Workstation Networks
A Technology Review for Managers

BUTLER COX FOUNDATION

Research Report 80, April 1991

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Report synopsis
Workstation networks are set to become the most important part of many organisations' IT infrastructures. This means that systems directors need to make strategic decisions about the workstation technologies that will be employed. The most important decisions concern graphical user interfaces, workstation operating systems, and client-server software. This report describes the state of the art in each of these areas and indicates the most likely developments. It also provides advice about the skills that will be required to move from today's largely mainframe-based infrastructure to one based on workstation networks.

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A management summary of this report has been published separately and distributed to all members of the Butler Cox Foundation.

Chapter 1

Personal workstations are becoming a critical part of the IT infrastructure

Each year, in one Foundation Report, we review developments in technology from the perspective of managers. Last year, in Report 73, *Emerging Technologies*, we drew members' attention to six new technologies that will become significant in the 1990s. This year, we concentrate on the technologies associated with networked workstations. Workstations, in the form of personal computers and more powerful technical workstations, are already important. During the 1990s, they will become the most important part of many organisations' IT systems.

For most Foundation members, this will represent a significant change in emphasis, because many of their existing systems are implemented on centralised mainframe computers. Over the years, these have been supplemented, first by minicomputers, and more recently, by personal computers and workstations, but corporate mainframes have retained a central role in most large organisations. Mainframes, however, are not only expensive, but the limitations of their architecture define the standards to which the smaller systems must conform. These standards are dictated by the type of computing work to which mainframes are best suited (high-volume transaction processing, and the storage and processing of structured data). Moreover, mainframe architectures and standards are almost entirely proprietary.

Networks of personal workstations are the best way of exploiting many new technological capabilities

Nevertheless, many organisations have made large-scale investments in PCs and workstations. These investments have resulted from growing demands from business users for systems for decision support and office automation, and for processing other forms of information, such as images, graphics, and text. At the same time, the development of new technologies has meant that new architectures, based on networks of personal workstations, have become feasible. Indeed, many of the new capabilities made possible by advances in technology are best exploited via personal workstations.

Personal workstations have, for some time, provided cheaper processing power than other types of computers, and their power and storage capacity continues to increase at a rapid pace. In 1988, we predicted in Report 63, *The Future of the Personal Workstation,* that by 1993, workstations with 32 mips of power and 16 megabytes of random access memory (RAM) would be available. Workstations approaching this power and memory are already available, and by 1993, will certainly be widely available at affordable prices.

In addition, by linking workstations to other computers through networks, they can be provided with the data-management, integrity, security, and system-management capabilities that were previously available only with minicomputers and mainframes. The focus of information systems architectures is therefore shifting away from central mainframes towards networks of intelligent workstations, supported by local servers. In this way, workstations can access a variety of information and communication services provided by minicomputers and mainframes, and by specialised 'servers' such as database machines.

Systems architectures are shifting away from mainframes to networks of workstations supported by local servers

Personal workstations meet a wide range of user needs

The widespread use of PCs is due not only to their superior price/performance, but also to the wide range of applications that can be run on them. Microsoft claims that, by the end of 1990, there were about 30,000 MS-DOS applications. Users also like the autonomy that standalone PCs provide them with. The PCs of today will, however, evolve to become tomorrow's networked personal workstations; they will make systems easier to use, they can support new kinds of applications, they will support the trend to downsizing, and they are developing the ability to support multi-user systems.

Personal workstations are the basis for easier-to-use systems

The greater ease of use provided by graphical user interfaces has been evident for some time in specialised systems such as CAD and CASE. Similar techniques are increasingly being used to improve the usability of general-purpose office systems and conventional data processing systems, especially where they are used on an occasional basis. The most cost-effective way of providing a graphical user interface is usually on a PC or a workstation. (Graphical user interfaces are discussed in Chapter 2.)

Workstations are the most cost-effective way of providing a graphical user interface

Personal workstations can support emerging applications

An increasing number of applications need to process and display images. We described the business benefits of document image processing in Report 70, *Electronic Document Management*, and of hypermedia systems in Report 73, *Emerging Technologies*. There is also increasing interest in geographical information systems (that is, systems that handle data about geographically dispersed assets, usually in terms of grid references and computerised maps). All of these types of applications need high-resolution screens, and powerful local processors to drive them. PCs and workstations are thus the obvious products to use for implementing such applications. In addition, the leading software products in new areas, such as groupware, neural networks, and AI-derived development tools, are often available only for PCs and workstations.

New types of software are often available only for workstations

Personal workstations support the trend to downsizing

Many businesses have recognised the price/performance advantages of smaller computers, and are building new applications on PCs or minicomputers, rather than on mainframes, or on PCs rather than on minicomputers. They are also transferring applications from mainframes and minicomputers to smaller computers, a process generally called 'downsizing'.

Superior price/performance is not the only reason for the trend to downsizing. Other important factors include the easier operation and better user interfaces available with workstations, the ability to link applications implemented on workstations with generic 'personal productivity tools', such as spreadsheets, and the desire to avoid being locked into a single hardware supplier. Downsizing also reflects the delegation of authority to lower management levels that has occurred in many organisations.

A survey of 50 major US computer users in 1990, by Forrester Research, a US market research company specialising in IT, showed that 72 per cent had already replaced some minicomputers with networked PCs and 8 per cent had replaced mainframes. Many European organisations have also made progress on downsizing their application portfolios.

Personal workstations can be used for multi-user applications

Personal workstations running Unix have been used in multi-user applications, such as the automation of a drawing office, for many years. PCs, however, have rarely been used in this way. Most PC software is single-user, and there has been a lack of system-management software for multi-user PC systems. In addition, the servers used on PC networks have, in the past, had limited data-handling capabilities, and there has been little software available to enable several users to access the same database concurrently.

Multi-user database management software is now available for servers

Recent advances in server technology have largely removed these problems. Data-handling limitations are being addressed by faster buses, and by the development of higher-performance data subsystems, such as 'redundant arrays of inexpensive discs' (RAIDS) and database machines. Furthermore, most major suppliers of database management systems now offer server versions of their products. These promise to combine the advantages of personal workstations with the integrity, recovery, and security features of a full multi-user database management system. (These advances are discussed in Chapter 4.)

IT infrastructures will be built around workstation networks

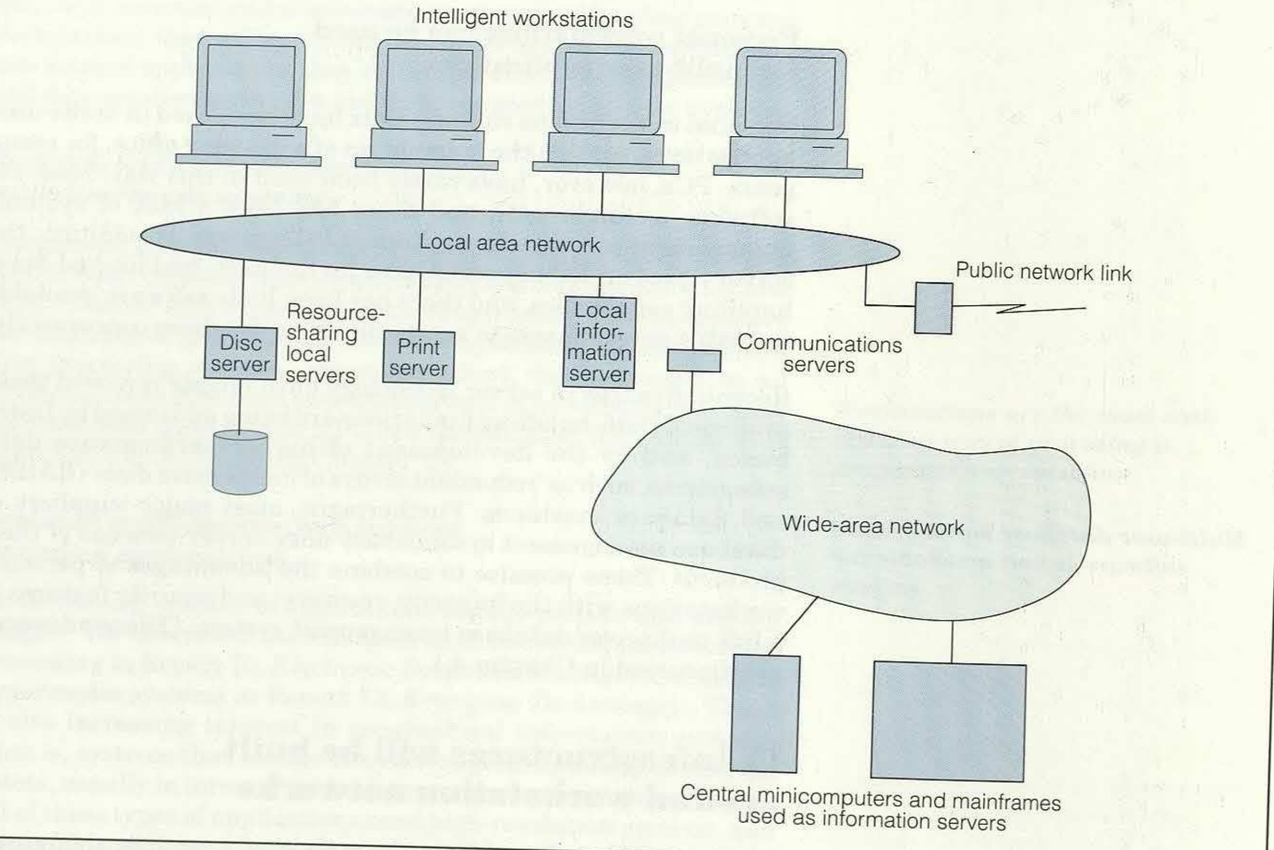
In Report 63, we foresaw the emergence of a two-tier computing environment comprising mainframes and workstations with their supporting servers. It is the principles of this environment that we describe in this report. The workstation network will be the central element of the IT infrastructure for two main reasons:

— It is the part closest to the user. To provide managerial and professional users and customer-contact staff with support facilities that are powerful enough to be valuable, yet simple enough to master quickly, the individual user will need to be placed at the centre of systems planning.

— It will continue to provide the most cost-effective form of computing, so organisations will continue to save money by downsizing.

The general shape of the future technical architecture is therefore clear; its main components are the workstation network, and resource-sharing and information servers. It is illustrated in Figure 1.1. Typically, resource-sharing servers provide workstations with access to resources (such as printers, discs, and files) that could, in theory, be provided by the workstation, but which, in practice, would not be cost-effective. Information servers provide access to resources (such as databases and applications) that are inherently shared. Resource-sharing servers are almost always located near the workstations that access them, whereas information servers need not be.

Figure 1.1 The main components of the emerging technical architecture are the workstation network, and resource-sharing and information servers



The most important part of the emerging architecture is the network of intelligent workstations. These will run multiple applications, accessed via a graphical user interface, and will support graphics and images, as well as data and text. These workstations will range from MS-DOS PCs to multiprocessor engineering workstations running Unix. They will be linked by a local area network, usually Ethernet or Token Ring. Networks based on the Fibre Distributed Data Interface (FDDI) will be used to interconnect several workstation networks on large sites, and to support the most powerful workstations. Emerging high-bandwidth public networks (which were discussed in Report 78, *New Telecommunications Services*), will be used to interlink workstation networks located at different sites.

General-purpose minicomputers will be retained, to run existing systems, to integrate local and wide-area networks, and to act as a focus for migrating to client-server architectures. In time, they will be displaced by more specialised, and thus more reliable and cost-effective, computers such as database machines and communications gateways.

Minicomputers will eventually be displaced by more specialised computers

Mainframes will also be retained for some time to run existing systems, although mainframe (and minicomputer) applications will increasingly benefit from the user-friendly interfaces provided on workstation networks. The role of the mainframe, however, will gradually change to one of providing basic processing and information services, such as data access and the processing of validated transactions that will be preprocessed on workstations. In the longer term, the existence of mainframes will be threatened by developments such as parallel computers (which were discussed in Report 73) and database machines, such as Teradata's DBC 1012, which will provide highly cost-effective processing.

Mainframes will be retained but their role will change

Purpose and structure of the report

The research for this report covered the technologies that we believe to be most significant to the evolution of the emerging, workstation-based, technical architecture. The research team and method are described in Figure 1.2.

Figure 1.2 Research team and scope of the study

The research for this report was conducted during 1990 under the leadership of David Flint, Butler Cox's head of research. He was assisted by Nick Bush, Simon Fedida, and Martin Langham (all from Butler Cox's London office), and by Marc Morin-Favrot (France), and Antonio Morawetz (Italy). The research included more than 100 interviews with suppliers in Europe and the United States, two workshops with members of the Butler Cox Foundation in the Netherlands and the United Kingdom, and further interviews with user organisations. Team members also attended relevant conferences and supplier briefings, conducted literature searches, and reviewed a large number of articles in the trade press.

The work also benefited from Butler Cox's previous and continuing work, from insights developed in consultancy assignments for a variety of organisations, and from contributions from Simon Forge in Butler Cox's Paris office, Robert Neely of the Cranfield IT Institute (a Butler Cox company), and Janet Cohen in Butler Cox's London office.

Chapter 2 deals with graphical user interfaces. We include graphical user interfaces because they make systems much easier to learn and use, raising productivity and reducing errors. Systems managers now need to take decisions about which standards and products to adopt.

Chapter 3 deals with workstation operating systems. These are the defining technology for workstations; knowing that a workstation runs MS-DOS or Unix is more useful than knowing that it is powered by an Intel 80386 or Motorola 68030 processor chip. Operating systems are evolving quickly, however, and it is important for systems managers to understand the nature of this evolution if they are to make informed decisions about future workstations.

Chapter 4 deals with client-server systems. Workstations would be no more than standalone PCs if they were unable to communicate with other systems. Client-server architectures provide the framework within which workstations can share information and access existing systems effectively. In this chapter, we also consider advances in the technology of network servers.

Developments in basic workstation hardware are not, however, discussed in detail in this report because it is the general trends in workstation performance and price/performance that are important, rather than the underlying developments in areas such as Risc or VLSI technologies.

As well as describing the benefits of and trends in graphical user interfaces, workstation operating systems, and client-server systems, Chapters 2, 3, and 4 provide advice about the standards and products that should be adopted, and highlight the areas where new skills and responsibilities are required. Taken together, the advice provides Foundation members with a sound basis for taking advantage of the technologies, and for moving from an established, usually mainframe-based, technical architecture and systems infrastructure to one that takes full account of the new opportunities provided by networks of intelligent workstations.

Chapter 2

Graphical user interfaces

Computer systems are being used increasingly by office staff, managers, and professionals on an ad hoc basis as support tools for their business activities. Such staff are not prepared to spend large amounts of time learning how to use the systems and applications, each with a different user interface. It has therefore become important to make systems easier to learn and to use, and to provide consistent user interfaces. In the past, it has been difficult and expensive to achieve this because easy-to-use systems require additional processing power, storage capacity, and communications bandwidth. However, advances in technology mean that the cost of powerful workstations with large memories has fallen to a level where applications with easy-to-use interfaces can now be widely implemented.

Powerful workstations with easy-to-use interfaces can now be widely implemented

The most important development in this area is the Window-Icon-Mouse-Pulldown menu (WIMP) graphical user interface, pioneered by Xerox and first provided to a mass market with the Apple Macintosh. A sample screen from the Macintosh user interface is shown overleaf in Figure 2.1. This sample illustrates some of the important features of a graphical user interface:

— The bar across the top of the screen, which lists the available menus (File, Edit, View, and Special). The items within each menu are revealed by using the mouse to point at the choice, and holding the mouse button down.

— The scroll bar on the right-hand edge of documents. The document can be scrolled forwards or backwards past the display window by adjusting the position of the 'current position marker' on the scroll bar.

— Different icons are used to indicate documents, folders, discs, printers, and so on. Positioning the cursor on an icon and double-clicking the mouse button will open a document, folder, or disc.

Graphical user interfaces are available for a wide range of workstations

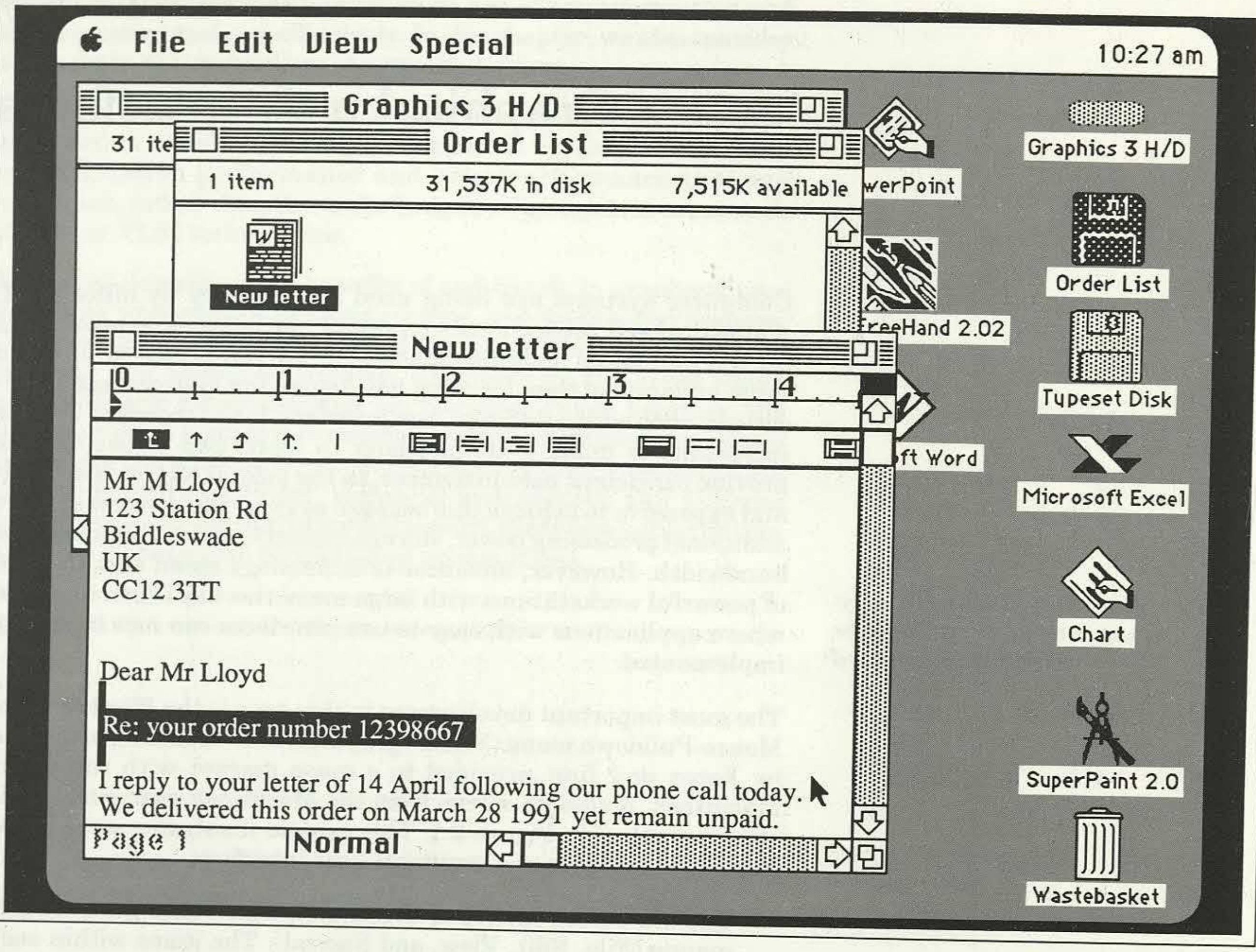
Similar user interfaces are now available for Unix workstations (for example, AT&T's Open Look), for IBM and compatible PCs (for example, Microsoft's Windows 3.0 and the OS/2 Presentation Manager), and for many other microcomputers.

In summary, the main messages about graphical user interfaces to emerge from our research are:

— Systems and applications are significantly easier to learn and use, resulting in measurable increases in user productivity.

— There are four main graphical interface styles (IBM's CUA, Apple's Macintosh, the Open Software Foundation's Motif, and

Figure 2.1 The Apple Macintosh still has the leading graphical user interface



AT&T's Open Look). Each style is implemented by several software products. Thus, Microsoft's Windows and IBM's Presentation Manager are implementations of CUA.

— There are considerable similarities between the styles. Thus, the choice of style is not particularly critical, although CUA and Motif are the emerging *de facto* standards.

— The future of Presentation Manager is in doubt. For the time being, the safest standard for PCs is Windows 3.0 (together with MS-DOS).

— Existing PCs may need to be upgraded (processor and memory) to implement a graphical user interface. At least a 286-based PC will be required, and preferably one based on a 386 processor.

— High-level development tools are becoming available that will enable application developers to use the power of graphical user interfaces without having to concern themselves with the technical details of how they work.

— Application developers will, however, need to acquire (or have access to) the skills required to design effective graphical user interfaces.

Our research confirmed that graphical user interfaces are now becoming the normal kind of user interface for major software packages, and they will thus become the norm in many organisations. Systems managers therefore need to understand the nature of graphical user interfaces, to be aware of the products that are available, and to find cost-effective ways of realising their benefits.

Use of graphical user interfaces brings many benefits

Graphical user interfaces provide intuitive and consistent interfaces

Graphical user interfaces provide significant benefits. In particular, they make it possible to access computing facilities and data in a way that is similar to the way users think. They enable different applications to have consistent interfaces, which means that skills and expertise gained in using one application can be transferred to another. They also offer a convenient means of providing tutorial and online context-sensitive help facilities, so that users can learn applications without the need for classroom training.

There can be disadvantages, however, particularly for experienced or intensive users. They may find some of the procedures tedious and long-winded. A well designed graphical user interface should therefore provide shortcuts for experienced users. Several vendors have recently responded to this requirement by introducing a 'toolbar' that is displayed below the main menu bar. This displays the most commonly used options on the menus.

In a non-graphical-user-interface environment (and in graphical-user-interface environments that are badly designed and implemented), users must remember the commands to type to produce a desired result, and the names of applications and files. They must also learn how to use each new application from scratch, since there is often little consistency in the way that different applications operate. In a graphical-user-interface environment, by contrast:

— The screen display suggests the facilities that are likely to be available.

— The available functions are listed on pulldown menus, which the user can view whenever he wants to, and from which he can select the one he needs.

— The names of available applications and files are presented on-screen. The user selects only those that interest him.

Graphical-user-interface applications are easier to learn

As a result, it is easier to learn to use graphical-user-interface applications than applications without a graphical user interface. In addition, users make fewer errors, are more productive, and need less support. Our own consulting experience, various laboratory and field studies, and surveys of users and IT professionals have confirmed these results. Three studies, in particular, have demonstrated the extent of the benefits:

— A study conducted in 1987 by Peat, Marwick, Main & Co of San Francisco and sponsored by Apple Computer compared the benefits of Macintosh and other PCs in 16 field studies.

— A survey of systems and user managers in Fortune 1000 companies, conducted in 1988 by Diagnostic Research Inc (an international research firm) and sponsored by Apple Computer, compared the benefits of Macintoshes and MS-DOS PCs.

— A study sponsored by Microsoft and Zenith Data Systems and conducted in 1989/90 by Temple, Barker & Sloane, a research company based in Massachusetts, compared, under laboratory conditions, the use of Macintoshes and PCs using Windows 3.0, with PCs without graphical user interfaces. Both novice and experienced users were included.

The results are summarised in Figure 2.2. These studies clearly show that a graphical-user-interface environment increases the effectiveness and productivity of staff and reduces the need for training. (The need for less training for Macintosh users was confirmed more recently by a Foundation member with extensive experience of both Macintosh and MS-DOS systems.) The 60 per cent productivity improvement found under laboratory conditions is, of course, unlikely to be replicated in a normal working environment. Nevertheless, improved productivity of only 15 per cent would justify the additional hardware and software costs associated with a graphical-user-interface environment within three years, assuming the system was used for about two hours a day. The implication is that graphical user interfaces will be cost-effective for both casual and intensive users.

A graphical-user-interface environment increases staff effectiveness and productivity

A graphical user interface has three elements

A graphical user interface is a protocol for the interaction between a user and the workstation. From the user's point of view, a graphical user interface has three elements — its visual appearance, its behaviour, and the 'metaphor' that describes the basic idea on which the interface is based. Together, these three elements are sometimes called the 'look and feel' of a graphical user interface. Each interface has a distinctive look and feel, although the differences can be subtle and there may be several different sets of functions that can provide the same look and feel. Even though a look and feel is difficult to define, it is far from imaginary. Law-suits in the United States suggest that a look and feel is a business asset, protectable by copyright.

The three elements of a graphical user interface constitute its 'look and feel'

Visual appearance

The visual appearance of a graphical user interface includes items such as the position and layout of the menu and scroll bars, the design of the icons used to represent applications and files, and the shape and size of the mouse-controlled cursor. The appearance of an interface contributes greatly to its ease of use. This is achieved by designing the visual clues for the user so that they immediately suggest what they represent. Thus, the icons used to represent applications should be distinguishable from those that represent files, and the icons used to represent files should indicate the type of file in question (text documents, spreadsheets, graphics, and so on). In the same way, a scroll bar should be immediately recognisable as such, and should include an indicator that shows which portion of the document is currently displayed on the screen. There are only minor differences in the visual appearances of the main graphical user interfaces. Most, however, allow the user to

The visual appearances of the main graphical user interfaces are very similar

Figure 2.2 The benefits of graphical user interfaces can be quantified

Type of benefit	Diagnostic Research	Temple, Barker & Sloane	Peat, Marwick, Main & Co
The system and applications are easier to learn	Users took 1.8 hours to learn the basics of the Macintosh, and 20.4 hours to learn an MS-DOS PC. Users took 8.7 hours to learn a new application on a Macintosh, and 24.3 hours on an MS-DOS PC. Users in graphical-user-interface environments learn and use more applications, and tend to use their workstations for longer each day. Macintosh users were familiar with 16 applications; MS-DOS PC users were familiar with only 10.	Novice Macintosh users attempted 23 per cent more tasks. New users of an application are productive more quickly with a graphical user interface than without.	
Users make fewer errors		Experienced users of graphical user interfaces made mistakes on 9 per cent of tasks, compared with 26 per cent for users of non-graphical interfaces. The advantage of a graphical user interface was even greater for tasks involving one or more applications.	With a graphical user interface, there were significant improvements in quality, due to the greater ease with which errors could be identified and corrected.
Users need less support	Macintosh users needed only 14 hours support per month; MS-DOS PC users needed 30 hours.	Users of graphical user interfaces felt less frustrated, suffered less fatigue, and were more able to learn for themselves about the operation of the packages.	
Users are more productive	Macintosh users were more productive than MS-DOS users and they produced higher-quality output.	Experienced users of graphical-interface applications worked 35 per cent faster and completed 50 per cent more multiple-application tasks than experienced users of non-graphical applications. Even novice users worked 42 per cent faster than equivalent users on non-graphical-interface systems. These results imply an increase in personal productivity of about 60 per cent for both levels of user. Only in the case of experienced users learning more about the packages did graphical user interfaces fail to provide some benefit.	The productivity and efficiency of Macintosh users and the quality of their work (especially document quality) was greater than that of other PC users.

(Sources: *The benefits of the graphical user interface: a report on new primary research.* Prepared by Temple, Barker & Sloane Inc, and cosponsored by Microsoft Corp, Zenith Data Systems, and Groupe Bull. Redburn, WA: Microsoft Corp, 1990.
Macintosh benefits study. Prepared by Peat, Marwick, Main & Co for Apple Computer Inc. Cupertino, CA: Apple Computer Inc, 1987.
Macintosh or MS-DOS? a synopsis of what MIS managers and other professionals in Fortune 1000 companies have to say. Prepared by Diagnostic Research Inc for Apple Computer Inc. Cupertino, CA: Apple Computer Inc, 1988.)

personalise the visual appearance — for example, by changing the background to the desktop, or the rate at which the cursor flashes.

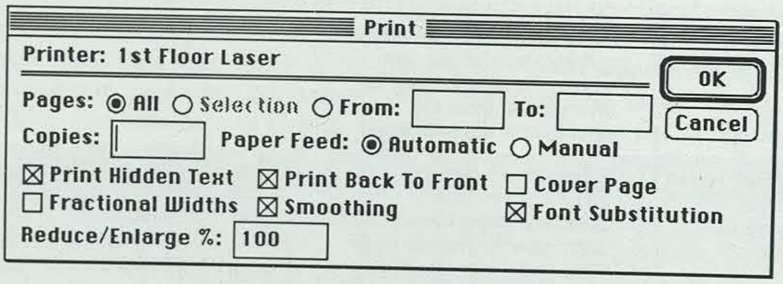
Behaviour

The behaviour of an interface is the way in which it responds to actions taken by the user. A graphical user interface does not display a static image, but changes in response to user actions with a keyboard, a mouse, or another pointing device. For example, positioning the cursor over an application icon and pressing the mouse button twice in rapid succession will result in the running of that application. Similar user actions should result in similar behaviour in different contexts.

Most graphical user interfaces behave in a similar fashion

The behaviour of various graphical user interfaces is quite similar. In most cases, one click on the mouse button selects the object under the cursor, while a diagonal movement of the mouse, with the button depressed, selects everything in the defined rectangular area. A double click activates the selected object or objects (by opening a file or running an application), although sometimes, a *pro forma* may appear, which has to be filled in to define the required action. (Figure 2.3 shows the *pro forma* presented to Macintosh users when they wish to print a document; this form is used to set the parameters for printing the particular document.)

Figure 2.3 Macintosh users fill in a *pro forma* to specify printing parameters



Metaphor

The term 'metaphor' is used by designers of graphical user interfaces to describe the analogy that they have used in implementing the interface. (Students of the English language will realise that the word 'metaphor' is misused in this context, but it is the term now commonly in use in the IT industry.) The most common analogy is that of the desktop — when the workstation is switched on, the possible applications are displayed, spread out on the electronic equivalent of a desktop.

The user-interface metaphor suggests to the user the likely consequences of his actions

The user-interface metaphor guides the developer of an application, and more importantly, helps the user foresee the consequences of his actions. Thus, with the desktop metaphor, it is possible to have several documents piled on top of each other on the desktop. The user sees the whole of the top document and is able to work on it. The edges of the other documents are visible, as if they were sticking out from under the top document. Any one of the other documents can be moved to the top of the pile by positioning the cursor on a part that is visible and clicking the mouse button.

Applications also use metaphors. A word processor, for example, uses typing on paper as a metaphor. (This seems so natural that it may be hard to see that it is a metaphor. However, text editors, which were used in online programming in the past, did not always work that way; they were less usable for that reason.) A ruler appears at the top of the screen, on which tabs and other controls can be set. The scroll bar is on the right, where a right-handed person would naturally reach for the typewriter's paper-advance wheel, whose function it replicates. Other application-level metaphors include accounting paper (used in spreadsheets and statistics packages) and a memo pad (used for electronic mail).

If, however, an application did no more than provide the same functions as those available on paper, it would be an inferior alternative to paper (because it is less familiar, more expensive, and less portable). Applications must therefore go beyond the base metaphor. One way of doing this is to implement several metaphors. For instance, most word processors support the scissors-and-paste metaphor (the menu may even say 'cut and paste') as well as the typewriter metaphor. Another way of going beyond the base metaphor is to provide features that are difficult or impossible in the original, such as changes of font and type size, or the facility to have several documents in the 'typewriter' at once.

In-house development staff will sometimes have to create new metaphors

New kinds of applications will need new metaphors. Usually, independent software developers will invent these and embody them in their products, but sometimes, where a user organisation needs to do something novel, in-house development staff will have to devise these themselves.

Many graphical user interfaces are available

Any one interface may be implemented by several software products

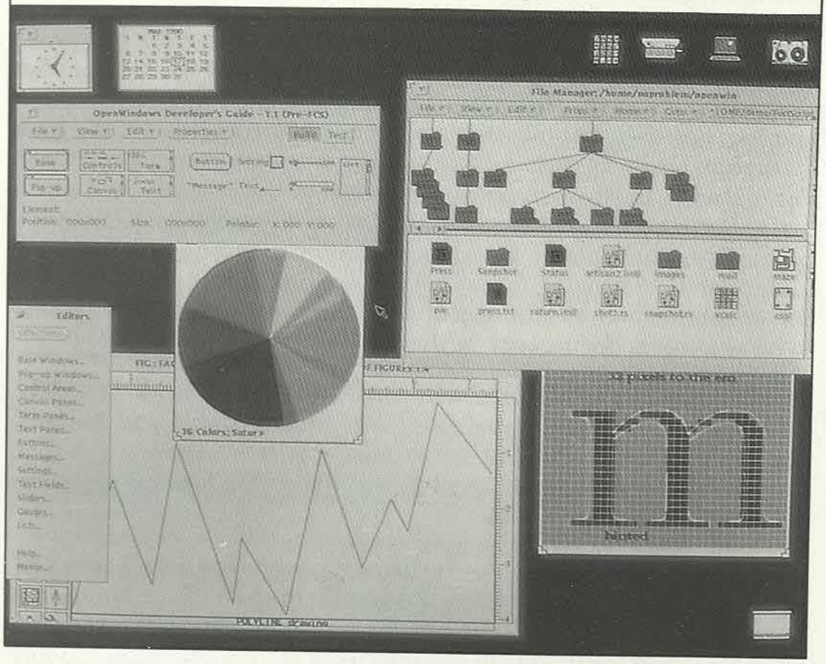
Some graphical user interfaces are integrated with operating systems. Others are provided as separate software products. Several suppliers have defined graphical user interfaces, and any one interface may have been implemented by products available from the defining supplier and from a variety of other suppliers. The oldest and best-established is that defined by Xerox for its Star work-station, but also implemented on subsequent Xerox workstations. Since Xerox has decided to discontinue its own workstations and to transfer some of its applications to Unix, applications based on this graphical user interface are becoming available to Unix users.

QuickDraw graphics functions are the core of the Macintosh's distinctive graphical user interface

The Apple Macintosh graphical user interface is based on concepts resulting from Xerox's research, but has been simplified so that it could be implemented on the original, less powerful, Macintosh machine. The QuickDraw graphics functions stored in read-only memory (ROM) are the core of the Macintosh's distinctive graphical user interface. The proprietary nature of the QuickDraw ROMs is the main reason that low-cost Macintosh clones are not available. The QuickDraw ROMs can be accessed only via the Macintosh Toolbox, a library available to software developers. As a result, the Macintosh screen can be controlled only in ways that are supported by the Toolbox, and this helps to maintain consistency between applications. The Macintosh interface is, however, also available on Apple IIs, on Commodore Amigas, and on PCs running Digital Research's GEM package.

Sun Microsystems developed the Network Extensible Window System (NeWS) for its Unix workstations. This system makes less use of graphical images than the Macintosh interface. NeWS formed the basis for AT&T's Open Look interface, which was announced in April 1988 and is now available from several vendors. A typical Open Look display is shown in Figure 2.4.

Figure 2.4 Open Look is one of the leading Unix graphical user interfaces



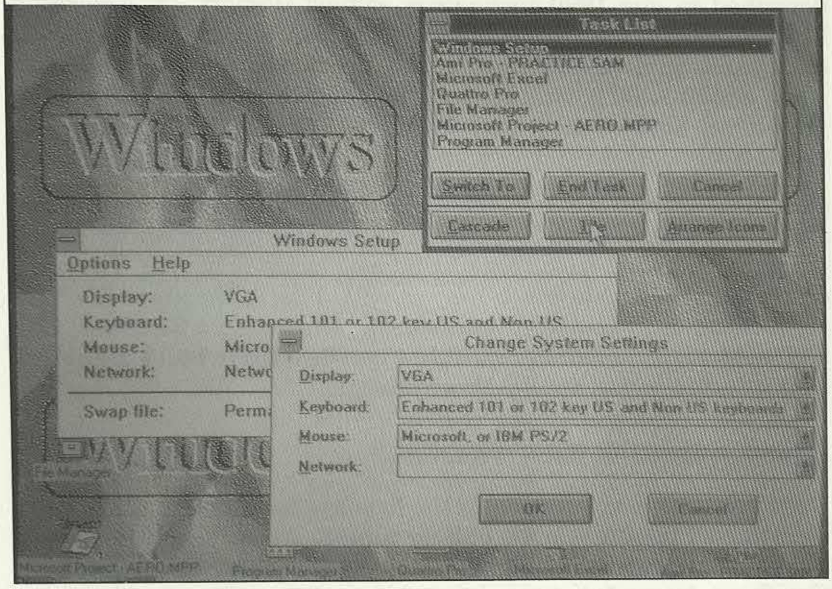
The next development, and the first graphical user interface to be deliberately defined for a variety of operating systems, was the Common User Access (CUA) element of IBM's Systems Application Architecture (SAA). (CUA actually defines user-interface styles for both graphical and non-graphical devices, the former being called Advanced CUA; we use the term CUA to mean Advanced CUA.) CUA was first implemented by the Presentation Manager component of the OS/2 operating system. Microsoft's Windows package predates CUA but its graphical user interface has evolved towards it and is, in Windows 3.0, almost indistinguishable from that of Presentation Manager. Windows is a software package that, as well as providing a graphical interface, extends the functions of MS-DOS by providing better memory management and multiprogramming facilities. Because of these facilities, we discuss it further in Chapter 3. A typical Windows 3.0 display is shown in Figure 2.5.

The first graphical user interface to be designed for a variety of operating systems was CUA . . .

. . . Presentation Manager and Windows 3.0 are both implementations of CUA

Hewlett-Packard has extended CUA in its NewWave package. NewWave has many interesting features, but it may best be thought of as an application integrator. However, only applications that have been specifically written for the NewWave environment can be fully integrated. Since it is much more than a user-interface product,

Figure 2.5 Windows 3.0 is the leading implementation of CUA



we return to NewWave in Chapter 3 when we discuss workstation operating systems.

Motif is very similar to CUA

The latest stage in this evolution is the creation, by the Open Software Foundation (OSF), of Motif as an alternative to AT&T's Open Look. (OSF is a joint development organisation providing Unix-compatible system software that is not dependent on AT&T. Its sponsors include Digital, Hewlett-Packard, and IBM. OSF's main function is to select software written by others and to integrate this into complete products. Its main products to date are Motif, the OSF/1 operating system, and the Distributed Computing Environment (DCE) communication package.) Motif is largely based on CUA, with some elements from NewWave, and a toolkit based on Digital's DECwindows. Motif will be supported on many future Unix systems, including those from IBM, Digital, and Hewlett-Packard. It is already available on workstations from non-OSF sponsors — for example, from Solbourne, a US manufacturer of clones of Sun's Sparc workstations. Third parties will make Motif available on the machines of other non-OSF sponsors, including Sun, ICL, and AT&T.

In Unix environments, Motif is emerging as the dominant standard

By the second half of 1990, OSF was claiming that more than 100 application packages using the Motif interface already existed, with many more 'nearing shipment'; at that time, there were only about 50 applications using the Open Look interface. Many software suppliers have announced their support for Motif, and we believe that the number of applications will now increase rapidly. In Unix environments, Motif is undoubtedly emerging as the dominant standard.

New developments will enhance existing graphical user interfaces

Graphical user interfaces are the subject of very extensive research and development, and we expect that new metaphors will be developed, perhaps based on quite new ideas. In particular, we expect to see new metaphors to support some of the technologies described in our 1990 technology review (Report 73, *Emerging Technologies*) — namely, groupware, hypermedia, and development tools based on artificial intelligence. The user interface for groupware systems, for example, may be based on a conference-room metaphor, and some hypermedia systems use a musical-score metaphor.

Graphical user interfaces will also be extended to incorporate other advanced interface techniques such as the use of sound, voice recognition, and AI-based 'intelligent assistants' or agents. The most significant developments, however, will occur in the areas of inter-application data transfer, online assistance, macro facilities, and higher-level development tools that can be used to build graphical user interfaces into application systems.

Inter-application data transfer

Clipboard facilities make it possible to transfer data between applications

Word processors were probably the first applications to enable data to be moved between parts of a document. Apple generalised this by introducing a 'clipboard' in the Macintosh, which allowed transfers to be made between applications. When part of a document is 'cut' or 'copied', it is held in a file, known as the clipboard. The document (or application) can then be closed, and a new one opened. The contents of the clipboard remain intact during this process, which means that the 'cut' part of the original document can be 'pasted' into the new document. Using this procedure, it is simple, for example, to include a diagram produced by a graphics package in a word processed text document. The clipboard is also used during normal editing of a document. Clipboard facilities make it easier to use several applications in combination and thus support cross-functional systems and the more complete collation of information for decision-making.

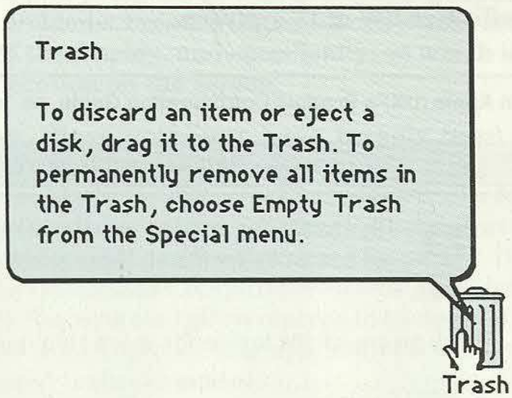
Inter-application data transfer is now supported in most graphical user interfaces. The X protocol (which was developed at the Massachusetts Institute of Technology for interoperability between engineering systems, but is now widely perceived as an open standard) has a function for this called Inter-Client Communication Conventions Manual (ICCCM). Windows and Presentation Manager also have such facilities. Hewlett-Packard's NewWave clipboard allows complete compound documents to be transferred and provides other ways of linking files and applications, which we discuss in Chapter 3.

Online assistance

Graphical user interfaces can provide context-sensitive help facilities

However good the metaphor, and however clear the menus, there will always be occasions when a user needs help to use the system. He may need to know what values he can enter into a field on a form, and more to the point, the consequences of choosing some particular value. In this case, he needs context-sensitive help — that is, help that is specific to the function he is trying to perform. One of the user-interface improvements to be introduced in Apple's Macintosh System 7.0 (which will be released in 1991) will be to provide explanations of windows, menus, and icons in on-screen 'balloons' (which may be turned off by experienced users), as illustrated in Figure 2.6. (System 7.0 will also include refinements

Figure 2.6 Online help in the Macintosh System 7.0 is provided in on-screen balloons



aimed at providing greater consistency and increasing the ability to customise the interface.)

In other cases, the user needs to know how to achieve some desired result. Context-sensitive help will not usually be sufficient, because the user may be uncertain which function to use. The system should therefore provide online access to its own documentation. Existing documentation, however, has generally been prepared for use in a printed form, and a new approach is essential if the documentation is to be available online.

Vendors are beginning to use hypertext to provide workstation documentation online

Vendors are responding to these requirements. Tektronix was one of the first vendors to supply workstation documentation online. Digital now supplies all VMS documentation on CD-ROM, from which it may be accessed using a utility called Bookreader. Hewlett-Packard's NewWave includes a context-sensitive help facility. All these online assistance systems use simple forms of hypertext, which allows the stored information to be accessed in a random way, under the control of the user. (Hypertext was described in a Butler Cox Foundation Position Paper, published in 1988, in which we drew attention to its value in supporting online help systems.)

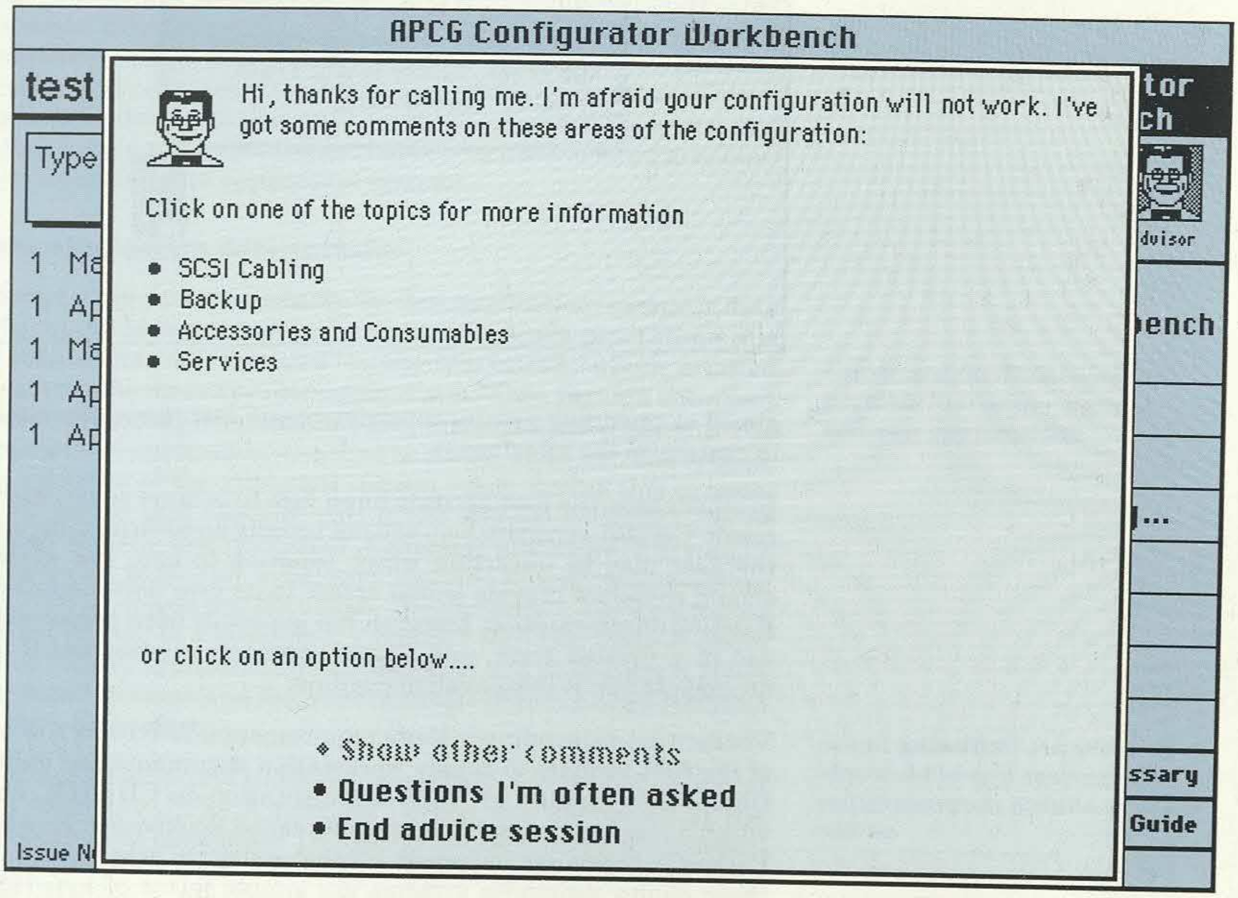
It is also helpful if the system can provide appropriate training when the user gets into difficulties. This can be achieved by providing computer-based training facilities via the workstation in a way that allows the user to select only the part that he really needs. (Again, this requirement is addressed in Hewlett-Packard's NewWave.)

'Intelligent agents' will help users to operate more effectively

In future, users may be assisted by 'intelligent agents', which include, and use, knowledge about the individual user, his applications, and the kinds of mistakes that people make. Such agents may be represented by animated pictures of heads. This technique is used in Apple (UK)'s Product Configuration Guide, a CD-ROM knowledge-based system developed by Cognitive Applications of Brighton. The agent, 'Phil', can be called at any point in the definition of a Macintosh configuration. Figure 2.7 shows his comments on one proposed configuration.

These advances will make graphical-user-interface systems even easier to use, and especially to use well. They will therefore extend further the effective use of IT systems.

Figure 2.7 In Apple (UK)'s Product Configuration Guide, an 'intelligent agent' comments on proposed configurations



(Source: Cognitive Applications Limited)

Macro facilities

Many PC users have found the macro facilities provided with their applications to be very useful. Usually, the facility is used to record the sequence of actions (known as a macro) performed by the user to achieve a desired result. The same result can be achieved on a subsequent occasion by running the macro. Macro facilities therefore provide users with an easy-to-use 'programming' capability that does not require a formal design process or the involvement of a data processing professional.

Macro facilities provide users with an easy-to-use 'programming' capability

Application-independent macro facilities are available with PC packages such as Borland's SUPERKEY (which does not work with Windows, however). Such facilities not only remove the need to learn several different application-specific facilities; they enable users to generate macros that use several different applications.

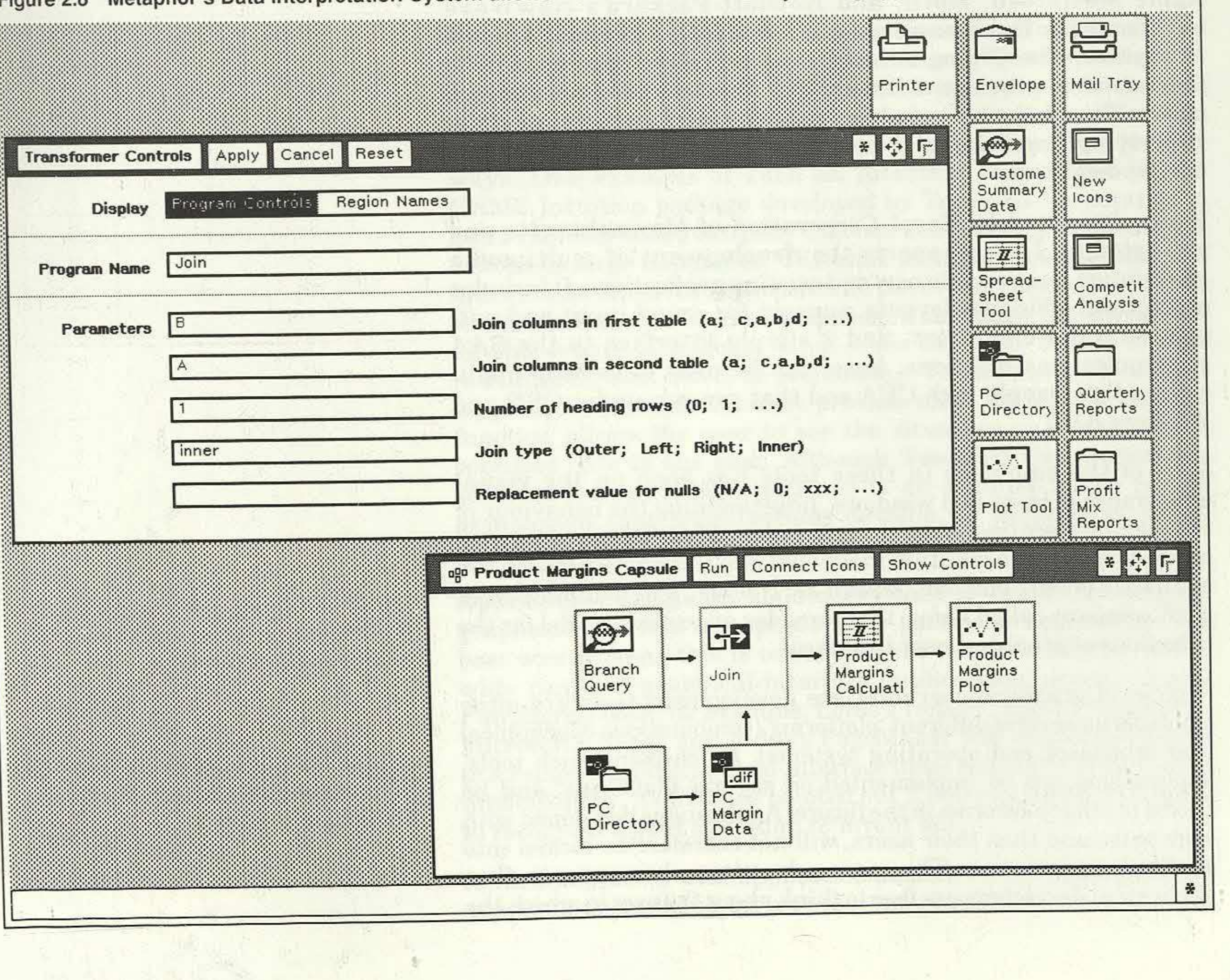
Most existing macro facilities have been developed to run in non-graphical-user-interface environments such as MS-DOS and Unix. To produce an application-independent macro facility for use in a graphical-user-interface environment, it is necessary to record mouse actions and positions as well as keyboard input. This poses considerable problems, because the result of a mouse action depends on the state of the display, and specifically, on which icon occupies a particular location on the screen.

Graphical macro facilities are starting to be introduced

Nevertheless, these problems have largely been solved and commercial products are becoming available. A leading example is the 'agent' facility in Hewlett-Packard's NewWave. Microsoft will introduce its own macro system, initially embedded in applications but later provided independently, over the period 1991 to 1993. Some systems (Metaphor Computer Systems' Data Interpretation System (DIS), for instance) allow macros to be defined graphically, by linking the icons representing applications, rather than in the more traditional textual manner.

Such graphical macro facilities allow users to automate routine tasks and to create new personalised 'applications'. Figure 2.8 shows a graphical representation of a DIS macro that is used in this way. This macro uses a relational 'join' to combine data on brand sales from a corporate database, with data on product

Figure 2.8 Metaphor's Data Interpretation System allows macros to be defined by linking application icons



margins from a PC spreadsheet. The combined data is used to calculate performance data for a branch, which is then plotted as a graph.

Higher-level development tools

The detailed work of tracking mouse movements and producing and modifying the windows and icons is performed by the systems software layer of a graphical user interface. Applications may call this layer directly via its application programming interface, but this requires complex programming merely to maintain the integrity of the interface. Vendors have therefore provided a variety of specialised development tools that make it easier for programmers to manipulate displays at a level appropriate to their current needs. Such tools do not require the application developer to be expert in the technology of windows, graphics, and mouse-movement analysis. They can be used with a variety of graphical user interfaces and are available from several vendors. For example, major tool vendors such as Oracle, Ingres, and Information Builders also now support graphical-user-interface development.

Specialised development tools make it easier for programmers to manipulate displays without having to understand the underlying technology

Using such tools means that applications can be implemented with a different graphical user interface simply by recompiling them in a different environment. Glockenspiel, for instance, a software house based in Dublin, has developed the Commonview system, which can be used in OS/2 EE (extended edition), Windows 3.0, Apple Macintosh, Motif, and Hewlett-Packard's NewWave environments. Commonview is based on C++, an object-oriented extension of the C programming language developed by AT&T. Commonview provides a library of 70 classes of user-interface objects. Together, these give access to the full functionality of the underlying graphical-user-interface systems. It also includes development tools.

Easel, developed by Easel Corporation of Massachusetts and marketed by IBM, supports the development of multimedia workstation front-ends to new and existing applications. It includes a graphical editor for layouts, support for sound input and output, terminal emulators, and a simple interface to the SAA communications functions. Easel can be used to develop applications that comply with CUA and that can run under OS/2 and Windows 3.0.

Most of the emphasis in these tools has been on the visual appearance of icons and windows. Implementing the behaviour of the user interface (including the processing of user-initiated actions) has been the responsibility of individual application developers. We are aware of only one tool (known as 'Horses', and available from a UK company called Pafec) that provides an explicit model for the behaviour of graphical user interfaces.

High-level graphical-user-interface development tools are often available for several different 'platforms' (combinations of graphical user interfaces and operating systems). By choosing such tools, applications can be implemented on several platforms, and be moved to other platforms in the future. Applications developed with such tools, and thus their users, will not therefore be locked into particular platforms. The main advantage, however, is that application developers are free to think about the way in which the

High-level tools allow applications to be developed independently of hardware application should appear to its users, rather than about the technical means of building the interface. This does, however, require development staff to have new skills.

Application developers will need new skills

The development of applications with graphical user interfaces differs from the development of traditional applications both in the technology that is used and in the design of the interface itself. Technically, the implementation of graphical user interfaces will require developers to use high-level tools (such as those described above) that shield them from most of the complexities. The skills required to use such tools can be learned on training courses, available from various sources.

Designing a natural and intuitive interface requires specialised skills

It is more difficult to acquire the skills required to design a graphical user interface that will provide users with a natural and intuitive interface. The main design tasks are the creation of appropriate metaphors, the specification both of the functions provided by the interface and of its behaviour, and the design of the graphical displays. These are highly creative tasks, and although they will not be required for every application, they will be an increasingly important part of the system designer's job. It is quite likely that system designers will need assistance from other professions.

The small number of metaphors in widespread use today indicates that it is very difficult to create a successful new metaphor. Application designers will, however, sometimes have to choose a metaphor for the graphical user interface. Often, the interface can be based on existing paper documents, perhaps organised in novel ways. One example of such an interface is provided by the HRMS Intuition package developed by Tesseract Corporation, a San Francisco-based company that markets human-resource applications to large companies. The basic metaphor used is folders of index cards. Some folders contain all the events that have occurred while a person has been employed by a company. Others contain all the events of a single kind — for example, details of staff recruitment, sick leave, or promotions. The information can also be presented as panels that provide more details. A 'regress' function allows the user to see the situation as it existed at a specified date in the past. Although Tesseract Corporation is a software house, HRMS Intuition is an example of the type of application that organisations develop for themselves, not of systems software.

Application designers can learn much from existing graphical-interface applications

Application designers should evaluate a variety of possible graphical-interface metaphors for a particular application. The best way of doing this is to ensure that they are familiar with a wide range of graphical-interface applications already in use. Familiarity with, for example, Lotus's Improv, Apple's Hypercard, Microsoft's Excel, and Aldus's PageMaker will expose developers to a range of good graphical-interface ideas that have already been implemented. As Pericles pointed out 2,500 years ago, it is easier to recognise a good idea than to invent one.

As has happened with application packages, we expect software suppliers to produce user-interface templates that developers can adopt or modify, instead of developing their own. These templates will often be superior, in both graphical design and in the completeness of their programming, to those that a developer in a user organisation would create for himself, and will therefore be very effective bases for in-house development. Some may even be suitable for use in an end-user computing environment.

User-interface templates from software suppliers will be an effective basis for in-house development

Choosing a corporate standard for graphical user interfaces is, however, closely linked with the choice of workstation operating system. Our advice about appropriate standards is therefore given in the next chapter, where we describe the most significant developments in workstation operating systems.

Chapter 3

Workstation operating systems

The main personal computer operating systems in widespread use today are Microsoft's MS-DOS, and Apple's Macintosh system. These are fairly limited systems, however. Unix, an inherently more advanced system, is well established for technical workstations and minicomputers, but is rarely used in general-purpose workstations. (In this report, we use the term 'workstation operating system' to include personal computer operating systems.)

There is vigorous competition between operating system suppliers

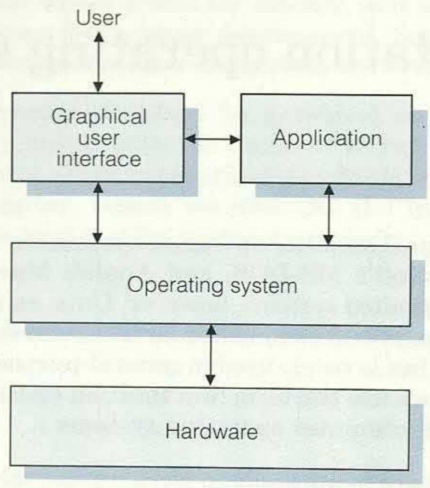
Rapid advances are being made in workstation operating systems (and in other workstation systems software), and there is considerable competition between rival products. Many systems managers are currently contemplating major upgrades, and it is important that they understand the nature of workstation operating systems and the changes that are taking place. In summary, the main findings of our research are:

- For low-powered workstations, the best choice at present is either PCs running MS-DOS or Macintoshes. By 1993, OS/2 plus Windows will be a viable upgrade path from MS-DOS/Windows.
- For high-powered workstations, the best choice is Unix. There is little to choose between the two main variants of Unix (AT&T's, and the Open Software Foundation's).
- For intermediate workstations, there is a wider choice — the main ones being MS-DOS, OS/2 (but with Windows emulation, not Presentation Manager), Macintoshes, and Unix. Unix, however, should be chosen if there is a need for compatibility with high-powered workstations.
- The *de facto* standards for PC operating systems are now being set by Microsoft, not by IBM. Thus, the choice between MS-DOS and OS/2 is subsidiary to the decision to standardise on Microsoft's Windows.
- Although its commercial success is not assured, Hewlett-Packard's NewWave provides good examples of the type of facilities that will be commonly available by the mid-1990s.
- By the late 1990s, there will be few differences between the main workstation operating systems. In effect, they are converging on a common set of functions and common interfaces.

Workstation operating systems derive from two sources

The basic structure of a workstation operating system is shown overleaf in Figure 3.1, which depicts, in general terms, the

Figure 3.1 **All workstation operating systems have the same basic structure**



relationships between the hardware, the operating system, the graphical user interface, and an application. Today's workstation operating systems derive from two sources — minicomputer operating systems and personal computer operating systems. These have different origins and have developed in different ways.

The first minicomputer operating systems were developed as single-user systems for small machines, but soon had to be extended, or rewritten, so they could support several users at a time. Later, some minicomputer operating systems (notably Unix and Digital's VMS) were transferred to engineering workstations, where they retained their multiprogramming and multitasking capabilities, partly for reasons of compatibility, and partly because these were useful to users and developers.

Minicomputer and personal computer operating systems were originally developed as small, single-user systems

Personal computer operating systems were also developed originally as small single-user systems, mainly because of the limited computing and storage resources available. As a result, and because of their heroic attempts to build powerful and responsive applications on low-powered machines, the developers of PC applications often used all the available processing and storage resources. This habit has made the subsequent introduction of multiprogramming and multitasking workstation operating systems particularly difficult.

PC applications did, however, provide user interfaces that, although often lacking in both ergonomic and aesthetic terms, were extremely responsive. As discussed in the previous chapter, users are now moving to graphical user interfaces that remedy the ergonomic and aesthetic deficiencies, but that do require additional processing power.

To overcome the inherent limits of MS-DOS, and to a lesser extent, of the Macintosh operating system, software suppliers have provided functions such as communications and database management that, ideally, should be an integral part of the operating system. These additional functions are provided as proprietary applications or as systems software utilities.

There are established and emerging contenders in the market

There are four established contenders

The four main established contenders in the workstation operating system market are Microsoft's MS-DOS/Windows 3.0, IBM's OS/2, the Macintosh operating system, and Unix. The original versions of MS-DOS, Macintosh, and Unix are well established, but provide a limited range of features; OS/2 is an example of emerging operating systems that provide a wider range of features. Other examples include later versions of Unix and the new Macintosh operating system (System 7.0).

NewWave indicates how workstation operating systems can be improved

We also describe Hewlett-Packard's NewWave. NewWave is not an operating system, as such, but a collection of systems software that provides a new architecture for applications. The software exists for the MS-DOS and Windows environment, and versions are being developed for OS/2 and Unix. In time, NewWave will also replace Hewlett-Packard's own Unix graphical user interface. We include it here because, although its commercial success is uncertain, it shows the way in which a variety of technologies can be integrated to improve a workstation operating system, and especially its user interface. It also indicates the complexity of the result.

The key features of established and emerging workstation operating systems are shown in Figures 3.2 and 3.3 (overleaf) respectively. Applications written for established operating systems are generally able to run under emerging operating systems. Thus, MS-DOS programs can run on OS/2, MS-DOS/Windows 3.0, Unix, and NewWave, and existing Macintosh applications can run under System 7.0 and Apple's own version of Unix, A/UX.

Figure 3.2 Established workstation operating systems have a limited number of features

	Operating system		
Features	MS-DOS	Macintosh	Unix
Graphical user interface	—	Macintosh	Various
Multiprogramming	—	✓*	✓
Multitasking	—	—	✓
Virtual memory	—	—	✓
Clipboard	—	✓	—
Hot links	—	—	—

*With MultiFinder

MS-DOS/Windows 3.0

Originally, MS-DOS was a re-implementation for the 16-bit Intel 8088 chip of CP/M, which was the most popular operating system for 8-bit chips. MS-DOS was, and largely remains, a fairly simple system. Despite successive enhancements to support larger memories, more powerful processors, and better displays, it is now showing its age. This is especially clear from its ability to address directly only 640k of memory. Although solutions have been found

Figure 3.3 Emerging workstation operating systems have an enhanced range of features

Features	OS/2	Unix (OSF or System V Release 4)	A/UX	Macintosh System 7.0	NewWave	MS-DOS/ Windows 3.0
	Operating system					
Graphical user interface	CUA	Motif or Open Look	Macintosh	Macintosh	CUA	CUA
Multiprogramming	✓	✓	✓	✓	(1)	✓
Multitasking	✓	✓	✓	✓	(1)	—
Runs DOS programs	1 only	(2)	(2)	—	(1)	(2)
Virtual memory	✓	✓	✓	✓	(1)	✓
Clipboard	✓	ICCCM	✓	✓	✓	✓
Hot links	—	—	—	✓	✓	✓

(1) Depends on the features of the supporting operating system
(2) Runs more than one (if memory is sufficient)

to this, they have been implemented in a variety of inconsistent ways.

Windows 3.0 completely changes the picture. Windows 3.0 is much more than a graphical-user-interface manager, however, because it also provides MS-DOS with memory-management and multi-programming features. Although Windows 3.0 can run in as little as 0.5 megabyte, early experience suggests that benefits will be limited without at least an Intel-286-based PC with 2 megabytes. For many users, a 386 PC and 4 megabytes are more appropriate.

With sales of 3 million copies in the first year, Windows 3.0 has ensured the survival of MS-DOS for many years to come. It also weakens the case for moving to OS/2, since Presentation Manager (which provides graphical-user-interface support) was the main reason for favouring OS/2. Windows will be developed over the next few years to make better use of the 32-bit 386 processor, and to provide features currently available only with more powerful operating systems like OS/2. This will further weaken the case for moving to OS/2.

The success of Windows 3.0 ensures the survival of MS-DOS

OS/2

OS/2 was launched in 1987 by IBM and Microsoft, supposedly as the natural successor to MS-DOS. It may be seen either as a carefully considered attempt to deal with the deficiencies of MS-DOS, or as IBM's attempt to reassert its domination of the desktop-computing market, and sell more PCs. It provided the first implementation of the CUA graphical user interface, a large address space, virtual memory, and a multitasking and multi-programming environment. Developers with experience of OS/2 now find it a satisfactory development environment (although all development environments for applications with graphical user interfaces are more complex than non-graphical ones).

User acceptance of OS/2 has been very limited so far, largely because of the lack of applications and the high cost of the hardware required to run it. The minimum configuration required to run OS/2 is a PC with a 386 processor and 6 megabytes of memory. (The recently announced cut-down version, known as OS/2 LITE, requires only 2 megabytes, but it is not yet clear whether this will be workable in practice.) Applications have not been available because of uncertainties about the future of OS/2, resentment of IBM's apparent attempt to lock up the market, and the difficulty of developing applications to run in a graphical-user-interface environment. At present, organisations are using OS/2 mainly for servers, not workstations.

OS/2 is being used mainly for servers, not workstations

IBM and Microsoft are each developing OS/2, but in rather different ways. By the start of 1991, Microsoft was positioning OS/2 as a rival to Unix — in other words, as an operating system for technical workstations. As such, it would be implemented on processors other than the Intel 80n86 series, including Sun's Sparc and MIPSCO's R series, and would support the Posix interface. Microsoft was de-emphasising the Presentation Manager component of OS/2, and was positioning the Windows applications programming interface as the standard for both MS-DOS and OS/2.

At the beginning of 1991, IBM's policy was still to position OS/2 and Presentation Manager as the natural successor to MS-DOS. However, its announcement of support for Windows "within the OfficeVision strategy", combined with industry speculation that IBM would drop OS/2, makes further revisions of its policy quite likely.

In the light of the problems and uncertainties over OS/2, and the rapid market acceptance of Windows 3.0, we recommend that, at present, users should not make any long-term commitment to Presentation Manager and should use OS/2 only when essential. However, since OS/2 is inherently a better operating system than MS-DOS, there will be situations where it is the better choice. Organisations choosing to adopt OS/2 can continue to run existing Windows applications, and OS/2 Release 3.0 will provide even better support for Windows. Moreover, there will soon be many more Windows than Presentation Manager applications.

Long-term commitment to OS/2 should be avoided, and it should be used only where essential

For most organisations, then, Windows 3.0 is the appropriate graphical-user-interface standard for PCs, the choice between MS-DOS and OS/2 being a secondary one. Even IBM has tacitly agreed that this is the case by agreeing to support Windows 3.0 within its OfficeVision strategy.

The choice between MS-DOS and OS/2 is secondary to deciding to standardise on Windows 3.0

Macintosh operating system

The basic Macintosh operating system is a single-user system with a graphical user interface and built-in support for networking using the proprietary Apple File Protocol (AFP). It does not support multiprogramming, although a multiprogramming version, MultiFinder, can be run on systems with 2 megabytes of memory or more (the basic version can be run in 0.5 megabyte). The new Macintosh operating system, System 7.0, will provide virtual memory, multiprogramming, and inter-application linkages.

Because of Apple's control over the architecture of the Macintosh, it will stay proprietary. However, it will continue to be more usable than PCs, and Macintosh applications will be more consistent in style.

Unix

Unix is already extensively used on minicomputers, and is the *de facto* standard for technical workstations, supercomputers, and parallel computers. It has also been implemented on mainframes, and forms the core of the open systems standards as defined in the X/Open Common Applications Environment (CAE) and various government standards initiatives. It therefore provides a measure of compatibility over a wide range of equipment from workstations to supercomputers. Owing to its history, applications cannot, in general, be transferred from one version of Unix to another simply by recompilation; some minor modifications are usually needed.

Unix is the de facto standard for a wide range of computers . . .

. . . but applications cannot be transferred unchanged from one version to another

Unix systems provide high performance and good price/performance, and the existing implementations are being migrated to one of two emerging Unix standards — AT&T's Unix System V Release 4, and the OSF/1 standards. Significant compatibility exists between these competing standards. For instance, both comply with the X/Open CAE.

Until recently, Unix workstations were significantly more expensive than PCs. During 1990, however, the announcement of low-cost Unix workstations, often based on Risc processor chips, brought prices down to the level of the larger PCs. Businesses that require significant workstation processing power can no longer reject Unix because of the cost of the workstations required to run it.

The price of Unix workstations is now competitive

A major drawback of Unix has been the cryptic and difficult command languages, although the general introduction of graphical user interfaces has now eased this significantly. The command language does sometimes show through, although this is also true of Windows 3.0. The best available graphical user interface for Unix is probably the Macintosh interface, provided by Apple's own Unix implementation, A/UX.

NewWave

NewWave requires applications to be divided between a 'command processor', which performs the useful work done by the application, and an 'action processor', which interfaces the command processor to the graphical-user-interface system, providing those features of the user interface that are particular to the application. When macros (known in NewWave as agent tasks) are being performed, the agent, instead of the action processor, drives the command processor.

NewWave integrates applications with each other and with the graphical-interface desktop environment, but it does so fully only if applications are developed especially for it. Existing applications developed for MS-DOS/Windows 3.0 (and soon for OS/2 and Unix) may be run under NewWave, although some work is required to provide them with their own icons on the NewWave desktop. However, significant effort, sometimes amounting to a rewrite, is needed before an existing application can make use of all the features provided by NewWave. Figure 3.4 indicates the level of effort required to adapt (or, in NewWave terminology, 'encapsulate') an existing MS-DOS application so it can run under the MS-DOS version of NewWave. It also shows that some features of NewWave cannot be used even by applications encapsulated to the advanced

The benefits of NewWave can be gained only by applications designed specifically for it

Figure 3.4 Existing applications 'encapsulated' in NewWave will obtain the advantages of the NewWave environment only if they are extensively adapted or rewritten

Existing applications can be adapted to run in the NewWave environment in an 'unencapsulated' form, or can be encapsulated in NewWave at a basic or an advanced level. Hewlett-Packard estimates that the effort required to adapt an existing MS-DOS program to run under the MS-DOS version of NewWave varies from 10 minutes (unencapsulated), to one hour (basic encapsulation), to 'significant programming' (advanced encapsulation).

NewWave feature	Unencapsulated MS-DOS program	MS-DOS program encapsulated to basic level	MS-DOS program encapsulated to advanced level
Start from graphical-user-interface desktop	✓	✓	✓
Clipboard	✓	✓	✓
Context switching	✓	✓	✓
Direct manipulation of graphical-user-interface objects	—	✓	✓
Printing by direct manipulation	—	—	✓
Visual view	—	—	✓
Data-passing links	—	—	✓
Context-sensitive help*	—	—	—
CBT*	—	—	—

*These features can be used only by applications designed specifically for NewWave

level. These features can be used only by applications designed specifically for NewWave.

Several dozen software vendors now offer packages for NewWave, although most of these have not been designed specifically for NewWave, and therefore do not provide all the potential benefits. The minimum configuration required to run NewWave is an Intel-286-based workstation with 3 megabytes of memory, and a 20-megabyte hard disc.

Other suppliers have adopted NewWave as part of their architectures

AT&T, Data General, Canon, and NCR have adopted NewWave as part of their own architectures, and are developing and extending it in various ways. (Some of the features provided by NewWave are described in more detail later in this chapter, on page 34.)

Workstation operating systems and graphical user interfaces cannot be chosen independently

Most organisations now have a range of personal workstations installed, using a variety of operating systems. At first sight, the ideal would seem to be to standardise on a single operating system and graphical user interface. The disadvantage of a single standard, however, is that it may not fully satisfy all users' needs. Furthermore, the devolution of authority that has occurred in many businesses may make it difficult to enforce a single standard, and any attempt to do so may create resentment.

In practice, businesses generally require a range of workstations, rather than a single model, with the power and price matched to the requirements of individual users. Three main levels of functionality and performance can usually be identified:

Most organisations require a range of workstations to provide three levels of functionality and performance

— Engineers (and some other professionals) may need high-powered workstations.

— Clerks (and some managers) may need low-powered inexpensive workstations that will be used to run one or two local applications and to access major transaction-processing systems.

— Professionals (and some managers and clerks) may need workstations of intermediate power that are able to run a wide range of applications, and provide some multiprogramming facilities.

The best course of action is to decide which standard would be most appropriate for each major group of staff, and then to see if it is possible to set a single standard.

High-powered workstations

The choice for high-powered workstations lies between Unix and various proprietary operating systems. For the reasons given in the Butler Cox Position Paper, *Open Systems* (published in July 1990), we believe that Unix will generally be the best choice. It will, however, be necessary to choose between the AT&T and OSF versions of Unix. Although each has strengths and weaknesses, both will be good products, and the differences are not as large as is sometimes suggested. It will also be possible for organisations with appropriate technical skills to use elements of both. For instance, it is possible to use OSF's Motif and Distributed Computing Environment with AT&T's Unix kernel.

Unix will be the best choice for high-powered workstations

If OSF's version is chosen, it will also be necessary to decide the correct rate of progress from existing semi-proprietary versions of Unix to fully open standards. OSF's version will not be fully established in the market until, perhaps, 1992.

Low-powered workstations

For low-powered workstations, the main choice lies between Macintoshes and low-power PCs running MS-DOS/Windows 3.0. The main advantage of the Macintosh is the superior integration of its facilities and its lower cost of ownership. (By the end of 1990, it was clear that the total cost of owning and using a Macintosh — purchase price, additional hardware, support costs, user training costs, and so on — was lower than for corresponding PCs.) The main advantages of PCs running MS-DOS/Windows 3.0 are its quasi-open status, and the similarity between the Windows 3.0 graphical user interface and Motif. Their main disadvantage is the higher user-support cost arising from the lower level of integration of their facilities.

The cost of owning and using a Macintosh is lower than for corresponding PCs

Intermediate workstations

The widest range of choice exists at the intermediate-workstation level. Unix, OS/2 with Presentation Manager, DOS/Windows 3.0, and Macintosh are all possible choices. In practice, OS/2 with

Presentation Manager can generally be excluded because of the uncertain future of Presentation Manager. Unix, also, will rarely be a serious contender, unless compatibility with high-powered Unix workstations is required. For the more powerful machines needed at this level, PCs are generally cheaper than Macintoshes, although this advantage will be offset to some extent by the lower support and training costs required for Macintosh users.

Adopting MS-DOS/Windows 3.0 for intermediate workstations will make it easy to migrate to OS/2 and Windows

At present, the most appropriate operating system and graphical user interface for intermediate-level PCs is MS-DOS/Windows 3.0. Organisations adopting this combination will benefit from further improvements in Windows, and by 1993, it will be possible to replace MS-DOS by OS/2 (but without Presentation Manager). The combination of OS/2 and Windows will provide full access to the facilities of the Intel 386 (and later) chips, a sound operating system, and an easy migration path.

Advances in workstation operating systems are occurring on several fronts

Workstation operating systems are constantly being enhanced. These enhancements fall into three groups. First, the basic capabilities of the operating systems are being increased, largely by including useful features from minicomputer operating systems. Second, new capabilities, not previously available with any type of operating system, are being added. Third, functions previously provided by applications are becoming part of the facilities provided by the operating system.

Workstation operating systems have an open architecture

These developments mirror the evolution of mainframe and minicomputer operating systems, but with two important differences. The evolution is occurring much faster, and many of the advances are embodied in software that is available to the whole industry rather than to purchasers of just one vendor's equipment. As a result, workstation operating systems (including the functions that integrate them with servers, discussed in the next chapter) have an open architecture, and in terms of features and capability, will soon overtake mainframe and minicomputer operating systems.

Advances in workstation operating systems are particularly apparent in four areas — memory and application management, linkages between documents, linkages between applications, and convergence between independently developed workstation operating systems.

Much of the value of these advances depends on the use of these operating system features by applications. The full value will therefore become available only as new or improved applications are introduced. In addition, the successful use of some new features, notably the linkages, depends on agreement between software vendors — for example, for the naming of 'events' that communicate information between applications. These agreements do not yet exist. In our view, applications to take full advantage of such features will be available, at the earliest, by 1992.

Memory and application management

Virtual memory is a technique used by operating systems to extend the random-access memory available for applications. It allows users to run programs that are larger than the real memory, or to keep several programs ready for execution. Unix, OS/2, and Macintosh System 7.0 all support virtual memory on appropriate hardware (that is, on machines that include hardware-supported memory management).

As workstation memories, real and virtual, have increased, it has become feasible to keep several applications in memory at once. Three approaches have been taken to avoid delay in switching between these applications — 'desk accessories', program switching, and multiprogramming.

Desk accessories

Macintosh systems have desk accessories — programs that are always available 'on the desktop'. They are typically small and therefore load quickly. Desk accessories allow users to do simple things, such as check the time, count the number of words in a document, redirect printing, perform calculations, or change the appearance of the desktop, without closing down the current application.

MS-DOS does not provide this type of feature, but some developers have produced 'terminate and stay resident' (TSR) applications that do just that. A TSR continues to occupy memory until needed, when a special keyboard sequence activates it. Because TSRs were not part of the original design of MS-DOS, their presence sometimes causes difficulties with other applications and TSRs. The best-known TSR is probably Borland's SideKick, which provides a variety of facilities including calculator, notepad, document outliner, communications, time planner, and telephone list.

Program switching

Program switching has been introduced both on the Macintosh (under Switcher or MultiFinder) and on PCs (using Windows or independently supplied utilities such as Software Carousel). With program switching, all the applications occupy memory, but only one can run at any time. This does not provide true multiprogramming, but it does make it much faster to switch from one application to another. It is particularly useful, for instance, when preparing illustrations for inclusion in a word processed document, because the user can switch quickly between his graphics package and his word processor.

Program switching is particularly useful for transferring data from one program to another

Multiprogramming

Multiprogramming allows different programs to run concurrently, and is supported by the most advanced workstation operating systems (OS/2, Unix, and Macintosh System 7.0). It is also a feature of minicomputer and mainframe operating systems, including Unix, where it is used to support multiple concurrent users. The operating system causes the processor to switch rapidly between applications. Multiprogramming allows a workstation to support, for example, an online user, and to respond to network traffic concurrently. In this way, the user need not be held up while electronic mail is being transmitted or while data is being retrieved from a remote system.

Multiprogramming enables different programs to run concurrently

Several parts of the same program can also be run concurrently, a capability known variously as multitasking and multithreading.

Multitasking is supported by Unix and OS/2. Within the OS/2 version of PageMaker, for instance, three threads run concurrently. One processes messages from the user interface or the operating system, a second redraws the screen, and the third (the service thread, which is the lowest in priority) is available for larger tasks. This division provides greater responsiveness to user actions than in the Macintosh and Windows versions of PageMaker. The ability to abort a task that has been allocated to the service thread has been found particularly useful since it facilitates a more rapid system response to user actions.

Linkages between documents

Advanced linking facilities maintain the connection between the source and recipient documents

The most basic method of linking documents (and applications) is the clipboard facility, now provided with most graphical user interfaces, and discussed in Chapter 2. More advanced facilities allow the connection between the source and recipient documents to be maintained, so that changes in the former are reflected in the latter. These facilities are known variously as 'hot links', 'live links', and Publish and Subscribe (Apple).

Live links may be used to create and maintain a compound document

One obvious use for live links is the inclusion in a report of a graph based on numbers held in a spreadsheet, or part of a spreadsheet. With a live link, any change made to the spreadsheet would automatically cause the graph in the report to be updated. Note, however, that the text of the report would not change, so care would be needed to keep the text in line with the latest version of the graph. A further problem is the possibility that changes in the size of the graph might upset the pagination in the report. Live links may also be used to create and maintain a compound document — including text, graphics, and pictures, for instance — that behaves as a single entity. In the NewWave environment, for example, an attempt to edit a chart in a word processed document will automatically activate the charting package.

Linkages between applications

Unix was one of the first operating systems to provide easy communication between applications while they are running. This facility is called a 'pipe' and is a valuable means of linking applications.

The Dynamic Data Exchange (DDE) facility in Microsoft's Windows extends the concept of a connection by defining a protocol for its use. DDE allows applications (called clients) to use objects maintained by other applications (known as servers). (Note that the terms 'client' and 'server' have a more specialised meaning here than the ones we describe in Chapter 4.) DDE links can be set up between executing programs on the same machine. Once the link is established, the client application can obtain the value, change the value, or request notification of any change in the value of the object maintained by the server. DDE links, like Unix pipes, are lost when either program is unloaded.

Apple's Macintosh System 7.0 also includes a powerful mechanism for communications between applications, known as Inter-Application Communication (IAC). IAC allows applications to send 'events' to other applications, instructing them to perform certain actions.

The most sophisticated approach to inter-application communications is that taken in Hewlett-Packard's NewWave. As Figure 3.5 shows, NewWave supports three kinds of inter-application links, each of which is maintained even when one of the applications is unloaded:

NewWave takes the most sophisticated approach to inter-application communications

— Data-passing links pass part, or all, of the data in an object to another application for processing. For instance, some cells of a spreadsheet might be passed to a statistical program for analysis, or to a business graphics program for plotting. Hewlett-Packard has defined standard formats for data exchange.

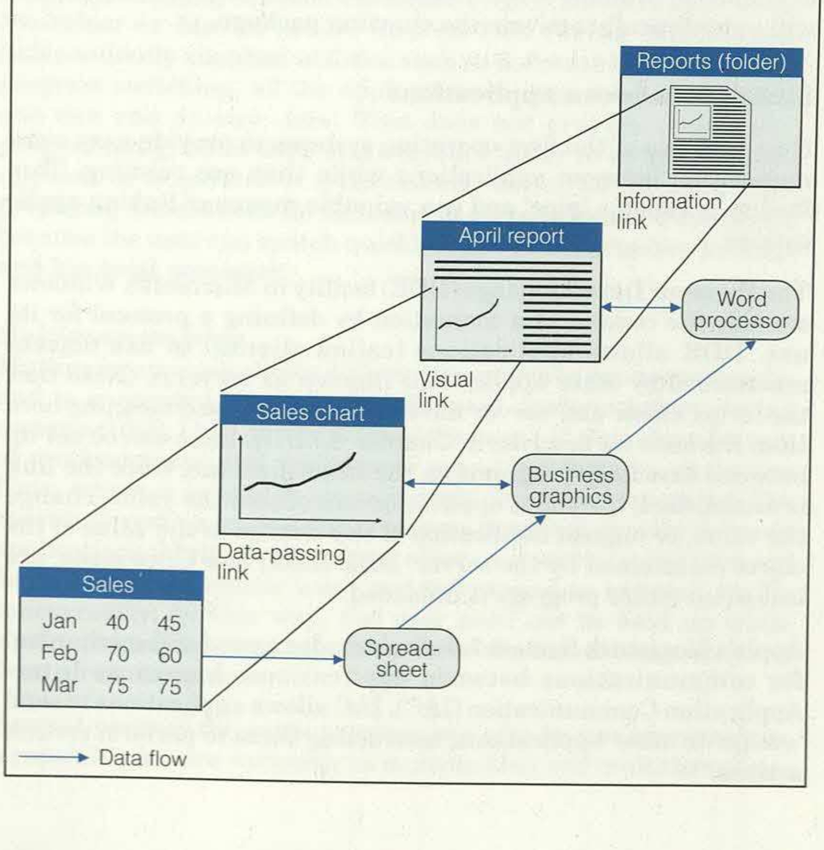
— Visual links pass the output of one program to another. For instance, a graph might be drawn by a graphics package and passed to a desktop publishing package, which would display it at a particular place in a report.

— Information links express relationships between objects. They may indicate containment (this chart is part of this report), or attachment (this is an annotation to the report).

These facilities, which are based on object-management principles and techniques, allow an application to treat other applications as suites of subroutines. This offers four major benefits:

— Code can be re-used by future applications, without any need for the developer to understand more than the calling interface to existing functions. This will provide major gains in development productivity.

Figure 3.5 NewWave supports three kinds of inter-application links



— Applications can be built by incorporating the most suitable components.

— Developers who are expert in one area — say, knowledge-based systems — can incorporate applications developed by experts in other areas. This should increase the numbers of applications and developers, and the quality of the applications.

— Consistency is increased because a particular function (speech recognition or control of a printer, for example) is always handled by the same piece of code.

Convergence on a common set of features

The trend is for workstation operating systems to become less distinctive and less proprietary. The differences between them are being reduced by continued enhancements such as the provision of graphical user interfaces, virtual memory, and multiprogramming support. In effect, they are converging on a common, though evolving, set of features.

All workstation operating systems will provide a similar set of facilities by the year 2000

By the year 2000, all workstation operating systems will provide a similar set of facilities (including the programming interfaces currently associated with MS-DOS and Unix), with competition restricted to higher-level functions, and some aspects of system management. Many of the higher-level functions will be defined and provided, not by workstation suppliers, but by independent software developers and industry consortia.

In the past, operating systems have been the most distinctive part of proprietary computer systems, and tied closely to particular hardware architectures. This has meant that user organisations have had to employ scarce and expensive technical specialists who are experts in the particular hardware/systems software combination.

The close linkage between hardware and operating systems is being weakened

The close linkage between hardware and operating systems is now being weakened. First, suppliers are increasingly making their operating systems emulate the systems programming interfaces of others. Thus, both Unix and OS/2 can run MS-DOS applications. Second, operating systems are being developed so that they can easily be transferred from one hardware architecture to another. Third, independent software developers are starting to offer their products for a variety of operating systems. Microsoft, Ashton-Tate, and Lotus, for instance, offer products for all the main workstation operating systems.

The result will be that user organisations will have much more freedom of choice, and will be able to construct the most appropriate technical infrastructure to meet their particular business needs. One of the most important means of achieving this will be by adopting client-server systems, which we discuss in the next chapter.

Chapter 4

Client-server systems

The advanced graphical user interfaces and the more powerful workstation operating systems discussed in earlier chapters will have a considerable impact on the productivity of workstation users. The benefits will be limited, however, if they apply only to applications that run on the workstation itself. Workstations must therefore be connected, via networks, to other computers.

Many attempts have been made in the past to use workstations as 'intelligent terminals' linked to mainframes or minicomputers and to use them for 'cooperative computing'. These attempts have often failed because of a lack of workstation processing power, immature standards, and over-complexity. The client-server approach is emerging as the most successful and practical method of developing and managing corporate distributed systems so that workstations can have access to all the resources of the corporate network.

The client-server approach is emerging as the best way of implementing corporate distributed systems

The most significant messages to emerge from our research into client-server systems are:

— Software products to support client-server systems are now available. Some organisations have based their entire systems architecture on client-server principles.

— Client-server systems allow each component of an application to be run on the most appropriate hardware. Thus, workstations can be used to provide the user interface and low-cost processing power; database machines can be used for database management; expensive peripherals can be shared by several workstations.

— By integrating applications and databases at the workstation, client-server systems provide users with a consistent interface.

— A new approach to systems development, and new skills, will be required. However, specialised development tools are becoming available.

— Remote procedure calls (RPCs) are an integral part of client-server systems. The leading RPC systems are those defined by Netwise, Digital, and Sun Microsystems.

— Products and standards are immature, and care should be taken to ensure that products can actually interwork.

— Networks may need to be upgraded to cope with the increase in communications traffic.

Client-server systems provide benefits both for the individual user and for the organisation as a whole. New developments are occurring very rapidly, however; both the hardware and the software for servers are becoming progressively more powerful and more sophisticated.

Client-server systems enable applications to be partitioned over several computers

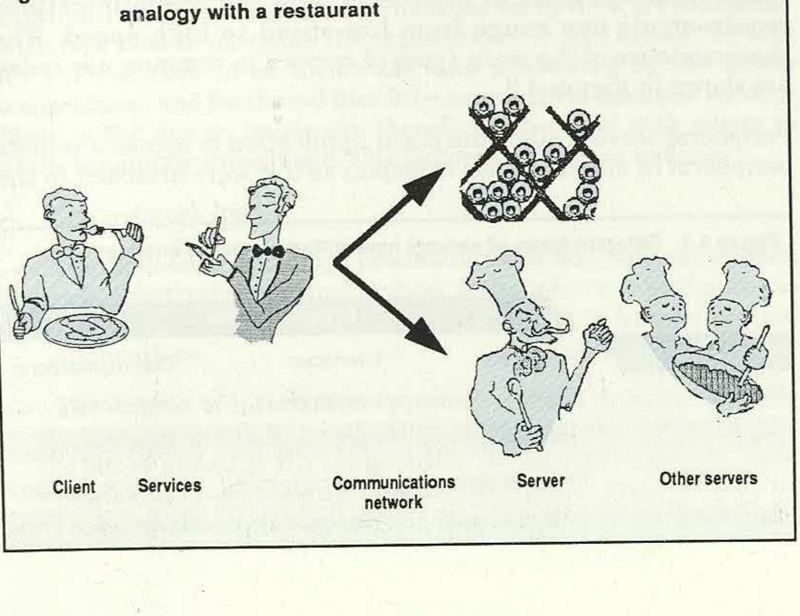
In conventional systems, all of an application runs on one computer and the different parts of the software communicate through shared data storage and by using procedure calls. In a client-server system, this structure is replaced by one in which many separate processes exchange messages over a network. It provides a simple form of parallel processing.

In a client-server system, the 'client' is an application and the 'server' is a distinct computer process

A client-server system divides processing into two parts. The 'client' is an application, usually running on a workstation operated directly by the user. The 'server' is a distinct computer process, usually running on a separate computer, that performs functions requested by the client application. (The term server is also used to designate the computer running server processes; moreover, some vendors now call all their multi-user computers 'servers', a confusion typical of the IT industry.) A client-server system is a set of several clients linked to one or more servers. The clients usually communicate only with the servers, but the servers may communicate with one another. (In some cases, the arrangements are more complex — some client applications and server processes, for example, may share one machine.)

The structure of the client-server system may be described by analogy with a restaurant, as shown in Figure 4.1. The client — in this case, the restaurant customer — selects items from the menu (services), and the order is relayed by the waiter (communications network) to the kitchen. In the kitchen, the chef takes the order, prepares the food using ingredients stored in the cupboards (servers), and hands over the finished dishes to the waiter to take back to the customer. The customer may also ask the waiter to bring him an apéritif from the bar (another server) and a bottle of wine from the cellar (yet another server). This analogy illustrates the main

Figure 4.1 The structure of the client-server system may be described by analogy with a restaurant

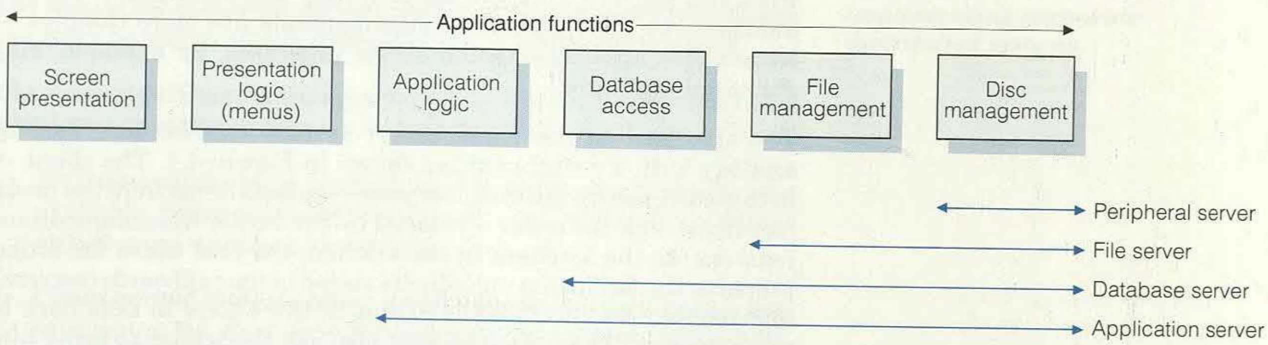


features of a client-server system — each client is able to use a variety of services, and communications between clients and servers are based on well-defined protocols. Finally, the customer may choose to pour his apéritif or wine into his soup, which is analogous to the capability that client workstations provide for assembling information from several sources to satisfy a particular requirement.

The impact of client-server systems is greatest when an application's functions are distributed over several computers

Client-server principles have their greatest impact when they are used to partition the functions of an application over several computers. As Figure 4.2 shows, an application may be seen as a set of separate functions, ranging from the control of the screen presentation to the management of the data held on discs. In creating a client-server system, the functions of an application can be divided in various ways. Depending on the division, the functions can be referred to as peripheral, file, database, and application servers. Thus, a peripheral server would handle disc management, a file server would handle both disc and file management, and so on. The servers themselves are of two basic types — resource-sharing servers, which provide access to shared resources such as printers, discs, and files, and information servers, which provide access to databases and applications.

Figure 4.2 Different types of servers handle different functions



Each division creates servers, and clients, with different characteristics and uses. The servers themselves can range from simple to complex, the interfaces between the client and the server can range from low-level to high-level, and the communications requirements can range from low-speed to high-speed. The characteristics of the main types of servers in common use today are shown in Figure 4.3.

Peripheral servers allow the client application to access a remote peripheral (a disc drive, for example) as if it were attached to the

Figure 4.3 Different types of servers have different characteristics

	Characteristics		
Server type	Complexity	Interfaces	Communications
Disc	Simple	Low-level	High-speed
File	Fairly simple	Fairly low-level	High-speed
Database	Fairly complex	Fairly high-level	Fairly high-speed
Application	Complex	High-level	Low-speed

workstation. A disc server allocates space on its discs that a workstation can treat as its own 'virtual' disc. Because of the high traffic volumes and requirements for rapid response, disc servers must work across reliable, high-speed communications links, such as those provided by local area networks. Disc servers are commonly used to support disc-less workstations. Compared with ordinary workstations, disc-less workstations provide better data security and recovery, and give management more control over the software used on the workstation. (We predicted the emergence of disc-less workstations in Report 63, published in 1988.)

Other peripheral servers in common use are print and communications servers. A print server allows a printer to be shared by several workstations while a communications server provides shared access to a communications link. (More sophisticated communications servers provide gateways into other networks, and also carry out format and protocol conversions.)

A file server allows a client application to access files held on the server. The file server manages each file separately, and can provide additional facilities for data sharing and security.

Database servers are the most advanced type of data server currently available

Database servers are the most advanced type of data server available today. Whereas a file server can respond only to simple file-access and transfer commands, a database server can respond to complex database-access and manipulation requests, sending the client application only the data items required. Database servers provide the benefits of database management to multi-user workstation-based systems. Individual database servers can be linked, using distributed database techniques, to enable a client application to treat a set of database servers as one server.

An application server supports both data-management and application functions; it processes business transactions rather than requests for data. Thus, an accounts-payable server might receive invoices and despatch payments. Application servers differ from conventional applications in that they do not provide a user interface: that remains the responsibility of the client. Client-server systems therefore increase the need for graphical user interfaces, both to provide user interfaces to applications servers and to provide consistent interfaces to local and remote applications.

The main client-server design decision is how to partition the applications

The main design decisions for a client-server system are concerned with how best to partition the applications. It will usually be best for information to be formatted and presented by the client workstation, and for shared files to be accessed via database servers. Most of the design issues are therefore concerned with where to place the applications logic. The factors to consider include:

— The network load.

— The processing load. High processing loads may be handled more cost-effectively on a workstation, although some workstations may have insufficient memory or power to handle certain applications.

— The degree of interaction required. A word processing application, for example, needs to respond to every character, and is better placed at the workstation. At the other extreme, some transaction-processing applications need respond only to complete transactions, and can sensibly be placed on a server.

Client-server systems benefit both individual users and user organisations

Client-server systems are an essential basis for the provision of integrated, easy-to-use facilities for the user. They also provide the flexibility to respond to business and technology changes. During our research, we investigated many organisations that have implemented, or are implementing, client-server systems. Figure 4.4 describes how one of them, a US manufacturing company, has replaced mainframe systems with PCs that access servers. The benefits of client-server systems to user organisations are better integrated user facilities, more flexible systems, better price/performance, and controlled user access to data and applications.

Figure 4.4 Echlin Manufacturing Company has replaced mainframes with PCs and servers

Echlin Manufacturing is a Fortune 500 company based in Bradford, Connecticut, that makes automobile parts for the aftermarket, selling its products to large retail chains such as Sears Roebuck. Annual sales are $1.1 billion. In 1984, Stephen Gold, manager of systems and programming, recognised that the IBM PC AT provided much cheaper processing power than the company's IBM 4341 mainframe and that Novell NetWare could be used to link PCs. Benchmark tests and a prototype application convinced him that there would be benefits in moving to a client-server system. Although there were no particular problems with the existing applications (which were all personnel and financial applications), he got agreement to move them from the mainframe to PCs.

All the head office applications were transferred over three years, at a cost of $500,000. The new hardware and software cost $85,000, and the mainframe was sold in August 1988. Echlin now has 65 PCs and four servers, two based on Motorola processors and two on Intel processors. As a consequence, the systems budget has been halved, representing an annual saving of $500,000, despite an increased workload. The operational performance of the systems has also improved considerably, and downtime has been reduced. More importantly, the systems are easier to use. Users can access data more easily, and through the use of PC Focus, applications are easier to amend.

The biggest problem encountered was convincing the users that a move from the mainframe-based systems was worthwhile. There has also been a very high level of staff turnover in the systems department — equivalent to 100 per cent over three years. However, the systems staff are now less technical and cost less to employ than those who ran the mainframe systems.

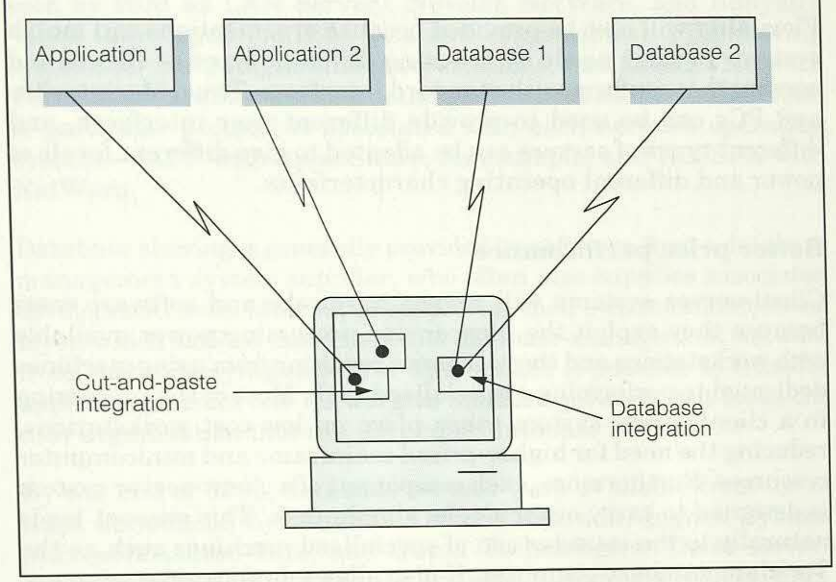
Better integrated user facilities

In a client-server system, a client workstation integrates databases and applications running both locally and on servers to provide a single 'seamless' application for the user. This is achieved in the workstation and without any need to integrate the separate applications directly. Figure 4.5 shows how user applications and data can be integrated at the workstation in a client-server system. This arrangement can therefore be used, for example, as an elegant and flexible way of implementing hybrid office systems (which integrate text, image, and data processing) without the need to write applications programs that deal with all the different types of information.

In a client-server system, there is no need to integrate the separate applications directly

A client-server system can also be used to provide the effect of cross-functional integration by bringing together separate applications at the workstation. (The importance of cross-functional applications

Figure 4.5 Client-server systems help to integrate applications and data



was highlighted in Report 79, *The Role of Information Technology in Transforming the Business.*)

Client-server systems can provide a bridge between old and new applications and databases

Client-server systems also provide a solution to the problem of migrating to new systems. Moving from an obsolete applications architecture to a new one is difficult because the systems department has to link old and new applications, and during the transition, users may need two terminals on their desks. Client-server systems avoid the need to do this by providing workstation facilities that will enable a bridge to be built between the old and new applications and databases. At its simplest, this could be achieved by using the clipboard facilities available with the graphical user interface.

More flexible systems

Client-server systems are easier to maintain

If the application functions in a client-server system are broken down in a consistent way, using well defined and stable interfaces between the components, the resulting applications architecture will be better integrated and more flexible. For example, if database access is provided via a database server, most application changes will be confined to the workstation-based client application. The changes are therefore easier to make, which means that the applications become more flexible and the cost of maintenance is reduced. The scalability of client-server systems (that is, the ability greatly to increase or decrease their size without disruption or the need to make complex changes) also increases their flexibility.

Client-server systems are also flexible because they can support a variety of workstations. If a particular user needs a more powerful workstation, it can be provided on an individual basis. For example, low-powered workstations may be adequate for accounts clerks, whereas the finance director could be given a high-powered workstation able to provide very short response times. It may not even be necessary for all members of a workgroup to have the same workstation or to be in the same location. Digital's Personal

Computer Support Architecture, for instance, allows PCs, Macintoshes, and VMS programs to share data.

Flexibility will also be provided because organisations can match systems to their needs by selecting different types of clients and servers that conform with standard interfaces. Thus, Macintoshes and PCs can be used to provide different user interfaces, and different types of servers can be adopted to give different levels of power and different operating characteristics.

Better price/performance

Client-server systems exploit inexpensive processing power in specialised machines

Client-server systems will reduce hardware and software costs because they exploit the inexpensive processing power available with workstations and the economies resulting from using machines dedicated to performing a specialised task. Most of the processing in a client-server system takes place on low-cost workstations, reducing the need for higher-priced mainframe and minicomputer resources. Furthermore, each component of a client-server system is designed to carry out a single, simple task. This concept leads naturally to the introduction of specialised machines such as the Teradata database computer. It also allows duplicated equipment to be provided at reasonable cost for the small proportion of applications that need a high level of fault tolerance.

Controlled user access

One result of the increasing involvement of users in the management of their information systems is the change from providing them with predefined reports, to allowing them to extract data from the corporate database for local processing and presentation. The challenge that accompanies this change is to provide central control over the quality and security of corporate data without unduly restricting users' freedom to access it.

Data management and data access and manipulation can be divided and managed separately in a client-server system

A client-server system allows the tasks of data management and data access and manipulation to be divided and managed independently. The database server handles data definition, quality, integrity, security, and recovery. The workstation client application handles data selection, manipulation, and presentation. Each of the tasks can then be managed in the optimum fashion.

User managers should, however, be aware of the potential risks of allowing their staff to control the formatting and presentation of information. Most systems managers can quote examples of users making silly mistakes with standard PC packages such as spreadsheets. The danger is that an enthusiastic user can inadvertently scramble vital information and not be aware that he has made a mistake.

Many software products support client-server systems

Each type of client-server relationship is implemented by software in both the client and server computers. Peripheral and file-sharing facilities are usually supplied by a network operating system, which comprises a 'requestor' (or 'redirector') in the client machine, and file, print, and communications servers in the server machine.

Leading network operating systems include AppleShare (developed for Macintoshes), Microsoft's LAN Manager (a version of which is sold by IBM as LAN Server), Novell's NetWare, and Banyan's Vines (developed for IBM PCs and compatibles). File-sharing systems for multiprogramming workstations, such as Sun's Network Filing System, allow workstations to act as both clients and servers. A particular protocol is associated with each network operating system — AFP with AppleShare, for example, and IPX/SPX with NetWare.

Database sharing is generally provided by software from a database management system supplier, who often also supplies associated development tools. Most suppliers provide their own communications layer, which isolates their client and database-management software from the underlying network. This makes it possible to transfer applications from one network to another network, but locks the user organisation into the particular database software.

Leading database systems are relatively untried as database servers

By the end of 1990, database servers were available from (or at least announced by) Adabas, Oracle, Informix, Ingres, Sybase/Microsoft/Ashton-Tate, and Gupta Technologies. These servers run under a variety of operating systems, including MS-DOS, Unix, OS/2, and VMS, and allow access from a mixture of MS-DOS, OS/2, Macintosh, and Unix workstations. The client-server protocol is, in each case, a proprietary dialect of SQL supported on a proprietary network protocol (running over one of the *de facto* standard local area network protocols). Although the leading database servers are based on well established database systems (such as Oracle and Sybase), they are still relatively untried as servers.

Application access may be provided by direct calls to the communications system, using, for instance, the SNA LU6.2 protocol or the OSI transport layer. The applications programmer would then need to define the exchange of messages and manage the connection. To ease this process, several vendors now offer remote procedure call (RPC) software. A client application can use an RPC to call a server procedure running in a remote computer as if it were on the same machine. RPCs are an integral part of client-server systems because they provide an applications programming interface that is independent of the nature of the underlying network and operating system. The leading RPC systems are those defined by Netwise, Digital (which has also been adopted by OSF), and Sun Microsystems (adopted by AT&T).

No single supplier offers all the components of a client-server system

No supplier is able, and none appears to be attempting, to provide all the components of a client-server system. Instead, different suppliers are making distinctive contributions and supporting *de facto* standards where they believe it commercially expedient to do so. As a result, client-server systems are 'open' in ways that are important to users.

Claims about the openness of client-server systems should be treated with caution

However, because of the immaturity of the technology involved, claims about the openness of client-server systems should, at present, be treated with a great deal of caution. Users and developers often find that two supposedly compatible products are unable to interwork in their particular environment. One developer, for instance, found that release 1.1 of IBM's Database Manager was 'effectively single user'. After upgrading to OS/2 release 1.2, the team found that it also needed to upgrade LAN Server and SQL Server to this release level. In another case, involving another vendor's products, such an upgrade prevented an existing communications function from working.

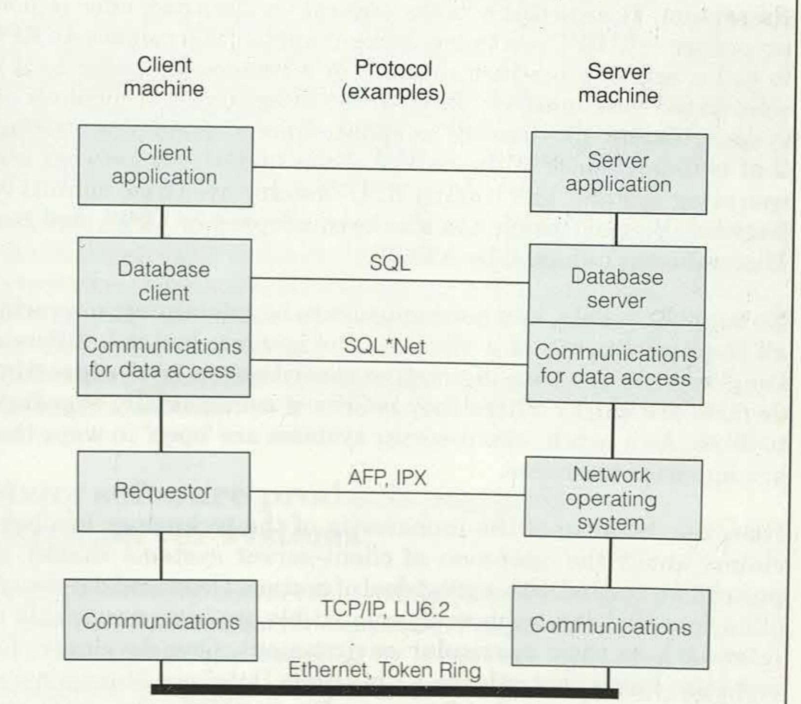
Organisations must therefore take care in deciding which releases of the various interacting products to use, especially where more than one product of one kind is to be used. Many of these problems, however, are due to the switch to client-server systems rather than to any flaws in the basic concepts. We therefore expect vendors to learn the lessons and take steps to avoid the most obvious problems recurring in the future.

Standards for client-server systems need to be chosen

Standards for the interfaces between clients and servers are fundamental to the client-server approach, and decisions will need to be made about which protocols to use to allow workstations to access peripheral and file servers. Figure 4.6 shows the software components, and examples of the protocols for linking them that might be found in a complex client-server system. As the figure suggests, client-server protocols are largely proprietary at present, and the choice is usually straightforward because some of these have emerged as *de facto* standards. Macintoshes will generally use the AFP protocol, which is an integral part of the Macintosh operating system. Unix workstations will generally use either Sun Microsystems' Network File System (NFS), or the equivalent that forms part of OSF's Distributed Computing Environment (DCE).

Client-server protocols are largely proprietary at present

Figure 4.6 Each type of client-server relationship is implemented by software in both the client and server computers



PCs will probably use Netbios, or Novell's IPX/SPX. Unless there are significant numbers of workstations that already use one of these protocols, the final decision should be taken in conjunction with the selection of the network operating system.

There is a clear trend towards *de jure* standards, however. Mail servers, for example, are tending to adopt the CCITT X.400 standard, and document servers are adding support for the International Standards Organisation's Office Document Architecture and Office Document Interchange Format.

The standardisation of database servers is inhibited by the limitation of the current SQL standard

The standardisation of database servers is inhibited by the limitations of the current SQL standard. An improved version of the SQL standard is under development by the American National Standards Institute (ANSI). The SQL Access Group (SAG) has also been established by leading relational database vendors (but excluding IBM) to define the applications interface and communications protocols. SAG is not expected to define a standard until about 1993. The work is aimed at producing a standard for a limited subset of SQL functions, based on X/Open's version of SQL. Meanwhile, users must continue to rely on functions developed by one supplier to access other vendors' database-management systems.

Technical and other policies should be reviewed

The introduction of client-server systems will require the systems department to review its technical policies in several areas, and it will be necessary to ensure that users are aware of their new responsibilities and provided with appropriate training.

The systems department will need to review its technical policies

Policies about resilience and fault tolerance should be reviewed in the light of client-server systems — in particular, to ensure that server machines and networks are sufficiently robust to enable a wide range of software to run with good performance. Conversely, limited network and server resources may make it necessary to restrict the range of software that users can install on network-connected workstations, and the relevant policy guidelines should be agreed before an organisation begins to implement client-server systems. It will be much easier to enforce a policy that restricts workstation software if workstations do not have their own discs, but use file servers instead. Client-server systems may also require policies on systems security and data integrity to be reviewed and revised.

Restrictions on workstation software will be easier to enforce with disc-less workstations, which always have to use file servers

The resilience, reliability, security, and capacity of the network infrastructure may also need to be upgraded. Client-server systems will require a local area network infrastructure to be developed, a coherent wide-area data network to be created, and comprehensive network management to be introduced (where this has not already occurred).

To meet the bandwidth requirements, organisations should base all their local communications on local area networks, and may need high-speed optical-fibre networks (based on the FDDI standard) on large sites. In most cases, however, existing structured cabling systems will provide an appropriate basis.

A fully developed network architecture is needed to provide the basis for client-server support services and to give a reliable service. Organisations will need to establish a network architecture that supports the seven layers of the ISO OSI model, or an equivalent, before developing client-server applications that can operate across a wide-area network.

Enterprise-wide networks, comprising local area networks interlinked by wideband communications services, will need a standard transport-level service, corporate-wide addressing for users and resources, and standards for file transfer and electronic mail. Where several network architectures are already in use (SNA, DECnet, and IPA, for example), the migration to workstation networks may be used as an opportunity to rationalise the situation.

Network management may become a problem with client-server systems

Widespread adoption of client-server systems can lead to a major network-management problem. There is a risk that failures in client applications can bring down the entire network. The problem arises from the increase in the numbers of network-connected computers running applications software. Thus, good tools are needed to avoid network management becoming an expensive burden.

Users need to be trained for their new responsibilities

Users will often have to sort out day-to-day operational problems on server machines

In many cases, the user community will need to take on the management responsibility for server machines, particularly print servers, and will have to develop the expertise to sort out day-to-day operational problems. In practice, it will often be appropriate to allocate this responsibility to secretaries or administrative staff. These staff will need to be trained to carry out these responsibilities, and all users will need training to help them understand the strengths and limitations of the new systems. If users are not willing to take on these responsibilities, the systems department will have to develop procedures for managing the server machines remotely.

Users may also need training in the data-access capabilities available through the new systems, because these may well be different from those they are used to. They will also need to be made aware of any changes in the systems security, data integrity, and recovery procedures that will arise from the introduction of workstation networks and client-server systems.

Client-server systems require a new development approach and new skills

Developers must be able to exploit the various system architectures in a client-server system

The development of applications designed to run as part of a client-server system requires a new approach to systems development. Above all, systems designers and development staff need to be able to construct applications that exploit the various systems architectures involved in client-server systems. In the past, systems departments have often had separate development teams for PC, minicomputer, and mainframe applications. This approach is not appropriate for client-server systems, which require designers to understand the strengths and weaknesses of each kind of system, so that they can allocate the functions between them in the best way. Ideally, analysts and programmers should be able to work in the various development environments found in a client-server system. (We described practical approaches to achieving this in Report 72, *Managing Multivendor Environments*.)

Special attention will also need to be paid to the technical quality of client-server applications, because a failure will affect many copies of an application rather than just one, and in extreme cases, could cause the network to fail. The testing of client-server applications will therefore require more care than will usually have been expended on single-user applications running on a PC.

Many vendors already supply client-server development tools

Client-server development tools are becoming available, particularly from database-server vendors. Some have gone further, however. Oracle, for instance, supplies tools that automatically convert single-user dBase applications into multi-user Oracle applications.

Other established suppliers have also responded. Revelation Technologies, a UK developer of system building tools, has added support for SQL Server to its Revelation product. It will add support for other database servers, making applications written with Revelation independent of the choice of server. Gnosis NV of Belgium, supplier of SequeLink (which provides users of MS-DOS, Windows 3.0, OS/2, and Macintosh workstations with access to various database-management systems), also supplies a toolkit that can be used to add server access to existing applications and systems.

Specialised tools will be needed to hide the complexities of the network from users

Specialised tools will also be needed to hide the complexities of the network from the developers (and users) of client-server systems. In the short to medium term, however, these tools will not remove the need for development staff to be aware of communications issues. Developers of client-server systems will therefore need both additional knowledge of communications and skills in the design of systems that use networks. They may, for instance, need to use communications principles in designing the exchange of messages between workstations and servers.

These skills are largely technical. The emphasis should, however, be on understanding and using protocols, rather than on communications engineering. The aim should be to train application developers so that they can use communications, rather than to convert them into communications experts. If knowledge of communications engineering is needed, it will probably be better to use staff from the telecommunications function.

Client-server systems are evolving rapidly

Client-server systems are evolving rapidly. Suppliers are developing more powerful and sophisticated hardware and software for servers, and providing the network-management facilities needed to build corporate-wide client-server systems.

Database servers

As database technology and standards develop, database servers will be given additional facilities, including the ability to support some applications processing. Some functions, notably integrity checks, will therefore be transferred from applications to database servers. Although a general migration from database servers to applications servers will become possible, this will not happen generally because it would undermine several of the prime advantages of client-server systems, which derive from performing as much processing as possible at the workstation.

Client software

Several developers of database servers already provide workstation client software that can be used to access the server. They are also providing interfaces to major workstation applications such as Lotus 1-2-3 and Microsoft Word.

Workstation vendors are adding more sophisticated communications functions to client software products

Workstation vendors are also adding more sophisticated communications functions to their client software products. This trend is most evident in the area of database access. Hewlett-Packard, for instance, has added remote-file-access functions to its NewWave software (which was described in Chapter 3). NewWave Access provides workstation users with access to databases maintained by dBase and R:BASE (on PCs), and by Oracle, DB2, and Hewlett-Packard's own database-management systems.

Suppliers of workstation applications are also adding network-based database-access functions to their products. Lotus Development's DataLens, for instance, provides access from 1-2-3 spreadsheets to SQL Server, Oracle, VSAM, and DB2 databases. Sapphire International's DataEase (a PC database-management and development system) now provides access to a wide variety of SQL database systems, including SQL Server, OS/2 EE Database Manager, DB2, SQL/DS, OS/400, Oracle, and Sybase, as well as to the Teradata database computer. Many other software vendors are planning to provide similar facilities.

There are also systems, such as Gnosis's SequeLink, that work on a variety of workstations and applications. One version of SequeLink is integrated with Excel, providing menu options for database access.

Server software

Vendors are adapting their integrated office systems for use in client-server environments

Although effective in themselves, integrated office systems, such as PROFS and ALL-IN-1, have not achieved a high penetration among office workers. Among the reasons for this is their lack of integration with personal computers and workstations. Leading vendors are now rewriting their integrated office systems so that they can be used in a client-server environment. Digital's ALL-IN-1 Phase 2, for instance, will provide office services such as electronic mail, document processing, and diary management to MS-DOS and Macintosh workstations.

ICL Powerfile Agent (a component of ICL's Office Power system) provides MS-DOS and OS/2 client applications with access to document stores on Unix and VME computers. The client does not need to know the location of the document, as the local document server will redirect the search as needed. Documents can be extracted from the document server, revised, and then restored.

In the future, we expect to see object-oriented database servers that will be able to support and link workstation object-management facilities of the type provided by NewWave. These will, for the first time, provide flexible integration between multi-user data processing and office applications. We expect that the first commercially available products of this nature will be available by 1992.

Improved network facilities

Existing network operating systems, such as Novell's NetWare, cannot link local area networks together seamlessly, nor can they manage large numbers of clients and servers. Vendors of network operating systems are therefore extending their products to manage multiple local area networks. Banyan's Vines, for instance, provides transparent support for linked local area networks. Its StreetTalk facility allows users to access resources, and to send mail to other users, without needing to know their locations.

Vendors of network operating systems are extending their products to manage multiple local area networks

Connections to existing wide-area networks and gateways to proprietary systems are also being provided, sometimes by independent suppliers. For example, Phaser Systems (which is owned by the chairman of Novell, although it operates independently) supplies software that links networks running NetWare to SNA networks, and thus allows them to communicate with each other and to share resources on IBM mainframes.

Sometimes, gateway services will be provided by integrating network operating systems with existing network architectures. Digital is taking this approach with its Personal Computer Support Architecture, which integrates LAN Manager 2 with DECnet to provide MS-DOS, OS/2, Unix, and Macintosh workstations with access to each other and to resources on Vaxes. The workstations can share files and printers, communicate transparently across DECnet, and access applications and databases on computers that implement the DECnet, TCP/IP, X, or SNA protocols.

Extended network architectures are being developed for both main versions of Unix

A further advance is the development of extended network architectures for both of the main versions of Unix. Both AT&T's Open Network Computing (ONC) and OSF's Distributed Computing Environment (DCE) provide an integrated set of communication and resource-sharing functions that exceed those usually available on PC local area networks. Both provide remote procedure calls, for instance. In the future, both will be given network-management functions. Although rooted in Unix, DCE (and possibly ONC) will be implemented in a variety of proprietary architectures. Since DCE can interwork with LAN Manager and Sun's Network Filing System, it will serve to integrate PC, Unix, and proprietary networks to a degree not previously possible.

Specialised server hardware

Most LAN servers are based on PC hardware and software, and are adequate for personal and small workgroup applications. However, these servers are inadequate when users wish to implement critical multi-user applications or to integrate their local area networks with other information systems. Large applications need servers that can support larger databases and more concurrent users. Applications that are critical for the success of the business need servers that provide high reliability, security, and data integrity. The need to integrate applications with other systems means that servers must have the power to run gateway software. Larger and more powerful servers are also needed because organisations do not want a large number of small servers.

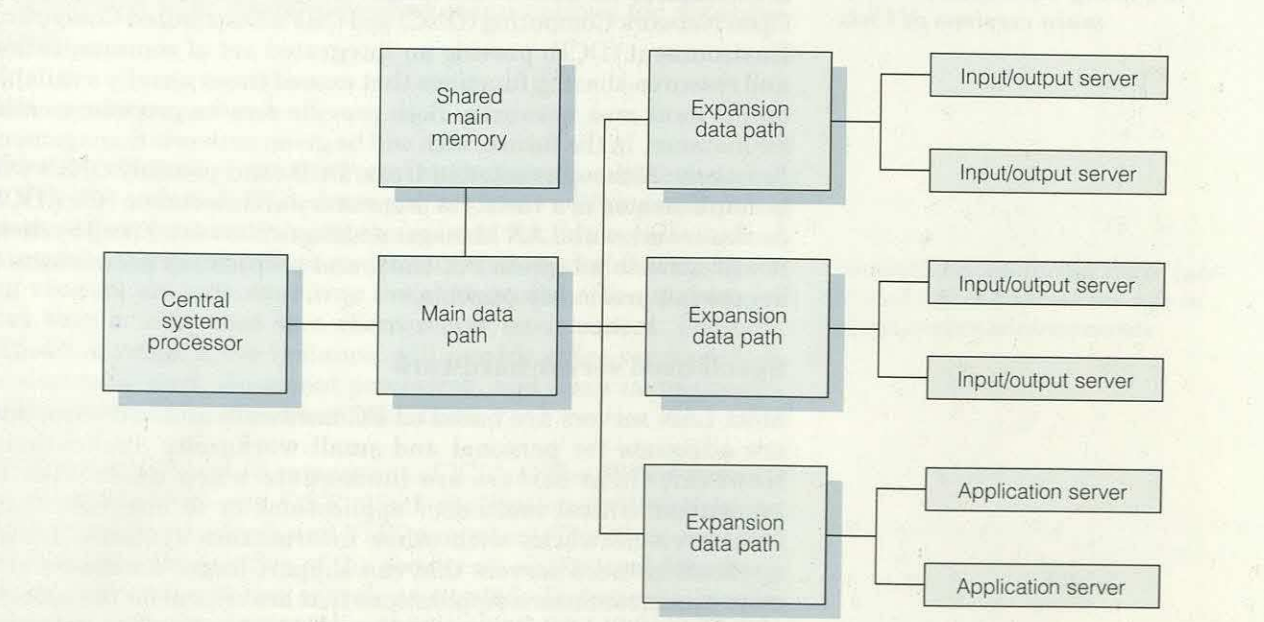
Mainframes and minicomputers can, in theory, be used as large servers, but because they are general-purpose machines, they are far from ideal. Specialised server hardware is therefore emerging to fill the gap. During 1990, high-performance servers were announced by PC vendors such as Compaq, Dell, GRiD, and Zenith, by mainstream vendors such as AT&T and IBM, and by new suppliers (Advanced Logic Research, NetFRAME Systems, Parallan, and Tricord Systems to name but four). Developers of specialised server hardware have concentrated on providing high performance and high reliability, including fault tolerance.

Developers of specialised server hardware are concentrating on high performance and reliability

One of the first of the new specialised server products was Compaq's SYSTEMPRO. SYSTEMPRO is based on one or two Intel 386 or 486 processors, giving a maximum speed of 40 mips. It can support up to 256 megabytes of memory and 840 megabytes of disc storage, with expansion to 40 gigabytes planned. It can be used to run MS-DOS, OS/2, Unix, and NetWare. Early user experience suggests that, in some circumstances, SYSTEMPRO performs up to six times better than a server based on a conventional large PC.

A more recent family of specialised server hardware comes from NetFRAME Systems of Milpitas, California. NetFRAME calls its products 'network mainframes'. Their most distinctive feature is the high throughput, which is achieved by using a mainframe-like system of intelligent channels, rather than a more traditional bus structure (see Figure 4.7). The largest model, the NF400, uses the Intel 486 chip and supports up to 6 gigabytes of mass storage, and 674 megabytes of memory. All models can be used to run OS/2 and NetWare. NetFRAME's products are offered in Europe by Olivetti.

Figure 4.7 The NetFRAME server has a mainframe-like bus structure



Although specialised servers benefit from the high price/performance of smaller machines, they are not cheap. Their prices range from $15,000 to $60,000 or more. They are being sold through existing distribution channels, both by major suppliers and by high-street computer shops. They are, however, more complex than PC-based servers and we are doubtful if these distribution channels will be able to provide the necessary levels of support.

The rate of announcements of client-server products and systems makes it clear that major vendors are now committed to the further development of the concept. The increasingly broad support by vendors for interworking between workstations, print servers, database servers, and so on, indicates an increasing maturity in the market for the enabling technologies.

Report conclusion

In this report, we have shown that workstation networks — in particular, client-server systems — will be a key element of a user-oriented technical architecture. The power and ease of use of the new client-server systems, and the ability of client workstations to access the organisation's entire information resources, will place unparalleled computing power in the hands of business users. They will be able to use the resources of the entire telecommunications network (though within security and budgetary limits) to access and communicate information anywhere in the organisation.

Workstation networks will remove the technical constraints imposed by mainframe-based technical architectures, enabling the IT infrastructure to support the organisation's computing needs at three levels:

- Individual needs, especially ease of use and ease of access to information. Intelligent workstations, with graphical user interfaces and other ease-of-use features, will become the normal means of accessing information systems and services.
- Workgroup needs, especially controlled information-sharing and the management of group interactions. These needs will be met by workstations connected to high-speed networks, mainly local area networks, shared information servers, and collaboration-support systems.
- Organisational needs, especially needs for vendor-independence, interoperability, portability, the management of interworking, and the exploitation of existing information investments. These needs will be met by the portability of workstation applications, and the interoperability of systems, especially the use of open systems. The division of applications into workstation-based client processes that access shared servers across networks will be crucial.

Increasingly, workstation-based applications will provide many of the functions that, until now, have been provided only by conventional mainframe and minicomputer applications. Some workstation users will go even further. By using powerful macro facilities, they will be able to develop their own personalised applications. For the first time, many business users will feel that they are truly in control of their own computing facilities.

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