADIUS FEET	PERIGEE RADIUS FEET	APOGEE ALTITUDE NMI	PERIGEE ALTITUDE NMI
78	SEMI-MAJOR AXIS FEET	SEMI-MINOR AXIS FEET	ECCENTRICITY	INCLINATION DEGREES	RT. ASCEN. NODE, AIRES DEGREES	ARGUMENT PERIGEE DEGREES	TRUE ANOMALY DEGREES
85	PERIOD MINUTES	RT. ASCEN. SAT., GRNWCH DEGREES	RT. ASCEN. SAT., ARIES DEGREES	(BLANK)	RT. ASCEN. NODE, GRNWCH DEGREES	ECCENTRIC ANOMALY DEGREES	MEAN ANOMALY DEGREES
92	(BLANK)	SEMI-LATUS RECTUM FEET	SPEED OF SOUND FEET/SEC	MACH NUMBER	DYNAMIC PRESSURE LB/FT**2	REYNOLDS NUMBER	TOTAL ENERGY FT-LBS
99	ATMOSPHERIC DENSITY SLUGS/FT**3	ATMOSPHERIC PRESSURE LB/IN**2	TEMPERATURE DEGREES RANKINE	XDDOT PIPA FEET/SEC**2	YDDOT PIPA FEET/SEC**2	ZDDOT PIPA FEET/SEC**2	PIPA TOTAL ACCELERATION FEET/SEC**2
106	XDOT PIPA FEET/SEC	YDOT PIPA FEET/SEC	ZDOT PIPA FEET/SEC	PIPA TOTAL VELOCITY FEET/SEC	AERODYNAMIC VELOCITY FEET/SEC	AERODYNAMIC PATH ANGLE DEGREES	AERODYNAMIC HEADING DEGREES
113	XDOT ESF WIND CORR. FEET/SEC	YDOT ESF WIND CORR. FEET/SEC	ZDOT ESF WIND CORR. FEET/SEC	WIND SPEED FEET/SEC	WIND DIRECTION DEGREES		

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3.1 INTRODUCTION AND SUMMARY

3.1.1 Sequence of Events

The Apollo 5 mission was launched from launch complex 37 B at Cape Kennedy, Florida, on 22 January 1968. Range zero was established at 22 hours, 48 minutes, and 8 seconds Greenwich mean time (GMT), with lift-off occuring 0.4 second later. Lunar module/Saturn IVB (LM/S-IVB) insertion occurred at 10 minutes and 3.3 seconds ground elapsed time (GET) with subsequent LM/S-IVB separation at 53 minutes and 56 seconds GET.

After two and a half revolutions, the first descent engine burn was initiated by the guidance computer. This burn was performed at less than full tank pressures; consequently, the thrust buildup was not adequate, and the engine was shutdown by the computer 4 seconds after ignition.

The premature cutoff of this burn required deviations from the planned mission. A modified alternate mission was used which combined mission program sequences III and V. Mission program sequence III was comprised of two descent engine burns and two ascent engine burns. However, the second ascent engine burn in sequence III was inhibited by ground command. Mission program sequence V was comprised of an ascent engine burn that continued until all the fuel aboard was depleted. Table 3-1 lists the times associated with events pertinent to this trajectory analysis. A complete mission description may be obtained from the Apollo 5 Mission Report. Figure 3-1 presents the AS-204 mission time-lines and tracking periods.

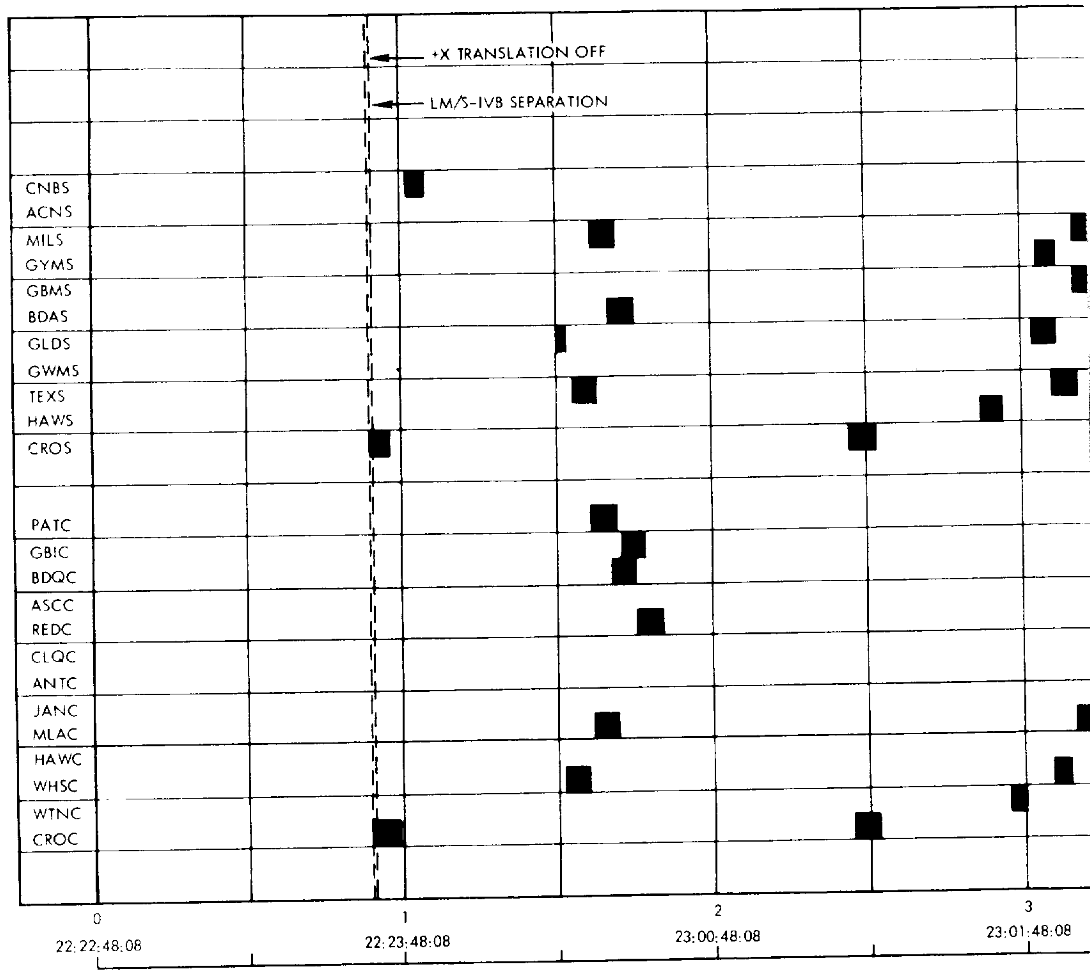
3.1.2 Analysis and Programs

This section describes the programs that are used in the postflight trajectory analysis. The programs used to reconstruct the orbital phase of a mission and associated programs are discussed first, followed by description of the programs used in the analysis of the guidance system and the reconstruction of the spacecraft trajectory during thrusting periods.

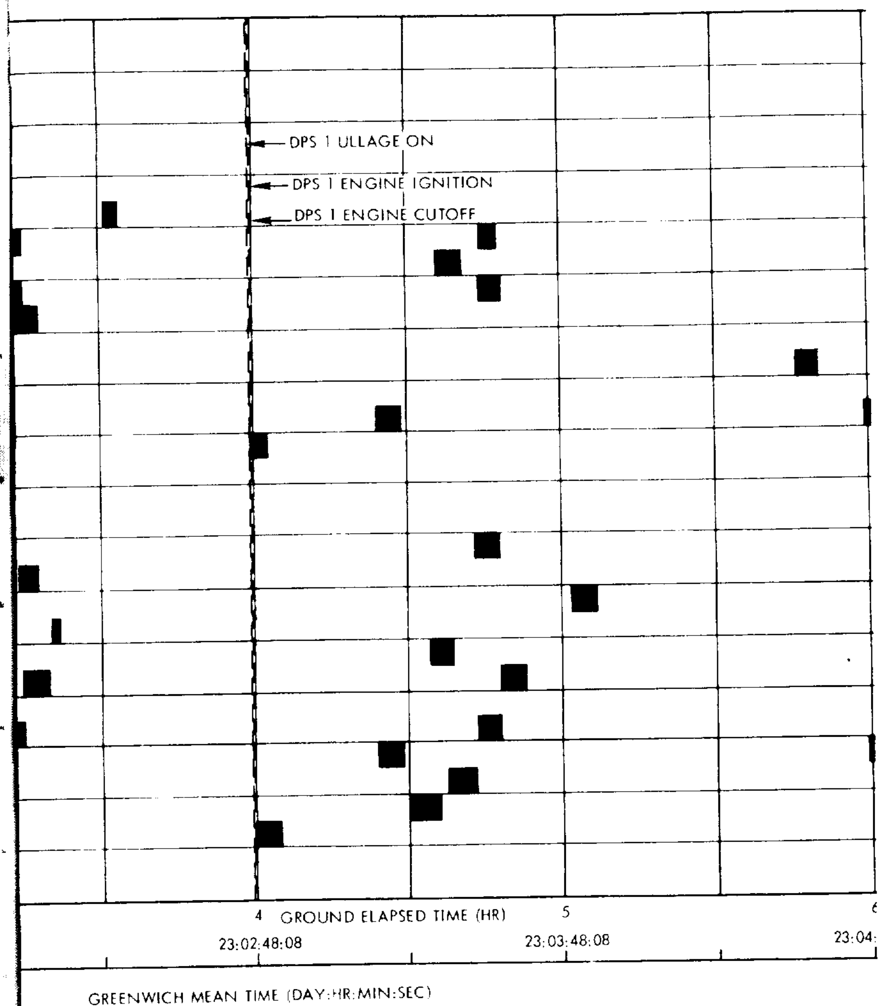
Table 3-1. Summary of Events

Event	Revolution	Date	Ground Elapsed Time (hr:min:sec)	Greenwich Mean Time (hr:min:sec)
LM/S-IVB Separation*	1	22 January	0:53:55.9	23:42:02.9
+X translation off	1	22 January	0:54:10.2	23:42:18.2
DPS 1 ullage on	3	23 January	3:59:33.9	2:47:41.9
DPS 1 engine ignition	3	23 January	3:59:41.7	2:47:49.7
DPS 1 engine cutoff	3	23 January	3:59:45.7	2:47:53.7
RCS +X ullage start (PRA III)	4	23 January	6:10:07.4	4:58:15.4
DPS engine igniton (PRA III)	4	23 January	6:10:41.7	4:58:49.7
FITH (PRA III)	4	23 January	6:12:14.7	5:00:22.7
APS engine cutoff (PRA III)	4	23 January	6:13:14.3	5:01:22.3
RCS +X ullage start (PRA V)	5	23 January	7:44:00.3	6:32:08.3
APS engine ignition (PRA V)	5	23 January	7:44:12.7	6:32:20.7
APS fuel depletion (PRA V)	5	23 January	7:50:03.0	6:38:11.0

*According to telemetry information separation occured at 53 minutes and 55.242 seconds GET



FOLDOUT FRAME 1



FOLDOUT FRAME 2

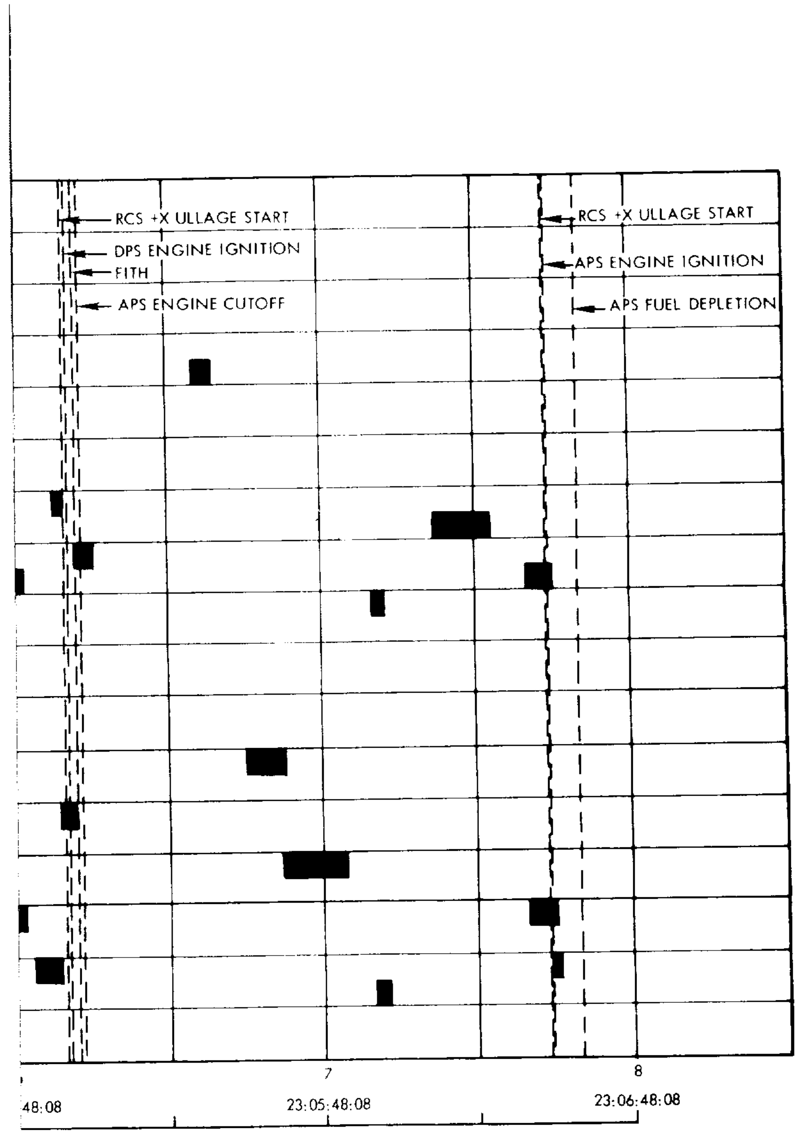


Figure 3-1. AS-204 Mission Timeline and Tracking Periods

FOLDOUT FRAME 3

Orbit Reconstruction Programs

Low-speed tracking data for a mission are received from MSC on a magnetic tape. The data tape is input into the Master Tape Generator (MATAG) Program which reformats the data into a format that is compatible with the TRW orbit determination program (ESPOD) and generates a time-ordered master data tape. The master data tape is then input into the ESPOD Data Generator (EDG) Program which edits the master data tape and outputs the data in the form of tape or cards.

The ESPOD Program determines the state vector for a spacecraft at a given epoch and the covariance matrix of uncertainties. This is accomplished by an iterative process which minimizes the weighted sum of the squares of the residuals, where the residuals are the difference between the actual observations and the computed observations based upon a current estimate of the spacecraft trajectory. ESPOD also has the capability of including in the solution vector such parameters as drag ($C_d A/2M$), radar errors, and station location errors.

There exist two versions of ESPOD, both of which have the general capability described above. The USB ESPOD is distinguished by the fact that it can process RAE$\dot{R}$, RXY, and doppler radar tracking data. It does not, however, have the capability of modeling burns. The IGS ESPOD, in contrast, can only process RAE$\dot{R}$ radar tracking data even though it does have two burn models, the LOP burn model and the IGS burn model. The LOP burn model uses an analytic thrust acceleration model - constant thrust oriented along the roll axis. Thrust/mass ratio, and orientation of roll axis are some of the parameters that can be included in the solution vector. The IGS burn model uses an acceleration burn tape based on telemetered data which is then input into ESPOD. Accelerometer and gyro errors may be modeled or included in the solution vector.

After a best estimate of the trajectory (BET) is obtained in ESPOD, a trajectory tape is generated and input into the RTCC Comparison Program. This program compares the RTCC trajectory and the BET by means of state vector differences exhibited in various coordinate systems. The total difference in position and velocity is also listed.

Guidance and Navigation Programs

The spacecraft trajectory during thrusting periods after S-IVB separation is reconstructed from inertial measurement data telemetered from the guidance and navigation system. Before an accurate reconstruction can be undertaken, it is necessary to determine the systematic errors present in the guidance system hardware so that appropriate corrections to the IMU data can be made. This procedure for trajectory reconstruction may be divided into three general areas.

Data Processing

The three sources of trajectory data used in Apollo IMU evaluation must be formated so that they are compatible with the trajectory computing programs.

a) The G&N Processor Program is used to edit Apollo downlink telemetry data and produce a regular ephemeris of measured position, velocity, and acceleration.

b) The S-IVB Processor Program is used to interpolate the S-IVB IU trajectory to the AGC/LGC time base and rotate the data into appropriate coordinate frames.

c) The General Data Processor Program is used to smooth, interpolate, and rotate high-speed tracking data (GLOTRAC, C-band) to an appropriate time base and coordinate frame.

IMU Evaluation

Determination of the systematic errors present in the Apollo guidance system is based primarily on comparisons of the trajectory (sensed and total) as measured by the AGC/LGC, with S-IVB and GLOTRAC trajectories. The boost phase of any mission is the most important for this analysis because of the relatively long time duration with high acceleration levels. The two principal tools used in IMU error analysis are discussed in the following paragraphs.

a) The Error Analysis Program (EAP) is used to compute the partial derivatives of sensed position, velocity, and acceleration ($\partial Ps/\partial Ek$, $\partial Vs/\partial Ek$, $\partial As/\partial Ek$) with respect to each of the error terms, E_k, in the Apollo IMU error model. The input which drives the EAP is the edited ephemeris of sensed acceleration obtained from the G&N Processor Program.

b) The Velocity Comparison Program (VELCOMP) corrects the Apollo sensed trajectory profile using the EAP partials and the best estimates of the IMU errors, E_k. It then compares the corrected trajectory (in both sensed and total coordinates) with external reference trajectory data (S-IVB and GLOTRAC). The recovered set of IMU errors must, of course, be compatible with the preflight test history of the onboard guidance system and with the known trajectory constraints during later phases of the mission.

Trajectory Reconstruction

During thrusting periods for which limited external trajectory data are available, a different technique for trajectory reconstruction is employed. This method relies on two external inputs: (1) the set of IMU hardware errors determined from ascent analysis and (2) an accurate state vector, (P_o, V_o), from the ESPOD program to initialize the total trajectory. The Trajectory Reconstruction Program is driven with the outputs of the G&N Processor and EAP Programs. At time, t_i, the total corrected velocity is computed from:

$$V_{Ti} = V_o + V_{si} - \sum_K \frac{\partial V_{si}}{\partial E_k} E_k + V_{Gi}$$

This quantity is integrated to obtain total position, P_{Ti}, which is extrapolated to time, t_{i+1}, for the next computation of velocity due to gravity, (V_{Gi+1}).

3.2 ASCENT ANALYSIS

Analysis of IMU errors consists of determining the physically acceptable set of errors which bring the LM G&N trajectory into agreement with the best estimate of the actual trajectory flown. This "best estimate" is referred to as the Best Estimate Trajectory (BET). During the boost phase there were eight trajectories available from which to chose a standard of comparison, or BET. These eight trajectories were classed into two independent groups. Five of the trajectories were generated by MSFC from the S-IVB Instrument Unit (IU) telemetry data. They represent a five-stage evolution in the processing of that data, from the raw (quick look) IU output through a final S-IVB BET designated the "Final S-IVB Observed Mass Point Trajectory (OMPT)". The three remaining trajectories represent a similar evolution in the processing of GLOTRAC radar data. The final OMPT and final GLOTRAC trajectories agreed closely throughout most of the burn. However, the GLOTRAC data BET became erratic near the endpoints of the burn, and the final trajectory generated from it was truncated to exclude data prior to 24 seconds and subsequent to 552 seconds. Therefore, in order to have a continuous trajectory available for comparisons with the LM G&N data, and since the S-IVB data agreed so well with the external source (GLOTRAC), the S-IVB final OMPT was chosen as the boost phase BET.

The error magnitudes associated with each IMU error model parameter were derived from comparisons of the LM G&N trajectory and the BET. These errors are presented in Table 3-2 together with their preflight estimates and uncertainties. In this table, the great majority of the derived error magnitudes lie within their associated uncertainty band. In general, errors satisfying that constraint will not be discussed further except to reiterate that they were selected because the state vector errors they produce coincide with observed residuals.

The IMU error set given in Table 3-2 was used to construct a compensated LM G&N trajectory. Plots of the trajectory comparisons are presented in this section to demonstrate the residuals in velocity and position which were obtained before and after compensation of the LM G&N trajectory. Figures 3-2 through 3-7 present the velocity and position residuals, respectively, which existed between the uncompensated G&N and BET trajectories. Figures 3-8 through 3-13 present the residuals remaining after the LM G&N trajectory had been compensated for errors.

Table 3-2. IMU Performance Parameters

Parameter	Actual Value (Inflight Performance)	LGC Compensation Value (Preflight Load)	Actual Error (Actual Minus Compensation)	Preflight Data Mean	Preflight Error Estimates (Preflight Data Mean Minus Compensation)	1σ Specification (GSOP)	Error Uncertainty* Maximum	Error Uncertainty* Minimum
ACBX(μg)	96.0	143.0	-47.0	154.0	11.0	204.0	215.0	-193.0
ACBY(μg)	-364.0	-224.0	-140.0	-263.0	-39.0	204.0	165.0	-243.0
ACBZ(μg)	19.0	122.0	-103.0	122.0	0.0	204.0	204.0	-204.0
SFEX(PPM)	-41.0	-145.0	104.0	-142.0	3.0	116.0	119.0	-113.0
SFEY(PPM)	-59.0	-74.0	15.0	-80.0	-6.0	116.0	110.0	-122.0
SFEZ(PPM)	-431.0	-519.0	88.0	-469.0	50.0	116.0	166.0	-66.0
MXAZ(arc sec)	21.0	Uncompensated	21.0	-6.0	-6.0	20.0	14.0	-26.0
MXAY(arc sec)	-5.0	Uncompensated	5.0	-3.0	-3.0	20.0	17.0	-23.0
MYAZ(arc sec)	24.0	Uncompensated	-24.0	10.0	10.0	20.0	30.0	-10.0
MYAX(arc sec	10.0	Uncompensated	10.0	-4.0	-4.0	20.0	16.0	-24.0
MZAY(arc sec)	13.0	Uncompensated	13.0	0.0	0.0	20.0	20.0	-20.0
MZAX(arc sec)	-5.0	Uncompensated	-5.0	-20.0	-20.0	20.0	0.0	-40.0
NBDX(deg/hr)	-0.1468	-0.120	-0.0268	-0.132	-0.012	0.030	0.018	-0.042
NBDY(deg/hr)	-0.1172	-0.117	-0.0002	-0.124	-0.007	0.030	0.023	-0.037
NBDZ(deg/hr)	-0.0179	-0.030	0.0121	-0.0345	-0.0045	0.030	0.0255	-0.0345
ADIAX(deg/hr/g)	-0.326	-1.005	0.679	-0.728	0.277	0.120	0.397	0.157
ADIAY(deg/hr/g)	-0.0954	-0.105	0.0096	-0.0345	0.0705	0.120	0.190	-0.0495
ADIAZ(deg/hr/g)	-0.131	-0.735	0.604	-0.568	0.167	0.120	0.287	0.057
ADSRAX(deg/hr/g)	0.208	0.107	0.101	0.102	-0.005	0.075	0.070	-0.080
ADSRAY(deg/hr/g)	0.0821	0.099	-0.0169	0.0855	-0.0135	0.075	0.0615	-0.0885
ADSRAZ(deg/hr/g)	0.0645	0.0	0.0645	-0.009	-0.009	0.075	0.066	-0.08
ADOAX(deg/hr/g)	0.0293	Uncompensated	0.0293	0.035	0.035	0.015**	0.050	0.020
ADOAY(deg/hr/g)	0.0195	Uncompensated	0.0195	0.018	0.018	0.015	0.033	0.003
ADOAZ(deg/hr/g)	0.0395	Uncompensated	0.0395	0.035	0.035	0.015	0.050	0.020

*The error uncertainty is formed in two steps. First, the difference (Preflight Data Mean - LGC Compensation) is formed. This represents the value of actual inflight error which would result if inflight performance coincided exactly with the preflight data mean. In the second step, the quantities (Data Mean - LGC Compensation) ± 1σ are formed. These quantities represent the maximum and minimum of the 1σ (specification) uncertainty band for the IMU performance error.

**The 1σ values listed for ADOA are not Block II specifications (none are available). They represent only an estimate of "reasonable values."

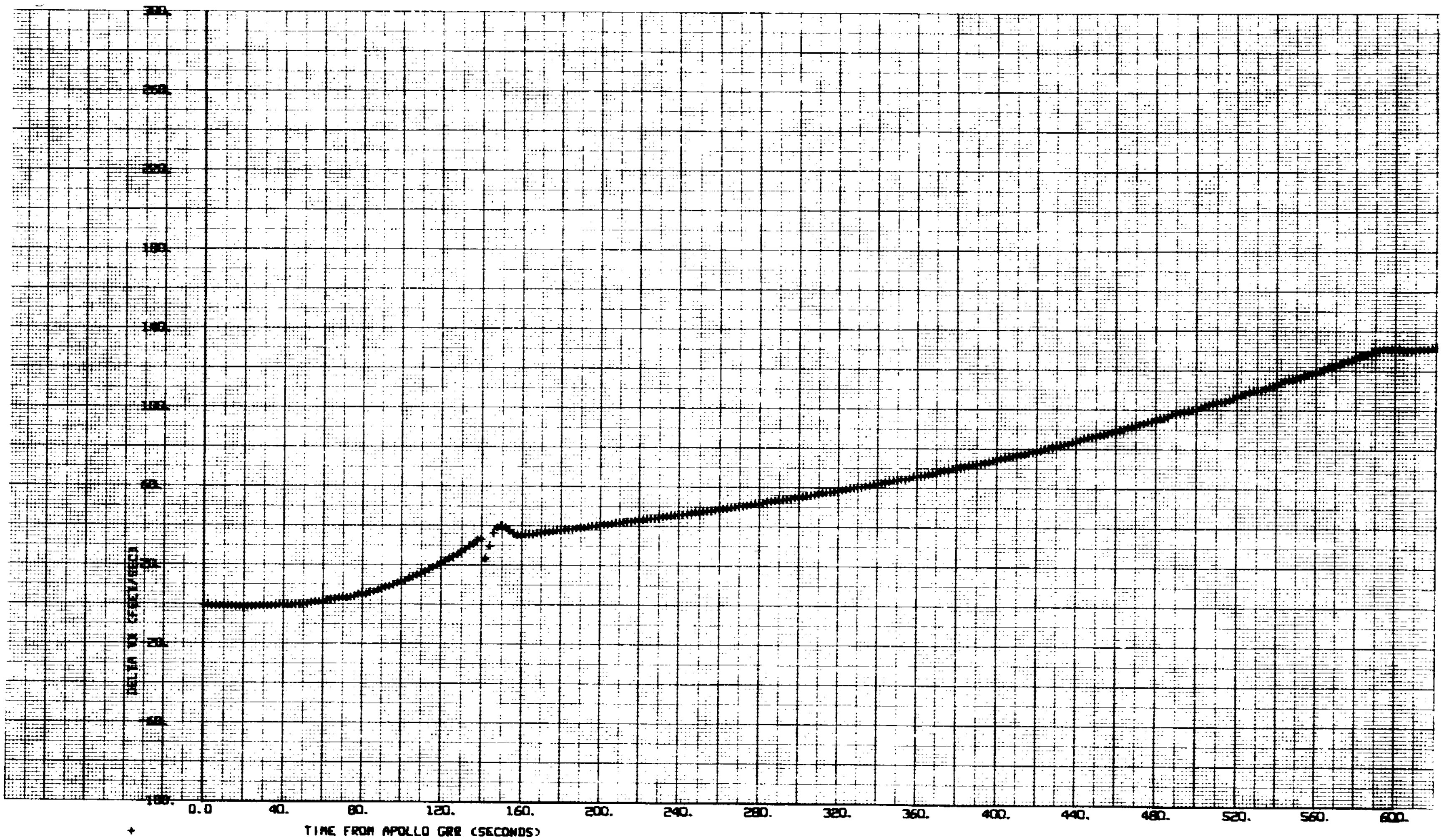


Figure 3-2. Uncompensated G&N Minus S-IVB (Boost) - Delta X Velocity

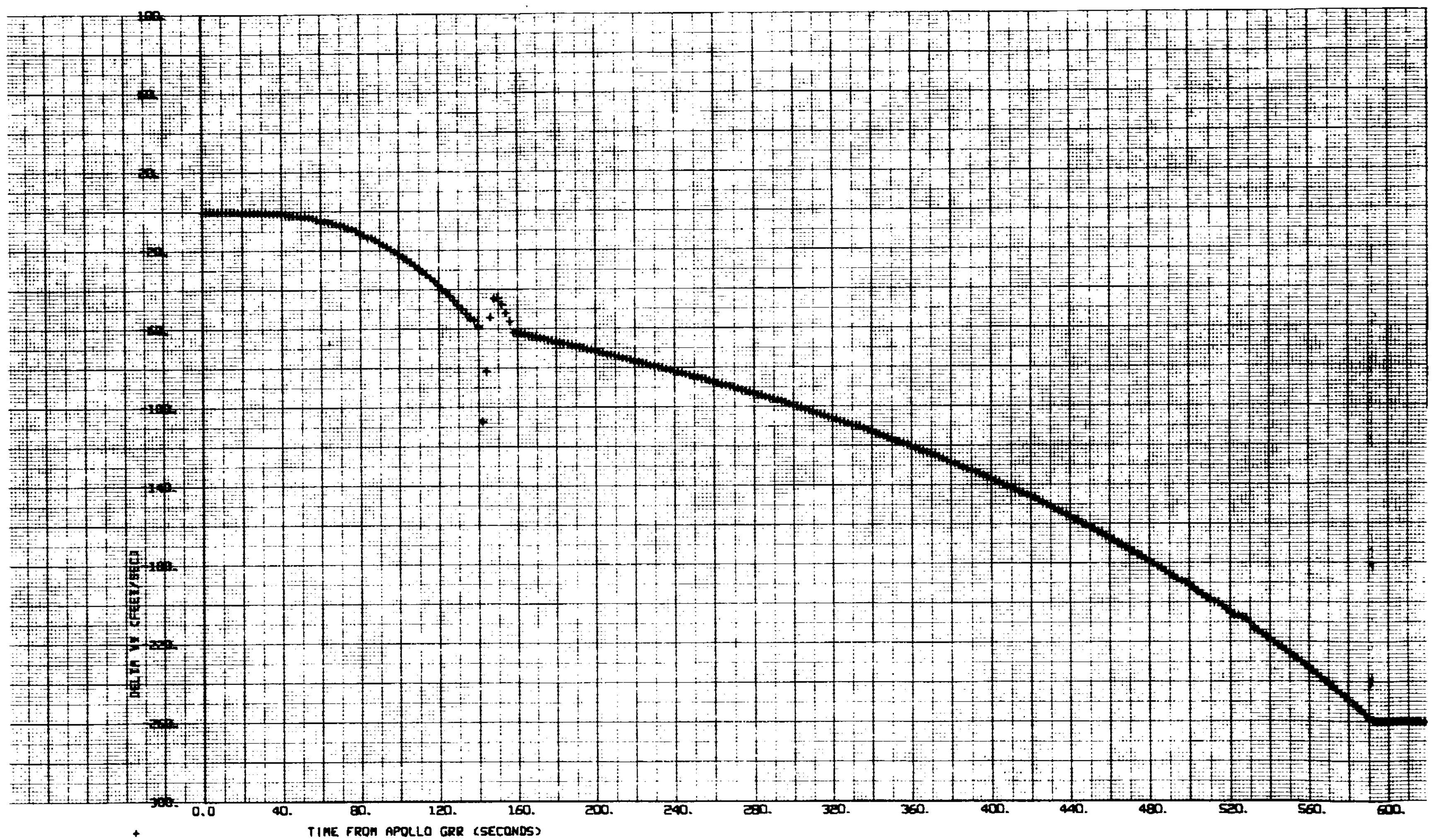


Figure 3-3. Uncompensated G&N Minus S-IVB (Boost) - Delta Y Velocity

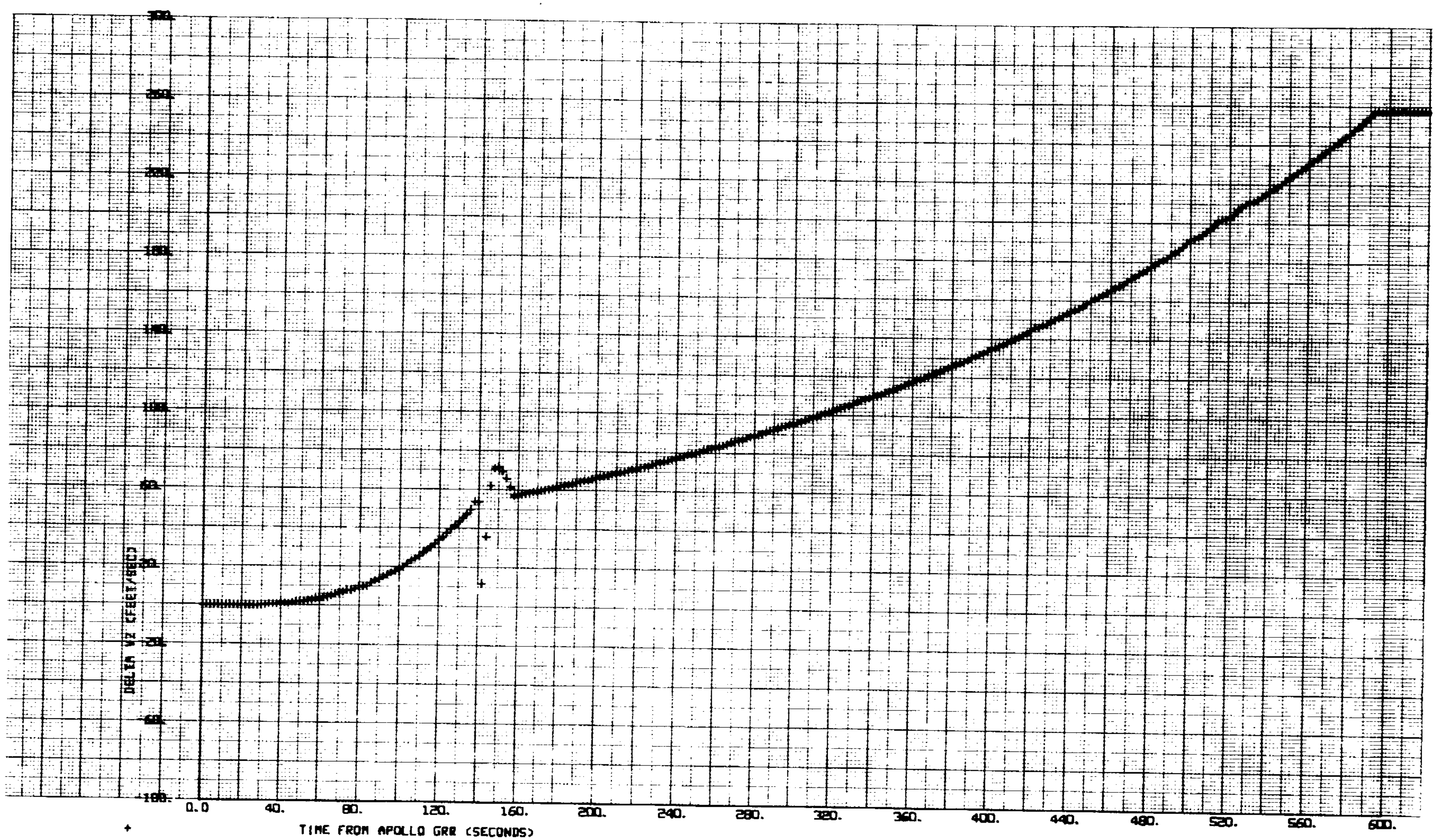


Figure 3-4. Uncompensated G&N Minus S-IVB (Boost) - Delta Z Velocity

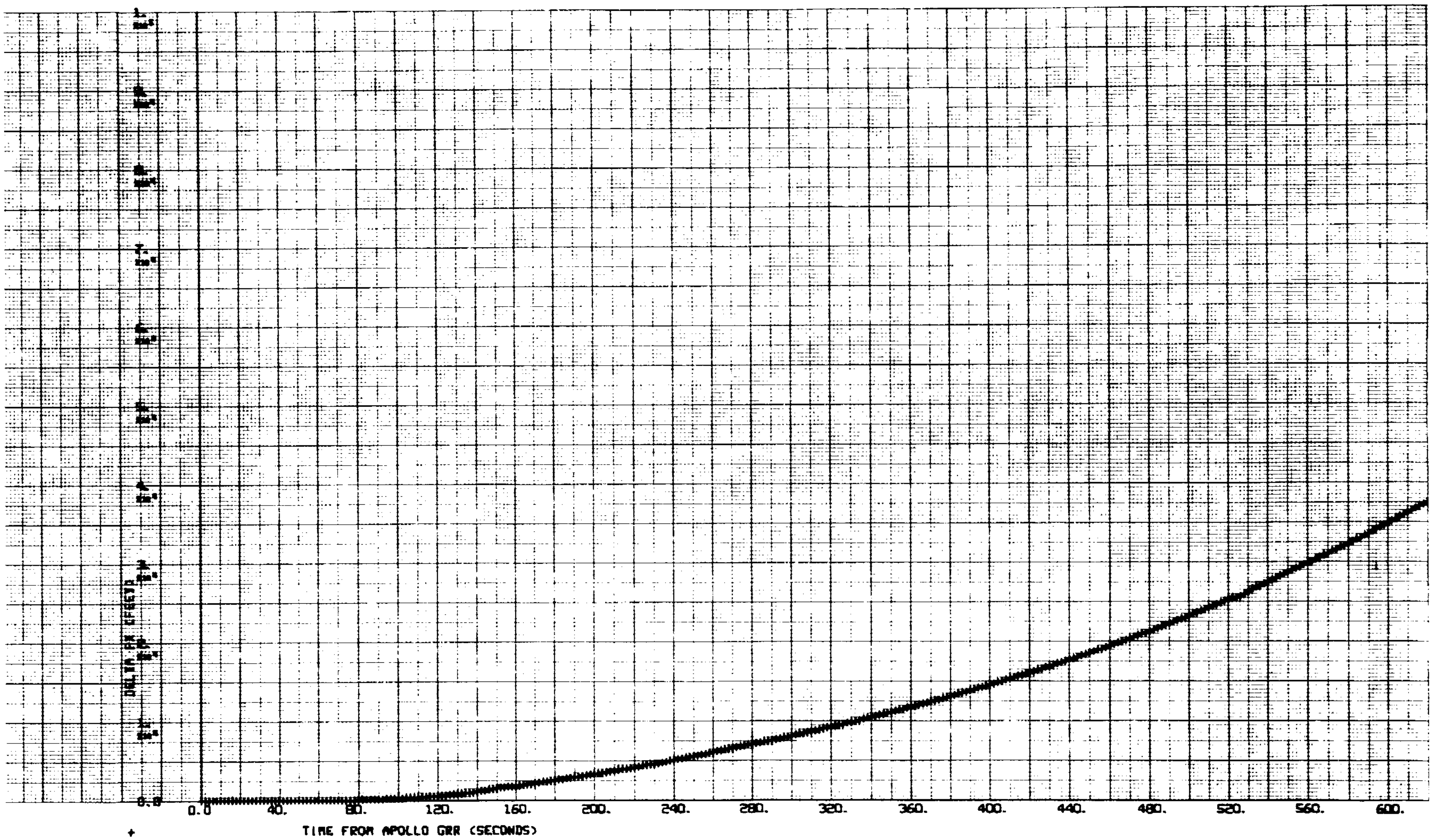


Figure 3-5. Uncompensated G&N Minus S-IVB (Boost) - Delta X Position

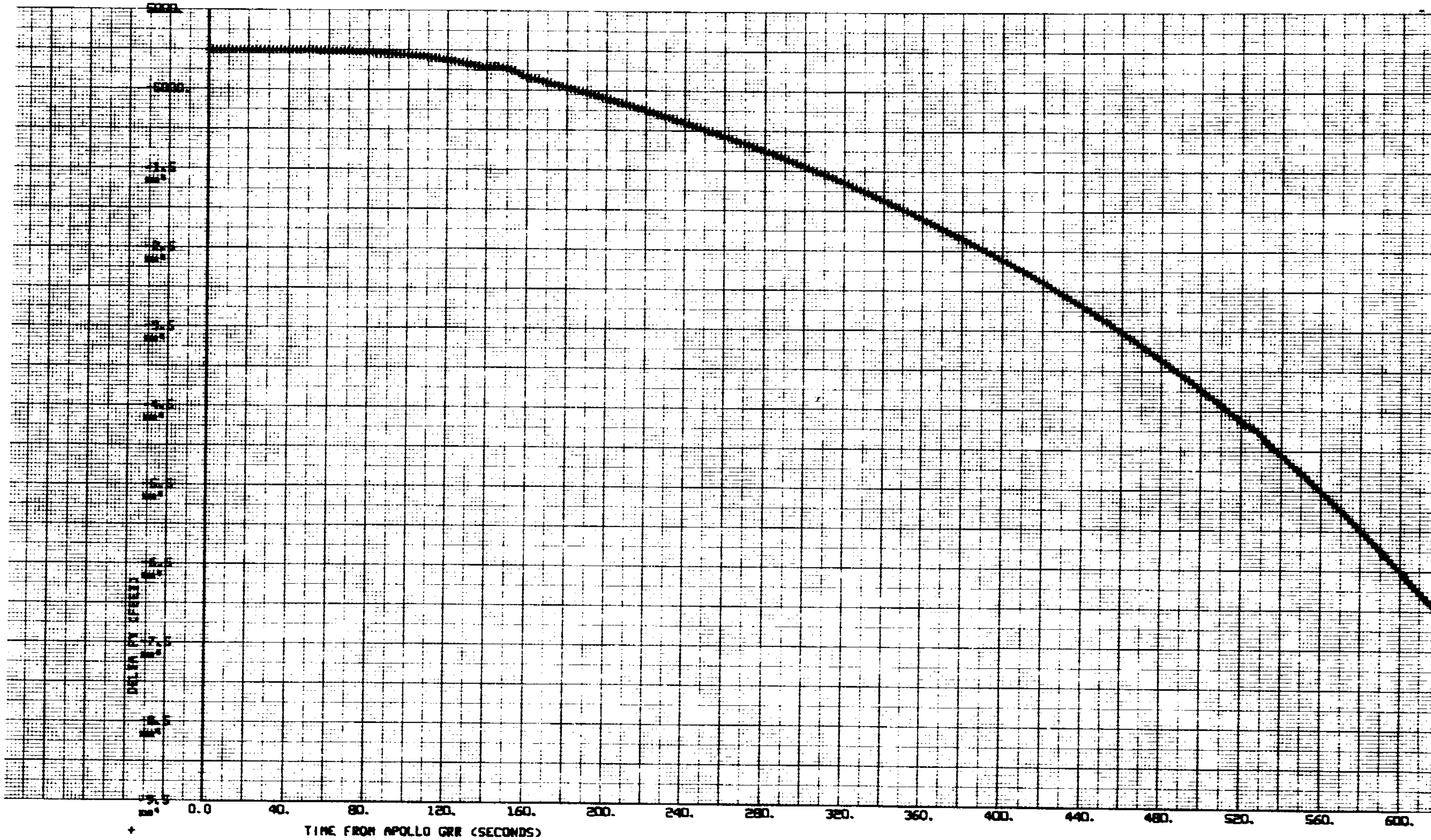


Figure 3-6. Uncompensated G&N Minus S-IVB (Boost) - Delta Y Position

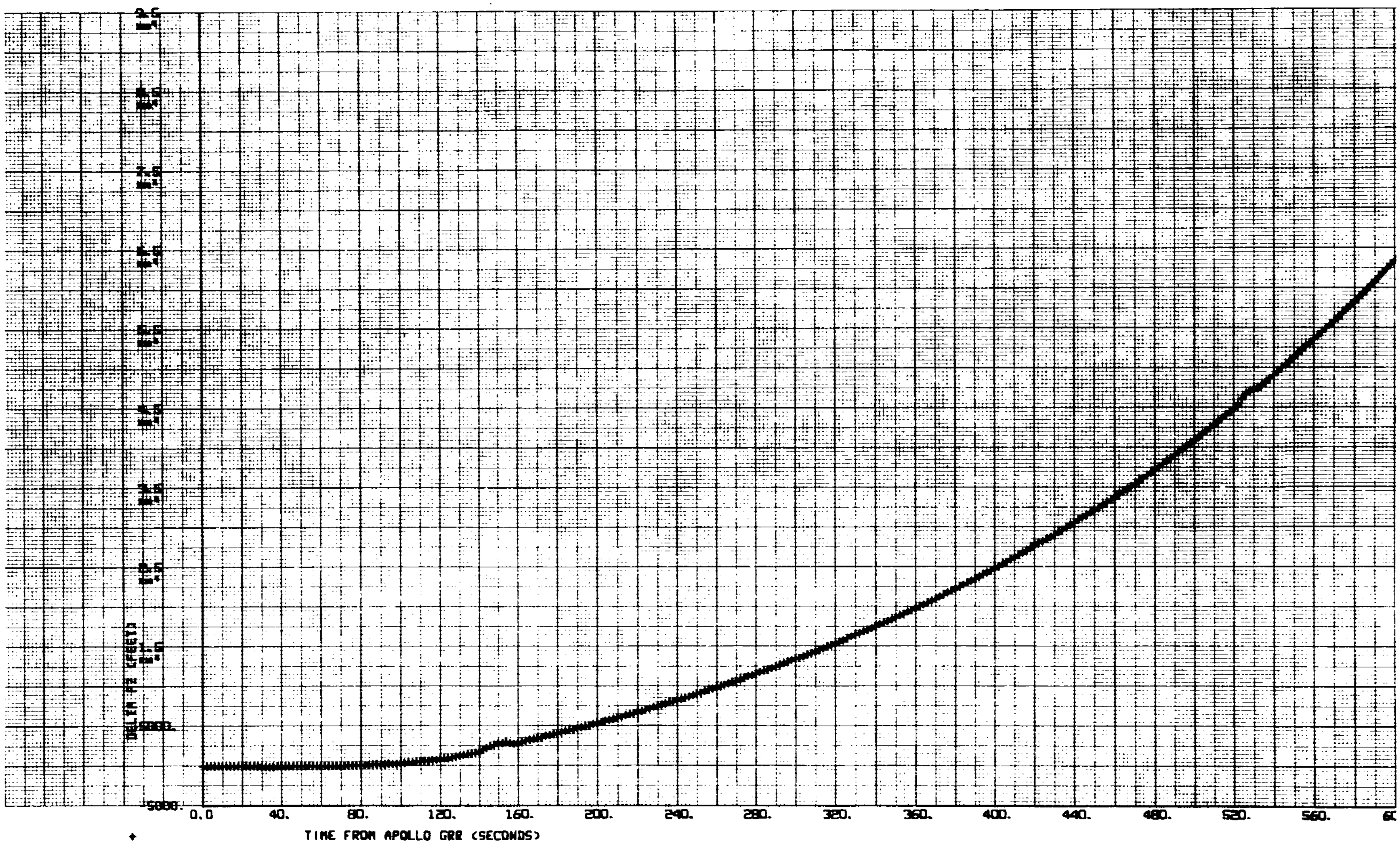


Figure 3-7. Uncompensated G&N Minus S-IVB (Boost) - Delta Z Position

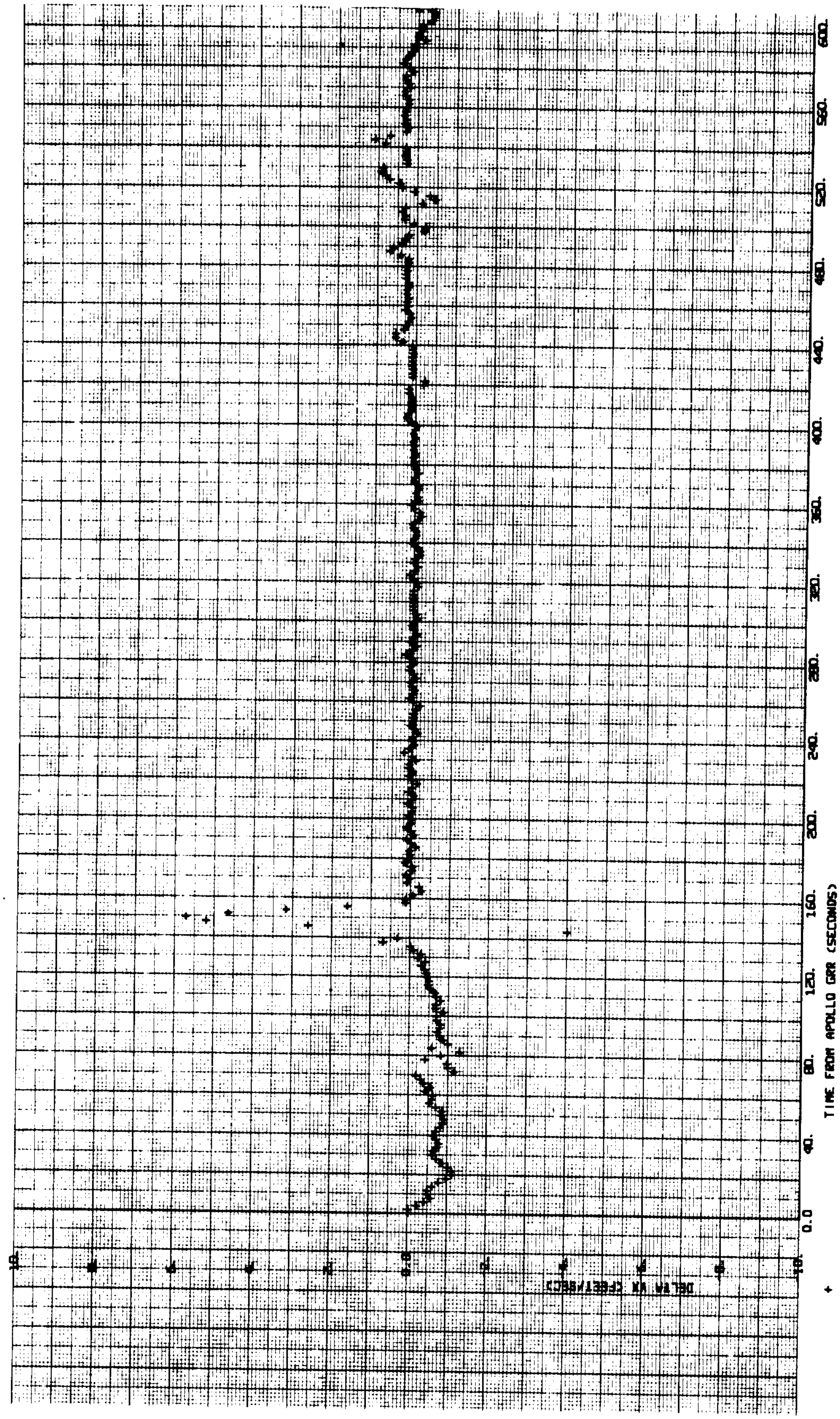


Figure 3-8. Compensated G&N Minus S-IVB (Boost) - Delta X Velocity

Figure 3-9. Compensated G&N Minus S-IVB (Boost) - Delta Y Velocity

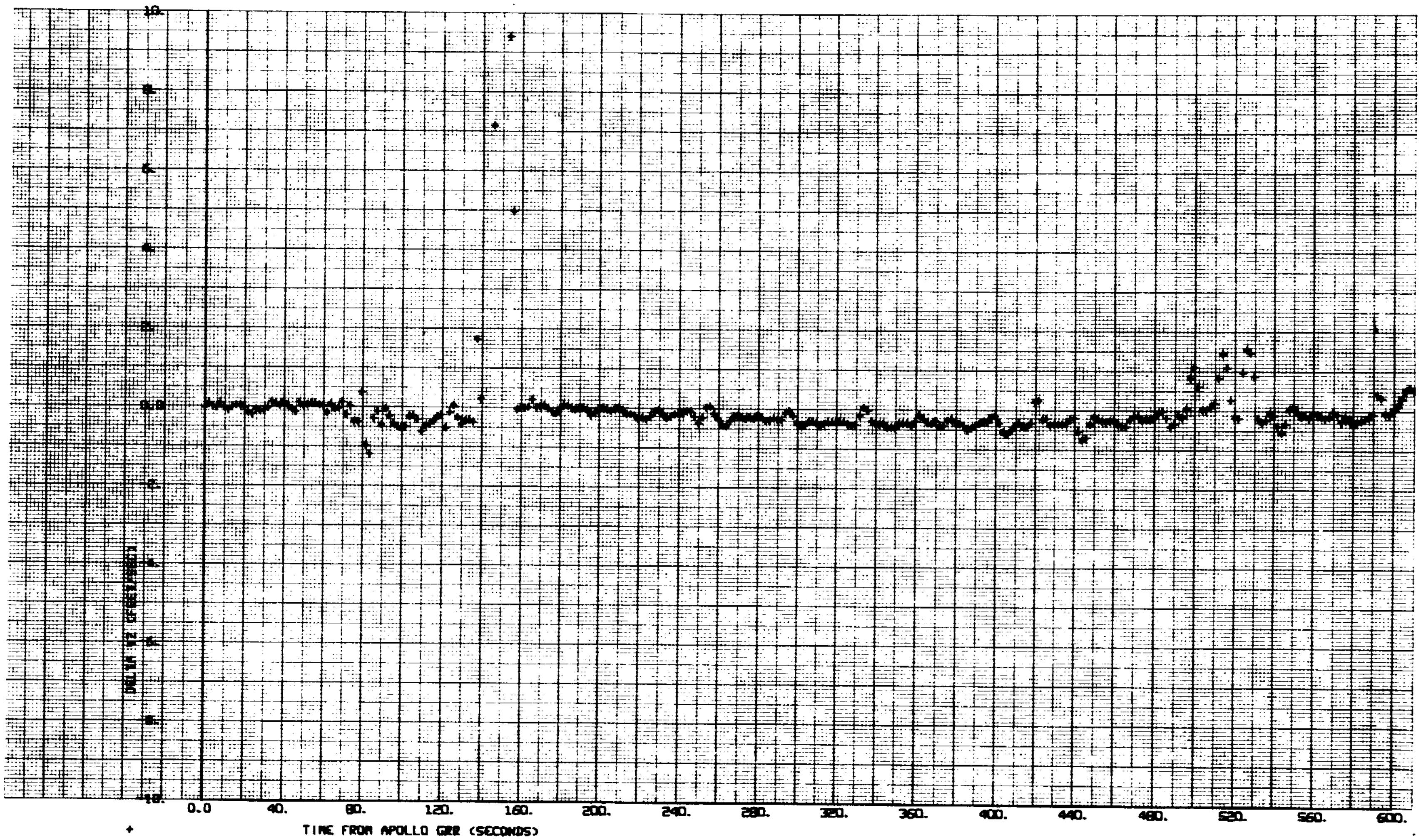


Figure 3-10. Compensated G&N Minus S-IVB (Boost) - Delta Z Velocity

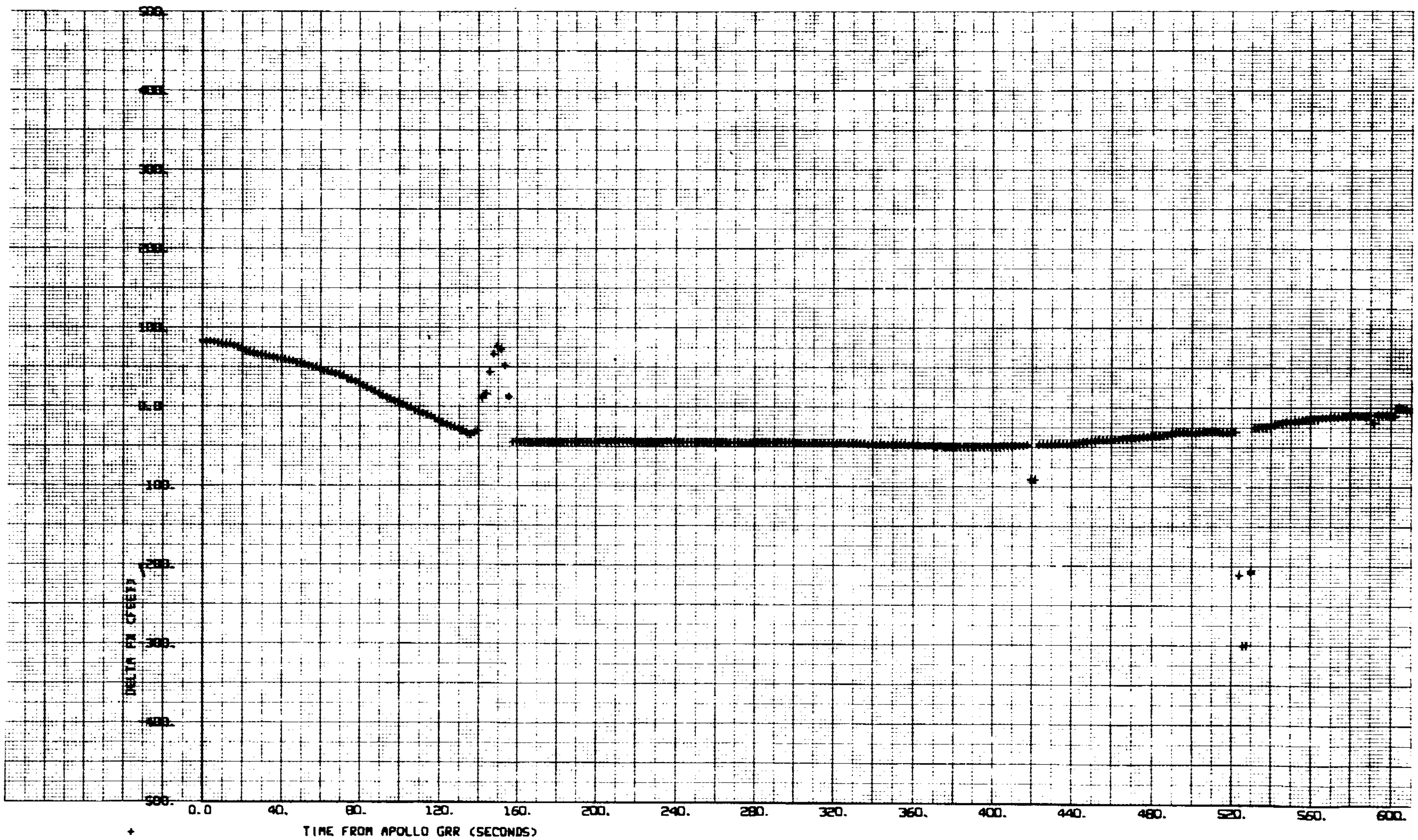


Figure 3-11. Compensated G&N Minus S-IVB (Boost) - Delta X Position

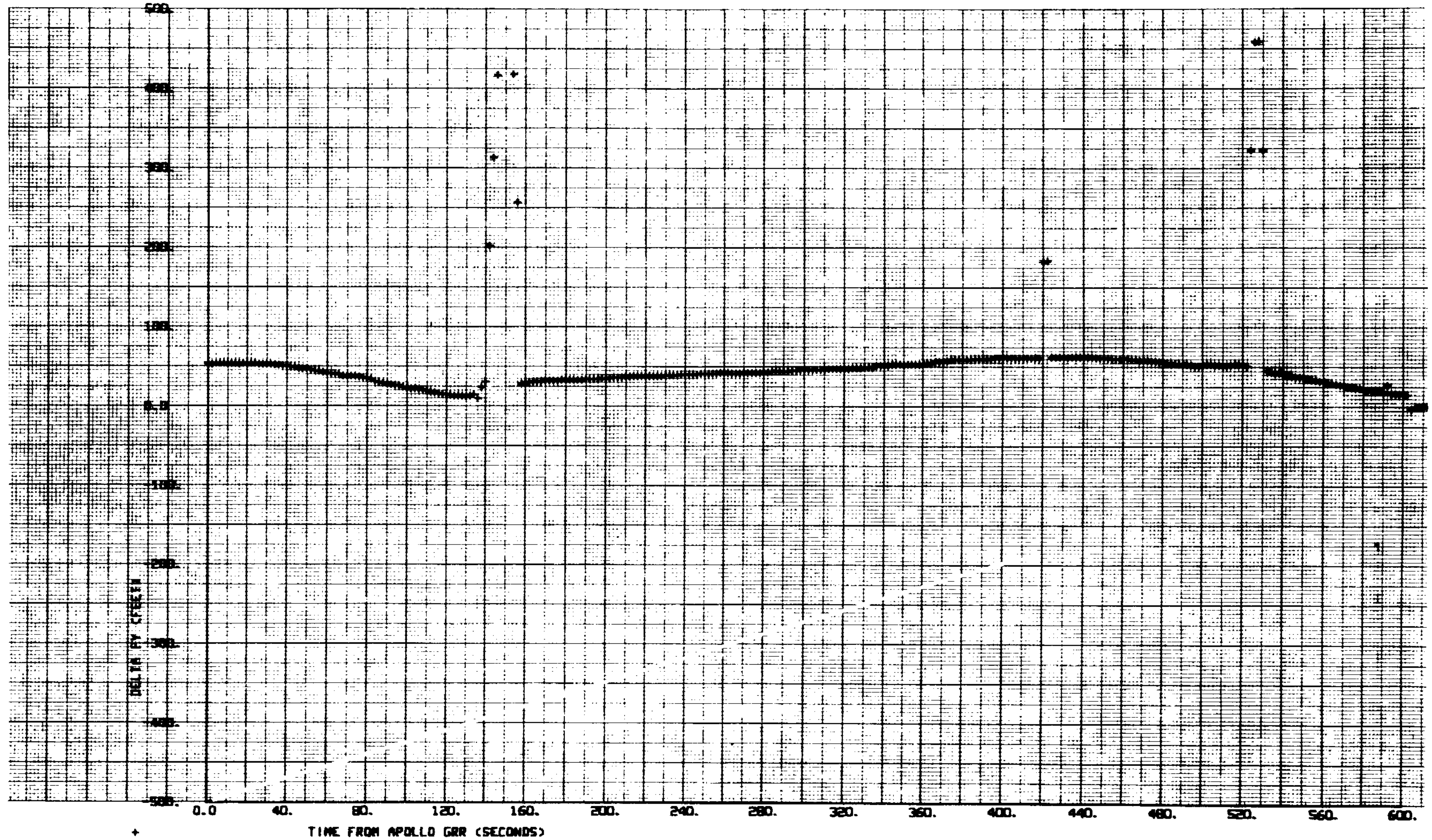


Figure 3-12. Compensated G&N Minus S-IVB (Boost) - Delta Y Position

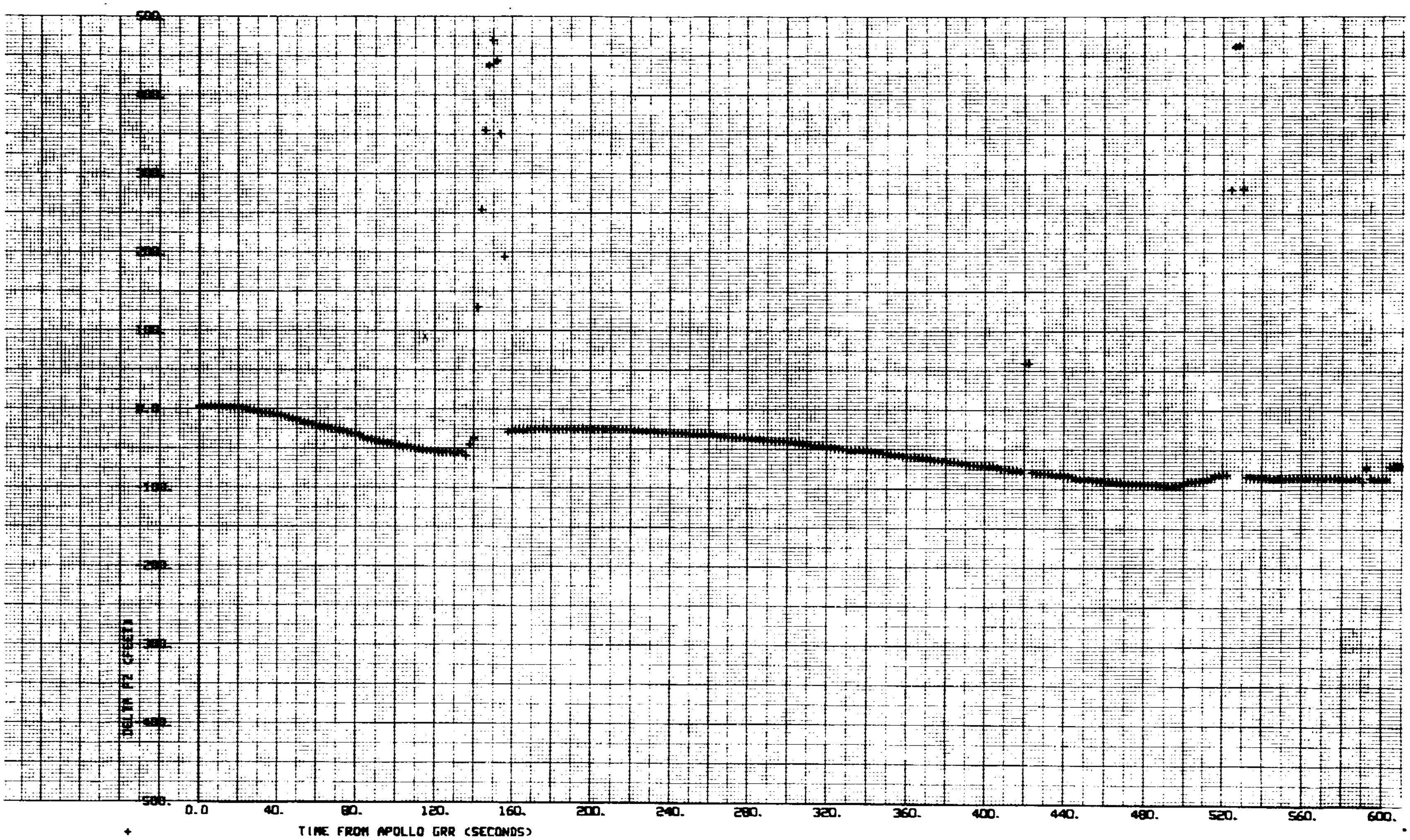


Figure 3-13. Compensated G&N Minus S-IVB (Boost) - Delta Z Position

Table 3-3 presented below summarizes these comparisons at 600 seconds (approximately 9 seconds after S-IVB cut-off). "V" denotes velocity in feet per second. "P" denotes position in feet. The vectors were compared in the LM G&N coordinate system.

Table 3-3. State Vector Comparison - Compensated LM G&N Minus BET, (t = 600. 0 seconds)

	Uncompensated	Compensated
VX (G&N)-VX (BET)	131.213	-0.044
VY (G&N)-VY (BET)	-260.148	-0.002
VZ (G&N)-VZ (BET)	257.367	0.035
PX (G&N)-PX (BET)	34,954.651	-8.390
PY (G&N)-PY (BET)	-64,879.780	16.613
PZ (G&N)-PZ (BET)	63,469.562	-85.887

The uncompensated residuals were between one and two orders of magnitude greater in all axes than those experienced on preceding Apollo flights. This was true for two reasons. First, the LM IMU was skewed with respect to the traditional "launch inertial" orientation so that both the "X" and the "Y" axes were out of the horizontal plane and no axis was oriented directly crossrange. One effect of this orientation was to make the "X" and "Y" IMU axes susceptible to substantial correlated misalignments arising from gyro drift errors. Assuming that each drift error varied randomly from the launch load, it can be seen that an extremely complicated pattern of super-imposed initial IMU misalignments could and did arise prior to lift-off. Secondly, one of the IMU error sources (ADIAX) was deliberately biased to an extreme value via the LGC compensation load, thereby producing "built-in" error. This resulted in an artificially large ADIAX error, which in turn generated enormous IMU misalignments (-3377 arc-seconds in "X" and -1951 arc-seconds in "Y") in addition to those resulting from the other terms.

All events in this section are related to the time base which defines time zero (t = 0.0) as the "instant" at which LM guidance reference release (GRR) occurred. The following table of launch events (Table 3-4) is included as a guide to the time relationships existing between LM GRR and other events of significance in the launch process. The times of these events are given in the Greenwich mean time (GMT) base.

Table 3-4. Timeline of Launch Events

Event	GMT (hr:min:sec)
S-IVB GRR	22:48:03.039
Range Clock Zero	22:48:08.000
Lift-off	22:48:08.000
LM GRR	22:48:08.860
LGC Clock Zero	22:48:08.960
PIPTIME	22:48:10.870

LM GRR was triggered by the LGC upon detection of an average lift-off acceleration at or above 1.1g over a half-second sample interval. From Table 3-4 it can be seen that LM GRR occurred 0.860 seconds after range clock zero. Thus, range time can be calculated from times in the LM GRR time base by addition of 0.860 seconds.

The LM-1 flight represented a substantial departure from earlier missions with regard to the amount of data available for postflight IMU analysis. In preceding missions, independent trajectory measurements of reasonable quality were available for several high acceleration flight phases. In general, usable data have been obtained during boost, during several orbital burn sequences, and during reentry. However, the LM-1 mission necessarily precluded an intact reentry and recover. In addition, revisions made in the flight profile were such that high quality tracking data were not available during the burns. As a consequence of this, determination of IMU performance errors depended entirely upon analysis of boost phase data. A summary of these errors is presented in Table 3-2. Most of the performance errors lay well within specified 1σ limits. Errors which exceeded these limits were X-accelerometer misalignment about Z (MXAZ); Y-accelerometer misalignment about Z (MYAZ), X-gyro input axis acceleration sensitive drift (ADIAX), Z-gyro input axis acceleration sensitive drift (ADIAZ), and X-gyro spin axis acceleration sensitive drift (ADSRAX). The ADIAX and ADIAZ results are of particular interest. The prelaunch calibrations for these parameters were widely dispersed. Postflight analysis resulted in estimates of these terms quite consistent with laboratory calibrations. These facts, coupled with prior flight history cast some doubt on the validity of preflight tests procedures and results.

As indicated earlier, the quality of tracking data during and after orbital burns was inadequate to obtain an accurate ESPOD trajectory. However, a comparison was made between the compensated LM-1 G&N burn trajectory and an ESPOD state vector at completion of the burn. The results of this comparison appear in Table 3-9. As can be seen from the table, the agreement is poor. The difference is believed to be largely attributable to the ESPOD trajectory for the postburn interval, which is considered unreliable.

3.3 ORBIT ANALYSIS

3.3.1 Lunar Module Orbital Reconstruction

The lunar module (LM) trajectory was reconstructed using low speed C-band and low speed S-band radar tracking data and the TRW Orbit Determination Program (ESPOD). The LM orbital segment of the flight begins at LM/S-IVB separation and ends at the ascent propulsion system (APS) fuel depletion burn. For the purpose of reconstructing a best estimate of the trajectory (BET), the LM orbital phase of the flight was divided into five segments as follows:

Segment 1 LM/S-IVB separation to first descent propulsion system burn (DPS-1) cutoff

Segment 2	DPS-1 engine cutoff to the beginning of program reader assembly III (PRA III)
Segment 3	End of PRA III to the end of the first period (5 hours and 9 minutes GMT) of reaction control system (RCS) thrusting following PRA III
Segment 4	End of the first period of RCS thrusting following PRA III to the beginning of the second period (5 hours and 59 minutes GMT) of RCS thrusting following PRA III
Segment 5	The beginning of the second period of RCS thrusting following PRA III to beginning of PRA V

Table 3-5 presents a summary of information pertinent to the reconstruction of each of the above mentioned segments.

Before the reconstruction of each segment is discussed in detail, a few assumptions concerning these fits should be stated. First, it is assumed that all stations are in perfect time synchronization with one another unless otherwise noted. Second, it is assumed that all data are time tagged on the receive pulse; thus, the light time correction retards the time tag of the data. Third, it is assumed that a 0.107-second timing bias added to all tracking data accounts for the difference between UT1 and UTC for 22-23 January 1968.

Information which is too detailed to present in the body of this report, but nevertheless has a significant influence on the resulting BET, is presented in Appendix B. The information found in Appendix B is listed below:

- A summary of radar observations for the lunar module spacecraft with comments on the use of each pass of data
- A summary of the station locations used in ESPOD
- A summary of drag parameter ($C_dA/2m$) values for various phases of the mission
- A table of radar data weights used in ESPOD for C-band and S-band radar data

Table 3-5. LM Orbital Fit Summary

BET	Date	Observation Span, GMT (hr:min)	Station/Pass, (Burn)	Drag (ft^2/slug)	Solution Vector
1	22-23 January	23:43-02:21	CROCO1, CROSO1, CNBSO1, GYMSO1, WHSCO1, TEXSO1, MLACO2, MLASO2, GBMSO2, PATCO2, BDQCO2, BDASO2, CROCO2, CROSO2, HAWSO2, GLDSO2, GYMSO2, TEXSO2, MLACO3, MLASO3, GBMSO3, BDQCO3, BDASO3, ANTCO3, ACNSO3, and (DPS 1).	0. 2039	State Vector, TEXS X-angle and Y-angle
2	23 January	02:48-04:58	CROCO3, CROSO3, HAWCO3, HAWSO3, GYMSO3, WHSCO3, MLASO4, MLASO4, GBICO4, ANTCO4, ASCCO4, CROSO4, GWMSO4, HAWCO4, HAWSO4, GLDSO4, and GYMSO4.	0. 2039	State Vector State Vector
3	23 January	05:02-05:08	GYMSO4, TEXSO4, WHSCO4 and MLASO5.	0. 4516	State Vector
4	23 January	05:22-05:59	ASCCO5, ACNSO5, TANCO5, CROCO5, and CROSO5.	0. 4516	State Vector
5	23 January	05:59-06:32	CROCO5, CROSO5, GWMSO5, HAWCO5 and HAWSO5.	0. 4516	State Vector

The free-flight portion of the trajectory for Segment 1 (see Table 3-5) was reconstructed using C-band and S-band radar tracking data; however, not all of the available data were used in the fit. All the doppler data were weighted out of the fit, although some of the doppler data were good. Angular information was also weighted out of the fit when suspicious residual patterns occurred that corresponded to low elevation passes. Another reason that the data were weighted out was the need for better data balance between stations in the southern hemisphere and stations in the northern hemisphere. See Appendix B for comments on the use of the available data for this segment.

A drag value of 0.2039 feet^2/slug was used in the fit which solved on the state vector and X- and Y-angle biases at TEXS01 and TEXS02. A 0.132-degree X-angle bias and 0.064-degree Y-angle bias were recovered for TEXS. The DPS 1 burn was modeled by the IGS burn model and initial misalignments in the platform and accelerometer biases were fixed at the values obtained by analyzing the guidance system.

The trajectory which resulted from a fit using only C-band data was compared with the BET at epoch. The comparison revealed a total difference in position of 268 feet and a total difference in velocity of 0.54 feet/second. Also a trajectory which resulted from a fit using only S-band data (RXY and doppler), when compared with the BET at epoch, revealed a total difference in position of 1017 feet and a total difference in velocity of 0.29 feet/second. These comparisons indicate that the C-band data and the S-band data were consistent.

The residual mean and RMS by station and data type are listed in Table 3-6 for Segments 1 through 5. All quantities are defined as usual, and N is the number of data points for each observation type. Residual plots for this segment can be found in Appendix A.

The trajectory for Segment 2 was reconstructed using C-band and S-band data. In a manner similiar to the Segment 1 trajectory reconstruction, the doppler data and angle data corresponding to low elevation passes were weighted out of the fit.

a. C-band data

Range (ft)											
Station	Rev.	Segment 1	Rev.	Segment 2	Rev.	Segment 3	Rev.	Segment 4	Rev.	Segment 5	
ANTC			4	77.0 124.0 33.0							Mean RMS N
ASCC			4	80.0 248.0 25.0			5	123.0 44.0 81.0			Mean RMS N
BDQC	2, 3	255.0 72.0 62.0									Mean RMS N
CROC	1, 2	191.0 121.0 72.0	3	-168.0 76.0 38.0			5	-17.0 20.0 10.0	5	-195.0 17.0 53.0	Mean RMS N
GBIC			4	-2.0 50.0 30.0							Mean RMS N
HAWC			3, 4	-165.0 142.0 55.0					5	-758.0 300.0 46.0	Mean RMS N
MLAC	2, 3	-96.0 71.0 46.0	4	18.0 48.0 35.0							Mean RMS N
PATC	2	-23.0 21.0 7.0									Mean RMS N
TANC							5	-35.0 92.0 39.0			Mean RMS N
WHSC	1	156.0 86.0 31.0	3	35.0 26.0 31.0	4	-91.5 8.0 7.0					Mean RMS N

Station	Rev.	Segment 1
ANTC		
ASCC		
BDQC	2, 3	0.0098 0.0123 62.0
CROC	1, 2	-0.0043 0.0054 72.0
GBIC		
HAWC		
MLAC	2, 3	-0.0041 0.0096 46.0
PATC	2	0.0071 0.0015 7.0
TANC		
WHSC	1	-0.0015 0.0024 31.0

b. S-band data

Range (ft)											
Station	Rev.	Segment 1	Rev.	Segment 2	Rev.	Segment 3	Rev.	Segment 4	Rev.	Segment 5	
ACNS							5	-35.0 92.0 39.0			Mean RMS N
CNBS	1	-263.0 157.0 21.0									Mean RMS N
CROS	1, 2	-28.0 144.0 44.0	3, 4	7.0 200.0 53.0					5	-177.0 67.0 41.0	Mean RMS N
GLDS	2	-31.0 57.0 31.0									Mean RMS N
GWMS			4	-249.0 118.0 16.0					5	309.0 245.0 76.0	Mean RMS N
GYMS			3, 4	266.0 524.0 32.0							Mean RMS N
HAWS	2	114.0 137.0 35.0	3, 4	33.0 140.0 47.0							Mean RMS N
MILS			4	-304.0 13.0 15.0	5	-21.0 45.0 11.0					Mean RMS N
TEXS	1, 2	-59.0 173.0 45.0			4	105.0 119.0 21.0					Mean RMS N

Station	Rev.	Segment 1
ACNS	2	0.0320 0.0133 23.0
CNBS	1	0.0054 0.0091 21.0
CROS	1, 2	-0.0337 0.0284 44.0
GLDS	2	0.0264 0.0059 31.0
GWMS		
GYMS	2	-0.0137 0.0146 21.0
HAWS	2	-0.0094 0.0221 35.0
MILS		
TEXS	1, 2	-0.0003 0.0183 45.0

FOLDOUT FRAME /

Azimuth (deg)

Rev.	Segment 2	Rev.	Segment 3	Rev.	Segment 4	Rev.	Segment 5		Station
	0.0048							Mean	
4	0.0082							RMS	ANTC
	33.0							N	
	-0.0045				-0.0036			Mean	
4	0.0314			5	0.0073			RMS	ASCC
	25.0				81.0			N	
								Mean	
								RMS	BDQC
								N	
	-0.0061				-0.0086		-0.0052	Mean	
3, 4	0.0094			5	0.0025	5	0.0040	RMS	CROC
	38.0				10.0		53.0	N	
	-0.0047							Mean	
4	0.0064							RMS	GBIC
	27.0							N	
	0.0148						0.0312	Mean	
3, 4	0.0103					5	0.0067	RMS	HAWC
	55.0						46.0	N	
	-0.0013							Mean	
4	0.0029							RMS	MLAC
	35.0							N	
								Mean	
								RMS	PATC
								N	
					-0.0650			Mean	
				5	0.0123			RMS	TANC
					101.0			N	
	-0.0004		0.0006					Mean	
3	0.0082	4	0.0037					RMS	WHSC
	31.0		7.0					N	

X-Angle (deg)

Rev.	Segment 2	Rev.	Segment 3	Rev.	Segment 4	Rev.	Segment 5		Station
					0.0213			Mean	
				5	0.0328			RMS	ACNS
					68.0			N	
								Mean	
								RMS	CNBS
								N	
					-0.0478		-0.0001	Mean	
				5	0.0184	5	0.0479	RMS	CROS
					20.0		33.0	N	
	0.0327							Mean	
4	0.0115							RMS	GLDS
	18.0							N	
	-0.0308						-0.0293	Mean	
4	0.0126					5	0.0311	RMS	GWMS
	16.0						102.0	N	
	-0.0128		0.0017					Mean	
3, 4	0.0114	4	0.0221					RMS	GYMS
	32.0		13.0					N	
	0.0007							Mean	
3, 4	0.0178							RMS	HAWS
	30.0							N	
			-0.0108					Mean	
		5	0.0311					RMS	MILS
			4.0					N	
			0.0649					Mean	
		4	0.0504					RMS	TEXS
			16.0					N	

FOLDOUT FRAME 2

Table 3-6. Residual Mean and RMS by Station and Data Type for Segments 1-5.

Elevation (deg)

Rev.	Segment 1	Rev.	Segment 2	Rev.	Segment 3	Rev.	Segment 4	Rev.	Segment 5	
			-0.0066							Mean
		4	0.0052							RMS
			33.0							N
			-0.0307				-0.0222			Mean
		4	0.0041			5	0.0104			RMS
			25.0				81.0			N
	0.0061									Mean
2, 3	0.0056									RMS
										N
	-0.0003		0.0054				-0.0120		0.0196	Mean
1, 2	0.0088	3, 4	0.0070			5	0.0065	5	0.0080	RMS
	72.0		38.0				10.0		53.0	N
			0.0109							Mean
		4	0.0050							RMS
			30.0							N
			-0.0018						-0.0224	Mean
		3, 4	0.0143					5	0.0169	RMS
			55.0						43.0	N
	-0.0087									Mean
2, 3	0.0065									RMS
	46.0									N
	0.0028									Mean
2	0.0031									RMS
	7.0									N
							-0.0209			Mean
						5	0.0069			RMS
							101.0			N
	-0.0052		-0.0047		-0.0297					Mean
1	0.0049	3	0.0077	4	0.0044					RMS
	31.0		31.0		7.0					N

Y-Angle (deg)

Rev.	Segment 1	Rev.	Segment 2	Rev.	Segment 3	Rev.	Segment 4	Rev.	Segment 5	
	0.0007						0.0127			Mean
2	0.0068					5	0.0113			RMS
	23.0						73.0			N
	0.0229									Mean
1	0.0038									RMS
	21.0									N
	0.0126						0.0110		0.0155	Mean
1, 2	0.0056					5	0.0060	5	0.0193	RMS
	44.0						21.0		51.0	N
	0.0181		0.0146							Mean
2	0.0077	4	0.0053							RMS
	31.0		20.0							N
			-0.0050						-0.0569	Mean
		4	0.0210					5	0.0146	RMS
			16.0						108.0	N
	-0.0484		-0.0455		-0.0462					Mean
2	0.0074	3, 4	0.0085	4	0.0043					RMS
	21.0		32.0		13.0					N
	-0.0238		-0.0223							Mean
2	0.0069	3, 4	0.0059							RMS
	35.0		36.0							N
					0.0346					Mean
				5	0.0346					RMS
					9.0					N
	0.0001				0.0673					Mean
1, 2	0.0101			4	0.0052					RMS
	45.0				16.0					N

An attempt was made to fit all the data from LM/S-IVB separation to the beginning of PRA III while modeling the DPS 1 burn. However, the poor data coverage prior to PRA III resulted in an unsatisfactory fit. Now the Segment 2 trajectory fit the data prior to PRA III better than the combined fit of Segment 1 and Segment 2. Therefore, in order not to compromise the initialization of the PRA III burn, the Segment 2 trajectory was chosen as the BET for this phase of the mission.

A drag value of 0.2039 feet^2/slug was used in the Segment 2 fit which solved on the state vector. TEXS03 had an X-angle bias of 0.148 degree and a Y-angle bias of 0.075 degree. These results compare favorably with the values recovered for TEXS in the Segment 1 fit. The Segment 1 trajectory was compared with the Segment 2 trajectory at DPS 1 engine cutoff. The comparison revealed a 2000-foot difference in total position and a 2.42-foot/second difference in total velocity.

The Segment 2 trajectory was also compared with two other trajectories at epoch. The first trajectory resulted from a C-band data fit; the second trajectory resulted from an S-band data fit (RXY and doppler). The comparisons indicate that both the C-band trajectory and the S-band trajectory are within 200 feet in total position and 0.15 foot/second in total velocity of the BET. This again indicates that the C-band data and the S-band data are consistent.

The residual mean and RMS by station and data type for Segment 2 are found in Table 3-6. The residuals for this segment are found in Appendix A.

The trajectory from the end of PRA III to the beginning of PRA V was divided into three segments (3, 4, 5) because low-level RCS thrusting occurred during this period. Segment 3 covers the period from the end of PRA III to 5 hours and 9 minutes GMT; RCS thrusting occurred during this segment. Segment 4 covers the period from 5 hours and 9 minutes GMT to 5 hours and 59 minutes GMT; this is a free-flight period. Segment 5 covers the period from 5 hours and 59 minutes GMT to the beginning of PRA V; RCS thrusting occurred during this segment.

The trajectory for Segment 3 was reconstructed using all available C-band and S-band data. Since more than half the available data were from TEXS, the TEXS data dominated the fit. Also the maximum elevations for the other stations (GYMS, WHSC, and MLAS) were all less than 8 degrees.

A drag value of 0.4516 feet^2/slug was used in the fit that solved on the state vector. Table 3-5 presents a summary of information for this fit.

The residual mean and RMS by station and data type for Segment 3 are listed in Table 3-6. Residual plots for this segment can be found in Appendix A.

The trajectory for Segment 4 was reconstructed using all available C-band and S-band data. The majority of the data, 271 observations of the total 380 observations, were observations that had elevations below 10 degrees. Available information indicated that no RCS thrusting occurred during this interval. Therefore, although the data situation is not the best, confidence can be placed in the reconstructed trajectory.

The solution vector consisted of the state vector with drag modeled using a value of 0.4516 feet^2/slug. The trajectory for Segment 4 was compared with the trajectory for Segment 3 at 5 hours and 9 minutes. The total difference in position was 1467 feet, and the total difference in velocity was 2.17 feet/second. These differences are a measure of the effect of the RCS thrusting on the Segment 3 trajectory.

The residual mean and RMS by station and data type for Segment 4 can be found in Table 3-6. The residual plots for this segment can be found in Appendix A.

The trajectory for Segment 5 was reconstructed using all available C-band and S-band data. As with Segments 3 and 4, the primary data problem was the lack of tracking data with elevations above 10 degrees. Only Guam had tracking data above 10 degrees elevation (maximum elevation was 28 degrees for Guam). RCS thrusting occurred for a period of about 30 minutes; therefore, the accuracy of the reconstructed trajectory is degraded by these conditions. The solution vector for the fit was the state vector with drag modeled by a value of 0.4516 feet^2/slug.

The resultant residual patterns (see Appendix A for the residual plots for this segment) were erratic and verify the fact that thrusting occurred. Also the Segment 4 trajectory was compared with the Segment 5 trajectory at 5 hours and 59 minutes GMT. The total difference in position and the total difference in velocity (5500 feet and 8.07 feet/second, respectively) are a measure of the effects of RCS thrusting on the Segment 5 trajectory.

Attempts were made to fit Segments 4 and 5 together using limited telemetered acceleration information from Carnarvon and Hawaii, but the lack of telemetry information from Guam prevented a good fit of Segment 4 and Segment 5 data.

The residual mean and RMS by station and data type for Segment 5 can be found in Table 3-6. The residual plots for this segment are given in Appendix A.

Table 3-7 lists state vectors corresponding to specific events. The quantities tabulated are defined as follows:

Symbol	Definition of Symbols
LAT	Geodetic latitude of the vehicle measured positive north of the equator (degrees)
LON	Longitude of the vehicle measured positive east of the Greenwich meridian (degrees)
BETA	Flight-path angle measured positive downward from the local vertical (degrees)
AZ	Azimuth of the velocity vector measured positive east of true North (degrees)
R	Magnitude of the position vector (feet)
V	Magnitude of the velocity vector (feet/second)

Table 3-7. State Vector Summary

Event	Time GET (hr:min:sec)	Latitude (deg)	Longitude (deg)	BETA (deg)	AZ (deg)	R (ft)	V (ft/sec)
+X Translation off (sep.)	0:54:10.2	-31.578148	107.15595	90.005536	93.961834	21,635,720	25,460.530
DPS 1 ullage on	3:59:33:9	-27.003219	101.99132	90.136776	72.594769	21,615,994	25,485.209
DPS 1 engine cutoff	3:59:45.7	-26.758944	102.79818	90.136960	72.209104	21,615,221	25,490.971
RCS +X ullage start (PRA III)	6:10:07.4	28.751790	241.60041	89.876680	104.15639	21,479,158	25,650.409
APS engine cutoff (PRA III)	6:13:14.3	24.907457	254.58882	90.364718	110.08745	21,490,924	26,316.044
RCS +X ullage start (PRA V)	7:44:00.3	30.360802	208.32355	91.497051	99.283024	21,617,284	26,160.508

Data Anomalies and Biases

The following data anomalies were observed on the Apollo 5 flight:

ASCC04	The range residuals exhibited a peaked pattern while the azimuth residuals had a 0.06-degree discontinuity at the maximum elevation of the pass (Appendix A).
CLQC	The radar site had a wrong fit for the azimuth and elevation angles.
WHSC02	Large angle residuals substantiated the fact that White Sands tracked on a side lobe.
TANC05	A minus 0.065-degree bias in azimuth was observed during this pass.

The following data biases were observed from Table 3-6:

CROC	The average azimuth bias for revolutions 1-5 was -0.0049 degree.
GYMS	The average Y-angle bias for revolutions 2-4 was -0.0466 degree.
GWMS	The average X-angle bias for revolutions 4-5 was -0.0295 degree.
HAWS	The average Y-angle bias for revolutions 2-4 was -0.0231 degree.
TEXS	The average X-angle bias for revolutions 1-4 was 0.1262 degree, and the average Y-angle bias for revolutions 1-4 was 0.0684 degree.

Maneuver Analysis

It was not possible to reconstruct the PRA III and PRA V maneuvers using low-speed C-band tracking data and telemetered acceleration information in the form of an acceleration burn tape, in IGS ESPOD for the following reasons:

- The lack of good C-band data
- The thruster activity following PRA III

However, DPS 1 was modeled in the Segment 1 trajectory by using the burn tape and values for platform errors that were obtained by analyzing the guidance system.

In order to give the reader some idea of the magnitude of the burns, the following information is tabulated. Table 3-8 lists the maneuver, the time of initiation of the maneuver (GMT), the source of the information, the duration of the maneuver in seconds (Δt), the component ΔV's in LM guidance platform coordinates (ΔVx, ΔVy, ΔVz), and the total velocity (ΔV). The listed velocities have not been corrected for guidance errors.

3.3.2 Orbital Burn Phases

Normally, the Apollo G&N trajectory (total position and velocity) estimates during all burns are available on downlink at 2-second intervals. However, after premature termination of the DPS-1 burn, the LGC was placed in idle mode. In this mode, only the accumulated accelerometer counts were available. Using these counts and compensating for the IMU performance errors determined from boost data, the LM-1 G&N trajectory for PRA III was reconstructed. PRA III was the second descent engine burn (the first successful descent engine burn, under program reader assembly control).

The LGC PRA III trajectory was initialized on (or made to coincide with) the ESPOD BET at time (t) = 22191.05 seconds for LM GRR immediately prior to DPS ignition. In this manner perfect agreement (LM G&N versus BET) was obtained at the beginning of the comparison interval. However, the ESPOD BET is discontinuous over the burn periods. It consists of two distinct segments, one terminating at ignition and the other beginning at shutdown. It was not possible to link these end points reliably with tracking data taken during the burn. Moreover, the BET sequence obtained after shutdown covers a period of only 5 minutes and is based on inadequate data (TEX, with twenty-one data points; WHS, with only seven data points). A better orbit determination during that period was not possible because of RCS activity during orbit five (for which there was no telemetry coverage). Consequently, the postburn BET was completely independent of the preburn trajectory (from which the initialization vector was taken) and was of uncertain quality. For this reason, the rather

Table 3-8. Maneuver Summary

Maneuver	Time of Initiation, GET (hr:min:sec)	Source	Δt (sec)	ΔV_x (ft/sec)	ΔV_y (ft/sec)	ΔV_z (ft/sec)	ΔV (ft/sec)
DPS I*	3:59:41.7	G&N	4.0	3.05	-0.49	-1.96	3.66
PRA III*	6:10:07.4	G&N	186.9	-612.56	-400.66	149.45	747.05
PRA V*	7:44:00.3	G&N	210.0	1,531.89	-427.55	-359.41	1,630.54

*This includes the ΔV due to ullage.

large postburn velocity discrepancies (Table 3-9) between reconstructed LM G&N and BET are not considered significant.

In like manner, the PRA V burn reconstruction was initialized with the ESPOD BET at t = 27,639.05 seconds, and the trajectory was reconstructed using LGC data and the IMU errors determined from ascent analysis. Since no useable telemetry data were available after occurence of the gimbal lock condition, the trajectory reconstruction was terminated at t = 28,051.05 seconds.

Table 3-9. Position and Velocity Comparison - LM-1 G&N versus BET/PRA III (t = 22,419.05 seconds)

LM IMU	Coordinates
VX (G&N)-VX (BET)	-0.39
VY (G&N)-VY (BET)	0.52
VZ (G&N)-VZ (BET)	-14.10
PX (G&N)-PX (BET)	-612.00
PY (G&N)-PY (BET)	-289.00
PZ (G&N)-PZ (BET)	-2048.00

3.4 RTCC TRAJECTORY COMPARISON

The state vectors obtained in real time by the RTCC for the Apollo 5 mission were compared with the Task A-50 best estimate of the trajectory (BET) at RTCC anchor times from LM/S-IVB separation to HAW05 (prior to PRA V). The purpose of making these comparisons is to aid the RTCC in evaluating fit procedures for this and subsequent Apollo Missions.

The state vector comparisons are discussed in this section. Also included in the discussion is a set of special state vectors comparisons of

Table 3-10. RTCC Summary of Radar Data for AS-204/LM-1

Code	Batch	Anchor Time (day:hr:min:sec)	N	E_{MAX} (deg)	A/R
BDAC	06	00:22:58:12	21	28	S
BDQC	08	00:22:58:12	21	28	A
REDC	02	00:23:00:24	34	25	R
CYIC	05	00:23:07:48	33	30	R
TANC	09	00:23:27:00	23	12	A
CROC	11	00:23:42:18	42	12	A
CROS	13	00:23:42:48	37	13	A
CNBS	12	00:23:50:18	27	8	A
WHSC	14	01:00:19:18	47	17	A
PATC	16	01:00:24:36	47	20	R
MLAC	17	01:00:24:36	51	23	A
MILS	18	01:00:26:48	24	23	R
BDQC	19	01:00:28:00	54	51	A
REDC	20	01:00:35:00	32	38	R
BDAS	21	01:00:29:54	32	50	A
REDC	20	01:00:35:00	32	38	R
TANC	23	01:00:58:48	50	26	A
CROC	22	01:01:15:06	52	20	A
CROS	24	01:01:16:48	35	20	A
HAWS	26	01:01:40:06	37	11	R
GDSS	25	01:01:50:24	29	15	A
WHSC	27	01:01:53:36	34	60	R
MLAC	29	01:01:57:48	53	39	A
BDQC	31	01:02:01:12	47	12	A
BDAS	35	01:02:02:54	30	12	R
ANTC	33	01:02:03:36	39	7	A
REDC	34	01:02:07:54	18	4	R
PREC	37	01:02:28:06	18	16	R
CROC	39	01:02:48:30	50	44	S
CROC	41	01:02:48:30	50	44	S

Table 3-10. RTCC Summary of Radar Data for AS-204/LM-1 (Continued)

Code	Batch	Anchor Time (day:hr:min:sec)	N	E_{MAX} (deg)	A/R
CROS	42	01:02:48:30	25	43	A
HAWC	44	01:03:12:42	53	24	A
WTNC	43	01:03:18:27	16	39	R
CLQC	48	01:03:22:29	42	13	R
GYMS	46	01:03:24:12	47	24	R
WHSC	47	01:03:25:30	49	42	A
MLAC	50	01:03:31:18	47	19	A
GBIC	51	01:03:31:24	54	25	A
MILS	52	01:03:33:48	22	17	R
ANTC	53	01:03:35:54	55	43	A
ASCC	54	01:03:49:48	54	14	A
CROC	55	01:04:22:54	6	3	R
CROS	56	01:04:22:54	8	3	R
GWMS	57	01:04:33:18	38	22	A
HAWC	58	01:04:47:12	32	6	R
HAWS	60	01:04:47:18	18	6	R
WTNC	59	01:04:51:37	24	42	R
GYMS	61	01:04:57:18	30	51	R
WHSC	56	01:04:58:36	33	10	R
TEXS	66	01:05:01:00	11	12	R
TEXS	67	01:05:02:12	15	15	R
ASCC	68	01:05:22:54	48	10	R
ASCC	70	01:05:22:54	80	10	S
ACNS	69	01:05:25:18	22	9	A
TANC	72	01:05:40:06	80	33	A
TANC	73	01:05:50:18	28	13	A
CROC	74	01:05:58:00	63	5	A
GWMS	75	01:06:10:48	66	29	A
HAWS	77	01:06:27:42	24	8	R
HAWC	79	01:06:27:48	49	8	A
WTNC	78	01:06:32:29	15	18	R

prime interest to the RTCC. As previously noted, a time bias was added to the time tag of the low speed tracking data to account for the difference between UT1 and UTC. The real-time orbit determination program does not account for the difference between UT1 and UTC. However, when the comparisons were made, the BET was adjusted so that the BET and the RTCC trajectory were using the same time scale (UTC).

Table 3-10 lists in detail the data received and processed by the RTCC. The maximum elevation of the pass (E_{max}), the anchor vector time (GMT), the number of valid points in each batch (N), and an indication that the data were either accepted or rejected (A/R) is tabulated. An "S" in the accept/reject column denotes an single station solution. The batch number is simply a numbering system used by the RTCC and has no special significance. The MSC memorandum on the RTCC Mission Data Summary was the source of Table 3-10.

RTCC Comparisons

A summary of comparisons is listed in Table 3-11. The table lists the data used in the fit to obtain the RTCC vector, the RTCC batch number, the RTCC anchor time (GMT), the maximum elevation of the pass (E_{max}), the BET segment number, the total difference in position (ΔR), and the total difference in velocity (ΔV).

It can be seen from the summary that good comparisons were obtained for Segments 1 and 2. The exceptions are the CROC 39, the CROC 41, and the CROS 42 comparisons. The large total velocity difference for these three comparisons can be explained by the fact that the RTCC fits occurred immediately following DPS 1 engine cutoff and were essentially single station fits.

The relatively bad comparisons for Segments 4 and 5 are the result of low level RCS thrusting which occurred from 5 hours, 1 minute, and 36 seconds GMT to 5 hours and 9 minutes GMT and from 5 hours and 59 minutes GMT to 6 hours and 32 minutes GMT on 23 January. Segments 4 and 5 were defined by these periods of RCS thrusting; consequently, the effects of the thrusting on the trajectory were minimized. The RTCC, however, was unaware that thrusting was occurring, and consequently, it tried to fit the data from ASCC 70 to HAWC79 which degraded the resulting trajectory.

The bad comparison for TANC73 can be explained by the fact that only 28 observations were used in this fit (80 observations were used in the TANC72 fit). The maximum elevation of the data in the TANC73 fit was 13 degrees compared to a maximum elevation of 33 degrees for the data in the TANC72 fit.

Special Comparisons

The summary of special comparisons can be found in Table 3-12. The vectors are time ordered according to anchor time and the total difference in position and velocity is listed.

The output of the RTCC Compare Program is listed for each vector appearing in Tables 3-11 and 3-12.

The results of the comparison program are given in the following listing. The definitions of the symbols used are as follows.

Symbol	Definition of Symbols for RTCC Comparison
X, Y, Z, $\dot{X}$, $\dot{Y}$, $\dot{Z}$	Components of the position and velocity vector referenced to a geocentric, inertial, Cartesian, coordinate system. It is a right handed system where the X-axis lies in the true equatorial plane in the direction of the Greenwich meridian at 0^h day of launch, the Z-axis is orthogonal to the true equatorial plane, and the Y-axis completes the right-handed system. The units are earth radii and earth radii/hour.
SEMI-MAJOR	Semi-major axis (feet)
ECCEN	Eccentricity of the orbit
INCL	Inclination of the orbit plane to the equator measured positive counter clockwise from the equatorial plane to the orbit plane at the ascending node (degrees)
NODE	Right ascension of the ascending node (degrees)

Symbol	Definition of Symbols for RTCC Comparison
ARG PERIGEE	Argument of perigee measured positive in the direction of motion from the ascending node (degrees)
TRUE ANOM	True anomaly measured positive in the direction of motion (degrees)
PERIOD	Osculating period of the orbit (minutes)
APOGEE	Altitude of apogee above a reference sphere (nautical miles)
PERIGEE	Altitude of perigee above a reference sphere (nautical miles)
VEL-MAG	Magnitude of the inertial velocity vector (feet/second)
FLT PATH	Flight path angle measured positive downward from the local vertical (degrees)
HEADING	Azimuth of the velocity vector measured positive east of true North (degrees)
DECLIN	Declination (degrees)
LONG	Longitude of the vehicle measured positive east of the Greenwich meridian (degrees)
HEIGHT	Height of the vehicle above a reference sphere (nautical miles)
DELTA U DELTA V DELTA W DELTA UDOT DELTA VDOT DELTA WDOT	Difference between the RTCC and TRW components of the position and velocity vector in a vehicle centered, coordinate system where the U-axis is collinear with the earth-centered inertial radius vector and is directed outward, the V-axis lies in the orbit plane and is orthogonal to the U-axis, and the W-axis completes the right-handed system.
DELTA POS	Magnitude of the difference between the RTCC position vector and the TRW position vector
DELTA VEL	Magnitude of the difference between the RTCC velocity vector and the TRW velocity vector

Table 3-11. RTCC Comparison Summary

Station	Batch	Anchor Time (day:hr:min:sec)	E_{max} (deg)	BET	ΔR (ft)	ΔV (ft/sec)
CROC	11	22:23:42:18	12.5	1	1126	0.88
CROS	13	22:23:42:18	12.5	1	1048	0.89
CNBS	12	22:23:50:18	8.1	1	552	0.51
WHSC	14	23:00:19:18	17.2	1	346	0.81
MLAC	17	23:00:24:36	22.5	1	335	0.77
BDQC	19	23:00:28:00	50.6	1	301	0.67
BDAS	21	23:00:29:54	50.5	1	317	0.60
TANC	23	23:00:58:48	26.0	1	546	0.76
CROC	22	23:01:15:06	20.2	1	394	0.55
CROS	24	23:01:16:48	20.3	1	331	0.33
GDSS	25	23:01:50:24	14.7	1	201	0.28
MLAC	29	23:01:57:48	39.2	1	232	0.22
BDQC	31	23:02:01:12	12.3	1	286	0.19
ANTC	33	23:02:03:36	7.4	1	333	0.17
CROC	39	23:02:48:30	43.7	2	724	3.29
CROC	41	23:02:48:30	43.7	2	723	3.29
CROS	42	23:02:48:30	43.4	2	632	3.59
HAWC	44	23:03:12:42	24.3	2	844	1.17
WHSC	47	23:03:25:30	42.4	2	276	0.44
MLAC	50	23:03:31:18	19.3	2	310	0.44
GBIC	51	23:03:31:24	24.6	2	284	0.40
ANTC	53	23:03:35:54	42.7	2	316	0.54
ASCC	54	23:03:49:48	14.4	2	121	0.16
GWMS	57	23:04:33:18	22.1	2	1013	0.75
ASCC	70	23:05:22:54	9.5	4	2585	1.15
ACNS	69	23:05:25:18	9.7	4	1778	4.01
TANC	72	23:05:40:06	33.4	4	1266	0.91
TANC	73	23:05:50:18	33.4	4	8111	23.01
CROC	74	23:05:58:00	5.0	4	2666	6.24
GWMS	75	23:06:10:48	28.5	5	2057	2.09
HAWC	79	23:06:27:48	8.5	5	1600	2.44

Table 3-12. RTCC Comparison Summary for Special Vectors

Vector Description	Anchor Time (day:hr:min:sec)	BET	ΔR (ft)	ΔV (ft/sec)
High speed radar vector following the separation maneuver	22:23:44:00	1	661	138. 59
Best RTCC vector prior to DPS 1	23:02:03:36	1	333	0. 17
High speed vector following DPS 1	23:02:48:34	2	6, 870	18. 47
Best RTCC vector prior to PRA 3	23:04:33:18	2	1, 013	0. 75
High speed vector from WHSC following PRA 3	23:05:02:13. 1	3	2, 640	49. 61
Vector used to build LGC Navigation update prior to PRA 5*	23:05:09:29	4	27, 918	65. 88
Best RTCC vector prior to PRA 5	23:06:27:48	5	1, 600	2. 44

*High speed vector from WHSC prior to PRA 5 (vector used to build LGC navigation update)

03/15/68 APOLLO RTCC COMPARISON

CROC11 42 OBS MS MAN ACC UPDATE 1EDIT 3ITER VEH3

TIME U.T. 22/ 1/68 23 HRS 42 MIN 18.000 SEC

TIME FROM LAUNCH 0 DAYS 0 HRS 54 MIN 10.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
-0.20897974E 00	0.85739464E 00	-0.53881492E 00	-0.42078318E 01	-0.11885057E 01	-0.25820325E 00	RTCC
-0.20896806E 00	0.85735212E 00	-0.53878406E 00	-0.42079141E 01	-0.11884685E 01	-0.25832366E 00	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21558449.00	0.00364170	31.63036299	201.27400970	81.65742493	181.88171959	RTCC
21556962.25	0.00365905	31.63028359	201.27575111	82.03473663	181.50284195	TRW
1486.75	-0.00001734	0.00007939	-0.00174141	-0.37731171	0.37887764	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.35007191	119.66342163	93.82141113	RTCC
88.34093189	119.47943115	93.51608276	TRW
0.00914001	0.18399048	0.30532837	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25460.0874	90.00687122	93.96459879	-31.40650058	107.14958000	119.64483643	RTCC
25460.5300	90.00551224	93.96564102	-31.40631390	107.14949799	119.45989990	TRW
-0.44262695	0.00135899	-0.00094223	-0.00018668	0.00008202	0.18493652	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
1124.	32.	-69.	-0.64	-0.44	0.43

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
1126.	0.88

03/15/68 APOLLO RTCC COMPARISON
CROS13 37 OBS MS MAN ACC UPDATE 1EDIT 4ITER VEH3

TIME U.T.
22/ 1/68 23 HRS 42 MIN 48.000 SEC

TIME FROM LAUNCH
0 DAYS 0 HRS 54 MIN 40.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
-0.24390566E 00	0.84695401E 00	-0.54062763E 00	-0.41738476E 01	-0.13163571E 01	-0.17698411E 00	RTCC
-0.24389610E 00	0.84691440E 00	-0.54059852E 00	-0.41739410E 01	-0.13163227E 01	-0.17710108E 00	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21558107.50	0.00365600	31.63015628	201.26887703	81.46793365	184.09815788	RTCC
21556850.00	0.00366516	31.63002229	201.27052116	81.89776516	183.66701317	TRW
1257.50	-0.00000916	0.00013399	-0.00164413	-0.42983150	0.43114471	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.34797382	119.65777588	93.71472168	RTCC
88.34024239	119.48251343	93.47598267	TRW
0.00773144	0.17526245	0.23873901	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25460.1270	90.01500988	92.72619438	-31.52459836	109.39150143	119.61096191	RTCC
25460.6125	90.01346397	92.72698402	-31.52440286	109.39161396	119.43905640	TRW
-0.48559570	0.00154591	-0.00078964	-0.00019550	-0.00011253	0.17190552	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
1045.	-34.	-76.	-0.65	-0.49	0.38

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
1048.	0.89

03/15/68 APOLLO RTCC COMPARISON
CNBS12 27 OBS MS MAN ACC NO UPD 3EDIT 5ITER VEH2

TIME U.T.
22/ 1/68 23 HRS 59 MIN 18.000 SEC

TIME FROM LAUNCH
0 DAYS 1 HRS 2 MIN 10.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
-0.70797911E 00	0.57360826E 00	-0.48720056E 00	-0.30759011E 01	-0.29544980E 01	0.10120433E 01	RTCC
-0.70798160E 00	0.57358610E 00	-0.48718645E 00	-0.30759367E 01	-0.29544822E 01	0.10119646E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21561184.50	0.00358707	31.63774991	201.19418526	77.60160351	218.38384247	RTCC
21560429.25	0.00358188	31.63736820	201.19528580	78.22507191	217.76054192	TRW
755.25	0.00000519	0.00038171	-0.00110054	-0.62346840	0.62330055	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.36688805	119.92144775	94.46383667	RTCC
88.36224651	119.77825928	94.35842896	TRW
0.00464153	0.14318848	0.10540771	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25479.5845	90.12800598	74.89334488	-28.13288450	142.43146706	117.15521240	RTCC
25479.5620	90.12598324	74.89347267	-28.13250875	142.43264961	117.09585571	TRW
0.02246094	0.00202274	-0.00012779	-0.00037575	-0.00118256	0.05935669	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
361.	-416.	-34.	-0.41	0.02	0.31

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
552.	0.51

03/15/68 APOLLO RTCC COMPARISON
WHSC14 47 OBS MS MAN ACC NO UPD 2EDIT 2ITER VEH3

TIME U.T. 23/ 1/68 0 HRS 19 MIN 18.000 SEC

TIME FROM LAUNCH 0 DAYS 1 HRS 31 MIN 10.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
-0.30109153E 00	-0.87755699E 00	0.43770511E 00	0.41403696E 01	-0.73942454E 00	0.13438156E 01	RTCC
-0.30109036E 00	-0.87754405E 00	0.43769491E 00	0.41403916E 01	-0.73929545E 00	0.13437666E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21563501.50	0.00497202	31.64316797	201.10461235	79.64050388	334.77912903	RTCC
21562679.00	0.00496602	31.64318228	201.10511780	80.12207413	334.29689407	TRW
822.50	0.00000599	-0.00001431	-0.00050545	-0.48157024	0.48223495	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.38113403	125.21917725	89.92880249	RTCC
88.37607574	125.06182861	89.81539917	TRW
0.00505829	0.15734863	0.11340332	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25665.0835	90.12077999	70.27431965	25.25702429	245.23898506	91.60363770	RTCC
25664.9910	90.12280464	70.27401543	25.25681043	245.23879433	91.54934692	TRW
0.09252930	-0.00202465	0.00030422	0.00021386	0.00019073	0.05429077	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
330.	88.	54.	0.80	0.09	-0.10

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
346.	0.81

03/15/68 APOLLO RTCC COMPARISON
MLAC17 51 OBS MS MAN ACC NO UPD 2EDIT 2ITER VEH3

TIME U.T. 23/ 1/68 0 HRS 24 MIN 36.000 SEC

TIME FROM LAUNCH 0 DAYS 1 HRS 36 MIN 28.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
0.77348030E-01	-0.87888168E 00	0.52233304E 00	0.43249516E 01	0.70979799E 00	0.54920114E 00	RTCC
0.77345848E-01	-0.87886735E 00	0.52232619E 00	0.43249257E 01	0.70992251E 00	0.54916380E 00	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21558008.00	0.00479893	31.63194585	201.05779457	82.72363186	353.53168106	RTCC
21557237.50	0.00478493	31.63213706	201.05857277	83.10408020	353.15053177	TRW
770.50	0.00001399	-0.00019121	-0.00077820	-0.38044834	0.38114929	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.34736156	123.69641113	89.64331055	RTCC
88.34262371	123.51934814	89.56674194	TRW
0.00473785	0.17706299	0.07656860	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25675.2124	90.03081989	81.67372417	30.62668920	267.87704468	89.75564575	RTCC
25675.1548	90.03251553	81.67325306	30.62677121	267.87698364	89.70080566	TRW
0.05761719	-0.00169563	0.00047112	-0.00008202	0.00006104	0.05484009	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
334.	15.	-33.	0.74	0.06	-0.20

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
335.	0.77

03/15/68 APOLLO RTCC COMPARISON
BOQC19 54 OBS MS MAN ACC NO UPD 2EDIT 2ITER VEH3

TIME U.T. — 23/ 1/68 0 HRS 28 MIN 0. SEC

TIME FROM LAUNCH — 0 DAYS 1 HRS 39 MIN 52.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
0.31773084E 00	-0.81312421E 00	0.53768297E 00	0.41172728E 01	0.15993344E 01	-0.98204700E-02	RTCC
0.31772802E 00	-0.81311012E 00	0.53768294E 00	0.41172143E 01	0.15994317E 01	-0.98384217E-02	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21556758.50	0.00475369	31.62951350	201.02158928	83.71228409	6.56158179	RTCC
21556059.50	0.00473091	31.62992334	201.02266502	83.94038582	6.33270347	TRW
699.00	0.00002278	-0.00040984	-0.00107574	-0.22810173	0.22887832	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.33968163	123.32931519	89.59912109	RTCC
88.33538342	123.13293457	89.56546021	TRW
0.00429821	0.19638062	0.03366089	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25674.7266	89.96904564	90.16867638	31.62911057	283.33845901	89.72097778	RTCC
25674.6145	89.97026443	90.16820145	31.62952328	283.33862305	89.67938232	TRW
0.11206055	-0.00121880	0.00047493	-0.00041270	-0.00016403	0.04159546	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
252.	-52.	-155.	0.61	0.11	-0.25

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
301.	0.67

03/15/68 APOLLO RTCC COMPARISON
BDAS21 32 OBS MS MAN ACC NO UPD 1EDIT 5ITER VEH3

TIME U.T.
23/ 1/68 0 HRS 29 MIN 54.000 SEC

TIME FROM LAUNCH
0 DAYS 1 HRS 41 MIN 46.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
0.44477133E 00	-0.75511839E 00	0.53239830E 00	0.38940784E 01	0.20583912E 01	-0.32401467E 00	RTCC
0.44476795E 00	-0.75510363E 00	0.53238818E 00	0.38940178E 01	0.20584727E 01	-0.32403547E 00	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21557046.00	0.00476152	31.63033557	201.00140190	84.23282051	13.87379074	RTCC
21556385.50	0.00473878	31.63070369	201.00234032	84.39308357	13.71294916	TRW
660.50	0.00002274	-0.00036812	-0.00093842	-0.16026306	0.16084158	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.34144588	123.40466309	89.61843872	RTCC
88.33738995	123.21478271	89.59097290	TRW
0.00405693	0.18988037	0.02746582	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25672.0305	89.93492508	94.96403885	31.27835584	292.01738739	90.11688232	RTCC
25671.9502	89.93596363	94.96375942	31.27876879	292.01768875	90.07418823	TRW
0.08032227	-0.00103855	0.00027943	-0.00041294	-0.00030136	0.04269409	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
259.	-82.	-162.	0.56	0.08	-0.20

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
317.	0.60

03/15/68 APOLLO RTCC COMPARISON
TANC23 50 OBS MS MAN ACC NO UPD 1EDIT 3ITER VEH3

TIME U.T. — 23/ 1/68 0 HRS 58 MIN 48.000 SEC

TIME FROM LAUNCH — 0 DAYS 2 HRS 10 MIN 40.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
0.59125454E 00	0.78325571E 00	-0.32115425E 00	-0.34942939E 01	0.18926225E 01	-0.18583764E 01	RTCC
0.59127041E 00	0.78327113E 00	-0.32114047E 00	-0.34941822E 01	0.18926226E 01	-0.18584440E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21567517.75	0.00345483	31.65476894	200.89212227	93.81240273	122.53288746	RTCC
21567615.50	0.00346881	31.65506005	200.89467430	93.71884346	122.62361813	TRW
-97.75	-0.00001398	-0.00029111	-0.00255203	0.09355927	-0.09073067	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.40582657	120.49807739	95.97189331	RTCC
88.40642738	120.56387329	95.93820190	TRW
-0.00060081	-0.06579590	0.03369141	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25500.2725	89.83284283	116.40827370	-18.12086987	37.22617054	114.79837036	RTCC
25499.9221	89.83238898	116.40936375	-18.11976600	37.22597218	114.85522461	TRW
0.35034180	0.00045395	-0.00109005	-0.00110388	0.00019836	-0.05685425	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-345.	248.	-342.	-0.49	0.35	0.46

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
546.	0.76

03/15/68 APOLLO RTCC COMPARISON
CROC22 52 OBS MS MAN ACC NO UPD 1EDIT 3ITER VEH3

TIME U.T. 23/ 1/68 1 HRS 15 MIN 6.000 SEC

TIME FROM LAUNCH 0 DAYS 2 HRS 26 MIN 58.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
-0.51301495E 00	0.72458043E 00	-0.52933200E 00	-0.37125840E 01	-0.22726165E 01	0.49853624E 00	RTCC
-0.51300456E 00	0.72457615E 00	-0.52934708E 00	-0.37125588E 01	-0.22726375E 01	0.49844659E 00	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	APG PERIGEE	TRUE ANOM	
21556727.00	0.00362530	31.63133550	200.75672150	81.18757534	201.26737595	RTCC
21556507.50	0.00363761	31.63199115	200.75933075	81.18619061	201.26607895	TRW
219.50	-0.00001231	-0.00065565	-0.00260925	0.00138474	0.00129700	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.33948708	119.32083130	93.59725952	RTCC
88.33813667	119.32824707	93.51760864	TRW
0.00135040	-0.00741577	0.07965088	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25467.7441	90.07557583	82.43285561	-30.80442095	105.48711872	118.43530273	RTCC
25467.6243	90.07579041	82.43424988	-30.80540895	105.48672962	118.43383789	TRW
0.11987305	-0.00021458	-0.00139427	0.00098801	0.00038910	0.00146484	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
9.	174.	353.	-0.11	0.12	0.53

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
394.	0.55

03/15/68 APOLLO RTCC COMPARISON
CROS24 35 OBS MS MAN ACC UPDATE 1EDIT 4ITER VEH3

TIME U.T. 23/ 1/68 1 HRS 16 MIN 48.000 SEC

TIME FROM LAUNCH 0 DAYS 2 HRS 28 MIN 40.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
-0.61423757E 00	0.65511916E 00	-0.51141812E 00	-0.34243775E 01	-0.26253305E 01	0.76534897E 00	RTCC
-0.61423324E 00	0.65510444E 00	-0.51142200E 00	-0.34243561E 01	-0.26253827E 01	0.76535606E 00	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21557947.75	0.00360055	31.63397789	200.74178314	80.30213451	209.04730988	RTCC
21557687.50	0.00360469	31.63446784	200.74273682	80.22802067	209.12087631	TRW
260.25	-0.00000414	-0.00048995	-0.00095367	0.07411385	-0.07356644	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.34699154	119.43469238	93.88525391	RTCC
88.34539127	119.40631104	93.82788086	TRW
0.00160027	0.02838135	0.05737305	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25472.9683	90.10040474	78.46405315	-29.66086459	112.91716957	117.80871582	RTCC
25473.0605	90.10078716	78.46414471	-29.66142774	112.91761017	117.77432251	TRW
-0.09228516	-0.00038242	-0.00009155	0.00056314	-0.00044060	0.03439331	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
209.	-99.	237.	0.29	-0.09	0.14

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
331.	0.33

03/15/68 APOLLO RTCC COMPARISON
GDSS25 29 OBS MS MAN ACC NO UPD 1EDIT 5ITER VEH3

TIME U.T.	TIME FROM LAUNCH
23/ 1/68 1 HRS 50 MIN 24.000 SEC	0 DAYS 3 HRS 2 MIN 16.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
-0.98566540E-01	-0.89330869E 00	0.49372533E 00	0.43204272E 01	0.36335760E-01	0.91609249E 00	RTCC
-0.98568458E-01	-0.89330823E 00	0.49373470E 00	0.43203991E 01	0.36357762E-01	0.91612417E 00	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21558341.25	0.00485986	31.63573575	200.61291695	82.56289005	344.06720352	RTCC
21558318.00	0.00485450	31.63639665	200.61353111	82.58160210	344.04796982	TRW
23.25	0.00000536	-0.00066090	-0.00061417	-0.01871204	0.01923370	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.34941196	123.96777344	89.48165894	RTCC
88.34926605	123.94488525	89.49691772	TRW
0.00014591	0.02288818	-0.01525879	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25672.5781	90.07604122	76.26766968	28.78258252	235.04236031	90.14691162	RTCC
25672.4573	90.07605267	76.26705074	28.78304839	235.04223442	90.16168213	TRW
0.12084961	-0.00001144	0.00061893	-0.00046587	0.00012589	-0.01477051	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-90.	-2.	-179.	0.01	0.12	-0.25

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
201.	0.28

03/15/68 APOLLO RTCC COMPARISON

MLAC29 53 OBS MS MAN ACC NO UPD 2EDIT 2ITER VEH3

TIME U.T. 23/ 1/68 1 HRS 57 MIN 48.000 SEC

TIME FROM LAUNCH 0 DAYS 3 HRS 9 MIN 40.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
0.42320748E 00	-0.76649813E 00	0.53355140E 00	0.39418533E 01	0.19717333E 01	-0.28555503E 00	RTCC
0.4232[illegible]45[illegible]E 00	-0.76649162E 00	0.53355984E 00	0.39418260E 01	0.19717497E 01	-0.28553327E 00	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21555586.75	0.00473799	31.63028622	200.53644753	84.88122845	12.25763595	RTCC
21555332.50	0.00472934	31.63084197	200.53736496	84.89079475	12.24727106	TRW
254.25	0.00000865	-0.00055575	-0.00091743	-0.00956631	0.01036489	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.33247757	123.07986450	89.46292114	RTCC
88.33091640	123.00714111	89.45196533	TRW
0.00156116	0.07272339	0.01095581	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25673.1333	89.94264126	94.37715912	31.35711145	268.38821793	89.84555054	RTCC
25673.0261	89.94281578	94.37676811	31.35772109	268.38825607	89.83966064	TRW
0.10717773	-0.00017452	0.00039101	-0.00060964	-0.00003815	0.00588989	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
36.	6.	-229.	0.37	0.11	-0.18

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
232.	0.22

03/15/68 APOLLO RTCC COMPARISON
BDQC31 47 OBS MS MAN ACC NO UPD 1EDIT 2ITER VEH3

TIME U.T.
23/ 1/68 2 HRS 1 MIN 12.000 SEC

TIME FROM LAUNCH
0 DAYS 3 HRS 13 MIN 4.000 SEC

X	Y	Z	XDOT	YDOT	ZDOT	
0.63190086E 00	-0.63326899E 00	0.50174995E 00	0.33874891E 01	0.27071938E 01	-0.83121820E 00	RTCC
0.63189658E 00	-0.63326014E 00	0.50175941E 00	0.33874677E 01	0.27071986E 01	-0.83119322E 00	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21557624.25	0.00479815	31.63478971	200.50194931	86.23806190	24.91154718	RTCC
21557298.75	0.00478805	31.63534904	200.50308800	86.18421745	24.96444297	TRW
325.50	0.00001010	-0.00055933	-0.00113869	0.05384445	-0.05289578	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.34500122	123.63018799	89.58316040	RTCC
88.34300137	123.54049683	89.56573486	TRW
0.00199986	0.08969116	0.01742554	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25664.8560	89.88472557	102.53144455	29.28625488	283.56947708	91.15573120	RTCC
25664.7505	89.88475513	102.53118896	29.28696990	283.56968689	91.14376831	TRW
0.10546875	-0.00002956	0.00025558	-0.00071502	-0.00020981	0.01196289	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
73.	-8.	-276.	0.02	0.11	-0.16

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
286.	0.19

03/15/68 APOLLO RTCC COMPARISON
ANTC33 39 OBS MS MAN ACC NO UPD 1EDIT 2ITER VEH3

TIME U.T.
23/ 1/68 2 HRS 3 MIN 36.000 SEC

TIME FROM LAUNCH
0 DAYS 3 HRS 15 MIN 28.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
0.75743695E 00	-0.51619618E 00	0.46125860E 00	0.28739652E 01	0.31320577E 01	-0.11882773E 01	RTCC
0.75743258E 00	-0.51618534E 00	0.46126939E 00	0.28739513E 01	0.31320587E 01	-0.11882517E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21560062.00	0.00485450	31.64011383	200.48089981	87.81822205	33.21119499	RTCC
21559750.75	0.00484605	31.64068174	200.48226357	87.72788811	33.30047989	TRW
311.25	0.00000844	-0.00056791	-0.00136375	0.09033394	-0.08928490	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.35998535	124.23330688	89.78253174	RTCC
88.35807514	124.15185547	89.76156616	TRW
0.00191021	0.08145142	0.02096558	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25656.0078	89.84834194	107.62099171	26.71262431	293.75521088	92.57806396	RTCC
25655.9194	89.84822464	107.62085438	26.71340632	293.75561905	92.56488037	TRW
0.08837891	0.00011730	0.00013733	-0.00078201	-0.00040817	0.01318359	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
80.	-41.	-320.	[illegible]	0.09	-0.14

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
333.	0.17

03/12/68   APOLLO RTCC COMPARISON
CROC39 5C OBS   MS MAN ACC NO UPD   1EDIT 4ITER VEH3

TIME U.T.
23/ 1/68   2 HRS 49 MIN 30.000 SEC

TIME FROM LAUNCH
0 DAYS 4 HRS 0 MIN 22.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
-0.79244215E 00	0.48607749E 00	-0.45002906E 00	-0.26894759E 01	-0.32166891E 01	0.12868893E 01	RTCC
-0.79245211E 00	0.48608758E 00	-0.44999751E 00	-0.26893959E 01	-0.32169384E 01	0.12863870E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21568337.00	0.00326752	31.64727712	200.23503304	73.32742786	230.52920914	RTCC
21568148.75	0.00326066	31.64162087	200.24472427	73.60773945	230.24108887	TRW
188.25	0.00000685	0.00565624	-0.00969124	-0.28031158	0.28812027	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.41086292	119.96847534	96.77111816	RTCC
88.40970421	119.91302490	96.76455688	TRW
0.00115871	0.05545044	0.00656128	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25494.1643	90.14474201	71.04883480	-25.83107209	105.24941635	115.71640015	RTCC
25494.0859	90.14377689	71.05630016	-25.82916403	105.24920654	115.71173096	TRW
0.07836914	0.00096512	-0.00746536	-0.00190806	0.00020981	0.00466919	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
28.	-167.	-704.	-0.23	0.38	3.28

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
724.	3.29

03/12/68 APOLLO RTCC COMPARISON
CROC41 50 OBS SS MAN ACC NO UPD 2EDIT 4ITER VEH3

TIME U.T.		TIME FROM LAUNCH
23/ 1/68	2 HRS 48 MIN 30.000 SEC	0 DAYS 4 HRS 0 MIN 22.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
-0.79244215E 00	0.48607749E 00	-0.45002905E 00	-0.26894759E 01	-0.32166891E 01	0.12868893E 01	RTCC
-0.79245211E 00	0.48608758E 00	-0.44999751E 00	-0.26893959E 01	-0.32169384E 01	0.12863870E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21568337.00	0.00326752	31.64727712	200.23503304	73.32749557	230.52914238	RTCC
21568148.75	0.00326066	31.64162087	200.24472427	73.60773945	230.24108887	TRW
188.25	0.00000685	0.00565624	-0.00969124	-0.28024387	0.28805351	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.41086292	119.96847534	96.77111816	RTCC
88.40970421	119.91302490	96.76455688	TRW
0.00115871	0.05545044	0.00656128	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25494.1643	90.14474201	71.04883480	-25.83107138	105.24941635	115.71640015	RTCC
25494.0859	90.14377689	71.05630016	-25.82916403	105.24920654	115.71173096	TRW
0.07836914	0.00096512	-0.00746536	-0.00190735	0.00020981	0.00466919	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
28.	-167.	-703.	-0.23	0.18	3.28

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
723.	3.29

03/12/68 APOLLO RTCC COMPARISON
CROS42 25 OBS MS MAN ACC NO UPD 2EDIT 5ITER VEH3

TIME U.T.
23/ 1/68 2 HRS 48 MIN 30.000 SEC

TIME FROM LAUNCH
0 DAYS 4 HRS 0 MIN 22.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
-0.79243088E 00	0.48607542E 00	-0.45001519E 00	-0.26896854E 01	-0.32165463E 01	0.12867666E 01	RTCC
-0.79245211E 00	0.48608758E 00	-0.44999751E 00	-0.26893959E 01	-0.32169384E 01	0.12863870E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21567563.25	0.00323313	31.64690304	200.23443604	74.31494808	229.54212189	RTCC
21568148.75	0.00326066	31.64162087	200.24472427	73.60773945	230.24108887	TRW
-585.50	-0.00002753	0.00528216	-0.01028824	0.70720863	-0.69896698	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.40610695	119.71868896	96.76623535	RTCC
88.40970421	119.91302490	96.76455688	TRW
-0.00359726	-0.19433594	0.00167847	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25494.0928	90.14114189	71.14889297	-25.83063793	105.24916172	115.66241455	RTCC
25494.0859	90.14377689	71.15630016	-25.82916403	105.24920654	115.71173096	TRW
0.00683594	-0.00263500	-0.00740719	-0.00147390	-0.00004482	-0.04931641	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-300.	-195.	-521.	1.4[illegible]	[illegible].[illegible]1	3.31

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
632.	3.5[illegible]

03/12/68 APOLLO RTCC COMPARISON
HAWC44 53 OBS MS MAN ACC NO UPD 1EDIT 3ITER VEH3

TIME U.T. 23/ 1/68 3 HRS 12 MIN 42.000 SEC

TIME FROM LAUNCH 0 DAYS 4 HRS 24 MIN 34.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
-0.50489812E 00	-0.81631918E 00	0.36485207E 00	0.37632650E 01	-0.15540096E 01	0.16996762E 01	RTCC
-0.50489110E 00	-0.81627839E 00	0.36486061E 00	0.37634020E 01	-0.15539020E 01	0.16995768E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21573374.50	0.00470565	31.65016890	200.19035530	75.00170898	327.61826324	RTCC
21572389.00	0.00471988	31.65061784	200.18737411	75.58446407	327.03775787	TRW
985.50	-0.00001422	-0.00044894	0.00298119	-0.58275509	0.58050537	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.44183826	125.90634155	92.49133301	RTCC
88.43578053	125.79394531	92.27938843	TRW
0.00605774	0.11239624	0.21194458	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25645.8286	90.14375877	65.60126781	20.81261349	188.97043419	95.07330322	RTCC
25646.0647	90.14648914	65.60166931	20.81381989	188.96950722	94.96014404	TRW
-0.23608398	-0.00273037	-0.00040150	-0.00120640	0.00092697	0.11315918	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
687.	108.	-546.	1.[illegible]9	-0.23	0.33

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
884.	1.17

03/12/68   APOLLO RTCC COMPARISON
WHSC47 49 OBS   MS MAN ACC NO UPD   1EDIT 3ITER VEH3

TIME U.T. 23/ 1/68   3 HRS 25 MIN [illegible] SEC

TIME FROM LAUNCH 0 DAYS 4 HRS 37 MIN 22.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
0.38760460E 00	-0.78445687E 00	0.53574086E 00	0.40110103E 01	0.18318198E 01	-0.21181880E 01	RTCC
0.38761257E 00	-0.78445401E 00	0.53575095E 00	0.40110304E 01	0.18318319E 01	-0.21174626E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21561881.00	0.00439453	31.62927532	200.07284355	82.99714088	12.30584896	RTCC
21562334.25	0.00441398	31.62967491	200.07450676	82.83434486	12.46767187	TRW
-453.25	-0.00001945	-0.00039959	-0.00166321	0.16279602	-0.16182292	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.37117100	122.90188599	91.71273804	RTCC
88.37395573	123.04577637	91.71792603	TRW
-0.00278473	-0.14389038	-0.00518799	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25660.7285	89.94658566	93.25798035	31.47835660	243.79293633	92.07366943	RTCC
25660.8442	89.94567299	93.25743675	31.47880912	243.79348564	92.09466553	TRW
-0.11572266	0.00091267	0.00054359	-0.00045252	-0.00054932	-0.02099609	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-127.	-166.	-179.	- .21	-0.12	-0.37

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
276.	0.44

03/12/68 APOLLO RTCC COMPARISON
MLAC50 47 OBS MS MAN ACC UPDATE 2EDIT 2ITER VEH3

TIME U.T.	TIME FROM LAUNCH
23/ 1/68 3 HRS 31 MIN 18.000 SEC	0 DAYS 4 HRS 43 MIN 10.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
0.73143671E 00	-0.54587905E 00	0.47027571E 00	0.30007564E 01	0.30329734E 01	-0.11229510E 01	RTCC
0.73144577E 00	-0.54587676E 00	0.47028721E 00	0.30007709E 01	0.30329427E 01	-0.11228839E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21566059.50	0.00450090	31.63844132	200.01714325	85.93116665	33.23707247	RTCC
21566224.50	0.00450917	31.63864541	200.01847458	85.72310638	33.44426727	TRW
-165.00	-0.00000826	-0.00020409	-0.00133133	0.20806026	-0.20719481	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.39686108	123.97009277	92.01983643	RTCC
88.39787292	124.02673340	92.01751709	TRW
-0.00101185	-0.05664063	0.00231934	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25644.8250	89.85921669	106.71430206	27.26066518	269.31035233	94.61489868	RTCC
25644.6609	89.85321383	106.71399975	27.26108432	269.31081009	94.65109253	TRW
0.16406250	0.00601286	0.00030231	-0.00041914	-0.00045776	-0.03619385	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-220.	-1[illegible].	-194.	-[illegible].33	0.17	-0.23

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
310.	0.44

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03/12/68         APOLLO RTCC COMPARISON
GBIC51 54 OBS    MS MAN ACC NO UPD    2EDIT 2ITER VEH3

 TIME U.T.                                                      TIME FROM LAUNCH
23/ 1/68   3 HRS 31 MIN 24.[illegible] SEC                       0 DAYS  4 HRS 43 MIN 16.[illegible]SEC

      X                 Y                 Z                 XDOT              YDOT              ZDOT
0.73641949E 00   -0.54081659E 00   0.46839376E 00   0.29782607E 01   0.30496255E 01   -0.11373774E 01   RTCC
0.73642834E 00   -0.54080793E 00   0.46840369E 00   0.29782713E 01   0.30495990E 01   -0.11373155E 01   TRW


DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)
  SEMI-MAJOR       ECCEN          INCL           NODE           ARG PERIGEE     TRUE ANOM
  21566198.00      0.00450421     31.63872647    200.01643181   85.99888039     33.58026457 RTCC
  21566330.75      0.00450999     31.63888192    200.01767159   85.80182171     33.77655888 TRW
       -132.75    -0.00000578    -0.00015545     -0.00123978    0.19705868     -0.19629431 (RTCC-TRW)

   PERIOD          APOGEE         PERIGEE
  88.39771080     124.00473022    92.03076172                                              RTCC
  88.39852715     124.04721069    92.03198242                                              TRW
  -0.00081635     -0.04248047    -0.00122070                                               (RTCC-TRW)

   VEL-MAG         FLT PATH       HEADING        DECLIN         LONG            HEIGHT
   25644.4260      89.85784149    106.91663837   27.14203072    269.72690201    94.68142700 RTCC
   25644.2686      89.85690022    106.91635990   27.14238214    269.72736359    94.71405029 TRW
   0.15747070      0.00094128     0.00027847    -0.00035143    -0.00046158     -0.03262329 (RTCC-TRW)


DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)
     DELTA U          DELTA V          DELTA W          DELTA UDOT       DELTA VDOT       DELTA WDOT
      -198.            -1[illegible]9.            -171.             -0.29             0.16            -0.22

MAGNITUDE OF VECTOR DIFFERENCE  (FT,FT/SEC)
    DELTA POS        DELTA VEL
      284.            0.4[illegible]
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03/12/68 APOLLO RTCC COMPARISON
ANTC53 55 OBS MS MAN ACC NO UPD 2EDIT 2ITER VFH3

TIME U.T. TIME FROM LAUNCH
23/ 1/68 3 HRS 35 MIN 54.000 SEC 0 DAYS 4 HRS 47 MIN 46.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
0.91821978E 00	-0.28829416E 00	0.36048067E 00	0.18283042E 01	0.36259151E 01	-0.17152705E 01	RTCC
0.91822936E 00	-0.28829189E 00	0.36049214E 00	0.18283522E 01	0.36259631E 01	-0.17152109E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21571843.25	0.00453799	31.65093374	199.98725319	90.46012497	47.59279871	RTCC
21571894.25	0.00454947	31.65111732	199.98824883	90.20930195	47.84284735	TRW
-51.00	-0.00001147	-0.00018358	-0.00099564	0.25082302	-0.25004864	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.43242359	125.05792236	92.83575439	RTCC
88.43273640	125.10714722	92.80331421	TRW
-0.00031281	-0.04922485	0.03244019	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25623.4875	89.82861996	114.63039970	20.53387761	287.46081543	98.04232788	RTCC
25623.2207	89.82751514	114.63029194	20.53431129	287.46111298	98.08349609	TRW
0.26684570	0.00109492	0.00010777	-0.00043368	-0.00029755	-0.04116821	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-250.	-28.	-192.	-0.46	0.27	-0.15

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
316.	0.54

03/12/69 APOLLO RTCC COMPARISON

ASCC54 54 OBS MS MAN ACC UPDATE 2EDIT 2ITER VEH3

TIME U.T.
23/ 1/69 3 HRS 49 MIN 48.[illegible] SEC

TIME FROM LAUNCH
0 DAYS 5 HRS 1 MIN 4[illegible].[illegible]SEC

X	Y	Z	XDOT	YDOT	ZDOT	
0.85076883E 00	0.55137672E 00	-0.13831831E 00	-0.22762049E 01	0.30222092E 01	-0.22315237E 01	RTCC
0.85077[illegible]75E 00	0.55138119E 00	-0.13832147E 00	-0.22761882E 01	0.30222198E 01	-0.22315030E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21578823.50	0.00349556	31.66650915	199.96983337	99.36134815	95.43717957	RTCC
21578889.00	0.00349876	31.66628647	199.96963120	99.35293961	95.44596481	TRW
-65.50	-0.00000319	0.00022268	0.00020219	0.00840855	-0.00878525	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.47534657	122.51985718	97.68145752	RTCC
88.47575188	122.53198242	97.68084717	TRW
-0.00040531	-0.01212524	0.00061035	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25532.6362	89.80083942	120.80956650	-7.70596540	334.04919434	111.22741699	RTCC
25532.5667	89.80041976	120.80930329	-7.70610952	334.04934692	111.24255371	TRW
0.06958008	0.00041966	0.00026321	0.00014412	-0.00015259	-0.01513672	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-92.	-77.	17.	-0.1[illegible]	0.07	-0.11

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
121.	0.16

03/12/68 APOLLO RTCC COMPARISON
GWMS57 38 OBS MS MAN ACC NO UPD 2EDIT 4ITER VEH3

TIME U.T. 23/ 1/68 4 HRS 33 MIN 18.000 SEC

TIME FROM LAUNCH 0 DAYS 5 HRS 45 MIN 10.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
-0.88904071E 00	-0.50580517E 00	0.10848340E 00	0.20872949E 01	-0.31502231E 01	0.22637844E 01	RTCC
-0.88906043E 00	-0.50578613E 00	0.10844352E 00	0.20872118E 01	-0.31503208E 01	0.22637857E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21579146.25	0.00448598	31.66753197	199.73621559	67.09624290	304.49307251	RTCC
21579600.75	0.00450999	31.66687799	199.73823929	67.01739383	304.56777573	TRW
-454.50	-0.00002401	0.00065398	-0.00202370	0.07884407	-0.07470322	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.47733212	126.08059692	94.21694946	RTCC
88.48012924	126.24102783	94.20611572	TRW
-0.00279713	-0.16043091	0.01083374	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25605.8889	90.21127224	58.85733986	6.05412459	140.13929939	101.07955933	RTCC
25606.0706	90.21212959	58.85761118	6.05187035	140.13782883	101.09158325	TRW
-0.18164063	-0.00085735	-0.00027132	0.00225425	0.00147057	-0.01202393	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-73.	999.	440.	-0.70	-0.18	0.19

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
1013.	0.75

03/13/68 APOLLO RTCC COMPARISON
ASCC70 80 OBS SS MAN ACC NO UPD 2EDIT 5ITER VEH3

TIME U.T.
23/ 1/68 5 HRS 22 MIN 54.000 SEC

TIME FROM LAUNCH
0 DAYS 6 HRS 34 MIN 46.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
0.65317386E 00	0.79209131E 00	-0.31962336E 00	-0.32014764E 01	0.21872576E 01	-0.19285529E 01	RTCC
0.65322377E 00	0.79220125E 00	-0.31959725E 00	-0.32015333E 01	0.21871229E 01	-0.19286868E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
22792683.00	0.05682140	31.49126363	199.94605637	134.51414680	80.16930008	RTCC
22797494.C0	0.05682664	31.49123979	199.95437813	134.62420082	80.05221653	TRW
-4811.00	-0.00000524	0.00002384	-0.0C832176	-0.11005402	0.11708355	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
96.04479122	523.01928711	96.72317505	RTCC
96.07520294	523.87573242	97.45031738	TRW
-0.03041172	-0.85644531	-0.72714233	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25171.6724	86.82625103	116.73617077	-17.29248357	328.55869675	261.83374023	RTCC
25171.8682	86.82745266	116.73810387	-17.28930950	328.56045151	262.19033813	TRW
-0.19580078	-0.00120163	-0.00193310	-0.00317407	-0.00175476	-0.35659790	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-2167.	-27.	-1409.	0.55	-0.23	0.99

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
2585.	1.15

03/13/68 APOLLO RTCC COMPARISON
ACNS69 22 OBS MS MAN ACC NO UPD 2EDIT 5ITER VEH3

TIME U.T.
23/ 1/68 5 HRS 25 MIN 18.000 SEC

TIME FROM LAUNCH
0 DAYS 6 HRS 37 MIN 10.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
0.51736962E 00	0.86921518E 00	-0.39238565E 00	-0.35726165E 01	0.16613836E 01	-0.17021490E 01	RTCC
0.51742129E 00	0.86927608E 00	-0.39235660E 00	-0.35725909E 01	0.16608724E 01	-0.17026121E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
22792104.25	0.05674615	31.48102260	199.93069267	134.48895073	89.34228992	RTCC
22794379.25	0.05666403	31.48573279	199.94572067	134.52701187	89.28958702	TRW
-2275.00	0.00008211	-0.00471020	-0.01502800	-0.03806114	0.05270290	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
96.04113388	522.63632202	96.91561890	RTCC
96.05551338	522.72399902	97.57687378	TRW
-0.01437950	-0.08767700	-0.66125488	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
24948.0149	86.75450516	113.83274078	-21.20179462	336.70497894	295.26324463	RTCC
24947.8096	86.75937939	113.84184647	-21.19886088	336.70422745	295.47994995	TRW
0.20532227	-0.00487423	-0.00910568	-0.00293374	0.00075150	-0.21670532	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-1317.	724.	-951.	1.34	0.13	3.78

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
1778.	4.01

03/13/68 APOLLO RTCC COMPARISON
TANC72 80 OBS MS MAN ACC UPDATE 1EDIT 3ITER VEH3

TIME U.T.
23/ 1/68 5 HRS 40 MIN 6.000 SEC

TIME FROM LAUNCH
0 DAYS 6 HRS 51 MIN 58.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
-0.45671274E 00	0.85799445E 00	-0.58887319E 00	-0.37332844E 01	-0.16675933E 01	0.18441009E 00	RTCC
-0.45670946E 00	0.85805449E 00	-0.58886648E 00	-0.37333142E 01	-0.16674896E 01	0.18429616E 00	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
22783876.25	0.05640309	31.47004294	199.84381485	134.10680771	142.88523102	RTCC
22785227.75	0.05639107	31.46823311	199.84461784	134.12892914	142.86098099	TRW
-1351.50	0.00001202	0.00180984	-0.00080299	-0.02212143	0.02425003	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
95.98913002	519.91897583	96.92471313	RTCC
95.99767113	520.10885620	97.17965698	TRW
-0.00854111	-0.18988037	-0.25494385	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
23791.1440	87.95900536	85.73879051	-31.20959377	31.78306818	472.52734375	RTCC
23791.0266	87.95834541	85.74037647	-31.20796013	31.78123426	472.66693115	TRW
0.11743164	0.00065994	-0.00158596	-0.00163364	0.00183392	-0.13958740	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-848.	599.	-725.	-0.87	0.15	0.24

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
1266.	0.91

03/13/68 APOLLO RTCC COMPARISON
TANC73 28 OBS MS MAN ACC NO UPD 1EDIT 2ITER VEH3

TIME U.T. 23/ 1/68 5 HRS 50 MIN 18.000 SEC

TIME FROM LAUNCH 0 DAYS 7 HRS 2 MIN 10.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
-0.96657126E 00	0.43213765E 00	-0.44901584E 00	-0.20800587E 01	-0.31705645E 01	0.14003419E 01	RTCC
-0.96645750E 00	0.43223037E 00	-0.44937459E 00	-0.20803416E 01	-0.31721425E 01	0.13967226E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
22786692.25	0.05618424	31.50766039	199.68770599	134.07080078	177.59150887	RTCC
22790994.50	0.05605952	31.48224092	199.78273964	134.02085495	177.54768562	TRW
-4302.25	0.00012472	0.02541947	-0.09503365	0.04994583	0.04382324	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
96.00692654	519.58786011	98.18273926	RTCC
96.03411770	519.86785889	99.31881714	TRW
-0.02719116	-0.27999878	-1.13607788	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
23496.6191	89.85667706	67.83034039	-22.98132730	67.11098576	519.37863159	RTCC
23497.3828	89.85441303	67.88710976	-22.99906445	67.10389042	519.65194702	TRW
-0.76367188	0.00226402	-0.05676937	0.01773715	0.00709534	-0.27331543	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-1662.	5346.	5869.	-6.15	-0.76	22.16

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
8111.	23.01

03/13/68 APOLLO RTCC COMPARISON
CROC74 63 OBS SS MAN ACC NO UPD 2EDIT 3ITER VEH3

TIME U.T.
23/ 1/68 5 HRS 58 MIN 0. SEC

TIME FROM LAUNCH
0 DAYS 7 HRS 9 MIN 52.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
-0.11212741E 01	-0.61087200E-02	-0.22874518E 00	-0.28658742E 00	-0.35373636E 01	0.19803068E 01	RTCC
-0.11213744E 01	-0.61867721E-02	-0.22875377E 00	-0.28553538E 00	-0.35373514E 01	0.19805163E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
22793142.00	0.05587000	31.49529266	199.76079559	133.80706787	203.69767570	RTCC
22797126.75	0.05587208	31.49578261	199.76330948	133.59453773	203.91172600	TRW
-3984.75	-0.00000206	-0.00048995	-0.00251389	0.21253014	-0.21405029	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
96.04769135	519.53018188	100.36337280	RTCC
96.07288170	520.23037720	100.97476196	TRW
-0.02519035	-0.70019531	-0.61138916	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
23623.2563	91.35567570	60.48714066	-11.53022218	89.58147144	499.86437988	RTCC
23623.3577	91.36713219	60.48639870	-11.52963543	89.58543110	500.21020508	TRW
-0.10131836	-0.01145649	0.00074196	-0.00058675	-0.00395966	-0.34582520	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-2102.	-1532.	585.	6.24	0.05	0.01

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
2666.	6.24

03/13/68 APOLLO RTCC COMPARISON
GWMS75 66 OBS MS MAN ACC NO UPD 1EDIT 6ITER VEH3

TIME U.T. 23/ 1/68 6 HRS 10 MIN 48.000 SEC

TIME FROM LAUNCH 0 DAYS 7 HRS 22 MIN 40.000SEC

X	Y	Z	XDCT	YDOT	ZDOT	
-0.84581161E 0C	-0.68221027E 0C	0.21813244E 00	0.27803664E 01	-0.24451794E 01	0.19853213E 01	RTCC
-0.84575722E 0C	-0.68213663E 00	0.21816826E 00	0.27801605E 01	-0.24453025E 01	0.19850540E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
22795831.00	0.05652975	31.48902321	199.75854874	133.12312889	249.01204681	RTCC
22790605.75	0.05653562	31.48709559	199.75C94032	133.29562378	248.84633636	TRW
5225.25	-0.0000C586	0.00192761	0.0C760841	-0.17249489	0.16571045	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
96.06468964	522.47262573	98.30599976	RTCC
96.03166199	521.58605957	97.47262573	TRW
0.03302765	0.88656616	0.83337402	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
24420.8608	93.08353424	60.42978144	11.35061061	124.94933510	375.68447876	RTCC
24419.7515	93.08091354	60.43282461	11.35332704	124.94811249	375.40966797	TRW
1.10937500	0.00262070	-0.00304317	-0.00271642	0.00122261	0.27481079	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
1669.	-121.	-1196.	-1.C5	1.05	1.47

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
2057.	2.09

03/13/68 APOLLO RTCC COMPARISON
HAWC79 49 OBS MS MAN ACC NO UPD 3EDIT 3ITER VEH3

TIME U.T.
23/ 1/68 6 HRS 27 MIN 48.000 SEC

TIME FROM LAUNCH
0 DAYS 7 HRS 39 MIN 40.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
0.25795557E 00	-0.85246552E 00	0.54418552E 00	0.41591508E 01	0.14913695E 01	0.45821100E-02	RTCC
0.25795797E 00	-0.85252695E 00	0.54423102E 00	0.41992151E 01	0.14910490E 01	0.48449755E-02	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
22774331.00	0.05718984	31.45591140	199.6493C153	134.15151978	313.44791031	RTCC
22777206.75	0.05717336	31.45639300	199.65C66719	134.05216789	313.54525375	TRW
-2875.75	0.00001648	-0.00048161	-0.0C136566	0.09935188	-0.09734344	(RTCC-TRW)
PERIOD	**APOGEE**	**PERIGEE**				
95.92881489	521.20828247	92.49343872				RTCC
95.94698715	521.64691162	93.00149536				TRW
-C.01817226	-0.43862915	-0.50805664				(RTCC-TRW)
VEL-MAG	**FLT PATH**	**HEADING**	**DECLIN**	**LONG**	**HEIGHT**	
25902.1536	92.28767300	88.53221893	31.42515755	188.63470840	153.22164917	RTCC
25901.8843	92.28319931	88.53096676	31.42558622	188.63371468	153.47817993	TRW
0.26928711	0.00447369	0.00125217	-0.00C42868	0.0C099373	-0.25653076	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-1559.	320.	-172.	-2.41	0.17	-0.32

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
1600.	2.44

03/15/68 APOLLO RTCC COMPARISON

HIGH SPEED RADAR VECTOR FOLLOWING SEPARATION MANEUVER

TIME U.T. 22/ 1/68 23 HRS 44 MIN 0. SEC

TIME FROM LAUNCH 0 DAYS 0 HRS 55 MIN 52.000 SEC

X	Y	Z	XDOT	YDOT	ZDOT	
-0.32639707E 00	0.81759216E 00	-0.54220925E 00	-0.40923150E 01	-0.16054599E 01	0.15678412E-01	RTCC
-0.32639691E 00	0.81757198E 00	-0.54218498E 00	-0.40712084E 01	-0.16161701E 01	0.18552793E-01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21712670.25	0.00479582	31.63116288	201.08886337	228.28256416	42.29122019	RTCC
21556766.25	0.00367226	31.62979007	201.25785637	81.57832146	188.85198212	TRW
155904.00	0.00112356	0.00137281	-0.16899300	146.70424271	-146.56076050	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
89.29980183	149.26162720	114.98638916	RTCC
88.33972836	119.49392700	93.43710327	TRW
0.96007347	29.76770020	21.54928589	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25552.6331	89.81586075	89.64658642	-31.62939405	114.78809166	119.41705322	RTCC
25461.4312	90.03244686	89.73497200	-31.62879467	114.78856945	119.31808472	TRW
91.20190430	-0.21658611	-0.08838558	-0.00059938	-0.00047779	0.09896851	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
601.	-155.	-226.	96.72	91.04	39.53

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
661.	138.59

03/15/68 APOLLO RTCC COMPARISON
BEST RTCC VECTOR PRIOR TO DPS-1

TIME U.T.
23/ 1/68 2 HRS 3 MIN 36.000 SEC

TIME FROM LAUNCH
0 DAYS 3 HRS 15 MIN 28.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
0.75743695E 00	-0.51619618E 00	0.46125860E 00	0.28739652E 01	0.31320577E 01	-0.11882773E 01	RTCC
0.75743258E 00	-0.51618534E 00	0.46126939E 00	0.28739513E 01	0.31320587E 01	-0.11882517E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21560062.00	0.00485450	31.64011383	200.48089981	87.81822205	33.21119499	RTCC
21559750.75	0.00484605	31.64068174	200.48226357	87.72788811	33.30047989	TRW
311.25	0.00000844	-0.00056791	-0.00136375	0.09033394	-0.08928490	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.35998535	124.23330688	89.78253174	RTCC
88.35807514	124.15185547	89.76156616	TRW
0.00191021	0.08145142	0.02096558	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25656.0078	89.84834194	107.62099171	26.71262431	293.75521088	92.57806396	RTCC
25655.9194	89.84822464	107.62085438	26.71340632	293.75561905	92.56488037	TRW
0.08837891	0.00011730	0.00013733	-0.00078201	-0.00040817	0.01318359	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
80.	-41.	-320.	-0.00	0.09	-0.14

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
333.	0.17

03/12/68 APOLLO RTCC COMPARISON
HIGH SPEED CUTOFF VECTOR FOLLOWING DPS1.

TIME U.T.
23/ 1/68 2 HRS 48 MIN 34.000 SEC

TIME FROM LAUNCH
0 DAYS 4 HRS 0 MIN 26.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
-0.79521711E 00	0.48272851E 00	-0.44867784E 00	-0.26763364E 01	-0.32253650E 01	0.12951066E 01	RTCC
-0.79543144E 00	0.48250785E 00	-0.44856319E 00	-0.26734543E 01	-0.32266630E 01	0.12954358E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21574639.75	0.00278630	31.64952922	200.22772598	73.26496410	230.85053635	RTCC
21568230.75	0.00325838	31.64179158	200.24424171	73.52270985	230.59686661	TRW
6409.00	-0.00047208	0.00773764	-0.01651573	-0.25774574	0.25366974	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.44962025	119.30050659	99.51367188	RTCC
88.41020870	119.91848755	96.78610229	TRW
0.03941154	-0.61798096	2.72756958	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25498.5398	90.12384319	73.92902088	-25.74851155	105.49789333	115.62777710	RTCC
25494.4377	90.14451218	73.93251324	-25.74112558	105.51635933	115.66955566	TRW
4.10205078	-0.02066898	-0.00349236	-0.00738597	-0.01846600	-0.04177856	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-255.	-6840.	-584.	17.26	4.14	5.13

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
6870.	18.47

03/12/68 APOLLO RTCC COMPARISON
BEST RTCC VECTOR PRIOR TO PRA3.

TIME U.T.		TIME FROM LAUNCH
23/ 1/68	4 HRS 33 MIN 18.000 SEC	0 DAYS 5 HRS 45 MIN 10.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
-0.88904071E 00	-0.50580517E 00	0.10848340E 00	0.20872949E 01	-0.31502231E 01	0.22637844E 01	RTCC
-0.88906043E 00	-0.50578613E 00	0.10844352E 00	0.20872118E 01	-0.31503208E 01	0.22637857E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
21579146.25	0.00448598	31.66753197	199.73621559	67.09624290	304.49307251	RTCC
21579600.75	0.00450999	31.66687799	199.73823929	67.01739883	304.56777573	TRW
-454.50	-0.00002401	0.00065398	-0.00202370	0.07884407	-0.07470322	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
88.47733212	126.08059692	94.21694946	RTCC
88.48012924	126.24102783	94.20611572	TRW
-0.00279713	-0.16043091	0.01083374	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25605.8989	90.21127224	58.85733986	6.05412459	140.13929939	101.07955933	RTCC
25606.0706	90.21212959	58.85761118	6.05187035	140.13782883	101.09158325	TRW
-0.18164063	-0.00085735	-0.00027132	0.00225425	0.00147057	-0.01202393	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-73.	909.	440.	-0.72	-0.18	0.19

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
1013.	0.75

03/13/68 APOLLO RTCC COMPARISON
HIGH SPEED VECTOR FROM WHSC FOLLOWING PRA3

TIME U.T.
23/ 1/68 5 HRS 2 MIN 13.100 SEC

TIME FROM LAUNCH
0 DAYS 6 HRS 14 MIN 5.100SEC

X	Y	Z	XDOT	YDOT	ZDOT	
0.85177272E 00	-0.40119180E 00	0.40917346E 00	0.23777173E 01	0.35362282E 01	-0.15381435E 01	RTCC
0.85188761E 00	-0.40118887E 00	0.40922555E 00	0.23836018E 01	0.35320981E 01	-0.15335436E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
22812199.25	0.058506C7	31.48768377	199.97515297	135.34968948	354.91287994	RTCC
22798515.25	0.0577C899	31.48185086	199.99253273	133.42329216	356.82698822	TRW
13684.00	0.00079708	0.00583291	-0.01737976	1.92639732	-1.91410828	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
96.16817570	532.73870850	93.42770386	RTCC
96.08165646	527.36407471	94.29812622	TRW
0.08651924	5.37463379	-0.87042236	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
26333.7566	90.28086567	111.59647369	23.48905778	258.03210449	94.19845581	RTCC
26323.9370	90.17304611	111.58702755	23.48943949	258.03524399	94.59426880	TRW
9.81958008	0.10781956	0.00944614	-0.CCC38171	-0.00313950	-0.39581299	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-2405.	-951.	-530.	-48.42	9.63	-4.91

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
2640.	49.61

03/13/68 APOLLO RTCC COMPARISON
HIGH SPEED VECTOR FROM WHSC PRIOR TOPRAS

TIME U.T.
23/ 1/68 5 HRS 9 MIN 29.000 SEC

TIME FROM LAUNCH
0 DAYS 6 HRS 21 MIN 21.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
0.10146604E 01	0.61129480E-01	0.17697947E 00	0.25607455E 00	0.39240984E 01	-0.22073063E 01	RTCC
0.10155696E 01	0.60446028E-01	0.17767679E 00	0.26526294E 00	0.39199361E 01	-0.22021385E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
22821442.00	0.05877669	31.50536704	199.95015335	135.99390030	24.84466863	RTCC
22803625.00	0.05782597	31.49857020	199.96555901	134.02966499	26.74542522	TRW
17817.00	0.00095072	0.00679684	-0.01540565	1.96423531	-1.90075660	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
96.22662830	535.36529541	93.84344482	RTCC
96.11396122	528.69259644	94.65155029	TRW
0.11266708	6.67269897	-0.80810547	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
26212.8650	88.65694141	120.06963253	9.87657642	284.87938690	112.10040283	RTCC
26180.2046	88.58248615	120.05343819	9.90644097	284.83788681	115.45346069	TRW
32.66040039	0.07445526	0.01619434	-0.02986455	0.04150009	-3.35305786	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-20382.	18971.	-2024.	-56.27	34.00	-4.20

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
27918.	65.88

03/14/68 APOLLO RTCC COMPARISON
HAWC79 BEST RTCC VECTOR PRIOR TO PRA 5

TIME U.T.
23/ 1/68 6 HRS 27 MIN 48.000 SEC

TIME FROM LAUNCH
0 DAYS 7 HRS 39 MIN 40.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
0.25795557E 00	-0.85246552E 00	0.54418552E 00	0.41991508E 01	0.14913695E 01	0.45821100E-02	RTCC
0.25795797E 00	-0.85252695E 00	0.54423102E 00	0.41992151E 01	0.14910499E 01	0.48449755E-02	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	
22774331.00	0.05718984	31.45591140	199.64930153	134.15151978	313.44791031	RTCC
22777206.75	0.05717336	31.45639300	199.65066719	134.05216789	313.54525375	TRW
-2875.75	0.00001648	-0.00048161	-0.00136566	0.09935188	-0.09734344	(RTCC-TRW)

PERIOD	APOGEE	PERIGEE	
95.92881489	521.20828247	92.49343872	RTCC
95.94698715	521.64691162	93.00149536	TRW
-0.01817226	-0.43862915	-0.50805664	(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	
25902.1536	92.28767300	88.53221893	31.42515755	188.63470840	153.22164917	RTCC
25901.8843	92.28319931	88.53096676	31.42558622	188.63371468	153.47817993	TRW
0.26928711	0.00447369	0.00125217	-0.00042868	0.00099373	-0.25653076	(RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-1559.	320.	-172.	-2.41	0.17	-0.32

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
1600.	2.44

APPENDIX A

TRACKER RESIDUAL PLOTS

This appendix contains plots of the range, azimuth, and elevation residuals to the reconstructed trajectory for the C-band radar data and plots of the range, X-angle, Y-angle, and doppler residuals to the reconstructed trajectory for the S-band radar data for the Apollo 5 mission. The trajectory was reconstructed using low speed C-band and S-band tracking data.

Each plot is identified by the name of the station, the revolution, the type of data, and the BET segment which generated the residuals. Near the bottom of each plot is listed representative spacecraft elevations above the local, station-centered, horizontal plane. This will help the reader to visualize the geometry of the pass. The time scale is given in minutes from 0 hour (GMT) of the day of epoch. The time scale may be correlated with the elapsed time from range zero by associating the first data point with the time listed near the top of each plot.

Below each plot comments will be made on such things as geometry of the pass, data quality, program model errors, etc., if applicable.

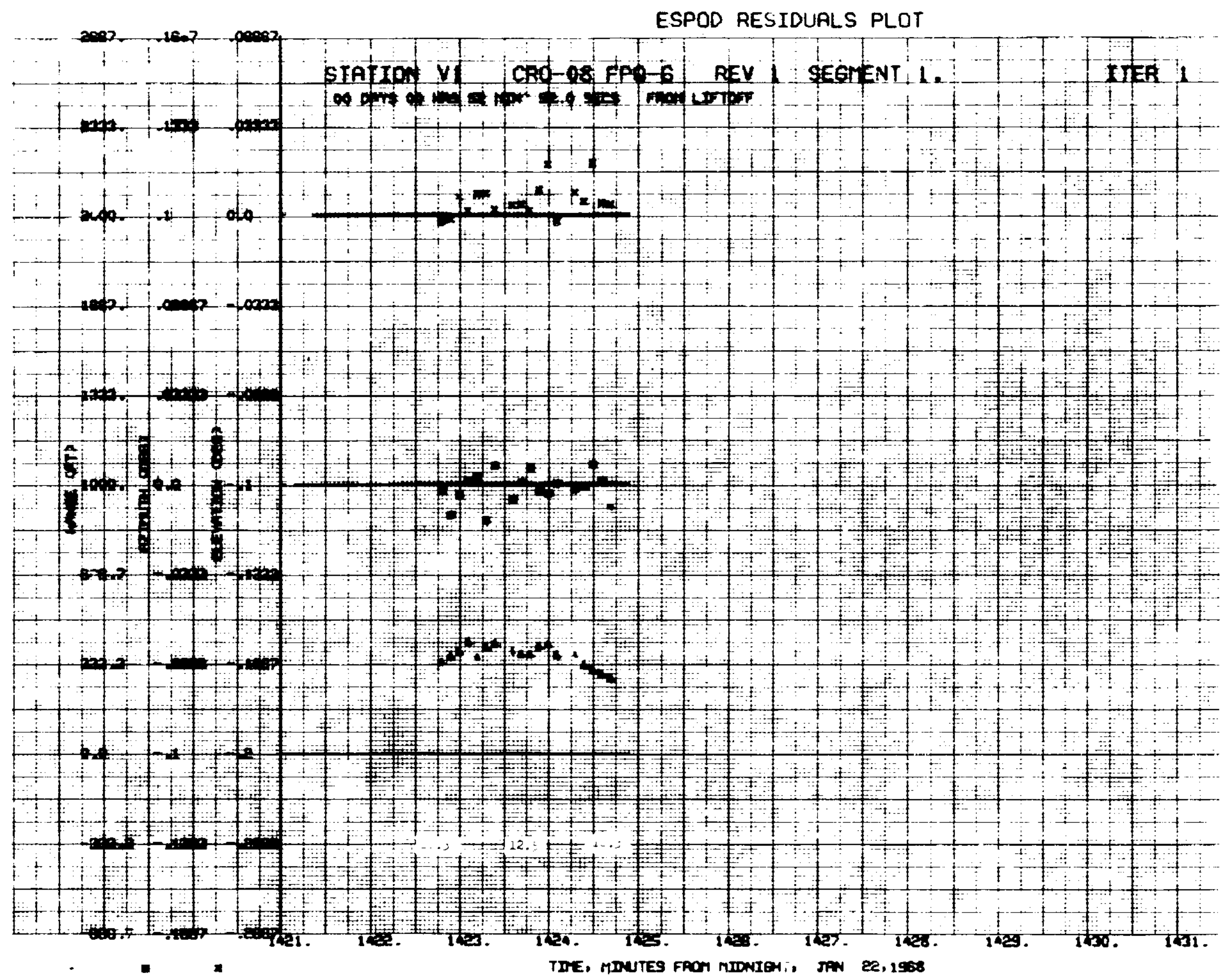
APPENDIX A

CONTENTS

CONTENTS (Continued)

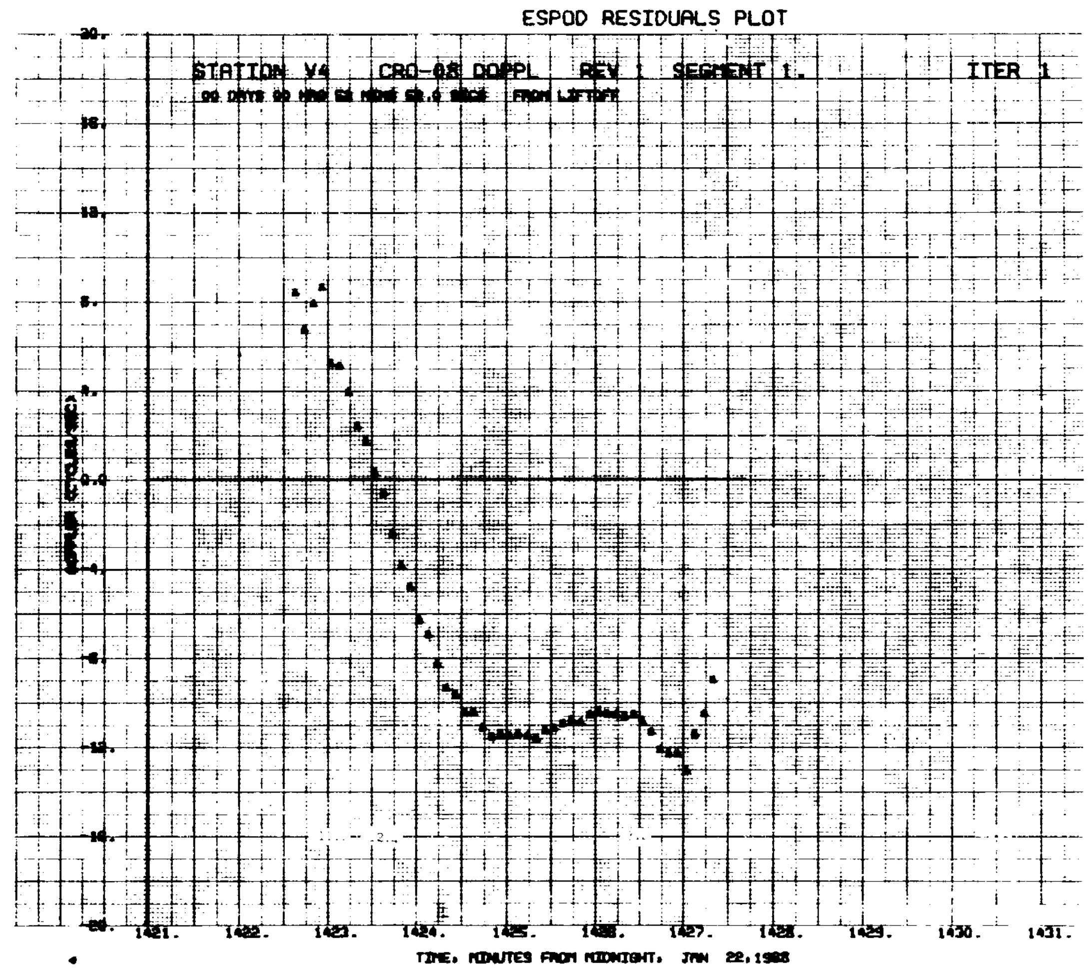
CONTENTS (Continued)

A-1. Revolution 1, Carnarvon: RAE (Segment 1 BET)



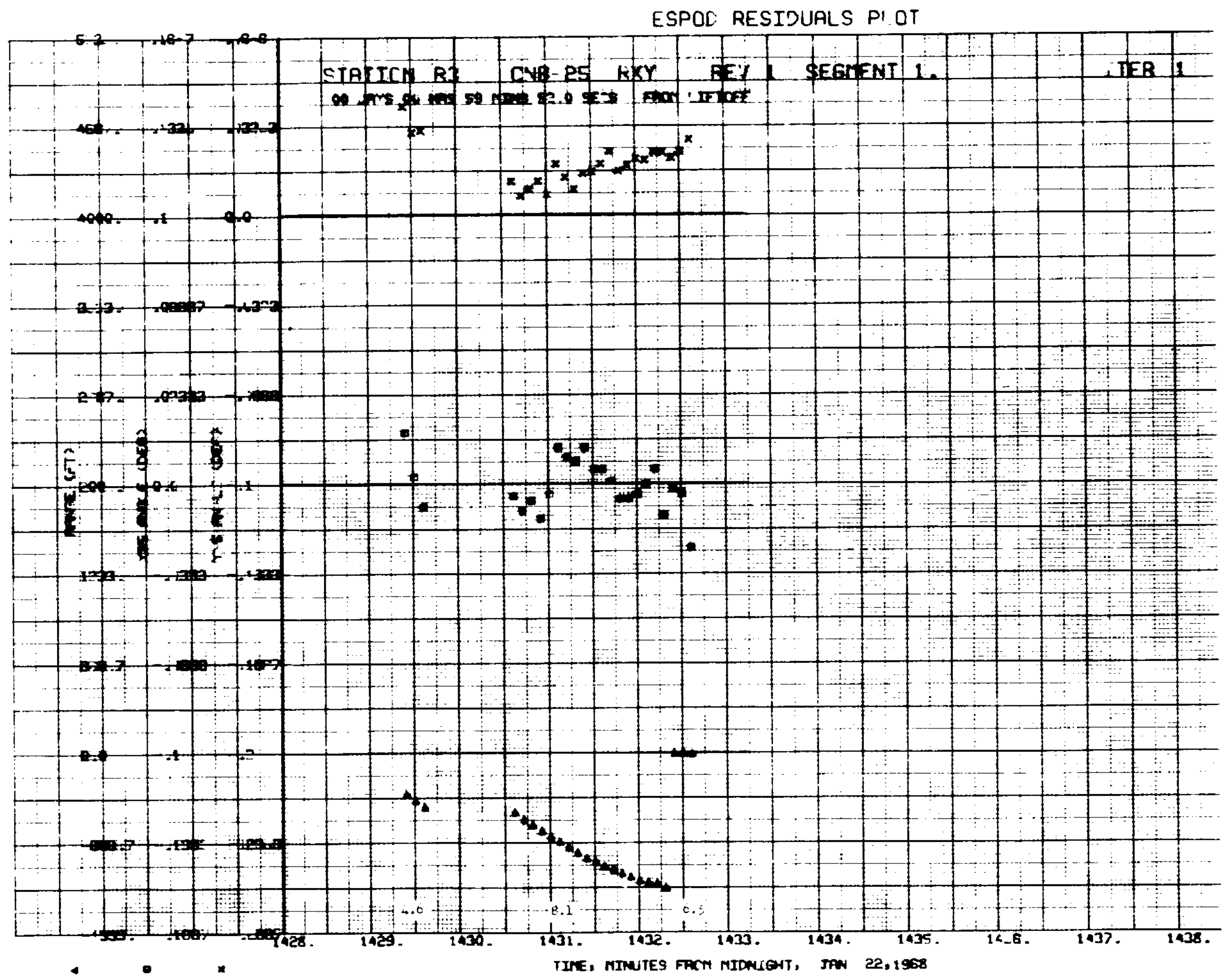
Note: ● These data occurred immediately after the separation maneuver.

A-2. Revolution 1, Carnarvon: Doppler (Segment 1 BET)

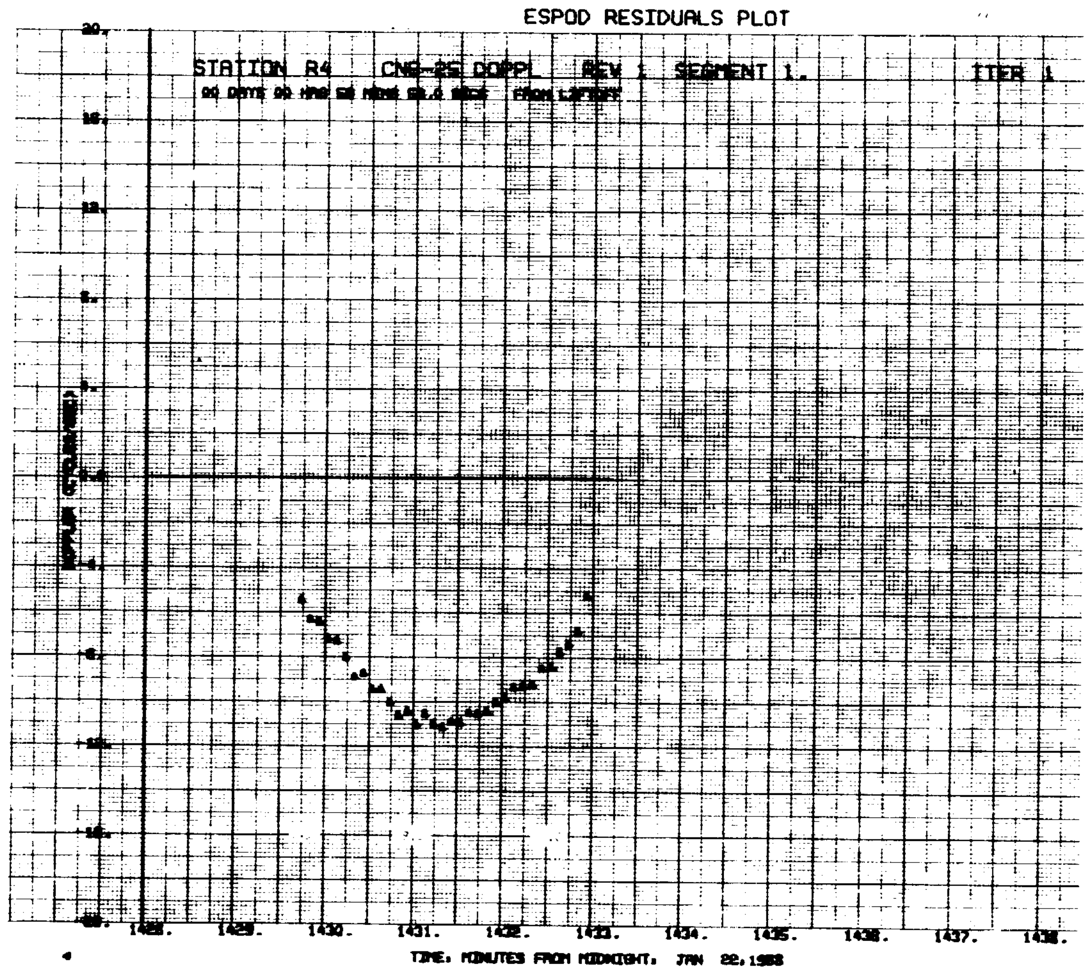


Note:
- These data occurred immediately after the separation maneuver.
- These data were weighted out of the fit for data balance.

A-3. Revolution 1, Canberra: RXY (Segment 1 BET)

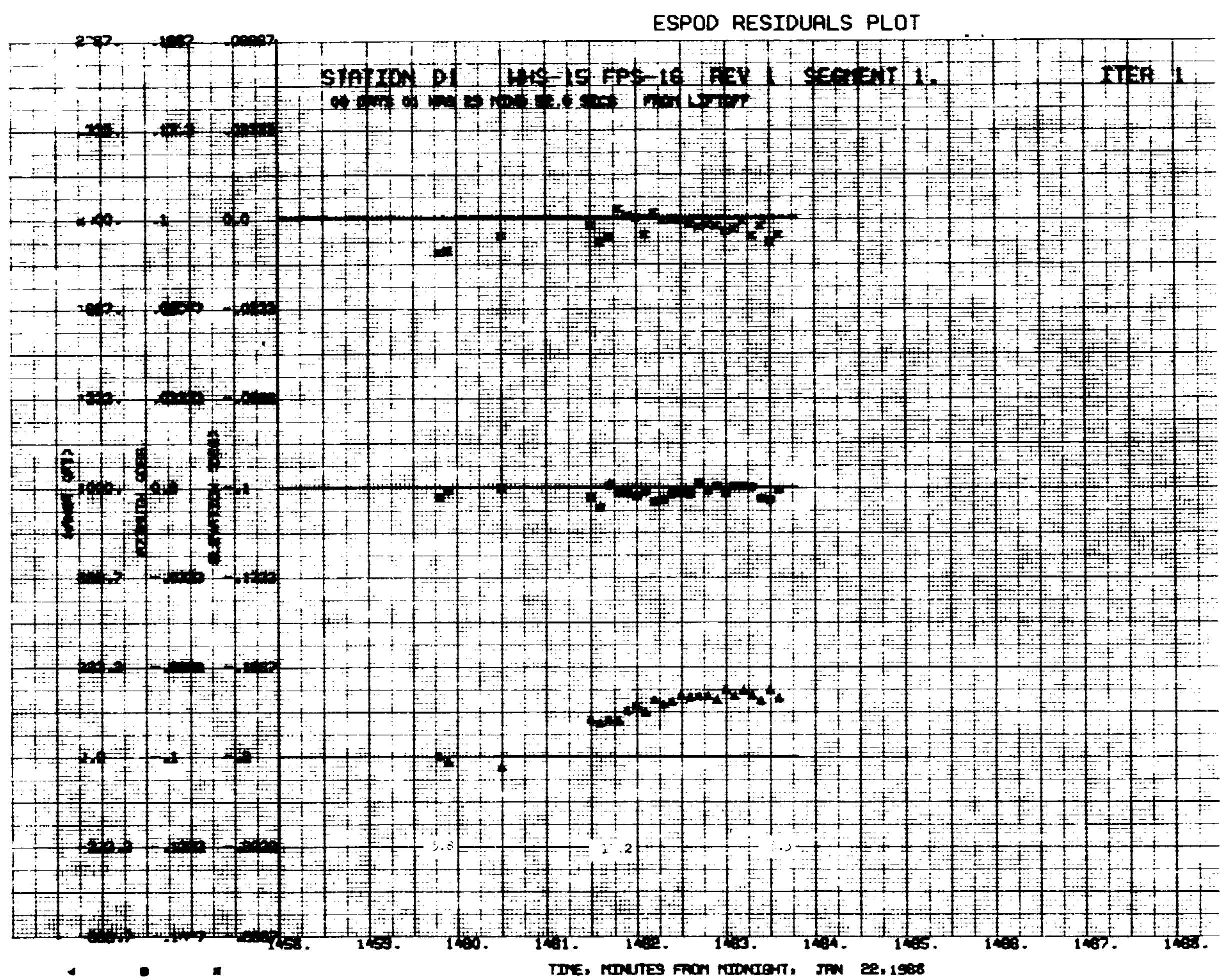


A-4. Revolution 1, Canberra: Doppler (Segment 1 BET)

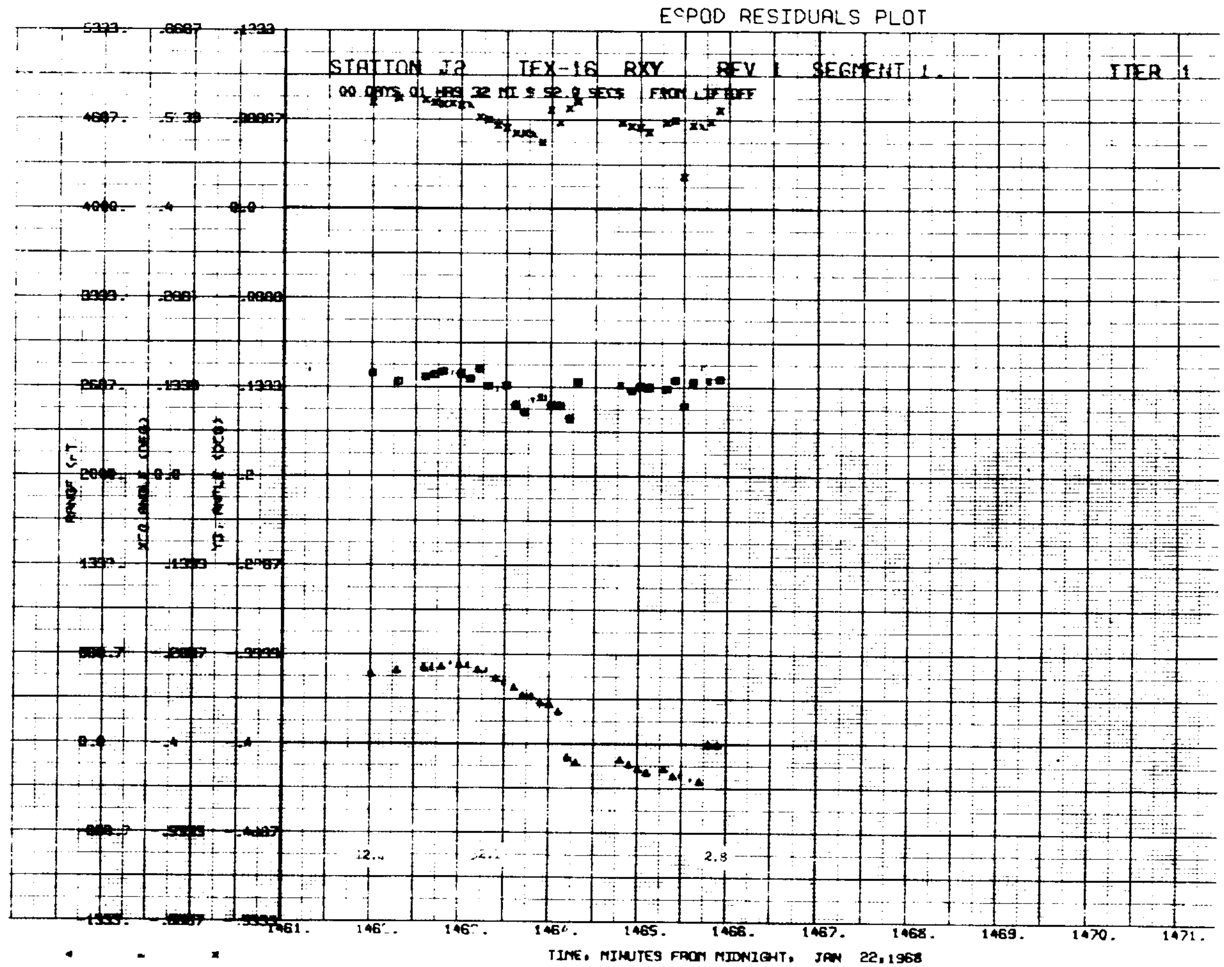


Note: ● These data were weighted out of the fit for data balance.

A-5. Revolution 1, White Sands: RAE (Segment 1 BET)

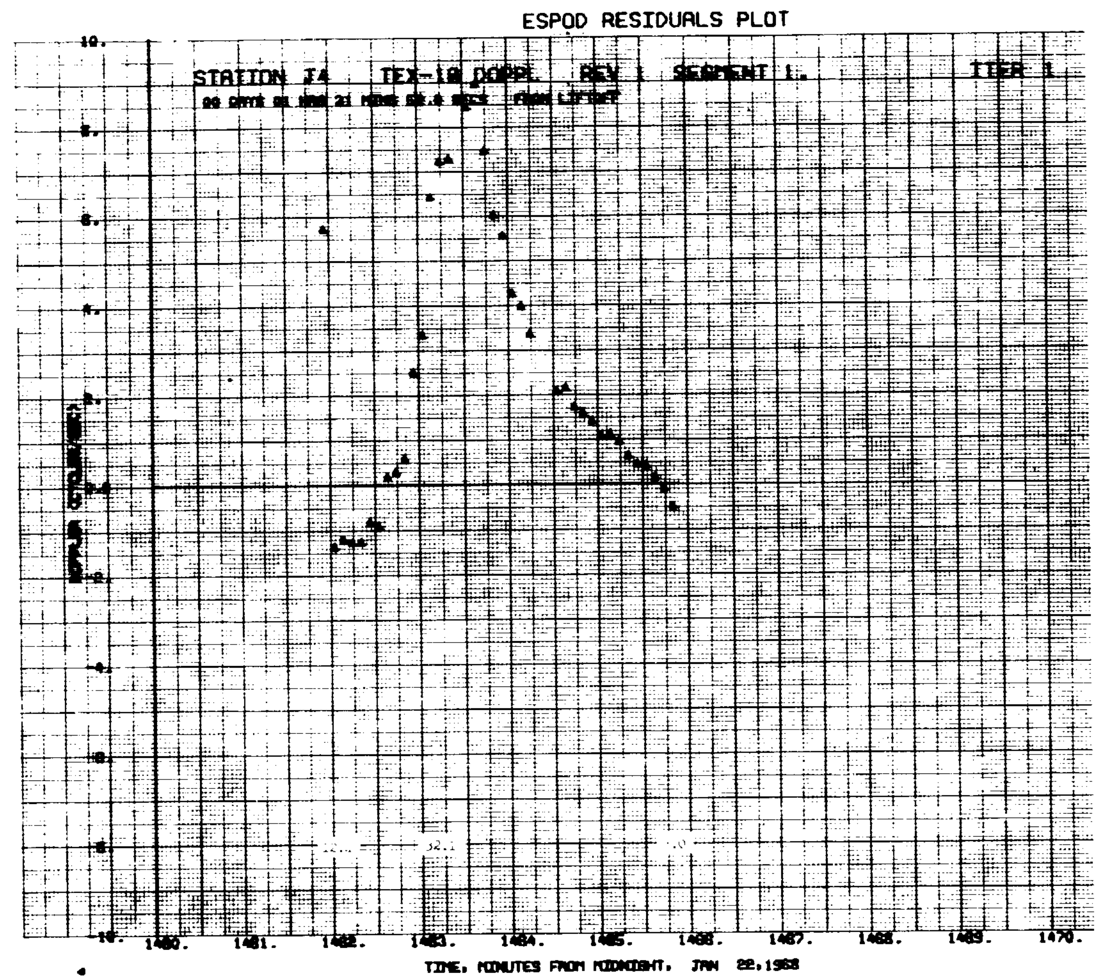


A-6. Revolution 1, Texas: RXY (Segment 1 BET)



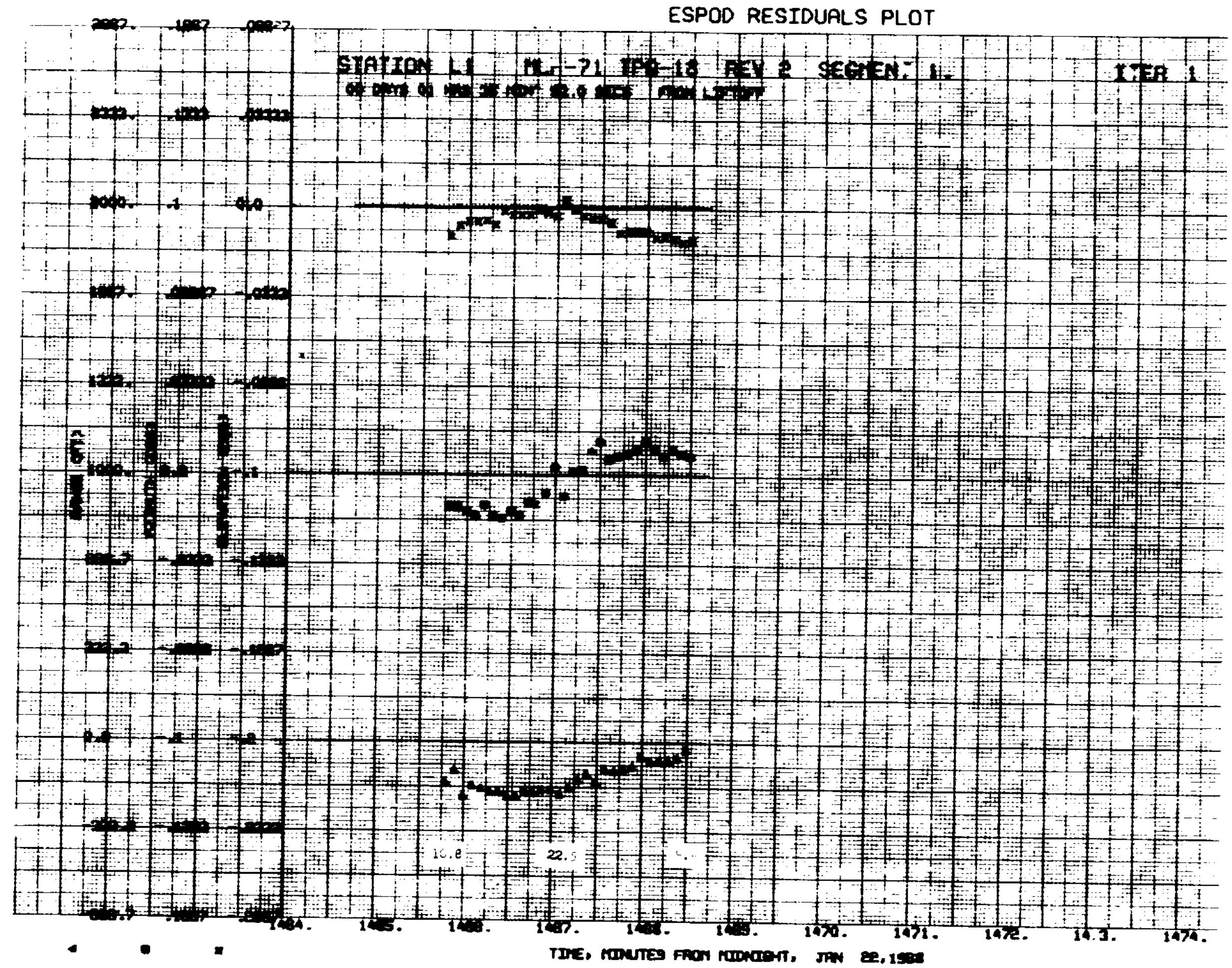
Note: ● Note the apparent X-angle and Y-angle biases.

A-7. Revolution 1, Texas: Doppler (Segment 1 BET)



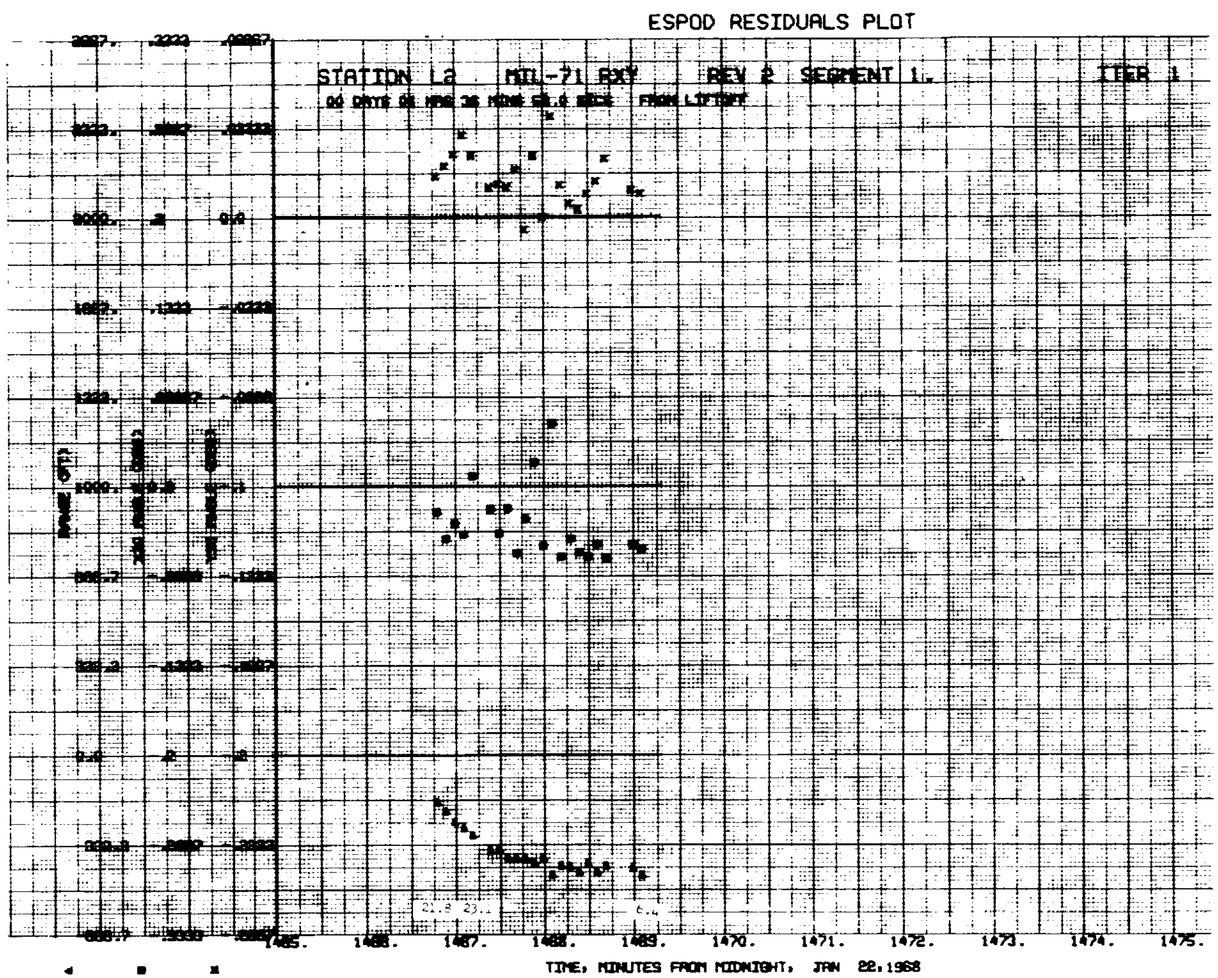
Note: ● These data were weighted out of the fit for data balance.

A-8. Revolution 2, Merritt Island: RAE (Segment 1 BET)



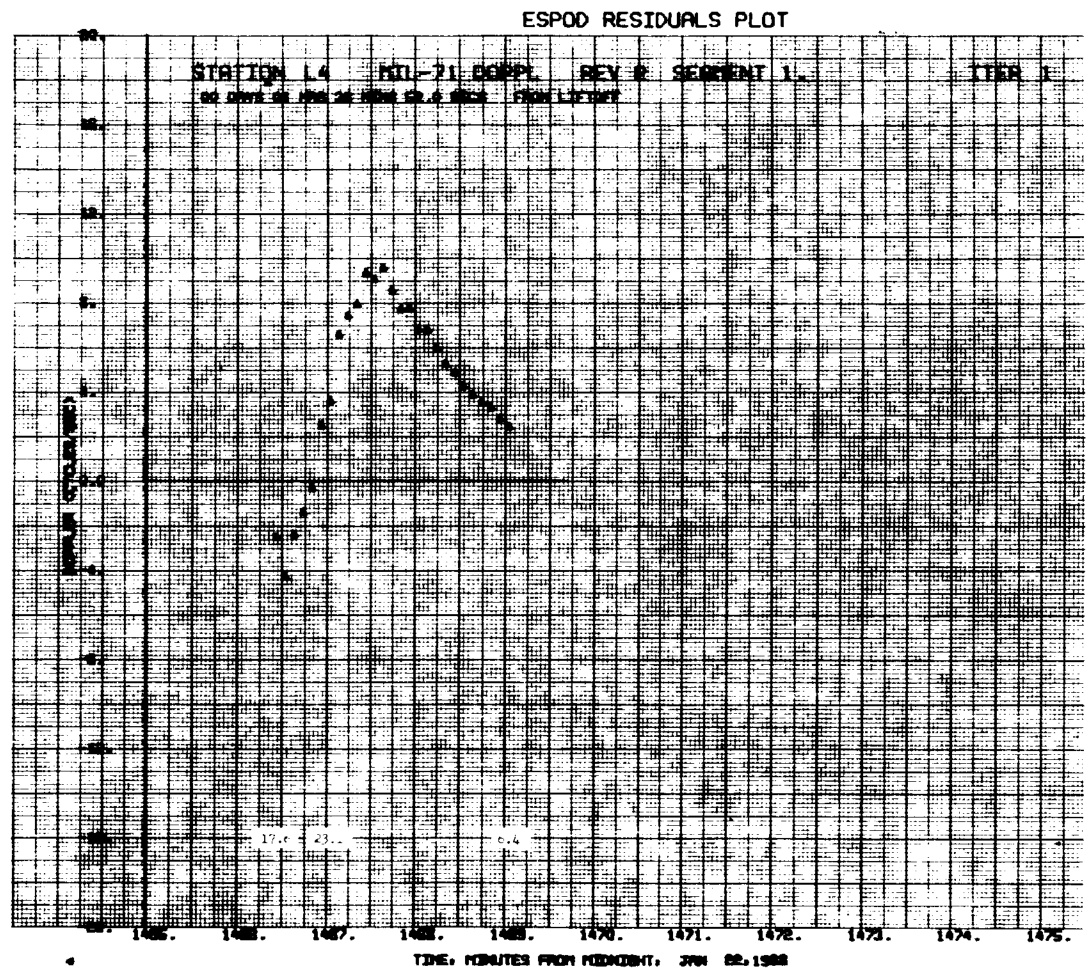
Note: ● The elevation residual pattern indicates a possible refraction problem.

A-9. Revolution 2, Merritt Island: RXY (Segment 1 BET)



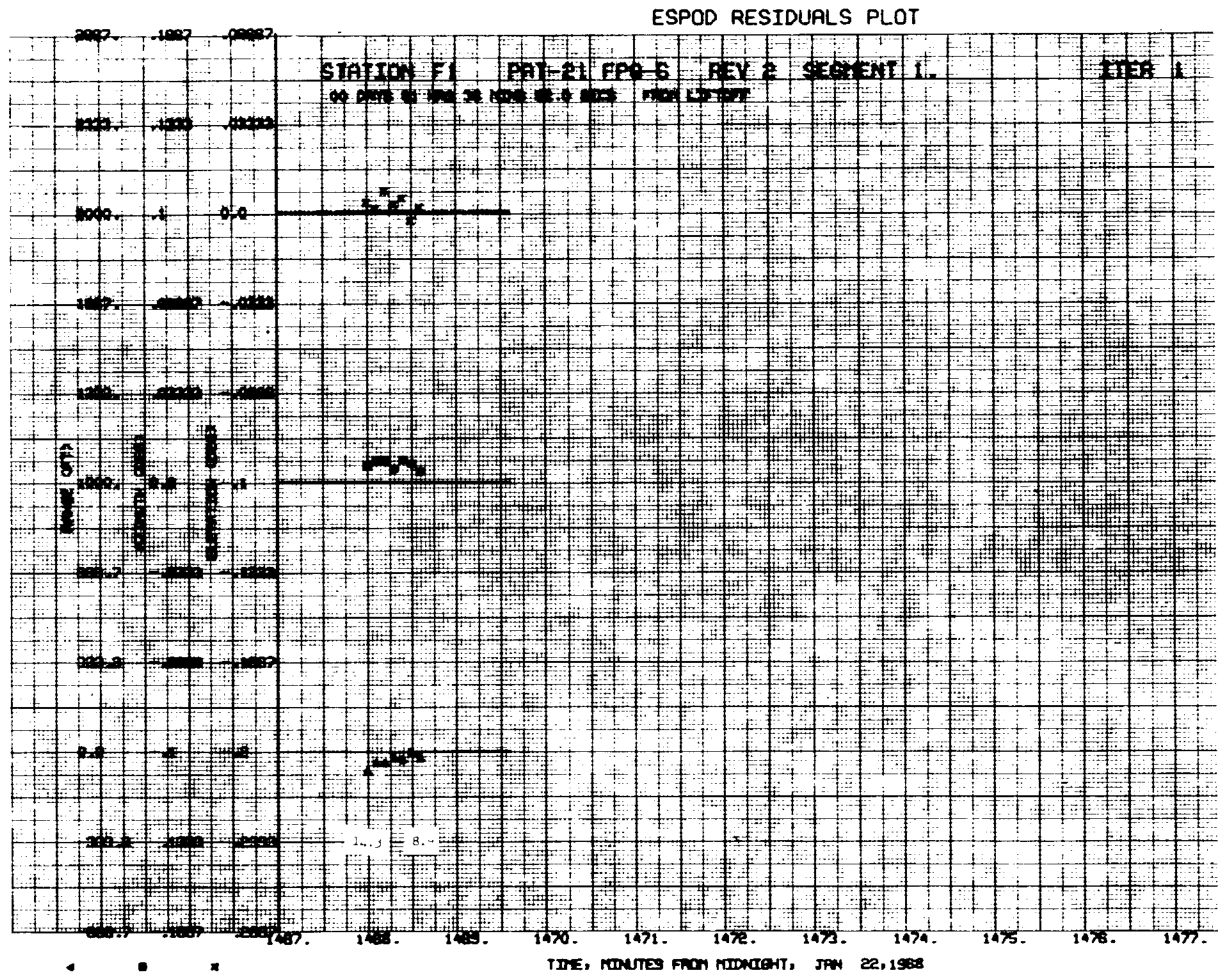
Note: ● These data were weighted out of the fit for data balance.

A-10. Revolution 2, Merritt Island: Doppler (Segment 1 BET)

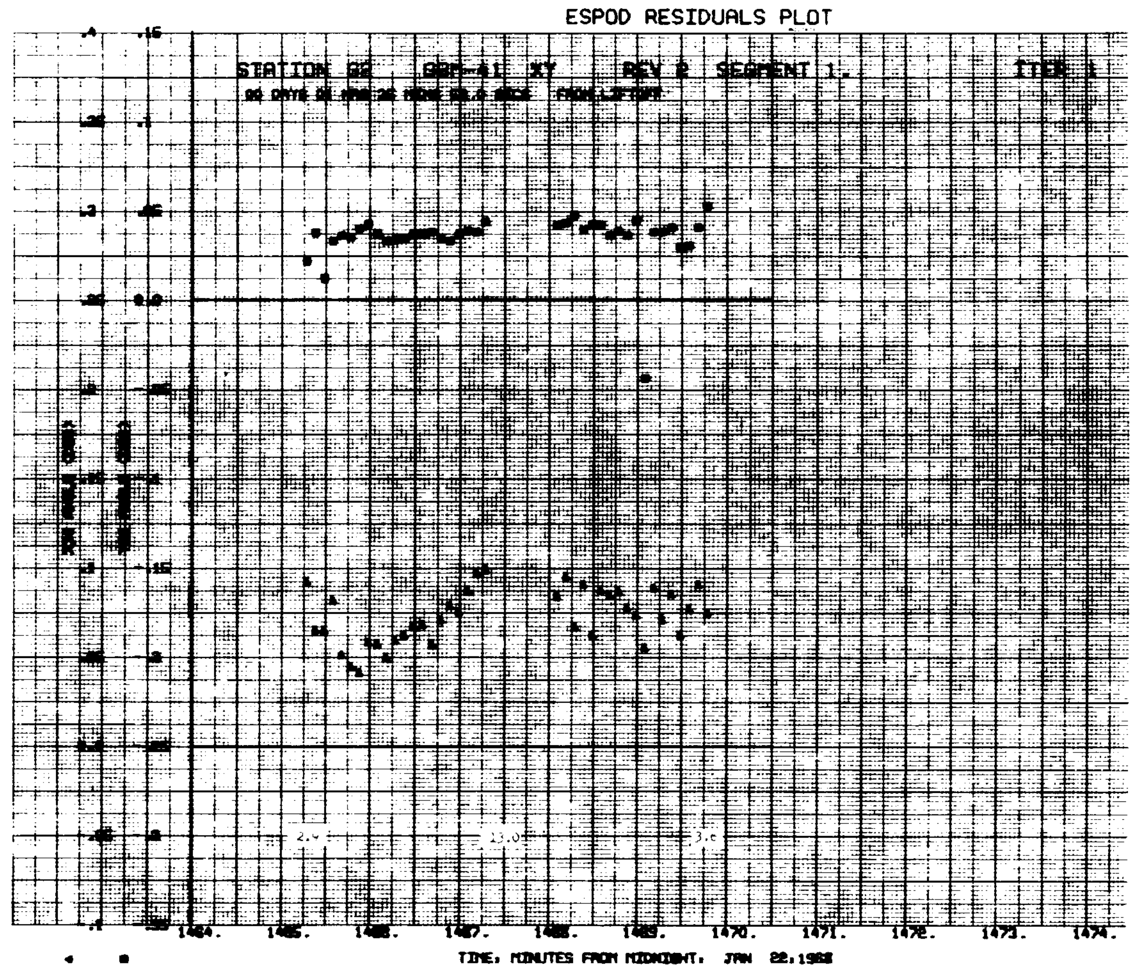


Note: ● These data were weighted out of the fit for data balance.

A-11. Revolution 2, Patrick: RAE (Segment 1 BET)

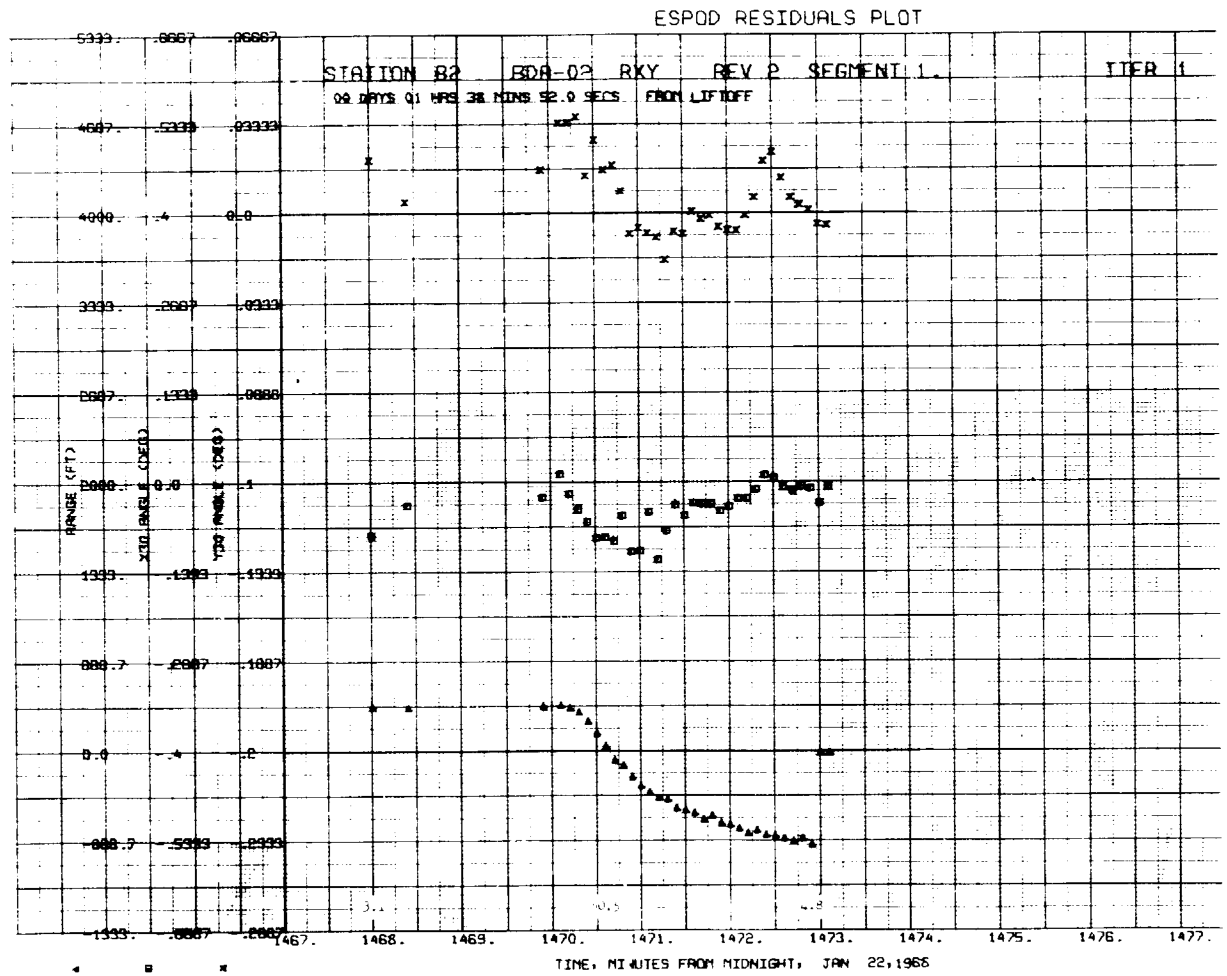


A-12. Revolution 2, Grand Bahama: XY (Segment 1 BET)



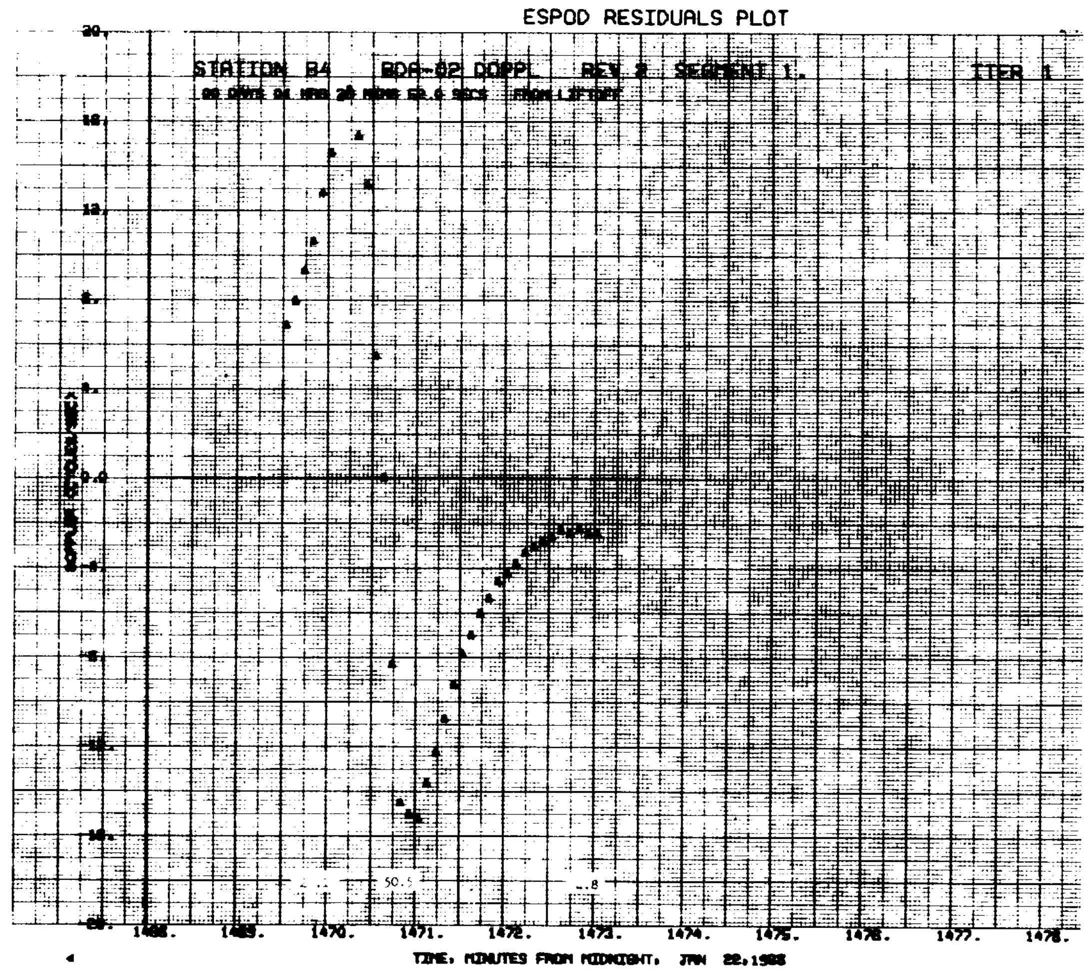
Note: ● These data were weighted out of the fit for data balance.

A-13. Revolution 2, Bermuda: RXY (Segment 1 BET)



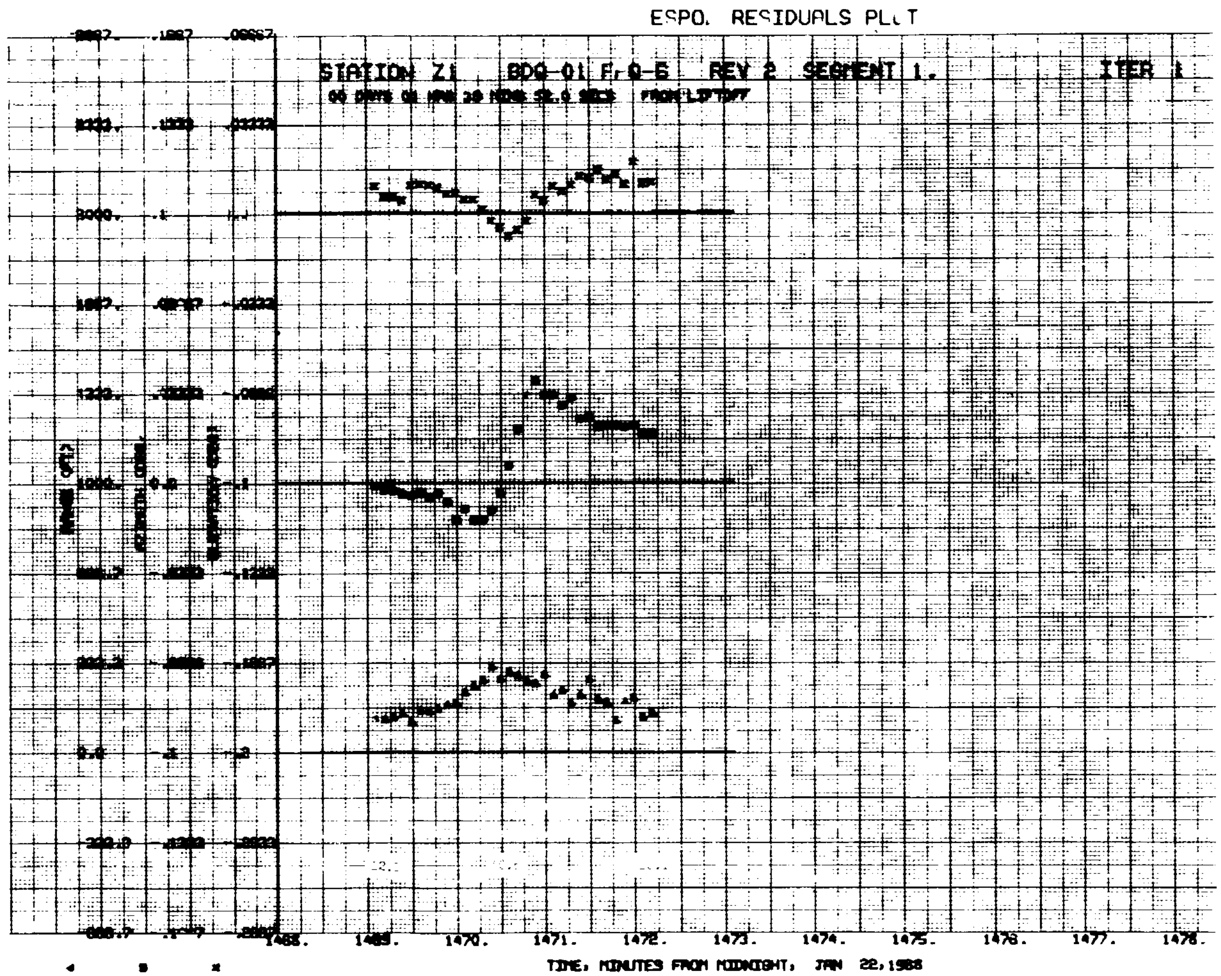
Note: ● These data were weighted out of the fit for data balance.

A-14. Revolution 2, Bermuda: Doppler (Segment 1 BET)

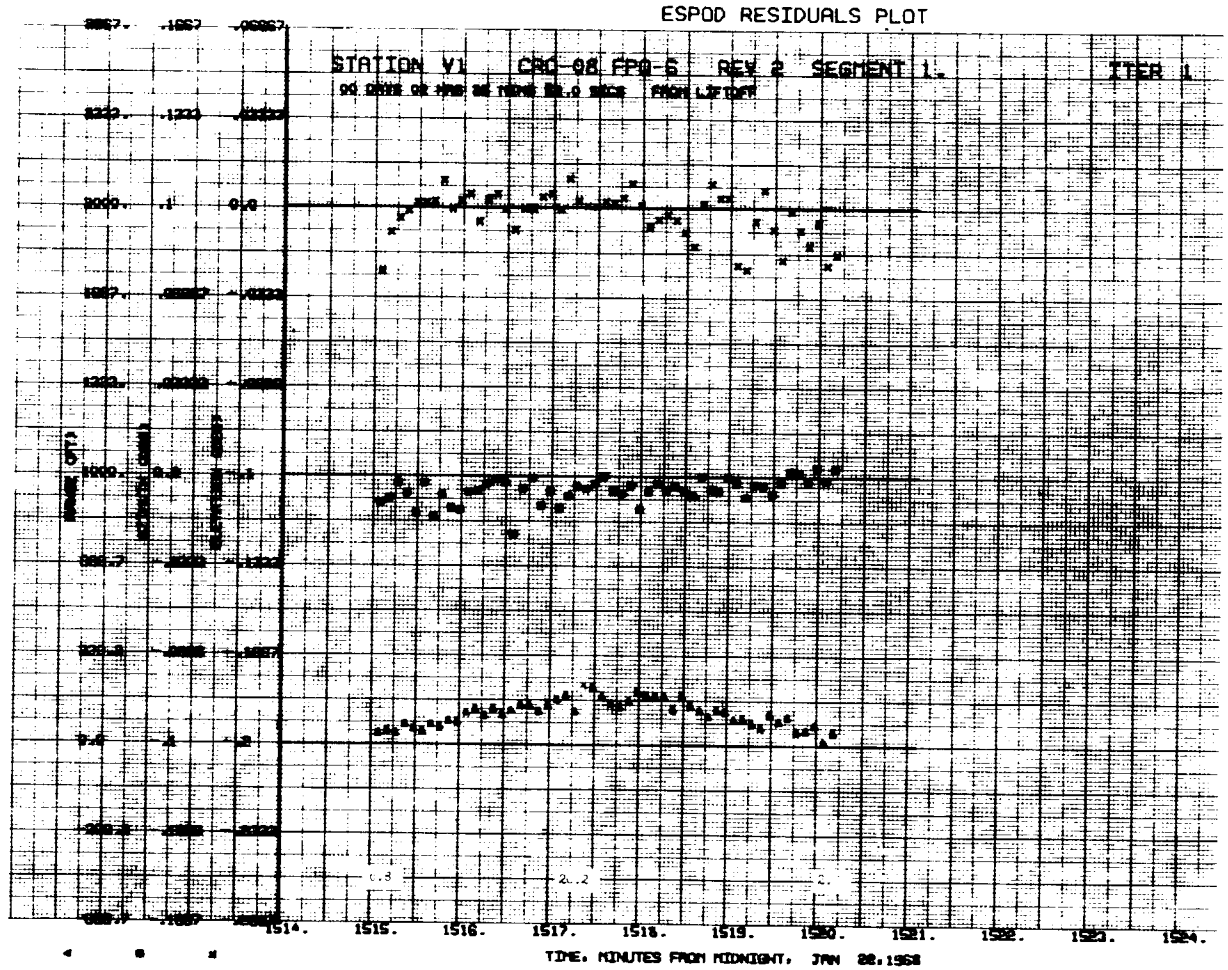


Note: ● These data were weighted out of the fit for data balance.

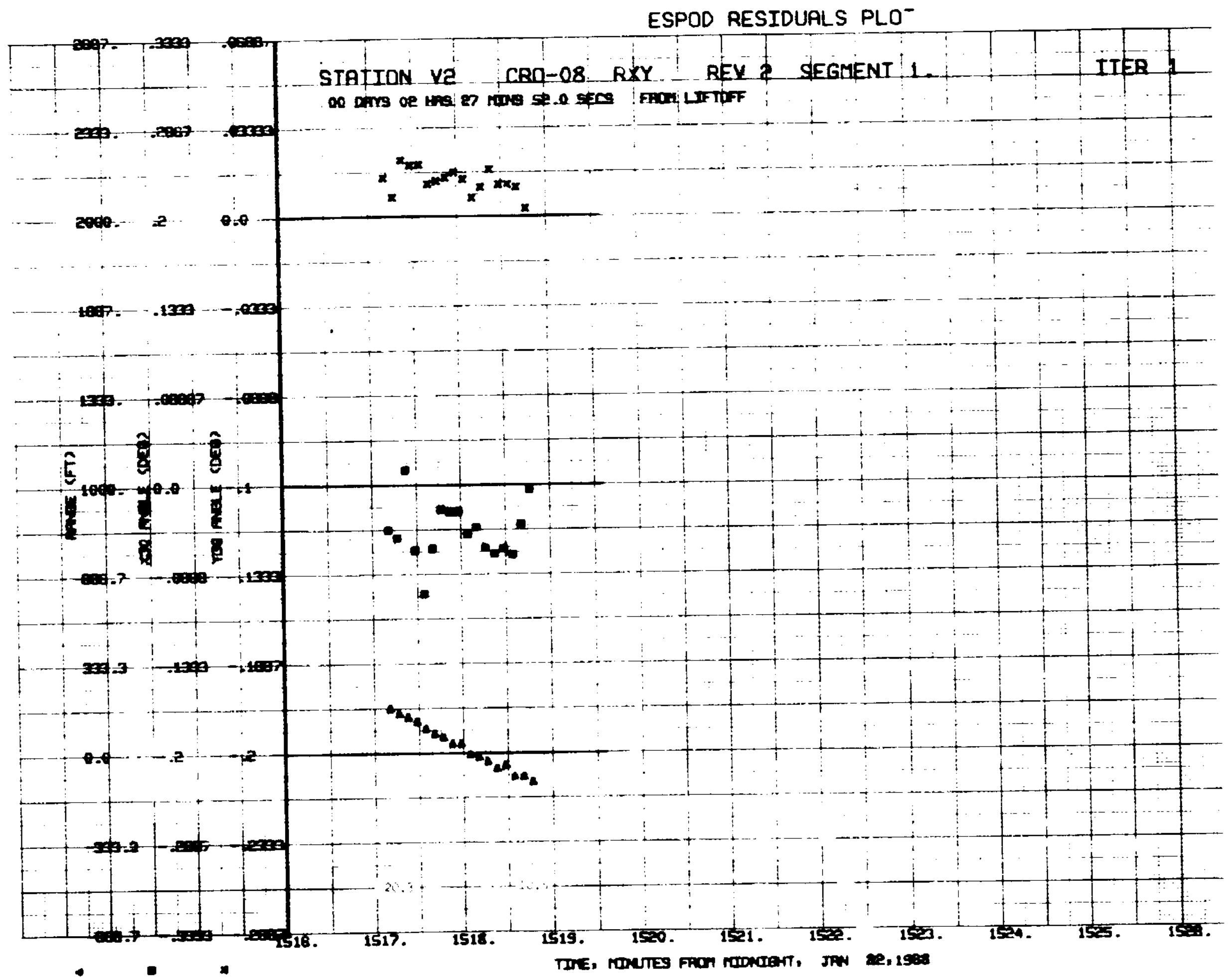
A-15. Revolution 2, Bermuda (Q): RAE (Segment 1 BET)



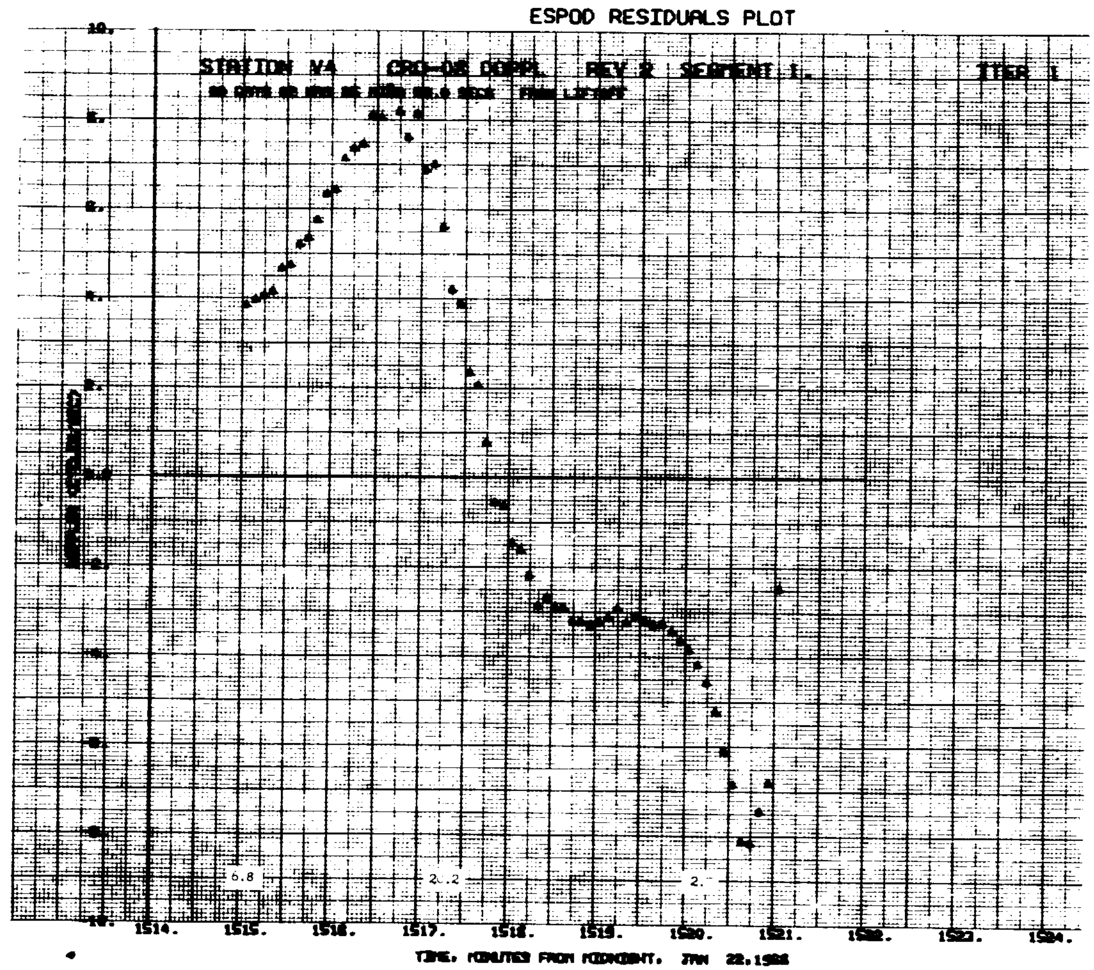
A-16. Revolution 2, Carnarvon: RAE (Segment 1 BET)



A-17. Revolution 2, Carnarvon: RXY (Segment 1 BET)

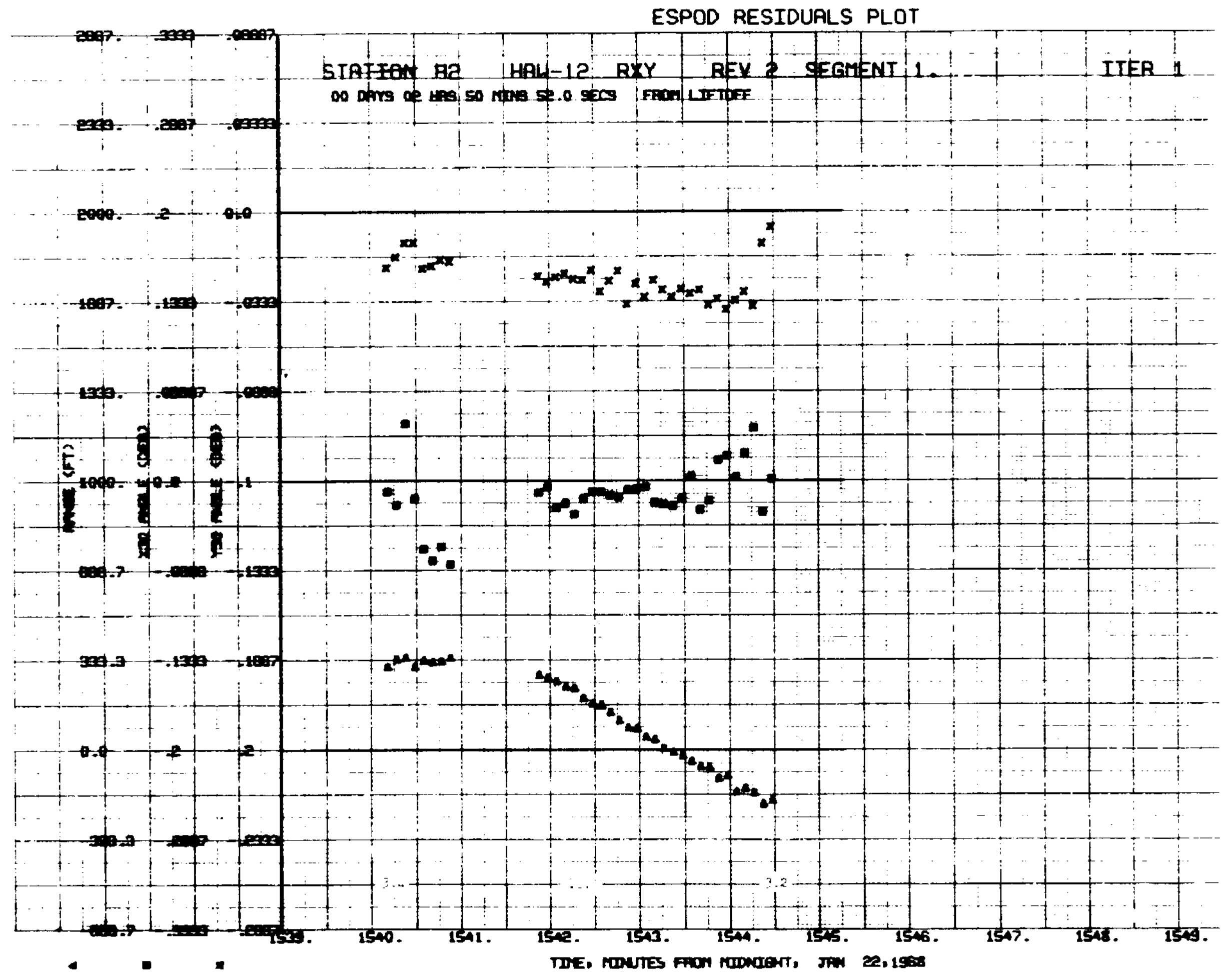


A-18. Revolution 2, Carnarvon: Doppler (Segment 1 BET)



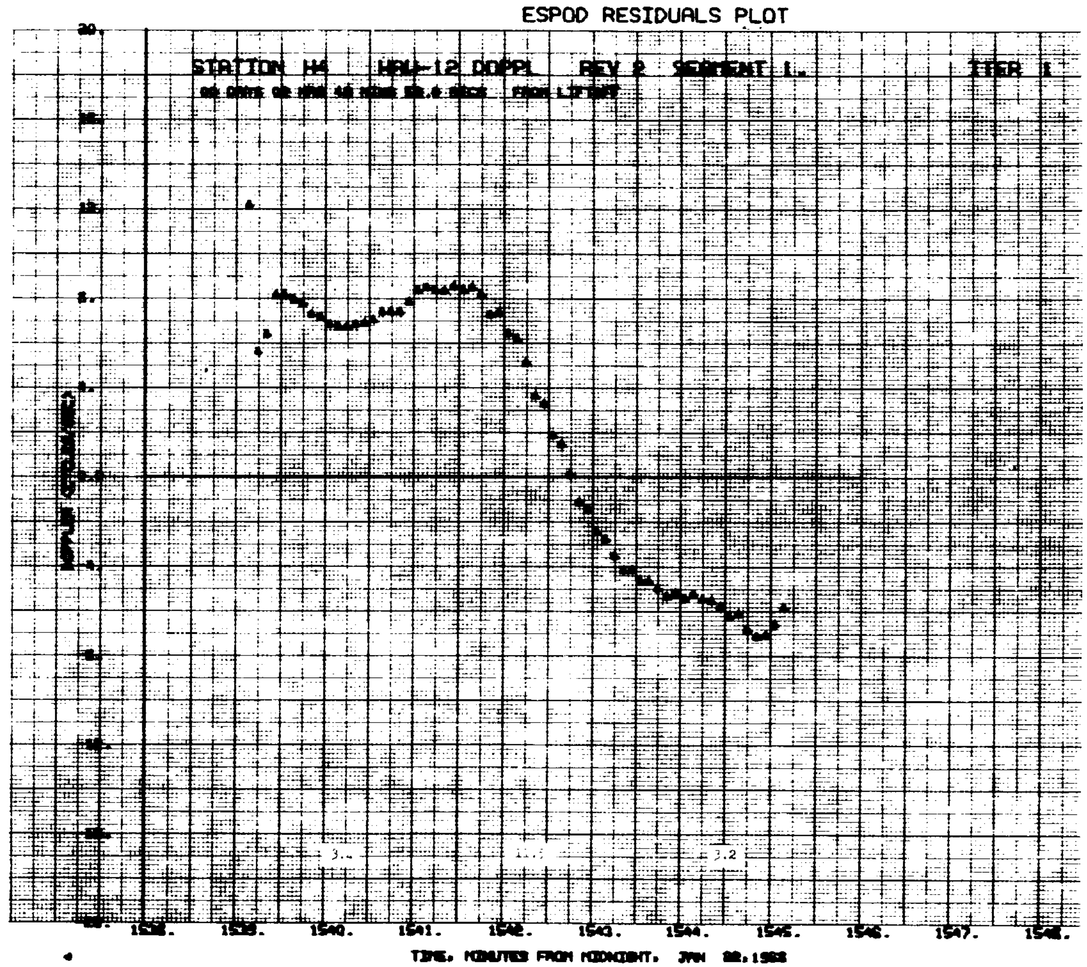
Note: ● These data were weighted out of the fit for data balance.

A-19. Revolution 2, Hawaii: RXY (Segment 1 BET)



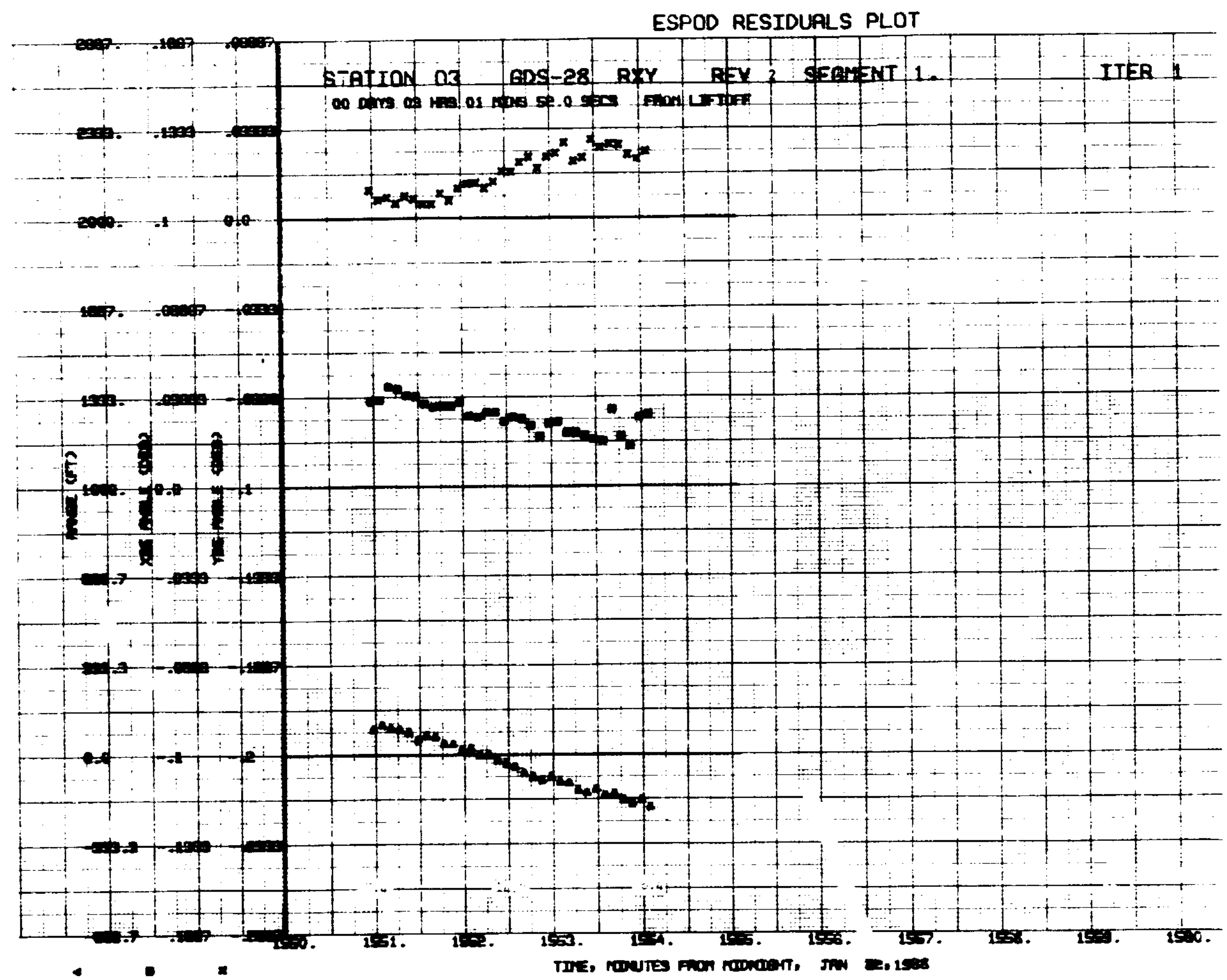
Note: ● The data between 1 hour, 40 minutes, and 54 seconds and 1 hour, 41 minutes, and 54 seconds were tagged invalid at the station.

A-20. Revolution 2, Hawaii: Doppler(Segment 1 BET)



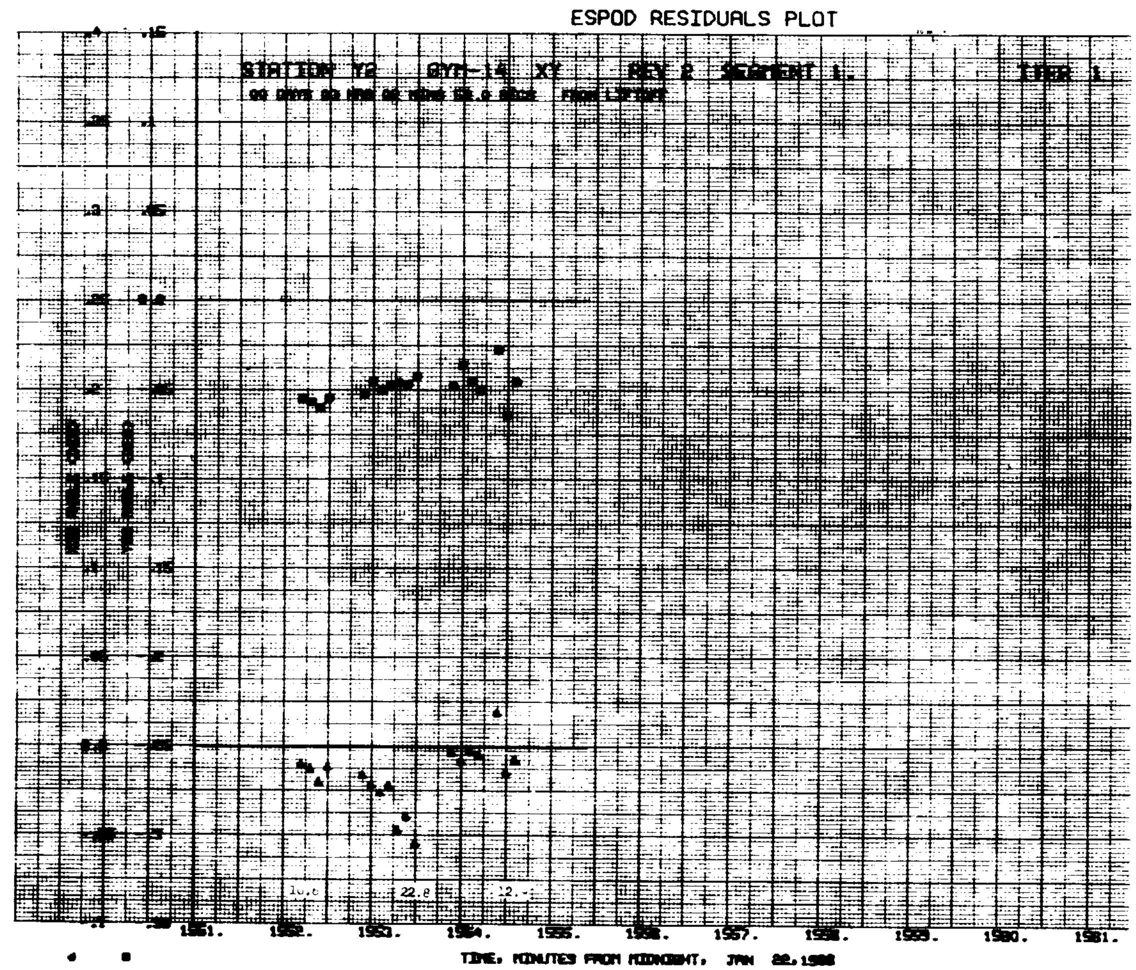
Note: ● These data were weighted out of the fit for data balance.

A-21. Revolution 2, Goldstone: RXY (Segment 1 BET)



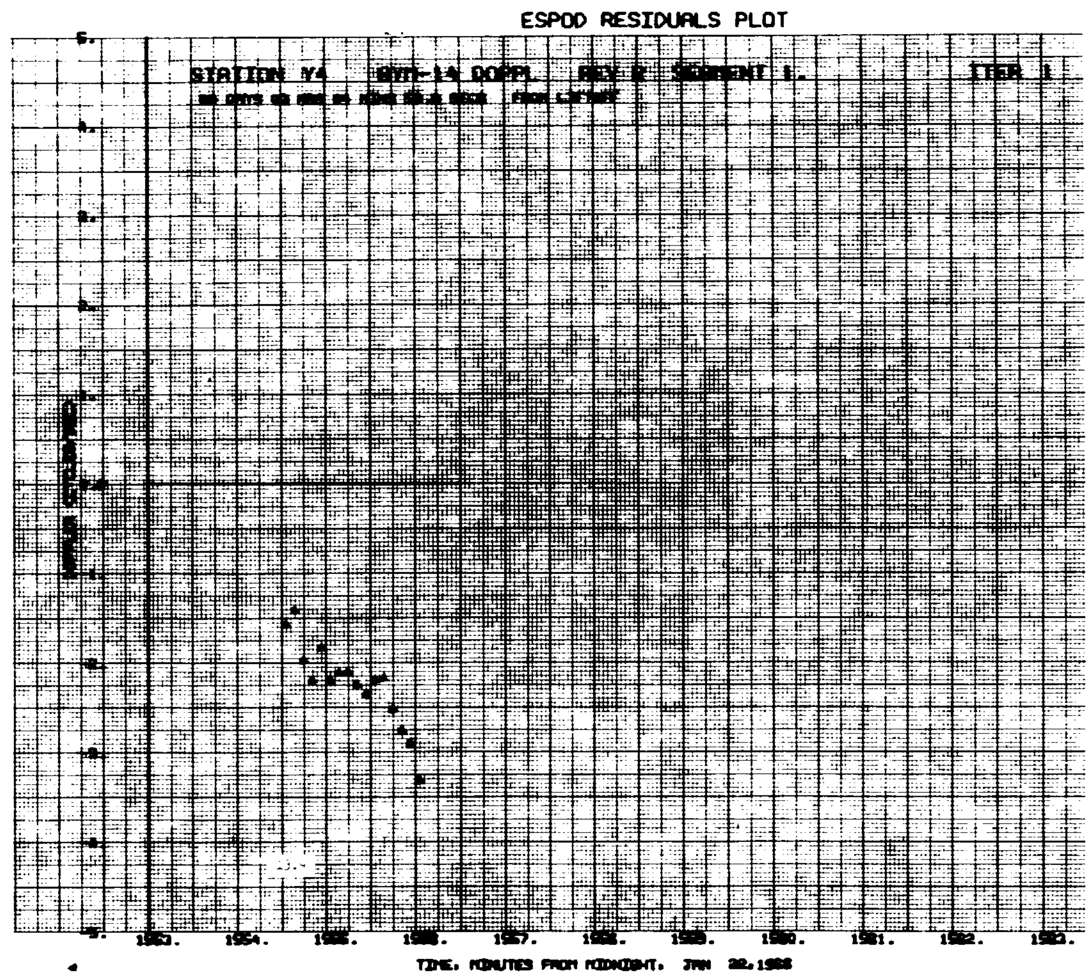
Note: ● Note the X-angle residual pattern.

A-22. Revolution 2, Guaymas: XY (Segment 1 BET)



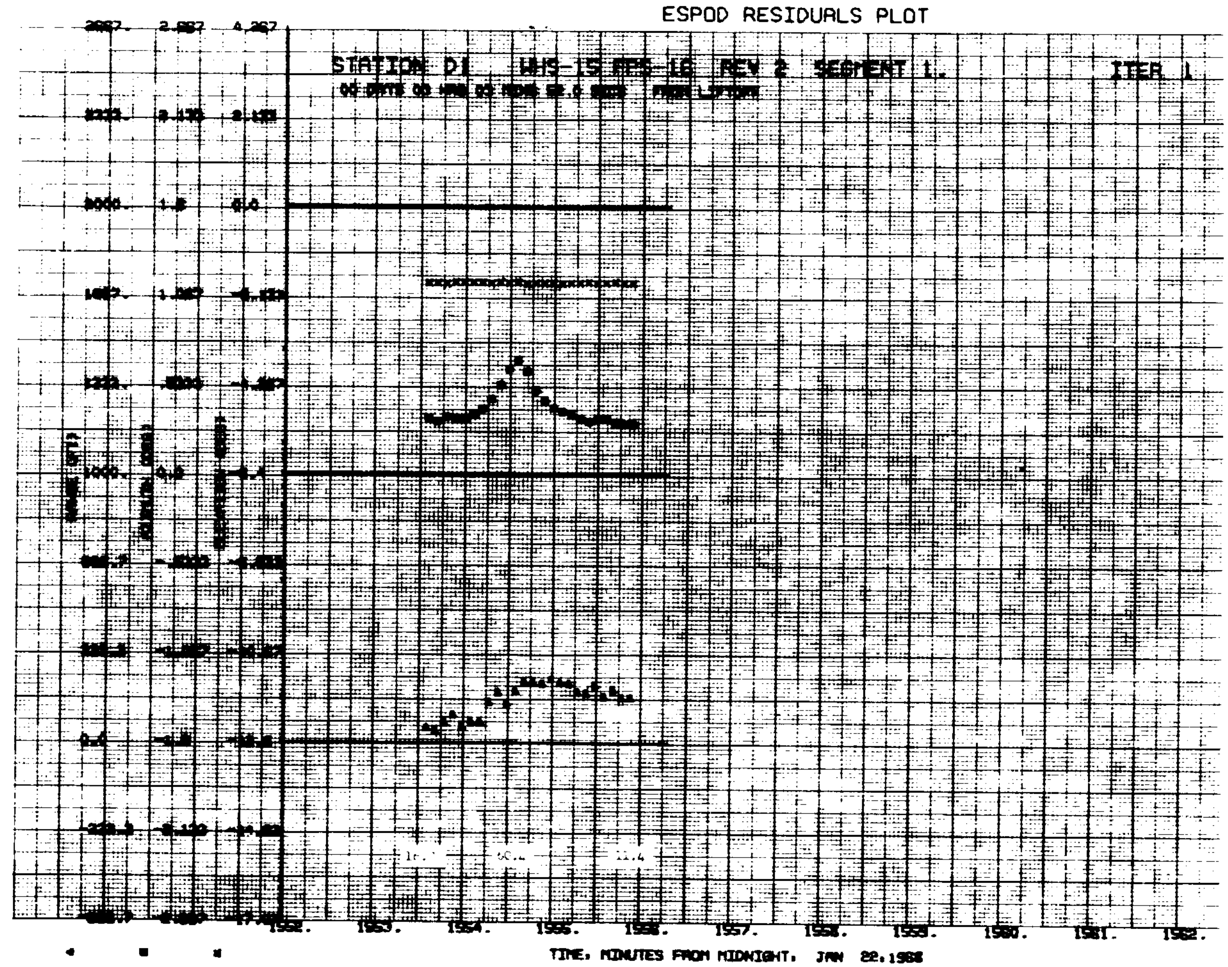
Note: ● These data were weighted out of the fit for data balance.

A-23. Revolution 2, Guaymas: Doppler (Segment 1 BET)



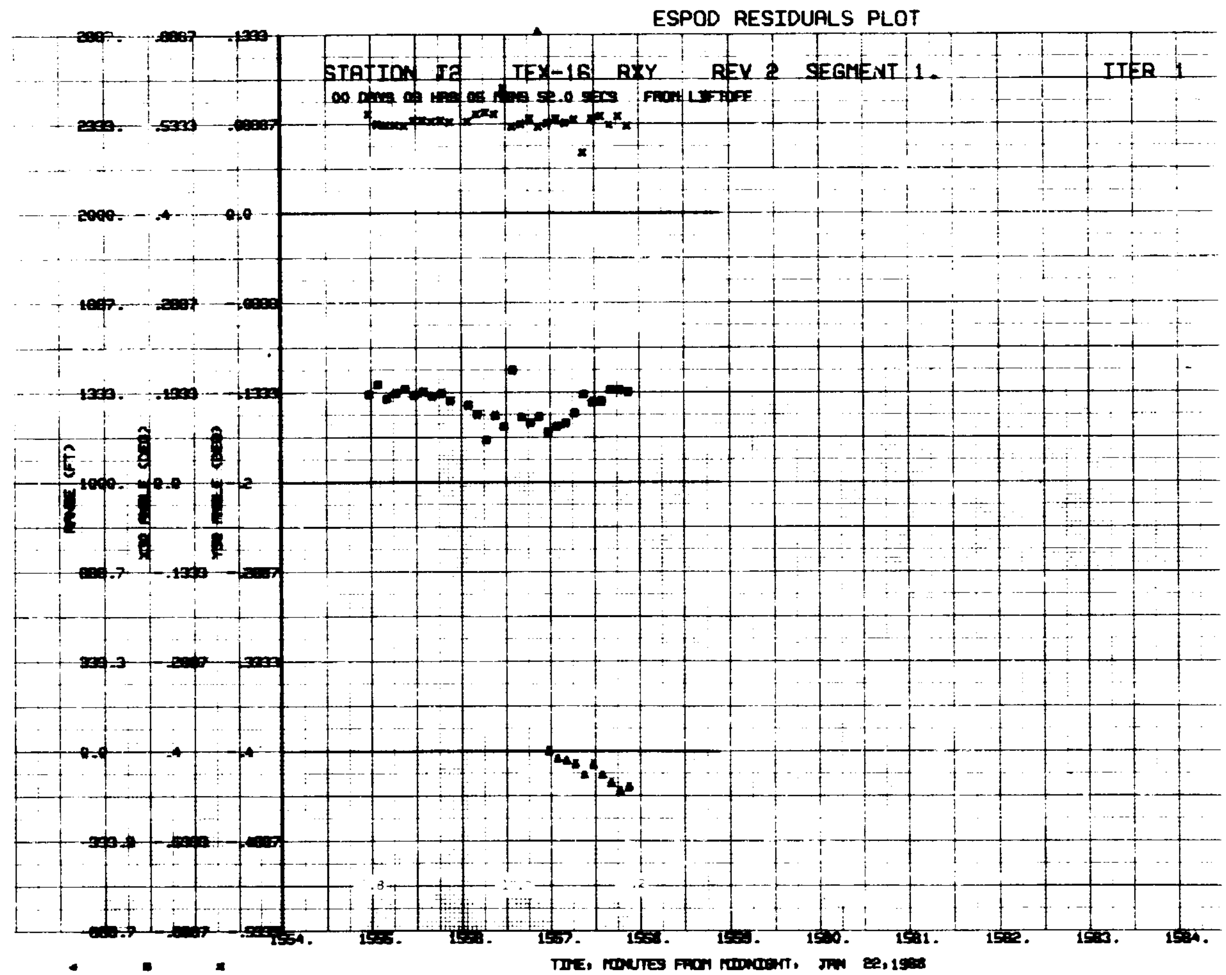
Note: ● These data were weighted out of the fit for data balance.

A-24. Revolution 2, White Sands: RAE (Segment 1 BET)



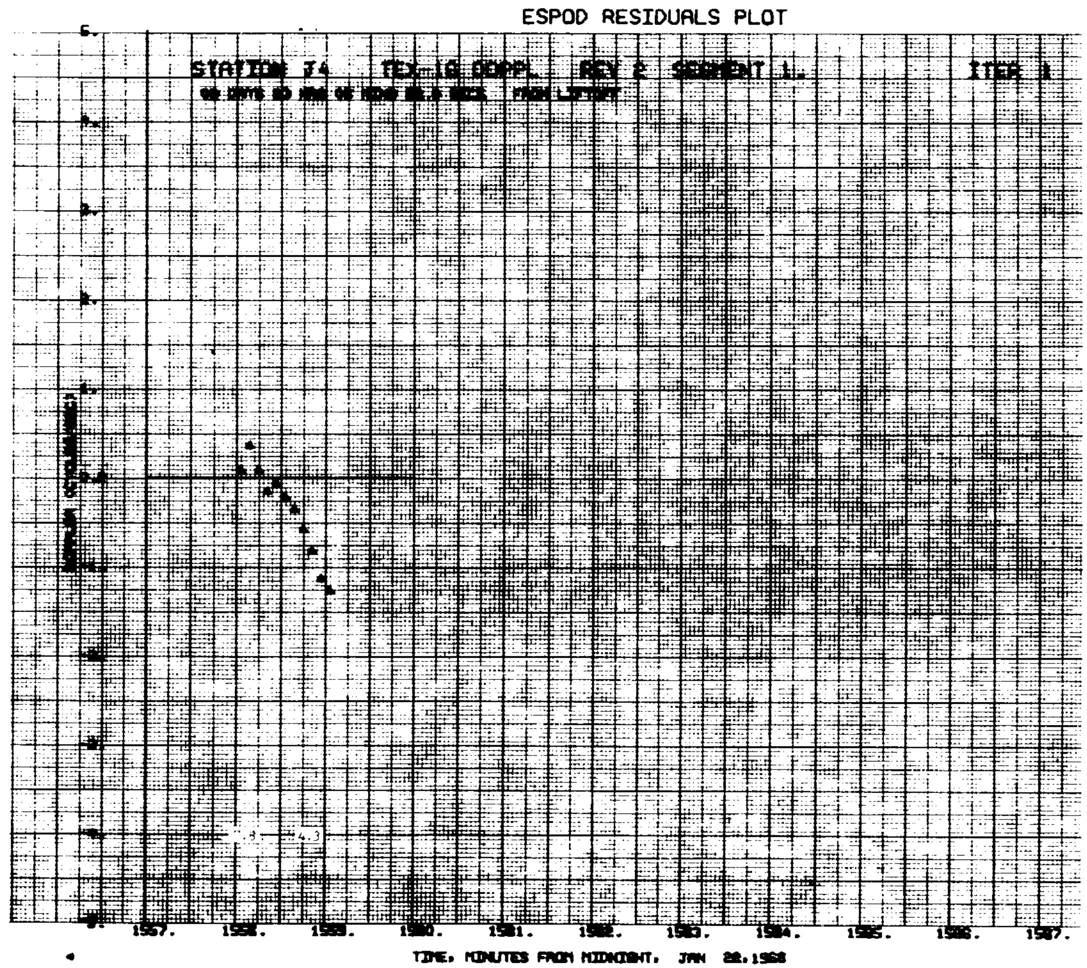
Note: ● The station tracked the vehicle on a side lobe for this pass.

A-25. Revolution 2, Texas: RXY (Segment 1 BET)



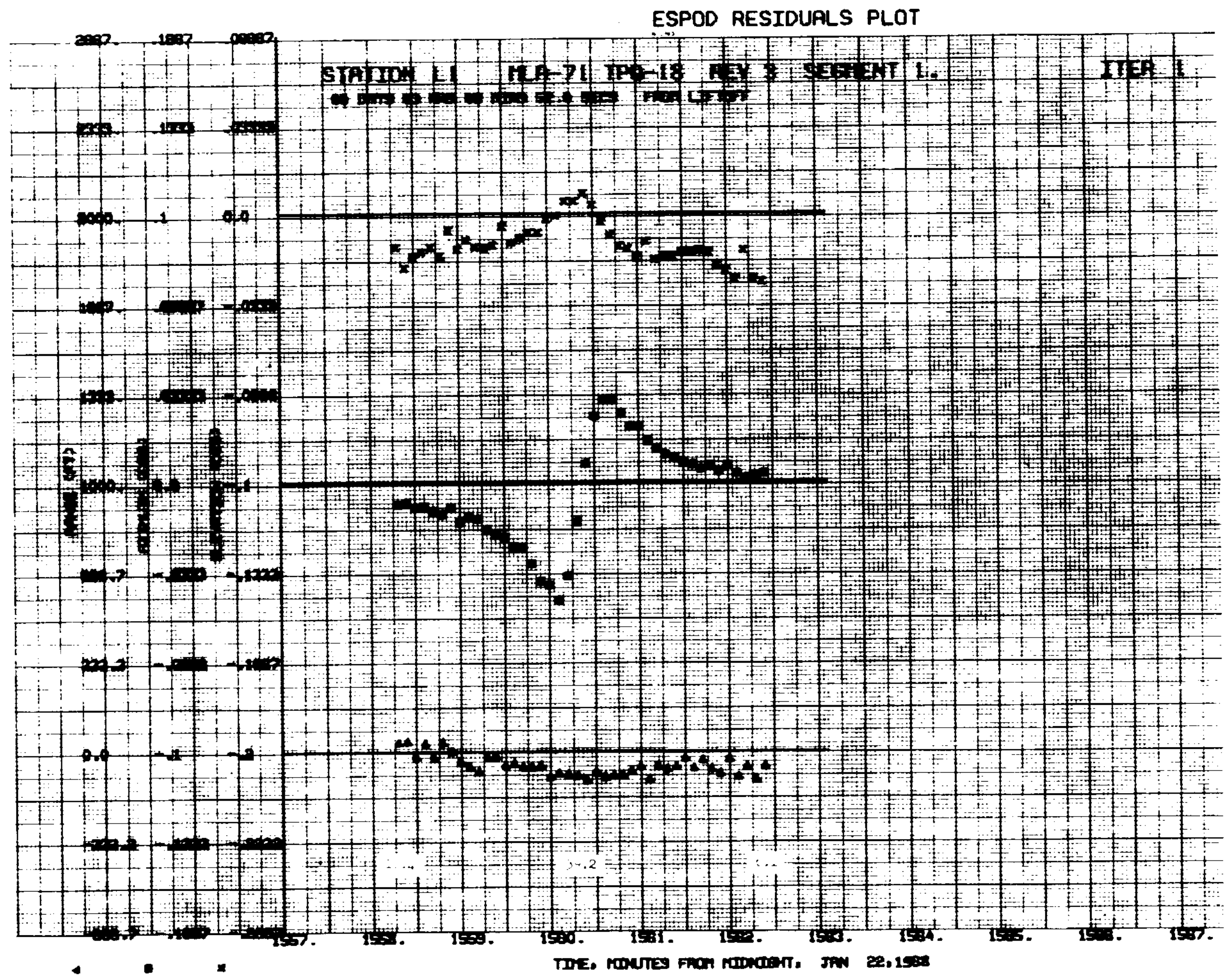
Note: • Note the apparent X-angle and Y-angle biases.

A-26. Revolution 2, Texas: Doppler (Segment 1 BET)



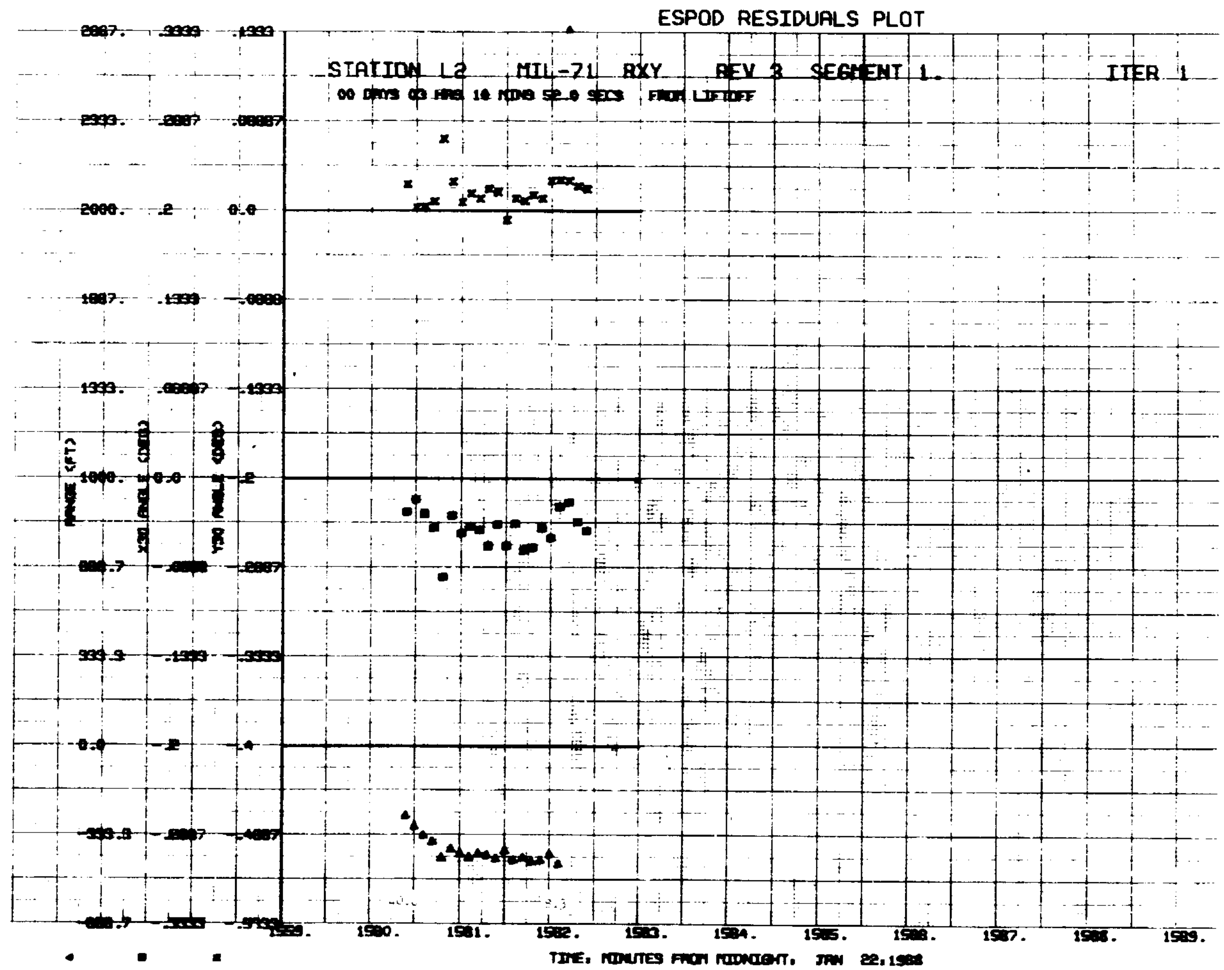
Note: • These data were weighted out of the fit for data balance.

A-27. Revolution 3, Merritt Island: RAE (Segment 1 BET)



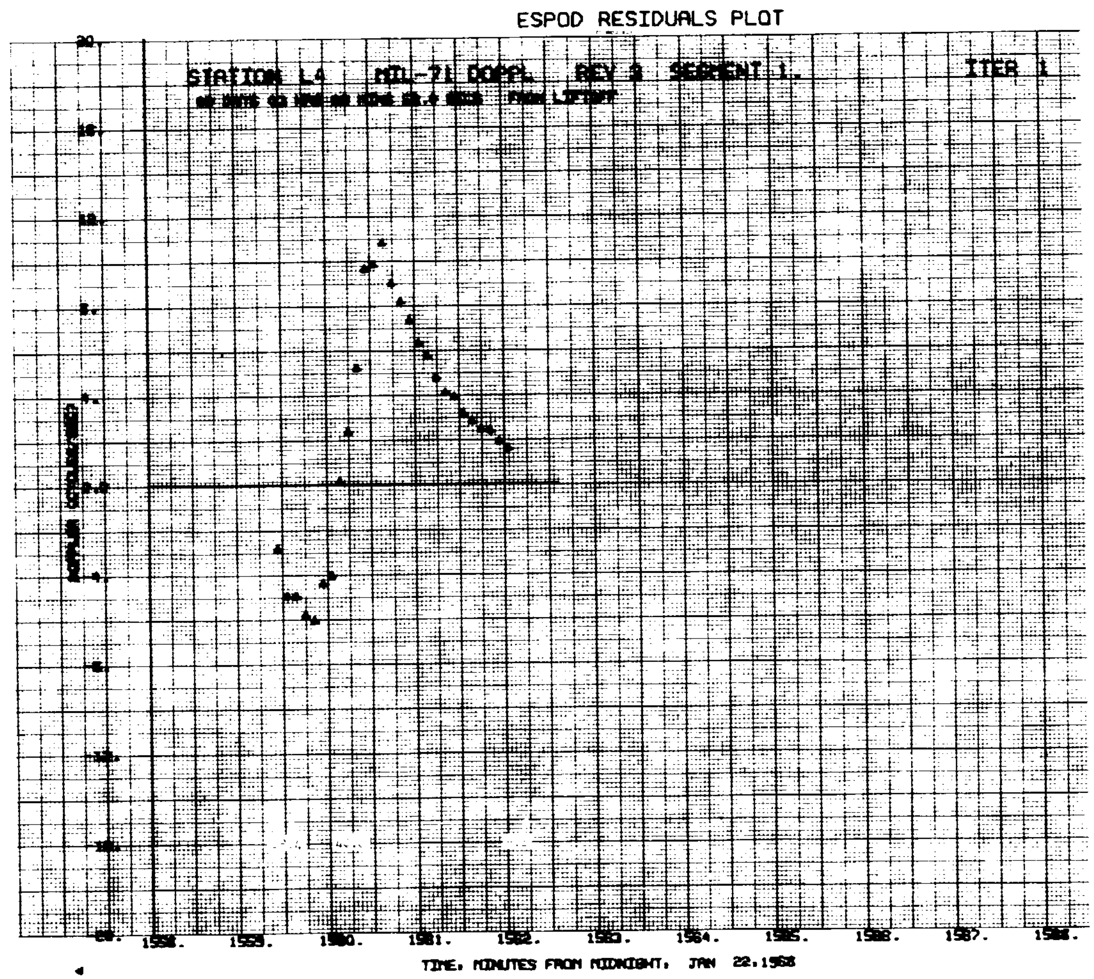
Note:
- Note the crossover pattern in the azimuth residuals.
- The elevation residual pattern indicates a possible refraction problem.

A-28. Revolution 3, Merritt Island: RXY (Segment 1 BET)



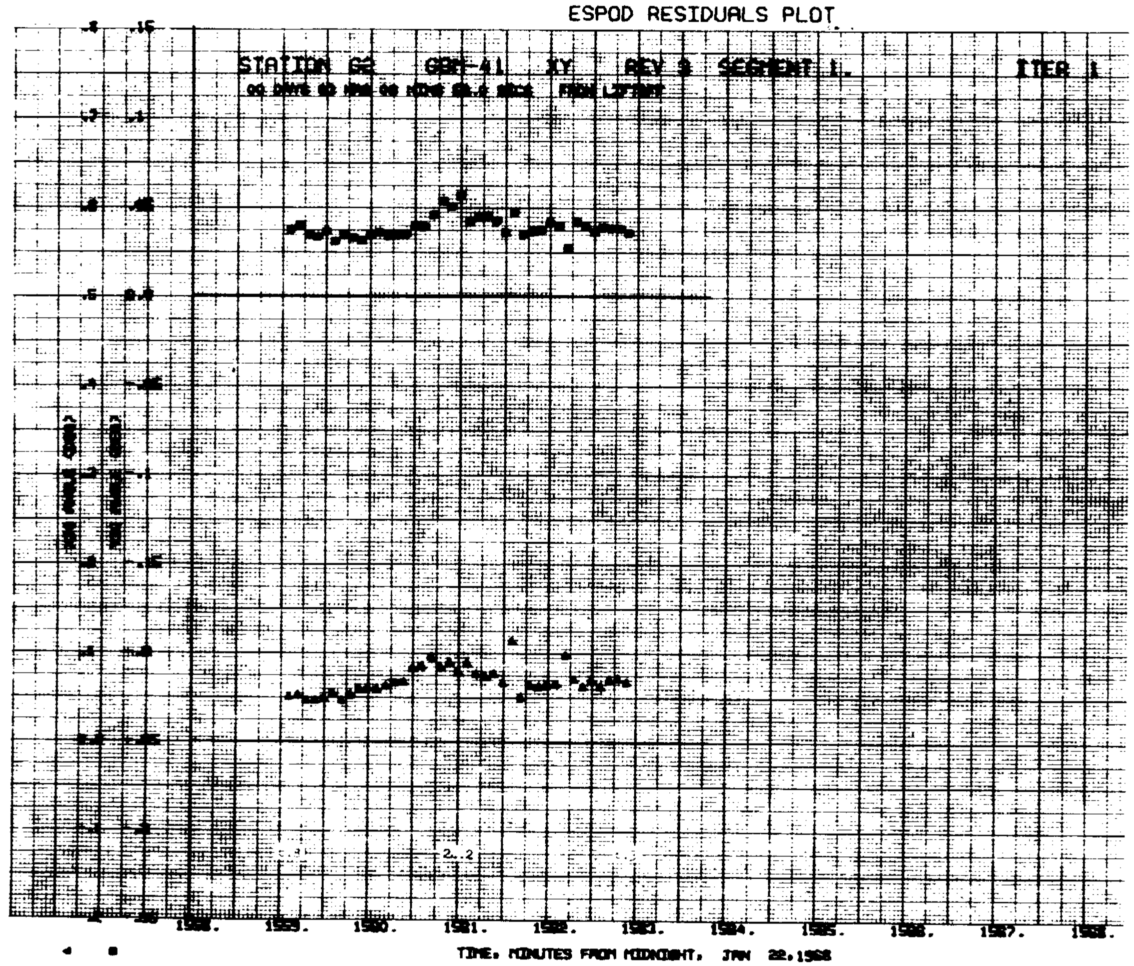
Note: ● These data were weighted out of the fit for data balance.

A-29. Revolution 3, Merritt Island, Doppler (Segment 1 BET)



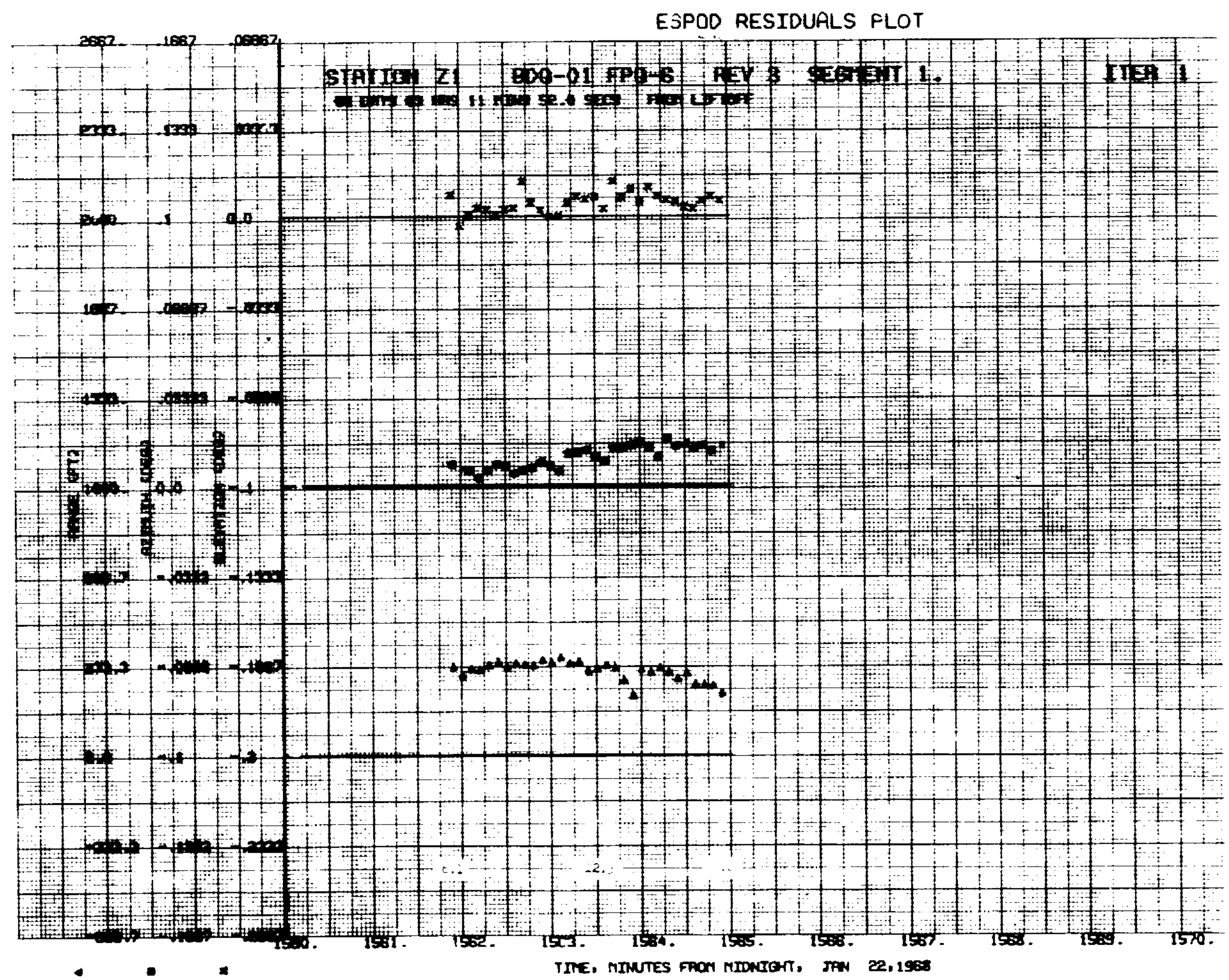
Note: ● These data were weighted out of the fit for data balance.

A-30. Revolution 3, Grand Bahamas: XY (Segment 1 BET)

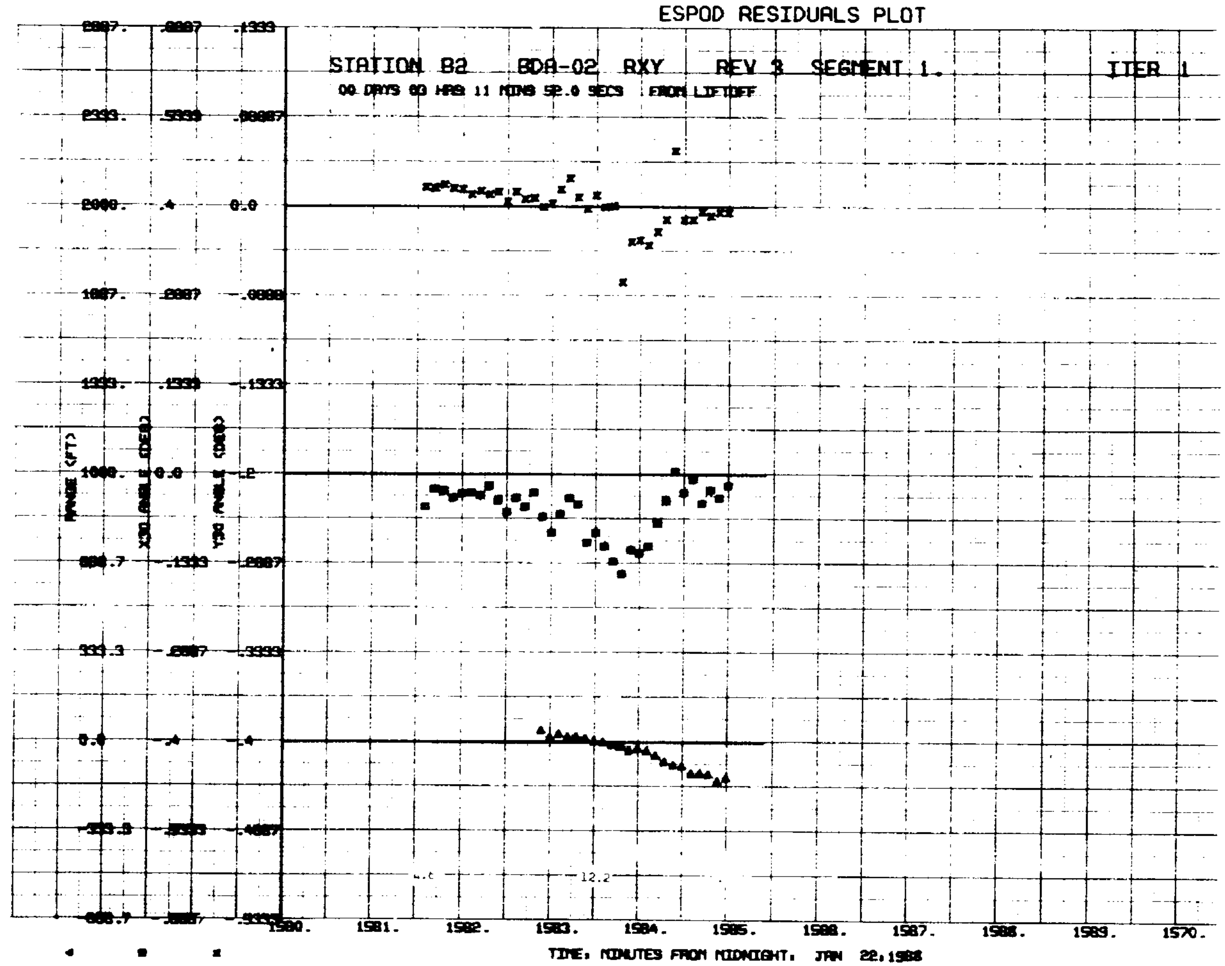


Note: • All the data were tagged invalid at the station.

A-31. Revolution 3, Bermuda (Q): RAE (Segment 1 BET)

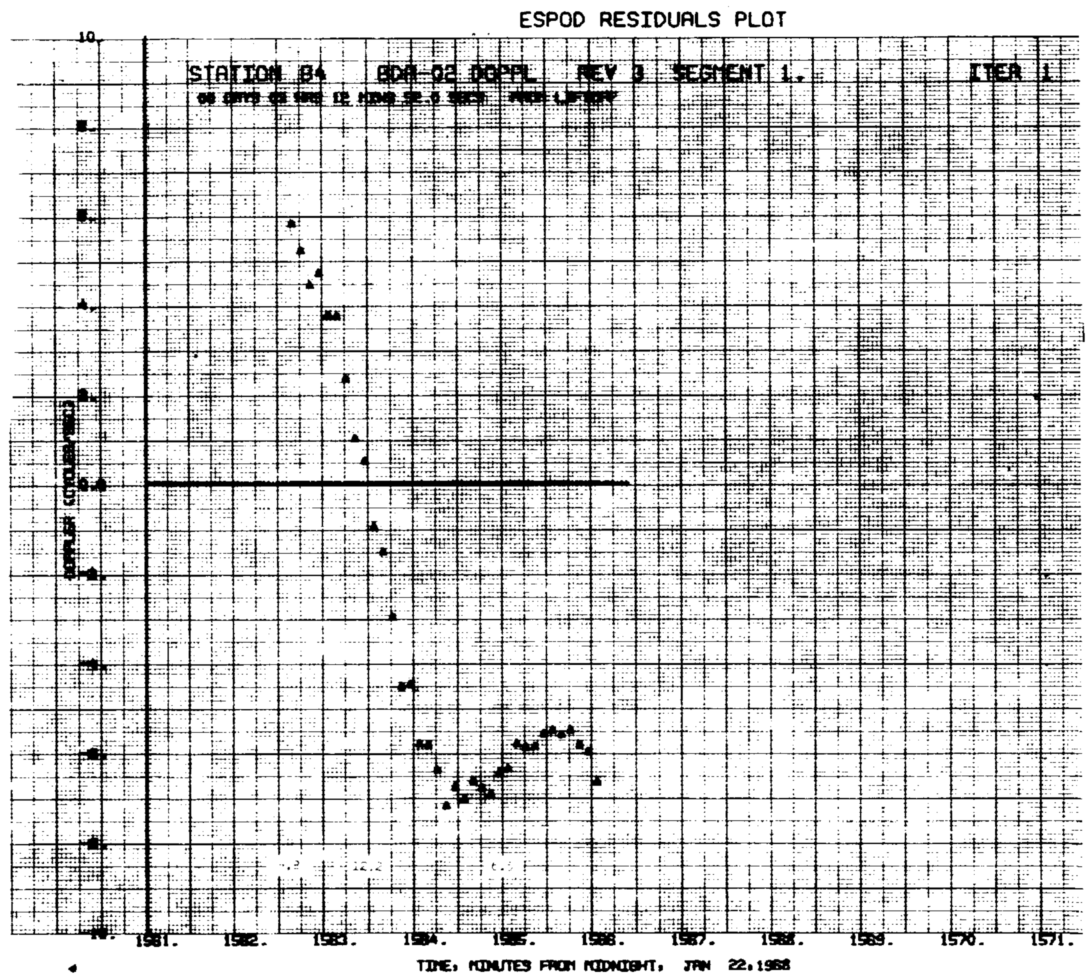


A-32. Revolution 3, Bermuda: RXY (Segment 1 BET)



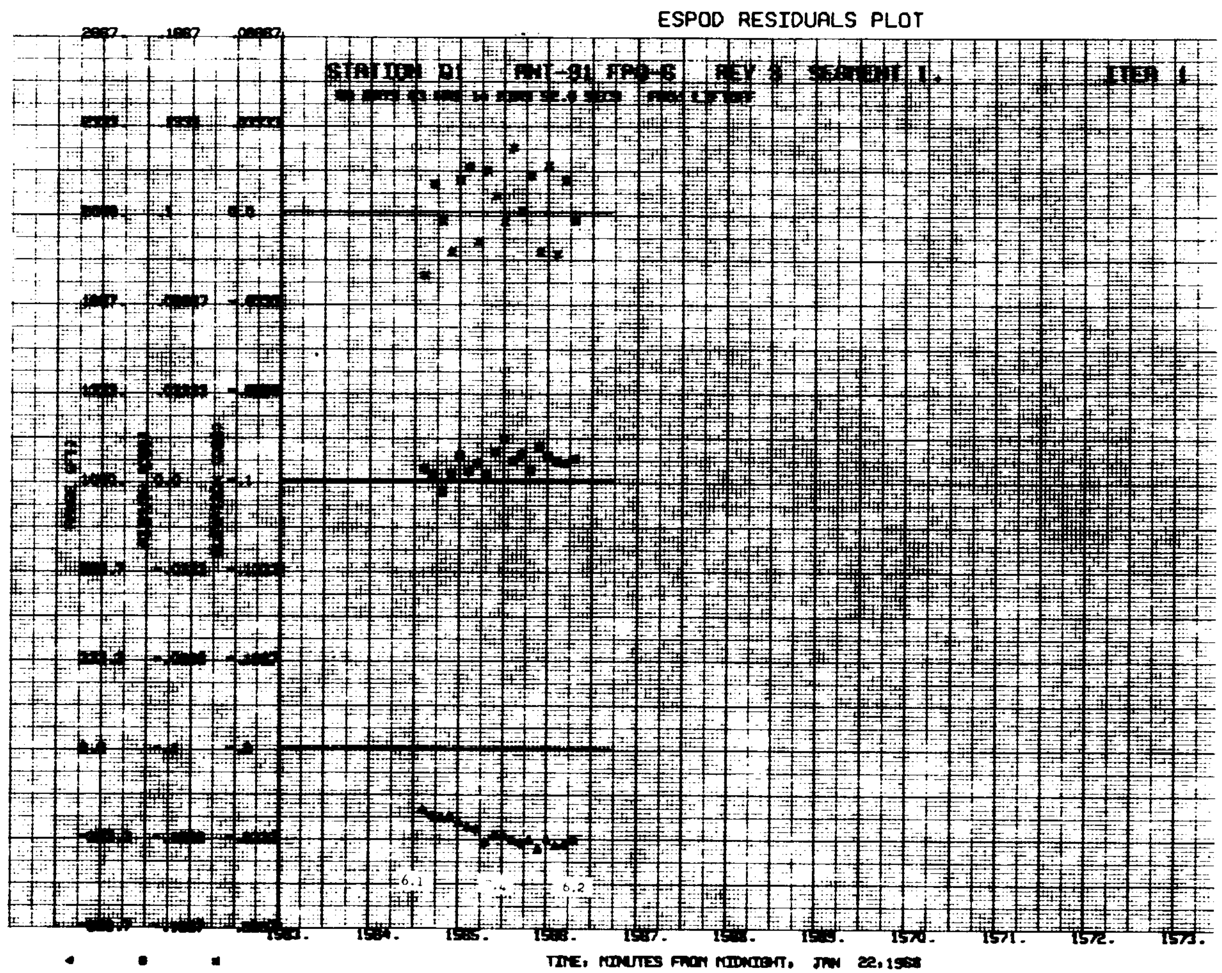
Note: ● The data were weighted out of the fit for data balance.

A-33. Revolution 3, Bermuda: Doppler (Segment 1 BET)



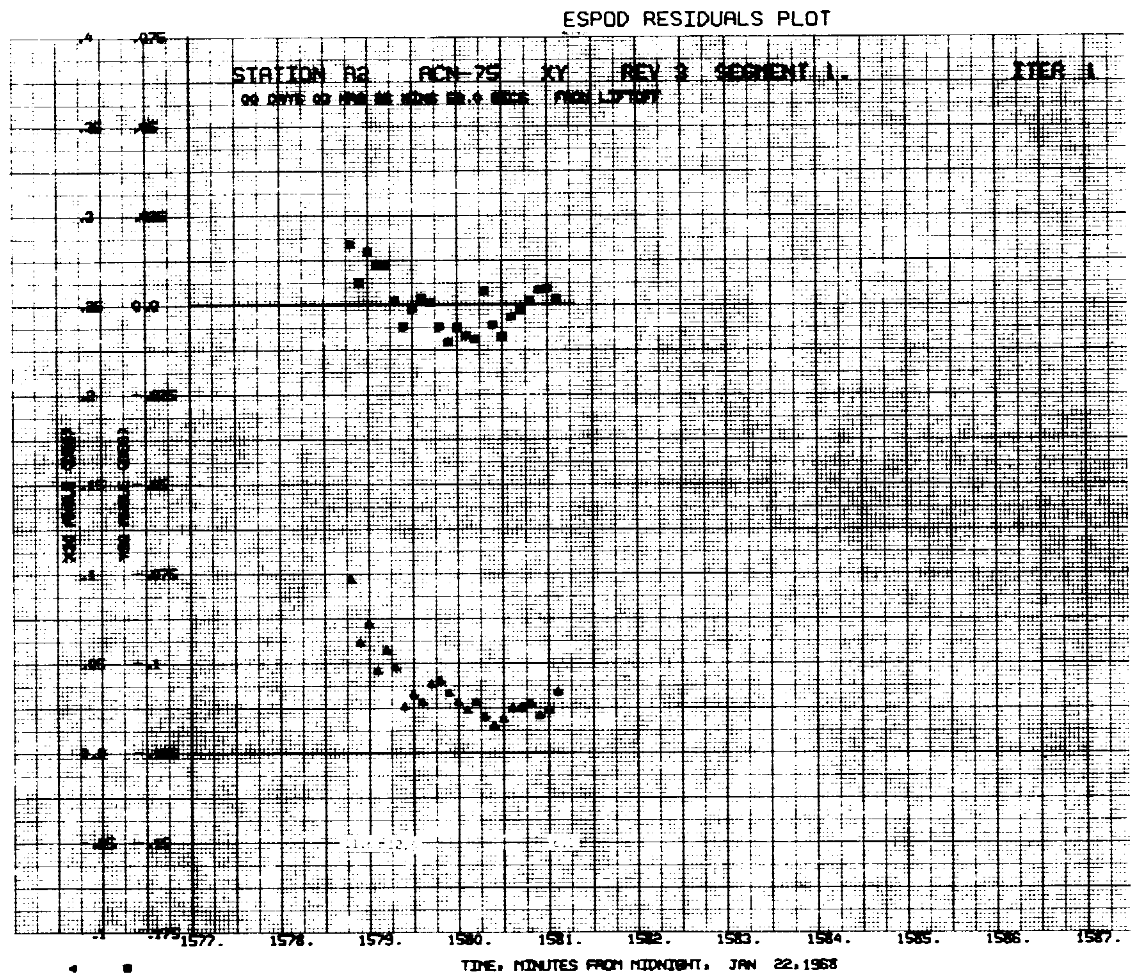
Note: ● The data were weighted out of the fit for data balance.

A-34. Revolution 3, Antigua: RAE (Segment 1 BET)

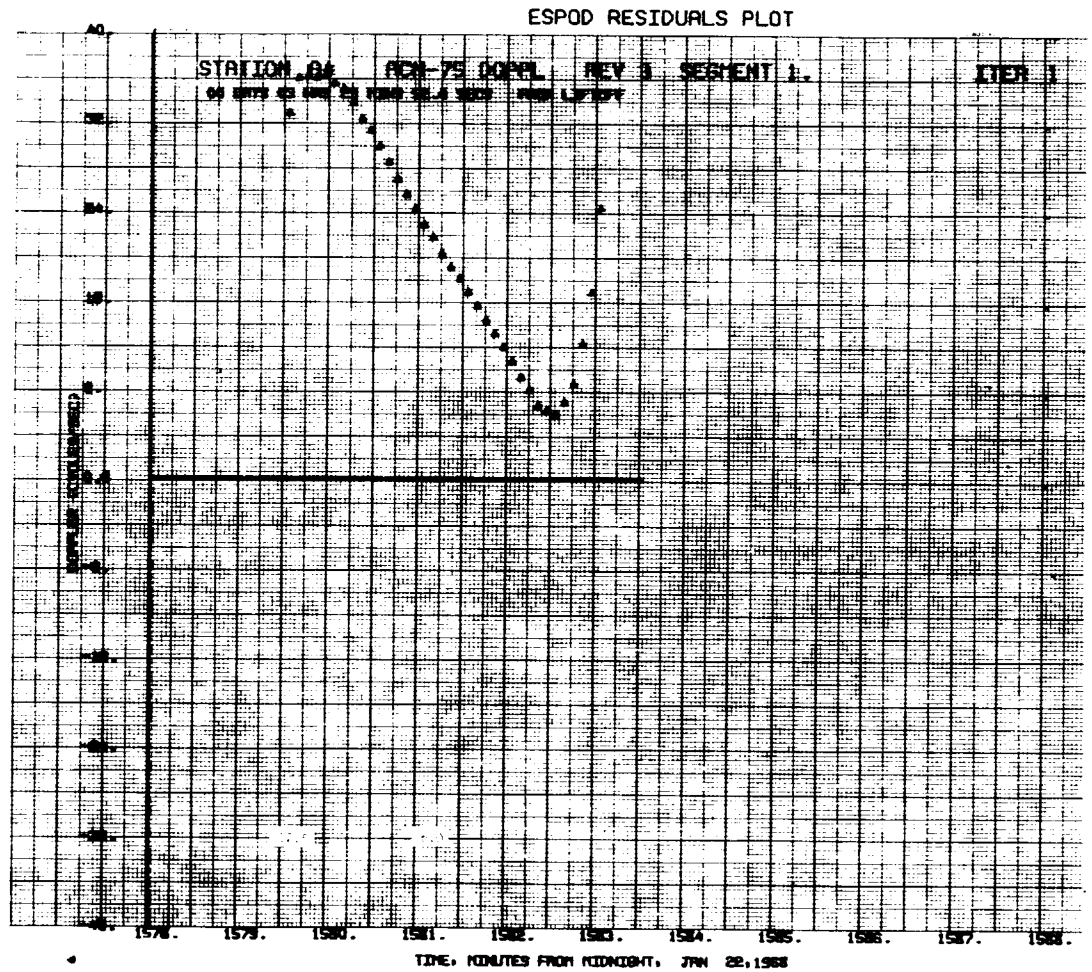


Note: ● The data were weighted out of the fit for data balance.

A-35. Revolution 3, Ascension: XY (Segment 1 BET)

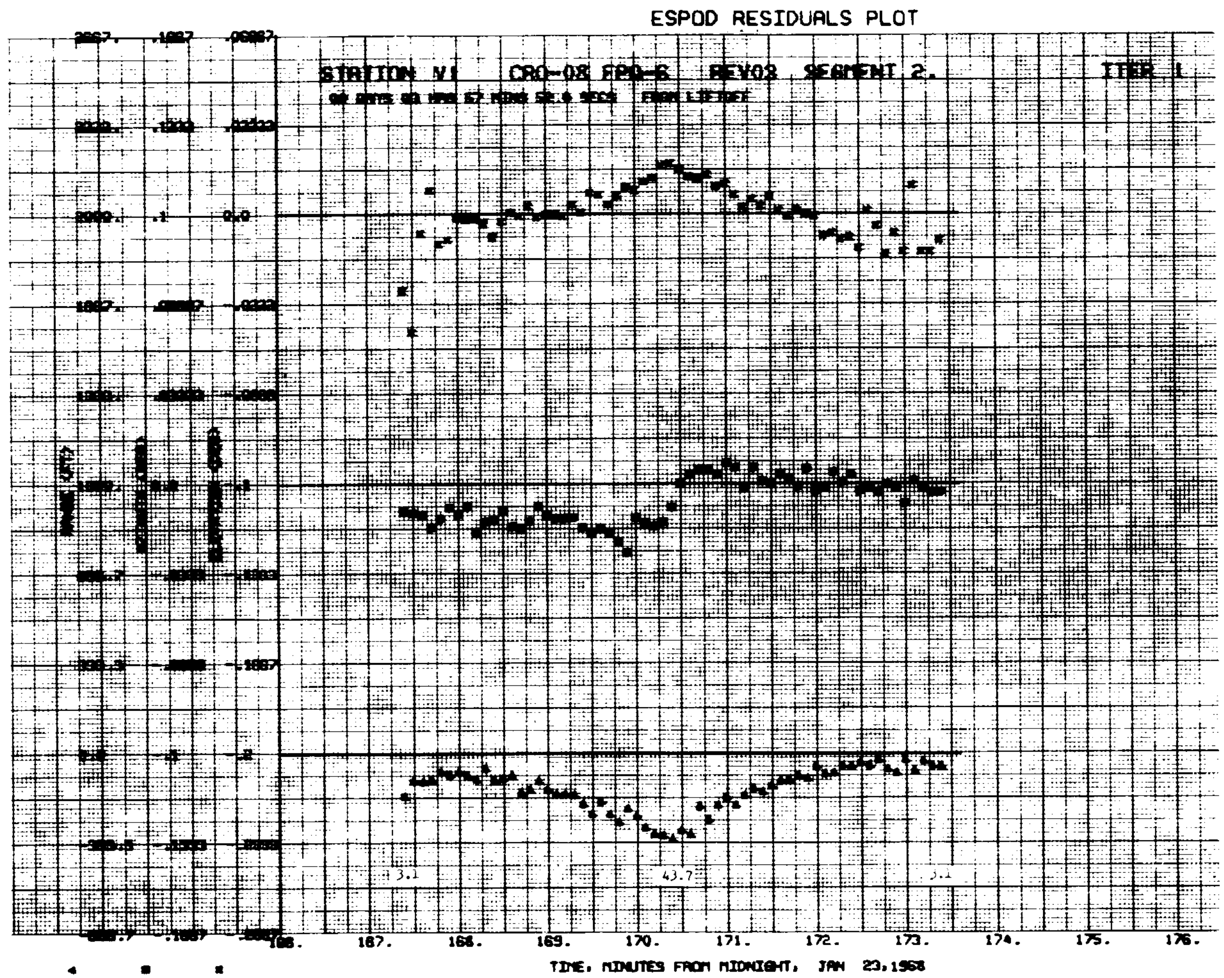


A-36. Revolution 3, Ascension: Doppler (Segment 1 BET)



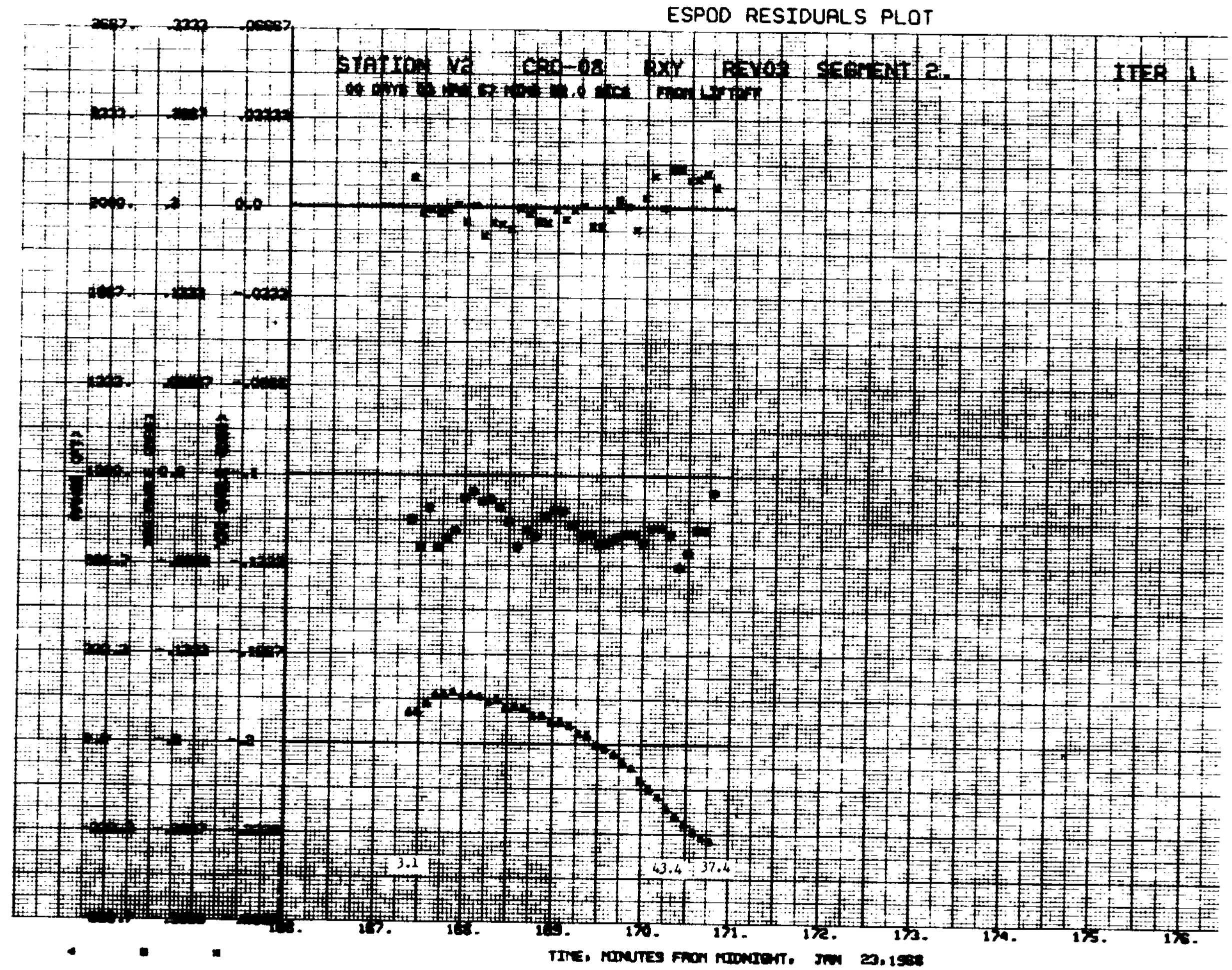
Note: • The data were weighted out of the fit for data balance.

A-37. Revolution 3, Carnarvon: RAE (Segment 2 BET)

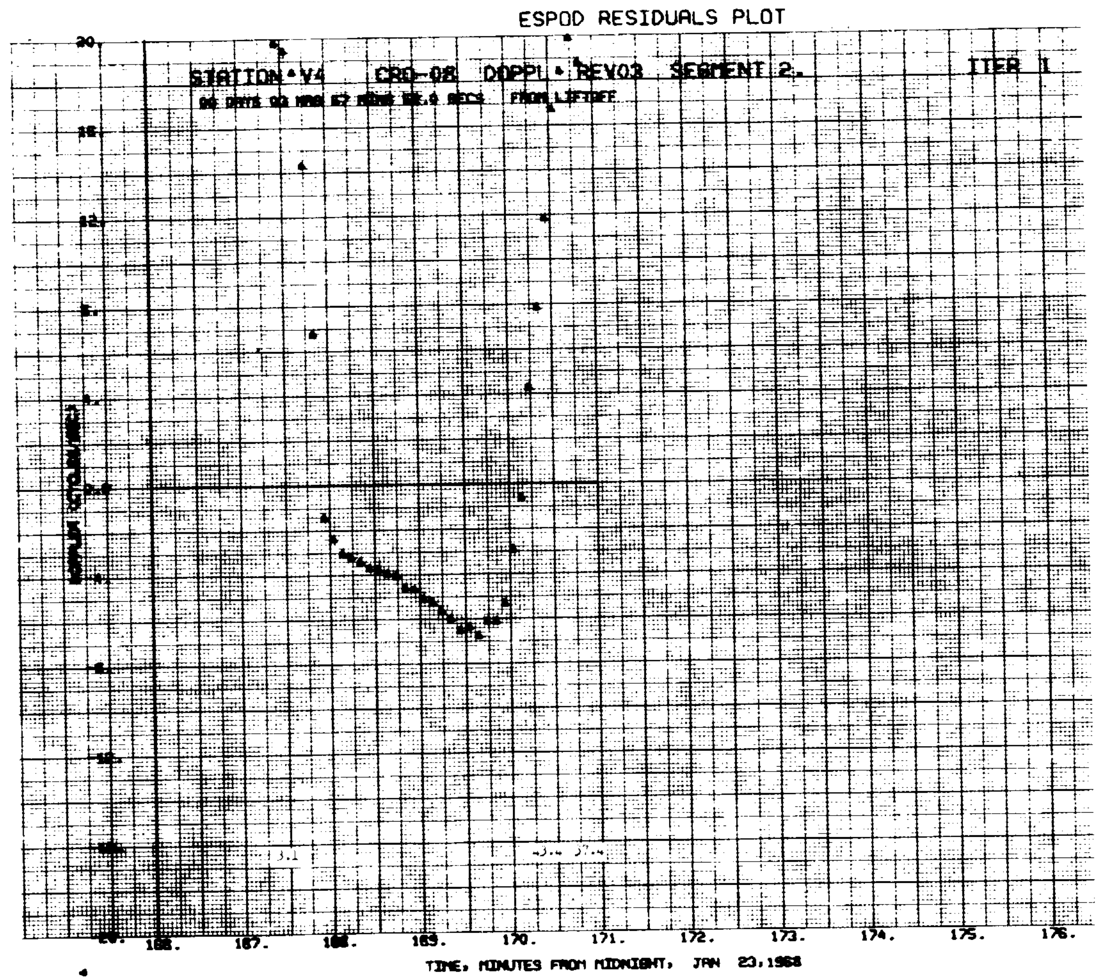


Note: • Note the positive jump in the azimuth residuals at 2 hours and 50 minutes GMT.

A-38. Revolution 3, Carnarvon: RXY (Segment 2 BET)

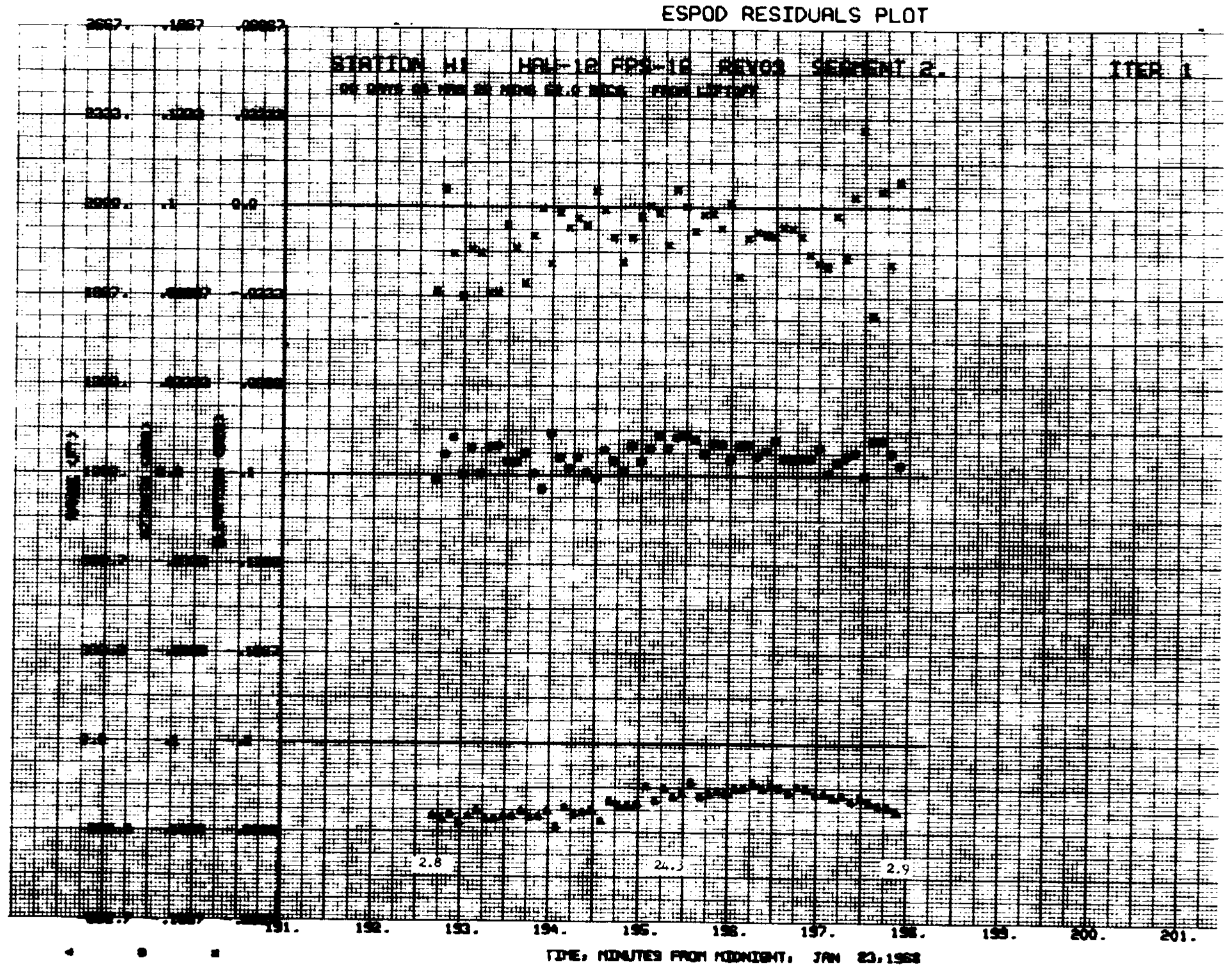


A-39. Revolution 3, Carnarvon: Doppler (Segment 2 BET)



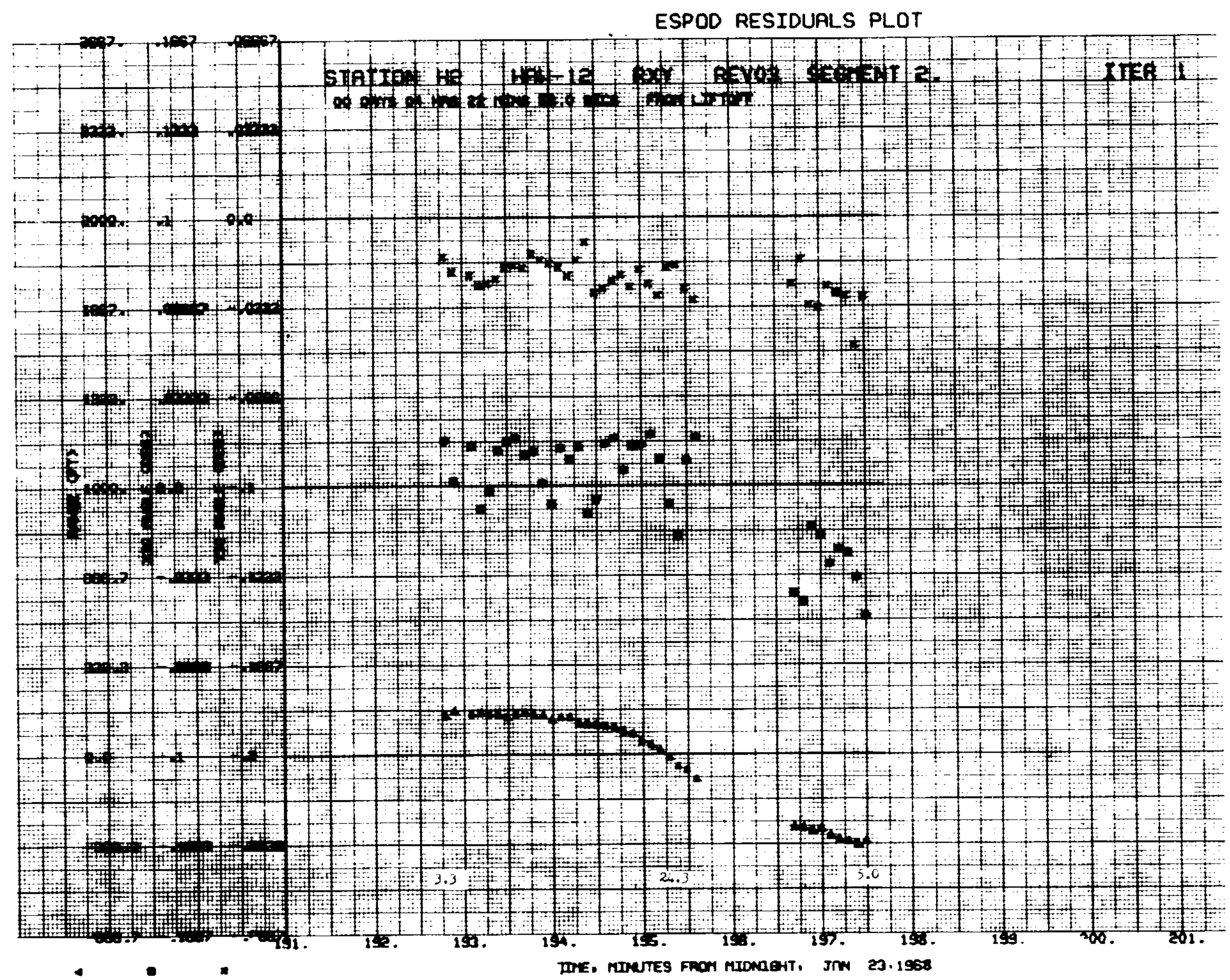
Note:
- Station location errors and timing errors do not account for this residual pattern.
- These data were weighted out of the fit for data balance.

A-40. Revolution 3, Hawaii: RAE (Segment 2 BET)

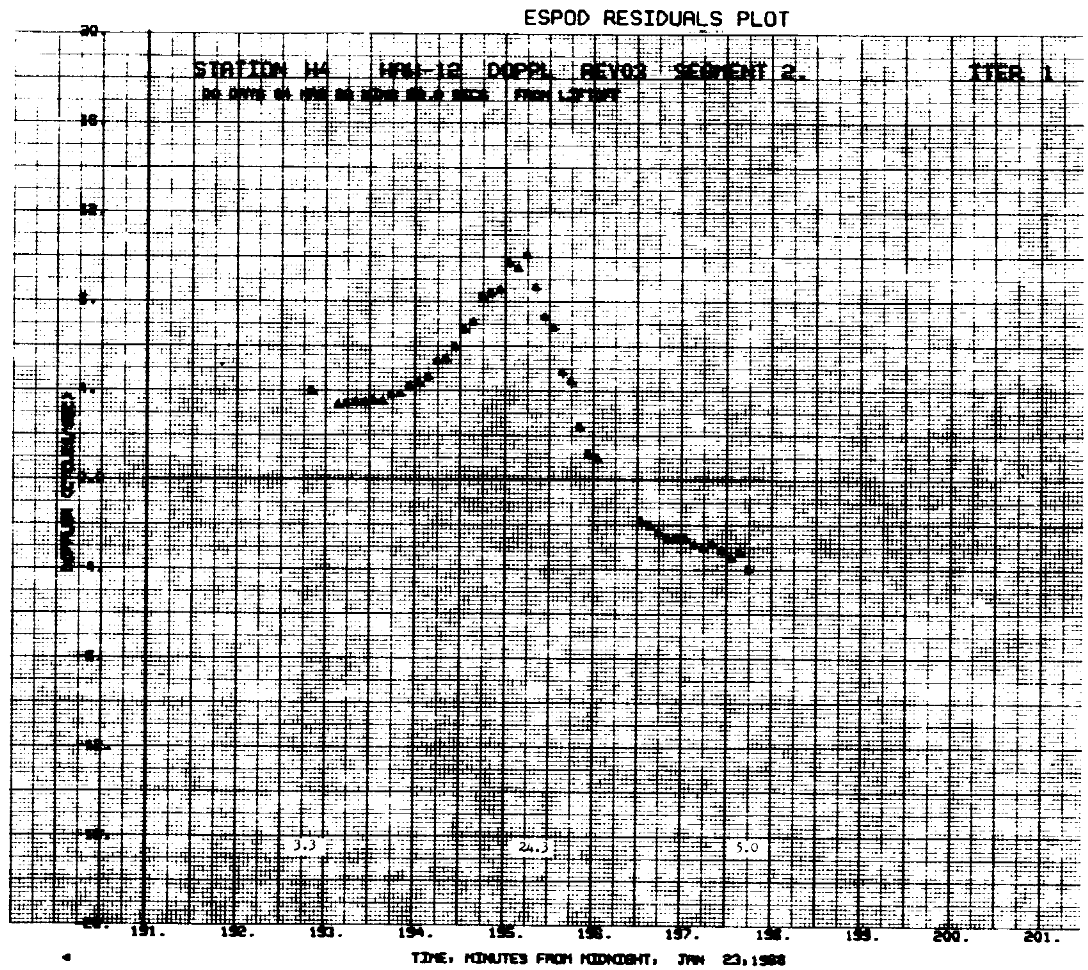


Note: ● During this pass the elevation residuals were noisy.

A-41. Revolution 3, Hawaii: RXY (Segment 2 BET)

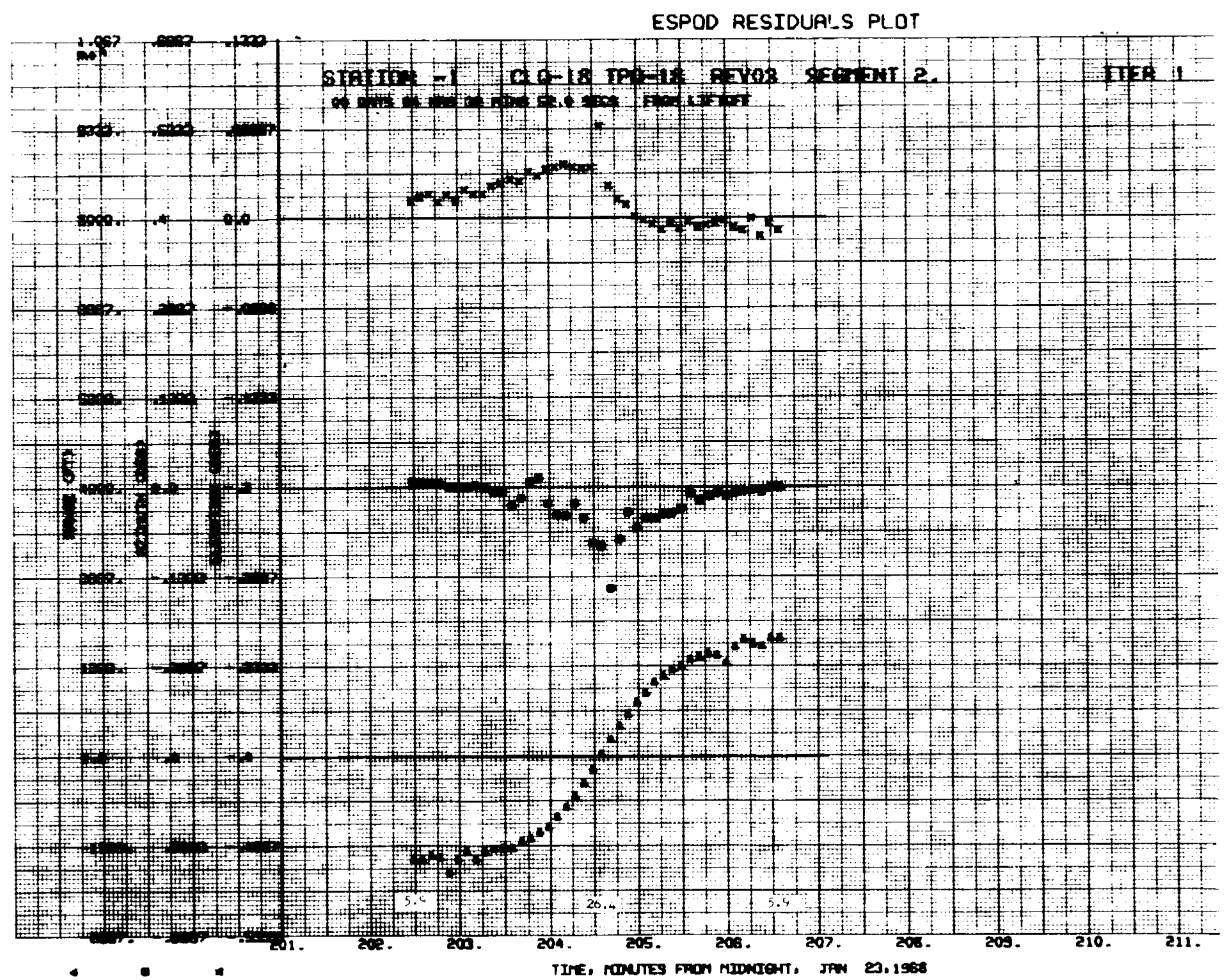


A-42. Revolution 3, Hawaii: Doppler (Segment 2 BET)



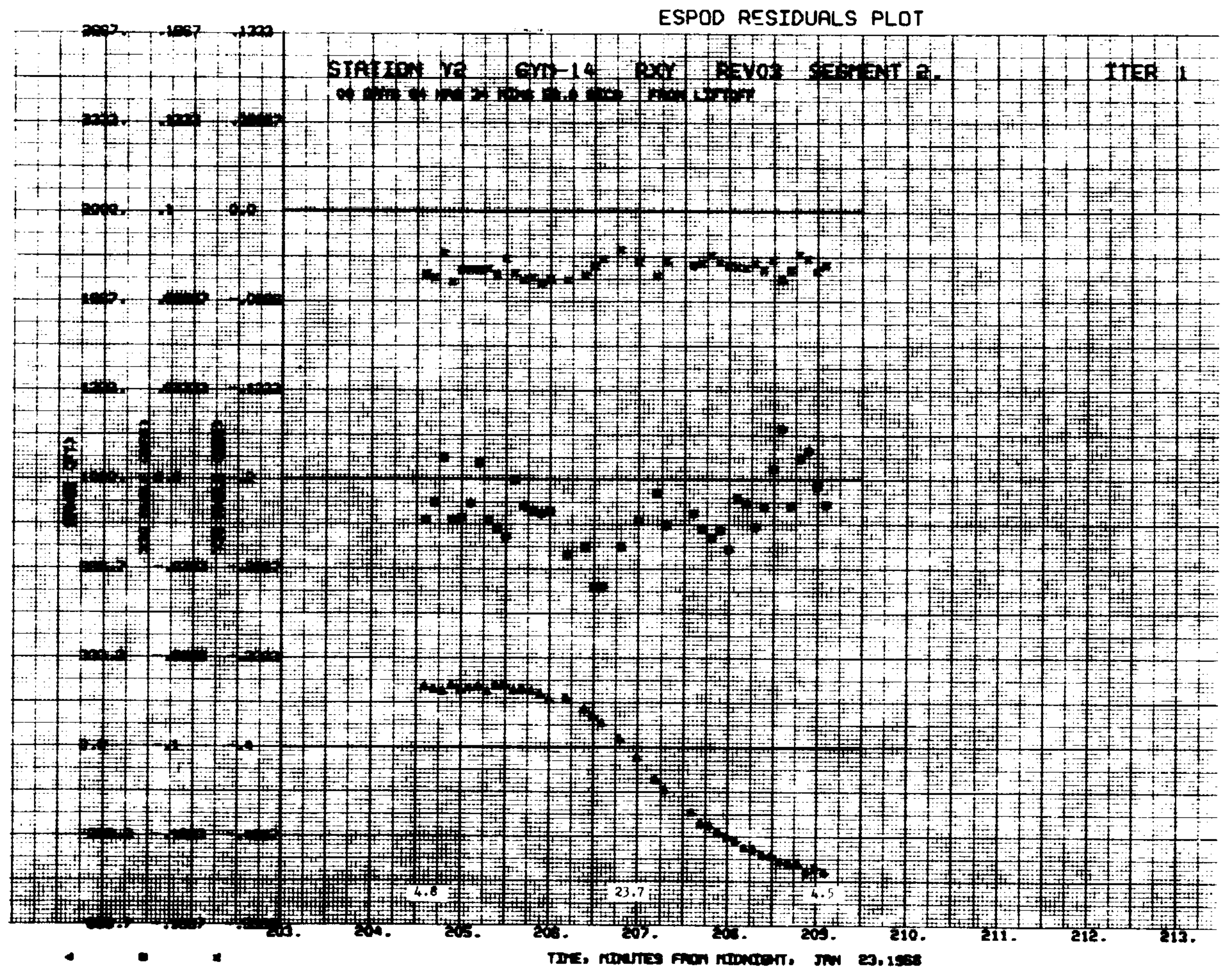
Note: ● These data were weighted out of the fit for data balance.

A-43. Revolution 3, California: RAE (Segment 2 BET)



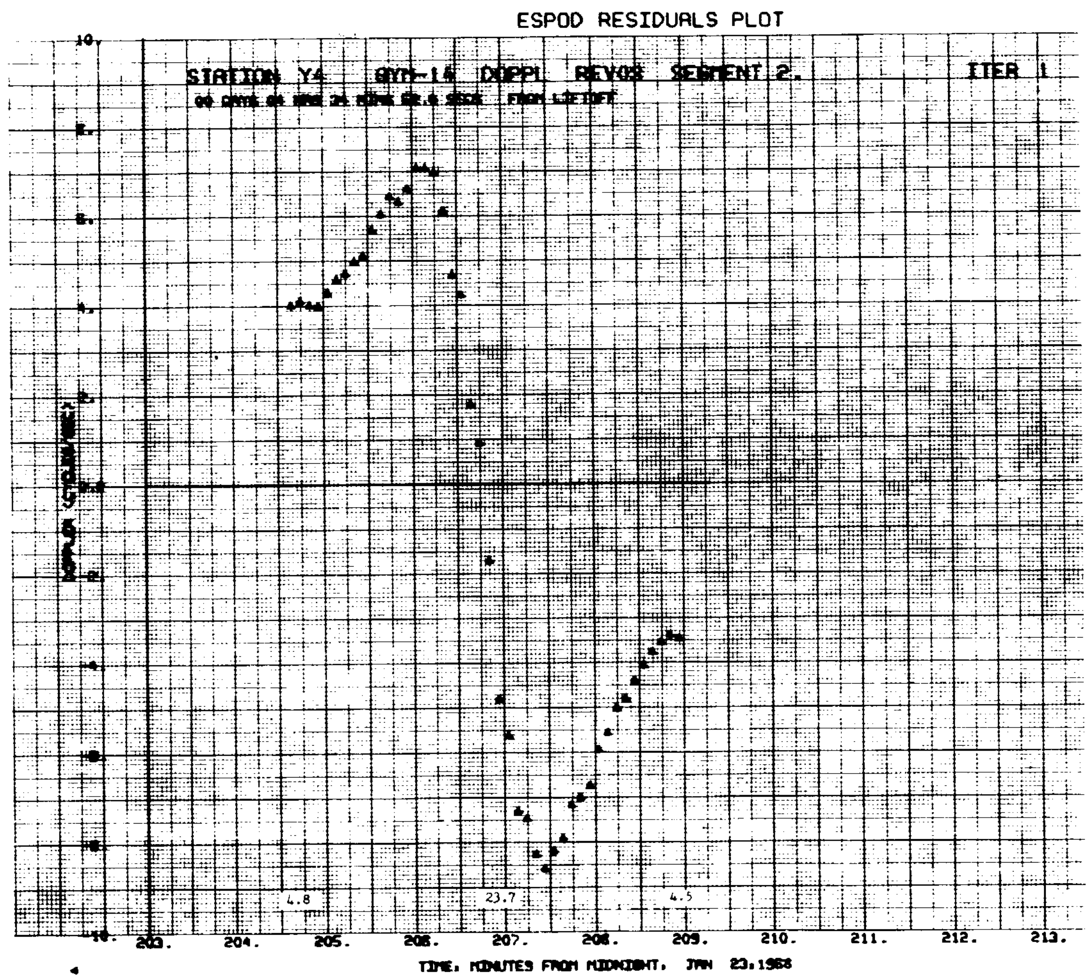
Note: ● The granularity that the RTCC used for the angle observations was doubled in order to plot the residuals for this pass.

A-44. Revolution 3, Guaymas: RXY (Segment 2 BET)



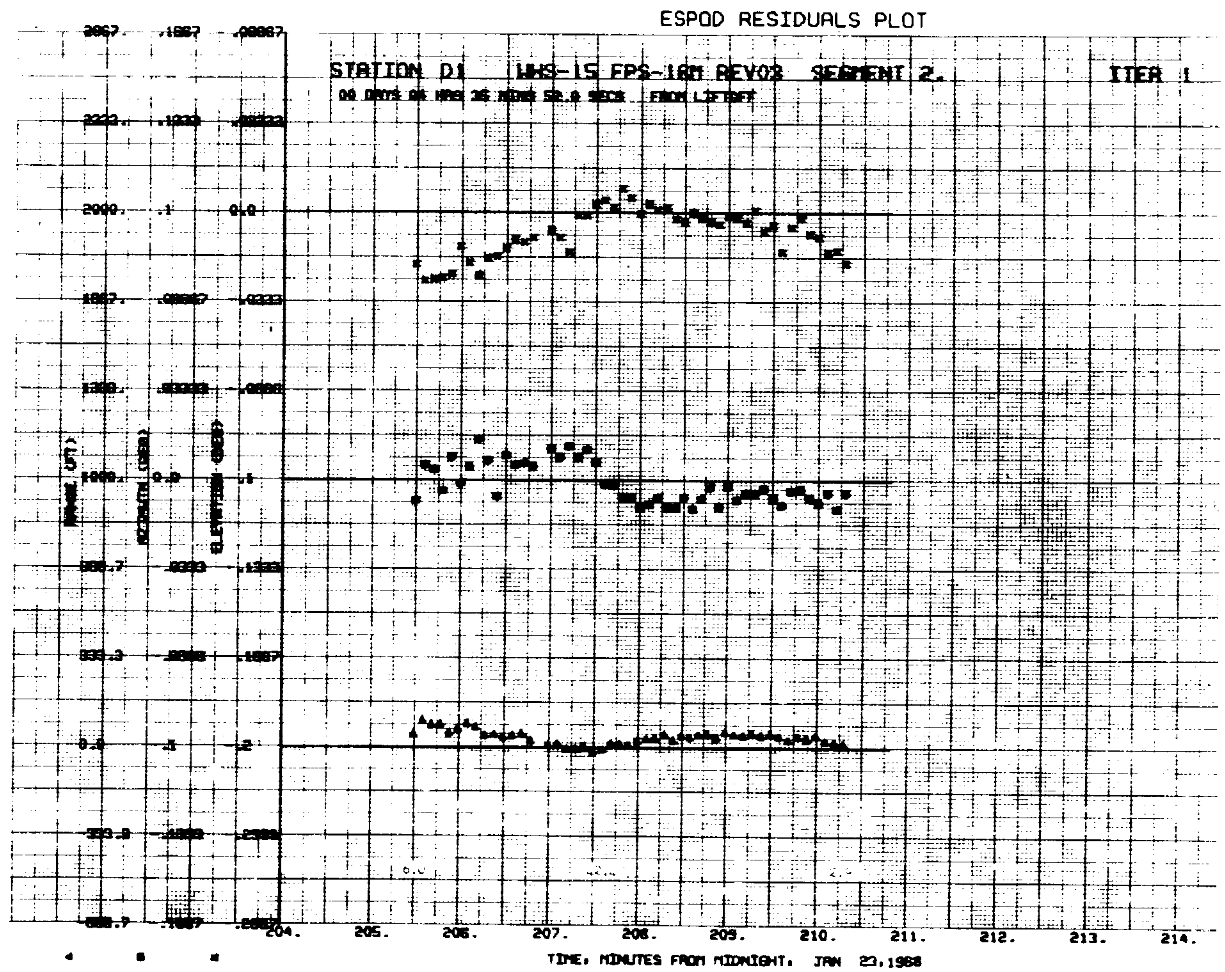
Note: • Note the noisy X-angle residual pattern for this pass.

A-45. Revolution 3, Guaymas: Doppler (Segment 2 BET)

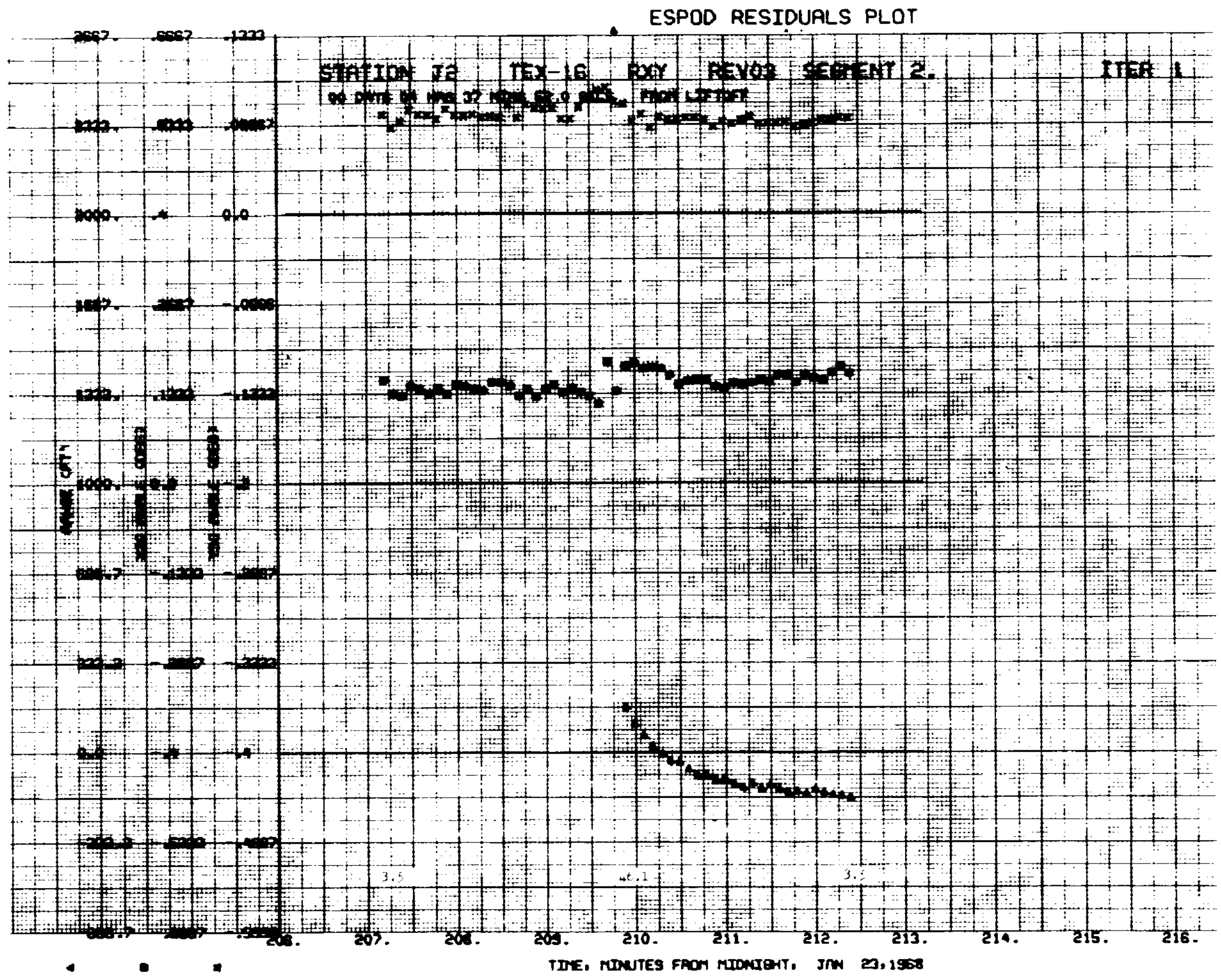


Note: • The doppler residual pattern indicates an apparent height error.
• These data were weighted out of the fit.

A-46. Revolution 3, White Sands: RAE (Segment 2 BET)

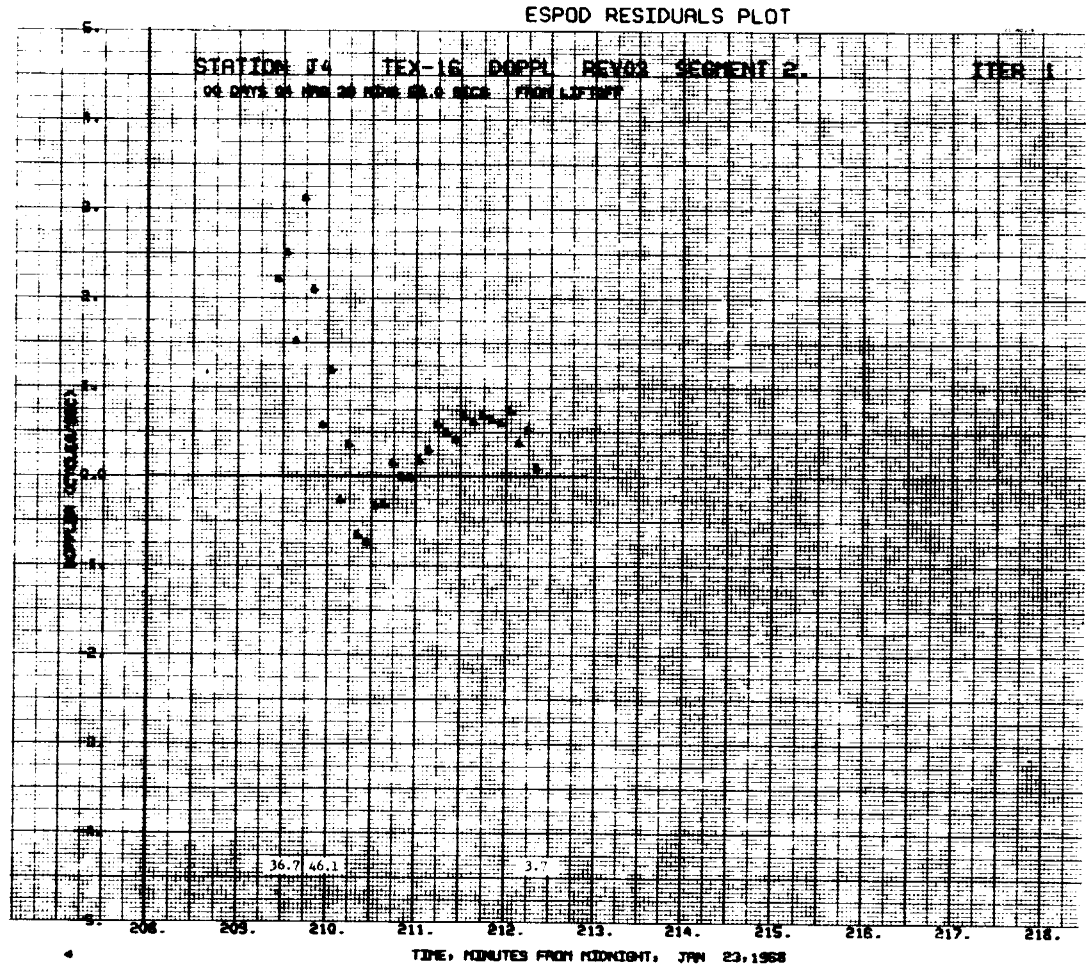


A-47. Revolution 3, Texas: RXY (Segment 2 BET)



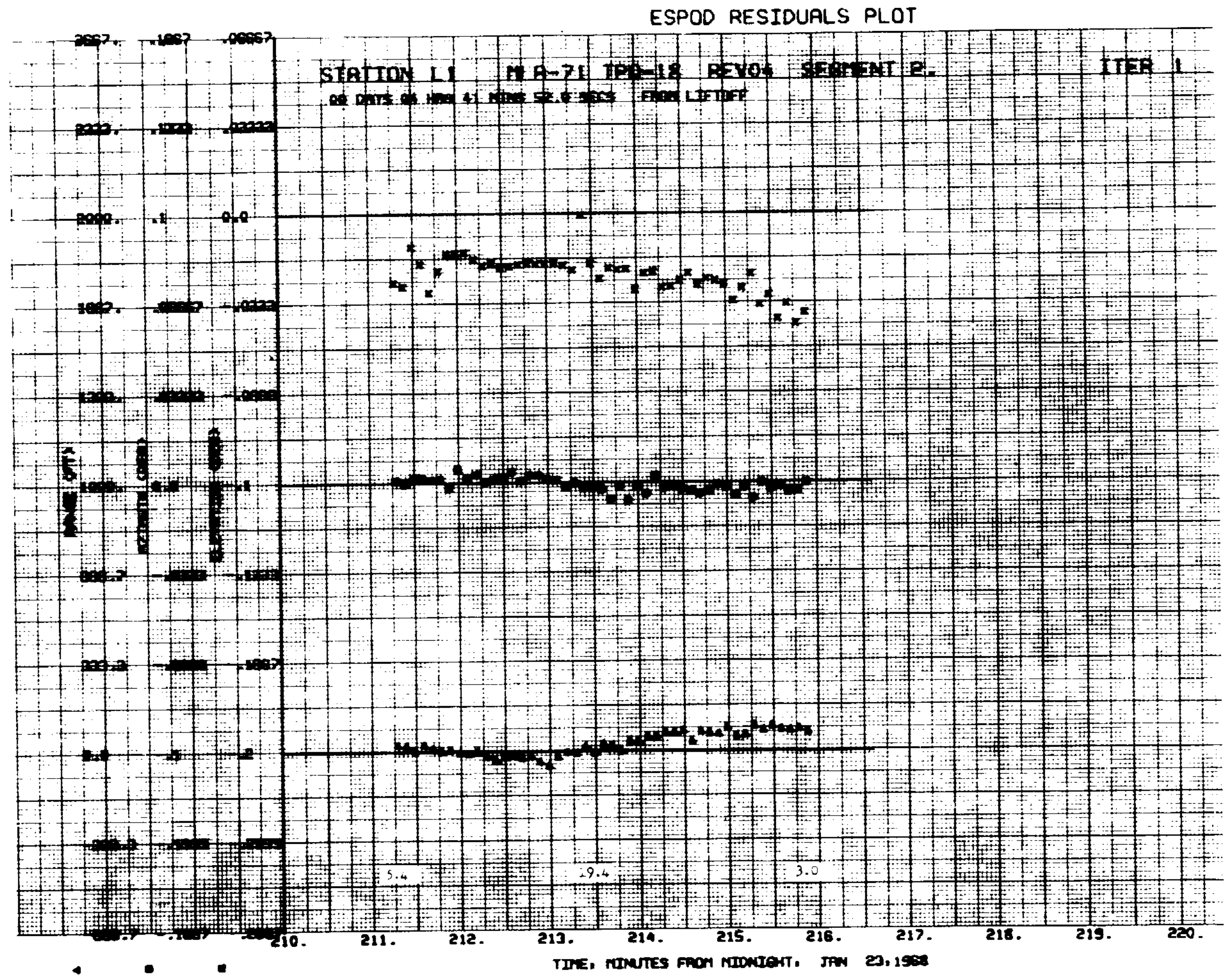
Note: • Apparent biases in the X-and Y-angles are indicated by the residual patterns.

A-48. Revolution 3, Texas: Doppler (Segment 2 BET)



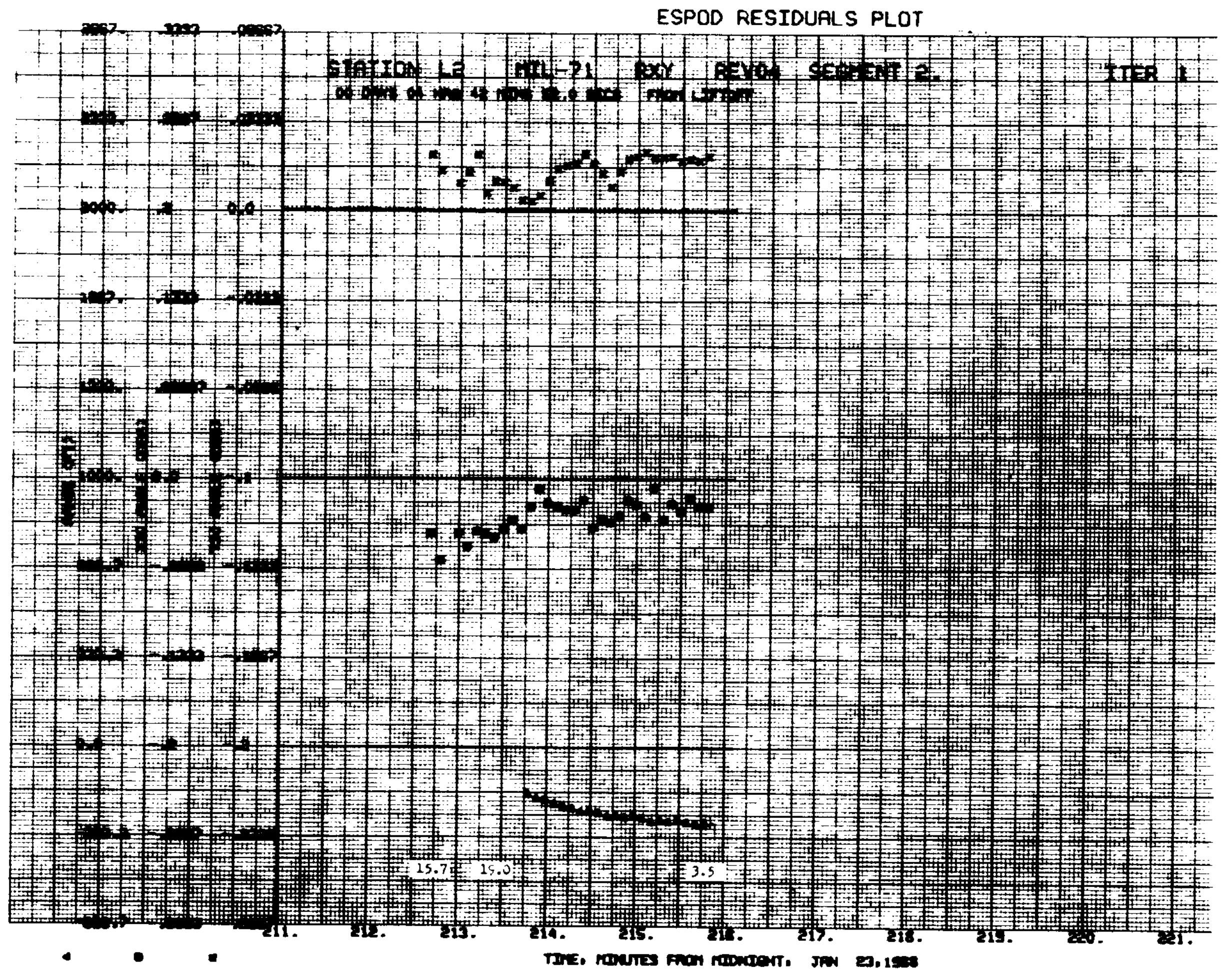
Note:
- This is the best doppler residual pattern for Segment 2.
- These data were weighted out of the fit.

A-49. Revolution 4, Merritt Island: RAE (Segment 2 BET)

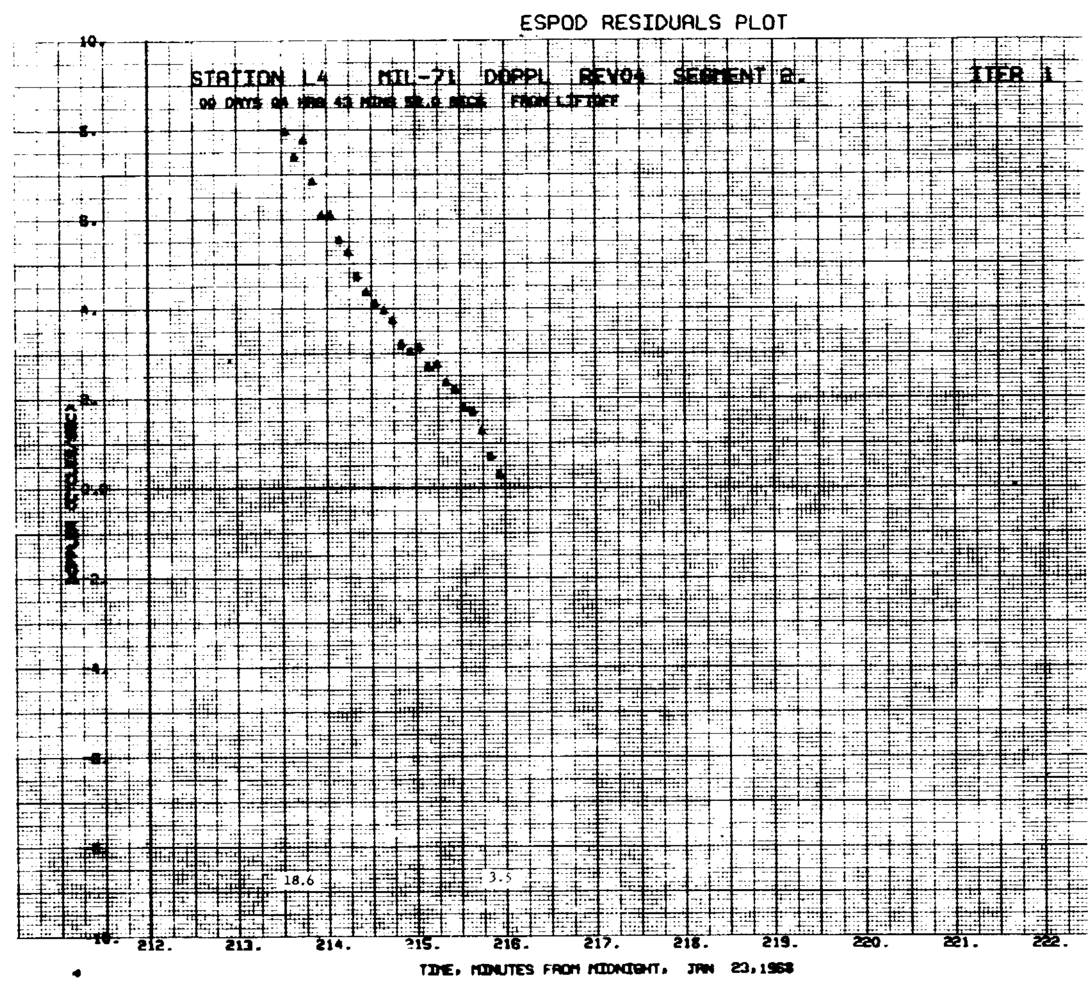


Note: ● The elevation residual pattern indicates a possible refraction problem.

A-50. Revolution 4, Merritt Island: RXY (Segment 2 BET)

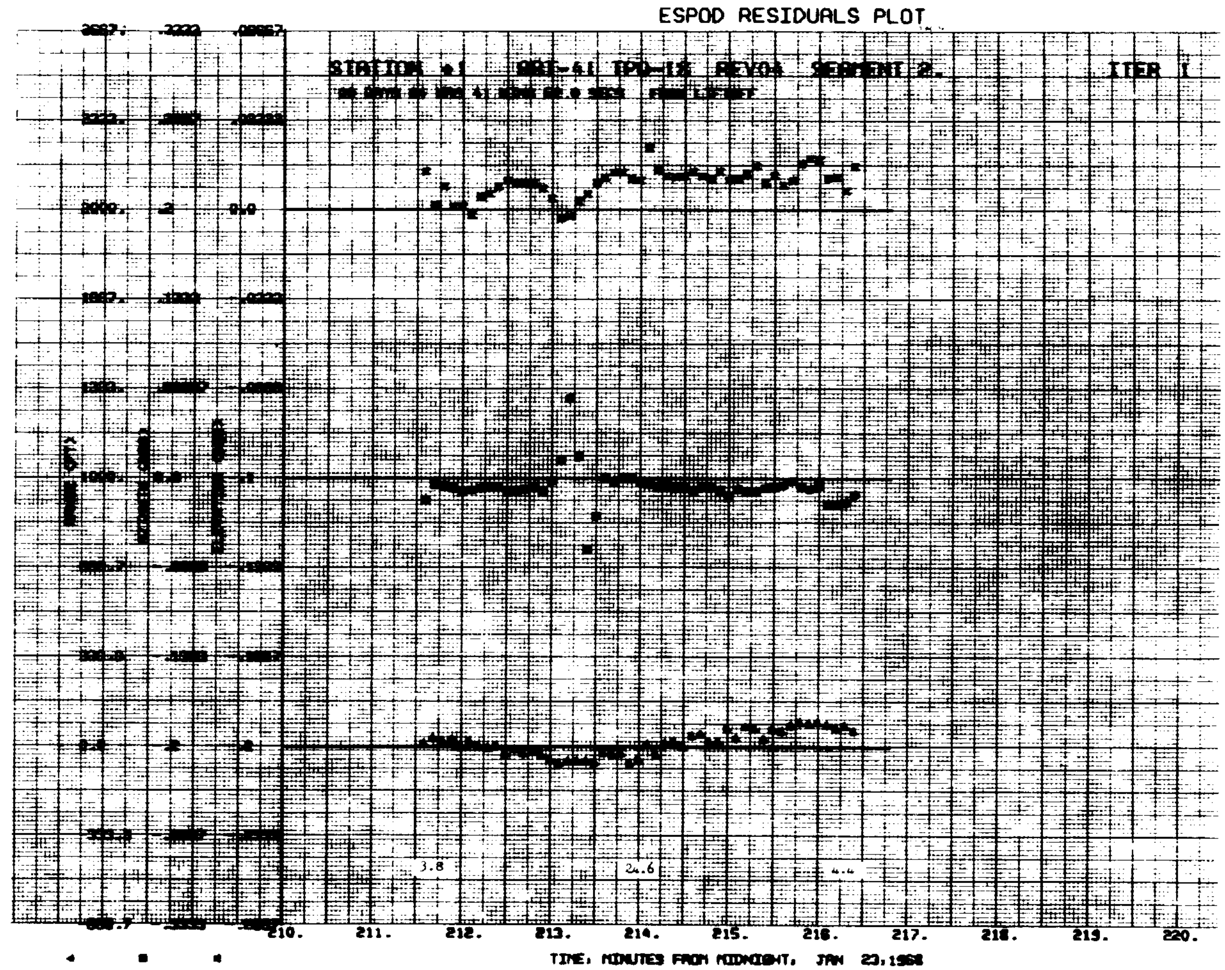


A-51. Revolution 4, Merritt Island: Doppler (Segment 2 BET)



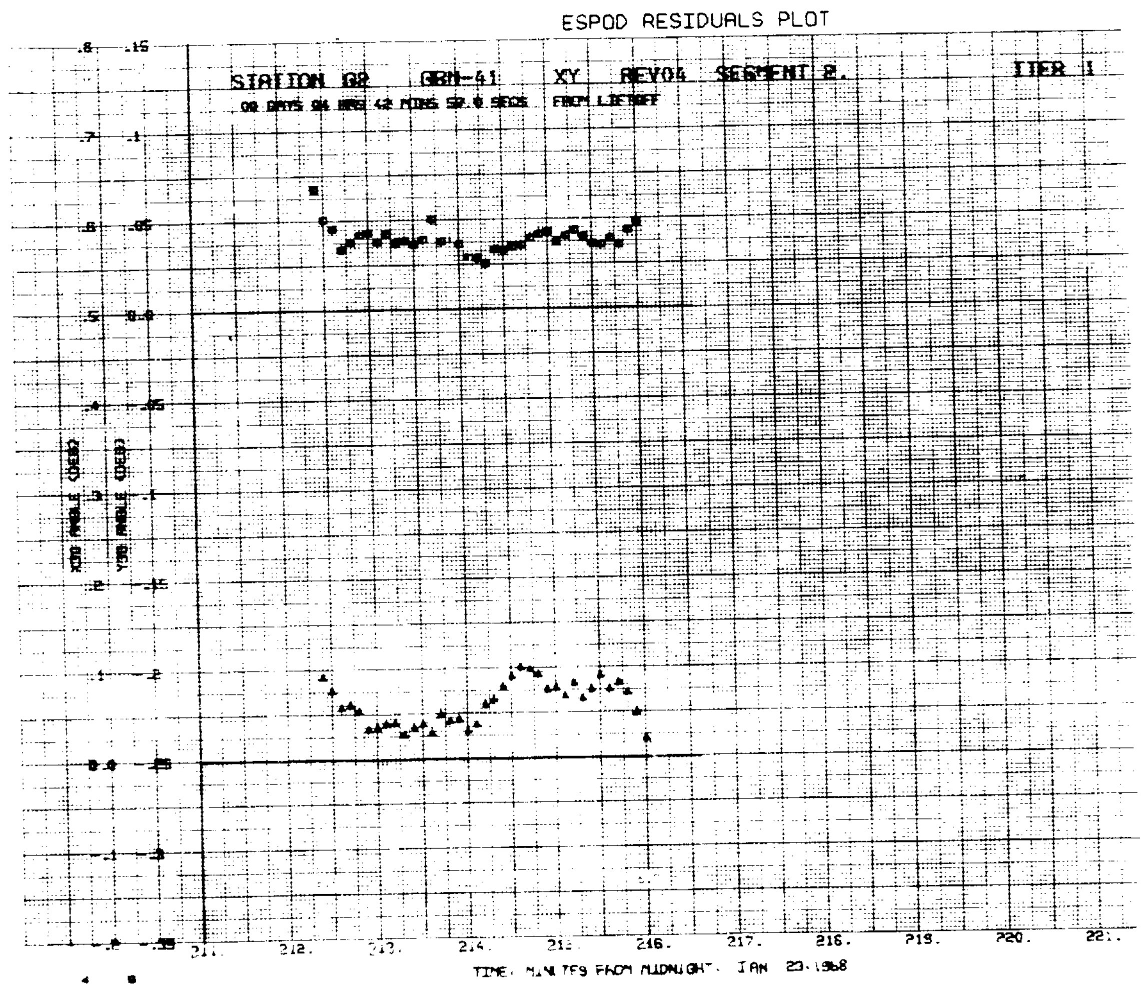
Note:
- The doppler residual pattern indicates a possible timing or longitude error.
- These data were weighted out of the fit.

A-52. Revolution 4, Grand Bahama: RAE (Segment 2 BET)

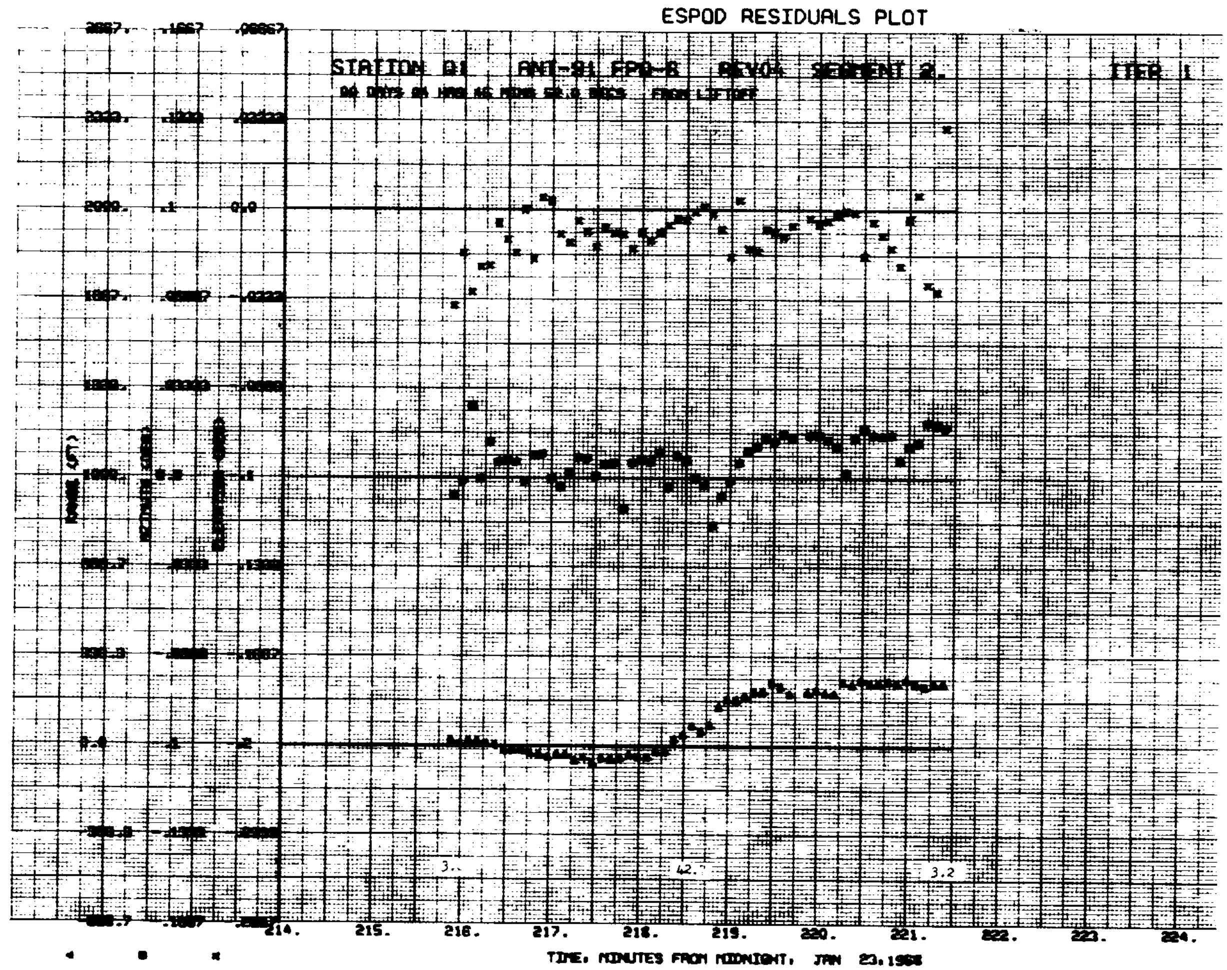


Note: • Note the azimuth residual pattern between 3 hours and 33 minutes GMT and 3 hour and 34 minutes GMT.

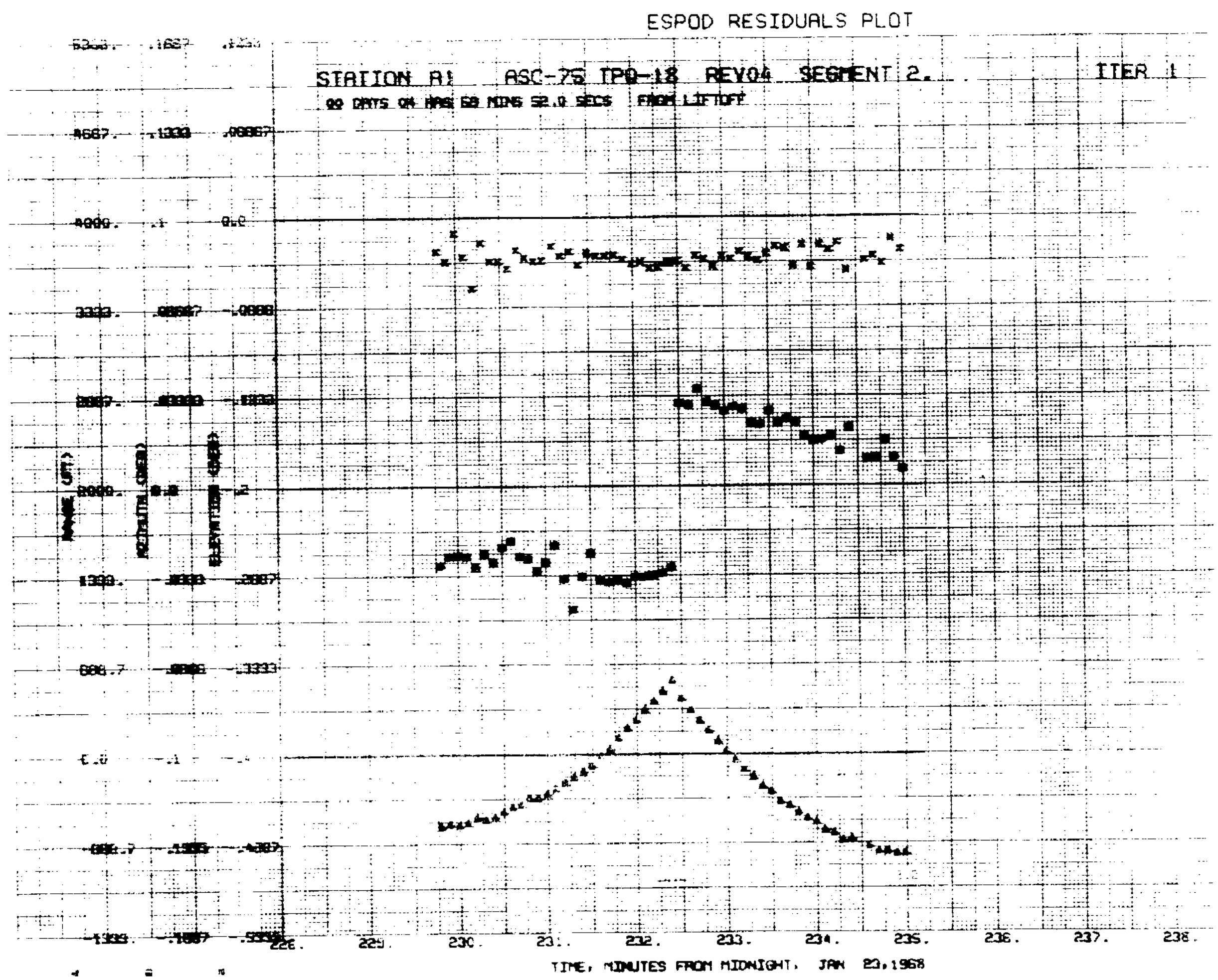
A-53. Revolution 4, Grand Bahama: XY (Segment 2 BET)



A-54. Revolution 4, Antigua: RAE (Segment 2 BET)

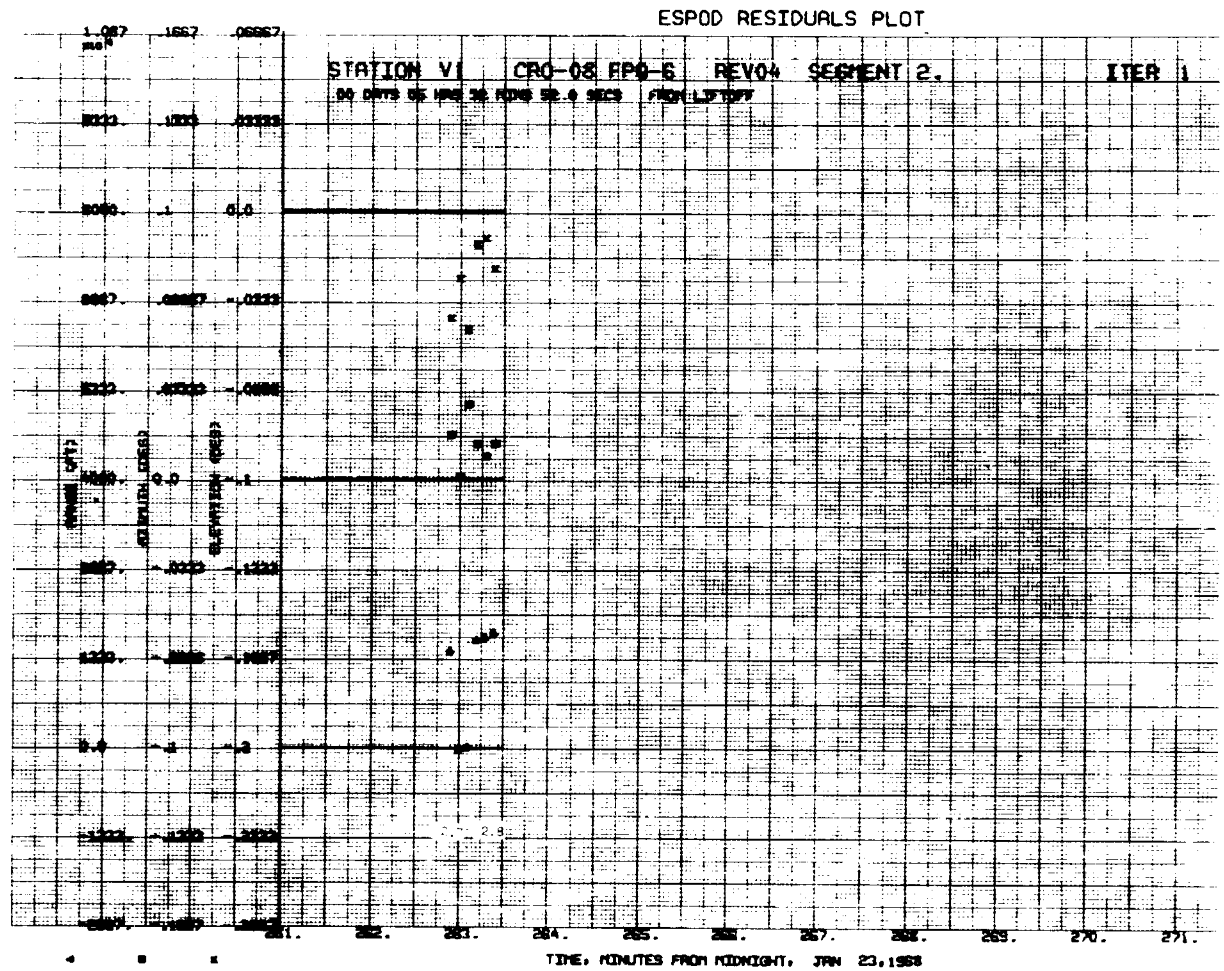


A-55. Revolution 4, Ascension: RAE (Segment 2 BET)



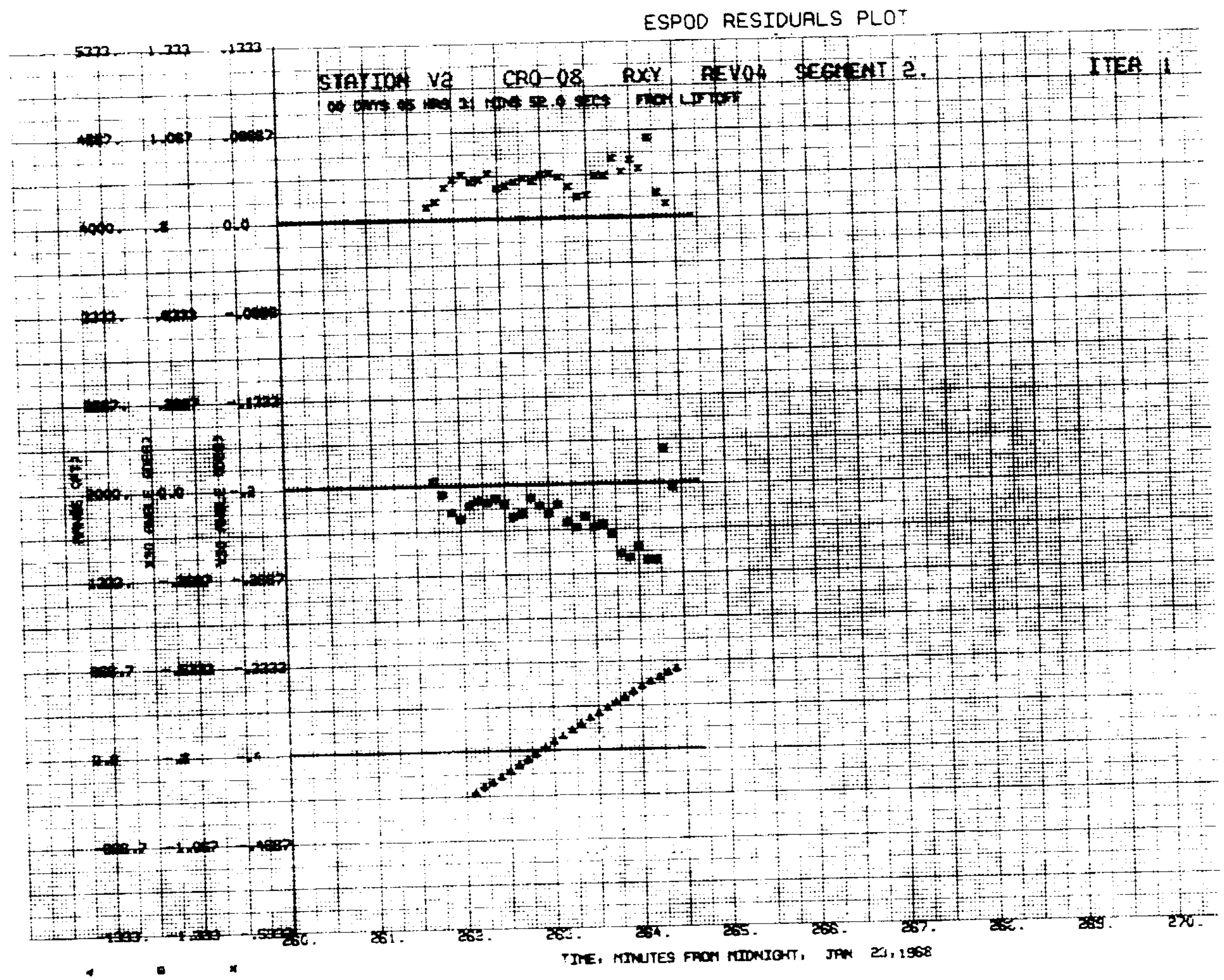
Note: • The discontinuity in the azimuth residuals at 3 hours, 52 minutes, and 24 seconds GMT corresponds to the maximum elevation of the pass. Also note the triangular range residual pattern. The radar operator indicated that a slight beacon frequency shift was observed during this pass.

A-56. Revolution 4, Carnarvon: RAE (Segment 2 BET)



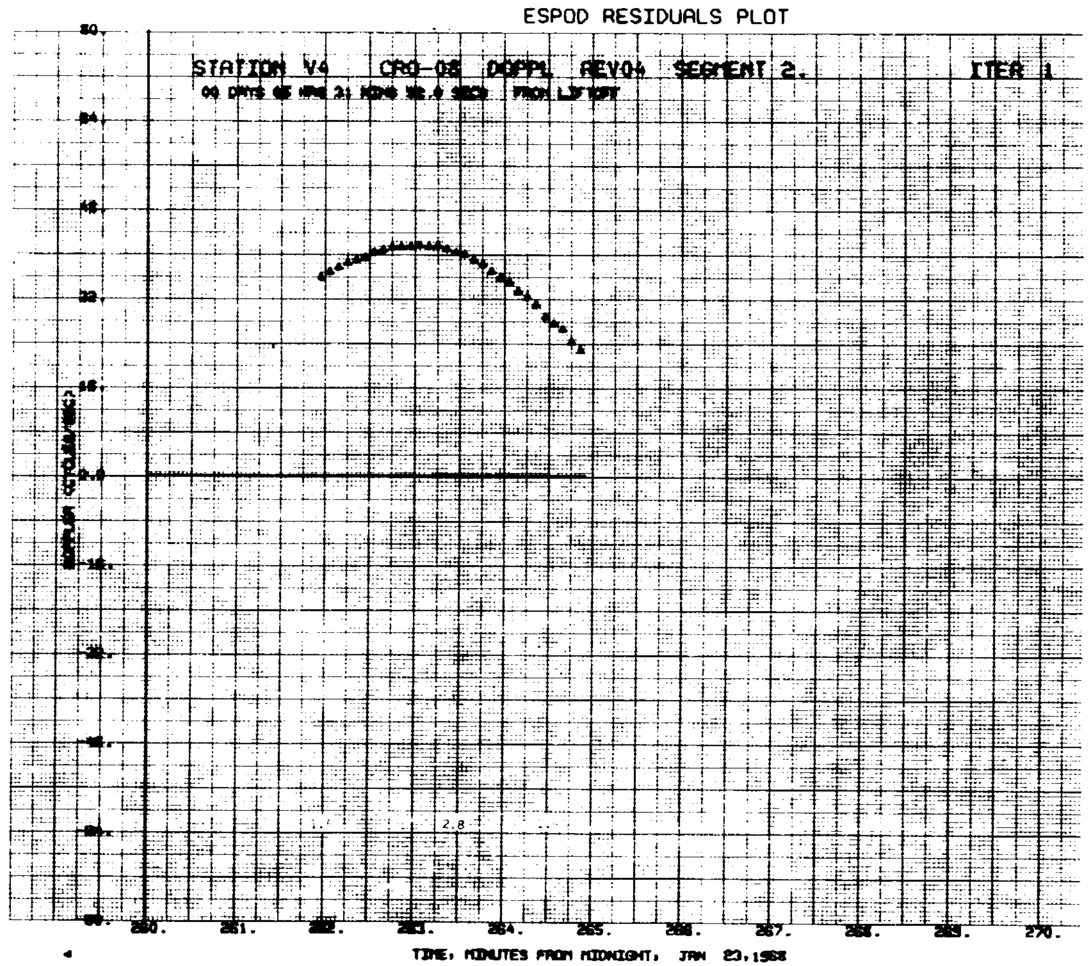
Note: • The maximum elevation for this pass was 3 degrees.

A-57. Revolution 4, Carnarvon: RXY (Segment 2 BET)



Note:
- The maximum elevation for this pass was 3 degrees.
- These data were weighted out of the fit.

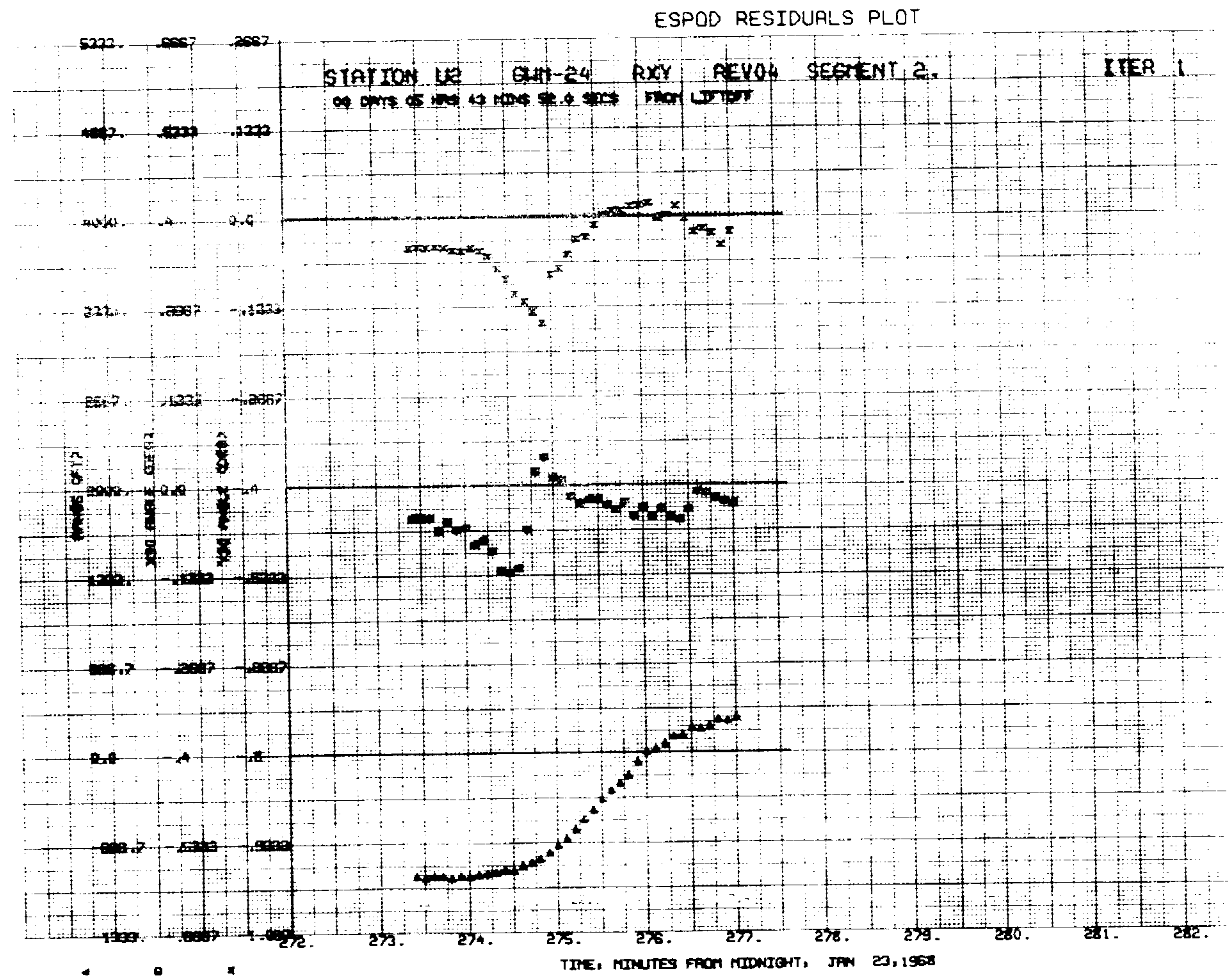
A-58. Revolution 4, Carnarvon: Doppler (Segment 2 BET)



Note: • The maximum elevation for this pass was 3 degrees.

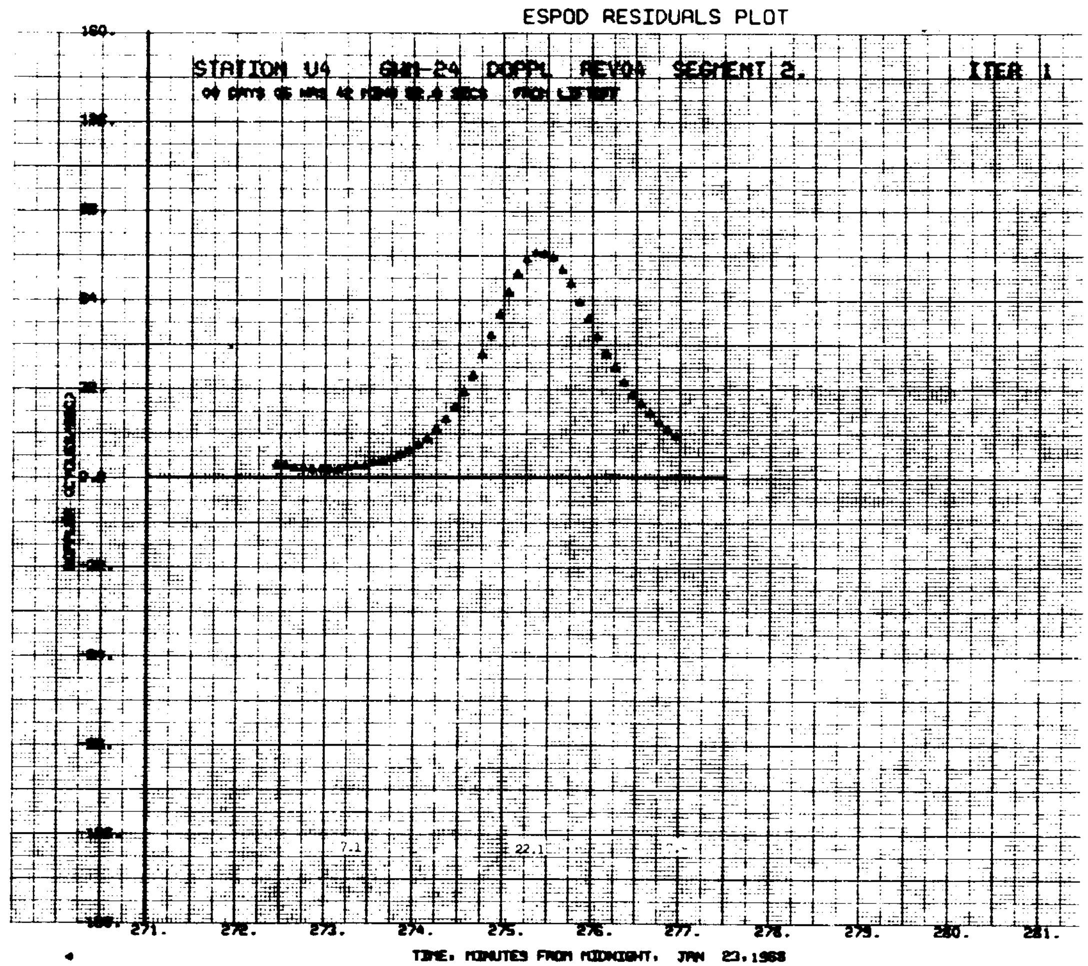
• These data were weighted out of the fit.

A-59. Revolution 4, Guam: RXY (Segment 2 BET)



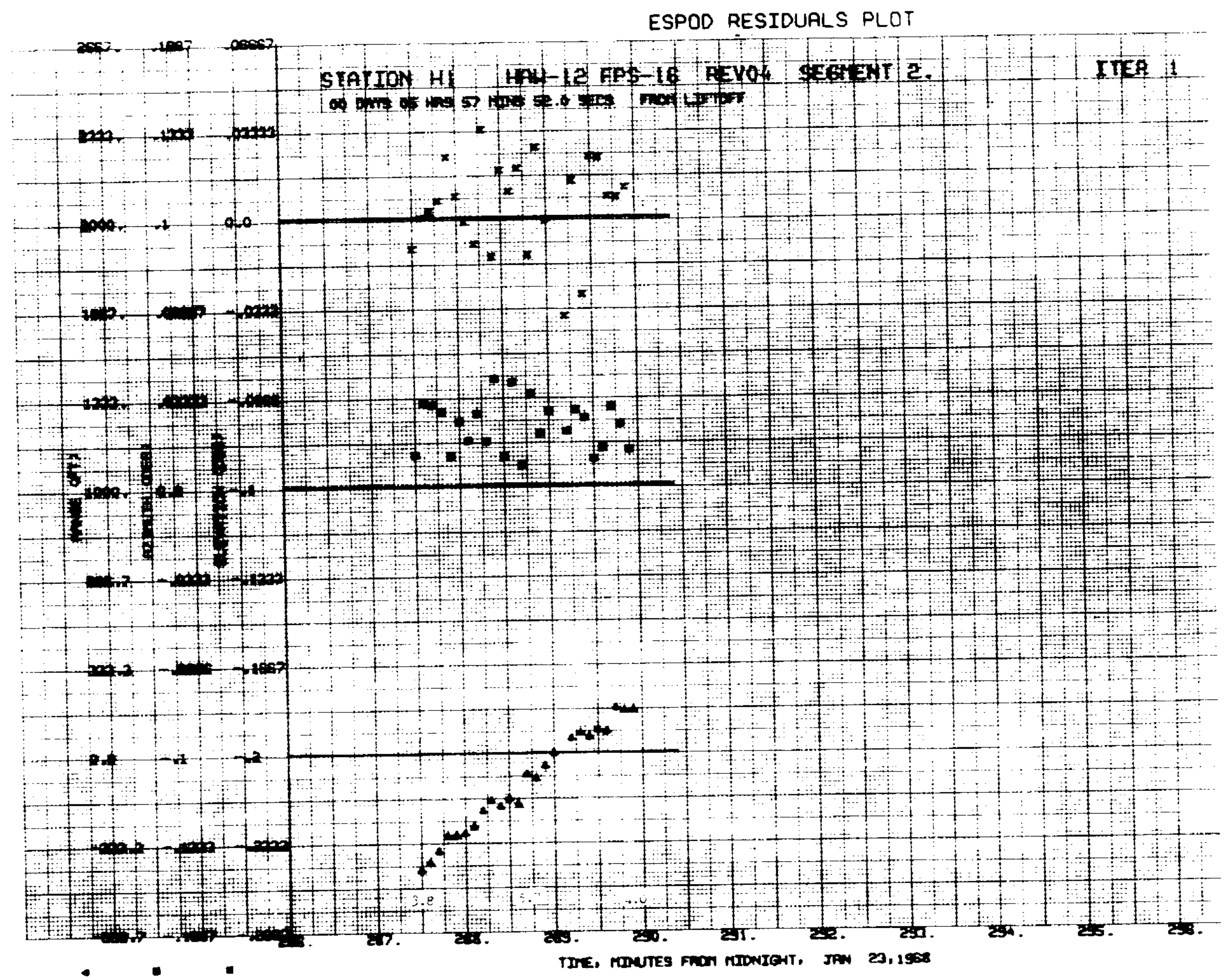
Note: ● There is a discontinuity in the Y-angle residual pattern at 4 hours, 34 minutes, and 54 seconds GMT.

A-60. Revolution 4, Guam: Doppler (Segment 2 BET)



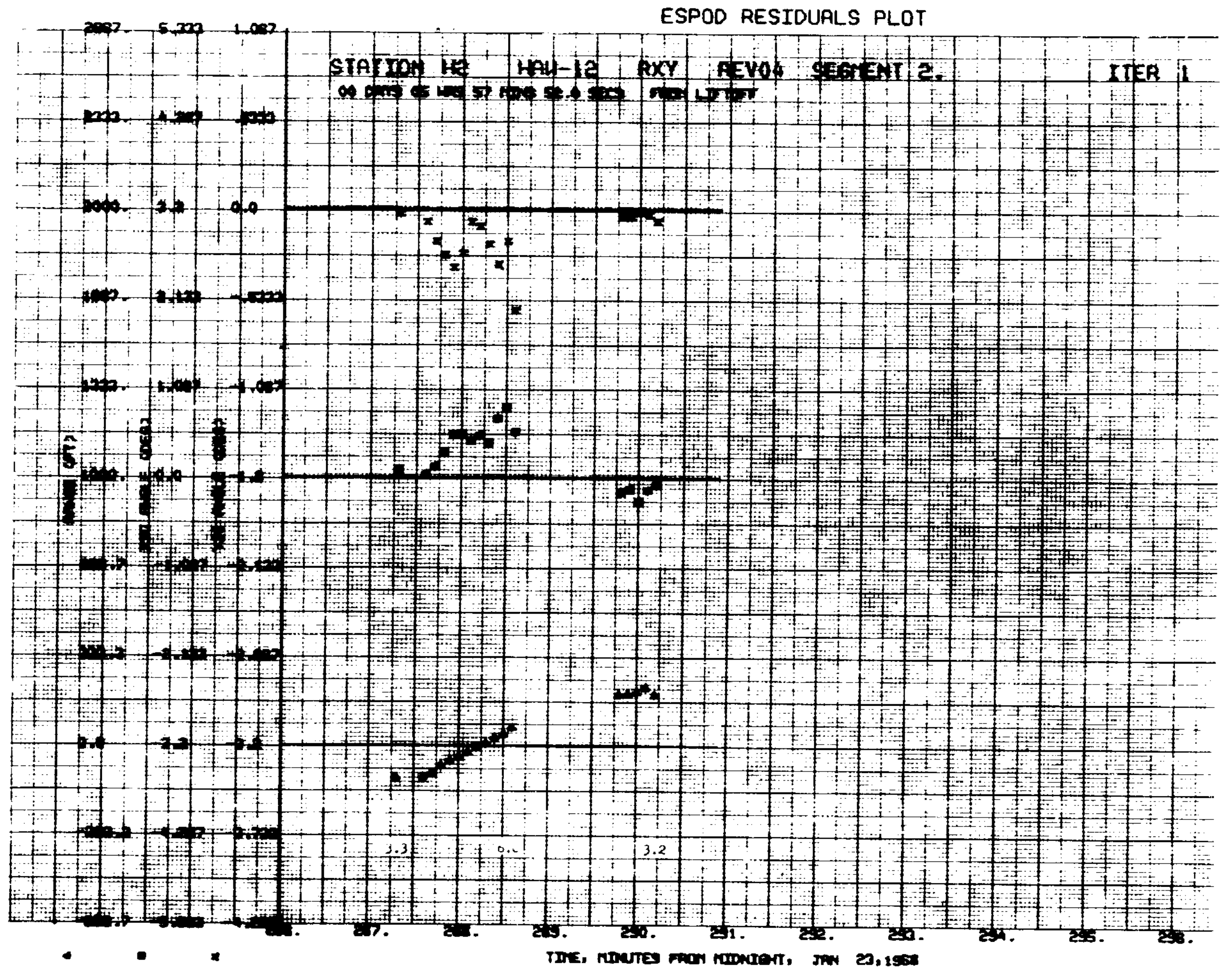
Note:
- The residual pattern indicates an apparent timing error.
- These data were weighted out of the fit.

A-61. Revolution 4, Hawaii: RAE (Segment 2 BET)



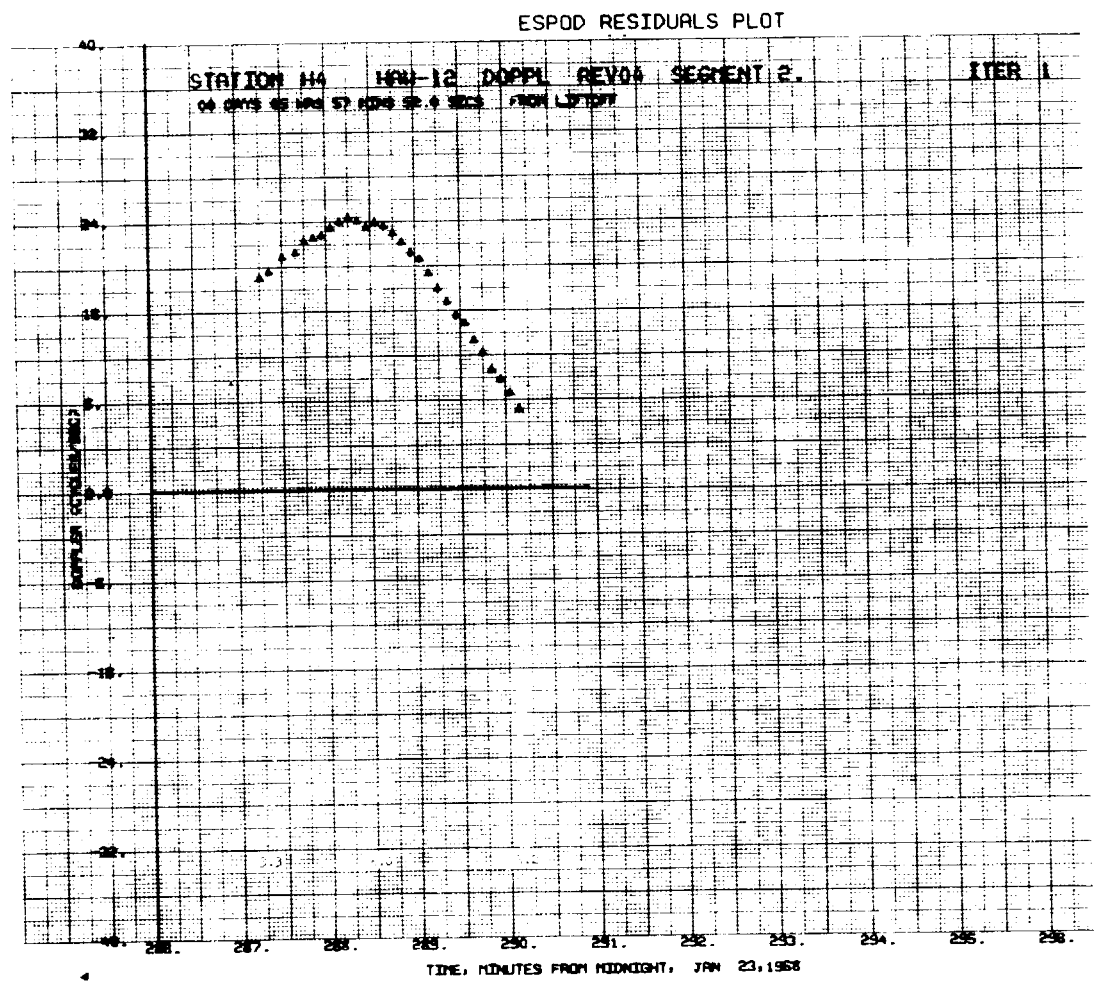
Note: ● The elevation residuals are noisy during this pass.

A-62. Revolution 4, Hawaii: RXY (Segment 2 BET)



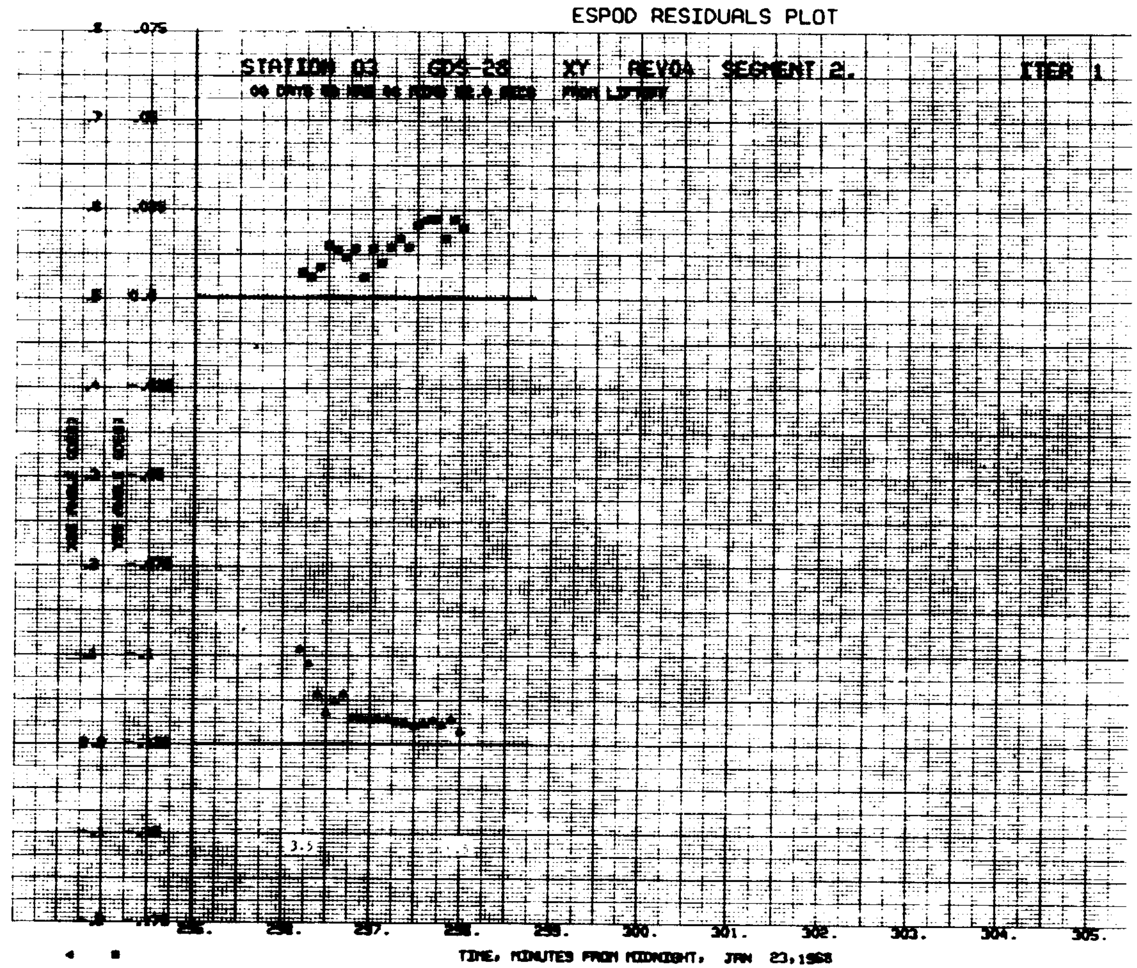
Note: ● The maximum elevation during this pass was 6 degrees.

A-63. Revolution 4, Hawaii: Doppler (Segment 2 BET)



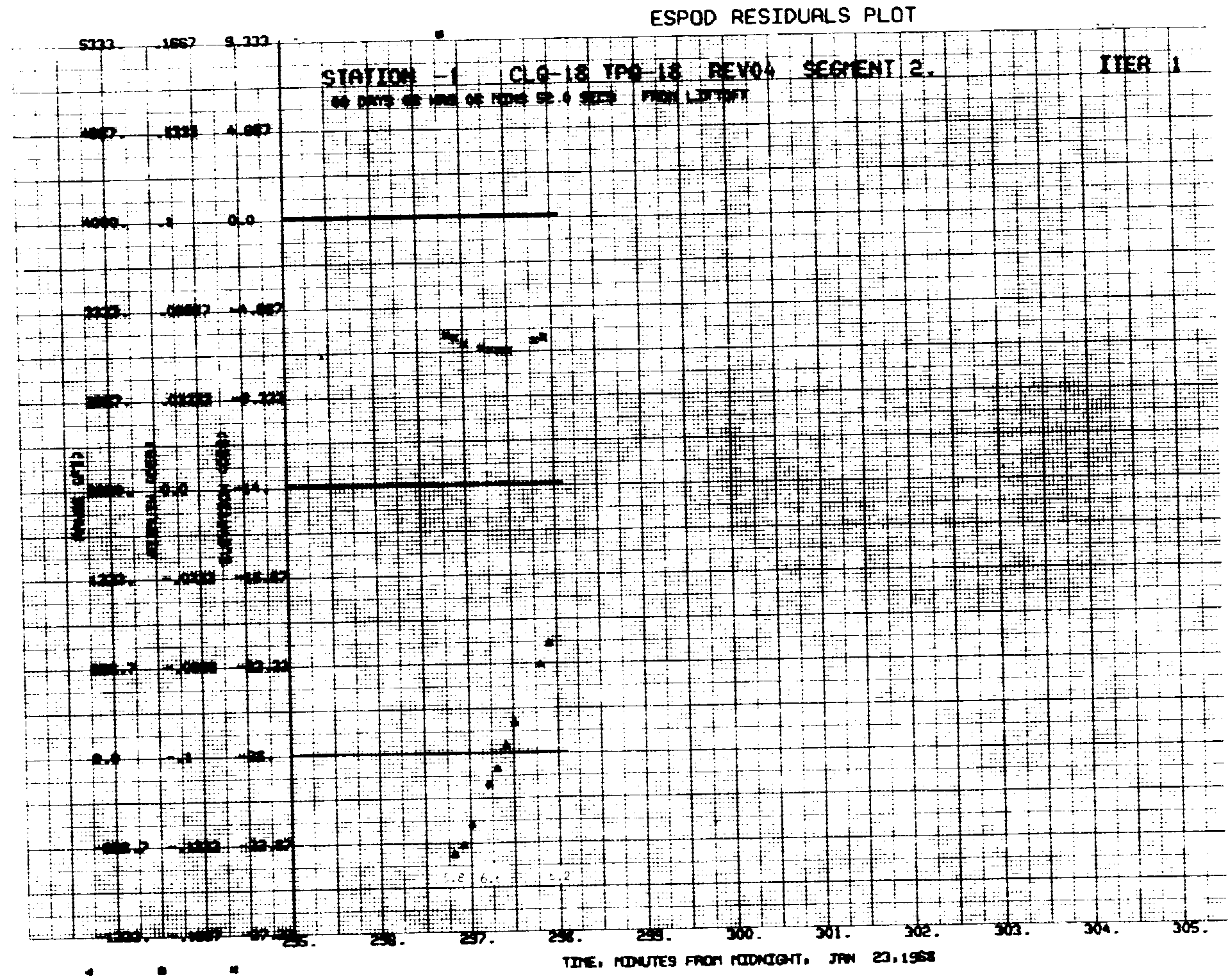
Note:
- The maximum elevation during this pass was 6 degrees.
- These data were weighted out of the fit.

A-64. Revolution 4, Goldstone: XY (Segment 2 BET)



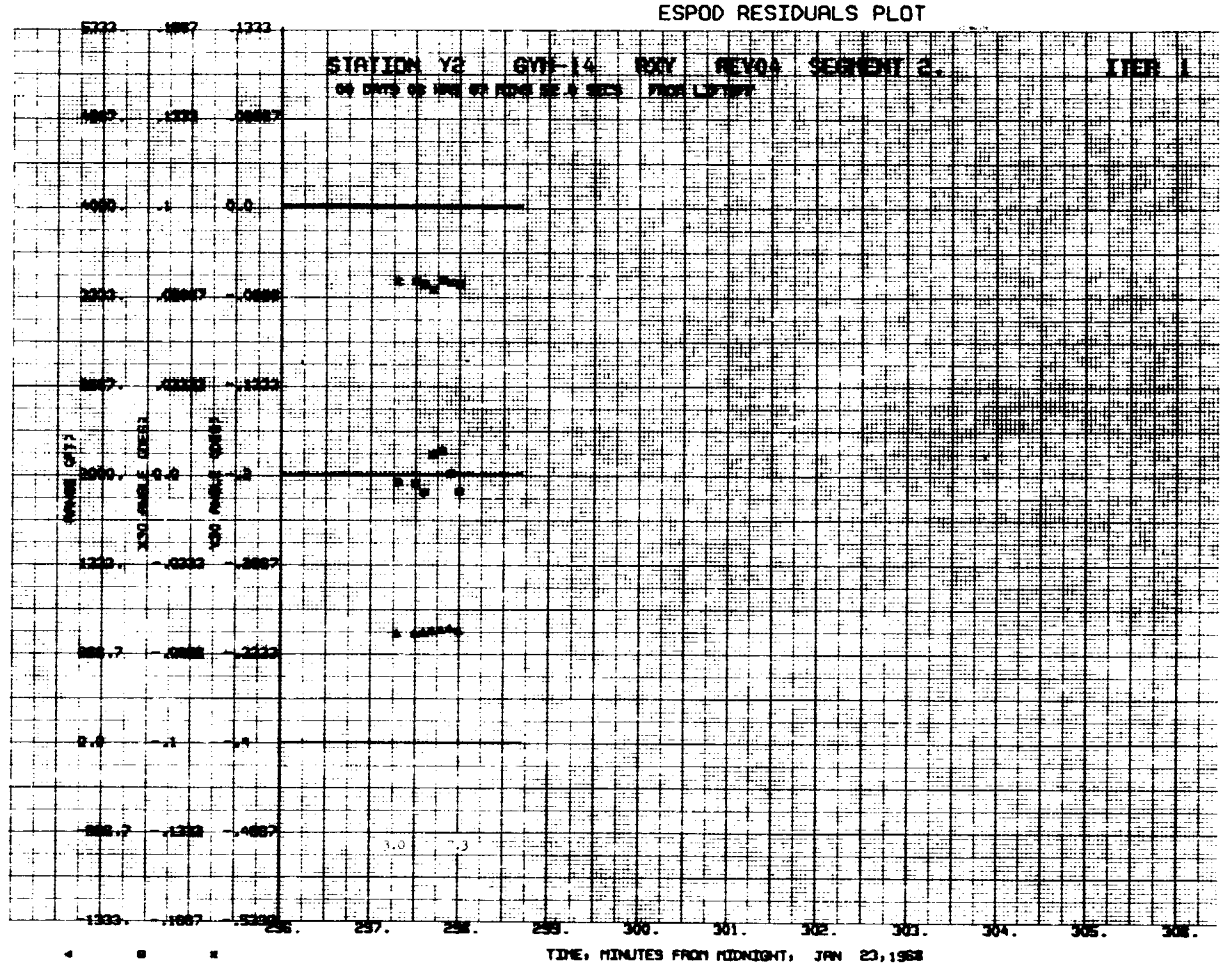
Note: ● These data occurred prior to PRA III.

A-65. Revolution 4, California: RAE (Segment 2 BET)



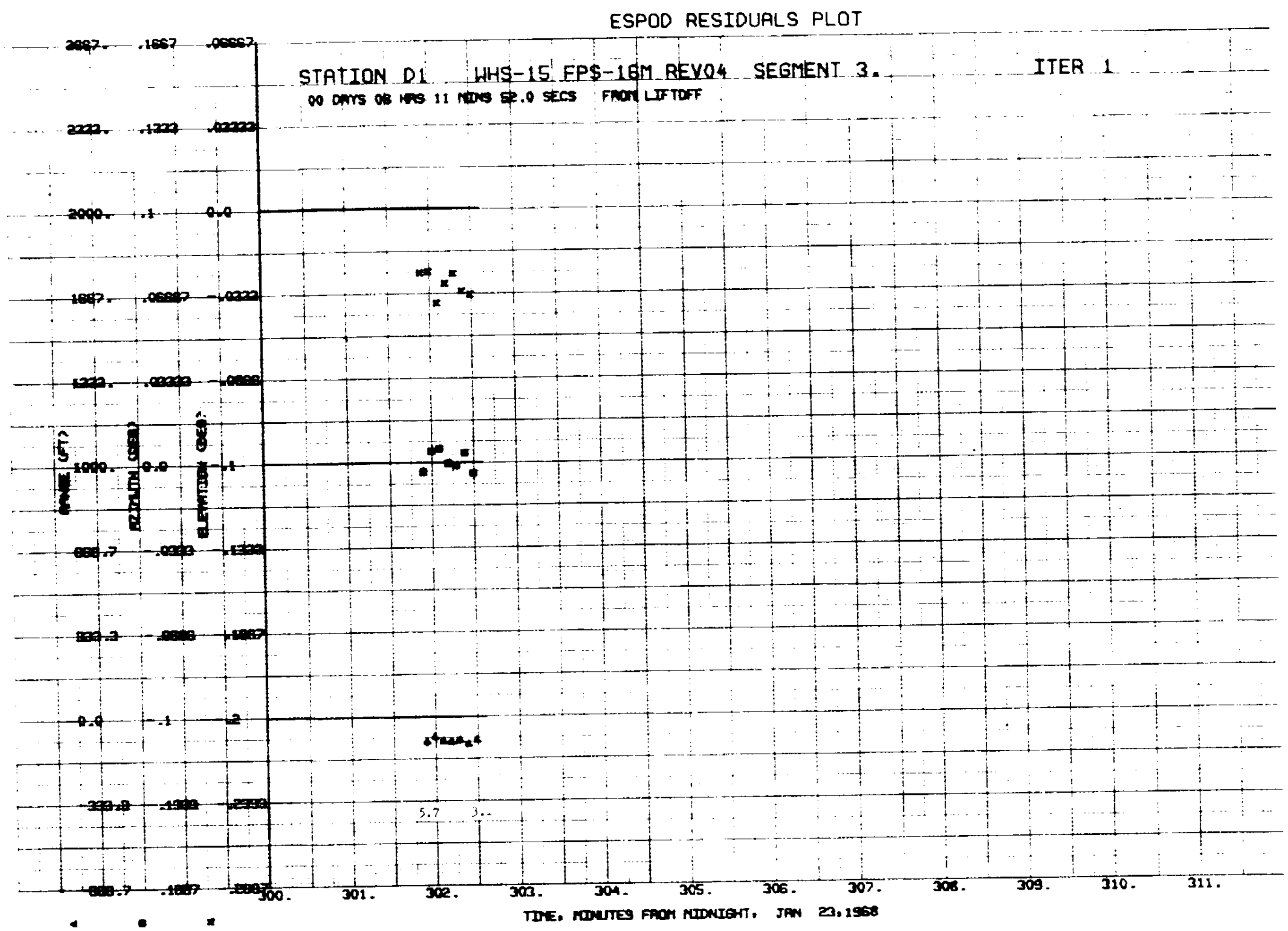
Note: ● The granularity that the RTCC used for the angle observations was doubled in order to plot the residuals for this pass.

A-66. Revolution 4, Guaymas: RXY (Segment 2 BET)



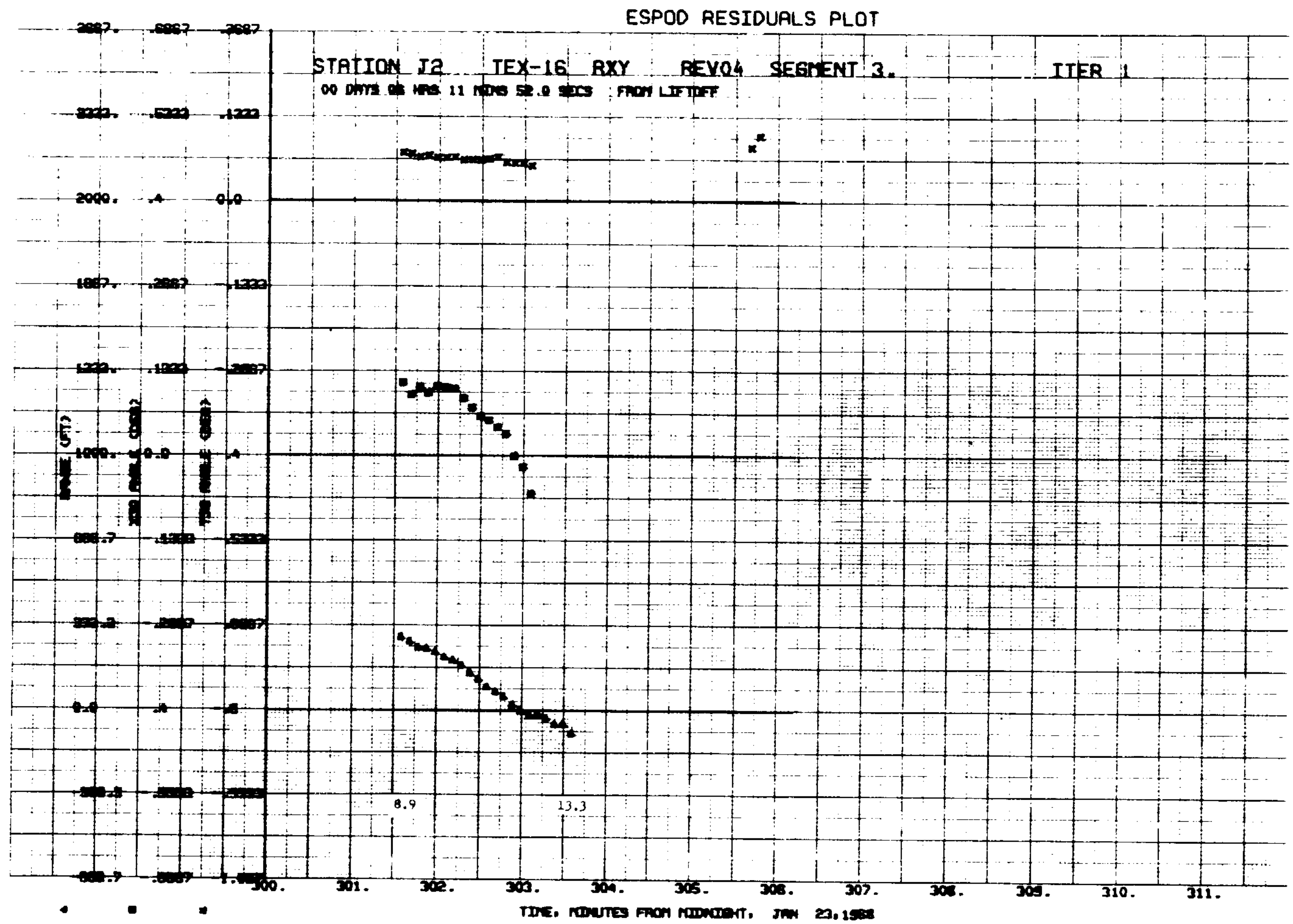
Note: ● These data occurred prior to PRA III.

A-67. Revolution 4, White Sands: RAE (Segment 3 BET)



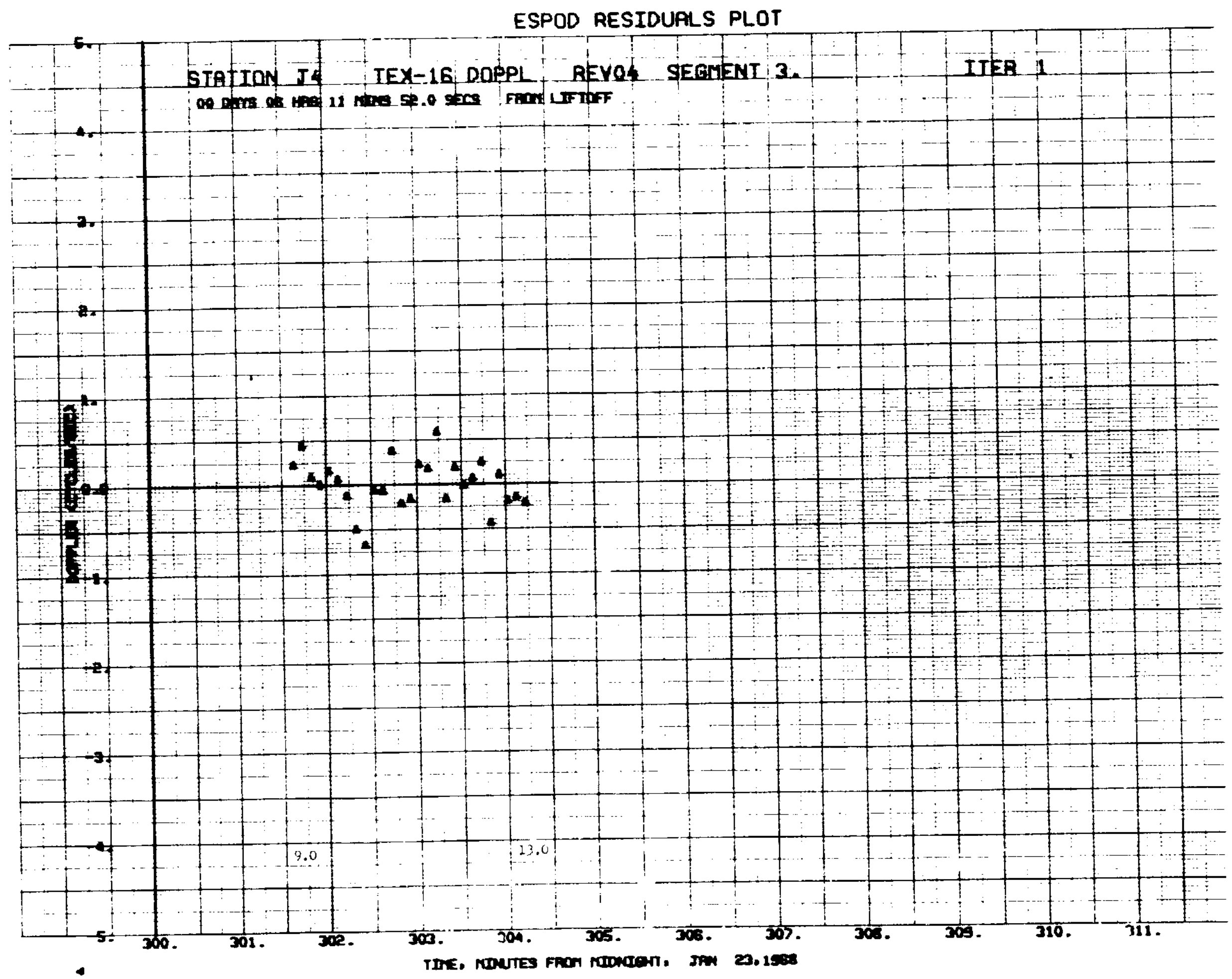
Note: ● These data occurred during the first period of thruster activity following PRA III.

A-68. Revolution 4, Texas: RXY (Segment 3 BET)



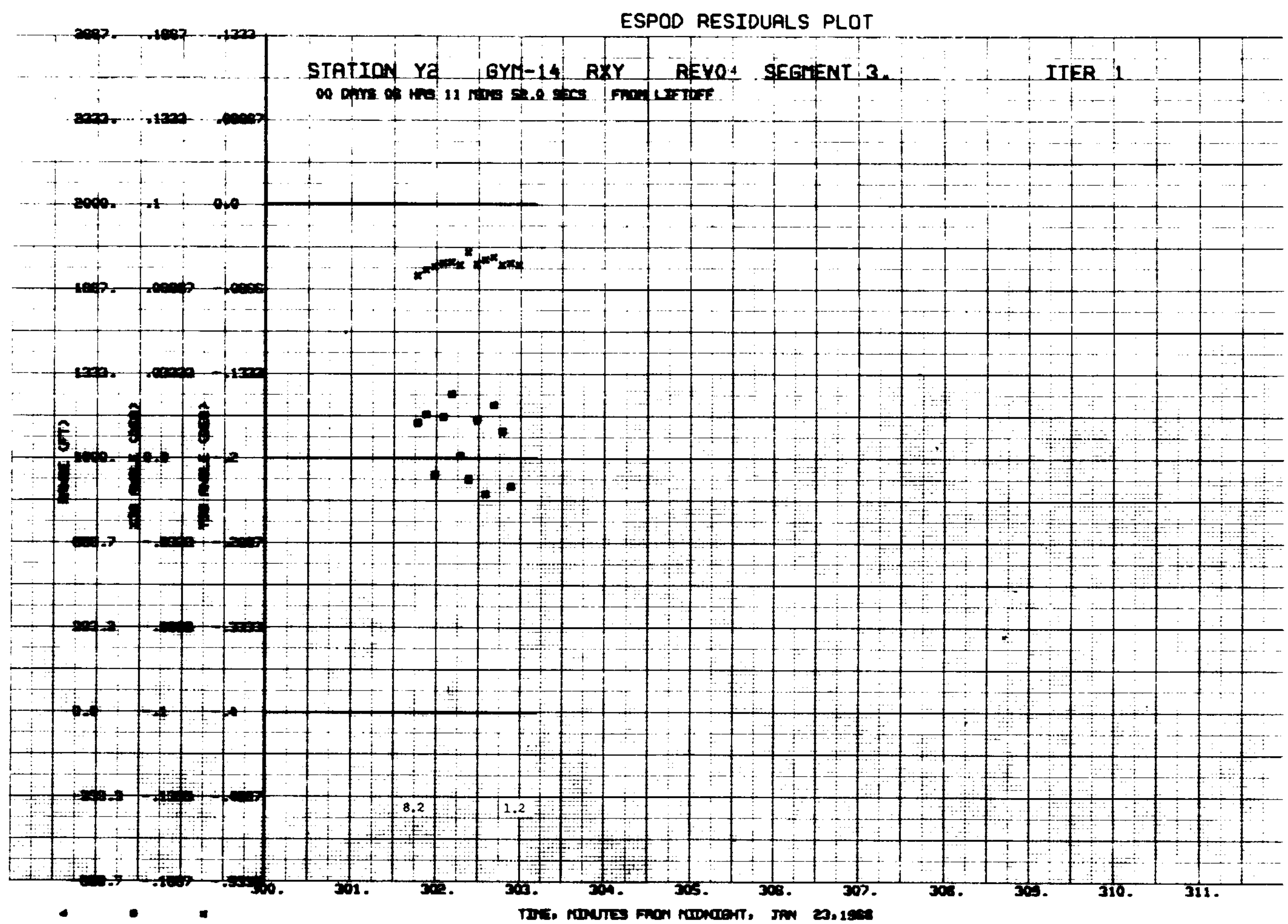
Note:
- These data occurred during the first period of thruster activity following PRA III.
- Note the Y-angle bias.

A-69. Revolution 4, Texas: Doppler (Segment 3 BET)



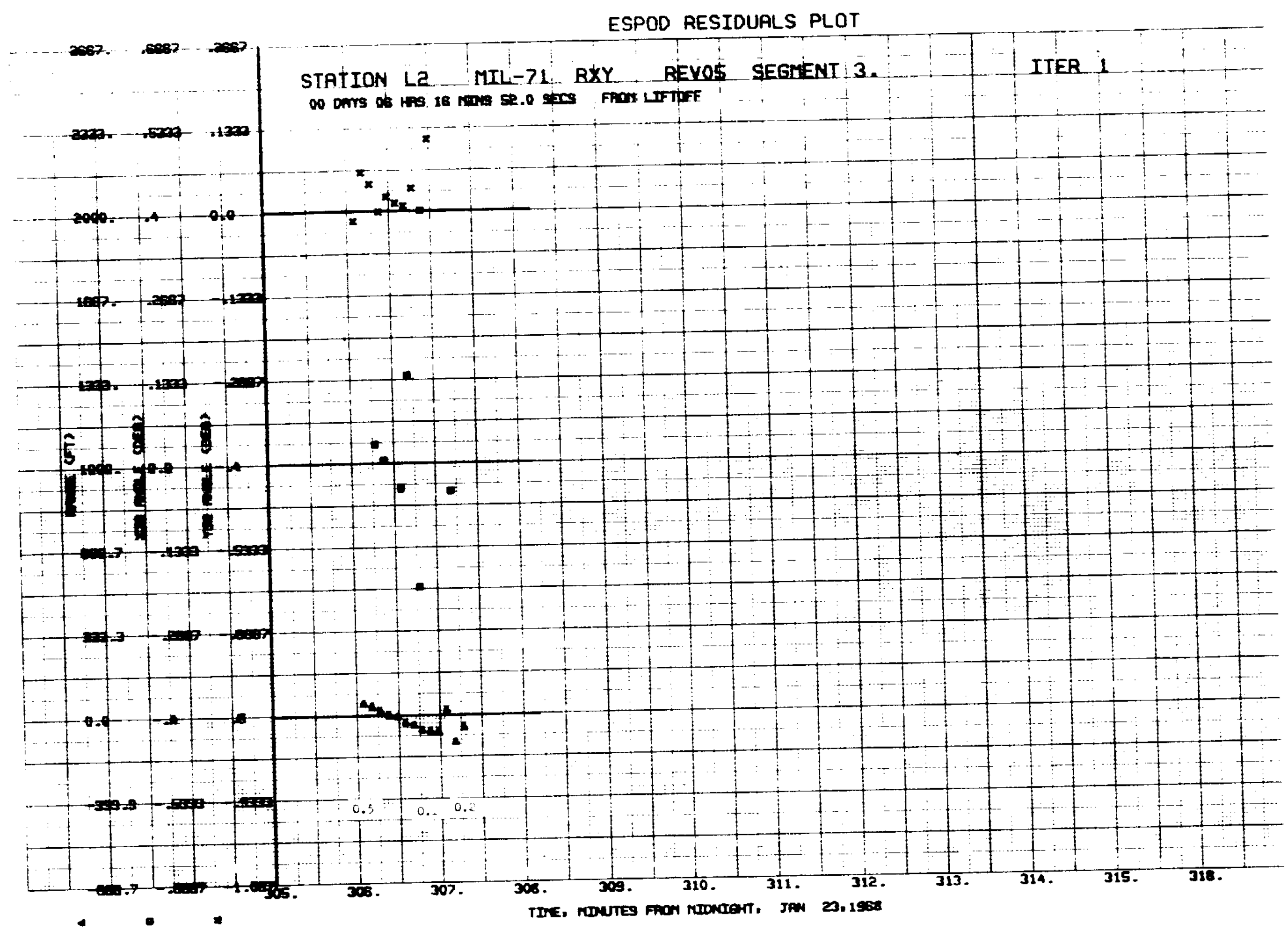
Note: • These data occurred during the first period of thruster activity following PRA III.

A-70. Revolution 4, Guaymas: RXY (Segment 3 BET)



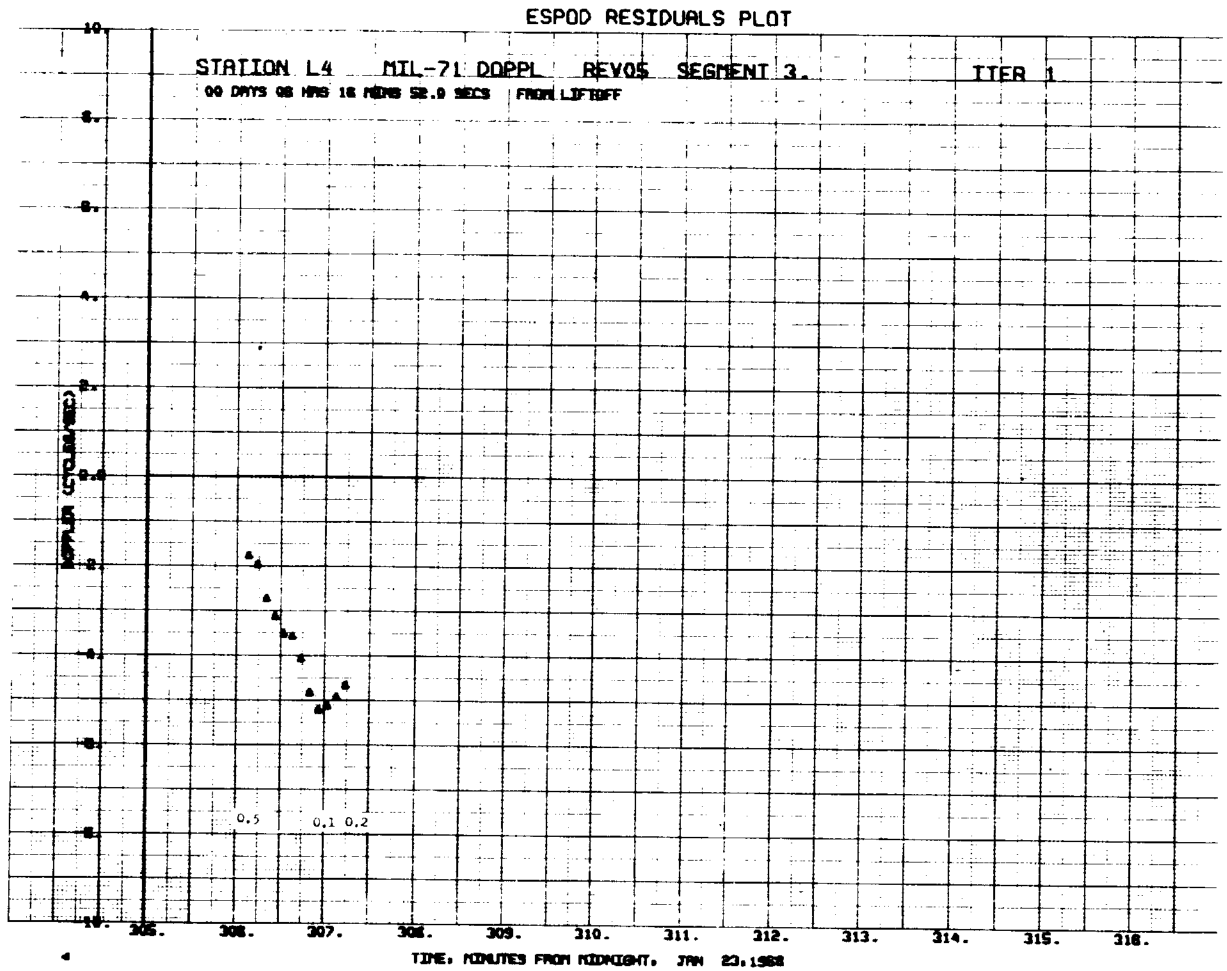
Note: • These X-, Y-angle data occurred during the first period of thruster activity following PRA III.

A-71. Revolution 5, Merritt Island: RXY (Segment 3 BET)



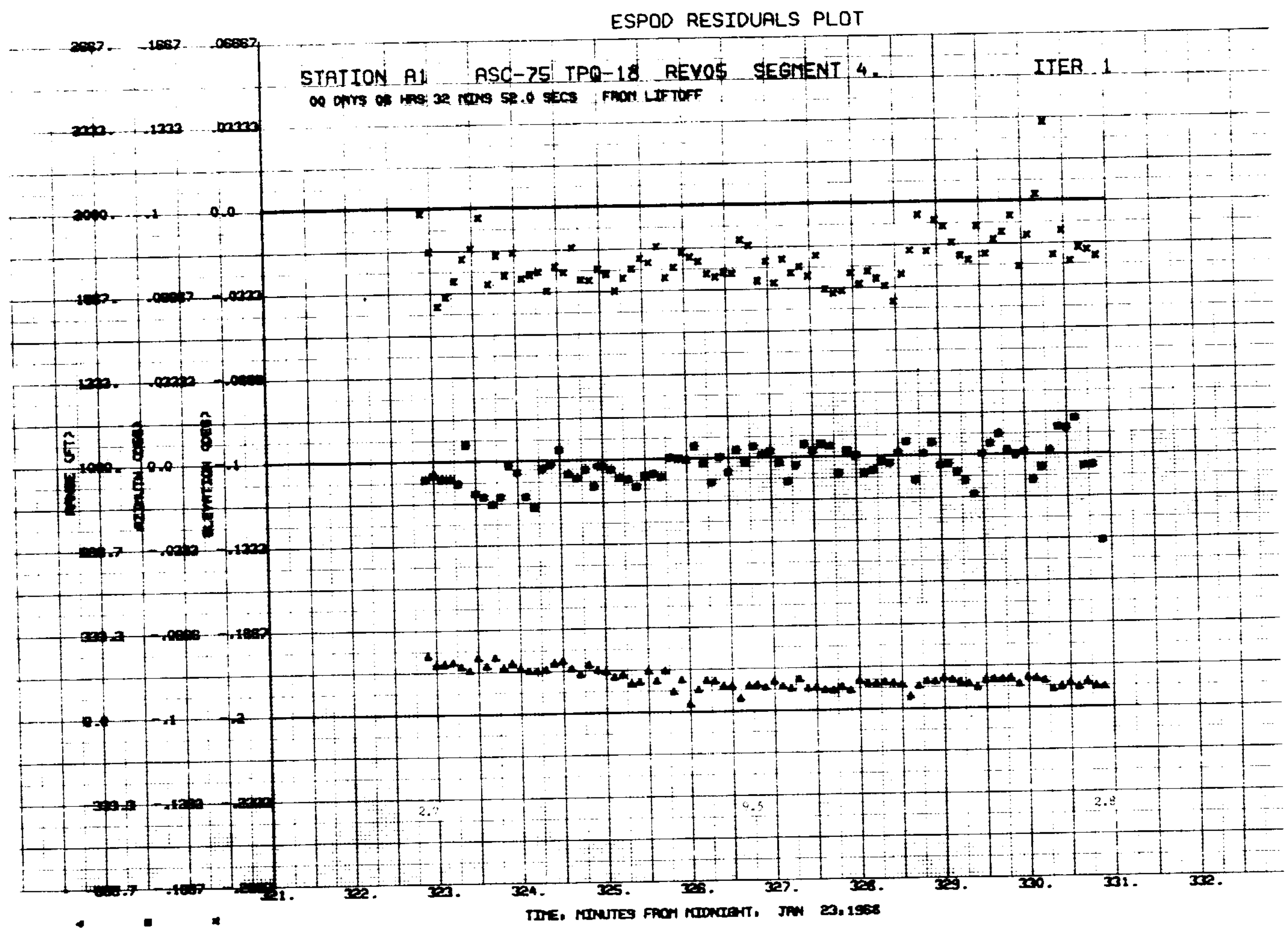
Note: ● These data occurred during the first period of thruster activity following PRA III.

A-72. Revolution 5, Merritt Island: Doppler (Segment 3 BET)

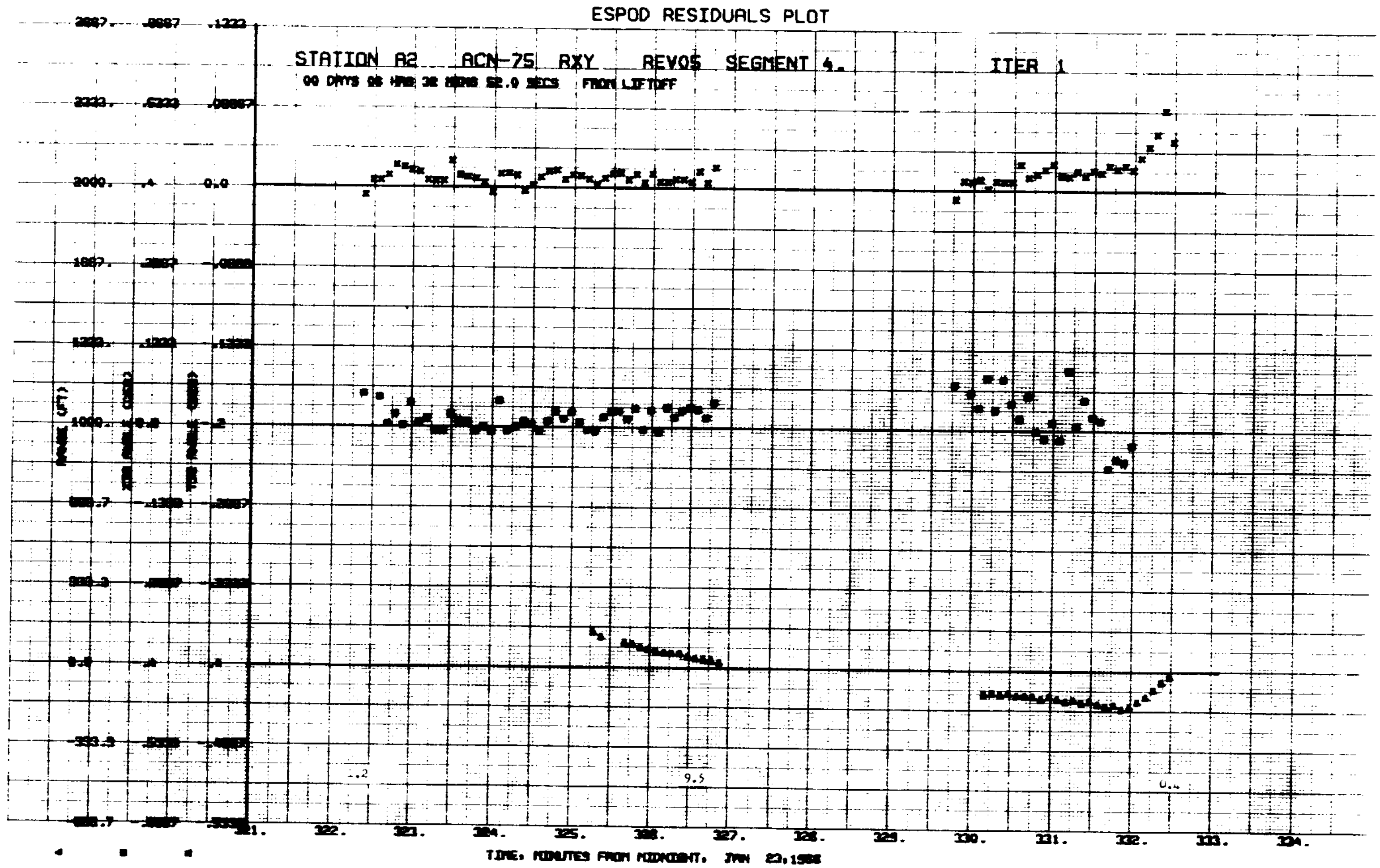


Note: • These data were not used in the fit.

A-73. Revolution 5, Ascension: RAE (Segment 4 BET)

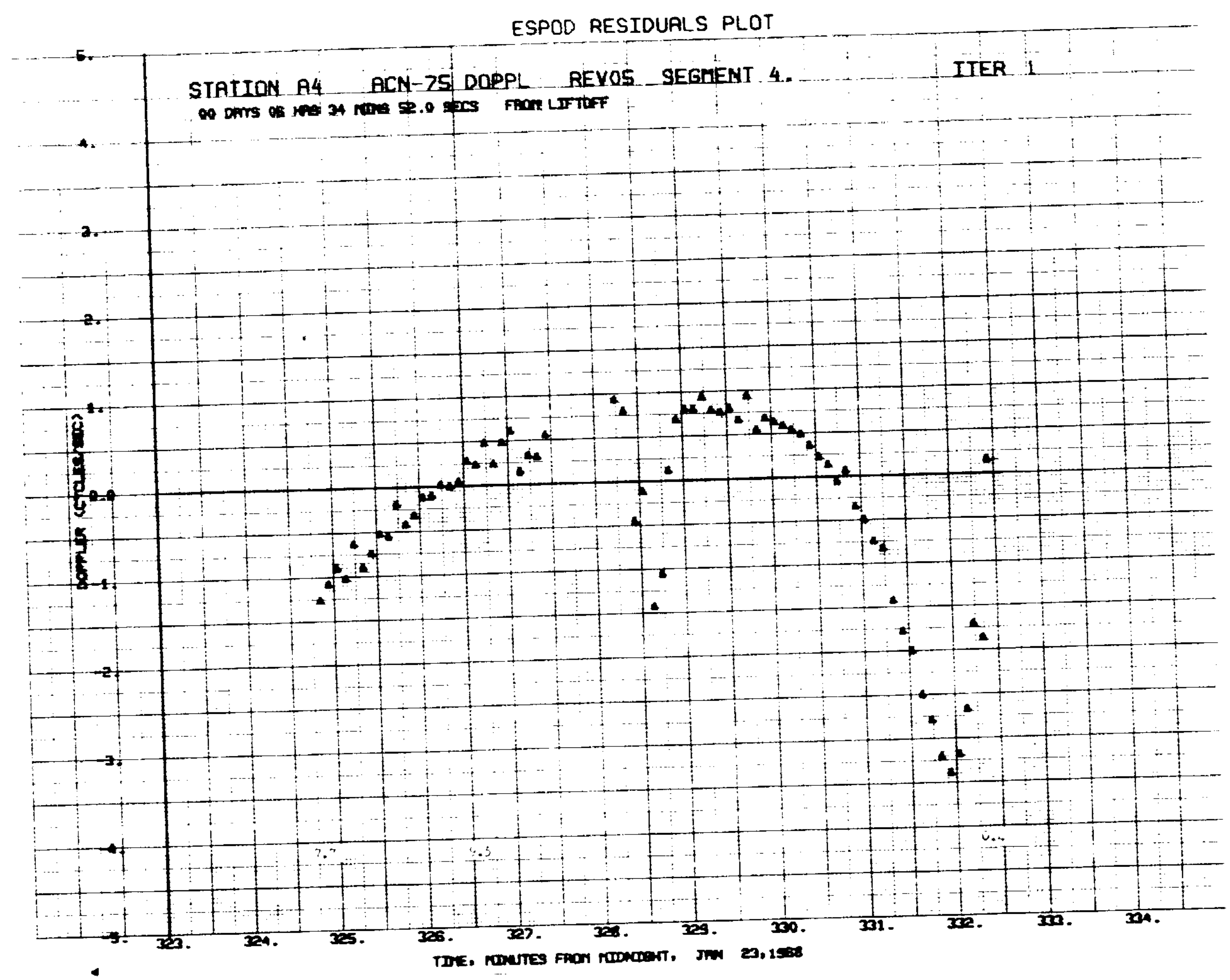


A-74. Revolution 5, Ascension: RXY (Segment 4 BET)

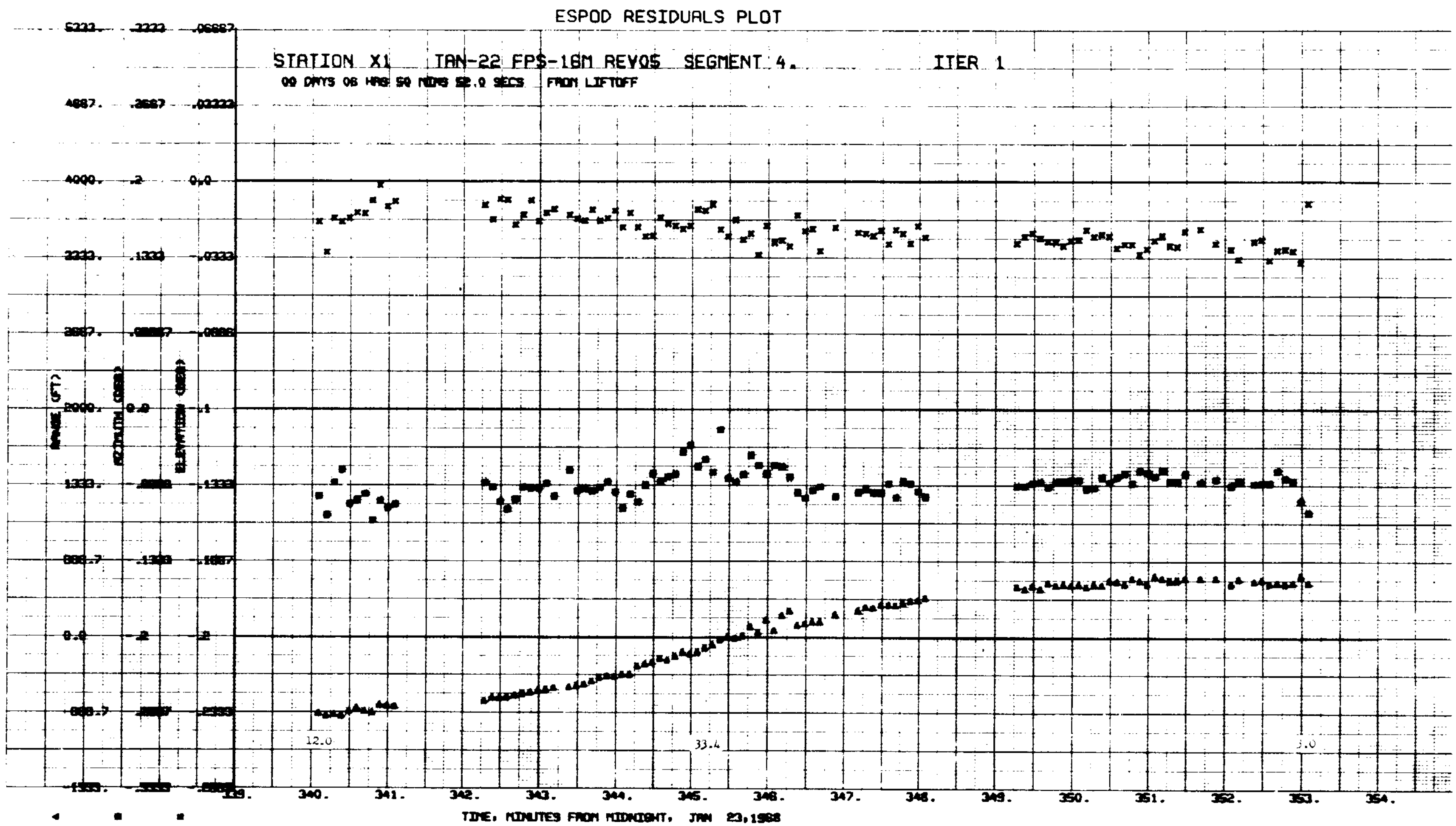


Note: • The data between 5 hours and 27 minutes GMT and 5 hours and 30 minutes GMT were tagged invalid by the station.

A-75. Revolution 5, Ascension: Doppler (Segment 4 BET)

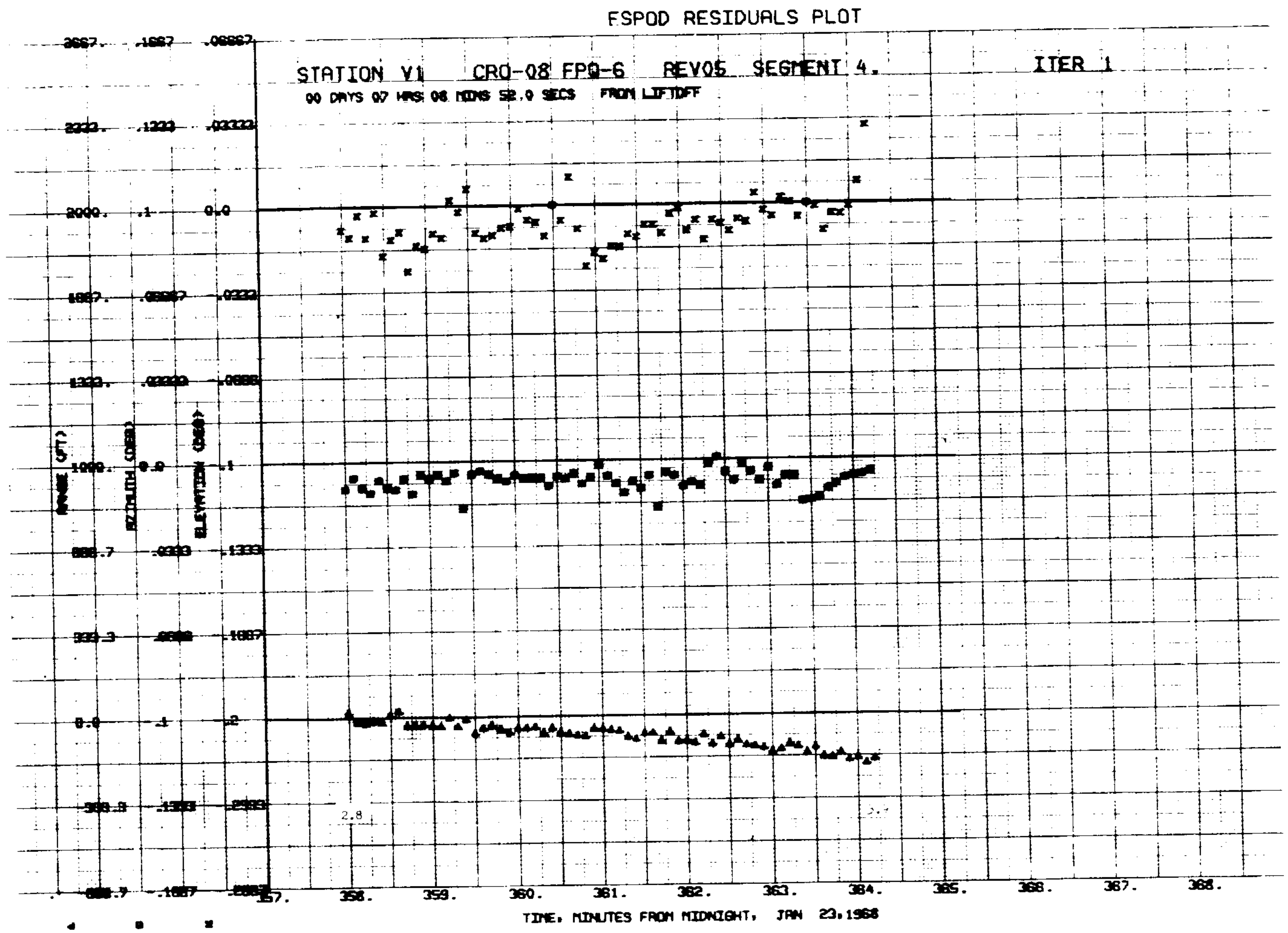


A-76. Revolution 5, Tananarive: RAE (Segment 4 BET)

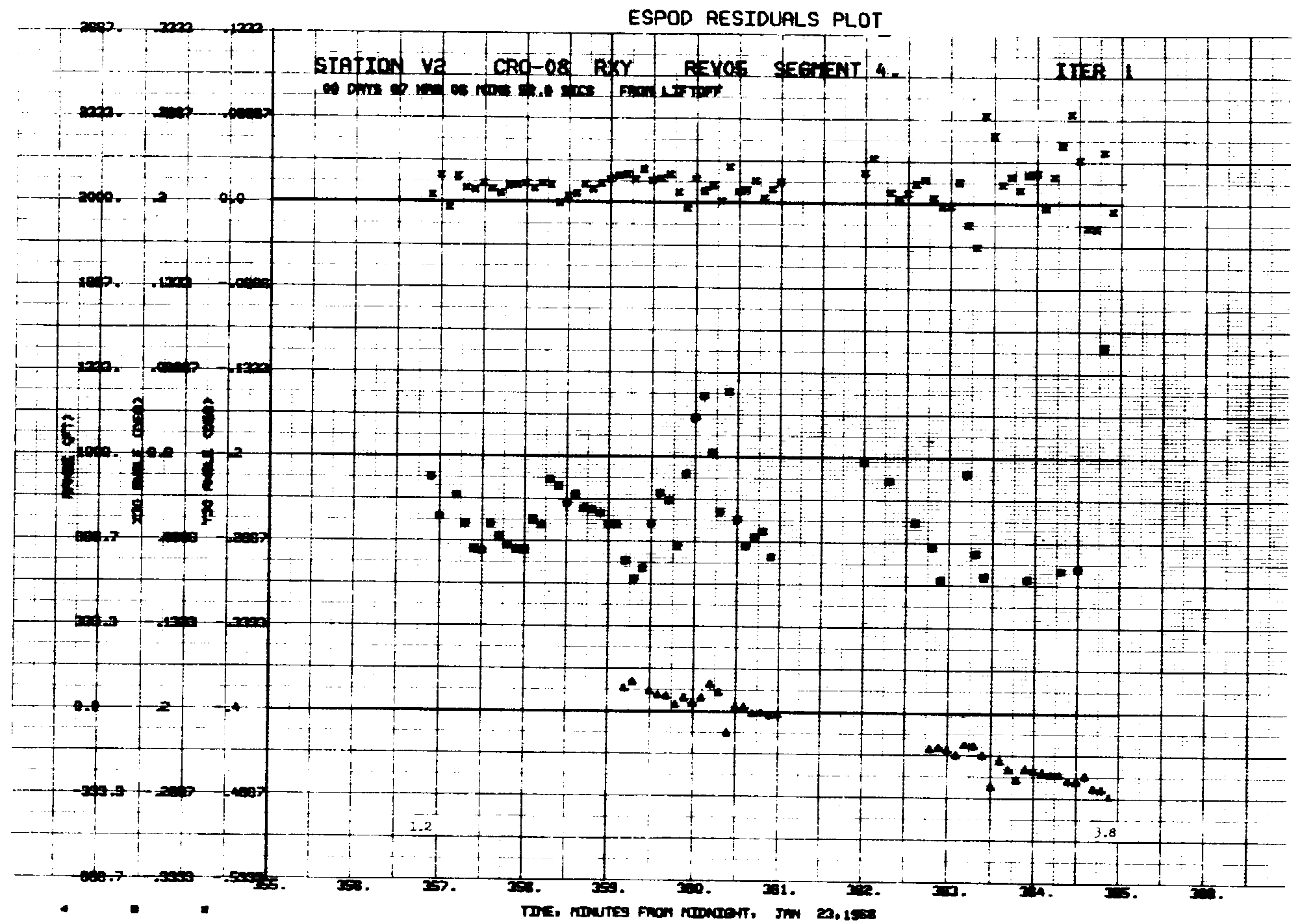


Note: ● Note the possible azimuth bias of -0. 065 degree.

A-77. Revolution 5, Carnarvon: RAE (Segment 4 BET)

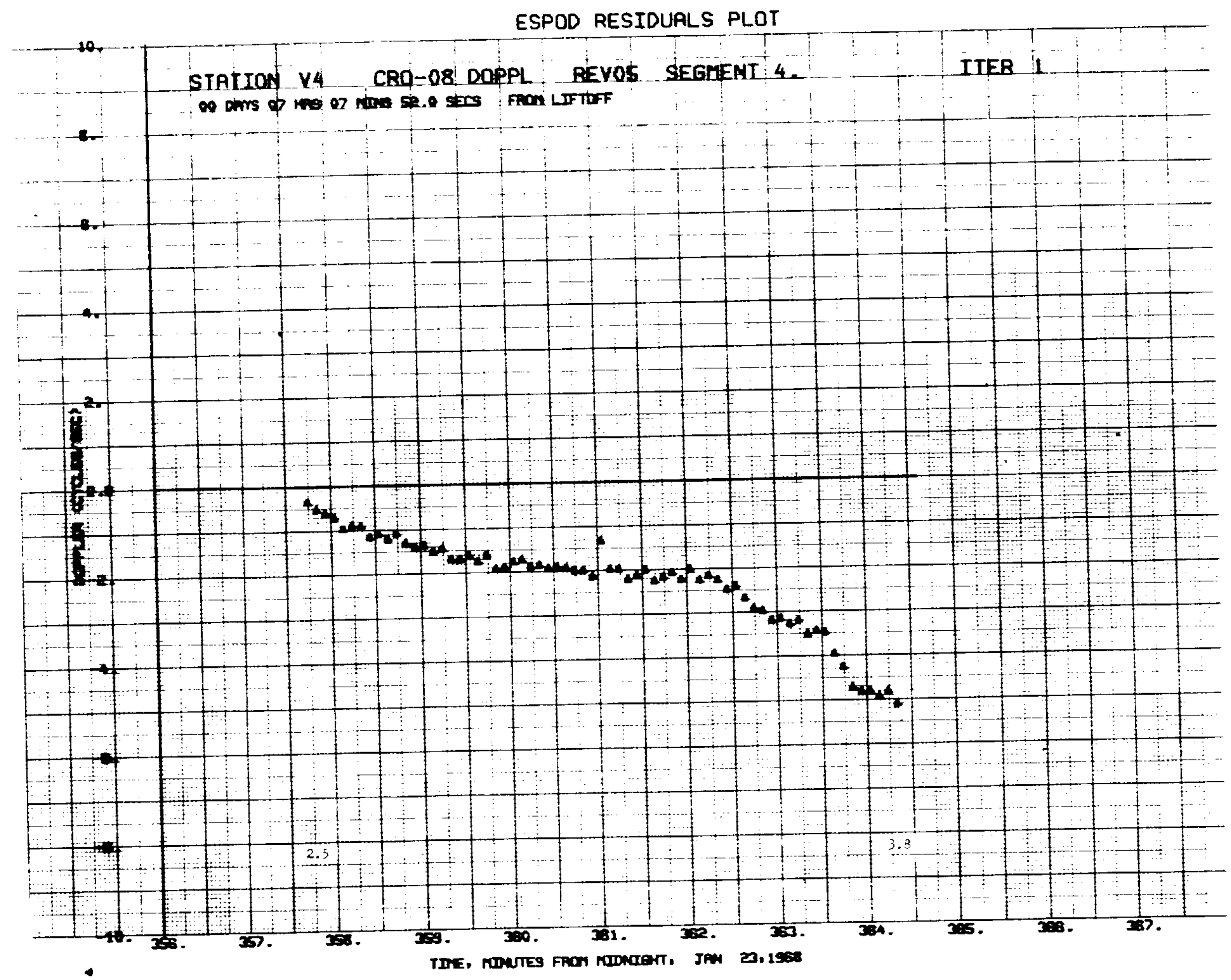


A-78. Revolution 5, Carnarvon: RXY (Segment 4 BET)

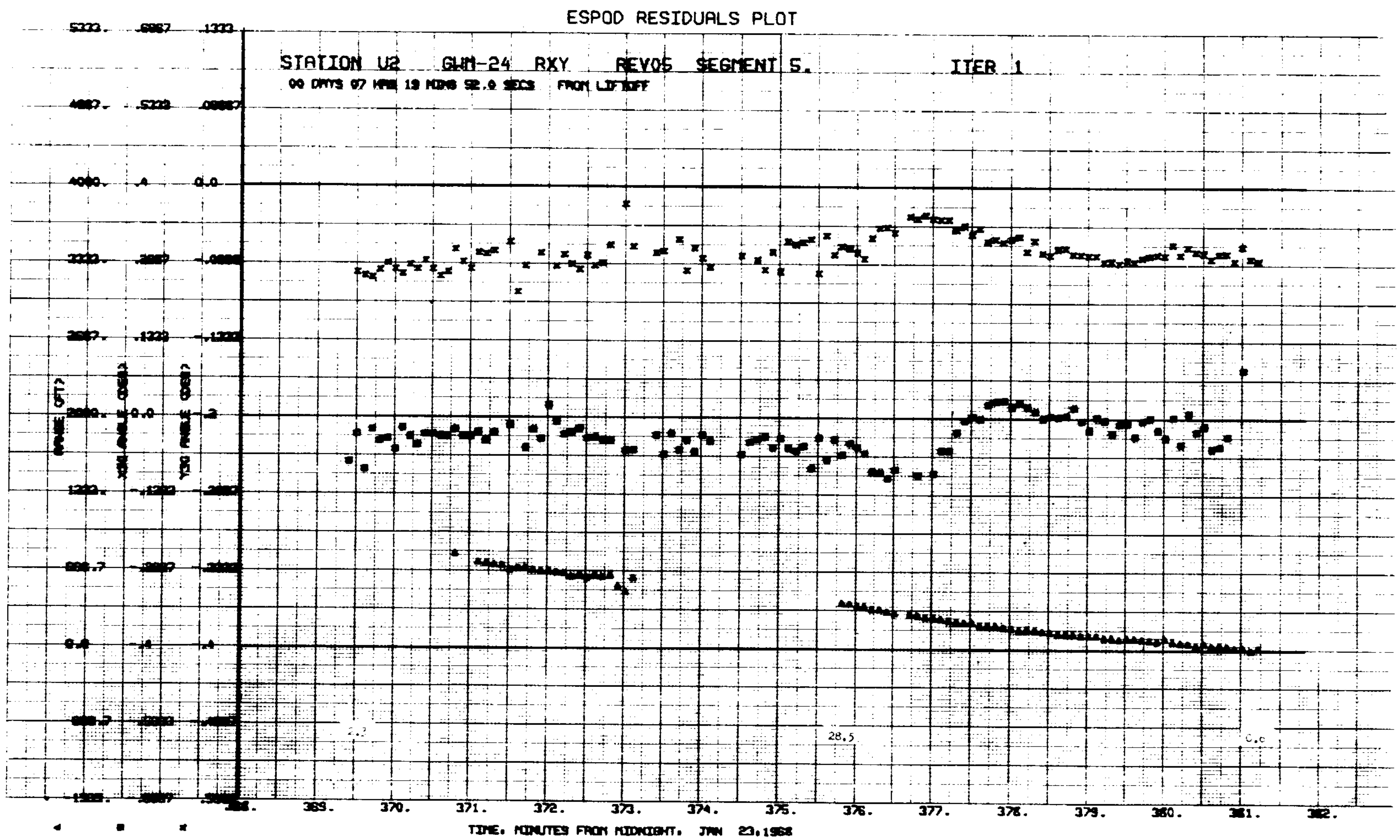


Note: ● Note the erratic X-angle residual pattern.

A-79. Revolution 5, Carnarvon: Doppler (Segment 4 BET)



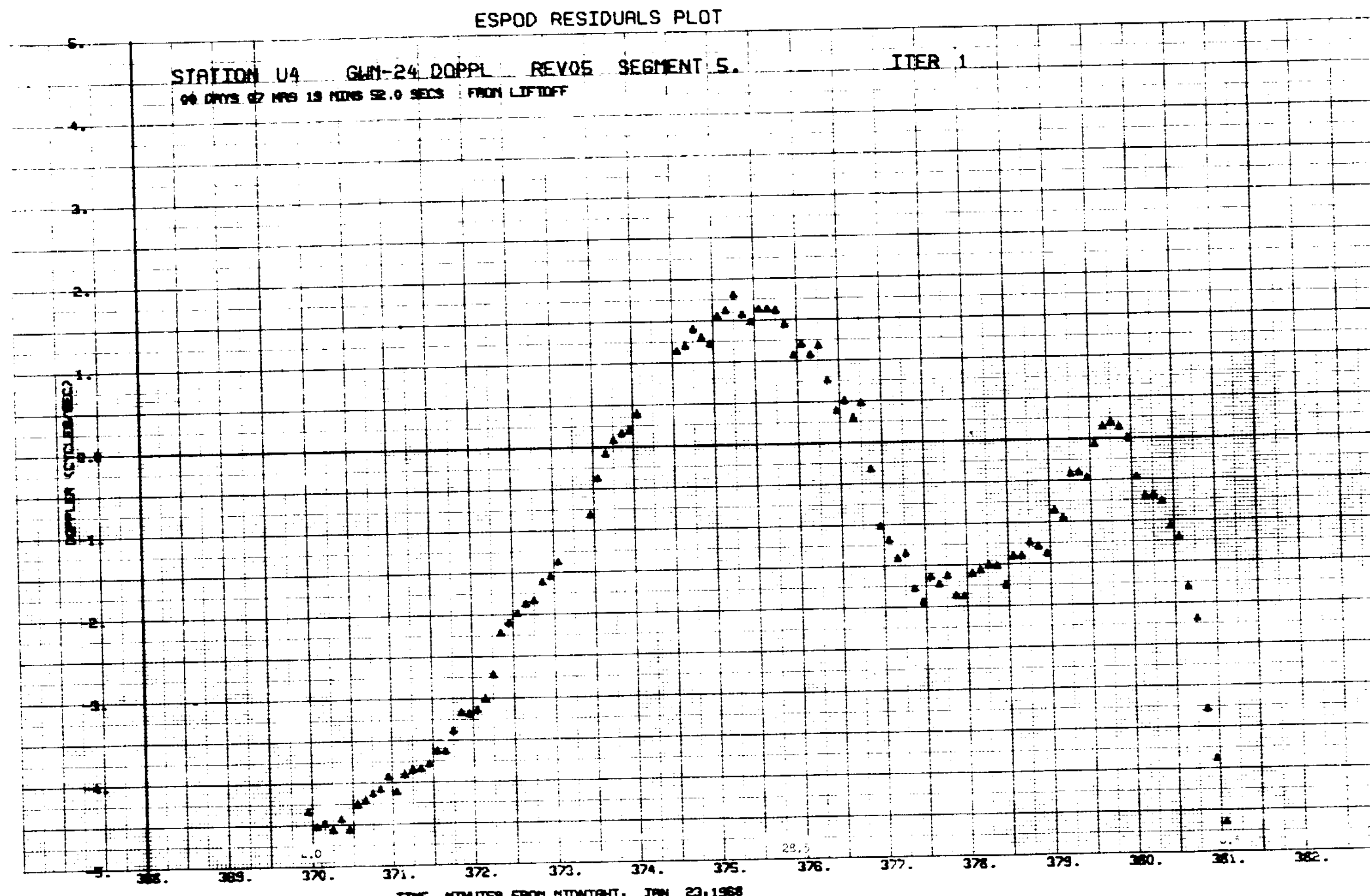
A-80. Revolution 5, Guam: RXY (Segment 5 BET)



Note:

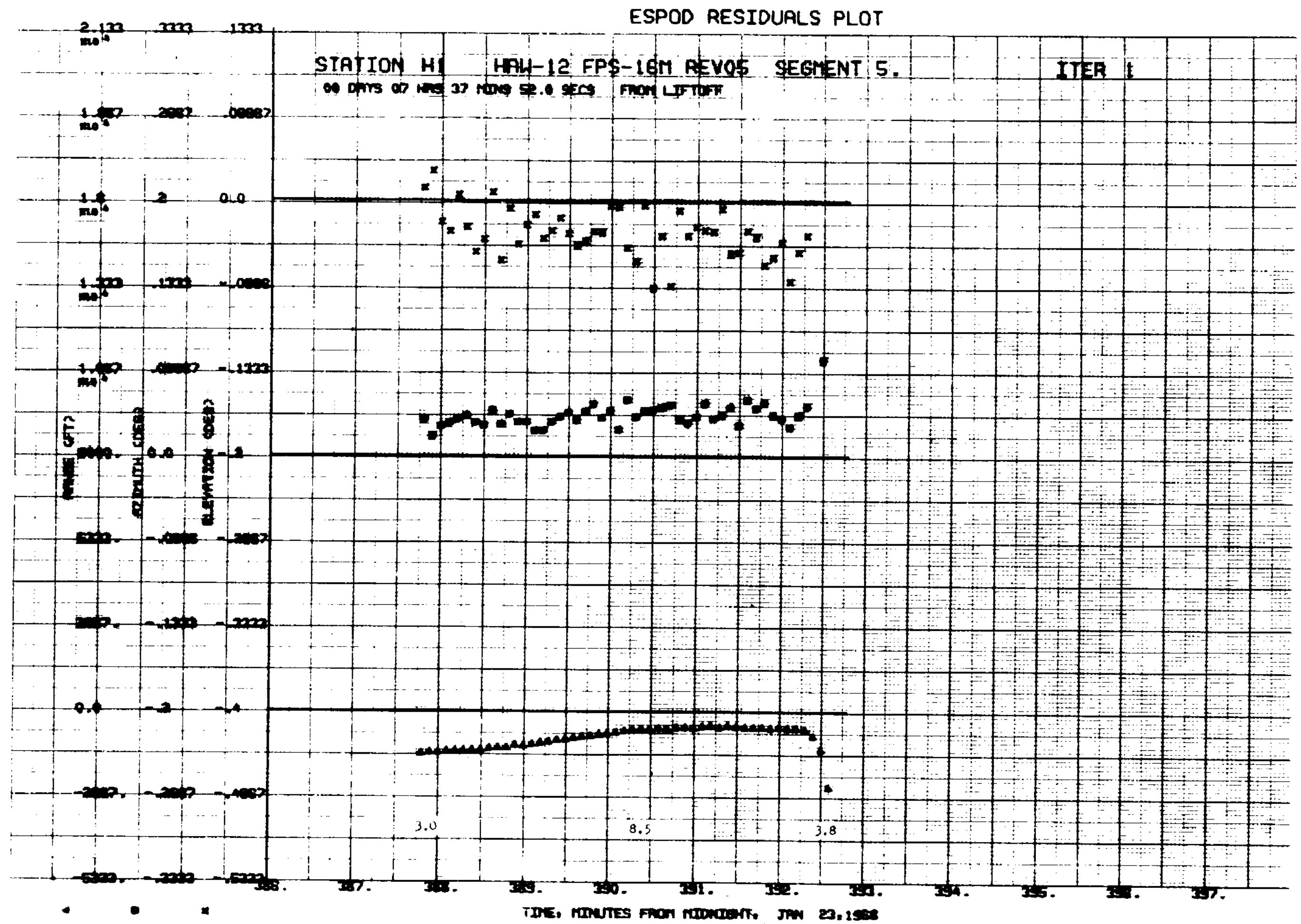
- These data occurred during the second period of thruster activity following PRA III.
- Note the data drops in the range data. These range data were tagged invalid at the station.

A-81. Revolution 5, Guam: Doppler (Segment 5 BET)



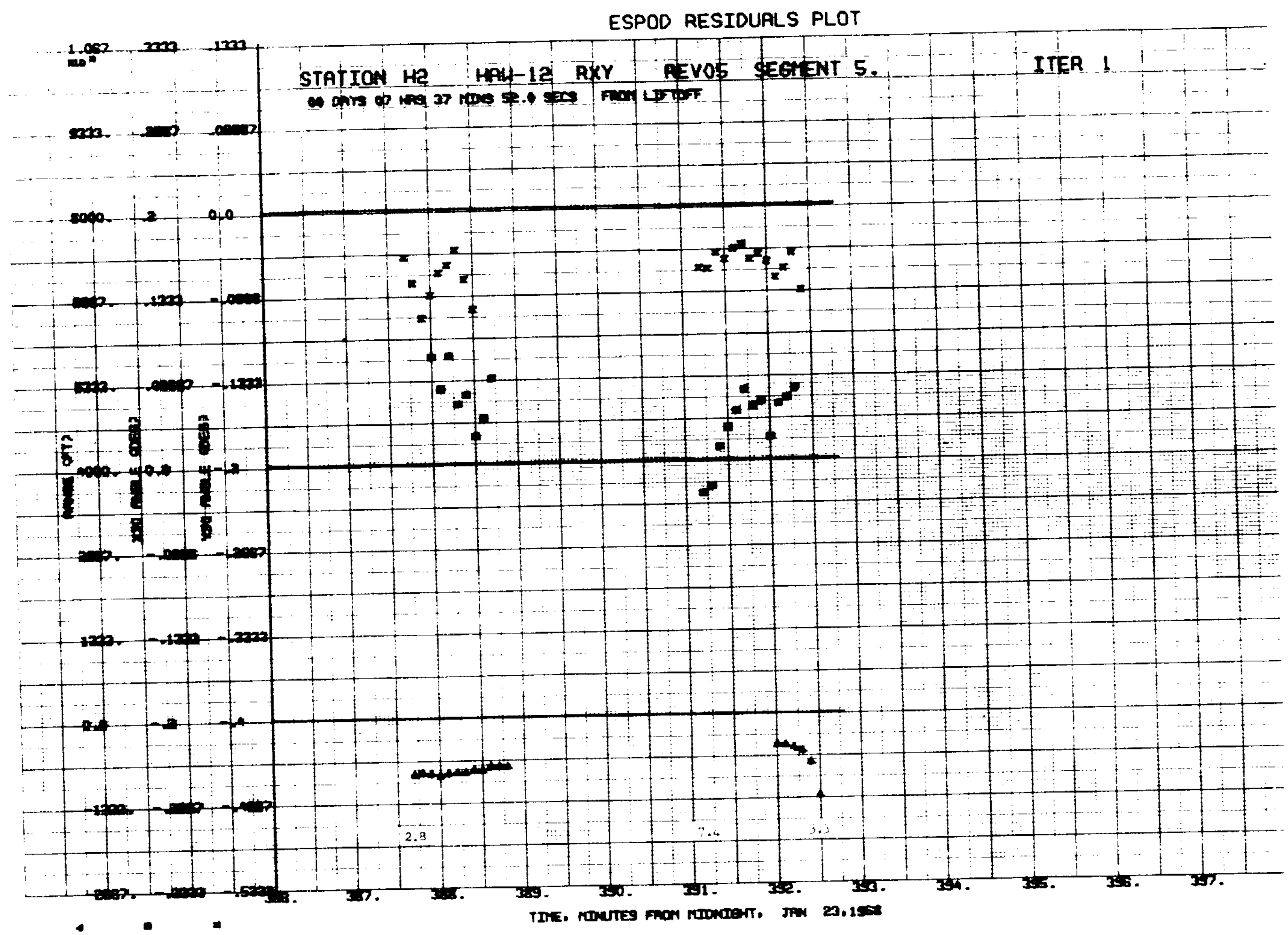
Note: • These data occurred during the second period of thruster activity following PRA III.

A-82. Revolution 5, Hawaii: RAE (Segment 5 BET)



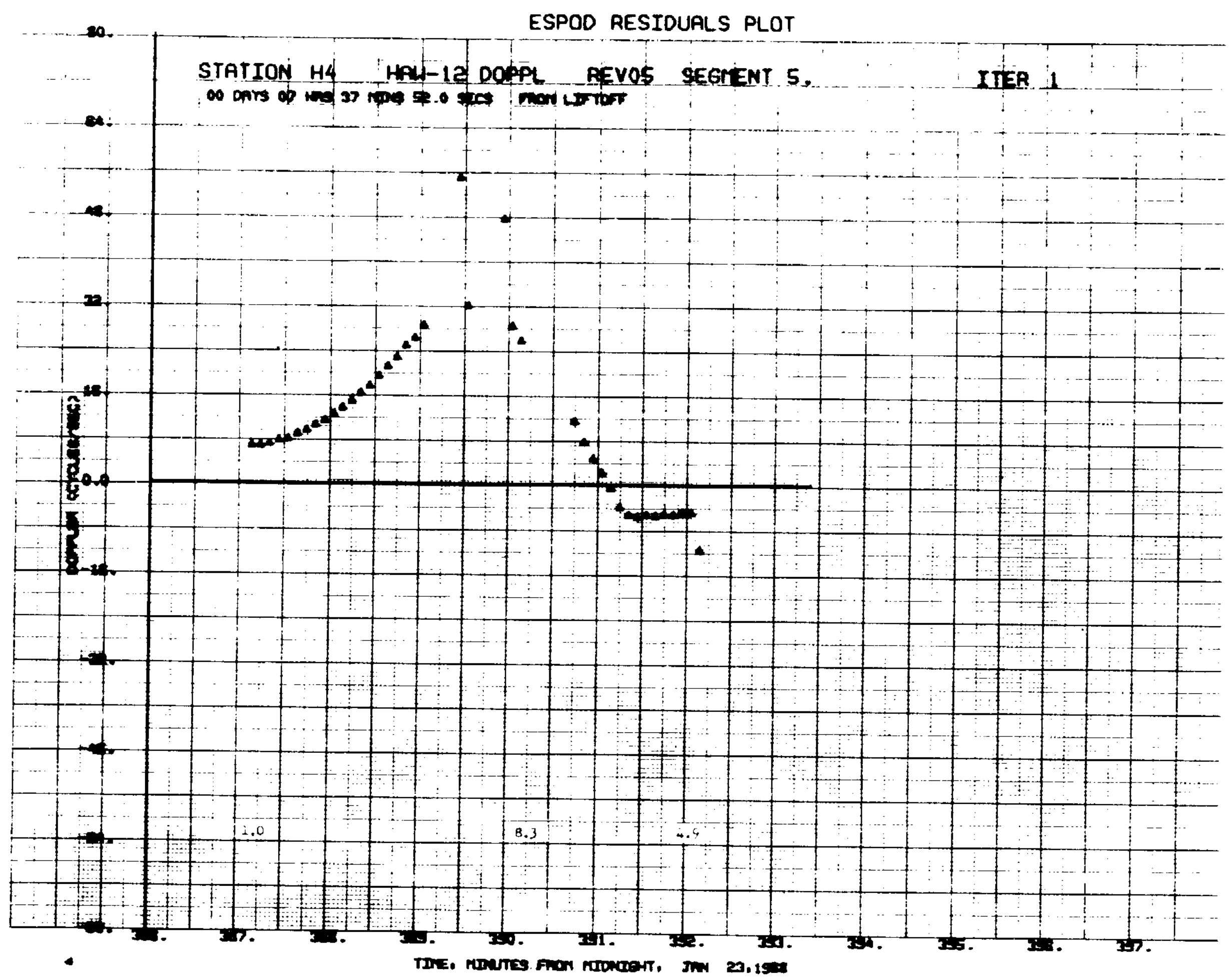
Note: ● These data occurred during the second period of thruster activity following PRA III.

A-83. Revolution 5, Hawaii: RXY (Segment 5 BET)



Note: ● These data were deleted from the fit.

A-84. Revolution 5, Hawaii: Doppler (Segment 5 BET)



Note: ● These data were deleted from the fit.

APPENDIX B

SUPPLEMENTARY DATA

Information which is too detailed for the body of the report is presented in this appendix. This information includes a summary of radar observations, a summary of station locations, a summary of drag values for various phases of the mission, and a summary of the radar data weights used in ESPOD.

Table B-1, a summary of data observations, lists the time of the first valid data point with an elevation above 3 degrees (rise time) and the elevation of this data point (rise elevation), the maximum elevation of the pass, the time of the last valid data point with an elevation above 3 degrees (set time) and the elevation of this data point (set elevation), and the number of valid data points by station and revolution. Also included is a comment regarding the use of each pass of data.

Table B-2 lists the C-band station locations used in ESPOD. These locations are referenced to the Fischer Ellipsoid of 1960.

Table B-3 lists the S-band station locations used in ESPOD. These locations are referenced to the Fischer Ellipsoid of 1960.

Table B-4, the drag summary, lists the vehicle configuration, the time interval for which the listed drag value is valid, vehicle weight for this time interval, vehicle cross sectional area, and the value of the drag parameter.

Table B-5 lists the values used by ESPOD to weight the radar tracking data from each station as a function of data type and radar type.

Table B-1. Radar Data Summary

Station	Revolution	Date (yr:mo:day)	Rise Time, GMT (hr:min:sec)	Rise* Elevation (deg)	Maximum* Elevation (deg)	Set Time, GMT (hr:min:sec)	Set* Elevation (deg)	Number of Observations	Comments
CROC	1	68:01:22	23:41:42	5.4	12.5	23:46:18	3.3	48	The data were used in the Segment 1 fit.
CROS	1	68:01:22	23:42:30	9.0	12.5	23:46:18	3.4	37	The RXY data were used in the Segment 1 fit.
CNBS	1	68:01:22	23:49:24	4.6	8.1	23:52:54	5.4	35	The RXY data were used in the Segment 1 fit.
GLDS	1	68:01:23	00:18:42	3.4	4.7	00:20:18	4.5	31	The data were not used in the Segment 1 fit.
WHSC	1	68:01:23	00:19:18	3.2	17.2	00:24:00	3.2	48	The data were used in Segment 1 fit.
TEXS	1	68:01:23	00:21:00	4.6	32.1	00:25:48	3.2	43	The RXY data were used in the Segment 1 fit.
MILS	2	68:01:23	00:24:36	3.1	23.0	00:29:36	3.1	51	The data were weighted out of the Segment 1 fit.
PATC	2	68:01:23	00:24:36	2.8	20.3	00:29:36	3.0	30	The data were used in the Segment 1 fit.
MLAC	2	68:01:23	00:24:36	3.0	22.5	00:29:36	3.0	50	The data were used in the Segment 1 fit.
GBMS	2	68:01:23	00:25:18	2.9	14.0	00:29:54	3.2	47	The data were weighted out of the Segment 1 fit.
BDAS	2	68:01:23	00:28:00	3.1	50.5	00:33:12	3.2	53	The data were weighted out of the Segment 1 fit.
BDQC	2	68:01:23	00:28:00	3.6	50.6	00:33:12	3.2	53	The data were used in the Segment 1 fit.
REDC	2	68:01:23	00:33:12	3.0	38.4	00:38:36	3.4	49	The ship data were not used in the Segment 1 fit.
CROS	2	68:01:23	01:14:36	4.2	20.3	01:20:06	3.2	55	The RXY data were used in the Segment 1 fit.
CROC	2	68:01:23	01:14:48	5.4	20.2	01:20:06	3.1	54	The data were used in the Segment 1 fit.
HAWS	2	68:01:23	01:40:06	3.0	11.4	01:44:30	3.2	36	The RXY data were used in the Segment 1 fit.
WTNC	2	68:01:23	01:45:08	3.3	14.9	01:48:20	11.4	26	The ship data were not used in the Segment 1 fit.
GLDS	2	68:01:23	01:50:12	3.3	14.7	01:54:54	3.4	47	The data were used in the Segment 1 fit.
GYMS	2	68:01:23	01:51:00	3.0	22.8	01:55:06	8.5	42	The XY data were not used in the Segment 1 fit.
WHSC	2	68:01:23	01:53:36	16.7	60.4	01:56:48	3.4	33	White Sands tracked on a side lobe; consequently, the data were not used on the Segment 1 fit.
TEXS	2	68:01:23	01:53:48	3.3	17.7	01:58:54	3.3	52	The RXY data were used in the Segment 1 fit.
MILS	3	68:01:23	01:57:48	3.4	41.0	02:02:54	3.3	51	The data were weighted out of the Segment 1 fit.
MLAC	3	68:01:23	01:57:48	3.5	39.2	02:02:54	3.3	52	The data were used in the Segment 1 fit.
GBMS	3	68:01:23	01:58:24	4.5	24.2	02:03:30	3.1	39	The data were weighted out of the Segment 1 fit.
BDAS	3	68:01:23	02:01:36	4.6	12.2	02:05:42	3.3	42	The data were weighted out of the Segment 1 fit.
BDQC	3	68:01:23	02:01:12	2.8	12.3	02:05:42	3.3	46	The data were used in the Segment 1 fit.
ANTC	3	68:01:23	02:02:36	2.9	7.4	02:07:18	3.1	38	The data were weighted out of the Segment 1 fit.
REDC	3	68:01:23	02:07:54	3.1	3.8	02:09:42	3.0	18	The ship data were not used in the Segment 1 fit.
ACNS	3	68:01:23	02:18:48	11.5	12.5	02:21:48	3.0	31	The XY data were used in the Segment 1 fit.
CROS	3	68:01:23	02:47:24	3.1	43.4	02:50:54	34.5	36	The range data were used in the Segment 2 fit.
CROC	3	68:01:23	02:47:24	3.1	43.7	02:53:24	3.1	61	The data were used in the Segment 2 fit.
HAWC	3	68:01:23	03:12:42	2.8	24.3	03:17:48	3.3	52	The data were used in the Segment 2 fit.

*These angles have been corrected for refraction effects.

Table B-1. Radar Data Summary (Continued)

Station	Revolution	Date (yr:mo:day)	Rise Time, GMT (hr:min:sec)	Rise* Elevation (deg)	Maximum* Elevation (deg)	Set Time, GMT (hr:min:sec)	Set* Elevation (deg)	Number of Observations	Comments
HAWS	3	68:01:23	03:12:48	3.3	24.3	03:17:48	4.3	47	The RXY data were used in the Segment 2 fit.
WTNC	3	68:01:23	03:18:20	6.8	63.3	03:24:15	4.5	56	The ship data were not used in the Segment 2 fit.
CLQC	3	68:01:23	03:22:35	3.1	13.2	03:26:29	3.1	39	The angle data were bad, consequently the data were not used in the Segment 2 fit.
GYMS	3	68:01:23	03:24:18	3.3	23.7	03:29:18	3.4	34	The RXY data were used in the Segment 2 fit.
WHSC	3	68:01:23	03:25:30	6.0	42.4	03:30:12	3.4	48	The data were used in the Segment 2 fit.
MLAC	4	68:01:23	03:31:18	5.4	19.3	03:35:54	3.0	46	The data were used in the Segment 2 fit.
GBIC	4	68:01:23	03:31:30	3.4	24.6	03:36:36	3.4	52	The data were used in the Segment 2 fit.
GBMS	4	68:01:23	03:32:24	8.8	24.6	03:37:30	3.2	52	The data were not used in the Segment 2 fit.
MILS	4	68:01:23	03:32:36	15.1	19.0	03:35:48	3.4	33	The data were weighted out of the Segment 2 fit.
ANTC	4	68:01:23	03:35:54	3.0	42.7	03:41:24	3.2	55	The data were used in the Segment 2 fit.
ASCC	4	68:01:23	03:49:48	3.1	14.4	03:55:00	3.2	53	The data were used in the Segment 2 fit.
GWMS	4	68:01:23	04:33:18	6.5	22.1	04:37:06	7.3	39	The RXY data were used in the Segment 2 fit.
HAWS	4	68:01:23	04:47:12	3.0	6.0	04:50:12	3.2	19	The range data were used in the Segment 2 fit.
HAWC	4	68:01:23	04:47:18	3.2	5.6	04:50:12	3.2	30	The data were used in the Segment 2 fit.
WTNC	4	68:01:23	04:51:37	3.0	43.1	04:56:14	3.6	44	The ship data were not used in the Segment 2 fit.
GLDS	4	68:01:23	04:56:06	3.1	9.5	04:58:00	9.5	20	The XY data were used in the Segment 2 fit.
CLQC	4	68:01:23	04:56:49	5.8	6.6	04:59:11	3.1	18	The angle data were bad, consequently the data were not used in the Segment 2 fit.
GYMS	4	68:01:23	04:57:18	3.0	8.2	05:02:36	3.0	49	The RXY data were used in the Segment 2 fit.
WHSC	4	68:01:23	04:58:42	4.2	9.8	05:02:30	3.1	37	The data were used in the Segment 3 fit.
TEXS	4	68:01:23	05:00:06	6.8	14.7	05:03:36	13.6	24	The data were used in the Segment 3 fit.
ACNS	5	68:01:23	05:23:06	3.2	9.7	05:26:54	9.7	39	The data were used in the Segment 4 fit.
ASCC	5	68:01:23	05:23:06	3.2	9.5	05:30:48	3.0	78	The data were used in the Segment 4 fit.
TANC	5	68:01:23	05:40:06	11.9	33.4	05:53:00	3.3	107	The data were used in the Segment 4 fit.
CROS	5	68:01:23	05:58:12	3.0	5.0	06:03:54	3.1	50	The data were used in the Segments 4 and 5 fits.
CROC	5	68:01:23	05:58:12	3.1	5.0	06:04:00	3.0	59	The data were used in the Segments 4 and 5 fits.
GWMS	5	68:01:23	06:09:48	3.6	28.5	06:20:30	3.2	104	The data were used in the Segment 5 fit.
HAWS	5	68:01:23	06:27:48	3.3	8.1	06:32:30	3.3	28	The data were used in the Segment 5 fit.
HAWC	5	68:01:23	06:27:54	3.3	8.5	06:32:30	3.4	48	The data were used in the Segment 5 fit.
WTNC	5	68:01:23	06:32:41	5.9	18.3	06:33:53	18.3	13	The ship data were not used in the Segment 5 fit.

*These angles have been corrected for refraction effects.

Table B-2. C-band Station Locations

Station	Radar Type	Identification	Latitude* (deg)	Longitude* (deg)	Altitude* (deg)
Antigua	FPQ-6	ANT	17.14403	298.20714	190.29
Ascension	TPQ-18	ASC	-7.97276	345.59830	469.16
Ascension	FPS-16	ASC	-7.95151	345.58740	360.90
Bermuda	FPS-16	BDA	32.34810	295.34620	59.06
Bermuda	FPQ-6	BDQ	32.34796	295.34626	62.34
California	FPS-16	CAL	34.58290	239.43885	2119.42
California	TPQ-18	CLQ	34.66598	239.41780	354.33
Canary Island	MPS-26	CYI	27.76321	344.36519	551.18
Cape Kennedy	FPS-16	CNV	28.48177	279.42349	45.93
Carnarvon	FPQ-6	CRO	-24.89740	113.71608	203.41
Eglin	FPS-16	EGL	30.42177	273.20189	91.86
Grand Bahama	FPS-16	GBI	26.61579	281.65215	45.93
Grand Bahama	TPQ-18	GBI	26.63636	281.73229	39.37
Grand Turk	TPQ-18	GTI	21.46289	288.86789	91.86
Hawaii	FPS-16	HAW	22.12209	200.33462	3740.16
Merritt Island	TPQ-18	MLA	28.42486	279.33560	39.37
Patrick	FPQ-6	PAT	28.22655	279.40017	49.21
Pretoria	MPS-25	PRE	-25.94373	28.35849	5334.65

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

Table B-2. C-band Station Locations (Continued)

Station	Radar Type	Identification	Latitude* (deg)	Longitude* (deg)	Altitude* (deg)
San Salvador	FPS-16	SSI	24.11883	285.49586	16.40
Tananarive	FPS-16	TAN	-19.00079	47.31505	4337.35
White Sands	FPS-16	WHS	32.35822	253.63044	4041.99
Woomera	FPS-16	WOM	-30.81973	136.83699	495.41

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

Table B-3. USBS Station Locations

Station	Antenna	Identification	Latitude* (deg)	Longitude* (deg)	Altitude* (deg)
Antigua	30'	ANG	17.01692	298.24715	141.08
Ascension	30'	ACN	-7.95506	345.67242	1843.83
Bermuda	30'	BDA	32.35129	295.34182	68.90
Canary Island	30'	CYI	27.76454	344.36519	567.59
Canberra	85'	CNB	-35.58474	148.97658	3766.40
Carnarvon	30'	CRO	-24.90759	113.72425	190.29
Goldstone	85'	GDS	35.34169	243.12670	3166.01
Grand Bahama	30'	GBM	26.63286	281.76234	16.40
Guam	30'	GWM	13.30924	144.73441	416.67
Guaymas	30'	GYM	27.96321	249.27915	62.34
Hawaii	30'	HAW	22.12490	200.33501	3772.97
Madrid	85'	MAD	40.45536	355.83261	2706.69
Merritt Island	30'	MIL	28.50827	279.30658	32.81
Texas	30'	TEX	27.65375	262.62153	32.81

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

Table B-4. Drag Summary

Station	Time Interval From (day:hr:min:sec)	Time Interval To (day:hr:min:sec)	Vehicle Weight (lb)	Vehicle Area (ft^2)	Drag (ft^2/slug)
LM/S-IVB	22:22:58:11.3	22:23:42:03.2	69,341	411.0	0.1897
LM	22:23:42:03.2	23:05:01:22.3	31,479	200.6	0.2039
LM	23:05:01:22.3	23:06:32:08.3	9,170	129.4	0.4516

Table B-5. Radar Data Weighting

Data Type	Type of Radar	Weighting
R:A:E	FPQ-6	60 ft: 0.0258 deg: 0.0258 deg
R:A:E	TPQ-18 and FPS-16	90 ft: 0.0354 deg: 0.0354 deg
R:A:E	MPS-26	180 ft: 0.1720 deg: 0.1720 deg
R:X:Y	USB: 30-ft antenna 85-ft antenna	90 ft: 0.1375 deg: 0.1375 deg
Doppler (2 way)	USB: 30-ft antenna 85-ft antenna	0.2 cycle/sec