PRAKLA-SEISMOS INFORMATION No. 4
SSP-11A
Seismic Data Processing System

Contents

Introduction

In 1972/73 PRAKLA-SEISMOS started to develope the SSP-11 Seismic Data Processing System. The algorithms, used over many years of quality seismic data processing at PRAKLA-SEISMOS, were newly written for the PDP-11/45 and convolver (SSP-11 System). This system was then announced in 1974. Practice and experience soon showed that an array processor was necessary. PRAKLA-SEISMOS was obliged to develope a concept for such an array processor and, in 1975, gave a commission for the construction of the Array Processor System APS. One year later, the first APS was installed and has since been successfully programmed for the SSP-11A Seismic Data Processing System.

Another main component of the SSP-11A System, the combined seismic/raster plotter KPU, designed and constructed by PRAKLA-SEISMOS, produces high-resolution plots of seismic sections including line headers and side labels. The APS and KPU, both specially designed for seismic data processing, and the PDP-11/60, the latest member of the PDP-11 computer family, guarantee an efficient SSP-11A System.

HARDWARE

CENTRAL PROCESSING UNIT

The CPU is the versatile PDP-11/60 with the following features

- 16-bit word
- memory addressable to 128K words
- integrated Floating Point Processor for single and double precision (32 or 64 bits) arithmetic
- comprehensive instruction set of over 400 instructions
- automatic bootstrap loader with self-diagnostic test
- real-time clock
- Power Fail and Automatic Restart

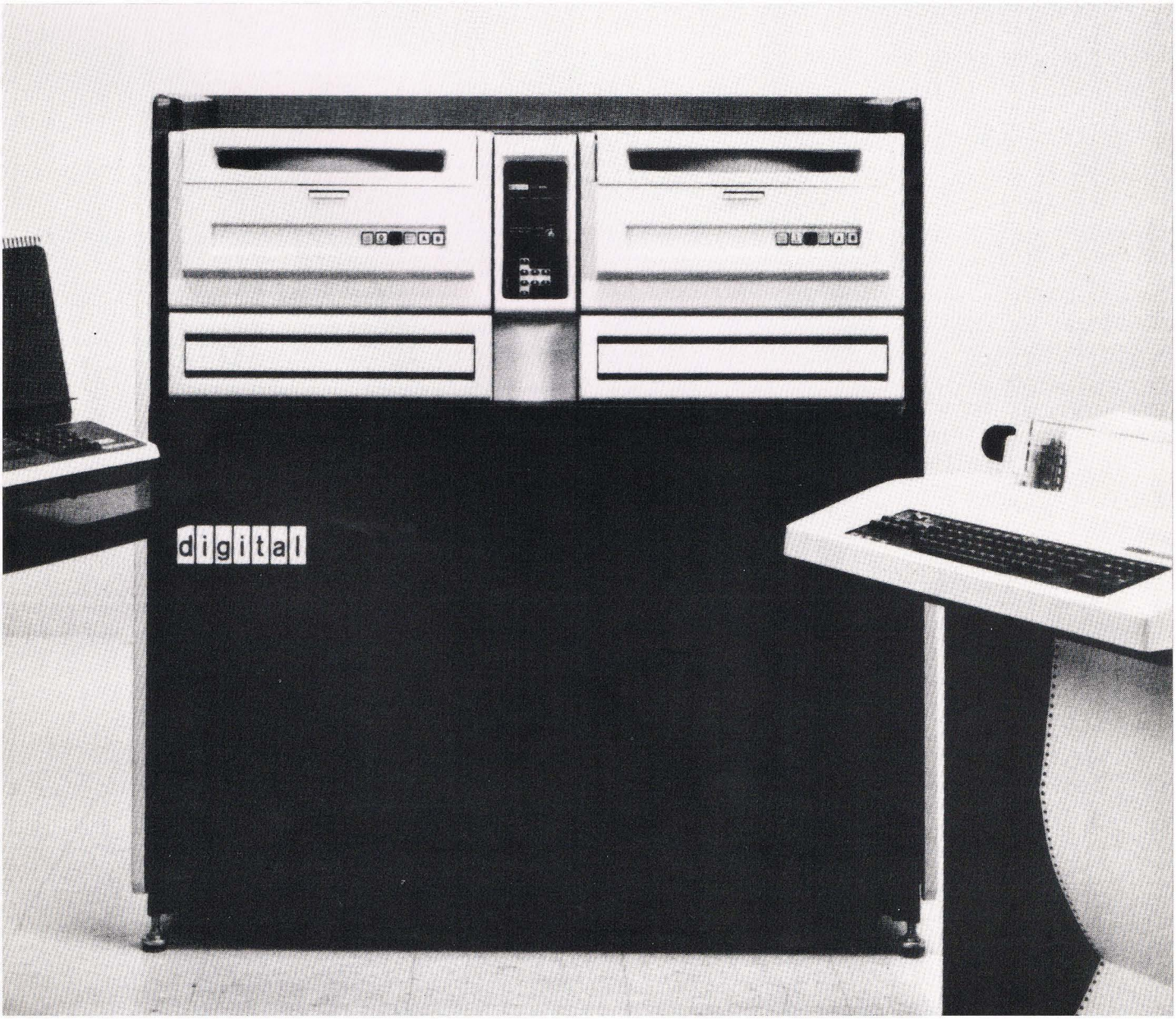
For communication between system components and peripherals the PDP-11 uses a single high-speed bus known as the UNIBUS. Addresses, data, and control information are transmitted via the UNIBUS. Device registers, located in the uppermost 4K words of address space, enable any peripheral connected to the system to be operated with the same set of instructions as used for memory.

The PDP-11/60 is offered with 32K words MOS memory (battery back-up) or core memory. For MOS memory, each 16-bit word has an additional 7-bit error correction code. In addition, a 1K 18-bit word cache memory frees the UNIBUS for other transfers, increasing throughput. The bus cycle time is 170 ns which gives an effective cycle time of 532 ns. The integrated Memory Management Hardware provides 18 bit addressing capability up to 128K words, as well as memory protection.
The PDP-11 operating system is disc-based and supports PDP-11 Assembler (Macro), FORTRAN IV, and COBOL, and includes an extensive function library. Other operating systems, such as data bank management, are available for the PDP-11.

The user communicates with the system via the console.

The CPU can also be the PDP-11/55, a fast FORTRAN computer with up to 32K bipolar memory.

PDP 11/60



PERIPHERALS

A wide selection of individual peripherals are offered to meet all processing requirements:

Array Processor System APS
- programmable multiprocessor
- modular system structure
- parallel operations in 4 processors and in 4 calculation units
- 48K words MOS memory for data, extendable up to 64K words, access time at overlapped operations 200 ns, direct addressing from APS as well as from PDP
- 1K bipolar memory for each processor program, cycle time 100 ns
- bus cycle time 180 ns

Fixed Head Disc and Controller

this disc is mainly used for demultiplexing
- capacity: 4M bytes unformatted (1, 2, or 3M bytes available)
- speed 3000 rpm, average access time 10.2 ms (operated at 50 Hz)
- transfer rate 0.6M bytes per second
- up to 8 discs per controller

Moving Head Disc and Controller

this disc is mainly used for sortings
- capacity: 33, 66, or 256M bytes
- average access time 30 ms (operated at 50 Hz)
- transfer rate 0.4M bytes per second with interlacing
- up to 8 discs per controller

9-track Tape Drive and Controller
- 800/1600 bpi, 75 ips
- up to 8 drives per controller

21-track Tape Drive and Controller
- 356/712 bpi, 90/45 ips
- transfer time for one frame 32 µs
- up to 2 drives per controller

Card Reader
- 300 cards per minute

Line Printer
- 132 characters (ASCII) per line
- 200 lines per minute (faster printers available)

Console
- 132 characters (ASCII) per line
- 30 characters per second printing speed

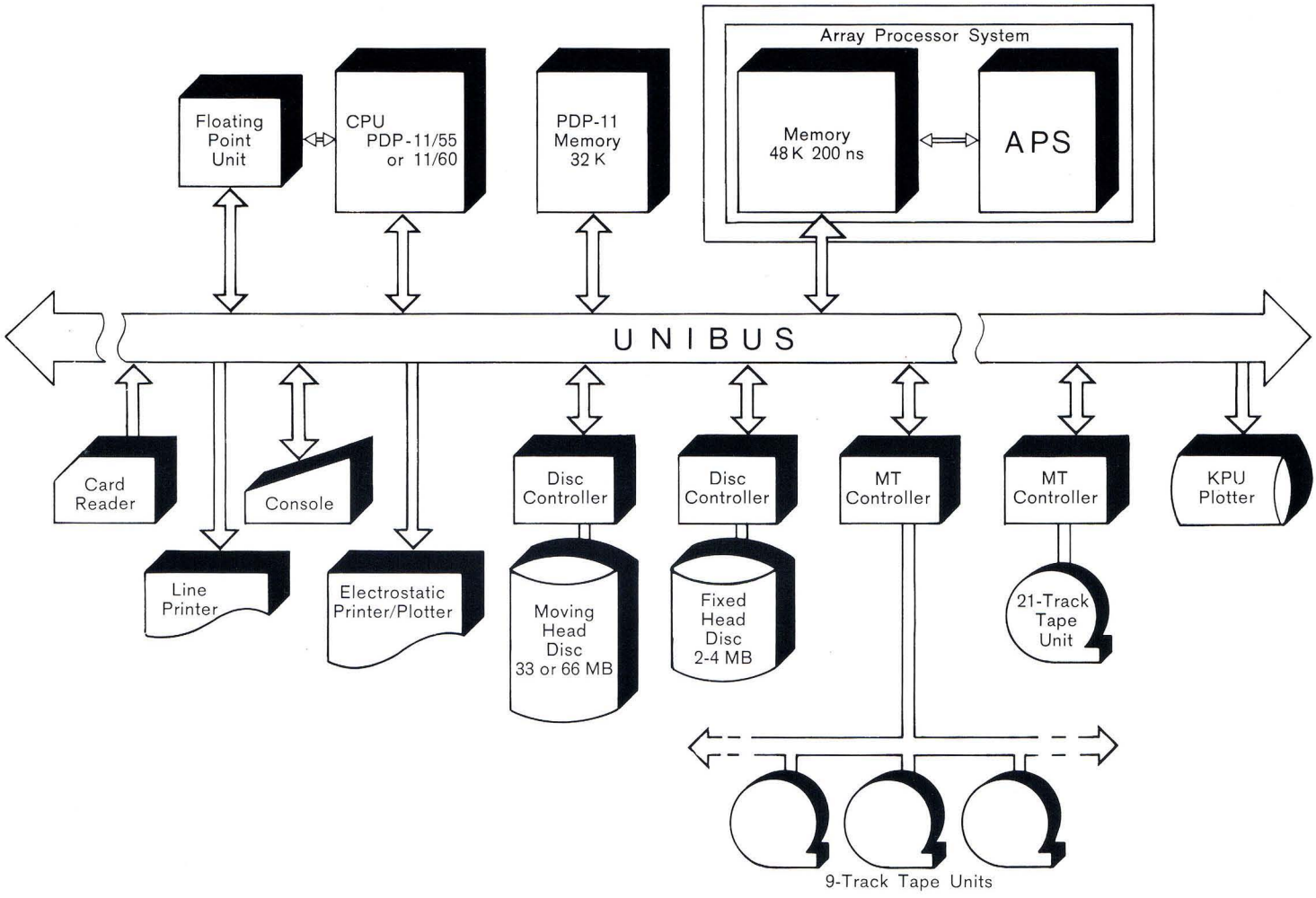
Electrostatic Printer/Plotter
- 20" display width
- resolution 160 dots per inch
- plot speed: 1.1 cm per second
- 180 characters per line
- print speed: 190 lines per minute

Plotters with different widths and resolutions are available.

Combined Seismic/Raster Plotter KPU
- plot area 920 x 1000 mm, accuracy 20 µm, plot speed 64 rpm
- seismic trace width 0.4 . . . 5.2 mm in steps of 0.1 mm vertical scale 30 . . . 255 mm per seismic second wiggle trace, variable area, variable density
- 64 alphanumeric characters, 2 or 4 mm high
- raster playback black/white or 16-tone grey, dot size 0.1 or 0.2 mm□

Other peripherals, such as paper tape reader/punch, cassette input, etc. may be requested.
A fixed point convolver may be used for a low cost configuration (SSP-11).

Seismic Data Processing System



SOFTWARE

The SSP-11A System offers comprehensive software based on well-proven algorithms for the complete processing of impulse seismic and VIBROSEIS*. The system is designed to relieve the input crew from time-consuming routine data organization and to minimize system operation. Routines, such as listing of data and parameters, plotting and labelling, are controlled by the system. Thus the input crew is free for specific seismic work.
The software is modular which allows the addition of any new modules and processes. In this way the system remains flexible and can easily be expanded and updated with future program developments.

PREPROCESSING

For maximal utilization of memory and disc capacity, as well as reduction of execution times, preprocessing uses its own operating system with optimized drivers for all peripherals during run time.
Preprocessing inputs data from field tapes, field parameters, and field geometry and outputs the demultiplexed, sorted, and edited traces in SSP-format or SEG Y-format. In addition, a separate documentation tape is generated containing all field parameters, e.g. shot point position, geophone position, elevations, coverage degree, etc. The display of parameters from this tape allows easy, quick, and reliable parameter checking before the actual processing starts. This tape is continuously updated during each further seismic processing step.
Each sorting is preceded by a simulation run which lists control parameters for the actual sorting, detects errors, indicates necessary subsequent sortings, etc.
Field tape utilities are included, such as dump programs for troublesome field tape input, scan interpolation for damaged scans, and further special options for various formats.

Preprocessing

- Demultiplexing of all standard 9- and 21-track tape formats
  - flexible field tape input, including standard format deviations
  - re-sampling
  - channel selection
  - special handling of sweeps
  - etc. . .
- CDP-sort with several options:
  - single coverage or any other trace gathering
  - polarity inversion
  - trace blanking
  - compositing
  - evaluation of water break times
  - output in SSP-format or SEG Y-format
  - etc. . .
- Subsequent trace handling for CDP-sort:
  - editing
  - resorting for display
  - format conversion
  - etc. . .
- Special sortings for Areal Seismic Survey
- Continuous processing documentation on tape

Seismic Processing

- Gain Recovery
- Normalization
- Velocity Analyses
- Corrections
  - static corrections
  - automatic residual static corrections
  - dynamic corrections
- Sortings
- Stack with Muting, Ramping
- Filtering** (Time Variant)
- Deconvolution** (Time Variant)
  - spike
  - predictive
  - VIBROSEIS*
- Autocorrelation**, Crosscorrelation**
- Migration
  - Kirchhoff summation
  - wave equation
- Power Spectra, Spectral Analyses
- Vibroseis processing
- Real Amplitude Processing
- Continuous processing documentation on tape
- Contouring program for Gravimetry and Magnetometry

* Trade Mark of Continental Oil Company

** in frequency or time domain

SEISMIC PROCESSING

The PDP-11 with the integrated Array Processor System APS is an optimal system for geophysical data processing: fast, precise, economical, flexible, expandable. All seismic processes have been programmed utilizing the features of PDP and APS. Both solve different problems independently at maximum speed — the APS for fast calculations of seismic processes in floating point, the PDP for processing organization and data transfer.

Special consideration was given to a fast solution of convolution and FFT during the development of APS. Therefore processes in time and frequency domain such as filtering, correlation etc. are especially efficient.

The documentation tape, generated before the first preprocessing run, is updated/supplemented at every seismic processing step, thus representing the complete processing history up to this point. The facility to print the contents of this tape or produce a plot showing all information in a graphical representation enables the analyst to instantly check all applied parameters. At any stage of seismic processing, a profile can be plotted together with the contents of the documentation tape in one display procedure on the same sheet of photographic film/paper (page 8, 9).

Example of a System Job for Seismic Processing

```
SYSTEM  STAC     VERS01
GENERL    11  12345678   102   101        TEST    NN   12345678
PROCPA  4000       4   460    -1   290   24   10
FILT       1      59     0   100     0   13   78   20     3  4000
FILT       2      59     0   100     0   15   65   20    10  4000
  ITAP     0
  TRUE     2
  AUTO   L70   L80    40
  DECP    40     2     5
  OTAP     1
  CORR    12   L10   L20   100    11
  FREQ     1
  STAC     0   200   100  4000   L30
  OTAP     2
  FREQ     2
  NORM     2   L40   L50   L60
  OTAP     3
EN
OS     1  143
     143  -22  144  -15  145  -18  146  -17  147  -18  148  -18
     149  -18  150  -21  151  -16  152  -16  153  -18  154  -20
     155  -22  156  -19  157  -20  158  -22  159  -20  160  -24
     161  -25  162  -19  163  -18  164  -23  165  -24  166  -24
     167  -27  168  -28  169  -30  170  -28  171  -22  172  -23
     173  -19  174  -19  175  -16  176  -14  177  -15  178  -15
     179  -15  180  -16  181  -13  182  -10  183  -11  184  -25
     185  -25  186  -25  187  -25  188  -22  189  -18  190  -15
     191  -15  192  -19  193  -19  194  -23  195  -24  196  -25
     197  -25  198  -30  199  -29  200  -30  201  -35  202  -32
     203  -27  204  -29  205  -31  206  -30  207  -28  208  -23
     209  -22  210  -18  211  -18  212  -20  213  -27  214  -26
     215  -22  216  -25  217  -23  218  -21  219  -22  220  -20
     221  -20  222  -22  223  -18  224  -20  225  -25  226  -28
     227  -23  228  -21  229  -20  230  -20  231  -19  232  -19
     233  -15  234  -16  235  -24  236  -16  237  -20  238  -16
     239  -17  240  -23  241  -24  242  -23  243  -21  244  -26
    -999
     060  -01  061  -01  062  -01  063  -01  064  001  065  002
     066  002  069  002  071  002  074  004  075  002  076  001
     078  001  079  -01  080  -04  082  002  084  -05  085  001
     086  002  089  005  090  005  091  002  092  004  093  001
     094  004  095  -02  096  004  097  002  098  001  099  001
     100  -01  101  -01  102  001  103  -05  104  001  108  001
     109  001  111  001  112  001  113  002  116  002  117  001
     118  003  123  003  127  003
EN
  L30      460     0
             0
  L31      460   240
             0
  L32      460   270
           200
  L33      460   840
           700
  L34      460  1080
          1000
  L35      460  1620
          1500
  L40      460
           800   400  1000  1000
  L50      460
             7     8     8     9
  L60      460
           400   850  1500  2500
  L70      460
           100
  L80      460
          2900
  L70      370
           100
  L80      370
          2400
  L70      290
           150
  L80      290
          3200
  L20      460
           100   200   300   400   500   600   700   800   900  1000
          1200  1400  1600  1800  2000  2500  3000  3500  4000
  L10      460
          1660  1690  1740  1800  1890  1950  2010  2140  2220  2420
          2800  2900  3000  3090  3200  3500  3600  3675  3750
  L10      416
          1660  1690  1740  1800  1890  1950  2010  2140  2270  2425
          2800  3025  3150  3240  3300  3500  3600  3675  3750
  L10      368
          1660  1690  1740  1800  1890  1950  2010  2080  2170  2360
          2800  3050  3150  3240  3300  3500  3600  3675  3750
  L10      290
          1660  1690  1740  1775  1810  1880  1930  1980  2100  2315
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EN
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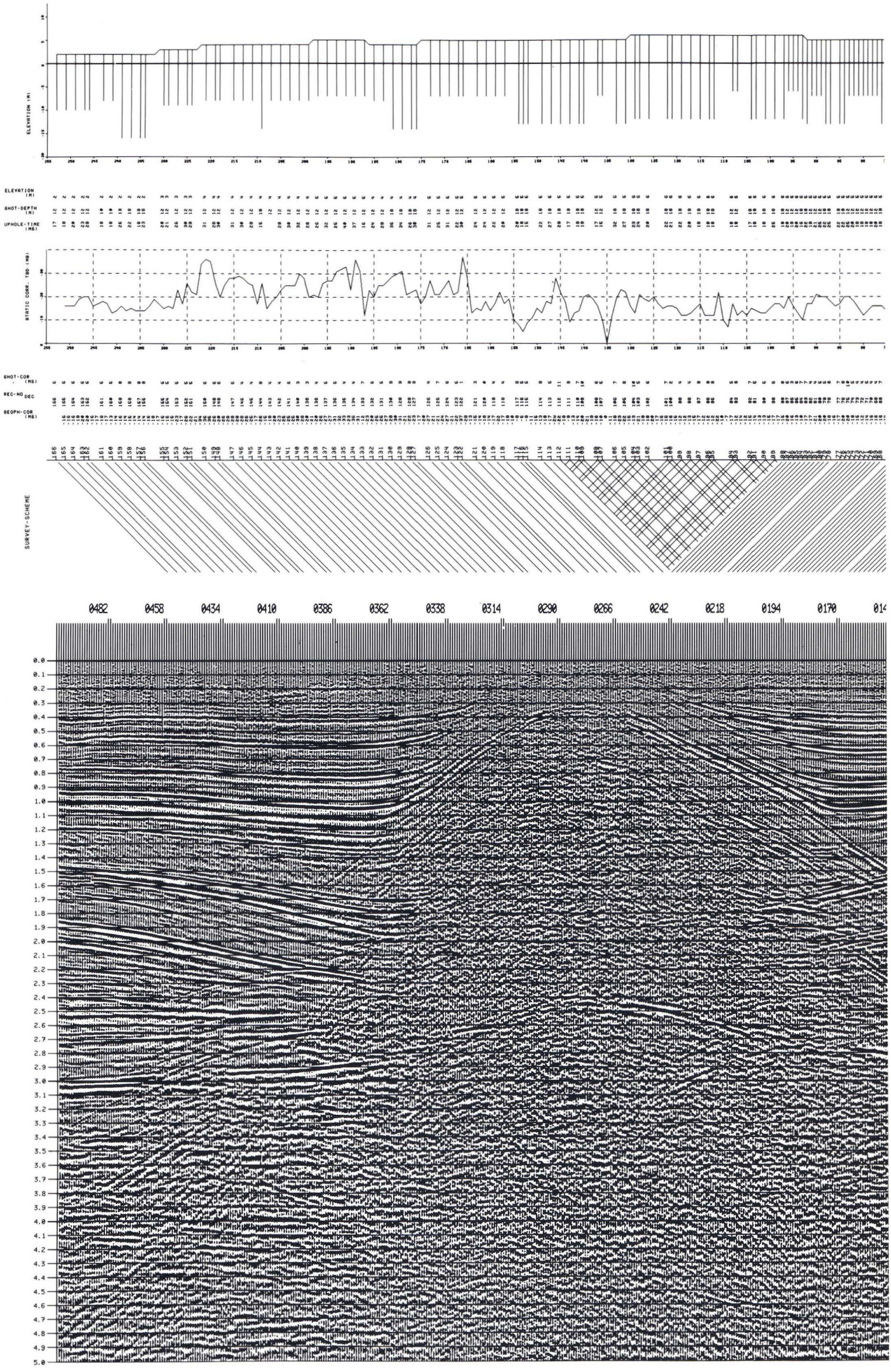
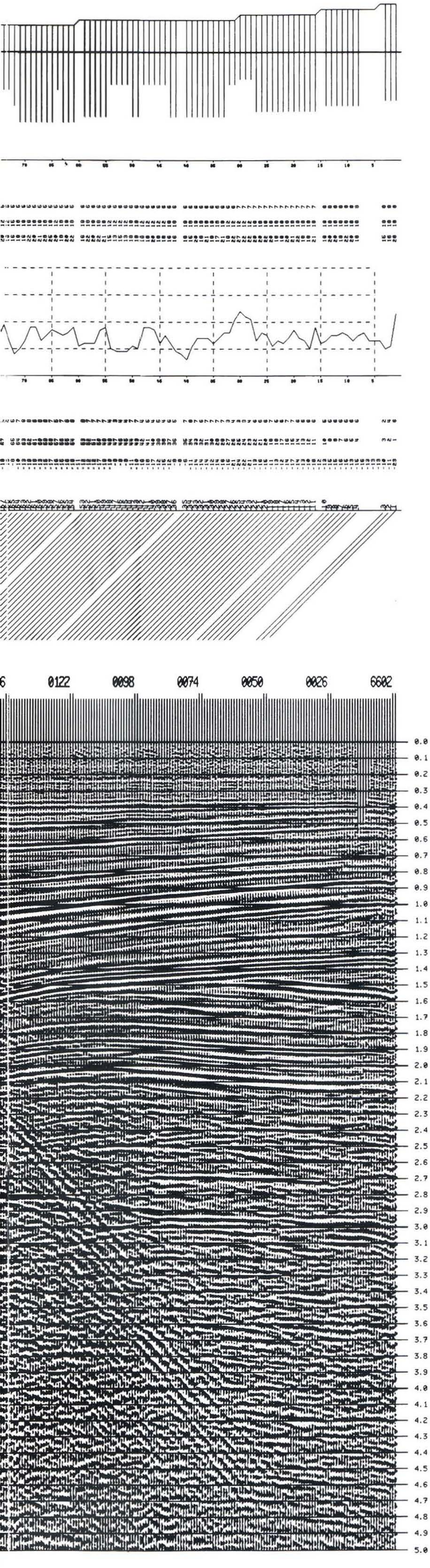

ELEVATION (M)
SHOT-DEPTH (M)
UPHOLE-TIME (MS)
STATIC CORR. TBD (MS)
SHOT-COR (MS)
REC-NO DEC
GEOPH-COR (MS)
SURVEY-SCHEME
0482
0458
0434
0410
0386
0362
0338
0314
0290
0266
0242
0218
0194
0170



GASOLIX OIL LTD. TULPENBERG 1977

40077
LINE 99

12-24-FOLD COVERAGE

RECORDING PARAMETERS

FIELD PARTY: MEIER
CONTRACT NO.: 40077, DATE OF RECORDING: FEBRUARY 1977
FIELD SYSTEM: TYPE DFS 3 / MDC 06
TAPE FORMAT SEG-A, 9 -TRACK, 800 BPI
SUBSURFACE COVERAGE: 12 -FOLD
RECORD LENGTH: 5 S, SAMPLING RATE: 2 MS
FILTER: LOW CUT 12 HZ, 18 DB/OCT
HIGH CUT 124 HZ, 72 DB/OCT
NOTCH FILTER HZ
GAIN CONTROL: BINARY GAIN
POLARITY: COMPRESSIONAL EVENTS = [ ] POS. [ ] NEG. NUMBERS
CABLE: TYPE SM 4 / 10 HZ
LENGTH 48 M, DEPTH 50 M
RECEIVER: TYPE
NO. OF GROUPS 48, SPACING 50 M
GROUP LENGTH 100 M, 36 RECEIVERS PER GROUP
RECEIVER ARRAY:

EMITTER ARRAY:

SPACING OF EMITTER GROUP CENTERS: 50/100 M
ENERGY SOURCE: DYNAMITE
DEPTH 12-18 M, CHARGE 3-5 X 1-3 KG, VOLUME L
SWEEP - HZ, LENGTH S
VIBRATOR CONTROL: [ ] ETL [ ] PELTON
TIME-DELAY: MS
VERTICAL STACK: -FOLD
CORRELATION: SWEEP [ ] FILTERED [ ] UNFILTERED
POSITIVE CORRELATION SIGNAL: = [ ] POS. [ ] NEG. NUMBERS
EMITTER RECEIVER CONFIGURATION:

PROCESSING SEQUENCE

1 INPUT: TAPE FORMAT SEG-A, 9 -TRACK, 800 BPI
SAMPLING RATE 2 MS, 48 TRACES
2 GAIN REMOVAL
CORRELATION: SWEEP [ ] FILTERED [ ] UNFILTERED
POSITIVE CORRELATION SIGNAL = [ ] POS. [ ] NEG. NUMBERS
4 STATIC CORRECTIONS TO DATUM LEVEL 0 M A.S.L.
INCL. TIME-DELAY CORRECTION MS
CORRECTION VELOCITY M/S
6 RESIDUAL CORRECTIONS, GATE: 600 - 1200 MS

5 DYNAMIC CORRECTIONS DERIVED FROM VELOCITY ANALYSES 'GENT'
7 STACKING: 12 -FOLD
3 DECONVOLUTION: TYPE: [X] SPIKE [ ] PREDICTIVE [ ] VIBROSEIS
[X] TIME-VARIANT, 4 GATES
GATE LENGTH: 1000 MS, FROM 300 MS TO 2800 MS
OPERATOR LENGTH: 80 MS
PREDICTION INTERVAL: MS
DECONVOLUTION: TYPE: [ ] SPIKE [ ] PREDICTIVE [ ] VIBROSEIS
[ ] TIME-VARIANT, GATES
GATE LENGTH MS, FROM MS TO MS
OPERATOR LENGTH: MS
PREDICTION INTERVAL: MS
COHERENCY FILTER:
MULTI-CHANNEL FILTER WITH TRACES, OPERATOR LENGTH MS
SUPPRESSION OF LONG-PERIOD MULTIPLES
MIGRATION WITH TRACES
[ ] LINEAR [ ] COHERENCY WEIGHTED [ ] WAVE EQUATION
Z = MS
TIME-DEPTH CONVERSION
8 FREQUENCY FILTER: [X] LINEARLY INTERPOLATED

TRAVEL TIME	LOW-CUT		HIGH-CUT	
S	HZ	DB/OCT	HZ	DB/OCT
0 - 0.6	18	24	60	24
0.6 - 1.2	16	24	56	24
1.2 - 2.2	14	24	52	24
2.2 - 4.9	12	24	48	24

AMPLITUDE CORRECTIONS

SCALING: FACTOR
X NORMALIZATION AFTER 2, 6, 8
GAIN CONTROL AFTER

REMARKS:

• 2563/3 , DATE: 20.04.77, CURRENT NO.: 422
INPUT CREW: WIESNER
SUPERVISOR: BODEMANN

DISPLAY PARAMETERS

SCALE: 1 : 25000, 1 S = 6 CM, TRACE SPACING: 1.0 MM
POLARITY: [X] POSITIVE [ ] NEGATIVE NUMBERS = [X] WHITE
REMARKS:

Seismic Section with automatic documentation – Line Header and Side Label – plotted on the KPU

Array Processor System APS

HARDWARE

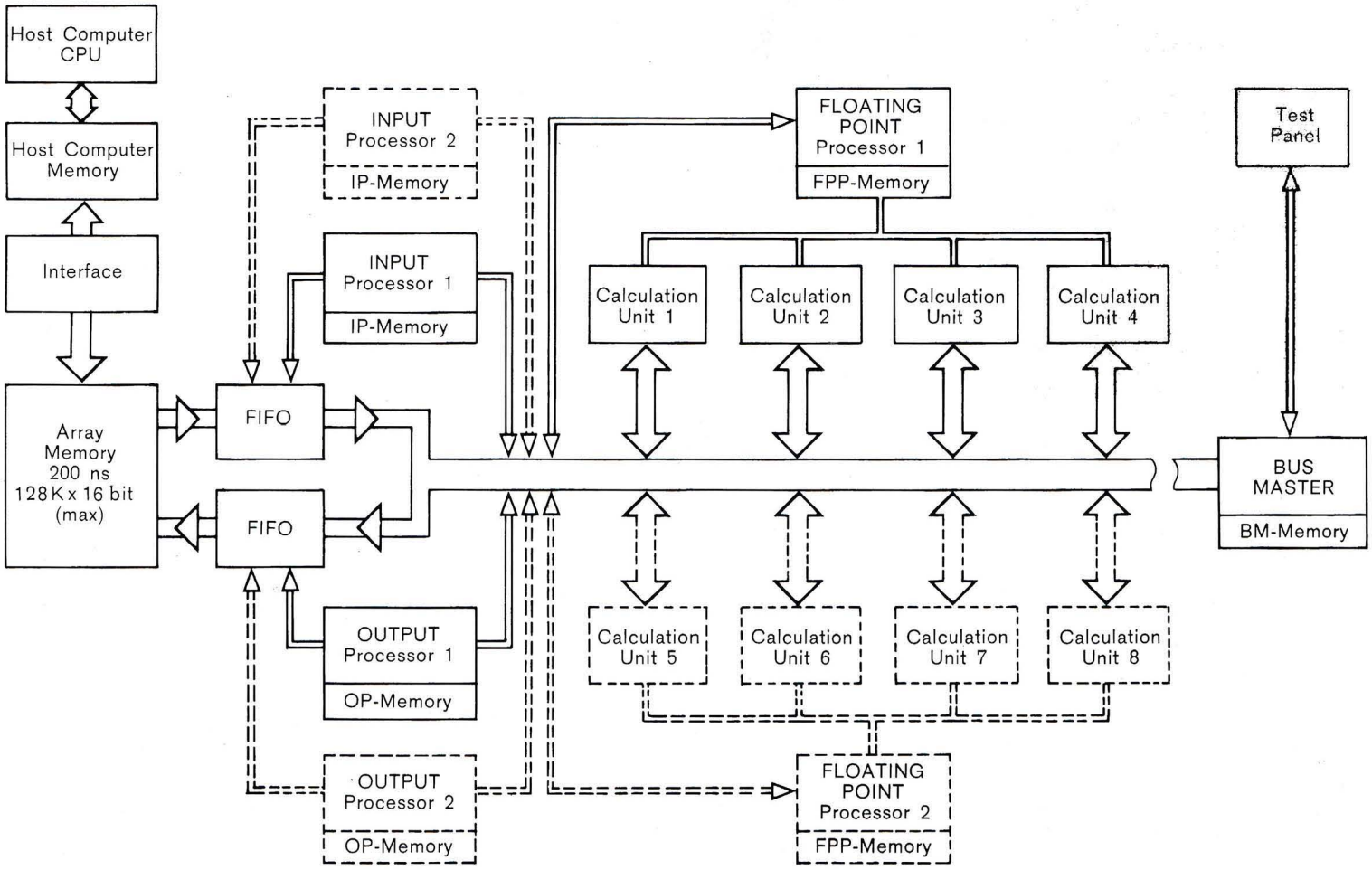
The Array Processor System APS (called APS below) is a self-contained multiprocessor operated independently from the CPU of the PDP. The APS controls the flow of data between memory and calculation units, and the parallel operation of all processors and all calculation units with its own operating system. At the same time, processing organization and data transfers are carried out by the PDP.

Since each processor of the APS is programmable, the system has immense flexibility. The modular structure of APS allows its application in all areas of geophysics and allows expansion of the system at any time.

The APS structure (page 11) shows its clear concept:

Bus	All processors, calculation units, and memory are grouped around this very fast data bus. Cycle time 180 ns.
Bus Master	has the function of a monitor: it controls access to the data bus and coordinates operation of each processor and calculation unit.
Floating Point Processor	controls the arithmetical and logical operations. With one Floating Point Processor, up to 4 calculation units can be operated in parallel. In addition, further Floating Point Processors, with their corresponding calculation units, can be applied to the same or different tasks.
Calculation Units	process data by means of microprogrammed arithmetic for floating point and integer calculation, data conversion, and logical operations. Each calculation unit has 32 data registers with 32 bits each which can be accessed in different addressing modes.
Input/Output Processor	Both processors carry out address calculation and transfer data between memory and the FIFO's.
FIFO's (Input/Output)	ensure the transfer of data at maximum speed. They uncouple the APS-memory cycle times from the internal processing speed of the processors and calculation units, convert formats during data flow and prevent conditions such as overflow.
Array Memory	is a fast MOS memory, extendable up to 64K 16-bit words. Using overlapped operation, an effective access time of 200 ns is obtained. Memory is directly addressed from both APS (word-wise) and from the PDP (byte-wise). This allows data transfer from peripherals directly into Array Memory without shuffling.
Program Memory	Each APS processor is free-programmable and has its own bipolar program memory of 1K 16-bit words. Cycle time 100 ns.

Array Processor System APS



SOFTWARE

In the SSP-11A System, the APS has been programmed in floating point for all seismic processes: True Amplitude Recovery, Deconvolution, Corrections, Stacking, Filtering, Correlation (frequency and time domain), Automatic Residual Static Corrections, Real Amplitude Processing, Migration.

The APS is easily programmed since each of the processors is programmed independently in a widely known nomenclature, and the instruction set of each processor is adapted to its particular task. The hardware of APS guarantees automatic overlapping of input, calculation and output operations, and allows memories, bus and processors to run at maximum speed with individual clocks. Thus a high data flow rate is ensured.

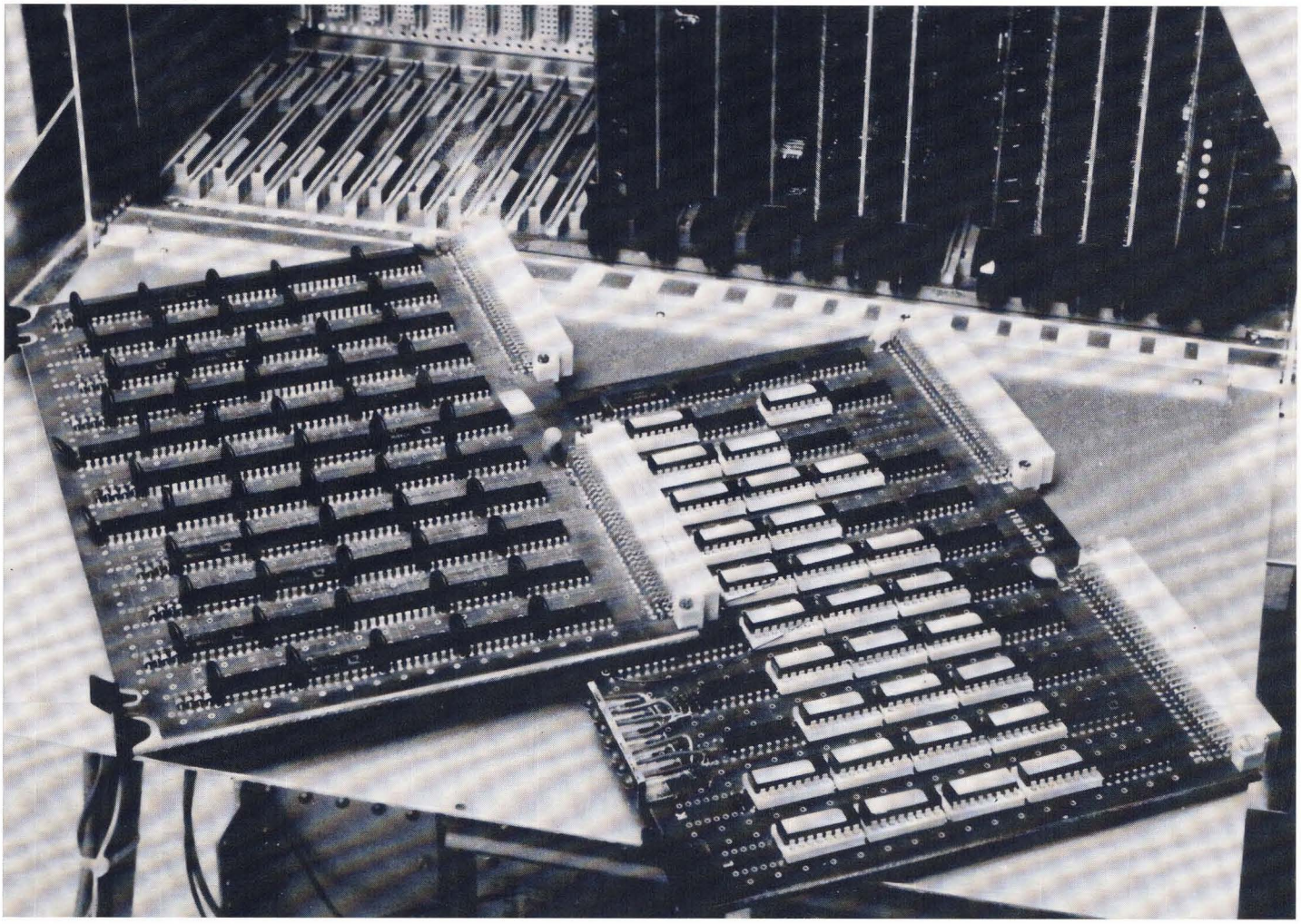
Execution Times Array Processor System	APS-4	APS-8	APS-16
Hardware Commands 32-bit floating point			
Add/Subtract	125 ns	63 ns	32 ns
Multiply	250 ns	125 ns	68 ns
Divide	550 ns	275 ns	138 ns
Add/Subtract, integer	75 ns	38 ns	19 ns
Logic operation	75 ns	38 ns	19 ns
Format conversion, fixed/floating point	150 ns	75 ns	38 ns
Algorithms 32-bit floating point			
1024 x 32 pts Correlation	16 ms	8 ms	4 ms
1024 pts real FFT	5,4 ms	2,8 ms	1,5 ms
1024 pts complex FFT	9,8 ms	5,1 ms	2,7 ms

APS-8 and APS-16 include an additional input processor and output processor.

The hard-wired APS-operating system organizes the loading, initialization, and execution of array processor programs. This allows the APS to change tasks within milliseconds. The software includes the following FORTRAN callable functions:

- Vector operations for logic and arithmetic functions:
  scalar terms and conversions
  vector element sum, maximum or minimum
  vector clipping, limiting
- Vector operations for exponential and trigonometric funktions:
  maximum and minimum magnitude
  peak
  two-vector maximum, minimum, magnitudes
- Matrix operation:
  inverse, transpose, multiply, vector multiply
- Signal processing functions:
  convolution
  FFT
  scrambling
  vector polynomial
  difference equation
  band pass filter
  recursive filter
  Wiener-Levinson
  power spectrum
  phase unwrapping
  cepstrum

Modern technology used in the APS



Combined Seismic/Raster Plotter KPU

The KPU, a high performance photographic drum plotter for seismic, raster, and alphanumeric display, is a result of PRAKLA-SEISMOS' methodical development and experience over more than 10 years in the construction and application of drum type plotters with cathode-ray tubes, first in analog, later in digital techniques. It was developed for outstanding quality seismic playback. Non-seismic plot modes benefit from the high mechanical and optical accuracy.
The entirely digital control supported by a PDP-11 computer — either on-line or as a stand-alone device — provides flexible job handling and high reproducibility of the image playback.

HARDWARE

TECHNICAL SPECIFICATIONS

General Data

maximum plot area:	920 x 1000 mm
drum speed:	64 rpm
reproducible positioning accuracy:	0.02 mm

parameter handling and plot control by a PDP-11 computer

Seismic Mode

display modes:	variable area, variable density, wiggle trace, and combinations variable area on peak (optional)
timing lines:	5 spacings and widths, software-controlled
trace width:	0.4 – 5.2 mm in steps of 0.1 mm 14 mm maximum wiggle amplitude
vertical scale:	1 s = 30 mm to 1 s = 255 mm iin steps of 1 mm
traces per drum revolution:	2 (1 when trace widths exceed 2.6 mm)

Raster Mode

dot size:	0.1 x 0.1 mm or 0.2 x 0.2 mm
normal strip width:	3.2 mm
presentations:	black/white or 16 grey tones (selectable out of 256)
alphanumeric generator:	hardware, 64 characters (2 or 4 mm high, 1 or 2 per strip)

CONFIGURATION OPTIONS

1. The minimum stand-alone KPU configuration consists of
   - the plotter electronics, including a PDP-11 computer with 32K core memory for complete digital plot control
   - the plotting unit composed of drum drive, special cathode ray tube and optical system in a light-proof case for the exposure of photographic paper or film.
   - the operator console with papertape reader/punch
   - an optional card reader for versatile input of job control cards or auxiliary data
   - the magnetic tape transport(s) for the input of all user-supplied data (seismic, alphanumeric, raster patterns)

2. Integrated in the SSP-11 system, the KPU shares computer, core memory, console, tape transports, and card reader with the host system.

3. The KPU can be connected to any other configuration using a PDP-11 computer system.

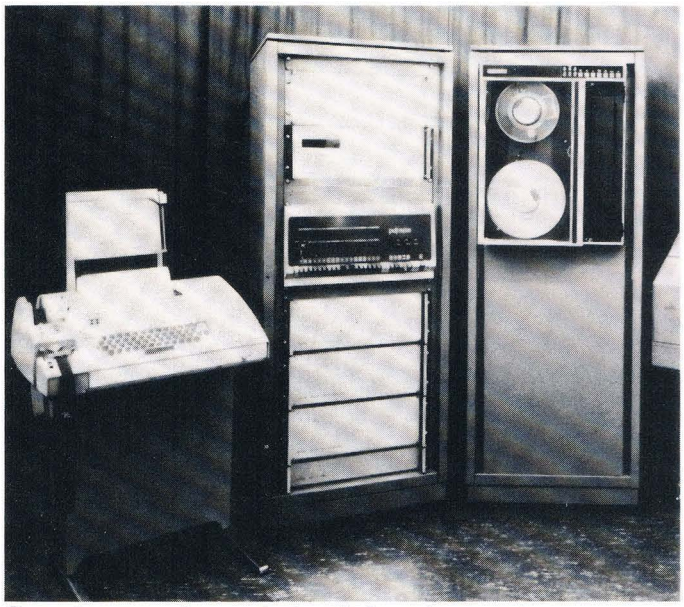
Additional equipment required or recommended: a dark room for the plotting unit, a developing device (e.g. KODAK processor), and a roll film dispenser.

SOFTWARE

KPU software is available in 4 different categories.

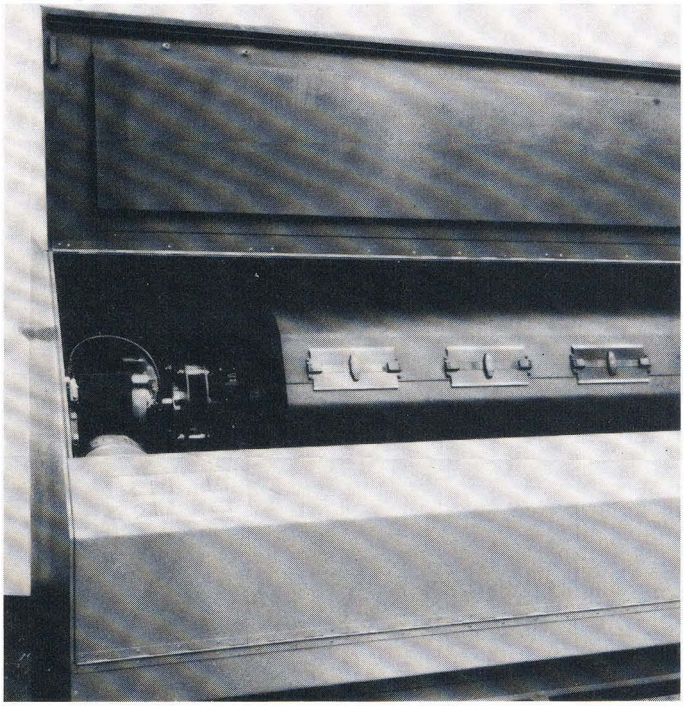
1. KPU operating software for playback job control when used as a stand-alone unit or connected to an SSP-11 system, handling:
   - the input of playback parameters and instructions from keyboard (operator dialog), paper tape or cards
   - the data input from tape, including seismic format conversion
   - shotpoint and trace selection, image position
   - control of timing lines and several kinds of standard annotation at a seismic section
   - conversion of linewise alphanumeric input to strips for output
   - complete hardware plot control by feeding the KPU registers and response to KPU interrupts during playback operation
2. KPU application software within the SSP-11 system including automatic seismic section labelling generated from the processing documentation tape:
   - line header
     (suitable for both KPU and electrostatic plotter)
   - side label
3. Fortran compatible software support for on-line KPU operation in a user's system with a PDP-11:
   - KPU driver routine to control all plotter functions for one strip
     (arbitrary sequence of plot modes, parallel operation of the user's program during plot)
   - routine to convert user-supplied parameters into bit patterns required for the KPU registers

   The user must provide all data, parameters, and playback control tables for the current strip.
4. General application software available for all users:
   - playback of satellite images, ERTS tape format handling, arbitrary grey level substitution, automatic contrast enhancement, statistics, 4-strip combination
   - input of standard text blocks from tape, insertion of actual data before plot
   - conversion and playback of raster images supplied on tapes for electrostatic plotters

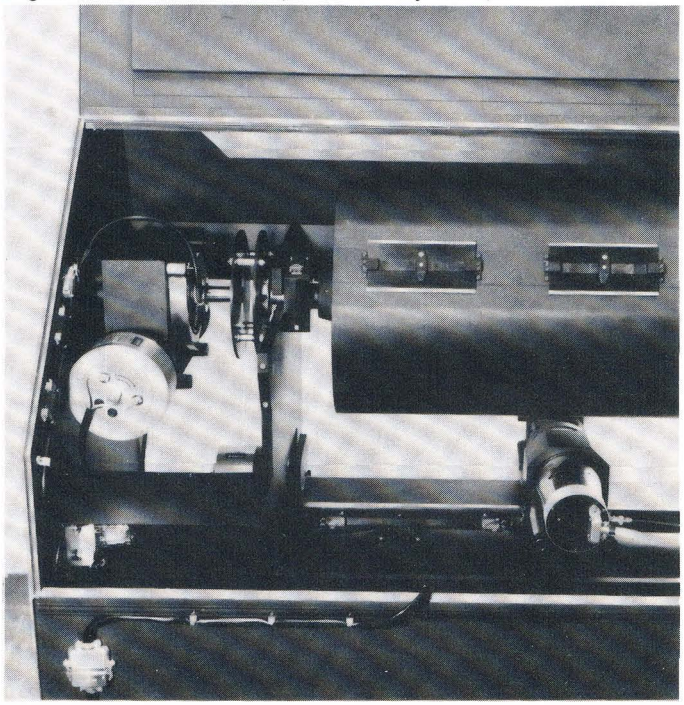


Operator console, control unit, tape transport

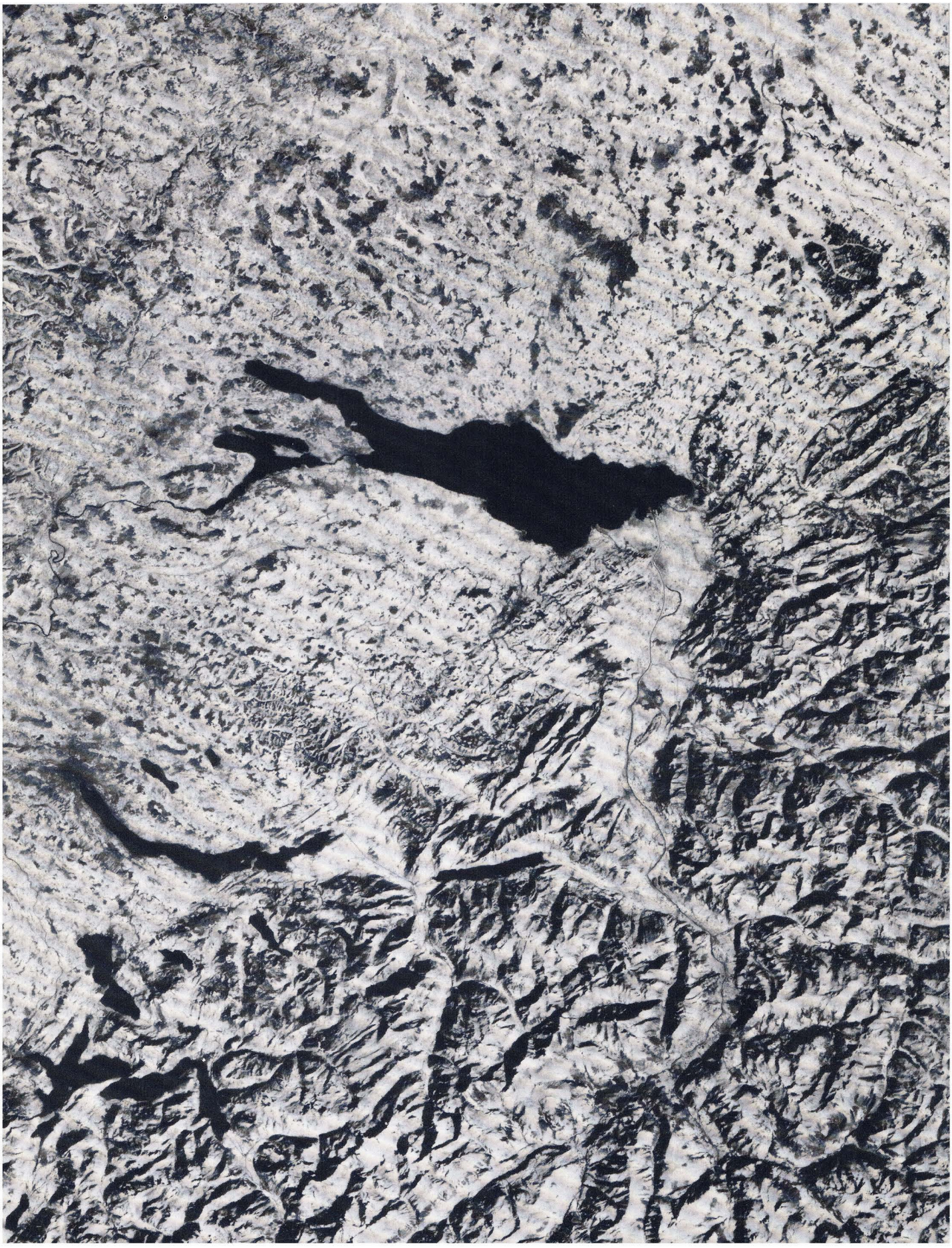
Plotting unit



Digital encoder/decoder, cathode ray tube, drum with motor



Satellite image playback,
region: lake Bodensee and The Alps, Zurich at the left



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