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From Tandem Computers Incorporated
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Contact James G. Treybig

TANDEM UNVEILS FIRST MULTI-PROCESSOR SYSTEM USING TEAM APPROACH FOR NONSTOP OPERATION

SANTA CLARA, Calif., Dec. 1, 1975 -- Tandem Computers Incorporated today introduced its Tandem 16 NonStop™ computer system, the first economical multiple processor system designed for uninterrupted fail safe operation by transaction-oriented computer users.

Each NonStop system consists of a minimum of two and a maximum of sixteen 16-bit processors interconnected by a redundant Dynabus™. Capable of supporting as many as 1,000 terminals, the system offers very low cost, high throughput and high probability of NonStop operation for users such as banks, insurance companies, the retail and wholesale trades and the transportation industry. In short, it is essential for any user with a need for a large number of terminals for inputting transactions or

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inquiring into file records, and whose own business requires that the computer does not shut down his terminals.

The minimum Tandem system, designated the NonStop 204, consists of two T16 processors with 32K words of core memory each; a 10 megabyte disk drive; a mag tape unit; an operator console; and 16 terminal lines -- all for a base price of $65,300. The NonStop system may be expanded to 16 processors with 512K bytes of high speed memory and up to 32 peripheral device controllers per processor.

The 204 system provides processing power and I/O throughput comparable to the PDP-11/45, the Eclipse or the IBM 370/168 computers -- plus it also offers complete security in the form of NonStop fail safe operation.

"Redundant systems aren't new, but NonStop marks the first time multiple processors have been both hardware and software designed to act as a team, virtually as one processor," said James G. Treybig, Tandem president.

"We believe that real NonStop operation means that if a failure occurs, not only must the system keep running, but the failure cannot contaminate the rest of the system and it must be repairable without interrupting operation," he explained. "This team approach means the user gets a powerful, high throughput computer system capable of handling his application, while specifying any degree of fail safe or NonStop operation desired. And all of this may be done using only standard hardware and software modules at costs considerably lower than

currently available systems."

Tandem also eliminates the high cost of custom programming for redundant operating systems, a cost usually borne by the user when he buys other systems, Treybig added. All fail safe features are included in Tandem's NonStop system. The user simply has to write his own application programs, the same way he does today on a single processor system.

"We anticipate that NonStop will be as important to the high throughput, transaction-oriented market as the IBM System 3 was to the data processing market," Treybig noted. "We believe this already important market will grow even larger in the future.

"The NonStop system hardware and software is fully developed and is right now undergoing extensive systems-level quality assurance testing in preparation for initial deliveries in April of 1976," he said.

The multiple processors of the NonStop system actually function in concert as a very powerful general purpose computer. The processors are Tandem's Model T16 units, which are built around a pipelined microprocessor with a cycle time of 100 nanoseconds, driven by a 32-bit wide control store. The processors are connected by Dynabus, a redundant independent bus structure with a 20 megabyte per second transfer rate and built-in bus control for automatic switchover or disconnect in the event of a processor failure or a bus failure between two processors. Each processor also incorporates an additional

microprocessor dedicated to I/O functions. I/O transfers are accomplished via a block-multiplexed DMA port at a four megabyte per second rate. In addition, all I/O device controllers are dual ported and thus are accessible from two processors.

The main semiconductor memory offers a 500 nanosecond access time, including mapping and error detection and correction. A unique four-map memory mapping system provides virtual memory in 1K word memory pages. Error correction in the semiconductor memory uses a full 22-bit error correction technique to correct all single-bit errors and detect all errors of two bits or more. The optional core memory provides a cycle time of 800 nanoseconds, including mapping and parity checking. Both the semiconductor and core memories are packaged on 32K boards. All software instructions are overlapped so that the next instruction is prefetched while the current instruction is executing.

Beyond these powerful computing capabilities, NonStop offers an order of magnitude greater probability, over other computer systems, that it will remain up and running. This is because the entire system is divided into modules. A module may be a CPU, an I/O device controller, a Dynabus link, an I/O bus or even a power supply. NonStop should be viewed as an assembly of such modules, configured so that whenever any one module that is necessary to assure NonStop operation fails, there is a redundant module to take over automatically.

This also is because whenever any module does fail, it cannot contaminate any other module. Thus the system can tolerate "disease" by isolating it and working around it.

For example, a particular processor, controller, peripheral, data port or even a power supply can go down without taking down any other portion of the system. Its workload is transferred automatically to another module in the system and the device itself can be physically removed for repairs without affecting the rest of the system. Additionally, because of the dual interconnects between all modules, if a bus failure should occur, all transactions would be shunted to the other port for devices affected.

Tandem refers to this total independence of operation as its "democracy" concept. Simply stated, it means that no module can destroy any other module or more than one interconnect path. No module can propagate problems that might cause further problems. And any module can be removed and repaired without disturbing the rest of the system because controllers are connected in a star pattern rather than a daisy chain format, and power distribution to all I/O controllers is also completely redundant.

"The primary difference between NonStop and all other systems is its unique matching of software and hardware to make multiple processors work like a single processor," Treybig explained.

"Most manufacturers sell single processors with operating

systems that only know what is going on within that processor, with I/O drivers for the peripherals that are actually connected to it. When connecting dual processors, therefore, the inter-processor bus looks like just another peripheral to the computer. This means that the user must overlay another operating system on it or rewrite the manufacturer's operating system from scratch to provide the complex systems functions of communicating with redundant computers and operating peripherals connected to other processors. This systems programming requirement often is beyond the capabilities of most applications programmers; many customers just don't have the people to do it."

NonStop processors have a specially designed operating system that allows each processor to know what is going on in all other processors and at every peripheral device. Because user programs, user files and I/O drivers all have geographic independence, the user's applications programmer need not concern himself with where an I/O device is connected or a file is stored. Rather than being a typical master/slave heirarchy of processors and peripherals, it is a democratic array of equals. Each processor is controlled by its own operating system and it can request help from other processors -- but it cannot demand help. In addition, each processor has a unique "kill" command to disconnect its own port to a controller if it runs amok.

The NonStop operating system thus has provided all the

systems functions. The user needs to write only his applications software and go to work, Treybig concluded.

"This system truly has been designed to eliminate computer downtime," he said. "Computers are being put into contact with people for the performance of their jobs. This means that transactional users cannot conduct their business when a computer fails. Most users are willing to permit some degree of reduced operation in a system, because of a failure, but they cannot tolerate a total shutdown.

"This is an important difference to the user -- between a terminal that goes completely dead and is unable to process a bank account transaction, and one that tells you there will be a momentary delay in processing the transaction because a disk controller has failed and the file is being transferred to another disk drive.

"Most importantly, NonStop provides this solution at an affordable cost for the smaller business and eliminates the need for skilled software capability on his part."

Tandem Computers Incorporated, headquartered in Santa Clara, was founded in November of 1974 specifically to design and manufacture the NonStop system.

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Contact Samuel J. Wiegand

A NEW APPROACH TO AN IMPORTANT, GROWING MARKET

The most frustrating problem that can occur to a company that relies on a central computer system for its transaction processing is to have that computer fail. To prevent a catastrophic total breakdown of the work process in the event of a computer failure, many organizations rely on redundant computer systems for fail safe operation.

Redundant systems aren't new. They range in size from the giant, globe-girdling computer network set up by the National Aeronautics & Space Administration, to the hotel/motel reservation system that may simply be a dual processor minicomputer system.

Currently this market accounts for some $250 million a year in computer sales and it is growing at a rate of about 30 per cent a year. No single manufacturer dominates the market presently and most manufacturers sell about five

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per cent of their volume into redundant applications, almost wholly through custom-designed special systems.

Tandem believes, however, that this market will grow to $800 million per year in size over the next five years, now that a standard, low-cost solution is available.

There are a number of common needs evidenced by users in this market. In general, they are:

- all applications involve the inputting of transactions to the computer or inquiring into files;
- most users have a broad range of operations and thus require a network of terminals;
- most users need a powerful, high throughput computer system to handle large volumes of transactions;
- and most must have multiple processors to provide backup processing capability in case of a failure anywhere in the system.

"Unfortunately, most manufacturers have responded to this need by providing redundant dual processor systems using their conventional hardware and software products," said Samuel J. Wiegand, Tandem vice president of marketing. "These conventional computers were not designed to work together and the resulting systems are extremely difficult to program, very expensive, difficult to expand and not truly fail safe in real operation.

"The problems encountered in implementing these patchwork systems are left entirely to the customer also," he explained. "Two conventional computers frequently may be slower than a

single processor because the communication between the two takes place at a much slower rate than that of a single computer dealing with its own peripherals. This leaves most users with a poor choice of alternatives: either use a lower cost, higher performance single processor system that has no fail safe provision; or implement a fail safe system using dual processors and bear the high cost of additional system software while paying a performance penalty."

Tandem's new NonStop™ system combines the best of both options. It provides users with multiple processors and totally redundant interconnections between all processors, controllers, power supplies and peripheral equipment. And it provides users with a very powerful, high throughput system at a relatively low cost. In addition, the user isn't required to have in-house software expertise to do any systems programming. All he needs to write is his own application programming. Thus the standard package, providing full hardware and software NonStop capability, is available at an affordable price for the smaller user -- an event that is expected to broaden the NonStop systems market considerably.

The major markets for which the new system is most useful include:

- banks and savings and loan associations, particularly smaller ones that haven't invested in fail safe computer systems yet. They now can develop the same type of system larger banks have, but without the high

cost and long development time.

- retail and wholesale sales operations;
- communications companies, for PABX line control, automatic answering systems, message switching, etc.;
- insurance companies;
- multi-divisional manufacturing companies;
- securities dealers and stock exchanges;
- the transportation and travel industries;
- hotel/motel networks;
- and computer service bureaus.

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Contact James G. Treybig

A UNIQUE COMBINATION OF HARDWARE & SOFTWARE FEATURES

The Tandem 16 NonStop™ system is not only a high volume transaction-oriented data processing system that is substantially more reliable than previous systems, it offers the capability at cost levels far below existing multi-processing systems. Its new computer architecture and software system give Tandem the ability to provide any level of NonStop operation using standard hardware and software modules.

The simplest system can be expanded to accommodate complex data networks supporting thousands of terminals and providing nearly 20 billion bytes of disk memory with a reliability unapproached by any commercial computing system.

The Hardware

Each T16 processor in the Tandem 16 system is built

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around a pipelined microprocessor that has a cycle time and clocking of 100 nanoseconds. The microprocessor is controlled by 32-bit microinstructions and has 15 microinterrupt levels. Just 2K bytes of the 8K bytes of microprogram storage provided are used for the basic instruction set. To enhance performance, a second microprocessor is dedicated to I/O functions.

Each processor has eight general purpose registers normally used as a stack. The 122 basic instructions include a powerful group of string manipulation instructions to enhance the processing of communications lines or terminal-entered data. The processor includes a built-in interval timer, seven memory addressing modes, microprogrammed bootstrap load, a power fail/auto restart feature, hardware multiply/divide, 32-bit add/subtract and DMA.

The NonStop system comes with standard semiconductor main memory that can support up to 512K bytes arranged as 22-bit words (16 data bits plus six error correction bits). All single bit errors are corrected automatically and all double bit errors are detected. Semiconductor memory cycle time is 500 nanoseconds, including time required for mapping and error detection or correction.

With optional core memory in place of semiconductor, the system can support up to 256K bytes arranged as 17-bit words (16 data bits plus one parity bit). Cycle time is 800 nanoseconds.

The main memory is mapped for complete memory protection

and relocation. Four maps are provided, for system code, system data, user code and user data. In fact, the memory mapping capability automatically reallocates user code or non-critical operating system code to alternate physical memory pages upon detection of a parity or uncorrectable memory error. Such errors cause most other systems to halt automatically rather than remain running.

The I/O structure of the NonStop system is a micro-processor controlled, block-multiplexed channel able to handle variable length transfers to buffered dual port controllers. The I/O channels have been designed so that no single module failure can impair system operation, yet to handle very high transaction rates and to maximize throughput. Each I/O transfer is handled as a sequence of data blocks, the length of which may vary from one byte to the total buffer size of the particular controller involved. Data transfers are controlled by the dedicated microprocessor in each T16 processor.

One processor can support up to 32 dual port controllers. All controllers have two ports so that they can be connected to two processors to prevent isolation through the loss of a processor or its I/O bus.

Each communications or terminal controller can handle up to 32 lines. Each disk controller can handle up to four drives, from 10 megabytes to 80 megabytes in size. Each mag tape controller can handle two 800 BPI units. Each printer

controller can handle two 600 LPM line printers. All peripherals are connected in a star pattern, rather than in a daisy chain format, so that if one device fails it won't take down any others in the group.

The Software

Tandem's Transaction Operating System (T/TOS) for the NonStop system is a multiprogramming, multiprocessing, virtual operating system designed for high transaction rates, easy expandability and NonStop operation. A copy of T/TOS software resides in each processor module so that a processor failure doesn't limit system capability.

T/TOS allocates execution time to multiple programs on a priority basis; allocates buffer space and control blocks; handles process synchronization; fault and trap handling; and interval clock maintenance. T/TOS also provides an efficient virtual memory management system in which all code is sharable by multiple programs and non-modifiable.

In addition, T/TOS provides a number of standard operating system features that, in the case of most other computer systems, usually are the responsibility of the applications programmer. These include:

- Geographic independence of programs and data. This feature means programs may run on any or all of the T16 processors in the NonStop system; that they may access any device in the system, even if the device

is not physically connected to the processor in which the program is running; and that the system can be expanded without reprogramming the application.

- Multiprocessor message system. This feature handles all communications between the processor modules, system processes and application programs. It routes all messages to the correct processor, verifies that they got there correctly and decides which program is to receive them in the destination processor.
- Data validation and processor protection. To prevent system corruption by a "mad" processor, comprehensive data validation is performed on all transfers between processors. Also, a faulty I/O device cannot corrupt a processor's memory because the address and count words are held by the I/O processor, not the device.
- Automatic detection and isolation of faulty modules. Every data path in the Tandem system has either parity, checksum or error correction logic. Additionally, all transfers between processor modules are provided with an application-dependent timeout used to determine when a processor is not responding.
- On-line diagnosis, repair and reintegration of a faulty module. T/TOS provides on-line diagnostics to test any system module without disturbing the operation of the rest of the system. The component can be electrically disconnected and repaired or replaced. After initial-

ization by a T/TOS command, the replaced module resumes its role in the system.

In addition, T/TOS provides as part of the operating software a file management system that allows an application program to communicate with disk files, serial I/O devices, conversational, page-mode and multi-drop terminals, and other application programs -- all through one standard set of routines. A number of fail safe features are provided here, also. Each file request is provided with a variable, application-assigned watchdog timer to be sure that an application program isn't stopped due to a faulty processor. When the watchdog expires the File Manager automatically informs the application and reroutes subsequent requests to a backup processor module that has been kept aware of the state of the device. This provides the application with a simple method to monitor the state of other processors and switch application execution to a backup processor in the event of a failure.

NonStop standard software includes T/TAL, Tandem's Transaction Application Language, which is a high level, block-structured language designed for easy implementation of transaction-oriented applications. It provides many high level constructs without sacrificing execution efficiency. T/TAL is a highly optimized compiler that produces object programs that are as efficient as those written in assembly language, but with a greatly reduced development time.

In addition to T/TAL, the standard software package includes a text editor, an object file editor, an interactive debugging facility for testing of application programs, and a complete set of processor and peripheral diagnostic programs.

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A computer that won't shut down

Jon Brenneis

Treybig: "Tandem incorporates all the interface devices the others sell as extras."

The proliferation of computer terminals at bank windows, airline counters, branch offices, and hotel reservation desks has brought a new problem for business: When an on-line computer stops, the business stops.

The surest and most obvious way to prevent such emergencies is to tie together two or more computers to create a "failsafe" system. Companies—mostly large ones—are already spending an estimated $200 million a year to avoid the consequences of computer breakdowns, and the expenditure is growing at about 35% annually.

But such failsafe systems are virtually custom built for the user, who must invest in specialized hardware and devise his own software to link the backup system to the primary computer. Such costs can easily double the price of the original computer installation. The so-called fourth-generation computers, which are expected to be widely available within the next five years, will solve some of these problems because they will rely more on networks of interconnected small computers, each assigned a specific task. For many applications, they will eventually replace current large central computers that do multiple jobs. In such multiprocessing systems, no one breakdown will shut down a company.

But until then, businesses that depend on continuous and reliable computer operation suffer from a technological gap. This week a fledgling computer company called Tandem Computers Inc. announced a product that will attempt to fill that gap at a cost lower than current solutions.

"Most computers are just not designed to run with each other," says James G. Treybig, Tandem's 35-year-old president. "We decided to start from scratch and design a different kind of computer—one that runs all the time." The Tandem 16, which Treybig says will be ready for shipment in April, builds on minicomputer technology. It is designed around a series of low-cost processor modules using stock components. Each module can jump into action if another fails or loses its power supply. Similarly, all the peripheral devices and their controllers are designed to keep going despite processor failures.

Tandem is intriguing computer industry observers for other reasons as well. The Santa Clara (Calif.) company has managed to secure $3 million in financing at a time when most venture capital sources have all but run dry. And Tandem's concept of linking multiple processing units is widely expected to be the hallmark of the next generation of computers.

Raiding. With its Model 16 still in the engineering prototype stage, Tandem has little to show potential customers now except the résumés of its founders. But these are impressive because Treybig and his financial backers pulled off the unusual feat of recruiting top engineers from Hewlett-Packard Co., a company known for its ability to keep

Tandem Computer's new failsafe system will prevent costly breakdowns

people. Treybig, a Texan with an MBA from Stanford University, was marketing manager for H-P's minicomputer operation. He lured to Tandem Michael D. Green, vice-president for software development who designed H-P's first timesharing system; James A. Katzman, vice-president for engineering, who was a key architect of the 3000, H-P's biggest computer; and John C. Loustanou, financial vice-president, who was finance and cost accounting manager for H-P's Data Systems Group.

Tandem got its start early in 1973, when Treybig left H-P after a management shuffle and took his idea for a failsafe computer to Thomas J. Perkins, another former H-P executive who is now a venture capitalist based in Menlo Park, Calif. Perkins was intrigued. "Jim had established that the idea was theoretically possible," he recalls, "but it needed development. So we hired him to work on Tandem and other ventures." Treybig worked about 18 months for Perkins and his partner, Eugene Kleiner, a founder of Fairchild Semiconductor, but he soon began spending all his time on Tandem. In mid-1974 Kleiner and Perkins put $50,000 into the company, allowing Treybig to recruit Green, who was still at H-P, and Katzman, who was then working for Amdahl Corp.

"The real start of the company was Mike [Green] and Jim [Katzman] sitting down and deciding which hardware and software combination would be the most efficient," Treybig says. Kleiner and Perkins were so impressed with the design that they anted up another $1 million to carry Tandem through 1975.

Last week Tandem closed the books on a second round of financing that brought in $2 million more from such sources as E. M. Warburg, Pincus, Princeton-based Data Science Ventures—and Kleiner and Perkins, who added another $500,000. Raising this amount of money at a time when few new ventures are finding financing is "a significant accomplishment," Tandem's Loustanou claims. "In fact," he adds, "we had to ask some potential investors to stop evaluating us."

Software support. What attracted the venture money was Tandem's unique approach to the backup market that today accounts for about 5% of mini-

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