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MONTANA LARGE APERTURE SEISMIC ARRAY

Robert E. Matkins

Philco-Ford Corporation

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THIRD QUARTERLY TECHNICAL REPORT, PROJECT VT 2708

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1 JUNE 1972 - 31 August 1972

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This report relates the technical activity associated with the operation, maintenance, and improvement of the Montana Large Aperture Seismic Array (LASA) during the period 1 June - 31 August 1972. The short-period (SP) and long-period (LP) seismograph sensitivity performance statistics are indicated. Performance data on the SP seismometer and LP seismic amplifier are presented. Initiation of an array surficial noise study is discussed. Improvement of the operating efficiency of the PDP-7 computer's on-line system program is described. Progress with the installation of the SP channel CTH gain control modification is reported. Statistics relating to the operation and maintenance of the array and data center equipment and land facilities support are provided.

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ACRONYMS

AC	Accumulator
ACC	Auxiliary Conditioning and Control
ADC	Analog to Digital Converter
AFSC	Air Force Systems Command
BCD	Binary Coded Decimal
ARPA	Advanced Research Projects Agency
ASCII	American Standardized Code II
CTH	Central Terminal Housing
D/A	Digital to Analog
DCASD	Defense Contract Administration Services District
DEC	Digital Equipment Corporation
EDP	Electronic Data Processing
IRSPS	Integrated Seismic Research Signal Processing System
IOT	Input Output Transfer
LASA	Large Aperture Seismic Array
LASAPS	LASA Processing Subsystem
LDC	LASA Data Center
LMC	LASA Maintenance Center
LP	Long-Period
MDC	Maintenance Display Console
MET	Meteorological Equipment
MINS	Manual Input System
MIT	Massachusetts Institute of Technology
MOPS	Multiple On-line Processing System
PC	Printed Circuit

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PDC	Power Distribution and Control
PLINS	Phone Line Input Systems
PMEL	Precision Measurement and Equipment Laboratory
RIM	Read in Mode
SAAC	Seismic Array Analysis Center
SDL	Seismic Data Laboratory
SEM	Subarray Electronics Module
SOU	Serial Output Unit
SP	Short-Period
TC	Telemetry Command
TELCO	Telephone Company
TFSO	Tonto Forest Seismological Observatory
TI	Texas Instrument
VLR	Very Low Rate
VSC	VELA Seismological Center
WHV	Well Head Vault

INTRODUCTION

This report presents the accomplishments and administration of Contract Number F33657-72-C-0390. This contract between the Philco-Ford Corporation and AFSC Aeronautical Systems Division is for continued operation, research, and development of the Montana Large Aperture Seismic Array (LASA).

The LASA is part of the Vela Uniform Program which is sponsored by the Advanced Research Projects Agency (ARPA) of the Department of Defense. LASA is an experimental system consisting of many seismometers installed near Miles City, Montana, (Figure 1.1) used for the development of appropriate methods for the detection and identification of seismic events. Initially, the detection, location, and identification of seismic data were performed at the LASA Data Center (LDC) located at Billings, Montana. However, subsequent to implementation of the Integrated Seismic Research Signal Processing System (IRSPS), the array data is now transmitted to the Seismic Array Analysis Center (SAAC) in Alexandria, Va., for processing and analysis.

1.1 History

The LASA, installed in Eastern Montana during 1964 and 1965, is used for experiments in advanced seismological detection and discrimination. The initial installation, composed of 21 subarrays geometrically placed at a diameter of 200 kilometers with 525 short-period and 63 long-period seismometers, has evolved into the present array with the original 21 subarrays reduced to 346 short-period seismometers and 51 long-period seismometers.

Philco-Ford's participation in the Montana LASA began in 1964 by providing MIT Lincoln Laboratory with field engineering assistance. In June 1966, Philco-Ford assumed operational and maintenance responsibilities for MIT Lincoln Laboratory. On 1 May 1968, the project direction was transferred to the Electronics Systems Division, AFSC, with prime contracts to Philco-Ford through 30 November 1970.

On 1 December 1970, technical direction of the Montana LASA was assigned to the Vela Seismological Center (VSC). Under Projects V/T 1708 and V/T 2708 Philco-Ford continues the work of previous Montana LASA projects. This work basically involves the continued operation and maintenance of the array and data center systems, logistics and administrative support, data provision, and hardware evaluation and installation.

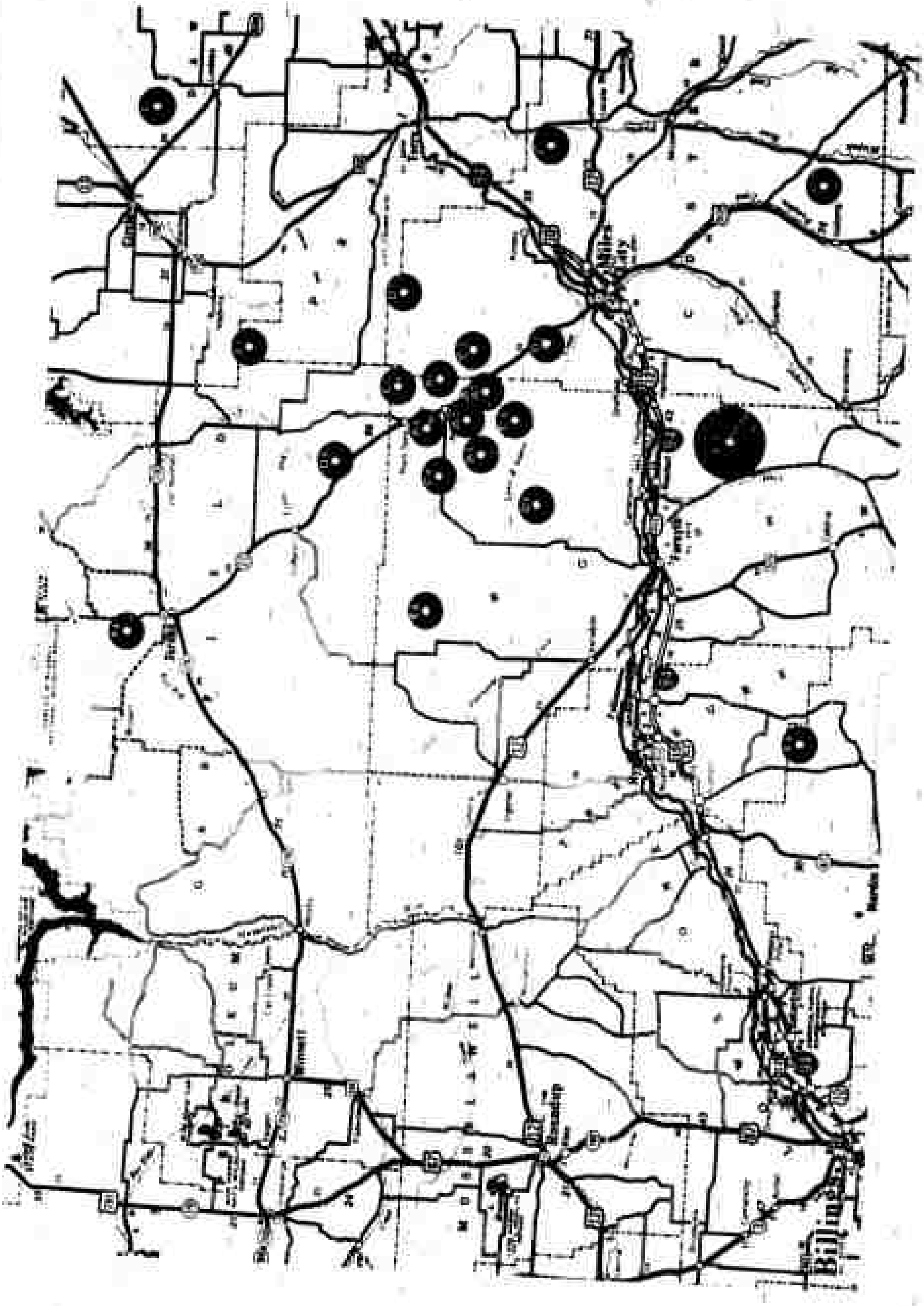


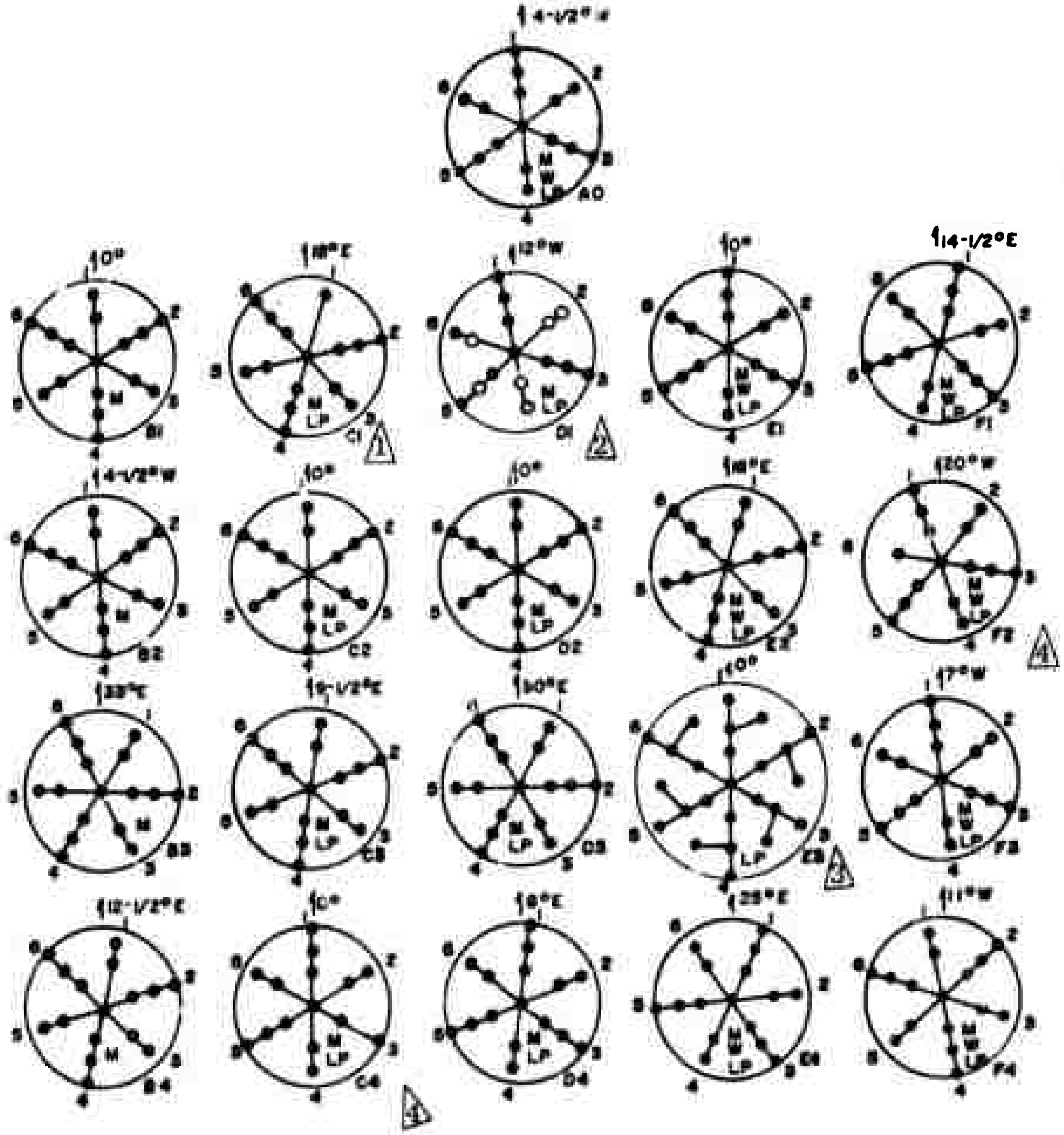
Figure 1.1 Montana LASA

The LASA with an overall diameter of 200 kilometers (124 miles) is composed of 21 subarrays arranged as shown in Figure 1.1. With the exception of subarray E3 which is 19 km in diameter, all subarrays are 7 km in diameter. Subarray E3 is configured with 25 short-period seismometers while others now have 16. All subarrays originally were designed with 25 seismometers each, however, programmed sensor removal has now lowered this number to 16 except at E3. The short-period seismometers are located along six radial cables which terminate in a central under-ground vault containing the Subarray Electronics Module (SEM). The subarrays also contain three-component long-period sensors, and weather sensors. Figure 1.2 shows the present configuration of each subarray.

The LDC controls the array operation by sending a command signal to each SEM at a rate of twenty times each second to cause sampling of the subarray signals. This command signal is suitably delayed at the LDC prior to transmission so that data from all SEM's will arrive at the LDC within predetermined time intervals.

The SEM responds to LDC timing system control signals with signal sampling, conversion, and transmission of all data to the LDC. Flexibility exists within the array in that the SEM can accomodate as many as 30 signal inputs; currently, signals from short and long-period seismometers, weather sensing equipment, and other measured parameters are telemetered. Signals from the 21 SEM's are transmitted to microwave junction points by open wire lines at a 19.2 kilobaud rate; from these points they are sent to the LDC by microwave radio facilities. At the LDC the data are processed and reformatted for transmission over a 50 kilobaud channel to SAAC. The LDC also contains the array timing and maintenance monitoring equipment. By means of telemetry commands, signal sources at the subarray are controlled to provide equipment calibrations and verify equipment performance.

The different LASA seismographs operating parameters and tolerances are identified in Tables I and II. Figure 1.3 shows the five different seismograph responses available.



Notes
1. SP Sensors removed from leg 1 because of access difficulties
2. O denotes near surface SP sensors
3. Expanded subarray, 18 km diameter
4. SP sensor inoperative and lost in cased hole

All degrees shown are orientations with respect to true north. The letters LP, M, and W denote long period seismic, microbarograph, and weather sensors installed at the center of the subarray. Microbarograph data was not available for transmission to SAAC after March 24, 1972.

Figure 1.2 LASA Subarray Configurations

TABLE I

LASA SEISMOGRAPH OPERATING PARAMETERS AND TOLERANCES

CHANNEL IDENT.	OPERATING PARAMETERS AND TOLERANCES				
	T_s	λ_s	(MP_s)	S_{chan}	Full Scale Within
SPZ	1.0±0.1	0.7±0.1		20±3mV/nm@1.0s	609-823nm@1.0s
SPIZ	"	"		"	"
SPTZ	1.15	0.7		"	"
SPTN	1.06	"		"	"
SPTE	1.03	"		"	"
SPAZ	1.0±0.1	0.7±0.1		636±95mV/μm@1.0s	19.2-25.9μm@1.0s
LPZ	20.0±5%	0.77	0±1.5mm	350±50mV/μm@25s	35.0-46.7μm@25s
LPH	"	"	"	"	"
LPAZ	"	"	"	11±1.7mV/μm@25s	1102-1505μm@25s
LPAH	"	"	"	"	"
LPWZ	"	"	"	55±8.3mV/μm@25s	221-300μm@25s
LPWH	"	"	"	"	"

LEGEND: T_s = Seismometer Free Period (Sec); λ_s = Seismometer Damping

(MP_s) = Seismometer Mass Position from Center

S_{chan} = Channel Sensitivity

TABLE II

LASA SEISMOGRAPH CHANNEL IDENTIFICATION

CHANNEL	MANUFACTURER/MODEL	SEISMIC AMPLIFIER MFGR/MODEL	FILTER MFGR/MODEL/TYPE
SPZ	GeoSpace/HS-10-1A	Texas Inst./RA-5	4 pole ½dB ripple Chebyshev low pass, f_c=5.0 hertz, @10 hertz, -30dB.
SPAZ	GeoSpace/HS-10-1A	Texas Inst./RA-5	
SPIZ	GeoSpace HS-10-1B	Ithaco/6072-65	"
SPTZ	Teledyne/TD-201D	Texas Inst./RA-5	"
SPTN	Teledyne/TD-201D	Texas Inst./RA-5	"
SPTE	Teledyne/TD-201D	Texas Inst./RA-5	"
LPZ	Geotech/7505A	Texas Inst./Type II	
LPH	Geotech/8700C	Texas Inst./Type II	Texas Inst. Type II/Response A. 24 dB/oct high-cut, centered at 65 sec.
LPAZ	Geotech/7505A	Texas Inst./Type II	"
LPAH	Geotech/8700C	Texas Inst./Type II	"
LPWZ	Geotech/7507A	Texas Inst./Type II	
LPWH	Geotech/8700C	Texas Inst./Type II	Texas Inst./Type II/Response C. 12 dB/oct high-cut, centered at approx. 100 sec.

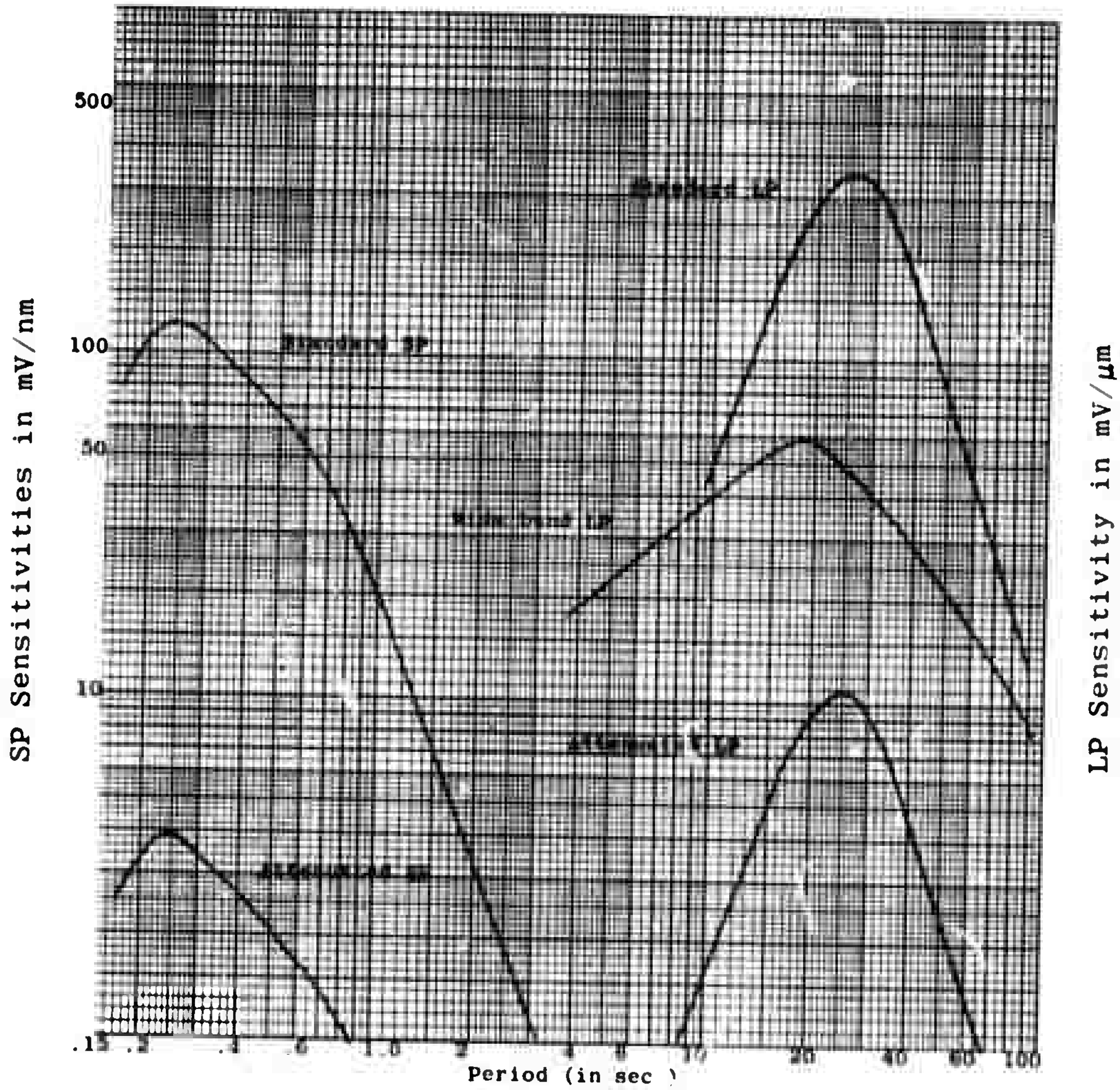


Figure 1.3 LASA Seismographs Response Curves

SECTION II

SUMMARY

The array operation, maintenance, and system improvement activities at the Montana LASA continue to be directed towards achieving efficient seismic array operation. Operations support provided to SAAC via the LDC computers totaled 96.2% for on-line data transmission and 3.8% for back-up recording during this period; for the contract the percentages are 94.6 and 5.4 respectively.

The results of the array monitoring and remote calibrations performed indicate the continued improvement over past performance and the previously predicted seasonal variations. The array seismograph channel sensitivities averaged over the 92-day period were 20.1 mV/nm at 1s and 339.5 mV/μm at 25s for the short and long-period channels respectively. The effort to improve the natural frequency variation among the SP seismometers with a program of field measurements and instrument replacements has increased the percentage of natural frequencies within the ±10% tolerance from 66 to 80% of the 191 sensors tested to date.

Programming changes have been made to the PDP-7 computer's Multiple On-line Processing System (MOPS) to increase the core memory available for the patch overlay programs used for semi-automatic array maintenance and monitoring. New array data recording formats have been prepared for the low-rate and very-low-rate recording modes available at the LASA Data Center.

Maintenance activity consisted primarily of SP subarray rehabilitation, installation of SP channel CTH gain control modifications, and PDP-7 tape unit repairs.

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SECTION III

OPERATION

3.1 General

Array operation is performed to provide data continuously from the array sensing and data acquisition systems to the LDC, to provide data on-line from the LDC to the SAAC, and to provide data recording in the event data transmission to SAAC is interrupted.

3.2 Data Center

The LASA Data Center (LDC) contains the equipment necessary to process the seismic array data either for transmission to SAAC or for recording locally. The activities in support of the LASAPS and other data center systems include: (1) IBM 360/44 computer operation on-line to SAAC, (2) PDP-7 computer operation to record array data in back-up of the 360 computer and to perform array monitoring, automatic calibrations, and off-line processing of array performance information, (3) maintenance display console operation for test and diagnosis of array equipment performance, (4) tape and film library operation for storage, handling, and shipment of array data recordings, (5) Develocorder operation for continuous recording of selected sensor channels for the Seismic Data Laboratory (SDL) and array quality control testing and analysis, and (6) telemetry link operation for continuous on-line data transmission of selected seismograph channels to MIT for data analysis.

3.2.1 SAAC/LDC Systems

Operation of the real-time data link between the SAAC and LDC so that a maximum amount of useful seismic data from the Montana array reaches SAAC for analysis is one of the main goals of our data center's operation. Monitoring of the SAAC/LDC operation during this quarterly period produced the operational statistics in Table III. Three operational modes which cause the outages shown are: (1) the SAAC computers are not available for LASAPS data acquisition, (2) the LDC Model 44 computer is not available for processing LASAPS data, and (3) the wideband communications channel between the LDC and SAAC is not in operation. These outage times are covered with digital recordings of the LASA data by the PDP-7 computer; however, no real time data is available at SAAC. Periods in which LASAPS data was not used in the IRSPS operation at SAAC totaled 84.7 hours so that for 96.16% of this reporting period the SAAC/LDC systems operated together. The wideband data link between the two centers was inoperative 33.0 hours or 1.49% of the period.

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TABLE III

SAAC/LDC SYSTEM OPERATING TIMES

June 72 - August 72

	JUNE	JULY	AUG.	TOTAL
SAAC & LDC 360 On-Line	684.1	726.6	712.6	2123.3
SAAC Off-Line, LDC 360 Running				
PDP-7 Recording	16.3	13.1	13.4	42.8
360 Training	.0	.0	.0	.0
SAAC Up, LDC 360 Down, PDP-7 Recording				
Scheduled	2.9	1.5	3.1	7.5
Unscheduled	.3	.9	.2	1.4
SAAC Up, Other Equipment Down, PDP-7 Recording				
Scheduled	.0	.0	.0	.0
Unscheduled	16.4	1.9	14.7	33.0
Totals (in hours)	720.0	744.0	744.0	2208.0

3.2.2 IBM/360 Model 44 Computer

The IBM/360 computer, the LASAPS data processor, was fully operational at the LDC for 99.60% of this quarter. The complete computer utilization statistics are given in Table IV. On-line processing time equalled 96.16% of the period. Maintenance activities used 7.5 hours or 00.34% of the available time.

3.2.3 DEC PDP-7 Computer

The DEC PDP-7 computer was fully operational for data center processing 95.52% of this quarter of which on-line processing accounted for 86.99%, and off-line 13.01%. The complete summary of computer utilization statistics are shown in Table V. The back-up operating mode of high-rate recording (Ref. 1) was required on 75 occasions covering an accumulated time period of 90.0 hours. During this operation 684 magnetic tapes were recorded by the computer on 57 of the 92 days of this reporting period. Low rate recordings totaling 1049.4 hours were also made. Both low rate and high rate recordings are retained at the LDC for at least 30 days of recycle time prior to reuse.

3.2.4 Analog System

Two Geotech Model 4000 Develocorders are operated at the LDC. One is used to support data analysis work at SDL and the other to support array maintenance by providing a means to display various sensor outputs during different intervals of time. The SDL Develocorder is operated 24 hours a day and each film record is scanned in the film viewer to determine the quality of the film record and provide a log of occurrences which affect the quality and usability of the film record.

3.2.5 Tape/Film Library

The data center's library is used to store the PDP-7 computer magnetic tape recordings, the 360 computer disc recordings, and the Develocorder film recordings (prior to distribution) for reuse or reference. As of August 31, PDP-7 high-rate back-up recordings dating back to 1 July 1972 were in the library awaiting request or recycling. The library of back-up recordings presently contains 500 tapes. During this period there were no tapes returned from SAAC and 60 faulty tapes were disposed of. A tape storage area has been established to hold the faulty tapes before final disposal is made because a use may still be possible for some tapes.

The library use statistics for this quarter are:

684 PDP-7 high rate format tapes retained for recycling.

0 PDP-7 high rate format tapes distributed to SAAC

TABLE IV

SYSTEM/360 MODEL 44 COMPUTER UTILIZATION

June 72 - August 72

OPERATION	ACCUMULATED TIME, HOURS			
	JUNE	JULY	AUG.	TOTAL
On-line processing including:				
Fully operational with SAAC	684.1	726.6	712.6	2123.3
Running at LASA only	16.3	13.1	13.4	42.8
Down-time operating including:				
Scheduled maintenance	2.9	1.5	3.1	7.5
Corrective maintenance	.0	.0	.0	.0
Training	.0	.0	.0	.0
Shut down - 360 equipment	.0	.0	.0	.0
Shut down - other equipment	16.4	1.9	14.7	33.0
Program halt or loop	.3	.9	.2	1.4
Idle time	.0	.0	.0	.0
Totals	720.0	744.0	744.0	2208.0

TABLE V

PDP-7 COMPUTER UTILIZATION

June 72 - August 72

OPERATION	ACCUMULATED TIME, HOURS			
	JUNE	JULY	AUG.	TOTAL
On-line program operation including:				
Monitor & Weather Processing only	145.4	289.4	266.8	701.6
VLR Recording only	2.5	.0	.0	2.5
High Rate Recording only	35.6	14.4	31.0	81.0
Low Rate Recording only	364.4	359.3	287.3	1011.0
VLR & High Rate Recording	.0	.1	.0	.1
VLR & Low Rate Recording	29.5	.0	.0	29.5
VLR & High & Low Rate Recording	.0	.0	.0	.0
High & Low Rate Recording	1.7	4.4	2.8	8.9
Off-line program operation including:				
Tape Duplication & Verification	.0	.0	.0	.0
Data Analysis	13.0	16.0	2.9	31.9
Utility Operation	22.4	12.8	4.1	39.3
Program Development	77.5	42.5	62.9	182.9
Diagnostic Programs & Testing	18.1	.0	.5	18.6
Training	1.7	.0	.0	1.7
Down-time operation including:				
Scheduled Maintenance	.0	.6	3.0	3.6
Corrective Maintenance	.8	.2	46.6	47.6
Shut down PDP-7 Inoperative	.3	3.4	27.3	31.0
Shut down - Other Equipment	.3	.1	.1	.5
Program Halts	6.8	.8	8.7	16.3
Idle	.0	.0	.0	.0
Totals	720.0	744.0	744.0	2208.0

1 PDP-7 high-rate format tapes distributed to Lincoln Laboratory

788 PDP-7 low-rate format tapes retained for recycling

92 Develocorder film distributed to SAAC

3.3 Array

Array operations functions performed include (1) monitoring of all array systems to detect equipment and data degradation, (2) testing of all array systems to measure equipment performance characteristics, (3) interfacing with telephone company personnel to determine communications equipment performance, and (4) processing of array maintenance and operation data to obtain statistics and information for efficient array management. These tasks are performed utilizing the PDP-7 computer, the maintenance display console, and the Develocorders. The overall system quality control efforts are applied through these activities.

3.3.1 Monitoring

Array monitoring refers to the sensing of performance of the operational equipment through the measurement of equipment characteristics on an essentially continuous basis. At the LDC continuous monitoring of the array systems is accomplished using the built-in data monitors, viz. (1) the MDC alarm monitor panel, (2) the PDP-7 monitor program and (3) the 360 computer's on-line system. The MDC alarm monitor panel provides instantly both a visual and audible indication at the occurrence of either a data link failure between the LDC and a subarray or an alarm signal of subarray power and vault failures transmitted on telemetry word 31. The PDP-7 monitor program outputs each telemetry word 31 data change from any subarray and also prints out the duration of subarray data interruptions. The 360 computer's on-line system program periodically generates a variety of monitoring messages.

Operation and maintenance of the array equipment requires that the data be interrupted at various periods, during which time normal or reliable data may not be available to the LASA data user. The reasons established for data interruptions are: maintenance, either being performed or initiated; subarray equipment failure in which no maintenance has been initiated; telephone company(s) performing tests on the communication link not functioning; power outage at the subarray; or special data center testing. In the event any of these situations occur, a notation is made in the data interruption log relating to the data affected and the time period. For the case of short-period and long-period interruptions, SAAC is alerted via the System 360 typewriter. The total duration of data interruption reported for each subarray is broken down by month in Table VI.

TABLE VI

SUBARRAY DATA INTERRUPTION OUTAGES

SUB ARRAY	DATA	TOTAL TIME DURATION OF DATA INTERRUPTIONS (HOURS:MINUTES)			
		JUNE	JULY	AUG.	TOTALS
AO	SP	:24	3:32	0:0	3:56
	LP	:24	3:32	0:0	3:56
	Meteor	:24	3:32	0:0	3:56
	Telco	4:24	2:12	1:50	8:27
B1	SP	0:0	0:0	0:0	0:0
	Telco	2:10	0:0	0:0	2:10
B2	SP	0:0	0:0	1:56	1:56
	Telco	1:26	1:58	0:0	3:24
B3	SP	0:0	0:0	0:0	0:0
	Telco	1:26	0:0	0:0	1:26
B4	SP	0:0	0:0	4:21	4:21
	Telco	1:26	0:0	0:0	1:26
C1	SP	0:0	0:0	17:19	17:19
	LP	0:0	0:0	17:19	17:19
	Telco	1:26	0:0	6:40	8:06
C2	SP	0:0	2:01	0:0	2:01
	LP	0:0	2:01	0:0	2:01
	Telco	4:04	1:58	0:0	6:02
C3	SP	:14	0:0	:05	:19
	LP	:14	0:0	:05	:19
	Telco	8:28	0:0	0:0	8:28

TABLE VI

SUBARRAY DATA INTERRUPTION OUTAGES (CONTINUED)

SUB ARRAY	DATA	TOTAL TIME DURATION OF DATA INTERRUPTIONS (HOURS:MINUTES)			
		JUNE	JULY	AUG.	TOTALS
C4	SP LP Telco	0:0 0:0 1:26	0:0 0:0 10:32	2:59 4:37 0:0	2:59 4:37 11:58
D1	SP LP Telco	0:0 0:0 1:26	0:0 0:0 0:0	8:14 8:14 0:0	8:14 8:14 1:26
D2	SP LP Telco	0:0 0:0 :18	0:0 0:0 0:0	4:08 4:08 0:0	4:08 4:08 :18
D3	SP LP Telco	0:0 0:0 6:30	6:12 6:12 0:0	9:57 28:46 0:0	16:09 34:58 6:30
D4	SP LP Telco	0:0 0:0 1:26	0:0 0:0 0:0	0:0 0:0 3:50	0:0 0:0 5:16
E1	SP LP Meteor Telco	0:0 0:0 0:0 6:51	11:35 11:35 11:35 :45	6:33 6:33 6:33 1:48	18:08 18:08 18:08 9:24
E2	SP LP Meteor Telco	:33 1:15 :33 2:22	2:00 2:00 2:00 0:0	8:30 8:30 8:30 :25	11:03 11:45 11:03 2:47

TABLE VI

SUBARRAY DATA INTERRUPTION OUTAGES (CONCLUDED)

SUB ARRAY	DATA	TOTAL TIME DURATION OF DATA INTERRUPTIONS (HOURS:MINUTES)			
		JUNE	JULY	AUG.	TOTALS
E3	SP	23:18	0:0	0:0	23:18
	LP	23:18	0:0	0:0	23:18
	Telco	2:13	0:0	0:0	2:13
E4	SP	0:0	0:0	3:21	3:21
	LP	0:0	0:0	3:21	3:21
	Meteor	0:0	0:0	3:21	3:21
	Telco	7:18	2:05	8:02	17:25
F1	SP	:17	0:0	1:27	1:44
	LP	:17	0:0	1:27	1:44
	Meteor	:17	0:0	1:27	1:44
	Telco	1:05	18:57	0:0	20:02
F2	SP	0:0	5:02	23:24	28:26
	LP	0:0	5:02	23:24	28:26
	Meteor	0:0	5:02	23:24	28:26
	Telco	:18	:10	1:21	1:49
F3	SP	14:17	10:54	9:27	34:38
	LP	14:17	10:54	9:27	34:38
	Meteor	14:17	10:54	9:27	34:38
	Telco	24:34	13:16	15:47	53:37
F4	SP	10:47	0:0	3:43	14:30
	LP	10:47	0:0	3:43	14:30
	Meteor	10:47	0:0	3:43	14:30
	Telco	56:42	3:15	10:29	70:26

3.3.2 Calibrations

Calibrations are performed from the data center to sense the performance of the operating array equipment through the periodic measurement and/or adjustment of one or more equipment characteristics. Calibrations are performed daily for the short-period seismographs and weekly for the long-period systems. A set of telemetry remote controls (Ref. 2) connects the data center with each subarray and provides the means for determining the condition of the array equipment. The PDP-7 computer controls the application of the various telemetry command and calibration signals to the subarray(s), measures the signal responses, calculates the seismograph signal parameters, and outputs the data on punched paper tape for off-line printout. Program TESP is used for the short-period seismographs; program TELP for the long-period seismograph (Ref. 3). Normal channel responses to these sinusoidal calibrations are shown in Table VII, where A (volts) is the analog value, A (digital) is the digital value in decimal, and Y is the corresponding equivalent earth motion.

The remote measurement and adjustment of the long-period seismometer positioning is also performed weekly by the PDP-7 computer using the appropriate telemetry commands. Program MASPOS maintains each seismometer mass to within ± 1.4 mm from its center position. Similarly, the seismometer natural frequencies are maintained to within 20 ± 1 seconds/cycle by program FREECK.

When the measured responses exceed the tolerances established for a particular channel, an equipment failure is reported to maintenance and to the users of the array data. The Defective Signal Channel Status Report is distributed each week to all agencies authorized by VSC. Table VIII indicates the incidence of defective channels detected during the three-month period for the three types of array data channels.

Further, for the interest of the array data user, precise times in which the array seismographs are interrupted for sinusoidal calibrations are reported here. These times are readily available from the PDP-7 computers MOPS on-line monitor program output and are indicated in Tables IX and X for the SP and LP sensors respectively. For the short-period calibrations only one calibration time is shown in Table IX for each week; the daily times are available upon request from the LDC. The equivalent earth motion of the calibration input signals to the seismometers are also shown in the two tables. Equivalent earth motion is determined from SEM channel 30 measurements during the calibration times. SEM channel 30 monitors the output of the sinusoidal oscillators which generate the signals applied to the seismometer.

3.3.3 Communications

The interface between array and data center provided by the communications systems plays an important part in the success

TABLE VII

LASA SEISMOGRAPH CALIBRATION RESPONSE TOLERANCES

CHANNEL IDENT.	TC	Peak-to-Peak Sinusoidal Amplitudes								
		A_{nom} Volts	A_{max} Volts	A_{min} Volts	A_{nom} Digital	A_{max} Digital	A_{min} Digital	Y_{nom}	Y_{max}	Y_{min}
SPZ	06[1]	7.91	9.09	6.72	9257	10638	7864	395nm	455nm	336nm
SPAZ	06[1]	.25	.289	.214	293	407	236	395nm	455nm	336nm
SPIZ	06[1]	7.91	9.09	6.72	9257	10638	7864	395nm	455nm	336nm
SPTZ	06[1]	7.91	9.09	6.72	9257	10638	7864	395nm	455nm	336nm
SPTN	06[1]	7.91	9.09	6.72	9257	10638	7864	395nm	455nm	336nm
SPTE	06[1]	7.91	9.09	6.72	9257	10638	7864	395nm	455nm	336nm
LPZ	20[2]	6.98	7.98	5.99	8168	9339	7010	20.0μm	22.8μm	17.1μm
LPH	20[2]	6.98	7.98	5.99	8168	9339	7010	20.0μm	22.8μm	17.1μm
LPAZ	20[3]	2.77	3.19	2.34	3242	3733	2738	252μm	290μm	213μm
LPAH	20[3]	2.77	3.19	2.34	3242	3733	2738	252μm	290μm	213μm
LPWZ	20[2]	1.10	1.26	0.93	1287	1475	1088	20.0μm	22.9μm	16.9μm
LPWH	20[2]	1.10	1.26	0.93	1287	1475	1088	20.0μm	22.9μm	16.9μm

Note 1. Amplitude measurements corrected for response to 400nm, 1s calibration signal.
2. Amplitude measurements corrected for response to 20μm, 25s calibration signal.
3. Amplitude measurements corrected for response to 222μm, 25s calibration signal.

TABLE VIII

INCIDENCE OF DEFECTIVE SUBARRAY CHANNELS

June 1972 - August 1972

SUBARRAY	CHANNELS		
	SP	LP	METEOR
AO	3	0 (8)	0
B1	3	-	-
B2	5	-	-
B3	1	-	-
B4	3	-	-
C1	5	4 (13)	-
C2	3	2 (14)	-
C3	1	0 (17)	-
C4	2	2 (13)	-
D1	1	0 (12)	-
D2	2	3 (12)	-
D3	3	2 (13)	-
D4	4	0 (21)	-
E1	3	1 (13)	0
E2	6	2 (6)	1
E3	6	0 (11)	-
E4	4	0 (14)	0
F1	4	2 (19)	0
F2	7	0 (21)	0
F3	5	0 (6)	0
F4	2	2 (11)	0
TOTALS	73	20 (224)	1

TABLE IX

SP ARRAY SINUSOIDAL CALIBRATIONS

SUBARRAY	Short-Period Array Sinusoidal Calibration Signal Start Times and Amplitudes										SUBARRAY
	Day 157 5 June 72		Day 164 12 June 72		Day 171 19 June 72		Day 178 26 June 72		Day 185 3 July 72		
	Start Time (GMT)	P-P Ampl. nm	Start Time (GMT)	P-P Ampl. nm	Start Time (GMT)	P-P Ampl. nm	Start Time (GMT)	P-P Ampl. nm	Start Time (GMT)	P-P Ampl. nm	
AO	1537:33	393	1627:57	394	1320:04	393	1742:10	392	1627:34	390	AO
B1	1538:03	405	1628:27	405	1320:34	405	1742:40	405	1628:04	405	B1
B2	1538:33	413	1628:57	408	1321:04	407	1743:10	407	1628:34	407	B2
B3	1539:03	407	1629:27	406	1321:34	405	1743:40	403	1629:04	405	B3
B4	1539:33	413	1629:57	412	1322:04	413	1744:10	414	1629:34	413	B4
C1	1540:03	401	1630:27	401	1322:34	400	1744:40	400	1630:04	400	C1
C2	1540:33	400	1630:57	400	1323:04	400	1745:10	398	1630:34	398	C2
C3	1541:03	404	1631:27	404	1323:34	404	1745:40	404	1631:04	404	C3
C4	1541:33	398	1631:57	400	1324:04	396	1746:10	397	1631:34	384	C4
D1	1542:03	407	1632:27	404	1324:34	407	1746:40	405	1632:04	408	D1
D2	1542:33	391	1632:57	391	1325:04	391	1747:10	392	1632:34	391	D2
D3	1543:03	400	1633:27	401	1325:34	401	1747:40	402	1633:04	402	D3
D4	1543:33	395	1633:57	391	1326:04	392	1748:10	390	1633:34	388	D4
E1	1544:03	408	1634:27	406	1326:34	404	1748:40	404	1634:04	405	E1
E2	1544:33	421	1634:57	421	1327:04	420	1749:10	418	1634:34	420	E2
E3	1545:03	407	1635:27	408	1327:34	410	1749:40	408	1635:04	410	E3
E4	1545:33	413	1635:57	412	1328:04	413	1750:10	412	1635:34	411	E4
F1	1546:03	400	1636:27	400	1328:34	401	1750:40	400	1636:04	397	F1
F2	1546:33	410	1636:57	410	1329:04	410	1751:10	408	1636:34	408	F2
F3	1547:03	414	1637:27	412	1329:34	413	1751:40	412	1637:04	412	F3
F4	1547:33	420	1637:57	420	1330:04	421	1752:10	420	1637:34	418	F4

TABLE IX

SP ARRAY SINUSOIDAL CALIBRATIONS (CONTINUED)

SUBARRAY	Short-Period Array Sinusoidal Calibration Signal Start Times and Amplitudes										SUBARRAY
	Day 192 10 July 72		Day 199 17 July 72		Day 206 24 July 72		Day 213 31 July 72		Day 220 7 Aug. 72		
	Start Time (GMT)	P-P Ampl. nm	Start Time (GMT)	P-P Ampl. nm	Start Time (GMT)	P-P Ampl. nm	Start Time (GMT)	P-P Ampl. nm	Start Time (GMT)	P-P Ampl. nm	
AO	1448:23	387	1433:53	388	1802:51	387	1431:11	386	1315:47	386	AO
B1	1448:53	405	1434:23	405	1803:21	405	1431:41	405	1316:17	405	B1
B2	1449:23	405	1434:53	405	1803:51	406	1432:11	405	1316:47	406	B2
B3	1449:53	404	1435:23	406	1804:21	404	1432:41	401	1317:17	402	B3
B4	1450:23	413	1435:53	413	1804:51	413	1433:11	415	1317:47	414	B4
C1	1450:53	400	1436:23	400	1805:21	400	1433:41	400	1318:17	400	C1
C2	1451:23	397	1436:53	398	1805:51	400	1434:11	398	1318:47	398	C2
C3	1451:53	403	1437:23	404	1806:21	404	1434:41	404	1319:17	403	C3
C4	1452:23	396	1437:53	401	1806:51	400	1435:11	400	1319:47	396	C4
D1	1452:53	407	1438:23	407	1807:21	407	1435:41	406	1320:17	406	D1
D2	1453:23	393	1438:53	392	1807:51	392	1436:11	393	1320:47	392	D2
D3	1453:53	403	1439:23	403	1808:21	403	1436:41	403	1321:17	403	D3
D4	1454:23	386	1439:53	387	1808:51	387	1437:11	385	1321:47	385	D4
E1	1454:53	405	1440:23	405	1809:21	402	1437:41	404	1322:17	403	E1
E2	1455:23	420	1440:53	420	1809:51	420	1438:11	420	1322:47	420	E2
E3	1455:53	411	1441:23	408	1810:21	411	1438:41	410	1323:17	408	E3
E4	1456:23	411	1441:53	413	1810:51	411	1439:11	412	1323:47	411	E4
F1	1456:53	397	1442:23	397	1811:21	397	1439:41	395	1324:17	396	F1
F2	1457:23	410	1442:53	408	1811:51	408	1440:11	410	1324:47	408	F2
F3	1457:53	411	1443:23	411	1812:21	411	1440:41	410	1325:17	410	F3
F4	1458:23	420	1443:53	420	1812:51	420	1441:11	421	1325:47	421	F4

TABLE IX

SP ARRAY SINUSOIDAL CALIBRATIONS (CONCLUDED)

SUBARRAY	Short-Period Array Sinusoidal Calibration Signal Start Times and Amplitudes						SUBARRAY
	Day 227 14 Aug. 72		Day 234 21 Aug. 72		Day 241 28 Aug. 72		
	Start Time (GMT)	P-P Ampl. nm	Start Time (GMT)	P-P Ampl. nm	Start Time (GMT)	P-P Ampl. nm	
AO	1435:28	384	1948:40	385	1306:01	384	AO
B1	1435:58	405	1949:10	405	1306:31	404	B1
B2	1436:28	401	1949:40	401	1307:01	401	B2
B3	1436:58	401	1950:10	400	1307:31	401	B3
B4	1437:28	415	1950:40	415	1308:01	414	B4
C1	1437:58	411	1951:10	412	1308:31	411	C1
C2	1438:28	397	1951:40	397	1309:01	396	C2
C3	1438:58	403	1952:10	404	1309:31	403	C3
C4	1439:28	397	1952:40	400	1310:01	400	C1
D1	1439:58	407	1953:10	405	1310:31	407	D1
D2	1440:28	392	1953:40	392	1311:01	392	D2
D3	1440:58	404	1954:10	410	1311:31	412	D3
D4	1441:28	382	1954:40	382	1312:01	382	D4
E1	1441:58	402	1955:10	402	1312:31	400	E1
E2	1442:28	418	1955:40	418	1313:01	404	E2
E3	1442:58	411	1956:10	411	1313:31	412	E3
E4	1443:28	411	1956:40	408	1314:01	406	E4
F1	1443:58	396	1957:10	394	1314:31	392	F1
F2	1444:28	408	-	-	1315:01	408	F2
F3	-	-	1958:10	408	1315:31	408	F3
F4	-	-	1958:40	420	1316:01	349	F4

X

LP ARRAY SINUSOIDAL CALIBRATIONS

SUBARRAY	Long-Period Array Sinusoidal Calibration Signal Times and Input Amplitude									SUBARRAY
	Day 157 5 June 72			Day 164 12 June 72			Day 171 19 June 72			
	Start Time (GMT)	Stop Time (GMT)	Input Ampl. µm P-P	Start Time (GMT)	Stop Time (GMT)	Input Ampl. µm P-P	Start Time (GMT)	Stop Time (GMT)	Input Ampl. µm P-P	
AO	1551:28	1554:28	20.4	1644:28	1647:28	20.5	1747:30	1750:30	20.5	AO
C1	"	"	20.2	"	"	20.4	"	"	20.6	C1
C2	1559:28	1602:28	270	1652:28	1655:28	265	1755:31	1758:31	267	C2
C3	"	"	20.3	"	"	20.3	"	"	20.3	C3
C4	1607:28	1610:28	20.8	1700:28	1703:28	20.9	1803:31	1806:31	20.6	C4
D1	"	"	20.5	"	"	20.5	"	"	20.7	D1
D2	1615:29	1618:29	20.5	1708:28	1711:28	20.5	1811:31	1814:31	20.5	D2
D3	"	"	21.1	"	"	21.1	"	"	20.7	D3
D4	1623:29	1626:29	20.9	1716:28	1719:28	20.9	1819:31	1822:31	21.1	D4
E1	"	"	20.1	"	"	20.0	"	"	20.1	E1
E2	1631:29	1634:29	20.2	1724:29	1727:29	20.7	1827:31	1850:31	20.8	E2
E3	"	"	20.1	"	"	20.9	"	"	20.7	E3
E4	1639:29	1642:29	20.5	1732:29	1735:29	20.3	1835:31	1838:31	20.3	E4
F1	"	"	20.6	"	"	20.4	"	"	20.3	F1
F2	1647:29	1650:29	21.0	1740:29	1743:29	21.0	1843:31	1846:31	21.0	F2
F3	"	"	20.2	"	"	20.0	"	"	19.9	F3
F4	1655:29	1658:29	19.6	1748:29	1751:29	19.9	1851:32	1854:32	19.6	F4

TABLE V

LP ARRAY SINUSOIDAL CALIBRATIONS (CONTINUED)

SUBARRAY	Long-Period Array Sinusoidal Calibration Signal Times and Input Amplitude									SUBARRAY
	Day 178 26 June 72			Day 185 3 July 72			Day 192 10 July 72			
	Start Time (GMT)	Stop Time (GMT)	Input Ampl. µm P-P	Start Time (GMT)	Stop Time (GMT)	Input Ampl. µm P-P	Start Time (GMT)	Stop Time (GMT)	Input Ampl. µm P-P	
AO	1808:36	1811:36	20.5	1831:56	1834:56	20.6	1508:02	1511:02	20.3	AO
C1	"	"	20.6	"	"	21.1	"	"	21.6	C1
C2	1816:36	1819:36	268	1839:56	1842:56	263	1516:02	1519:02	266	C2
C3	"	"	20.4	"	"	20.3	"	"	20.3	C3
C4	1824:36	1827:36	20.7	1847:57	1850:57	20.8	1543:54	1546:54	21.1	C4
D1	"	"	20.3	"	"	20.4	"	"	20.4	D1
D2	1832:36	1835:36	20.5	1855:57	1858:57	20.5	1551:54	1554:54	20.6	D2
D3	"	"	21.2	"	"	21.1	"	"	21.1	D3
D4	1840:36	1843:36	20.9	1903:57	1906:57	20.9	1559:54	1602:54	21.0	D4
E1	"	"	20.3	"	"	20.2	"	"	20.0	E1
E2	1848:37	1851:37	20.2	1911:57	1914:57	20.7	1607:54	1610:54	20.1	E2
E3	"	"	20.1	"	"	20.7	"	"	20.7	E3
E4	1856:37	1859:37	19.9	1919:57	1922:57	20.3	1615:54	1618:54	19.8	E4
F1	"	"	20.3	"	"	20.3	"	"	20.6	F1
F2	1904:37	1907:37	21.1	1927:57	1930:57	21.1	1623:55	1626:55	21.1	F2
F3	"	"	20.1	"	"	20.1	"	"	20.5	F3
F4	1912:37	1915:37	19.8	1935:57	1938:57	20.2	1631:55	1634:55	19.6	F4

TABLE X

LP ARRAY SINUSOIDAL CALIBRATIONS (CONTINUED)

SUBARRAY	Long-Period Array Sinusoidal Calibration Signal Times and Input Amplitude									SUBARRAY
	Day 199 17 July 72			Day 206 24 July 72			Day 213 31 July 72			
	Start Time (GMT)	Stop Time (GMT)	Input Ampl. μm P-P	Start Time (GMT)	Stop Time (GMT)	Input Ampl. μm P-P	Start Time (GMT)	Stop Time (GMT)	Input Ampl μm P-P	
AO	1557:26	1600:27	20.2	1816:16	1819:16	20.6	1520:42	1523:42	20.6	AO
C1	"	"	20.4	"	"	20.6	"	"	21.1	C1
C2	1605:27	1608:27	270	1824:16	1827:16	270	1528:43	1531:43	269	C2
C3	"	"	20.3	"	"	20.3	"	"	20.3	C3
C4	1613:27	1616:27	21.0	1832:16	1835:16	20.8	1536:43	1539:43	21.1	C4
D1	"	"	20.5	"	"	20.3	"	"	20.8	D1
D2	1621:27	1624:27	20.6	1840:16	1843:16	20.6	1544:43	1547:43	20.6	D2
D3	"	"	21.2	"	"	21.2	"	"	20.5	D3
D4	1629:27	1632:27	21.2	1848:17	1851:17	21.1	1552:43	1555:43	21.0	D4
E1	"	"	20.0	"	"	20.0	"	"	20.0	E1
E2	1637:27	1640:27	20.9	1856:17	1859:17	20.9	1600:43	1603:43	20.1	E2
E3	"	"	20.7	"	"	21.0	"	"	20.1	E3
E4	1645:27	1648:27	19.8	1904:17	1907:17	20.4	1608:43	1611:43	20.7	E4
F1	"	"	20.3	"	"	20.5	"	"	20.6	F1
F2	1653:28	1656:28	21.1	1912:17	1915:17	21.1	1616:43	1619:43	21.1	F2
F3	"	"	20.5	"	"	20.1	"	"	20.0	F3
F4	1701:28	1704:28	20.2	1920:17	1923:17	19.5	1624:44	1627:44	20.2	F4

TABLE X

LP ARRAY SINUSOIDAL CALIBRATIONS (CONTINUED)

SUBARRAY	Long-Period Array Sinusoidal Calibration Signal Times and Input Amplitude						SUBARRAY
	Day 220 7 Aug. 72			Day 227 14 Aug. 72			
	Start Time (GMT)	Stop Time (GMT)	Input Ampl. μm P-P	Start Time (GMT)	Stop Time (GMT)	Input Ampl. μm P-P	
AO	1329:51	1332:51	20.4	1540:13	1543:13	20.4	AO
C1	"	"	21.4	"	"	20.4	C1
C2	1337:51	1340:41	272	1548:13	1551:14	268	C2
C3	"	"	20.3	"	"	20.4	C3
C4	1345:51	1348:51	21.0	1556:14	1559:14	21.2	C4
D1	"	"	20.3	"	"	20.6	D1
D2	1353:51	1356:51	20.5	1604:14	1607:14	20.5	D2
D3	"	"	20.6	"	"	20.5	D3
D4	1401:52	1404:52	21.2	1612:14	1615:14	21.1	D4
E1	"	"	20.2	"	"	20.2	E1
E2	1409:52	1412:52	20.8	1620:14	1623:14	20.9	E2
E3	"	"	20.9	"	"	20.5	E3
E4	1417:52	1420:52	20.1	1628:14	1631:14	20.4	E4
F1	"	"	20.3	"	"	20.5	F1
F2	1425:52	1428:52	21.1	1636:14	1639:14	21.0	F2
F3	"	"	20.5	"	"	20.5	F3
F4	1433:52	1436:52	20.2	Site down			F4

TABLE X

LP ARRAY SINUSOIDAL CALIBRATIONS (CONCLUDED)

SUBARRAY	Long-Period Array Sinusoidal Calibration Signal Times and Input Amplitude						SUBARRAY
	Day 234 21 Aug. 72			Day 242 29 Aug. 72			
	Start Time (GMT)	Stop Time (GMT)	Input Ampl. μm P-P	Start Time (GMT)	Stop Time (GMT)	Input Ampl. μm P-P	
AO	2240:37	2243:37	20.5	0249:47	0252:47	20.3	AO
C1	"	"	20.2	"	"	20.6	C1
C2	2248:37	2251:37	263	0257:47	0300:47	269	C2
C3	"	"	20.3	"	"	20.4	C3
C4	2256:37	2259:37	20.5	0305:47	0308:47	21.0	C4
D1	"	"	20.7	"	"	20.6	D1
D2	2304:37	2307:37	20.5	0313:47	0316:48	20.6	D2
D3	"	"	19.3	"	"	19.3	D3
D4	2312:38	2315:38	21.0	0321:48	0324:48	21.2	D4
E1	"	"	20.2	"	"	20.1	E1
E2	2320:38	2323:38	20.6	0329:48	0332:48	21.1	E2
E3	"	"	20.9	"	"	20.2	E3
E4	2328:38	2331:38	20.6	0337:48	0340:48	20.8	E4
F1	"	"	20.5	"	"	20.5	F1
F2	2336:38	2339:38	21.1	0345:48	0348:48	21.1	F2
F3	"	"	20.1	"	"	20.4	F3
F4	2344:38	2347:38	20.2	0353:48	0356:48	20.6	F4

of the array operation. Determination of data interruptions due to telephone circuit outages is one responsibility of the LDC operations activity. All outages reported by data center personnel are assigned a ticket number to aid in accounting for and identifying of the data interruption. Weekly meetings are held with the telephone company, viz., Mountain Bell and Mid-Rivers, personnel to review and describe all outages.

For the period between 1 June and 31 August 1972, the communications outages which exceeded a two-hour duration and the reasons attributed to the outages are listed in Table XI. Open wire troubles and defective line filters caused an increase in the number and total duration of outages exceeding two hours. Twenty-six outages totalling 150.2 hours were reported as compared with thirteen outages totalling 41.5 hours for the previous quarter. Lightning was responsible for the broken open wire lines and the telco filter failures; high winds caused the instances of open wire wrap. Since these communication problems require field trips by telco repairman the duration of the outages are generally more lengthy.

The intermittent troubles previously reported with subarrays E1 and E4 during May in which several tests were performed to locate the trouble source without any success have now apparently cleared up since no further incidence has been detected.

TABLE XI

EXTENDED ARRAY DATA INTERRUPTIONS

DUE TO COMMUNICATIONS OUTAGES

DATE	DURATION	SITE	REASON FOR OUTAGE
06/03/72	4:06	F4	Mountain Bell on Patch causing timing problem
06/03/72	7:10	F4	Mountain Bell on Patch causing timing problem
06/06/72	3:23	F4	Mountain Bell on Patch causing timing problem
06/09/72	2:30	C3	Storm in array
06/09/72	2:30	D3	Storm in array
06/09/72	5:58	F3	Low Telco levels
06/10/72	2:25	C3	Storm in array
06/10/72	2:25	D3	Storm in array
06/18/72	9:25	F3	No trouble found
06/18/72	12:50	F4	Open wire wrap near subarray
06/20/72	8:13	F4	Open wire wrap near subarray
06/21/72	17:41	F4	Open wire wrap and Mountain Bell on defective Patch
07/19/72	2:35	F3	Low Telco levels

TABLE XI

EXTENDED ARRAY DATA INTERRUPTIONS

DUE TO COMMUNICATIONS OUTAGES (CONCLUDED)

DATE	DURATION	SITE	REASON FOR OUTAGE
07/19/72	10:32	C4	Lightening damaged Telco filter
07/19/72	3:21	F1	Storm in array
07/19/72	4:13	F1	Storm in array
07/20/72	3:15	F4	No trouble found
07/20/72	2:45	F3	Low Telco levels
07/25/72	2:15	F1	Storm in array
07/30/72	7:09	F1	Wire slap near subarray
08/01/72	3:41	F3	Open wire wrap
08/02/72	7:39	F3	Open wire wrap and defective Telco filter
08/09/72	3:50	D4	Open wire line broken
08/09/72	4:40	C1	Defective Telco KS amplifier
08/14/72	9:29	F4	Open wire line broken
08/21/72	6:14	E4	Open wire wrap

SECTION IV

ARRAY PERFORMANCE

4.1 Systems

The overall performance measure applied to each of the array's sensor systems is the array data availability. The percentage of time the array systems are on-line providing quality data determine the value of this measure. Data availabilities are calculated by combining the total subarray data interruption times shown in Table VI with the total sensor outage times reported on the Defective Signal Channel Status reports. The data availabilities compared with those of previous periods are as follows:

	3rd Quarter	Previous 3rd Quarter	Previous Contract
SP	94.28	97.4	96.7
LP	94.90	98.4	98.6
Met	99.18	98.3	99.2

Telephone circuit outages which affect all subarray systems are not included in the percentages. During this quarterly period the listed data availabilities were further reduced by 0.52% by the telco outages.

4.1.1 SP Seismograph

(a) Performance Monitoring using Program TESP

The performance monitoring from the sinusoidal calibrations of the 346 short-period seismograph channels during this three-month period has indicated an average channel sensitivity of 20.12 mV/nm at 1-second periods with an average standard deviation of 1.34 mV/nm. A summary of the test results obtained each week is shown in Table XII where the statistics are compared with those of the previous contract and those of the previous June - August period. The SP array maintenance programs continue to reflect increases in the amplitude stability of the SP seismographs. This is illustrated by the distribution of SP sensors within the ± 15% sensitivity tolerance plotted in Figure 4.1. This figure shows the weekly percentage of sensors within the tolerance since 30 March 1970. The cyclic variation that occurs with the seasonal temperature changes continues to be apparent.

(b) Channel Stability

To determine the individual channel stability of the SP seismograph, 86 sensors were selected to receive special study.

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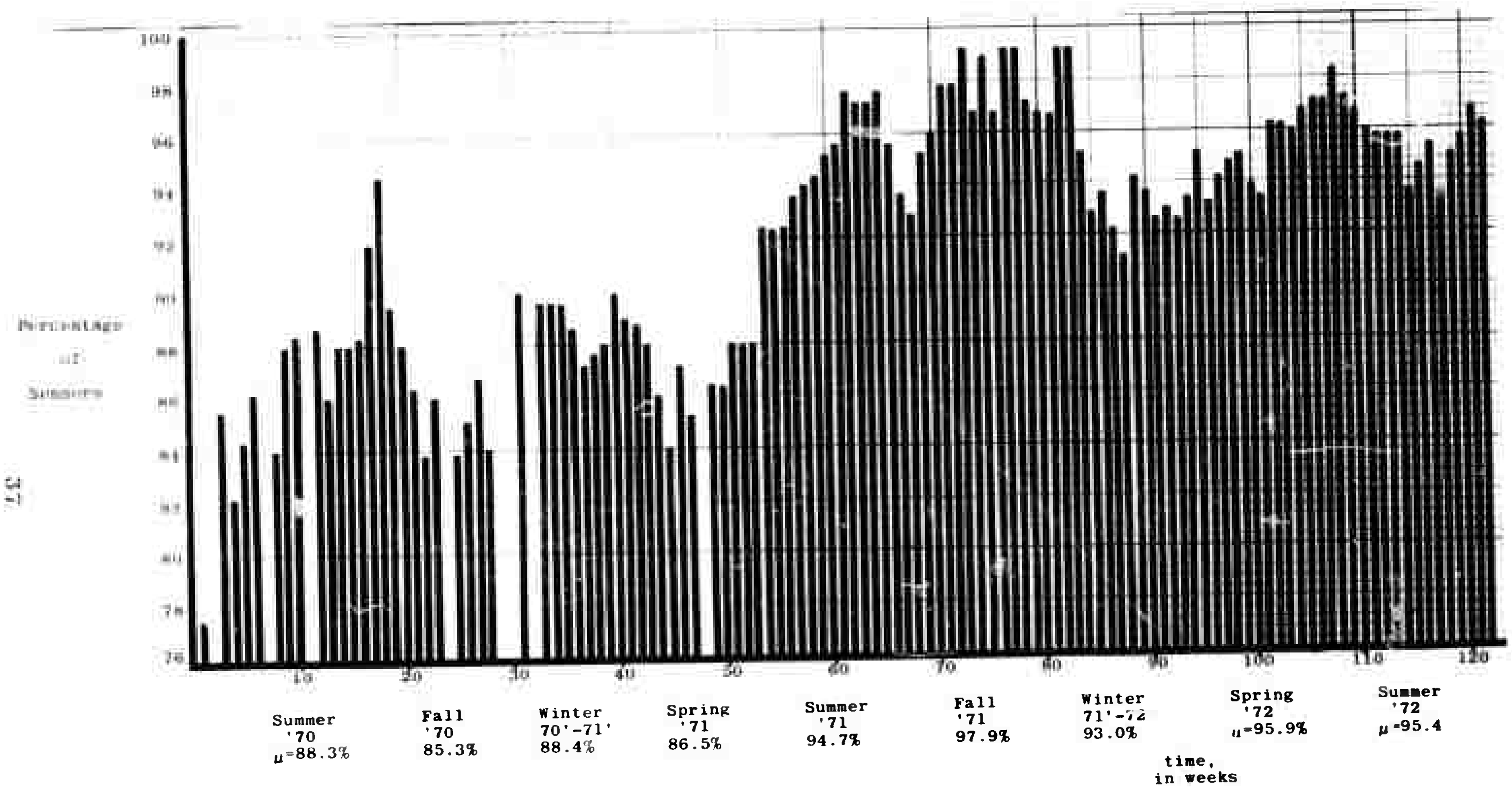
TABLE XII

SP ARRAY PERFORMANCE TESTING SENSITIVITY STATISTICS

DATE	NO. SENSORS	SENS. MEAN mV/nm	SENS. σ mV/nm	SENS. MAX. mV/nm	SENS. MIN. mV/nm	SENS. DEV. mV/nm
6/5	340	20.21	1.32	23.02	12.62	10.40
6/12	340	20.18	1.41	25.72	12.38	13.34
6/19	340	20.35	1.37	25.24	11.37	13.87
6/26	338	20.09	1.34	25.69	12.47	13.22
7/3	338	20.25	1.36	24.73	10.08	14.65
7/10	334	19.95	1.41	25.54	10.15	15.39
7/17	338	20.26	1.40	25.19	11.26	13.93
7/24	337	19.91	1.31	23.03	11.51	11.52
7/31	337	19.94	1.35	25.52	11.44	14.08
8/7	339	20.21	1.30	25.19	10.13	15.06
8/14	308	19.89	1.33	25.19	11.63	13.56
8/21	326	19.97	1.25	25.00	11.05	13.95
8/28	342	20.40	1.29	25.14	11.50	13.64
AVERAGE	335.15	20.12	1.34	24.17	11.35	13.59
PREVIOUS 2RD QTR. AVERAGE	343.6	19.86	1.50	24.9	14.1	10.8
CONTRACT AVERAGE	334.54	20.29	1.42	24.17	12.74	11.68
PREVIOUS CONTRACT AVERAGE	343.9	20.36	1.69	26.5	12.7	13.8



4.1 Percentage Distribution of SP Sensors in ± 15% Sensitivity Tolerance starting 30 March 1970 to date.

Six of the sensors were picked at random from subarray E3 and four were randomly sampled from each of the other 20 subarrays. The sensitivities of each of these 86 channels since 1 November 1971 have been obtained from the daily printout of program TESP. At the end of each month a standard deviation of the sensitivity is calculated for each channel. Table XIII summarizes this information.

Assuming the distribution of the sensitivity of an individual channel is normal or at least can be approximated by a normal distribution, Table XIII shows that in the large majority of cases the measured sensitivity of a channel will be within 1 mV/nm of the mean sensitivity.

In five of the eight cases of an individual channel's standard deviation being less than 0.3333 mV/nm for June and greater than .3333 mV/nm for July, the standard deviation for May was greater than 0.3333 mV/nm. In these five cases the standard deviation is near 0.3333 mV/nm and fluctuates enough from month to month to cause the majority of the variation in the percentage. The other six channels with standard deviation greater than .3333 mV/nm for June are either channels which are failing, i.e., sensitivity is steadily decreasing, or in the minority of cases the channel's sensitivity jumps around. The variation in percentage is caused primarily by those channels whose standard deviation is near 0.3333 mV/nm and fluctuates above and below this figure.

(c) Channel Frequency Response Measurement

Measurement of SP channel frequency response by subarray continued with the collection of response data from 79 sensors at five subarrays this quarter. Figure 4.2 shows the mean, the minimum, and the maximum response curves of the array as measured during the period May 1970 through August 1972. The average age of the subarray data used in preparing these sensitivity plots is 9.9 months. The sensitivities are calculated using the measured values of output amplitude and input current amplitude and period, and the nominal values of calibration constant and seismic mass. Table XIV shows the average and the standard deviation, of the channel sensitivities for each of the 16 frequencies used in the measurement. Individual plots are prepared to display the broadband response of each SP seismograph channel and to assist maintenance in determining channel malfunctions.

(d) Number of Sensors

A total of 366 SP seismograph channels originate from 346 individual seismometers installed at 344 sensor locations in the array. Twenty attenuated outputs and two horizontal component outputs are obtained from twenty-one locations to produce the 366 active channels. Twelve of the 346 seismometers vary from the configuration of the initial LASA installation. These are at subarray D2 where three channels are derived from a TD-202 tri-axial

TABLE XIII

DISTRIBUTION OF THE STANDARD DEVIATIONS OF 86 LASA SP CHANNELS

	MEAN S mV/nm	MAXIMUM S mV/nm	MINIMUM S mV/nm	% <.3333 mV/nm
Nov. 71	0.1831	1.072	0.0570	95.3
Dec. 71	0.2236	1.945	0.0277	86.0
Jan. 72	0.2902	1.306	0.0807	73.3
Feb. 72	0.2559	1.690	0.0630	80.2
Mar. 72	0.3075	2.050	0.0849	70.6
Apr. 72	0.2030	3.007	0.0415	93.0
May 72	0.2629	1.025	0.0625	79.1
Jun. 72	0.2190	1.582	0.0370	91.9
Jul. 72	0.2613	1.348	0.0640	83.7

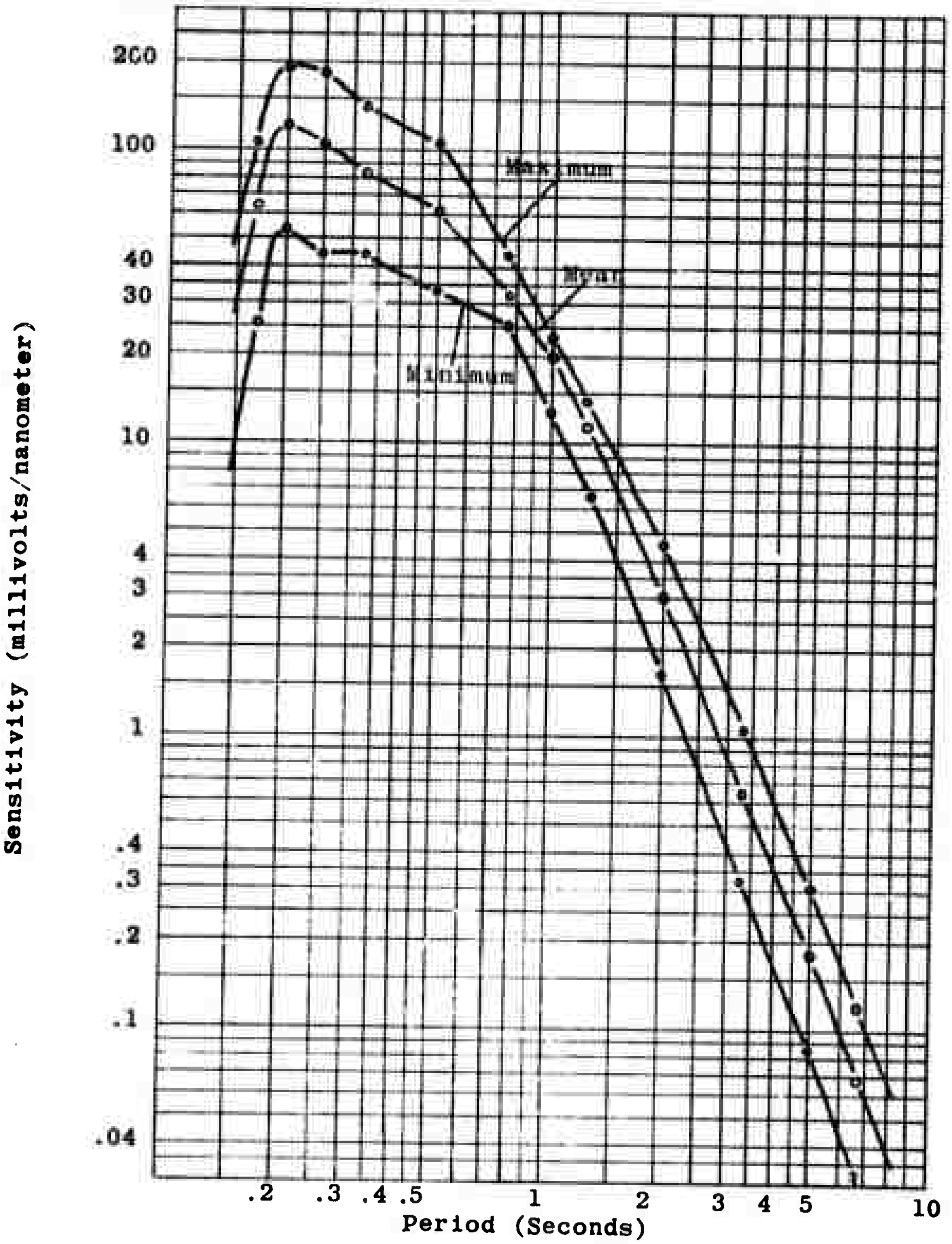


Figure 4.2 LASA SP Sensor Period vs Sensitivity Response Curves

TABLE XIV

SP SEISMOGRAPH FREQUENCY RESPONSE MEASUREMENT DATA

FREQUENCY, HERTZ	MEAN	SENSITIVITY, mV/nm STANDARD DEVIATION
0.15	0.0697	0.009
0.20	0.182	0.019
0.30	0.651	0.045
0.50	3.07	0.127
0.70	8.01	0.237
0.80	11.5	0.365
0.90	15.9	0.769
1.0	19.9	0.663
1.1	24.4	0.881
1.2	29.0	1.13
1.3	33.3	1.40
2.0	60.0	3.40
3.0	83.0	5.97
4.0	104.0	8.16
5.0	118.5	12.55
6.0	61.8	8.64

Number channels used = 339

seismometer in hole 10, and three channels are from high-level combination seismometer-amplifier sensors at holes 62, 23, and 46 and at subarray D1 where six channels originate in near-surface seismometers at holes 52, 72, 54, 74, 65, and 56.

4.1.2 LP Seismograph

The performance monitoring of the 45 standard LASA LP long-period sensors continued during the quarterly period following the procedures of the previous contract. A channel sensitivity average of 339.46 mV/μm at 25s and a standard deviation of 17.46 mV/μm are reported from these seismographs for the three month period. The weekly test results obtained are shown in Table XV where this quarter's statistics are summarized and compared with those of the previous contract and those of the previous June - August period.

Plotted in Figure 4.3 is the percentage distribution of the LP sensors within the 350 ± 50 mV/μm sensitivity tolerance throughout the 21-month period starting 8 December 1970 through 31 August 1972.

4.2 Equipment

The equipment within the array systems are being evaluated on a continuing basis to identify their individual performance characteristics, to detect signs of aging, and to improve methods of detecting malfunctions. Progress of these evaluation efforts is reported in this section as information is collected and/or analyzed and made available for publication.

4.2.1 SP Seismometer, HS-10-1A

The natural frequencies of the SP seismometers are becoming better identified by the measurements being made in conjunction with the SP subarray rehabilitation program (see paragraph 6.3.1). Seismometer natural frequency and damping measurements were made at 36 sensor locations during this quarter. The natural frequency data collected are tabulated in Table XVI where the measured value may be compared with the previous frequency measurement. These data have been combined with others collected during this measurement program to prepare the frequency distribution shown in Figure 4.4. This distribution covers 191 or 55.2% of the arrays seismometers. The tolerance allowed is ± 10% so that all seismometers measuring 1.0 ± 0.1 hertz are considered to be operating satisfactory. Natural frequency measurements are made at the wellhead with the seismometer at the bottom of the casing using the phase-resonant or Lisajous pattern method. Seismometer replacements and field corrections, i.e., repositioning the seismometer in the casing, during this quarter has increased the percentage of natural frequencies inside the tolerance from 66.0% to 80.0%. Of the 191 seismometers tested 38 are presently operating outside the natural frequency range of 1.0 ± 0.1 hertz. Figure 4.5 indicates the natural frequency status of each seismometer data channel in the array.

TABLE XV

LP ARRAY PERFORMANCE TESTING SENSITIVITY STATISTICS

DATE	NO. SENSORS	SENS. MEAN mV/μm	SENS. σ mV/μm	SENS. MAX. mV/μm	SENS. MIN. mV/μm	SENS. DEV. mV/μm
6/5	45	348.08	15.27	394.11	312.20	81.91
6/12	45	343.89	15.33	381.72	309.66	72.06
6/19	45	343.08	16.87	384.70	292.12	92.58
6/26	43	342.84	16.41	377.58	198.74	178.84
7/3	44	339.80	17.27	376.68	192.24	184.44
7/10	44	336.77	16.57	378.43	200.79	177.64
7/17	45	336.76	16.78	375.44	299.32	76.12
7/24	44	338.25	15.31	377.60	303.75	73.85
7/31	43	339.28	17.11	376.42	304.19	72.23
8/7	44	335.57	19.34	374.57	302.67	71.90
8/14	42	332.18	18.94	374.78	273.40	101.38
8/21	44	337.77	22.70	414.72	276.68	138.04
8/28	45	339.65	19.03	398.28	293.79	104.49
AVERAGE	44.08	339.46	17.46	383.46	273.81	109.65
PREVIOUS 3RD QTR. AVERAGE	44.5	341.6	18.5	387	304	81
CONTRACT AVERAGE	44.57	355.14	16.67	398.89	309.26	89.64
PREVIOUS CONTRACT AVERAGE	44.6	356.1	18.8	403	312	90

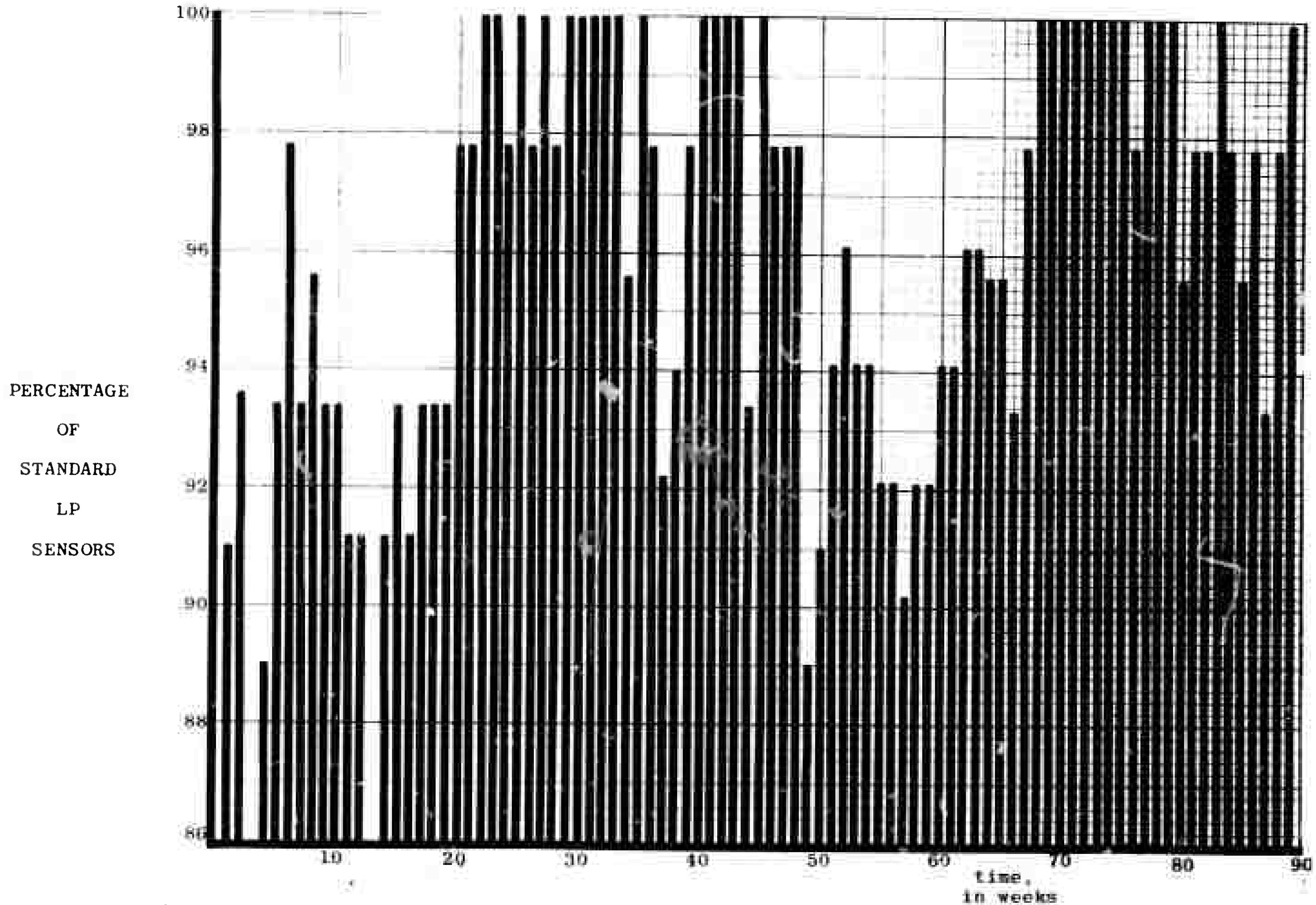


Figure 4.3 Percentage Distribution of LP Sensors within ± 50 mV/μm Sensitivity Tolerance starting 8 December 1970 to date.

TABLE XVI

SP SEISMOMETER NATURAL FREQUENCY MEASUREMENTS

JUNE - AUGUST 1972

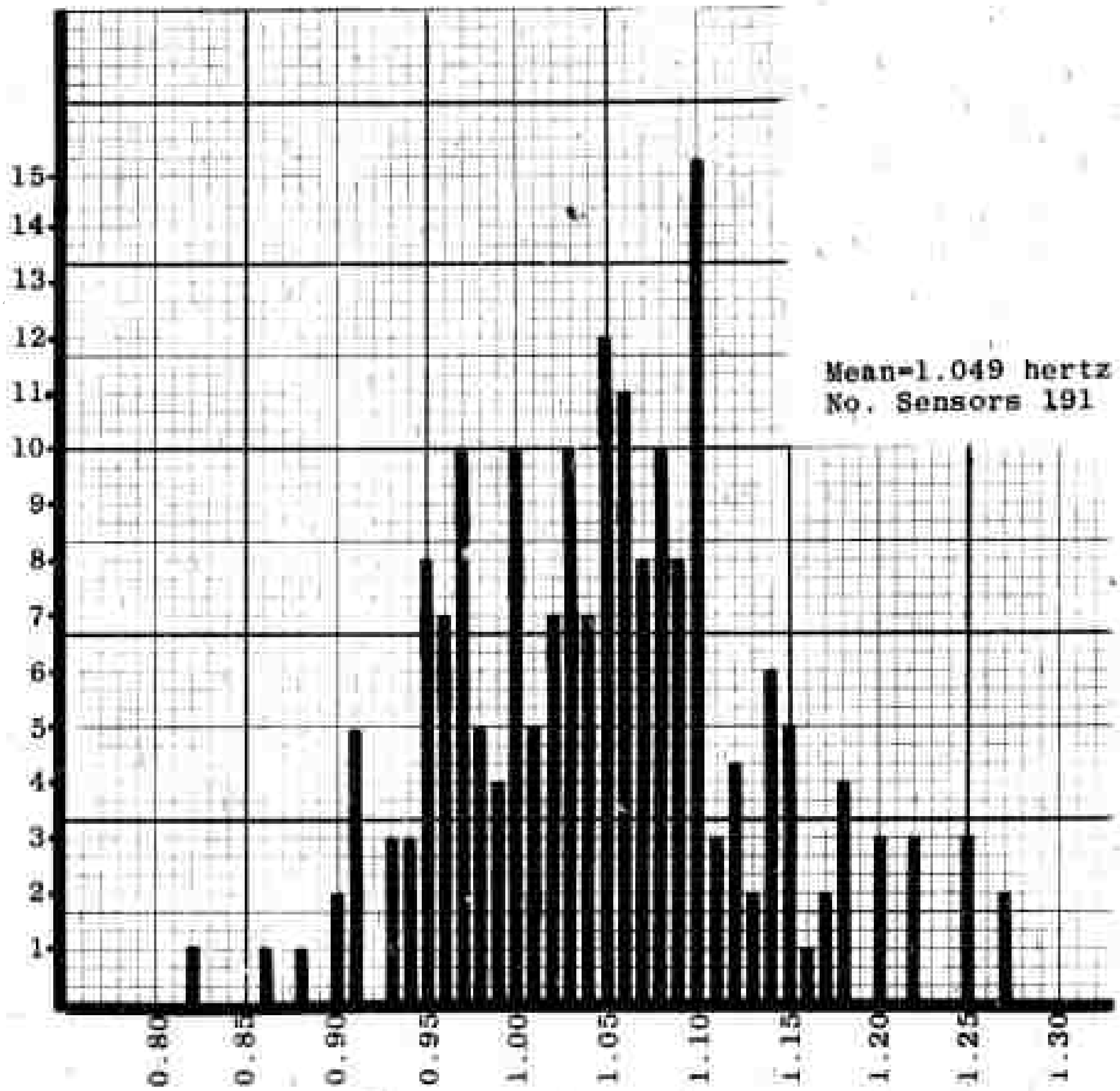
SUBARRAY SENSOR	f_n HERTZ	DAMPING RATIO TO CRITICAL	PREVIOUS f_n HERTZ	CHANGE f_n HERTZ
E1-10	0.97 (8/72)	0.677	1.13	-.16
E1-41	0.935 (7/72)	0.662	1.09 (9/70)	-.16 (22)
E1-72	0.910 (7/72)	0.677	1.02 (9/70)	-.11 (22)
E1-63	1.03 (7/72	0.662	1.13 (9/70)	-.10 (22)
E1-83	0.935 (8/72)	0.677	New Seis.	
E1-45	1.13 (7/72)	0.670	1.12 (9/70)	+.01 (22)
E1-65	1.22 (7/72)	0.653	1.22 (9/70)	.00 (22)
E2-10	1.05 (7/72)		1.12	-.07 (14)
E2-51	1.082 (7/72)	0.591	1.09 (5/71)	-.01 (14)
E2-42	0.911 (7/72)	0.690	New Seis.	
E2-62	1.02 (7/72)	0.677		
E2-73	1.09 (7/72)	0.653	1.17	-.08 (14)
E2-64	1.01 (7/72)	0.653	New Seis.	
E2-84	1.06 (7/72)	0.653		
E2-75	1.10 (7/72)	0.653	1.10 (5/71)	.00 (14)
F3-41	1.10 (6/72)	0.670	1.14 (8/71)	-.04 (10)
F3-52	0.96 (6/72)	0.670	New Seis.	
F3-72	0.90 (6/72)	0.653	New Seis.	

TABLE XVI

SP SEISMOMETER NATURAL FREQUENCY MEASUREMENTS (CONCLUDED)

JUNE - AUGUST 1972

SUBARRAY SENSOR	f_n HERTZ	DAMPING RATIO TO CRITICAL	PREVIOUS f_n HERTZ	CHANGE f_n HERTZ
F3-43	1.095 (6/72)	0.653		
F3-83	0.95 (7/72	0.690	New Seis.	
F3-74	1.08 (6/72)	0.677	1.[illegible]1 (8/71)	-.03 (10)
F3-65	1.00 (6/72)	0.670	0.98 (8/71)	.02 (10)
F3-56	0.91 (6/72)	0.683		
D3-10	1.01 (8/72)			
D3-71	1.03 (8/72)	0.653	New Seis.	
D3-42	1.00 (8/72)			
D3-62	1.00 (8/72)			
D3-53	1.03 (8/72)	0.653		
D3-73	0.97 (8/72)	0.662	New Seis.	
D3-64	1.01 (8/72)	0.670	New Seis.	
D3-55	0.93 (8/72)		New Seis.	
D1-72	1.06 (8/72)	0.643	New Seis.	
D1-54	1.08 (8/72)	0.653		
D1-74	1.09 (8/72)	0.643		
D1-65	1.10 (8/72)	0.670		
D1-56	0.98 (8/72)	0.677	1.00 (11/71)	-.02 (9)



Seismometer Natural Frequency (hertz)

Figure 4.4 SP Seismometer Natural Frequency Distribution, 1970-1972

Figure 4.5

Seismometer Natural Frequency Status of Array

Data Channel Number	Subarrays																			
	A 0	B 1	B 2	B 3	B 4	C 1	C 2	C 3	C 4	D 1	D 2	D 3	D 4	E 1	E 2	E 3	E 4	F 1	F 2	F 3	F 4
1	O	X		O		O	X	X	O	O				O	O		O		O	O	O
2	W	E	E	E	E	E	E	E	E	E		E	E	W	W		W	W	W	W	W
3	O	E	E	E	E	E	E	E	O	X		E	O	O	E		O		O	O	E
4	O	O		O	X	E	X	O	O						O		O				X
5							O	O				X									O
6	W	E	E	E	E	E	E	E	E	E	E	E	E	W	W		W	W	W	W	W
7	E	O	O	X	X	X	O		E	E	O		E	E	O		E	E	E	E	
8				O		X	X	X	O					O	O		O		O	O	
9	O	X			O		O	O		O				O					O	O	O
10	W	E	E	E	E	E	E	E	E	E		E	E	W	W		W	W	W	W	W
11	X	E	E	E	E	E	E	E	O	X		E			E		O	X	O	O	E
12		X	X		X	X	O		E				O	O			O		O		O
13			X		X		O	O	O	O	O	O	O	O	O		O		O	O	O
14	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E		E	E	E	E	E
15	W		X	O		O	X	O	E	E	O		E	E			E	E	E	E	O
16	O		O		O		O		O	O		X	O		O		O	O	O		O
17			O	O			O	O	O	O		O			O		O	O	O	O	O
18	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E		E	E	E	E	E
19	O	E	E	E	E	E	E	E		O	E	E		X	E		O	O	O	O	E
20	O				X		O		O	O	X			X	O		O		O	O	
21	O			O	O		O	O	O	X	O	O		O	O		O	O	O		
22	O	X		O		O	X	X	O	O				O	O		O		O	O	O
23	E	O		O	X			X	E	E			E	E			E	E	E	W	O
24	O	X		X			O	X	O	O	O		O						O	O	O
25	O	X	X		O		O	O			O		O	O				O	E		O

Legend: 0 - Natural frequency within 1 ± .1 hertz

X - Natural frequency exceeds 1 ± .1 hertz

E - Empty data channel, no sensor connected

W - Weather Instrumentation Data Channel

Blank - Natural frequency measurement data not current

Seismometer damping measurements have been made at 120 sensor locations since the collection of these data started. Previously the damping test was reported as satisfactory or unsatisfactory depending upon whether or not the damping ratio to critical was within 0.6 to 0.8. The frequency distribution of the damping measurement data collected from the 120 sensors or 31.8% of the array is plotted in Figure 4.6. These data indicate the arrays seismometers are somewhat underdamped from the nominal .7 damping ratio.

Since the internal damping of the HS-10-1A seismometer is significant enough to prevent seismometer oscillations from a single excitation pulse, the usual rate-of-oscillation-decay method of damping measurement cannot be used. However, the damping ratio can be determined by the overshoot method in which the mass is excited by a short-duration dc pulse applied to the calibration coil. The ratio of the positive half-cycle to the negative cycle output from the data coil determines the damping. An external damping resistance is selected so that the overshoot ratios corresponds to a damping ratio (to critical) range of .6 to .8. The external damping resistances are selected from a set consisting of these ohmic values: 51K, 82K, 110K and 120K.

4.2.2 SP Seismic Amplifier, Type II

An investigation of the spurious responses in the LP system reported by Lincoln Laboratory (Ref. 4) has been conducted. A series of tests on the TI Type II amplifier have been performed at the LMC to determine if spurious low frequency output responses could be produced from high frequency signal inputs. The test set-up, shown in Figure 4.7, utilized two signal generators to simulate the effect of changes to low frequency signal input to the amplifier and the effect of combining high frequency interferring signal with the low-frequency signal.

The results of the testing showed that suddenly decreasing the amplitude or increasing the frequency of the low frequency signal input did produce a spurious high level output pulse. However, introducing an increasing-amplitude high frequency signal onto a steady low-frequency signal input did not produce a very noticeable effect, viz., a slight negative shift in one cycle of the output waveform.

The significance of these test results have not been determined with regard to their application to real signals applied to the LASA seismographs.

4.3 Surficial Noise Studies

Surficial noise studies are considered a part of the performance measurement of the array's seismographs because of the relation between determining good instrument signal-to-noise ratio performance and the extent of interferring external noise. Further,

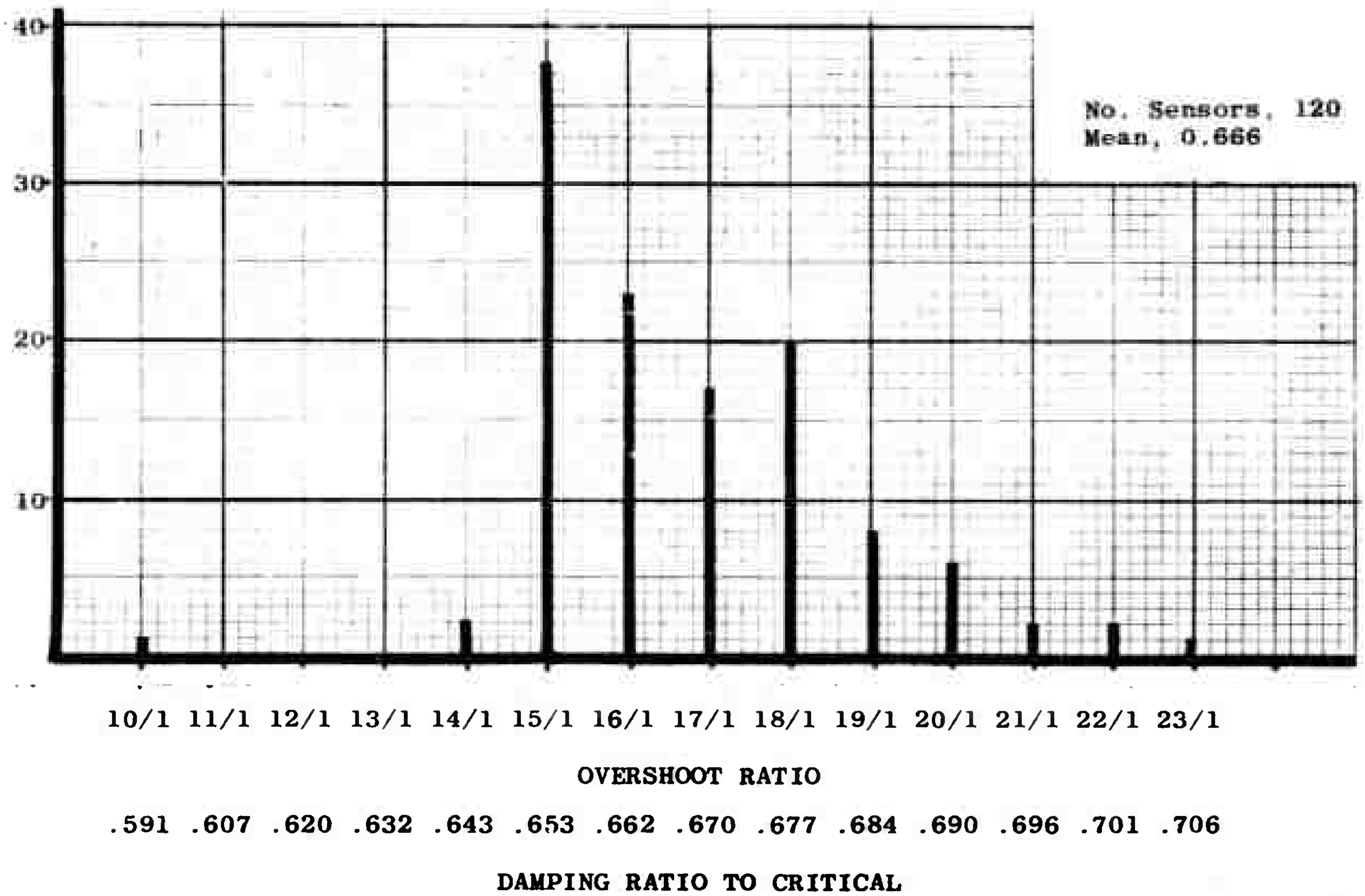


Figure 4.6 SP Seismometer Damping Ratio Distribution, 1972

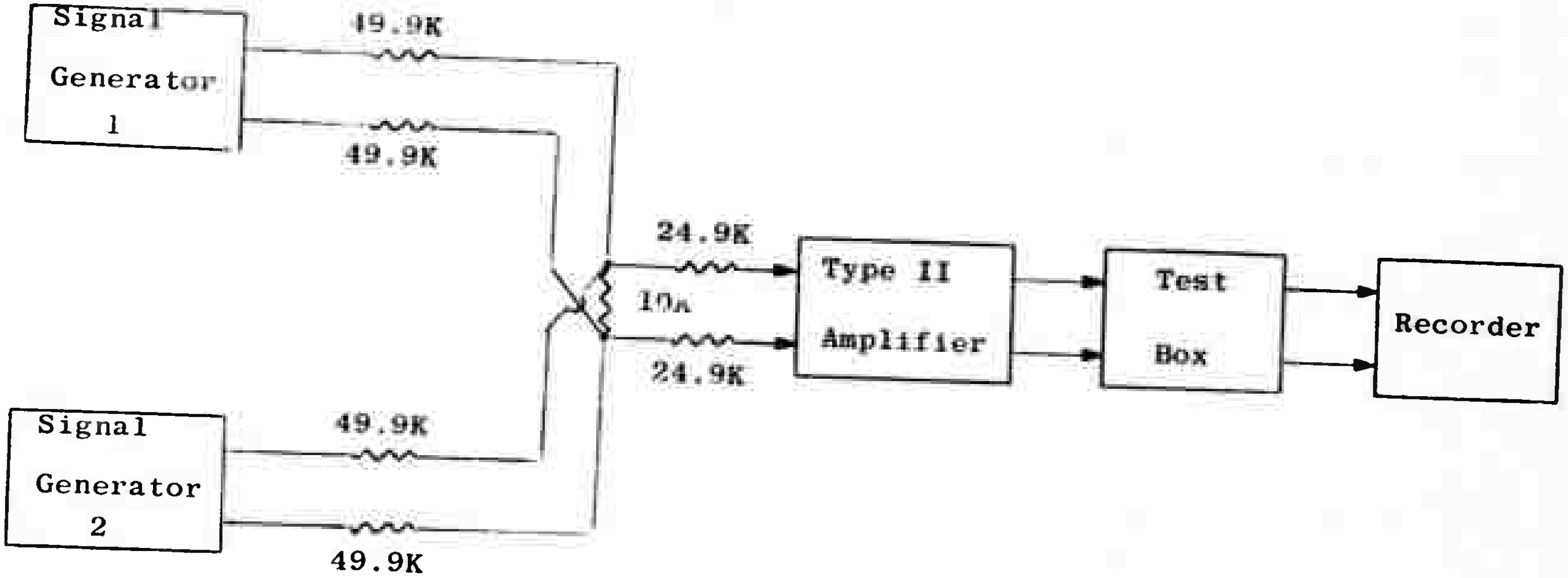


Figure 4.7 Set-Up for Type II Amplifier Spurious Response Test

since the seismometers are not decoupled from the earth when in the calibration mode, the time and duration of interferring surficial noise even if limited to a single subarray influence the periods in which calibrations may be performed. To help determine if intervals of noisy seismograph channel output result from the instrumentation or from external sources, a limited program to classify and identify some surficial and other interferring noise conditions is being initiated. Since the identification can be accomplished readily either on-site or at the LDC, time permitting the routine operation of the array is being modified to identify some of the interferring noise sources.

Local noise sources of the Montana array of interest to this study have been categorized as either natural or man-made. The man-made noise sources include: mine blasting operations, highway construction, sonic booms, oil and gas well drilling, train traffic, and agricultural activity. Natural sources include large weather systems and near-regional earthquakes from areas of high activity.

Disregarding the frequency of the noise and assuming a nominal system dynamic range (below the 84 dB theoretical value) for each seismograph channel, the goal of this study is to develop as a part of our PDP-7 on-line array monitoring program a method of determining when particular channels are being subjected to excessive amounts of interferring noise. During these times in which the system dynamic range is reduced to below an acceptable level, calibrations will not be performed. Further, on-line measurement should help determine the influence of an increased activity in certain of the local noise sources.

4.4 Failure Report

The array system and equipment failures which occurred this quarter are discussed in this section. All the failures are classified according to the type of failure and include these five classifications:

(1) System failure - A failure resulting in zero or no system output which prevents the system or equipment assembly from performing its primary function and identified as a Type 1 failure.

(2) Mode failure - A failure resulting in a zero or no system output only during one of several different modes of operation; a Type 2 failure.

(3) Limited failure - A failure resulting in a system output which is outside the allowable tolerance limits but permits degraded performance; a Type 3 failure.

(4) Latent failure - A failure which changes a system output either by an amount less than the allowable tolerance or from the nominal output when no tolerance limits have been established; a Type 4 failure.

(5) Temporary failure - A failure produced by an operating or environmental stress which results in no permanent physical damage; a Type 5 failure.

Table XVII indicates the number of failures detected and corrected in each of the ten array systems. In decreasing order the three systems with the largest number of failures were again the SP sensor, PDP-7 computer, and the LDC Test and Support. The 360 Computer system operated again during this quarter without any failures and the Meteorological system had only one failure. The distribution of the equipment failures within each system is shown in Table XVIII.

The HS-10-1A seismometer and RA-5 amplifier in the short-period system accounted for 68 of the 70 failures in the system. The seismometer failures were identified for repair during the current SP rehabilitation program. Of the 48 RA-5 failures seven failed completely, 15 were out-of-tolerance, four were intermittant, and the remaining 22 were latent failures identified for repair during the SP rehabilitation program.

The tape units accounted for 78% of the PDP-7 system failures, and the MDC 1 and 2 for all seven failures in the LDC Test and Support System. These type of failures have been previously reported and are expected due to constant use of this equipment. These failures are usually mechanical for the tape units and battery replacements in the zero suppression amplifiers of the Maintenance Display Console. Except for the PDP-7 tape units, all failures were isolated in nature and do not indicate trends on maintenance problems. Descriptions of pertinent equipment repairs can be found in Section VI.

The performance of the SP array in terms of the number and duration of channel failures detected can be seen from the distribution shown in Figure 4.8.

TABLE XVII

LASA SYSTEM FAILURE DETECTIONS AND CORRECTIONS

JUNE 1972 - AUGUST 1972

	STARTING BACKLOG	DETECTED	CORRECTED	ENDING BACKLOG
SP SENSOR	22	67	70	19
LP SENSOR	0	8	8	0
METEOROLOGICAL SYSTEM	0	1	1	0
SEM	0	9	9	0
POWER SYSTEM	0	10	9	1
360 COMPUTER	0	0	0	0
PDP-7 COMPUTER	3	49	45	7
LDC DIGITAL	0	3	3	0
LDC ANALOG	0	6	5	1
LDC TEST AND SUPPORT	1	18	17	2
TOTALS	26	171	167	30

TABLE XVIII

EQUIPMENT FAILURES

ARRAY SYSTEM/EQUIPMENT	NUMBER OF FAILURES					
	TYPE OF FAILURE					
	1	2	3	4	5	TOTAL
Short-Period System						
Seismometer	0	0	14	6	0	20
WHV Panel W/RA-5	7	0	15	22	4	48
RA 5 Power Supply	2	0	0	0	0	2
WHV Junction Box	0	0	0	0	0	0
WHV/Cables	0	0	0	0	0	0
CTH Junction Box (SP)	0	0	0	0	0	0
Total	9	0	29	28	4	70
Long-Period System						
Vertical Seismometer/Tank	0	0	0	0	0	0
Horizontal Seismometer/Tank	1	0	0	2	0	3
LP Vault/Cabling	0	0	0	0	0	0
LP Junction Assembly	0	0	0	0	0	0
Motor Assembly	2	0	0	0	1	3
Seismic Amplifier, Type II	1	0	1	0	0	2
Amplifier Power Supply	0	0	0	0	0	0
CTH Junction Box (LP)	0	0	0	0	0	0
Total	4	0	1	2	0	8
Meteorological System						
Aerovane, Wind Direction	0	0	0	0	0	0
Aerovane, Wind Speed	0	0	0	0	0	0
Pole Assembly	0	0	0	0	0	0
Pole Junction Box/Cabling	0	0	0	0	0	0
Temperature Probe	0	0	0	0	0	0
Electrobarometer/Baffle	0	0	0	0	0	0
Rain Gauge	0	0	0	0	0	0
Rain Gauge Electronics Panel	1	0	0	0	0	1
Total	1	0	0	0	0	1

TABLE XVIII

EQUIPMENT FAILURES (CONTINUED)

ARRAY SYSTEM/EQUIPMENT	NUMBER OF FAILURES					
	TYPE OF FAILURE					
	1	2	3	4	5	TOTAL
Subarray Electronics Modules						
Input Drawer #1	0	0	1	0	0	1
Input Drawer #2	0	0	1	0	0	1
Multiplexer/ADC	0	0	0	0	0	0
Output Drawer	3	0	1	0	0	4
PDC Drawer	0	0	1	0	0	1
ACC Cabinet	2	0	0	0	0	2
SEM Cabinet/Cabling	0	0	0	0	0	0
Alarms	0	0	0	0	0	0
Total	5	0	4	0	0	9
Power System						
Control Drawer	1	0	1	0	0	2
Inverter	7	0	0	0	0	7
Charger	0	0	0	0	0	0
Battery	0	0	0	0	0	0
SOLA Transformer	0	0	0	0	0	0
Rack Cabling	0	0	0	0	0	0
Isolation Transformer	0	0	0	0	0	0
Breaker Panel	0	0	0	0	0	0
Vault/Wiring/Breakers/Outlets	0	0	0	0	0	0
Total	8	0	1	0	0	9

TABLE XVIII

EQUIPMENT FAILURES (CONTINUED)

ARRAY SYSTEM/EQUIPMENT	NUMBER OF FAILURES					
	TYPE OF FAILURE					
	1	2	3	4	5	TOTAL
360 System						
CPU 2044	0	0	0	0	0	0
Disc Drive 2315	0	0	0	0	0	0
Typewriter 1052	0	0	0	0	0	0
Card Reader 2501	0	0	0	0	0	0
Data Control 1826	0	0	0	0	0	0
Data Adapter 1827	0	0	0	0	0	0
Data Adapter 2701	0	0	0	0	0	0
Total	0	0	0	0	0	0
PDP-7 System						
Computer	0	0	4	0	0	4
Teletypewriter KSR-35	0	1	1	0	0	2
Card Reader	3	0	0	0	1	4
SOU	0	0	0	0	0	0
Interface	0	0	0	0	0	0
Tape Unit #19	3	0	1	0	0	4
Tape Unit #32	3	0	8	0	1	12
Tape Unit #33	3	0	7	0	0	10
Tape Unit #22	3	0	6	0	0	9
Incremental Recorder	0	0	0	0	0	0
Total	16	0	27	0	2	45
Digital System						
Timing System #1	0	0	0	0	0	0
Timing System #2	0	0	2	0	0	2
Digital Data Simulator	0	0	0	0	0	0
Power System	0	0	0	0	0	0
PLINS	0	0	0	0	0	0
MINS	0	0	1	0	0	1
Total	0	0	3	0	0	3

TABLE XVIII

EQUIPMENT FAILURES (CONCLUDED)

ARRAY SYSTEM/EQUIPMENT	NUMBER OF FAILURES					
	TYPE OF FAILURE					
	1	2	3	4	5	TOTAL
Analog System						
D/A Patch Panel Cabinet	0	0	0	0	0	0
D/A Converter #1	0	0	0	0	0	0
D/A Converter #2	0	0	0	0	0	0
D/A Converter #3	0	0	0	0	0	0
D/A Converter #4	0	0	0	0	0	0
FM System	0	0	0	0	0	0
16 Channel Chart Recorder	0	0	1	0	0	1
WHV Receiver	0	0	0	0	0	0
Analog Calibration System	0	0	0	0	0	0
Analog Timing System	0	0	1	0	0	1
SP Develocorder	0	1	0	0	0	1
LP Develocorder	1	0	0	1	0	2
Total	1	1	2	1	0	5
LDC Test and Support System						
MDC-1	0	0	9	0	0	9
MDC-2	0	0	7	1	0	8
Clocks	0	0	0	0	0	0
Film Viewer	0	0	0	0	0	0
Film Duplicator	0	0	0	0	0	0
Copier	0	0	0	0	0	0
Emergency Lights	0	0	0	0	0	0
Compressor, Blower	0	0	0	0	0	0
Digital Clocks	0	0	0	0	0	0
Air Conditioners	0	0	0	0	0	0
Humidifier	0	0	0	0	0	0
Tape Cleaner	0	0	0	0	0	0
Electrostatic Filters	0	0	0	0	0	0
Total	0	0	16	1	0	17

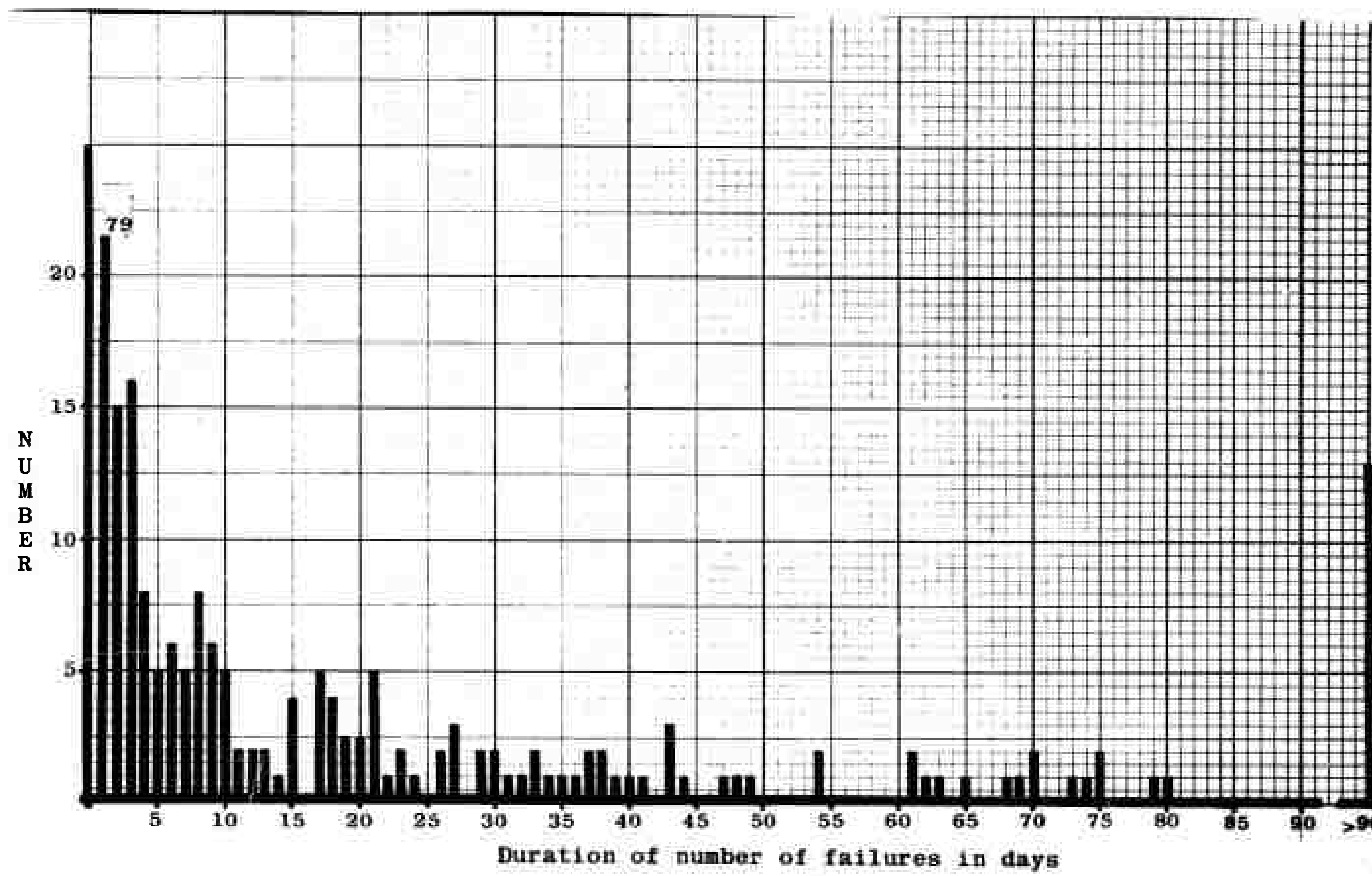


Figure 4.8 Distribution of the Number and Duration of the Defective SP Seismographs between 5 September 71 and 30 August 72

SECTION V

IMPROVEMENTS AND MODIFICATIONS

5.1 General

Important to the operation of the Montana LASA is the continuing incorporation of improvements and modifications into the various equipments. These improvements permit increased efficiency in the utilization, operation and maintenance of the seismic observatory's systems. The improvements are categorized into these three areas, PDP-7 programming, array equipment and data center equipment. Improvements in the PDP-7 programming result in more efficient operation and increase the data collection capability of the array performance measurement activity. Modifications to the array and data center equipment are made to reduce the need for maintenance (i.e. improve reliability), to improve data quality, or to extend the operating capability.

5.2 System

5.2.1 PDP-7 Program MOPS

Programming changes have been made to the PDP-7's Multiple-On-Line-Processing System (MOPS) to improve the efficiency of the on-line system operation. These changes to the original MOPS (Reference 5) were made primarily to increase the core memory available for the patch overlay programs used for semi-automatic array maintenance and monitoring. In the preparation of the new version certain other features were added to improve the overall system operation.

To provide increased core for the patch program: (1) the lower memory input/output buffers were realigned, (2) the on-line beam former was removed, (3) the core requirement for the on-line event detector was reduced, and (4) the interrupt answering program was rewritten. Other changes include: (1) improvement to the array monitoring output format, (2) addition of a third tape unit to the cyclic recording sequence during high-rate, back-up recording, (3) addition of a magnetic tape header check to prevent recording over a tape less than 30 days old, (4) rearrangement of the hourly weather output format to agree with the geometric configuration of the array and the calculation of a wind gust statistic, (5) incorporation of a keyboard priority to permit ready access by the operator to the program from the teletypewriter, (6) rearrangement of the on-line event detector output format to conserve paper, (7) addition of a tape edit process for recording onto a single tape the low-rate formatted data collected during the day from all event detector declared events, and (8) preparation of new low-rate and very-low-rate recording formats.

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Because of the importance of this PDP-7 computer system operation, a review of the overall MOPS II program is presented in paragraph 5.2.2.

5.2.2 Program MOPS II Description

a. Introduction

The function of the LASAPS Multiple On-line Processing System Version 2 (MOPS II) is to perform the requirements necessary for LASAPS operation. The system implements the Digital Equipment Corporation PDP-7 computing system which consists of four seven-track magnetic tape drives, card reader, Model 35 Keyboard Send-Receive (KSR 35) teletypewriter, paper tape reader, paper tape punch, and LDC recording systems which consists of a Kennedy Incremental Recorder, two eight-channel Sanborn chart recorders, one sixteen-channel Sanborn chart recorder, and one Develocorder.

The principal requirements of LASAPS operation are to provide a back-up system of recording seismic data in the event phone-line transmission to the Seismic Array Analysis Center (SAAC) cannot be accomplished and to assist with the monitoring and maintenance support of the array.

b. Preparation

The system is assembled from punched cards using the FLAP assembler. The output of the FLAP assembler is a binary RIM mode object program punched in paper tape and an assembly listing written on magnetic tape for output on a line printer.

c. Program Characteristics

The system program is a composite of several functions which are: initialization, interrupt servicing, reading array data, magnetic tape operations, punch card input, paper tape input, paper tape output, SOU output, telemetry generation, teletypewriter input, and teletypewriter output. Initialization includes all operations prior to receiving, processing, and monitoring the seismic array data. These operations involve disabling the interrupts and clearing the interrupt flags; setting up all address pointers, counters, flags, and locations which require a specific initial value; and setting up the subarray and seismometer status.

When the system is in operation, input and output on the various devices will cause interrupts. When an interrupt occurs, the current address is stored in location Ø and control is passed to location 1. Locations 1 and 2 are set up during initialization to transfer control to interrupt servicing. Interrupt servicing consists of sensing the interrupt flags of the various devices to determine which device caused the interrupt. The order in which the flags are sensed determines the priority of the particular device.

When the device has been serviced, control is passed back to the address stored in location Ø.

Array data is read in frames of 31 word groups at a rate of 20 frames per second. When a frame of data is ready to be read, a frame sync start interrupt occurs. Servicing of the interrupt provides the hardware with the starting memory location for reading in the frame, the number of word groups to be read, and a signal to start reading the frame. The frames are read into memory through a double buffering technique, two frames per buffer. Double buffering involves reading into one buffer while writing (recording) out of another and then switching their functions when the read and write are complete. The proper read and write sequence is maintained by manipulation of the starting locations of the frames and buffers.

The prinicpal magnetic tape operation is the recording of the array data in the high rate recording mode. Data is recorded in records of two data frames (0.1 second of data) and an occasional trailer field. The trailer field reflects the subarray and seismometer status of the array and is appended to the first or second record of each tape and to each record which covers a period in which a status change occurs. Paragraph 5.2.2 covers the recording format of the array data tapes.

The records are constructed in memory and output for writing on magnetic tape through the double buffering technique discussed above. Recording commences on logical unit number one and switches to logical unit number two when 4800 records are written or an end-of-tape is sensed. There-after, recording continues to alternate between logical units one, two, and three. When each tape is completed an end-of-file is written on the tape and it is rewound and unloaded. Each tape will contain a maximum of eight minutes of data.

The low-rate tape operation is the recording of selected array data. Data is recorded in records covering a period of twelve frames (0.6 second of data). Paragraph 5.2.2 covers the recording format of the array data tapes. The records are constructed in memory and output for writing on magnetic tape using the double buffering technique previously discussed. Recording commences on logical unit number four and switches to logical unit number five when 8000 records are written or an end-of-tape is sensed. Thereafter, recording continues to alternate between logical units four and five. When each tape is completed an end-of-file is written on the tape and it is rewound. Each tape will contain a maximum of eighty minutes of data.

The very-low-rate tape operation is the recording of selected array data. The record is constructed in memory and written on magnetic tape in groups of 55 words once every fifth frame. A record is completed every 15 seconds. Recording is done by a Kennedy Incremental Recorder. Recording continues for 2400 records or until operator action terminates the recording. When each tape is completed three end-of-files are written on the tape and a fresh tape is readied for further recording. Each tape will contain approximately 10 hours of data.

Punch cards may be used during the operation of Patch programs. Interrupt servicing is designed to handle the card reader interrupts leaving the reader initialization and control of the card data to the Patch overlay.

Paper tape may be used during the operation of the System or under control of the Patch Overlay. RIM mode tapes are used to change program tables for selecting various data words for SOU output, and to load Patch overlays for additional processing functions. ASCII code may be used for input under control of Patch Overlays. The Patch Overlay controls the necessary changes in the interrupt answering routine to process the ASCII code. Paper tape output is in the format of ASCII code and may be printed out by using the off-line printer.

The Serial Output Unit is composed of 31 analog channels constructed in memory through the double buffering technique. Selection of word(s) for output is determined by the particular requirements for data analysis.

Telemetry generation is under program control when the Auto-Manual switch located on the MDC is set to Auto. Selection of bit configurations with appropriate IOT commands initializes telemetry to the array for array analysis.

Teletypewriter input consists of control words which govern the initialization, control, and termination, of the functions discussed in this paragraph. Teletypewriter output consists of messages which are generated by the system as a result of operator or hardware error, operator output request, or changing conditions in the system or array.

d. Data Base Characteristics

The data base of the system consists of array input data, teletypewriter input data, and internal program data. The following paragraphs describe the particular data base characteristics.

The array input data consists of short-period seismic, long-period seismic, temperature, wind speed, wind direction, and barometric pressure signals. Array input data is read into sequential memory locations, one data word per memory location, in two's complement binary representation with odd parity.

Teletypewriter input data is read into a memory location, one eight bit ASCII character, right justified. The four high order bits of the character are dropped and the remaining four bits are added to a cleared core location and shifted left three bit positions, then stored back in the memory location until the next character is entered and added to the memory location. This continues until a period is entered and at that time a compare is made to determine the action the program is to take.

Internal program data is the fixed data which is present upon program loading as an integral part of the program. Internal program data is in the form of tables and constants suitable for efficient manipulation by the program.

Tables are collections of data stored in sequential memory locations and referenced by a label associated with the first memory location of the particular table. Table data consist of relative program addresses and masks (a one word bit configuration which specifies which bits of another word are to be operated on) which are used by the program to translate, reference, or store other data.

Constants may be relative program addresses, masks, BCD characters or numeric binary values. Constants may be manipulated individually or in groups as in the case of messages (packed line printer ASCII code in octal form). Constants may or may not have as associated label, or several constants may be associated with one label.

e. Timing

The timing sources of the system are frame sync start interrupts and computer clock interrupts. The frame sync start interrupts originate from an external source viz., the PLINS, at regular 50 ms intervals, while the computer clock interrupts occur at program controlled intervals. Two frame sync start interrupts and one clock interrupt constitute the timing for what may be termed as the basic computing cycle of the system.

The basic computing cycle of the system is 100 ms, in which two frames (even and odd) of array data are read into memory and the write of one data record is initiated. The basic computing cycle begins with a frame sync start interrupt. Approximately 1.56 ms after the frame sync start, the first word group of the even frame is available to the computer in the PLINS buffer. The frame sync start interrupt is serviced and the even frame is read into memory by the double buffering technique.

The second frame sync start interrupt occurs 50 ms later. The interrupt is serviced and the read of the odd frame into memory is initiated. In addition, the clock is set to a predetermined time interval and enabled. The clock interval is set to allow enough time for the odd frame to be read into the memory before initiating the data record write. If an end-of-file and rewind were initiated following the data record write of the previous cycle, the clock interval is set to allow additional time for their completion. When the time interval expires, a clock interrupt occurs. The clock interrupt is serviced and the write of the data record is initiated, completing the basic computing cycle. The system computing cycle timing is illustrated in Figure 5.1.

f. Storage Allocation

The LASA PDP-7 computer has two memory banks, lower and upper. Each bank contains 8,192 words, 18 bits per word. Both memory banks are required by the system program. Because of hardware limitations, which restrict hardware controlled input and output to lower memory, the lower memory bank is used primarily for input and output double buffering of array data. The only instructions located in lower memory are those used in Patch Overlays. The lower memory instructions are not present upon program loading, but rather, read in by instructions in upper memory for Patch Overlay loading. The storage allocation of the lower memory bank is illustrated in Figure 5.2.

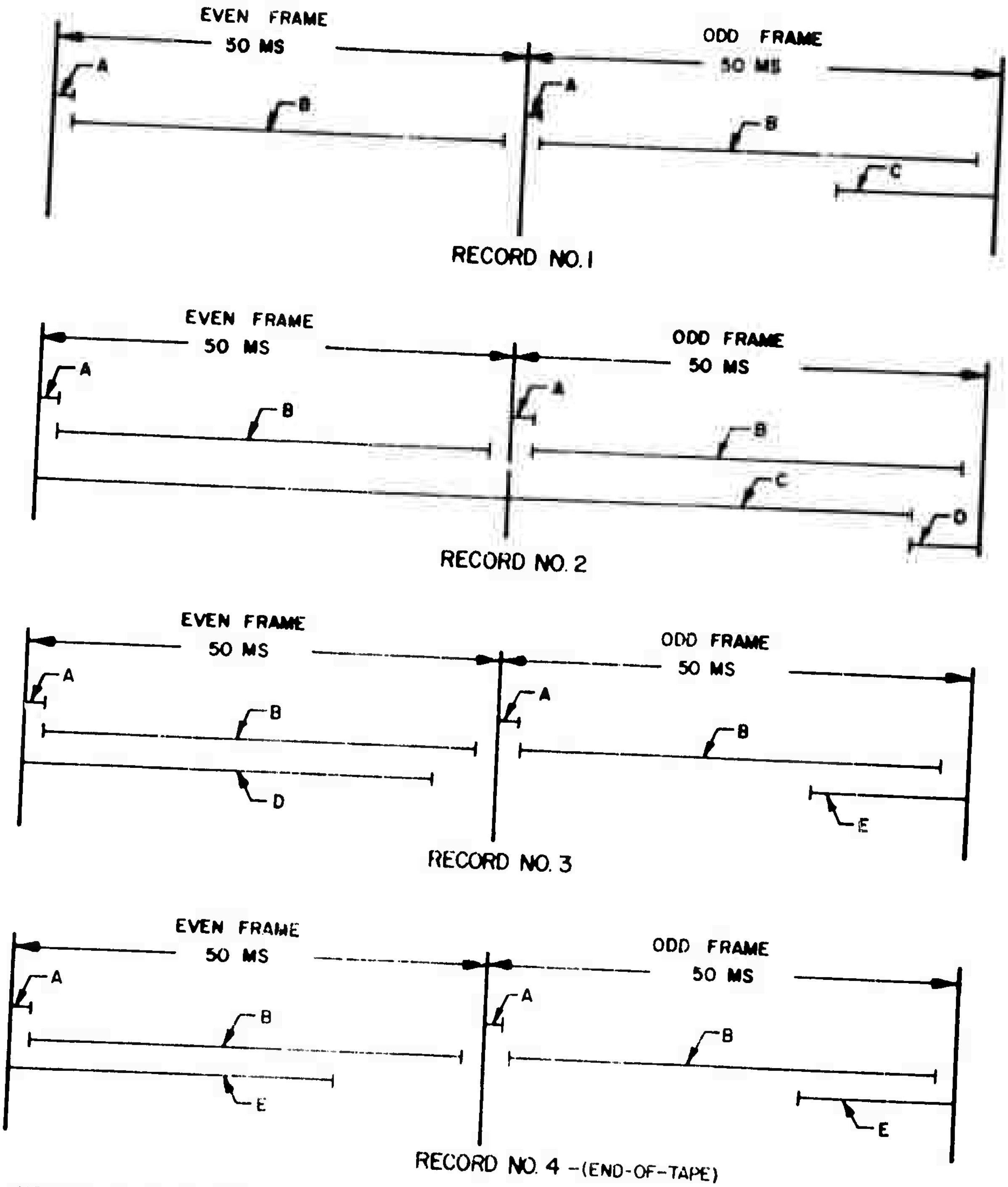
The system program is loaded into upper memory. The instructions and internal data which constitute the various functions of the system are present in upper memory upon program loading. The storage allocation of the upper memory bank is illustrated in Figure 5.3.

g. Special Functions

i) Array Monitoring:

The monitor function is designed for on-line analysis of array status and performance. The monitor function is an examination of word 31 from each site. Telemetry commands, alarm conditions, glitch errors, and sites deleted, are printed out on the teletypewriter.

The power condition and vault condition are general conditions and need further analysis. This can be performed in two ways: (1) in a manual mode from the MDC, or (2) in a computer mode by the PDP-7. If the operation is set for manual mode, the operator would have to initiate the TC-53 for a power condition or a TC-54 for a vault condition from the MDC. If the operation was set for computer mode the PDP-7 monitor would automatically initiate a TC-53 and/or TC-54 when a power and/or vault condition was detected. The telemetry initiated is sent to the designated site or sites for a six (6) second period and analyzed to output the condition message.



NOTES:
A - SEQUENCE AND INITIATE READ IN OF DATA FRAME
B - INPUT OF DATA FRAME - HARDWARE CONTROL (DATA BREAK)
C - WRITE MAG TAPE RECORD 1
D - WRITE MAG TAPE RECORD 2
E - WRITE MAG TAPE RECORD 2 + 1(N) WHERE N=1-4797

Figure 5.1 MOPS II Basic Computing Cycle Timing

LOWER MEMORY BANK

DECIMAL ADDRESS	OCTAL ADDRESS	TAG	
0-19	0-23	LM INTERRUPT ANSWERING, INDEX REGISTERS	
20-63	24-77		
64-1369	100-2531	FMHED FRAME 1 EVEN ARRAY DATA	RECORD A RECORD A IF TRAILER REQUIRED
(719)	(1317)	FRAME 2 ODD ARRAY DATA	
1370-1411	2532-2603	FMTAL	
1412-2717	2604-5235	FMHED 1 FRAME 3 EVEN ARRAY DATA	RECORD B
(2065)	(4021)	FRAME 4 ODD ARRAY DATA	
2718-2781	5236-5335	SOUBLK	SOU OUTPUT
2782-2785	5336-5341	HEDBUF	TAPE HEADER CHECK
2786-3404	5342-6514	SMHED LOW RATE RECORD BUILD	PACEXT
3405-4023	6515-7667	SMHED 1 LOW RATE RECORD BUILD	

Figure 5.2 MOPS II Storage Allocation

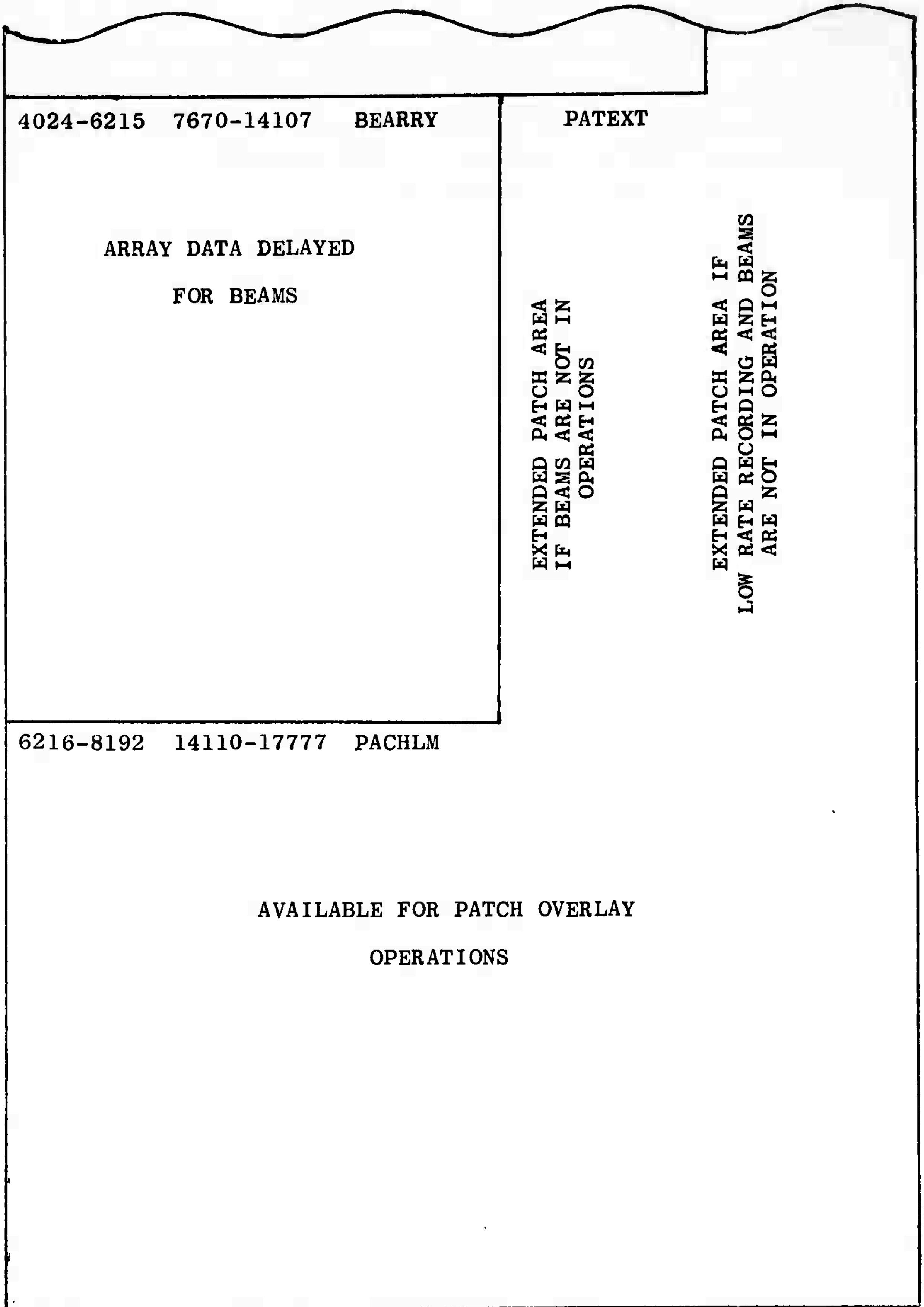


Figure 5.2 (Concluded)

UPPER MEMORY BANK

DECIMAL ADDRESS	OCTAL ADDRESS	ROUTINE
0-43	0-53	INTERRUPT ANSWERING, INDEX REG, CAL-HALT
44-122	54-172	POINTERS, FLAGS, TABLE OF SITE LETTERS
123-158	173-236	LOOP-WAITING FOR INTERRUPTS
159-1069	237-2055	INTERRUPT SERVICE
1070-1365	2056-2525	TYPEWRITER INPUTS
1366-1703	2526-3247	TYPEWRITER OUTPUTS
1704-2295	3250-4367	MAGNETIC TAPE OPERATIONS
2296-2584	4370-5030	INCREMENTAL RECORDER OPERATION
2585-2685	5031-5175	PROGRAM LITERALS
2688-4831	5200-11337	ARRAY MONITOR

Figure 5.3 MOPS II Storage Allocation

4832-5381	11340-12405	WEATHER
5381-5453	12406-12515	PROGRAM LITERALS
5456-5528	12520-12630	RECORD BUILD FOR LOW RATE
5529-5596	12631-12734	SOU OUTPUT
5597-6669	12735-15015	EVENT DETECTOR
6670-6692	15016-15044	PROGRAM LITERALS
6693-8192	15045-17777	

AVAILABLE FOR PATCH OVERLAY
OPERATIONS

7168-7513	16000-16531	CTLSYS

SYSTEM INITIALIZATION
THEN AVAILABLE FOR PATCH OVERLAY

Figure 5.3 (Concluded)

The operator has control over the telemetry initiated by the PDP-7 through the use of the "COMP-MANUAL" switch located on the MDC. If the switch is in the "COMP" position the PDP-7 will initiate the telemetry as needed. The operator can cancel the telemetry generated by the PDP-7 by setting the switch to "MANUAL" position at any time.

When any of the conditions occur other than telemetry, the message output is accompanied by an alarm bell to attract the operator's attention. This is a back-up feature in case the alarm panel on the MDC should fail.

A status report is printed out on the hour, giving any conditions that have been previously reported and are still existing. The glitch count for each site, if any, is reported and cleared for the next hours accumulation. Any sites that have been previously deleted and are currently flagged are printed.

If a power and/or vault condition exists at the time of a status report, a telemetry command of TC-53 and/or TC-54 is initiated to analyze the current condition in case the sub-condition has changed to other then previously reported.

Sub-Conditions:

Power: equalize batteries
inverter failure
low battery voltage
battery charger voltage high

Vault: temp
water

ii) Patch Overlays:

The Patch Overlay is designed to read in a program not contained in the main system program and operate in conjunction with the system in an on-line status. Operating instructions will be added as each new overlay is placed in service. "PROGLOAD." or "LOADUM." will be specified on the Patch Overlay tape depending on the conditions the Patch Overlay requires in core.

The patch overlays now available at the LDC are indicated in Table XIX.

iii) Keyboard Input Priority:

During system operations it may be necessary to input at times when system output is abnormal on the teleprinter. The operator may set AC switch zero (0) to gain priority. At the conclusion of the message printout will cease and allow the operator to input after restoring AC(0).

TABLE XIX

MOPS II PATCH OVERLAY PROGRAMS AVAILABLE FOR USE ON PDP-7

PROGRAM NAME	PURPOSE
BATCK	To check battery voltages at all subarrays
CARD	To list cards
DEVCAL	To provide sinusoidal calibration from seismometer thru either Develocorder or 16-channel recorder
DC OFF	To check SEM dc offsets at any subarray
FREECK	To measure LP seismometer free periods
FREQ	To assist MDC operator in recording SP channel frequency response test data
LPRPG	To send pseudo-random bit sequence (or an impulse) for controlling voltage input to LP seismometer
MASPOS	To check and correct (if required) the mass positions of all LP seismometers
TASP	To measure gain of seismic amplifier and SEM amplifier and output of SP seismometer at subarrays B1 and F3
TELP	To measure the sinusoidal response of the LP system, the LP amplifier channel, and the SEM LP amplifier
TESP	To measure the sinusoidal response of the SP system
STDDEV	To aid in statistical analysis of array performance data

iv) Magnetic Tape Header Checks:

The high-rate and low-rate recording are protected by a header check feature. This is automatically initiated on the high-rate recording two (2) minutes prior to a tape flip-flop.

The next sequential unit is checked for a ready status, then a write lock. The next check is to determine from the first record header that the tape is at least thirty days old. If the first record has a parity error it will read the next record, trying up to four records before unloading the tape with a "HEADER ER" message. If the tape is not thirty days old or if it does not have a write ring, the tape is unloaded and a message "ATTENTION FMX" or "ATTENTION SMX" is printed with a warning bell. If a tape is not readied, or has not passed the header check by the time the current tape is finished, the recording function will automatically shut off. If the header check is satisfactory a message "HEADER OK" is printed.

If after receiving a message "HEADER ER" or "NOT EXPIRED", the operator determines the tape may have been used for some other purpose, he may then use whichever command is necessary, CANFM or CANSM, to cancel the header check for this tape.

The next sequential tape may be checked manually prior to the program check by using the command CKFM or CKSM.

v) SOU Output:

The SOU outputs a computer-formatted frame of thirty-two 15-bit words on a serial line for transferring data to digital-to-analog converters and/or maintenance consoles for display purposes. (Reference 8) The format of the SOU output can be readily changed to display any thirty of the array sensor channels by a paper tape containing the new selections.

vi) Editing Low Rate Tapes

The operation of the Event Detector is designed to flag the first word of the header in a low rate recording with the octal value 055550 at the time an event is detected. When the low rate recording is completed the tape is rewound to load point, the operator changing the tape unit logical to 6, and having the daily edit tape on logical 7 types in EDITGO. When the event flag is detected on a record the tape is back-spaced to 1 minute prior to the event and the event time is printed out as: EDIT DDD-HHMM:SS.S. At this time the operator has determined if it is a legitimate event or false alarm. If it is a legitimate event, EDIT is typed in and a 3 minute time period is duplicated to the daily edit tape. If it is a false alarm, SKIP is typed in and the tape is moved forward to bypass the event detected, then continues to search the tape for any other detections. At the conclusion of the low rate tape being edited it is rewound and unloaded.

If a period of time is desired to be duplicated that has not been flagged by the event detector, the AC switches may be set as the edit is started and when reaching that time will process as described above.

AC switch settings are as follows in BCD:

0 1	2 3	4 5 6 7	8 9 10	11 12 13 14	15 16 17
DO NOT SET	TENS OF HOURS	UNITS OF HOURS	TENS OF MINUTES	UNITS OF MINUTES	TENS OF SECONDS

Section 5.2.3 shows the edit tape format.

5.2.3 PDP-7 Recording Formats

The PDP-7 system recording formats include (1) LASAPS Fast Mode (High Rate) used for back-up recording support of the IBM computers at SAAC and the LDC and of the 50 Kbaud data link, (2) LASA low-rate used for the recording of a selected number of the array's seismographs at a lower recording rate, and (3) LASA very-low-rate used for the recording of a selected number of low-frequency response sensor data at an even lower recording rate.

The high-rate recording format which records all the available array data onto eight minute PDP-7 seven track tapes is described in reference 6. The low-rate (LR) recording format is shown in Figure 5.4 and at the present time is configured with 50 short-period data channels consisting of the twenty-one subarray analog sum words, six subarray center hole 30-dB attenutated channels, and eighteen selected channels from the F-ring and E3 subarrays. The very-low-rate (VLR) recording format is shown in Figure 5.5 and at the present is configured with all 51 of the array's long-period data channels and four meteorological data words from subarray A0. The composition of the LR and VLR formats is flexible and changes can be readily incorporated.

5.3 Array Equipment

One modification of the array equipment is presently in progress, viz. SP channel CTH Gain Control, P-82.

5.3.1 SP Channel CTH Gain Control

Installation of the modification to provide a short-period sensor channel gain adjustment in the CTH (Ref. 7) has begun with installations now complete at six subarrays. These subarrays are: D2, D3, E2, E4, F1 and F4. Experience to date shows that each modification requires approximately eight hours of shop preparation and two hours on-site to complete.

LASA LOW RATE TAPE FORMAT

BEGINNING END

RECORD	RECORD GAP	RECORD	RECORD GAP	RECORD	RECORD GAP	END OF FILE RECORD

RECORD FORMAT

	HEADER	SELECTED DATA FROM 12 FRAMES	RECORD GAP	

Figure 5.4 LASA Low Rate Tape Format

Header Format:

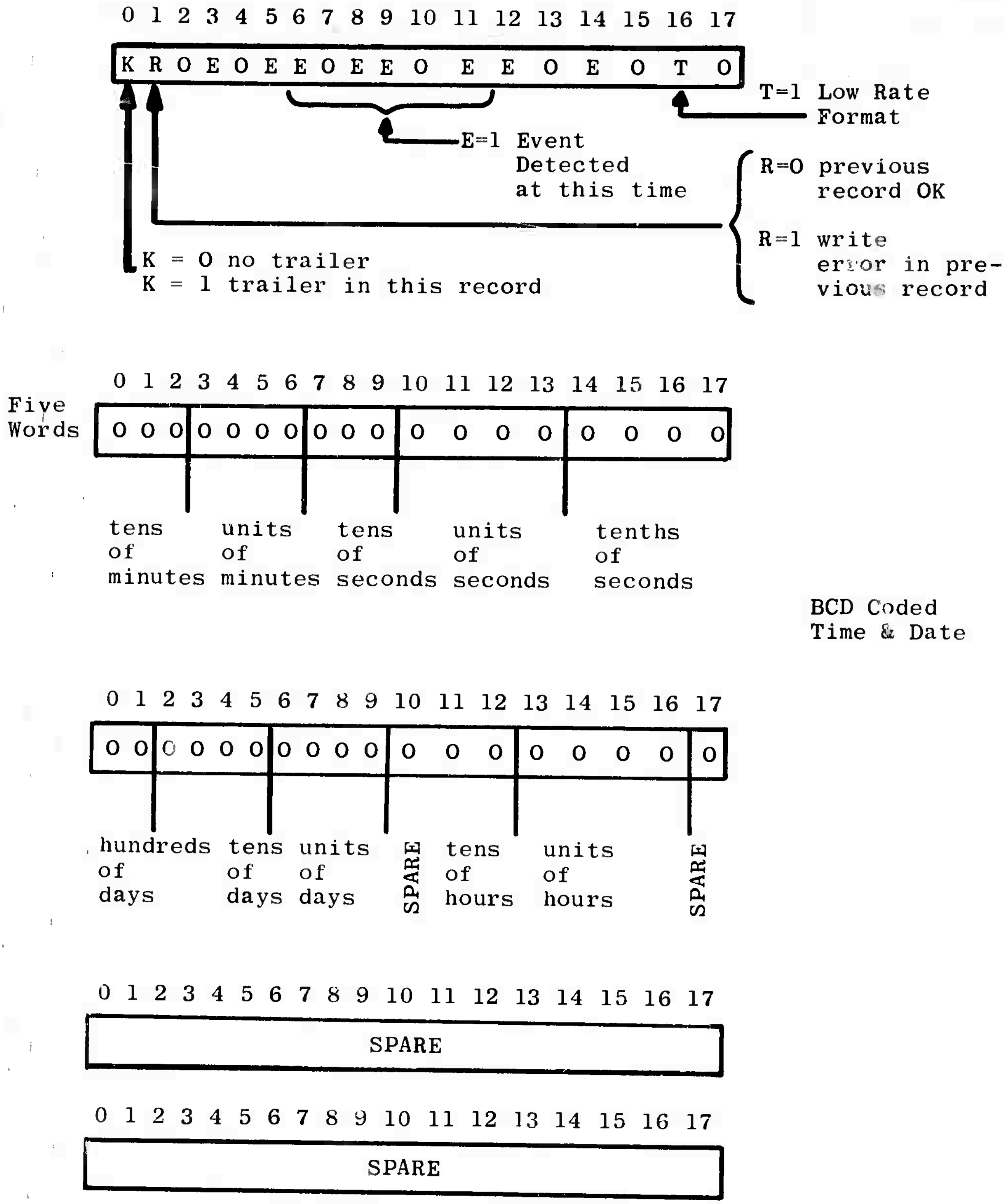


Figure 5.4 (Concluded)

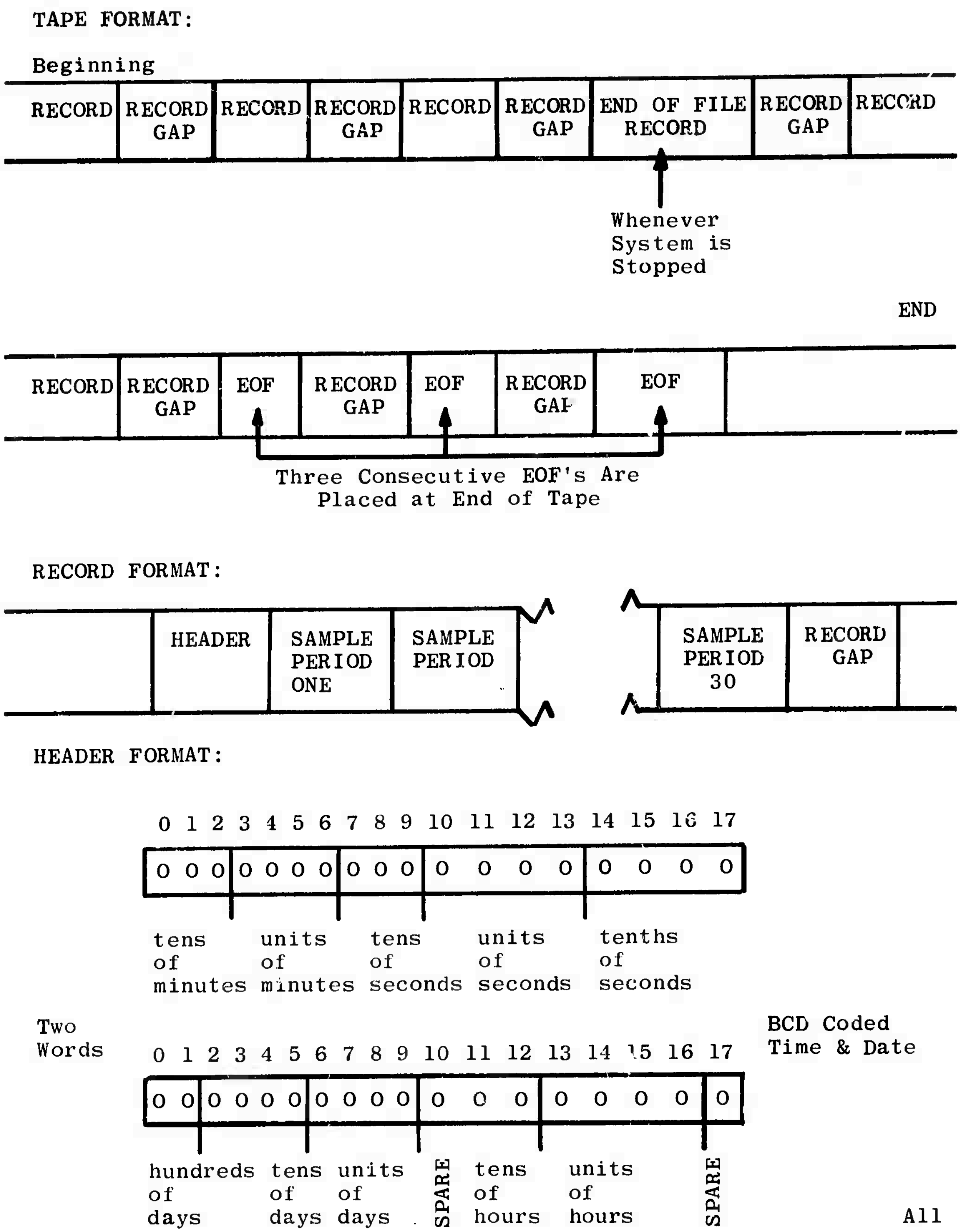


Figure 5.5 LASA Very Low Rate Format

The channel outputs from the standard sinusoidal calibrations have been adjusted following two different procedures in an attempt to determine the best use of the modification in improving the SP sensor performance. The outputs at subarrays D2 and D3 have been adjusted by the CTH gain control to the channel nominal level while the outputs at the other subarrays have been set to the value recorded just previous to the modification. As a test, the outputs of all channels will be reset at monthly intervals. At D2 and D3 the outputs will be reset to nominal and at the other subarrays the outputs will be set to limit the drift to within a specified range over a definite time period.

SECTION VI

MAINTENANCE

6.1 General

Maintenance activity at LASA includes correction of failures, preventive maintenance, modifications, special tests required for evaluations or quality control activities, facility and access maintenance, improvements, and vehicle maintenance. LASA maintenance activity is divided into three different catagories: Data Center (LDC), Maintenance Center (LMC), and Facilities Support. The LDC in Billings covers the following five systems: the IBM 360/44 computer, the DEC PDP-7 computer, LDC Digital, LDC Analog, and 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 sites, and CTH sites.

6.1.1 Philosophy

During the June-August period the weather conditions at the Montana LASA permit unrestricted travel to all subarray and sensor locations. During these months the SP sensor rehabilitation and installation of modifications requiring travel to the sensor WHV are given prime attention. Shop work at the LMC is limited to preparing RA-5 amplifiers and HS-10-1/A seismometers for sensor replacements. Other LMC work, such as printed circuit card repairs, are deferred until inclement weather makes array travel difficult.

The LDC maintenance program for all quarterly periods concentrates on timely repair of failures and completion of all scheduled preventive maintenance and equipment overhauls.

6.1.2 Summary

Array maintenance completed by LMC included SP rehabilitation at six subarrays, repair of RA-5 amplifiers and HS-10-1A seismometers, preventive maintenance, and installation of modification P-82 at six subarrays. The LDC effort centered mainly on the PDP-7 system and preventive maintenance. The DCASD facility inspection was completed at both LDC and LMC.

Table XX summarizes the number of all equipment (LASA) and facility (Utility) work orders completed this quarter. The 363 completed work orders represented 494 separate maintenance actions by technical personnel. The number and type of operational equipment failures corrected are discussed in paragraph 4.3. Work orders are used to document all LASA maintenance activities. The

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TABLE XX

WORK ORDER SUMMARY

JUNE 1972 - AUGUST 1972

WORK ORDER TYPE	BACKLOG START OF QTR	INITIATED	COMPLETED	BACKLOG END OF QTR
LASA:				
System - A	43	275	245	73
Subassembly - B	43	62	52	53
Component - C	23	37	16	44
Total	109	374	313	170
Utility:				
Cable trench & trail inspection	3	5	6	2
Cable trench backfill	0	2	1	1
WHV sites landscaped	0	12	12	0
Marker posts &/or WHV covers replaced	0	0	0	0
CTH maintenance	1	14	15	0
Vehicle maintenance and inspection	0	11	11	0
Fence inspections	3	4	5	2
Trail repairs	2	0	0	2
Total	9	48	50	7
WORK ORDER TOTALS	118	422	363	177

actual time or complexity required for a task is not indicated, but the summary does indicate the type of work performed and the size of the work load. The backlog buildup of B and C type work orders is expected as shop work is deferred until winter months.

6.2 Data Center

6.2.1 System 360

The IBM 360/44 system has now operated six months without any failures. All of the scheduled preventive maintenance procedures were completed and no discrepancies were noted.

6.2.2 System PDP-7

The majority of problems in this system remain with the TD-570 tape units. During the last quarter all units were repaired utilizing salvaged parts. The largest number of failures, 24 out of 35, occurred in July and consisted of power supply and lamp failure problems. Recent failures and adjustments have indicated more mechanical wear and may require additional replacements in the future. When repaired, the units still meet all specifications.

6.2.3 Other LDC Equipment

The Develocorder units are starting to develop leaks and show evidence of corrosion. Both units were overhauled about eighteen months ago and will be dismantled and checked again in the very near future. Deteriorated parts will be noted and scheduled for replacement on a shorter cycle to prevent machine failure.

6.3 Maintenance Center

The LMC maintenance efforts are divided into two activities: array tasks and shop testing and repairs.

6.3.1 Array Activities

All scheduled array activities were completed this quarter. There were 117 field trips covering 19,887 miles for this period and three trips were made to the PMEL at Great Falls to pick up and deliver test equipment for calibration.

The SP rehabilitation program was completed at subarrays D1, D3, E1, E2, F3, and F4 for a total of 10 subarrays of the sixteen planned for this summer season. Replacement and/or adjustment was made for thirty RA-5 amplifiers and twenty-six HS-10-1A seismometers. The seismometers in WHV's E1-36, E1-45, and F4-51 were high in natural frequency but could not be replaced. The seismometers are operational at their higher natural frequency but are stuck in the hole.

The installation schedule for modification P-82 for the six subarrays completed this quarter was as follows:

D2 - 8/18/72
D3 - 8/8/72
E2 - 8/25/72
E4 - 8/22/72
F1 - 8/23/72
F4 - 8/24/72

Table XXI reflects the SP channel status as of August 31. The information in this table summarizes the outstanding conditions in the SP array requiring maintenance attention. This information is based on the five test criteria shown in the column headings. The seismic event polarity and amplitudes were last checked utilizing an event that occurred at 0857:45.9 GMT on July 28, 1972 with no discrepancies noted. A total of 82 unsatisfactory test results are indicated, a decrease of 23% from the 107 reported last quarter.

Lightning damage occurred to the SEM at C1 in August. A near hit resulted in repairable damage to printed circuit cards in the Output, PDC, and ACC drawers.

6.3.2 Shop Activities

The repair of RA-5 amplifiers and HS-10-1A seismometers in support of the SP rehabilitation program, and modification of PDC drawers and printed circuit cards for modification P-82 were the main shop activities for this quarter. There were 28 RA-5 amplifiers and 14 HS-10-1A seismometers repaired and tested.

6.4 Facilities Support

All subarrays have been inspected for damage and necessary land repairs have been started. Major repairs completed this quarter are:

1. B3 - washed out culvert replaced.

2. C3 - culvert replaced, cattle guard and several bad crossings repaired.

3. E3 - washed out cable trench at two different places and several creek crossings repaired.

4. F2 - access to CTH area bladed.

A total of 29 landowners were contacted regarding LASA operations and lease agreements. [On August 17 a drowning calf was rescued from a stock tank near subarray E3. The landowner was contacted and he was very grateful.]

TABLE XXI

SP CHANNEL STATUS, 31 AUGUST 1972

SUBARRAY	CALIBRATION RESPONSE		NATURAL FREQUENCY		SENSITIVITY RESPONSE		SEISMIC EVENT POLARITY		SEISMIC EVENT AMPLITUDE	
	SAT.	UNSAT.	SAT.	UNSAT.	SAT.	UNSAT.	SAT.	UNSAT.	SAT.	UNSAT
AO	17	0	16	0	16	0	17	0	17	0
B1	11	6	11	5	16	0	17	0	17	0
B2	12	5	12	4	16	0	17	0	17	0
B3	12	5	14	2	15	1	17	0	17	0
B4	13	4	10	6	16	0	17	0	17	0
C1	11	5	12	3	15	0	16	0	16	0
C2	16	1	15	1	15	1	17	0	17	0
C3	17	0	13	3	15	1	17	0	17	0
C4	16	0	15	0	15	1	16	0	16	0
D1	16	1	13	3	15	1	17	0	17	0
D2	21	0	19	1	20	0	21	0	21	0
D3	16	1	16	0	16	0	17	0	17	0
D4	15	2	16	0	16	0	17	0	17	0
E1	15	2	14	2	16	0	17	0	17	0
E2	17	0	16	0	15	1	17	0	17	0
E3	24	1	25	0	25	0	25	0	25	0
E4	17	0	16	0	16	0	17	0	17	0
F1	15	2	15	1	16	0	17	0	17	0
F2	12	4	15	0	14	1	16	0	16	0
F3	15	2	16	0	16	0	17	0	17	0
F4	16	1	15	1	15	1	17	0	17	0
TOTAL	324	42	314	32	339	8	366	0	366	0

Oil exploration drilling occurred at the following eight locations in the array area; five in the F2 area:

1. SE SE Sec. 17-9 N 43 E 2800' approx. 3¼ miles from Sensor 75 Sub. C3 Location.

2. NW NW Sec. 1-13 N 44 E approx. 3 miles from Sensor 71 Sub. C1 Location.

3. SW SW Sec. 4-2 N 49 E 5300' approx. 6 miles from Sensor 76 Sub F2 Location.

4. SE SE Sec. 23-2 N 49 E 5300' approx. 5 miles from Sensor 76 Sub. F2 Location.

5. SW SW Sec. 27-3 N 50 E 5300' approx. 3 miles from Sensor 81 Sub. F2 Location, plugged and abandoned.

6. NE NW Sec. 9-3 N 50 E 5300' approx. 5½ miles from Sensor 81 Sub. F2 Location.

7. NE NE Sec. 33-3 N 50 E approx. 2 miles from Sensor 81, Sub F2 Location.

8. NE NE Sec. 9-11 N 38 E 3850' less than 1 mile from Sensor 74 Sub. E4 Location.

SECTION VII

ASSISTANCE PROVIDED TO OTHER AGENCIES

7.1 Seismic Data Laboratory

Develocorder film recordings of selected SP sensor data are made for SDL. Each film covers a period of approximately 24 hours; film change is made at about 2200 GMT. Ninety-two films with the format described in reference 6 were recorded during this period.

7.2 Weather Bureau

The Billings Weather Bureau office has resumed their request for periodic weather information from the outputs of the array's temperature, wind direction and speed, barometric presure, and rainfall sensors. Three times each day a complete report of the latest available data are provided to them by the LDC operator.

7.3 Visitors

Visitors to the Montana LASA during the 2nd and 3rd quarters were:

(a) Capt. John Fergus, VSC made an inspection tour of LDC on May 15 - 19.

(b) Henry Wopperer, DCASE-Seattle and Darrell Small performed the annual government property survey during May 30 - June 8.

(c) Cmdr. R. Iverson, DCASD-Seattle, toured the LDC on August 30.

SECTION VIII

DOCUMENTATION PROVIDED UNDER VT 2708

8.1 Technical Reports/Letters

The following reports were distributed during this period:

(1) Montana LASA Second Quarterly Technical Report Project V/T 2708. T/R 2056-72-21, 15 June 72.

(2) "Operation and Maintenance of LASA Monthly Progress Report" - June 1972 Report No. 2056-72-22.

(3) "Operation and Maintenance of LASA Monthly Progress Report" - July 1972 Report No. 2056-72-23.

(4) "Type II Amplifier Spurious Response Testing", letter, 17 July 72.

8.2 Operations Data

Thirteen weekly issues of the Defective Signal Channel Status and Data Interruption Log Reports and Develocorder Operations Logs were distributed to approved using agencies.

8.3 Alternate Management Summary Reports

Three Alternate Management Summary Reports (AMSR) were prepared and distributed from Philco-Ford C&TS Division Headquarters; one for each of the months June, July and August 1972.

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