Communications Research Centre

DATA TERMINAL TECHNOLOGY - PRESENT AND FUTURE
VOL. II - TECHNOLOGY FORECASTING AND ASSESSMENT

BY

STAFF OF URWICK, CURRIE & PARTNERS LTD.

EDITED BY

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CRC REPORT NO. 1276-2

Department of Communications
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COMMUNICATIONS RESEARCH CENTRE

DEPARTMENT OF COMMUNICATIONS

CANADA

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(Communication Systems Research and Development Directorate)

(Technology and Systems Branch)

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The information contained in this report is essentially in the form prepared for the Communications Research Centre (CRC) by Urwick, Currie & Partners Ltd., with the exception of minor changes to report format and presentation as mutually arranged. This report represents the views and conclusions of Urwick, Currie & Partners Ltd. The publication of the report by the CRC does not necessarily imply the agreement of CRC with these views and conclusions.

PREFACE

The Department of Communications (DOC) of the Government of Canada includes under its mandate a number of broad objectives. One of these is to "promote the orderly evolution and growth of efficient and effective communication systems and services for Canada". Towards this general objective the Department has in recent years carried out studies directed specifically at fostering the optimum development of the Canadian computer/communications industry – including the communications common carriers, the manufacturing industry and the service industry.

Thus the DOC Computer/Communications Task Force under Dr. H.J. von Baeyer in its report "Branching Out"*, and in subsequent studies, addressed this question and presented a number of specific recommendations. In particular, the Task Force cited the proliferation of data communications terminals as posing a problem and proposed that research be conducted on the use of hardware to overcome problems of incompatibility. Furthermore, the Task Force stressed the desirability of an indigenous hardware supply role, particularly with regard to data terminal devices and computer peripherals. In addition to suggesting that component and systems research and development should be performed primarily by private industry, the Task Force indicated that government research laboratories also had a role to play in the research and development activity with the ultimate objective of appropriately transferring the results of this research activity to private industry. "Branching Out" also addressed other subsidiary but relevant points, such as the role of government in the field of standardization and the use of government procurement practices to support Canadian industry.

Responding to these objectives, recommendations and policy proposals, the Communications Research Centre (CRC) of the Department of Communications initiated a broad research and development program in the area of computer/communications. Specific projects covering many aspects of the subject were undertaken. One of these projects is the "Data Terminal Research and Development Project"**, of which the study reported herein is a part. The broad objective of this project is to explore the use of hardware development as a vehicle to support government policy with respect to computer/communications systems and services relevant to future Canadian requirements. In particular, a data communications terminal is to be developed to meet existing or near-term user needs. The data terminal design is to include features which will encourage the evolution of a coherent data communications system for Canada. The area selected for study is that of interactive data terminals, on the premise that its future impact on data communications is expected to be high, both in terms of number of terminals and terminal data traffic, and that this area represents a viable opportunity for Canadian activity in the overall field of computer/communications. Though the Data Terminal Project has restricted its initial research activities to interactive data terminals, the project results are generally applicable to a wider area, for example, to remote job entry systems, and to local computer peripheral devices.

The work on the Data Terminal Project during the fiscal year 1973/74 constituted a feasibility study phase, with work carried out primarily by means of industrial contracts. To establish feasibility and to define the project in greater detail for subsequent phases of the project (also to be carried out mainly by industrial contracts), a series of studies was commissioned by CRC as follows:

a) A survey and assessment of user requirements and relevant market factors;

b) A survey and assessment of research and development, manufacturing, and marketing and servicing capabilities of Canadian firms in the data terminal area;

c) A survey and assessment of the state-of-the-art of data terminal equipments;

d) A forecast and assessment to 1985 of the technologies relevant to the data terminal field; and

e) A study of standards and protocols relevant to data terminal technology and their influence on the design and use of data terminal equipment.

* *Branching Out, Report of the Canadian Computer/Communications Task Force, Department of Communications, Ottawa, May, 1972.*

** *Project initiated in April, 1973.*

This report summarizes the work carried out with respect to topic d) under the title "Technology Forecasting and Assessment". It should be noted that this report complements the report for the companion study under topic c) entitled "State-of-the-Art", the former being Volume II and the latter Volume I. The first section of this report is the EXECUTIVE SUMMARY which highlights the major findings of the study. The remaining sections and appendices cover the details of data gathering and data analysis undertaken for the study.

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ABSTRACT

A preliminary forecast and impact assessment of technologies related to interactive data terminals covering the period 1973 to 1985, approximately is presented. Primary emphasis is on a systematic, detailed identification of the hardware and software technologies underlying present and potential future terminal types and on carrying out an exploratory forecast of the technologies. Some performance and cost trends for the technologies are presented. Less emphasis is placed on the assessment of impact of these technologies on the evolution of specific data terminal types. Quantitative cost-effectiveness and cost-benefit techniques for assessment of relative attractiveness of competing terminal types are also outlined.*

1. EXECUTIVE SUMMARY

This study, one of a series commissioned by the Communications Research Centre to foster research into interactive terminals, constitutes a forecast and impact assessment of technologies related to the data terminal field. The work, carried out by Urwick, Currie & Partners, International Research and Technology Corporation, and associated consulting specialists, extended over a period of 5 months.

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* Study conducted from November, 1973 to March, 1974.

The project was of an exploratory nature concerned as much with developing a methodology for updating the forecast as with providing the initial projections.

In analysing the functions of an interactive terminal, the study team judged the man/machine interface to be one of its most important characteristics. The spectrum of possible terminal input/output modes thus formed the basis of the morphological analysis which was used to identify the key technologies to be examined.

During the work two further analytical techniques were introduced: the first was the use of a cross-impact matrix of technologies to indicate the strength and nature of the relationship between technologies; the second was the development of tentative "benchmark" tasks with which to evaluate different terminal types on a cost effective basis.

The forecasts and assessments constitute the collective opinions of the specialist members of the study team based on the information gathered during the study through interviews and literature searches, and their own knowledge and experience.

It is emphasized that the projections presented in the report should be regarded as first approximations only and should not be used as a basis for significant investments without a more detailed analysis.

1.1 GENERAL

The data terminal is an integral part of a complete interactive system involving a task, a user, a user interface, communications and processing. While to some extent there is a "technology push" to its development, there is also "pull" from the many other factors involved.

Much of the past evolution in terminal technology has been the result of forces external to the data terminal market. Examples would be the technologies of LSI/MOS*, CRT's, printers, keyboards, teletypewriters, etc., which were in demand for other markets. Analysis of past experience must be tempered by this as the notion of self-motivated evolution will emerge only as the field matures. The market pull aspect, however, was not emphasized to any extent in this study.

From the initial analysis made, the major trends with respect to costs and performance are:

a) The development of Large Scale Integration (LSI) is the primary driving force in determining the future nature of the electronic component of interactive terminals. This is expected to lead to dramatic improvements in the intelligence component of terminals, through cheaper memory and processors. It will also have an impact on costs and range of input and display devices, and communications related hardware.

b) As a result of LSI and cheap micro-processors, "intelligent terminals" will become increasingly inexpensive. This, in turn, will lead to increased demands and further production economies as new applications are discovered. (This is essentially what has happened with mini-calculators in the last five years.)

* Large Scale Integration of Metal Oxide Semi-conductor circuitry

c) Optical character recognition and voice recognition terminals will benefit from LSI and become more prevalent in the future as a result of the ever-increasing demand for high speed information transfer.

d) As the price of sensors, controllers and analog/digital cricuits are reduced through LSI, and as the amount of automation in industry increases, the demand for, and number of, digital process control terminals will increase.

e) In general, software and human factors will be more important than hardware technologies in influencing the future nature of the man-machine interface at the terminal. This is the area where most research needs to be done in the next decade. Examples of such areas of study might be: What are the changes in message form and frequency which accompany changes in the mode of communication (e.g. voice, typing, handwriting)? Do users experience "machine-paced" pressures similar to those met on assembly lines? How should instructional programs be formulated where human contact is absent?

1.2 INPUT DEVICES

a) Probably the most important aspect of interactive terminal design in the future will be the data entry problem; that is, how should terminals be designed so that users can communicate with them in the most effective, natural, and convenient way that is feasible from a total economic standpoint.

b) Within the time horizon of the study, i.e. present to 1985, the dominant entry mode will remain keyboard oriented, because of the keyboard's intrinsic versatility to perform effectively in many applications. Keyboards, however, will be predominantly solid state devices, rather than electromechanical. "Modular" type keyboards, which can be built up easily for particular applications, will become more commonplace. Human factors will become an increasingly important area of investigation for input devices in future years.

c) Solid state chips might also become the controlling components in electric typewriters, which would mean that typewriters could be converted into interactive terminals relatively easily.

d) In the area of visual input, Charge Coupled Devices (CCD's) will have a significant impact in reducing the cost of imaging devices. User identification by terminal, e.g. using a "retina print", for purposes of security and financial transactions will probably be available by the end of the decade.

e) Optical and magnetic scanning devices will be increasingly used in point of sale, facsimile and data gathering applications. Optical character recognition (OCR) will continue to grow as an input mechanism, as pattern recognition research improves the state of the art, and as advances in LSI and increased demand reduce costs. Technical advances are still needed to permit machine recognition of handwritten characters.

f) Limited speech recognition terminals will become more prevalent in the next decade for special purposes such as user identification, and air traffic control. As with OCR, major technological advances have to be made in the area before a general speech recognition terminal becomes feasible from either a technical or economic standpoint.

g) Movement Transducers will become important adjuncts to interactive terminals as LSI reduces the cost of analog/digital circuits, and convenience features become more important criteria for terminal selection.

h) Direct biological input such as brainwave, heart beat, or blood sugar level monitoring will become available for medical applications such as multiphasic screening in the next decade.

1.3 OUTPUT DEVICES

a) For limited character displays, Light Emitting Diodes (LED's) will capture the short term market to be challenged in a few years by Liquid Crystal Displays (LCD's), particularly in applications requiring larger characters. Moderate though not drastic cost reductions can be expected.

b) Cost reductions in hard copy printers will be slight. Impact printers will be replaced in many instances when high speed with minimum sound level (and single copies) is required, by printers utilizing thermographic, electrostatic, electromagnetic, ink jet or photographic technologies.

c) For applications requiring limited hard copy, alphanumeric CRT displays equipped with photographic facilities will replace the low-speed impact printer before 1980.

d) The greatest impact in output technologies in the next decade appears to be in the area of graphic or visual displays.

e) The number of facsimile transmission terminals will greatly increase in the next decade as they become faster as a result of bandwidth compression techniques and/or wider bandwith communications technologies such as waveguides and fiber optics.

f) The number of graphics terminals will increase greatly in the next decade as LSI reduces the cost of their processing and memory components, and new displays such as LCD's are developed which can use LSI fabrication techniques to reduce production costs, and as the demand for convenient information systems increases. A basic graphics terminal system is expected to sell for $5,000. or less in the next decade.

g) In soft graphic displays, CRT's will continue as the dominant technology employed, possibly being replaced by plasma or Liquid Crystal Displays by 1985.

h) Limited forms of speech synthesis for output will receive continued attention and the cost for this mode of output is expected to decrease as answerback drums and discs are reduced in price by a factor of two or three in the next decade. Methods of speech synthesis, permitting some degree of inflection, are expected.

1.4 SOFTWARE, COMMUNICATIONS AND PROCESSING DEVELOPMENTS

a) The cost of logic circuitry will go down faster than communication costs, tending to lead to more routine processing being done on a local level on intelligent terminals and mini-computers. But at the same time new applications like teleconferencing and large question answering systems will increase the need to be able to interface with a remote network. The intelligent terminal will benefit from both of these trends.

b) Communication costs will be reduced somewhat through bandwidth compression techniques and electronic switching, but the real reduction will come when new extremely wide band carriers like waveguides and optical fibers are implemented. The rate of their implementation will depend on the rate at which the demand for information transfer can increase to use enough of their capacity to make them cost effective.

c) The implementation of electronic switching will allow communication costs to be reduced through packet and message rather than "hardwired" switching. Electronic switching will also allow many users to be connected together at the same time, thus increasing the feasibility of teleconferencing applications.

d) Network intelligence will be considered more and more as a feasible alternative to certain types of terminal intelligence or remote processing. It will also be used as a means of providing common interconnection between devices of different codes and speeds.

e) Software will place heavier demands on the CPU and hence processing costs will rise over the next decade as more sophisticated system applications are programmed. This plus a decrease in terminal costs will result in terminal costs being a much smaller percentage of the total system costs. In choosing a terminal qualitative factors like reliability and convenience, and special features such as automatic dialers will be given more weight than currently.

f) Machine intelligence research will be very important to developing better information systems in the future. It will also be important in perfecting pattern recognition systems and programs that converse in natural language, albeit with restricted vocabulary and syntax.

g) The demand for natural language processing will increase as more novices interact with the computer. Programs that communicate in a limited vocabulary of words from a natural language, e.g. English, French, will become commercially available in the next decade.

h) General speech and handwriting recognition will be an important area of research in the next decade, but these capabilities will not be commercially available during this time frame. Programs which recognize by contextual cues will be developed to supplement terminal feature extraction and classification.

1.5 METHODOLOGY FOR TECHNOLOGY FORECASTING

A number of techniques were used during the study. The experience obtained can be summarized as follows:

a) Forecasting

Because of the dynamic nature of developments in the technologies involved, a formal statistical analysis and projection of historical data was considered infeasible. In virtually all cases where projections have been made, they represent collective judgments based on an evaluation of existing trends.

b) Morphological Analysis

This technique was most helpful in identifying input and output mode combinations which are not now in common use but which may prove to be in demand in the future.

c) Cross Impact Analysis

This technique to assess the impact of one technology on others was used as a guide only in assessing the relationships and relative importance of the technologies. While this proved to be of some use for the technologies selected, it was evident that considerable effort must be expended in the rating process if the full potential of this method is to be realized.

d) Cost Effectiveness Analysis

Since it was evident that terminals could not be compared on the basis of their costs alone, given differences in convenience features and modes, some other framework for evaluation was sought. While the concepts for cost effectiveness analysis outlined in this report are rudimentary in nature, we believe that a more detailed development of the underlying logic could lead to a most useful tool for assessing trends in the evolution of interactive terminals.

2. INTRODUCTION

2.1 STUDY EMPHASIS AND OBJECTIVES

The primary emphasis of this study was recognized to be a technology forecast of an exploratory nature (as contrasted with a normative approach) concerning the various technologies underlying interactive data terminal devices. Thus relatively less emphasis was placed on detailed assessment of specific impacts of the technologies on the evolution of data terminal products. Recognizing also that the study was conducted in a climate of uncertainty in an area undergoing rapid change, the study team worked toward the following:

a) the identification of those technologies which can affect terminal design, manufacture and demand.

b) the forecasting of the timing of developments in these technologies and their impact on terminal component costs and performance within a ten to fifteen year time horizon.

c) the forecasting of the consequent effect of these technologies on the evolution of the terminal itself within this time period.

d) the development of a methodology which could be used by the Communications Research Centre to continue forecasting in the above areas.

e) the identification of opportunities for Canadian government activity and support and the development of recommendations for further action in areas which merit additional investigation.

These objectives have all been addressed and the results are given in this report.

2.2 SCOPE OF THE STUDY

As to the scope and general expectations for the study, it was recognized that technologies, computer usage and the market for terminals have all experienced an extremely rapid growth in the last 25 years (particularly since the late 60's when remote processing became commercially available), and that hard data on trends and relationships in cost and performance in the many areas concerned was sparse. Therefore, without a major amount of original research, any forecasting of this nature could realistically attempt to do only three things:

a) Set down the views currently held by experts regarding the timing and nature of developments in relevant technologies,

b) Try to identify those factors which will be key in motivating such developments - chiefly from a "technological push" standpoint but also from the "market pull" and other aspects, and

c) Having identified prime areas of interest suggest how further research and work effort could be applied beneficially.

The study was a joint effort by Urwick, Currie, and International Research and Technology Corporation carried out over a period of 5 months. The members of the team are listed in Appendix A.

While the study consisted of 5 phases:

a) Concept development,
b) Identification of relevant technologies,
c) Data and information gathering,
d) Forecasting, and
e) Impact assessment,

these were not entirely separate and distinguishable owing to the companion State-of-the-Art study which gave an early start to the formation of the data base for this study.

Phases a) and b) (concept development and identification of relevant technologies) absorbed perhaps 25% of the total work effort since a sound foundation was needed for the morphological analysis, the approach used to identify the technologies to be studied. The definition of an interactive terminal and the framework or taxonomy developed are discussed at greater length in Section 4.

Information was obtained from a number of sources. In addition to the interviews conducted by various members of the study team (see Appendix B), many literature references were consulted (see Sections 9 and 10.)

The forecasts themselves and the impact assessment constitute the collective opinions of the specialist members of the study team based on the information gathered during the study, augmented by their own knowledge and experience.

In the immediately following sections we discuss: Base for Technology Forecasting, Methodology, Hardware Technology Forecasts, Software and Human factors trends, Impact Assessment, and Conclusions and Recommendations.

The appendices include technical references and the mathematical formulation for the cost effectiveness methodology summarized in the Methodology Section.

3. BASE FOR TECHNOLOGY FORECASTING

As societies move from industrial to "post-industrial" or "service-oriented" economies, one can expect the amount of information transfer in society to greatly increase (References 1, 2 and 3). The results of a recent study by SRI indicate that the amount of data and video transfer per year will increase by two orders of magnitude between 1970 and 1990. (See Fig. 3.1). This increase in information transfer would seem to logically imply a parallel increase in the demand for interactive terminals. Indeed, industry projections like those in Fig. 3.2 indicate a very rapid increase in the number of terminals: an order of magnitude between 1970 and 1980. [See also additional relevant projections in the literature, viz. telephone coupled terminals (Reference 10), credit transactions (Reference 4 and Reference 11), computer usage (References 12, 13, 14, 16) and new service requirements (References 4, 10, 15, 17).]

It was understood that primary focus in this study was not to explore the "market pull" factors such as new services and applications which are creating a demand for interactive terminals, but rather the "technology push" factors such as cost and performance trends in component technologies, which, given this new demand, will significantly influence the resulting mix of terminal types.

The point is made strongly, however, that there are many considerations and factors influencing the evolution of data terminals *per se* and we believe that it is useful to comment on these first in order to put subsequent sections in a practical framework.

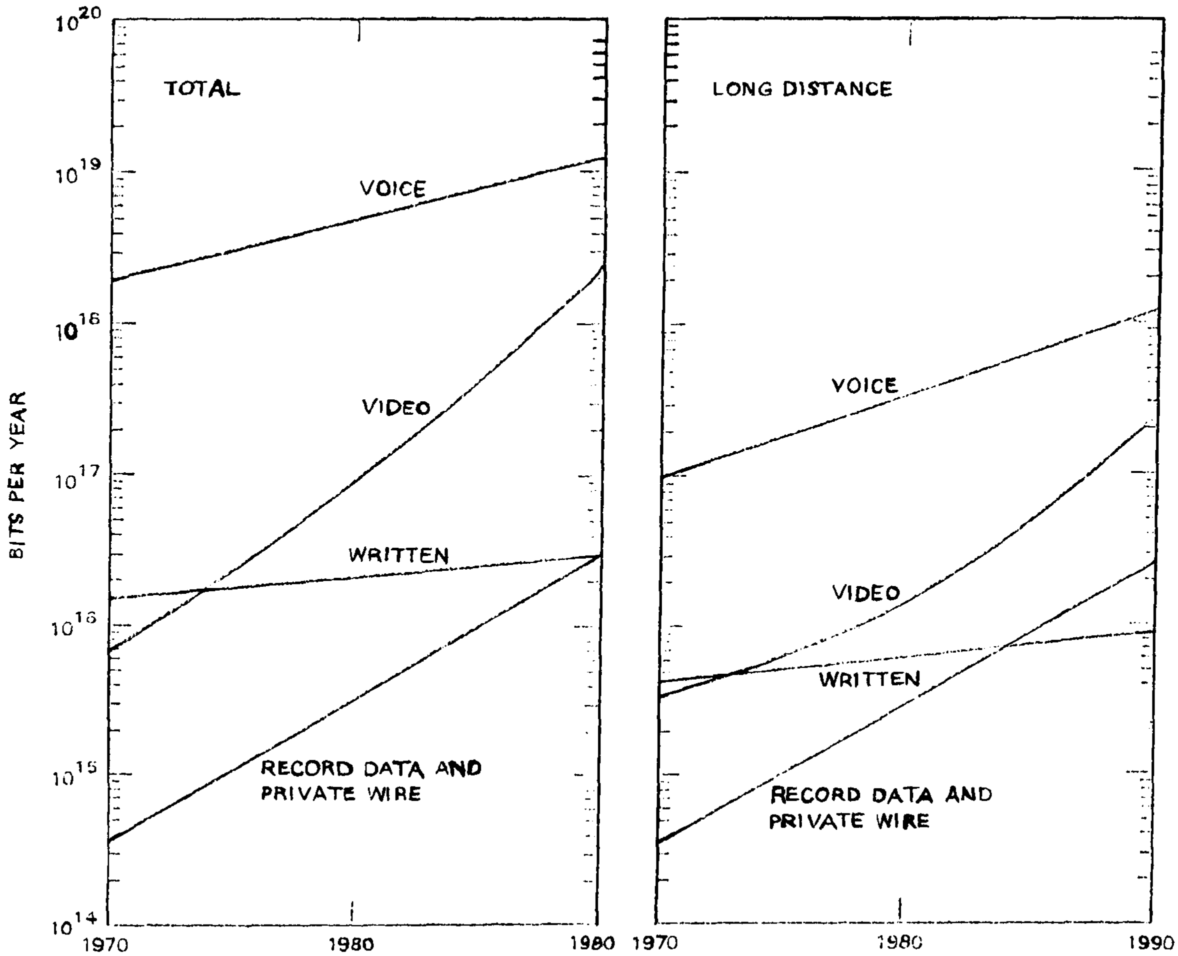


Figure 3.1

Projected Information Transfer Volume
in the United States, 1970-1990

Source: Reference 4

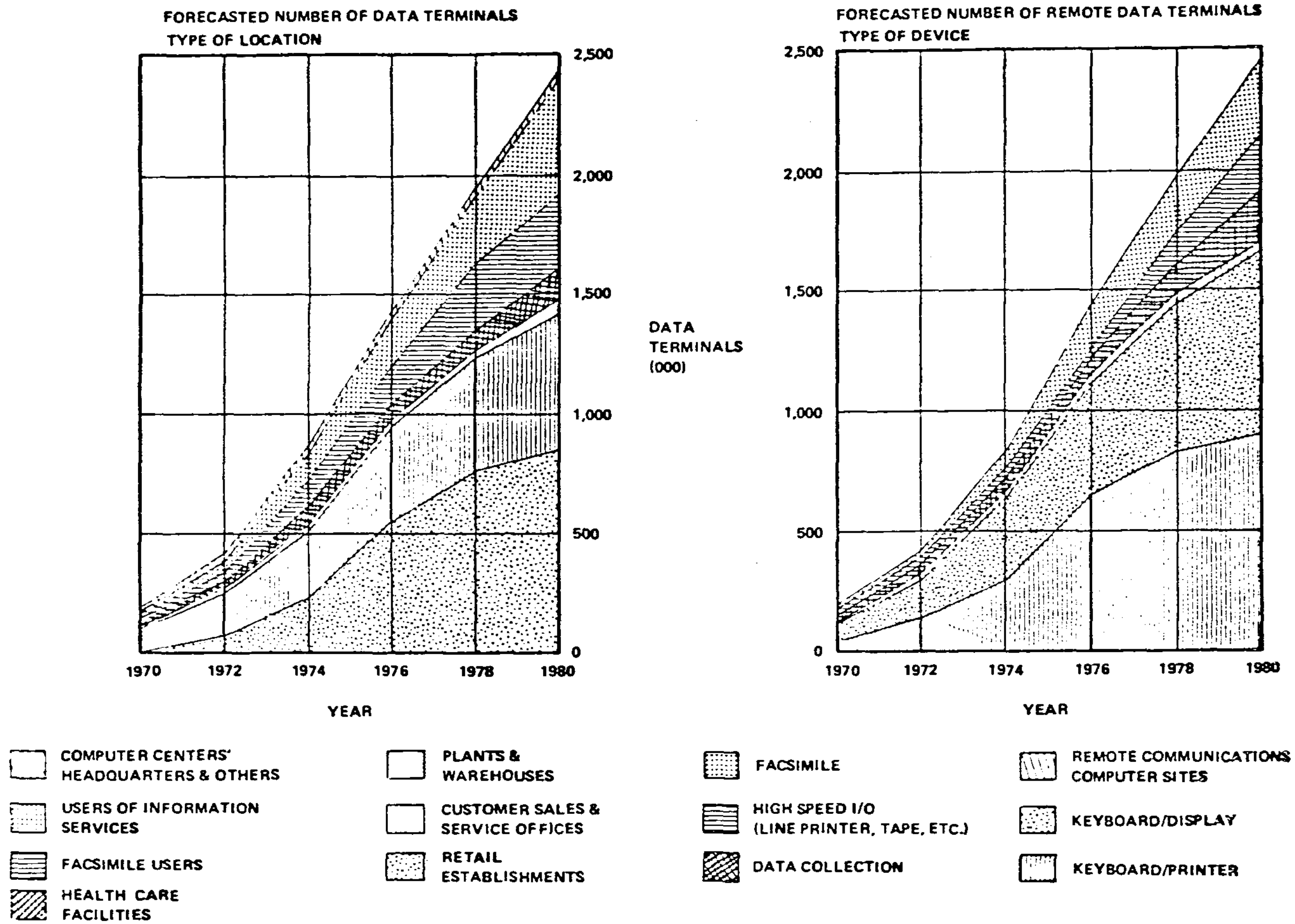


Figure 3.2

FORECASTED NUMBER OF TERMINALS

for the United States

Source: Reference 5

3.1 PAST EVOLUTION AND THE STATE-OF-THE-ART

In the companion study, Vol. I, State-of-the-Art, a methodical review was made of the technologies currently used in the major interactive data terminal types and of the trends that seem to exist.

While we refer the reader to Volume I for specific comments with respect to individual technology areas, we believe that there are at least three observations of a more general nature which are relevant to this study:

a) Technology (hardware) is identified with the component or sub-assembly rather than the complete data terminal,
b) Past technology development incorporated in data terminals has been influenced more by related fields or other markets than by the data terminal market itself, and
c) There is often a considerable time lag (5-8 years) between the initial appearance of a technology and its incorporation and/or predominance in commercial products.

As one might suspect, therefore, product evolution is not just a simple market pull or technology push relationship.

3.2 THE DATA TERMINAL AS A SYSTEM

It was generally agreed by the study team that the interactive data terminal is evolving in a very complex environment. This is illustrated in Fig. 3.3 which shows how the terminal is part of an overall system in which all parts are evolving rapidly.

While technology directly involved in data terminal components will play a major role in the evolution particularly in the shorter term, it is believed that more and more influence will come from factors related to the user, processing, and communications as well as forces quite external to the overall system. This suggests that equal attention must be given to human engineering and task analysis as well as to languages, software and economic trends.

From Fig. 3.3 we see that within each system component there are levels of competition influencing the relative position of that component in the system. For example, the development of digital switching will impact communications, which in turn can alter the relative position of communications in the equation.

In the task environment perhaps the most significant observation that can be made is how little is actually known about the influence relationships here, such as the conditioning or skills of the user (e.g. the doctor or the clerk).

Clearly, detailed examination of the full environment is beyond the scope of this study. It should be useful, however, to relate the interactive data terminal to the ranges of influences that exist and indicate the extent to which these factors are considered in the analyses that have been made.

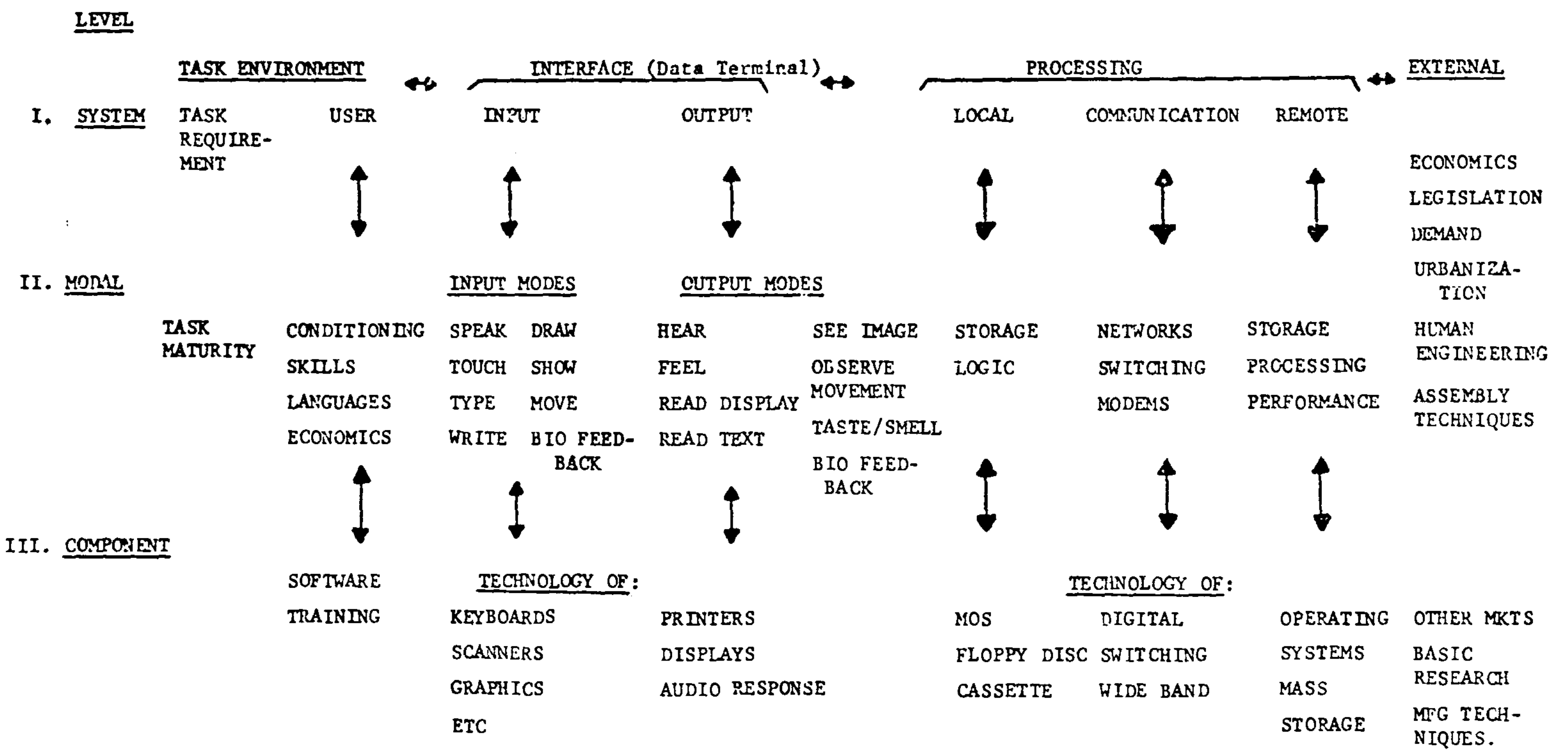


Figure 3.3

Hierarchy of Influence Relationships

(In projecting terminal profiles)

The Interactive System

(The data terminal is an integral part of a complete interactive system with at least three levels of influence.)

3.3 PRACTICAL MOTIVATING AND DEMOTIVATING FACTORS

While our study did not focus on the detailed phases of technology evolution, we believe that a number of comments made during interviews and discussions are relevant and worth recording. We list these with no significance to be attached to the order:

3.3.1 Resistance to Replacement

For a new technology to be accepted in an existing market, it must possess certain characteristics. For example, as a replacement technology, it must be less expensive, have superior performance and be easy to produce,utilizing mass production techniques.

The difficulty in achieving these parameters with new technologies is illustrated by the continuing dominance of the CRT display as an output device in interactive terminals despite the promise and advantages of new techniques.

3.3.2 Task Justification

Technology may be readily available to supply a new service but the need must be recognized and the service proven to be cost effective or cost justified when applied. (An example might be the possible use of slow scan T.V. terminals at international border crossings on-line to a passport photobank.) Because of the relatively recent development of interactive systems, the selection of terminals and software has often been performed on an *ad hoc* basis. As the field matures, it is expected that: more cost effectiveness studies will be performed, the costs themselves will become stabilized, and these new technologies will be given appropriate recognition.

3.3.3 Network Compatibility

Related fields, such as communications networks, play an important role in the development of interactive terminal technology. As an example, the slow penetration of the facsimile terminal is due, in part, to the machine having to be used over standard voice networks which in many ways are limiting because of billing algorithms and bandwidth. This puts facsimile at an economic disadvantage when compared to teletypewriters which operate on specially designed networks (e.g. TWX, TELEX) with appropriate billing algorithms. The end result, of course, is a "hold back" in the technology because of the limited market acceptance. Thus, facsimile could play a large part in future interactive terminals but this would be dependent upon the availability of a suitable network as well as the development of a less expensive facsimile terminal utilizing digital rather than analog techniques. (Such terminals now cost in excess of $15,000.).

3.3.4 Configuration Development

Interactive data terminals are basically a combination of input and output components interfacing with the computer through a communications link. As shown in Fig. 4.4, Section 4, the presently used combinations of input and output are limited. Moreover, for all practical purposes, the keyboard/printer and keyboard/CRT are the only terminals which have had a deep market penetration. Where the technology exists, many other combinations, shown in Fig. 4.5, Section 4 are possible configurations for future terminals. Their successful development will depend on a number of factors:

a) Market size,
b) Production costs,
c) Communications requirements,
d) Operating costs,
e) Operator skill required, and
f) Reliability.

These and many other practical considerations determine whether a particular interactive terminal will sell or not. With volume sales, the technology probably evolves rapidly; without volume sales, technology development tends to be slow.

3.3.5 Communication Costs

It has been mentioned previously that communication costs and networks have a definite effect on the development of interactive terminals.

The present networks existing in North America are much more suitable for alphanumeric stop/start telegraphic techniques than they are for, say, high speed digital facsimile or graphic information. The exception to this is TCTS' Dataroute and CN/CP's Infodat in Canada, although as yet these networks are primarily digital point-to-point links and do not provide a true switched network capability.

As both the common carriers and private organizations get more involved in "packet switching" and "value added networks" the interactive terminal designers will be able to utilize the various input/output technologies without the penalty of higher communication costs. For example, a terminal operating at 300 baud could communicate with a 110 baud terminal and the network would provide the necessary buffering.

3.3.6 Forms of Intelligence

Intelligence in a terminal generally relates to the computing or processing capability required for a user task, and in recent years the intelligent terminal has gained a certain amount of market penetration. The advances in processor design, mainly in the large scale integration (LSI) MOS technology, have made possible the design of micro-computers which are assembled integral with the interactive terminal to provide what is really a terminal plus a computer.

If this trend continues it would appear that the intelligent terminal concept would have a definite edge over other ways of providing processing, especially where communication costs are significant. However, it must be borne in mind that intelligence associated with terminals can be provided in a number of ways, all of which have to be considered in order to assess the future technology.

3.3.6.1 Local Intelligence

Local intelligence is the provision of a micro-processor within the terminal to provide local computing ability, or even such features as buffering and storage to allow more efficient use of the communications facility.
For example, an operator can input data by the "hunt and peck" method in an off-line mode, edit and store the information internally, and then transmit "on-line" at a high speed, thus reducing line costs as a result of the shorter "connect" time.

3.3.6.2 Remote Intelligence

This method of providing processing capability to the terminal from a remote CPU is the basis of interactive teleprocessing systems and multi-station key to disc systems. There are advantages to this approach such as central software libraries, common data bases, etc. but there are also the disadvantages of communication line costs (if outside the toll free areas), and total network failure should the central processor fail.

3.3.6.3 Network Intelligence

Another method of providing computing ability at the terminal is to make use of an "intelligent" network. This method is not widely used at present, but certainly has the potential for major market penetration. A so-called intelligent network incorporates digital message switching techniques (as opposed to step or crossbar switches) under the control of a "central office" computer. In addition to routing messages the network switching computer is also utilized to detect terminal code and speed, perform error detection and correction and also provide what is generally termed pre-processing capability. The end result is to give the "dumb" terminal a certain amount of apparent intelligence, allowing the operator to perform tasks and communicate with other terminals, for example, which would not be possible without the network intelligence.

3.3.7 Regulatory Concerns

As previously mentioned, communication networks will play a role in determining the interactive terminal of the future. In turn, any regulation by government agencies of network offerings will also affect the end product.

In Canada, there have been numerous studies associated with computer communications policy, but as yet no firm policy decisions have been legislated. Fundamental policies such as whether or not computer service organizations will be allowed to offer various network services, such as network switching, utilizing basic transmission facilities leased from the common carriers, will also be instrumental in the advance of various terminal technologies.

Consider, for example, a transaction type message terminal, capable of transmitting and receiving short messages up to fifty words at high speed. If the regulated network is based on a cost per minute algorithm with a one minute minimum, there would be no incentive to pursue the type of technology required for this terminal. If, however, the network is versatile and either unregulated, or regulated in such a way that would allow a user to be billed on a "per transaction" basis, the terminal becomes economically viable to potential customers. In turn the technological research moves ahead faster, lowering the costs of the terminal for an additional economic advantage.

To assess the potential of different configurations making up an interactive data terminal, it is, of course, first necessary to define the market or task for which they would be competing. This has been illustrated within this study by setting up benchmarks against which various terminal configurations might be tested.

Evaluation is an iterative process. If, in the first round of analysis, it is indicated that there is very little chance for displacement of an existing configuration by a new configuration, then the decision is clear. If, however, the first round indicates improvement or even reasonable competition, then the impact of this on technology development should be re-examined, in case a large assured market could accelerate the rate of change in the cost or performance curves which, in turn, could make benchmark comparison more favourable for the new product.

4. METHODOLOGY

As acknowledged in the original work statement, technological forecasting is a relatively new and important activity which has particular impact in a high technology industry such as terminal manufacturing. One of the key objectives of the study was to gain Canadian experience and knowledge of the applicable methodologies. This section, therefore, contains a description of the methodology used and documentation of the steps that were followed during the project so that they may be used for future forecasts.

4.1 FORMULATING THE PROBLEM

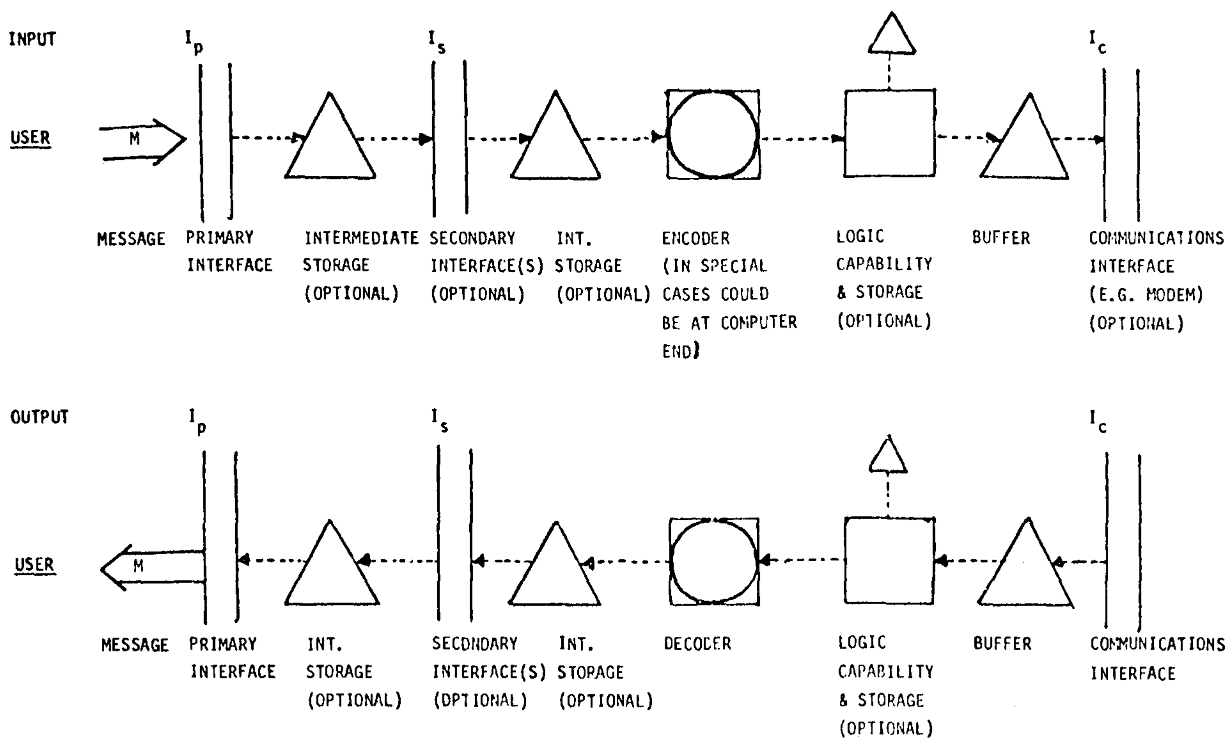
Since the study team's research was unable to find previous technology forecasts of a comprehensive nature specifically devoted to data terminals, it was necessary to lay the groundwork with some care. First, the major factors influencing terminal development were sought. At the same time, a taxonomy was developed which would highlight the key characteristics of an interactive terminal and hence lead to the identification of all relevant technologies regardless of whether or not they are now recognized as such.

Considerable time and effort was applied to this phase. A number of interviews were conducted with selected specialists in the field, and "brain storming" sessions were arranged with university and industry representatives. During this process a vast collection of literature was accumulated.

4.2 DEFINITION OF AN INTERACTIVE TERMINAL

Since this study deals with "interactive" terminals, it was necessary at the outset to reach agreement on the definition of such a terminal. A functional pictorial definition was chosen to emphasize the role of the various components associated with the terminal. This is illustrated in Fig. 4.1. (It should be noted that various intermediate input devices such as mark sense readers are admitted. In this case, it assumed that the mark sense card constitutes intermediate storage of the information.)

The man/machine interface was identified as the key determinant for the classification of terminal types and this is discussed more fully later in this Section under Morphological Analysis.



Functional Representation of an Interactive Terminal

Figure 4.1

4.3 MORPHOLOGICAL ANALYSIS

The descriptive label "morphological method" was coined by Fritz Zwicky, the famous astrophysicist and jet engine pioneer, to describe a technique for identifying, indexing, counting and parametrizing the collection of all possible devices to achieve a specified functional capability. Though not so used by its progenitor, the method can be used for identifying and counting all possible means to a given end at any level of abstraction or aggregation (Reference 18).

Whereas an extrapolation assumes a series of incremental changes in a certain known direction, the morphological approach has nothing to say about the rate or direction of invention but systematically catalogues all possible opportunities for invention in a field.

As indicated earlier, for purposes of this study, the interactive terminal has been viewed as "a real time interface through which users communicate with a machine or other users via a machine". Fig. 4.2 shows how an interactive terminal and its user act as a system to link a "task environment" to remote data processing and storage resources. As shown in Fig. 4.3 the technology components of a terminal may be classified into three categories:

1) User-Oriented Communication Components
    a) User Input Devices
    b) User Output Devices
2) Local Processing and Storage Technologies
    a) Internal Processing Structure
    b) Machine-Oriented Communication
3) Network-Related Technologies
    a) Hardware
    b) Software

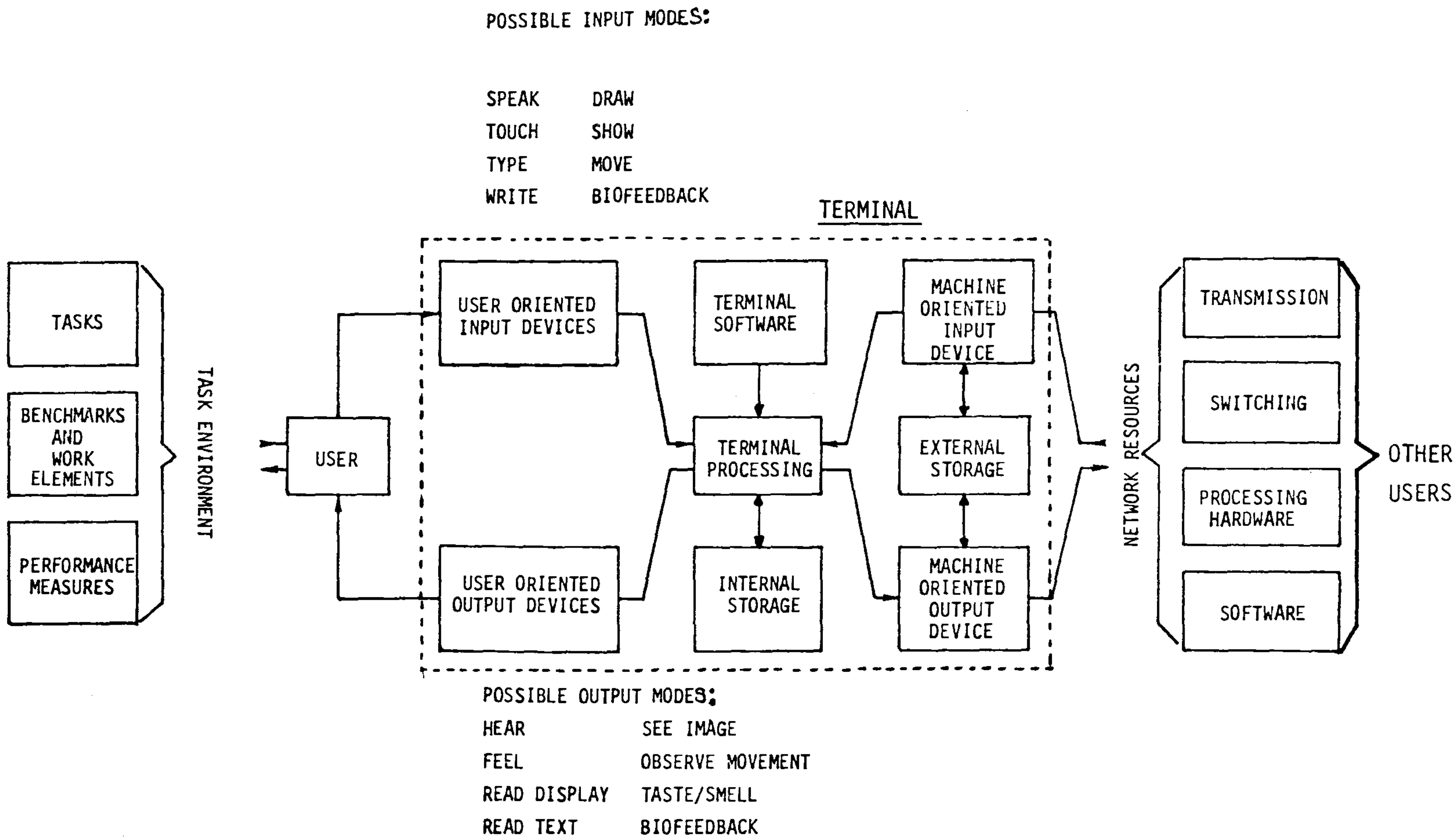


Figure 4.2 - The Man-Machine Terminal System as an Interface Between a Task Environment and Remote Data Processing and Storage Resources.

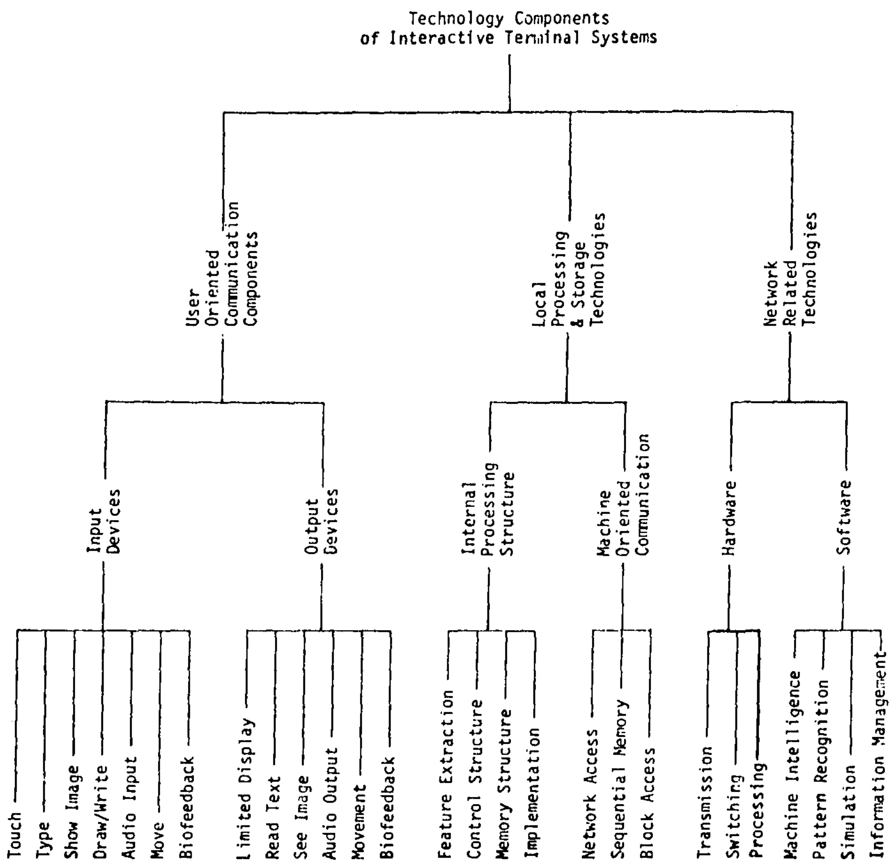


Figure 4.3
Morphological Tree of Component
Technologies for Interactive Terminals

This study has focused on the first category (user-oriented devices) because the man-machine interface, rather than hardware configuration, seems to be the crucial determinant of future terminal design. One reason for this is that men and machines process information very differently; a computer is a serial processor with very rapid internal transfer speeds, while the human nervous system is more nearly a parallel processor with relatively low internal speeds.

It is thus no surprise that a bottleneck arises at the interface of two such different systems (Reference 6). Also, much effort has been devoted to hardware problems in the past and many have been solved, but the man-machine interface problem has been neglected because hardware-oriented designers did not at first perceive it as a problem and human factor engineers and psychologists are just now beginning to get involved (Reference 7).

The morphological approach consists of the following four steps (Reference 18):

1) State problem to be solved, or the functional capability desired, as precisely as possible;
2) Identify the characteristic parameters;
3) Divide each parameter into distinguishable cases;
4) Devise some way of analyzing the performance of various combinations.

In line with this approach, a taxonomy of interactive terminals has been defined in terms of the input and output modes by which a user could communicate with a terminal. These then are the "characteristic parameters" (Step 2) and are divided (Step 3) into the "cases" shown on the two axes in Fig. 4.4. By combining input and output modes, a generic description of existing or potential terminals can be developed. For example, terminals in widespread use today are classified by I/O combinations in the matrix in Fig. 4.4. Note that very few of the possible I/O combinations are utilized.

There are, however, many new possibilities in experimental stages or on the horizon, many of which are shown in Fig. 4.5. This report attempts to be exhaustive in the sense that it evaluates the technologies relevant to each possible input or output mode - though no claim is made that all the technologies relevant to a given mode have been investigated nor each identified technology been studied to the depth that a completely definitive assessment would seem to require.

Step 4, the selection of a performance measure, is partially accomplished by the cost benefit methodology described later in this Section.

The relevant technologies for categories two and three (Processing and Network Related) were represented in morphological trees as in category one, but no concerted attempt was made to identify potential unknown technologies.

Moderate emphasis was placed on technologies in the second category (local processing and storage technologies) because it was felt that significant hardware improvement and cost reduction may be realized in this area in the next decade

OUTPUT

INPUT	HEAR	FEEL	READ DISPLAY	READ TEXT	SEE IMAGE	OBSERVE MOVEMENT	TASTE/ SMELL	BIO- FEEDBACK
SPEAK	Telephone							
TOUCH	Touchtone - Answer back drum		Point of Sale					
TYPE				"Glass Teletype" Keyboard/ Printer	Keyboard/CRT			
WRITE					Facsimile			
DRAW					Light pen - CRT			
SHOW					Closed Circuit TV			
MOVE					Joystick - CRT			
BIO- FEEDBACK								

Figure 4.4 - Established Types of Interactive Terminals

	OUTPUT							
INPUT	HEAR	FEEL	READ DISPLAY	READ TEXT	SEE IMAGE	OBSERVE MOVEMENT	TASTE/ SMELL	BIO-FEEDBACK
SPEAK			Voice Stress Analyzer Voice Identification	Speech Recognition	Vocoder	Verbal Robot Control		Deaf, Mute Speech Training
TOUCH		Touch tone - Skin Tapper	Polling Device				Choose Scent	Electric Stimulation of Muscles/ Nervous System
TYPE	Speech Synthesizer Music Synthesizer	Braille Printer			Slide, Microfilm selector	LOGO Turtle Robot	Smell/Taste Synthesizer	Remotely Administered Injections
WRITE				Handwriting Recognition				
DRAW		Picture project on person's back		Computer-Aided Graphics	Long Distance Chalk Board Data Tablet - CRT			
SHOW				OCR - Printer				Blind imaging aid, insulin card reader and treatment
MOVE	Tone varies as distance from terminal	Tactile Feedback or Mechanical Arm			Position Detector Output into Computer Animation	Mechanical Arm		
BIO-FEEDBACK	Heart Beat Brain Waves	Temperature	Alpha-wave monitor Lie Detector		EEG ECG			Computer Controlled Patient Monitoring - Examination

Figure. 4.5 - New Interactive Terminals.

(four to five orders of magnitude according to Reference 8), and this may create new markets for "intelligent" terminals much as the "cheap electronic calculator" has created new markets. Also, it appears that internal processing technology like Large Scale Integration (LSI) may significantly impinge on input or output technologies and affect the nature of the man-machine interface in future terminals.

Category three groups together technologies related to communications networks and remote electronic data processing resources.

Attention was directed to network trends as they appeared relevant to interactive terminals and to software which was judged to have a potentially significant impact on the man-machine interface in the future.

4.4 FORECASTING METHODOLOGY AND CAVEATS

Methods applicable to forecasting technological change have been described in detail elsewhere (References 18, 19) and this subject matter need not be reviewed in detail here. It is important, however, to emphasize one important aspect of the problem. Fundamentally, any quantitative forecast is based on a "model" of the underlying reality-system.

Reduced to fundamentals, most long-range forecasting models are *trend extrapolations*, although they may be carried out with a degree of elaboration that tends to obscure what is actually done. The econometric method is essentially as follows:

a) Select the "dependent" variable to be projected.

b) Select one or more apparently relevant independent variables.

c) Determine by appropriate statistical methods (e.g. multiple regression analysis) the model which best relates the past behavior of the dependent variable to changes in the independent variables. The result is often a linear equation among the variables, or their logarithms. If the explanatory power of the selected set of "independent variables" is not judged to be satisfactory, a new set of variables must be tried. *

d) Project the independent variables.

e) Using the fitted equation or model, project the dependent variable.

In principle, one can examine any so-called "independent" variable under a microscope and subject it to further analysis of the same kind, identifying still other "independent" variables on which it seemingly depends. But eventually the regression

---

* Note that a variable at a given time t may depend on earlier ("lagged") values of itself. Here, the earlier value is treated as independent (exogenous) while the later one is endogenous. Thus, one might expect to observe little or no correlation between current levels of spending on R&D in electronics and current usage of electronic computers. However, a very strong correlation would probably be found between current usage of electronic computers and spending on R&D two decades ago. This reflects the time lag in conversion of R&D into viable commercial products and their acceptance in a marketplace.

process must come to an end and at least one variable must be chosen as *ultimately* independent. (In practice, as a rule, several variables are so designated). For these variables, the problem of forecasting still remains. The standard approach is extrapolation.

More precisely, the method of extrapolation is to fit a smoothed time series to a mathematical function of time. Future values of the variable are then determined simply by substituting future times in the chosen function. Although there exists a high-order infinity of possible mathematical functions to choose from, the selection - in practice - tends to be limited to the following three functions of time:

a) Linear: $f(t) = a + bt$

b) Exponential: $f(t) = \exp k\,(t - u)$

c) Decreasing Exponential: $f(t) = b[1 - \exp(-kt)]$

A possible fourth choice (for which the fitting procedure is considerably more difficult, however) is:

d) Logistic: $f(t) = a + b[1 + \exp k\,(t - u)]^{-1}$

Use of a 4-parameter function such as the logistic function must inevitably result in some decrease in the *statistical significance* of any fit, even though the fit itself may be improved because of the extra terms(s) involved. Clearly there is a tradeoff here. In general, the minimum data base requirements for a significant 4-parameter fit are considerably more demanding than those required for a significant 2-parameter fit. For this reason, among others, the second of the three functions is by far the most widely utilized in long-range projection models; it is exactly equivalent to the familiar assumption of a *constant annual rate* of growth or decline. This exponential growth curve is commonly assumed, for instance, with regard to population (or labor force), productivity (or personal income, or GNP), energy consumption, vehicle miles travelled, and so on. The third function corresponds to some kind of saturation phenomenon, as when some measure approaches a natural (e.g. physical) limit such as the speed of light, the efficiency of an energy conversion device or the capacity of a communication channel.

It is important to understand the limitations of extrapolation as a method of forecasting. It takes into account observed regularities in the rate of change of the component elements of the dependent variable, so long as these occur at *lower* levels of systems aggregation. For instance, an extrapolation of cathode ray tube (CRT) performance will take into account an on-going rate of development of materials, manufacturing techniques and structural design but *not* the possibility of substitution of an alternative type of information display system. In other words, an extrapolation does not consider the possibility of competing technological possibilities (or alternative socio-economic scenarios) *at the same or higher levels of systems aggregation.*

Putting it in statistical terms, this means that the use of a "simple" 2-parameter curve in place of a more complex 3- or 4- (or more) parameter function that fits the data equally well maximizes the statistical significance of the fit on a *ceteris paribus* basis. It does not prove or imply that the underlying reality-system behaves according to the selected (simpler) function. It does imply that the function with the fewest degrees of freedom should be selected in the absence of additional information.

By the same token, however, it is often the case that, in addition to the purely historical time series data, other relevant information is also available. This supplementary information may shed light on the dynamics of the reality-system and may justify the selection of a more complex functional form (despite some sacrifice of statistical significance) that is a better predictor of the future. As a real-life example of the pitfalls of simplistic extrapolation, it is instructive to compare a number of projections of transit-use for the city of Chicago as against actual experience (Fig. 4.6). Clearly all of the projections were based on straightforward extrapolation - and all were qualitatively wrong. The errors occurred because of

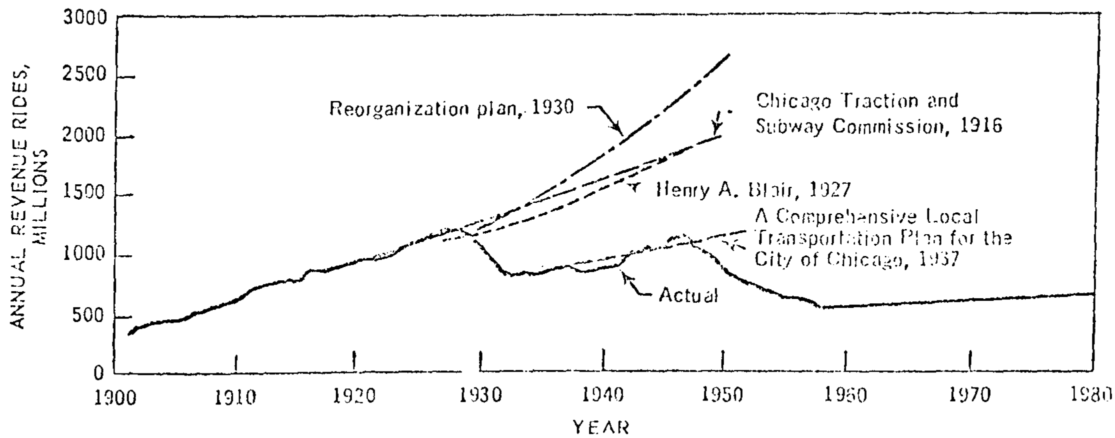


Figure 4.6 —Transit Use Projections—Chicago

Actual use of transit facilities from 1901 to 1960 and estimated to 1980 compared with various projections of estimated use (Chicago).

Source: Reference 20

"substitutions" by competing alternatives at higher levels of aggregation, viz:

a) Competition by an alternative means of transportation (the private automobile), and
b) An alternative socio-conomic "scenario" (the depression of 1929-1939 and World War II).

The minimum lesson to be drawn from the above example is that it is very unwise to base long-range plans on an extrapolation of past trends, just at the time when fundamental "system" substitutions (including socio-economic changes) are in progress.

The above example underlines a major potential problem of the present study. Most quantitative projections in the following sections are taken from secondary sources, and based on "eyeball" extrapolation or, at best, crude exponential curve fits based on past history. (In most cases we do not have access to the basic time-series data and must rely on published curves that are presented without any statistical documentation, either as regards goodness of fit or significance.) It is evident, however, that these parameters are not truly independent or "exogenous" in any meaningful sense: costs and performance of electronic components or mechanical devices in any near-future year are critically dependent on current levels of R&D expenditure which, in turn, depends on a host of technical, economic, legal and psychological factors.

The foregoing caveat is always true, to some degree, of course, but in the present case it is "more" true because the field is extremely volatile and rapidly changing at the present time. This is not to say that meaningful forecasts are impossible.

However, we do believe that simplistic extrapolation techniques are particularly risky in this area at this time. At most, they should be regarded as crude *first* approximations. Before embarking on any significant investment based on such projections, a deeper and more detailed forecasting analysis should be undertaken.

4.5 PRESENT STATE-OF-THE-ART AND DATA COLLECTION

As a base for the technology forecast, a companion study (Reference 36) was conducted during which extensive data was collected on the state of the art with respect to data terminal products and related sub-assemblies or components. The objective of this study was to evaluate present trends affecting the maturity and development of terminal products and technologies and, at the same time, to estimate terminal availability and markets in Canada as compared to the U.S. and foreign countries. Much of the information was communicated informally within the study team but, for further information, reference is made to Volume I of this study entitled "Data Terminal Technology-Present & Future, State-of-the-Art". In addition to this source, information was gathered from published material and personal interviews. A list of interviews and references is given in Appendix B and Sections 9 and 10, respectively.

4.6 CROSS-IMPACT ANALYSIS

Another technique for assessing the alternative technologies is cross-impact analysis. This procedure could conceivably be used to rank candidate technologies in terms of their contribution to an on-going R&D program.

To use this method, the technologies which have been identified are listed down the side of the page and across the top (See Fig. 4.7). Technical specialists then fill in the

Numbers indicate how technologies on the left affect technologies listed above the table:

3-significantly improve

2-moderately improve

1-modestly improve or inc. need for

-1-decrease need for

	AFFECTING TECHNOLOGIES / AFFECTED TECHNOLOGIES	LSI	CHEAP MICROPROCESSORS	FAST MEMORY	A/D CONVERTERS	INTELLIGENT TERMINALS	CCD	OCR	ROBOT CONTROLLERS	VOICE RECOGNITION	FACSIMILE	LCD	GRAPHIC DISPLAY	SPEECH SYNTHESIS	VIDEOPHONE	WIDEBAND TECHNOLOGIES	BANDWIDTH COMPRESSION	ELECTRONIC SWITCHING	PACKET SWITCHING	COMPUTER/CONF. NETS	INFORMATION MGMT.	MACHINE INTELLIGENCE	LEARNING	PATTERN RECOGNITION	PROCESS CONTROL	NATURAL LANGUAGE
PROCESSING	LSI																								
	CHEAP MICROPROCESSORS																								
	FAST MEMORY																								
	A/D CONVERTERS																								
	INTELLIGENT TERMINALS																								
INPUT	CCD																								
	OCR																								
	ROBOT CONTROLLERS																								
	VOICE RECOGNITION																								
OUTPUT	FACSIMILE																								
	LCD																								
	GRAPHIC DISPLAY																								
	SPEECH SYNTHESIS																								
	VIDEOPHONE																								
COMMUNICAT'N	WIDEBAND TECHNOLOGIES																								
	BANDWIDTH COMPRESSION																								
	ELECTRONIC SWITCHING																								
	PACKET SWITCHING																								
	COMPUTER/CONF. NETS																								
SOFTWARE	INFORMATION MGMT.																								
	MACHINE INTELLIGENCE																								
	LEARNING																								
	PATTERN RECOGNITION																								
	PROCESS CONTROL																								
	NATURAL LANGUAGE																								

For data, see Section VII

Figure 4.7

Cross-Impact Table

matrix, e.g. with a value of +2 when technologies are strongly synergistic, down to a value of 0 when there is no mutual influence, and perhaps a value of -2 when the technologies are directly competitive or "antagonistic". If the values are then summed across the rows, the magnitude of the row total will give an approximate measure of the over-all synergism of the technology listed down the side.

While this technique was not used extensively in the study due to limitations of time, an example is given in Section 7 together with the resulting conclusions.

4.7 A PROPOSED FRAMEWORK FOR COST EFFECTIVENESS ANALYSIS

The cost benefit framework described hereafter is an attempt to provide a quantitative cost basis for assessing relative attractiveness to the user given the choice of two or more terminal types to perform the same function (benchmark). To the extent that two different types provide exactly the same service, the selection between them is reduced to a comparison of direct user costs over the projected life of the installation. Insofar as the services are qualitatively different, of course, their benefits (i.e. utility) must also be compared. Both approaches will be considered, beginning with the comparison on the basis of costs alone.

4.7.1 Cost Effectiveness

For the purposes of discussion, one might consider the four types of terminals differing in input and output modes:

Type a) Typed input/typed output

Type b) Voice input/voice output

Type c) Handprinted input/graphic output

Type d) Voice and handprinted input/voice and graphic output

Initially we will assume that standard tasks (benchmarks) can be done equivalently well on all terminals, but not necessarily at the same speed or with the same amount of data processing. We also assume that all such tasks can be synthesized from the set of basic "work elements" listed in Table 4.1.

The relevant costs that must be considered for a given configuration of terminal equipment are as follows:

a) User costs, defined as wages or salary plus applicable overhead for the equipment operator (but not including secondary or indirect users), W(t);

b) Hookup costs, defined as the marginal cost of maintaining an open 2-way channel linking the terminal to the main data communication or data processing system (includes computer connect time and communications costs), X(t);

c) Data processing costs, defined as the marginal cost of processing data above and beyond "hookup" costs, Y(t). In the example, it was assumed that processing was done at the central site; otherwise, the portion of the processing costs attributable to the terminal would be included in the fixed terminal rental cost;

d) Terminal equipment rental costs, based on the base price of the equipment, its depreciation rate, maintenance costs and an appropriate return on invested capital, Z(t).

In order to bring different I/O modes onto a common basis for evaluation, it is necessary to introduce a number of additional coefficients relating to the effectiveness of "conversion" of information between forms understandable to humans and forms usable by machines. These parameters (explained in more detail in Appendix IV) account for changes in the characteristics of messages, when, say, voice is used rather than a typewriter as the input or output mode. The values of α, β etc. must be determined through experimentation. At present with the exception of the work of Chapanis (Reference 82) there is little in the literature related to this topic. For our example in Section VII we have used relevant data from Reference 82.

Table 4.1

Work Elements

Element	Description
E_1	Message from user to terminal (units of information content)
E_2	Message from terminal to user (units of information content)
E_3	Internal logic or arithmetic operations (number of processing steps)
E_4	Internal storage (number of bits)
E_5	User response time (on-line seconds)

Table 4.2

List of Some Possible Benchmarks

(Described in greater detail in Appendix C)

1. a) Transmit text
   b) Transmit numbers
2. Edit text
3. Perform calculations
4. Draw a 2-dimensional picture, map or graph
5. Purchase a theatre ticket
6. Select optimum route from A to B
7. Assemble puzzle
8. Use CAI package to learn some skill
9. a) Select a document
   b) Compile a bibliography
10. a) Play a game against the computer
    b) Play games via the computer
11. Run Delphi exercise

Costs will be estimated per standardized task (or set of tasks) with the explicit understanding that a given task may require more or less time on one configuration than on another. A list of suggested benchmark tasks is given in Table 4.2. The costs per task will decline as the average number of tasks carried out per year (i.e. the "load factor") increases, and fixed costs such as equipment rental can be allocated over more tasks. An efficient terminal configuration permitting a given task to be carried out in a shorter (than average) time will thus offer three cost advantages.

a) Savings in direct user time,
b) Savings in hookup time, and
c) A potential higher utilization rate or "load factor".

The terminals to be evaluated can be considered over a time span, the calculations being made periodically (e.g. at yearly intervals). The net effects of projected trends in the above costs and equipment rental costs will be reflected for each of the configurations and the task or mix of tasks selected for the analysis. The graphical display of the results of these calculations will show the relative position of each terminal in "lowest overall cost" over the forecast period. Formulas for the calculations described above are given in Appendix D.

4.7.2 Utility (Benefit) Analysis

To complete a cost benefit assessment there must be some comparison of relative benefits as well as costs. In the previous section it was assumed that each of the terminal configurations considered would be capable of carrying out exactly equivalent tasks. In practice, of course, this is usually not the case.

Differential benefits can take two forms. First, the range of tasks that can be undertaken may be greater in one case than another. For instance, a terminal capable of producing hard copy graphic outputs would provide a greater range of possibilities than a terminal with only a printer. Second, the quality of the output may differ from case to case. It is important to note that the real beneficiary may not be the user of the terminal but, rather, a higher level supervisor or client. If that person saves time or wear-and-tear, or is able to do his or her job more effectively, a benefit is accrued. The benefit might in principle be measurable in dollar terms, but - being somewhat indirect - it is not taken into account in the foregoing calculation of relative costs.

Utility analysis, in practice, is essentially concerned with attempting to capture and quantify these elusive and indirect contributions to net benefits. The following is an attempt to describe, in concept, a method by which this can be done.

The procedure for utility analysis would consist of three steps, which together comprise a technique for developing and utilizing quantitative values in order to calculate the comparative utilities of products (or services) under study.

Step 1 - Identification of the differential attributes and performance characteristics of the I/O modes of each terminal configuration (TC). Once this list is complete, each configuration is "rated" to determine the extent to which it possesses each attribute. (These ratings may vary according to what type of task is being performed.) This procedure could be carried out by a panel of specialists in which case the ratings would be averaged.

The following rating scale is appropriate for this type of analysis:

Rating Scale for Attributes*

3 - the TC possesses this attribute to a high degree

2 - the TC possesses this attribute to a considerable degree

1 - the TC possesses this attribute to a limited degree

0 - the TC does not possess this attribute.

See example Figure 4.8. In this example some cost attributes are included which would be omitted if the utility analysis were combined with the preceding cost effectiveness methodology.

---

* In the example, ratings from 1-10 were used instead of this scale, but 0-3 is adequate for this type of analysis.

Example of Utility Factor Calculation

Step 1

Rate each attribute for each configuration and task.

		Attributes						
		Learning Time	Elapsed Time	Browsing Rate	Programming Cost	Processing Cost	Terminal Cost	Naturalness
Task	I/O Mode of Configuration	Attribute Scores						
Computation	Type	9	9	0	0	10	10	8
	Write/draw	10	10	0	0	3	4	10
	Speak	10	10	0	0	3	4	8
	Write/draw,speak	10	10	0	0	3	2	10
Information Retrieval	Type	6	5	6	10	10	10	4
	Write/draw	9	7	8	10	8	4	7
	Speak	8	7	4	10	8	4	7
	Write/draw, speak	10	10	10	10	8	2	10
CAI	Type	4	5	6	8	10	10	4
	Write/draw	8	7	8	9	5	4	7
	Speak	6	7	4	8	5	4	7
	Write/draw, speak	10	10	10	10	3	2	10

Figure 4.8

Step 2 - Establishing weights which reflect the importance of each identified attribute to the principal users of the TC for each test.

Again, a quantitative rating scale is normally used to translate verbal evaluations (e.g., obtained by a survey of consumers, manufacturers and related literature) into well-defined ratings. The rating scale used is adjusted to take into account evidence that indicates that human beings tend to perceive order-of-magnitude (i.e., geometric) differences on an arithmetic (or logarithmic) scale.* In other words:

Rating Scale for the Importance of Properties

16 - critical
8 - very important
4 - somewhat important
2 - of little importance
0 - of no importance.

See example Fig. 4.9.

Step 3 - After completion of Steps 1 and 2, the final step is the multiplication of the attribute ratings of the products (Step 1) by the weights from Step 2 in order to obtain an overall utility factor for each configuration. Then the utility factors are normalized by dividing by the sum of the weights multiplied by 10. The utility adjusted cost is found by multiplying the costs found in the cost effectiveness analysis by the reciprocal of the utility factor. See example Fig. 4.10.

---

*This is an observed fact for perceptions of sound or light intensity. In the example, equally spaced values from 1-10 were used for weights but, in general, the logarithmic scale has been found more appropriate.

Step 2

Establish the weights reflecting the importance of each attribute for each task.

Task	Learning Time	Elapsed Time	Browsing Rate	Programming Cost	Processing Cost	Terminal Cost	Naturalness	Sum
	Attribute							
Computation	3	5	0	3	10	7	1	29
Information Retrieval	4	10	6	8	6	4	4	42
CAI	7	10	3	6	4	3	7	40

Figure 4.9

Example of Utility Analysis - Step 2

Step 3

Find the sum of the weighted ratings.

Task / Input/Output Mode	Un-normalized Sum of Weighted Attribute Scores: Computation	Inf. Retrieval	CAI	Normalized Sum of Weighted Attribute Scores: Computation	Inf. Retrieval	CAI
Type	250	306	242	.86	.73	.61
Write/draw	148	326	285	.51	.78	.71
Speak	146	298	253	.50	.71	.63
Write/draw, speak	134	376	348	.46	.90	.87

Figure 4.10

Example of Utility Analysis - Step 3

While this overall concept (shown schematically in Fig. 4.11) was not developed to the degree necessary for application to practical situations, a simplified example of cost effectiveness analysis is given in Section 7.3. This was not extended to include utility considerations. It should be appreciated that the results shown are meant to be illustrative rather than definitive. Too few experiments have been done as yet to obtain reliable performance parameters applicable to different terminal types for specific work elements. Moreover, non-quantitative attributes like realism and convenience of a terminal system to the ultimate user cannot yet be measured with any reliability. Further research must be done to identify work elements which hopefully can be made independent of the input or output mode employed. In summary, more experimental data is required relating to human behaviour differences resulting when different input/output modes are employed for communication and the relative effectiveness of each mode and specific configuration for various tasks.

4.8 SUMMARY OF METHODOLOGY

We have taken a morphological approach to analyzing a) the technological trends relevant to interactive terminals and b) the task environment in which terminals operate. Fig. 4.3 presented a morphological tree of the component technologies for interactive terminals, which classifies input and output devices into the possible modes of human sensory input and response, and other terminal (and network) devices into component functions. In sections 5 and 6 to follow, these modes and functions are broken down into alternative technologies in the morphological trees given in Fig.'s 5.3, 5.8, 5.18, 5.26, 5.34 and 6.4.

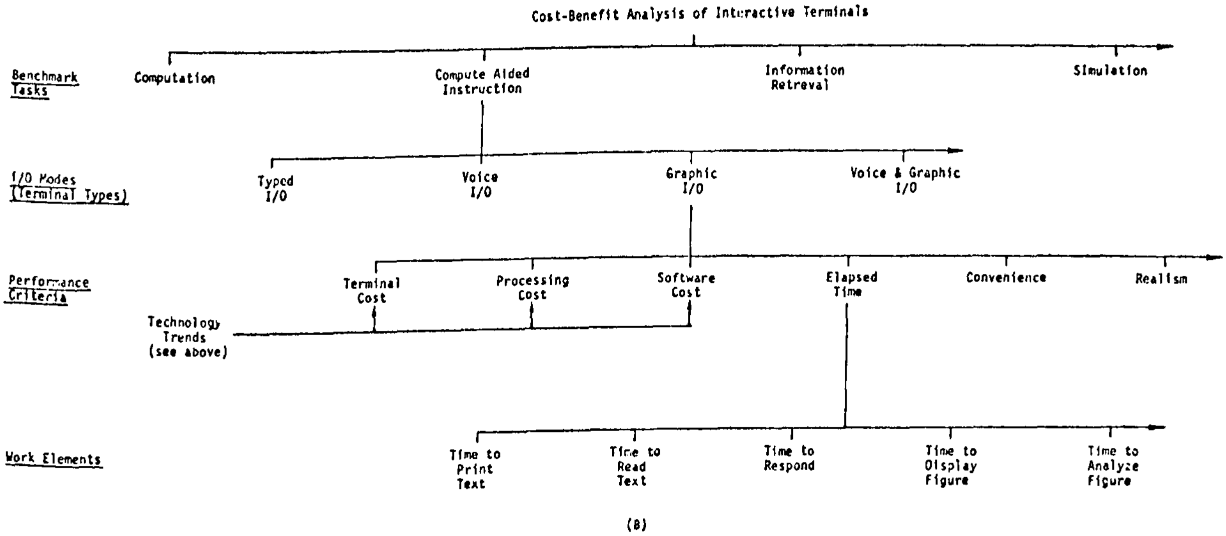


Figure 4.11

Cost Benefit Methodology (Schematic)

The text in Sections 5 and 6 is keyed to these trees, describing the pros and cons and cost-performance trends of each technological node. The morphological tree and accompanying text is intended to give a broad overview of the multiple technological trends likely to affect interactive terminals in the next decade.

In Section 7 Impact Assessment, the way in which the technological nodes of the morphological tree impinge upon each other is shown through a cross-impact matrix (Fig. 7.2 and accompanying text). This analysis leads to some conclusions about which technological trends will have the most impact on the terminal industry both directly and indirectly by affecting other technical trends, and identifies some general emerging trends resulting from a combination of technical trends acting together. Then, the most important technological and performance trends which will affect the interactive terminal market in the next decade are summarized and conclusions are made about the future terminal configurations based on these trends. Finally, a simple example using the cost effectiveness technique is given to demonstrate the method.

5. HARDWARE TECHNOLOGY FORECASTS

5.1 ORGANIZATION OF SECTION

Hardware technologies relevant to interactive terminals can be divided into the following categories:

a) INPUT DEVICES
b) OUTPUT DEVICES
c) INTERNAL STRUCTURE
d) REMOTE HARDWARE TECHNOLOGIES

AFter a brief section on terminal cost trends, these technologies will be covered in detail in Sections 5.3, 5.4, 5.5 & 5.6 respectively.

5.2 TERMINAL COST TRENDS

Fig. 5.1 shows predicted cost curves for different types of interactive terminals, made by Standford Research Institute in 1969 (Reference 21). Since that time several technologies such as Liquid Crystal Displays (LCD), Charge Coupled Devices (CCD), and MOS* Large Scale Integrated Circuits (LSI) have emerged and may be expected to significantly affect an extrapolation of these trends. In addition, technological advances in the next decade will make feasible terminals not even listed in the figure, such as terminals employing voice input and speech synthesis, movement sensing devices, and biological input. In the next sections we will summarize how these technological advances will change the components and costs of interactive terminals in the next decade.

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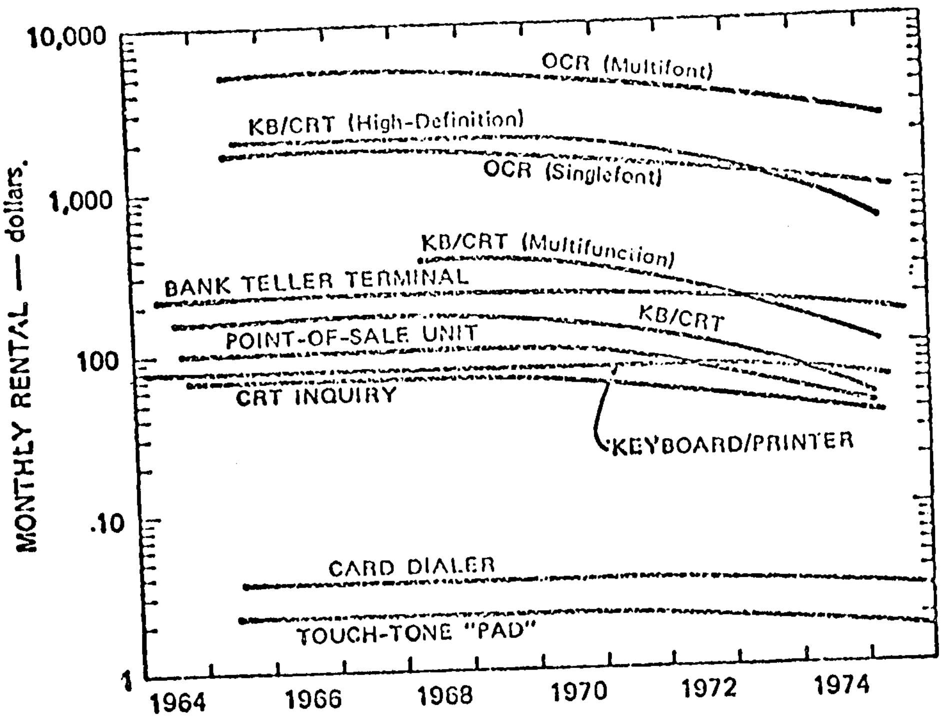
*MOS - Metal Oxide on Silicon



Source: Reference 21

Figure 5.1 - Monthly Rental of Data Terminal Units in the U.S.A.

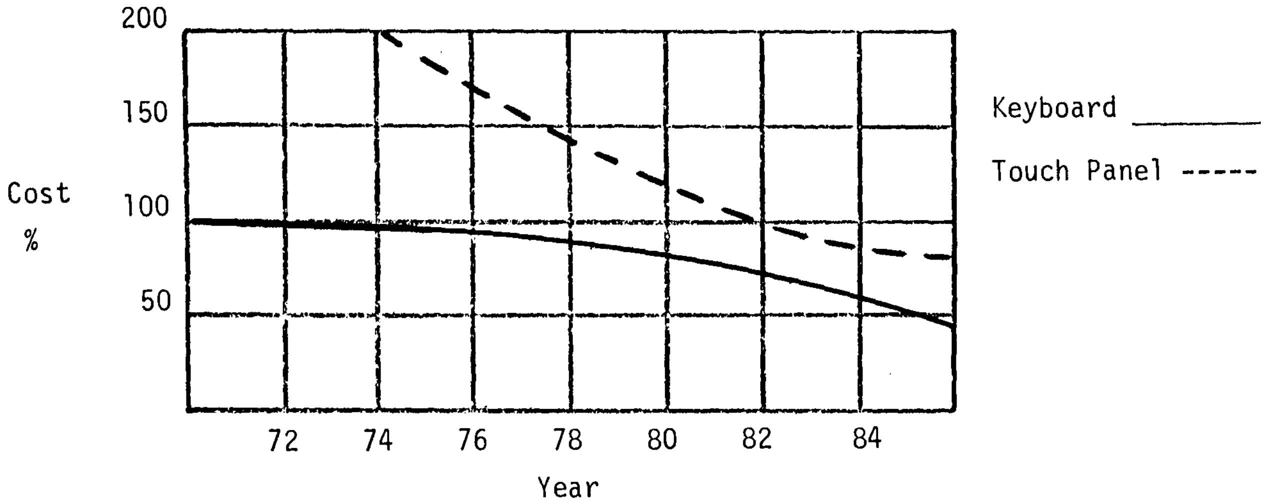
5.3 DATA INPUT DEVICES

Probably the most important aspect of interactive terminal design in the future will be the data entry problem; that is, how should terminals be designed so that users can communicate with them in the most effective, natural, and convenient way that is justified from an economic standpoint. Consequently, input devices will be the most diverse and innovative area of terminal development in the next 10 years. It is here that the most acute problems of man-machine interfacing must be solved.

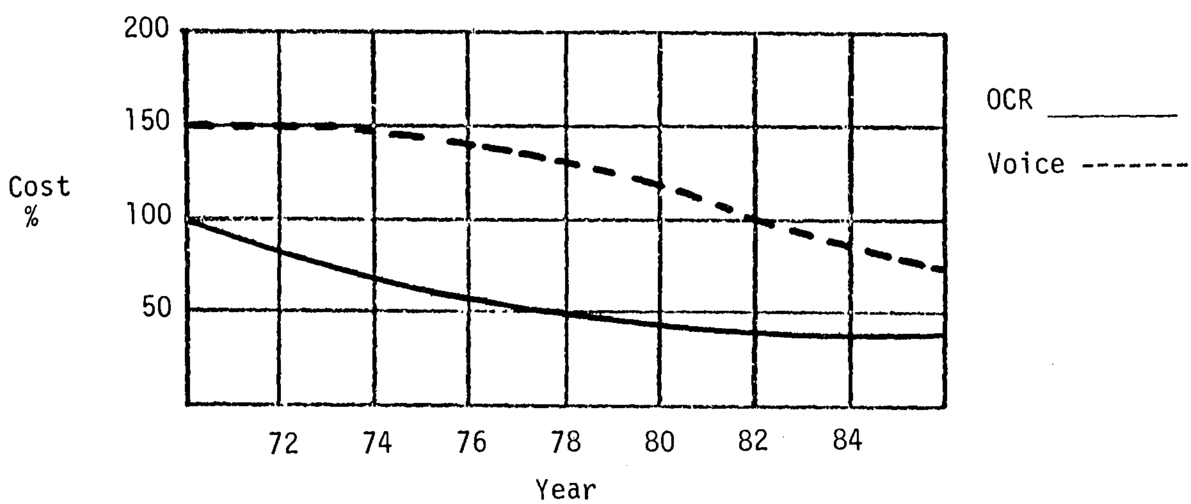
Within the study time horizon, i.e. to 1985, the dominant entry mode will remain keyboard oriented, because of the keyboard's intrinsic versatility to perform effectively in many applications. Keyboards, however, will be predominantly solid state devices, in place of electromechanical, and "modular" type keyboards which can be built up easily for particular applications will become more commonplace. With the advent of MOS and I^2L* and the resultant low power requirements, it will become possible to power a standard keyboard from the D.C.current in the normal telephone loop with a low cost (less than $50) data entry device. Comparative cost trends are shown in Figure 5.2.
Solid state chips might also become the controlling components in electric typewriters, which would mean that typewriters could be converted into interactive terminals relatively easily (Reference 22).

In the area of visual input, Charge Coupled Devices (CCD's) will have a significant impact in reducing the cost of imaging devices. User identification by terminal, e.g. by "retina print", for purposes of security and financial transactions will probably be available by the end of the decade.

* MOS - Metal oxide on Silicon
I^2L - Integrated Injection logic



Keyboard/Touch Panel



OCR/Voice

Figure 5.2

Comparative Cost Trends - Inputs

Optical and magnetic scanning devices will be increasingly used in point of sale, facsimile and data gathering applications. Optical character recognition (OCR) will continue to grow as an input mechanism, as pattern recognition research improves the state of the art, and as advances in Large Scale Integration (LSI) and increased demand reduce costs (Reference 23). Technical advances are still needed to permit machine recognition of handwritten characters. Relative cost trends are shown in Fig. 5.2.

Limited speech recognition terminals will become more prevalent in the next decade for special purposes such as user identification, and air traffic control. As with OCR, major technological advances have to be made in the area before a general speech recognition terminal becomes feasible from either a technical or economic standpoint.

Movement Transducers will become important adjuncts to interactive terminals as LSI reduces the cost of Analog/Digital circuits, and convenience features become more important criteria for terminal selection.

Direct biological input such as brainwave, heart beat, or blood sugar level monitoring will become available for medical applications such as multiphasic screening in the next decade.

Fig. 5.3 shows the present and emerging options for data entry at remote terminals.

5.3.1 Typing Inputs

Solid state electronic keyboards will replace electro-mechanical keyboards in many terminals; full alphanumeric keyboards now selling for less than $100 (See Vol. I) may be expected to cost less than $50 by 1976 (in lots of 5,000-10,000), as a result of conductive elastomers or capacitive keyboards.

Advantages	Disadvantages				
Inexpensive	Limited	Limited Keyboard		TOUCH	INPUT
Convenient	" "	Touch Panel		TOUCH	
Established	Reliability	Mechanical	Keyboard	TYPE	
Cheap, Reliable	Human Factors, Arrangement	Solid State	Keyboard	TYPE	
		Screen Feedback		TYPE	
Established	Power, Expensive	Vidiocon	IMAGING DEVICES	SHOW IMAGE	
Inexpensive	Reliability	Photo FET	IMAGING DEVICES	SHOW IMAGE	
	Yield Size	CCD	IMAGING DEVICES	SHOW IMAGE	
Less Band width Needed	Memory Realism	Slow scan	IMAGING DEVICES	SHOW IMAGE	
Point of Sales & Restricted Entry	Feature Extraction	Retina	MACHINE IDENTIFICATION	SHOW IMAGE	
	Large # of Potential Patterns; Standardization of Image	Fingerprint	MACHINE IDENTIFICATION	SHOW IMAGE	
Point of Sales & Restricted Entry	Limited	Optical	Wand — SCANNERS		
		Magnetic	Wand — SCANNERS		
Eliminates Keypunch		Mark sense	SCANNERS		
Established	Too slow, Quality of Paper	Slow	Facsimile — SCANNERS		
Compression Techniques	Bandwidth Requirements	Fast	Facsimile — SCANNERS		
Versatile	Expensive	Light Pen	DIRECT	DRAW/WRITE INPUT	
	Expensive	Data Tablet	DIRECT	DRAW/WRITE INPUT	
Eliminates Keypunch costs	Reading Different Fonts	OCR	MACHINE RECOGNITION	DRAW/WRITE INPUT	
More Versatile than Mark Sense	Expensive, Pattern Recognition	Printing/Limited	MACHINE RECOGNITION	DRAW/WRITE INPUT	
Adapt to Users Style	Experimental, Expensive	Adaptive	MACHINE RECOGNITION	DRAW/WRITE INPUT	
More Convenient	Very Expensive, Remote Processing	Contextual	MACHINE RECOGNITION	DRAW/WRITE INPUT	
Add Depth to Man-Maninteraction		Audio channel		AUDIO INPUT (Speak)	
	Expensive	Sonic Pen		AUDIO INPUT (Speak)	
		Identification	MACHINE RECOGNITION	AUDIO INPUT (Speak)	
Adds Non verbal Intelligence	Privacy Issue	Voice Stress Analysis	MACHINE RECOGNITION	AUDIO INPUT (Speak)	
Useful for Special Purposes	Expensive, Inconvenient	Limited Vocabulary	MACHINE RECOGNITION	AUDIO INPUT (Speak)	
Convenient	Experimental, Very Expensive	General Speech Rec	MACHINE RECOGNITION	AUDIO INPUT (Speak)	
		Joystick		MOVEMENT TRANSDUCERS (Move)	
Cheap, Convenient Input		Mouse		MOVEMENT TRANSDUCERS (Move)	
Transmit "Body Language"	Experimental, Expensive	Position Sensors		MOVEMENT TRANSDUCERS (Move)	
Non Verbal Intelligence	Expensive, Experimental	Eye Movement		MOVEMENT TRANSDUCERS (Move)	
Useful for Medical Purpose		ECG		BIOFEEDBACK	
Non Verbal Intelligence	Privacy Issue	Galvanic Skin		BIOFEEDBACK	
Medical Applications	Medical Technology	Chemical Levels		BIOFEEDBACK	
Direct Interface Possible	Limited Signals, Little understood	Brain Waves		BIOFEEDBACK	

Figure 5.3 - Technologies Relevant to Terminal Input

The use of keyboards as input devices will steadily increase, however, if only in line with the projected growth of interactive data terminals in general. In addition, Large Scale Integration (LSI) will make it cost effective to replace the active components of electric typewriters with IC chips, opening the possibility of using typewriters with acoustical couplers as inexpensive interactive terminals for editing, electronic mail correspondence and data entry (Reference 22). In the past, little effort has been devoted to the human factor in the design of terminal keyboards, but this will change in the next decade as more human factors engineers and psychologists become involved in terminal design. Alternatives to the "QWERTY" keyboard arrangement, like Dvorak's arrangement which minimizes the distance fingers must travel for typing in the English language, may be marketed (Reference 25). Also, keys may be arranged to better reflect the physiology of the human hand (Reference 26). In addition, keyboards may have built-in logic and memory which allow users to program special function keys (Reference 22). The U.S. National Academy of Engineering's study of telecommunications research cite the following as important areas for keyboard design (Reference 23):

a) size of keys
b) key spacing
c) operating force
d) displacement
e) keyboard shape (concavity)
f) keyboard slope
g) feedback (kinesthetic, auditory, visual)
h) keyboard format
i) key interlocks
j) application sensitivity.

5.3.2 Touch Panels

Touch panels and "screen feedback", which allow a user to enter information displayed on a screen by touching it, provide additional means of input. The cost of touch panels is decreasing quite rapidly as new technologies are developed. The use of these devices is expected to increase sharply between 1975 and 1980, with wide application in the education and medical fields. The Plato terminal touch panel which allows the user to input information by touching any of 256 areas on the screen now sells for $600 (Reference 22), but similar devices can be expected to sell for less than $100 in the next decade (Reference 28). In screen feedback a transparency of a keyboard or other input is placed on the screen and the user can touchtype directly on the screen (Reference 28). If such devices were produced in mass quantity (probably using surface wave technology), they could be expected to cost between $90-115, providing a cheap input for graphics terminals (Reference 28, page 211). LSI set up and masking costs for new devices usually dictate quantities in excess of 50,000 for economic mass production.

5.3.3 Imaging Devices

Charge coupled devices (CCD's) can be expected to significantly reduce the cost of video cameras and imaging devices. They have similar advantage to silicon-diode-array cameras which require low voltage and power, are self-scanning, have higher reliability, and are easy to fabricate (Reference 26; Reference 29).
CCD's have the additional advantage that they can be used as a storage device to retain video images so that slow scanning and bandwidth compression can be done cheaply. Slow scan videophone which now rent for about $225/month in the U.S. (Reference 26) can be expected to decrease in price as a result of CCD and LSI technologies.

5.3.4 Scanners

The attractiveness of CCD technologies may result in "line by line" optical scanners facsimile and data input being replaced by imaging devices which quantify whole pages in one operation. The main cost in the former devices which include facsimile scanners (see Fig. 5.12 and 5.13 for examples and costs), mark sense readers, point of sale scanners, badge and ID scanners, and OCR scanners, is in the scanning mechanism, for which costs are not expected to decline significantly in the next decade. Magnetic scanning devices which are already used extensively in cheque reading might be expected to be employed widely in point of sale applications, particularly in transportation ticket transactions in the next decade. At this point, it is not possible to predict whether optical or magnetic scanning technology will predominate in the future, although there seems to be a trend in point of sale applications to the optical scanner.

5.3.5 Direct Graphic Input

As the convenience of the interactive terminal becomes an increasingly important criterion, versatile means for interaction with graphics terminals such as light pens, joy sticks, data tablets, and touch panels will be seen as necessary adjuncts to keyboards, rather than luxury add-on items. This increased market will lead in turn to significant cost reductions in these devices. For example, the Scripto-graphics data tablet now costs over $3,000 (Reference 27), but it is estimated if data tablets were mass produced for home terminals, they could be sold today as cheaply as $250 to $300 (Reference 28, page 211). Similarly, it is estimated that a light or sonic pen could be produced for less than $150 if very large quantities were required. Human factors will be important in determining which of the many alternative devices in this area will eventually dominate the market. Fig. 5.4 indicates the advantages and disadvantages of various devices for interacting with graphic terminals.

1 = yes; 0 = no; A = advantage; D = disadvantage

	Can a projected keyboard be operated with ease?*	Any intermediate device needed to elicit feedback?	Can the terminal be operated from a distance?	Can tactile feelings be simulated?	Is there any active field the user has to be aware of?	Can the technology be modified for remote operation?	Can user keep an ink copy of his input?	Is there any noise associated with eliciting a response?	Does the user have to adjust TV controls?	Are there any wires across the screen that could disturb user?	Is the user required to exert some pressure whenever holding the input device?	Can the terminal be operated in horizontal position?	Human subjective preference for the specific technique**	Relative ease of operation**
Light matrix	1A	0A	1A	1A	1D	1A	0D	0A	0A	0A	0A	1A		
Sound pen	0D	1D	1A	0D	1D	1A	1A	1D	0A	0A	0A	1A		
Light pen	0D	1D	0D	0D	0A	0D	0D	0A	1D	0A	0A	0D		
Potentiometer	0D	1D	0D	0D	0A	0D	1A	0A	0A	1D	1D	0D		
SRI mouse	0D	1D	1A	0D	0A	1A	0D	0A	0A	0A	0A	1A		
Graphic tablet	0D	1D	1A	0D	0A	1A	1A	0A	0A	0A	0A	1A		

*In all screen-feedback techniques a projected keyboard can be operated. Easy operation is defined as one where the user can simulate real keyboard operation (using ten fingers).

**People can be expected to prefer one technique over the other for subjective reasons, which would not necessarily be rational from an efficiency standpoint. The relative ease of operation is also a subjective judgment. It is important to research these attitudes.

Figure 5.4 - Human Factors Comparisons of Graphical Input Devices

5.3.6 Machine Identification and Optical Character Recognition

Terminal devices which identify users will probably be available by 1980 and will be used in applications requiring security; however, they will probably be too expensive to be incorporated widely in point of sales terminals even though they would be a desirable addition. The most promising approach to user identification is currently matching the retina to a photographic template on file. This technique has an advantage over fingerprint identification in that the retina is always presented with the same orientation as the user looks at a certain spot, while a finger never touches the sensor with exactly the same orientation. A fingerprint indentifier now costs between $30,000 and $100,000.

Optical Character Recognition (OCR) devices are now relatively constrained in their input and are very expensive (Reference 23) - see Fig. 5.5 for some current examples - but technological improvements, such as mass-produced LSI MOS or LSI I^2L devices with high densities should significantly reduce these limitations in the next decades. As a result, there will be an increasing demand for OCR devices. Prices have dropped from $50,000 to $10,000 in the last 2½ years.

OCR costs are high mainly because of the logical circuit costs rather than the scanning components. If we assume the cost of these circuits will decline at the same rate as mini-computer costs (see Fig. 5.22), then Fig. 5.5 gives a rough estimate of cost trends for OCR over the next decade.* The use of this type of device will rise sharply towards the late 1970's, due to

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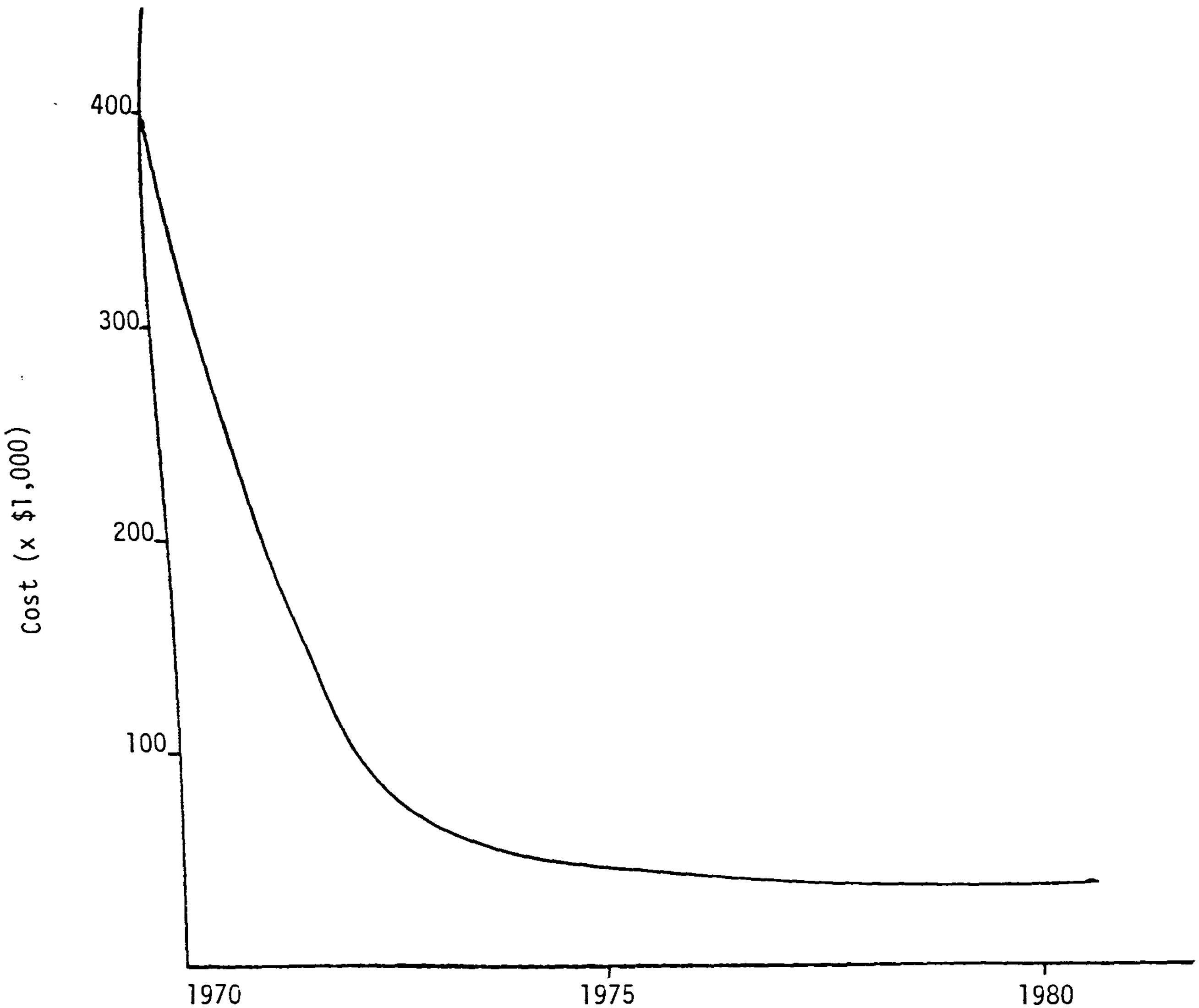
*This curve was developed by allowing the cost of OCR circuitry, which was estimated to be the average cost of multifont OCRs in Fig. 5.6 minus the average cost of scanners in Fig. 5.13, to decline at the same rate as mini-computer costs in Fig. 5.22. This is an optimistic projection because OCR probably will not develop the market that mini-computers have.

MANUFACTURER / CHARACTERISTICS	FARRINGTON	RECOGNITION EQUIPMENT INCORPORATED	IBM	SCAN DATA	PHILCO	CONTROL DATA (RABINOW)
Model	3030 Page Reader	Electronic Retina Rapid Index Page Reader	1288	300	6000	915 Page Reader
Document Size, Inches	4 1/2 × 5 1/2 to 8 1/2 × 14	3 1/4 × 3 1/4 to 14 × 14	3 × 6 1/2 to 9 × 14	6 1/2 × 8 to 11 × 14	5 × 7 to 8.5 × 14	4 1/2 × 2 1/2 to 12 × 14
Document Feed	Vacuum	Vacuum	Friction	Vacuum	Vacuum	Vacuum
Document Transport	Drive rollers	Rollers and drum	Belt and roller	Conveyor belt	Conveyer belt	Stepping belt
Scanning Technique	Rotating slitted disc	Photocell matrix	CRT	Flying spot	Flying spot	Column of photocells
Throughput Rate Documents/Min		30	444	33 est.	180	180
Recognition Technique	Stroke Analysis	Matrix matching	Curve tracing Matrix matching	Feature analysis	Matrix matching + feature analysis	Matrix matching
Font Style(s)	Self-check 12F and 12L, USASCOCR-A	Up to 360 characters multifont and handprinting	USASCSOCR-A, Hand printed numerals +5 alpha, 3/16 inch Gothic numerals	Multiple, hand-printed numerals + 10 alpha	Multiple type	USASC
Reading Rate, Char/Sec.	400	2400	1,000	600	1250	370
Monthly Rental	$3,625	$15,000	$5,725	$7,000	$12,500	$3,000
Purchase	$169,500	$550,000	$275,770	$400,000	$400,000	$110,000

Source: Reference 31

Figure 5.5 - Optical Character Recognition Equipment



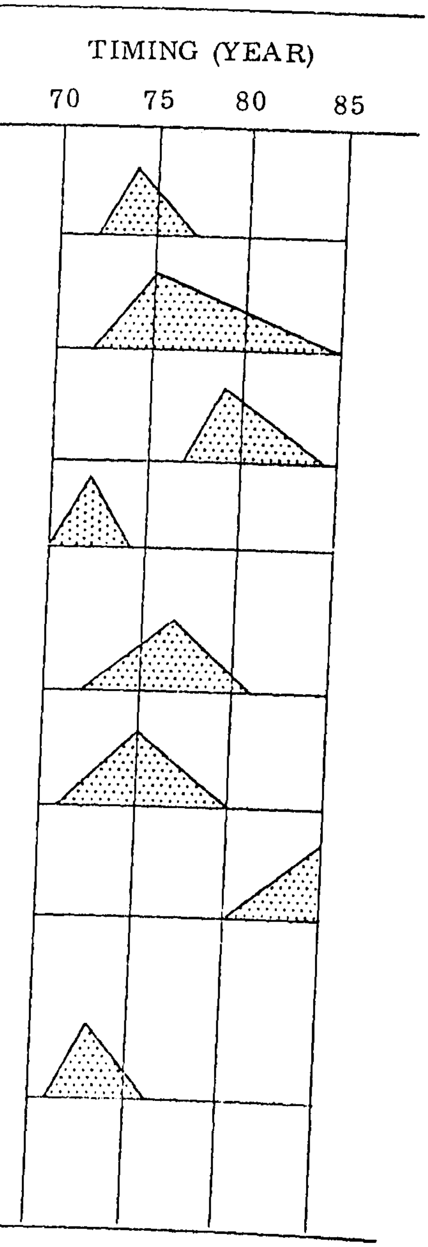
Source: IR&T

Figure 5.6 - Cost Trends for Multifont and Handprinted OCR Terminals

cost reductions and operation efficiencies, e.g. limited training required. Wider applications, such as reservation systems and information retrieval systems, will also open up.

Fig. 5.7 shows some Delphi estimates made in 1969 of the improvements in OCR performance for the following 15 years (Reference30). These estimates are probably about five years too optimistic, but significant improvement can be expected as a result of LSI and improvements in processing hardware and pattern recognition software. Current OCR machines use character by character recognition techniques such as optical matching, matrix matching, and stroke analysis (Reference 31), but to recognize large numbers of fonts or handwritten characters contextual cues have to be used. This will be feasible as OCR hardwired circuits are replaced by lower priced programmable micro-processors in the early 1980's (see Section 5.5). Programmable processors will allow OCR machines to be trained to recognize new characters and fonts which they weren't initially "trained" for; this additional flexibility will allow standard OCR devices to be adapted to a wide range of applications by their purchasers. For general recognition of a number of different users' handwritten characters, it will probably be necessary to connect the OCR device to a remote computer with sophisticated semantic processing and contextual analysis programs. A reasonably priced (around $50,000) OCR (reader/printer) for recognizing hand printing or special forms should be available by 1985. A general handwriting recognition machine will probably not be available until after 1985.

EVENT	FEASIBILITY %
1) Automatic reading of multifont (20) characters	90
2) Reading of print and handwritten print	30
3) Reading of script (requires large memories for storing context)	50
4) Low cost OCR (<$20,000)	80
5) Faster and more reliable document readers (10,000 characters/sec.)	50
6) Check on individual characters via spelling, grammar and context	80
7) Reading of U.S. mail zip codes and addresses (multifont, script, and handprint)	80
8) Elimination of need for OCR and fax by advent of dual-mode documents (conventional print/type + high density digital code)	60



Source: Reference 31

Figure 5.7 - Delphi Estimates Made in 1969 of Expected Improvements in OCR Performance

5.3.7 Audio Input and Recognition

Speech input devices are virtually unused in commercial applications due to the technical difficulties involved in speech recognition, but devices of this type will probably become available before 1985. Limited word recognition terminals like the one developed by Scope Electronics, Inc. will be used more widely in special applications where the hand or eyes are otherwise occupied, such as in sorting mail, or controlling air traffic, or in point of sale applications where only a limited number of commands need be recognized. The Scope terminal*, which recognizes 45 spoken words for which the user "trains" the terminal, now sells for US $15,000 (Reference 32). Since most of this cost, approximately 80%, is in electronic circuitry, the cost reduction in limited voice recognition devices can be expected to be similar to that of mini-computers, though not as steep, because the market will not be very large in the next decade. The Advanced Research Projects Agency (ARPA), an agency of the U.S. Defense Department, has launched a five year program in continuous speech recognition estimated to cost 15 million dollars, with the goal of developing a system to recognize a highly constrained command language, with a vocabulary of 1,000 words, by 1976 (Reference 33). The only non-trivial complete continuous speech recognition system, to date, is IBM's, developed at Raleigh for the U.S. Air Force which has a 250 word vocabulary, and has a 75% accuracy with multiple male speakers (Reference 23). Important references on speech recognition include References 33, 34 and 35.

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*With an accuracy of 98%, for classification of 13 words.

Another use of voice input terminals may be to identify when people are lying or under stress by analyzing the spectral lines of their speech. There may be wide-spread social objections to some of the potential applications of this device in the next decade because of sensitive areas such as use by employment agencies and credit agencies.

In summary, there will be a modest number of limited voice recognition terminals developed and marketed in the next decade for special purposes, but general speech recognition is beyond the 1980-85 timeframe, except for experimental systems.

5.3.8 Movement Transducers

Devices which convert movements into machine acceptable data (e.g. electrical) will be important in the next decade, both as adjuncts to general purpose displays and for special purposes like process control. The joy stick and SRI mouse* are examples of components which will be more widely used on display terminals. Mechanical arm controllers will be more widely used in special applications like handling hazardous materials and doing dangerous operations on assembly lines or in mines (see page 95). At present, robot controllers are utilized in the handling of radioactive equipment, and experimentally in automobile production lines. The cost of the mechanical portions of these devices will not be reduced significantly in the next decade but the decline in A/D conversion and control costs should bring their price down somewhat.**

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*The mouse is held in the hand and moved horizontally or vertically along a level surface to change the position of a point on the display screen.

**The price of the mouse is from $350. to $450.

More sophisticated movement transducers, such as a device for following eye movements, or sensors for detecting body position or facial expression might emerge during the next decade for sending non-verbal information and cues over a narrow bandwidth instead of sending a video image requiring wide bandwidth. For example, in the United States, NASA has developed a system for detecting body position in which the user wears a jacket with lights,and a photo scanner scans the lights and computes the position and angles of parts of the body. This data could be sent over a narrow channel and converted into a computer-animated picture at the other end to complement the verbal information communicated during a phone call.

5.3.9 Biofeedback

There are several possibilities for biological inputs to terminal devices. These include a) breathing, heart rate, ECG, or chemical level monitoring for medical purposes, and b) galvanic skin response, tension in muscles or the larynx (used in the voice stress analyzer to detect lying), and brainwave monitoring to detect stress and emotional states. Brainwaves might conceivably be used to control simple operations like setting or resetting a switch or controlling room lighting, but it is unlikely that any extensive computer-nervous system interface will be developed before 1985 and it will most likely take much longer than that.(See page 96).

5.4 DATA OUTPUT DEVICES

The technologies relevant to terminal output are organized in the "tree" in Fig. 5.8. Major categories are limited character displays, text displays, graphic displays and other signals (particularly audio) that may be significant to humans.

Advantages	Disadvantages				
Established	Power, Cost	Gas Discharge		LIMITED DISPLAYS (Read Display)	OUTPUT
Low Cost for Small, Long Life	Power, Material	Light Emitting Diodes		LIMITED DISPLAYS (Read Display)	OUTPUT
Low Voltage, Long Life		Florescent Tube		LIMITED DISPLAYS (Read Display)	OUTPUT
Low Power, Cost Independent of size	Short Life Time, Temperature Dependent	Liquid Crystals		LIMITED DISPLAYS (Read Display)	OUTPUT
Inexpensive	Slow speed, noise	Character	IMPACT	TEXT DISPLAYS (Read Text)	OUTPUT
	Mechanical Complexity	Line	IMPACT	TEXT DISPLAYS (Read Text)	OUTPUT
	Low Speed	Thermal	NON-IMPACT	TEXT DISPLAYS (Read Text)	OUTPUT
Speed, Standard Paper	Mechanical Complexity	Ink Jet	NON-IMPACT	TEXT DISPLAYS (Read Text)	OUTPUT
Speed, Graphic Capacity	Special Paper	Electro-static	NON-IMPACT	TEXT DISPLAYS (Read Text)	OUTPUT
	Mechanical Complexity	Eletro-magnetic	NON-IMPACT	TEXT DISPLAYS (Read Text)	OUTPUT
Speed, Flexibility	Cost, Hard copy	CRT	SOFT	TEXT DISPLAYS (Read Text)	OUTPUT
Hard Copy	Slow, Mechanical Complexity	Plotter	Hard	GRAPHIC DISPLAYS (See Image)	OUTPUT
"	Slow, Paper Quality	Facsimile	Hard	GRAPHIC DISPLAYS (See Image)	OUTPUT
Established, Versatile	Power, Life Time, Bulky	CRT	Soft – LIGHT EMITTING	GRAPHIC DISPLAYS (See Image)	OUTPUT
Inherent Memory, Flat	Power, No Gray Scale	Plasma	Soft – LIGHT EMITTING	GRAPHIC DISPLAYS (See Image)	OUTPUT
Flat, Gray Scale	No Memory, Low Reliability	Electroluminescent	Soft – LIGHT EMITTING	GRAPHIC DISPLAYS (See Image)	OUTPUT
Reliable, Good Appearance	Expensive Material	LED	Soft – LIGHT EMITTING	GRAPHIC DISPLAYS (See Image)	OUTPUT
Flat, Low Power,	Temperature dependent	Light Beam	Soft – LCD – LIGHT VALUE	GRAPHIC DISPLAYS (See Image)	OUTPUT
SIC Compatible	Limited Reliability, No	Thermal	Soft – LCD – LIGHT VALUE	GRAPHIC DISPLAYS (See Image)	OUTPUT
Low Cost Per Element	Memory	Matrix	Soft – LCD – LIGHT VALUE	GRAPHIC DISPLAYS (See Image)	OUTPUT
Flat, Potentially cheap	Thin Film Compatible	"Ceramic"	Soft – LIGHT VALUE	GRAPHIC DISPLAYS (See Image)	OUTPUT
Inexpensive, Hard Copy	Non Erasable, Experimental	Laser	Soft – LIGHT VALUE	GRAPHIC DISPLAYS (See Image)	OUTPUT
Large audience	Expensive	Large Screen		GRAPHIC DISPLAYS (See Image)	OUTPUT
Useful in Many Applications	Experimental, Expensive	Multi colored		GRAPHIC DISPLAYS (See Image)	OUTPUT
Improve Realism	Expensive, Experimental	3 Dimensional		GRAPHIC DISPLAYS (See Image)	OUTPUT
Inexpensive	No inflection, Unnatural	Answerback Drum		AUDIO OUTPUT (Hear)	OUTPUT
More natural	Experimental, Circuit Costs	Speech Synthesis		AUDIO OUTPUT (Hear)	OUTPUT
Useful in Onsite Applications	Expensive, Limited Market	Mechanical Arm	MOVEMENT CONTROLERS	MOVEMENT OUTPUT (See Feel Movement)	OUTPUT
Useful in Industrial Applications	Expensive, A/D Circuits	ROBOT Controlers	MOVEMENT CONTROLERS	MOVEMENT OUTPUT (See Feel Movement)	OUTPUT
	Experimental	Muscle Tension		MOVEMENT OUTPUT (See Feel Movement)	OUTPUT
Useful for Handicapped	Body acclimated to signal	Tactile Feedback		MOVEMENT OUTPUT (See Feel Movement)	OUTPUT
Hearing Heart beat at a distance		Audio		BIOFEEDBACK	OUTPUT
		Temperature		BIOFEEDBACK	OUTPUT
Patient Care	Social Objections, Reliability	Chemical Injection		BIOFEEDBACK	OUTPUT
Epileptic Control		Electrical Stimulation		BIOFEEDBACK	OUTPUT
Most effective Means Machine Interface	Unlikely before 2000	Neural		BIOFEEDBACK	OUTPUT

Figure 5.8 - Technologies Relevant to Terminal Output

General conclusions about the area follow: graphic displays can be expected to make significant inroads in the interactive terminal market in the next decade. They have come down in price from $75,000. to $15,000. in the last decade (Reference 51) and one might expect a similar drop (5x) in the next decade.* The "glass teletype" (alphanumeric CRT) will become cheaper than the slow speed teletype and will replace it in applications not requiring extensive hard copy. Impact printers will begin to be replaced by faster non-impact devices. Audio output will be more widely used in point of sale and educational systems and as adjuncts to visual terminals as cost of magnetic devices go down and speech synthesis is perfected. Remote control devices (e.g., mechanical arms and robots) will be a very significant area of research in the next decade, but will probably not be associated with interactive terminals in the near future. Any form of direct biological output is extremely unlikely in the next decade except in very specialized cases like intensive patient care.

5.4.1 Limited Character Displays

Limited Character Displays are panels of indicators or characters, e.g., the face of an electronic calculator, used in special applications like point of sale. The major competing technologies in this are a) gas discharge, b) light emitting diodes (LED's), c) Liquid Crystal Displays (LCD's) and d) Vacuum Florescence (Reference 36). LED's can be expected to capture most of the short-term market for small character displays and compete with established gas discharge tubes like the Nixie(TM) in other areas. In a few years LCD's will begin to challenge LED's, particularly in applications requiring large-sized characters. Moderate though not drastic cost reductions can be expected in limited character displays. It is expected that the price of LED's and Liquid Crystal displays will decrease by a factor of 2 in the next 4-5 years.

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* Though the drop might be less if materials become scarce, or more if emerging technologies like Liquid Crystal and Electroluminescence develop faster than expected.

5.4.1.1 Gas Discharge Tube

Gas discharge tubes in which neon, or other inert gases, glow around character-shaped cathodes is a mature technology available for at least 15 years. A new planar configuration, which is smaller, cheaper and consumes less power, has recently been developed. This is referred to as Plasma, and is actually a matrix of fine wires in a "gas sandwich". The cross points are energized by placing a voltage across them. However, because of the mechanical structure, inexpensive mass production becomes a problem. The use of plasma displays is not keeping pace with other devices due to the limited displays available and the overall cost of the display, and associated interface. Gas discharge tubes can be expected to lose much but not all of its market to more recent LED, Vacuum Fluorescent, and LCD devices.

5.4.1.2 Vacuum Fluorescent Displays

Vacuum fluorescent tubes are similar to gas discharge except the anode is coated with a phosphor which glows when bombarded by electrons emitted from a heated cathode. They require lower voltage and have a longer lifetime than gas discharge tubes and are now the most popular limited display device in Japan. Also, like gas discharge, they will probably lose out to solid state technologies in the long run.

5.4.1.3 Light Emitting Diodes

LED's are solid state devices which emit their own light. They have an extremely long lifetime and work over a wide temperature range. However, they are made of an expensive material, so large characters become expensive. The power consumption of LED's is relatively high in proportion to the size of the character In 1969, LED displays cost $25. per digit for the same character size; in 1973, they are as cheap as $ 3 per digit. However, light emitting diodes are reducing in cost along the same lines as semi-conductors. Significant developments by Bell Labs in new materials could bring a cost reduction in certain types by 1976 to 50¢ per digit if a mass produced Bell terminal were developed, but the costs will generally level off after that.

The LED could find its major use in transaction type terminals, and as these type of terminals become more popular the LED "population" will continue to grow.

5.4.1.4 Liquid Crystal Displays

LCD's are currently emerging as an alternative to LED's and earlier technologies for limited character displays, and there are still some difficulties to be overcome. Liquid Crystal Displays operate on the principle of changing the light transmission and reflection characteristics of (liquid) crystals by applying an electric field or light beam to the crystal. LCD's currently work only over a limited temperature range and have a relatively short lifetime (10,000 hours). The lifetime can possibly be increased by highly purifying the liquid-crystal materials, proper sealing, and using less driving current. It is also expected that the legibility of LCD displays will be improved by suspending a dye in the liquid crystal. If these improvements are made, LCD's are expected to be preferred over LED's in that they require much less power and their cost is less dependent on size.

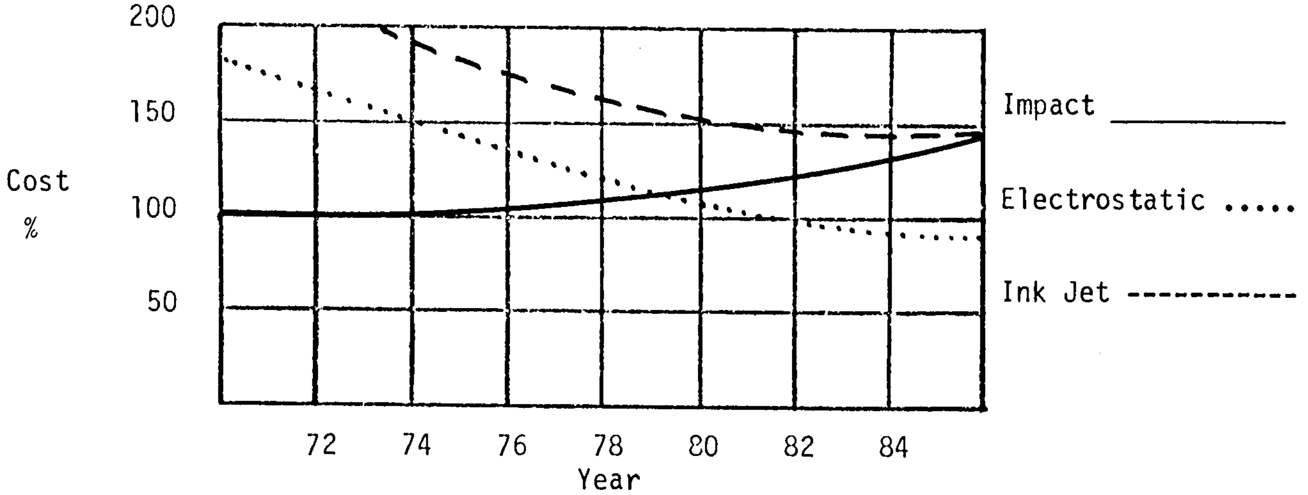
Liquid crystal displays are not as yet a mass produced item, and as such they are relatively expensive. However, improvements in the LCD technology and associated production techniques are bringing the costs down. The low power required to operate these devices will create a market for them and consequently lead to low cost mass produced LCD's.

The use of LCD's will increase widely from about 1975 and they will probably be the major display media on alphanumeric devices by the end of the study period.

5.4.2 Text Displays

Cost reductions in hard copy printers will be slight. The standard low-speed impact printer, e.g. the Model 33 Teletype, will even go up slightly as labor costs rise. Gradually it will be replaced by higher-speed "non-impact" printers which use electrostatic, electromagnetic, ink jet, photographic or thermographic technologies where the application does not require multiple copies. Projected relative costs are shown in Fig. 5.9.

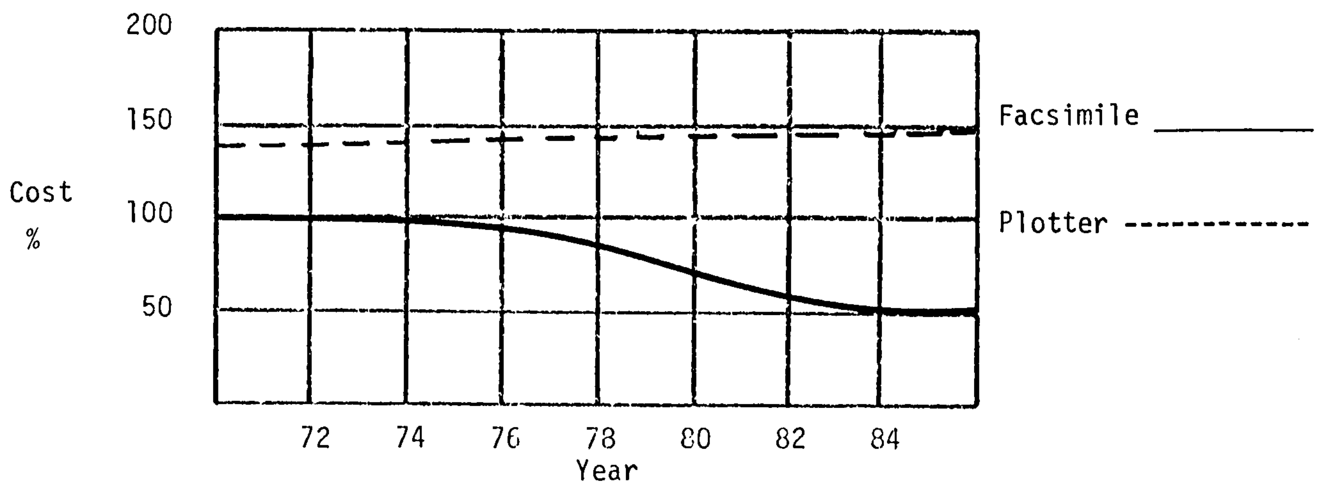
In applications not requiring much hard copy, photographable alphanumeric CRT displays (or "glass teletypes") will replace the low-speed impact printer before 1980. As Fig. 5.11 shows, based on estimates made in Reference 36, "glass teletypes" should be as cheap as slow speed teletypes by 1976-77, and their relatively low cost is expected to reduce, but at a relatively slow rate over the next ten years. The slow decline is due mainly to limitations in vacuum tube technology employed in the CRT display. Generally if non CRT display technologies develop as predicted, the rate of terminal price decline will increase.



Printers: Impact/Electrostatic/Ink Jet

Figure 5.9

Comparative Cost Trends - Output



Facsimile/Plotter

Figure 5.10

Comparative Cost Trends - Output

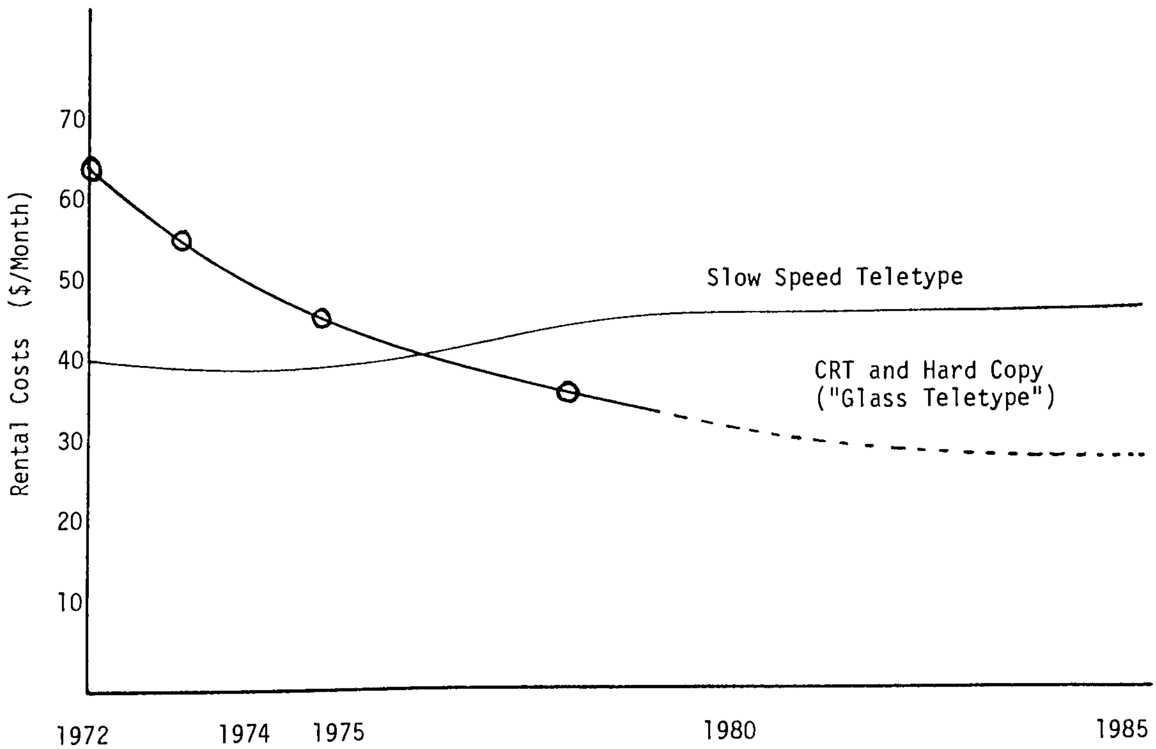


Figure 5.11
Cost Trends for Slow Speed Teletype vs. CRT and Hard Copier

5.4.3 Graphic Displays

These displays have the ability to display diagrams, graphs and pictorial information. A cathode ray tube can display graphic information when used with electronic circuitry capable of generating the resolution required. The greatest impact in output technologies in the next decade appears to be in the area of graphic or visual displays. One must be careful about being overly optimistic about new technological opportunities for there are often more problems than proponents will admit, but hard copy graphic display terminals have declined in cost by a factor of 5 in a decade ($75,000 to $15,000) and it is not unreasonable to expect a further 3-fold drop (to $5,000 or less) in the next decade. Most of these devices are servo-mechanisms. Such a drop would be caused by a) economies of scale produced by an increased market, b) reduction in processing and memory components of displays through large scale integrated circuits (see Section 5.5), and c) new display technologies which can utilize LSI fabrication methods. Several types of multi-color terminals will be put on the market in the next decade, and there is a possibility of a 3-D/holographic display by 1985.

5.4.3.1 Plotters and Facsimile (Hard Copy)

There will probably be no cost reduction in conventional plotters due to complexity and high labor content. They will be replaced by soft displays with auxiliary hard copy reproduction units, except in applications were ultra high quality or large graphics are needed. See Fig. 5.10 for projected relative costs.

Telefacsimile terminals on the other hand show signs of becoming extremely popular; there were over 2000 such terminals in Canada and 50,000 in the U.S. in 1972 and the growth rate between 1970 and 1971 was reputedly 500% (Reference 37). The several techniques for facsimile scanning are shown in Fig. 5.12. Characteristics of facsimile devices currently on the market are shown in Fig. 5.13. Many facsimile terminals are relatively inexpensive today - the Xerox Telecopier rents for $65/month for instance (Reference 38). The problem is that they are so slow compared to human response time: an average page contains the equivalent of about a million bits of graphic information (assuming 100 lines/inch scan), so it takes 4 to 6 minutes to transmit a page on 3 KHz lines (Reference 39). Facsimile operating speed could be increased by availability to user of wider band transmission facilities, e.g. fiber optics or millimeter waveguides, likely to emerge by 1980 (see Section 5.6), and/or by data compression techniques, which reduce bandwidth requirements, such as the "white space skip" scan (Reference 40), which moves rapidly over areas of uniform shading and slows down only when light intensity gradients are encountered. (Such a technique could, in principle, reduce transmission time to one minute or less)*. Development of digital facsimile terminals capable of operating on Dataroute or Infodat channels will effectively reduce the cost of communications for these devices. Besides acting as terminals, facsimile devices can be used as hard copy repro units with soft graphic displays. Here, bandwidth is not a problem and speeds of 10 seconds per page are achievable. The major limitations of facsimile terminals at present are bandwidth and analog coding techniques.

*Large Scale Integration (LSI) might be used to reduce the cost of bandwidth compression hardware (see Section 5.6).

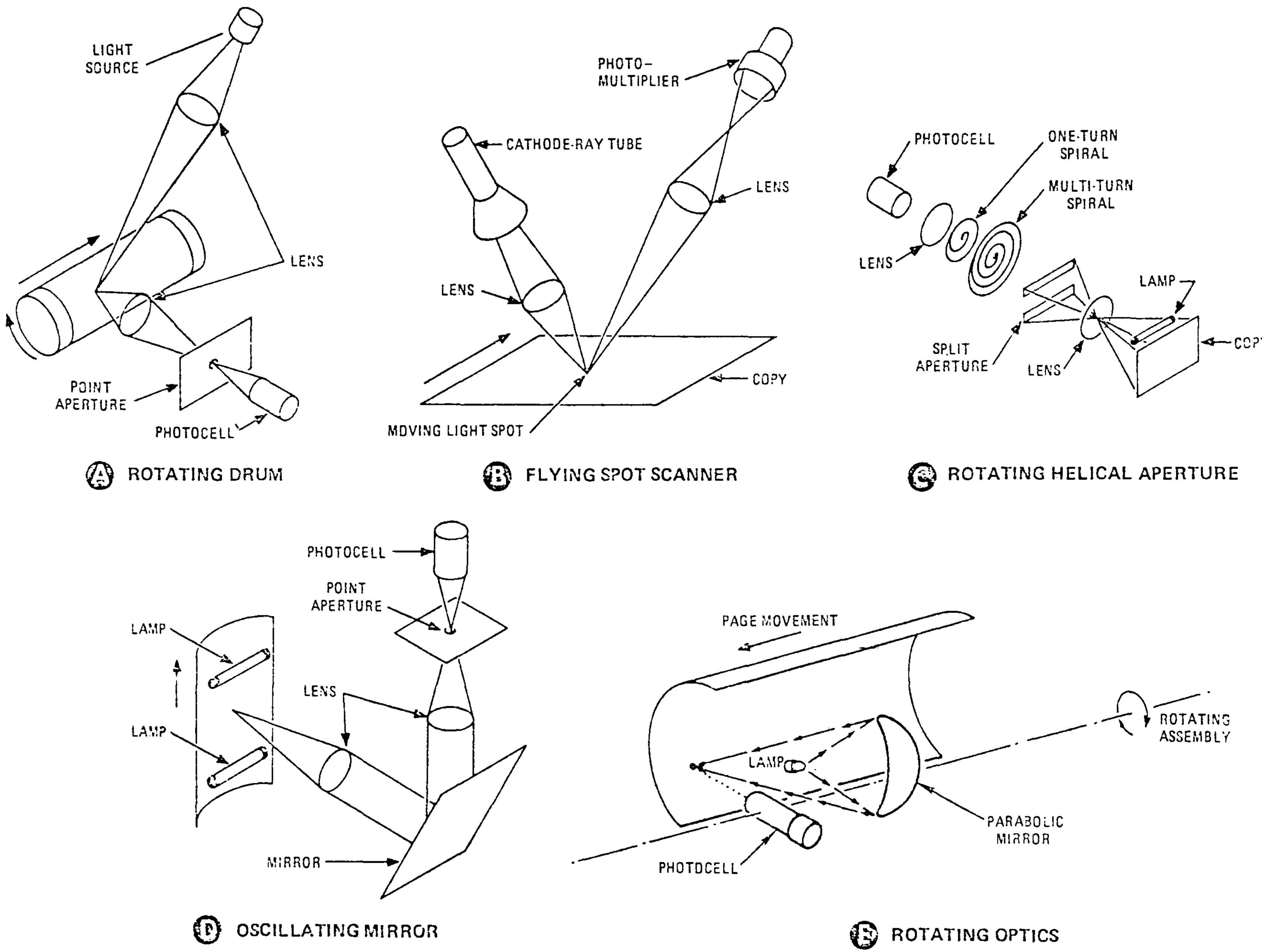


Figure 5.12
Facsimile Scanning Techniques (Reference 39)

CHARACTERISTICS \ MANUFACTURER	ALDEN	GRAPHIC SCIENCES	LITCOM	MAGNAVOX	MUIRHEAD	SCANATRON	SHINTRON	STEWART WARNER	TELAUTOGRAPH	XEROX
Model	11 Alspeed Docufax (9242 scanner)	dex I	Messagefax 4301	850	K400B	391	QIX 503	FT9095A	Quickfax 900	LXD C-135
Document Size, Inches	24 x unlimited	9 x 14	8-1/2 x 14	8-1/2 x unlimited	8-1/2 x unlimited	9-1/4 x unlimited	8-1/2 x 11 max.	9 x unlimited	8-1/2 x unlimited	9-1/2 x unlimited (3-1/2 x 5 min.)
Document Thickness, Inches	3/16 max.	0.008 max.	about 0.01 max.	about 0.015 max.	about 0.008 max.	1/16 max.	0.008	Probably 0.01 max.	1/16 max.	0.002-0.008
Scanning Technique	Rotating helical aperture	Rotating drum	Rotating drum	Rotatory Optics	Rotating drum	Rotating lenses and mirror	Rotating drum	Rotating helical apertures	Flat bed with slotted disk	CRT line scanner
Vertical Resolution, Lines/Inch	96	88	91	96	90	96	89	96	100	135
Scanning Rate, Lines/Sec.	16	2.5	5	3	8.3	16	3.6	15	15	215
Time/8-1/2 x 11 Inch Page. Sec.	66	360	200	352	119	66	270	60	72	6.9
Modulation Technique	AM DSB	AM VSB	AM VSB	FM	AM	AM VSB	AM VSB	AM VSB	AM VSB	Asynchronous binary
Carrier Frequency, kHz	32	2	2.75	None	DC	12	2.25	9.5	12	None
Transmission Frequency, kHz	18 - 46 (est.)	1 - 2	1.5 to 2.75	0.7 - 2.5	0 - 6 (est.)	0.8 - 9.5	0 - 1.5	1.3 - 9.5	5.4 - 14.5	0 - 250
Size, W x D x H, inches	30 x 21 x 50	22 x 15 x 5	21 x 18 x 6	19 x 16 x 12	16 x 16 x 9	19 x 16 x 18	20 x 15 x 5	17 x 20 x 15	18 x 18 x 18	24 x 46 x 46
Weight, lbs.	396	47	45	42	47	96	20	91	80	425
Power	500W	115 VA	600 VA	about 300 VA	100 VA	45W	50 VA	400 VA	200 VA	400 VA
Monthly Rental	$359	$75	$75	$65	$115 with service		$65	$135	$115	$550
Purchase	$7,950	$2,900	$2,200	$1,995	$2,400	$2,975	$1,795	$3,250	$3,000	No
Comment		Combined scanner-recorder		Combined scanner-recorder		Non-Mil. version available @$1,400 each including modem (qty > 100)	Available 1st or 2nd quarter of 1970	Compatible with Dacom DFC-10 bandwidth compressor.		5¢/ft. charge for 10^6 ft/month

Fig. 5.13. Facsimile Scanning Equipment (Reference 39)

5.4.3.2 Soft Graphic Displays

Soft displays can be divided into two categories: a) light emitting devices, and b) light controlling or light value devices. The advantages and disadvantages of the alternative devices in both classes are summarized in Fig. 5.14 (Reference 37). See Fig. 5.15 for projected relative costs.

i. Light Emitting Devices

Cathode ray tubes (CRT's) will continue to be the dominant form of soft display for the next 5 or 6 years mainly because they are versatile and established (Reference 37). Cost of the actual CRT and its associated driving circuit will probably only be reduced by a factor of two or less in the next 10 years (see Fig. 5.11) but the storing and processing circuits, which make up most of the CRT display's cost, will be reduced more significantly through large scale integration, bringing about an overall cost reduction of up to 3-fold (to around $4,000). Major disadvantages of CRT's are bulk, inherently curved geometry, high voltage requirements, and incompatibility with silicon integrated circuits. These disadvantages will accelerate the search for flat, low voltage alternatives in the period before 1985.

Plasma displays, in which an inert gas is ionized in the immediate neighborhood of intersections of a matrix of wires, are already available. Plasma terminals developed for the PLATO computer aided instruction network now sell for $5,500 (Reference 41) for a limited market. The advantages and disadvantages of the plasma display are shown in Fig. 5.14. People at the PLATO project believe the plasma terminal will replace the CRT by 1985, others are not as sure (Reference 42).

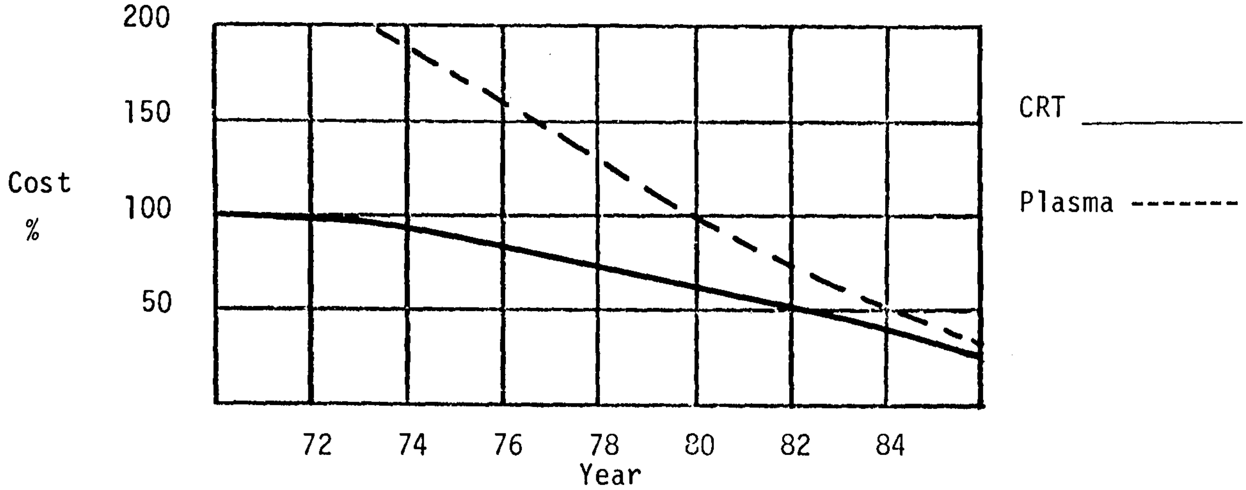
	LIGHT EMITTING	LIGHT VALUE	ESTABLISHED	COST	OPERATING VOLTAGE	FLAT COMPACT	RELIABILITY	RESOLUTION	SPEED	INHERENT MEMORY	ERASABLE	SIC COMPATIBLE	BRIGHTNESS-APPEARANCE	TEMPERATURE RANGE	MULTICOLOR-GRAY SCALE	UNIFORMITY OF PRODUCT	OVERALL EVALUATION
CRT	+		+	+	-	-		+	+	-	+		+	+	+	+	+
PLASMA (AC EXCITED)	+				-	+	+	-		+	+	-	+	+	-	+	+
ELECTRO-LUMINESCENT	+		-			+	-			-	+	-				-	-
LIGHT EMITTING DIODES	+		+	-	-	+	+		+	-	+	+	+	+		+	-
OIL-FILM DIFFRACTION		+		-	-	-	-	+	-	-	+	-	+		+		-
METAL FILM SYSTEMS		+	-	+				+	-	+	-	-	+	+	-	+	
FERRO-ELECTRIC CERAMIC		+	-	+			?	+	-	+	+		+	+		+	+
LIGHT ADDRESSED LCD		+	-	+	+		-	+	-	+	+			-	+	+	
THERMALLY ADDRESSED LCD		+	-	+	+		-	+	-	+	+			-	+	+	
MATRIX ADDRESSED LCD		+	-		+	+	-	-	-	-	+	+		-	+	+	+
ELECTRO-PHORETIC LCD		+	-	+	+	+	-	-	-	+	+	+	+	-	+	+	+

\+ ADVANTAGE

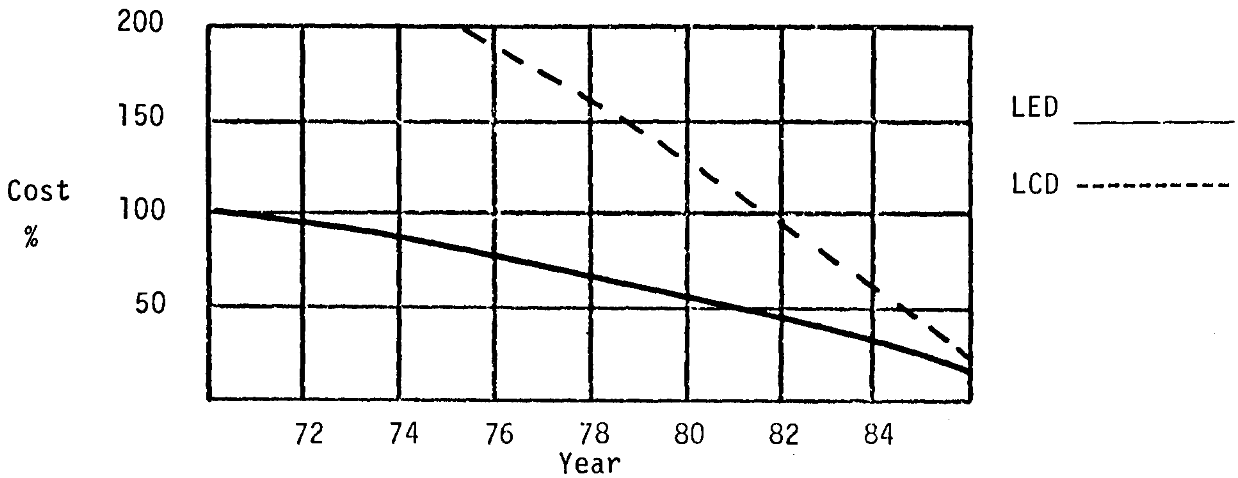
\- DISADVANTAGE

Figure 5.14

Advantages and Disadvantages of Soft Displays



(a) CRT/Plasma



(b) LED/LCD

Figure 5.15
Comparative Cost Trends - Soft Graphic Displays

The Matsushita Electric Industrial Company of Japan is developing another flat display based upon the use of solid state electro-luminescent materials (Reference 43); and, while there are still major problems of compatibility, uniformity, and reliability this area has good potential (Reference 37).

Light emitting diode matrices could be used as graphic displays, but the cost of the material, and thus the cost per area,is fundamentally high, so this is not an economically feasible alternative at this time.

ii. Light Value Displays

Light value displays can be classified in terms of the manner in which a point on the screen is accessed. The following three categories are distinguishable: a) electron beam-addressed, b) light beam-addressed, and c) matrix-addressed (Reference 37). Electron beam addressed devices are largely applicable to large displays and will be covered on page 93.

a) Light Beam-Addressed Displays

One technique for light addressed displays is to use a solid state infra-red (IR) laser to write on non-reusable metal film. This technology is potentially very inexpensive and should have wide applications in facsimile and data retrieval displays (Reference 37).

Erasable light addressed displays are being developed which utilize either a ferroelectric ceramic plate coated with a photoconductive film (Reference 37) or a liquid crystal cell coated with a photoconductor (Reference 44). These displays have the advantages of high resolution, low cost, and inherent memory, but they are relatively slow and will be useful only for slow changing or relatively fixed displays (Reference 45).*

b) Matrix-Addressed Light Value Displays

The most likely candidate for matrix addressed light value displays are liquid crystal devices because they can be fabricated cheaply and are compatible with the use of silicon integrated circuits (SIC's). LCD's, however, have had the disadvantages of short lifetimes, poor appearance and no inherent memory. The lifetime problem might be solved by better sealing and lower driving voltage. The poor appearance can be improved by using a pleochroic dye or electrophoretic colloided dye in the liquid crystal (Reference 37). It appears that these dyes may also be used to provide inherent memory (Reference 37). If not, inexpensive large scale integrated circuits may be used to supply the required memory. Matrix addressed liquid crystal displays will probably become cost competitive and may be less expensive than CRT's by 1985.

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*The same conclusions apply to thermally addressed LCD's which uses an IR laser to locally heat a region of the liquid crystal changing its optical properties (Reference 37).

5.4.3.3 Large Screen, Multicolored and 3-Dimensional Displays

Devices for projecting displays onto a large screen for viewing by a large audience such as in a movie theater or chart room are very expensive and will probably continue to remain so for the next decade. They will have a limited market - wall sized TV screens are unlikely before 1985. The most popular devices today, Conrac's EIDOPHOR and the GE LIGHT VALUE use a television signal to modulate an electron beam which deforms a thin oil layer on a concave mirror (Reference 37). The EIDOPHOR is $185,000 for color or $65,000 for black and white (Reference 37). The GE LIGHT VALUE is not as bright and sells for $41,500 ($30,000 for black and white). (Reference 41).

Multicolored displays would be very desirable for many of the emerging terminal applications. There are very few on the market today because the color television CRT is not appropriate for interactive terminal displays (Reference 41). However, new "penetration color tubes" have been developed which could change this (Reference 46). By 1985 there should be many color displays on the market, with costs approximately double that for black and white.

Human Resources Research Organization of Alexandria, Virginia, is developing a Color Halftone Area Graphic Environment (CHARGE) terminal which offers color and hardware for transforming 3-D to 2-D graphics and for generating perspectives. The terminal is expected to cost $10,000 in the U.S. and the image generator which can serve 100 terminals will cost about $200,000 (Reference 46). Large scale integration of circuitry could significantly reduce these costs in the future. The actual cost reduction would be dependent on the advances in MOS and I^2L techniques.

An alternative approach to dealing with 3-D graphics would be to develop a holographic display. Bendix Corporation has shown the feasibility of a three dimensional holographic display (Reference 41) which would make 3-D interactive terminals feasible, though expensive, by 1985.

5.4.4 Audio Output

Audio output will be more widely used for special purposes such as point of sale, and as a complementary information channel on visual displays. The cost of answerback drums and discs on which audio messages are prerecorded will probably be reduced by a factor of 2 or 3 in the next decade. An optional answerback disc for PLATO terminals on which 4,000 messages can be accessed from a disc with the capacity of 21 minutes of sound, can be purchased for $1,500 (Reference 47).

A more flexible and natural audio output system is becoming feasible as speech synthesis is perfected. In such systems, individual phonemes (the basic elements of speech), are generated by electronic circuits, which can be adjusted to give proper inflection, and combined in sequence to form natural sounding messages. These speech synthesis devices will be expensive initially, but should come down in price if the demand makes the use of LSI feasible. For applications requiring flexible and natural man-machine communication and and a large number of potential messages, speech synthesis devices may replace pre-recorded magnetic devices by 1985. A period of experimentation by Simpson-Sears and IBM Canada has led to the implementation of a catalog order system using touch-tone input and voice answerback.

5.4.5 Movement Output

Automation and remote process control should be a very important area for research and development in the next decade. Japan has embarked on a $180 million crash program to develop industrial robots (Reference 41). Stanford Research Institute and MIT in the U.S. also have very active programs in this area. There are already 140 firms in the world marketing robots of various kinds. Unimation, Inc., the largest such firm, sells robots that are basically multi-jointed arms with programmable mini-computer brains for $19,000 to $52,000 (Reference 48).

These efforts should be most relevant to special purpose inter-active terminals used in industrial process control or for terminals for the physically handicapped. In the industrial area, interactive terminals might be used to control robots on assembly lines, or open and close valves in a refinery, or to handle dangerous materials or operations from a remote location.* One development that would enhance these possibilities would

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*A GM Vega plant in Lordstown uses 26 Unimation Robots to turn out cars at double the conventional rate. Dow Chemical plans to build an automatic, robot-operated plutonium factory in Colorado (Reference 48).

be the emergence of a cheap, general purpose digital to analog interface through which computer signals could be used to control electromechanical devices. Such interfaces will emerge in the next 5 years as a result of LSI of linear (analog) and hybrid (digital and analog) circuits. In general, the price of logical and learning circuits in controllers will go down at the same rate as mini- and micro-processors (see Fig. 5.22) but the mechanical parts and the overall cost of these devices will remain high through 1985. Household robots are unlikely to be available until sometime after 1985.

Tactile and muscle feedback may be incorporated into terminals for the handicapped and as additional channels in process control terminals. Remote mechanical arms are now being made in which the tension in the control handle equals the tension in the claws of the arm so that fragile objects aren't crushed when handled. Such a principle might be applicable in terminals especially designed to assist blind persons. Also skin tappers have been developed which can tap out messages in braille on a person's arm, stomach or back. The problem with these devices is that the body acclimates and becomes insensitive to the tapping. Much R&D is still needed in the area of terminals for the handicapped.

5.4.6 Direct Biological Output

In a recent U.S. Delphi study (Reference 42) the following events were predicted to be 50% probable by 1984 and 1990 respectively:

a) Man-connected computer systems will be in common use for control of eye movement, muscle, or brain waves.*

b) Micro-electronic and medical technologies will reach the point where it will be possible to directly stimulate (by implementation or other means) the appropriate area of the human brain in order to produce sight and sound as an aid to the blind or deaf.**

These predictions are probably overly optimistic in view of lack of significant progress to date. The U.S. National Academy of Engineering has reported that:

"*a cursory investigation of physiological phenomena yielded no practical data entry mechanism.*" (Reference 49)

Apart from technical difficulties, there would be widespread social objections to machines controlling body functions. In short, direct chemical or electrical inputs into the body are unlikely before 1985 except in very special cases like intensive care monitoring stations and electrodes to inhibit the onset of epileptic fits. Ultimately a direct machine-nervous system interface may be the most effective form of man-machine communication, and eventually we may have to face the psychological and philosophical questions this implies. In the meantime, more mundane purposes will dominate the terminal market.

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*20% chance by 1975, and 90% chance by 1990.

**20% chance by 1985, and 90% chance by 2000.

5.5 LOCAL PROCESSING AND STORAGE TECHNOLOGIES

Local processing and storage technologies, the second main branch on the morphological tree in Fig. 4.3, may be divided into two categories: 1) the internal processing structure, and 2) the machine-oriented communication and storage devices. Figs. 5.16 and 5.17 show the likely decline in costs in these categories compared with transmission costs (see Section 5.6). Between 1970 and 1980 it is expected that transmission costs will decline by less than one order of magnitude (Reference 52), machine-oriented storage will decline between one and two orders of magnitude (References 53 and 54), and processing costs will decline between two and three orders of magnitudes (References 52 and 55).

The cost of local processing is almost directly dependent on advances in LSI semi-conductor technology, and to a degree on low cost peripherals such as "floppy discs" and magnetic tape cassette drives. Charge coupled device memories are expected to take over from the mechanical discs and tapes mentioned earlier, and cause a sharper drop in the cost curve, up to the early 1980's where a levelling off will occur.

The expectation is that the large reduction of electronic circuit costs relative to communication costs will influence the structure of terminal systems. It is expected that users will arrange their systems in such a way as to reduce their communications costs by substituting local processing for remote processing where possible. The TCTS Dataroute provides a reduction in tariff which makes low speed communication economical; it does not, however, reduce the absolute cost of communications.

5.5.1 Terminal-Processing Structure

Fig. 5.18 shows the components of, and alternative technologies for, local terminal processing. Processing costs have declined drastically in the past two decades, as shown in Fig. 5.19 and can be expected to do so in the future (though at some point there will be a levelling out). The greatest single factor in the

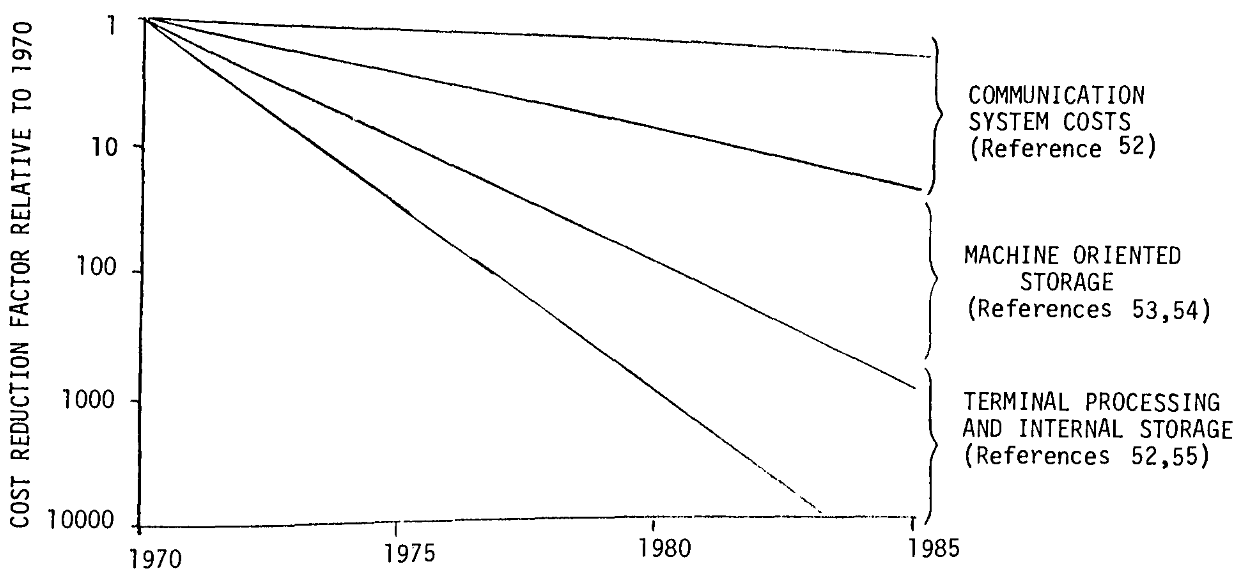
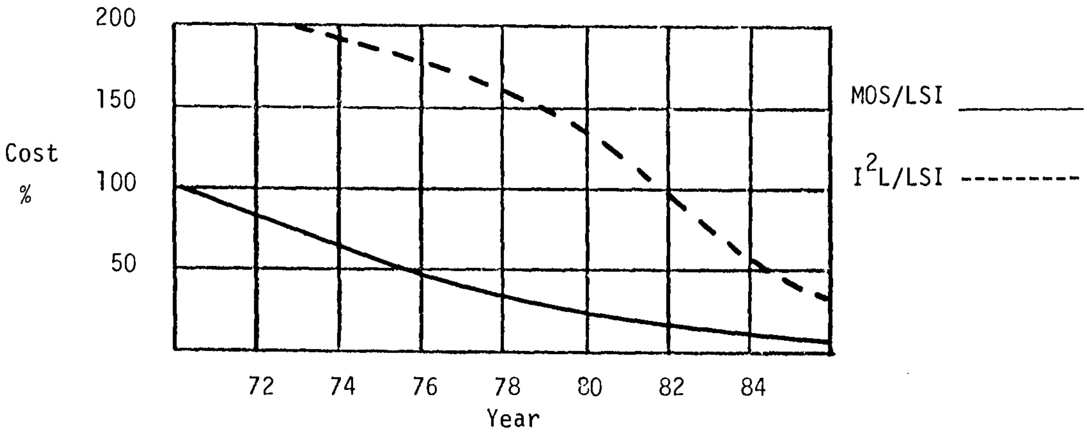
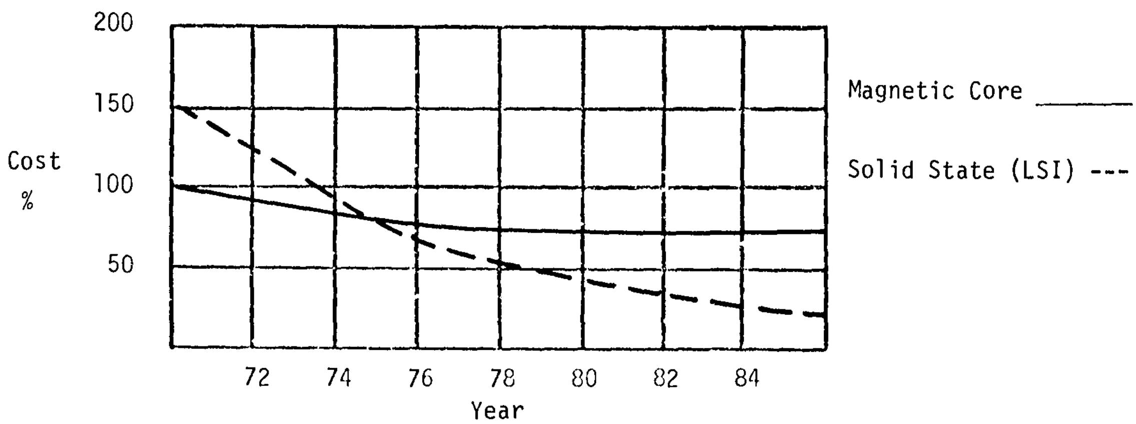


Figure 5.16-Expected Cost Reduction of Major Technologies



(a) Logic Functions



(b) Memory

Figure 5.17

Comparative Cost Trends

Advantages	Disadvantages
Inexpensive Useful for Special Purpose micro processors	Design Complexity Control Structure Implementation Design Methods
Top Down Programming Structural Programming Chief Programmer Team Flexibility Flexibility Speed	Estimation Sepcification Verification Use of Human Resources Speed Programming Architecture
Faster, Parallel Processing	Experimental Programming
Most Flexible Moderate Flexibility Cheapest	Memory Loss, Expensive Memory Loss Memory Loss Unflexible
Low Cost Low Cost Cost	Low Fabrication Yield Complex Fabrication Speed
Density Ease of Fabrication Speed	 Speed Density

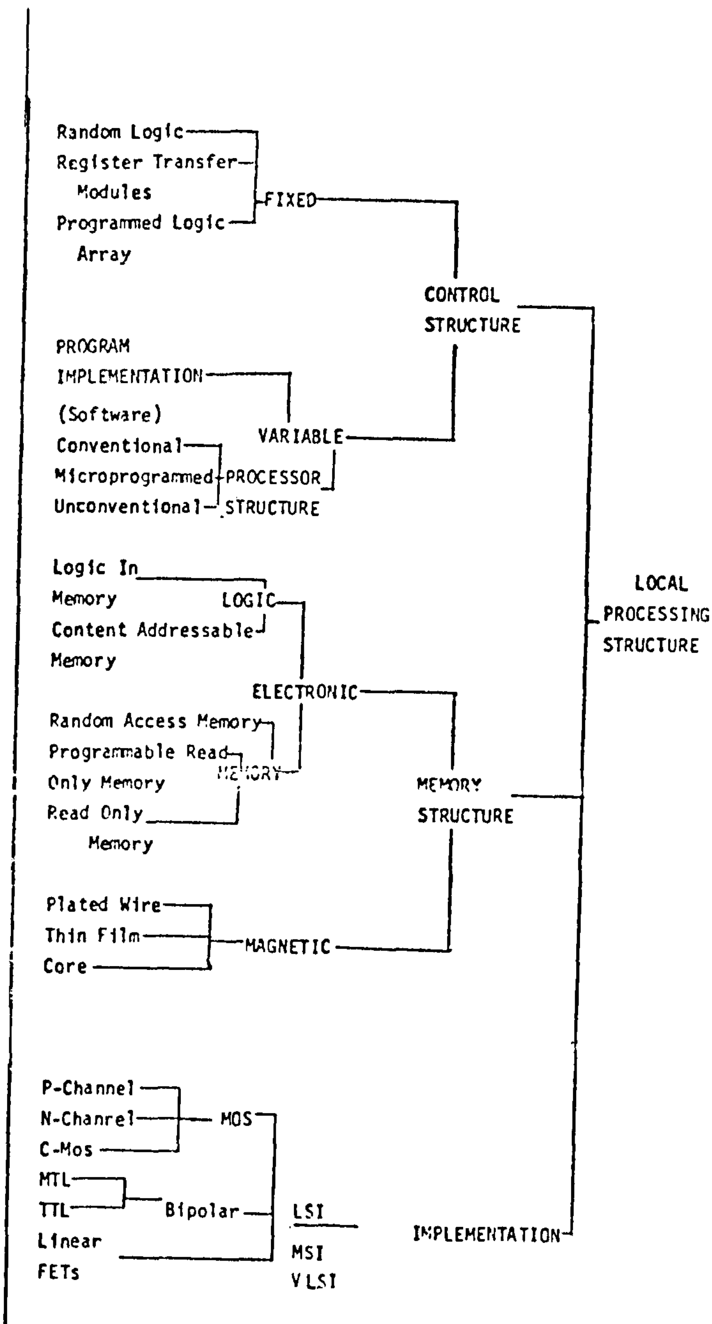
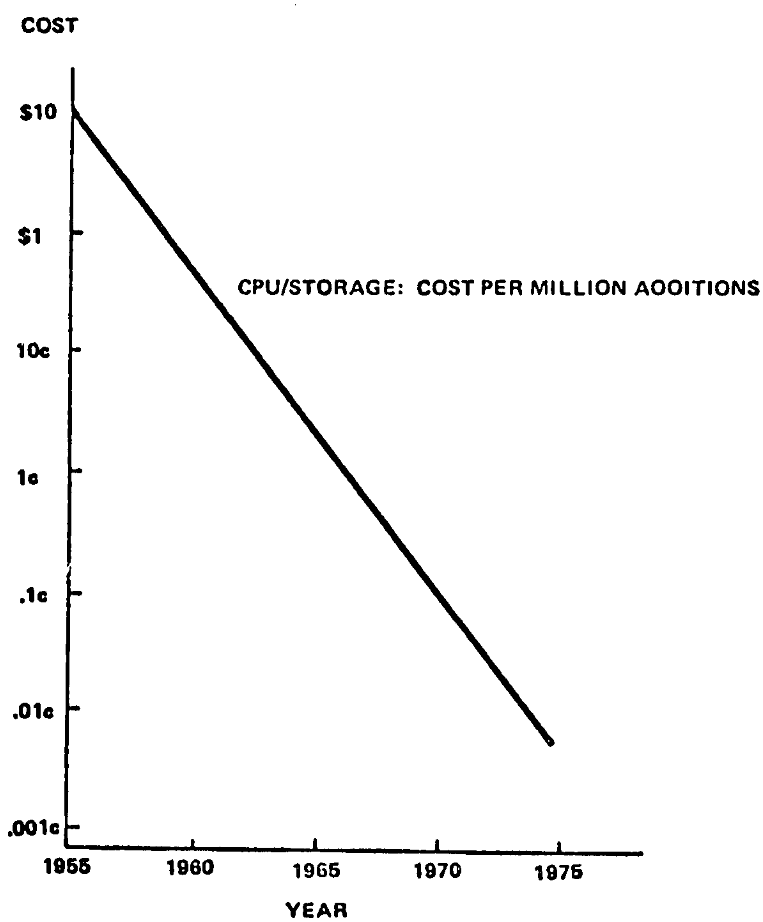


Figure 5.18 - Technologies Relevant to Terminal Processing



Source: Reference 65

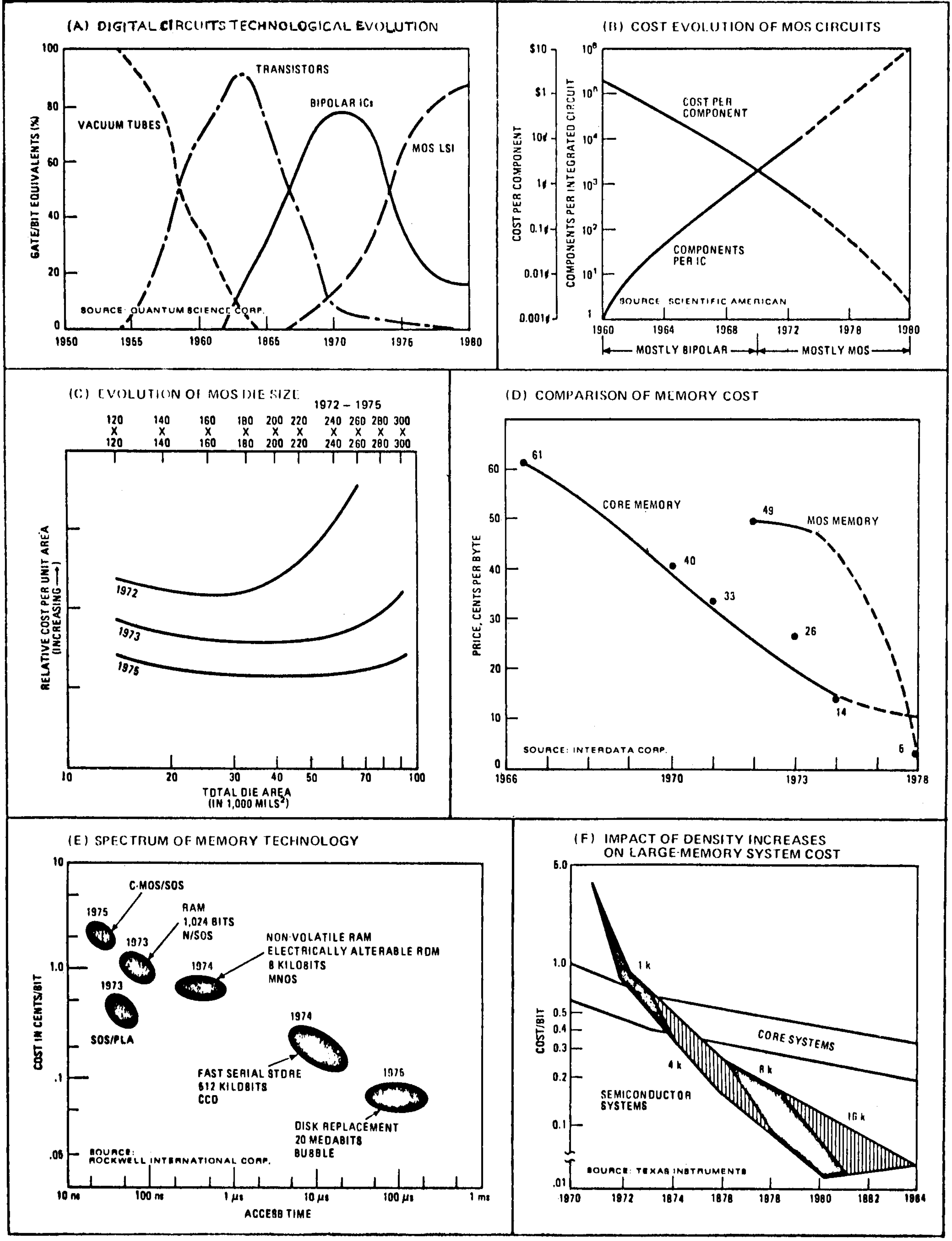
Figure 5.19 -Expected Cost Reductions in Computer Processing

reduction of processor costs today is the introduction to the fabrication of electronic circuits of large scale integration (LSI), a technique which allows the mass production of single devices which perform complex operations. A new solid state technology, integrated injection logic (I^2L) will reduce costs even further when fully developed due to its speed/power performance and high density. I^2L is only in prototype use today, but is expected to be widely used by the end of the 1970's. Fig.5.20 shows curves of how LSI can be expected to take over the circuit market (Gr.-A) and improve the speed (Gr.-E), cost (Gr.-B,D,F), and density of processors (Gr. -C;B). This can be expected to lead to the progressive shifts in terminal processor configurations shown in Fig. 5.21. By 1985, there will be many configurations of the stage 4 type. The average requirements cost of terminal processors can be expected to fall somewhat between the "stripped" mini- and micro-processor curves in Fig. 5.22.

A terminal processing structure has two components: a) a control structure, and b) an internal memory structure.

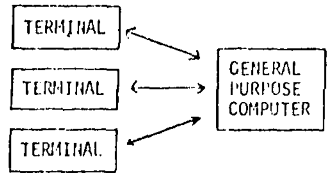
5.5.1.1 Control Structure

Depending upon the complexity of the control function to be performed, the terminal control structure may be either hardwired or programmable. Hardwired control structures are used when the terminal functions are simple or where unusually high processing speeds are necessary. Programmable structure, implemented as a stored program processor has greatly increased flexibility over hardwired structure implementations with a corresponding increase in cost and loss of speed.

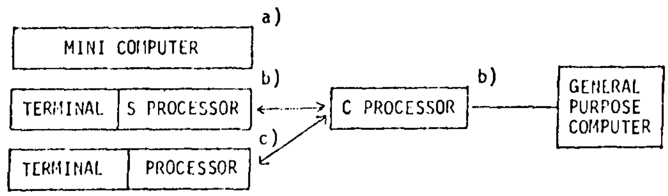


Source: Reference 55

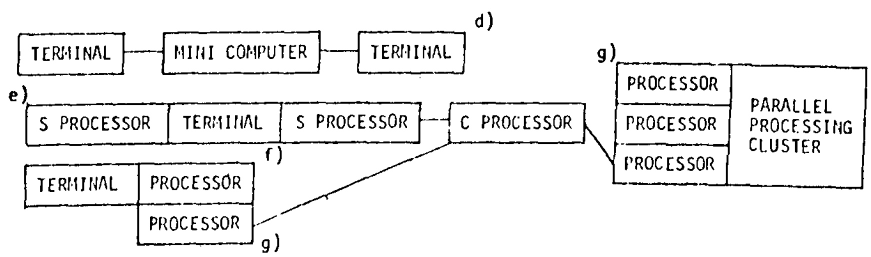
Figure 5.20 - Improvements Through LSI.



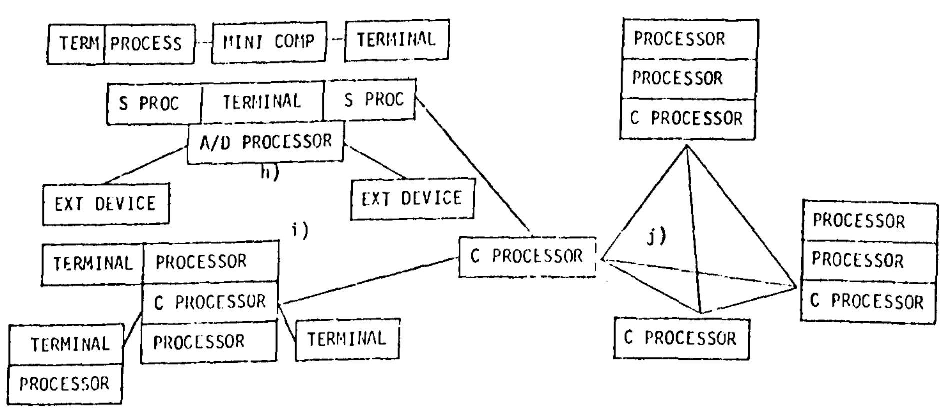
STAGE 1: CENTRALIZED PROCESSING AND STORAGE.



STAGE 2: FIRST ORDER DECENTRALIZATION: a) mini computers emerge, b) special processors to handle communication and bandwidth compression, c) remote text editing.

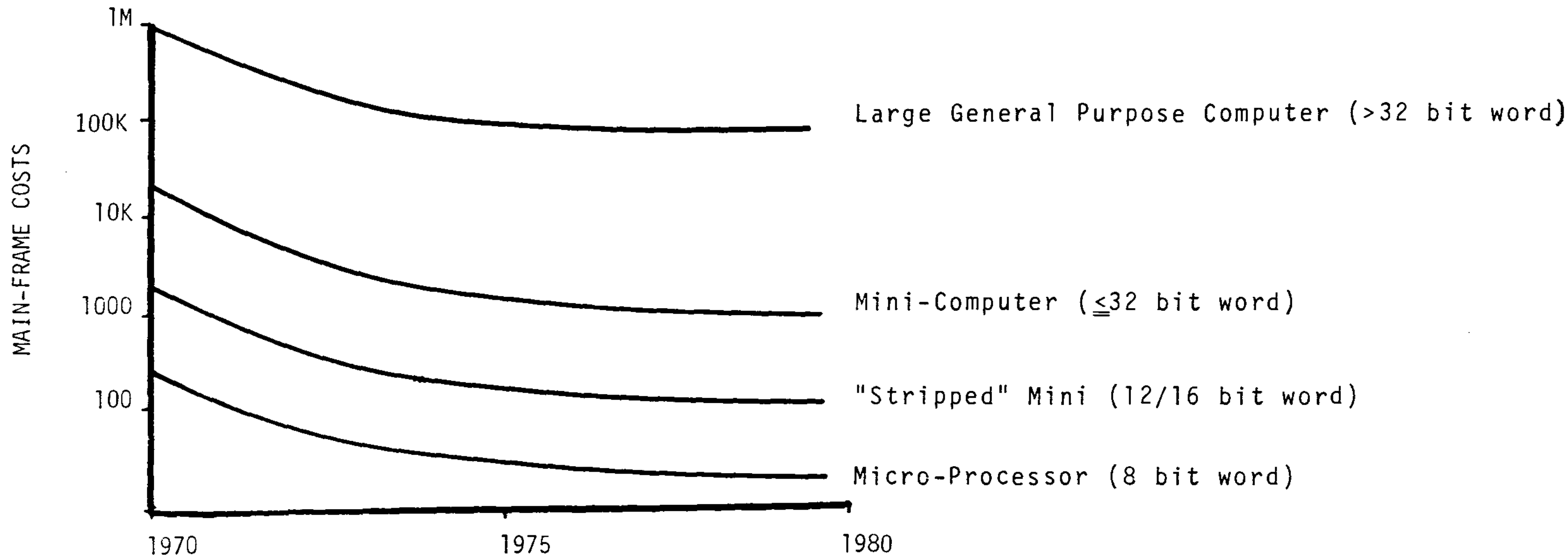


STAGE 3: CLUSTERING AND PARALLEL PROCESSING: d) mini computers sprout terminals, e) special processors for pattern recognition, f) terminal CPUs to handle BASIC, g) terminals and computers have parallel processors and associative memory.



STAGE 4: SECOND ORDER DECENTRALIZATION: NETWORK OF NETWORKS: h) terminals have special processors for handling external devices such as process controllers, i) terminals sprout terminals, j) network of computers and terminals.

Figure 5.21 - Stages in the Decentralization of Processing and Growth of Distributed Networks.



Source: Reference 54

Figure 5.22- Expected Cost Reduction in Main-Frames

i. Fixed Structures

Currently, most hardwired structures are implemented by means of the hardwired arrangement of logic chips usually SSI (small scale integration) or MSI (medium scale integration). Terminal construction requirements aside, the use of hardwired logic for any but the smallest control structures is costly due to the design time involved and large number of different functional units (the chips) which must be used. LSI devices now cost approximately 45¢ per gate in quantities of 10,000. Register transfer module (RTM) and programmed logic array (PLA) are evolving techniques which attempt to reduce both design time and the iventory of different units needed for a given control realization. RTM is a design technique in which a set of standard MSI or LSI modules are specified and interconnected in a standard way. A useful set of such modules is available in current MSI realizations for the processing of data but as yet standard modules to specify flow of control are not available.

Interest is increasing in Programmed Logic Array (PLA) design techniques. This technique is based on selective making of a standard LSI array to implement complex logical functions. The inventory of standard modules should be very small, but efficient design techniques are yet to be widely applied.

ii. Programmable Control Structure

A variable control structure may be implemented by means of a stored program processor. This implementation technique is expected to become more common with the rapid reduction in microprocessor costs due to LSI/MOS* technology. The stored program machine may be organized in several ways:

a) Conventional (Von Neumann),
b) Microprogrammed, and
c) Unconventional (e.g. associative)

In the conventional or Von Neumann architecture the terminal control structure would reside in the processor-stored program. In general, programmed control structures will operate at a lower speed than fixed, hardwired structures, although the available flexibility is far greater.

Microprogramming techniques may be used in the design of the terminal control structure to give the designer additional flexibility. Microprogramming, which is a hardware logic function, allows the designer to change the basic operational structure of the stored program processor and thus tailor the processor instruction set

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*LSI - Large Scale Integration
MOS - Metal Oxide on Silicon

to his particular needs. It is possible to microprogram a processor to directly execute a higher level language such as BASIC or APL. Direct execution of a higher level language is a possible way in which terminal processing capability can be increased for user convenience and to reduce the cost of communication resources.

Unconventional structures, such as associative and parallel processors, will eventually have an important effect on terminal control structure. The appeal of these structures is their capability for very high speed processing and their potential for low cost due to their regular structure. These structures could become important in special purpose terminals. For example, a three dimensional display could make use of a parallel processor to compute successive display output as the observer's point of view changes.

Usage of local terminal intelligence is at present increasing at a high rate, mainly due to the availability of inexpensive micro-processors. The advances in this technology and associated peripherals are expected to be significant until the late 1970's with a still high but slightly decreased activity in the 1980's, while the market assimilates the new products.

iii. Special Purpose Processors

In addition to general processing units for text editing, computation, and simple programming, terminals may contain special purpose processors for handling analog signals, extracting features for pattern recognition, and removing the redundancy in messages.

LSI will be applicable to linear (analog) devices as well as digital devices so the cost of analog to digital converters and signal processors can be expected to decline at a rate similar to that of digital devices. This will increase the feasibility of terminal processing and movement control.

As indicated in Section 5.3 pattern recognition will be an important function in many terminals. For relatively fixed patterns in which there is a small number of alternatives such as in magnetic ink cheque reading, a hardwired control structure (see page 107) will be adequate; however, in applications requiring recognition of a large set of patterns, or the learning of patterns, a programmable control structure will probably be most effective.

Decreasing processor costs will make it economical to compress or remove the redundancy from signals and, hence, send messages faster over limited bandwidth lines. This should be particularly important in digital facsimile systems, and high resolution graphics applications.

iv. Terminal Software

Terminal software will be discussed in Section 6.

5.5.1.2 Internal Memory Structure

Fig 5.23 shows cost projections for some types of internal (core, film, LSI) and external (disc, optical/bubble) memory derived from different sources. The curves for core agree fairly well, but the LSI projections vary widely indicating that there is uncertainty about how much cost reduction will eventually result from LSI. Indeed, what different people mean when they refer to LSI may vary. What is certain is that LSI components will replace core in many memory applications.

Internal terminal memory is generally random access (RAM) in organization and implemented either electronically or magnetically. Electronic realizations may be expected to take the lead over magnetic implementations in the near future because of their inherent speed advantage and the advances of LSI techniques which are rapidly reducing costs. Magnetic memories have an important advantage in that they retain data even when memory power is lost.

Electronic memories may be divided into three classes: RAM (random access memory), ROM (read only memory) and PROM (programmable ROM). For certain types of terminals, especially those with little or no non-volatile memory, the use of ROM or PROM memory is important. In general, ROM memory costs less than comparable RAM memory since ROM

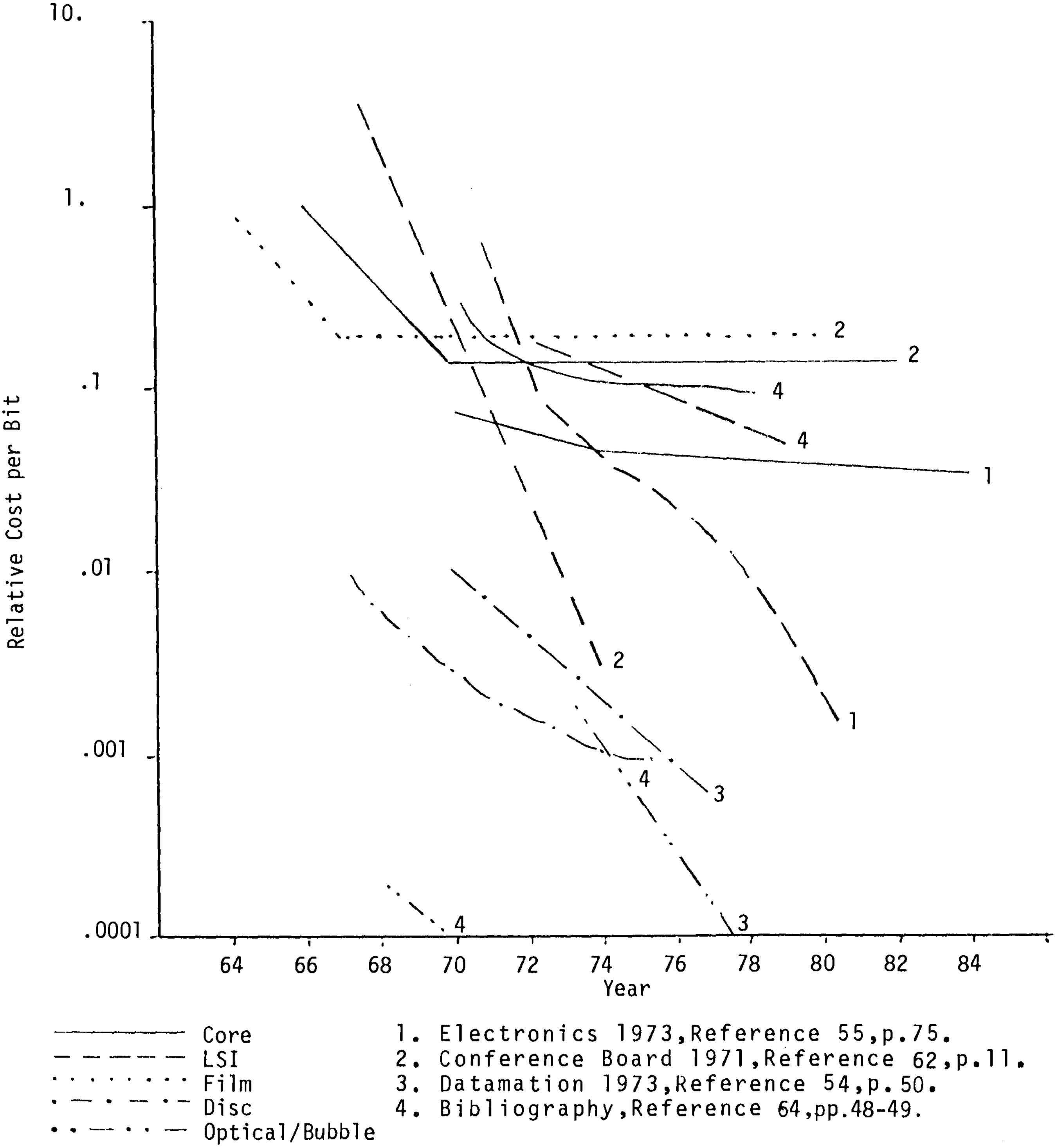

Figure 5.23 -Alternative Forecasts of Memory Cost Trends

structure is less complex. ROM has the disadvantage of being permanent. This can be overcome by using PROM which has permanent data retention but may be altered by using special reprogramming hardware. These devices are sometimes referred to as electrically alterable (EAROM). PROM densities are comparable to those of ROM.

There are currently three magnetic RAM technologies in general use - core, plated wire and thin film. The general consensus among experts today is that core technology is now reaching basic limits in terms of cost and speed. LSI fabrication techniques have helped to lower the cost of core electronics but cannot reduce the costs of the wired core matrices. Thin film and plated wire technologies attempt to take advantage of LSI mass fabrication techniques and also gain a speed advantage over cores because a smaller magnetic storage area is used. It appears, however, that advances in electronic memory technology are so great that thin film and plated wire memories will not have an important place in the internal memory structure of terminals.

5.5.1.3 LSI Technology

Fig. 5.24 indicates the rate at which memory density is increasing as a result of LSI. Currently, the competing LSI technologies are bipolar and metal oxide on semiconductor (MOS). Bipolar circuit implementations have an inherent speed advantage over MOS implementations. MOS, however, has a significant advantage in terms of chip

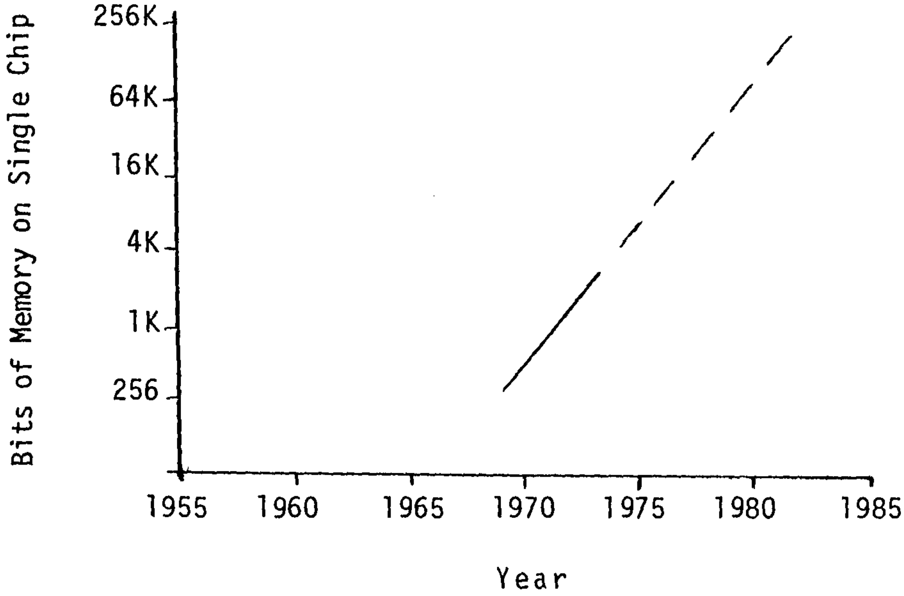

Figure 5.24 - Increasing Density of LSI Devices (Reference 58)

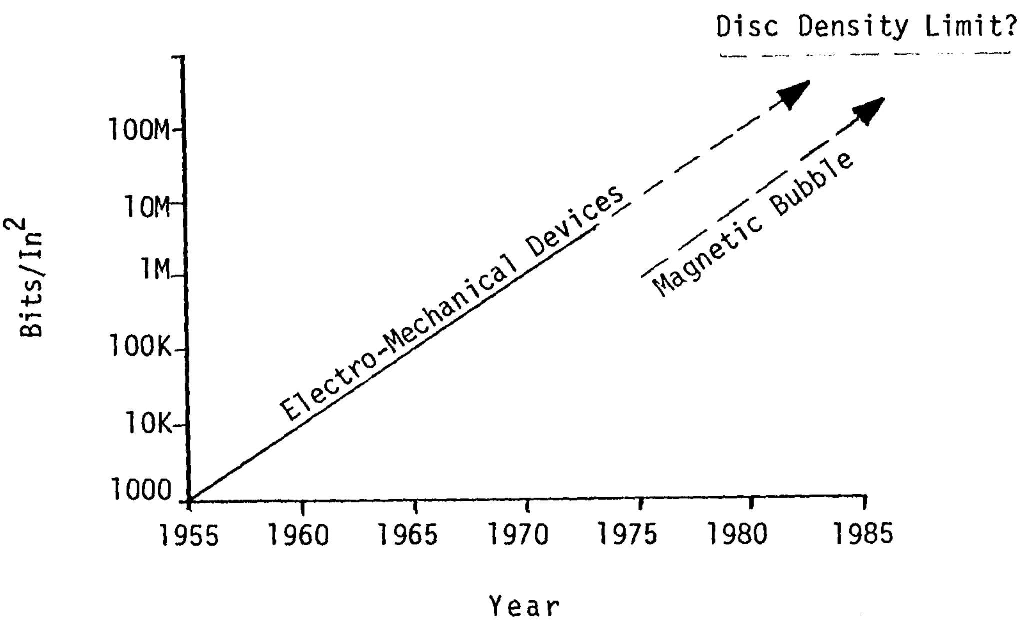

Figure 5.25 - Increasing Disc Density (Reference 53)

density. As a rough estimate one can expect a speed advantage of four to one for bipolar technology, (although recent advances, e.g. NMOS, reduce this to approximately two to one), and a density advantage of four to one for MOS. Advances in both technologies make it difficult to estimate which will be the dominant one for terminal applications where speed is not a primary consideration. Recent advances have brought about the introduction of integrated injection logic (I^2L), which, although still in the early stages of development, has speed, power and density advantages over MOS and other bipolar devices.

5.5.2 Machine-Oriented Communication and Storage Devices

The tree in Fig. 5.26 shows the technologies relevant to machine-oriented storage (external storage) and communication (network access).

5.5.2.1 Reducing the Gap Between Internal and External Memory Technologies

The performance of the differing memory technologies can be usefully compared by examining the relationship between the cost per bit of storage and the memory access time. This is done graphically in Fig. 5.27 for some current and future memory technologies. Generally, there is an inverse relationship between cost and access time. In examining the ordering of current technologies, it is clear that a gap exists between the fast and expensive memories (LSI, core) and the relatively slow and inexpensive technologies associated with magnetic disc, drum and tape. This gap has been an important factor in the design of processors.

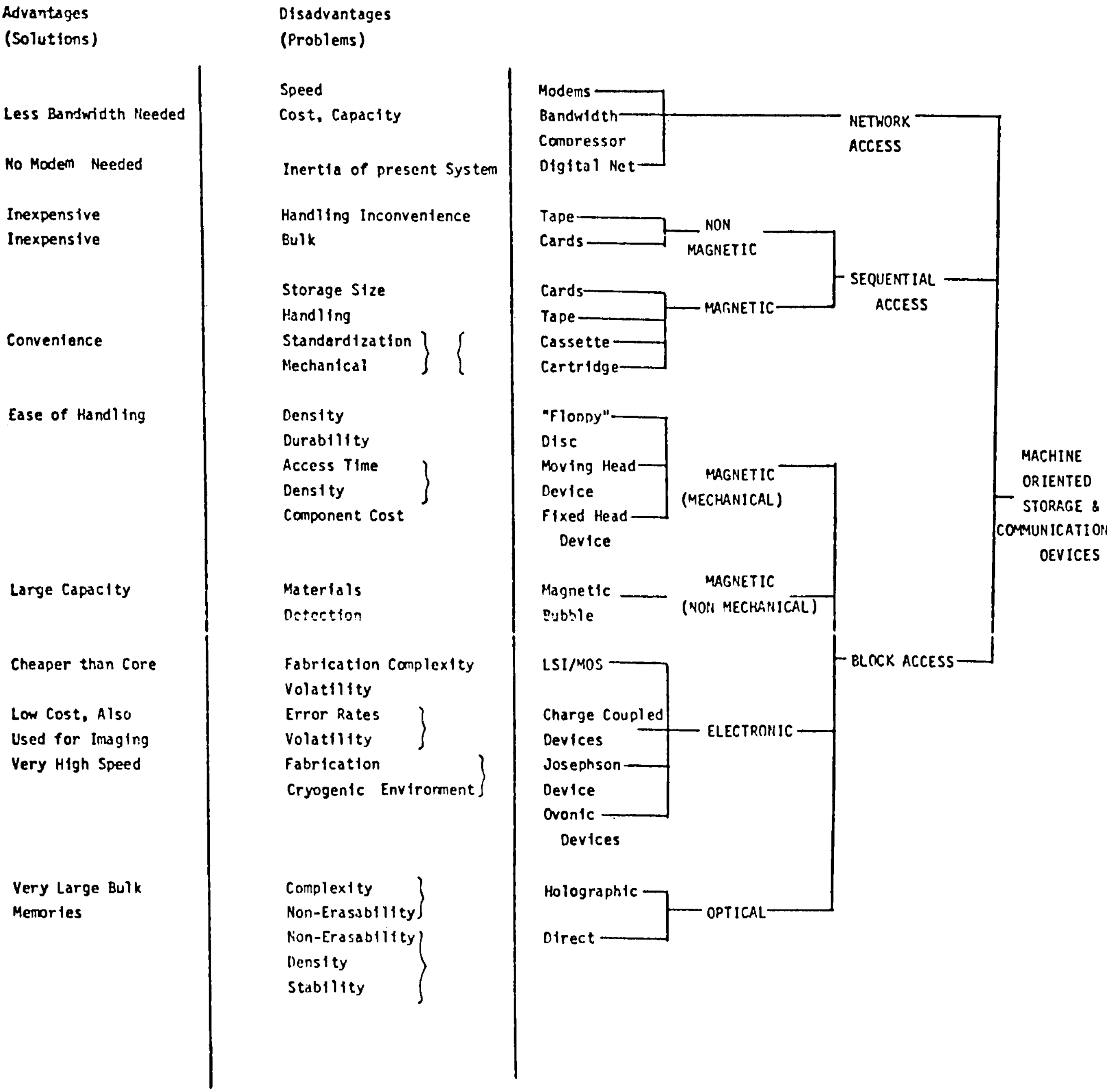

Figure 5.26- Technologies Relevant to Machine-Oriented Storage and Communication Functions

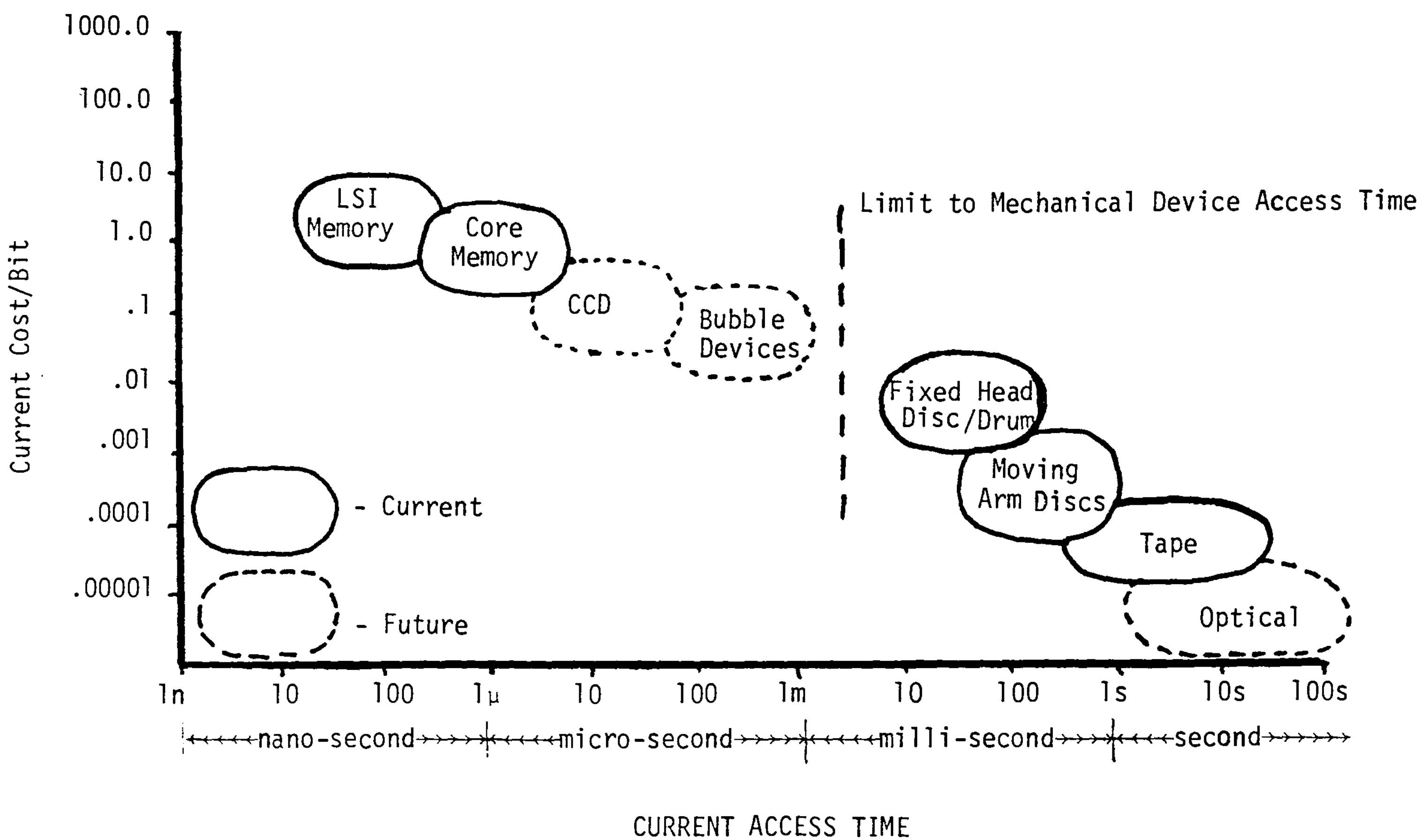

Figure 5.27 Current Status of Memory Technology (Reference 55)

The memory performance gap is bounded by two factors: viz. the limit of electro-mechanical device access time and the inability to further reduce core costs by trading off access time. During the next decade we expect that this performance gap will be narrowed as a consequence of the maturing of two new technologies, magnetic bubble memories and charge coupled devices (CCD's). Charge coupled device technology will benefit directly from advances in LSI techniques. Basically, a CCD memory is the solid state analog of rotating magnetic devices such as fixed head drum and disc. (Reference 60). These devices are fabricated with essentially the same techniques as used for current LSI random access memories. However, the greatly simplified design of the basic CCD cell pattern allows a one to two order of magnitude increase in density. The penalty paid is increased access time due to the internal storage organization which allows only sequential data access. CCD's are similar to LSI random access memories (RAM) in that data is lost in the event of a power failure.

Magnetic bubble memory technology is another candidate to fill the performance gap. Bubble devices are based on the propagation of magnetic bubbles on the surface of a thin magnetic material. As with CCD's, the internal structure is such that access is sequential, and thus the device is related to rotating fixed head devices. Bubble devices are constructed by techniques which are similar to those used in LSI circuit fabrication and thus LSI circuit cost reductions should apply also to bubbles. Bubbles have an important advantage over semiconductor storage devices in that data is retained during periods of power failure.

Both CCD and bubble memories are future competitors of fixed head disc and drum systems. Before predicting the demise of discs and drum it is appropriate to examine Fig. 5.25 which shows the expected increase in the density of disc storage devices. It is expected (References 53, 59) that improved technology will increase the storage density of rotating magnetic devices by at least two orders of magnitude. Comparable densities in bubble devices will lag that of electro-mechanical devices by at least five years. Within the next decade, CCD and bubble devices will probably replace disc systems only in small and medium size computer systems. Initially CCD's will probably be the most cost effective implementation of fast access memories with bubble memories being reserved for applications where data volatility is an important consideration, such as in a home terminal.

5.5.2.2 Sequential Access Memories

Sequential access memories are those memory systems in which data is organized in a basically linear manner. Examples of such memories are magnetic tape and punched cards. It is expected that non-magnetic technologies, such as punched cards and paper tape will slowly be replaced by magnetic tape technologies. Paper tape and cards have low storage density and are difficult and awkward to handle and store. Cards, of course, have a distinct advantage over magnetic tape in that they are user readable and may be rearranged without using special equipment. We expect this advantage to disappear as intelligent terminals reduce the cost and increase the convenience of magnetic tape handling.

Magnetic tape is currently available in three forms: open reel, cassette, and cartridge. Open reel tape has the highest storage density but is hard to handle and requires a relatively expensive transport mechanism. For use on small to medium sized terminals, it is expected that cassette or cartridge tape will be the choice. Cassettes, which are an adaptation of the familiar audio cassette, have problems with accurately moving the tape medium. Cartridges, while varying widely in design, are designed specifically for data storage and therefore have better error characteristics. The most pressing problem in the cassette and cartridge tape storage implementation is the establishment of standards.

5.5.2.3 Block Access Memory

Block access memories are those memory systems in which data is organized so that there is a substantial initial data access delay but once data is located, transfer is at a high rate. Several technologies are currently employed:

a) Magnetic-mechanical,
b) Magnetic-non-mechanical,
c) Electronic, and
d) Optical.

i. Magnetic-Mechanical Memories

Disc and drum are the usual form of magnetic-mechanical memories. Access to the moving magnetic surface may be either by moving or fixed read/write heads. Devices with moving heads are capable of accessing large amounts of data at low cost relative to fixed head devices. However, the moving head device has at least an order of magnitude greater access delay. Both types of devices have high costs per bit when storage size is low due to the overhead in control electronics and mechanical drive mechanisms. The mechanical and electronic control functions required in a moving head disc are basically similar for a 1 M/Bit disc as they are for a 100 M/Bit disc. Therefore, when the storage requirements are low, the control system becomes a major portion of the cost per bit. These devices therefore have questionable cost effectiveness on small terminals.

A recent storage innovation is the floppy disc (Reference 61). In this device the access head is usually fixed and the disc alone moves. Because of the extremely simple mechanism low cost is achieved. Access time is of the order of a second to any block of data, and storage capacity of the disc is comparable to that of cassette and cartridge tapes. Floppy discs are about the size of a small record and easy to handle. Because of the fast access of floppy discs relative to tape, it is felt that floppy discs will eventually replace cassette tapes as the external storage medium for small terminals.

ii. Magnetic Non-Mechanical

Magnetic bubble memories are currently being investigated as replacements for disc and drum storage systems (Reference 61). Problems that remain to be solved are related to the mass production of the magnetic base material and the development of effective methods to interface between the magnetic material and external electronic devices. Even when these problems are solved the magnetic bubble devices will still have low densities relative to their mechanical counterparts. Initial use of magnetic bubble systems will probably be as replacements for small disc systems.

iii. Electronic Block Access Storage

Charge coupled devices (CCD's) appear to be the most effective method of implementing fast block access storage devices. CCD technology is based heavily on current LSI technology and because the individual devices are extremely simple high storage densities are expected. The primary disadvantage of CCD implementations is that as with most other semi-conductor memories, memory power failure means loss of data. This may be overcome by the use of redundant power sources to guarantee continuous memory operation. Because of the rapid progress made in reducing CCD research to practice, we feel that CCD may become the dominant form of block access memory in situations where continuity of memory is not of primary importance.

A recent discovery which may ultimately have a great effect on memory and circuit technology is the Josephson* device. Laboratory devices have exhibited very small size and order of magnitude speed improvements over existing technologies. Because the Josephson devices are cryogenic, special refrigeration equipment is required to maintain the operating environment.

iv. Optical Block Access Storage

Optical memories offer the best prospects for high storage density of any block storage system. Two implementations are being investigated: direct storage and holographic storage. In direct storage systems, the information is stored on a film medium as a dot or line pattern which may be read directly with a laser light source. Holographic systems code all information in the form of holograms. In the holographic system, all recorded information is effectively distributed over the entire medium thus leading to a higher noise immunity over direct systems. On the other hand, holographic recording requires more complex recording and processing equipment. Both systems will require further improvements in laser directing devices and film medium stability and resolution. Because optical systems must be large to be economical, it is expected that they will not soon be used directly as terminal storage systems.

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* Wilhelm Anacker, "Potential of Superconductive Josephson Tunneling Technology for Ultrahigh Performance Memories and Processors", IEEE Transactions on Magnetics, Vol. MAG-5, No. 4, December 1969, pp. 968-975.

5.5.2.4 Network Access Devices

A communications network is usually accessed through the use of a network access device. These devices take the form of modems (modulator-demodulator), acoustic couplers or digital couplers, depending on speed, type of network, etc. The modem is the most widely used, and provides for the conversion of machine generated digital signals to analog signals suitable for use on the standard telephone network. Acoustic couplers are also widely used, and actually are much the same as a modem, with the exception that they are acoustically coupled via a telephone hand-set, as opposed to the hardwired coupling of a modem. The acoustic coupling puts limitations on the operating speed.

Digital couplers are a recent development, and are used to provide an active interface between a terminal and a digital network such as DATAROUTE.* They are digital/digital devices as opposed to digital/analog of the modem.

Because modems are basically circuit oriented devices, it is expected that continued reductions in circuit costs will lead to comparable reductions in modem costs. Bandwidth compression device costs can be expected to decline for the same reason. If local digital transmission lines become prevalent, modems would no longer be necessary on data terminals, as is the case now on digital systems such as DATAROUTE.

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*Bell Canada

5.6 REMOTE HARDWARE TECHNOLOGIES

Communications

Up to 1985 communications usage is expected to increase almost linearly (see Fig. 5.28), the major increases being due to tariff rearrangements in communications networks and the use of mini-networks comprising a "master" intelligent terminal, or mini-computer, with a common data base providing intelligence for interconnected "dumb" terminals. Remote processing service centres will also account for a growth in interactive terminal communications. The technical performance of existing and planned common carrier systems to 1980 is shown in Figs. 5.30 and 5.31.

It is generally expected that data transmission costs will decline by less than a factor of 10 in the next decade (Reference 66). See Fig. 5.29 Indeed, the curves in Figs. 5.31 and 5.32 indicate the decline may actually be much less. The main reason for this slow cost decline is the inertia built into the communication systems due to the size, complexity, and extent of monetary investment in the existing system. The amount of cost reduction will depend mainly on the extent to which new wide bandwidth technologies such as waveguides and optical fibres are exployed in long haul transmission. This in turn will depend on the demand for increased transmission resulting from wideband data transmission, videophone, and fast facsimile requirements. This demand will have to be very large to make it cost-effective for the phone company to develop the new technologies.

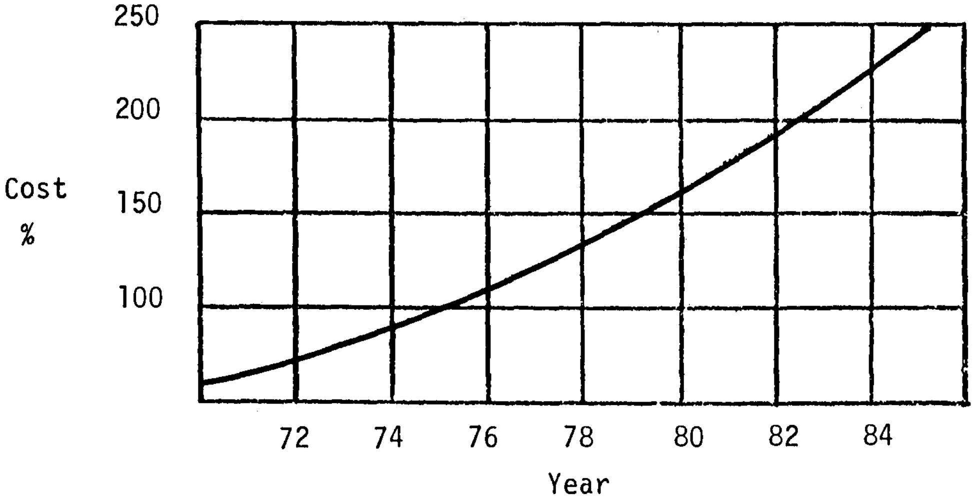


Figure 5.28

Communications Usage Trends

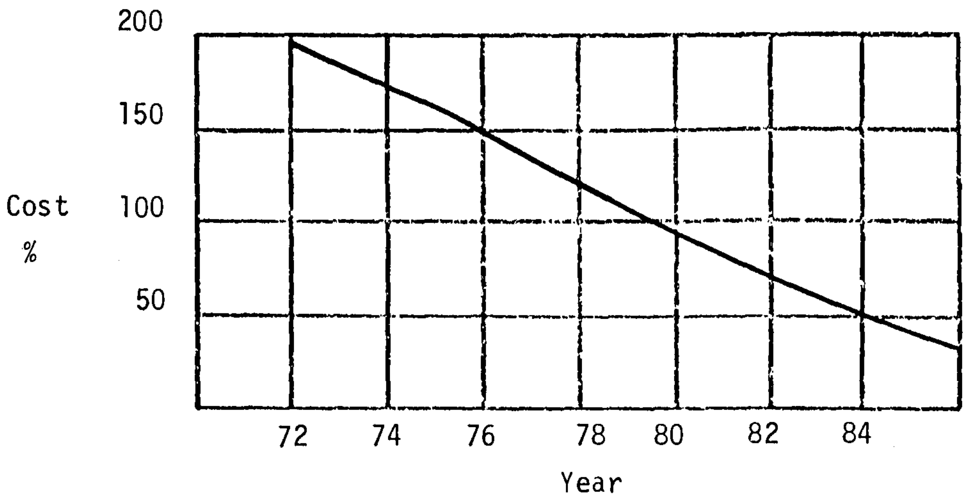
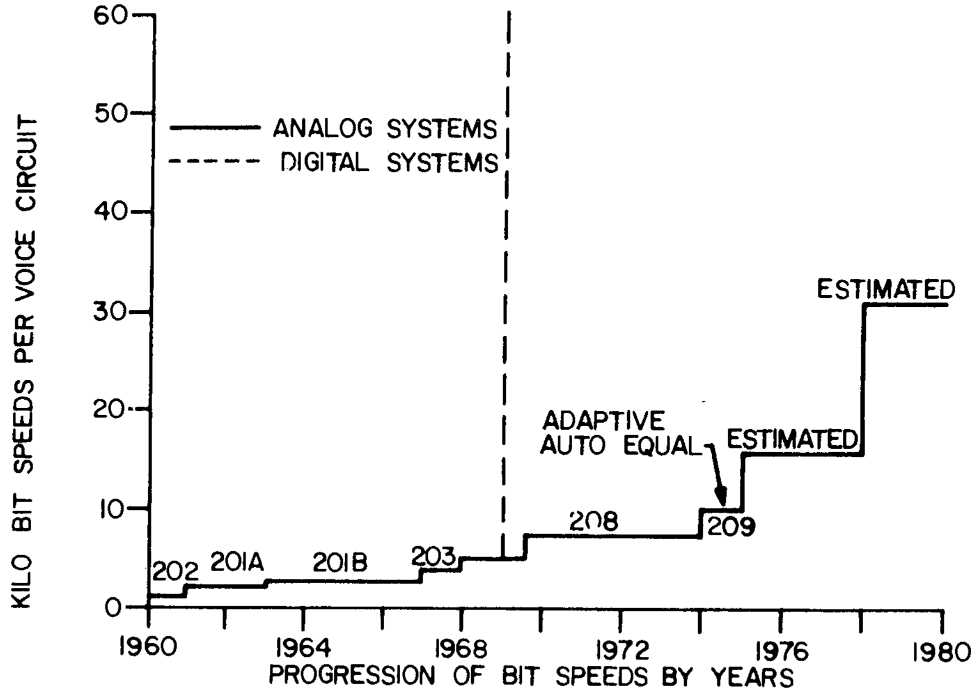


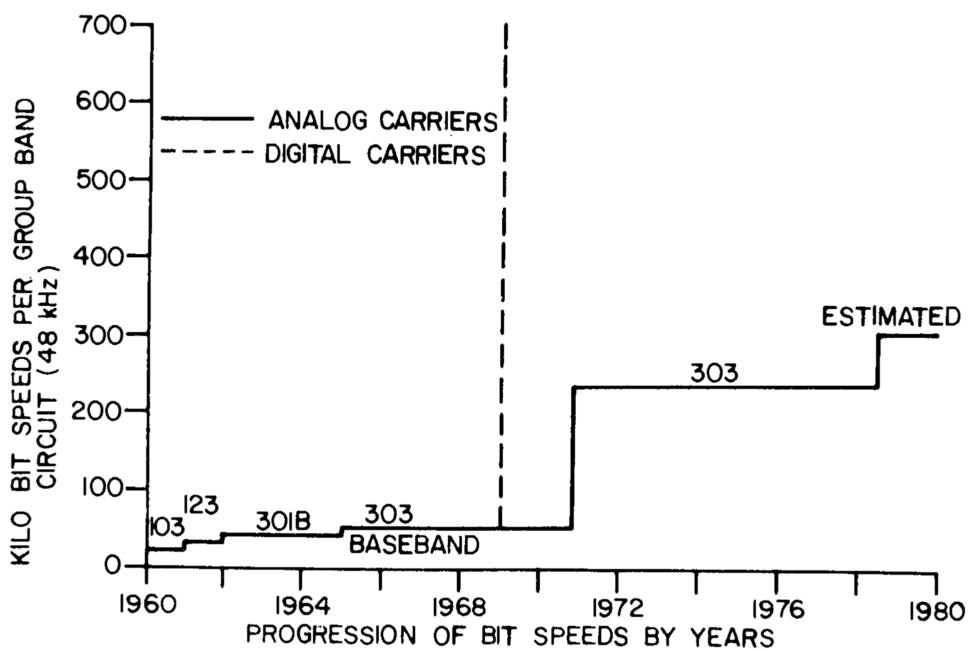
Figure 5.29

Communications Cost Trends



SOURCE: URWICK, CURRIE

Fig. 5.30. Technical Performance Trends of Common Carrier Systems-Voice Circuits



SOURCE: URWICK, CURRIE

Fig. 5.31. Technical Performance Trends of Common Carrier Systems - Group Band Circuits

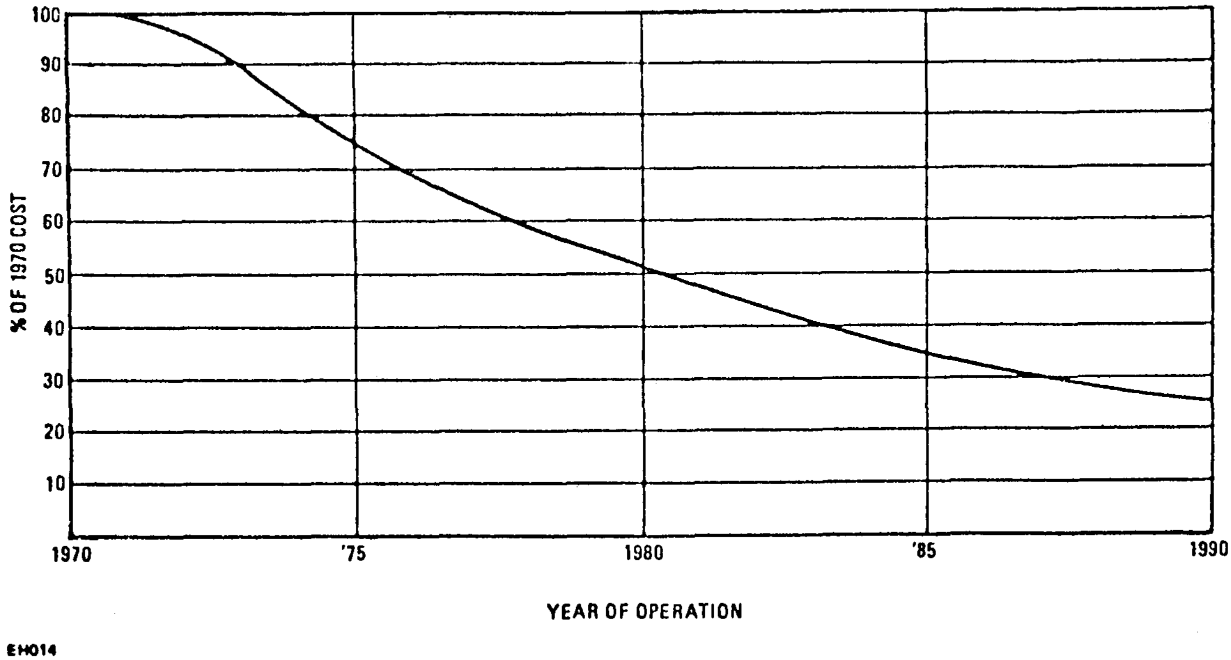


Figure 5.32 Trend in Transmission Cost Per Unit of Bandwidth

Source: General Dynamics Electronic Handling of Mail Study, 1969

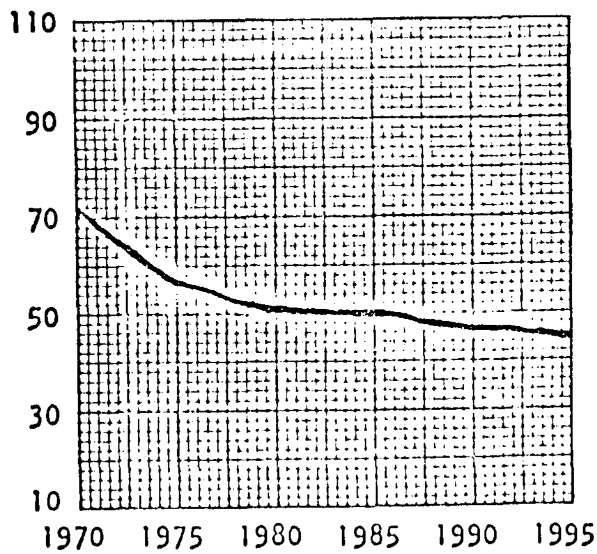


Figure 5.33 Cost of 3-Minute Station-to-Station Night Rate Call Across the Country (¢)

Source Paul Baran and Andrew J. Lipinski, *The Future of the Telephone Industry, 1970-1985*, Menlo Park, Calif., Institute for the Future, September 1971, R-20, p. 139.

The areas of local transmission and switching will probably see little cost reduction over the next decade because the rate at which voice communication switching equipment is replaced by electronic switching will be rather slow. Where message switching is installed there will be opportunities for new types of services like conference calls, store and forward (packet switching), abbreviated dialing, and call forwarding.

Fig. 5.34 shows the technologies relevant to network hardware which may most directly affect terminals. Network technologies can be divided into the areas of:

a) Transmission,
b) Switching, and
c) Processing

5.6.1 Transmission Technologies

Up to the early 1970's, all communications were analog and the costs were relatively high, reducing only because of efficiencies due to faster transmission speeds and buffering devices. In Canada, 1973 saw the introduction of digital systems, such as TCTS' Dataroute which effectively provides much cheaper communications by efficient multiplexing of the carrier facilities. This cost reduction accounts for the drop in communications costs in 1973. This service is at present only available in Canada but similar services will be in use in the United States before 1975. The addition of intelligent switches and transaction networks keep the cost of communications on a gradual downward slope.

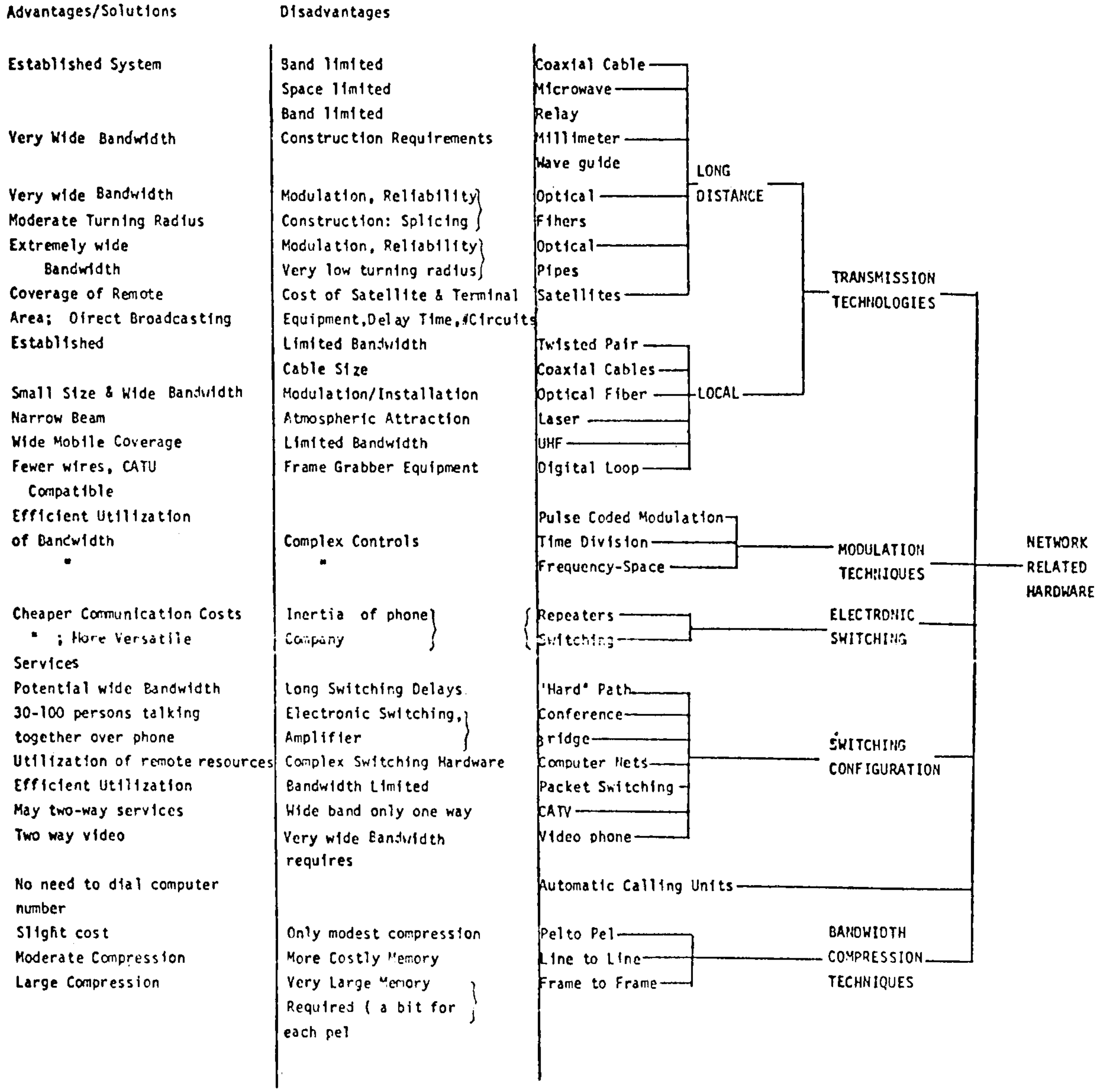


Figure 5.34 Technologies Relevant to Network Hardware Related to Terminals

Fig. 5.35 indicates the effect new wideband technologies like fibre optics and millimeter waveguides could have in reducing transmission costs, if there were enough demand to use their full capacity. Such a situation will not exist in the near future, unless the demand for digital and/or video (e.g. videophone) transmission greatly increases, but it could well be the case by 1985 (see Fig. 3.1).

5.6.1.1 Millimeter Waveguides

The current long distance carriers are primarily coaxial cable and microwave relay, but both are limited in their capacity to carry digital signals. Microwave in particular is reaching saturation in large urban areas. It is expected that millimeter waveguide systems will begin to augment cable and microwave facilities on heavy traffic routes during the next decade* (see Fig. 5.36). Because of the increased bandwidth in these areas, digital transmission should become more attractive. Preparation and construction are still major problems because waveguide has such a small bending radius.

5.6.1.2 Optical Systems

Optical communications in closed systems such as glass fibres and gas filled pipes offers the possibility of virtually unlimited bandwidth.

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*Waveguides can carry 240,000 voice or 180 TV channels. Cost per channel is not competitive until 50% of the capacity is used (Reference 67).

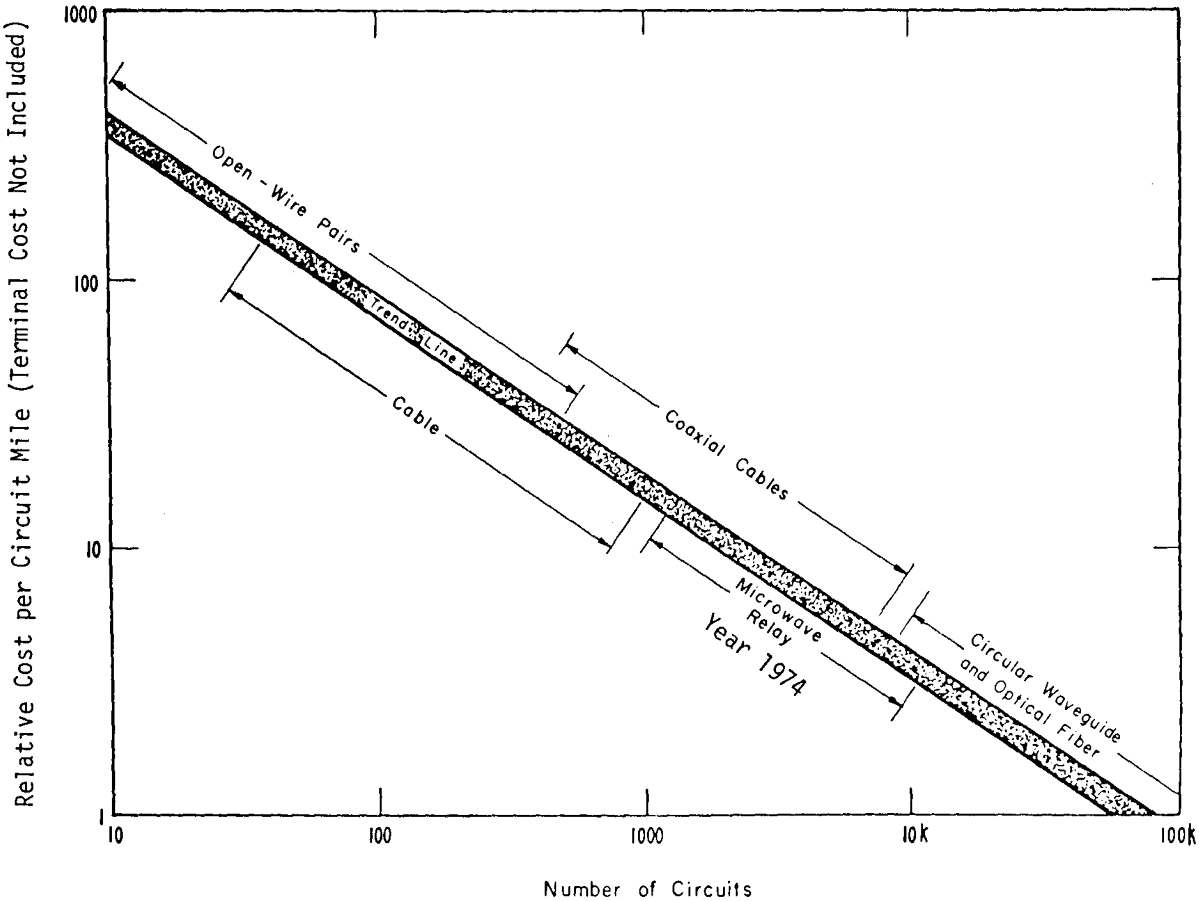


Figure 5.35- Trend line for Relative Cost per Circuit Mile

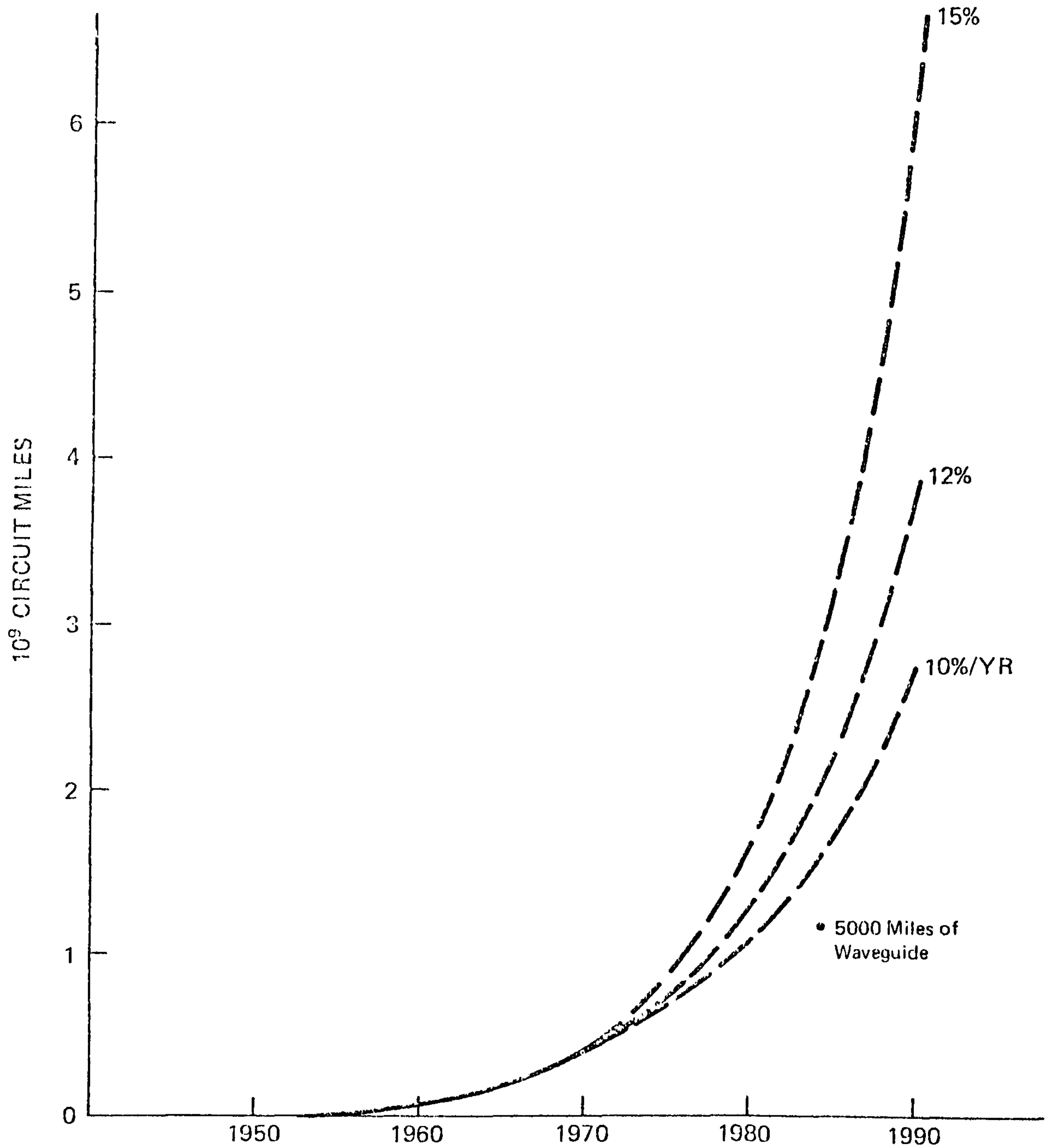


Figure 5.36 - Future Carrier Growth

Light pipes are gas-filled tubes through which a laser beam is directed. A drawback to such a system is that the pipe must be very straight or have expensive optical systems for reflecting the beam where the pipe curves. A more promising technology is optical fibres in which the light beam is internal refracted by the fibre allowing a relatively sharp bending radius.

Originally the main problem with fibre optics was attenuation, but Corning Glass Company has developed a fibre with reasonably low attenuation (Reference 62, p. 124). Now the major problems associated with fibre optics are:

a) Developing a cheap light source (LED may be used),
b) Light modulation and amplification,
c) Optical detectors, and
d) Field splicing and installation (Reference 67, p. 125-127).
e) Pulse dispersion which limit bit rate over long distances.

5.6.1.3 Satellite Transmission

Satellite transmission will have its greatest effect on the transmission of data between continents and to remote areas. Satellites will only have a finite number of circuits available and hence will not be able to supply the bandwidths available on land circuits. Direct broadcasting to special terminals will be an important area of investigation in the next few years, but terminal costs and long transmission delays will probably make these systems unacceptable for most interactive terminal applications. High power satellites will make communications in remote areas economical because of the ability to use low cost ground stations.

5.6.1.4 Modulation and Bandwidth Compression Techniques

Carrying capacity can be increased not only by developing new carriers with greater intrinsic capacity, but also by developing more effective modulation and compression techniques for better using the capacity of the existing carriers. New pulse coded modulation (PCM) digital system can be expected to increase the message carrying capacity of cables (Reference 68). Time division multiplexing also be expected to be used more widely as LSI reduces the cost of the complex controls needed for such modulation. Beyond these techniques differential pulse code modulation (DPCM), in which only the difference between successive signals (e.g. video frames) is transmitted can be expected to increase message capacity even further (Reference 69). DPCM could also benefit from LSI which could make it relatively inexpensive to store whole video frames, for comparison with successive frames, allowing one to send only the data pels (points in the picture) which change (Reference 69).

If waveguides and fibre optics are developed rapidly, the stimulus for compression techniques will be reduced; on the other hand, if compression techniques are widely applied it could delay the need for and employment of wideband carriers. Rising copper prices would play a role in the time frame within which fibre optics develop.

5.6.1.4 Local Transmission

Twisted pair cables will continue to be the dominant mode of local transmission in the next decade. A new possibility which might become feasible because of circuit cost reductions resulting from LSI would be a digital cable loop to which each user will be connected. Each terminal in such a system would send out a unique code and have a frame grabber for pulling messages out of the cable addressed to that terminal. This technique is utilized in the Bank of Montreal on-line banking network, although the "loop" is not digitized, making necessary the use of modems. Such a system saves the cost of wiring each user directly to the central office, also no modem would be required in a pure digital system. Widespread use of such loops is probably at least a decade in the future. The main use of coaxial cable in the near future will be for cable television.

5.6.2 Switching Technologies

Telephone companies are gradually replacing electro-mechanical switching exchanges with electronic switching exchanges. Bell's #4 ESS computerized switching system can handle about 350,000 calls in an hour and is scheduled for deployment in 1976 (Reference 70; 69). These new electronic switches can be fabricated using LSI techniques, so their costs can be expected to be reduced significantly over the next decade. The SP1 and SP2 electronic switching systems built by Northern Electric are now utilized in may parts of Canada.

New switching systems in addition to being faster and less expensive (though not significantly so in the short term) can be expected to be better adapted to data communications and conference arrangements as well as person to person voice communications. Message switching or store and forward switching and packet switching can be expected to become more widespread in the future. The ARPA computer network is already using packet switching to reduce the cost of communication between computer installations and the MSDS network and TELENET are presently providing such services for digital data traffic.

New conference bridge amplifiers have been developed which allow up to 100 people to talk together over phones at the same time (Reference 68). Electronic switching exchanges can also offer abbreviated dialing and automatic call forwarding services.

Mobile radio switching will be a very important area of research and development in the next decade. To make use of the scarce UHF radio spectrum, a form of space and time switching may be used (Reference 71). Under such a system the radio service area would be divided into sectors, each having a low powered station operating on specified frequencies. As a user moved from sector to sector, different stations on different frequencies would automatically be assigned to pick him up.

Automatic dialing units can be expected to decline in cost as a result of LSI, and many terminals will incorporate them in the future.

5.6.3 Remote Processing

Some very large computers will be developed in the next decade which extensively use parallel processing and associative memories. In general, the cost trends in remote processing will coincide with the local processing trends described in Section 5.5, (see particularly Fig. 5.22). Generally the aspect of processing which will be most important to interactive terminals is the software covered in Section VI.

The growth rate of intelligent terminals will exceed the general increase in the use of remote processing as more pre-processing in done "off-line" at the data terminal. A major factor in the processing use curve is the amount of pre-processing that can be performed by local intelligence. Lack of pre-processing power will tend to limit the rate of growth in the use of remote processing. Large service organizations will be capable of supply the computing power not possible with local intelligence, and computer/computer transactions will be more commonplace.

The costs of remote processing are geared to large main frame costs and service centre overheads. Costs of main frames in the large scale range are expected to drop slowly up to 1980 and then level off. Higher operating costs should be counteracted by increased system operating efficiencies, e.g. software improvements. The relative costs for remote processing are depicted as following the large main frame costs.

6. SOFTWARE AND HUMAN FACTORS TRENDS

6.1 INTRODUCTION

Fig. 6.1 shows the increasing percentage of the labour force that is expected to be working with computers without being familiar with the computer's operations. This means that it will become increasingly important to incorporate "human factors" considerations in both hardware and software in the next decade. Not only will software be important from a user point of view, but it will come to be the major portion of information system costs. The results of a recent U.S. Air Force study (Reference 73) which are shown in Fig. 6.2 , indicate that by 1985, 90% of total systems costs will be in the software. Factors contributing to this are:

a) Larger and more significant programming tasks;
b) Relatively low increases in software productivity;
c) The need to make software systems "layman proof"; and
d) The significant drop in hardware costs over the last decade.

As a result of 1-3 the total amount spent on software, particularly purchased software, will significantly increase in the next decade as shown in Fig. 6.3.

Man-machine interaction in the development and use of software will be a dominant trend in the 70's. Rather than completely "solving" a problem such as language translation, it is far more likely that the computer will develop a rough translation which a human user can refine and correct on-line. The pattern of evolution in simulation, machine intelligence, pattern recognition, and information retrieved (question answering) is unmistakably in this direction.

The software technologies relevant to terminal performance are shown in Fig. 6.4.

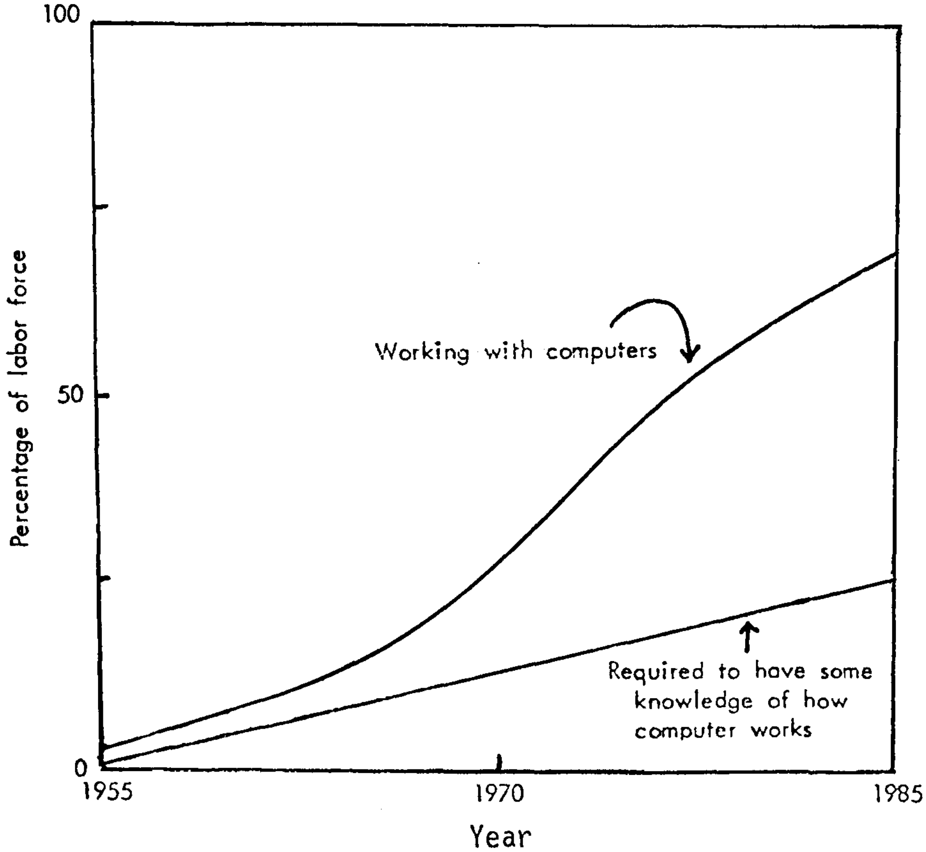


Figure. 6.1 Increase in number of users who are unfamiliar with computers (Reference 73)

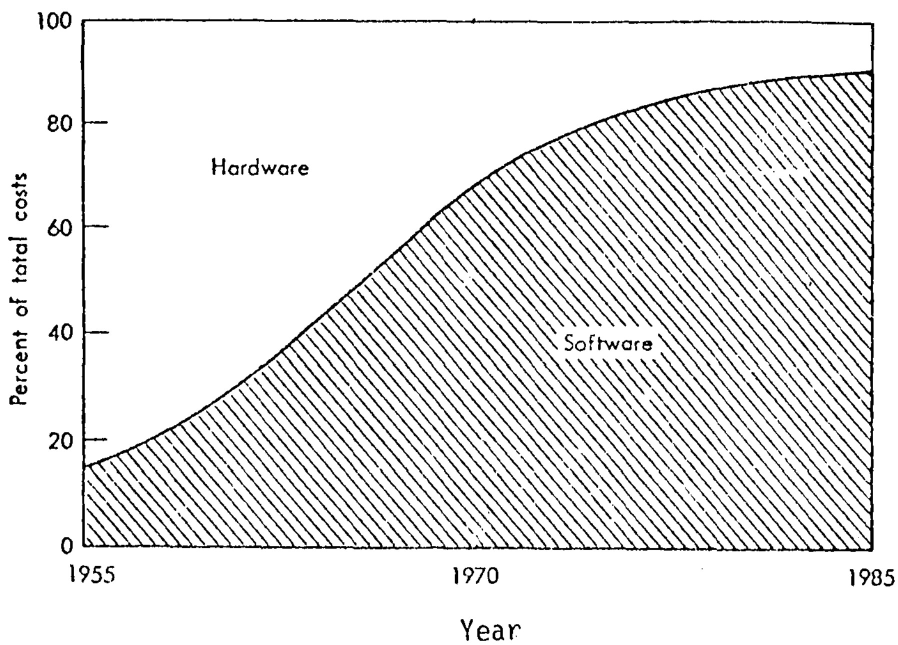
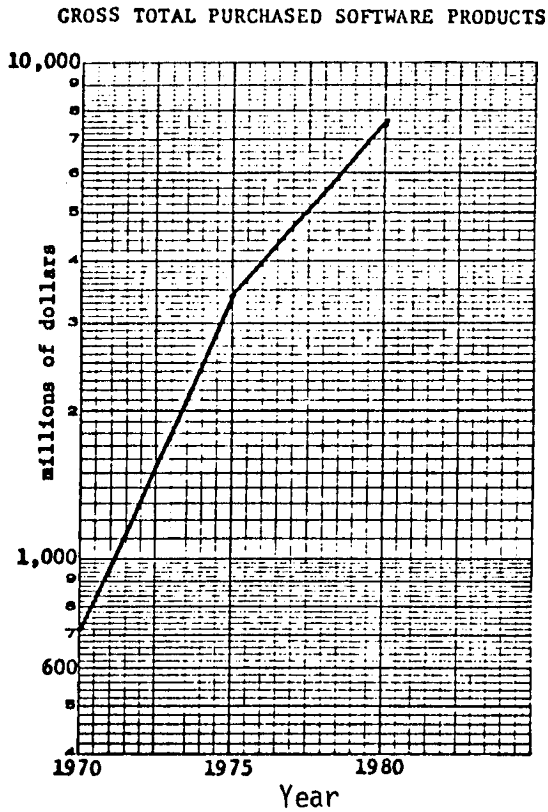
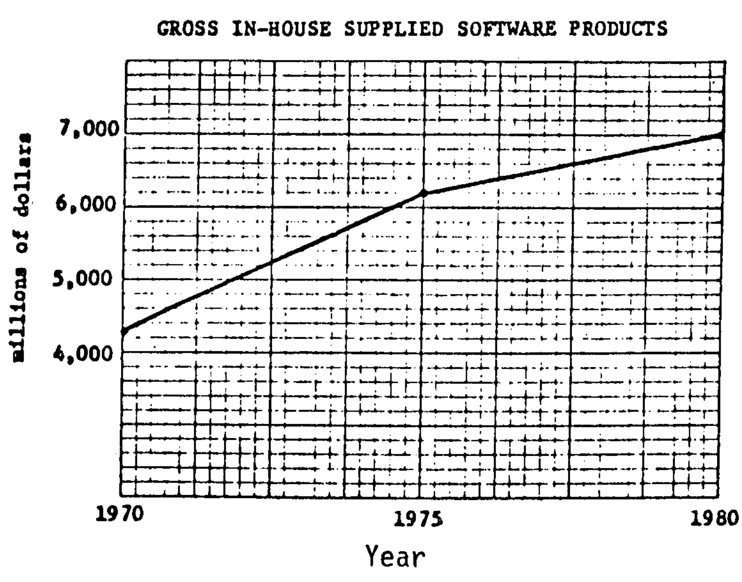


Figure. 6.2 Hardware/software cost trends. (Reference 73) (Main Frame Processors)





Source: Fred Gruenberger, EXPANDING USE OF COMPUTERS IN THE 70'S: Markets-Needs-Technology (C) 1971, p. 55. Adapted by permission of Prentice-Hall, Inc. Englewood Cliffs, N.J.

Figure 6.3 The Increasing Cost of Software

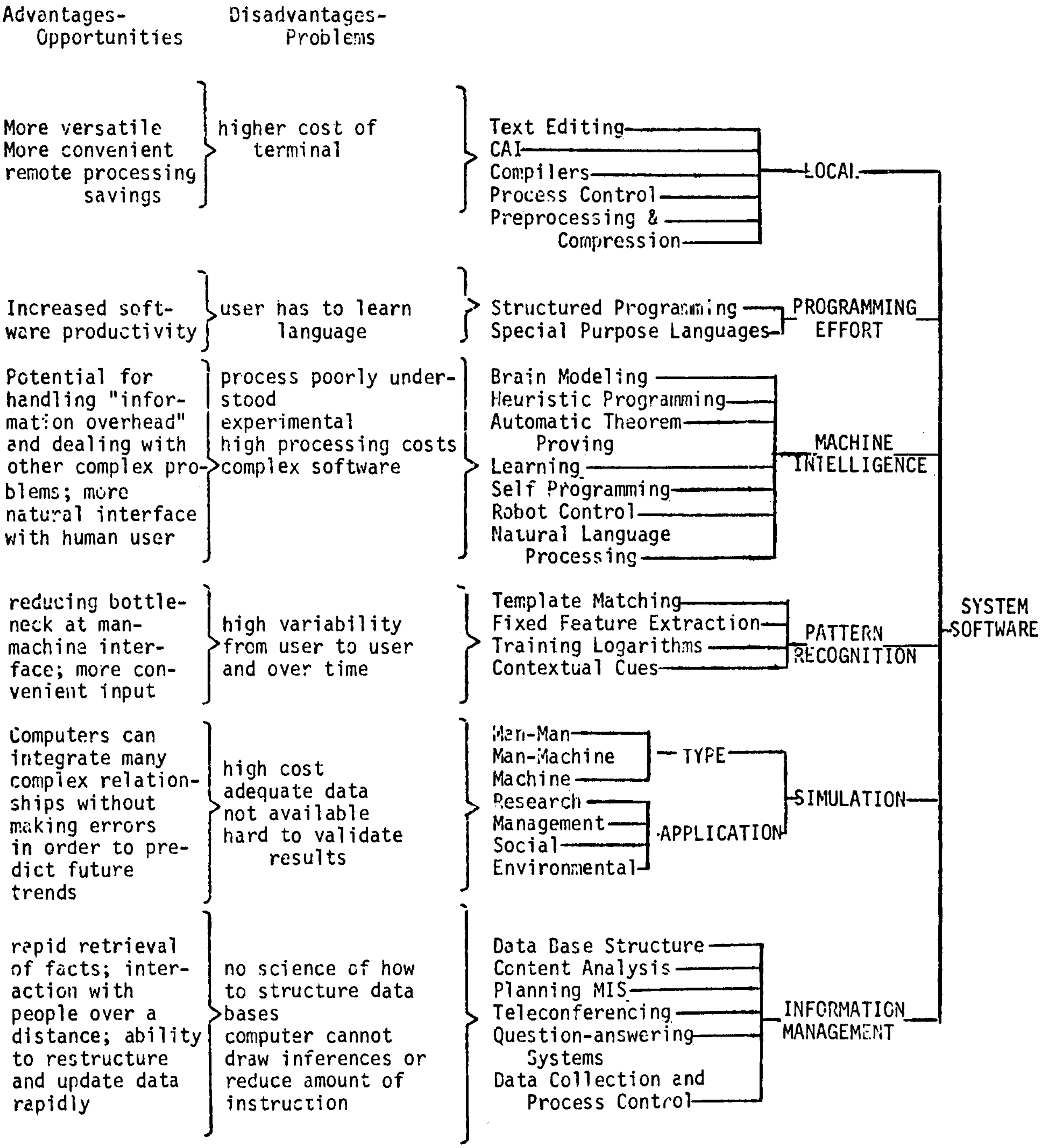


Figure 6.4
Software Technologies

6.2 LOCAL PROCESSING

Initially intelligent terminals were used mainly for text editing and off-line process control, but now some have their own BASIC or similar simple language compilers to do computations and small programs off-line. Intelligent terminals will also have special packages for use in Computer Aided Instruction, Game Playing, and for preprocessing data for interfacing with large data bases.

6.3 TECHNIQUES FOR INCREASING PRODUCTIVITY

The main problem areas in software production are:

a) Estimation,
b) Specification,
c) Verification, and
d) The use of human resources.

During the last several years, techniques have been developed which may remedy these problems somewhat. These techniques are described in the references under software technology. One important concept is that of "top-down" programming (Reference 74) in which program specification and writing proceeds from the most general to the most specific. While usage of this technique may increase production time it ultimately results in decreased costs since the probability of errors is reduced. Another technique is that of "structured" programming (Reference 75) in which the basic elements of program specification are limited to a small (but complete) set of easily understood constructs. This, in turn, limits the resulting structure of the program but when coupled with a strict discipline of code writing and documentation leads to programs which are easy to maintain and modify.

Efficient use of human resources is another area for improvement. In general, the rate of improvement in the individual's rate of software production has not kept pace with comparable rates of production in other technologies. A possible solution to this problem is the use of chief programmer teams (Reference 76). Under this arrangement a large programming task is placed under the control of a very small but tightly structured group, the programming team. One person, the chief programmer, has overall knowledge of the program and communicates closely with other team members. Communications between members are open, even to the extent that team members read each others code on a regular basis. The chief programmer team arrangement has been shown to greatly reduce to the cost and risk of software production.

As a result of these new techniques and the growth of special purpose languages and packages (Fig. 6.5) the range of software productivity, in terms of instructions/man-month, can be expected to shift upward as shown in Fig. 6.6.

6.4 MACHINE INTELLIGENCE

The trend in machine intelligence is toward developing programs which can write larger more complex programs (Reference 77). In this way it is hoped that computers can "boot strap" their way up to an intelligence comparable to man's. This is probably not a realistic goal for the next two decades, but programs with some semantic processing ability will be important in information management pattern recognition, and simulation applications.

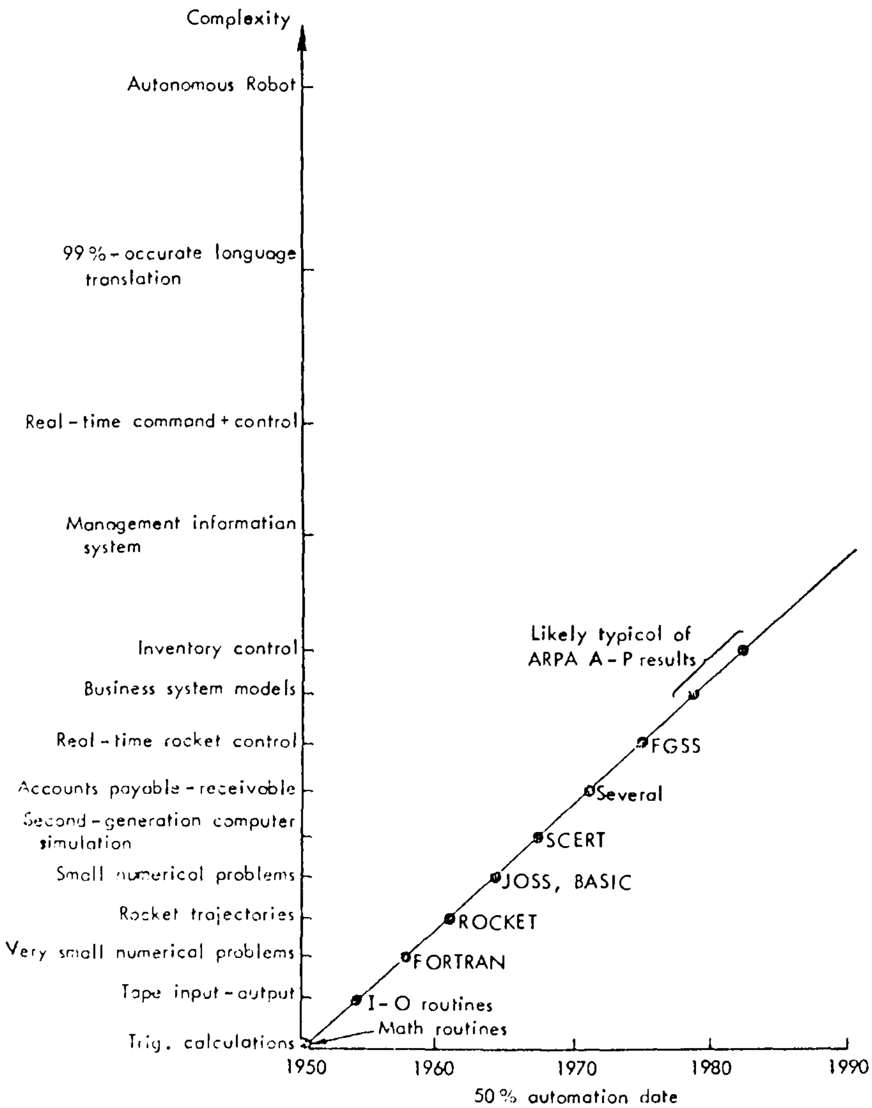


Figure 6.5
Growth of Automatic Programming
(Reference 73)

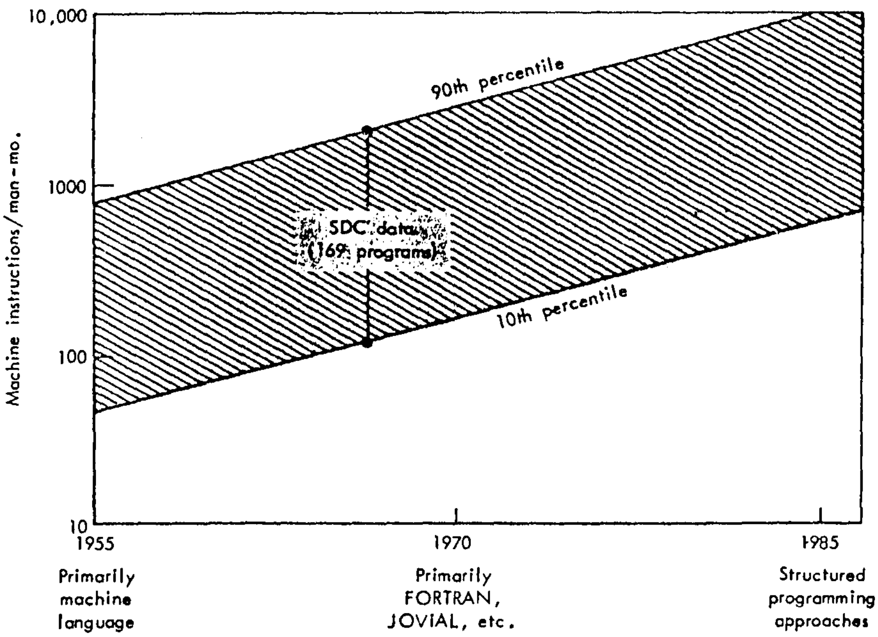


Figure 6.6 Technology Forecast:
Software Productivity (Reference 73)

Another approach to machine intelligence and question-answering systems is to phrase problems in the form of a theorem to be proved, and then use an automatic theorem proving routine to solve the problem. Attempts to generalize this method will be an important area of investigation in machine intelligence in the next decade (Reference 78).

Software for controlling robots will also be an important area of research in the 70's. MIT and SRI already have very active programs in this area (Reference 79).

Winograd has developed a computer program for understanding a special subset of natural language (Reference 81). Such natural language processors would be very useful to laymen using a terminal and could be expected to increase the demand for home terminals. Programs will probably be available between 1980-85 for communicating with terminals in special subsets of English for special application areas, but they will be expensive to run and will not become widely available until another decade or so after that.

6.5 PATTERN RECOGNITION

Pattern recognition programs will be important in the 70's for both identifying printed and speech inputs at the terminals, and for classifying complex visual patterns into correct categories. In the former case, remote programs will be used to provide contextual cues for characters and words which cannot be initially recognized by the terminal feature extraction hardware (see Section 5.3. In the latter case, programs will be used to "flag" unusual changes in repetitive medical monitoring patterns such as EEG's, or ECG's, blood tests, etc. Pattern recognition programs (e.g. of radar or sonar signals) will also have an important place in complex command and control systems.

6.6 SIMULATION

Simulation will move outward from modelling simple physical systems, to modelling very complex industrial, social, and environmental systems (Reference 81). Man-machine simulations, such as "gaming", in which interactive terminals must be used, are essentially models in which the human components cannot be quantified reliably and must be simulated by other persons. Many sophisticated man-machine simulations and games will be developed for entertainment purposes. This may in turn increase the demand for home terminals.

6.7 INFORMATION MANAGEMENT

A variety of large software packages have been and will continue to be developed to make data readily available, and control the information overload which is pervasive in our society today. Until machine intelligence research develops some practical techniques for the computer to "understand" and integrate what it processes, the main burden will fall on the user. One method to approach the problem is to have the user and computer work as a team - the computer making rough initial inferences, which the user scans and deletes mistakes and returns to the computer for further processing. General purpose interactive question-answering systems should become available well before 1985.

Another method for managing information is "computer conferencing" in which persons in different areas interact together via terminals over a computer network. The amount of such "teleconferencing" will probably increase significantly in the 70's as computer networks like the ARPA Network are developed, and remote communicating becomes more cost effective with travel.

A general effect of new software developments in the 70's will be in increase the demand for man-machine interaction and hence the demand for interactive terminals.

Equally important in the 70's will be research on the human factors involved in designing communication networks such as the work by Chapanis to determine the relative effectiveness of, and characteristic method of using, various input/output modes (References 7, 81, 82). Some of the results of his experiments are shown in Fig. 6.7.

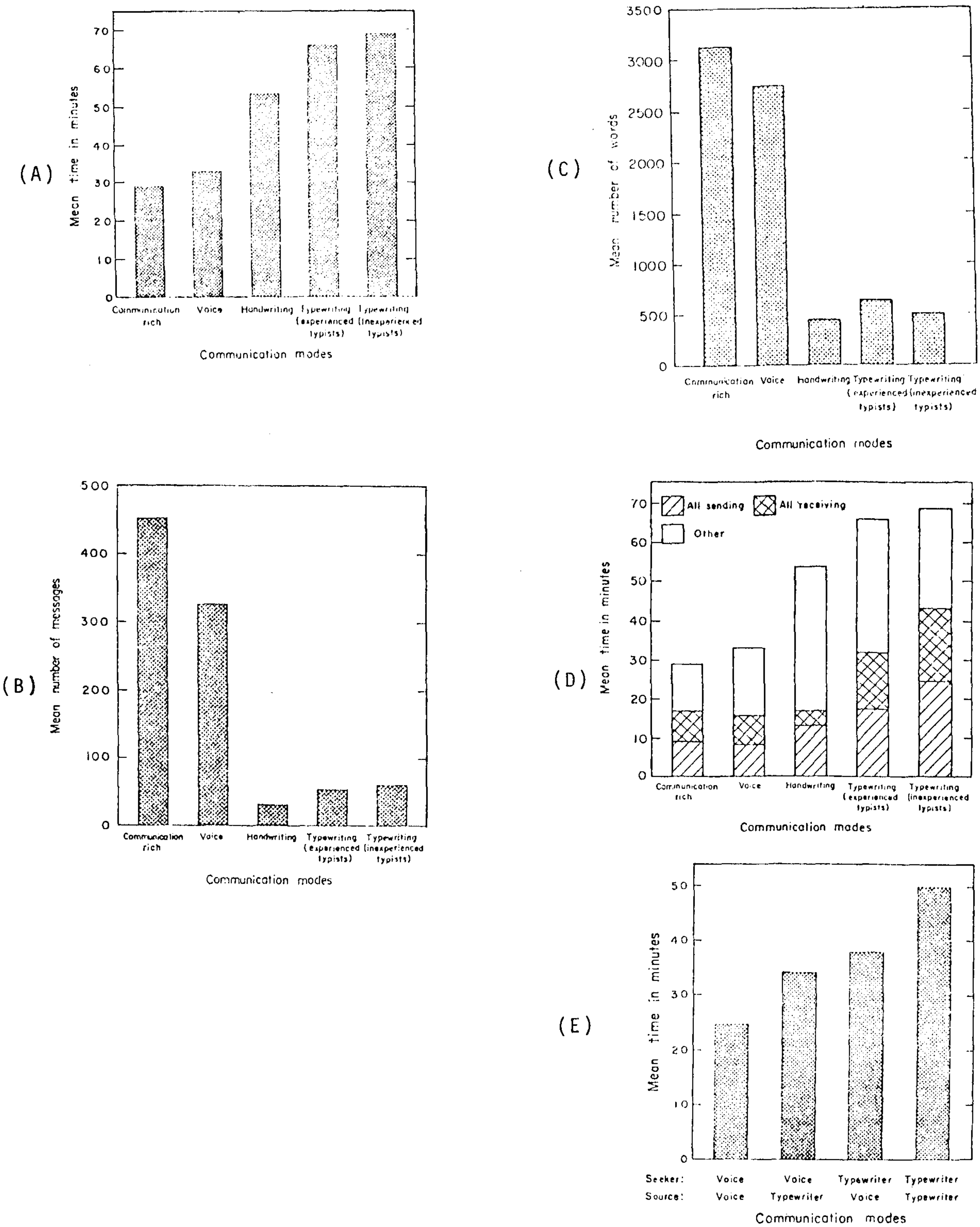


Figure. 6.7 Results of Chapanis' Studies of the Communication of Factual Information Through Various Channels (References 7, 81, 82)

7. IMPACT ASSESSMENT

An initial assessment of the impact on interactive terminal development of the technology forecasts presented in Sections 5 and 6 is discussed in this Section using three methods:

a) Cross-Impact of Technologies

b) Impact of Technology Developments on Interactive Terminals

c) Comparison of Cost Effectiveness

7.1 CROSS-IMPACT OF TECHNOLOGIES

The cross-impact interrelationships among the technologies described in Sections 5 and 6 are displayed in tabular form in Fig. 7.1 for illustration purposes. The values in the table indicate the degree to which technologies listed on the left will influence or impinge upon technologies listed along the top although the values and the completeness of elements should be considered tentative and subject to refinement. The following are representative conclusions that can be drawn from information using the forecasts contained in Section 5.

7.1.1

The ongoing research and development and subsequent availability of a wide range of large scale integrated devices, in one or more solid state techniques, will have a significant impact on all of the component parts utilized in interactive terminals.

The major impact, however, will be in the area of intelligent terminals, where components such as micro-processors and memory modules will be subject to significant cost reductions.

Figure 7.1

CROSS-IMPACT TABLE

Numbers indicate how technologies on the left affect technologies listed above the table:

3-significantly improve

2-moderately improve

1-modestly improve or increase need for

-1-decrease need for

	AFFECTING TECHNOLOGIES \ AFFECTED TECHNOLOGIES	LSI	CHEAP MICROPROCESSORS	FAST MEMORY	A/D CONVERTERS	INTELLIGENT TERMINALS	CCD	OCR	ROBOT CONTROLLERS	VOICE RECOGNITION	FACSIMILE	LCD	GRAPHIC DISPLAY	SPEECH SYNTHESIS	VIDEOPHONE	WIDEBAND TECHNOLOGIES	BANDWIDTH COMPRESSION	ELECTRONIC SWITCHING	PACKET SWITCHING	COMPUTER/CONF. NETS	INFORMATION MGMT	MACHINE INTELLIGENCE	LEARNING	PATTERN RECOGNITION	PROCESS CONTROL	NATURAL LANGUAGE
PROCESSING	LSI		3	3	3	3	3	2	2	2	1	3	1	3	1		3	3						2		
	CHEAP MICROPROCESSORS				1	3		3	3	3	1		2	3	1		3	1					2	3	3	
	FAST MEMORY				2	3		2	2	2	2	3	3		2		3	2	2	2			2	2	2	
	A/D CONVERTERS					2		1	3	3			1				1							3	3	
	INTELLIGENT TERMINALS								1	2			1		1				3	3	3		2	3	3	1
INPUT	CCD		1	3		1		2			3				3		1							1		
	OCR					1					-1										3			2	1	
	ROBOT CONTROLLERS																					2	1	1	3	
	VOICE RECOGNITION					1								3							2					1
OUTPUT	FACSIMILE												3			1	1		1	1	2					
	LCD												3		3						3					
	GRAPHIC DISPLAY					1									3	1	1				3					
	SPEECH SYNTHESIS					1				3											2					1
	VIDEOPHONE						2				1	2	3			2	2			3	1					1
COMMUNICAT'N	WIDEBAND TECHNOLOGIES										3		3		3		-1	2	2	3	2					
	BANDWIDTH COMPRESSION	1	1	1			1			1	3		3		3	-1		1	1	2	2			2	1	
	ELECTRONIC SWITCHING	1		1							1		1		3		3		3	3	3					
	PACKET SWITCHING					1					3		2		1					3	3					
	COMPUTER/CONF. NETS					2										2	1		2		3					2
SOFTWARE	INFORMATION MGMT.					1		1			1		1			1	1		1	1		1				1
	MACHINE INTELLIGENCE					1		3	3	3			1	1						2	3		3	2	2	3
	LEARNING					2		3	3	3				1							1	3		3	3	3
	PATTERN RECOGNITION		2		1	2		3	3	3				2							2	2	1		3	
	PROCESS CONTROL		2		2	2			3	2									1		2		1	2		
	NATURAL LANGUAGE					1		3	1	3											3	2	1			

7.1.2

In input modes, CCD would seem to have the greatest impact in the matrix shown. In the output area for limited character displays, the development of liquid crystal displays is certain to have a heavy impact on other technologies including light emitting diodes and limited display CRT's if the liquid crystal lives up to its early promise. Present indications are that liquid crystal and even plasma displays may offer serious competition to CRT's within 10 years.

7.1.3

Common carriers and their regulatory bodies can influence various technological developments. Typical of this situation would be the offering of a digital data network with associated intelligence (pre-processing ability). The impact of such a network would result in less emphasis being placed on modem-associated technologies, such as linear LSI, ultimately making modems completely redundant in data systems. Depending on the scope of the network intelligence, interactive terminals may have no built-in intelligence, but rather utilize the network to provide this feature. The resultant impact would curb the population growth of intelligent terminals and encourage the usage of low cost, simple interactive devices. Other changes in communications networks, such as tariff re-arrangements to enable billing on a "per transaction" basis on the standard telephone switched network, could result in the widespread use of transaction oriented terminals with high speed, limited input/output capabilities. However, without the provision of electronic switching systems, it is doubtful whether such a service would be profitable for the telephone company, as the older electro-mechanical switches in use today would be incapable of handling the high volume of calls inherent with a transaction system.

7.1.4

Where interactive terminals are used in a message environment, the teleprinter type of terminal, and its associated electro-mechanical technology will be affected by the development of low cost (in the $1000 range) facsimile terminals, where it is expected that digital encoding and data compression techniques will make these machines both efficient communications terminals and computer compatible.

Whether facsimile becomes a viable, truly interactive terminal is directly dependent on optical character recognition being developed to apoint where handwriting recognition at the central computer becomes an economical reality. An interim arrangement of a keyboard and limited display input coupled to a facsimile output device would suffice for numerous applications.

7.2 INTERPRETATION OF TECHNOLOGY TRENDS

A number of technology trends are referred to through Sections 5 and 6 from which inferences can be made as to the probable direction and timing of the events of terminal evolution. These observations are listed as follows:

7.2.1

Input devices will be the most diverse and innovative area of terminal development in the next 10 years. It is here that the most acute problems of man-machine interfaces must be solved. The dominant mode of data entry will continue to be keyed input.

7.2.2

The development of Large Scale Integration (LSI) is the primary driving force in determining the future nature of the electronic component of interactive terminals. This is expected to lead to dramatic improvements in the processing area, through cheaper memory, processors, and intelligent terminals. It will also have an impact on input (OCR, Voice Recognition), display (LSI technology can be used in fabricating LED's, LCD's, and Electroluminescent Displays, and in reducing the buffer memory costs), and communication (through reducing the costs of bandwidth compression). Higher speed, higher density and lower power logic will have positive effects on the processing power of intelligent terminals.

7.2.3

Optical character recognition and voice recognition terminals will benefit from LSI and become more prevalent in the future as a result of the ever increasing demand for information transfer.

7.2.4

As a result of LSI and cheap micro-processors, "intelligent terminals" will become less expensive. This, in turn, will lead to an increased demand for intelligent terminals as new applications are discovered. This is essentially what has happened with mini-calculators in the last five years.

7.2.5

In the near future, electronic micro-logic will be used as the controlling element in electric typewriters, vastly enhancing the possibility of using conventional typewriters as a base for interactive terminals or "self contained intelligence" terminals for text editing (an advanced form of IBM's MTST, and similar systems).

7.2.6

The number of facsimile transmission terminals will greatly increase in the next decade as they become faster as a result of compression techniques and/or wider bandwidth technologies such as waveguides and fiber optics and high speed digital systems.

7.2.7

The number of graphics terminals will greatly increase in the next decade as LSI reduces the cost of their processing and memory components, and new displays such as LCD's are developed which can use LSI fabrication techniques to reduce production costs, and as the demand for convenient information systems increases.

7.2.8

Processing cost will go down faster than communication cost, tending to lead to more processing being done on a local level on intelligent terminals and minicomputers, but at the same time new applications like teleconferencing and large question answering systems will increase the need to be able to interface with and access remote systems. The intelligent terminal will benefit from both of these trends and what can be expected to evolve is a network like the one in stage four of Fig. 5.21.

7.2.9
Communication costs will be reduced somewhat through bandwidth and data compression techniques, digital carriers and electronic switching, but the real reduction will come when new extremely wide band carriers like waveguides and optical fibers are implemented. The rate of their implementation will depend on the rate at which information transfer demand can increase to use enough of their capacity to make them cost effective.

7.2.10
The implementation of electronic message switching will allow communication costs to be reduced through packet and message, rather than circuit, switching. Electronic switching will also allow many users to be connected together at the same time, thus increasing the feasibility of teleconferencing applications.

7.2.11
Software and processing costs will rise over the next decade as more sophisticated information systems are programmed. This, plus decreasing terminal costs will result in terminal costs constituting a much smaller percentage of the total system costs. Consequently, hardware cost will be a less important factor in choosing terminals, and qualitative factors like realism, convenience and naturalness will be given more weight in terminal selection.

7.2.12
Machine intelligence research will be very important in developing better information management systems in the future. It will also be important in perfecting pattern recognition systems and programs that converse in natural language, albeit with restricted vocabulary and syntax.

7.2.13

The demand for natural language processing will increase as more novices interact with the computer. Programs that communicate in a limited subset of natural languages (e.g. English/French) will become commercially available in the next decade.

7.2.14

General voice and handwriting recognition will be an important area of research in the next decade, but it will not become commercially available. Programs which recognize by contextual cues will be developed to supplement feature extraction and classification.

7.2.15

As the price of sensors, controllers and A/D circuits are reduced through LSI, and as the amount of automation in industry increases, the demand for and number of process control terminals will increase.

7.2.16

In general, software and human factors will be more important than hardware technologies in influencing the future nature of the man-machine interface at the terminal. This is the area where most research needs to be done in the next decade.

7.3 EXAMPLE OF COST EFFECTIVENESS APPROACH

As an example of the methodology, consider the problem of evaluating the four terminal types given below for three hypothetical benchmarks:

a) Typed input/typed output
b) Voice input/voice output
c) Handprinted input/graphic output
d) Voice and handprinted input/voice and graphic output

The I/O modes differentiating the terminal types were selected because they are familiar or because they present interesting future possibilities and some comparative performance data was available (References 7, 81, 82).

The data required are of three kinds:

a) Work element frequencies and task (benchmark) frequencies
b) I/O and systems parameters that are independent of time
c) Economic parameters that will vary from year-to-year

The first category of data can be regarded as essentially arbitrary for purposes of this discussion. However, task element frequencies (or times) and computer operation weight factors can (in principle) be derived from a detailed breakdown of the task. Three hypothetical benchmarks were considered. These are labelled simply tasks 1, 2 and 3. A scheduled mix of tasks to be performed during the month was assumed and the four terminal types were evaluated for this job mix.

7.3.1 Assumptions

7.3.1.1 Work Element and Task Frequencies

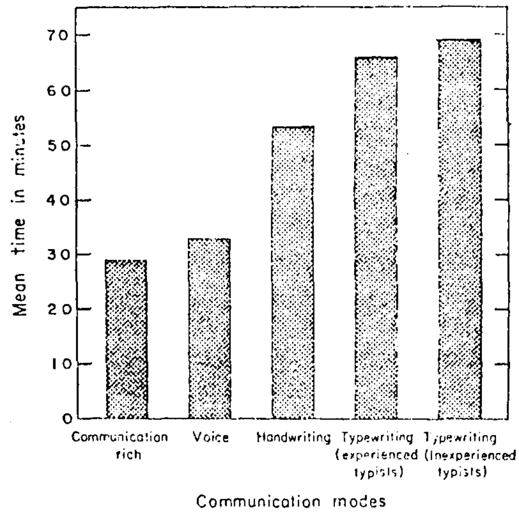
Table 7.1 Task Frequencies

Task	Monthly Frequency (f_K)
1	5
2	0.1
3	0.05

Table 7.2 Work Element Frequencies per Task* (W_{jK})

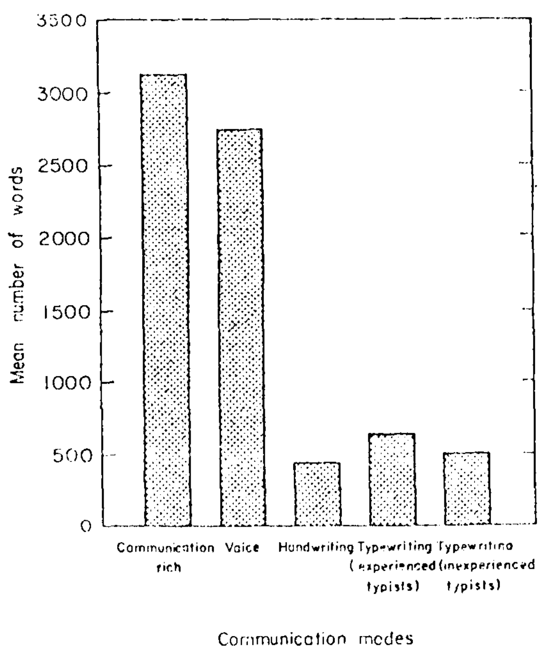
Element		Task 1	2	3
E_1	Message from user to terminal (Units of information content)	1	9	50
E_2	Message from terminal to user (Units of information content)	2	8	1
E_3	Internal logic or arithmetic op. (Number of processing steps)	3	7	3
E_4	Internal storage (Number of bits)	4	6	10
E_5	User response time (On-line records)	5	5	100

*These are totally arbitrary since tasks have not been specified in detail.



Mean times to solve problems in each of four communication modes.

Figure 7.2 Relative Performance (Reference 81)



Means of the total number of words used by each team during the solution of problems in each of four communication modes.

Figure 7.3 Number of Words Processed In Each Mode (Reference 7)

7.3.1.2 I/O and Systems Parameters*

	Input Formulation Multiplier α	Input Conversion Multiplier β	Output Conversion Multiplier γ	Output Assimilation Multiplier δ	Time Share Multiplier μ
(1) Typed input/typed output	2.5	1.0	1.0	5.0	1.0
(2) Voice input/voice output	1.0	1000	10	2.5	1.0
(3) Handprint input/ graphic output	1.5	100	10	1.0	1.0
(4) Voice and handprint input/ voice and graphic output	1.0	1000	10	1.0	1.0

Table **7.3** Time Independent I/O Parameters

* These numbers were chosen to be consistent with the data of Chapanis (Fig's. 7.2 and 7.3) where applicable and are intended to be plausible though not definitive. However, once again, alternative terminal equipment configurations have not been specified in sufficient detail to permit the determination of actual numbers.

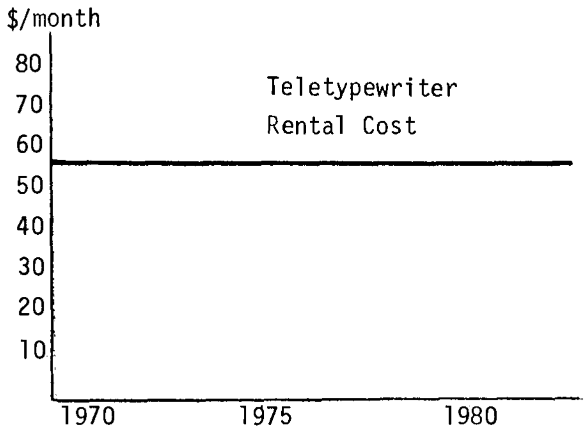


Figure 7.4 (A)

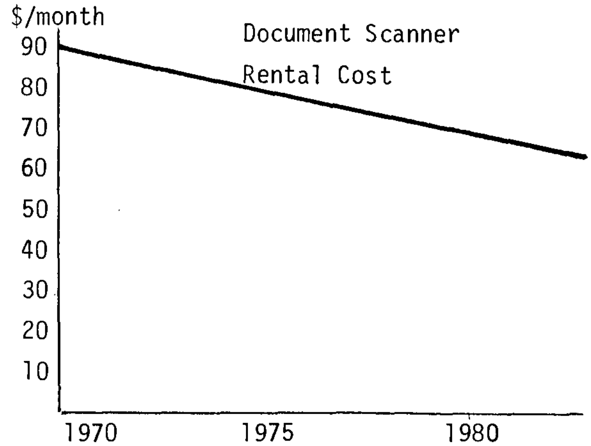


Figure 7.4 (D)

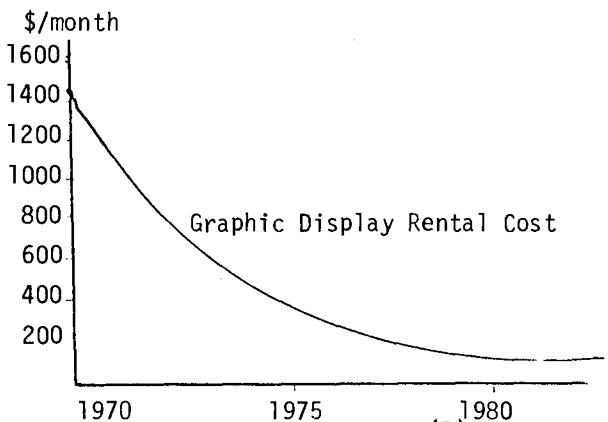


Figure 7.4 (B)

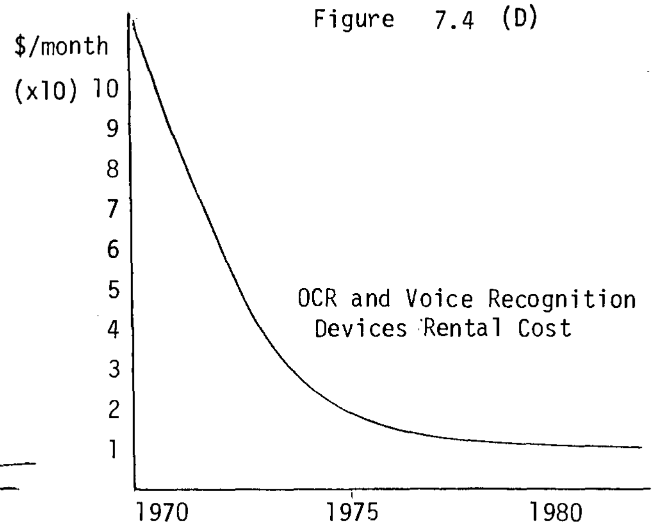


Figure 7.4 (E)

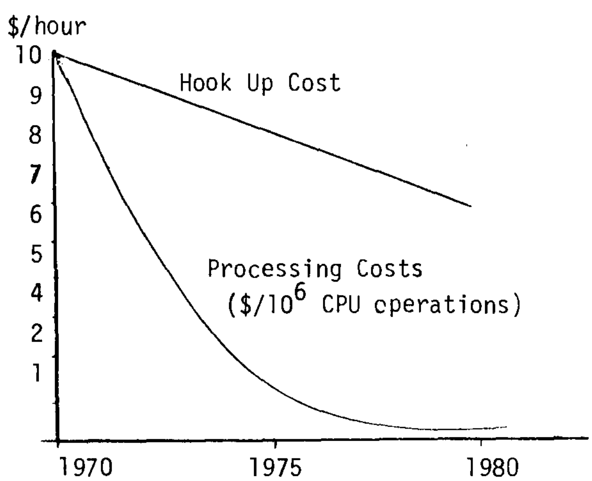


Figure 7.4 (C)

(A) - from Figure 5.11
(B) - from analysis in section 5.4
(C) - from Figure 5.19. Assume slow decline in hook up costs.
(D) - from Figure 5.13 + assumption of 50% drop by 1980
(E) - from Figure 5.6 for OCR. Assume Voice Recognition Machines drop at same rate as mini-computers (This is an optimistic projection!)

FIGURE 7.4
GRAPHS FOR COMPUTING COST-EFFECTIVENESS
OF FOUR I/O MODES

7.3.1.3 Economic Factors That Vary Over Time*

	Cost Parameter	(Unit)	Terminal Equipment Configuration	Time Period		
				1970	1975	1980
Wage cost of operator	$W(t)$	$/hour	all	10.00	11.00	12.00
Hookup cost	$X(t)^{(1)}$	$/hour	all	10.00	8.00	6.00
CPU cost	$Y(t)^{(1)}$	$$10^6$ CPU ops.	all	10.00	2.00	0.50
Terminal Rental cost	$Z(t)^{(2)}$	$/month	(a) Typed input/ typed output	56.	56.	56.
		"	(b) Voice input/ voice output	14,000	2,000	1,500
		"	(c) Handprint input/ graphic output	15,600	2,500	1,700
		"	(d) Voice & handprint input/voice & graphic output	29,600	4,500	3,200

Table 7.4 Time-Dependent Cost Parameters,

(1) Source - Figure 7.4 (C)

(2) These numbers are obtained from the graphs in Figure 7.4 as follows.

Configuration	Source of cost estimates
(a) Typed input/typed output	Graph (A)
(b) Voice input/voice output	Graph (E)
(c) Handprint input/graphic output	Graph (B)+(D)+(E)
(d) Voice & handprint input/voice & graphic output	Graph (B)+(D)+(E)+(E) (It is assumed that separate devices are required for voice & OCR recognition.)

7.3.2 Comparison of Cost Effectiveness

Using the formulas contained in Appendix D a computer program was written to calculate the estimated total monthly cost for each type of terminal to perform the scheduled task mix in 1970, 1975 and 1980. The costs include the operator's salary, terminal rental costs, computer processing costs and connect-time related costs.

The monthly costs given below are shown graphically in Fig. 7.5 While based on largely hypothetical data, the figures indicate that the difference between the most sophisticated terminal considered (involving handwriting recognition, voice I/O and graphic output) and the teletypewriter decreases from a factor of 40 in 1970 to a factor of 4 in 1980.

	Monthly Cost ($)		
Terminal Type	1970	1975	1980
a) Typed input/typed output	3,610	2,594	2,246
b) Voice input/voice output	102,068	20,765	7,201
c) Handprinted input/graphic output	32,354	7,057	3,910
d) Combination of b) and c)	116,368	22,838	8,650

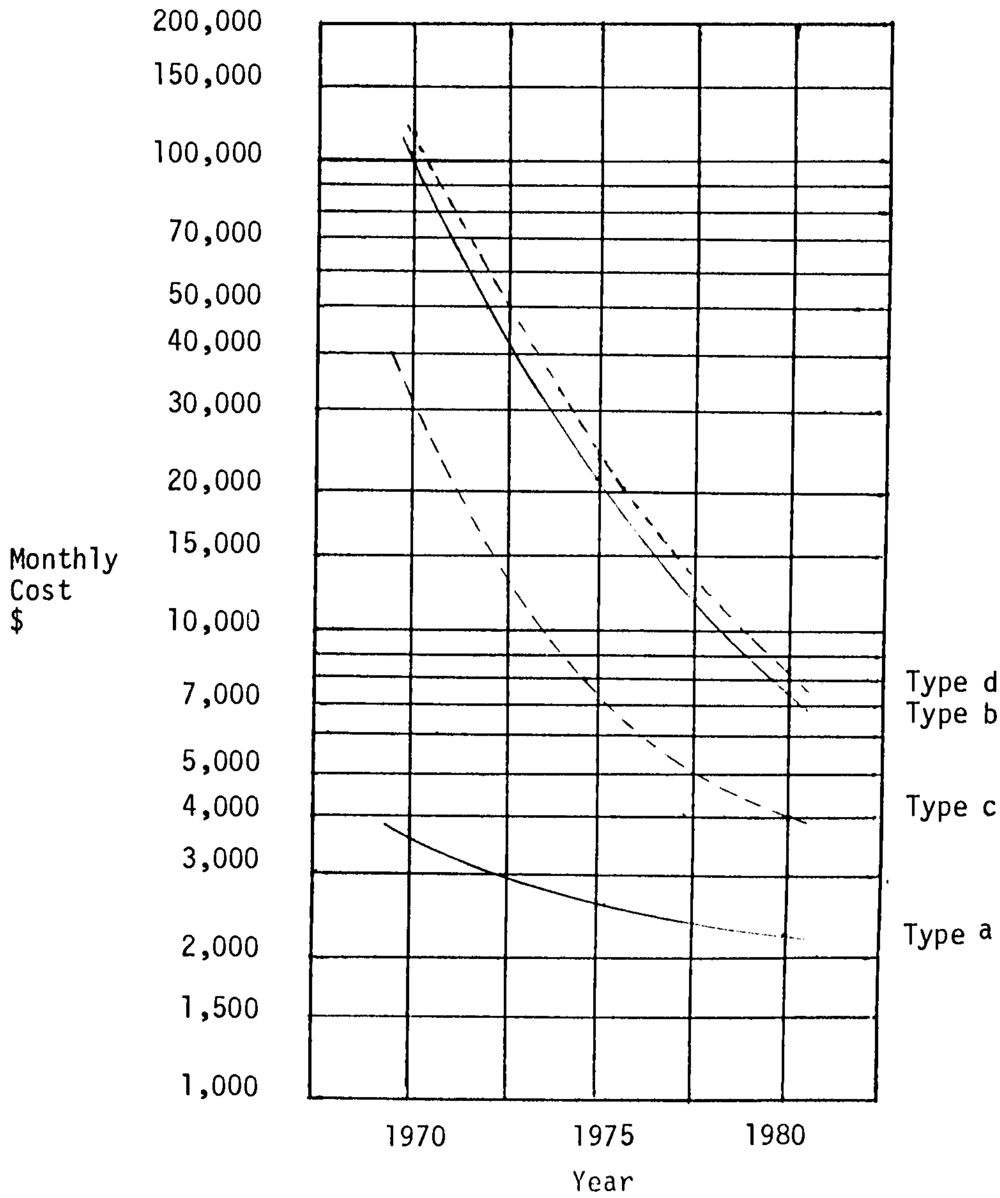


Figure 7.5
Cost Comparison of Four Terminal Configurations

8. CONCLUSIONS AND RECOMMENDATIONS

While the objectives of this study were to formulate the problem, develop methodology and carry out forecasts of relevant technologies, we will endeavour to draw some general conclusions and present recommendations, where appropriate, regarding further action or study which could be undertaken by the Canadian Government.

8.1 SEMICONDUCTOR TECHNOLOGY

In virtually all areas, the importance of LSI semiconductor technology seems to be paramount and growing. There is no doubt that the exploitation of present technology (MOS) and the application of developing technologies (CCD's and bubble memories) will have significant impact on the evolution of interactive data terminals.

Recommendation

There should be continuing support of the semiconductor industry in Canada by the Canadian Government with encouragement and/or Government research for new technologies such as CCD's.

8.2 DISTRIBUTIVE PROCESSING

The growth of distributive processing (intelligent terminals as opposed to teleprocessing) continues.

It is difficult to forecast future activity in this area because of the number and complexity of the factors at work, especially those related to communications.

8.3 DATA ENTRY

While it is believed that within the next 10 years, the dominant entry mode will remain keyboard oriented, due mainly to inertia, the advantages of other modes such as voice or optical character recognition, touch panel and other non-keyboard devices are thought to be highly significant. Their speed of acceptance, however, will depend largely on task analysis and human engineering.

Recommendation

Whereas in the past, the development of new modes has been held back by the practicalities of technology, and limited demand, it would appear that an additional major deterrent is the lack of knowledge about the man/machine communication process. Recognizing that such activity would have only long-range impact, we believe that the Government could usefully support research on the subject of man/machine interaction (human engineering).

8.4 DATA OUTPUT

Our study indicates that, in the short term, hard copy printers and electronic character display, will dominate on an equal basis as terminal output devices. In the longer term, however, graphics and/or facsimile type displays will become more and more prevalent.

8.5 GENERAL

A number of more general observations and recommendations can be made as follows:

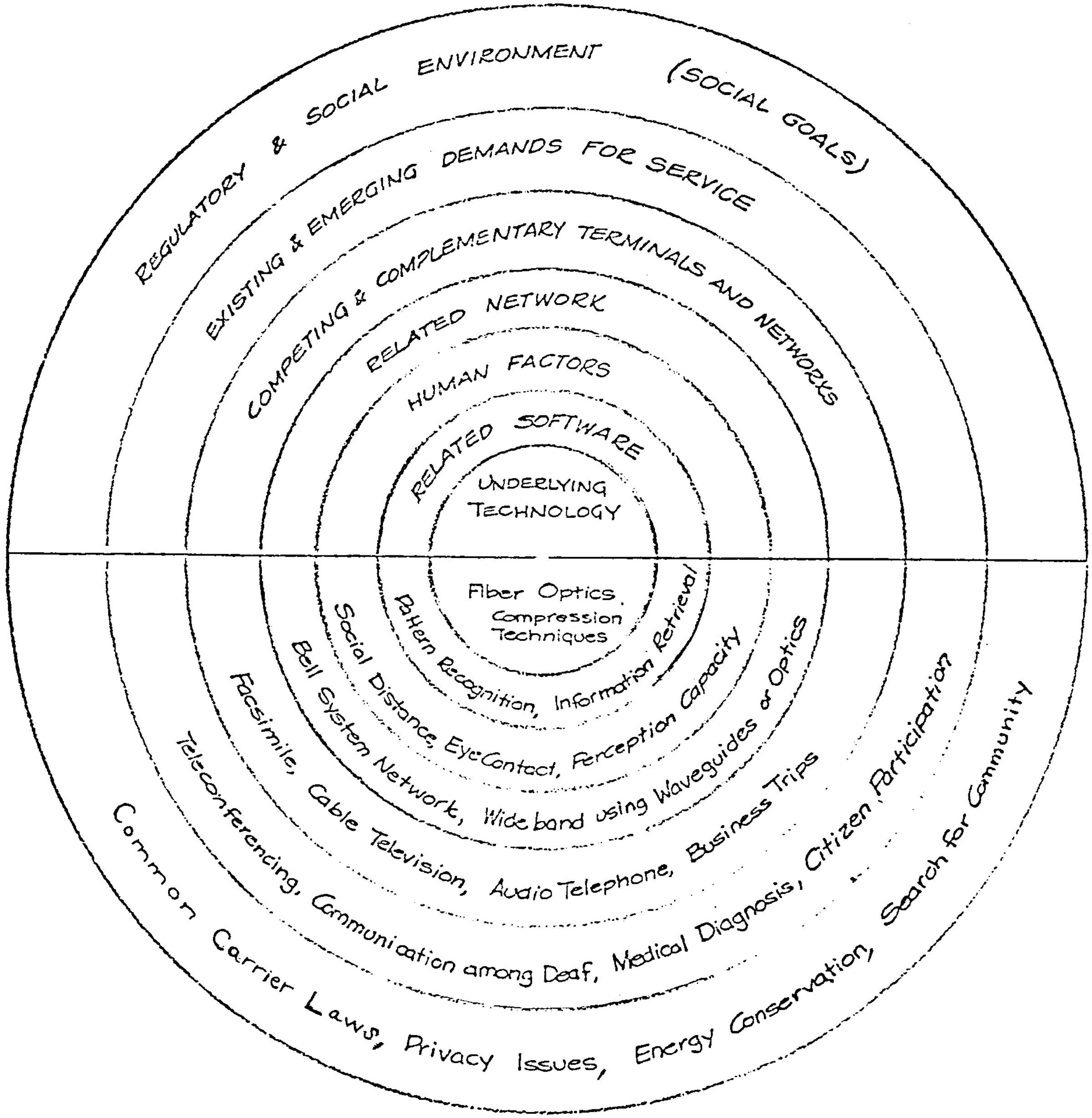
8.5.1

The market is not mature enough that the push of technology alone can shape the major advances in interactive terminals, particularly if innovative uses and a dynamic communications environment are to be anticipated.

Recommendation

While advances in hardware technologies are obviously one of the keystones in forecasting developments in data terminals, future forecasting studies should encompass other important areas such as those depicted in Fig. 8.1, i.e. software, human factors, etc.

Figure 8.1 Hierarchy of Catagories Envolved in Assessing a Terminal's Impact



8.5.2

The potential benefits and limitations of interactive systems have not to our knowledge been explored to the depth necessary that terminal and system specifications can be formulated for specific applications such as word processing. The work (which would be supplemented by market surveys) would probably require a real life laboratory in which a variety of terminal hardware and system software features would be tested. The output from such a study would be a set of specifications covering system operating costs, reliability, response time, terminal hardware, error recovery, software convenience features and command structure, confidentiality restrictions, etc.

Recommendation

The Government should set up an integrated task environment for selected applications of interactive terminal applications to carry out research on all aspects of the system: user training, hardware, software and communications. A substantial and unique contribution could thus be made to the development of products for a specific terminal market.

8.5.3

The competitive advantage of any particular terminal configuration can be determined only in relation to the task it is required to perform. As indicated in our discussions on cost effectiveness, a more formalized technique than is presently available is necessary to evaluate terminal performance for specific user tasks.

Recommendation

Further exploratory effort should be devoted to examining the task benchmark concept (presented in this report) to determine its usefulness for performance evaluation.

8.5.4

Information related to developments and technologies associated with interactive terminals was found to be widely dispersed and unorganized.

Recommendation

The Government should consider setting up an on-going function to continue the work reported here. The responsibility of such a group would be to maintain contacts with key organizations working in the field, monitor existing forecasts, update them as new information becomes available, and sponsor research (such as that suggested in this study) to provide missing data.

In addition to providing valuable information for terminal development, such a function could provide a useful data base for regulatory decisions related to this aspect of communication systems.

While a specific terminal configuration worthy of Government support did not emerge from this study, much was learned regarding: the technologies relevant to interactive terminals, the methodology for technology forecasting and the deficiencies in existing knowledge related to market needs and terminal performance evaluation. We believe that this work can provide a useful starting point for the more specific forecasts which will be necessary as the Government's overall strategy with respect to terminals unfolds.

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Latest developments in solid state imagers, *Electronics,* March 7, 1974, p. 67.

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Ion-implant metal gate n-channel MOS,*Electronics,* March 7, 1974, p. 117.

Reduction in Bipolar memory cell size, *Electronics,* March 7, 1974, p. 132.

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APPENDIX A

COMPOSITION OF STUDY TEAM

This study was carried out by the following staff members and technical consultants of the consultant firm of Urwick, Currie & Partners Ltd.* in collaboration with International Research and Technology Corporation**:

Urwick, Currie & Partners Ltd.

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P.F. Wade	Project Director
P.R. Kemball	Senior Consultant

Technical Consultants

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R.T. Marshall	Ruscom Logics Limited
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J. Sigurdson	McGill University
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International Research and Technology Corporation

R.U. Ayres	Vice-President
C. Decker	Consultant

The study was monitored by the following members from the Communications Research Centre:

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APPENDIX B

LIST OF INTERVIEWS

The following individuals and their organizations were especially helpful in supplying information and comments.

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(Cont'd)

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APPENDIX C

TENTATIVE BENCHMARKS

DESCRIPTIONS OF SOME TENTATIVE BENCHMARKS FOR MEASURING INTERACTIVE TERMINAL PERFORMANCE (in all cases several groups would be given similar but different tasks on each terminal, in rotation, as in duplicate bridge)

1\. A. Transmit Text: A standard purchase contract form is transmitted from one location to another via various terminals. Several queries are asked and answered with respect to provisions. Relevant measures would be the cost of equipment, cost of operation (exclusive of human input) and time of various users.

B. Transmit Numbers: A standard corporate balance sheet is transmitted, with queries, corrections, etc. Measures as above.

2\. Edit Text: A standard letter stored in the computer (or terminal) with certain spelling and punctuation errors, and deletions to be made is edited using different terminals. Relevant variables are arrangement of keys, output speed, type of feedback, whether the editing is done on- or off-line. Relevant measures would be as above.

3\. Calculations: A standard set of calculations (add, divides, multiplies, stores) would be done via alternative terminals, e.g. "invert a given 4 X 4 matrix" using an interactive "self-explanatory" software system. Relevant variables are arrangement of keys, type and speed of display, whether calculations are done on- or off-line. Relevant measures would be as above.

4\. Draw a 2-dimensional Picture, Map or Graph: A set of numerical coordinates and "links" will be supplied which form a specified pattern when connected correctly. The task is to display the pattern correctly. Relevant variables would be size and capacity of display, speed of display, type of software available. Relevant measures would be as above.

5. Purchase Theater Ticket: The task involves requesting a schedule of performances, ticket prices and locations, requesting a reservation for performance of choice with negative response followed by second or third choice selection, confirmation and payment using credit card. Ticket to be printed out. Relevant variables would be type of input device, and type and speed at the output device.

6. Select Optimum Route: Tables of the airline (or bus/rail) schedule between various cities would be stored in the computer. Users would be asked to select fastest round-trip sequence from mode X to mode Y (e.g. Washington, D.C./Ottawa) subject to some set of constraints. Relevant variables would be speed and capacity of the display, whether the display was hard or soft and the type of terminal memory.

7. Assemble Puzzle: A pile of unassembled parts (e.g. "Tinker-Toys") with appropriate labels or markings are given to a user, and he is asked to assemble them with the aid of assembly data stored in a computer. Assembly is done via different terminals. Relevant variables are speed of display, type of input, availability of graphics.

8. Complete CAI Package: A standard Computer Aided Instruction package (say, replacing a leaky head gasket on an auto engine) would be stored in the computer and run via different terminals. The package would include exercise questions, branching on answers, and graphical presentations. Relevant variables would be size and speed of display, type of input (keyboard, touch panel, light pen), availability of animation, color, and audio feedback. Performance measures would be time to complete package, scores on a past test, and subjective evaluation of users.

9. A. Select Document: A data base of documents, keywords, and abstract is stored in the computer. Users are given an abstract and asked to find the relevant document(s) via different terminals.

9. A. (continued)

Users are given a list of keywords and a description of commands for searching the file. Relevant variables are speed and size of display and whether it is hard or soft. Performance measures are time to retrieve document and subjective evaluations.

B. Compile Bibliography: A bibliography of 10 references relevant to a certain topic is to be compiled. Experts will develop a list of the best references to be used in evaluating performance. Relevant measures will be the time to complete the task and the number of "best" references on the users list.

10. A. Play Game Against Computer: A new game will be developed and programmed in the computer to test terminal performance. Users must try to identify a "target" on a grid within a fixed time by looking up data in auxillary tables. The relevant variables would be type of input (touch panel, light pen, etc.) and type and speed of output. Different games could be designed for different benchmark tests, depending on the terminal variables involved. The performance measure would be the users "score" in playing the game.

B. Play Games Via the Computer: Two or more users play a game such as Bridge, Chess, or "Go" via different terminals. Relevant variables would be the type of input, the type and speed of output, and the type of message switching involved. Relevant measures would be the time to complete a game (hand) and the player's subjective evaluation.

11. <u>Run Delphi Exercise</u>: A three round Delphi exercise will be run using N participants sitting at terminals. In the first round users will be asked to estimate when some event will occur (e.g. 150 m.p.h. train). The distribution of answers will then be displayed anonymously - and participants with high and low estimates will be asked to explain their reasons. These will also be displayed. Participants will then re-evaluate their estimates and new distribution will be calculated, along with measures of convergence or divergence. Relevant variables will be the type of message switching, and the type of terminal I/O. Relevant messages will be the time taken to complete the exercise, and subjective evaluations of the system.

APPENDIX D

FORMULAS FOR COST EFFECTIVENESS CALCULATIONS

DESCRIBED IN SECTION 4.7

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1. DATA REQUIREMENTS

(i) Frequencies

f_k - number of times each task, k, will be run during month

w_{jk} - weight or frequency with which task, k, involves element j

(ii) I/O and System Parameters That Are Independent of Time (but dependent on terminal configuration)

(α) Input Formulation Multiplier

The relative difficulty with which a user can translate a thought or concept into a message in a form *acceptable to the terminal,* measured as the ratio of elapsed time with respect to elapsed time for a standard terminal.

(β) Input Conversion Multiplier

The relative difficulty with which an acceptable message can be transferred to the CPU and internally converted by the CPU into "machine language", i.e., a given set of instructions and data words measured as the ratio of computer operations per message as compared to a standard terminal.

(γ) Output Conversion Multiplier

The relative difficulty with which a message from the Central Processor can be encoded into an acceptable form for transfer to the terminal and printing or display to the user.

(δ) Output Assimilation Multiplier

The relative difficulty with which a user can assimilate and understand a message in the output form utilized by the terminal.

Note that output mode may be different from input mode, hence input and output conversion multipliers may be different.

Note also, that input formulation difficulty tends to increase at the expense of internal conversion difficulty. Thus it is easiest for an untrained user to communicate by voice or handwriting. But these offer very severe recognition and translation problems for the terminal (or the central processor). It is much easier for a terminal to accept typewritten messages (from a limited set of symbols) and still easier to accept messages already in computer compatible languages in binary (rather than alphanumeric) form.

(μ) Time Share Multiplier (Ratio of Elapsed Time to CPU Time to Carry Out Task)

(iii) Economic Factors That Vary Over Time

$W_{(t)}$	Wage cost of operator ($ per hour)
$X_{(t)}$	Hookup cost ($ per hour)
$Y_{(t)}$	CPU cost ($ per 10^6 operations)
$Z_{(t)}$	Rental cost of terminal ($ per month)

2. CALCULATIONS TO DETERMINE COST EFFECTIVENESS OF A GIVEN TERMINAL TYPE

T_k (time in hours for completing of task k) $= w_{1k}\alpha + w_{2k}\delta + w_{3k}\mu + w_{5k}$

$$= t_{1k} + t_{2k} + t_{3k} + t_{5k}$$

T (total time in hours for terminal to complete all tasks in month) $= \sum_{k=1}^{K} f_k T_k$

V_k (number of computer operations for task k) $= w_{1k}\alpha\beta + w_{2k}\gamma\delta + w_{3k} + w_{4k}$

$$= v_{1k} + v_{2k} + v_{3k} + v_{4k}$$

$$= \sum_{j=1}^{J} v_{jk}$$

C_k^* (cost of task k) $= (X + W)T_k + YV_k$

C (total cost per month for all tasks) $= \sum_{k=1}^{K} f_k C_k + Z$

N (number of tasks per month) $= \sum_{k=1}^{K} f_k$

*Exclusive of terminal

3. ADDITIONAL OPTIONAL CALCULATIONS TO REFLECT SOFTWARE COSTS AND UTILITY

3.1 Processing and Software Costs

To more accurately reflect the cost comparison of alternative terminals, the total cost for the entire system should be commuted, hence :

$$V_i(t) = Z_i(t) + H_i(t) + U_i(t) + R_i(t) + P(t) + S$$

Where $Z_i(t)$ is the terminal cost

$H_i(t)$ is the hook up cost

$U_i(t)$ is the operator cost

$R_i(t)$ is the remote processing cost for recognition of terminal i inputs, and formation of outputs, P (t) is the remote processing cost for the tasks and S is the software development cost.

As indicated in Section 6, P(t) and S are likely to be very large in the future which means that terminal cost (Z_i) will be a relatively small % of V_i.

3.2 Utility Analysis

These factors can be incorporated by expanding the cost effective equation as follows"

$$V_i\ (t) = w_1 g_1(C_1) + w_2 g_2(H_i(t) + U_i(t)) + w_3 g_3(R_1(t)) +$$

$$w_4 g_4(P(t) + S) \cdot \sum_{j=5}^{n} w_j A_{ij}$$

where w_j are importance weights, g_{1-4} are functions which map values into the integers from 1 to 10, and A_{ij} is the rating of terminal i for the jth element.

In actuality, all the values in the above equation vary from task to task so that $V_i(t)$ is also a function of k the particular task for which the terminals are compared. In general a benchmark task K can be chosen which is similar to the desired task k, so that comparisons can be made on the basis of performance data for K.

APPENDIX E

DETAILED COST EFFECTIVENESS CALCULATIONS FOR SAMPLE ANALYSIS

FOR TERMINAL COMPARISON IN SECTION 7.3

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1. INPUT

Task Frequencies

Task	Monthly Frequency (f_K)
1	5
2	0.1
3	0.05

Table 7.2 Work Element Frequencies per Task* (W_{jK})

Element	Task 1	2	3
E_1 Message from user to terminal (Units of information content)	1	9	50
E_2 Message from terminal to user (Units of information content)	2	8	1
E_3 Internal logic or arithmetic op. (Number of processing steps)	3	7	3
E_4 Internal storage (Number of bits)	4	6	10
E_5 User response time (On-line records)	5	5	100

*These are totally arbitrary since tasks have not been specified in detail.

I/O and Systems Parameters*

	Input Formulation Multiplier α	Input Conversion Multiplier β	Output Conversion Multiplier γ	Output Assimilation Multiplier δ	Time Share Multiplier μ
(a) Typed input/typed output	2.5	1.0	1.0	5.0	1.0
(b) Voice input/voice output	1.0	1000	10	2.5	1.0
(c) Handprint input/ graphic output	1.5	100	10	1.0	1.0
(d) Voice and handprint input/ voice and graphic output	1.0	1000	10	1.0	1.0

Time Independent Cost Parameters (Table 7.3)

* These numbers were chosen to be consistent with the data of Chapanis (Fig's 7.2 and 7.3) where applicable and are intended to be plausible though not definitive. However, once again, alternative terminal equipment configurations have not been specified in sufficient detail to permit the determination of actual numbers.

Economic Factors That Vary Over Time*

	Cost Parameter	(Unit)	Terminal Equipment Configuration	Time Period 1970	1975	1980
Wage cost of operator	W(t)	\$/hour	all	10.00	11.00	12.00
Hookup cost	X(t)(1)	\$/hour	all	10.00	8.00	6.00
CPU cost	Y(t)(1)	\$/10^6 CPU ops.	all	10.00	2.00	0.50
Terminal Rental cost	Z(t)(2)	\$/month	(a) Typed input/ typed output	56.	56.	56.
		"	(b) Voice input/ voice output	14,000	2,000	1,500
		"	(c) Handprint input/ graphic output	15,600	2,500	1,700
		"	(d) Voice & handprint input/voice & graphic output	29,600	4,500	3,200

Time Dependent Cost Parameters (Table 7.4)

(1) Source - Figure 7.4 (C)

(2) These numbers are obtained from the graphs in Figure 7.4 as follows"

Configuration	Source of cost estimates
(a) Typed input/typed output	Graph (A)
(b) Voice input/voice output	Graph (E)
(c) Handprint input/graphic output	Graph (B)+(D)+(E)
(d) Voice & handprint input/voice & graphic output	Graph (B)+(D)+(E)+(E) (It is assumed that separate devices are required for voice & OCR recognition.)

2. OUTPUT

CALCULATION OF T_K AND V_K

(Symbols refer to formulas contained in Appendix D)

Tk (time in hours to complete task k)

Term conf.	Task	T_k	$w_{1k}\alpha$	$w_{2k}\delta$	$w_{3k}\mu$		w_{5k}
1	1	20.50	2.50	10.00	3.00	0.00	5.00
1	2	74.50	22.50	40.00	7.00	0.00	5.00
1	3	233.00	125.00	5.00	3.00	0.00	100.00
2	1	13.00	1.00	4.00	3.00	0.00	5.00
2	2	37.00	9.00	16.00	7.00	0.00	5.00
2	3	155.00	50.00	2.00	3.00	0.00	100.00
3	1	13.50	1.50	4.00	3.00	0.00	5.00
3	2	41.50	13.50	16.00	7.00	0.00	5.00
3	3	180.00	75.00	2.00	3.00	0.00	100.00
4	1	11.00	1.00	2.00	3.00	0.00	5.00
4	2	29.00	9.00	8.00	7.00	0.00	5.00
4	3	154.00	50.00	1.00	3.00	0.00	100.00

V_K (number of computer operations for task k)

Term conf.	Task	V_k	$w_{1k}\alpha\beta$	$w_{2k}\alpha\delta$	w_{3k}	w_{4k}	
1	1	19.50	2.50	10.00	3.00	4.00	0.00
1	2	75.50	22.50	40.00	7.00	6.00	0.00
1	3	143.00	125.00	5.00	3.00	10.00	0.00
2	1	1047.00	1000.00	40.00	3.00	4.00	0.00
2	2	9173.00	9000.00	160.00	7.00	6.00	0.00
2	3	50033.00	50000.00	20.00	3.00	10.00	0.00
3	1	197.00	150.00	40.00	3.00	4.00	0.00
3	2	1523.00	1350.00	160.00	7.00	6.00	0.00
3	3	7533.00	7500.00	20.00	3.00	10.00	0.00
4	1	1027.00	1000.00	20.00	3.00	4.00	0.00
4	2	9093.00	9000.00	80.00	7.00	6.00	0.00
4	3	50023.00	50000.00	10.00	3.00	10.00	0.00

2. OUTPUT (continued)

Monthly Costs for Scheduled Mix of Tasks
for years 1970, 1975, 1985
(by Terminal Configuration)

Configuration (a) - type in/type out

		1970	1975	1980
Task 1	CK	605	429	379
2	CK	2,244	1,566	1,379
3	CK	6,090	4,713	4,265
Total Monthly	C	3,610	2,594	2,246

Configuration (b)

Task 1	CK	10,730	2,341	758
2	CK	92,470	19,049	5,253
3	CK	503,430	103,011	27,806
Total Monthly	C	102,068	20,765	7,201

Configuration (c)

Task 1	CK	2,239	650	341
2	CK	16,060	3,834	1,509
3	CK	78,930	18,486	7,006
Total Monthly	C	32,354	7,057	3,910

Configuration (d)

Task 1	CK	10,489	2,263	711
2	CK	91,510	18,737	5,068
3	CK	503,310	102,972	27,784
Total Monthly	C	116,368	22,838	8,650

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09 Electronics and Electrical Engineering

09 05 Subsystems

8. ABSTRACT: A preliminary forecast and impact assessment of technologies related to interactive data terminals covering the period 1973 to 1985, approximately is presented. Primary emphasis is on a systematic, detailed identification of the hardware and software technologies underlying present and potential future terminal types and on carrying out an exploratory forecast of the technologies. Some performance and cost trends for the technologies are presented. Less emphasis is placed on the assessment of impact of these technologies on the evolution of specific data terminal types. Quantitative cost-effectiveness and cost-benefit techniques for assessment of relative attractiveness of competing terminal types are also outlined.*

* *Study conducted from November, 1973 to March, 1974*

SOMMAIRE: On présente une prévision préliminaire et une évaluation de l'influence des technologies relatives aux terminaux de transmission de données interactifs, couvrant approximativement la période de 1973 à 1985. L'accent est mis principalement sur un inventaire détaillé et systématique des technologies du matériel et du logiciel qui sont à la base des types de terminaux actuels et futurs et sur la préparation d'une prévision exploratoire des technologies. On présente certaines tendances de performance et de coût des technologies. On place moins d'importance sur l'évaluation de l'influence de ces technologies sur l'évolution des types particuliers de terminaux de transmission de données. On indique également des techniques d'évaluation quantitative coût-efficacité et avantages-coût de l'attrait relatif des types de terminaux concurrentiels.*

* *Étude effectuée de novembre 1973 à mars 1974.*

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