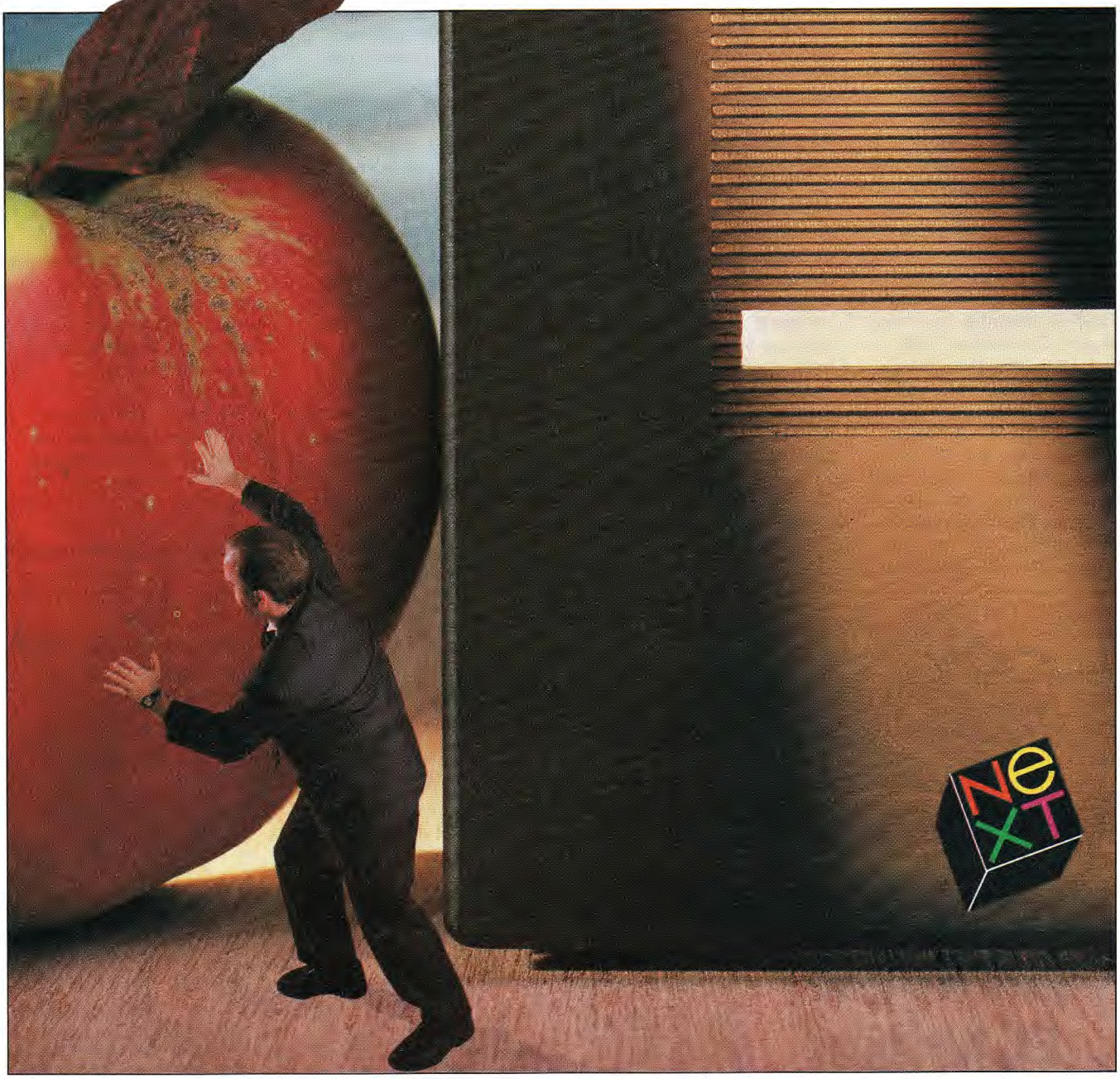
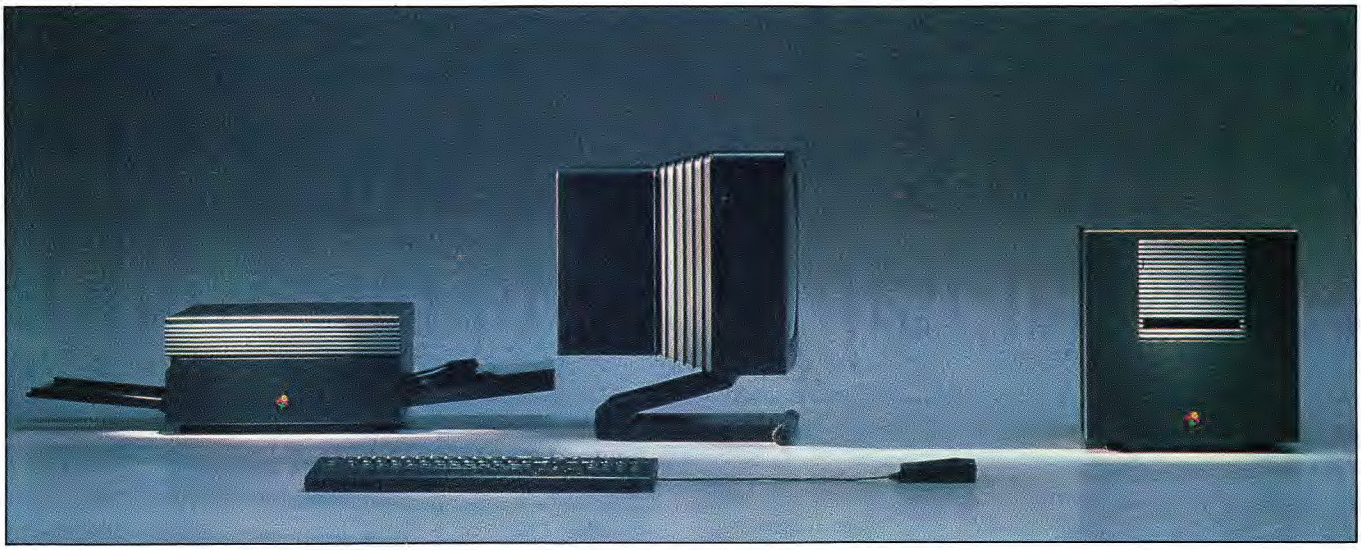
NeXT

The NeXT Computer System is very close to what designer Steve Jobs promised three years ago, and he is confident that it will be the micro for the next decade. Owen Linderholm says it's a breakthrough in price and power and may set an important standard.





When Steve Jobs left Apple three years ago and announced that he was going to build the NeXT thing in computers, he wasn't given much chance to succeed. But the NeXT Computer System is finally here. It has long been known to be intended as a Unix-based academic graphics workstation. However, it took so long to arrive that several other companies, notably Sun and Apollo, got well ahead in the field.

Out of the rumours, a few facts about the NeXT computer surfaced. It would use Display PostScript, a display version of the image control language PostScript, for screen output; it would have especially good sound quality and control built in; the processor would be the Motorola 68030; and the operating system would be loosely based around the Mach version of Unix.

The real thing, much to everyone's surprise, has turned out to be very close to what Jobs promised all along. It includes a coprocessor and a digital signal besides the 68030, all clocked at 25MHz, giving it a processing speed of five mips.

The most dramatic of its features is the first erasable optical drive, storing a staggering 256Mbytes. The main circuit board is a masterpiece of design, is very densely packed and uses surface mount techniques wherever possible. Even more amazingly, every single component apart from one is implemented in CMOS, meaning that it operates more coolly and uses considerably less power.

The board is made by an automated assembly line and is untouched by human hand from start to finish. The assembly line is able to produce boards much more quickly and accurately than boards this complex have been produced before; one of the reasons the final product is so cheap.

The system software is based on the Mach multi-processing version of Unix. Display PostScript is used to display a lightning-fast and very powerful graphical user interface with windows, menus, icons and object-orientated features.

It was designed in conjunction with an advisory board from US universities and colleges, and the collaboration shows in much of the design. The digital signal processor can be used for real-time data analysis, the 8Mbytes of RAM and 256Mbytes of disk storage provide ample space for research work and volumes of data. The operating system is based on Berkeley Unix, the academic standard, and a huge range of valuable research software is bundled with the computer.

Hardware

The computer is a matt, 30cm magnesium cube. It has stylish industrial design ventilation grilles on all sides. The only other features on the cube are two panels on the front for mass storage devices, one taken up by the optical drive with a wide slot showing; the NeXT logo at the bottom; the universal power supply connector at the back; and a cluster of ports along the bottom at the back.

There are seven ports at the back — two are 8-pin serial ports. There is also a standard coaxial connector for Ethernet, a 9-pin serial port for connecting to the NeXT Laser Printer, a SCSI (pronounced 'scuzzy') connector and a 15-pin D-connector to send and receive digital data from the digital signal processor chip.

The final connector is a 19-pin D-connector for the monitor, which carries the monitor power, mouse, keyboard and sound signals. The monitor (only one is currently available) is black and hooks up to this with a 3m cable. It has a 17in display and shows 1120 by 832 pixels in four grey scales, giving it an on-screen resolution of 92dpi. It rests on an ergonomic stand, which is adjustable for height and can tilt and swivel. The stand's wheels allow it to be easily moved around on a desktop. The monitor also has a small speaker.

The keyboard connects to the base of the monitor and is also black, as is the mouse. Other connectors on the monitor include a stereo headphone jack, two stereo connectors for hookup to external audio equipment and a microphone jack.

The keyboard has 84 keys, including cursor keys, a numeric keypad, a power on-and-off key (the only on/off switch for the computer) and two keys to control volume and screen brightness. There are two Alt and two Command keys on either side of the main keyboard. The mouse plugs into the keyboard completing a long daisy chain. It is a two-button mouse, but the buttons are small and awkwardly placed.

NeXT's own laser printer is a 400dpi unit using a modified Canon SX engine. It is smaller than most current 300dpi laser printers and is designed to reduce paper jams. The printer also has a 300dpi mode, or 'draft' quality as Steve Jobs described it. It has a universal power supply and a paper feed mechanism that can automatically handle different sized paper and envelopes.

Naturally, the printer is also matt black. It runs PostScript and has no external controls — everything is controlled from the NeXT Computer. It doesn't need an expensive PostScript interpreter and controller inside it since the computer al-

ready has the more advanced Display PostScript. Instead, the computer does the imaging and the printer only has a single VLSI custom chip inside.

Inside the cube

NeXT uses a 32-bit version of the NuBus architecture made popular by Apple in the Mac II. The cube has four slots for NuBus cards, with one holding the main board. The board is extremely dense; it is 30cm^2 and holds *all* the circuitry to control the computer and its peripherals. The only non-CMOS component on this board is a single array used for video and Ethernet I/O.

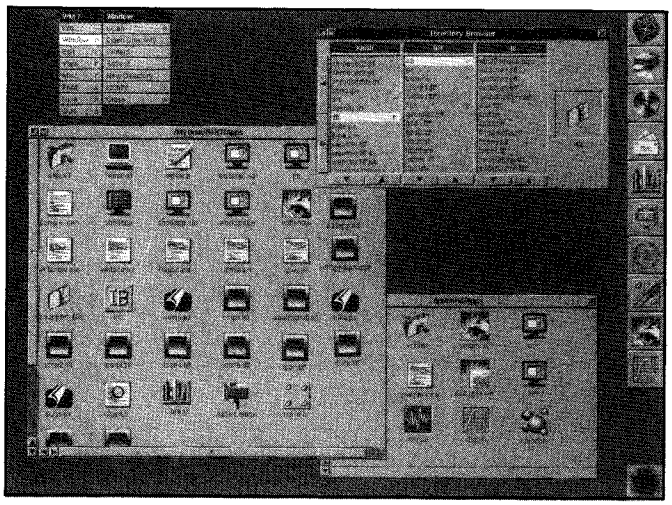
In the centre of the main board are the two custom VLSI chips that NeXT designed for the computer. These are the largest chips on the board, and both are twice the size of the main processor. One chip, the Integrated Channel Processor, is responsible for much of the performance of the computer; a concept taken from the mainframe environment. The main bottleneck for microprocessor-based computers has been access to memory, and most microcomputer manufacturers have solved the problem by providing disk caches and processor caches to speed access between these and the memory. Unfortunately, this isn't enough on a system designed for performance on a network. There are too many I/O demands on the system; it doesn't matter how fast the processor can run if it is constantly held up because of competing access for memory and processor time from the network, monitor, sound, printing, real time digital signal processing and disk access.

The measure of performance that NeXT is using bases 75 per cent of system performance on data throughput and 25 per cent on processor speed. NeXT concentrated on system throughput without compromising the basic processor speed and claims an average system throughput of 32Mbits per second, considerably better than comparably priced workstations or personal computers, and not much worse than a typical mainframe at 50Mbits per second.

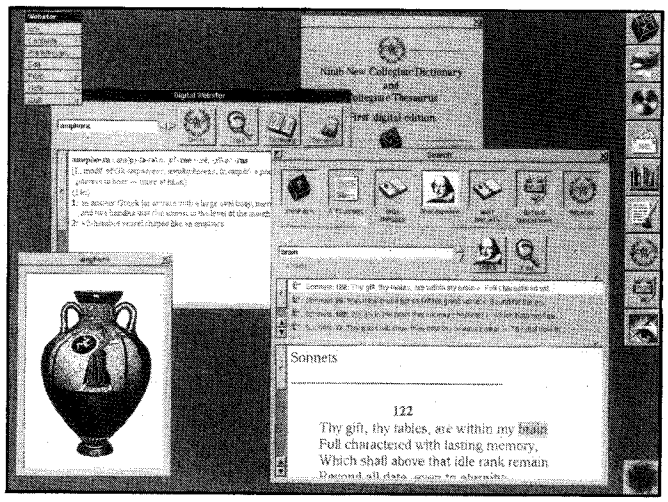
The solution to throughput in the mainframe world has been to add a separate processor for every I/O channel to manage the flow of data between the device and memory. NeXT uses the ICP chip for this, which has 12 DMA channels that can be used to move data between an I/O device and memory without interrupting the main 68030 processor. The ICP is optimised for these operations by including its own cache memory on-chip and by allowing it to make use of burst modes in transferring data to and from main memory, as well as by allotting a memory buffer to each DMA channel.

The other custom VLSI chip is allotted two DMA channels and it controls the 256Mbyte optical disk, the SCSI connector and the internal SCSI Winchester disk (if attached). This chip is known as the Optical Storage Processor and is required because the optical drive is so complex. The OSP includes error correction code circuitry that ensures the data on the optical disk is undamaged and it can correct read or write errors on the fly. It operates its DMA channels simultaneously — one is used for reading data off the drive or writing to it, and the other for transmitting data from the OSP to processor or memory.

In one corner of the main board is the system RAM — 8Mbytes in sixteen 100ns SIMMs of 500k each. RAM can be expanded on board to a maximum of 16Mbytes. The board also holds an additional port, a 50-pin SCSI for the optional internal hard drives. These are 330Mbyte and 660Mbyte full-size 5.25in drives made by Maxtor.



The NeXT Workspace: menus always pop onto the top of windows; the file browser includes filename filters; and windows can be shunted off-screen



The Webster dictionary and thesaurus and the complete works of Shakespeare on the CD can be accessed by any application running on the workstation

Also on the board is the main processor, the 68030, clocked at 25MHz, and the 68882 numerical coprocessor clocked at the same speed. An additional coprocessor, the Motorola 56001 digital signal processor, is responsible for much of the good, real-world performance of NeXT. It was originally added to the system for the digital sound synthesis and recording, because this requires handling vast quantities of digitised information, but once it was added, NeXT discovered it could be allocated a large number of other tasks. The 56001 is a very advanced chip capable of processing its instructions at 10 mips, and is suited to performing array processing on large quantities of digital information. The DSP is being used for voice recognition software and is under development at Carnegie-Mellon University.

The DSP is useful for analysing other kinds of externally gathered digital information, an obviously desirable trait for an academic workstation, especially in scientific areas.

NeXT also has 32k of 45ns static RAM for use as cache and buffers — 8k is for the optical drive, allowing it to achieve a better performance, and the other 24k is used by the ICP for buffering. The video display has its own 256k of RAM, just enough to cope with the 232,960 bytes required by the display. Finally, a single 128k ROM holds the startup code for Unix — everything else is loaded off Ethernet or off the optical disk.

Erasable optical drive

This is probably the most important innovation in the NeXT computer. Despite early rumours, it was not manufactured by Sony, but by Canon, which is not renowned for its mass storage technology.

The disks used by the drives look similar to standard compact discs in stereo systems. They have a 5in diameter and are contained in a plastic cartridge measuring 6in by 5.25in. The casing is otherwise similar to that of a standard 3.5in disk.

Although larger than a 3.5in disk, the optical disk cartridge is probably more robust, especially since it is less prone to damage from contact than a normal floppy disk. The disk surface has three layers — an aluminum surface, a substrate of a rare earth/transition-metal alloy, and a plastic coating for protection. The surface layers are translucent, so laser light can pass through and be reflected back from the aluminum.

The alloy layer is the key — it initially has a random crystalline structure and cannot be affected by a magnetic field when cool. To write information onto the disk, the laser is focused onto the alloy, heating it up to a point where it *is* affected by the magnetic field. If a magnetic field is applied, the crystals are aligned which gives the alloy layer different optical properties, so that a different amount of light passes through it. Two differing magnetic fields are used to produce two different alignments of the crystals and these correspond to the two binary states 0 and 1.

The disk works by first writing the whole area to be written to with the 0 orientation, which effectively erases it. Then a second pass writes 1s wherever required, and a read operation verifies the data.

To read information off the disk, the laser is focused on the aluminum without the magnetic field, which prevents the alloy from melting or realigning incorrectly. Depending on what state the portion of the alloy is in, a different amount of light is reflected back and converted to a signal, to be interpreted as 0 or 1.

Since the optical head can be fixed above the disk and uses a precise laser beam, the optical drive is inherently more reliable than a Winchester drive and a head crash is impossible. And with the perfection of this technique, it should be possible to create an optical drive with better performance than a Winchester.

The drive has an access time of 96ms but, since data can be read more or less continuously using the OCP chip and buffering, the effective time can be improved. At the launch, Steve Jobs claimed the effective transfer rate was comparable to that of a medium-to-fast Winchester.

In NeXT's mind, the optical disks are to be the floppy drives of the system — no other mass storage device is available except the fixed Winchester drives.

System software

The software is even better than the hardware. The basis for the system software is the Mach operating system, a variety of Unix (and compatible with Unix 4.3 BSD) developed at the University of California, Berkeley. Mach adds fast interprocess communication to the standard multi-tasking capabilities of Unix, allows shared memory use and adds threads. This theoretically allows NeXT to support multiple processors by giving separate threads to each processor, but in practice nothing has yet been

done with threads. However, Mach does currently allow NeXT to support true multi-tasking with full interprocess communication, which means that multi-tasking applications can very easily share data and information.

The NeXT operating system also supports TCP/IP (the Transmission Control Protocol/Internet Protocol) for communication with remote systems, a standard on Unix systems. NeXT has licensed Sun's Network File System, and, since NeXT comes with Ethernet hardware built in, it is ready for use on a standard Unix network.

On top of the basic operating system there are several layers of system software, which NeXT calls NextStep. One part is Display PostScript, which Adobe developed in conjunction with NeXT and which has several extensions and improvements specifically tuned for graphics displays.

Display PostScript is held inside the Window Server, and this performs the same kinds of functions that X-Windows does on many other Unix systems. The Window Server handles all mouse actions, interactions between windows and menus, keyboard commands and so on. It deals with what it can, such as resizing windows and passing on keystrokes. Anything else is passed on to the appropriate application, which then informs the Window Server what to do.

On top of the Window Server are other interconnected layers — the most important of which is the Application Kit. This collection of 25 classes of object is used for building application interfaces. The user interface is object-oriented, allowing any text object, for example, to immediately inherit a whole class of properties related to text, such as fonts, sizes and text editing.

The interface objects provided by the Application Kit are available to any program at a higher level, including NeXT's version of the 'desktop', the Workspace Manager, and to application programs.

The next level up is intended for use by application programmers. It is essentially an application that programmers can use to build interfaces to their own applications. The program, Interface Builder, is in some ways reminiscent of HyperCard on the Macintosh, but it is much more flexible, giving windows, pop-up menus and other controls to any application program. These can then be hooked up graphically with other objects and actions provided by the application programmer, letting the user build an interface by visually sticking it together.

NeXT has supplied Interface Builder as part of the system software in order to solve two big problems for programmers writing for the computer. The first problem is the inherent complexity of writing windowing interfaces for application programs, which can often take over half the programming time for an application and sometimes as much as 90 per cent. The second problem is the difficulty of porting existing applications between different systems. On Unix systems, the hard part has always been in converting the display and user interface portions of the program. NeXT estimates that Interface Builder can reduce the time to program the user interface to a negligible amount, at most 10 per cent of the time required for the application.

The Interface Builder generates code that can be integrated into a final application. All objects generated can be customised — it is even possible to continue extending Interface Builder, adding more objects, including application programming objects that might allow a programmer to build a complete application using only Interface Builder. This would allow a user to create a program simply by selecting a bunch of programming objects and linking them together — all done with the mouse, icons and windows! NeXT anticipates this will allow anyone with programming experience to create professional applications.

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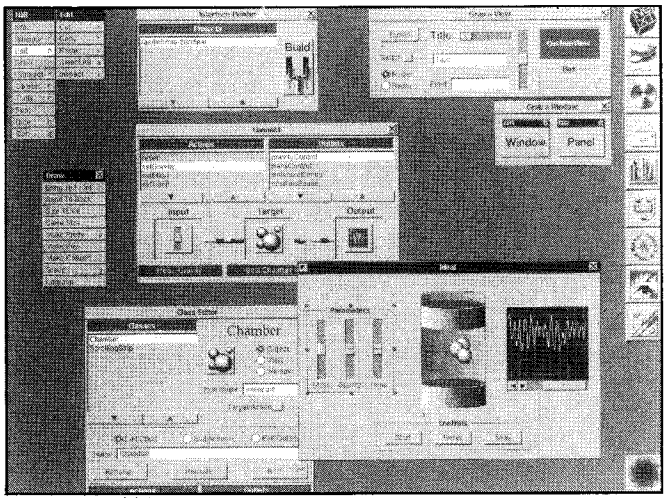
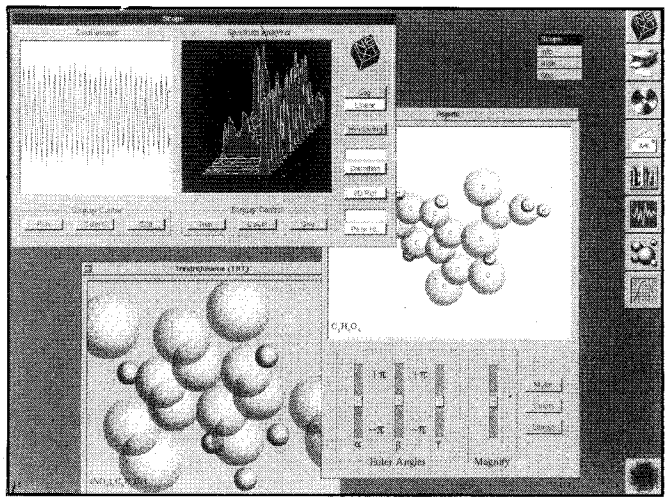
The user interface objects are very powerful. The basis of the interface is the icon — these are detailed enough to clearly show objects like a black hole (the NeXT equivalent of the trash can). Menus are fully hierarchical and pop-up, and they also stay popped-up until closed. Menus are all tear-off in that they can be separated from each other and moved anywhere on the screen; windows are fully movable and sizable and have scroll bars on the left and bottom, and there are boxes on the frame for closing and resizing. Like Microsoft Windows, windows can be collapsed to an icon while the application continues to run.

The final part of NextStep is the 'desktop', called the Workspace Manager. The basis for controlling the system here consists of two parts — in



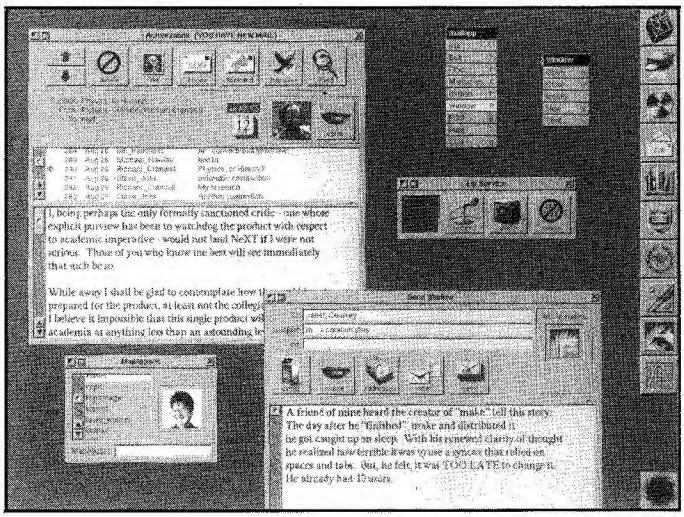
A physics application being constructed. Many tools are available to the programmer. Here, the user interface is being designed



While molecular models spin in two windows, the Scope function is analysing speech captured through the machine's built-in microphone

general use, the most important is the icon dock, a fixed line-up of icons down the right-hand side of the screen corresponding to the main menu on other systems. If the full screen is required for any reason, the icons can be slid downward leaving the NeXT icon alone in the bottom right corner.

The browser is the other main part of the Workspace. This is a sophisticated directory manager program and, while directories are usually displayed as file icons in a window representing a directory, files can also be looked at using the browser. This is a window that can be opened and which has at least three subwindows — the first is an iconic or test list of all the files and directories currently available. If an item is selected, a subtree appears in the next window, and so on. It is also possible to select to make visible only certain types of file, and these can be chosen on type, creator, date, size and so on.



Electronic mail like you rarely see it. Each person on the mail directory can have an associated photograph. Notice the 'Black Hole' used as a trash can equivalent

Application software

The application software bundled with the NeXT Computer System is just as impressive as the system software and a big incentive to buy the computer.

The most important section is the Digital Library, which allows users to store and access online versions of any text reference works, libraries of digitised graphic images and collections of digitised sounds. Included in the Digital Library is the Digital Librarian, an indexing and searching tool to give users almost instantaneous access to any textual information. The speed of search over many megabytes of information is phenomenal. The Digital Librarian took one second to find five references to the word 'books' in the Oxford edition of Shakespeare's 'Complete Works'.

Users can add to the Digital Library any textual, graphical or sound information they create or to which they have access. To get the average NeXT user started, the following reference works are included free: Webster's 'Ninth New Collegiate Dictionary' (complete text, including definitions, pronunciation, etymology and illustrations), Webster's 'Collegiate Thesaurus', 'The Oxford Dictionary of Quotations', The OUP Edition of 'William Shakespeare: The Complete Works', all the NeXT technical and user documentation and other technical references. These are all accessible from within applications. For example, the bundled word processor, WriteNow, uses the dictionary as its spelling checker: a double click on a word in the word processor brings up its definition from the dictionary.

Two object-orientated sound tools, called SoundKit and MusicKit, are available for developers as part of the application software. Used with the DSP chip, these allow the programmer to write applications to record, modify and play back digitised sounds and music.

A full range of programming tools is included such as Objective-C 4.0 from Stepstone, an object-oriented version of C used to interact with the object-oriented user interface. There is also a full GNU ANSI C compiler, a GNU C debugger with extensions for Objective-C, GNU EMACS for program editing, the standard 4.3 BSD Unix utilities, a terminal emulator, a windowing text-editor and a set of DSP tools for array processing.

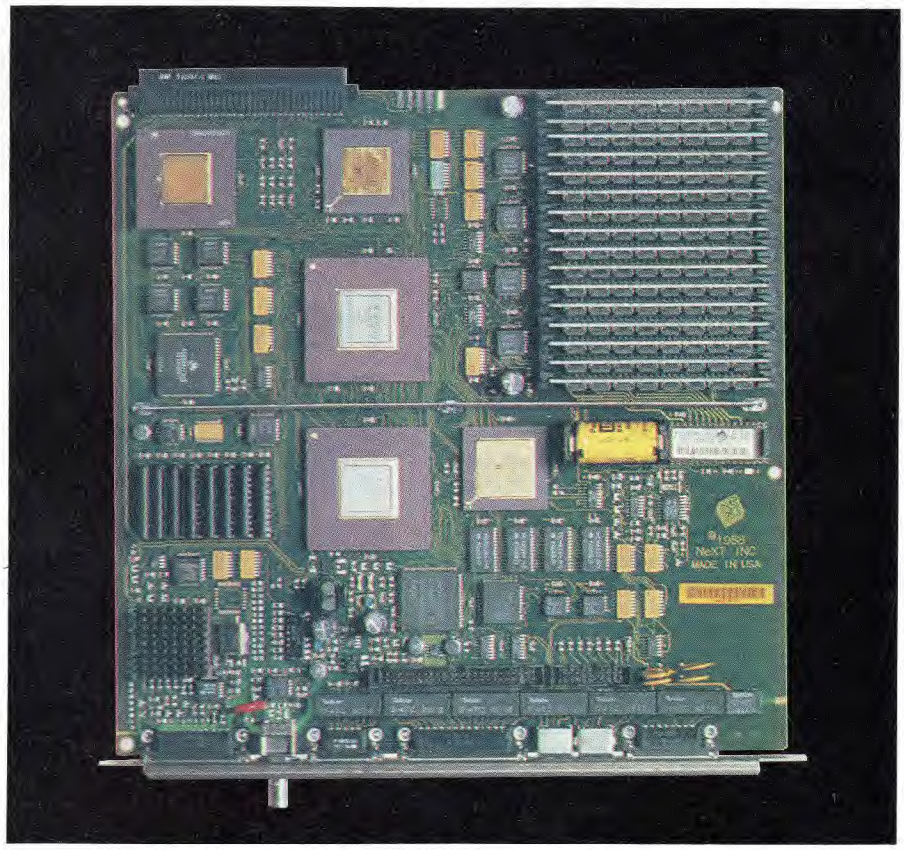
There is still a wide range of end-user applications to come in the list of software bundled with the NeXT Computer — there is an electronic mail program compatible with Unix mail, but with a graphical user interface and digitised sound for voice mail included; and Jot, a basic personal information manager for storing and retrieving notes, ideas, reminders, electronic mail, documents, papers and any other text information.

The word processor bundled with the computer is WriteNow, a graphics and text word processor with a great deal of power, re-designed specifically for NeXT. Mathematica, the analytical and calculation-based mathematical program, is also included free and is capable of solving complex calculus problems or differential equations as well as performing algebraic manipulations and final calculations. In addition, there are hooks into Mathematica enabling any external program to use it, so application developers can use its power in their own programs.

Also included are the Sybase SQL Database Server (so database applications can be easily created) and the AI language, Allegro CL Common Lisp.

Pricing

So what does it all cost? Even a conser-



The complex design of the NeXT system unit owes a lot to the design of the motherboard

vative estimate would put the value of the bundled software at close to $US3000; add in 8Mbytes of RAM (about $US4000), the advanced hardware (say, another $US3000) and you get a minimum price of $US10,000.

Incredibly, the complete NeXT Computer System will cost US universities only $US6500 with everything included, and the NeXT Laser Printer will cost only $US2000.

Only US pricing is available, as details of Australian distributorship have not been finalised. Megavision and the Lionel Singer Corporation are both currently negotiating for exclusive Australian rights to distribute the workstation.

Conclusion

NeXT is obviously a real breakthrough in price and power. It may even be the next big personal computer and NeXT thinks it will be the computer for the 1990s. Steve Jobs believes personal computers have life-cycles of about 10 years; the first of these was the Apple II line which is now almost finished; then came the IBM PC which, despite the clones, peaked technologically in 1986/87 and has another six years to go on a downward slope. Another 10-year cycle may occur with 80386 machines and OS/2, while the Apple Macintosh is due to peak technologically next year. NeXT believes it can take over the market as the Macintosh declines.

There are, however, serious doubts about NeXT, such as how compatible it is in the real world with other existing Unix systems; how easy it will be to port applications from other systems using different complex windowing systems, in particular, X-Windows; whether NeXT can really deliver the machines in quantity at that price; the limited nature of the academic workstation market; the lack of any floppy drive; the difficulty of backing up the optical disks; and how quickly the main memory will be eaten up by the memory-hungry system and applications.

NeXT can certainly sell every machine it makes in its first year to the US academic market, but what then? NeXT's investment in R&D and capital equipment, like its manufacturing plant, will take several years' sales to recover and maybe even longer at its current price. A year or so from now, I wouldn't be surprised to hear that the NeXT computer is going on sale worldwide to anyone with the money — but I bet the price goes up for non-academics.

Even at $US10,000, NeXT would be a killer. Until then, if you want one, enrol in a US university.

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