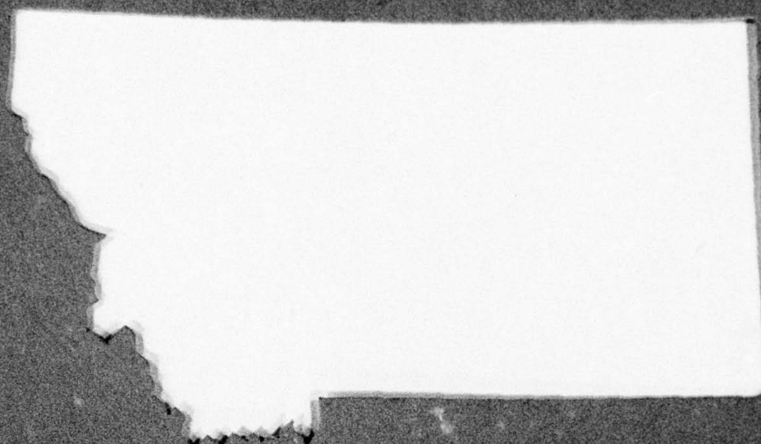

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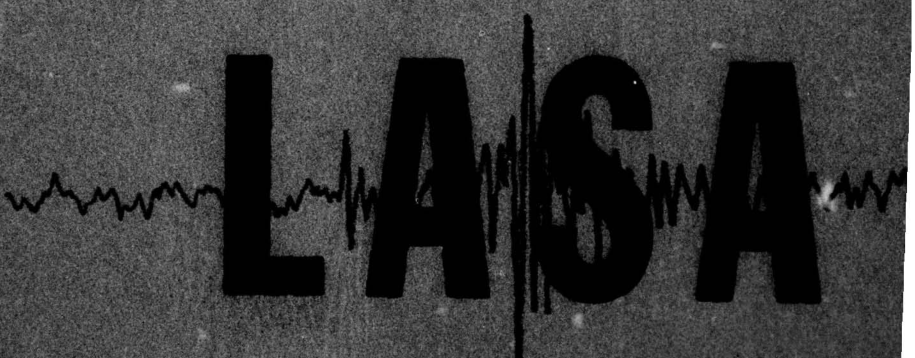

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Technical Report 2140-77-99

24

MONTANA LARGE APERTURE SEISMIC ARRAY

SEMI-ANNUAL TECHNICAL REPORT

PROJECT VT 7708

CONTRACT F08606-77-C-0009

1 APRIL 1977 - 30 SEPTEMBER 1977

FORD AEROSPACE AND COMMUNICATIONS CORPORATION
ENGINEERING SERVICES DIVISION
214 North 30th Street
Billings, Montana

MONTANA LARGE APERTURE SEISMIC ARRAY

SEMI-ANNUAL TECHNICAL REPORT

Report No. 2140-77-99

28 October 1977

IDENTIFICATION

AFTAC Project Authorization No.: VELA T/7708

Title of Work Montana Large Aperture Seismic Array

Name of Contractor: Ford Aerospace and Communications Corporation

Contract No.: F08606-77-C-0009

Time period covered: 1 April - 30 September 1977

Date of Issue: 28 October 1977

Program Manager: R. E. Matkins (406)245-6332

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ABSTRACT

The operation and maintenance activities at the Montana Large Aperture Seismic Array and Data Center during the period from April 1 and September 30, 1977 are described. Operations in data recording and event processing are detailed. Seismograph frequency response measurements and performance statistics are presented. Maintenance activities in the array and at the data and maintenance center are discussed.

ACKNOWLEDGEMENT

Ford Aerospace and Communications Corporation wishes to recognize the excellent technical direction provided to the Montana LASA project during this contract period by Capt. Robert J. Woodward at the VELA Seismological Center.

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INTRODUCTION

This is the final semi-annual technical report of the activity by Ford Aerospace & Communications Corporation on the Montana Large Aperture Seismic Array (LASA), Project VELA T/7708, under contract F08606-77-C-0009.

The primary goal of this project is to operate and maintain the LASA in a manner which produces unique high quality seismic data for use by other government sponsored research projects.

The work described here began 1 April 1977 and continued through 30 September 1977.

The sections following in this report describe the operation of the various systems installed at the LASA, the performance measurements on the equipment, the teleseismic and near-regional event reporting, the PDP-7 computer programming, and the maintenance performed on the systems.

SECTION I

SEMI-ANNUAL SUMMARY OF EVENTS

The activities at the Montana LASA facilities during April through September 1977 are described in this report. The LASA Processing System operated with the Seismic Data Analysis Center (SDAC) 94.5% of this final six-month period and 93.3% of the one-year contract. System/360 failure corrections accounted for 83.9% of the on-line data interruptions.

Digital recording of the array data by the PDP-7 computer continued on a full-time basis with the exception of an average 65 minute per day interruption for off-line program processing and system maintenance. These digital recordings were available from the LDC in Billings during the 60-day retention cycle before their reuse. Our system permits four recording modes by selection of either 10 or 20 sample/second array data in either a 10 or 16 SP sensor subarray configuration; all LP sensor data is included with both configurations. Edited recordings of the SP subarray summation signals for most event detection periods since 1 November 1975 are still available from our daily AUTO-EDIT system library.

Routine teleseismic event processing using film recordings and on-line computer playouts allowed our reporting an average of 18.6 events or phases daily to VSC. Periodic near-regional event and strip-mine blast listings added an average of 6.7 events/day to the LDC's event reports. The detection threshold for our daily teleseismic reports is estimated at 4.99 (90%) and 4.55 (50%). A study of the events reported by seismic region has allowed improvements in local event processing programs.

Seismograph frequency response measurements have been made and some results are presented in this report. A series of field tests has been initiated to collect data for verifying the results obtained from our computer measurement programs and to improve the seismograph response information presently available.

Again, equipment and facilities mainteance permitted the continued operation of the array in a manner similar to previous periods. The continued wear with age of the mechanical components increases the effort and concern during their maintenance. Development of our computer maintenance capability has reduced the level of IBM customer engineering diagnostic assistance necessary.

SECTION II

OPERATION OF ALL LASA SYSTEMS

A. LASAPS OPERATIONS

The LDC computer provided LASA data to the SDAC transcontinental data link 94.5% of the six-month period from April thru September 1977. The one-year percentage equalled 93.3%. Interruptions in the computer's on-line operation with SDAC which have occurred are listed in Table I.

TABLE I

LASAPS DATA INTERRUPTIONS

	April-Sept 77		Oct 76-Sept 77	
Cause	Hours	%	Hours	%
Corrective Maint.	203.4	4.63	491.5	5.61
active maint	108.1	2.46	220.3	2.51
awaiting pers.	76.8	1.75	195.9	2.24
awaiting parts	18.5	0.42	75.3	0.86
Program Halts/Power Loss	15.7	0.36	31.0	0.35
Admin. Use (training)	7.8	0.18	20.5	0.23
SDAC Line Inop.	6.0	0.14	15.7	0.18
Preventive Maint.	6.6	0.15	15.1	0.17
Other LDC Systems Inop.	2.3	0.05	12.1	0.14
TOTALS	241.8	5.51	585.9	6.68

B. PDP-7 COMPUTER OPERATIONS

1. Data Recording

The LASA Inner Array Recording System (LIARS) operated on an almost full-time basis to record LASA data. Recordings covering an average of 23.0 hr/day for the 183-day period were made. This system previously described by Potter (1975) provides four modes of array data recording either 10 or 20 samples/sec (s/s) from either a 10 or 16 SP sensor configuration of all 13 subarrays. LIARS tape recordings totalling 6302 were produced using the slow-mode (10 s/s), short (10 sensor) format; no recordings were made using the other modes. During the one-year contract period 12,590 tape recordings covered 8369.8 hours or 95.5% of the total time.

Interruptions in the data recording were necessary to support other LDC operations and logistics functions for 148.5 hr (3.4%) and for computer downtime 26.0 hr (0.6%). The contract totals were 309.8 hr (3.5%) and 62.5 hr (0.7%) for the two functions, respectively.

2. Auto-Edit

Recording edited event data from only the SP sub-array sum signals continued throughout this reporting period allowing the preparation of 13 new master-edit tapes containing 1377 event periods. These LDC recordings, described by Matkins (1976) provide an efficient means of data playout for event analysis and for event data retention at the LDC. For the one-year period 29 tapes covered 3104 event periods of interest.

3. Event Detection

Automatic event detection continued using the same event detection processor routine as used and reported by Needham (1969). The event detection lists speed the manual analog film reading process from which we prepare our daily teleseismic reports. Event detections also provide a means of verifying the SP array sensing performance.

4. Event Processing

Event processing at the LDC is performed to assist in our teleseismic event reporting to VSC. Event data with amplitudes too small to pick from the analog film recordings are processed digitally through a filter, a beam former, and a cross-correlation routine. The time picks from either these strip charts or film recordings are further processed to obtain location and other event parameter information. (See Section III.A.1)

C. ARRAY OPERATIONS

1. Monitoring

The array and data center systems are monitored on a continuous basis to provide an up-to-date site/sensor status

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Potter, George. (1975) "LASA Inner Array Recording System" LASA Program Description. Ford Aerospace & Communications. Billings MT 26 MAR 75.

Matkins, R. E. (1976) Montana LASA Semi-annual technical report. T/R 2126-76-75 (AD-A023 263) 23 JAN 1976.

Needham, R. and A. Steele. (1969) Montana LASA data analysis techniques. S-110-33 Billings, MT May 1969.

information input to the LASAPS processor and to alert maintenance to trouble sources. Interruptions of the array data are shown in the monthly operations summary reports. SP data was interrupted 476.2 hr during this period; LP 396.9 hr. Each SP subarray averaged 3.1 hr/month outage; LP, 3.7 hr/month. Table II indicates the data interruptions by the purpose of the outage and Table III shows a summary by subarray of the outages.

2. Communications Monitoring

Monitoring of the array communications circuits between each of the thirteen subarrays and the data center indicated about the same level of performance as previously observed. The long term circuit availability (since DEC 1970) of array circuits decreased slightly from 0.99687 to 0.99674. Circuit outages-those which normally exceed 2 or 3 minutes-of each subarray are shown together with the short-and long-term circuit availabilities in Table IV.

The extended outages exceeding a two-hour duration are listed in Table V.

3. Array Calibrations

Sinusoidal calibrations are performed daily using Program TESP for the SP seismographs to determine the condition of the array equipment. LP seismographs are routinely tested each week using Program TELP for sinusoidal calibrations, Program FREEK for free period measurement, and Program MASPOS for measuring and positioning the LP seismometer masses. Other computer controlled tests are periodically performed.

D. ANALOG SYSTEM

The LASA SP Develocorder operated on-line with the array. The recording format consisted of center holes from the C-and D-Ring and AO subarrays plus the attenuated signals from AO and D4. Develocorder film recordings dating from 24 DEC 73 are stored in the library.

Analog signals from two subarrays (D1 and C2) are transmitted to the National Earthquake Information Service facility in Golden, Colorado, as a part of their on-line seismic recording system.

E. DATA LIBRARY

Recording of the arrays seismic data by the PDP-7 computer's seven-track tape units using our LIARS format covered 4202.0 hours or 95.7% of the six-month period. These 6302 magnetic tape recordings were recycled through the LDC's Data Library so that each recording was retained for at least 60 days before reuse.

TABLE II

DATA INTERRUPTIONS BY PURPOSE OF OUTAGE

APRIL 1977 - SEPTEMBER 1977

SP ARRAY, 13 SITES	TOTAL HOURS OUT	AVERAGE PER SITE
LDC TESTING	25.56	0.45
SITE FAILURES	130.50	10.04
LMC MAINTENANCE	20.64	1.58
TELCO TEST/OUTAGE	283.77	21.83
POWER	0.00	0.00
LDC FAILURES	35.53	2.73
TOTAL SP ARRAY	476.23	36.63
LP ARRAY, 9 SITES		
LDC TESTING	18.79	2.09
SITE FAILURES	130.50	14.50
LMC MAINTENANCE	16.90	1.88
TELCO TEST/OUTAGE	195.20	21.69
POWER	0.00	0.00
LDC FAILURES	35.53	3.95
TOTAL LP Array	396.92	44.10

TABLE III

SUMMARY OF SUBARRAY DATA INTERRUPTION OUTAGES

APRIL 1977 - SEPTEMBER 1977

SITE	SP DATA	LP DATA	TELCO
A0	118.95	120.32	38.64
B1	5.27	-	17.06
B2	4.55	-	44.04
B3	4.32	-	18.65
B4	4.40	-	8.89
C1	5.42	8.06	8.47
C2	4.40	6.91	61.64
C3	7.04	9.29	17.28
C4	6.75	8.91	15.14
D1	12.22	8.16	20.82
D2	29.47	32.73	9.80
D3	5.32	9.41	11.40
D4	5.34	7.78	11.94
TOTAL HRS	213.45	209.59	283.77

TABLE IV

ARRAY COMMUNICATIONS OUTAGE STATISTICS

SITE	CIRCUIT	OUTAGE 04/77-09/77	CIRCUIT AVAILABILITIES SHORT TERM 04/77-09/77	CIRCUIT AVAILABILITIES LONG TERM 12/70-09/77
A0	4GD2704	38.64	99.120	99.448
B1	4GD2701	17.06	99.612	99.792
B2	4GD2710	44.86	98.979	99.712
B3	4GD2705	16.70	99.620	99.804
B4	4GD2707	8.39	99.809	99.736
C1	4GD2708	8.47	99.807	99.841
C2	4GD2709	67.64	98.460	99.585
C3	4GD2711	14.47	99.602	99.400
C4	4GD2706	9.14	99.792	99.746
D1	4GD2714	20.83	99.526	99.644
D2	4GD2715	9.80	99.777	99.838
D3	4GD2712	11.40	99.740	99.507
D4	4GD2713	11.95	99.728	99.708
Array	**Total**	**279.35 hr**	**99.506 (Ave)**	**99.674 (Ave)**

TABLE V

EXTENDED ARRAY DATA COMMUNICATIONS OUTAGES

DATE	DURATION	SITE	REASON
05/05/77	24 00	A0	HIGH LEVEL
05/05/77	3 18	B3	TESTING
05/06/77	2 06	B3	TESTING
05/08/77	6 00	C2	STORM
05/09/77	12 42	B2	STORM
05/09/77	12 36	D1	STORM
05/16/77	2 20	C3	STORM
06/07/77	2 35	A0	LOST DATA CAME CLEAR
06/10/77	2 26	C2	LOST DATA CAME CLEAR
06/15/77	4 20	(1)	INVERTER FAILED AT ANGELA
07/17/77	12 12	B2	ANGELA RADIO PROBLEM
07/17/77	11 13	C2	ANGELA RADIO PROBLEM
08/15/77	7 15	B1	LOST DATA CAME CLEAR
08/15/77	7 15	B2	LOST DATA CAME CLEAR
08/15/77	7 15	C2	LOST DATA CAME CLEAR
08/15/77	3 55	A0	LOST DATA CAME CLEAR
08/23/77	4 07	D2	LOST DATA CAME CLEAR
09/06/77	3 36	D4	BROKEN DATA CAME CLEAR
09/07/77	28 46	C2	BAD FILTER
09/24/77	2 50	C3	BROKEN DATA CAME CLEAR

(1) ALL SITES EXCEPT D2

The LASA Data Library now contains 3068 of the 2400-ft tapes which are currently divided into these categories:

LIARS Recording Cycle	236
Master Edit	74
Events (permanent files)	596
Programming (quality tapes)	128
Administrative	34

There are 4 disc packs with the LPS 75 (LASAPS) system available for use in the 360 computer operations.

SECTION III

ARRAY PERFORMANCE

The performance of the array as determined locally is based on the results of our seismic event processing, SP and LP seismometer testing and reliability studies. Results from each of these activities are summarized in the following paragraphs.

A. Seismic Event Processing

1. Teleseismic Processing Summary

We reported to VSC 3155 events and 245 phases between April 1, 1977 and September 30, 1977. These events are classified in Table VI and show an average of 18.6 detections per day. Approximate locations were indicated for 30% of the detected events.

Magnitudes were determined for the 894 located events. The smallest magnitude reported was 3.5; the largest 7.1. Figure 3.1 shows the distribution of these magnitudes. The distribution of all 4642 event magnitudes reported since July 1, 1975 is shown in Figure 3.2.

2. Near-Regional Detections

The LASA near-regional detection reports which indicate a portion of the near-regional activity continued with 21 issues between April 1 and September 30, 1977. A total of 78 near-regional or regional arrivals were reported.

Periodic supplements report the blasting activity at the known strip-mines located near the LASA. Table VII shows the number of blasts detected from each of the several strip mines in the region. The blasting activity during this six-month period decreased by about 1% to an average of 6.7 blasts/day from 6.8 reported for the previous period.

B. Seismic Event Processing Analysis

Limited analysis in selected areas of the LDC teleseismic reporting includes: (1) confirmation of reported events with NEIS/PDE lists; (2) location capability; (3) magnitude accuracy; and (4) detection threshold of the LDC teleseismic reports.

1. Confirmation

Investigation into the confirmation of events on a seismic region basis began this reporting period. To date, we have checked our daily reports against eight PDE monthly listings.

TABLE VI

CLASSIFICATION OF DETECTED TELESEISMIC EVENTS

April 1, 1977 - September 30, 1977

	Number of Events	Daily Average
Located teleseisms (excluding PKP's)	894	4.88
PKP (located)	43	0.23
PKP (unlocated)	384	2.10
Poor or weak telseisms (not located)	395	2.16
pP Phases	143	0.78
Other Phases	102	0.56
Unprocessed detections	1439	7.86
TOTAL	3400	18.57

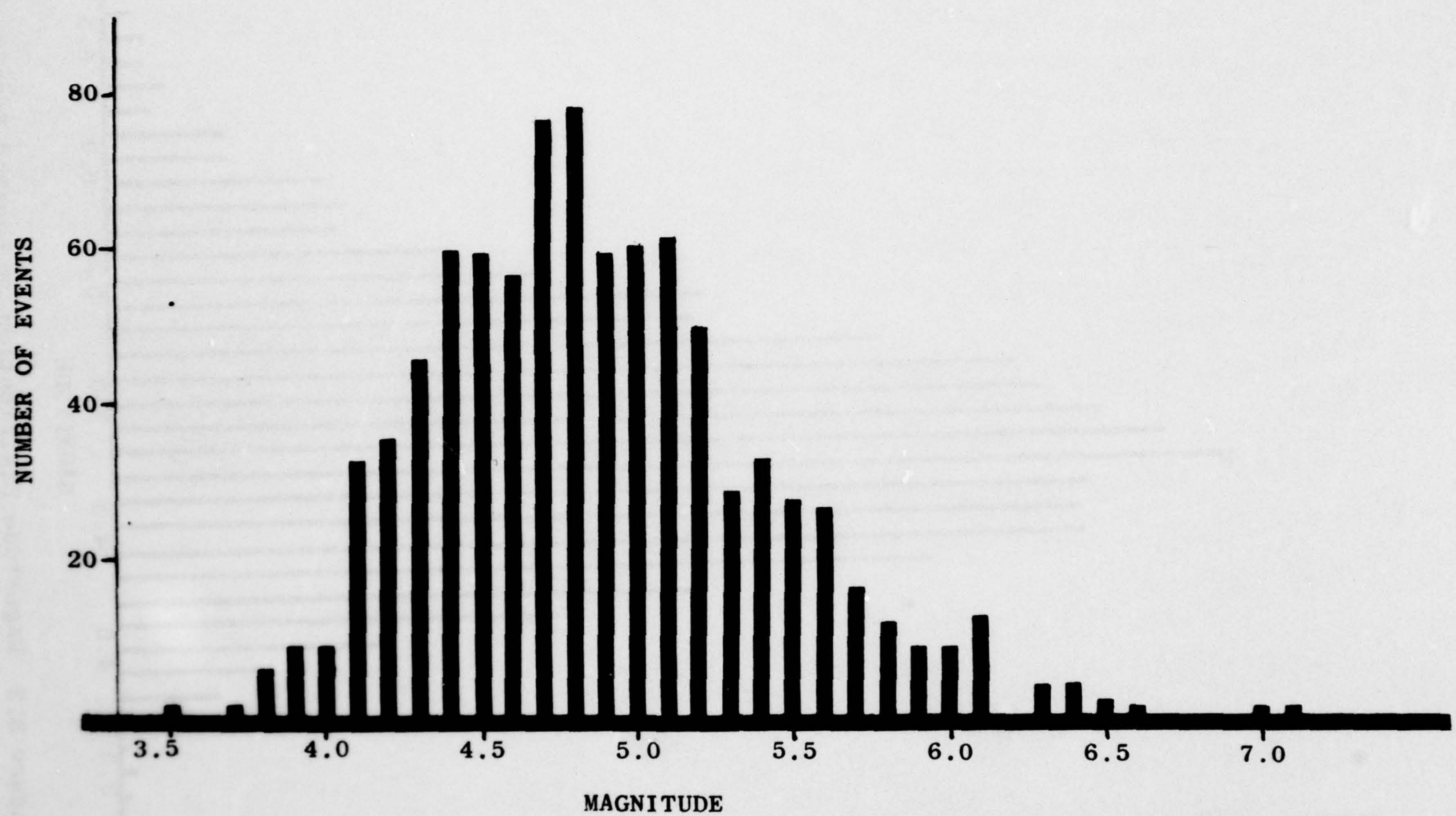


Figure 3.1 Magnitude Distribution of Located Events, April - September 1977

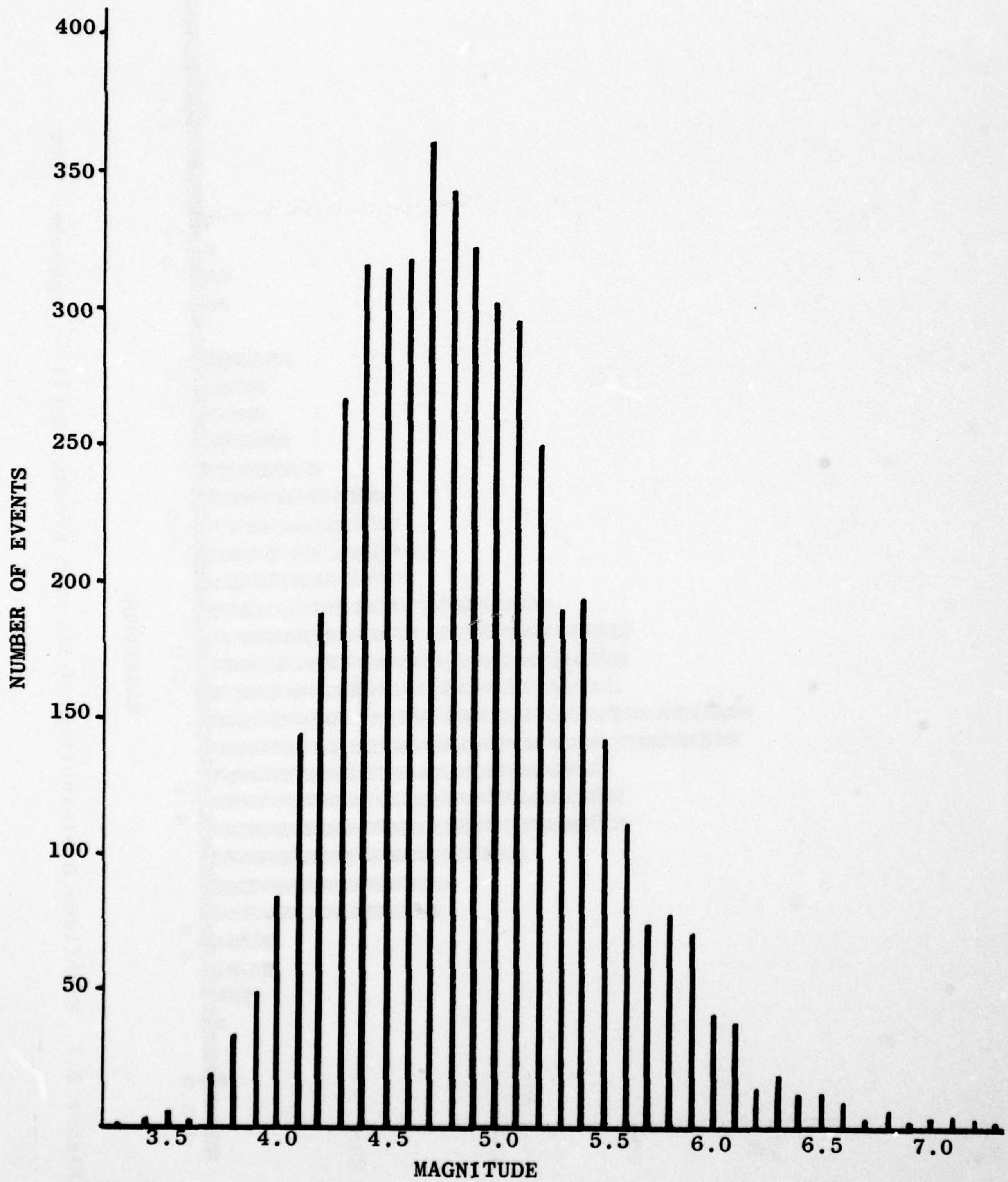


Figure 3.2 Magnitude Distribution of Located Events, July 1, 1975-September 30, 1977

TABLE VII

SUMMARY OF STRIP-MINE BLASTING ACTIVITIES REPORTED BY LDC

April 1, 1977 - September 30, 1977

	NUMBER BLASTS REPORTED	
Colstrip, MT (WE)	493	(40.0%)
Decker, MT	285	(23.1%)
Sarpy Creek, MT (W)	171	(13.9%)
Colstrip, MT (P)	94	(7.6%)
Wyoming	74	(6.0%)
British Columbia, Canada	68	(5.5%)
Unknown	24	(1.9%)
Unknown, NE	16	(1.3%)
Warren, MT	3	(0.3%)
South Dakota	3	(0.3%)
Roundup, MT	1	(0.1%)
TOTAL	1232	(100.0%)

We are using thirty-three regions in this study. Of the 2959 PDE events, LDC reported 1547 or 52.3%. Confirmations ranged from 91% in Central America to only 3% in the Philippines. This region study has indentified the regions with a high degree of detectability as well as the blindspots in our event reporting. We also analyzed these events according to size with the following results: events with $m_b \geq 4.6$ and within 90°, LDC reported 82%; events with $m_b \geq 4.6$ and over 90°, 37%; events with $m_b > 4.6$ and within 90°, 44%; events with $m_b > 4.6$ and over 90°, 13%.

2. Location

A comparison between event locations as determined at the LDC and those given on the eight monthly PDE's under study were investigated on a seismic region basis. Of the 990 events used, the average location error was 5.5°. Using only the 386 events with good signal correlation across the array (Type 1 classification) the location error averaged 4.9°. Confirmation on a seismic region basis ranged from an average error of 2.7° on 88 events from the Japan, Kuriles, Kamchatka region to 9.9° on 13 events from the Western Asia region. This study has pointed out the regions in our event processing program that need new station corrections.

3. Magnitude

Magnitude comparisons are made between the LDC calculations and the magnitudes of the events as they are later listed in PDEs. The results, which are shown in Figure 3.3 for the past six-months and in Figure 3.4 from July 1975. There were no changes in our local procedures in determining the magnitude estimate during this reporting period.

4. Detection Threshold

We estimate the m_b detection threshold of our daily reports at 4.99 (90%) and 4.55 (50%) based on 4642 event magnitudes reported during the 27 consecutive months between 1 July 1975 and 30 September 1977. The measurement method used a least squares fitted straight line through a part of the cumulative log frequency-magnitude distribution between 7.3 and 4.7 magnitude limits, a reasonably straight portion of the distribution. The 90% and 50% detection thresholds are those magnitudes at which the actual number of events falls 10% and 50%, respectively, below the level predicted by the extrapolation of the straight-line, frequency-magnitude distribution towards the lower magnitudes. The equation

$$\log N = 9.05 - 1.15\, m_b$$

defines the straight line used with this data set.

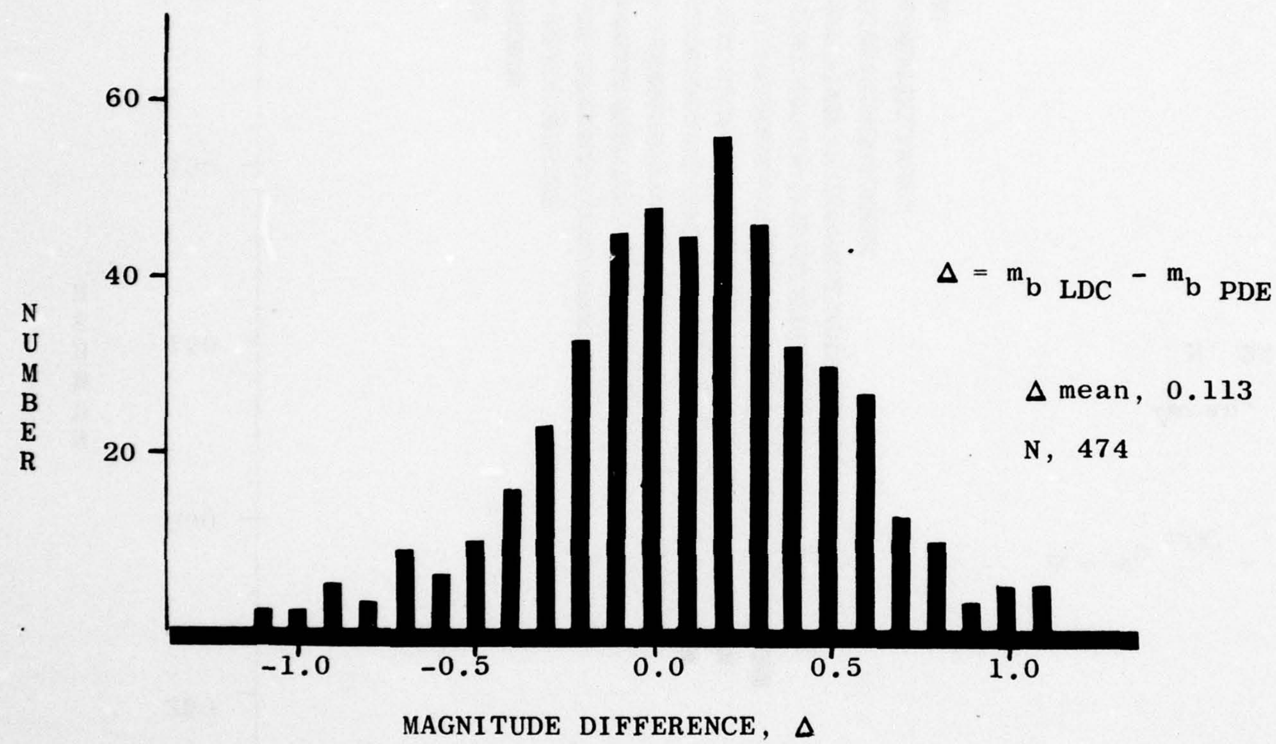


Figure 3.3 Magnitude Difference between LASA and PDE Calculations
April 1 - September 30, 1977

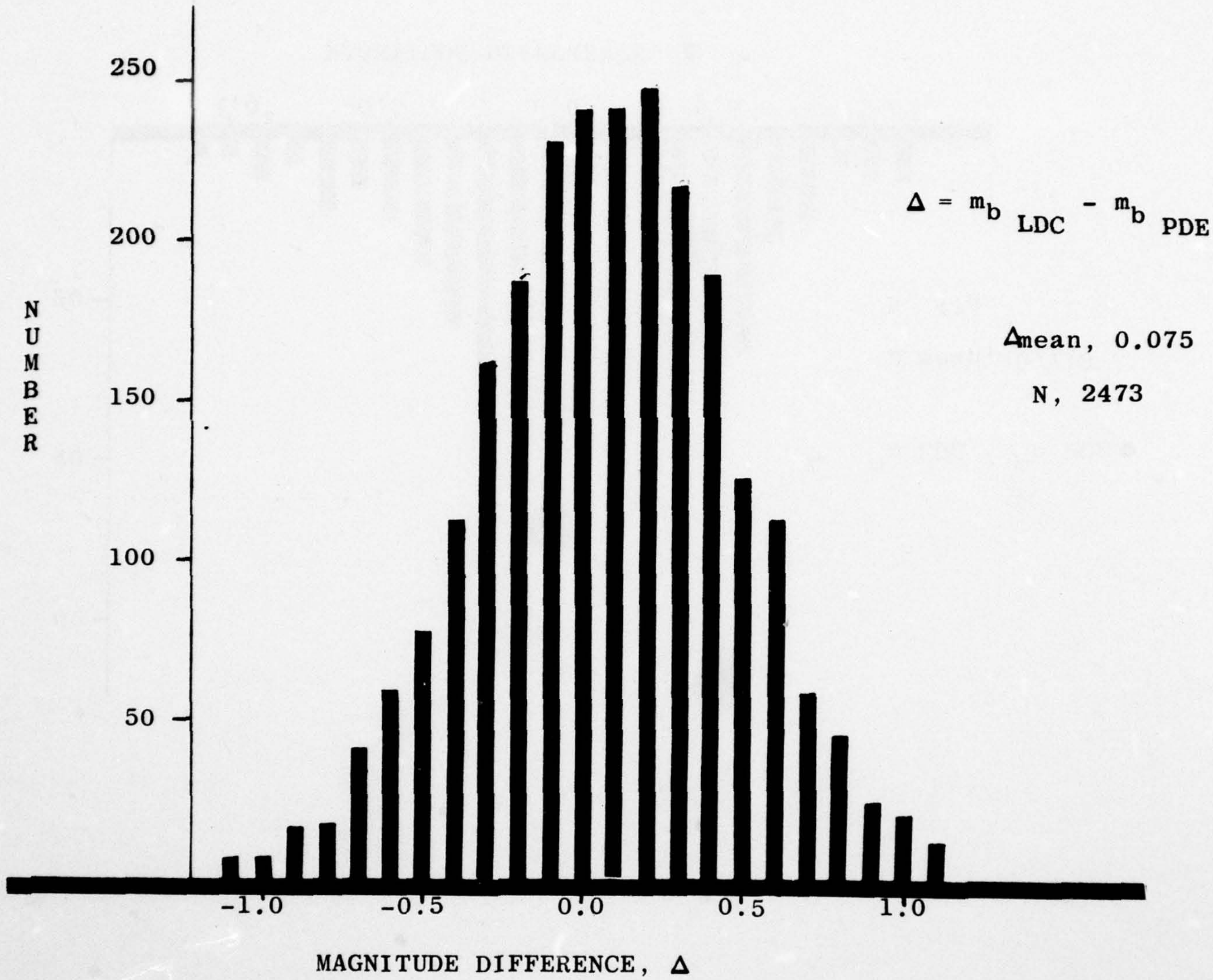


Figure 3.4 Magnitude Difference Between LASA and PDE Calculations July 1, 1975 - September 30, 1977

C. SP Seismometer Testing

1. Performance Measurement Using Program TESP

Weekly measurement of each of the LASA short period seismographs is provided remotely by PDP-7 program TESP, which measures the seismograph response to a one-second sinusoidal signal. During contract VT 7708 the average mean sensitivity of the 210 LASA SP seismographs was 19.83 mV/nm at one-second periods with the average standard deviation being 0.68 mV/nm. The tolerance limits for the SP seismograph sensitivity have been set at 20 ±3 mV/nm. The weekly test results are provided in Table VIII. The past three contract averages along with those of the current contract are summarized in Table IX. The number of functioning sensors, sensitivity mean, sensitivity standard deviation, maximum sensitivity for the array, minimum sensitivity for the array, and the difference between the maximum and minimum sensitivity are given by contract.

Sensitivity is a function of the output of the seismometer divided by the input to the seismometer and is calculated using the following relationship:

$$S = \left(\frac{4\pi^2 M}{G_c\ T^2}\right)\frac{E_o}{I} = 1.01 \times 10^3 \cdot \frac{E_o}{I} \text{ volts/meter}$$

where S = SP Channel Sensitivity at period T in seconds
M = SP Seismometer moving mass in kilograms
E_o = SP Channel Output in volts
G_c = SP Seismometer generator constant in newtons/amp
I = Calibration current into the SP seismometer calibration coil in amps.

2. Frequency Response Measurements Using RPGTWO

PDP-7 programs RPGONE and RPGTWO are used to measure the broadband response of the array's seismographs and to verify the responses are within the tolerances shown in Table X. Response data was collected using RPGONE on March 23 and September 10. Array off-line processing using RPGTWO provided the results for the array shown in Table XI.

D. LP Seismometer Testing

1. Performance Measurement Using Program TELP

Program TELP measures the response of the LASA long period seismographs to a 25-second sinusoidal signal. The tolerance limits for the 27 long period seismographs have been established at 350±50mV/μm. During the final six months of the current contract the weekly mean sensitivities of the LP seismographs averaged 345.1 mV/μm. Table XII gives the weekly test results. This average is compared with previous contract periods

TABLE VIII

SP ARRAY CHANNELS ONE-HERTZ SENSITIVITY STATISTICS, MV/NM

DATE	SENSORS	MEAN	STD DEV	MAX	MIN	MAX DEV
10/04	209	20.33	0.75	23.28	18.50	4.78
10/11	208	19.94	0.54	21.63	18.06	3.57
10/18	207	20.33	0.71	22.16	18.20	3.90
10/25	207	20.16	0.71	22.63	18.01	4.62
11/01	208	20.01	0.50	21.91	18.68	3.23
11/08	209	19.87	0.62	21.99	16.12	5.87
11/13	209	19.88	0.67	22.33	18.03	4.30
11/22	208	19.92	0.49	21.90	18.54	3.36
11/29	208	19.85	0.75	21.98	17.30	4.68
12/06	209	19.86	0.64	22.57	16.27	6.30
12/13	209	19.89	0.53	22.08	18.20	3.88
12/20	208	19.88	0.67	21.74	18.00	3.74
12/27	208	19.88	0.45	21.62	18.59	3.03
01/03	209	19.73	0.67	22.45	17.00	5.45
01/10	209	19.57	0.88	22.64	16.70	5.94
01/17	209	19.82	0.60	22.58	17.63	4.95
01/24	208	19.82	0.57	23.22	18.08	5.14
01/31	208	19.76	0.74	22.67	17.41	5.26
02/07	193	19.81	0.52	22.57	17.65	4.92
02/14	209	19.93	0.49	22.51	18.47	4.04
02/21	209	19.89	0.52	22.23	17.47	4.76
03/01	209	19.88	0.62	22.60	14.32	8.28
03/07	209	19.98	0.77	23.90	14.37	9.53
03/14	209	19.88	0.66	22.38	13.98	8.40
03/20	209	19.90	0.63	22.96	14.26	8.70
03/28	207	19.95	0.58	23.22	18.36	4.86
04/04	209	19.99	0.71	22.01	18.55	3.46
04/11	207	19.94	0.69	22.28	17.78	4.50
04/18	209	19.86	0.70	22.45	17.56	4.89
04/25	209	19.77	0.82	22.69	17.44	5.25
05/02	209	19.54	0.95	22.82	16.74	6.08
05/09	209	19.36	1.12	24.22	17.21	7.01
05/16	209	19.77	0.85	22.74	16.78	5.96
05/23	208	19.75	0.78	23.10	17.36	5.74
05/30	209	19.71	0.65	22.64	17.60	5.04
06/06	206	19.36	0.72	22.06	17.26	4.80
06/13	208	19.62	0.80	22.85	17.42	5.43
06/20	209	19.55	0.72	22.67	16.94	5.73
06/27	209	19.35	0.65	22.21	17.67	4.54
07/04	NO TESP AVAILABLE					
07/11	208	19.76	0.81	22.76	16.13	6.63
07/17	191	19.17	0.68	23.15	17.71	5.44
07/24	208	19.24	0.64	21.77	17.18	4.59
07/3[illegible]	206	19.56	0.64	22.42	17.66	4.76
08/0[illegible]	209	19.68	0.61	22.45	18.29	4.16
08/[illegible]	208	20.01	0.64	22.61	17.92	4.69
08/[illegible]	210	19.84	0.70	25.14	18.49	6.65
[illegible]/28	209	20.07	0.67	23.51	17.86	5.65
[illegible]/04	209	19.97	0.62	22.13	17.05	5.08
09/11	209	20.00	0.71	22.52	15.92	6.60
09/18	208	20.12	0.72	22.61	18.28	4.43
09/25	210	20.18	0.79	22.76	17.78	4.98
VT7708 AVERAGE	207.8	[illegible]	0.68	22.59	17.35	5.25

TABLE IX

SP ARRAY PERFORMANCE TESTING SENSITIVITY STATISTICS

SP	Sensors	Sens Mean mV/nm	Sens Std Dev mV/nm	Sens Max. mV/nm	Sens Min. mV/nm	Sens Dev. mV/nm
VT 7708 Contract Average	208	19.82	0.68	22.59	17.35	5.25
VT 6708 Contract Average	206	19.83	0.83	22.91	16.69	6.22
VT 4708 Contract Average	206	20.05	0.85	23.36	16.78	6.58
VT 2708 Contract Average	208	20.14	0.79	22.86	16.96	5.90

TABLE X

SP SEISMOGRAPH GAIN FREQUENCY RESPONCE TOLERANCES

FREQUENCY (HERTZ)	GAIN MAXIMUM (DB)	GAIN MINIMUM (DB)
0.07874	-29.43	-34.43
0.15748	-16.65	-21.65
0.23622	-11.30	-16.30
0.31495	-8.49	-13.49
0.39370	-6.40	-11.40
0.47244	-5.06	-10.06
0.55118	-3.63	-8.63
0.62992	-2.23	-7.23
0.70866	-1.46	-6.46
0.78740	-0.96	-5.96
0.86614	-0.19	-5.19
0.94488	0.17	-4.83
1.02362	0.32	-4.68
1.10236	0.27	-4.73
1.18110	0.72	-4.28
1.25984	0.62	-4.38
1.49606	0.04	-4.96
1.73228	-0.82	-5.82
1.96850	-1.70	-6.70
2.20472	-3.11	-8.11
2.44094	-3.88	-8.88
2.67717	-4.75	-9.75
2.91339	-5.41	-10.41
3.14961	-6.49	-11.49
3.38583	-6.91	-11.91
3.62205	-8.19	-13.19
3.85827	-8.15	-13.15
4.09449	-9.05	-14.05
4.33071	-9.11	-14.11
4.56693	-8.89	-13.89
4.80315	-9.54	-14.54
5.03937	-11.59	-16.59
5.27559	-12.69	-17.69
5.51181	-14.87	-19.87
5.74803	-18.07	-23.07
5.98425	-20.32	-25.32

TABLE XI

RESULTS OF SP SEISMOGRAPH BROADBAND RESPONSE TESTING

Seismograph Response	No. March Test	No. Sept Test
within tolerance	91	101
improper low frequency		
high amplitude	6	11
low amplitude	5	2
improper high frequency		
high amplitude	11	9
low amplitude	2	0
improper low and high frequency		
high amplitude	1	
low amplitude	1	
low/high	3	3
high/high	0	2
low/low	0	1
Not tested	10	1
No. SP Sensors	130	130

TABLE XII

LP ARRAY CHANNELS 25-SEC SENSITIVITY STATISTICS, MV/μM

DATE	SENSORS	MEAN	STD DEV	MAX	MIN	MAX DEV
10/04	24	341.4	17.70	376.51	309.19	67.3
10/11	24	342.3	19.09	376.51	301.23	75.3
10/18	24	341.8	21.51	381.89	297.82	84.1
10/25	24	344.9	22.56	384.86	298.89	86.0
11/01	24	340.8	27.28	387.02	259.89	127.1
11/08	18	346.0	19.92	377.02	300.55	76.5
11/15	24	357.4	38.83	472.42	302.60	169.8
11/24	24	350.4	20.92	393.50	313.83	79.7
11/29	24	351.5	17.96	378.08	299.65	78.4
12/06	24	351.4	17.95	384.08	301.90	82.2
12/13	24	354.9	20.02	400.62	301.23	99.4
12/20	24	352.6	24.51	407.63	302.58	105.1
12/27	23	352.5	21.17	386.28	297.40	88.9
01/03	24	349.7	20.03	388.27	300.78	87.5
01/10	24	350.6	21.36	390.36	298.74	91.6
01/17	24	350.5	23.05	395.53	293.08	102.5
01/24	24	354.9	20.37	395.37	306.28	89.1
01/31	24	354.6	16.51	396.42	325.40	71.0
02/07	18	357.4	16.75	395.37	333.85	61.5
02/14	24	353.6	17.69	397.47	314.00	83.5
02/21	24	355.6	18.19	395.37	324.43	70.9
02/28	24	353.2	16.52	395.37	322.81	72.6
03/07	24	353.7	17.80	392.23	319.30	72.3
03/14	24	351.4	17.16	393.27	318.80	74.5
03/21	24	350.9	19.04	394.32	307.81	86.5
03/28	24	347.0	20.17	384.48	316.61	67.9
04/04	24	352.2	17.50	391.18	321.29	69.89
04/11	24	345.5	20.04	388.03	284.24	103.79
04/18	24	344.9	16.47	384.88	318.06	66.82
04/25	23	344.4	14.09	376.49	319.57	56.92
05/02	24	333.3	14.27	361.37	298.80	62.57
05/09	24	339.9	11.25	359.48	313.31	46.17
05/16	24	340.6	10.95	357.28	313.31	43.97
05/23	24	340.1	11.14	358.38	317.10	41.28
05/30	21	333.8	29.60	394.32	247.49	146.83
06/06	24	336.1	12.75	367.08	310.17	56.91
06/13	24	331.2	14.03	349.74	292.42	57.32
06/20	24	331.5	21.38	360.84	247.55	113.29
06/27	20	330.5	18.51	357.17	288.81	68.36
07/04	24	341.1	30.75	436.45	309.13	127.3
07/11	24	340.4	29.01	417.75	306.00	111.8
07/17	22	330.7	13.76	357.28	312.90	44.4
07/24	22	333.3	13.38	354.12	307.91	46.2
07/31	22	330.8	17.46	360.20	298.53	61.7
08/07	27	339.6	11.77	364.77	317.66	47.1
08/14	27	339.3	17.42	376.82	298.87	77.9
08/21	27	334.4	20.53	369.37	296.12	73.2
08/28	27	341.6	20.27	378.31	261.22	117.1
09/04	19	348.4	30.49	399.18	247.47	151.7
09/11	27	348.6	15.74	382.20	315.55	66.6
09/18	27	349.8	18.22	393.22	313.83	79.4
09/25	27	350.0	14.09	383.28	315.55	67.7
VT7708 AVERAGE	23.8	345.1	19.21	384.60	302.73	81.9

in Table XIII. Included in the summary are the number of functioning sensors, sensitivity mean, sensitivity standard deviation, maximum sensitivity for the array, minimum sensitivity for the array, and the difference between the maximum and minimum sensitivity.

Sensitivity, a function of seismograph output divided by the input, is calculated according to the following relationship:

$$S = \left(\frac{4\pi^2 M}{G_c \; T^2}\right)\frac{E}{I} = 22.56 \; \frac{E_o}{I} \; \text{volts/meter}$$

where S. = LP Channel Sensitivity at period T in seconds
M = LP Seismometer moving mass in kilograms
E_o = LP Channel output in volts
G_c = LP Seismometer generator constant in newtons/amp
I = Calibration current into the LP seismometer calibration coil in amps

2. LP Seismometer Positioning Analysis

The long term positioning statistics for the LP seismometer are shown in Table XIV where the remote adjustments for both mass positioning (since 6 DEC 71) and free period correction (since 2 JAN 73) are shown and total 2150. The mean-time-between-adjustment (MTBA) for each seismometer is shown and varies from 12.32 days for sensor D1 N/S to 76.11 days for sensor D3 E/W. The average MTBA for the array is 1.16 days and for a seismometer is 31.37 days.

3. LP Seismometer Magnification Response Curves

Magnification response measurements on the LASA LP seismometers began in September 1977; subarrays D1 and D4 were completed. Since we have no means of measuring the displacement of the mass resulting from our signal input to the seismometer's calibration coil, the equivalent motion input was calculated. The magnification response curves for the D4 LP seismometers connected to the LASA Maintenance Display Console are shown in Figures 3.5 thru 3.7. These curves are based on the following magnification (M) relations

$$M = \frac{A}{Y}$$

where A is the peak-to-peak amplitude of the test signal on the chart record at the output of the seismograph and

Y is the equivalent peak-to-peak amplitude of the mass motion resulting from the test signal applied to the seismometer's calibration coil.

TABLE XIII

LP ARRAY PERFORMANCE TESTING SENSITIVITY STATISTICS

LP	No. Sensors	Sens Mean mV/μm	Sens Std Dev mV/μm	Sens Max. mV/μm	Sens Min. mV/μm	Sens Dev. mV/μm
VT 7708 Contract Average	24	345.1	19.2	384.60	302.7	81.9
VT 6708 Contract Average	25	339.9	19.2	383.9	294.9	89.0
VT 4708 Contract Average	26	337.4	18.2	376.7	297.9	78.8
VT 2708 Contract Average	22	347.0	16.0	382.6	319.0	63.6

TABLE XIV

LP SEISMOMETER REMOTE ADJUSTMENTS

	MASS POSITION ADJUSTS			FREE PERIOD ADJUSTS			COMBINED ADJUSTMENTS		
	10/76 THRU 09/77	12/71 THRU 09/77	AVG DAYS-BETWEEN ADJUSTS	10/76 THRU 09/77	01/73 THRU 09/77	AVG DAYS-BETWEEN ADJUSTS	10/76 THRU 09/77	LONG TERM	AVG DAYS-BETWEEN ADJUSTS
A0 V	10	49	43.49	5	15	115.60	15	64	33.30
A0 NS	8	38	56.08	3	19	91.26	11	57	37.39
A0 EW	7	60	35.52	2	9	192.67	9	69	30.88
C1 V	10	50	42.62	2	15	115.60	12	65	32.78
C1 NS	13	49	43.49	5	22	78.82	18	71	30.01
C1 EW	9	50	42.62	4	15	115.60	13	65	32.78
C2 V	11	59	36.12	4	16	108.38	15	75	28.41
C2 NS	18	73	29.19	12	44	39.41	30	117	18.21
C2 EW	21	99	21.53	2	15	115.60	23	114	18.69
C3 V	16	79	26.97	0	3	578.00	16	82	25.99
C3 NS	15	80	26.64	3	12	144.50	18	92	23.16
C3 EW	14	85	25.07	3	11	157.64	17	96	22.20
C4 V	11	59	36.12	0	4	433.50	11	63	33.83
C4 NS	7	29	73.48	5	9	192.67	12	38	56.08
C4 EW	6	60	35.52	0	2	867.00	6	62	34.37
D1 V	8	46	46.33	3	10	173.40	11	56	38.05
D1 NS	39	139	15.33	16	34	51.00	55	173	12.32
D1 EW	17	109	19.55	1	13	133.38	18	122	17.47
D2 V	13	63	33.83	0	7	247.71	13	70	30.44
D2 NS	6	52	40.98	0	2	867.00	6	54	39.46
D2 EW	12	84	25.37	1	3	578.00	13	87	24.49
D3 V	15	81	26.31	0	5	346.80	15	86	24.78
D3 NS	10	35	60.89	7	11	157.64	17	46	46.33
D3 EW	7	21	101.40	4	7	247.71	11	28	76.11
D4 V	11	61	34.93	4	7	247.71	15	68	31.34
D4 NS	24	140	15.22	7	30	57.80	31	170	12.54
D4 EW	6	50	42.62	0	10	173.40	6	60	35.52

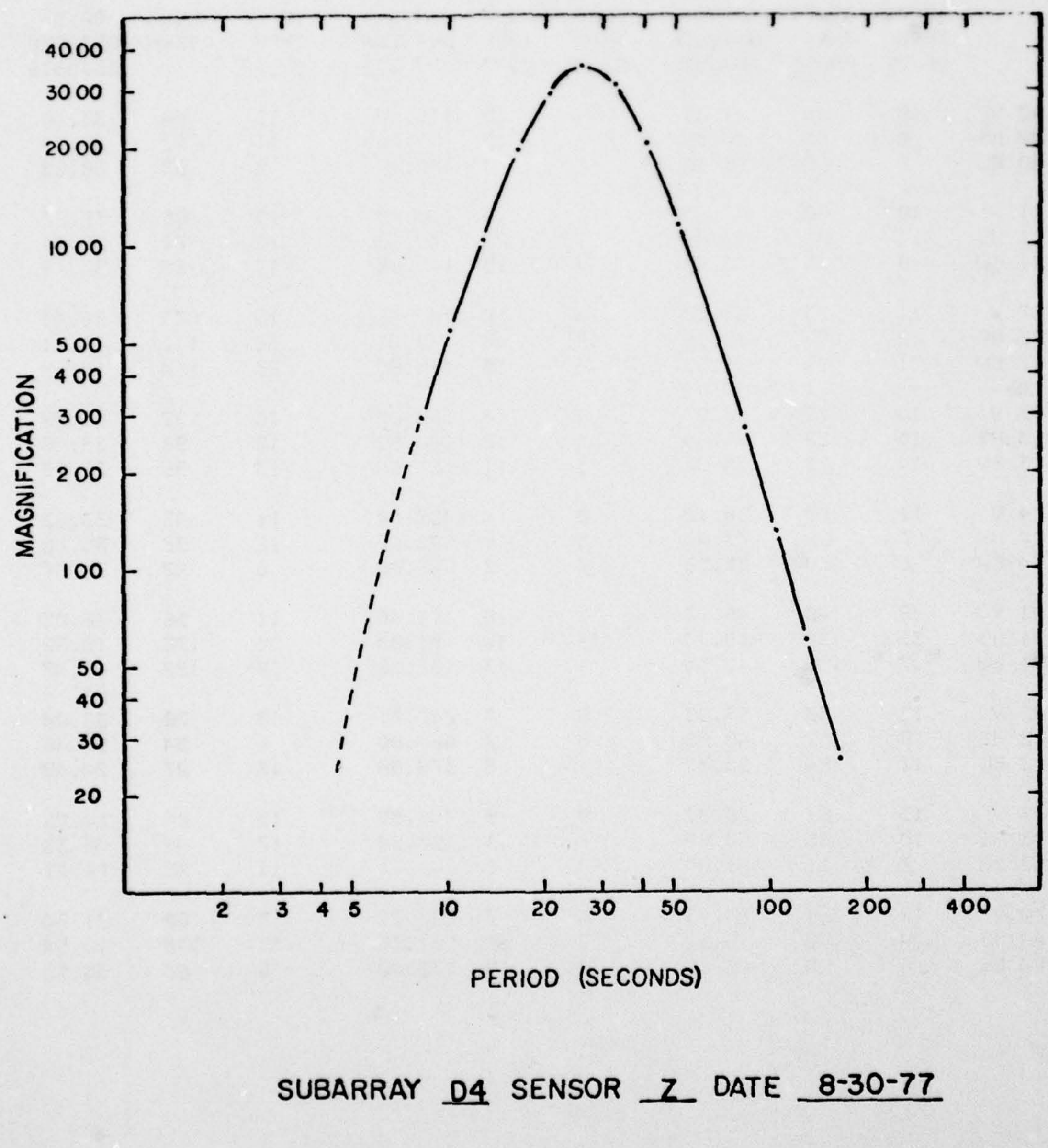


Figure 3.5 Montana LASA LP Sensor Magnification Response Curve

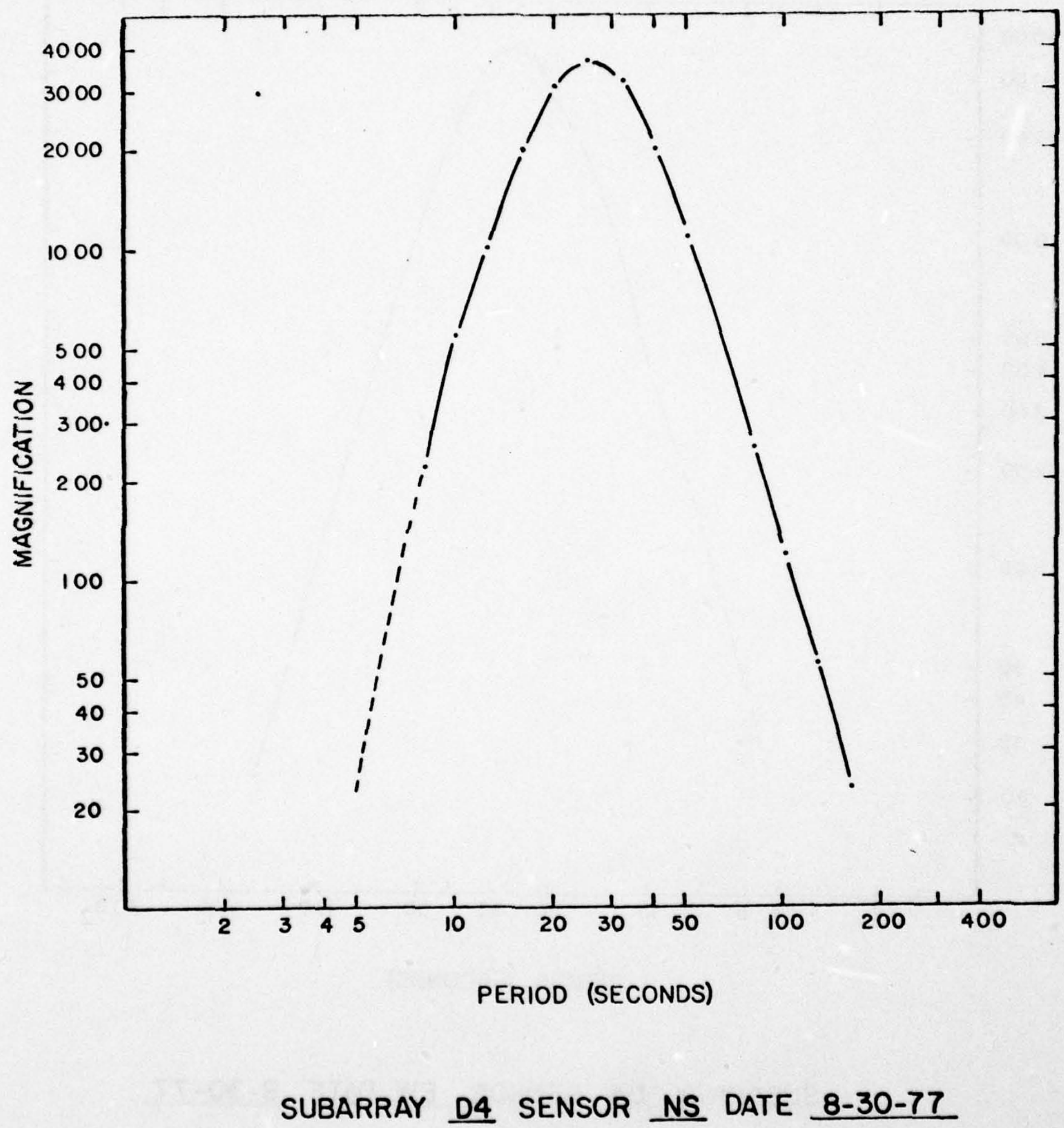
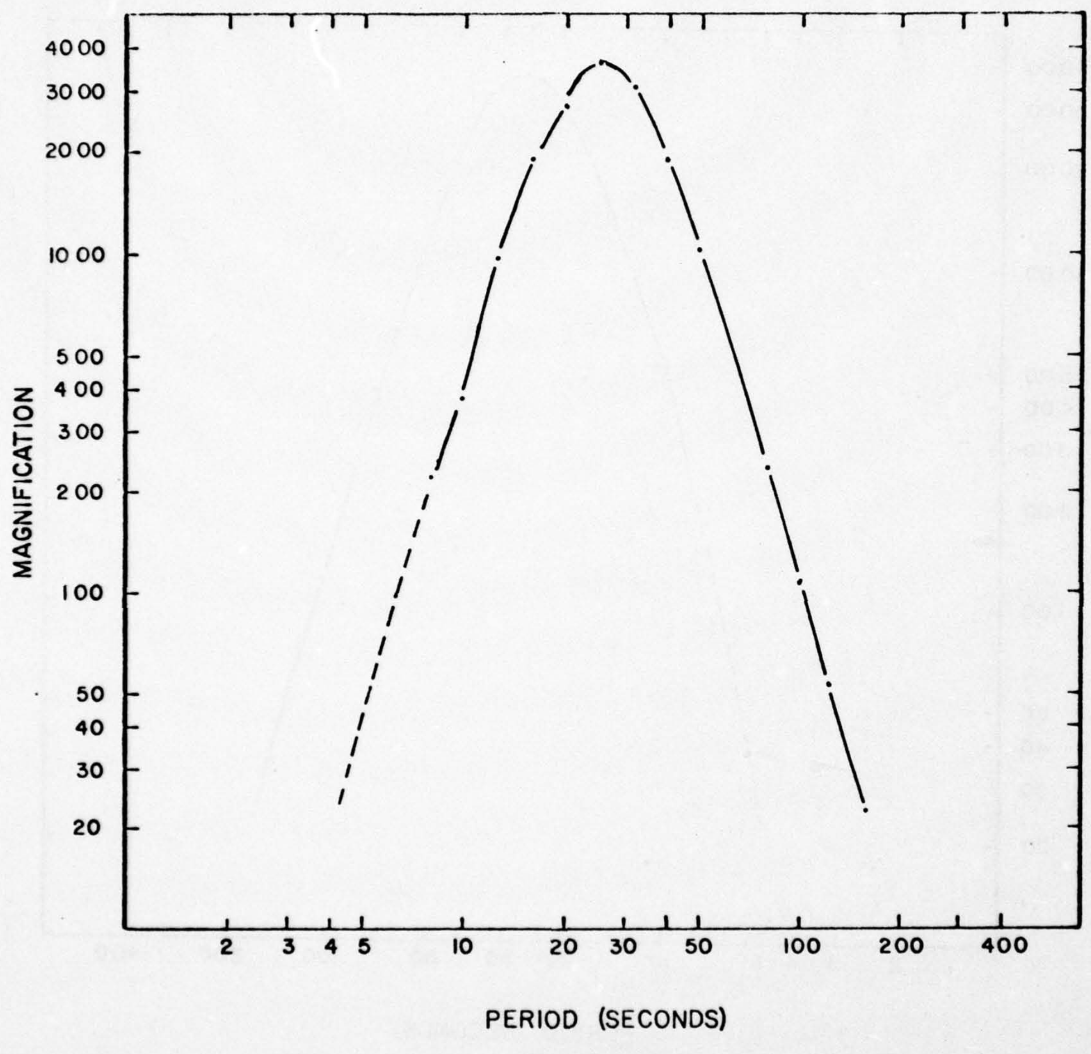


Figure 3.6 Montana LASA LP Sensor Magnification Response Curve



SUBARRAY D4 SENSOR EW DATE 8-30-77

Figure 3.7 Montana LASA LP Sensor Magnification Response Curve

$$Y = \frac{G_c\ i}{M_s W^2}$$

where G_c is the calibrator motor constant, standardized at 0.028 newtons/ampere at LASA,

i is the peak-to-peak amplitude of the current applied to the calibration coil,

M_s is the moving mass of the seismometer, nominally, 10 Kg, and

W is the angular frequency of the calibration signal current in radians/sec and equals $2\pi/T$ where T is the period of the calibration signal.

substituting gives,

$$M = \frac{A\ M_s\ W^2}{G_c i} = \frac{4\pi^2 A\ M_s}{G_c i T^2} = 14099 \frac{A}{iT^2}$$

$$M \simeq 15000 \frac{A}{iT^2}$$ where A is in volts, i is in amperes, and T^2 is in $seconds^2$

E. RELIABILITY

Reliability, as used in this section, is a term used to indicate the probability that a system will operate at any given time. As a measure of reliability we use the statistic: "Failures per Hour . The more failures per hour the lower the reliability.

A failure is defined to be any condition caused by a defective component that causes the system to be inoperative. An inoperative system which can be corrected by adjustment of any component is considered not in "failure" mode but rather in "trouble" mode. Our measure of reliability uses only failure modes and ignores trouble modes.

Table XV lists the failures per hour for most of the equipment used in connection with the LASA array. The reciprocal of failures per hour is the mean-time-between-failure (MTBF). Table XV also contains MTBF values in hours.

Each data set is given in two columns. The first column covers the time from 1 March 1970 through 30 June 1977 and the second column covers the time from 1 March 1973 through 30 June 1977. By comparing the failures per hour of the two columns we

TABLE XV

EQUIPMENT FAILURE RATES

ARRAY SYSTEM EQUIPMENT	FAILURES/HOUR SINCE 3/70	FAILURES/HOUR SINCE 3/73	MTBF SINCE 3/70	MTBF SINCE 3/73
SHORT PERIOD SYSTEM	0.00796	0.00525	126	191
SEISMOMETER	0.00149	0.00106	670	948
WHV AMPLIFIER	0.00631	0.00399	158	250
POWER SUPPLY	0.00019	0.00017	5358	5844
WHV CIRCUITS	0.00000	0.00000	--	--
WHV CABLING	0.00002	0.00003	64296	35064
CTH CIRCUITS	0.00003	0.00000	32148	--
LONG PERIOD SYSTEM	0.00045	0.00051	2217	1948
VERT. SEISMOMETER/TANK	0.00003	0.00006	32148	17532
HORZ. SEISMOMETER/TANK	0.00003	0.00006	32148	17532
LP VAULT CABLING	0.00000	0.00000	--	--
LP JUNCTION ASSEMBLY	0.00003	0.00006	32148	17532
LP VAULT TERMINAL	0.00000	0.00000	--	--
MOTOR ASSEMBLY	0.00002	0.00000	64296	--
SEISMIC AMPLIFIER	0.00031	0.00034	3215	2922
POWER SUPPLY	0.00002	0.00000	64296	--
CTH CIRCUITS	0.00002	0.00000	64296	--
SUBARRAY ELECTRONICS MODULES	0.00236	0.00148	423	674
INPUT DRAWERS	0.00053	0.00031	1891	3188
MULTIPLEXER ADL	0.00022	0.00031	4593	3188
OUTPUT DRAWER	0.00023	0.00014	4286	7013
CONTROL DRAWER	0.00131	0.00071	765	1403
AUXILARY CONDITIONING	0.00005	0.00000	21432	--
SEM CABINET/CABLING	0.00002	0.00000	64296	--
ALARMS	0.00002	0.00000	64296	--
SUBARRAY POWER SYSTEM	0.00028	0.00017	3572	5844
CONTROL ASSEMBLY	0.00011	0.00006	9185	17532
INVERTER	0.00012	0.00011	8037	8766
CHARGER	0.00002	0.00000	64296	--
BATTERY	0.00000	0.00000	--	--
SOLA TRANSFORMER	0.00002	0.00000	64296	--
RACK/CABLING	0.00002	0.00000	64296	--
ISOLATION TRANSFORMER	0.00000	0.00000	--	--
CTH WIRING/BREAKERS	0.00000	0.00000	--	--
360 COMPUTER	0.00092	0.00128	1090	779
CPU 2044	0.00036	0.00054	2795	1845
DISC DRIVE 2315	0.00006	0.00009	16074	11688
TYPEWRITER 1052	0.00044	0.00060	2296	1670
CARD READER 2501	0.00000	0.00000	--	--
DATA CONTROL 1826	0.00002	0.00003	64296	35064
DATA ADAPTER 1827	0.00003	0.00003	32148	35064
DATA ADAPTER 2701	0.00002	0.00000	64296	--

TABLE XV (CONTINUED)

PDP-7 COMPUTER	0.00076	0.00086	1312	1169
CPU	0.00044	0.00048	2296	2063
TELEPRINTER KSR-35	0.00023	0.00026	4286	3896
CARD READER	0.00008	0.00009	12859	11688
SERIAL OUTPUT UNIT	0.00002	0.00003	64296	35064
DIGITAL SYSTEM	0.00016	0.00023	6430	4383
TIMING SYSTEM	0.00011	0.00017	9185	5844
POWER SYSTEM	0.00002	0.00003	64296	35064
PLINS	0.00000	0.00000	--	--
MINS	0.00003	0.00003	32148	35064
ANALOG SYSTEM	0.00095	0.00128	1054	779
DA CONVERTERS	0.00002	0.00000	64296	--
FM SYSTEM	0.00008	0.00006	12859	17532
WWV RECEIVER	0.00002	0.00000	64296	--
ANALOG CALIBRATION SYSTEM	0.00000	0.00000	--	--
ANALOG TIMING SYSTEM	0.00002	0.00003	64296	35064
DEVELOCORDERS	0.00067	0.00103	1495	974
16 CHANNEL CHART RECORDER	0.00016	0.00017	6430	5844
LDC TEST AND SUPPORT	0.00061	0.00063	1649	1594
MAINT. DISPLAY CONSOLE	0.00037	0.00029	2679	3506
FILM VIEWER	0.00002	0.00003	64296	35064
TAPE CLEANER	0.00003	0.00000	32148	--
DIGITAL CLOCKS	0.00000	0.00000	--	--
EMERGENCY LIGHTS	0.00000	0.00000	--	--
BLOWER, COMPRESSOR	0.00002	0.00003	64296	35064
AIR CONDITIONER	0.00012	0.00020	8037	5009
HUMIDIFIER	0.00003	0.00006	32148	17532
ELECTROSTATIC FILTERS	0.00000	0.00000	--	--

determine if there has been a significant change in the reliability of a given system over the past four years. A significant increase in the failures per hour in the second column indicates a decrease in reliability and potential increases in future maintenance requirements.

1. Array Reliability

An inspection of Table XV reveals a change in the failures per hour of all four array systems. Only the Long Period System experienced a slight increase in the number of failures per hour. The other array systems show a significant decrease in failures per hour over the past four years.

The increased reliability of the Subarray Electronics Modules (SEM) is seen to be the result of improved reliability of the input, output and control drawers. A possible future problem exists with the multiplexer/ADC. There has been an increase in failure rate of this component over the past four years. The number of failures per unit over the period of time indicates that even this component is still reliable.

Two components of the short period system have contributed to its increased reliability. The seismometer and the WHV amplifier have both shown a significant improvement which is in turn reflected in an improved Short Period System

The improvement of the reliability of the LASA array is the result of improvements in maintenance procedures. Better testing methods have resulted in more reliable equipment being installed in the array. Equipment coming into the shop for repair or inspection is thoroughly tested before being returned to service. The experience of the LASA maintenance crews in diagnosing and repairing faulty components also makes a significant contribution to the measured reliability.

2. Data Center Reliability

At the data center Table XV indicates an increase in failure rates for the 360 computer and the Develocorders. All other systems show a nearly constant rate of failure over the past seven years.

There are two components of the 360 computer system which reflect the increased failure rate. The CPU and the 1052 typewriter. The 1052 typewriter is a mechanical unit which is expected to become less reliable as parts begin to wear out. Periodic overhaul of this unit is needed to control its failure rate.

The nature of the 360 system is such that failures to the CPU are usually accompanied by expensive repairs. Diagnostics are time consuming and parts must be ordered from IBM. Therefore, an increase in failure rate of the CPU is cause for concern. Paragraph 3 discusses the 360 system reliability. Our Develocorders are in a worn condition. We are unable to buy all replacement parts, however, we do have some replacement parts from scrap units. Maintenance of these units includes a periodic overhaul and refurbishing. With these practices the units lifetime can be extended.

Overall the reliability of the LASA systems is good. Good maintenance practices have insured that the systems are achieving maximum life and usefulness at a minimum cost to the government.

3. IBM 360/LASAPS Processor

The IBM 360 computer reliability and maintainability have been updated. The system reliability since 1 July 1973, a 1551-day period, improved with an increase in mean-time-between failure (MTBF) to 22.81 days (547.41hr). When the IBM 1052 Printer-Keyboard failures are substracted, the system MTBF increases to 50.0 days (1200.8hr). The CPU MTBF is 77.6 days (1861.2hr).

System maintainability statistics now show:

mean-time-between maintenance (MTBM)	7.60 days (182.47hr)
mean-time-to-repair (MTTR)	4.91 hours
mean-time-awaiting-parts	0.76 hour
mean-time-awaiting-personnel	6.05 hours
mean-time-to-correct-failures	11.72 hours
mean preventive maintenance time	1.45 hours
total maintenance downtime (MDT)	1355.7 hours (3.64%)

The incident of failure according to equipment category is shown in Table XVI. This breakdown is based on the 68 failures identified during the 51-month study period. The 1052 Printer-Keyboard accounts for 60% of the failures.

The system performed well during the past six months with five failure incidents. A 2701 Data Adapter Unit failure was the only one requiring an extended system outage. The system was interrupted 136.50 hours. Actual corrective maintenance, normally performed during the day shift, took 60.5 hours. Three mechanical failures occurred in the 1052 unit. An SLT card in the CPU Basic 1052 Adapter Gate was source the fifth failure.

TABLE XVI

CLASSIFICATION OF IBM 360 SYSTEM FAILURES
(SINCE JULY 1973)

360/44 System Equipment		Number of Failures
2044-G Processing Unit		21
CPU:	Cycle Control	0
	Storage Address Register	2
	Storage Data Register	1
	Operations Register/Comm Chan Control	1
	Controls Clock	2
	Data Flow (B2)	1
	Data Flow (B3)	0
	Display	0
	Interrupt Controls	1
	Controls (C2)	0
	Controls (C3)	0
	Operation Decode	2
	Interrupts	0
	Gen. Purpose Register Stack	2
	Console (E1)	0
	Console (E2)	2
High Speed Multiplexer:	Subchannel A1 (SCA)	1
	Subchannel B1(SCB)	0
	Common Control	0
	Common Data Flow	0
	Chan 1 IF Control	0
	Chan 1 Control SCA	0
	Chan 1 Control SCB	0
Multiplexer/1052 Adapter:	Priority Interrupt (A2)	1
	Priority Interrupt (A3)	0
	1052 Adapter Logic (B1)	0
	1052 Adapter Logic (C1)	2
	Data Flow	0
	Funnels	0
	Multiplexer Control (B3)	0
	Multiplexer Control (C3)	0
Memory Stack		1
Single Disc Storage Device:	Disc	6
	Disc Control	0
	Disc IF Control	0
1052-7 Printer/Keyboard		39

TABLE XVI (CONTINUED)

360/44 System Equipment	Number of Failures
2501-B1 Card Reader	0
1827-1 Data Control Unit	1
1826 Data Adapter Unit	2
2701-1 Data Adapter Unit	2

SECTION IV

IMPROVEMENTS AND MODIFICATIONS

A. PDP-7 PROGRAMMING

The development and maintenance of programs for the PDP-7 computer continue to provide an important part of the overall task of operating and improving the Montana Array as a seismological observatory.

The programs completed on Project VT/7708 are listed in Table XVII. Programming activity during the final six-months period supported LDC operations by (1) updating and reformatting our event processing program MANBUL into Epicenter Location 77 (EP77) and (2) upgrading four previously written programs into patch, overlay programs for use with our array on-line system, LIARS.

TABLE XVII

PDP-7 PROGRAMMING ACTIVITY

October 76 - September 77

PROGRAM	VERSION	BY	APPROVED
Property List	V1	Lidderdale	10/76
DIAZ	V2	Potter	11/76
POLCK	V2	Maxwell	12/76
TABLE LIST	V3	Lidderdale	12/76
PUNCH HRI	V2	Maxwell	01/77
GRAPH	V1	Potter	01/77
DUP/VER	VL1	Potter	02/77
Material Inventory	VL2	Lidderdale	03/77
Computer Use	V2	Maxwell	03/77
Computer Use	VL1	Maxwell	03/77
Property List	V2	Lidderdale	04/77
EP 77	V1	Lidderdale	04/77
Book 1	VL1	Maxwell	05/77
Noise	VL1	Potter	07/77
EP 77	V2	Lidderdale	07/77
Plot	VL1	Maxwell	08/77
Property List	VL1	Maxwell	09/77

SECTION V

MAINTENANCE

LASA maintenance activity is divided into three different categories: Data Center (LDC), Maintenance Center (LMC) and Facilities Support. The LDC in Billings operates and maintains the following five systems: The IBM 360/44 computer, the DEC PDP-7 computer, LDC Digital, LDC Analog and the LDC Test and Support. The LMC located in Miles City maintains all array equipment systems which are comprised of SP Sensor, LP Sensor, Meteorological, SEM, and Power. Facilities Support provides maintenance of buildings, vehicles, land leases, and array facilities such as cable trenches, access trails, fences, WHV site, and CTH sites.

A. SUMMARY

The maintenance activities during this six-month period included preventive maintenance with the start of the required annual servicing of systems at the subarrays, the start of a comprehensive calibration of the LP array, the installation of a WWV antenna at the LDC facility, the inventory of property and material, and the inspection of the array facilities, trails, cable trenches, etc. with required repairs.

A summary of the total maintenance activity is given in Table XVIII where the number of work order actions in the LMC, LDC and utility areas are shown. The completed work orders represent 500 separate and traceable actions by the maintenance activities and since several repair actions may result from the clearing of one particular trouble, the number of maintenance actions can exceed the number of work orders. The work orders do not indicate the man-hours involved but are indicative of the work load. The system work orders completed consisted of 232 preventive maintenance routines, 126 corrective maintenance, 2 modifications, 2 special tests and 74 utility actions. A total of 34 items of equipment were repaired in the LMC and LDC shops. The backlog in the shop of 83 items primarily consisted of printed circuit cards at LDC and RA-5 amplifiers and HS-10-1A seismometers at LMC. The 74 utility work orders consisted of 43 actions of inspection and repair of the leased land, 25 repairs of facilities, and 6 vehicle inspections.

B. DATA CENTER

A total of 209 work orders were completed for 287 maintenance actions plus 18 repairs in the shop. Table XIX provides a breakdown of the LDC maintenance actions by system and month.

TABLE XVIII

SUMMARY - WORK ORDERS

APRIL 1977 - SEPTEMBER 1977

WORK ORDER TYPE	BACKLOG START OF PERIOD	INITIATED	COMPLETED	BACKLOG END OF PERIOD
LMC				
SYSTEM -A	1	183	171	13
SUBASSEMBLY-B	28	22	6	44
COMPONENT -C	1	11	10	2
TOTALS	30	216	187	59
LDC				
SYSTEM -A	10	197	191	16
SUBASSEMBLY-B	1	5	5	1
COMPONENT -C	18	31	13	36
TOTALS	29	233	209	53
UTILITY	17	60	74	3
COMBINED TOTALS	76	509	470	115

TABLE XIX

DATA CENTER MAINTENANCE ACTIONS

APRIL 1977 - SEPTEMBER 1977

	APR	MAY	JUN	JUL	AUG	SEP	TOTALS
360							
CORRECTIVE	0	1	1	3	2	2	9
PREVENTIVE	0	3	3	1	1	2	10
PDP-7							
CORRECTIVE	6	4	8	12	5	3	38
PREVENTIVE	21	22	27	25	24	19	138
DIGITAL							
CORRECTIVE	0	1	1	2	0	0	4
PREVENTIVE	4	4	5	4	4	5	26
ANALOG							
CORRECTIVE	1	0	1	4	1	4	11
PREVENTIVE	1	0	0	0	0	0	1
TEST AND SUPPORT							
CORRECTIVE	4	2	7	4	3	5	25
PREVENTIVE	2	3	5	3	4	1	18
TOTALS	39	40	58	58	44	41	280

1. System 360

The maintenance responsibility for the IBM 360/44 is handled locally with assistance from IBM as needed. During this period there were 9 repairs on the system and 10 preventive maintenance actions.

The operation of the 360 system improved with only 9 repairs necessary during this period compared to 16 for the previous one. Three failures requried abnormal system down times.

When the cycle clutch failed on the 1052 Printer/ Keyboard, the removal of the entire print shaft was necessary before the clutch overhaul and repair. An SLT card failure in the CPU's 1052 interface circuits caused printing of the wrong characters but was readily diagnosed and repaired. A failure of two SLT cards in the 2701 caused an extended downtime period due to the difficulty of trouble-shooting the problem. Diagnostic programs available did not indicate any problems. Procedures were locally developed to enable the 2701 diagnostic program to indicate this type of failure.

2. PDP-7 System

Maintenance of the LDC's PDP-7 computer system which includes the peripheral equipment as well as the basic CPU, included 38 repairs and 138 preventive maintenance actions. The repair distribution follows: tape units, 31; paper tape reader, 2; line printer , 2; teletypewriter, 1; CPU, 1; and paper tape punch, 1. Generally, the system operation has been very reliable. The majority of the tape unit problems were lamp replacements and sensor cleaning. There were some failures on minor mechanical assemblies. The only major failure was a defective capstan motor.

3. Other LDC Systems

The other systems maintained at the LDC are the Digital, Analog, and Test and Support systems. There were 4 minor repairs and 26 preventive maintenance actions performed on the Digital System. The timing system has been very reliable and stable during this period.

Eleven troubles and one pm were required for the Analog System. The failures occurred mainly in the Develocorders and the D/A circuits.

A new antenna has been installed atop the 40-ft tower on the LDC building to improve WWV reception. The installation is complete and the antenna roughly tuned to 5 MHZ at 50 ohms. The antenna is a helix-wound, 20-ft vertical that was fabricated at the LDC using plastic pipe and fiberglass construction. When signal fading is not present the receiving antenna provides a good, clear signal. The WWV signal is used to set the TOD clocks.

The 14-bit D/A channels are being completely overhauled and calibrated. These channels are used for LP recording and had deteriorated due to a heat problem from the bit driver circuits. All of these driver circuits are being checked and repaired and the rack modified to provide air circulation through these cards.

The Test and Support System encompasses not only the two Maintenance Display Consoles (MDC) but all other equipment for the support of the data center's operation such as the environmental equipment (air conditioners, electrostatic air filters) and the film viewers and copiers. Of 43 maintenance actions on this system, 35 were corrective and 18 were for preventive maintenance. MDC II was overhauled to improve the channel reponses and stability.

C. MAINTENANCE CENTER

The LMC supports the LASA operation with both array activities and shop testing and repairs.

LMC personnel completed 187 work orders representing 213 separate maintenance actions plus 16 items repaired in the shop. The array work orders included 40 corrective maintenance, 127 preventive maintenance, 2 modification, and 2 special tests.

1. Array Activities

Table XX shows the array maintenance actions by system and month. To accomplish this maintenance, 122 visits to CTH's and 22 visits to WHV's were made. This required 100 trips to the field plus 4 trips to the Malmstrom AFB, PMEL and covered 12,052 miles. The array corrective actions included 20 on SP channels, 9 LP circuits, 3 power system repairs, and 5 on SEM units.

A defective seismometer in the uncased hole at D1 WHV 45 could not be replaced. As done previously at D1, the WHV was converted to a "shallow-hole" installation. There are now ten such installations at D1, viz., WHV's 41, 52, 72, 43, 53, 54, 74, 45, 65, and 56. There are only two seismometers in uncased holes still operating since they were installed 12 years ago; these are at locations 81 and 76.

The special calibration signals installed at subarray D2 were removed in August. The affected channels were SP words 2 and 14 and LP words 26, 27, and 28. These channels are now operationally normal.

A project has been started to test LP sensors to

TABLE XX

ARRAY MAINTENANCE ACTIONS

APRIL 1977 - SEPTEMBER 1977

	APR	MAY	JUN	JUL	AUG	SEP	TOTALS
SP							
CORRECTIVE	2	5	3	6	5	4	25
PREVENTIVE	21	18	13	13	12	14	91
LP							
CORRECTIVE	1	1	1	3	3	2	11
PREVENTIVE	0	0	0	0	0	0	0
SEM							
CORRECTIVE	0	1	3	0	1	1	6
PREVENTIVE	4	3	5	5	3	10	30
POWER							
CORRECTIVE	0	1	1	0	0	1	3
PREVENTIVE	4	3	5	5	3	11	31
WEATHER STATION							
CORRECTIVE	0	0	0	0	0	0	0
PREVENTIVE	0	0	0	1	0	0	1
TOTALS	32	32	31	33	27	43	198

determine the frequency response and linearity. All sensors will be manually tested for response using a signal generator at the CTH for a calibration signal and recording the results at LDC on MDCI. This test was completed at D1 and D4 and the results compared to the response data provided by a computer run LP PRBS test. The computer program provides the PRBS intervals to the LP sensor calibration coil via telemetry and calculates the results to provide channel response. When both manual and computer tests are run during very quiet periods, the results compare favorably. A manual test, performed at each subarray, provides a standard response. Periodic PRBS test data will be compared with the standard to detect deteriorated channels. Since our signal generator's (203A) maximum output of 30Vp-p will not check the LP seismometers at the high end of their amplitude range, a driver amplifier will be constructed that will provide a 40Vp-p maximum signal to the calibration circuits which should be adequate to test for maximum output. This will enable testing and plots to be made of the linearity of the LP channels.

2. Shop Activities

The extent of the shop work is summarized in Table XXI. The large backlog of shop work (Type B and C work orders) is mostly RA-5 amplifiers, HS-10-1A seismometers, and printed circuit cards. Final adjustments of the amplifiers and seismometers are made with the units in the environmental chamber at operating temperatures. As noted in our previous report the chamber was inoperative for an extended period while waiting for parts. The unit is now repaired and can be used for final adjustments and trouble-shooting. The LDC backlog contains 20 D/A driver cards from the 14-bit LP channels that are awaiting parts. There were 18 shop repairs at LDC and 16 at LMC.

D. FACILITIES SUPPORT

LASA operations are supported by the facilities and vehicles available.

1. Land Provision

Provision of the land for the array requires 50 leases. In the interest of good relations with the landowners, 41 contacts were made to deliver lease checks, discuss subarray access trails, and other matters concerning the land use.

There was drilling at one location in the array. A 6700-ft well, drilled 10 miles west of subarray D4 at SWNE Section 23, T14N-R40E during April and May, has been plugged and abandoned.

2. Land and Facilities Maintenance

The amount and type of utility work engaged in at the LMC is shown in Table XXII. The 74 completed work orders

TABLE XXI

EQUIPMENT SHOP REPAIR SUMMARY

APRIL 1977 - SEPTEMBER 1977

	APR	MAY	JUN	JUL	AUG	SEP	TOTALS
SEM ASSEMBLIES	0	0	3	0	0	0	3
SP ASSEMBLIES	0	0	0	1	1	1	3
LP ASSEMBLIES	0	0	0	0	0	0	0
POWER ASSEMBLIES	0	0	0	0	0	0	0
OTHER ASSEMBLIES	1	0	1	2	1	0	5
CARD REPAIRS	0	1	5	6	7	4	23
TOTALS	1	1	9	9	9	5	34

TABLE XXII

SUMMARY - UTILITY WORK ORDERS

APRIL 1977 - SEPTEMBER 1977

WORK ORDER TYPE	BACKLOG START OF PERIOD	INITIATED	COMPLETED	BACKLOG END OF PERIOD
CABLE TRENCH AND TRAIL INSPECTION	13	0	13	0
CABLE TRENCH BACKFILL	0	1	1	0
WHV SITES LANDSCAPED	0	25	25	0
MARKER POST OR WHV COVERS REPLACED	4	14	18	0
CTH MAINTENANCE	0	6	6	0
VEHICLE MAINTENANCE INSPECTION	0	6	6	0
FENCE INSPECTION	0	0	0	0
TRAILS REPAIRS	0	0	0	0
LMC FACILITY MAINTENANCE	0	8	5	3
TOTALS	17	60	74	3

show 43 land repairs, 25 facility repair/inspections, and 6 vehicle maintenance/inspections. The cable to D3-33 was exposed by erosion and was covered and tamped. Increased agricultural use of the land in the array resulted in several instances of damage from plows. The barrel at B4-23 was cut and since this WHV is not used it was removed and the cables spliced to bypass the location. At B4-46 the barrel had to be straightened and the lid and "coolie" hat replaced. Near C4-63 the cable was cut. Since the cable in this area lay within 4 inches of the surface, a new section of cable was spliced in and retrenched at a greater depth.

3. Vehicles

The mileage driven during this period in support of the LASA totalled 13,454 miles without any accidents.

SECTION VI

ASSISTANCE PROVIDED TO OTHER AGENCIES

A. SEISMIC DATA ANALYSIS CENTER (SDAC)

The LASAPS processor is operated at the LDC 24 hr/day and 7 days/week to provide real time array data on line to SDAC. The weekly near-regional reports with events and blasts within 20° of the array center are also distributed to SDAC.

B. NATIONAL EARTHQUAKE INFORMATION SERVICE (NEIS)

The LDC provides NEIS with the weekly reports of near-regional events and blasts, responds to their telephone requests for selected event information, and operates an FM telemetry link for transmitting data from three selected SP seismometer channels.

C. MIT LINCOLN LABORATORY

The periodic near-regional reports with the strip-mine blast supplements are distributed to Lincoln Laboratory. LASA digital data tapes are mailed upon request.

D. MONTANA DEPARTMENT OF STATE LANDS

The strip-mine blast supplement to the near-regional reports is mailed to the Dept. of State Lands in Helena, Montana.

SECTION VII

DOCUMENTATION DEVELOPED

A. TECHNICAL REPORTS

The following reports were prepared and distributed during the final six months of this project:

1. "Semi-Annual Technical Report 1 OCT 1976 - 31 MAR 1977" T/R 2140-77-92 (AD-A041 037) 26 April 1977.
2. "Montana LASA Operation Report for April 1976" T/R 2140-76-93, 5 MAY 1977.
3. "Montana LASA Operation Report for May 1976" T/R 2140-76-94, 7 JUN 1977.
4. "Montana LASA Operation Report for June 1976" T/R 2140-77-95, 7 JUL 1977.
5. "Montana LASA Operation Report for July 1977" T/R 2140-77-96, 8 AUG 1977.
6. "Montana LASA Operation Report for August 1977" T/R 2140-77-97, 8 SEP 1977.
7. "Montana LASA Operation Report for September 1977" T/R 2140-77-98, 6 OCT 1977.

B. MANUALS

A revision to the Montana LASA Long Period Seismic System manual, MLM-6, was prepared and distributed.

CONCLUSIONS

1. The LASAPS operation as observed from the LASA end of the 4800-baud line was successful during this contract period. The annual goal of 95% data availability was missed by only 1.7% while keeping both the maintenance premium time and IBM customer engineering assistance at a minimum.

2. The LASA Inner Array Recording System, which operated 95.5% of the year, handled the array monitoring, calibration, event detection and processing without interferring with the recording operation.

3. The Montana array systems continue to meet their expected performance levels. Increased maintenance attention in some areas has been necessary.

4. Cultural noise surrounding some array sensor locations has been observed and results from changes in agricultural activity in some areas.

5. Teleseismic event processing has been incorporated into the LDC's daily activities and is considered an important part of our array operation.

RECOMMENDATIONS

Based on the operation of the Montana array and data center during this contract period, we recommend:

1. That the seismograph frequency response measurements be continued and response curves prepared, especially for the long-period systems.

2. That the improvement of the LDC's event processing capability and techniques be continued and that the Montana site be considered as a source of seismic event information not available at SDAC from the 4800-baud line.

3. That the PDP-7 computer core memory size be increased either by the installation of a second system from government excess or by the installation of additional memory modules, or by the replacement with a new system.

REFERENCES

1. Potter, G. A. (1975) "LASA Inner Array Recording System (LIARS)" LASA Program Description. Ford Aerospace and Communications. Billings, MT.

2. Matkins, R. E. (1976) "Montana LASA Semi-annual Technical Report T/R 2126-76-75 (AD-A023263) Ford Aerospace and Communications. Billings, MT

3. Needham, R. and A. Steele. (1969) "Montana LASA Data Analysis Techniques" S-110-33. Ford Aerospace and Communications. Billings, MT

APPENDIX

LASA Short-Period and Long-Period Sinusoidal Calibration Times and Amplitudes

LASA Short-Period and Long-Period Seismograph Sinusoidal Calibration Times and Amplitudes

The LASA seismographs are tested on a regular basis to ensure their operation is within standard tolerances. One type of test is the remotely controlled sinusoidal calibration. During these tests a sinewave of known amplitude (approx. mid-range) is applied to the seismometer calibration coil input for a specific time period (30 seconds for SP and 210 seconds for LP). The seismograph output signals in response to these inputs provide a method of amplitude calibration for the LASA data user.

Knowledge of a calibration date and time provides an easy means of locating a sinewave signal. The tables which follow indicate a date and time of a calibration signal from each seismograph for each week during the contract period. The peak-to-peak equivalent earth motion (mμ or nm for SP and μ or μm for LP) of the signal is also listed.

SHORT-PERIOD ARRAY SINUSOIDAL CALIBRATION START TIMES AND AMPLITUDES

DATE	A0/C3	B1/C4	B2/D1	B3/D2	B4/D3	C1/D4	C2
76-292	1530:32-401	1531:02-400	1531:32-373	1532:02-416	1532:32-382	1533:02-393	1533:32-401
	1534:02-391	1534:32-401	1535:02-407	1535:32-394	1536:02-395	1536:32-401	
76-299	1242:03-403	1242:33-398	1243:03-383	1243:33-416	1244:03-382	1244:43-393	1245:03-402
	1245:33-391	1246:03-402	1246:33-410	1247:03-393	1247:33-396	1248:03-404	
76-306	1547:19-403	1547:49-400	1548:19-375	1548:49-417	1549:19-383	1549:49-392	1550:19-402
	1550:49-391	1551:19-404	1551:49-408	1552:19-393	1552:49-396	1553:19-405	
76-313	1634:27-404	1634:57-402	1635:27-375	1635:57-415	1636:27-383	1636:57-392	1637:27-402
	1637:57-391	1638:27-402	1638:57-410	1639:27-393	1639:57-396	1640:27-405	
76-31[illegible]	1426:49-406	1427:13-405	1427:49-272	1428:19-420	1428:49-384	1429:19-391	1429:49-402
	1430:19-387	1430:49-403	1431:19-412	1431:49-092	1432:19-396	1432:49-408	
76-327	1755:00-407	1755:30-403	1756:00-384	1756:30-417	1757:00-385	1757:30-391	1758:00-402
	1758:30-388	1759:00-400	1759:30-412	1800:00-391	1800:30-397	1801:00-410	
76-334	1526:38-410	1527:08-406	1527:38-383	1528:08-420	1528:38-385	1529:08-390	1529:38-402
	1530:08-385	1530:38-403	1531:08-413	1561:38-391	1532:08-397	1532:38-412	
76-341	1541:49-410	1542:19-407	1542:49-369	1543:19-422	1543:49-386	1544:19-390	1544:49-402
	1545:19-386	1545:49-402	1546:19-412	1546:49-390	1547:19-396	1547:49-414	
76-348	1530:24-411	1530:54-406	1531:24-373	1531:54-423	1532:24-386	1532:54-387	1533:24-403
	1533:54-384	1534:24-403	1534:54-414	1535:24-390	1535:54-396	1536:24-414	
76-355	1614:16-411	1614:46-406	1615:16-371	1615:46-423	1616:16-386	1616:46-386	1617:16-403
	1617:46-386	1618:16-403	1618:46-413	1619:16-390	1619:46-396	1620:16-414	
76-362	1553:00-411	1553:30-406	1554:00-370	1554:30-422	1555:00-386	1555:30-386	1556:00-403
	1556:30-385	1557:00-401	1557:30-412	1558:00-390	1558:30-396	1559:00-414	
77-003	2012:54-413	2013:24-410	2013:54-366	2014:24-423	2014:54-387	2015:24-385	2015:54-402
	2016:24-383	2016:54-402	2017:24-413	2017:54-388	2018:24-396	2018:54-415	

BEST AVAILABLE COPY

77-010	1610:31-415	1611:01-412	1611:31-371	1612:01-423	1612:31-387	1613:01-385	1613:31-402
	1604:01-383	1614:31-403	1615:01-413	1615:31-387	1616:01-396	1616:31-417	
77-017	1519:12-415	1519:42-410	1520:12-357	1520:42-422	1521:12-386	1521:42-385	1522:12-403
	1522:42-384	1523:12-400	1523:42-415	1524:12-388	1524:42-395	1525:12-416	
77-024	1512:59-416	1513:29-411	1513:59-364	1514:29-423	1514:59-387	1515:29-385	1515:59-402
	1526:29-384	1516:59-400	1517:29-415	1517:59-388	1518:29-396	1518:59-417	
77-031	1642:38-415	1643:08-410	1643:38-364	1644:08-425	1644:38-	1645:08-384	1645:38-402
	1646:08-383	1646:38-402	1647:08-415	1647:38-388	1648:08-397	1648:38-416	
77-038	1622:35-XXX	1623:05-411	1623:35-364	1624:05-425	1624:35-388	1625:05-383	1625:35-403
	1626:05-381	1626:35-402	1627:05-415	1627:35-388	1628:05-397	1628:35-416	
77-045	1515:51-415	1516:21-407	1516:51-364	1517:21-422	1517:51-388	1518:21-383	1518:51-403
	1519:21-383	1519:51-400	1520:21-413	1520:51-388	1521:21-397	1521:51-416	
77-052	1654:42-413	1655:12-408	1655:42-364	1656:12-422	1656:42-387	1657:12-383	1657:42-403
	1658:12-384	1658:42-402	1659:12-415	1659:42-390	1700:12-397	1700:42-415	
77-059	1521:13-413	1521:43-410	1522:13-356	1522:43-422	1523:13-387	1523:43-383	1524:13-403
	1524:43-385	1525:13-402	1525:43-415	1526:13-390	1526:43-397	1527:13-416	
77-066	1530:41-412	1531:11-407	1531:41-365	1532:11-423	1532:41-387	1533:11-383	1533:41-403
	1534:11-383	1534:41-400	1535:11-413	1535:41-390	1536:11-396	1536:41-415	
77-073	1529:59-412	1530:29-408	1530:59-365	1531:29-422	1531:59-387	1532:29-383	1532:59-403
	1533:29-385	1533:59-398	1534:29-413	1534:59-390	1535:29-397	1535:59-415	
77-080	1436:57-412	1437:27-410	1437:57-365	1438:27-423	1438:57-387	1439:27-383	1439:57-402
	1440:27-384	1440:57-402	1441:27-415	1441:57-390	1442:27-397	1442:57-415	
77/087	1539:59-412	1540:29-407	1540:59-365	1541:29-423	1541:59-387	1542:29-383	1542:59-403
	1543:29-386	1543:59-402	1544:29-413	1544:59-390	1545:29-396	1545:59-415	
77/094	1636:15-413	1636:45-408	1637:15-371	1637:45-424	1638:15-387	1638:45-382	1639:15-403
	1639:45-384	1640:15-400	1640:45-413	1641:15-390	1641:45-396	1642:15-416	

77/101	1343:08-410	1343:38-405	1344:08-361	1344:38-418	1345:08-386	1345:38-383	1346:08-402
	1346:38-384	1347:08-404	1347:38-412	1348:08-391	1348:38-396	1649:08-412	
77/108	1313:51-407	1314:21-408	1314:51-363	1315:21-416	1315:51-385	1316:21-384	1316:51-402
	1317:21-395	1317:51-400	1318:21-413	1318:51-392	1319:21-396	1319:51-410	
77-115	1202:47-405	1203:17-407	1203:47-363	1204:17-420	1204:47-385	1205:17-384	1205:47-403
	1206:17-386	1206:47-401	1207:17-413	1207:47-392	1208:17-395	1208:47-408	
77-122	1222:19-404	1222:49-405	1223:19-379	1223:49-418	1224:19-384	1224:49-384	1225:19-403
	1225:49-388	1226:19-402	1226:49-408	1227:19-393	1227:49-396	1228:19-406	
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	1222:41-386	1223:11-402	1223:41-411	1224:11-393	1224:41-396	1225:11-405	
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77-150	1328:06-402	1328:36-401	1329:06-367	1329:36-414	1330:06-383	1330:36-384	1331:06-402
	1331:36-391	1332:06-402	1332:36-410	1333:06-394	1333:36-396	1334:06-403	
77-157	1249:26-400	1249:56-400	1250:26-376	1250:56-412	1251:26-382	1251:56-385	1252:26-402
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	1230:25-391	1230:55-400	1231:25-406	1231:55-394	1232:25-396	1232:55-398	
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	2231:04-393	2231:34-393	2232:04-405	2232:34-395	2233:04-410	2233:34-394	
77-192	1411:11-396	1411:41-394	1412:11-373	1412:41-411	1413:11-380	1413:41-385	1414:11-401
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77-205	1321:36-392	1322:06-391	1322:36-381	1323:06-407	1323:36-379	1324:06-385	1324:36-401
	1325:06-394	1325:36-402	1326:06-405	1326:36-396	1327:06-412	1327:36-390	
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	1316:04-393	1316:34-403	1317:04-404	1317:34-396	1318:04-412	1318:34-392	
77-219	1305:26-392	1305:56-393	1306:26-379	1306:56-410	1307:26-379	1307:56-385	1308:26-401
	1308:56-393	1309:26-403	1309:56-406	1310:26-395	1310:56-413	1311:26-391	
77-226	1307:42-393	1308:12-395	1308:42-370	1309:12-410	1309:42-379	1310:12-385	1310:42-401
	1311:12-392	1311:42-401	1312:12-404	1312:42-395	1313:12-413	1313:42-392	
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	1325:12-391	1325:42-398	1326:12-404	1326:42-395	1327:12-412	1327:42-392	
77-240	1303:48-394	1304:18-392	1304:48-379	1305:18-412	1305:48-380	1306:18-384	1306:48-401
	1307:18-391	1307:48-402	1308:18-405	1308:48-395	1309:18-414	1309:48-394	
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77 275	1343:52-390	1344:22-398	1344:52-373	1345:22-412	1345:52-381	1346:22-384	1346:52-402
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LONG-PERIOD ARRAY SINUSOIDAL CALIBRATION TIMES AND INPUT AMPLITUES

DATE	A0/C1 START-STOP AMP	C2 START-STOP AMP	C3/C4 START-STOP AMP	D1/D2 START-STOP AMP	D3/D4 START-STOP AMP
76-285	1449:17-1459:05 20.1/20.5	1459:39-1503:17 19.8	1509:56-1513:23 20.8/20.6	1519:19-1523:28 21.1/20.0	1529:57-1533:24 18.9/20.6
76-292	1539:02-1542:49 20.0/20.5	1549:23-1553:00 19.8	1559:39-1603:20 20.9/20.6	1609:47-1613:23 21.1/20.0	1619:30-1622:57 18.8/20.6
[illegible]	[illegible] 20.1/20.4	[illegible] 19.8	[illegible] 20.8/20.6	[illegible] 21.0/20.0	[illegible] 18.9/20.6
76-306	[illegible]9:25 20.0/20.4	1605:59-1609:32 19.8	1616:11-1619:37 20.8/20.6	1626:03-1629:46 21.0/20.0	1636:14-1639:41 18.9/20.6
76-313	: - :	1843:29-1847:03 19.8	1853:42-1857:56 20.9/20.6	1903:42-1908:07 21.0/20.0	1913:55-1917:38 19.0/20.6
76-320	1658:00-1701:26 20.0/20.4	1707:35-1711:06 19.7	1717:45-1721:27 20.8/20.6	1727:52-1731:16 21.0/20.0	1737:20-1740:51 19.0/20.6
76-329	1541:33-1545:27 20.0/20.4	1552:01-1555:38 19.8	1602:17-1605:50 20.8/20.6	1612:15-1615:49 21.0/20.0	1622:17-1625:58 19.1/20.6
76-334	1534:47-1538:26 20.0/20.4	1545:00-1548:47 19.8	1555:26-1558:50 20.8/20.7	1605:16-1608:43 21.0/20.0	1615:11-1618:51 19.1/20.6
76-341	1551:17-1554:59 20.0/20.4	1604:33-1605:16 19.7	1611:56-1615:27 20.8/20.7	1621:53-1625:31 21.0/20.0	1631:59-1635:35 19.0/20.6
76-348	1538:23-1542:16 20.0/20.4	1548:50-1552:32 19.3	1559:12-1602:35 20.7/20.7	1609:01-1612:35 21.0/18.8	1619:04-1622:34 19.0/20.6
76-355	1720:38-1724:13 20.1/20.4	1730:47-1734:24 19.7	1741:04-1744:40 20.8/20.7	1751:07-1754:35 21.0/20.0	1801:05-1804:50 18.9/20.6
76-362	1601:04-1604:37 20.0/20.4	1611:12-1614:44 19.8	1621:24-1625:05 20.8/20.7	1631:32-1635:01 21.0/20.0	1641:30-1645:07 19.0/20.6
77-003	2021:09-2024:44 20.0/20.4	2031:19-2034:50 19.7	2041:30-2045:09 20.7/20.7	2051:35-2055:03 21.0/20.0	2101:32-2104:57 19.1/20.6

77-010	1618:27-1622:06 20.1/20.4	1628:41-1632:20 19.7	1639:01-1642:33 20.7/20.7	1648:59-1652:24 21.0/18.9	1658:53-1702:22 19.1/20.6
77-017	1527:04-1530:39 20.0/20.4	1537:15-1540:56 19.7	1547:37-1551:21 20.7/20.7	1557:47-1601:33 21.0/20.0	1608:02-1611:42 19.0/20.6
77-024	1526:03-1529:42 20.0/20.4	1536:18-1540:09 19.7	1546:50-1550:25 20.7/20.7	1556:51-1600:27 21.0/20.0	1606:56-1610:39 19.0/20.6
77-031	1651:00-1654:48 20.0/20.4	1701:24-1704:56 19.7	1711:37-1715:21 20.7/20.7	1721:48-1725:15 21.0/20.0	1731:44-1735:28 19.0/20.6
77-038	1655:24-1659:01 19.7/20.7	1705:42-1709:28 20.7	: - : . / .	1554:17-1557:45 20.2/20.0	1604:15-1607:54 19.1/20.6
77-045	1523:45-1527:20 20.0/20.4	1533:56-1537:27 19.8	1544:08-1547:50 20.7/20.7	1715:55-1719:03 21.0/20.0	1725:32-1729:19 19.0/20.6
77-052	1708:37-1712:11 20.0/20.4	1718:46-1722:38 19.8	1729:20-1732:44 18.9/20.7	1739:12-1742:53 21.0/20.0	1749:23-1753:08 19.1/20.6
77-059	1535:12-1538:43 20.1/20.4	1545:19-1549:08 19.7	1555:49-1559:16 20.7/20.7	1605:44-1609:28 21.0/20.0	1615:58-1619:29 19.1/20.6
77-066	1538:55-1542:39 20.0/20.4	1549:14-1552:46 19.7	1559:27-1603:11 20.7/20.7	1609:38-1613:22 21.0/20.0	1619:52-1623:38 19.1/20.6
77-073	1537:57-1541:23 20.0/20.4	1547:58-1551:45 19.7	1558:26-1602:07 20.8/20.7	1608:34-1612:06 21.0/20.0	1618:36-1622:11 19.1/20.6
77-080	1758:51-1802:17 20.0/20.4	1808:52-1812:26 19.7	1819:07-1822:44 20.8/20.7	1829:10-1832:47 21.0/20.0	1839:16-1843:00 19.0/20.6
77/087	1643:34-1647:07 20.1/20.4	1653:41-1657:12 19.8	1703:53-1707:27 20.7/20.7	1713:54-1717:19 19.2/20.0	1723:48-1727:11 17.5/20.5
77/094	1646:56-1650:41 20.0/20.4	1657:15-1701:02 19.8	1707:43-1711:24 20.7/20.7	1717:51-1721:25 21.0/20.0	1727:54-1731:18 18.9/20.6

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77-129	1635:12-1638:56 20.0/20.5	1645:31-1649:16 19.7	1655:56-1659:27 20.8/20.6	1705:54-1709:35 21.0/20.0	1716:04-1719:46 18.9/20.6
77-136	1454:26-1457:58 20.0/20.5	1504:32-1508:06 19.8	1514:47-1518:31 20.8/20.6	1524:58-1528:28 21.0/20.0	1534:58-1538:41 18.9/20.6
77-143	1555:24-1558:57 20.1/20.5	1605:33-1609:05 19.8	1615:46-1619:17 20.8/20.6	1625:45-1629:14 21.0/20.0	1635:44-1639:25 18.8/20.6
77-150	1456:16-1459:43 20.1/20.5	1506:18-1509:57 19.8	1516:38-1520:25 20.8/20.6	1526:53-1530:19 21.0/20.0	1536:49-1540:26 18.9/20.6
77-157	1526:52-1530:27 20.0/20.5	1537:02-1540:53 19.8	1547:34-1551:14 20.8/20.6	1557:42-1601:22 21.1/20.0	1607:52-1611:37 18.9/20.6
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77-171	1503:09-1506:46 20.1/20.5	1513:22-1516:59 19.8	1523:41-1527:15 20.8/20.6	1533:44-1537:30 21.1/20.0	1544:00-1547:43 18.9/20.6
77-178	1609:48-1611:14 [illegible]	1615:18-1618:49 19.8	1625:30-1629:07 20.8/20.6	1635:37-1639:17 19.4/20.0	1645:47-1649:28 19.0/20.6
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77-212	1507:57-1511:27 20.0/20.5	1518:01-1521:44 19.8	1528:25-1531:59 20.8/20.6	1538:27-1541:27 18.7/20.0	1547:57-1551:40 19.0/20.6
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)
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    LASA - Large Aperture Seismic Array
    Seismic Array
    Seismic Observatory Operation
    Seismic Measurement Channel Performance
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The operation and maintenance activities at the Montana Large Aperture Seismic Array and Data Center during the period from April 1 and September 30, 1977 are described. Operations in data recording and event processing are detailed. Seismograph frequency response measurements and performance statistics are presented. Maintenance activities in the array and at the data and maintenance center are discussed.

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