Electronically Enhanced Office Buildings (1988)

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Building Research Board
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FOREWORD

A great deal of interest has been generated in recent years by the concept of the "smart" or "intelligent" building. Although the intention seems clear, all too often the actual realization of these buildings falls far short of their potential. It is apparent, for example, that there is a market for versatile, convenient, and inexpensive telephone communication, but there are few buildings where there has been installed a fully integrated communication and control system. The situation is further confused by the fact that thus far the focus has been primarily on office buildings and office automation, to the neglect of the many other kinds of buildings that might be candidates for modern electronic systems. In fact, the phrase "intelligent building" has come to refer almost exclusively to the provision of shared communication and computation services in a multi-tenant office building.

This report is not concerned with the marketing or management of particular approaches to providing communication and computation services to building occupants. Rather, it is intended to serve as a guide to those who wish to know what opportunities are available as a result of new developments in electronics and how they might take advantage of those opportunities by acquiring, either through new construction or renovation, an "electronically enhanced" building. In particular, this report tries to sensitize corporate and government executives and facility managers to the ways in which the design and construction of an electronically enhanced building differ from the design and construction of a conventional building.

There is an emphasis on the use of diagnostics as an evaluation method for whole building systems. The report is addressed to client-occupants rather than to architects and engineers, in the belief that an educated client is more likely to utilize the advice, the professional services, and ultimately the building performance that are needed than is a client who does not understand the implications of the new electronic capabilities.

The report was prepared by two committees (with some members in common) over the course of three years.

John P. Eberhard
Executive Director
Building Research Board

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PREFACE

". . . the impact of new or improved technologies is not just a matter of enhanced technical performance. It is, rather, a matter of translating such information into its potential economic and social significance. Doing this is extraordinarily difficult. Understanding the technical basis for wireless communication, as Marconi did, was a very different matter from understanding the possibilities for an entertainment broadcasting industry that would reach into every household, which Marconi could hardly have been expected to envisage."

--Nathan Rosenberg, "A Good Crystal Ball Is Hard to Find," American Heritage of Invention and Technology, 1 (3), Spring 1986.

In recent years a considerable body of literature has arisen concerned with office automation. This literature provides guidance to managers, purchasing officials, and interior designers concerning the needs of the automated office in such areas as lighting, ergonomics, air quality, temperature, noise, office layout, and socialization. This report goes one step further. It is concerned with the design and construction of buildings capable of accommodating these new automated offices. It offers guidance to public and private decision makers responsible for ensuring that decisions about the acquisition of electronic technology and the buildings in which it will be housed are based on intelligent planning. The planning process suggested here starts with the development of a carefully worded statement about the purposes that the building and the technology contained in it are expected to serve. It goes on to underscore the importance of carefully developed performance requirements and of a quality assurance program that uses diagnostic procedures in all phases of the building process, from preliminary design through construction and occupancy, to ensure that the building is capable of meeting those requirements. Considerable emphasis is placed on the importance of utilizing independent expertise in a variety of technical fields not usually drawn upon in the acquisition of a conventional building.

Our goal in writing this report is to help institutions prepare to use modern electronic technology effectively. The fit between electronic technology and the buildings that house it has significant economic consequences. The early and proper use of appropriate expertise is essential to avoid inefficiency, added expense, and disappointment. As with organization and management, personnel selection, and procurement, an investment of time and money in planning can pay large dividends later on.

Organizations have been slow to act on the interdependence of buildings, occupants, and technology. As a consequence, organizations do not typically have a single individual, below the level of the Chief Executive Officer, who is responsible for all the aspects of buildings and technology that are discussed here, including facilities, organization, data processing, communication, and training. We suggest that it would be in the organization's interests to appoint a person, the Project Administrator, under the Chief Executive Officer, who will be responsible for managing and coordinating the integrated efforts of the multi-disciplinary team of experts through all aspects of the building acquisition process. This report is intended to serve as a guide for that individual.

Committee on Technologically Advanced Buildings
Committee on High Technology Systems for Buildings

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EXECUTIVE SUMMARY

The increasing reliance by many public and private institutions on electronic technology--particularly for computation, information processing, communication, and automation of control systems--has led to new modes of activity within office buildings. The computerized workstation, with its video display terminal and modem, is rapidly displacing the traditional office workstation with its typewriter and telephone. The use of automated equipment by professional and technical workers, and even by executives, is changing the numerical mix of professional and clerical employees. The shift in office population, from clerical to knowledge workers, has intensified the demand for a high quality work environment, relief from intensive video display terminal base work, and a "voice" in shaping and controlling the work setting. The underlying assumption made by knowledge workers, and increasingly supported by organization, design, information, and ergonomic professionals, is that increased organizational productivity is dependent on the "unleashing" of knowledge workers; i.e., providing them the tools and opportunities to use their skills, knowledge, and decision-making abilities. This is the major challenge in designing the technologically advanced office building. The physical layout of the office is changing to accommodate the new mix of people and electronic technology. In fact, physically flexible solutions which allow office spaces to readapt to changing work place demands should be included in program requirements. Even the organizational structure of many institutions is changing to be responsive to the new managerial demands that accompany the increased use of electronic technology.

Some of the physical requirements of the computerized office--a glare-free environment, suppression of acoustic noise, uninterruptible electric power, and cooling to offset the heat the electronic equipment gives off--are by now well known. Other requirements that involve the building's infrastructure are less well known--demands for an extensive and accessible network of wires and cables, for central equipment rooms to house mainframe computers and private communication branch exchanges, for battery rooms to provide uninterruptible electric power, for satellite dishes and microwave antennas, and for freedom from electromagnetic interference from lighting systems and other sources that can contaminate electronic data. These requirements are causing architects, engineers, and interior designers to realize that an office building capable of housing the new electronic technology must be designed, built, tested, and maintained quite differently from the traditional office building in which a standard shell and core are built and whatever equipment may be desired by the occupants is later installed. An office building that is to accommodate electronic technology successfully must be designed from the outset to suit the technological systems that will be incorporated in it. In order to increase the likelihood that the technologically advanced office will achieve its potential, performance criteria appropriate to the purposes should be formulated, and then a process should be established to ensure that the criteria are not compromised during the design phase.

An electronically enhanced building, as used in this report, is a building that is equipped with the electronic and physical infrastructure to support the use of advanced communication, data processing, and control technologies by its occupants and operating personnel. Such a facility is equipped with the necessary wires, cables, ducts, power supply, heating, ventilating, cooling, illumination, noise suppression, and security systems to support the performance requirements of today's office environment. These advanced technologies are incorporated in the building at the outset or are allowed for by providing ducts, channels, shaft risers for cabling, closets, and so forth, in which they can be installed later.

Intensive use of electronic technology, whether in the form of computers, communications, or automated control systems, imposes a number of demands on a building. First, electronic systems require networks of wires and cables, both for electric power and for voice, video, and data signals, and these cables must be distributed throughout the building and must be readily accessible. This generally requires far more space beneath or in floors, above ceilings, and behind walls than is allowed for in a traditional building. Second, both the electric power and the signal systems must be reliable, uninterruptible, and secure. This may require backup batteries for emergency use, electric power line conditioners, grounding and lightning protection systems, adequate shielding to avoid contamination of signals by electromagnetic interference, and uninterrupted lines of sight to satellites or microwave transmitters. Third, the building must be structurally capable of supporting the loads associated with mainframe computers, battery rooms, private branch exchanges, and rooftop antennas. Fourth, the building should have a heating and cooling system that is dynamically responsive to the occupants' unique or personal comfort requirements as well as coping with the heat load generated by the electronic equipment. Fifth, the building's interior lighting should permit comfortable use of video display terminals, its carpeting and other interior furnishings must be static-free, and its wall and furniture surfaces should not create problems in terms of glare or acoustic noise. Finally, because the technology and degree of use of computers and other electronic systems is rapidly evolving, the electronically enhanced office building should be flexible enough to accommodate not only today's electronic systems, but also to cope with the increased use of and demand for such systems that is expected in the future.

Many buildings have been equipped with electronic capabilities to some degree, either at the time of construction or in subsequent retrofitting. Few buildings now in existence, however, are as electronically enhanced, or as hospitable to electronic enhancement, as current technology would permit. The fully electronically enhanced building provides sufficient flexibility to permit the use of a broad range of electronic technologies in a variety of ways that may differ considerably among the building occupants and among the various parts of the building; a partially enhanced building is more limited in the range of electronic options that are possible. The so-called "intelligent" office building is seldom more than a conventional building with shared tenant telephone networks.

For electronically enhanced buildings, there are specific procedures that should be added to the traditional building acquisition process. First, the building's mission statement should be articulated in a manner that makes clear at the outset the performance that will be required of the building and its electronic infrastructure. Second, a multidisciplinary team of experts--independent of manufacturers and vendors--should provide guidance and critical reactions to all significant decisions made during planning, design, and construction. Third, there should be a period of "commissioning"--a period of about a year, from shortly before the completion and initial occupancy of the building well into its first year of operation, during which the building and its component systems are carefully assessed to determine whether it is indeed performing as it should under conditions of actual use, and to propose remedies where needed. Fourth, diagnostic procedures should be used during the design and construction process as well as during the period of "commissioning," in order to ascertain whether various subsystems of the total building system are meeting performance requirements and to make a prognosis about the future performance of the facility.

Once the building has been occupied, a form of post-occupancy evaluation should be made. To help in this process, there should be a trio of highly educated experts in today's high technology offices: (1) the facilities manager (managing all of the mechanical systems and high tech/intelligent systems interfaces, as well as an inventory of furnishings and finishes); (2) the information technology manager (managing all of the telecommunication systems and associated furnishings and finishes); and (3) the personnel manager (monitoring personnel satisfaction and productivity in relation to the facilities and technologies). These three players should now be a permanent part of the management of buildings, and should be involved from the outset of the design project. Moreover, they should be asked to work as a unit, not as individual or adversarial participants, throughout the programming, design, construction, commissioning, and operation of the building. Public agencies, as well as the private sector, need to make provisions in their staffing for this purpose.

An ongoing diagnostic program serves two purposes: (1) it provides continuing feedback to the building's owners and operators about the building's capabilities and the desirability of making modifications to the building or to the activities carried out in it; (2) it also provides what might be called "feedforward" to the knowledge base of the broad community of building owners, architects, and engineers that will, in the long run, make better design possible. Because the concept of an electronically enhanced building is so new, and because electronic technology is changing so rapidly, the number of experts is still small and many diagnostic procedures that would be useful have not yet been developed. This makes it tempting to shortcut the process and make do without the necessary expertise and without carrying out the necessary diagnostic assessments. This temptation should be resisted. When electronic functionality is central to a building, it makes sense to invest time and resources to develop the needed expertise and to design and implement diagnostic procedures suited to the particular project.

The purpose of this report is to provide guidance to a project administrator (a person responsible for all the aspects of buildings and technology who reports to the chief executive officer of the organization) as well as to building owners, chief executive officers, and facility planners who are concerned with the incorporation of modern electronic technology in a new or renovated building and who must determine the guidelines and criteria for the design, construction, procurement, and management of such a building.

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INTRODUCTION AND OVERVIEW

BACKGROUND

An electronically enhanced building contains the electronic and physical infrastructure necessary to support modern data processing and communication systems and to support the use of advanced technology in the building's electrical, mechanical, acoustical, lighting, ventilation, humidity control, heating, and cooling systems. The presence of this infrastructure facilitates adaptation to new technologies and new modes of organizational activity that may emerge during the building's life.

Traditionally, the construction of a building and the outfitting of its interior have been treated as separate and distinct activities. The building is designed and built primarily as an aesthetically pleasing and structurally secure shell that provides a certain amount of usable interior space and standard amenities such as heating, air conditioning, lighting, stairwells, elevators, and sanitary facilities. The owner/occupant then equips this interior space with fixtures, furnishings, and equipment suited to the activities that are to take place there. This is particularly true for speculative, multi-tenant office buildings, but it is also the case for most owner-occupied, special-purpose buildings such as corporate headquarters, retail stores, hospitals, schools, banks, post offices, and data processing centers. Even when the design, construction, and interior furnishing of a building are nominally under the control of a single corporate entity, the traditional approach is for an architect to design the structure and oversee its construction, after which an interior design firm plans and oversees the outfitting of the interior space.

This tradition should be altered if organizations are to make the most effective use of the electronic capabilities available today. Electronic technologies are potential tools to be employed by organizations, and ultimately the users of the building, to enhance their activities. It may not always be necessary to go to the opposite extreme--to design the building "from the inside out," with all decisions flowing from a detailed assessment of the occupants' activities. At the very least, however, the use that is anticipated for the interior space must be taken into account from the outset in the planning process. Experts in a broad range of disciplines, as well as representatives of the end users, should join the architects and engineers as members of the design team at an early stage. If adequate provision for the necessary physical hardware is not part of the design, many promising technological options for communication and building control will either be ruled out or, at the least, will be more expensive to introduce later.

The purpose of this report is to provide guidance to the project administrator (see Preface), but it should also be of interest to building owners, chief executive officers, and facility planners who are concerned with the incorporation of modern electronic technology in a new or renovated building and who must determine the guidelines and criteria for the design, construction, procurement, and management of such a building. The principles discussed here are applicable to: (1) private and public buildings, (2) renovation and new construction, (3) special-purpose facilities (such as banks, data processing centers, hotels, hospitals, factories, and research laboratories) and office buildings. Implementation of these principles will take different forms depending on the circumstances. However, because most of the experience that has been gained thus far with electronically enhanced buildings has been with office buildings, they are the primary focus of the report.

This report addresses those distinct aspects of the selection and installation of a building's electronic infrastructure that are less familiar than the traditional approaches. The first set of differences is based on the new technologies available and used in an electronically enhanced office building. The performance of advanced communications equipment, new computational hardware, and building sensors and control systems make higher performance buildings possible. This creates the need for rethinking traditional performance criteria, especially by those organizations; e.g., public agencies that have been clients of the construction industry for a long time and whose design criteria documents do not yet reflect this new potential.

The process of acquiring an electronically enhanced building differs from the traditional building acquisition process, and particularly with the decision-making sequences, the nature and timeliness of the information needed, and the expertise required at critical points in the process. This aspect is of particular concern to those who must appoint a project management team and oversee the process of planning, designing, constructing, operating, and maintaining the electronically enhanced building, and to the team members themselves.

Still another aspect concerns the potential for advanced building diagnostics which utilize the capability of the electronic infrastructure to evaluate periodically the performance characteristics of the facility, enable an expert prognosis about its likely future performance, and support remedial action if called for. This diagnostic aspect is of particular interest to those involved in the commissioning stage and those responsible for the operation, maintenance, and management of electronically enhanced buildings once they are occupied.

DEVELOPING AN ELECTRONICALLY ENHANCED BUILDING

A technologically enhanced building provides an ever changing complex system in support of an organizational mission. It is composed of a variety of systems and subsystems which serve building users, building operators, and building owner/managers. The effectiveness of these systems is dependent upon their responsiveness to the people who use and manage the building.

Such a building makes it possible to use modern electronics effectively to increase productivity, improve building management, and provide ready access to a wide range of information networks. Electronically enhanced buildings can also provide owners and occupants with the greater benefits of a higher performance and more supportive working environment and of a lower life-cycle cost.

However, technologies per se do not assure this outcome. Recent studies by Steelcase, the Office of Technology Assessment (OTA), and the National Bureau of Standards describe many of the problems that can be encountered. These reports point to organizational culture as a critical factor in determining whether technology solves or produces problems. For example, highly centralized decision making and intensive electronic performance monitoring, accompanied by limited job or environmental control by employees has led to many complaints by people working under such conditions. Electronic systems, because of their cable and power requirements, the heat they generate, and other ways in which they affect the interior environment, are most effective and most economical in buildings that are designed specifically to accommodate them, and even then only when they are installed at the time of construction (or, at least, when specific provision is made for their later installation). To a certain extent, the situation resembles the early days of central air conditioning--a technology that represented a significant advance in economy and efficiency over window air conditioners, but whose benefits could be fully realized only when it was incorporated in the design and construction of the building. Yet there is a significant difference. Central air conditioning was always viewed as part of the "infrastructure" of the building. Today's new systems reach down to the level of individual workstations and telephones--areas that have traditionally been thought of as furnishings provided by an occupant rather than as part of the building itself. These systems require their own electronic infrastructure--a network of wires, sensors, and switches that must be incorporated in the building if they are to be effective.

Yet the number of new buildings put into service each year is only a small fraction of the nation's building stock. Most organizations wishing to take advantage of the new technologies will, therefore, have to find ways to introduce them into existing buildings. Retrofitting advanced technology into a building that was not designed for it presents a significant challenge. It will be carried out most effectively if strategic planners and facility managers come to understand the nature of the trade-offs and compromises that will be required.

THE PERFORMANCE CAPABILITIES

Examples of electronic equipment with impressive performance capabilities that are available today include mainframe computers, minicomputers, and microcomputers; voice, video, and data telecommunications; internal (local area) communication networks; automated (computerized) workstations; and a variety of automated building sensors and control systems which can enhance performance. These include systems that:

- Sense human presence in a particular part of the building and turn on lights and heat;
- Activate elevators;
- Alert security and fire alarm systems;
- Sense the intensity and angle of exterior light and respond by adjusting interior lighting systems, window louvers, visual (as well as thermal) building envelope characteristics, etc., to provide specified levels of interior illumination without excessive glare;
- Sense the outside temperature and respond by turning on the heating system sufficiently far in advance of the arrival of employees to ensure a comfortable temperature at the start of the working day;
- Automatically increase the ventilation rate when tobacco smoke or noxious odors are detected;
- Distribute electric power to computers on demand or in accordance with a preset priority schedule and automatically activate reserve batteries or emergency generators when electric power fails to meet preset standards; or
- Automatically select the least-cost carrier or route when a long-distance telephone call is placed.

These performance possibilities are the result of recent advances in three application areas of electronic technology--computers, communications, and automated controls--along with the restructuring of the telecommunication industry that followed the breakup of AT&T. They have led to the development of a new approach to the conduct of many kinds of commercial and governmental activities. The development of microcomputers and of software for word and data processing has led to a new era of office operations. The computerized workstation with its keyboard and video display terminal has all but replaced the typewriter, and many functions involving text and data are carried out in a "paperless" fashion. The use of satellites and fiber optics for long-distance communication and the introduction of private branch exchanges and local area networks for internal communication have made the telephone a more versatile tool than ever before. Digital electronics has made sensors and actuators for automated control systems more precise and more programmable than their electromechanical predecessors.

As a consequence of such technological advances (including the introduction of microcomputers), automated data processing and the use of computers in a variety of business applications, which when first introduced were cost-effective only for organizations that utilized them on a massive scale, are now economical and manageable on a much smaller scale. Many public and private organizations are becoming convinced that they can increase efficiency and reduce costs by adopting new technologies. To use these new technologies, however, buildings must be capable of accommodating them.

CHANGING DEMANDS THAT WILL BE PLACED ON OFFICE BUILDINGS

Intensive use of electronic technology, whether in the form of computers, communications, or automated sensors and control systems, imposes a number of demands on a building. Although a single microcomputer or personal computer can easily be installed and used in today's buildings, problems arise when there is one computerized workstation for every one, two, or three employees.

The shift in office population, from clerical to knowledge workers, has intensified the demand for a high quality work environment, relief from intensive work at a computer terminal, and a "voice" in shaping and controlling the work setting. The underlying assumption made by knowledge workers, and increasingly supported by organization, design, information, and ergonomic professionals is that increased organizational productivity is dependent on the "unleashing" of knowledge workers; i.e., providing them the tools and opportunities to use their skills, knowledge, and decision-making abilities. This is the major challenge in designing the electronically enhanced building.

From a technological perspective, electronic devices require electric power; when they are installed in large numbers they may at times demand more power, or power that is more precisely controlled in quality, than the building's electric system can provide. They emit heat; when used in large numbers the consequent cooling demand may exceed the capacity of the building's cooling system. They produce noise; they require special illumination; and they make physical demands on the individuals operating them that require ergonomically designed, glare-free equipment and furniture, anti-static carpeting, and attention to the operators' visual and auditory environment. They require networks of wires and cables, both for electric power and for voice, video, and data signals, and these cables must be distributed throughout the building and must be readily accessible for repair and for network modification. This may require the provision of far more space beneath raised floors, above suspended ceilings, and within vertical risers than is allowed for in a traditional building. The information these wires and cables transmit must, in many instances, be secure from eavesdropping.

Both the electric power systems and the signal systems must be reliable, uninterrupted, and secure. This may require backup batteries for emergency use, electric power line conditioners, grounding and lightning protection systems, adequate shielding to avoid contamination of signals by electromagnetic interference, and uninterrupted lines of sight to satellites or microwave transmitters. Cost-effective long-distance communication is no longer a simple matter of buying the standard offering of the local telephone company; an organization may operate its own private branch exchanges, switches, wires, and satellite antennas, all of which must be installed in and on its buildings.

The building that is to house a substantial amount of electronic technology must contain adequate, accessible space for wires and cables. It must be structurally capable of supporting the loads associated with mainframe computers, battery rooms, private branch exchanges, and rooftop antennas. It must have a heating and cooling system that can cope with the heat load generated by the electronic equipment and provide the necessary climate conditioning in spaces occupied by people.

Finally, because the technology and the extent of use of computers and other electronic systems is rapidly evolving, the electronically enhanced office building must be flexible enough to accommodate not only today's electronic systems but tomorrow's, and to cope with the increased use of and demand for such systems that is expected in the future. In the next two sections issues of "content" (what goes into the building) and issues of "process" (how is the building acquisition process organized) are discussed.

BUILDING CONTENT ISSUES

"Content" issues deal with the actual electronic systems and equipment to be installed in the building--for example, computer systems and telephone systems. Computer systems include such features as central mainframe computers, control centers, desktop terminals, wires and cables, cable ducts, and equipment closets. Telephone systems include such features as switches (e.g., private branch exchanges), desktop telephones, the wires that connect them, and the wiring closets in which network connections are made.

These issues may be grouped in three categories. The first has to do with connections between the building and the outside world. This includes connections between the building's electronic systems and external sources of electric power, connections between the building's electronic systems and external communication signals (for example, signals transmitted via land lines, via radio and television broadcasting, via microwave communications, and via satellite communications), and connections between the building's electronic systems and external information networks and data bases. The second has to do with connections within the building--electric power distribution networks, building control system networks, and local area networks connecting telephones, computers, and various kinds of peripheral equipment. The third category treats the electronic equipment itself, both individually and in clusters, and their requirements for space, structural support, electric power, cooling capacity, security, fire suppression, appropriate illumination, and other essential physical and environmental attributes. (More detail will be found in Chapter 3.)

CHANGES IN THE PROCESS OF ACQUIRING A BUILDING

"Process" issues involve the approach used in managing the planning, design, construction, and operation of electronically enhanced office buildings. In the past, the incorporation of special electronic capabilities into a building was not an integral part of the architectural and engineering procedures that went into developing the building program, designing the building, completing the contract documents including specifications and working drawings, and overseeing construction. Rather, responsibility for incorporating electronic technology was left to equipment vendors and building occupants, who often had to make ad hoc building modifications in order to accommodate electronic equipment and cables. So long as the amount of electronic equipment was small, this was not a serious concern. However, as electronics have become all-pervasive, with the growing tendency to have a video display terminal or microcomputer on every employee's desk, it has become important that those responsible for building design take steps to ensure that the building is capable of accommodating and supporting the electronic systems that will ultimately be incorporated in it. This report offers guidance concerning the incorporation of such electronic technology considerations into the building acquisition process. (More detail will be found in Chapter 4.)

In the electronically enhanced building, far more than in the conventional building, it is advantageous to anticipate the use that will be made of electronic systems and to design the building to accommodate that use, rather than simply designing a versatile shell that individual occupants can equip to serve their own needs. Consequently, it is necessary to consult experts in electronics, computers, telecommunications, and office automation at a very early stage in the acquisition of an electronically enhanced office building. In contrast, when acquiring a traditional office building, such expertise is typically brought in only after the building shell and core are complete and attention is given to the interior design.

There are situations in which this is simply not possible--either because the building being designed is a speculative office building or because for some reason the specific activities to be carried out or the specific technologies to be used are insufficiently known or are expected to change rapidly. In such circumstances, it is best to design the building with appropriate flexibility, so that whatever technologies are selected, the building will be able to accommodate them. All such buildings should have a professional "technology capability rating" (a standard which the industry should develop as a public service) which will aid the prospective customer or tenant in making general comparisons between alternative buildings.

QUALITY ASSURANCE AND DIAGNOSTICS

It is more important for an electronically enhanced building than for a conventional building to incorporate a quality assurance procedure into the design and construction process. This procedure should ensure that individual electronic components function properly when connected to the complex systems that are installed in the actual building. It should reveal significant deviations from this performance early enough in the design and construction process to allow its correction with minimal disruption and cost. This is important because electronic systems have become both more complex and more interdependent. Individual components often do not function on a "stand-alone" basis in the actual working environment. The linkages that produce interdependence enhance functionality, but increase the vulnerability of each system (and of the building as a whole, and the institution that occupies it) by decreasing the number and magnitude of component failures required to bring operations to a halt. One solution to the problem is system redundancy--but redundancy is expensive, not only in money but in space and people. Another solution is enhanced reliability, of components and systems. A third is the development and use of techniques--many of which may themselves use electronic technology--that will allow the rapid detection, diagnosis, and repair of breakdowns that can lead to system failures. A fourth is the use of components that are capable of being operated as stand-alone or on an integrated basis. Indeed, in certain settings, reliance on diagnostics to identify and solve problems may be the only cost-effective way to assure smooth operations in an electronically intensive environment.

Many problems are easy to solve if they are caught early enough, but are difficult and expensive to correct once the building is being occupied and used. It is, therefore, important to incorporate in the building acquisition process procedures to ensure that such problems are anticipated during early planning and are dealt with at appropriate times during design and construction. To accomplish this there are specific measures that should be added to the traditional building acquisition process when the building is to be electronically enhanced:

- Articulation of the building's mission statement in a manner that makes clear at the outset the performance that will be required of the building and its electronic infrastructure;
- The use of a multidisciplinary team of experts--independent of system and component manufacturers (but utilizing their advice and suggestions)--to provide guidance and critical reaction to all decisions made during the process of planning, design, and construction;
- The inclusion of a stage that has come to be called "commissioning"--a period of about a year, from shortly before completion and initial building occupancy well into its first year of operation, during which the building and its component systems are carefully assessed to determine whether it is performing as it should under conditions of actual use, and to propose remedies where needed;
- The development and use of diagnostic procedures throughout the design and construction process and through the period of "commissioning," to ascertain whether various parts of the building system are meeting performance requirements and to make a prognosis about the future performance of the facility; and

- The use of diagnostic procedures, not only to provide continuing feedback to the building's owners, designers, and operators concerning the building's ability to perform effectively for its intended purpose, but also to provide "feedforward" to the knowledge base of the broad community of building owners and operators, architects, and engineers in order to make better design possible in the future.

Some of the essential requirements associated with electronic technology must be addressed during the planning phase. Others can be addressed during the design process, or even during construction. Still others can be put off until the period of initial occupancy. It is of critical importance, however, that a plan for the building acquisition process be developed in which the critical times for certain decisions are flagged, and it is essential that a team that includes expertise in all the necessary fields oversee the process. If the finished building is to perform as desired, performance criteria must be developed and performance assessed at appropriate times throughout the building acquisition process in order to determine whether those criteria are being met. If that assessment is put off too long, remedies may be costly, time consuming, or in some cases, virtually impossible.

Two of the most essential elements in the successful acquisition of an electronically enhanced office building are the appropriate and early use of multidisciplinary expertise and the appropriate use of diagnostic procedures. The field is so new and is changing so rapidly, however, that the number of individuals having the necessary expertise is still small and many diagnostic procedures that would be useful have not yet been developed. This makes it tempting to shortcut the process, but when electronic functionality is central to a building, it makes sense to invest the time and resources needed to develop the necessary expertise and to design diagnostic procedures suited to the particular project. (More detail will be found in Chapter 5.)

2

PERFORMANCE POSSIBILITIES

BACKGROUND

While the electronically enhanced building is a direct result of recent advances in the technology of computers, communications, and controls, it has also changed the way many organizations are managed and operated. Or, to reverse the logic, the newly emerging concepts of how to organize and operate government agencies, small and large businesses, banking and financial establishments, research organizations, and many others, are largely driven by the new performance possibilities for office environments. It seems clear that there are still more changes on the way. Some organizations change more slowly than others, but electronically enhanced spaces point to the direction of change for the vast majority of organizations that conduct business in "office" buildings.

The traditional office workstation, both for executives and secretaries, has centered for years around the telephone, the typewriter, and certain other peripheral equipment. The telephone was the basic instrument for communication and telephone service was provided by the local telephone company. With the advent of the minicomputer and then the microcomputer, the work space has become increasingly automated. The electronic terminal with its keyboard and video display is increasingly replacing the typewriter, and is the mainstay of the modern computerized workstation. The development of the digital Private Branch Exchange (PBX) has expanded the world accessible through traditional telephone wires and the range of services that can be integrated through the installation of adjunct processors in conjunction with the digital PBX. When combined with new transmission media (e.g., fiber optics and satellite and microwave links), the individual workstation has access to a world of unlimited bandwidth and ever increasing functionality. A bewildering array of communication options--transmission links provided by a variety of vendors, to transmit data, text, and video signals as well as voice communications--make possible a wide variety of configurations replacing a universally standard service.

Computer technology has evolved toward greater processing speed, greater memory capacity, greater reliability, lower cost, and equipment that is less bulky, demands less electric power, and produces less heat. The reduction in size accompanying the development of microcomputers has led to compact computerized workstations and an increasingly widespread use of portable terminals as well. Although the increasing use of electronic equipment has resulted in a heavier load on the "infrastructure" of the building, it is anticipated that this trend will not continue indefinitely.

Communication technology has produced a wide variety of options for both local and long-distance communication. These include private branch exchanges (PBXs); local area networks (LANs) and sophisticated signal distribution vehicles; local and long-distance voice, data, and video transmission systems; long-distance telephone routing systems; tele- and video-conferencing; and other services such as electronic mail. There are new approaches to wiring and cabling, including the introduction of multi-media cabling systems that can bundle optical fiber, coaxial cable, and twisted-pair wiring in a single sheath to pass all potential media to the workstation thereby assuring access to any bandwidth needed.

Control technology has produced digital electronic sensing and actuating devices less costly and more versatile than the electromechanical and pneumatic devices used in the past. When such controls are connected to networks and sensors added, the potential for highly responsive internal building environments becomes a reality.

Technological advances in these areas have led to a capability for versatile communication and computer systems for the use of building occupants as well as versatile automatic or semi-automatic management and control systems for supporting a more responsive internal environmental system. Although the underlying technology is the same, these two applications differ in many respects. Perhaps the most significant difference is that the building operating systems tend to be the responsibility of the building engineer whereas the occupants' computation and communication systems tend to be the responsibility of the individual and/or operating units.

This separation of responsibility masks the fact that the two sets of applications are interdependent. Computerized workstations, for example, make demands on the building's electric power distribution network and on heating, ventilating, and air-conditioning (HVAC) systems. If building occupants are to have the freedom to relocate workstations, the electric power distribution system and the HVAC system should be sufficiently flexible to accommodate this contingency. Similar considerations apply to such factors as structural load-bearing capacity, lighting, vertical transport, security, and safety. At the same time, basic building systems such as energy monitoring and control systems, to be effective, should take into account the temporal distribution of work activities, especially those that require electric power and generate heat, and also the variations in those activities in different parts of a building.

As new patterns of office management and use emerge from the increase in performance capability offered by the electronic technologies, the requirements for the designers of buildings, for space planning professionals, and for office equipment designers will all undergo changes. The following pages will provide more detail on the performance capabilities of present electronic enhancements; however, the reader should keep in mind that more changes are emerging in these technologies each day.

COMMUNICATIONS POSSIBILITIES

Voice and Data Communication Networks

Voice and low- to medium-speed data transmission form the backbone of modern communications. These draw on the local telephone company and possibly other carriers, for their cables and switches, but their heart of the system is the modern private branch exchange (PBX). The PBX, which may be located within the building or off-site, can serve as a switch for all voice and data traffic within the building, routing calls over the least expensive long-distance trunks, and to local numbers over central-office trunks. Additional application processors associated with the PBX can assist in allocating costs to individual cost centers and can provide electronic mail and message center services. Sophisticated PBX switching systems offer a number of opportunities beyond the basic service provided by local telephone companies. The user can place calls on hold, forward calls, confer with additional parties, have calls automatically transferred to other stations when the called party is unavailable, and restrict access to certain facilities by extension number. In addition, it is possible to use very sophisticated electronic telephone sets. These sets can provide signals indicating caller identities, programmable keys for autodial numbers, one-button access to special features, and a long list of other special features. These are available from a number of private sector firms on a competitive basis.

PBX-based telephone systems can also provide connections between data terminals and computer systems and between personal computers. This can save money and reduce complexity by eliminating wiring, reducing the number of computer ports, and increasing operation speed.

Data terminals generally require shielded twisted-pair cable connecting the terminal to the computer. The data communication capabilities of the PBX make it possible, in many circumstances, to use unshielded, twisted-pair, telephone wire to carry data as well as voice traffic.

To use terminals more than 50 feet from the computer, a device called a modem or a line drive may be required. Special devices designed for use with the PBX can eliminate the need for separate modems, and data can be communicated in digital form end to end. Modems are then only required for access to the external switched network and can be pooled to serve a number of terminals. Several options are available for connecting data terminals to computers outside the building, such as those at a home office or an information provider such as Dow Jones or The Source.

Most terminals are connected directly to a computer port. However, all terminals are seldom in use simultaneously. Typically, only one out of three terminals communicates with a computer at any one time. By using the switching and call-assignment capability of a digital PBX, users can dial up the computer and contend for the available ports, and quite possibly the number of computer ports needed can be reduced. When inexpensive modems are used to dial up computers within the same building, operating speed is normally reduced. With many PBX-based systems, however, data terminals can dial up computers within the same building and operate at sufficient speeds to provide satisfactory response time for most functions.

The PBX can also facilitate high quality alternatives to the traditional telephone answering service. An answering service is a facility staffed by telephone operators who answer calls and take messages for users of the system. New technology-based services utilize computer terminals that display the status of the individual whose phone is being answered and allow messages to be entered directly into the system; maintaining an efficient link between the caller and the operator. In many cases, an answering service can cost-effectively replace a secretary or receptionist, thereby, reducing personnel costs. The answering service can be integrated with the PBX and other office automation functions so that the user does not have to check for messages at a message desk. Instead, the user sees a "message waiting" light on the telephone, or a notice on the phone display, or a signal to retrieve the message on the electronic mail screen.

Use of a PBX with a long-distance telephone service makes it possible to track and control long-distance costs. Detailed reports can be generated that permit management to allocate costs by department or by individual extensions. Special restrictions can also be placed on extensions within an organization to control costs or for security reasons.

Internal Communication Systems

Among the new capabilities provided by electronic technology are local area networks, voice mail systems, and electronic mail.

Local area networks (LANs) make it possible to connect a variety of terminals together. Basically, a LAN is a wire system with its own intelligence, as opposed to using the intelligence of a mainframe computer to direct signals between devices. A LAN functions in a telephone system, much as a field interface or direct digital control function in an energy management and control system.

Voice mail systems, sometimes called voice messaging or "voice store and forward" systems, are electronic accessories to PBX systems that can record voice messages and play them back on demand. In a way they function like a gigantic answering machine. However, voice mail systems can also be used to distribute voice messages to a list of people, store messages for future reference, or pass along messages for further handling. These systems are alternatives to message centers and answering services.

Electronic mail is a computer application that allows customers to send and receive messages in electronic form, both within and outside their organization. Electronic mail systems sometimes require a special terminal to access the system and generate and retrieve messages.

External Communication Systems

Among the electronic capabilities for short- and long-range external communications are microwave transmission, packet-switched networks, electronic tandem networks, radio paging, and facsimile, teletype, and telex communications.

Microwave transmission can be used to provide high-speed communication links with nearby buildings and projects. Microwave communications allow projects to share PBX and office automation facilities.

Packet-switched networks are a special method of transmitting low-speed data at relatively low cost to computers in the United States and around the world. Tymnet, Telenet, and AT&T Net/1000 are examples of packet-switched networks in extensive use today. To attach to a packet-switched network, a packet assembler/disassembler (PAD) is required. These PADs provide high-speed connection to the packet network and are generally quite expensive if bought from the packet network company. Many advanced PBX systems have available relatively inexpensive PAD systems that can be integrated with the PBX system itself.

Electronic tandem networks (ETNs) are sophisticated systems of communications lines, PBX equipment, and PBX software. With them, multiple PBX systems in multiple locations can be tied together in a network. Using an ETN, a large company can make communication accessible to all its employees without a need to use special access codes. In addition, an ETN allows a company to share access to all long-distance communication lines in the company.

Certain radio paging systems provide for a high level of interaction between the PBX of the user and the radio paging system. This interaction allows incoming calls to go directly to the originator. These paging systems are typically expensive, however, and require a large number of users to be cost-effective.

Facsimile and Teletype or Telex permit organizations to communicate written messages rapidly from time to time, both within the United States and overseas. Facsimile equipment scans a document and sends an exact picture of it over telephone lines to another similar machine anywhere in the world. Federal Express ZapMail also uses this technology. It can be used for letter- and picture-quality documents. Teletype or Telex equipment allows the transmission of typewritten messages electronically to any one of several hundred thousand similar devices throughout the world. This technology is the common method of communicating electronically for international businesses.

Video-Conferencing and Teleconferencing

A video-conferencing facility generally consists of a specially designed meeting room with cameras, large-screen televisions, and special video processing and communication equipment. These rooms are expensive to build and operate and typically are developed in association with a nationwide service provider. A typical room might require 600 square feet for the meeting area and an additional 200 square feet for equipment.

There are other teleconferencing systems that are less sophisticated and consequently less expensive. The most promising system is audio-conferencing with facsimile and data communications. An audio-conferencing system would consist of a small meeting room, acoustically treated to deaden echoes and enhance voice transmission. Special highly sensitive microphones and high-fidelity speakers are built into the room to pick up voices and amplify conversations. Portable microphones could be available so that conversation can take place easily anywhere in the room. When combined with the ability to send pictures via facsimile and data via the terminal, this teleconferencing room would provide many of the same advantages of video-conferencing at a fraction of the cost.

Perhaps the most important trait of all these technologies is that they are not presently standardized in their ability to communicate with each other. The communications industry is developing standards to facilitate system interaction and integration.

NEW COMPUTER POSSIBILITIES

High-Speed Computer Printing

The increasing utilization of personal computers to perform word processing and report preparation tasks has increased the need for high-quality computer printing. In the past, high-speed, high-quality printing was expensive and was, therefore, usually available only to large organizations. Prices are rapidly falling, however, so that high-speed, high-quality printing is coming within the reach of every organization.

The data capabilities of the PBX and the communications capabilities of a high-speed LAN can provide access by users to centralized printing facilities. These facilities typically consist of one or more high-speed printers and at least one high-speed color graphics printer. A part-time technician is required to keep the printers operating and full of paper and to distribute output to the appropriate customers.

Word Processing Services

Word processing services require a word processor, access to a high-speed, high-quality printer, and a user with the needed typing skills (for many modern executives this has become an acquired skill, thus, reducing the number of clerk-typists required). Use of the PBX data facilities or the building LAN allows the user to exchange documents easily with customers' personal computers and word processors.

NEW ELECTRONIC SENSORS AND CONTROLS FOR BUILDING SYSTEMS

Controlling Building Systems

A secondary effect of recent technological advances concerns the systems that control the interior characteristics of a building--electric power, heating, cooling, air quality, noise, illumination, security, fire safety, etc. These systems can be made more versatile, more automatic, and more responsive to user's needs by a different set of applications of the same new communication and computation technologies that underlie the computerized workstation. Many of these applications rely on sensors to detect specified conditions in various parts of the building, wires and cables to transmit the information in digital form to computers, and wires and cables to transmit instructions for automatic responses to the conditions detected--responses that increase illumination, decrease cooling, sound evacuation alarms, etc.

Electronic building automation systems center on distributed data gathering panels (DGPs) that contain microprocessor-based "cards" which perform a variety of functions: automatic temperature control, fire detection, security monitoring, alarm monitoring, energy management, etc. The DGPs serve either one mechanical equipment room or an entire building. They are connected with each other and with a "head end" by means of a data highway, which can consist of twisted-pair copper wire, coaxial cable, or optical fiber depending on the complexity of the system and the distance between components. Fire detection and security can readily share a data highway; whether these two functions should share a data highway with energy management and temperature control depends on the philosophy of the building operator and, sometimes, on local code requirements.

Each DGP can operate in a stand-alone mode for most application programs other than global programs (such as electric power demand limiting and preventive maintenance management) which require interconnection. It is also possible for monitoring equipment to be located hundreds of miles away from the building, and send back signals to operating equipment from such remote locations. (See more detail in Chapter 3.)

Diagnostics by Sensors and Controls

One of the exciting areas of development that will be greatly accelerated by the introduction of electronic enhancements is building diagnostics. It should be emphasized at this point in the report that the process of diagnosis can be greatly facilitated by using built-in sensors and control devices in the building for producing necessary data and analysis. As an earlier study by the Building Research Board said,

> "Building diagnostics is the process of judging how well a building can be expected to perform its function. This judgment requires knowledge about the building's original purpose, its present purposes, its surroundings, and its history. . . Information obtained from the building's owners and occupants, visual observations, and measurements made by instruments provide the data on which the diagnostic assessment is based.
>
> Four elements are essential to the practice of building diagnostics: (1) knowledge of what to measure, (2) availability of appropriate instruments and other measurement tools, (3) expertise in interpreting the measurements, and (4) a capability for predicting the future condition of the building based on that interpretation.
>
> New diagnostic technology includes . . . small "tattletale" devices (such as streamers for air diffuser testing, color-changing desk thermometers for temperature assessment, and smoke pencils for infiltration testing) for intrusive testing of existing buildings and of mock-ups and models are finding increasing use along with sound-level meters, air quality testing equipment, light meters, flow meters, thermographic cameras, spot radiometers, moisture meters, and so forth." *

The ideas described in this section of the report are ones which could build on the sensors and control devices of the building. In Chapter 5 of this report a number of diagnostic procedures that might be particularly valuable in electronically enhanced buildings will be discussed.

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*Building Research Board, BUILDING DIAGNOSTICS: A CONCEPTUAL FRAMEWORK, National Academy Press, Washington, DC 1985.

3

DESIGN REQUIREMENTS FOR ELECTRONIC TECHNOLOGIES

GENERAL REQUIREMENTS

No one would propose to build a house in a new subdivision before the infrastructure of water, sewer, power lines, phone lines, and roads had either been installed or provided for. The eventual owner of such a house would not be able to operate any of the modern appliances, take a shower, or call a friend without the internal and external connections to infrastructure having been made. While it is less obvious, it is just as important that the total design of a modern office building be conceived and executed within the context of its required infrastructure. If the architectural team designs the building without considering the design requirements of the advanced equipment to go into the building, mistakes are likely to be made, or costly retrofits will be required. In the same way the owners and operators of the offices cannot wait until the building is finished to begin the planning of their equipment requirements. This chapter provides all of the parties involved in the process of designing and managing an electronically enhanced office building with information on the design requirements imposed by the electronic technologies.

First there are several general considerations that apply to the incorporation of electronic technologies in office buildings. These have to do with centralization, flexibility, and tolerance of less than ideal conditions.

Centralization or Decentralization

The electronic equipment in a building can be centralized or distributed, or it can be a mix of both. When equipment is centrally located it is easier to manage, maintain, troubleshoot, and repair, and it is easier to provide assistance to users and appropriate security for equipment and operations, but it is less convenient for users who have to go to a central location rather than having the equipment available within their work area. The more the equipment is distributed, the more such concerns as the physical arrangement of equipment rooms and wire closets and riser shafts and the physical and electronic control of the equipment in each equipment room will affect the design of the building and the activities of its occupants.

Flexibility to Accommodate Change

Depending on the use that is to be made of the building, there may be a high or low likelihood that, as time passes, changes will be made in system components and configurations. Different technological options and different building designs--having different costs--may be appropriate depending on whether the building's occupants will require continual rearrangement of workstation configurations and continual upgrading of system components or whether a particular configuration and choice of equipment are likely to remain in place for some time. Moreover, the technology is changing rapidly, and if changes are to be introduced into the building at a later stage in response to those changes--if coaxial cable is to be replaced with fiber optic cable, for example--the change will be difficult and expensive unless the building's infrastructure was originally designed with this change in mind. Such flexibility in design is itself costly, and may be worthwhile for some organizations but not for others.

Tolerance to Non-Ideal Conditions

The physical and environmental requirements associated with different electronic technologies vary considerably with regard to their tolerance to other-than-ideal conditions. Some requirements are virtually essential, while others are amenable to alternative approaches. For example, if satellite communications are required, then a line of sight from the building to the satellite is essential. On the other hand, if the building's floor-to-floor height does not allow enough subfloor space to house the cables for a local area network, networks can still be installed using a different approach, such as the installation of ducts or false columns in which cables can be housed, the use of cable trays to conceal flat wire under a raised floor, or the use of flat cable laid on the floor and covered with carpet tiles. Similarly, if the building's interior surfaces, as originally planned, are found to cause glare or to amplify acoustical noise, different finishes can be used or finished surfaces can be covered with material having more desirable properties. The availability of workable alternatives depends in part on the tolerance of the electronic system and in part on the cost of the various options. As a rule, the earlier the potential problem is identified, the lower will be the cost of avoiding or rectifying it. Consequently, the continuous use of diagnostics to evaluate the performance of the building and its systems is recommended.

There are major demands placed on the electronic enhancements in the modern office by changes in the design and selection of workstations. Work surfaces not only need to be larger, especially during the time of transition from a traditional work setting to the electronically enhanced setting, but they need to handle simultaneous paper and computer-based work. The workstations should be vertically adjustable (to position keyboards, screens, and papers appropriately), they need to incorporate cable management, computer paper, and disk storage, task lighting and appropriate acoustic and vibration control for equipment. They need to reflect the continuation of our paper-based working methods which use books, filing cabinets, paper clips, etc., along with the computer-based working devices such as VDTs, keyboard and graphic pads, floppy disks and disk drives, modems and printers. They also need to reflect the increased emphasis on the ergonomic needs of the worker, resulting from backache and neck strain, tired wrists and tired eyes. The impact of these changes in the physical setting is the need to carefully survey present working configurations and use and then examine product specifications for their ability to meet these combined needs, as well as the spatial, acoustic, thermal, and visual needs of the occupants.

THE REQUIREMENTS OF EXTERNAL CONNECTIONS

The first significant issues for the electronically enhanced office building are those related to providing the building with electric power and with a capability for receiving and transmitting electronic signals. Electronic signals may be in analog or digital form; they may carry information in the form of data, voice, or video signals; and they may be transmitted via copper wire land lines or fiber optic cables, via direct radio or television broadcasting, or via direct or rebroadcasting from microwave links or satellites.

The equipment involved in external connections includes the antennas mounted on the roof and the switches, electric power line conditioners, and other related items found in the communication rooms.

There are three major types of external connections: connections to a source of electric power; transmission and reception of broadcast signals; and transmission and reception of signals carried by wires and cables.

Electric power The most important aspects of electric power are capacity, quality, and reliability. It is important to ascertain the likelihood of power outages or lowered voltages, of unacceptable power surges or spikes, etc. This requires examination of the history of the local electric utility with regard to malfunctions. A poor record on the part of the utility may require either selection of a different site served by a more reliable electric power company or a building design that incorporates the possibility of a self-contained electricity-generating plant. For this reason, it is essential that electric power be considered at the very outset, during the site selection stage, and that this consideration encompass an analysis of the feasibility and cost of some form of electric power redundancy. Electric power failure may take several forms: (1) a sudden, total loss; (2) an occasional interruption; (3) a change in power quality.

In considering alternative sources, such as an on-site diesel generator or a backup battery room, it is important to ask how vital uninterrupted electric power is and what kinds of failures equipment to be installed cannot tolerate. For example, is uninterrupted power essential for the entire building, for parts of the building, or just for the computer? The answers will depend in large part on the activities performed. In many cases some form of uninterruptible power system (UPS), such as backup batteries and a standby electric generator, may be required. In that case the minimum building requirement is to leave room for later installation of such equipment. Another important attribute of the building's electric power system is the adequacy of the grounding arrangement; poor grounding may be the most common cause of electric power problems.

Broadcast signals The successful use of radio, television, microwave, and satellite receivers and transmitters depends primarily on the building site and on the position, orientation, and structure of the roof. If the height of the roof, the line of sight to distant transmitters or receivers, or the wire access rights are unsatisfactory, the use of microwave or satellite communication technology may be unworkable (although it is now quite common for an antenna to be located on the ground some distance from the building and connected to it via land lines). Rooftop receivers and transmitters must be free of interference from other nearby signal generators. For satellite dishes especially, structural support (e.g., bracing) is essential if the equipment is to withstand wind and snow loads, and cover is needed to protect the equipment from ice. The aesthetic appearance of antennas may also be an important concern in obtaining local building permits, or may clash with an image which requires a pyramid or "needle" top not able to accommodate an antenna.

Signals carried by wire and cable The effective use of wire and cable connections to external signal sources and receivers via copper wire land lines, coaxial cables (as in networks connecting buildings on a campus), and fiber optic cables depends primarily on the position and configuration of their point of entry into the building. (The point of entry is usually in the basement, but is not always the ideal one. The basement often offers structural advantages, and space not in demand for other purposes, but--along with any other underground space--it may be susceptible to flooding, in which case critical connections must be made waterproof.) At the point of entry, there must be secure and accessible trenches into well-located and well-configured communication rooms. Generally, the installation of wiring that brings external signals to a point of entrance at the building shell is the responsibility of a local provider (e.g., the local telephone company) rather than of the building owner. For a single building, the point of entry is usually also the demarcation between the responsibility of the outside provider (e.g., the local telephone company) and the operator of the building. Where the building is one of many on a campus, this demarcation may occur at a single location for all buildings on the campus, which may be a considerable distance from the cable entrance to any one building. If the building will require special voice, video, or data services local providers of those services are needed and the building must be capable of meeting any special requirements that those providers may impose.

Communication Rooms

The actual physical connections between the building and the outside world are usually made in communication rooms. In addition to containing the local connections to an external electric power supply and to electronic signal cables, these rooms may also house the building's UPS or battery backup system, its private branch exchange (PBX), and devices such as multiplexers, concentrators, and modem pools used to strengthen, concentrate, and consolidate signals and convert light signals in optic fibers to analog or digital electronic systems in copper wire. Communication rooms must be appropriately positioned for ready access to equipment on the roof (where satellite, microwave, radio, and television antennas are usually located) and in the basement (where external cables usually enter), and ready access to the cores, shafts, and ducts through which power and signal cables are distributed vertically and horizontally throughout the building.

Where there are separate network control centers, communication rooms are generally not occupied. In the absence of network control centers, the people who perform the control and "help" functions of such a center may be housed in the communication room. Even in occupied communication rooms for proper equipment functioning they must be heated and air conditioned, humidified (or dehumidified), and protected against damage from fire (usually by Halon fire suppression systems). They must also be ventilated, protected from dust and water, provided with sufficient electric power, and illuminated and designed for ready access and maintenance.

Since communication rooms, wire closets, and other equipment rooms (such as computer rooms) generally do not have raised floors, wiring may have to be distributed above a lowered ceiling, in which case it is important to ensure sufficient floor to ceiling height to accommodate equipment racks and wire racks. This is not a problem with new construction, but it may be in renovating an existing building.

Building Requirements

External connections should not be considered in isolation but examined in the context of the other issues discussed in this report. There are important trade-offs between the alternative investments in quality and reliability to be made. Once the value of quality and reliability has been identified, it is necessary to consider their costs as a function of building site, type, architectural design, etc., and to consider other factors early enough in the planning process that these building attributes can be modified when it would be beneficial to do so.

As an illustrative example, consider a bank, investment institution, or other financial organization that engages in electronic fund transfers to be carried out rapidly and without interruption at an extremely high level of quality, or a critical public service such as a fire department whose communication system must function without interruption. Regardless of the quality and reliability of the locally available electric power, this organization may find it worthwhile to have one or even more power backup systems to ensure uninterrupted and clean electric power. If the organization customarily receives financial or other data via satellite or microwave transmissions, it may be essential to have an alternative method for receiving the same data via land lines, as well as other system redundancies, to ensure that the speed and accuracy of its financial transactions or emergency operations are not compromised. Such an organization will take a very different approach to reliability and uninterruptibility than one in which down time is not as critical, and in which accuracy checks carried out at a later time can be used to reveal potential errors to then be checked, verified, and corrected if necessary. Quality of operations may be equally important in both kinds of organizations, but considerations of speed, timeliness, and the significance of errors may cause them to take a very different approach to features of the interface between the building and the outside world.

External Power Sources

From the point of view of the activities carried out in the building, the most significant issues concerning electric power and the transmission and reception of external signals have to do with quality and reliability. The electronic equipment used within the building may require electric power and electronic signals that fall within certain ranges in terms of voltage, frequency, amplitude, bandwidth, and freedom from transients, spikes, and other forms of electrical or electronic noise. The activities for which the electronic equipment is used may require uninterrupted power or other kinds of reliability. To the extent that either the necessary quality or the necessary reliability cannot be provided by external sources, it may have to be provided within the building--usually, but not always, near the point at which the connection is made between the building and the outside world. Quality may be improved by passing electric currents and electronic signals through appropriate line conditioning devices. Reliability may be improved by providing emergency backup systems or system redundancies.

INTERNAL NETWORK REQUIREMENTS

The design of the building's internal communication network is one of the most significant decisions in the electronically enhanced office building. It determines the limits of the hardware and software capabilities of the building. There are a number of decisions to be made, both with regard to the types of cables and wires to be installed and with regard to the network configuration of the system, often called cable or "system architecture."

For a number of reasons, it may not be possible or desirable to integrate all of a building's electronic signals into one wiring system. For some purposes, such as security and fire safety, existing protocols require independent circuits. Where the building contains a number of local area networks (LANs), it may be considered desirable to have them on separate circuits rather than to integrate them all. Automated system status and control systems may require circuits separate from those carrying data. Consequently, an electronically enhanced office building may contain a number of distinct communication systems that must be centrally controlled and managed, and whose wires and cables must maintain their integrity from each other.

Cable Choices

The types of wiring currently available include copper twisted-pair, flat wiring, coaxial cable, universal wiring, and fiber optic cable.

Copper twisted-pair is the most common cabling found in buildings today. It is usually the most compact and has the smallest diameter, which often allows its introduction into existing buildings with limited vertical shafts or horizontal plenum spaces. Nonetheless, twisted-pair wiring is becoming thicker to permit signals to be carried longer distances at greater speeds. Therefore, adequate space, both vertical and horizontal, is becoming increasingly important for twisted-pair cabling.

Flat wiring is a form of shielded copper cabling. Transition boxes house the connections between the twisted-pair wiring that runs through the building and the flat wiring that serves a particular room; the flat wires are then distributed horizontally under carpets. However, because they are thinner, they can only carry fast signals short distances, and are not shielded from electrostatic interference. Many computer experts opposed the use of flat wiring since any electrostatic discharge--from radios, other electronic equipment, or even feet on carpets--may contaminate the data flow.

Although the state of the art is changing rapidly, coaxial cables can now provide greater transmission speed than twisted-pair, offer greater bandwidth with less attenuation, can transmit signals at higher frequencies and can transmit stronger signals over greater distances. However, they are much heavier and thicker than twisted-pair cables. Consequently, where coaxial cables are used, considerable vertical and horizontal distribution space is necessary to contain them. Coaxial trunks must also be carried to the roof and basement, for signal input and output and for grounding. Clearly, tradeoffs must be made between the convenience and small size of twisted-pair wiring, with limited transmission capabilities, and the weight and bulk of coaxial cables having far greater transmission capabilities.

Universal wiring attempts to bridge the performance gap between twisted-pair cables and coaxial cables through the use of balance connectors. Although both data and voice signals can be carried through this "universal" wiring, there are definite limits to the speed and quantity of data that can be transmitted.

Fiber optic technology converts digital electronic signals to optical signals, using very thin wiring and a series of multiplexers (to convert from digital to optical and back to digital), with one port per peripheral unit. Fiber optic cable is very difficult and expensive to install, and very difficult to bend due to its large turning radius, although it is likely to improve in both respects in the future. However, it is excellent for data security. The most widespread use for fiber optic cables at the present time is for long distance transmission between mainframe computers.

Multiplexers are another critical component in the cable network. They are used to reinforce the signal as it travels over long distances. Not insignificant in size (they typically occupy a cubic foot of space), multiplexers are often noisy and generate heat. Consequently, they should be housed in cable closets distributed throughout the work space to keep horizontal runs as short as possible to ensure clear signals at the peripheral unit.

System Configuration

The configuration of the cabling network is the traffic pattern in which cables run from computer and communication rooms through vertical cores and horizontal plenums to distributed closets and from there to individual computers, peripheral units (input/output devices and processors), and telephones. The basic questions to be answered before designing the configuration of a local area network (LAN) concern the total capacity and the internal and external data links needed over the long term. There are four basic configurations for cabling runs and connections to computers and peripherals; they are known as bus, star, ring, and cluster networks.

The star network is the most popular and frequently incorporates secondary or satellite closets that serve as data termination centers connected by universal wiring. It is essential to understand the demands associated with this cable network and the importance of early use of cabling expertise in the design of the building. Not only are bending radii intolerant, but fire safety concerns create significant dimensional demands. Cables must either be laid inside fireproof, rigid, metal conduits or ducts (other than air supply or return air ducts) or they must be Teflon-coated and enclosed in a plenum space. Either way, sufficient clear space--i.e., space that is free of mechanical and structural obstructions--is required in ceiling plenums or raised floor plenums. The amount of space required may range from as little as four inches in an office to as much as eighteen inches in a computer room. If several complex cabling networks serving different terminals are to run in the same plenum, multiples of this amount of clear space must be provided. Moreover, sizable satellite closets are required to house controllers and multiplexers to maintain signal strength or permit the transfer of data from optical to digital cables. These closets have special requirements for electric power, fire safety, security, and air quality. They must also be well organized and accessible to allow for effective cable management (and to avoid inadvertent cutting of wires).

In designing a computer system in all its aspects, decisions must be made about global services (e.g., libraries and data bases), their networking (e.g., intercommunication), and their control (e.g., centralized "corporate" control or distributed "campus" control); departmental services and their networking and control; and individual services and their control. The implications of ring, bus, star, and cluster configurations must be considered, along with their vertical and horizontal space and location requirements. Decisions about clean power and uninterrupted power must be made for the entire system, and the implications of these decisions for the enclosures of mainframes and minis as well as their connections must be taken into account. One approach that has been widely adopted uses systematically distributed "enhanced closets" filled with minis and peripheral output devices (laser printers) and tied together in a token ring LAN. The stacked enhanced closets provide absolutely vertical cores, and their distribution allows enhanced microcomputer workstations to be close together, greatly simplifying cable management, freeing up space, and allowing considerable flexibility.

Tying the entire cable network system to a grounded cable is essential, and there are various termination schemes for ensuring that the entire system of cables is adequately grounded. Access to the basement and beyond is absolutely necessary, with critical dimensions for the depth of grounding rods (up to 20 feet) and the separation between them. The continuity and size of the vertical shafts are also related to effective grounding. Electric power generators and back-up batteries must also be incorporated in the grounding design.

Accommodating Future Change

In making provisions for flexibility to meet future changes, several principles apply; these are particularly important in buildings characterized by frequent office rearrangement and frequent computer or telephone system updating, and are less important in buildings where office arrangements, equipment, and systems are more stable. Where frequent changes are deemed likely, the original plan should provide for the making of these changes at minimal cost and disruption to operations. An important principle is to be able to make as much of the change locally as possible. If new wiring is required, for example, it should run only from the workstation to the closest wiring closet; there should be no need to rewire all the way back to the cable entrance. This can be accomplished by initial laying of spare wire from the communication room to each wiring closet, or at the very least, by providing risers, ducts, or channels to accommodate such wiring when it is needed.

Cable management represents a significant hardware and software consideration in the electronically enhanced office building. To keep track of the wire location, type of wire (twisted-pair, coaxial, universal wire), signal (electric power; voice, video, or data; analog, digital, or optical), and transmission capacity requires not only clear architectural design, but often the installation of a computer-aided wire management (CAWM) system. Such a system can avoid waste accompanying hardware modifications or personnel relocations by enabling the reuse of existing conduit. Alternatively, cables must be "chased" at great cost, ignored, or completely pulled out.

There are innovations in internal signal propagation currently under development that have the potential to contribute to effective network management. These include wireless data transfer using radio frequencies for interoffice communication and "intelligent" communication systems. In the latter, "smart" wiring combines sensors with a logic board, identifying through the plug what the type of peripheral unit attached and its power, speed, and capacitance demands.

Electric Power

In addition to the requirements noted earlier for adequacy and quality, other important considerations concerning electric power networks are: (1) the availability of power outlets of adequate capacity at widely distributed locations within the building; (2) a capability for modifying the power distribution system when necessary to meet new occupant needs; (3) provisions for trouble-shooting, diagnosis, and repair of the power distribution system with minimal disruption to occupant activities; and (4) provisions for monitoring and metering power use, both for billing and accounting purposes and as an aid to electric power management.

New approaches to distributing electric power include raised floors to accommodate power, communication, and air-conditioning ducts; flat cable under carpeting for relatively short runs; more careful planning of services using computer-aided design to permit change with minimum disruption; electrical service to modular office furniture designed to accommodate cables and outlets; electrified movable partitions; dedicated (clean) electrical circuit networks distributed throughout the building to computer equipment; and uninterruptible power supplies for main computer operation, internal services, and general office areas.

In the past, the usual practice was to provide clean power circuits only to selected locations and equipment. Clean power was not generally available throughout the floor or the building. Filters were provided for individual pieces of equipment requiring clean power. Now, areas expected to have a heavy density of equipment requiring clean power are provided with central filters, separate clean power panel terminals in electric closets, and parallel distribution with normal power through raised floors or by whatever distribution system is used to accommodate normal power.

New electrical loads requiring additional uninterrupted service call for additional generating capacity. In the future, such loads will constitute a much higher percentage of the total building load, requiring careful pre-design planning and installation of added emergency power capability at the start. Diesel generators will not provide utility service sufficient to retain computer memory in case of a power failure, and, thus, a series of batteries, rectifiers, and battery chargers must also be included.

Internal Signal Distribution

Later, in the working drawing and final occupancy stages of the project, other matters become important, including the control of internal electrical interference from radios and transformers (such as occurs when "white noise" devices or fluorescent light fixtures are situated close to telephones or telephone connections), and protection of the cable network and its associated hardware from abuse.

The greatest possible degree of versatility in relocating equipment is provided by a distribution of both signal receptacles and power distribution modules throughout the building, just as ordinary electric power outlets are distributed throughout a conventional office. This makes it possible to "plug in" computer terminals wherever desired. This versatility is possible only if the necessary wiring is initially put in place. Since the computer typically requires clean power, and other electrical equipment (such as task lighting) does not, it may be most economical to have both a "clean power" and a "dirty power" outlet at each workstation. Every "clean power" outlet does, however, require monitoring to ensure that the power quality is satisfactory.

Computer System Configuration

The most important requirement pertaining to computer system configuration is the adequacy of vertical and horizontal distribution space. Other important factors are access to the roof and basement for external signal propagation and mechanical conditioning. The existing interior elements--ceiling, partitioning, and flooring systems as well as workstation furniture--are also important considerations.

Provision for Maintenance

Interstitial space, raised floors, and enlarged service closets reduce the impact of routine maintenance and repair on the activities being carried out in the building. Computerized preventive maintenance programs can be used to provide analyses, and repairs can be scheduled for nonoccupied hours whenever possible. Automated monitoring systems can activate audio signals from equipment rooms to indicate water leakage, bearing wear, and other system malfunctions. Infrared sensors at electric cabinets and junction areas can be used to detect and indicate overloads and overheating. For optimum building performance, ease of maintenance is an essential early consideration in the design process.

ELECTRONIC DEVICES AND EQUIPMENT

Four categories of devices and equipment are discussed here: (1) computers, (2) peripherals (which include input and output devices such as printers), (3) telephone systems, and (4) automated sensors and controls for building systems (such as heating, ventilating, and air-conditioning) and for management services. A variety of other special purpose categories of equipment are not specifically addressed, such as those used in teleconferencing rooms, but the major issues discussed below apply to most new technologies.

Computers

There are three general categories of computers: mainframes, minicomputers, and microcomputers. Each of these can be provided with enhanced capacity or speed to become super mainframes, superminis and supermicros. Although the differences among the categories were once very pronounced, each having unique physical and environmental requirements, the boundaries are now becoming blurred. Even micros can have 40 to 80 megabytes or more of memory capacity and 4 to 5 mips (million instructions per second) of processing speed, without large power requirements or significant heat output. Nonetheless, the number of each of these types of computers already in the workplace make their impact significant.

Mainframe and supermainframe computers, such as the Cray, require especially designed computer rooms or data centers. Adequate electric power, an UPS system, and special grounding are required. The weight of the equipment is significant and requires enhanced structural support and vibration control. Structural demands become particularly important if the computer room is to use a raised floor to accommodate cabling. The computer itself and such ancillary equipment as magnetic media safes are very heavy and cannot be supported by a typical raised floor without the addition of special structural measures. The air conditioning capacity required for these spaces is significant (it may be five to ten times the cooling capacity required for conventional office space), the equipment must be water cooled, and the humidity must be precisely controlled. Because condensation of water may present serious problems, computer rooms must be isolated from the building's window wall. Security and fire are major concerns, calling for controlled access and halon fire systems with their own sensors, alarms, and pumps with cabling independent of other systems.

Sophisticated alarm systems may be required for remote equipment on large campuses, which may either be integrated with the overall communication system or controlled separately. Finally, massive amounts of cable are required for electric power, data, and voice inputs and outputs to numerous distributed workstations, telephone gateways, and controllers (operating substations), and the cable arrangements must be amenable to frequent change. As a consequence, control rooms for super mainframe and mainframe computers have requirements for electric power, air conditioning, humidity control, security, and fire safety, as well as cable management, that create stringent demands for access floors or trough walls for the servicing systems.

It is most common to locate computer rooms in basements, and in the renovation of an existing building this may be the only feasible option. Because of the potential flooding problem, already discussed steps must be taken to protect the equipment in a basement computer room from water damage. This problem can be avoided by placing computer rooms at higher levels, but here the competition for space is more intense.

Superimposed on the demands of the equipment are the demands associated with the people who work in computer rooms and data centers as well as those who work elsewhere in the building. Vibration, for example, must be controlled with two aims in mind--the long-term durability of the equipment, and the physical and psychological effects of vibration and acoustic noise on people, both those in the computer room and outside. Lighting must be considered both from the viewpoint of the low ambient light levels, supplemented by local task lighting, required for direct computer-related tasks, and the secondary lighting systems required for people occupying the same space performing paper-based work. Thus, the mainframe centers must be placed in locations in the building that allow for efficient cabling and access and at the same time minimize the effect of acoustic noise, traffic, heat generation, and cabling on the remainder of the building. Because of the high cost of fitting up these data centers, it may be cost-effective to have minicomputers, controllers, and joint peripherals (output devices such as printers, etc.) share space rather than fitting up additional equipment rooms to house them elsewhere in the building. Alternatively, mainframe centers are sometimes located in more remote but less expensive and less sensitive locations outside the building and connected to the building via optic fiber, telephone, satellite, or copper land lines capable of providing the high transmission speeds that are required.

Minicomputers, while significantly smaller than mainframes, share many of the environmental requirements and drawbacks. They require significant amounts of electric power, generate heat and noise, are sensitive to dust, require security and fire suppression, and have extensive cable management needs. If, in facilitating shared access, they are placed unenclosed in the open office environment significant adverse impacts are likely on the equipment longevity and on the physical and mental state of the people nearby. If minicomputers are housed in spaces intended as telephone or power closets or janitorial closets, contamination is possible, resulting from interference from power transformers and water pipes in those closets. Inadequate space and cramped access for changing or adding cables, risk of water damage, and a chaos of cabling (not the familiar thin wiring) are other potential problems. Indeed, the concept of closets in the core is inadequate for the electronically enhanced office building.

One common use of super minicomputers today is to power a cluster of CAD (computer-aided drafting or computer-aided design) workstations. The minicomputer itself should be enclosed at the very least in an "enhanced closet" with adequate space, independent electric power, appropriate cooling capacity, and adequate control of acoustic noise.

Central controllers are similar to minicomputers except for the user interface features permitting individual use. They are also less expensive. Controllers act as "traffic cops" between the mainframes and the microcomputers (or dumb terminals), distributing signals. They have similar requirements to the minicomputers in terms of space, electric power, heat and noise generation, sensitivity to dust, security, and fire suppression, and specific cabling requirements. Generally, controllers should not be more than 50 to 10 feet from the mainframes or more than 300 to 400 feet from the microcomputers or dumb terminals. This implies a strategic distribution of controller rooms (not enhanced closets) throughout the electronic office.

Finally, there are the microcomputers (e.g., personal computers and terminals with varying degrees of "intelligence") located throughout the building's working space and networked with one of several system configuration options (ring, bus, star, cluster). The first concern here is the distribution of electric power cables and signal cables to the individual units. Once cables are brought vertically to each floor of the building, a limited number of design choices are available for horizontal cable distribution: raised floors, cellular decks, poke-throughs (from plenums below), power poles (from plenums above), "draping and taping," flat wire, and strategically located repetitive enhanced closets. The actual choices available are entirely dependent on the building's geometry and interior systems. Ultimately, the power, data, and voice cables must be "managed" by the workstation, making design of the workstation as critical as the horizontal distribution paths. Cable management is often inadequate in even the best of electronic workstations, typically underestimating cable size; separation needed between power, data, and voice cables; and cable turning radii, distribution, and trunking.

Generally speaking, there is more flexibility with regard to the selection and integration of microcomputers into any existing or designed setting. However, there are some requirements that, if not met, might make their integration expensive or inadvisable. Given the number and the extent of networking of microcomputers in the electronic office, adequacy and reliability of power are critical. The specification, condition, and orientation of the exterior enclosure can be critical. It may be very expensive to upgrade existing wall and windows to ensure rain and condensation protection (often requiring double glazing), adequate thermal and humidity control, adequate daylighting control, and adequate draft control (affecting thermal comfort, pollution, dust, and noise isolation). Existing workstation furniture is also a critical factor with regard to adequacy of the worksurface area, storage space, cable management, acoustic absorption, lighting control, and mean radiant balance necessary for the individuals working with microcomputers, and terminals must be positioned to reduce window glare. Clearly, the organizational layout, the workgroup layout, and the workstation layout can help to resolve or aggravate these problems of adequate worksurface, storage, cable management, acoustic isolation, and lighting control.

Peripherals

There are three general categories of peripheral equipment: input devices for receiving data, voice, video, graphics, and data from environmental sensors; processors for reading, processing, computing, filing, storing, or transferring this input; and output devices such as printers, plotters, projectors, speakers, tapes, disks, and commands to action (robotics). There is also a fourth possible category, combining these three sets of hardware into dedicated packages of hardware for specific services such as electronic mail, video teleconferencing, electronic data bases, and building security. The physical and environmental requirements for these devices depend on the type and density of hardware chosen, as well as the corporate policy towards worker comfort and productivity.

The peripheral equipment available for inputting information in the electronic office includes tactile and optical input devices such as keyboards, keypads, mouses, light pens, joy sticks, touch (screen) readers, digitizers, scanners (such as bar code readers), and copiers; sound inputs such as telephones, pagers, voice recognizers, and music readers; data inputs such as clocks, card readers, tape readers, and optical disk readers; visual or luminous inputs such as video cameras and 3-D laser cameras; and environmental detectors that sense temperature, humidity, light, sound, and smoke. For many of the tactile and visual information input devices, appropriate illumination (task and ambient light levels, color rendition, and contrast) and appropriate spatial quality (ergonomic, anthropocentric) are essential both for the equipment and for the workers. Dust and static control is very important along with some concern about noise (clicks, beeps, whirs) in the inputting process. For the sound inputs, noise is the most critical environmental concern for the effectiveness of both the reader hardware and the worker, and control of the sound source intensity, background noise, and sound paths (isolation for adjacent workstations) is essential. For the data inputs, dust and static control and the overall integrity (maintenance) of the physical and environmental setting becomes most important. Finally, the environmental inputs are critically dependent on appropriate spatial zoning, on interfering visual, acoustic, or thermal information, and again on the overall integrity of the physical setting.

Peripheral equipment used for reading, computing, filing, storing and transferring the various inputs starts with disk drives, modems, multiplexers, and controllers. Then there are major data readers and storers such as central card, tape, and disk drives and storers; magnetic, optical, and laser readers and storers; and bubble memories. There are also telephone processors for automatic call sequencing and distribution, and private automatic branch exchanges for offices depending on telephone input and output such as travel, insurance, and investment companies. The smallest disk drives and modems may easily fit on or in a typical workstation, but the larger processors, seen more and more frequently today, can occupy as much as 2,000 cubic feet. The result is that space, both in terms of capacity and location, is one of the most demanding requirements for the effective introduction of most processing hardware. Other significant requirements include adequate and reliable power, plenum space (horizontal and vertical) for cables, adequate air conditioning to offset the heat output of the equipment; adequate sound absorption and noise isolation to protect the occupants from the noise of the equipment, and adequate security and protective enclosures to protect the equipment from dust, static, abuse, and vandalism. It is also important to ensure adequate thermal quality for the occupants, balancing the uncomfortable mean radiant temperatures that often result from processor power demands.

There are many kinds of peripheral devices available for outputting information in the electronic office, depending on whether a temporary working medium or hard copy, sound, video, or mechanical action is to be the result. Output hardware that serves only as a working medium (without hard copy) includes the full range of computer screens (e.g., VCR, CRT, LCD, plasma, or electron gas)--a technology with great potential for change in the near future in terms of the size of the equipment, its position in the workstation, the illumination required, and the kind of input it accepts. Hard copy outputs include printers (impact carbon printers, non-impact jet or heat printers, laser printers, and photo printers); analog and digital plotters (ink, ammonia, laser, electrostatic); and such hard copy as disks, tapes, or chips. Sound outputs include telephones, intercoms, pagers, and bells. Video outputs include 2-D projectors, light beams, and holographs. Finally, output may take the form of an electronic command triggering a mechanical action, and this kind of output is the basis for computer-aided manufacturing (robotics) and computer-aided facility management (e.g., environmental control).

The most significant concerns for all varieties of output hardware are the adequacy of space in terms of capacity, configuration, and location (centralized, decentralized); the availability of adequate electric power; the adequacy of horizontal and vertical plenum space for cable management; the adequacy of acoustic control for isolating the equipment's noise from the occupants; and the adequacy of air conditioning for offsetting the heat load from the equipment. Other significant concerns center around the readability or audibility of the output, which requires controlled lighting (task, ambient, and daylight) and controlled acoustics (sound source intensities, background noise, and sound path control). These requirements depend on the design and specification of the ceiling, partitioning, and flooring systems, the lighting and acoustical systems, the interior furniture, and the building enclosure. Some of the peripheral output devices available today also raise serious air quality concerns, requiring increased levels of fresh air and adequate fresh air distribution and control, especially if this equipment is enclosed for acoustical reasons. Finally, it is important to provide physical and visual diversity and relief for workers tied for long hours to these "output devices" in the form of windows (however, located to avoid glare), lighting diversity and control, lounges, or more and varied social settings. Such social spaces will range from spaces for two people to discuss their work, to coffee break/lunch areas, to work group conference areas, to major conference rooms. There is also a greater need for personalization, within each person's workspace, as well as for the work group.

The fourth category of peripheral equipment consists of combinations of the first three into dedicated packages that perform specific functions. Electronic mail, video teleconferencing, electronic data bases, and building security are the most common peripheral packages today. The simplest service, an electronic mail system, might connect a personal computer with a keyboard or facsimile input through a modem or controller to a telephone receiver connected to another computer or to a printer. Data base services such as "Balor," "Dialogue," "Lexus" (a legal data base) or "BCS" often require dedicated circuits, controllers (in closets), and coaxial cabling, in addition to the computer terminals and modems. Some electronic data services require antennas, small microwave dishes, and special telephone switching devices. These requirements make access to the roof and to the vertical plenum space essential, along with access to the basement telephone switching center.

The most complex package of peripherals is the video teleconferencing center, which has massive cabling requirements in order to connect such input devices as voice activated cameras, telephones, microphones, audio and video scanners, electronic blackboards, copy machines, keyboards, and plotters to such processors as signal control units that convert the data from analog to digital form, to a telephone center, thence through an antenna to a satellite receiver, ultimately terminating at output devices such as screens, speakers, plotters, and printers. The architecture of the video teleconferencing room is dependent on such conditions as adequacy of room space, horizontal and vertical plenum space, and roof and basement access. It is also essential to have effective thermal, air quality, acoustic, and lighting design and control, well beyond any conventional conference room.

Apart from the teleconferencing center, there may be other special function rooms that contain concentrations of peripheral equipment.

Reproduction centers may contain printers, photocopying machines, and related equipment such as computerized photo-offset printers. Information centers may contain a variety of terminals, printers, microfilm and microfiche readers, etc. Training centers may contain all the kinds of equipment that are used in the organization. Network control centers may contain computer and communication controls and equipment that is used to report the status of the building's electronic systems and to diagnose and correct system failures.

Telephone Systems

Whereas many of us are still accustomed to thinking in terms of a single type of telephone service provided by a telephone company, there are a variety of kinds of telephone systems available today with considerable diversity in size, features, intelligence, and complexity. These systems are offered by a variety of manufacturers and vendors, and it is by no means easy to determine which type of system is appropriate for a particular organization. As a general rule, the occupants of a building will select their telephone systems and there may well be a number of different systems serving a single building. Although the systems differ, the building attributes they require are quite similar.

The most common types of telephone systems available today are central exchange (Centrex) systems, private branch exchange (PBX) systems, and key systems. (See descriptions in Chapter 2 for more detail on these systems.)

If it is to be hospitable to a variety of telephone systems, a building must provide the necessary enclosed space (in risers, closets, conduits, wire ducts, sleeves, c-decking, or provisions for poke-through wiring) to permit the necessary vertical and horizontal distribution of telephone cables. It must have a heating and cooling system capable of maintaining the necessary ventilation and air quality in battery rooms, switching rooms, and all other building locations in which the telephone equipment has special environmental requirements. It must have an electric power system capable of meeting the telephone system's power needs with adequate grounding, voltage protection, and backup (or uninterruptible) power. Generally speaking, these requirements are common to all three major systems, although the details may differ for particular systems in specific buildings.

The manner in which building characteristics impact the telephone system or systems within the building should be considered as they apply particularly to the telephone switch room and to the telephone distribution system. The most important building requirements relative to telephone switch rooms involve the location of the system within the complex, the environmental treatment of the room and the adequacy of electrical services. The factors that involve the distribution system concern the capacity and geography of the riser closets and the availability of properly designed horizontal wire distribution plans to support changing space utilization schemes. Obviously the issues indicated are not all inclusive design considerations for telephone and other communication systems within a building, but rather reflect only those features considered most significant.

The proper placement of the telephone switch room within the building is important from both an economic and an operational view. Although the placement of a switch room for a single-tenant building may be different from that for a multi-tenant building, the general characteristics are the same. A properly planned switch room should be adjacent to or a part of the vertical riser system of the building. The placement should also provide access to the external system with ready access to such facilities in adjacent spaces being optimum. Proximity of the switch room to the data processing center may also be important when either the twisted wire plant or the PBX is used for data transmission.

The switch room must be placed in a dry area of the building and not subject to flooding due to natural causes or utility failures. All of these considerations, as well as structural considerations, point toward selectively locating the switch room in or near the core of the building, at or above ground level.

The environmental treatment required to support most switching systems is not stringent, but requires attention. The operating range for most telephone switching systems allows variations from 55 degrees to 85 degrees Fahrenheit; however, degraded operations can be expected above 90 degrees. Similarly, the relative humidity range is generally extended over a range from 20 to 60 percent relative humidity, with 50 percent being optimum.

Temperature control is often a significant consideration when power failures are experienced and backup battery and/or generator power is only provided for the switching and other technical equipment. The air-conditioning system supporting telephone operations should be available 24 hours per day, seven days per week. Special provisions are necessary in buildings using chilled water or similar arrangements which normally operate only during the business day.

Although battery systems supporting telephone systems also do not have stringent temperature requirements, ventilation of the battery room is often necessary to meet local code requirements. These requirements may also apply to "sealed" battery systems depending again on local code requirements.

The availability of properly designed electrical services is very important to a properly operating telephone system within the modern building. Such electrical services must be dedicated back to the main distribution point within the building or otherwise isolated to insure that other electrical loads do not impact the operation of the telephone system. The proper sizing of the electrical service based on the maximum load of a fully expanded telephone system and the manufacturer's specification is necessary to support continued operations even in a growth situation. Separation of the technical and utility load in the switch room is also important. Motors, lighting systems, and compressors in the room often can induce noise into systems or cause other undesirable occurrences.

Similarly, the provision of a properly sized and terminated earth ground is very important to the telephone system. Normally, manufacturers require that the signal ground be dedicated to the switching system. This normally involves taking a large conductor back to the building or floor transformer location, the building ground point, or to the building's structural steel. The electrical ground is normally used to satisfy the other grounding requirements in the room.

The availability of an alternative power source within the building is also important to a survivable telephone system. A backup battery system will economically provide power for the telephone system during relatively short commercial interruptions, but does not normally have the capacity to support lighting and HVAC requirements. During extended commercial outages, the telephone system may become erratic or disable itself due to high temperature conditions even though the battery system has not been expended.

Riser closets are required on each floor in the same relative position vertically within the building. This stacked arrangement with the proper floor penetrations allows the installation of heavy cables in a timely and cost-effective manner. The area provided for the riser system should be dedicated for voice and data communication purposes only. This is necessary to ensure that proper security is afforded these services and to avoid interruption of telephone service due to some inadvertent action by building or electrical maintenance personnel.

The conduits and the floor and wall space within the riser system require detailed management due to the multiple users now using these facilities. The allocation of the conduits and space should be considered during design and followed carefully by management. Wall space must also be allocated and controlled since multiple voice and data providers require equipment and wire terminal space near user locations on each floor. Many building designs now provide separate space for voice and data wires in the riser and in some cases have segregated the spaces of the local availability from that of other providers.

The proliferation of telephone, data and other communications with the office environment requires extensive wire distribution schemes. The distribution arrangement must have the flexibility to support evolutionary changes in the technology similar to what has been experienced in the recent past. The availability of a properly designed in-floor or in-ceiling distribution system with distributed cross-connect and test points provides the flexibility necessary to meet the changing arrangements of the office spaces. When adequate distribution facilities are not provided, the cost and time required to support change can be extensive. In any case, the wire distribution must be continuously managed to insure that abandoned wire and cable is routinely removed and that wire and blocks are tagged and labeled properly.

AUTOMATED SENSORS AND CONTROLS FOR BUILDING OPERATIONS

It is increasingly common for office buildings to be equipped with automated electronic controls for mechanical systems such as heating, ventilating, and air conditioning. As the amount of electronic technology in buildings grows, additional systems tend to be provided with automated controls. Examples are halon fire suppression systems, electric power usage monitoring and billing systems, and systems for controlling communication system access and billing, lighting, elevators, security, building access, data access, employee working time, employee credit and financial management, and personnel management. For many of these systems, access and use must be limited to authorized personnel, so control system security and traffic management often become necessary. Since these control systems are likely to be operated by a variety of individuals, it is essential that the system software be user-friendly and that the personnel operating them be adequately computer-literate.

The automated controls that are available today for managing and operating building environmental systems are known as direct digital controls. The primary difference between conventional controls and direct digital controls is that the former use independent pneumatic or electric activation while the latter use a low-tension data highway, usually in the form of a twisted pair of wires, to transmit data from a sensor to a microprocessor-based controller which activates a valve or damper to produce the desired change. This means that a building in which automated controls are to be used must contain the necessary cabling to serve both sensors and control mechanisms, and that there must be one or more control centers in which the monitoring, troubleshooting, diagnosis, adjustment, and control of system operations can be carried out.

Similar requirements pertain to other building systems and services. Fire and security systems incorporate sensors, alarms, and automated responses. Electric power usage systems require continuous monitoring, recording, and signalling of unusual use patterns. Lighting systems require monitoring of both natural and artificial illumination, sensing of human occupancy, and the necessary controls and adjustments. Employee service and financial systems require a variety of automatic recording and data logging systems. All of these have their own requirements for cable and for control centers.

We will first consider controls for the building systems that pertain to the indoor environment--heating, ventilating, air conditioning, air quality, and lighting. We will then turn briefly to such supplemental building systems as electric power usage monitoring, fire suppression, and security.

Assuring a satisfactory indoor environment involves not only heating, ventilating, and air-conditioning (HVAC) but also air quality and illumination. While this is true for all buildings, an electronically enhanced office has some unique requirements. For each of these environmental control systems, a choice must be made between building-wide (or zone-wide) control and local control, and between central or programmed control and individual occupant control. Whatever choice is made, the system must be capable of either continuously measuring a particular attribute or detecting a threshold point and responding to that measurement.

In a traditional office setting, workers spent as much as 35 percent of their time on the move, delivering documents, copying documents, in group discussions, or on coffee breaks. Upper management spent as much as 70 percent of its time away from desks, in meetings and in the field. This minimized the length of time any individual spent under the air diffusers and lights over their desk, in contact with a cold floor or sun-broiled window, enveloped by non-muted office noise or completely removed from daylight and view. The electronic workstation, however, has changed the allocation of time at the desk and away, to such an extent that the environmental conditions, once tolerable, are no longer so. This dissatisfaction is further aggravated by the equipment itself, with its heat and noise generation, and its sensitivity to light reflection. The result is a far greater need for locally or individually controlled environmental conditions--individual input into the control of lights, heat, air, noise as well as access to and control of windows (contact with a "healthy" environment). This in turn requires a greater investment into the initial mechanical system.

Heating, Ventilating, and Air Conditioning

In the past, office environments were relatively uniform, except for the climatic factors that beat on the facades. Buildings could be simply zoned for north, south, east, and west, with core loading and straightforward mechanical "trades" laid out. Today, however, without coordination of individual space planning in each office, the differential loading can occur a dozen times on each floor, not to mention from floor to floor, requiring a drastically different (and flexible) mechanical network for infinite zoning, and major increases in local control technologies. As with the cable network, the HVAC network in such offices can be infinitely flexible (and expensive), or it can be modularized and coordinated with the space planning of the office in the conceptual design stages.

Electronic equipment generates heat, and electronically enhanced buildings require more cooling capacity than conventional buildings in order to offset this. Moreover, the heat generated by electronic equipment is not likely to be uniformly distributed within the building, and the location of "hot spots" may change with time as new electronic equipment is added and as office layouts are reconfigured. Therefore an electronically enhanced office building needs not only more cooling capacity than a conventional building, but a cooling system of sufficient flexibility to accommodate change and reconfiguration.

Electronically enhanced office buildings are also, because of their extensive use of electronics, prime candidates for automated control of their heating and cooling systems. The use of automated controls can enhance the building's ability to cope with variations in heating and cooling demand associated with variations in the distribution and use of electronic equipment. New installations in conventional buildings often use central energy management and control systems, some with direct digital control for air-handling units. Central control systems without energy management are also common.

The air distribution systems used today in conventional buildings do not lend themselves to ready change as workstation heat loads or their locations change. Instead, individual closed-loop unitary heatpump systems are installed, and fan coil units equipped with heating and cooling coils are used. Neither of these systems provides any humidification. Moving them or adding new ones at dispersed locations involves new condensate drains, electric power (especially where heat pumps are used), new duct installations, and new controls.

Induction systems for office conditioning are supplied with air and hot or cold water; they can heat and cool simultaneously. They can also offer central humidification. In high-rise buildings these systems are usually controlled by the outside air temperature, with two zones (north and east, south and west) operating in either a heating or cooling condition with no provision for humidity control. Supplemental air conditioning is frequently provided by air-cooled direct-expansion units located in the ceiling plenum. In the rehabilitation of existing buildings these air-conditioning units frequently are not exhausted or supplied directly to or from the exterior. This results in heat build-up in the plenum and work space. This type of retrofit does not provide additional ventilation for the occupants. In addition conventional systems include terminal reheat systems, which are energy-intensive, and dual-duct systems, which require large quantities of space for ducts and are also energy-intensive.

Air ducts are located under raised floors or in ceiling plenums. Locating the cable under a raised floor separate from the return air plenum and supply ductwork can be a cost-saver. This reduces the quantity of expensive Teflon-coated wiring required and is applicable to raised floors of less than 6 inches. On the other hand, design to accommodate both ductwork and cabling under a raised floor allows central computer equipment to be cooled directly (applicable to raised floors of over 6 inches to 1 foot). Access and relocation are easier than with a ceiling plenum.

Supply air and return air, under a raised floor, can be distributed relatively easily to individual workstations and the distribution paths can be modified easily as heat loads become greater and their locations change. All ventilation air can be supplied centrally in the floor. Individual zones can be controlled by variable air flow boxes, mixing dampers, or fan coils connected to the central outdoor air supply through the plenum.

In the past, buildings were often designed with high ceilings, sometimes with exposed construction, hung ceilings with higher floor-to-floor heights, and limited vertical chase area. Modern practice can provide raised floors from 5 to 12 inches high that accommodate air-conditioning supply or return as well as power and communications cable. These can then eliminate the hung ceiling and reduce the floor-to-floor height. Raised floors require less space than hung ceilings that must be installed with clearance below the structural beams. In new buildings the reduced building height may save more in construction cost than the additional cost of the raised floor. When doing a life-cycle cost analysis with raised floors, the possible savings in first cost in the installation of duct work and wiring with the raised floor (it costs less to work on the subfloor than from ladders and scaffolding) and the savings in future installation costs for mechanical and electrical systems to accommodate change should be taken into consideration.

New Technical Developments

Among the new technical developments applicable to HVAC systems for electronically enhanced office buildings are the following:

Variable-air volume (VAV) supplies can be provided at each open-plan workstation. The supply quantity can be controlled by a thermostat located at the occupant's workstation. The advantages of such a system include better distribution to each workstation, localized control according to occupant needs, adaptability for relocation or reorganization of space, and reduced energy use during off-peak periods.

Air can be centrally filtered and individual fine-tuning can be provided at the workstation, under the control of the occupant. Central system controls can include chilled-water temperature control and condenser-water temperature control to vary the supply according to load. Minicondensing units can be added to existing floors as loads change to provide localized cooling and dehumidification. Most existing air-conditioning systems, including dual-duct, terminal reheat systems, constant-volume, variable-temperature models, and multi-zone units, can be converted to VAV systems to meet zone temperature requirements and conserve energy. Because electronically enhanced buildings have greater heat loads than conventional buildings, it is important to conserve energy in all systems to compensate for these loads. Cooling storage using ice or chilled water can be a peak-demand saver. Latent heat storage systems are emerging that will reduce the cooling storage bin volume and costs.

Heat recovery from lighting, mechanical equipment, computers, and occupants can be provided through a variety of systems, including heat pumps (water-source, central, or closed-loop), air-to-air energy recovery units, refrigerant-to-water heat-recovery systems, compressor heat recovery, and heat-reclaim chillers. The application of heat-recovery equipment has increased with the increased heat loads of computerized facilities. The use of thermal storage systems is increasingly feasible for a building complex that requires year-round air conditioning for its equipment. Generating chilled water at off-peak hours offers additional reliability for high-technology buildings as it reduces the risk of brown-out and takes advantage of lower off-peak rates.

The growing use of electronic equipment will increase the need for humidification. Many buildings do not provide winter humidification. Those buildings that do frequently use steam pans, steam injection, spray, or air atomizing. These systems are generally incorporated into the air-handling unit. In some special applications, unitary humidifiers are installed. Condensation occurs on single- and even double-glazed windows. New capabilities include sensors to detect humidification levels and signal the humidifier to provide more or less moisture; triple and quadruple glazing to eliminate condensation on windows; glazing coatings that raise the glazing temperature to prevent condensation; unitary humidifiers that operate by compressed air to eliminate algae growth and other biological problems; and ultrasonic humidifiers that do not create conditions for algae growth or bacteria production.

Direct digital control (DDC) for air-handling units is cost-effective, saves energy, and responds quickly. DDC for individual terminal equipment is emerging but is more costly at present. DDC can be used to control building systems with computerized management systems, providing quick response. This allows computer rooms and areas that require off-hours cooling to be conditioned as required without cooling general office areas. Use of modular chiller equipment with building controls allows the building to operate efficiently and to provide a variety of environmental conditions, including selective temperature control, humidification, dehumidification, and air filtration for people and equipment.

It is also possible to utilize co-generation based on balanced thermal and electrical loads in buildings. These systems require a steady year-round demand for electric power and thermal energy. The systems, which generate electricity at a building site, capture the waste heat for space and water heating and absorption cooling, but may not be as reliable or offer the same "quality" of power.

Air Quality

Problems with air quality have always existed, but they have become more pronounced in recent years. Outgassing from particle board and synthetic materials yields formaldehyde and other contaminants. The addition of electronics in workstations can lead to increased levels of contamination from insulation outgassing. The situation has been further aggravated as the use of outdoor air for ventilation has been reduced and buildings have been made tighter to reduce infiltration and conserve energy.

New technical capabilities for controlling air quality include decreasing pollutants at the source by understanding the nature of materials and carefully specifying materials that do not outgas; monitoring air conditioning before occupancy and before issuing occupancy certificates; installing sensing and monitoring equipment that will detect the type and quantity of contaminants and toxic gases and operate the outdoor air dampers to increase outdoor air quantity as required for dilution; and installing induction or power units at the outlet of the VAV box to maintain constant air delivery to the space, and therefore constant air pattern, regardless of thermal requirements.

VAV systems are controlled by sensing thermal conditions only, so that in the cooling cycle, for instance, the mixing dampers modulate to a 75 to 90 percent closed condition as the space cooling requirements are reduced and less air is supplied to the space. The amount of outdoor air is also proportionately reduced, and the air distribution pattern designed for full air delivery is changed so that short-circuiting can occur between supply diffuser and return grille. Less, or no, air is circulated at the occupant level in the workstations, and,thus, contaminants are not diluted and not flushed out of the building.

It is now possible to maintain constant outdoor-air ventilation quantity in a VAV system. As the variable air volume supply fan is modulated to circulate less total air, the variable outdoor air intake damper is modulated open to maintain the basic outdoor air quantity to the system. Thus, the two potential problems of a VAV system can be overcome: fan-powered VAV boxes to maintain constant air distribution in the occupied space and automatic increase of outside air to compensate for reduced total air flow.

Illumination and Daylight Control

Long hours of word processing on a microcomputer, or short hours doing fine graphic work on a CAD/CAE workstation will quickly emphasize the inadequacy of conventional task-ambient lighting systems and conventional window controls for daylighting. The reflection of bands of ceiling light fixtures or windows is as much a problem as the high contrast ratios created by uncontrolled expanses of lighting and daylighting and the images on the screen of a CRT. The solution goes beyond the simple specification of an appropriate task and ambient lighting system, to the rethinking of enclosure design in relation to interior spaces (or vice versa). Each of the daylight innovations, light shelves, top lighting, side lighting, splayed windows, and daylight diffusers or blinds must be considered in relation to the design of the artificial lighting system, for task or for ambient lighting needs. Careful attention needs to be paid to window sizing and configuration, and their relationship to interior lighting grids.

Electric lighting in the past was generally a uniform pattern of fluorescent fixtures--recessed, surface-mounted, or pendant-hung--with limited controls. New emphasis has been placed on the optimization of daylight and the control of electric light in the office environment. The use of light shelves and glare free skylights is evidence of this trend. Sophisticated photosensitive switching and dimming systems lower electric lighting levels to take advantage of available daylight. Other automatic lumen maintenance controls allow for the tuning of electric lighting systems for particular task needs. Lumen maintenance controls respond to the changes in lumen output of a lighting system that occur as lamps and luminaires age. Automatic occupancy sensors can turn lights off in unoccupied areas. The thoughtful integration of these automatic lighting control strategies is an important step in the design of enhanced working spaces.

Task-ambient lighting systems are a response to the prevalence of electronic equipment in the office environment. Low ambient lighting, often provided by floor, furniture or ceiling mounted indirect fixtures, or brightness direct parabolic louvered luminaires, is sensitive to the needs of VDT users. Individually controlled task lights integrated into workstations allow for increased light levels needed for reading printed materials.

Acoustic Requirements

If the noise in the traditional office was bad, electronic offices can be unbearable without a major reconsideration of acoustic quality. The keyboards, disk drives, printers, and mainframes each contribute to distracting and high pitch noise levels. The new office environment requires that accessible rooms for shared services which are acoustically treated be dotted around the floor plan. Peripherals such as dot-matrix printers that are to be located with individuals have to be accompanied by acoustic covers or acoustic surrounds for the workstation. Floor, ceiling, and wall surfaces as well as window controls have to be selected to diminish sound reflection within the spaces and transmission between spaces. Vibration must be handled, especially from large mainframe computers and printers. The noise and vibration specifications of each piece of electronic equipment must be known, along with translations by the technology manager as to its design significance.

Monitoring of Electric Power Usage

The method of metering electricity in any building depends on local power company rules and on the rate structure. A tenant occupying several floors in an electronically enhanced building may wish to monitor the usage on each floor. Meters can be installed at the takeoff from the electric power riser at each floor. If demand charges decline with increasing demand, metering each floor is a disadvantage because the larger, aggregate demand measured by a master meter may call for a lower rate. Similarly, time-of-day rates, which are coming into widespread use for large customers, would also favor the use of a master meter. If information on specific area consumption is desired, check meters could be installed downstream of the master meter without affecting the rate charged.

Common building services, such as central refrigeration, central air conditioning, fans, cooling towers, public area lighting, and power for elevators are metered and billed to the building owner. The proportion of this cost charged to each tenant must be clearly established in the lease.

Fire Suppression Systems

General office spaces in electronically enhanced buildings should be equipped with sprinkler systems in the same manner as conventional office spaces in accordance with local codes and insurance carrier requirements.

Computer rooms and magnetic tape storage rooms should be protected by preaction sprinkler systems using two-position heads activated only by intense heat in order to minimize water damage. These are hybrid systems that remain dry until a valve is opened in response to a fire detection sensor.

Raised floors should be protected with halon systems (Halon 1301 is a gas twice as heavy as air and is capable of seeping through cracks inaccessible to water). Halon systems can extinguish fires under raised floors quickly with little damage.

Entire computer rooms can be protected with halon systems but it is essential to evacuate the room before the system is activated. The amount of halon required to protect an entire computer room makes this a costly option. An exhaust fan must be used to vent the halon from the room after discharge.

Security Systems

Two types of security are important in electronically enhanced buildings--physical security and information security.

Physical security can be provided by barriers, gates, mantraps, and intrusion prevention systems. Access to areas within a building can be controlled by locks, card access devices, closed circuit television, watch tour stations, and motion detectors. The extent of security provided will depend on the type of operation being conducted and the philosophy of the facility operator.

Information security can be provided through communication scrambling devices, secure telephone systems, nonradiating cable systems, and cryptographic devices.

Building security services package a variety of environmental sensors (that detect sound, motion, light, or time) with mini- or microcomputers as processors, and with data, sound, light, or action command output devices, either through an extensive cabling network or through wireless (radio) communications.

TAKING FUTURE CHANGE INTO ACCOUNT

When planning a building that is likely to have a useful life of many years, it is reasonable to anticipate a succession of users or occupants moving through the facility during that period. Each succeeding "generation" of users will have a new purpose and make new demands on the building. Even a static building population will continually seek to make more effective use of the space and to acquire furnishings, fixtures, and equipment that offer higher performance and make a greater contribution to individual productivity and organizational effectiveness. In addition, throughout the life of the building there will be new technological developments, new approaches to the organization of work, and changes in the economic climate.

The project administrator working in this environment must determine three things: (1) how much and what kinds of capacities are likely to be needed in the future; (2) when those needs will occur; and (3) where in the building they will be needed. The location factor is already of concern. One major corporation has reported that in a recent year, 50 percent of the office workers at one location were relocated within the building at least once. This "churn rate" is not excessively larger than industry-wide estimates. To a great extent, the strategic planner must choose to spend resources for a higher level of service or greater capacity now or to postpone them. In other words, an organization must decide whether to expend resources now in anticipation of an as-yet nonexistent need, or to defer expenditures, when it is likely to cost more.

If unused capacity, in the form of oversized plenums, ducts, risers, etc., is installed too soon, then two kinds of costs are incurred: (1) other, more urgent expenditures may be postponed and (2) the unused capacities must be maintained. Alternatively, these capacities may be increased after the building is in service, with the attendant disruption. These factors relate to the costs of flexibility, and the strategic planner should choose the least-cost alternative over the facility's life cycle. The alternatives--capacity now, capacity later--must be expressed in terms of their (discounted) present value. But calculations of this sort may be misleading if they are based on an assumption of uniform level of service or performance now or in the future. What is likely to occur, given the recent history of electronics and telecommunications, is a continued increase in levels of service, including greater computational capacity, greater speeds, and more stable, reliable performance. Although this suggests that there is little advantage in being overly precise about the exact nature of the emerging technologies, it does not imply that technical judgments should be deferred. Rather, choices must be made as to the degree of flexibility or adaptability to be incorporated in the design.

These terms--flexibility and adaptability--are not synonymous but are closely related. They may be distinguished as shown in Table 1. An electronically enhanced building may provide adaptability or flexibility or even a little of each, depending on the strategic course adopted.

TABLE 1 Characteristics of Flexibility and Adaptability

Quality or Attribute	Flexibility	Adaptability
Definition	Provides a uniform level of service at multiple points	Provides a capability to accommodate change
Technological locus	In the mechanical service	In the structure or enclosure system
Relation to space	Subdivides a fixed magnitude	Extends, possibly irregularly
Relation to time	Anticipates, proacts	Accommodates, reacts
Expenditure of resources	Now	Later, on demand
Level of service	Uniform	Point-specific variation
Aesthetic form	Regular or periodic modularity	Free-form; amorphous
Scale of change	Smaller, incremental, early obsolescence, initial expense for services that may or may not ever be required, assumes an upper limit, not easily changed	Larger, chunkier, takes advantage of changed technology, expense for defined requirements only as they occur, can accommodate whatever is required in the future
Disruption	Less if no new services are added	More
Volumetric needs	Can be done in less space, but space is highly engineered and surfaces finished	More extensive in space use, but spaces required are not expensive because of fewer environmental requirements
Maintenance	High	Lower
Foresight needed	More	Less
Optimal tenant "size"	Suited for larger number of smaller tenants	Suited for smaller number of larger tenants

4

THE PROCESS OF ACQUIRING AN ELECTRONICALLY ENHANCED BUILDING

BACKGROUND

Elevators became important in office buildings toward the end of the last century, but architects had not yet acquired sufficient knowledge of their technology to incorporate them in their working drawings. As a result, office buildings were designed in the traditional way without any reference to the use of elevators, and specialty contractors were brought in by the owner once the buildings were constructed to design and install the elevator(s). Obviously this was more costly for the owner, ignored the need to design the building's spaces and structure to reflect the use of elevators, and added loads to the electrical system (which was still primitive itself) and raised questions of fire safety. Similarly, the modern office building is often designed without a real recognition of eventual electronic enhancements. Many architects are still not knowledgeable enough to incorporate these systems in their original designs, and most electronic enhancements are added by specialty contractors after the building is done.

When the project's mission statement has identified the decision to incorporate advanced electronic technology into a new building the acquisition process is straightforward if untraditional. Rather than proceeding in the usual way--designing the structure and its exterior first and the interior afterward--the entire building should, to the extent possible, be designed as an integrated system. It is necessary to define, as completely as possible, the activities likely to be carried out in the building and to identify the degree of flexibility and adaptability likely to be needed to modify those activities in response to changes in the business world and changes in technology. Then decisions can be made concerning the occupant requirements that will define the basic building systems--requirements for electric power, interior environmental control, communications, security, safety, and various organization-specific issues. These requirements will lead to criteria that the building design must satisfy.

To do this requires anticipating the activities to be carried out in the building to a degree not normally practiced, and to do so at an earlier stage in the process. It requires bringing together a multidisciplinary team of experts. It is this assemblage of expertise, and the integrated, iterative process of designing the building's structure and infrastructure that it implies, that represents a break with tradition. Involvement of in-house operating personnel and maintenance supervisors in review meetings during design and construction can provide an opportunity to foster quick and efficient repair later. Although this is not normally an element of professional design programming, it is an opportunity for the strategic planner to benefit from his maintenance staff's knowledge. In turn, an understanding by the maintenance crew of the reasons behind the building's design will enhance overall operations. For buildings in the public sector it may be necessary to remove organizational constraints to gaining wide participation by legislative action.

This approach will produce a coherent, integrated plan for use of the building's interior that takes into account the space requirements for wires and cables, the heat load from computerized workstations, and the need for adaptability and flexibility in the use of both technology and people. This plan will encompass such basic building systems as heating and air conditioning, electric power, illumination, and security. It will also include consideration of the suitability of the building and its site for microwave, satellite, and groundline signal propagation.

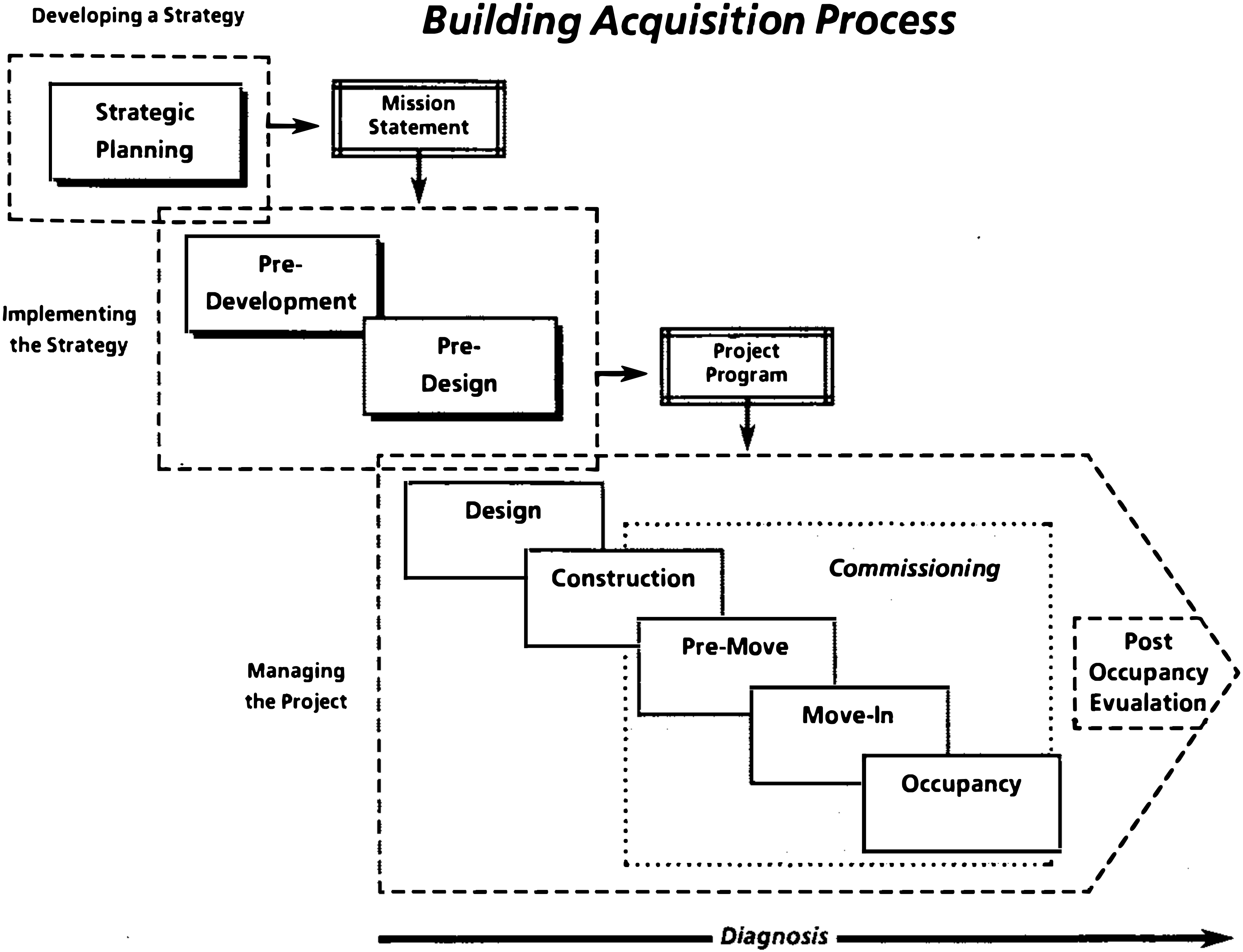
The technicalities of physically accommodating office automation are not unusually complicated. However, it is important to obtain the technical advice necessary with regard to telecommunications, office automation, building management and control, etc. It is also essential to orchestrate the proceedings of the team of experts to ensure timely completion of their activity to maintain the budget and schedule.

In addition to considering electronic enhancements in the design stage, the planning team must examine evolving changes in the organization of the work place and work force. These changes might include flex-time (which encourages sharing of offices and facilities), the changing ratio of professional employees to clerical staff, the spreading emphasis on health and day-care facilities in the workplace, and the emergence of team interfacing via personal computers at the workplace. This serves to emphasize the paramount importance of adaptability and flexibility in the building to accommodate changes in work, style, and structure.

The single most important requirement in the design of a new electronically enhanced building is that the right questions are asked, and the right expertise sought, at an early enough stage in the planning process. The project administrator should draw on whatever information and expertise is necessary at an appropriate and timely stage in the process. This will avoid the later discovery that a particular option has been ruled out, or rendered unduly expensive, by a decision made earlier without realizing its full implications. This same concern for timely solicitation of expertise exists at all later stages. However, it begins at the strategic planning stage, and requires an understanding of the entire building process.

The acquisition of a building is a continuous process. Breaking it up into stages is somewhat arbitrary, and there is no one best way to do this. For the purposes of this discussion of strategic planning, it is useful to think of the following distinct but overlapping stages:

Building Acquisition Process



THE EARLY STAGES

The traditional office had a forgiving list of needed, shared facilities, a coffee pot at the receptionist's desk or an office lounge with a kitchen, a copy machine in the hall or a print room, distributed file cabinets or a file/storage room. In addition, the functions and furnishings of these shared facilities were easily within the expertise of the architect. Today's electronically enhanced office buildings, however, are a completely different story. There are cable management rooms (6 feet by 8 feet), sometimes two to a floor--a far cry from the telephone closet panels in more traditional designs. There are now mainframe computer rooms to house the large, noisy, heat- generating equipment needing an expert technician for maintenance. There are shared minicomputeer, microcomputer and CAD/CAE spaces, where one-of-a-kind or expensive peripherals are housed. Finally, there are the innovative teleconferencing and video rooms, with very specific requirements for layout, cabling, heating, cooling and ventilating, lighting and acoustics. In the design of these advanced facilities a technology manager is needed for ensuring that such issues as appropriate location, organization, access, structure, environmental controls and interior finishes are adequately addressed.

In the building acquisition process, the strategic planning stage represents the first opportunity to think in an integrated way about all aspects of the building, from its location and aesthetic image to its floor plans and interior design. It is in these early stages that the importance of anticipating in detail the activities that will be carried out in the building and the demands they will make on the building and its equipment and services first becomes apparent .

The implementation of the strategic planning stage consists largely of an expansion, refinement, and detailed reconsideration of the strategic decision process and its resulting mission statement. The pre-development activities include attention to such external factors as: (1) laws, regulations, zoning codes, building codes, and union agreements; (2) investments, taxes, and real estate; (3) the commercial availability of technology, expertise, equipment, materials, and labor; and (4) the availability of capital. It also includes consideration of such internal factors as: (5) the organization's overall goals and long-term strategies; (6) the organization's image, culture, and traditions; (7) the organization's size, management structure, and operating style and the implications these have for its utilization of building space; (8) the organization's financial situation; (9) and the organization's leaders, employees, and customers or clients.

Against this background, the goals and constraints set forth in the mission statement are reexamined, and the organization's needs and the opportunities it faces are addressed. A broad set of options, encompassing such aspects as location, architectural character, and site planning, are identified. These options are assessed in terms of their cost, feasibility, contribution to the organization's mission, and corollary requirements. The latter include such features as the electronic infrastructure to be built in or prepared for, the ventilating and cooling capacity required, and the options for achieving energy efficiency. At this point it should be possible to produce a document containing preliminary design guidelines. This document might be an expanded version of the mission statement, setting forth a summary of the options and the assessment of each and defining the criteria that will guide the design process.

These initial design guidelines are examined for feasibility and consistency with overall corporate goals. They are then subjected to final review and formally adopted. They are used as a starting point for the pre-design process.

In the pre-design process, the design guidelines are developed further; more detailed requirements and criteria are written; and a complete set of requirements is developed. This stage, too, is carried out in several iterations, with the final program subject to extensive review before being adopted. The pre-design stage sometimes reassembles or reexamines information originally developed in the pre-development stage, always with the goal of specifying the information for a particular building project. It identifies how big the building should be, the groups to be located there, the technologies to be incorporated, and the design direction the building (or retrofit) will take.

The general procedure just outlined will be carried out for any project involving new construction or renovation. The important factor when advanced electronic technology is envisaged for the new or renovated facility is that consideration be given to: (1) the activities anticipated for the building, with emphasis on their electronic aspects (computers and communication systems); (2) the basic building systems that will be needed, with emphasis on automated electronic controls; and (3) the interdependencies between the two. This will be accomplished most effectively if the pre-development and pre-design processes receive the benefit of input from a multidisciplinary team of experts. Such a team might include, in addition to executives of the organization that will occupy the building, experts in project management, architecture and engineering design, construction, interior design, materials, ergonomics, organization and management, training, industrial and environmental psychology, health, safety, security, law, communications, computers, office automation, indoor air quality, lighting, building systems, wire management, and building operation and maintenance. These individuals may be in-house experts or consultants.

There are at least four different sets of concerns that do not apply to conventional buildings but that should be taken into account in developing the design requirements for an electronically enhanced building:

Infrastructure concerns deal with capacity and geometry of the vertical and horizontal distribution of wires and cables, whether the wiring and cable is all installed initially or some of it is deferred for future installation; heating, ventilating, and air conditioning systems; power and uninterrupted power supply issues; equipment space allocations; structural ability to support roof top antennae and other heavy support equipment; access to utility services for telephone, fiber optic cables, CATV cable, and other communication services; lighting; acoustics; floors and walls; fire safety; and security.

Management concerns involve the competition for space and for electronic resources within an organization; the selection of external providers of equipment and services; the maintenance and repair of equipment, and, in a multitenant building, the possible provision of common communication and computation services to tenants on a shared-use basis. Ideally, all of these will consider life-cycle costs. Management of the roof--i.e., determining the line-of-sight satellite access from the roof and managing installations to ensure there is no interference from one with another--has become a new concern of great importance to the communications requirements of building occupants.

Legal concerns include contractual matters, building code issues, and the complex regulatory issues surrounding telecommunications and shared tenant services in the wake of the AT&T divestiture. Questions regarding permits, building codes, and union agreements are common to all construction and renovation, but they can be more complex and sensitive where electronic enhancements are contemplated. Shared tenant service offerings must be cleared by the regulatory agencies (usually state public utility commissions) that have jurisdiction over a project. Such offerings must also be weighed with regard to the risks (including potential increased liability) to which they expose building owners and managers. Guarantees of indemnification by communications providers, and proper exculpatory language in tenant leases and contracts for the purchase of communications and other electronic services, are essential if the property developer's and owner's interests are to be protected.

Economic concerns have to do with the successful economic performance of the space for both the building owner and the tenant. What constitutes an improved economic return will be measured in hard and soft terms, and the value will be in great part subjective, depending on the value judgments of the individual participants. Such factors as first cost, life-cycle costs, base building costs, marketing costs, tenant improvement costs, and other traditional developer or tenant costs can be represented in a matrix or similar format that allows each party to appreciate the contribution that such values provide to their individual operations. Through this process, the developer can make informed decisions on the amounts and nature of pre-design costs to be developed, and the tenant can compare alternative space choices and their contribution to the overall economic return in the site selection process. In the speculative building, a trade-off is made with regard to the question of which costs will be borne by the developer in the construction of the shell and core, and costs will be borne by the tenant. Often it may be the case that a developer chooses to shift expenses from the building to the tenant, thereby, making the building less expensive to construct but more expensive to occupy. In sum, such a shift may not be cost effective in an overall sense, but it may make the building more marketable by reducing perceived rents.

THE ROLE OF THE PROJECT ADMINISTRATOR

Managing the process of acquiring a technologically enhanced building requires the coordinated efforts of architects, engineers, building contractors, skilled craft workers, and a host of other experts. A principal figure is the project administrator, who must manage and coordinate these efforts and ensure that the right expertise is called on at appropriate stages of the process.

With the basic design requirements for the building determined, a key role is performed by the individual assigned the task of shepherding the processes of design, construction, and initial occupancy. This is true both for new construction and for renovation. The project administrator is in a position to play a role far greater than what is now normal practice for a project manager. A primary function is to serve as an integrator and facilitator. The project administrator should have been involved in the pre-design stages and in early discussions with the multidisciplinary team. It will be his or her job to assemble and utilize an appropriate group of experts, to handle the bidding and contracting, to incorporate modifications as necessary, and to work with the building's future occupants to develop the procedures and training programs needed if the building is to be used effectively.

The project administrator will be the "information broker" between the various experts and the building owner and occupants. Much of the responsibility for the successful introduction and use of advanced electronic technology will rest with this individual.

The project administrator has a unique opportunity to foster integration of the new or renovated facility with its advanced electronic capabilities into the occupying organization's structure and working style. To achieve this, the project administrator should interact closely with the organization's leaders, strategic planners, and managers. The administrator should understand the organization's goals, its corporate culture, and the attitudes of its managers, employees, customers, and clients. He or she should be able to anticipate the likely resistance to and acceptance of the new technologies and should work with managers in developing familiarization and training programs. He should understand changes in the organization's management structure that may result from new technological capabilities and should work with top management to bring these about in an orderly manner. He should be sensitive to the effects of the new technology on individual employees from the points of view of training, career development, health, and well-being. He should understand the importance of new physical arrangements for individual workstations, new options for individual control of lighting, noise, and temperature, and ergonomic design of furniture.

He should understand the demands that the new technology will make on the personnel responsible for building operation, maintenance, safety, and security. He should play a lead role in developing "feedback" mechanisms to ensure that new capabilities are being used properly and effectively.

In short, the project administrator is the single individual best suited to manage the implementation and effective integration of new electronic building technology into the organization's activities.

THE DESIGN, CONSTRUCTION, AND COMMISSIONING STAGES OF THE BUILDING ACQUISITION PROCESS

The design stage has as its goal the development of a complete set of construction documents for the building shell and, to the extent required, for the interior layout of the building. To accomplish this, thorough consideration of the building's architectural character; its structural, mechanical, and electrical systems; its communication infrastructure; and the activities to take place in it, will be necessary.

The construction stage centers on carrying out the construction or renovation, including the structural elements of the interior layout, as specified in the design. Changes are often necessary during construction, either because of unavailability of certain equipment or materials, unanticipated availability of new equipment or materials, or changes in the demands of the occupying organization. It is important that all such changes be monitored and integrated as necessary with other components of the project.

The commissioning stage of the acquisition process is a set of activities devoted to assuring the building owner that all systems are in working order. These activities include:

The pre-move stage centers on completing the interior layout and installation of basic equipment. This stage is also characterized by the start of an extensive period of acceptance testing, trouble-shooting, and quality control and by programs of familiarization and training for building occupants and building operations and maintenance staff.

The move-in stage is characterized by the moving in of people, furniture, and equipment. It is marked by continued acceptance testing, troubleshooting, familiarization, and training.

The occupancy stage is the period during which all of the building's systems and equipment are used under actual operating conditions. Modifications in devices, services, spatial layout, building systems, and training programs may be required. Continued feedback from all participants is necessary to ensure effective use of the building and its electronic infrastructure.

RETROFITTING NEW ELECTRONIC TECHNOLOGY INTO AN EXISTING BUILDING

Although in principle the building acquisition process is the same for new construction and for renovation, there are some significant differences. In new construction the widest range of electronic options is available. On the other hand, the construction process is a lengthy one and the move may require both a disruption of activities and an abrupt change in the organization's mode of functioning. In renovation, many options may not be available because of constraints imposed by the nature of the existing building. On the other hand, renovation can often be carried out for a section of a building at a time, the process may not be as lengthy, and the change in the organization's activities may not be as disruptive. Renovation may be the more expensive way to achieve a given level of electronic enhancement, but for nontechnological reasons (e.g., location and image) renovation may be the preferred strategy. In new construction, the cost of a given degree of flexibility is low and it is easy to be very flexible. In renovation, the cost of flexibility is high and it is important to be precise about the occupants' needs. When the renovation of a building involves the building being gutted and completely rehabilitated, there is very little difference between the new building and the renovation scenario.

Only a small fraction of the nation's building stock is constructed new each year. Of necessity, most organizations wishing to take advantage of new electronic technology will have to accommodate it in existing buildings.

This is already going on, in an ad hoc manner, through the introduction of computers, word processors, PBXs, and local area networks in buildings already in use. As long as the new technology introduced is not extensive, no serious problems arise. But as the ratio of computers and similar devices to employees rises, building systems may be strained beyond acceptable limits. Many buildings were never equipped to provide the electric power or to accommodate the equipment, the heat load, and the noise associated with today's electronic machinery. Buildings constructed during the country's efforts to conserve energy and contain spiraling construction costs, even though they are relatively new, contain no provision for increasing electric power capacity or cooling capacity. Moreover, many buildings were designed with cooling systems geared toward heat-generating machinery that was segregated from workstations. Now, with computer equipment scattered throughout the work space, this approach is no longer adequate.

Heat is not the only problem associated with electronic enhancement of older buildings. A proliferation of ducts containing communication and power cables intrudes into the work space. Not only is this unsightly, but the electronic traffic can become very complex, and troubleshooting difficult, with the result that efficiency suffers. Noise associated with computers and printers, as well as eye fatigue and eye strain associated with lighting that was never designed for video display terminals, adds to the problem.

This is not to imply that nothing can be done. The interior design, the floor plan, the distribution of activities throughout the building, and the lighting can all be changed. Here again, as with the new building, there is value in assembling a multidisciplinary team to assess future needs and decide on the best approach. In contrast with the new building, the existing building and its limitations must be accepted as given. Trade-offs and compromises will have to be made. Unexpected conditions may be discovered that will have to be taken into account. But a systematic approach can be taken, from four distinct viewpoints: (1) the nature of the building occupants' activities and the technology they wish to use; (2) the existing building structure; (3) the existing building systems--electrical wiring, heating, ventilating, air conditioning, lighting, and communications--and their capacity for modification; (4) and the existing use of interior space and the constraints imposed by walls, columns, floor-to-ceiling heights, and the like.

Retrofitting an existing building is challenging but not impossible. It is likely to be most successful, in the long run, if it is undertaken in an integrated, coherent fashion and not an ad hoc, one-step-at-a-time manner.

From the point of view of new electronic capabilities, the most significant distinctions between new construction and renovation are that, in a renovation project, a great many building elements can potentially act to constrain or make more costly the modifying of an existing building to accept electronic technology. These constraining elements may include the following:

- Floor-to-ceiling distance that limits the height of raised floors,
- Inadequate riser and horizontal distribution capacity,
- In a multi-story building, lack of access by a single floor to roof space for cooling towers, water for chilled-water HVAC equipment, or vertical chase and access space,
- Floor and roof loads that limit equipment loads and/or penetration,
- Fixed partitions required for fire safety,
- Existing distribution such as an east-west floor duct system,
- Limited ventilation opportunities,
- Single glazing with accompanying condensation,
- Absence of vapor barriers,
- Humidity control with induction system,
- Limits on use of under-carpet wire,
- Vibration limits,
- Building orientation for glare,
- Building operating hours,
- Existing sprinkler system,
- Existing HVAC system, and
- Electrical closet sizes.

A significant number of problems may arise with the electrical distribution system. Existing wire often cannot be used, requiring the merging of old and new over time; this calls for extensive planning and coordination. Most existing buildings have incomplete or nonexistent as-built wiring diagrams. Furthermore, electric power may have to be distributed from existing panels where capacity may or may not be available. Because unanticipated situations may require cost-effective improvising, it is especially important to be aware of the track record of subcontractors.

Existing buildings with tenants (users) have the advantage that tenants are known and can be interviewed for a more accurate determination of need for electronic (computer and telecommunication) systems. However, it is generally more costly to work around tenants.

The constraints listed here may exist in part or in totality. The effect of these constraints may result in one more of the following situations:

- Electronic devices cannot be accommodated because of space limitations or inappropriate space;
- Services required to operate electronic equipment cannot be distributed to the equipment locations; or
- Proper environmental systems cannot be installed because of capacity deficiency, distribution system sizing, or insufficient space to accommodate vertical and horizontal distribution conduits and ducts.

It may ultimately become necessary to acquire a new building to meet the organizational objectives.

5

BUILDING DIAGNOSTICS AND PERFORMANCE EVALUATION

DEFINITIONS

Building diagnostics is the name given, collectively, to procedures used by knowledgeable professionals that enable a building owner, operator, or manager to have an assessment made of the current performance capability of their building and its predicted performance in the future. Building diagnostics can play a valuable role in the acquisition and operation of any building, but it has special importance in electronically enhanced buildings.

While building diagnostics is most commonly thought of as a set of procedures used when a problem becomes evident and that serve to pinpoint its cause, the concept is really much broader. Diagnostics can be used at a number of stages in the life of a building to evaluate its performance and make a "prognosis" of its likely future condition. Even before construction is underway diagnostic techniques can be applied to the "virtual building" that exists in the mind of the designer and implicit in working drawings and specifications. They can be applied during construction, when components and assemblies can, for the first time, be tested "in place." Other procedures are available for when the completed building is ready to be turned over to its owner for initial occupancy, to assess its "as-built" performance capability. Building diagnostics can be used for a number of purposes throughout the period when the building is in use, both in connection with normal preventive maintenance and in connection with the process of identifying the causes of failure of some part of the building. Finally, diagnostics can assess the building's suitability for conversion to some other use and, ultimately, to determine appropriate methods of demolition.

Building diagnostics have four essential elements: knowledge of what to measure; availability of appropriate instruments; expertise in interpreting measurements; and a capability for predicting the future condition of the building on the basis of that interpretation. While building diagnostics rely heavily on measurements and tests, it is not solely a measurement science. The essence of the diagnostic process involves the formulation and testing of a series of hypotheses concerning the likely performance of a building or part of a building. The success of a diagnostic procedure depends as much on the diagnostician's knowledge and ability to formulate appropriate hypotheses and interpret measurements as on the availability of measuring instruments.

Building diagnostics is closely linked with the concept of building performance. It is not possible to evaluate a building's condition without having some standard against which to measure that condition, i.e., without first specifying the performance that is required and the criteria for evaluating that performance. If a building is to serve its purpose properly, it must be designed, built, operated, and maintained with the performance requirements as goals. This means that performance requirements must be formulated to serve as useful guides to the architects and engineers who design the building, the construction firm that builds it, and the management firm that operates and maintains it. They must also be specified in sufficient detail so that it is possible to determine, either by interpretation of appropriate measurements, or by expert judgment, whether they are indeed being met. These determinations must then be done and the results made available to the building's designers, owners, and managers so that corrective action, if needed, can be decided upon and undertaken.

Building diagnostics is of particular importance for electronically enhanced buildings because:

- The novelty of these buildings precludes there being a pool of experts capable of "intuitively" determining whether the design and construction of such buildings are being carried out effectively,
- The complexity and interdependence of the electronic systems contained in such buildings virtually requires a total systems assessment procedure,
- The electronic components and systems installed in electronically enhanced buildings must function properly in the completed building as an integrated system (this functioning is highly susceptible to failure if any of the component parts fail), and
- If failures (in the building's wiring, for example) are not detected until after the building is complete and occupied, modifications may be very costly.

Failures and potential failures in electronically enhanced buildings can be detected at many points in the building acquisition process, from the initial formulation of the mission statement and program through design, construction, commissioning, and normal use. Some of the uses of diagnostics at these various stages are described in the following sections.

DIAGNOSIS FOR EXTERNAL SIGNAL PROPAGATION

A major difference in the electronically enhanced building is represented by that set of technologies utilized in bringing external signals into the building, especially if this capability is as complete as what is described in Chapter 3. There is a variety of possible configurations, each with substantial hardware performance requirements for the related physical and environmental settings. This includes: microwave receivers, satellite receivers, copper wire T-1 networks, fiber optic networks, two-way radio receivers, and associated multiplexers (to strengthen the signals).

Radio, microwave and satellite receivers rely heavily on the position and structure of the roof for signal output. If the height of the roof, the line of sight from far away signal generation, or access and air rights (such as those imposed by the Federal Aviation Administration) cannot be attained, the entire electronically enhanced building project may not be possible. While these performance factors can be evaluated in the design stage, they are finally most crucial once they are actually in place. It is also critical that these devices be free of interference from other nearby signal generators. While these can be simulated in the design stage, the crucial evaluation is made once the systems are in place. This is also an area which will clearly require a continuing program of diagnosis on a periodic basis, since new interference could develop as other activities are organized in the vicinity of this installation. For satellite dishes, especially, structural bracing is critical to withstand wind and snow loads. Shelter also needs to be provided as protection from icing.

To add to the complexity of the performance requirements of location and structure related to the building roof, there are the hardware connections to external signals such as copper T-1 networks (landlines), "campus" coaxial networks and fiber optic networks which rely heavily on basement location and configuration. There must be secure (from outside interference) and accessible trenches into well-located and well-configured communications rooms. The definition of "well-located" and "well-configured" is determined by the professional judgment of the diagnostician since there are so many variables involved in the performance aspects of such trenches. Generally, hardwiring for external signals is completed by a telephone company, with significant entry costs and switch ownership costs involved.

No matter which receiver type is selected, associated communications rooms will be necessary. These rooms will house a small rack for power, printed circuits and cable management. They may also house the uninterrupted power supply (UPS) or battery backup systems for the building, and the multiplexers needed to strengthen the incoming signals. Again, it is possible to evaluate these performance factors during the design stage, but they can be thoroughly evaluated only after the entire complex has been put in place and the building is in the commissioning stage. It is also important that these communications rooms be heated and air conditioned to maintain temperatures within the range of 35 to 115 degrees Fahrenheit, be humidified (or dehumidified) to within 20 to 30 percent relative humidity, be ventilated yet protected from dust, be effectively lit, be protected from fire and water damage, and be arranged for easy access and maintenance. While each of these factors can be measured separately it is the interaction of these performance requirements with the room and installed equipment once in place that is most important.

Finally, the receiver and communication room must be connected to a vertical shaft for connection to the various computers. Consequently, it will be critical that adequately sized and placed core space be provided as with any cabling network. Once again professional judgment is needed to evaluate the performance requirement of "adequately sized and placed."

When all of these performance requirements for external signal propagation are evaluated for an actual installation it is obvious that considerations of roof height, line of site exposure, interference protection, basement trenches which are secure and accessible, uninterrupted power supply, satisfactory heating, air conditioning, ventilating, lighting, and spatial arrangements form a complex set of criteria. During the design stage it is important that a team with sufficient breadth of expertise be assembled to evaluate the design alternatives, and potentially recommend other sites if satisfactory external signal propagation cannot be assured. It is during the commissioning stage, when all of the building and equipment installations have been made, that the critical diagnostics can be made. With the total set of performance criteria in mind the diagnostic team can hypothesize the likely performance of the external signal propagation system, exercise all parameters of the installation to observe its performance, and make recommendations for corrective action in order to assure future effectiveness.

DIAGNOSIS FOR INTERNAL SIGNAL PROPAGATION (CABLING NETWORK)

The selection and configuration of the cabling network is one of the most critical and costly up-front decisions (not to mention visible) in the electronically enhanced office, determining the ultimate hardware and software capabilities (limits) of the building (as noted earlier in Chapter 3). There are significant choices in the types of cables or wires to be introduced, including copper twisted-pairs, coaxial cables, universal wiring, fiber optic cables and wireless options. The choice of the cabling network's configuration is also significant. When these decisions are being made it would be possible to use a simulation of the building and its critical subsystems to do a diagnosis of those performance requirements important to the choice of alternatives.

These performance requirements would include: (1) the adequacy of vertical shaft space and horizontal plenum space; (2) adequate "clean" power; (3) when flat wires are being evaluated, then shielding from electrostatic interference from radios, other equipment, or feet on carpets needs to be made to avoid disturbances in the data flow; (4) both vertical and horizontal distribution must be ample to accommodate all long term cabling demands, with easy access and management throughout the distance laid; (5) since tying the entire configuration of the cabling network to a ground cable is critical at all times, and since there are various termination schemes for ensuring that the entire system of cables is adequately grounded, access to the basement and beyond is absolutely necessary, with critical dimensions for the depth of rods (up to 20 feet!) and the distances that the rods are apart; (6) the continuity and size of the vertical shafts are also crucial parameters to effective grounding; and (7) due to the size of the cables, bending radii, connections and multiplexers, as well as fire protection, access and management, significant space is demanded in: the central core or distributed cores (with large floor plates), the horizontal plenum space above the ceiling or beneath the floor (free of structural and mechanical elements), and the final vertical riser space in walls, furniture or in pack poles.

Without adequate distribution space, an adequate cable network may not be installable, expandable, or maintainable.

As a result of these performance needs (horizontal and vertical distribution space), there are also several other critical conditions to the effectiveness of internal signal propagation: (1) fire safety for the entire network is critical through enclosures and coatings; (2) security from sabotage or worker error is critical; (3) for certain clients a mandatory condition can be the configuration (depth, clutter), material and detailing of the interior ceiling; and (4) floor and partitioning systems will be critical to the cost-effective integration and management of cables (if floor-to-floor heights are inadequate and existing ceiling plenums are cluttered, horizontal cable distribution may have to be laid out in exposed trays hung from the ceiling, with continuous fire protection, or a flat wire configuration).

The configuration of the cabling network, combining vertical cores to horizontal runs to the computers and peripheral units (input/output devices and processors), including the basic questions to be answered before designing the architecture or local area network (LAN), add up to make the diagnostic project at the design stage a challenge which will again require a team of experts. There are three basic configurations for cabling and connecting computers and peripherals known as bus (wangnet, ethernet), star and ring networks. It is critical to understand the sizable dimensions of this cable network or tree throughout the building. No less significant than the mechanical "tree" or the structural "tree", an expert must be called in early in the building's design to participate in a complete internal signal propagation diagnosis. This will be done for the "virtual" building (i.e., the building which exists only on paper, but is capable of being simulated in physical models or computer models). The large number of variables listed above give an indication of the complexity of the diagnosis and the types of expertise required.

Once the building has actually been constructed, cable management is a significant hardware and software consideration in the electronically enhanced office of today and tomorrow. Keeping track of where all the wire is, what type of wire it is (power, voice, or data--digital or optical), and what capacity it has, requires not only clear long-term architectural design, but calls for the installation of a computer-aided wire management (CAWM) system. This system (CAWM), while intended primarily as a management tool for the building operators, might also be utilized for a continuous diagnosis of the condition of the internal signal propagation system.

DIAGNOSIS FOR COMPUTERS AND THEIR NETWORKS

As indicated in Chapter 3, the three general categories of computers--mainframes, minis and micros--have differences between them which were once very pronounced, but the boundaries are now becoming blurred. Even micros can have 40 to 80 megabytes of memory (capacity), with 4 to 5 mips of speed, without large power requirements (or heat output). The example we will discuss here, to illustrate another prospective application of diagnostic procedures, is the mainframe and the supermainframe, such as a Cray computer, which require their own specially designed rooms or "data center."

The performance requirements for these large mainframes include:

- The guarantee of additional power;
- The need for an uninterrupted power supply or UPS system;
- Special grounding is required;
- The weight of the equipment is significant, requiring enhanced structural support and vibration control;
- Atypical quantities of air conditioning must be provided for the space (5 to 10 times typical occupancy), along with water cooling capabilities for the equipment, and humidity control;
- In addition to thermal and humidity control, condensation is of serious concern making isolation from the window wall desirable;
- Security and fire become major concerns, requiring controlled access to the room, and Halon fire systems with their own sensors and pumps; and
- Massive and often changing cabling must be dealt with, to manage data, power and voice inputs and outputs to numerous distributed workstations, telephone gateways and controllers (operating sub-stations).

These special requirements for the mainframe control rooms have critical specifications for power, air conditioning and humidity, security and fire, as well as cable management, which often additionally demand access floors or trough walls for the servicing systems. Superimposed on these equipment demands are the demands of the occupancies within the outside of these data centers. Although the computers benefit from very low ambient light levels, with task lights for the equipment (front and back), people working within these spaces would require secondary lighting systems. Although vibration and acoustic noise must be considered for the long-term durability of the equipment, vibration and acoustic noise must be critically controlled for the occupants within and outside these spaces. Thus, the mainframe centers must be strategically placed for efficient cabling and access, while minimizing the effect of the noise, traffic, heat generation, and cabling on the remaining office settings.

The eight performance requirements listed above are the critical performance requirements. Some other important concerns include: minimized exterior exposure (to sun, heat loss or gain, potential leakage); adequate space for the equipment and its peripherals, access, maintenance, changing configurations; adequate ventilation or the occupancies, along with humidity, static and dust control (pressurized spaces) for the equipment; and mean radiant temperatures should be countered for occupants within the space.

During the commissioning stage, when all of the systems have been installed in the building but before the occupants have taken possession, a team of diagnostic experts could be brought in to evaluate the performance of the mainframe computer support system. This does not mean the evaluation of the computer(s) as such (although this might be a good time to perform that function as well), but the evaluation of the eight critical factors mentioned above, and the other related concerns. Since the goal of the diagnosis is to provide a "prognosis" of how the system will perform over time, and to propose interventions (in the form of corrections to the computer room or its support systems) if the long-term prognosis is not good, the diagnostic team will have to include the architects and engineers for the building as well as experts on mainframe functions and use. These are not skills likely to be found in the computer staff of the organization, nor on the staff of the building operations and maintenance department. Diagnosis at this stage will be expensive, but the cost of avoiding serious problems later is more than enough incentive.

The performance requirements for minicomputers and microcomputers are generally less crucial, but must be considered.

DIAGNOSTICS FOR DEDICATED PERIPHERAL PACKAGES

There are three general categories of peripheral hardware: (1) input devices for receiving data, voice, video graphics, and environmental input; (2) processors for reading, processing, computing, filing, storing or transferring this input; and (3) output devices such as printers, plotters, projectors, speakers, tapes or disks, and commands to action (robotics). In this section, however, we will focus on a fourth possible category, combining these three sets of hardware into dedicated packages for specific services such as electronic mail, video teleconferencing, electronic data bases, and building security.

The performance requirements for these packages (as installed in a building) require that the physical and environmental setting conditions support the type and density of hardware chosen (not just generically, but specifically). The three categories of peripheral components have requirements which include:

Input Devices

There are a wide variety of devices used for input purposes. Requirements include: (1) good lighting conditions, color, contrast and glare control for visual tasks; (2) adequate user spaces to meet ergonomic requirements; (3) control of static electricity and dust which can damage the devices; (4) acoustical control of the clicks, beeps, and whirs of typical devices for those located close to them; (5) control of background noise, sound source intensity, and sound isolation if the device is intended to record sounds; (6) overall maintenance of the spaces and equipment that surround the devices; and, finally, (7) appropriate spacial arrangements as well as protection from unintended effects of the acoustical, thermal or lighting on environmental sensors.

Processing Devices

Hardware for reading, computing, filing, storing and transferring the variety of information being processed requires: (1) that space, both quantity and location, be adjusted for these demanding conditions; (2) also adequate and reliable power; (3) and plenums (horizontal and vertical) for the extensive and ever changing cabling; (4) adequate air conditioning to offset the heat output of the equipment; (5) adequate sound absorption and noise isolation to protect the occupants from the noise of the equipment; (6) adequate security and enclosure methods to protect the equipment from dust, static, abuse, or vandalism; and (7) adequate thermal quality for the occupants, balancing poor mean radiant temperatures that often result from processor power demands.

Output Devices

Such diverse output devices as impact carbon printers, nonimpact jet or heat printers, laser printers, and photo printers; analog and digital plotters; and such hard copy as disks, tapes, or chips, and sound output devices including telephones, intercoms, pagers and bells, and video output devices including 2-D projectors, light beams, holographs, all require: (1) well planned space of sufficient size (centralized, decentralized); (2) adequacy of power; (3) horizontal/vertical plenum space for cable management; (4) adequate acoustic control for isolating the equipment noise from the occupants; (5) adequate air conditioning for offsetting the heat load from the equipment; (6) controlled lighting (task, ambient, and daylight); and (7) controlled acoustics.

When we focus on those peripherals which are the combinations of these three sets of components into dedicated packages for specific services, such as electronic mail, video teleconferencing, electronic data bases, and building security, we find that the most complex package of peripherals is the video teleconferencing center, with great demands for specific physical and environmental settings. The video teleconferencing package combines, through massive cabling, such input devices as voice-activated cameras, telephones or microphones, audio and video scanners, electronic blackboards, copy machines, keyboards and plotters, to such processors as a signal control unit that converts the data to digital, to a phone center, to an antenna to a satellite receiver terminating at output devices such as screens, speakers, as well as plotters and printers. Clearly, the architecture of the video teleconferencing room is dependent on a combination of all of those performance requirements for the three separate sets of components, plus its own special set of needs such as controlled lighting for video camera work. The diagnosis of this total package will once again require a team of experts with differing skills. The most effective application of diagnostic techniques for video teleconferencing rooms is likely their use during the operating life of the facility as a form of "health maintenance." This area of diagnostics, more than most others, requires the diagnostician to understand the "etiology" (the causes of abnormal conditions) in order to know what it is important to be monitoring, and how to take corrective action before failure occurs. This special knowledge and the wisdom to understand what is being observed is the reason that diagnostics requires an expert human.

DIAGNOSIS FOR HVAC SYSTEMS

There is more reason to address the total system's performance of the building, its electronic enhancements, and the supporting mechanical equipment, than to look at the performance of separate systems such as the heating, ventilating and air-conditioning system (HVAC). However, it may be desirable to undertake a diagnostic procedure just for these systems during the commissioning stage of the building. This is especially true since the investment in the HVAC system can be a major component (as much as 30 percent) of the initial cost of the building, and a significant part of the operating costs. If the price of fossil fuel energy goes back to 1974 levels (and some observers believe that it will do so), then this area of diagnosis increases in importance.

The air conditioning that must be provided for electronically enhanced buildings offsets the added electrical heat load generated by office equipment such as main frame computers, telephone switches, personal computers and peripherals. The two predominant issues are, (1) the configuration of air conditioning available in the building, and (2) the amount of additional heat load to be handled (expressed in watts per square foot). The electrical loads for this purpose are distinctly different from total building electrical capacity.

Conventional office space makes provision for .5 watts per square foot of equipment and 2 watts per square foot of lighting. The provision of personal computers and peripheral equipment generally adds between 1 and 2 watts per square foot to the requirements. Heat loads generated by major computers and telephone switches are almost always offset by discrete air conditioning units of the self-contained, direct expansion type, with condenser water supplied by separate cooling towers.

Ventilation requirements include the fact that computer rooms are frequently protected against fire by means of halon, an inert gas that must be ventilated after discharge. Battery rooms provided in connection with uninterruptable power systems (UPS) require constant ventilation. Emergency generators, designed to provide standby power, require large amounts of ventilation air.

Humidity controls are not generally required in conventional office buildings. To avoid the build-up of static electricity in electronically enhanced buildings, humidification to 30 percent relative humidity (RH) should be provided in winter throughout. Computer rooms may require as much as 50 percent RH.

Indoor air quality is especially important in tightly constructed buildings where impurities in the air, including particulates (solids or liquids) and vapors which are generated outdoors are brought inside, with possible damage to the performance of electronic equipment.

At the commissioning stage, or later during a post-occupancy evaluation, the combination of these ambient conditions should be the subject of a diagnostic procedure. In most cases many of these variables will be controlled by automatic equipment. Space conditions may be controlled by functional areas, but an evaluation should include the flexibility of the system for adding discrete zones. An experienced mechanical engineering consultant should be able to provide a prognosis of the long-term performance of the HVAC equipment based on the evaluation of these variables, and to propose any modifications or repairs to assure proper performance.

SUMMARY

Building diagnostics, as a field of practice, is still evolving. Electronically enhanced buildings, as a building type, are still new. What this means is that potentially desirable diagnostic procedures must be developed. Consequently, part of the process of acquiring an electronically enhanced building must address the development of diagnostic techniques appropriate to that particular building. Since diagnostic techniques are closely tied to performance requirements, the identification of desirable diagnostic procedures should be carried out hand in hand with the development of the building performance requirements. This process begins with formulation of the building's mission statement, and continues throughout the building acquisition process. The examples that were discussed in this chapter--which are by no means exhaustive--illustrate the kinds of diagnostics that could be done. We know of no building designed to date that has had such sophisticated diagnosis performed, but we believe that the need for developing such procedures is clear.

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CONCLUSIONS AND RECOMMENDATIONS

In the preface we recommended that organizations appoint a person, the project administrator, just below the level of Chief Executive Officer, responsible for all aspects of building and technology as discussed in this report. We believe this is especially important for any organization in the process of building a new electronically enhanced office building, or any organization that is about to make major revisions to their office facilities in order to gain the performance advantages of electronic enhancements. We indicated that we intend this report to serve as a guide for that individual. These conclusions and recommendations are, in turn, directed to a person with such responsibilities.

The recommendations fall into three categories: (1) those related to the process of acquiring an electronically enhanced office building; (2) those related to diagnostic procedures; and (3) those addressed primarily to organizations in the public sector (and even more specifically federal agencies) concerning the development of expertise and techniques.

RECOMMENDATIONS CONCERNING THE BUILDING ACQUISITION PROCESS

The new elements that should be incorporated into the building acquisition process for each electronically enhanced building are:

- Project Administrator One person should have overall responsibility for the building acquisition project. This responsibility should encompass the building itself (including both its shell and core and its interior layout), the technology that will be housed in it, and the impacts that the building and its technological capability will have on the organizational structure of the occupying institution and on its personnel. This responsibility, which is considerably more than the traditional project manager, should extend from the initial building plan through programming, design, construction, commissioning, initial occupancy, post-occupancy evaluation, and routine operation and maintenance. The individuals who will become the facility manager, the technology manager, and the personnel manager should work in close coordination with the overall project administrator from the outset.

- The Mission Statement A mission statement for the building should be developed at the outset. It should reflect the mission of the occupying institution and the anticipated use of the building, taking into account the institution's current and anticipated needs, perceived shortcomings of its present facilities (if any), and growth or other changes that are anticipated during the life of the new (or renovated) building. In the case of speculative office buildings, it is generally not known at the outset who will occupy the building, what the interior layout will be, or what technologies will be used. Nevertheless, it is essential to consider the generic likelihoods concerning these matters, and to consider them at an earlier stage than is currently the standard practice.
- Use of the multidisciplinary team in initial decision making The multidisciplinary team should provide advice and guidance with regard to such initial decisions as site selection (in the case of new construction) or evaluation of alternative options using existing buildings (in the case of renovation). The multidisciplinary team should also be alert to problems that are likely to arise and steps that must be taken to have a fully operable building ready for occupancy at the desired time. This includes such requirements as approvals, permits, and licenses as well as requirements that pertain to physical readiness of the building.
- The electronic technology program With the advice and guidance of the multidisciplinary team, the mission statement should be converted into a technologically functional program statement that identifies crucial performance requirements that must be taken into account in the design of the building. This "electronic technology program" should make clear those physical requirements demanded of the building to accommodate the technology it will house and form the basis for the performance criteria established for the building. This program should be developed before the design process gets underway. It should go hand in hand with the traditional architectural program in guiding the design of the building. Because the two programs interact, they should be developed in an iterative and interactive mode.
- Users' evaluation of the mission statement, architectural program, and technological program The architectural program and the electronic technology program should be evaluated to determine whether they truly meet the requirements of the mission statement. This evaluation should be carried out from the point of view of those who will use the building; e.g., the institution's top management, the building manager, the maintenance staff, the security officer, the personnel department, information and automation managers, representatives of various parts of the institution, and others whose work will be affected by changes from current practices required to accommodate the new (or renovated) building and the new technology it will contain.
- A plan for the overall building acquisition process. Once the mission statement, architectural program, and electronic technology program are in hand, a plan should be developed for the entire building acquisition process, flagging critical decisions, indicating a schedule

for diagnostic assessments, and indicating points at which particular kinds of expertise will be needed.

RECOMMENDATIONS CONCERNING THE USE OF DIAGNOSTICS

In Chapter 5, we have described at some length the concept of building diagnostics and have developed a number of examples of how the concept might be applied to an electronically enhanced office building. Based on that work, we wish to recommend more specifically:

- Development of diagnostic procedures Diagnostic procedures appropriate to the building should be developed. These may include, during the planning and design phases, the construction of mockups of sections of the building that can be used to simulate the performance of the building for diagnostic purposes.
- Diagnostic assessments Diagnostic assessments should be conducted at key points in the building acquisition process including the period of planning, programming, design, construction, commissioning, and routine occupancy and use.
- Commissioning When the building is being "commissioned," i.e., beginning shortly prior to the completion of construction and extending well into the first year of occupancy, diagnostic tests and assessments should be conducted as a guide to operation and maintenance and to modifications in the building or in the activities carried out in it. This should be carried out by a top management group, with advice and guidance from the multidisciplinary diagnostics team.
- Post-occupancy evaluation Diagnostic assessments and other evaluations of the performance of the building's physical and environmental setting with respect to the activities carried out in it and the technologies incorporated in it should be continued throughout the building's life. Assessments of productivity and other measures of the quality of the activities might be done using "post-occupancy techniques" (see Building Research Board report POST-OCCUPANCY EVALUATION PRACTICES IN THE BUILDING PROCESS: OPPORTUNITIES FOR IMPROVEMENT, National Academy Press, Washington, DC, 1987) and should, where possible, be causally related to building attributes as well as to aspects of management, training, etc. These assessments should provide guidance for the routine operation and maintenance of the building. Through the "feedforward" process, they should also provide guidance to the design and construction of future electronically enhanced buildings.

The steps listed above will be effective only if the institution that occupies the building has a genuine commitment to the concept of an effective building system that meets carefully designed performance requirements. This commitment must come from the very highest levels within the organization, and must be enthusiastically supported by middle level managers and by employees.

RECOMMENDATIONS FOR THE DEVELOPMENT OF EXPERTISE AND TECHNIQUES

There are also a number of generic measures that should be undertaken in both the public and private sectors (with special emphasis on the federal agencies) to foster development of a pool of expertise and a body of diagnostic procedures that are applicable to electronically enhanced office buildings. The most important of these can be summarized as follows:

- Facilities for development, testing, and training Public agencies and the building industry should foster the expanded use of building testing laboratories, both for the development and testing of design and engineering techniques appropriate to electronically enhanced buildings and for the training and education of architects, engineers, technology managers, and building managers. In particular, the federal government--with its own unique building needs and procurement practices--should establish and maintain an experimental and training facility oriented specifically to government buildings. In such a facility, design and engineering techniques, as well as diagnostic procedures appropriate to electronically enhanced buildings can be developed and tested, and personnel can be trained in the operation and maintenance of electronically enhanced buildings.
- Information exchange programs Public agencies and the building industry should establish and maintain an information exchange system, incorporating a computerized information base, to foster the dissemination of knowledge about all aspects of electronically enhanced office buildings. In particular, the federal government should take steps to improve the level of competence and expertise with electronically enhanced office buildings among its project managers, designers, architects, engineers, and facility managers by: (1) establishing programs for personnel exchange among federal agencies to expedite the dissemination of knowledge gained from personal experience throughout the federal government, and (2) establishing programs for continuing education, using lectures, seminars, workshops, publications, and other extension activities.
- Development of standards and criteria The federal government and the building industry should support the development and continuous updating of standards and criteria applicable to electronically enhanced office buildings. A special emphasis should be placed on developing such standards in the international arena, where the opportunity for the U.S. to compete in a global market is now being shaped.

APPENDIX

BIOGRAPHICAL SKETCHES OF COMMITTEE MEMBERS

PIERO PATRI, FAIA (Chairman) is president of Whisler-Patri, an architecture, interior design, planning, and facilities management firm whose work includes new construction, renovations, and interior design. Mr. Patri is a member of the research subcommittee of the Urban Land Institute's High Tech Committee. He served on the Publications Review Committee for the ULI book, Smart Buildings and Technology-Enhanced Real Estate, and is a contributing author to their forthcoming publication, The Changing Office Workplace. In addition, he recently co-authored a chapter on "Retrofitting Existing Facilities to Accommodate Office Automation" for the book High Tech Real Estate published by Dow Jones-Irwin, and is currently contributing a chapter on "Teleports and Real Estate Development" for a book soon to be released by Dow Jones. Mr. Patri was educated in Milan and Florence and graduated Phi Beta Kappa from the University of California at Berkeley.

MICHAEL BRILL is professor of architecture and environmental design at the State University of New York at Buffalo and is president of the Buffalo Organization for Social and Technological Innovation, Inc. He is an "environmental diagnostician" with more than 25 years of experience in research, systems analysis, architecture, and planning. He has been a consultant to the U.S. General Services Administration, National Institute of Mental Health, Department of Housing and Urban Development, National Bureau of Standards, and to state, county, and city agencies and many corporations. He has published more than 40 papers, articles, and book sections about, the effects of work environment on behavior, productivity, and satisfaction; the design of high-performance work environments, including pre-design programming and post-occupancy evaluation; the reduction of vandalism, hazards and accidents (the "dirty secrets" of architecture) through research-based design; community participation in planning of human service systems; and the theory and applications of behavioral and economic research in place-making and place management.

BRYAN CLARK is construction manager at Harwood Ventres a subsidiary of Turner Construction. He manages 600,000 square feet of commercial office and retail space in various stages of completion in the Northern Virginia area, including the administration of architecture, engineering and general construction contracts. His work includes a responsibility for directly subcontracting tenant improvements for current projects and property management for projects through the initial two years of occupancy. He has a degree in Civil Engineering from Cornell University.

NANCY CANESTARO is an interior design instructor for the department of Housing, Interior Design, and Resource Management, College of Human Resources, Virginia Polytechnic and State University. She has been a research associate in the Facility Management Institute of the Herman Miller Research Corporation, and worked as a space planner with Design Resource Service in Washington. She is the developer and coordinator of "The Facility Management Dilemma", a gaming-simulation that improves awareness of how corporations operate and how the integration of facilities with the work process results in greater individual and corporate productivity. She has a B.S. from VPI and an M.S. from Drexel University, and is presently a doctoral candidate at the University of Michigan's College of Architecture.

MICHAEL CLEVENGER is the manager of real estate and administration for the Xerox Corporation. He has been the Xerox principal consultant on office standards and has been adjunct professor of construction and real estate management in the Real Estate Institute of New York University. He has also taught construction management at California State University, Long Beach and at UCLA. Mr. Clevenger is a member of the Panel on Technology Changes and Impacts on the Building Construction Industries for the U.S. Office of Technology Assessment. His area of expertise is in "smart" office buildings as a generic high-tech type.

FRED S. DUBIN is a mechanical engineer and architect. He is president of Dubin-Bloome Associates and a partner in Fred S. Dubin International in Rome. He has been on the faculties of several universities, and most recently he served as visiting Andrew Mellon Professor of Architecture at Carnegie-Mellon University. Among his major design projects are the Salk Institute for Biological Studies, the Phytotrons at Duke and North Carolina State Universities, and the headquarters of the UN Environment Program in Nairobi, Kenya. He has written several books and numerous articles and has been a consultant to a number of federal agencies. He holds a bachelor's degree in mechanical engineering from the Carnegie Institute of Technology (now part of Carnegie-Mellon University) and a master's degree in architecture from the Pratt Institute of Technology. He is a registered professional engineer in 24 states and five foreign countries.

RONALD GOODRICH is director of research for Cushman and Wakefield, New York. He is an environmental psychologist with extensive experience in therapy, teaching, research, and consulting, with emphasis on the influence of the physical environment on individual and social behavior. He has done considerable work on the incorporation of behavioral considerations into the design of office buildings and on assessment of user and employee response to changed work environments. His clients have included major corporations engaged in engineering, mining, petroleum, and banking, the Federal Reserve Bank, and the U.S. Senate. Mr. Goodrich received his B.A. with honors from DePaul University in 1968 and his M.A. from Hunter College in 1974.

NORMAN D. KURTZ is a principal in the firm of Flack and Kurtz, New York City, a firm which is involved in the design and retrofit of major institutional, commercial and industrial projects all over North America. The firm includes the disciplines of mechanical, electrical, sanitary, life safety, energy conservation, and telecommunications. Mr. Kurtz has a degree in mechanical engineering from Princeton and a masters degree from Stanford. He is recognized as one of the forerunners in research and application of energy technology. He is registered in 38 states and provinces.

HENRY LEVINE, a graduate of Yale College, Harvard Law School, and the Kennedy School of Government at Harvard, is a partner in the Washington, D.C. office of the law firm of Morrison & Foerster, specializing in telecommunications. In addition to an active federal and state regulatory practice which includes work on shared tenant services issues, he represents major real estate developers and communications companies across the country in planning shared service projects and negotiating shared tenant service agreements with telecommunications companies. He has written and lectured extensively in the field, including numerous articles on shared tenant services and a chapter on the subject in the Dow Jones-Irwin book, Hi Tech Real Estate. He is the Co-Editor-in-Chief of Telematics: The National Journal of Communications Law and Regulation, and he chairs the Subcommittee on State Regulation, a sub-unit of the Communications Committee of the American Bar Association's Section of Corporation, Bank, and Business Law.

VIVIAN LOFTNESS is an associate professor in the School of Architecture at Carnegie-Mellon University. Her research work has included World Climate Programs for the World Meteorological Organization, energy conservation and solar energy studies for the AIA Research Corporation, and work on the total building performance concept for Public Works Canada. She served on an earlier committee of the BRB on the subject of diagnostics. She has been a visiting faculty member at a number of universities including MIT, where she obtained her graduate degree in architecture. She is the author of numerous publications, and a recipient of many fellowships and awards.

JAMES MCCUE is president of Building Owners and Managers Institute, International. This firm provides training programs for building owners and managers in the United States, Canada, Australia and Japan. He has a graduate degree from Wheaton College and a Ph.D from Michigan State University. He has served on the faculty of several universities.

HERBERT ROSENHECK is president of Technology Planning Associates, a consortium of specialists in information systems and services, communications, and engineering that provides technology management services to owners, end users, architects, interior designers, construction management, and other firms related to the building sciences. Prior to this, he was a consultant for management advisory services to major industrial and financial service firms and to government agencies, where he provided a broad integrated range of business and technical skills to insure that current and projected office automation, distributed data processing, communications, and other function requirements are satisfied. He has been Vice President and general manager for TRW Inc., where he was responsible for development and operations of the high-technology Information Services Division, serving the largest nationwide credit reporting service.

ARTHUR I. RUBIN is an experimental psychologist working on the development of building criteria within the Building Physics Division of the Center for Building Technology of the National Bureau of Standards. He has been responsible for research projects ranging across noise, energy conservation, fire safety, lighting, post occupancy evaluation, and man enviroment issues. Dr. Rubin has worked closely with other federal agencies in the development of research programs (e.g., HUD, EPA, GSA) and with private sector professional and scientific organizations. He has served as a research psychologist at the Human Engineering Laboratory, Rome Air Development Center, Rome, New York. He has a degrees in industrial psychology from City University of New York and Pennsylvania State University, and a PhD from George Washington University.

LISA G. SAURWEIN is director of facilities operations at the National Broadcasting Company. Some of her recent projects include a complex retrofit by modification of the Rockefeller Center HVAC system to increase comfort, reduce energy consumption, and provide a proper working environment for electrical equipment, and an international activity involving the design of a prototype building for energy conservation in a semi-tropical setting. She has also been a project engineer for the installation of office and technical spaces incorporating extensive telecommunications, computer, and audio visual capability under a raised floor. She received her B.S. from the Cornell University School of Mechanical and Aerospace Engineering.

THEODORE H. SCHELL is president of RealCom Communications Corporation, a subsidiary of IBM. RealCom provides comprehensive communications services to tenants in new and existing multi-tenant office buildings. He was formerly vice president of strategic and corporate planning at the Urban Investment and Development Company, a national real estate development firm headquartered in Chicago. Prior to joining Urban, he served in the U.S. Department of Commerce as counsellor, chief of staff, and senior advisor to the Secretary of Commerce; special assistant and director of operations for the Office of Productivity, Technology, and Innovation; and director of the President's study on industrial innovation. Mr. Schell received his B.A. from Johns Hopkins University and his M.A. from its School of Advanced International Studies.

PETER VALENTINE is president of COMSUL, Ltd. His major areas of expertise are planning, specifications development, consultation in telecommunications, and telecommunications-real estate shared tenant services projects. Before becoming president of COMSUL, he was a partner for operations of the Schwabasher Company in San Francisco where his experience included facilities and operations management in securities. He is a member of the High-Tech Council at the Urban Land Institute.

FRANCES T. VENTRE is professor of environmental design and policy and director of the Environmental Systems Laboratory at Virginia Tech. Before joining the faculty in 1983, he was senior research architect and chief of the Environmental Design Research Division for the Center for Building Technology (CBT) at the National Bureau of Standards. At CBT he directed a program in lighting, acoustics, circulation (including accessibility and emergency egress), safety, environmental psychology, and site analysis. He has taught at UCLA, MIT, and the University of Maryland. He received his Ph.D. in urban studies and planning from MIT. He also has a master of city planning degree from the University of California at Berkeley and a bachelor of architecture degree from Pennsylvania State University.