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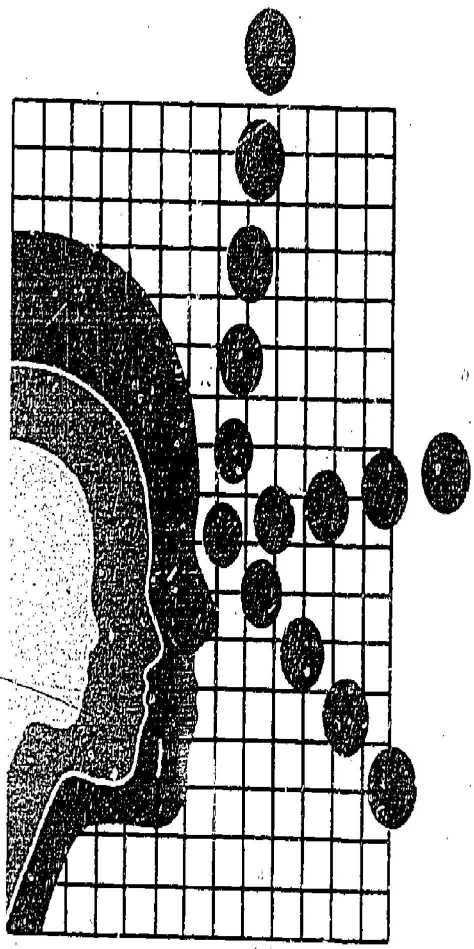
ABSTRACT

The report examines cultural and social forces in the United States which discourage innovation and creativity. The history of American innovation is reviewed; innovation is defined as the process by which new knowledge is generated and applied in the material and intellectual operations of society. Effects on innovation of the changing economic environment are noted; and trends in demographics, education, institutional structure, and the international environment which work against innovation are analyzed. Schools are criticized for ignoring the needs of gifted and talented, treating science as a fringe benefit that can be deleted from the curriculum, and developing a two track academic and vocational system. Informal learning environments which stimulate innovative skills are said to involve parenting and personal contact, toys as a teaching tool, film and drama, books and magazines, science museums, television, and prizes and awards. Six critical issues in public school education are raised, including the identification and encouragement of the specially gifted and the rejuvenation of an aging teaching population which enjoys tenure but suffers from professional obsolescence. Also considered is the situation in professional education, the corporate environment, university-industry relations, and military training. Recommendations are made regarding informal learning environments, continuing education, public schools, vocational education, government/industry/school system participation, and university/corporate cooperation. (CL)

CTAB RECOMMENDATIONS ON

Learning Environments for Innovation



A Report of the
Commerce Technical Advisory Board
to Jordan J. Baruch
Assistant Secretary for Productivity, Technology and
Innovation

This report was prepared for CTAB under the direction of Anne W. Branscomb, Chairman, Kalba Bowen Associates, Inc., and a member of the Commerce Technical Advisory Board. This report does not necessarily represent the policy of the Department of Commerce or any other agency of government.

DEPARTMENT OF COMMERCE · UNITED STATES OF AMERICA

U.S. Department of Commerce
Philip M. Klutznick, Secretary
May 1980

Contents

4

...ericans— An Innovative People

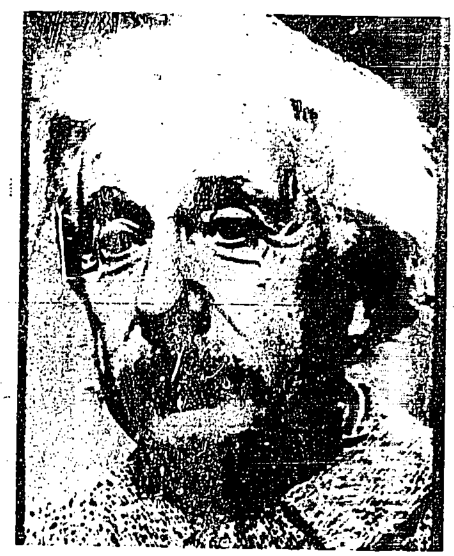
...ns pride themselves on ... innovative people. In ... days settlers made ... axes to clear the forests ... scythes to cut the tall ... constructed schooners ... the tricky coastline ... rifles to defend ... in the outposts. Later ... the frontier was con... American ingenuity built st... powered vessels much im... over the European frig... they invented automobiles t... come great distances rap... id... and became the first to fly in

self-prop... motorized ...anes. The heroes ... American ... klore include the names of as many inventors from Frankl... Edison as presidents ... as ... entrepreneurs ... Hewlett and Pack... heroes. In the minds ... observers the American econ... and its high standard of livi... have become inextricably ... up with innovation. Indeed ... January 1978 Harris poll ... ated that a majority of Americans expect U. S. leadership ... science and technology to help solve the problems of inflation, unemployment, and trade deficits. Yankelovich, Skelly and White in their "Monitor 1979" find that 80 percent of Americans have a modest to strong faith in science and 76 percent expect life to be simplified by technology.

In view of this long-held tradition the U. S. has been particularly jolted in recent years by the growing perception that our continued leadership in innovation may be threatened.

Perhaps our society in its maturity has become less tolerant of the pioneer spirit which characterizes the American dream. However, if we really wish to "encourage a new surge of techn... al innovation by U. S. indust... in the generations now grow... up in the country, the pool of ... an resources for innovation m... increase rather than diminis... and we must examine the instit... ons and environments in which such skills are encouraged and nourished.

We know that the innovative urge and entrepreneurial behavior are culturally biased [2] and the environments in which they can be fully realized have historical dimensions; e.g., in the late nine-



teenth century Marconi's Irish mother took the young Guglielmo and his crystal radio from Italy to England because she felt his invention would be readily received and find willing investors to promote its development.[3]

The United States is primarily a population of migrants, many of whom left their homelands to escape conformity or depressed economies which offered few opportunities for improvement. The great economic expansion of the United States may have been fueled by a liberal immigration policy which permitted the most adventurous and creative minds to escape the institutional confines in their native lands which restricted them from realizing their potential. Today there is increasing fear that prevailing attitudes and forms of behavior which occur in the educational, industrial, and informational environments of a mature United States society tend to discourage rather than encourage innovation. In the growing public and private bureaucracies where zero based budgeting requires constant justification of cost/benefit ratios, the reward system favors conformity and efficiency. Thus, both failure and risk taking are discouraged. Yet failure is not a luxury in the innovative process, but a necessary component of a process which filters out the more productive and successful technological innovations. When one of Thomas Edison's discouraged associates suggested they give up because almost every experiment had failed, the optimistic inventor responded, "Failed, no. We have learned several thousand things that do not work."[4]

We are concerned, therefore, that we may not fully understand the reasons why we have been a more innovative society than others or how recent historical forces may be increasing the odds against a more innovative future.

II. What Is Innovation?

We have chosen an expansive view of "innovation" because we believe that the United States is moving from an economy based primarily on manufacturing to an economy based upon services, and particularly information services in which artistic and aesthetic skills may be as important as technological ones. Furthermore, artists and musicians also rely upon technological innovations to further their productivity—as in the use of acrylics in painting and electronic devices to amplify, record, and even create musical sounds. Thus, we adopted the following definition

"By innovation we mean the process by which new knowledge is generated and applied in the material and intellectual operations of society."

This definition is broad enough to include not merely products but also services and artistic endeavors of an innovative nature which contribute to the economy. It is also broad enough to include the knowledge producer or theoretical work which is the basis of invention as well as invention, the entrepreneurial talent which packages the invention or new idea for market, the supporting personnel who take the new product or service to market, and the consumers whose receptiveness make new products successful.

We cannot exclude public receptivity as an integral part of the innovative process. The general cultural climate in which the intellectually curious and inventive and entrepreneurial people in society can come forward and be productive is as important as the assurance that the active participants in the process will obtain the necessary skills to carry out their chosen missions. Therefore, sympathetic taxpayers and willing consumers are equally as important as knowledge generators, inventors, entrepreneurs, and marketeers if innovation is to be successful.

III. Why Is Innovation Important?

We agree with President Carter that improving the environment for innovation is essential in maintaining a healthy economy.

"Industrial innovation—the development and commercialization of new products and processes—is an essential element of a strong and growing American economy. It helps ensure economic vitality, improved productivity, international competitiveness, job creation, and an improved quality of life for every American. Further, industrial innovation is necessary if we are to solve some of the Nation's most pressing problems—reducing inflation, providing new energy supplies and better conserving existing supplies, ensuring adequate food for the world's population, protecting the environment and our natural resources, and improving health care." [5]

We have agreed upon the major reasons why the United States must remain an innovative economy.

1) A high level of productivity is a necessary foundation to maintaining the quality of life expected by most Americans. The major strength of the United States economy in international markets has been and will continue to be based upon technological expertise, products, and processes. Thus, the creative genius of United States scientists, engineers, and the skills and foresight of technicians, administrators, and investors who translate this force into marketable products must be identified, encouraged, and nourished.

2) The United States faces more and stronger competition from other developed nations, Japan and Germany particularly,

but will also continue to face greater competition in international markets as developing countries fulfill their aspirations for economic growth. Thus, turning around a negative trade balance and maintaining a strong position in international markets may require greater innovativeness than we have experienced in the past.

3) As a mature industrial economy, we have placed substantial inhibitions on production such as control of gasoline exhaust fumes, and recycling of waste products, so that alternative technology for solving the problems of modern society is a necessary attribute of survival.

4) The United States is dependent on other countries for natural resources, particularly oil, and must rely upon its innovative talents to develop alternate means for satisfying the needs of its economy.

5) The mutual interdependence of nations in the world's economy and wise management of global resources will require innovative thinking not only in the use of high technology, but in organizational structures and procedures for greater international cooperation.

IV. The Changing Economic Environment

Although there is much ferment in the news about the faltering rate[6] of innovation in the United States, we do not have direct quantitative evidence that the rate of innovation has fallen off since the sixties. Indeed, some sectors of the economy such as semiconductors are enjoying a burst of innovative activity.[7]

While average labor productivity has not been increasing as rapidly as it had been, this fact may be influenced by a number of factors.

1) In a steady state economy which has already achieved a high level of productivity, it may be more difficult, i.e., require "more" innovation to induce additional productivity gains under conditions of high than of low productivity. Presumably, the early technological changes could have skimmed the cream of "easy" labor economies.

2) Increases in productivity in services and government, if there are any, are difficult to measure, because it is hard to distinguish measures of inputs from measures of outputs in such sectors. These sectors constitute a growing proportion of total output.

3) Changing social and environmental priorities pose significant challenges. It is sometimes hard to increase productivity while maintaining environmental standards. Older populations require more medical attention than younger, and so on. Under these conditions, it may be deceptive to gauge the rate of innovation by the rate of increase of factory productivity. In another perspective, our society is now committed to maintaining the well-being of a larger number of non-working citizens than previously and to making educational, medical, and other services universally available to all citizens regardless of their individual earnings.

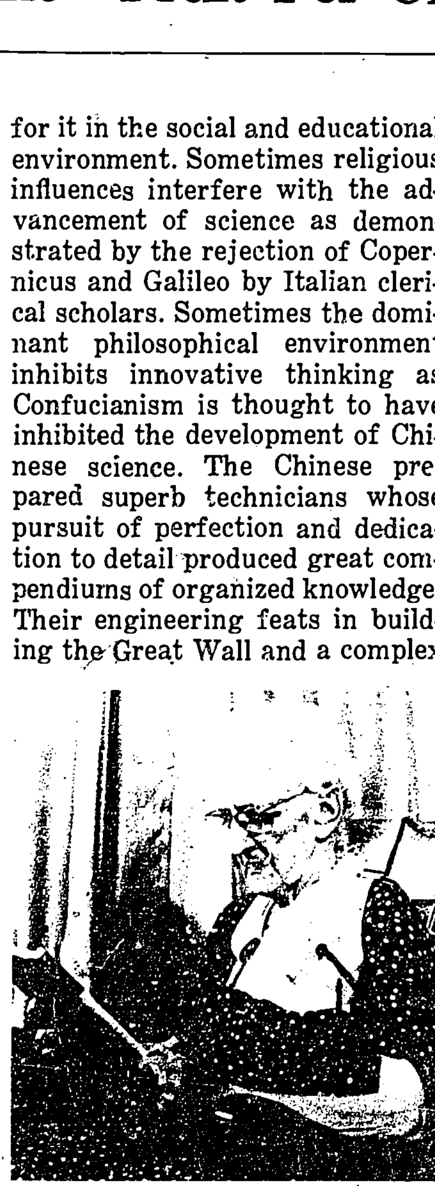
These commitments make real demands on productive resources that are larger than most people are ready to acknowledge. With deceleration in productivity gains we are faced with inflationary pressures in our attempts to supply these amenities. Given the changed demographic composition of the population and increased levels of government programs, even the old rates of innovation would probably seem inadequate to meet current social demands. It may well be that public disappointment with the inadequacy of innovation should be seen primarily as a matter of increased challenge rather than atrophy of the innovation process.

V. Seeds Of Decline—Fruit For Challenge

The decline of innovation—or at least its failure to grow—is not a new phenomenon in the history of science and technology. Over the years many countries have moved into leadership positions in a given branch of technology, only to founder and sink into second place or worse, while others assumed the lead.

Many reasons can be found for such shifts in position—ranging from serious political upheavals to simple stagnation, and from aggressive competition to placid lack of concern. One of the historically recent examples of upheaval is that of Germany, which was once paramount in physics and mathematics and in the technologies that sprang from strength in these disciplines. However, with the rise of Nazism and the persecution of academicians, the nation's leadership role in these fields slipped badly. On the other hand, the scientists persecuted by Germany fled to the United States, where they helped make the United States the world's leader in atomic physics and its products.

In contrast to violent upheavals innovation can suffer simply because there is no encouragement for it in the social and educational environment. Sometimes religious influences interfere with the advancement of science as demonstrated by the rejection of Copernicus and Galileo by Italian clerical scholars. Sometimes the dominant philosophical environment inhibits innovative thinking as Confucianism is thought to have inhibited the development of Chinese science. The Chinese prepared superb technicians whose pursuit of perfection and dedication to detail produced great compendiums of organized knowledge. Their engineering feats in building the Great Wall and a complex network of canals were also unmatched historically. However, the penchant of Confucian scholars for long fingernails and quiet contemplation separated the thinkers and philosophers from the makers and doers unlike the American frontier society where thinkers, makers, and doers were all wrapped into one. Thus, Chinese science seemed to lack intuitive, speculative, and deductive insight to push forward the frontiers of science.



Sometimes a decline in improvement in the environment for innovation is due to social forces. The Japanese in the early part of the twentieth century seemed able only to copy Western manufacturing designs and technology which they were able to do exceptionally well with lower costs and sell at a competitive advantage on the international market. However, the Japanese were astute enough to transform their imitative talents to innovative skills. Even by the second World War they were becoming leaders in the field of optics. Certainly their post war policies have contrived to promote high technology fields where innovation in the automotive industry and consumer electronics have rivalled anything the rest of the world has to offer.

The seeds of decline may be rooted in various evolutionary changes that are appearing on the American scene. We see alarming trends in four areas:

(a) the shifting and aging composition of the population;

(b) the divergence of intellectual and manual skills in our classrooms;

(c) the increasing size and bureaucratic structure of our institutions;

(d) the increasing complexity, diversity, and competitiveness of the international marketplace.

A. Trends in Demographics

The reasons for our concern about a continued flow of innovative human resources moving into the labor force are derived from the following demographic trends:

1) The population is aging as a result of better health care and nutrition and as the younger generations are giving birth to fewer children. Life expectancy has increased since 1900 from 48.2 years to 69.7 years for white males and 51.1 years to 77.3 years for white females. Even more dramatic are the increases in life expectancy for blacks, from 32.5 years in 1900 for males to 64.1 years and from 35 years to 72.6 years for females. The average household has decreased since 1790 from 5.79 persons to 3.14 in 1970 (which included extended families) but the birthrate has also been decreasing steadily from 55.2 per thousand in 1820 to 18.4 per thousand in 1970 and only 13.8 per thousand for white females in 1976. The "greying of America" portends ominously, for innovation is primarily the province of the young, according to conventional wisdom.

2) Unprecendented numbers of women are entering the labor force—approximately one million more each year. By the first half of 1979, about 43 million women —51 percent of all women over 16—were in the work force. Women as a percentage of the civilian labor force have increased their numbers from 32.3 percent in 1960 to 41.2 percent in 1979.[7a] Woman are less than 6 percent of scientists and engineers and a tiny fraction of technicians and craft workers. Despite affirmative action, they continue to be primarily in traditional female-dominated fields.

3) Minority youth are proliferating both by higher birth rates and immigration, legal and illegal, from south of the border. Projections of current trends from 3.1 million in 1960 to 19 million today indicate Americans of Spanish ethnic derivation will be our largest minority by the year 2000. Those of Hispanic and Afro descent represent an abnormally high ratio of the unemployed; compared with the overall unemployment rate of 6.3 percent in the first quarter of 1979, blacks have twice as much unemployment at 12.8 percent and Hispanics at 8.3 percent. It is a common concern that such youths are often discouraged from critical educational training which is prerequisite to careers in science and mathematics; as well as later employment in high technology companies.

B. Trends in Education

Public education in the United States is a matter of public concern in general, but we are particularly concerned about trends which augur ill for the future if we wish to foster the identification and development of innovative talents:

1) Proposition 13 fever means fewer financial resources for public education.

2) The "back to basics" movement treats science as a fringe benefit which can be cut from the curriculum.

3) Competency tests tend to drive all education toward a national median level of acceptability. Thus, the primary purpose of public school education is directed toward a remedial goal rather than attaining excellence.

4) The separation of vocational

education from the college bound or academically oriented curriculum leads to a two track system which discourages the manually trained from developing their conceptual abilities and may also handicap the intellectually gifted from the kind of "hands on" experiences which may include the likelihood that they will become innovators.

5) In their march toward egalitarianism, public schools have neglected the special needs of the academically gifted and unusually talented from whom innovations are most likely to come. Indeed, some school systems are now recognizing that the problems of the "severely gifted" can be at least as difficult to handle as those of the disadvantaged and physically or psychologically handicapped.

C. Trends in Institutional Structure

The American dream persists as one rugged individual conquering the world, and the research literature on entrepreneurship supports the thesis that the small company is a seed bed for innovation. However, the historical trend is toward larger and larger entities for better management and more efficient utilization of economic resources. This trend persists for business, government, and educational institutions alike.

Although small companies produce more patents per capita, 35 percent of the R & D in the country resides in only eight large companies and 80 percent of it is in the Fortune 500. Thus, the human resources for innovation are more likely to reside in large companies where the marketing skills and capital to support development are readily available. The successful marketing of a new product most often occurs in a well established corporation which is seeking new products and services, but also has the working capital and skills to couple invention with consumer demand. Also, small start-up companies operate most effectively in a symbiotic relation to large companies which may give birth to innovation through an exodus of talent which feels stifled or through active encouragement and capital investment in the new venture. The parent company or another large company may later provide development capital by acquisition or merger. For instance, Bell Labs spawned Texas Instruments, IBM spawned Amdahl, Control Data gave birth to Cray computers, and Fairchild fathered the entire Silicon Valley complex of small specialty electronics companies in the San Francisco Bay area. Many of these companies now supply components or services to the companies that gave rise to them and in turn use their products and services. However, the success of such spinoffs depends on the existence of considerable venture capital which in turn depends on an atmosphere of optimism toward the future. In view of the recent wave of regulatory negatives as well as the problems of inflation, very few spinoffs have occurred recently as compared to the period of 1955-65.

On the other side of the coin, some capital-flush companies merge with innovative but capital poor small companies, which then become branches or subsidiaries of the large company. General Tire absorbed Aerojet General, a rocket manufacturer; Rockwell picked up a number of smaller companies once associated with North American Aircraft; General Motors, General Electric, RCA, Honeywell, have all expanded in part through acquisition of small innovative companies. It is important therefore to place high priority on improving the corporate environment and nurturing its human resources as well as in encouraging cooperation with universities to optimize the chances of eventually fertilizing the soil for innovation.

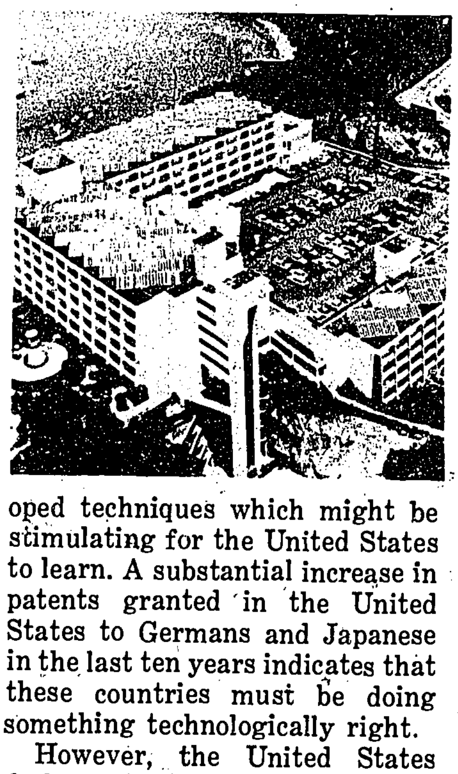
Moreover, we must be concerned about management of human resources for innovation within the corporate environment as well as the education of decision makers who influence corporate choices for product development. The reality of corporate innovation is a far cry from the Thomas Edison image to which the public clings[8] and requires substantial teamwork and complex interaction among individuals with a variety of skills.

The management of a large public sector and non-profit institutions is at least as troublesome as those of larger corporations. Here the profit motive or growth rate provides no measure of success. Yet the decisions concerning grants from foundations and government agencies, as well as direct procurement and development of public policy in governmental institutions requires a sensitivity and understanding of the innovative process—and last, but by no means least, the management of large universities affects the working environments of that category of human resources from which the greatest expectations exist for ideas to fuel the innovative process.

D. Trends in the International Environment

For years America has been the mecca for the technologically aspiring countries of the world. The best and brightest of the developing world—India, China, and the South American and African nations—have flocked to American universities and corporations to learn the latest science and technology which could then be applied back home. Similarly the United States has held special attractions for the Germans and Japanese, whose own centers of learning had been depleted during and after World War II. The brain drain—the movement of leading innovators from abroad to the United States—was a significant factor in United States technological growth in the fifties and early sixties.

Today both Japan and Germany have strengthened their educational institutions and have developed techniques which might be stimulating for the United States to learn. A substantial increase in patents granted in the United States to Germans and Japanese in the last ten years indicates that these countries must be doing something technologically right.



However, the United States finds itself ill positioned to take advantage of these developments. For one thing, the number of U. S. citizens who are literate in any foreign language is small. This was underscored recently when the White House had to scurry to find a Chinese interpreter in anticipation of the recent visit of the Vice Premier of the Peoples Republic of China. A qualified individual was located only at the last moment. The Presidential Commission on Foreign Languages recently reported that the number of United States colleges requiring a foreign language for admission has fallen dramatically from only 34 percent in 1966 to a sparse 8 percent today, a "scandalous incompetence", according to the commission, in a country which purports to lead the world diplomatically as well as technologically.

The encouragement of innovation fueled by the ideas of scientists and engineers abroad will be greatly helped by changes in American education. We will need heightened foreign language training, as well as the increased translation and distribution of literature related to innovation from foreign sources as recommended by President Carter in his October 31, 1979 message to Congress. In addition, we should increase reciprocal exchanges of scholars and technicians with countries from which we have as much to learn as they from us.

VI. Exploding Myths About Innovation

There are three myths about the innovative process which we would like to dispell:

1) That scientific discovery and invention are isolated activities which take place in ivory towers and/or garages.

2) That scientists and engineers are a strange breed of animals.

3) That education for innovation takes place only in public schools and universities.

The optimum learning environment that can nurture innovation continues to be something that is elusive. But one thing is sure—isolation seldom produces anything new. The myth of the genius locked in a remote ivory tower developing an earth shaking breakthrough continues to be just that, a myth. Only the social and intellectual exchanges that occur through formal and informal networks of communication and inspiration will generate sparks that fire up the spirit of those individuals who will become the innovators of tomorrow. To quote Dr. Allen S. Russell, Vice President for Science and Technology, Aluminum Company of America:

"While the hero concept is a charming notion, it has little basis in fact. For surely, few of mankind's great inventions and discoveries were the result of one person's perception, talent, or wisdom. Rather the germ of an idea must grow and swell in the minds of many people, until one day the hero adds the spark that makes it a workable entity." [9]

We reject C. P. Snow's "other culture" as a model. Scientists and engineers are human beings very much like other human beings. They watch football, go to the movies, and live in large metropolitan areas in much the same way other citizens do. Two of the most successful communities for innovative enterprise in recent years have been Boston's Route #128, and San Francisco's "Silicon Valley". Both areas have first rate universities, a high level of cultural activity, and ample opportunities for recreation. Many scientists/engineers are musicians, opera lovers, sailors, mountain climbers, even devotees of the Grand Ole Opry. To suggest otherwise, as television often does, will accelerate the exodus of talented young people from the fields of science and technology.

Concerning the third myth of public schools and universities having a corner on education—we note that learning takes place at diverse times and in odd places—watching television, reading a book, visiting a museum, walking through the woods, or engaging in lively conversation with one's colleagues. Indeed, as the educational system comes under more and more stress and has less relevance to today's world, less education takes place inside formal educational institutions and more by individual acquisition. Moreover, as the pace of technological change accelerates, more training occurs on the job or in a corporate environment where the skills are known and the new knowledge generated.

VII. Understanding Innovation Environments

What are the social forces at work in our society which may inhibit our ability to innovate? What social levers can we push or pull which may improve our chances to innovate? Many of these factors have been identified and addressed by the Department of Commerce. New policies have been recommended by the President, Congressional and industry leaders. It was not our intention to duplicate, analyze, or replicate these efforts. What we have tried to address are the longer term environmental factors which affect the development of human resources for technological innovation. Those we have identified are neither intended to be exhaustive nor all inclusive. We are merely taking another small step to improve our understanding of ourselves as an innovative people. We have identified some of the learning experiences which stimulate, nourish, and encourage innovative skills. We hope this small but intensive effort will stimulate others to more thoughtful, careful, and long term consideration of these problems.

A. Informal Learning Environments

1. Parenting and Personal Contact

"When I was a boy Dad and I took long walks in the woods and he showed me things I would never have noticed by myself. He told me about the world and how it looked many years ago. He would say: 'See this leaf? It has a brown line; part of it is thin and part thick. Why?' And when I tried to answer my father would make me look at the leaf and see whether I was right and then he would point out that the line was made by an insect that devotes its entire life to that project. And for what purpose? So that it can leave eggs which turn into new insects."

"My father taught me continuity and harmony in the world. He didn't know anything exactly, whether the insect had eight legs or a hundred legs, but he understood everything. And I was interested because there was always this kick at the end—a revelation of how wonderful nature really is."

Thus Richard Feynman, a Nobel Prizewinning theoretical physicist, reminisces and intimates that stimulation and encouragement and early background are important considerations in developing innovative individuals in the sciences. To what extent, of course, is not known. In one of the few studies extant, Ann Roe studied the backgrounds of leading scientists and mathematicians and found that in most cases it was not the father's influence which was most important but that of a loving, caring mother with artistic or musical talents who took her son to art galleries, concerts, and museums.

We know that learning does not start when a child enters school nor stop when the young adult receives the imprimatur of an M.B.A., LL.B., J.D., or Ph.D. Thus, we are concerned about the parenting process both prior to and during the school years. We need to know more about the family environment which sparks creativity and risk taking and the manner in which families or related individuals learn together or support each other through reading books and watching television, excursions to historical sites, such as Kitty Hawk or Cape Canaveral, and museums such as the Smithsonian or San Francisco's Exploratorium where both children and adults can experience physical phenomena and the excitement of scientific discovery. We also need to focus on community organizations such as Girl Scouts, Boy Scouts, and Junior Achievement which pair young people with adults of special talents and skills which neither parents nor schools can provide. We need to understand the mutual support systems which provide an underpinning for or motivation to innovate. For example, although the phenomenon of a large number of theoretical physicists having come from Hungary and through a specific high school in Budapest is well known (e.g., Edward Teller, Peter Goldmark), what is not so well known is that all did not receive the same educational training, but all of their families were well known to each other so that the key ingredient may have been culturally rather than institutionally based. The existence of an intellectually supportive network of human beings, "the invisible college", seems to foster innovation as does the mentor relationship or apprenticeship. The one surrounding Albert Einstein was called, "The Olympian Academy", and one organized by Benjamin Franklin was called, "The Junto Society".

The role of early childhood contacts—and supportive networks of parents and relatives and friends—has not been well explored. Such a study might shed light on the underpinnings of innovative success in the individual.

2. Toys as a Teaching Tool

In his autobiography, the maverick inventor, Peter Goldmark, recalls that one of the early influences on his career was the toys he found in a neighborhood store. Such things as a "coherer", a predecessor of the radio, and a variety of lighting gadgets fascinated him and led him to develop an interest in electronics.

We need to understand better the role of toys in the learning process and whether or not parental or other supervision is a necessary ingredient to successful absorption of useful information. Interestingly enough, since most of the social research on television has been federally funded, the bulk of the findings are related to the deleterious effect of sex and violence in television upon the actions of children.[10] Virtually nothing has been generated to determine what positive effects may have resulted, for example, from the vast coverage of the space exploration and moon landing which appear to have spawned a new generation of television programs like "Star Trek", "Battleship Galactica", "The Six Million Dollar Man", "Bionic Woman", and multimillion dollar movie successes such as "Star Wars" as well as their toy counterparts. These represent a substantial portion of the $3.4 billion a year toy market or $95 per year per child which is invested in this informal learning environment of childhood.[11] We are reminded in observing the proliferation of science fiction programs and their toy offspring of Sir Arthur Clarke's comment:

> **"The purpose of science fiction is to prepare people to accept the future without pain and to encourage flexibility of mind. Politicians should read science fiction not westerns and detective stories."** [12]

If we wish to encourage innovation rather than destruction we may be encouraged by the increasing popularity of computer games (10 percent of the toy market) over toy pistols, tanks, and submarines. Public policy could provide tax incentives for the development of toys which spark imagination and encourage innovation in much the same way we foster investment in solar energy or exploration of gas and oil. It could also insure that research on the interrelationship between childhood play and learning skills is thorough and readily available to toy manufacturers who determine the nature of this important link in the innovative process.

3. Film and Drama

It has been a while since the popular dramatizations of the day treated sympathetically the lives of the hero-inventor-entrepreneur. The age of the generation which thrilled to Don Ameche's Alexander Graham Bell, or the lives of Edison, Louis Pasteur, and Madame Curie, is now over 50. No comparable modern versions of the lives of inventors Chester Carlson, Edwin Land, or David Packard have appeared. Even the entrepreneurial success of Ray Kroc's MacDonald Hamburger or Colonel Sander's Kentucky Fried Chicken has not attracted film or dramatic attention. Instead our film heroes have focused on pop stars like Elvis Presley and Elton John or social deviants like "Bonnie and Clyde". The film has made a tragic hero out of anti-technologists as in the case of Jack Lemmon in "The China Syndrome" who died while trying to convince the world of the dangers in nuclear generating plants.

In a recent review of innovation on the motion picture screen from 1939 to 1976, George Comstock discovered that only 3.6 percent of the 15,000 films depicted innovative activities at all.[13] Moreover, the trends were historically patterned both by genre and by period. While dramatic presentations were the more dominant vehicle during World War II and its aftermath (1939-52), the portrayal was less frequent, but the impression [illegible]ye[illegible] more positive. Durin[illegible]tnik era (1953-1963) [illegible]tnam War years [illegible], there was more freque[illegible]en[illegible]ion of innovation b[illegible]ss favorable commentary [illegible]

Science fic[illegible]s and horror films (of which about three quarters are science fiction) were the predominant vehicle in the Sputnik and Vietnam years. However, science fiction and horror films (41 percent of the films) presented a most pessimistic view of innovation as did comedy. About one of four of both science fiction and comedy films presented an unsuccessful attempt at innovation when the failure rate in the dramatic film was a mere 2 percent. Moreover, the science fiction portrayed not a single instance in which positive attributes of the innovator played a role. Ill consequences were credited with half the successes and the other half credited chance. Contrary to known fact that innovation is rarely the work of a single mind, in 75 percent of the films the innovator was a loner with another 10 percent attributing the work to a partnership. However, reflecting the current reality, 92 percent of the films portray innovation as a province for males only, although the trend has been downward from 95 percent in the Sputnik period to 87 percent in the seventies. As far as ethnicity is concerned, innovation on film is predominantly a North American (50 percent) and European (40 percent) phenomenon with no African participation.

The motivation prompting the innovation was more often malevolent in science fiction (38.46 percent), benevolent in drama (64.29 percent), and monetary in comedy (36.84 percent). The consequences are more often negative in science fiction but more often positive in drama (51.72 percent) or comedy (46.15 percent).

As far as offering attractive role models for young people to follow, the films as a rule more often portray negative consequences (usually death) for the innovator and more than twice as often negative consequences for other individuals, groups, or society. When the innovator is not depicted as decidedly malevolent, he is usually depicted as mad or consumed by the excitement of conception without regard to the social effects. Thus, the message seems to come through strongly and clearly that innovation is a mighty risky business because if the peril is not immediately apparent, it is bound to hit you sooner or later. "The Nutty Professor", a 1963 Jerry Lewis film, is probably typical of the comic portrayal of innovation—the discovery of an elixir which transforms the bumbling loner inept in the social graces and unattractive to the opposite sex into a suave, debonair, pianist-singer who is adored by the female students who formerly scorned him. The message is clear—get out of the lab if you want to be loved. So much for the contribution of film to motivating young people to become innovators.

One might take heart in the declining theater attendance, a decrease from an average 85-90 million persons weekly from 1939-1948, during which period drama presented innovation favorably, to only 40-44 million per week for 1960-65. However, one must keep in mind that the theater audience is predominantly young, 15 percent are 2-15 years old and 60 percent are aged 16-29. Moreover, the theater attendance must be augmented by the national TV audience of approximately 28 million daily in the afternoons and late evenings when movies dominate the TV screen.

What we must ask ourselves is whether exposure to films influences our opinions or merely reflects them. Certainly the subject matter of such dramatic productions reflects general social and political trends. It is no small coincidence that three new plays on Broadway treat severely handicapped, two contenders for the Academy Award involved returning disabled Vietnam veterans, and specials about retarded, sightless, and psychologically disturbed children are finding their way to the television screen.

The federal government is not completely lost as far as making a direct investment in diversifying the marketplace for films since approximately $1.5 billion dollars in films is funded by the U. S. government directly; many of these find their way into the school system. The greatest leverage that the federal government may provide to address the long term problem is through investment in the education of film makers, independent producers, and writers who serve both the television and movie industries — since people who write and produce both documentary and fictional drama are more likely to treat subjects which they understand and with which they feel comfortable.

However, this is not to advocate federal involvement in the content of entertainment, but merely to underscore the inadequacies of an educational system which segregates most students from exposure to technologically oriented subjects. For they cannot portray sympathetically subjects about which they have a long-standing aversion. Surely this is an anomaly of an educational structure which a society dependent for its economic health on technological innovation cannot tolerate.

4. Books and Magazines

The influence of books and articles on the lives of inventors seems well established. Marconi read of Hertz which sparked his interest in electronic communication;[14] Carlson went to the public library to glean information about image processing from which he launched xerography.[15] The early antecedent of the American Philosophical Society, the Junto, founded by Benjamin Franklin, promoted the establishment of the postal service to foster and encourage the exchange of written communication between peer groups of thinkers or "invisible colleges".[16]

Books and articles proliferate. We spend an average of $35.00 per person per year on books which may be found on almost any subject. On a technical level, many computer services have emerged that offer bibliographic information on almost any subject desired. On the popular level magazines on science are more diverse and widespread than ever. The largest and most popular science magazines are showing an annual growth of 18 percent in newsstand circulation and 14 percent total circulation. No other magazine category approaches this growth. Popular Science and

Smithsonian each have circulations of approximately two million, roughly *double* that of the new Life and Look magazines. Scientific American sells more over-the-counter copies than Esquire and has roughly *double* the overall circulation of this magazine as well as the New Yorker, Harper's, and the Atlantic.

Moreover, during the past year two more popular science magazines have hit the market:

1) Omni, which combines science fiction with scientific fact, and

2) Science 80, a popular vehicle by the American Association for the Advancement of Science intended to reach the general public rather than the scientific public which is served by Science magazine.

Three other publishers have announced plans for science magazines: Time, Inc., Hearst, and VNU, a Dutch concern.

Most of the major newspapers have science writers on their staffs and THE NEW YORK TIMES has started publishing a special science section several times a week.

There does not seem to be any reason for concern about the paucity of written material or its accessibility at the present time. Paperbacks are generally available at modest cost, and we are unaware of any severe deficiencies in library resources within easy reach of most citizens.

However, there may be a need to address the question of the future of the postal service and its impact on equitable access to books and periodicals which have enjoyed a subsidy for distribution. We may also find that transfer of distribution to electronic services or on line computerized data banks may restrict the availability of material to a smaller user group. It may also affect professional organizations that provide editing and publishing services for their members.

5. Science Museums—Learning By Doing or Participatory Exploration

For years museums have been regarded as dusty places where people stared briefly and dully at mummies and old coins. This is no longer true. Museums today have taken on a new vitality. They provide a sense of belonging to the excitement of our times. The Exploratorium in San Francisco offers the opportunity to learn by participation in activities that bear on modern technology. At the National Air and Space Museum in Washington, visitors can walk through a space shuttle, and can come close enough to rocketry through dynamic exhibits and movies to make them feel a part of the adventure. The Museum of Science and Industry in Chicago provides interactive computerized dialogs on economics, energy, communications, food, even a fairy castle to emphasize the role of fantasy to inspire innovation. In view of this it is no surprise that science centers attract 40 million visitors a year, 38 percent of all museum attendance.

A number of museums are exploring innovative outreach programs, presenting astronomy lectures in the national parks, taking hands on exhibits into shopping malls, conducting evening science policy debates and so on. Hundreds of trailside nature centers have been established throughout the country and many musuems engage in activities in cooperation with the formal school system.

But the immense potential of such programs is, in fact, greatly limited because there is very little systematic support for the science museum community. There are national endowments charged with the health of the arts and humanities as part of our cultural heritage. But there is no endowment for C. P. Snow's "other culture". Funding for science museums is inconsistent, sporadic, and largely of local origin, supplemented by occasional grants for research, experimental education and public understanding of science as well as occasional support for an "artistic" or "humanities" related event. Science centers are not even considered "educational" institutions by either the federal grant agencies or the corporate or foundation world. In a technological culture, where science and technology *are* the "humanities" of our time, this is incongruous.

6. Television—The Pervasive Teacher

Most of us know by now that people of all ages spend more time in front of television than they do anywhere else except in bed. Many people combine the two. What is the effect of all this viewing on the atmosphere for innovation?

Although television may not be the place where substantive knowledge for the innovator is acquired, it is the most likely environment where an early interest in children may be sparked and where the public will acquire the bulk of its understanding about technological innovation, if only because that is where both children and adults spend the most time. It is also the place where innovators may learn about the public attitudes and tastes to which they must relate if they are to be successful. Television viewing is a passive pastime. Even if the only piece of useful information is the overwhelming amount of time spent sitting rather than doing, that has implications for innovative activities.

We know from research findings that TV watchers do not usually discriminate about what to watch—the decision is to turn the set on or off.[17] Thus, some of us may discount the potential for optimization of innovation through the use of the TV screen. However, even if we assume that television is primarily an entertainment medium and not expected to bear the burden of explaining what $E=MC^2$ means to the layman,[18] nonetheless, we must be concerned about the cultural cues we absorb from this very powerful medium which eats up so much of our time, and from which the majority of us receive our only source of daily news.[19]

In this pervasive information environment, we know that many perceptions of reality are skewed to the TV version on the 17″ screen. Thus, the absence of programs about science and technology may be as significant as the available images.

The Annenberg School of Communications at the University of Pennsylvania which has a data base of 1,400 programs since 1967, found more than half involved a science related theme and about 5 percent have science or technology as a major theme. Of the 15,000 character protrayals, however, only 1 percent were portrayed in science related activities and 100 as scientists. However, the studies reflect the net effect of the exposure to television on the public's confidence in the scientific community. While only college educated whites have a confidence level of over 50 percent even with light viewing, the confidence level falls perceptibly with heavy television viewing for all categories except non-whites. They start from such a very low percentage (19 percent) expressing confidence that the 15 percent whose attitudes are changed only brings those expressing confidence up to one third of the black respondents. Even more disturbing is that the level of confidence drops the greatest (14 percent) among the college educated who are heavy viewers.

If television gives us our cultural cues, most Americans derive from television their attitudes about doctors, lawyers, political leaders, policemen,[20] scientists, engineers, and businessmen.

Ben Stein in a recent book, *The View from Sunset Boulevard*, has revealed how small in number are the television writers and producers who dominate the content of the TV screen.

"As I was writing this book, it became clear that Kracauer's thesis—that popular culture represents and reflects national dreams and nightmares—is untrue in the case of prime-time television. Television in this case represents nothing more than the

views of a few hundred people in the western section of Los Angeles." [21]

Ironically, although these few represent the realization of the American dream of a truly mobile society in which the ethnic migrant may rise from the ghetto through education, risk taking, personal effort, and imagination to become a millionaire — and many of them do, their view of the fruits of entrepreneurial spirit is quite negative.

According to Stein, the Hollywood view is that the entire world is run at worst by a conspiracy of bankers, financiers, and the Mafia, or at best by "a consortium of former Nazis and executives of multinational corporations". [22]

Not only is the Horatio Alger Syndrome, which dominated nineteenth century literature, dead, the social indicators are inverted. One producer described businessmen as "cannibals" (seeking nothing but profit) who distrust brilliant people. The ladder to success on TV is marked by greed and cheating. People on television are never motivated by social ethic, but only by personal gain.[23]

"It is also a world that largely inverts traditional standards of what is good and worthwhile. Education on television is absolutely valueless. Generally, a highly educated man is a fool or a knave. Deep thought is the villain's tool. . . . and only villains have a library." [24]

If television programs, like film, are giving the impression that inventors are as nutty as fruitcakes, scientists are bent on destroying the world, and businessmen are avaricious monsters without hearts—then children are more likely to choose to be a glamorous "Policewoman" or a private eye like Rockford. If our "best and brightest" shun science, engineering, and business for law school, then we are more likely to end up with more intricate, imaginative, and effective regulations than innovative new products—as recent history may prove more accurately than some might have wished. Indeed, if the only negative result on television is the survival of the math and science avoidance syndrome, as transmitted by the actors, writers, and producers who package our television fare, that may prove a substantial inhibition to public support of the innovative process.

However, if television has great potential to transit cognitive information (Bogatz and Ball, 1971, Alper and Leidy, 1970, Ward, 1972) and/or is the most powerful educational tool of our time (Newsweek, February, 1977) as some proponents believe, then we must be concerned about the factual content of televised information, as well as cultural cues, and the underutilization of this medium for educational purposes. Certainly, as Daniel Boorstin has observed, television is one of the most democratizing forces of our time since it is inherently avail-

Scientists On Network Dramatic Television

The Average Viewer of Network Dramatic Television Will See:	All Speaking Characters		Total Scientists		Women Scientists	
	Total	Major	Total	Major	Total	Major
Weekend Daytime (per week)	136	41	3	1		
Prime Time (per week)	300	69	1.5	.5		
TOTALS	436	110	4.5	1.5		
Weekend Daytime (per year)			156	52	10	1
Prime Time (per year)			78	26	19	8
TOTALS			234	78	29	9

Of these major characters, the following % are:	Daytime		Prime Time	
	% Scientists	% All Characters	% Scientists	% All Characters
Clearly "Good"	36	60	54	59
Clearly "Bad"	48	16	15	12
Clearly "Succeed"	29	44	54	36
Clearly "Fail"	43	21	16	16
Commit Violence	52	50	62	42
Suffer Violence	57	69	46	46

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Contribution of Television Viewing to Expressing "High" Confidence in the Scientific Community

National Opinion Research Corporation General Social Survey, 1975 (N=558)

	Percent Expressing "High" Confidence		
	Light Viewers of TV	Heavy Viewers of TV	CD*
All respondents	49	40	−9**
College educated	58	44	−14**
Whites	51	41	−10**
Non Whites	19	34	+15***
Males	48	44	−4
Females	49	37	−12**
News readers—daily	50	43	−7
Sometime news readers	46	33	−13**

*"Cultivation Differential"(CD) is % difference between light and heavy viewers
**Difference is statistically significant
***This CD was not statistically significant and did not hold up in subsequent surveys

These are preliminary results of a pilot study for the National Science Foundation's Public Understanding of Science Program. It comes from a large project called Cultural Indicators which has been studying dramatic network television and viewers' conceptions of social reality. For more information, write George Gerbner, The Annenberg School of Communications, University of Pennsylvania, Philadelphia, Pennsylvania 19104.

able to all[25] with TV in 99 percent of American homes, 50 percent with two or more sets. Moreover, the number of channels available for viewing has proliferated phenomenally over the last few years: 96 percent of United States homes receive four or more stations, 65 percent receive seven or more TV signals, and 27 percent receive ten or more.[26] So the three commercial networks can no longer monopolize television service to the American people. Indeed, over 30 percent of the nation's families have access to cable systems with 12 or more channels of service and 18 percent are already subscribing to cable service with over 2 million subscribing to additional programming.[27] Already eighteen different programming services are being transmitted to such subscribers via satellite and the Public Broadcasting Service has the capability to transmit three, soon four, different programs simultaneously. Thus, if television is a major educational environment, as many believe, then the opportunities for diverse programming to specialized audiences are becoming more and more available. The challenge is to find the will and the way to fund programs which will capture the imagination of the audience—for truly the TV set in the living room or bar, shopping center or schoolroom, provides access to all to a wider variety of information than currently available. Whether for entertainment, information, or instruction, TV will play a role in the innovative process whether planned or unorchestrated.

Thus, we believe a high priority must be to mobilize both public and private resources so we may optimize the use of this informal educational environment to improve lifelong learning and stimulate innovation.

The federal government can play an important role in this endeavor. The federal involvement today is not negligible. HEW has been a major investor in "Sesame Street" ($46.2 million), the most successful educational television venture to date. Other programs have been subsidized to bring minorities into the educational process. CTW, the producer of "Sesame Street", has recently launched a new television series, "3-2-1 Contact", to stimulate an interest in science among junior high school students. It is jointly funded by NSF and HEW/OE and United Technologies Corp., but this is only a small beginning to tackle a very large problem.

Previously the only regular program on science was "Nova", produced weekly by WGBH-Boston for PBS. The audience is estimated at 5 million. Another program developed by the BBC, sponsored for public television by AT&T, is "Connections", which is a free wheeling examination of the evolution of familiar technological discoveries. In view of growing public interest in science, however, some attempts should be made to draw commercial television into this area.

7. Prizes and Awards—The Joy of Achievement

In his autobiography, *The Wind and Beyond,* Theodore von Karman, the great Hungarian-born aerodynamacist, relates how a national mathematics prize, in Hungary known as the Eotvos Prize, led to the eventual development of the world's leading thinkers in mathematical sciences. "I tried out for the prize and to my delight I managed to win," von Karman reports. "Now I note that more than half of all the famous expatriate Hungarian scientists and almost all the well known ones in the United States such as Edward Teller, Leo Szilard, and the late John von Neumann have won the prize. Between von Neumann and me there is a twenty year difference in age so one sees the continuity started by this competition. . . ."

Prizes and awards help to nurture early the rare talents that may go on to become the great innovators of their time. Participation in science fairs, the winning of fellowships and scholarships, and other forms of recognition have historically stimulated young people to proceed with their careers in science and technology. Such awards are of course helpful to young people whose families do not have the funds to support promising talent.

However, one must recognize that not all awards are equally meritorious. Some of them reward patterns of behavior that are not necessarily reflective of the innovative spirit. They may reward the ability to acquire book information without sparking an inquisitive or creative mind which the Eotvos Prize was designed to detect. Under such circumstances the prize might hamper rather than encourage the innovative spirit.

New tests should be devised that help point out these distinctions among prize winners. The Office of Education has made some moves in this direction but needs further reinforcement. Insights into both the creative and entreprenuerial talents encourage innovation within the corporate environment as well as in the schools.

Widely publicized awards may also convey a sense of the importance of innovation to the public. Since most successful innovators are rewarded by the free enterprise system through the accumulation of financial wealth, it might be useful to establish a prize which is awarded to a person or institution named by the innovator as most influential in early childhood development and motivation. The chain of innovation can thus be given a personalized identity and recognition.

B. Formal Learning Environments

1. Public Schools

Marshall McLuhan once remarked that kids don't like public school because it interferes with their education. This is not just an irreverent cynicism. Most studies of innovative individuals, particularly in the sciences, do not regard the formal part of their schooling as the primary source of their inspiration. They may have first been motivated by a teacher, but they usually attribute early inquisitiveness to a personal contact often outside the formal curricuum. Thus, Glenn Seaborg, the eminent nuclear scientist, has nothing but praise for a high school teacher who encouraged him to study the physics that led him eventually to the Nobel Prize. Very often the success of a given school is due to the influence of a single teacher. This was true in the education of Fermi and was also true of the teachers of the Minta, the model gymnasium in Budapest which influenced the lives of such scientists as Szilard (atom bomb), von Neumann (computer), Teller (H-bomb), and von Karman (supersonic aerodynamics). These Hungarian scientists later provided the theoretical foundations of the technological age in America.

Of course the effect of teaching or the lack of it does depend on the student. As Peter Ustinov said: "About science Einstein and I had only this in common. We both hated the way it was taught to us in school. He transcended that. I drowned in it." [28]

On the other hand, an inquiring mind may overcome disadvantages of early environment. It is said that the black scientist George Washington Carver—who was denied access to the white school of his community—would surreptiously plant himself outside a school window and listen to the lectures of the white teacher, leaving the scene before he was caught. This formed the basis of his education, most of it self-managed, that led him eventually to produce his remarkable contributions to science.

Because the education system is the basic source of individuals who will provide increased technological capacity for the nation, the nature of the educational enterprise, including the use of the best technological practice, applications of the latest understandings, and attitudes toward innovation may well be of great significance. For this reason, it is timely and appropriate to review basic federal education policy to determine whether some shift in educational policy is needed to give greater emphasis to qualitative and talent development aspects.

Such a review need not and should not result in a simple reversion to principles and procedures for talent development of 25 years ago. Such a review would need to take into account the problems of increasing the participation of under-represented groups, such as minorities and women, in the nation's scientific and technical enterprise. There is evidence that traditional methods of educational selection are inherently discriminating against three groups. Thus, what is required is a new conception of the role of education in stimulating innovation and talent development while facilitating participation of previously excluded groups.

We are very concerned about the current state of public school education which has been described in a recent popular newspaper as a mess.[29] However, our concerns are very different from those of the journalist who described the "mess" as a failure to teach "basic skills". What we fear is that the basic educational philosophy is far too biased in the direction of remedial learning and fails to identify, much less foster the development of special talents or unique skills. The United States educational system is better at preserving convention than sparking invention, developing logical rather than conceptual thinking, promoting risk aversion rather than acceptance of change, specialization rather than multiple skills, conformity rather than distinctive talents, independent rather than joint responsibility. The Follow Through studies showed the basic education good for developing excellence and rigid discipline, but not so good for encouraging high attendance, independence, responsibility, or creativity.

A recent study of the Task Force on the Education of the Gifted and Talented to the Commissioner of Education reports that the schools are woefully deficient in their ability to identify gifted children. A gifted child has only one chance in twenty to be identified by the school system; for the gifted disadvantaged child the chances are a factor of ten worse—less than one chance in 200. The only category of five types used in which an acceptable level of performance is identified or recognized is "general intellectual ability". Thus, those with special academic or creative skills, or leadership, or manual skills have little chance of being recognized by the school system. Even if the unusually talented are lucky enough to be identified, the amount of money available to enrich their academic programs can only be described as shocking. Although gifted and talented students comprise 3-5 percent of the school age population, only .003 percent of the federal funds for education are allocated for their benefit. Even more distressing is the fact that only fifty teachers are being graduated per year with special qualifications to teach gifted children when an estimated 22,560 teachers are needed. Yet only 34 institutions of higher learning offer degree programs in teaching the gifted child. The funding priority at the state level is no better than at the national level—less than $60 million total annually with 83 percent of that spent in only eight states.

The situation is so bad that one father has filed a suit for $1 million in damages against an Illinois school district citing as evidence of discrimination the fact that Illinois spends only $40 per gifted child while lavishing $740 on each handicapped child.[30] This token assistance is based on the assumption that the smart children can teach themselves. This may be true for the generally academically gifted whose needs seem reasonably well understood but overlooks the fact that the truly innovative minds are nonconformist. These questioning and unconventional ways of doing things may upset the normal teaching routines and create behavior problems. This may lead to an early squelching of the very innovative urges which we seek to encourage. How to save such children from the boredom of rigidity is a serious question.

Unfortunately, the most often given answer to a parent who recognizes the special talents is to remove the child from the public school to a private school environment. This merely perpetuates the situation which currently exists with respect to the disadvantaged but gifted children never reaching their potential. Researchers who have looked at the differences between the left and right brained characteristics note that the logical and analytical left brain traits are easily identifiable, whereas the difference between the more visual, holistic, and creative right brain traits make it difficult to distinguish between true genius and mere eccentricity.

Moreover, we are concerned that the present trends of back to basics and dispense with the frills more and more eliminate the "hands on" experience which may be necessary to develop right brained skills which we believe are essential to innovative technologists and managers as well

as creative artists.

The current status of science curriculum in the public schools is deplorable with much taught by book learning and recitation rather than learning by the joy of physical discovery. Most science in the early grades is taught by teachers who are themselves uninterested in and unfamiliar with the subject matter and who have little or no interaction with scientists or engineers in technologically innovative companies. The National Science Foundation is currently reviewing its programs to develop science curriculum, since the level of funding has dropped since 1971.

Another of our concerns with the state of public school education in the United States lies with the tenure system — a system which not only protects teachers' jobs in the event of professional, personal, or political differences with school administrations, but also from critical professional evaluation which could result in dismissals or demands that skills be upgraded and/or teaching methods modified.

The result is an educational system in which dismissals for incompetence are practically unheard of and upgrading of teaching skills through additional education or professional organizations is purely voluntary or for personal advancement. It shuts out for the most part the best and brightest college and university graduates from teaching our children when declining school enrollments result in fewer job openings in school systems where the majority of teaching positions are held by tenured teachers. The younger and newer teachers are excised by the "last in, first out" rule when layoffs occur unless older teachers can be enticed to retire.

When the extrinsic reward is job security and preservation of the tenure system is emphasized over the intrinsic goal, professional excellence, the result is a generally static teaching population committed to the status quo, steadily growing older, whose skills are becoming obsolete and "burnt out" by teaching the same subjects year after year.

Thus, we are concerned about six critical issues in public school education:

1. The identification and encouragement of the specially gifted.
2. The decline in support for curriculum development in the sciences.
3. The divergence of academically and manually skilled students rather than fostering equal opportunities to develop both.
4. The loss of funds for the physical tools of learning.
5. The rejuvenation of an

aging teaching population which enjoys tenure while also suffering from professional obsolescence.
6. The utilization of outside resources to supplement the in-school program.

2. Professional Education for Innovation

Great emphasis has been placed on developing curricula for the professional scientist and engineer, and United States scientific training is second to none. But in recent years it is increasingly apparent that entry into these fields is limited by social and institutional barriers. And there is increasing concern that our system tends to "throw away" mature talent rather than provide supplementary opportunities and talent. The reasons for this are complex —economic and exploitative— and the industrial environment is often intellectually stultifying. So that we tend to hire younger and cheaper talent, rather than accept substantial costs of maintaining the vitality of our more experienced technical talent.

Such indiscriminate culling of talent by limited entry and hastening obsolescence is both cruel and wasteful, a loss of human resources which may be expedient for individual firms but inestimably costly to society. Education programs like the MESA program of the Lawrence Hall of Science and the continuing education activities of Bell Laboratories have demonstrated that such waste is not necessary. We need far greater support for efforts to broaden the pool of potential talent, and we need incentives that will encourage industry to maintain and improve, rather than discard its maturing talent.

At the same time we must address the lack of curricula and technological literacy that is characteristic of the non-scientist. Despite the technological nature of our society, there is little concern that our managers and decision makers (and reporters and citizens) generally have only a token familiarity with the principles of science and technology around which our economics and life styles revolve. We need to change the image and training of the "educated" persons to include a reasonable familiarity with the technological culture of our times.

Such an education must differ from the training of professional technologists — an overview of basic principles, literacy and historical perspective, rather than the skills orientation of the professional. We urge that universities explore the need for such literacy and begin to develop and integrate science curricula intended specifically for the manager, decision maker and non-scientists in general. Is it not appropriate that degrees in Business Administration, Political Science and Journalism should also imply a familiarity with the scientific and technical underpinnings of society?

The universities, and particularly the engineering schools, can have a major role to play in fostering technological innovation because this process depends to an ever increasing degree on scientific and technological knowledge. Engineering schools will respond to the needs to prepare people who can contribute more effectively to the process of technological innovation, if this goal is perceived to be important and if the schools are convinced that there will be a demand for the students that they train.

At present, the engineering schools are emphasizing far more analysis and design than the discovery of new laws of nature or the process of invention and entrepreneurship. To be sure, a capacity for analysis and design provides an important element in the whole process of technological innovation, but is not sufficient to a fostering of innovation.

What is required is not a drastic change of the goals of the engineering schools, but some *change in emphasis*, so as to make the schools contribute, through their curricula, their research and their public service, to an acceleration of the rate of discovery and, above all, of invention and entrepreneurship. This should occur without impairing the traditional role of the engineering school to prepare technically competent cadres for analysis, design and research.

Since the overwhelming majority of the students in the engineering schools will still need to be prepared for these traditional roles, *dual curricular tracks* should be contemplated: A traditional set of tracks, and a set oriented more to technological innovation—tracks for particularly inventive people or people whose career goal is entrepreneurship.

The distinction between these sets of tracks will be more a matter of orientation and emphasis than of vastly different subject matter. Students in the tracks aimed at encouraging the development of technological innovation will generally need most of the courses of traditional engineering curricula. In turn, engineering students in the traditional tracks need to be exposed and educated more deeply to issues pertinent to innovation, so as to be able to better recognize them to be supportive in their professional careers—in industry, government, or the private profession—of the process of innovation.

It will be necessary to recognize that the orientation towards discovery and inventiveness are close to each other, while the orientation towards entrepreneurship is quite distinct, rare being the inventor who is also a good entrepreneur. Entrepreneurship requires people who have the capacity to rapidly assimilate, are gifted in human interactions, and have a well developed business sense, while the discoverer and inventor are more interested in pitting their wits against nature, and may be very poor entrepreneurs.

An essential need of an education for technological innovation is to provide *hands-on experience.* For those students with a greater bent for discovery and innovation, this means access to non-regimented laboratory facilities in which they can spend as much time as they want and pursue their creative ideas wherever they may take them. For students with a bent toward entrepreneurship, hands-on experience means an opportunity, as part of their education, to go through the experience of assembling capital, ideas, people, and make a commercial go of their enterprise.

The engineering schools represent an indispensable element in the development of an aggressive posture toward technological innovation in the country. They can have a major impact in accelerating the process, but this can be achieved only if the involvement of the engineering schools becomes systematic and involves all of them, rather than a few selected institutions.

Unfortunately, in a period of essentially stagnant demography, engineering schools are not likely to greatly expand their faculties, which are today highly tenured and middle-aged. Thus, the schools cannot be expected to make substantial commitments to the development of technological innovation, as outlined, without major assistance from the federal government, and without a commitment from employers to absorb the students who graduate from new curricula.

A case can be made that education for the management of innovation is different from education for carrying on the normal work of the society. Most of society's work is performed through effective and efficient carrying on of normal activities. Innovation by its definition is new and may require different kinds of thinking.

Law schools train patent lawyers, yet patent law is not considered part of the main stream of legal education. The legal aspects of small business practice are not a major part of the law school curriculum. However, as law schools move into interdisciplinary programs, some attention to the interface between law and technology seems imperative.

A special case can be made for government support of research in business and law schools on innovation. Only a few thoughtful scholars have worked in this field, yet it is one that is important to the nation. Most of the work will be basic, but there are many more immediately valuable studies and analyses that can be carried out.

3. The Corporate Environment for Innovation

Bureaucracy is effective in coping with routine, recurring chores and with problems which come up repeatedly and that can be solved in the same way. Thus, business organizations may be conditioned in such a way as to call for a high degree of conformity and disciplined adaptors, not innovators. In such organizations, successful solutions tend to be repeated. Innovations are not welcome.

To many corporations, innovation is disruptive and creates risks which often prove difficult to manage. For this reason, many firms have mechanisms and controls to keep their momentum going and to keep innovation out of the "gears". Often such controls are instituted ostensibly to enhance the climate for innovation, but in reality their effect is to diminish the probability of innovation.

Adding to the problem is the fact that many chief executive officers of firms rise to command primarily because they are proficient in some functional area like finance, marketing, or law, not because they are creative or understand how to create a climate favoring innovation. That they have "succeeded" as executives may indicate that they have shown themselves to be effective decision makers. Making decisions is a judgmental process, not a creative process. To avoid making decisions that could later be judged as mistakes may require, in addition to large amounts of luck, an enormous amount of information to "reduce the risks of failure in decision making".

At one end of the spectrum of decision making, everything is known. In this comfortable region for managers, decisions are so easy to make that they make themselves. At the opposite end of the decision making spectrum everything is new. It is a region where comparatively little information is available to reduce the risk of decision making. It is not a region where many managers and decision makers are comfortable. Yet, it is where innovation takes place.

Many business executives and particularly chief executive officers are under pressure from directors and stockholders to show "growth". In the early 1960's, it became fashionable in financial circles to evaluate company performance by the rate of growth as measured by annual percentage increases in net profits after taxes. The market value of a firm's stock reflected its current and projected growth performance. Thus, the "price-earnings ratio" of a stock (the multiple by which the market value of a share exceeds current earnings per share) was and is a powerful reminder of the need to grow. Also, in the mid 1960's, acquisition became a fashionable way to grow. There were and are tax and other incentives which favor acquisition and merger as a strategy for growth over investment in efforts which could lead to innovation.

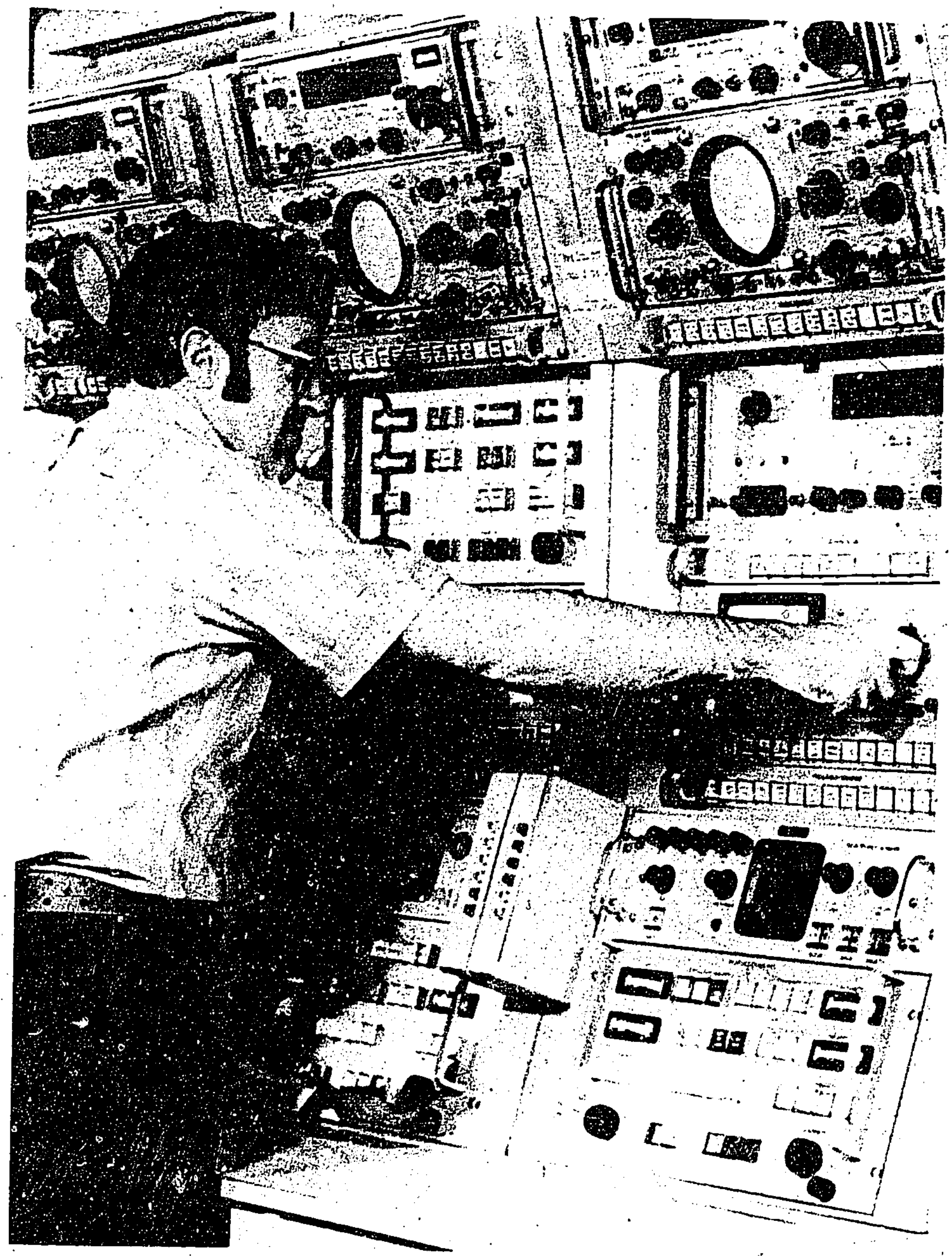
By the mid 1960's, also, the business literature began to take note of the risks of innovation. The Boston Consulting Group released a position paper entitled, "Research: An Investment or Just a Gamble?", stating, "Research for completely new products or ventures is a form of speculation that can hardly be called an investment". Such pronouncements have had a predictable impact on harried corporate decision makers: less investment in innovation; more effort toward acquisitions and mergers.

Another constraining factor is an artificially compressed time frame existing in the corporate world which must be a special case of Einsteinian relativity. Eager MBA's want to demonstrate to their employers that they can get things done in a hurry and that they know how to carry results down to the "bottom line". Innovation tends to be a long, uncertain process as compared to making minor modifications or to mergers and acquisitions. (Never mind that serious students[31] have questioned whether acquisition strategies for growth are in the best long term interests of the stockholders.) As a consequence, these junior-level executives tend to shun innovation as a valid strategy for their own personal growth.

Few recommendations of the Domestic Policy Review on Innovation addressed the question of how to make innovation more attractive as a route to growth than acquisition and merger. Only by making innovation a sound business investment rather than a gamble, can a climate be created where "market pull" will create a demand for students who can contribute effectively to the innovation process.

4. University-Industry Relations

The relationship between universities and industry in competitive societies often reflects a direct and pragmatic government involvement. The independence of these institutions is an important aspect of our society and must be preserved, but we see an important need for a close symbiotic relationship. Industry contributes substantial funding to univer-



sities and ultimately provides the employment for graduates. Thus, university recruitment policies have a substantial impact on the curriculum choices of students. The entire recruiting function and potential coordination with the later recruiting activities of industry have been ignored in terms of focusing future resources.

Increased involvement of university faculty and staff as consultants and advisors to industry can be a major source of innovative stimulus and improved university perspective. The phenomenon of innovative enterprise which characterizes the areas around the California Institute of Technology, MIT, and Stanford, needs to be better understood and fostered.

The phenomenon may be equally dependent on the presence of good managerial consulting pools and sympathetic investment capital with an interest in the potential of technological development. Clearly there are pools of complementary talents—scholars, investors and industrial innovators—who provide mutual stimulation and support that is valuable to both university and industry. We need far better insight into the skills and environment that constitute a critical mass.

Closer cooperation between universities and industry might help to address the problems of obsolescence and declining efficiency in senior members of the R&D work force. A number of universities have explored this area, but it is not clear that conventional classes are appropriate for this population and the wide variation in background and goals of senior research personnel. It is also not clear that all creative talent can respond to such opportunities and it may well be that some talents, like athletes, have a limited period of strength. While there are many examples of enduring talent combined with maturing judgment, there is also the question of whether it is a general pattern and it may be that we need to explore new patterns of mid-career change and early retirement.

The most impressive examples of sustained creativity, such as the Bell Laboratories, reflect a combination of rigorous initial selection to collect the most promising talent; together with continuing heavy investment in training to maintain state-of-the-art skills and knowledge. Although the results are impressive, the costs include study and classes during working hours as a normal job activity and it is not clear that a less elite staff would respond as well to such a costly investment. Furthermore, a less prestigious organization might well find itself training talent for competitors.

There is a strong need for research to examine the characteristics and patterns of industrial R&D talents. We need to know more about the patterns of declining creativity and technological skills. We need to explore the potential effects of training, career change and early retirement. And we need to explore better means to identify and cultivate talent.

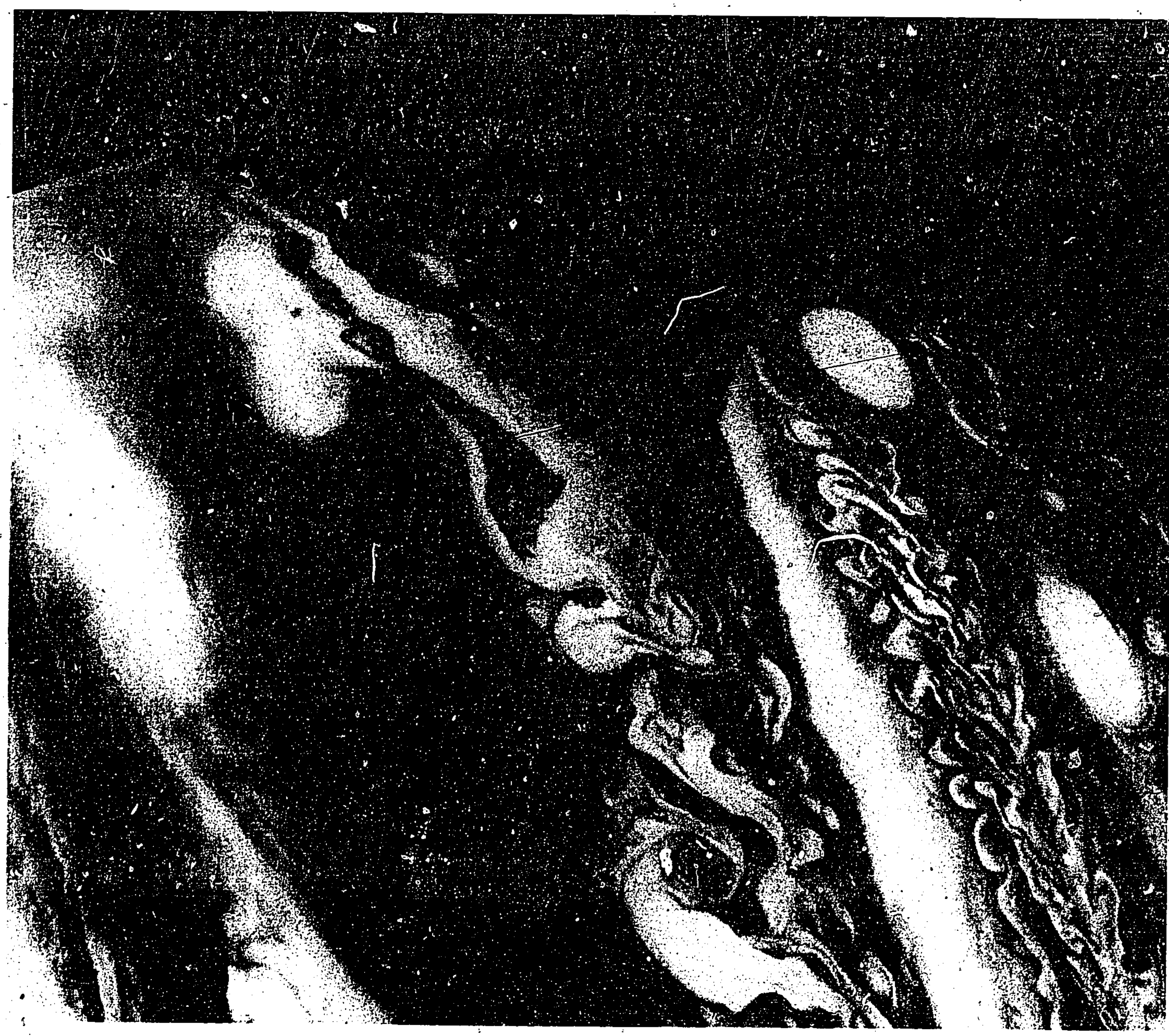
5. Military Training

The Department of Defense is one of the United States' largest educational activities, employing one out of every six people in educational activities, and spending $6 billion per year on training programs. These training programs and the military academies have had an important role in providing entry and training to men and women of all economic levels, geographic areas, and ethnic origins. Many of our most innovative minds have benefitted from this education and career potential. And many research laboratories and electronics firms are staffed by electronics experts trained in the military service.

On the other hand, a high premium exists in the military (and indeed in any large organization) *against* risk taking and independent action. In the military one follow orders as part of a team. The benefits and demands of discipline usually outweigh the potential of innovation. A major challenge to the military establishment is how to balance requirements against the needs for imagination and change in response to new technology. And how to develop training programs which cultivate innovation and independent judgment without loss of discipline and control.

This ambivalence differs from industry only in degree, and it may be that the only solution lies in identifying talents and establishing different "tracks". Increased attention to this problem within the military establishment could serve as a model as well as a training ground.

It is also within the military context that much of our understanding concerning the methodology of instruction has come. Thus, we must wonder if the Army cannot teach without "hands-on" experience or "performance-based instruction"[32] whether we can expect our engineering schools and universities to spawn inventors through passive instruction which matches a lecturer's wits with a student's concentration span, retentiveness, and regurgitative writing skills. Many of our ivory towered institutions of learning, we understand, no longer have laboratory experimentation and/or the equipment provided is obsolete or in disrepair. We need to know, therefore, whether "hands-on" experience is the very essence of the skills we need to nurture if we want to encourage innovation —and, if so, is it feasible for institutions of learning at all levels to acquire and provide access to such equipment whose cost has multiplied. Are there other ways in which access to such equipment and/or "hands-on" experience can be provided by institutions which have a continuing and ongoing use of the instrumentation or equipment? The National Science Foundation is currently organizing an effort to explore the present availability, use, need, and access to equipment for engineering education. We believe it is important also to understand the role of such equipment as teaching tools and/or toys at earlier ages—for the toys of the child become the tools of the adult or vice versa, and one of the more successful courses offered at Cornell University is a course in the physics of toys which attracts a sizeable enrollment from non-science concentrators.



VIII. What Shall We Do?—Recommendations

Because much of the available evidence suggests that the informal environment is influential in shaping the opinions of persons of all ages about science and technology, our recommendations for developing human resources for innovation are not limited to the formal educational system. We also address the major informal environments, notably science centers and television. And we see the need for interaction between educational institutions at all levels and the world of technological entrepreneurship. We treat formal and informal learning environments as mutually dependent partners in education for innovation.

The recommendations follow.

Informal Environments for Learning

One of the greatest deficiencies (as well as one of the strengths) of the American political system is the inability of the federal government to influence the content of the mass media. In a society dedicated to diversity and pluralism this is a philosophical principle which will not and should not change.

Yet we know from the meager research which is available to us that we are a nation addicted to television and movies, that 99 percent of our homes have television sets. We spend more than 25 percent of our time (almost as much time as sleeping) watching the cathode ray tube and with profound effects on our society which are only barely becoming apparent to us. As far as innovation is concerned, we have discovered that only a smattering of movies from 1935-1976 even addressed the question (3.6 percent and less than 5 percent of television programs treat scientific subjects). The television screen by and large has inverted the Horatio Alger spirit which motivated late nineteenth and early twentieth century immigrants to pursue free education and by dint of their own hard work, entrepreneurial drive, imagination, to climb the social, economic, and cultural ladder to success in a highly mobile society. Today's television writers who have achieved their own positions of influence through this very system, present a view of the world which denigrates the very attributes by which they succeeded. Big business is not only bad, it is in collusion with big government and the Mafia. The only way to survive is to beat the system by dint on one's own cunning and self-interest. Education is unimportant, only villains have libraries.

Scientists fare poorly, too. Even though most of the public will concede that our future financial and economic health depends on our scientific and technological skills, the notion that those who pursue these carers are either "nutty" or malevolent is difficult to eradicate. A negative attitude toward science appears to increase with heavy television viewing except for blacks who start with such a low esteem for scientific and technological subjects that their attitudes are somewhat improved by exposure to television.

We urge, therefore, that leaders of the motion picture and television industries take cognizance of the impact of their programs on social attitudes and particularly their impact on the highly successful technologically based society. Its profits support investment in our entertainment industry. They are the underpinnings of an economic system which is so efficient that it provides leisure time to its citizens to enjoy the fruits of the entertainment industry. Thus, we have attained a high standard of living which sustains the consumer purchases which provide financial support for broadcast advertising, motion pictures, cable and pay television.

Indeed, if the philosophical goal of a free and independent society is a marketplace of ideas, we feel that the marketplace is woefully deficient in treating subjects which are crucial in maintaining our leadership technologically in the international market. It is an appropriate roll of government to stimulate production by a multiplicity of private and independent sources and to expedite "delivery" systems which will take advantage of new technological opportunities. *We urge: that the National Science Foundation and/or the Department of Commerce should convene a broadcasting industry conference of broadcasters and corporate sponsors and foundation officers to discuss the representation of science and technology in prime time and children's television, and to develop mechanisms for continuing consultation on relevant programming.*

While the federal government may not regulate the content of the program, we do urge: *1) that all federal departments and agencies interested in the innovative process be encouraged to provide funds to independent production groups to treat the serious social problems addressed in this report, and 2) that such program grants should include authorization for impact research to assure that program design is developed in an optimal manner to assure that it reaches the audiences for which it is intended.* More imaginative and appealing programs and dramatic presentations must be produced to compete favorably for audiences with what Hollywood currently offers United States as well as world audiences.

Most important, we feel, is the packaging of programs for the American public. In addition to increasing the quantity of programs related to the scientific and technological skills and talents, we need to accumulate more programs which treat business activities which translate ideas and designs into tangible benefits for our citizens. Thus, we urge: *that Congress authorize the Department of Commerce, the Department of Education and the National Science Foundation to invest in the collection and distribution of programs about technological innovation through all available media of expression, including radio, commercial and noncommercial television stations, videotapes, videodiscs, motion picture films for educational institutions. We also urge that cooperative ventures with government and industry participation be explored.*

In addition to the classroom and cathode ray tubes as environments for learning, we are compelled to add our insight that innovators learn not merely by seeing and hearing, by reading and writing, but by feeling and doing. Practical experience is as much a part of the education of an innovator and/or entrepreneur as "book learning". Thus, use of the hands is as important as the use of the eyes and ears, much in the same way that farm children learned the skills of an agricultural society while working with their parents until they were sent off to the land grant colleges to learn the latest agricultural theories and practices.

Such considerations have two practical implications for our new Department of Education—1) To review the equipment available to school systems and universities, and 2) to develop a means of sharing equipment among educational institutions and/or with private industry. Modern equipment in engineering schools has been found to be woefully inadequate and especially in the area of microprocessors in which the United States is supposed to be the strongest competitor in international trade.[33] Thus, our school system is far behind industry in support of our most successful technological innovations and this imbalance should be remedied immediately.

Although we are unable to find data to support our conclusion that science and technology museums (or centers for participatory experimentation) are significant components in supporting the infrastructure for innovation, we note that the centers of the country which are highly industrialized such as Boston, San Francisco, and Chicago, do have strong science museums. We also note that many scientists and engineers mention an encounter with such an institution as important in the development of their interest in the field. Thus, we feel reasonably comfortable with the notion that children who do not have such a community resource within easy reach of their residence, may be technologically deprived. This deprivation may be assuaged somewhat by the availability and careful choice of toys by parents or the existence of a school program. The present trend in parenting suggests less rather than more involvement of parents with the early education of their children; and school-enrichment programs appear to be more readily available in the locations that do in fact have such science and technology centers. It is shocking that art, history, and humanities museums receive roughly 10 times as much federal support ($20 million) for education and exhibits as science museums ($2 million) when 80 percent of the public believe our future depends upon our scientific and technological skills. It is even more incomprehensible when 45 percent of total museum attendance and 40 percent of museum costs are for science museums.

Thus, we urge that the Department of Commerce take the initiative to stimulate local science and technology centers similar to The Exploratorium in San Francisco, the Museum of Science and Industry in Chicago, and the Science Museum in Boston, in all major metropolitan areas of the country. This should be a cooperative effort between the federal government and local initiatives with both parties accepting responsibility. To be successful we feel that local businesses engaged in high technology activities should also be partners and tax incentives should be provided to encourage their participation. It is possible that a traveling science and technology exhibit could be organized to serve communities too small to support a permanent center. The support of professional societies should be encouraged and the establishment of a science and technology festival comparable to the Smithsonian Folklife festival on the mall should be explored.

Furthermore, we urge corporate and foundation executives responsible for grants to educational institutions to take a careful look at the role of science museums in our society and to increase their support to such institutions. We especially urge that science museums be included on lists of institutions which qualify for corporate matching funds.

Continuing Education

Because our society like the rest of the world is aging, the majority of our citizens—now over 30—may never see the inside of a school again. Because technology itself is causing revolutionary changes in our society as well as rendering obsolete the specific skills we have learned in our youth, more and more burden will be placed on lifelong learning if we are to retain our innovation qualities. *Thus, we recommend: the Department of Labor, the Department of Education, the Department of Commerce, the Small Business Administration, and the National Science Foundation develop a coordinated plan for federal stimulation of continuing education programs which will:*

a. *Increase the participation of mature workers in the innovative process.*

b. *Improve the understanding of the nature of the innovative process.*

c. *Facilitate the acceptance of innovation in products and processes.*

Such a plan should provide for the use of a variety of instructional media that are suitable for individual use and the plan should allow for participation by organizations such as trade associations, industry consortia, and professional groups that are not part of the formal educational system.

Retraining takes time and many individuals must forego present income unless they find institutional or corporate sponsorship for retraining. Human resources as well as tangible equipment must be recognized as a capital asset which rapidly depreciates in a technologically volatile environment. *We recommend that:*

a. *Tax credits should be granted for corporate investment in human capital.*

b. *Depreciation should be allowed for obsolescence of human skills.*

c. *Full deduction should be permitted for tuition and living expenses with a carry forward of five years for mature individuals seeking to upgrade their skills.*

The Public School System—"Basics" Includes Science

As the future need for human capital for ventures in innovation increases, so too does the need for an attitude of acceptance and encouragement of technological advance by the public at large. Both of these put a heavy burden on our institutions for primary and secondary education. It is here that basic attitudes toward intellectual inquiry, risk taking, and coping with change and uncertainty are developed. Key career decisions are strongly biased and often determined by education at these levels. The characteristics that encourage inventiveness, innovation and entrepreneurship can be either developed or squelched.

These matters are not likely to be dealt with adequately without special attention. We note the uncertainty and ambiguity of the values of teachers and students *vis a vis* growth and technology. At a time that exceptional achievement demands an early introduction to increasingly sophisticated and quickly changing subject matter, our schools face increasing costs, public and private resistance to meeting these costs, aging tenured faculties, and a demand for "back to basics". In a declining student population, we must do better in identifying those with exceptional creative abilities, helping them fulfill that creative potential, and fostering a friendly familiarity with science and technology among all students.

The "back to basics" movement has been stimulated by the reaction to the permissiveness and experimentation in education of the past few decades, plus the more recent decline of student scores on standardized achievement tests (which need not necessarily be related). "Basics" in this context is a euphemism for emphasizing competence in reading, writing, and computational mathematics. We believe that society does a disservice to its young people if it allows them to leave high school without adequate skills in these areas. However, we also believe that we are past the time when the "basics" can be construed so narrowly. In particular, we believe that science-based technology has become such an important part of our daily lives and is involved in so many of our collective social and political decisions that an understanding of what it is about must be included within the core curriculum. Science education is in danger of falling into the "nice, but not necessary" category. Instructional materials that teach about science and technology must be woven into the fabric of primary and secondary education. To do so would not only broaden young people's career horizons, but would prepare the vast majority who will not choose science or engineering to better cope with life as citizens in a technological society.

Thus, we urge that academic courses in science and mathematics be considered "basic" skills pursued by all students.

Exceptionally Gifted and Talented Children

Human achievement in any of its major dimensions—social, economic, political, technological, or scientific—does not progress at a uniform rate. Rather, at particular points in history, individuals of rare creative qualities whose accomplishments have greatly accelerated progress have appeared on the scene; Einstein, Gutenberg, and Marconi, among others, come to mind. Nations can ill-afford not to identify the limited amount of such talent they may have nor to encourage its development. Nevertheless, a recent report to the United States Commissioner of Education from a Task Force on the Gifted and Talented states that, "although gifted and talented students comprise 3 percent-5 percent of the school age population, they receive only 0.003 percent of the federal funds for education". This statistical disparity reflects special efforts to give many categories of disadvantaged youngsters an education for useful roles in society. Such striving to provide equal opportunity is the keystone of our educational policy—and it should be so. But when the future demands so much of us in creative achievement—technological and otherwise—we question the wisdom of so dramatic an imbalance. Were the unusually creative child simply to be ignored, that would be bad enough; but worse, the behavioral manifestations of such immense talent are often unrecognized as such and brand the child as a "problem". Such "problems" are rare opportunities. They should be sought out and cultivated. *Thus, we urge that immediate steps be taken by federal, state, and local officials to give programs for the identification and training of gifted students their immediate attention and priority.*

Developing Innovation-Related Talents

While achievement of the truly rare individual is often the basis for technological innovation, the total process of innovation involves a team of individuals with a variety of skills, knowledge, and attitudes that are not so rare and that many believe can be taught—problem solving, engineering design, organizational and managerial skills, communication, and leadership, for example. The principal attitudinal factors seem to be a willingness to do things in new ways and to take risks. In sum, participation in innovation and entrepreneurship need not, of necessity, be limited to an elite few. We believe it is possible to create school environments that will reveal and develop such talents. *We recommend that federal resources available through the National Institute for Education and the National Science Foundation address the identification and development of talents in school age children, especially among girls, that are relevant to innovation and entrepreneurship.*

Today the educational system diverts those with primarily manual skills from those with primarily intellectual skills, a practice which we feel may seriously hamper innovation in both groups of young people. The bit of insight gleaned from anecdotal data suggest that most creative genius and many with the entrepreneurial drive and organizational skill have benefitted from "hands-on" experience sometime in their lives. Innovators are not only avid readers; they are avid tinkerers and they learn by both theoretical analysis and the experience of failure. *Thus, we have two recommendations for the new Department of Education: 1) That vocational education should be examined for its theoretical and conceptual content, and 2) intellectually oriented programs should be examined for their practical hands on experience.* Otherwise, we may be hampering the integration of skills which lead to technological innovation and reducing the pool from which innovators may be drawn.[34]

Vocational Education

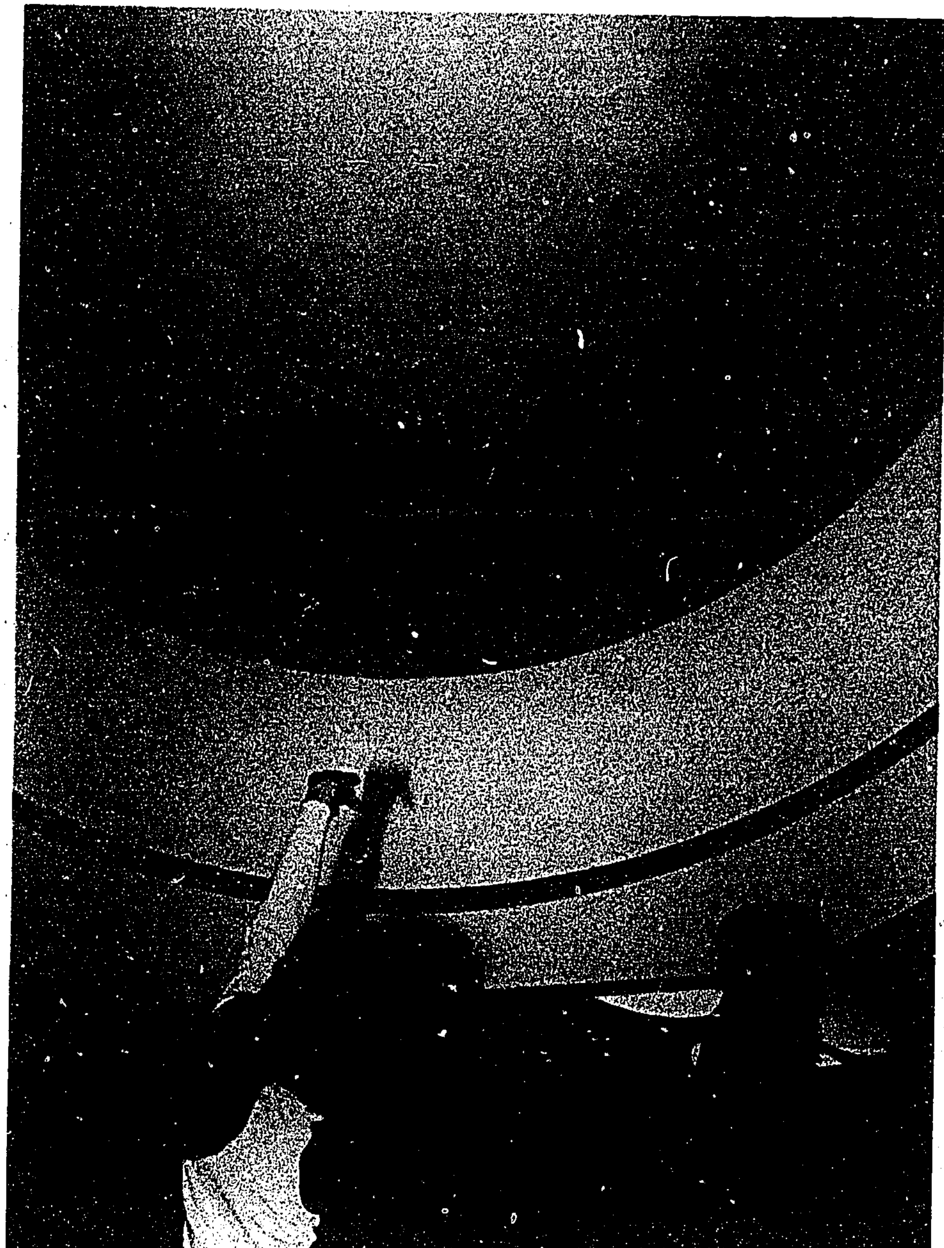
The potential of vocational education as a spawning ground for future inventors, innovators, and entrepreneurs tends to be ignored. The emphasis in federal support of vocational education is remedial—limited to training for initial employment. This sells short the more than 16 million youngsters and adults who are enrolled in vocational education nationally. More than 50 percent are female while nearly 25 percent are ethnic minorities. There is no reason for believing that the fraction of them that are capable of creativity, innovation, and entrepreneurship is any smaller than in the academically oriented student population. In fact, one can expect a large percentage of highly motivated young people whose proclivity to work with their hands may incline them toward invention and innovation. Many will find employment in or become proprietors of small businesses and have the opportunity to exercise their talents for innovation and entrepreneurship. For mature workers vocational education offers the opportunity to develop new skills that will prolong their employability in technologically changing industry. The interface betwen vocational and academic education needs to be highly permeable. Vocational students need access to academic courses that will enhance later career mobility while academic students can benefit from the hands-on emphasis of vocational training. The expensive physical plant required for vocational programs should be more widely used outside of normal school hours for continuing adult education in technological areas. *We recommend that federal policies for vocational education and employment training programs (e.g., CETA) moderate their present emphasis on first employment and recognize the potential of such programs to prepare students for lifetime careers in technology, innovation, and entrepreneurship.*

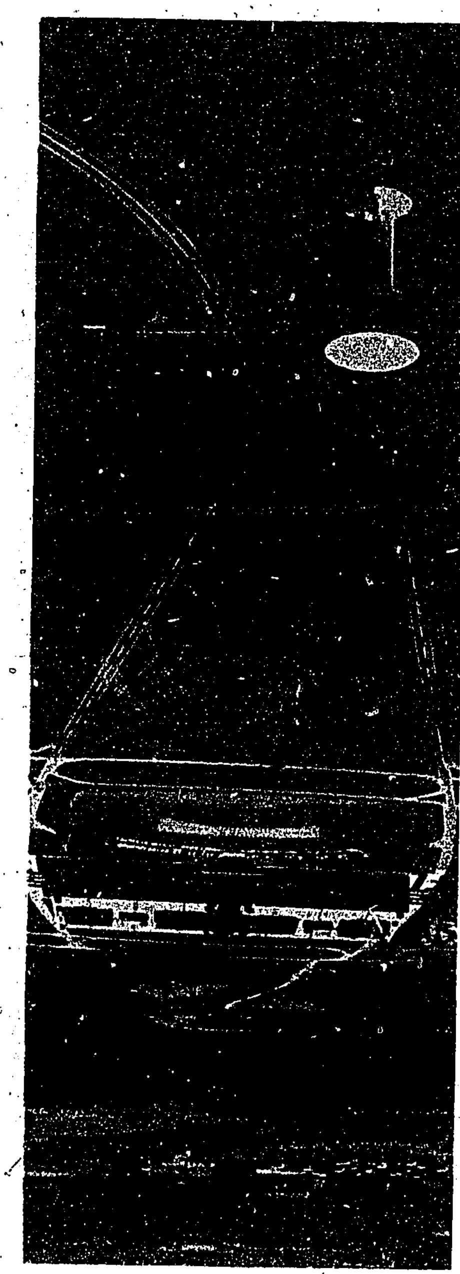
Government/Industry/School System Participation

Students need to develop role models based on contact with those whose vocation is invention and entrepreneurship. They need the opportunity to test their skills on real problems in a realistic setting. The fact that very few teachers in primary and secondary schools have had any training or experience in technological matters—either in their substance or their management—is a substantial handicap. One must rely on in-service training to prepare teachers for stimulating children's interest in and knowledge of technology. Teachers, too, need relevant "hands-on" experience in order to communicate an understanding of technology and innovation in a real life context. Their students should be awakened to the career opportunities in applying technology to meet the needs of society. *We recommend that federal support of in-service teacher training provide for expanded teacher contacts with science-based industry and with technological ventures in the public and private sectors.*

We believe, however, that educators and government officials cannot, by themselves, convey to students or teachers either the vitality or the reality of innovation and entrepreneurship. We believe that the industrial sector has too large a stake in a technologically competent work force not to seek a role for itself in enhancing primary and secondary education. We trust that industry representatives, educators, and government officials will each find their appropriate roles in this cooperative effort to improve the quality of education.

We also urge the Department of Commerce and other agencies involved to sponsor a conference of industry, government, and academia meeting with middle and secondary school educators to develop strategies for more effec-





tive collaboration between high technology industries and school systems.

The objective of such a conference should be the linking of education and work into programs that will better prepare young people for full participation in our technological society. Many programs—career days, speakers—are in process, but much more could be done to develop collaborative models for curriculum development, teaching and in-service programs. However, such a conference must take account of the appropriate tension between industry goals and educational goals and consider how to allocate "education" and "training".

University/Corporate Cooperation

Universities and corporate employers are equally important in providing learning environments for innovation. While the former may provide the more theoretical framework and the latter a more practical experience, we believe for reasons previously discussed, that an optimum atmosphere conducive to innovation requires a healthy cross fertilization of the two environments. It is a well known fact that start up companies thrive in close proximity to strong universities—and often the innovators have a foot (if not also a head and a hand) in both doors.

Cooperative efforts between the two are becoming more and more recognized as a desirable economy especially for professional schools which lack resources for equipment, as useful guides to career paths with productive avenues for development, and as a source of inspiration and ideas to stimulate the innovative process within industry.

While our recommendations represent only a modest beginning into this very fruitful area for future policy development, we have concentrated on the role of engineering schools as a good place to start. However, we note that business schools, law schools, as well as the newly proliferating public policy schools, are equally deserving of a careful examination, and we hope others in the foundation world may find the interest and financial resources to pursue the role of these institutions in stimulating and servicing innovation.

We recommend that:

1) *The federal government should strengthen its long term support for university/industry cooperative programs which continue to provide training grounds for innovators.*

2) *In university/industry cooperative programs, the Departments of Education and Commerce should seek to insure that the interaction between university and industrial participants involve university departments, such as the social sciences, in addition to the physical sciences and engineering. Other aspects of innovation than simply research (e.g., development, manufacturing, marketing, finance, and sales) should be included. Informal network relationships among students, faculty, and industry should be encouraged.*

3) *The Department of Commerce should promote the establishment of industrial fellowships for United States students to participate in the innovative process of selected fields of technology in foreign countries.*

4) *The Department of Commerce and the National Science Foundation should support courses (similar to Dartmouth's "ES-21") which introduce engineering students to the twin concepts of innovation and entrepreneurship and embody elements of network interaction among faculties of several college departments, adjunct-industrial faculty and industry representatives.*

5) *The Department of Commerce should administer a program of federally funded fellowships for students and teachers as summer internships.*

6) In the President's Message on Industrial Innovation, he pro-

posed several initatives aimed at stimulating industrial innovation. We believe that the implementation of these initiatives presents the Department of Commerce and the National Science Foundation with unique opportunities for leadership on the human resource issues dealt with in this report. For example, the President proposed an initiative to gather unpublished technical information by sending technical and business teams to other nations. Such teams represent an especially useful opportunity to gather information on the management of human resources in other nations. *In the implementation of these initiatives, the Department of Commerce should use graduate students and teachers to the maximum extent possible in order to ensure the transfer of the results to the educational system.*

Engineering Schools and Innovation

We recommend establishment of a National Commission (with representatives from the universities, industry, the federal government, the National Academy of Engineering and the Engineering Council for Professional Development) to formulate plans to assist engineering schools in contributing to national productivity and technological innovation.

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Appendix

The following have given generously of their time to the deliberations contained in this report:

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