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RESULTS FROM THE EVALUATION OF TRACKING SYSTEM MEASUREMENT ERRORS ON THE APOLLO-SATURN 201-204 FLIGHT TESTS

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ABSTRACT

The TEMS Multiple Regression Analysis Method for post-flight tracking system error model analysis is used to evaluate measurement errors on the Apollo-Saturn IB flight test data. The concept of least squares adjustment with parameter constraints is involved in the evaluation process.

A stepwise regression procedure is used in conjunction with the TEMS method to establish truncated tracker error models for the AS-204 tracking radars. The guidelines used in obtaining these truncated error models show considerable usefulness for constructing models containing the most significant variables. An overall summary of results obtained on the AS-201 through AS-204 flight tests shows that the standard deviations for several of the error model coefficients do not vary significantly from test to test or from radar to radar.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA-GEORGE C. MARSHALL SPACE FLIGHT CENTER

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COMPUTATION LABORATORY
RESEARCH AND DEVELOPMENT OPERATIONS

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DEFINITION OF SYMBOLS

Symbol	Definition
$\Delta R, \Delta A, \Delta E$	functional expressions for the systematic errors in range, azimuth, and elevation, respectively
$\Delta R^0, \Delta A^0, \Delta E^0$	observed tracking errors in range, azimuth, and elevation, respectively
V_R, V_A, V_E	residuals in range, azimuth, and elevation, respectively
$V_{C_0}, V_{C_1}, \ldots, V_{F_{12}}$	coefficient observational residuals
n	number of observations
TEMS	acronym for Tracking System Error Model Studies
$C_0, C_1, \ldots$	coefficients in range error model
$D_0, D_1, \ldots$	coefficients in azimuth error model
$F_0, F_1, \ldots$	coefficients in elevation error model
R^0, A^0, E^0	measured tracking parameters in range, azimuth, and elevation, respectively
R^r, A^r, E^r	reference tracking parameters in range, azimuth, and elevation, respectively
$\dot{R}, \dot{A}, \dot{E}$	first derivatives of range, azimuth, and elevation, respectively, with respect to time
$\ddot{A}, \ddot{E}$	second derivatives of azimuth and elevation, respectively, with respect to time
X_e, Y_e, Z_e	reference position of vehicle in an earth-fixed plumbline coordinate system with origin at the launch site
X_{es}, Y_{es}, Z_{es}	reference position of vehicle in an earth-fixed plumbline coordinate system with origin at the tracking site

DEFINITION OF SYMBOLS (Continued)

Symbol	Definition
X, Y, Z	reference position of vehicle in an earth-fixed ephemeris coordinate system with origin at the tracking site
$\sigma^2_R, \sigma^2_A, \sigma^2_E$	variances in range, azimuth, and elevation, respectively
$\sigma^2_{VR}, \sigma^2_{VA}, \sigma^2_{VE}$	least squares residual variances in range, azimuth, and elevation, respectively
σ^2_0	unit variance
$\overline{\dot{W}}$	parameter weight matrix
$\overline{W}$	observational weight matrix
h_L, h_T	height of launch site and tracking site, respectively, above reference ellipsoid
Φ_L, λ_L	geodetic latitude and geocentric longitude, respectively, of launch site
Φ_T, λ_T	geodetic latitude and geocentric longitude, respectively, of tracking site
r_L, r_T	radius of earth at launch site and tracking site, respectively
K_L	firing azimuth of vehicle
$\hat{a}, \hat{b}$	semi-major and semi-minor axes, respectively, of earth
AA(I, J)	18 x 18 control matrix associated with $(\overline{B}^T \overline{W}\, \overline{B} + \overline{\dot{W}})$
BB(I, 1)	18 x 1 control matrix associated with $(\overline{B}^T \overline{W}\, \overline{N} - \overline{B}^T \overline{W}\, \overline{B}\, \overline{C} - \overline{\dot{W}}\, \overline{\epsilon})$
D(I, 1)	18 x 1 control matrix associated with $\overline{\delta}$

DEFINITION OF SYMBOLS (Concluded)

Symbol	Definition
$\tilde{C}_0, \tilde{C}_1, \ldots$	parameter approximation values
$\delta C_0, \delta C_1, \ldots$	parameter corrections
$\sigma^2_{C_0}, \sigma^2_{C_1}, \ldots$	parameter variances
$C_0^\infty, C_1^\infty, \ldots$	parameter a priori values
$\sigma_0^2(\overline{B}^T \overline{W}\,\overline{B} + \overline{W})^{-1}$	variance-covariance matrix of the regression parameters
Y^c	computed response variable
$Z_1, Z_2, \ldots, Z_p$	independent variables
$b_0, b_1, b_2, \ldots, b_p$	partial regression coefficients
$F_{I(OUT)}$	F value used to determine whether the i-th variable should be deleted from the regression equation
$F_{q(IN)}$	F value used to determine whether the q-th variable should be entered into the regression equation
df	degrees of freedom
$\tilde{r}_1, \tilde{r}_2, \ldots, \tilde{r}_7$	range error model factors
$a_1, a_2, \ldots, a_9$	azimuth error model factors
$e_1, e_2, \ldots, e_9$	elevation error model factors

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RESULTS FROM THE EVALUATION OF TRACKING SYSTEM MEASUREMENT ERRORS ON THE APOLLO-SATURN 201-204 FLIGHT TESTS

SUMMARY

The TEMS Multiple Regression Analysis Method for post-flight tracking system error model analysis is used to evaluate measurement errors on the Apollo-Saturn IB flight test data. The concept of least squares adjustment with parameter constraints is involved in the evaluation process.

A stepwise regression procedure is used in conjunction with the TEMS method to establish truncated tracker error models for the AS-204 tracking radars. The guidelines used in obtaining these truncated error models show considerable usefulness for constructing models containing the most significant variables. An overall summary of results obtained on the AS-201 through AS-204 flight tests shows that the standard deviations for several of the error model coefficients do not vary significantly from test to test or from radar to radar.

INTRODUCTION

This report presents the regression analysis results obtained from the evaluation of tracking system measurement errors on the Apollo-Saturn IB flight test data. Included are the results obtained through the AS-204 launch. The basic concept in the evaluation process is given in the TEMS (Tracking System Error Model Studies) Multiple Regression Analysis Method. The method involves establishing the tracker errors and then determining, in the least squares sense, error model expressions to describe the established errors.

A stepwise regression procedure is used in conjunction with the TEMS Method to establish truncated tracker error models for the AS-204 tracking radars. The basic approach in the stepwise procedure consists of examining at each step the variables incorporated into the regression model in previous steps. The final error model results in only the most significant variables being retained.

THE TRACKING SYSTEM ERROR MODEL EVALUATION METHOD

The mathematical developments in the TEMS Multiple Regression Analysis Method for post-flight tracking system error model analysis are presented in Reference 1. Basically, the Method provides for a comprehensive evaluation of systematic errors in measurements obtained from various radar tracking systems. It involves establishing the tracker errors from the radar measured parameters and from a reference trajectory representing the best estimate of the trajectory from a composite of data. Error model expressions to describe these established errors are then determined by a least squares adjustment procedure. Radar error model parameter constraints and a priori values for the parameters and their variances are utilized in the adjustment. A by-product of the adjustment is the variance-covariance matrix of the parameters.

Truncated tracker error models for representing the systematic errors in the AS-204 data are established from guidelines using the TEMS Method in conjunction with a stepwise regression procedure. The approach to constructing the truncated error models is based on the significance of an individual variable and its correlation with other variables. The stepwise regression procedure involves examining at every step the variables incorporated into the error model in previous steps. At a given step in the analysis, a specific variable is deleted from or entered into the regression model by utilizing the Gaussian Elimination Method for solving the linear system of normal equations in the regression. Results from a given step provide statistical F tests whereby we can determine whether a specific variable should be deleted from or entered into the regression model. The final regression model results in only the most significant variables being retained in the model. A summary of the stepwise approach is given in Figure 1. Detailed development information can be found in Reference 1.

The computer program for the TEMS Multiple Regression Analysis Method is summarized in Figure 2. The utilization of the TEMS program in conjunction with the stepwise regression program is summarized in Figure 3. As pointed out in this figure, the results from the stepwise regression analysis are analyzed to determine the variables for consideration in the final TEMS error model.

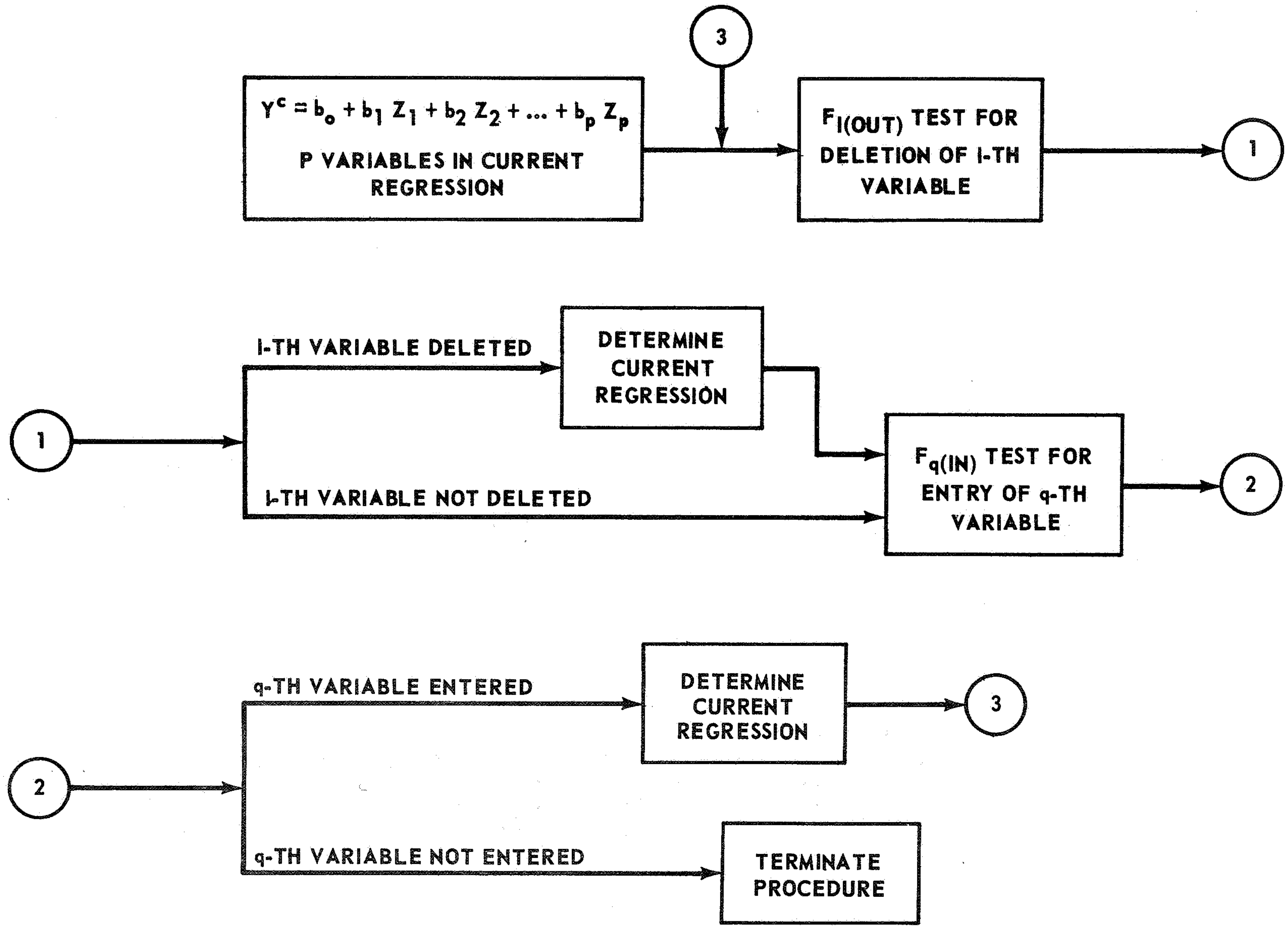

FIGURE 1. BASIC STEPWISE APPROACH

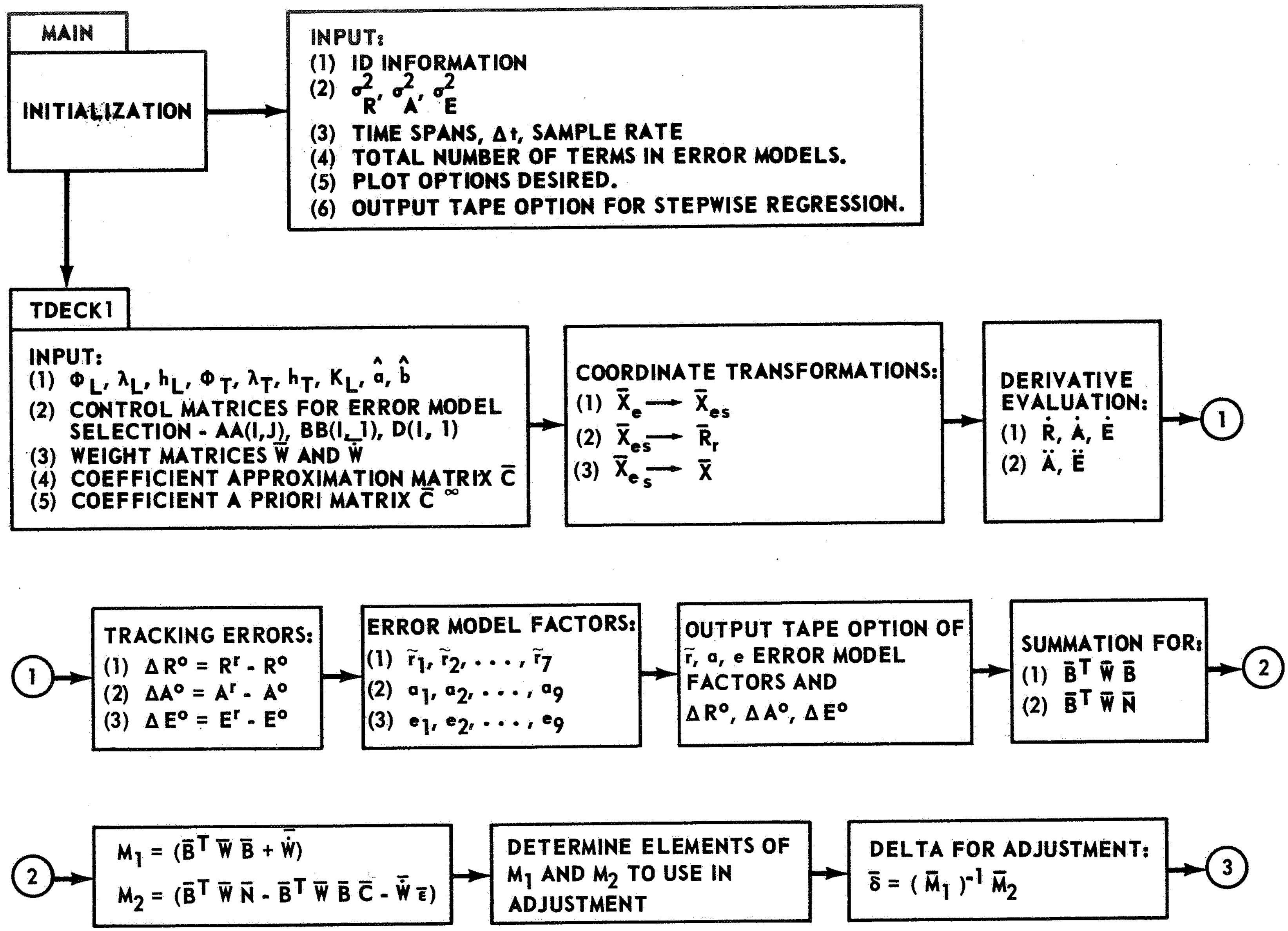

FIGURE 2. TEMS PROGRAM FLOW CHART

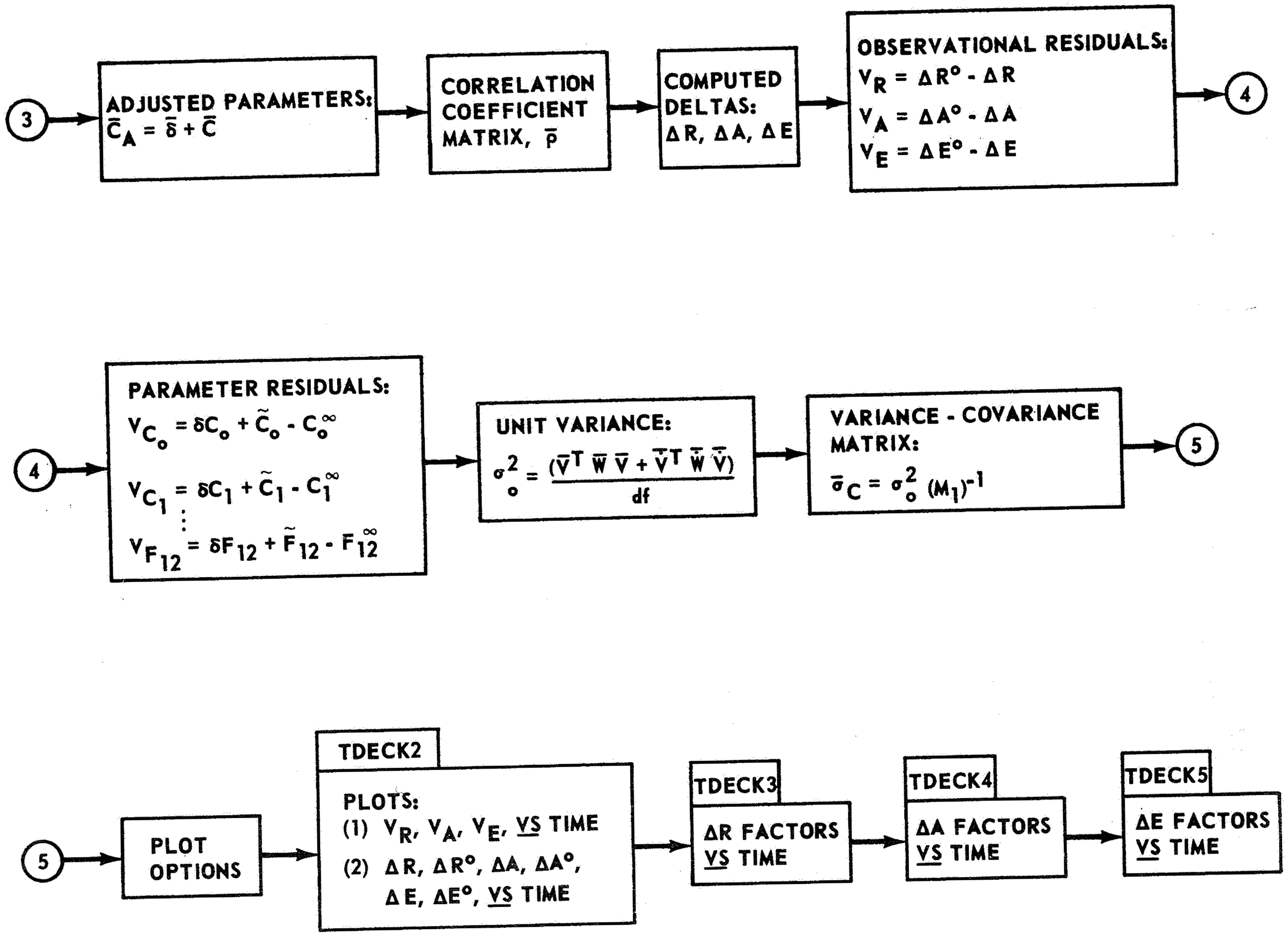

FIGURE 2. (Concluded)

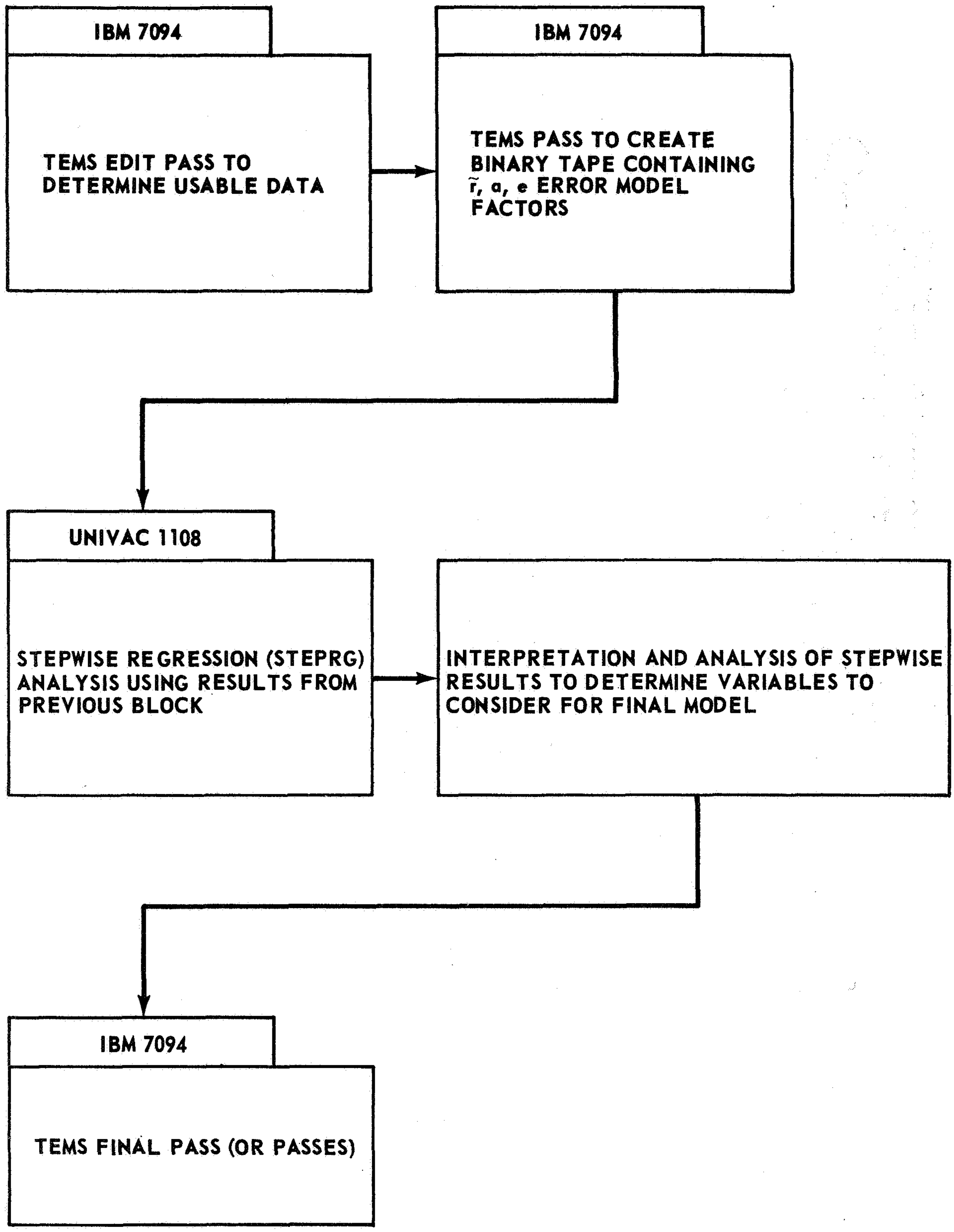

FIGURE 3. UTILIZATION OF THE TEMS AND STEPRG COMPUTER PROGRAMS

SUMMARY OF APOLLO-SATURN IB RESULTS THROUGH THE AS-204 LAUNCH

The Apollo-Saturn AS-204 vehicle was launched at $5^H\ 48^M\ 8^S$ (PM) Eastern Standard Time on January 22, 1968 from Kennedy Space Center, Launch Complex 37, Pad B. Tracking data from six C-band radars were utilized in the reduction. The post-flight reference trajectory used as the standard is presented in Reference 2. The relation between the vehicle trajectory and the various C-band radar tracking sites is shown in Figure 4. This figure also contains significant event times through insertion. Table I contains location data for the launch site and the various tracking stations.

The AS-204 tracking data utilization is shown in Figure 5. These usable data were determined from an edit pass through the TEMS program. The preliminary edited data for all the radars were processed with the parameter weight matrix ($\overline{W}$) and approximation matrix ($\overline{C}$) equal to zero. A priori estimates of zero for the error model coefficients were also entered into the final TEMS computer runs.

The general approach for obtaining truncated error models to describe the AS-204 range, azimuth, and elevation response variables is summarized in the following guidelines:

1. It was assumed that the survey terms, rate bias term, and the azimuth and elevation velocity lag terms were not essential in obtaining truncated error models to describe the response variables.

2. The first two variables entered in the stepwise regression (excluding those left out under the assumption in Guideline 1) were selected for consideration in the final TEMS error model.

3. A third variable was considered if an adequate description of the response variable was not obtained with the first two, or if a constraining condition required an additional variable in the model.

This approach actually results in entering the most significant variables into the error model. It should be pointed out that the third variable selected in guideline 3 often involved selecting one of two variables that represented borderline cases sofar as the order of entry in the stepwise regression was concerned; i.e., the two variables had partial correlation coefficient values nearly equal.

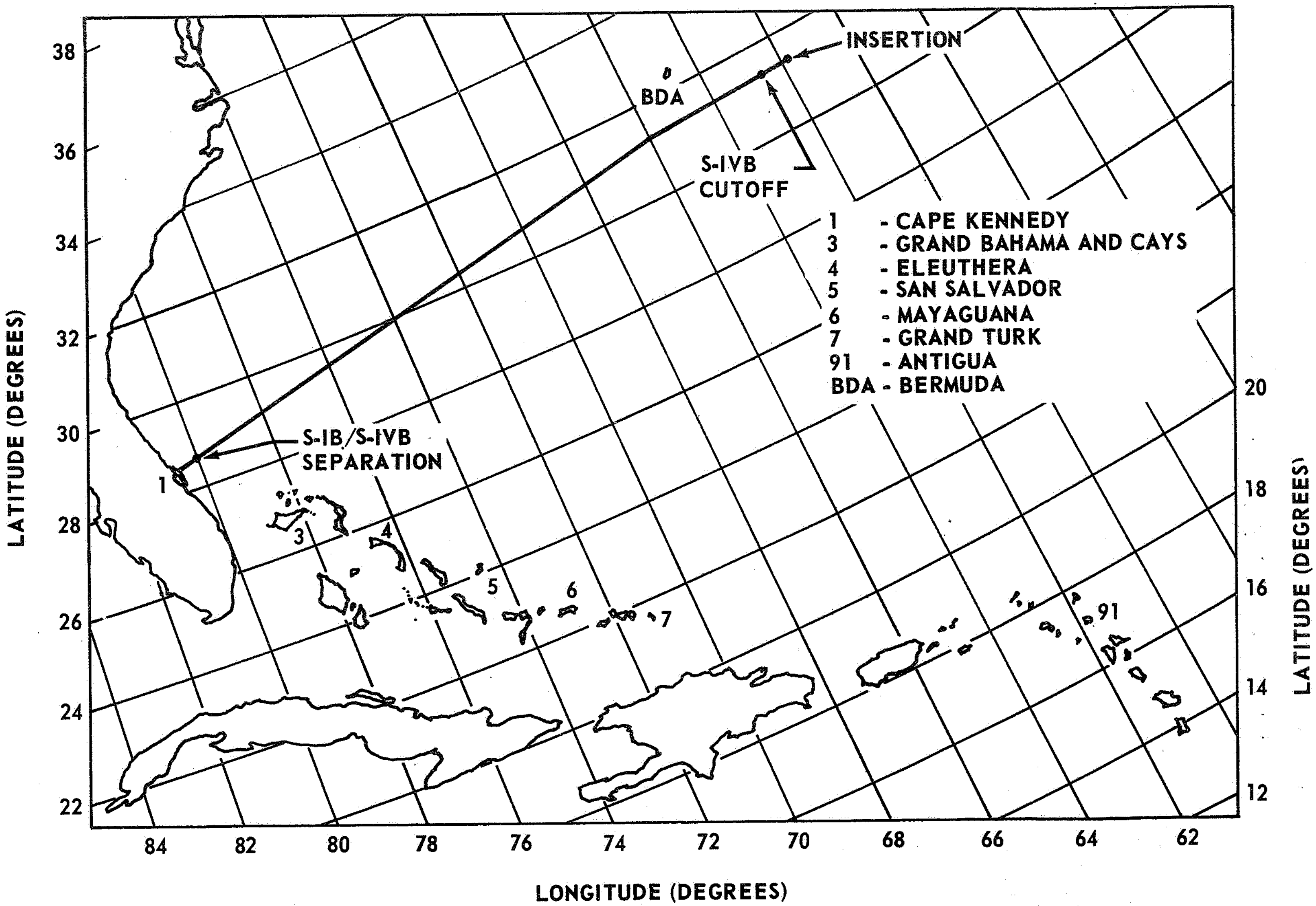

FIGURE 4. GEOMETRICAL RELATION BETWEEN THE AS-204 FLIGHT PATH AND THE TRACKING STATIONS

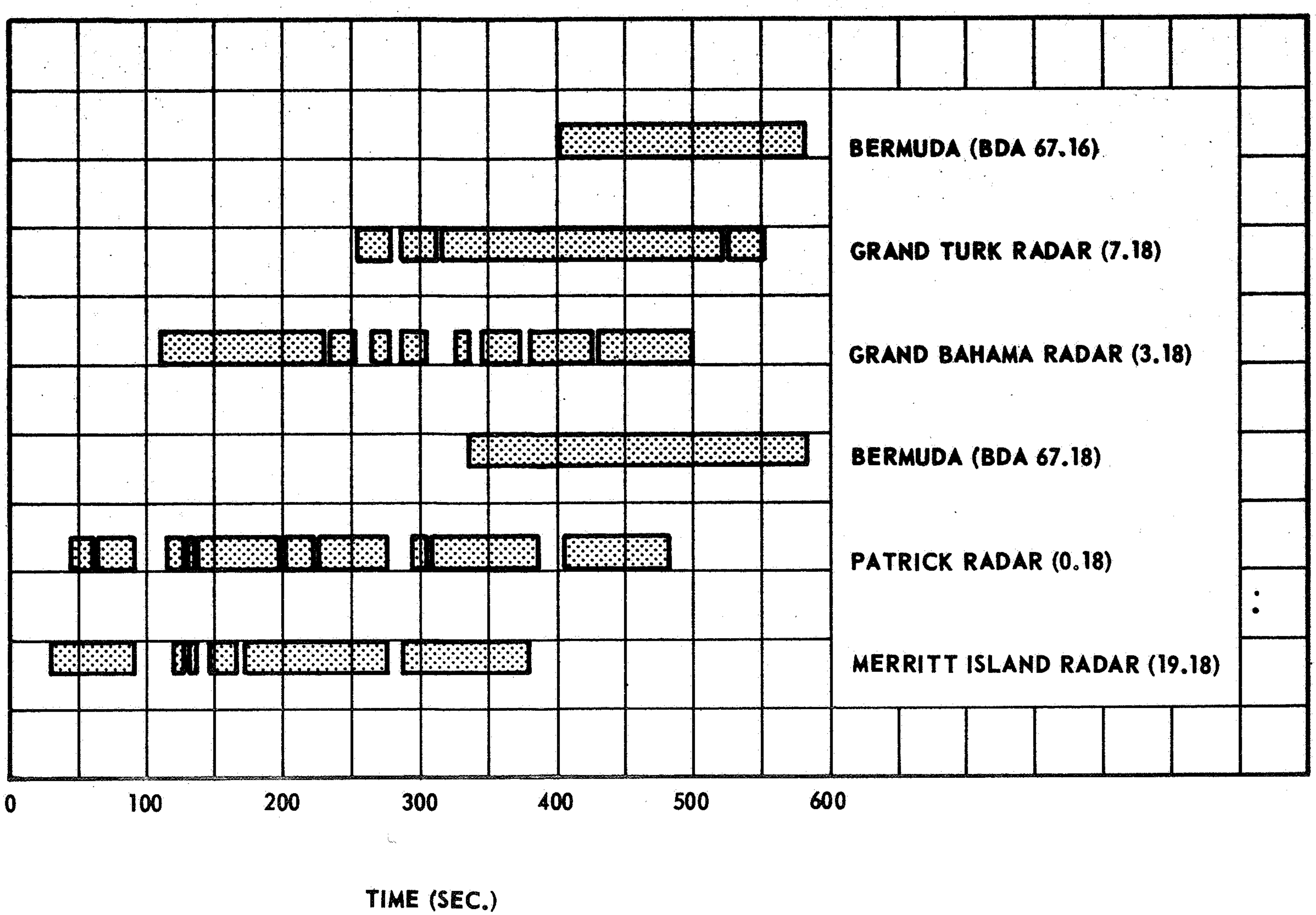

FIGURE 5. TEMS AS-204 TRACKING DATA UTILIZATION

The approach given by guidelines 1 through 3 has generally resulted in acceptable error models for the AS-204 data. The approach used to obtain the AS-201, AS-202, and AS-203 truncated error models presented in Reference 3 actually constitutes a qualitative examination of a subset of regressions from the all possible regressions approach. This approach is extremely time consuming and has required an average of 10 to 12 runs per radar on each of the three tests. Under guidelines 1 through 3, however, four runs may be sufficient to obtain truncated error models for a particular radar.

It is noted that the stepwise results presented in the appendix for the AS-204 data indicate several cases where the σ_Y curve fit value is not improved significantly by the introduction of additional variables into the regression. It appears that a rather critical examination of results from applications of the stepwise regression procedure is required to obtain meaningful and useful information for input to the TEMS program. It does, however, show considerable usefulness for constructing truncated tracker error models containing the most significant variables.

An overall summary of the truncated error model results on the AS-201 through AS-204 flight tests is presented in Tables II through VIII. It is noted in these tables that the standard deviations for several of the coefficients do not vary significantly from test to test or from radar to radar. Coefficient correlations and plots of the observed deltas, computed deltas, and the least squares residuals are given in the appendix. The average random errors remaining in the least squares residuals are 7.27 meters in range and 0.0058 degrees in azimuth and 0.0067 degrees in elevation. These values are in close agreement with the input accuracy estimates of 5 meters in range and 0.006 degrees in azimuth and elevation. As shown in Table IX, no less than four and no more than nine terms, excluding constraints, have been retained in the truncated error models.

CONCLUSIONS

Results from the evaluation of tracking system measurement errors on the Apollo-Saturn IB flight test data (AS-201 through AS-204) are obtained using the TEMS Multiple Regression Analysis Method. The method involves establishing the tracker errors and then determining, in the least squares sense, error model expressions to describe the established errors.

Truncated tracker error models representing the systematic errors in the AS-204 data are obtained under guidelines using the TEMS Method in conjunction with a stepwise regression procedure. These guidelines show considerable usefulness for constructing tracker error models containing the most significant variables and represent an improvement in the area of model construction. An overall summary of results obtained on the AS-201 through AS-204 flight tests shows that the standard deviations for several of the error model coefficients do not vary significantly from test to test or from radar to radar. The average random errors remaining in the least squares residuals are in close agreement with the input accuracy estimates of 5 meters in range and 0.006 degrees in azimuth and elevation.

TABLE I. LOCATION OF LAUNCH SITE AND C-BAND TRACKING RADARS USED IN TEMS AS-204 REDUCTION

Site	Latitude, Deg.	Longitude, Deg.	Height,* meters
Launch Complex 37B	28.531857	80.564953	59.70**
Patrick (0.18)	28.226553	80.599293	15.51
Merritt Island (19.18)	28.424862	80.664404	12.02
Grand Bahama (3.18)	26.636350	78.267708	12.05
Grand Turk (7.18)	21.462890	71.132114	28.45
Bermuda (67.16)	32.348103	64.653801	24.31
Bermuda (67.18)	32.347964	64.653742	25.51

* Elevation above the Fischer Ellipsoid

** Elevation of the C-Band radar antenna above the Fischer Ellipsoid

TABLE II. TRUNCATED ERROR MODEL REGRESSION ANALYSIS RESULTS FOR RADAR 0.18

Coefficient Value and Standard Deviation	Flight Test No.			
	201	202	203	204
C_0	———	30.39	15.37	-56.69
σ		0.58	0.70	1.25
C_1	———	———	- 0.446E-4	———
σ			0.37E-5	
C_2	-0.0197	0.0055	———	0.0041
σ	0.34E-3	0.20E-3		0.58E-3
C_4	-172.32	-18.49	-271.06	-302.11
σ	9.69	4.50	20.22	11.22
D_0	-0.0142	-0.0040	-0.00067	0.0148
σ	0.73E-3	0.28E-3	0.53E-3	0.0010
D_3	———	0.0094	0.5220	———
σ		0.036	0.151	
D_5	0.0139	———	———	———
σ	0.0018			
D_7	———	———	———	-0.0622
σ				0.0042
D_8	———	0.0172	———	0.0582
σ		1.1E-3		0.0042
F_0	0.000115	0.0212	0.0112	0.0681
σ	0.35E-3	1.1E-3	0.46E-3	0.0053
F_3	———	1.084	-0.2633	-0.2701
σ		0.100	0.134	0.212
No. Data Pts.	323	377	259	356
σ_{VR}	3.30	3.65	2.33	15.02
σ_{VA}	0.0049	0.0050	0.0082	0.0081
σ_{VE}	0.0086	0.0068	0.0086	0.0085

TABLE III. TRUNCATED ERROR MODEL REGRESSION ANALYSIS RESULTS FOR RADAR 19.18

Coefficient Value and Standard Deviation	Flight Test No.			
	201	202	203	204
C_0 σ	———	57.57 0.62	51.61 0.36	6.90 0.89
C_1 σ	0.075E-4 0.14E-5	0.349E-4 0.14E-5	-0.50E-4 0.20E-5	———
C_2 σ	-0.0105 0.26E-3	———	———	———
C_4 σ	———	-23.29 10.50	-275.03 11.07	-9.25 13.54
D_0 σ	-0.000101 0.24E-3	0.0016 0.75E-3	0.0020 0.25E-3	-0.88E-3 0.46E-3
D_3 σ	———	-1.253 0.061	0.4070 0.126	3.57 0.143
D_5 σ	———	-0.0362 0.0017	———	———
D_7 σ	———	0.0143 0.0011	———	———
D_8 σ	———	———	———	———
F_0 σ	0.0036 0.23E-3	0.0368 0.35E-3	0.0398 0.23E-3	0.0027 0.45E-3
F_3 σ	0.3424 0.034	0.1828 0.049	-1.189 0.078	1.224 0.070
No. Data Pts.	455	360	279	287
σ_{VR}	3.13	4.64	1.86	5.65
σ_{VA}	0.0049	0.0071	0.0039	0.0092
σ_{VE}	0.0061	0.0070	0.0045	0.0066

TABLE IV. TRUNCATED ERROR MODEL REGRESSION ANALYSIS RESULTS FOR RADAR 3.18

Coefficient Value and Standard Deviation	Flight Test No.			
	201	202	203	204
C_0 σ	-7.65 0.68	55.19 0.39	-72.32 1.21	-13.05 0.39
C_1 σ	-0.197E-4 0.15E-5	———	2.087E-4 0.46E-5	0.624E-4 0.93E-6
C_2 σ	0.0013 0.29E-3	0.0039 0.11E-3	-0.0273 0.50E-3	———
C_4 σ	———	-77.15 4.00	———	139.55 4.16
D_0 σ	0.0143 0.46E-3	-0.00086 0.29E-3	———	0.0115 0.20E-3
D_3 σ	0.0975 0.200	0.4300 0.056	0.3084 0.109	1.392 0.090
D_5 σ	———	———	0.0492 0.0016	———
D_7 σ	-0.0016 0.0011	———	———	———
D_8 σ	———	0.0043 0.38E-3	0.0038 0.77E-3	———
F_0 σ	0.0371 0.45E-3	0.0181 0.33E-3	0.0348 0.47E-3	-0.0196 0.212E-3
F_3 σ	———	0.0846 0.094	0.0586 0.201	0.5901 0.126
No. Data Pts.	427	435	270	326
σ_{VR}	6.36	2.69	2.96	2.20
σ_{VA}	0.0044	0.0034	0.0068	0.0047
σ_{VE}	0.0128	0.0085	0.0079	0.0032

TABLE V. TRUNCATED ERROR MODEL REGRESSION ANALYSIS RESULTS FOR RADAR 7.18

Coefficient Value and Standard Deviation	Flight Test No.			
	201	202	203	204
C_0 σ	———	25.45 0.40	-85.14 2.95	12.20 1.59
C_1 σ	-0.638E-4 0.30E-6	———	———	———
C_2 σ	0.0027 0.80E-4	0.0048 0.16E-3	0.0073 0.42E-3	———
C_4 σ	———	29.78 2.00	-195.46 10.88	39.50 5.38
D_0 σ	-0.0047 0.30E-3	0.0043 0.34E-3	0.000251 0.60E-3	-0.0082 0.56E-3
D_3 σ	-1.667 0.122	0.2910 0.120	———	———
D_5 σ	———	———	———	———
D_7 σ	———	———	———	———
D_8 σ	-0.0072 0.43E-3	0.0059 0.60E-3	———	———
F_0 σ	0.0041 0.32E-3	-0.0092 0.30E-3	0.0113 0.60E-3	0.0394 0.56E-3
F_3 σ	1.049 0.359	———	———	———
No. Data Pts.	536	338	168	280
σ_{VR}	7.13	1.74	2.93	6.34
σ_{VA}	0.0060	0.0040	0.0055	0.0059
σ_{VE}	0.0051	0.0074	0.0115	0.0130

TABLE VI. TRUNCATED ERROR MODEL REGRESSION ANALYSIS RESULTS FOR RADAR 67.16

Coefficient Value and Standard Deviation	Flight Test No.			
	201	202	203	204
C_0 σ	NA*	NA*	84.68 1.08	13.56 1.31
C_1 σ			-0.58E-4 0.14E-5	-0.636E-4 0.26E-5
C_2 σ			———	0.0079 0.27E-3
C_4 σ			———	———
D_0 σ			-0.0076 0.41E-3	-0.0081 0.66E-3
D_3 σ			0.3350 0.079	0.2405 0.0126
D_5 σ			———	———
D_7 σ			———	———
D_8 σ			———	———
F_0 σ			-0.0065 0.44E-3	0.0106 0.63E-3
F_3 σ			0.190 0.075	0.2604 0.0236
No. Data Pts.			139	180
σ_{VR}			1.44	11.16
σ_{VA}			0.0028	0.0037
σ_{VE}			0.0063	0.0038

* Not Available

TABLE VII. TRUNCATED ERROR MODEL REGRESSION ANALYSIS RESULTS FOR RADAR 67.18

Coefficient Value and Standard Deviation	Flight Test No. 201	202	203	204
C_0 σ	NA*	NA*	NA*	30.62 0.85
C_1 σ				-0.585E-4 0.11E-5
C_2 σ				0.0095 0.18E-3
C_4 σ				———
D_0 σ				-0.0019 0.40E-3
D_3 σ				———
D_5 σ				———
D_7 σ				———
D_8 σ				-0.0032 0.70E-3
F_0 σ				-0.0041 0.65E-3
F_3 σ				———
No. Data Pts.				247
σ_{VR}				6.98
σ_{VA}				0.0036
σ_{VE}				0.0040

* Not Available

TABLE VIII. TRUNCATED ERROR MODEL REGRESSION ANALYSIS RESULTS FOR RADAR 91.18

Coefficient Value and Standard Deviation	Flight Test No.			
	201	202	203	204
C_0 σ	47.02 1.52	———	NA*	NA*
C_1 σ	-1.260E-4 0.18E-5	———		
C_2 σ	0.0014 0.10E-3	0.0024 0.47E-3		
C_4 σ	———	-7.67 7.30		
D_0 σ	0.0038 0.44E-3	-0.0092 2.9E-3		
D_3 σ	-1.639 0.110	———		
D_5 σ	———	0.0975 0.032		
D_7 σ	———	———		
D_8 σ	-0.0125 0.68E-3	———		
F_0 σ	0.0054 0.42E-3	0.0191 0.90E-3		
F_3 σ	-2.204 0.233	———		
No. Data Pts.	342	73		
σ_{VR}	7.59	1.49		
σ_{VA}	0.0050	0.0070		
σ_{VE}	0.0076	0.0111		

* Not Available

TABLE IX. TOTAL NUMBER OF TERMS IN TRUNCATED ERROR MODELS FOR AS-201 - 204 FLIGHT TESTS

Radar	Flight Test No.			
	201	202	203	204
0.18	5	8	7	8
19.18	5	9	7	6
3.18	7	8	8	7
7.18	7	7	5	4
91.18	8	5	NA*	NA*
67.16	NA*	NA*	6	7
67.18	NA*	NA*	NA*	6

* Not Available

APPENDIX

RESULTS FROM THE APOLLO-SATURN IB FLIGHT TESTS

The basic radar error models for describing the systematic errors in the range, azimuth, and elevation measurements are given by the following equations:

Range

$$\Delta R = C_0 + C_1 R + C_2 R + C_3 t + C_4 (-0.022 \operatorname{cosec} E)$$

$$+ C_5\left(\frac{X}{R}\right) + C_6\left(\frac{Y}{R}\right) + C_7\left(\frac{Z}{R}\right) \tag{1}$$

Azimuth

$$\Delta A = D_0 + D_1 \dot{A} + D_3 \ddot{A} + D_5 \tan E + D_6 \sec E + D_7 \tan E \sin A$$

$$+ D_8 \tan E \cos A + D_9\left(\frac{\sin A \cos A}{X}\right) + D_{10}\left(-\frac{\sin A \cos A}{Y}\right)$$

$$+ D_{11} \dot{A} \sec E \tag{2}$$

Elevation

$$\Delta E = F_0 + F_1 \dot{E} + F_3 \ddot{E} + F_5 (-\sin A) + F_6 \cos A$$

$$+ F_7\left[\left(\frac{0.022}{R \sin E} - 10^{-6}\right) \operatorname{cotan} E\right] + F_9\left(\frac{-X \tan E}{R^2}\right)$$

$$+ F_{10}\left(\frac{-Y \tan E}{R^2}\right) + F_{11}\left(\frac{\cos E}{R}\right) + F_{12} \dot{E} \cos E \tag{3}$$

The specific physical interpretation of the terms appearing in equations (1), (2), and (3) are given in Reference 1. These equations require modifications depending on the particular tracking system being considered and on the flight trajectory geometry. The IBM 7094 FORTRAN IV Computer Program was thus developed such that any combination of terms appearing in the error models can be retained in a given adjustment through the use of appropriate program control matrices.

Results for the truncated versions of these error models on the AS-201-204 data are presented in this appendix. Coefficient correlations are given in Tables A-I through A-IV. The stepwise regression analysis results for the AS-204 data are given in Tables A-V through A-X. Plots of the observed deltas, computed deltas, and the least squares residuals are presented in Figures A-1 through A-42. The tracking errors for the various radars are represented by dots in these figures. The description of these errors as obtained from the TEMS least squares adjustment program is represented by the solid computed curves.

The least squares residuals for the truncated error models presented in this appendix can be thought of as being composed of (1) random errors and (2) unmodeled systematic errors. A high random error content in the data may prevent a systematic error of comparable magnitude from being determined. The latter errors are those that can be attributed to uncertainties in the standard used in establishing the tracking errors, unknown systematic errors not absorbed by those that are modeled, and/or geometry limitations. The presence of a significant unmodeled systematic error may prevent an adequate description of the data from being obtained.

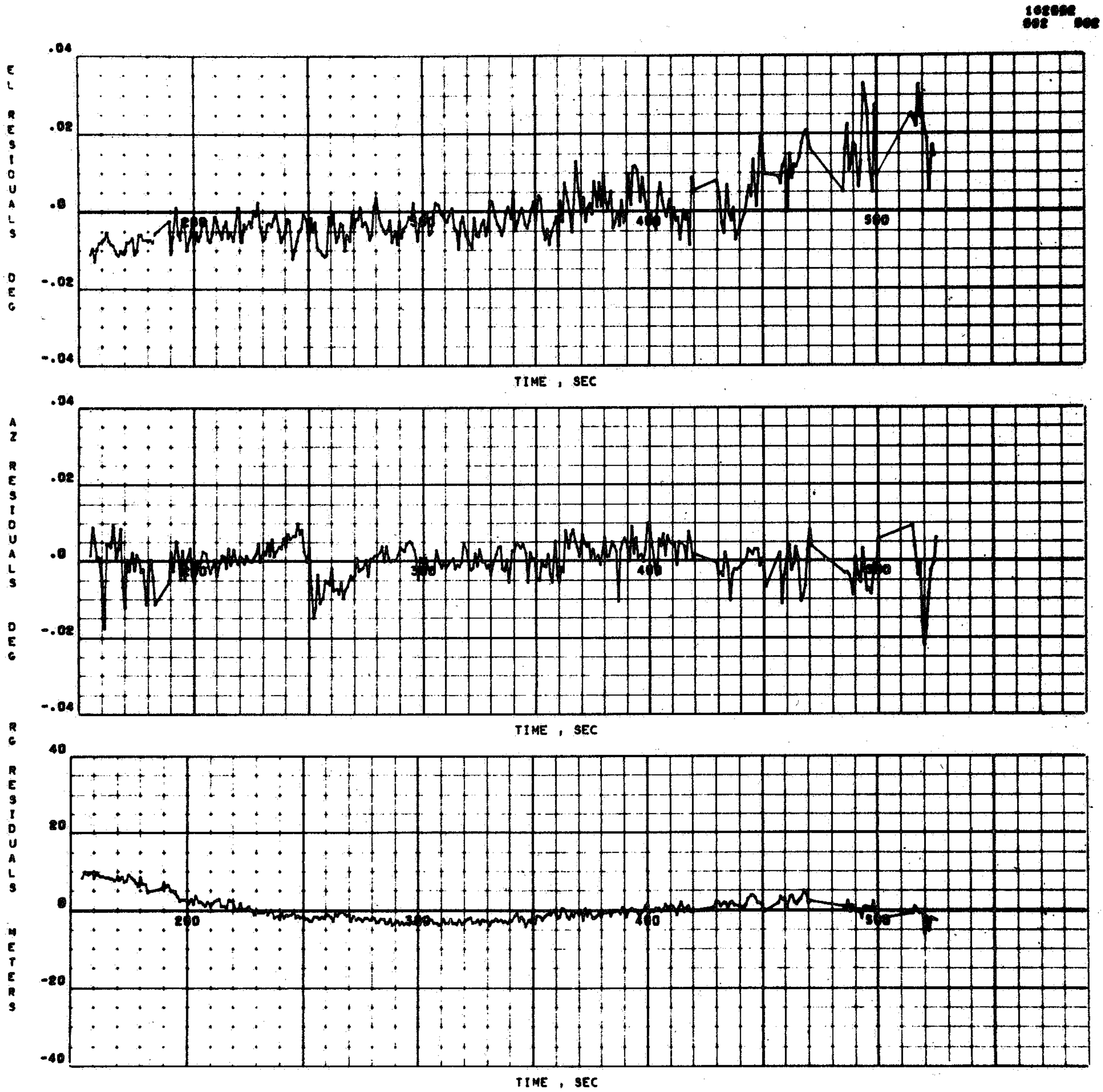

FIGURE A-1. RADAR 0.18 RESIDUALS ON AS-201

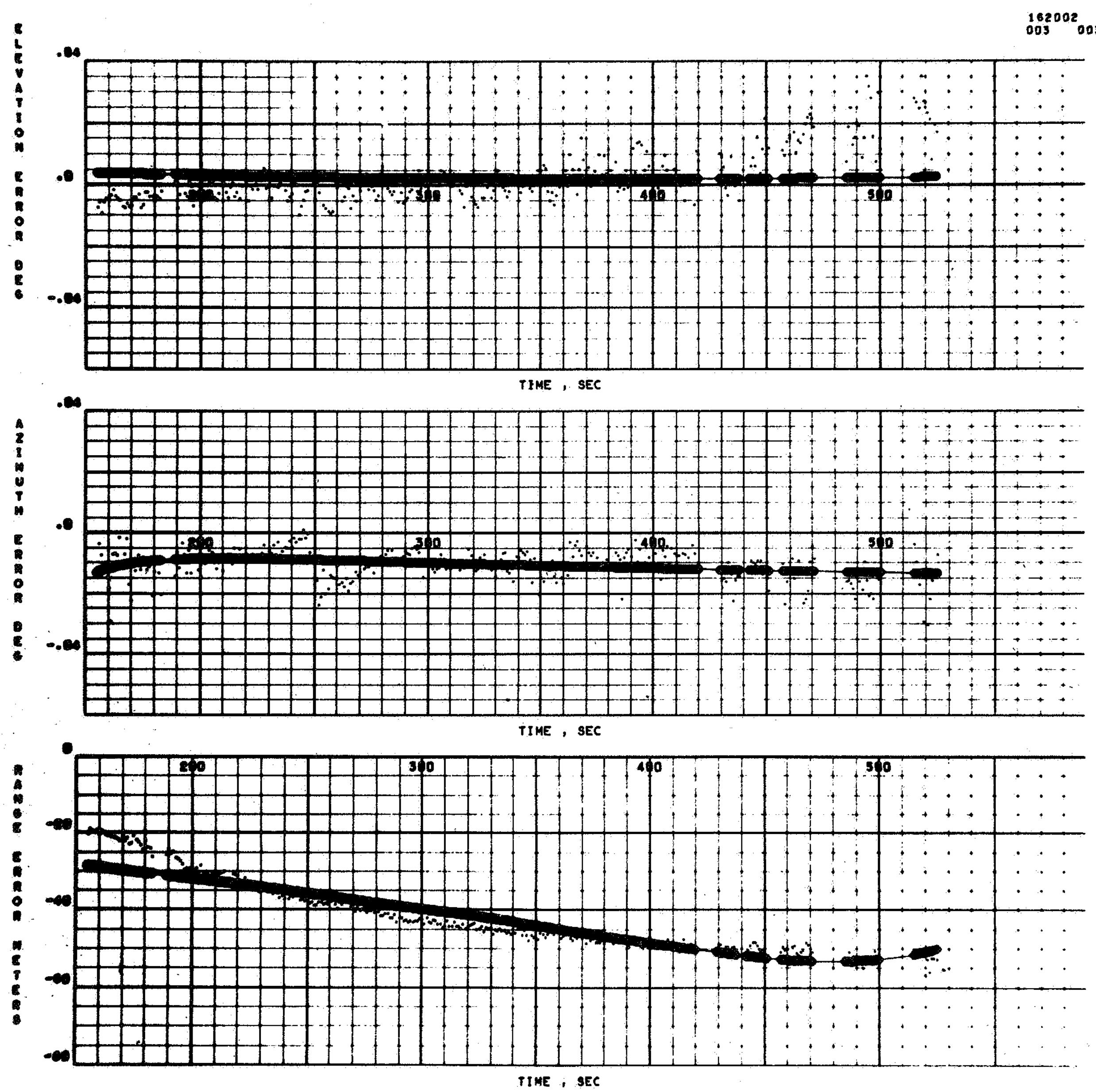

FIGURE A-2. RADAR 0.18 RANGE, AZIMUTH, AND ELEVATION ERRORS ON AS-201

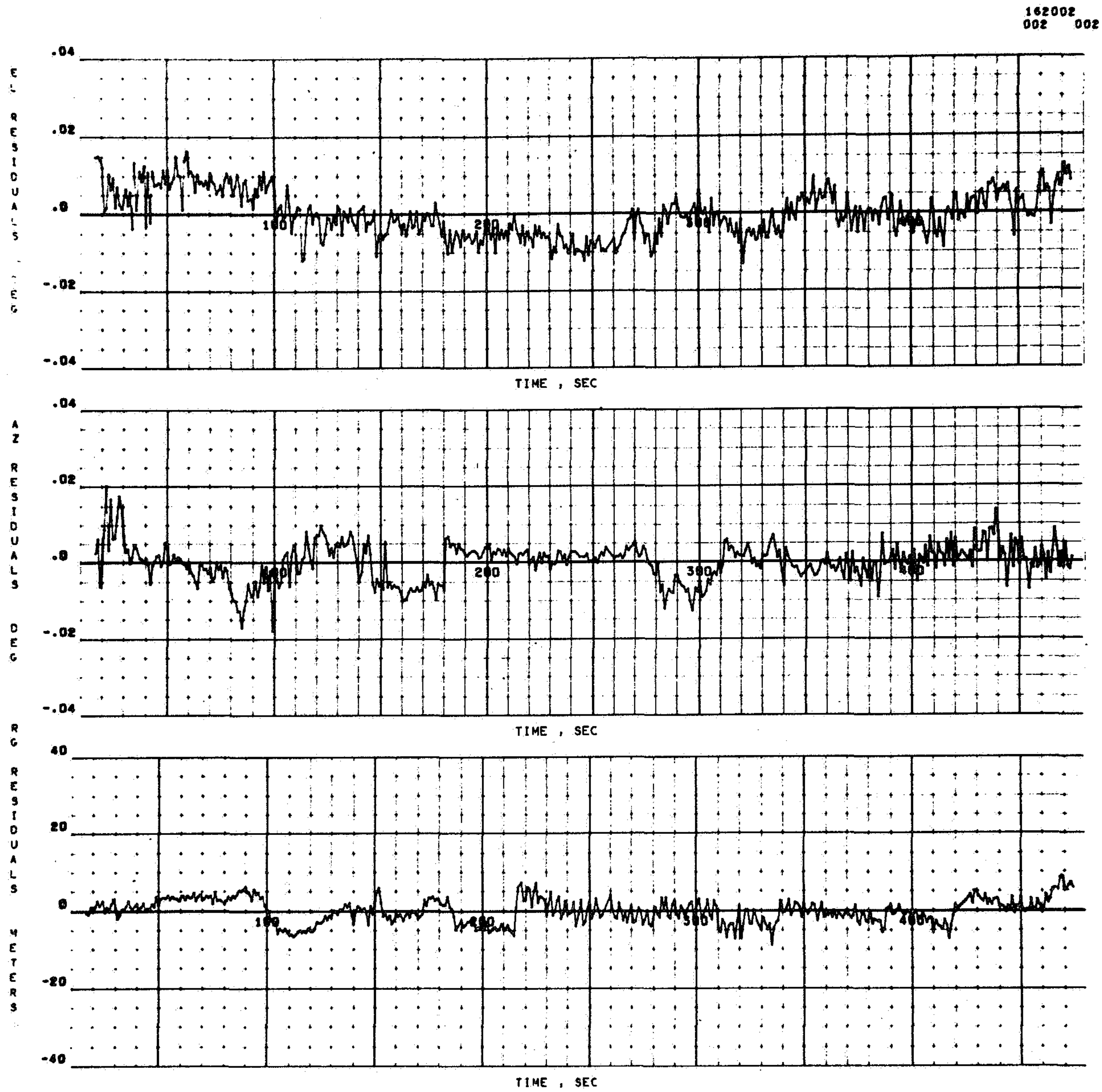

FIGURE A-3. RADAR 19.18 RESIDUALS ON AS-201

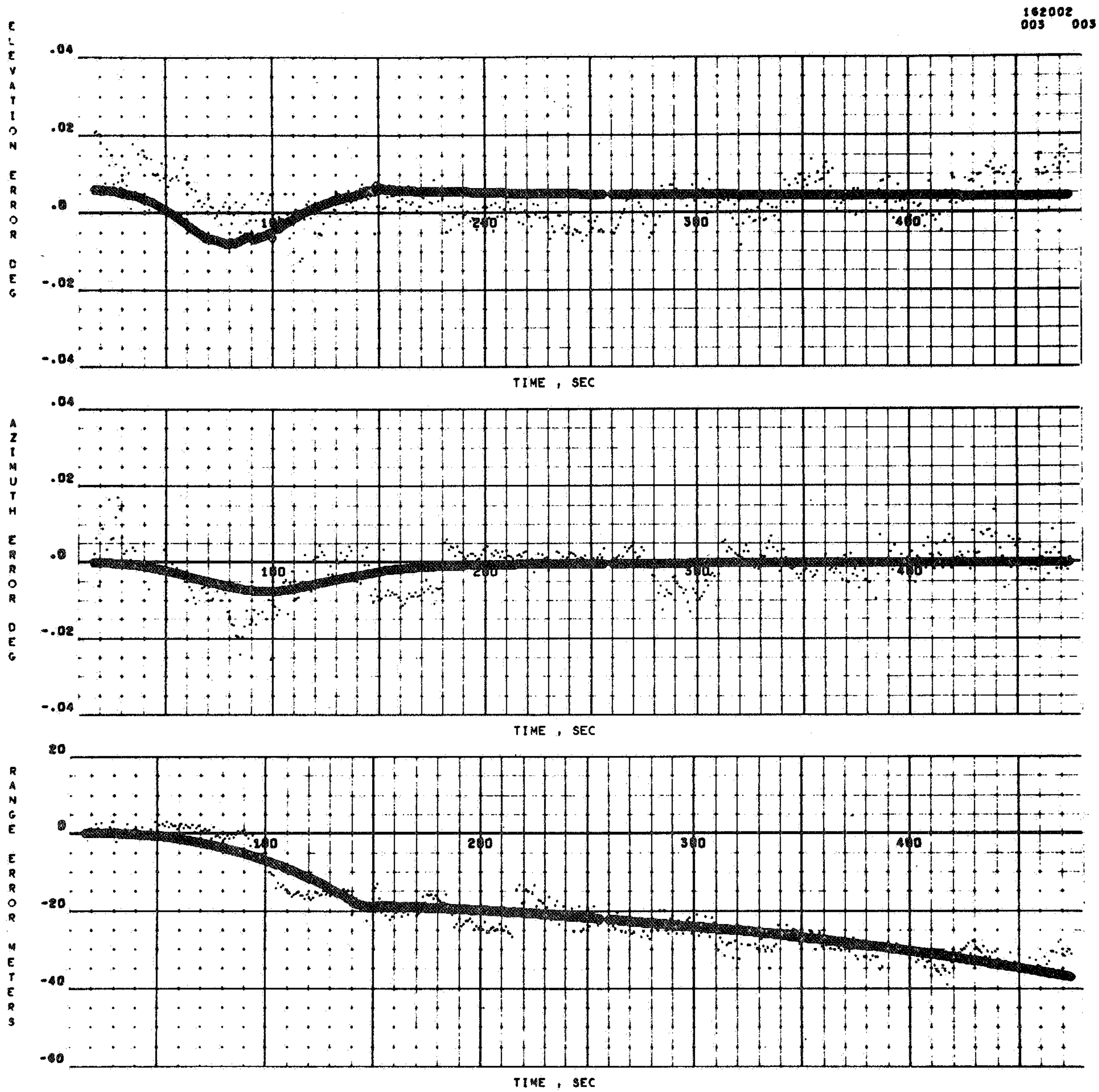

FIGURE A-4. RADAR 19.18 RANGE, AZIMUTH, AND ELEVATION ERRORS ON AS-201

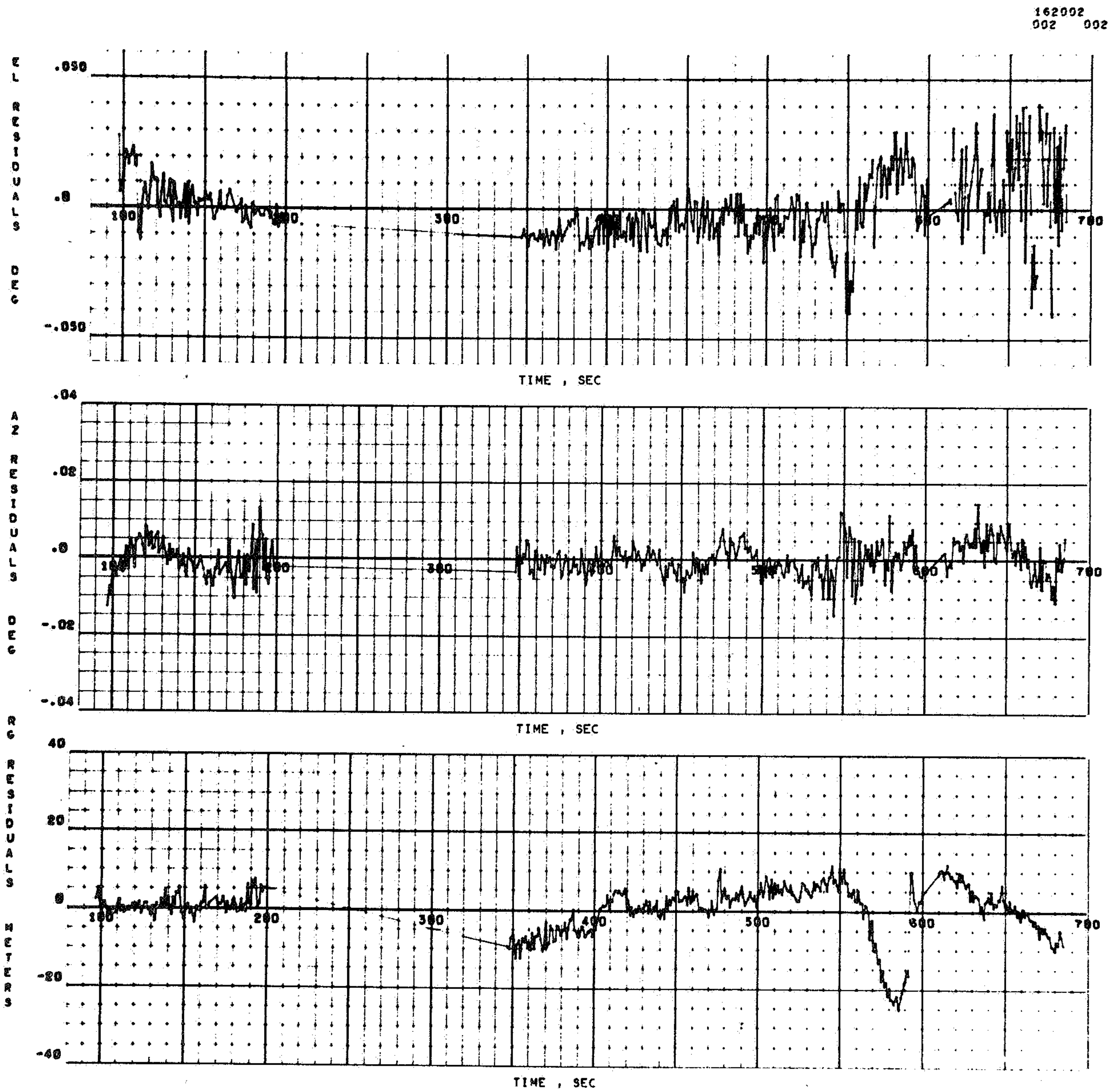

FIGURE A-5. RADAR 3.18 RESIDUALS ON AS-201

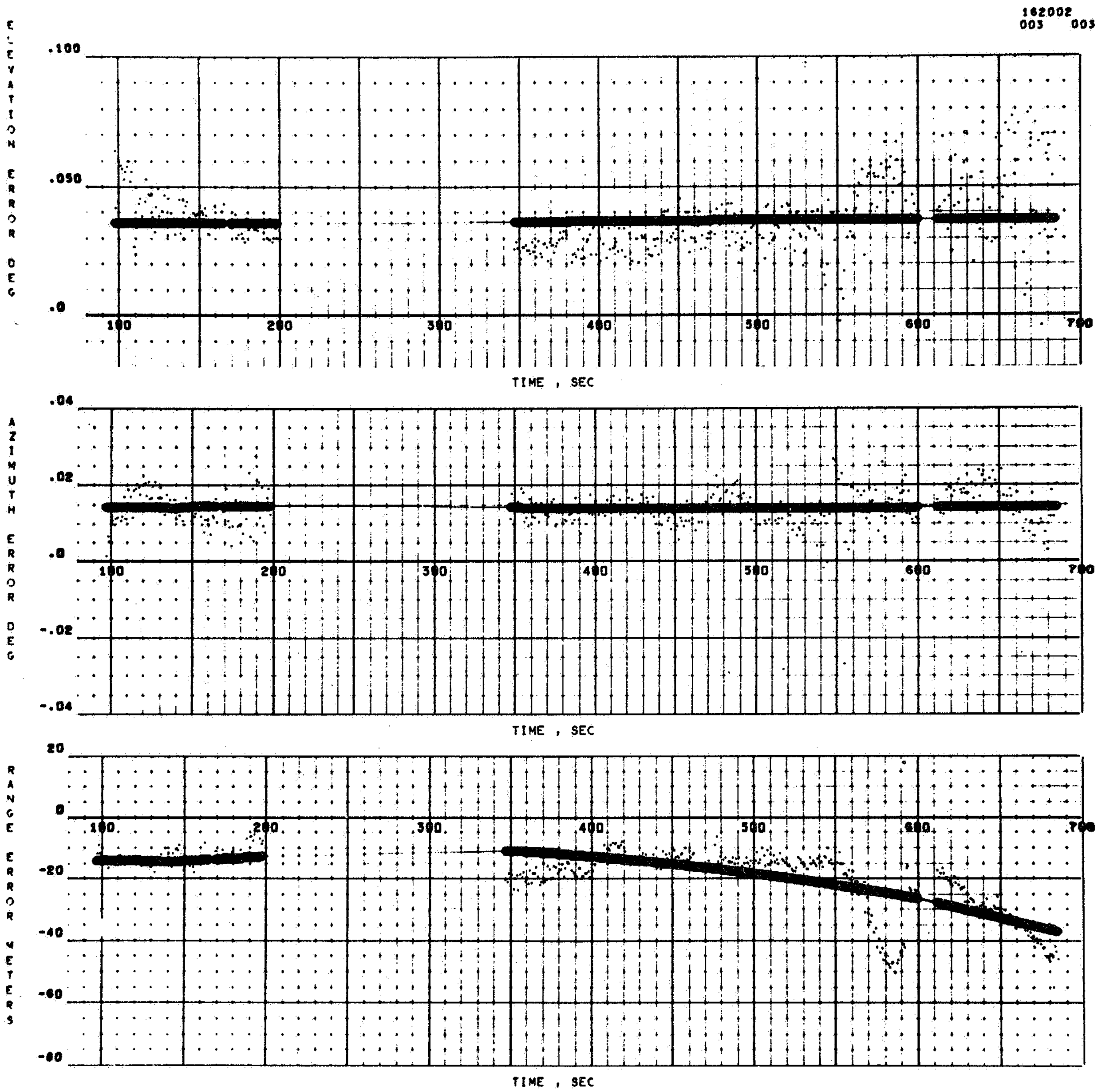

FIGURE A-6. RADAR 3.18 RANGE, AZIMUTH, AND ELEVATION ERRORS ON AS-201

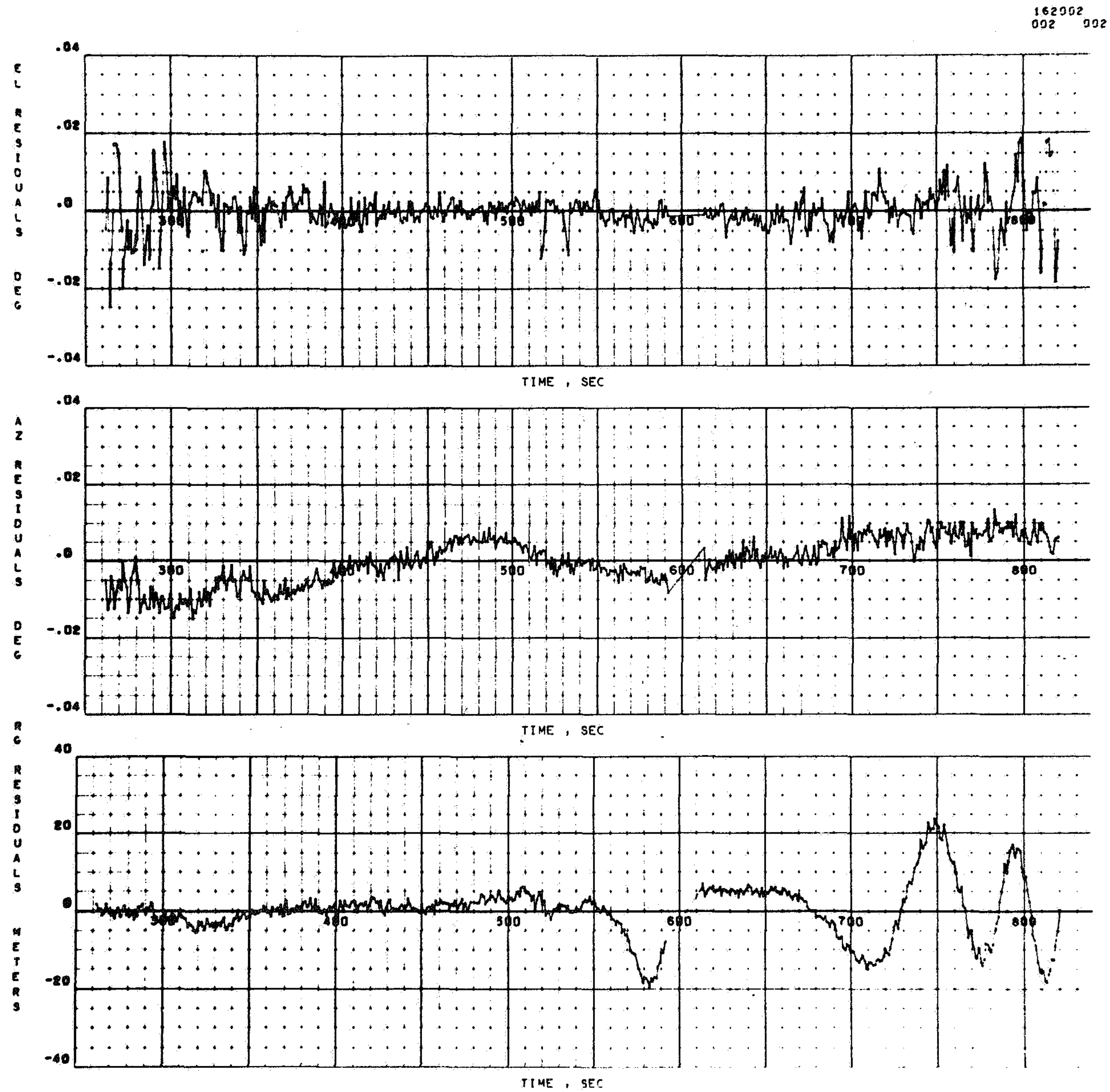

FIGURE A-7. RADAR 7.18 RESIDUALS ON AS-201

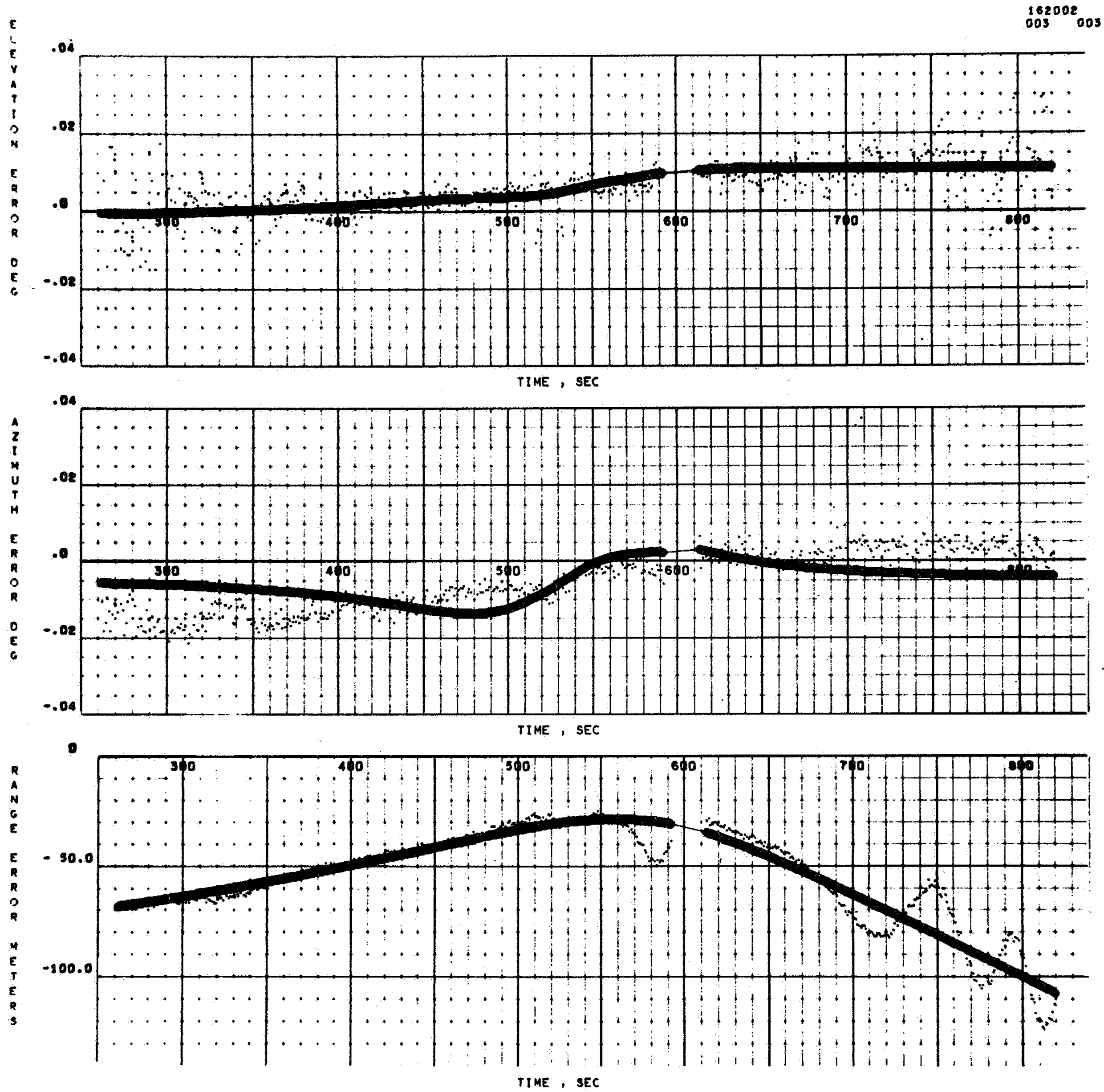

FIGURE A-8. RADAR 7.18 RANGE, AZIMUTH, AND ELEVATION ERRORS ON AS-201

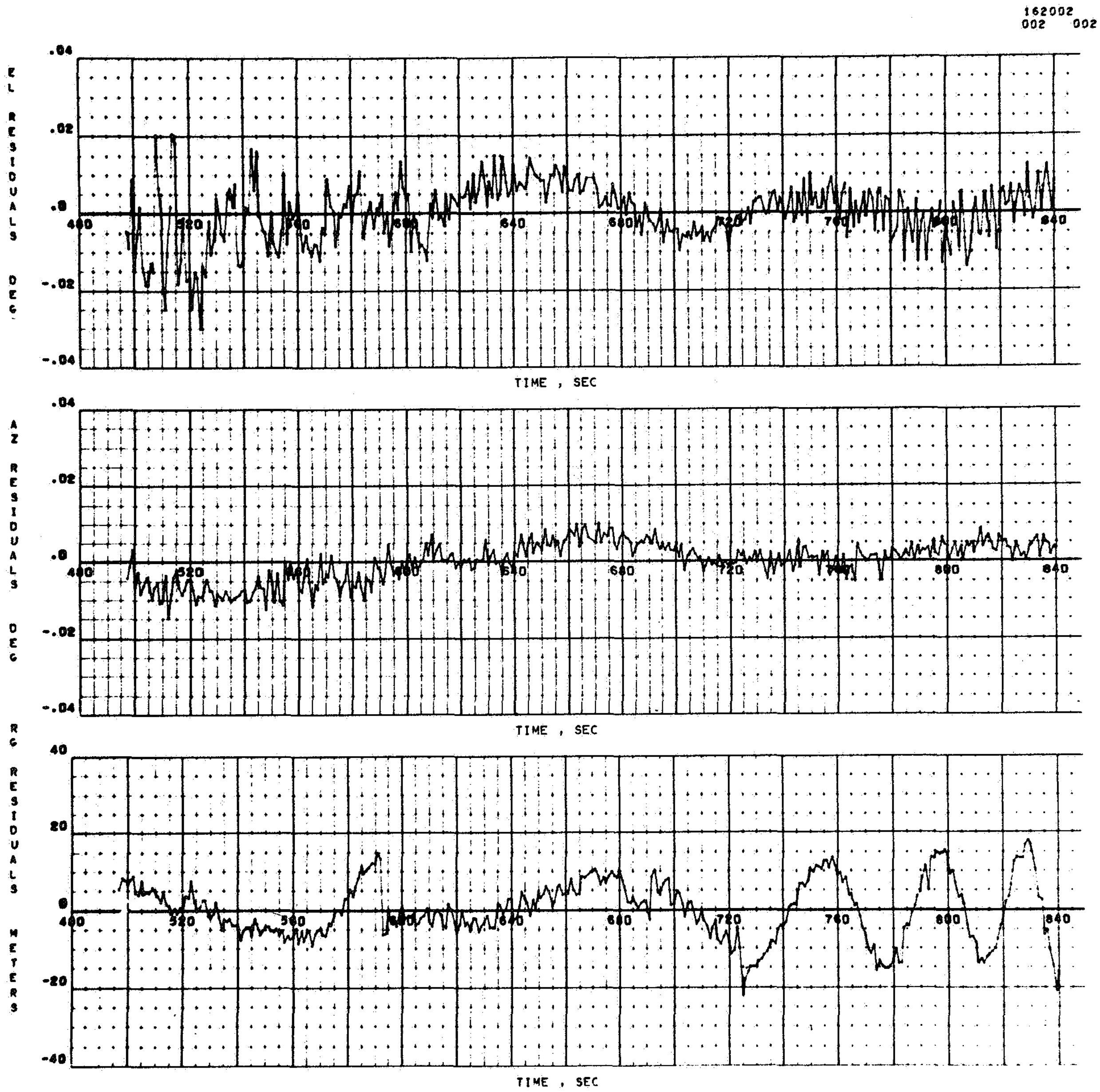

FIGURE A-9. RADAR 91.18 RESIDUALS ON AS-201

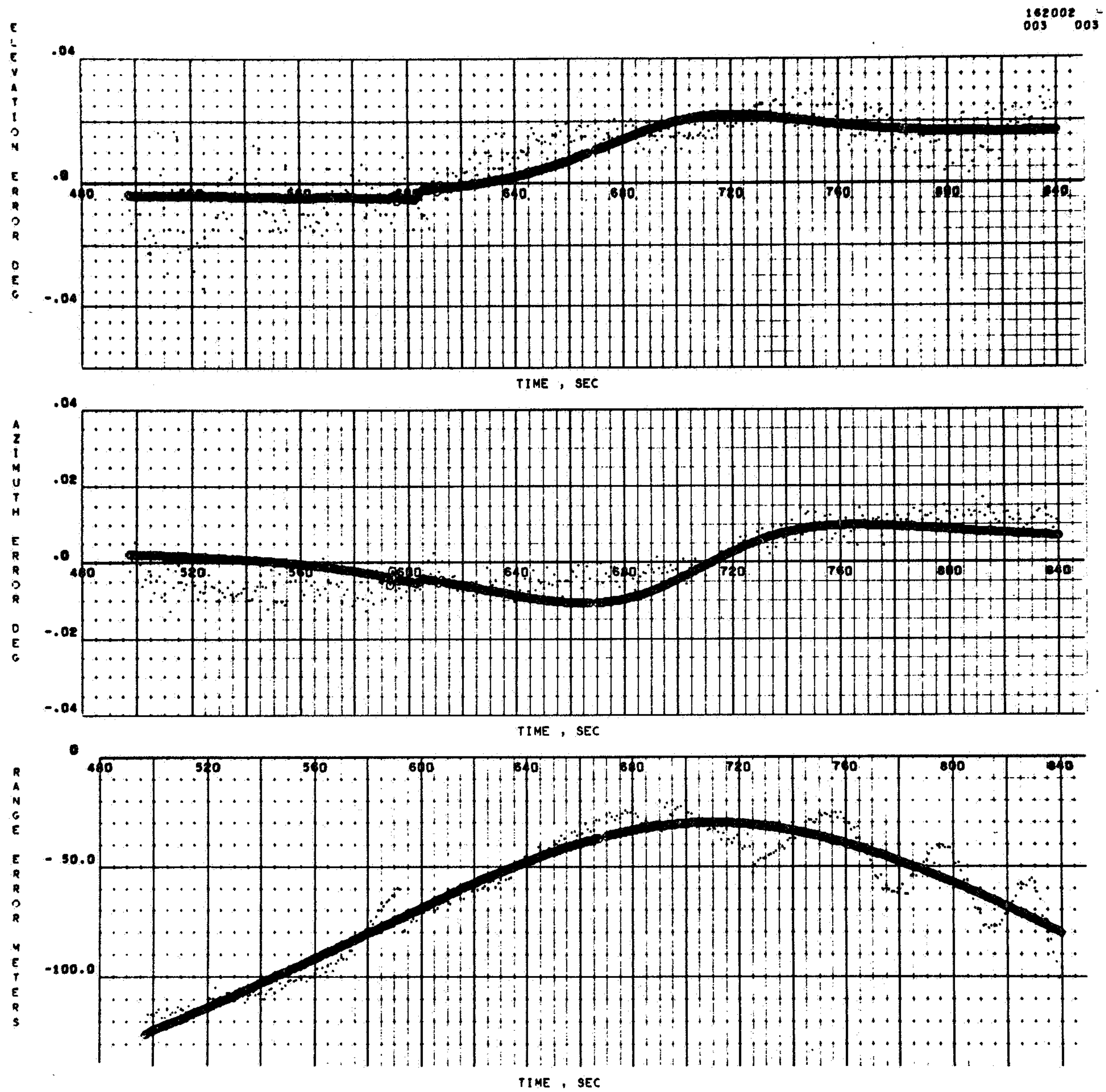

FIGURE A-10. RADAR 91.18 RANGE, AZIMUTH, AND ELEVATION ERRORS ON AS-201

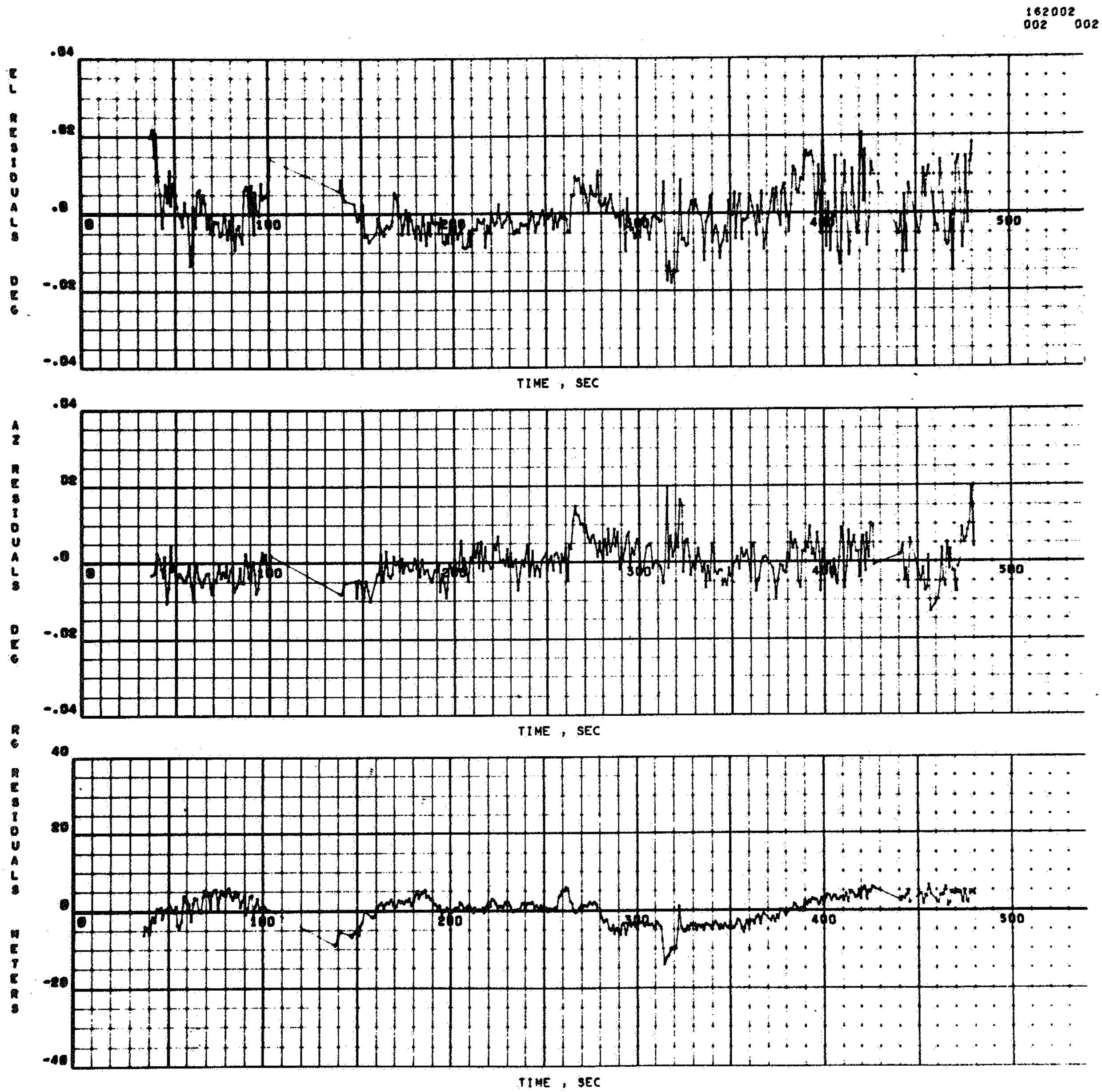

FIGURE A-11. RADAR 0.18 RESIDUALS ON AS-202

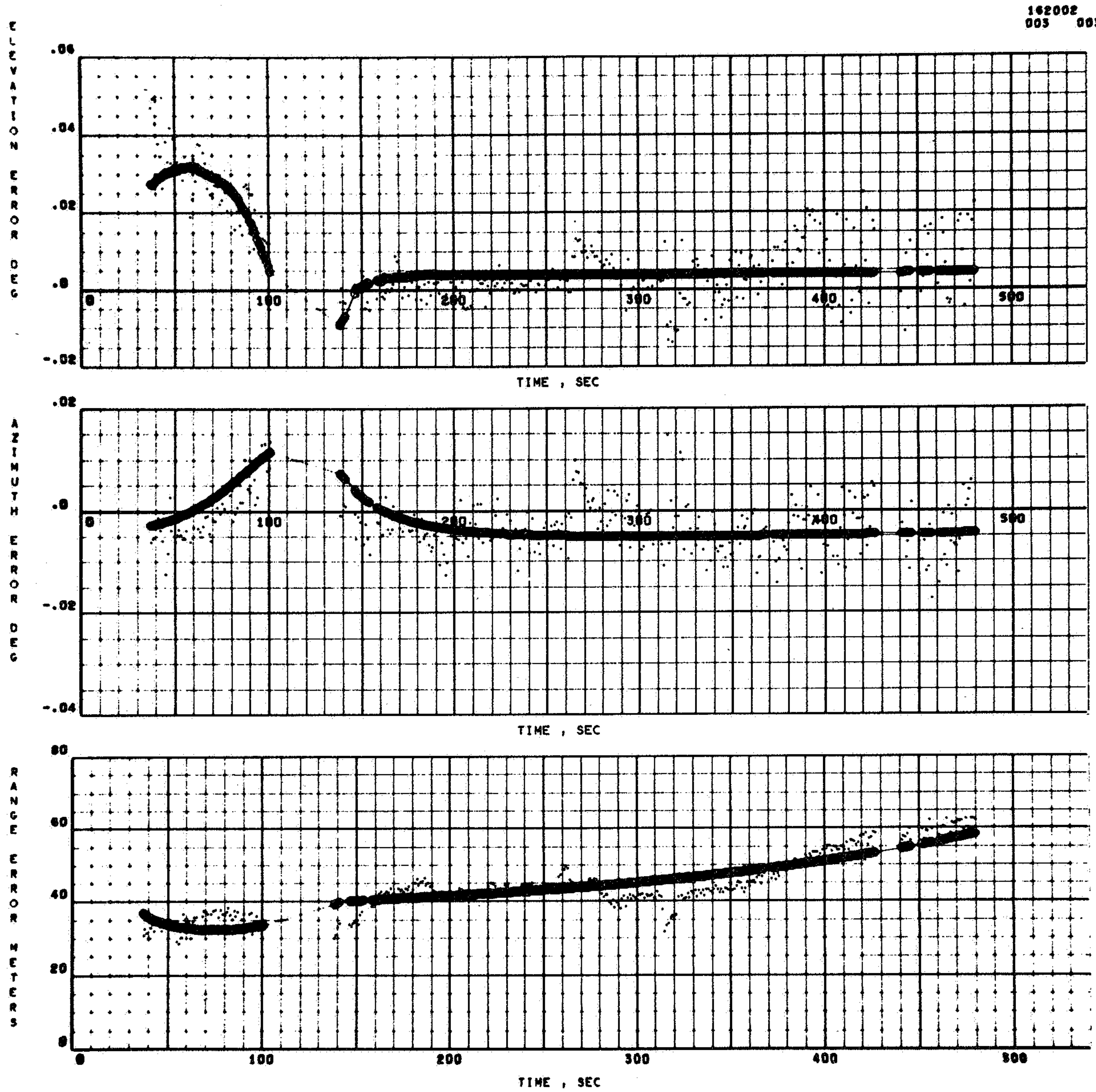

FIGURE A-12. RADAR 0.18 RANGE, AZIMUTH, AND ELEVATION ERRORS ON AS-202

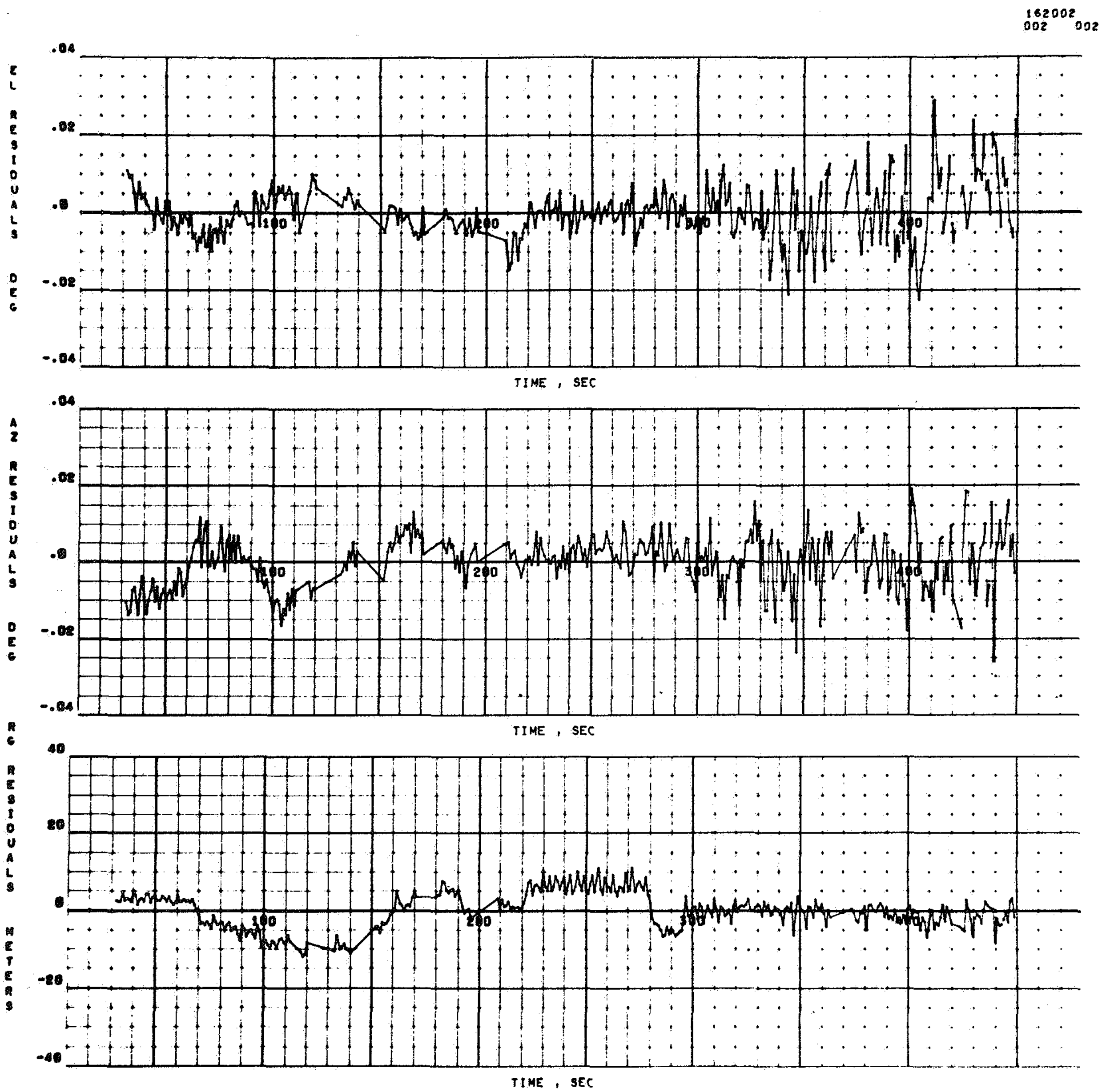

FIGURE A-13. RADAR 19.18 RESIDUALS ON AS-202

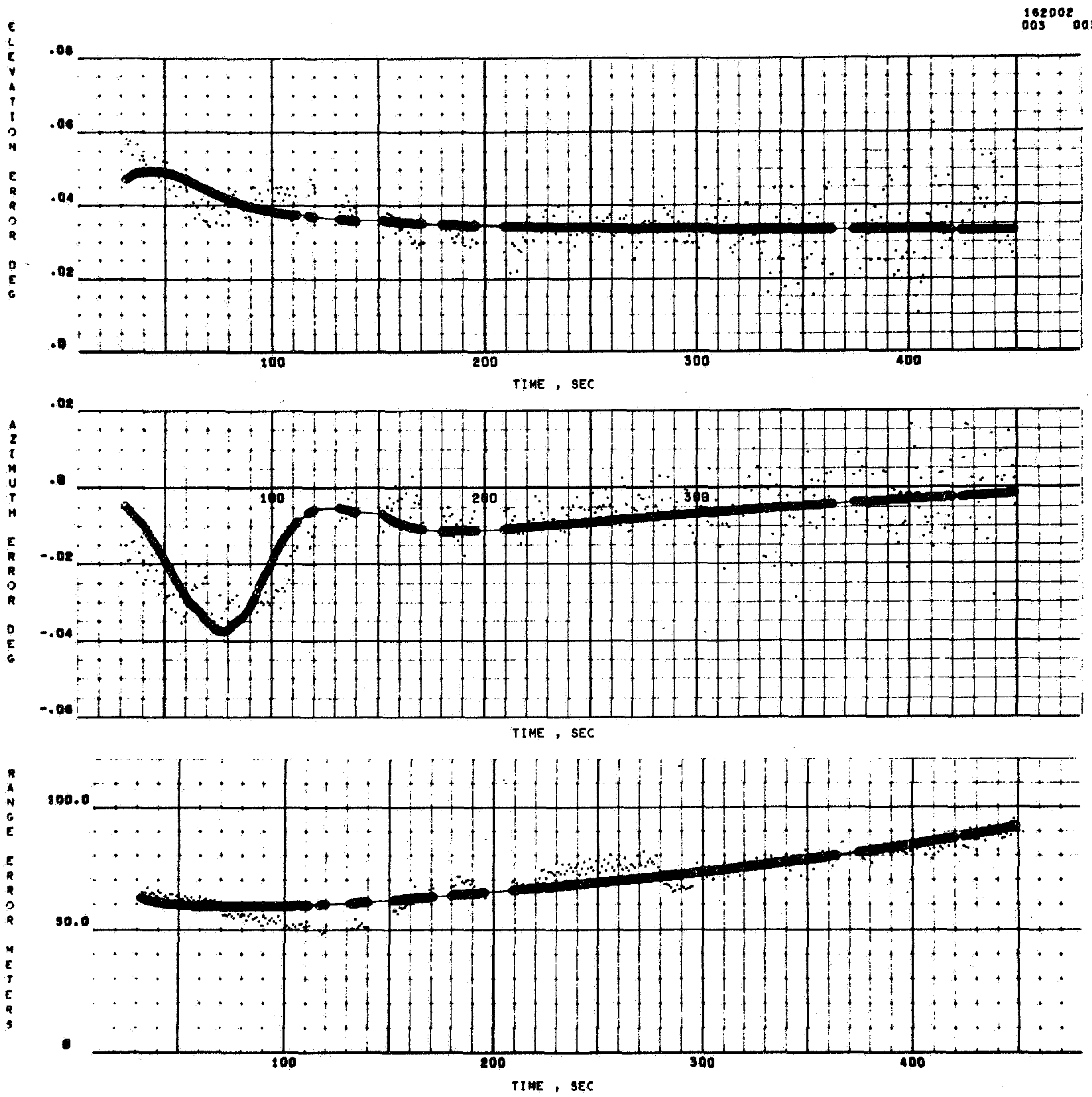

FIGURE A-14. RADAR 19.18 RANGE, AZIMUTH, AND ELEVATION ERRORS ON AS-202

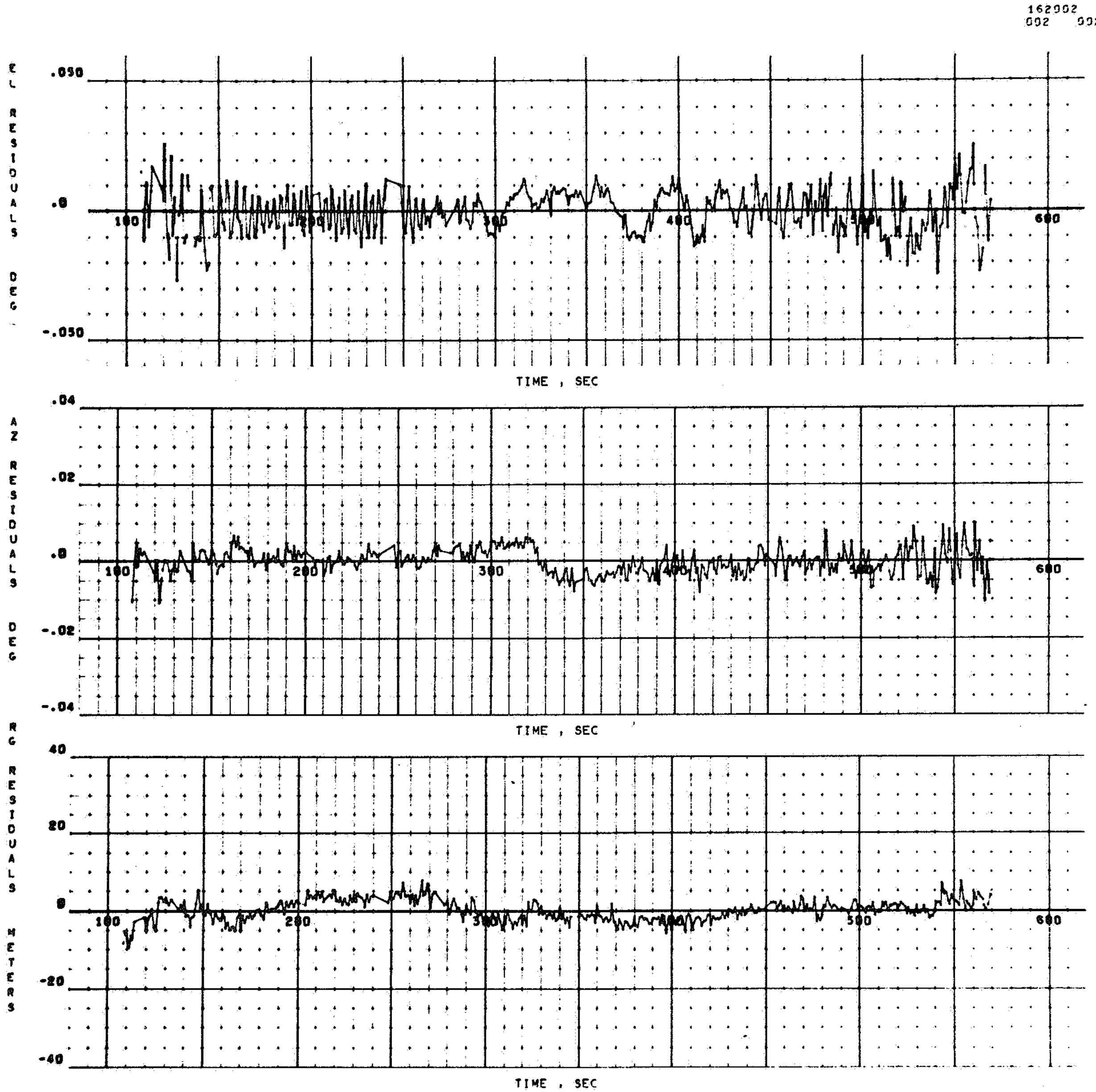

FIGURE A-15. RADAR 3.18 RESIDUALS ON AS-202

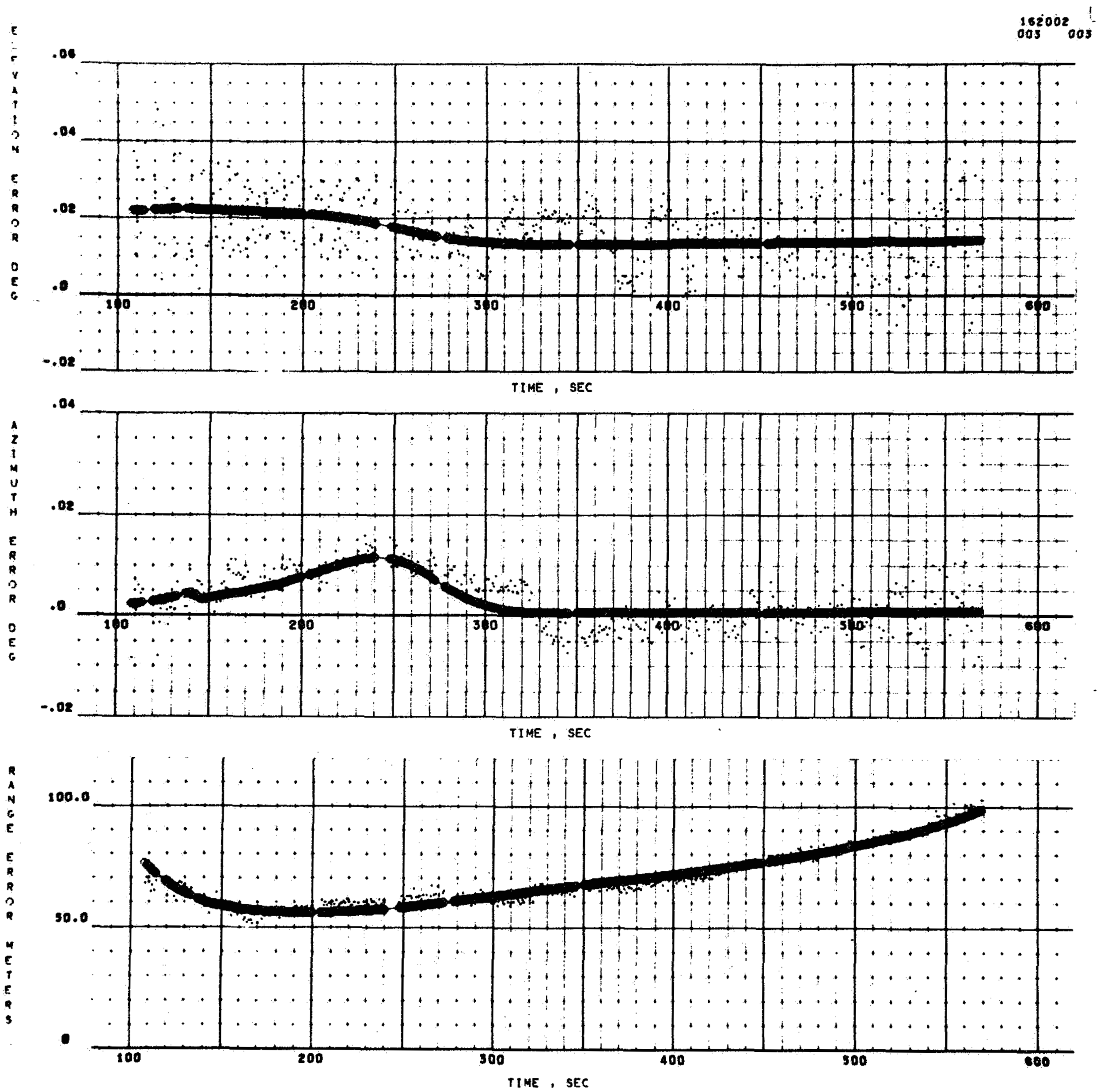

FIGURE A-16. RADAR 3.18 RANGE, AZIMUTH, AND ELEVATION ERRORS ON AS-202

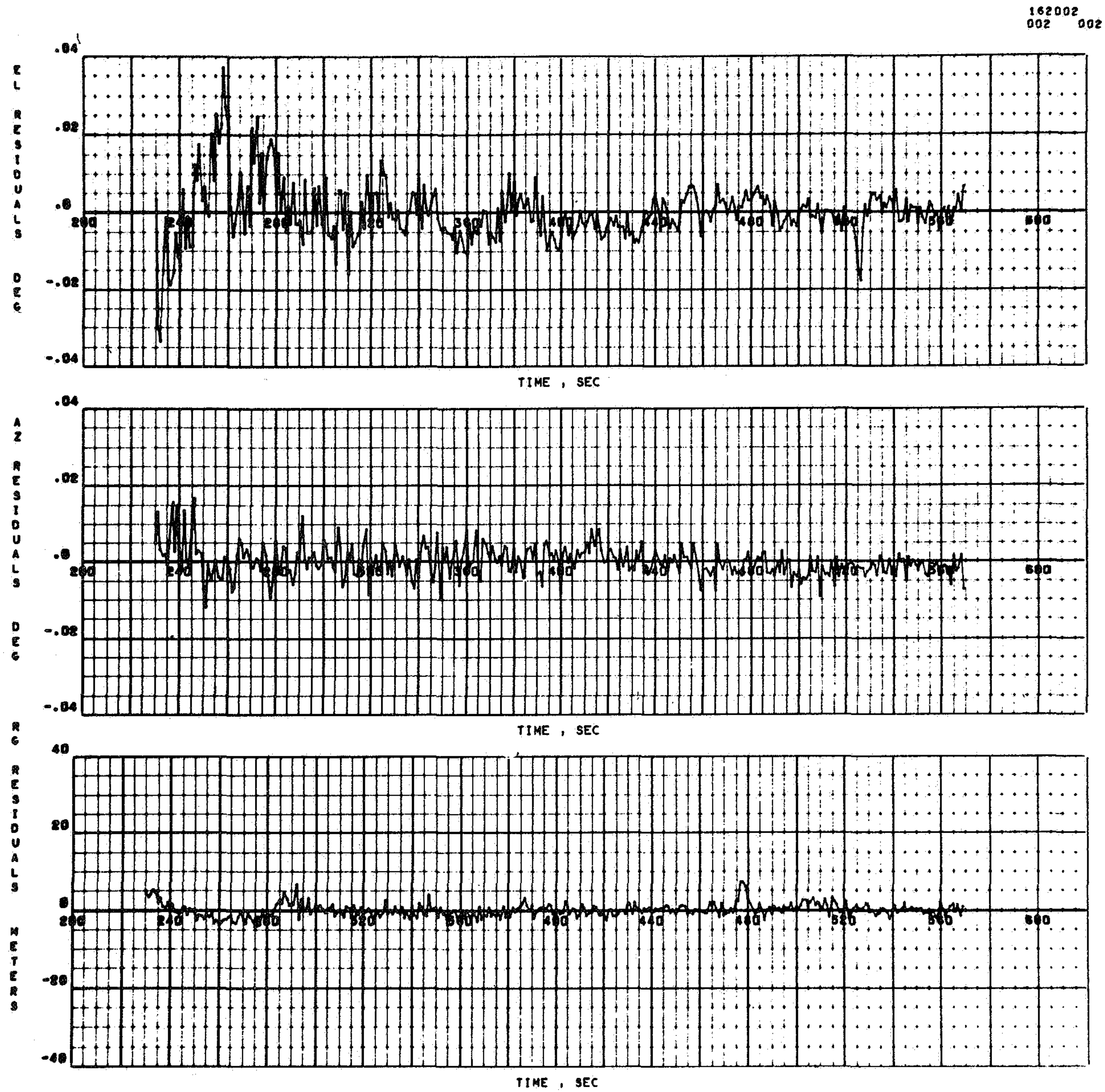

FIGURE A-17. RADAR 7.18 RESIDUALS ON AS-202

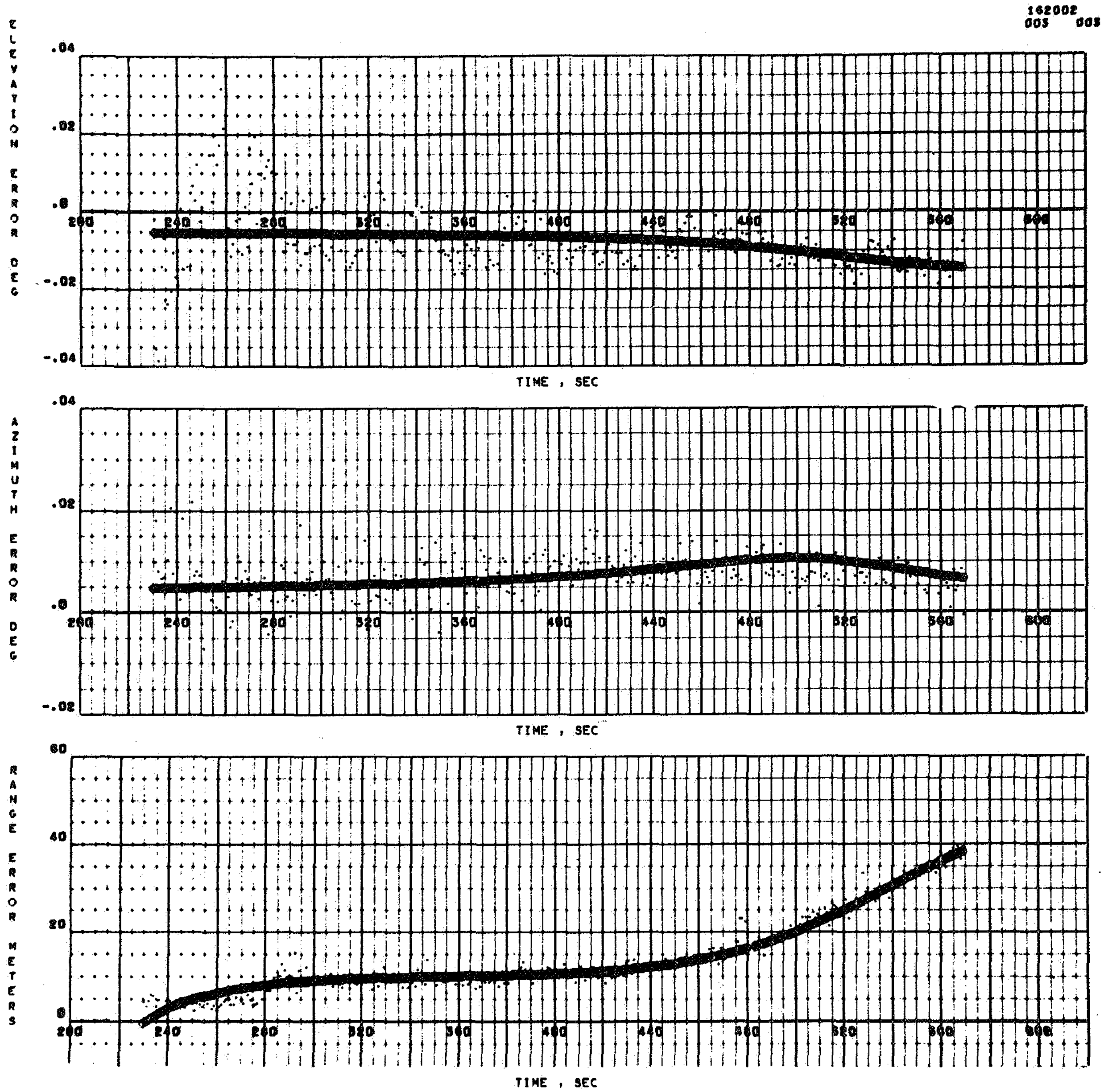

FIGURE A-18. RADAR 7.18 RANGE, AZIMUTH, AND ELEVATION ERRORS ON AS-202

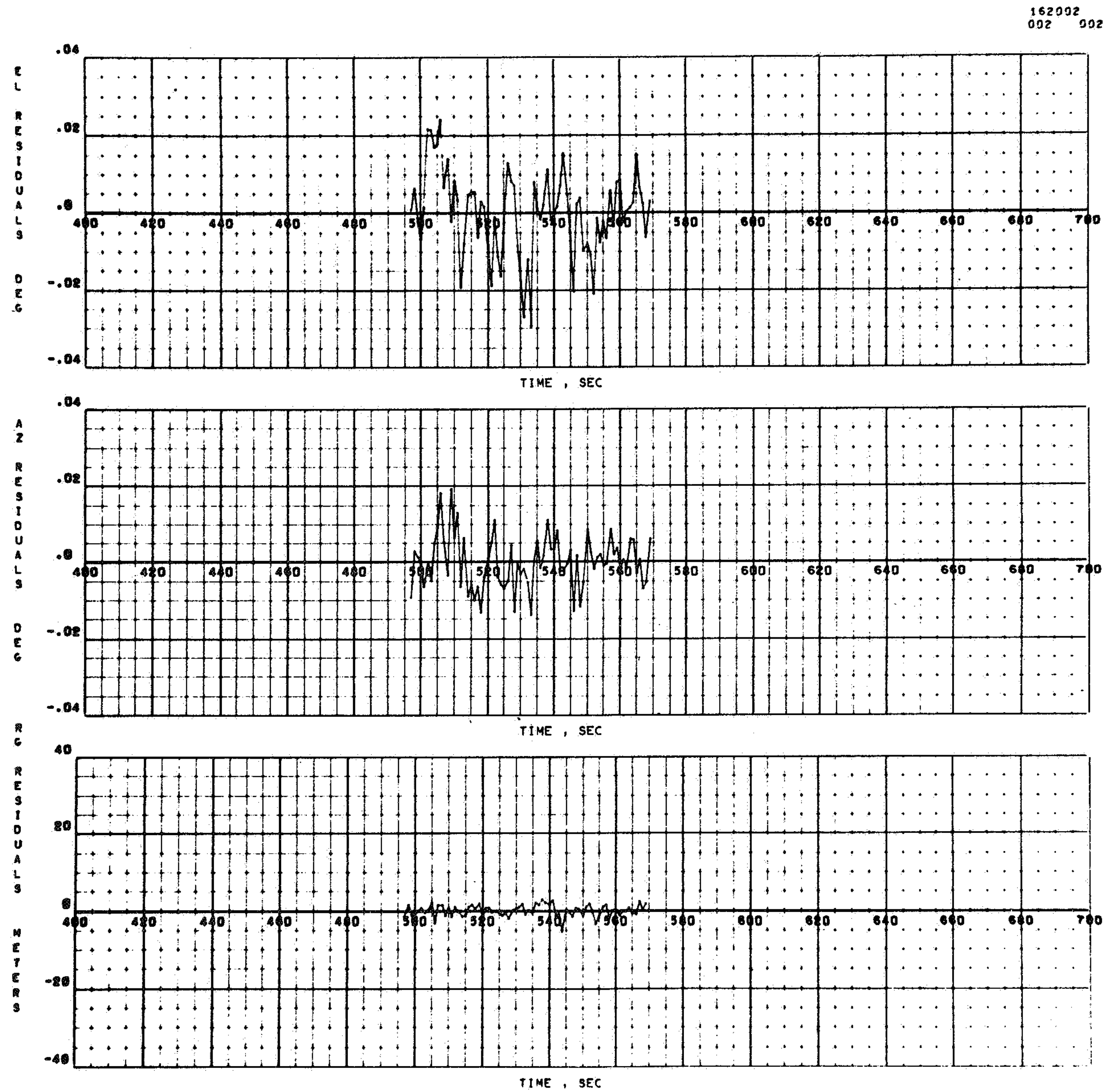

FIGURE A-19. RADAR 91.18 RESIDUALS ON AS-202

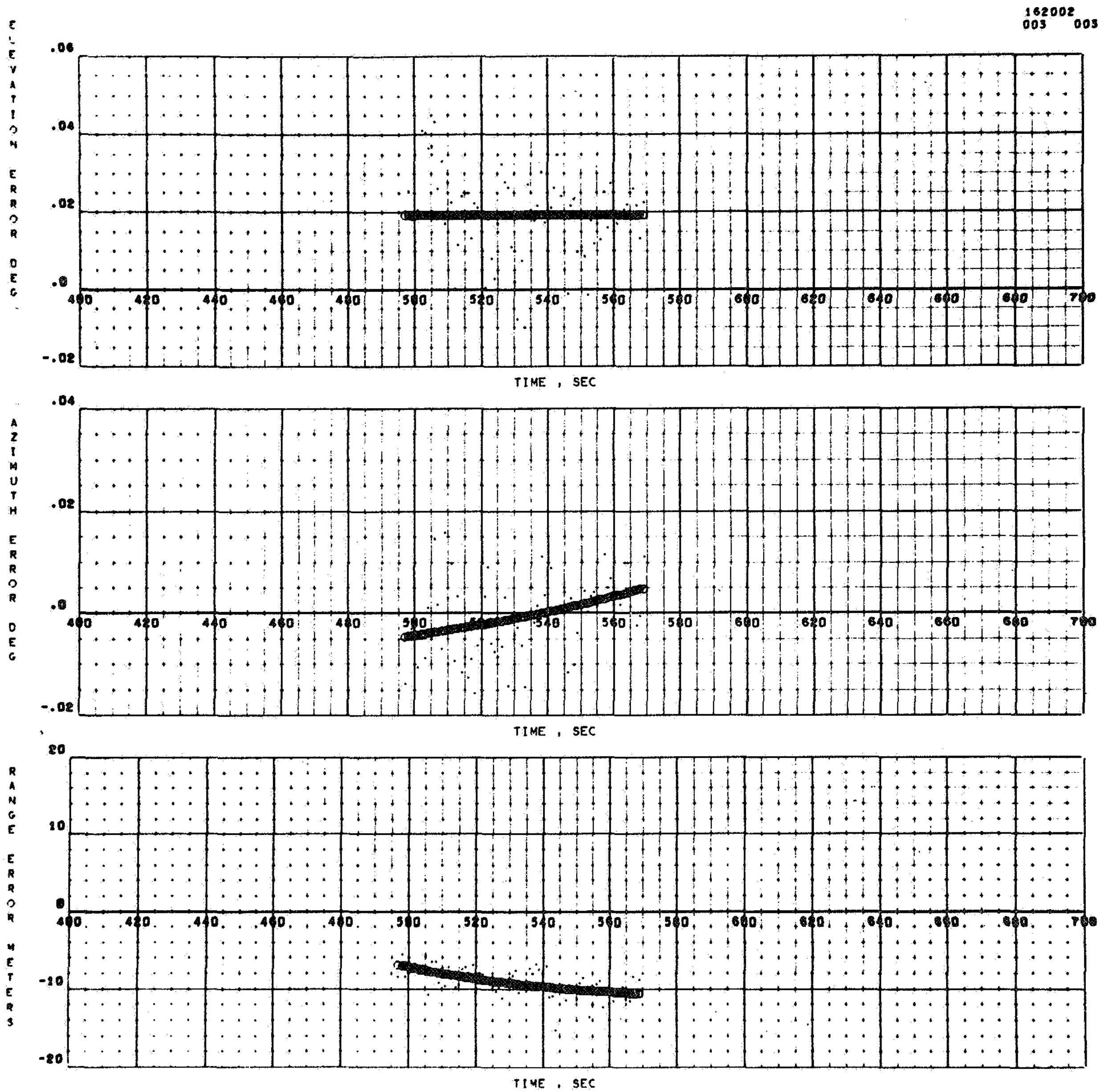

FIGURE A-20. RADAR 91.18 RANGE, AZIMUTH, AND ELEVATION ERRORS ON AS-202

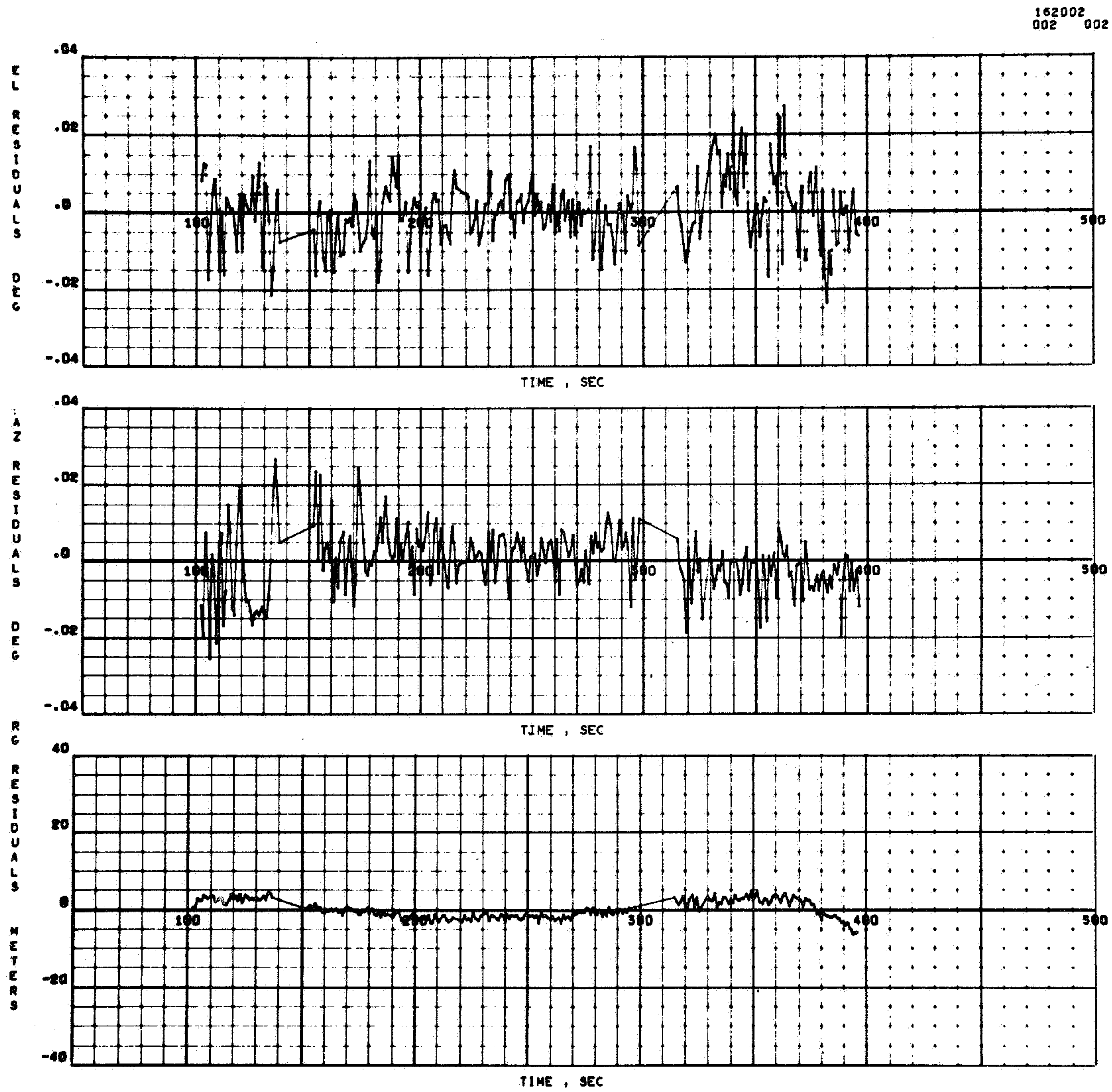

FIGURE A-21. RADAR 0.18 RESIDUALS ON SA-203

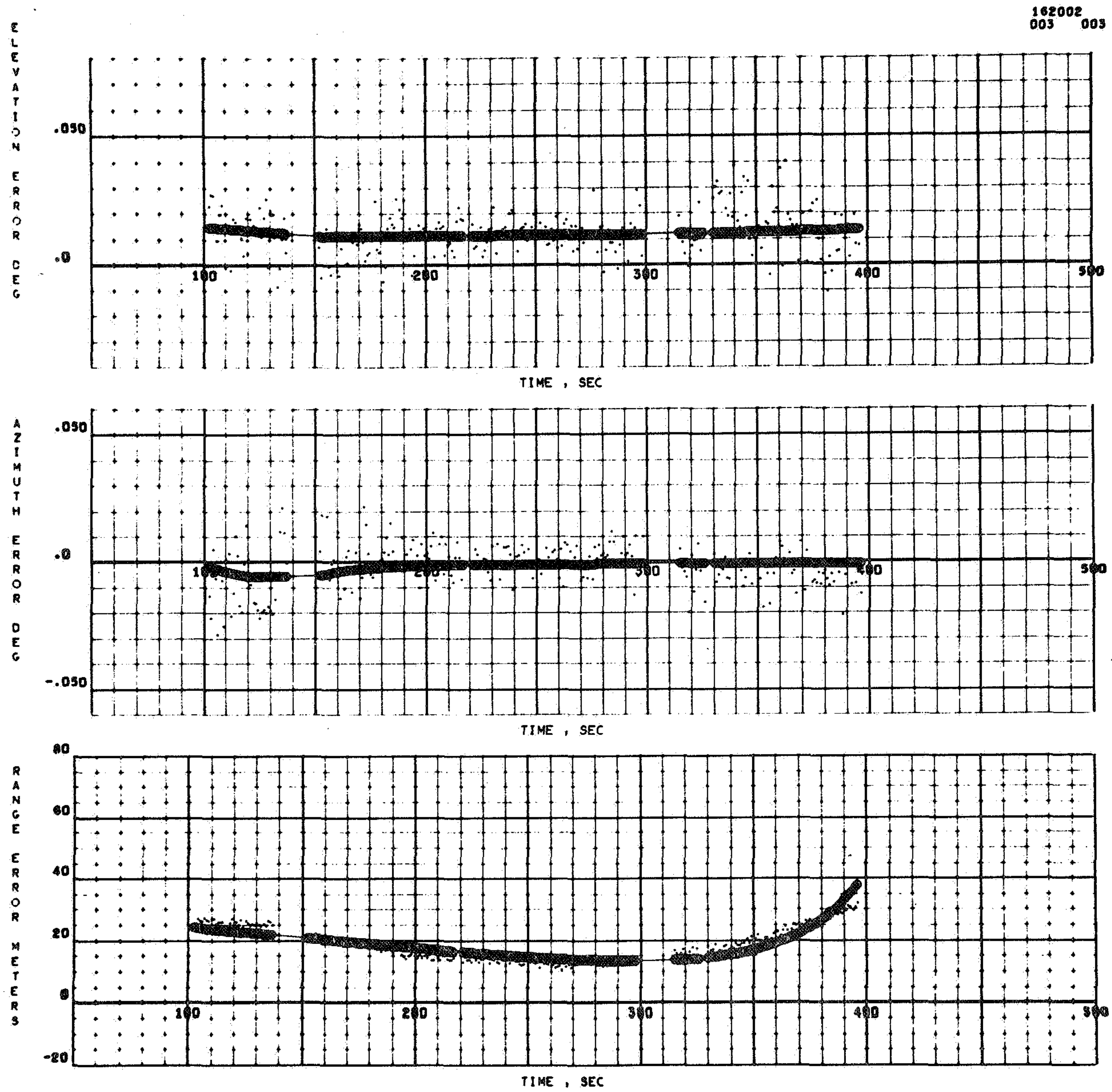

FIGURE A-22. RADAR 0.18 RANGE, AZIMUTH, AND ELEVATION ERRORS ON SA-203

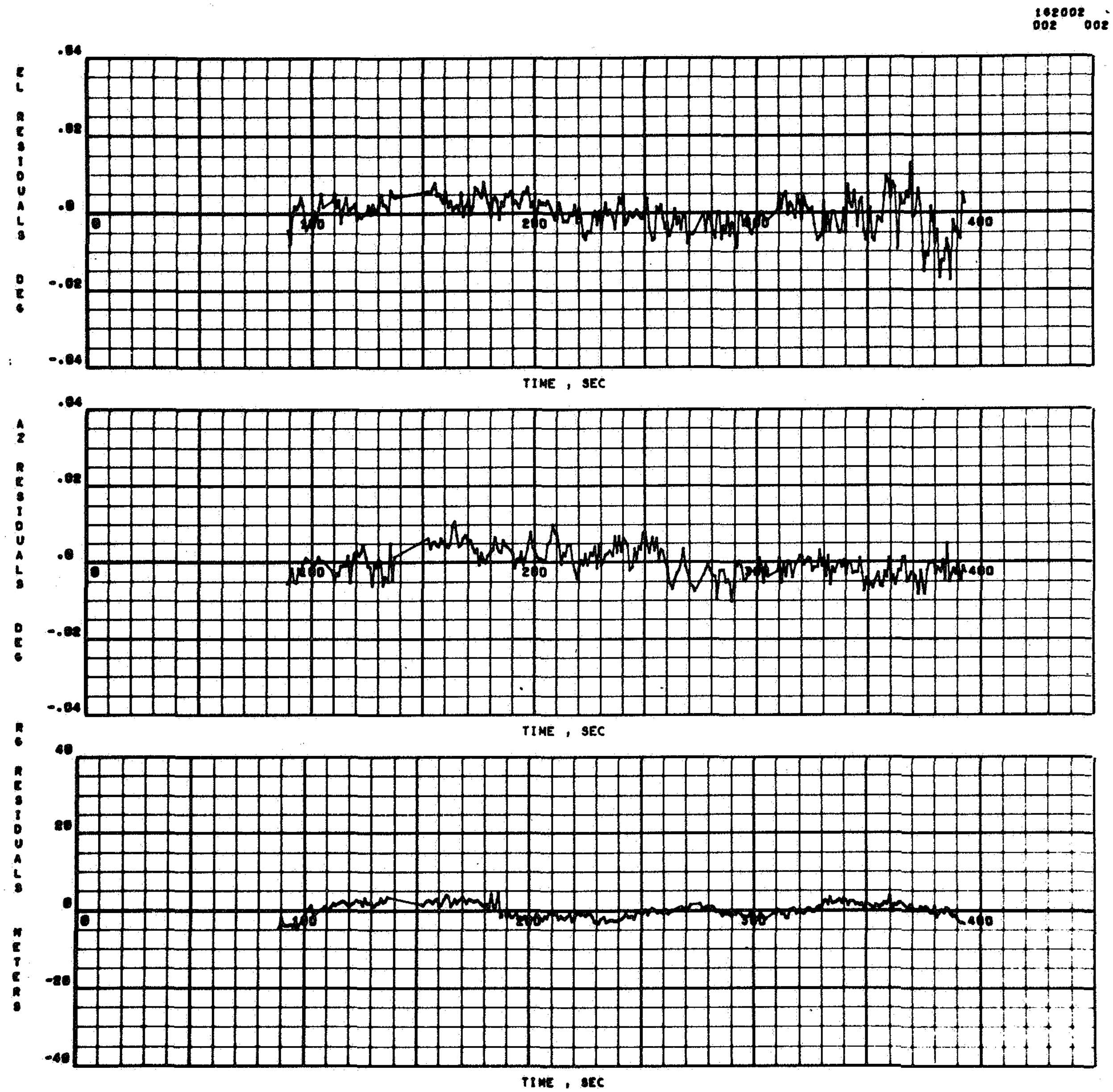

FIGURE A-23. RADAR 19.18 RESIDUALS ON SA-203

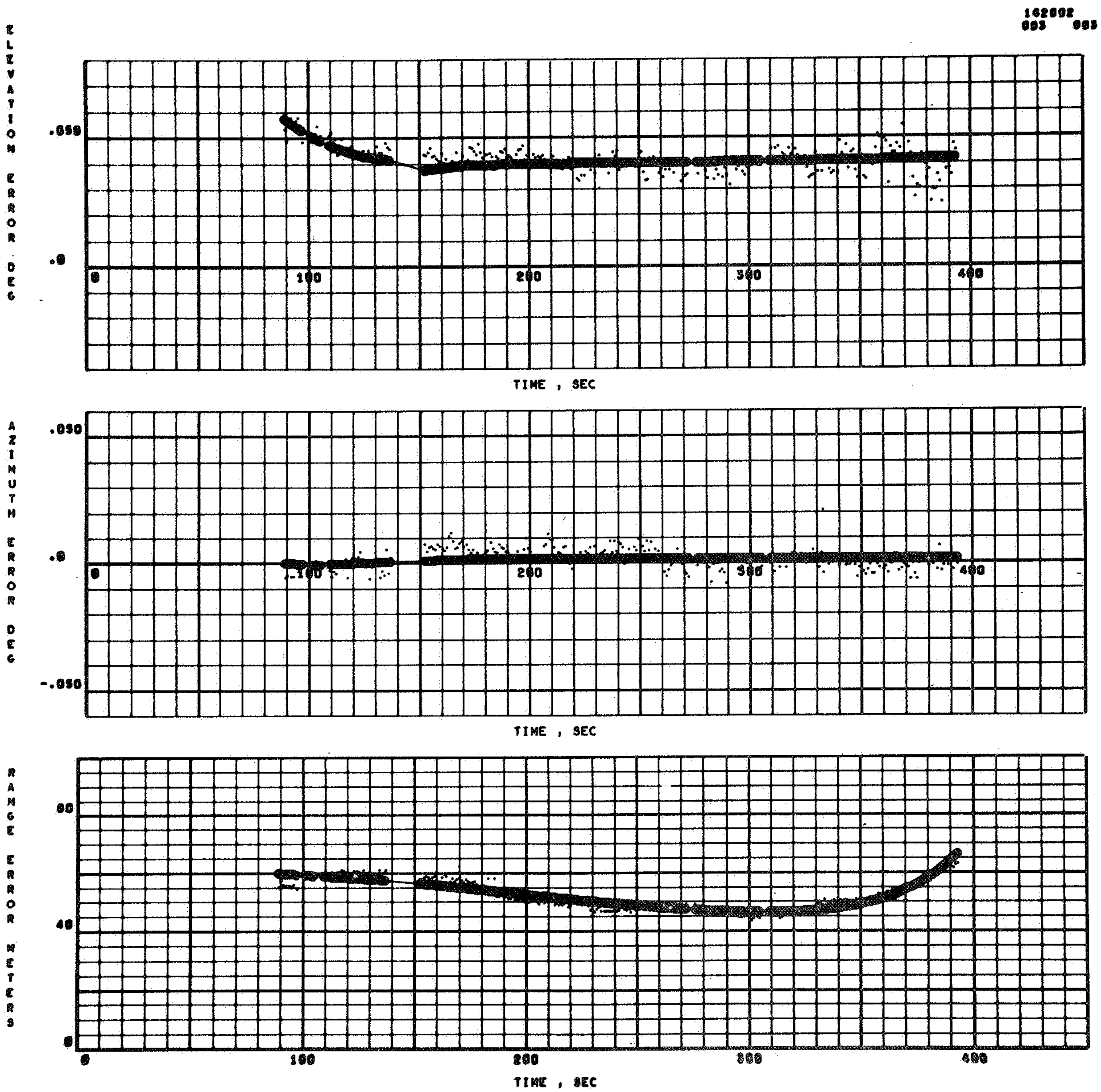

FIGURE A-24. RADAR 19.18 RANGE, AZIMUTH, AND ELEVATION ERRORS ON SA-203

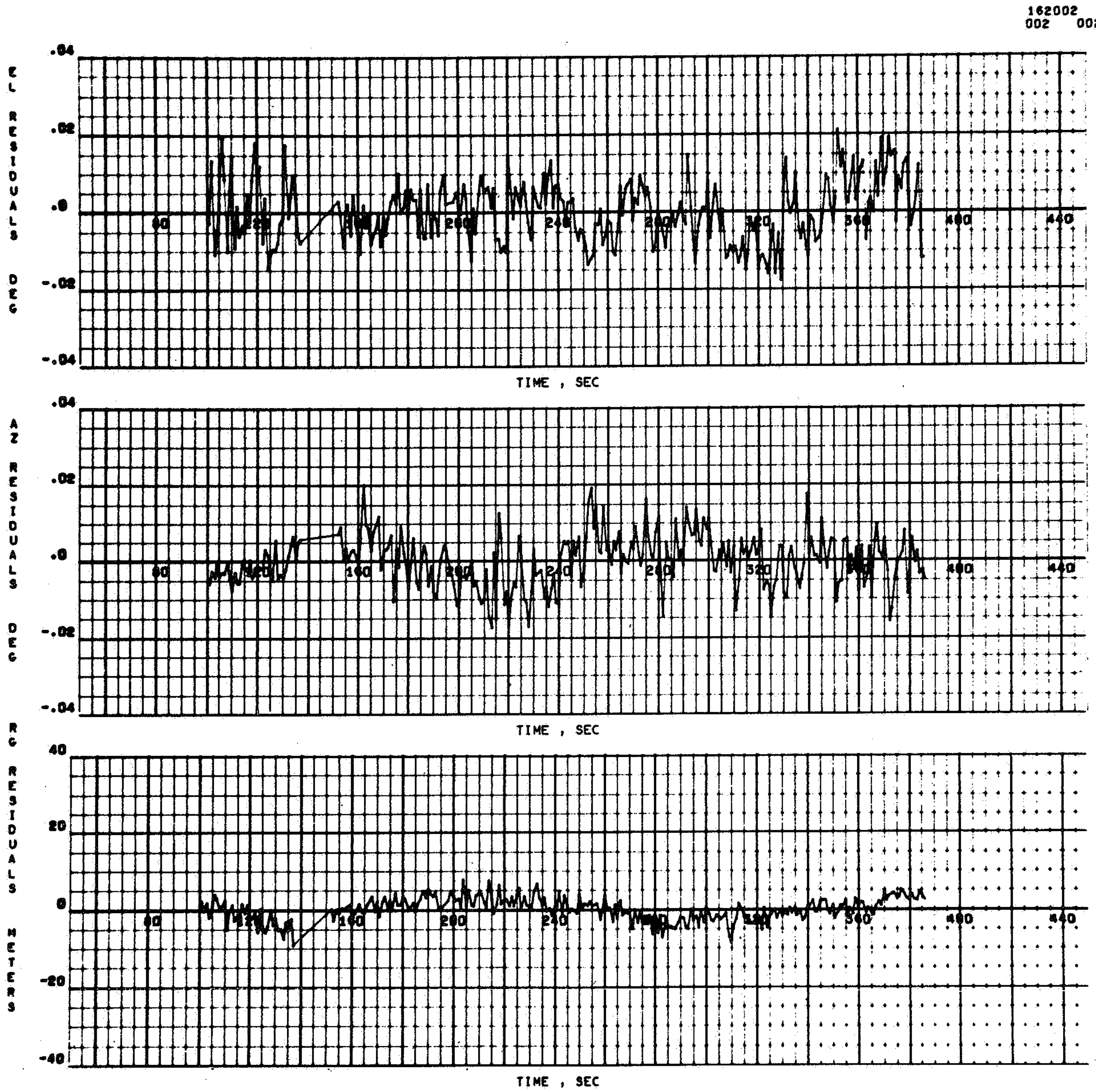

FIGURE A-25. RADAR 3.18 RESIDUALS ON SA-203

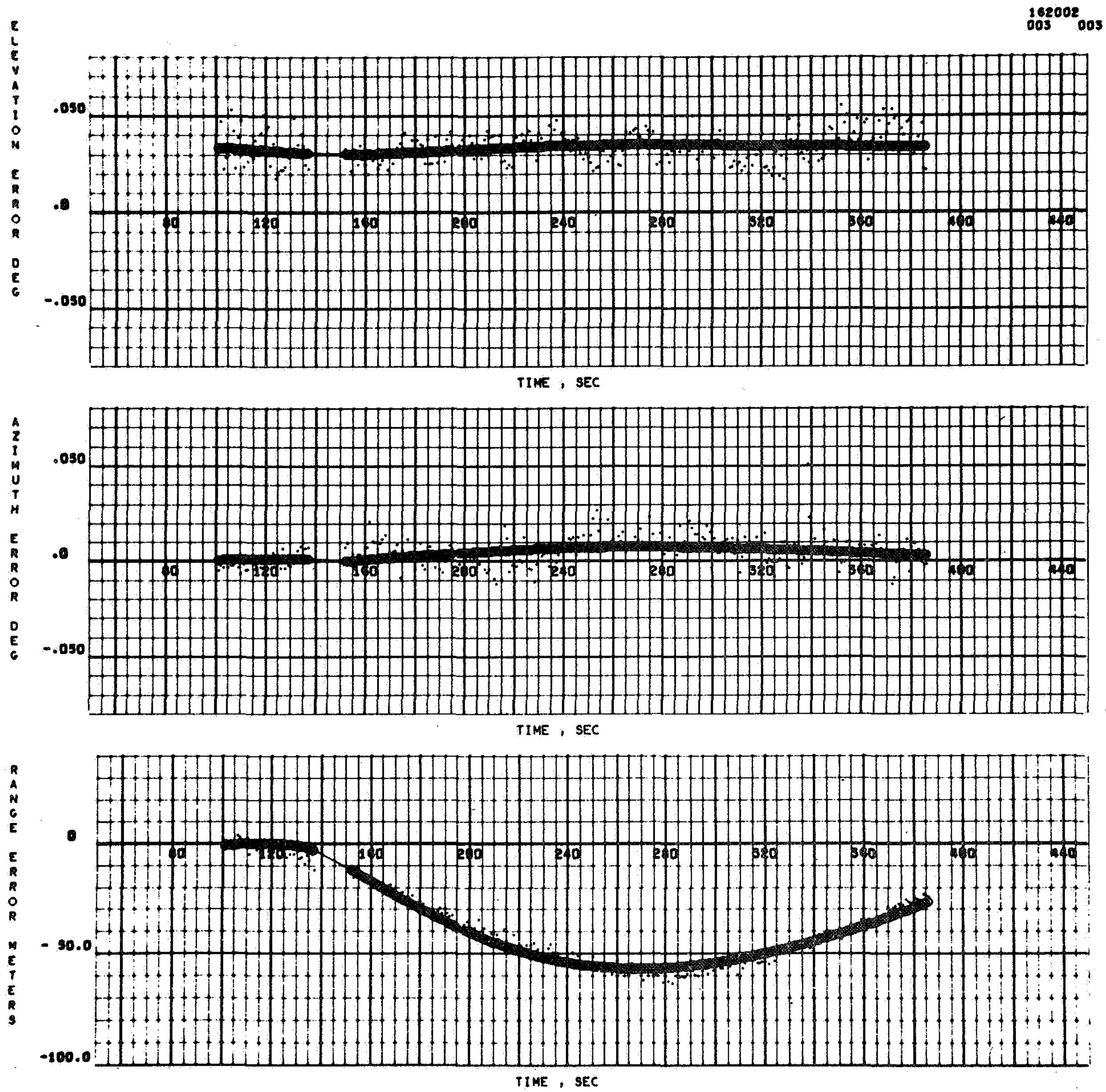

FIGURE A-26. RADAR 3.18 RANGE, AZIMUTH, AND ELEVATION ERRORS ON SA-203

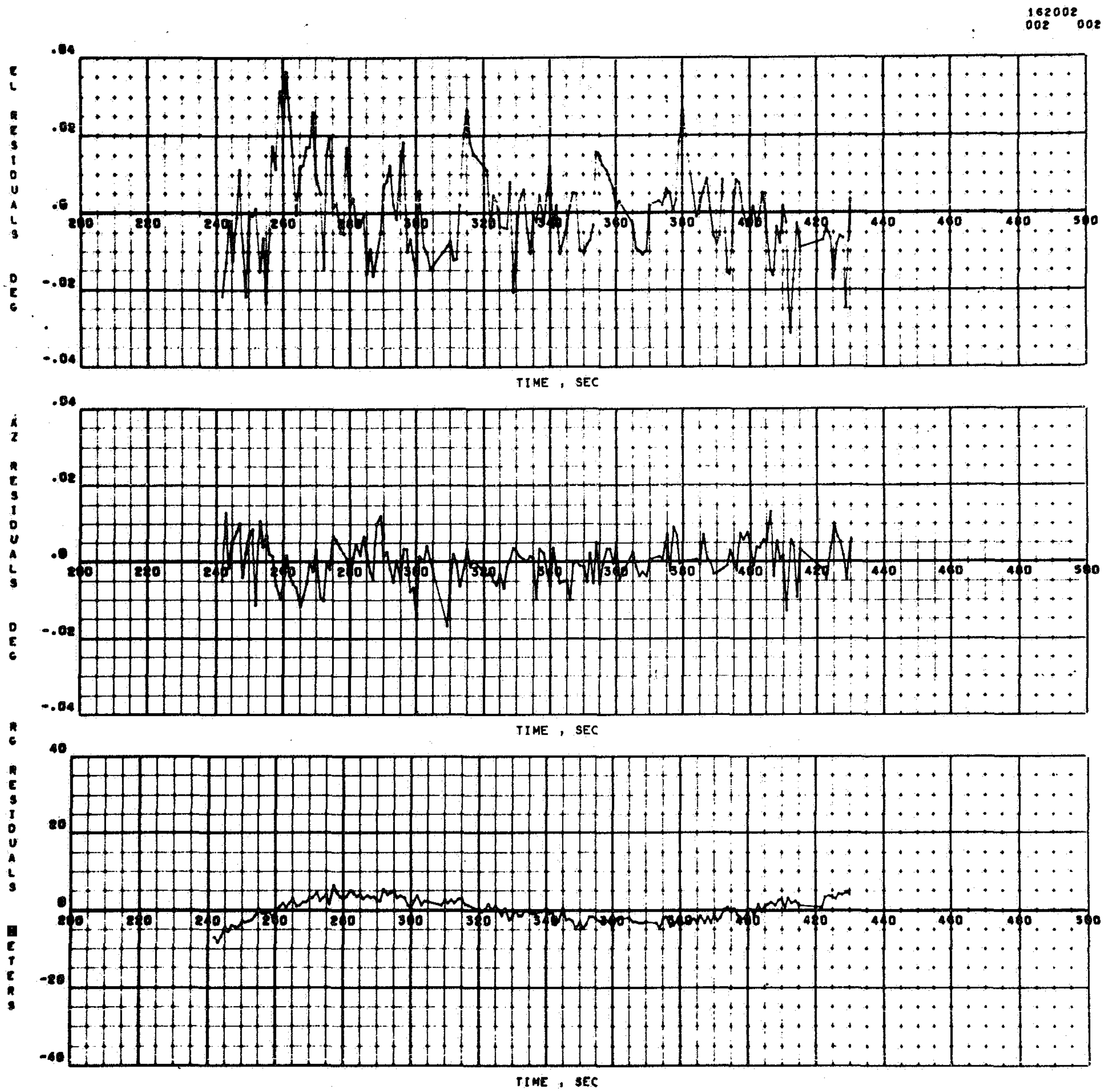

FIGURE A-27. RADAR 7.18 RESIDUALS ON SA-203

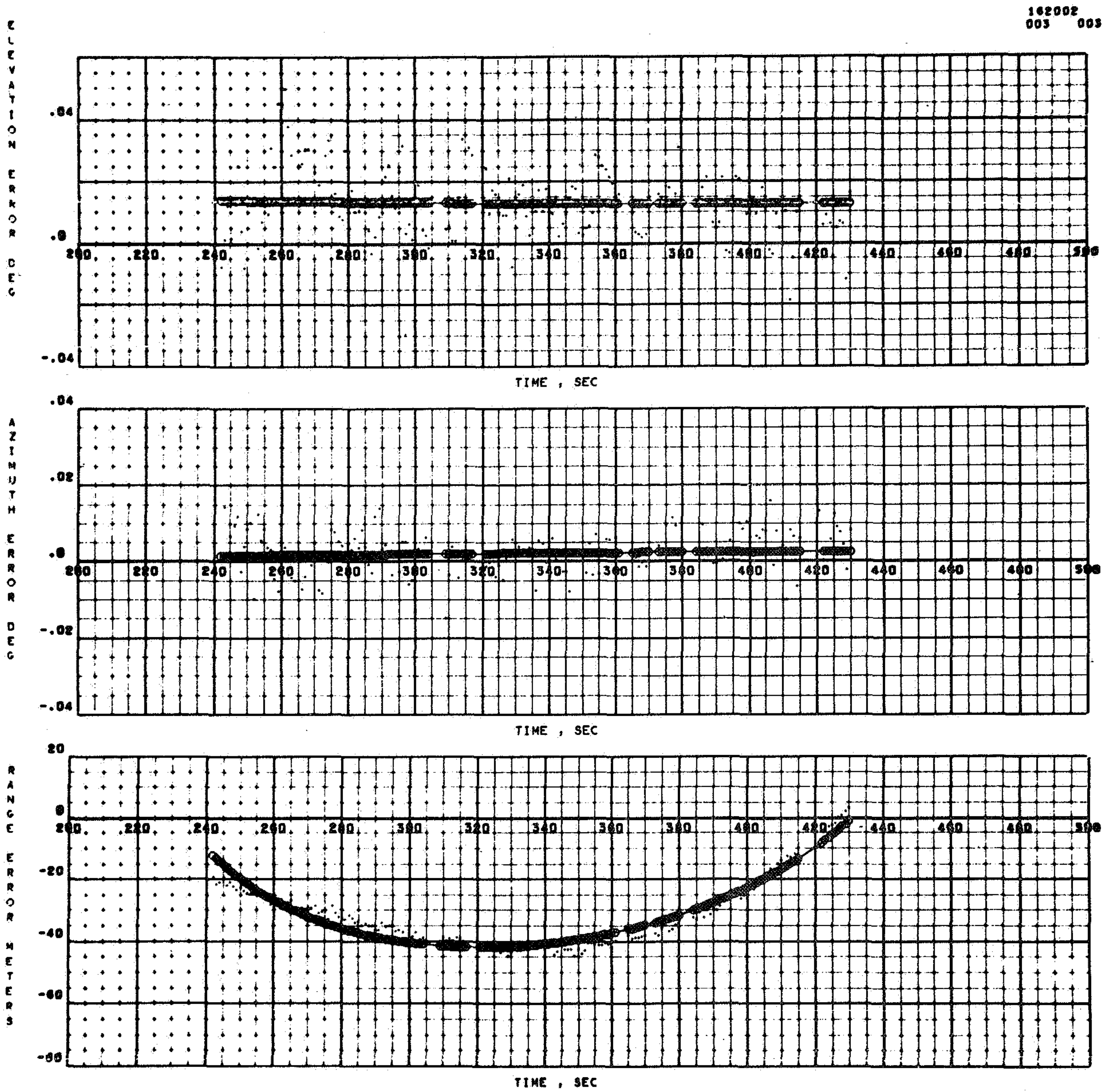

FIGURE A-28. RADAR 7.18 RANGE, AZIMUTH, AND ELEVATION ERRORS ON SA-203

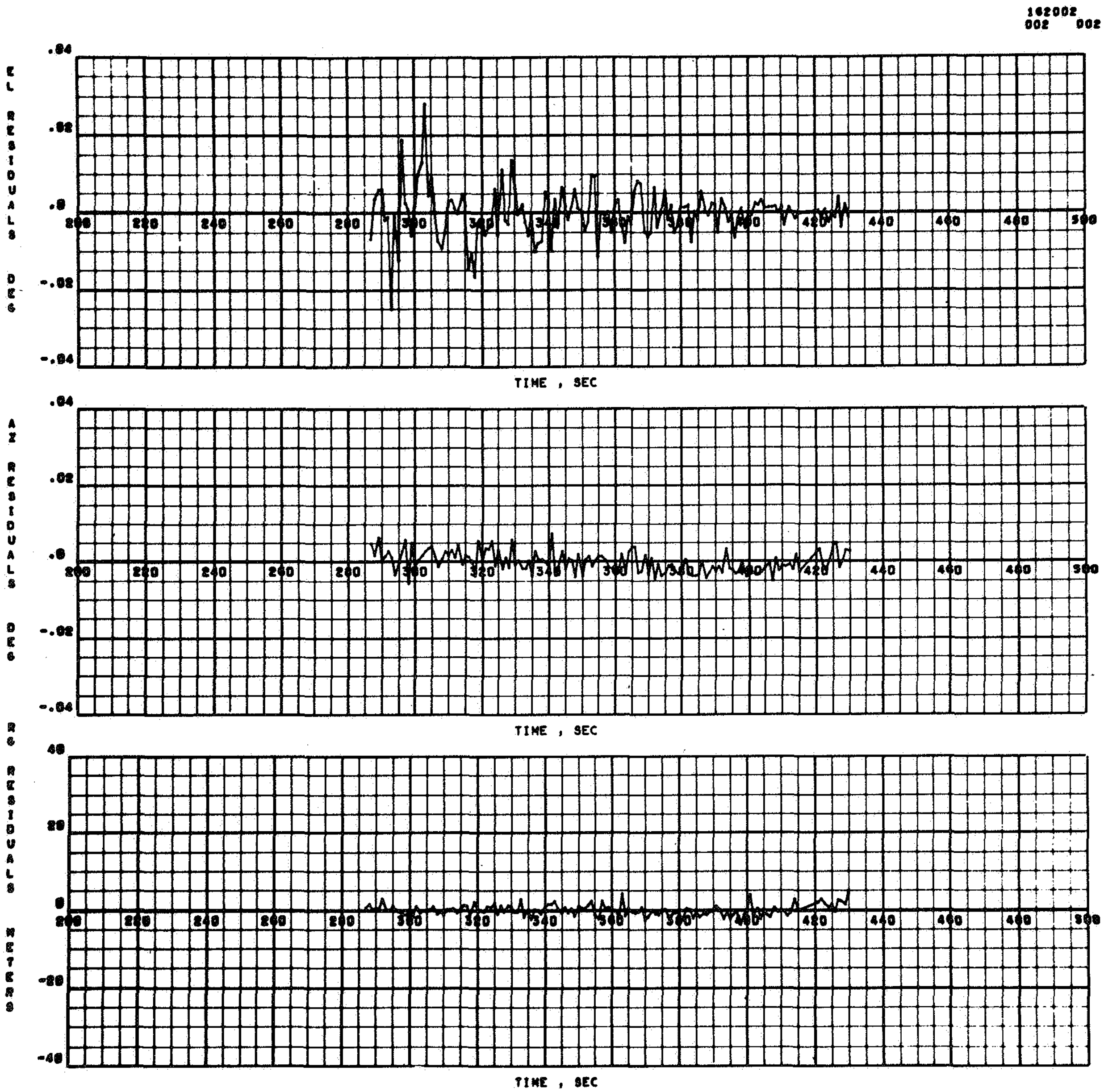

FIGURE A-29. RADAR 67.16 RESIDUALS ON SA-203

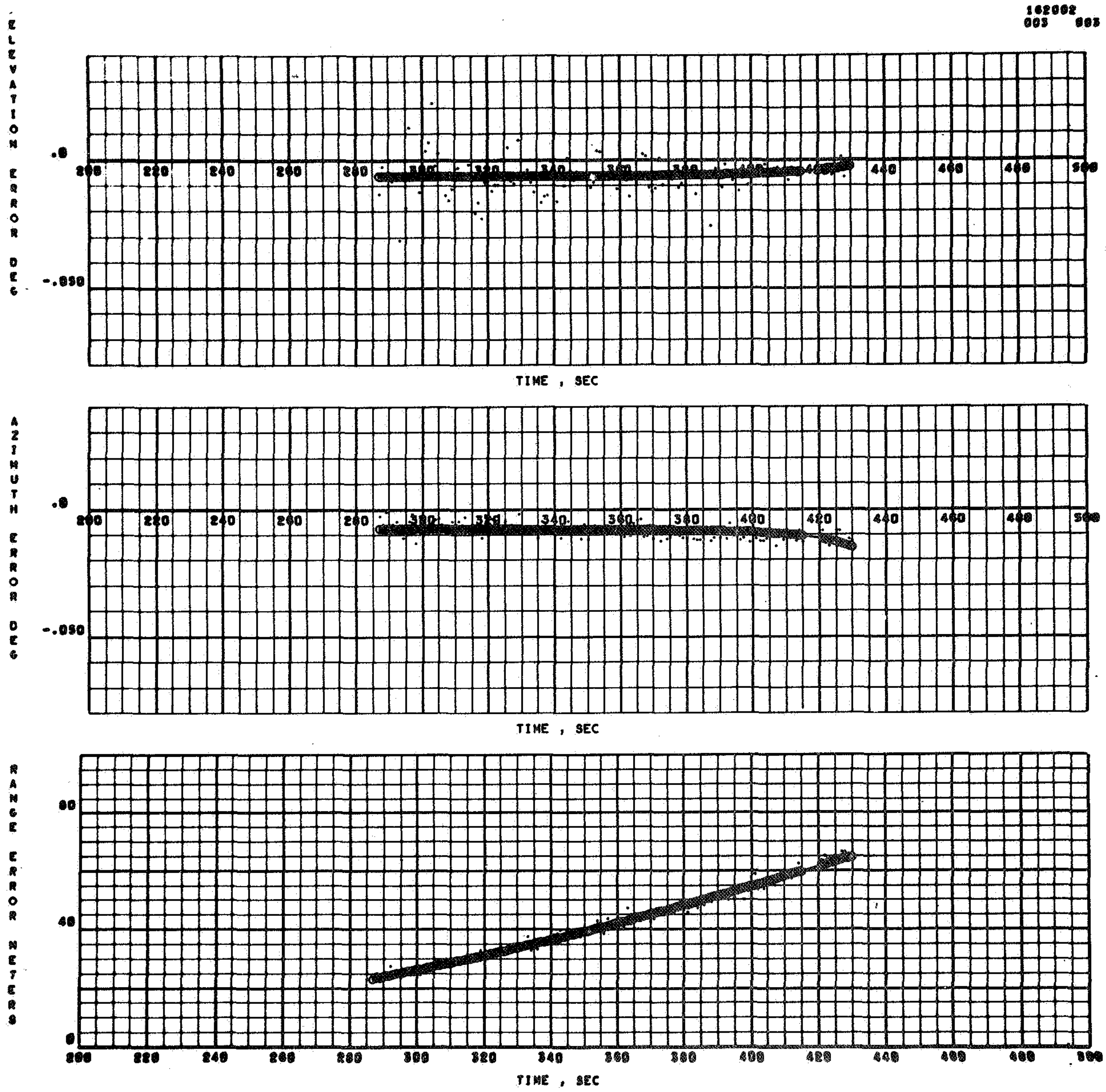

FIGURE A-30. RADAR 67.16 RANGE, AZIMUTH, AND ELEVATION ERRORS ON SA-203

180042
002 002

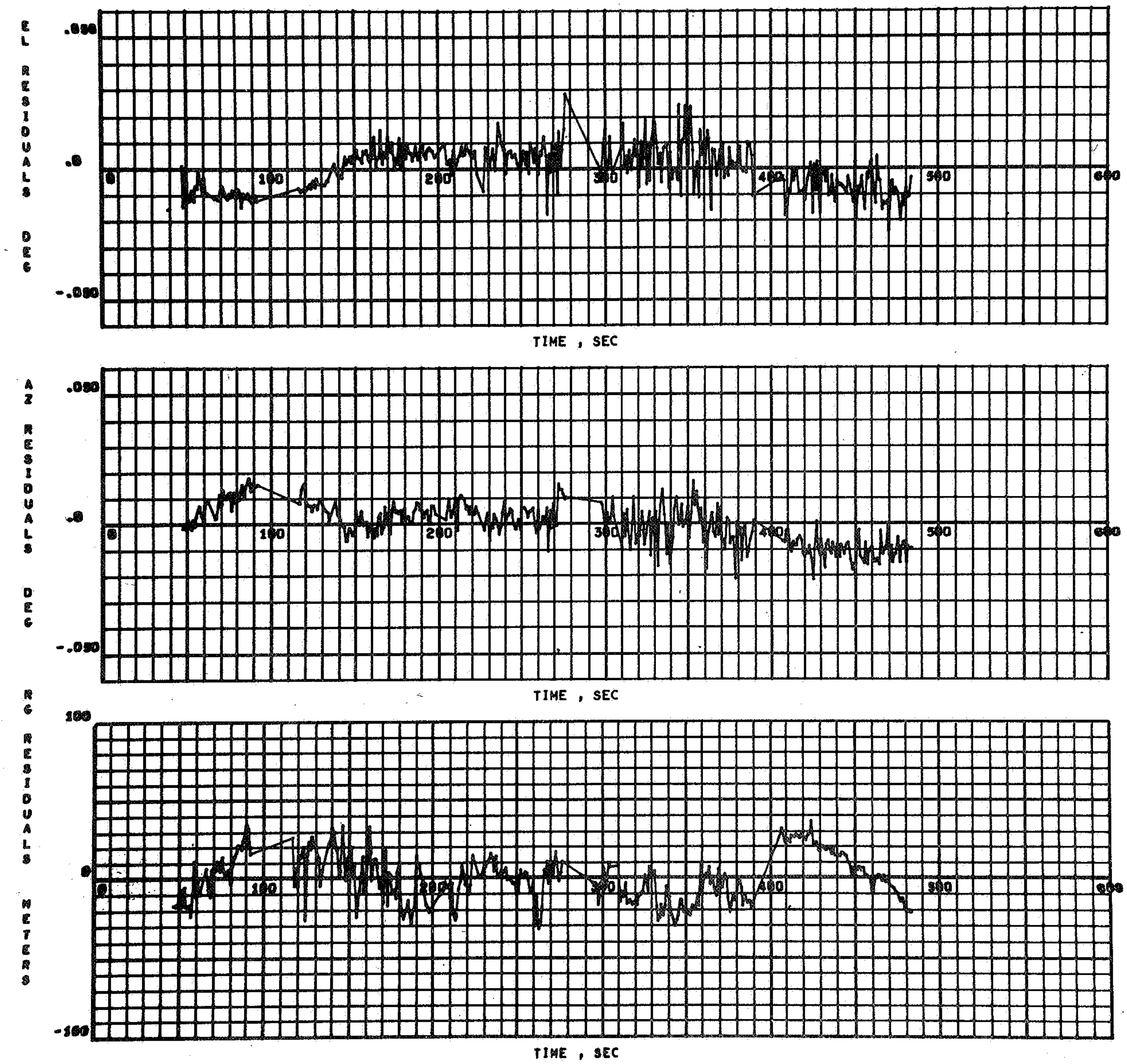

FIGURE A-31. RADAR 0.18 RESIDUALS ON AS-204

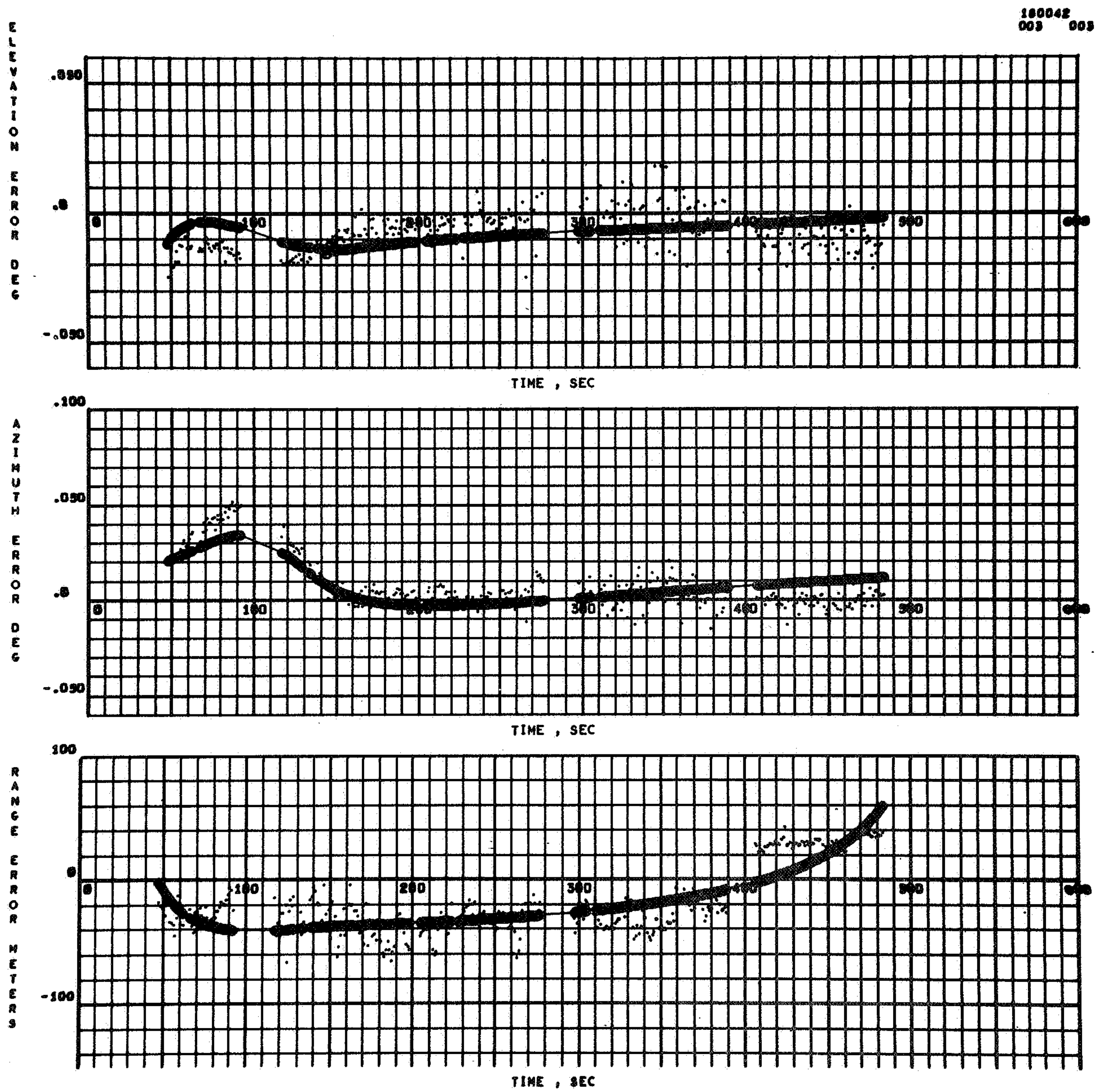

FIGURE A-32. RADAR 0.18 RANGE, AZIMUTH, AND ELEVATION ERRORS ON AS-204

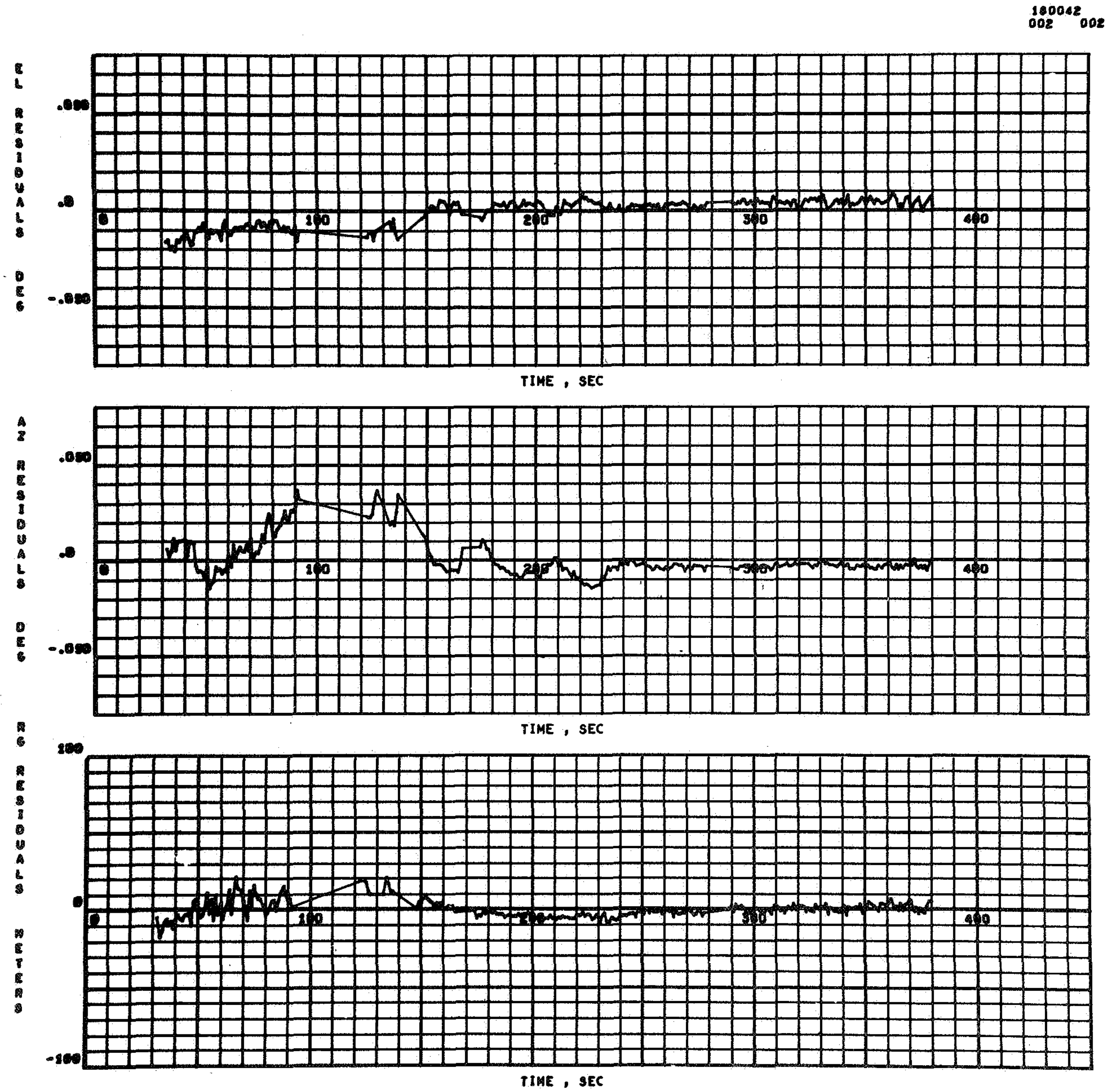

FIGURE A-33. RADAR 19.18 RESIDUALS ON AS-204

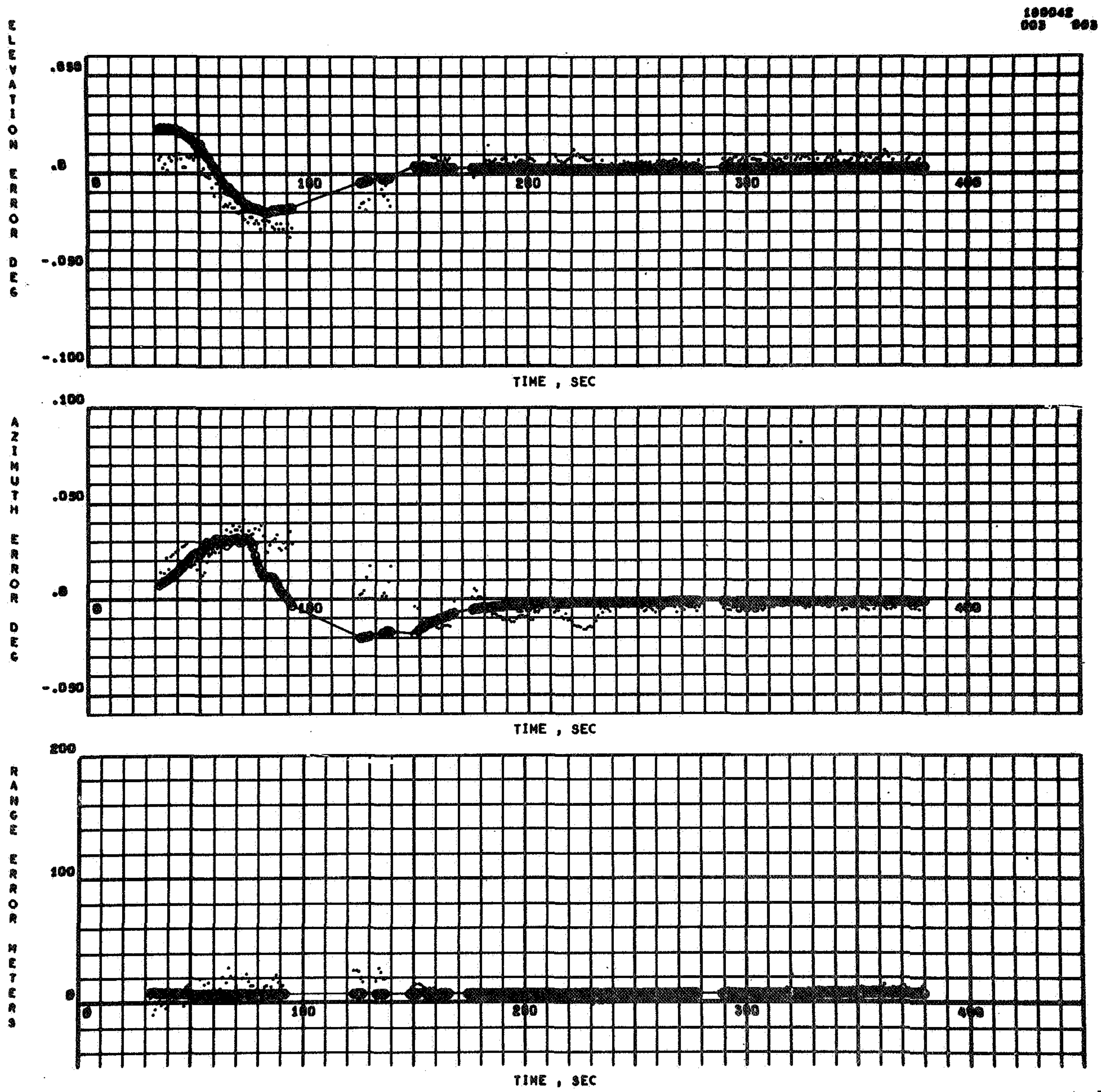

FIGURE A-34. RADAR 19.18 RANGE, AZIMUTH, AND ELEVATION ERRORS ON AS-204

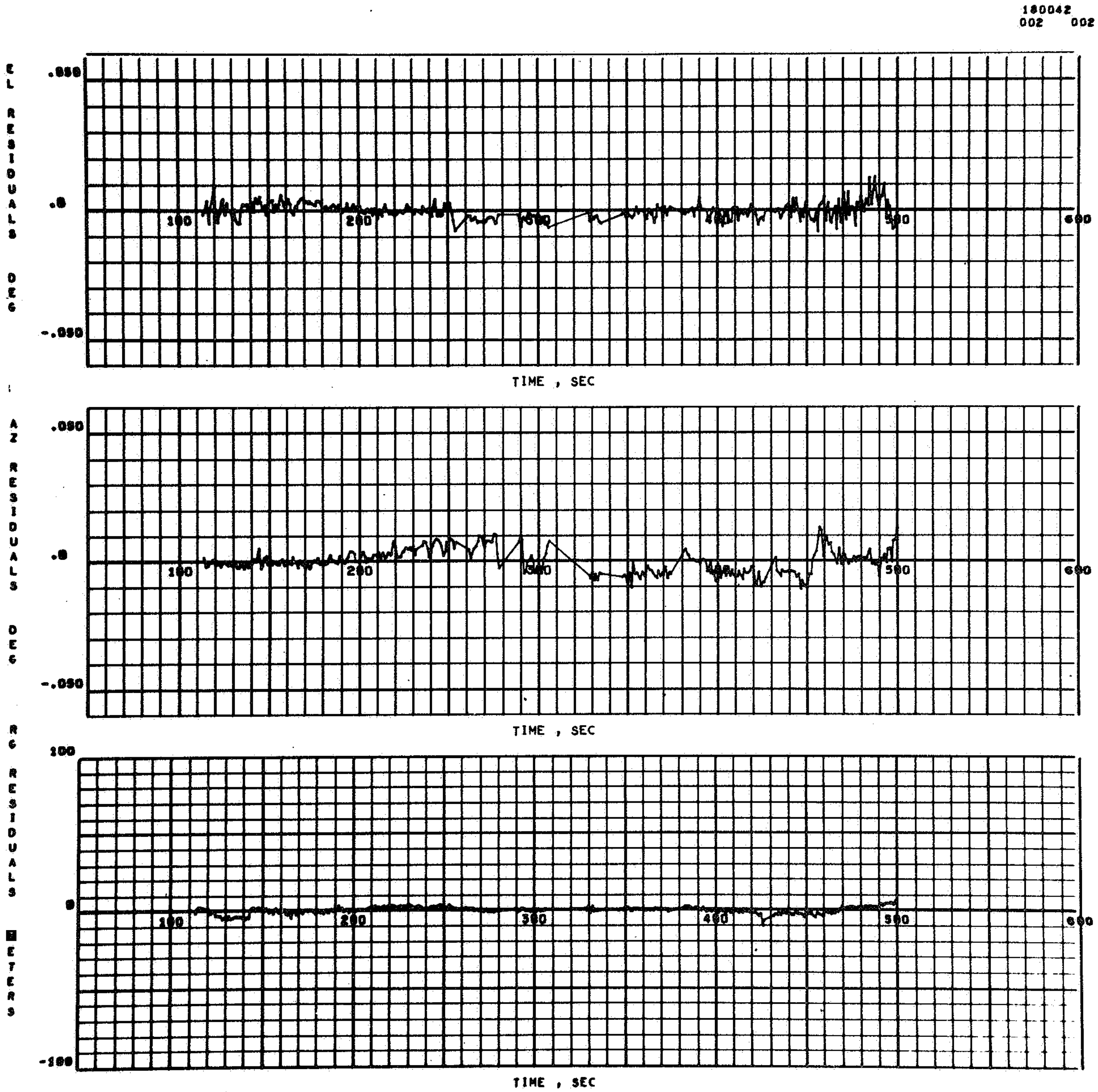

FIGURE A-35. RADAR 3.18 RESIDUALS ON AS-204

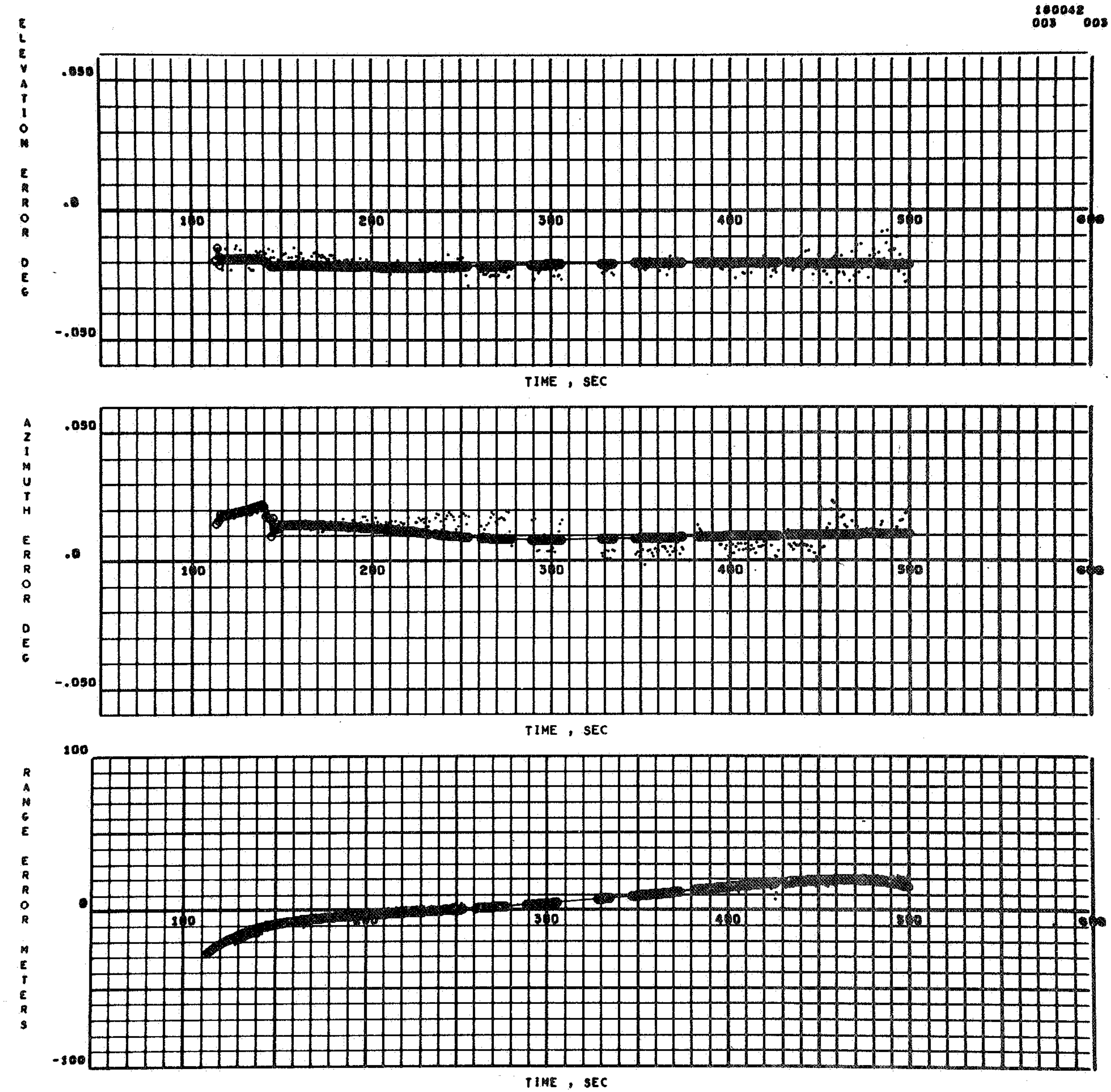

FIGURE A-36. RADAR 3.18 RANGE, AZIMUTH, AND ELEVATION ERRORS ON AS-204

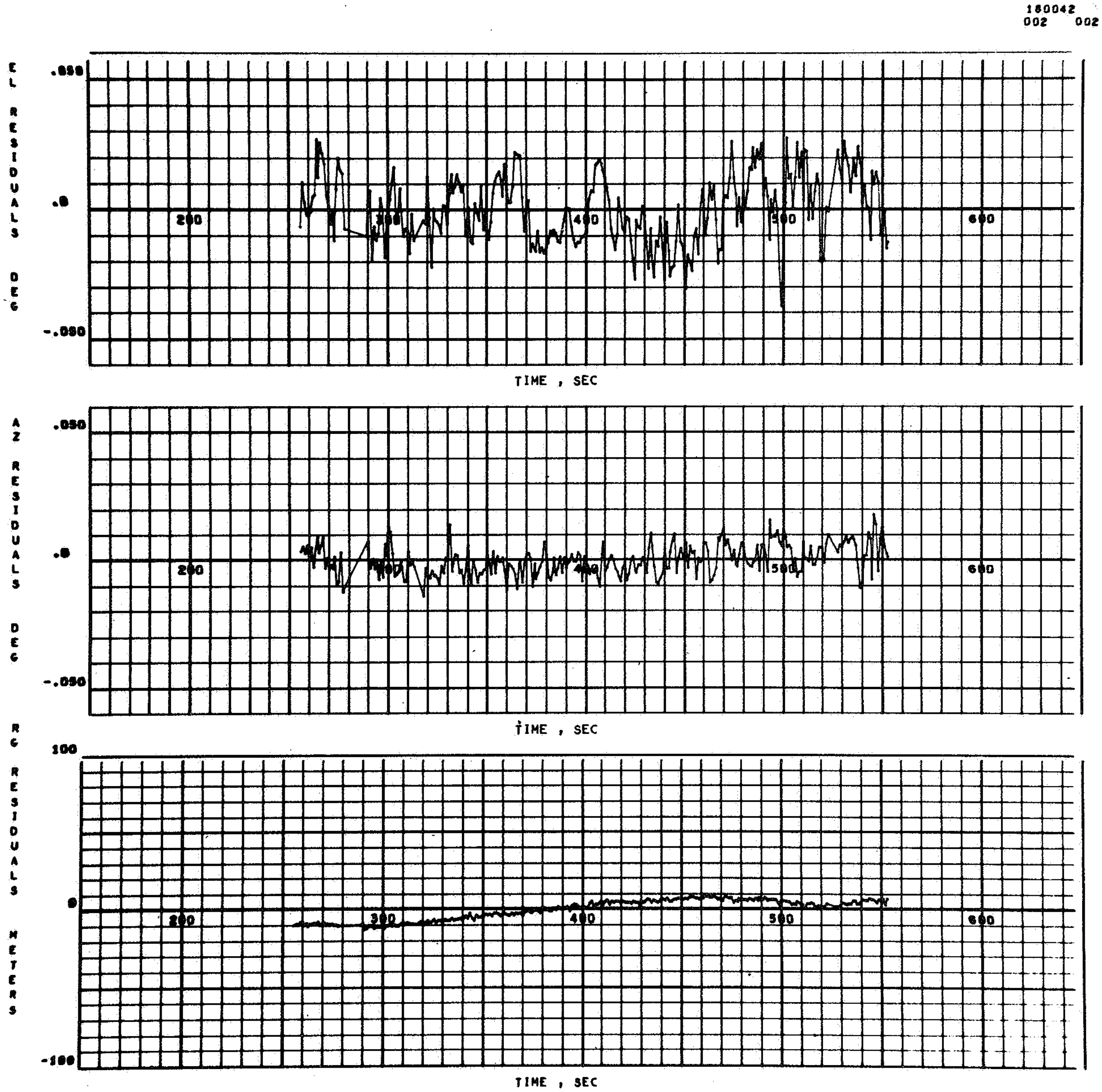

FIGURE A-37. RADAR 7.18 RESIDUALS ON AS-204

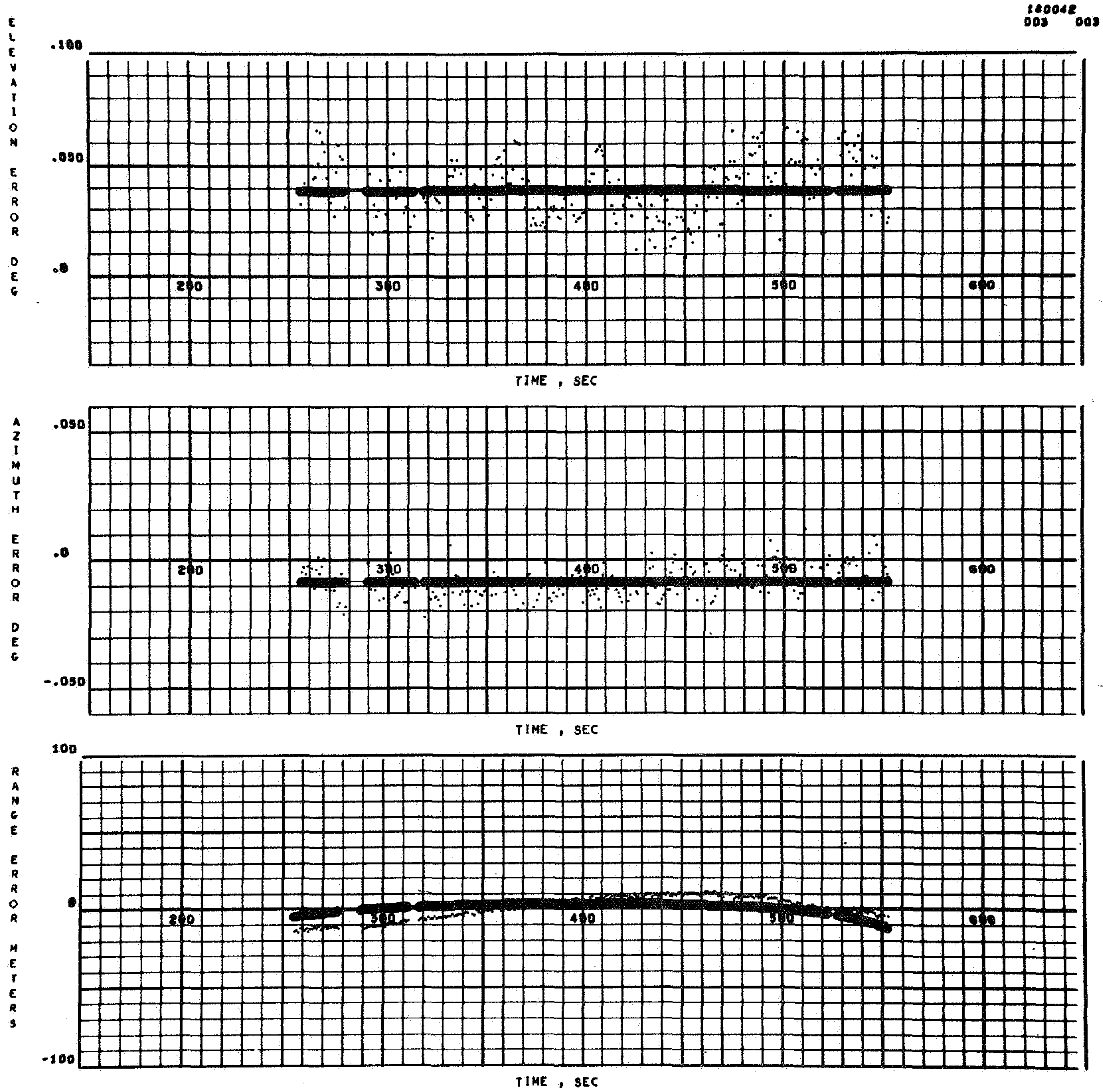

FIGURE A-38. RADAR 7.18 RANGE, AZIMUTH, AND ELEVATION ERRORS ON AS-204

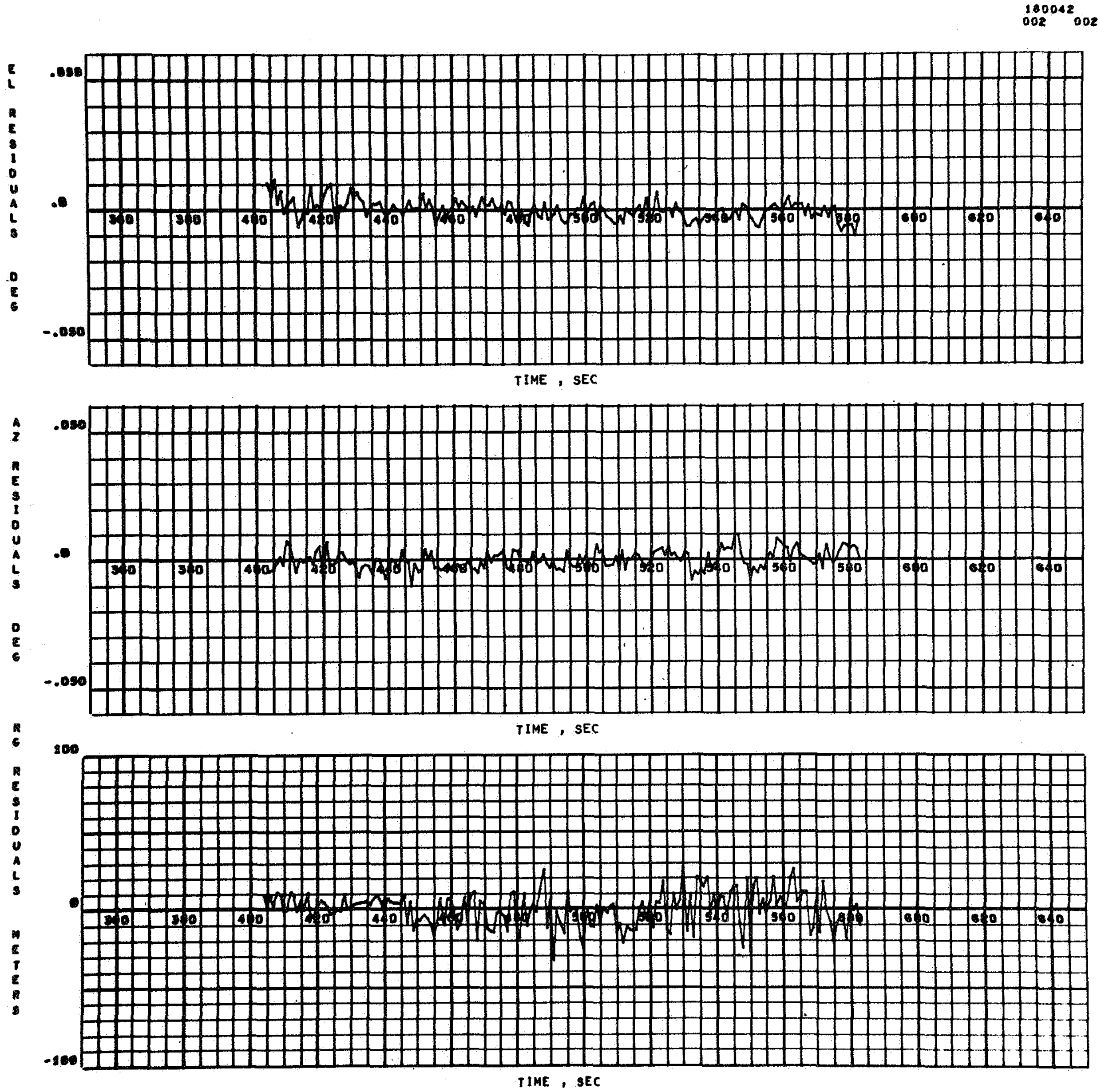

FIGURE A-39. RADAR 67.16 RESIDUALS ON AS-204

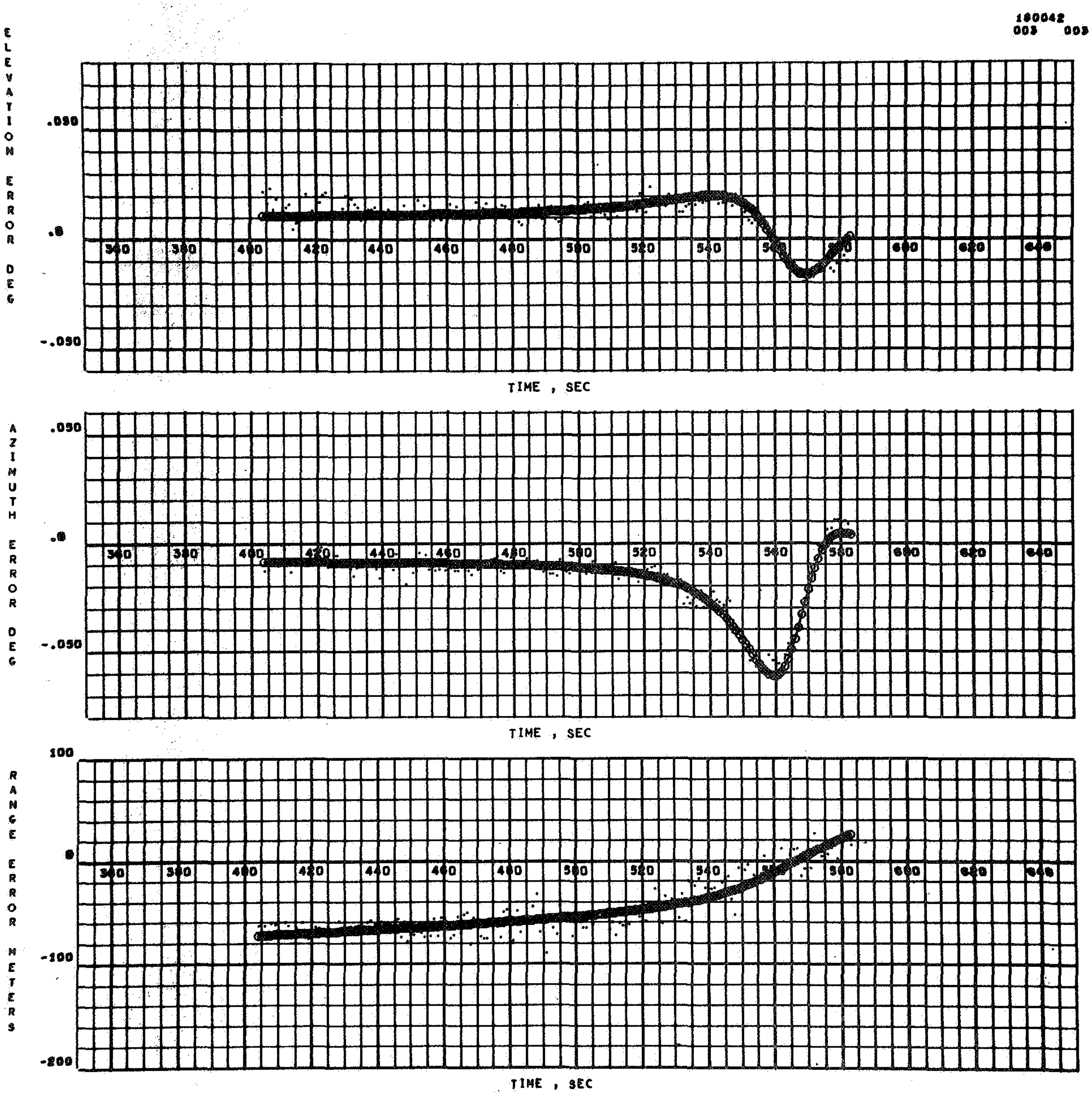

FIGURE A-40. RADAR 67.16 RANGE, AZIMUTH, AND ELEVATION ERRORS ON AS-204

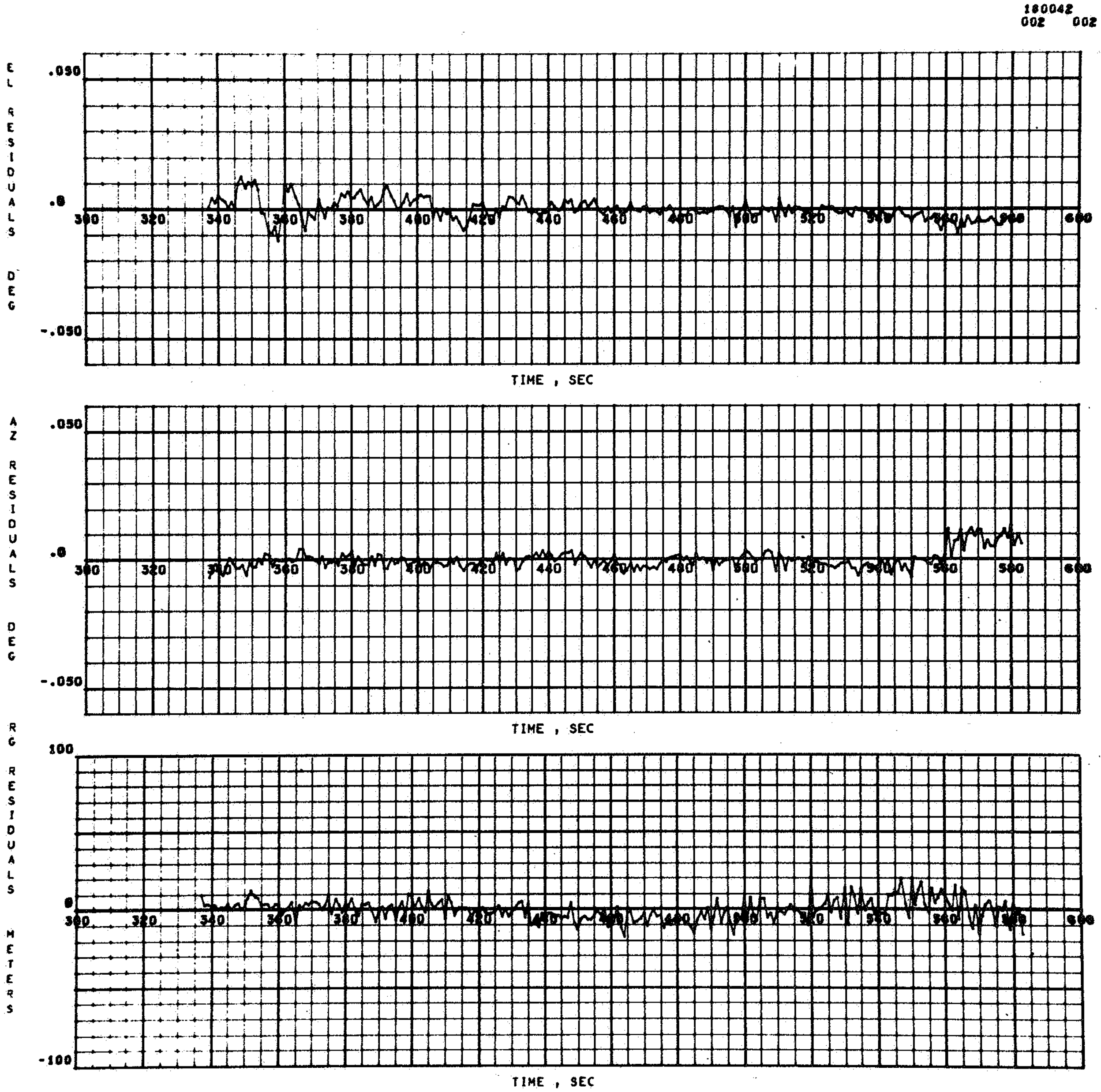

FIGURE A-41. RADAR 67.18 RESIDUALS ON AS-204

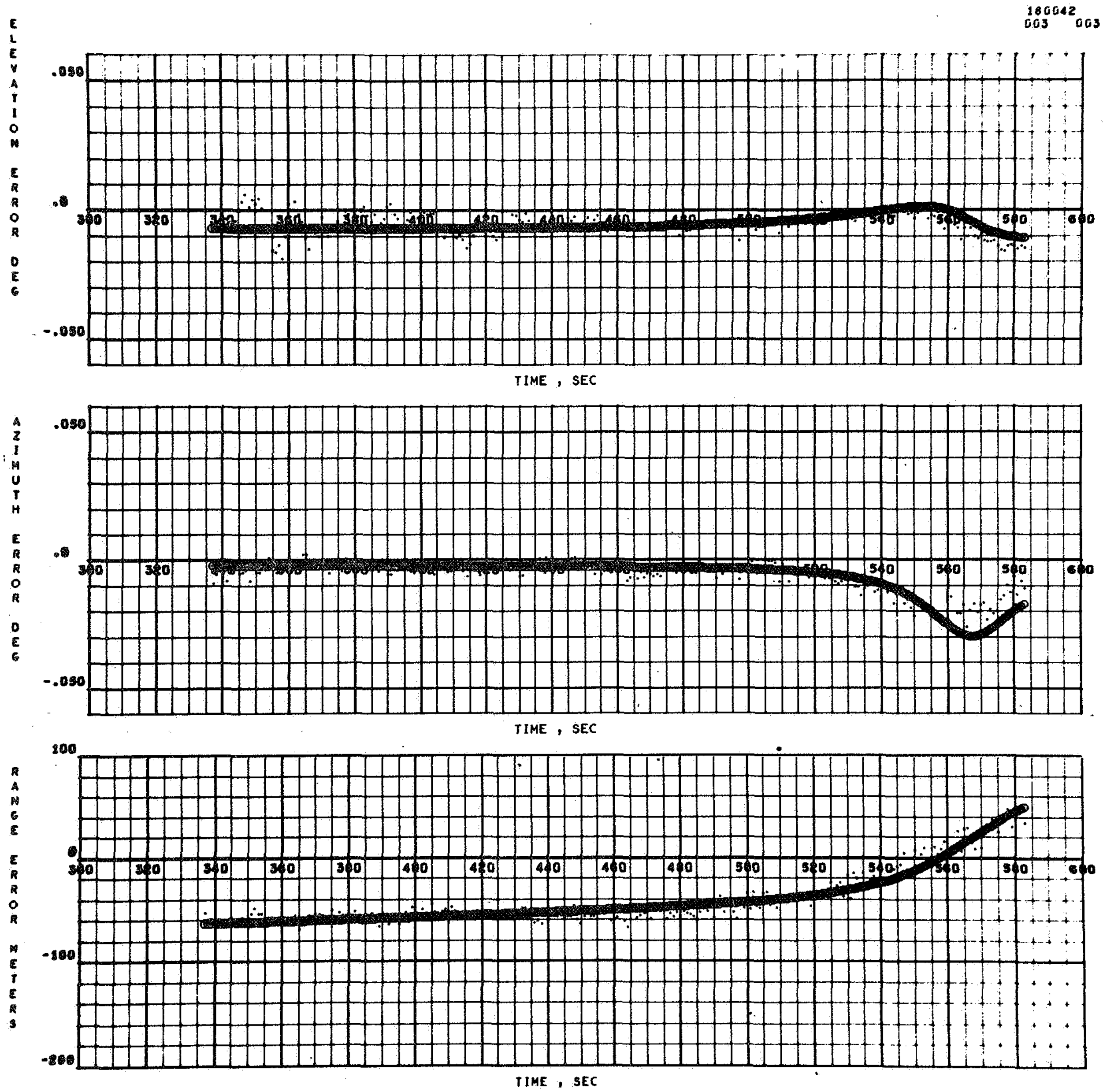

FIGURE A-42. RADAR 67.18 RANGE, AZIMUTH, AND ELEVATION ERRORS ON AS-204

TABLE A-I. COEFFICIENT CORRELATIONS FOR THE TRUNCATED AS-201 RADAR ERROR MODELS

RADAR 3.18

	C_0	C_1	C_2	D_0	D_3	D_7	F_0
C_0	1.00	-0.49	0.11	0.	0.	0.	0.
C_1		1.00	-0.88	0.	0.	0.01	0.
C_2			1.00	0.	0.	-0.01	0.
D_0				1.00	-0.22	-0.34	0.08
D_3					1.00	0.41	-0.10
D_7						1.00	-0.25
F_0							1.00

RADAR 91.18

	C_0	C_1	C_2	D_0	D_3	D_8	F_0	F_3
C_0	1.00	-0.97	-0.30	0.	0.	0.	0.	0.
C_1		1.00	0.35	0.	0.	0.	0.	0.
C_2			1.00	-0.01	0.	0.	0.	0.
D_0				1.00	-0.05	-0.41	-0.03	0.19
D_3					1.00	-0.06	0.	0.3
D_8						1.00	0.08	-0.46
F_0							1.00	0.18
F_3								1.00

TABLE A-I. (Concluded)

RADAR 7.18

	C_1	C_2	D_0	D_3	D_8	F_0	F_3
C_1	1.00	-0.62	0.	0.	0.	0.	0.
C_2		1.00	-0.01	0.	0.	0.	0.
D_0			1.00	-0.03	-0.20	-0.07	0.03
D_3				1.00	-0.10	-0.04	0.01
D_8					1.00	0.38	-0.14
F_0						1.00	0.15
F_3							1.00

RADAR 19.18

	C_1	C_2	D_0	F_0	F_3
C_1	1.00	-0.96	0.01	0.	0.
C_2		1.00	-0.01	0.	0.
D_0			1.00	0.	0.
F_0				1.00	0.07
F_3					1.00

RADAR 0.18

	C_2	C_4	D_0	D_5	F_0
C_2	1.00	0.96	0.	-0.01	0.02
C_4		1.00	0.	-0.01	0.02
D_0			1.00	-0.88	0.
D_5				1.00	0.
F_0					1.00

TABLE A-II. COEFFICIENT CORRELATIONS FOR THE TRUNCATED AS-202 RADAR ERROR MODELS

RADAR 0.18

	C_0	C_2	C_4	D_0	D_3	D_8	F_0	F_3
C_0	1.	-0.67	0.50	0.06	-0.02	0.09	0.09	-0.08
C_2		1.	0.16	-0.08	0.05	-0.20	-0.18	0.04
C_4			1.	-0.01	0.03	-0.10	-0.09	-0.07
D_0				1.	0.	-0.08	-0.08	0.06
D_3					1.	-0.30	-0.29	0.18
D_8						1.	0.96	-0.59
F_0							1.	-.063
F_3								1.

RADAR 19.18

	C_0	C_1	C_4	D_0	D_3	D_5	D_7	F_0	F_3
C_0	1.	-0.04	0.66	0	-0.02	0.10	-0.17	-0.06	-0.14
C_1		1.	0.64	0	-0.02	0.10	-0.16	-0.05	-0.14
C_4			1.	0	-0.03	0.15	-0.25	-0.08	-0.21
D_0				1.	-0.23	-0.71	-0.02	0	0
D_3					1.	0.07	0.11	0.01	0.02
D_5						1.	-0.58	-0.07	-0.10
D_7							1.	0.13	0.18
F_0								1.	0.16
F_3									1.

TABLE A-II. (Continued)

RADAR 3.18

	C_0	C_2	C_4	D_0	D_3	D_8	F_0	F_3
C_0	1.	-0.18	0.63	0.02	0	0.01	0.03	0.01
C_2		1.	0.46	-0.08	0.01	-0.12	-0.05	0.01
C_4			1.	-0.04	0.01	0.06	0	0.02
D_0				1.	0.07	-0.30	-0.17	0.02
D_3					1.	-0.10	-0.06	0.01
D_8						1.	0.57	-0.06
F_0							1.	0.07
F_3								1.

RADAR 7.18

	C_0	C_2	C_4	D_0	D_3	D_8	F_0
C_0	1.	0.36	0.59	-0.05	0	-0.01	0.01
C_2		1.	-0.30	-0.12	0	-0.05	-0.01
C_4			1.	0.03	0	0.03	0.03
D_0				1.	-0.47	-0.29	0.14
D_3					1.	-0.09	0.04
D_8						1.	-0.47
F_0							1.

TABLE A-II. (Concluded)

RADAR 91.18

	C_2	C_4	D_0	D_5	F_0
C_2	1.	-0.94	0	-0.02	-0.11
C_4		1.	0	0.01	0.11
D_0			1.	-0.95	0
D_5				1.	0
F_0					1.

TABLE A-III. COEFFICIENT CORRELATIONS FOR THE TRUNCATED SA-203 RADAR ERROR MODELS

RADAR 0.18

	C_0	C_1	C_4	D_0	D_3	F_0	F_3
C_0	1.	-0.04	0.23	0	0	0.04	0.01
C_1		1.	0.95	0	0	0.15	0.04
C_4			1.	0	0	0.16	0.04
D_0				1.	0.57	0	0
D_3					1.	0	0
F_0						1.	0.30
F_3							1.

RADAR 19.18

	C_0	C_1	C_4	D_0	D_3	F_0	F_3
C_0	1.	0.06	0.32	0	0	0.05	0.01
C_1		1.	0.95	0	0	0.16	0.04
C_4			1.	0	0	0.16	0.04
D_0				1.	0.49	0	0
D_3					1.	0	0
F_0						1.	0.21
F_3							1.

TABLE A-III. (Continued)

RADAR 3.18

	C_0	C_1	C_2	D_3	D_5	D_8	F_0	F_3
C_0	1.	-0.90	0.73	-0.07	-0.25	-0.11	-0.05	0.01
C_1		1.	-0.94	0.09	0.32	0.14	0.06	-0.01
C_2			1.	-0.10	-0.34	-0.15	-0.07	0.01
D_3				1.	0.30	0.01	0	0
D_5					1.	-0.35	-0.16	0.01
D_8						1.	0.46	-0.05
F_0							1.	0.31
F_3								1.

RADAR 7.18

	C_0	C_2	C_4	D_0	F_0
C_0	1.	-0.41	0.98	0.07	0.16
C_2		1.	-0.36	-0.18	-0.06
C_4			1.	0.07	0.16
D_0				1.	0.01
F_0					1.

TABLE A-III. (Concluded)

RADAR 67.16

	C_0	C_1	D_0	D_3	F_0	F_3
C_0	1.	-0.96	0	0	0	0
C_1		1.	0	0	0	0
D_0			1.	0.53	0	0
D_3				1.	0	0
F_0					1.	-0.62
F_3						1.

TABLE A-IV. COEFFICIENT CORRELATIONS FOR THE TRUNCATED AS-204 RADAR ERROR MODELS

RADAR 0.18

	C_0	C_2	C_4	D_0	D_7	D_8	F_0	F_3
C_0	1.	-0.65	0.02	0.01	-0.04	0.10	0.08	-0.01
C_2		1.	0.67	0.01	0.05	-0.17	-0.12	0
C_4			1.	0.02	0.02	-0.12	-0.08	-0.02
D_0				1.	-0.59	0.23	0.37	-0.07
D_7					1.	-0.83	-0.92	0.25
D_8						1.	0.97	-0.29
F_0							1.	-0.27
F_3								1.

RADAR 19.18

	C_0	C_4	D_0	D_3	F_0	F_3
C_0	1.	0.91	0	0	-0.05	-0.18
C_4		1.	0	0	-0.06	-0.19
D_0			1.	-0.22	0	0
D_3				1.	0	0
F_0					1.	0.09
F_3						1.

TABLE A-IV. (Continued)

RADAR 3.18

	C_0	C_1	C_4	D_0	D_3	F_0	F_3
C_0	1.	-0.46	0.23	0	0	0.02	0
C_1		1.	0.70	0	0	0.05	0.01
C_4			1.	0	0	0.07	0.02
D_0				1.	-0.06	0	0
D_3					1.	0	0
F_0						1.	0.33
F_3							1.

RADAR 7.18

	C_0	C_4	D_0	F_0
C_0	1.	0.96	0	0.09
C_4		1.	0	0.09
D_0			1.	0
F_0				1.

TABLE A-IV. (Concluded)

RADAR 67.16

	C_0	C_1	C_2	D_0	D_3	F_0	F_3
C_0	1.	-0.65	0.29	0.08	-0.01	-0.03	-0.02
C_1		1.	0.45	0.13	-0.01	-0.04	-0.03
C_2			1.	0.28	-0.03	-0.10	-0.06
D_0				1.	0.18	-0.03	-0.02
D_3					1.	0	0
F_0						1.	0.21
F_3							1.

RADAR 67.18

	C_0	C_1	C_2	D_0	D_8	F_0
C_0	1.	-0.60	0.54	0.04	-0.18	0.13
C_1		1.	0.26	0.02	-0.09	0.06
C_2			1.	0.08	-0.33	0.24
D_0				1.	0.37	-0.31
D_8					1.	-0.83
F_0						1.

TABLE A-V. RADAR 0.18 STEPWISE REGRESSION
ANALYSIS RESULTS FOR AS-204 DATA

Variable No.	Linear Correlation	Step No.	Variables in Regression		F Level
1	$r[C_1 \mid \Delta R] = 0.76$	1	C_0, C_4	15.54	801.7
2	$r[C_2 \mid \Delta R] = 0.66$	2	C_0, C_4, C_1	15.01	26.6
3	$r[C_4 \mid \Delta R] = -0.83$	3	C_0, C_4, C_1, C_8	13.51	83.5
4	$r[C_5 \mid \Delta R] = 0.28$				
5	$r[C_6 \mid \Delta R] = 0.61$				
6	$r[C_7 \mid \Delta R] = -0.50$				
7	$r[C_8 \mid \Delta R] = 0.67$	Final	C_0, C_4, C_1, C_8, C_5	12.5	60.4
1	$r[C_2 \mid \Delta A] = 0.66$	1	D_0, C_5	0.0093	430.8
2	$r[D_3 \mid \Delta A] = 0.58$	2	D_0, C_5, C_2	0.0077	162.4
3	$r[D_5 \mid \Delta A] = 0.14$	3	D_0, C_5, C_2, D_3	0.0052	420.6
4	$r[D_6 \mid \Delta A] = 0.11$	4	D_0, C_5, C_2, D_3, D_6	0.0052	5.6
5	$r[D_7 \mid \Delta A] = -0.26$				
6	$r[D_8 \mid \Delta A] = 0.51$				
7	$r[C_5 \mid \Delta A] = 0.74$				
8	$r[C_6 \mid \Delta A] = -0.12$	Final	$D_0, C_5, C_2, D_3, D_6, D_5$	0.0050	16.2
1	$r[C_2 \mid \Delta E] = -0.41$	1	F_0, D_7	0.0069	73.7
2	$r[F_3 \mid \Delta E] = 0.17$				
3	$r[D_8 \mid \Delta E] = -0.40$				
4	$r[D_7 \mid \Delta E] = -0.42$				
5	$r[C_4 \mid \Delta R] = -0.16$				
6	$r[C_5 \mid \Delta E] = 0.25$				
7	$r[C_6 \mid \Delta E] = 0.03$				
8	$r[C_7 \mid \Delta E] = -0.39$				
		Final	F_0, D_7, C_4	0.0068	20.3

TABLE A-VI. RADAR 19.18 STEPWISE REGRESSION ANALYSIS RESULTS FOR AS-204 DATA

Variable No.	Linear Correlation	Step No.	Variables in Regression		F Level
1	$r[C_1 \mid \Delta R] = -0.09$	1	C_0, C_4	5.52	13.33
2	$r[C_2 \mid \Delta R] = -0.10$	2	C_0, C_4, C_5	5.42	11.62
3	$r[C_4 \mid \Delta R] = 0.21$	3	C_0, C_4, C_5, C_2	4.31	168.8
4	$r[C_5 \mid \Delta R] = -0.20$	4	C_0, C_4, C_5, C_2, C_8	3.87	70.1
		5	$C_0, C_4, C_5, C_2, C_8, C_1$	3.71	25.8
5	$r[C_6 \mid \Delta R] = -0.202$	6	C_0, C_5, C_2, C_8, C_1	3.71	-1.1
6	$r[C_7 \mid \Delta R] = 0.19$	7	$C_0, C_5, C_2, C_8, C_1, C_6$	3.57	24.0
7	$r[C_8 \mid \Delta R] = -0.11$	Final	$C_0, C_5, C_2, C_8, C_1, C_6, C_7$	3.50	13.8
1	$r[C_2 \mid \Delta A] = 0.79$	1	D_0, C_5	0.0074	790.7
2	$r[D_3 \mid \Delta A] = 0.75$	2	D_0, C_5, C_2	0.0053	287.9
3	$r[D_5 \mid \Delta A] = 0.05$				
4	$r[D_6 \mid \Delta A] = 0.09$				
5	$r[D_7 \mid \Delta A] = -0.19$				
6	$r[D_8 \mid \Delta A] = 0.60$				
7	$r[C_5 \mid \Delta A] = 0.86$				
8	$r[C_6 \mid \Delta A] = 0.001$	Final	D_0, C_5, C_2, D_6	0.0041	190.0
		1	F_0, C_5	0.0046	1190.9
1	$r[C_2 \mid \Delta E] = -0.57$	2	F_0, C_5, F_3	0.0031	339.1
		3	F_0, C_5, F_3, C_4	0.0029	46.2
2	$r[F_3 \mid \Delta E] = 0.76$	4	F_0, C_5, F_3, C_4, C_6	0.0027	30.7
3	$r[D_8 \mid \Delta E] = -0.55$	5	$F_0, C_5, F_3, C_4, C_6, C_7$	0.0027	9.7
4	$r[D_7 \mid \Delta E] = -0.61$	6	F_0, C_5, F_3, C_6, C_7	0.00269	-0.04
5	$r[C_4 \mid \Delta E] = 0.000$	7	F_0, F_3, C_6, C_7	0.00269	-0.7
6	$r[C_5 \mid \Delta E] = 0.90$	8	F_0, F_3, C_6, C_7, D_8	0.00267	5.6
7	$r[C_6 \mid \Delta E] = -0.67$				
8	$r[C_7 \mid \Delta R] = -0.45$				
		Final	$F_0, F_3, C_6, C_7, D_8, C_5$	0.00262	11.9

TABLE A-VII. RADAR 3.18 STEPWISE REGRESSION ANALYSIS RESULTS FOR AS-204 DATA

Variable No.	Linear Correlation	Step No.	Variables in Regression		F Level
1	$r[C_1 \mid \Delta R] = 0.86$	1	C_0, C_8	3.22	4036.
2	$r[C_2 \mid \Delta R] = 0.94$	2	C_0, C_8, C_6	2.00	517.1
3	$r[C_4 \mid \Delta R] = -0.27$	3	C_0, C_8, C_6, C_7	1.83	64.
4	$r[C_5 \mid \Delta R] = 0.96$				
5	$r[C_6 \mid \Delta R] = 0.81$				
6	$r[C_7 \mid \Delta R] = -0.60$				
7	$r[C_8 \mid \Delta R] = 0.96$	Final	C_0, C_8, C_6, C_7, C_5	1.54	133.1
1	$r[C_2 \mid \Delta A] = 0.42$	1	D_0, D_7	0.0042	253.3
2	$r[D_3 \mid \Delta A] = 0.55$	2	D_0, D_7, C_6	0.0036	134.7
3	$r[D_5 \mid \Delta A] = 0.10$	3	D_0, D_7, C_6, D_6	0.0035	5.7
4	$r[D_6 \mid \Delta A] = 0.17$	4	D_0, D_7, D_6, C_6, D_5	0.0034	27.2
5	$r[D_7 \mid \Delta A] = -0.66$	5	$D_0, D_7, D_6, C_6, D_5, D_3$	0.0033	14.8
6	$r[D_8 \mid \Delta A] = 0.22$	6	$D_0, D_7, C_6, D_6, D_5, D_3, C_2$	0.0033	4.5
7	$r[C_5 \mid \Delta A] = 0.52$	7	$D_0, C_6, D_6, D_5, D_3, C_2$	0.0033	-0.01
8	$r[C_6 \mid \Delta A] = 0.40$	Final	D_0, D_6, D_5, D_3, C_2	0.0033	-1.0
1	$r[C_2 \mid \Delta E] = 0.32$	1	F_0, C_5	0.0030	64.1
2	$r[F_3 \mid \Delta E] = 0.25$	2	F_0, C_5, D_7	0.0028	47.8
3	$r[D_8 \mid \Delta E] = 0.23$				
4	$r[D_7 \mid \Delta E] = -0.18$				
5	$r[C_4 \mid \Delta E] = -0.22$				
6	$r[C_5 \mid \Delta E] = 0.41$				
7	$r[C_6 \mid \Delta E] = 0.36$				
8	$r[C_7 \mid \Delta E] = 0.11$				
		Final	F_0, C_5, D_7, C_7	0.0027	5.3

TABLE A-VIII. RADAR 7.18 STEPWISE REGRESSION ANALYSIS RESULTS FOR AS-204 DATA

Variable No.	Linear Correlation	Step No.	Variables in Regression	σ_Y	F Level
1	$r[C_1 \mid \Delta R] = -0.40$	1	C_0, C_7	1.57	5576.3
2	$r[C_2 \mid \Delta R] = 0.35$	2	C_0, C_7, C_4	1.48	39.7
3	$r[C_4 \mid \Delta R] = 0.48$	3	C_0, C_7, C_4, C_1	1.35	55.5
4	$r[C_5 \mid \Delta R] = 0.55$	4	C_0, C_7, C_4, C_1, C_6	1.13	121.5
5	$r[C_6 \mid \Delta R] = 0.551$				
6	$r[C_7 \mid \Delta R] = 0.98$				
7	$r[C_8 \mid \Delta R] = 0.63$	Final	C_0, C_4, C_1, C_6	1.12	-0.7
1	$r[C_2 \mid \Delta A] = -0.07$	1	D_0, D_7	0.0054	51.7
2	$r[D_3 \mid \Delta A] = -0.072$				
3	$r[D_5 \mid \Delta A] = -0.341$				
4	$r[D_6 \mid \Delta A] = -0.33$				
5	$r[D_7 \mid \Delta A] = 0.40$				
6	$r[D_8 \mid \Delta A] = -0.28$				
7	$r[C_5 \mid \Delta A] = -0.06$				
8	$r[C_6 \mid \Delta A] = -0.19$	Final	D_0, D_7, C_6	0.0053	14.4
1	$r[C_2 \mid \Delta E] = -0.08$	1	F_0, C_7	0.0124	26.9
2	$r[F_3 \mid \Delta E] = 0.26$		Only 1 step		
3	$r[D_8 \mid \Delta E] = -0.11$				
4	$r[D_7 \mid \Delta E] = -0.17$				
5	$r[C_4 \mid \Delta E] = -0.29$				
6	$r[C_5 \mid \Delta E] = -0.14$				
7	$r[C_6 \mid \Delta E] = 0.10$				
8	$r[C_7 \mid \Delta E] = -0.30$				
		Final			

TABLE A-IX. RADAR 67.16 STEPWISE REGRESSION ANALYSIS RESULTS FOR AS-204 DATA

Variable No.	Linear Correlation	Step No.	Variables in Regression	σ_Y	F Level
1	$r[C_1 \mid \Delta R] = -0.77$	1	C_0, C_5	10.69	1070.
2	$r[C_2 \mid \Delta R] = 0.81$				
3	$r[C_4 \mid \Delta R] = 0.72$				
4	$r[C_5 \mid \Delta R] = 0.93$				
5	$r[C_6 \mid \Delta R] = -0.34$				
6	$r[C_7 \mid \Delta R] = 0.90$				
7	$r[C_8 \mid \Delta R] = 0.81$	Final	C_0, C_5, C_7	10.46	9.0
1	$r[C_2 \mid \Delta A] = 0.54$	1	D_0, D_3	0.0079	433.8
2	$r[D_3 \mid \Delta A] = 0.84$	2	D_0, D_3, C_2	0.0036	711.1
3	$r[D_5 \mid \Delta A] = -0.59$				
4	$r[D_6 \mid \Delta A] = -0.594$				
5	$r[D_7 \mid \Delta A] = 0.44$				
6	$r[D_8 \mid \Delta A] = 0.64$				
7	$r[C_5 \mid \Delta A] = -0.10$				
8	$r[C_6 \mid \Delta A] = -0.48$	Final	D_0, D_3, C_2, C_5	0.0035	4.8
1	$r[C_2 \mid \Delta E] = 0.62$	1	F_0, C_5	0.0037	952.
2	$r[F_3 \mid \Delta E] = 0.864$	2	F_0, C_5, F_3	0.0035	15.4
3	$r[D_8 \mid \Delta E] = 0.86$	3	F_0, C_5, F_3, C_2	0.0035	9.5
4	$r[D_7 \mid \Delta E] = 0.61$	4	F_0, C_5, F_3, C_2, C_4	0.0032	29.6
5	$r[C_4 \mid \Delta E] = -0.43$				
6	$r[C_5 \mid \Delta E] = 0.93$				
7	$r[C_6 \mid \Delta E] = -0.59$				
8	$r[C_7 \mid \Delta E] = -0.40$				
		Final	F_0, F_3, C_2, C_4	0.0032	-0.30

TABLE A-X. RADAR 67.18 STEPWISE REGRESSION ANALYSIS RESULTS FOR AS-204 DATA

Variable No.	Linear Correlation	Step No.	Variables in Regression	σ_Y	F Level
1	$r[C_1 \mid \Delta R] = -0.77$	1	C_0, C_5	6.01	5060.9
2	$r[C_2 \mid \Delta R] = 0.77$	2	C_0, C_5, C_7	5.90	10.3
3	$r[C_4 \mid \Delta R] = 0.65$				
4	$r[C_5 \mid \Delta R] = 0.98$				
5	$r[C_6 \mid \Delta R] = -0.48$				
6	$r[C_7 \mid \Delta R] = 0.95$				
7	$r[C_8 \mid \Delta R] = 0.79$	Final	C_0, C_5, C_7, C_4	5.84	6.7
1	$r[C_2 \mid \Delta A] = 0.89$	1	D_0, D_8	0.0025	1209.9
2	$r[D_3 \mid \Delta A] = 0.31$	2	D_0, D_8, C_6	0.0024	22.2
3	$r[D_5 \mid \Delta A] = -0.90$	3	D_0, D_8, C_6, D_6	0.0023	7.9
4	$r[D_6 \mid \Delta A] = -0.91$				
5	$r[D_7 \mid \Delta A] = -0.06$				
6	$r[D_8 \mid \Delta A] = 0.912$				
7	$r[C_5 \mid \Delta A] = -0.02$				
8	$r[C_6 \mid \Delta A] = 0.09$	Final	D_0, C_6, D_6	0.0023	-0.8
1	$r[C_2 \mid \Delta E] = 0.53$	1	F_0, C_2	0.0035	96.3
2	$r[F_3 \mid \Delta E] = 0.34$				
3	$r[D_8 \mid \Delta E] = 0.42$				
4	$r[D_7 \mid \Delta E] = 0.12$				
5	$r[C_4 \mid \Delta E] = -0.13$				
6	$r[C_5 \mid \Delta E] = 0.47$				
7	$r[C_6 \mid \Delta E] = -0.08$				
8	$r[C_7 \mid \Delta E] = -0.07$				
		Final	F_0, C_2, C_4	0.0034	29.8

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APPROVAL

RESULTS FROM THE EVALUATION OF TRACKING SYSTEM MEASUREMENT ERRORS ON THE APOLLO-SATURN 201-204 FLIGHT TESTS

By Bobby G. Junkin

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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