CORONA J

PERFORMANCE EVALUATION REPORT

MISSION 1116-1 and 1116-2

FTV 1661, CR-16

Approved [redacted] Manager
Advanced Projects

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Program [redacted]

FOREWORD

This report details the performance of the payload system during the operational phase of the Program [redacted] Flight Test Vehicle 1661.

Lockheed Missiles and Space Company, Inc. has the contractual responsibility for evaluating payload performance. This document is the final payload test and performance evaluation report for Mission 1116-1 and 1116-2 which was launched on 19 April 1972.

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INTRODUCTION

This report presents the final performance evaluation of Missions 1116-1 and 1116-2 of the Corona Program. The purpose of this report is to define the performance characteristics of the CR-16 payload system and to identify the source of in-flight anomalies.

The performance evaluation was jointly conducted by representatives of Lockheed Missiles and Space Company, Inc. (LMSC) and ITEK at the facilities of NPIC. The off-line evaluation of Corona engineering photography acquired over the United States was not available at LMSC for this flight.

Most of the quantative data normally used for this report are obtained from government organizations. With the impending completion of the program, these data are no longer required. The vehicle attitude error values and frame correlation times normally are made at NPIC. These data are derived from stellar photography not acquired on this mission because there was no DISIC subsystem installed.

Computer programs developed by A/P are utilized to calculate and plot the frequency distribution of the various contributors to image smear to permit analysis and correlation of the conditions of photography to the information content and quality of the acquired pictures. Because of the absence of stellar photography, these programs cannot be used. Image quality analysis is limited to subjective methods.

SECTION 1

MISSION SUMMARY

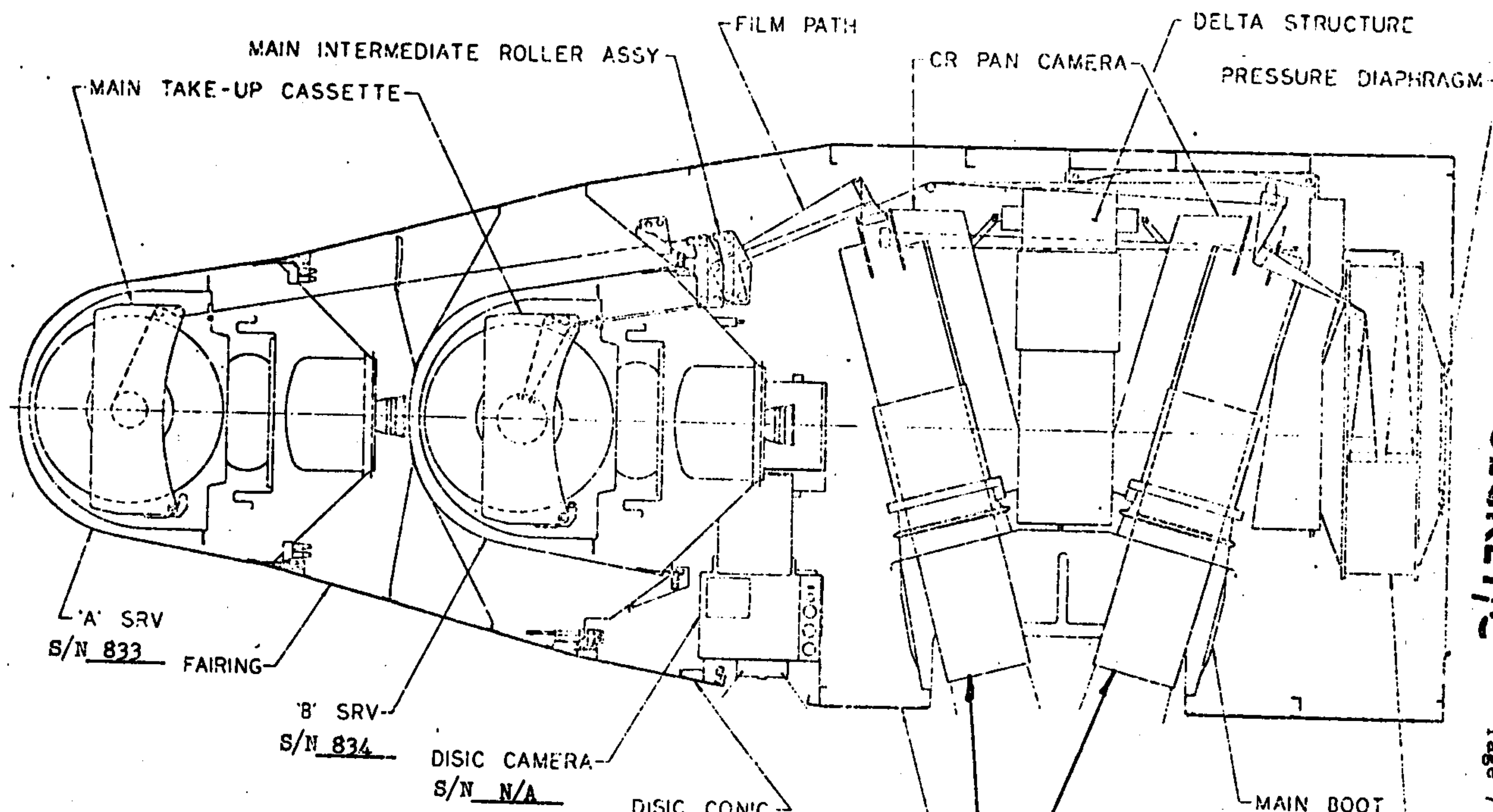
A. MISSION OBJECTIVES

The payload section of Mission 1116, placed into orbit by Flight Test Vehicle 1661 and THORAD Booster #569, consisted of two panoramic cameras, two Mark 5A recovery capsules and a space structure to enclose the cameras and provide mounting surfaces for all equipment. The usual DISIC subsystem was not included. Figure 1-1 presents an inboard profile of the CR-16 payload system. The Corona "J" system is designed to acquire search and reconnaissance photography of selected areas of the earth from orbital altitudes. A nine day -1 mission and a ten day -2 mission were conducted.

B. MISSION DESCRIPTION

The payload was launched from Vandenberg Air Force Base (VAFB) at 2144Z (1344 PST) on 19 April 1972, from SLC-3 west pad. Ascent and injection were normal and the achieved orbit was within nominal tolerances. Tracking and command support was effected by the Air Force Satellite Control Facility consisting of tracking and command stations at [redacted] under central control of the Satellite Test Center at Sunnyvale, California. Mission 1116-1 consisted of a 9-day operation and was completed by air recovery on Rev 180 at 1702 PDT on 30 April 1972. Mission 1116-2 was completed with an air recovery on Rev 309 at 1535 PDT on 8 May 1972, following a 10-day photographic operation.

2. PAYLOAD PROFILE AND SERIAL NUMBERS



SYSTEM NO. CR-16
TEST Flight Configuration
PMU S/N 1018
SLOPE PROGRAMMER S/N 218
CLOCK S/N 619
SWITCH PROGRAMMER S/N 215

FIGURE 1.1

The comparison of the planned and actual orbit parameters is tabulated as follows:

ORBITAL PARAMETERS

Parameter	Predicted	Orbit 2 Actuals
Period (Min.)	88.67	88.85
Perigee (N.M.)	84.5	83.8
Apogee (N.M.)	146.2	152.3
Inclination (Deg.)	81.50	81.48
Eccentricity	0.0088	0.0091

DMU Operation. The initial orbit period was high by an amount approximately equal to the impulse of one DMU rocket. Thus the ground track errors were large prior to the first DMU rocket firing. Throughout the remainder of the flight the ground track error was maintained at approximately 170 nautical miles west of the nominal at the equator. Eight of the twelve DMU rockets available were used to maintain period control.

C. PANORAMIC CAMERAS

Both panoramic cameras operated satisfactorily throughout both missions. The imagery from both cameras was rated as good for both mission segments and retained its edge sharpness at 100 times magnifications. The film supply was 3414 material and was exhausted on Rev. 301 for both cameras.

D. OTHER SUBSYSTEMS

The pressure make-up unit, the clock, command and instrumentation, and the thermal control subsystems performed satisfactorily throughout both missions.

The slope programmer provides continuous V/h error correction. V/h errors were maintained at less than $\pm$ 1% throughout 84% of the -1 mission and 75% of the -2 mission by the use of several flat ramps programmed throughout the mission.

The exposure control programmer operated satisfactorily throughout both missions. The tape recorder data from SRV-1 and from SRV-2 was extracted normally. The payload clock system performed normally throughout both missions with the tape recorder subsystem.

The twelve-second telemetry delay timer failed on Rev. 89, with the result that several telemetry channels could not be selected for the remainder of the mission. The vehicle telemetry Link I failed on Rev. 105 with the result that Link II was used for both operational and diagnostic data for the duration of the flight.

E. COMPONENT IDENTIFICATIONS AND SETTINGS

1. Forward Looking Panoramic Camera

a. Component Assignment

Component	Serial Number
Main Camera	333
Main Camera Lens	I221
Supply Horizon Camera Lens	E40788
Take-up Horizon Camera Lens	E40769

b. Camera Data and Flight Settings

Main Camera:

Lens	24"f/3.5
Slit Widths	
S_1	0.134"
S_2	0.169"
S_3	0.202"
S_4	0.244"
F/S	0.146"

Filter Types

Primary	Wratten 25, 0.037" glass
Secondary	Wratten 25, 0.040" glass

Film Types

Primary	Eastman Type 3414 (16,300 Ft.)

Supply (Port) Horizon Camera:

Lens	55 mm f/6.3
Aperture Setting	f/6.3
Exposure Time	1/100 second
Filter Type	Wratten 25

Take-up (Starboard) Horizon Camera:

Lens	55 mm f/6.3
Aperture Setting	f/8.0
Exposure Time	1/100 second
Filter Type	Wratten 25

2. Aft Looking Panoramic Camera

a. Component Assignment

Component	Serial Number
Main Camera	332
Main Camera Lens	I222
Supply Horizon Camera Lens	E40779
Take-up Horizon Camera Lens	E40790

b. Camera Data and Flight Settings

Main Camera:

Lens	24'f/3.5
Slit Widths	
S_1	0.111"
S_2	0.130"
S_3	0.162"
S_4	0.196"
F/S	0.119"
Filter Types	
Primary	Wratten 23, 0.037" glass
Secondary	Wratten 23, 0.040" glass
Film Types	
Primary	Eastman Type 3414 (16,300 Ft.)

Supply (Starboard) Horizon Camera:

Lens	55 mm f/6.3
Aperture Setting	f/8.0
Exposure Time	1/100 second
Filter Type	Wratten 25

Take-up (Port) Horizon Camera:

Lens	55mm f/6.3
Aperture Setting	f/6.3
Exposure Time	1/100 second
Filter Type	Wratten 25

3. DISIC Camera

Not installed.

SECTION 2

PRE-FLIGHT SYSTEMS TEST

The CR payload systems are subjected to a sequential series of tests required to demonstrate a satisfactory confidence level in the flightworthiness of the systems. These tests include static verification, dynamic performance, operation in simulated thermal-altitude environment, light leak evaluation and dynamic photographic performance measurements.

The panoramic cameras were received at A/P in August 1970. Modifications to update the configuration and acceptance testing were completed in September 1970. Final system tracking tests were completed in November 1970. Light leak testing, in January 1971, revealed a faulty horizon camera filter assembly which was corrected. The CR-16 system was then prepared for environmental testing. Significant baseline levels and anomalies experienced during the environmental testing are as follows:

A. ENVIRONMENTAL TESTING

The CR-16 payload system was environmentally tested in the Sunnyvale HIVOS chamber between February 2 and February 9, 1971. Testing on the first day was interrupted by erratic operation encountered on the No. 2 supply cassette telemetry data. It was found that the problem was due to an unbalance in the No. 2 instrument transport system, but that corrective action could be deferred until completion of the test.

Examination of the processed payload revealed two significant anomalies. There were five instances of an input horizon camera shutter failure on the No. 1 instrument. This shutter unit was subsequently repaired and replaced in the camera.

January and February 1972. The final low contrast resolution values observed at this time were as follows.

Instrument #332

W-23A type filter, 0.037" glass

158 lines/millimeter at +0.0001" focal position.

Instrument #333

W-25 type filter, 0.037" glass

144 lines/millimeter at -0.0004" focal position.

SECTION 3

FLIGHT OPERATIONS

A. SUMMARY

Mission 1116 utilized a Thorad booster (SLV-2H) S/N 569, Agena Vehicle 1661, and payload system CR-16. The CR-16 payload system contained panoramic cameras S/N 330 and 331. There was no DISIC camera installed.

Lift-off occurred at 1344 PST on 19 April 1972 from the Vandenberg SLC-3 west pad. All payload ascent events were normal with In-flight Reset (door ejection), AP to Orbit mode, instrumentation switchover, and panoramic camera transfer to orbit mode occurring as programmed. The orbit attained was within the three sigma of predicted.

Panoramic cameras S/N 332 and 333 performed normally throughout the flight. The film supply of both cameras was exhausted on Rev 301.

The panoramic camera A-to-B transfer sequence was performed on Rev 155 [redacted] with all events occurring normally. The -1 mission recovery capsule was recovered by air catch on Rev 180 at 1702 PDT on 30 April 1972. The -2 mission recovery capsule was recovered by air catch on Rev 309 at 1535 PDT on 8 May 1972.

The -1 and -2 mission SRV tape recorder systems performed normally with all data extracted.

The twelve second instrumentation delay timer failed on Rev 89 [redacted] with the relays latched in the instrument mode for the duration of the flight.

The vehicle Link I failed on Rev 105 [redacted] and remained inoperative for the remainder of the flight.

The slope programmer, switch programmer, command system, pressure make-up system, clock system, and the thermal environment were normal throughout the flight.

B. PANORAMIC CAMERAS

Panoramic cameras S/N 330 and 331 performed normally during the -1 and -2 missions. Film consumption and type were as follows:

Film Consumption

	Frames	
	Pan 332	Pan 333
Sample	21	21
Pre-launch	133	133
-1 Mission	2938	2936
-2 Mission	3083	3083
Total	6175	6173

Film Supply Length and Type

Pan 332	Pan 333
16300 FT/3414	16300 FT/3414

C. COMMAND AND CONTROL SUBSYSTEMS

The DSR malfunctioned three times during the flight, with no impact on the mission. On Rev 66[redacted] and Rev 288[redacted] the DSR memory did not erase when receiving the Silo 309 command. The load was disabled with a Silo 319 command and the next Silo 309 did erase the DSR memory. The block load was then sent and disabled. In testing the DSR in its early stages, this problem had been observed in some units; these units were reworked to eliminate the problem. There is no record of this DSR unit being reworked. On Rev 129 [redacted] a new block load was sent which contained 4 Silo 309's, 4 Silo 319's, and 12 Silo 309's. This command was made to eliminate a question of not erasing the DSR memory. Although the DSR memory was erased, a problem occurred, the third word, not the first, in the memory was shifted to the output register upon execution of the next Silo 319. This new block was used only once and due to a lack of data the problem could not be resolved.

FMC Match. The ramp to orbit match was maintained satisfactorily throughout the flight. Approximately 84% of the first mission and 75% of the second mission operations were less than ± 1.0% mismatch error.

Exposure Control System. The slit width control programmer performed satisfactorily throughout the -1 and -2 missions.

D. DATA SYSTEMS

Instrumentation. The instrumentation system performed normally through Rev 88. The twelve second telemetry delay timer failed on Rev 89 [redacted] This resulted in the following telemetry channels being locked in the instrument mode: Link I, Channels 9, 10, 11, and 18. The relays remained latched in the instrument mode for the remainder of the flight.

The vehicle telemetry Link I failed on Rev 105 [redacted] and resulted in the use of Link II for both the operational and diagnostic data verification. Link I remained inoperative for the duration of the flight.

The slit width telemetry monitor on instrument No. 1 was intermittent throughout the flight. However, there was no operational impact.

The other anomaly was corona and dendritic electrostatic marking on the film from the No. 1 instrument. This marking was of low density (0.42 maximum over a base fog level of 0.21) and occurred at pressures equivalent to from 2 to 10 micrometers of mercury. The condition was not acceptable per normal test specifications. A waiver was requested from and granted by the customer for the following reasons: (1) the maximum density and extent of marking would never cause a catastrophic loss of information; (2) the marking did not occur at either normal PMU pressure or hard vacuum, which would be the normal operating and failure conditions respectively; (2) the marking occurred only intermittently even at the pressures noted; and (4) corrective action and retest would not insure better flight performance.

Several anomalies in time word recording on both instruments were corrected by subsequent electrical adjustments of the clock system.

There was no DISIC subsystem installed in CR-16 for environmental test.

B. ASCHENBRENNER GRID TEST

A series of fifteen tests were conducted in April 1971. The No. 2 instrument demonstrated acceptable film flatness on the first trial, while the No. 2 instrument did not achieve acceptable flatness until the fifteenth trial. Performance of both instruments was excellent except at the ends of scan.

C. RESOLUTION TESTS

Initial resolution and theodolite tests were performed in April 1971. Both main instruments met acceptance criteria at that time. However, mechanical rework of the scan heads necessitated reverification of performance in

Clock System. The payload clock system performed normally throughout the -1 and -2 missions. Due to failure of the 12-second delay timer, the real time verification of the clock system was not possible. However, the parallel clock word on the film performed satisfactorily throughout the flight. The constants and coefficients for a third order fit in time computations are given below.

Third Order Fit

$$\text{System Time} = A_0 + A_1\,(\text{Clock Time}) + A_2\,(\text{Clock Time})^2 + A_3\,(\text{Clock Time})^3$$

$A_0 = 0.9321553467460832 + 05$

$A_1 = 0.9999999354786997 + 00$

$A_2 = 0.1105562847760144 - 12$

$A_3 = 0.1226092317364113 - 18$

Sigma = 0.00127336

Number of points = 161

SRV Tape Recorder. The -1 SRV tape recorder performed normally throughout the -1 mission with 102.7 minutes of data retrieved satisfactorily. The -2 SRV tape recorder performed normally throughout the -2 mission with 109.8 minutes of data retrieved satisfactorily.

E. RECOVERY

-1 Mission. The -1 recovery capsule was successfully recovered by air catch on Rev 180 at 1702 PDT on 30 April 1972. All re-entry events were within tolerance with the impact close to nominal.

	Actual	Predicted
Impact Location	$24^\circ 37'$N/$172^\circ 30'$W	$24^\circ 44.6'$N/$172^\circ 38.7'$W

<u>-2 Mission</u>. The -2 recovery capsule was successfully recovered by air catch on Rev 309 at 1535 PDT on 8 May 1972. All re-entry events were within tolerance with the impact within 5 miles of the predicted.

	Actual	Predicted
Impact Location	27°06'N/166°49'W	27°53'N/166°51.4'W

F. ORBITAL PARAMETERS

The orbit achieved was within the predicted 3 sigma dispersion. The following tabulation describes the orbital parameters based on Rev 2, both predicted and actual.

<u>Orbital Parameters</u>.

Parameter	Predicted	Tolerance	Actual(STC)	Actual(APF)
Period(Min.)	88.67	+0.35,=0.37	88.85	88.85
Perigee(N.M.)	84.5	±9	83.8	83.8
Apogee(N.M.)	146.2	+13,-16	152.8	152.3
Eccentricity	0.0088	+0.0027,-0.0030	0.0101	0.0091
Inclination(Deg.)	81.50	+0.18,-0.16	81.46	81.48
Arg. of Perigee(Deg.)	146	+79,-68	165.4	166

Orbital history of perigee altitude, perigee latitude, period error and longitudinal error are shown in graphs 3.1 and 3.2. The latitudes and altitudes of operations are shown on graph 3.3.

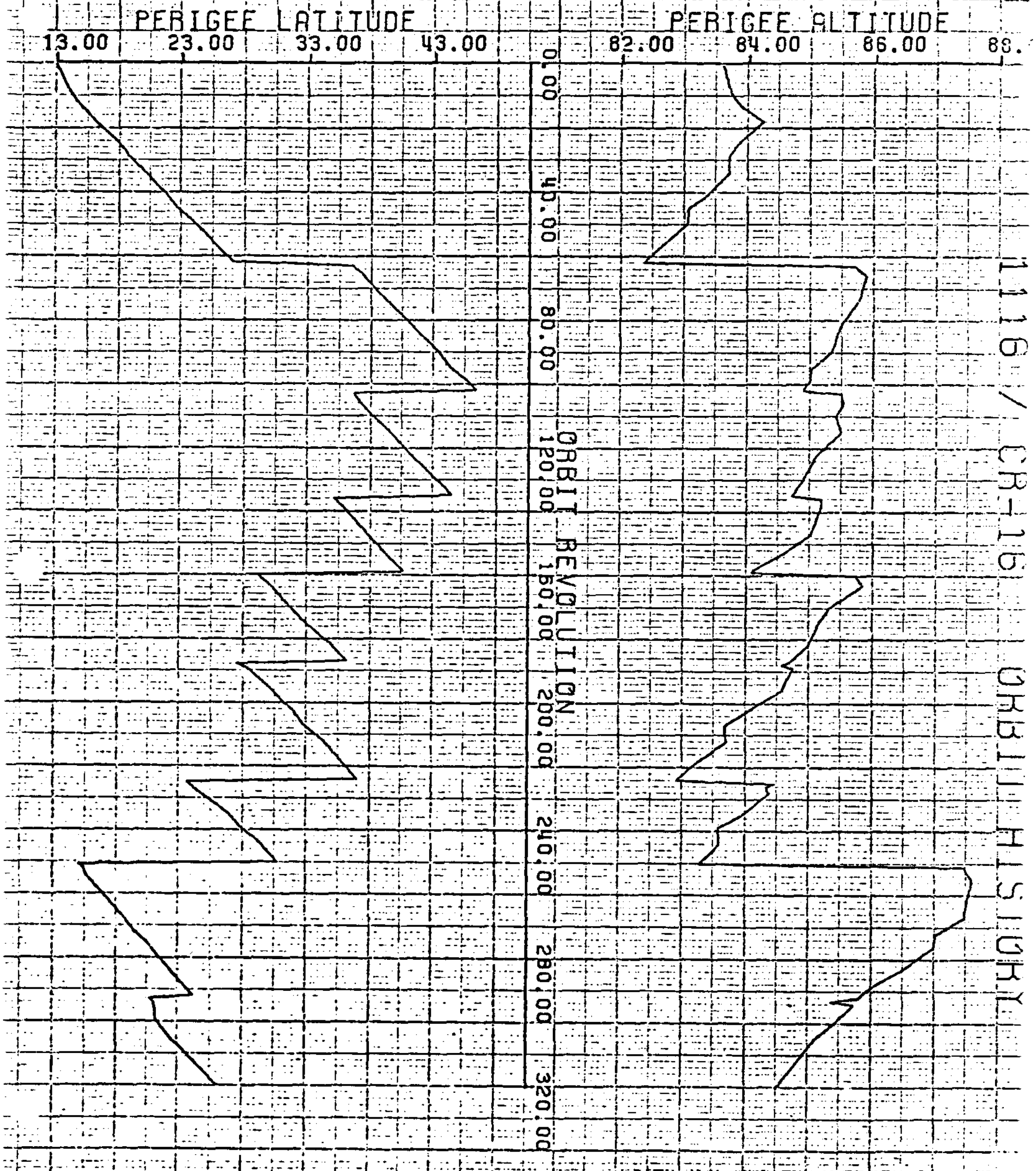

PERIGEE LATITUDE
13.00
23.00
33.00
43.00
PERIGEE ALTITUDE
82.00
84.00
86.00
88.
ORBIT REVOLUTION
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
1116 / CR-16 ORBIT HISTORY

FIGURE 3.1

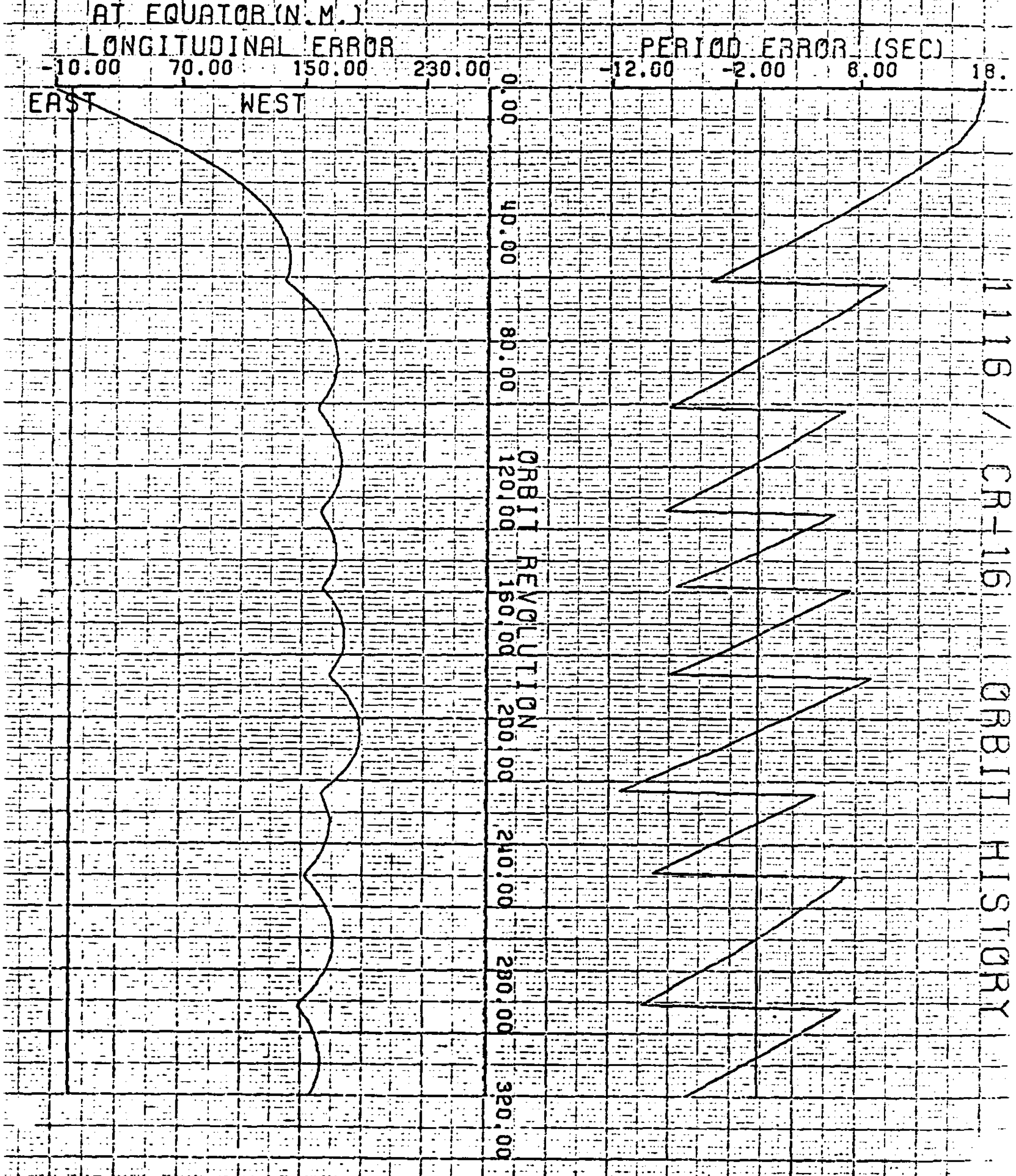
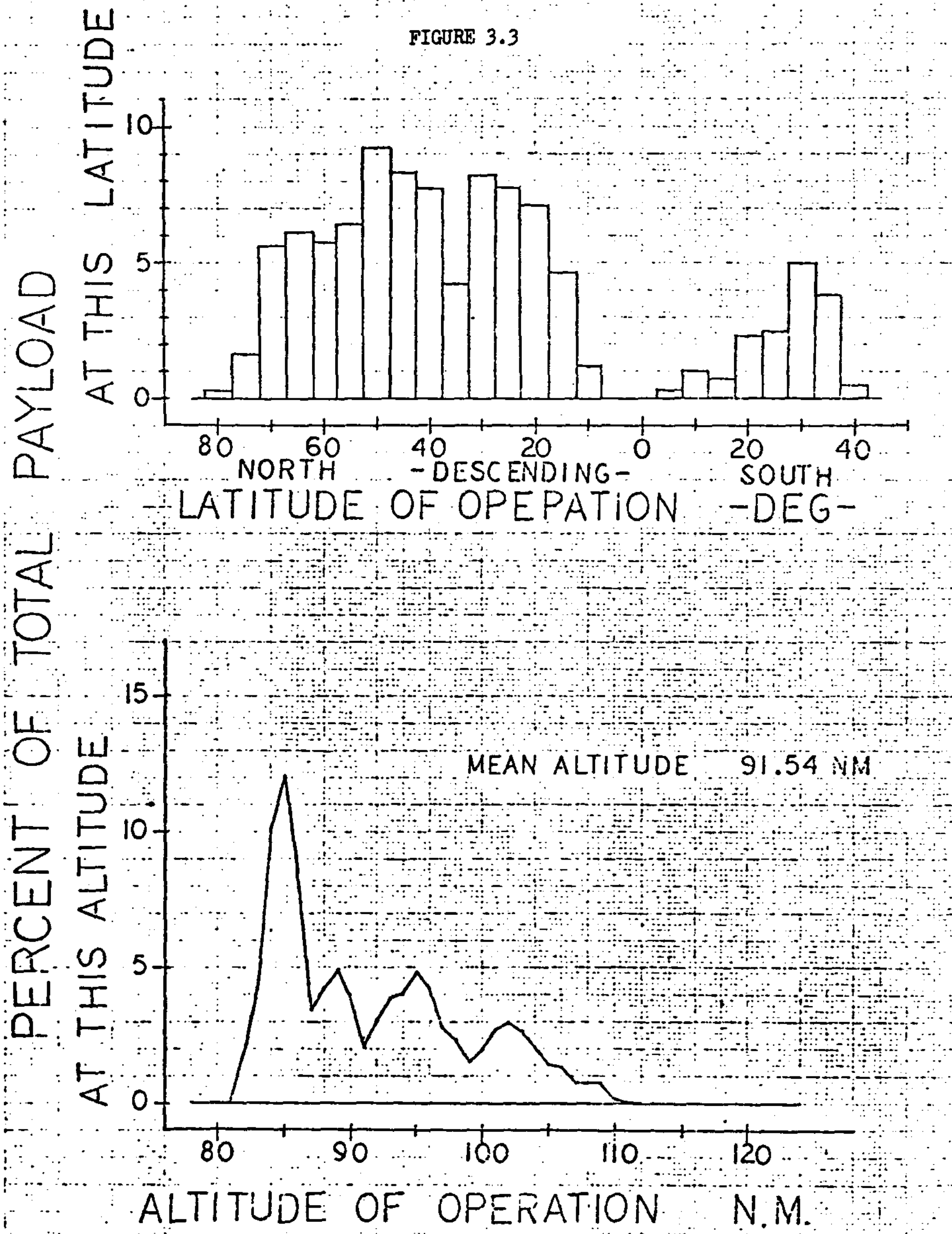

1116 / CR-16 ORBIT HISTORY
AT EQUATOR (N.M.)
LONGITUDINAL ERROR
-10.00
70.00
150.00
230.00
EAST
WEST
PERIOD ERROR (SEC)
-12.00
-2.00
8.00
18.
ORBIT REVOLUTION
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00

FIGURE 3.2

FIGURE 3.3


PERCENT OF TOTAL PAYLOAD
AT THIS LATITUDE
10
5
0
80
60
40
20
0
20
40
NORTH
-DESCENDING-
SOUTH
LATITUDE OF OPEPATION -DEG-
AT THIS ALTITUDE
15
10
5
0
MEAN ALTITUDE 91.54 NM
80
90
100
110
120
ALTITUDE OF OPERATION N.M.

G. DMU OPERATION

The initial orbit period was high by the impulse energy of one DMU rocket. Thus, the ground track location errors were large prior to the first DMU rocket firing. Throughout the remainder of the flight, the ground track error was maintained at approximately 170 N.M. west of the nominal at the equator.

Eight of the twelve DMU rockets were used to maintain period control. Their use is summarized in the following table.

DMU Performance

Rocket No.	Rev No.	System Time (Sec)	Period Change (Sec)	Velocity Change (Ft/Sec)	Period at Firing (Min)	Impulse (lb/Sec)
1	61	56934	14.60	23.32	88.49	3106
2	101	11674	14.93	23.81	88.43	3160
3	134	14216	14.75	23.60	88.43	3031
4	158	55635	14.45	23.12	88.44	3019
5	186	31240	15.75	25.25	88.44	2920
6	223	55392	15.50	24.78	88.35	2876
7	249	21130	16.09	25.67	88.41	2967
8	291	70437	16.19	25.83	88.42	2956

NOTE: DMU Rockets 9 and 10 were fired after Event 2.

H. ENVIRONMENTAL CONTROL

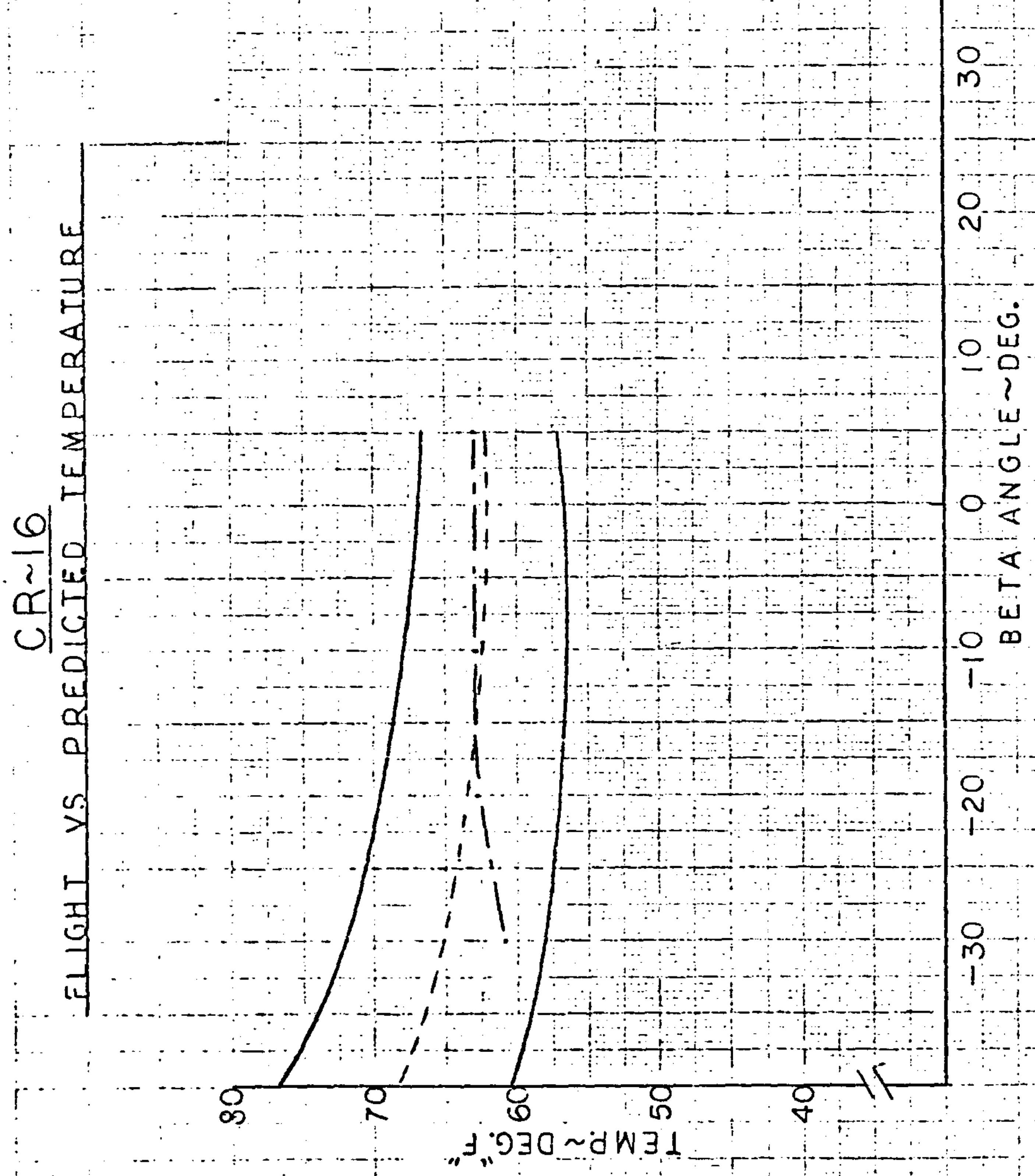
Pressure Make-up System. The pressure make-up system (PMU) operated properly throughout the flight. There were 163 panoramic camera operates for a total of 195.5 minutes which resulted in a gas consumption rate of 7.4 psi/min of operate time.

Thermal Environment. The temperature data obtained indicated the temperature environment was within the pre-flight predictions through Rev 88. The real time temperature data was lost when the 12-second delay timer failed. The temperature environment for the remainder of the flight was obtained once a day from the vehicle tape recorder. The averages of the panoramic camera temperatures ranged from 60°F to 65°F for S/N 332 and 64°F for S/N 333 during the flight. See Figure 3.4.

I. POST EVENT 2 TESTING

The panoramic cameras were enabled at the end of the H-timer tape in order to deplete the surplus vehicle power. No other payload testing was performed.

FIGURE 3.4


CR~16
FLIGHT VS. PREDICTED TEMPERATURE
BETA ANGLE~DEG.
-30
-20
-10
0
10
20
30
TEMP~DEG. F
80
70
60
50
40

SECTION 4

PHOTOGRAPHIC PERFORMANCE

Both panoramic cameras were operational throughout both missions. The film supply for the forward-looking camera #333 was exhausted on Frame 3 of Rev 301 and the aft-looking camera #332 supply was exhausted on Frame 4 of Rev 301.

An MIP rating of 115 was assigned to Frame 4 of Rev D095 from the forward-looking camera for the 1116-1 mission.

An MIP rating of 115 was assigned to Frame 2 of Rev D161 from the forward-looking camera for Mission 1116-2.

The forward-looking camera produced 6024 frames and the aft-looking camera produced 6022 frames during both mission segments. The post flight performance evaluation team reported that the overall mission probably yielded as large a quantity of high quality photography as any Corona mission. The MIP rating was as high as any mission except 1114, in spite of the fact that limited cultural coverage necessitated MIP chip selections from unfavorable format positions. Resolution target coverage was limited to one frame from each camera during the 1116-2 mission. This coverage was the high contrast target at Ft. Huachuca. Both cameras produced a ground resolved distance of 4.5 feet, which is equivalent to about 200 lines per millimeter on the film.

The anomalies affecting the photographic systems were of a minor nature with minimal effects on the imagery, and resulted in no action items. There were six instances of a horizon camera single-cycle open shutter failure (output side, No. 1 instrument) that caused serious over exposure of twelve panoramic frames. Emulsion scratches affected the No. 2 instrument payload intermittently, apparently due to emulsion buildups. A crease or fold in the No. 1 camera film, combined with an unusually dry condition, weakened the film at pass 250, frame 230, sufficiently to require tape reinforcement after processing. Minor static and light leak conditions were also noted.

Mission 1116-1 was processed at the primary processing facility and was the last Corona mission material to be processed at that location. Mission 1116-2 was processed at the back-up processing facility. No significant difference in processing results was noted between the two segments.

SECTION 5

PANORAMIC EXPOSURE

A. INTRODUCTION

Exposure of the CR systems is a function of scan rate, filter, slit width and scene luminance. Since scan rate is adjusted in flight to compensate for forward image motion, exposure control is exercised during flight only by the selection of the filter and slit opening.

The Wratten filter is selected prior to flight and is therefore fixed for a given film type. The slit width is selectable by real-time command in flight. Four different slit widths may be selected by automatic sequencing or any one of five fixed slits may be selected.

B. EXPOSURE ANALYSIS

The filters for the forward-looking camera, #333, were both Wratten 25 and the filters for the aft-looking camera, #332, were both Wratten 23. The filters selected for both primary and secondary positions were all glass. The somewhat greater light filtration of the shorter wave lengths provided by the W-25 filter reduces the amount of non-image forming haze light in the forward-looking camera. Since the W-25 filter provides more light filtration than the W-23, the slits selected for the forward camera are wider than the slits selected for the aft camera.

The exposure slits selected for the forward and aft-looking cameras were as follows:

Slit Width (inches)

Slit	Fwd (#333)	Aft (#332)
S4	0.244	0.196
S3	0.202	0.162
S2	0.169	0.130
S1	0.134	0.111
F/S	0.146	0.119

The automatic slit sequencing system was adjusted to accommodate either predicted snow or no-snow conditions. It was found during the mission, and verified afterward, that snow coverage was unusually extensive for this time of the year.

Normally, extensive film density data is collected to provide objective measures of exposure and processing performance. With the approaching termination of this program, these activities have been terminated and only subjective analysis is available. It was found that exposure control was effective with densities ranging from medium to high. The high densities were associated with snow cover and were within a range that appeared correct for the scene conditions.

SECTION 6

VEHICLE ATTITUDE AND IMAGE SMEAR

A. VEHICLE ATTITUDE

The vehicle attitude errors for Corona Missions are normally derived from the reduction of the Stellar camera photography. This attitude data is supplied to A/P by NPIC. Since a DISIC subsystem was not used on this mission, these data are not available.

The attitude errors for each frame and the attitude control rates are normally calculated at the A/P computer facility. The computer also plots the frequency distribution of the rates and errors. Since objective measurements are not available, the analysis is limited to subjective examination.

Since this mission consistently produced excellent photography, among the best of the Corona program, it is evident that attitude and rate errors, along with resulting smear, were minimal.

SECTION 7

RELIABILITY

MISSION 1116 (CR-16)

Reliability estimates presented in this section begin with samples taken from the Mural Program, M-7 system. As a result, most of the Mural Program and all of the "J" program have been included in the reliability analysis. The DISIC camera is not listed since it was not flown on this mission.

Reliability estimates are shown for the primary category that includes the panoramic cameras, main panoramic door ejection, payload command and control, payload clock, and overall payload functioning on orbit. The secondary reliability category includes the auxiliary camera functions such as the DISIC and Horizon cameras.

Reliability estimates deal entirely with the payload. Only electrical and mechanical functions are considered. Vehicle failures are not included. Early recovery is treated as a complete mission provided that early termination was not caused by payload malfunction.

The following tabulation summarizes the reliability estimates for Mission 1116. It is not directly comparable with some prior tabulations since it is based on a 9½ day average mission segment rather than a seven day segment. A 50 percent confidence level is used.

TABLE: 7-1

Primary Function (M-7 and Up)	Sample Size	Failures	Estimated Reliability
Panoramic Cameras	279 segments	5	98.00%
Panoramic Camera Doors	162 segments	0	99.58%
Command and Control	19536 (Hrs.)	2	96.91%
Clock	19536 (Hrs.)	0	99.19%
Total Combined Functions above:	-	-	93.81%
Recovery System	133 segments	1	98.75%

Secondary Function	Sample Size	Failures	Estimated Reliability
Horizon Camera (Sample begins with J-5)	181,000 cycles	0	99.42%

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[redacted]	