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ABSTRACT

This volume summarizes the results of a 2-year technology assessment of personal computers. The purpose of this study was to explore possible future modes of growth of the personal computer and related industries, to assess the impacts and consequences of that growth, and to present some of the policy issues and options which may arise as a consequence of the development of personal computer technology. However, due to limitations of time, funds, and personpower, detailed analyses were restricted to three main issue areas: (1) the growth of personal computer technology, (2) the expected impacts of the technology, and (3) the public policy implications in areas of education, employment, and international trade. Much of the information generated in this report was based upon the results of Delphi surveys. Tables of data are included. (Author/LLS)

A TECHNOLOGY ASSESSMENT OF PERSONAL COMPUTERS
VOLUME I: SUMMARY

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Any opinions, findings, conclusions and/or recommendations expressed herein are those of the authors and do not necessarily reflect the views of the National Science Foundation or of the University of Southern California.

Preface

This set of reports is the last in a series covering the first two years of progress of the Personal Computer Assessment Project at the University of Southern California. The Principal Investigator of the project is Jack M. Nilles, Director, Interdisciplinary Programs. Organizationally, the Office of Interdisciplinary Programs is a unit of the Office of the Executive Vice President of USC. A technology assessment is a complex, broad-scope activity. As such, it requires the participation of researchers from a number of disciplines and the cooperation of a variety of experts from outside the university. The purpose of the Office of Interdisciplinary Programs is to develop such projects on a university-wide basis.

The USC research team has included the following individuals:

Jack M. Nilles	Director, Interdisciplinary Programs Office of the Executive Vice President (Project Director; Impact and Policy Analysis; Reports Editor)
F. Roy Carlson, Jr.	Assistant Dean, School of Engineering Director, Engineering Computer Lab (Technology Forecast; Scenario Development; Education Policy Analysis)
Paul Gray	Professor, Decision Sciences [Now Chairman, Management Science and Computers, Cox School of Business, Southern Methodist University] (Scenario Development; Impact Analyses)
John P. Hayes	Associate Professor, Electrical Engineering (Technology Forecast)
Milton G. Holmen	Professor, Management, Public Administration (Market Analysis)
Michael J. White	Associate Professor, Public Administration (Policy Methodology; Employment Policy)
Celeste B. Akkad	Office of Interdisciplinary Programs Project Assistant (until June, 1980)
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Charles Steinfield (Delphi Survey Analysis)
Patricia Walters (Scenario Development, Educa n)

In addition to the project staff, we have been given much valuable assistance and advice from a Board of Advisors. The composition of the Board has been as follows:

Robert W. Barmeier	Director, Planning & Research, Sears, Roebuck & Company
Alfred Bork	Professor, Department of Physics, University of California, Irvine
John Craig	Publisher, <u>InfoWorld</u>
Robert Daly	Special Assistant to the Director, Office of Technology Assessment, U.S. Congress
Edward E. Faber	President, Computerland Corporation
Portia Issaacson	Research Fellow, Electronic Data Systems
Hank Koehn	Vice President, Futures Research, Security Pacific National Bank
Ryal R. Poppa	President, PERTEC Computer Corp.
John Ratliff	Consultant
R. B. Shirey	Vice President, General Telephone Company

We have also been fortunate to enlist the cooperation of a number of experts in various aspects of our research by means of our Delphi surveys. The Delphi panelists and our advisors contributed their time, interest and insights far beyond the call of duty. We are also grateful for the time spent by those who participated in the surveys associated with the project.

Finally, we are greatly indebted to Dr. G. Patrick Johnson, of The National Science Foundation, for his interest, advice, and encouragement. Although many improvements in our research have resulted from the contributions of these advisors, panelists, and respondents, any failings must remain the responsibility of the research team. Readers interested in gaining further information may contact:

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CONTENTS

I. PROJECT OVERVIEW

This is the summary volume of a three volume report covering the results of a two year research program performed at the University of Southern California. The project involved the participation of four schools of the University under the management of USC's Office of Interdisciplinary Programs. In the course of its research the project team also enlisted the aid of an advisory board comprising a diverse group of experts in various aspects of personal computer technology, technology assessment, and related areas of technology impact. We were also assisted by a broader array of experts in the Delphi surveys and other surveys completed during the course of the research. The support and cooperation of these individuals and of the National Science Foundation's staff, particularly Dr. G. Patrick Johnson, is gratefully acknowledged.

1.1 Introduction

The formal art of technology assessment is relatively recent, the term having been coined only a few years ago. It springs from the broadening recognition by many citizens in technological societies, and by public policy makers in particular, that developing technologies can have unforseen and, frequently, undesirable and massive consequences. The fundamental goal of a technology assessment is to somehow anticipate both the societally desirable and undesirable impacts of developing technology, estimate the extent to which public policy decisions might be able to influence the impacts, and to suggest policy options accordingly. Technology assessment is an advisory process. Its findings, if successful, help decision makers in direct proportion to the extent to which they minimize surprises in the decision making process.

The purpose of this technology assessment of personal computers is to explore possible future modes of growth of the personal computer and related industries, to assess the impacts and consequences of that growth, and to present some of the policy issues and options which may arise as a consequence of the development of personal computer technology. Because of limitations of time, funds, and personpower not all of the potential issue areas could be examined.

A decision was made by the project team at about mid-point in the project, in consultation with the various advisors to the project and with the National Science Foundation, to restrict the more detailed analyses to three main issue areas. These areas are sufficiently broad to give the reader an idea of the variety and pervasiveness of the potential impacts of personal computers. The results of the research are presented in three components.

The first of these describes our analysis of the current status of personal computer technology, its probable growth over the next decade, the users of personal computers and the applications to which they are most likely to put them, and some alternatives to personal computer technology. All of this is summarized in the next chapter (Chapter 2) of this volume. Chapter 3 summarizes the anticipated impacts on our information society of the widespread use of personal computers and discusses some of the socioeconomic influences on the growth and application of the technology. Chapter 4 examines the specific, public policy related implications of personal computer technologies in the areas of education, employment, and technological innovation (the latter especially as it relates to international trade).

The remaining two volumes of this report cover the material summarized here in much greater detail. Volume II contains the material related to chapter II of the summary while Volume III covers the impact studies, public policy issue analyses and detailed conclusions of the project.

1.2 Conclusions

The primary conclusions of the project are grouped into five areas: the growth of personal computer technology, the expected impacts of the technology, and the public policy implications in the areas of education, employment, and international trade. They are as follows.

1.2.1 Personal Computer Technology

Personal computers will rapidly develop in sophistication, basic capability, and reliability as secondary products of the microelectronics and computer industries.

Summary
Overview

Hardware technology will continue to lead software technology for the foreseeable future, due to a growing shortage of competent and sophisticated programmers.

Personal computers will be connected to telecommunications networks with increasing frequency, as related technologies such as teletext, videotex and generalized data bases develop.

By the turn of the century, personal computers will have extremely sophisticated information processing, and massive information storage and access capabilities, measured by contemporary standards.

1.2.2 Impacts

The U.S. market for **consumer computers** will be between $1 billion and $3.5 billion in 1990. The market in the rest of the world will be about half as large.

Most owners of consumer computers over the next decade will come from the middle and upper classes. Their use of personal computers will tend to cause the development of an "information elite," with consequential development of issues of equity between the information advantaged and disadvantaged.

Software quality will be the pacing item in the acceptance of consumer computers. The failure of existing copyright and/or patent laws to protect software, unless rectified, will be a major barrier to growth of the industry.

Office personal computers will be the mainstay of the industry in its formative years. Beginning with small-to-medium sized businesses and government organizations, personal computers will see increasing use in large organizations. By 1990 the market for office personal computers will be between $4 billion and $18 billion. The market in the rest of the world will be at least half as large.

The use of personal computers by the **education** "establishment" will be limited, with a 1990 market of at most $500 million, under present conditions. Changes in public policy can materially affect this outcome.

Effects of the uses of personal computers on **employment** will be mixed. There is not likely to be any major net change in the number of jobs as a consequence of the use of personal computers. However, there may be significant job displacement in the information industries as some routine tasks are replaced and new tasks made possible by personal computers. Requirements for computer literacy will mount.

U.S. firms currently dominate **international trade** in personal computers. This technology, as a product of microelectronics and computer technologies, is a major target of the economic plans of the developed countries, particularly Japan, France, West Germany, and the U.K. Unless U.S. industrial and trade policies and practices are changed, one or more of these countries is likely to capture the dominant share of the world market from the U.S. by the end of the decade.

1.2.3 Public Policy

Education — Federal

Increased support is needed for basic and applied research and development of educational technology and courseware. Federal support might best be directed toward investigation of basic learning processes, and development of pilot programs which are easily transportable to a variety of personal computers.

Central to the mass distribution of instructional software is the development of uniform

standards and guidelines for it, together with adequate patent and copyright protection for publishers in the private sector.

The Federal government can support the purchase and oistribution of personal computer hardware and software through a variety of existing mechanisms.

State and local education policy decisions can be influenced by Federal information dissemination activities. Two such are already under consideration in Congress.

Education — NonFederal

Lack of teacher training and motivation are central barriers to the active use (as contrasted with passive acceptance) of personal computers, even in the types of instructional assisstance where they have been proven most effective. Shifts of state and local education policy from capitation to student performance standards, coupled with suitable teacher training programs, could materially improve this situation.

Approval by accreditation groups of curricula which use personal computers as integral instructional technologies will increase the rate of diffusion of the technology.

Pressures from external interest groups may ultimately be the most effective in effecting the general use of personal computers in schools, absent the other policy steps just mentioned.

Employment

Specific Federal support may be needed for training computer specialists over the next decade if the industry is to continue to grow. Several indirect means of supporting retraining of those displaced by personal computers currently exist, but should be used cautiously. Past experiences with retraining programs, such as those used for aerospace industry workers circa 1970, show that the programs must be extremely well defined and managed to be effective. Particular attention might be paid to subsidizing retraining of skilled workers who have been displaced by personal computers.

Increasing use of telecommunications-interconnected personal computers may result in excessive employer surveillance of employee activities. Effective regulatory or other mechanisms, consistent with democratic societal goals, should be explored for minimizing such abuses of privacy.

Occupational health issues of personal computers (or of larger computers) are largely unexplored; more research is required to assess possible effects on health.

There is almost no quantitative evidence of the effects of computers on jobs. As a prerequisite to any major Federal policy decisions regarding employment effects of personal computers it is necessary to develop a better understanding of the interrelationships between the two and a variety of externalities through Federally supported research. Appropriate job monitoring programs could provide the necessary information on job creation and loss.

Employment forecasting, including consideration of the influences of education, immigration, and national and international economics, should focus on job creation and loss by (and between) specific industrial sectors. Effects of personal computers on productivity and employment may otherwise go unrecognized and uncompensated.

All of the above point to the conclusion that at present the United States does not have an integrated body of employment (as contrasted with unemployment) policy. Although technological change, such as that induced by personal computers, is only one of the factors affecting employment policy, it must be considered. Employment policy must take into account both the short- and long-term impacts of information technologies such as personal computers.

Summary
Overview

International Trade — Industrial Policy

Fundamental to the growth of the personal computer and other technology intensive industries is the economic climate for technological innovation, from the laboratory to the salesroom. The U.S. has neither coherent, integrated industrial nor international trade policies at present. Potential competitor nations have. Although not all policies adopted by other countries are transplantable to the U.S., some appear to be worth further consideration and Americanization. These include:

1) **Tax incentives**: depreciation periods consonant with the useful lifetimes of personal computers in business applications (3 to 5 years); optional expensing of personal computers or the capital equipment required for their production; increases in investment tax credits for equipment which demonstrably improves productivity; refundable tax credits for small businesses characteristic of the personal computer industry.

2) **Stimulation of personal savings** (as a major source of investment capital) through such means as exemption of a significant portion of interest income from income taxes (Japan exempts the first $5000, the U.S. exempts the first $200).

3) Federal Reserve encouragement of **loans to high growth industries.**

4) Partial Federal **subsidy** of small, technology-intensive firms.

International Trade — Trade Policy

Until very recently the international trade policy responsibility within the Federal government was split among many independent organizations. Trade issues were frequently subordinated to other issues in the several agencies or were neglected for long periods. Decisions made by one agency were often not coordinated with other agencies with overlapping mission responsibilities. Part of the recent history of the steel, automobile, and consumer electronics industries reflects this confusion. In January, 1980, the Executive Branch was reorganized as a step toward correcting this situation. However, by July, 1980, there was little evidence of substantive action in this regard.

If the personal computer industry is to avoid some of the same problems that have troubled the U.S. consumer electronics industry, the Federal government must take <u>swift</u> action to enforce reciprocity in international trade agreements. The major potential competitor countries in the personal computer market routinely erect tariff and a variety of nontariff barriers against undesired products such as semiconductors, consumer electronics and, potentially, personal computers. Because of the dynamism of the market, long delayed reactions are useless.

Similar policy measures need to be considered with regard to foreign ownership of U.S. firms in the personal computers and supporting industries. Because of difficulties in obtaining capital for expansion in the United States, a growing number of firms in the personal computer industry, including the second largest, have obtained significant portions of their financing from, or have been acquired by, interests from other countries. This trend is more advanced in the semiconductor and computer industries, at least among the middle tier and smaller firms.

Specific export incentives should be considered for U.S. firms, including aid in obtaining export licenses, export loan subsidies from the Export-Import Bank, and special tax incentives to exporting firms. Some of these incentives may be retaliatory in nature, used as a means for ensuring reciprocity.

International Trade — General

None of these trade-related policy issues is unique to personal computer technology.

Rather, they are typical of the issues raised by increasing competition with the U.S. in technology-intensive industries. Policy changes which benefit the personal computer industry are likely to benefit other technology-intensive industries as well.

1.3 Time Considerations

Consideration of the dynamics of market growth leads us to believe that the personal computer manufacturers will reach their highest level of sales to first-time users some time near, or after, 1990. Since the impacts associated with personal computer technology tend to be proportional to market size, we do not expect them to become pervasive prior to that period. This gives the policymaker some time to collect information and develop coherent and effective bodies of policy in anticipation of, rather than in reaction to, the effects of the technology. However, this does not mean that the policymaker can ignore the issues for several more years, waiting for them to become serious before taking action. First, it is clear that personal computers will affect public policy decisions at all levels of government from federal to local. Second, many of the impacts of personal computer technology, although not necessarily unique in their basic nature, will directly affect individuals on a scale comparable to that of the telephone, television, and the private automobile. Third, many, if not most, of the policy issues of personal computer technology development are highly interrelated. Education policy, to the extent that it affects computer literacy, has effects on employment. Increased computer literacy among the employed, to the extent that it improves productivity, directly or indirectly affects the general international trade competitiveness of the United States. The continuing availability of improved personal computer hardware and software, as a consequence both of increased international trade and increased employment in the industry, creates greater requirements for computer literacy, which in turn creates increased demand for improved and less expensive hardware and software, and so on. It is impossible, at this stage of our knowledge of the details of these interconnections, to quantitatively assess the degree of synergism resulting from specific sets of policy decisions. A considerable amount of "homework" has yet to be done.

It is also apparent that these interactions are not "steady state" in nature. There is time interdependence among them. We postulate that there may be some critical series of time dependent and interrelated policy decisions in education, employment, and international trade, among others, although we have only begun to explore them. The time dependence must include consideration of the actions of others in other countries as well as our own.

Of particular importance is the necessity to take into account reaction or "start up" times in making these decisions. If, for example, we are to have a substantial increase in computer literacy by 1990 in order to correspondingly increase workforce productivity and improve our competitive position in international trade, we must first establish and implement educational policies leading toward increased computer literacy, create market conditions for the development of suitable software and hardware, ensure that proper curricula exist for training teachers in the techniques of computer literacy, provide incentives for teachers to be trained, and then begin the education of the future computer literates. Although some of these activities can be carried out in parallel, others are sequential. All are necessary conditions to the success of the overall policy action. Some of the requirements are being and will be satisfied by market processes, others will need assistance from government policy actions.

II. PERSONAL COMPUTERS AND PERSONAL COMPUTING

The term "personal computer" is totally inadequate to describe the technology we have been considering; unfortunately, to paraphrase Winston Churchill, it is the best term we have been able to find. Rather than try to describe what a personal computer is, we more often find it easier to describe what it is not. The personal computer is not a pocket calculator, a simple computer terminal that must be connected to a bigger computer somewhere, a smart device like a microwave oven or home security system, or a room-sized, expensive, impersonal machine (the image that flashes through the minds of most people when they hear the word "computer"). What is left, then? A personal computer is a small, general purpose computer, using advanced microelectronics technology, which is designed to be conveniently operated by a single individual, an individual who need not have extensive (or even any) prior training in computer technology or operation.

Personal computers come in many forms. The three most popular versions at the time of this writing (as determined from estimates of 1979 sales) are the Radio Shack TRS-80, the Apple II, and the PET; all directed toward the small business, home and school user, in descending order of manufacturer's preference. Some personal computers are almost indistinguishable from their bigger and more expensive siblings, the minicomputers. Frequently during our research we have described the personal computer an information technology equivalent of a personal automobile; it allows its owner to conveniently tackle a variety of information tasks, free from any requirement to interface with a timesharing "mainframe" computer – which is the information technology equivalent of mass transit.

Personal computers did not exist before 1975. They are the product of the swift technological advances made in the past few years by the microelectronics industry. Their future pervasiveness is signalled by the fact that the developed nations of the world are steadily becoming information intensive. At least half of the jobs in these societies deal mainly with some form of information processing. More and more frequently, the routine, and even the very highly creative aspects of these jobs are computer aided. It is a "technology push" environment; the existence of the capability creates a demand for it.

2.1 Technology

The central element in personal computer technology is the microprocessor, a small (.25" x .25"), thin "chip" of silicon containing tens of thousands of individual electronic circuit elements. Because of the rapid rate of development of microelectronic technology, the number of elements that can be squeezed into a single chip – and, consequently, the computing power of a microprocessor – is doubling every other year and appears likely to maintain that rate of progress throughout the decade if economic conditions continue to be favorable. As the computing power of new microprocessors steadily increases, the cost per computation steadily decreases, currently the annual rate of decrease is almost 30%. These increases in capability and reductions in cost also apply to the other microelectronic components of the personal computer: memory chips, signal interface processors and controllers, and a variety of specialized devices, including data encryptors. Because of this steady escalation of capability and shrinking of price, the computing power of a system that cost tens of thousands of dollars in the mid '60's can be purchased today for less than a thousand dollars.

Microelectronics are not the only contributor to the rapid growth of personal computer technology. Of comparable importance have been advances in information recording technologies ranging from the familiar audio tape and video cassettes, to "floppy", "hard" and video disks, and "bubble" memories. The home TV set has been turned into the display device for the consumer computer. The manual or electric typewriter has been replaced by an electronic version ranging in price (in early 1980) from $450 to $4500 and in capability from production of draft quality copy at about two minutes per typewritten page to print quality copy at less than one minute per page. Other accessories (peripherals) for personal computers include a wide array of sensors of various sorts, controllers for a variety of devices ranging from home appliances to robots, and communications interfaces allowing different computers to talk to each other, or to literally talk to (not with) their owners.

Personal computers are a watershed technology; except in a small number of areas of technology they depend primarily upon innovations made originally for large computer systems,

automobiles, word processing systems, consumer electronics, and the like. The research and development that goes into the production of innovations in these other areas is captured by the personal computer industry. Thus, the personal computer industry depends on the fruits of the investments made in the supporting industries, even when those investments were made for other purposes. For example, the microprocessor was developed as a means for putting some "intelligence" into a variety of devices such as production machinery, calculators (of which the pocket calculator is a stellar example), automobile ignition and fuel control systems, and microwave ovens. Personal computers form just one of the additional sets of applications of these devices. Nevertheless, as more applications develop that are oriented strictly toward the personal qualities of the personal computer we can expect developments in personal computer technology to enrich these other areas as well.

Although the productivity gain of the more mechanical components of personal computer technology has not yet been quite as spectacular as the improvements in microelectronics, it has still been substantial. We estimate that the capability per dollar (neglecting inflation) of personal computer peripherals will increase at an annual rate of about 20% for the next decade. This does not mean that the costs of personal computers will diminish at an annual rate of about 25% over the next decade. For one thing, as the costs of the hardware increase, other costs, such as distribution and advertising, tend to stay relatively constant (or, being more labor intensive, increase) and hence constitute an increasing proportion of the sales price of the hardware. In addition, although the price of a minimum capability personal computer will tend to decrease over the coming years, the middle to high price range personal computers will tend to sell at about their present level (again, neglecting inflation effects). However, for a fixed dollar cost, the capability of the hardware will increase. As a consequence, potential purchasers of personal computers who have redtricted budgets will have an increasingly broad spectrum of technological capabilities from which to choose.

It is in the area of software, the instructions required by the computers, that there is considerably more uncertainty as to the rate of technological progress. The development of hardware technology, although by no means simple, is relatively straight-forward; the components involved all obey well known physical principles and their desired performance can be specified in quantitive detail. In many cases this is true of software technology as well. The nature and form of the information to be given to a computer (the input) as well as the desired results of the computer operations (the output) are well defined. This is particularly the case for most scientific and accounting oriented information processing. However, in areas where either or both of the input and output are less well defined the situation can be considerably more complex and existing technological tools and much less capable of coping with the issues.

As one example, it is a relatively straight-forward task to design software that will allow a computer to "speak" to its user in a reasonably humanlike manner, as has been successfully demonstrated by Texas Instruments', "Speak and Spell" microcomputer. The task of making a computer understand ordinary conversation is thousands of times more difficult and is not expected to be solved much before the end of this decade, if then. The more natural, the more "transparent", the interaction between the computer and its human user must be, the more difficult the software design problems are. Thus, in a very real sense, the rate of software technology development may be the primary determinant of growth of the personal computer industry, since, as will be seen shortly, the size of the potential market for personal computers greatly depends on their ease of use.

To put it another way, until personal computers appeared on the scene computers were mostly owned by large organizations and operated by highly trained individuals in laboratory-like surroundings. Expertise in one or more complex computer language was an employment prerequisite for these computer specialists. With the advent of personal computers the situation has changed drastically. The owner/operator can no longer be expected to be conversant, or even acquainted, with formal computer languages. Neither can contemporary consumer computers "understand" the natural language of their operators, complete with errors in syntax, grammar, and spelling, and ambiguities in context. Significant advances in software technology are required before this capability is widely available.

2.2 Users

There is a general theory of technological innovation that goes as follows: The first users of a newly developed technology are individuals who tend to be highly innovative themselves; they will try a new technology just to see if it works, almost without regard to its economic value to them.

They are risk takers. As this small number of initial users deals with the technology and causes improvements to be made, the technology becomes more attractive to somewhat less innovative users. These venturesome users cause further improvements to be made, to the point where still less adventurous users adopt the technology and so on. The market for the technology expands, slowly at first, then more rapidly, until the annual increase in the number of new users reaches a peak at about the point where half of those who will ever use the technology have begun using it. At some point essentially all of those who will ever use the technology are using it and the user population reaches a maximum. The progress in time of this diffusion of the technology traces an "S" shaped curve. It is shown in Figure 2-1 for pocket calculator technology. The general form of this curve seems to hold for a variety of technological and natural phenomena, from the spread of epidemic diseases, the growth of animal populations, or the development of technological markets. As nearly as we can tell, personal computer technology will trace a similar pattern of growth. The key questions are: what is the ultimate size of the market, and how fast will it grow?

In the autumn of 1978, to develop some perspective on these questions, the USC Research Team conducted a survey of existing users of personal computers. The results were compared with others made at about the same time by independent market research firms and by two national personal computer oriented periodicals. All of these surveys gave roughly equivalent results: the typical personal computer owner in late 1978 was a college educated white male in his middle 30's with an annual income of about $25,000 and an average total investment in his personal computer, software, and accessories of about $4,500. Three quarters of these users were employed in the science or engineering fields (including medicine) while 1/5 were businessmen.

These characteristics are typical of what we might expect to see at the very early stages of a technological innovation. The initial group of personal computer owners was predominantly composed of hobbyists, those to whom the operation of the personal computer was an end in itself. Yet, even at this relatively early stage of development of personal computer technology, the next wave of innovators was beginning to appear. These were the businessmen, educators, and professionals who were interested primarily in the practical applications of personal computers in earning a livelihood. By 1980, business and professional users constituted the majority of new purchasers of personal computers, according to informal surveys of computer retailers made by our research team.

Although there is still great diversity in the personal computer market we have, somewhat arbitrarily, divided it into three broad categories. These are: 1) the general consumer, 2) institutional education, and 3) offices.

The general consumer. This category encompasses the lowest price range of personal computers, the so-called home computers. Although the home computer may ultimately have the broadest variety and scope of uses of the total class of personal computers, its chief characteristic is that it is relatively inexpensive at the entry level and is relatively simple to operate. Although the least expensive, consumer computers are not toys; they are fully functional, general purpose computers.

Institutional Education. This category of personal computer includes those used by the traditional education systems from kindergarten through college, and by other groups, such as industry and government, directly involved in formal education programs. The educational computer can range in price from a moderately sophisticated consumer computer to the upper limits of our definition of a personal computer – close to $20,000. This category is restricted to those personal computers used directly by these institutions for educational or education-related administrative purposes. In our later discussions of market size, consumer-owned computers used for educational purposes are assumed to be in the genaral consumer category.

Offices. The emphasis in this category is on the systems, costing in the order of $10,000 (including software) in 1980, although, like the other two categories, both less and more expensive personal computers are included. Both large and small organizations are using or will use personal computers. For the small business and professional office the personal computer may be the first general purpose computing capability owned by the organization. In large business and government offices personal computers are seen as one means for achieving

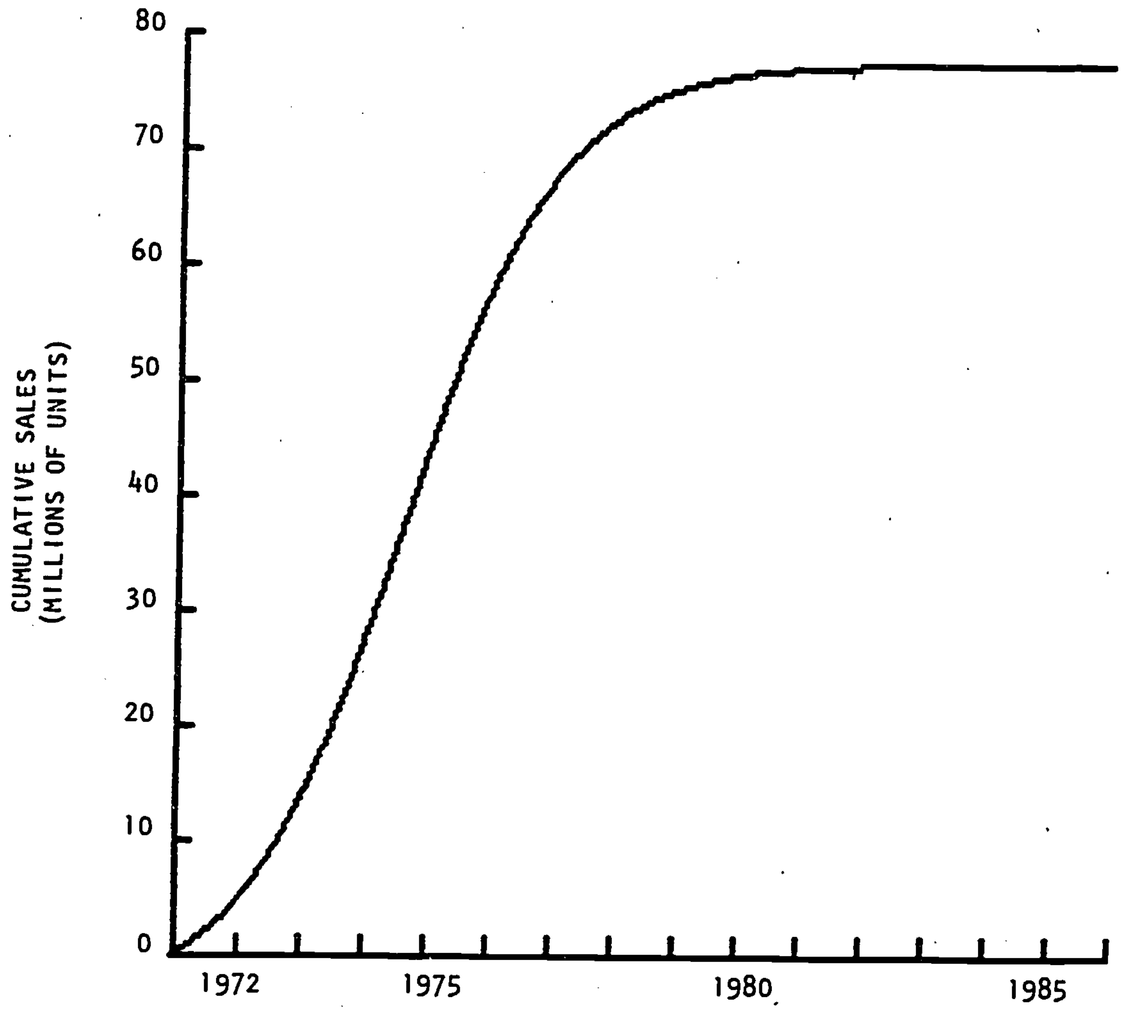


Figure 2-1: Electronic Calculator Initial Buyers

distributed processing, helping to alleviate the workload on the central large mainframe computer within the organization.

We estimate that consumer computers will ultimately constitute the largest group in terms of the number of units in operation, with office computers occupying second place. In terms of the economic impact of personal computers by category, the first two places may be interchanged. There is still considerable uncertainty as to the near-term rate of growth in the use of personal computers, since growth is dependent on a number of factors. These include current economic conditions, the continued rate of growth of hardware and, especially software technologies, and the continued trend in the developed countries toward conversion from an industrial to an information intensive society. We estimate that near the turn of the century the equivalent of four out of every five households in the United States will have a consumer computer, that 10 million personal computers will be in offices and that about three million will be in classrooms throughout the country if all of the conditions mentioned above are positive. [To put these numbers into perspective, there are about 300,000 mini and mainframe computers and about 500,000 personal computers in operation in the United States today]. If some or all of the assumed contributory growth rates falter, the rate of growth of the personal computer industry will also be slowed. Our estimate of the probable "envelope" for these alternative growth rates (both in number of units sold to first time users and in the annual dollar value of these units – expressed in terms of 1980 dollars) are shown in figures 2-2 through 2-7.

2.3 Uses

Personal computers intrinsically can be used for almost any type of information processing task. In practice, the uses to which personal computers are actually put depend on the availability of hardware and software technology at an appropriate price compared with the price of alternatives. The "price" may include considerations of the value of the user's time and effort as well as money expenditures. Thus a $2,000 to $20,000 out-of-pocket expense for a business organization, to perform sophisticated information processing functions, may be totally inappropriate for the home user. Conversely, the hobbyist may be prepared to spend tens or even hundreds of hours in developing and maintaining his or her personal computer; a price that would be totally unacceptable to either the typical consumer or the office user of a personal computer. These differing user valuations of time and effort are fundamental determinants of market structure.

At the time of this writing, the realized capabilities of personal computers are confined to the most part to those capabilities that already exist on mini and mainframe computers, as might be expected at this stage of development of technology. Thus the least expensive components are those that enjoy the benefits of the learning curve price reductions caused by their development for other purposes, as mentioned previously. Available applications software falls for the most part into two general categories: interactive computer games and office oriented applications such as text processing, accounting and inventory control packages. The games result from the early dominance of the field by hobbyists who spend large amounts of time devising them. The office oriented applications software has frequently been adapted from similar software running on larger systems.

This simple situation will gradually change as the general market for personal computers increases in size and breadth. Many of the all-important software developments are occurring, as are continuing hardware improvements. In general, the market process appears to be working effectively. The typical personal computer hardware firm, at the current stage of the industry's development, is small (generally with fewer than 100 employees), young (generally the chief executive officer is under 40), and entrepreneurial. This is also true of the software firms and of the personal computer distribution chain, except that the firms tend to be even smaller. Since there are a relatively large number of firms in the industry, the prospects appear good that a variety of applications packages will be presented to potental users through the next decade unless various economic conditions (to be discussed) act to change seriously the competitive nature of the industry.

Table 2-1 shows some of the uses to which personal computers are being, or will be, put in the home, educational institutions, and in small and large organizations. The table also shows some of the current economic/technologic barriers to development of these uses. Most of these barriers are

FIGURE 2-2

CONSUMER COMPUTER
CUMULATIVE SALES
TO FIRST-TIME BUYERS

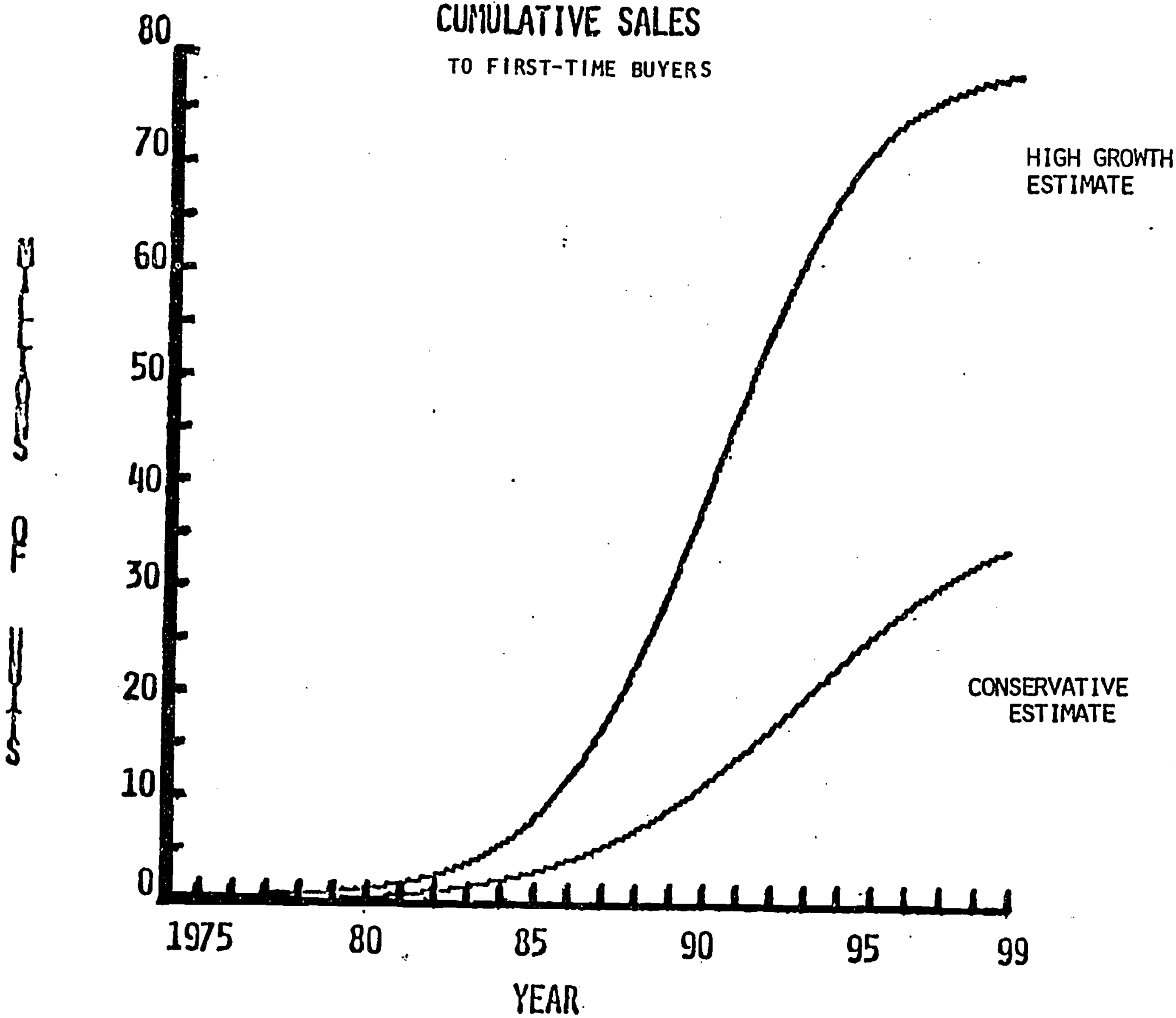


FIGURE 2-3

CONSUMER COMPUTER
ANNUAL SALES
TO FIRST-TIME BUYERS

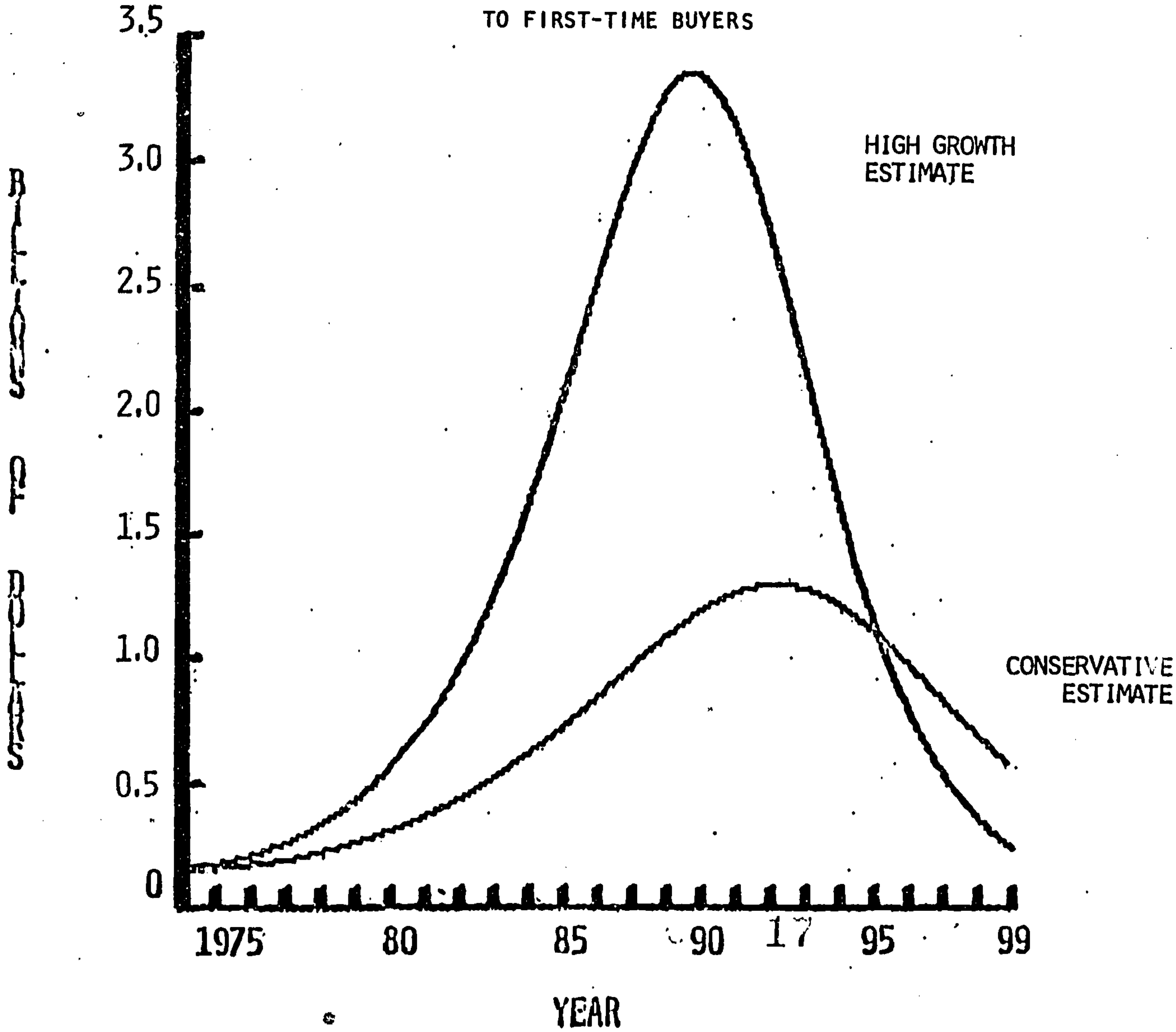


FIGURE 2-4

PCs IN EDUCATION

CUMULATIVE SALES

TO FIRST-TIME BUYERS

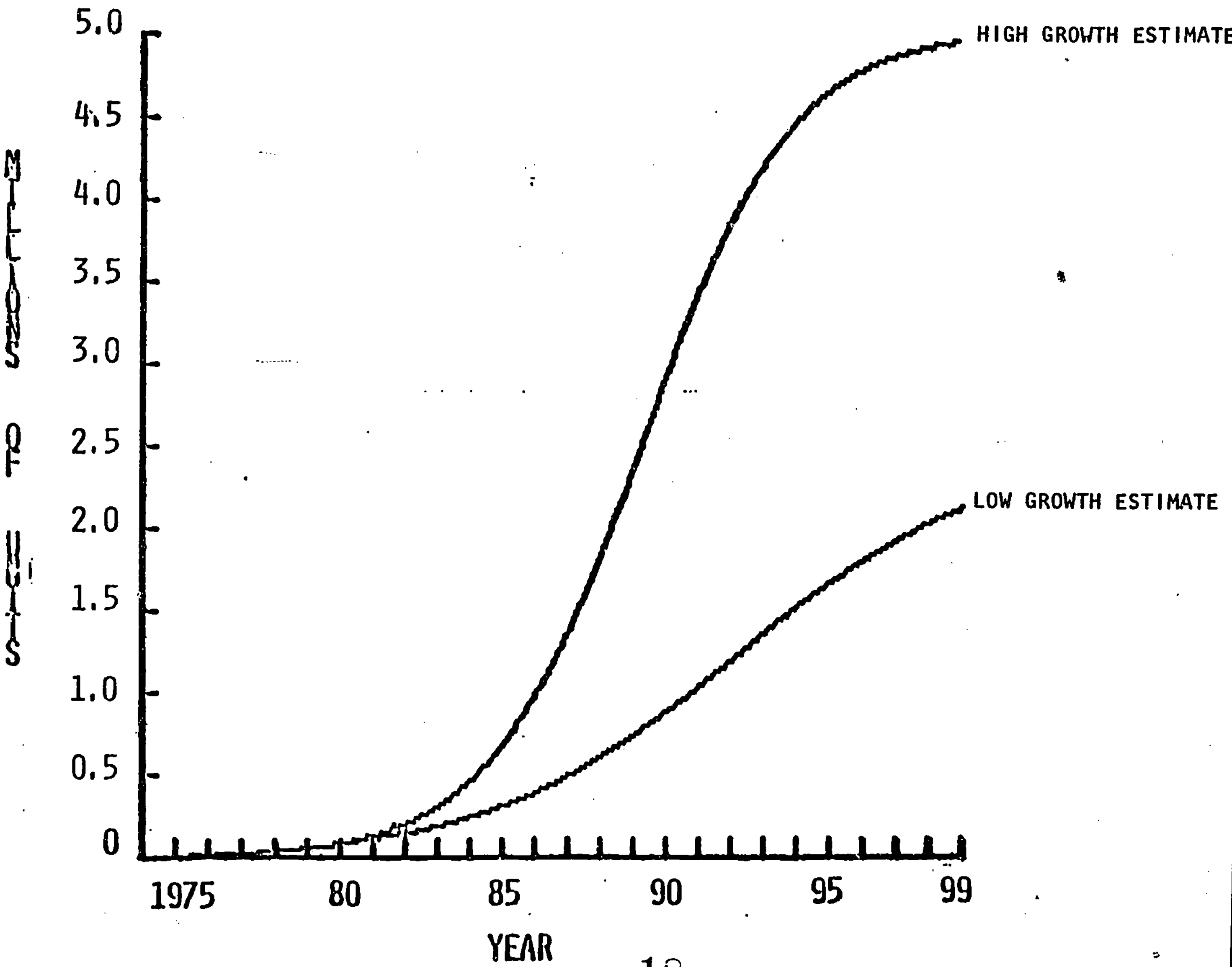


FIGURE 2-5

PCs IN EDUCATION

ANNUAL SALES

TO FIRST-TIME BUYERS

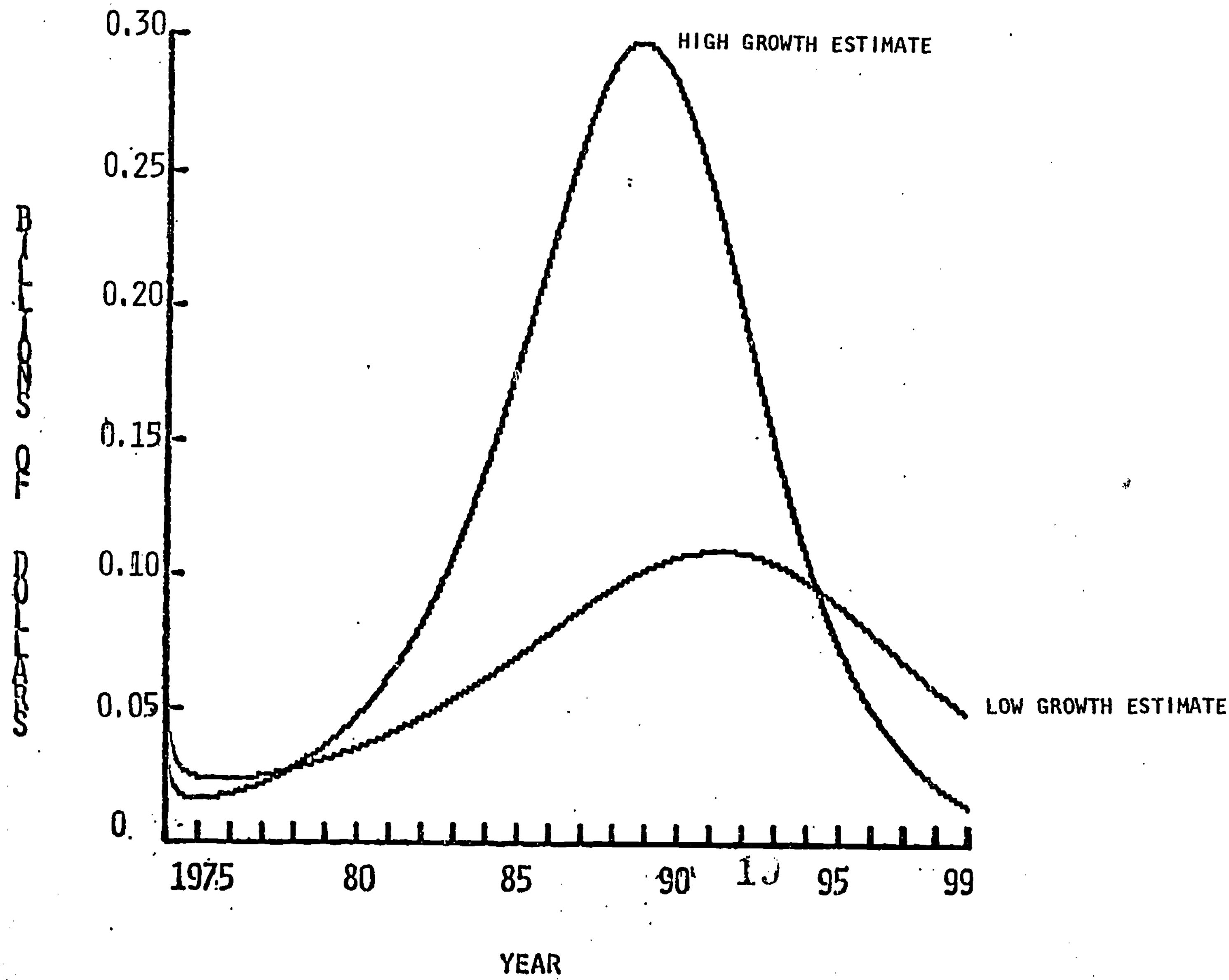


FIGURE 2-6

OFFICE COMPUTER
CUMULATIVE SALES
TO FIRST-TIME BUYERS

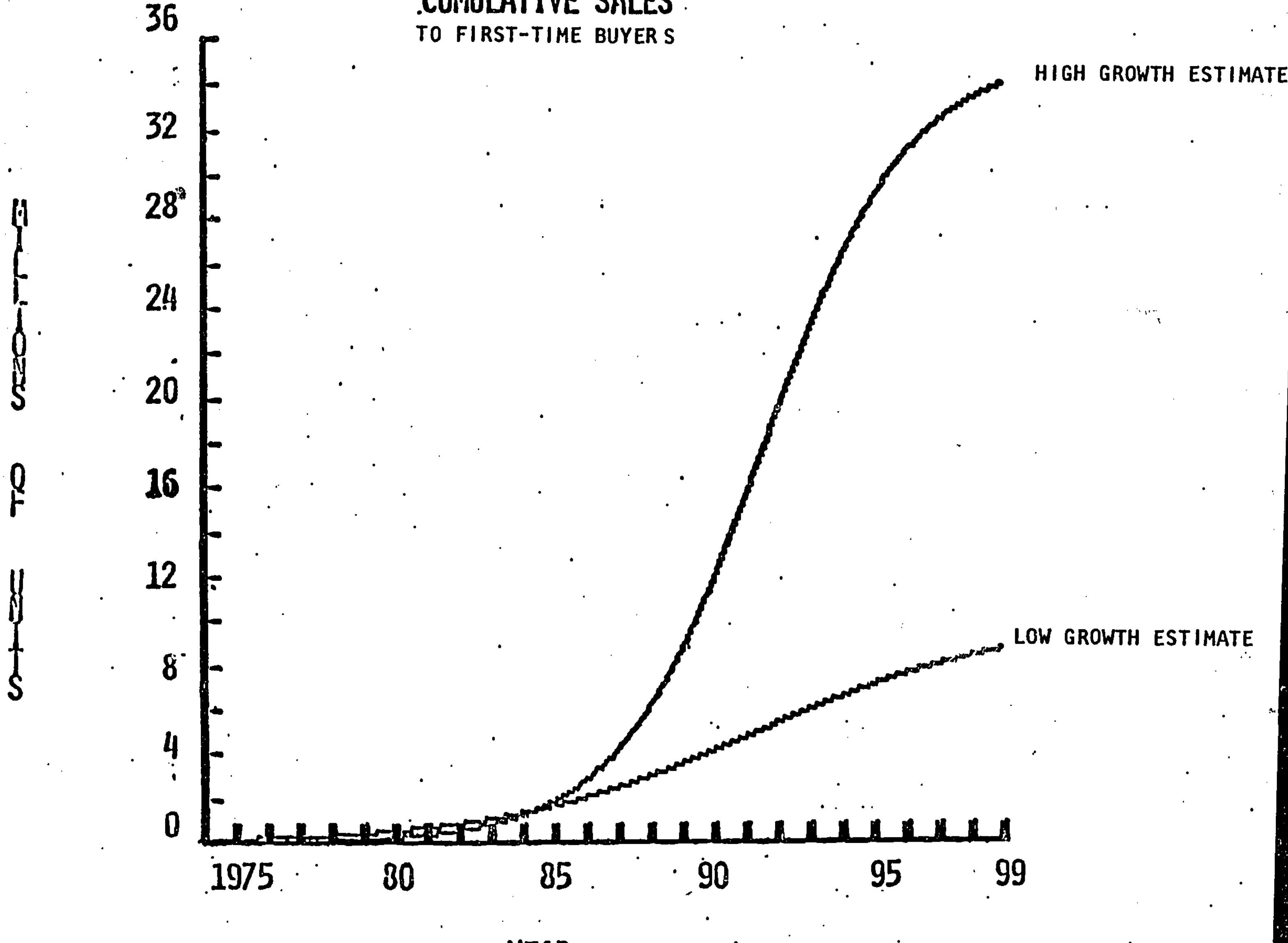


FIGURE 2-7

OFFICE COMPUTER

ANNUAL SALES

TO FIRST-TIME BUYERS

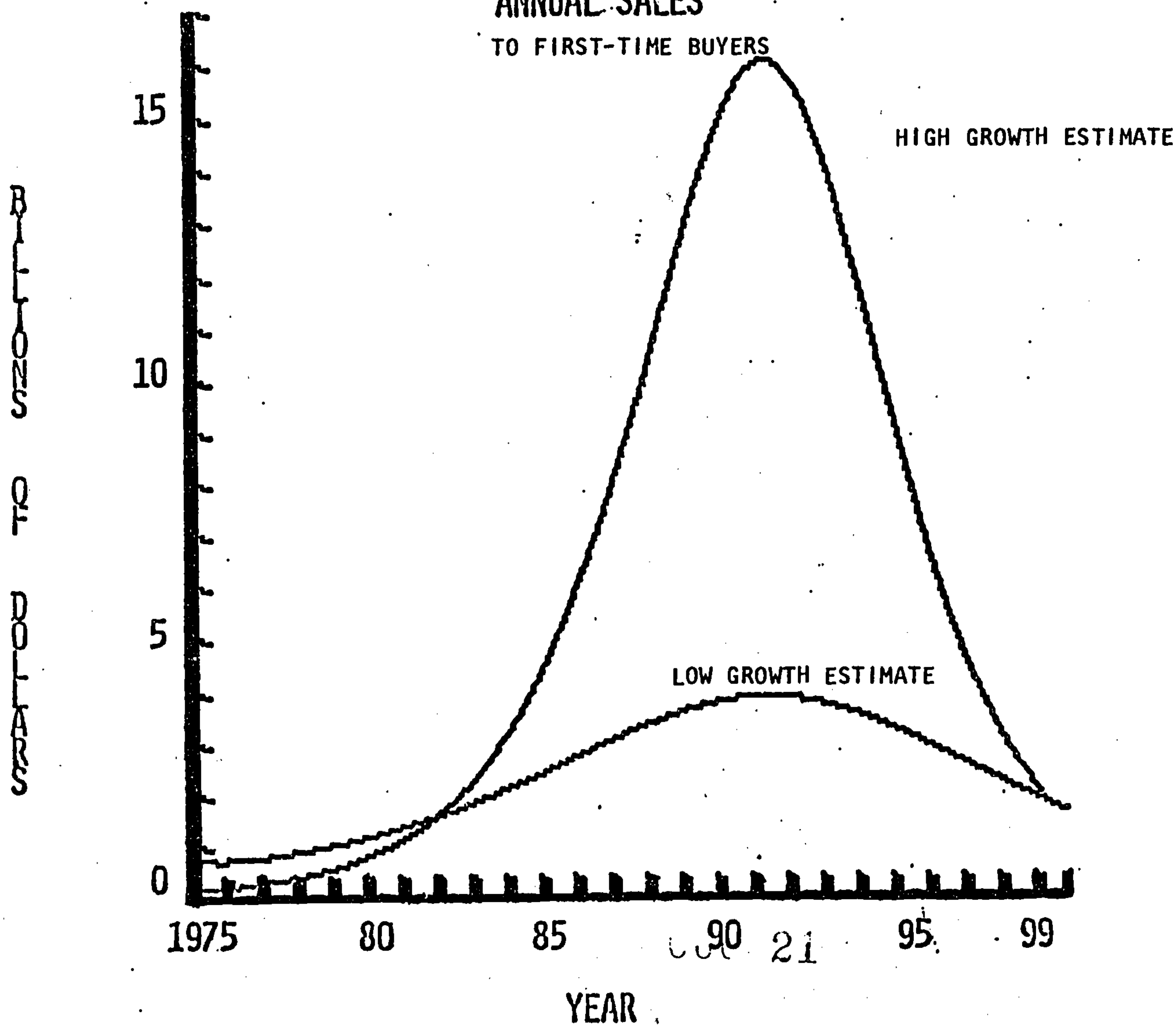


TABLE 2-1

USES FOR PCs, MARKET SECTORS, AND BARRIERS

USE*	HOME	EDUCATION	SMALL BUSINESS	LARGE ORG. (SMALL UNITS)	Economic/Technological Barriers: HARDWARE	Economic/Technological Barriers: SOFTWARE
COMMUNICATIONS					Cost reduction desirable.	Interface standards.
Autodialing	P	S	P	P		
Telephone Answering ("Dumb")	P	S	P	P		
Network Interface Processing & Electronic Mail	S	S	S	P		
EDUCATION						Significant lack of well designed software in all areas of application.
Computer Assisted Instruction	P	P	S	S/O		
Modeling	P	S	S	S/O		
RECREATION (Other than Education, Picture Processing)					Requires substantial cost reduction in digital sound hardware as above plus picture processing.	Will require increasing sophistication, versatility, user interface transparency in all areas of application.
Games	P	S	N	N		
Music	P	S	N	N		
Video Synthesis (Do-It-Yourself Cartoons, Sound Movies)	P	S	N	S/O		
ENVIRONMENTAL OR OTHER CONTROL					Requires low cost sensors, D/A converters, actuators.	Requires multi-tasking software.
Energy (Heating, Cooling, Air Conditioning, Electricity)	P	O	S	O		
Irrigation (Lawns, Fields)	P	O	N'	N'		
Appliance Control	P	S	S	N		

* N = Not Used
N' = Not Used Except Farms
O = Other Systems Provide Function
P = Primary or Frequent Use
S = Secondary or Infrequent

USE*	HOME	EDUCATION	SMALL BUSINESS	LARGE ORG. (SMALL UNITS)	Economic/Technological Barriers: HARDWARE	Economic/Technological Barriers: SOFTWARE
FINANCIAL						Increased reliability, adaptability, user interface "transparency."
Budgeting, Forecasting	P	P	P	P		
General Ledger	P	S	P	P		
Funds Transfer	S/O	S	S/O	S/O		
Tax, Payroll Accounting	T	O	P	P		
Investment Analysis	P	N	S	S		
INVENTORY/DATA BASE						Increased reliability, adaptablity, user interface "transparency."
Personal Records (Medical, Educ., Finan., Etc.)	P	P	P	P/O		
Inventory Goods	P	S	N	N		
Task Assignments	P	P	P	P		
Recipes	P	N	N	N		
Files	P	P	P	P/O		
Message Logs	P	S	P	P		
Visitor Logs	S	S	S	P		
Calendar	S	P	P	P		
PICTURE PROCESSING/GRAPHICS					Requires memory cost reduction, array processing(?) ergonomic interface design.	Greater sophistication, flexibility
Art Form	P	S	N	N		
Directed Communication (Sales, Reports, etc.)	S	S	P	P		
SECURITY					Requires low cost sensors, converters, actuators.	Requires multi-tasking software, sophistication in decision processing.
Physical Intrusion, Structural (Incl. Fire, Smoke Detect.)	P	S/O	P	O		
Countermeasures (Warning messages, Communication, Physical measures)	P	S/O	P	S		
Inhabitant Monitoring (Children; e.g., Sudden Infant Death Syndrome; Adults, e.g., Heart Monitoring)	S	S	N	S/O		

* P = Primary or Frequent Use
T = Primary or Frequent Use Exc. Payroll
S = Secondary or Infrequent
N = Not Used
O = Other Systems Provide Function.

Economic/Technological Barriers

USE*	HOME	EDUCATION	SMALL BUSINESS	LARGE ORG. (SMALL UNITS)	HARDWARE	SOFTWARE
TEXT PROCESSING (Letters, Reports, Literature, Learning)	P	P	P	P	Requires lower cost for high quality printers in home market memory for voice interface.	Greater sophistication desirable, especially voice interface.

* P = Primary or Frequent Use

being eroded by continuing developments in the industry.

2.4 Alternatives to Personal Computers

Most new technologies are initially justified to prospective purchasers on the basis of their ability to replace economically a function and/or process previously dominated by some earlier technology. Rarely are the new possibilities offered by the emerging technology stressed at its introduction. Only slowly, as these entirely new capabilities become apparent through use of the technology, does its ultimate impact begin to be felt. This appears to be the case for personal computer technology as well. It is presently being examined primarily in terms of its ability to perform well known functions in new, more economical ways. Hence, there are existing alternatives for many of the functions presently being considered for performances by personal computers.

The most prevalent alternative is paper based information storage, processing, and retrieval systems; the filing cabinets of the world. Personal computers are introduced in those cases where the time and money costs of maintaining the traditional system appear to the user to be higher than the costs of performing the same functions with personal computers. One of the costs in these considerations, both in business organizations and in families with decreasing amounts of discretionary time and income, is that human labor is more expensive, or even may be no longer available, to perform the functions (see Section 4).

Another significant alternative to personal computers is personal computing, using telecommunications networks and timesharing of larger (mainframe) computers. As competition is increased in the telecommunications industry, as a consequence of recent actions of Congress, this alternative to the ownership and maintenance of personal computers may remain quite viable for many individuals and offices that might otherwise switch to the use of personal computers. On the other hand, it is at least as likely likely that the availability of telecommunications-based network information services will result in the expansion both of the use of these alternatives and of the market for personal computers. Two commercial time sharing networks oriented toward personal computer users are already in operation as this report is written. One of them will be distributed through Radio Shack retail stores.

The interconnection of personal computers via telecommunications networks also constitutes an alternative to another technology: Delivery of mail by the U.S. Postal Service. There appears to be no reason why, barring Federal regulatory action proscribing the transmission of personal messages between personal computers, personal computer technology may not result in a substantial decrease in the use of first class mail by individuals over the coming years.

III. IMPACTS

The research team's analysis of the possible patterns for future growth of personal computer technology and the developments of the personal computer market led to a series of questions concerning the details of this growth and of the probable direct and indirect impacts of these developments. The research team investigated the likelihood of a broad array of primary and secondary impacts of personal computer technology. The impact estimates were then used to develop corresponding estimates of their public policy implications.

Two techniques were used to develop these impact estimates. First, information on the primary demographic characteristics of U.S. society and on the likely paths of development of personal computer technology end markets were extrapolated generally to the end of the century. These extrapolations were used to develop a series of scenarios of possible future states of U.S. society which might result from the development of the technology. These general scenarios then divided a series of shorter scenarios dealing with specific, public-policy-related aspects of the development of personal computer technology.

Shortly after the beginning of this period of impact analysis, the research team had categorized the potential impacts of personal computers into 14 areas. These covered the effect of personal computers on:

1. Job Displacement; changes in the nature or existence of employment,

2. Privacy and Security, both individual and institutional,

3. The rate of change of technological innovation, including changes in management and organizational technologies,

4. The level of homogeniety or uniformity of societies using personal computers,

5. Misuse and crime; intended (by perpetrators) and unintended consequences of computer errors, computer fraud, etc.,

6. Class stratification; development of an "information elite", increasing educational and economic gaps between the elites and the information underprivileged (the "haves" and the "have nots"),

7. Education and cognition; this to include such issues as changes in the effectiveness of education, broad scale increases in educational quality, and effects on intuitive and, affective thought processes,

8. Expansion of personal freedom and capability, including expanded choices of vocation and avocation, extensions to the physically handicapped,

9. International trade, particularly impacts on the relative position of the United States in the World market as a consequence of the manufacture and/or use of personal computers,

10. Standards for personal computers, with emphasis on the desirability and consequences of development of various types of standards in a dynamically evolving technological market,

11. Industrial organization, particularly impacts on the relative extent of competition vs. monopolistic practices,

12. Consumer protection, particularly the relative merits of government aids to increasing consumer computer literacy and regulation of personal computer technology,

13. Energy conservation, particularly the potential effects of the use of personal computers on the rate at which individual consumers and organizations would conserve energy, and

14. Health; the potential impacts of personal computer technology on the methods and quality of health care.

Note that this list is not in any order of priority. The impact areas were also examined in terms of any differences which might occur as the consequence of having widespread availability of network information services usable with personal computers.

It was soon clear that within the limited time available for performance of the assessment, not all of these impact areas could be analyzed in detail, consequently, a set of screening criteria was developed in order to reduce the number of impact areas to be investigated. These criteria were the following:

1. The **uniqueness** of the impact and/or policy issues vis-a-vis-personal computer technology; would the impact be unique to personal computers or would the impact of personal computer technology provide unique policy perspectives on impacts or issues deriving from other technologies?

2. The **magnitude** of the impact; would the overall impact of the technology be significant? That is, would large numbers of people be affected or would the effect be economically, politically and/or socially substantial, even if it were to involve a relatively small number of people?

3. Existing **public agency responsibility**; are there identifiable public agencies which presently have, or may have, responsibility for the development and/or implementation of policy concerning the impact area?

4. Potential **agency interest**; furthermore, are the identified agencies at all likely to believe that they have an interest in the impact areas sufficient to pursue available policy options?

5. Analytical **tractability**; is it possible to get a reasonably accurate estimate of the extent or magnitute of the impacts or consequences of public policy actions or are the impacts and action consequences so diffused as to defy measurement by existing techniques?

Through the use of the selection criteria, the research team was quickly able to reduce the list of impact areas from 14 to 7: workforce and employment, international trade, education, privacy, crime, standards, and consumer protection.

At this point, the research team engaged in a series of three Delphi Surveys. [A Delphi Survey is one in which a structured questionnaire covering events, trends, impacts, and policy options, is administered, usually by mail, to a group of experts in the areas covered in such a way that the experts do not meet face-to-face to debate.] The first survey was confined to the Advisory Board for the assessment. The second round went to a panel of 150 experts, 64 of whom responded. We also asked the experts to "vote" on the relative viability of the issue areas, using the screening criteria. As a consequence of this round, and the distribution of expertise of the experts on the panel, we reduced the number of areas for detailed study during the remainder of the research project to three: education, employment, and international trade (see Section 4). In none of these areas is the introduction of personal computer technology likely to have entirely unique consequences; in all of them the analysis of the potential impacts of personal computers provides important perspectives on other technology related issues.

3.1 Events and Trends

One of the primary uses of the Delphi surveys was to provide balance to our independent analyses and to suggest potential impacts, trends, or areas of investigation which we might otherwise have overlooked.

3.1.1 Events

The Delphi panel was asked to evaluate the earliest, most likely, and latest time (which might be never) of the occurrence of a number of potential events relevant to the growth in usage of personal computers. Table 3-1 lists the event statements and the short form used to refer to them. Table 3-2 summarizes the panel's opinions on the most likely time of occurrence of these events. The table indicates the mean value of the most likely time of occurrence. It can be seen from Table 3-2 that events can be grouped into near term (1980-84) intermediate term (1985-1990) and long term (beyond 1990 or never). In fact, some of the events had already occurred while the questionnaires were being completed, others shortly after. For example,

- Sears has begun marketing the ATARI computer system

- IBM is offering its 5120 system as a relatively high-priced competitor in the small business market. This computer fits within the definition of personal computers used in this project.

- Mattell toys is offering units that are more than game units (Intellivision) and is promising BASIC shortly.

- Nippon Electric showed various complete personal computer units at the 1980 National computer Conference in Anaheim, CA. However, they were noncommittal as to when or whether these units would be introduced in the United States.

- Tandy Corporation announced a new unit, called Videotex, at the beginning of June 1980. This unit, to be sold at $400 to the commercial market initially, (and anticipated by Tandy to be sold at $200 to consumers later if successful) has a full keyboard and permits inquiry of network information services. It is a successor to Green Thumb (see below). Compuserve, a Columbus Ohio based time-sharing service simultaneously announced that it would offer dial-up access to its data bases via sales made through Tandy's Radio Shack outlets. The Radio Shack stores would act as sales agents for Micronet, the existing PC network information system currently operated by Compuserve.

- Encryption software for PC's (meeting NBS standards) appears to be available, although not widely used at this time.

- Although some software has been supplied by Tandy for the TRS-80's sold to school districts, the number of units sold thus far is quite small and little specialized software seems to be available.

Examining the mid-term (1985-1990) developments, one sees that some (e.g., network information services and software protection) are extensions of near-term developments. Others (e.g., the technological developments and home monitoring) seem to require more time to gestate but are evolutionary. Two of the developments are relatively major departures: government subsidies and communications substitution for transportation. However, even for these developments there are precursors.

Project Green Thumb, alluded to above, is an example of government subsidy to bring information to specific societal groups. In this project, sponsored by the Department of Agriculture at the University of Kentucky, 200 farmers in two counties in Kentucky were given simple chip-based keyboards which they could use to obtain Viewdata-type information. The Green Thumb box looks like a standard touchtone telephone augmented by four functions. The user first decides from a printed menu what information is desired (the most popular seems to be weather and market price data). He dials the central computer, obtains a dial tone, punches in the menu items for up to 16 pages (a "page" is one TV screenful), and then hangs up. The information requested is sent to his Green Thumb box which stores it and displays it in sequence on his home television screen. This system is intriguing both as a rudimentary form of Viewdata at the PC level and as a form of

TABLE 3-1

INITIAL LIST OF EVENTS

1. Sears: Sears, Macy's Ward's enter PC merket.

2. IBM: IBM, Control Data, Sperry Rand-size company enters the PC market.

3. TIMEX: Major U.S. company not in computer manufacture (e.g., Timex, Westinghouse, Maytag, Xerox) enters PC market.

4. JAPAN: Japanese (or Europeans) enter the PC market in United States (as major competitor?)

5. CB Craze: A CB-like craze for computer entertainment occurs.

6. PC NIS: Commercial firm develops and successfully markets a low-cost computer-based network information service for PCs.

7. PC Viewdata: Establishment of national commercial information retrieval network for PCs such as Viewdata.

8. PC Polling: Establishment of a network of PCs in a community or region capable of polling voters.

9. AT&T: Revision of 1934 Communication Act is passed to permit AT&T to compete in information services industry.

10. 32-bit PC: A 32-bit address register is introduced for PCs by one of the top 4 PC producers.

11. $50 flat screen: Commericialization of a low cost ($50 to produce) flat screen for TV.

12. Dynabook: DynaBook-size and capability PC is introduced.

13. PC Registration: Passage of law requiringregistry of PC ownership just as FCC requires registration of CB radios.

14. Pirateless software: Development of software or hardware other than ROM to make PC software effectively pirate-resistant.

15. Institutional Software protection: Establishment of measures (Institutional, organizational, or contractual) that effectively make PC software resistant.

16. Encryption for PCs: First commercialization of "break-proof" encryption module for PCs.

17. Privacy Act applies to PC's: Enactment of Federal legislation that makes home PCs subject to Privacy Act of 1974.

TABLE 3-1 Cont'd

INITIAL LIST OF EVENTS

18. Subsidy for low-income PC use: Establishment of direct government subsidy for PC access for low income people (e.g., through libraries, churches or other public centers).

19. Courseware development: Initial marketing of PC courseware for elementary school instruction by major publisher or computer industry firm.

20. Home monitoring: At least 50% of all homes built in a year for $100,000 or more (1978 prices) include a dedicated PC for complete monitoring.

21. IRS requires Computer reports: IRS requires that income taxes for all businesses with at least $1 million (1979 dollars annual sales be submitted in machine-readable form.

22. 10 Fortune 500's use PC's to substitute for travel: Chronic gasoline shortages cause at least 10 of Fortune 500 companies to set up local work centers using PCs and telecommunicastions for information transfer.

TABLE 3-2
DELPHI PANELISTS' FORECASTS
OF
MOST LIKELY TIME OF OCCURRENCE OF EVENTS

		81-84	85-90	+90	Never
1.	Sears	$\boxed{\bullet}$			
2.	IBM	•			
3.	TIMEX	•			
4.	JAPAN	•			
5.	CB Craze		$\boxed{\bullet}$		
6.	PC NIS	$\boxed{\bullet}$			
7.	PC Viewdata		$\boxed{\bullet}$		
8.	PC Polling		•		
9.	AT&T		•		
10.	32-bit PC	•			
11.	$50. flat screen		$\boxed{\bullet}$		
12.	Dynabook		•		
13.	PC Registration				•
14.	Pirateless software	←—	—→		
15.	Insitutional Software protection		•		
16.	Encryption for PC's	•			
17.	Privacy Act applies to PC's			•	
18.	Subsidy for Low-income PC use		•		
19.	Courseware development	$\boxed{\bullet}$			
20.	Home monitoring		$\boxed{\bullet}$		
21.	IRS requires Computer reports			•	
22.	10 Fortune 500's use PC's to substitute for travel		•		

□ - Major impact on home market when event occurs

government subsidy for special groups. In the case of the panel forecast, the concept is to provide PC access to those who cannot otherwise afford it so that the U.S. does not create a class of information-poor individuals.

The substitution of communications for transportation ("telecommuting") has been discussed in the literature since the early 1960's. Two major studies of possibilities were sponsored by NSF during the 1970's, one at the University of Southern California and the other at SRI International. The University of Southern California study of telecommuting included, among other things, a case study of a major insurance firm that showed that such substitution were economically advantageous to both the company and its employees. There are currently a few scattered working examples of such substitutions. Thus, its introduction by large firms as a regular mode of operation is certainly within the reasonable range of expectations for the 1985-90 period.

Three of the events in the Delphi inquiry were judged to be most likely to occur beyond 1990 or never. In all three cases, there were many panelists who believed that there was no probability at all of these events occurring. The events were:

1. A requirement to register personal computers, just as CB's are registered

2. Enactment of Federal legislation that would make home PC's subject to the Privacy Act of 1974.

3. Imposition of a requirement of the Internal Revenue Service that income tax returns for all businesses with at least $1 million (1978 dollars) annual sales be submitted in machine readable form.

Of these, the registration concept was expected never to occur.

A corollary question to event occurrence is event impact. The occurrence of an event may be interesting, but if it has little or no side effect, there may be few or no policy implications. The Delphi panel was therefore asked to assess impacts of events on one another, on the various PC markets, and on general societal issues. In terms of policy planning, it is the combination of timing of events and size that are important.

Table 3-3 shows the estimated effects of each event on the four segments of the PC market <u>if</u> the event occurs. It was intriguing to the technology assessment team that the panelists, with only one exception (registration of PC's), on balance forecast positive effects from each of the events listed. We therefore examined the detailed data distributions to see whether the results appeared consistent. Our subjective conclusion is that they do. For example, in the case of a CB-like craze for personal computer entertainment the major effect is on the home market (Table 3-4). The values for small business indicate a small sentiment for some spillover into this market. For the business market, the panel strongly sees no effect whereas for the education market, there is a division of opinion with a few feeling that this event would inhibit rather than encourage educational adoption.

In the case of registration of PC's (Table 3-4) as a crime prevention measure, the responses balanced were clustered closely to the no effect point. In the case of each market, there were individuals who felt that registration would enhance the market by making PC's more secure against theft while others felt this policy would deter purchase. The predominant response in all four markets was that of no effect.

Examination of the other events both in summary and in detail on individual questionnaires also indicates consistency of the results. We can find no evidence of panelists mistakingly marking positive effects when they intended negative ones. The conclusion we draw is that our panelists tend to judge effects broadly and perhaps enthusiastically, thereby resulting in very positive average values. However, by discounting these numeric results and only assigning significance to averages of less than two, we believe we have compensated for panel enthusiasm.

3.1.2 Trends

Whereas events are one-time or repeating occurrences, trends represent continuous, ongoing processes. Typical familiar examples of trends are population growth, the number of people employed,

TABLE 3-3

EXPECTED EFFECTS OF EVENTS ON PERSONAL COMPUTER MARKETS IF THEY OCCUR

EVENT	Home	Small Business	Large Business	Education
1. SEARS	$\boxed{1.4}$	2.3	3.7	2.5
2. IBM	2.8	$\boxed{1.9}$	$\boxed{1.7}$	2.3
3. TIMEX	2.1	2.8	3.0	2.6
4. JAPAN	2.0	2.2	2.7	3.4
5. CB CRAZE	$\boxed{1.2}$	3.0	3.6	2.6
6. PC NETWORK INFORMATION SYSTEM	$\boxed{1.6}$	$\boxed{1.8}$	2.7	2.2
7. PC VIEWDATA	$\boxed{1.6}$	2.1	2.7	2.2
8. PC POLLING	2.7	3.5	3.5	3.3
9. AT&T	2.3	2.4	2.4	2.7
10. 32-BIT PC	2.8	2.0	2.0	2.3
11. $50 FLAT SCREEN	$\boxed{1.7}$	2.2	2.6	$\boxed{1.9}$
12. DYNABOOK	$\boxed{1.4}$	2.1	2.4	$\boxed{1.5}$
13. REGISTRATION OF PC's	4.3	4.0	4.0	4.2
14. PIRATELESS SOFTWARE	3.1	2.8	3.0	3.0
15. INSTITUTIONAL SOFTWARE PROTECTION	3.0	2.7	3.0	2.9
16. ENCRYPTION FOR PC's	2.9	2.6	2.6	2.8
17. PRIVACY ACT APPLIES TO PC's	3.9	3.5	3.4	3.6
18. SUBSIDY FOR LOW-INCOME PC USE	2.6	3.2	3.4	2.4
19. COURSEWARE DEVELOPMENT	$\boxed{1.9}$	3.4	3.5	$\boxed{1.2}$
20. HOME MONITORING	$\boxed{1.7}$	3.3	3.6	3.5
21. IRS REQUIRES COMPUTER REPORTS	3.5	$\boxed{1.8}$	2.7	3.6
22. 10 FORTUNE 500's USE PCs TO SUBSTITUTE FOR TRAVEL	2.6	2.6	$\boxed{1.6}$	3.3

☐ = SIGNIFICANT POSITIVE EFFECT

MAGNITUDE OF EFFECT SCALE

1 = High Positive
2 = Medium Positive
3 = Low Positive
4 = No Effect
5 = Low Negative
6 = Medium Negative
7 = High Negative

TABLE 3-4

Distribution of Responses For Market Impacts of Two Events

Event 5: CB-like Craze for Personal Computers

MARKET

SIZE OF RESPONSE		HOME	Small BUSINESS	Large BUSINESS	EDUCATION
H	1	21	2	1	6
M	2	2	5	1	9
L	3	2	9	6	3
0	4		9	16	6
-L	5				1
-M	6				1
-H	7				
Mean		1.2	3.0	3.6	2.6

Event 13: Registration of PC's

MARKET

SIZE OF RESPONSE		HOME	Small BUSINESS	Large BUSINESS	EDUCATION
H	1	1			
M	2	2	1	1	1
L	3	3	5	6	4
0	4	9	13	14	12
-L	5	5	7	4	6
-M	6	5		1	1
-H	7	1			1
Mean		4.4	4.0	4.0	4.2

and gross national product. Although most trends tend to fluctuate, smoothed curves through the data indicate the general direction and magnitude of changes. In the Delphi study, inquiries about a number of trends were included that dealt with the market for personal computer hardware and software, the associated costs, and types and extent of applications of personal computers.

Market Forecasts

Table 3–5 summarizes the forecasts of market trends for both hardware and software. The panelists were asked to estimate the annual sales, in number of units, for the total PC market, small business, large business, and education. For both types of business users, the market estimates were further divided into units costing less than $5,000 (in 1979 dollars) and more than $5,000. The "home and other uses" category reported in Table 3–5 was obtained by subtracting the market segment estimates from the estimates of the total number of units.

Forecasts of annual sales are presented in Table 3–5 in terms of the number of units sold in 1978, 1985, and in 1990. The results show an average annual growth rate of 32.3% between 1978 and 1985 and 26.6% between 1985 and 1990 for the total market. That is slightly faster growth in the early period and slower growth in the latter period. However, the growth rates differ by segment. These differences in growth may be due, in part, to the anticipated decline in computing costs. The capabilities of the Apple II computer were used as a reference standard for cost comparison. The costs of obtaining the capabilities of the basic unit were estimated to be halved by 1985 (from $1200 to $590), and halved again (to $300) by 1990. This decline in cost for equivalent capabilities is reflected in the slower growth in PC sales above $5,000, compared to those below $5,000, for both large and small business users in the 1985–90 period. Furthermore, the data imply that acceptance of PC's will be more rapid in the business community than in other segments.

The growth rate in the educational sector will be quite slow, according to the panelists. Actual 1978 sales to education are known to be small (of the order of several thousand) but are not known exactly. However, after an initial surge in the early 1980's, the educational market is forecast to be essentially flat during the 1985–1990 period. Furthermore, the educational segment appears to be quite small, with sales of only 60,000 units by 1990. These data support the point of view (in Section 4.1) that the educational market will not have significant growth. Note: the estimates for the educational market refer to units bought by school systems, not the use of PC's by individuals or noneducational organizations for educational applications.

The estimates of PC sales by the Delphi panel are compared in Table 3–6 with the high and low estimates made independently by the USC Project Team. The Delphi panel estimates fall between these high and low estimates. Since most of the purchases occur in the later years, the number of repeat purchasers should be small relative to the total and hence should not affect the conclusion.

The software estimates in Table 3–5 are in constant (1979) dollars. Since software costs do not correlate with machine cost, small and large business users are aggregated. Dealing with dollar costs requires some care, even when inflation factors are removed because of the increases in productivity to be anticipated for software. Specifically, the panel was asked to estimate the cost of a quality payroll program that cost $500 in 1978 as a surrogate for estimating software costs. The estimates of $400 in 1985 and $200 in 1990 imply that, to a first approximation, a software cost index should be defined. That is, software costs are 0.9 in 1985 and 0.4 in 1990, as compared with 1.0 in 1978. The annual growth rates in dollar value of software sales for the 1985–1990 period, based on Table 3–5, are in the 30 to 40% range and are greater than the growth rate for the number of units. In particular, the education market appears, despite its relatively small sales in number of units to be a significant potential user of software (See Section 4.1).

Although software sales have high growth rates, these growth rates really reflect the growth in the number of units sold. Table 3–7 shows the number of dollars spent per unit sold. The data show relatively small expenditures for software/unit. It is probably reasonable to assume that most software (with the exception of entertainment software) is bought with the unit or shortly after its acquisition and therefore appropriate to attribute software sales to new unit sales.

Although the absolute dollar values of software sales may seem small from the point of view of software vendors, the data make more sense if the productivity increases anticipated are taken into account. Table 3–7 also shows "1978 equivalent costs". The numbers on these columns of

HARDWARE	1978	1985	1990	Software	1978	1985	1990
Price of Apple II	$1200	$590	$300				
No. of Units sold (Annual)							
Total	225K	1.6M	5.2M				
Small Business <$5000	30K	290K	1M	All Small Business	$2M	$26M	$97.5M
Small Business >$5000	15K	75K	130K				
Large Business <$5000	25K	220K	570K	All Large Business	$1M	$19.4M	$98.3M
Large Business >$5000	15K	100K	200K				
Education	several K	50K	60K		$50K	$5.2M	$20.5M
Home and other uses	140K	850K	3.2M		$1M	$21M	$105M
oftware Cost Index					1	0.8	0.4
o. Who can Program in U. S.	5M	10.3M	21.4M		5M	10.3M	21.4M
o. of Retail Outlets in U.S.	8200	18K	41K				

M= millions
K= thousands
All dollar values in 1979 dollars

TABLE 3-5

DETAILED MARKET FORECASTS BY DELPHI PANEL

TABLE 3-6

COMPARISON OF DELPHI PANELISTS MARKET ESTIMATES WITH USC HIGH AND LOW ESTIMATES

	Annual Units Sold (000's) 1978	1985	1990	Cumulative Units Sold (000's) 1985	1990
USC HIGH					
CONSUMER	170	3,050	8,803	7,610	39,083
EDUCATION	15	250	538	650	2,875
OFFICE	40	788	3,450	1,865	11,848
TOTAL	225	4,088	12,800	10,225	55,800
DELPHI PANEL					
	225	1,600	5,200	5,800	23,000
USC LOW					
CONSUMER	125	882	2,424	3,070	11,092
EDUCATION	15	74	150	304	886
OFFICE	85	350	604	1,587	4,041
TOTAL	225	1,306	3,178	4,961	15,999

TABLE 3-7

DOLLARS SPENT OF SOFTWARE/UNIT SOLD

USER	DOLLAR VALUE			1978 COST EQUIVALENT	
	1978	1985	1990	1985	1990
SMALL BUSINESS	44	71	86	89	215
LARGE BUSINESS	25	61	127	76	317
EDUCATION	-	104	340	130	850
HOME	7	25	33	9	82
(INDEX)				(.8)	(.4)

the tables were obtained by dividing the actual dollar sales by the productivity increases. Thus, for example, an $86 expenditure by a small business in 1990 buys the equivalent of $215 in 1978 software. A second factor that needs to be taken into account in interpreting the data is that software becomes more significant relative to the cost of the computer.

Based on the data, it is possible to speculate that new simplified programming languages for PC's will come into being and into general use, and that these languages will be furnished as part of the initial unit sales. The trend to simplified languages is already in evidence in some of the financial planning languages that are available for large mainframes. The alternative hypothesis that computer programming skills will disseminate at a rate sufficient to sustain the market is not supported by the data. With 5.4 million people in the U.S. estimated to be able to program in some computer language, in 1978, less than 10% had actually bought PC's. The estimate for the number who can program increases to 21.4 million in 1990. With cumulative sales of 23 million forecast by that time, the ratio of machines to programmers becomes greater than one. It appears highly unlikely that such a ratio can be achieved without major changes in educational activities, computer languages, and available "canned" programs for PCs.

The Personal Computer Distribution Network

The 1979 estimate for the number of retail outlets for PC's was 8200. This number includes the over 7000 Radio Shack stores that market the TRS-80 series as well as 1000 independent computer stores, and 200 others, such as department stores. As a first approximation, it can be assumed that home and small business users would deal primarily with retailers while large business and education users would deal with wholesalers or directly with manufacturers. Even in the present market this dichotomy is not exactly true; however it will serve to indicate the over-all direction in which things are moving. We assume, for purposes of illustration, that the $1200 Apple II is the average unit sold. This point can be argued, but the Apple II serves as a reference for the decline in PC mainframe prices. Based on the number of units sold to consumers and businesses, the number of retail dealers, and the dollar cost per unit, it is possible to compute:

- the average number of units sold per dealer
- the average annual dollar sales of mainframes per dealer.

As can be seen from the results in Table 3-8, although the average number of units goes up from 24 to 102, the decrease in unit price from $1200 to $300 results in a relatively stable income from mainframes for the dealers. The growth in income (and hence in profitability) will have to come from the sale of peripherals (printers, modems, storage, etc.). The growth of the software market has already been discussed; the trends in peripheral costs are discussed later in the chapter.

Related Trends

The Delphi panel provided forecasts for a number of trends that relate to the personal computer business. These trend values are given in Table 3-9. Several of these trends relate to the detailed studies undertaken as part of this assessment, while others deal with costs that will be affected by technological growth.

The panel forecasts a growth to 300,000 of the total number of new jobs to be created by the personal computer industry (implying an industry with $6 billion in annual sales). These jobs include both those within the industry (manufacture, sales, maintenance, software) as well as those in industries created by PC's (consumer-oriented software, maintenance services, information services, accessories). The PC was also forecast to become a major item in international trade. By 1985, 510,000 units are expected to be exported and 190,000 imported. Assuming a conservative $500 average wholesale price per unit, this would imply a net contribution of $160 million to the balance of trade. By 1990 however, while the volume of exports is expected to increase to 1.1 million units the volume of imports increases much more rapidly to 970,000. Thus, while the balance of trade would be favorable, the net difference of 130,000 units at a conservative wholesale price of $250 (based on decreasing cost of Apple II capability) would contribute only $32 million to the nation's balance of trade (see Section 4.3 for a discussion of our independent estimates).

TABLE 3-8

THE PC DISTRIBUTION NETWORK

	1978	1985	1990
No. of Units Sold to Home and Small Business Users	200K	1.14M	4.2M
No. of Retail Dealers	8,200	18,000	41,000
No. of Units/Dealer	24,4	63.3	102.4
Average $/unit	1,200	590	300
Average/Annual Dollar Sales of Mainframes/Dealer	$29,200	$37,300	$30,700

TABLE 3-9

TRENDS IN THE PERSONAL COMPUTER BUSINESS

TREND	1978	1985	1990
Net No. of New Jobs Created by PC's	10K	50K	300K
PC Exports (Units)	20K	510K	1.1M
PC Imports (Units)	0	190K	970K
Cost of 1 Megabyte of Storage (Dollars)	15K	4,400	940
Cost of 512x512 Element Display (Dollars)	10K	2,500	750
Cost of Modem For PC's (Dollars)	150	75	25

ALL DOLLAR VALUES IN CONSTANT 1978 DOLLARS

Impacts

The panel was also asked to forecast the trends in costs for three PC peripherals: secondary storage, displays, and modems. The survey of current users indicates that many PC buyers intend to upgrade their mainframes rather than replace peripherals.

3.2 Cross-Impact Analysis

The forecasts from the Delphi panel represent expected values. That is, they are based on "all other things being equal". However, all other things are rarely equal in real life. An event either occurs or does not occur. If it occurs, it happens at a particular time. When an event occurs, it can affect the probability for other events occurring and it can result in changes in trend values. For example, the Delphi panel indicated that if Sears were to enter the market, this event would increase the probability of both IBM and Japan entering the market (presumably by increasing the size of the market channel substantially). Furthermore, occurrence of this event would make a CB-like craze for personal computers more likely and would also lead to a significant increase in the trend values for annual sales to the home market. Note that by inference, if the event is highly likely (as the Sears market entry was) the non-occurrence of the event should have an inverse effect on these probabilities and trend values.

Cross-impact analysis provides a systematic way of taking these interactions into account. For each event, the Delphi panelists were given a list of potential events and trends that might be affected if the event occurred. For each such interaction, a possible direction of change, increase or decrease, was indicated. The panelists were asked to agree or disagree with the potential impact and with its direction. They were also asked to add other events and trends that would be affected if the event occurred. These relatively open-ended questions were in addition to the questions on the effect on the sales in various market segments (home, small business, large business, educational) described in Table 3-3. The data in Table 3-3 reflect cross-impacts on market trends.

Table 3-10 summarizes the additional cross-impact information that was obtained. In this matrix, each event is shown as both a row and a column. The abbreviations are those which were used in Table 3-3, the event set of the Delphi inquiry. Two events and a trend were identified as interacting with the event set. These were:

Event X1 Development of natural language software

Event X2 Occurrence of a depression

Trend X3 Increasing level of PC crime

The + and – in Table 3-10 should be read in the following way:

For +: If the event whose name appears in the row occurs, the occurrence of the event in the column becomes more likely (If it has not already occurred).

For –: If the event whose name appears in the row occurs, the occurrence of the event in the column becomes less likely if the event in the column has not yet occurred.

It can be seen that the matrix is relatively sparse with only 39 of the 625 possible interactions taking place. This 6.24% density (10 to 20% densities are more typical) reflects the fact that the range of the inquiry was large. There are, however, clusters of interaction, with the market items and the software/hardware protection items having fairly strong interactions.

With only 2 rounds of the Delphi process, it was not possible to obtain quantative estimates of the magnitudes of the interactions among events and run a formal cross-impact analysis. However, the matrix shown in Table 3-10 does provide a framework for thinking about the interactions among events.

Event No.	Event Name	1	2	3	4	18	8	9	12	19	5	17	25	7	13	14	24	15	16	20	21	22	23	X1	X2	X3	
1	SEARS		+		+	+																					3
2	IBM			+																							1
3	TIMEX					+																					1
4	Japan		-			+																					2
18	CB CRAZE		+	+	+																						3
8	PC Network Info System								+			+											+				3
9	PC Viewdata					+			+																		2
12	PC Polling																	+									1
19	AT&T						+	+																			2
5	32 Bit PC												+														1
17	$50 Flat Screen												+														1
25	Dynabook																										
7	Registration of PC's																									-	1
13	Pirateless Software															-											1
14	Institutional Software Protection														-		-										2
24	Encryption for PC's														+			-								-	3
15	Privacy Act applies to PC's						-										+										2
16	Subsidy for low-income PC use																						+				1
20	Courseware Development																										
21	Home Monitoring																									-	1
22	IRS Requires Computer Reports																									+	1
23	PC's Used to substitute for trip to work																		+								1
X1	Natural Language Software	+				+																					2
X2	Depression	-	-																								2
X3	High PC Crime Level													+			+										2
		3	3	2	2	5	2	1	2	0	0	1	2	1	2	1	3	2	1	0	0	0	2	0	0	4	39

TABLE 3-10

CROSS IMPACT MATRIX FOR EVENTS

IV. PUBLIC POLICY IMPLICATIONS

The picture of the personal computer industry and its near term future, as developed by our internal analyses and by the responses of our Delphi panelists, is one of a vigorous, rapidly expanding industry which is highly innovative, very competitive, and is dominant in the world market for this technology. Most applications of personal computer technology to date, and most projections of their future applications, seem to be quite benign or, at worst, neutral in terms of their societal consequences. Thus, at first glance, there appears to be little reason for concern with the public policy aspects of the development of personal computer technology.

Our analysis of the three issue areas on which we have concentrated for the past several months, education, labor force and international trade, does not entirely support that conclusion. We identify two categories of situations where public policy actions should be considered:

1) those in which existing policies act as impediments to, or fail to encourage proper support of, the diffusion of the benefits (or suppression of the disbenefits) of personai computer technology, and

2) those in which there is essentially no operating national policy covering the types of impacts that we envision but where government intervention in the market may be needed to produce a societally desirable level of benefits.

4.1 Education

Properly defined, the educational enterprise is the largest industrial enterprise in the United States. This is so if we include all forms of formal education, from kindergarten through formal "schooling" in high schools and universities, vocational training, industrial and adult education, and military training. Annual expenditures for the combined total of these forms of education are diffiult to determine. However, even if we confine our attention to primary and secondary schools and colleges — the educational "establishment" — we account for 7.1% (in 1978) of the Gross National Product, or just over 1/3 more than the amount the United States spends on national defense. Budgeted Federal outlays for education and training in FY 1981 are $25.7 billion. The educational establishment, then, is one in which public policy has a major economic impact in both the near and long terms. Since personal computers, as the embodiment of a highly developed information technology, hold considerable promise for revolutionizing education and consequentially many other aspects of contemporary American society, they have been a primary focus of our interest.

4.1.1 The Roles and Capabilities of Personal Computers

As a result of our research we have come to two primary conclusions concerning the potential impacts of personal computers on the educational establishment:

– The impact of personal computers on the educational process is likely to have no effect on the educational establishment.

+ The impact of personal computers on education is likely to be more profound than any technology since the blackboard.

These two statements are not necessarily contradictory, assuming one adds to each statement the phrase "all other things being equal". The following sections povide background to these statements.

There are two basic ways in which personal computers are being and will be used in the educational system: as a means of increasing the efficiency of the educational enterprise, and as an element of the curriculum. In the first of these applications, the personal computer is used in a manner similar to its use in any other office-oriented organization; that is, as an aid to accounting, inventory control, transaction processing, and the like. In the case of education, many of the "items" to be accounted for and inventoried, etc., are students, their supplies, and their grades. Anticipated productivity increases in educational administration could be expected to be comparable to those experienced in small businesses as a consequence of the introduction of personal computers. Consequently, personal computers may replace larger computers in many school districts, or may provide

administrative computing power which would otherwise be unavailable.

The second area of potential impact of personal computers is on the instructional process itself. Here some perspective may be gained by examining another quotation:

> "[Personal computers] are making their educational debut within the course of classroom instruction in present day schools and colleges. Coupled with a large scale basic research program in education [personal computers] offer new dimensions for future design in instructional programs. More emphasis can be put on independent learning by students in the classroom and the 50 minute period may become a thing of the past. Textbooks of the future and other printed material may be radically altered to become convenient learning tools to the [personal computer] program. Teachers may enter on a new era of freedom from educational drudgery, leaning heavily on modern technology to give them more time for working with the learning problems of students in their own scholarly pursuits."

The above is an excerpt of testimony given to the Senate Committee on Interstate and Foreign Commerce in January, 1959. Since the hearings at that time were on the subject of educational television, the original testimony had the word "television" in every place where we have inserted the words "personal computer."

The realities of the use of instructional television in the educational process seem to be a pale imitation of the prospects discussed more than 20 years ago. Thus, we conclude that (all other things being equal), in the year 2,000, after personal computers have been around the educational system for 20 years, the average classroom will be almost indistinguishable from that of today. This may be the case independent of any inherent virtues or liabilities of personal computer technology.

Before discussing the reasons for this seemingly bleak forecast we believe that it is important to point out that there are basically two ways in which personal computers become involved in the instructional process: 1) to develop computer literacy, and 2) to teach other topics and thought processes. As the industrialized nations become more information intensive, the importance of computer literacy will increase proportionately. Personal computers appear to provide a very cost effective means for individual development of familiarity with the techniques for computer interaction, just as courses in typing or driver education may have been instrumental in developing functionality in important areas of contempory life. Thus, **by the turn of the century, most Americans will have to be able to directly interact with computers even if they are not familiar with the inner workings of the computer.**

The use of computers as means for teaching other topics, that is, computer aided instruction (CAI), is more controversial. The use of computers to teach well-defined subjects, dealing with factual data, mathematical processes, logical operations and the like, is well established, as is the superiority of CAI over human teachers in routine drill and practice. Because of the much more complicated requirements for software in other areas of education, however, the utility of CAI, particularly using personal computers, is much less well proven. Nevertheless, in those areas in which appropriate CAI software exists or could exist in the reasonably near future, personal computers could reduce classroom time devoted to the teaching of the subjects substantially covered in the available software.

A major distinction between personal computers and television as an instructional technology is that personal computers are **interactive**, while television sets are not. Personal computers, especially when combined with video media such as tape cassettes and/or videodiscs, can provide a much richer educational experience than TV cassettes or videodiscs alone. Thus, the technological potential is there to make the learning situation in the Year 2000 considerably different from that which exists today. However, our understanding of how people learn is sufficiently rudimentary that instructional programming is still fundamentally an art. Thus, prerequisites to the development of good software are the enlistment of the few educational software artists, development of more such artists, and research into the methodology of instructional programming. All of these may be pacing items in the development of instructional technology.

4.1.2 Barriers to the Use of Personal Computers

There are significant structural barriers to the use of personal computers in school systems. The most fundamental of these is economic. Most education, in grades Kindergarten through 12 (K-12), is funded by individual states, by local governments and/or by local school districts. From 80% to 85% of the school dollar is spent on personnel. The remaining 15% to 20% is used for facilities, maintenance, fuel costs (particularly in areas with extensive busing programs or large heating bills), and educational materials. Less than 2% of a school district's budget, usually considerably less, is available for all forms of educational computing. A typical distribution of the computing fraction of the school budget is given in Figure 4-1. This percentage distribution apportions at most $770 per classroom which might be spent by schools in the United States for computing (about $43 per student per year). The amount available for the purchase of personal computers and associated software to be used in the instructional process is consequently quite small, about $10 per student per year if the funds were to be averaged over all students in grades K-12.

The laws in many states fix the student to teacher ratio. The actual national average in 1977 was about 22 students for teachers in elementary schools, and 18 students per teacher in public secondary schools (16 in private schools). Consequently, any improvement in teacher productivity which might be engendered by the use of personal computers would have no immediate effect on personnel costs since the student-to-teacher ratio can not be affected because of this institutional barrier.

Improvements in learner productivity, which might be significant in some topics, as mentioned above, also have relatively little effect on the school system. The performance criteria of the school systems are predicated more on student classroom attendance days than on student achievement. [Note: Only in a few states, such as New York, are specific student performance criteria major elements of school performance measurement.] This is not the case in industrial and military training situations, where improvements in learner productivity can be directly translated to reduced training costs. In these areas, personal computers might become educational tools of significant use.

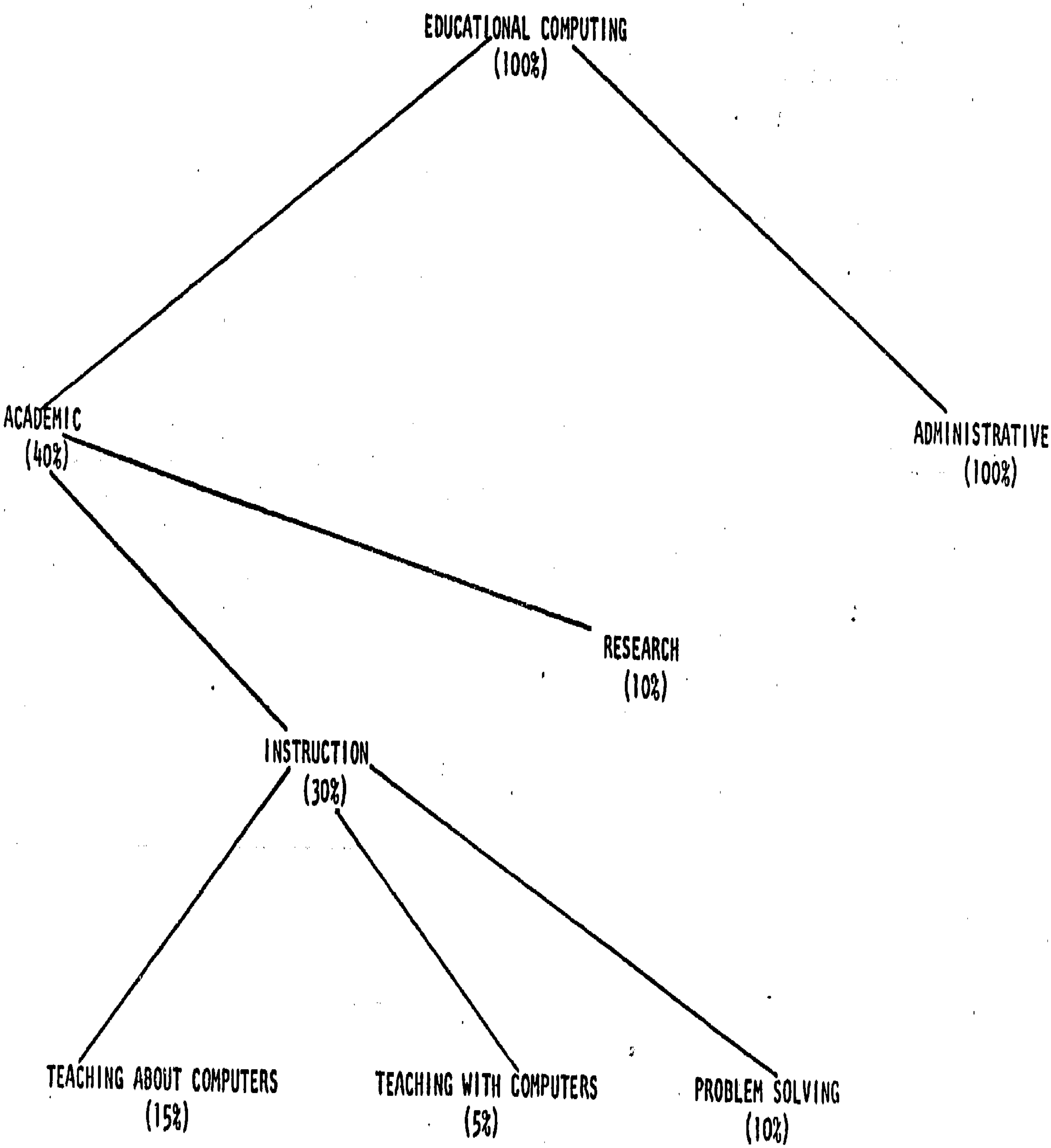
Finally, the school systems provide no incentives for teachers to use personal computer technology, even if it is proven to be exceptionally effective in certain learning situations. In fact, in most systems there are no teacher incentives for any type of improved teacher performance because school enrollments will be generally falling throughout the 80's, the rate of production of new teachers has slowed and the average age of teachers in the school systems is steadily increasing. Since very few colleges and universities require computer literacy and teach familiarity with computers, even in 1980, the level of computer literacy among the average teacher in the educational system is understandably quite low. Thus the typical teacher would have to learn a new topic in some detail, requiring a substantial investment in time and effort, before introducing it into the classroom. School districts and schools of education would have to emphasize computer literacy in in-service training to make even a moderate dent in the knowledge base of the current, aging teacher population.

In higher education the conditions are similar, with the added factor that the purchasers of the educational services, the students, seek personal attention through a low student to teacher ratio. Further, the types of classes in which personal computers would be most effective are those involving basic knowledge acquisition (algebra, basic economics, etc.) or those which are already quite cost effective. These classes have large student-to-teacher ratios and are usually taught by the lower paid faculty. The higher paid senior faculty usually teach advanced or graduate courses with much smaller numbers of students; courses in which personal computers are not as yet highly effective. Thus, college and university administrators interested in using these technologies as a means for increasing the productivity of higher education run into significant obstacles.

These severe financial constraints are exacerbated by the fact that education is a fragmented market: the details of curricula vary widely from state to state and from school district to school district. Personal computer manufacturers are generally not also software suppliers, and vice versa, so that "turnkey" systems suitable for a wide variety of educational situations simply do not exist at present. Because of market fragmentation, sufficiently broad and well defined markets are not likely to arise within the next few years unless the policies and practices of the U.S. educational system change markedly, an unlikely prospect. Consequently, prospective providers of educational personal computer hardware and software, particularly smaller entrepreneurs, are likely to search for other markets after their first few traumatic encounters with the existing one.

In short, even though there may be significant national goal incentives for rapidly increasing

FIGURE 4-1



/Source: Association For Educational Data Systems

the rate of computer literacy in the United States, and for training more people in computer science and technology, the existing institutional barriers, reward structures and financing of the educational system do not appear to be innately responsive to these needs.

It should be emphasized that there is ample evidence that there are a number of situations in which computers are clearly the best choice for inctruction. The routine drill and practice applications were already mentioned. Others include situations where complex manipulative tasks must be quickly learned and/or where it is impractical to teach them by traditional methods. Simulators, for example, the Link trainers, have been shown to be very cost effective in these situations. Personal computers can be equally cost effective in a variety of more conventional simulation situations; for example, in secretarial and specialist training. Most of these situations occur in education outside the school system and colleges, such as in industry and the armed forces. In these cases the performance criteria and the incentives for both teacher and pupil are quite different from those of the school systems. Personal computers may have a significant impact in the area much sooner. Further, there is evidence that an innovation in educational technology, once it is accepted by the system, spreads much more rapidly than do new consumer goods; effectively reaching the saturation level in just a few years.

The question is, to what extent can Federal policy change this situation? The Federal Government has an important but often indirect influence on the state of education in the United States. Much of the direct change in educational policies and practices occurs as a consequence of state and local actions. Consequently the next section will treat these as well as Federal policy options.

4.1.3 Federal Policy Options

The Federal Government has a variety of policy options and instruments by which it can influence the impact of personal computers on education in the future. The basic role of the Federal government in education can be viewed as that of a market aggregator, lending order to an otherwise highly fragmented situation. Two aspects of the development of educational technology can be influenced by Federal policy: 1) the supply and quality of educational materials, and 2) the economics of the educational technology market.

The most fundamental role is played by Federal <u>support of basic and applied research and development</u> of educational technologies and courseware. This support ranges from basic research on cognitive processes (that is, understanding the ways in which different people think and the relative effectiveness of various techniques for teaching), to the development of specific "courseware" for teaching well-defined subjects. Because the development of courseware for computer aided learning is highly labor intensive, it is important that the best qualified teachers and instructional technologists be used. It would appear from our research that the costs of courseware for general education under forseeable market conditions would at least equal hardware costs for a well developed computer assisted learning curriculum in 1990. Our Delphi panelists fell that funding for this development effort is unlikely to be supported solely by the Federal government. If traditional paths are followed, the Federal role would be to support the critical core efforts, particularly in basic research in cognitive processes, and development of prototype courses in a variety of fields, so that broader developments could be undertaken by the private sector. However, this role, although necessary, may not be sufficient. The developed materials must be useable by a variety of institutions, using a variety of personal computers.

This further requirement leads to a necessary accompaniment to the Federal role of research and development support: leadership in the <u>development and coordination of uniform standards</u> and guidelines for the computer-based educational materials. Two types of standards are of greatest importance: 1) those relating to minimum acceptable quality of developed courseware, and 2) those requiring a high level of transportability of developed courseware among a variety of potential computer systems. The latter element is of particular importance when one considers that a typical complete one-year course suitable for use on a microcomputer may cost anywhere from $100,000 to several million dollars (including marketing and distribution costs), depending on its complexity, number of options available, extent of interactivity, etc. At the present, diversified state of the personal computer industry, there are very few computer applications programs which are useable with large numbers of different computers. If transportability is not achieved, then it would be necessary either

to develop uniform equipment standards (generally by fixing them at present levels of development, which might seriously slow the rate of technological development of the hardware), or to allow one or two companies to dominate the education market. The latter action, or consequence of a failure to take action, would result in the creation of a de facto monopoly position to achieve software transportability.

In addition to the role of development of versatile, transportable educational software, there appears to be a Federal role in evaluating the consequences of the uses of educational technologies. As mentioned earlier, educational technology, however effective it may be, may only have an influence on the breadth or incremental rate of learning of children. Motivation, "readiness," and other external factors may play a significantly greater role. Nevertheless, computer aids to education may be particularly effective in some educational modes. The Federal role would be to develop evaluation standards and support longitudinal and other studies to assess the relative effectiveness of various approaches. In this way the maximum benefits of the technology may be realized over the long term.

One critical factor in the rate at which the private sector may assume the long term responsibility for development of low cost, effective transportable educational materials is that of patent and copyright protection. As stated elsewhere in this report, there is, in practice, essentially no existing effective means for the protection of the property rights of the creator of computer software. This issue is a serious one in many aspects of the applications of personal computer technologies but may be particularly critical for educational applications. Even under existing law for printed educational materials the "fairness" doctrine limits copyright protection by allowing extensive, royalty-free copying of materials. The prospective publisher of courseware is thus faced with the prospect of recovering his investment with a very few, rather than thousands of sales, a situation entirely counter to the concept of low cost personal computers.

Federal actions can also play a direct economic role in the rate of growth of educational personal computers. First the government can directly purchase personal computers for distribution to various school systems. A more likely role, however, is that of Federal support of personal computer hardware and software purchases through various education aid programs, such as Title III of the Elementary and Secondary Education Act (ESEA). The government can also indirectly influence purchase through mandated procurement, in which Federal support of certain education programs may be contingent upon purchase by the recipient agency of educational personal computers. To be most effective, this support should be accompanied by the standards considerations just discussed.

Finally, the government plays a major role in development of educational policies at other levels through its widespread information dissemination activities. Two such activities were already under consideration in Congress. These were: HR 3822, which would amend Title III of the ESEA to establish a National Center for Personal Computers in Education, and the broader scope HR 4326 to establish a national commission to study the implications of information technologies in science and technology education. The newly established Department of Education should play a major role in the dissemination of information about the educational applications of personal computers.

The critical point to be made here is that the development of quality educational technology for microcomputers is expensive and consumes scarce resources (independent educators and computer programmers). This can easily develop into a continuation of the cottage industry situation, replete with small entrepreneurs (individual teacher programmers), none of whom has sufficient staff to create truly competent courses. Federal Policy can act in this situation to provide some integrative influence without stifling the competition necessary for the creation of innovative programs.

4.1.4 Non-Federal Policy Options

Non-Federal public agencies, private groups, and individuals can influence the rate and character of the diffusion of personal computers in education. In addition to support of research and development, information dissemination, and procurement alternatives, similar in nature to Federal options, there are some specifically non-Federal options.

The most central of these state and local options involves teacher training and motivation. Unless the great majority of teachers learn to treat personal computers as useful aids rather than threats to their jobs, personal computers are not likely to be used extensively in public school systems. Furthermore, unless teachers are trained to use personal computers effectively, they will not materially alter the educational results: the depth, breadth, and quality of education provided our children.

Finally, the de facto objectives of the school system must be changed from "babysitting" to maximizing the performance results of an educational process carried out over a period of 12 years. Otherwise, it is not clear that personal computer technology will have a major effect on any but the brightest students.

The broad acceptance of personal computers in education also depends on accreditation. In general, the accreditation process is a reactive one; school curricula, course contents, etc. are developed and evaluated by state, local and/or regional accreditation committees for adequacy and suitability. The accreditation committees do not dictate curricula, courses, or technologies used by the schools desiring accreditation. However, if individual schools and/or school systems using personal computers are given recognition for that use in their accreditation, the expected result would be a more rapid rate of diffusion of the technology throughout the country.

The rate of diffusion of personal computer technology will also be affected by pressure from interest groups outside the direct operations of the school system. These groups include parent teacher associations, industry spokesmen (as prospective employers), and individual concerned parents. For example, interest in, and access to, educational use of personal computers is quite high in the San Francisco Bay area, the home of much of the microelectronics industry. This is also true in the State of Minnesota, where there is a well developed consortium for educational computing, and in Michigan, where there is program for dissemination of information on personal computers to the educational community. In fact it appears that, unless policies in the traditional "educational establishment" change, these external interest groups may have the greatest influence among all the possibilities for increasing the rate of diffusion of personal computer technologies in education.

Finally, of steadily increasing popularity in a number of states, is a set of alternatives to the public education system as it exists today. If, and as, quality software for inexpensive personal computers becomes available, adult learners and parents may opt for a return to the home as the primary learning environment for themselves and/or their children. One consequence of this scenario would be decreased use of existing school facilities. Since enrollments in Kindergarten through college are expected to decrease anyway in the 1980's, this would put further pressures on school budgets.

Another possibility often mentioned is the voucher system. In this system, which has been discussed for decades, individual parents would be given vouchers worth a fixed amount by their state or local school boards. The parents would then be free to "spend" these vouchers at educational institutions of their choice. The voucher system is also claimed to have a major influence in increasing competition between educational systems. To the extent that this competition would increase the quality of education, force general curriculum updating, and put greater emphasis on the production of results rather than babysitting children, the voucher system could win the votes of many concerned parents. Through the curriculum updating process there would likely be a consequential general increase in the use of personal computers in education. However, the voucher system also has great potential for negative results. It can be used to resist school integration. It may result in even greater fragmentation of the education market, causing further inefficiencies in the development of education and educational technology. Nevertheless, it is clear that public pressure will increase to explore alternatives such as these if the existing educational establishment does not mend itself.

4.2 Employment

The economies of the United States and the other developed countries in the world are information dominant. About half of the labor forces in these economies are engaged in information processing of one sort or another. Consequently, any new information technology is likely to have a material effect on the nature of the economy and the balance between its factors of production and consumption. Personal computers, as the embodiment of a continuing reduction in cost and improvement in capability of computer technology can, therefore, be expected to have a major effect on the information economy. Or so the theory goes.

4.2.1 Displacement Mechanisms

There are a number of ways in which the introduction of personal computers into the office can affect employment. A "simplified" flow chart of some of the alternatives available within a single company is given in Figure 4-2. Personal Computers can:

1. Eliminate jobs by automating them

2. Create jobs by allowing new functions to be performed which otherwise would have been impractical

3. Alter jobs by increasing (or decreasing) their value and information manipulation power.

4. Have no net effect.

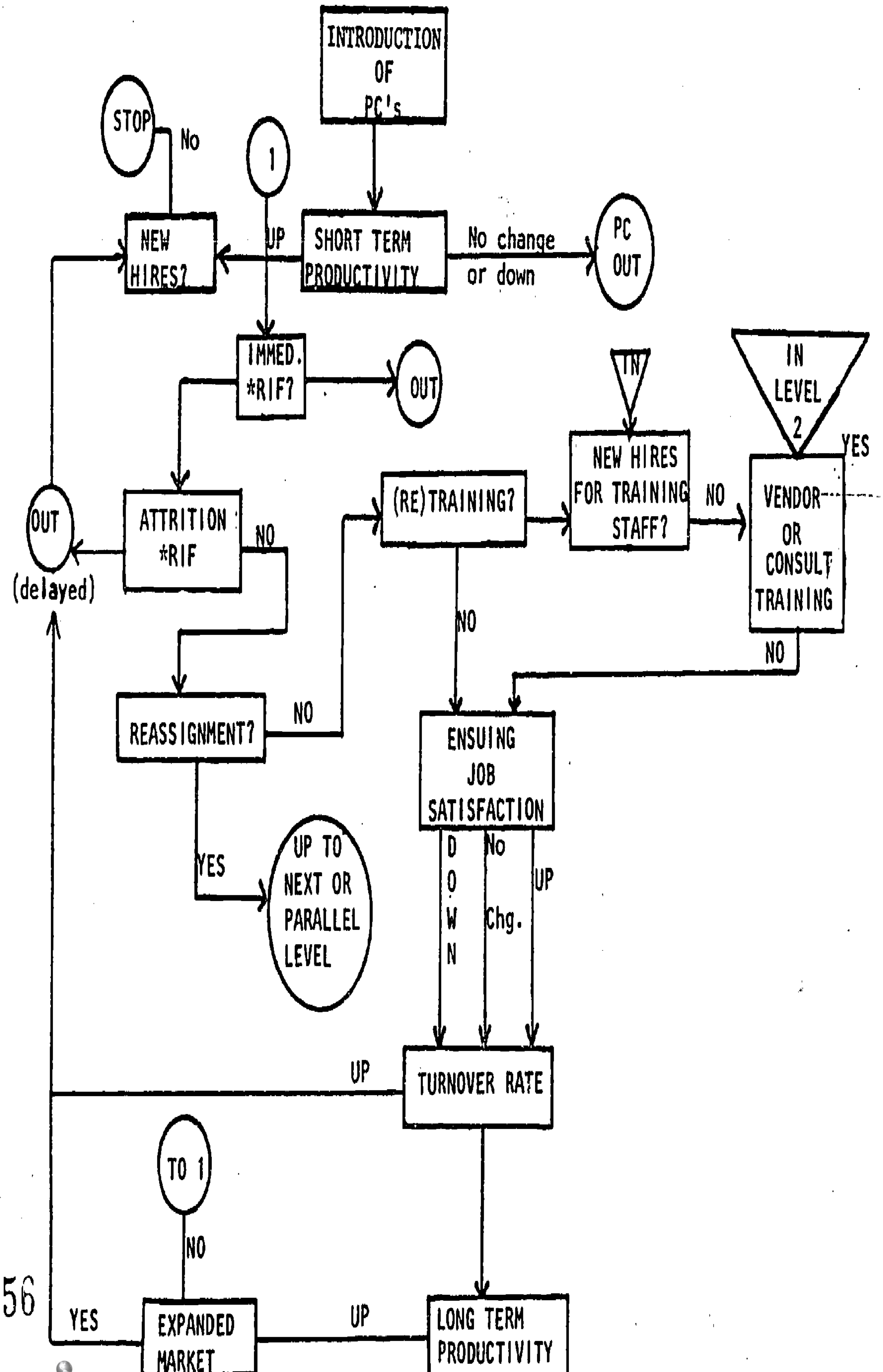
As Figure 4-2 intimates, within an organization of reasonable size it is quite possible that each of the above will be the case in some portion or another of the organization. These substitution or augmentation consequences of the introduction of personal computers can occur within single units of an organization, within the entire organization, between organizations in an industry or sector of the economy, and within the entire economy. Although the question of job alteration, changes in job satisfaction, and job variety or stultification are of great interest in our office automation research, the primary near term concern of most of the major stakeholders in employment issues is the basic question of employment: will personal computers result in more or fewer jobs?

The basic considerations are shown in Figure 4-3. As the cost of computer technology decreases and as its versatility increases, personal computers will become increasingly able to take over routine information processing tasks which are now performed by people. The basic decision by an organization's management is an economic one, although it may be tempered by non-economic considerations. The basic economic consideration is that the cost per unit capability of personal computer hardware is decreasing at an annual rate of from 20% to 30%, in real terms. Personal computer software costs for many routine office functions are now, and will be, decreasing at a rate comparable to that of hardware as the software becomes available via mass distribution techniques. This is particularly true for financial and text processing software. At the same time, the cost of labor to perform information processing functions is rising in real terms at an annual rate of from 6 to 15% or more. This increasing labor cost is generally unaccompanied by increases in productivity. Productivity may even go down if the increases go to the hiring of new, untrained workers. Traditionally, productivity increases primarily as a result of the introduction of better technology.

At some point, where the cost per unit capability of the personal computer becomes sufficiently low relative to the same cost for a human worker, the personal computer will replace the human and the human worker will be displaced. Whether or not this displacement results in unemployment depends on the structure of the firm and of the industry, the ability of the individual worker to adapt to a different job, the existence of a demand for new types of jobs which cannot be performed by computers, and similar factors. Thus the worker displaced by a personal computer may be fired immediately, may be "invisibly" fired (that is, when the worker leaves for some other reason he or she is not replaced), may be "hang fired" (that is, moved to a similar job in a unit of the organization which has not yet acquired personal computers but which will in the future), or may

JOB DISPLACEMENT DYNAMICS

Figure 4-2



POSSIBLE LEVELS

1. Intraorganizational (shown here)
2. Interorg/but intraindustry.
3. Cross Industry.
4. Extraindustry. (e.g., reduction of home service worker demand thru do-it-yourselfism)

TYPES OF CONSEQUENCES

A. Nonzero (Pos.) Sum

1. Productivity, Profitability and market size increase.
   - net new jobs
2. Net increase in job quality.
   - reduced anomie (increased?)
   - increased interest

B. Zero (or negative) SUM

1. Net increase in mal-, under-, unemployment.
2. No net change.
3. Increased anomie, dissatisfaction

*RIF - REDUCTION IN FORCE

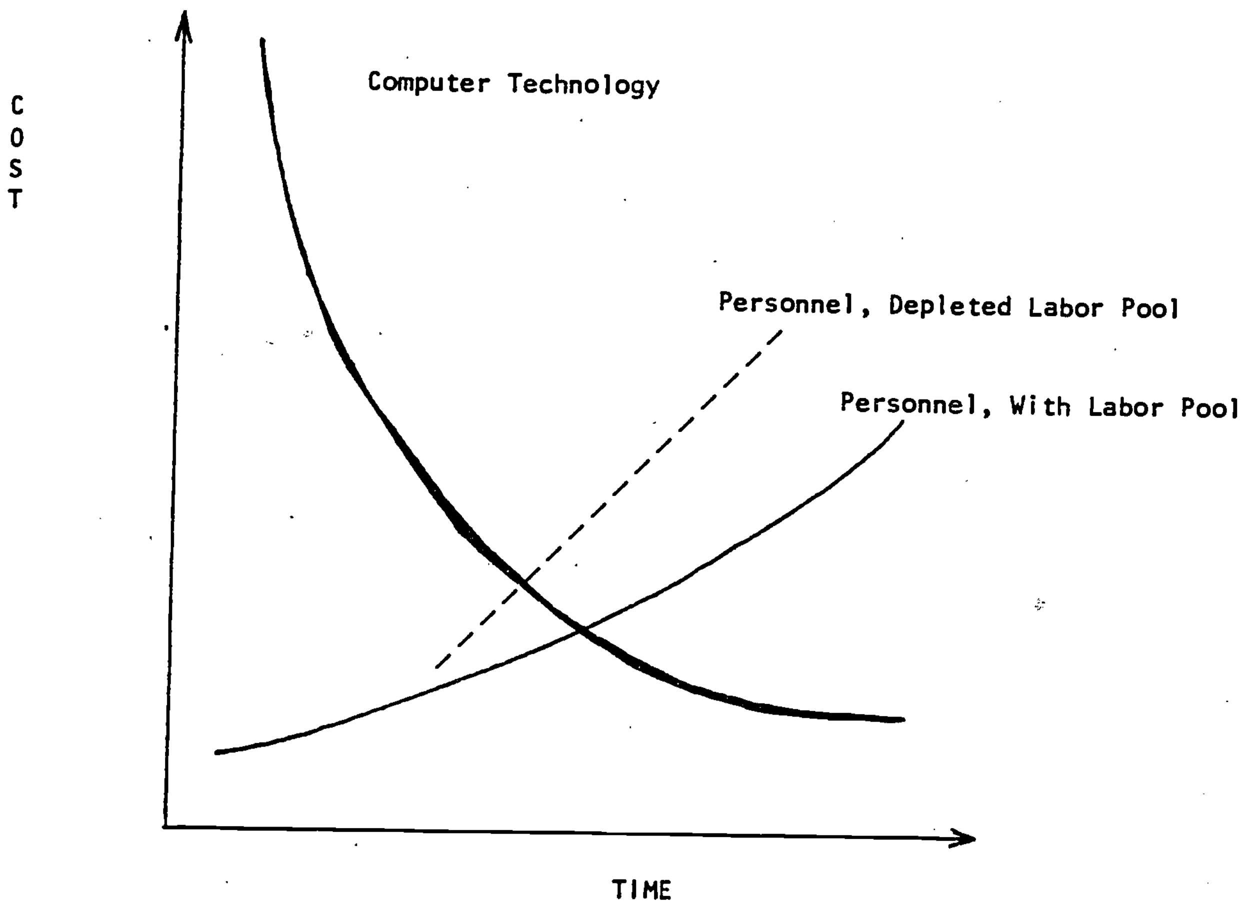


FIGURE 4-3 BASIC ECONOMIC CONSIDERATIONS

retrain, or be retrained, for a new job.

Aside from these specific direct employment effects of the introduction of persal computers, there are broader forms of unemployment which may be partially attributed to the use of personal computers. These are:

1. Structural Unemployment – in which available jobs require skills not possessed by available workers.

2. Capital Deficient Unemployment – in which local industry uses obsolete or inefficient equipment and therefore cannot compete in the market, experiencing net loss in income and jobs, and

3. Demand Deficient Unemployment – in which there is insufficient demand for the product being produced by the organization, whether the product is machine screws or information.

There appears to be a reasonable amount of structural unemployment at present in information work. A recent spot check of the classified section of the Los Angeles Times showed that, of 5,000 advertised job openings, 75% were for information workers. Twenty three percent of all openings were for secretarial and clerical workers, including 1% of the total for word processing specialists. Structural unemployment provides an increased incentive for employers to attempt to automate the information processing functions for which structural unemployment exists. This factor, shown in Figure 4-3 as the dashed line, would tend to cause an increased rate of diffusion of the information technology.

Capital deficient unemployment in information industries might be caused by the inability of small firms to attain levels of automation adequate to compete with larger firms. In these cases, personal computers, because of their lower cost for the same capability as older, larger machines, may act to increase employment by making the smaller businesses more competitive.

Thus, it can be seen that there are a number of plausible mechanisms by which personal computers may be used to displace human workers in existing information jobs. (Microelectronics also have great potential for displacing blue collar workers, or converting them to white collar workers, via robotics and other forms of manufacturing automation.) Personal computers also, because of their ability to take on the more routine and tedious information processing tasks, provide a variety of opportunities for employment which would not otherwise be available. This has been repeatedly demonstrated in the past, with larger computers, in the science and engineering professions. Many recent technological achievements, including the developments of microprocessors and personal computer technology, would not have been feasible were it not for the prior existence of computers. The electronics industry, which has the highest employment growth rate in the U.S. economy (more than three times the national average) further demonstrates this relationship. The fundamental question is whether these positive net employment effects of the introduction of computers will hold for other sectors of the economy as well.

4.2.2 Policy Implications

Among the reasons for the concern with employment, several stand out. First, unemployment is a lively public issue. The unemployment rate, along with the consumer price index, the prime lending rate, and the price of gold have become staple numbers on the six o'clock news regardless of their precision or utility. Second, the unemployed are a potential political force, though existing studies of political behavior indicate that this potential may not easily be exploited. Third, human concern and feelings of equity encourage attention to those displaced from their livelihood regardless of reason. Fourth, in economic terms, unemployed or underemployed workers are wasted resources and, possibly, adverse contributors to the social dependency ratio. Fifth, continuing in social efficiency terms, labor requirements may not be met without special training, retraining, or other worker assistance programs, with a consequent loss of otherwise achievable production, trade, and cost saving. Sixth, the examination of employment consequences of personal computers points out the substantial lack of an employment focus in national economic planning in other than now questionable

aggregate demand ways.

The net can be cast a bit wider than employment levels, however, to consider additional factors such as worker representation in computerization decisions, occupational health threats, changing arrangements for and definitions of work, tradeoffs among demographic groups competing in the labor market (e.g., young vs. old workers), the adequacy of our factual knowledge regarding employment, and problems of labor surplus in the midst of high unemployment rates.

The central tendency of diverse studies of net employment level consequences of computers in general or of microcomputers, as available, lean toward the projection of at best minor employment loss. The attention here will therefore not be directed at the issue of aggregate employment levels, but rather at issues of more limited scope. First, however, a few summary comments regarding aggregate employment levels will be offered.

Aggregate Employment Levels

Concern for aggregate employment levels, or for major displacement in specific industrial sectors such as financial services or automotive, appears in both the popular press and in the publications of trade unions. Examination of this literature reveals little hard data, and less hard analysis behind the numbers advanced. The Nora Report to the President of France, which is concerned with technology of which personal computers are but a part, foresees changes in labor force requirements in financial services from what would be possible in the absence of computerization. In other office industries, job loss is dismissed as unlikely due to bureaucratic inertia and worker resistance for at least the coming decade. In financial services, the projections are for slower growth than might otherwise occur, rather than for noticeable job loss. Nora and his study colleagues see the manufacturing sector as far more threatened by low wage foreign competition than by computerization. American studies, including our own survey which obtained responses from 20 large corporations, do not foresee job losses due to small computers that come anywhere near the figures publicized by union organizations.

As often as not, these studies see computerization expanding job opportunities for educated workers. Among low-skilled workers, jobs are often seen as decreasing. However, many of these jobs are either going unfilled or are seen by the public as worthy of elimination because of their routine, machine-paced, dirty, or dangerous nature. Industries most evidently subject to net job loss, for example, telephone communications, may also be those showing the greatest productivity increases at a time when American productivity growth is otherwise distressingly modest. In general, whenever net job loss is raised as an issue, powerful compensating justifications or intractable measurement problems quickly obscure the debate.

Even if the issue is engaged at the symbolic level the personal computer remains just a piece of the picture and, likely, a very small piece if all forms of automation are incorporated into the rhetoric. Public attention is unlikely to distinguish among types of computers or other electronic devices. However, from the detailed analysis of employment issues included in Volume III of this report, a number of issues of limited scope do deserve federal consideration. These issues can be categorized as follows:

Education, training, and promotion
Subsidies of people or activities
Regulation of employer activity
Enhancement of the political process
Monitoring
Research
Planning

Few of the policy issues mentioned are specific to the personal computer. This technology raises issues which would be raised by any pervasive new technology (such as molecular biology, a new type of motor, or a new medium of communication). Thus the policy issues discussed here are often quite broad. Nonetheless, the personal computer is a major factor in making any of these policy issues urgent.

Policy Implications
Employment

Education, Training, and Promotion

Three problems, each of a different nature, emerge under the heading of education: the retraining of displaced workers, the shortage of computer professionals, and alternative work arrangements.

Regardless of net effects, some workers will find their jobs altered significantly. Corporations responding to our survey indicated that they favor retention of existing workers through retraining, but it remains to be seen to what extent they follow their espoused preferences. The same skepticism might be advanced regarding large government and third-sector employers. Nonetheless, government training efforts, though directed largely at hard-to-employ rather than to employed persons, in general have received unfavorable evaluations even from sympathetic observers. Thus the possible federal role in educating workers displaced by personal computers (or by any other technological advance) must be approached cautiously. Further, there are no apparent reasons for treating persons displaced by personal computers as a special case. Granting this, the federal government might still choose to express concern for the retraining of displaced workers through regulations directed at employers, through legislation favorable to worker organizations, through monitoring of displacements, and through research on the social and economic burdens of displacement and who should bear them.

A possible bottleneck inhibiting the full exploitation of personal computer technology is a shortage of appropriately trained programmers, software designers, and other technical specialists. While the student aid programs which originated in the 1950's were targeted toward steering individuals into specific majors, the trend since that time has been toward ever more general forms of assistance. A decision to sponsor the training of computer specialists as a special emphasis within federal post-secondary aid would represent more than a reversal of a 20-year trend in federal policy; it would also represent a decision to stimulate the personal computer industry. Since such stimulation could be (in theory) designed in infinitely fine gradations, this type of educational program has much to recommend it. On the other hand, training subsidies are only one way of stimulating this industry. Statutory reform of the copyright laws might provide comparable stimulus at less expense, for example. Nonetheless, given the potential contribution of personal computers to foreign trade (see Section 4.3), as well as the possibilities for direct and indirect job creation from the personal computer industry, government encourgement of this industry deserves consideration. Subsidized training in critical skills areas is one way to do it. Before such a program is undertaken, however, serious labor market projections need to be made. These studies could be undertaken by the Department of Labor for a cost that must be considered small compared to overall Departmental expenditures. Subsidized education would most logically originate in the Department of Education; $50 million would provide $5,000 for subsistence and $5,000 for tuition and supplies for each of 5,000 students (over and above funds available in other post-secondary programs).

A third policy implication in the education area concerns alternative work arrangements. Personal computers are likely to expand the possibility of work at home, through telecommuting. It is easily conceivable that, properly programmed, the personal computer will facilitate job sharing and expand organizational control over work in general. The computer provides a neutral interface between the employer and employee in a telecommuting environment (as does the telephone in some circumstances). The information products of the employee, rather than other employee attributes, become the dominant elements of the employee-management relationship. The concerns of managers in this environment will be directed to the timely arrival over the telecommunications network (via Electronic Message Systems) of the required information products, regardless of when or where the information worker actually produced them. As a consequence, persons as well as locations and time blocks will become more interchangeable. Given the growth of two-job couples and an increasing attention to work-family tradeoffs and worklife - personal life tradeoffs by younger workers, the Department of Labor and/or the Department of Education might consider what can be done to make people more aware of the alternative work arrangements permitted by personal computers and related technologies. Productivity concerns might well motivate educational efforts in this area; however, assisting people to evolve work arrangements more suited to their family and personal satisfactions is also a worthy concern. Costs here could be quite modest; other Federal departments might be enlisted in promotional efforts targeted toward specific clientels (such as Health and Human Services toward the health professions, Justice toward law enforcement agencies, etc.)

Subsidies

The potential impacts of personal computers on job displacement lead to a reconsideration of disability benefits payments. Disability benefits have been expanded and eligibility loosened with a consequent substantial increase in beneficiaries in recent years. While disability programs tend to benefit older workers directly, younger workers receive some benefits from the early retirement of their elders from the labor force. Yet the nation loses well-trained productive workers if disability programs encourage substantially able-bodied workers to retire early. The use of personal computers to bring work to the mobility handicapped via telecommuting may act to diminish the loss of these otherwise able workers. Given the gradual elimination of mandatory retirement thresholds, the combined effect on older workers is not known. Disability programs need to be redesigned with these effects on the labor force in mind.

Hiring subsidies are used in Europe to encourage the employment of youth or other groups thought to need special assistance to compete in the market for labor. In an economy characterized by high unemployment as well as shortages in specific occupations, hiring subsidies should be considered with extreme caution. This is particularly true where younger workers are concerned, for in a new industry, like the personal computer industry, younger workers have an advantage because of their receptiveness to learning.

Looking at older workers, however, the literature on secondary sector manufacturing industries suggest that numbers of skilled crafts workers are being displaced by electronic innovations that are related to personal computers. Employment in telephone and telecommunications, for example, has dropped in recent years by well over 100,000 employees. Many of these employees were skilled installers and maintenance persons for electromechanical equipment. Similarly, in other electromechanical industries such as adding machines, skilled workers have already been displaced. Some of these workers will find it difficult to regain the income they derived from skills of diminishing usefulness in the labor market. Yet, by the fact of their attaining these skills, such workers have demonstrated their intelligence, craftsmanship, and work discipline. Such skilled workers should be considered an important economic resource worthy of further investment in counseling, relocation, craft retraining, or administrative retraining so that they can continue to contribute their productive abilities and to maintain their hard-earned economic standing. The exact shape of any program of temporary subsidies requires more detailed specification of the beneficiary population. This would be located most appropriately in the Department of Labor.

Since some occupations suffer labor shortages and others labor surplusses, incentives for labor-saving computer applications makes more sense in the former than in the latter. For example, although considerable concern has been expressed regarding the employment consequences of word processing equipment, the job of typist has not been an easy one to fill in recent years. On the other hand, many social service occupations are facing sizable employment surpluses. Unless, computerization can guarantee sizable net savings, it makes little economic or political sense to replace abundant clerical workers in the Welfare Department with scarce computer programmers and systems analysts. A major concern in application subsidies is their targeting toward labor-shortage and away from labor surplus fields. This requires the identification of surpluses and shortages, analysis of their likely continuation, and development of a means for identifying (at a minimum) existing Federal applications-oriented subsidies such as research and/or demonstration grants, conferences and other dissemination efforts. If the concern is limited to applications receiving some Federal financial assistance, the National Science Foundation might be the most appropriate coordinating agency, perhaps acting in a staff capacity to OMB. No single agency may have the breadth of contacts and knowledge necessary for a review of the private economy, suggesting instead that information be collected through regulatory agencies such as the SEC. It seems prudent to examine the Federal Government's own subsidies and disincentives first, however. In such a review, discouraged opportunities may be as important as active subsidies.

Regulation of Employer Activity

An issue that threatens to have increasing salience is that of worker surveillance. As more and more work becomes performed on personal computers, especially computers connected to larger

systems, employers will find it increasingly tempting to collect detailed records on employee work effort, pace, breaks, errors, requests for help, etc. Inevitably, someone will exceed the bounds of propriety. For the many industries without significant employee organization, few institutions insert themselves between the individual worker and the corporation or agency. Since the Federal Government already regulates many conditions of work the Department of Labor might begin developing standards for worker surveillance via interconnected mainframe, mini-, and personal computers. This is one case where the computer technology now available does permit what has been largely a theoretical possibility to become an actuality. Implementation of standards could be fairly expensive for the likely gains, or, properly designed, could be quite cheap. For example, employer violations could be linked to government contracts or other assistance. This would be a blunt and imperfect mechanism but would discourage a sizable number of potential abusers even if many slipped through the net.

Some occupation health issues may be raised by personal computers. To the extent that they encourage sedentary monitoring on a video screen, of complex and costly processes, such as papermaking, stress-related illnesses may be induced. An issue that has received some attention already is the effects of CRT's on human vision. Extended use of inferior quality video graphics may, after proper research, become a subject of regulation. Professional or trade associations, or trade unions, may be adequate to this task. The most logical Federal agency for administering any regulations might be the OSHA, though it is often considered by its supporters and its detractors alike, to be the victim of its enabling legislation and budget. Another area of regulation concerns the internalization of displacement costs. While personal computer technology may appear to improve productivity in an industry, such gains may depend in part on the industry's ability to externalize costs of employee displacement onto government at every level. To the extent that this is true, economic resources are misdirected away from true productivity gains and into false ones. Here, too, research is needed to identify the existence of the problem first. In some industries, costs of technological displacement may be effectively internalized in the collective bargaining agreement, but in most the workers have no representation. On the other hand, any Federal program to internalize costs needs careful coordination to prevent duplication of private by public benefits.

Enhancement of the Political Process

Political participation can be considered both within the organization and in the wider society. Public forums of greater or lesser formality and government sponsorship have developed around many issues of science and technology policy in industrial countries. These forums have considered issues such as nuclear power, molecular biology research, supersonic commercial transport, dam and irrigation projects, and weather modification. These forums provide opportunities for hitherto unrecognized possibilities to be brought to public attention and for committed citizens and groups to be heard. The former benefit affects social efficiency; the latter affects regime stability. While personal computers do not have the catastrophic life or properly threatening attributes of some of the issues just mentioned, that does not obviate the public's concern with computerization exclusively to market forces and private firms. A national technology forum on personal computers or computerization might be conducted under the auspices of NSF.

A second problem of participation results from the inability of many employees to participate meaningfully in computerization decisions which affect their lifes in significant ways. The stronger craft and industrial unions protect their workers in the contract, perhaps at the expense of productivity which would benefit the general public, through many unions, such as the UMW and the Longshoremen have embraced technology with proper incentives for the surviving workers. At the other end of the scale stand banking and insurance employees with little employee organization. It is felt by some writers that Federal policies inhibit white collar unionization. Since computerization depends upon employee cooperation for effective implementation, meaningful employee participation may in many instances serve employees, organizational and public interests simultaneously. While white-collar unionization is not an issue raised solely by personal computers, it is an issue particularly germane to the workplace disruption which can attend computerization. NLRB policies may be most relevant here, but any considered change in Federal support for worker organization regarding computers or any other technological change will quickly be shifted into the Congressional arena and excite the attention of peak interest groups.

Policy Implications
Employment

Regardless of this study's conclusions about net changes in employment levels, many jobs are likely to change. These changes will affect formal and informal social relations on the job; community status of occupational specialties; hours, location, and pacing of work; skills requirements; and many other matters of concern to workers. Employers should not be considered prescient regarding worker needs, yet employees in many industries, particularly information industries, lack institutional channels for advancing their collective interests. Since personal computers and related technology do hold the promise of both productivity improvements for existing products and services, and the generation of new products and services, the national interest is served by efforts to reduce unnecessary disruption from the introduction of these technologies. Additionally, however, to the economic argument is a legitimate concern with quality of work life and citizenship in the workplace.

Research

Several research issues have already been mentioned under other headings. The major research need relevant to personal computer concerns the magnitude and cost of displacement. Studies are needed of specific occupations and industries, and these studies should be repeated periodically in order that cumulative patterns be identified. Such studies are an essential prelude to informed policy making, and should not be expensive. The several industry studies of automation which have been cited in Volume III are good examples of what can be done. An ongoing program of research on the effects of technological change could be carried out with very modest resources by the Labor Department staff. Such a program would be aided by a general economic model of displacement costs which attributed these costs properly. Such a model would direct the attention of industry or occupation studies to externalities, secondary costs, hidden subsidies, and related phenomena that muddy the economic analysis of displacement. The model would assure a degree of comparability among studies that would be useful for policymakers and otherwise difficult to obtain. Suggested, then, is a research program that involves formal models and field studies.

Attention will likely be given to the physical and mental health consequences of small computers. NIOSH, NIMH, and the Department of Labor each have interests here. One Federal role might be the establishment of central coordination for the studies that are likely to take place in a dispersed manner. NIOSH seems the appropriate locations.

There seems little evidence to suggest that computerization will dramatically expand employment, so the Federal Government might begin developing the research and conceptual support for efforts to adjust labor supply to demand. This seems most appropriate for an inter-departmental effort, but systematic attention to this kind of a subject would not only be a substantial departure from past practices, but also would likely occasion much attention from interest groups. The subject is potentially as controversial as "family policy" has proven to be. Yet, this is not a sufficient reason to avoid it.

Monitoring

Since no good data exists on job loss and creation relating to personal computers or similar technology, the Department of Labor should collect this kind of data systematically and regularly from employers. The institutionalization of such monitoring efforts requires an investment in proper data gathering instruments as well as the operating costs of collection and analysis. The specific topic of the consequences of personal computers is too limited to justify the investment, but the consequences of technological innovation in general, or even of computers and automation, is not. Such data collection is essential for rational employment policy, for currently we lack solid information on job creation and loss, and thus lack basic information on employment.

Planning

Several planning matters can be suggested, although the political system has not shown itself receptive to planning efforts with horizons beyond a Congressional term. First, national economic planning must shift to include specific employment goals. By this we mean not aggregate demand notices of "full employment" but rather specific attention to job creation and loss in specific industrial sectors. This means conscious decisions as to what industries make sense for the U.S. in an

internationalized market (see Section 4.3). Employment must be more than an "aggregate level" or a resultant. Second, manpower and immigration policy should be coordinated. Illegal (and some legal) immigrant workers accept many low-wage and manufacturing jobs shunned by other workers. As economic planning increasingly recognizes employment and other supply-side objectives, immigrations policies will likely be seen to have major economic policy aspects. Finally, some attention should be given to the labor surplus among the educated. Perhaps computerization will mitigate this surplus as it upgrades the intellectual content of jobs. But this is not assured, and computerization may also increase the productivity of the well-educated. For example, legal research has been aided by computerization of law libraries. All these planning issues have systemic political implications and might best be considered by staffs and task forces at the highest executive levels and by elite private think-tanks and research institutes.

4.3 International Trade

Personal computers are but the latest in a series of technological innovations produced by the electronics industry in the United States. Development of the personal computer market for business use in the near term, and for consumer use in the longer term, can provide a major stimulus to economic growth within the United States and in the rest of the world. If the world market for personal computers is proportional to that for larger computers then it is reasonable to expect that sales of personal computers in the rest of the world will range from one-half the volume to equal the volume of sales within the United States. Evidence gathered from manufacturers and computer stores in 1980 suggests that the current international market is about one third that of the U.S. market. Currently, although there are some foreign manufacturers of personal computers, notably in Sweden and Japan, the international market is dominated by U.S. manufacturers.

The issues discussed here relate to the extent to which the United States will continue to play an active part in the world development of the personal computer market and the potential consequences of any changing role of the United States in that market. Table 4-1 shows our estimates of the potential world market for personal computers.

Because of the uncertainty in the rate of growth of certain components of the market, particularly the consumer computer market, total world sales of personal computer hardware and software in 1980 are estimated to range somewhere between $11 billion and $40 billion. The opinion of the international trade experts among our Delphi panelists was that U.S. firms would account for about 80% of the domestic and personal computer market and about half of the market of the rest of the world, assuming world conditions roughly equal to those at present. If these estimates were proved valid then the direct effects on the U.S. international balance of trade in 1990 would be a contribution to a positive U.S. balance of from $6 billion to $23 billion, or as much as 1% of the Gross National Product. This would translate to some quarter-million to a million jobs directly related to these exports.

It is not at all clear, according to our research, that the United States will maintain, or even approach its current dominance of the world market in personal computers by 1990. Naturally, to the extent that the world market's share in personal computers is captured by manufacturers from other countries the results will be a decrease in the potential positive contribution to the U.S. international balance of payments and to the number of new jobs created within the United States (again, "all other things being equal"). If U.S. firms were to lose or reduce their share in the domestic and world markets for personal computers it would be due primarily to a loss in comparative advantage of U.S. firms relative to the firms in the rest of the world. However, comparative advantage is composed of two components, 1) the health of the industry, and 2) international trade activity, both of which may be heavily influenced by government policy.

The first of these components is the basic state of health of the producing industry, the efficiency with which the industry produces desirable products (relative to other products produced within the country). It is clear that U.S. firms have a clear comparative advantage, as well as a direct advantage, over competitors from other countries at the present stage of market development. However, it is not at all clear that U.S. firms can maintain this advantage in the face of growing competence of competing firms in other countries. This is not a problem which is unique to the personal computer industry; it exists and has existed for some time in several other industries in which the once dominant position of United States firms is being eroded or has disappeared. This is occurring partially because of increasing native technological innovation, partially because of substantial "infant industry" subsidies and protection on the part of governments in competitor countries.

The other means by which the comparative advantage of industries in different countries can be changed is through international trade policy, through the use of tariff and/or nontariff barriers to trade. In these cases the competing governments, while allowing, and possibly providing incentives for, the export of a product to the United States would prohibit the import of the same category of product from the United States.

Finally, there are a series of related second and third order effects which have to do with the extent to which the development of the market in personal computers alters other international markets. This can be done by inducing changes in patterns of demand for manufactured products and services or by altering the comparative advantage of other sectors of the economy which make use of personal computers, such as by improving their productivity or allowing the development of new or

TABLE 4-1

Estimated Potential 1990 Personal Computer Market

TYPE OF APPLICATION	US SALES ($B)[1]	REST OF WORLD SALES ($B)[1]	TOTAL SALES ($B)[1]
EDUCATION			
Hardware	0.1 to 0.3	0 to 0.1	0.1 to 0.4
Software[2] (@40% of HW)	0 to 0.1	0 to 0	0 to 0.1
BUSINESS			
Hardware	3.8 to 15.2	3.8 to 15.2	7.6 to 30.4
Software[2] (@20% of HW in US, @10% of HW, ROW)	0.8 to 3.0	0.4 to 1.5	1.2 to 4.5
CONSUMER			
Hardware	1.2 to 3.3	0.2 to 0.7	1.4 to 4.0
Software[2] (@30% of HW in US, @20% of HW, ROW)	0.4 to 1.0	0.1 to 0.2	0.5 to 1.2
TOTAL	6.3 to 22.9	4.5 to 17.7	10.8 to 40.6

1. Constant, 1980 Dollars.

2. Software sales estimates are confined to sales where the user interface is in English.

more efficient products and services.

It is important to point out some significant contrasts between U.S. Federal policy and national policies in other developed countries. All the Western European countries and Japan have well developed, integrated bodies of industrial and international trade policies, together with well staffed bureaucracies with specific responsibilities for enforcing existing policies and recommending new policies. The United States government has no coherent body of industrial policies and a highly fragmented, often contradictory body of international trade policy. Only in the last few months has specific organizational responsibility for a centralized international trade policymaking function been established within the U.S. government and, at this writing, the new organization has not developed either the staff or the political leverage comparable to that of its counterparts in other countries.

This is not necessarily due to any massive dereliction of responsibility on the part of the Federal Government. Until fairly recently, in historical terms, the United States has been largely self-sufficient. Very little thought has been directed by native manufacturing industries or by the government to the promotion of international trade. It has only been in the last decade that issues of international trade have achieved greater prominence in national policy deliberations. The other developed countries, on the other hand, have long been in the position where international trade was a vital factor in maintenance of their economic health. Consequently, matters of international trade policy assumed prominence at a much earlier stage in the development of these countries. Nevertheless, the U.S. are now in a position where this aspect of our international econmy can no longer be neglected.

Although several of the developed countries are potential major competitors of the United States in the personal computer market of the future, Japan is clearly the most formidible competitor at present. Consequently, our research concentrated on a comparative analysis of the policies of the U.S. and Japanese governments as they might relate to the future of personal computer technology.

As has been the case for our analysis of the effects of personal computers on education and on employment, there are no existing data from which one can draw rigorous conclusions; the comparisons have had to deal with functionally similar situations. Since the personal computer has some of the characteristics of consumer electronics as well as those of larger computers, and since personal computer technology depends heavily on progress in microelectronics technology, our analysis concentrated on these three industries.

Japan has grown to be a dominant force in the field of consumer electronics. The majority of stereo systems, television sets, and related electronic appliances sold in the United States are of Japanese (or other Asian) origin, or manufactured by U.S. based plants of Japanese firms, even in those cases where they are sold under U.S. brand names. Yet, 20 years ago, almost the entirety of the U.S. market, and a reasonable proportion of foreign markets in these product areas, were dominated by U.S. firms. Although the Japanese share of the world computer and microelectronics markets is considerably less than their share of the consumer electronics market at present, the rate of growth of market share attributable to the leading Japanese firms is significant and has surpassed that of many firms in the United States. Furthermore, the Japanese have made a national commitment to rival or dominate the United States in information processing technologies in general. Their actions demonstrate that they are seriously following this committment.

4.3.1 Industrial Policy: the Basic Health of U.S. Industry

As mentioned earlier, the personal computer industry is not unique but rather is typical of the growing, technology intensive industries which provide a substantial portion of the positive side of the U.S. international balance of payments. There are two primary reasons why the U.S. personal computer industry and other technology intensive industries may not be in an adequate state of health a decade from now. The first of these is lack of availability of capital at rates suitable (as viewed from an international perspective) for continued technological development. A second reason for potential failure in health is an inadequate rate of development of trained scientific and technological personnel. The present status and projected growth of the microelectronics industry provide examples of these.

In testimony to Congress, Robert Noyce, representing the Semiconductor Industry Association (SIA), provided the following analysis:

Policy Implications
International Trade

In 1979 U.S. IC sales worldwide were $4.6 billion. My basic assumptions are that:

— the IC market will continue to grow in the 1980s as it did in the past decade at an average annual rate of 22%, compounded (although growth of nearly 42% occurred in 1979);

— the U.S. will retain its 60% share of the world market;

— annual asset turnover (sales divided by total assets) will decline from 1.5 to 1.0 due to increasing equipment costs; and

— the average debt-to-equity ratio of the semiconductor industry will increase from its present 15:85 to the U.S. industry-wide average of 25:75.

With projected cumulative sales for the ten years ending December 31, 1979, of $2067.4 billion, annual sales of IC's by American producers should rise to $41 billion by 1990, which would be nine times our 1979 sales volume. Given the increasing capital intensity in our industry under the foregoing assumptions we can achieve this sales growth in the decade ahead only by making a cumulative investment in IC plant and equipment of approximately $28 billion.

If no new equity is raised by the U.S. industry and with a debt/equity ratio of 25:75, the U.S. semiconductor industry will have to increase after tax earnings to 13.5% of sales to finance capital requirements. Please bear in mind that a return of is over three times the average U.S. semiconductor earnings on 4.3% of sales during the period 1968–77, as reported during the period 1968–77.

In general, suitable funding for this magnitude of capital investment has not been found in the U.S. financial community. As a consequence, semiconductor firms have increasingly turned to foreign sources of investment. Table 4-2 lists the ownership of the major semiconductor firms and of one firm in the personal computer industry.

Although the United States Government was instrumental in the initial development of the semiconductor industry, through its support of the R D efforts necessary to develop large scale integrated circuits, the level of support has steadily diminished. In contrast, in other countries, government support for their native semiconductor industries has steadily increased, as is shown in Table 4-3.

In addition to direct support of R D, governments in the EEC, Japan and other Asian countries provide or indirectly influence a number of other incentives to their favored industries. These include a variety of tax incentives and lowered interest rates on debt capital. In general, Japanese and European companies, at least in the growing industries, have a higher proportion of their financing from debt than is the case within the United States. Table 4-4 gives some examples. All of these measures in other countries stem from the actions of a national industrial policy. These policies are generally oriented toward the promotion of potential growth industries, that is, those most likely, in the views of the government, to have the greatest natural comparative advantage once they are developed. The favored industry promotion policy is coupled with policy for the dismantling or realignment of low growth or declining industries. In the United States, on the other hand, the de facto industrial policy was compared with Japan by the U.S. Comptroller General as follows: "**Japan encourages its strong industries; the United States protects its weak ones.**"

The major tools used by the Japanese Government to stimulate favorite industries have been the following:

1. Allowance of extra-accelerated depreciation and shorter terms for depreciation of capital equipment and R D investments for industries which are either felt to be important to the country's economic growth or for which the government requires maintenance of a basic capability for strategic reasons;

TABLE 4-2

Acquisitions of U.S. Semiconductor Firms

Est. 1979 I.C.

		SALES ($ Million)	
1.	TI Semiconductors	$680	Div. of TI, Inc.
2.	Motorola Semiconductors	425	Div. of Motorola, Inc.
3.	Intel	400	---
4.	National Semiconductor	320	---
5.	Fairchild	305	acquired by Schlumberger (France)
6.	Signetics	250	acquired by N.V. Philips (Netherlands)
7.	Advanced Micro Devices	160	owned by Siemens (W. Germany)
8.	MOSTEK	155	acquired by United Technologies
9.	RCA Semiconductors	145	Div. of RCA
10.	Harris	100	Div. of Harris Corp.
11.	American Microsystems	95	acquired by Robert Bosch Gmbl (W.Germany)
12.	Rockwell Semi	85	Div. of Rockwell International
13.	General Instrument	80	Div. of G.I., Inc.
14.	Intersil	75	acquired by Northern Telecom (Canada)
15.	Synertek	50	acquired by Honeywell
16.	Analog Devices	40	acquired by Standard Oil
17.	Monolithic Memories	35	acquired by Northern Telecom
18.	Siliconix	30	acquired by Lucas (Great Britain)
19.	Solid State Scientific	22	acquired by Adolf Schindling (W.Germany)
20.	Zilog	15	acquired by EXXON

/Source: Datamation, April 1980/

COUNTRY	MAIN RECIPIENT	PROPOSED & ACTUALS STATE FUNDS	TERM	REFERENCE
EEC	IN PLANNING STAGES			ROCKWELL
GERMANY		$ 100 MILLION ($30 - $40 MILLION YEARLY)	3 YEARS	EL 9-28-78 EW 7-5-78,7-26-78
ITALY	SGS-ATES (LOAN & SUBSIDIES)	$ 135 MILLION	4 YEARS	
FRANCE	ST. GOBAIN PONT A MOUSSON	$ 50 MILLION		ECON 8-5-78,EW 2-21-79
	MINISTRY OF INDUSTRY TO THOMPSON CSF-SSC	$ 120 MILLION TO		ECON 8-5-78
	THOMPSON CSF + CEA (SESCOSEM/EFCIS)	$ 200 MILLION	5 YEARS	EW 11-15-79
	RADIOTECHNIQUE COMPLEC	$ 25 MILLION		EW 7-5-78, 2-21-79
UK	UK TOTAL $330 M		3 YEARS	EW 2-21-79
	NEB AVAILABLE FUNDS LIMIT: $6B			EW 12-13-78
	NEB TO INSAC (SOFTWARE CONSORTIUM)	$ 40 MILLION	3 YEARS	EL 9-28-78
	NEB TO INMOS LTD.	$ 90 MILLION	BY 1981	BW 7-3-78 EN 6-5-78, 7-3-78
	NEB TO PLESSEY (LOAN)	$ 40 MILLION		ECON 7- -78
	DOI TO MISP (MICROELECTRONIC INDUSTRY SUPPORT PROGRAMME)	$ 140 MILLION	5 YEARS	EW 8-2-78, 12-13-78
	DOI TO MAP (UP APPLICATIONS PROJECT)	$ 180 MILLION		EW 12-13-78
	E-BEAM FAB TECHNIQUES	$ 1.8 MILLION		EL 9-28-78
	NCC - AWARENESS PROGRAM (SOFTWARE TRNG)	$ 90 MILLION		EW 12-13-78
JAPAN	VLSI SUBSIDY (LOAN)	$ 250 MILLION	4 YEARS	ROCKWELL
KOREA	GOLD STAR, ET AL (WORLD BANK LOAN)	$ 600 MILLION		ICE
USA	VHSI NBS	$ 250 MILLION	5 YEARS	
	TOTAL GOVERNMENT EXPENDITURES WORLDWIDE FOR PROMOTING SEMICONDUCTORS	$ 2.3 BILLION+	3 - 5 YEARS	

 LW = ELECTRONICS WEEKLY BW = BUSINESS WEEK EN = ELECTRONIC NEWS ECON = ECONOMIST EL = ELECTRONICS MAGAZINE

TABLE 4-3

GOVERNMENT SUBSIDIES AND LOANS FOR SEMICONDUCTORS

TABLE 4-4

	1978 Average After Tax Return on Equity	1978 After Tax Earnings As % of Sales	1978 Debt/Equity Ratio
Six U.S. Companies	16.3%	6.4%	16%
Four Japanese Companies	8.0%	1.9%	345%
Two European Companies	9.6%	2.4%	47%

/Source: Noyce, 1980/

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2. Further tax incentives for firms engaged in export of their products in these favored industries;

3. Imposition of restrictions on foreign capital investment;

4. Encouragement of a high rate of personal savings;

5. Backing of low interest and/or guaranteed loans to preferred firms;

6. Maintenance of limited mobility of the best entrepreneurs, engineers and workers (through social as well as governmental pressures).

7. Direct or mandated procurement by the government of the output of the emerging or renovated industry in its "infant stages".

Clearly, because of basic cultural differences, the United States cannot emulate all of the incentives provided by the Japanese Government to its industries. However, it would appear that a coherent industrial policy would be able to address some of the more serious of the differences in incentives and support.

The basic scenario we have projected for the personal computer industry under existing Federal policies and practices, as a consequence of the history and prospects of the consumer electronics; semiconductor, and computer industries, is as follows:

1. The United States, as a consequence of its large and continuing investment in basic research, develops the scientific base for a number of innovations. These innovations are first developed by U.S. firms, generally those which have already participated in the initial basic and applied research efforts.

2. The U.S. captures essentially the entirety of the domestic market and a major fraction of the world market, during the initial stages of the development of the market. (These steps have already occurred in the personal computer industry.)

3. Firms from other countries, through individual negotiatins with U.S. firms and/or individuals, rapidly gain access to and purchase essential "know how" and production equipment.

4. These countries restrict the import of the products of the new technology which were made in the United States, with the exception of a sufficient quantity to be used for analysis and emulation by native industries.

5. Foreign governments provide incentives, as listed above, to accelerate growth of a competitive capability in their native industries.

6. The native industries achieve near technological parity with U.S. manufactured products, improve upon the quality of some products, and develop superior products in other cases.

7. These products are sold almost entirely locally, during the initial "debugging" and learning period, until they have achieved a level of perfection and reduced cost adequate to successfully compete in the U.S. market.

8. The products are then introduced to the U.S. and world markets at competitive prices. The native firms begin rapidly eroding the market share previously enjoyed by U.S. firms.

This scenario has occurred in the consumer electronics industry (with Japan), is occurring in segments of the microelectronics industry (for example, Japanese gains in the high density memory chip segment), is occurring in the computer industry (with peripheral equipment and IBM plug-compatible computers),

and could well occur in the personal computer industry.

Not all of these real and potential woes can be laid at the feet of the U.S. government. There are also numerous examples of failures of U.S. industry to perform (or listen to) adequate long-range planning in order to anticipate these scenarios and devise appropriate reactions to them. For example, with a few exceptions, U.S. firms seem not to have engaged in the development of export markets on anything close to the scale and intensity routinely practiced by foreign firms. A major share of the credit for the increase in the Japanese share of the semiconductor memory market appears traceable to excess conservatism in production planning on the part of U.S. manufacturers.

Fortunately, the personal computer industry, at least at its present state of development, appears to be pursuing vigorously the foreign trade opportunities available to it. The corporate committment to foreign trade, seems to be flourishing in the most rapidly growing companies.

Another issue of basic health of the industry relates to the supply of adequately trained professionals. Figure 4-4 depicts the microelectronics industry's requirements for technically trained professionals if the microelectronics industry is to continue expanding at the rate that it has experienced over the last decade. In effect the figure points out that, if this expansion occurs and if our current rate of production of "computer specialists" continues, then all computer specialists in the United States will be devoted to design of new microelectronics chips by 1990, an obviously impossible situation. Either 1) the rate of growth of the industry must decrease, 2) productivity aids in chip design must be developed, 3) the rate of production of trained professionals must significantly increase within the United States, or 4) the development tasks, and the market, will be increasingly assumed by firms in other countries. Thus there are employment and education policy implications in the continued development of international trade in the personal computer and related industries.

4.3.2 International Trade Policy

As alluded to previously, foreign governments have frequently engaged in practices which are in restraint of free trade. Although occasionally the barriers to free trade have been tariffs, the most common contemporary restraints are nontariff barriers, such as import quotas, export subsidies, tax incentives, and quota-like import restrictions.

Contemporary economic thought, regardless of the diversity of "solutions" offered for current economic woes of the United States, appears to agree that reactions by the United States to the barriers to free trade just mentioned should not include the development of similar barriers unless foreign governments prove to be otherwise intransigent to other means of persuasion. Rather, our best long term interests are served by our insistence on, and actions toward enforcing free international trade. The recent reorganization of the Executive Branch to centralize U.S. International Trade activities in to a policymaking arm, the U.S. Trade representative, andan enforcement arm in the Department of Commerce, appear to be the first step toward achieving this goal. However, this newly reorganized body of Federal personnel are still not the equivalent in political power and prestige to its counterparts in the other developed countries. For example, a single individual in the office of the U.S. Trade Representative has a responsibility for developing trade policy for the automobile, computer, and electronics industries, a task for which large staffs are employed in our competitor countries. Although numbers of bureaucrats and consequential productivity improvements are generally considered to be antithetical in the U.S., the evidence from abroad indicates that highly qualified international trade bureaucrats, in Japan at least, can have definite positive effects on the economy. Unfortunately, press reports indicate that the new organization is making little progress toward effective countermeasures.

Finally, the issues discussed above are not ones whose consideration can be deferred indefinitely. The personal computer industry is representative of a number of high technology industries in the United States which face serious challenge from foreign competition within the next few years. It is much more difficult to capture the dominant share of a developed market than it is a developing market. Personal computers clearly constitute a developing market, one in which the United States is presently dominant. If, over the next decade while the personal computer market is maturing, firms from other countries capture the dominant share of the personal computer market, due in part to the international trade policies of their governments -- and the lack thereof on the part of the U.S. government -- then a recapture of the market by the United States will be considerably more difficult.

MICROELECTRONICS INDUSTRY
ENGINEERING REQUIREMENTS [2]

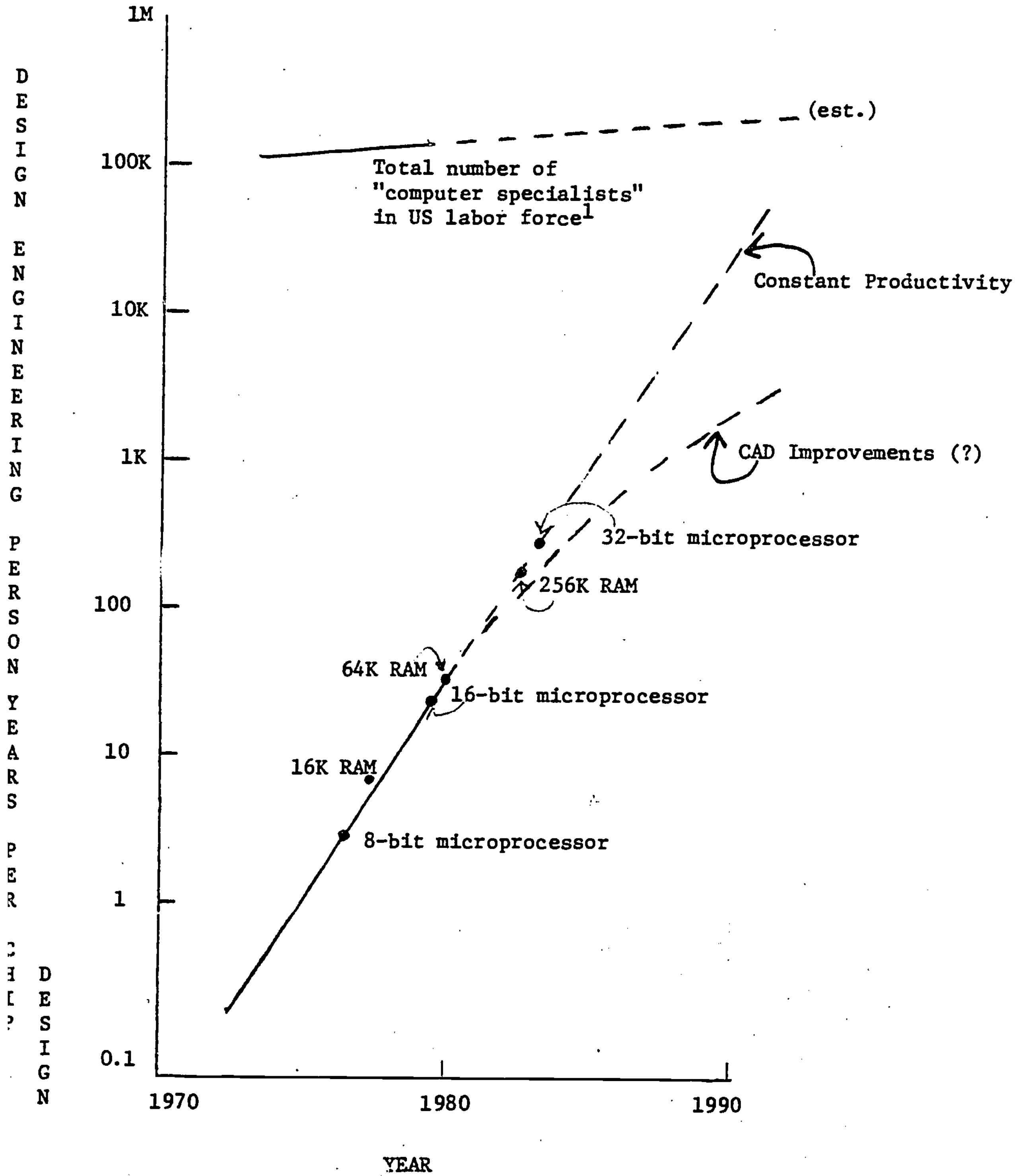

FIGURE 4-4

1 Source: Science Indicators, 1978.

2 Source: Moore's Law; Science, 2 May 1980, p.483; JMN Calculations.

Policy Implications
International Trade

At present, we have a variety of options available to insure the continued health and international competitiveness of the personal computer industry. These are summarized in Table 4-5.

4.4 Synthesis; Interactions and Dynamics

Several things have become apparent as a consequence of our research into the public policy implications of personal computers. First, it is clear that personal computers will affect public policy decisions at all levels of government from federal to local. Second, many of the impacts of personal computer technology, although not necessarily unique in their basic nature, will directly affect individuals on a scale comparable to that of the telephone, television, and the private automobile. Third, many, if not most, of the policy issues of personal computer technology development are highly interrelated. Education policy, to the extent that it affects computer literacy, has effects on employment. Increased computer literacy among the employed, to the extent that it improves productivity, directly or indirectly affects the general international trade competitiveness of the United States. The continuing availability of improved personal computer hardware and software, as a consequence both of increased international trade and increased employment in the industry, creates greater requirements for computer literacy, which in turn creates increased demand for improved and less expensive hardware and software, and so on. It is impossible, at this stage of our knowledge of the details of these interconnections, to quantitatively assess the degree of synergism resulting from specific sets of policy decisions. A considerable amount of "homework" has yet to be done.

It is also apparent that these interactions are not "steady state" in nature. There is time interdependence among them. We postulate that there may be some critical series of time dependent and interrelated policy decisions in education, employment, and international trade, among others, although we have only begun to explore them. The time dependence must include consideration of the actions of others in other countries as well as our own.

Of particular importance is the necessity to take into account reaction or "start up" times in making these decisions. If, for example, we are to have a substantial increase in computer literacy by 1990 in order to correspondingly increase workforce productivity and improve our competitive position in international trade, we must first establish and implement educational policies leading toward increased computer literacy, create market conditions for the development of suitable software and hardware, ensure that proper curricula exist for training teachers in the techniques of computer literacy, provide incentives for teachers to be trained, and then begin the education of the future computer literates. Although some of these activities can be carried out in parallel, others are sequential. All are necessary conditions to the success of the overall policy action. Some of the requirements are being and will be satisfied by market processes, others will need assistance from government policy actions.

POSSIBLE IMPLEMENTATION Mechanism / POLICY MAKING ORGANIZATION	DIRECT PROCUREMENT	MANDATED PROCUREMENT	RISK MITIGATION	LICENSING	Property Protection	TRAINING	TECHNICAL ASSISTANCE	EXCLUSIONS (TARIFFS, NTBS)	INFORMATION DISSEMINATION	COMMENTS
Executive Office of The President U.S. Trade Representative			x	x	x		x	x		Establishment of Trade Policy
U.S. Congress	X	X	X(R&D)			X	X	X	X	Budget Approval, Restrictions
		X	X	X	X			X		Regulatory, Patent, Copyright Legislation
Dept. of Commerce				X			X		X	Export Assistance
		X		X	X			X		Trade Treaty Enforcement, Tariffs
			X				X		X	Standards
			X			X	X		X	Trade Adjustment
Depts. of Defense, NASA, HHS	X	X	X				X	X	X	Procurement, R & D
				X	X					Patent, Copyright Licensing
						X				Personnel Training
Education						X			X	Computer Specialists, Computer Literacy
		X	X					X		School Support, R & D
Department of Justice			X		X					Limited Antitrust Exemptions For Technological Innovations
Treasury Dept. IRS			X							Corporate and Personal Tax Incentives
GSA	X	X	X							Market Stability Through Large Volume Steady Ordering
Patent Office					X					Software Protection
Copyright Office					X					
Small Business Admin.			X				X		X	Loans to Innovative Firms
			X				X		X	

POLICY IMPLEMENTATION OPTIONS - INTERNATIONAL TRADE

TABLE 5