Tandem Non-Stop Systems

MANAGEMENT SUMMARY

Tandem Computers Incorporated began operations in 1974 with the goal of developing and marketing minicomputer systems for businesses which depend heavily on the continuous availability of their computers. Such businesses are characterized by high-volume on-line transaction processing or message handling requirements. Further, Tandem sought to provide for flexible modular expansion without reprogramming. In the ensuing years, Tandem has stuck to these goals, and in 1976 the company began marketing its current product line.

The principles that lie behind the Tandem Non-Stop Systems concept are not very complex. The company employs multiple processors, multiple controllers, multiple data paths between the system modules, and multiple power supplies in all system configurations. The benefits, according to Tandem, are twofold. First, the multiplexed configurations offer a high probability that at least one processor and one data path will always be operable. Secondly, a Tandem system in normal use may employ all its processing modules and data paths to some degree for running daily workloads. Thus, at any given time, a processing module may have excess capacity available to run jobs from a failed module. The capability to switch from a failed module to an operational module is accomplished through a hardware/software technique.

An added strength of this type of configuration is that defective modules can be replaced without powering down the balance of the system. Likewise, additional computing power can be introduced through the addition of more processing modules, memory, or peripherals without any reprogramming or other detrimental effects on the original system.

Tandem processing modules are 16-bit units which include two microcoded pipelined processing units, one for CPU ➢

Tandem is the only manufacturer of 16-bit minicomputers offering standard (rather than customized) systems designed to operate continuously despite breakdowns of key components. Aimed primarily at the end-user market, the Tandem product line consists of a processor module with either core or MOS memory, some peripherals, and three packaged systems. A typical small two-processor system is priced at $150,000, while the purchase price for a processor with 384K bytes of MOS memory is $36,400.

CHARACTERISTICS

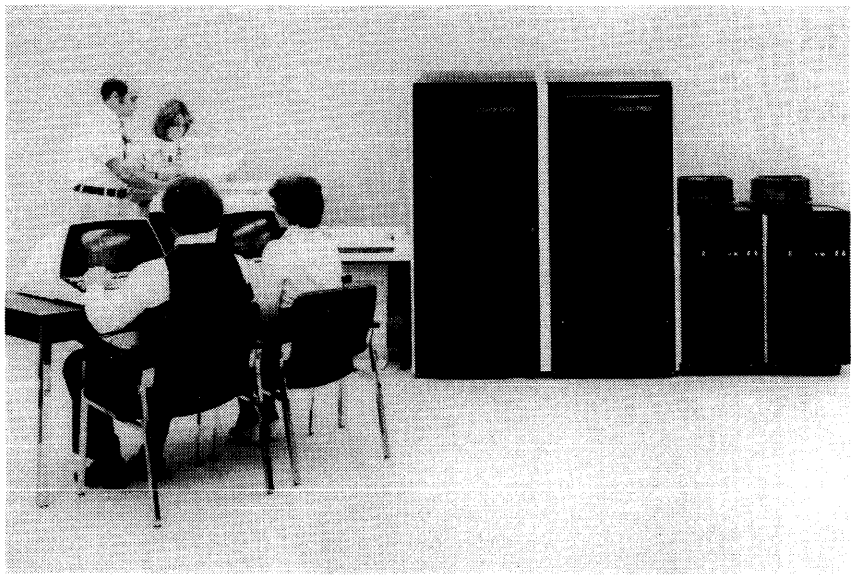
MANUFACTURER: Tandem Computers Incorporated, 19333 Vallco Parkway, Cupertino, California 95014. Telephone (408) 996-6000.

Tandem's sole business involvement is the design, development, manufacture, marketing, and servicing of multiple-processor computer systems. Approximately 25 percent of subassembly production for printed-circuit boards and cables takes place at Tandem's manufacturing facilities, with the remaining 75 percent provided by subcontractors. The company purchases substantially all of the required components and peripherals from other manufacturers. Established in November 1974, Tandem employs 446 persons, including 65 in engineering and software development, 109 in manufacturing, 244 in marketing and field service, and 28 in general management. Tandem systems are marketed through 25 U.S. and 6 European sales offices.

MODELS: T16/1102, T16/1403-1, and T16/1412-1 processors and T16/242, T16/212-1, T16/244-2, and T16/244-3 packaged systems.

DATE ANNOUNCED: November 1974.

DATE OF FIRST DELIVERY: May 1976. ➢



Tandem Non-Stop Systems can be configured to include up to 16 processor modules with either core or MOS memory and a variety of peripherals. The Guardian/Expand communications network can accommodate up to 255 geographically dispersed systems, each with a maximum of 16 central processors.

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and Dynabus (interprocessor bus) control and one for I/O control; a complete DMA-only I/O system; virtual memory control; memory mapping and protection for up to two megabytes of memory; hardware multiply/divide; power fail/auto restart; bootstrap loader; interval timer; control panel; Dynabus controller and interface; interfacing for 32 I/O controllers; a 173-member instruction set; and a power supply. The purchase price of a processing module includes the Guardian Operating System, Envoy Data Communications Manager, T/TAL language, Edit, Update, Debug, and Sort.

Packaged systems include twin processing modules with either core or MOS memories, system cabinets, and a magnetic tape module. Systems may be configured to include up to 16 processing modules.

Tandem's Dynabus hardware provides two autonomous data paths for high-speed transmission of data among processors without tying up normal communications between the processors and peripheral devices. The Dynabus is also used for periodic interprocessor checks, which permit isolation of any processor failure and also indicate at which point in the sequence of program steps the remaining operational system should begin in order to complete an interrupted assignment. Similarly, Tandem's peripheral device controllers are dual-ported. This construction provides communications paths from each controller to two different modules in the system.

Tandem offers a variety of peripherals, including 10-megabyte cartridge disc drives; 50-, 64-, 160-, or 240-megabyte pack disc drives; 36- to 120-KBS magnetic tape drives; a 600-cpm card reader; 120-, 300-, 600-, 900-, or 1500-lpm line printers; character or page-mode CRT terminals; and synchronous or asynchronous controllers.

Tandem software includes the Guardian Operating System, Enscribe Data Base Management System, Expand Networking System, Exchange Remote Job Entry Program, Entry Screen Formatter, Envoy Data Communications Manager, T/TAL (Tandem's own language), COBOL, FORTRAN, and Enform (Query Language/Report Writer). All of these software products except T/TAL, Guardian and Envoy are unbundled.

Tandem systems are marketed for both OEM and end-user sales, although primary emphasis is on the end user. Arrangements for third-party leasing are primarily the responsibility of the user, although Tandem will provide assistance in making such arrangements. Employing its own sales organization, Tandem markets its products through sales offices in Chicago; Houston; New York; Seattle; Phoenix; Boston; Columbus; Denver; Omaha; Detroit; Dallas; Greensboro; Los Angeles; Bellevue; Philadelphia; Cincinnati; Pittsburgh; San Francisco, Long Beach; Minneapolis; St. Louis; Stamford; Washington, D.C.; Hasbrouck Heights; Cupertino; Zurich; Toronto; London; Frankfurt; Dusseldorf; and Munich. The systems are sold with a 90-day warranty.

NUMBER INSTALLED TO DATE: Over 100 customers and over 250 processors.

DATA FORMATS

BASIC UNIT: 16-bit words; 8-bit bytes, 32-bit double words, and 64-bit quadruple words can also be accessed and manipulated.

FIXED-POINT OPERANDS: 8, 16, 32, or 64 bits in memory or register stack as designated by the instruction type. Bytes can be loaded into and stored from the register stack; moved from one memory location to another; compared to the contents of another memory location; or scanned in a block of one, two, or four words. Bytes represent unsigned values in the range of 0 to 255. Words, double words, and quadruple words can be loaded and stored from the register stack. Both logical (unsigned) and integer (signed) arithmetic can be performed on word operands. Double words and quadruple words may only have integer arithmetic performed on them. Word operands can represent signed numbers in the range of --32,768 to +32,767 and unsigned numbers in the range of 0 to 65,535. Double-word operands can represent signed numbers in the range of -2,147,583,648 to +2,147,583,647. Quadruple-word operands can represent 19-digit numbers in the range of -9,223,372,036,854,775,808 to +9,223,372,036,854,775,807. For words, double words, or quadruple words, positive values are represented in true binary notation. Negative values are represented in two's-complement notation with the sign bit of the most significant word set to one.

FLOATING-POINT OPERANDS: 23-bit single-precision and 55-bit double-precision operands, in normalized form; all 9-bit exponents are expressed in excess-256 notation.

INSTRUCTIONS: All 43 floating-point instructions are one word long and can be divided into 17 categories, each with a unique format which varies only for immediate-operand instructions. The instruction word is generally divided into five 3-bit fields and one 1-bit field. Fields are sometimes combined, for example, to represent mode and displacement. Likewise, fields may be subdivided to represent a one-bit indicator (such as indexing or no indexing) and a two-bit register identifier. Immediate-operand instructions have bits 7-15 reserved for the immediate operand.

INTERNAL CODE: Binary.

MAIN STORAGE

TYPE: Core and N-channel dynamic MOS semiconductor; refresh cycle time varies with the technology used.

CYCLE TIME: Core—800 nanoseconds with an access time of 500 nanoseconds; MOS—500 nanoseconds with an access time of 500 nanoseconds.

CAPACITY: 65,536 to 524,288 bytes per processor in increments of 65,536 bytes for core memory, and 98,304 to 2,097,152 bytes per processor in increments of 393,216 or 98,304 bytes for MOS.

CHECKING: Core memory employs one parity bit per word; MOS memory employs 6 check bits per word for error checking and correcting (ECC).

The parity bit is added by the parity controller to each 16-bit word written into core memory and checked when read by the same controller.

ECC detects and corrects all single-bit main memory errors, and detects all double-bit errors and most multiple-bit errors. ECC generates a 6-bit check field for each 16-bit data word as it is written, and recomputes the field when the word is read. If the check bits do not match, the erroneous bit is corrected

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PERIPHERALS/TERMINALS

DEVICE	DESCRIPTION & SPEED	MANUFACTURER
MAGNETIC TAPE EQUIPMENT		
T16/5104	Transport; 9-track, 800 bpi (NRZI)/1600 bpi (PE), 125 ips, 10.5-inch reels, tension arms, read-after-write and power-fail/auto-restart electronics; 36 KBS	Kennedy
T16/5103	Transport; 9-track, 800 bpi (NRZI)/1600 bpi (PE), 45 ips, 10.5-inch reels, tension arms, read-after-write and power-fail/auto-restart electronics; 36/72 KBS	Kennedy
PRINTERS		
T16/5508	Serial matrix printer; 132 positions, 96 ASCII character set, 10 characters per inch, 15-inch paper (width), 6 lines per inch, electronic VFU; 200 cps	Diablo Series 2300
T16/5502	Drum, impact printer; 132 positions; 64 ASCII character set (96 optional), 10 characters per inch, 4 to 16.75-inch paper (width), 6 or 8 lines per inch, 12-channel VFU optional; 300 lpm (240 lpm with 96-character set)	Dataproducts 2230
T16/5503	Same as T16/5502 but 600 lpm (436 lpm with 96-character set)	Dataproducts 2260
T16/5504	Same as T16/5502 but 900 lpm (436 lpm with 96-character set)	Dataproducts 2290
T16/5505	Same as T16/5502 but 1500 lpm (1220 lpm with 96-character set)	Dataproducts 2550
PUNCHED CARD EQUIPMENT		
T16/5301	Reader; 80-column, 1000-card input hopper and output stacker; 600 cpm	Documation M6002
TERMINALS		
T16/6603	Hard-Copy Terminal; 132 positions, 63 or 95-character set, 10 characters per inch, 3 to 14.9-inch paper (width), 6 lines per inch, standard typewriter keyboard with 10-key numeric pad, 30-cps printing, half duplex transmission, RS-232 interface; 110-1200 bps	DEC DECwriter II
T16/6604	Same as T16/6603 but 20-mA current loop interface; 110-1200 bps	DEC DECwriter II
T16/6401	CRT Character Terminal; 1920 characters, 24 lines by 80 characters, 64 displayable characters, half and full duplex transmission, RS-232 interface; 75-19.2K bps	Lear Siegler ADM3
T16/6402	Same as T16/6401 but 20-mA current loop interface; 75-19.2K bps	Lear Siegler ADM3
T16/6511	CRT Page Mode Terminal; 1920 characters, 24 lines by 80 characters, 64 displayable characters, protected and unprotected screen-areas, full and half bright video, blinking, half and full duplex transmission, RS-232 interface; switch-selectable 110-19.2K bps	Lear Siegler
T16/6512	Same as T16/6511 but 20-mA current loop interface; switch-selectable 110-19.2K bps	Lear Siegler
T16/6552	Same as T16/6511 except uses polling protocol for multidrop communications lines; switch-selectable 110-19.2K bps	Lear Siegler

Field engineering is provided on an 8 a.m. to 5 p.m. prime-shift basis. Other hours of service may be arranged through negotiation with Tandem.

Training is offered at Tandem's corporate headquarters and regional offices in COBOL, FORTRAN, T/TAL, and hardware. Software courses are priced at $300 per week, and hardware courses at $500 per week.

Tandem considers its prime competitors to be the computer vendors that have the capability to offer dual computer systems on a customized basis. These include Burroughs, Data General, Digital Equipment, Hewlett-Packard, Honeywell, and IBM.

before data is transmitted to the processor. Correction and virtual memory address translation is included in the stated access times of 500 nanoseconds. ECC helps to ensure uninterrupted operation and is transparent to the user. A Hamming code is used by the hardware encoder on each memory board to construct the check field.

STORAGE PROTECTION: Via memory mapping provisions.

RESERVED STORAGE: Up to 1280 bytes of memory are reserved in the system data area for three specific tables. The System Interrupt Vector table consists of 128 bytes divided into 16 four-word entries. Each of these entries defines the executing environment for one of the 16 operating system interrupt handlers. The Bus Receive Table consists of 128 bytes divided into 16 four-word entries. Each of the 16 entries

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USER REACTION

At the time of this writing, five Tandem users had responded to Datapro's 1979 survey of minicomputer users. In addition, Datapro contacted six users from a list supplied by Tandem. These 11 users had a total of 14 systems installed.

Seven of the systems included two processor modules, one system included three modules, four systems included four modules, and two systems included 10 processor modules. Main memory capacity ranged from 256K bytes to 1920K bytes, and disk storage ranged from 100 million bytes to 9.6 billion bytes. The number of interactive terminals on line ranged from 6 for a user with 2 processor modules on his system to 2400 for a user who had two Tandem systems with a total of 14 processor modules integrated with a Xerox Sigma 9 computer.

The length of time these systems had been installed averaged about 13 months. Programming languages used included COBOL and T/TAL.

The ratings assigned by these users are shown in the following table.

	Excellent	Good	Fair	Poor	WA*
Ease of operation	6	5	0	0	3.5
Reliability of mainframe	8	3	0	0	3.7
Reliability of peripherals	4	7	0	0	3.4
Maintenance service:					
Responsiveness	4	7	0	0	3.4
Effectiveness	6	5	0	0	3.5
Technical support	6	3	2	0	3.4
Manufacturer's software:					
Operating system	9	2	0	0	3.8
Compilers and assemblers	4	7	0	0	3.4
Application programs	1	4	0	0	3.2
Ease of programming	7	3	1	0	3.5
Ease of conversion	0	2	2	1	2.2
Overall satisfaction	7	4	0	0	3.6

*Weighted Average on a scale of 4.0 for Excellent.

These users were obviously very satisfied with their Tandem systems. While ease of conversion received the lowest rating, none of the five users who rated this aspect of the system saw fit to comment further. One user said he had gone through conversions before and would only say that "some were easier, some harder," but he declined to point to anything specific. Two users commented that vendor support and responsiveness were "irregular," while two others commented that their printers were only "fair."

On the positive side, the non-stop architecture and the T/TAL compiler were praised by four of these users. Specific comments regarding the system architecture included "No single point of failure," and "Absolutely reliable." In addition, one user singled out Tandem's COBOL, another called the documentation "excellent," and two were impressed with the company's maintenance, citing specifically the responsiveness to their service requests.

corresponds to one of the 16 possible processors. The I/O Control Table consists of up to 1024 bytes divided into up to 256 entries corresponding to the 32 possible controllers. Each controller can handle up to eight units connected to an I/O channel. An entry describes the number of bytes to be transferred and the system data location where the data transfer takes place.

CENTRAL PROCESSOR

Each Tandem processor (T16/1102 or T16/1403) is built around a pipelined, microprogrammed central processor with a cycle time of 100 nanoseconds. The processor is operated by 32-bit micro-instructions, each of which consists of combinations of up to 7 of the 168 mirco-operations available. The T16/1102 and T16/1403 processors are essentially the same, differing only in main memory type (core/MOS) and error checking technique (parity/error correction and detection).

The Tandem processor features 16-bit data paths and memory addressing; memory mapping; an instruction set that includes string manipulation and double-word arithmetic; a floating-point option; a decimal arithmetic option; stack architecture; non-modifiable code areas of memory; hardware power fail/auto restart; hardware multiply/divide; a block-multiplexed I/O channel; and dual high-speed interprocessor buses.

Tandem employs a true virtual memory system in the sense that besides the software designed for memory management, a number of features are incorporated into the processor module's hardware to aid in reducing the amount of swapping that occurs:

- **A "dirty" bit is associated with each data map entry; only if a data page has been modified is it ever swapped out.**
- **A reference bit is associated with each map entry to record access to a particular page. The memory manager also maintains a list of maps (each process has a separate map) active in a processor module. When memory space is needed for an overlay, the memory manager selects the physical page that has been the least recently used for overlaying.**
- **Paging hardware is provided in the form of memory maps.**

Each Tandem processor module is integrated into a Tandem 16 Computer System, which consists of from 2 to 16 processor modules. Processor modules are interfaced to one another by means of two interprocessor buses, which are a standard feature of each processor module. A processor module may interface to I/O devices by means of its input/output channel.

Each processor module is capable of operating independently of, and simultaneously with, all other processor modules in the system. The Guardian-controlled interprocessor buses (Dynabuses) are used to transfer data between the memories of the processor modules. Each bus offers a transfer rate of 13 megabytes per second, block transfers of 1 to 32,767 bytes, and packet-multiplexed transfers between any number of processor modules. The dual interprocessor buses contained in each processor module operate simultaneously. Data is actually sent across a bus in 16-word groups (including one check-sum word).

CONTROL STORAGE: Up to 3,072 32-bit pre-programmed words of PROM microprogram storage are available to implement the decimal and floating-point instruction options. The basic instruction set utilizes 1024 words. Approximately half of these are used to implement privileged operating system functions. Cycle time is 100 nanoseconds.

REGISTERS: Eight accumulators (registers) are accessible by the programmer, and numerous additional registers are

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With over 100 customers and more than 250 processors installed since the delivery of its first system in May 1976, Tandem appears to have found its niche in the computer marketplace. If the company can keep all of its users as satisfied as the group we interviewed seemed to be, it should capture a sizeable share of the market for systems of the fail-safe type.□

available for use by the microprogrammed central processor. Registers include the 16-bit P (program counter) register, the 16-bit I (current instruction) register, the 16-bit NI (next instruction) register, the 16-bit E (environment) register, the 18-bit L (local data-pointer) register, the 16-bit S (top of stack) register, and the 8-element register stack. The eight 16-bit accumulators are contained in the register stack. Additional registers are found in the hardware, including the Map registers of the memory management system and the two registers associated with the interrupt system: the 16-bit Mask register and the 16-bit INT register.

The E register maintains the CPU state of the currently executing program. The individual bits and bit fields of the E register are continually referenced and updated by the CPU hardware. The E register contents are used (along with the contents of the P and L registers) by the hardware to save the executing state of a program when a procedure is invoked or when an interrupt occurs. The hardware restores the E register to its previous state when the procedure or interrupt finishes. The L register contains the relative address of the word at the beginning of the local data area. Each subprogram or subroutine in active execution has associated with it a dynamically allocated data area designed for its own use; this is the local data area.

The register stack consists of eight 16-bit registers designated R(0) through R(7). Three of these registers, R(5) through R(7), may also be used for indexing. All arithmetic computations are performed in the register stack. All comparisons except for compare words and compare bytes are also performed in the register stack. The register stack is of the first-in/first-out type.

ADDRESSING: Programs in the execution environment are broken into a code area and a data area. The code area consists of instruction codes and program constants. The code area may not be written into and therefore cannot be modified. Code areas are re-entrant and sharable by numerous programs. Each code area can consist of up to 131,072 bytes. Addresses in the code area are calculated relative to the current setting in the P register. Data areas for programs are organized into main memory first-in/first-out stacks. Therefore, subprogram/subroutine data areas are allocated dynamically, thus keeping the amount of memory required by a program to a dynamic minimum.

The data area contains a program's temporary storage locations (i.e., variables). Information in this area consists of single-element items, arrays, and address pointers. Input/output transfers are via arrays in a program's data area.

Part of the data area is used for dynamic allocation of storage when procedures are invoked. This area is referred to as the "memory stack."

The data area consists of up to 131,072 bytes logically separated into global (addressable by any instruction in the program), local, and top-of-stack areas.

Data elements in the data area are addressed in terms of a word address regardless of the type of operand involved. All addressing is relative to one of three addressing bases: global, local, or top-of-stack. Instructions that reference data locations contain a 9-bit address field for specifying one of the bases plus a field for relative displacement. The following are direct addressing modes, indicated by bit 0 of the instruction word being 0: G-Relative mode addresses the first 256 words of the global area; L-Plus-Relative mode addresses the first 128 words of a subprogram/subroutine's local data area; L-Minus-Relative mode addresses the 31 words just below the word pointed to by the current L register setting; and S-Minus-Relative mode addresses the 32 words just below and including the current top-of-stack word. A privileged mode, SG-Relative, addresses the first 64 words of the operating system's data area.

Indirect addressing is indicated by bit 0 of the instruction word being 1. The same five direct addressing modes as previously indicated can be used in indirect addressing. However, the memory location retrieved, instead of being the actual word sought, contains the address of the actual word sought. Under this scheme, all 65,535 words of the data area may be referenced.

Indexing, utilizing R(5), R(6), or R(7), can be employed with both direct and indirect addressing. In direct addressing, the index value is added to the direct address to obtain the referenced word. In indirect addressing, the indirect address is first obtained, and then the index value is added to obtain the referenced word.

MEMORY MAPPING: Translation of a 16-bit logical address used in a program to the 20 bits needed to address physical memory is accomplished through the use of memory maps. Memory is arranged in 2048-byte pages. The pages in a program are referred to as logical pages, and the pages in physical memory are called physical pages. Each logical area in a program (i.e., code or data) consists of 64 pages, the first of which is designated logical page 0. Each logical page has a corresponding entry in a memory map. The 6 high-order bits of a logical address designate a logical page (and, therefore, a map entry), while the 10 low-order bits designate a word within the logical page. When a logical address is presented to the hardware, the designated map entry is read, and the 10-bit physical page number it contains is combined with the 10 low-order bits of the logical address to generate the unique 20-bit physical address of a word in memory.

Four separate memory maps are provided: the user code map, which defines the currently executing application program's code area; the user data map, which defines the currently executing application program's data area; the system code map, which defines the area where the operating system's instruction codes are located; and the system data map, which defines the area where the operating system's memory stack, buffers, and tables reside.

Because actual memory locations are associated with entries in a map register, pages assigned to a particular program can reside in non-contiguous locations. The user code and data maps are shared by all user processes present in a processor module; the operating system dynamically loads the user maps from a table indicated by the appropriate process control block (using a single machine instruction) just prior to dispatching that processor for execution. The system maps are used only by the operating system and are never modified (except for entries of non-resident pages).

INSTRUCTION REPERTOIRE: The standard set includes 173 instructions broken down as follows: 15 16-bit arithmetic, 8 32-bit arithmetic, 5 16-bit signed arithmetic, 9 register stack manipulation, 8 Boolean operations, 9 bit deposit and shift, 1 byte test, 15 memory stack/register stack, 14 branching, 6 moves/compares/scans, 11 program register control, 7 routine recalls and returns, 4 interrupts, 1 bus, 5 I/O, 3 maps, 50 operating system primitives, and 2 miscellaneous. The decimal arithmetic option adds 32 additional instructions. The floating-point option adds an additional 43 instructions.

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INSTRUCTION TIMINGS: The following timings are for full-word fixed-point operands, and are given in microseconds.

	MOS Memory	Core Memory
Load/Store:	1.4/1.1	1.6/1.6
Add/Subtract:	0.5/0.5	0.8/0.8
Multiply/Divide:	3.4/3.1	3.4/3.1 (integer)
Compare:	0.5/0.5	0.8/0.8
Branch:	1.0 to 1.7	1.6 to 2.4

INTERRUPTS: A 16-level vectored interrupt system is employed on the Tandem processors. Events causing interrupts include power on, uncorrectable memory error, map parity error, instruction failure, memory stack overflow, page fault, arithmetic overflow or divide by zero, power fail, correctable memory error; high-priority I/O, X-bus (interprocessor) receive completion, Y-bus (interprocessor) receive completion, interval clock, standard I/O, and dispatcher.

PHYSICAL SPECIFICATIONS: The typical Tandem system is housed in two cabinets, each of which is 73 inches high, 28 inches wide, and 32 inches deep. The cabinet pair weighs 770 pounds, 338 pounds for the processor cabinet and 432 pounds for the mag tape enclosure. Recommended floor area for the typical installation is 160 square feet; a typical installation includes the processor and mag tape cabinets, two disk drives, console terminal, two application terminals, and a line printer.

Operational ambient temperature for the Tandem processors is 60 to 90 degrees F. with a relative humidity between 30 and 80 percent, noncondensing. Power requirements are 120/208 VAC +10 percent at 100 amperes or 230/400 VAC ±10 percent at 100 amperes, 47 to 63Hz, 3 phase. Maximum power consumption and heat dissipation are dependent upon the specific configuration, which can range from 2 to 16 processors.

INPUT/OUTPUT CONTROL: Each processor module has one block-multiplexed I/O channel that is capable of communicating with up to 256 I/O devices (32 controllers with a maximum of 8 devices each). I/O devices are interfaced to I/O channels by dual-port controllers. Each dual-port controller is connected to the I/O channels of any two processor modules. Therefore, each I/O device can be controlled by either of two processor modules. (In actual practice, an I/O device is controlled exclusively by one processor module until a failure occurs such that the processor module can no longer communicate with the I/O device. If such a failure occurs, the other processor module takes control of the I/O device.)

A single I/O operation is capable of transferring data in blocks of from 1 to 4096 bytes. Data is buffered by each dual-port controller so that data is transferred in bursts over a channel at memory speed. The number of bytes in a burst is dependent on a controller's buffer size.

SIMULTANEOUS OPERATIONS: Data transfers on both interprocessor buses can occur simultaneously. I/O transfers occur directly between memory and I/O devices currently with program execution. This is possible because of the microprocessor control built into the I/O channel. Further, all 256 I/O devices can be transferring data simultaneously, with bursts from one device being interleaved with bursts from others.

CONFIGURATION RULES

Two to 16 processors and up to 256 peripheral devices per processor are addressable on a Tandem system. Up to 255 systems can be addressed in a network using Guardian/Expand.

MASS STORAGE

T16/4101 MOVING-HEAD DISC DRIVE: Provides formatted storage for 10 million bytes per drive. This drive is employed in conjunction with the T16/3102 Single-Port Disc Controller. The controller is connected to dual channels and thus can be powered from either processor in the event of a single processor failure. The T16/3102 can control up to four T16/4101 or T16/4102 drives in any mix and employs the IBM 2314 recording technique. This controller does not hold the address and count words; these are held in the I/O processor, so that a disc failure cannot corrupt the system processor's memory.

The T16/4101 employs a top-loading, industry-standard, 5440-type removable disc cartridge and a single fixed disc to provide a total of four recording surfaces. The fixed and removable discs each provide formatted storage for 4,915,200 bytes. Each surface is organized into 408 tracks, including 8 spares. Track density is 200 tracks per inch. There are 24 sectors of 256 bytes per track. Total track capacity is 7812 bytes unformatted and 6144 bytes formatted. Recording density is 2200 bits per inch (inner track). There are 4 tracks per cylinder and 408 cylinders per drive. Actual formatted drive capacity is 9,830,400 bytes.

The drive rotates at 2400 rpm with an average rotational delay of 12.5 milliseconds. The data transfer rate is 312,500 bytes per second. Track-to-track, average, and across-all-tracks head positioning times are 7, 35, and 60 milliseconds, respectively. The T16/4101 is manufactured by Control Data (CDC 94274).

T16/4102 MOVING-HEAD DISC DRIVE: This drive provides formatted storage for up to 50 million bytes per drive on a 22-surface, industry-standard, 2316-type disc pack. Data is recorded on 20 surfaces at a track density of 200 tpi, yielding 406 tracks per surface, including 6 spare tracks. There are 24 sectors of 256 bytes per track. Total track capacity is 7812 bytes unformatted and 6144 bytes formatted. Recording density is 2200 bpi (inner track). There are 20 tracks per cylinder and 406 cylinders per drive. Actual formatted drive capacity is 50,000,000 bytes. The T16/4102 requires the same T16/3102 controller as the T16/4101.

The drive rotates at 2400 rpm with an average rotational delay os 12.5 milliseconds. The data transfer rate is 312,500 bytes per second. Track-to-track, average, and across-all-tracks head positioning times are 10, 35, and 70 milliseconds, respectively. The T16/4102 is manufactured by Control Data (CDC 9746).

T16/4103 MOVING-HEAD DISC DRIVE: This is a 160-megabyte drive that is dual-ported, allowing it to be attached to two T16/3105 Dual-Port Disc Controllers simultaneously. With this facility, if one disc controller should fail, the other controller is able to maintain an open path for data.

Besides its support of dual-access disc units, the T16/3105 Controller features a 4K memory for buffering logical records between the channel and a disc unit. (This function is not used by Guardian or Enscribe because of a conflict with NonStop.) Up to eight T16/4103, T16/4104, or T16/4105 drives can be daisy-chained to the T16/3105 controller.

The T16/4103 drive uses a linear DC motor (voice coil) combined with 3330-technology on-track servo techniques (track-following method). The pack employed is a 22-surface, industry-standard, 3336-11 type. Data is stored on 19 surfaces, with one surface reserved for servo use and the remaining two surfaces employed for protection. Track density is set at 390 tpi, resulting in a total of 808 tracks per surface plus 7 spares. There are 19 tracks per cylinder and 815 cylinders per pack. Bit density is set at 4040 bpi. There are 512 bytes per sector, 20 sectors per track, and

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10K bytes per track. Actual formatted drive capacity is 158,600,000 bytes.

The drive rotates at 3600 rpm with an average rotational delay of 8.35 milliseconds. The data transfer rate is 806K bytes per second. Track-to-track, average, and across-all-tracks head positioning times are 10, 28, and 55 milliseconds, respectively. The T16/4103 is manufactured by Ampex (Model 9200).

T16/4104 MOVING-HEAD DISC DRIVE: Employing the same electronics, disc pack controller, and recording technology as the T16/4103, the 240-megabyte T16/4104 differs primarily in bit density, transfer rate, and total capacity. Bit density is set at 6060 bpi. There are 512 bytes per sector, 30 sectors per track, and 15K bytes per track. Actual formatted drive capacity is 240,000,000 bytes.

The drive rotates at 3600 rpm with an average rotational delay of 8.35 milliseconds. The data transfer rate is 806K bytes per second. Track-to-track, average, and across-all-tracks head positioning times are 10, 28, and 55 milliseconds, respectively. The T16/4104 is manufactured by Ampex (Model 9300).

T16/4105 MOVING-HEAD DISC DRIVE: The 64-megabyte T16/4105 is a pedestal-mounted drive utilizing the T16/3105 controller. The drive employs a 5-platter disc pack, with 5 recording surfaces per pack. The drives employ a technology similar to that of the IBM 3330 applied to the actuator and disc pack design. The top and bottom platters are designed to protect the pack. The bottom surface of the second platter is for servo use, leaving platters 3 and 4 and the top surface of platter 2 for data storage. The T16/4105 contains 823 tracks per surface (808 active data cylinders per spindle). Bit density for the drive is 6038 bpi, while track density is 384 tpi. Unformatted track capacity is 20,160 bytes. A drive has 30 sectors per track and 512 bytes per sector. Actual storage capacity is 64,000,000 bytes.

The drive rotates at 3600 rpm, resulting in an average rotational delay of 8.3 microseconds. Track-to-track, average, and across-all-tracks head positioning times are 7, 30, and 55 milliseconds, respectively. Head positioning is performed by a closed-loop proportional servo system driving a voice-coil actuator. The drive has a data transfer rate of 1.2 megabytes per second.

Data security is provided by a write protect feature with positive manual control, electronically inhibiting write functions upon detection of a seek error, track position error, loss of rotational speed, or loss of voltage. The last two malfunctions also cause head retraction. The drive is manufactured by Control Data as Model 9762.

INPUT/OUTPUT UNITS

See Peripherals/Terminals table.

COMMUNICATIONS CONTROL

T16/3401 UNIVERSAL INTERFACE (UI): This interface provides the ability to interface custom equipment to a Tandem 16 Computer System. The UI is capable of connecting two devices that have 8- or 16-line parallel data interfaces to the Tandem system. The interface provides a device data path that is buffered (16 words deep), bi-directional, and capable of operating in half-duplex mode at a sustained data transfer rate of up to 4 megabytes per second, depending on the channel configuration. It interfaces to one device over positive or ground true TTL lines for distances up to 25 feet and to the second device over differential lines for longer distances up to 500 feet. The data path between either or both of the two devices and the UI can be either one byte (8 bits) or one word (16 bits) wide. Configuration of the UI is accomplished by software and by jumpers. Odd parity is generated and checked for each data word that is transferred between the channel and the UI. The parity that exists between the UI and each device is defined by configuration jumpers in the connector hood. The jumpers select odd, even, or no parity.

T16/6301/6302 ASYNCHRONOUS CONTROLLER: Handles from 2 to 32 asynchronous communications lines per controller with line speeds ranging from 50 to 19.2K bits per second. The controller is sufficiently fast to support 32 lines all running at 19.2K bps. The T16/6301 provides for the first two lines, while the T16/6302 Asynchronous Extension Board provides for an additional 15 lines. Up to two T16/6302 boards are allowed per controller. The T16/6301 provides DMA access to main memory on all I/O transfers and modem support for Bell-type 103 and 202 modems (including reverse channel). Each line is individually programmable with respect to: bps rate; character size; parity generation and checking; enable/disable checking for signal characters; half-duplex modem turn-around character(s); read completion on ETX (end of text) character; default transfer mode; conversational mode line termination character, backspace type, carriage return/line feed delay, forms control delay, and automatic line feed on input; page mode termination character; and pseudo-polling trigger character.

For point-to-point applications, the standard Guardian I/O Subsystem will support any RS-232 or current loop terminal by merely configuring the line in SYSGEN. Standard I/O calls (READ, WRITE, WRITEREAD) provide access to the terminal. For multipoint applications, the Envoy Data Communication Manager provides the ability to interface polling terminals such as the T16/6552 CRT Polling Terminal.

T16/6202 BYTE SYNCHRONOUS COMMUNICATIONS ADAPTER: This controller, utilizing microprogrammed technology, supports up to four lines. Each line can be configured dynamically for translate enable, transparent text capability, full or half duplex operation, polling address, and selection address. Speeds up to 80K bps per line are supported by the controller.

The T16/6201 also features automatic generation and detection of block check characters with support for VRC, LRC, and CRC; 16 modes of operation; automatic code translation to ASCII and EBCDIC; DMA access to main memory; auto-insertion of DLE and SYN characters; and support for Bell-type 201, 203, 208, and 209 modems.

The polling of multipoint stations is, for the most part, handled by the controller. The Envoy Data Communication Manager formats a polling list (on behalf of the application process) for the controller to use to poll the multipoint tributary stations. Envoy then commands the controller to begin polling. CPU processing is interrupted only when a polled station responds.

The controller has the capability to recognize if a line is being polled or selected. For each line, the controller stores the first byte of the station's polling address and the first byte of the station's selection address. Only when the line is polled or selected and the corresponding poll or select byte matches is CPU processing interrupted.

SOFTWARE

OPERATING SYSTEM: The *Guardian Operating System* is the only operating system currently offered by Tandem. An older operating system, the Transaction-Oriented Operating System (T/TOS), is no longer being marketed.

The Guardian Operating System provides the multiprocessing (parallel processing in separate processor modules), multiprogramming (interleaved processing in one processor module), and nonstop capabilities of the Tandem 16 Com-

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puter Systems. The nonstop character of the Tandem systems is preserved by keeping master copies of Guardian, configured for the specific application, in a system area on mirrored (duplicate) disc volumes. Each mirrored volume is meant to be mounted on a separate disc device and contains Guardian, virtual swapping memory space, system and application programs, and application data. This mirroring is transparent to the user. Other transparent-to-user functions include allocation of buffer space and control blocks, fault handling, the preparation of a program for execution in virtual memory when a request is made to run a program, the capability for processes to communicate with each other regardless of the processor modules in which they are executing, the scheduling of processor module time among multiple executing programs according to their application-assigned priorities, and provision of the virtual memory function by automatically bringing absent memory pages in from disc when needed.

Guardian isolates the application from physical memory constraints by providing a virtual memory management system. Paging hardware is provided in the form of four 128K-byte memory maps (user code, user data, system code, and system data). All code is both sharable by multiple programs and non-modifiable, two features which reduce overlay and swapping overhead. Code pages are never swapped out to disc. In addition, hardware is used to record the frequency of access to all memory pages and modification of data pages, thus providing a low-overhead method of determining the correct page to be replaced.

In a typical system, master copies of the Guardian Operating System, configured for the specific application, are kept in a system area on mirrored disc volumes. Critical and frequently used parts of Guardian are resident in each processor module's memory. Thus, the system's capabilities are maintained even if a processor module, I/O channel, or disc drive fails. Non-critical or less frequently used parts of Guardian are virtual and are bought into a processor module's memory from disc only when needed.

Likewise, a mirror principle permits data to be written simultaneously onto two disk devices. If a failure occurs in one of the devices, data is read from the other device. Upon restoration of the failed disk drive, the system automatically updates the restored device while continuing to process transactions. The mirroring is transparent to both the application programmer and the computer operator.

To prevent data degradation resulting from a processor failure, an active processor signals an alternate processor (which contains a backup program) at the start of a file update. If the update is not completed correctly, the operating system alerts the other processor to perform the update.

Concurrently with application program execution, Guardian continually checks the integrity of the system. This is accomplished by having each processor module, at a predefined interval, transmit an "I'm alive" message to Guardian in every other processor module. (This interval is typically one second.) If Guardian in one processor module finds that an "I'm alive" message has not been received from another processor module, it first verifies that it can transmit a message to its own processor module; if it can, it assumes that the non-transmitting processor module is inoperative; if it can't, it takes action to ensure that its own module does not impair the operation of other processor modules. In either case, Guardian then informs the system processes and interested application processes of the failure.

Guardian provides multiple system services that can be requested by programs or that affect application program design. These include the program control functions of run, suspend, and stop; I/O file management; system messages; utility procedures; a checkpointing facility; traps and trap handling; a command interpreter program for communicating run-time information to an application program; an interactive debug facility; and security for controlling access to data files.

TYPICAL STORAGE REQUIREMENTS OF TANDEM SOFTWARE

	Main Memory (bytes)	Disk Storage (bytes)
Guardian	94K	488K
T/TAL	60K	208K
COBOL	90K	64K
FORTRAN	56K	80K
Enscribe	58K	152K
Entry	2.6K	—
Sort	48K	50K
Envoy	23K	—
Expand	25K	—
Enform	38K	—

The executing environment of a given program is a single processor module (specified at run time). A program's environment consists of a code area, containing instruction codes and program constants, and a separate data area, containing variables and hardware environment information. A given code area is shared by all processes that are executing the same program file. This is permissible because information within the code area cannot be modified. Each program, however, has its own separate, private data area.

It is possible for a properly coded application process to recover from any type of hardware failure except one—a failure of the processor module in which it is executing. Because of this, NonStop applications consist of one or more primary/backup "process-pairs." A process-pair consists of two copies of the same program and data. Logic in the program indicates whether the process is executing in the primary mode, to perform the designated work, or in the backup mode, to monitor the operability of the primary.

Procedures provided by Guardian to perform utility operations include a debug facility, provision of the global address of the last word in the application's data area, conversion of the ASCII representation of a number into its binary equivalent, conversion of the internal machine representation of a number to its ASCII equivalent, and provision of the current date and time.

The Checkpointing Facility provides the capability for writing application programs that can recover from a processor module failure. To use the Checkpointing Facility, an application program must be executing as a process-pair. The Checkpointing Facility is used by the primary process of a process-pair to "checkpoint" pertinent data to its backup process. It is used by the backup process to receive the checkpoint data, to monitor the primary, and to begin executing at the point indicated by the latest checkpoint message.

Certain critical error conditions occurring during process execution prevent the normal execution of a process. The errors, which are for the most part unrecoverable, cause traps to operating system trap handlers. The conditions include illegal address reference, instruction failure, arithmetic overflow, stack overflow, process loop timer time-out, memory manager disc read error, no memory available, uncorrectable memory error, and map parity error.

The Guardian Operating System's security capability is designed to prevent inadvertent destruction of files through purging or overwriting and to prevent unauthorized access to sensitive data files by programmers or operations personnel.

Security is enforced by assigning a group name, user name, and (optionally) a password to individuals that are to access

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the system. For each file, file access at each level may be restricted to reading, writing, executing, and/or purging.

Using the debug facility, a program location can be designated a "breakpoint." The subsequent execution of the breakpoint location during otherwise-normal processing causes the process to enter the debug state. While the process is in the debug state, the programmer can interactively display and modify the contents of the process's variables, display and modify the contents of the process's registers, and designate other breakpoints.

The file management system provides access to, and operations on, "unstructured" disc files. An unstructured disc file contains information placed in it by an application program. There is no logical record size imposed by the system, and there is no implicit difference between sequential and random access to an unstructured disc file. Enscribe, Tandem's data base management system, is an extension of Guardian that provides access to and operations on three additional file structures: relative files, in which records are stored relative to the beginning of the file; entry-sequenced files, in which records are appended to a file in the order presented to the system; and key-sequenced files, in which records are placed in a file in ascending sequence according to the value of a key field in the record.

Guardian program development tools include the command interpreter (Comint), the text editor (Edit), the T/TAL compiler, the cross-reference program (Xref), the object file editor (Update), and the interactive debugging facility (Debug).

Comint is a program that is used interactively to run programs, check system status, create and delete disc files, and alter system hardware states. An important feature of Comint is its ability to pass user-specified parameter information to a program at run time.

Edit is used to prepare source programs written in T/TAL. It is an interactive program that allows the programmer to enter and make changes to the source program through an interactive terminal. Text entered through the text editor is stored in a file on disc under a name given by the programmer. This name also specifies the source program to the T/TAL compiler and is used later if the programmer wishes to "edit" the file.

LANGUAGES: Tandem currently offers three high-level languages: Transaction Application Language (T/TAL), a language developed exclusively for use on Tandem systems; COBOL; and FORTRAN.

T/TAL is a high-level, block-structured, procedure-oriented language designed, according to Tandem, for ease of programming and efficient use of the architectual features of the Tandem 16. Similarities exist between T/TAL and ALGOL, PL/1, and COBOL in that they all offer machine-independent procedure blocks and high-level constructs. Other characteristics of T/TAL include free-form structure; machine-dependent statements; programmer-assigned identifiers; single- and double-word integer, byte string, and 18-digit fixed-point data types; multiple-element block operation such as move, compare, or scan block; bit operations such as bit deposit, bit extraction, and bit shift; and procedures, recursive procedures, and subprocedures.

T/TAL's machine dependence makes it possible for the compiler to generate optimized code that takes advantage of the Tandem 16's hardware characteristics. It also enables the programmer to code at an assembly-language level through the use of the CODE statement and to operate on hardware registers through the use of STACK and STORE statements.

Program elements such as constants, variables, labels, and procedures are identified throughout a source program by the use of symbolic, programmer-assigned identifiers. This eliminates the need for a programmer to keep track of specific memory addresses. An identifier can contain up to 31 alphanumeric characters.

A procedure is a block of machine instructions that exists only once in a program but can be called into execution from any point in the program. Procedures, as implemented in the T/TAL language, have special properties. A program has a global data area that is accessible only by statements within that program; a procedure has its own (local) data area that is assessible only by statements within that procedure. Unlike the program's global data area, however, a procedure's local data area is allocated and initialized only when the procedure s executed. Because a procedure has its own local data area which is initialized each time the procedure is entered, a procedure can call itself (recursive procedure). Subprocedures are similar to procedures in that they can have their own variables and can be called recursively. However, a subprocedure is a part of a procedure and therefore can be called only from the procedure in which it resides.

The T/TAL compiler program (TAL) reads source statements from one or more files and compiles the statements into a ready-to-run object program. Like the source program file, the object program file is given a name. The object program name is used to run or modify the program. As a by-product of the compilation, a completely annotated listing of the source program is provided. Certain listing options provide the machine instruction code generated and a map of all the identifiers used in the program.

Tandem COBOL conforms to the ANSI COBOL-1974 language specifications and runs in a mixed-language environment with T/TAL. Features of Guardian are supported through extensions to the language, including nonstop operations, shared and re-entrant code, virtual memory, geographic independence of I/O devices, and checkpoint/checkmonitor facilities.

STARTBACKUP and CHECKPOINT are the verbs that make the program nonstop. STARTBACKUP is normally called once at the beginning of the program to set the nonstop mode. Thereafter, the CHECKPOINT verb is used to pass information to the backup process at critical points in the processing. In a nonstop program, checkpoints will also occur automatically upon any OPEN or CLOSE executed after the backup has been established. Both of these verbs will set the special register, PROGRAM-STATUS, to indicate the outcome of the checkpointing operation.

Geographic independence of I/O devices is provided by several Tandem extensions to COBOL. The verbs LOCKFILE, UNLOCKFILE, and UNLOCKRECORD allow the use of the corresponding system file and record locking routines. This addition allows separate processors to share a common data base.

The READ and REWRITE verbs are extended to allow the specification of a LOCK or UNLOCK operation. The OPEN syntax is extended to specify the file access (EXCLUSIVE, SHARED, or PROTECTED), and to permit the SYNCDEPTH for files opened in the OUTPUT, I-O, or EXTEND mode.

Enscribe data base management features included in Tandem COBOL include key-sequenced, entry-sequenced, and relative file structures; logical file sizes of up to four billion bytes; one primary and up to 31 alternate keys; and optional mirror data base recording.

The level of support provided by Tandem COBOL for the various ANSI modules includes: Nucleus, level 2; Table Handling, level 1; Sequential I/O, level 2; Relative I/O, level 2; Indexed I/O, level 2; Sort-Merge, level 2; Library, level 1; Debug, level 1; and Interprogram Communication, level 1.

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Report-Writer, Communication, and Segmentation are not supported. Segmentation, however, is supported automatically via Guardian.

Tandem FORTRAN conforms to the full language specifications of ANSI FORTRAN-1978. All features of Guardian are supported through extensions to the language, including nonstop operation, shared and re-entrant code, virtual memory, checkpoint/checkmonitor facilities, Enscribe data base facilities, and interprocess communications.

STARTBACKUP and CHECKPOINT functions allow a FORTRAN program to utilize the nonstop capabilities of GUARDIAN. STARTBACKUP is called once at the beginning of a program to establish the nonstop mode. Thereafter, CHECKPOINT is used to pass critical information to the backup process. Checkpoints will occur automatically upon any OPEN or CLOSE after the backup has been created.

Extensions to the FORTRAN READ and WRITE statements permit the full use of the Enscribe data base facilities. Thus, it is possible with FORTRAN statements to access key-sequenced, relative, and entry-sequenced files by primary keys or up to 255 alternate keys. Provision has been made to allow exact, approximate, or generic positioning into an Enscribe file structure using FORTRAN. Concurrent record access is supported with LOCK mechanisms at either the record or file level.

FORTRAN processes can communicate with one another or with processes written in other languages through the standard FORTRAN READ and WRITE statements. Communication with other processes is implemented using the interprocess communication facilities of the GUARDIAN. In addition, FORTRAN is enhanced so that the Tandem Data Definition Language can also be used to transcribe a schema into FORTRAN record structures.

ENSCRIBE DATA BASE MANAGEMENT SYSTEM: This package provides high-level access to, and manipulation of, records in data bases. Enscribe operates under Guardian in a distributed manner across multiple processors to ensure the integrity of the data base in the event of a processor, I/O channel, or disk drive failure.

Enscribe offers three disk files structures: key-sequenced, with variable record lengths; relative, with fixed record lengths; and entry-sequenced, with variable record lengths. A data definition language, along with edit and schema programs, is provided to describe the access structure of the data base.

Records can be accessed randomly by specifying a key or keys, or sequentially by consecutively accessing the records in the collated order of an index. Since multiple key fields can be defined, multiple indices allow an indexed file to appear as sequential. Moreover, Enscribe provides three indexing options: exact key match, approximate key match, and generic key match. Approximate match means that the record key may be equal to or greater than the search key; this allows a user program to access records without knowing the exact key. Generic key match means that only the initial portion (partial key) of a key need be specified (such as the prefix to a part number in a vendor's record).

Other features of the system include multi-key access to records (up to 255 alternate key fields), automatic maintenance of all keys, data compression for key-sequenced files, index compression, record locking, multiple-volume files, a cache buffering scheme, and a file utility program to create data base files.

Enform, used in conjunction with Enscribe, is a nonprocedural language that enables the user to make ad hoc queries with simple requests in English-like statements. In addition to being invoked interactively via terminals, Enform procedures may be used in COBOL, FORTRAN, or T/TAL programs.

ENTRY SCREEN FORMATTER: Entry performs tasks including forms creation, display of forms, access to individual fields, and testing of forms independently of application programs. In addition, Entry provides facilities to modify or update old forms, insert multiple forms in a single disc file, and provide length and field validity checking attributes for user-defined error checking.

Extensive validity and error checking is accomplished via the Tandem-supplied Entry procedures. When an error is made in the creation or data entry process, a flashing cursor is positioned over the field in error and an error message is printed to pinpoint the error.

TANDEM SORT: This program reorders a set of records according to the values of sort key fields defined within the records in either ascending or descending order. It can be driven by a set of commands entered conversationally, by a text file containing the commands, or by a user's application program.

Records can be passed to Sort from a file, or sent one by one through procedure calls from a user's program. Similarly, the sorted set of records can be written to a file, or the user's program can call a procedure to retrieve the records, one per call.

Actual sorting runs as a separate process from the host program. Standard interface procedures, which are present in the sort command interpreter program or called from the user's program, handle process creation, control, and communication.

In most large sorts, the memory is insufficient to sort all the data at once, so Sort splits the input data into sorted pieces (runs) it can handle and puts them into a scratch file. Sort then uses the replacement/selection method of merging runs together to produce the final product.

EXCHANGE REMOTE JOB ENTRY SUBSYSTEM: The software provided in this subsystem enables a Tandem 16 linked to an IBM System/360 or 370 computer to emulate the IBM 2780 or 3780 remote batch workstation. Exchange handles batch I/O from/to all devices, including terminals, tape transports, disk drives, and printers. Commands utilized by Exchange can be entered conversationally from a stored command file or programmatically from an application routine. ASCII or EBCDIC, horizontal tab and vertical forms control codes, EBCDIC transparent code, and blocked link messages can be transmitted or received. Exchange also performs short-record truncation and blank-field compression.

Support is provided by Exchange for file transfers between workstations. Exchange generates warning codes for conditions such as inability of the system to transmit or receive because it is already handling an uninterruptible process run.

ENVOY DATA COMMUNICATIONS MANAGER: Envoy, Tandem's software interface between transaction-oriented application programs and a telecommunications network, operates under control of Guardian. Envoy supports IBM Binary Synchronous, ADM-2 Asynchronous, Burroughs Synchronous, and TINET Asynchronous protocols. ADM-2 Burroughs protocol is used to communicate with the T16/65XX Page Mode Terminals with the polling interface option installed or with Burroughs terminals that interface to the Burroughs Basic Poll/Select protocol. TINET protocol is used to communicate with Texas Instruments Numeric Entry Terminals operating as multipoint tributary stations.

Envoy supports point-to-point lines for bisync protocol, centralized multipoint supervisor lines for all protocols, and

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centralized multipoint tributary for bisync protocol. Additionally, for synchronous protocols, Envoy supports multipoint polling and ASCII/EBCDIC translation, both performed by synchronous controller hardware. Further, transparent text is recognized by synchronous controller hardware.

Hardware supported by Envoy includes Bell type 103 and 202 modems for asynchronous operations, Bell type 201 and 208 modems for synchronous operations, and an auto call facility.

Envoy provides a trace facility, line usage and error statistics, and on-line testing. The Envoy trace facility works with all line types except auto call units. It records line events in a table where each entry provides sequence number, controller and line number, line state, line event, and time stamp. Line statistics are maintained for each line from the time a line is opened until the line is closed. The statistics appear on the system console when a predetermined error threshold is exceeded, when a path switch occurs, or when the line is closed. On-line testing is used to verify the operation of the data communications process and the synchronous controller operating as a point-to-point nonswitched primary or secondary line, point-to-point switched primary or secondary line, or multipoint supervisor or tributary line.

Envoy supports synchronous transmission at speeds up to 80K bps and asynchronous transmission at speeds up to 19.2K bps.

GUARDIAN/EXPAND NETWORK: In October 1978, Tandem announced Guardian/Expand, a communications network system. An extension of the Guardian operating system, Guardian/Expand can accommodate up to 255 geographically dispersed systems, each with a maximum of 16 central processors, all operating in Tandem's fault-tolerant mode.

Guardian/Expand provides for automatic routing, and rerouting as necessary, of communications among network modes. Any system located within the network can communicate with any other system without traditional point-to-point connections between all the systems. Also, systems capable of network communications may be added to the network by simply being connected to any one of the existing systems.

Computing resources and data bases in an Expand network are location-transparent to operators and programmers, and application programs are identical for single or multiple systems. A program resident in any system in a Tandem network may access data (subject to user-imposed security restrictions) resident in any other system. The program will be executed in the system on which the program file resides, or the user may request that the program be run remotely.

Automatic routing in the Guardian/Expand network is accomplished by the Network Control Process (NCP) which resides in each system. Through an algorithm, the NCP assures that data is communicated via the best path in terms of minimum travel time. In the event of a line failure, the NCP automatically reroutes communications in accordance with the next best travel time between communicating systems.

Keys to the automatic routing process are NETMAP, the Network Routing Table (NRT) data arrays, and NETCHANGE, a message service, all managed by the NCP. If the NCP is advised by NETCHANGE of a change in status of a line or system node, it determines via its algorithm if there is a path of communications shorter than the one currently being utilized and accordingly alters NETMAP. All systems are then notified by NETCHANGE, and the NRT is updated with this latest information and forwarded data packets are directed to the proper systems. Residing within the Network Control Process is a tie-breaker algorithm for use in the event that two or more alternate routes are identical in terms of travel time between two communicating systems.

APPLICATIONS: Tandem does not provide application software at the present time, but from time to time it may assist customers with particular programs.

PRICING

POLICY: The manufacturer offers the Tandem systems on a purchase-only basis, with some bundled and some separately priced software. Maintenance is also separately priced. Tandem can assist the customer in obtaining third-party leasing.

System deliveries are F.O.B. Tandem's plant. The warranty period extends for 90 days after initial delivery. Tandem provides on-site installation for fixed fees stated in the equipment price list at the purchaser's location within the contiguous United States. For other locations, consult Tandem. Installation facilities, including electrical power and connector requirements, are the responsibility of the user and must be completed prior to installation.

Tandem provides training classes on a fee basis in software programming (COBOL, FORTRAN, and T/TAL) and hardware maintenance. Classes range in duration from one to three weeks. Software courses are priced at $300 per week per student, and hardware courses at $500 per week per student.

Tandem provides post-warranty maintenance service under a standard maintenance contract.■

EQUIPMENT PRICES

PACKAGED SYSTEMS

All packaged systems include twin processing modules, each with power-fail/auto restart, memory mapping, bootstrap loader, interval timer and DMA. Core memory systems employ one parity bit per 16-bit word; MOS memories, 6-bit Hamming code for error detection and correction. Systems also include dual Dynabus redundant interprocessor links rated at 13 megabytes per second each, two block multiplexer channels rated at 4.0 megabytes per second each (MOS memory systems) or 2.5 megabytes per second each (core memory systems), and a T16/6001 Console Subsystem with patch panel. Bundled software includes Guardian Operating System, T/TAL language, Edit, Update, and Debug.

		Purchase Price	Monthly Maint.	Installation
T16/212-1	Core 4" measure System; includes two T16/1102 processors each with 192K bytes of 800-nanosecond core memory expandable to 448K bytes, 14 unassigned I/O slots for system expansion, T16/7102 System Cabinet, T16/3202 Magnetic Tape Controller, and T16/5103 Magnetic Tape Drive	98,975	552	—

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EQUIPMENT PRICES

		Purchase Price	Monthly Maint.	Installation
PACKAGED SYSTEMS (Continued)				
T16/244-2	Semiconductor System; includes two T16/1403-1 processors each with 96K bytes of 500-nanosecond MOS memory expandable to two megabytes, 14 unassigned I/O slots for system expansion, T16/7104 System Cabinet, T16/302 Magnetic Tape Controller, T16/5103 Magnetic Tape Drive, and two T16/7303 Battery Packs	84,575	552	—
T16/244-3	Same as T16/244-2 except that each processor is the 384K-byte T16/1412-1	98,975	552	—
PROCESSORS				
	Tandem processors include two microcoded pipelined processing units, one for CPU and Dynabus control and one for I/O control, each with 100-nanosecond cycle time; complete DMA-only I/O system (2.5 megabytes per second in core memory systems and 4 megabytes per second in MOS memory systems); virtual memory control; memory mapping and protection for up to 512K bytes of memory; hardware multiply/divide; power fail/auto restart, bootstrap loader; interval timer; control panel; Dynabus controller and interface; interfacing for 32 I/O controllers; 123-member instruction set; and power supply. Bundled software includes Guardian Operating System, T/TAL language, Edit, Update, and Debug.			
T16/1102	Processor with 64K bytes of 800-nanosecond parity core memory	20,400	106	60
T16/1403-1	Processor with 96K bytes of 500-nanosecond error detection and correction MOS memory; includes floating point	22,000	136	80
T16/1412-1	Same as T16/1403-1 but 384K bytes of memory	36,400	196	80
PROCESSOR OPTIONS				
T16/2001	Decimal Arithmetic Package	1,500	20	80
T16/2002	Enscribe Microcode; allows Enscribe software to run on the specified processor	1,000	—	40
T16/2003	COBOL Microcode; allows COBOL compiler to run on the specified processor; not required once program is compiled	500	—	40
T16/2205	Floating Point Hardware; adds 40 instructions to basic set	1,500	20	—
T16/7301	Power Module; supplies power for I/O controllers in large configurations	2,400	34	320
T16/7302	Isolation Transformer; 15 KVA	4,000	15	50
T16/7303	Battery Pack Backup for MOS memory	1,500	15	50
T16/7901	Service Panel; plug-in service and maintenance panel	5,000	15	—
MEMORY				
T16/2102	64K-byte Parity Core Memory Module; 800-nanosecond cycle time	8,000	30	60
T16/2403	96K-byte Error-Correcting MOS Memory Module; 500 nanosecond cycle time	7,200	60	60
T16/2412	384K-byte Error-Correcting MOS Memory Module; 500-nanosecond cycle time	21,600	120	80
MASS STORAGE				
T16/3102	Single-Port Disc Controller for up to four drives; powered from either processor; uses 2314 recording technique	4,800	21	60
T16/4101	10-megabyte Moving-Head Disc Drive; top-loading, fixed and removable cartridge; includes cartridge; requires T16/3102	8,000	63	160
T16/4102	50-megabyte Moving-Head Disc Drive; 11-platter pack included with drive; requires T16/3102	14,500	171	160
T16/3103	Dual-Port Disc Controller for up to eight drives; powered from either processor; uses 3330 recording technique	10,500	50	160
T16/4103	160-megabyte Moving-Head Disc Drive; 11-platter pack included with drive; requires T16/3103	24,500	180	160
T16/4104	240-megabyte Moving-Head Disc Drive; 11-platter pack included with drive; requires T16/3103	31,500	180	160
T16/4105	64-megabyte Moving-Head Disc Drive; 5-platter pack included with drive; requires T16/3103	15,500	150	160
T16/7504	Disc Patch Panel; provides connection between T16/4103 and T16/3103; supports up to six controllers and 24 drives	775	—	60
MAGNETIC TAPE EQUIPMENT				
T16/3201	Magnetic Tape Controller for up to two drives; 800 bpi, dual channel connected; can be powered from either processor	3,800	20	60
T16/3202	800/1600 bpi Controller; otherwise same as T16/3201	4,800	20	60
T16/5104	Magnetic Tape Drive; 125 ips, 9-track, 800 bpi NRZI and 1600 bpi PE; requires T16/3201 or T16/3202	14,500	95	240
T16/5103	Magnetic Tape Drive; 45 ips, 9-track, 800 bpi NRZI and 1600 bpi PE; requires T16/3202	8,000	50	240
PRINTERS				
T16/3302	Line Printer Controller for two printers; one T16/5501 or 5506 and one T16/5502, 5503, 5504, or 5505; dual channel connected; can be powered from either processor	2,800	17	60
T16/3305	Card Reader/Line Printer Controller for one printer and one card reader; dual channel connected; can be powered from either processor	2,800	17	60
T16/5508	Serial Printer; 200 cps, 96-character set	4,500	48	120
T16/5506	With pedestal mounting	5,975	60	120
T16/5507	With connection for asynchronous controller	5,975	65	120

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EQUIPMENT PRICES

		Purchase Price	Monthly Maint.	Installation
PRINTERS (Continued)				
T16/5502	Line Printer; 300 lpm, 64-character set	11,500	133	180
T16/5503	Line Printer; 600 lpm, 64-character set	14,000	154	180
T16/5504	Line Printer; 900 lpm, 64-character set	21,000	175	180
T16/5505	Line Printer; 1500 lpm, 64-character set	42,000	225	200
T16/5A	96-character Drum Option; for T16/5502, T16/5503, T16/5504, or T16/5505	950	—	240
T16/5B	OCR-A Drum Option; 64-character set; for T16/5502, T16/5503, T16/5504, or T16/5505	—	—	240
T16/5C	OCR-B Drum Option; 64-character set; for T16/5502, T16/5503, T16/5504, or T16/5505	—	—	240
T16/5D	OCR-A Drum Option; 96-character set; for T16/5502, T16/5503, T16/5504, or T16/5505	—	—	240
T16/5E	OCR-B Drum Option; 96-character set; for T16/5502, T16/5503, T16/5504, or T16/5505	—	—	240
PUNCHED CARD EQUIPMENT				
T16/5301	Card Reader; 80-columns, 600 cpm; requires T16/3305	4,800	40	140
TERMINALS				
T16/6603	Hard-Copy Terminal; 30 cps, 132 columns; RS-232 interface	3,200	44	120
T16/6604	With 20-ma current loop interface	2,900	40	120
T16/6001	Console Subsystem; includes dual channel connected T16/6301 Controller and T16/6604 Hard-Copy Terminal	4,300	60	80
T16/6401	CRT Character Terminal; 24 lines by 80 characters; local or modem attachment; RS-232 interface	1,500	25	120
T16/6402	With 20-ma current loop interface	1,500	25	120
T16/6511	CRT Page Mode Terminal; character or page mode; RS-232 interface	1,500	25	120
T16/6512	With 20 ma current loop interface	2,400	35	1-0
T16/6552	With pooling protocol for multidrop communications lines	2,700	38	120
T16/6C	Upper/Lower Case CRT Option; for T16/6401 and T16/6402	150	—	40
COMMUNICATIONS EQUIPMENT				
T16/7501	Terminal Patch Panel; provides connection between asynchronous controllers and up to 17 17 terminal ports	775	5	60
T16/7502	Synchronous Patch Panel; provides connection between synchronous controllers and up to 12 synchronous lines (3 controllers)	775	5	60
T16/7503	Twin-Mini Terminal Patch Panel; provides connection between asynchronous controllers and up to 17 terminal ports in a Twin-Mini system	775	5	60
T16/7507	Sync/Disc Patch Panel; provides connection for up to 8 synchronous lines (2 controllers) and 8 T16/4103 Disc Drives or 2 T16/3103 Controllers, (whichever comes first) on Twin-Mini configurations	775	5	60
T16/6202	Byte Synchronous Controller; dual channel connected; may be powered from either processor; controls up to four synchronous communication lines, either point-to-point or multidrop	5,800	25	80
T16/6301	Asynchronous Controller; dual channel connected; may be powered from either processor; controls up to two terminal lines, either hard-wired or modem-connected	2,900	15	100
T16/6302	Asynchronous Extension Board; provides additional control for 15 asynchronous lines	4,300	18	60
T16/3401	Universal Interface; dual channel connected; can be powered from either processor; controls any two devices having 16-line parallel interface	2,800	17	60
HARDWARE				
All system cabinets include Dynabus redundant interprocessor priority resolution circuitry and data paths, provide I/O controller power switching, and provide processor I/O channel wiring.				
T16/7100	Small System Cabinet; provides space for up to 2 processors and 8 I/O controllers, each processor having 5 memory slots; can accommodate 128K bytes of core memory or 320K bytes of semiconductor memory per processor	3,800	30	320
T16/7102	Large System Cabinet; provides space for up to 2 processors and 16 I/O controllers, each processor having 14 memory slots; can accommodate up to 448K bytes of core memory or 512K bytes of semiconductor memory per processor; can accommodate up to 2 additional I/O expansion boards (T16/7801)	6,800	30	320
T16/7104	Large System Cabinet; provides space for up to 4 processors and 16 I/O controllers, each processor having 6 memory slots; can accommodate up to 192K bytes of core memory or 512K bytes of semiconductor memory per processor; can accommodate up to 2 additional I/O expansion boards (T16/7801)	6,800	30	320
T16/7801	I/O Expansion Board; provides eight additional I/O slots for systems cabinets; maximum of two per cabinet	970	—	320
T16/7901	Service Panel; plug-in panel for servicing and maintenance	5,000	15	—

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SOFTWARE PRICES

		Microcode	One-Time License Fee	Monthly Maint. Fee
T16/9002	Enscribe Data Base Record Manager	$1,000	$4,000	$ 40
T16/9201	Tandem COBOL	500	7,000	60
T16/9202	Tandem FORTRAN	500	6,000	60
T16/2005	Microcode for floating point	1,500	—	—
T16/9005	Exchange RJE	—	2,000	20
T16/9608	Entry Screen Formatter	—	2,000	20
T16/9609	Entry 270 Screen Formatter	—	2,000	20
T16/9006	Xray System Performance Monitor	—	2,500	25
T16/9007	Expand	1,500	10,000	100
T16/9101	Spooler	—	2,000	20
T16/9102	Enform	1,500	7,000	70