DEC VAX-11 Systems

MANAGEMENT SUMMARY

The VAX-11/750 and 11/780 are 32-bit multi-user, multiprogramming systems that feature 4.3 billion bytes of virtual address space, a maximum program size of 2 billion bytes, 244 instructions (9 address modes, 6 data types), and 4 hierarchical protection modes. The major components of the VAX systems are:

- Processor—the VAX-11/780 includes the basic CPU, 8K bytes of bipolar cache memory, 12K bytes of writable diagnostic control store, optional floating point accelerator, clocks and console, up to 8M bytes of MOS memory with main memory controllers, input/output bus adapters, optional multiport memory (up to 4M bytes total), and optional high-performance 32-bit interface. The VAX-11/750 includes the basic CPU, 4K bytes of bipolar cache memory, 10K bytes of writable storage, clocks and console, up to 2M bytes of MOS memory with main memory controllers, and peripheral bus adapters.
- Operating System—including a virtual memory manager, swapper, system services, device drivers, file system, record management services, command language, and operator's and systems manager's tools.
- Languages—including the native mode languages VAX-11 MACRO and optionally, VAX-11 FORTRAN, VAX-11 COBOL, VAX-11 BASIC, VAX-11 PL/1, VAX-11 PASCAL, VAX-11 BLISS-32, and VAX-11 CORAL 66, and VAX-11 DSM. Also supported in compatibility mode are PDP-11 BASIC-PLUS-2/VAX, PDP-11 FORTRAN IV/VAX to RSX, and MACRO-11. Development tools for both native and compatibility mode programs include editors, linkers, librarians, and debuggers.
- Peripherals—including a range of small- and large-capacity disk drives, magnetic tape systems, hard copy and video terminals, line printers, card readers, and real-time I/O devices.

The VAX-11 Series computers are 32-bit systems based on the PDP-11 family of 16-bit minicomputers. VAX provides 32-bit addressing for a 4 gigabyte program address space, and 32-bit arithmetic and data paths for processing speed and accuracy. The VAX/VMS virtual memory operating system features a two billion byte virtual addressing user program space and a full demand-paging operation.

MAIN MEMORY: 256KB to 12MB (8MB local and 4MB shared)
DISK CAPACITY: 512KB to 300MB per drive
WORKSTATIONS: Up to 384 (96 per UNIBUS)
PRINTERS: 230 lpm to 1200 lpm
OTHER I/O: Magnetic tape, card readers, real-time I/O devices, console storage devices

CHARACTERISTICS

MANUFACTURER: Digital Equipment Corporation (DEC), 146 Main Street, Maynard, Massachusetts 01754. Telephone (617) 897-5111.

DEC is a worldwide corporation and the world's largest manufacturer of minicomputer systems. The company employs about 23,000 persons and maintains sales and service offices in all major U.S. cities and in major cities throughout Canada and the Western world.

MODELS: VAX-11/780, and VAX-11/750.

DATE ANNOUNCED: VAX-11/780, October 1977; VAX-11/750, October 1980.

NUMBER INSTALLED TO DATE: Over 2,000 VAX-11s.

The VAX-11/780 32-bit computer system supports up to 96 interactive users per UNIBUS as well as multi-stream batch processing. The VAX/VMS virtual memory operating system features a full demand-paging operation that allows addressing space of up to one billion words. The 32-bit word length system supports up to 2 million words of real, error-correcting MOS memory.

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VAX SYSTEM COMPARISON CHART

HARDWARE	VAX-11/750	VAX-11/780
Word Length	32-bit	32-bit
Virtual Address Space	4.3 gigabytes	4.3 gigabytes
Maximum Program Size	2 gigabytes	2 gigabytes
Circuit Technology	Lower Power bipolar Schottky	TTL Schottky
Implementation	Gate array (488 logic gates per chip)	Integrated circuits (MSI)
Memory Type	16K ECC MOS RAM	16K ECC MOS RAM
Memory Capacity	256KB-2MB	256KB-8MB (12MB with multiport memory)
Cache Memory	Integral bipolar, 4KB	Integral bipolar, 8KB
User Control Store	1K RAM, 80-bit words (optional)	1K RAM, 99-bit words (optional)
Buses	1 UNIBUS, 3 MASSBUSes (optional)	UNIBUS (1 standard, 3 more optional); MASSBUS (optional, up to four)
I/O Bandwidth	5.0MB/sec.	13.3MB/sec. (with interleaved memory)
Instruction Set	244 instructions, 9 address modes, 6 data types	Same as VAX-11/750
Access Control	4 hierarchical protection modes	Same as VAX-11/750
Effective Memory Access Time	400 nanoseconds	280 nanoseconds
Maximum UNIBUS I/O Throughput	1.5MB/sec.	1.35MB/sec.
Maximum MASSBUS I/O Throughput	2MB/sec.	2Mb/sec.

- Network Services—including the DECnet/VAX network software and the DMR11 interprocessor communications link, 2780/3780, MUX200, and 3271 protocol emulators using DUP11.

Introduced in 1977, the VAX-11/780 is the first and larger family member. The processor provides 32-bit addressing, sixteen 32-bit general registers, and 32 interrupt priority levels. The instruction set operates on integer and floating-point operands, character and packed decimal strings, and bit fields, and supports nine fundamental addressing modes. The processor includes an 8K-byte write-through cache memory that results in an effective 290-nanosecond memory access time, and also a 12K byte Writable Diagnostic Control Store for diagnostic software. The processor's memory management includes four hierarchical processor access modes that are used by the operating system to provide read/write page protection between user software and system software.

Error-correcting code (ECC) MOS memory is connected to the main control and data transfer path (called the Synchronous Backplane Interconnect or SBI) via a memory controller. Physical memory is built using 16K-bit MOS RAM chips and is organized in 72-bit words (64 bits for data and 8 for ECC). Each memory controller includes a request buffer that substantially increases overall system throughput and eliminates the need for interleaving in most applications.

The processor uses two standard clocks—a programmable real-time clock used by the operating system and diagnostics, and a time-of-year clock used for system operations. The time-of-year clock includes battery backup for automatic system restart operations.

The processor's console consists of an LSI-11 microcomputer with 16K bytes of read/writer memory and 8K bytes of ROM, a floppy disk, and a terminal for local operations and an LSI-11 microcomputer for

DATA FORMATS

BASIC UNIT: 32-bit word.

FIXED-POINT OPERANDS: Integers can be 8-bit bytes, 16-bit words, 32-bit longwords, and 64-bit quadwords. All have the same general format, with the high-order bit used as the sign. Negative numbers are represented in two's complement form.

FLOATING-POINT OPERANDS: Two floating-point formats are available: single-precision (called floating) that uses a 4-byte format, and double-precision (called double floating) that uses an 8-byte format. In both formats, the high-order bit is used as a sign and the next seven bits for the exponent. Single-precision fractions are 24 bits long, while double-precision fractions are 56 bits long. The 4-byte format provides approximately 7 decimal digits of precision, while the 8-byte format provides approximately 16 decimal digits of precision. A loadable microcode package is available on the 11/750 for extended precision floating-point arithmetic operations (G- and H-floating-point data types).

INSTRUCTIONS: The native instruction set is an extension of the PDP-11 instruction set that consists of 244 basic instructions, most of which can be applied to any one of several types of data, which can in turn be addressed in any one of nine ways. The native instruction set provides 32-bit addressing, 32-bit I/O operations, and 32-bit arithmetic. The instructions can be grouped into related classes based on their function and use: instructions to manipulate arithmetic and logical data types, instructions to manipulate special kinds of data, instructions to provide basic program flow control, instructions to perform special operating system functions, and instructions provided specifically for high-level language constructs.

Instructions and data are available in length. They need not be aligned on longword (32-bit) boundaries in physical memory, but may begin at any byte address (odd or even). Thus, instructions that do not require arguments use only one byte, while other instructions may be two, three, or up to 30 bytes in length, depending on the number of arguments and their addressing modes.

In addition to its 32-bit native instruction set, the processors can concurrently execute a compatibility-mode instruction set, which is a subset of the DEC PDP-11 instruction set. This is not done by emulation or simulation; both

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PERIPHERALS/TERMINALS

DEVICE	DESCRIPTION	MANUFACTURER
MAGNETIC TAPE		
TEE16-AE (AJ)	Program-selectable 800 or 1600 bpi, 9-track, 45 ips magnetic tape transport and VAX-11/780 MASSBUS adapter; expandable to eight TE16 transports and seven MASSBUS disk drives	DEC
TEU45-KA (KB)	Program-selectable 800 or 1600 bpi, 9-track, 75 ips transport and VAX-11/780 MASSBUS adapter; expandable to eight TU45 transports and seven MASSBUS disk drives	DEC
TEU77-AB (AD)	Program-selectable 800 or 1600 bpi, 9-track, 125 ips transport and VAX-11/780 MASSBUS adapter; expandable to four TU77 transports and seven MASSBUS disk drives	DEC
TGU77-AB (AD)	Program-selectable 800 or 1600 bpi, 9-track, 125 ips transport and VAX-11/750 MASSBUS adapter; expandable to four TU77 transports and seven MASSBUS disk drives	DEC
LINE PRINTERS		
LA11-PA (PD)	132-column, 96-character matrix printer and control unit; 180 cps	DEC
LP11-AA	132-column, 64-character band printer and control unit; 285 lpm	DEC
LP11-BA	132-column, 64- and 96-character band printer and control unit; 285 lpm when using 64-character set, 204 lpm when using 96-character set	DEC
LP11-CA (CD)	132-column, 64-character high speed printer and control unit; 900 lpm	DEC
LP11-DA (DD)	132-column, 96-character high speed printer and control unit; 660 lpm	DEC
LP11-VA (VD)	132-column, 64-character printer and control unit; 300 lpm	DEC
LP11-WA (WD)	132-column, 96-character printer and control unit; 240 lpm	DEC
LP11-YA (YD)	132-column, 64-character printer and control unit; 600 lpm	DEC
LP11-ZA (ZD)	132-column, 96-character printer and control unit; 436 lpm	DEC
LPR11-VA (VD)	132-column, 64-character remote printer subsystem; 250 lpm	DEC
LPR11-WA (WD)	132-column, 96-character remote printer subsystem; 240 lpm	DEC
LPR11-ZA (ZD)	132-column, 96-character remote printer subsystem; 420 lpm	DEC
CARD READERS		
CR11 (-A)	300 cpm reader and control unit; reads 80-column punched cards	DEC
CR11-BC (BD)	600 cpm reader and control unit; reads 80-column punched cards	DEC
CME11-KA (KB)	250 cpm reader and control unit; reads 40- and 80-column punched cards	DEC
TERMINALS		
LA34-DA	Table-top DECwriter IV printing terminal; can accommodate single sheets and roll paper; 30 cps print speed and baud rates up to 300 bps	DEC
LA38-GA	Table-top DECwriter IV printing terminal; can accommodate up to a 4-part computer form as well as single sheets and computer paper; 30 cps print speed and 300 bps baud rate	DEC
LA38-HA	Free-standing DECwriter IV printing terminal; 30 cps print speed, and 300 bps baud rate	DEC
LA120-DA	Free-standing DECwriter III high-speed interactive hardcopy terminal; 180 cps bidirectional printing with baud rates up to 9600	DEC
VT100-AA (AB)	High-performance, table-top, video display terminal includes double-width/double-size characters, 80 columns x 24 lines or 132 columns x 14 lines, and 95-character detachable keyboard	DEC

remote diagnosis. The console operator uses keyboard commands for diagnosis, bootstrapping, and incorporating software maintenance modifications.

Medium-capacity disk drives, unit record devices, terminals, interprocessor communications links, and user-specific devices are UNIBUS peripherals. The UNIBUS adapter provides the hardware pathways for data and control information to move between the UNIBUS and the SBI. The maximum aggregate throughput rate is 13.3 million bytes per second with interleaved memory.

High-performance MASSBUS mass storage peripherals are connected to the SBI via a buffered MASSBUS adapter. The MASSBUS adapter provides the hardware path for data and control information to move between a MASSBUS peripheral controller and the SBI, and allows high-speed data transfers at a maximum aggre-

instruction sets are built into the microcode and logic of the processor. The compatibility-mode instruction set contains all the PDP-11 instructions except those which perform the following functions:

- **Execution of floating-point instructions.**
- **Use of both instruction space and data space.**
- **Execution of privileged functions such as: 1) HALT, RESET and special instructions, such as traps and WAIT, which are normally reserved for operating system usage; 2) direct access to internal processor registers such as the Processor Status Word and the Console Switch Register; 3) direct access to the trap and interrupt vectors, which must be initialized for interrupt servicing; and 4) execution in any mode other than user mode, along with the corresponding access to the alternate general register set.**

INTERNAL CODE: ASCII for text-oriented data; binary for calculations.

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gate throughput rate of 2 million bytes per second for each adapter. The MASSBUS adapter performs parity checking on both data and control information.

The processor includes 12K bytes of writable diagnostic control storage for updating the instruction set microcode. The control storage is also used for executing microcode diagnostics, which can be loaded from the console's floppy disk.

The VAX-11/750, introduced in October 1980, is the mid-range family member that offers improved price/performance benefits while extending full software compatibility to a new market base. The VAX-11/750 is billed as having 60 percent of the VAX-11/780 performance for less than 40 percent of its CPU price. This is accomplished through the use of gate array technology which reduces the number of interconnects by a factor of five. This advantage provides an increase in reliability with a decrease in power consumption for a system which is smaller both in physical dimensions and in the size of its price tag.

The VAX-11/750 uses the same architecture, operating system, and language processors as the VAX-11/780 to offer another setup in DEC's 32-bit virtual memory system progression. For a hardware comparison of the two systems, see the chart on page

The two VAX systems also share such features as sixteen 32-bit general registers, 32 priority interrupt levels (16-hardware, 16-software), nine addressing modes, and four hierarchical protection modes, each with read/write access control. The VAX-11/750 also features a cartridge tape drive for software updates; a UNIBUS interface for terminals, serial devices and medium-speed peripherals; and up to three optional MASSBUS adapters for up to 24 high speed disk and tape units. A real-time clock is also a standard feature, as is a time-of-year clock with battery backup to enable automatic restart even after extended power failures. Options include a writable control store of 1K 80-bit words for unique, user-defined code. A memory battery backup unit is available to sustain two megabytes of memory for ten minutes.

The instruction set executed on the VAX processors is selected under operating system control as either the native-mode or compatibility-mode set. The native-mode instruction set includes over 200 different opcodes, which can be grouped into classes based on their function and use. Instructions used to manipulate the general data types include integer and floating point-instructions, packed decimal instructions, character string instructions, and bit field instructions. Instructions used to manipulate special kinds of data include queue manipulation, address manipulation, and user-programmed general register control instructions. Instructions that provide basic program flow control and call procedures include branch, jump, and case instructions, subroutine call instructions, and procedure call instructions.

MAIN STORAGE

GENERAL: The main memory system is connected to the Synchronous Backplane Interconnect (SBI) via the memory controller. Physical memory is built using 16K MOS RAM chips. Memory types are organized in quadwords (64 bits) plus an 8-bit error-correcting code (ECC), which allows the correction of all single-bit errors and the detection of all double-bit errors and approximately 70 percent of errors which exceed 2 bits. On the 11/750, physical memory is organized into an array of 32-bit longwords plus an additional 7 bits per longword dedicated to ECC. Interleaving is possible with two controllers and equal amounts of memory on each. Interleaving is enabled/disabled under program control. It is performed at the quadword level because of the memory organization. The memory controllers allow the writing of data in full 32- and 64-bit units. Also, upon command from an SBI device, individual bytes (or a single byte) may be written.

Each memory controller buffers up to four memory access requests. This "request buffer" substantially increases memory throughput and overall system throughput and decreases the need for interleaving for most configurations. With this buffer, memory bandwidth essentially matches that of the SBI—13.3 million bytes/second, including time for refresh cycles with interleaved memory. This is because a number of transactions can occur concurrently. For example, the memory controller can accept a WRITE command from a MASSBUS adapter while it is reading previously requested data by the processor for increased throughput. Were it not for the request buffer, there would be about a 50 percent degradation in memory bandwidth, making interleaving necessary to approach the bandwidth.

TYPE: ECC MOS RAM.

CYCLE TIME: The VAX-11/780 has a 600 nanosecond cycle time. Its processor includes an 8K byte write-through memory cache that results in an effective 290 nanosecond memory access time. On the VAX-11/750, effective memory access time is 400 nanoseconds.

CAPACITY: The minimum memory requirement on the VAX system is 256K bytes. Memory can be added in increments of 256K bytes. Maximum memory capacity is 2MB on the 11/750, and 8M bytes on the 11/780. By adding the MA780 shared-memory option, memory on the 11/780 can be expanded to 12M bytes.

CONTROL STORAGE: On the 11/780, 12K bytes (plus parity) of Writable Diagnostic Control Store (WDCS) are provided to allow the Diagnostic Console Microcomputer to verify the integrity of crucial parts of the CPU, the intelligent console, the SBI, and the memory controller. In addition, the WDCS can be used to implement updates to the system microcode. The optional User Control Store (UCS) on the VAX-11/750 includes 10K bytes (1K bytes of 80-bit microwords) of writable storage. This allows users to augment the speed and power of the basic machine with customized microcode functions. Such customized functions include the loadable microcode package for extended precision floating-point arithmetic operations.

STORAGE PROTECTION: The system's memory management logic divides memory into 512-byte pages. Each page is assigned a protection code specifying which, if any, access modes are to be permitted read or write access to the page.

CENTRAL PROCESSOR

GENERAL: The VAX-11/780 processor has a 32-bit architecture based on the DEC PDP-11 family of 16-bit minicomputers. While using address modes and stack structures

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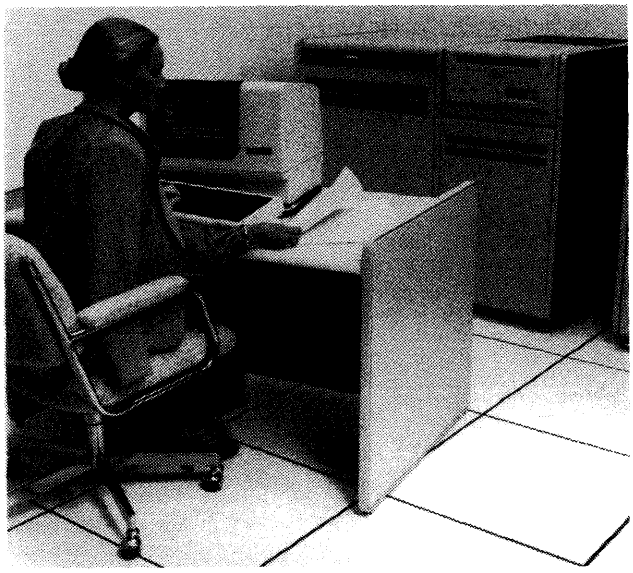

The VAX-11/750 virtual memory computer is a 32-bit system that uses advanced LSI circuit technology to achieve low price and compactness for a wide variety of environments. The entry-level system configuration, with 512K bytes of memory and two 28-million-byte disk drives, is priced at $89,900.

The compatibility mode provides the PDP-11 instruction set, with the exception of privileged and floating-point instructions. Under control of the operating system, the processor can execute PDP-11 instruction streams within the context of any process. When executing in compatibility mode, the processor interprets the instruction stream as a subset of PDP-11 code that does not include floating-point hardware instructions or privileged instructions. The compatibility mode enables the VAX/VMS operating system to provide an environment for executing most user-mode programs written for a PDP-11 (except stand-alone software). The processor expects all compatibility-mode software to rely on the services of the native operating system for I/O processing, interrupt and exception handling, and memory management. There are some restrictions, however, on the environment that the native operating system can provide for a PDP-11 program. For example, certain PDP-11 memory management instructions cannot be simulated by the operating system since they do not trap to native-mode software.

For compatibility with the PDP-11, the VAX systems use both the DCL and MCR command languages and implement upper compatible FORTRAN, BASIC, and COBOL languages. Languages that produce native mode code include BASIC, COBOL, FORTRAN, PASCAL, PL/1, DSM, CORAL 66, BLISS-32, and Macro.

The VAX systems can also be used as host development systems for RSX-11M and RSX-11S operating systems running on PDP-11 minicomputers. Like the PDP-11, the systems use a UNIBUS for connecting peripherals; and like the PDP-11/70, they use integrated MASSBUS adapters for interfacing high-speed peripherals. The disk structure is the same as that of the PDP-11 RSX-11

similar to those of the PDP-11, the VAX-11/780 provides 32-bit addressing for a large program address space, and 32-bit arithmetic and data paths for increased processing speed and accuracy. The processor includes the basic CPU, synchronous system bus, intelligent microcomputer console, interval and time-of-year clocks, and 8K bytes of cache memory. Up to twelve million bytes of memory, up to four MASSBUSES, a UNIBUS (1 standard, 3 optional), and a floating-point accelerator can be included with the processor. The processor provides 32-bit addressing, sixteen 32-bit general registers, and 32 interrupt priority levels. The instruction set operates on integer and floating-point operands, character and packed decimal strings, and bit field data. The instruction set supports nine fundamental addressing modes.

The smaller VAX-11/750 processor also has a 32-bit architecture, and is the first 32-bit mini to employ gate array circuitry. The CPU performs the logical and arithmetic operation requested of the computer system. Its user-programmable registers include sixteen 32-bit general purpose registers for data manipulation, and the Processor Status Word for controlling the execution states of the CPU. The processor instruction set is defined by the microcode contained in its control store. The CPU also include a 4K byte bipolar cache memory, 10K byte user control store, clocks and console. Up to 2M bytes of main memory can be added. Each VAX-11/750 system contains one UNIBUS adapter for standard peripherals and up to a maximum of three MASSBUS adapters for high speed peripherals.

Memory management on VAX systems includes four hierarchical processor access modes that are used by the system to provide read/write page protection between user software and system software. Memory is connected to the main control and data transfer path (the SBI) via a memory controller. Each memory controller includes a request buffer that substantially increases overall system throughput and eliminates the need for interleaving in most applications.

The processors use two standard clocks: a programmable real-time clock used by the operating system and by diagnostics, and a time-of-year clock used for system operations. The time-of-year clock includes battery backup for automatic system restart operations.

The "intelligent" console on the 11/780 consists of an LSI-11 microcomputer with 16K bytes of read/write memory and 8K bytes of ROM, a floppy disk unit, a terminal for local operations, and an optional port for remote diagnosis. The console operator uses keyboard commands for diagnosis, bootstrapping, and incorporating software maintenance modifications.

The 11/750 console enables the computer system operator to control the processor operation directly. The console subsystem consists of the console terminal (LA38 DECwriter), the front panel, the user-oriented console command language, and a TU58 tape cartridge drive. Also optionally available for the console is the remote diagnosis interface.

Medium capacity disks, unit record devices, terminals, interprocessor communications links, and user-specified devices are UNIBUS peripherals. The maximum UNIBUS I/O throughput per UNIBUS is 1.35M bytes per second on the 11/780, and 1.5M bytes per second on the 11/750.

High-performance mass storage devices are connected to the VAX systems via up to 3 optional MASSBUS adapters on the 11/750, and up to 4 optional MASSBUS adapters on the 11/780. Maximum MASSBUS I/O throughput is 2M bytes per second on both VAX systems. The MASSBUS adapter does parity checking for both data and control information.

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Real-Time Operating Systems and IAS (Interactive Application System). File inquiry methods using DATATRIEVE/VAX are the same as those available with DATATRIEVE-11, the PDP-11 inquiry and report writing system.

The operating system for the VAX systems is VAX/VMS, a general-purpose operating system that provides for the concurrent execution of multi-user time-sharing, batch, and time-critical applications. VAX/VMS provides: 1) virtual memory management for the execution of large programs; (2) event-driven priority scheduling; 3) shared memory, file, and interprocess communication data protection based on ownership and application groups; and 4) programmed system services for process and subprocess control and interprocess communication.

VAX/VMS performs process-oriented paging, which allows the execution of programs larger than the physical memory allocated to them. Four billion bytes of addressing space are provided. Paging is handled automatically by the system, freeing the user from any need to structure the program. In the VAX/VMS operating system, a process pages only against itself; thus, individual processes cannot significantly degrade the performance of other processes.

The memory management facilities provided by VAX/VMS can be controlled by the user. Any program, with sufficient privilege, can prevent pages from being swapped out, or prevent the entire working set from being swapped out, to optimize program performance in time-critical or interactive environments. Sharing and protection are provided for individual 512-byte pages. Four hierarchical modes (kernel, executive, supervisor, and user) provide page protection.

VAX/VMS schedules CPU time and memory residency on a preemptive priority basis. Thus, time-critical processes do not have to compete with lower-priority processes. The scheduler adjusts the priorities of processes assigned one of the low 16 priorities to overlap I/O and computation. Time-critical processes can be placed in one of the top 16 scheduling priorities, in which case the scheduler does not alter their priorities, but they can still be altered by the system manager or an appropriately privileged user.

The operating system also includes system services to control processes and process execution, control time-critical response, control scheduling, and obtain information. Process control services allow the creation of subprocesses as well as independent detached processes. Processes can communicate and synchronize using mailboxes, shared areas of memory, or shared files. A group of processes can also communicate and synchronize using multiple common-event flag clusters.

VAX/VMS provides a program development capability that includes editors, language processors, and a symbolic debugger. The BLISS-32 implementation

REGISTERS: The VAX systems provide sixteen 32-bit general registers that can be used for temporary storage, as accumulators, as index registers, and as base registers. The processor offers a variety of addressing modes that use the general registers to identify instruction operand locations, including an indexed addressing mode that provides a true post-indexing capability.

Four registers have special significance: the Program Counter contains the address of the next instruction to be executed; the Stack Pointer contains the address of the base (or top) of a stack maintained for subroutine and procedure calls; the Frame Pointer contains the address of the base of a software data structure stored on the stack and called the stack frame, which is maintained for procedure calls; and the Argument Pointer contains the address of the base of a software data structure called the argument list, which is maintained for procedure calls.

In addition, the first six registers have special significance for character and packed decimal string instructions and the Polynomial Evaluation instruction. These instructions use the first six registers to store temporary results and, upon completion, leave results in the registers that a program can use as the operands of subsequent instructions.

A register's special significance does not preclude its use for other purposes, except for the Program Counter. The Program Counter cannot be used as an accumulator, as a temporary register, or as an index register. In general, however, most users do not use the Stack Pointer, Argument Pointer, or Frame Pointer for purposes other than those designated.

Registers can be used for temporary storage, accumulators, base registers, and index registers. A base register contains the address of the base of a software data structure such as a table or queue, and an index register contains a logical offset into a data structure. Whenever a register is used to contain data, the data is stored in the register in the same format as it would appear in memory. If a quadword or double floating operand is stored in a register, it is actually stored in two adjacent registers.

ADDRESSING: The processor's addressing modes allow almost any operand to be in a register or in memory, or used as an immediate constant. There are seven basic addressing modes that use the general registers to identify the operand location, including:

- **Register Mode, in which the register contains the operand.**
- **Register Deferred Mode, in which the register contains the address of the operand.**
- **Autodecrement Mode, in which the contents of the register are first decremented by the size of the operand, and then used as the address of the operand. The size of the operand (in bytes) is given by the data type of the instruction operand, and depends on the instruction.**
- **Autoincrement Mode, in which the contents of the register are used as the address of the operand, and then incremented by the size of the operand. If the Program Counter is the specified register, the mode is called the Immediate mode.**
- **Autoincrement Deferred Mode, in which the contents of the register are used as the address of a location in memory containing the address of the operand, and then are incremented by four (the size of an address). If the Program Counter is the specified register, the mode is called the Absolute mode.**
- **Displacement Mode, in which the value stored in the register is used as a base address. A byte, word, or**

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language was designed for the development of operating systems, data base file systems, communications software, and utilities. All VAX languages are native mode.

The VAX/VMS operating system provides a file and record management facility that allows the user to create, access, and maintain data files and records within the files with full protection. The record management services handle sequential, relative file and indexed sequential organizations, sequential and random record access, and fixed and variable-length records.

Data communications capabilities for the VAX systems are provided by DECnet, a family of network products developed by DEC that add networking capabilities to all of the company's computer families and operating systems. Using DECnet, various kinds of computer networks can be constructed to facilitate remote communications, resource sharing, and distributed computation.

DECnet/VAX is designed to:

- Provide an interprocess communication facility that is highly transparent and easy to use.
- Provide a high-level language programming interface.
- Allow programs to access files at other systems.
- Allow users and programs to transfer files between systems;
- Allow users to transmit command files to be executed in other systems; and
- Allow an operator to down-line load RSX-11S system images into other systems.

The VAX-11/780 has proven to be an impressive system moving into the scientific, industrial, and educational markets where time-critical, computational, and control applications are important. Moreover, because of the increase in performance, reliability, and maintainability when related to the price, size, and power decreases, the VAX-11/750 can move into areas not open to larger VAX-11/780 systems. The product OEMs have a powerful, compact unit to incorporate into larger systems. Educational, governmental, and medical applications are now well within the reach of a VAX-11/750.

In all these markets, DEC will compete with an ever-expanding arena of 32-bit systems including Perkin-Elmer's 3200 Series systems, SYSTEMS 32 Series computers, and Data General's MV/8000.

USER REACTION

Seventeen VAX users responded to Datapro's 1980 user survey. All the systems were VAX-11/780s; 14 were

longword signed constant is added to the base address, and the resulting sum is the effective address of the operand.

- **Displacement Deferred Mode, in which the value stored in the register is used as the base address of a table of addresses. A byte, word, or longword signed constant is added to the base address, and the resulting sum is the address of the location that contains the actual address of the operand.**

Of these seven basic modes, all except Register Mode can be modified by an index register. When an index register is used with a basic mode to identify an operand, the addressing mode is the name of the basic mode with the suffix "Indexed." Therefore, in addition to the seven basic addressing modes that use registers, the processor recognizes six indexed addressing modes.

The processor also provides Literal Mode addressing, in which an unsigned 6-bit field in the instruction is interpreted as an integer or floating-point constant.

INSTRUCTION REPERTOIRE: The native-mode instruction set that the processor executes is based on over 200 different opcodes. The opcodes can be grouped into classes based on their function and use. Instructions used to manipulate the general data types include:

- **Integer and floating-point instructions.**
- **Packed decimal instructions.**
- **Character string instructions.**
- **Bit field instructions.**

Instructions that are used to manipulate special kinds of data include:

- **Queue manipulation instructions.**
- **Address manipulation instructions.**
- **User-programmed general register control instructions.**

Instructions that provide basic program flow control and permit the calling of procedures are:

- **Branch, jump, and case instructions. (The processor provides a branch instruction, CASE, that implements higher-level language computed GO TO statements. For CASE, the user supplies a list of displacements that generate different branch addresses indexed by the value obtained as a selector. The branch falls through if the selector does not fall within the limits of the list.)**
- **Subroutine call instructions.**
- **Procedure call instructions.**

INSTRUCTION TIMINGS: All times shown are for longword (32-bit) operands, in microseconds. Floating-point instruction times are for systems that include the Floating-Point Accelerator.

	Fixed Point	Floating Point
Add/Subtract	**0.4**	**0.8**
Multiply	**1.6**	**1.2**
Divide	**9.8**	**4.2**

INTERRUPTS: The processor recognizes 32 interrupt priority levels. The highest 16 interrupt priority levels are reserved for interrupts generated by hardware, and the lowest 16 levels are reserved for interrupts requested by

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purchased and 3 were leased. By far, the principal application was engineering and scientific functions followed by accounting, education, and distributed processing. The primary source of applications programs came from in-house personnel.

Memory capacities, ranging from 512K bytes to 4M bytes, averaged 1.5M bytes per user. On the other hand, disk capacities averaged 320M bytes per user. A total of 298 workstations were in use among the 17 users. FORTRAN was the primary programming language and six of the users had installed data base management systems. Only one was using the DECnet networking software and another used the DCL communications link; however, six said they expected to expand their data communications facilities in 1980.

The results of the user's ratings of the VAX-11/780 are shown below. One user declined to give specific answers because, at the time, the system had only been installed for a short time:

	Excellent	Good	Fair	Poor	WA*
Ease of operation	10	5	1	0	3.6
Reliability of mainframe	11	5	0	0	3.7
Reliability of peripherals	4	9	2	0	3.1
Maintenance service:					
Reponsiveness	5	9	1	1	3.1
Effectiveness	2	11	3	0	2.9
Technical support:					
Trouble-shooting	2	8	4	1	2.7
Education	1	8	5	1	2.6
Documentation	3	9	3	1	2.9
Manufacturer's software:					
Operating system	9	6	0	1	3.4
Compilers and assemblers	9	6	0	1	3.4
Application programs	2	6	0	1	3.0
Ease of programming	9	6	1	0	3.5
Ease of conversion	5	10	1	0	3.3
Overall satisfaction	8	7	0	1	3.4

*Weighted Average on a scale of 4.0 for Excellent.

Only a minimal number of users responded when asked to state significant problems with the system. The greatest number—four users—stated that delivery and/or installation of the equipment was late. A majority of the users, however, responded favorably when asked to state the significant advantages of the system. Sixteen said that the system was easy to expand/reconfigure, 15 said they were happy with response times, 12 stated that productivity aids helped them keep programming costs down, and 10 said that programs and data carried over from other systems were compatible as the vendor had promised. Fifteen users did not expect to replace their system in 1980. Moreover, when asked if they would recommend the system to another user, 15 said yes.□

software. Normal user software runs at the process level, which is interrupt priority level zero.

To handle interrupt requests, the processor enters a special system-wide context. In the system-wide context, the processor executes in kernel mode, using a special stack called the interrupt stack. The interrupt stack cannot be referenced by any user-mode software because the processor selects the interrupt stack only after an interrupt, and all interrupts are trapped through system vectors.

The interrupt service routine executes at the interrupt priority level of the interrupt request. When the processor receives an interrupt request at a level higher than that of the currently executing software, the processor honors the request and services the new interrupt at its priority level. When the interrupt service routine issues the REI (Return from Exception or Interrupt) instruction, the processor returns control to the previous level.

PHYSICAL SPECIFICATIONS: Nominal operating environment for the VAX-11/780 processor is 59 to 90 degrees Fahrenheit (15 to 32 degrees Centigrade), at 20 to 80 percent relative humidity within specified wet-bulb and dew-point limits. These are *processor* specifications; electromechanical peripherals may be more sensitive to their environments. The CPU is housed in a five-foot-tall, four-foot-wide, double-width highboy cabinet.

The VAX-11/750 is 42 x 29 x 30 inches in size (106 x 74 x 76 cm), approximately one third the size of a VAX-11/780. Maximum weight is 400 pounds. Power requirements are 120 volts at 30 amps, and 240 volts at 15 amps, single phase. Maximum power consumption is 1,700 watts, and maximum heat dissipation is 5,800 BTU/hr.

INPUT/OUTPUT CONTROL

UNIBUS: All devices other than the high-speed disk drives and magnetic tape transports are connected to the UNIBUS, an asynchronous bidirectional bus. These include all Digital- and user-developed real-time peripherals. The UNIBUS is connected to the memory interconnect through the UNIBUS adapter. The UNIBUS adapter does priority arbitration among devices on the UNIBUS. Up to four UNIBUS adapters on the 11/780, and one on the 11/750, can be placed on the memory interconnect.

The UNIBUS adapter provides access from the VAX processors to the UNIBUS peripheral device registers by translating UNIBUS addresses, data transfer requests, and interrupt requests to their memory interconnect equivalents, and vice versa. The UNIBUS adapter address translation map translates an 18-bit UNIBUS address to a 30-bit memory interconnect address (24 bits on the 11/750).

On the 11/780, the UNIBUS adapter provides buffered DMA (NPR) devices. Each of these channels has a 64-bit buffer (plus byte parity) for holding four 16-bit transfers to and from UNIBUS devices. The result is that only one memory interconnect transfer (64 bits) is required for every four UNIBUS transfers. On the 11/750, the UNIBUS adapter facilitates high-speed DMA transfers by providing buffered DMA data paths for up to 3 high-speed devices at one time. Each of these channels has a 32-bit buffer (plus byte parity) for holding two 16-bit transfers to or from UNIBUS devices. The result is that only one memory transfer (32 bits) is required for every two UNIBUS transfers. The maximum aggregate transfer rate through the buffered data path is 1.5M bytes per second on the 11/750, and 1.35M bytes per second on the 11/780 (per UNIBUS).

Any number of unbuffered direct memory access transfers are handled by one direct DMA data path. Every 8- or 16-bit transfer requires one 32-bit transfer on the memory interconnect. The maximum transfer rate through the direct data path is 500,000 bytes per second on the 11/780 and 1M bytes per second on the 11/750. The UNIBUS adapter permits program interrupts, unbuffered and buffered data transfers to occur concurrently.

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MASSBUS: Used to attach high-speed disk or magnetic tape devices, the MASSBUS adapter performs control, arbitration, and buffering functions. Up to four MASSBUS adapters can be connected to the memory interconnect on the 11/780, and up to three adapters on the 11/750.

Each VAX MASSBUS adapter includes its own address translation map that permits scatter/gather disk transfers. In scatter/gather transfers, physically contiguous disk blocks can be read into or written from discontiguous blocks of memory. The translation map contains the addresses of the pages, which may be scattered throughout memory, from or to which the contiguous disk transfer takes place.

Each MASSBUS adapter includes a 32-bit silo data buffer. Data is assembled in 32-bit longwords plus parity (64-bit quadwords plus parity on the 11/780) to make efficient use of the system bus. On transfers from memory to a MASSBUS peripheral, the MASSBUS adapter anticipates upcoming MASSBUS data transfers by fetching the next 32 bits (64 bits on the 11/780) from memory before all of the previous data are transferred to the peripheral. The maximum MASSBUS I/O throughput on both VAX processors is 2M bytes per second. On-line diagnostics and loop-back enable adapter fault isolation without requiring the use of a drive on the MASSBUS.

CONFIGURATION RULES

The VAX-11/780 contains the CPU, memory management, bootstrap loader, standard instructions, 8K-byte parity bipolar cache memory, programmable real-time clock, time-of-year clock (with battery backup), and 12K bytes of writable diagnostic control store.

Also included as standard equipment is an integral diagnostic console subsystem, for use in both local and remote operations, which consists of a microcomputer (LSI-11 with 16K bytes of read/write memory and 8K bytes of read-only memory) to which an RX01 floppy disk unit and an LA120 DECwriter are connected.

Optional expansions of the VAX-11/780 can be made through the use of the CPU, UNIBUS, or VAX-11/780 expansion cabinets. Options mounted in the CPU cabinet include a high-performance Floating-Point Accelerator with power supply, 12K bytes of writable control store, a total of 4MB of error-correcting memory, memory battery backup for up to four megabytes of memory, a serial line unit for remote diagnosis, and up to two MASSBUS adapters. The VAX-11/780 expansion cabinet offers expansion for up to four megabytes of memory with control, up to two more MASSBUS adapters, and one memory backup unit.

The dual RK07 disk-based VAX-11/750 system features dual RK07 disk storage devices, 512K bytes of ECC MOS memory, an RK711 UNIBUS controller with two top-loading RK07 cartridge disk drives for a total of 56M bytes of on-line storage, one DZ11-A asynchronous multiplexer for connection to eight EIA communications lines, and an LA38 console terminal with stand.

The basic equipment includes the CPU, bootstrap leader, standard instruction for floating and fixed point arithmetic, 4K byte bipolar cache memory with parity, high precision programmable real-time clock, and time-of-year clock with battery backup. Also included as standard equipment is the console subsystem made up of an integral TU58 tape cartridge unit and an LA38 terminal.

Options include the 10K byte user writable control store, an additional 1,536K bytes of memory, a remote diagnosis module (RDM), and up to three MASSBUS adapters.

On VAX systems, the DMR11 series synchronous communications line provides high-performance point-to-point interprocessor connection using the DIGITAL Data Communications Message Protocol (DDCMP). For very high-performance interprocessor communications, the 11/780 offers both multiport memory (MA780) and a high-speed channel interface (DR780). For real-time applications, VAX supports the LPA11-K and DR11-13 Direct Memory Access (DMA) interfaces. The LPA11-K is an intelligent (dual micro-processor) controller that provides high speed data sampling, operates in both dedicated and multi-request mode, and supports a number of peripheral devices. The DR11-W is a general purpose interface that performs high-speed block data transfers between the VAX memory and user peripheral devices.

WORKSTATIONS: The systems support full-duplex handling for both hard copy and video terminals. The LA120 is a hard copy terminal that offers moderate throughput and advanced print features; the VT100 video terminal offers a variety of controllable character and screen attributes including 24 lines by 80 columns or 14 lines by 132 columns screen sizes, smooth scrolling, and split screen. The VAX-11/780 can physically support up to 384 terminals; the VAX-11/750 up to 64.

DISK STORAGE: Each MASSBUS adapter can support up to eight disk drives or seven disk drives and one magnetics tape controller. In addition, up to eight medium-capacity disk drives can be connected to the system's UNIBUS.

MAGNETIC TAPE: See above.

PRINTERS: Card readers and line printers can be spooled input and output devices managed by operator-controlled queues. Up to four LP11 printers and up to 16 LA11 printers can be used on the system.

MASS STORAGE

RP06 DISK DRIVES: A single- or dual-access, free-standing 176M byte removable disk pack drive. One RP06-P disk pack is included. Peak transfer rate is 806KB/second, average access time is 38.3 milliseconds, and average rotational latency is 6 milliseconds.

RM05 DISK DRIVES: A single- or dual-access, 256MB removable disk pack drive. Packaged in one free standing disk drive cabinet plus one utility cabinet which houses the RM05 drive adapter and contains space for one additional RM05 drive adapter. One RM05-P disk pack is included. Peak transfer rate is 1.2MB/second, average access time is 38.3 milliseconds. For VAX-11/780 only.

RM03 DISK DRIVES: A single- or dual-access, free-standing 67MB removable disk pack drive. One RM03-P disk pack is included. Peak transfer rate is 1.2MB/second, average access time is 38.3 milliseconds.

RL02 CARTRIDGE DISK DRIVE: A 10.4MB disk drive. One RL02K-DC data cartridge is included. Average access time is 67.5 milliseconds, peak transfer rate 512KB/second. For VAX-11/750 only.

RK07 CARTRIDGE DISK DRIVES: A single- or dual-access, free-standing 28MB disk drive. One RK07K-DC data cartridge is included. Average access time is 49.0 milliseconds, peak transfer rate is 538KB/second. The RL02 disk drive is used only as a data disk, not a system disk.

RX02 FLOPPY DISK SUBSYSTEM: A 512KB floppy disk subsystem for VAX-11/750 systems only. The peak transfer rate is 55KB/second, average seek time is 263 milli-

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seconds, and average rotational latency is 83 milliseconds. The RX02 subsystem is used only as a data disk.

RM80 FIXED MEDIA DISK DRIVE: A single- or dual-access, free-standing 124MB fixed media disk drive. Peak transfer rate is 1.2MB/second, and average access time is 33.3 milliseconds.

CONSOLE STORAGE

RX01 FLOPPY DISK CARTRIDGE: An integral part of the VAX-11/780 console subsystem, the RX01 is a random access mass memory subsystem that stores data in fixed length blocks on a flexible diskette with preformatted, industry standard headers. The RX01 is a single drive floppy capable of storing 256KB of data. The RX02 floppy disk system can also read/write data formatted for the RX01 floppy disk.

TU58 TAPE CARTRIDGE DRIVE: As part of the VAX-11/750 console subsystem, the TU58 connects directly to the CPU and maintains the capability to administer diagnostics even with some system components inoperative. The tape cartridge is preformatted to store 2,048 records, each containing 128 bytes. The controller provides random access to any record. The TU58 searches at 60 ips to find the file requested, then reads at 30 ips. Data read from the tape are verified through checksums at the end of each record or header. All data transfers between the TU58 and the host are in 512 byte blocks, with the TU58 concatenating four 128 byte records to accomplish this. Data is transferred to the CPU at approximately 2KB per second.

INPUT/OUTPUT UNITS

Please refer to the Peripherals/Terminals table on page M11-384-403 for information on the DEC peripheral equipment for the VAX systems.

DATA COMMUNICATIONS

DEC offers a number of interface controllers for the VAX systems. The systems can be connected to almost any type of communications channel (private phone, dial-up phone, 20-ma line, telegraph line), terminal, or modem. Supplementing these interfaces is additional data communications hardware to provide flexibility in unique situations.

There are six variations of the *DZ11 Asynchronous Multiplexer* available with VAX-11/780 systems. Three variations are designed for EIA/CCITT terminals or lines, and the other three are for 20-ma current loop terminals or lines. The DZ11 provides control for up to 16 asynchronous terminal devices or 16 full- or half-duplex lines. Each line can be individually programmed through software control for one of 15 line speeds between 50 and 9600 bps. The DZ11 includes modem controls to operate a Bell 103, 113, or equivalent 300-bps data set, or a Bell 212 at up to 1200 bps. Interrupts can be programmed to occur for each character or after 16 characters. The DZ11 is generally transparent to data, but can report parity errors and framing errors. Input characters are buffered with identification hardware in a first-in/first-out (FIFO) buffer, or "silo" (in DEC terms). Up to 96 asynchronous lines per UNIBUS can be used in a system.

The DMC11 *Network Link*, available on both VAX systems, is designed for high-performance point-to-point interprocessor connection based on the Digital Data Communications Message Protocol (DDCMP). The DMC11 provides local or remote interconnection of two computers over a serial synchronous line. Both computers can include the DMC11 and DECnet software, or both computers can use the DMC11 and implement their own communications software. For remote operations, a DMC11 can also communicate with a different type of synchronous interface, provided that the remote system has implemented the DDCMP protocol.

The DMC11 supports full- or half-duplex operation. Full-duplex operation offers the highest throughput and is used when the communications facilities permit two-way operation. The DDCMP protocol permits continuous simultaneous transmission of data messages in both directions when buffers are available and there are no errors on the channels.

When both computers are located in the same facility, the DMC11 permits transmission at speeds up to 1,000,000 bps over coaxial cable up to 6,000 feet long, or speeds up to 56,000 bps over coaxial cable up to 18,000 feet long. The necessary modems for local interconnection are built in. Where the computers are located remotely and connected using common-carrier facilities, the DMC11 permits transmission at up to 19,200 bps using an EIA interface. A DMC11 or DMR11 can interface with synchronous modems such as the Bell 208 and 209, or with other synchronous modems conforming to the RS-232-C standard.

The *MA780 Multiport Memory* is a bank of MOS semiconductor memory with error-correcting code (ECC) that can be shared by up to four VAX-11/780 systems. Each system can randomly access all of the shared memory in exactly the same way it accesses its local memory.

Each MS780 can be expanded from a minimum of 256K bytes to a maximum of 2M bytes. This storage is in addition to each system's local memory, which can be as large as 8M bytes. Since there can be up to two MA780s connected to a CPU, a VAX-11/780 system can now directly address up to 12M bytes of physical memory.

COMMUNICATIONS CONTROL

DECnet is a family of network products that add networking capability to all of DEC's computer families, including the VAX systems. Using DECnet, various kinds of computer system networks can be constructed to facilitate remote communications, resource sharing, and distributed computation. DECnet is highly modular and flexible, and enables the user to select the appropriate hardware and software to build a network that satisfies a particular application's requirements.

DEC's Digital Network Architecture (DNA) provides the common network structure upon which all DECnet products are built. DNA is designed to handle a broad range of application requirements. All the functions of the network—from the user interface to physical link control—are completely modular. DNA allows nodes to operate as switches, front ends, terminal concentrators, or hosts.

Using DECnet, each node of the network has both common DECnet attributes and system-specific attributes. The attributes provided by DECnet/VAX include:

- Interprocess (task-to-task) communication. Programs executing on one system can converse with programs executing on other systems.
- Inter-system file transfer. A program or a command language user can transfer an entire data file from one system to another.
- Inter-system resource sharing. Programs executing on one system can access files physically located at other systems in the network. Access to devices in other systems is provided only through the file system of the target node and is subject to that system's Data Access Protocol (DAP) implementation or file system restrictions.

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- Down-line system loading. Initial load images for RSX-11S systems in the network can be stored on the host VAX system and loaded on request into PDP-11 systems configured for the RSX-11S operating system.

- Down-line command file loading. Programs or command language users can send command files to a remote node to be executed there. However, no status information or error messages are returned.

- High-level language interface. This facility allows programs written in any VAX native programming language to access some of the network facilities.

Some of the DECnet protocols and their functions are as follows:

- Digital Data Communications Message Protocol (DDCMP) handles the physical link control and error recovery within DECnet. DDCMP has been designed to operate with existing hardware interfaces over full- and half-duplex facilities.

- Network Services Protocol (NSP) handles network management functions within DECnet. This is the protocol that allows interprocess communication within DECnet.

- Data Access Protocol (DAP) enables programs on one node of the network to use the file system services available on other network nodes. Each operating system in DECnet provides facilities for translating its own unique I/O structure into the DAP standard, and vice versa.

- Network Information Control Exchange Protocol (NICE) enables the user to control the status of a network node, and enables the nodes to exchange status information.

- Maintenance Operation Protocol (MDP) permits down-line loading and some loop-back tests.

Interprocess communication is the one feature common to all DECnet implementations. Interprocess communication allows programs (tasks, processes, etc.) to create one or more logical links, which are full-duplex virtual data paths. Programs have the capability to create these connections, transmit and receive data over them, and destroy them. Data transmission can be done on a normal or priority (i.e., interrupt) basis.

In DECnet/VAX, the interface itself can be transparent (each program looks like a sequential device to the other), or non-transparent (each program knows that it is using DECnet and has the opportunity to acquire information about the network). Each access method has its advantages. Transparent access is easier to learn, and it allows great flexibility in that the location of files, devices, and the program itself need not be determined until run time. Under non-transparent access, the programmer can take advantage of known properties of the protocols, providing the ability to transmit and receive interrupt messages, connect initiates, and disconnect notification.

Task-to-task communication and file access between systems is transparent. These inter-system facilities appear to be no different from the intra-system interprocess communication and file access facilities. In transparent access, the program opens the network interchange as if it were preparing device access, and then performs a series of reads and writes, just as it would to a pair of serial devices, one for input (reception) and the other for output (transmission). By its very nature, transparent access has no calls specifically associated with DECnet. The calls used for interprocess communication are the same as the calls used for accessing a sequential file in a high-level language—OPEN, CLOSE, READ, WRITE, etc. The programmer can choose to include the target node name in the OPEN statement, or he can defer assignment using logical names.

In non-transparent access, a program can obtain information about the network status to control the nature of its communication with other processes or tasks. Non-transparent access is available only through calls to operating system service procedures. A program can issue the following requests:

- CONNECT—Establish a logical link (the analog of OPEN).

- CONNECT REJECT—Reject a connect initiate.

- RECEIVE—Receive a message (the analog of GET).

- SEND—Transmit a message (the analog of PUT).

- SEND INTERRUPT MESSAGE—Transmit a high-priority message.

- DISCONNECT—Terminate a conversation (the analog of CLOSE).

The process can send optional data along with the connect request, such as the size or number of messages that it wants to send. The receiving process or task can accept or reject the connect initiate. A process can accept multiple connect requests.

A process can send or receive unsolicited messages to or from another process or task. Unsolicited message traffic is essentially no different from solicited message traffic except that it uses a system's software interrupt mechanism to transmit a message. A logical link, therefore, has two subchannels over which messages can be transmitted, one for normal messages and another for high-priority messages. In DECnet/VAX, an interrupt message is written to a mailbox that a process supplies for that purpose. The process can request that an asynchronous system trap routine be executed when a message is queued to that mailbox.

A program can issue a synchronous disconnect, which guarantees the receiver that it got every every message that was sent, or it can issue a disconnect abort, which terminates the logical link immediately.

In DECnet/VAX, a program using non-transparent access normally opens a control path directly to the Network's Ancillary Control Process (NETACP) and designates a mailbox for receiving information from the NETACP about the logical or physical links over which the process is communicating. The NETACP can notify a process when: a connect is attempted, a partner requests a synchronous disconnect, a partner requests a disconnect abort, a partner exists, a partner has sent an interrupt message, a physical link goes down, or an NSP protocol error is detected. If the process has the diagnostic privilege, it can also stop and start DDCMP protocol over a physical link.

Using the VAX/VMS command language, operators and terminal users can copy files from a VAX system to another system, delete files in other systems, and transfer command files for executing on other systems. Programs have access to all of the above file operations, and they can also read and write records sequentially and randomly.

The down-line loading and network status interface for the operator is a function of the Network Control Program (NCP) utility that accepts parameters such as the location and name of the RSX-11S system image and the name of the node to be sent the load image.

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Booting the RSX-11S operating system requires the presence of a read-only memory bootstrap program and, for a cold start, an operator to power-on the system and switch the DMC11 to "remote load detect." For a warm start, when an operating system is already running, no operator intervention is required, as the system automatically jumps to the bootstrap when requested to do so via MDP. For a cold start, the operator of the RSX-11S system starts the ROM bootstrap. It sends a special BOOT-ME message to the host, which automatically sends the proper system over the link.

A watchdog timer is available that will automatically put the RSX-11S system into BOOT mode whenever the operating system fails to reset a bit within a specified period. In this case, no operator intervention is required at either end. In all cases, the satellite system can start automatically after a boot operation.

SOFTWARE

OPERATING SYSTEM: The operating system for VAX computers is *VAX/VMS*, a general-purpose operating system that provides the environment for the concurrent execution of multi-user timesharing, batch, and time-critical applications. Applications can be divided into several independent subsystems whose data and code are protected from one another but which have general communication and data sharing facilities. Jobs can communicate using general, group, or local communication facilities.

Jobs can be scheduled as time-critical jobs that have strict priorities of execution. When a time-critical job is ready to execute, it executes until it becomes blocked or until another time-critical job of higher priority needs the resources of the processor. Normal jobs can be scheduled using a modified preemptive algorithm that ensures that they receive processor and peripheral resources at regular intervals commensurate with their processing needs.

If insufficient memory is available for keeping concurrently executing jobs resident, the operating system will swap jobs in and out of memory to allocate each its share of processor time. Time-critical jobs can be locked in memory to ensure that they can be started up rapidly when they need to execute.

The operating system provides a dynamic virtual-memory programming environment. Large programs can be executed in a portion of physical memory that is considerably smaller than the program's memory requirements, without requiring the programmer to define overlays. The operating system optimizes its virtual-memory system for program locality and provides tools that support optimization. It makes program performance predictable and controllable by restricting paging to the process program, and by allowing the user to cause large amounts of a program to be brought in at one time.

The operating system provides sophisticated peripheral device management for sharing, protection, and throughput. Devices can be shared among all jobs or reserved for exclusive use by particular jobs. Input and output for low-speed devices is spooled to high-speed devices to increase throughput. Files on mass storage devices can be protected from unauthorized access on an individual, group, or volume basis.

The I/O request processing system is optimized for throughput and interrupt response. The operating system provides the user with several data accessing methods, from logical record accessing for device-independent programming to direct I/O accessing for rapid data processing. Files can be stored in any of several ways to optimize subsequent processing.

VAX/VMS provides the programming tools, scheduling services, and protection mechanisms for multi-user program development. Programmers can write, execute, and debug programs interactively, and can also create batch command files that perform repetitive program development operations without requiring their attention.

The VAX/VMS operating system's own jobs run as independent activities. They include the Job Controller, which initiates and terminates user processes and manages spooling; the Operator Communications Manager, which handles messages queued to the system operators; and the Error Logger, which collects all hardware and software errors detected by the processor and the operating system.

A command interpreter executes as a service for interactive and batch jobs. It enables the general user to request the basic functions that the operating system provides, such as program development, file management, and system information services.

Both hardware-detected and software-detected exception conditions are tracked through the exception dispatcher. The exception dispatcher passes control to user-programmed condition handlers or, in the case of system-wide exception conditions or the absence of user routines, to operating system condition handlers.

The operating system's memory management routines include the virtual activator, which controls the mapping of virtual memory to system and user jobs, and the pager, which moves portions of a process in and out of memory as required. They respond to a program's dynamic memory requirements and enable programs to control their allocated memory, share data and code, and protect themselves from one another.

The scheduler controls the allocation of processor time to system and user jobs. The scheduler always ensures that the ready-to-execute time-critical job of highest priority receives control of the processor until it relinquishes it. When no time-critical jobs are ready to execute, the scheduler dynamically allocates processor time to all other jobs according to their resource requirements. The swapper works in conjunction with the scheduler to move entire jobs into and out of memory when memory requirements exceed memory resources. The swapper ensures that the jobs most likely to execute are kept in memory.

The operating system's I/O processing software includes interrupt service routines, device-dependent I/O drivers, device-independent control routines, and user-programmed record processing services. The I/O system ensures rapid interrupt response and processing throughput, and provides programming interfaces for both special-purpose and general-purpose I/O processing.

COMMUNICATIONS SOFTWARE: The *VAX 2780/3780 Protocol Emulator* allows data files to be transferred between VAX systems and other host computer systems capable of using 2780 or 3780 communications protocol. VAX-11 2780/3780 emulates binary synchronous communications (BSC) protocol, appearing to be an actual IBM 2780 or 3780 remote batch terminal on a point-to-point line. The product can run concurrently on up to four lines, each with a different set of attributes at speeds up to 9,600 bps per line. Minimum system requirements include any valid VAX/VMS system with a DUP11 synchronous communication interface.

MUX200/VAX is a VAX based software package that allows communication with a CDC 6000, CYBER series, or other host computer system capable of using 200UT mode 4A communication protocol. It can be configured to support either the ASCII or the extended BCD versions of the protocol. MUX200/VAX provides for one syn-

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chronous communication circuit to a host computer system and allows several users to communicate simultaneously with the host computer over a single line. Minimum system requirements include any valid VAX/VMS system with a DUP11 synchronous communication interface.

LANGUAGES: VAX/VMS provides a native programming environment. The native programming environment consists of the language processors that produce native object code and the program development tools that support native program development. VAX-II FORTRAN, COBOL, BASIC, PL/1, PASCAL, CORAL 66, and BLISS-32, and DSM are native mode language processors that produce native object code, and take advantage of the native instruction set and 32-bit architecture of the VAX hardware.

VAX offers many PDP-11 compatibility features:

- The VAX processor can execute a subset of PDP-11 16-bit instructions in compatibility mode.
- The VAX/VMS operating system provides functionally equivalent system services for many RSX-11M executive directives.
- The VAX/VMS high-level language compiler accepts source languages that are upwardly compatible with the same PDP-11 compilers.
- The VAX/VMS file system can read and write disk volumes and magnetic tapes written under RSX-11 and IAS operating systems.
- The VAX/VMS record management services provide record processing methods that are upwardly compatible with RMS-11 record management services.
- The VAX/VMS operating system provides an RSX-11 MCR command language, as well as DCL.
- The DECnet-VAX package supports RSX-11S system image down-line loading.

VAX-11 FORTRAN is an optimizing FORTRAN compiler designed to achieve high execution speed. It is an implementation of full language FORTRAN-77 which is based on ANSI FORTRAN X3.9-1978. The shareable, reentrant compiler operates under the VAX/VMS operating system to take full advantage of the VAX floating point and character instruction set and the VAX/VMS virtual memory operating system. It includes switch-selectable support for programs conforming to the previous standard, ANSI X3.9-1966.

VAX-11 FORTRAN also provides a number of extensions beyond the current ANSI standard, including language elements for keyed and sequential access to VAX-11 RMS multikey ISAM files and a set of data types beyond those specified for full language FORTRAN-77.

VAX-11 COBOL is a high-performance, interactive language processor based on the ANSI X3.23-1974 standard. VAX-11 COBOL also incorporates many features planned for the upcoming ANSI standard, including more structured programming to allow simplification of complex coding procedures.

VAX-11 COBOL takes full advantage of the VAX hardware, generating in-line instructions for high-speed compilation and program execution and support of larger programs. It includes full implementations of nine ANSI modules, including SORT/MERGE. Utilities are included to aid users in migrating other COBOL programs to VAX-11 COBOL.

VAX-11 BASIC is a native mode language processing system. It is an excellent instructional language as well as a general purpose programming language with a variety of industrial, technical, and commercial applications. VAX-11 BASIC is a superset of PDP-11 BASIC-PLUS-2/VAX, which is itself a highly extended superset of standard BASIC language developed at Dartmouth College. VAX-11 BASIC produces shareable native objective code, makes full use of the VAX floating point and character string instructions, and is itself shareable.

VAX-11 PASCAL is a re-entrant, native mode compiler particularly suited to instructional use. PASCAL is a structured, high-level programming language that provides a modular systematic approach to computerized problem solving. VAX-11 PASCAL takes full advantage of the VAX hardware floating point and character instruction sets and the virtual memory capabilities of the VAX/VMS operating system.

VAX-11 CORAL 66 is a high level block-structured programming language. It is the standard, general-purpose language prescribed by the British government for real-time applications and system implementation. VAX-11 CORAL 66 is designed to replace assembly level programming in a number of commercial, process control, research and military applications. It is particularly adapted to long-life products requiring flexibility and ease of maintenance.

VAX-11 PL/1 is a comprehensive and powerful language that supports scientific computation, commercial data handling and data organization, and extensive string manipulation capabilities. Block structuring provides for programs which are easier to understand and less error prone.

VAX-11 PL/1 is an extended implementation of the proposed ANSI X3.74 PL/1 General Purpose Subset. Extensions to the subset language are either full language PL/1 features, or system-specific features that provide more complete access to VAX/VMS features. The VAX-11 PL/1 compiler generates optimized, shareable, native object code.

VAX-11 BLISS-32 is a high level systems implementation language for VAX systems. BLISS-32 supports development of modular software according to structured programming concepts by providing an advanced set of language features for VAX systems to facilitate programming of real-time and/or hardware-independent applications. VAX-11 BLISS-32 is especially intended for the development of operating systems, compilers, run-time system components, data base file systems, communications software and utilities.

PDP-11 BASIC-PLUS-2/VAX is a superset of the RSTS/E BASIC-PLUS, BASIC-11 IAS-RSX, and Dartmouth BASIC languages. It includes CALL statements, COMMON statements, and record I/O. The BASIC-PLUS-2/VAX compiler generates code for compatibility mode.

FORTRAN IV/VAX-to-RSX Cross Compiler is a software tool for the development and execution of RSX-11M or RSX-11S FORTRAN programs. It is based on ANSI FORTRAN, X3.9-1966. The compiler operates in compatibility mode under the RSX-11M Application Migration Executive (AME) or VAX/VMS systems. Programs compiled and tasks built can be transported to remote RSX-11M or RSX-11S target systems or executed on VAX/VMS in compatibility mode.

The *VAX-11 MACRO* assembler accepts one or more source modules written in MACRO assembly language and produces a relocatable object module and optional

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assembly listing. VAX-11 MACRO is similar to PDP-11 MACRO, but its instruction mnemonics correspond to the VAX native instructions.

DATA MANAGEMENT: *PDP-11 DATATRIEVE/VAX* is an interactive query, report, and data maintenance system designed for unsophisticated computer users. DATATRIEVE utilizes the RMS record management services to access data contained in files of sequential, indexed, or relative organization. It also provides facilities for selective data retrieval, sorting, formatting, updating, and report generation without the need for programming overhead.

VAX-11 FMS (Forms Management System) is a set of utilities and subroutines that provide screen formatting capabilities for application programs written in a variety of standard programming languages. Forms defined using VAX-11 FMS can use many of the features of the VT100 video terminal including reverse video, bold, underlined and blink characters and split screen and scrolling capabilities.

VAX RMS FILE MANAGEMENT SYSTEM is a record management input/output system that provides device-independent access to disks, tapes, unit record equipment, terminals, and mailboxes. RMS allows user and application programs to create, access, and maintain data files with efficiency and economy. Under RMS, records are regarded by the user program as logical data units that are structured and accessed in accordance with application requirements.

RMS provides sequential record access to sequential file organizations, sequential, random, or combined record access to relative file organization and sequential, random, or a combination using index key access to multikey indexed files. Multikey indexed file processing includes incremental reorganization.

WORD PROCESSING: *DX/VMS* is a VAX-11 FORTRAN software package that executes on a VAX/VMS operating system. It enables a WPS-8 word processing system running WPS-8, WPS-8/78, or WPS-8/MTS software to communicate with the VAX/VMS host over an asynchronous terminal interface. DX/VMS enables distributed stand-alone WPS-8 systems and the host VAX system to be linked together for better system utilization and data sharing.

UTILITIES: The VAX utility programs (or, as DEC categorizes them, program development tools) include several text editors, a linker, a librarian, a common run-time procedure library, and a symbolic debugger. These tools are available to the programmer through the VAX/VMS command language.

The text editors can be used to create memos, documentation, and data files, as well as source program modules for any language processor. The linker, librarian, debugger, and run-time procedure library described below are used only in conjunction with the language processors that produce native code. The language processors that produce compatibility-mode code offer their own task building, library, and debugging facilities and include their own object-time system libraries.

SOS is an interactive text editor that enables the programmer to create and modify text files using commands entered from either a hard-copy or video terminal. The user can insert, delete, and replace lines, find and substitute strings, or modify the text a character at a time. Lines can be identified by line number, by relative position, or by content. An adjacent group of lines can be copied or transferred from one place to another. Editing can be done in any order in the file. Editor parameters can be set to user-specified values, and the current values can be shown. User-specific parameters can be set automatically at editor start-up.

SLP is a programmed text editor that enables the user to modify an existing file by supplying a command file containing a list of the modifications to be made. The command file provides a reliable way to duplicate the changes made to a file at a later time or on another system. SLP provides a formal record of changes made to files, both in the source file and in an audit-trail listing.

The *EDT* editor lets users enter and manipulate text and programs. EDT, with its extensive HELP facility, is designed to be learned easily by novices. EDT features line and character editing facilities, screen editing and keypad editing on the VT52 and VT100 video terminals, a start-up command file, a journaling facility, and the ability to work on multiple files simultaneously. It is shipped as part of VAX/VMS.

VAX-11 RUNOFF is a document formatter. A RUNOFF-processed document can be updated without extensive retyping because text changes, via the text editors, do not affect the basic design. The input to RUNOFF is a file containing the text of the document and the RUNOFF instructions. It is shipped as part of VAX/VMS.

The *VAX/VMS Linker* accepts one or more native object modules produced by an assembler or compiler, resolves the symbols and procedure references between them, and produces an executable program image. The linker also enables a programmer to create shareable images that can be linked subsequently with other modules to produce an executable image. Furthermore, the linker not only accepts object modules to produce executable or shareable images, but can also accept object module libraries, shareable images, and shareable image libraries.

The *Librarian* enables a programmer to create, update, modify, list, and maintain library files. A library file can be a collection of object modules or shareable images. A programmer can request the linker to use one or more library files from which the linker can obtain modules to resolve references during linking.

The *Run-Time Procedure Library* is a collection of general-purpose and language-specific libraries available to any native program, regardless of the source language in which the program was written. The run-time library is a shareable program that allows the choice of either incorporating procedures from the library into an executable image or mapping the global sections into a process virtual address space at run time. A single copy of the library can be shared by all processes, and a new library can be installed without the need to relink existing programs. The run-time library includes a mathematical library, a general utility library, a condition-handling facilities library, a language-independent support library, and a FORTRAN IV-PLUS language-specific support library.

The *Symbolic Debugger* can be linked with a native program image to control program execution during development. The debugger can be used interactively or controlled from a command procedure file. The debugging language is similar to the VAX/VMS command language. Expressions and data references are similar to those of the source language used to create the image being debugged. Debugging commands include the ability to start and interrupt program execution, to step through instruction sequences, to call routines, to set break or trace points, to set default modes, to define symbols, and to deposit, examine, or evaluate virtual memory locations.

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VAX/VMS supports an *RSX-11M program development package* that enables users to write, assemble or compile, and link RSX-11M task images. The task images can be written to execute on a PDP-11 under RSX-11M or RSX-11S; or, if properly coded, they can be written to execute in the VAX compatibility-mode environment.

The RSX-11M development package includes both the PDP-11 MACRO assembler and the PDP-11 FORTRAN IV compiler, plus RSX-11M program development utilities. Programmers can use the VAX/VMS command language to edit, copy, or back up their files. They can also use the RSX-11M MCR command interface on the VAX-11/780 system. MCR enables the programmer to run the standard RSX-11M utilities such as the EDI and SLP editors, the PIP and FLX file transfer utilities, and the Task Builder, Librarian, and patch utilities.

GRAPHICS UTILITIES: *The VAX-11 Pen Plotter Utilities* is a library of FORTRAN subroutines used to produce graphical output on most of the CALCOMP range of Pen Plotters. Included are all the standard CALCOMP calls (LINE, SYMBOL, WHERE, ETC.) and a handler for the CALCOMP 906 controller which connects to the VAX system via an EIA asynchronous line (DZ11).

The *VAX-11 Digitizer Utilities* is a library of FORTRAN subroutines for acquiring data from the TALOS range of digitizer tablets. The TALOS digitizers provide a means of accurately capturing graphic information through the position of either a hand-held pen or a tracking "mouse." VAX-11 Digitizer Utilities includes such single calls as fetch AREA, LENGTH, etc., in any scale of units specified by the user, and allow flexible creation of MENU areas on the digitizer surface.

VAX-11 Engineering Drawing Utilities is a library of FORTRAN callable subroutines used to provide high level control plotting devices. Single calls are included to produce complex output with the minimum of applications programming effort, including routines to create circles, arcs, graph axes with labeling, dimension lines, arrowheads, etc., as well as a library of over 60 standard mathematical, logic and electronic symbols. Users may define their own symbols within 100 x 100 matrix and reference them with a unique calling number.

PRICING

POLICY: DEC provides VAX systems on a purchase basis, with separately priced maintenance agreements. Leasing arrangements are available through DEC's joint venture with U.S. Leasing Corporation at a monthly charge of 2.4% of the purchase price. DEC software is licensed rather than sold. Users purchase licenses and distribution rights separately.

pickup

EQUIPMENT: Six standard VAX-11/780 systems and three VAX-11/750 system configurations follow. All VAX systems have provisions for additional memory and peripherals.

DUAL RK07 DISK-BASED VAX-11/780 SYSTEM: Includes a VAX-11/780 CPU with 512KB of ECC MOS memory, an RK711 UNIBUS controller with two top-loading RK07 cartridge disk drives for a total of 56MB of on-line storage, one DZ11-A asynchronous multiplexer for connection to eight EIA communication lines, and an LA120 console terminal. Also included as standard equipment is an integral diagnostic console subsystem, for use in both local and remote operations, which consists of an LSI-11 microcomputer to which an RX01 floppy disk and the LA120 are connected. The purchase price is $143,000.

RM03/TU77-BASED VAX-11/780 SYSTEMS: Includes a VAX-11/780 CPU with an RM03 disk and the TU77 magnetic tape storage devices. The RM03/TU77-based system is configured with 1MB of ECC MOS memory. Both systems include an REM03 single-access 67MB disk drive with MASSBUS adapter, the TEU77 magnetic tape transport unit with MASSBUS adapter, one DZ11-A asynchronous multiplexer for connection to eight EIA communications lines, and an LA120 console terminal. Also included is an integral diagnostic console subsystem. The RM03/TU77-based system is $230,000.

RP06/TU77-BASED SYSTEM: Includes a VAX-11/780 CPU with 1.5MB of ECC MOS memory, and REP06 single-access 176MB disk drive with MASSBUS adapter, TEU77 magentic tape transport unit with MASSBUS adapter, one DZ11-A asynchronous multiplexer for connection to eight EIA communication lines, and an LA120 console terminal. Also included is an integral diagnostic console subsystem. The purchase price is $257,600.

RM05/TU77-BASED VAX-11/780 SYSTEM: Includes VAX-11/780 CPU with 1.5MB of ECC MOS memory, an REM05 single-access 256MB disk drive with MASSBUS adapter, a TEU77 magnetic tape transport unit with MASSBUS adapter, one DZ11-A asynchronous multiplexer for connection to eight EIA communication lines, and LA120 console terminal. Also included is an integral diagnostic console subsystem. Purchase price is $257,600.

RM80/TU77-BASED VAX-11/780 SYSTEM: Includes VAX-11/780 CPU, 1MB of ECC MOS memory, an REM80 single-access 124MB fixed media disk drive with MASSBUS adapter, a TEU77 magnetic tape transport unit with MASSBUS adapter, one DZ11-A asynchronous multiplexer for connection to eight EIA communication lines, and an LA120 console terminal. Also included is an integral diagnostic console subsystem. The purchase price is $225,000.

DUAL RK07 DISK-BASED VAX-11/750 SYSTEM: Includes VAX-11/750 CPU with 512KB of ECC MOS memory, an RK711 UNIBUS controller with two top-loading RK07 cartridge disk drives for a total of 56MB of on-line storage, one DZ11-A asynchronous multiplexer for connection to eight EIA communication lines, and an LA38 console terminal with stand. Also included is the console subsystem. Purchase price is $89,900.

RM03/TS11-BASED VAX-11/750 SYSTEM: Includes VAX-11/750 CPU, 1MB of ECC MOS memory, an RGM03 single-access 67MB disk drive with MASSBUS adapter and a TS11 magnetic tape subsystem with UNIBUS controller, one DZ11-A asynchronous multiplexer for connection to eight EIA communication lines, and an LA38 console terminal with stand. Also included is the console subsystem. Purchase price is $125,000.

RM80/TS11-BASED VAX-11/750 SYSTEM: Includes VAX-11/750 CPU, 1MB of ECC MOS memory, an RGM80 single-access 124MB fixed media disk drive with MASSBUS adapter and a TS11 magnetic tape subsystem with UNIBUS controller, one DZ11-A asynchronous multiplexer for connection to eight EIA communication lines, and an LA38 console terminal with stand. Also included is the console subsystem. Purchase price is $120,000.■

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EQUIPMENT PRICES

		Purchase Price	Monthly Maint.
STANDARD SYSTEMS			
SV-AXHHV-CA (CD)	VAX-11/780 System includes CPU with dual RK07 disk storage devices, 512KB ECC MOS memory, an RK711 UNIBUS controller with two top-loading RK07 cartridge disk drives, one DZ11-A asynchronous multiplexer for connection to eight EIA communication lines, LA120 console terminal, and diagnostic console subsystem.	$143,000	$ 779
SV-AXTVB-CA (CD)	VAX-11/780 System includes CPU with TE16 magnetic tape storage, 512KB ECC MOS memory, an REM03 single-access 67MB disk drive with MASSBUS adapter, one DZ11-A asynchronous multiplexer for connection to eight EIA communication lines, an LA120 console terminal, and diagnostic console subsystem.	196,000	857
SV-AXTBB-CA (CD)	VAX-11/780 System includes CPU with TU77 magnetic tape software device, 1MB ECC MOS memory, an REM03 single-access 67MB disk drive with MASSBUS adapter, TEU77 magnetic tape transport unit with MASSBUS adapter, one DZ11-A asynchronous multiplexer for connection to eight EIA communication lines, an LA120 console terminal, and diagnostic console subsystem.	230,000	1,065
SV-AXCBB-CA (CD)	VAX-11/780 System includes CPU with an RP06 disk and TU77 magnetic tape storage device, 1.5MB ECC MOS memory, an REP06 single-access 176MB disk drive with MASSBUS adapter, TEU77 magnetic tape transport unit with MASSBUS adapter, one DZ11-A asynchronous multiplexer for connection to eight EIA communication lines, an LA120 console terminal, and a diagnostic console subsystem.	257,600	1,233
SV-AXDBB-CA (CD)	VAX-11/780 System includes CPU with an RMOS disk and a TU77 magnetic tape storage device, 1.5MB ECC MOS memory, an REMOS single-access 256MB disk drive with MASSBUS adapter, a TEU77 magnetic tape transport unit with MASSBUS adapter, one DZ11-A asynchronous multiplexer for connection to eight EIA communication lines, an LA120 console terminal, and a diagnostic console subsystem.	257,600	1,312
SV-AXWBA-CA (CD)	VAX-11/780 System includes CPU with an RM80 disk and TU77 magnetic tape storage device, 1MB ECC MOS memory, an REM80 single-access 124MB fixed media disk drive with MASSBUS adapter, a TUE77 magnetic tape transport unit with MASSBUS adapter, one DZ11-A asynchronous multiplexer for connection to eight EIA communication lines, an LA120 console terminal, and a diagnostic console subsystem.	225,000	969
SV-BXHHA-AA (AD)	VAX-11/750 System includes CPU with dual RK07 disk storage devices, 512KB ECC MOS memory, an RK711 UNIBUS controller with two top-loading RK07 cartridge disk drives, one DZ11-A asynchronous multiplexer for connection to eight EIA communication lines, an LA38 console terminal with stand, and a console subsystem.	89,900	568
SV-BXTAA-AA (AD)	VAX-11/750 System includes CPU with an RM03 disk and TS11 magnetic tape storage device, 1MB ECC MOS memory, an RGM03 single-access 67MB disk drive with MASSBUS adapter and a TS11 magnetic tape subsystem with UNIBUS controller, one DZ11-A asynchronous multiplexer for connection to eight EIA communication lines, an LA38 console terminal with stand, and a console subsystem.	125,000	651
SV-BXWAA-AA (AD)	VAX-11/750 System includes CPU with an RM80 disk and TS11 magnetic tape storage device, 1MB ECC MOS memory, an RGM80 single-access 124MB fixed media disk drive with MASSBUS adapter and a TS11 magnetic tape subsystem with UNIBUS controller, one DZ11-A asynchronous multiplexer for connection to eight communication lines, an LA38 console terminal with stand, and a console subsystem.	120,000	606
VAX-11/780 PROCESSOR OPTIONS			
FP780-AA (AB)	High Performance floating-accelerator for single- and double-precision floating-point instructions plus POLY, EMOD, and MULL	10,600	48
DW780-AA (AB)	UNIBUS adapter	12,300	37
KU780-YY	12K byte User Writable Control Store	10,700	53
VAX-11/750 PROCESSOR OPTIONS			
KU750-YG	10K byte (1K word—80-bit words) User Writable Control Store	6,000	—
VAX-11/780 EXPANSION MEMORY			
MS780-CC (CD)	512K byte ECC MOS 16K chip memory with controller	26,600	158
MS780-DA	256K byte ECC MOS expansion memory	9,100	58
MS780-DB	512K byte ECC MOS expansion memory	13,900	116
MS780-DC	1M byte ECC MOS expansion memory	19,800	231
MS780-DD	2M byte ECC MOS expansion memory	31,900	462
VAX-11/750 EXPANSION MEMORY			
MS750-AA	256K byte ECC MOS expansion memory	9,100	58
MS750-AB	512K byte ECC MOS expansion memory	13,900	116
MS750-AC	1M byte ECC MOS expansion memory	19,800	231
VAX-11/780 AND VAX-11/750 MEMORY OPTION			
H7112-A (B)	MOS memory battery backup	1,250	11

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EQUIPMENT PRICES

		Purchase Price	Monthly Maint.
VAX-11/780 SYSTEM UPGRADE OPTION			
H9604-BA (BB)	System upgrade option for dual RK07-based VAX-11/780 packaged system	25,000	NC
VAX-11/780 MULTIPORT MEMORY OPTIONS			
MA780-AA (AB)	256K byte ECC MOS multiport memory subsystem	37,300	179
MA780-BA (BB)	Additional 256K byte MA780 multiport memory subsystem	32,700	179
MA780-C	MA780 multiport memory port interface	7,000	21
MA780-D	VAX-11/780 multiport memory selective cache invalidate option	9,000	58
MASSBUS PERIPHERALS			
VAX-11/780 DISK DRIVE SYSTEMS			
REM03-AA (AD)	Single-access, free-standing 67MB removable disk pack drive and VAX-11/780 MASSBUS adapter	30,300	179
REM03-BA (BD)	Dual-access, free-standing 67MB removable disk pack and two VAX VAX-11/780 MASSBUS adapters	39,900	226
REM05-AA (AB)	Single-access, 256MB removable disk pack drive and VAX-11/780 MASSBUS adapters	44,000	310
REM05-BA (BB)	Dual-access, 256MB removable disk pack drive and two VAX-11/780 MASSBUS adapters	56,600	395
REM80-AA (AD)	Single-access, free-standing 124MB fixed media disk drive and VAX-11/780 MASSBUS adapter	29,900	132
REM80-BA (BD)	Dual-access, free-standing 124MB fixed media disk drive and two VAX-11/780 MASSBUS adapters	39,500	179
REP06-AA (AB)	Single-access, free-standing 176MB removable disk pack drive and VAX-11/780 MASSBUS adapter	44,000	231
REP06-BA (BB)	Dual-access, free-standing 176MB removable disk pack drive and two VAX-11/780 MASSBUS adapter	56,600	284
VAX-11/750 DISK DRIVE SYSTEMS			
RGM03-AA (AD)	Single-access, free-standing 67MB removable disk pack drive and VAX-11/750 MASSBUS adapter	30,300	179
RGM03-BA (BD)	Dual-access, free-standing 67MB removable disk pack drive and two VAX-11/750 MASSBUS adapters	39,900	226
RMG80-AA (AD)	Single-access, free-standing 124MB fixed media disk drive and VAX-11/750 MASSBUS adapter	29,900	132
RGM80-BA (BD)	Dual-access, free-standing 124MB fixed media disk drive and two VAX-11/750 MASSBUS adapters	39,500	179
RGP06-AA (AB)	Single-access, free-standing 176MB removable disk pack drive and VAX-11/750 MASSBUS adapter	44,000	231
RGP06-BA (BB)	Dual-access, free-standing 176MB removable disk pack drive and two VAX-11/750 MASSBUS adapters	56,600	284
ADD-ON DISK DRIVES			
RM03-AA (AD)	Single-access, free-standing 67MB removable disk pack drive	20,300	147
RM03-BA (BD)	Dual-access, free-standing 67MB removable disk pack drive	22,500	163
RM05-AA (AB)	Single-access 256MB removable disk pack drive packaged in one free-standing disk drive cabinet plus one utility cabinet which houses the RM05 drive adapter and contains space for additional RM05 drive adapter	34,000	240
RM05-AC (AD)	Single-access 256MB removable disk pack drive packaged in free-standing disk drive cabinet only; one RM05-P disk pack is included	34,000	240
RM05-BA (BB)	Dual-access 256MB removable disk pack drive packaged in one free-standing disk drive cabinet plus one utility cabinet which houses the RM05 drive adapter and contains space for one additional RM05 drive adapter	39,140	255
RM05-BC (BD)	Dual-access 256MB removable disk pack drive packaged in free-standing disk drive cabinet only; one RM05-P disk pack is included	39,140	255
RM80-AA (AD)	Single-access, free-standing 124MB fixed media disk drive	19,900	100
RM80-BA (BD)	Dual-access, free-standing 124MB fixed media disk drive	22,000	116
RP06-AA (AB)	Single-access, free-standing 176MB removable disk pack drive	34,000	200
RP06-BA (BB)	Dual-access, free-standing 176MB removable disk pack drive	39,140	221
DUAL ACCESS AND UPGRADE OPTIONS			
REM03-DA (DB)	RM03 dual-access conversion kit contains RM03-C, VAX-11/780 MASSBUS adapter with power supply to convert REM03-A to REM03-B	11,700	48
REM05-CA (CB)	RM05 dual-access conversion kit contains RM05-C, VAX-11/780 MASSBUS adapter with power supply to convert REM05-A to REM05-B	14,700	85
REM80-DA (DB)	RM80 dual-access conversion kit contains RM80-C, VAX-11/780 MASSBUS adapter with power supply to convert REM80-A to REM80-B	11,700	48
REP06-DA (DB)	RP06 dual-access conversion kit contains RP06-C, VAX-11/780 MASSBUS adapter with power supply to convert REP06-A to REP06-B	14,700	53
RGM03-C	RM03 dual-access conversion kit contains RM03-C and VAX-11/750 MASSBUS adapter to convert RGM03-A to RGM03-B	11,700	48
RGM80-C	RM80 dual-access conversion kit contains RM80-C and VAX-11/750 MASSBUS adapter to convert RGM80-A to RGM80-B	11,700	48
RGP06-C	RP06 dual-access conversion kit contains RP06-C and VAX-11/750 MASSBUS adapter to convert RGP06-A to RGP06-B	14,700	53

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EQUIPMENT PRICES

		Purchase Price	Monthly Maint.
DUAL ACCESS AND UPGRADE OPTIONS (Continued)			
RM03-C	RM03 dual-access kit containing drive logic and cables to convert RM03-A to RM03-B	2,150	16
RM05-C	RM05 dual-access kit containing drive logic and cables to convert RM05-A to RM05-B	5,150	15
RM80-C	RM80 dual-access kit containing drive logic and cables to convert RM80-A to RM80-B	2,150	16
RP06-C	RP06 dual-access kit containing drive logic and cables to convert RP06-A to RP06-B	5,150	21
RP06-U	RP05 to PR06 upgrade kit includes drive upgrade parts and RP06-P disk pack	10,500	—
RM03-P	67MB removable disk pack for RM03	635	—
RM05-P	256KB removable disk pack for RM05	1,450	—
RP06-P	176MB removable disk pack for RP06	875	—
MAGNETIC TAPE EQUIPMENT			
TEE16-AE (AJ)	Program-selectable 800 or 1600 bpi, 9-track, 45 ips magnetic tape transport and VAX-11/780 MASS-BUS adapter; prerequisite, VAX-11/780	25,000	155
TEU45-KA (KB)	Program-selectable 800 or 1600 bpi, 9-track, 75 ips magnetic tape transport and VAX-11/780 MASS-BUS adapter; prerequisite, VAX-11/780	29,000	279
TEU77-AB (AD)	Program-selectable 800 or 1600 bpi, 9-track, 125 ips magnetic tape transport and VAX-11/780 MASS-BUS adapter; prerequisite, VAX-11/780	34,800	247
TGU77-AB (AD)	Program selectable 800 or 1600 bpi, 9-track, 125 ips magnetic tape transport and VAX-11/750 MASS-BUS adapter; prerequisite, VAX-11/750	34,800	247
TE16-AE (AJ)	Program-selectable 800 or 1600 bpi, 9-track, 45 ips magnetic tape transport unit in dedicated cabinet	15,000	92
TU45-KE (KF)	Program-selectable 800 or 1600 bpi, 9-track, 75 ips magnetic tape transport unit in dedicated cabinet	18,000	216
TU77-AF (AJ)	Program-selectable 800 or 1600 bpi, 9-track, 125 ips, automatic loading magnetic tape transport unit in dedicated cabinet	23,000	184
DW780-AA (AB)	VAX-11/780 UNIBUS adapter	12,300	37
UNIBUS PERIPHERALS			
FLOPPY DISK SUBSYSTEM			
RX211-BA (BD)	1.0MB RX02 floppy disk subsystem includes controller and two 0.5MB RX02 drives; prerequisite, VAX-11/750	4,150	48
CARTRIDGE DISK SUBSYSTEMS			
RL211-AK	10.4MB disk drive and control unit; one RL02K-DC data cartridge is included; expandable to a total of four RL02 drives; prerequisite, VAX-11/750	6,900	68
RK711-EA (ED)	Single-access, free-standing 28MB disk drive and control unit expandable to a total of eight RK06 or RK07 drives; one RK07K-DC data cartridge is included; prerequisite, VAX-11/780	17,000	153
RK711-FA (FD)	Dual-access, free-standing 28MB disk drive and two control units expandable to a total of eight RK06 or RK07 drives; one RK07L-DC data cartridge is included; prerequisite, VAX-11/780	23,500	200
RK07-EA (ED)	Single-access, free-standing 28MB disk drive; one RK07L-DC data cartridge is included; prerequisite, VAX-11/780	12,000	121
RK07-FA (FD)	Dual-access, free-standing 28MB disk drive; one RK07K-DC data cartridge is included; prerequisite, VAX-11/780	15,800	137
RK07-PA (PD)	Single-access, free-standing 28MB disk drive; one RK07K-DC data cartridge is included; prerequisite, VAX-11/750	12,000	121
RL02-AK	10.4MB disk drive; one RL02K-DC data cartridge is included; prerequisite, VAX-11/750	5,600	60
RK711-C	Dual-access kit containing drive logic and hardware, one controller and cables to convert an RK711-E to an RK711-F	11,200	48
RK07-C	Dual-access kit containing drive logic, hardware and cables to convert an RK07-E to an RK07-F	4,100	16
RK07K-EF	Error free 28MB disk cartridge for RK07	785	NC
RK07K-AC	28MB alignment cartridge for RK07	1,483	NC
RK07K-DC	28MB disk cartridge for RK07	430	NC
RL02K-DC	10.4MB disk cartridge for RL02	199	—
MAGNETIC TAPE SUBSYSTEMS			
TS11-BA (BB)	1600 bpi, 9-track, 45 ips magnetic tape transport and control unit in a dedicated 60 inch H9602 cabinet; prerequisite, VAX-11/780	15,400	75
TS11-CA (CB)	1600 bpi, 9-track, 45 ips magnetic tape transport and control unit in a dedicated 60 inch H9646 cabinet; prerequisite, VAX-11/750	15,400	75
ASYNCHRONOUS MULTIPLEXERS			
DZ11-A	Asynchronous 8-line multiplexer for connection of eight EIA/CCITT terminals or lines	2,570	31
DZ11-B	Eight-line EIA/CCITT expansion multiplexer	2,050	27

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EQUIPMENT PRICES

		Purchase Price	Monthly Maint.
ASYNCHRONOUS MULTIPLEXORS (Continued)			
DZ11-C	Asynchronous 8-line multiplexer for connection of 20mA current loop terminals	2,805	31
DZ11-D	Eight-line 20mA current loop expansion multiplexer	2,200	27
DZ11-E	Asynchronous 16-line multiplexer for connection of EIA/CCITT terminals or lines	4,300	53
DZ11-F	Asynchronous 16-line multiplexer for connection of 20mA current loop terminals	4,675	53
SINGLE LINE SYNCHRONOUS INTERFACES			
DMC11-AR	Network link DDCMP microprocessor module (for remote support)	1,700	20
DMC11-DA	Network link remote line unit module interfaces to EIA/CCITT synchronous modems (Bell series 200 compatible)	1,200	7
DMC11-FA	Network line remote line unit module interfaces to CCITT V.35/DDS synchronous modems (Bell 500A L1/5 or equivalent) at speeds up to 250,000 bpi	1,500	7
DMC11-AL	Network link DDCMP microprocessor module (local)	2,500	31
DMC11-MA	Network line local line unit module up to 1,000,000 bpi	2,500	7
DMC11-MD	Network link local line module; 56,000 bpi	2,000	7
DMR11-AA	Network link DDCMP microprocessor and line unit modules for remote support; speeds up to 19,200 bpi	4,200	37
DMR11-AC	Network link DDCMP microprocessor and line unit modules for local support; provides high speed connection to another DMR11 or DMC11	4,200	37
DUP11-DA	Full half-duplex synchronous interface	1,500	11
GENERAL PURPOSE UNIBUS INTERFACES			
DR11	High-speed direct memory access interface	1,750	14
PCL11-B	High-speed multiple computer link (500K bpi)	7,750	63
LINK PRINTERS			
LA11-PA (PD)	132-column, 96-character matrix printer (Digital's LA180 Line Printer) and control unit	4,455	58
LP11-AA	132-column, 64-character bank printer and control unit; 285 lpm	8,350	95
LP11-BA	132-column, 64- and 94-character band printer and control unit; 285 lpm when using 64-character set and 204 lpm when using 96-character set	8,950	95
LP11-CA (CD)	132-column, 64-character high speed printer and control unit; 900 lpm	27,800	195
LP11-DA (DD)	132-column, 96-character high speed printer and control unit; 600 lpm	29,700	195
LP11-VA (VD)	132-column, 64-character printer and control unit; 300 lpm	16,400	163
LP11-WA (WD)	132-column, 96-character printer and control unit; 240 lpm	19,500	163
LP11-YA (YD)	132-column, 64-character printer and control unit; 600 lpm	20,200	158
LP11-ZA (ZD)	132-column, 96-character printer and control unit; 436 lpm	21,900	158
LPR11-VA (VD)	132-column, 64-character remote printer subsystem; 250 lpm	19,000	207
LPR11-WA (WD)	132-column, 96-character remote printer subsystem; 240 lpm	21,500	207
LPR11-YA (YD)	132-column, 64-character remote printer subsystem; 525 lpm	27,200	242
LPR11-ZA (ZD)	132-column, 96-character remote printer subsystem; 420 lpm	28,900	242
CARD READERS			
CR11 (-A)	300 cpm reader and control unit; reads 80-column punched cards	8,250	70
CR11-BC (BD)	600 cpm reader and control unit; reads 80-column punched cards	11,700	72
CME11-KA (KB)	250 cpm reader and control unit; reads 40- and 80-column punched cards	4,950	70
TERMINALS			
LA34-DA	Table-top DECwriter IV printing terminal; includes universal power supply, standard EIA interface and EIA null modem cable; 30-character per second print speed and baud rates up to 300 bps	1,450	18
LA38-GA	Same as LA34-DA except can accommodate up to 4-part computer form as well as single sheets and computer paper	1,750	18
LA38-HA	Free-standing DECwriter IV printing terminal; includes stand, universal power supply, standard EIA interface and EIA null modem cable; 18-button numeric keypad, 30 cps print speed and band rates up to 300 bps	1,850	18
LA120-DA	Free-standing DECwriter III high-speed interactive hardcopy terminal; 180 cps bidirectional printing with baud rates up to 9600	2,800	32
VT100-AA (AB)	High-performance, table top, video display terminal includes double-width/double-size characters, 80 columns x 24 lines or 132 columns x 14 lines, 95-character detachable keyboard	2,150	18
VT1XX-AB	Advanced Video Option; adds 10 additional lines of 132-column data for a total of 132 columns x 24 lines	320	4
VT1XX-AA	20mA current loop adapter	140	4

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DEC VAX-11 Systems

SOFTWARE PRICES

		Purchase Price	Monthly Maint.
QE001-AM	VAX/VMS operating system for VAX-11/780 on 9-track magtape	$20,000	$46
QE001-AV	VAX/VMX for VAX-11/780 on RK07 disk cartridge	20,000	46
QD001-AM	VAX/UMS for VAX-11/750 on 9-track magtape	20,000	46
QD001-AV	VAX/VMS for VAX-11/750 on RK07 disk cartridge	20,000	46
QE100-AY	VAX-11 FORTRAN on floppy disk (VAX-11/780)	8,050	47
AD100-AG	VAX-11 FORTRAN on TU58 tape (VAX-11/750) cartridge	7,000	47
QE099-AY	VAX-11 COBOL on floppy disk (VAX-11/780)	13,800	47
QD099-AG	VAX-11 COBOL on TU58 tape cartridge (VAX-11/750)	13,800	47
QE101-AY	VAX-11 COBOL-74 on floppy disk (VAX-11/780)	10,240	48
QD101-AG	VAX-11 COBOL-74 on TU58 tape cartridge (VAX-11/750)	10,240	48
QE095-AY	VAX-11 BASIC on floppy disk (VAX-11/780)	9,200	48
QD095-AG	VAX-11 BASIC on TU58 tape cartridge (VAX-11/750)	9,200	48
QE110-AY	VAX-11 PASCAL on floppy disk (VAX-11/780)	5,500	48
QD110-AG	VAX-11 PASCAL on TU58 tape cartridge (VAX-11/750)	5,500	48
AE067-AY	VAX-11 CORAL 66 on floppy disk (VAX-11/780)	10,000	49
QD067-AG	VAX-11 CORAL 66 on TU58 tape cartridge (VAX-11/750)	10,000	49
QE114-AY	VAX-11 PL/1 on floppy disk (VAX-11/780)	13,800	49
QD114-AG	VAX-11 PL/1 on TU58 tape cartridge (VAX-11/750)	13,800	49
QE106-AY	VAX-11 BLISS-32 on floppy disk (VAX-11/780)	13,800	49
QD106-AG	VAX-11 BLISS-32 on TU58 tape cartridge (VAX-11/750)	13,800	49
QE102-AY	PDP-11 BASIC-PLUS-2/VAX on floppy disk (VAX-11/780)	5,870	50
QD102-AG	PDP-11 BASIC-PLUS-2/VAX on TU58 tape cartridge (VAX-11/750)	5,100	50
QE107-AY	FORTRAN IV/VAX-to-RSX Cross Compiler on floppy disk (VAX-11/780)	1,150	50
QD107-AG	FORTRAN IV/VAX-50-RSX Cross Compiler on TU58 tape cartridge (VAX-11/750)	1,150	50

COMMUNICATIONS

QED01-AY	DECnet-VAX on floppy disk (VAX-11/780)	3,100	50
QDD01-AG	DECnet-VAX on TU58 tape cartridge (VAX-11/750)	3,100	50
QE111-AY	VAX-11 2780/3780 Protocol Emulator on floppy disk (VAX-11/780)	5,900	51
QD111-AG	VAX-11 2780/3780 Protocol Emulator on TU58 tape cartridge (VAX-11/750)	5,900	51
QE070-AY	MUX200/VAX on flopy disk (VAX-11/780)	8,100	51
QD070-AG	MUX200/VAX on TU58 tape cartridge (VAX-11/750)	8,100	51

DATA MANAGEMENT

QE105-AY	PDP-11 DATATRIEVE/VAX on floppy disk (VAX-11/780)	5,180	52
QD105-AG	PDP-11 DATATRIEVE/VAX on TU58 tape cartridge (VAX-11/750)	5,180	52
QE701-AY	VAX-11 FMS Forms Management System on floppy disk (VAX-11/780)	4,500	52
QD701-AG	VAX-11 FMS on TU58 tape cartridge (VAX-11/750)	4,500	52
QE707-YY	DX/VMS on floppy disk (VAX-11/780)	2,900	53
TD707-YG	DX/VMS on TU58 tape cartridge (VAX-11/750)	2,900	52

ENGINEERING GRAPHICS UTILITIES

QE051-YY	VAX-11 Pen Plotter Utilities on floppy disk (VAX-11/780)	5,000	54
QD051-YG	VAX-11 Pen Plotter Utilities on TU58 tape cartridge (VAX-11/750)	5,000	54
QE055-YY	VAX-11 Digitizer Utilities on floppy disk (VAX-11/780)	5,000	54
QD055-YG	VAX-11 Digitizer Utilities on TU58 tape cartridge (VAX-11/750)	5,000	54
QE053-YY	VAX-11/Engineering Drawing Utilities on floppy disk (VAX-11/780)	2,750	54
QD053-YG	VAX-11/Engineering Drawing Utilities on TU58 tape cartridge (VAX-11/750)	2,750	54

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