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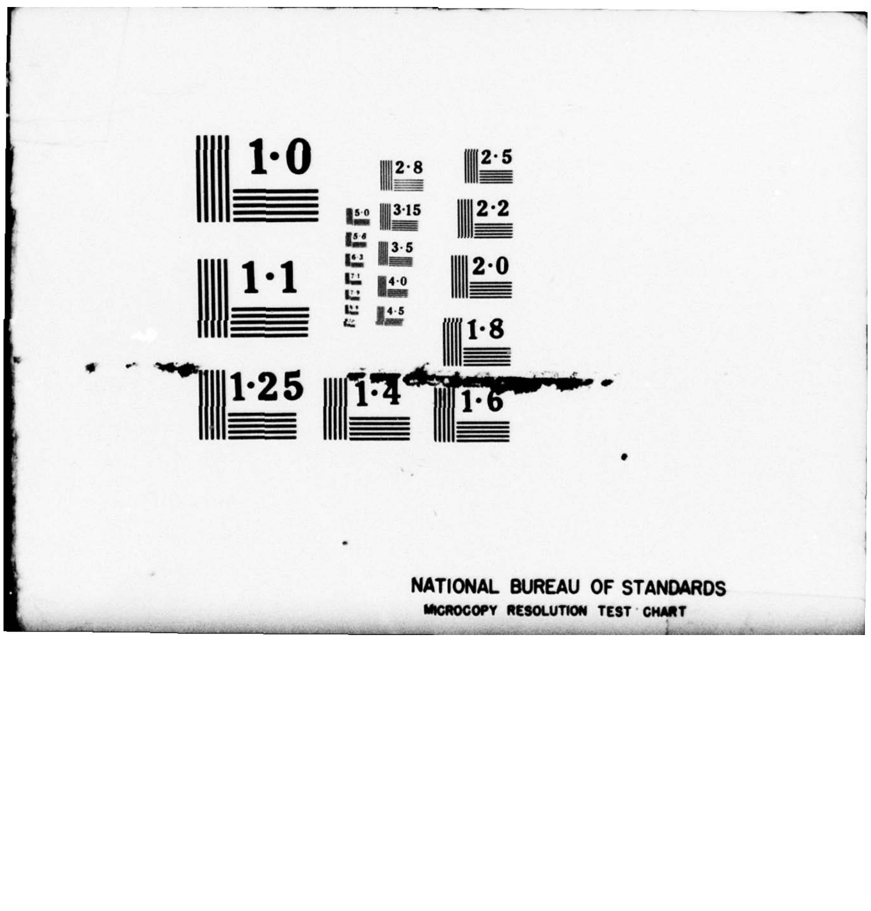
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214 NORTH 30TH STREET
BILLINGS, MONTANA

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Technical Report 2145-78-107

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MONTANA LARGE APERTURE SEISMIC ARRAY

SEMI-ANNUAL TECHNICAL REPORT

PROJECT VT 8708

CONTRACT F08606-78-C-0003

1 OCTOBER 1977 - 31 MARCH 1978

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

by

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

(6) MONTANA LARGE APERTURE SEISMIC ARRAY.

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ABSTRACT

The continued operation, maintenance and array improvement activities at the Montana LASA during the period between October 1, 1977 and March 31, 1978, are described. Array operations, including the preparation of daily teleseismic event reports, are detailed. Results of the seismic event processing effort are reported. Seismograph system performance measurements are presented. Maintainability statistics on the IBM 360 Model 44 computer are given. Program maintenance for the PDP-7 computer system is indicated. Maintenance activities at both the data and maintenance centers 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 first semi-annual technical report of the activity by Ford Aerospace & Communications Corporation on the Montana Large Aperture Seismic Array (LASA), Project VELA T/8707 under contract F08606-78-C-0003.

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 October 1977 and continued through 31 March 1978.

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

This, first Semi-annual Technical Summary report, describes the activities at the Montana LASA during October 1977 through March 1978. These activities include the operation and maintenance of the systems installed both in the array and at the data center (LDC).

The LASA Processing System (LASAPS) operated continuously with the Seismic Data Analysis Center (SDAC) 95.0% of this six month period. System/360 failures and their correction accounted for the majority of the on-line interruptions (86.4%).

Digital recording of the array data by the PDP-7 computer continued on a full-time basis with the exception of an average 40 minute per day interruption for off-line program processing and system maintenance. The digital recordings were available from the LDC during the 60-day retention cycle before their reuse. Recordings of event periods since November 1, 1975, are still available at the LDC on edited tapes produced by the PDP-7 AUTO-EDIT system.

Teleseismic event processing using film recordings and on-line computer playouts were routinely performed with the average daily result of 23.2 events or phases reported to VSC. Also, periodic near regional and strip-mine blast listings added an average of 9.0 events/day. Comparisons with USGS show our reported magnitudes slightly higher (0.08 units ave) than the PDE's, our locations differing by about 5.5 degrees, and the 90% detection threshold of our reports at 5.08.

Equipment and facilities maintenance allowed the continued operation of the array in a manner similar to previous periods. Mechanical components with their inherent wear with age do cause added concern to the maintenance effort in implementing repairs and replacements.

SECTION II

OPERATION OF ALL LASA SYSTEMS

A. LASAPS OPERATIONS

The LDC computer provided LASA data to the SDAC transcontinental data link 95.0% of the six-month period from October 1977 thru March 1978. The one-year percentage equalled 94.7%. Interruptions in the computer's on-line operation with SDAC which have occurred are listed in Table I.

TABLE I

LASAPS DATA INTERRUPTIONS

Cause		Hours (October 77 - March 78)	%
Corrective Maint.		192.2	4.40
Active Maint.	74.1		1.70
Awaiting Pers.	106.0		2.43
Awaiting Parts	12.1		0.28
Preventive Maint.		9.6	0.22
Program Halts/Power Loss		9.2	0.21
Admin. Use (Training)		5.4	0.12
SDAC Line Inop.		6.0	0.14
Other LDC Systems Inop.		0.0	0.00
TOTALS		222.4	5.09

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 23.3 hr/day for the 182-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 6375 were

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

produced using the slow-mode (10 s/s), short (10 sensor) format and covering 97.3% of the total time; no recordings were made using the other modes.

Interruptions in the data recording were necessary to support other LDC operations and logistics functions of 88.8 hr (2.0%) and for computer downtime 20.5 hr (0.5%).

2. Edited Data Recording

Recording edited event data from only the SP subarray sum signals continued throughout this reporting period allowing the preparation of 16 new master-edit tapes containing 1449 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. There are now 90 master-edit tapes containing 9370 events.

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)

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 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

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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.

203.2 hr during this period; LP, 332.5 hr. Each SP subarray averaged 2.6 hr/month outage; LP, 6.2 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. The extended C1 LP data interruption was caused by moisture in the LP tank which was dried out over a weekend.

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 increased slightly from 0.99674 to 0.99675. 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. The increase in extended outages over the previous two winter periods was due to the extreme winter weather conditions in eastern Montana. The single and greatest outage, which accounted for 35.3% of the extended outages, was due to Telco's power supply problem at the Angela microwave.

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

TABLE II

DATA INTERRUPTIONS BY PURPOSE OF OUTAGE

OCTOBER 1977 - MARCH 1978

SP ARRAY, 13 SITES	TOTAL HOURS OUT	AVERAGE PER SITE
LDC TESTING	19.50	1.50
SITE FAILURES	.00	.00
LMC MAINTENANCE	8.02	.62
TELCO TEST/OUTAGE	175.65	13.51
POWER	.00	.00
LDC FAILURES	.00	.00
TOTAL SP ARRAY	203.17	15.62

LP ARRAY, 9 SITES		
LDC TESTING	42.32	4.70
SITE FAILURES	.00	.00
LMC MAINTENANCE	141.57	15.73
TELCO TEST/OUTAGE	148.63	16.51
POWER	.00	.00
LDC FAILURES	.00	.00
TOTAL LP ARRAY	332.52	36.94

TABLE III

SUMMARY OF SUBARRAY DATA INTERRUPTION OUTAGES

OCTOBER 1977 - MARCH 1978

SITE	SP DATA	LP DATA	TELCO
A0	2.73	7.88	22.27
B1	1.67	-	8.11
B2	1.60	-	5.08
B3	1.50	-	8.75
B4	1.50	-	5.08
C1	3.40	123.73	5.08
C2	1.95	10.30	34.47
C3	3.04	5.70	21.75
C4	2.27	11.78	5.08
D1	2.37	5.15	18.72
D2	2.34	7.83	.13
D3	1.65	6.78	22.08
D4	1.50	4.63	19.06
TOTAL HRS	27.52	183.78	175.66

TABLE IV

ARRAY COMMUNICATIONS OUTAGE STATISTICS

SITE	CIRCUIT	OUTAGE 10/77-03/78	CIRCUIT AVAILABILITIES SHORT TERM 10/77-03/78	LONG TERM 12/70-03/78
A0	4GD2704	22.27	99.995	99.451
B1	4GD2701	8.11	99.998	99.794
B2	4GD2710	5.08	99.999	99.724
B3	4GD2705	8.75	99.998	99.803
B4	4GD2707	5.08	99.999	99.746
C1	4GD2708	5.08	99.999	99.844
C2	4GD2709	34.47	99.992	99.561
C3	4GD2711	21.75	99.995	99.407
C4	4GD2706	5.08	99.991	99.755
D1	4GD2714	18.72	99.996	99.639
D2	4GD2715	.13	100.000	99.849
D3	4GD2712	22.08	99.995	99.507
D4	4GD2713	19.06	99.996	99.698
ARRAY TOTAL		175.66 HR	99.996 AVG	99.675 AVG

TABLE V

EXTENDED ARRAY DATA COMMUNICATIONS OUTAGES

OCTOBER 1977 - MARCH 1978

DATE	DURATION	SITE	REASON
10/30/77	4 06	C2	LOST SYNC-OSC IN OFFICE
11/09/77	4 17	A0	BAD LL CONNECTOR
11/09/77	3 02	B1	BAD LL CONNECTOR
12/09/77	2 20	C2	LOST DATA
12/24/77	4 25	C2	BROKEN DATA
12/27/77	5 30	A0	BROKEN DATA-FROST ON LINES
12/27/77	5 30	C3	BROKEN DATA-FROST ON LINES
12/27/77	5 30	D3	BROKEN DATA-FROST ON LINES
12/27/77	5 30	D4	BROKEN DATA-FROST ON LINES
01/05/78	3 30	D3	BAD DATA
01/05/78	2 30	C2	BAD DATA
01/11/78	3 55	C2	BAD DATA
01/11/78	2 53	C2	BAD DATA-BROKEN BRIDLE WIRE
01/14/78	8 00	D3	BAD DATA-FROST ON LINES
01/14/78	7 15	D4	BAD DATA-FROST ON LINES
01/14/78	7 57	D1	BAD DATA-FROST ON LINES
01/14/78	6 45	C3	BAD DATA-FROST ON LINES
01/14/78	6 15	A0	BAD DATA-FROST ON LINES
01/16/78	3 40	B3	HEAVY ICE + WIND
01/20/78	2 16	D1	POSSIBLE FROST
01/20/78	4 38	*1	POWER SUPPLY PROBLEMS-ANGELA
02/20/78	3 25	C3	BROKEN DATA
02/20/78	3 25	D1	BROKEN DATA

*1 ALL SITES EXCEPT D2

computer's seven-track tape units using our LIARS format covered 4248.0 hours or 97.25% of the six-month period. These 6375 magnetic tape recordings were recycled through the LDC's Data Library so that each recording was retained for at least 60 days before reuse.

The LASA Data Library now contains 3128 of the 2400-ft tapes which are currently divided into these categories:

LIARS Recording Cycle	2290
Master Edit	90
Events (permanent files)	608
Programming (quality tapes)	76
Administrative	64

There are 6 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 3724 events and 496 phases between October 1, 1977 and March 31, 1978. These events are classified in Table VI and show an average of 23.2 detections per day. Approximate locations were indicated for 32% of the detected events.

Magnitudes were determined for the 1338 located events. The smallest magnitude reported was 3.5; the largest 7.2. Figure 3.1 shows the distribution of these magnitudes. The distribution of all 5980 event magnitudes reported since July 1, 1975 is shown in Figure 3.2.

The daily teleseismic report has been keypunched and listed by an on-line program on the PDP-7 computer since January 1, 1978. This information on punched cards provides us easy accessability for special studies such as region studies, magnitude studies, etc. An example of our new report is shown in Figure 3.3.

2. Near Regional Detections

The LASA near-regional detection reports continued with 18 issues between October 1, 1977 and March 31, 1978. A total of 135 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 increased by about 23% to an average of 8.3 blasts/day from 6.7 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

TABLE VI

CLASSIFICATION OF DETECTED TELESEISMIC EVENTS

October 1, 1977 - March 31, 1978

	Number of Events	Daily Average
Located teleseisms (excluding PKP's)	1338	7.35
PKP (located)	52	0.29
PKP (unlocated)	317	1.74
Poor or weak teleseisms (not located)	368	2.02
pP Phases	376	2.07
Other Phases	120	0.66
Unprocessed detections	1649	9.06
TOTAL	4220	23.19

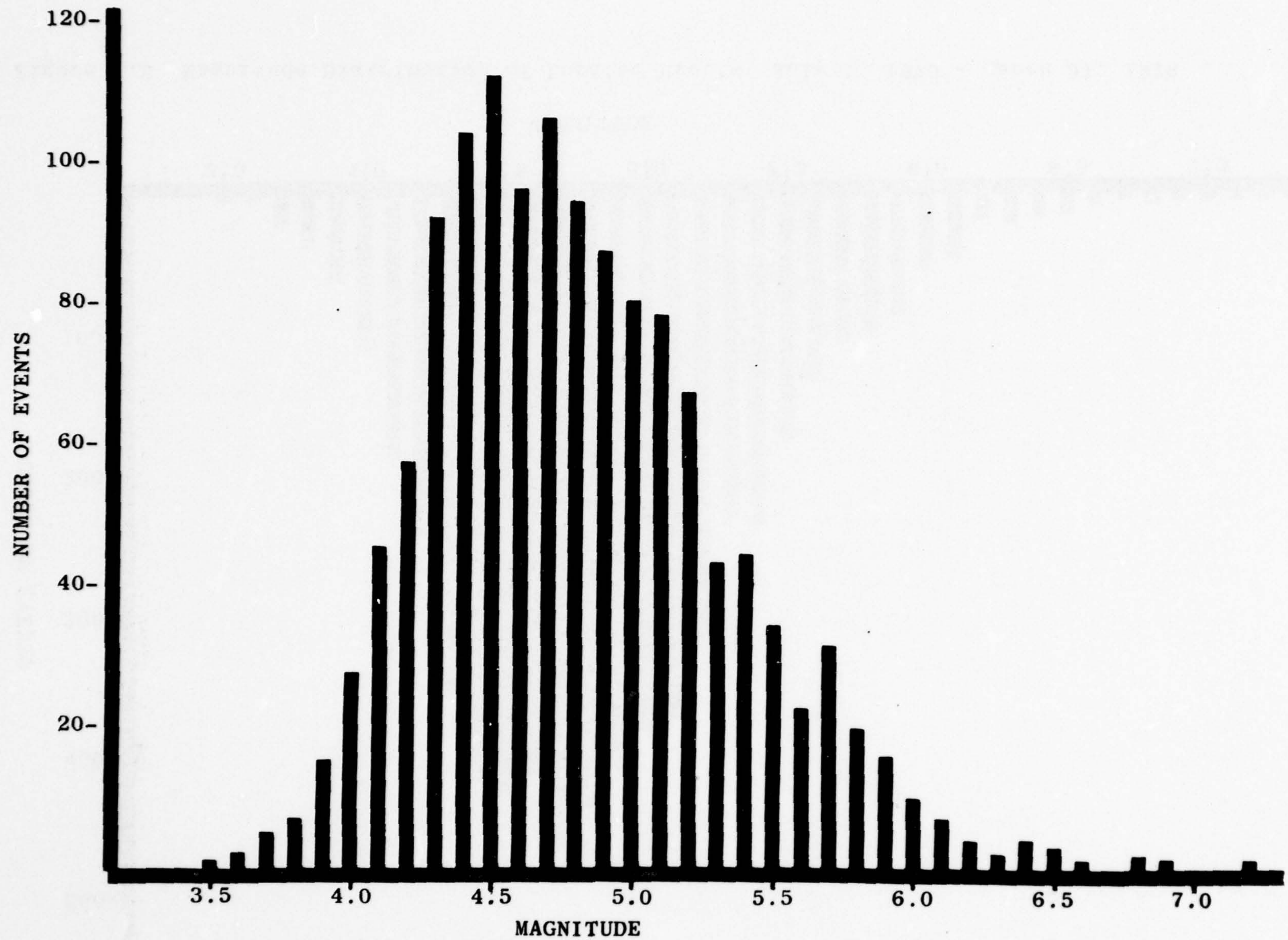

Figure 3.1 Magnitude Distribution of Located Events, October 1, 1977 - March 31, 1978

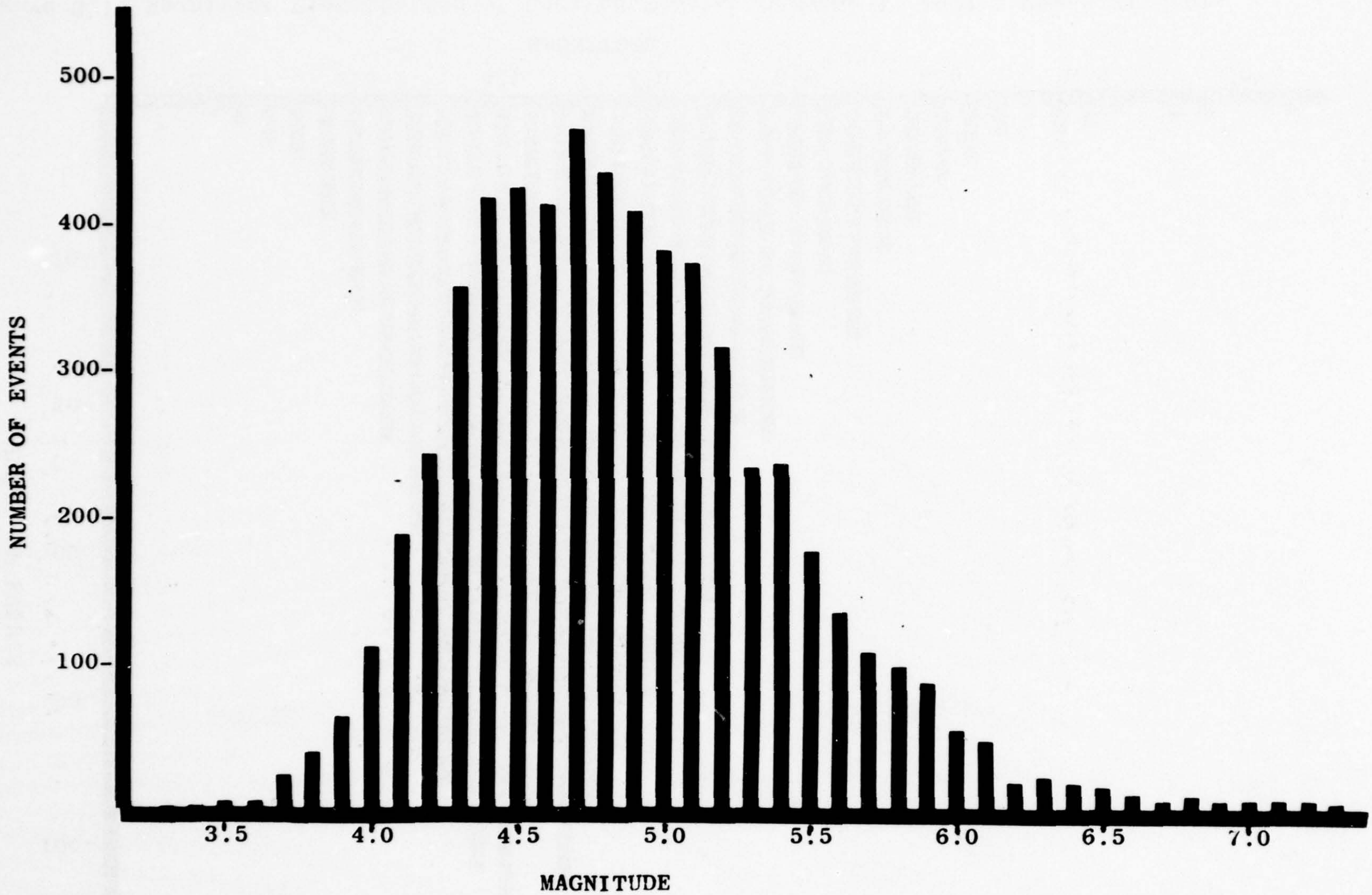

Figure 3.2 Magnitude Distribution of Located Events, July 1, 1975 - March 31, 1978

LASA DATA CENTER TELESEISMIC REPORT

78-051 02/20/78

ARR TIME	SITE	REGION	GEOGRAPHIC REGION	STA	LHAT	DEP	AMP	PER	VEL	DIST	AZ	LAT	LONG	MAG	R	SEC
0209:08.5	AOR	693 44	EAST CENTRAL PACIFIC OCEAN	8	.036		15.4	0.9	14.5	49.4	196.9	1.4S	119.0W	5.0	1	01
0057:21.5	AOR		PKP	.			7.0	0.8	.	.	.	.	.	.	1	02
0225:12.9	AOR		PKP	.			15.4	0.9	.	.	.	.	.	.	2	03
0354:17.7	AOF	006 01	RAT ISLANDS, ALEUTIAN ISLANDS	8	.021		1.5	0.8	14.3	48.1	305.5	51.7N	177.1E	4.0	3	04
0448:36.4	AOR	228 19	NEAR EAST COAST OF HONSHU, JAPAN	7	.032		1 283.1	1.1	20.1	77.8	311.5	36.8N	139.7E	6.0	1	05
0505:09.1	AOR	228 19	NEAR EAST COAST OF HONSHU, JAPAN	9	.041		16.2	0.8	20.1	77.8	311.5	36.8N	139.7E	5.1	1	06
0512:09.1	AOR	228 19	NEAR EAST COAST OF HONSHU, JAPAN	9	.041		11.5	0.9	20.1	77.8	311.5	36.8N	139.7E	4.9	1	07
0526:10.9	AOF	222 19	KURILE ISLANDS REGION	7	.039		4.3	1.0	16.3	60.2	311.6	45.4N	156.9E	4.5	3	08
0551:25.1	AOF	228 19	NEAR EAST COAST OF HONSHU, JAPAN	7	.036		1.0	0.7	19.1	74.0	311.9	40.1N	142.5E	3.9	3	09
0653:14.1	AOF	179 12	SOUTH OF KERMADEC ISLANDS	11	.035		2.3	0.8	25.0	102.5	237.0	31.7S	180.0E	FKP	3	10
0722:58.8	AOR	127 09	CHILE-ARGENTINA BORDER REGION	8	.023	83	8.7	0.9	21.3	81.4	145.9	27.1S	67.8W	4.6	1	11
0728:18.7	AOF	099 07	NORTHERN COLOMBIA	9	.057		1.7	0.8	14.5	49.5	136.3	5.5N	74.3W	4.0	3	12
0915:07.3	AOR	181 13	FIJI ISLANDS REGION	8	.025		17.9	1.1	24.1	92.3	240.7	21.4S	175.6W	5.3	2	13
0939:24.1	AOR		POOR	.			.	.	.	.	.	.	.	.	3	14
1423:49.3	AOR	221 19	KURILE ISLANDS	8	.020	29	7.0	0.8	16.7	62.5	313.3	49.1N	152.7E	4.8	2	15
1539:45.8	AOR	241 20	PHILIPPINE SEA	9	.045		7.8	0.7	24.3	93.5	307.1	21.8N	132.6E	5.1	1	16
1750:21.8	AOR	226 19	NEAR WEST COAST OF HONSHU, JAPAN	8	.040		4.5	0.8	21.5	79.2	313.0	36.8N	137.2E	4.5	2	17
2032:01.2	AOF	171 12	SOUTH OF FIJI ISLANDS	13	.033		7.8	1.0	24.2	92.8	241.2	21.5S	176.4W	5.0	2	18
2100:02.4	AOR	123 08	NORTHERN CHILE	8	.022	142	54.9	1.0	20.3	77.9	145.4	23.7S	68.9W	5.2	3	19

OTHER UNPROCESSED EVENT DETECTIONS

0017:26/0351:55/0744:32/0001:31/0830:44/1156:50/1557:22/1801:26/2358:16/

Figure 3.3 Sample of LASA Data Center's Daily Teleseismic Report

TABLE VII

SUMMARY OF STRIP-MINE BLASTING ACTIVITIES REPORTED BY LDC

October 1, 1977 - March 31, 1978

	NUMBER BLASTS REPORTED	
COLSTRIP, MT (WE)	608	(40.2%)
DECKER, MT	448	(29.6%)
SARPY CREEK, MT (W)	134	(8.9%)
WYOMING	110	(7.3%)
COLSTRIP, MT (P)	85	(5.6%)
BRITISH COLUMBIA, CANADA	75	(5.0%)
UNKNOWN	26	(1.7%)
UNKNOWN, NE	19	(1.3%)
SOUTH DAKOTA	6	(0.4%)
TOTAL	1511	(100.0%)

accuracy; and (4) detection threshold of the LDC teleseismic reports.

1. Confirmation

Investigation into the confirmation of events on a seismic region basis continued during this reporting period. To date, we have checked our daily reports against twelve PDE monthly listings. Of the 4294 PDE events used in our region study, LDC reported 2347 or 54.7%. We also analyzed these events according to size with the following results: events with $m_b \geq 4.6$ and within 90°, LDC reported 83%; events with $m_b \geq 4.6$ and over 90°, 40%; events with $m_b < 4.6$ and within 90°, 48%; events with $m_b < 4.6$ and over 90°, 12%.

Our region study has identified the regions with a high degree of detectability as well as the blindspots in our event reporting. Table VIII shows the twelve month results of all events on PDE with a reported magnitude and our detectability of each region.

2. Location

A comparison between event locations as determined at the LDC and those given on the 12 monthly PDE's under study were investigated on a seismic region basis. Of the 1367 events studied from our region study there was an average location error of 5.5°. Using only the 517 events with good signal coherence across the array (Type 1) the location error averaged 4.8°. Confirmation on a seismic region basis ranged from an average error of 2.7° on 119 events from the Japan, Kuriles, Kamchatka region to 9.0° average error on 7 events from the S.E. and Antarctic Pacific. This study has pointed out the regions in our event processing that need new station corrections. We have reviewed the present event location program and have found that there were regions that had either no station corrections or had correction factors based on a small number of events. We have, during this reporting period, started a data base of events dating from 1 May 1977. The procedure being used is to use only rate 1 events (events with good signal coherence) and the event locations as given in the PDE's are calculated using an SR-52 calculator routine and a distance-velocity table. The calculated delays are subtracted from the actual delays. These values are then averaged and modified to be referenced to subarray AO. Initial tests on limited data thus far show significant improvement on the LASA location capability.

3. Magnitude

Magnitude comparisons are made between the LDC calculations and the magnitudes of the events as they are later listed in PDE's. The results, which are shown in Figure 3.4 for the past six months and in Figure 3.5 from July 1, 1975.

TABLE VIII

PERCENTAGE OF PDE-REPORTED EVENTS DETECTED BY LASA

Seismic Region No.	Percentage of Detections			Seismic Region No.	Percentage of Detections		
	mb≥4.6	mb<4.6	All mb		mb≥4.6	mb<4.6	All mb
1	83.1(59)	67.2(61)	75.0(120)	26	17.0(53)	0.0(17)	12.9(70)
2	87.1(31)	41.0(39)	61.4(70)	27	51.9(27)	0.0(1)	50.0(28)
3	80.9(47)	30.4(56)	53.4(103)	28	94.1(17)	16.7(6)	73.9(23)
4	95.0(20)	93.8(16)	94.4(36)	29	61.0(82)	27.7(83)	44.2(165)
5	87.0(69)	68.2(44)	79.6(113)	30	86.6(67)	24.8(161)	43.0(228)
6	93.2(132)	87.3(55)	91.4(187)	31	52.2(23)	6.8(44)	22.4(67)
7	89.7(58)	72.2(18)	85.5(76)	32	61.5(65)	63.6(11)	61.8(76)
8	92.9(168)	57.9(57)	84.0(225)	33	68.9(45)	40.0(5)	66.0(50)
9	77.8(9)	-	77.8(9)	34	62.5(8)	42.9(7)	53.3(15)
10	69.2(26)	100.0(1)	70.4(27)	35	100.0(1)	-	100.0(1)
11	25.0(16)	-	25.0(16)	36	34.2(38)	25.0(24)	30.7(62)
12	38.9(350)	7.1(28)	36.5(378)	37	38.5(13)	0.0(9)	22.7(22)
13	79.0(105)	61.5(13)	77.1(118)	38	-	0.0(1)	0.0(1)
14	12.7(134)	0.0(15)	11.4(149)	39	80.0(5)	75.0(4)	77.8(9)
15	31.2(170)	10.0(20)	29.0(190)	40	87.3(55)	45.7(35)	71.1(90)
16	19.0)116)	5.6(18)	17.2(134)	41	82.8(58)	75.0(16)	81.1(74)
17	66.7(15)	100.0(1)	68.8(16)	42	100.0(5)	0.0(4)	55.6(9)
18	89.0(109)	46.3(41)	77.3(150)	43	79.2(48)	100.0(6)	80.4(51)
19	83.1(356)	51.1(94)	76.4(450)	44	100.0(10)	100.0(2)	100.0(12)
20	75.9(29)	57.1(7)	72.2(36)	45	75.0(8)	-	75.0(8)
21	41.0(39)	0.0(8)	34.0(47)	46	79.4(63)	7.1(14)	66.2(77)
22	32.5(203)	14.3(21)	30.8(224)	47	0.0(1)	0.0(2)	0.0(3)
23	71.2(111)	28.6(7)	68.6(118)	48	36.1(61)	2.0(100)	14.9(161)
24	64.7(102)	36.4(22)	59.7(124)	49	100.0(2)	0.0(2)	50.0(4)
25	18.2(33)	0.0(18)	11.8(51)	50	-	-	-

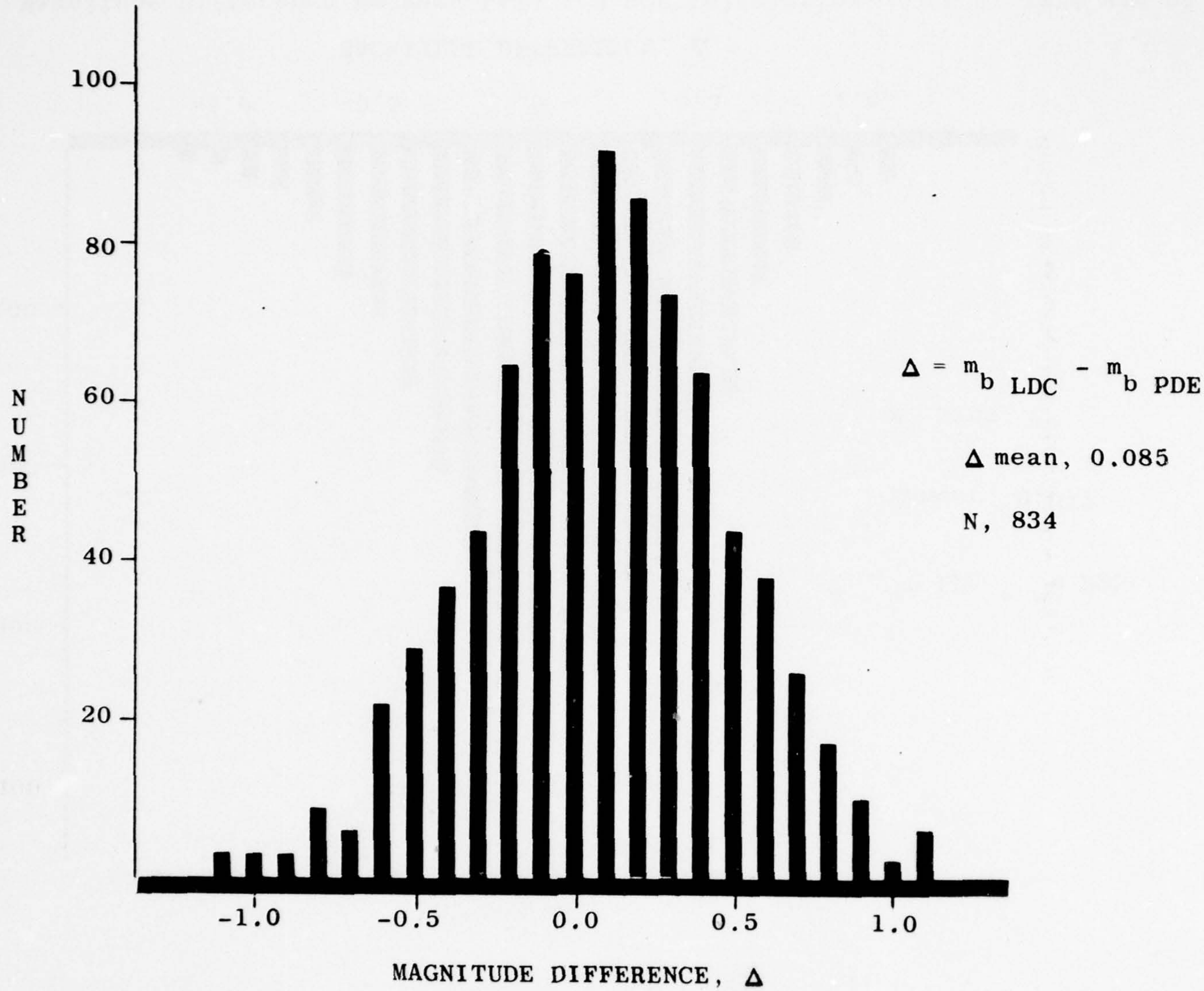

Figure 3.4 Magnitude Difference Between LASA and PDE Calculations, OCT 1, 1977-MAR 31, 1978

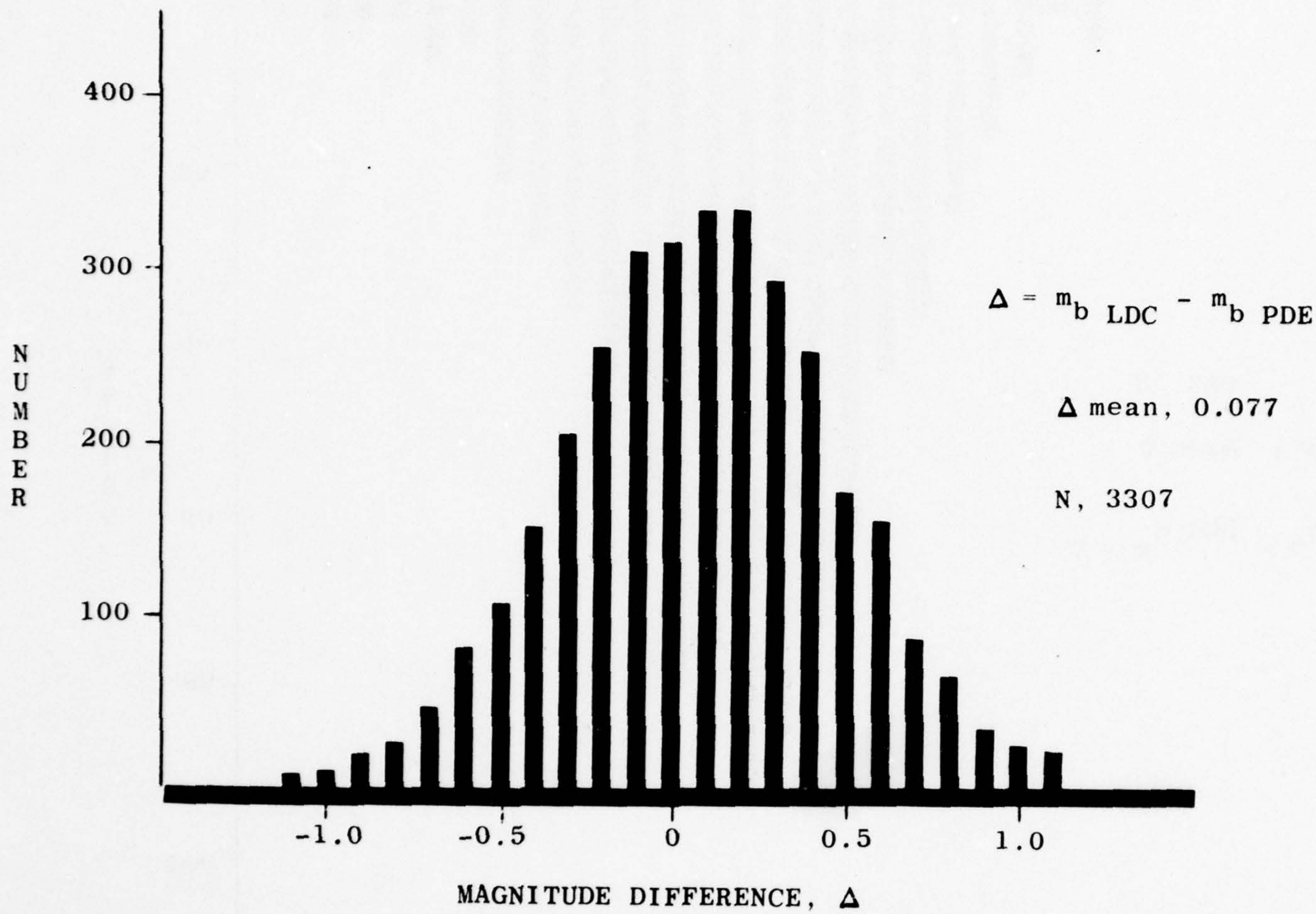

Figure 3.5 Magnitude Difference Between LASA and PDE Calculations, JUL 1, 1975-MAR 31, 1978

There were no changes in our local procedures in determining the magnitude estimate during this reporting period.

4. Detection Threshold

We are continuing our estimates of the detection threshold of our daily teleseismic reports. The data base of 5980 event magnitudes now extends from July 1, 1975, through March 31, 1978, a 2 3/4-year period. Noting that variation in seismicity from a particular region can influence the estimated thresholds when a limited number of events is used in the calculations, we hope to build a consistent data base for determining threshold values. By periodically updating our statistics, we hope to recognize when the data reaches a degree of consistency and to improve our confidence in the use of the cumulative event detection measurement method.

We now estimate the 90% and 50% detection thresholds at 5.08 and 4.82, respectively (See Figure 3.6). Again, the measurement method used a least squares fitted straight line (determined by SR-52 calculator) through the cumulative log frequency-magnitude distribution from the highest magnitude value to the 0.1 magnitude unit above the value that the incremental magnitude distribution begins to decrease, viz., 4.7. The 90% and 50% detection thresholds are those magnitudes at which the actual number of events falls 10% and 50%, repsectively, below the level predicted by the extrapolation of the straight-line, frequency-magnitude distribution towards the lower magnitudes. The equation

$$\log N = 9.40 - 1.19\ m_b$$

defines the straight line used with this data set.

These threshold detection values are based on only the body-wave magnitudes (m_b) calculated at LASA. Since the LASA m_b values are somewhat higher than the USGS PDE calculations as shown earlier in Figure 3.5, a bias of 0.08 m_b units might be subtracted from the thresholds. Considering this correction, the 90% and 50% detection thresholds become 5.00 and 4.74 respectively.

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 8708 the average mean sensitivity of the 210 LASA SP seismographs was 20.11 mV/nm at one-second periods with the average standard deviation being 0.82 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 IX.

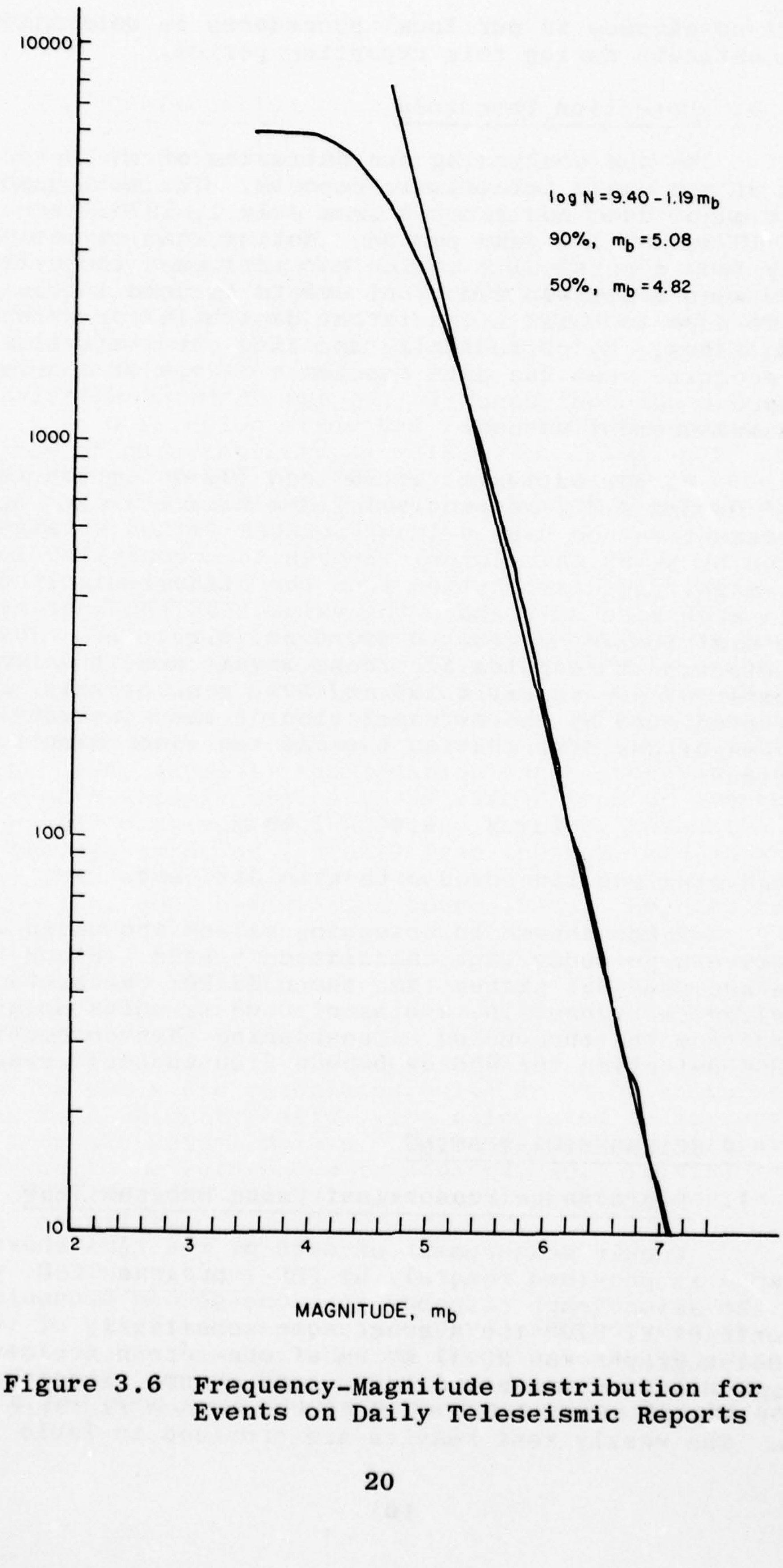

Figure 3.6 Frequency-Magnitude Distribution for Events on Daily Teleseismic Reports

TABLE IX

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

1977 DATE	SENSORS	MEAN	STD DEV	MAX	MIN	MAX DEV
10/02	210	20.35	0.78	22.99	17.16	5.83
10/09	210	20.27	0.74	22.71	17.04	5.67
10/16	210	20.30	0.83	23.15	17.19	5.96
10/23	210	20.33	0.79	22.93	17.17	5.76
10/31	210	20.35	0.76	22.71	17.21	5.50
11/06	210	20.25	0.85	22.67	17.60	5.07
11/15	210	20.32	0.93	22.67	17.24	5.53
11/21	NO TESP AVAILABLE					
11/28	210	20.30	1.00	24.44	17.94	6.50
12/07	210	20.26	1.15	23.30	15.77	7.53
12/12	210	20.27	1.00	22.50	15.42	7.08
12/19	209	20.31	0.98	22.53	16.55	5.98
12/25	210	20.23	1.03	23.52	15.96	7.56
01/02	209	20.11	0.82	22.53	16.74	5.80
01/09	210	19.97	0.95	22.81	16.96	5.85
01/16	210	19.88	0.82	22.87	17.02	5.85
01/23	210	19.96	0.76	22.83	17.02	5.81
01/30	210	19.83	0.79	22.03	14.93	7.10
02/06	209	19.84	0.59	21.49	17.63	3.86
02/13	209	19.94	0.61	21.56	17.62	3.94
02/20	193	19.94	0.60	21.50	17.40	4.10
02/27	210	19.90	0.69	21.51	15.37	6.14
03/06	209	20.11	0.82	22.53	16.74	5.80
03/13	210	19.93	0.72	21.61	14.89	6.72
03/20	210	19.97	0.65	21.68	17.36	4.32
03/27	210	19.89	0.80	22.25	16.51	5.74
VT8708 AVERAGE	209.1	20.11	0.82	22.53	16.74	5.80

The past three contract averages along with those of the current contract are summarized in Table X. 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:

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

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. Broadband Response Using Program 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 XI. Response data was collected using RPGONE on March 8, 1978. Array off-line processing using RPGTWO provided the results for the array shown in Table XII.

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 first six months of the current contract the weekly mean sensitivities of the LP seismographs averaged 359.9 mV/μm. Table XIII gives the weekly test results. This average is compared with previous contract periods in Table XIV. 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:

TABLE X

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 8708 Contract Average	209	20.11	0.82	22.53	16.74	5.80
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 XI

SP SEISMOGRAPH GAIN FREQUENCY RESPONCE TOLERANCES

FREQUENCY (HERTZ)	GAIN MAXIMUM (DB)	GAIN MINIMUM (DB)
0.07874	-29.43	-34.43
0.15740	-16.65	-21.65
0.23622	-11.30	-16.30
0.31496	-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 XII

RESULTS OF SP SEISMOGRAPH BROADBAND RESPONSE TESTING

Seismograph Response	Number MAR 77 Test	Number SEP 77 Test	Number MAR 78 Test
Within Tolerance	91	101	108
Improper Low Frequency			
High Amplitude	6	11	6
Low Amplitude	5	2	4
Improper High Frequency			
High Amplitude	11	9	0
Low Amplitude	2	0	3
Improper Low/High Frequency			
High Amplitude	1	0	0
Low Amplitude	1	0	0
Low/High	3	3	2
High/High	0	2	1
Low/Low	0	1	2
Not Tested	10	1	4
No. SP Sensors	130	130	130

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TABLE XIII

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

1977 DATE	SENSORS	MEAN	STD DEV	MAX	MIN	MAX DEV
10/02	27	350.0	14.09	383.28	315.55	67.73
10/09	27	351.3	17.24	391.41	313.83	77.58
10/16	27	352.1	15.95	384.18	313.83	70.35
10/23	27	350.6	19.43	403.56	312.78	90.78
10/31	27	349.4	16.01	387.65	312.78	74.87
11/06	27	355.2	20.93	407.95	312.78	94.17
11/14	27	355.4	19.48	395.09	318.30	76.79
11/21	NO TELP AVAILABLE					
11/28	27	362.6	19.62	404.67	314.89	89.78
12/05	27	366.4	19.54	404.67	314.89	89.78
12/12	26	367.6	18.46	407.66	325.05	82.61
12/19	27	368.3	18.12	411.29	327.16	84.13
12/25	25	363.0	15.20	390.53	326.10	64.43
01/02	27	359.9	18.62	398.65	313.83	84.77
01/09	27	362.3	16.95	396.24	320.83	75.41
01/16	26	363.1	17.62	401.04	317.66	83.38
01/23	27	361.9	17.79	397.38	316.61	80.77
01/30	27	361.9	18.99	396.24	314.49	81.75
02/06	27	362.3	19.16	402.17	315.55	86.62
02/13	27	363.5	18.70	397.62	313.44	84.18
02/20	26	354.2	33.19	398.52	22[illegible].38	173.14
02/27	27	360.7	18.45	399.90	315.55	84.35
03/06	27	359.9	18.62	398.65	313.83	84.77
03/13	27	363.3	17.27	396.24	320.83	75.41
03/20	27	365.7	18.62	405.32	322.94	82.38
03/27	27	365.9	17.54	406.34	326.93	79.41
VT8708 AVERAGE	26.8	359.9	18.62	398.65	313.83	84.77

TABLE XIV

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 8708 Contract Average	27	359.9	18.62	398.65	313.83	84.77
VT 7708 Contract Average	24	345.1	19.2	384.60	302.7	81.9
VT 6708 Contract Average	25	339.9	19.2	383.90	294.9	89.0
VT 4708 Contract Average	26	337.4	18.2	376.70	297.9	78.8
VT 2708 Contract Average	22	347.0	16.0	382.60	319.0	63.6

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

where S = LP Channel Sensitivity at period T in seconds
M = LP Seismometer moving mass in kilograms
E_e = 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 XV where the remote adjustments for both mass positioning (since 6 DEC 71) and free period correction (since 2 JAN 73) are shown and total 2257. The mean-time-between-adjustment (MTBA) for each seismometer is shown and varies from 12.44 days for sensor D1 N/S to 82.61 days for sensor D3 E/W. The average MTBA for the array is 1.20 days and for a seismometer is 32.53 days.

3. LP Seismograph Magnification Curves

Magnification response measurements on the LASA LP system seismographs began in September 1977. These measurements provide magnification response curves for the LASA LP seismometers combined with the LDC's MDC chart recorder at a gain setting of 6.25 mV/mm. Curves are available for 15 of the 27 LP sensors, viz., those at subarrays C2, C4, D1, D2, and D4. The magnification curve for the D4 LP vertical sensor shown in Figure 3.7 is typical of this data set.

The system sensitivity response curves of the LASA SP and LP seismographs, such as those shown in Figure 3.8, can be converted to magnification curves by combining sensitivity of the recorder used in the seismogram playout as described in Appendix A. Note the similarity in the results obtained from the two different measurement methods.

E. NOISE

Array noise is being measured from both the SP and LP array sensors. Previously these measurements were made on an intermittant basis to collect noise samples from the array. A new version of our Auto-Edit on-line event edit recording program completed in November now allows a measurement of the average noise level of the SP and LP sensors every 15 minutes. The short-term data collected from this system show an average zero-to-peak SP (1.0 Hz) noise level variation of 5.7 nm from the array 13 subarray analog summation signals and an average zero-to-peak LP (25 sec) level variation of 46 nm from the 9 vertical instruments, 124 nm from the 9 N/S horizontals, and 110 nm from the 9 E/W horizontals. These data are being incorporated into our long-term measurements.

TABLE XV

LP SEISMOMETER REMOTE ADJUSTMENTS

	MASS POSITION ADJUSTS			FREE PERIOD ADJUSTS			COMBINED ADJUSTMENTS		
	10/77 TO 04/78	12/71 TO 04/78	AVG DAYS-BETWEEN ADJUSTS	10/77 TO 04/78	01/73 TO 04/78	AVG DAYS-BETWEEN ADJUSTS	10/77 TO 04/78	LONG TERM	AVG DAYS-BETWEEN ADJUSTS
A0 V	2	51	45.35	2	17	136.06	4	68	34.01
A0 NS	5	43	53.79	5	24	96.38	10	67	34.52
A0 EW	1	61	37.92	1	10	231.30	2	71	32.58
C1 V	3	53	43.64	2	17	136.06	5	70	33.04
C1 NS	3	52	44.48	1	23	100.57	4	75	30.84
C1 EW	1	51	45.35	1	16	144.56	2	67	34.52
C2 V	4	63	36.71	2	18	128.50	6	81	28.56
C2 NS	1	74	31.26	0	44	52.57	1	118	19.60
C2 EW	4	103	22.46	3	18	128.50	7	121	19.12
C3 V	1	80	28.91	1	4	578.25	2	84	27.54
C3 NS	1	81	28.56	0	12	192.75	1	93	24.87
C3 EW	1	86	26.90	0	11	210.27	1	97	23.85
C4 V	1	60	38.55	0	4	578.25	1	64	36.14
C4 NS	1	30	77.10	1	10	231.30	2	40	57.83
C4 EW	1	61	37.92	0	2	1156.50	1	63	36.71
D1 V	3	49	47.20	1	11	210.27	4	60	38.55
D1 NS	7	146	15.84	6	40	57.83	13	186	12.44
D1 EW	2	111	20.84	0	13	177.92	2	124	18.65
D2 V	5	68	34.01	3	10	231.30	8	78	29.65
D2 NS	3	55	42.05	1	3	771.00	4	58	39.88
D2 EW	1	85	27.21	0	3	771.00	1	88	26.28
D3 V	2	83	27.87	0	5	462.60	2	88	26.28
D3 NS	1	36	64.25	1	12	192.75	2	48	48.19
D3 EW	0	21	110.14	0	7	330.43	0	28	82.61
D4 V	1	62	37.31	0	7	330.43	1	69	33.52
D4 NS	6	146	15.84	4	34	68.03	10	180	12.85
D4 EW	2	52	44.48	3	13	177.92	5	65	35.58

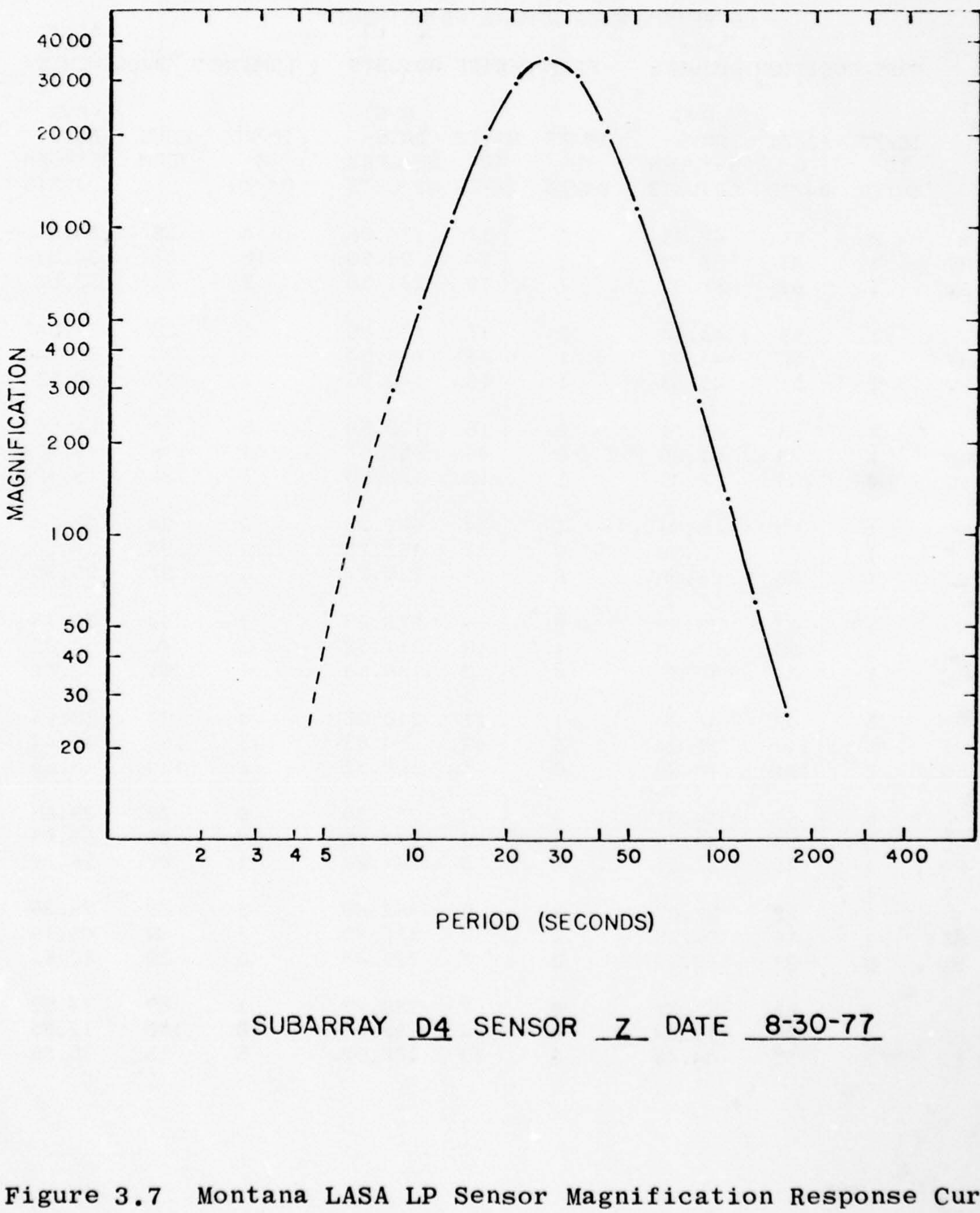
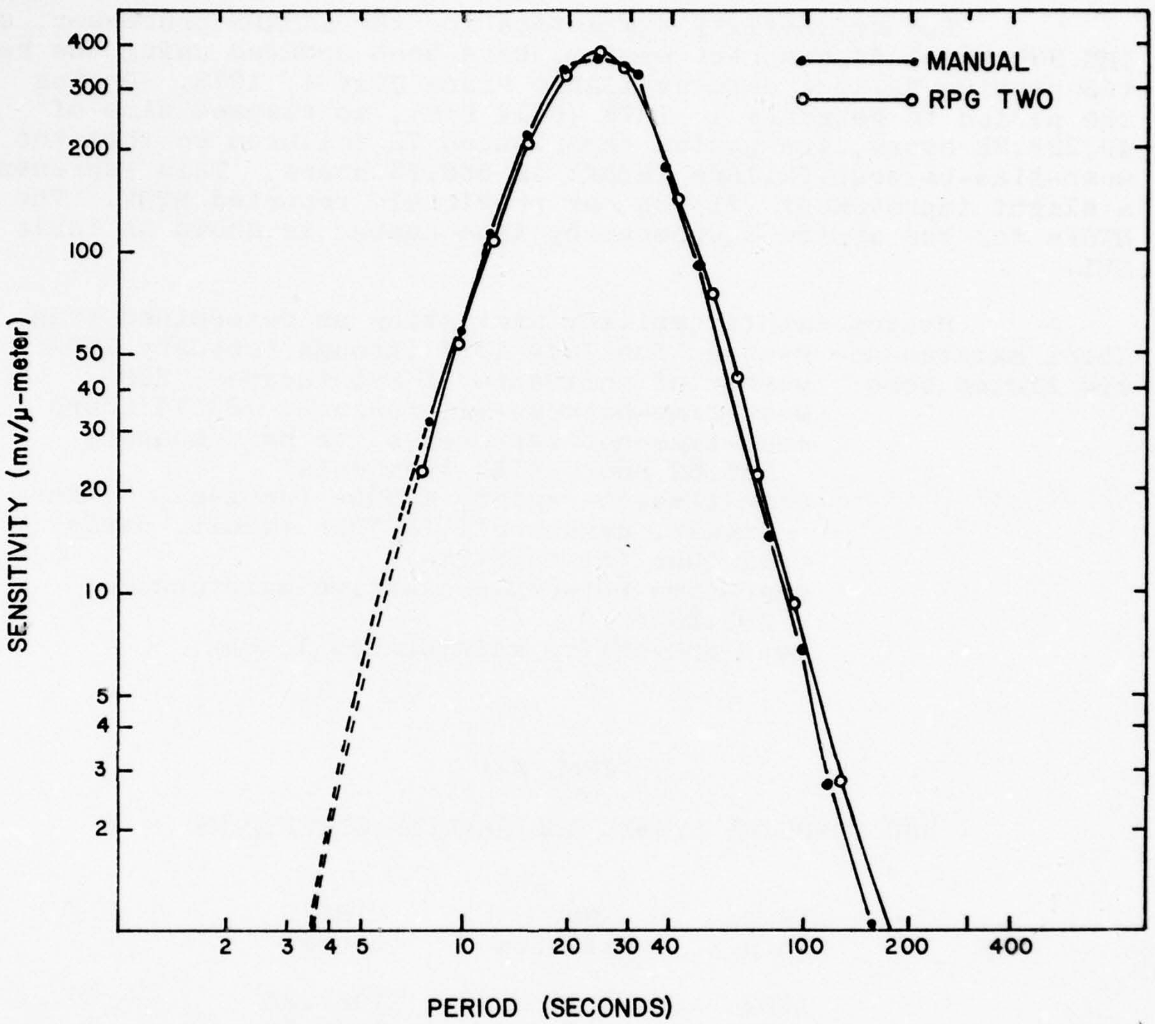


Figure 3.7 Montana LASA LP Sensor Magnification Response Curve



SUBARRAY C2 SENSOR Z DATE 11-9-77

Figure 3.8

MONTANA LASA LP SENSOR SENSITIVITY RESPONSE CURVE

F. 360 COMPUTER RELIABILITY

The reliability statistics for the LASAPS processor, an IBM 360 Model 44 computer system, have been updated using the retrospective failure data available since July 1, 1973. During the period to February 1, 1978 (0414 UTC), an elapsed time of 40,228.23 hours, the system experienced 72 failures so that the mean-time-between-failure (MTBF) is 558.73 hours. This represents a slight improvement (2%) on our previously reported MTBF. The MTBFs for the system equipment by type number is shown in Table XVI.

System maintainability statistics as determined from local maintenance records for July 1973 through February 1978 are listed here:

- number of incidents of maintenance, 219
- mean-time-between-maintenance, 186.74 hours
- mean-time-between-corrective maintenance, 355.62 hours (115 incidents)
- mean-time-to-repair, 4.89hr (active), 5.89hr (await. personnel), 0.72hr (await. parts), 11.50hr (cm downtime)
- mean-time-between-preventive maintenance, 393.23hr
- mean preventive maintenance 1.46hr.

TABLE XVI

360 COMPUTER SYSTEM RELIABILITY STATISTICS

Type Equip.	No. Failures	MTBF (hours)
1052	37	1087.25
CPU	22	1828.56
SDSD	6	6704.71
1826	3	13409.41
2501	2	20114.12
2701	1	40228.23
1827	1	40228.23
System	72	558.73

Of the total 115 incidents of corrective maintenance, 25 or 21.7% occurred after normal working hours. This increased the system downtime while awaiting maintenance personnel. In the majority of cases the downtime was extended until normal working hours. The average period awaiting personnel has been 26.5 hours. This unusually high figure results from the accumulated awaiting personnel time associated with an extended corrective maintenance incident, i.e., maintenance quitting for the day and not returning until the next morning. Four incidents of extended downtime while awaiting for parts have occurred. Parts are usually flown into Billings from Seattle. The total maintenance downtime (MDT) statistics for July 1973 through February 1978 are summarized below:

corrective maintenance time,	552.39hr	(115 incidents)
awaiting personnel time,	661.86hr	(25)
awaiting parts time,	77.91hr	(4)
preventive maintenance time,	152.24hr	(104)
MDT,	1444.40hr	(219)

MDT represents 3.53% of the time available. In percentage, the MDT divides into: cm 38.2%; await. pers. 45.8%; await. parts 5.4%; and pm 10.6%.

The incident of failure according to equipment category is shown in Table XVII. This breakdown is based on the 72 failures identified during this 56-month period.

TABLE XVII

CLASSIFICATION OF IBM 360 SYSTEM FAILURES
(1 Jul 73 - 28 Feb 78)

360/44 System Equipment	Number of Failures
2044-G Processing Unit	23
CPU: Cycle Control	0
Storage Address Register (SAR)	2
Storage Data Register (SDR)	2
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
Cooling Fan	1
Single Disc Storage Device: Disc	7
Disc Control	0
Disc IF Control	0
Assembly	1

TABLE XVII (CONCLUDED)

	Number of Failures
1052-7 Printer/Keyboard	39
2501-B1 Card Reader	0
1827-1 Data Control Unit	1
1826 Data Adapter Unit	3
Address Decode	1
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 programming activity during the six-months period supported LDC operations by (1) updating our Auto-Edit patch program to include data for noise, and the capabilities of on-line tape duplication and (2) updating RPG I and RPG II for an expanded frequency response. The programs completed during the period are listed in Table XVIII.

TABLE XVIII

PDP-7 PROGRAMMING ACTIVITY

October 77 - March 78

PROGRAM	VERSION	BY	APPROVED
Auto-Edit	VL5	Potter	11/77
RPG I	VL4	Lidderdale	11/77
RPG II	V6	Lidderdale	11/77
DGAV	V1	Lidderdale	1/78
LIST EP 77	VL1	Lidderdale	3/78
CAL LP	VL1	Potter	3/78
Noise Data Analysis	VL1	Potter	3/78

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 at both LMC and LDC, checkout of all stand-by array spares, construction of a trace multiplexer for a scope-modified Develocorder, repair of teletypewriters, IBM-360 repairs, and limited array activities December through February due to snow conditions.

A summary of the total maintenance activity is given in Table XIX where the number of work orders actions in the LMC, LDC and utility areas are shown. The completed work orders represent 609 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 248 preventive maintenance routines, 115 corrective maintenance, 3 special tests and 18 utility actions. A total of 99 items of equipment were repaired in the LMC and LDC shops. The 18 utility work orders consisted of 9 repairs of facilities, and 9 vehicle inspections.

B. DATA CENTER

A total of 231 work orders were completed for 329 maintenance actions plus 22 repairs in the shop. Table XX provides a breakdown of the LDC maintenance actions by system and month.

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 16 repairs on the system and 9 preventive maintenance actions.

TABLE XIX

SUMMARY - WORK ORDERS

OCTOBER 1977 - MARCH 1978

WORK ORDER TYPE	BACKLOG START OF PERIOD	INITIATED	COMPLETED	BACKLOG END OF PERIOD
LMC				
SYSTEM -A	13	157	158	12
SUBASSEMBLY-B	44	37	66	15
COMPONENT -C	2	13	12	3
TOTALS	59	207	236	30
LDC				
SYSTEM -A	16	202	209	9
SUBASSEMBLY-B	1	2	2	1
COMPONENT -C	36	0	20	16
TOTALS	53	204	231	26
UTILITY	3	30	18	15
COMBINED TOTALS	115	441	485	71

TABLE XX

DATA CENTER MAINTENANCE ACTIONS

OCTOBER 1977 - MARCH 1978

	OCT	NOV	DEC	JAN	FEB	MAR	TOTALS
360							
CORRECTIVE	0	3	2	3	4	4	16
PREVENTIVE	0	2	4	1	0	2	9
PDP-7							
CORRECTIVE	8	2	3	5	5	6	29
PREVENTIVE	28	22	25	25	22	31	153
DIGITAL							
CORRECTIVE	0	0	0	1	0	2	3
PREVENTIVE	4	4	5	4	4	6	27
ANALOG							
CORRECTIVE	3	2	2	1	2	3	13
PREVENTIVE	1	0	0	0	0	0	1
TEST AND SUPPORT							
CORRECTIVE	4	4	4	11	1	5	29
PREVENTIVE	4	6	3	2	8	3	26
TOTALS	52	45	48	53	46	62	306

The operation of the 360 system required 16 repairs during this period and all were completed by LDC personnel. Five of the failures caused downtimes in excess of eight hours. An unusual problem occurred in November when an extended power outage allowed the temperature in the computer room to stay at a very low level. The SDSDA disc would not operate until equalization temperatures were reached. Three of the extended outage troubles were SLT card failures in the CPU. One required extended trouble-shooting time, one was diagnosed quickly but the system remained down until a new SLT card was obtained, and a failure in February occurred during a holiday weekend and repair was delayed until maintenance personnel were located. The 5th extended outage was an SLT card failure in the 1826 input data adapter that resulted in inputs on the CPU data bus at all times. This caused all data and clock inputs to be improper and the trouble was very difficult to isolate.

An intermittant problem in the CPU occurred on three occasions. The system stops with bits 0-15 high from all core locations up to 64K. The trouble always clears itself before the problem can be located.

On four occasions cooling fans have been replaced or repaired. Spares are now maintained in case these mechanical units continue to fail.

Problems in the data lines between SDAC and LASA caused intermittant alarm conditions at the LASA. The system prints out 2701 input errors and indicates the one-second message from SDAC is missing. Occasionally the system program halts and requires IPL. The trouble is isolated by using the test procedures for the 208-L1A data set. The procedures are in AT&T publication Data Set 208A-Type Transmitter-Receiver Test Procedures, Section 592-027-500, Table B and page 3.

Three tests can be performed by the operators at each end of the line that will isolate the problem. The Analog Loop-Back Self Test checks the local data set. The Remote Loop-Back Self Test To Distant End transmits marks to the remote set, looping the marks back to the local receiver, and the End-To-End Self Test has each transmitter send marks to the remote receiver. Failures in all tests are indicated by an ER error light.

One problem was isolated to the LASA data set by the Analog Loop-Back Self Test and the local TELCO contacted for repair.

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 29 repairs and 153 preventive maintenance actions. The repair distribution follows: tape units, 14; teletypewriters, 9;

line printer, 2; paper tape reader, 2, and CPU, 2. The tape unit failures were all minor in nature and the only serious problems were the teletypewriters.

We have an ASR-35 on-line with the PDP-7 computer with a KSR-35 and ASR-33 as spares. During this period all three experienced mechanical failures that required extensive repairs. Most of the problems were worn clutches in the printer assemblies. The ASR-35 was overhauled and is now on line, the ASR-33 was repared and is now the backup unit, and the KSR-35 is waiting for parts. No further problems are anticipated with the teletypewriters.

3. Other LDC Systems

The other systems maintained at the LDC are the Digital, Analog, and Test and Support systems. There were 3 repairs and 27 preventive maintenance actions performed on the Digital System. An inverter failure was caused by a defective lamp holder in the meter relay. This was locally repaired and caused no further trouble.

Thirteen troubles and one PM were required for the Analog System. The troubles were mostly minor problems with the Develocorders. Work continues on the 14 bit D/A channels used for LP signals. The interface cards were all repaired of damage caused by heat in the data display baskets. These cards were the only discrete component assemblies in these drawers and generated enough heat to cause circuit damage. A cooling fan has been installed in this rack (D/A #1) that flows air over these cards. There are 9 other channels in this rack that require further maintenance but enough are operating at present to operate the LP Develocorder.

A 16-channel multiplexer system has been designed and fabricated to interface the D/A with a modified LP Develocorder. This Develocorder has a CRT in place of a galvo block. The multiplexer provides a 16 step staircase signal to the CRT, through it's oscilloscope circuits, with each step representing the dc level of an input channel. The CRT display is 16 dots, aligned on the vertical axis, whose positions represent the individual channel dc levels at that time. There is no horizontal sweep. The Develocorder records the dots in the same manner as a galvo block display. The system has worked well in a mock-up and will be installed in the Develocorder rack, on-line, in the near future.

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 55 maintenance actions on this system, 29 were corrective and 26 were for preventive maintenance. Nineteen of the corrective actions were the replacement of the bias batteries in MDC #1 and are an expected consumption. The other 10 repairs were minor problems.

C. MAINTENANCE CENTER

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

LMC personnel completed 236 work orders representing 262 separate maintenance actions plus 77 items repaired in the shop. The array work orders included 25 corrective maintenance, 130 preventive maintenance, and 3 special tests.

1. Array Activities

Table XXI shows the array maintenance actions by system and month. To accomplish this maintenance, 61 visits to CTH's and 9 visits to WHV's were made. This required 53 trips to the field plus 3 trips to the Malmstrom AFB, PMEL and covered 9,290 miles. The array corrective actions included 9 on SP channels, 13 LP circuits, 2 power system repairs, and 5 on SEM units.

The winter road conditions in the array were the worst encountered in the LASA history. Travel was very limited every month except October. The snow tractor was used on all trips in January, February, and March. Only subarray B4 was visited in February and cross country skis were used from the road to the vault.

The snow started melting in late March and fortunately the melt was gradual with freezing temperatures every night. Subarray B2 was the only CTH to accumulate enough water to set off the alarm. The vault was pumped and dried out without any damage. About a gallon of water was cleaned up at subarray D1 without any damage. At the end of this reporting period all other CTH's were without damage problems.

The LP tanks in the vaults at subarrays AO, C1, C3, and D3 were dried out in October. Moisture had accumulated over a three-year period and caused calibration and signal level problems due to moisture across signal and calibration line terminal strips and connectors. Drying the vault and tanks with forced air and replacing all silica-gel eliminates the problem.

2. Shop Activities

The extent of the shop work is summarized in Table XXII. The emphasis at LMC was the checkout of all standby spare SEM assemblies and repair of RA-5 amplifiers. Thirty RA-5 amplifiers will be maintained in field-ready condition while the others will have the batteries removed. This will eliminate battery corrosion and deterioration in storage. At the LDC,

TABLE XXI

ARRAY MAINTENANCE ACTIONS

OCTOBER 1977 - MARCH 1978

	OCT	NOV	DEC	JAN	FEB	MAR	TOTALS
SP							
CORRECTIVE	1	1	1	2	0	4	9
PREVENTIVE	22	18	13	13	1	11	78
LP							
CORRECTIVE	6	3	3	0	0	1	13
PREVENTIVE	0	0	0	0	0	0	0
SEM							
CORRECTIVE	2	2	0	0	1	0	5
PREVENTIVE	9	6	3	6	0	6	30
POWER							
CORRECTIVE	0	0	1	0	0	1	2
PREVENTIVE	9	6	3	6	0	6	30
WEATHER STATION							
CORRECTIVE	0	0	0	0	0	0	0
PREVENTIVE	0	0	0	0	0	0	0
TOTALS	49	36	24	27	2	29	167

TABLE XXII

EQUIPMENT SHOP REPAIR SUMMARY

OCTOBER 1977 - MARCH 1978

	OCT	NOV	DEC	JAN	FEB	MAR	TOTALS
SEM ASSEMBLIES	1	0	1	0	24	1	27
SP ASSEMBLIES	1	10	10	14	0	1	36
LP ASSEMBLIES	0	0	0	0	2	0	2
POWER ASSEMBLIES	0	0	0	0	0	0	0
OTHER ASSEMBLIES	1	0	0	1	0	2	4
CARD REPAIRS	4	0	4	0	20	3	31
TOTALS	7	10	15	15	46	7	100

repairs included the overhaul of 20 D/A driver cards from the 14-bit LP channels in the analog system.

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, 50 contacts were made to deliver lease checks, discuss subarray access trails, and other matters concerning the land use.

2. Land and Facilities Maintenance

The amount and type of utility work engaged in at the LMC is shown in Table XXIII. The 18 completed work orders show 9 facility repair/inspections, and 9 vehicle maintenance/ inspections. The road conditions during this report period prevented any repairs in the array. Site inspections will start in April to determine the condition of the array.

The local power company and fire department inspected the LMC facility in Miles City and found all building equipment satisfactory.

3. Vehicles

The mileage driven during this period in support of the LASA totalled 11,511 miles without any accidents.

TABLE XXIII

SUMMARY - UTILITY WORK ORDERS

OCTOBER 1977 - MARCH 1978

WORK ORDER TYPE	BACKLOG START OF PERIOD	INITIATED	COMPLETED	BACKLOG END OF PERIOD
CABLE TRENCH AND TRAIL INSPECTION	0	13	0	13
CABLE TRENCH BACKFILL	0	0	0	0
WHV SITES LANDSCAPED	0	0	0	0
MARKER POST OR WHV COVERS REPLACED	0	2	0	2
CTH MAINTENANCE	0	6	6	0
VEHICLE MAINTENANCE INSPECTION	0	9	9	0
FENCE INSPECTION	0	0	0	0
TRAIL REPAIRS	0	0	0	0
LMC FACILITY MAINTENANCE	3	0	3	0
TOTALS	3	30	18	15

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 first six months of this project:

1. "Semi-Annual Technical Report 1 April 1977 - 30 Septemper 1977" T/R 21450-77-99 (AD-A041 037) 28 Oct 1977
2. "Montana LASA Operation Report for October 1977" T/R 2145-77-100, 7 Nov 1977.
3. "Montana LASA Operation Report for November 1977" T/R 2145-77-101, 6 Dec 1977.
4. "Montana LASA Operation Report for December 1977" T/R 2145-78-102, 10 Jan 1978.
5. Gress and Matkins. "South American Event Detection Study" T/R 2145-78-103, 10 Jan 1977.
6. "Montana LASA Operation Report for January 1978" T/R 2145-78-104, 6 Feb 1978.
7. "Montana LASA Operation Report for February 1978" T/R 2145-78-105, 6 Mar 1978.
8. "Montana LASA Operation Report for March 1978" T/R 2145-78-106, 11 Apr 1978.

CONCLUSIONS

Operation and maintenance performed at the Montana LASA during the past six months allows us to conclude:

1) That the LASAPS operation as observed from the LASA end of the transcontinental data was again successful during this period. The goal of 95% data availability was met while both the maintenance premium time and IBM customer engineering assistance was at an historic low.

2) That the LASA Inner Array Recording System, which operated 97.3% of the period, handled the array monitoring, calibration, event detection and processing without interferring with the data recording.

3) That the Montana array systems continue to meet their expected performance levels. No decrease in the reliability of the 360 computer system has been observed.

4) That the teleseismic and near-regional event processing incorporated into the data center's daily activities continue to be important to our insuring the array is operating as an effective seismic observatory.

RECOMMENDATIONS

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

1) That data set tests be performed by SDAC and LASA operators when the 4800 baud transcontinental data line does not appear to operate properly.

2) That the LP seismometer tanks be routinely dried out at a two-year interval.

3) That the results of our 12-month region study be analyzed further to determine the detection threshold of each region.

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 A

RELATIONSHIP BETWEEN SEISMOGRAPH MAGNIFICATION AND SENSITIVITY VALUES

The LASA seismograph frequency response curves are usually plotted in system sensitivity vs period. System sensitivity is used instead of magnification because typically the array's seismometer data is collected in digital form for playout on a variety of seismograph recorders both locally and remote from the array. When combined with the LASA data, each seismograph recorder has its own magnification value. Magnification curves can be prepared from the LASA system sensitivity curves if the sensitivity of the recorder system is known.

The magnification, M, of a seismograph system is defined as

$$M = \frac{A_o}{Y} \qquad (1)$$

where A_o is the displacement amplitude at the seismograph output for a displacement amplitude Y at the input of the seismometer

The system sensitivity, S_s, of a seismometer-amplifier combination is given by

$$S_s = \frac{A_v}{Y} \qquad (2)$$

where A_v is the amplitude of voltage output of the amplifier resulting from a displacement amplitude Y at the input of the seismometer

Next, the sensitivity, S_r, of the recorder-playout system is given by

$$S_r = \frac{A_o}{A_v} \qquad (3)$$

where A_o is the displacement amplitude at the seismograph output for an input voltage A_v.

The magnification, M, can be expressed in terms of the sensitivities given in equations (2) and (3) by

$$M = S_s \cdot S_r \quad (4)$$

Since $M = S_s \cdot S_r = \frac{A_v}{Y} \cdot \frac{A_o}{A_v} = \frac{A_o}{Y}$

Magnifications for the twelve recording scales available at the LDC's maintenance display console are given for both the LASA-SP and LASA-LP seismograph systems as determined by equation (4). The six recorder gain scales are doubled by using either the 10 most-significant bits (MSB) of the 14-bit LASA data word or the 10 least-significant bits (LSB). The value of one LASA bit is 0.8545mV. Magnifications for other recording systems which play-out LASA SP and LP data can be obtained using this same equation with the LASA system sensitivity values, which are 20 mV/nm at 1.0 sec and 350 mV/μm at 25.0 sec for the SP and LP seismographs respectively.

TABLE A-1

LASA SEISMOGRAPH MAGNIFICATION VALUES

(for use with the MDC 8-channel chart recorder)

SP Seismographs: S_s = 20± 3mV/nm at 1.0 sec.

Recorder Scale Position MSB	SP Sensitivity, mV/nm 17	20	23	Recorder Scale Position LSB	SP Sensitivity, mV/nm 17	20	23
20	48.6K	57.1K	65.7K	20	777 K	914 K	1.05M
10	97.1K	114 K	131 K	10	1.55M	1.83M	2.10M
5	194 K	229 K	263 K	5	3.11M	3.65M	4.21M
2	486 K	571 K	657 K	2	7.77M	9.14M	10.5M
1	971 K	1.14M	1.31M	1	15.5M	18.3M	21.0M
.5	1.94M	2.29M	2.63M	.5	31.1M	36.6M	42.0M

LP Seismographs: S_s = 350±50 mV/μm at 25.0 sec.

Recorder Scale Position MSB	LP Sensitivity, mV/μm 300	350	400	Recorder Scale Position LSB	LP Sensitivity, mV/μm 300	350	400
20	857	1.00K	1.14K	20	13.7K	16.0K	18.3K
10	1.71K	2.00K	2.29K	10	27.4K	32.0K	36.6K
5	3.43K	4.00K	4.57K	5	54.9K	64.0K	73.1K
2	8.57K	10.0K	11.4K	2	137 K	160 K	183 K
1	17.1K	20.0K	22.9K	1	274 K	320 K	366 K
.5	34.3K	40.0K	45.7K	.5	549 K	640 K	731 K

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LASA - Large Aperture Seismic Array
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20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)
The continued operation, maintenance and array improvement activities at the Montana LASA during the period between October 1, 1977 and March 31, 1978, are described. Array operations including the preparation of daily teleseismic event reports are detailed. Results of the seismic event processing effort are reported. Seismograph system performance measurements are

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BLOCK 20

presented. Maintainability statistics on the IBM 360 Model 44 computer are given. Program maintenance for the PDP-7 computer system is indicated. Maintenance activities at both the data and maintenance centers are discussed.