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Information, Technology and Communications

In recent years the effects and advances in information technology on society have been viewed as more disruptive than any previous technological impact. On the one hand, the advances have been seen as a universal panacea heralding an automated society of abundance, in which undue leisure may be the only major threat, while on the other hand, there are those who see such advances leading to an oppressive Orwellian state in which 'the machine' would exert electronic surveillance over every aspect of the individual's private and public life.

Our discussion will range between these two extremes. We may ask, what do we mean by the changing information environment? Are we talking about information or knowledge, or about the technological systems through which these are communicated? How might changes in these systems in the next few decades affect the relationships between information, knowledge and social action?

It is not without significance, for example, that the central social dialogues, which have been a major preoccupation and a disruptive influence of western society in recent years, have been arrayed around 'information as a resource' issues. The Pentagon Papers, the Watergate affair(s), etc., revolved entirely around who had obtained, or tried to obtain, which kinds of information, who transmitted what to whom, and when such information was associated with this or that power play. It is also noteworthy that the older forms of power currency, such as money or material rewards, played a relatively insignificant role in these political shifts which toppled a Presidency. This dialogue has lead to other reverberative information issues ranging from the right to privacy, disclosures on intelligence surveillance, to the legal regulation of consumer information with regard to products.

From this initial enquiry regarding changes in the information environment of society we may infer certain sets of impacts upon the nature of both physical and social resources. It is possible, for example, that such impacts will change the very locus and function of power in society—as happened with the set of technological impacts which comprised the First Industrial Revolution of the nineteenth and early twentieth century.

What effects may be surmised regarding the relationship of the individual to society, changes in individual perceptions and roles and underlying transformations in values, attitudes and capabilities? What changes may be inferred in the nature of work, of life styles and social interaction? Will they lead to more cohesion in society, or are they likely, without appropriate policies and initiatives, to be potentially more disruptive than any other set of technological impacts?

Given these more generalised enquiries, we can ask how they may, in turn, have more specific effects on various sectors of the society—on education and culture, business and politics, from the local to the global level.

It may be useful to summarise this process of enquiry, in a more schematic and non-linear fashion, by reference to the circular diagram, Figure 1.1. This model can be used to get a clearer understanding of how information technology affects the individuals and society that

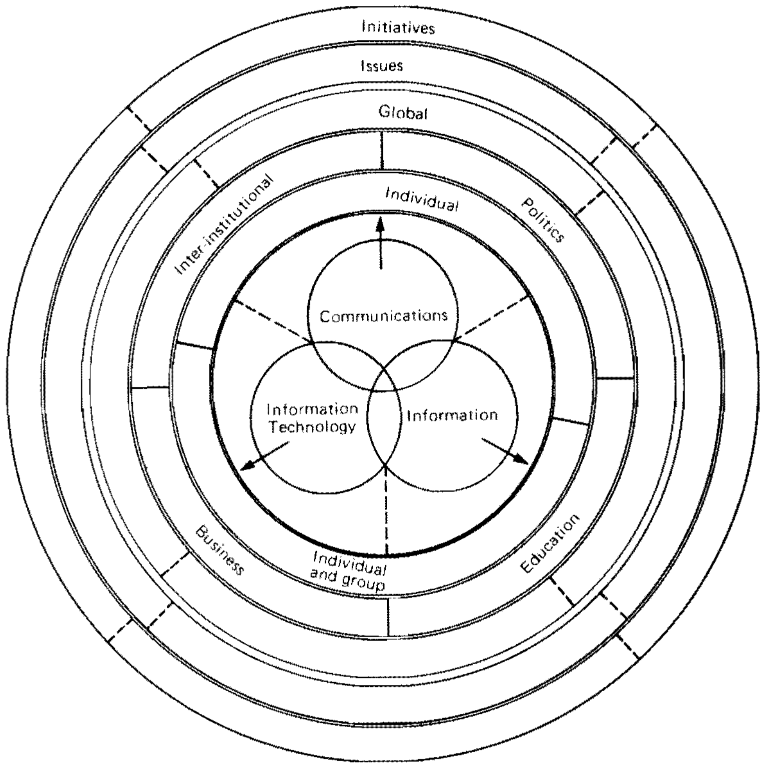


FIGURE 1.1 Potential impacts

comprise its environment. It should be envisaged as a multi-dimensional model in which the various rings around the central core may be separately rotated in different directions, to give different perspectives on the interaction and feedback of one set of impacts upon another. For example, we may go outwardly from *communications* to specific impacts on the *individual* and then to second order consequences of these impacts on the *political sector*; then we can go to their *global aspects* and to the outer rings of *possible issues and initiatives*. This could also lead us to examine other impact relationships indicated at this setting. By rotating the rings in various combinations, we may begin to view a number of other possibilities and interrelated impacts. Also, and importantly, we may start from external ring sets of *indicated initiatives*, go to *related issues*, and then move inwards to check their variously related *sector consequences*, down to *indicated adjustments*, *regulations*, etc., of the central core section.

Playing with such a model in this way suggests a useful corrective to the conventional deterministic way of considering the impacts of technologies on man. It suggests that we start by considering the ways in which human initiatives and decisions may deal with impending issues by impacting upon and changing the technological modes!

The Information Process and Technology

The information process as such is not new. All living species survive by using their senses to collect information about their environment. This information is processed and stored and subsequently translated into actions which are advantageous to their well-being and survival.

Human information processing is unique in the degree to which we have consciously elaborated and transmitted our personal information interactions through sophisticated symbol systems. We use a great variety of languages, both verbal and nonverbal. We have developed visual symbolic systems of very high orders of complexity, and powerful symbol manipulation codes through which we may order our information and use it to manipulate our environment in myriad ways.

The evolution of these modalities of human information processing has augmented and amplified our inter-personal and inter-environmental transactions to an awesome degree. Human society is essentially dependent upon its common symbolic systems both for its physical and psychosocial survival. They provide both its cohesion and its reality!

The agreed 'real world' we share is that consensual set of sensed perceptions which are filtered through our symbolic screens and given meaning by the symbols we use to express them and the language through which we communicate them to others. In this regard, we should always be aware of the fact that we are dealing with signals that change us, as well as those through which we change our environment.

It is important to distinguish the difference between information and knowledge. At its simplest, knowledge is ordered information, and there are many levels of such ordering.

> Information has far less structure than knowledge: much information in fact consists of isolated and unrelated facts. In general, unrelated information can be filed in a human memory only when it has become associated with some prior structure of understanding and has become part of a person's knowledge.[1]

This distinction may be somewhat blurred in practice, but it is important to keep it in mind; for we tend to use terms such as data, information and knowledge as interchangeable and, often, as synonymous with one another.

A further distinction which should be made early in any discussion of information and communications technologies is that between software and hardware. Human language and symbol systems—visual, tactile, aural and even olfactory—may be termed software, to distinguish them from the physical tool which they may use to store, process, and communicate information in various ways.

> Information technologies are therefore viewed not only as hardware developments but as software . . . as well as behavioral and social technologies . . . as part of important political, economic, cultural, and aesthetic dynamics . . . (as) dealing with a matter whose importance is pervasive to the extent that information is the essential commodity in both individual and social order and organization. (Adelson)

What is new and critical in human affairs is the recent externalisation of these software information processes into hardware tool systems. These perform various types of information processing—at greater speeds, with greater precision—and have the capacity to deal with greater quantities of information than the unaided human senses.

In Figure 1.2, we have separated some of the components of information technology. On the right hand are the 'organic' information software items; on the left hand, some elements of computer hardware. The central intersection of these two is what is more usually termed software, i.e. those specific languages and modes of translation for

converting organic information into forms which computers can deal with.

The advent of information technology has been termed the Second Industrial Revolution; its later developments and widened applications

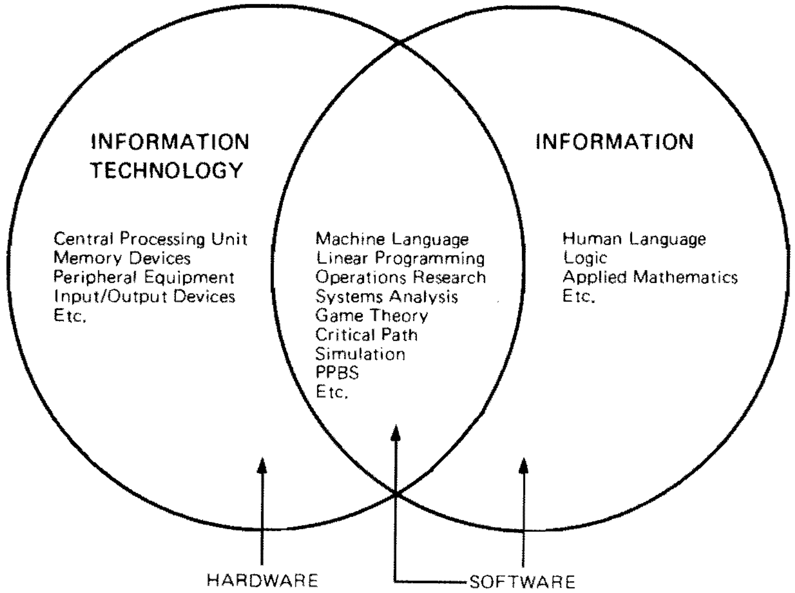


FIGURE 1.2 Information process

in automated process and controls have been called a Third Revolution. The core of these revolutionary transitions, and its most visible component, is electronic data processing via the computer.

Developments in Computer Technology

The core discipline of cybernetics (defined, oversimply, as the mechanisation of intellectual control processes) involves principles already operative in the First Industrial Revolution—like Watt's steam governor which was a self-regulating device. Cybernetics is, however, essentially productive of a new evolutionary stage in technology. As more directly the product of pure science, it embodies series of systematic principles that have much wider applicability than previous physical inventions in technology such as the steam engine or the automobile. Through these principles we can make super adding machines, or replace the sensory control of the worker on an assembly line by a more sensitive electro-mechanical device. But more significantly, via the same principles, we may replace many hierarchies of production, inventory and distribution controls in industry, handle extremely complex problems in airline scheduling, banking and credit systems, etc., monitor and control national economic operations and begin at the global level, via orbiting satellites, to oversee the manifold changes on and below the surface of the planet itself.

In the technology itself, the trends which we may specifically note are those which bear upon the speed, cost and size of computers and their extended systems (Table 1.1). It may be emphasised also, that the

TABLE 1.1

The effect of the new information technology on the speed and cost of multiplication.

From *Computers, Office Machines and the New Information Technology*, Carl Hegel, The Macmillan Company, London, 1969, p. 96

Means	*Time to do one multiplication*	*Cost of 125 million multiplications* $
Man	1 minute	12 500 000
Desk calculator	10 seconds	2 150 000
Harvard Mark I	1 second	850 000
ENIAC	10 milliseconds	12 800
Univac I	2 milliseconds	4 300
Univac 1103	500 microseconds	1 420
IBM 7094	25 microseconds	132
Stretch, IBM	2·5 microseconds	29
CDC 6600	0·3 microseconds	4

growth of, and in, computer technology itself is more rapid than in any other technological area. So swiftly has this growth occurred internally within the field that the development of new systems has been in generation terms, i.e. first, second and third generation systems, embodying radically new jumps in capability.

> In this area . . . three words can be used to describe the trends. They are: faster, smaller, and cheaper. . . . The physical size of computers of the same power has diminished by a factor of about 1000 since the start of industrial production in the early 1950s. Reliability has advanced about the same factor. At the same time, costs have dropped by a hundredfold and the potential capacity of systems has grown by about 1500 . . . Computer memories have become larger and speedier. It is possible to order from several manufacturers a memory which can best be described as approximately equivalent to a 300 000 volume library. This memory is, in physical size, about a six-foot cube . . . the cost of such a memory is about $\frac{1}{4}$ of what a building would cost to house an equivalent library. Furthermore, it is possible to get any specific piece of information by index, address, in roughly 0·3 of a second. (Glaser)

Some performance characteristics of computers (Figures 1.3 and 1.4) may be noted as follows:

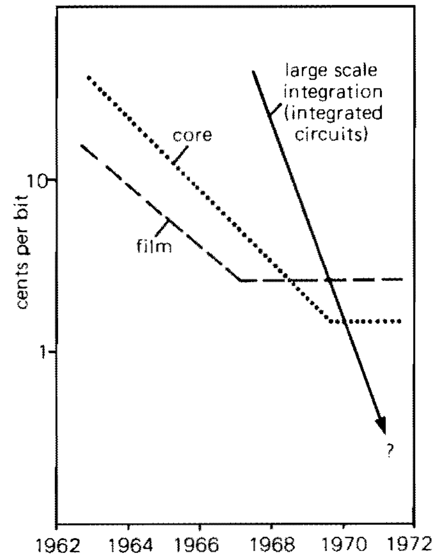


FIGURE 1.3 Developments in computer technology

Weight, Volume, Power Costs: In 1953 a computer weighed approximately 5000 pounds, occupied 300–400 cubic feet and required 40 kilowatts of power. Today's computer weighs approximately 50 pounds, is a thousand times smaller and uses 265% less power than the 1953 model.

In 1945 (at a labour cost of $1.00/hour and at rate of 16 operations per minute) it cost about $1000 to do a million operations on a keyboard and took at least a month. Today, computers can do a million operations for less than six cents. By 1975 this is estimated at less than $\frac{6}{10}$ cents.

The economic value of human operations is now reduced by a factor of 10, i.e. the value of uniquely human operations (thinking) at a computational level changed by a factor of 10.

(A) Storage Size: From 1955–65 the storage size of central processing computer unit (CPU) decreased by a factor of ten. During the next decade, fully integrated circuits begin to reduce this size by a factor of about 1000.

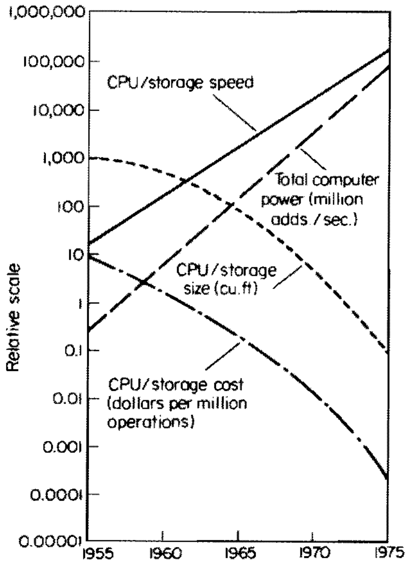


FIGURE 1.4 Computer performance

(B) Storage Speed: From 1955–65 internal speeds have increased by a factor of 200 and by 1975 such speeds are expected to again increase by this amount.

(C) Storage Cost: During the first decade of the computer the cost of performing one million operations decreased from $10.00 to about 5 cents. By 1975 it is estimated that this decrease will amount to an additional factor of about 300 (i.e., $\frac{1}{200}$ of 1955 values).

(D) Computer Power: The total installed computer power in the United States during 1955 had a capacity of about one-half million additions per second. By 1965 this capacity increased to 200 million per second and if growth rates are sustained through 1975, the increase in capability will be about 400-fold.[2]

Some more recent estimates[3] of such improvements in performance note that computing costs may fall further by a factor of 40 to 50 in another decade: storage technology is expected to improve dramatically via holographic techniques and magnetic bubble memories. Through the latter development by Bell Laboratories, it is suggested that the size of computers could be reduced two thousand-fold, to cigarette package dimensions, with a memory circuit about 5 microns in diameter having 10 to 100 times the capacity of present magnetic disc or drum storage.

Many of the indirect factors in cost reduction occur, of course, from the wider distribution and sharing of computer power through remote access terminals by growing numbers of users.

To these quantitative trends within computer technology may be added comparable qualitative changes in computer programming, i.e. in software. These changes are not only in the development of new programming languages and new programs themselves but in the ancillary range of operating instructions, more sophisticated systems analysis in general, and, importantly, in the development of automatic programming.

One analyst[4] suggests that as hardware costs decrease with increase in systems capability and sophistication, the critical cost factor will pass over into software—(see Figure 1.5 on hardware/software cost trends).

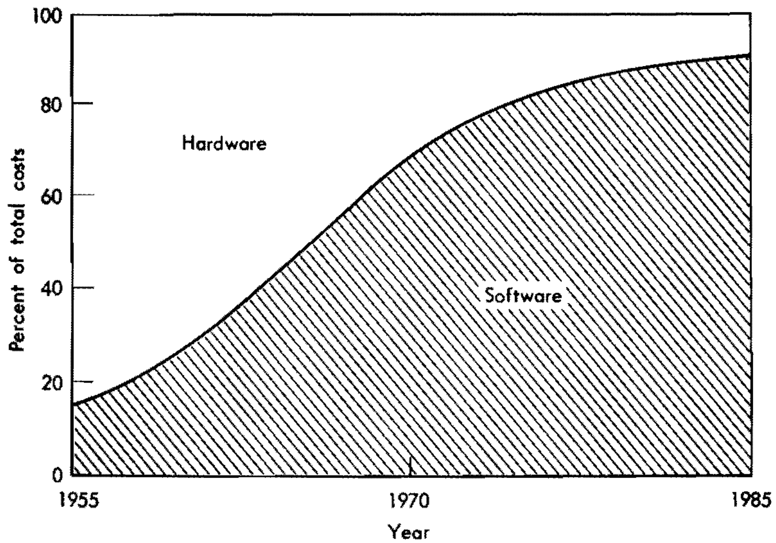


FIGURE 1.5 Hardware/software trends. (After Boehm, 1972, Rand Publication P–4947)

However, this will be somewhat balanced by the development in automatic programming mentioned above which will increase software productivity—(see Figure 1.6 on growth of automatic programming).

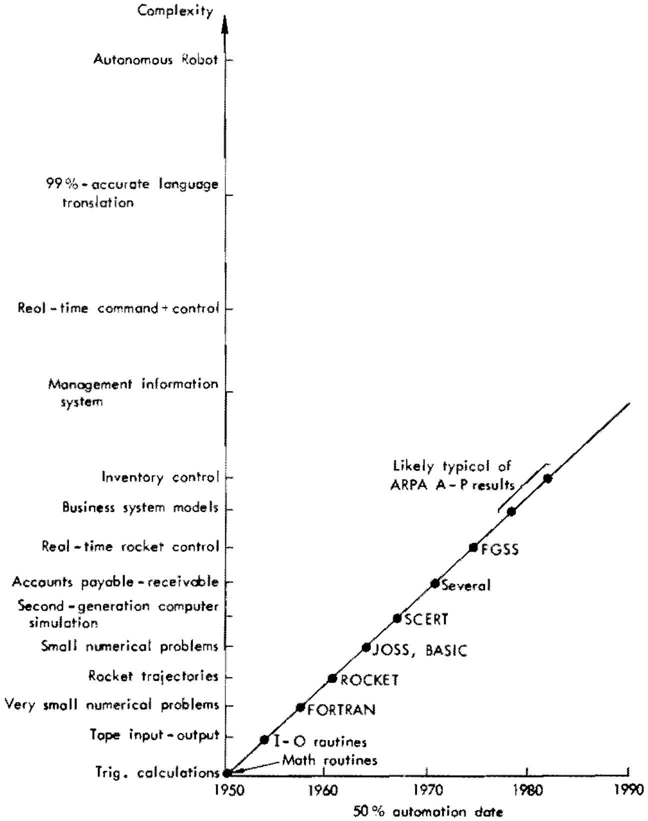


FIGURE 1.6 The growth of automatic programming. (After Boehm, 1972, Rand Publication P–4947)

There is a key, qualitative direction in the impact of computer development on individual human augmentation that is somewhat allied to automatic programming. This is the pre-programming of complex mathematical functions into the machine for routine use by those not explicitly skilled in these functions.

It has been noted that any form of recording makes possible the freezing of information in time. Specialised pre-programming provides a new version of this through which people can perform highly complex tasks without acquiring the detailed knowledge previously required for its performance. The most dramatic example of this is in the recent introduction of pocket electronic calculators which carry out many complex functions which their operators do not necessarily have to be

able to do themselves, for example, calculation of percentages, square roots and trigonometric functions.

We might refer to this as a way of 'canning specialisation', a process which started with the printing of books so that access to specialised expert knowledge was no longer confined to those who had laboriously acquired it through detailed skill training. The newer electronic modes of access may have considerable impact not only on the general educational process but also in many areas of professional activity where the practitioners are specifically trained to be highly specialised, walking information storage units!

A more generalised aspect of the qualitative impacts of computers lies with the rapid extension of their uses through many different areas of human activity, from the individual, community or local business levels to national and international levels.

The increase in the growth and interlinkage of large computer networks and their control capacities represents a significant change, not just in magnitude, but in the qualitatively pervasive impact on human society, as it begins to rely more and more on cybernetic control systems for many routine production, service and maintenance functions. Rather than machines dominating man, however, this growing interdependence begins to resemble his other relations with the natural environs. Symbiosis means the interdependence of two, or more, different organisms. Using the biological analogue, the relationship between machines and man is, in effect, a new symbiosis.

The most immediately visible aspect of this symbiosis has been the offloading into automated control of large areas of production, services, and information in advanced economies. Human role, and position, in society have become less and less determined by the part the person plays in the direct production of material goods, the organisation and transmission of routine information, and the performance of standard physical services. Roles and status are no longer so closely tied to occupational role and economically productive function when occupational roles change more frequently and routine human energies are less needed for production. Product wealth may be more easily generated with decreasing inputs of human energy, intervention, and decision making.

The less visible aspect of this new symbiosis is the extent to which automated systems begin to assume the routine operation of the 'basic metabolic' functions of industrial societies, in much the same way that the autonomic nervous system regulates the metabolism of the human organism. As well as automated factories, transport reservation and accommodation systems, continentally linked automatic inventory, dispatch and control systems, etc., large areas of our energy conversion and transmission networks are increasingly coming under automated control.

The point was reached recently when such metabolic type systems were potentially linked to the remote sensing, monitoring, and control capacities of orbiting satellites. This moves the extension of this new man/machine symbiosis abruptly to the planetary level.

The Critical Interaction

So far we have placed a major emphasis on computer technology *per se*, with communications technology as an obvious ancillary development. Communications technology has had, however, more than an ancillary role for some time. The electronic advances common to both developments mean that it is difficult within a discussion of this nature to refer wholly to one or the other technology in terms of socio-environmental impacts.

Figure 1.7, which shows the sequence of inventions in telecom-

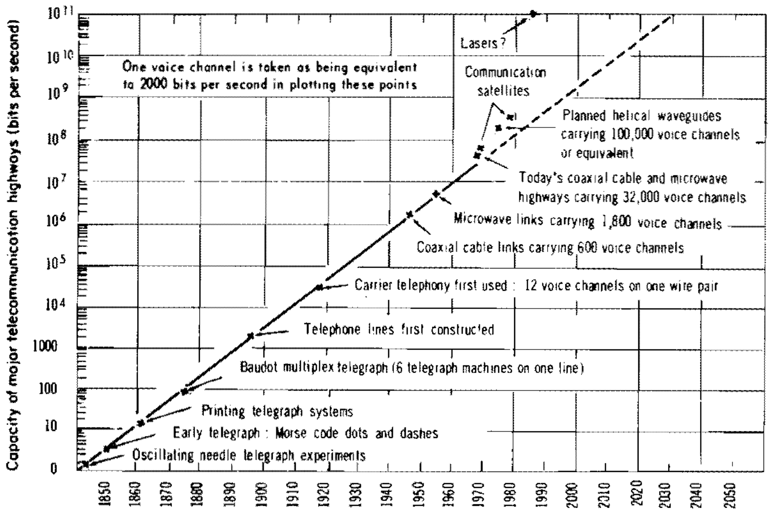


FIGURE 1.7 The sequence of inventions in telecommunications. (From, James Martin, *Future Developments in Telecommunications*, 1971)

munications, may be compared usefully with those presented earlier on future trends in computer technology.

The crucial development point in the swift growth and diffusion of our extended cybernetic systems has, indeed, been the convergent interaction of information and communications technologies. At the

simpler level, we may refer to the extension of information processing systems (including computers, but not exclusively so) using telecommunication links with a variety of input and output devices and time-sharing mechanisms. At the largest and most complex level we may use the example of a spacecraft mission, such as the moon landing, not only in terms of its internally extended cybernetic network, linking the individual astronauts and their craft's computers to central and remote control stations, but also to the simultaneous external participation in the various events of a world-wide audience.

Although Figure 1.8 gives only an approximate mapping of the

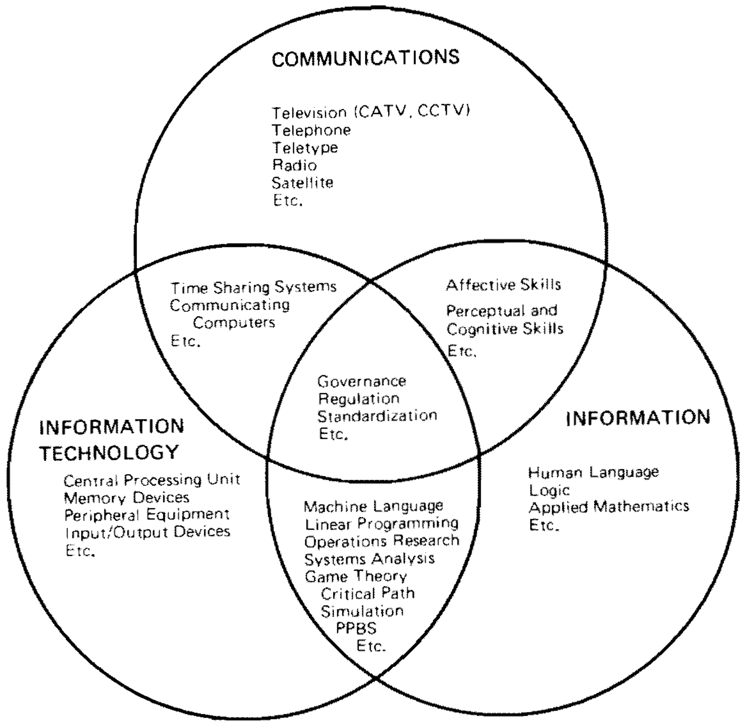
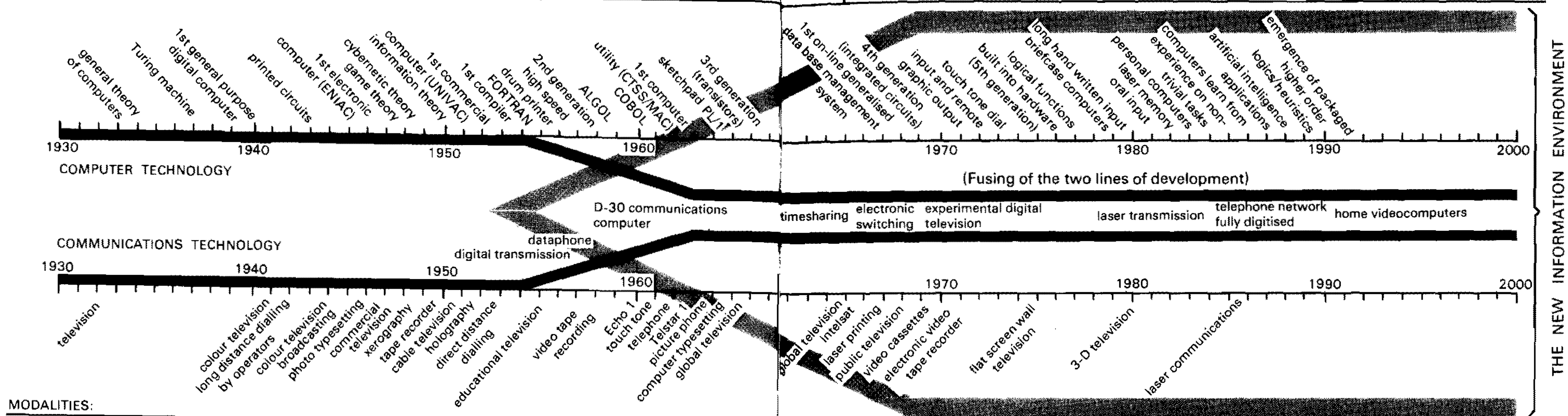


FIGURE 1.8 The interaction of information and communication technologies

various domains and intersections of information, communications and information technologies, it may serve to mark the significant shift which occurs when these areas are interwoven.

When we speak of the changing, or new, information environment, we refer in a more inclusive sense to those changes which are introduced by the electronic processing, reproduction and transmission of

COMPUTER COSTS	In 1945 it cost about $1,000 to do a million operations on a keyboard and took at least a month	In 1952 it cost about $300 to do a million operations and took ten minutes	In 1960 it cost $.75 to do a million operations and took a second	Computers can do a million operations for less than 6 cents in about 1/2 a second	Computers can do a million operations for 1/10 a cent in 1/10 a second	Between 1983 and 1997 computer cost to decrease by a factor of 100
COMPUTER SIZE		In 1954 computers have a speed of 2000 operations per second	From 1955–1965 internal speeds have increased by a factor of 200 Computer speed is up to 150,000 operations per second	From 1965–1975 internal speeds have increased by a factor of 200 Computer speeds are up to 4,000,000 operations per second		
COMPUTER SPEED		Computers have capacity of 40,000 characters	From 1955–1965 the physical size of the central processing unit decreased by a factor of 10 Computer capacity is up to 200,000 characters	By 1975 fully integrated circuits begin to reduce the size by a factor of about 100 Computer capacity is up to 15,000,000 characters		



MODALITIES:

ONE/ONE MODE OF COMMUNICATION	Modes of communication such as word-of-mouth, drums, smoke, relay runners and hand printed manuscripts were the major means of communication till the invention of the printing press.	Telephone and telegraph now provide individuals with access to a system which accommodates personalised, almost instantaneous communication over distance—with ease of access, wide availability and individual control over content.	Telephone networks and equipment become increasingly complex, dial telephone, direct distance dialling, picturephone. Dataphone, tele-xerox facsimile services extend this into other modalities.	Computer applications and communications satellites provide highly sophisticated nationally and internationally linked one-to-one communication networks possibilities.	Developing are audio/video tape cassette systems enabling highly personalised and potentially one-to-one communication—with wider access, availability and personal control over content.
ONE/MANY MODE OF COMMUNICATION	The introduction of the movable type printing press enhanced the possibilities of communication in a one-to-many print mode.	Mechanical improvements in techniques of printing resulted in proliferation of printed materials, e.g., books, newspapers, periodicals. Aural one-to-many communication was limited by range of unaided voice until the invention of the radio.	Radio and television provide high capacity information systems to the home and give a variety of choices of news, entertainment and other information. Range of choices of programmes but little direct control over content.	Print technology further augmented by the introduction of computer and laser technologies, e.g., computer typesetting and laser printing. Copying machines extend print technology into highly selective, personalised mode.	
MANY/MANY MODE OF COMMUNICATION			Sophistication of one-to-many and one-to-one modes convert these to potential many-to-many modes. News gathering through wire services and disseminating through newspapers, radio or television are examples.	Also note the recent growth of 'underground' services—news services and papers, journals, cinema, audio and video cassettes.	
MANY/ONE MODE OF COMMUNICATION			Increased efficiency and sophistication of media will make possible an expansion of existing modes into many-to-one situations. Community antenna television, video cassettes and electronic video tape recorders are emerging systems potentially capable of many new services.	Examples are more individually oriented information and educational services, specialised news services, remote marketing catalogue services, etc.	Potential but currently experimental and very limited are systems which may be used for polling, plebiscites and other interactive response situations.

FIGURE 1.9 A simplified chart of the developments, uses and impacts of information technology

information *including* the use of telephone, TV, microwave and satellite broadcasting, etc.

> We presuppose a vastly increased capability for the rapid, low cost electronic transmission of messages received as sound, image or electronic notation from anywhere to anywhere, integrated with the capability for cheap rapid storage, reproduction and computer programmed processing of messages. (Solo)

In combination with other technical developments, such as digitised transmission of graphic and audio inputs, image technology, holography, etc., this portends a further quantum jump in the uses and impacts of these vastly amplified capabilities. *It is precisely this convergence and interlinkage which create the radically new information environment into which we are now entering.*

Figure 1.9 shows many of the trends which we have referred to above, and identifies one important area of convergence and interlinkage with the digital transmission of information by telephone line in the mid 1950s. The range of communication modalities at the bottom of Figure 1.9 should also be considered in terms of the technical transition in computerised communications from presently expensive, sophisticated terminals towards high speed, low cost, television-type interactive facilities capable of wider unskilled use and mass distribution.

It should be noted in concluding this part of the discussion, that we are dealing with a phenomenon that is not unprecedented in socio-technical innovation. The characteristics of any one set of its technical aspects (Figure 1.10) considered in isolation may not enable us to predict the overall implications and potential consequences of their interactive combination. The behaviour of the whole is more than the sum of its parts!

We may underline, therefore, that it is not just the computer and its specific impacts with which we are centrally concerned but (a) the expansion and interlinkage of computer based systems and their extension into larger areas of automated control; (b) the convergence and relationship of such systems with concurrently developing communications technologies and (c) the ways in which these combine together to create a radically new information environment, whose major impacts will be felt most critically within the next time frame of five, ten, or twenty years.

We are faced, therefore, with the emergence of a new and powerful fusion of technological capabilities which not only potentially amplifies our capacities to deal with our social and physical environment

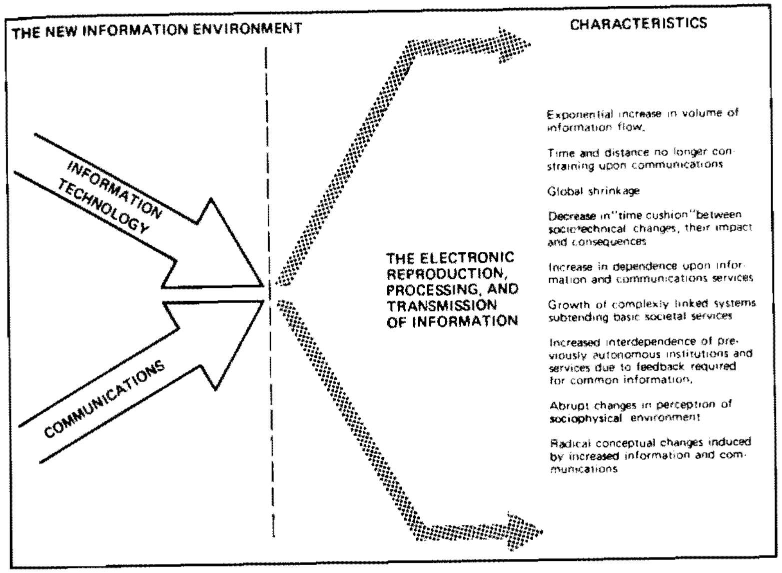


FIGURE 1.10 **Characteristics of the new information technology**

transactions but which by its function as screen, channel and multiplexer of information actually reshapes the information content and perception of society—in ways that our conventional wisdom and traditional institutional means may not be able to foresee, comprehend or effectively control.

As is not unusual in periods of rapid technological change, the full significance of such capabilities and possibilities may not be fully understood—even by those who have invented its components, organised its productive capacities and are responsible for its expansion—until it is too late and too costly to remedy such maldirections as may occur.